Predictive Numerical Models for Invasive Species Transport

Water sampling at Lake Massawippi (2019)

May 26, 2023

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UCDAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER

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Decline in Lake Tahoe Clarity

- Over the past 30 years, there has been a continuous decline in lake clarity

- What is the role of aquatic invasive species (AIS) in this change?
- What can be done to mitigate change?

R/V Bob LaConte on Lake Tahoe (photo courtesy of B. Allen)

Keep Tahoe Blue

Past condition …

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Corbicula Fluminea (Asian Clam)

- Asian clams are one of the most recent AIS to invade the basin
- *Need tight monitoring and control of boat traffic to minimize impact and stop future invasions*
- All efforts need to be made to quantify impact in future climate scenarios

Examples of adult *Corbicula Flumina* (photo courtesy of the Tahoe Environmental Research Center)

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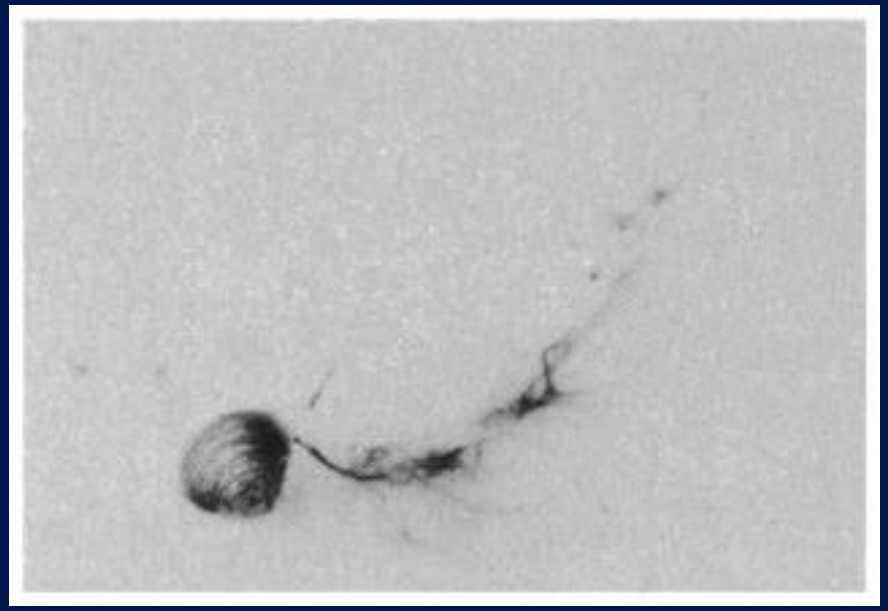
Clam Dispersal



- Pediveligers can remain pelagic for up to 2 days
- Potential dispersal via currents

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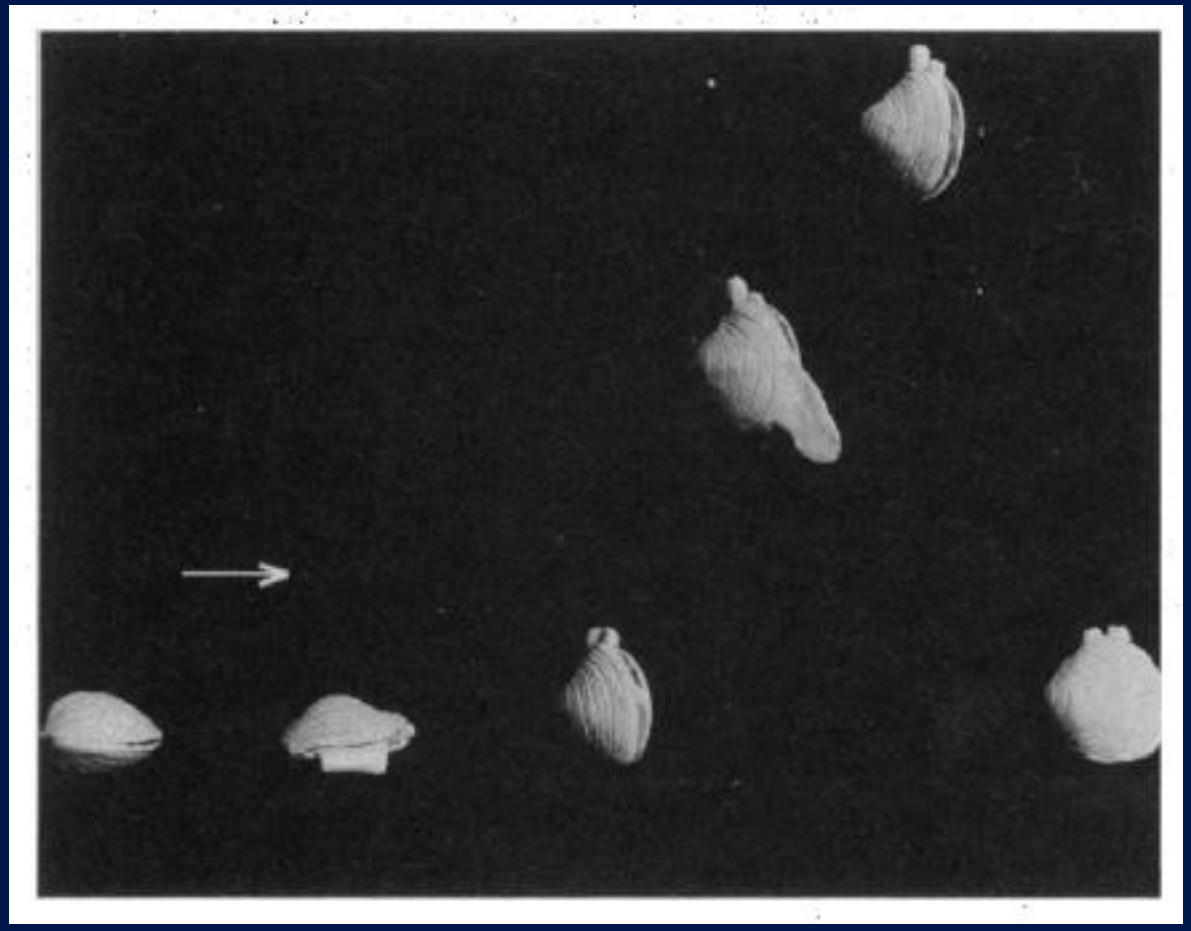
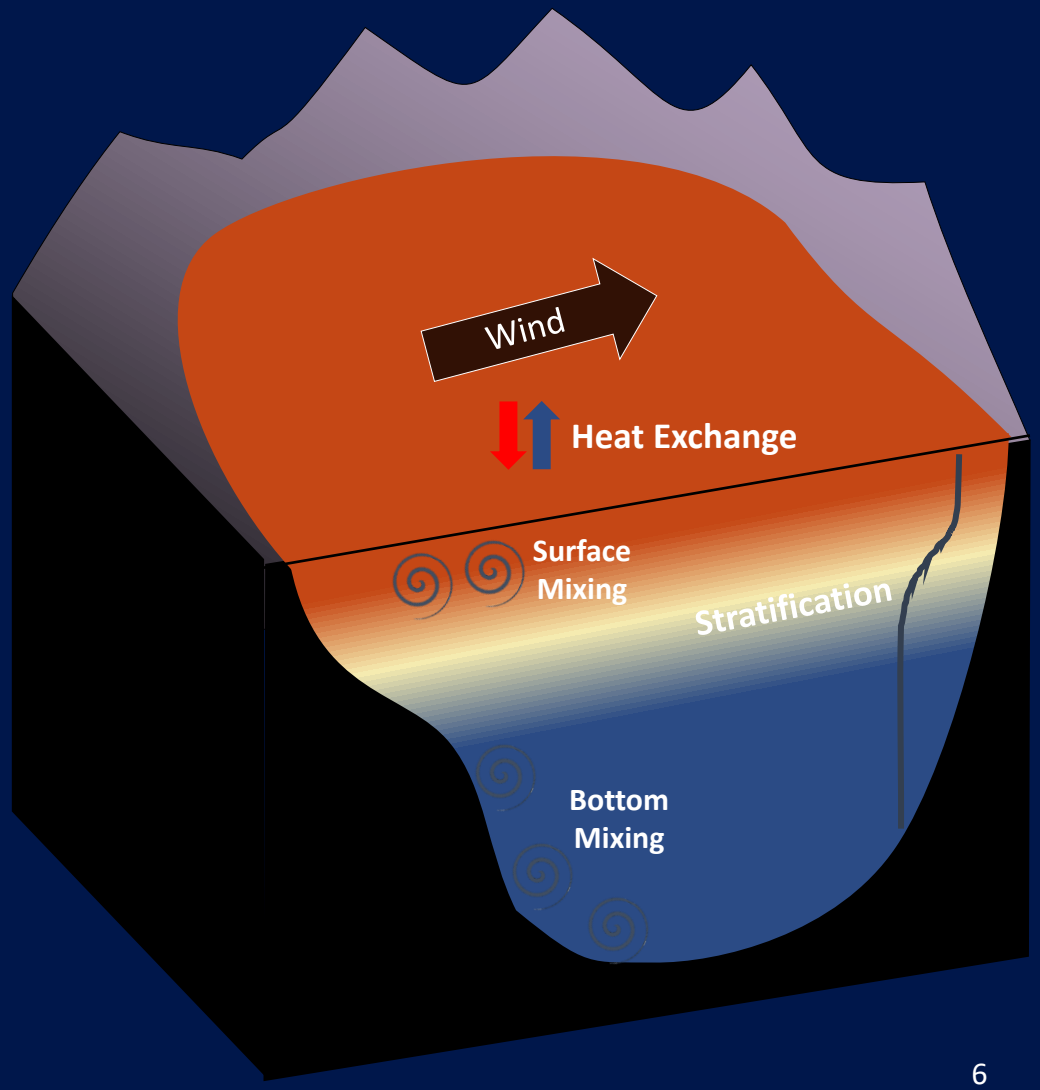
Science, New Series (1984), 225 (4669): 1491 – 1493



