Oceanography of Nantucket Shoals and Vicinity

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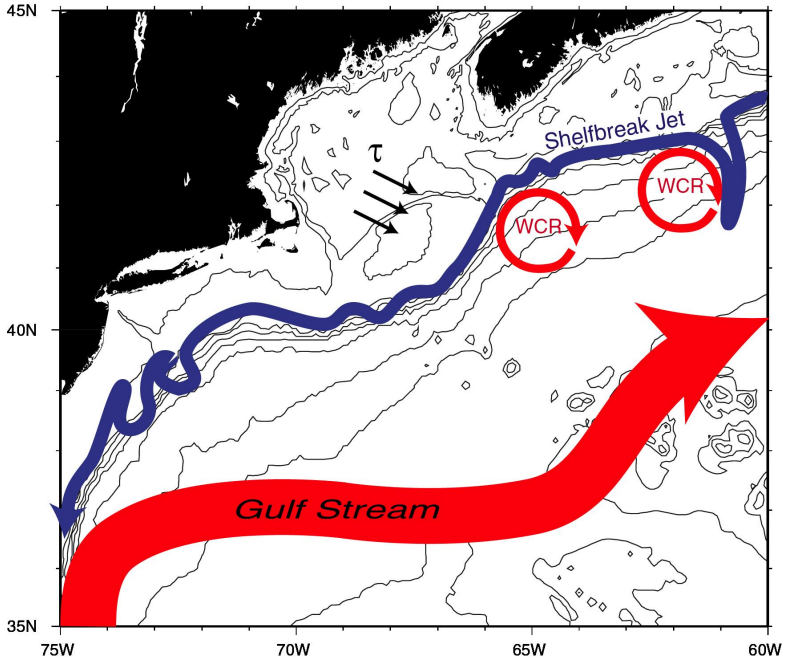
Outline

- Regional Circulation
- Ocean Warming and Marine Heatwaves
- Changes in Stratification
- Gulf Stream Variability and Shelf Impacts
- Onshore Displacement of the Shelfbreak Front in 2021
- Recommendations for Moving Forward

