Title:	Lake Superior moored temperature and currents, Spring 2015 to Spring 2021
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Introduction

This document describes the data archive for 2015-2020 Lake Superior moorings. Data types include temperature, velocity, and acoustic backscatter. Temperature data comes from thermistors and χpods while velocity and acoustic backscatter intensity data comes from Acoustic Doppler Current Profilers (ADCPs). Covered in this dataset are 46 mooring deployments, 514 thermistor records, 10 χpod records, and 26 ADCP records. This archival entry covers moorings deployed in 2015 through 2020; data from 2020 deployments extends into 2021. See also the previous archival entry for 2005-2014 deployments (Austin and Elmer 2021) and archival entries for the Radiatively Driven Convection (RDC) deployments of 2019 (Austin 2020) and 2021 (Elmer and Austin in progress).

Locations

Mooring sites are located throughout Lake Superior (Figure 1), including one (WM) co-located with National Data Buoy Center (NDBC) surface buoy 45006. In most years, moorings occupied only sites GM1, GM2, and WM (Figure 2). The major exception is 2017 during the Near-Inertial Coastal Experiment (NICE), when moorings additionally occupied sites with prefix M (Figure 2). Names and approximate positions and depths are located in Table 1. Actual positions and depths are available in summary documents and data files.

Table 1. Approximate mooring locations

Mooring	Description	Latitude	Longitude	Depth
GM1	Grand Marais 1	47° 40.0’	90° 26.0’	155
GM2	Grand Marais 2	47° 33.4’	90° 20.7’	165
WM	Western Mooring	47° 19.3’	89° 48.1’	185
M04	NICE Mooring 4	47° 11.4’	90° 1.7’	155

M05	NICE Mooring 5	47° 10.4’	89° 41.3’	200
M06	NICE Mooring 6	47° 24.3’	89° 35.0’	200
M07	NICE Mooring 7	47° 28.7’	89° 56.6’	150
M08	NICE Mooring 8	46° 59.4’	89° 50.1’	200
M09	NICE Mooring 9	46° 50.7’	89° 45.2’	50
M10	NICE Mooring 10	47° 47.1’	89° 55.8’	200
M11	NICE Mooring 11	47° 40.0’	89° 49.5’	185
M12	NICE Mooring 12	47° 5.6’	89° 21.1’	130
M13	NICE Mooring 13	46° 58.2’	89° 14.9’	40
M14	NICE Mooring 14	47° 55.4’	89° 34.8’	240
M15	NICE Mooring 15	47° 8.2’	88° 55.4’	40
45027	McQuade onshore	46° 51.9’	91° 55.6’	50
45028	McQuade offshore	46° 48.7’	91° 50.1’	50

Deployment method

There are three primary deployment platform types in this archival entry (Figures 3-5).

The first type of platform is a subsurface mooring, which consists of a large concrete anchor, an acoustic release, a length of steel cable with scientific instruments attached at specified locations, and subsurface flotation around 10m depth (Figure 3). Instruments have included thermistors, pressure sensors, and/or ADCPs. A subsurface float depth of 10m was chosen to keep the mooring below large vessel draft. However, this means we do not measure temperature in the top 10m of the water column. If near-surface thermal structure is of interest, we recommend surface buoy data from NDBC (ndbc.noaa.gov). Note that these buoys are not deployed during winter when near-surface thermal structure is typically uniform. During these times, the subsurface mooring 10m measurement is likely adequate for most purposes. The pressure sensors are deployed at multiple depths to determine the actual, as opposed to design, depth of the instruments on the mooring. We do not include this pressure data in this archive.

The second type of platform is a WireWalker mooring. These moorings consist of a bottom anchor, a length of steel cable, a heavy weight, a length of steel cable with the WireWalker instrument package, and a surface buoy (Figure 4). The WireWalker, developed at the Scripps

Institute of Oceanography, uses wave motion to ratchet down the steel cable. When the WireWalker reaches a bumper installed on the cable, it releases and floats to the surface due to its positive buoyancy. Upon reaching the surface, the WireWalker continues its journey down the cable again.

