Impact of Mesoscale Eddies on the Gulf Stream and the Shelf Ecosystem in the Southeastern U.S. Coastal Ocean

Ruoying He

Dept. of Marine, Earth & Atmospheric Sciences

North Carolina State University, U.S.A.

In collaborations with

Y. Li, Y., Gong, A. Todd (NCSU), R. Castelao (UGA)

T. Kellison, C. Taylor (NOAA), C. Lambke and D. Mann (USF)

powered by

Benjamin Franklin published this map of the Gulf Stream in 1769

Fig. 173. — FRANKLIN'S CHART OF THE GULF STREAM.

Data and Methods

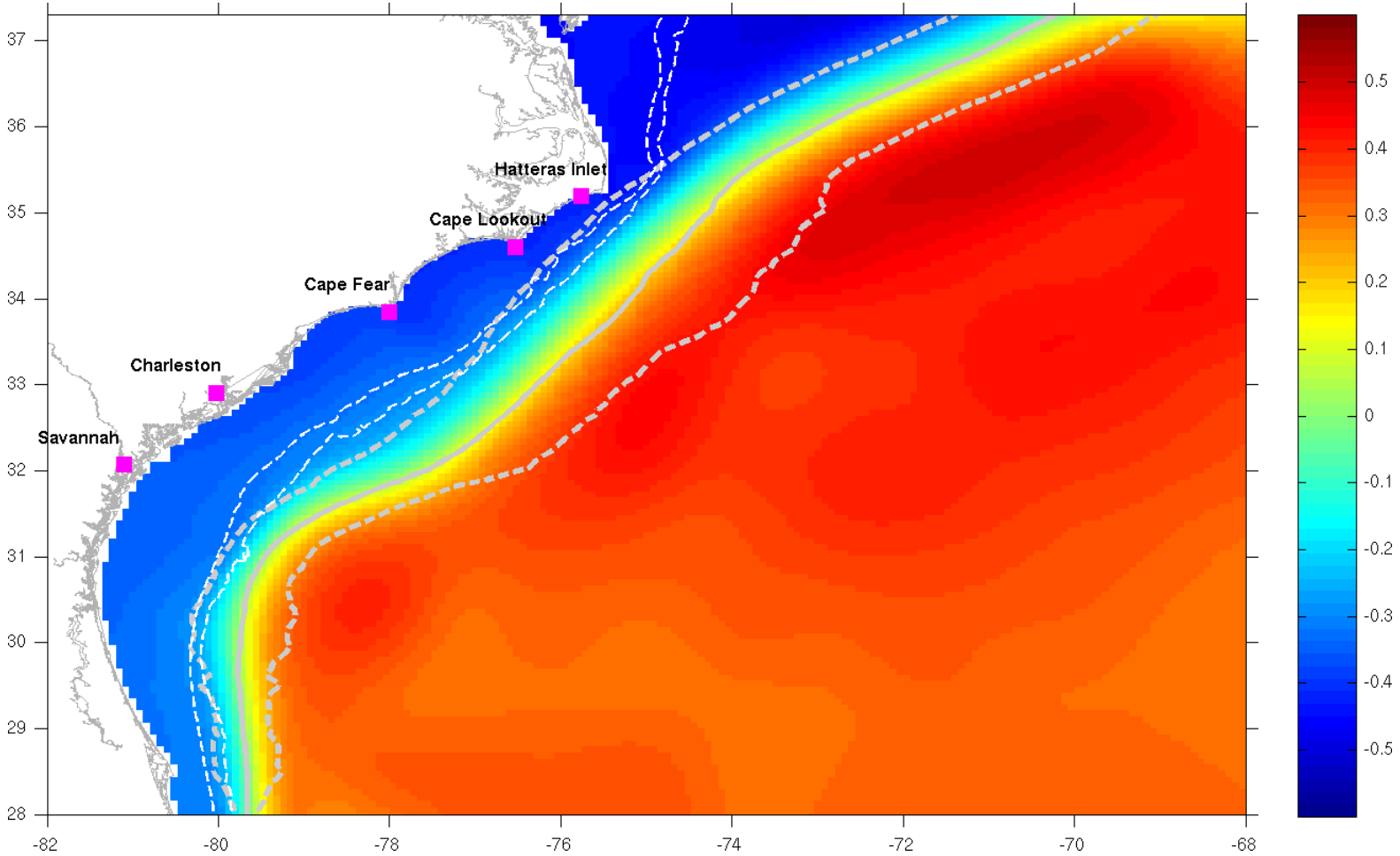
- Daily Sea Surface Height (SSH) field over 10 years (2003-2013) from AVISO.

- We tracked the Gulf Stream (GS) front in the South-Atlantic Bight (SAB) based on the maximum SSH gradient, and computed daily nearest cross-shore distance between GS and coastline

- Hourly Coastal sea level in the South Atlantic Bight from NOAA National Ocean Service

NC STATE UNIVERSITY

Mean SSH (unit: m) during 2003-2013



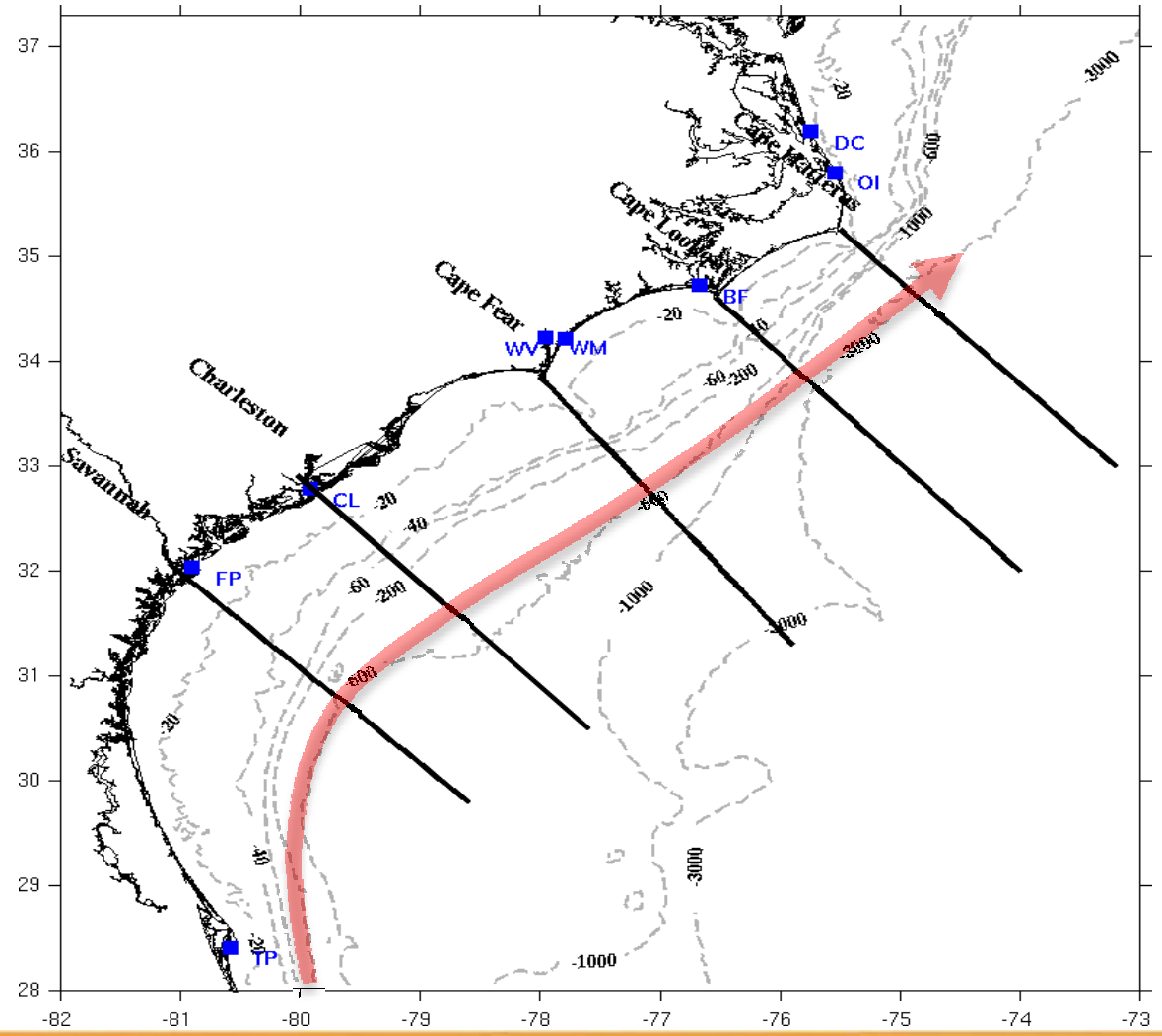
Thin white dashed line: **50-m and 250-m isobaths**.