Background- Regional Circulation

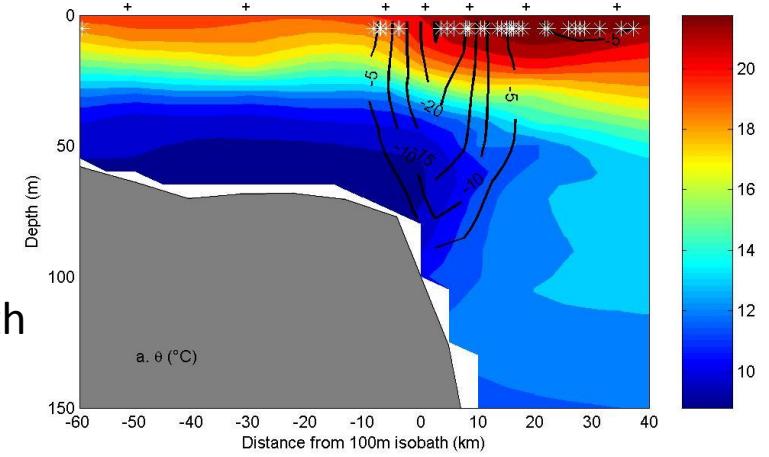


The Shelfbreak Jet and the Gulf Stream

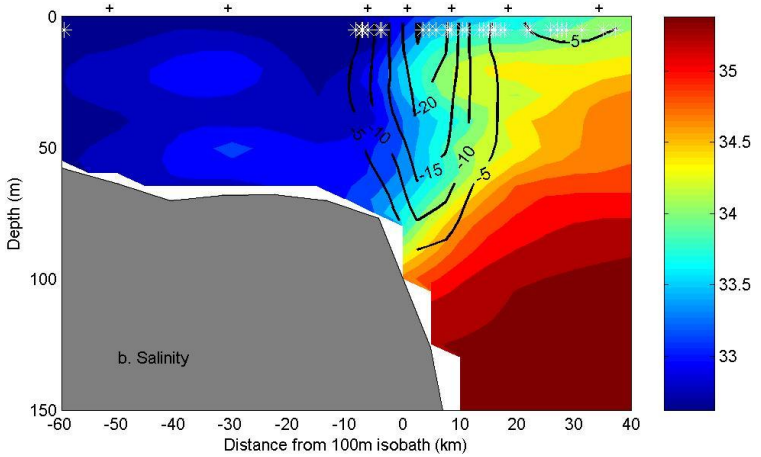
Figure courtesy
P. Fratantoni

Temperature

Depth

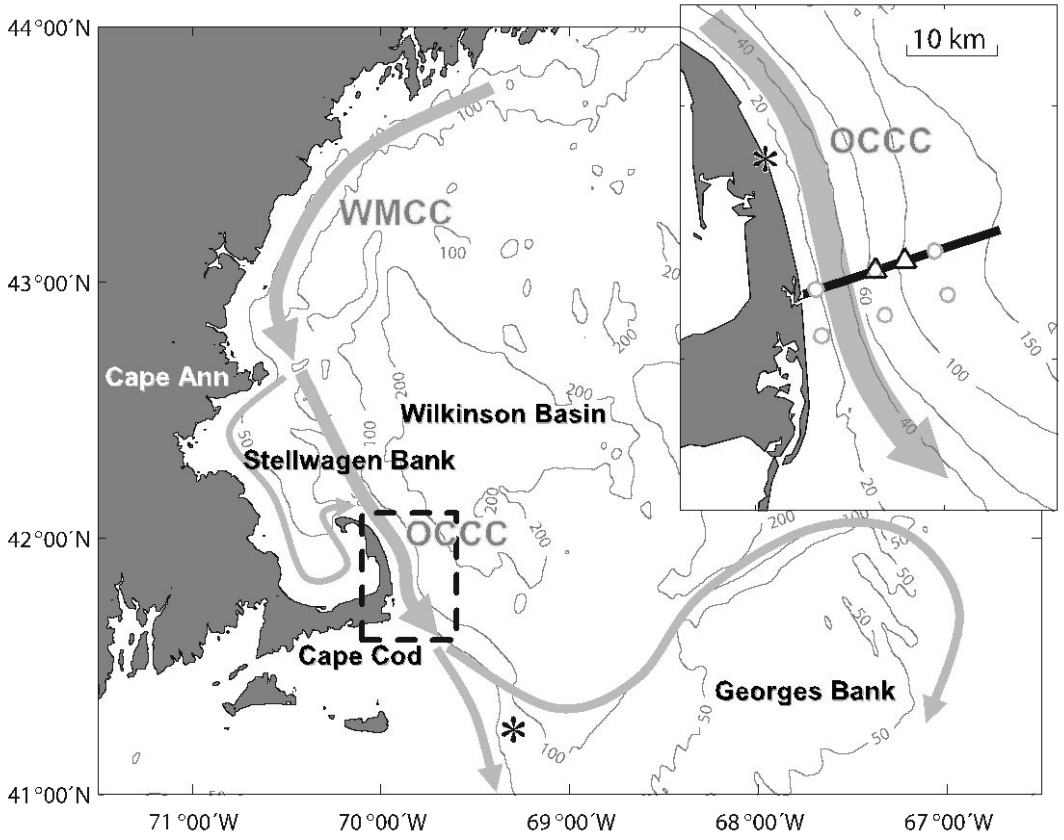


Salinity

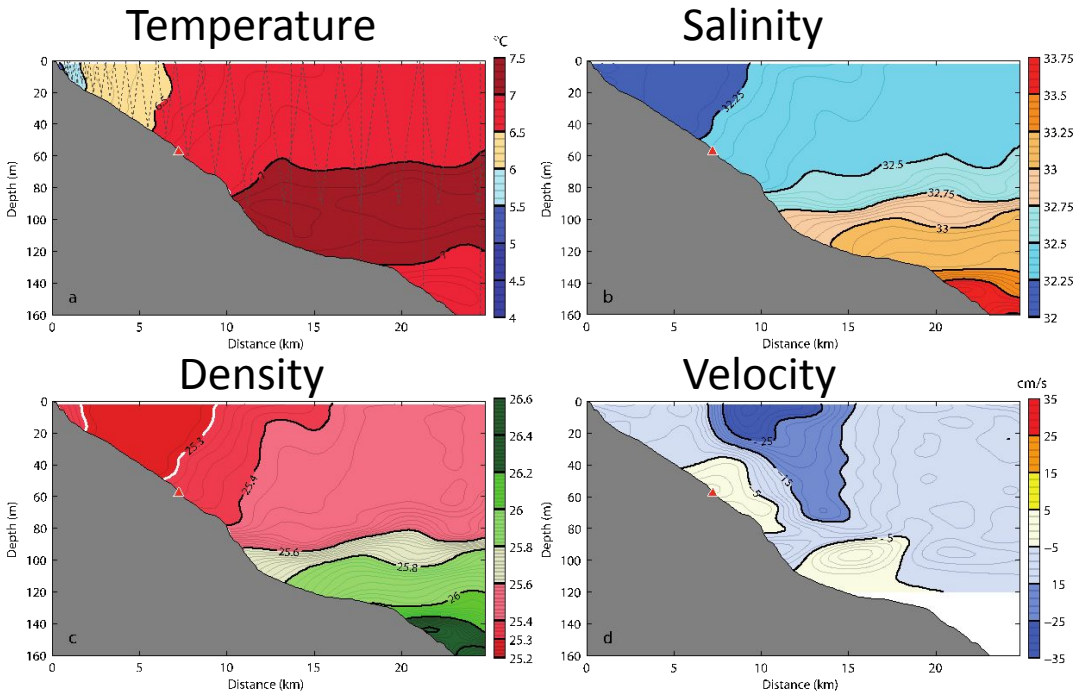


Offshore Distance

Upstream- The Outer Cape Coastal Current



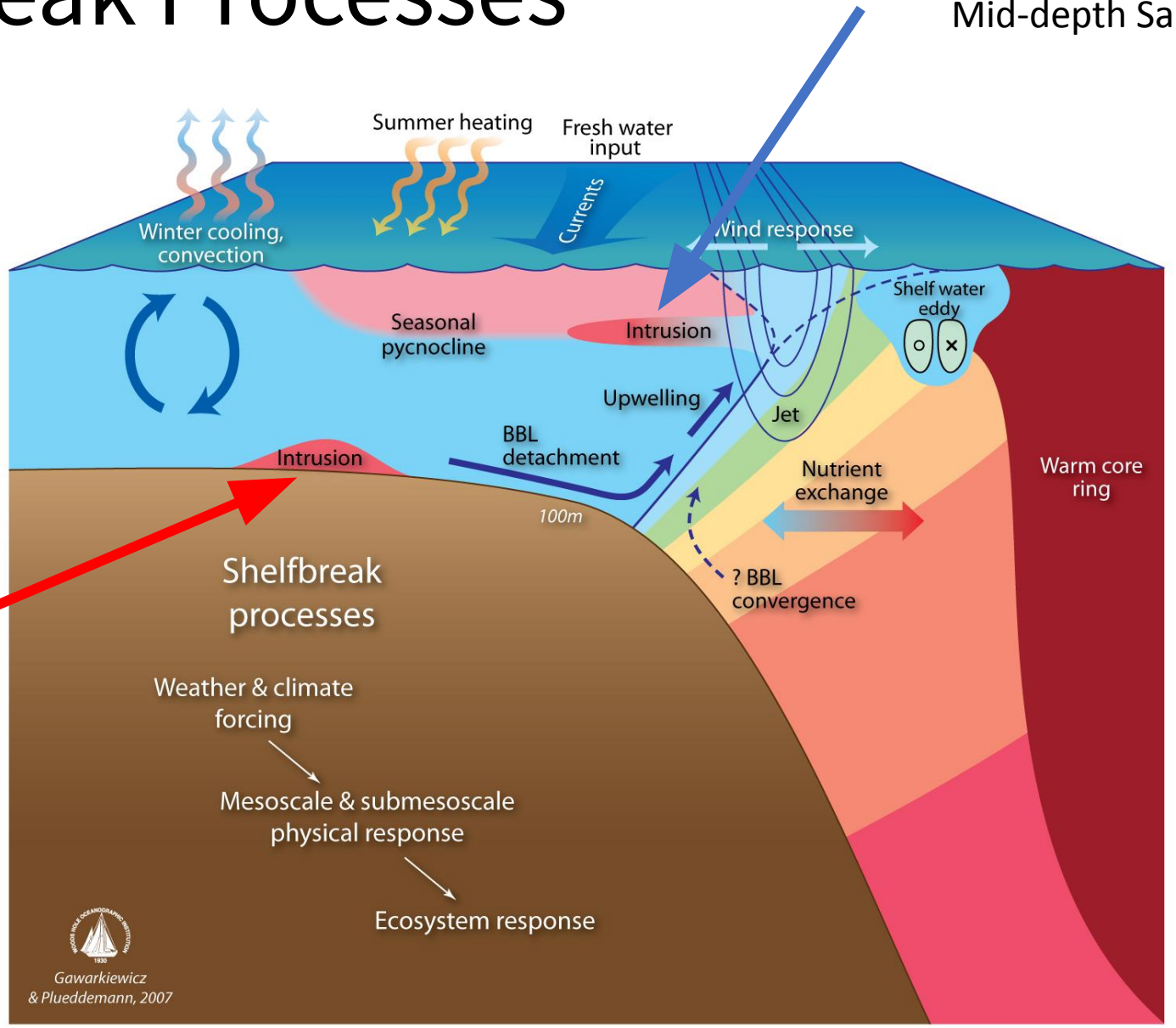
From Shcherbina and Gawarkiewicz 2008



REMUS 100
Vehicle
2006
Non-optimal
Deployment

Shelfbreak Processes

Mid-depth Salinity Maximum Intrusion

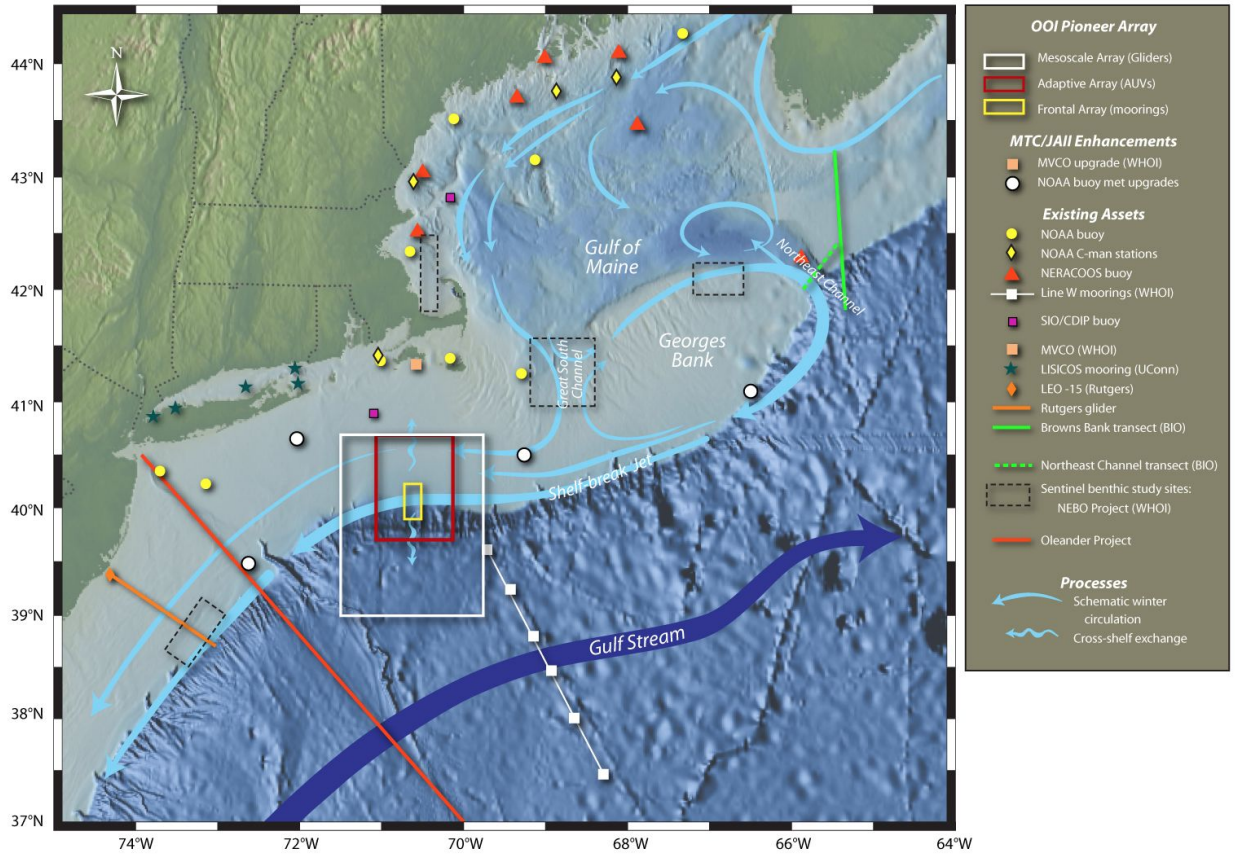


Bottom Intrusion

Chen et al., 2021

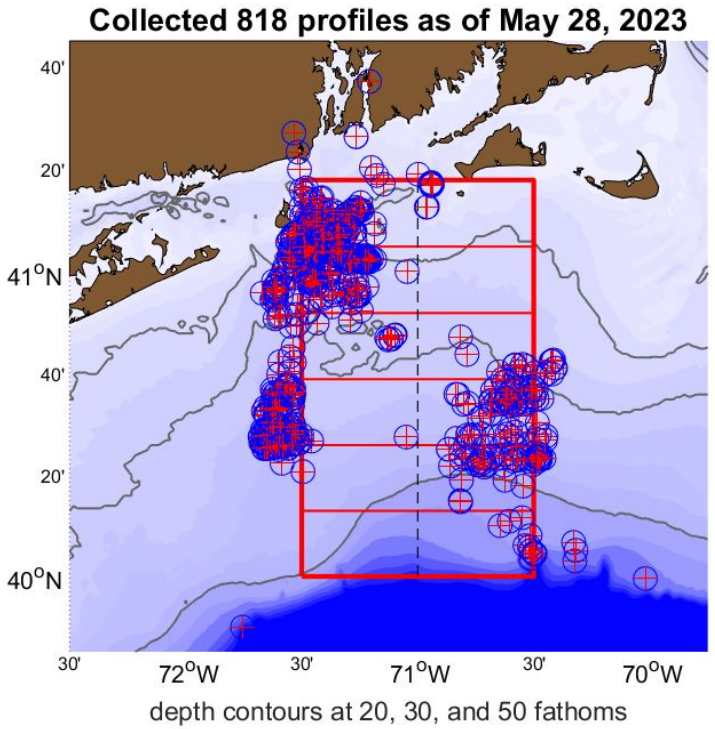
Boicourt and Hacker, 1975
Gordon and Aikman, 1981
Aikman, 1984
Flagg et al., 1994
Lentz, 2003

Plan View of the OOI Pioneer Array and Regional Assets

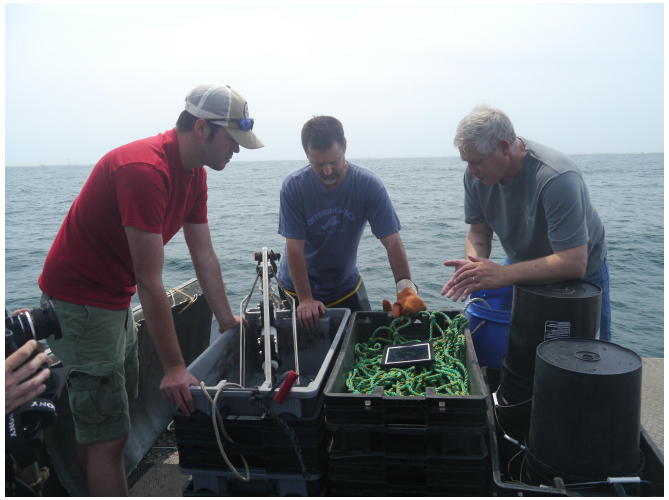


Yellow Rectangle- Mooring Array
Red Rectangle- AUV operational area (REMUS 600)
White Rectangle- Glider operational area (Slocum)

