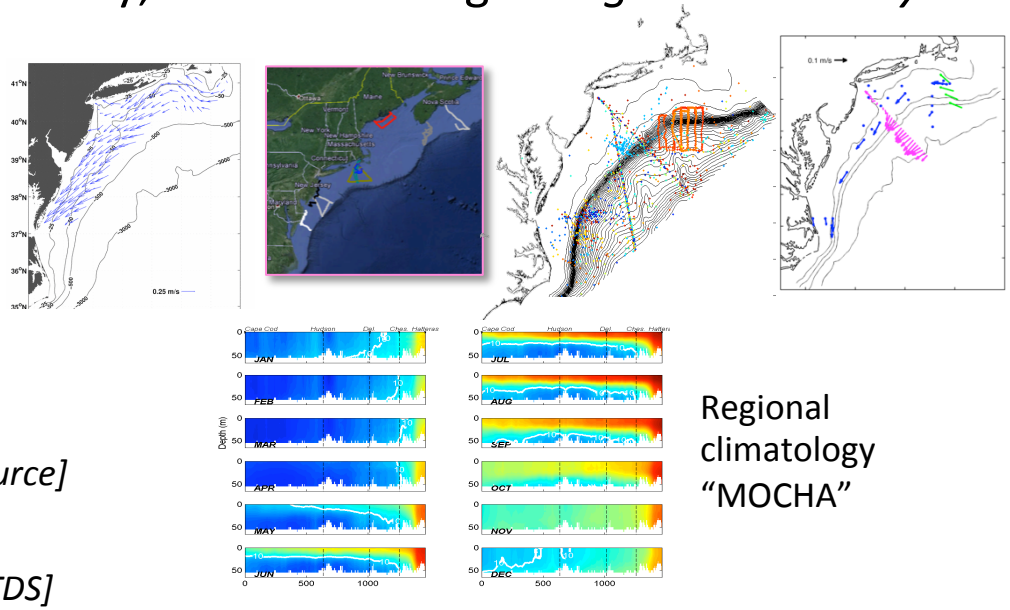
DATA ASSIMILATIVE REANALYSIS OF THE U.S. MID ATLANTIC BIGHT SHELF

John Wilkin, Julia Levin, Javier Zavala-Garay, Naomi Fleming: *Rutgers University*

Experimental System for Predicting Shelf-Slope Optics ***ESPreSSO:***

- MAB shelf/slope with ROMS 4D-Var
- Use all available data from a modern Coastal Ocean Observing System



Regional climatology "MOCHA"

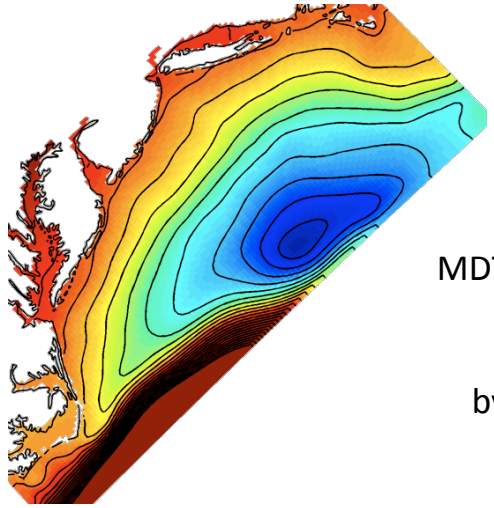
<u>Assimilation data sets:</u> *[real-time source]*

Regional CODAR hourly: 4-hr delay *[RU TDS]*
MARACOOS.org glider T,S (1-hr delay) *[RU TDS]*
AVHRR IR passes 6-8/day (2-hr delay) *[HRPT]*
REMSS MW+IR daily SST *[NASA PODAAC]*
Jason-2, CryoSat, AltiKa OGDR *[RADS.nl]*
GTS XBT/CTD, Argo floats *[OSMC NOAA ERDDAP]*

<u>Model surface and boundary forcing:</u>

72-hour forecast NAM 0Z *[NCEP NOMADS]*
USGS daily average flow *[waterdata.USGS.gov]*
HYCOM NCODA 7-day forecast daily *[NRL ftp]*

4DVAR seasonal and annual mean



MDT and mean T,S for bias correction by 4D-Var on mean data

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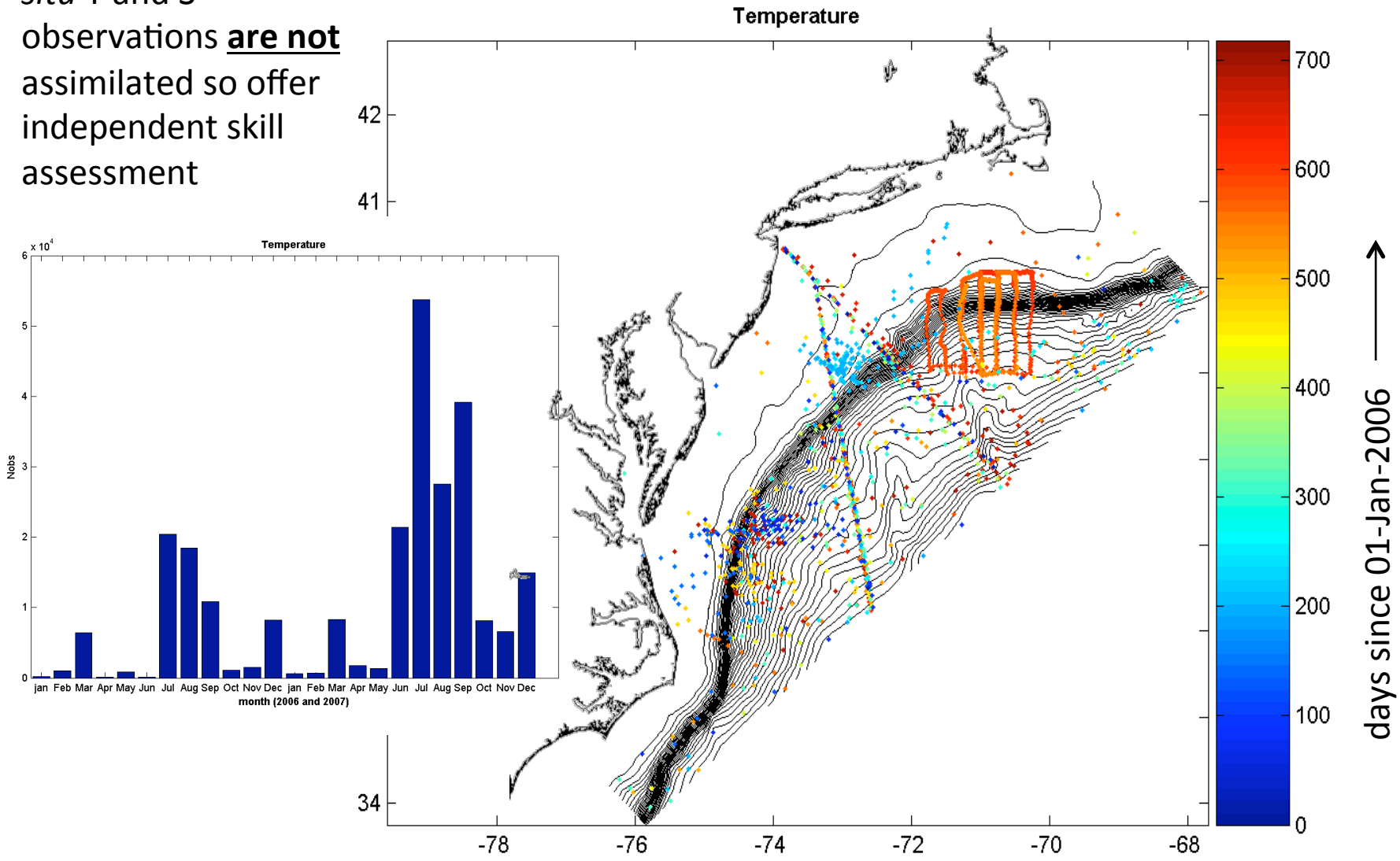
  - Satellite SSH and SST, HF-radar, gliders, Argo, GTS XBT/CTD
  - More and diverse data is better; Bias removal essential
- Useful skill for real-time forecast applications
  - 4 days for temperature and salinity; 1-2 days for velocity
- Reanalysis output of full model solution on THREDDS: 3 versions …
  - Satellite data only
  - Satellites plus CODAR and in situ CTD
  - Sat/ CODAR/in situ plus Craig and Banner wave breaking parameterization

- IODA development path for IODA
  - 2-way nesting for enhanced resolution of internal tide generation and propagation
  - Nested 4DVAR assimilation: (1) downscaling increments in “parent” grid to “child” grid background trajectory, then (2) independent 4DVAR in child

Sub-surface T/S analysis and forecast skill

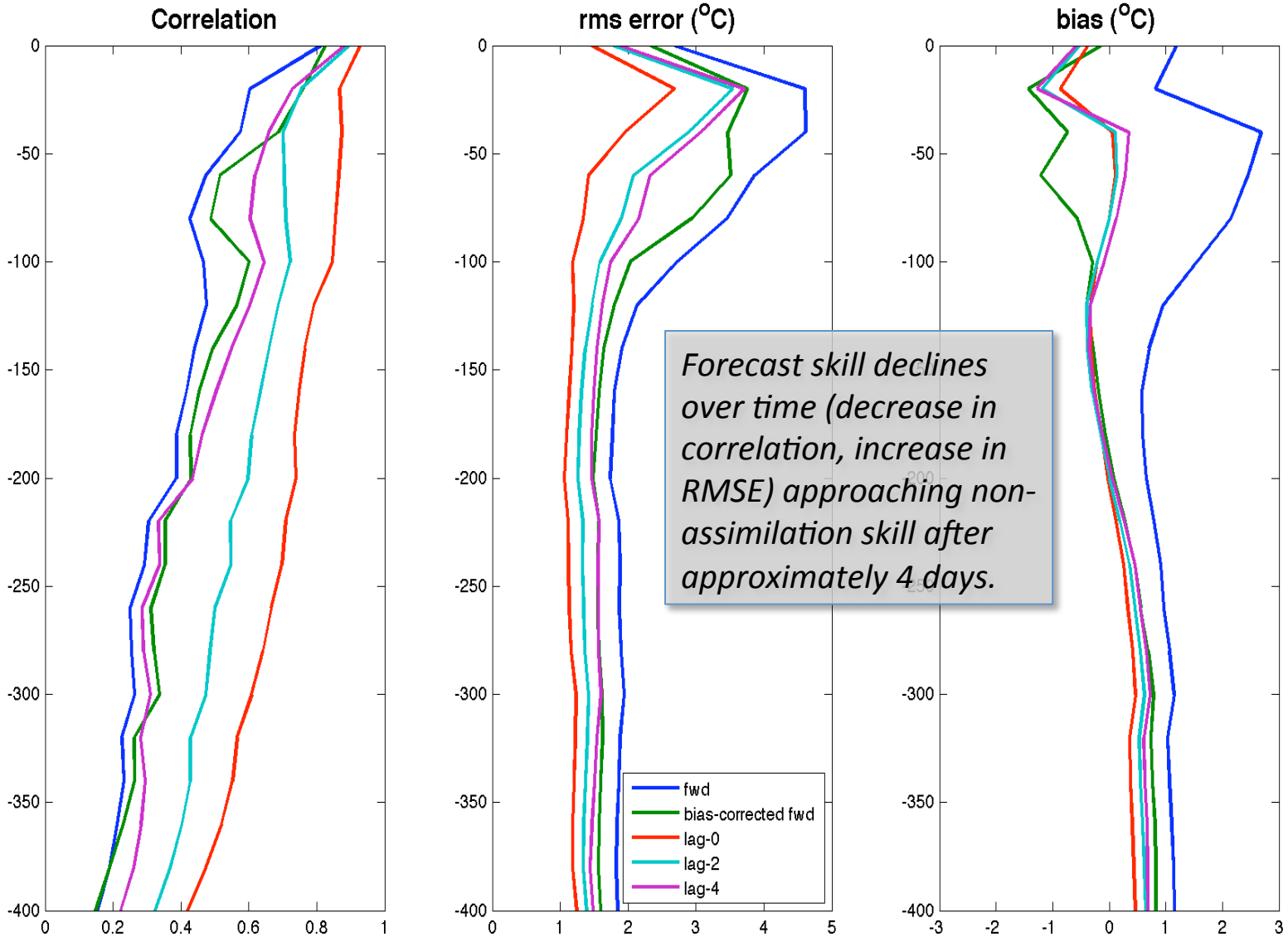
We conduct a skill assessment w.r.t. *in situ* T and S observations **<u>are not</u>** assimilated so offer independent skill assessment

There is a sizeable archive of observatory data from CTD, gliders and XBTs for 2006 (SW06) and 2007