Gray solid line: **Mean GS front** at the largest SSH gradient.

Gray dashed lines: **Mean GS+STD; Mean GS-STD**.

NC STATE UNIVERSITY

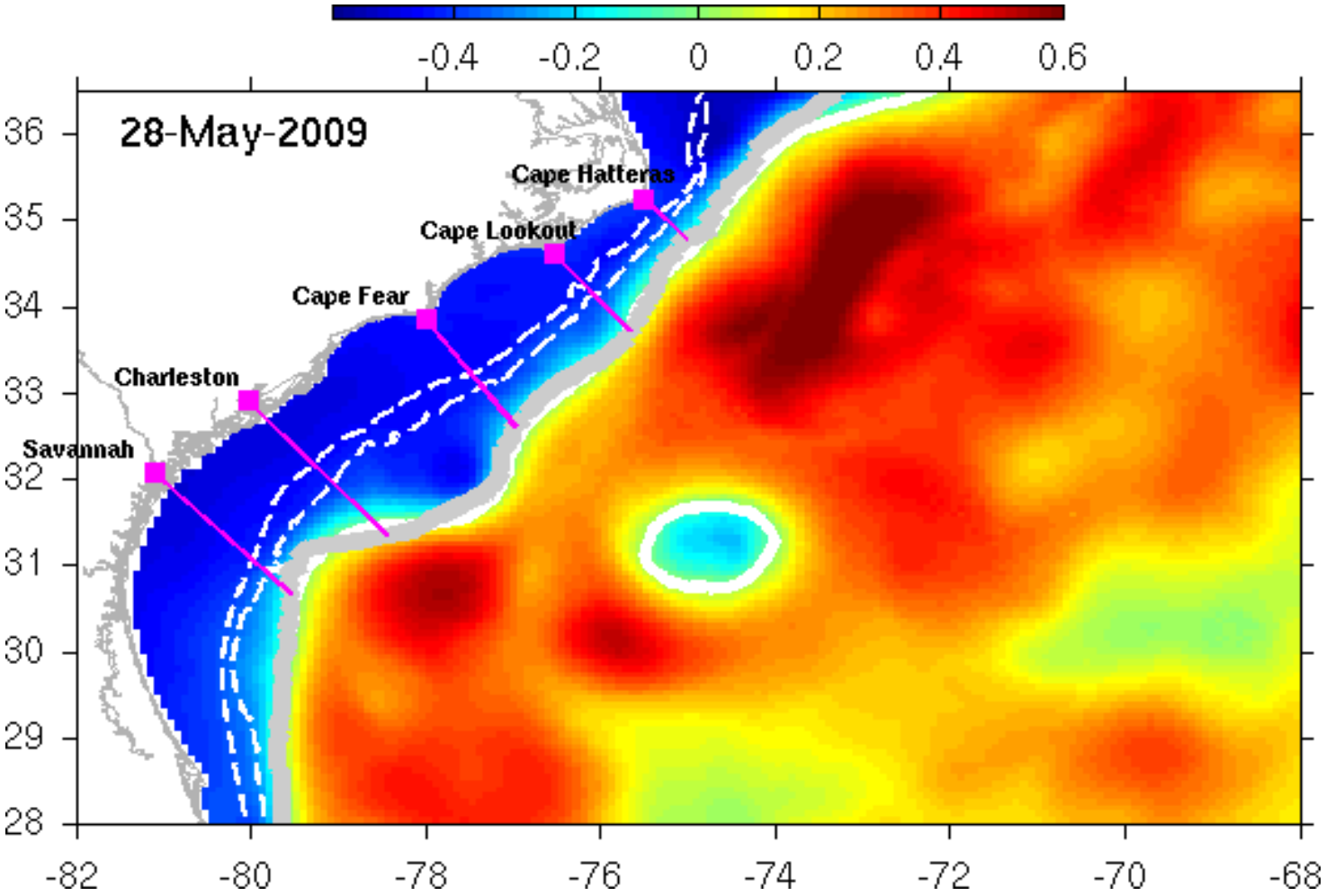
Five transects used to determine the offshore distance of the GS



Coastal Sea Level Stations:

TP: Trident Pier, FL
FP: Fort Pulaski, GA
CL: Charleston, SC
WV: Wrightsville Beach, NC
WM: Wilmington, NC
BF: Beaufort, NC
OI: Oregon Inlet, NC
DU: Duck, NC

Daily position of GS and cross-shelf distance

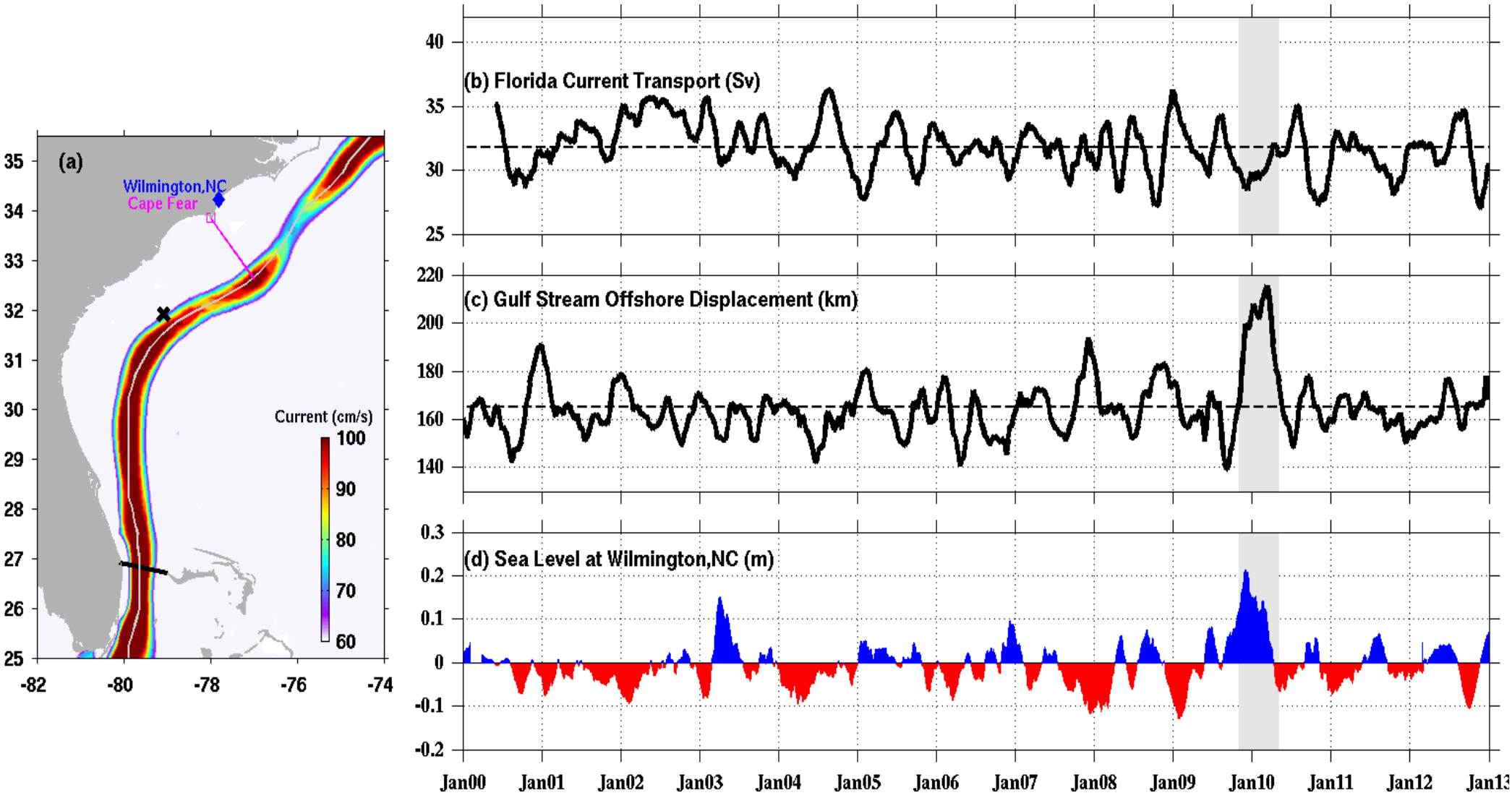


Pink: Cross-shelf distance of GS to the 5 coastal sites.

Gray: GS locations based on maximum SSH gradient.