Shelf Research Shelf Fleet- Commercial Fisheries Research Foundation (R.I.)/WHOI



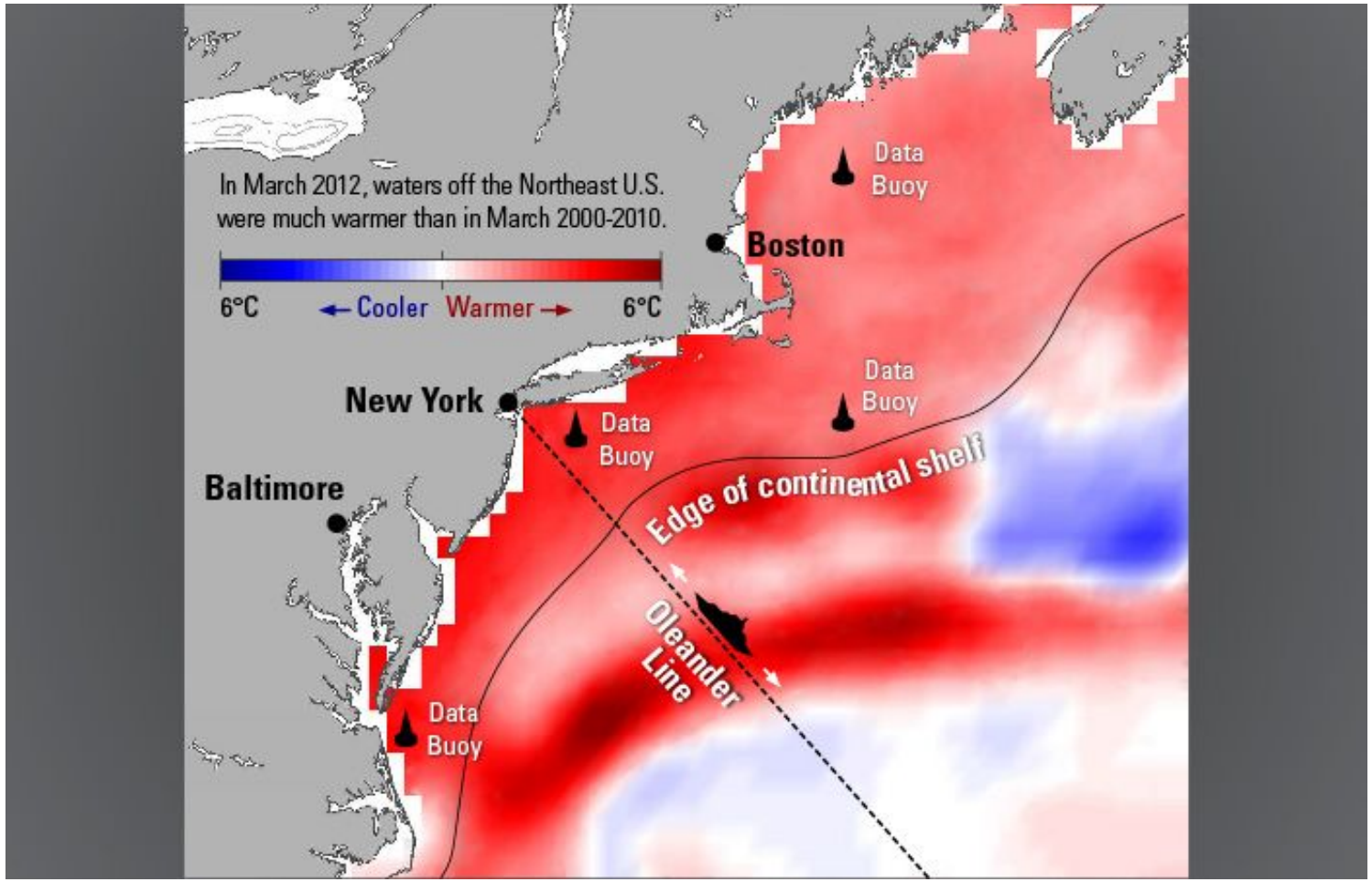
Collecting temperature and Salinity data since Nov. 2014 (funding from MacArthur/ van Beuren Foundations)



On fishing boat off Point Judith RI

Meeting at Commercial Fisheries Center (URI)

Ocean Warming
SST Anomaly for March 2012
Maximum of 6 Deg. C



Courtesy Ke Chen WHOI

Temperature Anomalies- NDBC Buoys in Gulf of Maine and Middle Atlantic Bight

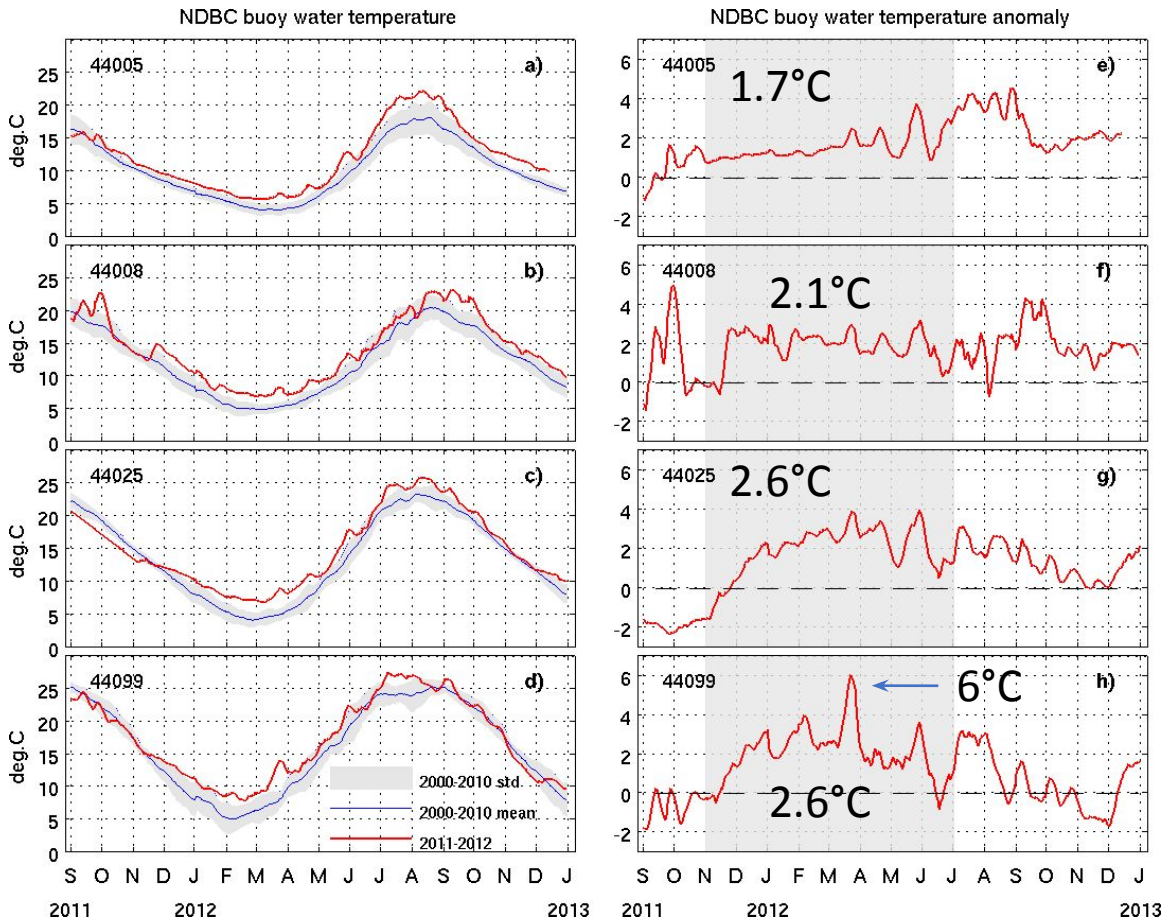
Relative to 2000-2010 mean

Gulf of Maine

Nantucket Shoals

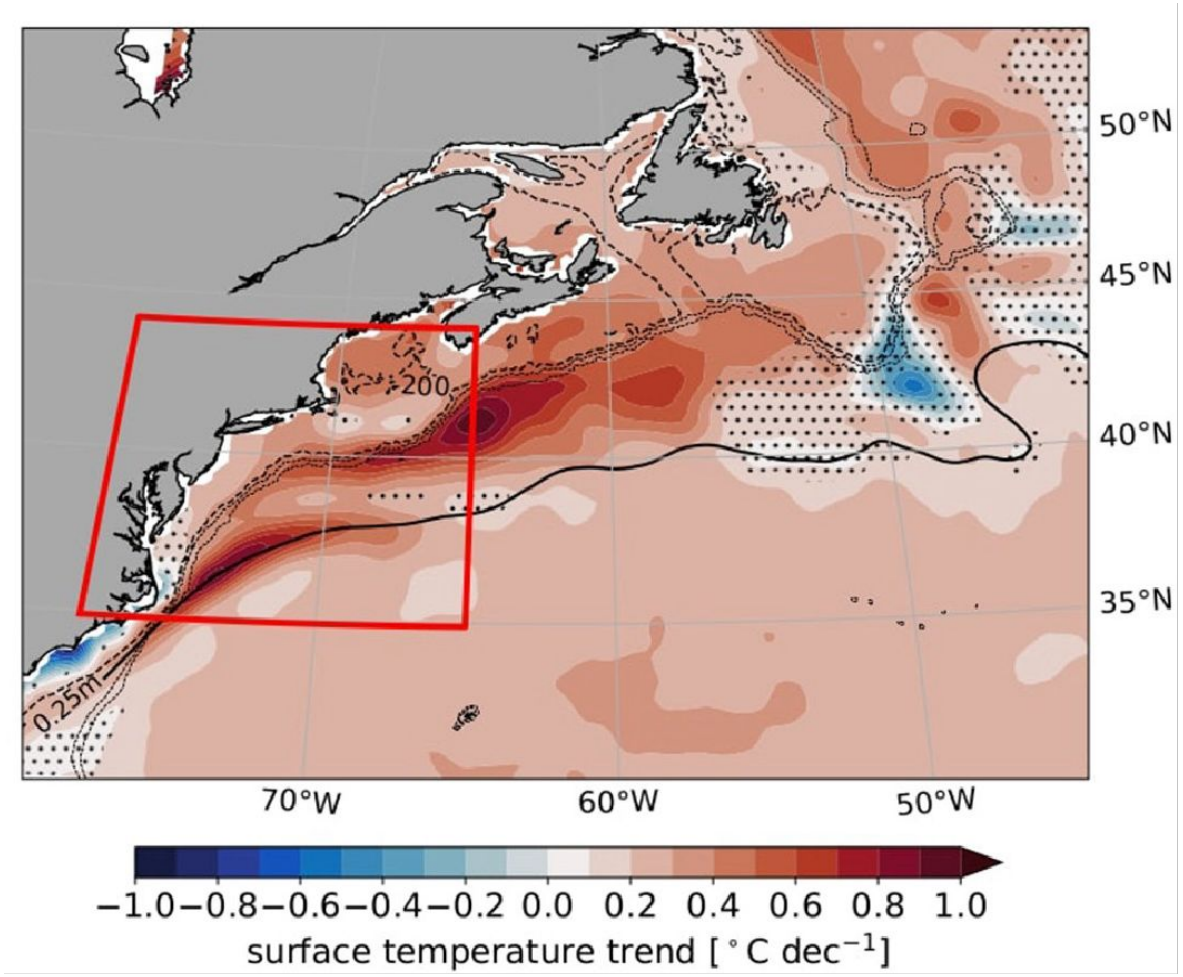
Long Island

Chesapeake Bay Mouth



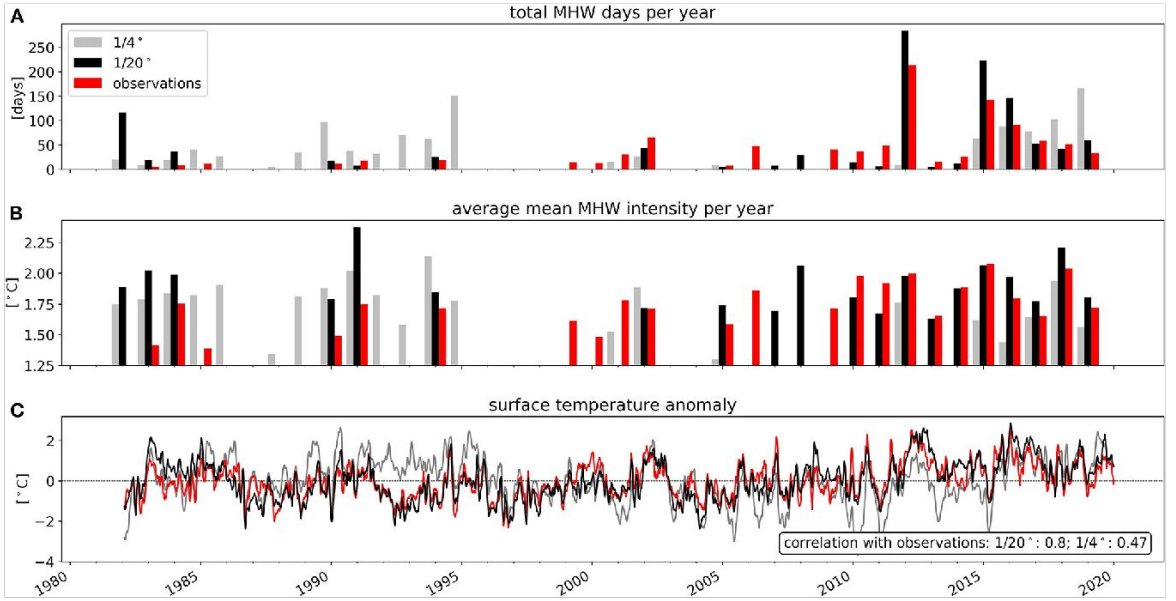
Chen et al. (2014)