The third type of platform are surface meteorological buoys. These buoys have a bottom anchor, a length of steel cable, a heavy weight, a length of steel cable with a thermistor string mounted to the upper 40m, and a surface buoy with meteorological instruments (Figure 5). In this archive, we provide only the water temperature data. For other data from these buoys, including meteorological data, we recommend visiting the NDBC website (ndbc.noaa.gov).

Deployment naming convention

Individual deployments are named with the mooring site, “S” for spring/summer or “F” for fall, and two digits representing the year of deployment (-2000). For example, GM1S15 is the mooring deployed in the summer of 2015 at the Grand Marais 1 mooring site. Data is organized into directories following similar naming conventions, with main directories named “YYYY mooring deployments” for each year. The exception to this convention are the three 2017 directories, which are split due to large file sizes. All main directories contain subdirectories named “MMMSFYY files” where MMM is the site name, SF the deployment season, and YY the deployment year (-2000). These subdirectories are further organized into “ADCPs”, “Thermistors”, and “WireWalkers” subdirectories as applicable.

Types of data

The primary data types are temperature, currents, and backscatter at a range of depths.

Temperature was collected using a variety of thermistors: Richard Brancker Research (RBR) solo, duet, TR-2050, and XR-420, SeaBird Scientific SBE-39, and Oregon State University χpods. In the case of RBR XR-420 thermistor strings mounted on surface buoys, we broke up the datasets into files similar to those for individual thermistors for ease and consistency of use.

Currents and backscatter were collected using various ADCPs: Teledyne RDI WorkHorse Sentinel 300kHz and 600kHz, Nortek Aquadopp Profiler 600kHz and Signature500. ADCP compasses are calibrated on land prior to all deployments.

Summaries

Metadata for each instrument and mooring are included in this archival entry as .xlsx (Microsoft Excel-readable) files.

- mooring summary table.xlsx with metadata columns
    - deployment name
    - deployment date
    - recovery date
    - longitude
    - latitude
    - depth in meters
    - number of thermistors
    - number of ADCPs
    - number of WireWalkers
- thermistor summary table.xlsx with metadata columns
    - deployment name
    - instrument model
    - deployment date
    - recovery date
    - serial number
    - file name
    - depth in meters
    - sampling period in seconds
- ADCP summary table.xlsx with metadata columns
    - deployment name
    - instrument model
    - deployment date
    - recovery date
    - serial number
    - file name
    - depth in meters
    - orientation
    - sampling period in minutes
    - bin size in meters
- WireWalker summary table.xlsx with metadata columns
    - deployment name
    - deployment date
    - recovery date
    - file name
    - maximum pressure
    - sampling period in seconds

Data

Data in this archival entry is in two formats: raw and hourly averaged. Most users will only ever use the hourly averaged data.

Raw Data

Raw data is minimally processed, and so may contain pre- and post-deployment “deck data” that will need to be trimmed before use. It is organized into directories and subdirectories (named as described above).

Thermistors

Thermistor raw data file names are of the form ssssss_yymmdd.mat where ssssss is the serial number followed by yy, mm, and dd the recovery year, month, and day, respectively. The files contain the variables

t	UTC time, MATLAB format (fractional days since 1 Jan 2000)
T	temperature, degrees C
dep	thermistor depth, m
sensor	sensor type/model number
lat	latitude, degrees N
lon	longitude, degrees W
SN	serial number (redundant with file name)

WireWalkers

WireWalker raw data file names are in the form MMMSFYY_WW.mat where MMMSFYY is the deployment name and WW indicates WireWalker. The files contain the variables

t	UTC time, MATLAB format (fractional days since 1 Jan 2000)
T	temperature, degrees C
P	pressure
dPdt	change in pressure per time step

ADCPs

ADCP raw data file names are in the form MMMSFYY_UD_ZZ.mat where MMMSFYY is the deployment name, UD is U or D for upward or downward facing instrument, and ZZ is the design depth of the ADCP. For example, GM1S15_U_60.mat is data from an ADCP deployed at Grand Marais 1 in summer of 2015 looking upward at 60m depth.

