Planetary Sea: Oceanography and the Making of the World Ocean

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Dedication

This dissertation is dedicated to my grandfather, John Traynor, who taught me about wonder.

Abstract

How has the concept of a world ocean emerged in a world of difference? This question reveals the crucial problematic of planetary environmental politics, which attempt to contend with global-scale environmental crises caused by the human species, at the risk of ignoring geographical specificity and different ways of knowing and experiencing life on Earth. By tracing the emergence of the world ocean concept in international oceanographic science, my research explores key practices and paradigms that characterize this tension. Drawing on expert interviews as well as archival materials from the US, UK, and South Africa, I study the world-making practices of three projects in physical oceanography: the International Geophysical Year (1957-58), the World Ocean Circulation Experiment (1990-2002), and the Global Ocean Observing System (current). Finally, I suggest the ocean archive as an alternate role for the ocean in planetary thought.

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INTRODUCTION: THINKING TOWARDS A PLANETARY SEA

I first became compelled to think with the ocean in 2009, in Eastern Sri Lanka, a place that bore the ocean's imprint in myriad traceable and invisible ways. It was five years after the Boxing Day tsunami and one month after the end of Sri Lanka's 30-year civil war. The East coast of the island nation had absorbed much of the violence, slow and fast, from both events. I was 22 years old, doing my MA research, with few resources, some amateur translators, and strict limitations on my mobility due to the ongoing security situation. I frequently found myself on a narrow strip of beach, between the ocean and the lagoon, trying to communicate with small-scale fishermen and their families, to talk about the past and the future, about disaster and change, sitting in the sand, drinking tea, watching the sea. Trying to find an entry point into the complex nexus of factors that impacted their lives, from the military to fish prices to tides to natural disasters to the huge presence of international aid organizations was daunting. It was the ocean in front of us, usually visible, always present, that provided a material entity on which we could hang our conversations, to talk about change and stability and enduring violence as well as possible responses and planning. In this way we were able to tackle complex issues together, always partially, of course, but the ocean helped us to draw conclusions and to think about the future.[1] Some days were full of buoyant feelings, my

[1] See Lehman, J. S. (2013). Relating to the sea: enlivening the ocean as an actor in Eastern Sri Lanka. *Environment and Planning D: Society and Space*, *31*(3), 485. And Lehman, J. (2014). Expecting the sea: The nature of uncertainty on Sri Lanka's East coast. *Geoforum*, *52*, 245-256.

team exploring coral reefs, climbing in and out of a small boat in our clothes, the local fishermen diving for rocks and plants to show me. Other times were more harrowing, like a late night motorbike ride to visit an elderly man whose sandy yard was filled with puppies, animals he had taken in after losing his family in the tsunami, refusing to move away from where he had lived with and lost them, despite the urging of other family members and various resettlement agencies.

When I returned to my home in Vancouver, the ocean was still there. I began to notice that it was a different color every day. I watched the tankers that lined up in the bay and wondered where they came from, and where they were going. When I kayaked or swam in the water, I thought about the animals and plants that I could barely sense in the waves below me. I became increasingly curious about this world, and I thought about how it connected me to people and dynamics all over the planet, which felt both bigger and smaller than it ever had. The ocean turned my mind, even as it was where I went to feast on open spaces, to clear my head.

But all of these embodied and imagined impressions of the ocean, of these different and similar oceanic places, were entwined with images of the ocean from other sources. This other ocean resided not at the end of the shore but in my computer, in my books, in the climate model outputs I studied. This second ocean was most of all a sea of data, but it contributed to imaginations of connection, dynamism, and change just as much as the sea around me. And so I was prompted to think about how we've come to know the ocean; how we have come to think of the ocean as one entity with dynamics felt on bodies and on the planet. Most of all, as my world became rife with oceanic relations, I became interested in what kinds of worlds are made by efforts to think with the sea.

Of course, 'the sea' implies the existence of a world ocean, a single body of water, which makes our planet a blue planet and has a distinct set of qualities even as it varies in depth, temperature, chemical composition, and biological activity over the globe. While the ocean has perhaps always provided glimpses of both its distancing immensity and its power to transport and connect, the ability and compulsion to know the ocean as a world ocean is relatively new. Prior to World War II, oceanographic efforts mainly attempted to make knowledge about certain paths through, creatures in, or physical qualities of the ocean. It was not until the mid-century emergence of Earth Systems Science as an overarching umbrella for geophysical research that oceanography began to attempt to grasp the ocean as a whole.[2] This concept of a world ocean invited me to think further, to link concepts of the ocean to notions of not just the global, but to the planetary. Beyond the embodied experiences of individuals interacting with the sea, and beyond the gridded, mapped and measured global ocean, what is the power of a planetary ocean? This is an ocean that ties us to deep time, to the history of life, that conjures notions of fundamental unknowability, of totality, of singularity.

These attempts to grapple with the full conceptual and material weight of a planetary ocean are linked to contemporary environmental and philosophical ideas. In particular, they emerge with the notion of the Anthropocene: the idea that human influence on the planet's permanent geological record is so legible that it ushers in and

[2] Lövbrand, E., Stripple, J., & Wiman, B. (2009). Earth System governmentality: Reflections on science in the Anthropocene. *Global Environmental Change*, *19*(1), 7-13.

defines a new geological epoch. But it is also related to critiques of Anthropocene discourse, which has had a tendency to elide difference, inequality, and contingency in positing a unitary human species that both threatens the future of the planet and may itself be headed for extinction.[3] Tied to justice concerns within this context, the planetary is an invitation, a provocation, to think otherwise about processes of globalization and the conceptions of nature that underlie them. It is worth quoting Gayatri Spivak's formulation of the planetary at length:

> "Globalization is the imposition of the same system of exchange everywhere. In the gridwork of electronic capital, we achieve that abstract ball covered in latitudes and longitudes, cut by virtual lines, once the equator and the tropics and so on, now drawn by the requirements of Geographical Information Systems. To talk planet-talk by way of an unexamined environmentalism, referring to an undivided "natural" space rather than a differentiated political space, can work in the interest of this globalization in the mode of the abstract as such [...] The globe is on our computers. No one lives there. It allows us to think that we can aim to control it. The planet is in the species of alterity, belonging to another system; and yet we inhabit it, on loan."[4]

This alterity, Spivak explains, is within and about us, even as it is also difference in its purest form. The alterity of the planet goes by different names, invoking non-hegemonic relations, even universalisms. Spivak enters the planetary by way of the uncanny; the making unhomely of our home. By amplifying alterity and the uncanny in my reading of the international technoscientific projects that make the world ocean, I am attempting to amplify the planetarity that both overwrites and underwrites the globe.

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[3] See for example, Malm, A., & Hornborg, A. (2014). The geology of mankind? A critique of the Anthropocene narrative. *The Anthropocene Review*, *1*(1), 62-69; Head, L. (2014). Contingencies of the Anthropocene: Lessons from the 'Neolithic'. *The Anthropocene Review*, *1*(2), 113-125;

[4] Spivak, G. (2003) *Death of a discipline.* New York: Columbia University Press, 72.

Thinking difference in the Anthropocene is particularly difficult because the concept posits humanity as a species, yet clearly not all humans have the same geologic influence, and humans will not suffer and flourish equally in the Anthropocene. While geographers and others have frequently championed the local as the scale for analysis and action, and the particular over the universal, the question still remains: "how do we massify the particular into the universal without asserting particularity as immediately representative of universality, thereby magnifying our local epistemological standpoints into global universalisms?"[5] This question clearly has both epistemological and ethico-political dimensions. It is not just a matter of how we know the Earth. This is the question of how to understand ourselves as humans. This goes beyond debates about the justification of the species concept and inquires into how we position ourselves as beings, both at risk of extinction or ecologically destructive, and with "something *in common* with the geologic forces that are mobilised and incorporated."[6]

Yet, understanding the human subject in this way cannot be separated from the challenge of locating Anthropocene subjectivities in a highly differentiated world, one overcoded by legacies of imperialism, capitalism, and colonialism. Herein lies the challenge that this dissertation addresses: on one hand we are compelled by the world ocean on a planetary scale; we cannot *not* think it. On the other hand, such a notion risks taking the ocean's planetary nature as inevitable and as grounds for ignoring brutal inequalities and particular histories that challenge ideas of a unitary human species, one

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[5] Canavan, G., Klarr, L., & Vu, R. (2010). Ecology and Ideology: An Introduction. *Polygraph: An International Journal of Culture and Politics*, *22*, 11.
[6] Yusoff, K. (2013). Geologic Life: Prehistory, Climate, Futures in the Anthropocene. *Environment and Planning D: Society and Space 31*(5), 781.

world to which the ocean might, in some way, belong. The conundrum is heightened by the fact that the ways in which the ocean is known as a world ocean have themselves been on the side of militarized, capitalist, West-centric power, thereby producing some of the inequalities and tensions that the world ocean concept seems to elide.

This dissertation both mines and minds this conundrum, this apparent impasse, by exploring some of the conditions of possibility for the emergence of the world ocean; the assemblages of humans, nonhumans, technologies, and Earth forces that have brought it into being and through which its contradictions and tensions are expressed. Through a historical and material engagement with the ways that the ocean has come to be known on a planetary scale, I explore and broaden the stakes of the world ocean, and examine how it might, read differently, compel us toward more ethical relations across difference in a time of dramatic environmental change.

Oceanography and knowing the world ocean

Oceanography is the discipline that is fundamentally occupied with knowing the world ocean, and therefore marks an important entry point for understanding the politics of the world ocean. In this dissertation, while acknowledging the longer history of oceanography and other forms of making meaning with/about the sea, I focus on the radically distinct form that oceanography adopted during World War II and that developed further in the years following. These efforts, which aimed to qualitatively and quantitatively know the ocean as one dynamic entity, form the basis of my empirical and conceptual exploration in this dissertation.

Therefore, in this work, I argue that the emergence of the world ocean was concurrent with the emergence of modern oceanography, and both heralded a new way of understanding the planet and its relation to an imagined global humanity. As an inroad, we might take oceanography's relative novelty as instructive. Stengers writes: "the existence of a new scientific field, when it regards itself as interdisciplinary, always depends upon its capacity to mobilize."[7] We might ask, what and whom does oceanography mobilize? What are its mobilizing tactics? In recent years, as I will show, the effort to understand the ocean as a world ocean has become both an overarching umbrella and a mobilizing foist for the coherence of oceanography, although the questions of how, to what ends, and for and by whom are still open questions.

In this dissertation, I trace the emergence of the world ocean as a concept that reconfigures material practices of making sense with and of the sea. The construction of the world ocean requires the interest of scientists, politicians, and other world-makers just as much as it requires material artifacts or the discovery of physical properties. Writing about the emergence of artificial life, Stengers has this to say:

> "The scientist's care is addressed not to this or that emergent collective property as such, as having a meaning by itself, testifying for instance for this or that configuration of the automata's interconnections. It is addressed to possibility, to the possible meaning or relevance such an emergent property could acquire from his or her outside point of view."[8]

I use Stengers' words here not to say that the world ocean constitutes a kind of 'artificial life' but to appreciate more fully what is at stake in the emergence of the planetary scale, using a scientific standpoint not as a grounds for some false positivity, but as a way of

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[7] Stengers, I. (2000). God's Heart and the Stuff of Life. *Pii 9*, 89.
[8] Ibid., 111.

understanding potential, and as a way of considering the forms of attention that science engages. It is to encourage us to take on the view of the scientist, thus imagined: to ourselves pay attention not to the 'truth' of a world ocean, but to the possibilities it opens, and moreover to understand the full meaning of the world ocean then both as a consequence of its properties and of our interest.

Such an approach allows me to both write and not write a dissertation about oceanography. While I hope to contribute to the underdeveloped field of social science studies of oceanographic science, and relatedly of climate and earth sciences, my study analyzes how the ocean has come to be understood, without losing sight of its materiality. As Naomi Oreskes has said, "The stuff of science itself—the materials of the natural world that natural science aims to understand—in many ways continues to elude [historians of science]."[9] An interest in learning how the world ocean comes to be known, how efforts to know it incorporate or elide geopolitics and social variables, and how difference and inequality shape and are shaped by ocean world-making on a planetary scale, all lead me to international oceanographic projects that have been designed and executed in the last 75 years. Hence, existing literature on the politics and epistemologies of oceanographic science, as well as the daily practices of oceanography, can provide helpful guideposts for how oceanography has unfolded and the impacts it has had.

In a 2014 special issue of the history of science journal *Isis*, Naomi Oreskes asserted that historians of science had not paid due attention to oceanography, not to

[9] Oreskes, N. (2014). Scaling up our vision. *Isis*, *105*(2), 380.

mention the sea more broadly.[10] One potential reason, according to Oreskes, is that oceanography itself has a short history, and even in its current form barely holds together as a cohesive discipline. While oceanography now commands large budgets and significant expertise, for much of human history the sea was thought to be uninteresting for science, largely stagnant and devoid of life, or else too hard to access; oceanography then was "opportunistic, as scientists (or their proxies) worked from ships that sailed for commercial or military reasons, creating some well-studied oceanic pathways (such as the Atlantic Gulf Stream) but leaving large swaths of territory virtually untouched."[11] Even now, oceanographers tend to have greater affinity with the disciplines that govern their subfields (e.g. physical oceanographers with physicists, marine biologists with biologists, etc) than with oceanographers in other subfields. As Oreskes writes, "Oceanography as a discipline still, in some ways, does not quite exist."[12]

At the same time, oceanography is 'big science' in every sense of the term.[13] It consists of long relational chains with unapologetically global aims. It is largely funded by Western navies and uses tools that have both been adapted from, and provide fodder for, Western militaries. In conventional oceanographic studies, particularly of 'blue

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[10] Ibid.
[11] Ibid., 381.
[12] Ibid., 382.
[13] See for example Harris, S. (2011). Long distance corporations, big sciences, and the geography of knowledge, in Harding, S. (ed) *The postcolonial science and technology studies reader.* Durham, NC: Duke University Press, 61-83; Aronova, E., Baker, K. S., & Oreskes, N. (2010). Big science and big data in biology: from the international geophysical year through the international biological program to the long term ecological research (LTER) network, 1957–present. *Historical Studies in the Natural Sciences 40*(2), 183-224.

water,' or non-coastal oceanography, there has been little room for what we might call traditional or minoritarian knowledge. Hegemonic and positivist forms of knowledge are primarily responsible for giving us the picture of the world ocean that many of us can easily call to mind. Is it possible for the notion of the world ocean, created by big militarized technoscience and called up by the most reactionary and mainstream environmental conservationist politics, to be redirected toward any more emancipatory potentials? Is it possible for the 'world ocean' to lead not just back to business as usual, but to a better, more just world? If we want to answer this question in the affirmative, we must not denounce technoscience as a whole, but rather try to understand its workings so we can intervene in its constitutive relations and claim it for alternate ends.

When it comes to big science, critical scholars have taken two seemingly opposite approaches. On one hand, many are critical of big science for its pervasive and seemingly inevitable flattening of difference and the ways in which it perpetuates falsely positivist beliefs, not to mention racial, economic, and gender inequalities. It legitimates one kind of knowledge at the expense of others. On the other hand, some critical scholars think the time for such critiques has passed. 'Big science' is necessary for the work we must do to address the causes and effects of global environmental change. I take both of these positions as starting points rather than conclusions. How can we think on the planetary scale without erasing difference? Moreover, how is difference woven into our very understandings of the planetary? How is the planetary scale formed through difference? How is the becoming of the planet tied up with other becomings? These are the questions that animate my inquiry.

Feminist STS and the world ocean

Fortunately for me, feminist science studies scholars provide rich roadmaps for thinking the co-constitution of science and difference. In particular, I follow Donna Haraway and Karen Barad's development of diffraction as a methodological approach to "reading insights through one another in attending to and responding to the details and specificities of relations of difference and how they matter."[14] They pose diffraction to counter reflection. Both are optical metaphors, and reflection (or reflexivity) has gained much popularity as a methodology in the social sciences and humanities in particular during the last several decades. Scholars, particularly those aiming to make truth claims, are exhorted to be reflexive about their positionality, the situated nature of their knowledge, possible sources of error and inaccuracy, etc. In other words, reflexivity is supposed to account for the role of the knower in the production of knowledge. Science studies scholars were particular champions of reflexivity. Barad outlines two major critiques of reflexivity as methodology, which come from feminist science studies scholars. First, these methodologies attend to "science-in-the-making" without attending to how science, gender, race, and other "social variables" are co-constituted.[15] They take these variables as fixed categories. Barad's second critique is rooted in the fact that reflexivity "is based on the belief that practices of representing have no effects on the objects of investigation and that we have a kind of access to representations that we don't have to objects

[14] Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Durham, NC: Duke University Press, 71.
[15] Ibid., 87.

themselves."[16] Reflexivity then creates the illusion that the knower can be known (even to themselves) and that the effects of their knowledge practices can be distinguished from the thing they are studying itself. In other words, reflexive practices create (or maintain) a distance between the subject and the object, even when "raised to the nth power."[17] It is nothing more than a "self-referential glance back at oneself," which "still holds the world at a distance."[18] Even if not trying to make an ontologically accurate copy, it still promotes belief in that possibility.

Diffraction is a different kind of optical metaphor altogether. When light is reflected, it bounces back, creating a mirror image: a copy that maintains fidelity to the original. However, when light is diffracted (through a screen, grating, or crystal), it creates patterns of difference, of interfering or overlapping waves. These waves tell as much about the diffractive instrument as they do about the nature of light. A diffractive methodology, then, is one that is attentive to the ways in which knowledge practices create and arise from differences. In other words, it is not concerned with whether accurate representations are made (in science or elsewhere), but asks a different sort of question, about how different disciplines are co-constituted and how through these relations they make worlds. As Barad writes, "making knowledge is not simply about making facts but about making worlds, or rather, it is about making specific worldly configurations - not in the sense of making them up *ex nihilo*, or out of language, beliefs, or ideas, but in the sense of materially engaging as part of the world in giving it specific

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[16] Ibid.
[17] Ibid., 88.
[18] Ibid., 87-88.

material form."[19] A diffractive reading is one that sees knowledge practices as making difference and seeks to understand what differences they make, as well as "how [these differences] matter, and for whom."[20]

For my project, diffraction is both a methodology and a goal. I share Haraway's (and Barad's) aim of "diffract[ing] the rays of technoscience so that we get more promising interference patterns on the recording films of our lives and bodies."[21] And yet, a diffractive reading of oceanography, or any reading that tries to understand oceanography and politics together, is not an obviously natural fit. Post-WWII oceanography is disciplinarily silo-ed in both science and the study thereof. Marine biology and fisheries science tend to get the lion's share of attention from social science scholars. Similarly, feminist science studies scholars have rarely studied the physical or Earth sciences (Barad, and to some extend Stengers, being exceptions). This is not without reason; physics, chemistry, and their oceanographic kin are frequently relegated to the realm of 'pure science,' and not only does their validity depend on their apparent divorce from social influences but their practitioners have sought, in many instances, to maintain this divide. For example, many prominent oceanographers tried to widen the gulf between oceanography and marine biology/fisheries science, with statements such as this: "[fisheries scientists] have been so much occupied with urgent day-to-day problems, immediate applications and remedial measures that they have been able to spare too little

[19] Ibid., 91.
[20] Ibid., 90.
[21] Haraway, D. J. (2004). *The Donna Haraway reader*. New York: Routledge, 16.

effort to make the science really effective."[22] More broadly, the biological sciences are by definition concerned with life, and therefore would seem to be more closely aligned with or relevant to politics, especially biopolitics, which seek to govern forms of life. Definitions of social difference, and knowledge forms that have perpetuated its exploitation, are frequently aligned with the life sciences. Yet, under current regimes of environmental change, the Earth sciences are taking on an increasingly political nature.

Studying social difference, not to mention the foundations for capitalism and imperialism, by focusing on a physics subdiscipline seems at first counterintuitive. While gendered practices have been well documented in the life sciences, physical oceanography might be seen as exclusionary to the point of being uninteresting from a gender studies perspective. There is no doubt that oceanography, especially in the Western world, extended the traditions of white masculine seafarers, on militaristic missions of imperial expansion, conquering with knowledge instead of arms but for the same ends. Yet, as Oreskes points out, although nearly all the big names in physical oceanography are men, women in fact participated in oceanographic science in important although more hidden ways.[23] Furthermore, gender and race are made in the process of doing oceanography, just as they are made in the process of practicing the life sciences.[24] I want to ask after the spaces that have been seen as outside the study of race, gender, and politics, ocean spaces that are outside both national sovereignty and to the daily

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[22] The National Archives of the UK, ED 121/721, Martin to Dovey.
[23] Oreskes, N. (2000). " Laissez-tomber": Military patronage and women's work in mid-20th-century oceanography. *Historical studies in the physical and biological sciences*, 373-392.
[24] Haraway, The Donna Haraway Reader.

experiences of most human bodies and explore "how to imagine human presence - ethnographic, oceanographic - in or in relation to these realms."[25]

For these reasons, I think my reading of oceanography can push a diffractive methodology, and indeed feminist science studies, in different directions, as we are asked anew to consider what gender means, what life means, and to what feminism and science might each be addressed. A diffractive reading of oceanography and social theory allows me to attend not to differences and similarities between the fields, but instead to "the specific material relations and how these intra-relations matter."[26] The emphasis here is on how oceanography, ideas about planetary nature, geo-politics, and markers of difference such as race and gender have been co-constituted; and how my work contributes to these material entanglements. There are three facets to this concern with material relations. First, I am concerned with the co-constitution of oceanographic science, international geopolitics, and markers of difference, such as race and gender. Second, I examine how oceanography and those fields concerned with politics and difference are united by material influences; by concern with, or entanglement with, similar Earth forces (even while recognizing these Earth forces are always in the process of becoming). For example, how might oceanography and Atlantic studies be understood to influence one another through a mutual concern with ocean circulation, even if they understand it quite differently? Finally, how has my research (recognizing that it is

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[25] Helmreich, S. (2008). *Alien ocean: Anthropological voyages in microbial seas*. Berkeley, CA: University of California Press, 28.
[26] Barad, Meeting the Universe Halfway, 94.

unbounded and impossible to reflect objectively upon) engendered its own set of material entanglements?

A diffractive reading constitutes what some might call a transdisciplinary approach, which "does not merely draw from an array of disciplines but rather inquires into the histories of the organization of knowledges and their function in the formation of subjectivities."[27] Antonio Benitz-Rojo puts it in more sensuous language, quoting Braudel: "Interdisciplinarity is the legal marriage of two neighboring sciences. But as for me, I am for generalized promiscuity."[28] My project asks what might be gained from a generalized promiscuity between oceanography and critical social theory, particularly, as Benitez-Rojo presciently notes, when knowing global environments no longer involves asking how to "represent reality through an equation or a poem, but works rather toward imparting an ever more acute sense that reality is not representable."[29]

Methodology

Even when equipped with the theoretical tools for studying something like big science, one can face a conundrum of how and where to begin. For me, locating my world ocean research was an incidental but non-random process. Beginnings, as always, are false markers. My work began many times over, with my first move away from my land-locked hometown to a city by the sea, with six weeks of Masters research in Sri Lanka, where the sea was always present, with a largely failed trip to understand ocean politics

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[27] Hennessy, R. (1993). *Materialist feminism and the politics of discourse*. New York: Routledge, 12.
[28] Benitez-Rojo, A. (1992). *The repeating island: The Caribbean and the postmodern perspective*. Durham, NC: Duke University Press, 150.
[29] Ibid., 151.

in North Africa. But I can say with some honesty that my project was catalyzed by the opportunity to speak with oceanographers at the Woods Hole Oceanographic Institute (WHOI) in November 2013, when I visited the institute for the Graduate Climate Conference. Here I had the opportunity to talk with prominent oceanographers about my interests, and to see how the notion of the world ocean might catalyze thinking about the politics of oceanic relations. Not only did they help me to periodize my framework and identify interesting concepts, but I was also struck by how readily the oceanographers pointed to the politics of their research, and by the potential for making other connections that I could sense in the science they explained to me.

The kindness and creativity of oceanographers would be a repeating theme in my research, as I conducted approximately 40 interviews at the National Oceanographic Centre in the UK, WHOI again, and the Marine Research Institute in South Africa in 2014. These interviews were largely unstructured and somewhat meandering, as I both tried to learn more about oceanographic science and to understand the 'story' of oceanographic projects: their motivations, what technologies were used and how, and how they 'saw' the world ocean. I also spoke with bureaucrats at the Intergovernmental Oceanographic Commission (IOC) in Paris and with science funders at the National Science Foundation in Washington DC. The science bureaucrats at the IOC gave me insight into how international oceanography is organized at the highest levels, and how it is integrated with other intergovernmental diplomatic dynamics. The NSF officers helped me understand changing priorities in US-funded research and new developments in international collaborations and international science governance.

In addition to these interviews, which each lasted about an hour in duration and took place during visits of a few days or weeks, I draw on experience and conversations as a visiting researcher with the Marine Research Institute (Ma-Re) at the University of Cape Town (UCT) in South Africa. During this time, I attended regular seminars, daily informal departmental teas, and shared many conversations and meals with my lab-mates, departmental colleagues, and visiting scholars. I also was able to interview scientists at Ma-Re and UCT with more familiarity, both with them and their work. I decided to pursue this residency as the scientists with whom I worked in the US and UK identified South Africa as a global South collaborator. In addition, South Africa has a unique geographical and geopolitical position. At the confluence of two major ocean currents (the Agulhas and the Benguela) and three oceans (the Indian, the Atlantic, and the Antarctic or Southern), there is a lot going on, and local dynamics are understood as immediately global due to the huge importance for the global climate of the Southern Ocean in particular. South Africa is also a continental leader in oceanography, although it maintains developing nation status and is a frequent target and host to capacity-building workshops and other efforts.

Of course, oceanography in South Africa is inseparable from the politics of Apartheid and ongoing inequality. Apartheid, and global responses, created an interesting landscape for South African oceanography; on one hand, the Apartheid government actively invested in oceanography, as a way to build national scientific expertise to counter international exclusion. On the other hand, South African scientists were frequently the only people affiliated with the government (however loosely) who were able to travel and participate in international projects due to long-standing policies of international scientific unions to not exclude representatives from any nation for political reasons. Oceanographic labor was further influenced by racial politics, and oceanography today remains an elite occupation of mainly white men, although there are different interpretations of the cause of these uneven demographics. Much more could be said about inequality and oceanography in South Africa than I am able to include here given the overall focus of the dissertation. Unfortunately it will have to suffice here to say that the politics of difference were apparent to me not as deviations from a normal system of objective science but as always constitutive of it. Relatedly, I am glad to be able to include views and expertise from South Africa not as an alternative to big science from the US and UK but as a core part of what makes oceanography global.

My interviews with scientists and my residency at Ma-Re were paired with extensive research in archives in the US, UK, and South Africa. I asked similar questions of the archives as I did of the scientists, especially about scientific projects that occurred prior to the careers of most currently practicing scientists. My work in the archives was also a chance to glimpse the larger context in which these scientific projects transpired: the geopolitical machinations around their conceptions and executions, as well as how they were interpreted in various media forms. The archives also prompted me to think more deeply about the materiality of history, the process of interpreting history, and the bureaucratic frameworks for collecting, organizing, indexing, and making available historical texts.

To some extent, this dissertation follows scientists to learn what can be said about 'big science' through a genuine engagement with the people who do it. One could write a critique of oceanography without ever speaking to a scientist. I take a different approach, attentive to their forms of world-making, open to the complexities of their motivations and methods. Yet in the end this is not a dissertation about scientists; they are not the subjects of my study. Nor do I afford the kind of attention to the daily practices of oceanography that a traditional STS or even political ecology study might. While I do focus at times on key technologies, methodologies, and scientists, I cast my analytic net wider, enquiring into organizing principles, paradigmatic shifts, and geopolitical influences that go into studying the world ocean. This is not necessarily a better method than one that focuses more specifically on daily practices, but it is a different one, and with it I hope to have sketched the project of knowing the world ocean in the most expansive sense.

Dissertation Outline

My dissertation focuses on key planetary knowledge practices that have been developed in historically and geographically contingent scientific projects from which the world ocean concept has emerged. The first chapter discusses the concepts of world, globe, and planet, which underlie my project. The second and third chapters analyze the advent of the two governing paradigms of planetary oceanographic thought: synopticity, or the study of the ocean as a single coherent entity; and systematicity, or the view of the ocean as a dynamic system. The fourth and fifth chapters examine contemporary ocean technopolitics, in particular the multiple dimensions of a shift from ship-based oceanography to sensing by distributed, remote, and robotic sensing. Finally, I propose the ocean archive as an interdisciplinary way of conceiving the planetary ocean that takes into account legacies of difference and ongoing relations of oppression and injustice.

The first chapter of *Planetary Sea* provides a review of the concepts of world, globe, and planet, and explores how they have been deployed with regard to the sea. I argue that these terms are not mutually exclusive, but rather all are necessary for understanding the world ocean. I also explore what it means to know planetary environments, a question that remains central throughout the dissertation.

The second chapter explores the emergence of the synoptic paradigm by examining the oceanographic program of the International Geophysical Year (IGY, 1957-58), widely recognized as the first sustained attempt to develop comprehensive knowledge about the Earth at a global scale. I argue that the IGY inaugurated an enduring regime of planetary knowledge production that posited a global environment that elided human difference. This global milieu is legible in contemporary discourses of the Anthropocene. Moreover, I show how synoptic science sutured together old and new forms of imperialism, demonstrating 'big science' dynamics that traditional STS approaches are likely to miss.

Chapter Three examines the advent of systematicity as a complimentary paradigm to synopticity. I explore early efforts to understand the ocean and atmosphere as one dynamic system in the World Ocean Circulation Experiment (WOCE, 1990-2002), which sought to obtain the first complete picture of global ocean circulation. Systematicity is crucial to climate change scientists, but it has been approached with suspicion by some scholars in the social sciences and humanities, who argue that it propagates a simplistic view of the Earth as equilibrium-seeking or entirely interconnected, ignoring both the seriousness of contemporary environmental issues or, conversely, providing a false justification for top-down, non-democratic measures of planetary management (e.g. Colebrook, 2012). However, my analysis provides a different interpretation: that a close examination of systems dynamics explored in WOCE shows the ocean-atmosphere system to reveal unexpected planetary volatility, indicating that Earth systems are neither self-healing nor easily managed through planetary controls like geo-engineering.

In Chapter Four of *Planetary Sea,* I aim to sketch the conceptual political contours of contemporary ocean technopolitics, which are changing knowledge and governance of the world ocean. The Global Ocean Observing System (GOOS) comprises a largely autonomous and distributed network of ocean sensors. The GOOS shows the ambiguous role that technological Earth observing systems occupy in planetary politics: some authors argue that they erase politics and promote a flattening and false "view from everywhere."[30] Others, primarily scientists, laud their potential to democratize science through open access and real-time data (e.g. Wilson, 2000).[31] In Chapter Four, I analyze the problem that GOOS poses for biopolitical analysis; it makes the ocean informational, treating it as streams of data similar to how human subjects are treated, yet the ocean cannot be considered as one subject among many. Rather, I argue that Elizabeth

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[30] See for example Hulme, M. (2010). Problems with making and governing global kinds of knowledge. *Global Environmental Change*, *20*(4), 559; Litfin, K. T. (1997). The gendered eye in the sky: a feminist perspective on earth observation satellites. *Frontiers: A Journal of Women Studies*, 26-47.
[31] See for example Wilson, S. (2000). Launching the Argo Armada. *Oceanus, 42*(1), 17-19.

Povinelli's formulation of geontopolitics is helpful in diagnosing the role of geophysical systems and their attendant knowledge practices in emergent modes of government directed to potentiality rather than to life as such.

In Chapter Five, I address the daily practices of doing oceanographic research under new regimes of remote and robotic ocean observations. I seek to understand the affective and embodied implications of this shift away from ship-based oceanographic research. While some may see this trend as a key step in the dangerously distancing abstraction of nature, I argue that it deserves closer study. The opportunities for new relations created by a move to distributed, robotic, and remote sensing show some of the inequalities and violences that are elided by romantic notions of going to sea for science.

Finally, I offer an alternative knowledge practice that would build on two oddly resonant traditions to understand the ocean as a lively planetary archive. Some postcolonial scholars have written of the ocean as an historical repository; a collector of the histories, bodies, and ways of life that dominant narratives would rather forget.[32] Scientists also recognize the ocean as a kind of record, following materials or water masses through time to understand ocean circulation and trace the impacts of substances such as radioactive isotopes and plastics. The concept of the ocean archive prompts questions: who is recognized as a writer? Who reads the ocean archive? What materials get preserved, how they are they arranged and catalogued, and who has access to them? These questions are impossible to answer definitively; despite the efforts that I chart

[32] See for example Benitez-Rojo, The Repeating Island; Tynan, M. (2010). Polyps, Plankton, and Passages: Mythopoeic Islands and Long-Memoried Seas. *Space and Culture*, *13*(2), 144-153.

above, we still simply do not know much about what the sea contains, much less where, when, or how it might surface and become available to a human reading. It is therefore the questions rather than their answers that suggest an alternative understanding of the ocean, one in which planetary thought is possible without the erasure of difference.

For oceanic relations

The ultimate aim of my dissertation is to read 'big science' in a way that promotes and deepens the politics (and poetics) of relation, forwarded by postcolonial writers such as Edouard Glissant, Alexander Weheliye, and John Mbiti, among others. To rethink relation along planetary terms, from a perspective that takes into account all the violences and possibilities of international ocean science. Postcolonial studies, broadly put, has seized the ocean as a spatial heuristic, and a constitutive part of racialized experience across the Atlantic. How could both the material insights offered by oceanographic science and the material entanglements that result from *doing* science augment the promise of the ocean as a space for imagining emancipatory relations? Relations that emerge through difference, not despite it; relations that are uncanny; relations that are weighted with history while at the same time capable of imagining history differently.

Glissant is a great thinker of relation through the sea.[33] He advocates for a rhizomatic method of thought (similar to that which informs assemblage thinking) which he terms errantry. Errantry, according to Glissant, cannot be realized by circular nomadism or voyages of conquest; it comes after the establishment of territory and the self as well as the conquest of the 'other,' it "silently emerges from the destructuring of

[33] Glissant, E. (1997). *Poetics of relation*. Ann Arbor: University of Michigan Press.

compact national entities that yesterday were still triumphant and, at the same time, from difficult, uncertain births of new forms of identity that call to us."[34] It is also worth noting that sea imagery figures prominently in Glissant's exploration of errantry and relation, a reflection, perhaps, of his Caribbean origins and the root of his theory in the experience of Antillean slavery. For Glissant, the achievement of errant thought will be creative and unbounded relation, such that totality might be thought without generalization. Crucially, Glissant's relational thought denies the Western desire to make the 'other' transparent, and thus capable of being grasped, enclosed, and known. He advocates for the opacity of the 'other' and of the self, such that one's identity need not (and indeed cannot) be fully known in order to be worthy of recognition.

For Spivak the drive for relation comes from what she calls the human trait of tendency toward the 'other', which may be understood as at the heart of every risky voyage across the sea.[35] For Glissant, relation is prompted by an attempt to grapple with the unknown, an attempt he historicizes as central to the oceanic experience of slavery (as mentioned above). As Monique Allewaert points out, the ball and chain gone green from ocean journeys, washed up on the shore, cannot tell the specific histories of individual slaves.[36] But, "this absence and opacity suggests a myth of history whereby it is possible to hold together noncontiguous historical moments, to open each to the other and to fill this opening with repetitions and resonances that, as they accumulate, allow historically

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[34] Ibid., 18.
[35] Spivak, Death of a Discipline.
[36] Allewaert, M. (2013). *Ariel's ecology: Plantations, personhood, and colonialism in the American tropics*. Minneapolis, MN: University of Minnesota Press.

informed speculations about the artifacts and persons who vanished without being included in traditional historical archives."[37]

What is at stake in Glissant's writing, and that of the others mentioned above, is the possibility and promise of new "we-formations."[38] This is a 'we' that "holds together human beings, terraqueous powers, and artifacts."[39] My work builds from this to understand the we-formations that have produced the world ocean and considers how alternative we-formations might be developed from the world that has been made by international oceanographic technoscience. What special role might science have in building this 'we'? The point is not to denounce science nor scientists; this is especially risky in the current political climate. Rather, it is to facilitate the questioning, sorting out, and realignment of interests between and within scientists and others. In Stengers' words, I hope that my work on science might "actively create the possibility of new types of 'we' which will undo the molar socioprofessional strata and their order-words."[40] Ultimately, Stengers' words again seem appropriate: "In the scientific comedy, I hope scientists will be able to heartily laugh when they understand that their bond with their creation has actually transformed them, lured them towards new feelings, new possibilities, new ways of becoming."[41]

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[37] Ibid., 24.
[38] Glissant, Poetics of Relation; see also Macharia, K. (2015). Mbiti and Glissant (blog post). *The New Inquiry* 9 March 2015 http://thenewinquiry.com/blogs/wiathi/mbiti-glissant/
[39] Allewaert, Ariel's Ecology, 50.
[40] Stengers, God's Heart and the Stuff of Life, 90.
[41] Ibid., 117-118.

CHAPTER ONE: WORLD, GLOBE, PLANET

NASA's spectacular *Perpetual Ocean* visualization is something of a wish fulfilled. Its short and long videos, as well as resulting stills (see Fig. 1.1), represent a feat of both design and data processing. It shows the planet as defined by one dynamic, interlinked ocean. The viewer swoops low and easily over the surface, and the patterns of eddies and trade winds unfurl beneath. One can imagine that if we were able to dive below the planet's blue skin, we might be able to similarly see the deep ocean currents, the global conveyor belt, responsible for transporting heat and nutrients between the equator and the poles. And if we were visualizing different (yet related) processes we might see, for example, the ocean absorbing the majority of the heat in the atmosphere and massive quantities of our CO2 emissions, while, on different timescales, weathering heavy metals

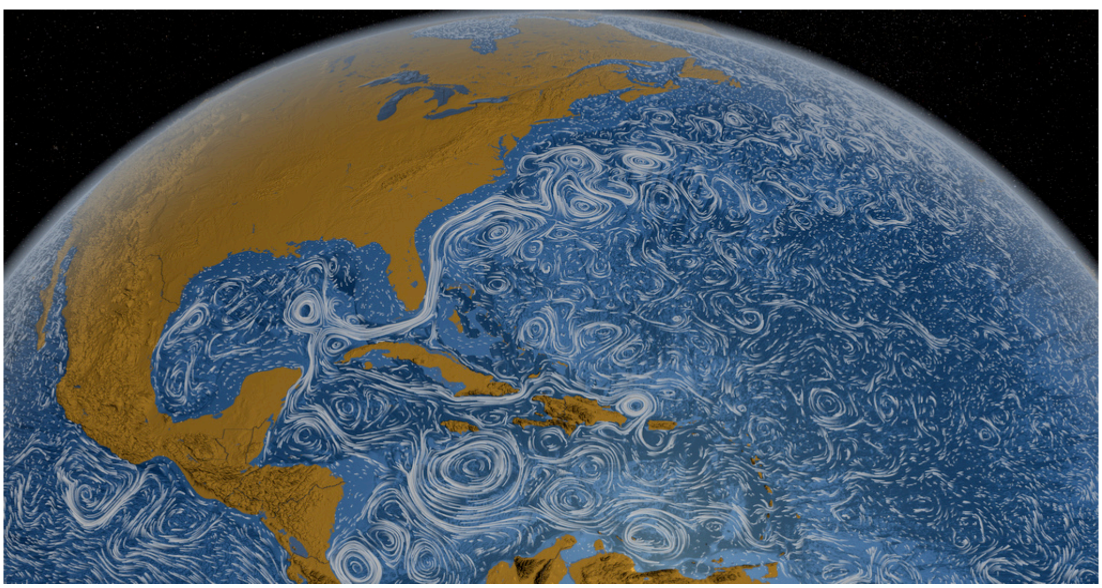

Fig. 1.1: Still from NASA *Perpetual Ocean* (Source: http://www.nasa.gov/topics/earth/features/perpetual-ocean.html#.VxguuxJrjUp)

and radioactive wastes that have been accumulating for decades if not centuries. It is a world ocean.

Why is this conception of the sea as a world ocean, a single dynamic entity with an intimate and vital relationship to all life on Earth, significant? Clearly, this is a view of the ocean that has to be constructed; no one experiences the ocean as a world ocean in their daily lives, just as no one experiences the global climate.[1] The construction of the world ocean is then a process that deserves the attention of political ecologists, political geographers, and science and technology scholars. Its construction is necessarily one involving geopolitical tensions, epistemological battles, and a truly fascinating array of everyday material entanglements between bodies, technologies, and Earth forces. In this sense, a study of the construction of the ocean as a world ocean might have much to contribute to emerging humanistic and social scientific research on the ocean, including human geography of the ocean.[2]

However, the stakes of this inquiry are higher. The politics of understanding the ocean as one planetary entity point directly to a tension regarding the politics of scale, knowledge, and representation that is central to contemporary environmental thought, and to which I have already alluded. Put simply, how can we grapple with global-scale understandings of environmental dynamics, while accounting for the uneven, and frequently unjust, experiences of existence (both human and nonhuman)? When attention to local practices, embodied connections, and micropolitics has been critical social

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[1] Edwards, P. N. (2010). *A vast machine: Computer models, climate data, and the politics of global warming*. Cambridge, MA: MIT Press.
[2] See for example Anderson, J., & Peters, K. (Eds.). (2014). *Water worlds: human geographies of the ocean*. Burlington, VT: Ashgate Publishing, Ltd.

science's rallying cry, how can we contend not simply with global environmental change but also the practices by which it comes to be known? How can we hold intimate embodied experiences and global ocean environmental dynamics in our thought (and our politics) at once? Even more, how might our capacities for imagining and enacting a more just and sustainable future be augmented by planetary concepts of the ocean? These are some of the questions that I tackle in the rest of the dissertation as I attempt a diffractive reading of international marine technoscience.

Before we begin, however, it is necessary to unpack some of the concepts mentioned above – concepts of world, globe, and planet, which contain within them different ontologies and scholarly traditions regarding scale, space, and practice. The notions of world, globe, and planet are all necessary for my analysis. While one could interpret them as contrasting one another, I find it useful to take together their different conceptual emphases, considering how each is drawn through the others. In this chapter, I argue that world, globe, and planet are all necessary for understanding the emergence of the world ocean as not simply a representation of the sea but as a complex entity, felt in individual bodies, operative on inhuman spatial and temporal scales, and ultimately with the possibility of fostering conditions for more ethical planetary relations. In making this argument, I hope to ultimately make clear what is at stake in the concept of the planetary; that it is more than a 'scaling up' or amalgamation of various 'locals,' and that moreover it is shot through with alterity that opens rather than forecloses opportunities for more just engagements.

The world

While ideas of the world as a concept have varied lineage, for my project Heidegger's ontology, in particular as it is taken up (and, I would argue, extended) by Donna Haraway, remains at the fore. Worlds, for these scholars, are always worlds for someone (or something). In other words, the world cannot be separated from heterogeneous experiences of it. The world, then, cannot be understood as a pre-existing entity (what Heidegger calls an ontical reality).[3] Put differently, the world, Heidegger says, is not a totality of what the subject is not; it is the environment of the subject (Dasein). This idea resonates with von Uexküll's assertion that all creatures dwell within an *Umwelt*, or entirely subjective perceptual milieu.[4] Crucially, then, because worlds are based on sensation and relation, they are always becoming, never stable entities that can be determined in advance. This ontology becomes especially important when we move to consider the globe as a form of world-making, because it refuses the illusion that the globe presents, of a self-evident and pre-given whole.

Haraway raises the stakes further, and it is through her contributions that I theorize the making of an oceanic world. She emphasizes that not only are worlds subjective, but they are formed through encounter with human and nonhuman others.[5]

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[3] Heidegger, M. (2008). Being and time (Macquarrie, J & Stambaugh, J, Trans.) New York: Harper Perennial. (Original work published in 1927) p. 93.

[4] Von Uexküll, J. (2010). *A foray into the worlds of animals and humans* trans. (J O'Neil, Trans.) Minneapolis, MN: University of Minnesota Press. (Original work published 1929).

[5] See for example Haraway, D. J. (1994). A game of cat's cradle: science studies, feminist theory, cultural studies. *Configurations*, *2*(1), 59-71; Haraway, D. J. (2004). *The Donna Haraway reader*. New York: Routledge; Haraway, D. J. (2008). *When species meet*. Minneapolis, MN: University of Minnesota Press.

For Haraway, worlding is a collective process that gives shape not only to the world but also to all its entities, including humans. All encounters are ways of becoming worldly, or making worlds, and the task is to attend to the specificities of particular embodied encounters. But technoscience is also a form of world-making or becoming worldly for Haraway, and it is a non-optional one. She is careful never to privilege 'pure' nature or 'pure' unmediated encounter. For Haraway, worlding is always "mortal, situated, and relentlessly relational."[6] Haraway takes this logic further, adamant that worlds are not formed from the encounter of already-existing individuals, but that individuals (and the very idea of individuals) result from encounters; no essence precedes or survives encounters with others. World-making also emphasizes the co-constitution of discourse and materiality, without privileging either. In sum, worlds do not emerge randomly nor can they be willed into existence, but neither are they pre-determined or complete; they are always being changed through encounter. And through participating in these encounters themselves, researchers might "learn something about how worlds get made and unmade, and for whom."[7]

If world-making is Haraway's focus, she sees her project as *autre-mondialization,* or other-worlding; refiguring technoscience so as to bring another world into being. As Haraway writes, the term autre-mondialization was "invented by European activists to stress that their approaches to militarized neoliberal models of world building are not about antiglobalization but about nurturing a more just and peaceful other-

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[6] Gane, N. (2006). When we have never been human, what is to be done? Interview with Donna Haraway. *Theory, Culture & Society*, *23*(7-8), 143.
[7] Haraway, A Game of Cat's Cradle, 70.

globalization."[8] The idea of non-optional world-making stresses the need for affirmative critique - a position of pure negativity is not even possible because worlds are always being made anew. While Haraway does not cite them specifically in this instance, this desire for other-worlding can be found throughout the writing of the post- or anti-colonial scholars on which I draw. This desire to bring another world into being animates my approach to ocean technoscience and to the broader project of critique in regard to technoscience and geopolitics.

Literature on oceanic world-making until recently has been rather sparse. There has been a long tradition in Western scholarship of portraying the ocean as separate from culture, language, politics; the blank space on the map, the zone of the sublime, far from daily embodied experience, requiring much technological mediation, special equipment and training, only accessible for short periods of time, prone to causing the human body and psyche great discomfort.[9] Even now, this literature remains patchy, focusing on somewhat esoteric encounters, such as leisure activities, natural disasters, and fishing/coastal livelihoods. For example, Jon Anderson believes that surfers have an exceptional affective relationship to the ocean, though he does not acknowledge the systems of privilege that underlie such an account.[10] The ocean, of course, also makes worlds during natural disasters such as tsunamis, hurricanes, and storm surges, and this has been so well documented in both critical and mainstream geographic literature that

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[8] Haraway, When Species Meet, 3.
[9] Steinberg, P. E. (2001). *The social construction of the ocean*. Cambridge, UK: Cambridge University Press.
[10] See for example Anderson, J. (2014). Exploring the space between words and meaning: Understanding the relational sensibility of surf spaces. *Emotion, Space and Society*, *10*, 27-34.

the sources are too numerous to cite here. And then there are those who make their livings on or with the sea: fishers, sailors, and tourism-industry workers, as well as those who live in oceanic spaces such as small islands, estuaries, and tidal zones. The material aspects of their encounters with the sea are increasingly acknowledged in this literature, although rarely emphasized as practices of world-making.[11] The beach is somewhat of an exception, frequently understood as a liminal zone of encounter; however it implies that only when the ocean comes in contact with the land does it become a meaningful space of embodied politics. Therefore the ocean is somewhat siloed in geographic literature, seen as a special kind of area studies rather than central to heterogeneous world-making practices.

