



# Drones, Satellites, & Climate

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Brown University  
Earth, Environmental, & Planetary Sciences

2nd C-AIM Brown Bag Seminar. June 10, 2021, 12-12:45

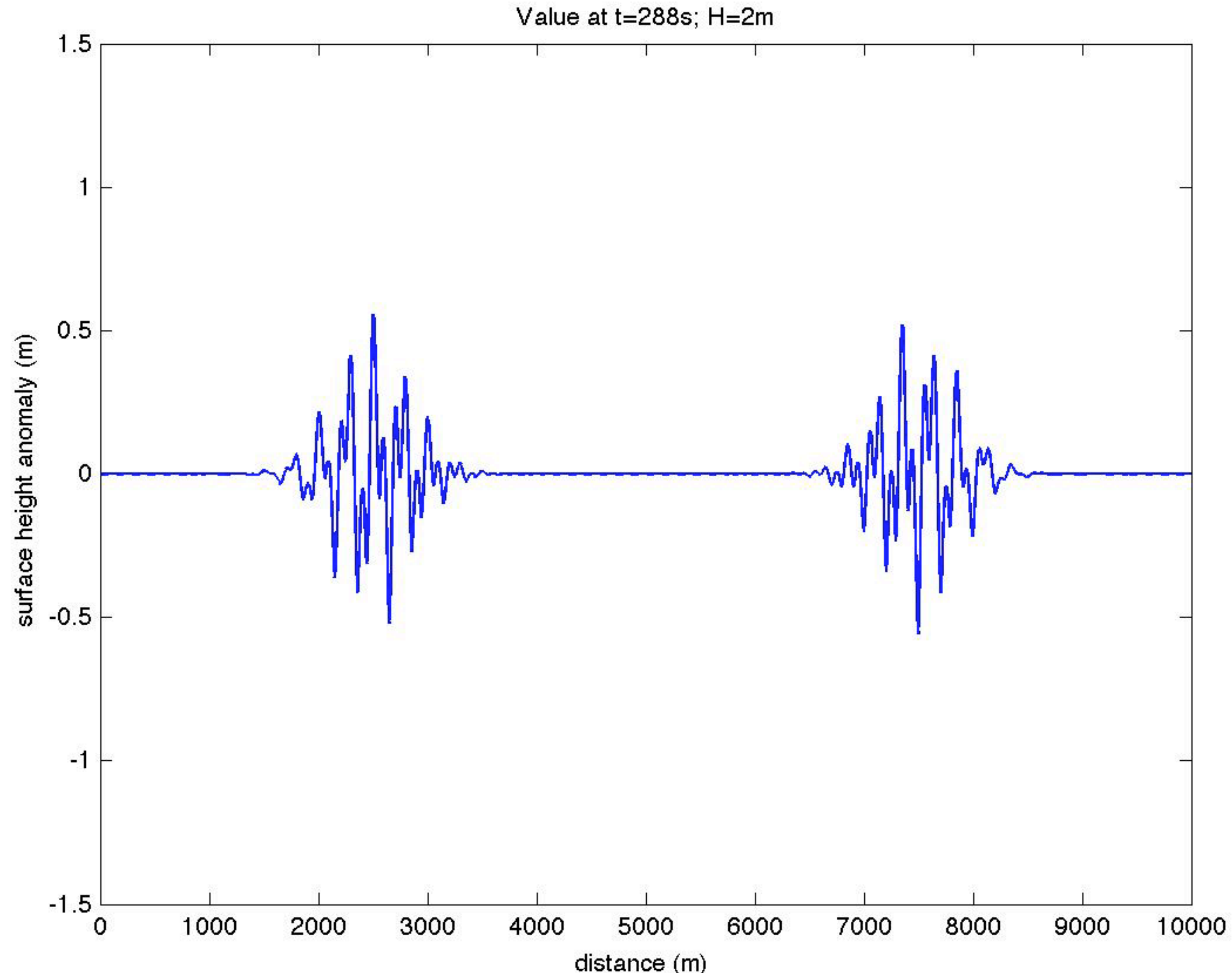


# Some Undergraduate Projects in My Group

- Currents from Drones
  - Seth Wojciechowski w/ Matt Cecchini & Danny Cruz (URI)
- Satellites (Landsat SST in Narragansett Bay)
  - Jonny Benoit (SST), Alice Foster (buoys), Austin Smith (Chl) (Brown)
- Climate
  - John Nicklas, Galen Hall, Patrick Orenstein, Hannah Kolus, Mara Freilich, Ana Ordonez,

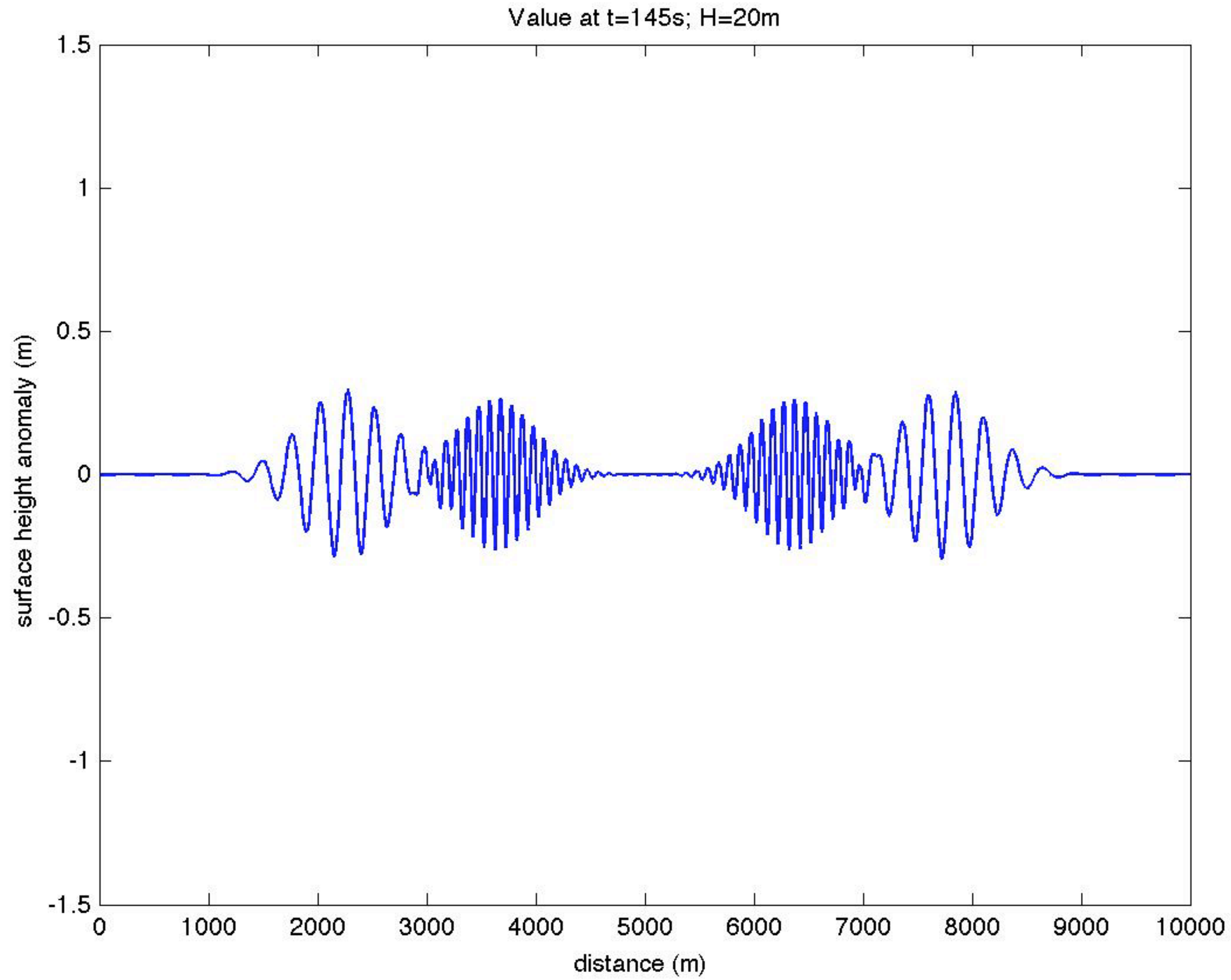


Here are some surface gravity waves of two different wavelengths in shallow water ( $kH=0.05, 0.12$ )



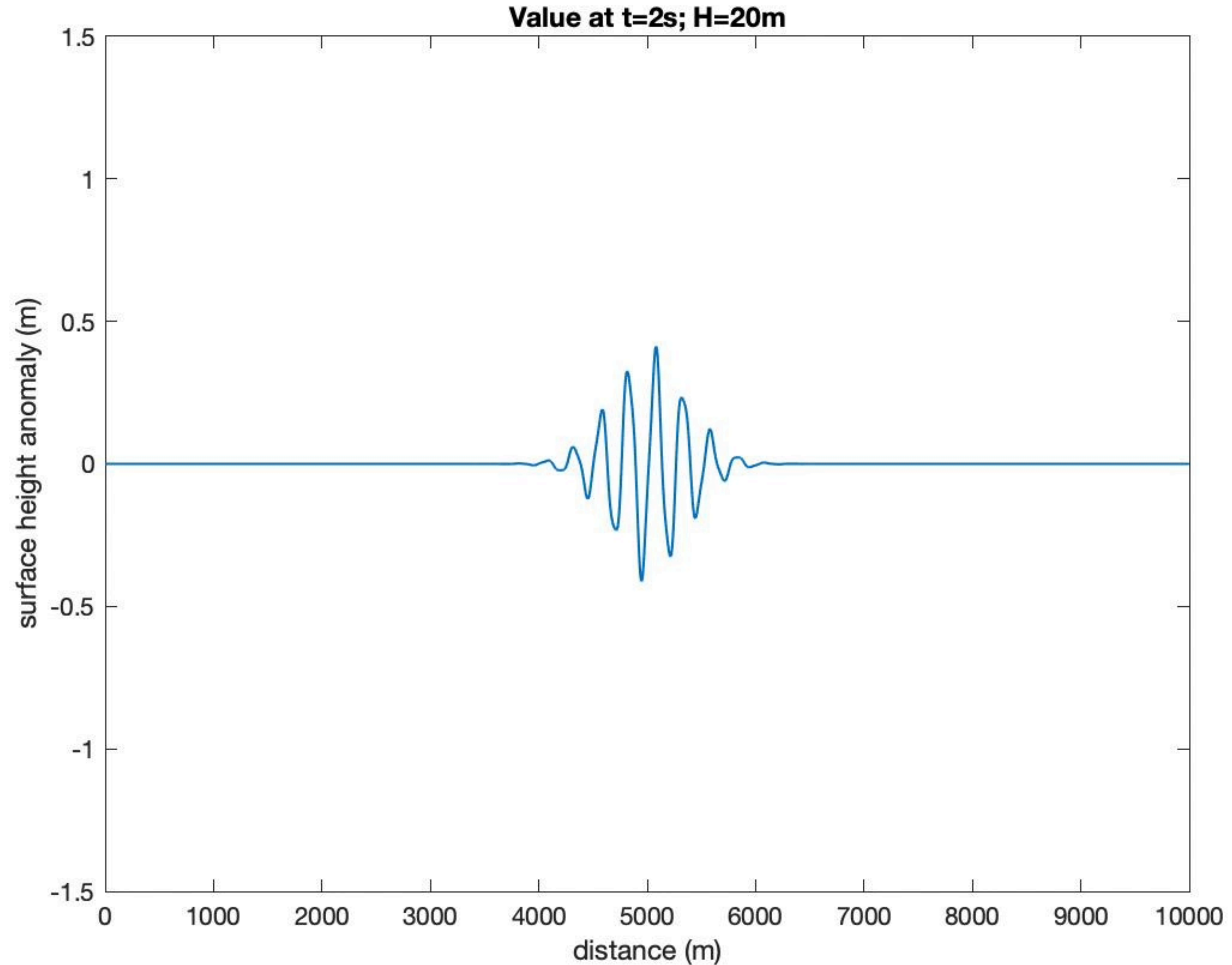


Here is a the same packet of gravity waves of two different wavelengths in deep water ( $kH=0.5, 1.2$ )