Analysis/forecast skill with respect to subsurface OBS that are NOT assimilated

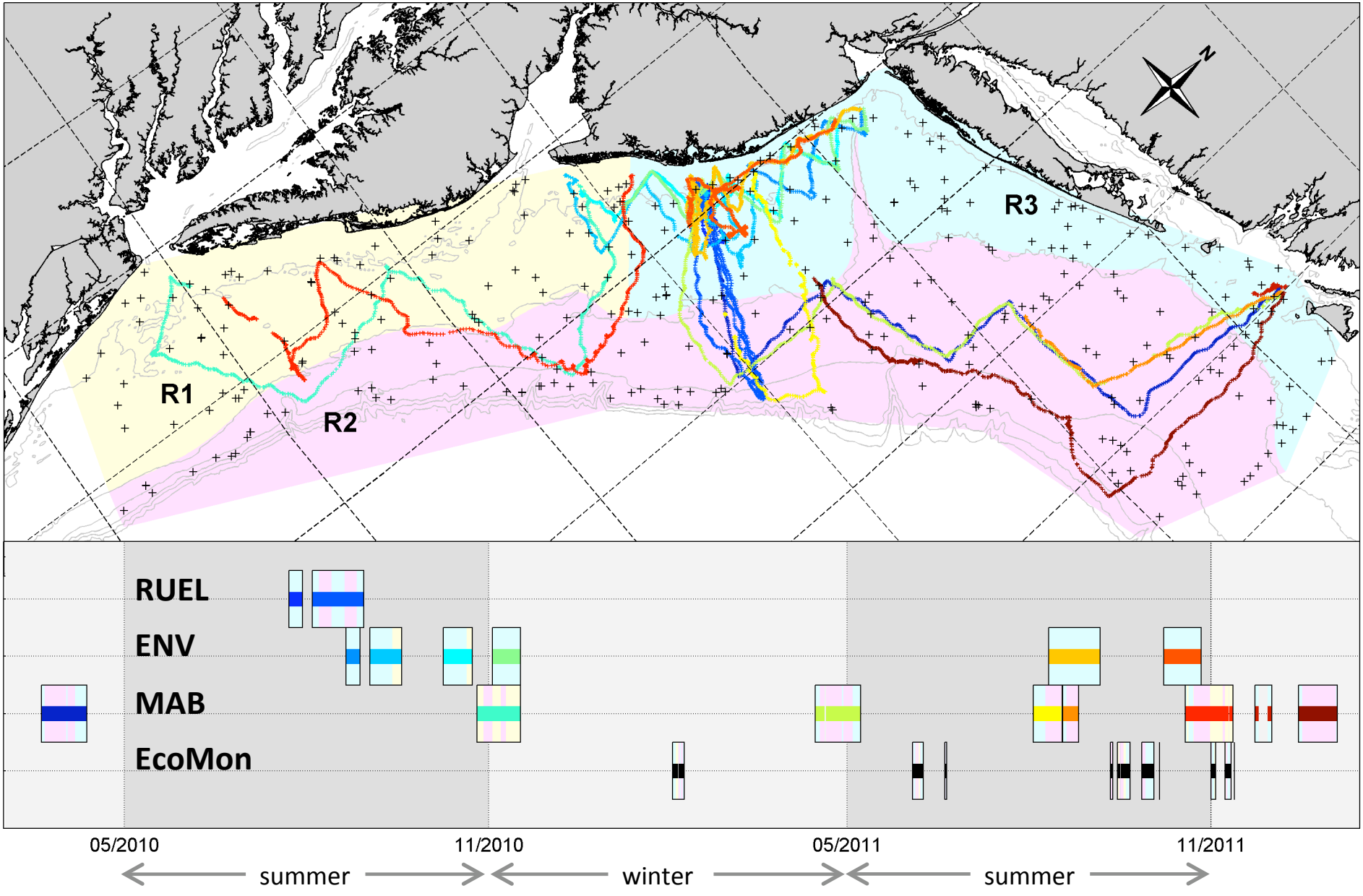
Temperature



Forecast skill declines over time (decrease in correlation, increase in RMSE) approaching non-assimilation skill after approximately 4 days.

MARACOOS glider data, and NMFS EcoMon surveys in 2010-2011

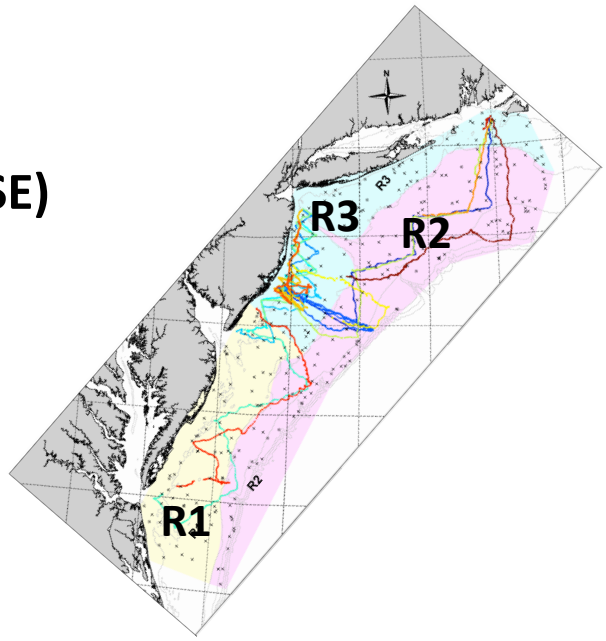
10 months of data in 2 years



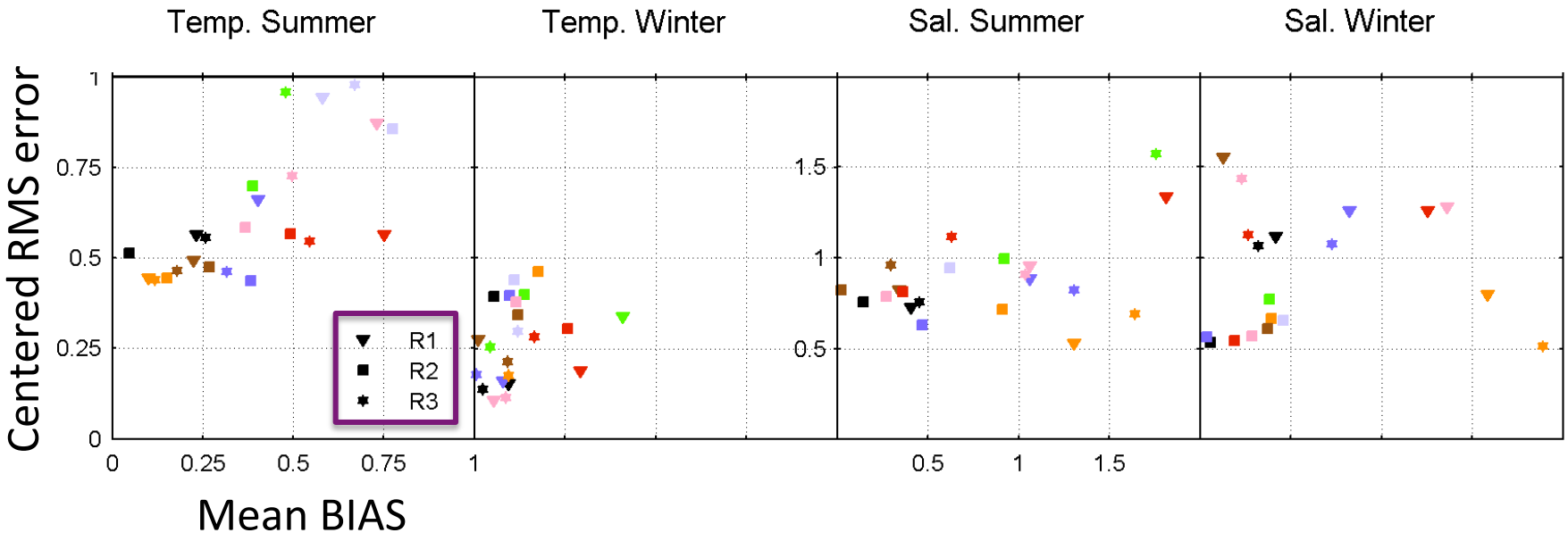
Skill assessment

Mean BIAS (x-axis) and Centered RMS error (y-axis)
Distance from origin is Root Mean Squared Error (RMSE)

Results by sub-region R1 – R3 not appreciably different



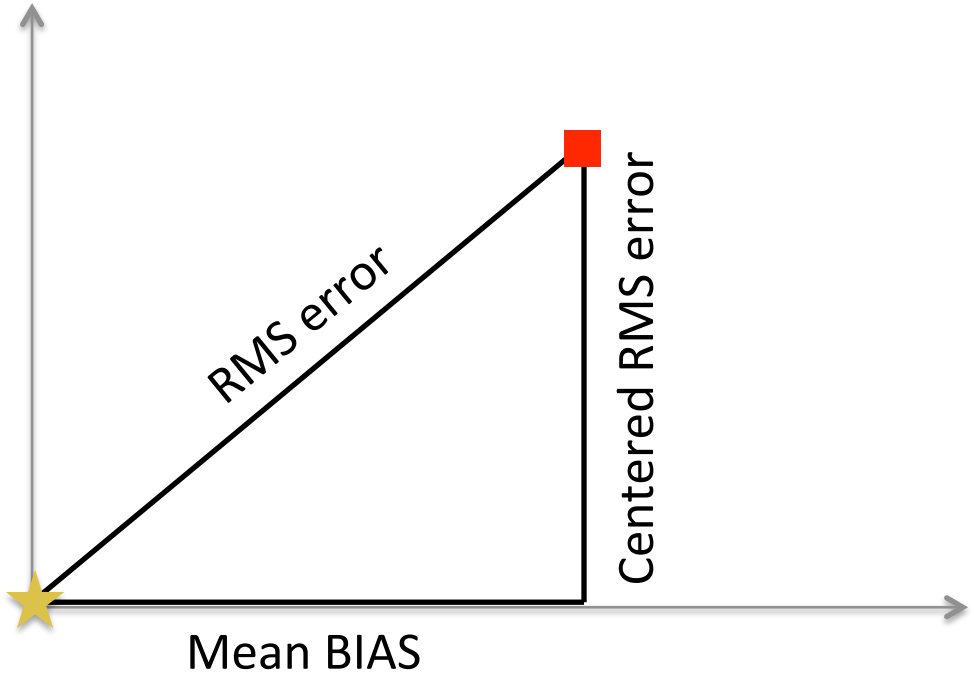
NYHOPS
COAWST
ESPRESSO
UMASSHOPS
NCOM_R1
HYCOM
MERCATOR
MOCHA



Skill assessment

Mean BIAS (x-axis) and Centered RMS error (y-axis)
Distance from origin is Root Mean Squared Error (RMSE)

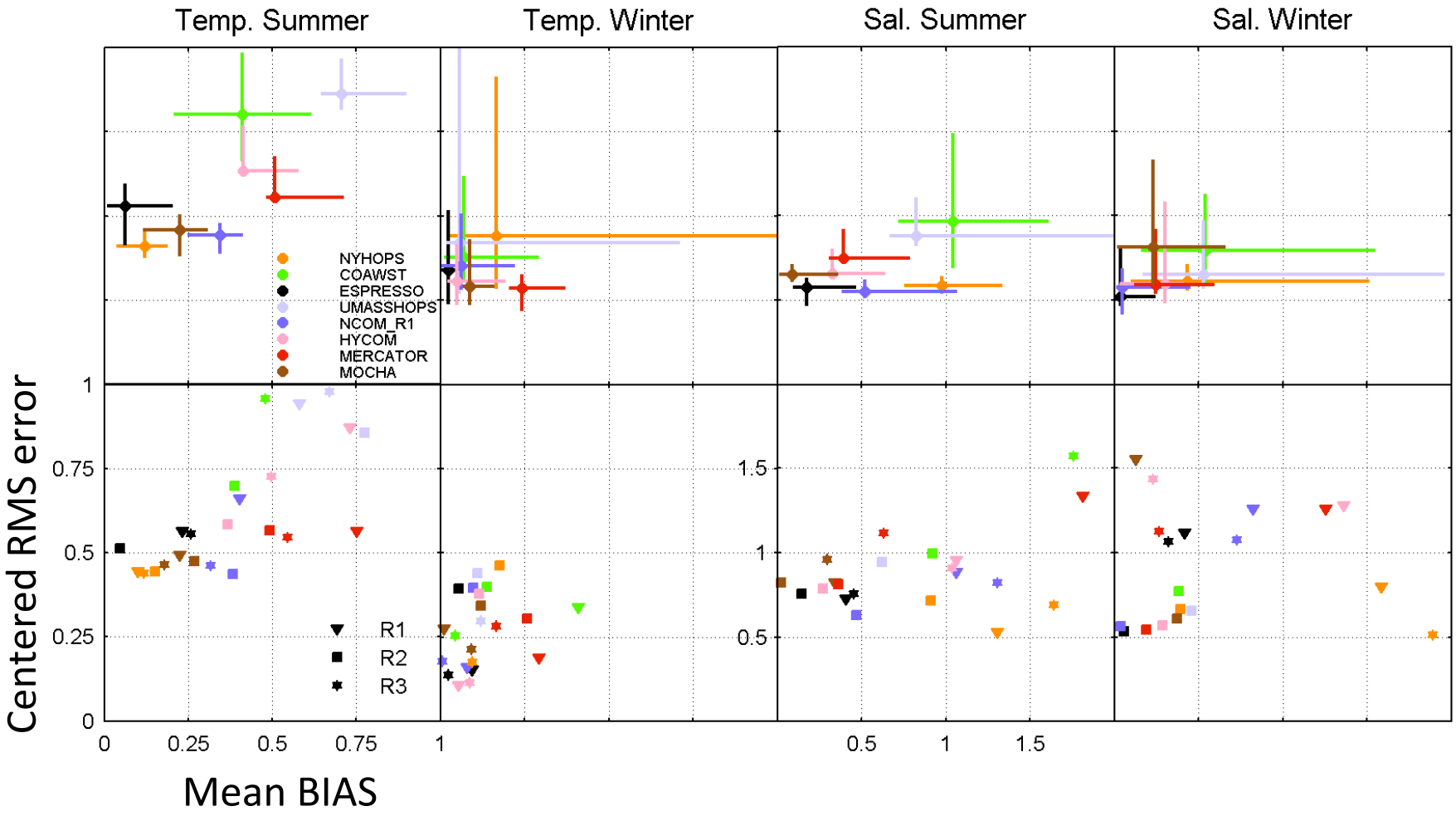
This is one quadrant of a "target" diagram



Skill assessment

Ensemble Mean BIAS (x-axis) and Centered RMS error (y-axis)