Furthermore, what work on the encounter, and critical scholarship more broadly, remains challenged to account for are the ways in which the ocean makes worlds in complex and subtle ways with human and nonhuman populations that live nowhere near the coast, and seem to rarely interact directly with the sea. How to account for oceanic influences on our climate, in our food, energy, and medicine, and in our broader understandings of natural and human history? Does it make any analytical sense to study these influences in connection with the sea-worlds of tsunamis, fishermen, and surfers? If the sea is in fact omnipresent in our climate and in our bodies how can we talk about difference and politics in relation to marine spaces? What knowledge practices make this

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[11] Cardwell, E., & Thornton, T. F. (2015). The fisherly imagination: The promise of geographical approaches to marine management. *Geoforum*, *64*, 157-167; Fajardo, K. B. (2011). *Filipino Crosscurrents: Oceanographies of Seafaring.* Minneapolis: University of Minnesota Press; Lehman, J. S. (2013). Relating to the sea: enlivening the ocean as an actor in Eastern Sri Lanka. *Environment and Planning D: Society and Space*, *31*(3), 485-501.

ocean available for such readings? Or, to rephrase some of Haraway's fundamental questions of encounter, what do we touch when we touch the sea? How does the sea touch us? How is touching the sea not just becoming worldly but also becoming oceanic, and what difference does this make? These questions point to another shortcoming in literature on ocean worlds. While some authors now investigate how certain representations of the ocean facilitate certain worldly relations, they neglect the relations that go into creating these representations, and the worlds that are themselves engendered through these practices.[12] Although Helmreich has described the worlds made by marine microbiology, the worldly practices of physical oceanography have gone largely unstudied, even though they equally beg to be understood through an analytic that privileges sensation and perception in the making of truth claims.[13] This has left us with an impoverished sense of both oceanic world-making and geophysical practice, both of which are central to the current conjuncture of global environmental change. We must also ask, how do the oceanic encounters of a select few (scientists) make worlds for many others? These are worldly issues the heart of my project - ones that lead me to the ontology and politics of the globe, and, in turn, to the planetary.

The globe

The globe is more than just the result of scaling-up local world-making practices. It is a kind of world-making that deserves special attention for the prominent role it plays in

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[12] See for example Jue, M. (2014). Proteus and the digital: Scalar transformations of seawater's materiality in ocean animations. *Animation*, *9*(2), 245-260.

[13] Helmreich, S. (2009). *Alien ocean: Anthropological voyages in microbial seas*. Oakley, CA: University of California Press.

contemporary configurations of knowledge and power, and for the dangers that it embodies. There are two valences in which I will consider the global here. First, there is the question of how oceanography has contributed to scientific representations of a global environment, and in so doing became a global science. Second, and related, there is the question of how the ocean has been co-constituted with broader dynamics of globalization. As a foundational concept, the global environment is frequently taken for granted. However, many critical scholars have brought attention to the ways in which the globe and the global environment, while appearing to be "at once everywhere – and nowhere" are in fact not self-evident and are constructed through particular processes and result in specific ways of understanding the world and worldly relations.[14]

Perhaps most salient among globe-making's risks is that the globe-form gives the illusion of commensurability, eliding the embodied, contingent, and heterogeneous practices that constitute worlds - including the world of the globe.[15] The globe thus risks positing an increasingly hegemonic view of an "abstract ball covered in latitudes and longitudes, cut by virtual lines, once the equator and the tropics and so on, now drawn by the requirements of Geographical Information Systems."[16] The danger of the globe, then, is to give an impression of a world that is gridded and rationalized, a blank map on which human dramas unfold, an abstract space that plays no active role in life, love, struggle, endurance, encounter, death. The gridded globe gives the dangerous illusion of being the

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[14] Blok, A. (2010). Topologies of climate change: actor-network theory, relational-scalar analytics, and carbon-market overflows. *Environment and planning. D, Society and Space*, *28*(5), 896.
[15] Spivak, G. C. (2003). *Death of a Discipline*. New York: Columbia University Press, 72.
[16] Ibid.

same for all subjects rather than a world shaped through experience and encounter. Furthermore, the globe has been constructed largely through the efforts of Western technoscience, emerging hand-in-hand with capitalist globalization. Thus the representation of the globe ultimately threatens to serve hegemonic interests, though as I will discuss below some authors argue this need not be the case.

For many, the globe, and global ways of thinking, were born in 1968, with the first images of the Earth from space, captured by the Apollo moon mission.[17] However, as I will argue in Chapter Three, attempts to understand the Earth as a planet (necessary for, but not to be confused with, planetary politics as discussed later in this chapter) began much earlier, and were taking shape in significant and scientific ways at least a decade prior to the moon landing. In concert with the rest of the global environment, the ocean has undergone a process of gridding and rationalization, which has accelerated and intensified rapidly in the last several decades. Once seen as primarily the unruly outside to land-based surveying and territorialization, the ocean is increasingly quantified in global climate models and gridded in marine spatial planning efforts. The rest of this dissertation discusses several of the scientific projects that have contributed to making the ocean global.

These projects are not simply practices of mapping, measuring, and standardizing. In making the ocean global, they also entail attempts at "grasping the planet as a dynamic system: intricately interconnected, articulated, evolving, but ultimately fragile and

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[17] Edwards, P. N. (2010). *A vast machine: Computer models, climate data, and the politics of global warming*. Cambridge, MA: MIT Press.

vulnerable."[18] Thus to make the ocean global requires first a radical conceptual shift. Thinking the ocean as a global entity involves conceptualizing it as something that can be known, even whilst recognizing its complexity. Although we are inundated with representations of the global ocean, none of us experience it in an embodied way; our experiences of the ocean are heterogeneous and full of contradictions in scale and affect. To imagine the global ocean, we must imagine the Earth as a planet; we must see it from the outside, employing a cybernetic view from space, a "machinic Umwelt […] of satellite technology."[19] Indeed, it bears repeating that to imagine the world as a globe is to envision it from the outside.[20] While such views are indispensible in a time of climate change (to which the ocean is central), they also require an "adjustment [in the] ways in which we think about the relations among time, space and species."[21] At the same time, global views of the sea also involve the very practical elements of what Edwards calls "making global data," or collecting observations and historical data for the whole planet, and "making data global," the processes by which "coherent global data images are created from highly heterogeneous, time-varying observations."[22]

Making global data, and making data global, have both given rise to and justified what we might call 'big science.' As Aronova and colleagues explain, big science is a term that came into use in the early 1960s to signal that "academic research had

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[18] Edwards, *A Vast Machine*, 2.
[19] Jue, Proteus and the Digital, 250.
[20] Ingold T, 1993, ``Globes and spheres: the topology of environmentalism", in *Environmentalism: The view from anthropology*. Milton, K (ed). London: Routledge, 31-42.
[21] Colebrook, C. (2014). *Death of the posthuman: Essays on extinction, Vol. 1*. Open Humanities Press, 9.
[22] Edwards, *A Vast Machine*, xv.

increasingly become bonded to big government and big industry."[23] Big science also marks a turn from individual projects to initiatives carried out by interdisciplinary teams funded by government agencies, and furthermore toward alignment with efforts at military domination and economic growth. As Aronova and colleagues go on to argue, while big science was typically associated with centralized, large-scale, ground-breaking enterprises such as the Manhattan project, other, more dispersed models of big science are in fact prevalent. Notably, the geosciences, including oceanography, follow a big science model of dispersed yet coordinated projects driven by data collection rather than hypothesis testing or technological development. The advancement of big science in the post-war era made oceanography, already an inherently international discipline, into the shape it currently takes. All of the scientists with whom I spoke have or have had government-funded grants and many have had revolving-door positions with government and/or industry. Their projects are, for the most part, enormously expensive, high-tech, executed by international teams, and generative of massive amounts of data.

At the same time, global science is not a homogeneous field, and it does not enjoy unchallenged dominance. It involves competing objectives and individual motives, not to mention massive constraints and uncertainties, frequently imposed by the very phenomena it seeks to master. Conservative governments in many countries have defunded and silenced even the most prominent Earth scientists, fostering a climate of

[23] Aronova, E., Baker, K. S., & Oreskes, N. (2010). Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957-Present. *Hist Stud Nat Sci*, *40*(2), 183-224.

science skepticism and causing many of the oceanographers with whom I spoke to voice fears over the future of Earth science research. The process of making the ocean global, then, is not simply a flawlessly executed project of global superpowers. As Blok writes, "Whatever ends up being taken as a 'global view' is the always provisional and vulnerable product of a long process of stabilizing linkages between sites."[24]

Further, legion participatory mapping, community GIS, and other projects have arisen to challenge notion that technologies of the globe are oppositional to social justice goals. Kingsbury and Jones characterize debates over the technologies of the globe as a "fear-hope dialectic," wherein "the military-industrial complex is positioned against well-meaning, progressive social theorists of technology and their diverse, now GIS-equipped publics aiming to expose, through mapping and spatial analysis, legacies of local socio-environmental degradation."[25] They advocate instead a more complex understanding of not only the relations that comprise global environments, but also the politics of making the globe. They use Google Earth to show that even what appear to be standardizing, governmentalist technologies such as satellite mapping can reveal uncertain, weird, and "intoxicating" realities, such as naked sunbathers, crashed airplanes, and many more which have recently been curated on numerous websites.

The becoming-global of the ocean in oceanographic science is co-extensive with the ascendancy of global capitalism. As Blok and others have pointed out, the history and dynamics of capitalist and imperialist globalization are directly tied to the making of the

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[24] Blok, Topologies of Climate Change, 901.
[25] Kingsbury, P., & Jones, J. P. (2009). Walter Benjamin's Dionysian adventures on Google Earth. *Geoforum*, *40*(4), p. 503.

globe.[26] The acceleration of capitalist globalization in the last few decades can also be tied to the "rupture" in global thought heralded by the advent of computerization.[27] Furthermore, the ocean has been central to these processes. Ignored for decades in literature on globalization, the sea has recently been highlighted in a range of work that seeks to complicate narratives of capitalist globalization as the seamless fulfillment of "the imposition of the same system of exchange everywhere."[28] For many authors, this means bringing attention not only to understudied spaces, but also certain kinds of labor (labor at sea and in ports) and certain forms of cultural production; for example, the production of identities that takes place among laborers on the cargo ships that still transport the majority of the worlds' goods.[29] As Taussig argues (perhaps a bit polemically), "The conduct of life today is completely and utterly dependent on the sea and the ships it bears, yet nothing is more invisible."[30] Accordingly, many political economists and postcolonial scholars alike agree that capitalism can not properly be called capitalism unless one takes into account the history of cross-Atlantic relationships between Europe, Africa, and the Americas; even Marx and Smith agreed on this.[31] Linebaugh and Rediker argue that "the seizure of land and labor" across the Atlantic "laid

[26] Blok, Topologies of Climate Change.
[27] Spivak, Death of a Discipline, 73.
[28] Ibid., 72.
[29] Fajardo, K. B. (2011). *Filipino crosscurrents: Oceanographies of seafaring, masculinities, and globalization*. Minneapolis, MN: University of Minnesota Press; Taussig, M. (2000). The beach (a fantasy). *Critical Inquiry*, *26*(2), 249-278.
[30] Taussig, The Beach, 251.
[31] Rediker, M., & Linebaugh, P. (2000). *The Many-Headed Hydra: Sailors, Slaves, Commoners and the Hidden History of the Revolutionary Atlantic*. Boston: Beacon Press; see also Benitez-Rojo, A. (1992). *The Repeating Island: The Caribbean and the Postmodern Perspective*. Durham, NC: Duke University Press.

the military, commercial, and financial foundations for capitalism and imperialism."[32] The ocean, then, can be seen as vital to empire building as a medium of movement, friction, and distance that permitted market expansion, access to new resources, and produced financialized forms of value.[33]

However, if the ocean provided the means for the expansion of capitalist world-making, it also reflected and intensified the conditions of crisis out of which capitalism has taken shape. Casarino places the space of the ship at the center of what he sees as the formative crisis conditions of modern capitalism.[34] Modernity's crisis, for Casarino, is the problematic of the "synchronicity of the nonsynchronous" (after Bloch) by which he means that modern capitalism finds its conditions of possibility in the "potentially explosive spatial coexistence in the same time period of historically heterogeneous practices and social formations."[35] Nowhere, for Casarino, is this truer than at sea, where the spatial coexistence of practices of mercantile and industrial capitalism coexist in fractious proximity. Moreover, through his reading of imperialist desire latent in the space of the ship, Casarino ties oceanic forms of life not only to processes of globalization but also links these processes to intimate forms of gendering and the marking of social difference; politics of race, gender, and class that have previously been assumed to emerge on dry land.[36]

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[32] Rediker and Linebaugh, *The Many-Headed Hydra*, p. 145.
[33] Baucom, I. (2005). *Specters of the Atlantic: finance capital, slavery, and the philosophy of history*. Durham, NC: Duke University Press.
[34] Casarino, C. (2002). *Modernity at sea: Melville, Marx, Conrad in crisis*. Minneapolis, MN: University of Minnesota Press.
[35] Ibid. p. 6.
[36] See for example Steinberg, The Social Construction of the Ocean.

Linebaugh and Rediker also theorize the sea as a space characterized by the potential for revolution - a potential formative of the modern state system. The pirate ship might be understood as in particular constituting a space of "hydrarchy," where dominant political forms are inverted: the pirate ship in the early 18th century was "democratic in an undemocratic age" with a distinct element of class consciousness and a resistance to unquestioned authority.[37] The ship was itself a space of transformation, where the "docile and slavish" peasants become the "rebellious and self-active" many-headed monster, mobile, restless, and with a resilient vision of an alternative world; an *autre-mondialization* at the formation of hegemonic worldings.[38] Similarly, and perhaps most famously, Gilroy suggests the Atlantic as a heuristic that situates the Middle Passage as well as abolitionist and radical racial politics in trans-oceanic exchange, celebrating ongoing forms of black culture that defy categorizations that would unite culture and nation.[39]

While the notion of seafaring has faded from popular imaginaries of the global economy, its economic significance still looms large, as over 90% of the world's goods are still transported by boat, and this industry still employs many workers.[40] Seaside places, too, have transformed throughout much of the world. Ports have changed from "grimy pirates' haven[s]" in the early stages of nation-building to "sphere[s] of civilian

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[37] Linebaugh and Rediker, The Many-Headed Hydra, 162-163.
[38] Ibid., 328.
[39] Gilroy, P. (1993). *The black Atlantic: Modernity and double consciousness*. Cambridge, MA: Harvard University Press.
[40] Fajardo, Filipino Crosscurrents; Levinson, M. (2008). *The box: How the shipping container made the world smaller and the world economy bigger*. Princeton, NJ: Princeton University Press.

concourse," with religious, commercial, and cultural institutions, and then eventually to standardized container terminals from which the public is excluded.[41] Beaches, too, have changed from risky, unpredictable spaces of encounter and the precarious procurement of maritime livelihoods to sites of wealth and leisure.[42] But not only is the former character of these human-ocean assemblages never fully gone; the coexistence of their temporally disjointed elements is what makes them thoroughly modern.[43] Thus understanding globalization through an oceanic lens shows dynamics that do not follow imaginary trajectories, from disorder to standardization, antiquity to modernity, precarity to calculable profit, ship to factory. These are not simply false teleologies, as 'the globe' of modern capitalism depends for its coherence on the coexistence of heterogeneous elements even as it posits interlinked unity and systems of equal exchange. Oceanic understandings of globalization show that the 'ingredients' for the ways the present could have been otherwise are found in the most fundamental workings of today's hegemonic systems of modern global capitalism.

If oceanic globalization is a story of crisis and contingency, it is also one of nearly incomprehensible and surely transformative violence and loss - historic and ongoing. As Stephen Helmreich writes, "global warming, coral bleaching, and contamination refer us to older images of the sea as a space of drowning, death, and shipwreck [...] visions of the sea as a space of healing, therapy, and recreation wash over the twin history of the sea as

[41] Ho, E. (2006). *The graves of Tarim: genealogy and mobility across the Indian Ocean*. Berkeley, CA: University of California Press, p. 169; Levinson, *The Box;* Taussig, "The Beach."
[42] Taussig, The Beach.
[43] Casarino, Modernity at Sea.

a space of imperialism, the Middle Passage, submarine warfare, and radioactive waste."[44] Somewhat differently, Elizabeth Deloughrey suggests that given the dark histories beneath the waves, we should consider "the violence of Atlantic history as leading not to a liberating mobility but to the cessation of movement across space, an immersion in the heavy waters of history."[45]

Deloughrey's attempt to think differently about the materiality of the sea in relation to history points to a central disconnect between literature on the emergence of the global ocean and ocean-centric narratives of globalization. In short, they fail to recognize each other. With few exceptions, literature on the emergence of the global ocean in science and the popular imaginary neither accounts for the role of the ocean in globalization more broadly, nor for the dimensions of loss and violence that permeate oceanic presents.[46] Conversely, scholarship on oceanic globalization rarely acknowledges the making of global science as the preconditions for imagining the ocean as a planet-scale environment, nor that the study of the ocean is a realm where the dynamics of globalization more broadly are shaped. What both neglect, then, is the nexus of scientific world-making, representations of the global ocean, and dynamics of imperialism and global capitalism. Why, beyond the telling of certain elided stories, does this matter? I began this section with a warning about the hazards of privileging the globe as a certain kind of world-making. In a sense, both literatures on the emergence of the global ocean and those on oceanic globalization risk falling into this trap. They risk taking elements of

[44] Helmreich, Alien Ocean, 12.
[45] DeLoughrey, E. (2010). Heavy waters: Waste and Atlantic modernity. *PMLA*, *125*(3), 703-712.
[46] Helmreich is an important exception, as is some of Steinberg's work.

the global ocean for granted; the assemblages necessary to allow a global view, the violence and loss associated with global oceanic movement, and the contingency of global dynamics. Thus, these literatures miss the opportunity to fully explore the radical shifts in thought that are necessary for conceptualizing the globe and its attendant dynamics.

This makes it difficult to think through the possibilities for taking that shift in thought in more emancipatory directions. Despite the risks associated with global views, the globe cannot and should not be discarded. For example, on a most fundamental level, we need a concept of global climate to explain how climate change and other environmental impacts are felt most by those who contribute to them least. But more broadly, the globe and its attendant technologies are a central part of the non-optional worlding of technoscience of which Haraway writes.[47] To put it in Spivak's terms, we cannot *not* be occupied with the global. Spivak recognizes this by proposing the planetary not to replace or contrast the globe, but to overwrite it.[48] She recognizes the kind of thinking that results in the globe as containing the possibility of thinking other abstractions, not in terms of distancing but of intuition.[49] Similarly, I attempt to avoid conservative technological determinism by investigating the assemblages that make a global view of the ocean possible, attending to how these assemblages are linked to the histories of global capitalism in both oppressive and liberatory ways. By doing so, I hope to unearth the possibilities for planetary thought that are latent in notions of the globe.

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[47] Haraway, A Game of Cat's Cradle.
[48] Spivak, Death of a Discipline, 72.
[49] Ibid.

The planet

The planet, and the planetary, include elements of the world and the globe, but also exceed these concepts in novel and important ways. On a most fundamental level, planetary politics provides a way to connect and name some features of the current conjuncture. While situated knowledges are clearly important, and all knowledges might be understood as situated, these politics are not adequate to an era of global environmental change. This has led authors such as Ursula Heise to argue that we should be cultivating a sense of planet rather than a sense of place.[50] But like the global, planetary politics are more than a matter of 'scaling up' through additive logic. Our theories of risk and uncertainty, even those that account for capitalist globalization, are challenged by phenomena such as global terrorism, disease epidemics, speculative capitalism, and global environmental change. The latter is perhaps that which truly heralds the emergence of planetary politics, as it is linked to the realization that humans have a lasting impact on the planet itself. We are compelled to turn our attention to new dynamics, which Litfin has identified as:

> "complex linkages between the local and the global; the necessity and inherent difficulty of North-South cooperation; intergenerational time horizons which are typically articulated on the basis of scientific models; a strong tendency toward a holistic understanding of the Earth's systems; and an incremental institutionalization of the precautionary approach."[51]

Planetary politics, then, authorizes new forms and scales of government, from the intimate control of global disease agents to the increasingly inter-and trans-national

[50] Heise, U. K. (2008). *Sense of place and sense of planet: The environmental imagination of the global*. Oxford: Oxford University Press.
[51] Litfin, K. (2008). Planetary politics. In Agnew, J. A., Mitchell, K., & Toal, G. (eds.). *A companion to political geography*. Hoboken, NJ: John Wiley & Sons, 470.

governance of environment and trade. This involves calling into question standbys of political theory, such as the nation-state. [52] Relatedly, planetary politics empowers and seizes upon different forms of knowledge, especially scientific knowledge, even though it is "framed and interpreted in light of contending material and ideal interests."[53]

But planetary politics also names more broadly an emerging orientation that may be understood to result from the strange folding of power and vulnerability on the part of the human in an era of global environmental change. The event of the Anthropocene (even if it is not named as such) may finally lead to the re-centering of human agency and to a fundamental interrogation of such a category.[54] Planetary politics emerge at a juncture when the future of life on the planet is called into question, due in large part to human activities. Extreme weather events, mass extinctions, and the degradation of entire planetary systems bring the possibility of the end of life on Earth (or at least life as we know it) to the table in ways that were likely simply not prescient for previous generations. While it may have been possible to take a position of distance and mastery over a 'natural world,' seen mainly as a reserve of resources, the Anthropocene concept both definitively dismantles the distinction between nature and society and prompts what some have termed a "politics of attachment," not to an impossible return to a pristine nature, but an orientation toward new social ecologies in the ruins of capitalism.

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[52] Ibid.
[53] Ibid., 471; See also Braun, B. P. (2014). A new urban dispositif? Governing life in an age of climate change. *Environment and Planning D: Society and Space*, *32*(1), 49-64.
[54] For a summary and critique of these arguments, see Malm, A., & Hornborg, A. (2014). The geology of mankind? A critique of the Anthropocene narrative. *The Anthropocene Review*, *1*(1), 62-69.

The planetary, then, in threading the world and the globe through one another, multiplies the alterity that is latent in each, and in doing so suggests an alternative reading of Earthly relations. Alterity can be understood as pure difference, that defines most axiomatically the other. Yet this difference, as Spivak argues, is not external to our worlds, even our bodies; "it contains us as much as it flings us away."[55] It makes us human; alterity, for Spivak, is that which intends us toward others, even as it goes under many different names.

One way of approaching alterity is through the notion of the uncanny, which Spivak posits as a doorway into planetary thought. The uncanny invokes the process of making a home unhomely; if the globe produced a world that could be known and mastered, a home for *homo economicus*, then the planet suggests not only the outer limits of this knowledge but also the inner uncertainties and dark spots that lurk below the surface. Uncertainty might be one of alterity's many names, and it will return in many guises throughout this project. In the Anthropocene, uncertainty has a spotlight. We are increasingly aware of the uncertainties in our most intimate daily encounters, as well as in the conclusions drawn by scientists. Uncertainty takes on new scales, extending to the conditions for life on Earth, from the deep past to immediate and long-term futures.

As all of this suggests, planetary thought is at least as much an ethical and political position as an ontological one. It takes as a starting point that the tendency to be inclined toward the other is the fundamental condition of being human. It recognizes scale-defying connections such as those posed by feminist theorists of the global

[55] Spivak, Death of a Discipline, 73.

intimate, but moreover, planetarity asks us to "write the self at its othermost" and to connect this figure to planetary dynamics, perhaps primarily those of globalization.[56] Moreover, it emphasizes that all of these relations are suffused with irreducible difference and uncertainty, prompting, perhaps, different responses than those to traditional narratives of imperialism, capitalism, and globalization. A planetary politics, then, recognizes the absolute necessity of embodied encounters with the other while not posing them against uncertainty, difference, or what we have come to think of as properties of the global scale.

Moreover, a planetary politics thought through the sea asks us to think beyond the Anthropocene as it is currently understood. If 'big science' provides guiding principles for or even constitutes the majoritarian politics of the Anthropocene, we must attend equally to other possible worlds, *autre-mondializations* or minoritarian politics of the planetary. Amidst talk of apocalypse for Western civilization and perhaps concomitantly the human species, the planetary, I believe, compels us to draw attention to those for whom the apocalypse has already happens, and continues to happen. Who have long been forced to live in a strange new world, who have experimented and learned and endured. Their stories are not always stories of the sea, but you can hear their stories in almost any story of the sea if you listen well enough. These other politics are not divorced from globe-making technoscience; it runs alongside and through them, in oppositional and potentially emancipatory ways.

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[56] Ibid., 91; Mountz, A., & Hyndman, J. (2006). Feminist Approaches to the Global Intimate. *Women's Studies Quarterly*, *34*(1/2), 446–463.

In the remaining chapters of this dissertation, I explore the ocean as a space *par excellence* for the enactment of planetary politics. The relatively short history of oceanographic data collection and the difficulties of gathering comprehensive measurements at sea mean that efforts to grid the ocean are always haunted by alterity, an immensely powerful world ocean that asserts is presence but refuses to offer itself easily to human knowledge practices. Its sheer immensity and the inapplicability of land-based notions of territory and sovereignty have long brought it under the purview of international governance structures. It both brings different countries and cultures into contact and creates distance between them. Allewaert uses two oceanic viewpoints to show how oceans both reify and challenge land-based notions of territory. She says: "First, the sea journey is a sojourn between land and landings that, even if it evades the dictates of territorial orders, leaves territorial orders in place. Second, the underwater journey is a site of loss that engenders a creolization that fantasizes and in some cases effects a movement beyond territorial orders."[57] The sea has no essential meaning, then, but is a space of historically inscribed possibility. What I ask, then, is how an oceanic orientation might both expand and concretize possibilities for us, in all our different subjectivities, to "imagine ourselves as planetary subjects rather than global agents, planetary creatures rather than global entities."[58] My project is not to recuperate technoscience, nor absolve it from its collusions with capitalist and imperialist world-making projects. Rather, I seek to understand what differences could be made by

[57] Allewaert, M. (2013). *Ariel's ecology: Plantations, personhood and colonialism in the American tropics*. Minneapolis, MN: University of Minnesota Press, 175.
[58] Spivak, Death of a Discipline, 73.

attending closely to the practices and paradigms that guide technoscientific projects, reading technoscience against and through insights from critical social theory, and seeking new understandings, new concepts, new problems, informed by these practices.

Knowing Planetary Environments

How are planetary environments known? How is the production of knowledge a form of world-making? What worlds are made by knowledge-making practices? These are some of the questions I address in this dissertation. Global environments are not self-evident; no one has unmediated, embodied experience of global systems and how they change; as Paul Edwards puts it, "no one lives in a 'global' climate."[59] Rather, claims to have knowledge of planetary systems are the achievement of what Edwards has called a *global knowledge infrastructure*. And while that is not to say that forms of long-distance relation or large-scale knowledge are new, it is to say that there are and continue to be multiple ways and scales for knowing environments such as the sea, the atmosphere, and so on.[60] Knowing global environments is both the result of specific, contingent, material encounters, and what Paul Edwards has called knowledge infrastructures, or "enduring, widely shared, sociotechnical systems[s]."[61] To understand how planetary environmental systems come to be understood as such, we must then attend to both the embodied entanglements of world-making and the ways in which these encounters and their results are made legible and durable, in the globe-form or otherwise.

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[59] Edwards, A Vast Machine, 4.
[60] For a refutation of the association of the large scale with technological advancement, see Morton, T. (2013). *Hyperobjects: Philosophy and ecology after the end of the world*. Minneapolis, MN: University of Minnesota Press.
[61] Edwards, A Vast Machine, p. 17.

As discussed above, the question of how planetary environments come to be known is not just an epistemological one; it is also a political one. One only needs to think about the role of climate science in national and international politics to begin to see this. But in fact, as I will show, every stage of making the knowledge that is debated in international negotiations is shot through with politics, involving power relations, geopolitics, legacies of previous negotiations, and debates about expertise, legitimacy, and adequacy. Who gets to do what kinds of science, who must do what kinds of science, who is included in the 'international scientific community,' and how identities are formed through the practices of doing science are open questions at different scales. Although for the Earth sciences observational data is required, what counts as a reliable observation is contested.[62] And it is in the process of making observations, processing data, and presenting it that, for example, international scientific communities are formed, the nature of gendered practices is determined, and territorial claims are played out.

Furthermore, as I mentioned above, knowledge about global environments plays a central role in emerging regimes of planetary politics writ large. As Braun writes, "In the face of climate change, what we see is that the administration of life—biopolitics—is itself changing, not only combining diverse elements into new heterogeneous formations, but also taking hold of new knowledges, technologies, and practices that either did not previously exist or had not previously been appropriated as a means of administration."[63] New knowledges are created, and old knowledges play new roles in planetary politics; different forms of knowledge and new meaning-making practices are authorized by

[62] Ibid.
[63] Braun, A new urban dispositif? 51.

emergent forms of government. For example, where previously it might have been unimaginable to breach territorial borders in order to collect scientific data, collective understandings of environmental risk may now make such actions seem not only worthwhile but inevitable. As Litfin asserts, "while nation states remain key players, they are generally pushed and pulled by new actors who are increasingly empowered by the very nature of planetary politics: scientists and environmental non-governmental organizations."[64]

In some ways, making knowledge about the ocean belongs inherently to the category of the planetary, even as it has operated in the framework of nation-states. Oceanography is considered to be inherently international for two reasons. First, due to the large-scale unbounded nature of the sea, contemporary oceanographers must collaborate on developing and maintaining global observing systems and creating integrative global models. Second, oceanography has long attempted to address issues that have broad impacts across territorial boundaries, such as global fisheries stocks, waste disposal, weather, and climate.[65] In recent years, oceanography has participated in the turn to the planetary in new ways. Enabled by new and emerging technologies, internationalism in oceanography has perhaps reached unprecedented levels. Satellites, drifting floats, and autonomous or remotely controlled underwater vehicles have drastically changed oceanography, a discipline that previously relied on costly and infrequent ship-based expeditions to collect relevant data. Furthermore, the high quality

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[64] Litfin, Planetary Politics, 471.
[65] Edwards, A Vast Machine; Jappe, A. (2007). Explaining international collaboration in global environmental change research. *Scientometrics 71*(3), 367-390.

datasets produced by these new technologies are available for free online; hence researchers can analyze and model data without ever going to sea themselves.

How can the planetary be highlighted in an already international science? My strategy is to amplify the role of the uncanny, that which compels large-scale thinking beyond rationalization and gridding; to highlight that which makes our home uncanny.[66] The story of how planetary environments come to be known is not just one of technological advancement, human ingenuity, or even of contested negotiations and periodic failure. Key to the ocean's planetary nature is its stunning unknowability, and its inhospitability to the technologies and techniques by which humans make nature legible. If there is one phrase that has come up more than any other in my research, in archives and interviews, educational materials and scientific articles, it is that we know more about outer space than we do about the ocean. This claim was even made at the very beginning of the space program! A dearth of oceanographic data has haunted scientific efforts in multiple fields, not only oceanography but also related disciplines such as climatology.[67] In the last 75 years, a huge amount of data, even a "data deluge" has been generated from increasingly high-tech oceanographic observations.[68] At the same time, some parts of the ocean have never been sampled, and new ocean creatures are constantly being discovered. The history of knowing the planetary sea is entangled through and through with nonhuman forces that do not simply serve as the background for history, but

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[66] Spivak, Death of a Discipline.

[67] See for example Wunsch, C. (1992). Decade-to-century changes in the ocean circulation. *Oceanography*, *5*(2), 99-106.

[68] Conway, E. M. (2006). Drowning in data: Satellite oceanography and information overload in the Earth sciences. *Historical Studies in the Natural Sciences*, *37*(1), 127.

have the power to change it. They work on the very instruments that seek to study them; barnacles encrust instruments, waters swallow ships and drifting floats.[69] They interject elements of surprise, and sometimes catastrophe. And they require us to rethink our basic ontological assumptions about time, space, and other fundamental concepts.

Conclusion

The world, globe, and planet concepts as I have outlined them here diverge fundamentally from many of the debates surrounding scale that have both plagued and enriched the discipline of geography.[70] None ally closely with the familiar categories of local, regional, global, etc. Moreover, there is clear evidence that the categories of world, globe, and planet are not meant to imply an exclusive truth about something but are distinctly strategies of representation (as one might argue of all scalar practices).[71] When it comes to the conventional scalar categories that geographers (and others) use, we are frequently entreated to consider the material consequences of the enactment of these categories. What does it mean that a problem is considered local, for example? Who wins and who loses? In the case of world, globe, and planet, this form of analysis certainly has some use. Concepts of the world and ontologies of worlding emphasize encounter, embodiment, and partial perspectives that are a part of knowledge claims at any scale.

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[69] See for example Jue, Proteus and the Digital.

[70] See for example Brenner, N. (2001). The limits to scale? Methodological reflections on scalar structuration. *Progress in human geography*, *25*(4), 591-614; Hoefle, S. W. (2006). Eliminating scale and killing the goose that laid the golden egg?. *Transactions of the Institute of British Geographers*, *31*(2), 238-243; Marston, S. A., Jones, J. P., & Woodward, K. (2005). Human geography without scale. *Transactions of the Institute of British Geographers*, *30*(4), 416-432.

[71] See for example Jue, Proteus and the Digital; Helmreich, "From Spaceship Earth to Google Ocean."

Analyzing the category of the global shows how particular forms of worlding have come to privilege certain perspectives and associated dynamics. And the planetary points to emerging political arrangements as well as the potential for a different orientation that weaves difference and uncertainty through global and worldly ontologies, bringing them together with the possibility for more ethical relations. Therefore, for my purposes, rather than choosing between world, globe, and planet to analyze different phenomena, I understand them as necessary to one another.

In particular, my analysis tracks the movement of the planetary in and through these categories and others, as I believe this concept is the most underdeveloped even as it shows great potential for advancing contemporary environmental politics. Moreover, I strive for attention to the ways in which ocean dynamics and entwined human and natural histories compel us to move between these analytic categories, blurring their boundaries and expanding their potentials. Yet as Steinberg and Peters write, "one is continually faced by the paradox that any attempt to 'know' the ocean by separating it into its constituent parts serves only to reveal its unknowability as an idealised stable and singular object."[72] Thus what compels movement between these categories, and an expansion of their boundaries, is not simply what we know of the ocean, its forces and materialities, but equally its alterity, its capacity for fundamental difference or unknowability. This is evidenced countless times in the research that follows. The ocean, then, can never be statically conceptualized as worldly, global or planetary, but rather its

[72] Steinberg, P., & Peters, K. (2015). Wet ontologies, fluid spaces: giving depth to volume through oceanic thinking. *Environment and Planning D: Society and Space*, *33*, 249-250.

difference inspires movement through and beyond the analytical tools we have available at hand.

CHAPTER TWO: WHAT NEW WORLD: SCIENCE AND EMPIRE IN THE INTERNATIONAL GEOPHYSICAL YEAR, 1957-58.

Celebratory accounts of the International Geophysical Year (IGY, 1957-1958) write of a new world in the making, one where the Earth functions as a planet-scale laboratory for intrepid scientists. These international actors are shown as engaged in cooperative pursuit, not only unraveling the mysteries of the natural world in service of all of humanity, but also showing how postwar international cooperation is possible. In this vision of the world, territorial boundaries, now established, fall away in the pursuit of global environmental knowledge. Political differences are set aside, subsumed under the possibility, even necessity, of understanding the planet as a whole and tackling its mysteries unconstrained by geopolitical limits. This was a new world: a world where geographical exploration had ceased but scientific exploration was just beginning.

This vision of the world has non-coincidental resonances with the environmental politics of the Anthropocene. The very idea of a new epoch, defined by the activities of the human species, finds its conditions of possibility in "species-thought" that ties human history to deep time and the natural history of the planet. In species-thought, "all living and dead humans are absorbed into a single body (e.g. humankind) that becomes the universal subject of history."[1] Of course, this view has been roundly critiqued for its universalizing tendencies and moreover elision of the unequal processes of history, yet the concept of the epoch, and its planetary-scale massification of human traces, persists.

[1] Lepori, M. (2015). There Is No Anthropocene: Climate Change, Species-Talk, and Political Economy. *Telos*, *2015*(172), 104.

Even more, and much less frequently challenged, it seems that political boundaries must be overcome and tensions put on the back burner in the interest of human survival in our planetary milieu. Our brightest minds must work together, unhampered by political divisions, if not this time for the mastery of nature, then for the "recapture of the strange planet to which capital has abducted us."[2]

But at the start of the IGY another kind of new world was possible: a decolonized world, where those subjugated by imperial forces might reconfigure global economies, geopolitics, and knowledge. This is because the IGY occurred at the beginning of the great wave of decolonization that began with Ghana in 1957 and quickly spread around the African continent, building on previous movements elsewhere. These radical movements in the global South followed the Bandung Conference and gained momentum through the Non-Aligned Movement, raising the possibility of a new world order. Yet in all of the IGY literature and archival materials I read, from the minutes of planning meetings to critical analysis by geographers and historians, this co-incidence was never explicitly mentioned. The presence of geopolitics in the IGY is fairly widely acknowledged, but it is almost always framed as an East-West power struggle and a competition for legally ambiguous territories in the poles, outer space, and the ocean, rather than a question of a new postcolonial world order.

I argue that to understand this silence, and what it elides, we must inquire into the nature of global science at a foundational moment – the IGY. Science and technology

[2] Dyer-Witherford, N. (2009). Twenty-first century species-being. Presented at the Sixth Annual Marx and Philosophy Conference. Institute of Education, University of London, 6 June 2009, 7.

studies (STS) scholars, such as Donna Haraway, in concert with postcolonial writers such as Dipesh Chakrabarty, have theorized universal knowledge, revealing how concepts, technologies, and objects defined through Western epistemologies became transferable and thus seemingly objective fact about the world. But universal knowledge, as I will show, is not the same as global knowledge; it depends not the transferability of scientific fact but on the collection of data from points throughout the globe simultaneously so that a global summary, or synopsis, might be made. It is not a "view from nowhere" but from everywhere.[3] While some geographers and STS scholars frequently rejoin claims to global knowledge with the insistence that all knowledge is local, scholarship that stops there is inadequate to explaining the politics of global knowledge's formation or effects. Rather, we need different kinds of study, capable of analyzing the chains of relations that make global science and the ways that global science, while indispensible, frames the world environment as a project for science and thus calls into being a particular kind of global humanity. It is only through this sort of analysis that we might understand the global knowledge upon which the Anthropocene concept is based, and its attendant dangers and promises.

In this chapter, I show that global knowledge cannot be reduced to local knowledge, but, following Haraway, it can be understood as knowledge situated in many places and connected by heterogeneous relations.[4] It has a geography and a set of

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[3] See also Hulme, M. (2010). Problems with making and governing global kinds of knowledge. *Global Environmental Change*, *20*(4), 558-564.

[4] Haraway, D. (1988). Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist studies*, *14*(3), 575-599. Thanks to Kara Wentworth for this formulation.

relations that provide the conditions of possibility for knowing the Earth in such a way, and highlight the contingency of our global perspectives. Yet this situatedness is not be simply declared, but attended to – that is the point, after all. Hence, in my analysis of the International Geophysical Year, I follow Redfield to "examin[e] intersections of place, power and time implicit in the location and operation of a vast technical network."[5] I emphasize not how knowledge and technology *travels*, for example from the field to the lab, or from one site of implementation to another, but rather I try to understand how knowledge infrastructures and scientific projects were designed to 'scale up' from the very beginning, and how this might impact our analysis. I aim to show what distinguishes synoptic science from other forms of large-scale knowledge production, in order to understand the role of geophysical technoscience in contemporary environmental politics. I also respond to recent calls to question some of the established mores of STS, asking whether and how it is possible to critique so-called 'global' or universal scientific knowledge by going beyond the common analytical move to label all such practices as local. I argue that although we never leave the local behind, when we recognize the always-already global nature of synoptic scientific undertakings, we can see that global science is not (only) a process of standardization and abstraction but instead generative of relational chains in which difference and alterity are centrally imbricated.

The IGY provides a key entry point to understanding the global science that underpins Anthropocene politics. The IGY was an international scientific program carried out over 18 months, July 1 1957-Dec 31 1958, which involved scientists from 54

[5] Redfield, P. (2002). The half-life of empire in outer space. *Social Studies of Science*, *32*(5-6), 795.

nations as well as a cadre of amateurs, all who were "working on the boundaries of their own knowledge of the physical world."[6] Originally proposed as a follow-up to the International Polar Years of 1882-1883 and 1932-1933, plans for the IGY rapidly expanded to cover the whole Earth, as in just the few decades since the second polar year, "science had raced far ahead with new discoveries, and [these] had spawned scores of complex problems related not to the polar regions alone but to the entire Earth."[7] The geophysical realms that were explored in the IGY fell into ten categories, encompassing the whole of the liquid, solid, and gaseous Earth: meteorology, oceanography, glaciology, ionospheric physics, the aurora, geomagnetism, cosmic rays, seismology, gravity, and latitudes and longitudes. In addition to individual programs in each of the sciences, coordinated measurements were taken across disciplines along particular longitudes and on designated days, called World Days, "when certain predictable events of nature, such as solar and lunar eclipses and meteor showers, were to occur."[8]

The IGY set the stage for planetary geophysical research that would provide evidence for the periodization for the Anthropocene, as well as possibilities for its amelioration. It also provided the justification for major injections of funding into many nations' geophysical research budgets, and led to the creation of various international scientific unions that now set the agendas for global scientific research. But moreover, it placed international emphasis on what would come to be hallmarks of Anthropocene

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[6] Fraser, R. (1958). Once Round the Sun: The Story of the International Geophysical Year. New York: The Macmillan Company, xv.
[7] Ross, F. (1961). Partners in science: The story of the International Geophysical Year. New York: Lothrop, Lee & Shepard Co., Inc., 12.
[8] Ibid., 17.

thought: the consideration of the planet as an object of study for all of humanity, a common milieu for the human species, which must be thought of as one cohesive, dynamically-linked entity, with essential and determinant links both to deep time and the distant future.

In this chapter, I begin by explaining the approach that I take to understanding big science and global synoptic knowledge as requiring an approach distinct from many traditional STS analytics. I show why such an approach is necessary for studying the IGY and how it might tell us something that has been left out of previous accounts. In the following two sections, I analyze links between attempts to synoptically study the global environment and IGY discourse of a whole Earth common to all of humanity. Next, I show how this discourse elided political divisions throughout the IGY, between the East and West but also with regard to the global South. Then, I delve into the oceanographic program of the IGY in particular. I show how the two components, hydrographic and sea level studies, employed different methods but must be taken together to understand how old and new forms of imperialism were stitched together in constituting a global environment.

Universal vs. global knowledge

Although their connections remain underdeveloped, both STS and postcolonial literatures have developed stringent critiques of universal knowledge and its close cousin, 'objective' or positivist science. Science studies scholars have pulled back the veil on the 'view from nowhere' model of science, showing how these views are always situated in historical and geographical contexts, and that certain kinds of labor and power are necessary to make ‘facts’ that can travel between different contexts. Postcolonial scholars have shown how the promise of objective science not only elides Western epistemologies and posits them as universally true but also was used as a form of subjugation in colonial contexts. In summary, they argue that all knowledge is local, (i.e. partial, and situated) and that the perspective of the historically marginalized should be privileged, in the interest of righting past wrongs and of making clear the power relations undergirding and allying with hegemonic knowledge formations.

Where does this leave geoscience, a set of disciplines that Chakrabarty might call “indispensible but inadequate” for basic knowledge of climate change and other planetary-scale phenomena?[9] The geosciences require global-scale forms of vision and international standardizations of measurement and expertise to give us the most basic understandings of Earth system dynamics. Synoptic oceanography, which aims at a comprehensive yet broad-brush understanding of the ocean as a whole, is a prime example. Crucially, the synoptic approach “starts with the observation of data and then continues with the preparation of a concise description, i.e. a ‘synopsis.’”[10] From this description, interpretations can be made and theories can be drawn. Yet it is important to note that the emphasis of synoptic oceanography, the raw materials with which it draws conclusions, is observational data. This distinguishes it from theoretical oceanography, which applies mathematical theories to oceanographic phenomena, and, to a lesser degree, process studies, which seek to make relatively small-scale observations in order

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[9] Chakrabarty, D. (2009). *Provincializing Europe: Postcolonial thought and historical difference*. Princeton, NJ: Princeton University Press.
[10] Pickard, G.L. and Emery, W.J. (1990). Descriptive physical oceanography: An introduction (5th edition). Wiltshire, UK: Antony Rowe, Ltd., 4.

to determine particular ocean mechanisms that can be generalized to similar circumstances. Synoptic oceanography's focus on observational data also distinguishes it, along with most other geosciences, from experimental sciences, such as biology, which depend on controlled variables and the development of testable hypotheses.

In his work on the emergence of space exploration, Redfield shows that while we should be skeptical of universalizing knowledge claims, it is important to understand how and why some knowledge becomes global.[11] Redfield brings Chakrabarty's attention to asymmetrical power relations and geographic and historic contingencies to bear on Latour's (and others') assertions about how things (microbes, technologies, measurement techniques, etc) become stable, interchangeable and mobile. Latour has crucially asserted the necessity of examining how and why certain nodes of knowledge creation are able to "act at a distance," thus privileging actual practices over transcendental theories or ideas in the study of science.[12] This has led him to argue that even universal truth claims can be 'localized' in certain practices that facilitate the mobility, stability, and combinability of knowledge. The immensity of space and time is, then, created and given meaning inside such networks, rather than being something within which scientific practices operate. This argument resonates with the work of geographers, who are well positioned to examine the creation of space and time within scientific practice.[13] However, as Redfield argues, a methodological approach that treats all knowledge practices as equally 'local' is

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[11] Redfield, Half-Life of Empire.
[12] Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Cambridge, MA: Harvard University Press.
[13] See for example, Livingstone, D. N. (1995). The spaces of knowledge: contributions towards a historical geography of science. *Environment and Planning D: Society and Space*, *13*(1), 5-34.

likely to miss the politics that make some places and practices not simply appear as ‘more’ local but also subjects them to the violences of imperialism and colonialism. Latour and his adherents, Redfield claims, “move almost carelessly” through *actual* places and events, “following specific, but ultimately interchangeable (and often nonhuman) elements like a microbe or a door closer.”[14] Instead, Redfield encourages us to ply the edge between metaphor and materiality in concepts like the global and the local. Claims that all knowledge is local are insufficient if they stop short of explaining how particular localities are put into spatial and temporal relation in projects that are designed to be global from the start.