Marine Heatwaves



Temperature Trends from NOAA OISST

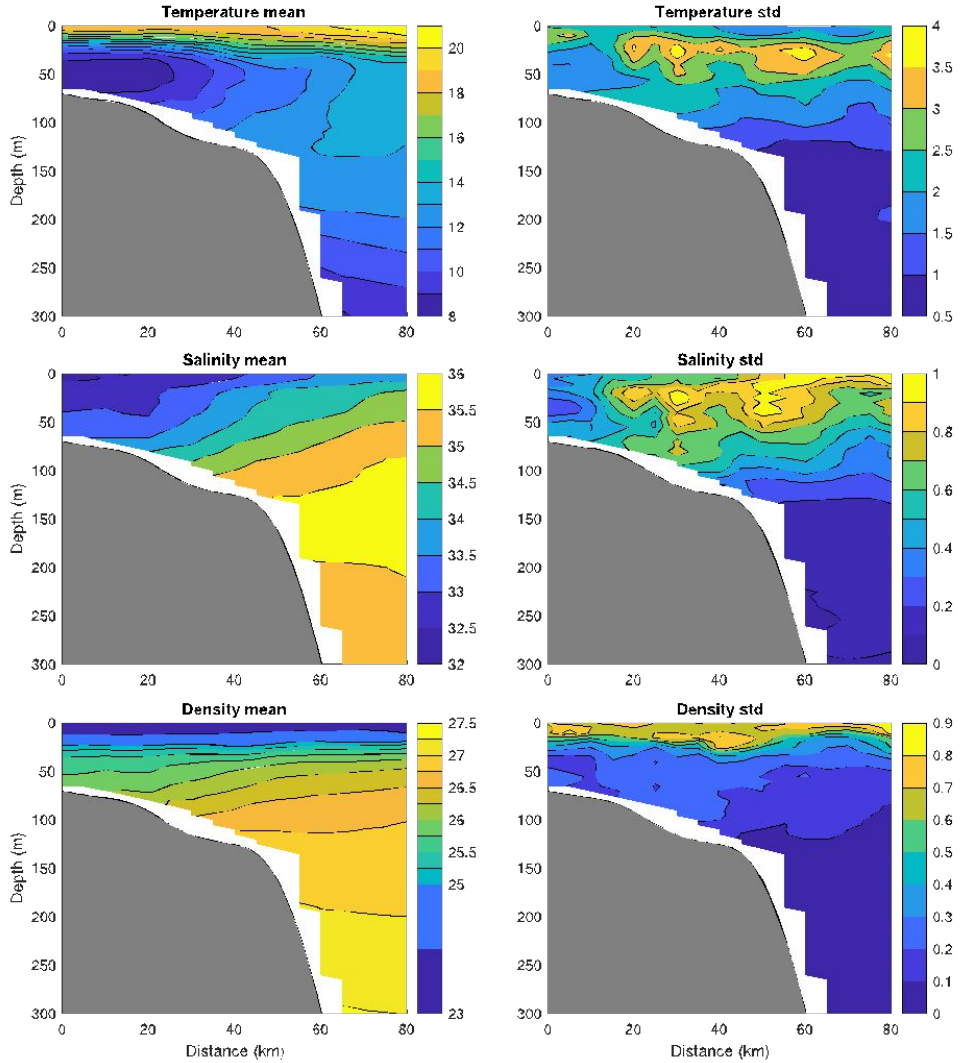
Significant Increase in MHW Days and Intensity since 2010

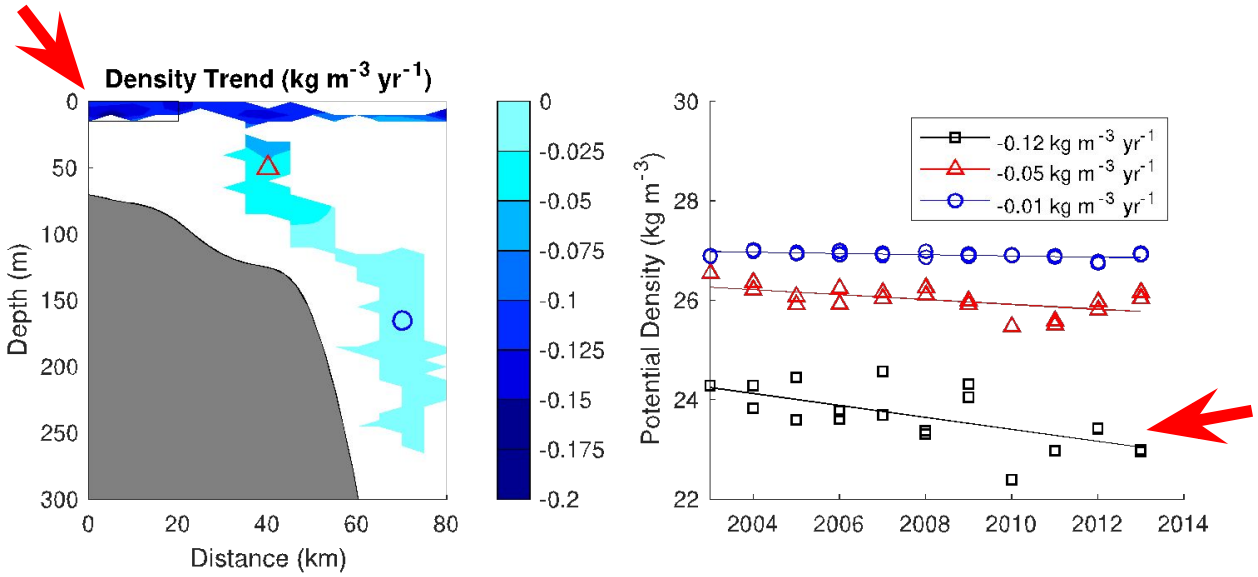


Red bars- Observations
Black bars- 1/20 Degree model

From Grosselindemann et al. 2021

Impact on Stratification for Shelf/Slope South of New England 2003-2013 (Harden et al. 2020)





Steep decrease in near surface salinity (black squares) -0.12 kg/m3 per year!

Approximately half that rate at 50 m depth near the front

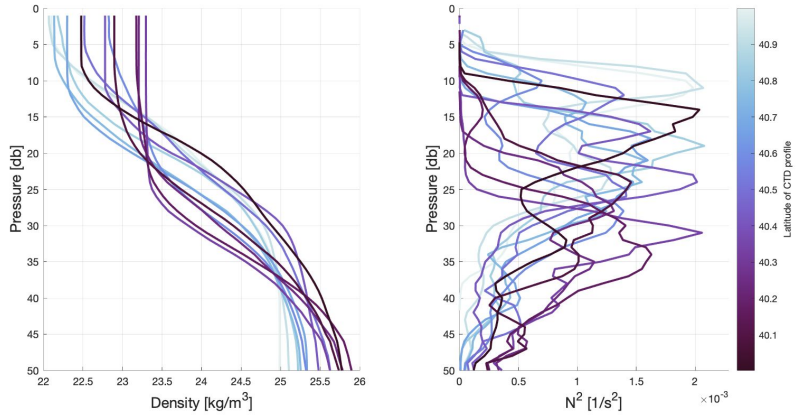
Much smaller at 150 m depth

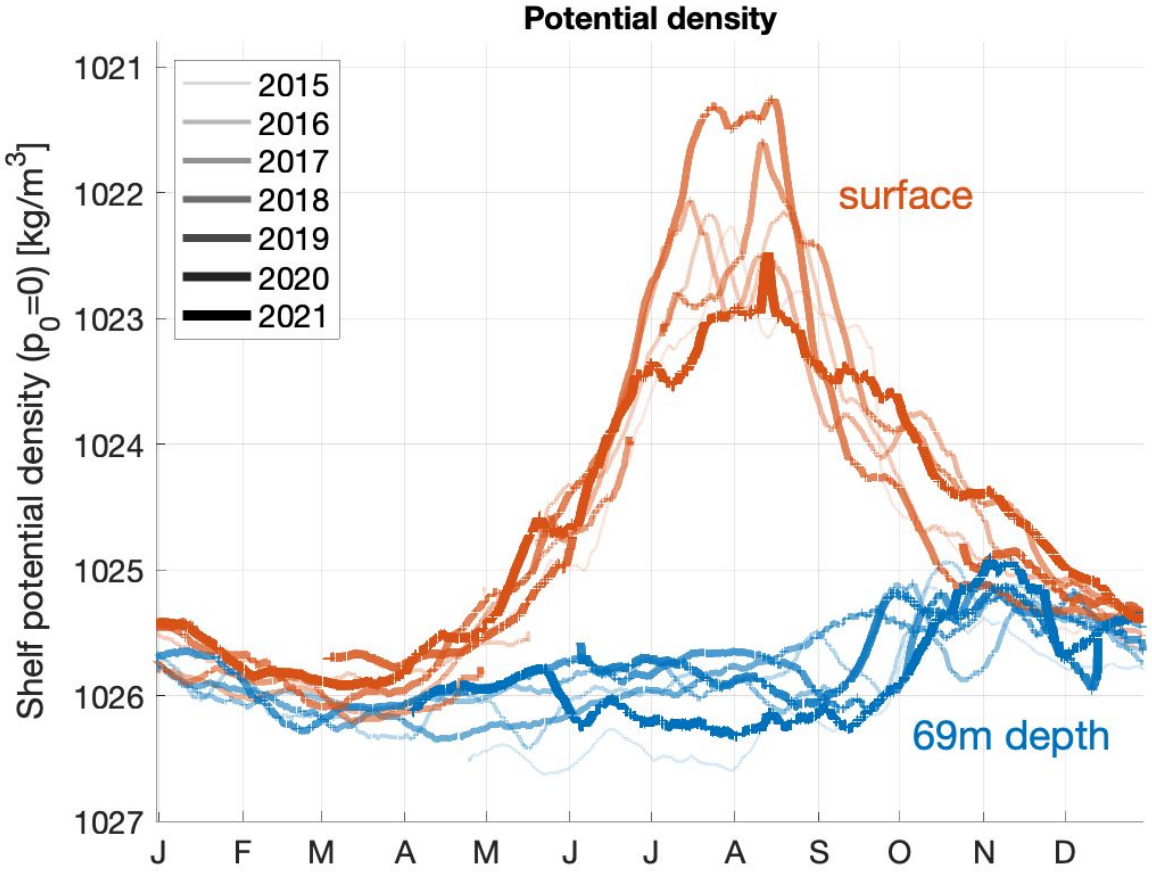
Surface and 69 m Potential Density from OOI Pioneer Array Inshore Mooring