NC STATE UNIVERSITY

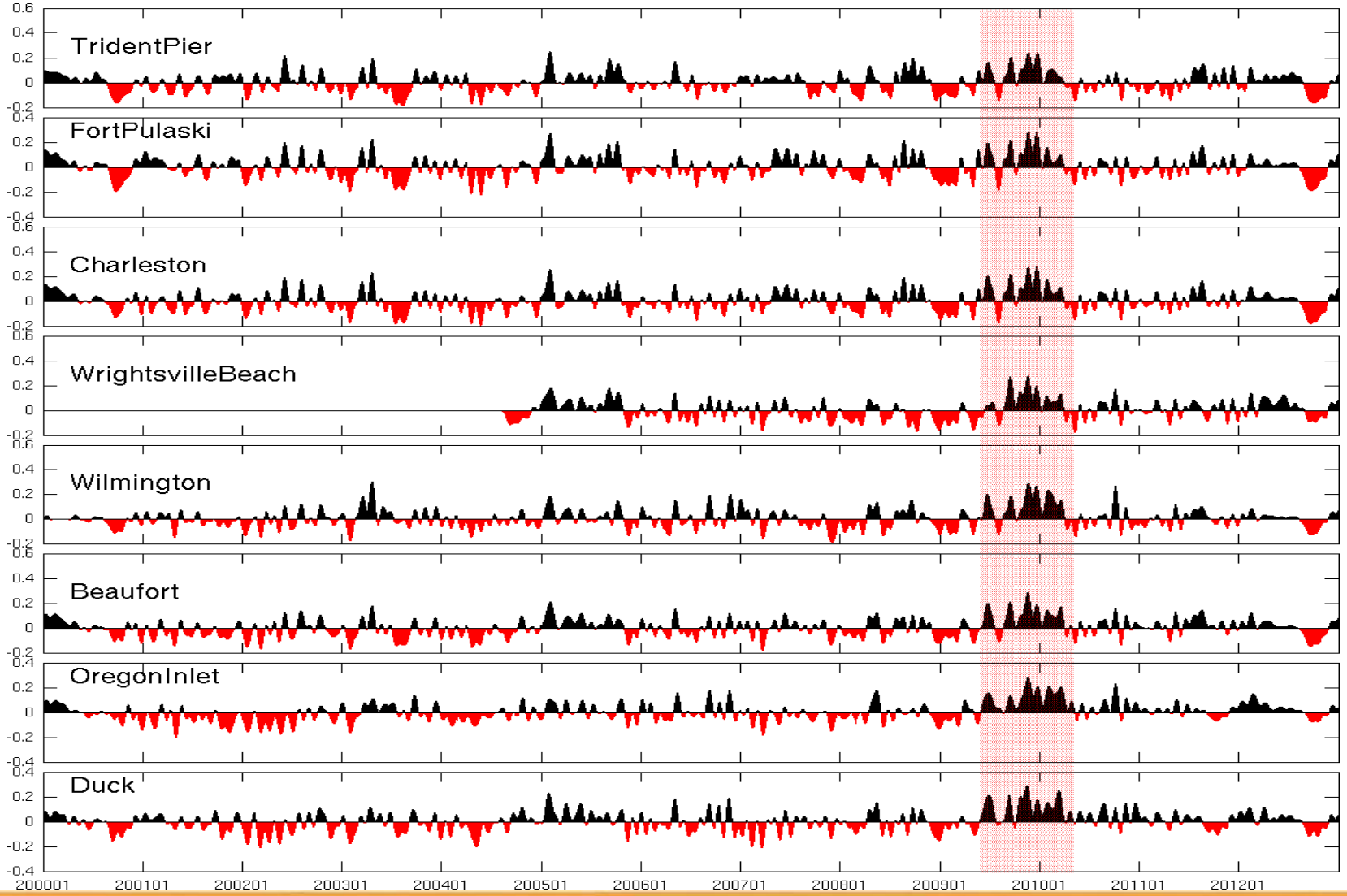
Zoom-in view of GS daily position off Cape Fear



NC STATE UNIVERSITY

10-yr of Coastal sea level variability (30-day low pass)

A persistent, positive sea level anomaly is present in Sep '09 – April '10 (8 months)



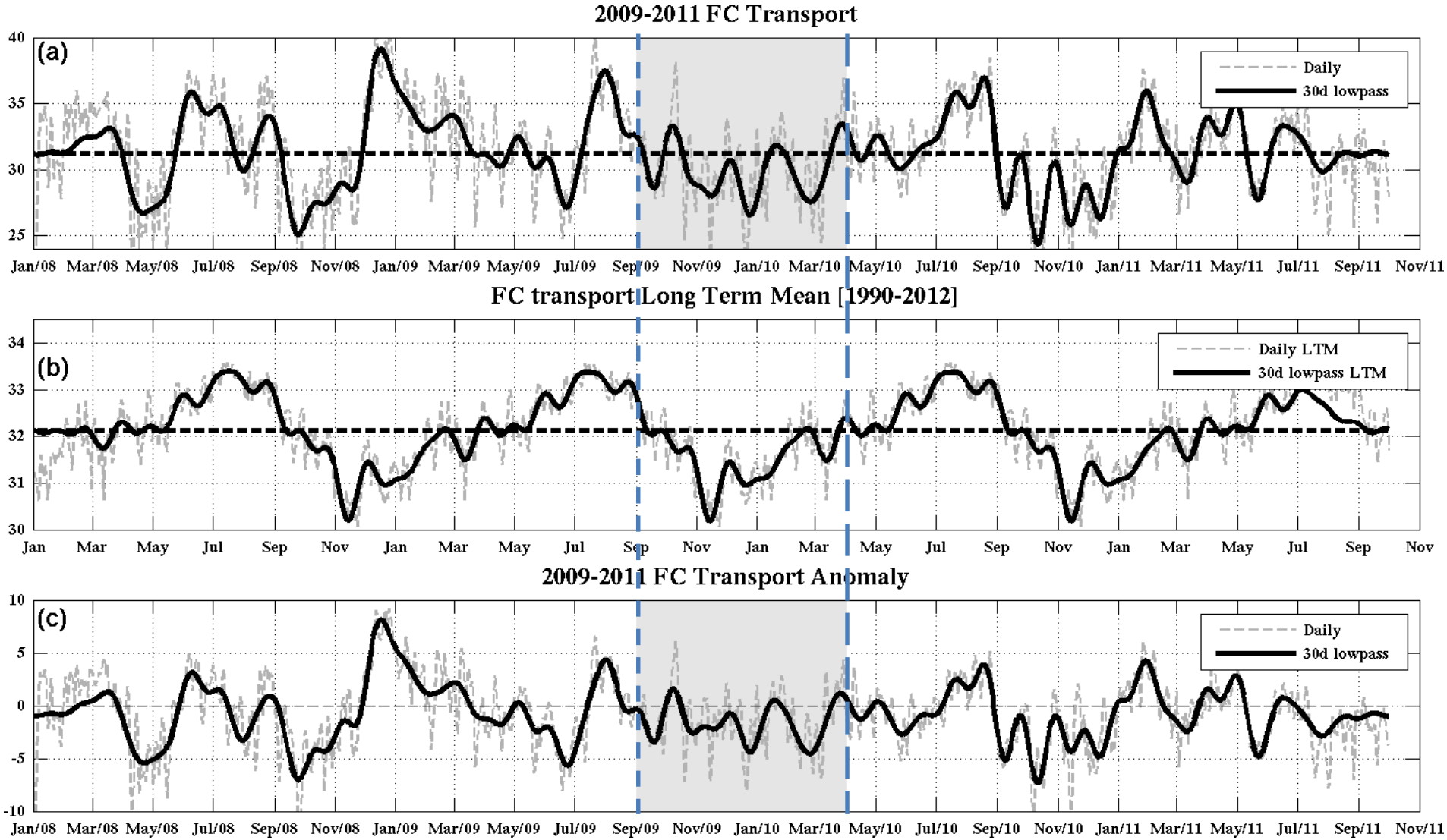
Question

Why was there a ~ 8 months long GS offshore Displacement, and at the same time significant sea level rise at the coast?