In a 2011 essay, Harris makes a complimentary contribution, asking science studies scholars to not just consider where science is done and by whom, but to develop analytical approaches adequate to the study of sciences that span vast temporal and spatial scales.[15] Such attention to the geography of science can help us to better understand what Paul Edwards has called a “global knowledge infrastructure.”[16] But perhaps even more significantly, a geographic approach to science might help to correct what Harris identifies as a prevailing bias in science studies that limits its contemporary relevance. Harris argues that many accounts of scientific advances, both from conventional proponents of the ‘Scientific Revolution’ narrative and those from the social constructivist camp, have focused on what he calls ‘small science’: “the work of just a

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[14] Redfield, Half-life of Empire, 795.
[15] Harris, S. (2011). Long-Distance Corporations, Big Sciences, and the Geography of Knowledge. In Harding, S. (ed) *The Postcolonial Science and Technology Studies Reader.* Durham, NC: Duke University Press, 31-83.
[16] Edwards, P. (2010). *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. Cambridge, MA: MIT Press.

few people working over a short period of time in a restricted geographical setting."[17] Small sciences, according to Harris, might include anatomy and surgery, experimental philosophy, and many other 'classical sciences.' What the study of 'small science' ignores are the sciences such as astronomy, cartography, meteorology, natural history, and oceanography. These sciences entail "the long-term labor of large numbers of people scattered across wide geographical fronts."[18] Harris links the tendency to focus on small sciences with popular assertions that all global knowledge can be localized, and with a somewhat ironic tendency of both heterodox and unconventional studies to focus on a limited number of influential technologies, theoretical 'discoveries,' and the "biographies of a handful of great men."[19] As Harris writes, "the 'localist thrust,' in other words, has not only predisposed researchers to choose research sites that are spatially and temporally circumscribed, it has also encouraged the selection of scientific practices that were themselves spatially and temporally circumscribed."[20]

The "big sciences" and Earth systems sciences in particular, are gaining in significance due to Anthropocene calls to address global-scale environmental crises. But the study of science and technology, although it increasingly focuses on these disciplines, must still catch up when it comes to analytical approaches. How we employ "both an epistemology and a narrative format capable of moving across scale"?[21] How can we

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[17] Harris, Long-Distance Corporations, 76.
[18] Ibid.
[19] Ibid., 77.
[20] Ibid., 78.
[21] Ibid., 79.

grasp the "diffuse discoveries and communal labor characteristic of the big sciences"?[22] Our typical models of scientific discovery depend on a familiar narrative of individual scientific discoveries being 'scaled up' to effect changes in how we see the world. Yet not only is that model inaccurate for sciences like synoptic oceanography, for which "it is difficult to isolate crisis-producing anomalies, arational paradigm shifts, or debilitating incommensurabilities," but also it ignores the geographically diffuse and frequently mundane work of manifold laborers incrementally instantiating 'big science' knowledge[23]. Accounting for this type of scientific work resists cultures of "scientific heroism" that credit advances to a few charismatic individuals (usually white men).[24] Further, it is a postcolonial move, away from the established centers of scientific discovery and more closely attuned to global dynamics of power and knowledge that constitute contemporary worlds of science, and that surely characterize modern synoptic oceanography.

Knowing the planet, knowing the ocean

We might begin by noting that the synoptic view of the ocean is historically contingent. While we are now all familiar with the view of the ocean from space, which shows it to be one world ocean, continuous in extension and dynamics, synoptic oceanography is a unique viewpoint that only cohered relatively recently. While it is true that humans have gleaned knowledge from the sea for a very long time, this knowledge was collected in a relatively haphazard manner, focused on particular coastlines, currents, and ocean

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[22] Ibid., 80.
[23] Ibid., 79.
[24] Oreskes, N. (1996). Objectivity or heroism? On the invisibility of women in science. *Osiris*, *11*, 87-113.

creatures rather than the ocean as a whole. Rozwadowski argues that sustained exploration of the deep sea, as well as its development as a subject of art and culture, only really emerged in the 19th century. Before this, she asserts, "the deepest parts of the ocean existed only as unfathomable barriers between places or as watery highways bounded by waysides," or in other words, "understanding of the ocean's depths derived mainly from the imagination."[25]As Oreskes puts it, until in fact the late 1920s, "three-quarters of the globe was virtually unknown from a scientific standpoint."[26] Even as scientists became interested in questions that would require the study of the sea, limited funding prevented them from making many advances.[27]

The World Wars, and especially WWII, radically changed oceanography. As Oreskes writes, "the demands of coastal landings, weather prediction, and particularly anti submarine warfare made the value of oceanographic research increasingly evident."[28] During this time, oceanographers discovered that sound waves were bent and channeled by the variations in temperature and pressure that occur with depth in the sea. Of particular interest was the position of the thermocline, a segment of the water column at 100-300 meters' depth where the temperature drops very rapidly, thus 'bending' sound waves, allowing them to travel very far unattenuated, or conversely allowing for

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[25] Rozwadowski, H. (2005). *Fathoming the ocean: The discovery and exploration of the deep sea*. Cambridge, MA: Harvard University Press, 5-7.
[26] Oreskes, N. (2000). "Laissez-tomber": Military patronage and women's work in mid-20th century oceanography." *Historical Studies in the Physical and Biological Sciences* (2000), 380.
[27] Ibid.
[28] Ibid., 381.

submarines to 'hide' in the thermocline's "sonic shadow."[29] Thus, knowledge of the ocean's fundamental properties was required for effective submarine warfare, as well as for finding downed pilots. Furthermore, "for tactical purposes it was sufficient to know the position of the thermocline in the vicinity of a ship, but for strategic purposes geographically distributed data were wanted. The more comprehensive the data, the more valuable they would be."[30] Hence, along with increased funding came the compulsion and technical possibility for knowing the ocean as a whole.

There were, of course, other reasons for collecting comprehensive information about the ocean. At the end of the second World War, some of the most pressing reasons for broadly studying the ocean included gaining increased knowledge about fisheries, the risks and opportunities of nuclear dumping, and the nascent possibility of climate change. Overall, it was becoming clear that the oceans were vital to life on Earth, and that they were full of untapped resources while at the same time unable to endlessly absorb humanity's wastes. As Oreskes writes, "By the middle of the twentieth century, it was clear that earlier views of the deep-ocean environment were incorrect. Scientists came to understand that the deep ocean does sustain life, it does sustain currents, and while it is vast and has been used for disposal of the diverse products of industrial life, including various forms of nuclear waste, garbage, and wreckage, its capacity to absorb those wastes is not infinite."[31] Thus the stage was set for oceanography's inclusion in the IGY program, as a burgeoning science that took the world ocean as its object.

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[29] Ibid., 376.
[30] Oreskes, Laissez-Tomber, 378.
[31] Oreskes, N. (2014). Scaling up our vision. *ISIS*, 105(2), 383.

The IGY has been storied in two seemingly conflicting ways, both of which emphasize geopolitics while missing some key analytical moves necessary to understand the full implications of big science for planetary politics. Mostly during and just after it occurred, the IGY was chronicled with a highly celebratory tone, especially by popular science writers and analysts of the times, as well as those involved in its planning and execution. These authors stress not only the scientific significance of IGY achievements, but also the program's political triumphs, narrating the endeavor as overcoming Cold War divisions in the interest of solving scientific mysteries for the greater good. A second body of scholarship takes a more critical tone. This work, mostly undertaken by historians of science and other social scientists, emphasizes the national priorities that were implicit (or explicit) from the beginning of IGY planning. Moreover, these authors show how, rather than abandoning the notion of sovereignty in the name of science, IGY programs involved jockeying for national control of territories such as the poles (and the potential natural resources within) as well as technological dominance in realms such as outer space.[32]

While scholarship on the IGY has stressed its international character and the planet-scale nature of its scientific undertakings, this work has largely left out the participation (or lack thereof) of global South countries, and hence it has missed a significant dynamic in the politics of Earth science as big science. Even while Eva Lövbrand and colleagues have shown that the IGY ushered in a new form of global

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[32] See for example Collis, C. and Dodds, K. (2008). Assault on the unknown: The historical and political geographies of the International Geophysical Year (1957-8). *Journal of Historical Geography,* 34(2008), 555-573.

governmentality based on the Earth as a planet, the role of global South nations remains underexplored.[33] The quest to know the Earth as a planetary environment was not carried out equally across the world, and both accounts that emphasize international cooperation and those that focus on East-West political jockeying leave out most of the Global South, where many countries, particularly in Africa, were on the verge of decolonization, and on the brink of setting new world agendas. This seems to be a notable omission; one might assume that since the purpose of the IGY was to make knowledge about the Earth as a whole, it could not simply consist of scientific efforts from Europe and North America. Not only would this belie the language of widespread international cooperation, but it would leave much of the Earth incompletely accounted for; while European and North American scientists traveled the globe during IGY, geopolitical constraints kept them from collecting data everywhere. Furthermore, participation and training in science and technology is frequently seen as a hallmark of development, one that new nations might readily seize in a project such as the IGY.[34]

It is not as though the Global North was sole or even primary focus of the IGY: deep seas, poles, and outer space were spaces of alterity that the IGY sought to bring under scientific and legal jurisdiction. If these places, which seemed "safely free from human difference" got much attention, then the frictions of "human difference" in the decolonizing world have been largely ignored. [35] The documents available indicate that

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[33] Lovbrand , E., Stripple, J., & Wiman, B. (2009). Earth Systems governmentality: Reflections on science in the Anthropocene. *Global Environmental Change, 19*(1), 7-19.
[34] See for example Harding, S. (ed). (2011). The postcolonial science and technology studies reader. Durham, NC: Duke University Press.
[35] Redfield, Half-Life of Empire, 792.

many of these Southern nations participated by hosting measurement instruments and observation stations, participating essentially as technicians rather than agenda-setting and theory-testing scientists. Thus while they were nominally included in the IGY, filled in in every map of participating countries, their participation was uneven and colored by imperial relations. A closer look at the way that the Earth was imagined during the IGY and the details of the oceanography program may shed some light.

The whole Earth of the IGY

The IGY imagined the Earth in a particular way, which shaped and was shaped by its role in defining new strategies and goals for governance.[36] At the center of IGY ideology was the assertion that the IGY was a kind of post-political exploration, a sort of adventure not for political but for scientific ends. Ronald Fraser puts it thus:

> "The high aim of the IGY effort, in short, is not technical but scientific. It is the first concerted world-wide attack by man on the mysteries of his own environment. It would be surprising if it were the last. This key feature of the enterprise cannot be emphasized too strongly. The urge which has led scientists of 54 nations to install their instruments on ice floes in the Arctic, on remote islands in the Pacific, on high peaks in the Andes, in the frozen wastes of Antarctica, is not an urge to discover new lands, or to blaze new geographical trails. It is an urge to a new kind of adventure - the scientific exploration of the earth as a planet."[37]

The mutual relationship between science and international cooperation looms large in most accounts of the IGY, and there was the sense that both elements would have lasting impact; as one token example, Fraser's book on the IGY is dedicated simply "to the next generation."[38] Eisenhower's words at the start of the IGY reflect as much: "As I see it, [...] the most important result of the International Geophysical Year is the

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[36]Löbrand et al., Earth Systems governmentality.
[37] Fraser, Once Round the Sun, 24.
[38] Ibid.

demonstration of the ability of peoples of all nations to work together harmoniously for the common good. I hope this can become common practice in other forms of human endeavor."[39]

This view was deemed necessary for studying the Earth as a planet, the code of entry and ultimate signature of the IGY. To participate in IGY, national programs had to show that their efforts were aimed at understanding the Earth as a planet: "In a sense, the IGY was a scientific club. To gain admittance - that is, to be included in the IGY program - a scientific project had to be concerned with 'specific planetary problems of the earth.'"[40] As the Canadian geophysicist J. Tuzo Wilson put it, one of the IGY's principle achievements was "the transformation of earth science into planetary science."[41] In another example, Ross states that among IGY's distinctive features, "first and foremost was the fact that it used the earth and the enveloping world of space as a gigantic laboratory. These areas, together with the sun, were observed and studied as never before by scientists working on an international co-operative basis."[42]

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[39] Remarks by the president in connection with the opening of the International Geophysical Year; International Geophysical Year 6/30/57; Dwight. D. Eisenhower National Archive, Abilene, KS.
[40] Sullivan, W. (1959). The International Geophysical Year. *International Conciliation,* (521), 259-336.
[41] Wilson, J.T. (1961). *IGY: The year of the new moons*. New York: Alfred A. Knopf, 320.
[42] Ross, Partners in Science, 7.

The ability to see Earth from space especially captured the imaginations of the new planetary science. The most notorious outcome of the IGY was certainly the launch of Sputnik, which inaugurated the Space Race and was closely followed by American and additional Russian satellites.[43] The turn toward the skies, to the polar extremes, and to the

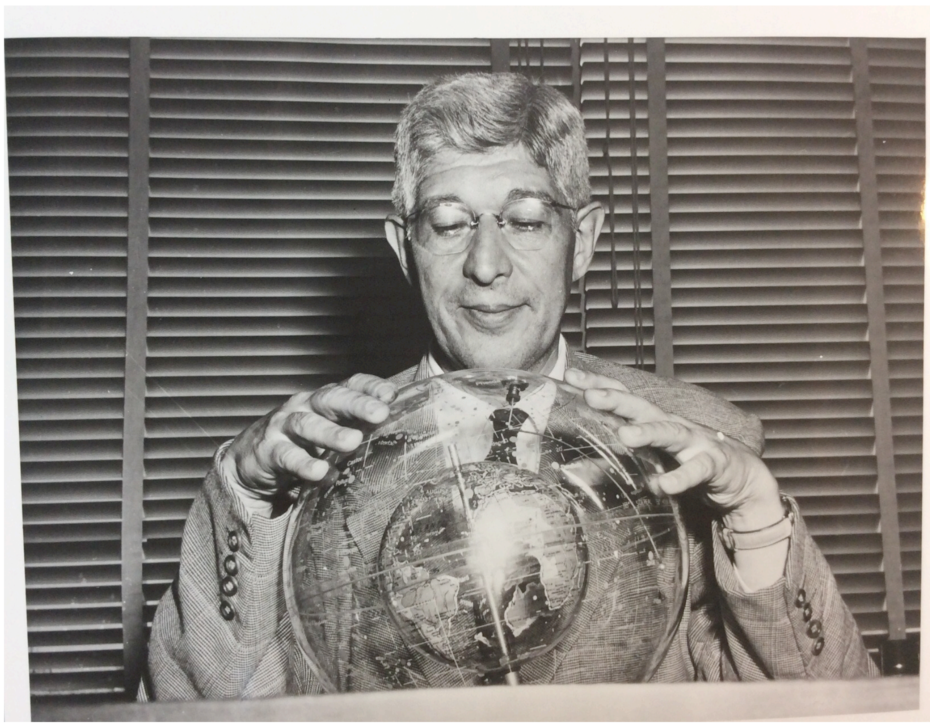

Fig. 2.1: Joseph Kaplan, chairman of the US National Committee for the IGY, looks at a transparent globe of the universe (Source: Special Packet: The United States and the International Geophysical Year, U.S. Information Agency, 1957)

deep sea was certainly integral to igniting an imagination of the Earth as a planet in the minds of scientists and the general public. Fig. 2.1 is an exemplar, showing the chairman of the US national IGY committee gazing into a model of the universe from above.

[43] The launch of Sputnik was an unpleasant surprise to the Americans and likely all those involved in the IGY, despite the ostensible cooperative planning that was to characterize the IGY. The Americans had planned to launch the first satellite, embarrassingly named the Vanguard.

The vouchsafe storage and open circulation of data was equally important for planetary-scale Earth science. If the views provided from space, the Earth's ends, and the deep sea were vital to a new view of a dynamically-linked, self-referential Earth, then the data collected during IGY was even more important to its modeling and analysis. Early in the IGY planning process, it was decided that all data collected was to be freely circulated. Three World Data centers were established along geopolitical lines: World Data Center A in the United States, World Data Center B in Moscow, and World Data Center C, consisting of subcenters in eight nations in Western Europe, Japan, and Australia. While all data was to be duplicated at WDC A and B, WDC C "would consist of only a partial collection, representing certain scientific disciplines."[44] As Lövbrand and colleagues write, it was not simply the bird's-eye view of the planet from space that inaugurated views of the Earth as a planet during the IGY, but even more, "The systematic and global-scale collection of geophysical data during this year, and the growing technological capacity of storing and processing such data, paved the way for global biogeochemical and biogeophysical models and their visual representation of an integrated planetary environmental system."[45]

The focus on international collaboration for the mastery of planetary science called into being a singular planet that was, above all, the provenance of a universal humanity. In this ideology, humanity as a whole had moved past political frictions and territorial divisions for nobler goals of scientific knowledge. The main adversary now was the Earth itself. An editorial in the issue of the American oceanography journal

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[44] Ross, Partners in Science, 19.
[45] Lövbrand et al., Earth System Governmentality, 9.

Oceanus reflects this mindset: "the sea and the continents more often than not will be the only non-cooperative IGY participants in our struggle to understand the earth in order to learn how to become master rather than slave of our environment."[46] This strong discourse of mastery, predicated on a strict division between man (gender intentional) and his environment is found throughout IGY literature. Moreover, this relationship of adversity was highlighted as a relationship of knowledge (or lack thereof). Mastery was equated with *knowing* global environments, a goal placed above (though certainly linked to) other forms of control. This relation of knowing was indelibly gendered, even though men were not the only producers of geophysical knowledge, as evidenced by a cartoon, appearing at the start of the IGY in South Africa's Cape Argus (and possibly elsewhere), which shows a woman, "Miss World," on display for a bevy of male IGY scientists, who regard her with a variety of instruments (Fig 2.2).

[46] Men, Earth and Instruments. (1957). Unsigned editorial. *Oceanus, 5*(3&4), 1.

Fig. 2.2: IGY cartoon. (Source: Cape Argus, 1 July 1957)

East-West tensions and other occlusions of the IGY

If themes of planetary unity and scientific objectivity dominated official IGY discourse, it doesn't take much searching to find their cracks. Perhaps the most obvious and remarked-upon were tensions regarding East-West Cold War politics. One does not have to spend much time in any IGY archive to become first impressed and soon after exhausted by the immense amount of bureaucracy, intelligence gathering (most seemingly incidental) and general fretting about Soviet affairs (as well as extended debates about the participation of Communist China). Although the poles and outer space get a great deal of attention for being stages where East-West tensions played out, oceanography was also a contentious field with its own dynamics. The cooperative spirit of the IGY, and the relatively low risk to national security posed by oceanography research, meant that oceanographers and other scientists (as well as the ships' crews) traveled more freely between Western nations and the USSR/China bloc than most others at this time. Of course, cultural exchanges occurred during oceanographic voyages and port calls. For example, when a Soviet vessel obtained permission to visit New York in 1959, as part of the follow up to the IGY and the related International Oceanography Conference, the *New York Herald Tribune* reported that the Russians aboard the boat and Americans at the pier exchanged photo ops and vodka toasts, and discussed a recent exhibition about the US in Moscow. They also noted, in contrast to the custom aboard American vessels, that about a quarter of the Russian scientists were women (first subheading in article: "11 Scientists are Women").[47] Yet while the US felt pressured to allow Soviet vessels to dock and refuel in its ports, and sometimes for scientists to come ashore, the risks and benefits were always carefully weighed. To provide an example, below is a table copied from an assessment on the initial request for the visit that was the subject of the *Herald Tribune* story mentioned above. [48]

[47] Silberfarb, E. J. (1959). "41 Scientists Dock Aboard Russian Ship." *New York Herald Tribune*, 29 Aug 1959 (no page given).
[48] Memorandum for: Secretary, USIB Committee on Exchanges, 19 June 1959; Folder 1601(c) – Internatl.Geo.Year Mikhail Lomonosov 1958-1967; Bilateral Files: Soviet Union Affairs; National Archives at College Park, College Park, MD.

Possible Intelligence Gains to US	Possible Intelligence Losses to US
a) Evaluation by competent U.S. Oceanographers of the ship and associated equipment and instrumentation as a research facility.	a) Passive ELNIT surveillance, including operations near U.S. Texas Tower
b) Evaluation of capabilities of the scientists and the Research program.	b) Photographic intelligence on Brooklyn Navy New York if berthed in East River near site of UN Building, where conference will be held
c) Factory markings exploitation	c) Radar scope photography of New York approaches
d) Provide basis for requesting permission for U.S. ships to make reciprocal visit to Soviet port of U.S. choice.	d) Soviet Propaganda gain from positive reaction of delegates to ship and its program

The significant oceanographic prowess that the USSR showcased during the IGY and in following oceanography projects caused great consternation as well. Soviet expertise and resources in oceanography were always threatening to outstrip those of the US. There was also great concern that Soviet oceanographic power reflected Soviet sea power more generally, and that they would be able to leverage the legally indistinct high seas to tip the balance of power. This is evidenced in the following transcript from the 1970 film *Soviet Sea Power Today,* which shows many images of Soviet military, commercial, and research marine activity, all colored by a red filter (see Fig. 2.3 for two stills from this film).

> "A nation's total sea power contains one final element: it is the study of the sea itself. It goes by various names, such as oceanography, marine science, or marine engineering and ocean development. Here too the Soviet Union is hard at work. We have only recently glimpsed the shape and composition of Soviet work in the oceans. The size of their program is equal to that of the United States, and it

already has passed other contenders, such as Japan, France and Great Britain [...] Even though thought of primarily as a land-oriented people, the Soviets are educating five times more students in oceanic studies than we are. At the PhD level, marine scientists working at the Kremlin can expect assistance from 10-15 junior scientists. His moral is good and his prestige is high. The results of his work back up the total effort of his country at sea. More, he sets the foundation for future expansion, whether it be for naval, maritime, or fishing fleets, or for the exploitation of the boundless wealth of the sea [...] So fundamental a thing as a storm reminds us that environmental studies of the sea may one day bring us weather control. The sea has its treasure to give up. The Soviets know this as well as we do [...] The sea is neutral; it doesn't care who understands or misunderstands its use. It will work for us, or it will work against us. But the Soviets' will to use the sea is something else."[49]

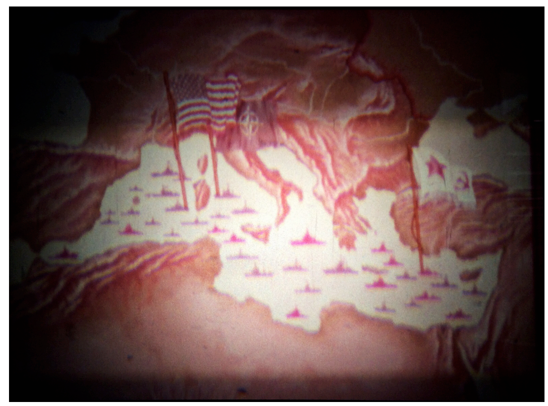

Fig. 2.3: Still images from film *Soviet Sea Power Today* (1970).

But accounts of these tensions and the game-theory-esque plotting and strategizing that surround them were not the extent of the fracturing of the one-world image that the IGY purported. It is important to remember that the East-West contestations over spaces like the poles, outer space, and the deep seas are indicative of broader efforts to bring heretofore common or unclaimed spaces under territorial and legal jurisdiction. As Collis and Dodds write:

[49] Video Recording No. 428-NPC-52854; "Soviet Sea Power Today," 1970; Moving Images Relating to Military Activities, ca. 1947 – 1980; Record Group 428: General Records of the Department of the Navy, 1941-2004.

> "On the eve of the IGY, the legal status of the Antarctic, the High Seas, the ocean floors and outer space was legally unfixed and largely undefined. By the 1960s, this had changed. Three landmark treaties were central to this transformation – the 1959 Antarctic Treaty, the 1958 United Nations Conference on the Law of the Sea and the 1967 Outer Space Treaty. The IGY was central to this legal and geographical transformation."[50]

These agreements not only parceled out parts of previously commonly-held spaces for exclusive use by individual nations, they also gave increased authority to intergovernmental agencies. The move toward international governance is a hallmark of linked legal and ecological management in the Anthropocene, as well as a key feature of the broader turn to planetary politics.[51]

Although much less frequently mentioned, the IGY also had divisions along colonial lines. Again, literature on the participation of the colonized and decolonizing world is scant. One report, called "The International Geophysical Year in Africa South of the Sahara," prepared by one S.P. Jackson, the "Interafrican Scientific Correspondent for Climatology," which I located in the National Library in South Africa, does provide a small window into the IGY from the perspective of the colonized world.

This report follows Jackson's tour of the continent in advance of the IGY in 1956 and indicates that IGY activities were organized around colonial lines. The report begins with the usual celebratory IGY language, but immediately includes acknowledgement of limited resources: "Everywhere in Africa, the importance of the International Geophysical Year is appreciated and scientists are eager to take part in the programmes

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[50] Collis and Dodds, Assault on the Unknown, 559.
[51] See for example, Litfin, K. (2008). Planetary politics. In Agnew, J. A., Mitchell, K., & Toal, G. (Eds.). (2008). *A Companion to Political Geography*. Hoboken, NJ: John Wiley & Sons, 471-482; Lövbrand et al., Earth System Governmentality.

as far as their resources will allow."[52] He goes on to say that in the Belgian, French and Portuguese territories, "busy preparations are going on, and in those branches of geophysics in which synoptic observations are wanted, the density of observing stations - for meteorology, geomagnetism, seismology, and ionospheric soundings, - is likely to be about as good as could be expected in a continent like Africa."[53] As indicated in this statement, Jackson evaluates the IGY plans of various countries by grouping them by their colonial overseers. He writes that while "the French and Belgian programmes in Africa have been carefully planned and adequately financed," the story in the British territories is different: "there were strong expressions of frustration and disappointment - no additional funds have been voted for even relatively inexpensive equipment and the costs of participation in the programme of the International Geophysical Year will have to be met out of already overstrained budgets for ordinary work."[54] Moreover, he writes, the arrangement of the IGY programs in Africa "has some disadvantages from the point of view of African science; there has been very little discussion of plans between neighbouring territories and no co-ordination except in the field of meteorology which is undertaken by the African Regional Association of the World Meteorological Organization."[55]

If report indicates some of the general woes of IGY research in the global South, then the oceanography program provides a more precise bellwether. Although 36 nations

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[52] Jackson, S.P. The International Geophysical Year in Africa South of the Sahara. Commission for Technical Co-operation in Africa South of the Sahara. 1. National Library of South Africa.
[53] Ibid., 2.
[54] Ibid., 3.
[55] Ibid.

participated in IGY oceanographic research, only three of these were African nations (compared with six South/Central American, seven Asian, 15 European, plus the US, Australia, Canada, New Zealand, and the USSR). Moreover, South Africa, which, though still under Apartheid rule, had become independent from the United Kingdom 20 years prior, was the only African nation to have a program that involved research cruises as opposed to simply the maintenance of tide and sea-level gauges.

Already we can see that even what appears as synoptic science is still uneven, and serves to further scientific expertise and political ends in some geographic areas and not others. But to more deeply understand how difference both constituted and destabilized synoptic oceanography, and how imperial relations were elided in producing a global environment, we must look in greater detail at the oceanographic program of the IGY itself. Here I change focus from the efforts of individual nations and look more closely at the overall program of coordinated measurements, and examine how geopolitical and imperial power is expressed in, and emerges from, these efforts.

Long waves and open ocean: the IGY oceanographic program

Although outer space and the poles have garnered much greater attention than the IGY's oceanography program, the latter exemplified the program's guiding aims and principle challenges, and played a significant role in new conceptions of the Earth as characterized by planetary-scale dynamics. The IGY oceanography program considered not only the ocean as a system but also as a system in time, aiming for both spatial and temporal views that were more comprehensive than ever before. When it came to the sea, the IGY looked back in time, using seabed cores to attempt to understand the planet's natural history through the sea, in particular the spreading of the seafloor, which confirmed tectonic plate theory and provided insight into the forming of the continents. Oceanography also looked ahead, attempting to determine potential catastrophes, whether from the dumping of atomic wastes, severe weather, or slower climatic changes.

Notwithstanding the seafloor studies, there were two general main programs to study the liquid sea: one to study ocean circulation, especially of deep-sea currents, and one to measure changes in sea level and ocean waves. Currents, of course, had been observed throughout the history of human engagement with the sea. Scientists knew that they were caused by surface winds as well as by the shape of ocean basins, the rotation of the Earth, and differentials in temperature and salinity that cause water masses to sink in some places and float to the surface in others. Yet the particular mechanisms by which these currents function, especially the interaction of the forces described above, remained unknown, much less quantified (see Fig. 2.4). This was a far from academic question; not only do currents affect marine navigation and fisheries but Fraser pinpointed new concerns:

> "The age of the atomic energy power station is already upon us, and we must ask ourselves betimes whether it is really sensible to use the ocean floor as a dump for radio-active waste. If the turnover of the ocean waters is too slow, we may soon poison large areas of the sea; if fast enough, then the dispersion of the radio-active waste might be so complete as to be harmless, even in the face of the incredible power of living organisms to concentrate minute traces of rare elements in their own blood and tissue."[56]

[56] Fraser, Once Round the Sun, 7.

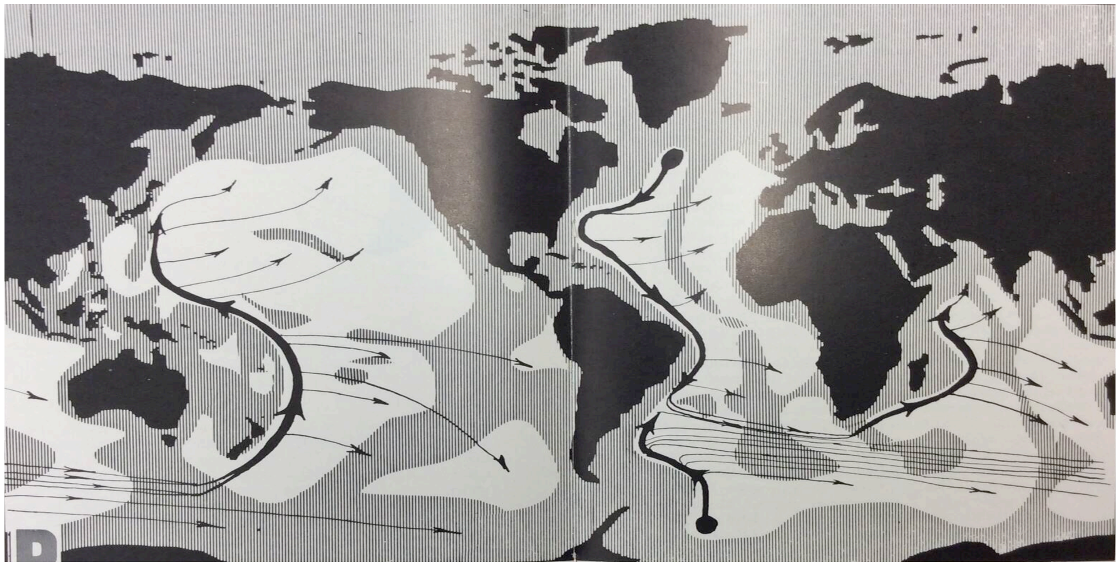

Fig. 2.4: Prediction for deep currents at the start of IGY (Source: *Oceanus, 5*(3-4), 20-21)

The second part of the IGY oceanography program sought to solve some mysteries regarding variations in sea level over both short and long time spans. In particular, scientists were interested in explaining seasonal change in sea level, and understanding if observed changes were consistent from place to place, and whether they were caused by changes in the properties, such as temperature and density, of water masses, or by variations in volume due to exchanges with the atmosphere and land-based freshwater. They also sought to understand "long waves which travel the whole width of the oceans."[57] The executive committee for oceanography describes this puzzle in the *Annals of the IGY*: "It is well known that there are many kinds of surface oscillations longer than ordinary waves and shorter than the main tidal periods, but little is known about their propagation in deep water."[58] These waves were thought to be generated from weather events and pressure changes as well as seismic events, as in the case of tsunami

[57] Laclavère, G. (1960). Oceanography. *Annals of the IGY, 10*, 176.
[58] Ibid.

waves, and studying them had potential impacts for weather forecasting, disaster planning, and coastal infrastructure.[59]

The characteristics of the wave conditions of the world's oceans as a whole and of their separate parts cannot be obtained by simple accumulation of observational data and their subsequent statistical processing. Rather,

> "The synoptic processes and other factors which are responsible for the wave conditions of some ocean areas are so diverse that it would take many decades of continuous observation at a great number of points to obtain the data that would represent, even to a limited extent, the whole variety of natural conditions. It is apparent that the only practical way to solve this problem is to organize and carry out integrated experimental and theoretical researches directed at studying sea and swell physics, in order to establish the general laws of the processes."[60]

Because long wave study involved new research, while the sea level studies primarily involved the coordination of already routinely captured data, I focus on the former in this chapter.

The two parts of the IGY oceanography program, ocean circulation and sea level and long wave recording, entailed two very different sets of methodologies, which enrolled different actors and had different sets of challenges. The program to study ocean circulation consisted almost entirely of measurements taken during highly coordinated oceanographic research cruises. At "intervals during the course of a voyage," measurements were taken, most frequently "those termed 'serial observations,' which provide data on a variety of elements (temperature, salinity, dissolved gases, etc) at different levels between the surface and the bottom of the sea."[61] Most of these

[59] Deacon, G. (1957). Oceanography. In Guide to the IGY, London: Methuen and Co.
[60] Deacon, G. (1961). Oceanography. *Annals of the IGY, 11,* 325.
[61] Lumby, J.R. (1960). IGY Oceanography Report Series No. 1 Atlas of Track Charts of IGY Cruises Part I: North Atlantic. *IGY World Data Center A: Oceanography,* 1.

measurements were made by collecting water samples at various depths using Nansen bottles, which could be deployed on wires and then shut using a metal 'messenger' sent down the wire to close the bottle and trap water inside (see Fig. 2.5).

Measurements and observations on a number of other topics were also recorded on these cruises, including water color and transparency, "state of the sea and swell," bathymetry, and biology.[62] Two new technologies also aided the study of ocean circulation. The bathythermograph (Fig. 2.6), developed in the United States to aid in WWII submarine warfare, allowed measurements of temperature variation with depth to be taken by 'non-experts' on moving ships.[63] Second, neutrally buoyant floats, invented in the United Kingdom, allowed for currents to be tracked at different depths (Fig. 2.7). The

Fig. 2.5: IGY scientist Roger Revelle prepares to deploy a Nansen bottle. (Source: Scripps Institute of Oceanography, Edward Sheldon Barr Papers, 1950-1975. Available online at http://library.ucsd.edu/dc/object/bb93867956.)

[62] Special Committee for the IGY. (1959). Oceanography. *Annals of the IGY, 7*, 298.
[63] See Oreskes, Lassiez-Tomber, for a detailed analysis of the politics of bathythermograph measurements.

floats were designed to sink to certain depths and contained a sonar ‘ping’ that could be detected from listening ships on the surface. These technologies, in addition to previously existing methods, allowed scientists to sample the sea at regular intervals and to generate an unprecedented amount of oceanographic data, even though most of the sea remained un-sampled.

The coordinated nature of the cruises allowed, for example, for scientists to confirm the presence of a deep current below the Gulf Stream, running in the counter direction along North America’s East Coast. Furthermore, both the bathythermograph and the neutrally buoyant float, have enduring legacies. While the bathythermograph is used today in a very similar form, altered mainly to be expendable, neutrally-buoyant floats have undergone several stages of innovation which now allow them to be highly

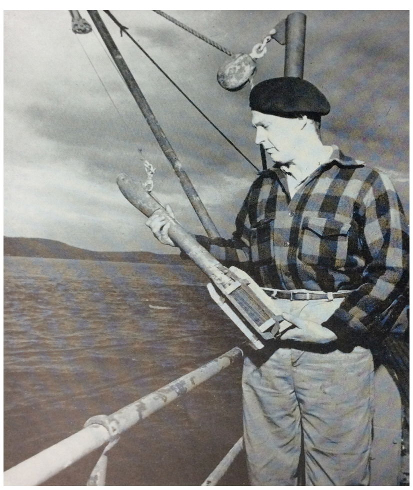

Fig. 2.6: A scientist prepares to deploy a bathythermograph during the IGY. (Source: Odishaw, H. (1958). The International Geophysical Year. *Science,*

Fig. 2.7: John Swallow works on the neutrally-buoyant float that he is credited with inventing shortly before the start of the IGY. Source: http://act.rsmas.miami.edu/journal/2010/april-

programmable, to collect data such as temperature, salinity, and dissolved oxygen, at various depths, and to be tracked via satellite. I discuss the implications of these technological changes in later chapters.

The long wave and sea level programs required a much different set of methods. Rather than being measured using instruments deployed from ships on high-seas missions, sea level and long waves were mostly measured using gauges or recorders installed in ports, on reefs, or on other coastal infrastructures. Recording long waves, in particular, presented some challenges. Ideally, long wave recorders should be set up away from the influence of coasts and coastal infrastructures, which interfere with the propagation and travel of the waves. Yet, the recorders of the 1950s needed to be attached to rigid frames (contemporary versions are now usually attached to buoys, or measure pressure and depth variations in the water column from the sea floor). An IGY long wave recorder (Van Dorn recorder) is pictured in Fig. 2.8.

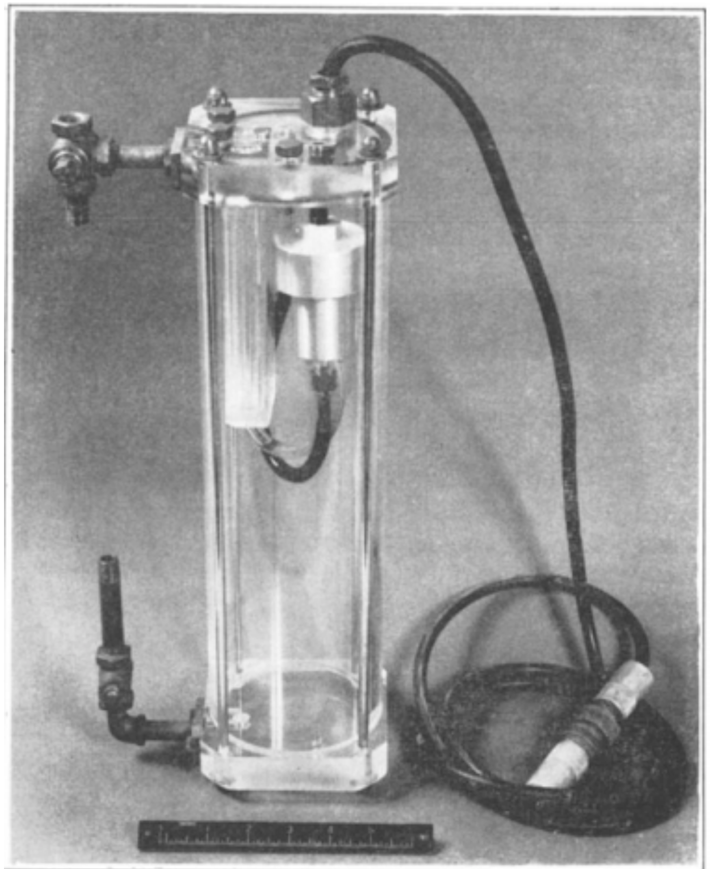

Fig. 2.8: A Van Dorn long wave recorder, a slight variation on the main design used during the IGY. (Source: Van Dorn, W. (1960) "A New Long-Period Wave Recorder." *Journal of Geophysical Research* 65(3) p.

Therefore, IGY scientists decided that "the most practical compromise so far employed is the installation of special recorders on small, isolated Pacific Islands, with the detector located on a steep offshore slope, well removed from reef channels leading to interior lagoons where harmonic oscillations may occur."[64] In the next section, I will discuss the significance of the long wave program in comparison to the IGY study of ocean circulation.

Seafaring imperialism and the nuclear Pacific

[64] Van Dorn, W.G. and Donn. W.F. (1969). Long Waves. *Annals of the IGY*, *46,* 47.

The reliance on oceanographic research cruises for the circulation studies of the IGY hence extended the tradition of blending oceanographic science with sea-faring adventure and exploration. The IGY study of ocean circulation was executed through a number of coordinated cruises carried out by 70 ships from 35 nations.[65] Yet, the US and UK, as well as the USSR, conducted the lion's share. Other wealthy nations with traditions of seafaring also participated, including Germany, France, and Norway. Navies still funded much of this research, and in one UK ship's log for IGY cruises, HMS (Her Majesty's Ship) had been crossed off and RRS (Royal Research Ship) penned in, indicating the close ties between the Navy and oceanographic research.[66] In the US, the national committee for the IGY suggested that the Office for Naval Research take control of the IGY program because "the ONR has had a long and successful history in organizing and managing an effective oceanographic program."[67] Participation in the IGY was a way for oceanographers in these military superpowers to show the relevance of their discipline beyond its wartime applications, thus ensuring continued governmental and public support. This was largely successful; both countries saw significant investment in oceanography following the IGY, most immediately in support for the Indian Ocean Expedition that immediately followed, and the International Decade of Ocean Exploration that kicked off in 1969.

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[65] Schlee, S. (1973). The edge of an unfamiliar world: A history of oceanography. New York: E.P. Dutton & Co., Inc. p. 346.
[66] Ship Log Discover II, 6 Sept - 7 Dec 1957. Located in the National Oceanography Centre library archive, Southampton.
[67] Minutes of Fifth Meeting, USNC Executive Committee March 8, 1955 Washington DC. In File: International Geophysical Year U.S. National Committee Meetings - 1955, National Archives at College Park, College Park, MD.

Walter Sullivan, the New York Times full-time reporter for the IGY, was quick to equate the physical presence of American scientists with their ability to make oceanographic knowledge, for example describing Roger Revelle as “an enormous man (6ft 4 in) who looks as if he were specially designed, both physically and temperamentally, to study the Pacific Ocean."[68] In fact, Sullivan’s words indicate the way that oceanographic cruises during the IGY carried on legacies of exploration and adventure, despite assertions of international cooperation and a new era of scientific exploration:

> "These men, accustomed to living with salt in their hair and their lives in jeopardy, typify oceanography as it was in the United States at the start of the IGY - a science pursued by barefoot youths in ragged shorts and greasy shirts on the wave-swept decks of sailing ships. What a contrast to the surroundings of other IGY explorers - the men on the launching pads at Cape Canaveral, or those with their instruments mounted in multi jet aircraft!"[69]

Fig. 2.9 shows the sort of scene that inspired this sentiment, aboard the US research vessel *Atlantis.* Well-muscled and scantily clad white male sailor/scientists, at home on the sea, invoke explorers and soldiers of (recently) bygone years, in contrast to the technological pioneers of other branches of IGY science.[70]

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[68] Sullivan, Assault on the Unknown, 346.
[69] ibid.
[70] It must be noted that this photo begs for a different (though not unrelated) interpretation, regarding displays of homosocial masculinity in the heterotopia of the ship. Some of these dynamics are discussed in Chapter 5; see also Casarino, C. (2002). Modernity at sea: Melville, Marx, Conrad in crisis. Minneapolis: University of Minnesota Press.

Fig. 2.9: A scene from a cruise on the RV *Atlantis*. This photo has no date but was probably taken around the time of the IGY, as the *Atlantis* was used by the Woods Hole Oceanographic Institute between 1931 and 1966. (Source: Rocky Miller Papers "Photos – Atlantis" Woods Hole Data Archive and Library).

The discussion of the ship-based ocean circulation research during the IGY provides some insight into how the long networks of oceanography as a 'big science' built upon imperial legacies and geopolitical tensions to give birth to new ideas of the Earth as a planet. However, this account risks remaining focused on a few ships, a select number of scientists, and a set of key technological developments; the hallmarks of Harris's characterization of 'small science' analytical bias. To truly account for the 'big science' of oceanography, it is not enough to remark upon the geopolitical power imbalances of international open-sea oceanography. Power imbalances flourished within oceanography programs as well; for example, Oreskes has also written about the gendered nature of oceanographic labor during the post-war period, analyzing the work typically done by women of compiling bathythermograph records to conclude that male scientists "high-graded" intellectual labor in order to glean accolades for scientific insights only made possible through the labor of many women data processors.[71] This has resulted in a story of oceanography that makes it seem as though the discipline's main insights can be understood as a the product of a few (mainly white) men, assembled in crews aboard intrepid sailing ships. This view also does little to challenge the idea that synoptic or global science is like a photograph; the narrative of imperial adventure follows easily into one of technological distance and easy universalism. In other words, both critical and conventional narratives of synoptic science have missed fully accounting for the distinctive, dispersed, and heterogeneous processes by which synoptic science actually gets made; the non-local work of making global knowledge. In addition to the labor of women, who processed much of the data from oceanographic cruises and performed countless other unacknowledged tasks while frequently being forbidden from going to sea themselves, we must also pay attention to the much slower, less exciting work of recording sea levels and long waves, done not by intrepid scientists emanating from centers of expertise but by technicians, natural resource managers, lighthouse keepers, and others on remote islands and colonial coasts.[72] We must not only account for their labor, but also show how these seemingly 'boring' forms of knowledge production were also tied into networks of imperialism and militarism.

[71] Oreskes, Lassiez-Tomber.
[72] Ibid.

The design of the long wave and sea level programs, their associated technologies, and their roots in nuclear experimentation introduce networks of relation that emphasis on the ship-based study of ocean circulation misses. By locating wave recorders on remote islands, the IGY oceanography program enrolled a set of actors distinct from the intrepid high-seas scientists from major research centers. The labor of local technicians and resource managers was required to keep the gauges in working order as well as to collect and report the data; for example, South Africa's IGY plans included the suggestion that "the light house keepers at Dassen and Bird Islands respectively be paid an honorarium of 5 pounds per month […] to look after the equipment after it had been installed and to change the recorder paper, etc."[73] Not only were places that previously had little contact with imperial oceanography included; they were specifically targeted: "Cooperation [was] solicited from countries bordering on oceanic areas where specific gaps existed in the network of stations previously proposed, such as, the South Atlantic and Indian Oceans."[74]

Discussion of the wave recorder and sea level programs of the IGY break with the usual narrative tropes of IGY reporting and provide a rare opportunity to view the IGY as something other than an unqualified success. Here is a report on the sea level program from 1960:

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[73] Program Report, South Africa National Committee for the International Geophysical Year 1957-58, Third Assembly of the Special Committee for the International Geophysical Year (CSAGI) 1957-1958, Brussels, September 1955. In RG 59 General Records of the Department of State, Records Relating to International Conferences, 1949-1958, and to the International Geophysical Year 1954-1958 (Multiple Lots) (Lot) 61D333 S/Sa Box 9 NN3-89-15, National Archives at College Park, College Park, MD.
[74] Van Dorn and Donn, Long Waves, 49.

> "Most of the sea level stations scheduled for the IGY have been set up and have been in continuous operation. But it will be some time before all the records have been measured for hourly heights and averaged for monthly mean sea level. There will also be some delay in assembling the necessary data on variations of temperature and salinity with depth."

Though still steeped in pervasive IGY optimism, this report on the long wave recorder program is perhaps even more telling:

> "It is doubtful whether the study of long waves is entirely successful. It is a new venture and there was insufficient time to gain experience with the apparatus designed for the purpose. There will be gaps in the observations, and some uncertainty about the exact response of some of the instruments to different periods, owing to changes in the characteristics of the hydraulic filters used to regulate the frequency response, but there will probably be enough data to give the time of onset and duration of outstanding disturbances. This will be a great step forward, and the difficulties that have been experienced have led to research on alternative methods that will help to make the most of the results. Possible failure to complete as much as was hoped is not surprising."[75]

It is difficult to obtain information on the day-to-day work of the long wave and sea level programs; human operators of the wave recorders are rarely mentioned. But some statements indicate that not all went smoothly; for example, Van Dorn, the inventor of the most prominent IGY long wave recorder, wrote that the instruments were "susceptible to storm damage and local vandalism."[76]

Why would local residents vandalize long wave recorders? Justification for this statement is lacking here, but we can imagine why tensions might exist. The imperial legacies of oceanography are not limited to the trope of adventuring sailor. The recording of long waves is also directly tied to US imperialism albeit in more modern forms. The first long wave recorders were established near the Scripps Institute for Oceanography in

[75] Laclavère, Oceanography, 177.
[76] Van Dorn, W. (1960). A New Long-Period Wave Recorder. *Journal of Geophysical Research, 65*(3), 1012.

