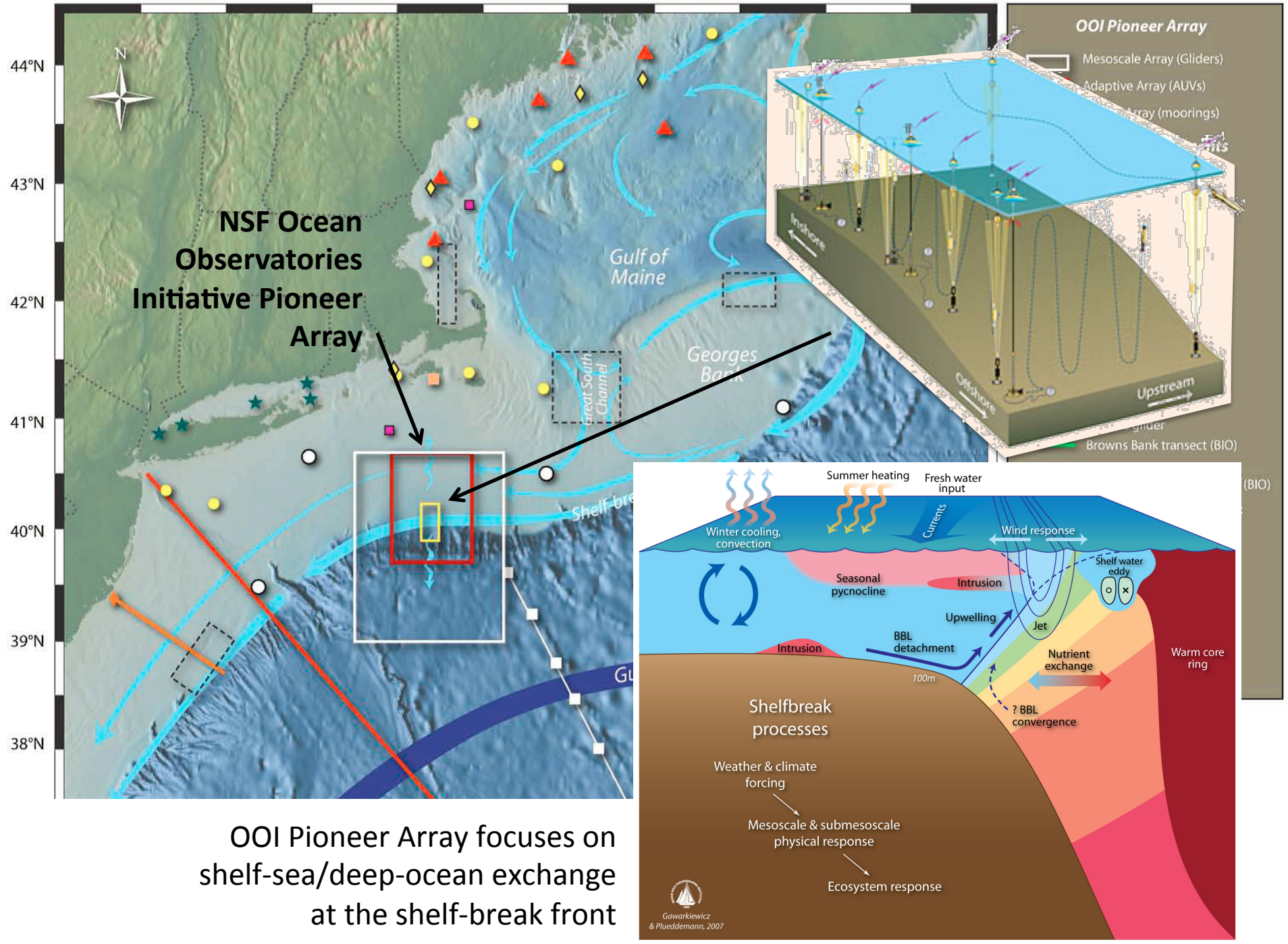
Coastal Mean Dynamic Topography Computed Using ROMS* Variational Assimilation of Long-Term Mean Observed Currents and Hydrography

John Wilkin
Julia Levin and Javier Zavala-Garay

Institute of Marine and Coastal Sciences
Rutgers, the State University of New Jersey

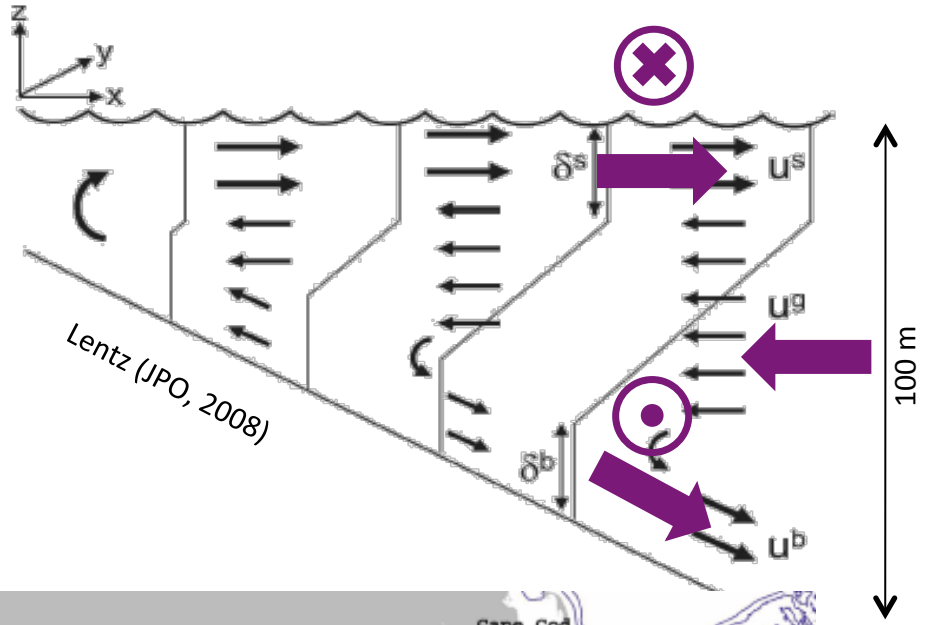
*Regional Ocean Modeling System www.myroms.org



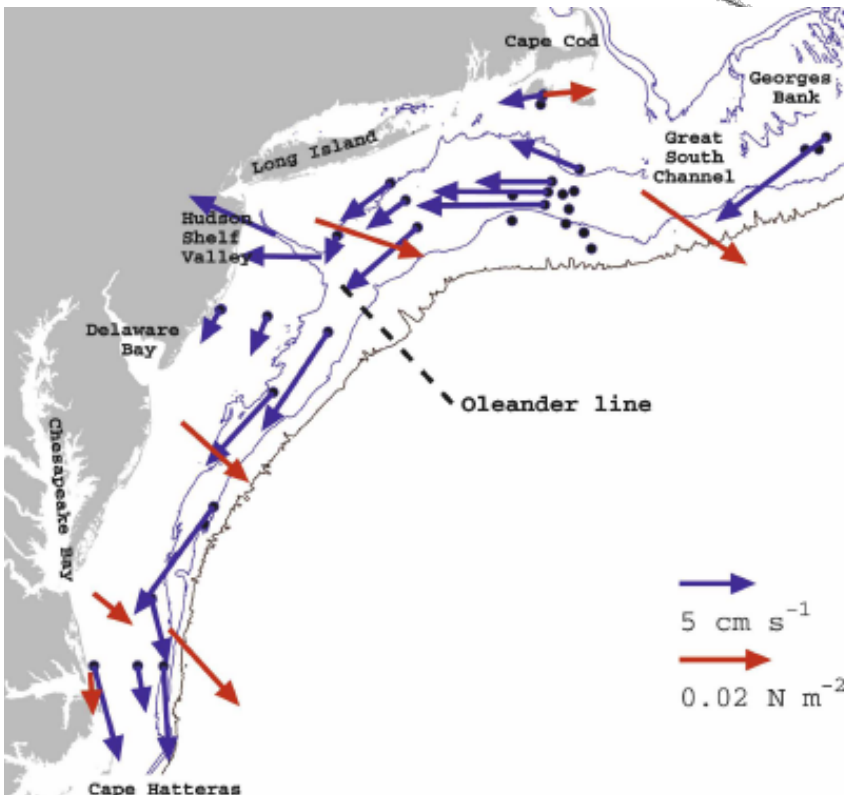
OOI Pioneer Array focuses on shelf-sea/deep-ocean exchange at the shelf-break front

Mean circulation from an idealized 2-D model of MAB shelf dynamics (Lentz, 2008)

Along-shelf momentum includes significant along-shelf pressure gradient.



Lentz (2008) estimates slope of $3.7 \times 10^{-8} = 0.03$ m in 800 km

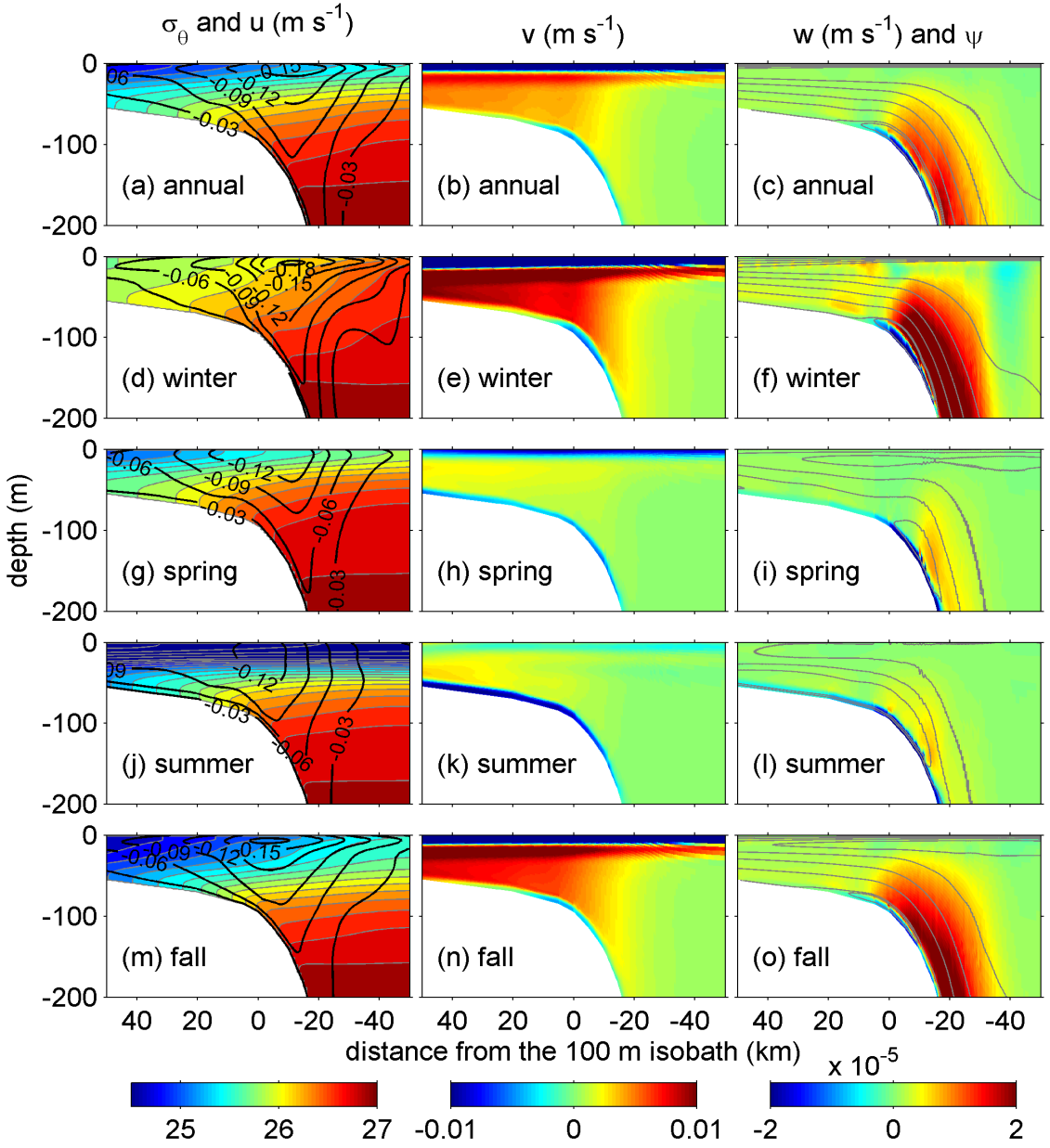


Lentz, S., 2008: Observations and a model of the mean circulation over the Middle Atlantic Bight continental shelf, *JPO*, *38*, 1203-1221