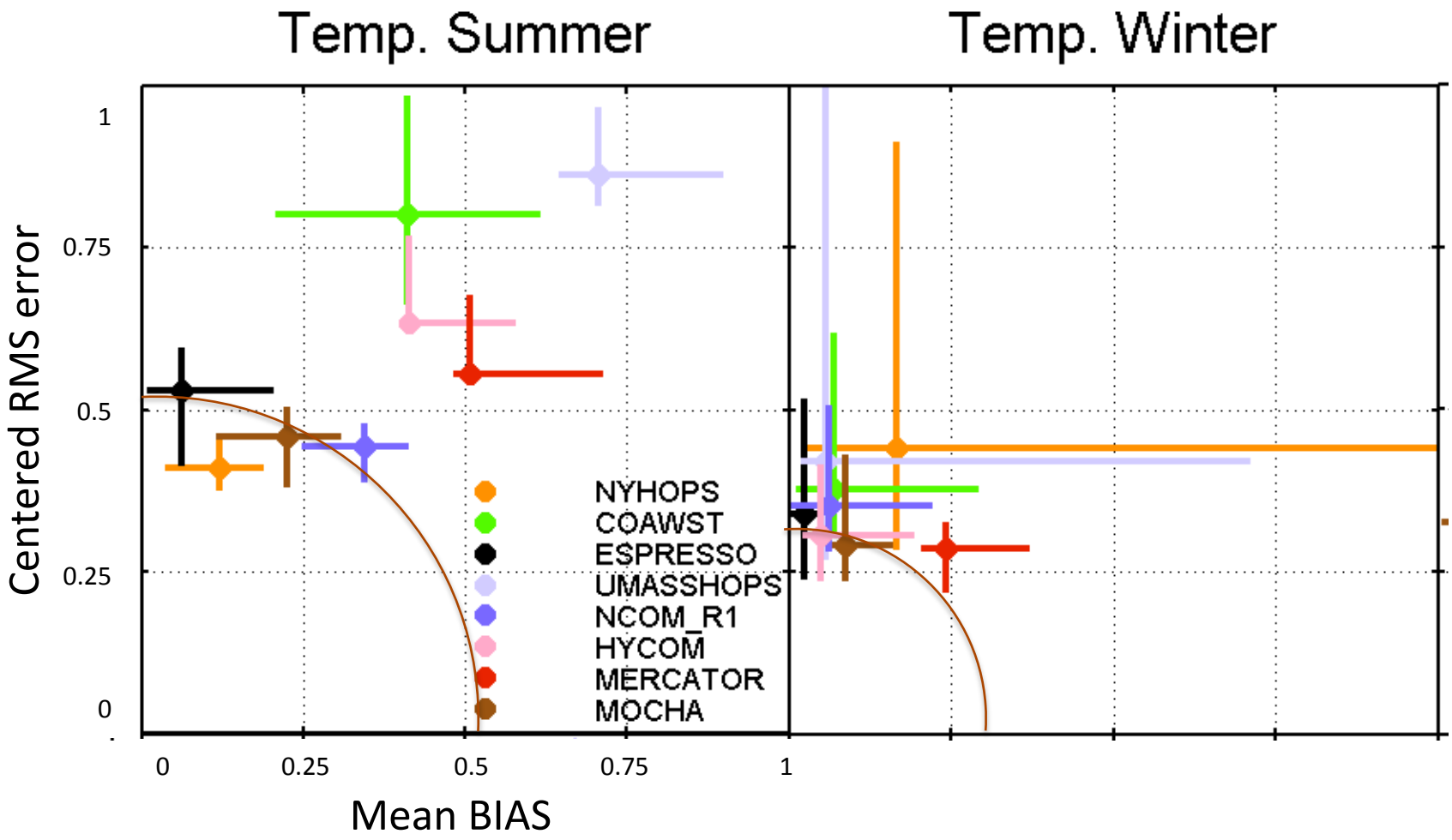
Distance from origin is Root Mean Squared Error (RMSE)

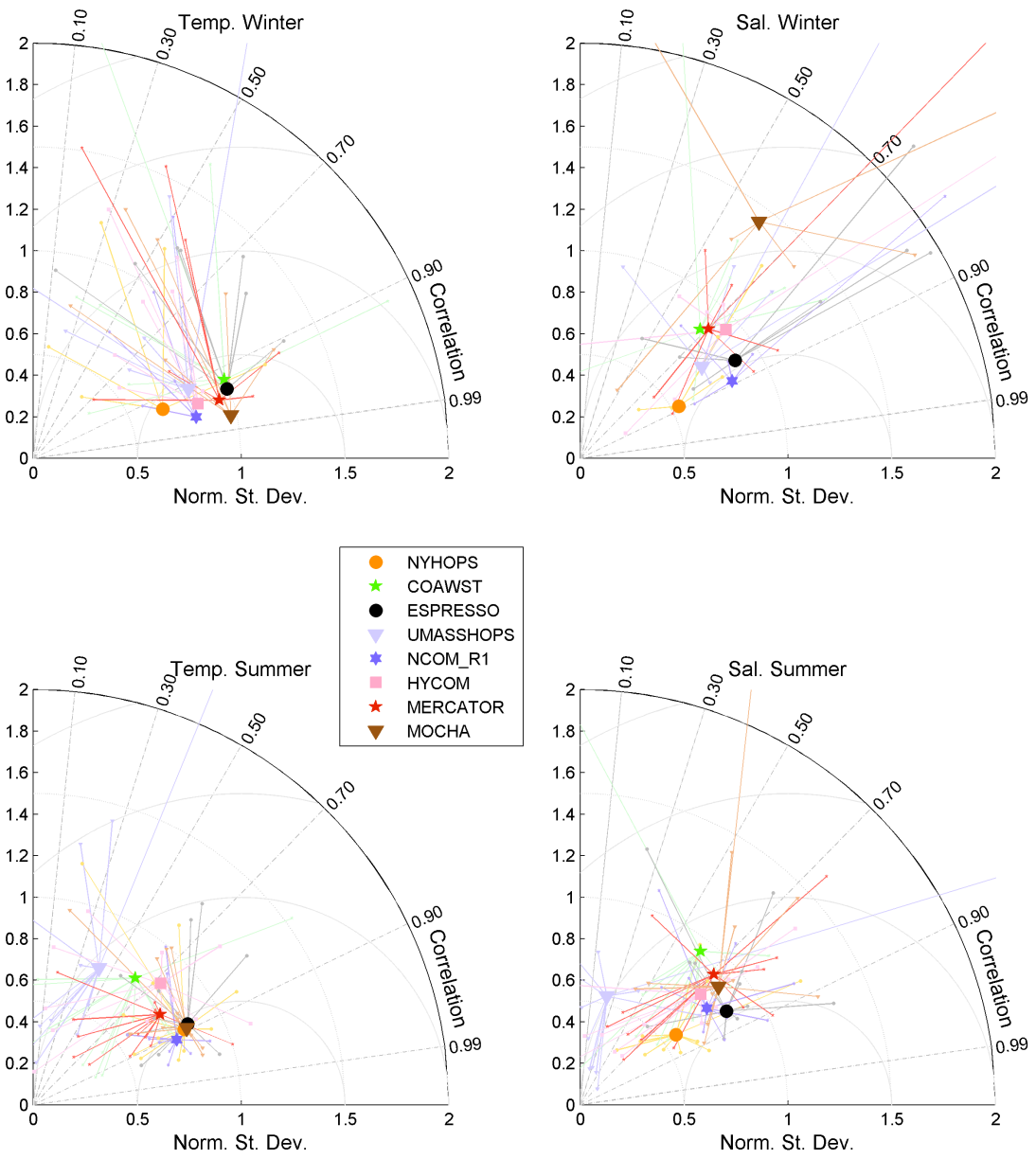


Skill assessment

Ensemble Mean BIAS (x-axis) and Centered RMS error (y-axis)
Distance from origin is Root Mean Squared Error (RMSE)

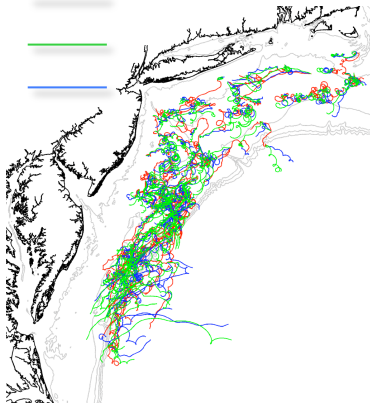
Error bars are 95% conf.



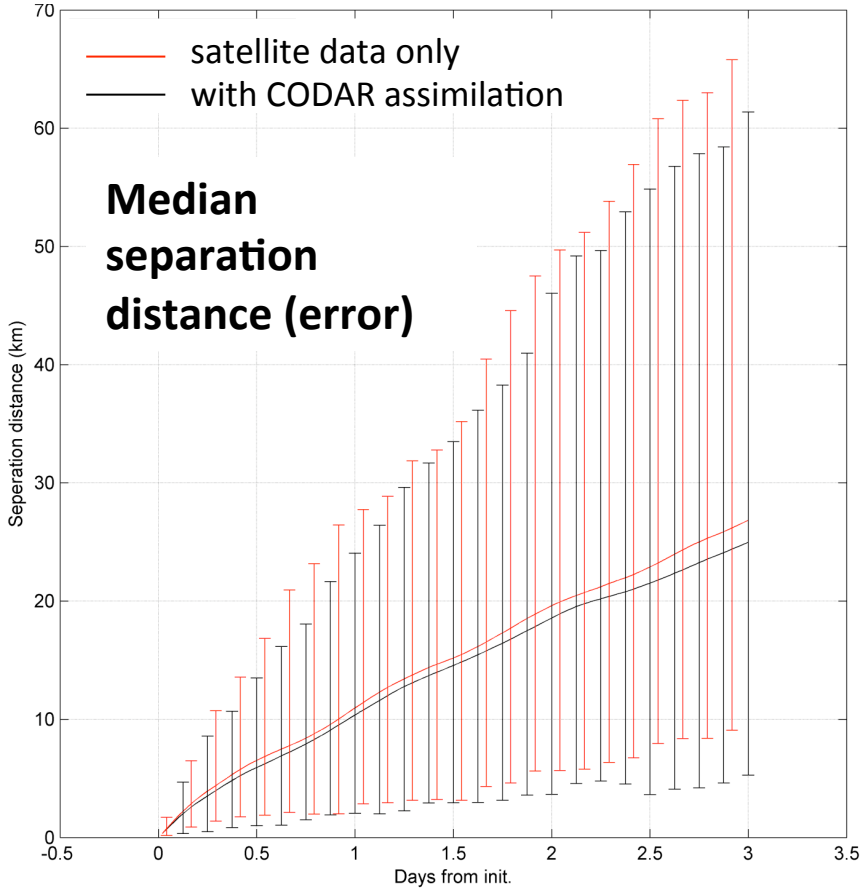

Temp. Winter
Sal. Winter
Temp. Summer
Sal. Summer
Norm. St. Dev.
Correlation
0.10
0.30
0.50
0.70
0.90
0.99
NYHOPS
COAWST
ESPRESSO
UMASSHOPS
NCOM_R1
HYCOM
MERCATOR
MOCHA

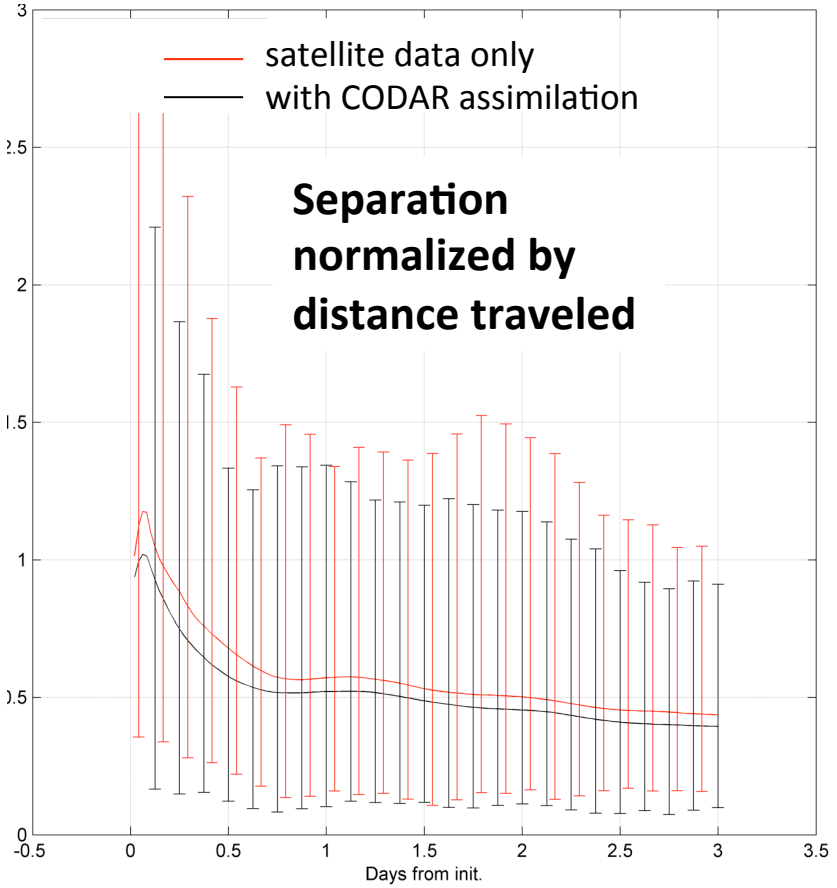
Lagrangian forecast skill w.r.t. U.S. Coast Guard (SLDMB) drifters

Observed
Forecast: with satellite data only
also with CODAR assimilation

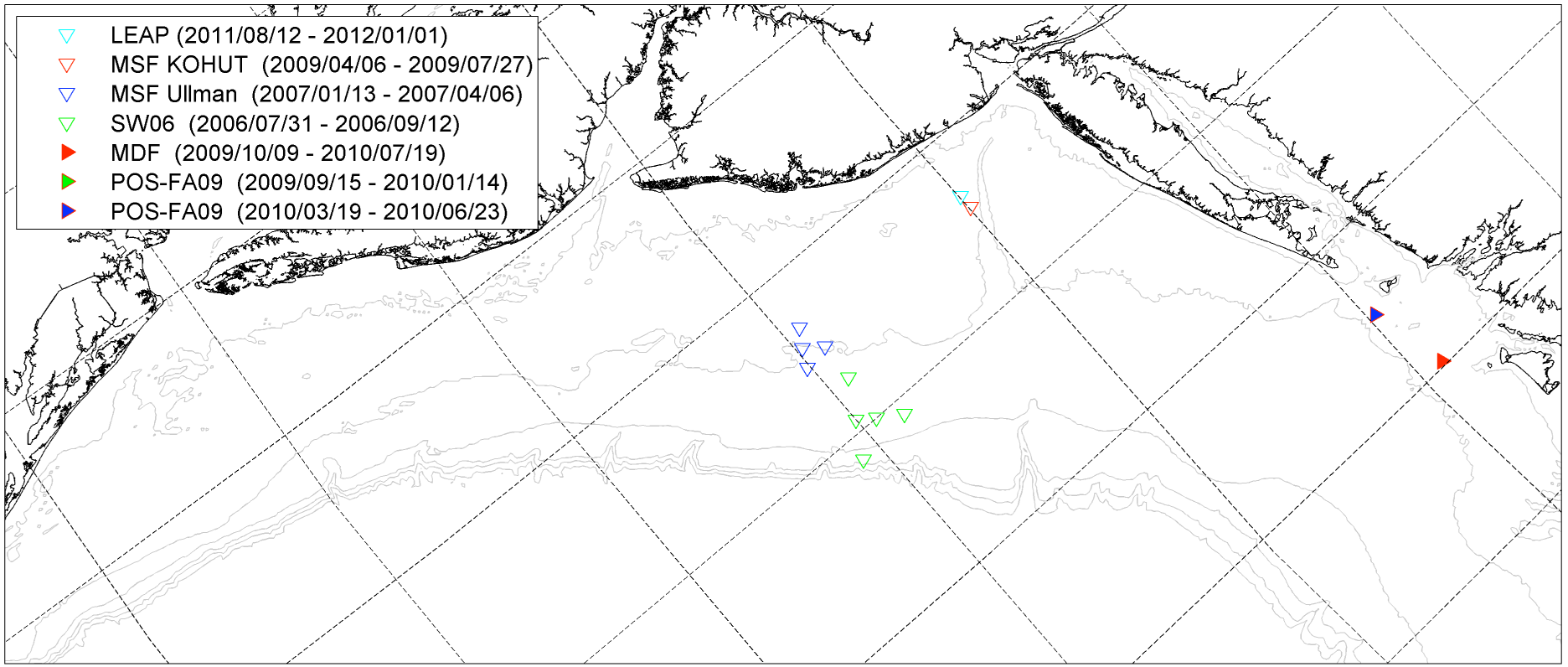


Addition of HF-radar (CODAR) to assimilation system gives modest error reduction, but more significant reduction in uncertainty (error bars are 5% and 95%)

