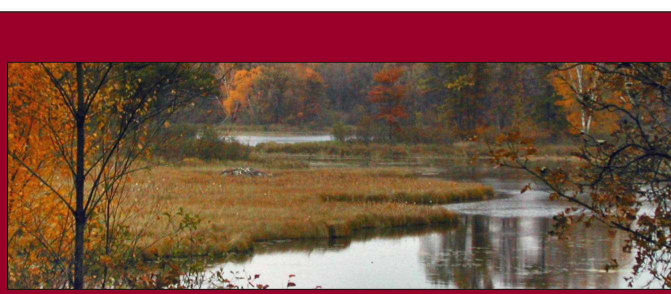
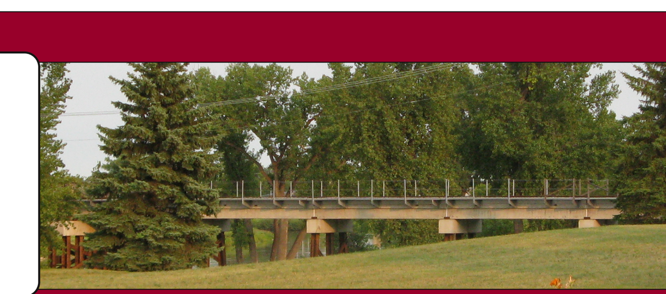


