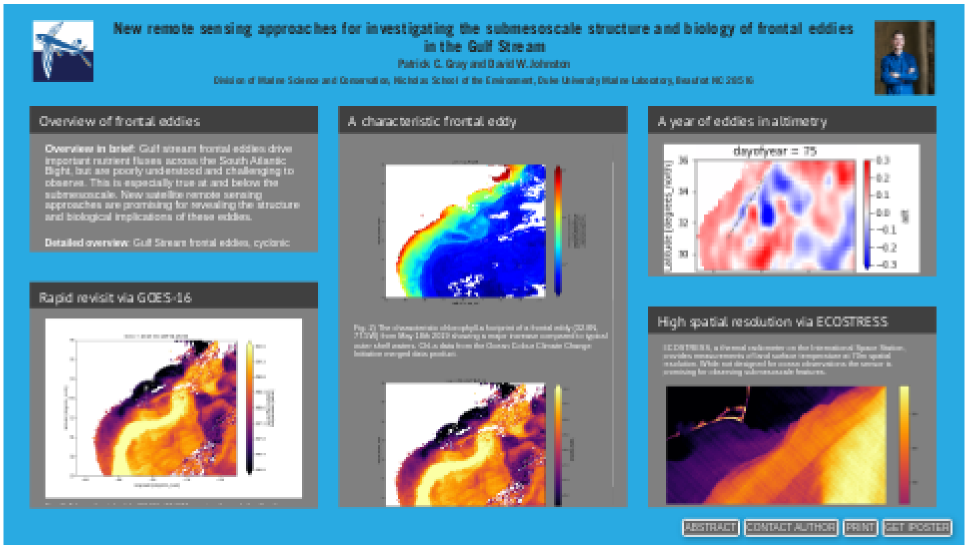
# New remote sensing approaches for investigating the submesoscale structure and biology of frontal eddies in the Gulf Stream

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# OVERVIEW OF FRONTAL EDDIES

**Overview in brief**: Gulf stream frontal eddies drive important nutrient fluxes across the South Atlantic Bight, but are poorly understood and challenging to observe. This is especially true at and below the submesoscale. New satellite remote sensing approaches are promising for revealing the structure and biological implications of these eddies.

**Detailed overview**: Gulf Stream frontal eddies, cyclonic features that form in the trough of meanders in the South Atlantic Bight, provide a natural mesocosm for investigating questions around submesoscale spatial and temporal variability. These frontal eddies drive important nutrient fluxes into the euphotic zone which generate considerable productivity on the outer shelf of the Southeast US coastline. Fine scale physical models suggest there is a substantial amount of submesoscale vertical mixing, but current observational approaches miss much of these dynamics and the potential biological response to them. This biological response could be considerable given the intense front these eddies have with the Gulf Stream. Thus current ecological and biogeochemical models could be missing these submesoscale contributions to productivity and carbon export.

New remote sensing platforms may provide a window into the hidden spatial and temporal scales that could reveal more about the overall impact of these eddies on the South Atlantic Bight. NOAA's GOES-16 geostationary satellite provides hourly SST data, the ISS-based ECOSTRESS instrument provides 70m spatial resolution SST data, and the Ocean Colour Climate Change Initiative's merged chlorophyll-a product helps reveal change over time in the biological response.