1) Upstream GS transport
2) GS Instability induced by bathymetric feature
3) Open ocean mesoscale eddy impact

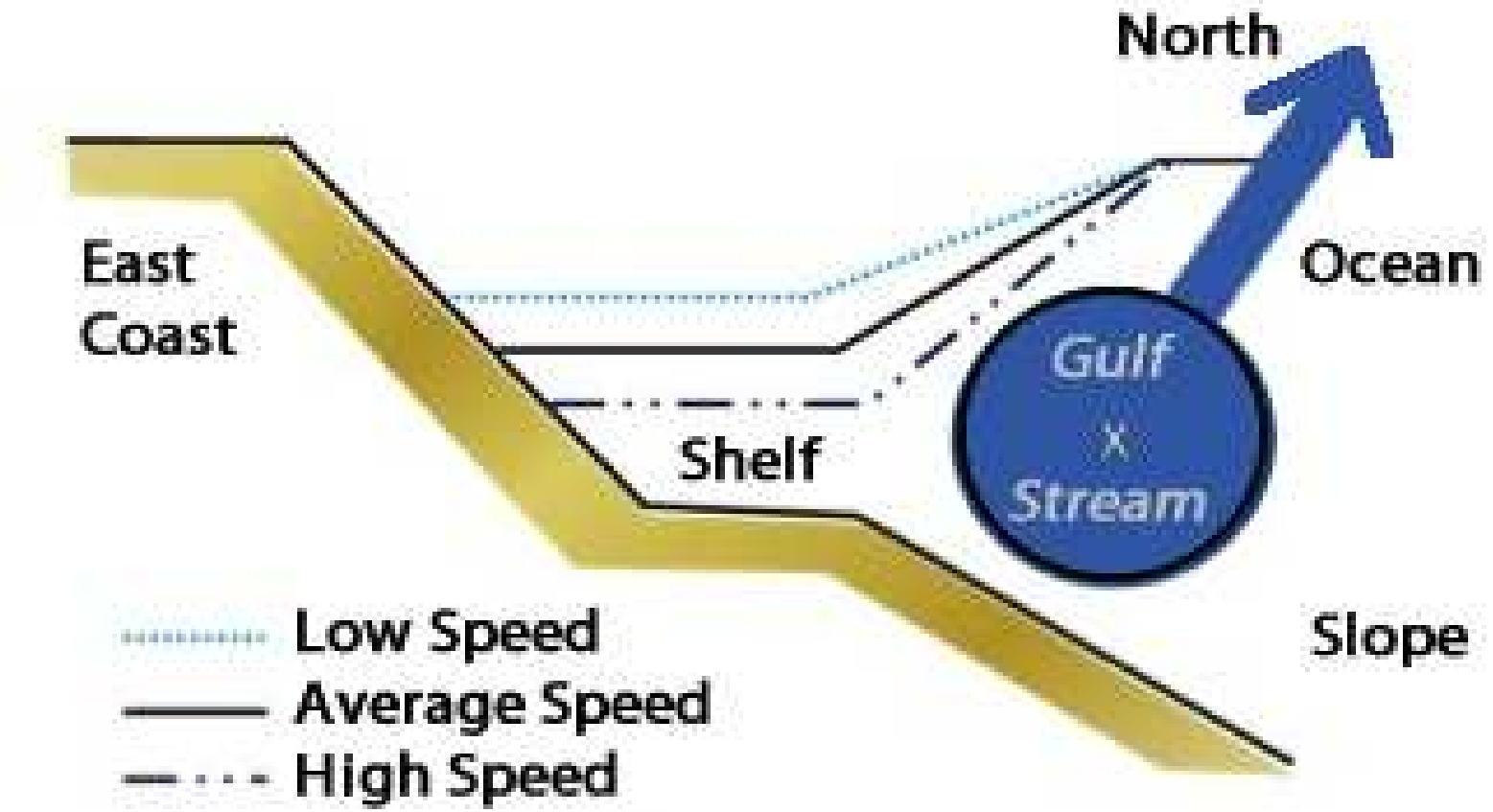
NC STATE UNIVERSITY

(1) Florida current transport (upstream forcing)



FC transport in Sept 2009- Apr 2010 was 3-4 Sv (10%) lower than the climatological mean. Such negative anomaly lasted 8 months, and was one of the most persistent.