Here is a the same packet of gravity waves of two different wavelengths in deep water ( $kH=0.5, 1.2$ ), with current added

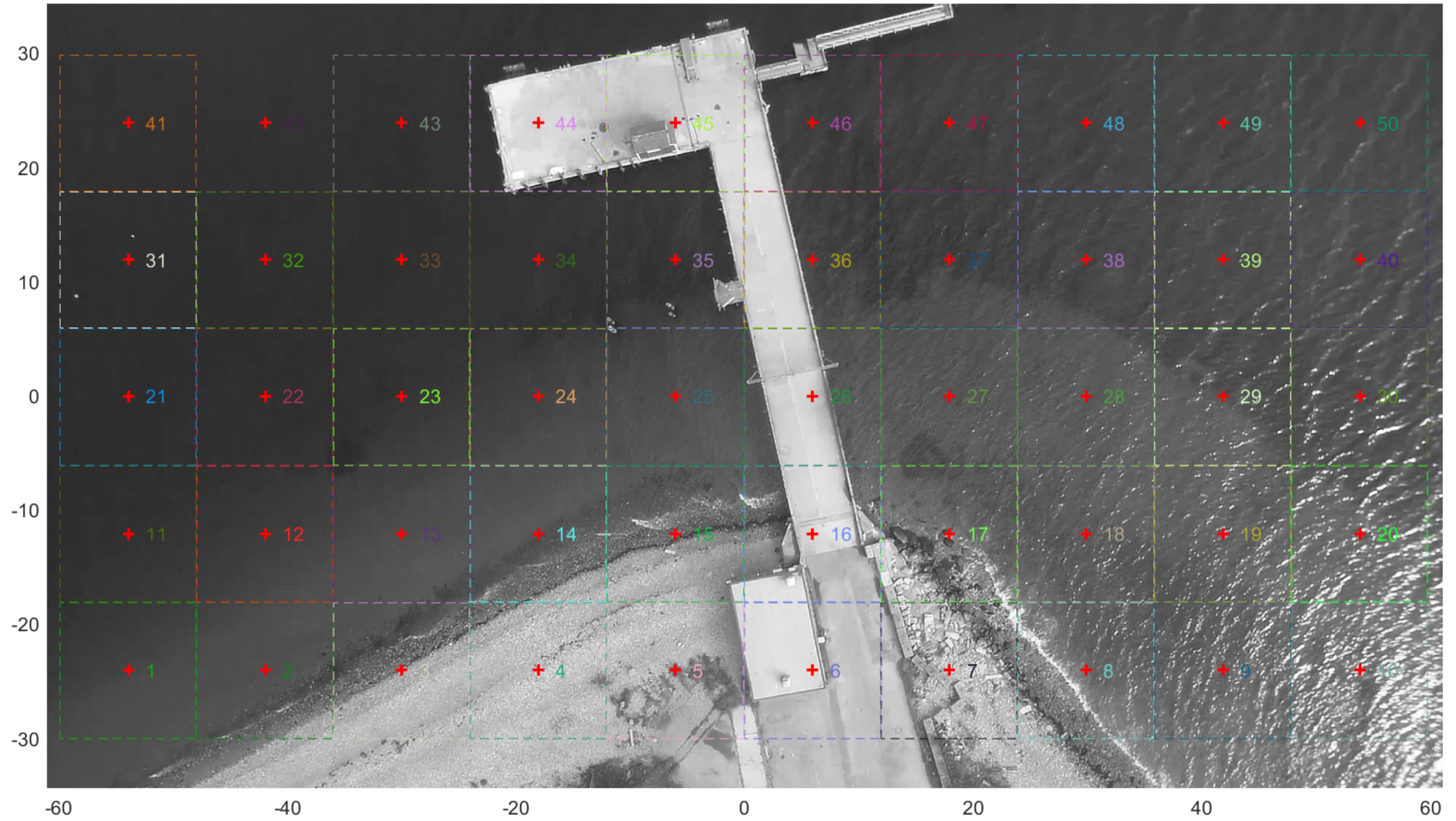




Orientation to North: 0 [deg]. date: 12:00 AM



Seth  
SURF  
2020









Chris Horvat  
Brown University  
<http://enduringice.com>



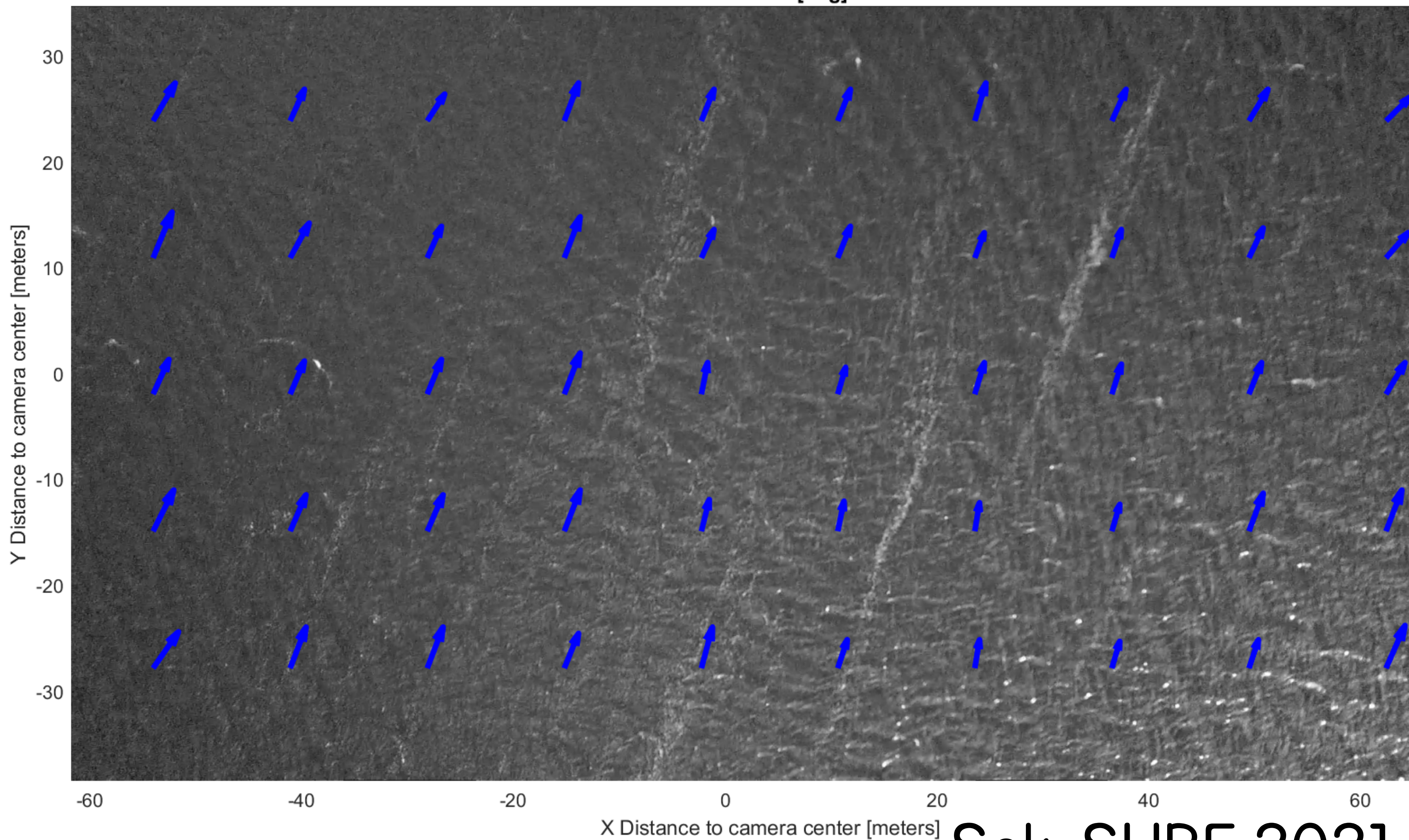
# ENDURING ICE

[THE PROJECT](#) [THE DOCUMENTARY FILM](#) [MORE](#)





Orientation to North: 116.9 [deg]. date: 12:00 AM



Sok, SURF 2021



# Some Undergraduate Projects in My Group

- Satellites (Landsat SST in Narragansett Bay)
- Jonny Benoit (SST), Austin Smith (Chl) (Brown)

J. Benoit and B. Fox-Kemper. Contextualizing thermal effluent impacts in Narragansett Bay using Landsat-derived surface temperature. *Frontiers in Marine Science: Marine Pollution*, May 2021. Submitted.

<http://www.geo.brown.edu/research/Fox-Kemper/pubs/pdfs/BenoitFox-Kemper2021.pdf>