Hydrodynamic Models – Si3D

- Hydrodynamic models are used to predict lake response to wind forcing
- Powerful tools to examine physical processes
- Particle tracking is also a possible solution
- Si3D is commonly used by UCDavis



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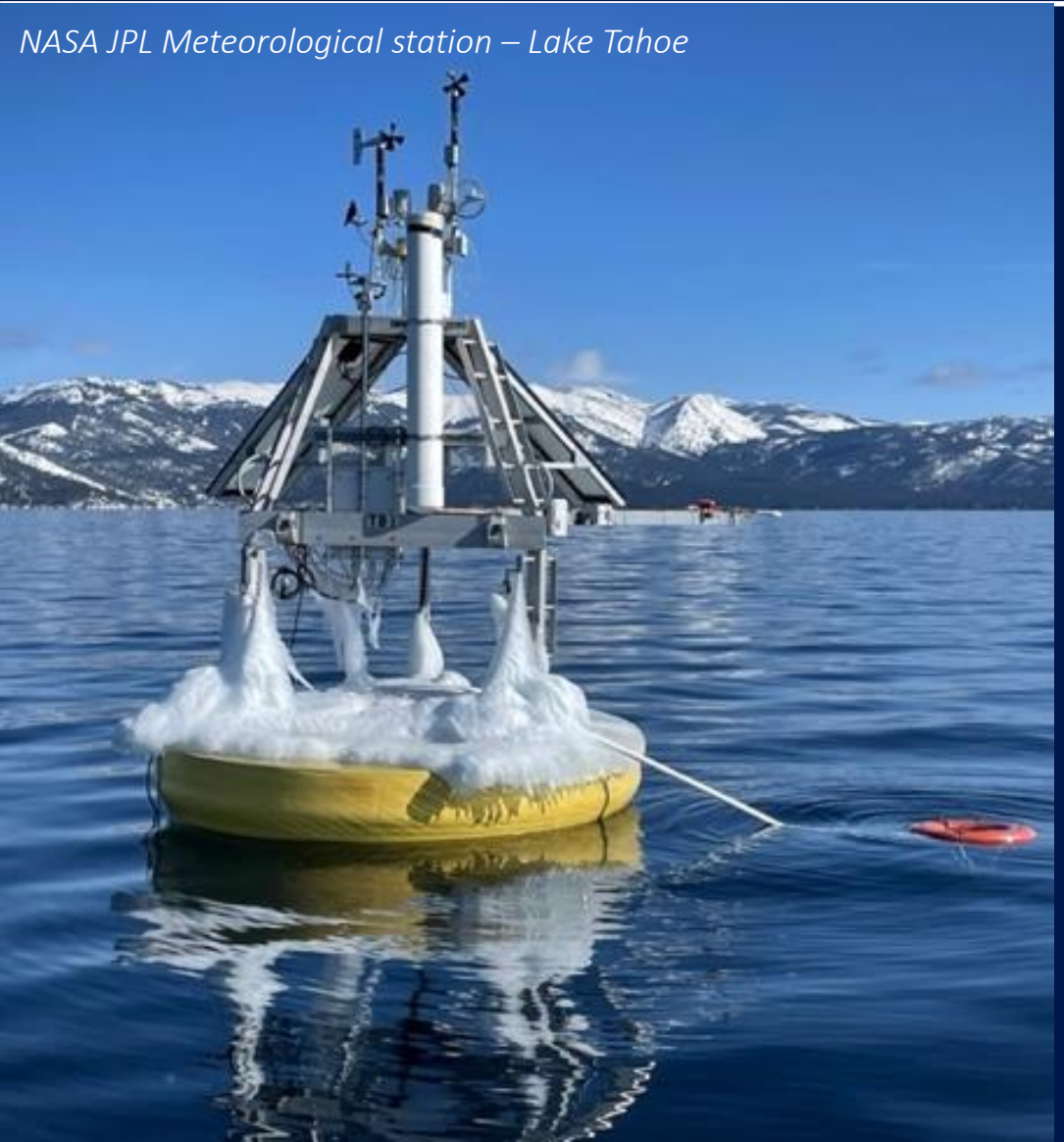
Si3D Inputs