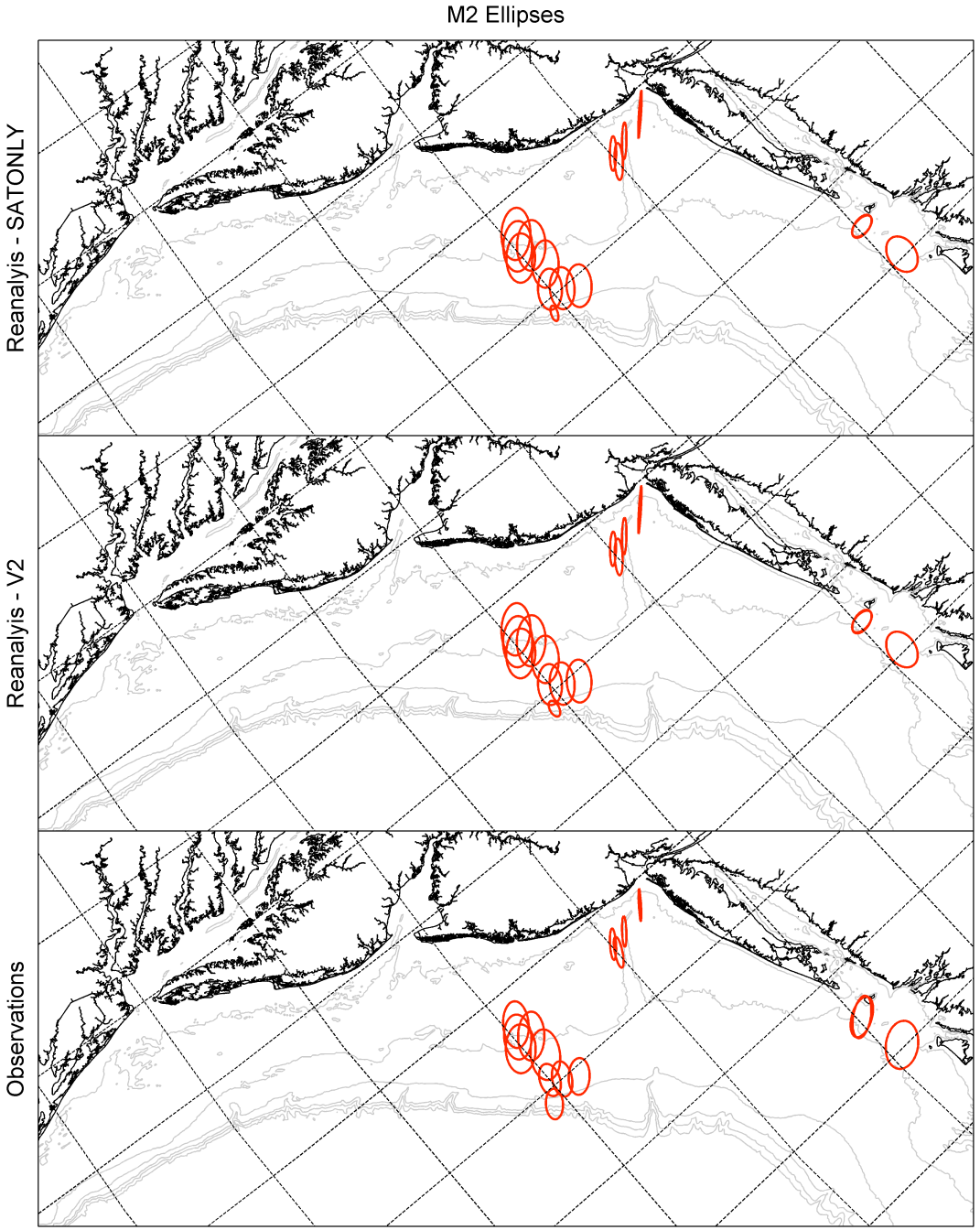




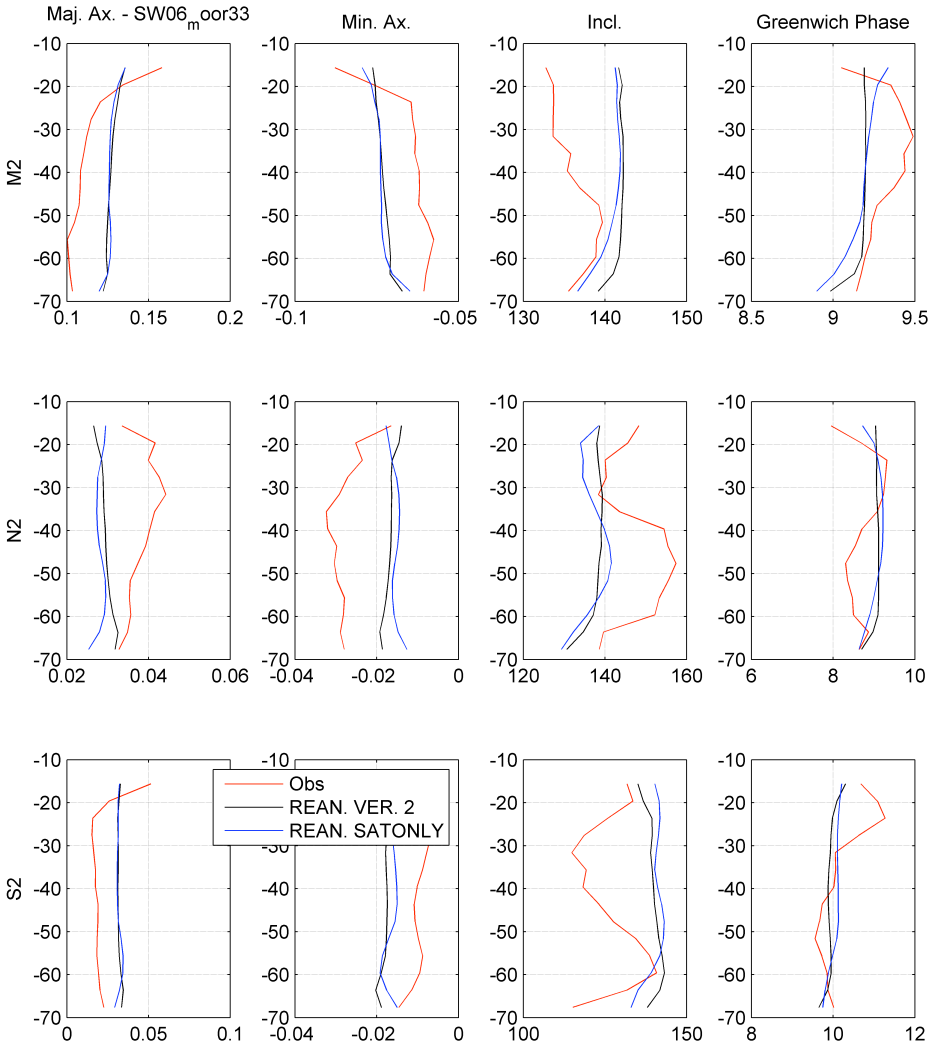
Subsurface velocity skill w.r.t.
long term current meter deployments



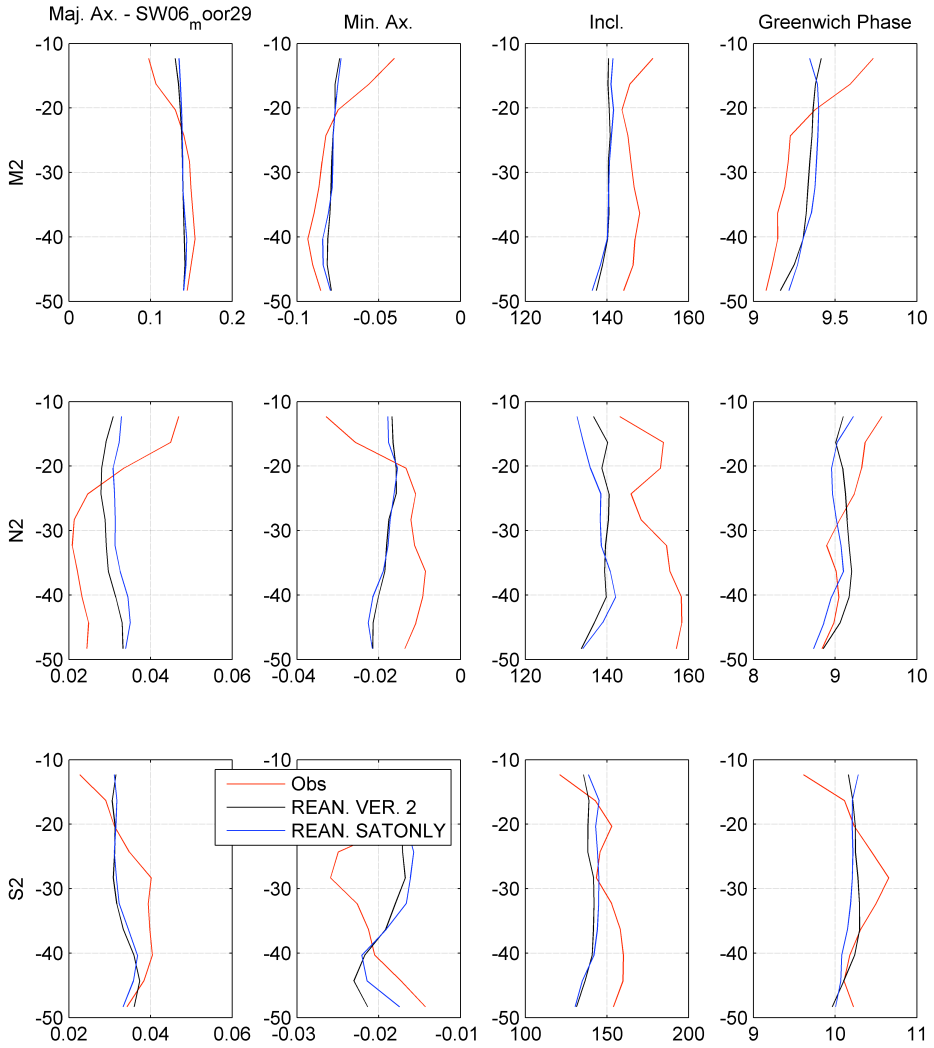
M_2 tidal ellipses



SW06 mooring 33

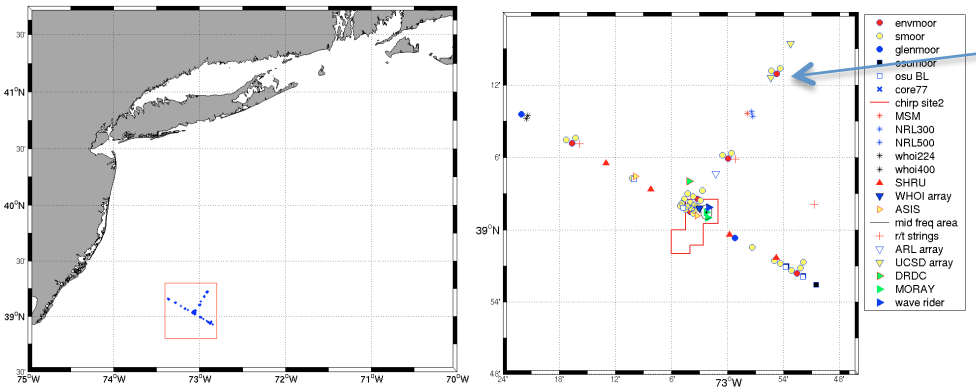


SW06 mooring 29



Sub-surface velocity analysis skill

Shallow Water 2006



SW06 mooring 32 N-S velocity skill scores

R (corr. coeff.)
BIAS (m s^{-1})
CRMS (m s^{-1})