# RAPID REVISIT VIA GOES-16

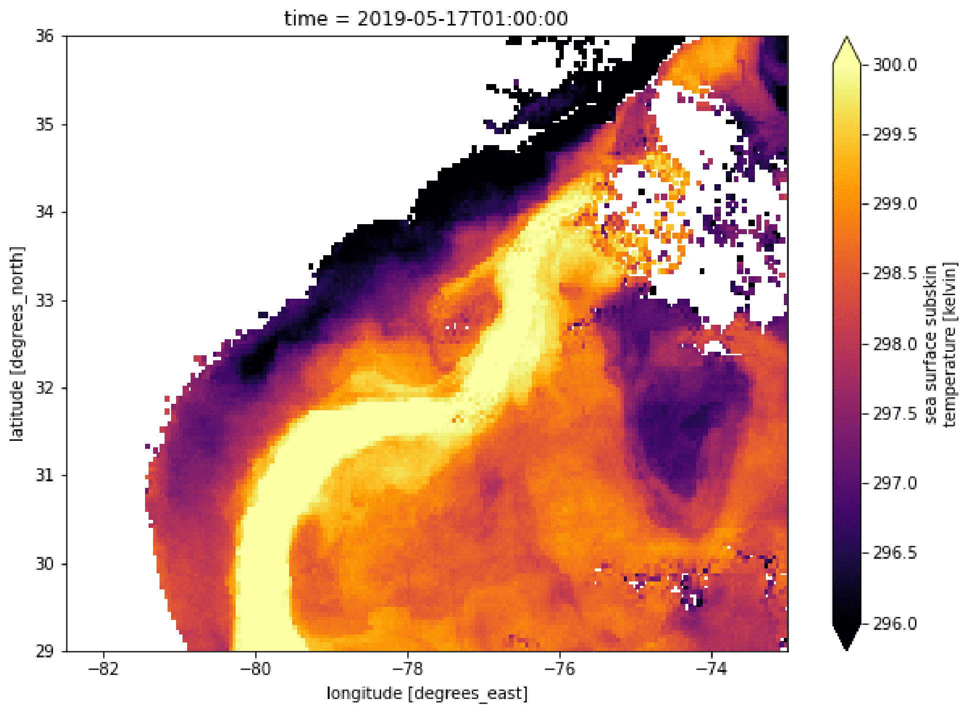


Fig. 1) A large frontal eddy (32.5N, 77.8W) moving through the South Atlantic Bight at approximately as seen in hourly sea surface temperature imagery via GOES-East's Advanced Baseline Imagery. Clouds are masked.

# A CHARACTERISTIC FRONTAL EDDY

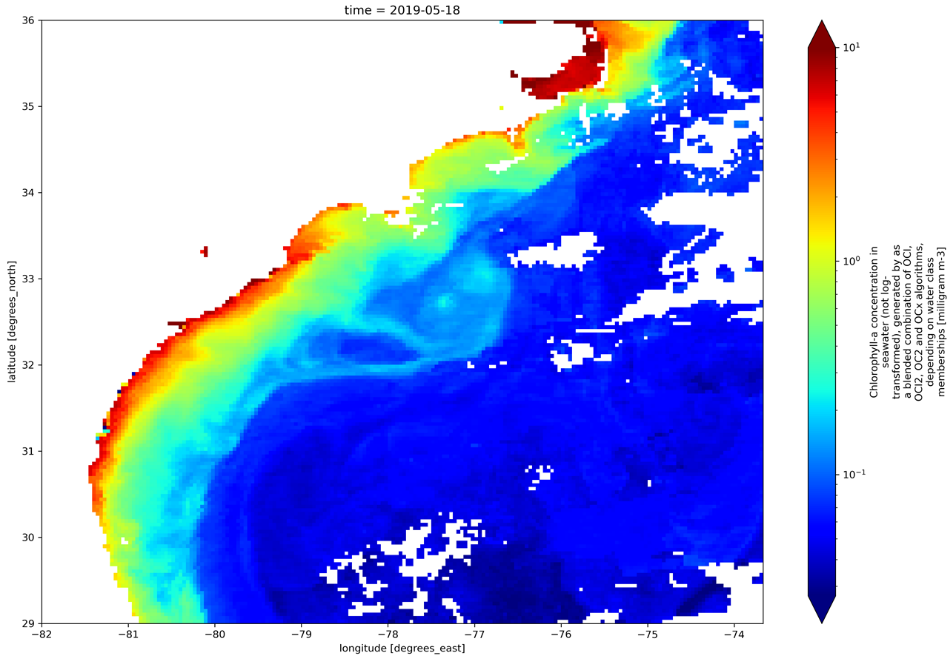


Fig. 2) The characteristic chlorophyll-a footprint of a frontal eddy (32.8N, 77.5W) from May 18th 2019 showing a major increase compared to typical outer shelf waters. Chl-a data from the Ocean Colour Climate Change Initiative merged data product.