In the case of RDI ADCPs, data was processed from binary with Rich Palcowicz's `rdradcp.m` code. Relevant variables include

mtime	UTC time, MATLAB format (fractional days since 1 Jan 2000)
intens	four beam backscatter intensity
east_vel	east velocity component, m/s
north_vel	north velocity component, m/s
vert_vel	vertical velocity component, m/s
config.ranges	ADCP to bin distance, m

In the case of Nortek Aquadopp ADCPs, binary data was processed first with Nortek Aquadopp Profiler software as ascii files and then read into MATLAB to be saved as mat files. Relevant variables include

t	UTC time, MATLAB format (fractional days since 1 Jan 2000)
user.coord	coordinate system; ENU for east-north-up or BEAM for beam
a1	backscatter intensity; east if ENU, beam 1 if BEAM
a2	backscatter intensity; north if ENU, beam 2 if BEAM
a3	backscatter intensity; up if ENU, beam 3 if BEAM
v1	velocity, m/s; east if ENU, beam 1 if BEAM
v2	velocity, m/s; north if ENU, beam 2 if BEAM
v3	velocity, m/s; up if ENU, beam 3 if BEAM
cell_center_dist	ADCP to bin distance, m

In the case of Nortek Signature500 ADCPs, binary data was processed with Nortek SignatureViewer software as multiple mat files and then concatenated in MATLAB. Due to the large file sizes, only certain variables were retained in the final version. Relevant variables include (* indicates both Average and Burst mode variables exist)

*_Time	UTC time, MATLAB format
Config.*_CoordSystem	coordinate system; ENU for east-north-up or BEAM for beam

*_AmpBeamX	backscatter intensity for beam X
*_VelBeamX	velocity, m/s, for beam X
*_VelEast	velocity, m/s, east
*_VelNorth	velocity, m/s, north
*_VelUp1	velocity, m/s, up 1
*_VelUp2	velocity, m/s, up 2
Config.*_CellSize	distance between bins, m
Config.*_NCells	number of bins

Hourly data

Hourly-averaged data in the hourly data 2015-2020 directory provides a more user-friendly format. File name convention follows deployment name convention described above plus the letter “h” to indicate it is hourly-averaged data. These files include hourly-averaged temperature, velocity, and backscatter intensity on a regular grid excluding pre- and post-deployment data. Hourly averages are hour-centered i.e. the data reported for 02:00 is the average of the data collected from 01:30 to 02:30. Similarly, WireWalker pressure averages are pressure-centered. When present, ADCP data bins are limited according to $R_{max} = D\cos(\Theta)$ where R_{max} is the maximum acceptable range, D is the distance from the ADCP to the surface (for upward-facing ADCPs) or bottom (for downward-facing ADCPs), and Θ is the beam angle (Gordon 1996). Each hourly file includes the variables

t	UTC time, MATLAB format (fractional days since 1 Jan 2000)
Z	water depth, m
lat	latitude, degrees N
lon	longitude, degrees W

And when appropriate, any of the following variables

SN	thermistor serial numbers; correspond to T columns
dep	thermistor depths, m; correspond to T columns
T	temperature, degrees C. Rows: times; Columns: thermistors
adcp_SN	serial number of ADCP(s)

adcp_dep	deployed depth of ADCP(s), m
bins	ADCP sampling bin depth; correspond to _vel and intens columns
east_vel	east velocity, m/s; direction where water is going to; Rows: times; Columns: bins
north_vel	north velocity, m/s; direction where water is going to; Rows: times; Columns: bins
vert_vel	vertical velocity, m/s; direction where water is going to; Rows: times; Columns: bins
intens	backscatter amplitude averaged between all beams; Rows: times; Columns: bins
P	uniform pressure grid; correspond to T_ww columns
T_ww	WireWalker temperature, degrees C. Rows: times; Columns: P