Raw (hourly) **Lowpass (33-hr cutoff)**

SW06 mooring

ROMS model

SW06 Mooring

ESPRESSO

-20 -30 -40 -50 -60

08/01 08/11 08/21 08/31 08/01 08/11 08/21 08/31

0.6 0.4 0.2 0 -0.2 -0.4 -0.6

Raw

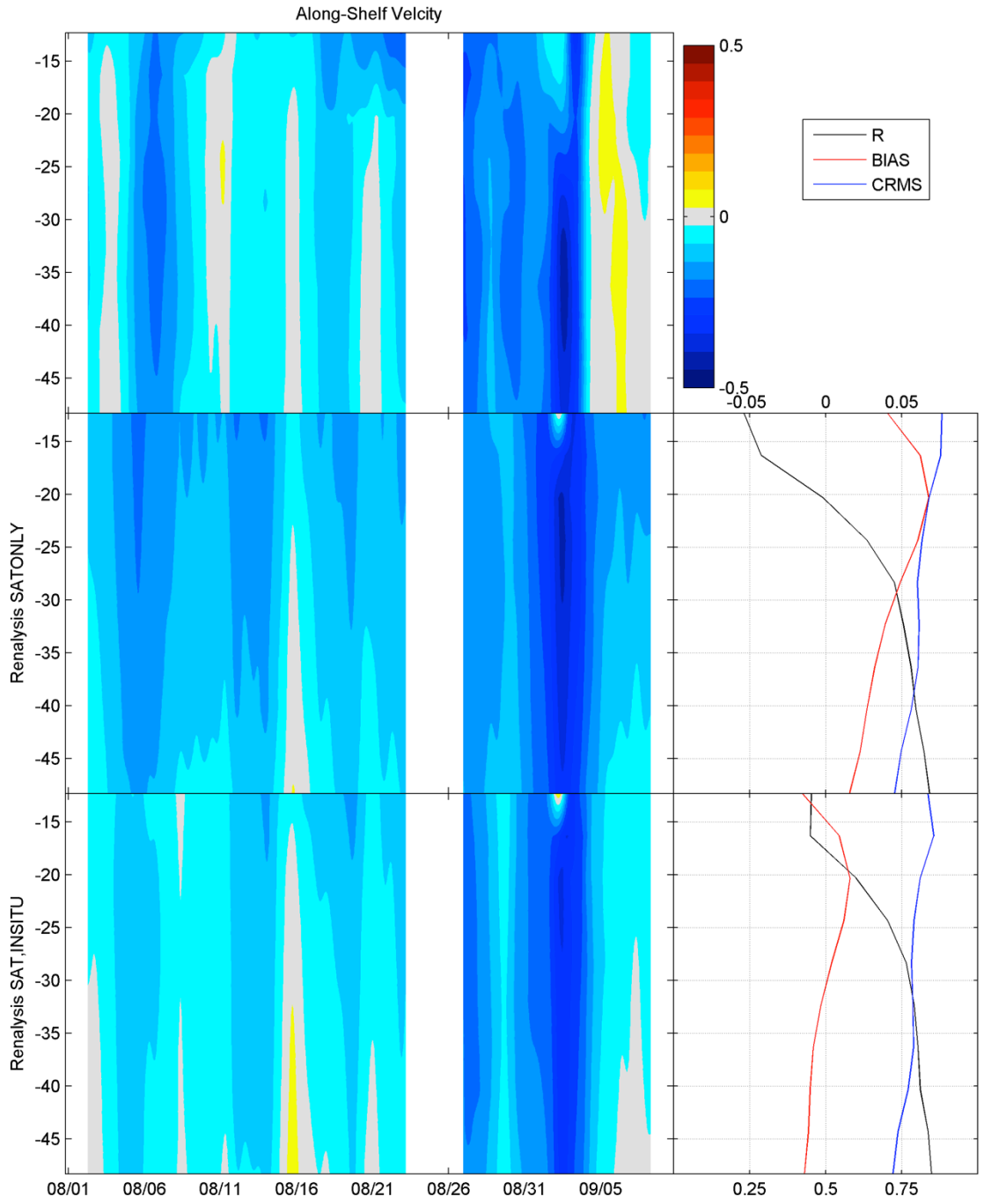
Lowpass

Raw

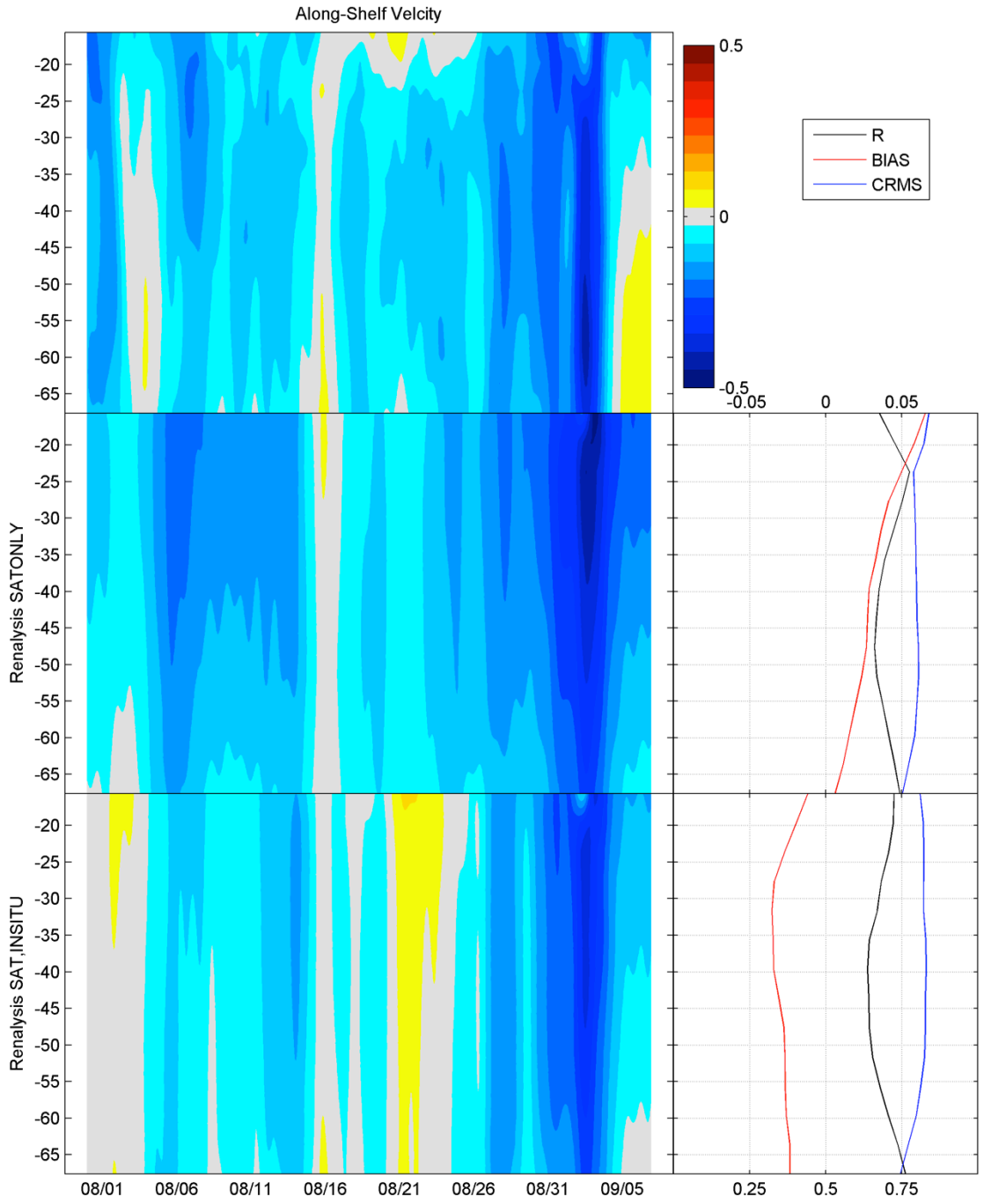
Lowpass

0 0.5 1

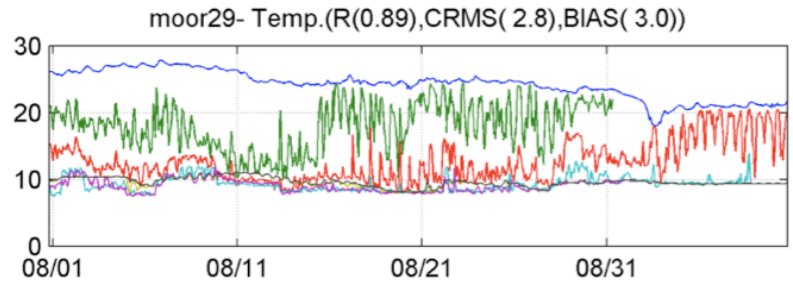
SW06 mooring 29

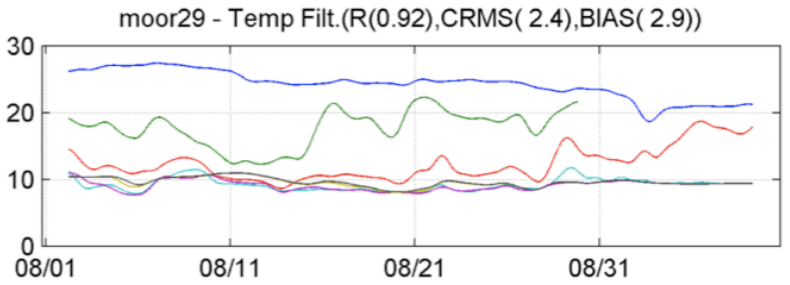


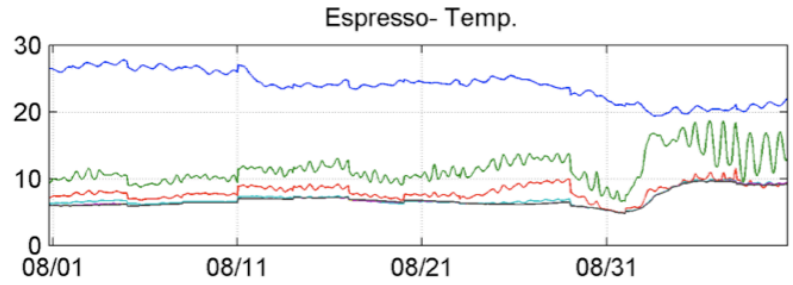
SW06 mooring 33

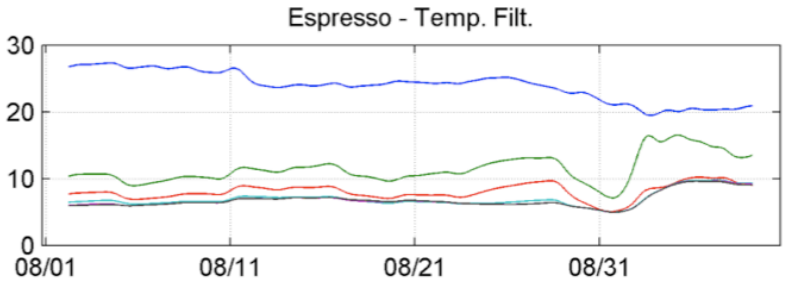


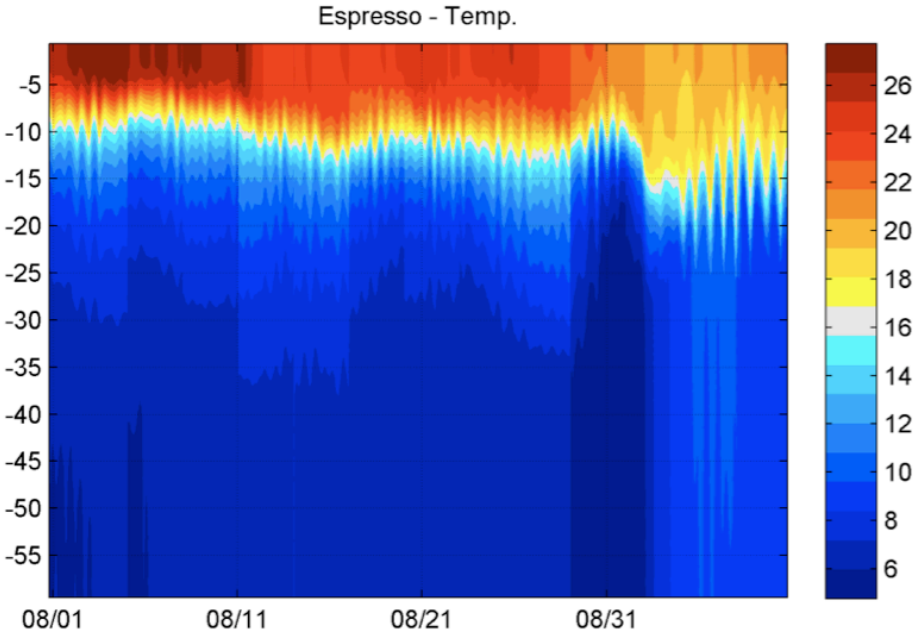
SW06 mooring 29

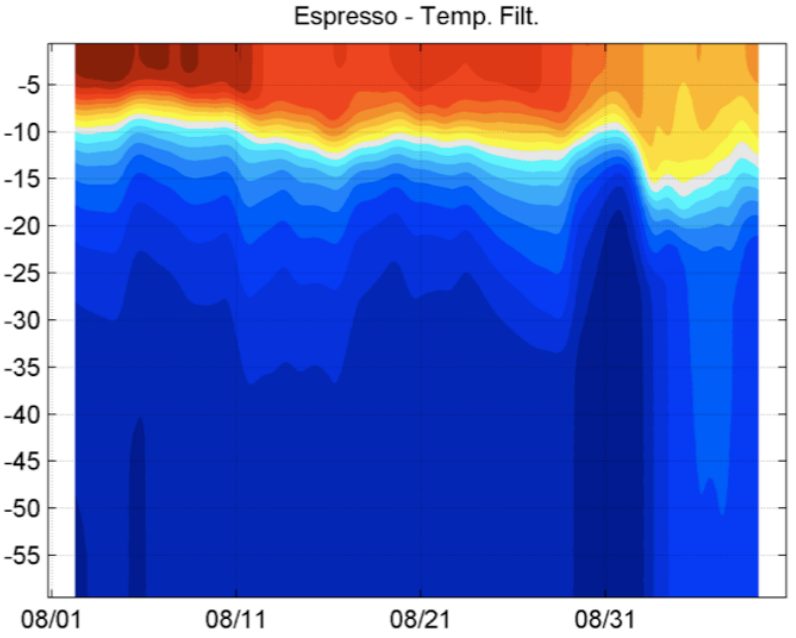












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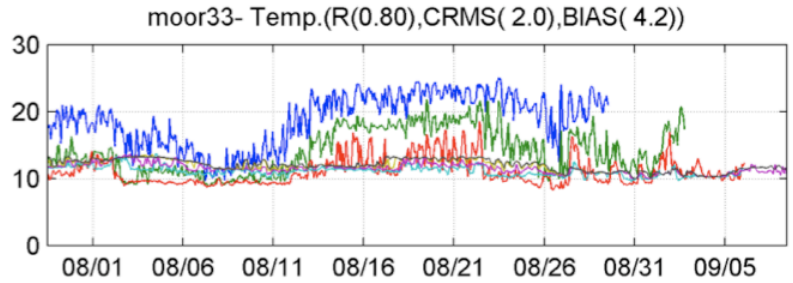

