Wind-driven Modulation of Cross-shelf Exchange Driven by Gravitational Relaxation on a Shelf During Winter

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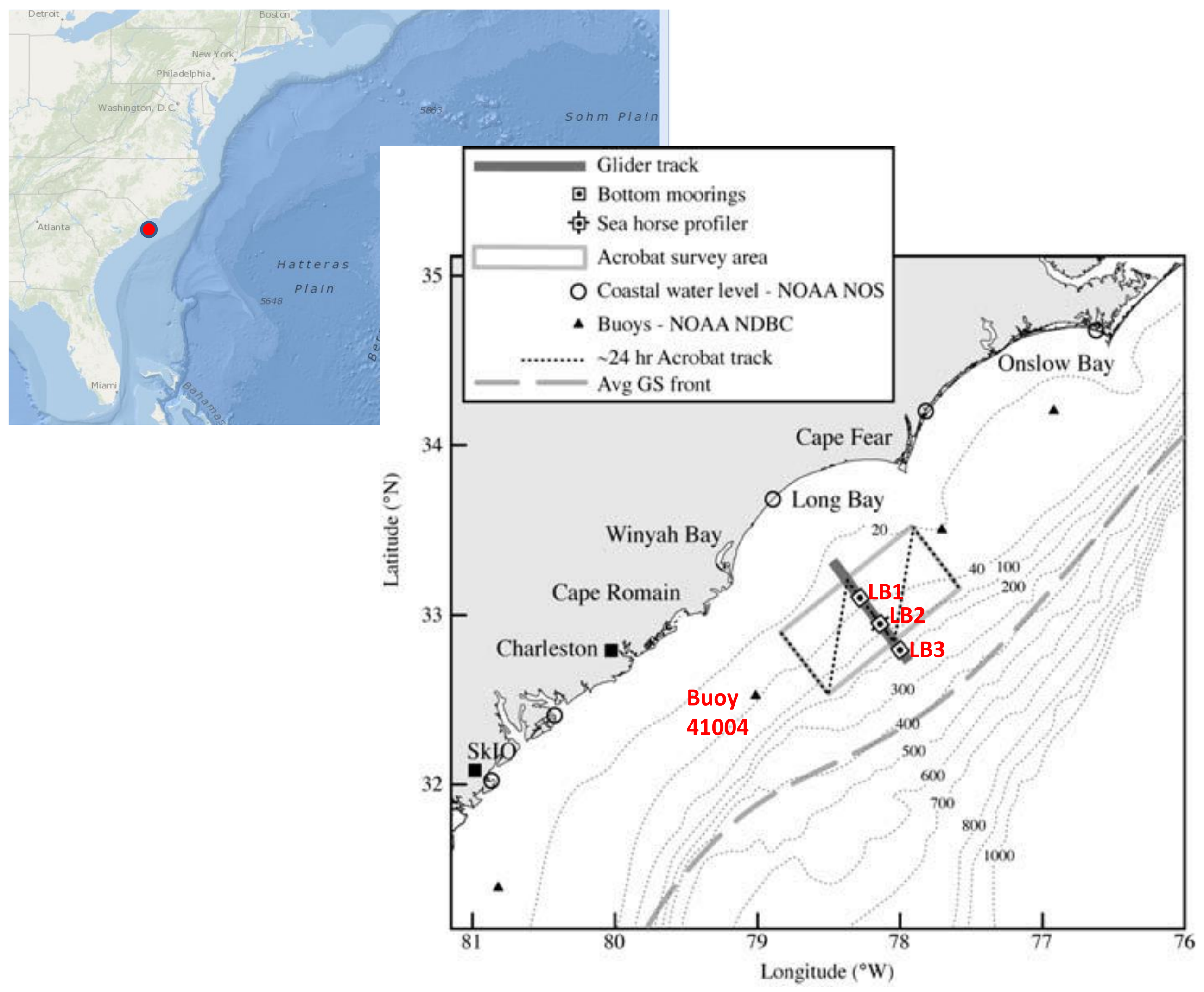
Overview



Using CZCS imagery of the outer shelf of the South Atlantic Bight (SAB), Ryan and Yoder (1996) found high wintertime productivity off of Long Bay, South Carolina . Our goal is to understand the physical processes that contribute to high wintertime productivity in this region.