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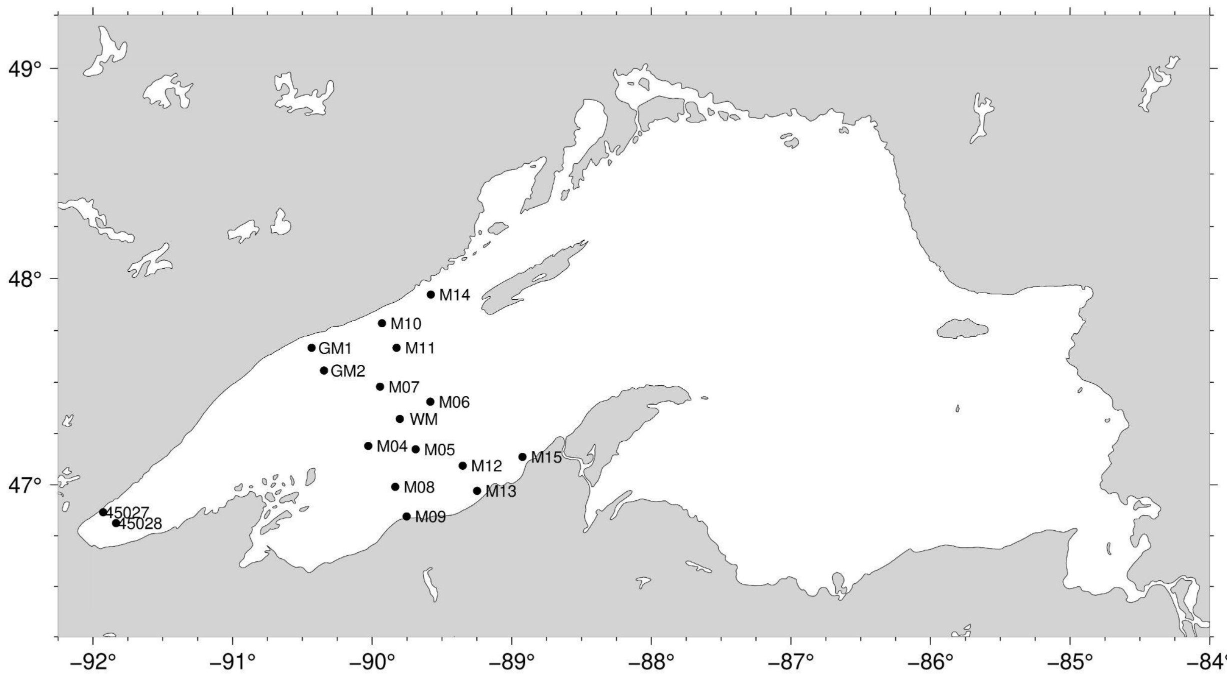