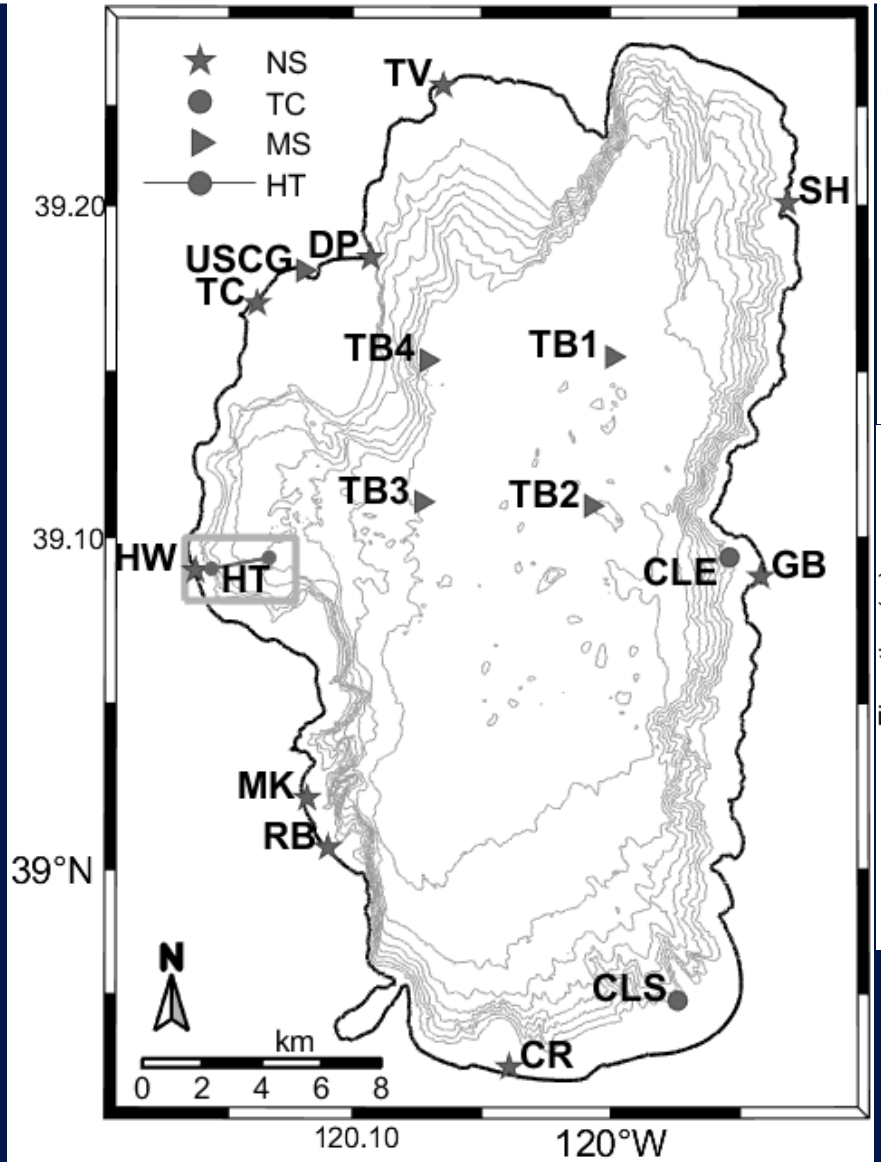


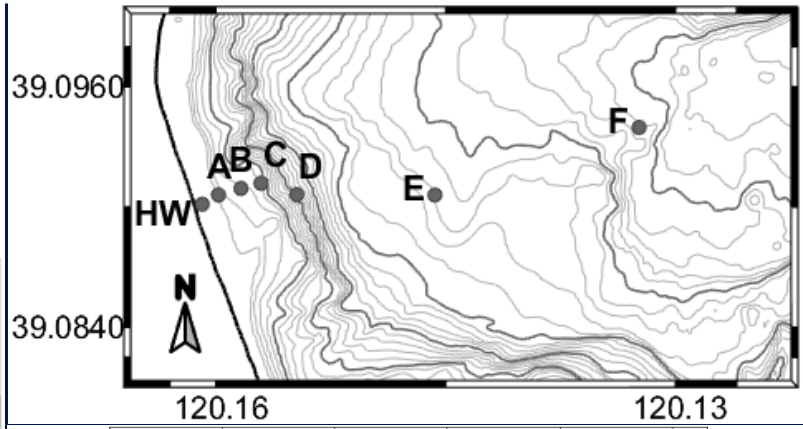
NASA JPL Meteorological station – Lake Tahoe

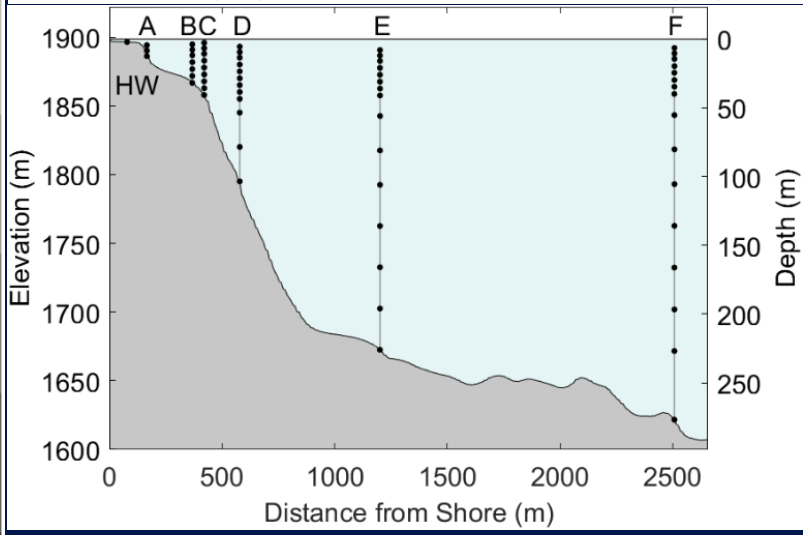
- Meteorological data for heat exchange:
  - Incoming and outgoing shortwave solar radiation
  - Incoming and outgoing longwave solar radiation
  - Air pressure
  - Air temperature
  - Relative humidity
  - Light attenuation coefficient
  - Lake surface temperature
- Initial conditions:
  - Description of temperature profile in depth.
- Inflows and Outflows
  - Optional for site specific research interests

Lake Tahoe Application

- Multiple site database for model calibration and validation for velocity and temperature
- Multiple site meteorological database
- Fine resolution bathymetry ($10\ \mathrm{m}$)
- Mean $RMSE = 0.8\,^{\circ}C$







Extracted from Valbuena et al. (2022)

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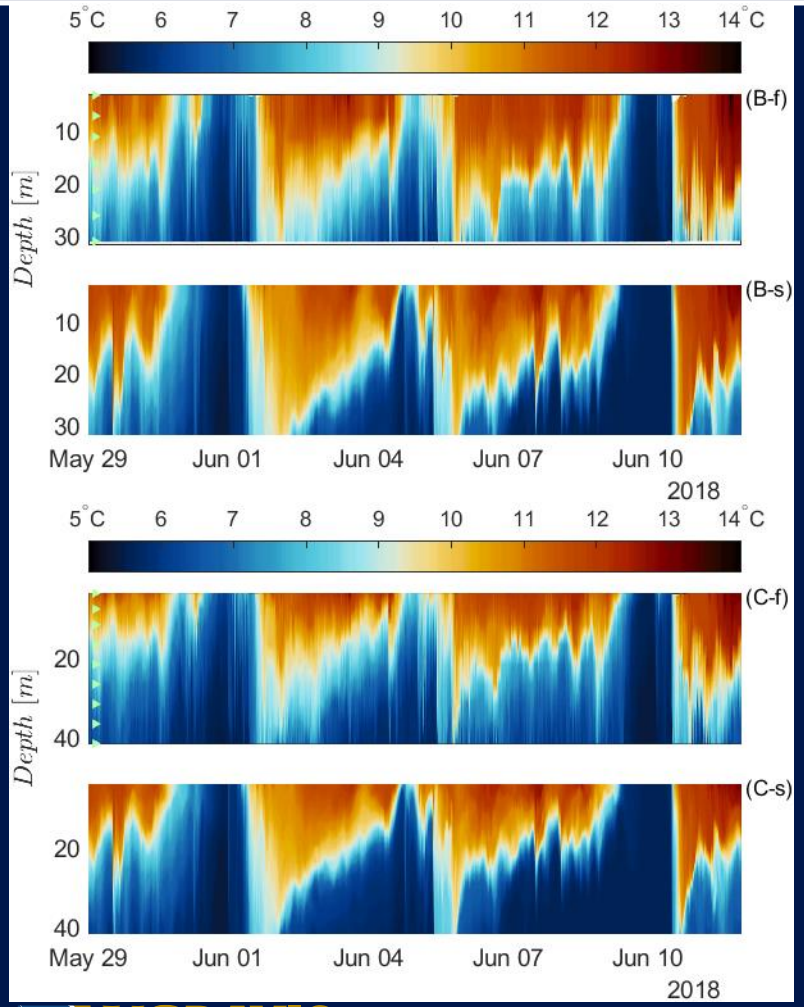
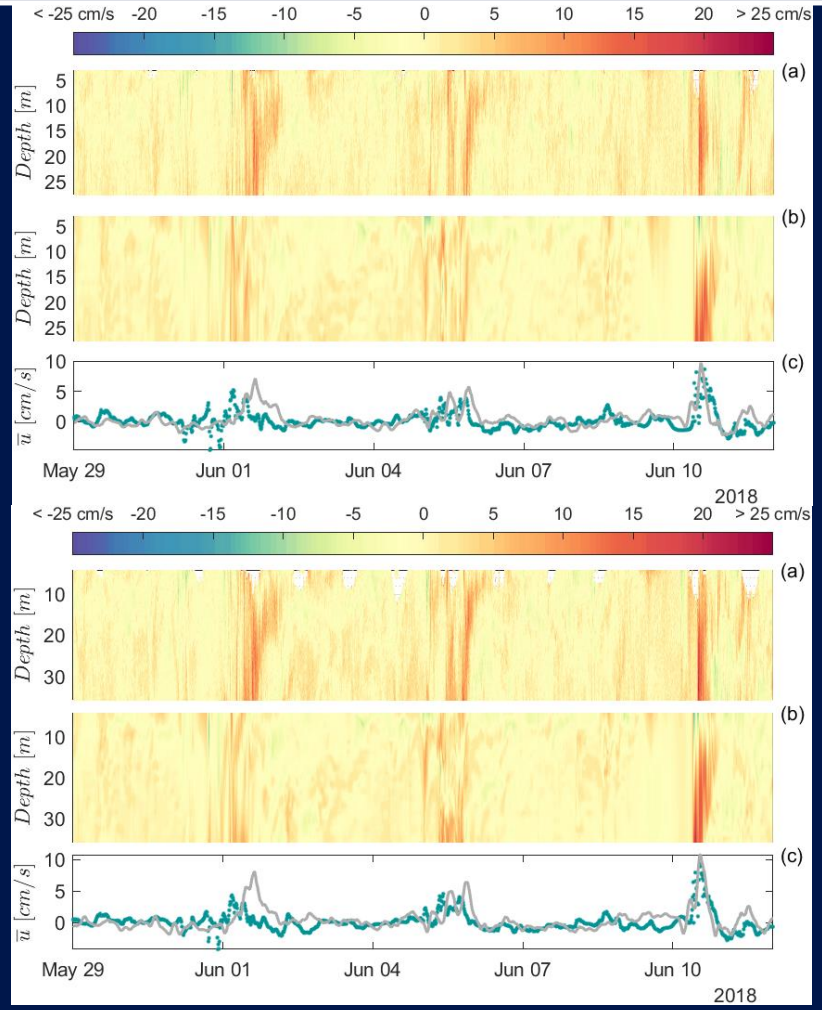
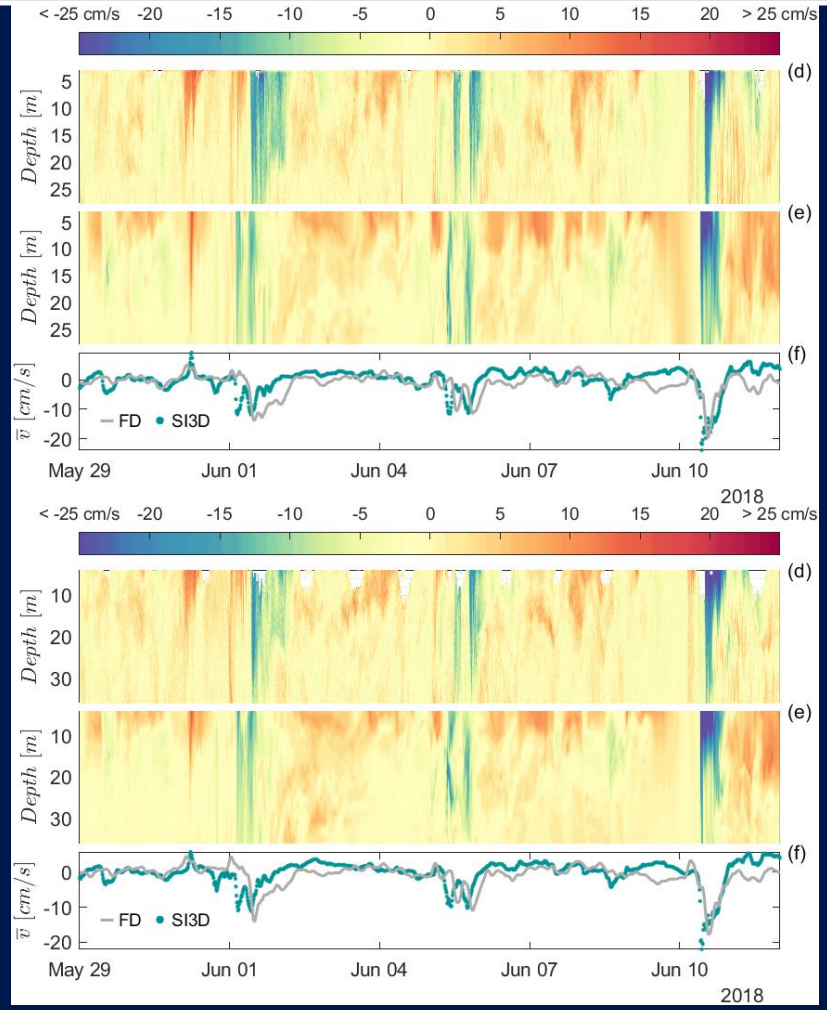
Lake Tahoe Model Validation







