# The Increasing Influence of Gulf Stream Variability on Shelf/Slope Processes in the Northwest Atlantic

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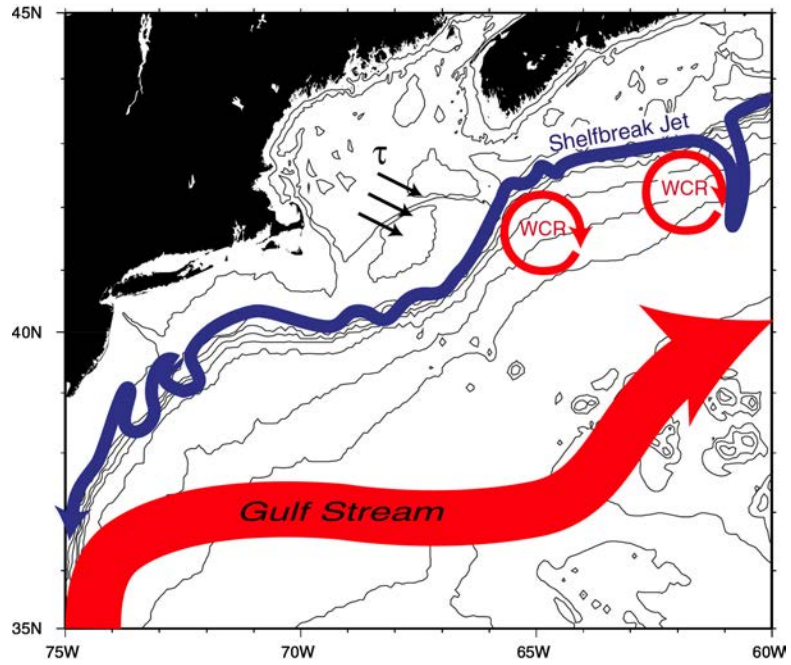
CLIVAR Meeting

August 2, 2023

# Outline

- Regional Circulation in the Middle Atlantic Bight
- Shelfbreak Processes and Observational Assets
- Changes in Stratification over the Continental Shelf
- Gulf Stream Variability and Shelf Impacts-Salinity Maximum Intrusions
- Onshore Displacement of the Shelfbreak Front in 2021
- Recommendations for Moving Forward