During winter, the shelf water is often well-mixed from top to bottom. Instead of vertical density gradients, we often see horizontal density gradients—with denser water closer to the coast.

We observed several stratification events in January and February of 2012, driven primarily by a horizontal advection of buoyancy--some due to downwelling favorable winds, others due to a Gulf Stream filament interacting with the outer shelf.

Wind-driven stratification events can be expected along the entire outer shelf of the SAB, not just off of Long Bay. On the other hand, since this region off Long Bay is a frontal eddy growth region, the filament-related stratification events could explain the higher wintertime productivity here.

This analysis focuses on the LB1 location, where we have a mooring at the bottom (30m), equipped with CTD and ADCP. Also at LB1 we have a thermistor chain with sensors at 25 different depths. From the thermistor chain data, the potential energy anomaly is calculated as a function of time. It is also estimated by integrating the individual forcing terms.

POTENTIAL ENERGY ANOMALY EQUATIONS:

$$\Phi = (1/h) \int g\,(\langle\rho\rangle - \rho(z))\,z\,dz \qquad [\mathrm{J/m^3}]$$

$$\frac{d\Phi}{dt} = \underbrace{\alpha g Q / 2c_p}_{\text{heat term}} - \underbrace{e\tau_b \langle u\rangle / h}_{\text{bottom-stress term}} - \underbrace{e_s \tau_w u_s / h}_{\text{wind-stress term}} + \underbrace{(g/h)(d\rho/dx) \int (u - \langle u\rangle)\,z\,dz}_{\text{Horizontal advection of buoyancy term}} \qquad [\mathrm{W/m^3}]$$

- α thermal volume expansion coefficient of seawater [°C^{-1}]
- c_p specific heat capacity of seawater [J/kg/ °C]
- Q sum of heat flux terms (sensible, latent, sw, lw) [W/m^2]

- e efficiency of mixing (for bottom-stress)
- τ_b bottom stress [N/m^2]
- $\langle u\rangle$ vertically averaged water velocity [m/s]

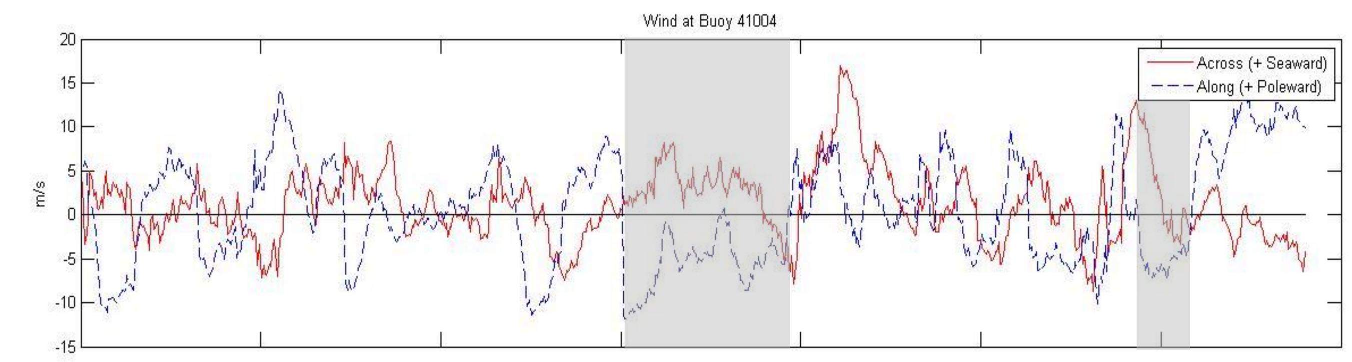
- e_s efficiency of mixing (for wind-stress)
- τ_w wind stress [N/m^2]
- u_s $\gamma_s u_{air}$ [m/s]
- γ_s surface water velocity/wind speed
- u_{air} wind velocity at 5m above ocean surface [m/s]
- h water depth [m]