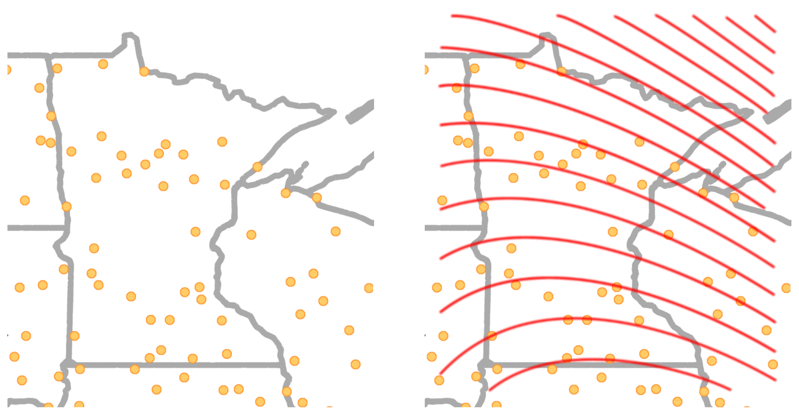


CLIMATE TRACKING

APPLICATIONS OF A NOVEL TECHNIQUE TO SUSTAINABILITY

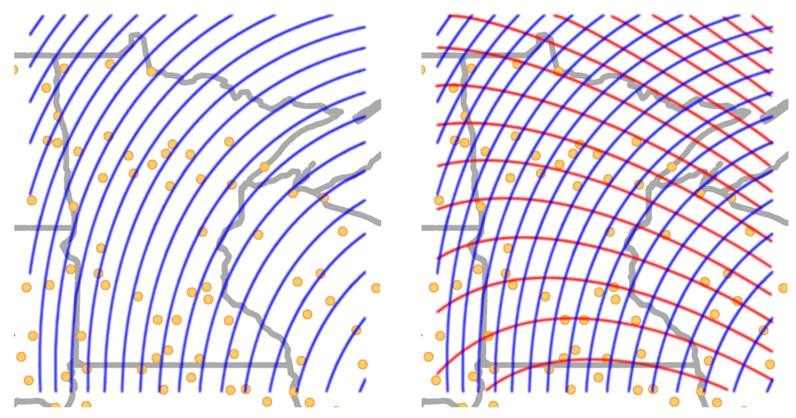
RICHARD BARNES, CLARENCE LEHMAN, SHELBY WILLIAMS, LEE FRELICH

A NEW CLIMATE TRACKING TECHNIQUE



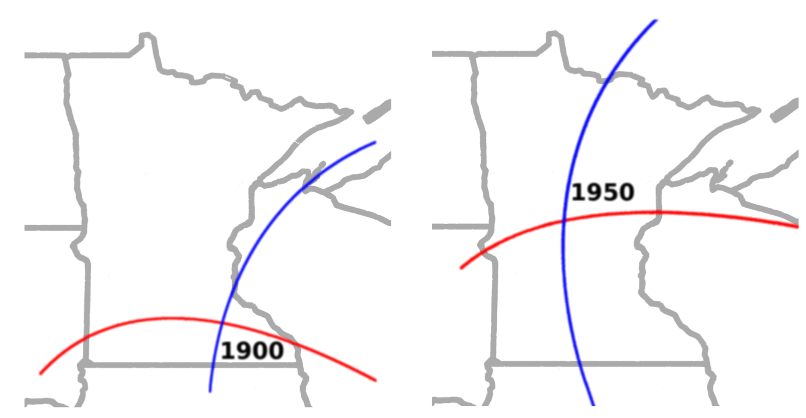
Data

There are 1200 historic weather stations in the U.S. A subset of stations is chosen and a running 30-year average calculated for each station. This average represents that station's climate.



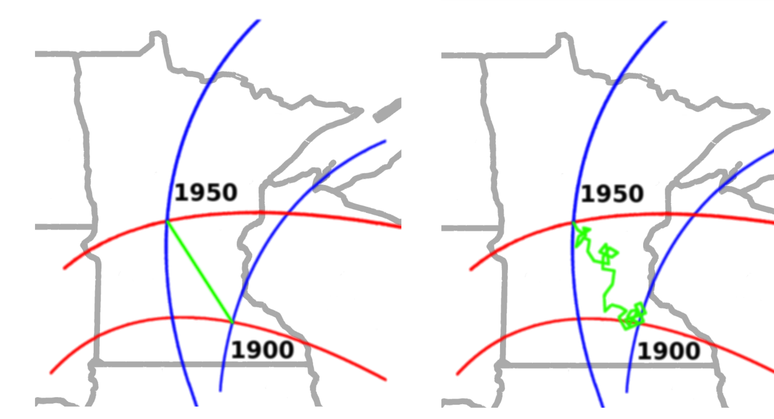
Fitting

For each year, and each climate variable, a mathematical surface is fit to a subset of the stations. Temperature and precipitation are used here, but others, such as growing degree days could be used.



Tracking

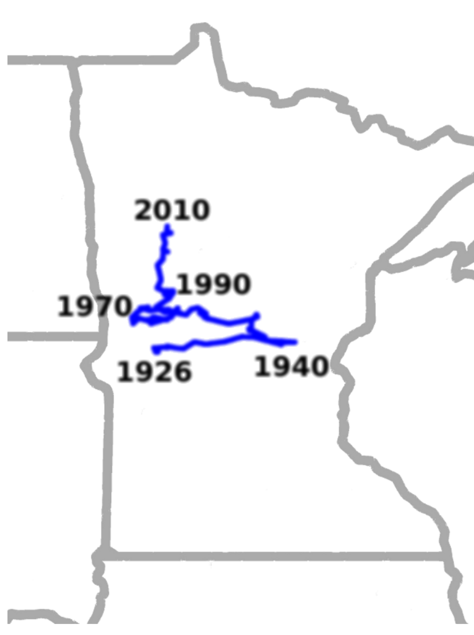
The intersection of the isoclines of a particular year's set of climate variables indicates a specific "climate point" whose movement can be traced either forward or backward through time.