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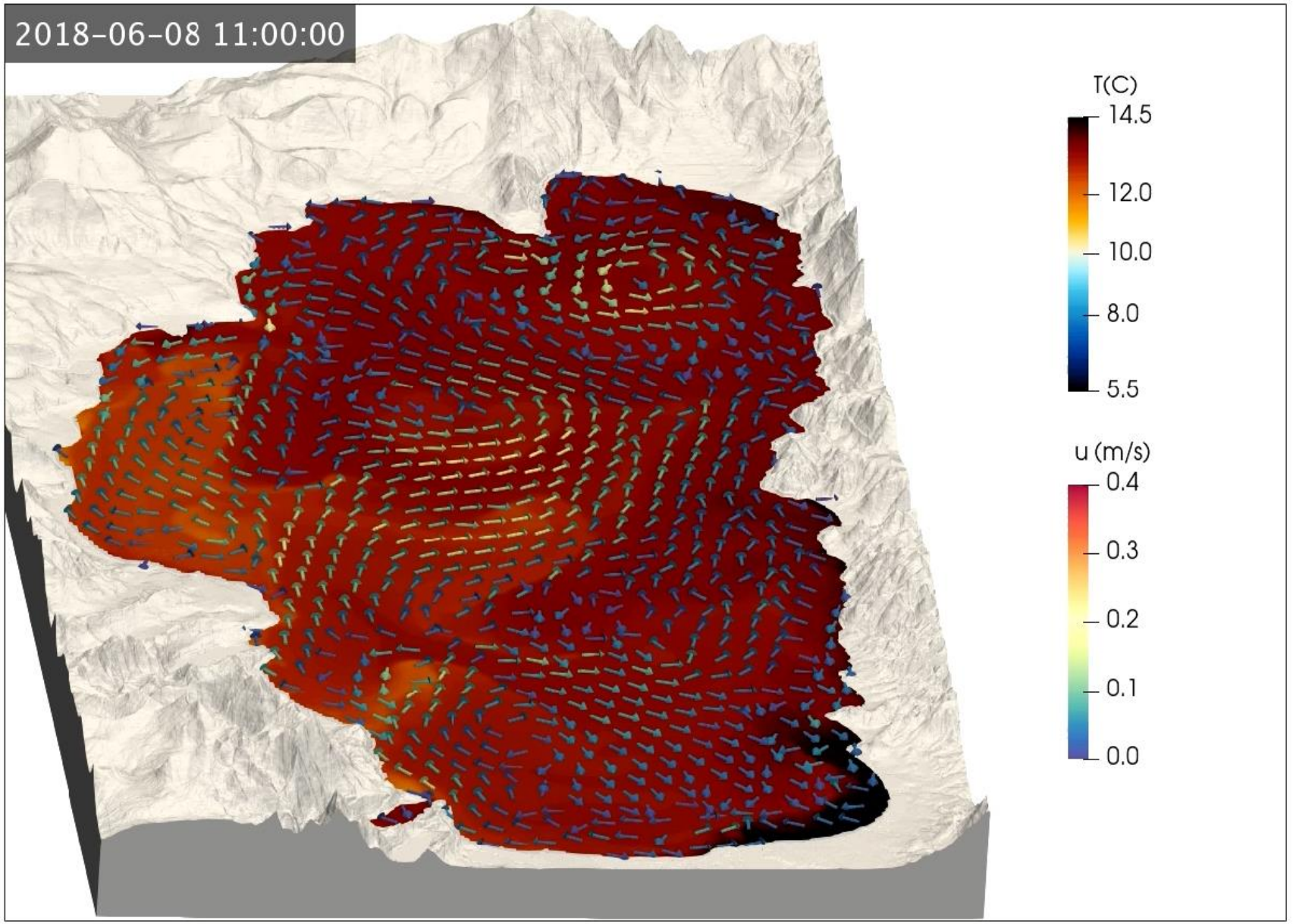
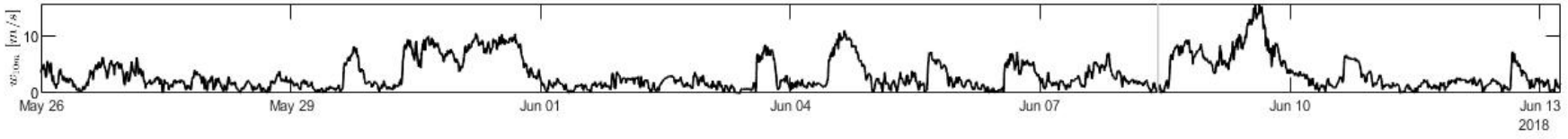
Extracted from Valbuena et al. (2022)