# Background- Regional Circulation

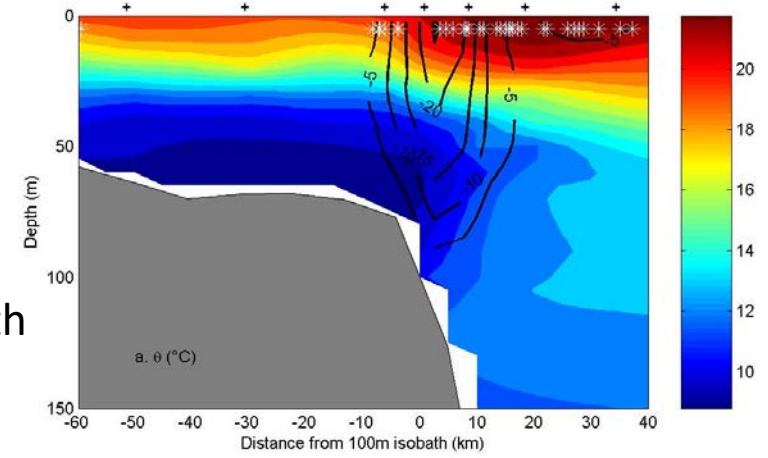



The Shelfbreak Jet and the Gulf Stream

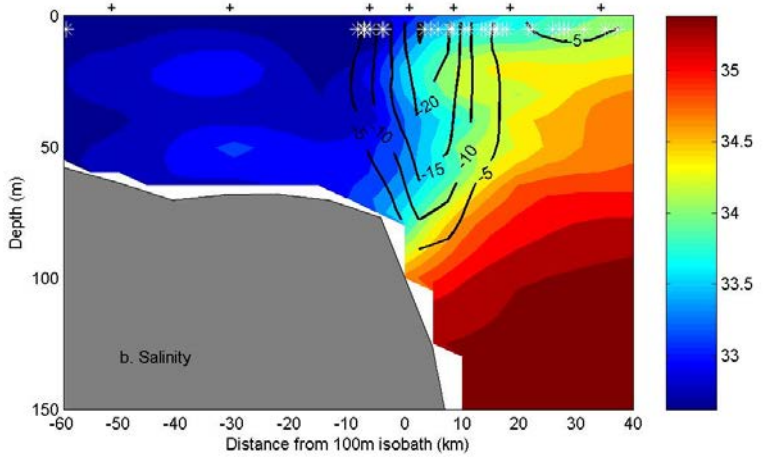
Figure courtesy
P. Fratantoni

Temperature

Depth



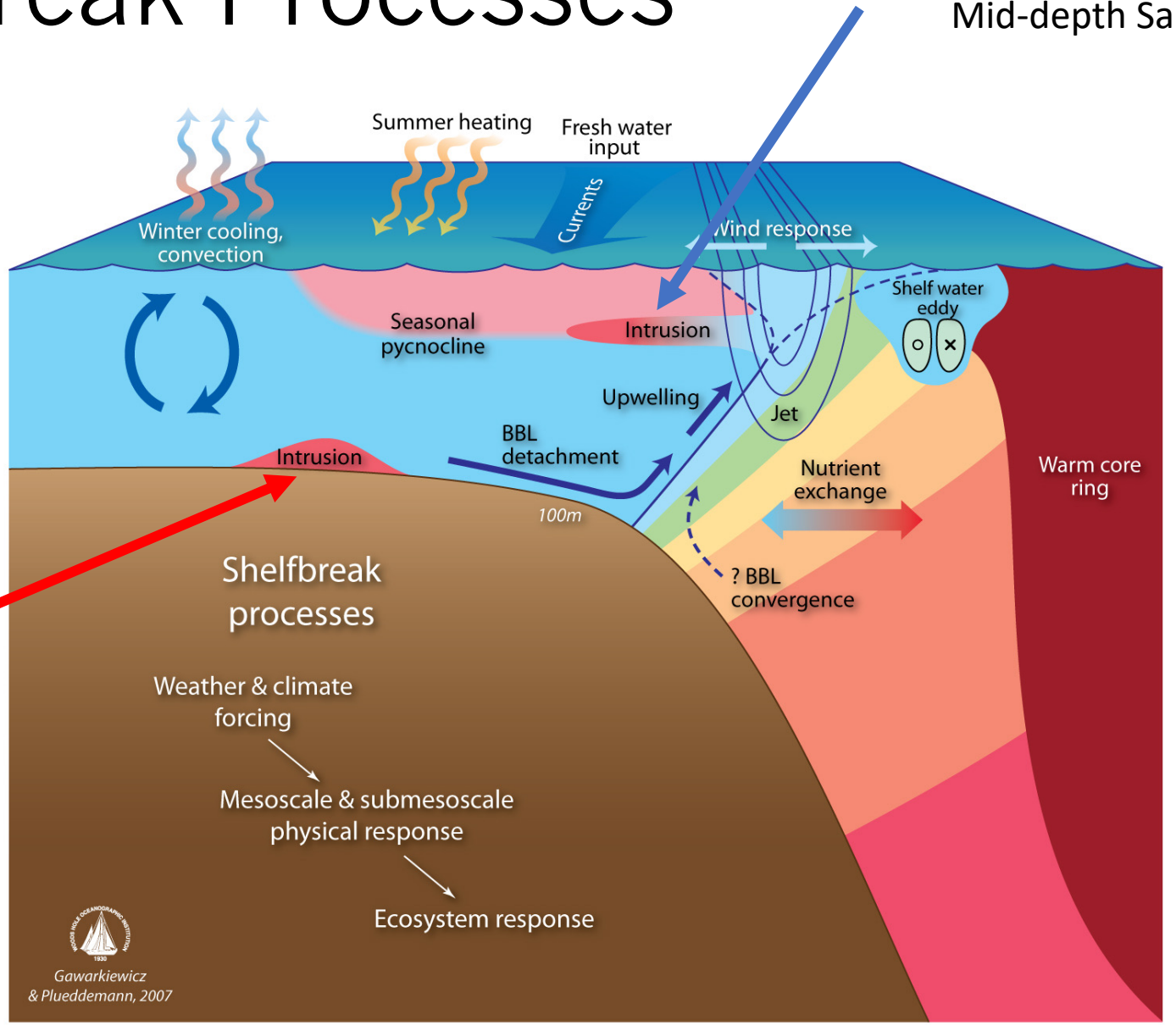

Salinity




Offshore Distance

# Shelfbreak Processes

Mid-depth Salinity Maximum Intrusion

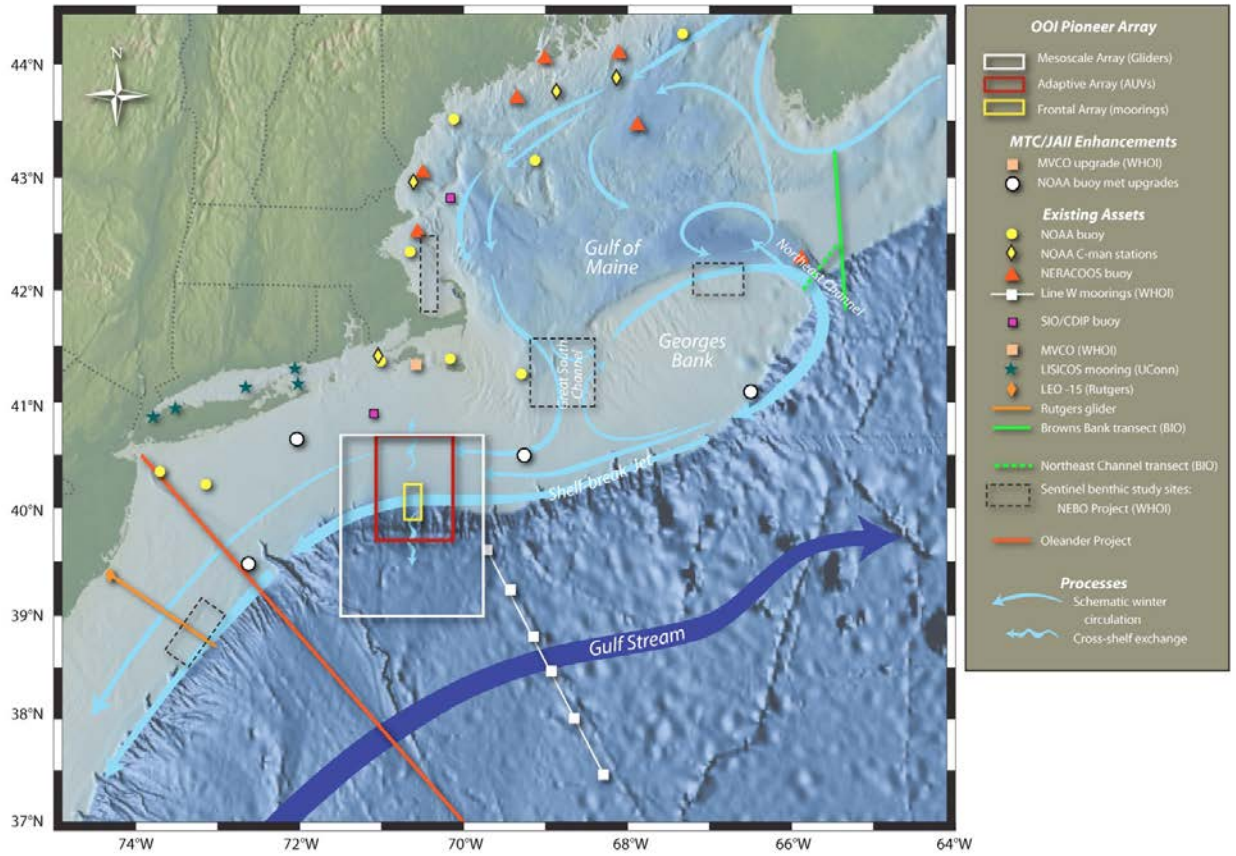



Bottom Intrusion

Chen et al., 2021

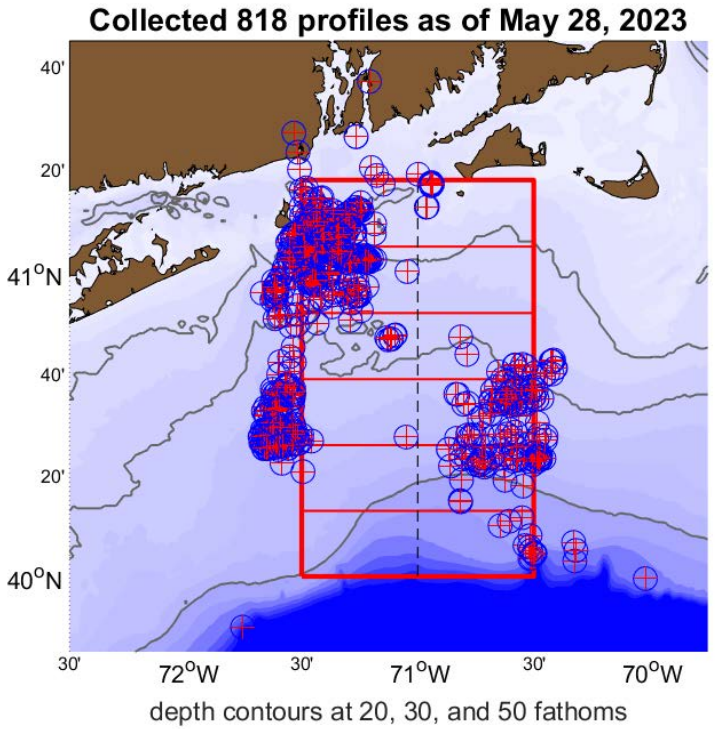
Boicourt and Hacker, 1975
Gordon and Aikman, 1981
Aikman, 1984
Flagg et al., 1994
Lentz, 2003