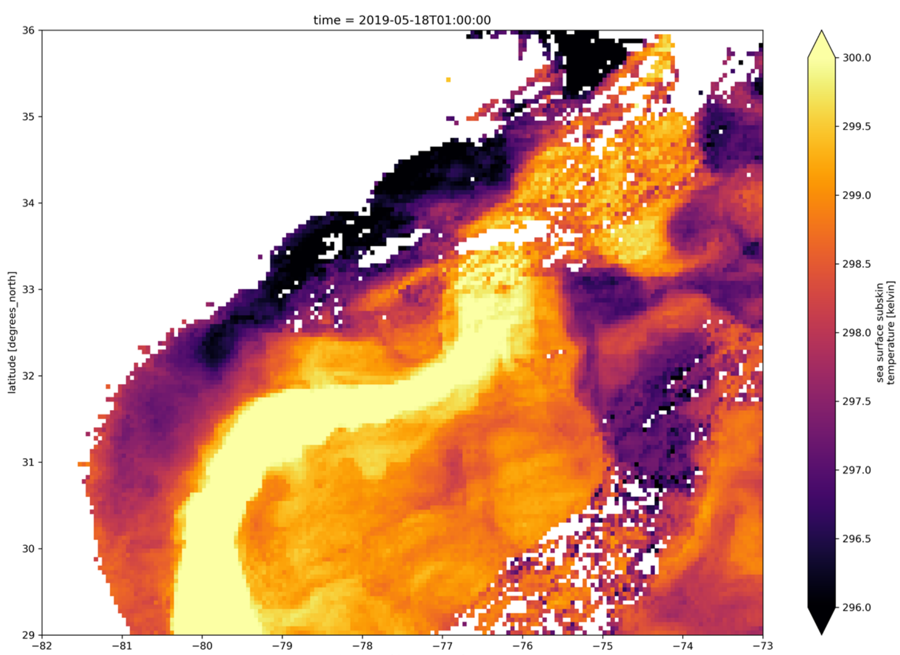

Fig. 3) Sea surface temperature footprint of the same eddy as Fig 2 showing the characteristic meander in the Gulf Stream that spawns the cyclonic eddy, the lower than average temperature at the core of the eddy, and the streamers of higher temperature water on the landward side as evidence of the rotation. SST data from GOES-16.

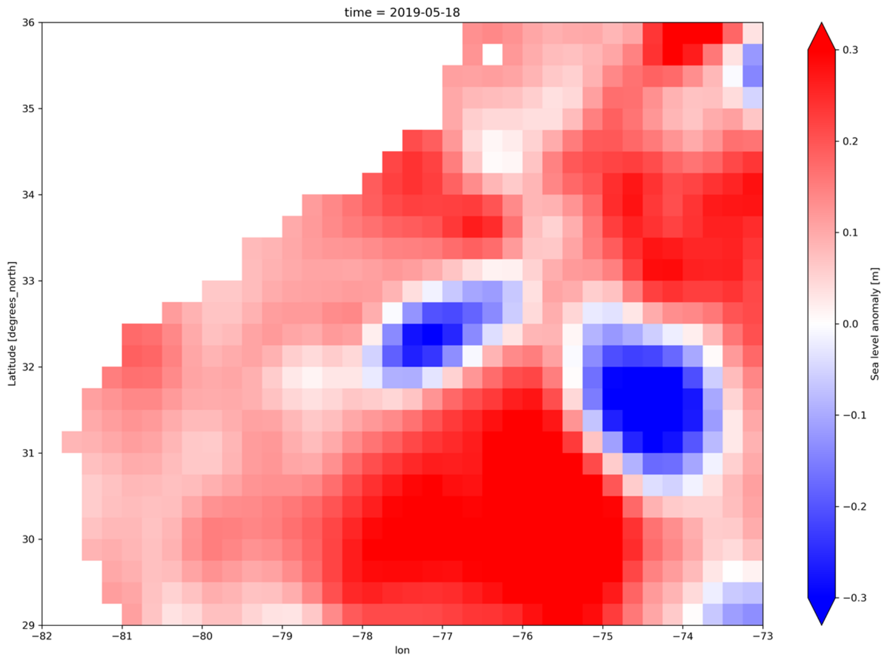


Fig. 4) Sea level anomaly data from AVISO of the same eddy as Figs 2 and 3. The negative anomaly covers the same general area as the deviation in SST and chl-a.