La Jolla, CA in 1947 and 1948. However, their development was slow and "analysis of these records failed to produce any consistent cause and effect relationship."[77] Then, in 1952, oceanographers were invited to make long wave measurements during the US's first thermo-nuclear weapons test in the Bikini Atoll. The recorders they used were "hastily improvised and crudely designed," but opportunities to improve them were proffered by more nuclear tests in 1954 and 1956, leading the developer of the recording device used during IGY to conclude that "while most of these studies remain unclassified, it can be stated that coherent crest arrivals were observed at all stations, and consistent empirical relationships have been derived from these data which have materially improved our understanding of the generation and propagation of long waves in the open sea."[78] It was these results that helped to justify the inclusion of a long wave study in the IGY program. The US Pacific nuclear tests did not simply provide an invaluable opportunity for the testing and development of technologies. They also informed the scientists' decision to install the long wave recorders on isolated Pacific islands, chosen ostensibly because of the high incidence of tsunamis nearby but surely aided by the scientists' past experience in the region.

The IGY long wave program followed closely in the footsteps of the nuclear tests. Again, oceanographers from SIO developed instruments to be used (manufactured by Non-Linear Systems in nearby Del Mar, CA), and "personally visited Chile, Peru, New Zealand, Tahiti, and Japan to instruct local scientists in the operation of the instruments

[77] Van Dorn & Donn, Long Waves, 48.
[78] Van Dorn & Donn, Long Waves, 49.

and, where possible, to assist them in site location and installation."[79] Due to its high cost ($2600 US) and "the limited number of suitable and accessible islands," two other long wave recorders were also developed and used during the IGY.[80] Fig. 2.10 shows the location of US IGY stations throughout the Pacific. Note the stations (Wake, Johnston, Canton) clustered around the Pacific islands that were (and are) administered by the US Department of Defense. When it was not local fisheries managers, light house keepers, etc managing long wave and sea level data collection, it was frequently the US military.

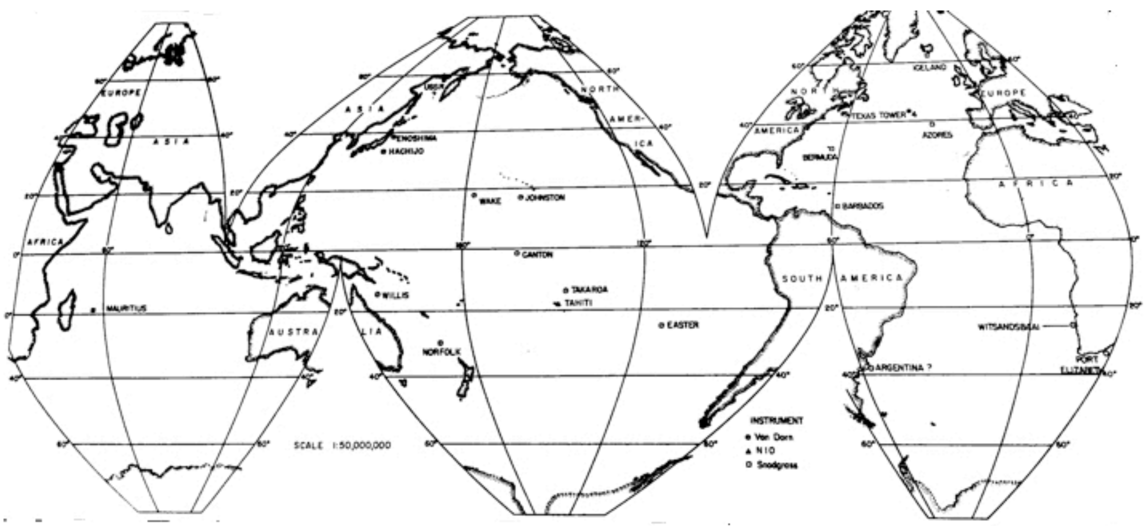

Fig. 2.10: International distribution of long wave recording stations. (Source: Van Dorn, W.G. and Donn. W.F. (1969). Long Waves. *Annals of the IGY*, *46,* 51).

The legacy of long wave recorders in nuclear experimentation points to another globality that is indelibly entangled with the IGY's storied globality of international cooperation, scientific diplomacy, and collaborative quest to solve the puzzles of the planet. As several authors have argued, a globality of nuclearism underlies a globality of international unity; perhaps in fact "the planetary extent of this militarized radiation

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79 Ibid.
80 Ibid.

inspired the modern concept of globalism itself."[81] Elizabeth Deloughrey argues that the myth of island isolation resides at the heart of Cold War science, linking the atom bomb tests with the emergent study of ecosystems. The connection between long wave recorders and nuclear testing and their installment on 'isolated' islands during the IGY points to similar dynamics. On one hand, the isolation of the islands was understood as important for studying long waves unfettered by the influence of other landmasses. On the other hand, the long wave program was designed to reduce the islands' isolation, bringing them into networks of measurement by both covering previous gaps in global measurements and establishing new ongoing research stations by installing equipment and training local technicians.

Conclusion: Imperial Earth, Global Humanity

I began this chapter with a conundrum: how to account for the silence I found in the IGY literature around the rapidly decolonizing global South (especially Africa) and potential new world order that occurred at the same time as this scientific project? What I have attempted to show is that this silence is non-incidental; it is not simply a question of benign neglect, or of science (and historical analysis of science) being narrowly focused or trying to stay 'pure' of politics. Rather, the scientific framing of the world as a common environment for a human species was a way to elide other, perhaps more revolutionary possibilities, keeping hegemonic nations at the helm of scientific expertise and territorial control. But this was not just ideological or geopolitical; the practices of doing global science, in this case global oceanography, involved suturing together new

[81] Deloughrey, E. (2012). The Myth of isolates: Ecosystem ecologies in the nuclear Pacific. *Cultural Geographies*, *20*(2), 168.

and old forms of colonialism in the name of the scientific exploration of a planetary environment.

The global humanity that the IGY called into being in this way underlies the logic of the Anthropocene. Lövbrand and colleagues connect Earth systems science, born during the IGY, to a comprehensive view of the Earth as one dynamically linked planet, subject to human monitoring, by which human influence might be monitored and ameliorated. They name this as a new form of governmentality, built upon the compulsion to model the Earth dynamically and thus bring it into the knowledge relation as a coherent and self-referential whole.[82] Here I have examined what went into the capacity to see the ocean in this way, tracing the politics of the 'big science' of oceanography to understand its legacies and conditions of possibility.

My analysis tells us something new about the IGY, showing how it was an important juncture for international oceanography and its world-making projects. The IGY indicates a coming-together on the knife-edge of militarism, technological change, and new ideas about the promises and threats of a global environment and a common humanity. More specifically, I have shown here how the oceanography program of the IGY tied together old and new forms of colonialism and imperialism, from seafaring adventurers to nuclearism. The politics of the IGY, then, go beyond a sort of geopolitical jockeying in which struggles for sovereignty and East-West ideology were couched in language of pure science and common enterprise. They also include a complex suturing of old and new colonial dynamics with new forms of internationalism in the name of

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[82] Lövbrand et al., Earth Systems Governmentality.

scientific pursuits. This can provide insight into the seemingly paradoxical politics that oceanography frequently seems to inhabit, helping me to make sense of moments like when scientists express concerns about the military-industrial complex and then in the next breath reminisce fondly about the days when their research was funded by the Office for Naval Research instead of the National Science Foundation.

But more than bringing new insights to the history and geopolitics of oceanography, or the IGY itself, I hope that my analysis helps us to better understand the distinctive dynamics of global knowledge creation. Oceanographic expertise, in the IGY and beyond, did not simply spread from knowledge centers in the metropoles to colonial peripheries. And inequalities and unevenness in the production of knowledge cannot be attributed simply to unequal capacities for scientific work (or these nations effectively being told 'not yet,' when it comes to participation in global science).[83] Assertions that all knowledge is local miss the power relations that *include* marginalized actors and locales as central not to creating knowledge that can be standardized and travel from place to place but knowledge that summarizes a global environment through widespread data collection.

I have experimented here, then, with a different method of analysis, one that tries to account for the long relational chains of big science rather than zeroing in on a few technologies, laboratories, and scientists.[84] I have done so by taking a wide-lens analytical frame, trying to give equal weight to geopolitical negotiations and scientific undertakings, drawing on a wide variety of sources from research articles to popular

[83] Chakrabarty, Provincializing Europe.
[84] Harris, Long Distance Corporations.

science writing to meeting minutes. Moreover, I have tried to show how science and geopolitics were intertwined not only in the results of scientific projects and their dissemination but also in the worlds that were built through their design and execution. Rather than localizing knowledge, I have tried to keep its most worldly and planetary inflections at the forefront even as I pay attention to the specific interactions from which global knowledge emerged. In doing so, I have examined the international division of labor that has produced our globe, and our world ocean. This analysis has demonstrated that efforts to know the Earth as a globe have not just papered over or reflected existing social and political unevenness, but have actively produced it. In going beyond attempts to castigate or debunk global knowledge by showing its roots in power-laden local encounters, I have taken seriously its power in constituting new worlds, or in making one world and not others.

By taking this approach I hope to add to new efforts to study big science, such as those cited earlier in this paper. In particular, I hope to aid in efforts to understand the dynamics of scientific knowledge in the Anthropocene, and especially the role of the world ocean in it. While critical scholars have been quick to point out that not all humans contributed equally to the conditions that brought about the so called ‘age of man,’ they have been less apt in diagnosing inequalities and geopolitics in the formation of the planetary science on which our understandings of the Anthropocene depend. It seems at times like there are only two possible positions to take. On one hand, even many critical social sciences and humanities scholars have been quick to adopt the findings of global science at face value, even celebrating the alleged politicization of disciplines such as geology that have recently garnered their attention as a result of the Anthropocene hypothesis. On the other, many have remained mired in the position that all knowledge is local, and that all ‘big science’ is inherently universalizing and hence oppressive. When it comes to the ocean, both of these positions are inadequate for understanding not only the role of the ocean in the planetary environment but also how it was called into being as a dynamic entity in concert with other geophysical systems and the relational chains engendered by the process of doing so. In this chapter, I have shown that while we can never leave ‘the local’ behind, we must not conclude with the assertion that all knowledge is local but rather employ an analytical and methodological approach that can account for how, and with what results, particular localities are put into relation in global-scale technoscience.

It is not enough, of course, to simply say that things are more complex than these two poles allow, but my hope is that I have some suggestions here as to how these complexities *matter*. Further, by showing that global scientific practice is indeed situated in particular places and practices, but cannot be reduced to local knowledge, I hope to make space for global knowledge claims that are not universal claims. We need the global to understand and contend with events like climate change; we should not cede the ability make claims about large-scale phenomena to hegemonic powers. I thus aim to push us closer to an understanding that would see big science as Chakrabarty sees Western philosophy, as “indispensible but inadequate” for imagining and enacting new and better worlds. Could a vision of a common planetary milieu square with revolutionary anti-colonial politics rather than simply eliding them? Could international science, with dynamics that are inherently unequal across the globe, play a part in creating the conditions of possibility for such a scenario? These questions cannot be answered here, but a methodology for studying big science, and an understanding of its origins, is a necessary start for a critical and ethical practice of planetarity.

CHAPTER THREE: THE OCEAN, THE ATMOSPHERE, AND THE VARIABIILTY OF THE WHOLE EARTH

I write this in the midst of an El Niño spring. It is widely recognized that the unseasonable temperatures we are experiencing in Minneapolis's usually lion-like March can be attributed to a variation in ocean temperature thousands of miles away. Or, more accurately, they can be attributed to complex linkages between the ocean and the atmosphere, understood to regulate or disrupt climate on a planetary scale. As popular scientific literature on climate change and phenomena like El Niño remind us, it is these linkages that bring the ocean into our everyday lives, even if we live quite far from the coast. The notion of an interlinked ocean-atmosphere is perhaps the most complete and powerful concept of a world ocean. It is, in large part, our perceptions of the complex yet indelible links between ocean and atmosphere that give us the impression not simply of a world ocean, but of an oceanic world.

Uniting sea and sky, comprising the largest and most influential elements of the planetary life-milieu, the ocean-atmosphere is epitome of the planetary scale. Moreover, it is both suggestive of and essential to notions of the 'whole Earth': the planet as an interlinked, self-regulating, self-referential coherent whole. Yet this concept of a linked ocean-atmosphere, like the closely-related global climate, is not self-evident. As Claire Colebrook writes, the "indispensible concept" of a global climate requires a "radical alteration of knowledge and affect."[1] A significant component of the alteration necessary to comprehend a global climate is the quantification of the ocean-atmosphere connection. The ability to measure exchanges between the ocean and atmosphere, and the effects of these relations, such as the slowing or acceleration of currents and the release of stored heat and carbon, is absolutely necessary for accurate climate modeling and forecasting. Yet while oceanographers and others have heuristically conceptualized the ocean-atmosphere system for some time, the ability to comprehensively understand its specific mechanisms and quantify them such that future behavior can be predicted has proved elusive. The World Ocean Circulation Experiment (WOCE), which took place from 1990 to 2002, was the first and perhaps largest effort to do so.

In this chapter, I query WOCE to ask how efforts to understand the ocean and atmosphere as one dynamic system have influenced conceptions of the world ocean, and how, in turn, these novel concepts of the world ocean introduce new dimensions of planetary environmental politics. If the ocean and atmosphere work together to determine weather patterns and climate history for the entire globe, then to think the ocean and atmosphere together is to think how they collectively constitute a world: our world. So, to interrogate the knowledge practices required to think this relationship is to interrogate the forms of planetary knowledge that give us ideas of a whole and singular Earth, the ideas that make species-thought possible and necessary in the Anthropocene.

In Chapter Two, I showed how the advent of synoptic oceanography engendered new understandings of the world ocean and extended new relational chains in pursuit of a

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[1] Colebrook, C. (2014). *Death of the Posthuman: Essays on Extinction, Vol. 1.* Ann Arbor, MI: Open Humanities Press, 10-11.

global picture of the sea. In this chapter, I turn to understandings of the ocean as not simply one entity with a planetary extent, but as a planetary *system*, interlinked through a set of dynamic exchanges. In doing so, I show how efforts to think the ocean-atmosphere as one system are linked to the compulsion to think the systematicity of the planet. In particular, I engage with Claire Colebrook's arguments regarding the 'whole earth' as a bounded form characterized by auto-coherence, self-healing, and homeostasis. I argue that on the contrary, scientific understandings of the ocean-atmosphere system have within them ideas of immense volatility and contingency. A careful exploration of oceanographic practice during WOCE shows the impact of this understanding on concepts of the world ocean and the global climate. I further employ Deleuze and Guattari's theorization of intensive processes to show how a mode of ocean study that attempts to grasp this variability has impacts on our understandings of Earth systematicity. Yet this understanding, rather than being simply celebrated as revealing lines of flight from the cloying, ineffective liberal mantras of whole Earth politics, must be set within its own historical and geographical context. By exploring the geopolitical dynamics of WOCE and its aftermath, I show how the discovery of the ocean's volatility and climate connections was linked to the classification of what constitutes global oceanography. This definition of global oceanography as open-ocean research has ongoing implications for how ocean volatility is understood and contended with. I argue, then, for the consideration of the boundary between sea and sky as a zone of linked political and material intensity. While geographers, historians, and cultural theorists have drawn attention to the space where land and sea meet at the shore as a zone of encounter, I propose that the zone where sea and sky differentiate deserves greater attention as key for understanding the geopolitics of science and emerging possibilities for planetary politics.

In making this set of arguments I employ a diverse range of sources, including ocean science publications, archival WOCE documents, and interviews with a number of scientists, including a project director of WOCE and the WOCE staff scientist, as well as scientists in the US, UK, and South Africa who were more peripherally involved in the program, yet watched it with a close eye. These sources help me to read oceanography through a set of ideas and thinkers more familiar to those in the social sciences and humanities, in particular Deleuze and Guattari and DeLanda. As I explain below, the spirit of improvisation and bricolage is alive and well in oceanographic science and practice, and serves my purposes as well.

Systematicity and the whole Earth

The desire, or even imperative, on the part of science to know the ocean and atmosphere as one dynamic system is tied to more widespread efforts to think the systematicity of the planet. Complex systems science has sought to understand the self-organizing nature of coupled social-ecological systems, characterized by scale-independent mechanisms of interacting feedback loops, bifurcations, and attractors, among others.[2] Systems dynamics and complexity theory underwrite contemporary thought on a wide variety of modern processes, such that their ontology has become pervasive and seemingly inevitable.

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[2] See for example Protevi, J. (2006). Deleuze, Guattari, and Emergence. *Paragraph 29*(2), 19-39.

Climate change, capitalist globalization, exponentially expanding networks of communication and information, are all predicated on and prompt further understandings of complex systems dynamics. A spate of recent scholarship seeks to historicize systems thinking and, though not exclusively, to indicate the ways in which their roots in cybernetics and information theory embroil these logics in Cold War politics of surveillance, control, and mastery over planned worlds and imagined futures.[3] At the same time, many of these authors point out systems theory's novel and extremely influential approaches to a wide gamut of topics, including understanding and ordering natural phenomena, such as the development of the ecosystem concept.[4] The potentially politically dangerous aspects of the adoption of systems thinking writ large, or conversely its merits, are too numerous and weighty to consider properly here. Instead I want to take up one possible consequence of thinking the ocean and atmosphere together: the systems theory-informed concept of a whole earth. The ocean-atmosphere system, with its planetary-scale dynamics and disregard for territorial boundaries, conforms to the logic and provides the spatial material for the immensely powerful concept of the Earth as a

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[3] Bousquet, A. (2009). *The Scientific Way of Warfare: Order and Chaos on the Battlegrounds of Modernity.* New York: Columbia University Press; Edwards, P. (1997). *The Closed World: Computers and the Politics of Discourse in Cold War America*. Boston: MIT Press; Hayles, K. (2008). *How we Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*. Chicago: University of Chicago Press; Mirowski, P. (2002). *Machine Dreams: Economics Becomes a Cyborg Science.* New York: Cambridge University Press; Pickering, A. (2010). *The Cybernetic Brain: Sketches of Another Future.* Chicago: University of Chicago Press; Wolfe, C. (1998). *Critical Environments: Postmodern Theory and the Pragmatics of the 'Outside.'* Minneapolis MN: University of Minnesota Press.
[4] See for example Edwards, P. (2010). *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming.* Cambridge MA: MIT Press; Hayles, How We Became Posthuman.

bounded, self-regulating, interconnected globe. The ocean-atmosphere system is the functional and dynamic fulfillment of the 'blue planet' seen from space.

Yet, this view of a whole earth is both inadequate and dangerous for a politics that aims to extend emancipatory potentials beyond the status quo of global capitalism. Claire Colebrook provides a particularly incisive critique that addresses and extends similar arguments by other scholars.[5] She notes that the figure of the earth as a whole, bounded only by its globe-form, is broadly subject to somewhat paradoxical interpretations. On one hand, there is the globe of globalization – despite capitalism's necessary exclusions and hierarchies, increasingly "an earth of a single time, single market and single polity."[6] This globalized world, Colebrook notes, might be met with nostalgia for lost diversity, or with optimism for the potential of a global consciousness à la Hardt and Negri. Another view is one frequently championed by environmentalists: the earth as an organism, self-regulating, equilibrium-seeking, and interconnected both in its vulnerability and its tendency toward or natural desire for balance. But these two views have one thing in common: the belief that there is an eventuality that we are rushing toward, and that is the full potential of a whole earth, a single, bounded, self-regulating entity: global fullness and presence no matter its flavor.

Colebrook's perhaps most insightful move is to tie the logics behind the whole earth concept to Giorgio Agamben's critique of biopolitics. Agamben, Colebrook claims, mourns the loss of the properly political under biopolitics as the misaddress of power to

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[5] Colebrook, C. (2012). A Globe of One's Own: In Praise of the Flat Earth. *SubStance 41*(127), 30-39.
[6] Ibid., 31.

bare life rather than to life as *bios*, the "properly political life of self-formation and speaking in common."[7] *Bios*, then, is the realization of man's proper form, bounded only by his own self-definition (gender intentional). Instead, Colebrook argues, we should attend to Michel Foucault's rather different formulation, which shows that the very concepts on which biopolitics rests in fact emerge from a particularly modern kind of global thought. Foucault, Colebrook claims, writes that the concept of life as such, or life as a concept to which power might be addressed, is made possible by the logics of the bounded globe or self-determining form. The concept of the globe as inherently life-fostering, self-referential, with a "proper potentiality that might be restored" is necessary for biopolitics, as it seeks to establish norms and govern life itself. [8] In other words, the possibility of biopolitical life as self-evidently valuable, the possibility of the *bios* as capable of fulfilling its political potential, is only raised by the notion of the globe as humanity's milieu. So, it is the 'whole earth' that makes biopolitics possible; the same bounded form to which anti-globalization and environmental activists, not to mention Agamben (along with Hardt and Negri), pursue recourse.

Besides the problems that might be intrinsic to the use of the logics of globalization to address environmental crisis, Colebrook points out a number of ways in which this whole earth concept misidentifies what is lost under biopolitical governance and is bound to fail emancipatory politics. First, the notions upon which it rests are not an adequate understanding of "a temporality and politics that is no longer that of contesting agents waging a war for the sake of a determined end," the figures of which range from

[7] Ibid., 35.
[8] Ibid., 38.

terrorism to viral epidemics to climate change.[9] For addressing such forms of power, the bounded earth, or the properly political as a pre-defined potentiality, is "both a lure and an alibi."[10] But more importantly, Colebrook argues, it is only man (gender intentional) whose milieu is the globe, who is capable of the suicidal planetary destruction of which we are presently both witness and antagonist. This is the human with access to the fulfillment of globalization's logics coupled with no limits except those he creates for himself. A humanity with no laws but the making its own 'natural' laws (the bios of Agamben's biopolitics) living in what it perceives as a self-healing planet is the humanity of the worst possible Anthropocene, and a humanity already on an accelerated march toward extinction.

Colebrook advocates, then, forcefully doing away with the whole earth image and on the contrary searching for and nurturing "forces that resist recuperation, incorporation and comprehension—forces that operate beyond intentionality and synthesis."[11] Does this mean we must do away with complex systems thinking? Other scholars have suggested that complex systems thinking might lead to conclusions different from those of interconnectedness, equilibrium, and boundedness that have served imperialism and capitalism so well; in fact, neoliberal capitalism might even be understood as, in part, an attempt to contain some of systems theory's radical impulses.[12] As I will argue, paying

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[9] Ibid., 33.
[10] Ibid., 35.
[11] Ibid., 39.
[12] See especially: Braun, B. (2015). New Materialisms and Neoliberal Natures. *Antipode*, *47*(1), 1-14; Nelson, S. H. (2014). Resilience and the neoliberal counter-revolution: from ecologies of control to production of the common. *Resilience*, *2*(1), 1-17.

attention to early efforts to think the ocean-atmosphere relation show that attempts to measure systems dynamics might lead to alternate conclusions than those commonly suggested by adherents to the 'whole earth' concept.

In Deleuzian terms, the realization of complex systems science in oceanography shifted the understanding of the atmosphere and ocean as extensive spaces to one of entities characterized by intensive differences. Being attentive to these intensive differences, I argue, compels different readings of the whole earth, showing that the current arrangement is but one possibility. The intensive relations of the ocean and atmosphere are ones of memory and movement, and should be considered as the defining spaces of potential for this and other possible worlds. Yet the processes by which these relations came to be known matter too. These knowledge practices must be historically and geopolitically contextualized in order to understand how this volatility has come to have particular meaning and how other paths of exploration have been curtailed. In particular, I show how the discovery of ocean volatility by global North-led scientific projects resulted in the definition of global oceanography as 'open-ocean' or 'blue water' oceanography, sidelining possibilities for international alliances around coastal issues and instantiating a 'pay-to-play' field, which contemporary efforts at capacity building and equality in science must seek to correct.

Conceptualizing the ocean-atmosphere: the conveyor belt diagram

While the deep sea was once thought to be stagnant, devoid of interest to land-based creatures such as humans, by the advent of modern oceanography, these assumptions were being questioned.[13] In the previous chapter, I discussed the discovery of deep ocean currents and the early inklings of their role in climate during the International Geophysical Year (1957-1958). Since then, decades prior to the advent of ocean-atmosphere modeling capabilities, the ocean has frequently been called the "flywheel" of the climate system.[14] In other words, the ocean acts as a "governor on climate variability" through its motion and slow release of energy and other properties.[15] While scientists have long known that the ocean has a large impact on climate, the extent and mechanisms of this relationship have been relatively underexplored. As eminent oceanographer Walter Munk wrote, "The oceans are the principal reservoir for the storage of CO_2, of heat and of ignorance."[16]

In the years leading up to WOCE, global ocean circulation and its role in climate was summarized by geochemist Wallace Broecker's 'conveyor belt diagram,' which first appeared in the November 1987 issue of the popular science magazine *Natural History* and soon after became the logo for the Global Change Research Initiative (Fig. 3.1).[17] The use of the conveyor belt diagram as the logo for the GCRI was to suggest that

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[13] Rozwadowski, H. (2005). *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea*. Cambridge, MA: Harvard University Press.
[14] See for example: Bretherton, F. (1982). Ocean Climate Modeling. *Physical Oceanography 11*(2), 93; McGowan, J.A. & Field, J.G. (2002). Ocean Studies. In Field, J.G., Hempel, G., & Summerhayes, C.P. (eds). *Oceans 2020: Science, Trends, and the Challenge of Sustainability.* Washington DC: Island Press, 9; Sullivan, W. (1961). *Assault on the Unknown: The International Geophysical Year.* New York: McGraw Hill, 348.
[15] McGowan and Field, "Ocean Studies," 9.
[16] Munk, W. (2002). The Evolution of Physical Oceanography in the Last 100 Years," *Oceanography, 15*(1), 135.
[17] Broecker, W. (1987). The Biggest Chill. *Natural History Magazine, 97*, 74-82; see also Broeker, W. (1991). The Great Ocean Conveyor. *Oceanography, 4*(2), 79-89.

“changes in the Atlantic’s thermohaline circulation were responsible for the abrupt and large climatic changes experienced by the north Atlantic basin during the last glacial period” and thus emphasize the emerging concern that “complex interconnections among the elements of our Earth's climate system will greatly complicate our task of predicting the consequences of global pollution.”[18] Thermohaline circulation refers to ocean circulation caused by heat and salt differentials, rather than surface winds or ocean bathymetry, and is the primary mechanism of interest, particularly when it comes to climate. The conveyor belt diagram illustrates the ocean’s role in climate by showing how currents distribute warm and cool waters around the globe, which in particular explains Europe’s latitude-incongruous warm winters. The diagram, still reproduced in oceanography textbooks today, conveys a picture of ocean circulation that is very compatible with the ‘whole earth’ notion: seawater is seen to move sinuously around the globe, cyclical with regard both to deep-shallow current patterns and to global surface extent; the diagram “implies that if one were to inject a tracer substance into one of the conveyor's segments it would travel around the loop as a neat package eventually returning to its starting point.” [19]

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[18] Broecker, The Great Ocean Conveyor, 79.
[19] Ibid.

Even at the time of the diagram's publication, Broecker acknowledged its oversimplification of complex patterns of ocean circulation, stating that the diagram's suggestion of the ocean's simple circularity mentioned above was in fact its "main problem," and that different circulation "loops" and mixing processes surely exist.[20] Broecker's contemporary and future colleagues would echo this criticism.[21] However, it was not until the advent of satellite oceanography, complex modeling of the ocean-

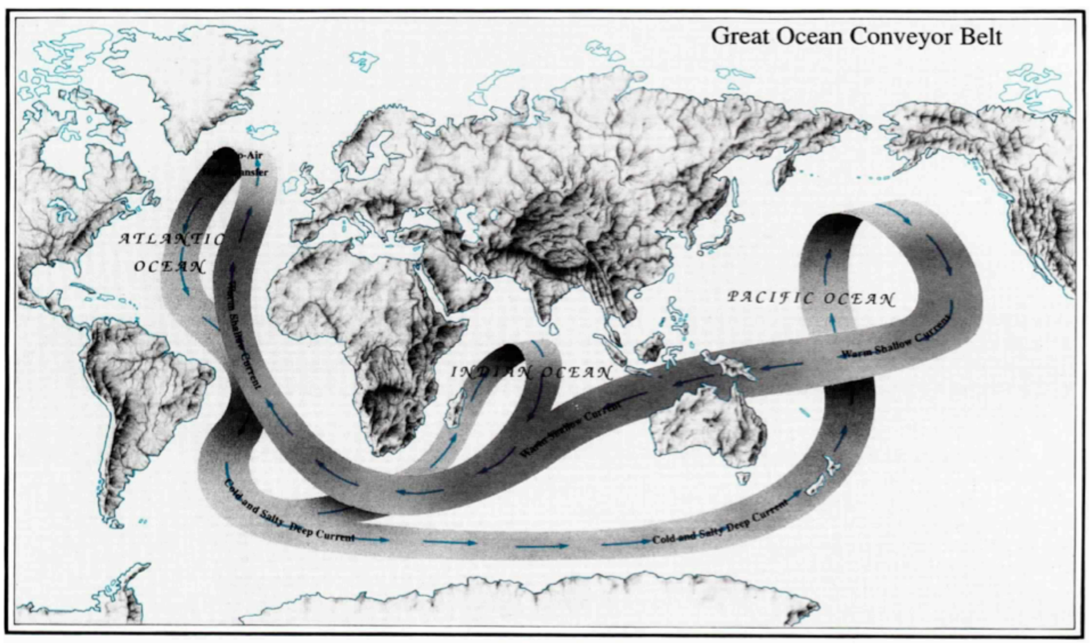

Fig. 3.1: Broecker's conveyor belt diagram (Broecker, 1991; reproduced from Joe Le Monnier's 1987 rendition).

atmosphere system, and improved datasets, all of which began to cohere during WOCE, that the conveyor belt model and its linear, closed-circuit model of ocean circulation would be fundamentally challenged.

[20] Ibid.

[21] John Gould, personal communication, Southampton UK, 19 February 2014.

The efforts at synoptic oceanography that ultimately disputed the conveyor belt model of ocean circulation might be understood as attempts to understand the ocean and atmosphere not only in their spatial dimensions, but perhaps more importantly as constituted through differentials of heat, fresh water, and other properties exchanged at varying rates through their interlinked and constantly moving surfaces. This conceptual shift was only realized through an iterative relation to processes of data collection and numerical modeling. In Deleuzian terms, this is a shift from focusing on the ocean and atmosphere's extensive qualities to trying to understand their intensive relations, which I will discuss in greater detail below.

Measuring and mapping the circulation of the world ocean

Systems science aside, it was clear to the oceanographic community as the last decade of the 20th century approached that it was time for the next big scientific effort in oceanography. The future of oceanography was both literally and figuratively on the horizon; not only had a new satellite been launched to measure sea surface height, but a global-scale ocean observing system consisting mainly of unmanned ocean sensors was within the range of technical possibility. To not dream up a global scale oceanographic project, following on the heels of programs such as the Mid Ocean Dynamics Experiment (MODE) and the Tropical Ocean Global Atmosphere (TOGA) project would have been a missed opportunity. But the future was also coming too fast: a changing climate was calling for these developments more rapidly than they could emerge. A series of concerns - ozone depletion, acid rain, nuclear winter and anthropogenic climate change - came to the fore that emphasized the truly global impact humans could have on the atmosphere and hence the ocean.[22] Climate change was becoming a threat at the same time that the techniques and technologies for measuring it were being realized.[23] It was increasingly obvious that the ocean plays a major role in climate, particularly in the transport and storage of heat and carbon, and in anomalies that affect precipitation patterns. Yet these mechanisms, and the state of the ocean more generally, were barely understood, largely due to the scarcity of oceanographic data and limited computing power for modeling the ocean-atmosphere relationship. When it came to claims to understand the climate system "the ocean was the 800 pound gorilla in the room."[24] At the same time, throughout the world oceanography was being pressed to be more directly useful, and creating useful knowledge for contending with climate change was a vital way to address this call.[25]

The overarching goal of WOCE was to, for the first time, get a picture of global ocean circulation such that decadal climate predictions could be made. This goal could be broken down into the following objectives: "to develop models useful for predicting climate change and to collect the data necessary to test them; and to determine the representativeness of the specific WOCE data sets for the long-term behavior of the ocean, and to find methods for determining long-term changes in the ocean circulation."[26] These dual emphases on data collection for modeling, and how to measure long-term

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[22] Edwards, A Vast Machine.
[23] See for example Fofonoff, N. (1992). WOCE now entering 'Intense observation stage.' *Sea Technology,* (Oct 1992), 49-54.
[24] Weller, personal communication.
[25] Thompson, B.J., Crease, J., & Gould**,** J. (2001). The origins, development and conduct of WOCE. In Siedler, G., Church, J., & Gould, J. (eds). *Ocean Circulation and Climate: Observing and Modelling the Global Ocean.* San Fransisco CA: Academic Press, 37.
[26] Thompson, Crease, and Gould**,** The origins, development and conduct of WOCE, 37.

changes in the sea, would guide the project throughout; I discuss them in greater detail below.

The terms with which scientists speak of these overarching aims point to the degree to which the ocean was unknown prior to WOCE, and consequently to the complexity and necessity of the questions the project sought to answer, many of which might seem very basic to an outsider. As oceanographer Kenneth Brink states, "WOCE was driven by, basically there was a question about what actually is the ocean circulation like? You know, how strong is the Gulf Stream, really? And at that time we still only had vague numbers on that."[27] Penny Holliday, WOCE's staff scientist, identified similar concerns: "You know, you have typically kind of a cartoon picture in your mind of what the sort of, the general ocean circulation looks like. And we just didn't know what the current, heat transport of these sections really was."[28] Perhaps Harry Bryden best expresses the progress WOCE made in such an unknowable realm: "I think WOCE probably moved us from the ocean as a mysterious place where there were […] giant squid, you know, 20,000 leagues under the sea and it was really unknown. Well, it still is."[29]

WOCE had two main components: a field research phase, which was intended to last from 1990-1995 but was extended for two years due primarily to a delayed satellite launch, and a phase of analysis, interpretation, modeling, and synthesis (AIMS) from 1997 to 2001, although the last WOCE hydrographic atlas was finally published in 2013.

[27] Brink, personal communication.
[28] Penny Holliday, personal communication, Southampton UK, 19 February 2014.
[29] Harry Bryden, personal communication, Southampton UK, 19 February 2014.

It should also be noted that WOCE data is still being processed in various ways, facilitated by online open access to WOCE data products. Altogether, the program cost between $0.5 and 1.5 billion; the exact amount is difficult to estimate because individual nations shouldered the financial responsibility for each of their national contributions.[30] WOCE received support from the Special Committee for Oceanographic Research (SCOR) to finance its international project office (IPO) in the UK (first in Wormley, then Southampton), and to fund workshops and meetings. The funding for the research itself had to come from the participating nations' science budgets.[31] To refine the objectives and accordingly determine the execution of the field research phase, a Scientific Steering Group (SSG) was established in 1983, and in 1985 held its first international meeting to "present the Implementation Plan to national authorities, to gain their interest, and to gauge their commitment."[32] Of the 31 countries that initially expressed interest, 22 eventually ended up participating in the project.[33]

Implementing WOCE

The WOCE SSG, composed primarily of scientists from the US, UK, France, Germany, Russia, and Japan, drew up a detailed science plan, which was essentially a "wish list" of data to be collected.[34] Two main different types of programs were delineated: repeat hydrography and process studies. Repeat hydrography consists primarily of sections, or

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[30] Gould, J. The World Ocean Circulation Experiment and the Ocean's Role in Climate, 86.
[31] Holliday, personal communication; Edward Urban, personal communication, Cape Town South Africa, 20 October 2014.
[32] Thompson, Crease, and Gould, The origins, development and conduct of WOCE, 37.
[33] Ibid.; Holliday, personal communication; see conflicting number (30) in Gould, The World Ocean Circulation Experiment and the Ocean's Role in Climate, 86.
[34] Holliday, personal communication.

series of stations along prescribed lines of latitude or longitude at which certain data (usually temperature, salinity, dissolved oxygen, etc) is collected at various depths. The most basic observations collected this way are arguably the most important: measurements of how temperature and salinity change with depth. These measurements are compiled to create a “profile” of the water column at a given location (see Fig. 3.2 for an example). Taken together, temperature and salinity profiles allow scientists to ‘see’ the structure of the ocean and to trace the position and movement of particular water masses. This strategy of data collection aims at a global ‘snapshot’ of ocean circulation and also provides baseline data for future studies. Fig. 3.3 shows an image from the WOCE hydrographic atlas of temperature profiles compiled to create continuous data across one of the WOCE hydrographic sections.

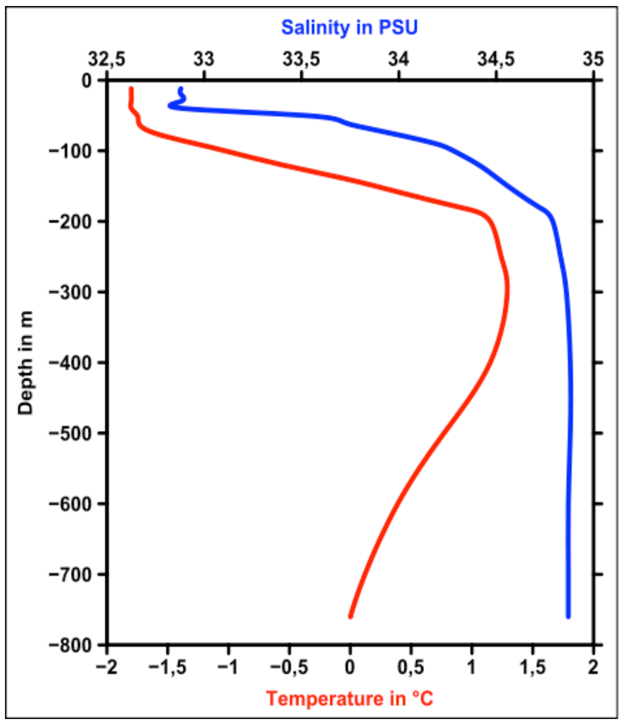

Fig 3.2: An example of a temperature and salinity profile. (Source: U.S. National Oceanographic Data Center: Global Temperature–Salinity Profile Program)

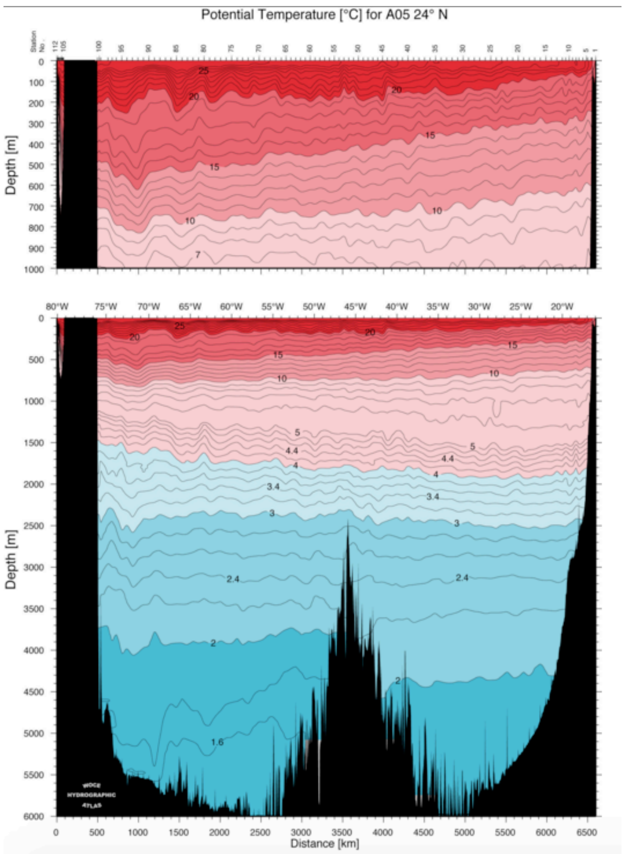

Fig. 3.3: Temperature plot for WOCE section A05 (across the Atlantic at aproximately 35° N). (Source: WOCE Atlantic Ocean Atlas)

Process studies entail more intensive measurements taken on a smaller scale with the intent of gaining a better understanding of specific ocean mechanisms such as gyre formation or air-sea fluxes that can then be generalized across broader and different locations. Hydrographic and process studies often (though not always) require different sampling technologies; for example, process studies are more likely to use moorings, while repeat hydrography traditionally relies primarily on ship-based measurements. While the initial WOCE plans called for ambitious programs of both repeat hydrography and process studies, financial difficulties over its duration limited what could realistically be executed. Global scale measurements, in other words the repeat hydrography program, were prioritized at the expense of the program of process studies.[35] Fig. 3.4 shows the global survey of WOCE, while Fig. 3.5 shows stations that were occupied repeatedly and areas of intensive study.

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[35] Weller, personal communication. The US WOCE budget for hydrography between 1987 and 1996 was about twice that of process studies during that time. See Ocean Studies Board, Commission on Geosciences, Environment, and Resources, National

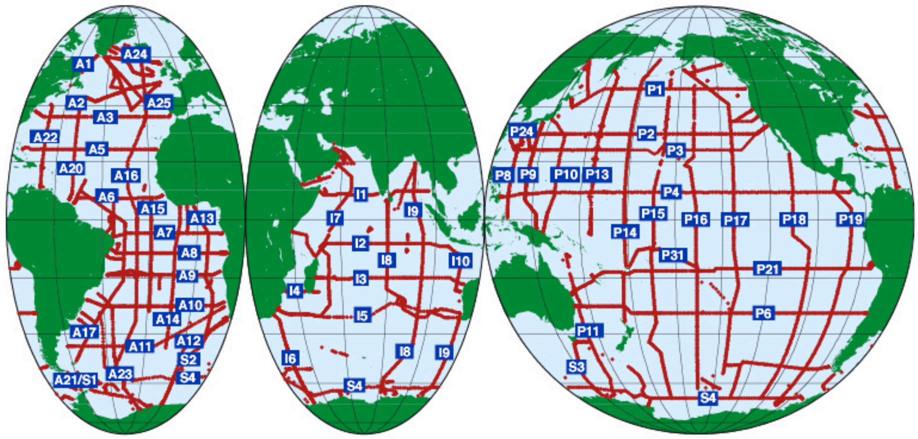

Fig. 3.4: WOCE one-time global survey (source: Sparrow, M., P. Chapman, J. Gould (eds.). (2005-2013). The World Ocean Circulation Experiment (WOCE) Hydrographic Atlas Series (4 volumes), International WOCE Project Office, Southampton, UK)

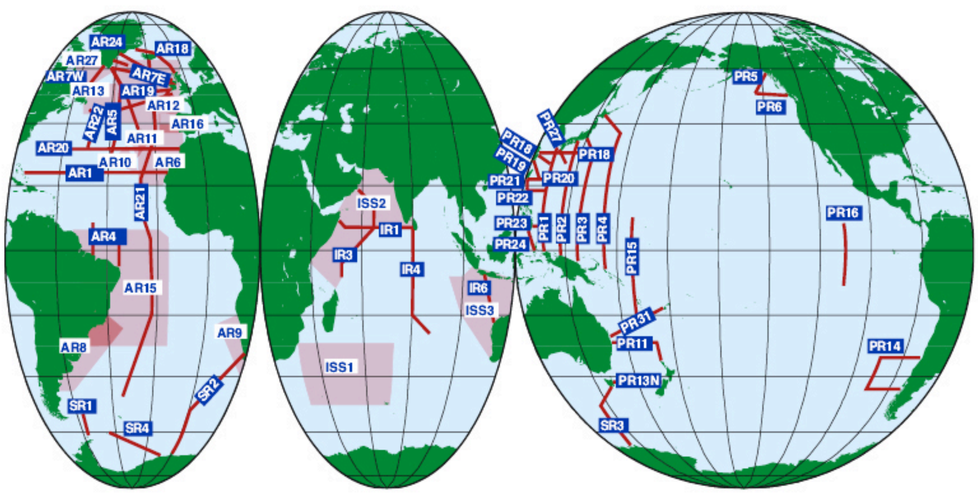

Fig. 3.5: WOCE repeat hydrography and areas of intensive study [shaded regions] (source: Sparrow, M., P. Chapman, J. Gould (eds.). (2005-2013). The World Ocean Circulation Experiment (WOCE) Hydrographic Atlas Series (4 volumes), International WOCE Project Office, Southampton, UK)

Resource Council (1999). *Global Ocean Science.* Washington DC: National Academy Press, 134-135.

WOCE's ship-based program was augmented by observations from other *in situ* instruments and from new satellites. The joint US/French designated altimetric satellite TOPEX/Poseidon was launched at the outset of WOCE, and the program also benefited from Europe's ERS-1 satellite and Japan's ADEOS mission, as well as others. Satellite technologies were among the most exciting and new methods to be developed during WOCE, and many scientists emphasize that satellite oceanography revolutionized the field. However, it remains true that satellites only measure the surface of the ocean and do not measure all relevant properties; thus an advanced array of *in situ* methods was also necessary.[36]

WOCE scientists used a variety of methods to measure ocean properties. Of particular interest were exchanges (fluxes) of heat, water, and dissolved chemicals, "requir[ing] a complex variety of measurements."[37] The WOCE hydrographic survey program consisted of 65 sections throughout the world ocean where temperature, salinity, density, and chemical tracers were measured throughout the water column. A series of approximately 2,200 surface drifters measured properties of the surface layer, in large part to determine the role it plays in heat exchange (flux) with the atmosphere, and transmitted their position via satellite, thus measuring the flow of surface currents. Other floats drifted at predetermined depths, measuring subsurface currents by transmitting their positions like the surface drifters. Subsurface drifters were intended to provide data for 250 x 250-kilometer grid squares of the global ocean. Expendable bathythermographs took temperature readings from cargo ships, also called voluntary observing ships or

[36] Gould, personal communication.
[37] Fofonoff, WOCE Now Entering 'Intense Observation Stage,' 51.

ships of opportunity. This data is valuable because it can be gathered at high density along frequently traveled routes in the waters of many nations as well as the high seas, at low cost to scientific programs. Programs of both high- (16-20 profiles per day) and low-density profiles (four profiles per day) were designated in the WOCE science plan. The WOCE program also called for about 70 moorings. These sets of instruments, suspended between surface or subsurface buoys and the ocean floor, make time series measurements, especially of currents, throughout the water column. At the time of WOCE they had to be recovered for their data to be retrieved. Finally, about 100 new sea level gauges were installed, mainly to calibrate the satellites and to make some current measurements.[38]

A big responsibility for the participating scientists was not just collecting the data but reporting it to the WOCE Data Assembly Centers. WOCE had very high standards for both data collection and reporting, much higher than most previous projects in global oceanography.[39] It was the job of the staff scientist in the project office to remind the investigators of their obligation to report data in a timely fashion, and to resist any proprietary urges and career incentives they had to maintain exclusive access to their data.[40] The staff of the Data Assembly Centers was also tasked with a high degree of quality control, towards which they took measures both before and after data collection. Penny Holliday's explanation is worth quoting at some length:

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[38] For a summary of WOCE data collection methods, see Fofonoff, WOCE Now Entering 'Intense Observation Stage'; for datasets and summaries see the World Ocean Circulation Experiment Global Data Resource, WOCE Data and Summaries at http://www.nodc.noaa.gov/woce/wdiu/diu_summaries/default.htm
[39] Fofonoff, WOCE Now Entering 'Intense Observation Stage,' 52.
[40] Holliday, personal communication.