# 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

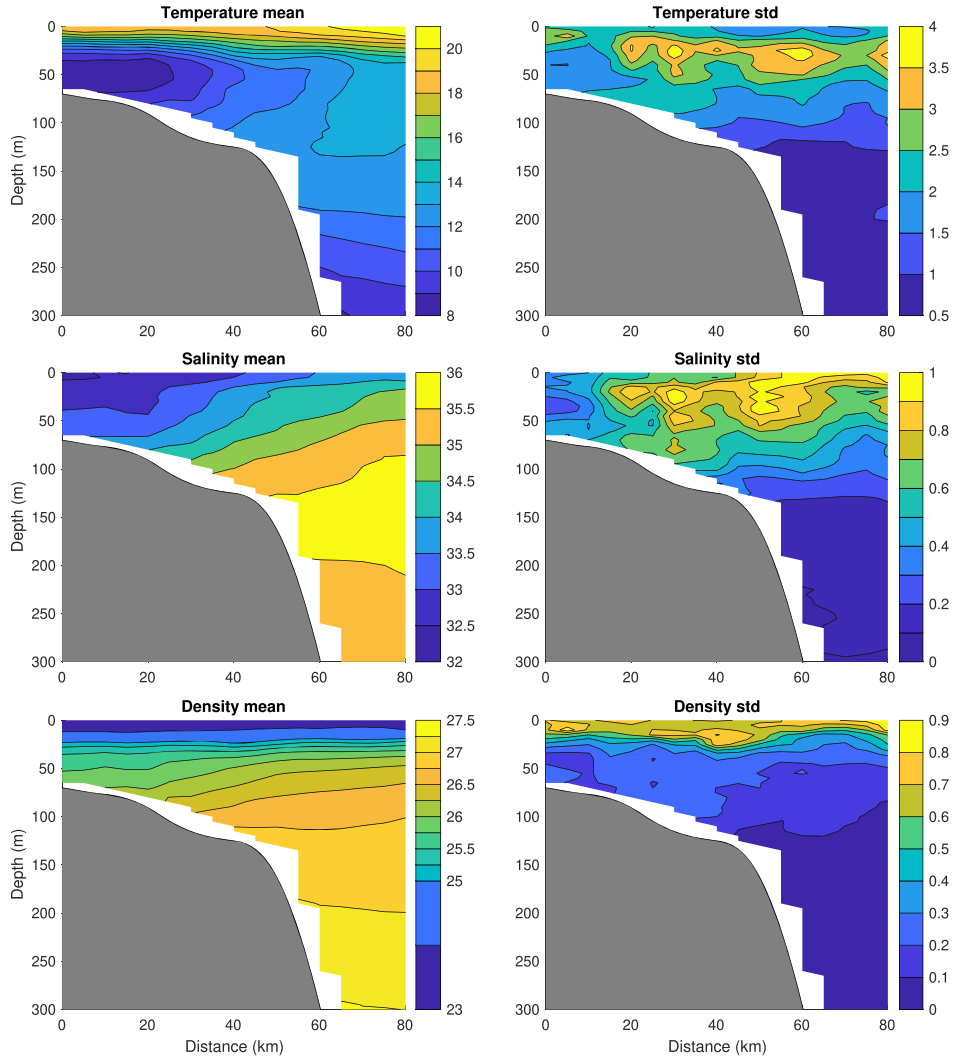


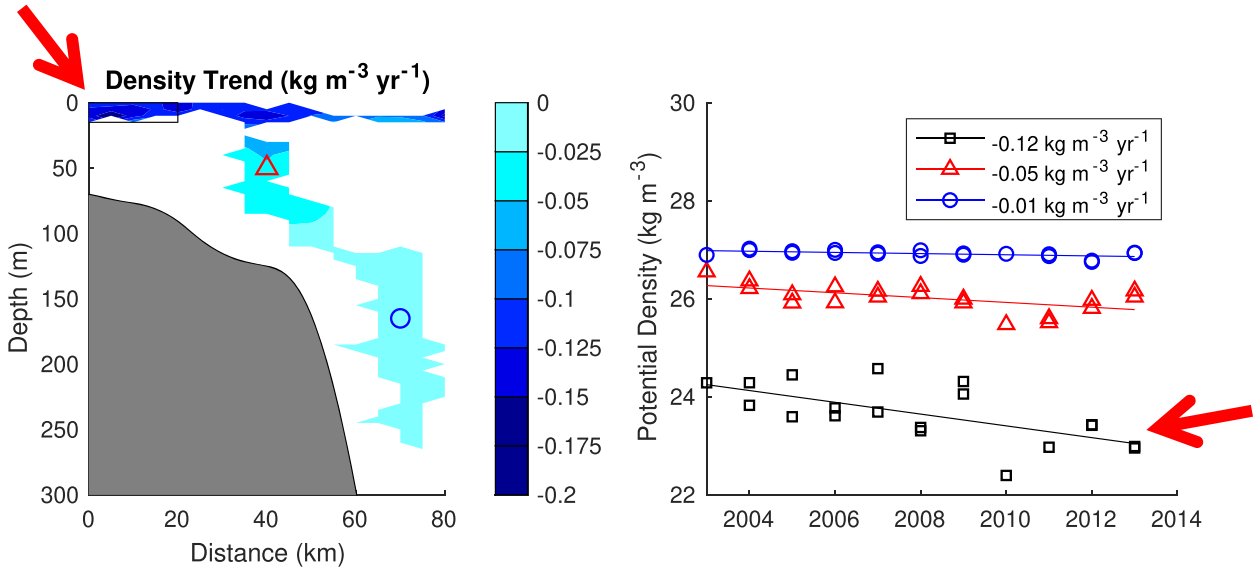

Collecting temperature and Salinity data since Nov. 2014 (funding from MacArthur/ van Beuren Foundations)

On fishing boat off Point Judith RI

Meeting at Commercial Fisheries Center (URI)

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




Steep decrease in near surface density (black squares) -0.12 kg/m$^3$ per year!

Approximately half that rate at 50 m depth near the front

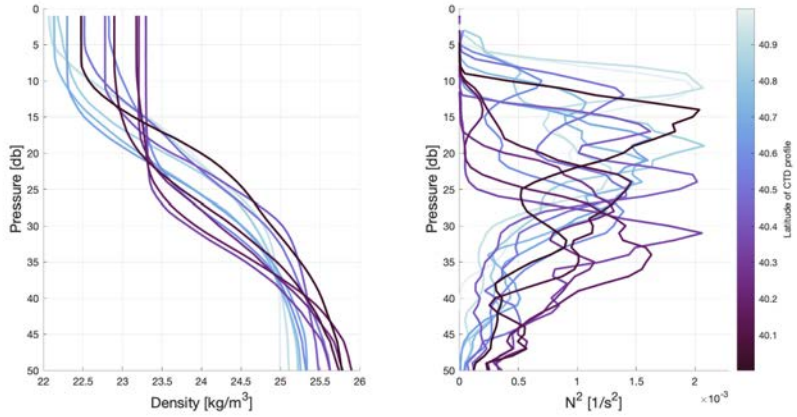
Much smaller at 150 m depth

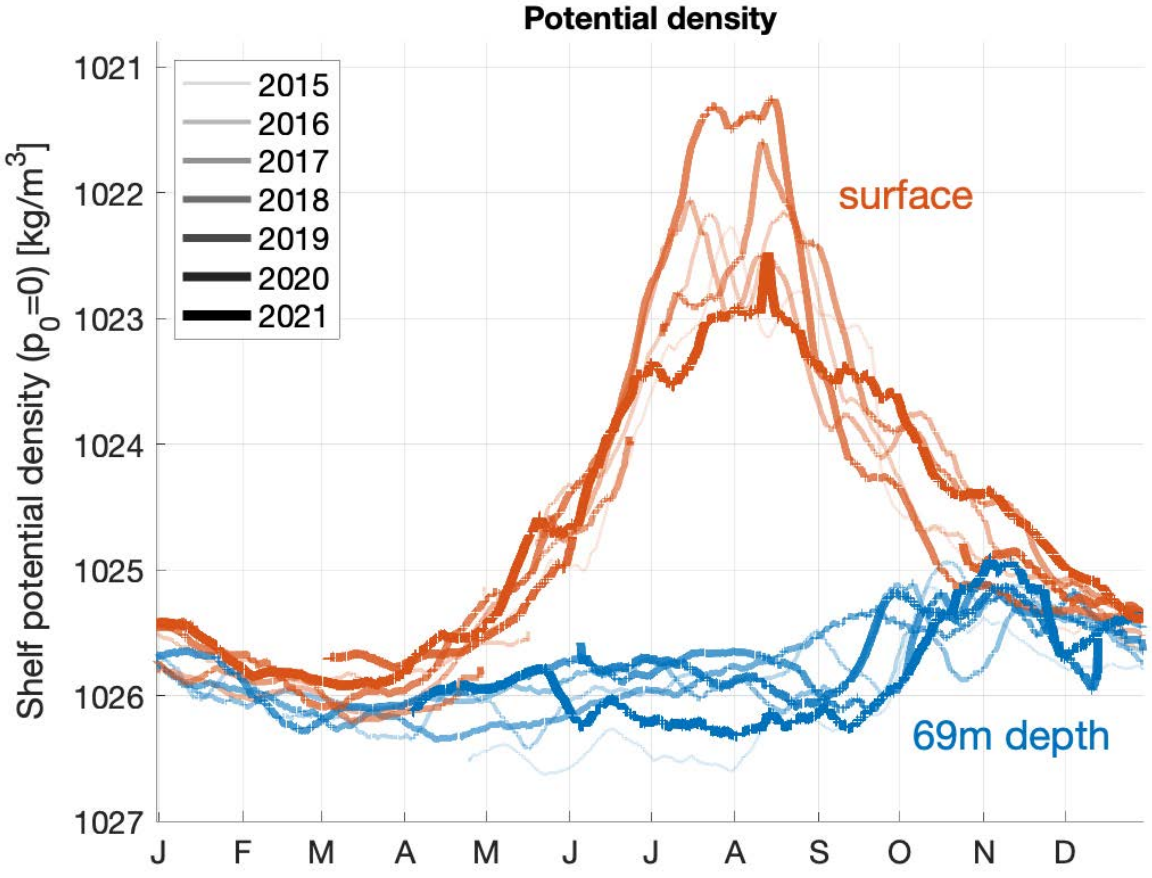
# Surface and 69 m Potential Density from OOI Pioneer Array Inshore Mooring