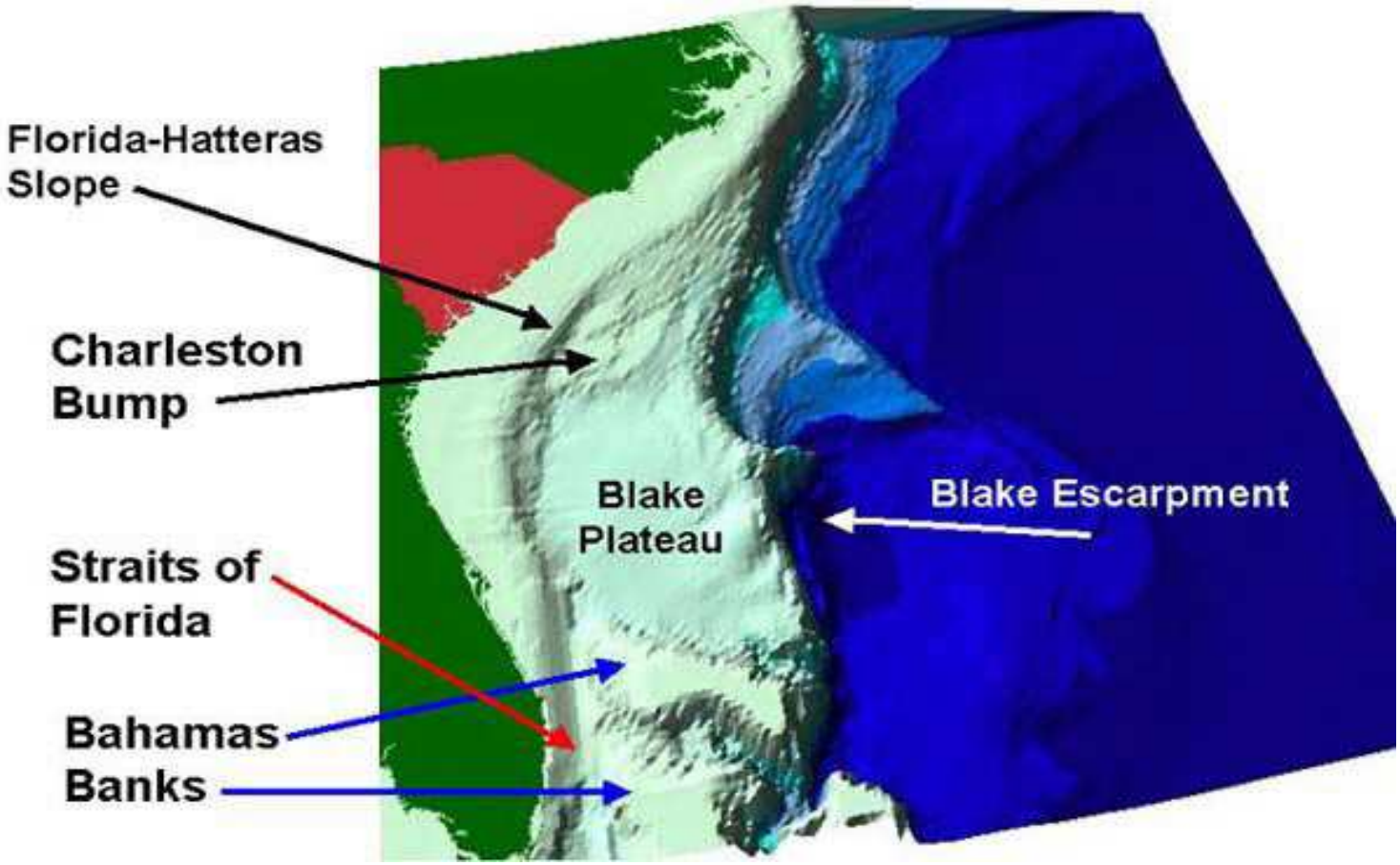
Conceptual model



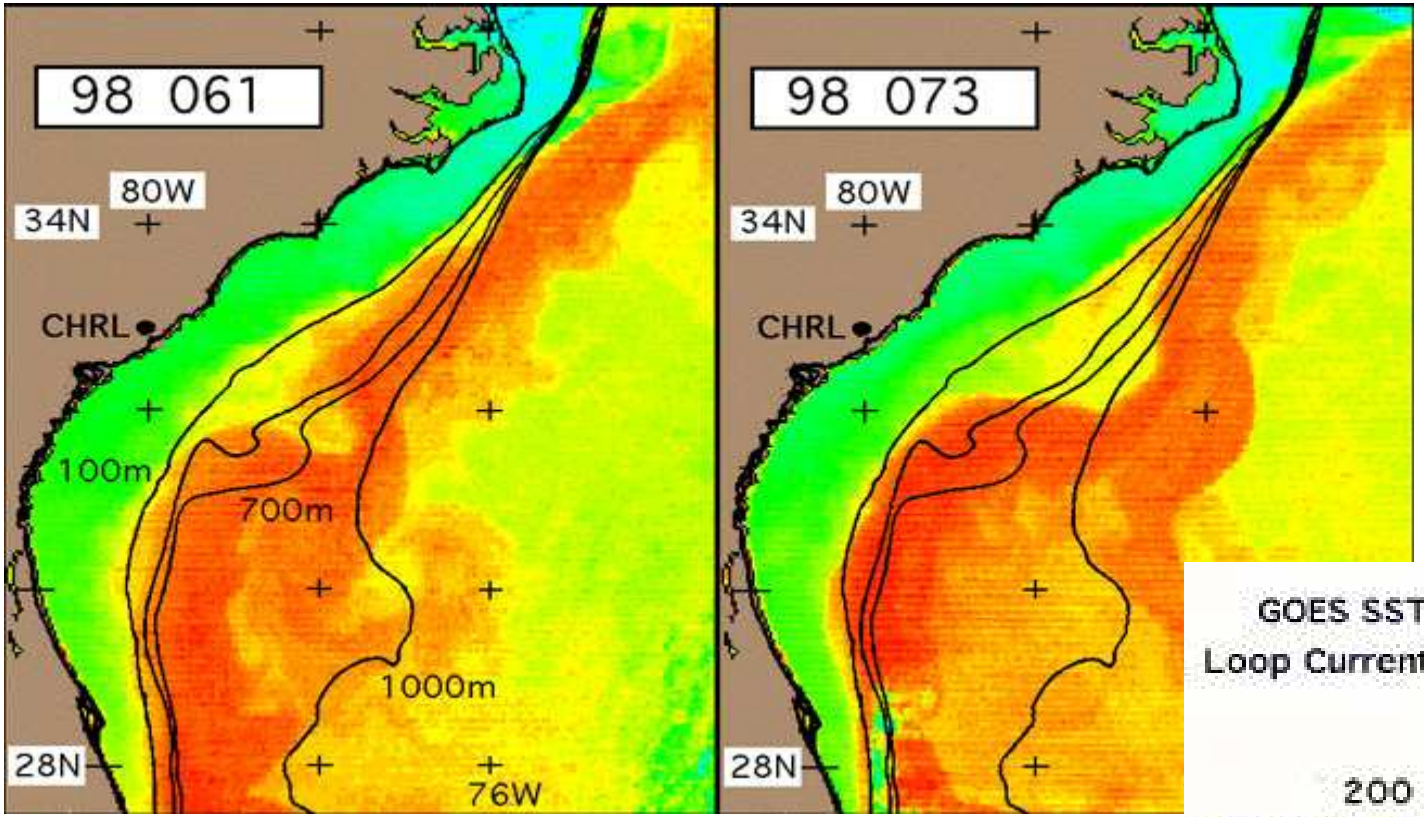
Nobel and Gelfenbaum (1992)

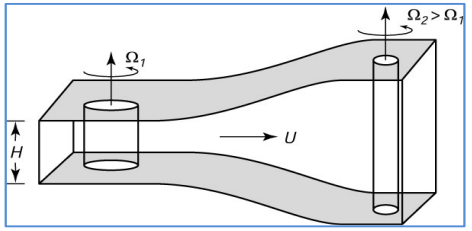
(Figure courtesy: B. Sweet)

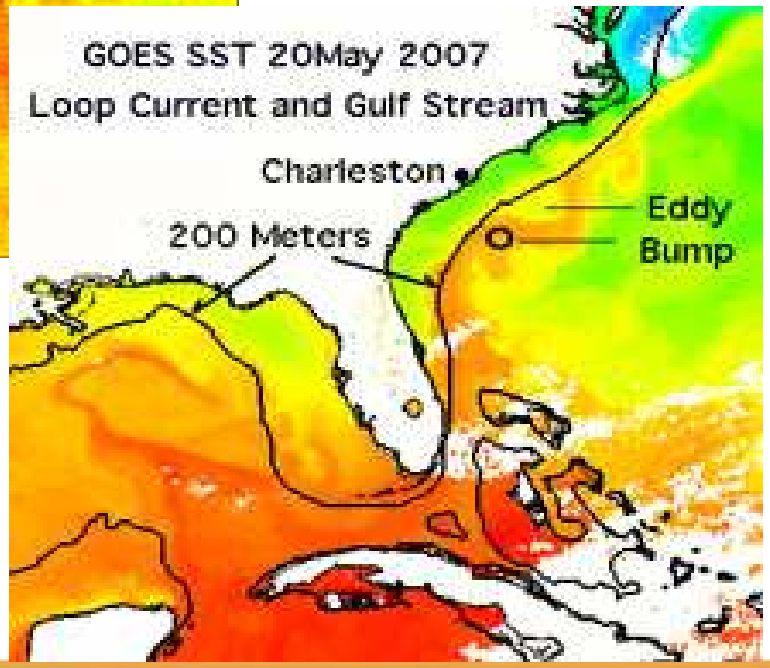
(2) GS instability over Charleston Bump



The Charleston Bump is a deep-water, rocky bottom feature on the Blake Plateau southeast of Charleston, South Carolina.

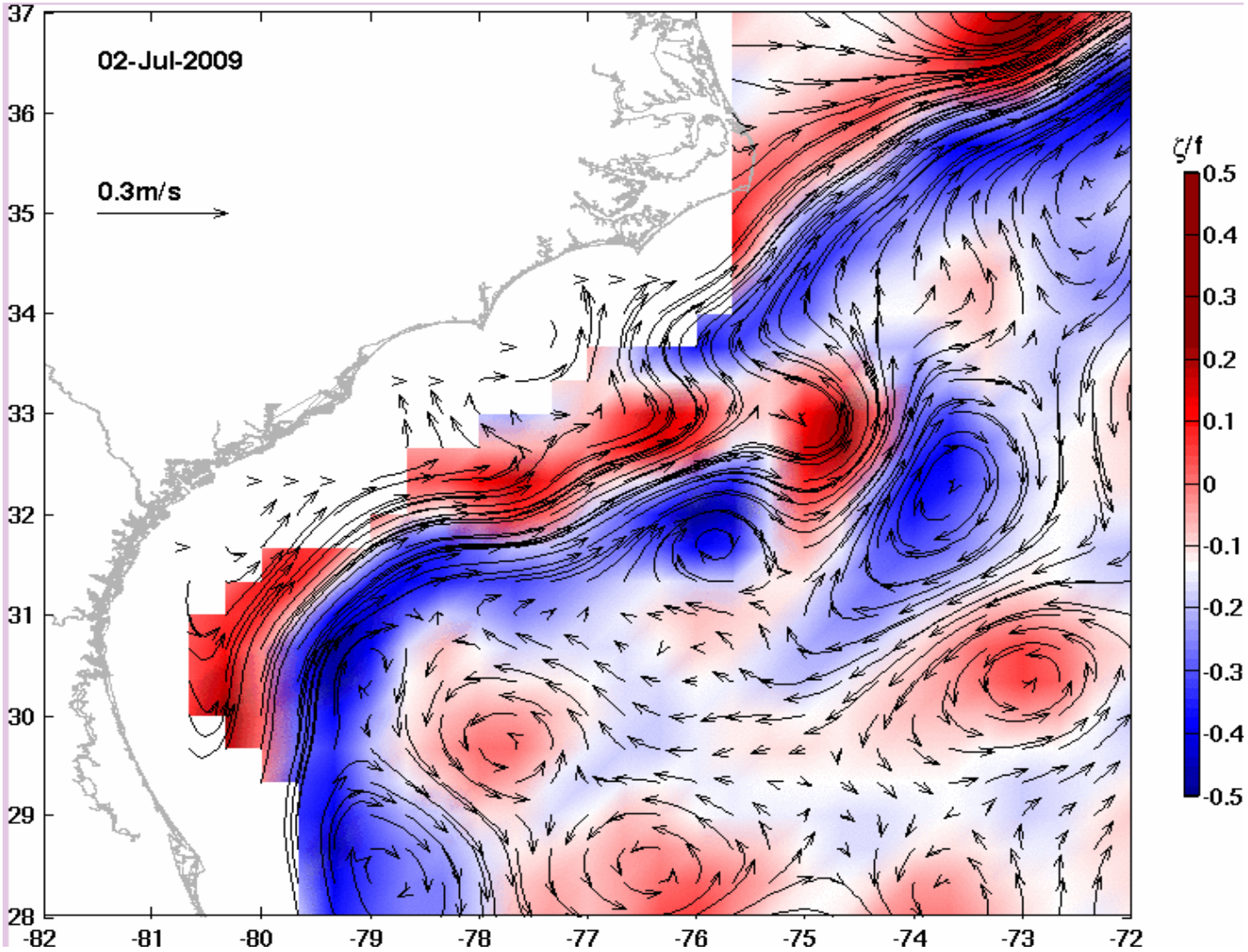






Satellite images show that the warm waters of the Gulf Stream current (orange) deflect consistently seaward soon after passing over Charleston Bump and spin off into an eddy

Bane and Brooks (1979), Bane and Dewar (1988)