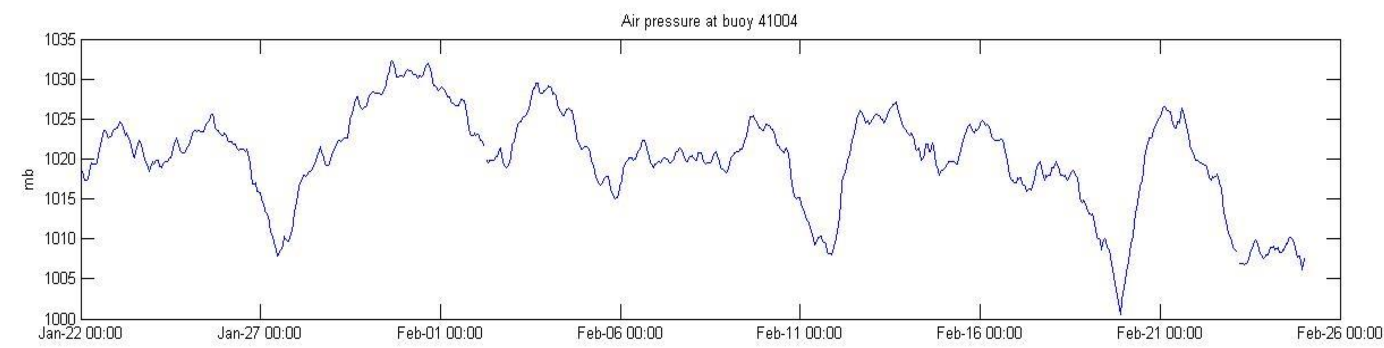
(Simpson and Sharples, 2012)

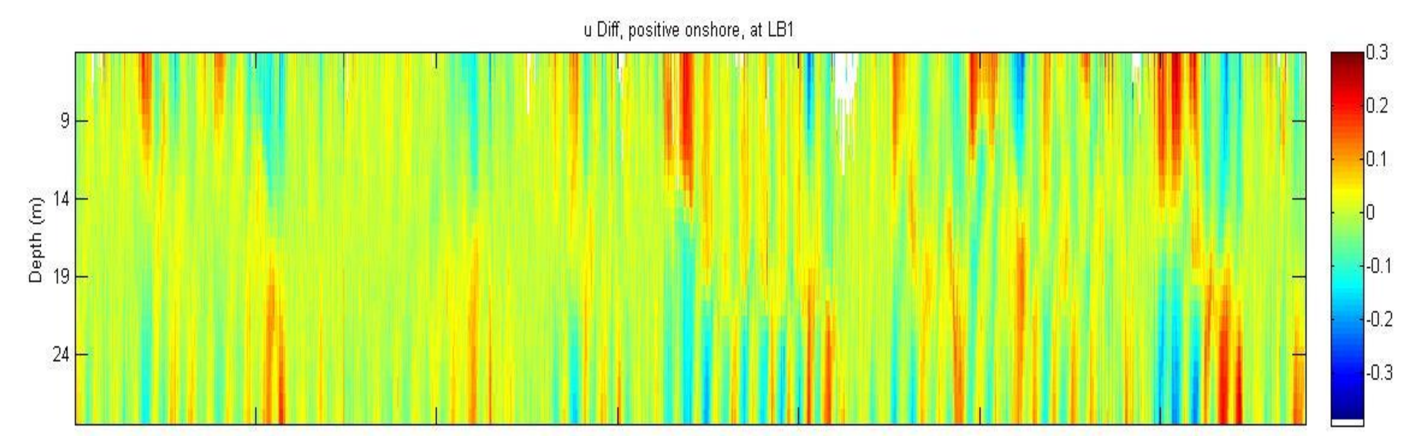
REFERENCES:

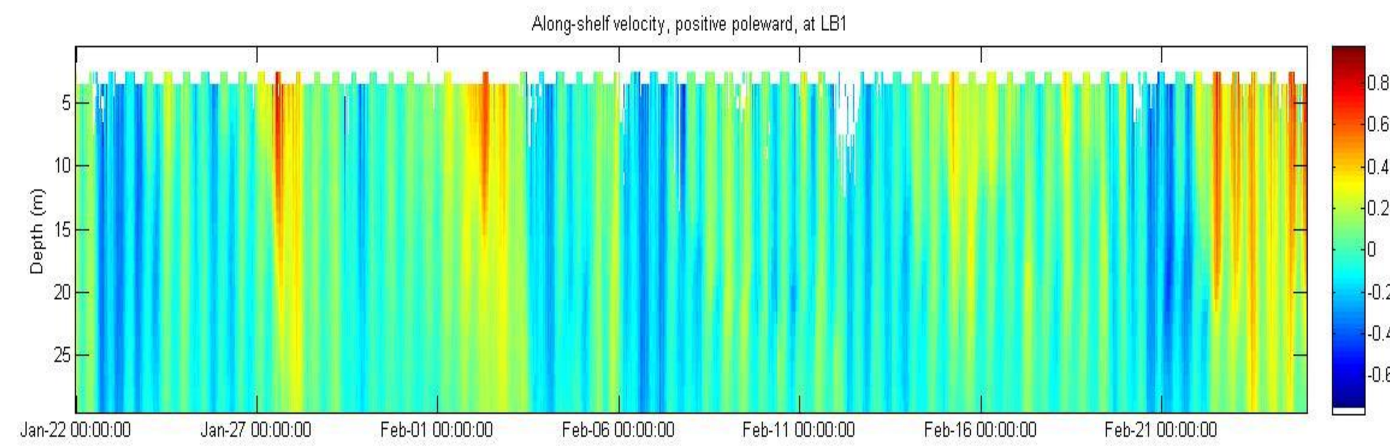
- Ryan, J.P. and J.A. Yoder, 1996. Long-term mean and event-related pigment distributions during the unstratified period in South Atlantic Bight outer margin and middle shelf waters. Cont. Shelf Res. 16:1165-1183.
- Simpson, J. H. and J. Sharples. (2012). Introduction to the Physical and Biological Oceanography of Shelf Seas, Cambridge University Press.