Interpretation

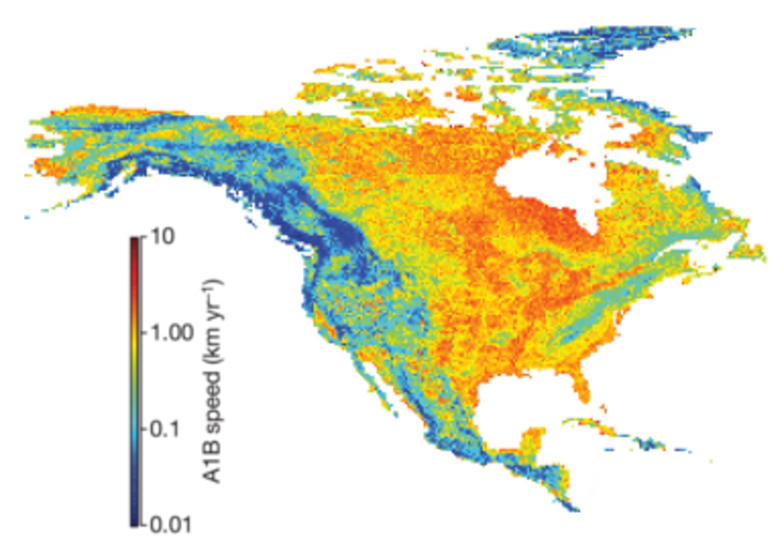
Connecting the intersections of subsequent years yields the path of a specific climate point. Each segment yields a velocity in miles per year. In combination, these paths can show regional climate changes.

CONFIRMS HISTORIC TRENDS... AND OTHERS' MODELS



The Dust Bowl

In the late 20's changing precipitation patterns began to dry Minnesota out and the state's climate tracked directly eastward. In 1940, just before the climate reached Wisconsin, it abruptly changed course and headed back West, but at half the speed, and with some warming. By the 70's, the Dust Bowl had finally past and the climate stabilized for the next decade. Since 1980, the state has been becoming warmer at three miles per year without much change in precipitation.

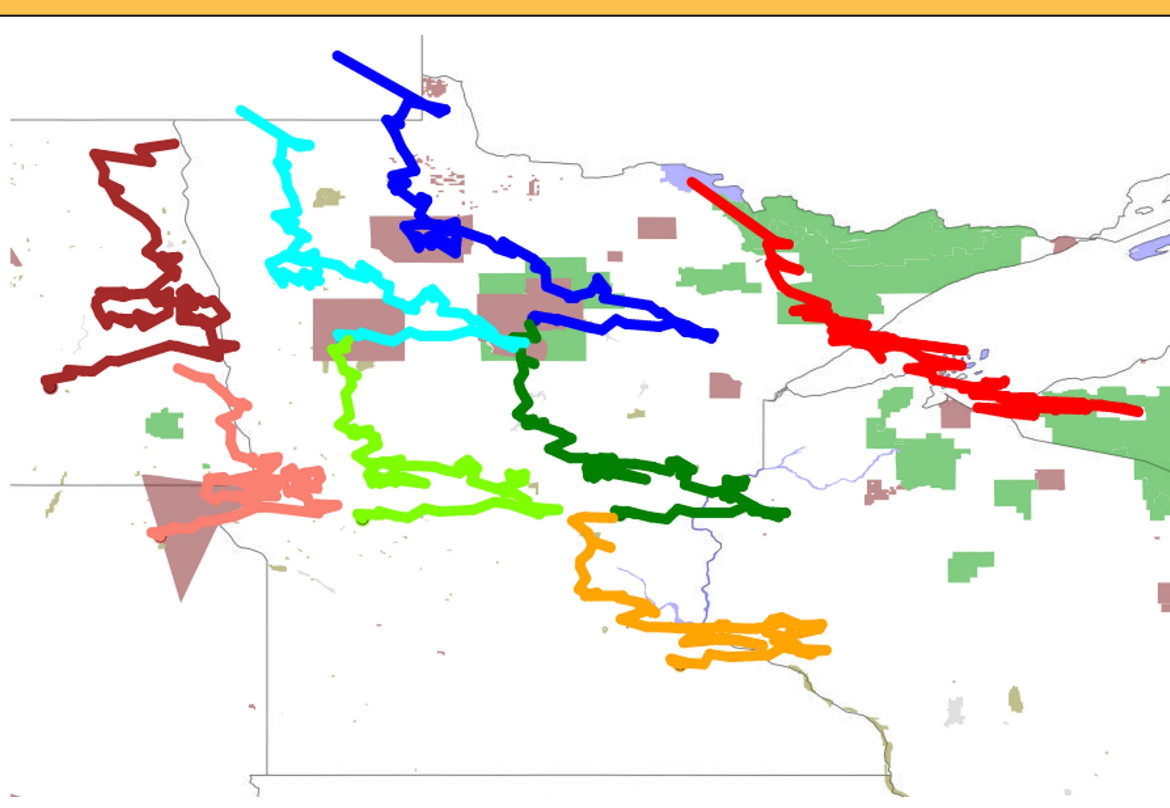


Loarie et al, Nature, Dec 2009.