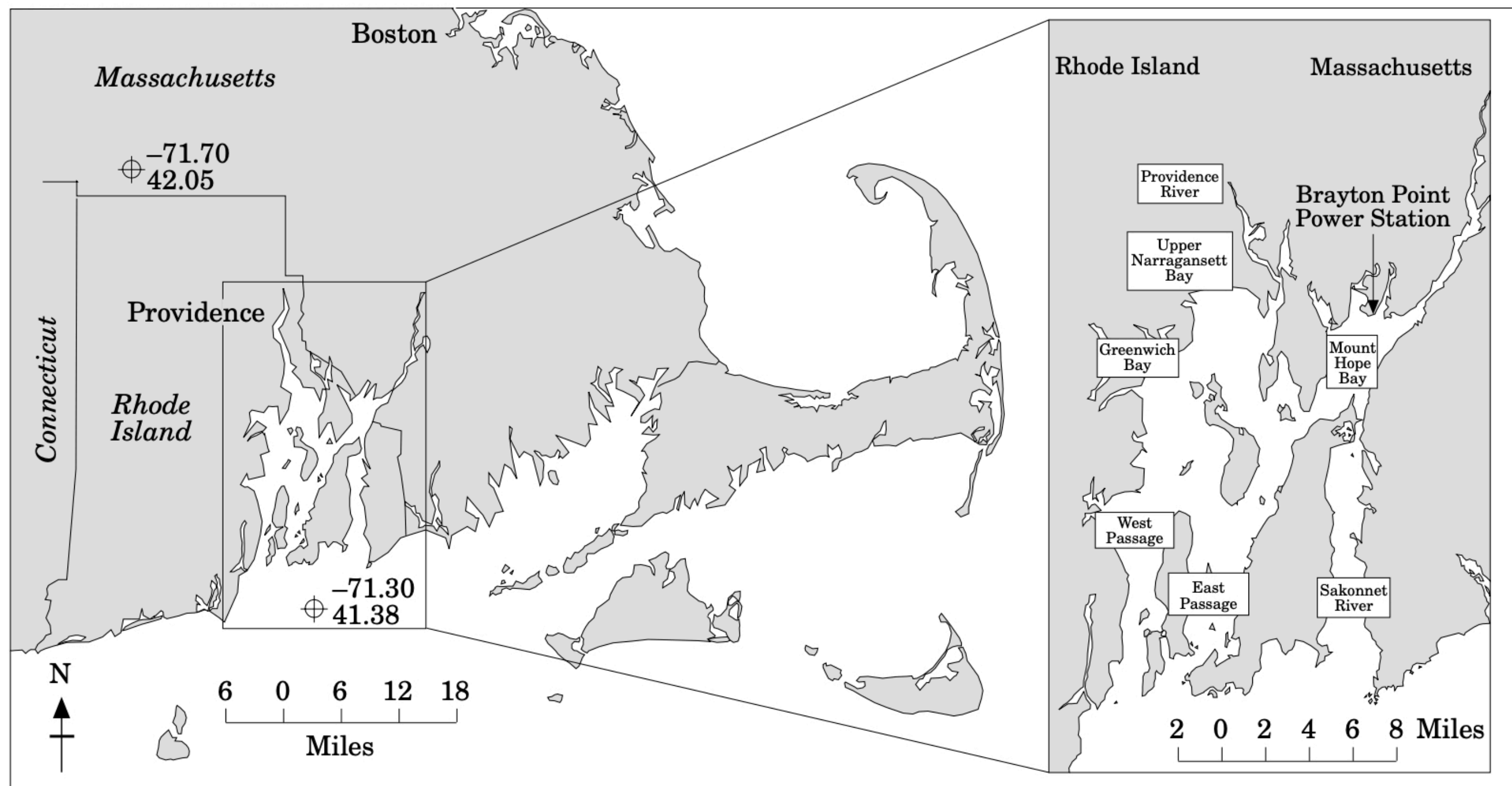


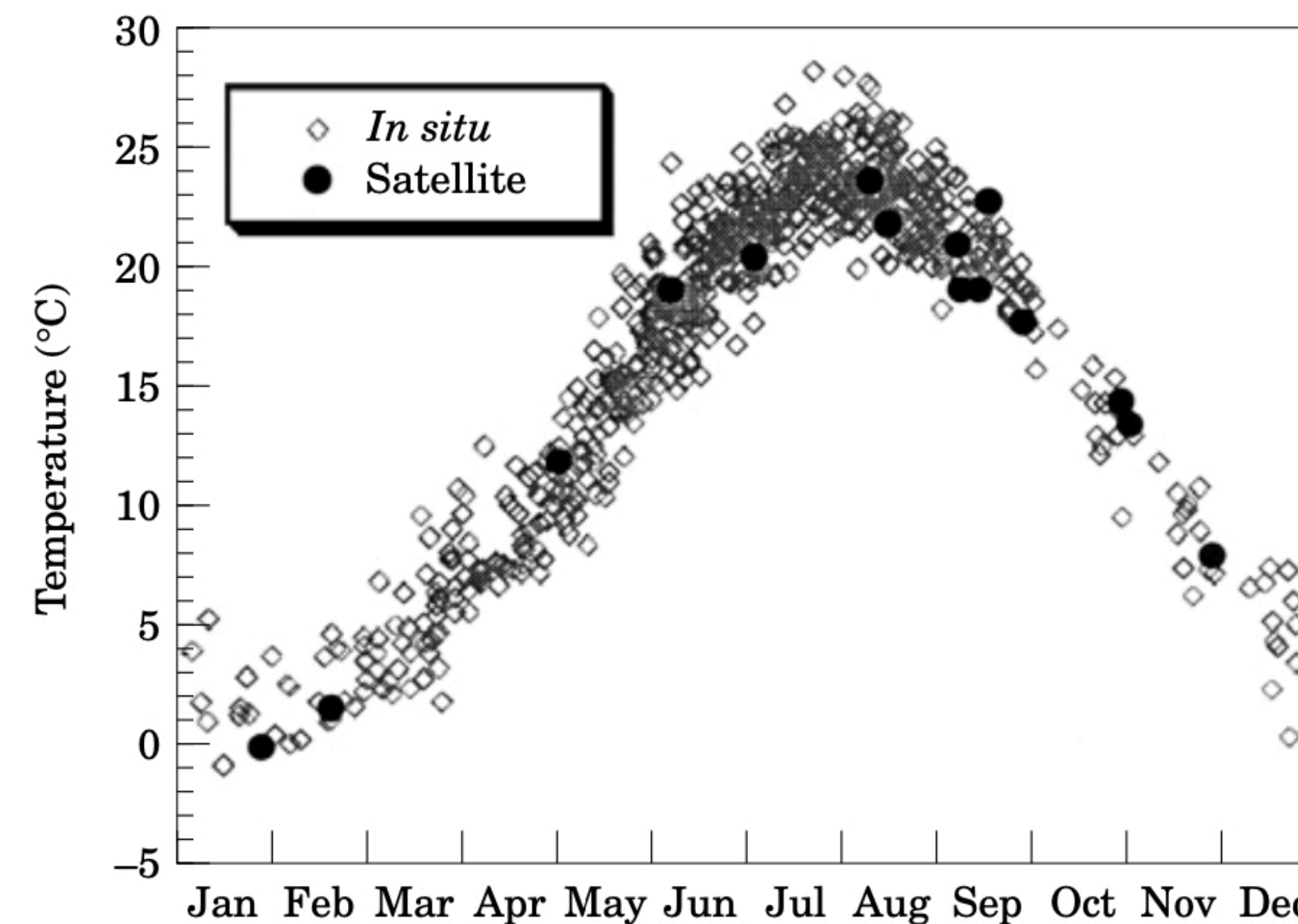
FIGURE 1. Location of the study area. Narragansett Bay is largely within the state of Rhode Island, although Mount Hope Bay and the Brayton Point Power Station are within the state of Massachusetts.



Video credit: @CoreyWelch

# Mustard *et al.* 1999

A classic paper from Brown DEEPS,  
 Illustrating that Mt Hope Bay is  
 anomalous.



site of satellite derived temperatures, covering the period 1984–1996

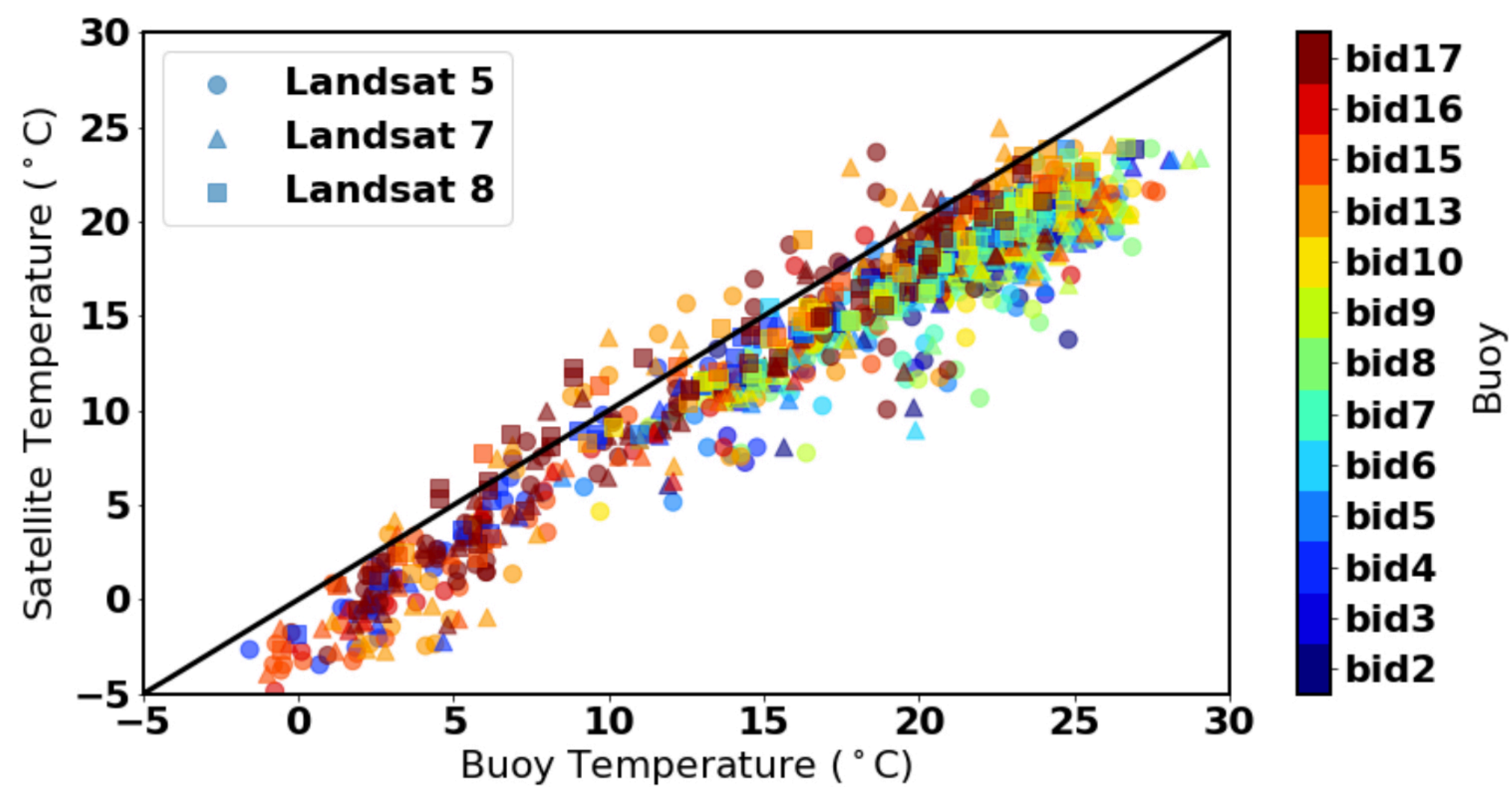


# As a SURF, Jonny had been working with buoys in the bay...



- Jonny had figured out how to access a variety of buoy data in the bay and nearby, from DEM & NDBC websites
- He and Alice Foster had been working on cleaning the data, sometimes with machine learning approaches
- Jonny also did the C-AIM Vis-A-Thon, converting the buoy data into music (<https://vimeo.com/513231285>)

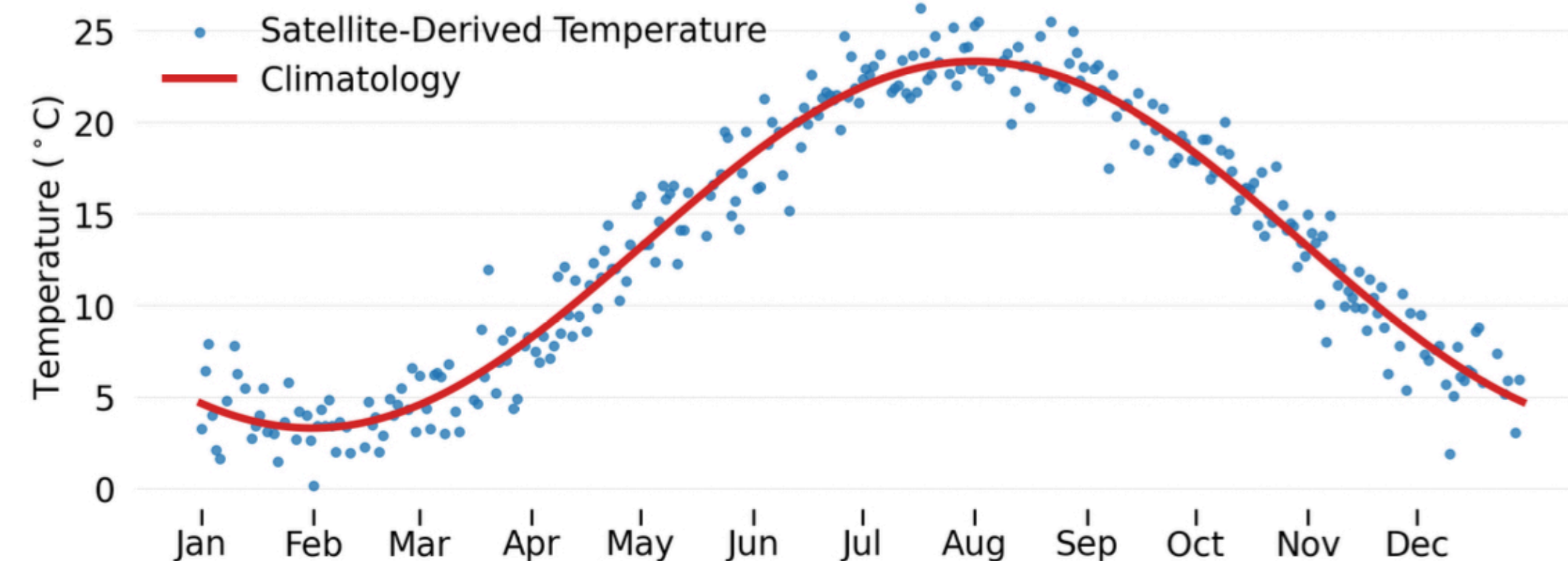
Then, Jonny took Jack Mustard's Remote Sensing Class, and Karianne Berger's Machine Learning for Earth Sciences class, and...