Model Output





- Coastal jet formation from bathymetric influences
- Anti-cyclonic gyre formation
- Velocity and temperature predictions

Lake Massawippi Model

- $\Delta t = 10\ s$
- $\Delta x = \Delta y = 50\ m$
- $\Delta z = 1\ m$
- $cd = 0.002$
- Horizontal and vertical turbulence closure models
- 30 days simulated in summer 2019
- 100 runs were processed to minimize the uncertainty and error

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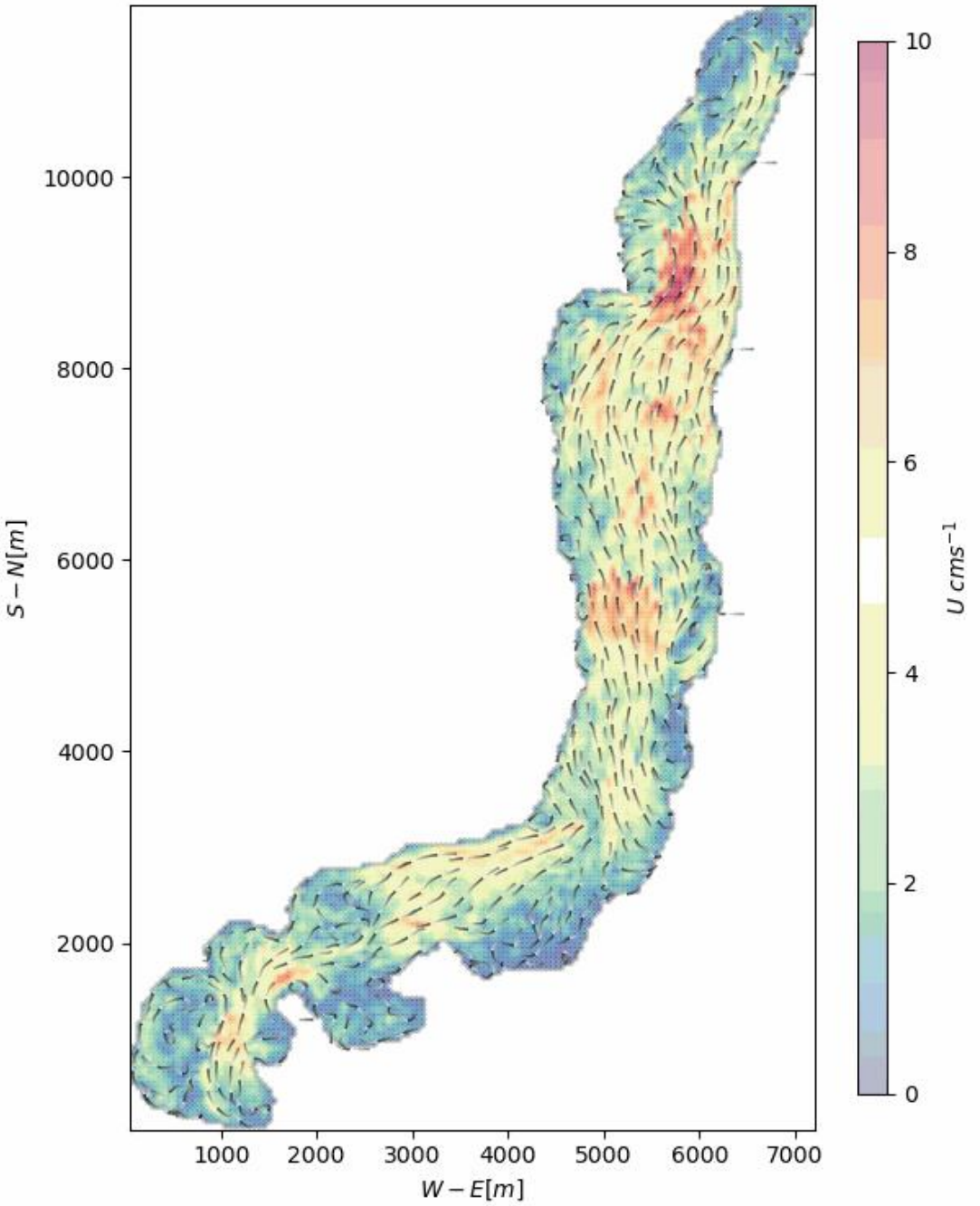
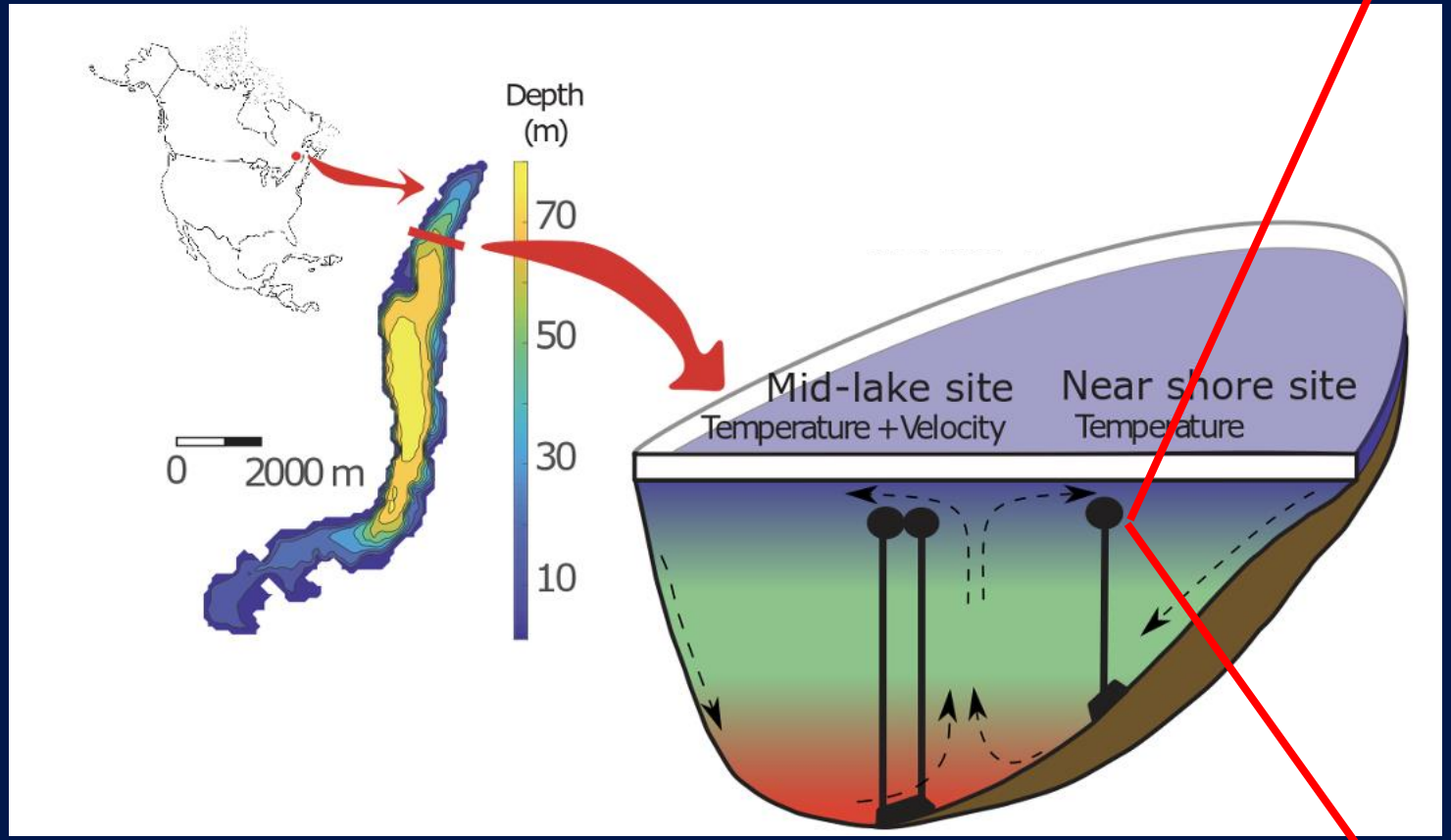