Topoclimatic Gradients

Using known variations in temperature and precipitation with elevation, and projected or historic changes over time, other authors have derived climate velocities in a different way, confirmed by our method. Topoclimatic gradients detail generalities in a global picture of change, whereas our Climate Tracking method tells a more specific and local story.

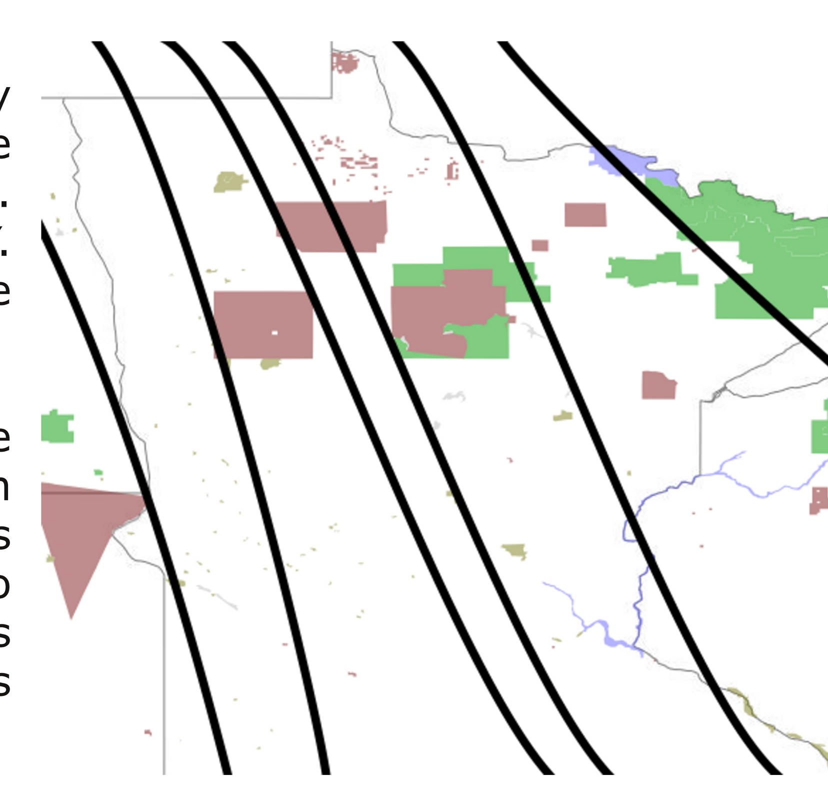
WITH IMPLICATIONS FOR...



Species Conservation

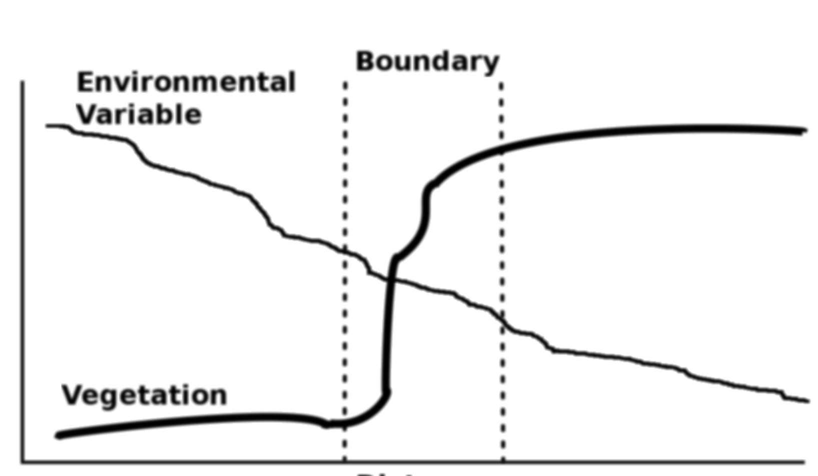
Changing climatic parameters alone are rarely responsible for a species' extinction; rather, it is the impact of these changes on a species' environment. Minnesota's climate is moving northward at ~3MPY. Individual species, such as the rare dwarf trout lily, move much slower; invasive pests move much faster.