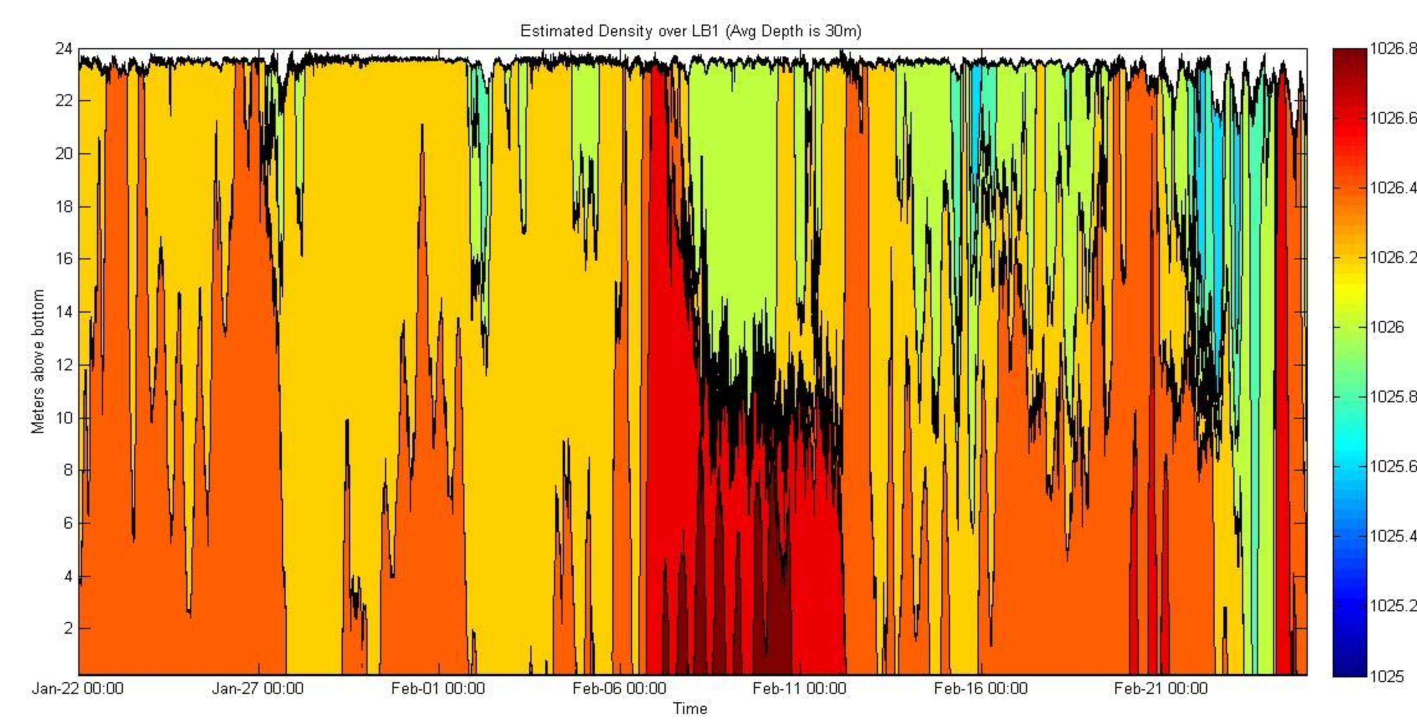
Stratification Events Observed on the Shelf