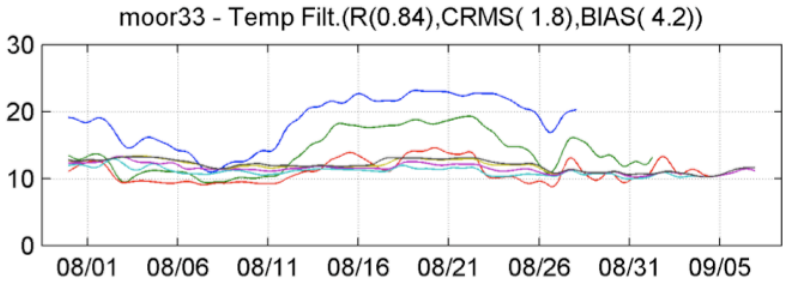

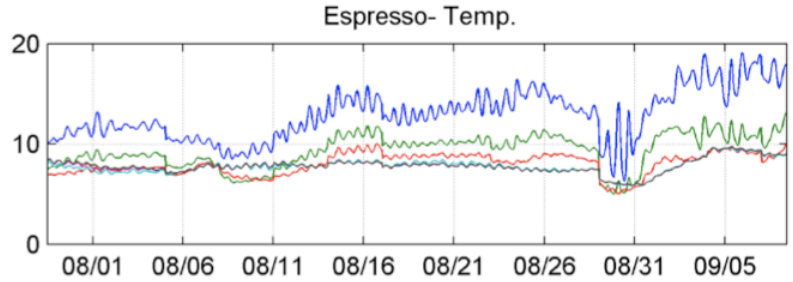

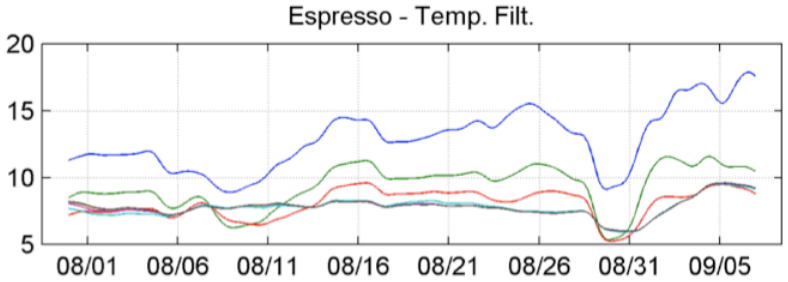

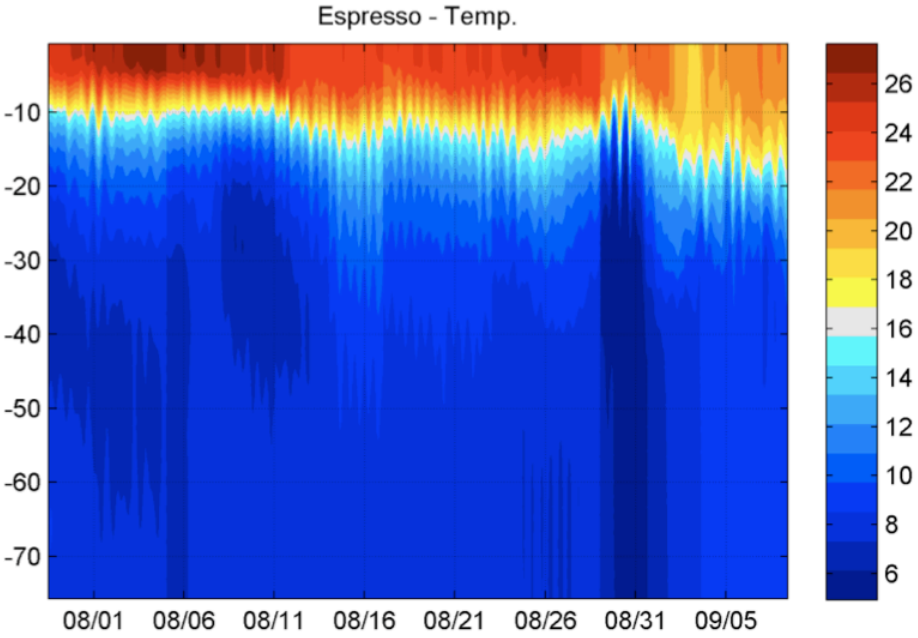

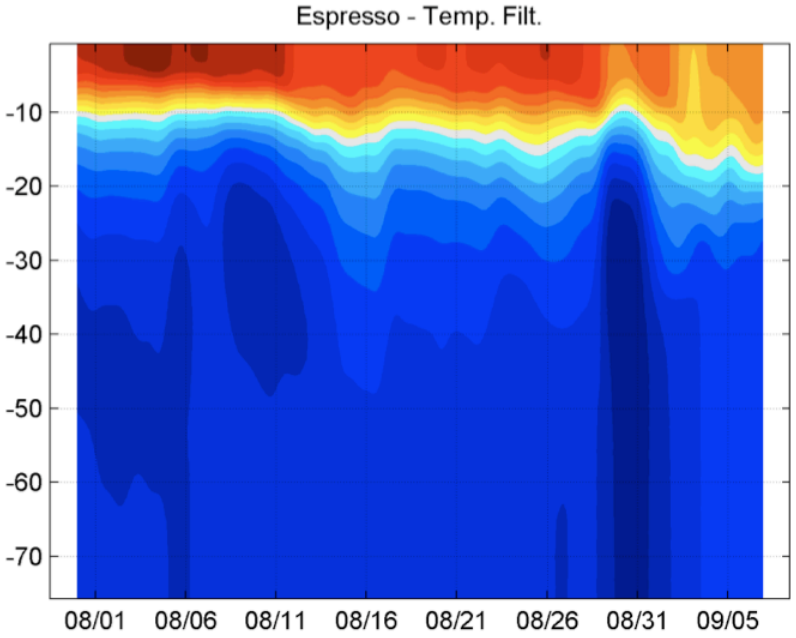

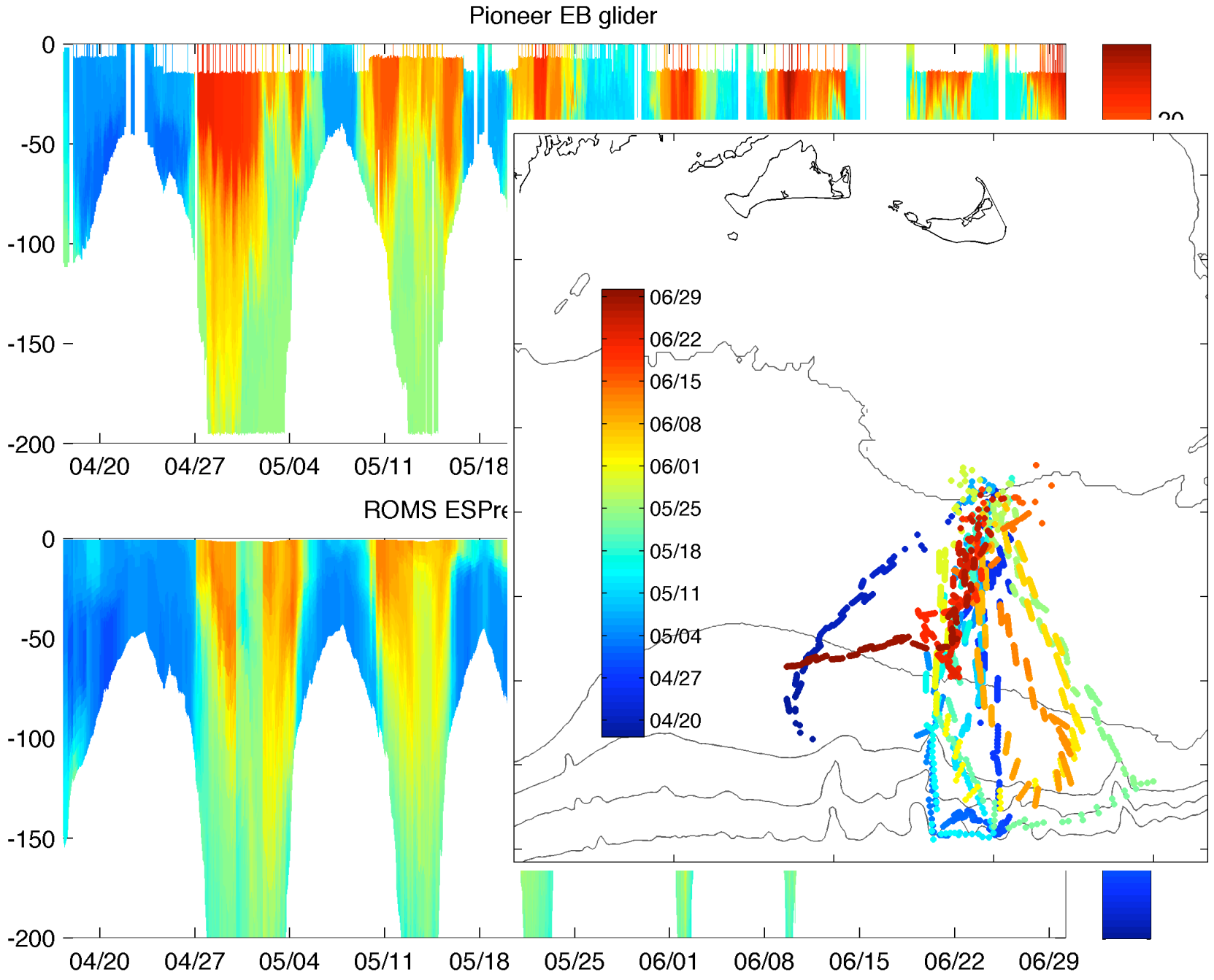
Pioneer EB glider
0
-50
-100
-150
-200
04/20
04/27
05/04
05/11
05/18
ROMS ESPre
0
-50
-100
-150
-200
04/20
04/27
05/04
05/11
05/18
05/25
06/01
06/08
06/15
06/22
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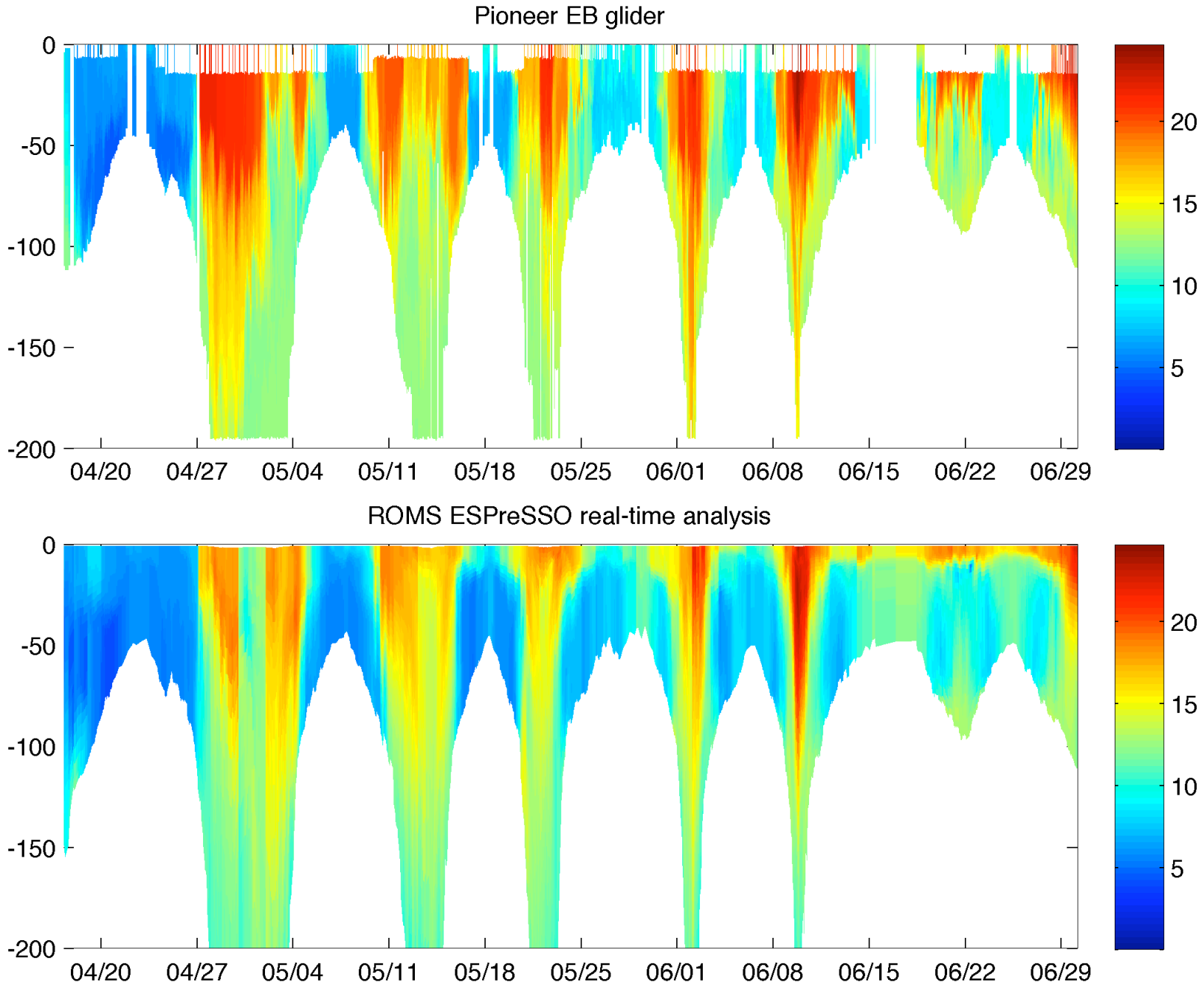
05/25
05/18
05/11
05/04
04/27
04/20


Pioneer EB glider
0
-50
-100
-150
-200
04/20
04/27
05/04
05/11
05/18
05/25
06/01
06/08
06/15
06/22
06/29
20
15
10
5
ROMS ESPreSSO real-time analysis
0
-50
-100
-150
-200
04/20
04/27
05/04
05/11
05/18
05/25
06/01
06/08
06/15
06/22
06/29
20
15
10
5