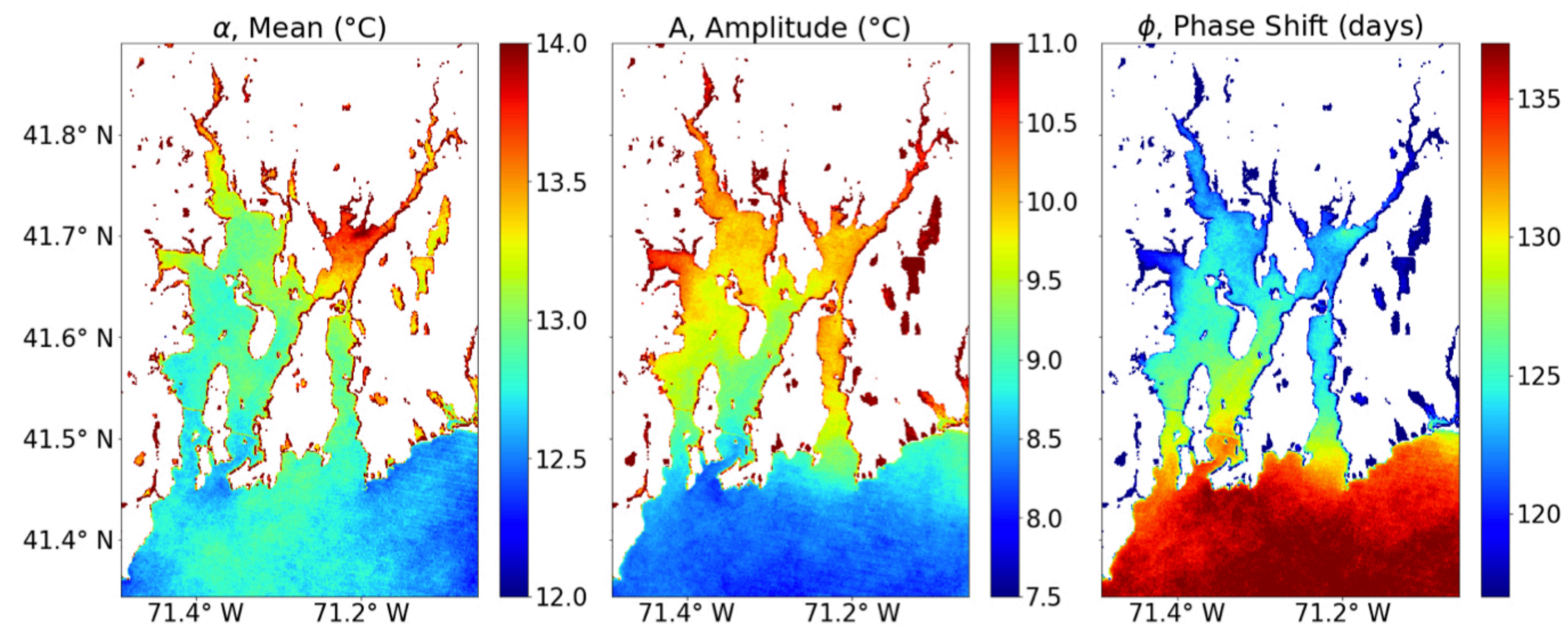
**Figure 2.** Comparison between Landsat-derived temperature and surface *in situ* buoy measurements. The black line represents a 1:1 relationship for reference.

**Benoit and Fox-Kemper**

**Thermal Effluent in Narragansett Bay**



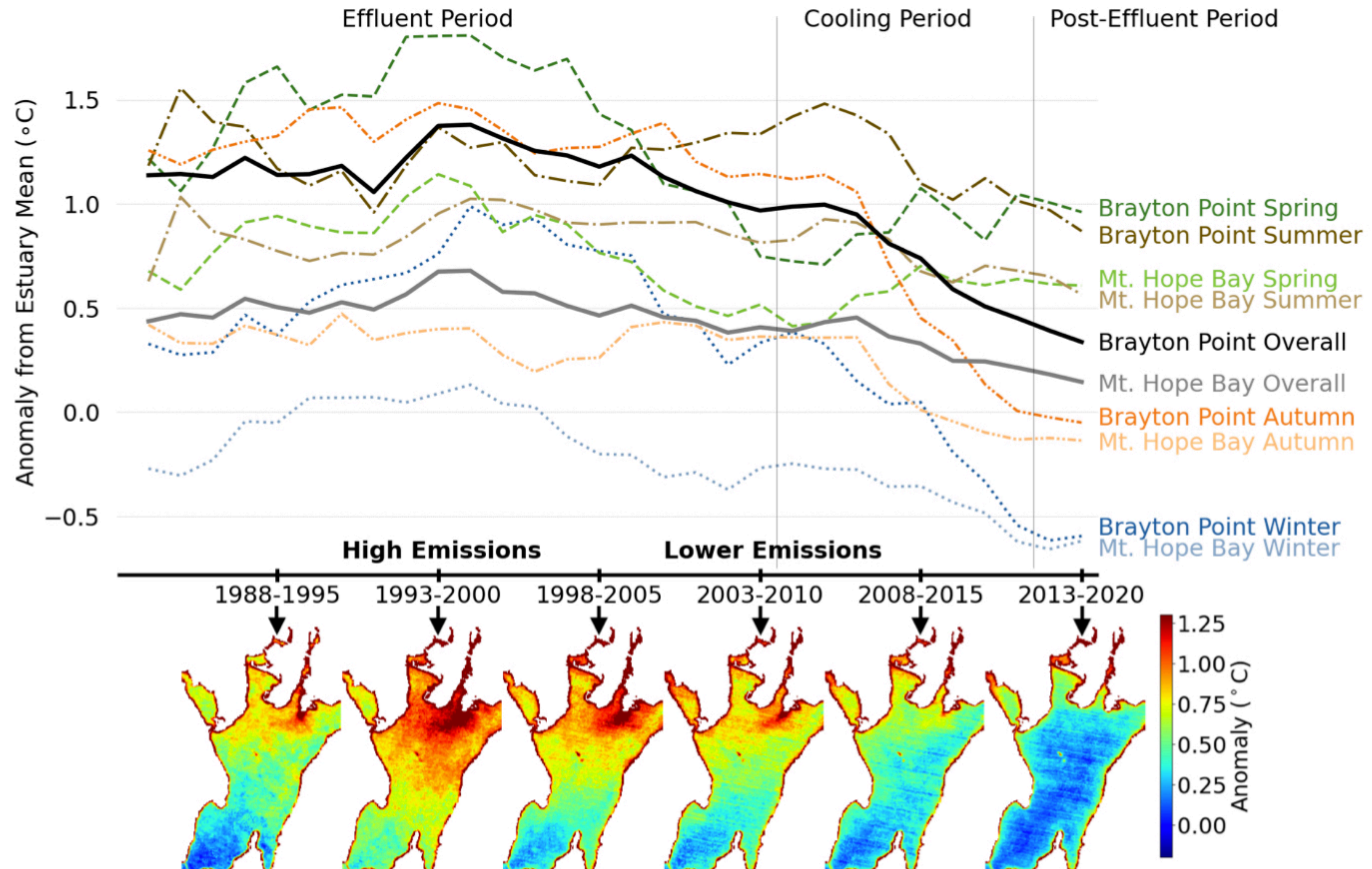
**Figure 4.** Sample climatology for a pixel in Providence River after satellite bias correction.



**Figure 5.** Maps of climatology coefficients as described by Equation 1.2 calculated over 1984-2010. The climatology from the entire observation period (1984-2021) was used to seasonally detrend the data. Here the impact of the BPPS effluent is visible as an increased  $\alpha$  term and decreased  $\phi$  term near Brayton Point, representing greater mean temperature by 1°C or more and a delayed seasonal cycle by up to 4 days.

# Brayton Point Power Station Impact on Mt. Hope Bay

During operation,  
After cooling towers,  
After stopping.

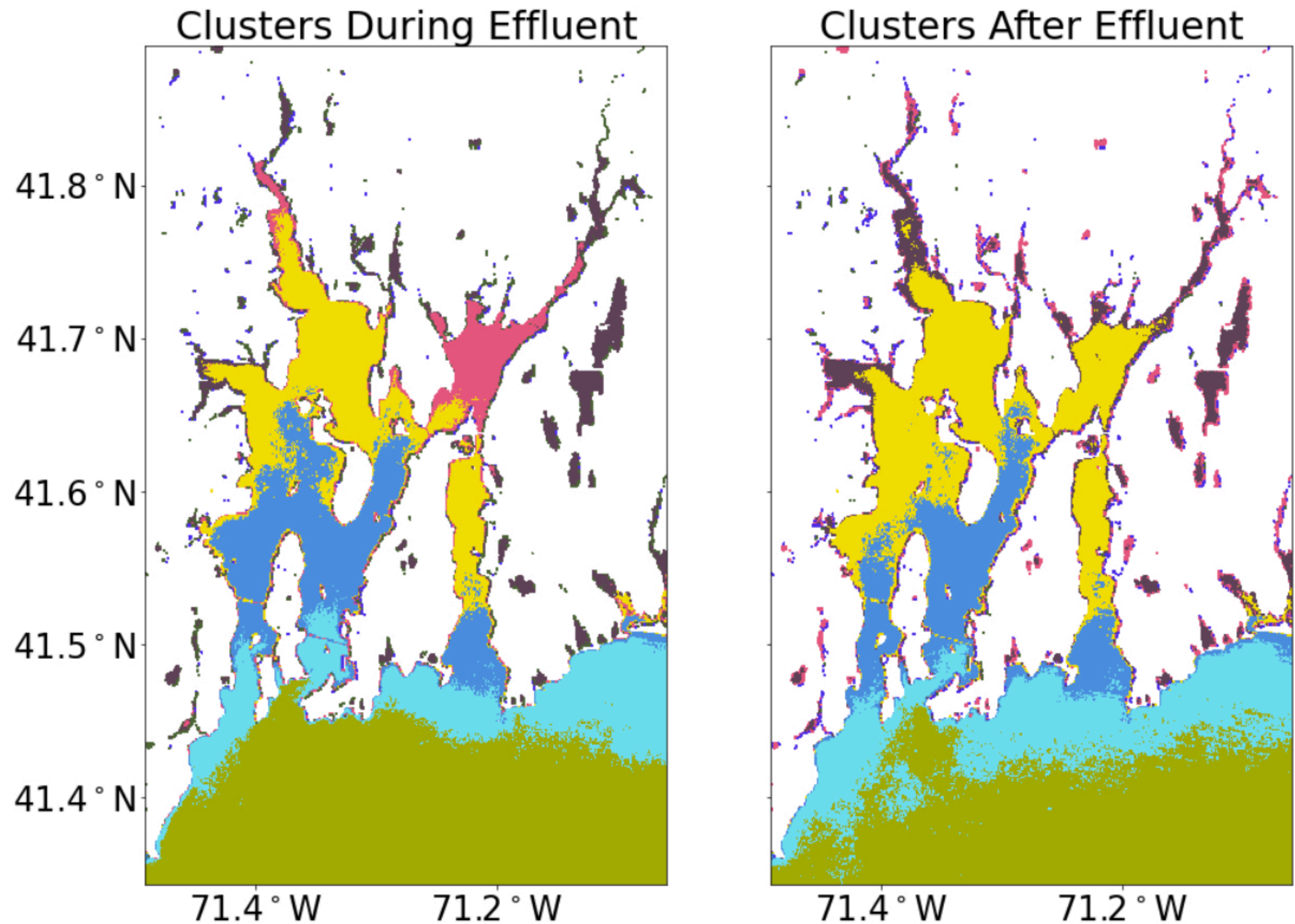


**Figure 6.** Average Mt. Hope Bay and Brayton Point temperature anomaly minus average Narragansett anomaly for each season using an 8-year moving average. The cooling period includes data from during and after effluent release due to the moving average. Plotted below the x-axis are maps of mean temperature anomaly in Mt. Hope Bay as determined by subtracting the mean  $\alpha$  term from Equation 1.2 from the  $\alpha$  values determined at each pixel for the labeled periods.