Very large interannual variations in Summer minimum surface potential density

Values as low as 1021.3 kg/m$^3$ in 2020

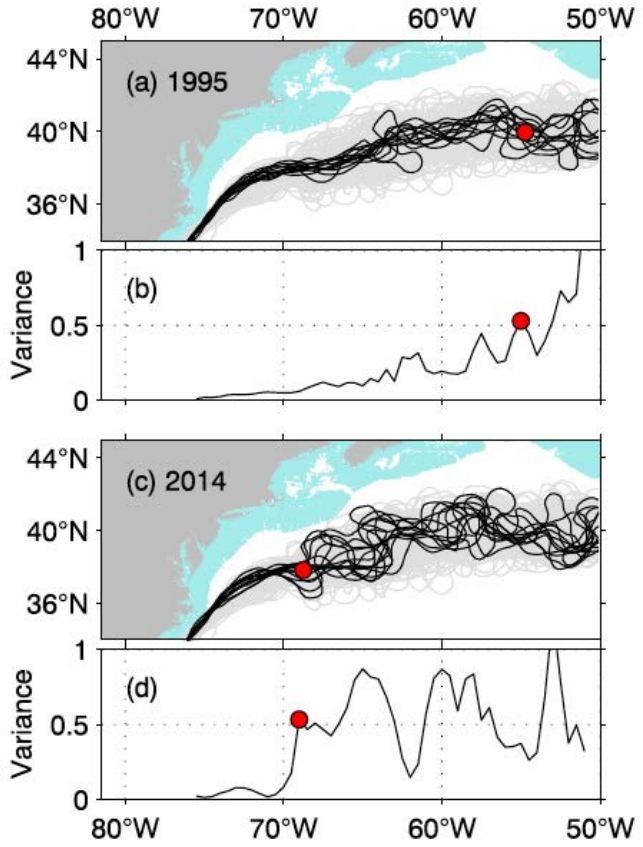
Surface values in September 2022 were as low as 1022.0 kg/m$^3$ (R/V Endeavor EN690)



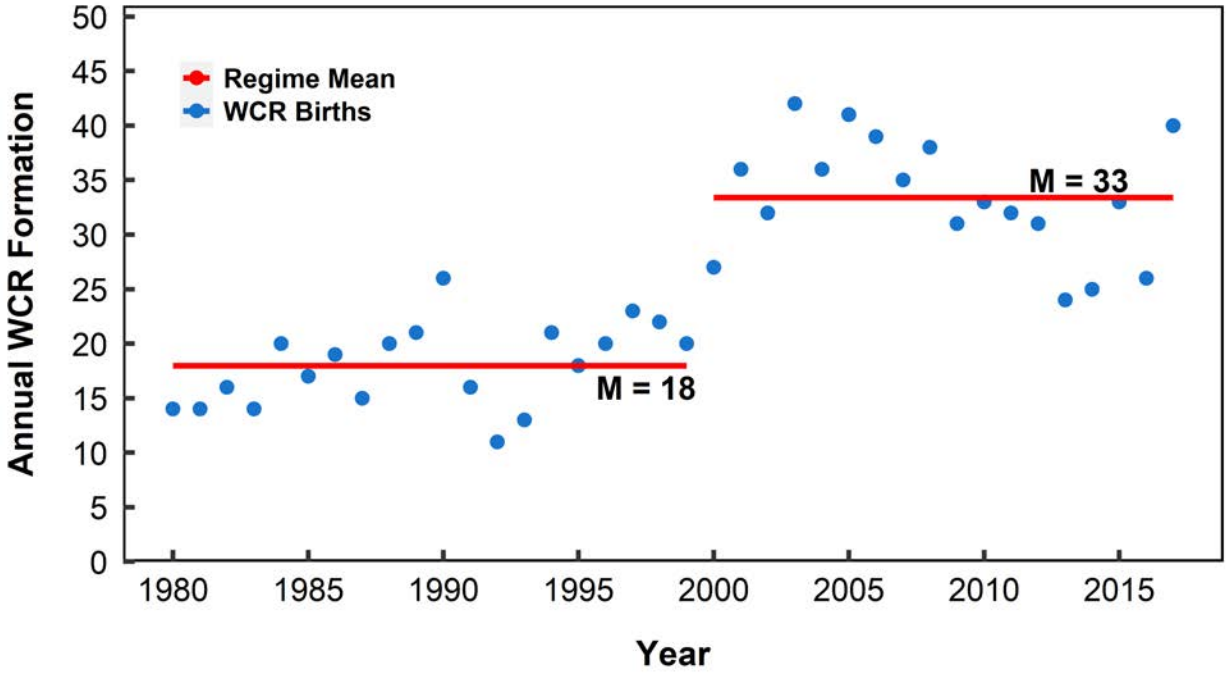




Figures courtesy Lukas Lobert MIT/WHOI Joint Program

# What is happening with the Gulf Stream?

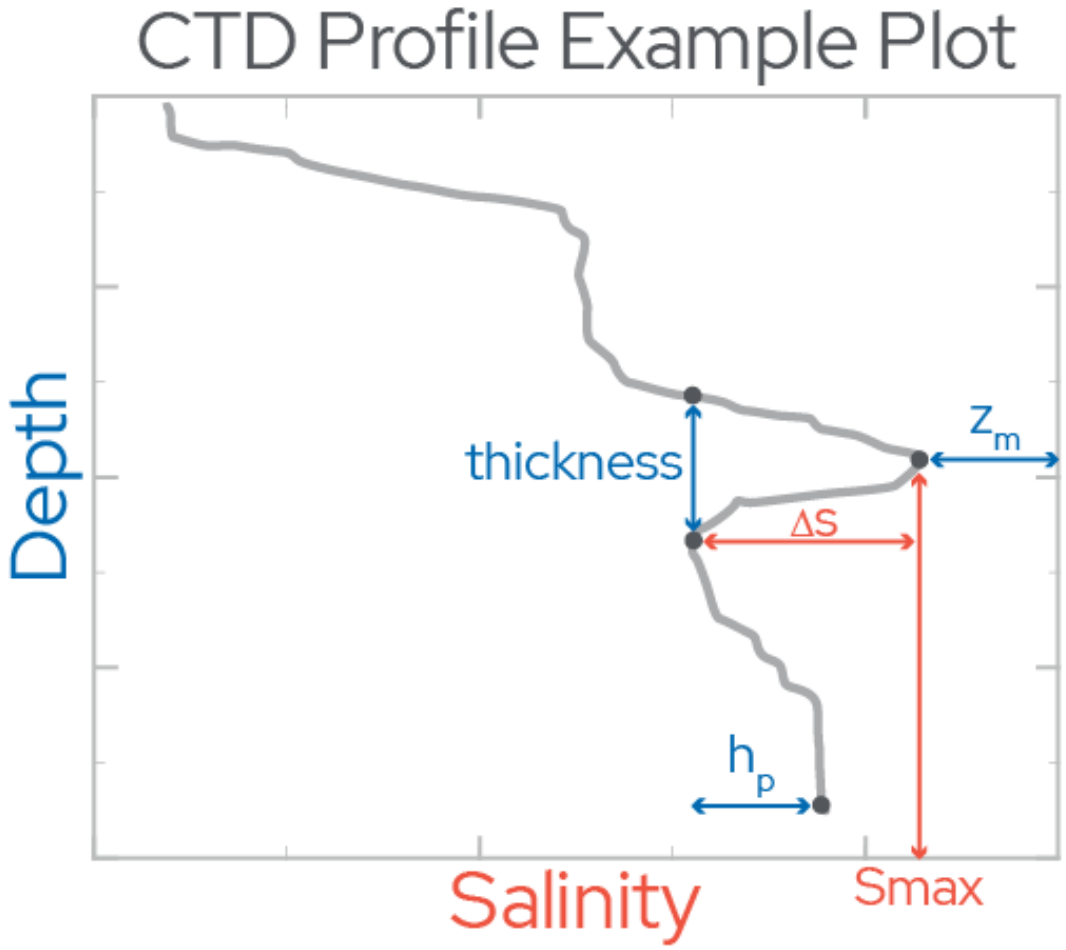



Large amplitude meanders of the Gulf Stream are beginning further to the west (from SSHA)
Andres 2016