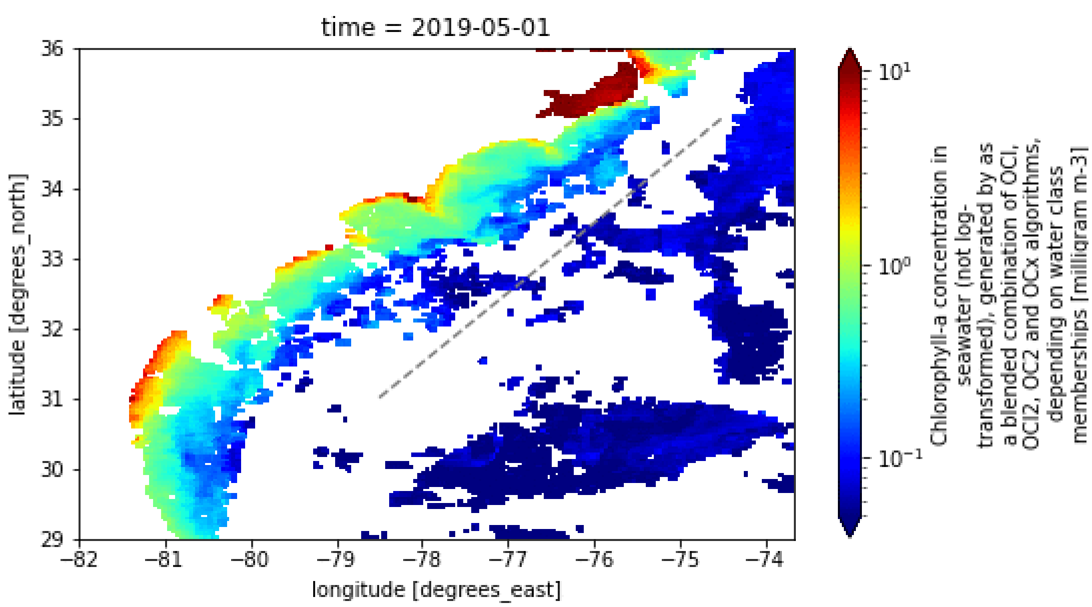


Fig. 5) The a month long time series of chl-a as this frontal eddy moves north east along the wall of the Gulf Stream. Note the shearing apart and loss of coherent shape as it approaches Cape Hatteras. Chl-a data from the Ocean Colour Climate Change Initiative merged data product.

# A YEAR OF EDDIES IN ALTIMETRY

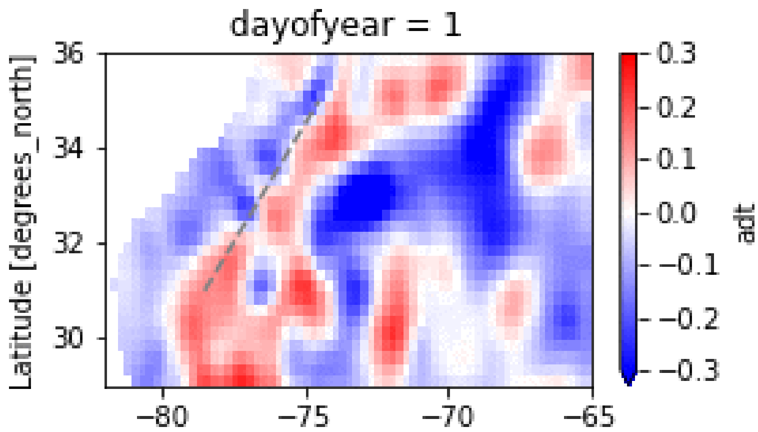


Fig. 6) Animation of sea level anomaly showing cyclonic frontal eddies (negative anomalies) moving upward along the landward side of the Gulf Stream wall (represented by the grey dashed line). This shows around half a dozen major frontal eddies and another half dozen smaller frontal eddies moving up the South Atlantic Bight.

Except for the largest and most coherent features, frontal eddies are not generally detected in most eddy detection schemes or eddy atlas databases. These features are not sufficiently cyclonic and deviate too much from a typically circular mesoscale eddy. Additionally there is a considerable seasonality in the absolute sea level height on the landward side of the Gulf Stream leading to more noise in the sea level anomaly product used for detection.