ROMS 2-dimensional climatological simulation (Zhang et al. 2011)

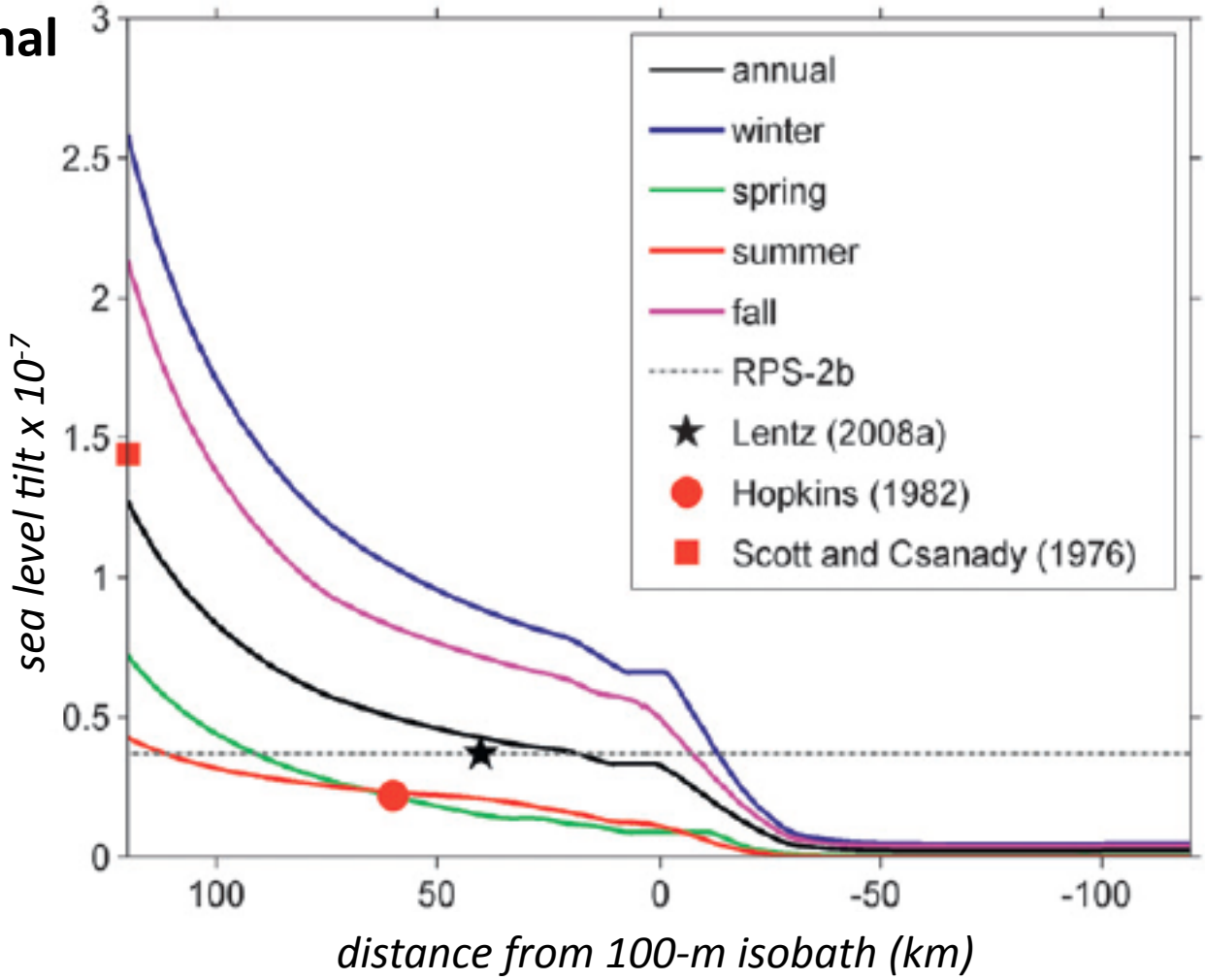
Nudges to along-shelf average of regional 3-D climatology "MOCHA" (Fleming and Wilkin) and **imposes** along-shelf pressure force equivalent to a mean sea level tilt

- Offshore flow near surface and bottom in all seasons, balanced by onshore flow at mid-depth
- Mean flow is similar to long-term mooring measurements
- Persistent upwelling near shelf-break



Zhang, W. G., G. Gawarkiewicz, D. McGillicuddy and J. Wilkin, 2011, Climatological mean circulation at the New England shelf break, J. Phys. Oceanogr., 41, 1874-1893, doi: 10.1175/2011JPO4604.1

ROMS 2-dimensional climatological simulation
(Zhang et al. 2011)



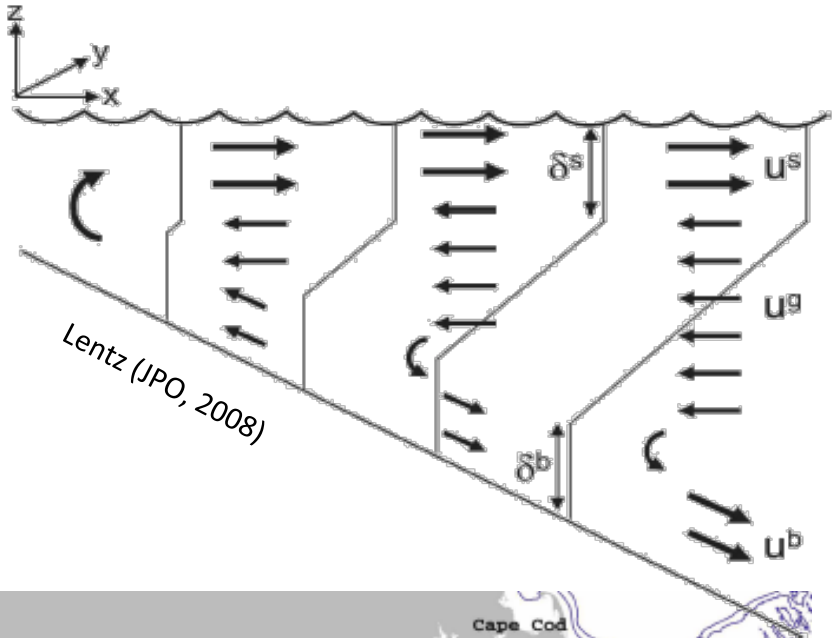
Cross-shelf distribution of the along-shelf sea level tilt imposed in simulations. Symbols show previous estimates of annual mean (★) and summer mean (■, ●) tilt.

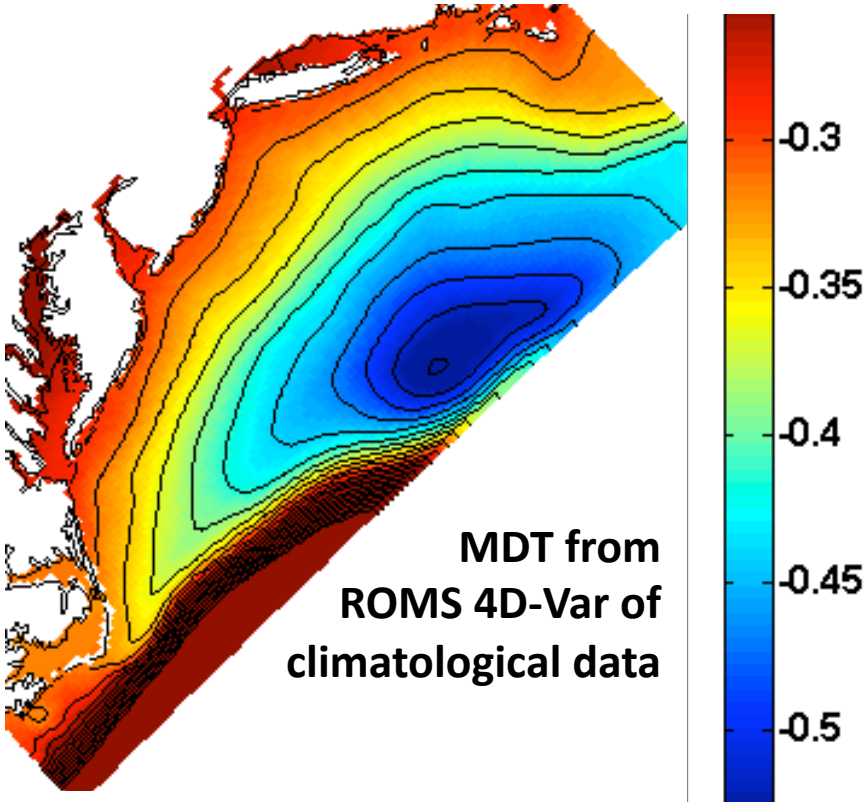
Zhang, W. G., G. Gawarkiewicz, D. McGillicuddy and J. Wilkin, 2011, Climatological mean circulation at the New England shelf break, J. Phys. Oceanogr., 41, 1874-1893, doi: 10.1175/2011JPO4604.1

Mean circulation from an idealized 2-D model of MAB shelf dynamics (Lentz, 2008)

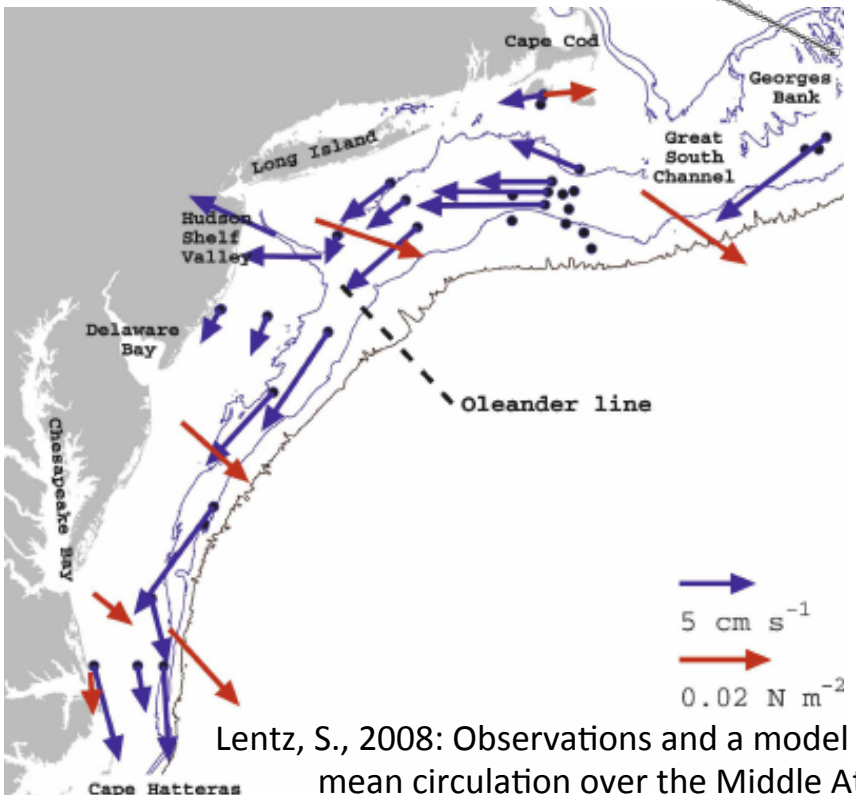
Along-shelf momentum includes significant along-shelf pressure gradient.