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

# Defining Smax from Shelf Fleet data



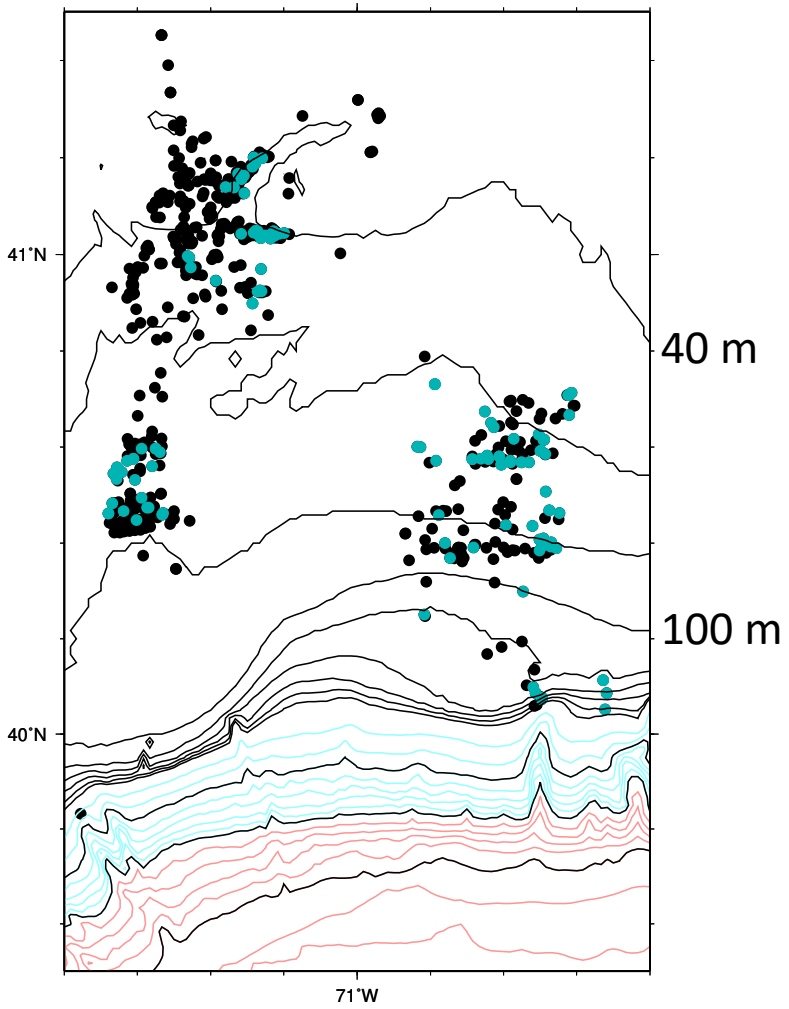

Delta S > 0.2 PSU  (Lentz used 0.1 PSU)