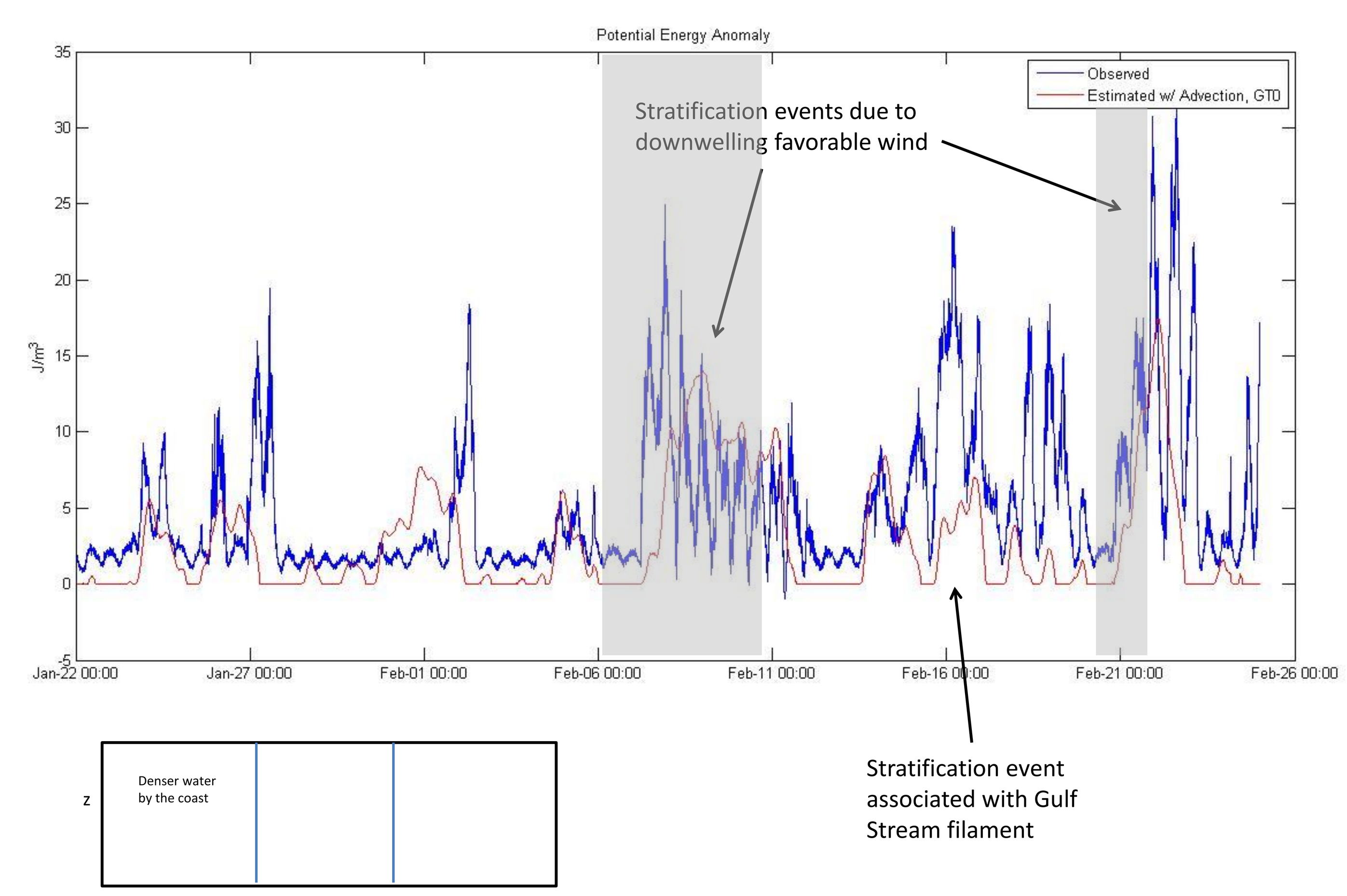


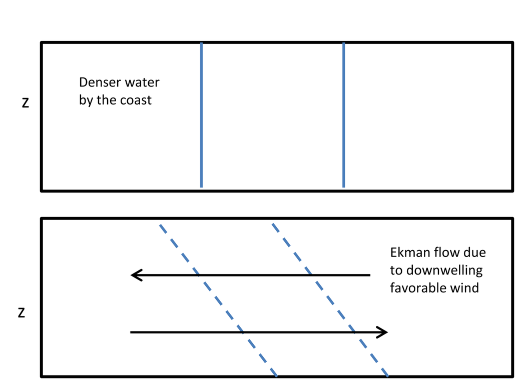




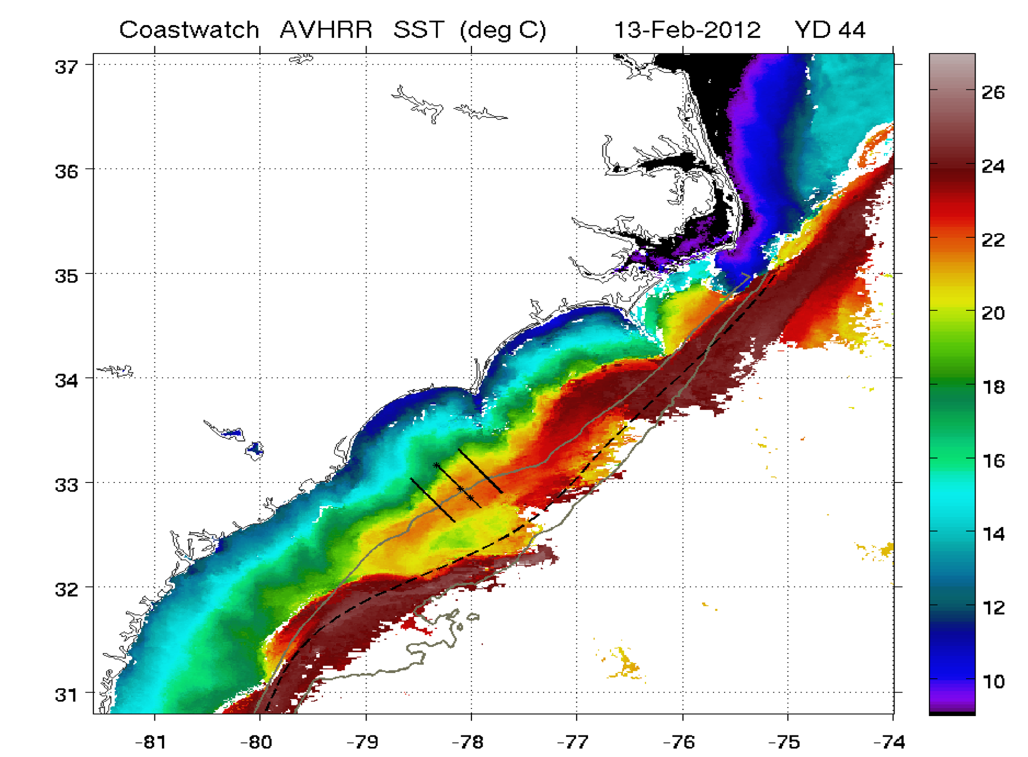


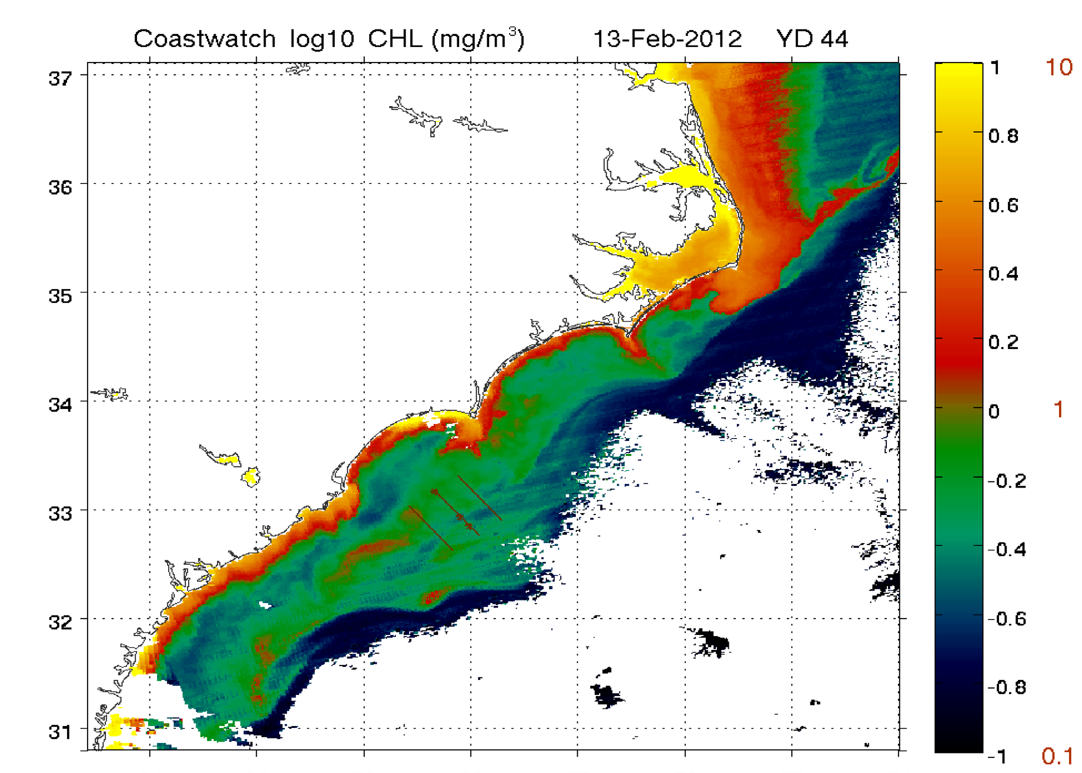


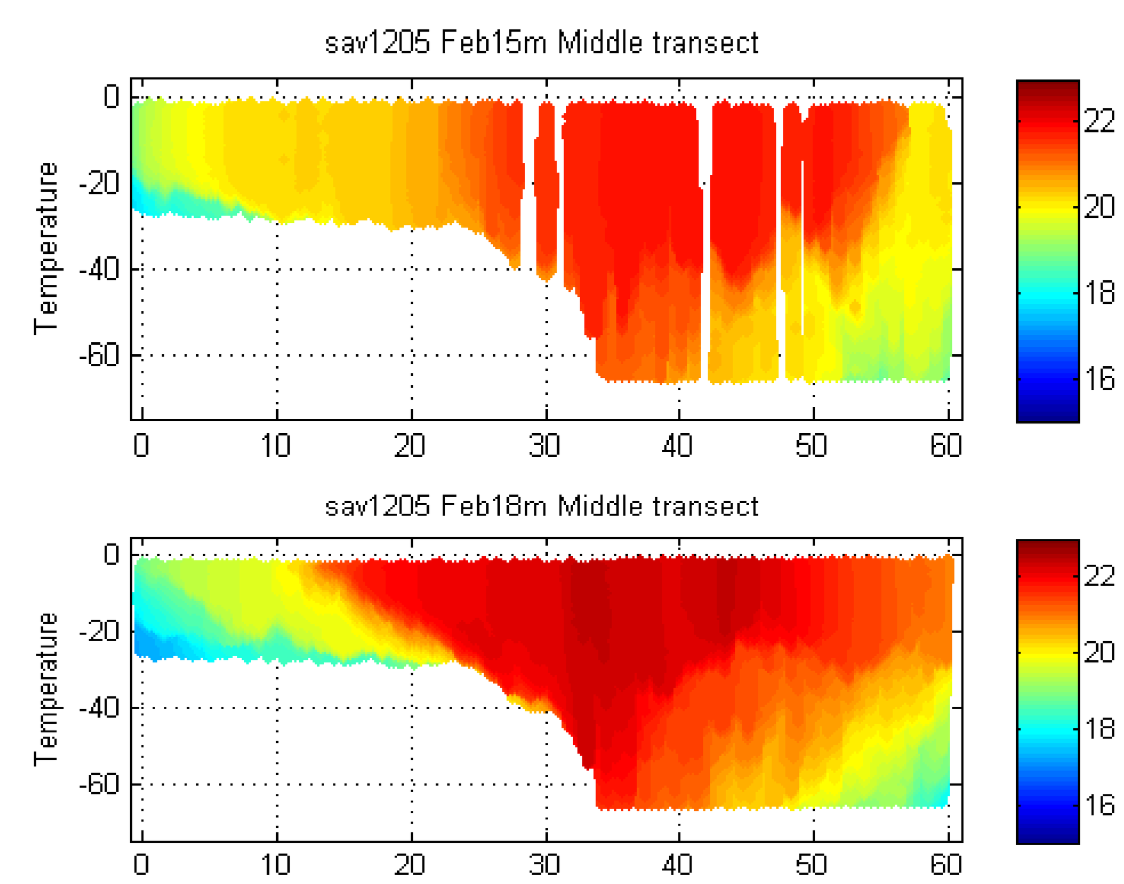




Gulf Stream Filaments







A Gulf Stream filament passed over our moorings in mid-February. We can see the filament in satellite imagery. We also have transects of the filament on February 15 and February 18. (The moorings are along this "middle transect.") The filament's interaction with the outer shelf results in increased stratification there. Stratification increases even over LB1 (roughly at zero on the x-axis). Note that surface chlorophyll is seen in the 18 degrees C water on the shoreward edge of the filament.

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