Lentz (2008) estimates slope of $3.7 \times 10^{-8} = 0.03$ m in 800 km





MDT from ROMS 4D-Var of climatological data

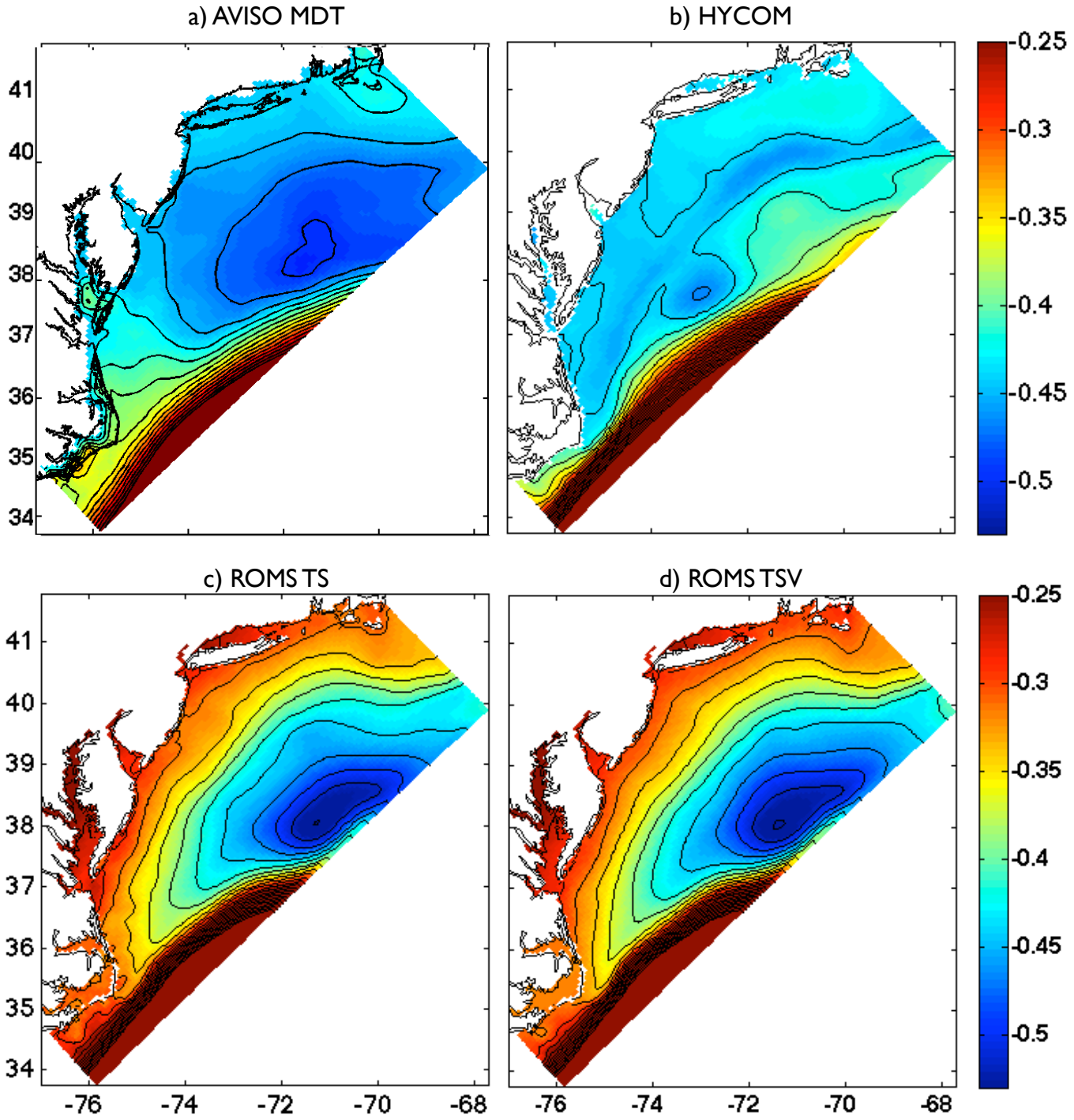


Lentz, S., 2008: Observations and a model of the mean circulation over the Middle Atlantic Bight continental shelf, *JPO*, *38*, 1203-1221

MDT

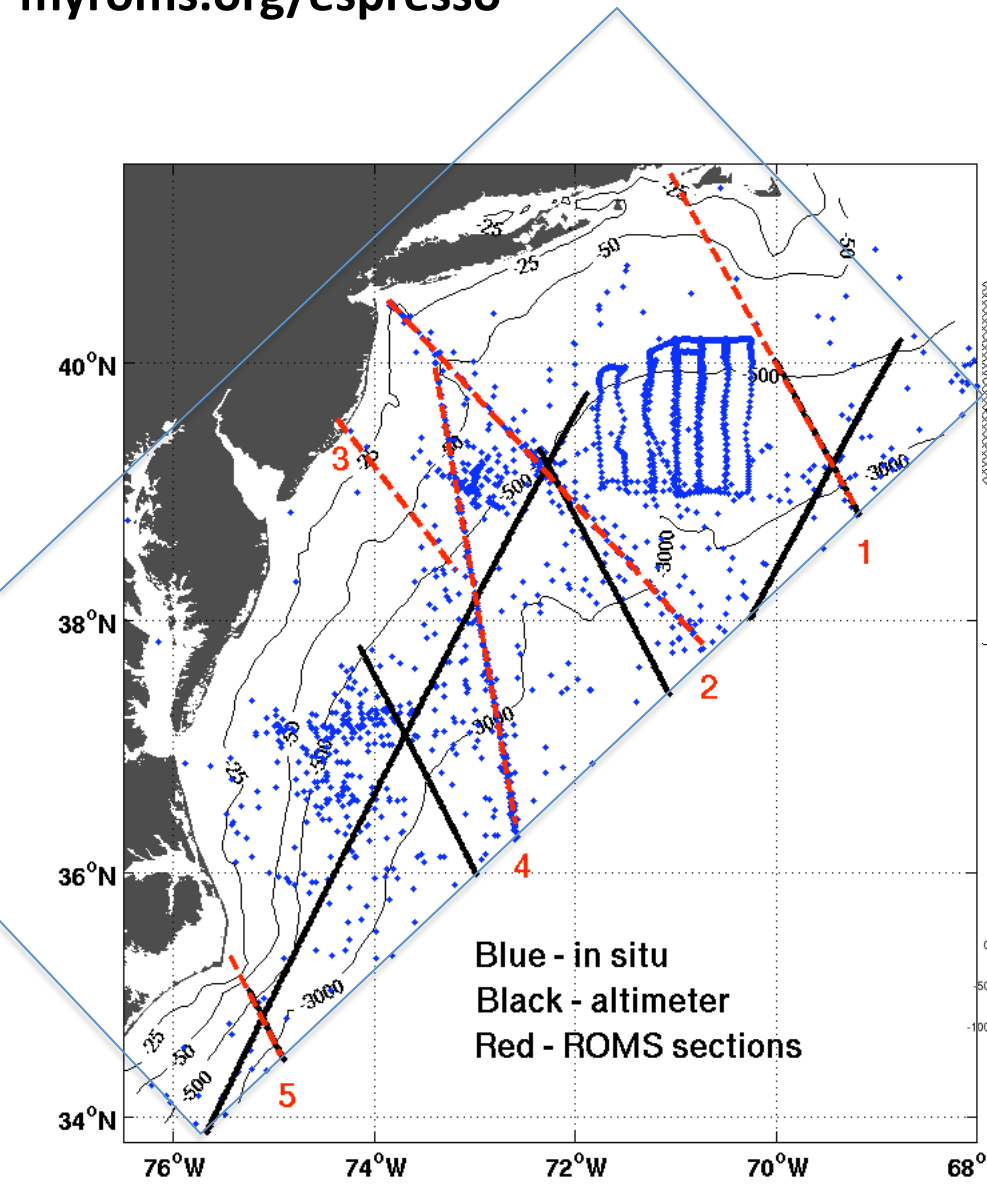
from

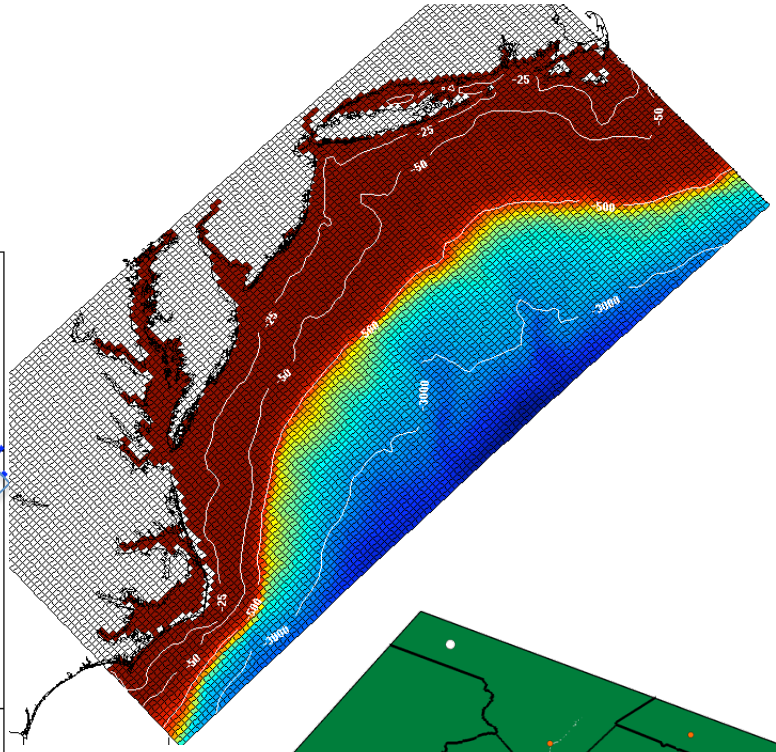
4D-Var

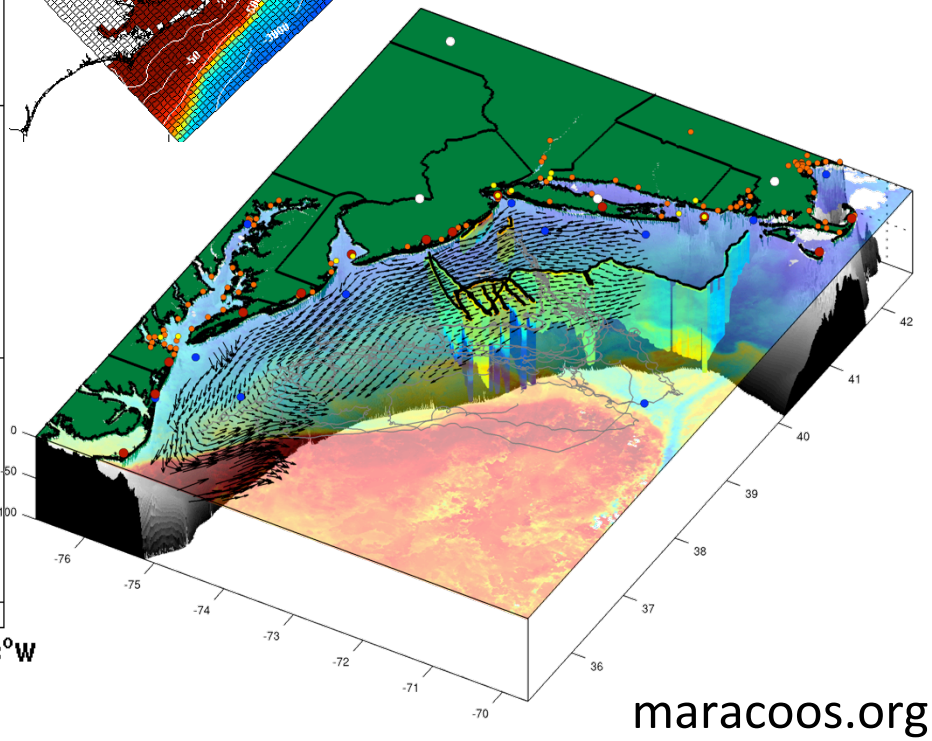

a) AVISO MDT
b) HYCOM
c) ROMS TS
d) ROMS TSV
41
40
39
38
37
36
35
34
-76
-74
-72
-70
-68
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5