> "For the hydrographic sections for example, the data needed to be of a certain spacing of stations, they needed to have a specified number of parameters that needed to be measured, and those parameters needed to be to a particular quality. And this was the same in all aspects of the field program, the different data types all had their own specifications, and that was a deliberate policy to reduce the uncertainties due to poor data quality. […] The key thing was that all of the data assembly centers […] were situated within research institutes, and were run by scientists, not data managers, and that was key because assessing the quality of the data, not just in terms of its accuracy, you know against standard sea water or something, but also to see whether the CTD [conductivity-temperature-depth measuring instrument] wasn't working properly, or the XBT [expendable bathythermograph] had a spike in it […], or a blip in it that wasn't a real temperature inversion, it was the wire stretching or something. So every single bit of data, every profile, and every segment in a time series was examined visually by a human being who knew what they were doing, so we could flag data, […], so that users would know what the quality of the data was, and wouldn't be using spurious data. And that was a massive challenge, and also that was another example of cooperation. That could only be done cooperatively."[41]

Thanks largely to these efforts, likely the most important output of WOCE was a series of high-quality datasets that are still available free of charge on the internet. This data was also packaged in a variety of outputs, including a series of regional atlases that include various visualizations of the different kinds of data collected, as referenced above.

WOCE and the modeling imperative

WOCE was remarkable in its explicit and concerted effort to collect data for the purpose of modeling, and the corresponding collaborations it entailed between modelers and observational scientists.[42] Due to the immense nonlinear complexity of coupled dynamics and the amount of computation required, models are necessary for understanding the ocean-atmosphere, let alone predicting its future character. Perhaps more accurately, observational data can (with some limitations) describe the state of the ocean but

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[41] Holliday, personal communicaton.
[42] Thompson, Crease, & Gould, The origins, development and conduct of WOCE.

modeling is necessary to understand its processes.[43] Scientists make this blatantly clear: "You can't understand the ocean without models now. Or you never could."[44] Or similarly: "If you're to understand climate you're not going to understand it solely through observations. You've got to have a model of the atmosphere and the ocean coupled together."[45] Moreover, observations and modeling have an iterative relationship: observational data is required to make and test the models, and model shortcomings and inaccuracies indicate to scientists the data they must collect.

Science studies scholars and others have analyzed the creation and use of models, their assumptions, and their effects, in great detail elsewhere.[46] Here I will focus on the elements of modeling that were crucial to WOCE and that are involved in conceptualizing the ocean-atmosphere as one dynamic system. Put simply, oceanographic models bridge the gap between theories and observations. They rely on numerical equations, adjusted by observational data. Models "have theories as inputs, and in so doing connect theories to data; they generally make more precise predictions than do theories, or make predictions where the theories can make none."[47] They also allow scientists to make long-range predictions, and to perform virtual experiments, rendering

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[43] Francis Marsac, personal communication, 28 November 2014.
[44] Holliday, personal communication.
[45] Gould, personal communication.
[46] See for example, Turkle, S., ed. (2009). *Simulation and its Discontents* Cambridge MA: Duke University Press; de Chadarevian, S. & Hopwood, N., eds. (2004). *Models: The Third Dimension of Science.* Stanford, CA: Stanford University Press; Edwards, A Vast Machine.
[47] Sismondo, S. (1999). Models, simulations, and their objects. *Science in Context, 12*(2), 249.

them invaluable to Earth systems science, in which experiments are often too expensive or risky, or simply impossible, and the time scales of inquiries are frequently vast.

However, the relationship between empirical observations, models, and theory in oceanography is highly complex. Oceanographic models operate in a paradigm of what Paul Edwards calls "reproductionism." That is, they "[seek] to simulate a phenomenon, regardless of scale, using whatever combination of theory, data, and 'semi-empirical' parameters may be required."[48] To put Stengers' words in a slightly different context, modelers attempt to "[bring] into existence a being that will serve as a reliable witness to whatever determines that being's behavior."[49] But serving as a reliable witness does not mean reproducing exactly, or by the same dynamics. A sort of 'whatever works' approach is used to call into being the model as reliable witness, and the reliability of the witness is determined by the factors that are deemed important to the ocean's behavior. Therefore, modelers do not expect models to accurately simulate reality, but rather to be useful for making improved simulations and refining dynamical understandings.

The limiting factor for modeling advances is almost invariably computing power, and occasionally mathematical or data constraints. Although numerical models have been central to many sciences, perhaps especially meteorology, for some time, computer models were not considered important or viable parts of science before the 1970s; science without them is now nearly inconceivable.[50] However, in computer models the ocean would remain a stagnant bottom layer for several more decades, until computing power

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[48] Edwards, A Vast Machine, 281.
[49] Stengers, I. (2010). *Cosmopolitics.* Minneapolis MN: University of Minnesota Press, 68.
[50] Edwards, A Vast Machine.

and data availability caught up such that modelers could begin to simulate the ocean's dynamic variability. WOCE aimed to develop models for climate change and also to improve theoretical methods of modeling improved, in particular data assimilation.[51] In the decades leading up to WOCE, data assimilation, which iteratively uses data to 'nudge' models closer to observations, emerged as an important modeling method.[52] Data assimilation is an interesting development because it incorporates observational data into the very constitution of the model, building a form of model testing and refinement into the modeling mechanisms. For scientists involved with WOCE, data assimilating models and served as both an exciting new tool and an imperative to collect more, and more continuous, data.

A significant challenge for ocean modeling came in the form of what oceanographers call mesoscale features. While ocean circulation had long been understood in terms of global-scale heuristics, "many of the eddy processes in the ocean are governed by short spatial scales ranging from about 10 kilometers in the polar regions to about 25 kilometers in the sub-tropics."[53] As I describe below, during WOCE these eddies were discovered to have a great deal of influence on ocean circulation, and modeling them became a priority. Developing models that could express eddy processes required finer resolution, which requires greater computing power. Hence, with the impetus to better understand mesoscale processes and their impact on the system as a whole, modelers quickly took advantage of the large increase in computing power that

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[51] Fofonoff, WOCE Now Entering 'Intense Observation Stage.'
[52] Edwards, A Vast Machine; Bjorn Backeburg, personal communication, 14 November 2014.
[53] Fofonoff, WOCE Now Entering 'Intense Observation Stage,' 53.

occurred in the 1990s for the development of eddy-resolving models. Yet, ocean modeling is still fraught with uncertainties; as one climate scientist told me, "it's the missing link of Earth science, really."[54]

Contending with ocean variability

WOCE built on and contributed to new understandings of the very nature of ocean circulation. Prior to the 1970s, studies had mainly focused on linear processes such as "gyre circulation, westward intensification, [and] thermohaline circulation."[55] Then, in the early 1970s, a set of experiments and related modeling work by American and Soviet scientists (independently and in collaboration) using a new generation of current meters and drifting buoys indicated highly complex features on the mesoscale.[56] These features, or eddies, indicated complex vertical structure, i.e. mixing between different vertical layers (turbulence), as opposed to the smooth sliding of one layer over another (laminar flow), which is how currents were previously thought to function.[57] But they lacked other unifying characteristics, appearing to vary so greatly in size and formation mechanisms that oceanographers wrote of "new animals for the eddy zoo."[58] Fig. 3.6 is an example of different sorts of eddies off the coast of South Africa, spiraling off from the strong

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[54] Chris Lennart, personal communication, 17 February 2016.
[55] Thompson, Crease, and Gould, The origins, development and conduct of WOCE, 31.
[56] Shillington, personal communication. See also Wunsch, C. (1999). Where Do Ocean Eddy Heat Fluxes Matter? *Journal of Geophysical Research, 104*(C6), 13,235-13,249; Stammer, D. & Böning, C.W. (1992). Mesoscale variability in the Atlantic Ocean from Geosat altimetry and WOCE high-resolution numerical modeling, *Journal of physical oceanography*, *22*(7), 732-752.
[57] Wunsch, Where Do Ocean Eddy Heat Fluxes Matter?
[58] Richards, K.J. & Gould, J. (1996). Ocean Weather – Eddies in the Sea. In Thorpe, S.A. (ed). *Oceanography: An Illustrated Guide.* London: CRC Press, 63.

Agulhas current that runs from North to South on the Indian Ocean side of the continent (darker colors indicate greater velocity).

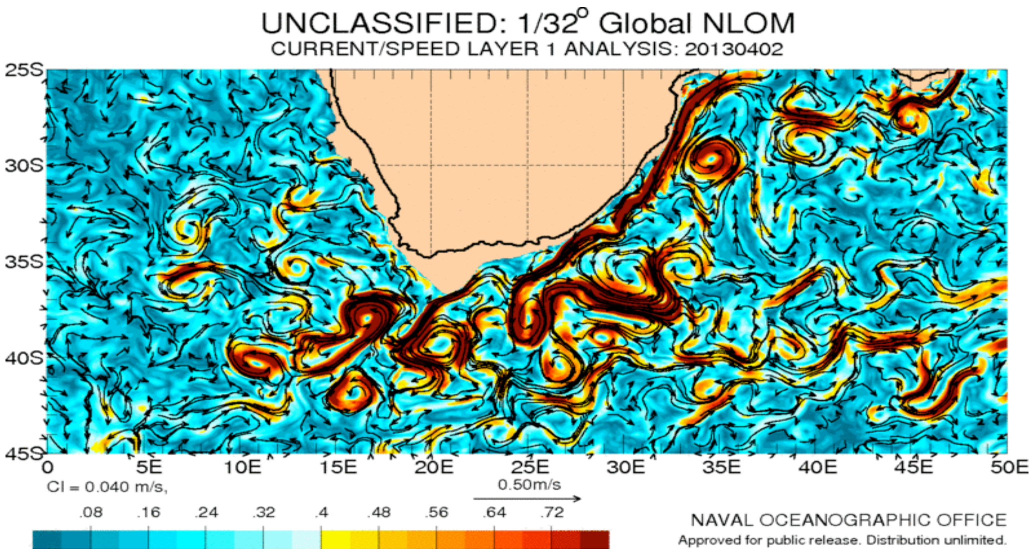

Fig. 3.6: Agulhas eddy field (source: US Naval Oceanographic Office)

The advent of satellite altimetry was truly revolutionary in revealing even further the influence of this mesoscale variability. While sea surface temperature had been measured by satellite for some time, the first satellite to measure sea surface height (called SeaSat) was launched in 1968. Though it only produced data for 100 days, it made eddies and other forms of 'ocean weather' visible on a global scale for the first time.[59] Lack of systematic and frequent ocean sampling had missed crucial eddy formations: "Incredible as it may seem, for one hundred years this dominant component of ocean circulation had slipped through the coarse grid of traditional sampling."[60] In fact, the ocean is fraught with these disruptions, along with meanders, fronts, and other

[59] It is rumored that the US government covertly disabled SeaSat after 100 days because it showed the location of submarines.
[60] Munk, The Evolution of Physical Oceanography in the Last 100 Years, 137.

irregularities. Fig. 3.7 is an output of SeaSat, showing a dynamic and variable ocean – note the widespread presence of eddies, in contrast to the loops of the conveyor belt diagram.

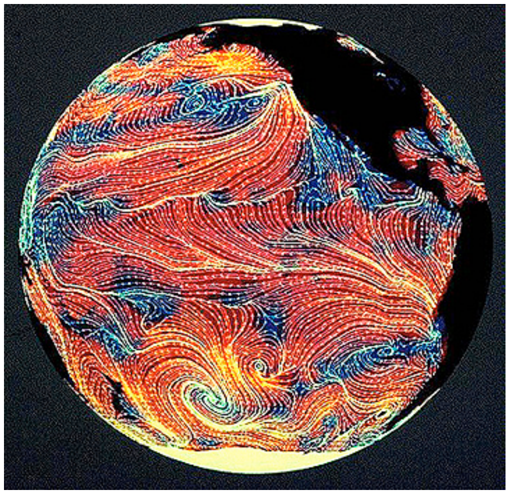

Fig. 3.7: Image from SeaSat (source: http://fas.org/irp/imint/docs/rst/Sect14/Sect14_12.html)

The data obtained from satellites and other new or improved forms of sampling began to suggest that eddies were not (only) deviations from the mean ocean circulation but in fact were formative features of the state of the ocean at any given time. In other words, ocean circulation is characterized less by the steady flows of the conveyor belt heuristic and more by swirling, fluctuating, meandering features that follow the laws of chaos and complexity rather than linear calculation. Due to the advances of the 1970s, "[oceanographers had] become aware that the oceans were as variable as the atmosphere. Before that, the view was that the oceans were rather sluggish, slow-moving and passive in a sense."[61] Hence WOCE scientists were forced to grapple with this newly dynamical

[61] Gould, personal communication.

and complex view of ocean circulation, as the first and largest attempt to understand the ocean in dynamical terms on a global scale.[62]

Particularly challenging was the imperative for any attempt to model the ocean to contend with this massive complexity. To quantify global ocean circulation in order to run predictive models, one must obtain mean or average values (or parameters) for factors such as momentum, transport, volume, and others. In other words, it is necessary to estimate an average state of the ocean, and how and when the ocean diverges from the average. This is especially important for understanding climate change: we must understand what the ocean is like, and what it has been like, to understand if and how it is changing, and on what scales. Yet this mean ocean state is incredibly difficult to determine, especially given the shift to more dynamic understandings of ocean circulation mentioned above. The difficulty of making ocean measurements, and hence their relative scarcity, is one major contributing factor. Samples taken on an annual basis cannot capture seasonal variability, whereas samples taken over shorter time scales might miss long-term changes, and might generate too much data for existing computational power to contend with. Furthermore, because of the scarcity of ocean observations, ocean data has frequently been treated as simultaneous even when it was collected over long periods of time.[63] Spatial variability suggests similar problems. In fact, it has been suggested that it is not even possible to conceive of a mean state of ocean circulation.[64] While WOCE

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[62] Ibid.
[63] Wunsch, C. (1992). Decade-to-Century Changes in the Ocean Circulation. *Oceanography 5*(2), 99-106; Toole, personal communication.
[64] Ibid.

provided valuable baseline data for evaluating climate change, ocean variability continues to be a topic that places great demands on oceanographic research worldwide.

WOCE and the intensity of the whole earth

The immense variability revealed during WOCE was perhaps the project's most crucial insight. Already we can mark a departure from the steady, self-regulating world ocean of the whole earth image. While it is mainly composed of mesoscale phenomena, ocean variability makes the ocean seem bigger, full of uncountable features that are constantly forming and dispersing, that may send ships, instruments, or sea creatures to unexpected parts of the sea, and that moreover may capriciously control the flows that determine the conditions of life on the planet. The elements of ocean variability (eddies, filaments, jets, and other 'beasts') are forces of relation, but they do not lend themselves to a notion of self-healing interconnectedness. Rather, they materially and discursively, in Spivak's terms, fling us away; both from major ocean currents and the diagrams and theories that led us to believe these large-scale features characterized ocean circulation.[65] Moreover, it cannot be said that the ocean exhibits great variability but returns over time to a steady state; despite the ocean's role as a regulator of climate, the most advanced scientific methods cannot determine over what timescales this holds true. In fact, scientific results suggest that on long time scales, the ocean is highly unstable, and drives instability in the ocean-atmosphere system and thus for life on Earth.

The interconnectedness of the ocean and atmosphere that WOCE revealed is far from comforting. Although WOCE was heralded as a great success, and did produce a

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[65] Spivak, G. (2003). *Death of a Discipline.* New York: Columbia University Press, 73.

very robust dataset, the high cost and immense amount of international collaboration emphasize the difficulty of producing comprehensive knowledge about the world ocean. Furthermore, the ocean's variability became more obvious; the ocean appeared more chaotic and less stable. While WOCE greatly aided efforts to understand and model the ocean and atmosphere as one system, this system, and the exchanges that define it, properly examined, are not easy sites for the attachment of simplistic and placatory politics of interconnectedness but are loaded with anxiety.

To more thoroughly understand the implications of the systemic ocean-atmosphere concepts that WOCE facilitated, it is useful to read relevant systems dynamics through Deleuze and Guattari, with the help of Manuel DeLanda, who has made significant efforts to explain and mobilize the scientific foundations of much of Deleuze and Guattari's ontology. Deleuze and Guattari were often-uncritical systems theory enthusiasts, and their uptake of these concepts is particularly interesting for my purposes because they are creative and experimental with these logics yet also rigorous with regard to their scientific and mathematical origins or applications. As Protevi writes, the work of Deleuze and Guattari "establishes the ontology of a world able to yield the results forthcoming in complexity theory."[66] DeLanda fully investigates and explicates the scientific underpinnings of Deleuze and Guatarri's concepts, which helps me to link them to oceanographic science.[67] As DeLanda notes, one of Deleuze's favorite concepts

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[66] Protevi, Deleuze, Guattari and Emergence, 19.
[67] See especially DeLanda, M. (2002). *Intensive Science and Virtual Philosophy.* New York: Continuum; DeLanda, M. (2005). Space: Extensive and Intensive, Actual and Virtual. In Buchanan, I. & Lambert, G. (eds). *Deleuze and Space.* Edinburgh: Edinburgh University Press, 80-88.

from systems theory and nonlinear mathematics more broadly was that of intensive relations: it is found in and beyond his collaborations with Guattari.[68] While extensive relations refer to an entity's dimensions in Cartesian space, intensive relations have to do with variations along a differential, or changes in one variable in relation to another. Intensive relations are, then, rates of change, having to do fundamentally with a Deleuzian notion of difference.[69] Intensive relations are fundamental to processes that produce extensive differences, apparent to us, in the case of the ocean-atmosphere, as the entities 'sea' and 'sky.'

Ancient mariners and early oceanographers alike were mostly concerned with the ocean's extensive properties; they set out to measure it, to chart its dimensions. At first glance, the intention of WOCE seems similar: to get a snapshot of ocean circulation, to determine its essence, at least at one point in time. But to do so, particularly for modeling purposes, required conceptualizing the ocean-atmosphere instead as one entity, best understood as characterized by intensive relations. Further, the discovery of the extent of variability opened up a new set of challenges and possibilities, calling into question any notion of a mean ocean state, or an ocean-atmosphere at equilibrium. Scientists began to understand the ocean as characterized by various morphogenic processes that define a set of possible forms and movements the sea can take, and hence the forms and movements that the atmosphere can have. This new understanding finds resonance with Deleuze's notion of intensive relations. Against an essentialist ontology, which understands entities

[68] DeLanda, Space.
[69] Ibid; see also Deleuze, G. (1994). *Difference and Repetition.* New York: Columbia University Press.

as copies based on an ideal model that produces defining traits, Deleuze offers “a theory of morphogenesis based on the notion of the different.”[70] This theory is based on the mathematical notion of the manifold or multiplicity, another name for a phenomenon characterized by intensive relations.[71]

The components or expressions of ocean variability (fronts, jets, eddies, filaments, and others) might be effectively understood, taken together, as characteristics of intensive relations, compelling scientists to understand the oceans as an entity always in the process of becoming, one that can no longer be mapped with simplistic heuristics like Broecker’s conveyor belt diagram.[72] The highly variable ocean provides a line of flight from the concept of a unified ‘whole earth.’ As scientists are increasingly convinced that ocean variability in fact defines the ocean, it is helpful to consider that intensive relations “specify the structure of spaces of possibilities.”[73] These relations are highly challenging for both conceptual mathematics and computing power because they “constantly construct and dismantle themselves in the course of their communications, as they cross over into each other at, beyond, or before a certain threshold.”[74] Fully conceiving these becomings has been the challenge of oceanographers since WOCE.

This move from essences to processes provides us with some opportunities for thinking systematicity without falling into the pitfalls of the ‘whole earth’ ideal. Another important move, and one that Colebrook and other systems theory critics often miss, is

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70 Ibid., 4.
71 Ibid.
72 Broecker, The Great Ocean Conveyor; Holliday, personal communication.
73 DeLanda, Intensive Science and Virtual Philosophy, 10.
74 Deleuze, G., & Guattari, F. (1987). *A Thousand Plateaus: Capitalism and Schizophrenia*. Minneapolis: University of Minnesota Press, 33.

from first-order systems theory, which emphasized self-regulation, homeostasis, and linear and closed systems, to second-order systems theory, which instead draws attention to self-organizing, far-from-equilibrium, nonlinear systems that are critically open to their environments.[75] Second-order systems theory emerged in radically diverse strains of thought in time to resonate strongly within WOCE-era oceanographic models. In an equilibrium or steady-state model of a system, the processes set in motion by intensive differences cancel each other out, producing a return to "equilibrium and average values."[76] But in the nonlinear, far-from-equilibrium models of the ocean-atmosphere system that second-order insights increasingly compel oceanographers to use, strong and continuous flows of matter and energy create differences that define systems dynamics and form.[77] Applied to our case, in pre-1990s models of the ocean-atmosphere system, ocean variability would eventually tend toward equilibrium, giving the possibility of a mean ocean state as a useful concept. But in a far-from-equilibrium model, which variability has caused oceanographers to favor, these differences are recognized as productive of the extensive features of the system, implying that matter has the capacity to shape the system such that no imposition of form from the outside is required.[78] DeLanda writes that these systems operate in "zones of higher intensity."[79]

Considering the ocean-atmosphere exchange as a zone of high intensity with

[75] See for example Clarke, B. and Hansen, B. (eds). (2009) *Emergence and Embodiment: New Essays on Second-Order Systems Theory.* Durham NC: Duke University Press. Wolfe, Critical Environments.
[76] DeLanda, Space, 81.
[77] Ibid.
[78] Ibid., 82.
[79] Ibid.

Deleuze and Guattari and DeLanda offers ways of thinking of the ocean as multiple but not as simply random. Ocean processes, in Deleuzian terms, define phase space, that is, how much change can be incorporated before the system changes its fundamental characteristics. So, to say that the ocean's intensive processes are ones of movement and memory permits many degrees of freedom before confronting the rigidity of essentialism, or of the pre-defined, bounded form of which Colebrook warns.[80] Furthermore, the fact that these processes are nonlinear suggests that the 'whole earth' is only one possible semi-permanent end state or attractor for the ocean-atmosphere system. Ocean variability as the expression of intensive processes of memory and motion structures the space of possibilities for the ocean-atmosphere system, but the equilibrium model of the 'whole earth' of interconnected, life-fostering conditions (such that it can be said to exist) is only one outcome towards which these processes might tend.

For example, the Southern Ocean (south of 30 degrees) was an area of special focus during WOCE because it absorbs up to half of all anthropogenic carbon emissions and links the other oceans together.[81] While the Southern Ocean is a significant carbon *sink*, carbon stored in the deep waters also upwells, moving through the water column, and exchanges directly with the atmosphere, releasing the stored 'memory' of hundreds of years of fossil fuel emissions. Thus, given changes in the rates and mechanisms of exchange as predicted under climate change, and the vast variability of the regional seas, the Southern Ocean may shift from being a sink to a source of carbon emissions, with

[80] Colebrook, A Globe of One's Own.
[81] Gould, personal communication.

potentially catastrophic impacts on the conditions for life on Earth.[82] The dynamical role of the Southern Ocean, then, asserts other possibilities than the self-regulating, bounded 'whole earth,' from within the very systems dynamics that suggest it as (just one possible) form of attractor. Even without anthropogenic forcing of heat and carbon, the balanced 'whole earth' may be currently understood as a steady-state attractor, but ocean variability raises the specter of periodic or chaotic attractors that could easily destroy the ideologies that depend on the closed form, the self-regulating world. What is remarkable about these other potentialities is that they become apparent by using the same logics that underlie the 'whole earth' concept. Contrary dynamics were discovered during the very efforts to understand the ocean-atmosphere as a stable system.

Contextualizing ocean systematicity

Efforts to understand systematicity must be understood within their historical context, in order to understand the worlds they have created: not just in the representations they have produced but also the relations that have proliferated around associated knowledge practices. Put differently, concepts of the differentiating ocean-atmosphere were made possible by differentiating global oceanography from regional or local concerns. This examination contributes to the many efforts to contextualize the development of systems theory in Cold War geopolitics as well as in larger shifts within militarism and economic theory. Here I want to take a closer look at the worlds that have emerged around the discovery of ocean variability. I argue that this analysis both shows that lines of flight can

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[82] See for example Council for Scientific and Industrial Research. (2011). Ocean Systems and Climate.
http://www.csir.co.za/nre/coasts_and_oceans/osc.html#SOCARBONCYCLE

emerge from within mainstream science itself, and cautions against a wholesale celebration of their discovery as inherently destabilizing power relations.

Like many projects in international oceanography (and perhaps international oceanography itself), notions of global cooperation in the name of universal knowledge for the broader good can mask hierarchical power structures in the actual operation of the project. Further, what frequently goes ignored are the issues or research topics that get sidelined in deciding upon and directing resources toward what are perceived as global concerns. Both of these tendencies can be seen in WOCE and its aftermath. Hence attempts to understand and quantify the systematicity of the world ocean must be understood as both located within and productive of the politics of oceanographic knowledge.

The statements of those closely involved with WOCE are indicative of the complex interplay of international collaboration and top-down management that characterized WOCE from the start. While in hindsight (or even at the time) WOCE seems like a natural or even inevitable development in oceanographic science, its extent and success was due in no small part to the early championing (and maybe even strong-arming) of its early advocates, most of whom were located in prestigious oceanographic institutes in Europe and the United States. Exceptional among these was Carl Wunsch, then of the Woods Hole Oceanographic Institute; one oceanographer even joked with me that the WOCE acronym most accurately stands for "Wunsch's Own Circulation Experiment."[83] Another put it a bit more generously: "Carl was remarkable because he was sort of the, in

[83] Frank Shillington, personal communication, 21 October 2014.

a sense the political leader of this thing […] And at the same time he was doing all this wonderful science."[84] Wunsch was able to mobilize a small but influential network of collaborators to launch WOCE as a project of the new World Climate Change Research Program (WCRP).[85] The influence of this small group of European and North American oceanographers also set a precedent for WOCE to be led from established centers of oceanographic research.

As WOCE expanded its international purview, decision-making became somewhat more democratic, although it would continue to be led by the Scientific Steering Group (SSG), composed mainly of members from hegemonic oceanographic knowledge centers. Again, those closely involved with WOCE speak of the project execution somewhat whimsically, emphasizing international cooperation. As I mentioned previously, to assign responsibility for the WOCE field program a series of international meetings were held at the behest of the SSG, at which scientists from various collaborating countries volunteered to "go out and measure lots of different bits of the ocean, their own favorite bits of the ocean."[86] Sections across ocean basins were generally carried out by individual nations, but sometimes several nations collaborated on a single section. Penny Holliday, the staff scientist at the IPO in the UK, kept track of the

[84] Kenneth Brink, personal communication, 29 April 2014.
[85] The WCRP was sponsored by the World Meterological Society (WMO) and the International Council of Scientific Unions (ICSU). WOCE itself emerged from and was overseen by the Committee on Climate Change and the Ocean (CCCO) (part of ICSU's Scientific Committee for Ocean Research [SCOR]) and UNESCO's Intergovernmental Oceanographic Commission (IOC).
[86] Holliday, personal communication.

field program, accounting for which sections had been completed, and holding scientific programs accountable for collecting the data for which they were responsible.

To fully appreciate WOCE's geopolitical context, however, one must hold in tension its genuinely unique international character with the realities of unequal control and execution. WOCE was undeniably ambitious both in its scientific goals and, related, program of international collaboration; as Holliday said,

> "[Prior to WOCE] individual experiments had been done, [but] they were all sort of analyzed individually, and there wasn't this sort of coherent global effort to come up with a very large picture with everybody sort of contributing to it. I mean, it was hugely ambitious, I think, […] to get the cooperation of an entire international community. It's fantastic, an amazing thing to do, I think, and something that hasn't been repeated, and I don't know if it ever will be repeated."[87]

This kind of international ambit took a great deal of coordination, which served to cohere an international oceanographic community through rather mundane newsletters, workshops, trainings, data transmissions, and various other communications. The International Project Office (IPO) in the UK coordinated a set of workshops that brought together international participants around the main issues with which WOCE dealt, such as ocean modeling, heat and carbon fluxes, and data management. Another set of conferences was organized around regional WOCE programs. In addition, the IPO produced a series of international newsletters, which were circulated to more than 1000 recipients.[88] These missives not only kept collaborators abreast of the progression of the field program, but also included early reporting of results, announcements of workshops

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[87] Ibid.
[88] WOCE IPO newsletters can be found online at the World Ocean Circulation Experiment Global Data Resource: http://www.nodc.noaa.gov/woce/wdiu/wocedocs/newsltr/index.htm

and meetings, and dispatches from the director and the IPO. These messages from the administrative and executive staff had practical purposes of, for example, urging contributors to report their data in a timely fashion, but they also served to impart a sense of community and accomplishment, as they often reflected on the broad achievements of WOCE and situated those achievements in the context of previous science. For example, a 1995 newsletter included this admonishment from then-director John Gould:

> "WOCE has presented a new set of challenges to oceanographers. WOCE has made many observational oceanographers think globally about the ocean for the first time. The assembly of basin-wide, and ultimately global, data sets of uniformly high quality is a large undertaking. The first and essential step towards that goal is for individual PIs to submit their data to the WOCE Data Assembly Centres in a timely fashion."[89]

National programs such as the UK and US also produced their own newsletters with similar missions.

Despite these efforts, WOCE was not without complications. Some issues had to do with the phenomenon of study itself; certain segments of the hydrographic program, especially in the Southern Ocean, proved difficult to execute due to the remote nature and rough seas. When gaps in the data collection were discovered, the IPO coordinated voluntary efforts of other scientists to execute the cruises.[90] Yet many other problems had distinctly geopolitical, and technopolitical, dimensions. In many places throughout the world, the years leading up to and encompassing WOCE bore witness to transitions that affected the oceanographic program. For example, the collapse of the Soviet Union led to

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[89] Gould, J. (1995). 1995 – A Turning Point for WOCE *WOCE International Newsletter 18*(March 1995), 2. See also: Gould, J. (1994). Planning for the Future of WOCE. *WOCE International Newsletter*, *17*(November 1994), 2.; Gould, J. How Would You Answer Henry Stommel? *WOCE International Newsletter, 23*(July 1996), 2.
[90] Ibid.

the withdrawal of many Soviet scientists and their advanced fleet of research vessels.[91] Worldwide economic recession between the planning and implementation phases of WOCE also resulted in significant adjustments to the program.[92] And while new communication technologies such as email and electronic file sharing greatly improved international coordination, they did not make exchange seamless, especially between the IPO and more far-flung participants. For example, despite a significant amount of communication between the directors of South Africa WOCE and the IPO in 1990-91, a set of emails between these parties in 1993 reveals much confusion as to whether any WOCE cruises had been executed, and the status and location of the resulting data.[93] The field program was extended from five to seven years in part to contend with some of these challenges.[94]

However, the geopolitical dimensions of WOCE must be understood not only to have complicated the program. Nor should WOCE be understood in terms of simply increasing international collaboration in and beyond the sciences. Rather, it should be contextualized as differentiating and cohering a international oceanographic community – a term frequently parried about uncritically by scientists and others. WOCE itself can be understood as a morphogenic process, giving shape to what is considered oceanographic expertise on an international stage. National interest in global oceanography is not self-

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[91] Ibid.
[92] Ibid.
[93] Emails between Chuck Corry and Johann Lutjeharms, February-March 1993, WOCE archive, National Oceanography Centre Library, University of Southampton, Southampton UK.
[93] Holliday, personal communication.
[94] Ibid.

evident. There are numerous reasons that a nation might have global oceanographic interests. Moreover, what is defined as a global interest is an open question, one that was narrowed with WOCE. In the administrative and conceptual organization of oceanographic science, a division is frequently made between coastal science and what is called open-ocean, blue-water, or high-seas research. Coastal oceanography focuses mainly on concerns regarding fisheries, coastal tourism, and the pollution and health of coastal ecosystems, and it is frequently subject to local or national governance as it occurs mainly in territorial waters. Coastal research is most often prioritized by nations without large budgets for scientific research.[95] Open-ocean research occurs mainly in international waters, or the high seas, and therefore often (though not always) requires greater international coordination on the diplomatic level. Open-ocean research is usually concerned with macro- and meso-scale dynamics, such as ocean circulation, eddy formation, current transport, and other climate interactions. However, ocean dynamics such as eddy formation and other forms of variability have impacts at a variety of scales, and across scales; in the US, this is acknowledged by recent increased emphasis on cross-scalar studies at the level of the National Science Foundation.[96] Ocean variability might even have greater impacts in coastal environments, as the seabed geology, influence of the landmass, and local weather patterns compound the complexity.[97] Further, while open-ocean research might need more attention from an access standpoint, 'global oceanography' could also be defined as regarding issues faced by coastal communities

[95] Brundrit, personal communication.
[96] Eric Itsweire, personal communication, 29 July 2014.
[97] Stewart Bernard, personal communication, 16 February 2016.

across the globe. However, this has not been the case. An exploration of WOCE and its aftermath shows the active formation of an international oceanographic community that focuses on open-ocean research, therefore prioritizing the interests and abilities of countries with large oceanographic budgets and overseas geopolitical (and frequently colonial) activities.

The open-ocean research community coheres around nations with high investment in oceanography; national income is a large contributing factor, and frequently a condition of possibility. During WOCE national investment in oceanography and geographic range and extent of oceanographic surveys were directly related. National programs with significant historical investment in oceanography also pioneered technologies and data reporting strategies. Countries with smaller budgets emphasized the need for WOCE activities to demonstrate national benefits and to include training and capacity building for their scientists. Furthermore, for these countries, WOCE activities were carried out as part of normal operations, requiring simply added data reporting and sometimes new technological investments, in contrast to wealthier nations which undertook more intensified cruise programs.[98] Accordingly, nations with fewer oceanographic resources tended to work on their own coasts or nearby oceans while countries with larger budgets, and hence research vessels capable of being at sea for

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[98] See Lutjeharms, J. "A Suggested National Programme for WOCE South Africa," February 1986, South Africa, WOCE archive, National Oceanography Centre Library, University of Southampton, Southampton UK.

many days, ranged more widely over the globe. And as the most significant collaborator, the US program, Holliday reports, "went everywhere, yeah. Anywhere."[99]

But investment in oceanography does not correlate directly with gross domestic product or other national-scale economic measures, and it was not just that countries chose to take on the sections they found scientifically the most interesting. Countries with larger exclusive economic zones and greater international responsibility for providing marine meteorological data are more likely to be invested in global-scale research projects, while countries with smaller EEZs and fewer international obligations are frequently more concerned with coastal issues such as fishing, tourism, and coastal degradation.[100] For example, the only country on the African continent with responsibilities for marine meteorological forecasts (due to their participation in the Antarctic Treaty) is South Africa. This was one of the main reasons that it was the only African country to participate in WOCE.[101]

Moreover, WOCE contributed to iterative cycles of expertise and investment. Patterns of responsibility and reputation for oceanographic research are of course self-reproducing: countries with reputations for excellent global oceanography are asked to be scientific and monitoring partners, and are better able to benefit from their marine resources. Likewise, WOCE provided the initial funding impetus for many national programs that have continued to develop. For example, the United States' global expertise in moored measurements of air-sea fluxes was catalyzed by the WOCE effort,

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[99] Holliday, personal communication.
[100] Geoff Brundrit, personal communication, 26 November 2014.
[101] Ibid.

even though these kinds of process studies were not the main focus of WOCE in the end.[102] In addition, WOCE provided a framework for the reinvigoration of participating oceanographic programs, such as the refurbishment of research vessels and development and refinement of new float technologies.[103] When it came to the ships this was no small undertaking; at least three major research vessels were "chopped in half, lengthened, given longer endurance, bigger scientific party; really equipped [for] the century."[104]

In the years following WOCE, countries in the global South strongly advocated for coastal concerns to have greater priority on the international oceanography agenda, hence questioning the meaning and scope of global oceanography. In the IOC, they attained some of these goals.[105] However, it still occurs that countries with extra-territorial interests prioritize the sorts of international projects that are associated with global oceanographic expertise. For example, France has the second-largest Exclusive Economic Zone (after the USA) due to its large number of island territories. It is also an original signatory to the Antarctic Treaty. Consequently, France has taken a large interest in the Southern Ocean, the Indian Ocean, and large-scale dynamics. It is seen as a major player in international oceanography; the oceanography department at the University of Cape Town was rife with French scientists during my tenure as a visiting scholar. Ghana, to take an example for the sake of comparison, has significant oceanographic interests, such as resource exploitation, coastal tourism, and of course the impacts of climate change. However, because it has no overseas territories, but rather its interests lie mainly

[102] Weller, personal communication.
[103] Gould, personal communication; Toole, personal communication.
[104] Gould, personal communication.
[105] Ibid.

in its EEZ waters and the seabed of the continental shelf, it is not seen as a significant factor in international oceanography. Moreover, in order to participate in global oceanography, nations must 'buy in' to expensive technological programs. For example, South Africa attracted a great deal of international attention and collaboration when it recently purchased cutting-edge oceanographic robotic sensors. Thus, because global oceanography tackles issues that require high-tech instrumentation, it is difficult for global South nations to participate without highly prioritizing this kind of science in their national budgets.

By now we seem to have moved quite far from Deleuze and Guattari and the discussion of systematicity and ocean variability. Yet if these ideas are going to have weight, they cannot refer simply to abstract material conditions. Processes of differing lead not only to the differentiation of the ocean and atmosphere, but also the discovery of these processes has contributed to the differentiation of international oceanographic expertise away from routine coastal monitoring. Hence locating ocean variability in a world shaped by economic and political forces can tell us much more about seascapes of expertise, power, and uncertainty that are just as much a part of the worlds made and unmade by variability. They show us that lines of flight might be found from within hegemonic scientific expertise, as it was these global technoscientific projects that created the possibility for imagining an ocean characterized by variability. At the same time, this contextualization admonishes against the uncritical celebration of the discovery of ocean variability, or other lines of flight. We must be equally attentive, as Deleuze and

Guttari themselves caution, to the reterritorializations that capture such dynamics and frequently reinscribe them within networks of power.

Conclusion: differentiating the ocean-atmosphere, differentiating global oceanography

New paradigms of global oceanographic data collection and modeling during WOCE allowed the ocean-atmosphere to be understood as constituted by intensive relations; that is, varying exchanges of heat, energy, dissolved chemicals, and other properties. Morphogenic processes in the ocean-atmosphere create phase changes, giving us the entities we know as air and sea. But, importantly, this process is ongoing and iterative: heat, carbon, oxygen, and other properties continue to be exchanged between the ocean and atmosphere, resulting in the scientific term 'air-sea flux.' The system is recursive; the ocean and atmosphere are both preconditions and results of these dynamics; not only do the ocean and atmosphere influence each other, but moreover their boundary is indistinct, chaotic and dense, a place of various potential and actualized phase changes.[106] This is not to say that the ocean and atmosphere are the same but rather that they are created through singular processes of differing such that they are in dynamical relationship across a zone of intensity. During WOCE, the emergent idea that air-sea fluxes are formative of the ocean and atmosphere indicates that attempts to grapple with nonlinear ocean variability gave rise to an ontological shift in ocean science, in addition to the epistemological changes that were occurring at the time of WOCE with the rapid

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[106] Clarke, B. (2009). Heinz von Foerster's Dreams. In Clarke, B. & Hansen, M (eds). *Emergence and Embodiment: New Essays on Second-Order Systems.* Durham NC: Duke University Press, 34-61.

development of satellites, modeling, and other technologies. This ontological shift provides us with the materials to challenge notions of a bounded, self-referential 'whole earth' with the very dynamics that suggested it in the first place.

Mainstream marine environmentalist and even policy discourse often asserts the ocean's allegedly exceptional and essential qualities; for example, "intrinsic power to relax, rejuvenate, and inspire."[107] It can be tempting for ocean scholars to write accordingly, in pursuit of acknowledgment for the under-studied sea. Yet, the focus on intensive properties suggested here encourages us to think of the ocean-atmosphere in terms of *processes* rather than *essences* – what the ocean can do, in a material sense, rather than what it is. When it comes to the co-constitution of the atmosphere and ocean, these are processes of memory and motion. This shift in focus from essential characteristics to processes makes a case against considering ocean as an exceptional space with essential characteristics but rather compels us to ask about processes of differing – what makes certain entities capable of memory or forgetting? What makes certain spaces conducive of movement? How might these processes change and with what effect? How do oceanic processes of memory and motion interact with other planetary feedbacks? These are questions for ocean science but they are also ways in which ocean scholars from all disciplines might contribute to and extend debates in environmental geography. Put differently, they are questions to which ocean physics are vital but not sufficient on their own. While some geographers and others have considered

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[107] United States Commission on Ocean Policy. (2004). *An Oceanic Blueprint for the 21st Century* http://govinfo.library.unt.edu/oceancommission/documents/full_color_rpt/welcome.html, xxxii.

the ocean as a place of movement, even as materially constituted by motion, and (at least metaphorically) as a place of memory, the questions above suggest the opportunity to push these analyses further.[108] Deleuze's philosophy of difference compels us to understand the world ocean not as given but as the product of historical and ongoing processes of differing.

But these processes are not just those of carbon fluxes, heat exchanges, or circulation dynamics. They are equally the processes by which the ocean-atmosphere came to be understood as such. Global scientific projects are often understood as processes of standardization, aggregation, and making the same. But they also differentiate who can, should, and does collect global data from those who focus on coastal, local, or purely instrumental science, hence coalescing an international oceanographic community that continues to set the agenda for international research and whose interests determine what is known as global or blue-water oceanography. Furthermore, as Edwards points out, the validity of the data collected and conclusions drawn by this global scientific community depends upon its ability to maintain its coherence.[109] Therefore, and as evidenced in the case of WOCE, scientific knowledge of the intensive properties of the ocean-atmosphere system is directly dependent on these processes of differentiating the global oceanographic community.

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[108] See especially Anim-Addo, A., Hasty, W., & Peters, K. (2014). The mobilities of ships and shipped mobilities. *Mobilities*, *9*(3), 337-349; DeLoughrey, E. (2010). Heavy waters: Waste and Atlantic modernity. *PMLA*,*125*(3), 703-712.; Philip Steinberg, P. (2013) Of other seas: metaphors and materialities in maritime regions. *Atlantic Studies, 10*(2), 156-169.

[109] Edwards, A Vast Machine.

A closer focus on the ocean-atmosphere system, and in particular on the zone of intensity at their boundary, also suggests new directions for humanities and social science scholarship on oceans. Historians, anthropologists, and cultural theorists have long described the beach, that frontier between land and sea, as a particularly generative zone of encounter.[110] The boundary between sea and sky has received less attention, though it is crucial to conditions for life on earth, not to mention perceptions of the form and dynamical processes of the globe. Some geographers have made gestures in this direction through analyses of verticality and volume as under-examined yet crucial components of geopolitics.[111] Yet the processes by which verticality and volume are produced and their various zones differentiated deserve greater attention. In this chapter I show how the sea-sky zone of intensity has been formative of international scientific culture, of an entire apparatus of scientific infrastructure requiring the coordination of ships, scientists, instruments, data storage centers, models, and funding agencies. While I have focused on scientific culture around the ocean's role in climate, the sea-sky frontier is generative of many other encounters and material processes as well, for example cycles of ocean pollution and acid rain.

If the intensive processes of ocean variability lead to the differentiation of ocean and atmosphere, then they also have led to the differentiation of global oceanography. While perhaps the most significant elements of ocean variability are mesoscale

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[110] See for example: Gillis, J.R. (2012) *The human shore: Seacoasts in history*. Chicago: University of Chicago Press; Taussig, M. (2000) The beach (a fantasy). *Critical Inquiry,* (2000), 249-278.
[111] See especially: Dalby, S. (2013). The geopolitics of climate change. *Political Geography, 37*, 38-47; Elden, S. (2013). Secure the volume: vertical geopolitics and the depth of power. *Political Geography, 34*, 35-51.

phenomenon, measuring them and understanding their significance requires access to and participation in an entire apparatus of global physical oceanography. Coordinated movements with regard to models, international workshops, observational technologies, databases, and more were (and are) required to put ocean variability into context, revealing ever more its formative impact on the ocean-atmosphere system. The quest to understand variability and its planetary influence continue to play a significant role in defining what is considered global oceanography, and thus the provenance of oceanographic superpowers, and what is more likely relegated to the margins as coastal and fisheries concerns. The global oceanographic community is an extensive entity that has emerged from attempts to grapple with ocean variability. Networks of collaboration and exchange of information and technologies not only reinforce patterns of scientific expertise but also determine what concerns drive the research agenda, as international scientific organizations such as SCOR decide whether to support research projects mainly based on what they discern to be the priorities of the oceanographic community.[112]

Colebrook urges us to look for forces that escape, that indicate lines away from the valorization of a bounded earth, but offers no clues as to how to find these forces, how to identify them, or how exactly their emancipatory potential might play out. [113] In this chapter I have responded to this call in two ways. First, I have pointed to ocean variability as one of these forces that destabilizes the 'whole earth' heuristic. The extent of ocean variability suggests that any equilibrium achieved with the atmosphere is tenuous and temporary. Furthermore, ocean variability menaces the current form of life

[112] Urban, personal communication.
[113] Colebrook, A Globe of One's Own: In Praise of the Flat Earth.

on Earth with its ability to unleash catastrophic quantities of carbon and heat to the atmosphere over very short timescales. Second, I encouraged critical environmental scholars to dwell a moment longer in the systematicity of the Earth, integrating Deleuzian and second-order systems theory insights with discoveries about the ocean-atmosphere system made during WOCE to suggest a different way of reading it. Yet, such an analysis must also take into account the ways in which these processes have come to be known through particular techno-political relations. Only then is it possible to begin to account for the ways in which ocean-led processes of memory and motion express non-intentional geopolitical morphogenesis.

CHAPTER 4: THE GEONTOPOLITICS OF OCEAN OBSERVATIONS

The United Nations Educational, Scientific and Cultural Organization (UNESCO) headquarters in Paris are a singular place, and the Annex, where the Intergovernmental Oceanographic Commission (IOC) was based until late 2014, has a unique ambience. Despite the high security, marble-floored lobby, and well-dressed dignitaries, the Annex has a more-than-slightly dated and somewhat surreal quality due to the tiny offices with shabby wooden doors bearing plastic nameplates for each country, the banks of now-obsolete pay phones, and the gently dilapidated primary-color décor. But inside this strange world-out-of-time are the men and women who coordinate some of the newest and most advanced technologies for collecting and storing scientific data: those that constitute the Global Ocean Observing System (GOOS). These technologies and the systems that organize them are changing the way the world ocean is known.

Most of the men and women who sit at the IOC secretariat have some scientific training, but they are also diplomats, educators, technicians, and talented managers of people, projects, and data. Although their mission is largely scientific, they are subject to the tribulations and idiosyncrasies of the United Nations (UN) structure; for example, the IOC faced financial hardships due to the United States' policy to refuse funding to any agency that recognizes Palestine's statehood, following the UN's decision in 2012.[1] Moreover, as a specialized agency of the UN, IOC officers are invested in ordering the world in way that contextualizes and furthers the UN's long genealogy of (mostly

[1] Albert Fischer, personal communication, 12 March 2014.