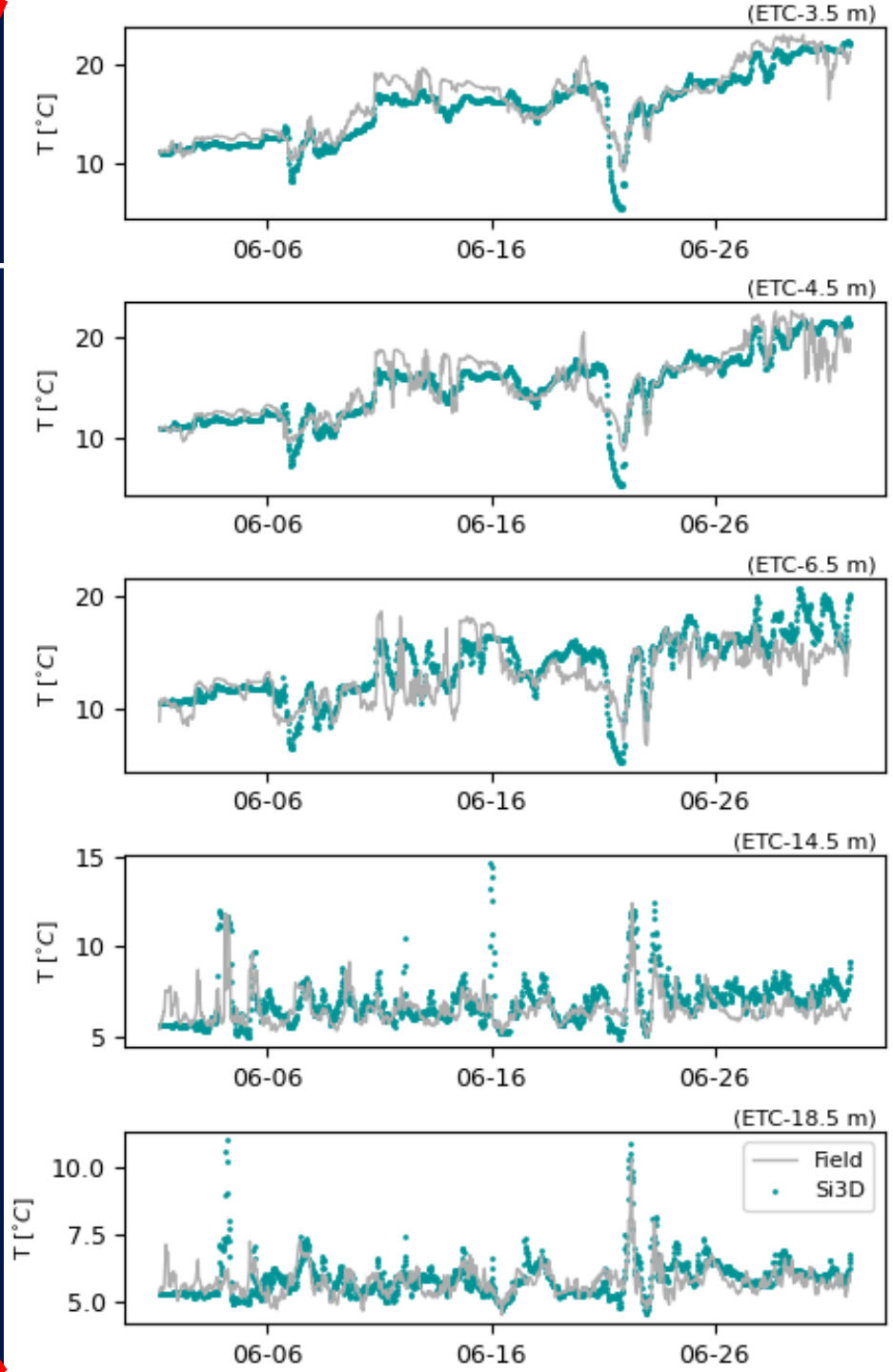
Model Inputs for Lake Massawippi


Meteorological station – Lake Massawippi (Lacey, 2018)

- Meteorological data
  - Station located in North Hatley
  - Data gaps filled from the Sherbrooke Airport
- Initial condition for temperature
  - Temperature profile extracted from thermistor chain 2019 deployment
- Initial condition for velocity follows:
  - $u = v = w = 0$
- Initial conditions are why spin-up time is always required for Si3D

Si3D Validation – June 2019





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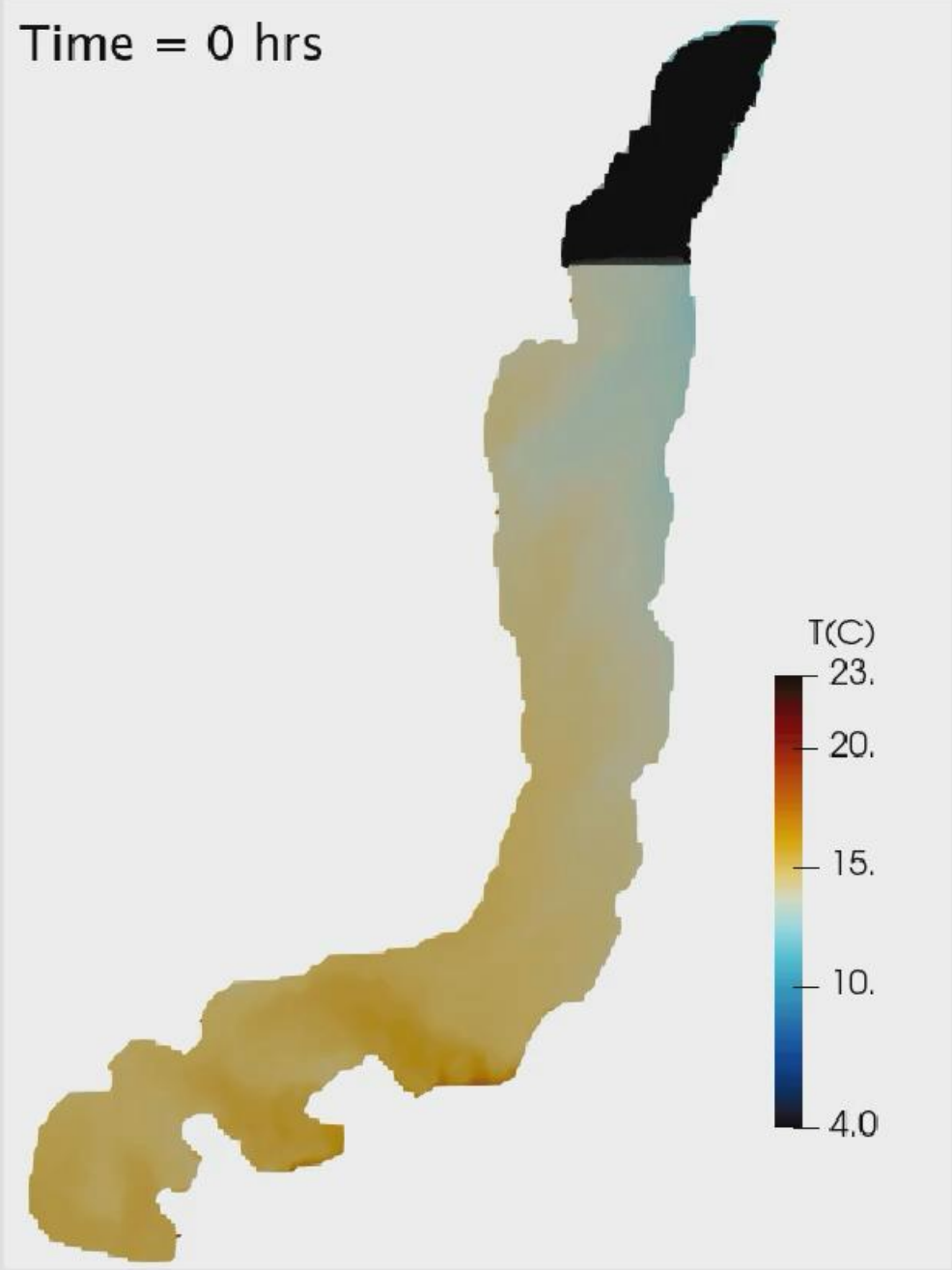
Measures of Model Effectiveness

- Model provides good representation of the temperature measurements and dynamics in the water column. Including the passage of a cold front on the mixed layer at the Eastern thermistor chain
- Validation for temperature shows $RMSE = 1.51\ ^{\circ}C$ for the East thermistor chain and $RMSE = 1.21\ ^{\circ}C$ for the West thermistor chain
- Comparable to other research studies such as Valbuena et al. (2022) and Valipour et al. (2019).
- Velocity measurements during the simulated period of interest did not allow validation of the numerical velocity results