ESPreSSO real-time ROMS system

myroms.org/espresso

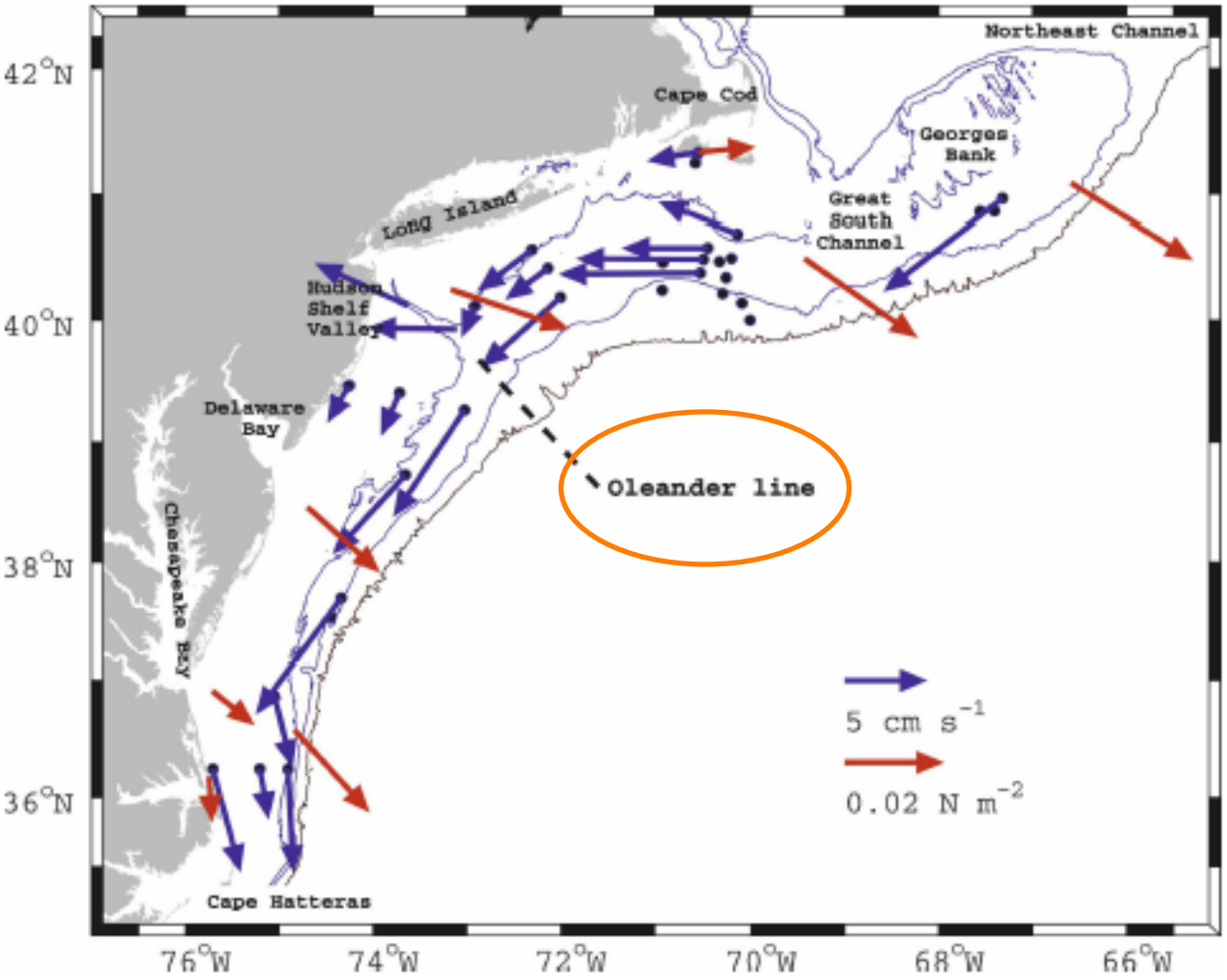






maracoos.org

MARACOOS Observing System



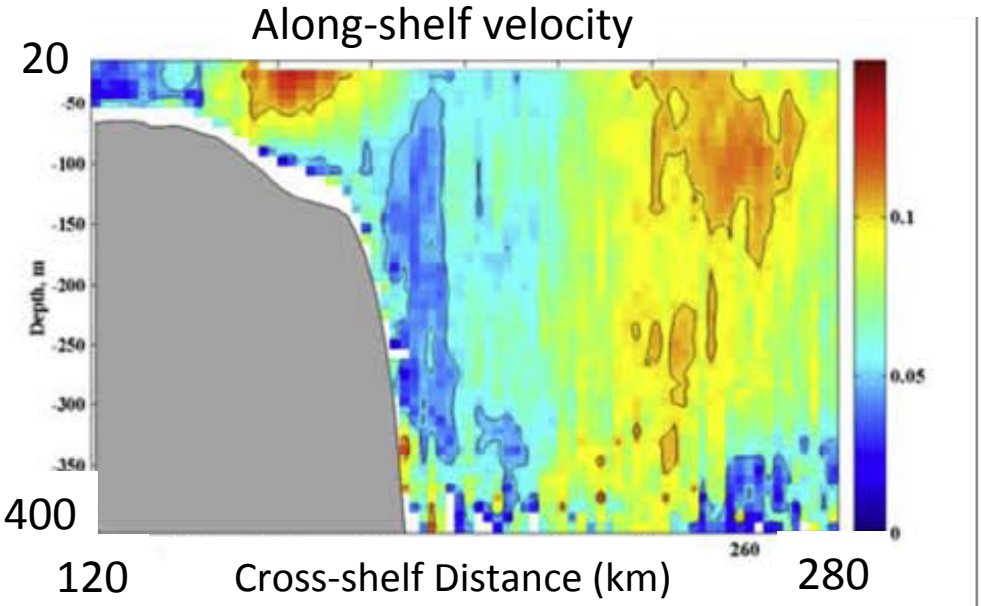
Mean depth-averaged current (blue), and mean wind stress (red) from current time series longer than 200 days. Light lines are 50-, 100-, and 1000-m isobaths.

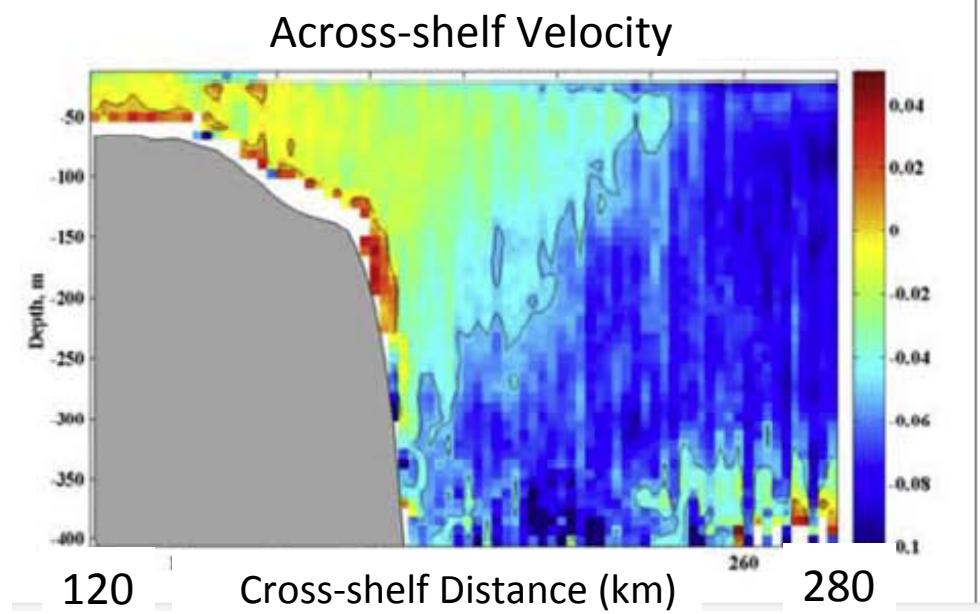
Lentz, S., 2008: Observations and a Model of the Mean Circulation over the Middle Atlantic Bight Continental Shelf, *JPO*, *38*(6), 1203.

Long-term mean velocity from M/V *Oleander* ADCP transect (Flagg et al. 2006)

ADCP mounted on vessel making monthly transits from NY to Bermuda

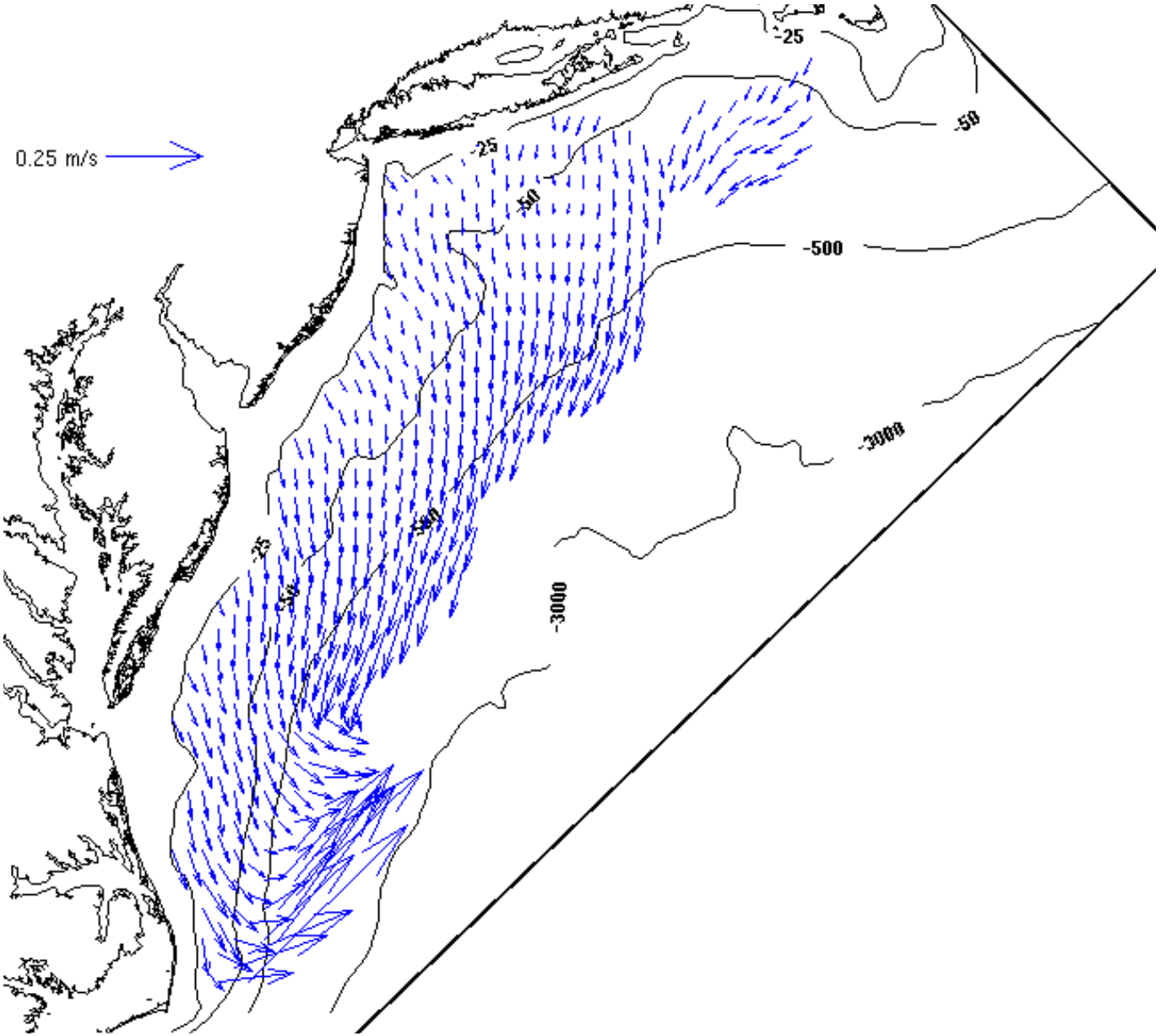
- Mean shelf-break jet 13 cm/s, max 35 cm/s, 30 km jet width
- Vertical scale of jet is 50 m, relative vorticity/f ~ 0.2
- Data shows offshore flow near bottom consistent with observations
- Jet core is over the 120 m isobath but varies from 80 to 150 m isobaths

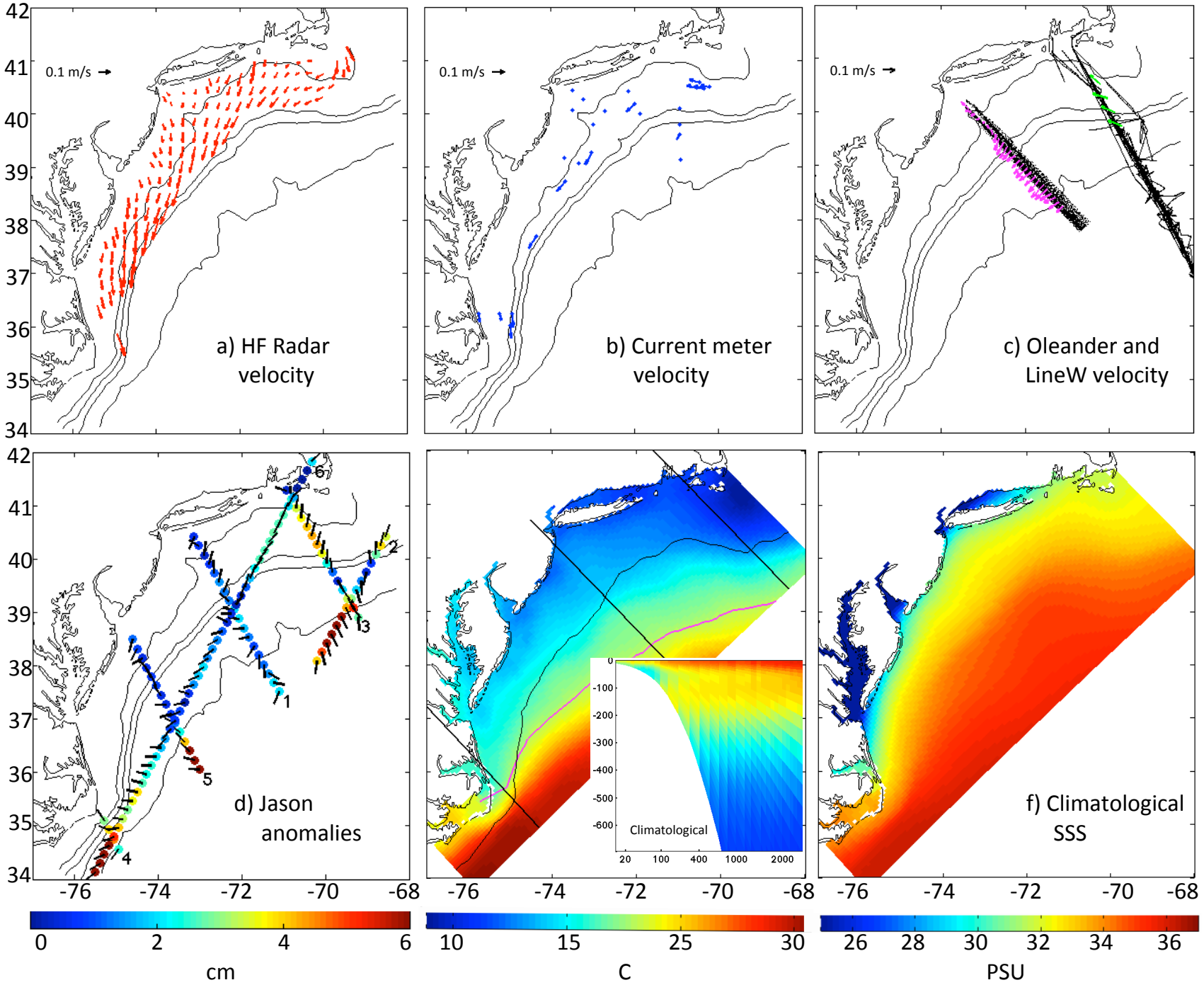




Flagg, C., M. Dunn, D.-P. Wang, H. Rossby, and R. Benway, 2006: A study of the currents of the outer shelf and upper slope from a decade of shipboard ADCP observations in the Middle Atlantic Bight, *J. Geophys. Res.*, *111*, C06003.