Figure 1. Station locations in Lake Superior

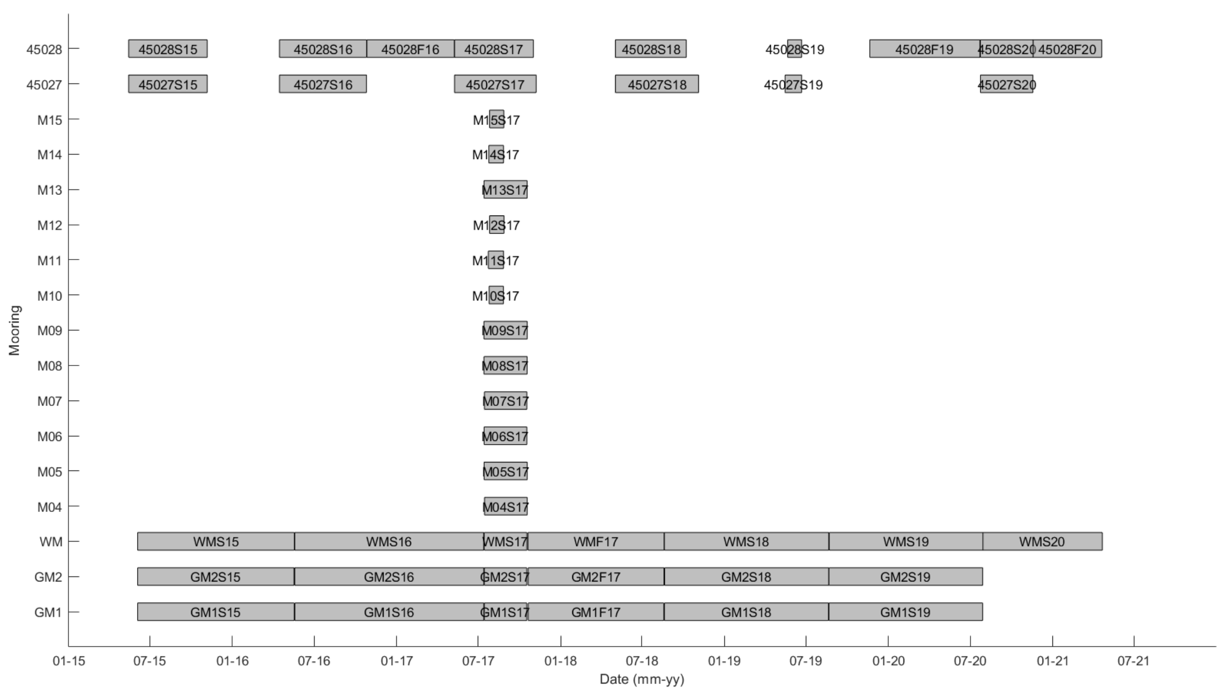

Figure 2. Data coverage

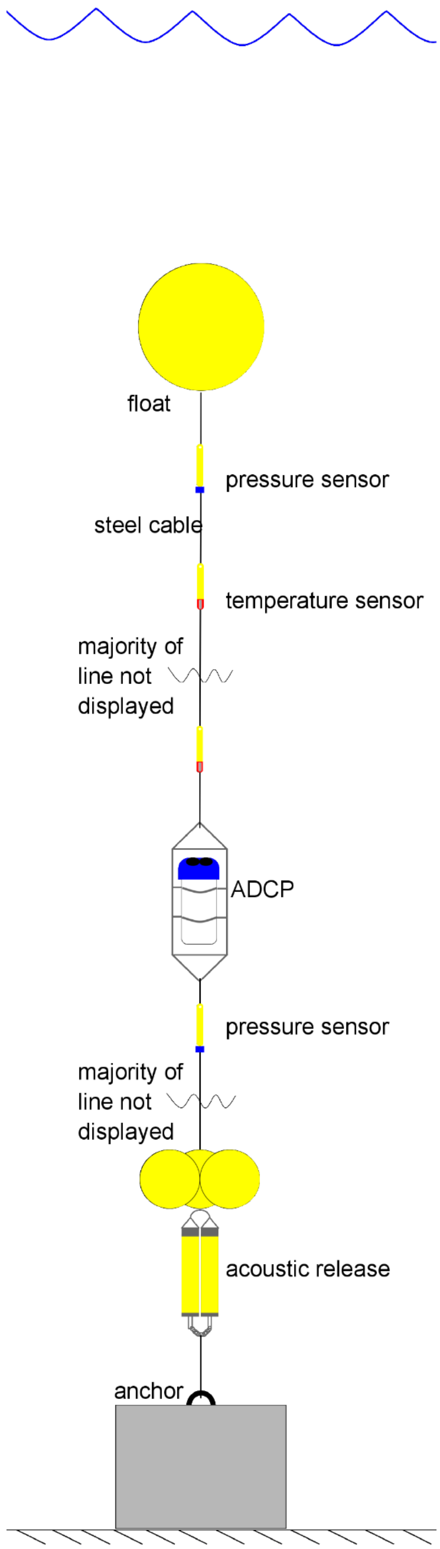

Figure 3. Basic subsurface mooring diagram

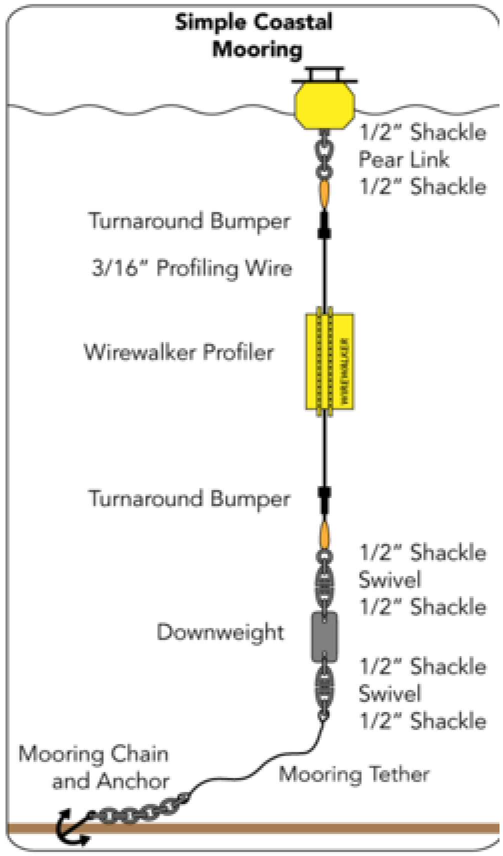

Figure 4. Basic WireWalker mooring diagram (Del Mar Oceanographic 2020)