Gulf Stream reconstruction based on Altimetry SSH & surface wind fields

Potential vorticity Conservation:

$$\frac{f+\varsigma}{H} = \text{const}$$

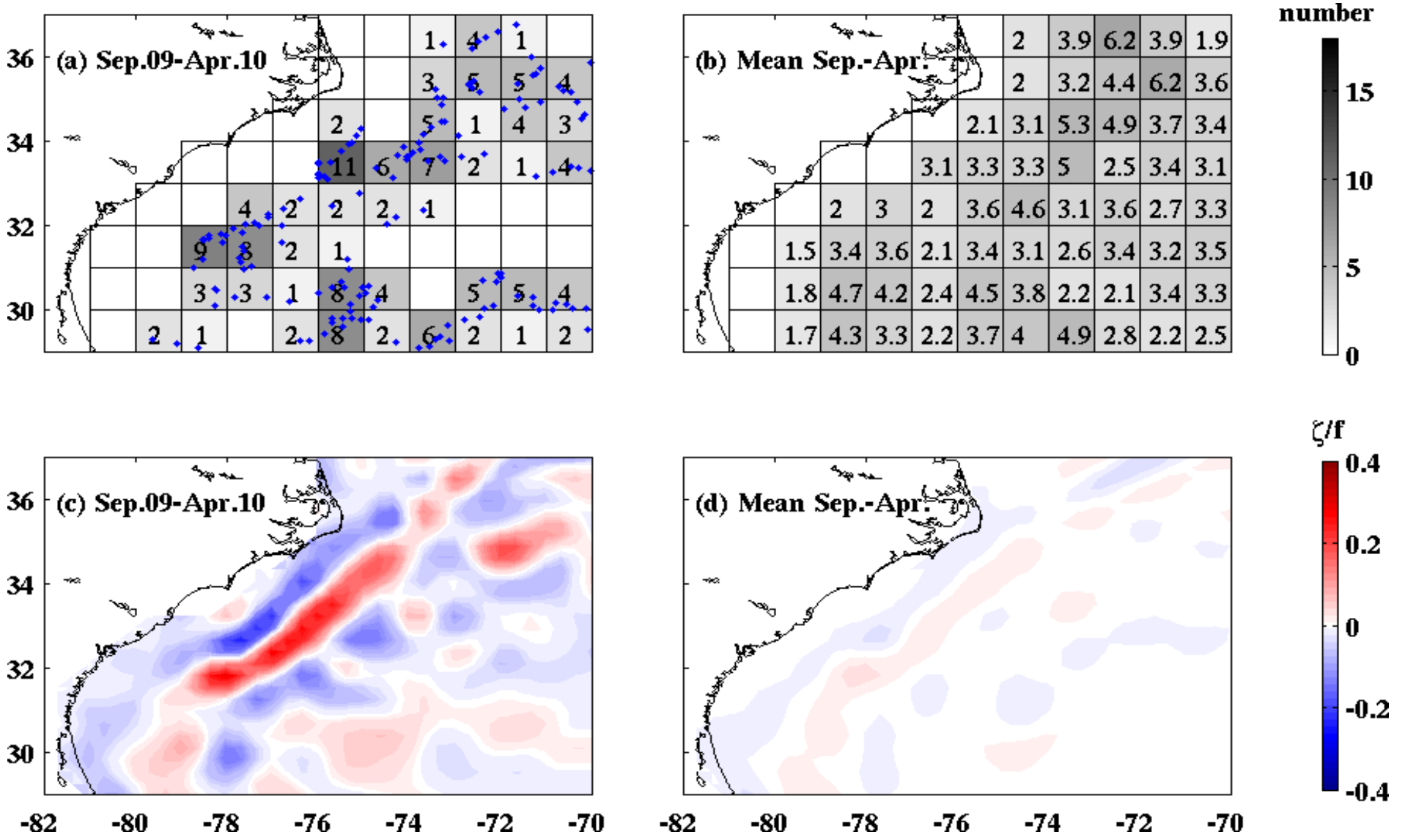
ς: increase
H: increase

(3) Open ocean mesoscale eddies

(positive vorticity injection into GS)