Long-term mean surface current from HF radar (CODAR) velocity




0.1 m/s
a) HF Radar velocity
0.1 m/s
b) Current meter velocity
0.1 m/s
c) Oleander and LineW velocity
d) Jason anomalies
1
2
3
4
5
6
Climatological
f) Climatological SSS
42
41
40
39
38
37
36
35
34
-76
-74
-72
-70
-68
0
-100
-200
-300
-400
-500
-600
20
100
400
1000
2000
0
2
4
6
cm
10
15
25
30
C
26
28
30
32
34
36
PSU

Model configuration for climatological simulations

- 7 km horizontal grid; 36 s-levels
- surface stress and air-sea fluxes from mean of 1998-2007 NCEP NARR reanalysis
- mean USGS river discharge
- no tides

Prior solution:

- average of 12 short forward (no DA) simulations
  - initial and boundary T/S from climatology, sea level and velocity from HyCOM

Data Assimilation experiments

IS4DVAR: 2-day analysis window:

- Control variables
  - initial conditions, boundary conditions, and surface forcing
- Data:
  - T/S 3-D climatology, and velocity
  - data are repeated in the analysis interval to constrain time evolution of solution

Annual mean DA analysis:

- MDT becomes prior for subsequent seasonal mean experiments

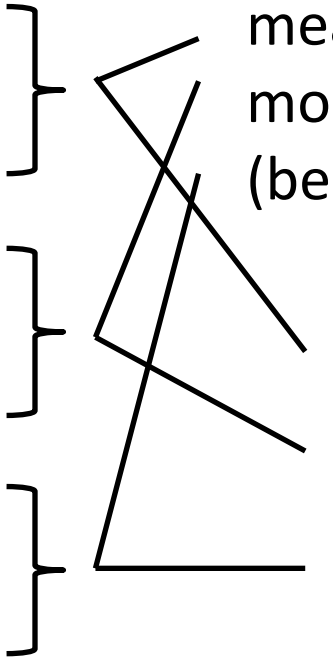
Seasonal DA experiments:

- TS, TSV and TSVH …

Seasonal Data Assimilation experiments

Analyses for each month using that month's average of surface forcing and data (T/S velocity, and Jason SLA)

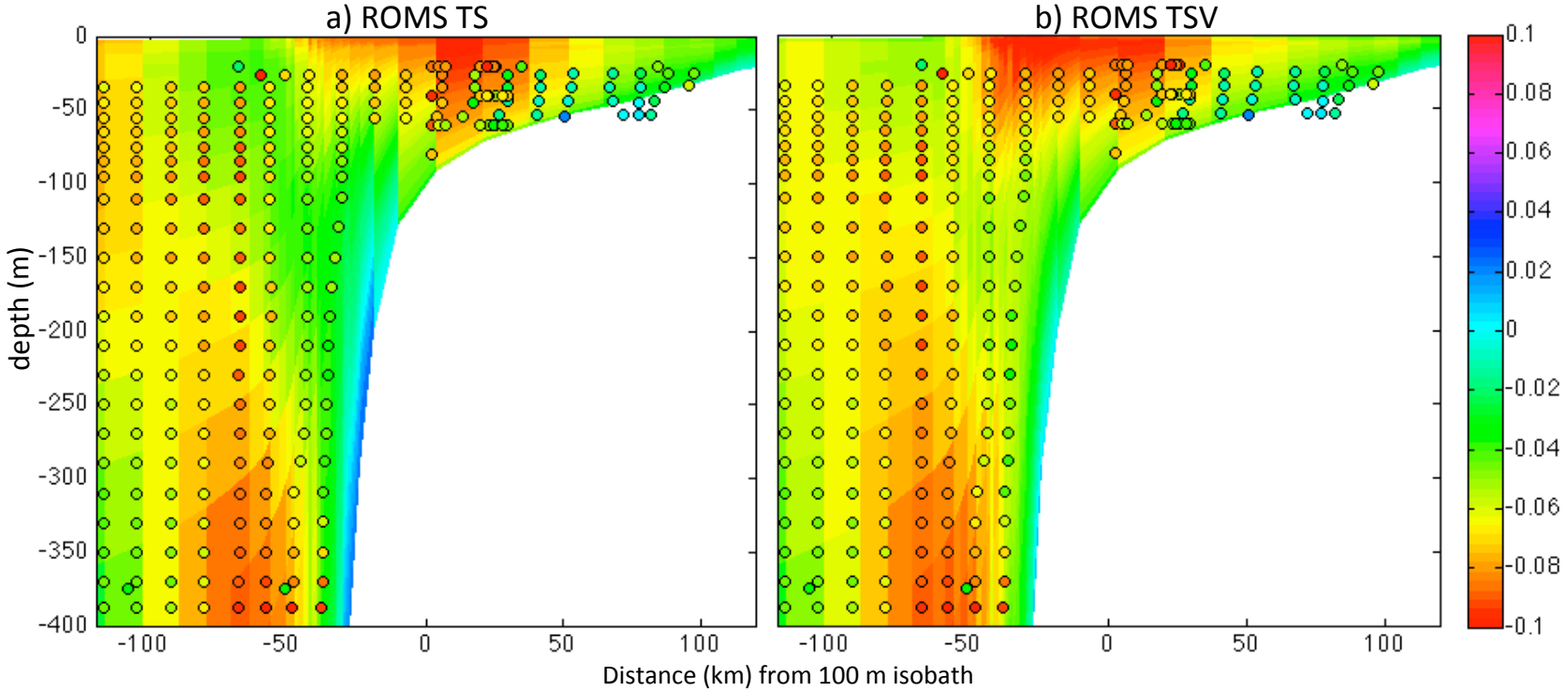
- **TS:** 3-D temperature and salinity climatology only
- **TSV:** T/S and velocity (current-meters, Oleander and CODAR)
- **TSVH:** T/S, velocity and monthly altimetry



Compute new annual mean fields from monthly mean analyses (best estimate of MDT)

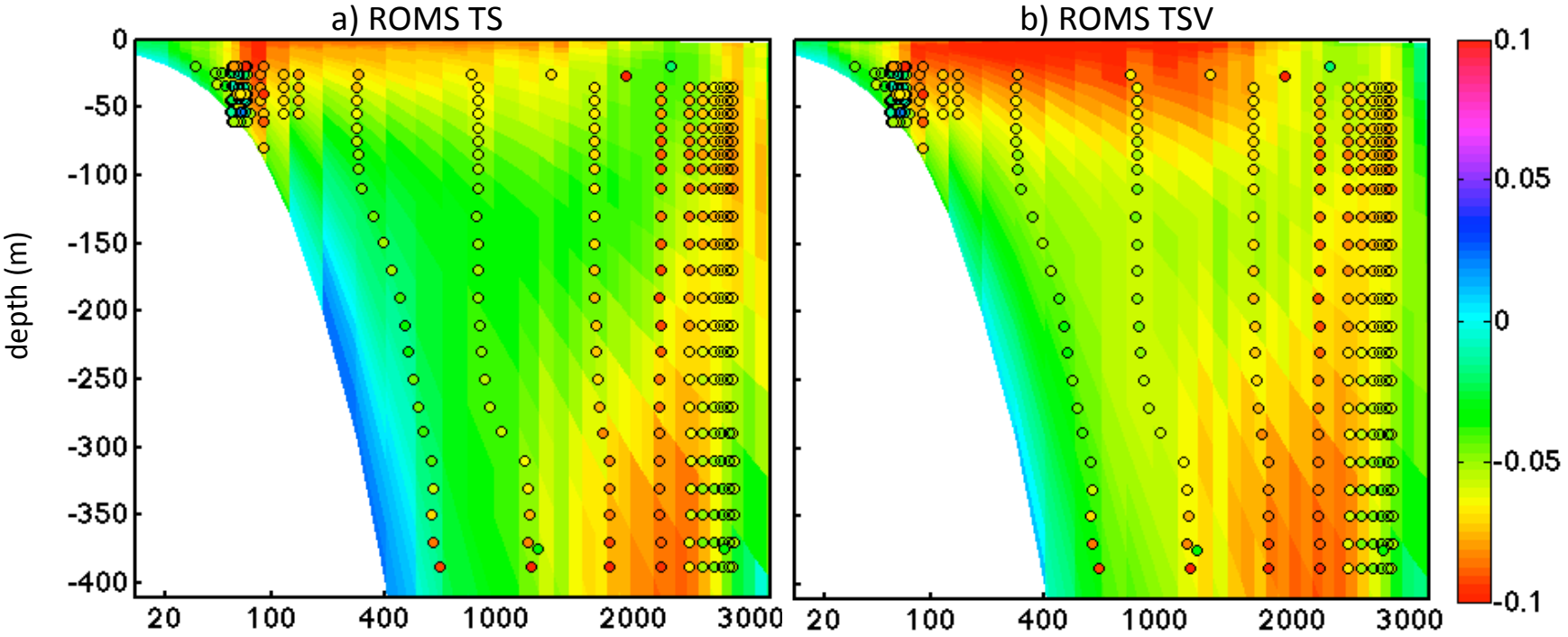
Compute seasonal means for analysis of seasonal cycle of MAB dynamics

Along-shelf velocity



Comparison of ROMS (color) and observed (circles) along-shelf velocity averaged along iso-baths over the MAB region away from Gulf Stream. Annual ADCP velocity observations from Oleander line (binned in horizontal and vertical) and annual current meter observations are used.