Western) ideals around peace, security, and democracy.[2] Yet their work deserves closer scrutiny on its own terms. IOC officers and the scientists and technologies they orchestrate are responsible for the creation of a new concept of the world ocean, or perhaps more accurately a new world ocean: an ocean of data, a digital doppelganger for the wet and wild ocean out there, an ocean made informational. Perhaps the most familiar output of this ocean emerges on the computers of non-expert Internet users, as a Google Earth layer or a snapshot from NASA's Perpetual Ocean data visualization (See Fig. 3.1).

But these seemingly instantaneous God's-eye views belie the complex processes by which they are made, and the extensive systems of sensors, scientists, and technicians that make these processes possible.[3] Far from a virtual camera, the GOOS comprises a vast, heterogeneous, and always changing network of ocean observations. These measurements are collected by a number of technologies, including a multitude of in situ and remote sensors, such as satellites, moored instruments, research vessels, and measurements taken by commercial ships (see Fig. 4.1 for a visual heuristic). Recently, geographers and other scholars have begun to analyze the politics of representation with regard to Earth systems.[4] Simultaneously, scholarship is burgeoning on the politics of the ocean as a particular kind of space, with a specific materiality that makes a difference to

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[2] Amrith, S., & Sluga, G. (2008). New histories of the United Nations. *Journal of World History, 19*(3), 251–274.
[3] See also Helmreich, S. (2011). From Spaceship Earth to Google Ocean: Planetary icons, indexes, and infrastructures. *Social Research, 78*(4), 1211-1242.
[4] Ibid.; see also Farman, J. (2010). Mapping the digital empire: Google Earth and the process of postmodern cartography. *New Media & Society 12*(6), 869-888; Jue, M. (2014). Proteus and the digital: Scalar transformations of seawater's materiality in ocean animations. *Animation, 9*(2), 245-260.

how we understand human and nonhuman history, politics, and agency.[5] This chapter both builds on and diverges from these bodies of work as I probe the contemporary knowledge relations that produce the world ocean as one dynamic entity with a special relationship to life on Earth. I ask what the attempts to first know and then govern this world ocean might indicate for emerging relations of nature, technology, and government.

Fig. 4.1: Visual schematic of the GOOS, showing its various components for making ocean observations (Source: Intergovernmental Oceanographic Commission. "GOOS Systems" http://www.ioc-goos.org/)

In this chapter, I turn from the guiding paradigms of global oceanography to the technopolitics of contemporary global ocean observations. The historical detail provided in previous chapters provides an important view into the technological and geopolitical conditions of possibility for the current system of ocean observations that gives us the world ocean with which we have become familiar. Yet as I show here, paying attention to ocean observations might point us to the future as well as the past, as ocean observations

[5] See for example, Oreskes, N. (2014). Scaling up our vision. *Isis*, 105(2), 379–391; Steinberg, P., & Peters, K. (2015). Wet ontologies, fluid spaces: Giving depth to volume through oceanic thinking. *Environment and Planning D: Society and Space*, *33*(2), 247-264; Peters, K. (2014). Tracking (im) mobilities at sea: Ships, boats and surveillance strategies. *Mobilities*, *9*(3), 414-431; Steinberg, P. E. (2013). Of other seas: Metaphors and materialities in maritime regions. *Atlantic Studies*, *10*(2), 156-169; Anderson, J., & Peters, K. (eds.). (2014). *Water worlds: Human geographies of the ocean*. Burlington, VT: Ashgate Publishing, Ltd.

are wrapped up in the political questions around how we might seek to be governed in the natures that we now are making.

In this chapter, then, I provide one interpretation of the politics of modern ocean observations. This work contributes to recent efforts, cited above, to account for the role of the ocean in a changing geopolitical environment. Whether acknowledged or not, these efforts have as their context a fundamental shift in the reimagining of the relationship of government and nature, as signaled by the advent of the Anthropocene in political and environmental discourse. To locate contemporary understandings of the world ocean in this context, I draw especially on the recent work of Elizabeth Povinelli, who is remarkable for theorizing life in late capitalism in such a way that not only dispels the nature/society division but moreover shows how its invocations and betrayals are at the heart of modern government.[6] As I will show, methodologies of ocean observations on the global scale indicate a shifting focus from the ordering of life to the monitoring and modulation of potentiality, across not only the nature/society divide but also, perhaps even more crucially, the life/nonlife distinction.

I argue that contemporary practices of ocean observations, and hence the world ocean that is given to us by these observations, pose problems for our established forms of political analysis. Povinelli's concept of geontological power helps me to think through the challenges that the contemporary world ocean raises with regard to both

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[6] Povinelli, E. (2014). Interview with Elizabeth Povinelli by Mat Coleman and Kathryn Yusoff [web log post]. *Society and Space*. Retrieved from http://societyandspace.com/material/interviews/interview-with-elizabeth-povinelli-by-mat-coleman-and-kathryn-yusoff/; Povinelli, E. (2015). Transgender creeks and the three figures of power in late liberalism. *Differences, 26*(1), 168–187.

established modes of government and our tools for analyzing them. She names *geontological power* as an emerging movement away from the governance of life as such (conventional biopolitics) and toward a mode governance that operates on the contemporary indistinction between life, death, and nonlife.[7] While Foucault theorized the address of power to *life*, Povinelli inquires after the address of power to *potentiality*, in the context of new understandings of potentiality, effort, and uncertainty that extend across geological, biological, technological and cyborg entities.[8] Geontopolitical power is the emergent form of government that newly attempts to grasp contemporary planetary environmental conditions and the challenges they present. The concept of potentiality is central to Povinelli's formulation; she argues that potentiality, or the capacity to change in unforeseeable ways, was previously considered a property only of life; but now the potentiality of the non-living threatens in such ways that the distinction between life and nonlife loses its pivotal power.

While Povinelli has much to offer to the development of theories of power, her main contribution, I think, is to help us understand the "composite nonlife nonsovereign being[s]" – like the world ocean, the global atmosphere, and our own familiar geophysical landscapes that today seem both threatening and in jeopardy.[9] These complex associations loom large in many of our political and everyday geographies and scramble the meanings associated with life and death themselves, even as we, as critical

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[7] Ibid.
[8] See especially Foucault, M. (2003). *Society must be defended: Lectures at the Collège de France 1975-1976*. Trans. David Macey. New York: Picador; Foucault, M. (2009). *Security, territory, population: Lectures at the Collège de France 1977-1978*. Trans. Graham Burchell. New York: Picador.
[9] Povinelli, Transgender Creeks, 173.

thinkers, resist taking them ontologically at face value. By following Povinelli's lead, we come to see the problems that our contemporary analytics of power face in accounting for these entities, and we may see the presage of new modes of power developing. We may even be able to propose, as Povinelli has done, figures that, like Foucault's figures of biopolitics, are "symptomatic and diagnostic" of these yet-emergent forms of power.[10]

With this in mind, my project here is threefold. First, and perhaps most straightforwardly, I want to further cement the ocean's place at the center of contemporary debates connecting nature, technology, and government. Second, by using ocean observations as my point of entry, I draw attention to the knowledge relations that underpin geontological power in ways that are somewhat underexplored in Povinelli's own work, and in literature on the environmental politics of the Anthropocene more broadly. How do we know an ocean? A desert? A terrorist? Addressing these questions is not simply matters of procedure. As I will show, these knowledge relations are central to the relations of government themselves, a fact which pervades Foucault's own work. Furthermore, focusing on ocean observations can show *how* governance mechanisms are contending with new understandings of nonliving potentiality. Finally, and by way of bringing together the first two goals, I want to offer a modest contribution to the development of Povinelli's theory by proposing the world ocean as a key figure of geontopolitics, indicating that which is so imbricated with life as to become indistinct from it.

In order to accomplish these goals, I first contextualize ocean observations in

[10] Ibid., 168.

changing perceptions of the ocean as both threatening and central to life on Earth and then describe in greater detail how ocean measurements are coordinated and executed on the global scale. Next, I highlight a recent shift in how the sea is informationalized, arguing that this change brings the ocean into the logics of government found in what Gilles Deleuze has called societies of control.[11] Then, I explain why we need an extended version of Povinelli's geontopolitics, one that centers knowledge relations, to fully account for these changes to the governance of ocean observations. I show how using this approach can help us to understand the significance of ocean observations to new configurations of nature, territory, and power, as well as new conceptions of risk. Finally, I suggest the figure of the world ocean to supplement the three figures of geontopolitics that Povinelli has proposed.[12]

A central and dynamic ocean

In order to properly understand ocean observations and their import, we must first briefly locate them in the context of changing views of the ocean and its role in planetary life. In recent decades, understandings of the ocean have undergone radical change in nearly every arena, from science to government to popular culture. Historian of science Naomi Oreskes traces what she calls "one of the most important cultural and scientific shifts of the twentieth century," in which the ocean went from being viewed "as a world not only without us but without much of anything to a world of profound significance and import," and from something seen "as static to something now seen as highly dynamic, a

[11] Deleuze, G. (1992). Postscript on the societies of control. *October*, 3–7.
[12] Povinelli, Transgender Creeks.

driving force in diverse physical, biological, and social systems."[13] Prior to the mid-late 20th century, Oreskes argues, even scientists thought of the deep sea as mostly stagnant and lifeless, even if it was important for military and commercial purposes.[14] But this notion was radically overturned by an increasing realization of the ocean's role in climate, and the ability of humans to change the constitution of the entire ocean through fossil fuel emissions, nuclear dumping, overfishing, and other practices. The value of ocean resources was newly accounted for in emerging metrics of ecosystem services; it has been estimated that "the value of marine ecosystem services alone exceeds the world GNP based on conventional economic appraisal."[15] (Boesch, 1999, p.189). Finally, the ocean asserted its material agency at the beginning of the 20th century: the Indian Ocean Tsunami, Hurricane Katrina, and the looming specter of sea level rise put it back into the popular imaginary as an entity with planetary import.

As Oreskes suggests, new understandings of the ocean as central to contemporary life are paired with new realizations of its variability and dynamism. No longer is the ocean thought of as a static entity whose nature could be durably mapped, known, and projected into the future. As I discussed in Chapter Three, nonlinear dynamics are now understood to characterize an always-varying far-from-equilibrium ocean. For example, eminent oceanographer Carl Wunsch challenged the assumption of a steady-state ocean, writing that not only was existing data too scarce to reach any conclusions about the

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[13] Oreskes, Scaling Up Our Vision, 384; see also Rozwadowski, H. M. (2005). *Fathoming the ocean: the discovery and exploration of the deep sea*. Cambridge, MA: Harvard University Press.
[14] Ibid.
[15] Boesch, D. F. (1999). The role of science in ocean governance. *Ecological Economics, 31*(2), 189–198.

overall circulation of the ocean, but also that "the system does indeed fluctuate on all space and time scales."[16] With these fluctuations come great uncertainties; perhaps the most important regards the ocean's role as a climate buffer. Ocean dynamics are arguably the most significant source of uncertainty for future climate predictions; for example, as we saw in Chapter Three, scientists are unsure whether the ocean will continue to act as a carbon sink, absorbing excess carbon and thus helping to maintain Holocene conditions, or become a carbon source, releasing stored carbon to the atmosphere and contributing to warming conditions.[17] The increasing presence of planetary environmental change and its attendant uncertainties has made necessary a different way of knowing the ocean. We might go even further to say that it calls a different world ocean into being; a world ocean characterized by flows and becomings, uncertainty and volatility, disequilibria and change.

It is this new world ocean, increasingly prescient and ever varying, that has recently demanded attention not only in the natural sciences but also from human geography and related disciplines.[18] For example, Steinberg and Peters call for a "wet

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[16] Wunsch, C. (1992). Decade-to-century changes in the ocean circulation. *Oceanography, 5*(2), 99–106.

[17] See for example Fung, I. Y., Doney, S. C., Lindsay, K., & John, J. (2005). Evolution of carbon sinks in a changing climate. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(32), 11201–11206; Swart, S., Chang, N., Fauchereau, N., Joubert, W., Lucas, M., Mtshali, T., Roychoudhury, A., Tagliabue, A., Thomalla, S., Waldron, H., and Monteiro, P. M. (2012). Southern Ocean Seasonal Cycle Experiment 2012: Seasonal scale climate and carbon cycle links. *South African Journal of Science*, *108*(3/4), 11-13.

[18] See for example Oreskes, Scaling Up Our Vision; Anderson and Peters, Water Worlds; Steinberg & Peters, Wet Ontologies; Cardwell, E., & Thornton, T. F. (2015). The fisherly imagination: The promise of geographical approaches to marine management. *Geoforum, 64*, 157-167.

ontology" to contend with the notion that "the ocean […] creates the need for new understandings of mapping and representing; living and knowing; governing and resisting."[19] It seems that an underlying aim of much of this literature is how to account for relations of difference, uncertainty, and governance across scales, and perhaps ultimately at the scale of the planet.[20] These efforts align with new materialist attempts to theorize the agency of nonhuman and nonliving forces, and moreover how close attention to the material world and its 'intra-actions' can compel new or revised theories of classical topics such as subjectivity, politics, and nature.[21] (e.g. Barad, 2007; Coole and Frost, 2010; Bennett, 2009). Steinberg and Peters go on to say "like the ocean itself, maritime subjects and objects can move across, fold into, and emerge out of water in unrecognised and unanticipated ways."[22] Once relegated to the margins of both natural and social science, not to mention critical theory, the ocean has become that which we cannot afford to ignore.

Ocean observations

It is within this context of a variable and newly centered ocean that we must understand

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[19] Steinberg & Peters, Wet Ontologies, 260-261.
[20] See especially Helmreich, S. (2008). *Alien ocean: Anthropological voyages in microbial seas.* Oakland, CA: University of California Press; Lehman, J. (2014). Expecting the Sea: The nature of uncertainty on Sri Lanka's East coast. *Geoforum 52*, 245-256; Peters, Tracking Im(mobilities) at Sea; Peters, K. (2012). Manipulating material hydro-worlds: Rethinking human and more-than-human relationality through offshore radio piracy. *Environment and Planning A, 44*(5), 1241-1254; Steinberg, Of Other Seas.
[21] See for example Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Durham, NC: Duke University Press; Bennett, J. (2009). *Vibrant matter: A political ecology of things*. Durham, NC: Duke University Press; Coole, D., & Frost, S. (Eds.). (2010). *New materialisms*. Durham, NC: Duke University Press.
[22] Steinberg and Peters, Wet Ontologies, 261.

ocean observations. Moreover, ocean observations (and the data products they inform) both shape and are shaped by these new visions of the world ocean in fundamental ways. It is important to note that in this chapter I am discussing *scientific* measurements, rather than surveillance-style observations carried out by military and other enforcement agencies such as border patrols and fisheries regulators, although there is some crossover that I will discuss later. As I have discussed in previous chapters, ocean observations, especially measurements of temperature and salinity across space (including depth) and time, form the "bread and butter" of oceanographic knowledge, and the first steps to analyzing, representing, and making knowledge claims about the sea from a scientific perspective.[23] In Chapter Three, I showed that in turn, these observations facilitate scientists' understanding of how the ocean exchanges heat, carbon, and other properties with its co-constituted counterpart, the atmosphere. Other key ocean observations include measurements of dissolved oxygen and ocean color, which indicate primary productivity, measurements of current speeds at different depths, the concentration of different chemicals in the sea, and other biogeochemical indicators.

It bears repeating that while many scientific disciplines depend variously on hypotheses tested in laboratory experiments or on the development and modeling of mathematical theories, oceanography, like many other geosciences, arguably relies primarily on observational data. As one oceanographer explained to me, "[theoretical work and modeling] are still quite heavily dependent on ocean measurements. And in our science there have really only been one or two theoretical predictions that we can verify

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[23] Cai, W., Avery, S. K., Leinen, M., Lee, K., Lin, X., & Visbeck, M. (2015). Institutional coordination of global ocean observations. *Nature Climate Change, 5*(1), 4–6.

experimentally."[24] More broadly, "the systematic and global-scale collection of geophysical data [... has] paved the way for global biogeochemical and biogeophyscial models and their visual representation of an integrated planetary environmental system."[25] Large-scale geophysical data collection, then, has formed the basis for contemporary understandings of planetary dynamics.

Moreover, ocean observations, and their 'parent' category of Earth observations, are immediately relevant to understandings of the planet that underlie strategies of government. In Chapter Two, I showed how the mid-century emergence of synoptic science linked geophysical observation practices to concepts of the planet as a place for common human scientific endeavor. Similarly, Lövbrand and colleagues argue that the discipline of Earth Systems Science, of which synoptic oceanography was a part, provided not only a new way of visualizing the relationship between nature and society, but also the basis for a novel or revised form of government. In particular, they assert that the birth of Earth Systems Science heralded an understanding of the Earth as one integrated system and established the notion of global environmental change, to which systems of government were forced to adapt even as they were given new images and materials to grasp.[26] Again reiterating a point from Chapter Three, beyond the ocean's formative role in the establishment and maintenance of the state system, it is central to the concept of the Earth as a lively, complex, and interconnected planet. Prior to the

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[24] Robert Weller, personal communication, 24 April 2014.

[25] Lövbrand, E., Stripple, J., &Wiman, B. (2009). Earth system governmentality: Reflections on science in the Anthropocene. *Global Environmental Change, 19*(1), 7–13.

[26] Ibid.

capacity of the Earth to inform government decisions, biopolitical government rests on this concept of the planet, the known world, as an holistic system, both life-giving and faithfully life-recording.[27] Geophysical observations are required to call that world into being even as they are made from within a world constituted by this system of government. It is not too much of a stretch to say that geophysical observations and biopolitical government are co-constituted.

However, it also bears repeating that ocean observations are far from complete or conclusive. While perhaps no nonhuman nature presents itself readily to human senses, technologies, and knowledge practices, the ocean is particularly intractable; an alien space.[28] Oceanographers are the first to admit and even emphasize this. The omnipresence of statements emphasizing the difficulty and high cost of observing the ocean, in official documents, journal articles, and casual conversation, is striking. One oceanographer put it this way: "You can actually touch the ocean, you know, it's there, but you have no idea what is inside it. It's totally inaccessible, much more inaccessible than space."[29] Ocean observations, then, are always partial, and the knowledges they produce incomplete. Their gaps, silences, and erasures are equally informative and deserving of our critical attention.

The Global Ocean Observing System

The knowledge oceanography can produce and the uncertainties that haunt it have changed in both quantity and quality as the spaces and practices of ocean observations

[27] Colebrook, C. (2012). A globe of one's own: In praise of the flat earth. *SubStance*, *41*(1), 30–39.
[28] See for example Helmreich, Alien Ocean.
[29] John Gould, personal communication, 19 February 2014.

have developed since the advent of modern oceanography during the World Wars. Early on, observations were taken primarily from aboard research ships and submersible vessels, augmented by tide gauges and a set of relatively rudimentary drifting floats that acoustically conveyed their position to listening vessels or shore stations. Now, thanks largely to a spate of technological developments that I will discuss in greater detail below, a new army of robotic sensors roams the world ocean. Frequently flaunting notions of marine sovereignty codified in the United Nations Convention on the Law of the Sea, autonomous and remotely operated sensors, in concert with satellites and supercomputer data storage centers, make available an unprecedented amount of oceanographic data. With their more conventional counterparts, these technologies form the basis and justification for the GOOS: a new generation of ocean observations coordinated, albeit loosely, at what approaches a planetary scale.

As such, the GOOS presents problems for our conventional modes of analysis for technical objects, before we even get to its challenges to analytics of government. It is not a scientific project or technology but rather more accurately the organizational infrastructure for a large set of ocean observing technologies and programs; the GOOS is a cohesive 'thing' only in its organization and vision, not necessarily in its daily execution. There is no 'daily practice' of the GOOS, except perhaps in the rarified halls of the IOC. Rather there are vastly varied quotidian experiences of working with the GOOS components, which space prohibits me from exploring in detail here, though I go analyze some of these dynamics further in Chapter 5. Included under the umbrella of the GOOS are dozens of projects and programs organized by individual scientific institutions as well as more permanent international installations, such as arrays of deep-sea moorings and drifting floats. These programs and projects use a wide variety of oceanographic technologies, including ship-based measurements taken from research and commercial ships, moorings, drifting and programmable floats, and other autonomous or remotely operated underwater vehicles. The GOOS provides a way to integrate "communities of practice," often organized around a single technology such as autonomous gliders or drifting floats, into a larger international structure for ocean observations.[30]

Neither the GOOS nor its parent organization, the IOC, provide funding or oversight for most of these projects and technologies themselves, only for their organization into a coordinated system of oceanographic measurements and hence data. The IOC also provides funding for workshops and training sessions associated with GOOS technologies, organization, and data, especially in areas where oceanographic expertise is underdeveloped according to Western standards. For these reasons the GOOS is aptly understood as a loose network, tightly bound only by a sort of grand vision of universal observational coverage, efficient and effective data delivery, and the free flow of data. And like other such systems, although it "can be coordinated or regulated to some degree, it is difficult or impossible to design or [manage], in the sense of imposing (from above) a single vision, practice, or plan."[31] The ad-hoc nature of the GOOS, then, is integral to its existence in more ways than one (more on this later). Finally, the GOOS

[30] Fischer, personal communication.
[31] Edwards, P. N. (2010). *A vast machine: Computer models, climate data, and the politics of global warming*. Cambridge, MA: MIT Press, 12.

must be contextualized as the oceans component of the Global Earth Observing System of Systems (GEOSS), in other words a part of the relatively vague and loosely networked structure of Earth system observing infrastructures that are emerging as scientists attempt to facilitate comprehensive planetary views of the systems that determine the conditions of possibility for life on Earth.

Impossible to understand as a technical object, then, the GOOS demands special analysis as a knowledge infrastructure, subject to "perpetual oscillation between the desire for smooth, system-like behavior and the need to combine capabilities no single system can yet provide."[32] Although one of the GOOS's most obvious functions is to contribute to new representations of the world ocean, the GOOS shows us how the politics of knowledge both underlie and extend beyond those of representation. Digitized, planet-scale views of Earth systems and of the planet itself have garnered the attention of political and environmental geographers, and other scholars of technology, ecology, and media.[33] My work here and in the next chapter builds on that of these authors, particularly in trying to stay attuned to the relation between embodiment and planetary representations, between life and the digital, between materiality and information, as I, like them, grapple with new ways of seeing and acting upon the milieu of human life at various scales. Like them, I think, I am interested in alternatives to what Kingsbury and Jones call the "fear-hope dialectic" of debates on global-scale technpolitics, wherein "the military-industrial complex is positioned against well-

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[32] Ibid.
[33] See for example Jue, Proteus and the Digital; Helmreich, From Spaceship Earth to Google Ocean; Kingsbury, P., & Jones, J. P. (2009). Walter Benjamin's Dionysian adventures on Google Earth. *Geoforum, 40*(4), 502-513.

meaning, progressive social theorists of technology and their diverse, now GIS-equipped publics aiming to expose, through mapping and spatial analysis, legacies of local socio-environmental degradation."[34] In particular, I share Helmreich's alternate goal of revealing the "infrastructural history and conditions of possibility" of new understandings of the world ocean in particular and geophysical systems more broadly.[35]

Yet the GOOS compels me to mind the perhaps subtle but important gap between the politics of representation, which these authors masterfully handle, and the politics of knowledge, which goes beyond what the users of Google Earth/ocean see on the computer screen. While these authors focus primarily on relations that emerge *from* representations of the ocean, here I focus on the knowledge relations that *produce* these representations. I ask what can be learned from paying attention to the organization and vision of the GOOS as a knowledge infrastructure, a way of organizing and making available geophysical observational data to a variety of uses and of assembling various scientists, technologies, government officials, and earth forces. I focus on these observational technologies as a crucial pivot point that helps us understand the knowledge relations that I argue are at the heart of emerging forms of government.

Informationalizing the world ocean

In order to understand the significance of the GOOS as a knowledge infrastructure we must understand a bit more about the changing organizational and operational strategy of ocean observations. At the beginning of modern ocean observations, following the end of the World Wars and the rapid development of political and scientific capacity for

[34] Kingsbury & Jones, Walter Benjamin's Dionysian Adventures on Google Earth, 503.
[35] Helmreich, From Spaceship Earth to Google Ocean, 1211.

coordinated oceanographic measurements, the world ocean called into being by ocean science was an entity with knowable and relatively stable properties. Limits to knowledge and hence power over ocean space were attributed to a lack of data.[36] Due in part to the difficulty of making ocean measurements, for a long time ocean data was treated as simultaneous, even though measurements were made over widely varying timespans.[37] Spatial sampling was equally unstandardized. Thus the implication, born in part from lack of alternatives based on the available data, was that the ocean's basic nature did not change in significant or unforeseeable ways. The ocean's qualities, then, could be measured and known; more measurements, following this logic, would be all that was necessary for making more complete knowledge. As Wunsch put it during this time period, "the main problem [for understanding the ocean's role in climate change] is the very poor historical coverage, which effectively prevents us from detecting any climatic shifts of oceanic hydrography."[38] Therefore, an approach that aimed mainly to increase the extent of data collection emerged and governed ocean measurements for a number of decades. The "measure everything everywhere" ethos is aptly captured in this stanza from a 1957 poem by meteorologist Aaron Fleisher:

> "More data, more data,
> From pole to equator;
> We'll gain our salvation
> Through mass mensuration.

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[36] See for example Oreskes, N. (2000). "Laissez-tomber": Military patronage and women's work in mid- 20th-century oceanography. *Historical Studies in the Physical and Biological Sciences, 30*(2), 373–392.
[37] Wunsch, Decade-to-Century Changes in the Ocean Circulation; Derber, J., & Rosati, A. (1989). A global oceanic data assimilation system. *Journal of Physical Oceanography*, *19*(9), 1333–1347.
[38] Wunsch, Decade-to-Century Changes in the Ocean Circulation, 99.

Thence flows our might,
Our sweetness, our light.
Our spirits full fair, our souls sublime;
Measuring everything, everywhere,
All the time."[39]

Although the poem is of course tongue-in-cheek, it aptly captures the essence of the quest for more data, and the surety that it was a one-way road to better science and a complete, almost divine understanding of the planet. However, in the years that followed, strategies for ocean observations would undergo some dramatic changes.

In a sense, changes in ocean observations were driven by technological development. Since the advent of satellite technology and the 'digital revolution,' the development of ocean sensing technology has experienced exponential growth. Prior to the 1980s data collection was undertaken mainly on ship-based (and occasionally diving) expeditions, which sought to answer specific questions or to explore particular sea basins, ocean currents, or other phenomena.[40] Consequently, data was sparse and its collection was expensive; in most cases, funding had to be obtained on a project-by-project basis, rather than the continuous "line item" monetary flows that are designated to, for example, meteorological measurements.[41]

An integrated, multi-purpose, continual data collection system of a global scale became both possible and urgently required with the advent of satellite technology, robotic sensors, and improved computing technologies. Since the early 1980s, satellites

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[39] Fleisher, A. (1957). Theme song of the Sixth Weather Radar Conference. Cited in Austin, P.M., & Geotis, S.G. (1990). Weather radar at MIT. In Atlas, D. (Ed.), *Radar in meteorology: Battan Memorial and 40th Anniversary Radar Meteorology Conference*. Boston: American Meteorological Society, 31.
[40] See for example Oreskes, Scaling Up Our Vision.
[41] Weller, personal communication.

have provided synoptic measurements of sea surface height, temperature, and other properties, the range of which is constantly expanding. However, satellites cannot penetrate into the ocean's depths, nor can they contend with sea ice or cloud cover. Satellites then work in concert with the newest generation of automated sensors: moored, drifting, and remotely operated instruments. The high cost of operating research vessels has only pushed the move to alternative kinds of sensors further.[42] The explosion of technological sensors in the sea has led one scientist to claim in a popular news source, "we are on the verge of wiring the ocean."[43]

One prominent example of the impact of technological advancement for oceanography that I have also discussed elsewhere is Argo, a project involving 30 countries that has launched network of over 3500 drifting floats that sample the upper 2000 meters of the ocean every 10 days. This technology has been rolled out in a relatively short period of time; floats that could collect temperature and salinity profiles were first developed in the 1980s and pioneered during the World Ocean Circulation Experiment discussed in Chapter 3, but it was not until after the turn of the 21st century that comprehensive observing programs were able to fully utilize this technology.[44] Not only has the increased amounts of data from Argo already improved ocean models, but also "this program, for the first time, allows continuous monitoring of ocean temperature

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[42] Isabelle Ansorge, personal comm., 18 Nov. 2014
[43] "The Plan to Create a 'Fitbit for the Oceans'" (2015, August 13). Retrieved from http://motherboard.vice.com/read/the-plan-to-create-a-fitbit-for-the-oceans.
[44] Gould, J., Roemmich, D., Wijffels, S., Freeland, H., Ignaszewsky, M., Jianping, X., Pouliquen, S., Desaubies, Y., Send, U., Radhakrishnan, K., Takeuchi, K., Kim, K., Danchenkov, M., Sutton, P., King, B., Owens, B., & Riser, S. (2004). Argo profiling floats bring new era of in situ ocean observations. *Eos, Transactions American Geophysical Union, 85*(19), 185–191.

and salinity on a global scale, with all data relayed and made publicly available within hours after collection."[45] In just a few short decades the problem of not enough data has turned into one of too much data.[46]

But this change was more than technological. There was also the realization that ocean observations, and indeed Earth measurements, had to be coordinated at the global scale. At the outset of the GOOS, some 25 years ago, its purpose was to coordinate the handover of ocean observations from the scientific research community to operational agencies, which would employ technicians to routinely carry out observations, just as occurs in meteorology.[47] The original plan for the GOOS would have accorded rather neatly with common conceptions of information that supports biopolitical government; ocean observations would have been made for better ocean governance and especially to "provid[e] information for safety of life at sea."[48] However, in the last several years, the international organization of ocean observations has undergone, in the words of Albert Fischer, Chief of the GOOS project office, "a little bit of a revolution."[49]

Following the focus on oceans at the 2002 Earth Summit (also known as Rio+10), there was recognition within and outside of the international oceanographic community that "we're at this stage in the world where things are happening so quickly we don't actually understand what's going on in the earth in terms of ecosystems and the human

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[45] Cai et al., Institutional coordination of global ocean observations; Ansorge, personal communication.
[46] Conway, E. M. (2006). Drowning in data: Satellite oceanography and information overload in the Earth sciences. *Historical Studies in the Physical and Biological Sciences*, *37*(1), 127-151.
[47] Fischer, personal communication.
[48] Ibid.
[49] Ibid.

impact on the earth and ecosystem services and things like that."[50] Not only were more and better observations called for, but also they must be coordinated on the global scale to address societal needs and not simply science questions. But this proved hard to organize within the existing GOOS goals. Technology continues to develop too rapidly to be handed over to operational technicians, but moreover needs for ocean observations remain too diverse; there are no standard operational agencies for comprehensively making and processing relevant measurements.[51] Instead, IOC-UNESCO's "Framework for Ocean Observing" (FOO), which resulted from OceanObs '09, an international conference held in Venice ten years after the initial OceanObs '99, lays out a new approach to the Sisyphean task of measuring the ocean.[52] Stating that "we cannot measure everything, nor do we need to," the FOO proposes that the oceanographic community, through the mechanism of physical ocean, biogeochemical, and biological and ecosystem panels, identify Essential Ocean Variables (EOVs) to guide the future of ocean observations.[53]

While the process of identifying and codifying EOVs, let alone setting up protocols for their measurement, is still ongoing, those identified range from basic variables such as sea surface temperature to more complex measurements such as the impact of oil and gas wells and pipelines.[54] The FOO tasks oceanographers with

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[50] Sarah Grimes, personal communication, 11 March 2014.
[51] Fischer, personal communication.
[52] UNESCO. (2012). A Framework for Ocean Observing. IOC/INF-1284, doi: 10.5270/OceanObs09-FOO
[53] Ibid., 5.
[54] Intergovernmental Oceanographic Commission. (2013). Report of the First Workshop of Technical Experts for the Global Ocean Observing System (GOOS) Biology and

specifying EOVs that are not driven solely or even primarily by the needs of the research community but rather foremost by "international decision-makers, and the public at large."[55] As one IOC officer told me, "to make policy decisions you actually need the data."[56] Further, the FOO guides the GOOS toward an integrated and systematic approach to ocean measurements; given the difficulty and expense of observing the ocean, the GOOS seeks to avoid redundancy and operates on the principle of "measure once/use many times."[57] The governance of the GOOS under the FOO is designed to maintain its ad-hoc nature into the future; the steering group for the Framework is meant to be "highly flexible, characterized by simplicity, based primarily on functional needs, focused on bringing together stakeholders throughout the community, and operating with nominal associated costs."[58]

With the adoption of the FOO, the GOOS has not only become more systematic and streamlined. An apparatus of modern international government, it has also come to actively produce its object, the world ocean, in new ways.[59] Although the seeds of its creation were planted just as the ocean was becoming a relatively legally fixed territory, the GOOS's existence and operation affirms the idea that the oceans are a continuous

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Ecosystems Panel: Identifying Ecosystem Essential Ocean Variables (EOVs). GOOS Report no. 207.

[55] UNESCO, A Framework for Ocean Observing, 5.

[56] Grimes, personal communication.

[57] UNESCO, A Framework for Ocean Observing, 5.

[58] Ibid., 9.

[59] Agamben, G. (2009). *What Is an apparatus? A other essays*, trans. David Kishik and Stefan Pedatella. Stanford: Stanford University Press.

entity that is an object of concern and administration for all of humanity.[60] Moreover, it asserts that knowledge about the global ocean is appropriately administered at a global intergovernmental level. It produces a planetary relationship between knowledge and government that asserts that not only do common interests of humanity supersede territorial and property rights, but also that relevant knowledge can only be made in a way divested from these boundaries. Put a bit differently, the GOOS creates the world ocean as a certain kind of object due to the knowledge it produces.

In particular, recent developments in the structure and operation of the GOOS produce the world ocean as *informational* in new ways, bringing it into a regime of government that stretches the notion of the biopolitical. The ocean, like the human subject of biopolitical government, must be known, an objective that is placed above controlling, disciplining, or shaping; hence it is brought under what Clarke has called "dataveillance," or routine, digital, "watch and report" monitoring.[61] But GOOS and the systems of knowledge to which it belongs do not attempt to know it in all its complexity; rather it seeks to break it down "into a series of discrete signifying flows" – the flows of carbon, oxygen, salinity, temperature, and other properties indicated by the GOOS's EOVs.[62] This allows for the creation of a "space of comparison," wherein different parts of the ocean can be compared, identified, and classified, and temporal comparisons can

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[60] Collis, C., & Dodds, K. (2008). Assault on the unknown: The historical and political geographies of the International Geophysical Year (1957–8). *Journal of Historical Geography*, *34*(4), 555–573.
[61] Clarke, R. (1988). Information Technology and Dataveillance. *Communications of the ACM, 31*(5), 501.
[62] Haggerty, K. D., & Ericson, R. V. (2000). The surveillant assemblage. *The British Journal of Sociology*, *51*(4), 612.

be made.[63] But even further, these flows are reassembled into what Haggerty and Ericson call the subject's "data double," a new subject consisting exclusively of information.

One way to understand the GOO's current regime, then, is that it brings the ocean into what Deleuze has called societies of control. Government in control societies is concerned with modulating flows of information, capital, and matter, rather than exerting disciplinary power over populations.[64] In societies of control, subjects are defined by the traces of information they emit from their daily activities. Rather than being concerned with discipline of already committed transgressions, government monitors and modulates behavior, all while giving the impression of freedom and openness. Surveillance, or the collection of observations, "transform[s] the body into pure information," which can then be acted on algorithmically, such that government does not even appear as such.[65] Through the systematic and networked collection, compilation, and analysis of observations, the ocean's flows, just like the flows of data emanating from the activity of contemporary individuals, are isolated and transformed into flows of actionable information. Its streamlined and flexible governance structure is designed to keep it adaptable to the type of contingent futures that face the contemporary government of the future in the present.[66] Yet biopolitical power, even in societies of control, targets populations of living individuals, not Earth systems. Rather, we might try to understand

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[63] Ibid.
[64] Deleuze, Societies of Control.
[65] Haggerty and Ericson, Surveillant Assemblage, 613; see also Braun, B. (2014). A new urban dispositif? Governing life in an age of climate change. *Environment and Planning D: Society and Space,* 32(1), 49–64.
[66] Anderson, B. (2010). Preemption, precaution, preparedness: Anticipatory action and future geographies. *Progress in Human Geography*, *34*(6), 777–798

what new modalities of power emerge when the government of control societies is forced to account for Earth systems, as is increasingly the case in the Anthropocene era. Hence we might look to the GOOS and other Earth system observation strategies to better understand the problems facing our current analytics of power.

Turning to geontopolitics?

Above, I have shown that ocean observations, organized through the GOOS, play a fundamental role in new understandings of the ocean environment under contemporary regimes of government. Indeed, one consequence of applying the logics of population government to the ocean might be that it is increasingly figured as a kind of body, as not just central to life but as alive. This is evidenced in such phrases as "taking the ocean's pulse," and the lexical designation of hypoxic waters as "dead zones."[67] (e.g. Wilson, 2000; Gould et al., 2004). Yet the ocean is not simply brought to life by the GOOS and related mechanisms; it cannot be reduced to one body, one lively subject, among many. To understand the informationalized world ocean in this way is to miss the paradoxes it poses for our analytics of government. Our attempts to "apprehend [the ocean] through a philosophy of life" inevitably fall short (Povinelli, 2015, p. 174). Comparable to a situation Povinelli describes in her 2015 essay, the ocean seems to at once have some sovereign power, or agency, compelling particular arrangements of scientists, technologies, diplomats, and more as it threatens with its changing tides, but it also depends on these arrangements to appear to us as such. Moreover, what the ocean is

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[67] See for example Gould et al., Argo Floats Bring in a New Era of In Situ Ocean Observations; Wilson, Stan. "Launching the Argo Armada: Taking the Ocean's Pulse with 3,000 Free- Ranging Floats" *Oceanus*, 42(1), 17-19.

composed of, whom it affects, and what conditions for life it fosters, depend on a vast and constantly changing assemblage. What the world ocean *is* then is a very difficult question to answer. We ultimately need a way to understand the relationship between power and whatever the world ocean is that does not reduce the ocean to a form of biological life; as something that does not derive its meaning from its birth and death, but rather produces "a realm of *inertness* more terrifying than death itself."[68] We need an analytic of government for understanding the address of power to *potentiality* rather than to life as such.

A closer look at how Foucault understands life, nature, and potentiality in a biopolitical matrix shows how this challenges conventional understandings of power. For Foucault, the art of modern government is addressed to "a sort of complex composed of men and things."[69] He emphasizes that modern government is concerned with this relation between human subjects and objects, territories, and resources, as well as "accidents and misfortunes such as famine, epidemics, death, etc."[70] In his 1976 lectures, Foucault is more specific about how biopolitics, as a preeminent mode of modern government, acts upon the distinction between life and nonlife, asserting that it is lastly concerned with "control over relations between the human race, or human beings insofar as they are a species, insofar as they are living beings, and their environment, the milieu

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[68] Povinelli, Transgender Creeks, 174.
[69] Foucault, M. (1991). Governmentality. In Burchell, G., Gordon, C., & Miller, P., (eds). *The Foucault effect: Studies in governmentality.* Chicago: University of Chicago Press, 93.
[70] Ibid.

in which they live."[71] Here the liveliness of humans is clearly demarcated from their nonlife surroundings.

Foucault goes on to say that biopower's concern with living beings, "includes the direct effects of the geographical, climatic, or hydrographic environment [...] And also the problem of the environment to the extent that it is not a natural environment, that it has been created by the population and therefore has effects on that population. This is, essentially, the urban problem."[72] In the first part of this statement, biopolitics is understood to address the actuality of the geophysical: its effects on human populations. The second part of this passage claims that biopolitics applies to man-made environments, inferring that it is through human creation that the geophysical might have potentiality; it might change in not only unforeseen but unforeseeable ways. In other words, humans must 'give life' to the geophysical for this mode of analysis to apply, by lending it potentiality instead of simply actuality. Of course, this distinction is one that must be maintained, i.e. constantly worked upon in order to appear true; "no life is sovereign in the sense of an absolute structural and functional compartmentalization and self-organization."[73] Therefore, while Foucault's biopolitics can encompass the relationship between humans and their milieu, or between life and nonlife, a major task and pivot point of government is the maintenance of that distinction, in a way that the GOOS shows us is shifting in the contemporary era.

As Povinelli writes about a transgender creek in Australia, the ocean "is a nonlife

[71] Foucault, Society Must Be Defended, 245.
[72] Ibid.
[73] Povinelli, Transgender Creeks, 184.

entity that demands her position be a part of the governance of the late-liberal demos."[74] How is this demand made, and through what kind of knowledge practices is it made legible? Here I posit that the creation of the ocean's "data double" not only indicates but also plays a role in the emergence of Povinelli's geontopolitics. Povinelli's central claim is that biopolitics affords potentiality, or the capacity for "persisting in an ever-altering environment, creatively maneuvering and adjusting and slowly, perhaps at the end, coming to be something different than it was in the beginning" only to life, and uses this assignation as the basis for government.[75] In an era of fundamental environmental change, uncertainty about the very conditions of life on Earth, and the realization that humans are geological actors, a mode of government or form of analysis that sees the nonliving environment as simply the inert background for life is obsolete. This is evidenced in the shifting priorities that govern the GOOS in an attempt to understand the ocean as a dynamic and far-from-equilibrium entity; as a space of becoming.

Kathryn Yusoff points to Anthropocene understandings of nonliving potentiality when she calls for new conceptions of humans as sharing characteristics and forces with the geological, and asks us to consider what she terms "geologic life."[76] Povinelli's formation of geontopower broadens and furthers this provocation. Previously thought of as distinctly nonlife, geophysical systems trouble this distinction between life and nonlife, as we increasingly realize that not only is what appears as 'life' or the conditions for life far more complicated than we previously imagined, but nonlife entities are so

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[74] Ibid., 183.
[75] Povinelli, Interview with Povinelli, n. pag.
[76] Yusoff, K. (2013). Geologic life: Prehistory, climate, futures in the Anthropocene. *Environment and Planning D: Society and Space, 31*(5), 779–795.

interwoven with what constitutes ‘life’ as to be indistinct from it. If biopolitics relates power to life, then geotonpolitics relates power to potentiality. Potentiality can no longer be defined, even ambivalently, as the provenance of life, but rather as something that characterizes nonlife entities such as Earth systems. Therefore ocean observations and other forms of geophysical monitoring are a particularly dense node of government for geontopower. As governments contend with uncertain futures, the monitoring and management of geophysical systems must be understood as central. Far from being an exercise in pure science, or science for science’s sake, ocean and other geophysical observations are now vital to the government of the future in the present. Below, I show how the geontopolitical analytic suggested by contemporary ocean observations can contribute to understandings of the changing nature of territory, risk, and power.

Power, territory, and ocean observations

Since the early days of ocean observations, the sea has played a foundational role in the relationship between territory and population that forms the basis for modern biopolitical government.[77] Moreover, as Braun has pointed out, in Foucault’s formulation territory and its qualities should be understood as historically contingent and socially produced, which is not to say invented or immaterial.[78] Therefore, how the qualities of the territory come to be known demands attention; we must consider how the types of observations that are made, and the means by which they are collected and analyzed, matter to the modes of government they inform.

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[77] Lövbrand et al., Earth System Governmentality; Foucault, Governmentality; Foucault, Security, Territory, Population.
[78] Braun, B. (2000). Producing vertical territory: Geology and governmentality in Late Victorian Canada. *Cultural Geographies, 7*(1), 7–46.

To be sure, the ocean perhaps fundamentally presents challenges to prevailing land-based notions of territory, which rely on fixity and demarcate-able boundaries. But as several scholars remind us, the concept of territory as it relates to government is about ordering space, implying the primacy of the knowledge relation between the territory to be governed and its outside, and the significance of calculation as a strategy of defining this relation.[79] As Steinberg writes, the ocean performed a key role in the establishment of territoriality: "The idealization of the ocean as the ultimate outside, beyond civilization, bolstered the construction of the rest of the world - the universe of territorial states as sovereign insides."[80] While the ocean might have been external to the Westphalian territory, it has been vital for defining the territory, both conceptually and materially, as not only the constitutive outside but also as a space of warfare, mobility, and transport.[81]

Moreover, Elden has recently argued that territory is enacted not simply by controlling vertical and horizontal surfaces, but rather it is a political technology that it is concerned with the control of volumes. He joins a bevy of political geographers who recently insist that geopolitics is not about strategy and tactics on a flat map but rather ever more about the politics of all of Earth's materialities.[82] The FOO, and the GOOS

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[79] See for example Elden, S. (2007). Governmentality, Calculation, Territory. *Environment and Planning D: Society and Space, 25*(3), 562.
[80] Steinberg, P. E. (2009). Sovereignty, territory, and the mapping of Mmobility: A view from the outside. *Annals of the Association of American Geographers*, *99*(3), 473.
[81] Ibid.; see also Fajardo, K. B. (2011). *Filipino crosscurrents: Oceanographies of seafaring, masculinities, and globalization*. Minneapolis: University of Minnesota Press.
[82] See for example Elden, Governmentality, Calculation, Territory; Steinberg & Peters, Wet Ontologies; Dalby, S. (2013). Biopolitics and climate security in the Anthropocene. *Geoforum, 49*, 184–192.

more broadly, bring the ocean squarely into this relation. The EOVs are precisely the qualities of the ocean that are of interest to government, broadly defined. The ocean is no longer the constitutive outside but at the center of modern government concerns, indicated by new enthusiasms for marine spatial planning, marine domain awareness, marine protected areas, and others.[83] The geopolitics of the ocean is fundamentally based on these systems of observation and their ability to be recombined in ad-hoc ways to govern not only the present but also many possible futures through modeling and forecasting. And yet the move to understand geopolitics in this way indicates not simply an expanded project for modern government but a world that demands to be governed differently.

Whether or not the scientific community officially designates the Anthropocene as a new geological era, emerging modes of government are developed in a world in which, as Dalby writes, "the environment is not a given context for geopolitics."[84] Furthermore, certain factions of humanity are seen as capable of altering these conditions, in the past, present, and future, in the folded temporalities of geology and capitalism.[85] The question of securing certain forms of life now must take into account planetary-scale environmental conditions not as predictable background conditions that can easily be mapped and known but as sources of potentiality and uncertainty in themselves. Oels notes that this has led to the "climatization" of the security discourse, "linked to

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[83] See for example Ryan, Barry J. (2015). Security spheres: A phenomenology of maritime spatial practices. *Security Dialogue 46*(6), 568-584.
[84] Dalby, Biopolitics and Climate Security in the Anthropocene, 189.
[85] Dibley, B. (2012). "The shape of things to come": Seven theses on the Anthropocene and attachment. *Australian Humanities Review, 52,* 139–158.

observable policy changes in the security field."[86] These policy changes are based on new knowledge relations in the informationalizing of the sea; even the open-access nature of contemporary ocean observations, obviously a boon for science in general, is justified by the needs of policy users.[87] The ad-hoc and flexible-by-design nature of ocean observations, in which the ocean is rendered as streams of information that can be combined and recombined by different users, indicates an oceanic potentiality that moves back and forth and between living and nonliving forces. One example of how this matters is in the conception of new conundrums for risk discourses. As Dalby writes, "the logics of risk and strategies of managing contingencies come up against the unavoidable recognition that their context is also part of the new emergent condition of life in the Anthropocene."[88] Thus ocean observations are drawn into, and in turn shape, new concepts of risk that are compelled by shared potentiality between the traditional subjects of security and their milieus.