For the past century, the residence time of a climate track within any given parcel of protected land has been short, yet these lands are home to many of Minnesota's endangered species. In some cases, it is possible to transplant a species; our climate tracking model provides some indication of when and where such plantings should occur.



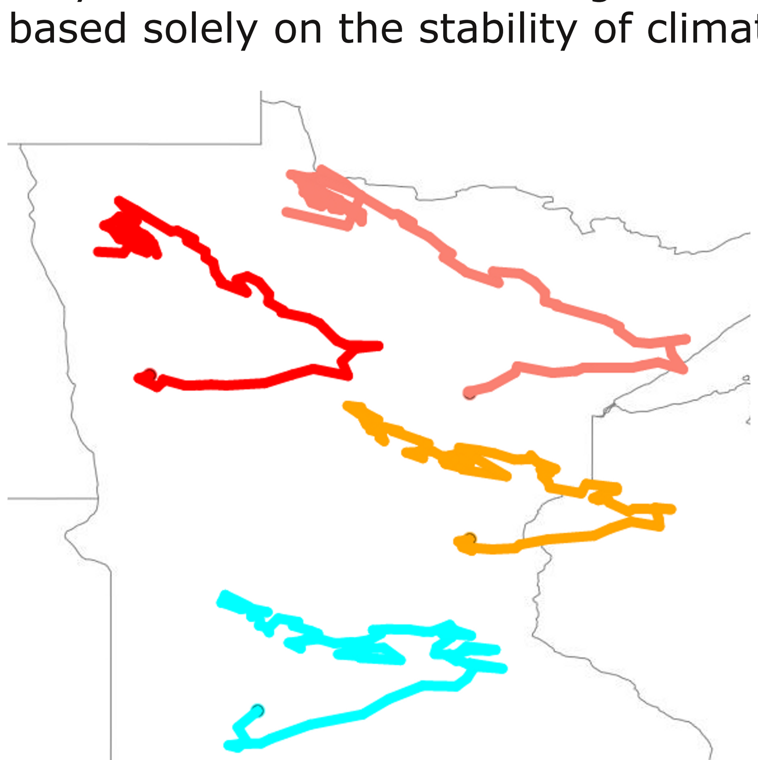
Biome Stability

In transects of biome boundaries, other authors (e.g. Danz 2011, Fagan 2003) have observed nonlinear changes in vegetation and other response variables across smooth gradients in climate. The derivative of their fitted vegetation functions multiplied by the reciprocal of the surface derivative of a climate surface gives a semi-empirical estimate of the expected vegetation change at such boundaries. Future work may enable extraction of vegetation boundaries in our model based solely on the stability of climate variables.



Ecosystem Conservation

While individual species may be replanted, it is infeasible to move entire ecosystems, often intact only within protected areas. As such, it is relevant to ask whether changing climate will guide them to other safe refuges. Itasca, Red Lake, and the Northwest Angle form a "conservation corridor", but the Dakota Tallgrass Prairie and the northern parts of Wisconsin and Michigan are isolated. Knowing this provides a basis for action.



Agricultural Productivity

Growing degree days are accumulated when the mean daily temperature is within some defined range. Every crop requires some minimal accumulation of GDDs; thus, GDDs are used as a metric of a region's potential for agricultural productivity.

Our model indicates an eastward trend in productivity during the Dust Bowl, followed by a statewide northwestward trend through 1966. After this, productivity gains in northern Minnesota ceased, while a westward trend persisted in the south. This suggests that Minnesota's north and south are equally productive in terms of temperature; further productivity gains will be driven by moisture alone, and concentrated to the southwest.

Concluding Thoughts

Climate Tracking offers a new and powerful method to visualize the flow of climate over the land. It illustrates historic trends, provides a succinct confirmation of more complex methods, and offers insight into relations between climate and sustainability.

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