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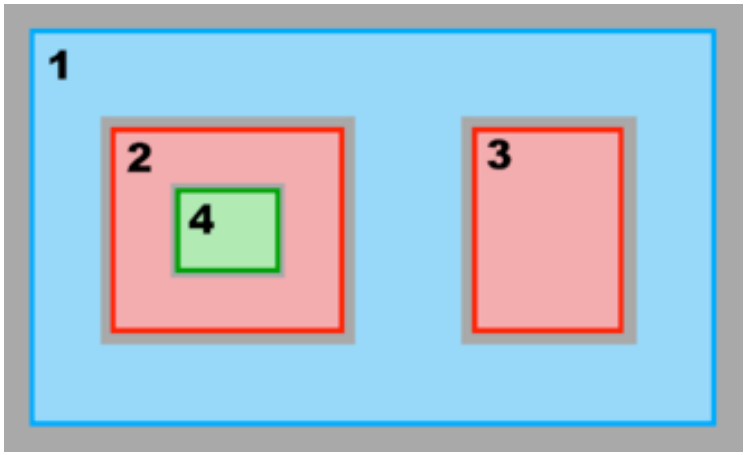
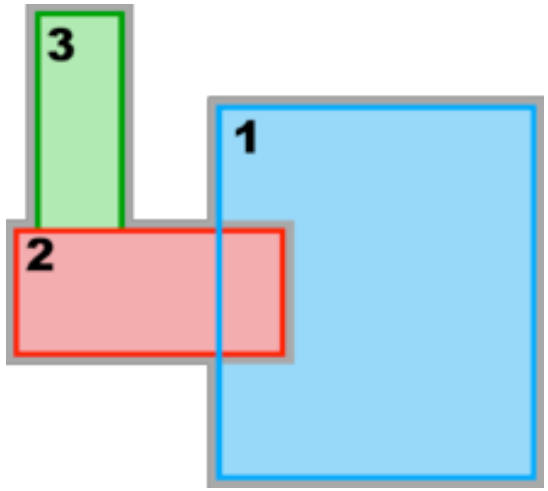
ROMS model development: nested and composite grids

IODA-related tests of “simple” refinement grids, allowing for multiple and multiple levels of nesting grids within and single application:



Multiple Refinement Sub-Class:
Ngrids = 4
NestLayers = 3
GridsInLayer = 1 2 1
Ncontact = 6

Composite/refinement: ROMS nesting software design allows for composite overlapped grids, including with refinement, to focus on bathymetric and/or coastal detail.

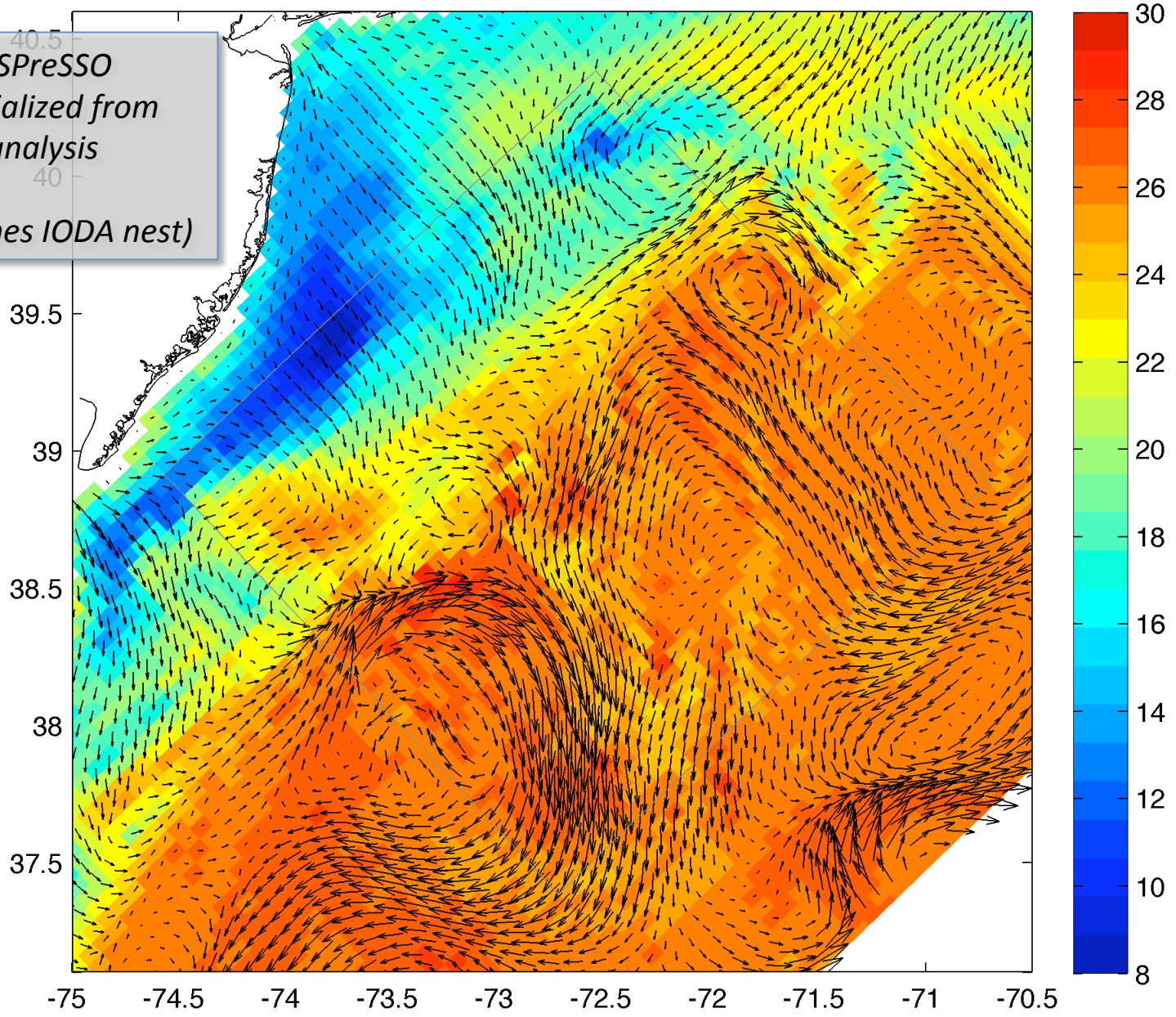


“Estuary” Refinement-Composite Sub-Class:
Ngrids = 3
NestLayers = 2
GridsInLayer = 1 2
Ncontact = 4

file: http://tds.marine.rutgers.edu:8080/thredds/dodsC/projects/wilkin/ioda/yojo/his_esp_nstd017_0050.nc
Temperature 19-Aug-2006 01:00:00 - Depth 10 m

Forward ESPreSSO model initialized from 4DVAR reanalysis

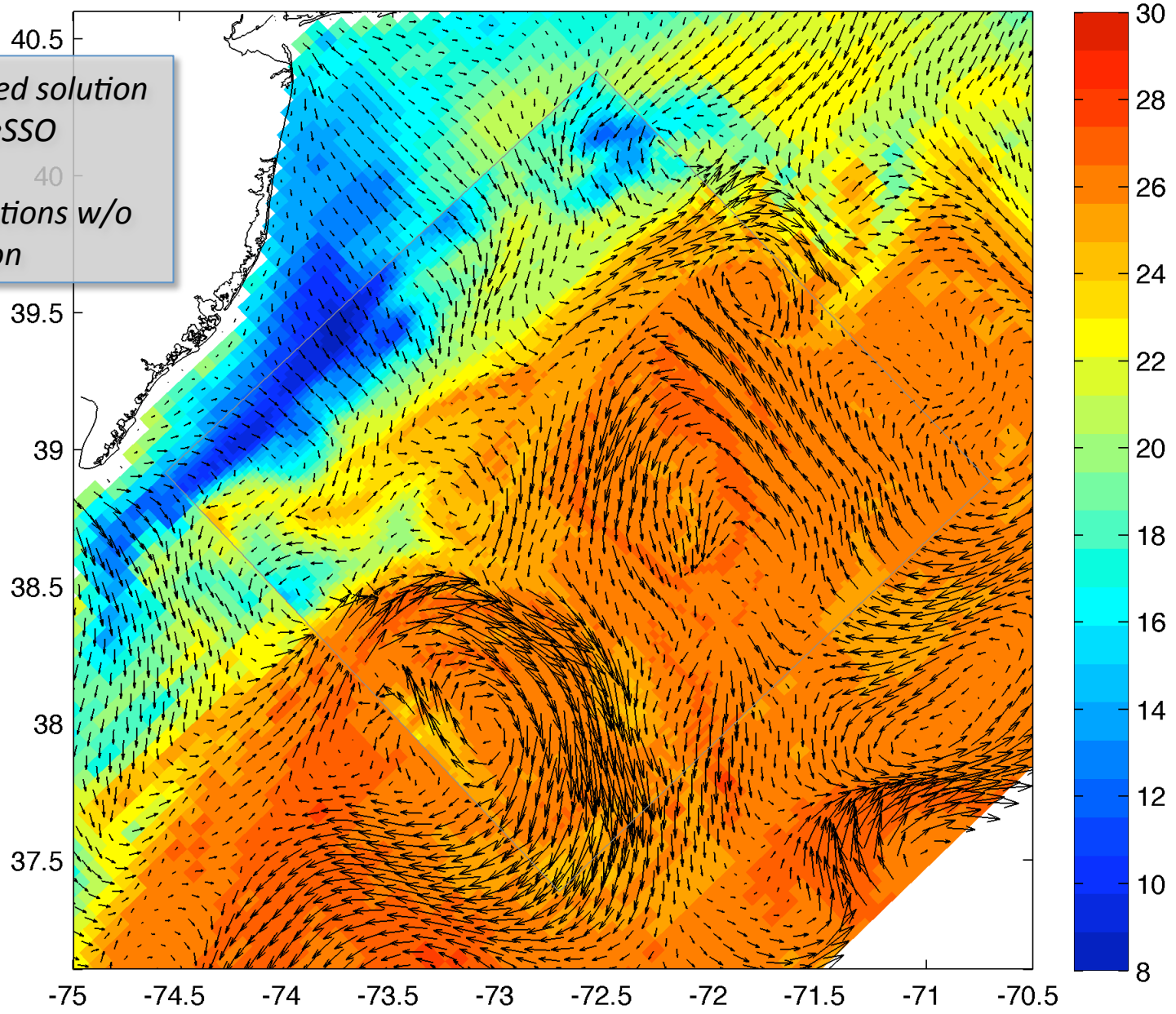
(Box outlines IODA nest)

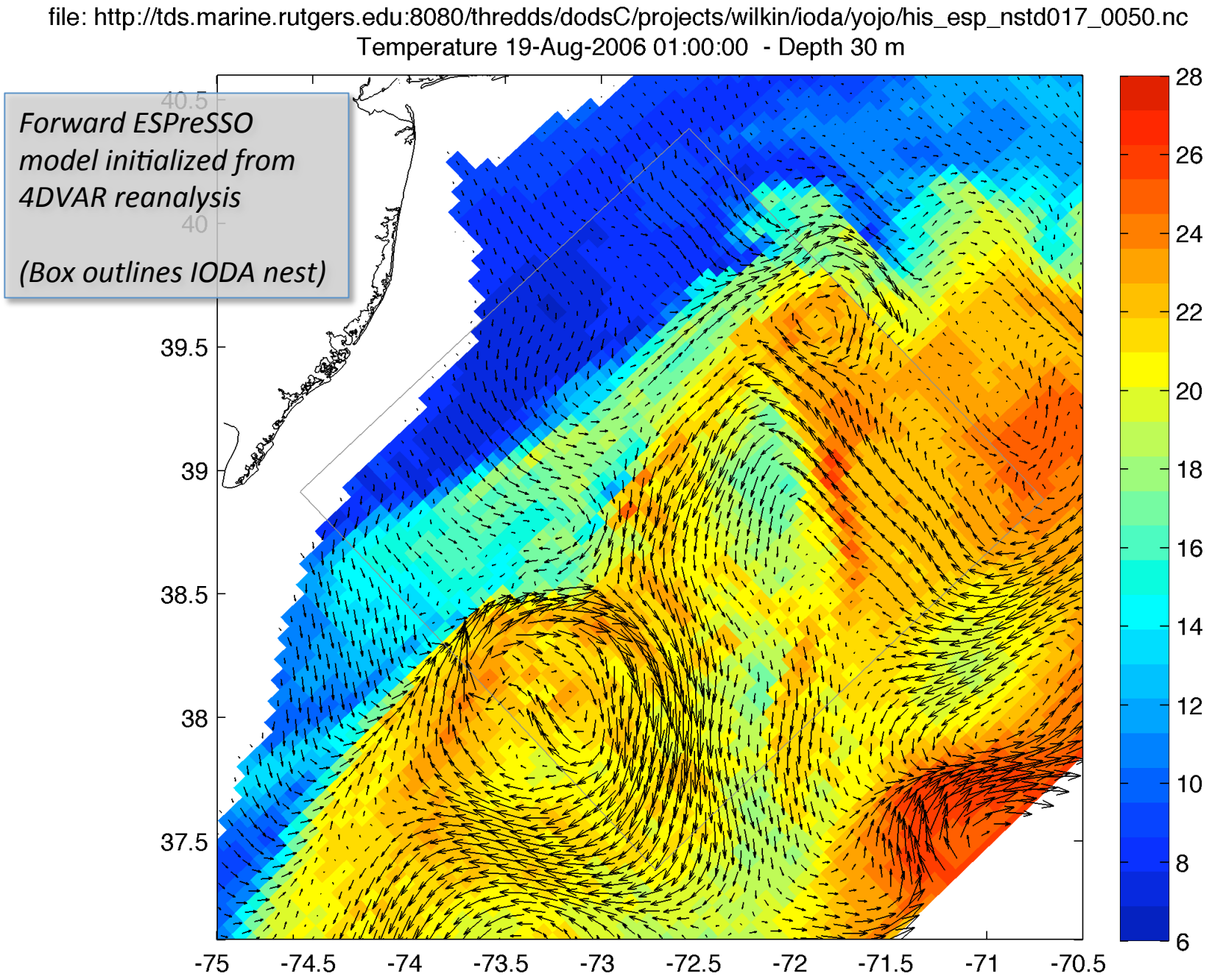


file: http://tds.marine.rutgers.edu:8080/thredds/dodsC/projects/wilkin/ioda/yojo/his_ioda_nstd017_0050.nc
Temperature 19-Aug-2006 01:00:00 - Depth 10 m