A risky ocean

The challenges of governing the sea lie not simply in delimiting its constant movement with enforceable territorial boundaries. It is not just that terra-centric territoriality is expanded to the sea, nor that the materiality of the sea as a space of fluidity and motion calls for different forms of governance.[89] Rather, the recognition of the sea's potential to change in unpredictable ways, its potentiality, poses problems for the ontologies on

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[86] Oels, A. (2013). Rendering climate change governable by risk: From probability to contingency. *Geoforum, 45*, 18.
[87] See for example Dickey, T., & Bidigare, R. (2005). Interdisciplinary oceanographic observations: The wave of the future. *Scientia Marina, 69*(Suppl. 1), 23-42.
[88] Dalby, Biopolitics and Climate Security in the Anthropocene, 188.
[89] See for example Steinberg, Of Other Seas.

which biopolitical government relies. Bringing the ocean into societies of control and thus recognizing its potentiality reflects new understandings of risk and uncertainty that are nascent in evolving modes of government. As Ben Anderson explains, the threats that face us in the 21st century, such as global environmental change, terrorism, and pandemics have different dynamics than those of classical biopolitical analysis. These new disasters are seen as "potentially catastrophic," with the capacity to suddenly alter the conditions of possibility for life across scales.[90] Additionally, risks within this new paradigm are understood to be "incubating within the present," threatening to cross critical thresholds as a result of processes that are already in effect.[91] Change is thus understood as inevitable and non-linear, the result of both slow and fast processes that jump spatial and temporal scales. This conception of risk leads to an understanding of the future as not only uncertain but also indeterminate, calling for action even while complete knowledge is acknowledged as impossible. Liberal-democratic government has responded with an emphasis on anticipatory government, with logics that both produce and are rooted in Deleuze's societies of control.

Ocean observations integrate old and new security concerns in accordance with these contemporary understandings of risk. In addition to their inarguable (although perhaps a few steps abstracted) relevance to fisheries, tourism, resource extraction, and property protection, it is worth noting that contemporary ocean observations do not break the strong although complex association between oceanography, the state, and military

[90] Anderson, Preemption, Precaution, Preparedness, 779.
[91] Ibid., 780.

interests.[92] In an era where drone warfare and other advanced aerial missile systems dominate the public eye (and perhaps justly so), it is easy to forget that sea is still a battlefield; there are currently more than 600 submarines in operation by 43 countries.[93] Furthermore, the most basic ocean observations continue to support military interests; navies are interested in the hydrographic structure of the sea because it reveals rapid changes in temperature and salinity, which deflect submarine-finding SONAR, creating places in the open sea where submarines can 'hide' from detection. In fact, as I mention elsewhere, the United States Navy is likely the largest consumer of temperature and salinity data.[94] Yet, perhaps as a symptom of what Derek Gregory has called the current condition of "Everywhere War," the Navy no longer needs to provide the majority of funding for this information.[95] In one prominent example, the lion's share of funding provision for physical oceanography in the United States has shifted from the Office of Naval Research to the National Science Foundation in recent years.[96]

While ocean observations were 'relevant' to one section of government (defense) for some time, their broader societal importance is being asserted anew. One of the main aims of the FOO is to have communities of users, across various segments of society,

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[92] See for example, Oreskes, Lassiez-Tomber; Hamblin, J. D. (2005). *Oceanographers and the Cold War: Disciples of marine science.* Seattle, WA: University of Washington Press; Mukerji, C. (1990). *A fragile power: Scientists and the state*. Princeton, NJ: Princeton University Press; Weir, G. E. (2001). *An ocean in common: American naval officers, scientists and the ocean environment*. College Station, TX: Texas A&M University Press.

[93] Chief of Naval Operations Submarine Warfare Division. (no date). "Submarine Frequently Asked Questions" http://www.navy.mil/navydata/cno/n87/faq.html.

[94] Steven Piotrowicz, personal communication, 6 August 2014.

[95] Gregory, D. (2004). *The colonial present: Afghanistan, Palestine, and Iran*. London: Wiley/Blackwell.

[96] Weller, personal communication.

drive the justifications for ocean observations. In the FOO and beyond, scientists are making an effort to address claims that, for example, "there are no substantial international science efforts to address issues important for the sustainable governance of the ocean," and that previous programs were "at best, weakly linked with the development and function of governance."[97] It is because of this increasing recognition of the potentiality of the sea and the relevance of ocean observations that Google Ocean and related platforms have become such rich and important subjects of analysis.[98]

With the integration and streamlining of the GOOS and its open access format, the same data sources can be used to find submarines, predict climate patterns, and select sites for oil drilling. This is not to say that these observations are inherently militarized or sinister, but to recognize the way in which risk at sea moves across human and nonhuman forces. As Braun writes, in a world of unstable geophysical forces, government is "not only combining diverse elements into new heterogeneous formations, but also taking hold of new knowledges, technologies, and practices that either did not previously exist or had not previously been appropriated as a means of administration."[99] The subject and object shift; a recognition within relations of knowledge and government that, as Steinberg has asserted, the ocean is not just a space where movement, uncertainty, connections, and difference proliferate, but itself constitutes and is constituted by these qualities.[100]

Conclusion: the open future and the world ocean

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[97] Boesch, The Role of Science in Ocean Governance, 191.
[98] See for example Helmreich, From Spaceship Earth to Google Ocean; Farman, Mapping the Digital Empire.
[99] Braun, A New Urban Dispositif?, 51.
[100] Steinberg, Of Other Seas.

My intention above is to argue that the significance of these changes cannot be fully comprehended without understanding them as not (simply) biopolitical, but increasingly geontopolitical. This entails recognizing a new or emerging form of government, one no longer predicated on the distinctions between life and nonlife, between human subject and natural resource. It is this form of government that both feeds and responds to a future that is radically open – not just to human inventiveness or cruelty, but on a planetary scale, to forces of potentiality shared across geologic and human bodies. As Dalby argues, "what kind of nature gets produced is now the political question of our times."[101] What is happening in the seemingly anachronistic halls of the IOC is in fact very timely.

With this in mind, we can see that governing the future in the geontological present has two valences. On one hand, it is an attempt to secure the future for certain valued forms of life.[102] On the other, it indicates a future that will undoubtedly be different from the present. In the first journal article that explicitly outlines the concept of geontopower, Povinelli frames her intervention around what she identifies as the three figures of geontopower, following Foucault's four figures of biopolitics. Povinelli's figures include The Desert (that which is currently barren of life but with technology could be made to foster life), The Animist (that which insists "there is no nonlife, because all is life") and The Terrorist, (that which "seek[s] to disrupt the current biontological

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[101] Dalby, Biopolitics and Climate Security in the Anthropocene, 185.
[102] Anderson, Preemption, Precaution, Preparedness.

organization of state, market, and sociality by opening the political and social to the non-human animal, the vegetal, and the geotic."[103]

Povinelli's figures are concerned with a world where life is, or is not, where it could be, or from where it could be annihilated. But to truly begin to address the problems that the world ocean (as we now know it) poses to biopolitical government, we need a figure that provides a key to the ways in which life and nonlife are imbricated with each other to the point of becoming indistinct. We need a figure that indicates the ways in which potentiality moves across subject and object such that it blurs these boundaries. For this figure, as for all the potential figures of geontopolitics, knowledge relations must be foregrounded. Just as a divide between materiality and social construction cannot hold, a division between the ocean as pure stubborn materiality and the ocean as given by digital representations suggests two objects for government that are not so cleanly divided.

While cautious of making assumptions about Povinelli's intentions, I would like to submit for consideration a fourth figure of geontopolitics: The World Ocean, that which, on a planetary scale, is understood to be so imbricated with life as to be indistinguishable and inseparable from it. Povinelli points out that the figure of bio- or geontopower do not simply stand as archetypes of a mode of government, nor are they its limits. On the contrary, they point to that which they are not; that to which they might become. Again, it bears emphasis that knowledge relations remain central. Attempts to know the ocean point to an ocean that cannot be known: an ocean for which the most

[103] Povinelli, Transgender Creeks, 170.

highly technical and coordinated monitoring efforts may prove inadequate. As Steinberg and Peters argue, "one is continually faced by the paradox that any attempt to 'know' the ocean by separating it into its constituent parts serves only to reveal its unknowability as an idealised stable and singular object."[104] The governance of ocean observations, understood thus, gestures toward a world in which monitoring the ocean may make no difference, or may make a difference in ways we cannot yet imagine.

[104] Steinberg & Peters, Wet Ontologies, 249-250.

CHAPTER FIVE: FROM SHIPS TO ROBOTS: TECHNOLOGICAL AND AFFECTIVE SHIFTS IN SENSING THE WORLD OCEAN

It was a chilly day in April 2014. The wind was blowing around the docks in the Woods Hole Harbor and the grey sky was low. I followed Dr. John Toole onboard the *Knorr*, one of the US's world-class research vessels (Fig. 5.1). The ship was teeming with activity in preparation for a cruise to replace some moored instruments between New England and Bermuda. In one of the corridors we stopped to talk to Amy, a technician who's been sailing on the vessel since 2000. She and Dr. Toole reminisced about some of the cruises they had been on together; the time they had an emergency two day port stop in Greenland, and what it was like to work with crews from other countries with different dining habits. The general air of nostalgia that suffused the conversation is non-

Fig. 5.1: RV *Knorr*. (source: author's photograph)

incidental; talk kept coming back to the fact that it was the Knorr's last year as a research vessel for the Woods Hole Oceanographic Institute (WHOI). Another scientist arrived, remarking, "I want to go out on this thing before she retires. I'm going to miss her." Amy replied, "Yeah. I think a lot of us will."

The Knorr first arrived in Woods Hole in 1970, just in time to kick off the International Decade of Ocean Exploration. And since then, the vessel has done great things; cruises that she has hosted have discovered life in deep-sea vents, found the Titanic, and pioneered seabed coring techniques. But soon after my tour she was jettisoned,[1] and replaced by a smaller, more fuel-efficient vessel named after a man who embodies the more sky-ward dreams of modern science: Neil Armstrong. This gesture to space, and the fact that although the new vessel is more technologically advanced, it has less sea-going capacity in terms of time and number of scientists, hints that perhaps oceanographers are saying goodbye not just to the *Knorr* but also to a ship-based way of doing oceanography, or a ship-based geography of ocean knowledge.

What are the implications of this shift away from ship-based research, done by scientists at sea, and to observations taken by robotic or remotely operated sensors? In Chapter Four, I showed the implications of such a shift in terms of how observations are organized, for what purposes, and contextualized this within wider shifts in government. Here, I turn to the more quotidian aspects of doing oceanography to ask what it means for oceanographers to spend more time at a computer than on a ship and for the sea to be

[1] In just one incidence of transnational science-military exchange, the *Knorr* was sold to the Mexican Navy for oceanographic research (see http://www.capecodtimes.com/article/20160314/NEWS/160319696).

studied by machines and computers rather than by human eyes and hands on the deck of a research vessel or inside a submersible.

Oceanography currently inhabits conflicting desires for the kind of universal, high quality, and high volume data that can only be produced by remotely operated or autonomous *in situ* technologies and the oceanographer's foundational desire to go to sea for science. This is a practical conflict, involving the allotment of research dollars and the focus of capacity-building efforts. Yet it is also affective, in a strictly Deleuzian sense, having to do with the interaction between bodies and Earth forces, that increase or decrease a body's capacity to act; "the aleatory dynamics of experience, the 'push' of life which interrupts, unsettles, and haunts persons, places, or things."[2] The shift toward robotic and remote sensing, then, is both a technological and embodied shift, which affects how different ways of becoming with the ocean are realized.

My purpose in exploring this shift is, primarily, to understand what science does, what kinds of becomings (always becomings-with) it enacts in the world. It is to understand how science contributes to the making of worlds. But it is also to understand how meaning is made, and in particular the relationships through which meaning is made. I have covered what this transition meant in terms of how we see the ocean elsewhere, as have others.[3] What I want to discuss here is what this meant for how oceanographers and

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[2] Anderson, B. and Harrison, P. (eds). (2010). *Taking-place: Non-representational theories and geography.* London: Ashgate, 16-17; Deleuze, G. (2001). *Spinoza: practical philosophy.* San Francisco, CA: City Lights Publishing.
[3] Helmreich, S. (2011). From Spaceship Earth to Google Ocean: Planetary Icons, Indexes, and Infrastructures. *Social Research 78*(4), 1211-1242; Jue, M. (2014). Proteus and the digital: Scalar transformations of seawater's materiality in ocean animations. *Animation*, *9*(2), 245-260.

others interact with the ocean; what it means to make meaning with the sea, and what it looks like to do so on a daily basis. It is, as Stengers writes, to learn "what a meaning-producing relation as such demands."[4] What is required to make meaning with and of the sea? What affects, understood as relationships between bodies and Earthly forces, are implicated in doing so? What desires are expressed or latent in these relations? How is this meaning-making relation changing, and with what implications? These are questions about the world-making practices of oceanographers, how they become-with their object of study.

Focusing on the embodied practices of oceanographers may seem trivial; we are talking about maximum a few thousand people in the world, all experts, highly educated, at least somewhat elite. However, their sensing practices shape the understandings of the ocean that underlie everything from pop culture to climate change negotiations. In addition, understanding the affects of new sensing technologies can show us how relations with sensing technologies vary, helping us to avoid overgeneralizing new human-machine relations and characterizing remote and robotic sensing as simply another form of the abstraction of nature.[5] And furthermore, changing regimes of ocean sensing relate to changing practices in other field sciences, particularly the geosciences, which aim at planetary-scale data and monitoring. Changing priorities and practices for data collection have immense influence on university education, popular science, capacity building, and beyond.

[4] Stengers, I. (2000). God's Heart and the Stuff of Life. *Pli 9*, 86-118.
[5] See also Helmreich, S. (2009). Intimate Sensing. In Turkle, S. (ed). *Simulation and its Discontents*. Cambridge, MA: MIT Press, 129-150.

In addition, studying these experiences and their geopolitical and affective reverberations might contribute something to how geographers and other social theorists regard materiality and the abstraction of nature. Much geographic literature promotes firsthand, embodied engagement with Earth forces as a privileged way to understand the power of the geo, the emancipatory potential of Earth's power and surprise, the forces that are shared across geological, nonhuman, and human bodies. However, in the case of oceanography and likely other field sciences, these types of engagement not have indelible imperial legacies, but also rely upon and propagate unequal worlds with distinct gender, racial, and class dimensions. Oceanography has tied a division of labor to a division of perception; how we are able to sense the sea depends very much upon our subject positions in terms of class, gender, and other markers of difference.[6]

In this chapter, I first describe a perhaps unforeseen shift from ship- and submersible-based oceanography to remote and robotic sensing. Then, I use mainly primary source interviews to explore scientists' reactions to this shift, in particular their nostalgia surrounding ship-based sensing. I show that these sentiments have perhaps unexpected resonance with how we might theorize this shift as participating in the abstraction of nature. In the third section, I suggest taking a closer look at what may initially appear to be a process of abstraction. While a shift to robotic and remote sensing may limit certain meaning-making practices, it might also open up a host of new ones, which could allow the discipline to extend in directions that are less masculinist and imperialist than has historically been the case. Throughout this analysis I draw on a

[6] Ibid.

variety of primary and secondary source material, including interviews with oceanographers as well as science writing from the early days of modern oceanography. One source deserves special mention: *Sea of the Beholder*, the unpublished biography/autobiography co-authored by Henry Stommel, considered by many to be the founder of dynamical oceanography, and his wife, Elizabeth "Chickie" Stommel.[7] This document provides rare reflections on changing concepts of the ocean and practices of ocean sensing over Henry Stommel's career, as well as even rarer reflections on the personal impacts of being the partner of a sea-going scientist.

Going to Sea for Science

Henry Stommel writes,

> "what distinguishes my life has been the happy chance to study the ocean. This marvelous opportunity has meant more to me than acquiring power over others, than making money, than seeking publicity or academic distinctions. By comparison with the chance to contemplate the oceanic portion of the universe these worldly goals have seemed mere dross."[8]

In his career, this undoubtedly meant going to sea for large portions of time. At the beginning of modern oceanography, scientific explorations of the ocean were seen as closely related to geographical explorations of the ocean and both were carried out on ships. Relatedly, being an oceanographer meant going to sea. It meant leaving behind families, students, and laboratories for days and nights wrestling, sometimes quite

[7] Stommel, H. & Stommel, E. *Sea of the Beholder*. Unpublished manuscript, Woods Hole Data Library and Archive. This draft is dated November 5, 1984. I have used the pagination given in this draft. For the first chapter, the numbers correspond to the page number. For the others, the chapter number is given first, followed by the page number.
[8] Stommel & Stommel, Sea of the Beholder, 3; In this statement Stommel is also demonstrating textbook rhetoric of what Haraway calls the "modest witness," wherein "his subjectivity is his objectivity." See Haraway, D. (1997). *Modest_Witness@Second_Millennium. FemaleMan©_Meets_OncoMouse[a]: Feminism and Technoscience.* New York and London: Routledge, 24.

literally, with the object of their study. In Chapter Two, I explained how ship-based oceanography extended imperial tropes of seafaring adventure and exploration. Not only did oceanography draw from these pasts, but also ship-based oceanography seemed to be the way of the future, especially for global-scale or blue-water oceanography. Enhancing their fleet of research vessels was seen as among the most important investments a nation could make to develop their expertise in oceanography. Expansion in many national oceanographic programs was catalyzed by the success of the IGY and the subsequent declaration of the 1970s as the International Decade of Ocean Exploration (IDOE). This extended experience at sea was at the root of many oceanographic advances. In 1955, Stommel outlined the problems that physical oceanography was attempting to solve, and the progress that had been made in doing so. Here is how he described the first stage of oceanographic problem-solving:

> "Before there is a problem in physical oceanography we have to recognize a phenomenon in a mass of observational detail. We try to dissect nature at the 'joints' so to speak. Thus certain subjects of study, such as tides, or the Gulf Stream, stand out quite clearly in our collective experience, whereas other phenomena, such as the electric potentials induced by ocean-wide water movements, are not so immediately obvious from experience. The recognition of a phenomena sometimes arises from a lucky chance observation but more often as a result of extensive exploratory survey work, such as that of the *Challenger,* the *Meteor*, and the early *Atlantis* cruises."[9]

Of course, many scientists were aware that such a method of data collection, much less problem identification, was situated and hence biased, even if they believed their discoveries might reveal something universally true about the sea.

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[9] Stommel, H. (1955) "On the Present Status of Our Physical Knowledge of the Deep Ocean." p. 1. Unpublished manuscript. Located at the WHOI Data Library and Archives.

Exploring the ocean was not limited to surface ventures. The deep sea had become a realm of intrigue; the 'inner space' that provided a counterpoint to concurrent outer space explorations. As Athelstan Spilhaus, a scientist at the forefront of both space exploration and oceanographic research wrote,

> "Even though I was one of those who early urged that our government should support the development of research vehicles such as satellites and rockets to probe space, I wonder now whether enthusiasm and the propaganda race in space are perhaps causing us to over-emphasize outer space at the expense of understanding the unknown reaches of the earth on which we live […] we should not forget the earth on which we stand and the great storehouse of living needs…ours for the taking…held for us in the seas."[10]

Investment in inner space explorations was obvious perhaps nowhere as much as in the development of the first bathyscaphes. Building off of Otis Barton's 1930 steel diving sphere, the Swiss father-son team of Auguste and Jacques Piccard invented an underwater vehicle, called the *Trieste*, attracting the attention of the US Navy Electronics Laboratory, which purchased the vessel in 1958. On Jan 23 1960, Jacques Piccard and Lieutenant Don Walsh piloted the *Trieste* down 10,915 meters to the bottom of the Mariana Trench (Challenger Deep), a

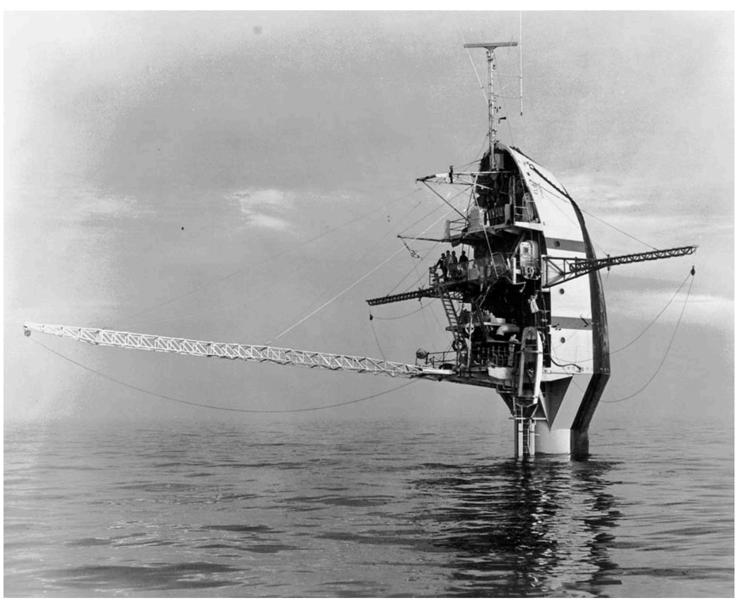

Fig. 5.2: RV *FLIP*. (source: wiki images)

[10] Spilhaus, A. (1959). *Turn to the Sea*. Washington, DC: National Academy of Sciences – National Research Council, 44.

feat that would not be repeated for another 35 years.[11]

The Trieste is perhaps the most remarkable in a set of submersible manned research vessels that seemed, during the 1960s and 70s, to be the future of oceanographic research. Mainly capable of operations along the continental shelf, these included Jacques Cousteau's *Denise*, a "two-man diving saucer," and Westinghouse's self-propelled *Deepstar*, as well as Woods Hole's *Alvin*, a research submarine with capacities for observation and sampling.[12] In addition, Scripps Institute of Oceanography designed and built FLIP (Floating Instrument Platform) shown in Fig. 5.2, which used ballast tanks to flip the vessel into a vertical position, serving "as a stable and noise-free platform for delicate underwater acoustical observations."[13]

In addition to technological capacity and exploratory spirit, the enthusiasm for research submersibles and ship-based oceanography highlighted a desire to immerse oneself in the ocean environment, and a belief that this was necessary not only for scientific research but to expand the limits of human capacities. One author put it this way:

> "Present planning in the United States for future deep-sea exploration calls for construction of other and better bathyscaphes. Submarine craft capable of moving up and down, or horizontally at any depth, and crawling like gigantic lobsters along the bottom, will enable oceanographers to see with their own eyes the shape and appearance of the ocean floor and the behaviour of the creatures living there. Direct viewing will be supplemented by television cameras that will reproduce the panorama of surrounding underseascapes on screens inside the cabins. Study of

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[11] Yasso, W. (1965). *Oceanography: A Study of Inner Space*. Holt, Rinehart and Winston, Inc.
[12] Ibid, 155.
[13] Ibid, 160.

> the ocean depths by direct observation will multiply many times over the amount of information which hitherto has been secured by instruments alone."[14]

A film on oceanographic research produced by the US Navy in 1972 used perhaps more whimsical terms: "Must man depend on remotely controlled devices, or can he learn to work in the deep ocean himself, free like the fish and the porpoise and the seal, to move where he will?"[15]

This excitement for research vessels and submersibles did not anticipate that mere decades later, much oceanographic research would be done using remote and robotic sensors, and that oceanographers would spend much more time on land, most of it behind a computer. This shift can be attributed to a number of factors, including increased costs for fuel and salaries on ocean expeditions and increased professionalization of oceanography and science more broadly. As Stommel writes, "academic schedules do their awful work in keeping students and their professors from the sea. Even in the summer when one might expect to find young people enjoying a shipboard apprenticeship one is much more likely to find them in a semidarkened office hunched over a computer terminal."[16] Perhaps most influential, however inseparable from the changes mentioned above, was the development of satellite oceanography as well as huge advances in miniaturization, battery life, data storage, and other technologies relevant to unmanned operations at sea.

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[14] Daugherty, C.M. (1961). Searchers of the Sea. London: Phoenix House Ltd.
[15] Video Recording No. 330-DVIC-25626; "Assault on the Unknown: Oceanographic Research Platforms," 1972; Series: Motion Picture Films and Video Recordings on Five Decades of U.S. Military Activities Around the World, ca. 1950 - ca. 2000; Record Group 330; National Archives at College Park, College Park, MD.
[16] Stommel and Stommel, Sea of the Beholder, 6-28.

When it comes to a shift away from ship based sensing, there are three relevant alternative types of measurements. The most well-established, and consequently the most critiqued in critical literature, are satellite measurements. When I was selecting ways to periodize oceanography, several scientists recommended that I use satellite oceanography to recognize a significant regime change. As one scientist put it, satellite oceanography "is it's own kind of revolution. So the ability to image the entire sea surface every I don't know, week maybe, through […] compositing satellite tracks, was a real revolution."[17] Satellites measure a wide variety of oceanographic variables, including sea surface height (altimetry), temperature, color, and perhaps most recently, salinity. Satellite measurements make it possible to get a view of the entire ocean at once. They are limited, however, because satellites can only measure the surface, so they miss much of what is going on in the ocean, such as the processes of vertical mixing, deep water formation, and subsurface currents that are of great interest to scientists. So, while satellite measurements are now indispensible in oceanography, they are not sufficient on their own.

[17] Al Pluedemann, personal communication, 22 April 2014.

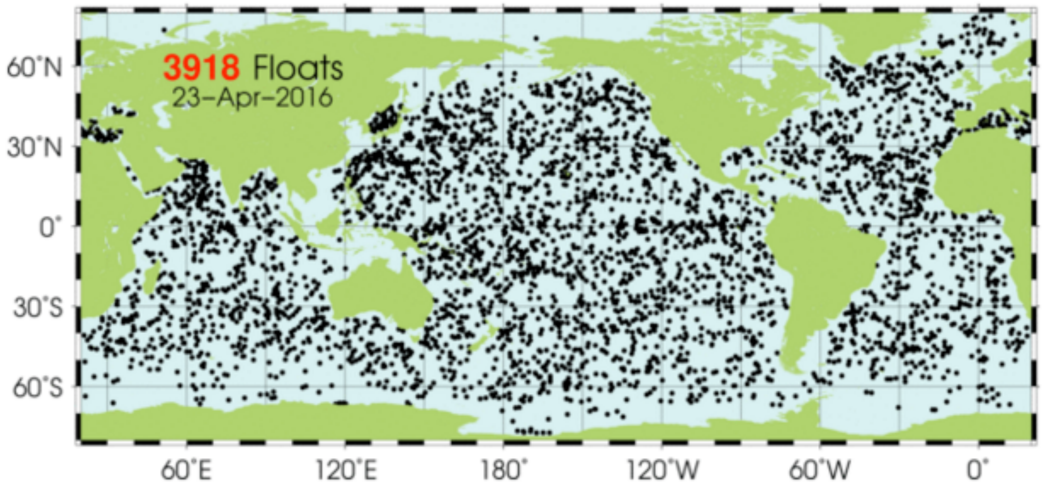

Fig. 5.3: Global distribution of Argo floats at time of writing.
(source: www.argo.ucsd.edu)

A second category of alternatives to ship-based measurements is distributed sensing networks. These are not forms of remote sensing as they make *in situ* measurements of ocean properties. Chief among these is Argo, a program of over 3500 drifting floats that measure temperature and salinity in the upper 2000 meters of ocean; the distribution of Argo floats is shown in Fig. 5.3. To do this, they descend using a simple mechanism to a predetermined depth, where they drift for a prescribed number of days (usually ten). As they rise to the surface, they make a temperature and salinity profile and then communicate this data, along with their position, to satellites. Argo operates in a liminal space between objective-driven research oceanography and the long-term monitoring aims of operational science. With a large number of floats and new ice-sensing technology, Argo has been able to achieve near- global coverage, making it a proxy for satellite coverage under the ocean. New developments are underway to extend these capacities to the deep seas (Deep Argo) and to include biological and geochemical sensors (Bio Argo). Argo data is automatically reported via satellite and made available for free to online users in two forms: uncorrected real time data, and quality-controlled delayed mode. Human labor is necessary at a few steps in the process: deploying the floats, which is usually done from a research, commercial, or sometimes sport vessel; quality control, which takes an international team of data experts; and in analysis and processing for various outputs, including models. But the floats themselves (shown in Fig. 5.4) lead lives that are mostly their own; unlike most other oceanographic equipment, they are not designed to be retrieved once they are deployed. For the standard Argo floats, it is not cost effective to find and fix broken floats, and even at the end of their lives (on average five to eight years) there is no recovery plan.

Fig. 5.4: Argo float being deployed. (source: www.argo.ucsd.edu)

The third kind of sensors is remotely operated vehicles, or ROVs, another form of *in situ* sensing with different scales and purposes than distributed sensing networks. ROVs are generally ‘driven’ by a human operator, and have a much higher cost than Argo’s drifting floats, although some generate their own power by harnessing the energy of ocean waves. Rather than aiming for large-scale coverage, they are usually used exclusively by researchers, and on shorter spatial and temporal scales to understand smaller-scale processes and the intricacies of fluid dynamics that can shed light on larger-scale processes or dynamics in other locations. ROVs, then, can be understood as types of undersea drones. There are many designs of ROVs; Fig. 5.5 shows one.

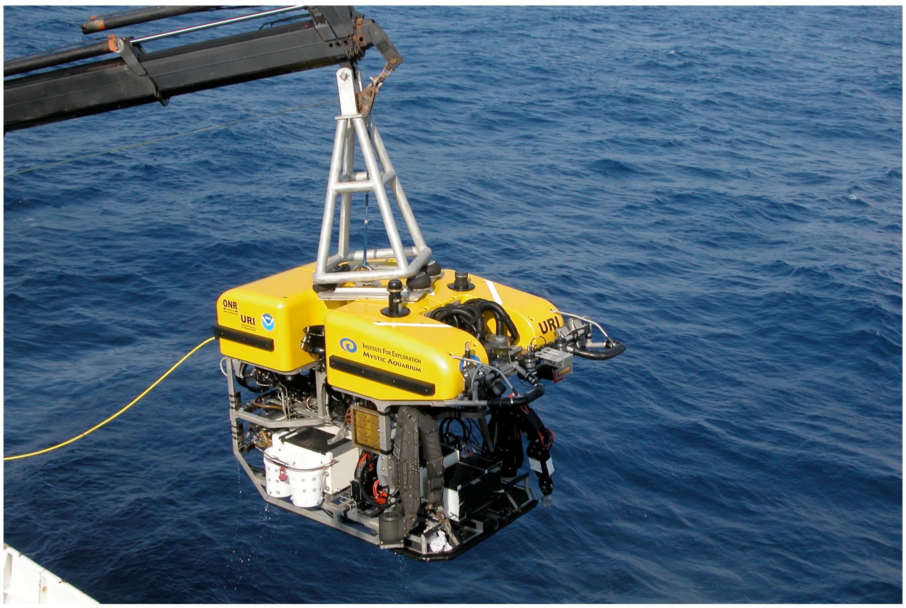

Fig. 5.5: An example of an ROV. (source: wiki images)

Of course, oceanographers do still engage with the ocean, and undertake ship-based research; those with whom I spoke were always quick to assert that this practice, at least at this time, is still necessary to the integrity of their science. Yet many of them feel that ship-based oceanography will be reduced even further, replaced by satellites and networked, robotic, and remotely operated sensors. As one scientist said,

> "The idea is that instead of a ship going out there to make a measurement, or a ship going out there to replace a piece of instrumentation, maybe you're going to have a robotic vehicle that does that. That's important and it's all part, but what it is, is more like the cable TV truck, or, you're maintaining a network, right, you're deploying sensors and you're maintaining these things and it's sort of the sensing

> and network and communications that's really making the discoveries, and part of what we're doing is basically just enabling that to be successful."[18]

A South African scientist corroborated: "I think the push now is to go into this sort of robotic state."[19]

Bemoaning the shift away from ship-based oceanography

Research at sea constitutes a special space for oceanographers. It facilitates single-minded obsession, as not only are there few distractions, but also collecting and processing samples and participating in round-the-clock watches require near constant attention during waking hours. As one oceanographer put it to me: "It's just being away from it all that makes it, it's a different life. I mean it does become sort of a bit repetitive. But I, I don't know, it's just being at sea and having hands on experience, and seeing your data come up."[20]

While the ship certainly has a carefully maintained order, it is also a place where hierarchies, such as those between professor and student, are frequently relaxed in the face of common goals and shared experiences isolated from normal institutional structures. Stommel's analysis is illustrative:

> "Let me contrast the life of a professor at an important university to that of a scientist at sea. Each professor is an individualist, bent on carving out a specialty, a special place for himself in his discipline. He is a little king with a coterie of students and laboratory assistants. He is very much on his own, and takes all the credit he can. We are all familiar with the type. It is common in the business world. […] The competition is polite but cut-throat. The dormitory towns where their families are house[d] are sterile. The social life is shallow – of the cocktail party variety. Each man is cultivating his own garden.
>
> Life on board ship is different. The technical jobs that need to be done are joint tasks. One grows to respect the homely knowledge of the bosun, the quiet

[18] Andy Bowen, personal communication, 23 April 2014.
[19] Isabelle Ansorge, personal communication, 18 November 2014
[20] Isabelle Ansorge, personal communication, 18 November 2014

> skill of the captain. It is an enlarged family. Cooperation, working together under sometimes difficult circumstances is the rule. Tasks are undertaken with deliberation. The sea, and not ones fellow man, is the enemy."[21]

Furthermore, most of the oceanographers with whom I spoke, and whose accounts I read, got into oceanography because they love the ocean. From Stommel, considered the founder of oceanography, to the young graduate students who I met in each institute I visited, they are surfers, fishers, and sailors. They are lovers of marine life, even if most of their days are occupied with numerical models. They are fascinated with the ocean and the mysteries it hosts, prone to statements such as this:

> "I mean, I chose oceanography because I wanted to go to sea. So if we start seeing a shift in that I think...I'm not attracted to running models, or just doing number crunching. I go to sea, collect data so I have an ownership of what I've done and an experience of what I've done and then I put that into my research. And if I was, if you were to remove that, oceanography wouldn't be sexy for me, it wouldn't be fascinating."[22]

Beyond personal proclivities, without the shared experience of going to sea, oceanography as a discipline might face an identity crisis. In 1980, prominent South African oceanographer published an essay called "oceanography is what oceanographers do!" If this is true, then oceanography, nominally defined by material engagement with the sea, may be becoming indistinct from information sciences such as data processing and computer science. Oceanography's disciplinary cohesion is already fragile, as it is a relatively young science and moreover one composed of many different methods and foci borrowed from other disciplines such as biology, chemistry, and physics. With the turn to remote and robotic sensing, oceanography's unifying features may be lost. As Helmreich writes, oceanographic cruises are about not simply gathering information, but making

[21] Stommel & Stommel, Sea of the Beholder, 6-11.
[22] Isabelle Ansorge, personal communication, 18 November 2014.

meaning: "oceanographic discovery is about *human* encounter with the sea" [emphasis in original].[23] This is a view echoed, even perhaps amplified, in the sciences. For example, one Earth observations specialist told me he wasn't really sure what oceanography was, saying that any problem he could imagine oceanographers currently puzzling seemed like a data management problem to him. This wasn't just an outside perspective. One oceanographer put it this way: "Oceanography is not a science. It's a place where you do whatever you do."[24]

Of course, as suggested above, scientists themselves express some ambivalences about the shift away from ship-based research and toward satellite, robotic, and remotely-operated sensing. Many of the same scientists who work on cutting-edge iterations of these technologies and express much excitement about their potentials also bemoan reduction in ocean-going capacity and loss of ship time for scientists. They also widely agree that ship-based measurements will never be phased out entirely, as they are needed to calibrate instruments, a process that deserves its own analysis when it comes to making truth claims. Yet as the opening anecdote in this chapter illustrates, the oceanographers with whom I spoke often talked nostalgically about a bygone or rapidly waning era of ship-based oceanography.

Oceanographers' reluctance to depart from ship-based research resonates with some frequent critiques made in different branches of human geography in the last several decades. In short, sensing through remote or robotic means can be seen as a form of abstraction in two related ways. First, the turn away from ship-based oceanography

[23] Helmreich, Intimate Sensing, 133.
[24] Russ Davis, personal communication, 13 April 2016.

can be seen as abstracting the ocean from the daily lives of oceanographers. Second, it can be seen as essential for the production of representational abstractions of the ocean in digital forms, both models used by scientists and data visualizations such as Google Earth/Google Ocean, which circulate in a broader media ecology. In other words, remote and robotic sensors might be understood as key players in the reduction of the ocean's complexity and the vastly different embodied experiences of interacting with it to data that give the illusion of unbiased and objective fact.[25] Scholars have made a related argument when critiquing digital representations of the ocean, to which these kinds of measurements are crucial, and with which they may be understood as conceptually aligned. For example, Jue argues that such representations seek to "seamlessly link the real ocean with its digital replica," treating the ocean not simply as a potential source of data, but as data itself.[26] She argues that this consideration of the ocean as data privileges the satellite's view of the world given in Google Ocean, which also lends itself to notions of disembodied observation, mastery and control. Such views take the ocean as a kind of spatial container and seawater as transparent, not only ignoring the physical capacity of seawater to chemically transform matter, but also providing the prerequisite imaginary for imperial expansion. Helmreich makes a slightly different argument, asserting that data-driven representations such as Google Earth, while the latest iteration of scientific attempts to make the ocean visible/transparent, tend away from the photographic and

[25] McCormack, D. (2012). Geography and abstraction: Towards an affirmative critique. *Progress in Human Geography*, *36*(6), 715-734.
[26] Jue, Proteus and the Digital, 252.

toward a “mottled mash” of representational layers.[27] This allows Google Earth both to provide a unifying view, as in ‘whole earth’ representations, and to exhibit rhizomatic qualities, multiplying perspectives and possibilities, even as it “floats in a media ecology that tends to occlude its infrastructural history and conditions of possibility.”[28]

For both these authors, then, there is a tendency in digital representations of the ocean to create a distancing effect from the materiality of the ocean and the realities and diversity of embodied encounters with it. Not only are the massive amounts of data collected by satellite and robotic sensors necessary for such representations, there is also a qualitative resonance with these data collection methods as well. It is easy to see how such representations would emerge from scientific practices that deal with streams of numbers rather than the sea itself.

Just as Google Ocean and similar data visualizations lend themselves to notions of a distanced, transparent, and manipulable ocean, collecting data using remote and robotic sensors might be seen as a withdrawal from the materiality of the sea, leading to its reduction to streams of data, paradigmatic and problematic characteristics of abstraction against which geographers and others have railed.[29] If the quantification of the ocean in global oceanography is the first step in denying diverse embodied entanglements with the ocean’s materiality and instituting a system of gridding, territorialization, and the illusion of equal exchange, then surely the shift to remote and robotic sensing takes these processes further, removing the daily reminders of human fallibility and scientific

[27] Helmreich, From Spaceship Earth to Google Ocean, 1211.
[28] Ibid.
[29] See for a review McCormack, Geography and Abstraction.

uncertainty offered by life at sea. Remote sensing, measurement, and quantification lead to the illusion of not only complete knowledge but also disembodied objectivity. The argument follows that measuring and quantifying nature makes it more 'visible' to capital and biopolitical government.[30] It elides uncertainty and unknowability, not only reducing uncanny qualities but doing so in a way that makes nature less 'natural,' i.e. available for capture by capital and government. It is much easier for scientists to produce the illusion of an impersonal view in order to convincingly posit objectivity when machines are in fact making the measurements.

(Re)considering abstraction

There is no doubt that abstractions are at the heart of capitalist and imperial logics, as well as implicit in the domination of nonhuman nature, and that they thereby have the capacity to catalyze great violence.[31] Yet abstractions are also necessary; if it is possible to conceptualize something like global climate change without them, then I am not sure how. Moreover, some critical scholars have begun to call for a more careful approach, even an affirmative critique, to abstractions and the processes from which they result.[32] The purpose of such a critique, as McCormack points out, is not to separate 'good' abstractions from bad. Rather, the objective is to understand how abstractions happen and what they do; "the multiple ways in which abstraction participates both in the worlds we

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[30] See for example Demeritt, D. (2001). Scientific forest conservation and the statistical picturing of nature's limits in the Progressive-era United States. *Environment and Planning D: Society and Space*, *19*(4), 431-459; Robertson, M. (2006). The nature that capital can see: science, state, and market in the commodification of ecosystem services. *Environment and Planning D: Society and Space*, *24*(3), 367-387.
[31] Loftus, A. (2015). Violent geographical abstractions. *Environment and Planning D: Society and Space*, *33*(2), 366-381.
[32] McCormack, Geography and Abstraction.

inhabit and in our efforts to make sense of them."[33] Rather than being set against abstraction, we must pursue our analyses with the perspective that "the question of how abstraction works and comes to make a difference remains an open one."[34]

This is the question that I take up here with regard to ocean abstractions carried out by remote and robotic sensors. First, as already suggested, we must realize that arguments against abstraction in this case begin to break down even in the dichotomy between ship-based and other forms of sensing. In ship-based oceanography, scientists were also quantifying the ocean, distilling its properties, and trying to create the sense of producing unbiased data, even if they themselves both enjoyed and endured sustained engagement with their object of study, thus putting embodied encounter more squarely in the center of oceanographic meaning-making. Furthermore, abstractions are necessary for making meaning of the ocean. Stommel's words, written before the widespread use of computer models, provide an illustration in his writing on the mind's eye, or the "sea of the beholder." Contrasting imaginaries of the ocean with various views of from aboard ships or on coasts, he writes:

> "By tricks of image-processing, masking and referencing – above all by focusing, it can form pictures of the ocean that the optical eye itself can never see. These strange pictures are in the eye of the beholder and are sometimes closer representations of the ocean than what we can hope to perceive from the bridge of little vessel plodding over the top surface of a dark, invisible, three-mile deep mass of water below. Our physical eyes do not see the system of great currents that make up the ocean circulation on a grand scale. Even the wide perspective of the artificial satellite does not encompass these depths."[35]

[33] Ibid., 716.
[34] Ibid.
[35] Stommel & Stommel, Sea of the Beholder, 8.

Carrying Stommel's words into the present, we might note that while the data and digital representations emanating from robotic and remote sensors may "tend to occlude its infrastructural history and conditions of possibility," to recall Helmreich's words, they, along with their accompanying algorithms, also make perceptible patterns and phenomena that would otherwise be incomprehensible.[36] Thus these technologies can be understood to extend and multiply embodied relations, even if they remove human oceanographers from the ship.

Furthermore, as I will discuss below, designing and operating robotic and remote sensors involves material relations with the sea, even if they are not from aboard a ship, or directly embodied by oceanographers. Even if we take these sensors as the conditions of possibility for the construction of abstract models and digital representations of the ocean, we can see this labor as also embodied, of course, as it is carried out by humans who cannot escape their bodies. Even though modelers and data processors usually do not have sustained embodied encounter with the ocean as part of their profession, such activities do not exist in some realm separate from lived experience. Finally, ship-based and remote and robotic sensing depend on one another in order to make the abstractions that give us the idea of a world ocean. Rather than opposed to one another, it is possible to see them as different parts of the same system.

But, if we do concede that there is a marked difference between ship-based oceanography and research done by remote and robotic sensors, then we must ask how this difference matters. While oceanographers bemoan the reduction in ship-based

[36] Helmreich, From Spaceship Earth to Google Ocean, 1211.

oceanography and critical scholars critique the disembodied view created by satellites and robotic sensors, it is worth noting that ship-based oceanography itself has problematic legacies and plays on troublesome tropes. Research vessels are very expensive, especially those with the capacity to venture beyond coastal seas on longer expeditions. A day at sea on a US global-class research vessel can cost $20,000, not including the cost of salaries for any scientists on board. Therefore, it has been mostly white men from elite universities in the global North (and, increasingly, the BRIC countries) that are able to take to the seas in pursuit of science. Thus, as I discussed in Chapter Two, ship-based oceanography has participated in legacies of imperial expansion across the seas. This is more than coincidental; exploring the seas for territorial control easily shifted to exploring the seas for science in the rhetoric of these nations. Military and economic goals have been thinly veiled in these scientific ventures, as discussed in previous chapters of this dissertation.

Robotic and remote sensors do not escape from this legacy: in fact, far from it. For example, the US Navy is perhaps the most significant funder and user of Argo data.[37] They are interested in the changing structure of the sea in areas where they have marine interests, not just off the US coast but also, for example, in the South China Sea, and Argo readily provides that data. But, the life-worlds of the oceanographers involved are now relatively different. Rather than bonds formed in the homosocial spaces of the seafaring research vessel, scientific community is increasingly based on attending workshops, co-habiting robotics labs, and communicating electronically. While we might

[37] This was verified by a number of scientists with whom I spoke.

imagine scientists alone, in front of the computer, downloading data and monitoring robots, this kind of science in fact requires much human and machine interaction, and an intimate knowledge of the ocean's material properties. While Jue urges producers and consumers of digital ocean representations to be more cognizant of seawater's transformative properties, I can think of perhaps no one who understands these better than scientists and technicians who design and implement ocean robotics. The ocean is a very difficult environment in which to deploy and maintain robotics, or any kind of machinery for that matter. This is especially true when it comes to designing instruments that do not need to be recovered for repairs and calibrations. The ocean subjects instruments to immense pressures, extreme temperatures, and various forms of chemical assault. Furthermore, *in situ* sensors are affected by marine life as well, though it is not usually sharks snacking on profiling floats. Rather, mollusks and, even more frequently, marine microorganisms colonize any surface of an instrument that operates in the upper reaches of the ocean, where light can reach.[38] This presents significant problems for sensing technologies; for example, it causes inaccuracies over time in Argo's salinity sensors, requiring the data to be corrected using ship-based measurements and laboratory-prepared standards. As these examples show, the materiality of the sea is far from absent in remote and robotic sensing. Even if these factors do not appear in the representations of the ocean given by visualizations such as Google Earth, scientists are the first to recognize that they are very significant in creating these images. A reduction in ship-

[38] Roemmich, D., Boebel, O., Desaubies, Y., Freeland, H., Kim, K., King, B., Le Traon, P.Y., Molinari, R., Owens, B.W., Riser, S. and Send, U. (2001). Argo: The global array of profiling floats. In Koblinsky, C.J. and Smith, N.R. (eds). *Observing the Oceans in the 21st Century: A Strategy for Global Ocean Observations.* CSIRO Publishing, 248-257.

based oceanography does not mean, then, a wholesale withdrawal from the ocean's materiality; it may mean contending with it in other ways, not as a solitary explorer but in concert with many other machines, humans, and nonhumans.