Very large interannual variations in Summer minimum surface potential density

Values as low as 1021.3 kg/m3 in 2020

Surface values in September 2022 were as low as 1022.0 kg/m3 (R/V Endeavor EN690)



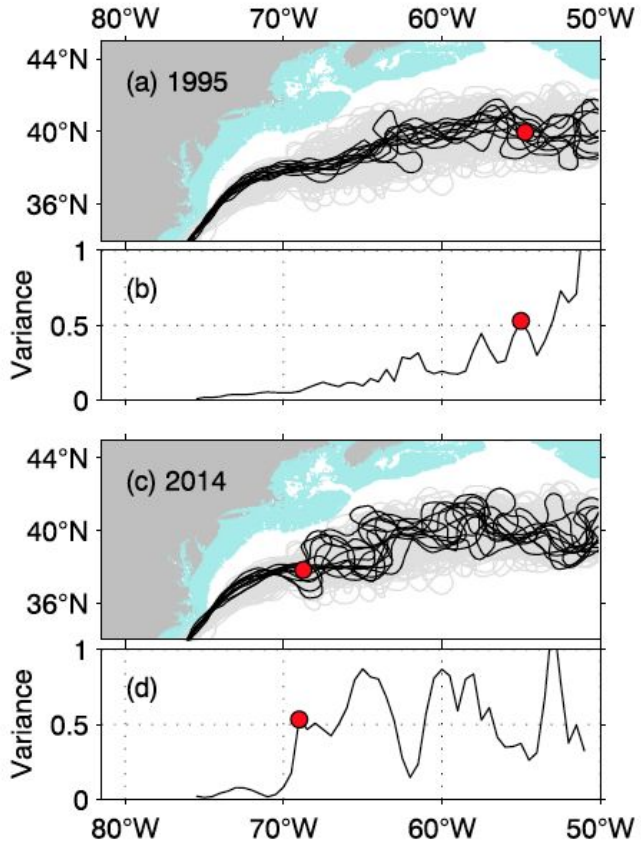


Figures courtesy Lukas Lobert MIT/WHOI Joint Program

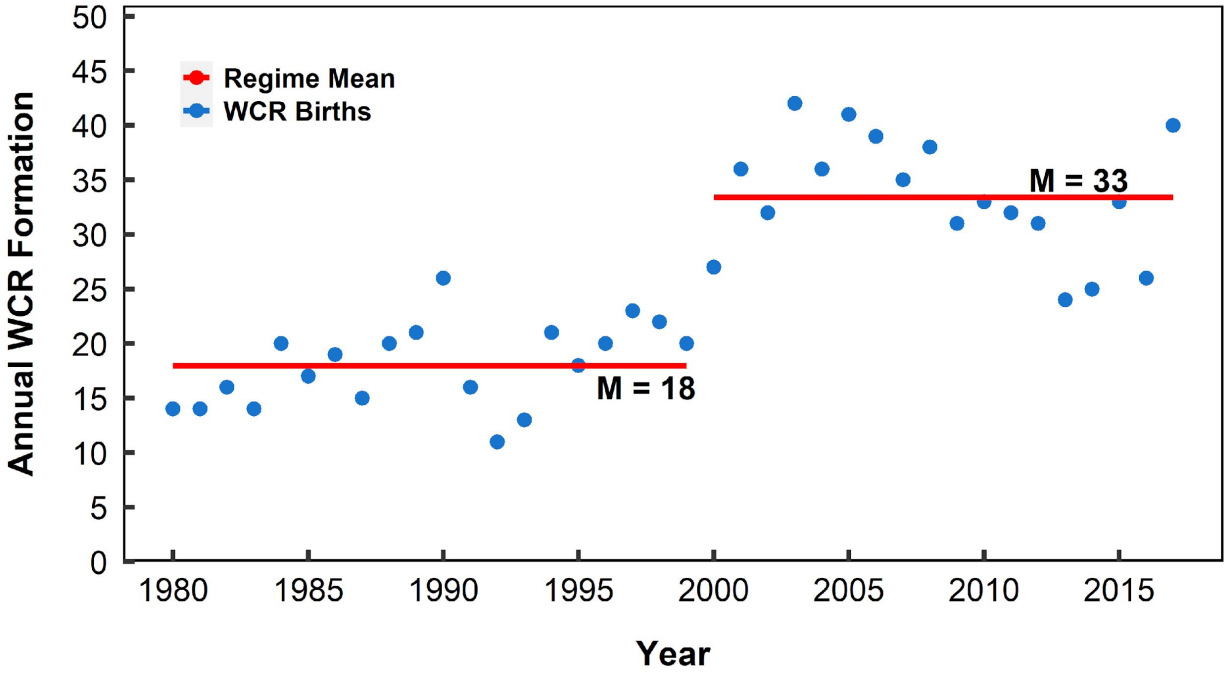
Modeling Challenge #1

- Can hydrodynamic models accurately describe inter-annual variations in peak stratification in summer?
- Can hydrodynamic models accurately capture the seasonal evolution of stratification throughout the year?
- Can hydrodynamic models produce a trend for the decrease in surface potential density that is consistent with observations?

What is happening with the Gulf Stream?

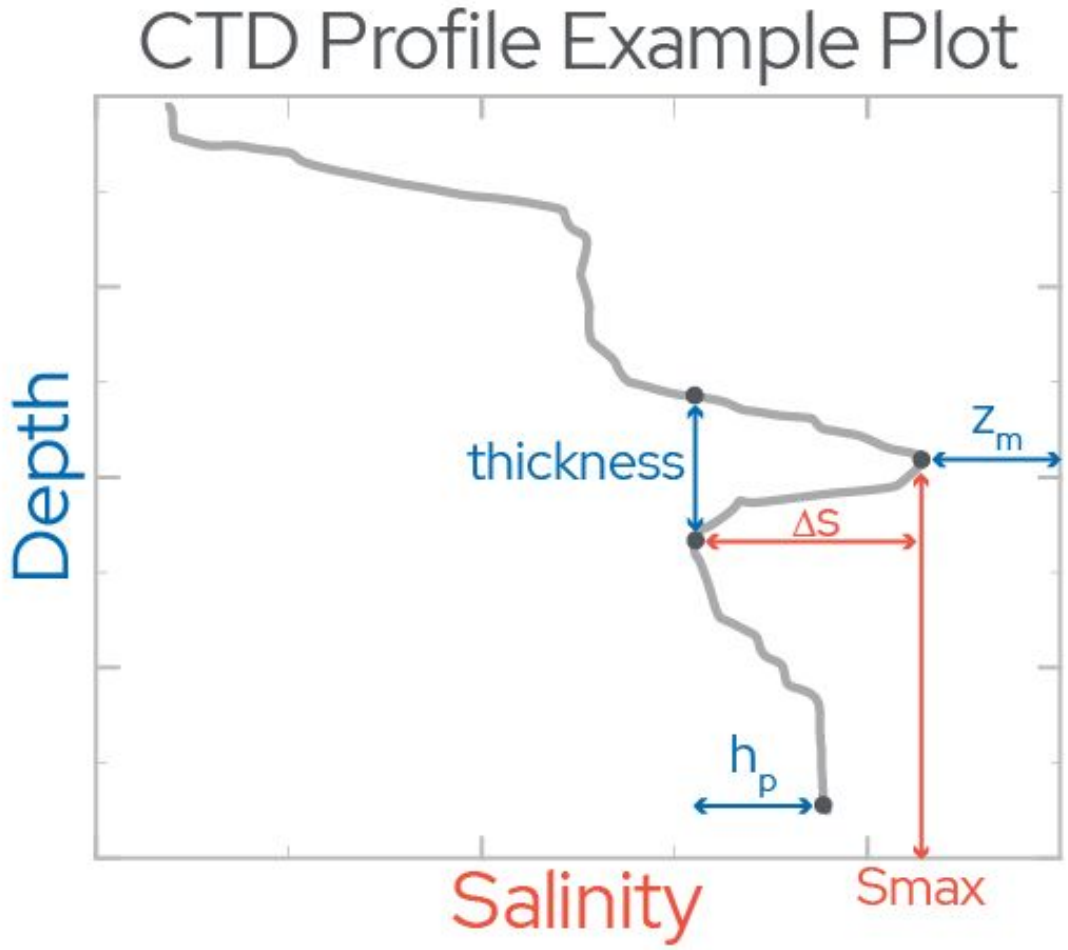


Large amplitude meanders of the Gulf Stream are beginning further to the west (from SSHA)
Andres 2016



Annual formation rate of Warm Core Rings nearly Doubled after 2000
Gangopadhyay et al., 2019

Defining Smax from Shelf Fleet data



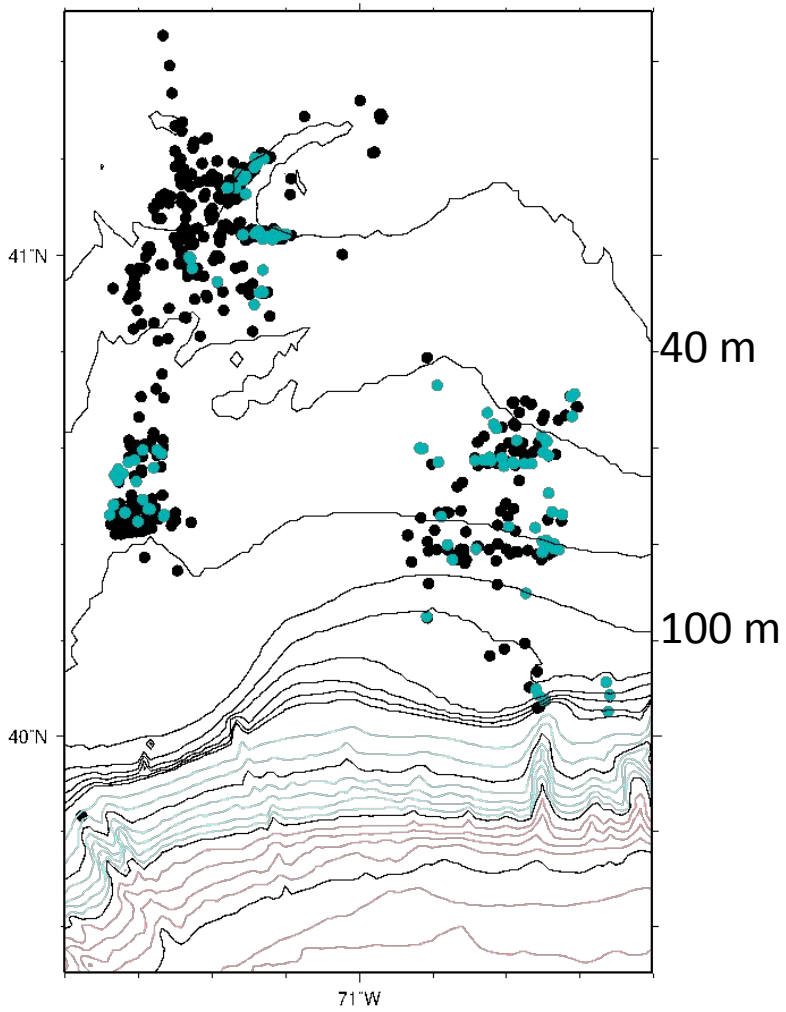
Delta S > 0.2 PSU (Lentz used 0.1 PSU)