Particle Tracking Model

- Seed the model with neutral, non-sticky particles at the northern end
- See a slow, southward migration down the west shore
- Large events drive episodes of significant transport
- Need to have further field data to validate central and southern regions of the lake
- Need to have more detailed meteorological data



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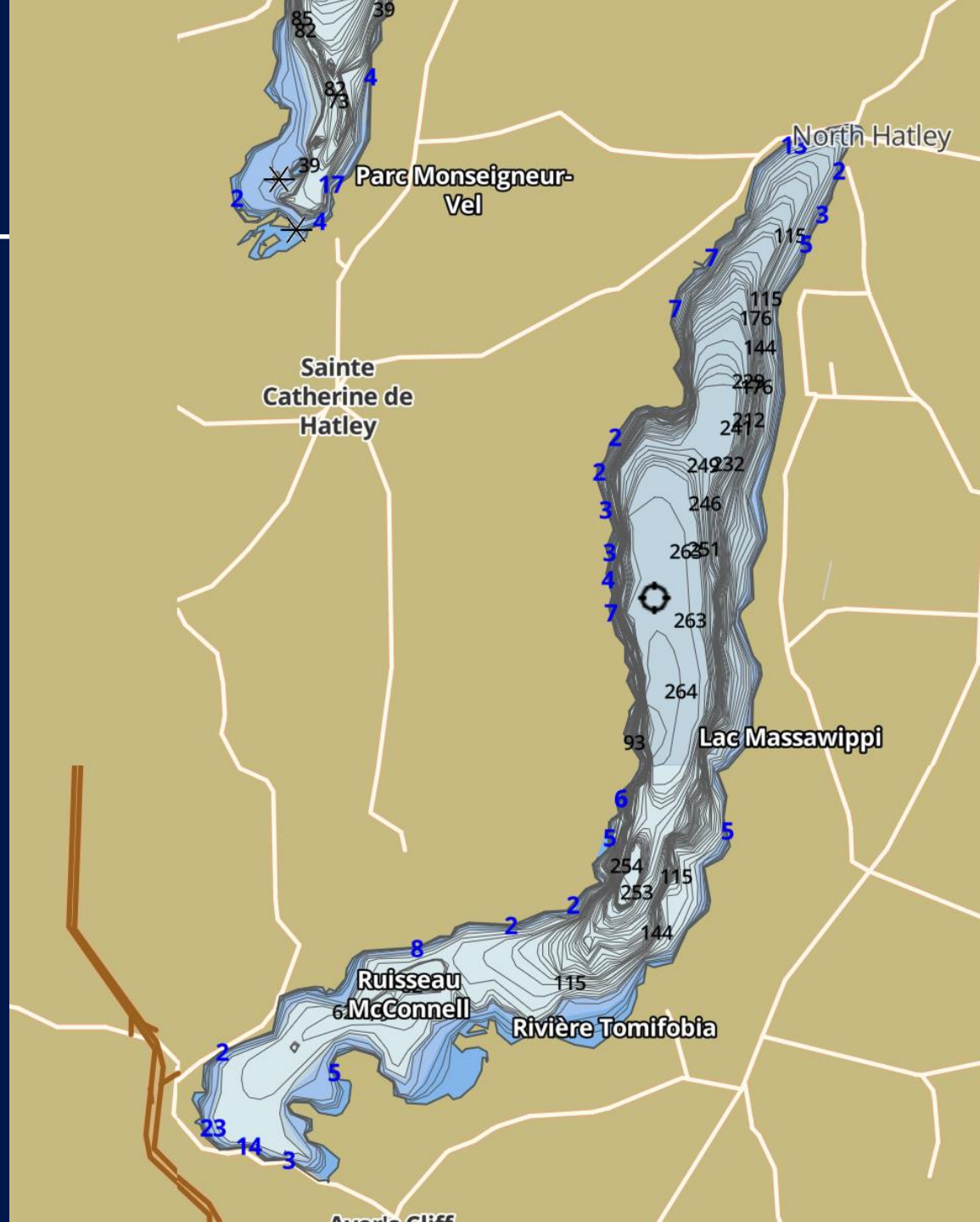
Bathymetry for Models

- Finer grid size in the numerical model requires finer bathymetry
- Current bathymetry is 100-200 m but lake model uses 50 m for grid size
- Hydrodynamics in the E-W direction finer grid size can be implemented with a finer bathymetry



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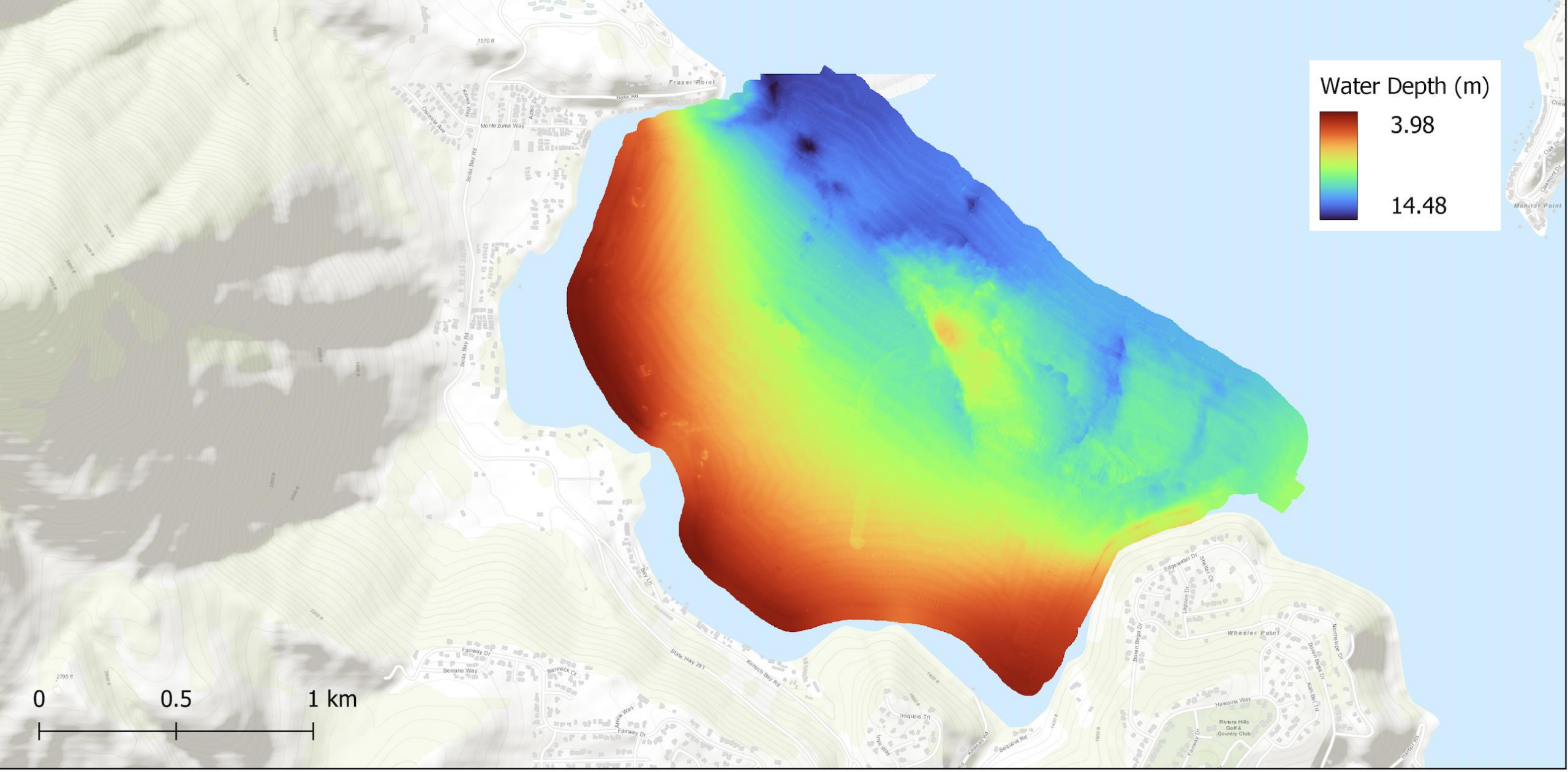
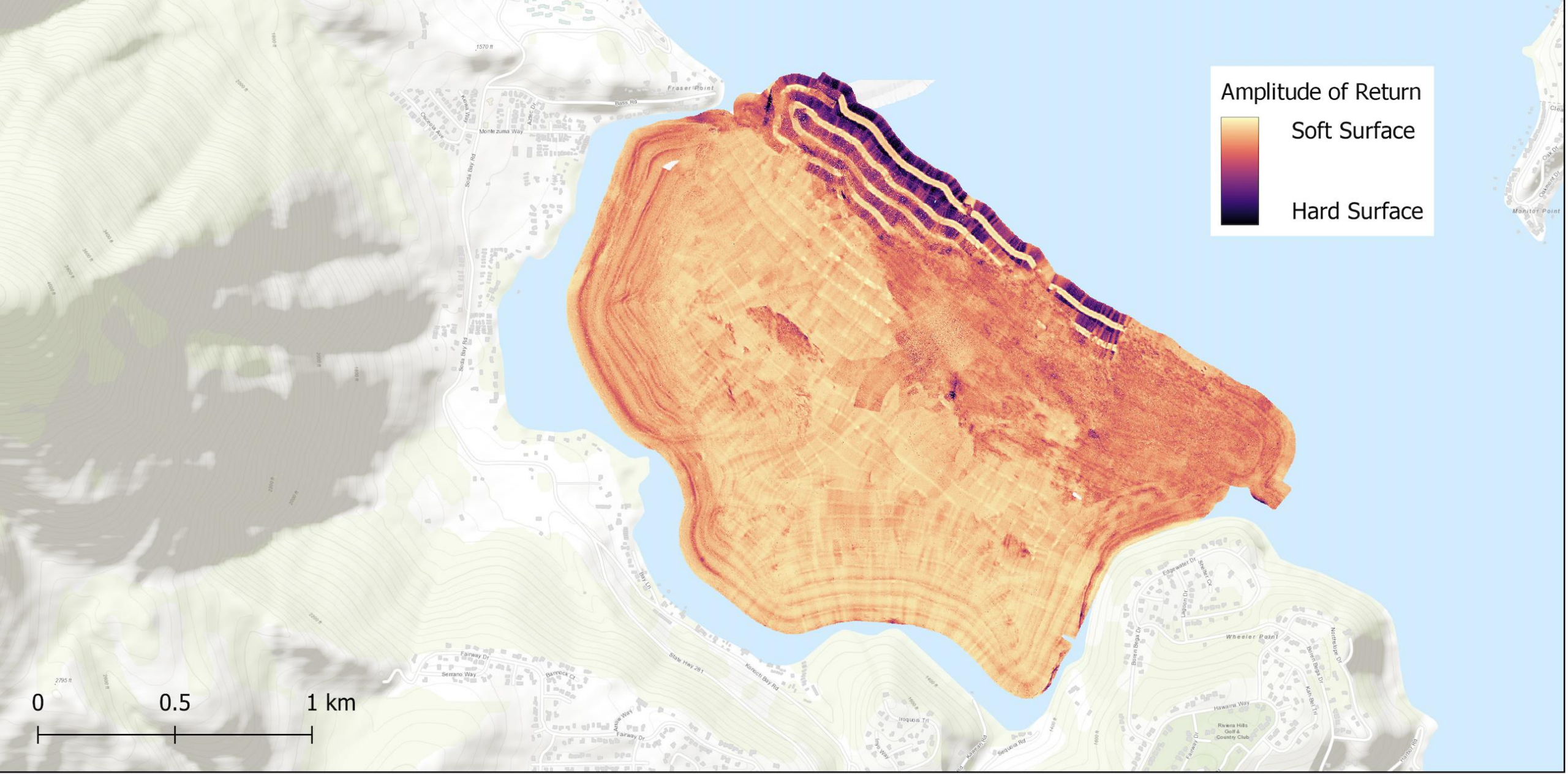