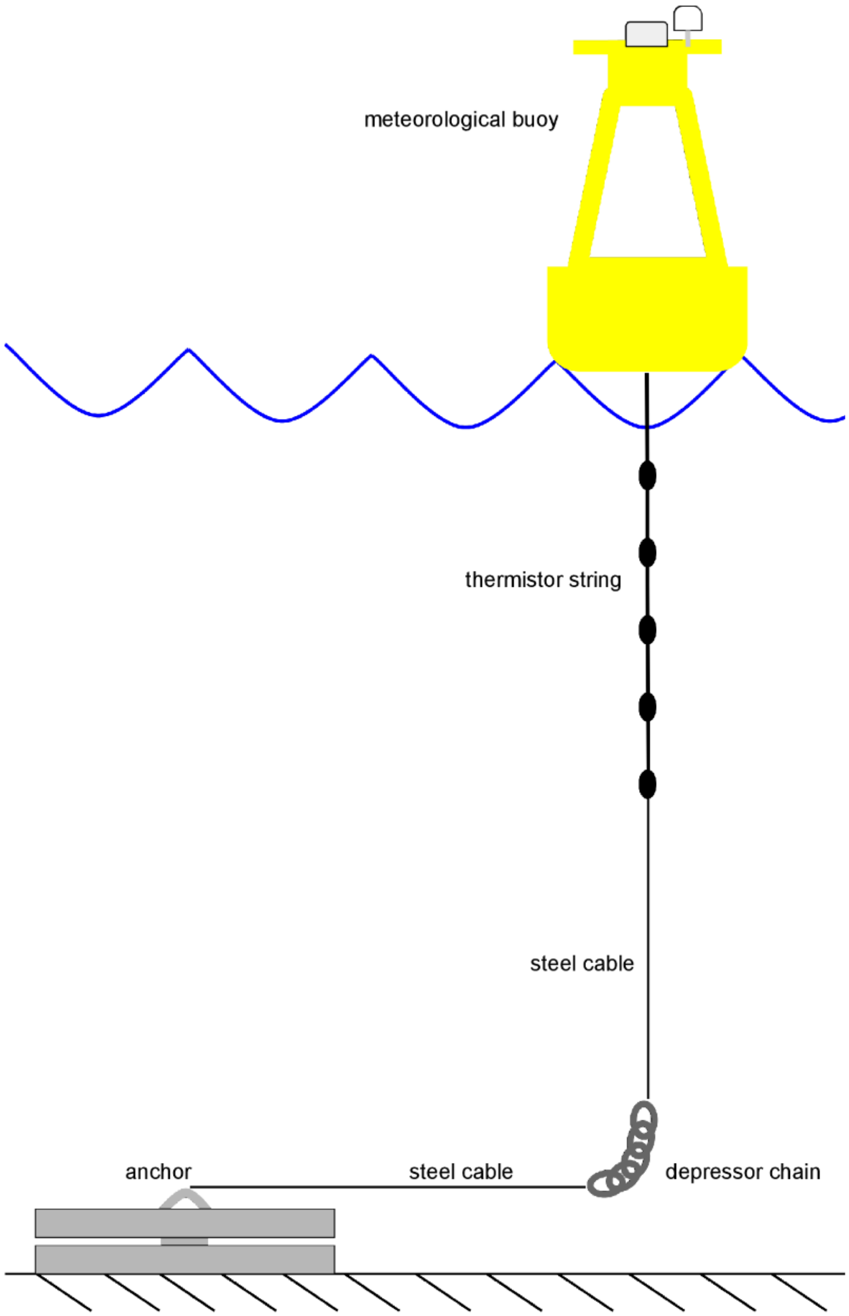

Figure 5. Basic meteorological buoy diagram