# Brayton Point Power Station Impact on Mt. Hope Bay

Using unsupervised  
Machine learning  
Pattern recognition.



**Figure 7.** K-means clustering on mean, amplitude, and phase shift coefficients from climatology fitting as described by Equation 1.2 during and after the BPPS effluent.



# Ocean State Ocean Model.....does it work?

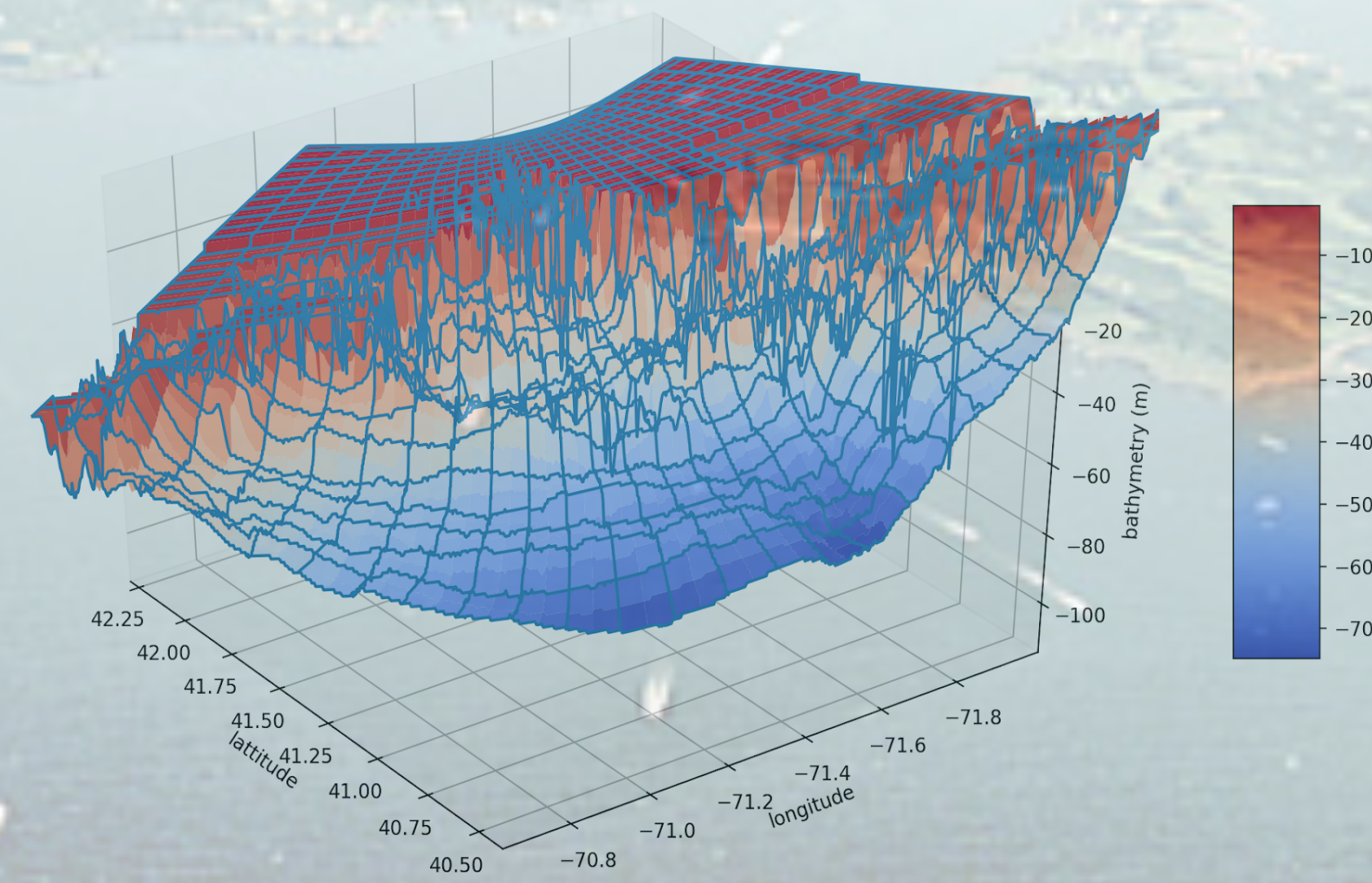
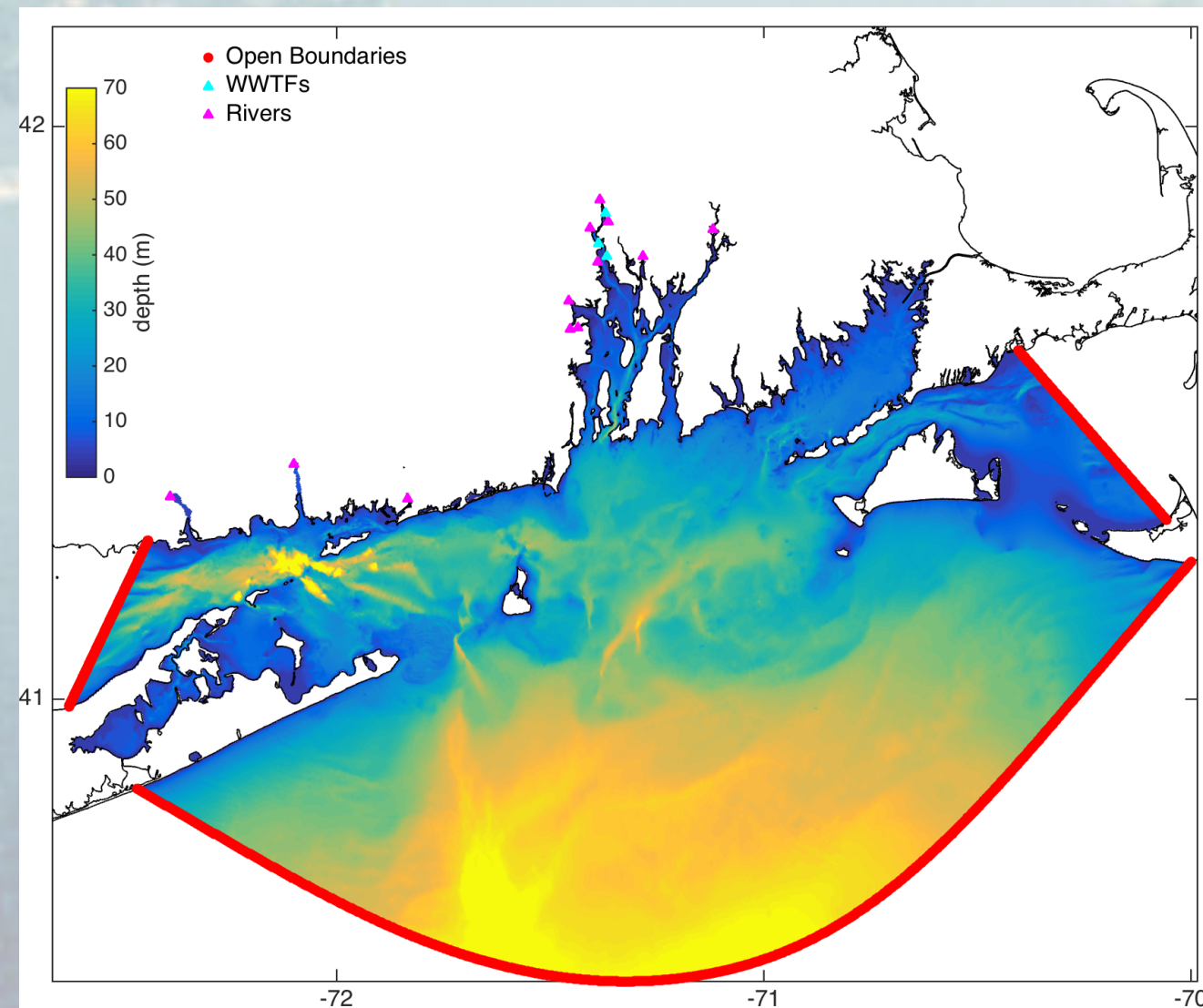
OSOM is:

A collection of physical, chemical, biological rules collected together on a computer.  
Forced by winds, tides, rivers, sun, nutrients, wastewater, etc. from observations and weather/  
climate models.



Predicts: sea level, temperature, salinity, velocity, nitrogen, silicate, carbon, phytoplankton,  
zooplankton, sediments

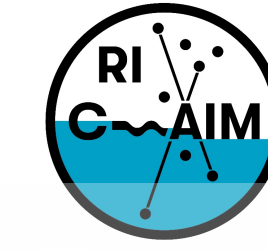
Takes 1 computing day to make a 10 day prediction