# HIGH SPATIAL RESOLUTION VIA ECOSTRESS

ECOSTRESS, a thermal radiometer on the International Space Station, provides measurements of land surface temperature at 70m spatial resolution. While not designed for ocean observations the sensor is promising for observing submesoscale features.

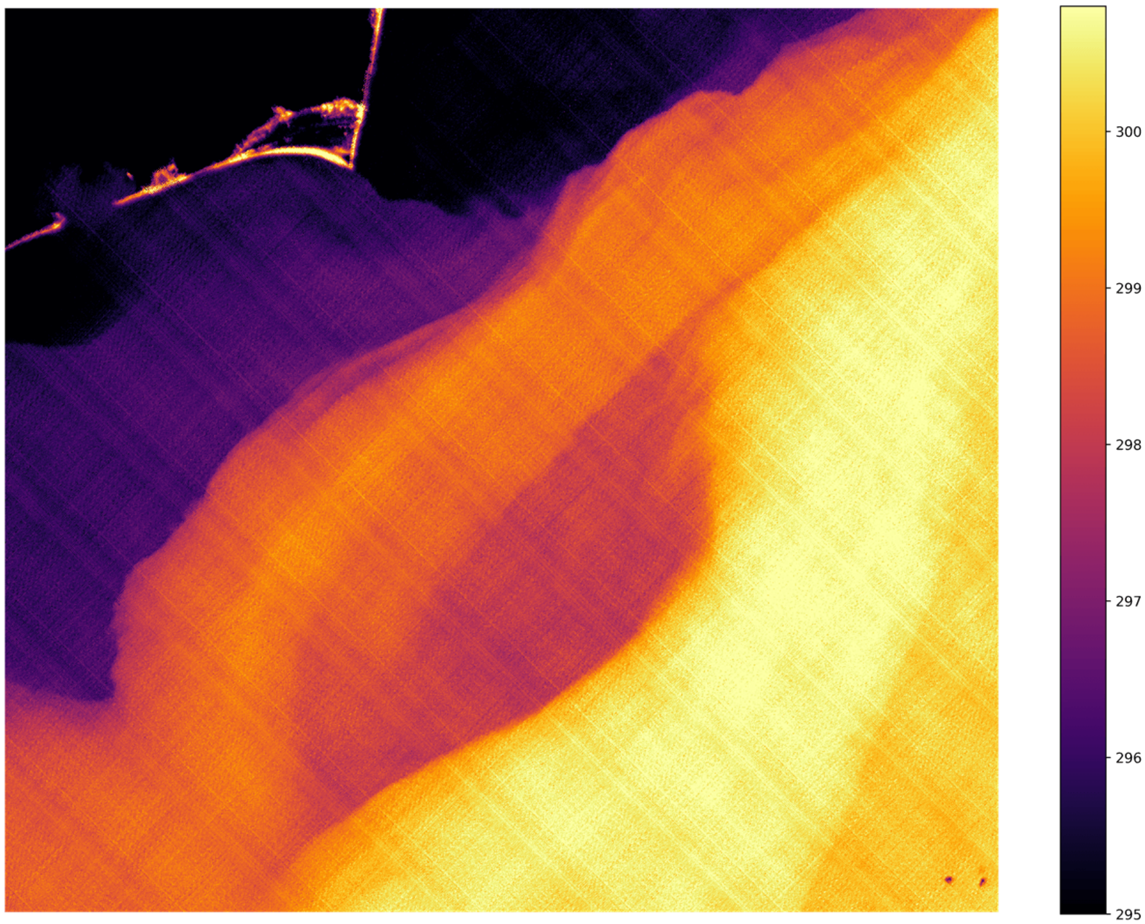


Fig. 7) Typical frontal eddy viewed via ECOSTRESS just off Cape Hatteras. Note the intense front on the Gulf Strea side of the eddy.