Zm not located at surface or bottom
Only consider mid-depth intrusions

Delta S is defined as the minimum of the difference between Smax and the local minimum above and below Smax

From Gawarkiewicz et al. 2022

Shelf Fleet- Location of Profiles with Intrusions

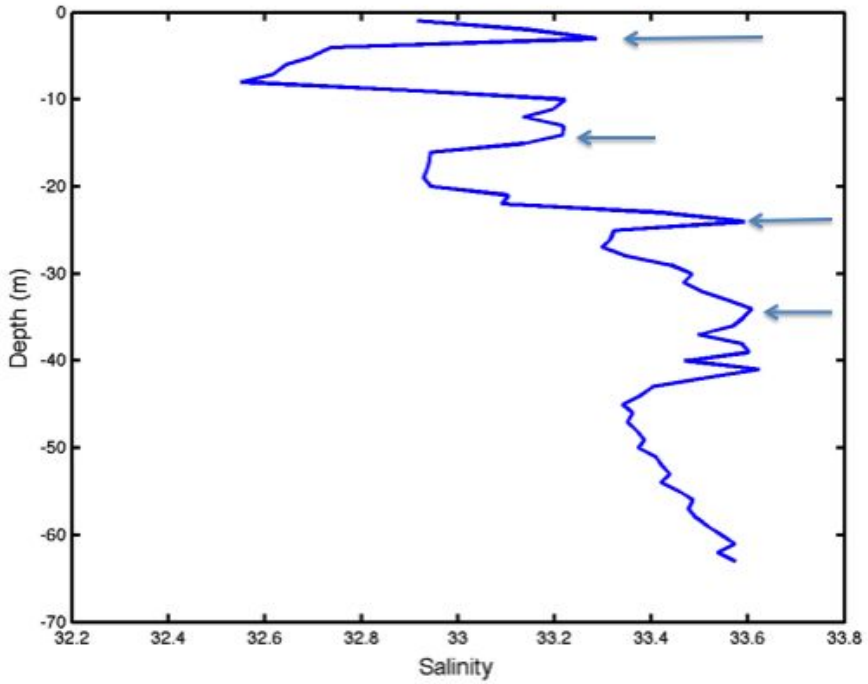


Black dots- Profiles with no intrusion

Green dots- Profiles with Smax intrusion

BIG SURPRISE- Numerous profiles with intrusions well north of Shelfbreak, north of 41 Deg. 00’ N

Shelf Fleet- Multiple Intrusion Profiles

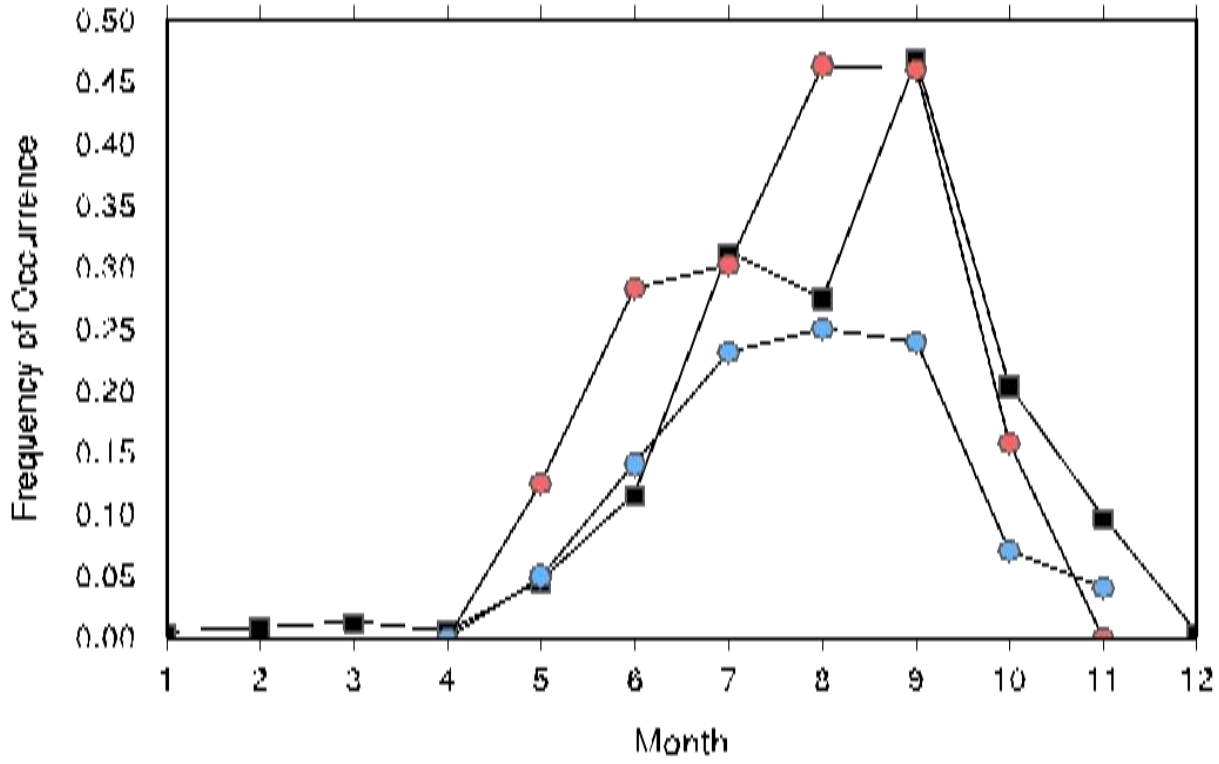


One profile had 4 different Smax intrusions

Approximately 10% of the Shelf Fleet profiles had multiple intrusions

May be very significant ecologically as organisms may concentrate on different layers

Frequency by Month compared to Lentz climatology



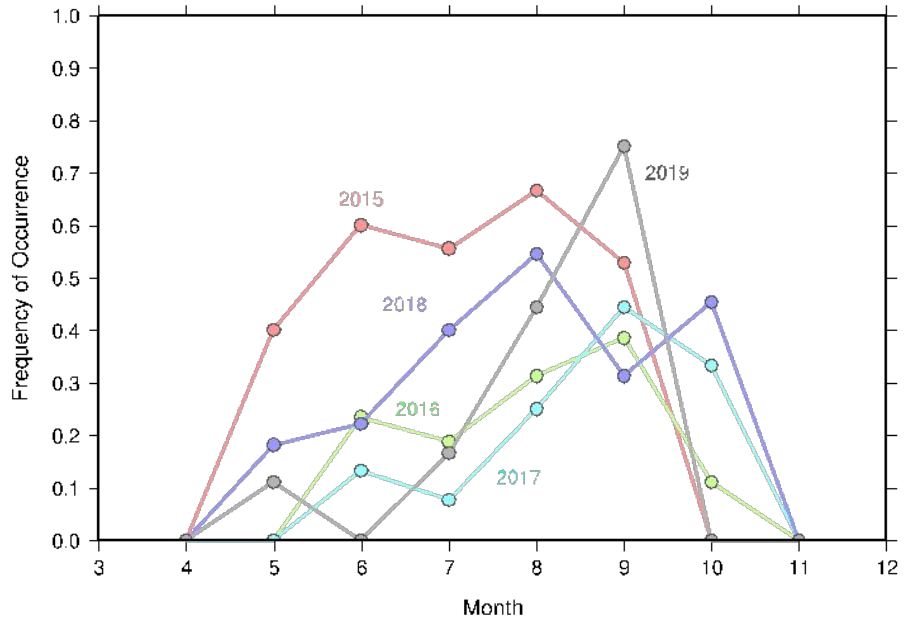
Red- Shelf Fleet

Black- ECOMON

Blue- Climatology

Shelf Fleet and ECOMON similar for July, September, October
Differences for May, June, August
Overall confirms a significant increase particularly for September/October

Shelf Fleet- Frequency of Intrusions by Month and Year from Shelf Research Fleet data