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

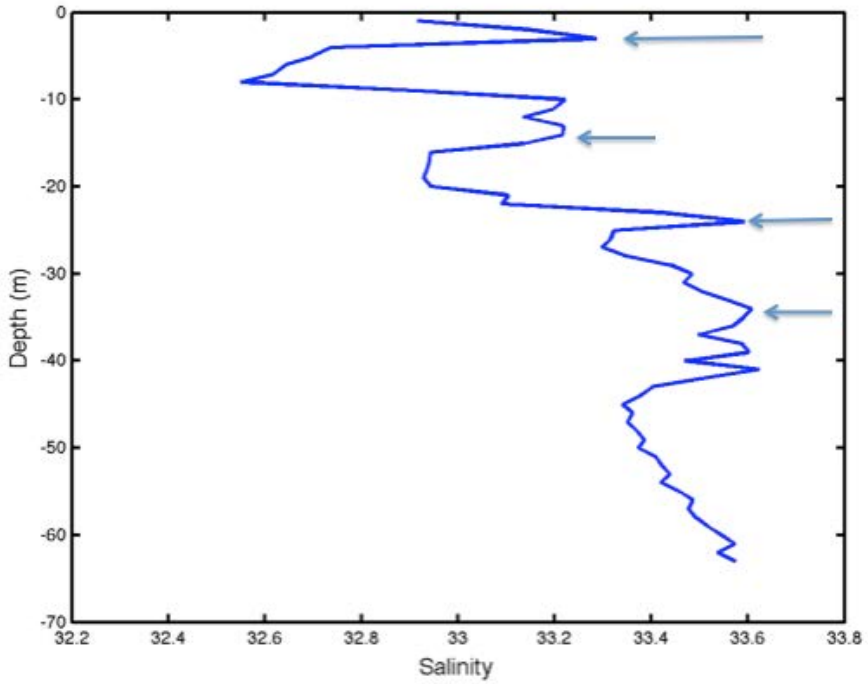



Black dots- Profiles with no intrusion

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

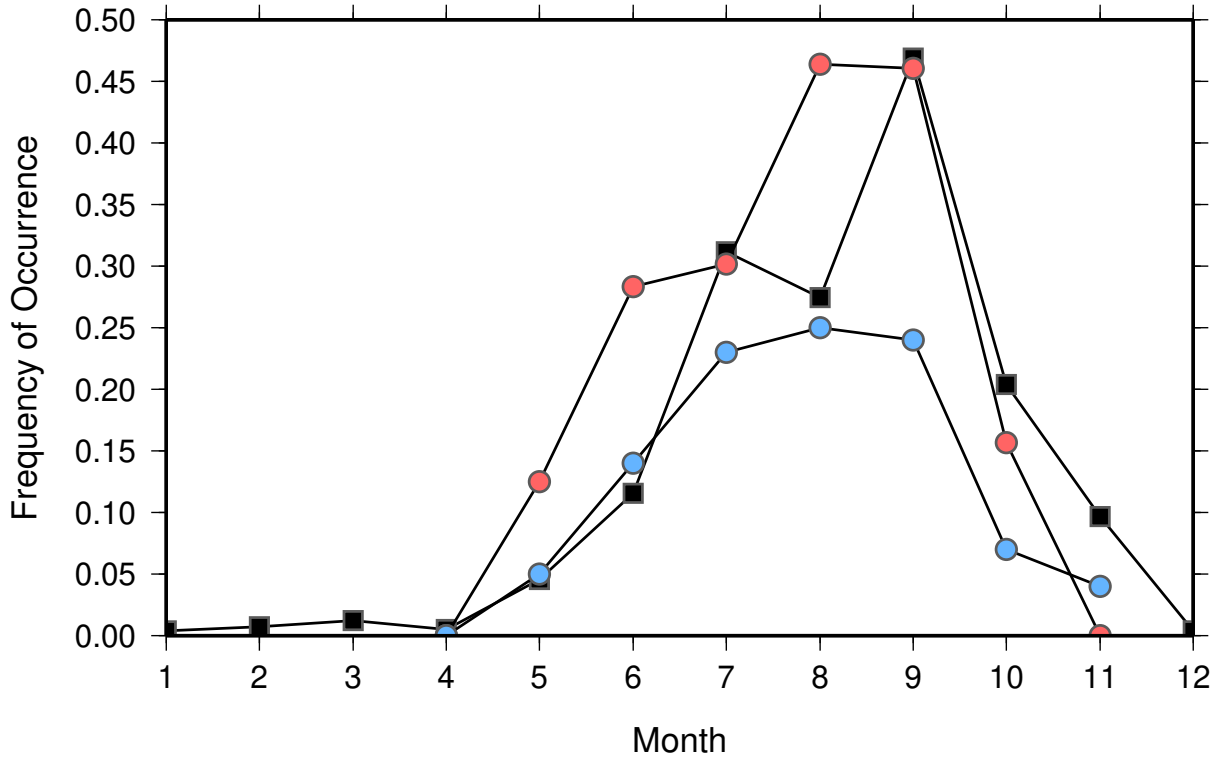



One profile had 4 different Smax intrusions

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



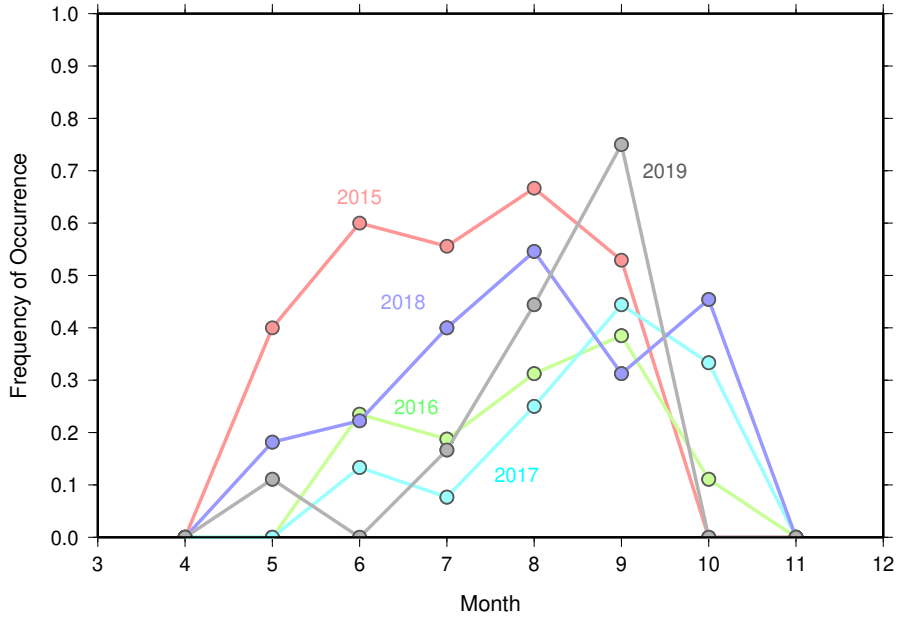

Red- Shelf Fleet

Black- ECOMON

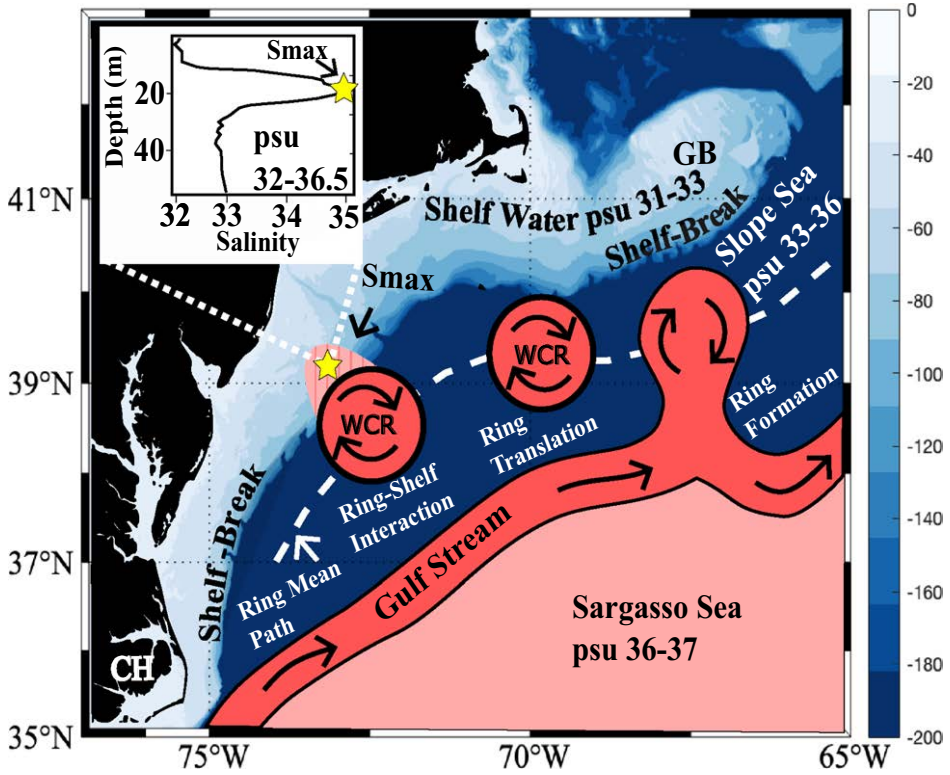
Blue- Climatology

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

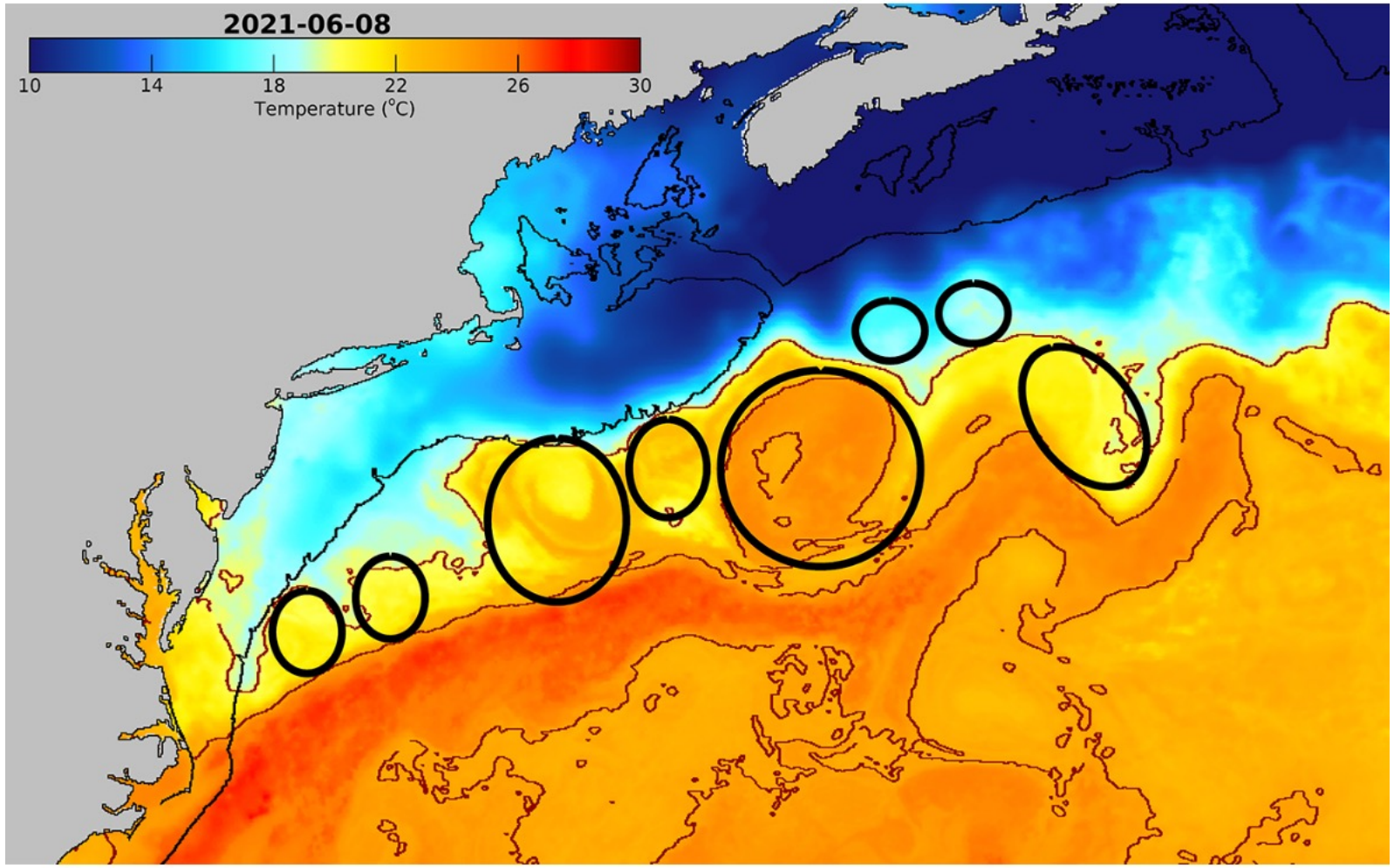



Shelf Fleet shows significant year to year variation in the timing of high frequency of intrusions (Gawarkiewicz et al. 2022)