It is not through just material wear and tear on robotics, nor biological interference, that that the materiality of the ocean asserts itself to today's oceanographers. It is also a matter of communicating with the robots. As one scientist put it,

> "the ocean is just so different in terms of supporting many of the ways in which we […] think of communicating and building our technologies, it's you know, there's not only tremendous pressures and cold temperatures but there's really importantly no way for us to talk to our sensing network, or talk to our robots, right, except when they come to the surface, or through very imperfect and difficult to deploy means of communication. [There's] no GPS underwater, so you know where nothing is."[39]

Moreover, Stephan Helmreich has argued that even though humans using new sensors may not be physically entering into or onto the ocean, many scientists who use remotely operated vehicles "feel a direct body-to-body connection with these objects." This leads him to argue that they are not so much technologies of remote sensing but of "intimate sensing."[40] Rather than being abstracted from nature, such technologies build on notions of "the union of self and sea as one of the most privileged ways to appreciate nature."[41] At the same time, he argues, such technologies give the impression that immediate and unbiased views of the sea are possible. There is a difference between the remotely operated deep sea vehicles that Helmreich discusses, and the physical oceanographic sensors I am discussing here, as the latter are not precisely aimed at directly extending

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[39] Andy Bowen, personal communication, 23 April 2014.
[40] Helmreich, Intimate Sensing.
[41] Ibid, 141.

vision to the sea. They do further goals to metaphorically or literally ‘see what’s happening’ in the sea, but information, or numerical data, is the first goal. Nonetheless, parallels can be drawn between human and machine sensing, even with distributed networks of sensors like Argo. Here is how one scientist described it:

> “’Human’ can be a network of neurons, right? And those are incredibly simple distributed systems. That’s human. And you know in a certain sense that kind of sensing network, which could be taste buds on a tongue or nerves on a fingertip, I mean those can be human and they can be incredibly powerful concepts in terms of sensing the ocean environment. So, what is, you know, I think that because the ocean is so vast and because it sort of, it basically is just vast, the challenges that come up with streamlined lower cost solutions that give this sort of wide-area view of the ocean and through that you get many different sort of senses of scale. So you know, maybe to use the nerves on your fingers as an analogy, an individual nerve can feel one thing, but it’s not until you sort of map them together that you make more interpretive and important discoveries let’s say, right?”[42]

Furthermore, the ability of remote and robotic vehicles to allow people to sense the sea within the intimate spaces of their home offices inaugurates, for Helmreich, “a new order of intimate sensing.”[43]

The turn to robotics has also perhaps opened new spaces for interdisciplinary cross-fertilization. While scientists from different disciplines sometimes share space aboard research vessels, it is more often the case that ship time is dedicated to one specific project at a time. But in the development of new sensing technologies that put biological and geochemical sensors on the same floats or vehicles, biological, chemical, and physical oceanographers, along with engineering experts, are collaborating on similar questions. For example, Bio Argo brings together biological oceanographers and Argo’s original development team of physical oceanographers and marine engineers; moreover,

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[42] Bowen, personal communication.
[43] Helmreich, Intimate Sensing, 149.

some of these scientists are not only collaborating with those from other disciplines but are asking transdisciplinary questions of their own regarding the interaction of biological and physical features.

If the development of satellite, robotic, and remote sensing has potentially opened space for more science from underfunded institutions, there is also something to be said about inclusion and exclusion of women scientists. As Oreskes writes, women have long been present in oceanography, but they have been relegated to under-celebrated roles as data processors and administrative assistants. This is not because they were seen as not capable of objective analysis, but because the role of the heroic scientist was claimed by the adventuring, pioneering, sea-going man.[44] Moreover, women were historically not permitted to undertake oceanographic voyages in many countries. [45] Elizabeth Stommel describes the gender dynamics of Woods Hole Oceanographic Institute in the 1940s and 50s in straightforward terms: “Women, working as laboratory assistants or secretaries, didn’t go to sea because they weren’t allowed. Living conditions on shipboard were said to be too primitive to accommodate both sexes.”[46] Her husband, Henry Stommel recounts an incident involving a female scientist who attempted to join a coastal cruise in 1956:

> “Roberta Eika, a Harvard student, had to hide herself in the bilges of the *Caryn* in order to go on a three day cruise. After a day and night lying on the lead-pig ballast, when she emerged as the first woman stowaway, her faculty advisor […]

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[44] Oreskes, N. (1996). Objectivity or heroism? On the invisibility of women in science. *Osiris*, *11*, 87-113; Oreskes, N. (2000). " Laissez-tomber": Military Patronage and Women's Work in Mid-20th-Century Oceanography. *Historical studies in the physical and biological sciences*, *30*(2), 373-392.

[45] It is worth noting that this was not the case in the USSR, and when these ships made rare visits to the U.S., the presence of female scientists aboard Soviet research vessels was among the most noteworthy elements to Americans.

[46] Stommel & Stommel, Sea of the Beholder, 20-4.

> nearly cancelled her fellowship, and the episode was regarded as a scandal. There was a strong current of disapproval, especially amongst that portion of our crews who counted the absence of females as one of the felicities of life at sea."[47]

The first woman to participate in an American extended oceanographic cruse was Helen Hill Raitt, who joined the Capricorn Expedition in 1952-53. While this seems historically close to what I have identified as the birth of modern oceanography, we must remember that men had established the discipline on extensive Navy-funded cruises during the World Wars. Furthermore, while Raitt did conduct research on "Problems of the Underwater Swimmer in the South Pacific" for the National Research Council, she joined the cruise because her husband, Russell Raitt, was a geophysicist on the Capricorn Expedition. Her participation in oceanographic work on the cruise is described as such: "she kept the log, stood watches, typed reports, took dictation for Dr. Revelle, and assisted with oceanographic work."[48] Nearly all of the archival photos of Raitt on the cruise show her doing clerical work (see Fig. 5.6).

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[47] Stommel & Stommel, Sea of the Beholder, 6-26.

[48] Helen Hill Raitt Biography, http://scilib.ucsd.edu/sio/biogr/Raitt_Helen_Biogr.pdf

Fig. 5.6: Helen Hill Raitt doing clerical work on the *Spencer W. Baird* during the Capricorn Expedition. (source: UCSD digital archives)

Largely because going to sea was seen as necessary for doing oceanographic research, and women had very circumscribed roles at sea, oceanography at mid-century and beyond was a very male-dominated discipline. As Elizabeth Stommel wrote, "The only excitement I could see in this [oceanography] was the business of going to sea, and there was no room for women on oceanographic ships. It was clearly a profession for men only."[49] Circumstances have certainly improved for women, and although they remain under-represented in the field, a recent study found that "women in oceanography are better represented at all ranks, except department head, than the geosciences as a whole."[50] Yet women still face challenges in doing ship-based research. One oceanographer, herself an accomplished female scientist committed to training students at sea, when asked who succeeds in ship-based work answered thus:

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[49] Stommel & Stommel, Sea of the Beholder, 20-4.

[50] O'Connell, S. & Holmes, M. A. (2005). Women of the Academy and the Sea. *Oceanography 18*(1), 21.

> "If I look at the female students [who show aptitude for ship-based work] it's the ones that are more like tomboyish. And the guys that like it are the ones that are interested in technology, and curious about how things are collected. So you know, more technically driven. […] You know for girls it's a male-dominated environment so you've got to be quite tough. I think you've got to be quite tomboyish, you've got to be able to cope being in a basic mix of men, and not be shy of that. You know a lot of girls are, a little bit nervous, and I feel they wouldn't necessarily cope. Yeah guys, just technology, the interest, you know."[51]

In this response, we can see that ship-based oceanography can still be very much a man's world. Moreover, in reading technoscience, Haraway reminds us to be attentive not just to science-in-the-making but also gender-in-the-making.[52] Here we can see that to be a woman is still to be defined by gender expression and personality traits rather than skills and interests.

In addition to being excluded or undervalued in the discipline of oceanography, the social reproduction necessary for scientists to be away at sea for extended periods has fallen largely to women. This is not just a question of 'who will raise the kids?' but of what it takes to maintain a life that can be easily dropped off at the dock and then picked up again on return. Again, Elizabeth Stommel's reflections are illuminating. She writes, "Many of my limitations and all of my opportunities were defined or created by Henry's needs."[53] She mentions frequently the loneliness and hard work she endured when he enjoyed what he calls "large tastes of salt water."[54] Most plainly, she states, "Henry returned home invigorated and renewed by his adventures; I felt emotionally exhausted

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[51] Ansorge, personal communication.
[52] Haraway, D. (2003). *The Haraway Reader*. New York: Routledge.
[53] Stommel & Stommel, Sea of the Beholder, 20-2.
[54] Stommel & Stommel, Sea of the Beholder, 6-20.

by double parental and household duties."[55] Of her frustrations, she writes, "I don't know whether to blame him or the science of oceanography."[56]

All of this is not to say that we should embrace robotic and remote oceanographic sensing because women are incapable of ship-based work. This is obviously not the case, and the struggles of women who want to do research at sea should be validated and supported. Rather, this shift might help in creating a disciplinary culture that turns away from gendered notions of scientific heroism. It is not only aspiring female scientists who stand to benefit from more equitable (and realistic) notions of how scientific progress happens; it is all who are relegated to the more seemingly mundane tasks that are necessary for scientific advancement, including the work of social reproduction.

Conclusion

In this chapter, I have advocated for a careful consideration of the linked affective and political dimensions of a shift from ship-based to robotic and remote sensing. While it may be easy for theorists to decry this shift as a move toward the abstraction of scientists from the medium they study and consequently the production of abstract representations of the ocean, I suggest that declaration may be too hasty. Not only does drawing such a binary miss key ambiguities regarding the significance and problematics of abstraction, but it also ignores the alternate relations that may be propagated by this shift. My purpose here is not to argue that remote and robotic technologies are inherently more emancipatory than ship-based sensing. It is simply to ask critical scholars, and perhaps oceanographers, to pause before making the converse assumption. After all,

[55] Ibid. 20-17.
[56] Ibid., 20-9.

oceanography is under greater threat from conservative politicians than computers. The question of what is to be done, then, remains a tricky one. What is the ethical position to take? Should we work to valorize the frequently unseen labor of data entry, computing, and modeling (or wait for this to naturally occur as ship-based oceanography becomes more rare)? Or should we advocate for more women, minorities, and other less privileged people to have the chance to go to sea? I am not in a position to answer this question, but we may start by pointing out this is not a dilemma that faces white men.

CONCLUSION: THE OCEAN AS PLANETARY ARCHIVE

My project in this dissertation has been to undertake a diffractive reading of global technoscience in the making of the world ocean. This has entailed reading international oceanographic projects differently; not as distant from politics, imposing a god's eye view of nature, steamrolling over uncertainties and human differences in the interest of a universal nature, but as producing and produced by difference at every step. I read difference and alterity, potential and unknowability, as forces shared across human and nonhuman bodies, matter, and forces.

Part of this work has been explanatory. How have we come to know the ocean as one dynamic entity, rather than as composed simply of the parts we can experience with our own bodies and minimal technological intervention? How do we know when or if the ocean, as one entity, is changing? How do we measure something that is defined by motion, that has ambiguous legal status, and that is largely inhospitable to our technologies, bodies, and ways of knowing? How do these efforts create new encounters, shake up or extend old political formations, and herald new relations between nature, technology, and government? Despite the recent interest in ocean space in geography and cognate disciplines, the materiality of the ocean is frequently taken for granted, and questions of how we arrive at these understandings are rarely asked. Not only does this leave some fundamental assumptions unquestioned, but it also ignores the worlds that are made through attempts to know the ocean.

But an explanatory analysis is not enough. A diffractive reading aims for the creation of "interference patterns" between different ways of knowing such that more emancipatory knowledge practices might be enacted.[1] So here, in the conclusion to the dissertation, rather than engaging in a straightforward summary of the arguments within, I want to offer an experimental concept that has emerged through my diffractive investigations. This is the concept of the ocean archive. In part, I was compelled by my own initial forays into traditional archives in different locations. Deciphering what materials were stored, how they were organized, and how access was regulated compelled me to think about the making of history in new ways. But I was also inspired by the words of several of the oceanographers with whom I spoke, who emphasized the ocean's role in recording at once planetary and human history, albeit in ways that are frequently quite unlike our conventional understandings of how history is written and recalled. The words of these geoscientists had strange resonance with what I was reading in postcolonial theory, as well as new materialist writing on the agency of matter to shape knowledge. The ocean archive is my attempt to build on these resonances for an affirmative critique of transdisciplinary oceanic thought.

Anthropocene history

The advent of the Anthropocene, and the realization that humanity as a species is a geologic agent, prompts us to rethink the relationship between human history and natural history; to dismantle this distinction and begin to think of planetary history, and

[1] Haraway, D. J. (2004). *The Donna Haraway Reader*. New York: Routledge,

planetary futures.[2] We are compelled to grapple with nature and with history on a planetary scale, while at the same time resisting massifying universals. We are asked to think about totality rather than universalism, planetarity rather than globalism. To think of the Earth as not flat but full, to think not of generalizations that can be applied anywhere but rather relations that reach everywhere. Maybe in fact, some have suggested, 'Anthropocene' is a new word for relation, "the overstepping that grounds [our] unity-diversity."[3]

The ocean archive concept is a possible response to Dipesh Chakrabarty's fundamental question, "How does the crisis of climate change appeal to our sense of human universals while challenging at the same time our capacity for historical understanding?"[4] First, I explore some ways in which conventional understandings of history are challenged by the current conjuncture, and the opportunities that these challenges reveal. I situate the changing attitudes toward the sea that I have discussed throughout this dissertation within these problematics that the Anthropocene presents, with special attention to the ways in which historians and other cultural theorists have focused on the ocean to assert alternative narratives of capitalist globalization. Working from this context, and resonant discoveries in oceanographic science, I propose the notion of the ocean as a planetary archive, following Gayatri Spivak's theorization of planetarity that I have worked with throughout this project.[5] I forward the concept of the ocean as a

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[2] Chakrabarty, D. (2009). The climate of history: Four theses. *Critical Inquiry*,*35*(2), 197-222.
[3] Glissant, E. (1997). *Poetics of relation*. Ann Arbor, MI: University of Michigan Press.
[4] Chakrabarty, The Climate of History, 201.
[5] Spivak, G. C. (2003). *Death of a discipline*. New York: Columbia University Press.

planetary archive in two related senses: one, as an already-existing yet ever-changing material archive of that which has been jettisoned, lost, or absorbed throughout planetary natural history, and two, as a way of thinking about what it means to write history (and read technoscience) such that we might be compelled to more ethical planetary relations. In the second section, I describe some characteristics of the ocean archive. Then, I provide some conjectures on how the ocean archive might be read, and by whom. Ultimately, I suggest that the ocean archive can provide a critical practice of planetarity: an opening for thinking politics on a planetary scale in a way that does not erase relations of difference that have structured world history.

It is clear that our conventional methods of making history are likely to find their end in the Anthropocene. History has been concerned with understanding human experience, but now it must grapple with species existence: something that we can never directly experience.[6] This new reckoning poses a groundbreaking challenge to our historical methods, not least the archive. The role of the traditional archive is to stop and isolate history; to periodize, to make index-able, to put history in a building and control who accesses it, to catalogue completely collective and individual experience. The conventional archive makes the past an object of governance in the present. This relationship is simply untenable in the Anthropocene, when we are increasingly realizing that it is impossible to stop or cordon off history, when we are already living in the

[6] Chakrabarty, The Climate of History.

aftermath of the event.[7] We are increasingly aware that we are making geologic history, all the time, with every exhalation and trip to the grocery store; we are acting into history as we once acted into nature.[8] And we are realizing that there are no clear lines between documenting the past and governing the future, from neither hegemonic nor emancipatory positions; crises of climate, energy, and capitalism call our contemporary modes of governance into question. As Chakrabarty writes, "what scientists have said about climate change challenges not only the ideas about the human that usually sustain the discipline of history but also the analytic strategies that postcolonial and postimperial historians have deployed in the last two decades in response to the postwar scenario of decolonization and globalization."[9]

Crises of capital, energy, and environment, when framed in terms of salient injustices, also point to the necessary exclusions that have made their progression possible. We are also increasingly compelled to consider what was elided in the making of dominant historical narratives, how those very exclusions have brought us here, and what must be remembered in order to make a better future possible. These histories are coming to the surface, and they are demanding to be told. No longer can history be posited as a teleological progression toward a modern form of capitalized, digitized connectivity, in which Western (especially North American) ways of knowing and being in the world are taken as universal and ahistorical inevitabilities. This traditional

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[7] Johnson, E., Morehouse, H., Dalby, S., Lehman, J., Nelson, S., Rowan, R., Wakefield, S. & Yusoff, K. (2014). After the Anthropocene: Politics and geographic inquiry for a new epoch. *Progress in Human Geography, 38*(3), 439-456.
[8] Chakrabarty, The Climate of History.
[9] Ibid., 198.

historical narrative suggests that globalization is a relatively new phenomenon that can only take its current, allegedly universal form.[10] It thus elides both uneven lived experiences of globalization, which are now the archetypes of life in the contemporary crises, and denies the possibility of alternative forms of globalization, both past and present. In geographic scholarship (and in other disciplines) a common way to retaliate against this narrative has been to (re)assert the importance of local specificity, and, perhaps with more traction, to show how the global is inevitably constructed through local actions; as Mignolo puts it, how "knowledge and aesthetic norms are not universally established by a transcendent subject but are universally established by historical subjects in diverse cultural centers."[11] Yet these arguments are too quick to cede large-scale thought to dominant narratives, and risk further eliding certain large-scale processes that have been central to world history and that dominate Anthropocene epistemologies. Rather, a more relevant challenge is issued in the question: "If, indeed, globalization and global warming are born of overlapping processes, the question is, How do we bring them together in our understanding of the world?"[12]

At the same time, and in perhaps strange accordance, we are becoming aware that humans are not the only or most significant makers and recorders of history, and that environments have particular and contingent ways of relating to history. A great deal of recent focus has been on how the geosphere, and rock in particular, record human

[10] See for example Abu-Lughod, J. (1989). *Before European Hegemony: The World System A.D. 1250–1350*. Oxford: Oxford University Press; Spivak, Death of a Discipline.
[11] Mignolo, W. (1993). Colonial and Postcolonial Discourse: Cultural Critique or Academic colonialism? *Latin American Research Review, 28*(3), 129.
[12] Chakrabarty, The Climate of History.

activity. But some authors have cautioned that this turn to geology does away too quickly with *geophysics*, that materially-specific combination of matter and force that produce different kinds of earth dynamics in rock, ice, seawater, and gas. Rather than become mired in an obsession with strata, attention to geophysics might attune us to the nonlinear, chaotic dynamics that perhaps better characterize time, life, and matter in the Anthropocene. Peters and Steinberg write that geological conceptualizations of the Anthropocene

> "Are reliant on a linear trajectory of time that stabilises history into material strata and immaterial epochs that can be neatly bordered, bounded, and contained—marking one material layer and social era from another. Implicit in the idea of 'geo' as 'Earth' when periodised through concepts like the Anthropocene is the notion of a solid, grounded, earthly materiality that can be worked on, and with, by humans."[13]

In offering the concept of the ocean archive, I attempt to un-ground Anthropocene concepts of natural and human history and propose an understanding of Earthly relations compelled by the inseparability of human histories and (understandings of) ocean dynamics. I posit this potential understanding of how history is made as a relational offering of a planetary sea.

Oceans of history

Shifts in understandings of the participation of Earth forces in making and recording history are nowhere as obvious as with regard to the sea. For much of Western history, it was widely believed that the ocean was essentially a great void.[14] Waste, whether

[13] Steinberg & Peters, Wet Ontologies, 255.
[14] Alaimo, S. (2013). Violet-black. In Cohen, J. J. (ed.) *Prismatic Ecology: Ecotheory Beyond Green*. Minneapolis, MN: University of Minnesota Press, 233-251; Oreskes, N. (2014). Scaling up Our vision. *Isis*, *105*(2), 379-391; Steinberg, P. E. (2001). *The social construction of the ocean*. Cambridge: Cambridge University Press.

sewage, radioactive byproducts, or corporeal remains could be dumped into the sea, never to be seen again. The ocean was thought to wash humanity clean, and to buffer us from the effects of climatic changes, over-pollution, and nuclear experimentation. But as I discussed earlier, in the last century or so, this view of the ocean has been revealed to be a dangerous illusion.[15] The ocean serves constant reminders that what is put into its waters may sink, but it is likely to circulate and emerge at some difficult-to-predict time and place.

This transformation in common conceptions of the ocean can be linked to several events, perhaps most strikingly to debates around the disposal of nuclear waste in the sea.[16] Altogether, the shift from viewing the ocean as an abyss, apart from culture and politics, or at best an impediment to seamless capitalist globalization, to an understanding of the central role it plays in life on Earth, has been what Naomi Oreskes calls "one of the most important cultural and scientific shifts of the twentieth century," to return to a quote I have cited previously.[17] This shift entails, most fundamentally, the recognition of the mutual constitution of capitalist modernity and the world ocean. Rather than the irrelevant 'blank space on the map,' the sea has come to be known as shaping the form that global capitalism/capitalist globalization has taken; it has constituted its engine and its limits.[18] Antonio Benitez-Rojo is quite plain about it: the Atlantic can only be the

[15] Fajardo, K. (2011). *Filipino crosscurrents: oceanographies of seafaring, masculinities, and globalization*. Minneapolis, MN: University of Minnesota Press.
[16] Hamblin, J. (2008). *Poison in the Well: Radioactive Waste in the Oceans at the Dawn of the Nuclear Age.* New Brunswick, NJ: Rutgers University Press.
[17] Oreskes, Scaling Up Our Vision, 384.
[18] Casarino, C. (2002). *Modernity At Sea: Melville, Marx, Conrad In Crisis*. Minneapolis, MN: University Of Minnesota Press.

Atlantic because of the relationship between Europe and the Caribbean, which involved "inseminating the Caribbean womb with the blood of Africa."[19] Elizabeth Deloughrey argues that it is not only the sea that forms modernity and capitalism, but also that these forces make the sea as we know it.[20] She asserts that while the ocean has been emphasized as a space of mobility, we should also consider its heavier and slower dimensions; the ocean is a receptacle of waste, much of which remains interred there forever. Certainly recent scientific findings on the impacts of climate change in the ocean corroborate this view.

Following new understandings of the sea and the compulsion to rethink the ontologies and epistemologies of history, postcolonial writers have developed an innovative way of relating the sea to the project of alternative histories. The cultural shift in our understanding of the ocean has provided a spatial heuristic for postcolonial and other cultural theorists to contest dominant narratives of capitalist globalization. This has been most evident in the burgeoning subfield of Atlantic Studies, which mainly aims to contend with enduring legacies of the slave trade and resulting diasporas. Atlantic studies uses the Atlantic basin to focus on connections between Africa, Europe, and the Americas, to memorialize and center the Middle Passage, and to theorize the vibrancy, heterogeneity and connectivity of diasporic relations.[21] Similar although less extensive

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[19] Benitez-Rojo, A. (1997). *The Repeating Island: The Caribbean and the Postmodern Perspective*. Durham, NC: Duke University Press Books.
[20] Deloughrey, E. (2010). Heavy Waters: Waste and Atlantic Modernity. *PMLA,* 125(3), 703-712.
[21] Gilroy, P. (1993). *The Black Atlantic: Modernity and Double-Consciousness.* Harvard University Press.

bodies of scholarship have centered on other ocean spatialities, notably the Indian Ocean and Oceania.[22]

As I discussed in Chapter One, these narratives can be considered alternatives to conventional tropes that promote Eurocentrism and give the impression of capitalist globalization's smooth and total ascendancy; moreover they might contain the seeds of capitalist globalization's undoing. Cesare Casarino theorizes this double nature, starting from the position that modernity cannot be understood as a smooth process of global connection and the co-liberation of markets and oppressed people.[23] Rather, for him, modernity (which is coterminous with modern capitalism) is and always has been characterized by crisis. As I described in Chapter One, this crisis, for Casarino, is the problematic of the "synchronicity of the nonsynchronous" (after Bloch) by which he means that modern capitalism finds its conditions of possibility in the "potentially explosive spatial coexistence in the same time period of historically heterogeneous practices and social formations."[24] For Casarino this is especially true in oceanic exchange, where practices of mercantile and industrial capitalism are frequently juxtaposed.

While history, anthropology, cultural studies and other humanistic disciplines began to re-incorporate the ocean into their analyses, science also began to consider the sea anew. During the World Wars, and throughout the Cold War that followed, the ocean

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[22] See for example Hau'Ofa, E. (2008). *We Are the Ocean: Selected Works*. Honolulu: University of Hawaii Press; Ho, E. (2006). *The graves of Tarim: genealogy and mobility across the Indian Ocean*. Berkeley, CA: University of California Press.
[23] Casarino, C. (2002). *Modernity At Sea: Melville, Marx, Conrad In Crisis*. Minneapolis: University Of Minnesota Press.
[24] Ibid, 6.

became a strategic military space, particularly with the rise of submarine warfare. As I mentioned elsewhere, the imperative for basic knowledge about the ocean as a singular entity led to the rapid development of the oceanographic sciences, especially physical oceanography.[25] As I discussed in Chapter Three, in the 1970s and 1980s, satellites, computer modeling, and communication technologies provided not only new optics but also the ability to create more complete pictures of ocean circulation, air-sea fluxes, and other ocean properties than ever before, and to store and share this data.[26] Yet throughout this time the ocean continued to surprise scientists with its influence and ability to threaten the conditions for life on Earth. Hopes of a 'final solution' for nuclear waste in the sea were dashed when it not only resurfaced in distinct locations but could be detected throughout the seas.[27] The collapse of various regional fisheries quelled dreams of feeding growing populations with marine protein. And the immense and volatile role of the ocean in the global climate became more and more apparent, such that the ocean has become the "800 pound gorilla in the room" when it comes to climate change predictions. [28]

At the juncture of new technology and funding for oceanography and increased realization of the importance of the sea, scientists began to make concerted efforts to study the sea in the context of world history, paying attention both to 'deep time' and to

[25] Oreskes, N. (2000). " Laissez-tomber": Military patronage and women's work in mid-20th-century oceanography. *Historical studies in the physical and biological sciences*, 373-392; Weir, G. E. (2001). *An Ocean in Common: American Naval Officers, Scientists and the Ocean Environment*. College Station, TX: Texas A&M University Press.
[26] See also Edwards, A Vast Machine.
[27] Hamblin, Poison in the Well.
[28] Robert Weller, personal communication, 24 April 2014.

more immediate human timelines. In Chapter Three, I explained that as scientists came to realize that the ocean was changing, perhaps in unprecedented ways, they were compelled to establish a baseline or average state of the ocean against which to compare temporal and spatial variations.[29] Yet this mean ocean state is incredibly difficult to determine, especially given the shift to more dynamic understandings of ocean circulation mentioned above. Throughout this dissertation I have highlighted the difficulty of making ocean measurements, and explained that their relative scarcity is one major contributing factor. Samples taken on an annual basis cannot capture seasonal variability, whereas samples taken over shorter time scales might miss long-term changes, and might generate too much data for existing computational power to contend with. Furthermore, because of the scarcity of ocean observations, ocean data has frequently been treated as simultaneous even when it was collected over long periods of time. Spatial variability suggests similar problems; sampling practices may likely lead to miscalculations of the impact of eddies and other structures on the scale of hundreds of kilometers that change in force and extent over hours, days, and weeks. In fact, as we learned in Chapter Three, it has been suggested that it is not even possible to conceive of a mean state of ocean circulation.[30]

As I argued in Chapter Three, what was revealed to oceanographers during their efforts to understand the basic characteristics of ocean circulation was the ocean's vast potential for movement and memory; its ability to store and circulate heat, energy,

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[29] Thompson, B.J., Crease, J., & Gould**,** J. The origins, development and conduct of WOCE. In Siedler. G., Church, J., and Gould, J. (eds). *Ocean circulation and climate: observing and modeling the global ocean.* Academic Press, 37.
[30] See for example Wunsch, C. (1992). Decade-to-century changes in the ocean circulation. *Oceanography 5*(2), 99-106.

carbon, and other materials and properties. There are a variety of processes and methods by which scientists make meaning from the ocean's capacities for memory and motion. In addition to the methods I have discussed in previous chapters, oceanographers found a perhaps unexpected aid in attempting to understand the spatial and temporal movement of ocean waters: human historical events that had introduced certain chemical isotopes into the sea. Scientists use certain isotopes to trace the movement of different water parcels. Some of these isotopes are naturally occurring, but many are anthropogenic, such as CFCs and radioisotopes from nuclear testing.[31] These enter the ocean through contact with the atmosphere, and they stay with a particular parcel of water as it travels throughout the ocean, across longitude and latitude and from surface to depth. Hence oceanographers can use these chemical tracers to determine when a water parcel was last at the surface.[32] Oceanographers read this social-natural composition of the sea, its propensity for collecting and storing materials made through human-induced and earthly processes, in order to learn about possible futures, unraveling questions about the ocean's capacity to store carbon, heat and other properties, and the likely time and place of their release.

While historians and cultural theorists have shown that oceanic assemblages are an important part of the narratives elided by dominant discourses of globalization, they often miss key material characteristics of the sea that would take this rethinking of history

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[31] See for example Lindahl, P., Lee, S. H., Worsfold, P., & Keith-Roach, M. (2010). Plutonium Isotopes as Tracers for Ocean Processes: a review. *Marine environmental research*, *69*(2), 73-84.

[32] See for example Broecker, W. S. (1974). *Chemical oceanography*. San Diego: Harcourt Brace Jovanovich.

further.[33] They get mired in a contradiction: on one hand, the ocean suggests different ways of writing history. On the other, it questions write-ability at all, suggesting erasure, circularity, and opacity.[34] But a closer look at the ocean's material properties suggests that this need not be an either/or question, but rather an opportunity to more closely examine what it means to record history. The ocean archive neither offers an alternate history that is readable in conventional terms but nor does it suggest complete erasure. Ocean-enabled counter histories are dependent on the fact that the world ocean is not a self-contained or stable entity, but rather one always in the process of becoming.

The ocean archive

My notion of the ocean archive builds on the transformations in cultural and scientific understandings of the sea detailed above, and makes an effort to think them together, with the aim of advancing planetary thought. In other words, I believe the ocean archive can point us toward thought that is capable of accounting for the uneven and frequently exploitative processes that have made world history, the global methods by which they are known, and the perhaps radically different planetary futures that await. The ocean archive, then, is a planetary archive in the sense proposed by Spivak. Let us recall that Spivak "propose[s] the planet to overwrite the globe."[35] As I discussed in Chapter One (and showed throughout the dissertation), the globe is a concept that lends itself to gridding and other forms of rationalization, while "the planet is in the species of alterity,

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[33] Steinberg, P. (2013). Of other seas: Metaphors and materialities in maritime regions. *Atlantic Studies,* 10(2), 1-15.
[34] Tynan, M. (2010). Polyps, plankton, and passages: Mythopoeic islands and long-memoried seas. *Space and Culture*, *13*(2), 144-153.
[35] Spivak, Death of a Discipline*,* 72.

belonging to another system; and yet we inhabit it, on loan."[36] Spivak therefore puts the human into a curious relationship with global nature that defies modernist order and rationalization: a relationship not of knowledge, domination, or even belonging, but of temporary, corporeal inhabitance. Spivak is careful to explain that the figures of the globe and the planet do not contradict one another, for "alterity remains underived from us; it is not our dialectical negation, it contains us as much as it flings us away."[37] The planet, after Spivak, might be understood as an impossible, undecidable, yet necessary totality.

Spivak argues that planetary thought is predicated on the shift from the canny, or home-like to the uncanny, or unfamiliar. Drawing on psychoanalytic tropes of the female genitalia as the uncanny entrance to the first home for humans, she argues that this shift can also be seen in processes of "colonization, decolonization, and postcoloniality [which] involved special kinds of traffic with people deemed 'other' – the familiarity of a presumed common humanity defamiliarized, as it were."[38] Spivak argues for the Earth as not pre-national, but as a "paranational image that can substitute for international and can perhaps provide, today, a displaced site for the imagination of planetarity."[39] Here the ocean might also be a kind of paranational image, one to which concepts of belonging and history might inhere even as it challenges received notions of a nation-state system.

The accounts above demonstrate how the ocean's unbounded presence in history's necessary alterity makes it an especially apt entity for large-scale counter-hegemonic thought: an avenue for thinking the planetary that cannot be ignored. The

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[36] Ibid.
[37] Ibid., 73.
[38] Ibid., 77.
[39] Ibid., 95.

ocean is a space that humans have inhabited in temporary, corporeal ways throughout history, and these forms of dwelling and movement have lacked essential or transcendent meaning, despite the narratives of cohesion upon which modern global capitalism has depended. Further, to trace the turning of the planet from the canny to the uncanny is to trace the shift of the ocean from the origin of all life, and, in a different valence, the origin of the processes of globalization, to a space, medium, or materiality that is always unknowable and inhospitable, that threatens notions of coherence and practices of rationalization at every turn, even as it becomes present through them. Of course, to make these tracings is not to argue for a pre-capitalist, romantic unity between humans and the sea, but rather to trace the shifting shapes of human-ocean assemblages that have emerged, persisted, and repeated through the various non-teleological and non-linear temporal and spatial dynamics discussed above.

As mentioned above, a close look at ocean histories reveals the sea as an archive of materials for history's alternative potentials, of which dominant narratives require both presence and silence.[40] But the material properties of the global ocean prompt us to go further, to reconsider the relationship between past, present, and future, and how the traces of these relationships are made available to differently-positioned planetary subjects. Far from the pristine blue waters of our new-age old times, the Anthropocene ocean is monstrous in the distinctly temporal sense that Haraway uses the term.[41] The Anthropocene ocean both threatens and promises a different future.

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[40] Benitez-Rojo, The Repeating Island.
[41] Haraway. The Haraway Reader.

For Foucault, archiving functions as a form of administrative work that configures "power, discourse, and the quotidian."[42] In contrast to conventional archives, the ocean archive has no apparatus of bureaucratic labor, and it legitimates no state power. It is actively, always undoing, but never erasing. It gives no illusion of transparency. But like conventional archives, the ocean archive raises questions about what we need to know, how to know it, and who knows it – questions that remain central and powerful to our age. The notion of the ocean archive builds on scholarship that reads even the most traditional archives as unstable and contested collections of "active, generative substances with histories, as documents with itineraries of their own."[43] It also contributes to and imaginatively extends work by natural scientists, archaeologists, and environmental historians who attempt to read 'natural' materials for clues to world history. In a perhaps unexpected way, it furthers attempts to attend more closely to archival labor and to the procedures by which archives are produced and read.[44] In a sense, this is a new way of seeing an already-existing ocean. But it is also to do something, to gesture towards new theoretical and material moves, by asking certain questions of and about the ocean archive.

Characterizing the Ocean Archive

Absences, presences, and opacity

[42] Foucault, M. (2000). *Essential Works of Foucault 1954-1984, Volume 3: Power*. New York: New Press, 166.
[43] Stoler, A. L. (2010). *Along the archival grain: Epistemic anxieties and colonial common sense*. Princeton, NJ: Princeton University Press, 2.
[44] Ibid.

The ocean archive interrogates and challenges capitalist globalization's promissory foundation of seamless global connection and instant presence. The desire for immediate and omnipresent connectivity embodied in globalization's various expressions is so pervasive as to be nearly invisible. Moreover, it is easy to forget that this desire may take on different forms than the modern, capitalist one in which we currently find ourselves. The contemporary discourse of globalization has three main themes, each related to the others: the unfettered rise to dominance of the global capitalist economy; seamless connective networks for the free flow of people, capital, and things; and the viral proliferation of cultural contact and exchange between even the most distant societies. While in reality highly heterogeneous, globalization might be understood as the desire for "the imposition of the same system of exchange everywhere."[45]

The ocean archive draws attention to the ways in which these desires remain unfulfilled, and moreover, the ways in which disconnections and absences have been compulsory to illusions of globality. The ocean archive hence prompts us to rethink the actual effects of these narratives, and to challenge their generalizations and universalisms in favor of more complex relations. Engseng Ho points out that multi-generational diasporas formed by long histories of transoceanic migration and travel are characterized by absence, an important corrective to dominant narratives of a globalization that "loudly shouts its presence everywhere."[46] For contemporary migrants as well, the experience of globalization is one of absence more as much as instant presence.

[45] Spivak, Death of a Discipline, 72.
[46] Ho, Graves of Tarim, 3.

The ocean archive is characterized not only absences but also opacity, again both materially and discursively. The deep sea, where sunlight cannot penetrate, makes up "78.5 percent of the planet's habitat" by volume and is surprisingly full of life.[47] Pressures and temperatures in this zone, the bathypelagic, are so intense that humans cannot survive, even for brief visits.[48] Yet this is where the real work of the ocean archive occurs. It is where materials are processed by the ocean and by its various inhabitants. It is where they are reformulated, recombined, stored, and circulated; and it is where they rest, temporarily inert, containing the materials for future worlds. But this is not a condition to be mourned; transparency is not to be celebrated in the ocean archive. Edouard Glissant calls opacity "the real foundation of Relation."[49] The very concept of opacity reminds us of limits and uncertainties, keeping totality open and permitting difference that one does not strive to grasp, that is irreducible. Such opacity is central to the ocean archive's uncanny planetary nature.

Rhythms

Concepts of rhythm and repetition, put simply as those patterns that distill out of chaos without necessarily being attributable to cause or effect, are central to the organizing principles and processes of the ocean archive. Benitez-Rojo claims that the Caribbean is "a chaos that returns, a detour without a purpose, a continual flow of paradoxes; it is a feed-back machine with asymmetrical workings, like the sea, the wind, the clouds, the uncanny novel, the food chain, the music of Malaya, Godel's theorem and fractal

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[47] Alaimo, Violet-black, 234.
[48] See for example Nestor, J. (2014). *Deep: Freediving, renegade science, and what the ocean tells us about ourselves*. San Diego: Houghton Mifflin Harcourt.
[49] Glissant, The Poetics of Relation, 190.

mathematics."[50] In large part, Benitez-Rojo's proclivity for reading the Caribbean in this way is a counter-effort to scholarship that tends to get stuck on the isolation, fragmentation, and heterogeneity of the Caribbean, thus "[defining] the Caribbean in terms of its resistance to the different methodologies summoned to investigate it."[51] His reading, therefore, might be seen as an attempt to approach the Caribbean on its own terms. He explicitly recognizes that the Caribbean may be validly read either as characterized by unities within the archipelago (cultural, historical, etc), or by particularities; yet he decides on a third reading, one he calls Chaos, "where we detect dynamic regularities – not results – within the (dis)order that exists beyond the world of predictable pathways."[52]

The same dynamics that inspire Benitez-Rojo's reading are central to the most recent developments in assemblage thinking, and have also been highly influential in the physical sciences, including oceanography. What makes Benitez-Rojo's reading unique is that he resists linear cause-and-effect explanations for culture, instead elaborating on his assertion that the Caribbean can productively be understood as a polyrhythmic area. To fully theorize rhythm in all its valences is beyond the scope of my project. Here it will suffice to identify three characteristics of rhythm that are important for Benitez-Rojo and can be usefully applied to the work of other ocean scholars as well. First, rhythm is both as literal and as metaphorical as one can imagine. For Benitez-Rojo, rhythm does not just define music and dance, although these are important elements of Caribbean culture, and

[50] Benitez-Rojo, The Repeating Island*,* 11.
[51] Ibid., 2.
[52] Ibid., 36.

ones through which the Caribbean people can be understood as being "in the same boat," in Benitez-Rojo's words.[53] Rhythm can also be found "in architecture, in poetry, in the novel, in the theater, in bodily expression, in religious belief, in idiosyncracies, that is, in all the texts that circulate high and low throughout the Caribbean region."[54] Second, rhythm can be understood as regularities or patterns that emerge from diverse, conflicting, unpredictable, and discontinuous forces (the forces of chaos but also of capitalism, globalization, etc). Third, rhythm is syncretic, operating with a logic of *and*, where new elements are composed with others rather than overwriting them. It is always possible to add other notes with the result of new sounds, new expressions, that are unlikely to be known in advance.

Syncretism

As suggested above, the ocean is a particularly apt archival substance because it operates materially and discursively with a logic of *and* rather than *or.* That is to say, the ocean is an important site of human and nonhuman conscription into modern capitalist projects of globalization. But the very conditions that make it so also contain within them the possibility of being otherwise. It is not that the ocean contains the possibility for oppression *or* resistance; it is rather *both*, and that *both* is analytical and productive rather than a expression of indecision. The logic of *both* shows the ocean to be a syncretic space, super-saturated with meaning, providing depths from which immanent becomings might arise, even as each possibility unfolds "*as if* […] totally finite, isolated, self-

[53] Ibid., 75.
[54] Ibid., 80.

contained and mutually exclusive with the next".[55] This additive logic also permits the ocean the possibility not just for localized formations but also for alternative global (or planetary) ways of knowing and being.

Subaltern human-ocean assemblages and their imperialist counterparts were vital to the formation of capitalism; as I reviewed in Chapter One, it is likely no stretch to say that capitalism was born at sea (Benitez-Rojo, 1997). For Casarino (2002), as mentioned above, economic processes at sea perhaps best exemplify the "synchronicity of the non-synchronous," the juxaposition of elements from different origins and temporalities, which he claims characterizes modern capitalism. Thus it follows that one of Benitez-Rojo's chief arguments is that the culture of the Caribbean is super-syncretic.[56] That is, different dynamics come to be composed together in different and changing regularities.

Reading the ocean archive

Who reads the ocean archive, and how? Even perhaps more fundamentally, how are materials archived and made available for reading? These are far from mundane questions; they indicate some of the morphogenic processes through which the ocean archive functions and that give it its planetary nature. They are fundamental for meaning-making with and through the ocean archive. This is an archive that does not have humanity at its center; more often than not, the 'who' of these questions is a technology or an Earth force.

The sea is the most significant archivist in the ocean archive. Like the geologic record in which theorists of the Anthropocene have taken great interest, the ocean has

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[55] Casarino, Modernity at Sea*,* 35 (emphasis in original).
[56] Benitez-Rojo, The Repeating Island

strata, and there materials become lodged and transformed. But ocean water masses move on different scales than geologic strata and they do not offer themselves for easy reading by humans. The ocean claims bodies and materials; it takes in what is surrendered to it, but threatens to issue forth strange returns. Unpredictable weather, plastic-loving creatures, and radioactive matter may emerge even as the ocean continues to buffer humans and other terrestrial life forms from extreme temperatures and various forms of toxicity.[57] Following Spivak, this is an uncanny archive; while history tells us that the ocean is life's origin, we simply don't know what is inside, much less where, when, or how it will emerge from the depths and make itself available to a human reading.[58]

When humans have tried to read the ocean archive, they have generally done so from ships or on dives. But these methods are far from comprehensive. It is not unusual for rough weather to prevent data collection on half of the days or more of a scheduled oceanographic cruise. Until the 1990s, most of the ocean remained un-sampled. Ship-based oceanography is, however, being phased out in favor of new methods, changing drastically if perhaps a bit unwittingly how we understand the ocean archive. As I explored in Chapters Four and Five, a new generation of autonomous sensing technologies is revolutionizing oceanography. In concert with satellites, underwater robots roam every corner of the world ocean and remotely deliver temperature, salinity and other data, for a fraction of the cost of ship-based measurements.[59]

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[57] Zaikab, G. (2011). Marine microbes digest plastic. *Nature News* 28 March 2011, http://www.nature.com/news/2011/110328/full/news.2011.191.html
[58] Spivak, Death of a Discipline.
[59] See for example Wilson, S. (2000). Launching the Argo Armada. *Oceanus 42*(1), 17-19.

While these technologies deliver an unprecedented amount of information to humans, in Chapters Four and Five I showed that they also have lives that are increasingly their own. We might return to the words of the director of the US's National Deep Submergence Facility:

> "The ocean is just so different in terms of supporting many of the ways in which we kind of think of communicating and building our technologies […] there's not only tremendous pressures and cold temperatures but there's really importantly no way for us to talk to our sensing network, or talk to our robots, […] except when they come to the surface, or through very imperfect and difficult to deploy means of communication."[60]

These new technologies interact with other nonhumans in the sea. As I explained in Chapter Four, one of the biggest influences on their usefulness to human oceanographers is the degree to which they are colonized by mollusks and marine microbes, a hazard that oceanographers call "biofouling."[61] While new sensing technologies participate in new regimes of Earth system surveillance, they also lead lives beyond extension of human intention, simply due to their ability to abide in parts of the ocean that are out of bounds for humans.

Nonhuman animals are also ocean archivists, and readers of the ocean archive. They sense, and create, changes in ocean composition at various scales. Some of them stratify the ocean, and interrupt other processes of stratification; for example, whales influence the spatial distribution of ocean nutrients through the behavioral and metabolic

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[60] Andy Bowen, personal communication, 23 April 2014, Woods Hole MA.
[61] Roemmich, D., Boebel, O., Desaubies, Y., Freeland, H., Kim, K., King, B., Le Traon, P-Y., Molinari, R., Owens, B., Riser, S., Send, U., Takeuchi, K., & Wijffels, S. (2001). Argo: the global array of profiling floats. In Koblinsky, C.J. and Smith, N.R. (eds.) *Observing the Oceans in the 21st Century: A Strategy for Global Ocean Observations*. CSIRO Publishing, 248-258.

patterns.[62] Nonhuman animals even participate in oceanographic data collection. Citizen science at sea is difficult: unless your citizens are nonhuman animals. Scientists affix sensors to marine mammals, who inhabit parts of the ocean, such as icy seas, that are inhospitable to research vessels and satellite-dependent sensors. These seals and other animals not only unwittingly record data about their behavior but also collect temperature and salinity data with their cyborg sensors.[63]

Of course there is much more to the ocean archive than data collected by oceanographers and their technologies (or by technologies and their scientists). The ocean archive is read by the bodies of those who consume marine proteins and catalogue the heavy metals that march through the ranks of bioaccumulation. It is read in climate records, and it is read in the traces of El Niño droughts and floods, and the famines and loss of life and property that have accompanied them.[64] It is read imaginatively through diasporic genealogies, and through the holes and absences in these genealogies. It is read through artistic, musical, culinary, and various other customs and practices shared across and transformed by ocean basins. Indeed, for the "Peoples of the Sea," or for the readers of the ocean archive, "scientific knowledge and traditional knowledge coexist as differences within the same system."[65]

Conclusion: For the ocean archive

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[62] Roman, J. & McCarthy, J. The Whale Pump: Marine Mammals Enhance Primary Productivity in a Coastal Basin. *PLoS One, 5*(10) e13255.
[63] Hooker, S. K., & Boyd, I. L. (2003). Salinity sensors on seals: use of marine predators to carry CTD data loggers. *Deep Sea Research Part I: Oceanographic Research Papers*, *50*(7), 927-939.
[64] Davis, M. (2002). *Late Victorian holocausts: El Niño famines and the making of the third world*. New York: Verso.
[65] Benitz-Rojo, The Repeating Island, 17.

In the conclusion to my dissertation, I have forwarded a notion of the ocean archive with the aim to examine different dimensions of a planetary sea. It is a material archive that records human traces differently than the geologic archive, and as such may point us toward different Anthropocene conceptions of political possibility and ethical responsibility. Emerging from my attempts to read oceanography and postcolonial scholarship diffractively, the ocean archive concept suggests that the ocean is not something to be mastered, mined, and explained. Rather we all now can claim a temporary oceanic inhabitance; or put differently, all we now can claim is a temporary planetary inhabitance.[66] It is not only the contemporary readers of the ocean archive that will interpret it, of course. Anthropocene imaginaries are frequently concerned with the nature of the future readers, but this can only be addressed with the most speculative of gestures. Yet what might it mean to imagine ourselves as all potential readers of the ocean archive, in our bodies, cultures, and knowledge systems, at the same time that all of those collective and individual materials are also eventual matter *for* the ocean archive? Might we think differently about how we are intended towards others, and toward the history and future of the planet, as a species cohered only through our differences? It is not so much the answers to the questions I have suggested here but rather the asking of them that I believe may point us to a planetary understanding of the ocean, one that accounts for difference through the characteristics of the sea.

[66] Spivak, Death of a Discipline.

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