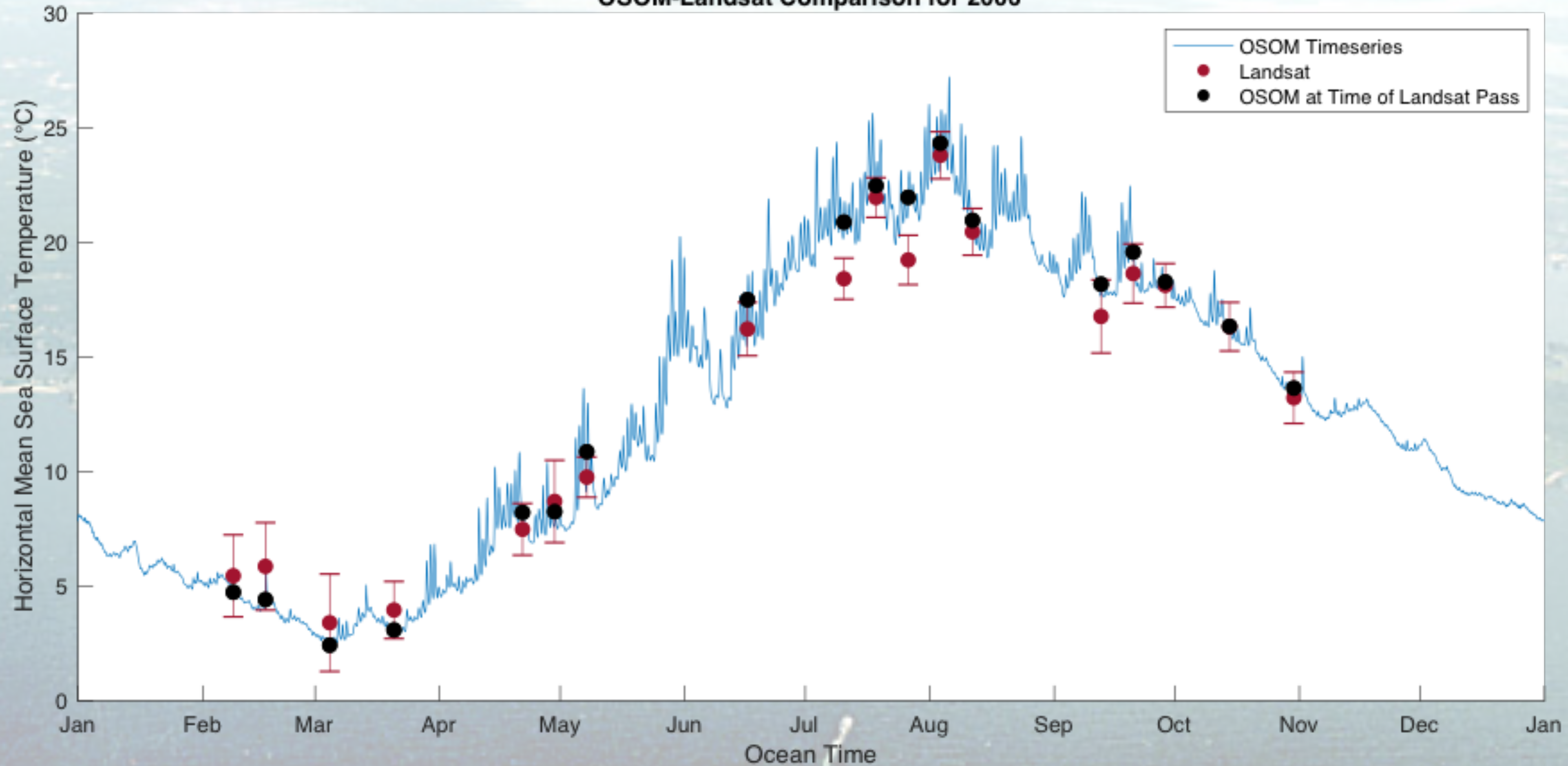
## Present Foci: Nesting, Predictability



# Ocean State Ocean Model.....does it work?

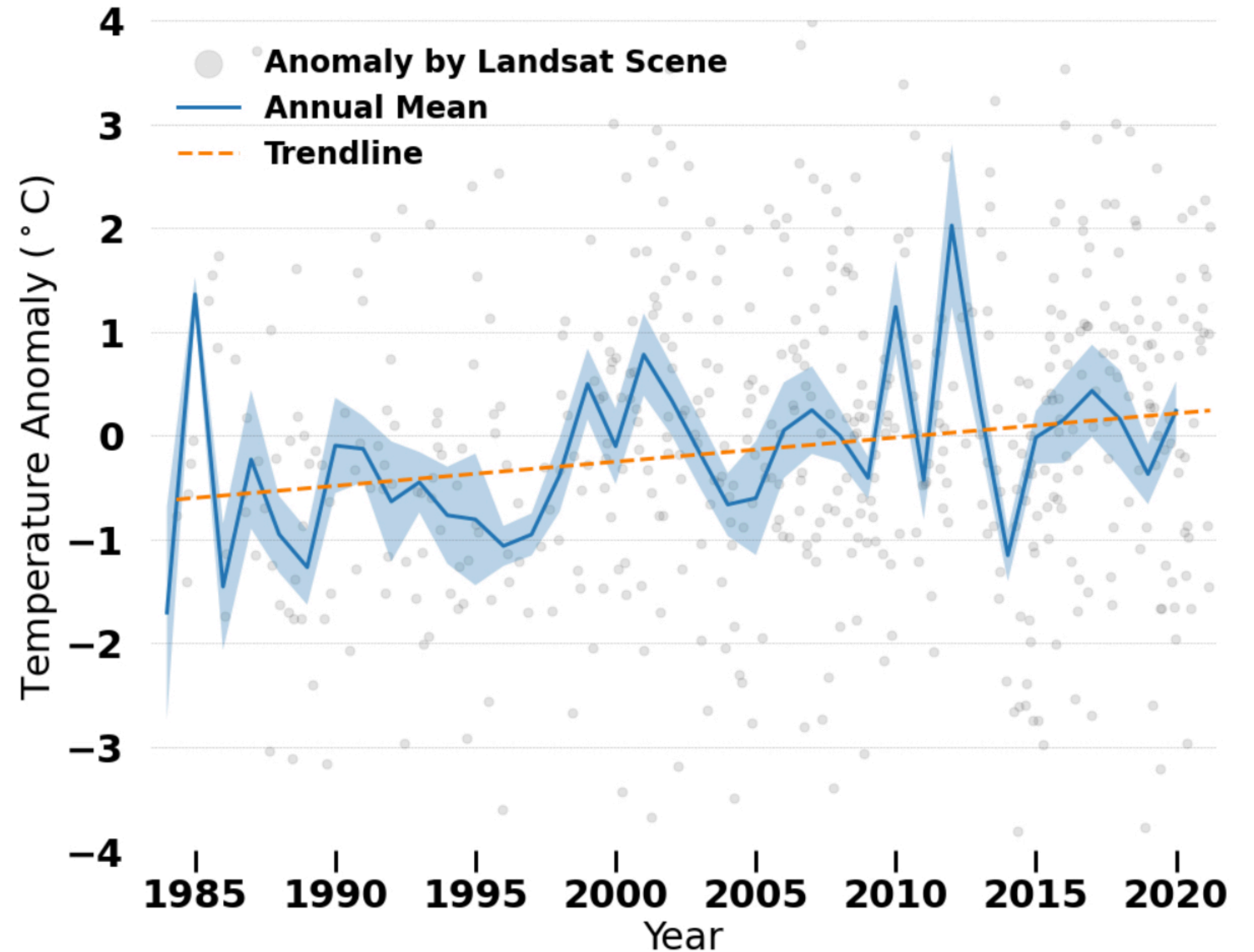


OSOM-Landsat Comparison for 2006



# Climate Change and Interannual Variability in Narragansett Bay

1984–2021



**Figure 8.** Timeseries of seasonally-detrended surface temperature anomaly over Narragansett Bay with the annual mean and a linear trendline taken before averaging. The uncertainty around the annual mean represents sampling uncertainty.

# Contextualizing Thermal Effluent Impacts in Narragansett Bay Using Landsat-Derived Surface Temperature

**Jonathan Benoit and Baylor Fox-Kemper**

*Department of Earth, Environmental and Planetary Sciences (DEEPS), Brown University, Providence, RI, USA*

Correspondence\*:  
jonathan\_benoit@brown.edu

## **ABSTRACT**

This work utilizes remotely sensed thermal data to understand how release of thermal pollution from the Brayton Point Power Station (BPPS) affected the temperature behavior of Narragansett Bay. Building upon previous work with Landsat 5, a multi-satellite analysis is conducted that incorporates 582 scenes from Landsat 5, Landsat 7, and Landsat 8 over 1984-2021 to explain seasonal variability in effluent impacts, contrast data after the effluent ceased in 2011, identify patterns in temperature before and after effluents ceased using unsupervised learning, and track how recent warming trends compare to the BPPS impact. Stopping the thermal effluent corresponds to an immediate cooling of  $0.26 \pm 0.1$  °C in the surface temperature of Mt. Hope Bay with respect to the rest of Narragansett Bay with greater cooling of  $0.62 \pm 0.2$  °C found



# Some Undergraduate Projects in My Group: Climate

- John Nicklas (geoengineering with genetically modified plankton)
- Mara Freilich (biophysical reactions)
- Galen Hall (mixed layer depth constrains climate sensitivity)
- Hannah Kolus (simulations of boundary layer physics)
- Patrick Orenstein (Bay of Bengal sensitivity to ocean mixing)
- Ana Ordonez (wave power site selection)

Student publications on [Fox-Kemper.com/pubs](https://fox-kemper.com/pubs)





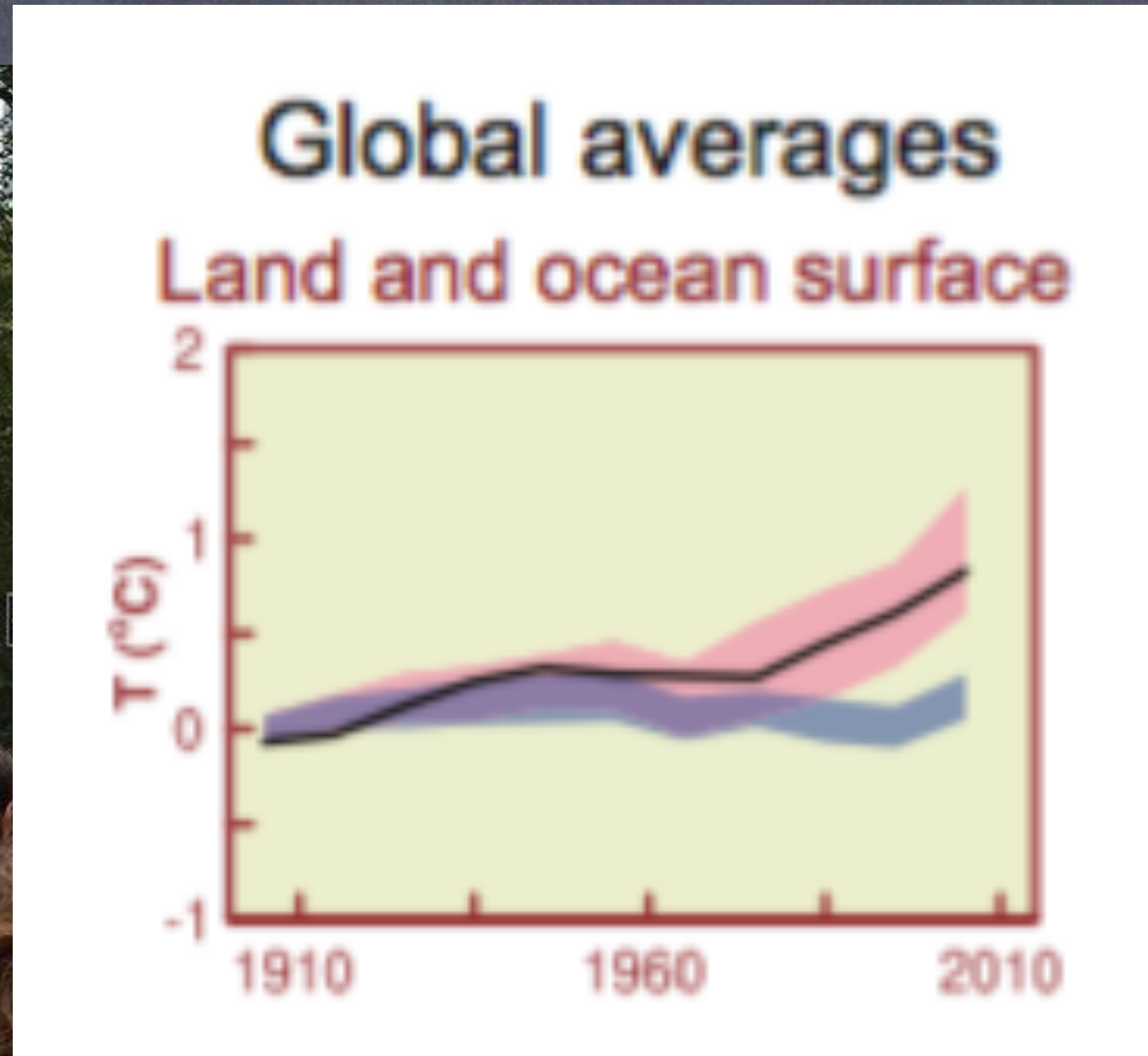




Video: ZEKE HAUSFATHER, Carbon Brief, 2017  
[www.carbonbrief.org/analysis-how-well-have-climate-models-projected-global-warming](http://www.carbonbrief.org/analysis-how-well-have-climate-models-projected-global-warming)