NC STATE UNIVERSITY

More numbers of cyclonic eddies in Sep 2009 – Apr 2010 than the mean

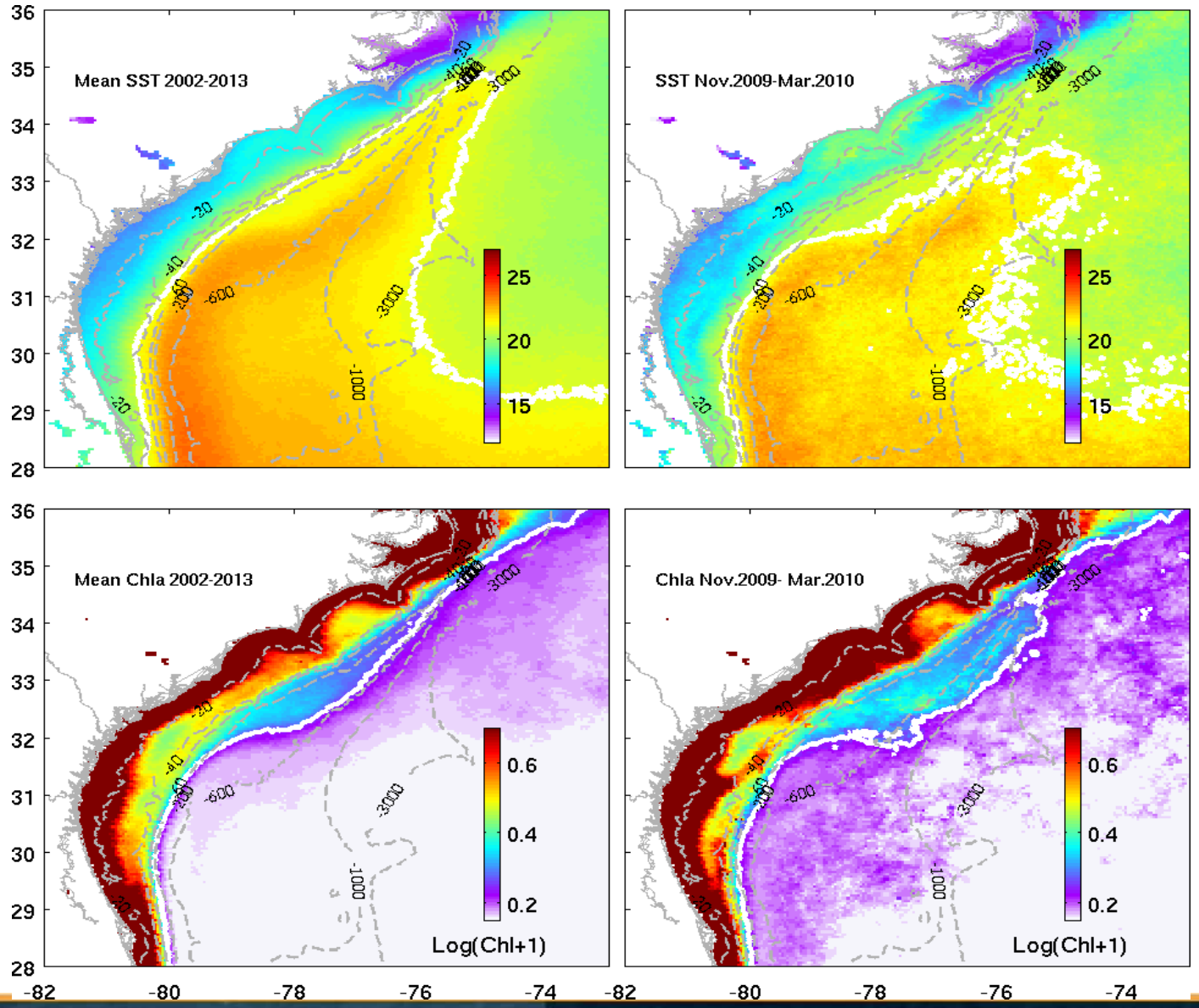


NC STATE UNIVERSITY

Comparisons of SST & ocean color

Long term Mean SST

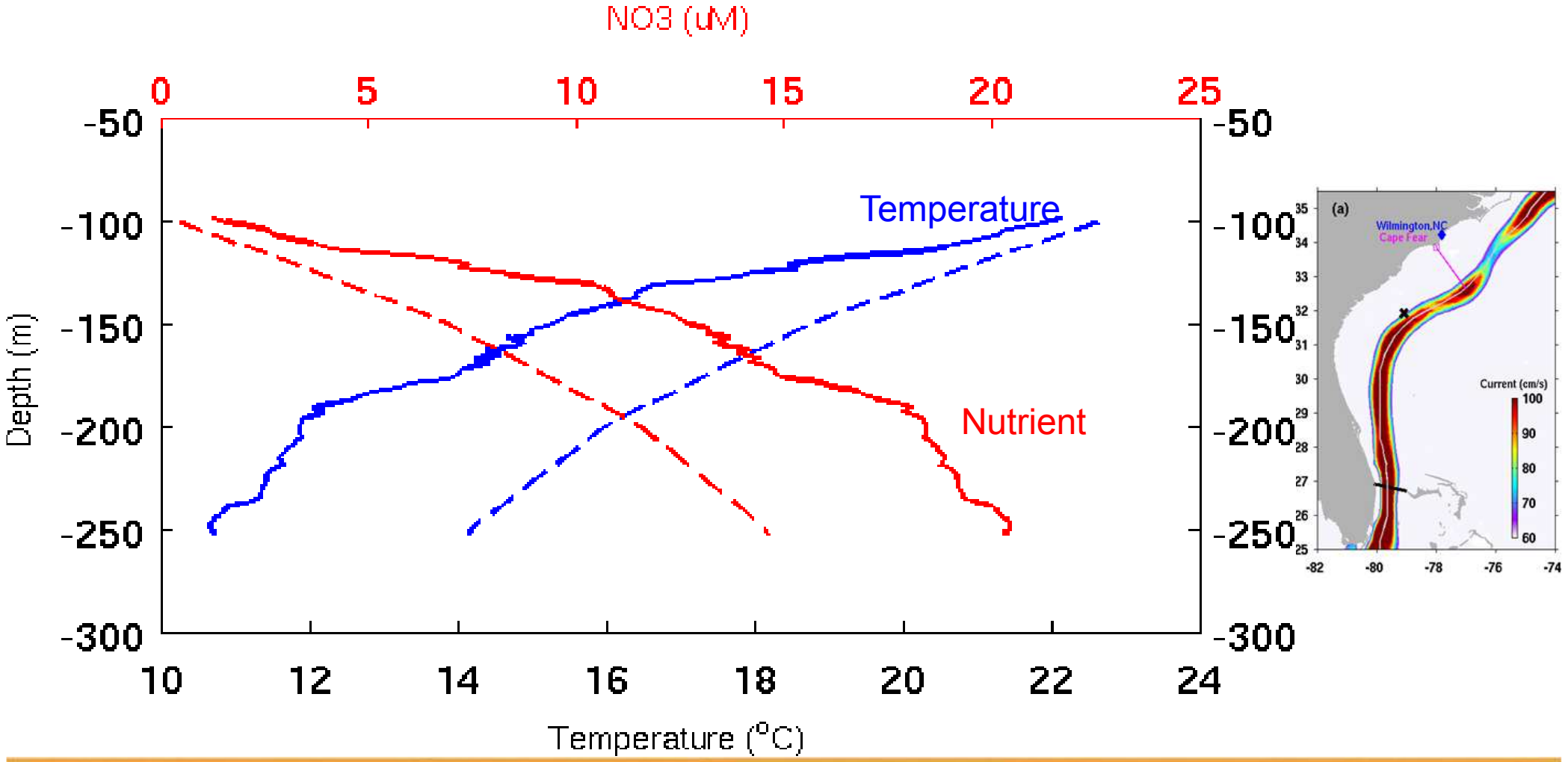
Nov 2009-Mar 2010 Mean SST



Chl-a

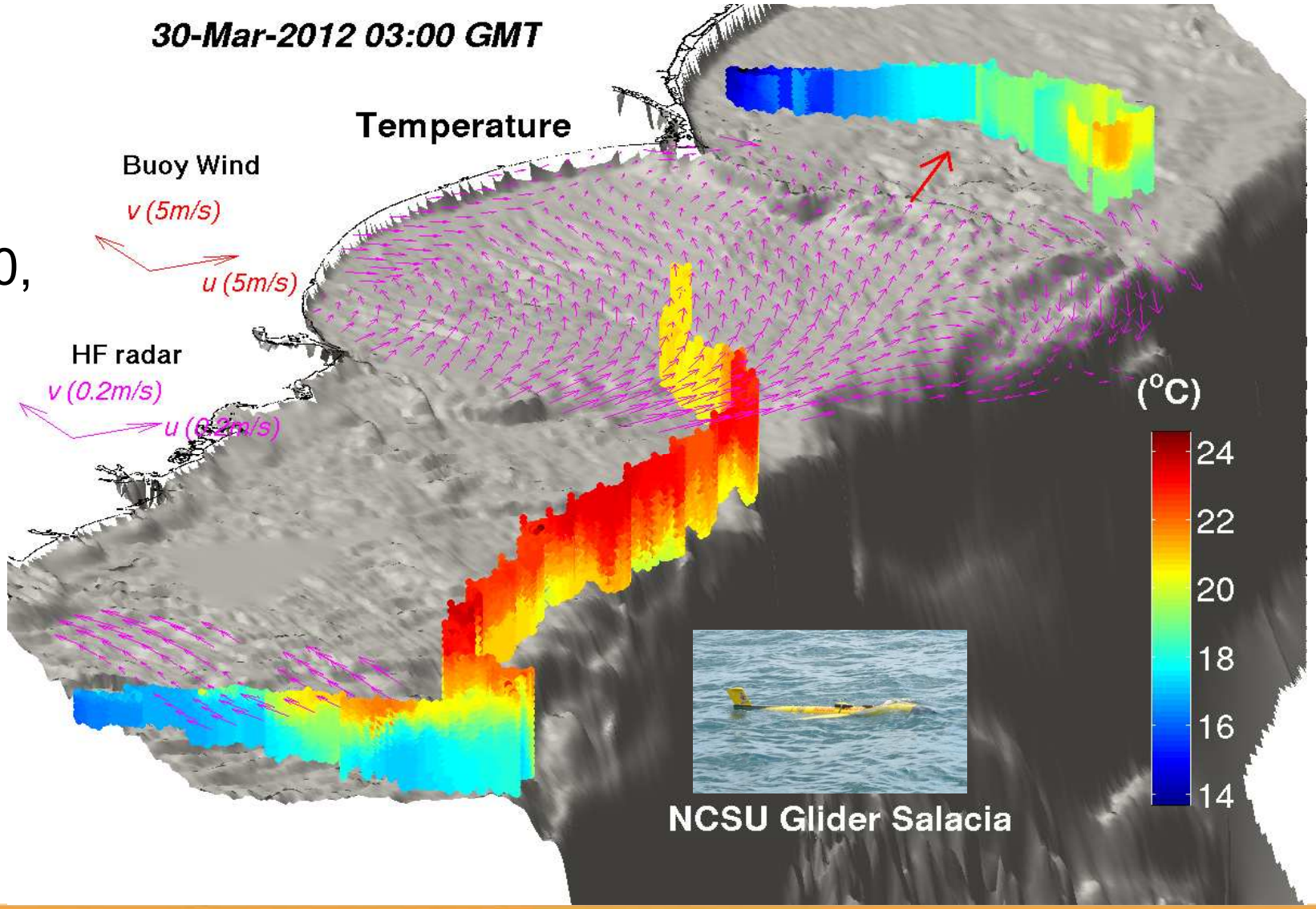
Chl-a

Comparisons between observed temperature and nutrient profiles in Nov 2009 (solid) and their respective long term means (dashed, from NODC)



Mapping regional-wide ocean conditions

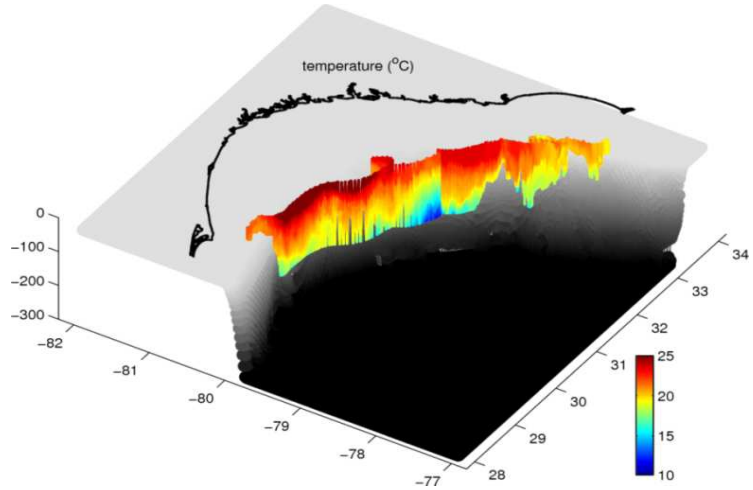
Glider Survey (March 2-30, 2012)