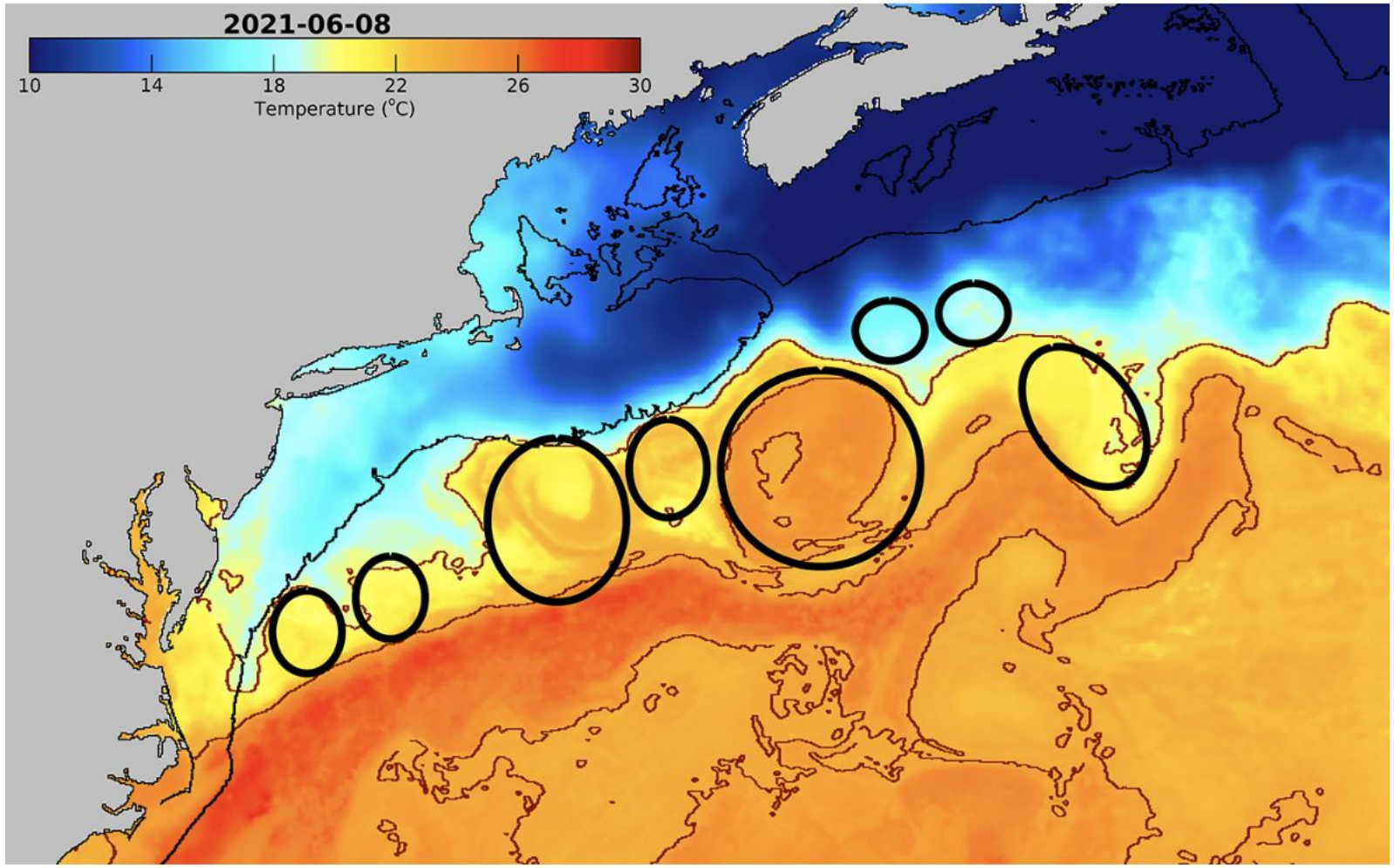
Shelf Fleet shows significant year to year variation in the timing of high frequency of intrusions

72% of Smax intrusions from ECOMON data were in proximity of Warm Core Rings (Silver et al. 2023)

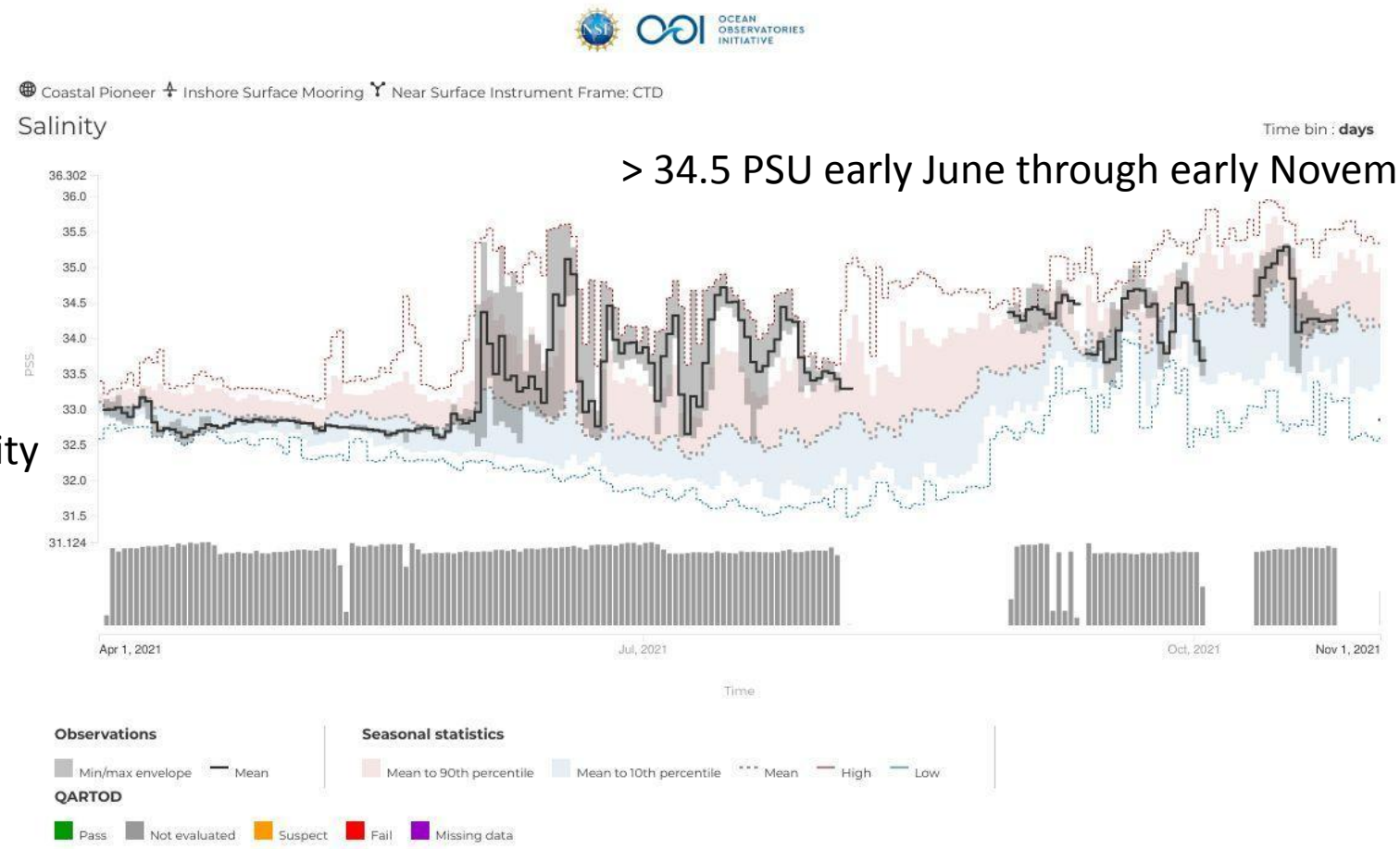
Modeling Challenge #2

- Can hydrodynamic models accurately capture onshore advection of Warm Core Ring water masses?
- Can hydrodynamic models produce complex layering and temperature/salinity structure commonly observed during the stratified season as a result of intrusions?

Warm Core Rings June 2021



Pioneer Inshore Mooring
Near Surface (7 m) Salinity April/Nov 2021

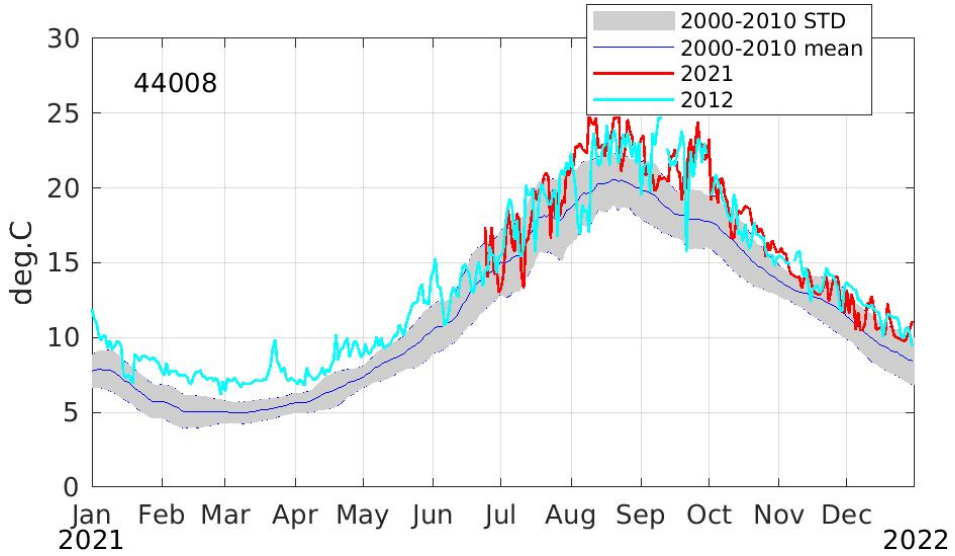


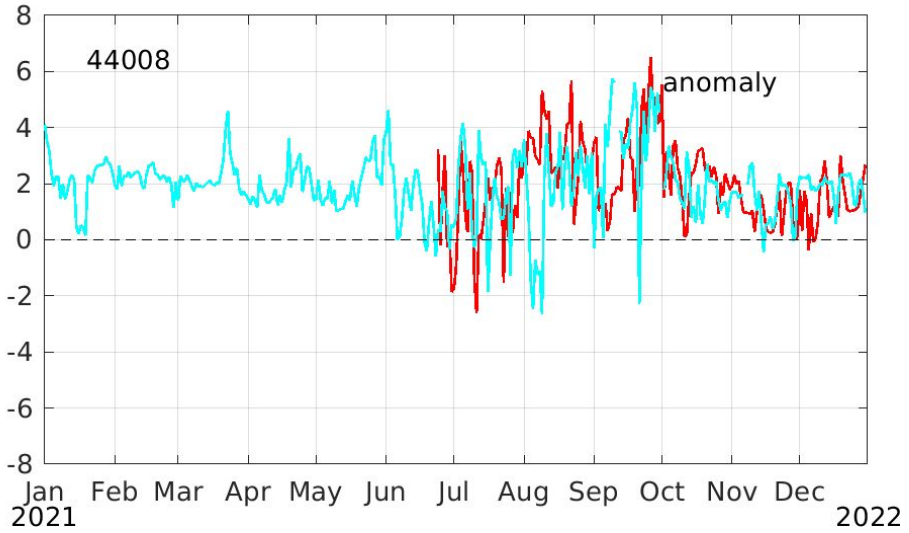
> 34.5 PSU early June through early November

Normal
Shelf Salinity
< 33 PSU

Shelfbreak Front well inshore of 95 m isobath for 5+ months!!!