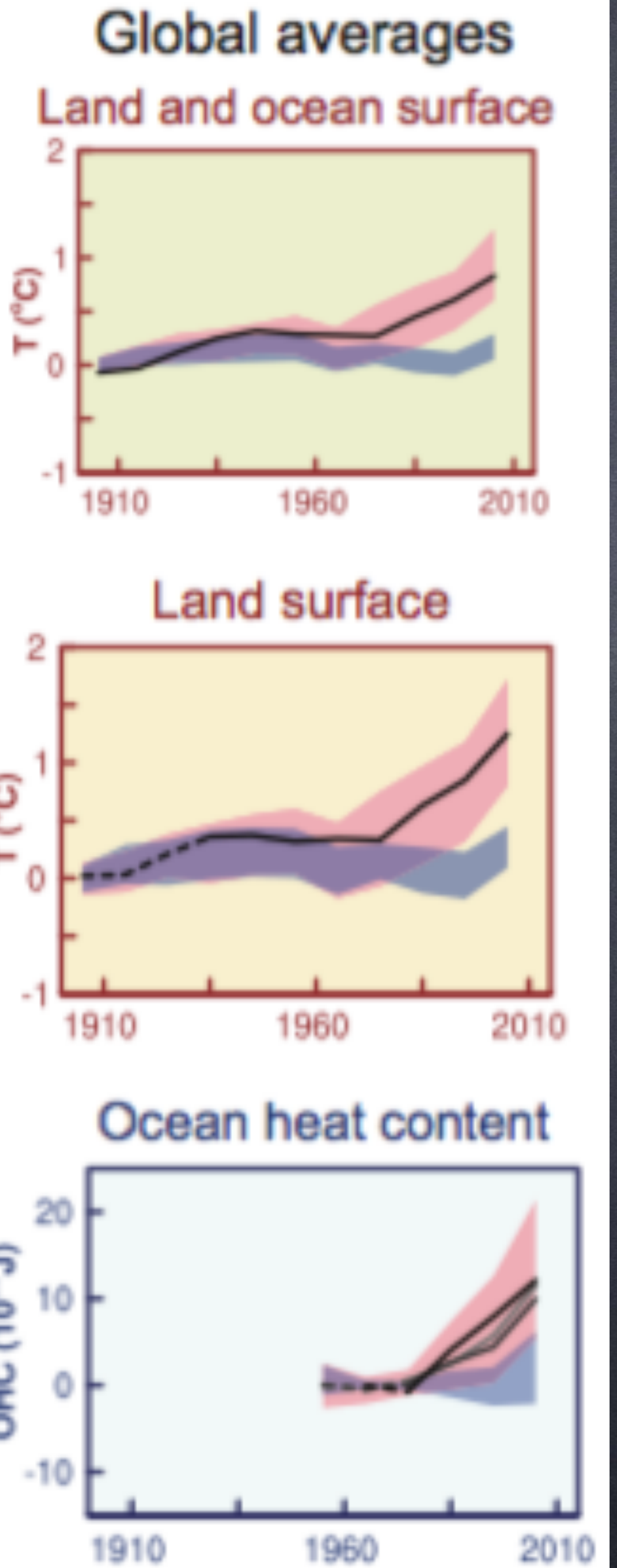
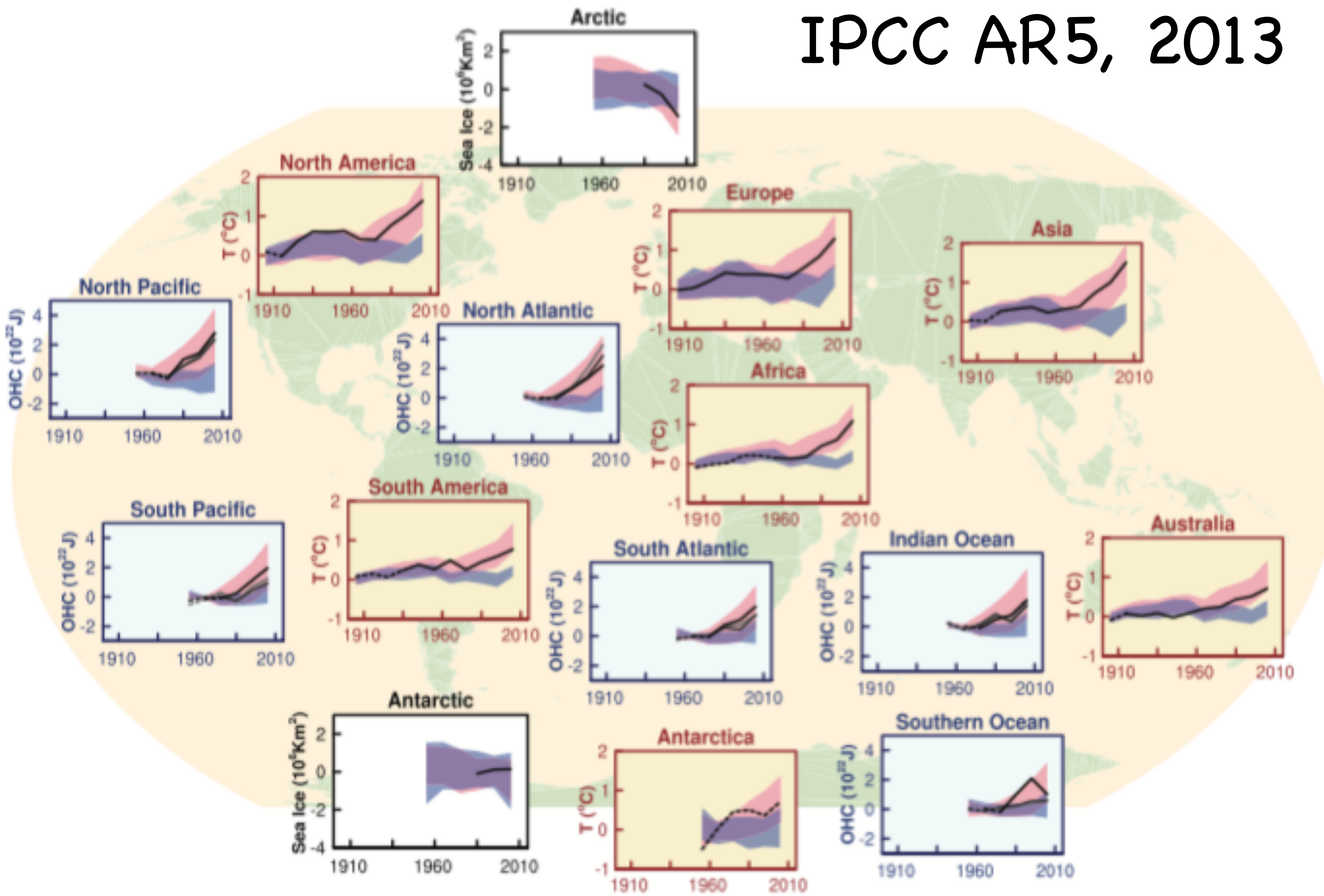
# Why do we want climate models?

Projections, but especially for experiments:  
Detection & Attribution of Anthropogenic Effects



≡ Observations      ■ Models using only natural forcings  
                                 ■ Models using both natural and anthropogenic forcings

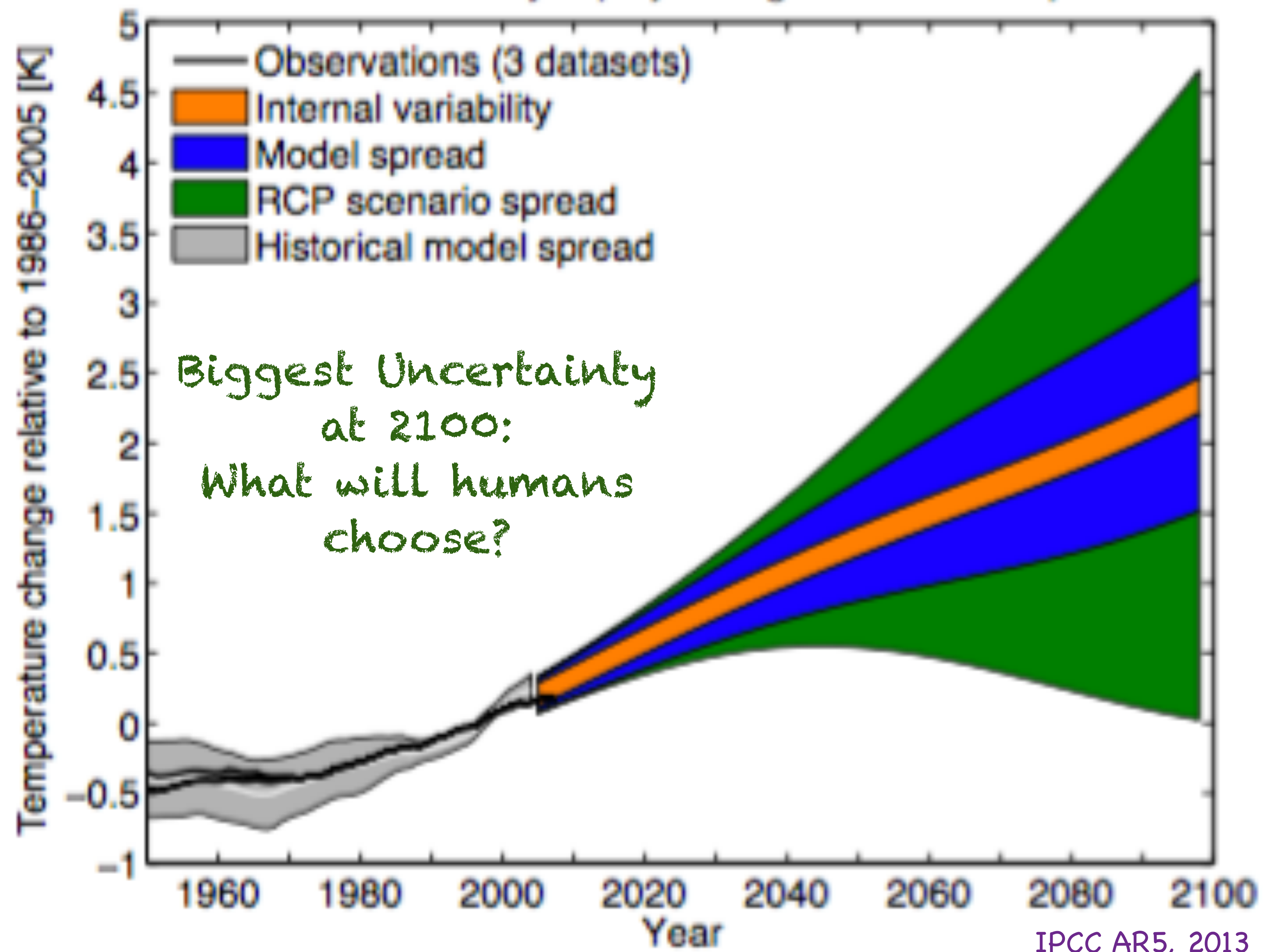
# IPCC AR5, 2013



≡ Observations  
■ Models using only natural forcings  
■ Models using both natural and anthropogenic forcings