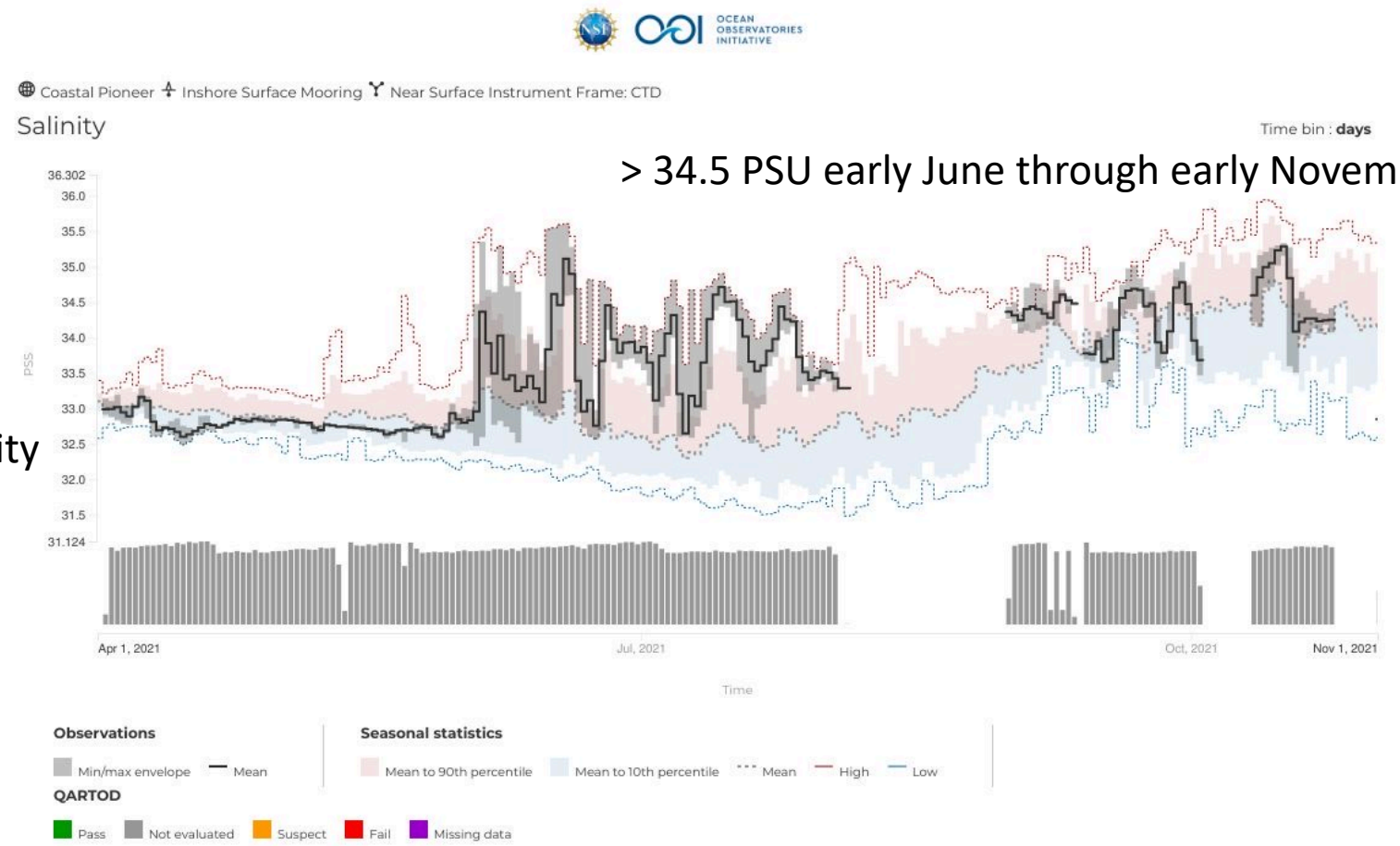



72% of Smax intrusions from ECOMON data are in proximity to Warm Core Ring (Silver et al. 2023)