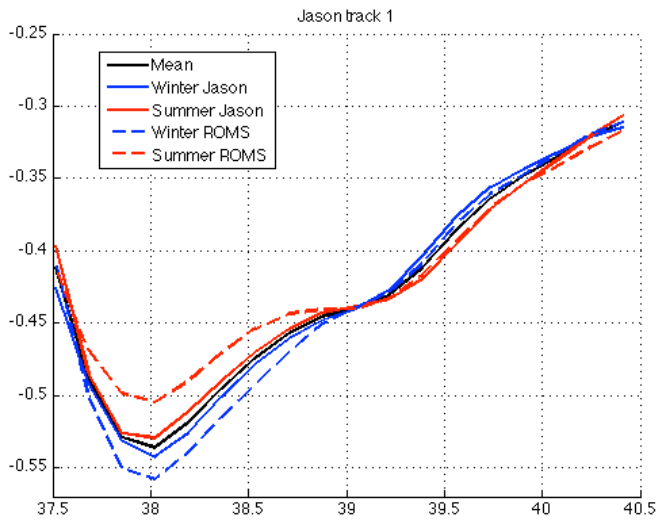
Along-shelf velocity

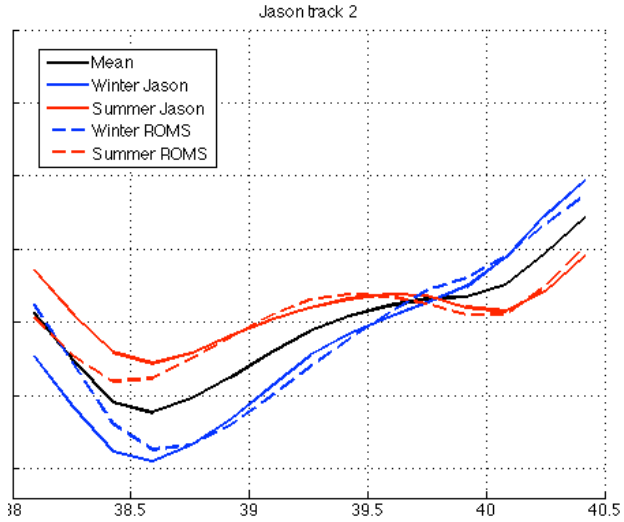


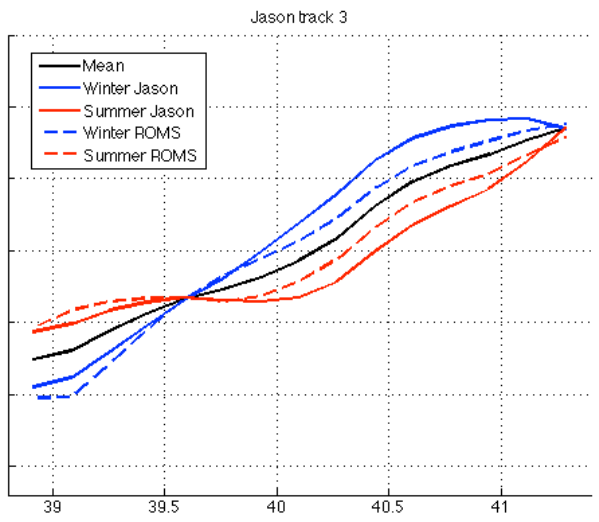
Comparison of ROMS (color) and observed (circles) along-shelf velocity averaged along iso-baths over the MAB region away from Gulf Stream. Annual ADCP velocity observations from Oleander line (binned in horizontal and vertical) and annual current meter observations are used.

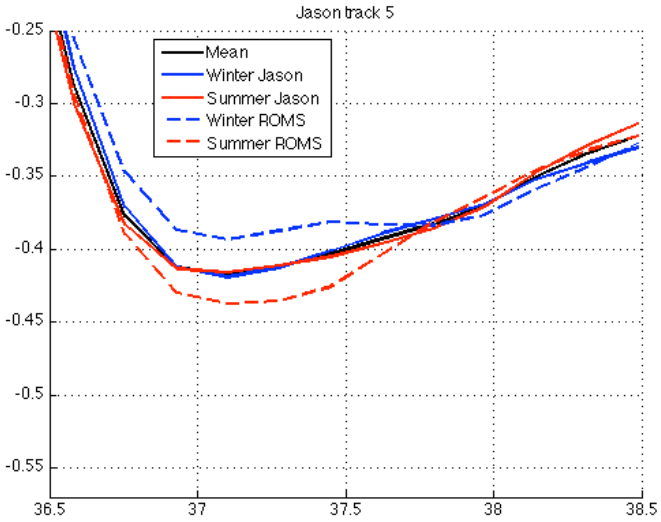
TS

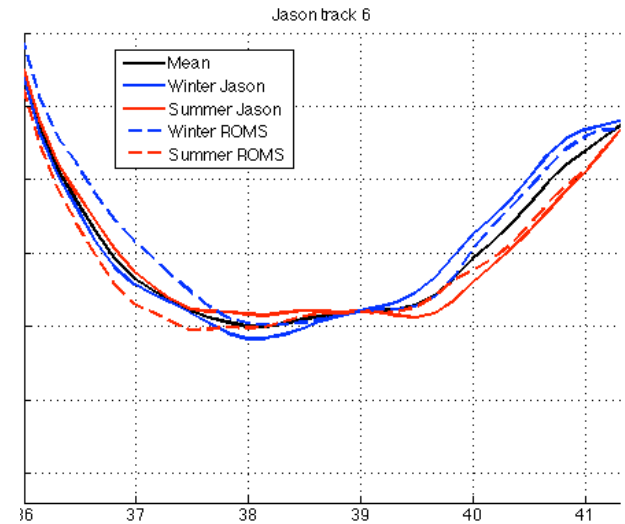
Summer-winter cycle of SSH along Jason ground-tracks compared to 2006-2011 mean of Jason

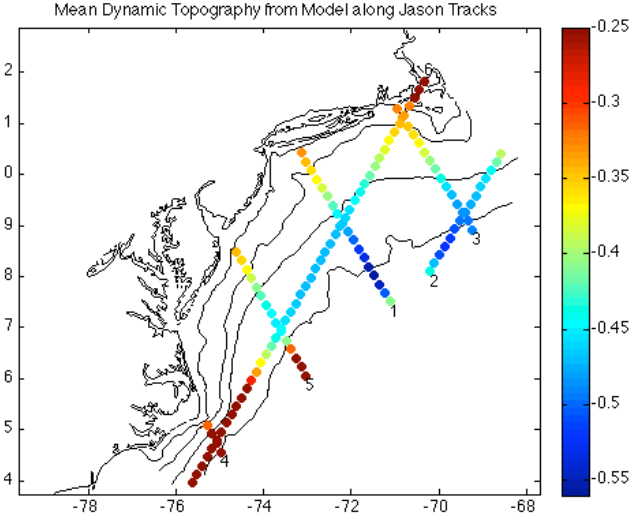






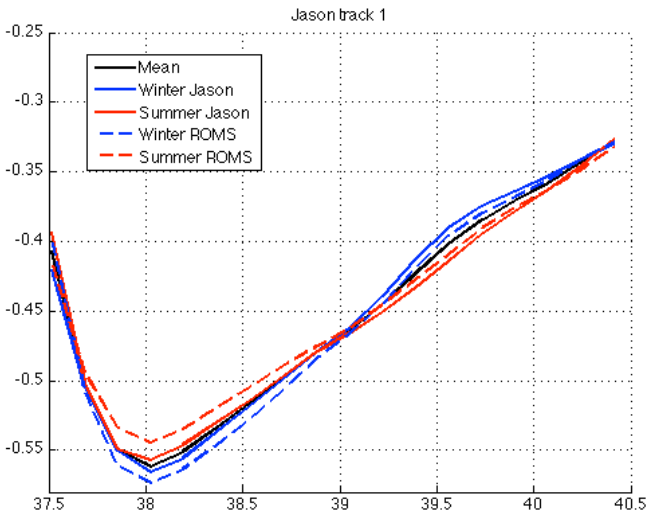


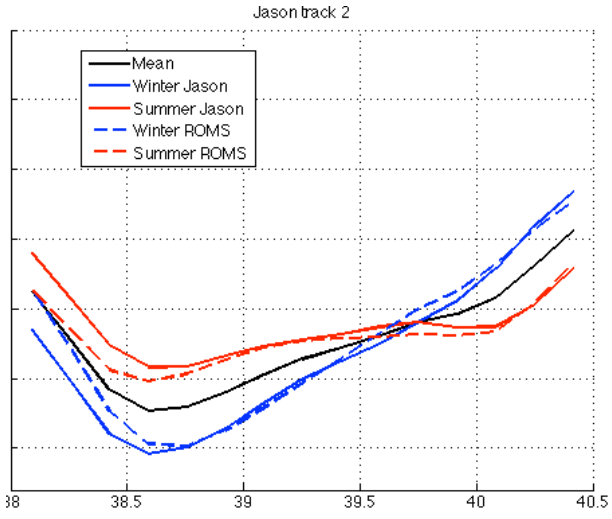


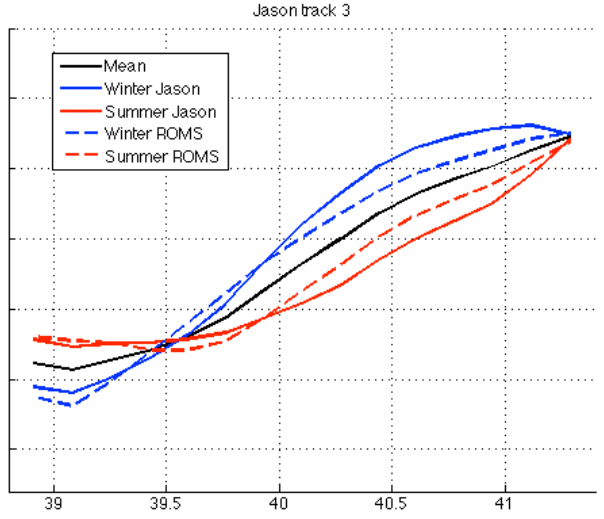


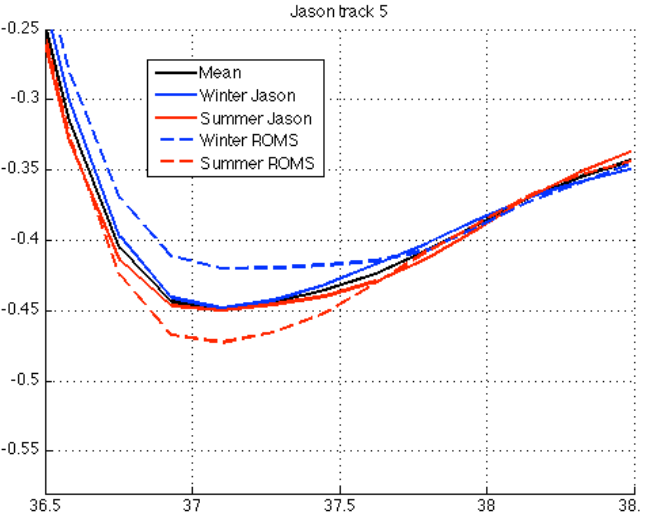
TSV

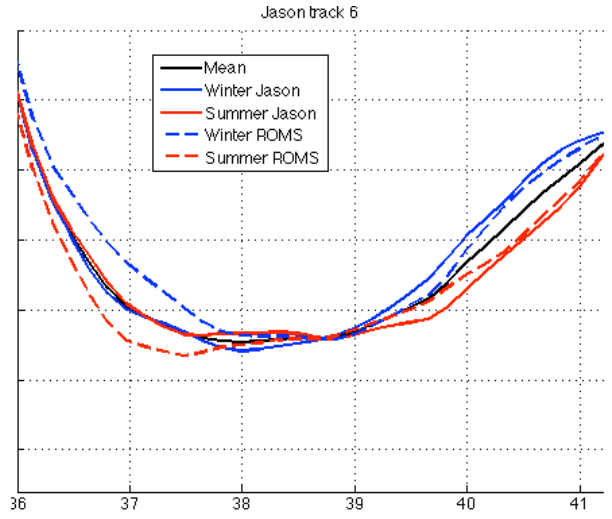
Summer-winter cycle of SSH along Jason ground-tracks compared to 2006-2011 mean of Jason