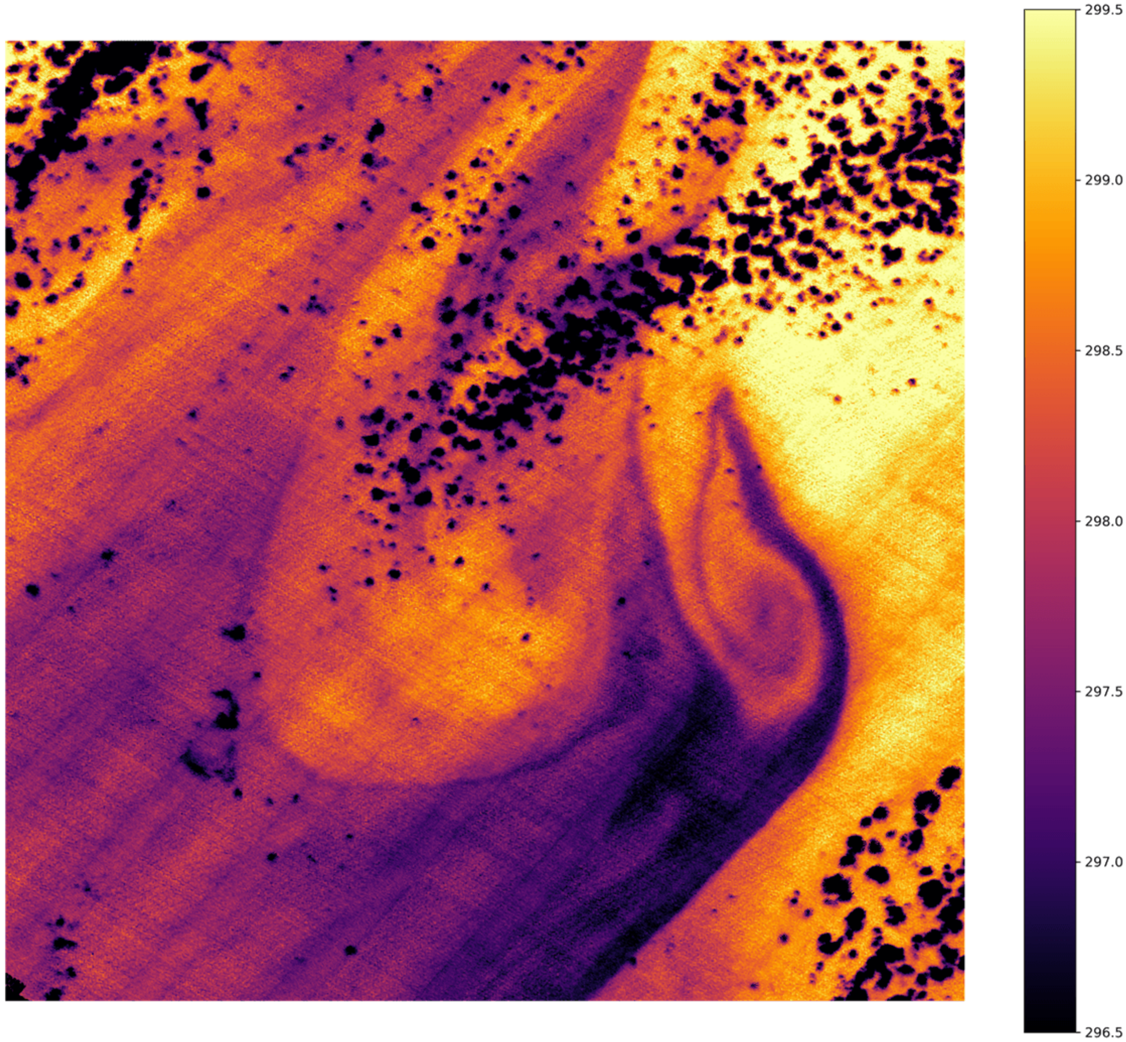


Fig. 8) Complex frontal eddy with multiple submesoscale eddies contained within it via ECOSTRESS. Clouds are not masked due to an issue where the masking algorithm mistakes intense gradients in SST with clouds.