Ocean Surface Temperature 2021
NDBC 44008 Nantucket Shoals



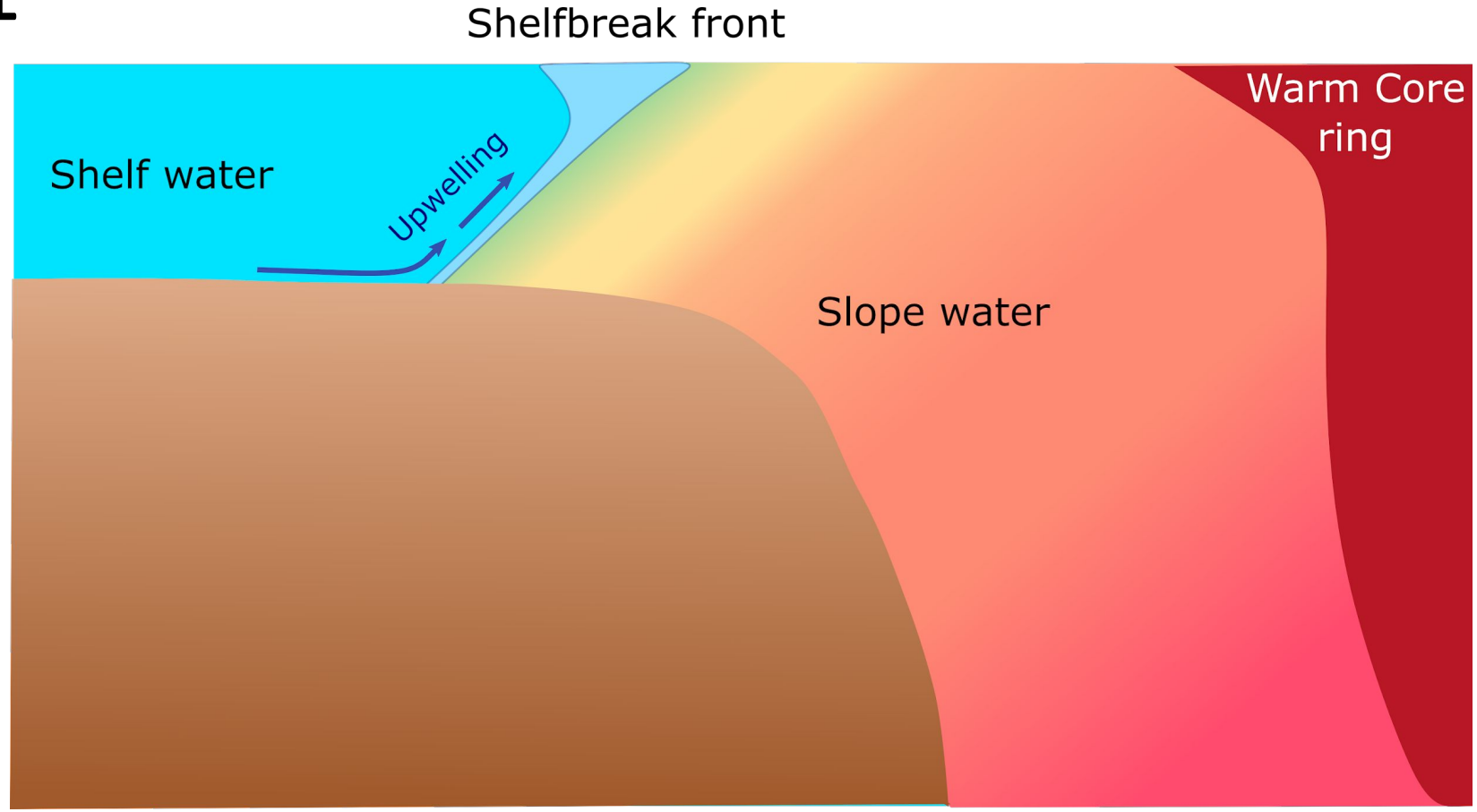


Warmest summer temperatures
in 2021 exceed 2012 values

Largest temperature anomaly
Occurred in late September
> 6 Deg. C (11 Deg. F)

Figure courtesy Ke Chen WHOI

Onshore Displacement of Shelfbreak Front 2021

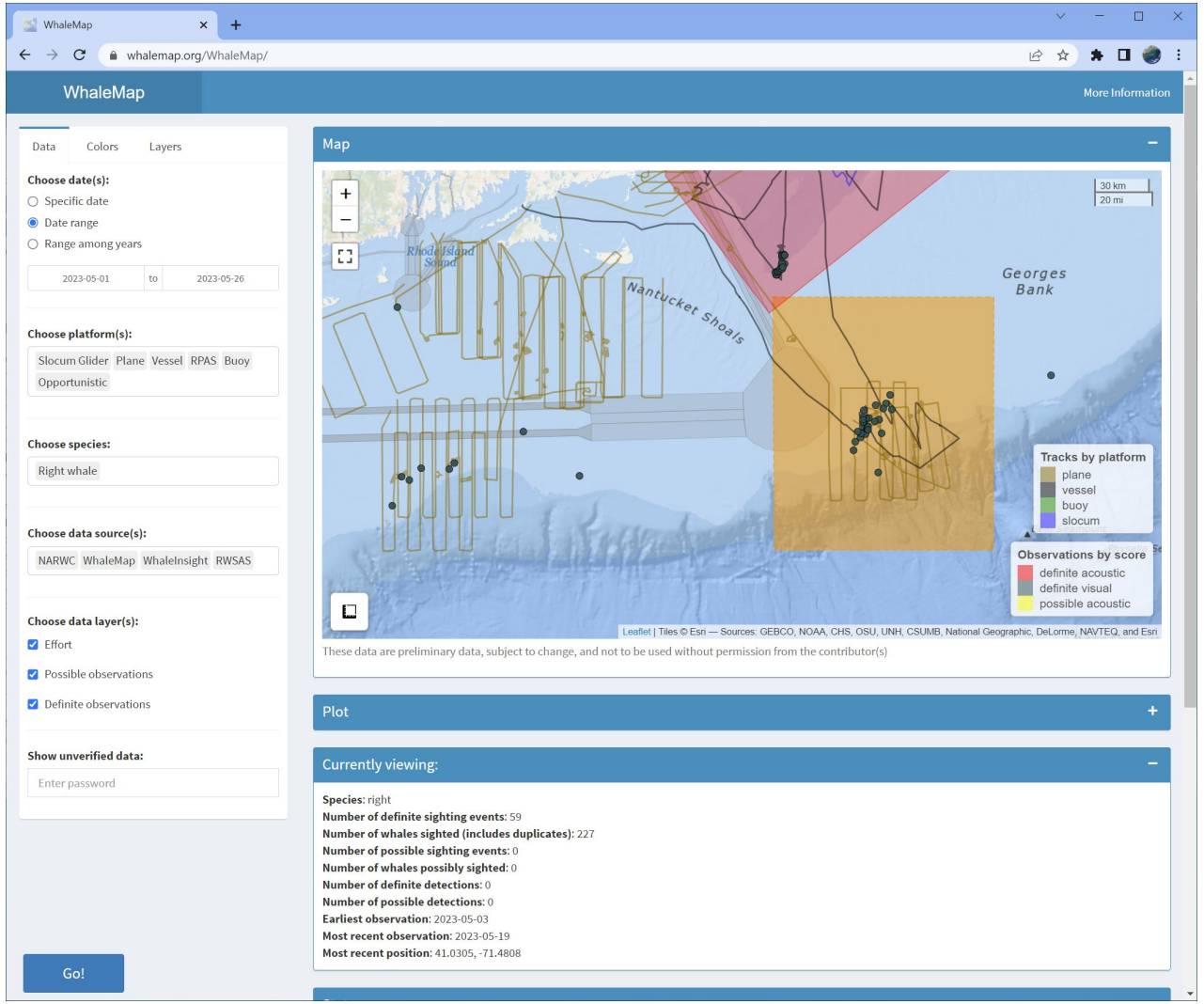


Major Ecological impacts- yellowfin tuna present over outer shelf for most of summer, bluefin tuna moved onshore in June (not at canyons!) and present inshore throughout summer, commercial fishers reported large aggregations of marine mammals at mid-shelf

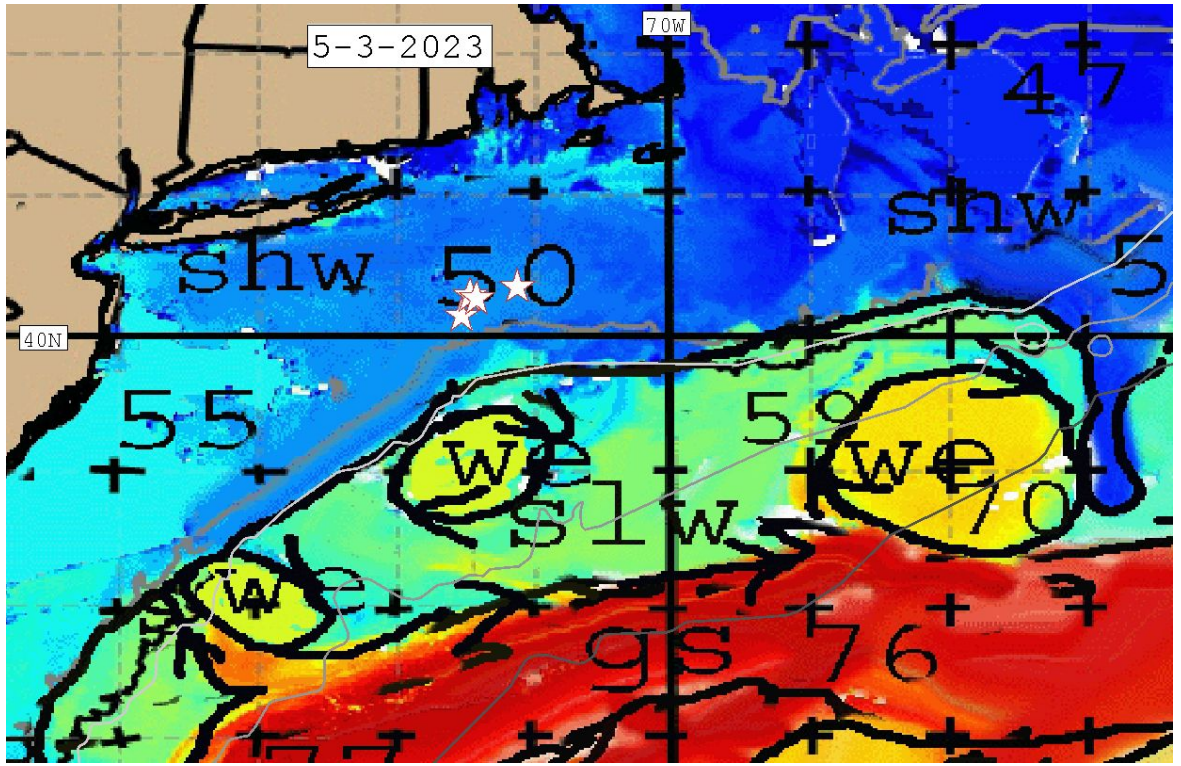
Modeling Challenge #3

- Can hydrodynamic models capture large onshore displacements of the Shelfbreak Front that may last for months?
- Can hydrodynamic models accurately represent the cross-frontal temperature, salinity, and density gradients across the front when the front has a pronounced onshore displacement?
- IMPLICATION- Shelfbreak frontal displacements may move marine mammals to mid-shelf in the heart of turbine development areas

Right Whale Distribution May 12, 2023



From whalemap.org



From Grace Jensen/Avijit Gangopadhyay U. Mass.-Dartmouth

Recommendations

- Focus on accurately modeling stratification is important as a necessary step in modeling prey fields.
- Emphasis on how ocean processes are changing is CRITICAL. There needs to be dialogue between modelers and observationalists (and ideally the fishing industry) to identify major changes in frontal positions, warm core ring frequency and structure, and upstream influences.
- The departure of the OOI Pioneer Array from the vicinity is a major loss. Observational assets that include real-time mooring data streams are vital.
- Oceanographic data relating to the Offshore Wind industry should be made public whenever possible and as rapidly as possible.