# Warm Core Rings June 2021



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

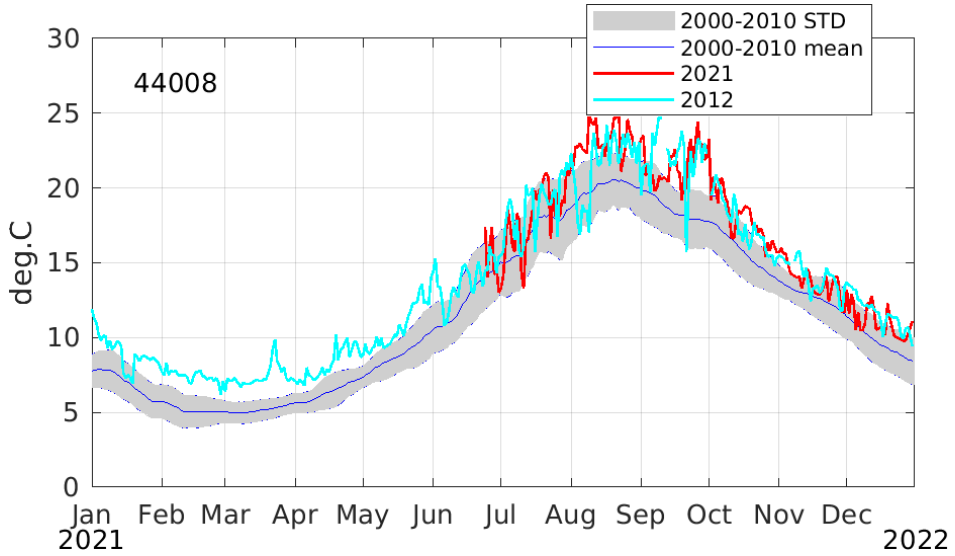


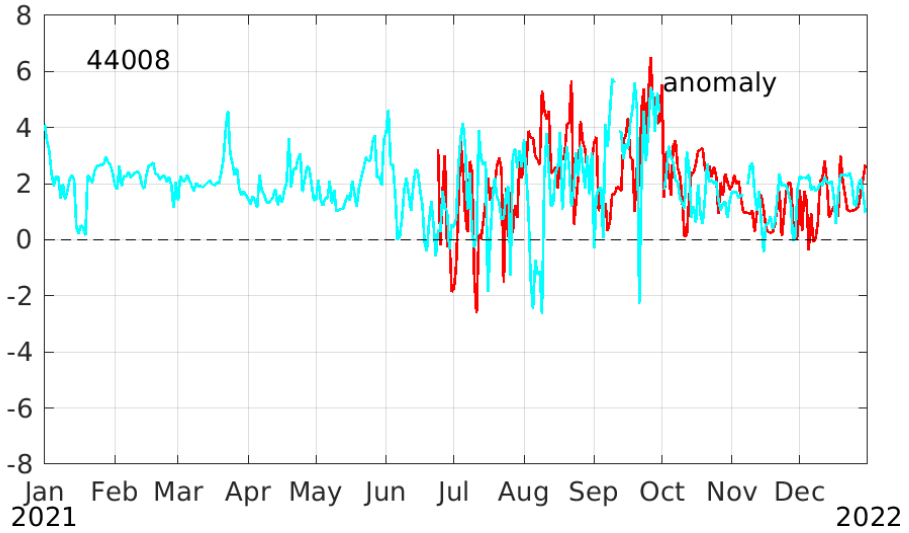

> 34.5 PSU early June through early November

Normal
Shelf Salinity
< 33 PSU

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

# Ocean Surface Temperature 2021
# NDBC 44008 Nantucket Shoals



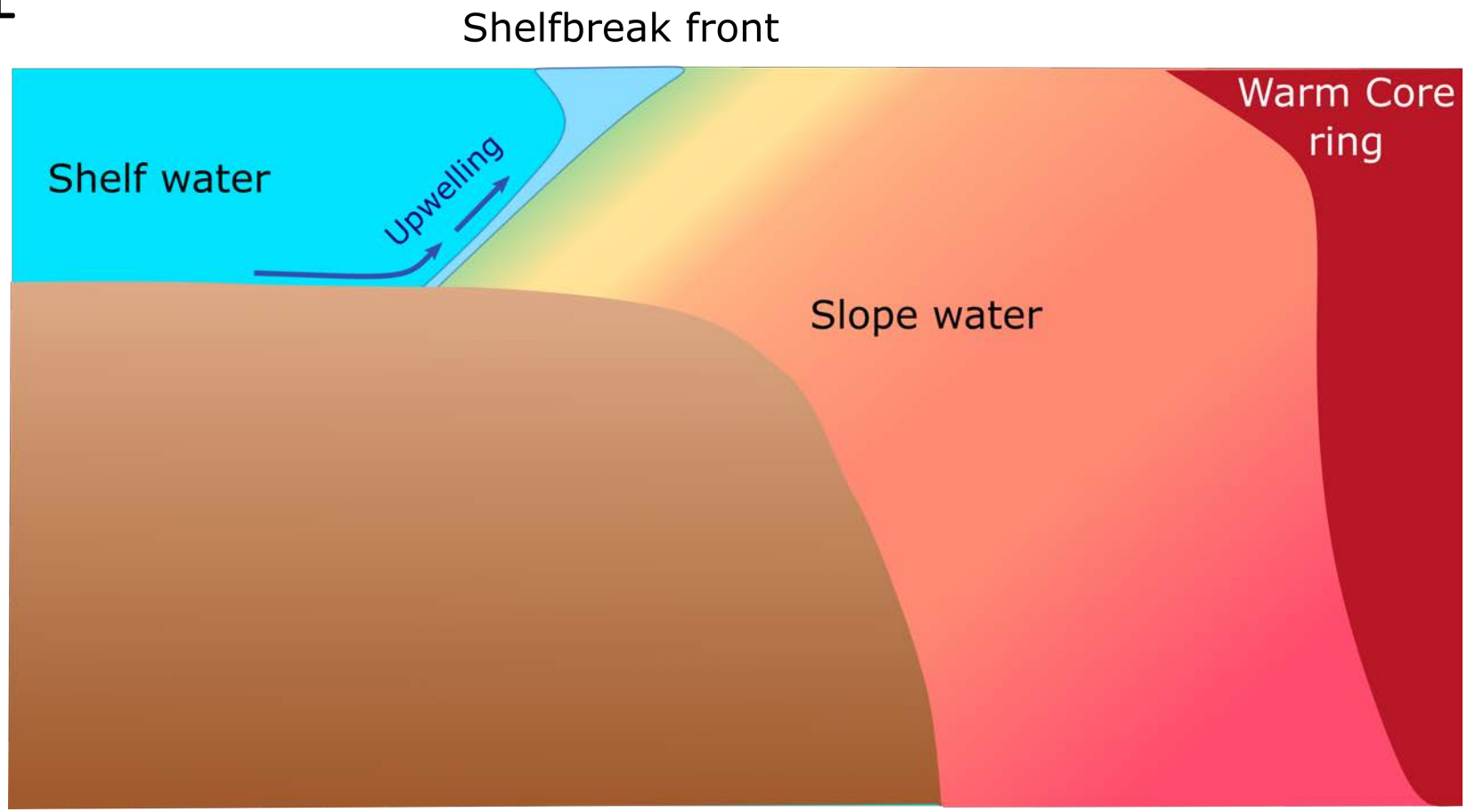




Warmest summer temperatures
in 2021 exceed 2012 values

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

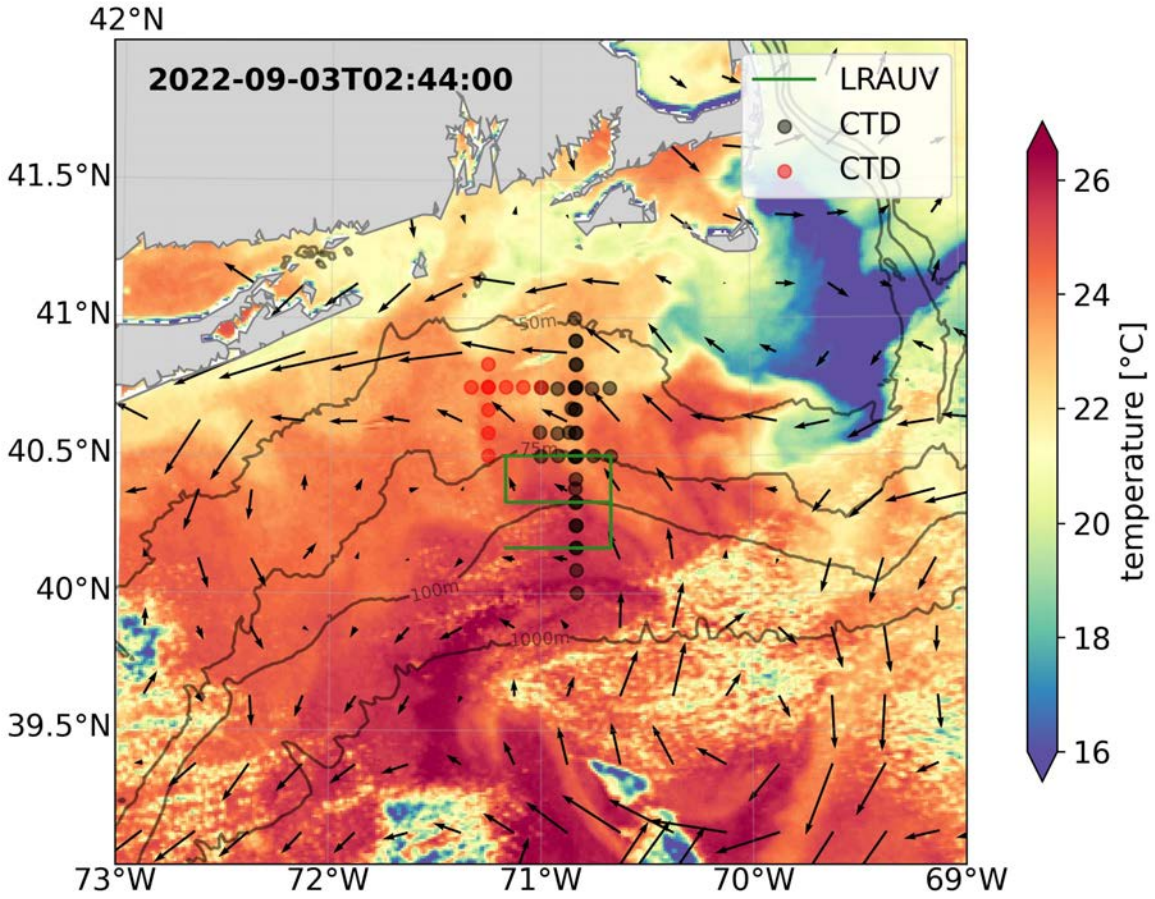
Figure courtesy Ke Chen WHOI

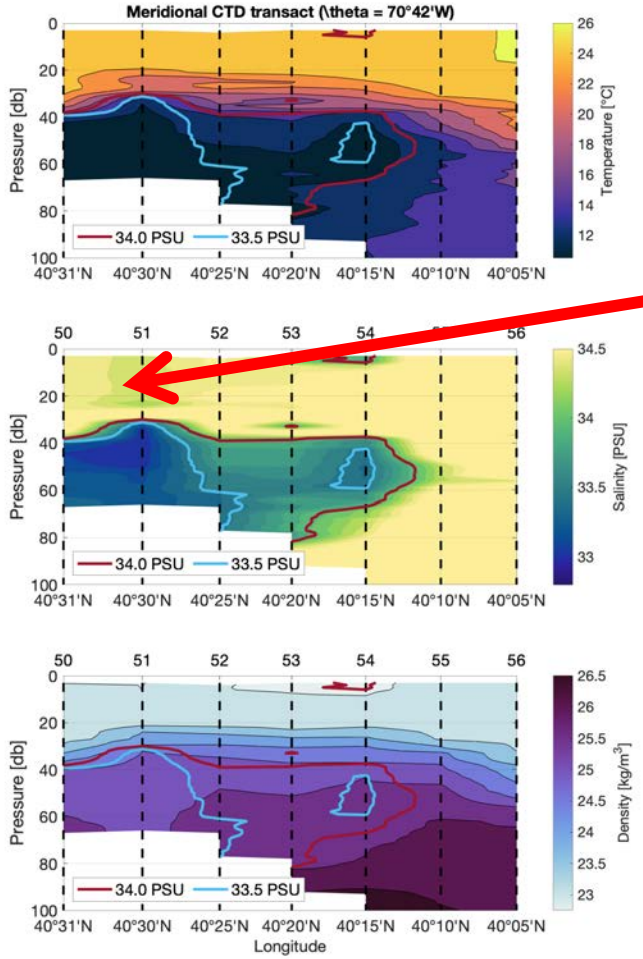
# Onshore Displacement of Shelfbreak Front 2021




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

# September 2022- No barrier to onshore transport in upper 40 m at the shelfbreak




Offshore waters
With Salinity 34.5
Freely pass over
Cold Pool to
mid-shelf

# Recommendations

- Focus on accurately modeling stratification is important as a necessary step in accurately modeling shelfbreak exchange processes.
- 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.
- Changes in ocean processes related to increasing stratification need to be examined closely in terms of implications for the shelf/slope ecosystems.

# References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Gangopadhyay, A., Gawarkiewicz, G., Silva, E. N. S., Monim, M., & Clark, J. (2019). An observed regime shift in the formation of warm core rings from the Gulf Stream. *Scientific Reports*, *9*(1), 1–9. https://doi.org/10.1038/s41598-019-48661-9

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