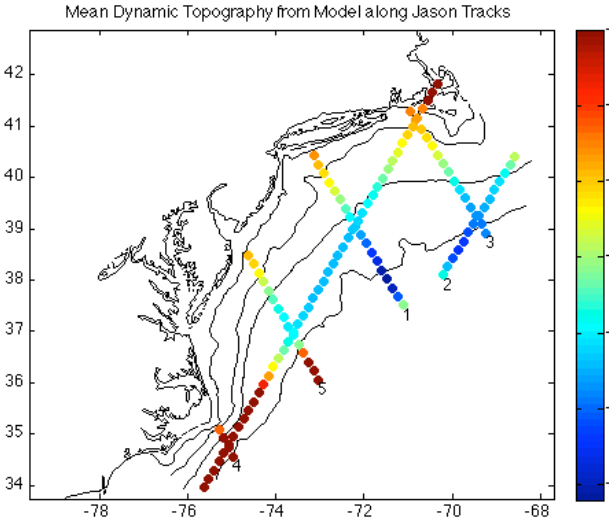






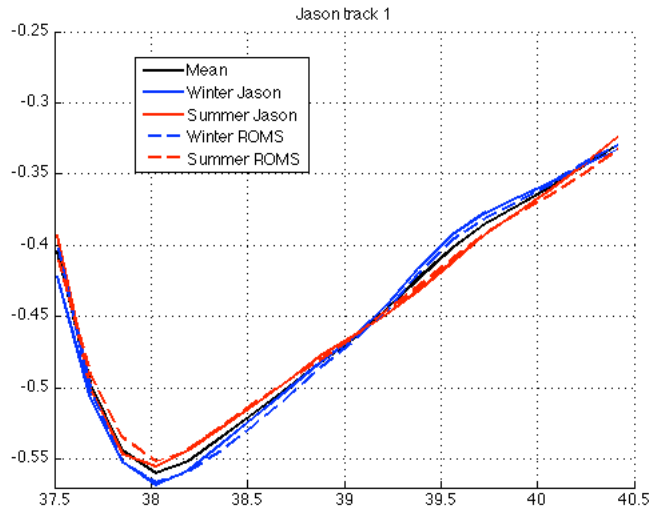


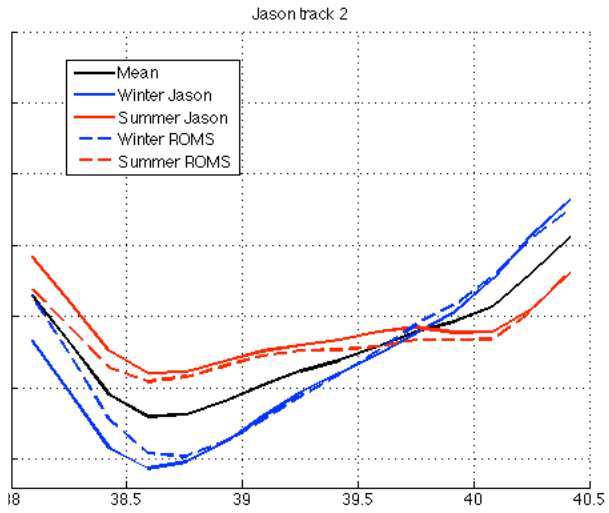


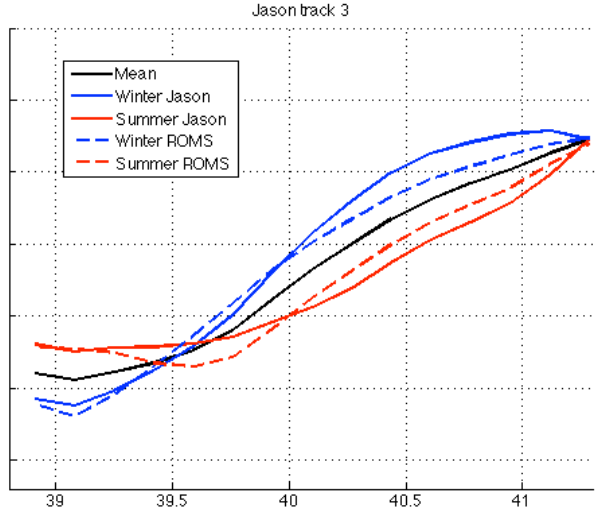


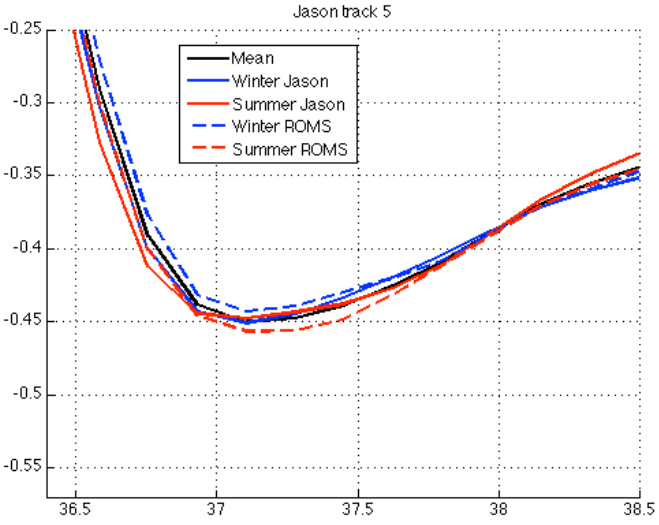
TSVH

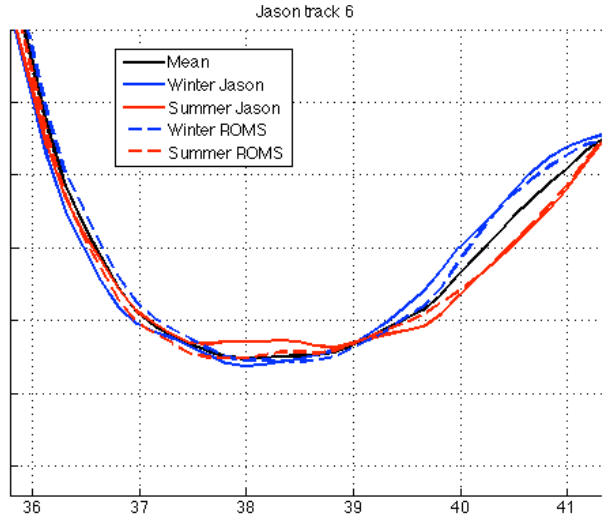
Summer-winter cycle of SSH along Jason ground-tracks compared to 2006-2011 mean of Jason