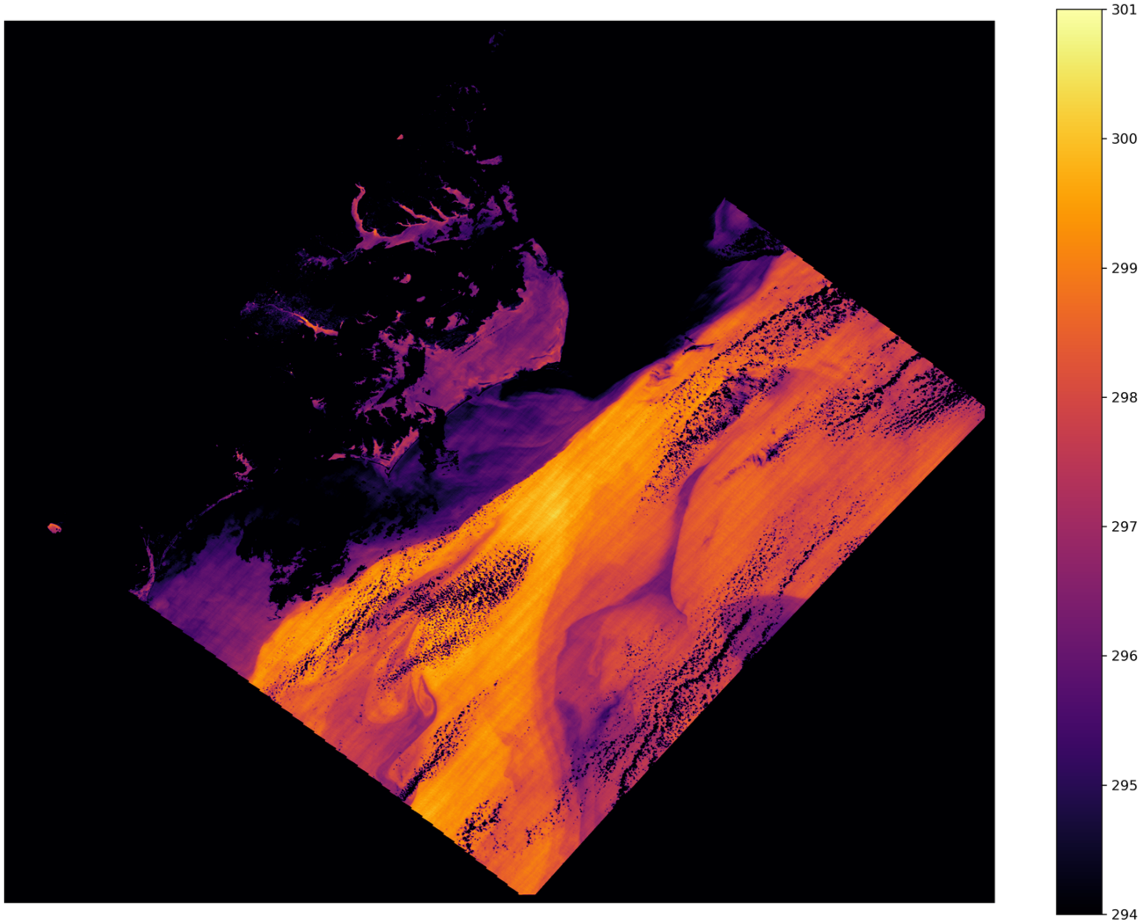


Fig. 9) Zoomed out view of the frontal eddy shown in Fig. 8.

# ABSTRACT

Gulf Stream frontal eddies, cyclonic features that form in the trough of meanders in the South Atlantic Bight, provide a natural mesocosm for investigating questions around submesoscale spatial and temporal variability. These frontal eddies drive important nutrient fluxes into the euphotic zone which generate considerable productivity on the outer shelf of the Southeast US coastline. Modeling suggests these nutrient fluxes are partly due to submesoscale physics, but current observational approaches miss much of these dynamics and the biological response to them. As a result, current global biogeochemical models are not parameterized to account for potential submesoscale contributions to productivity and carbon export.

We present work observing these frontal eddies from new satellite platforms such as ECOSTRESS which provides an order of magnitude higher resolution SST compared to MODIS, GOES-16 which provides an order of magnitude higher temporal cadence SST compared to MODIS, and VIIRS for ocean color. Characterizing spatial patterns and temporal variation of SST and chlorophyll-a within frontal eddies at finer spatiotemporal resolution provides a better understanding of whether their submesoscale variability is captured by current remote sensing products, and insight into their overall role in ocean productivity and biodiversity.