# Sources of uncertainty in projected global mean temperature

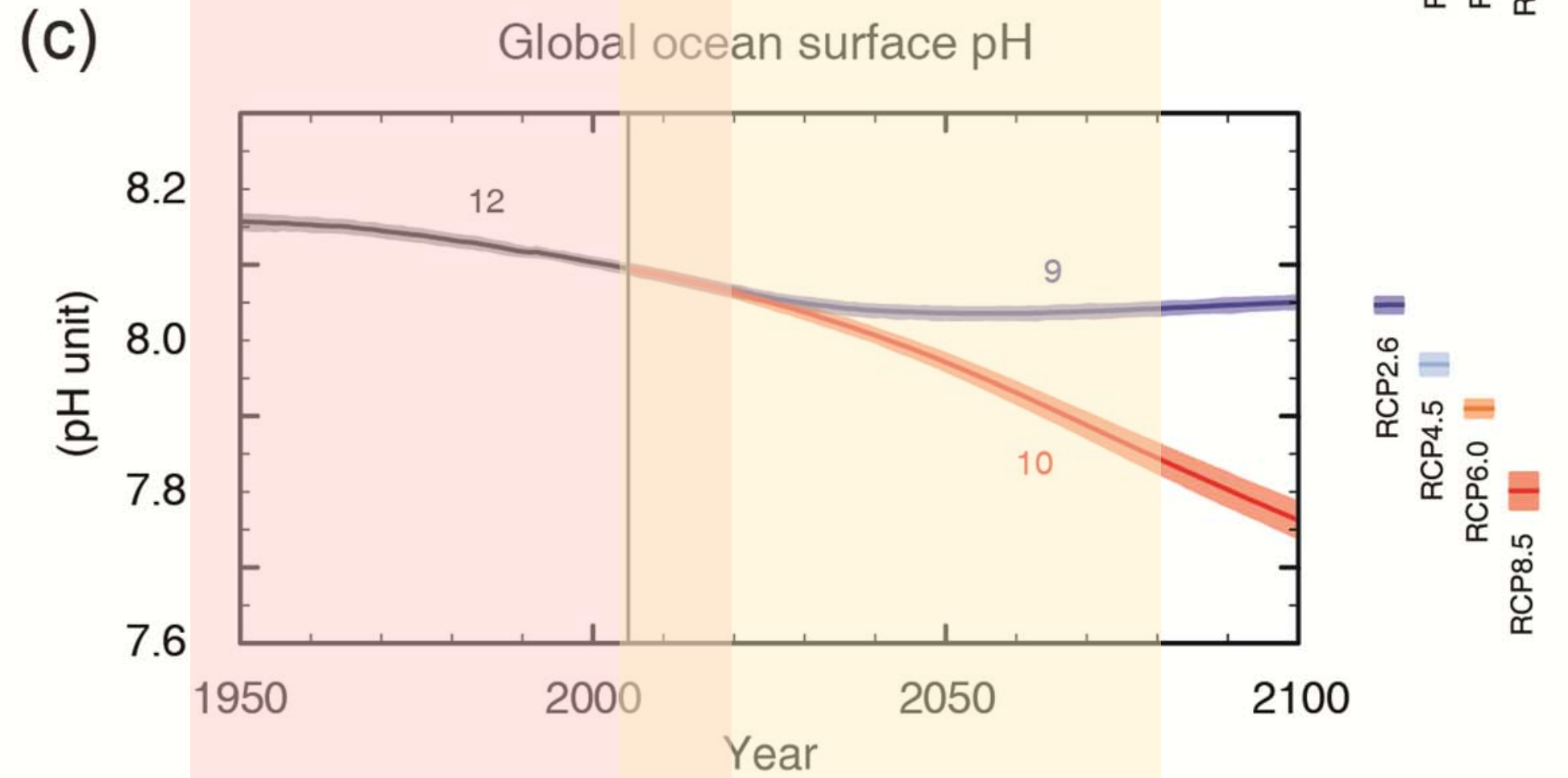
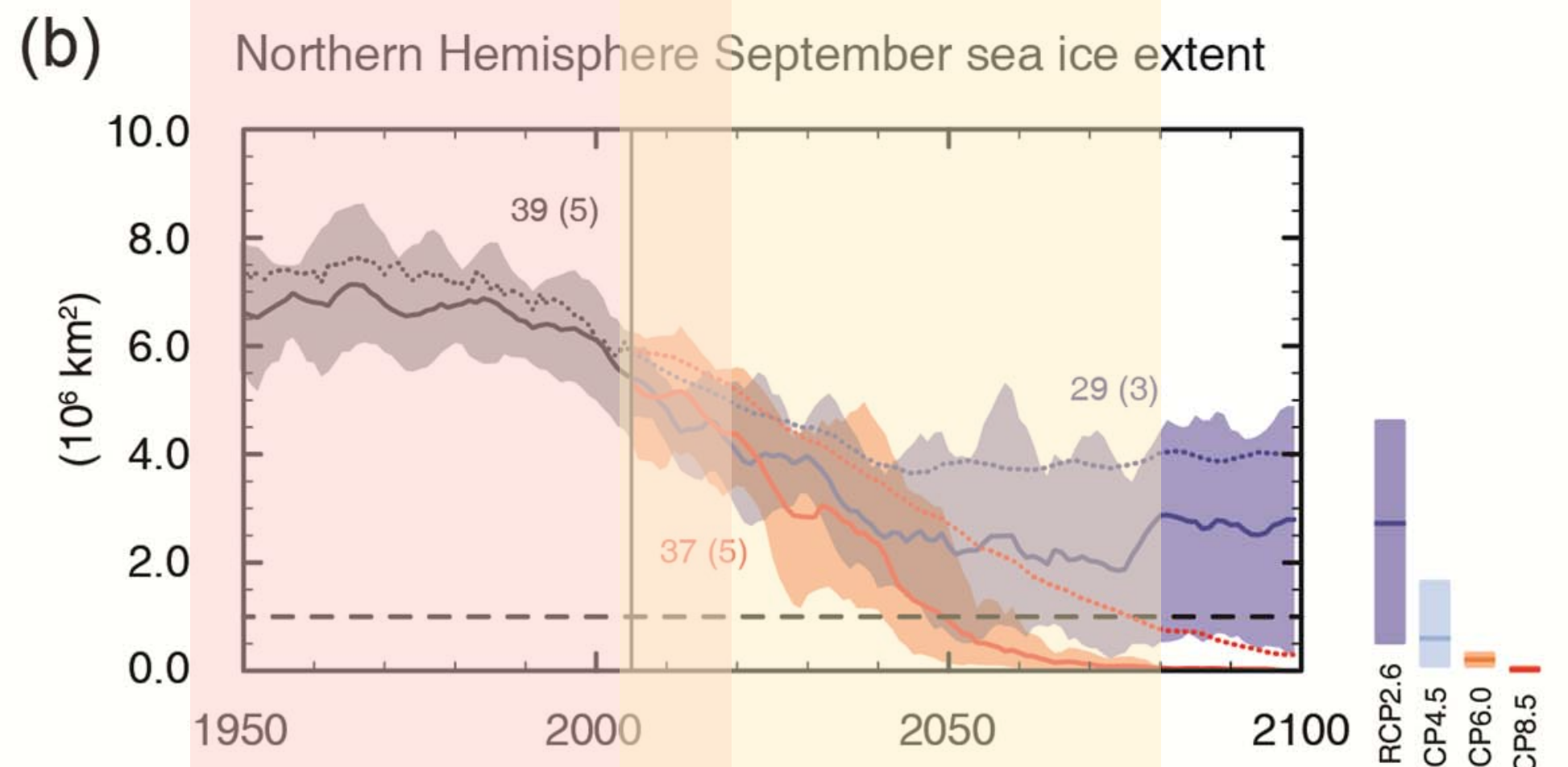
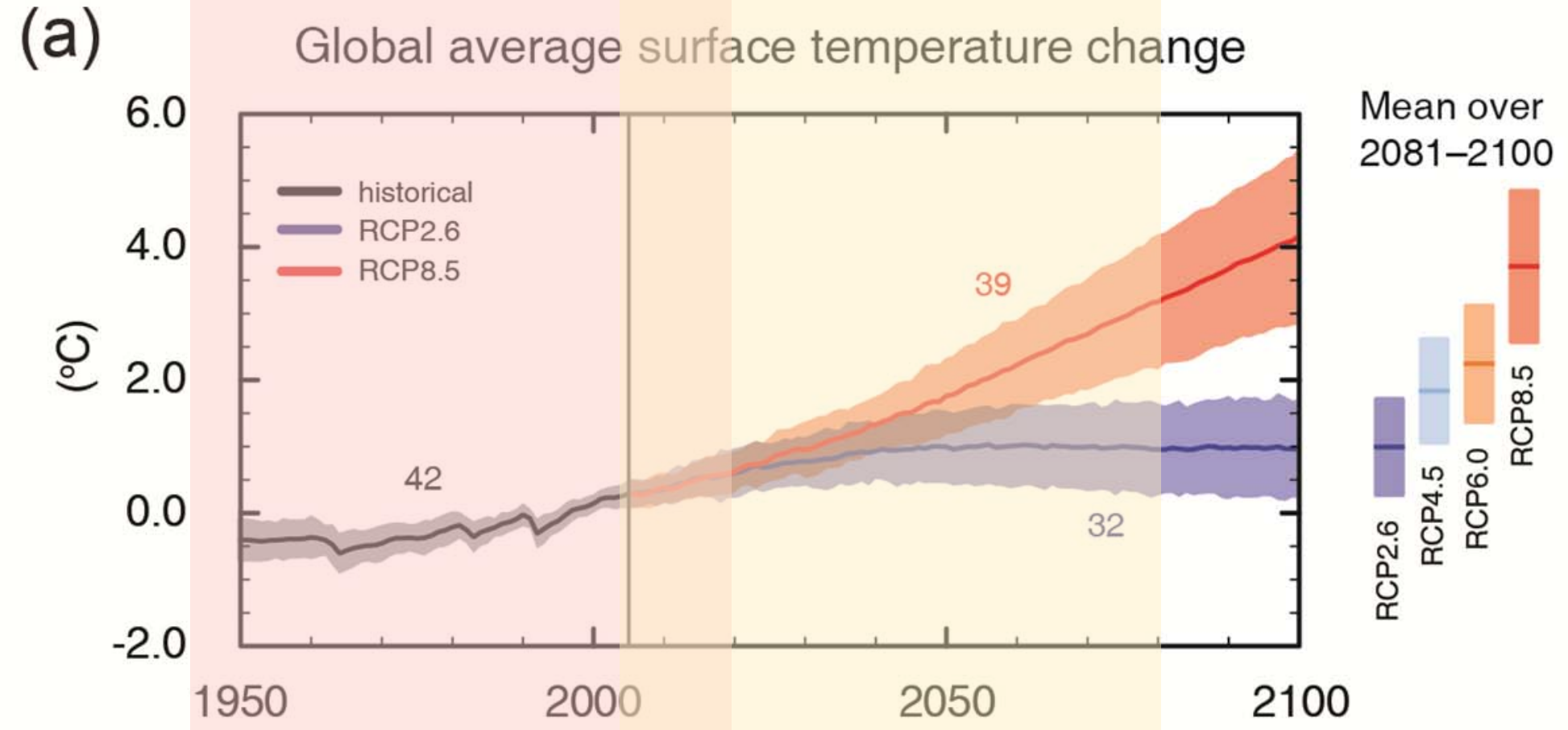




Who is affected by Climate Change?



floridapolitics.com



# Model Projections



Data: IPCC AR5 (2013)

Shading: Me



# Questions? Comments?

- Currents from Drones & Waves
- Satellites (Landsat SST in Narragansett Bay)
- Climate Change