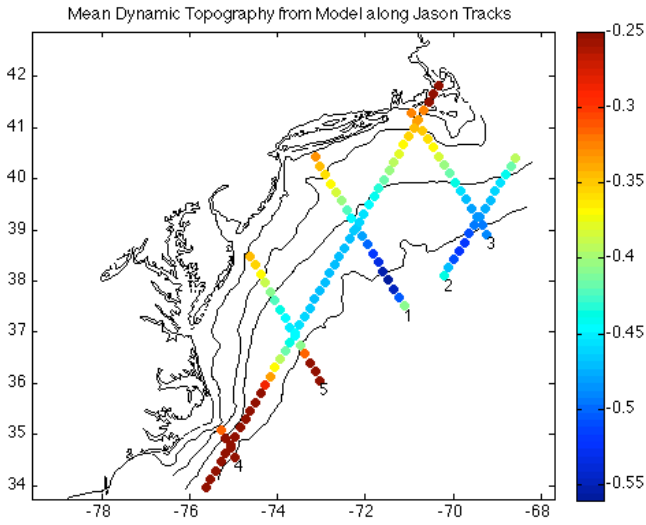




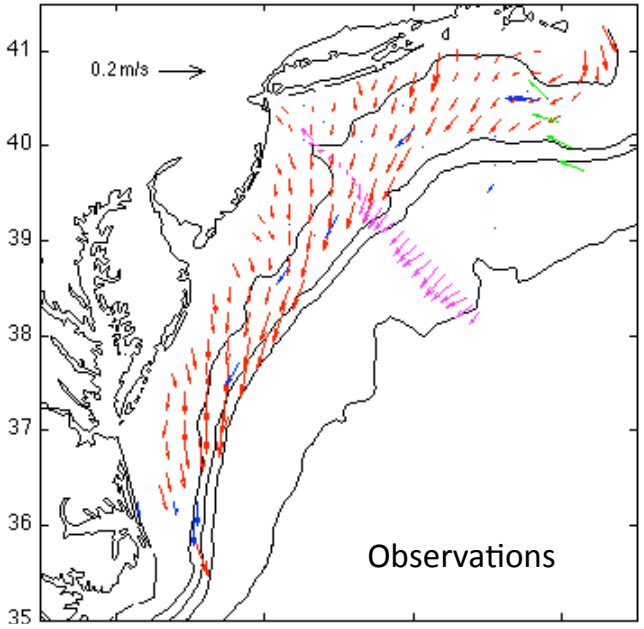


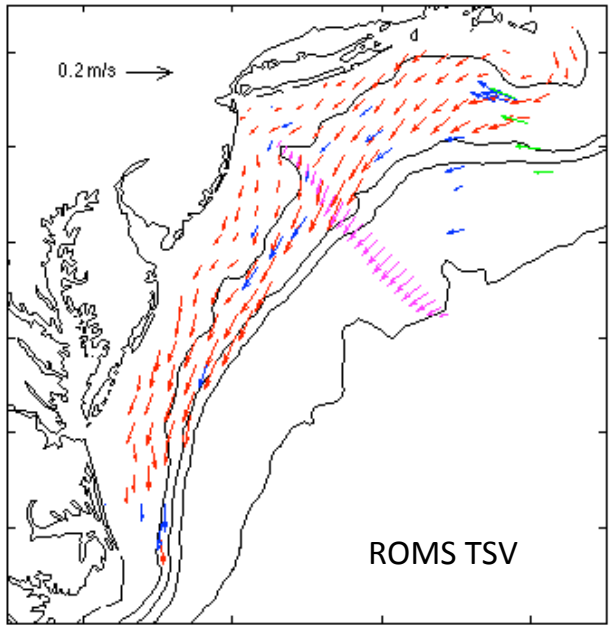


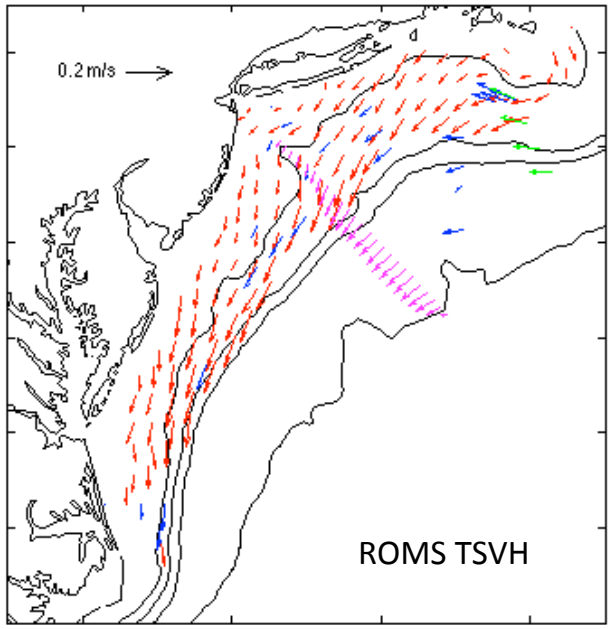




DA fit to data: mean velocity







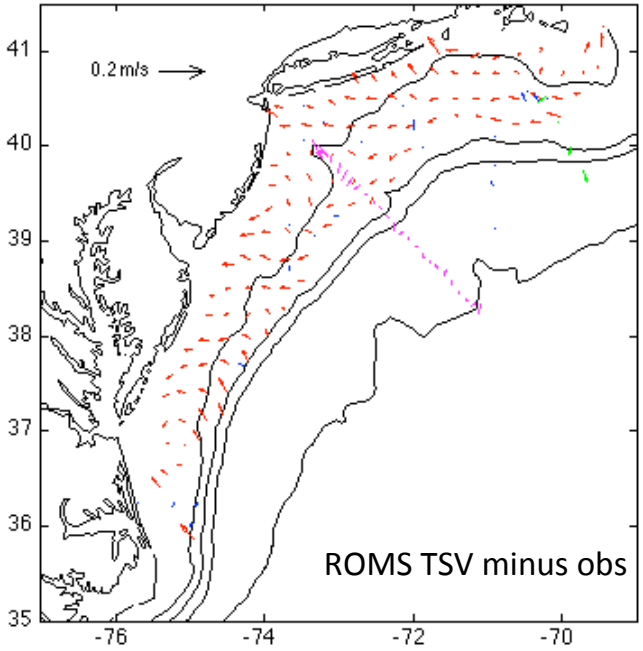
Red - HF Radar

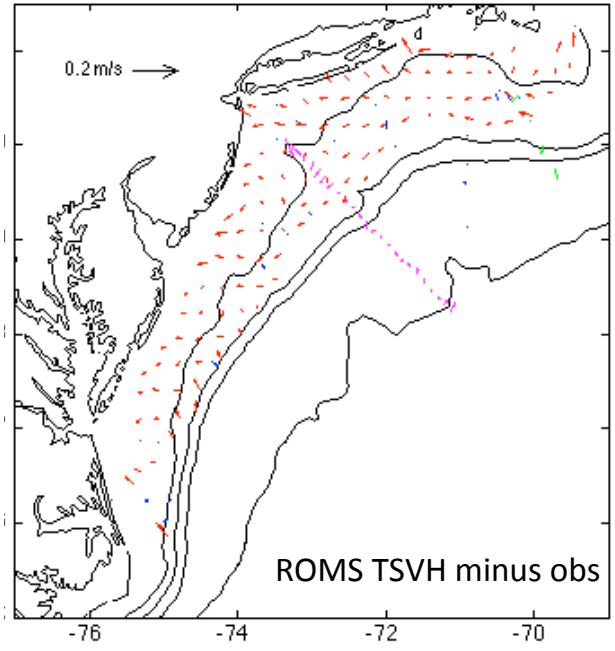
Blue - Current meter at 20m from Lentz

Magenta - ADCP at 35m from Oleander cruise line

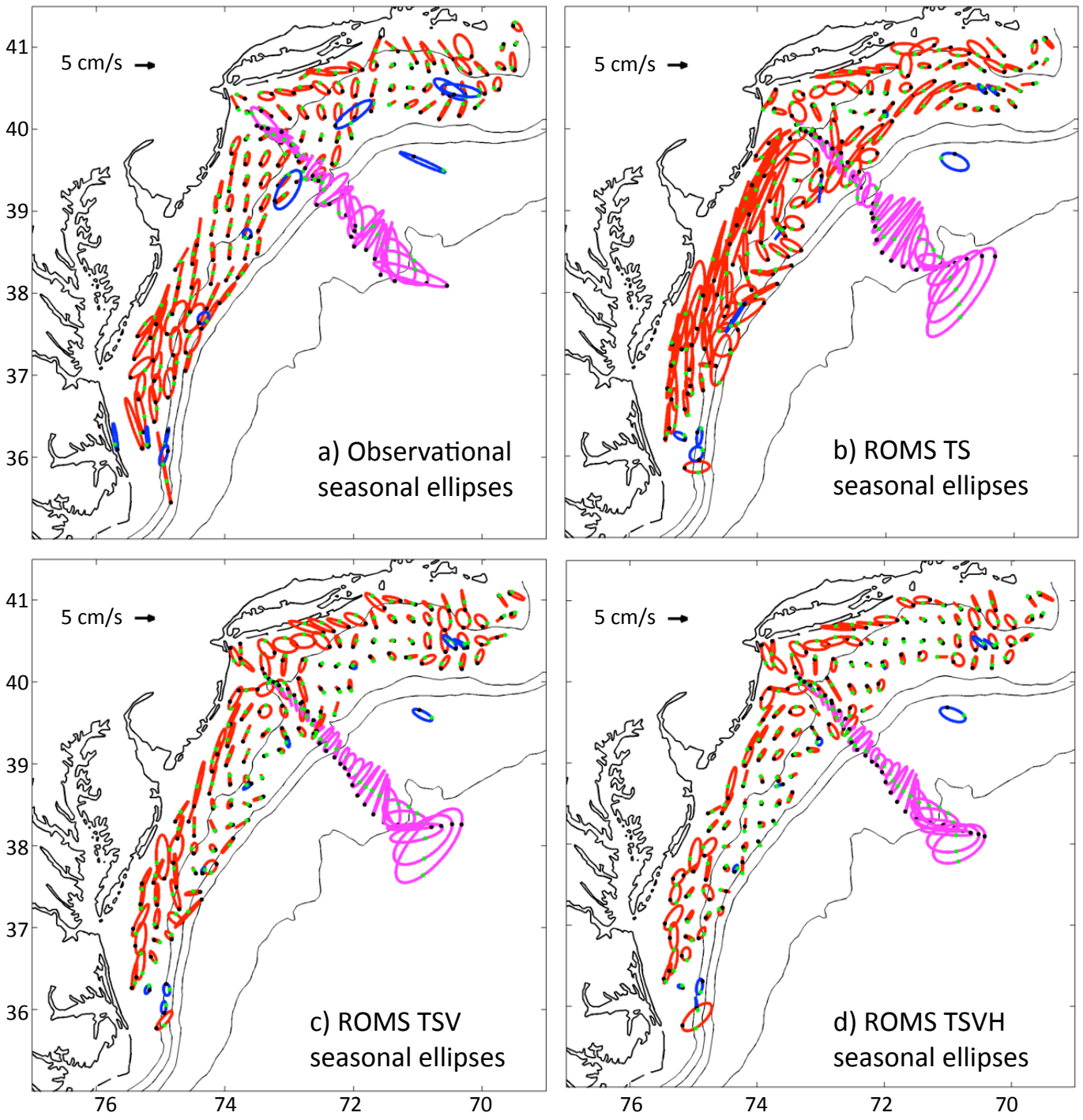
Green - Underway ADCP at 20m from Line W

Model is interpolated at the same locations
as observations.

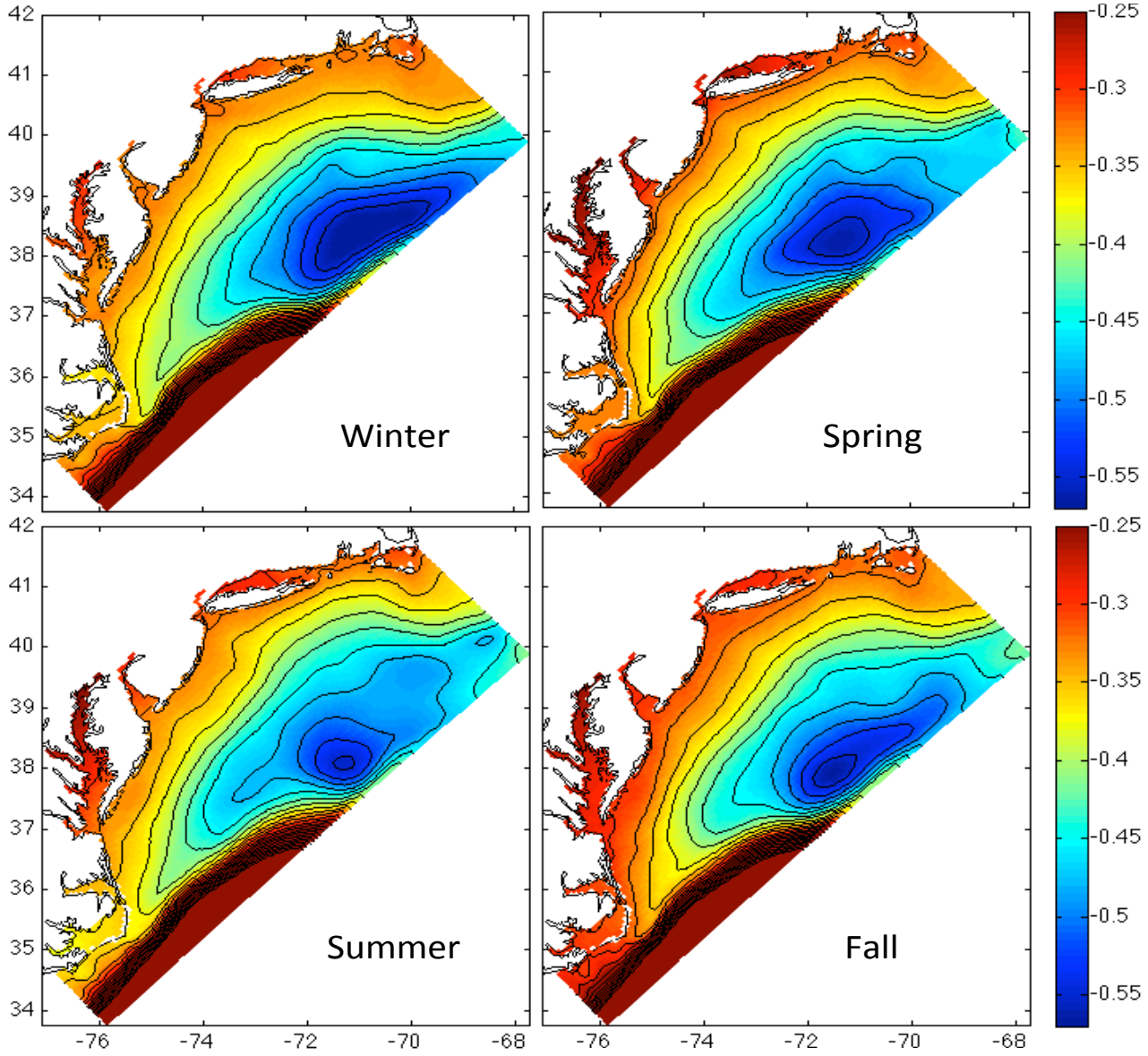




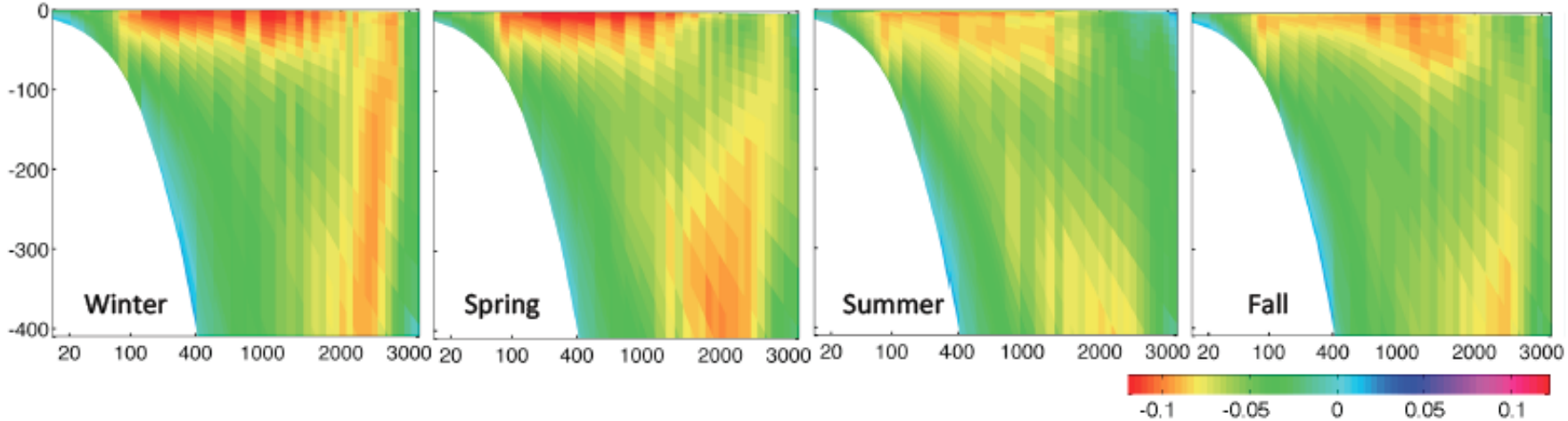
DA fit to data: velocity variance



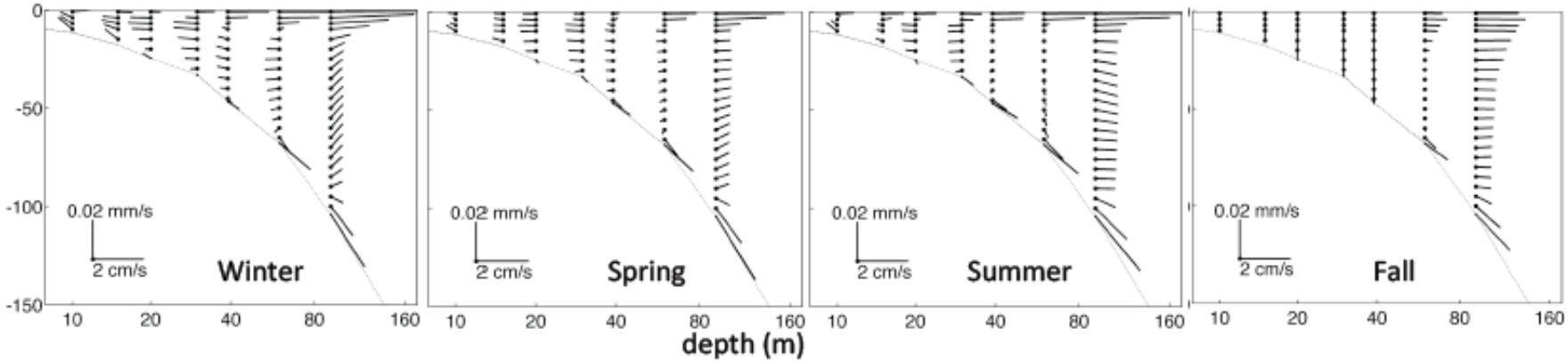
Seasonal cycle in dynamic topography



Seasonal cycle across-shelf flow and stratification



Seasonal along-shelf velocity (m/s) in ROMS TSVH, averaged along iso-baths over the MAB region away from the Gulf Stream.



Seasonal cross-shelf circulation in ROMS TSVH, averaged along iso-baths over MAB (top row) region away from the Gulf Stream.

Computing MDT to combine with coastal altimetry in a real-time coastal ocean forecast system

- 4D-Var with boundary sea level and velocity in control variables
- Data: Regional hydrographic climatology of temperature and salinity; surface current from HF-Radar; mean of monthly shipboard ADCP currents (the *Oleander Line*) and Line W; ~40 moored current-meter deployments (> 200 days)
- Annual mean and seasonal mean analyses (seasonal analyses included Jason SLA in the assimilated data)
- Best estimate MDT derived from mean of monthly analyses
- MDT recovers along-shelf mean slope absent from boundary conditions adopted from a global data assimilative model.
- Forecast model improves using new MDT in altimetry DA, and freely running simulations improve with MDT in open boundary conditions