Konocti Bay Bathymetry, Clear Lake, CA

CRS: EPSG:4326 (WGS 84)

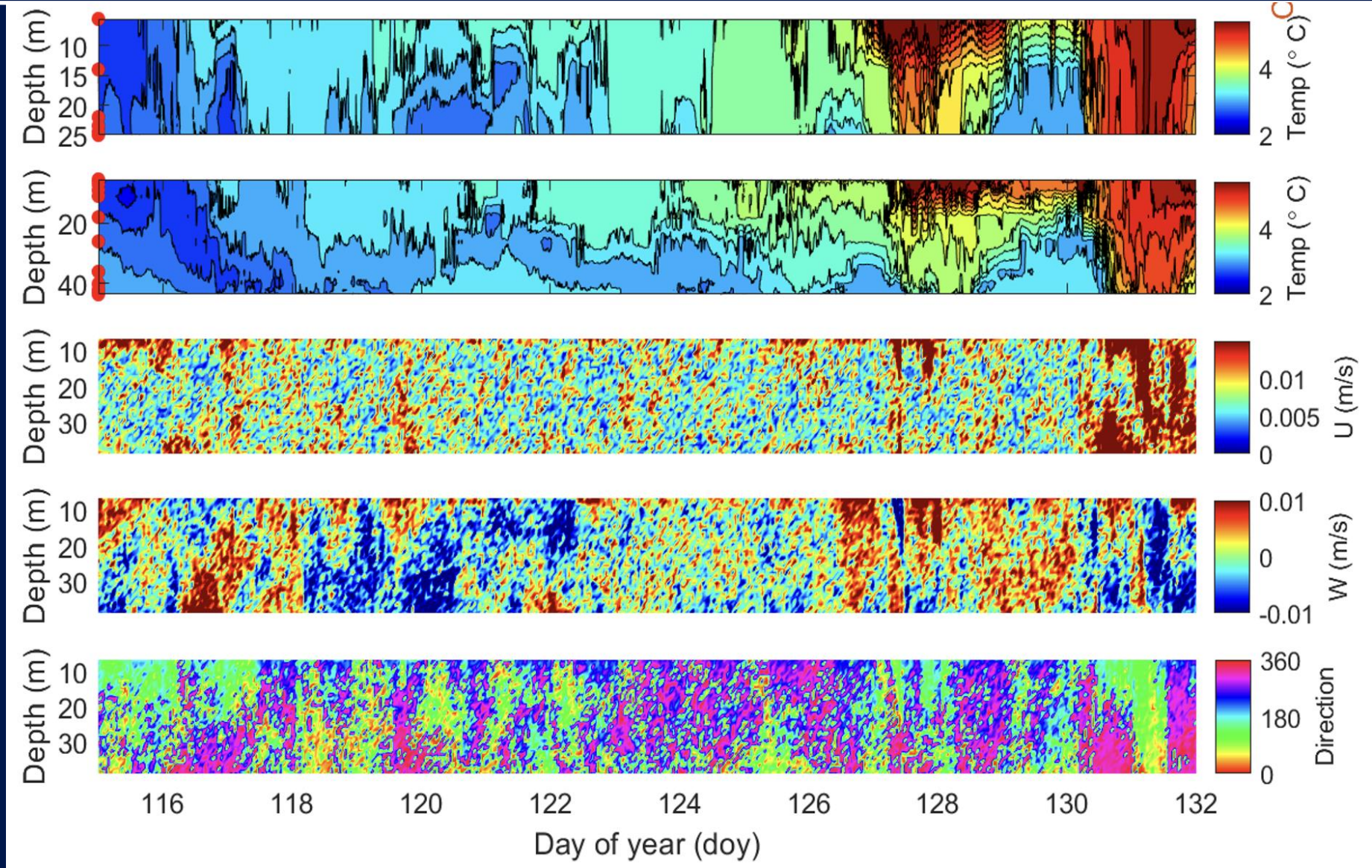


Konocti Bay Side-scan Sonar, Clear Lake, CA

CRS: EPSG:4326 (WGS 84)

Seasonal Ice Modeling

- Calibration and validation for multiple seasons in Lake Massawippi
- Data for velocity and temperature at different locations



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Further Lake Model Improvements

- Data for meteorological forcing with more frequent sampling
- Development of ice module for Si3D to study seasonality in the flow dynamics and year-round hydrodynamics that control the ecology in the lake
- Development of spatially-variable bottom drag coefficient

Conclusions

- Numerical models are a tool to target efforts to control zebra mussels
- Need to refine tools using observations techniques
- Success is possible but *continuous* monitoring is required

https://steinw.com/missionlake

Questions?