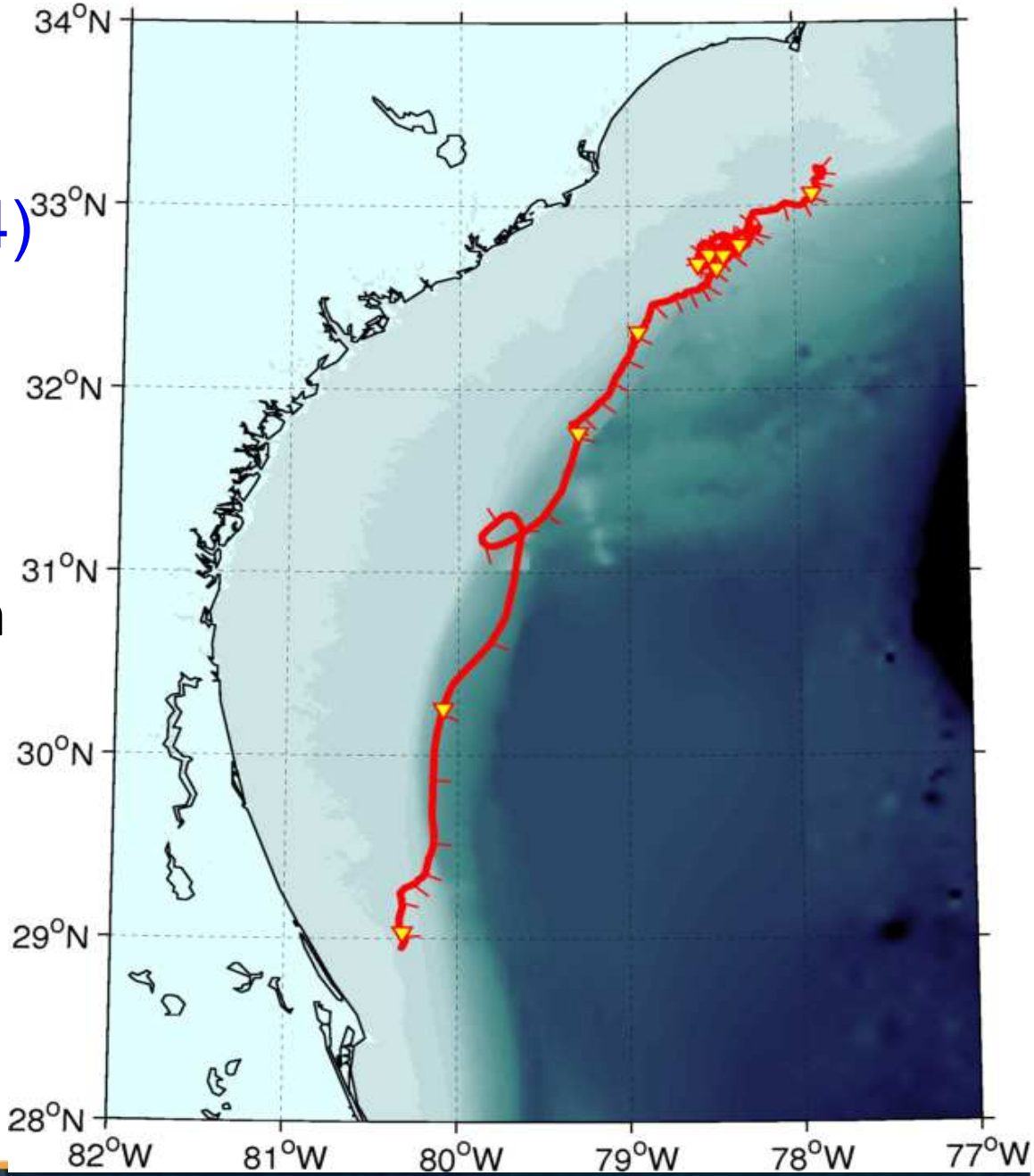


NC STATE UNIVERSITY

Along shelfbreak Glider Survey (March 1-31, 2014)

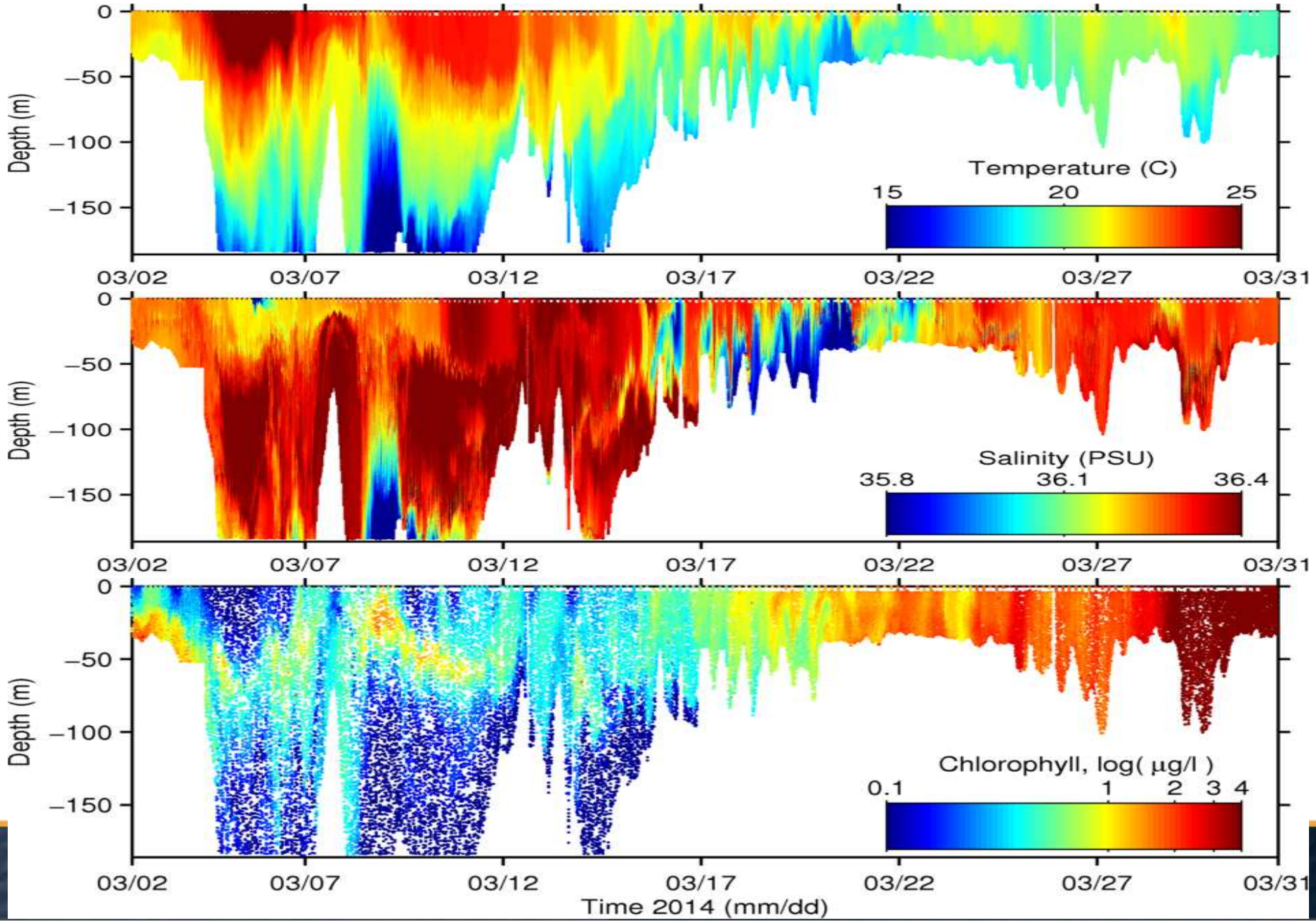
- Spent most of the time in GS
- assess mesoscale and submeso-scale features in the GS





NC STATE UNIVERSITY

Glider observed T/S/chl-a distributions (March 1-31, 2014)



NC STATE UNIVERSITY

Summary

1. Large offshore GS meander and coastal sea level rise in Sept 2009 – Apr 2010 were **triggered** by combined effect of reduced GS transport and topographic effect.

2. More than normal open ocean cyclonic eddies occurred during the same time and helped to **maintain** such offshore displacement by injecting positive vorticity into the GS.

3. Stronger GS upwelling was induced, transporting more cold and nutrient rich deep-ocean water onshore and **stimulating** a larger marine productivity in the southeastern U.S. coastal ocean.

4. Numerical modeling experiments have used to examine dynamical details.

5. Routine 4-dimensional (x, y, z, time) GS measurements by satellite remote sensing, coastal tidal gauges, moorings, HF radar, gliders, etc. are much needed.