IODA nested solution over ESPreSSO

These solutions w/o assimilation

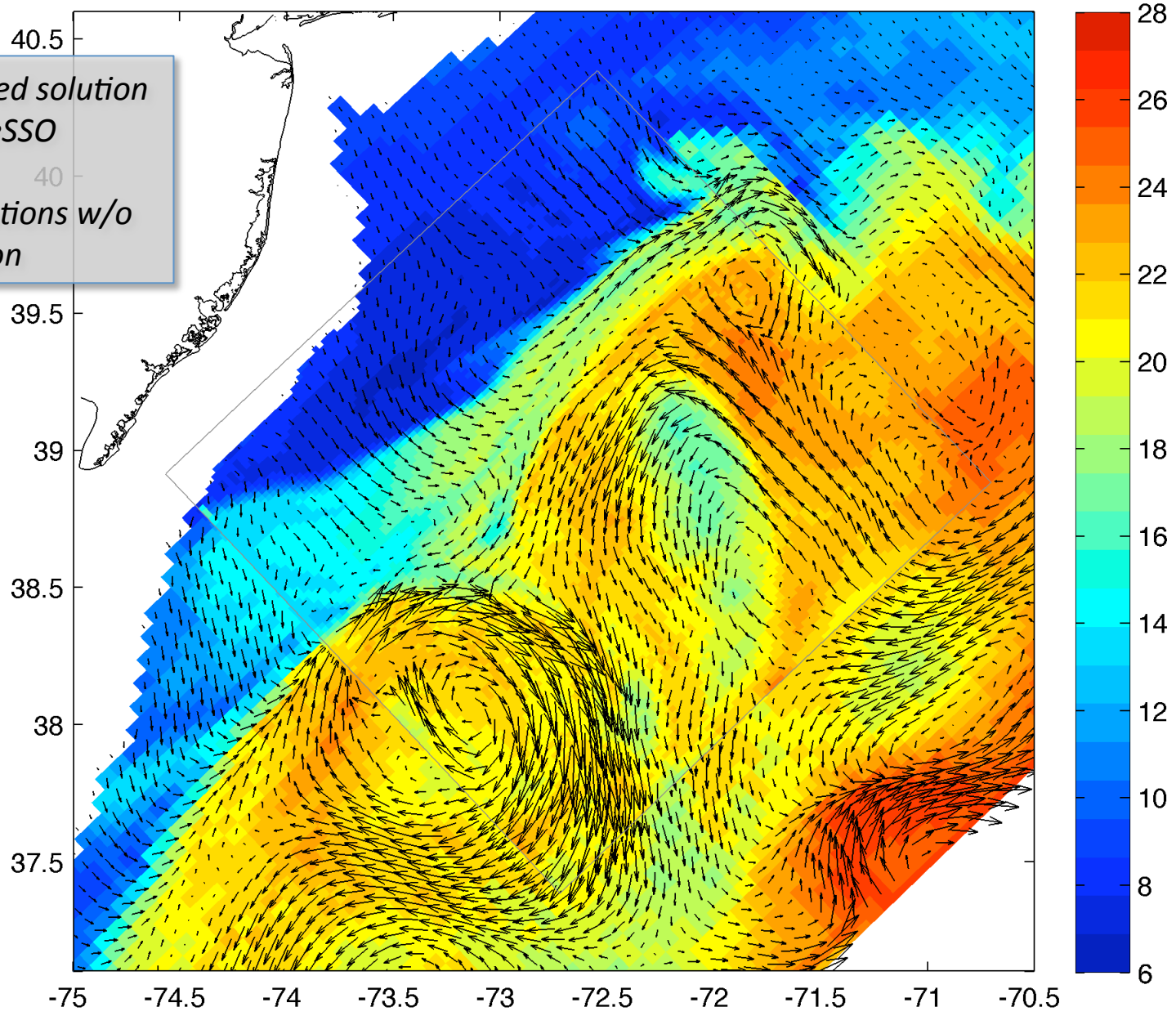



file: http://tds.marine.rutgers.edu:8080/thredds/dodsC/projects/wilkin/ioda/yojo/his_esp_nstd017_0050.nc
Temperature 19-Aug-2006 01:00:00 - Depth 30 m
Forward ESPreSSO model initialized from 4DVAR reanalysis
(Box outlines IODA nest)
40.5
40
39.5
39
38.5
38
37.5
-75
-74.5
-74
-73.5
-73
-72.5
-72
-71.5
-71
-70.5
28
26
24
22
20
18
16
14
12
10
8
6

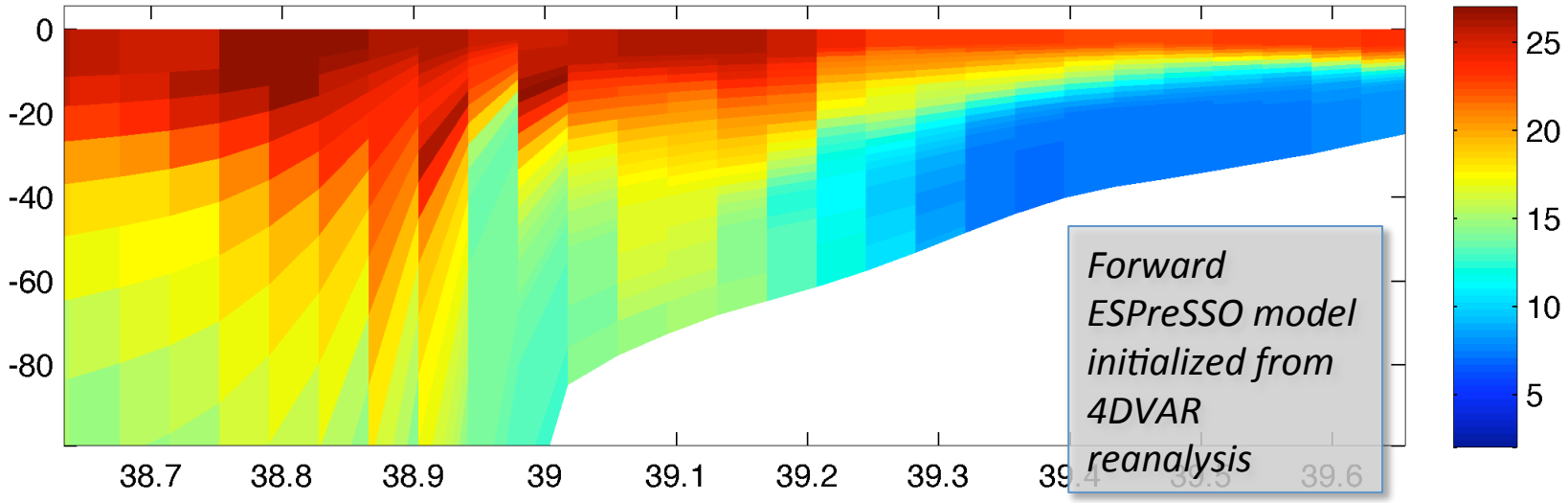
file: http://tds.marine.rutgers.edu:8080/thredds/dodsC/projects/wilkin/ioda/yojo/his_ioda_nstd017_0050.nc
Temperature 19-Aug-2006 01:00:00 - Depth 30 m

IODA nested solution over ESPreSSO

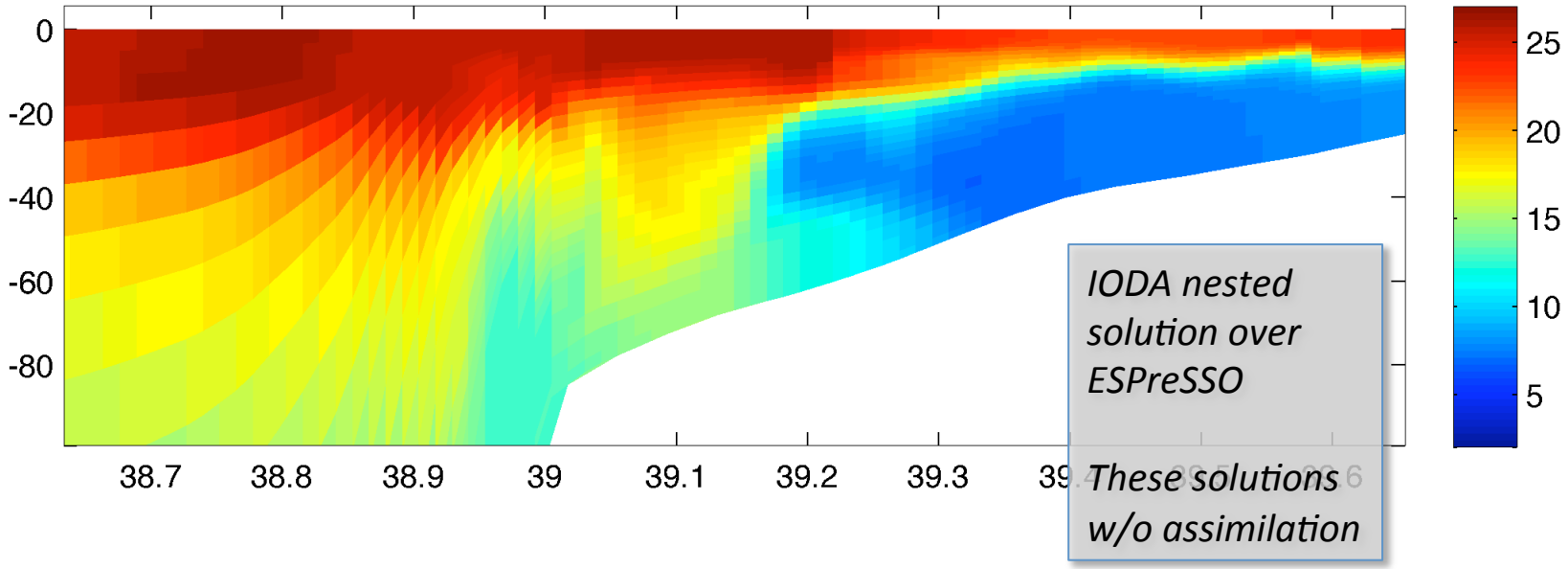
These solutions w/o assimilation

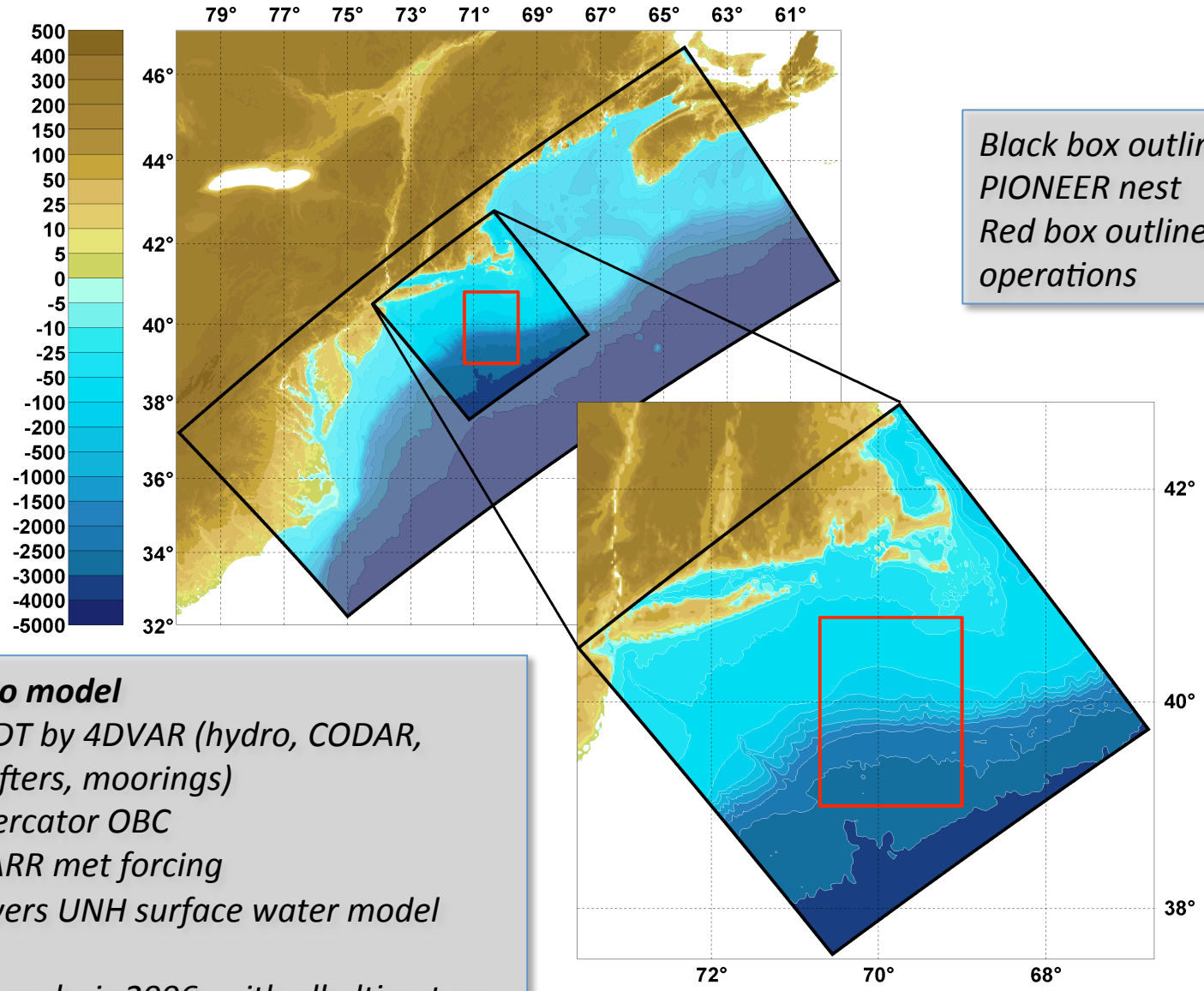


file: http://tds.marine.rutgers.edu:8080/thredds/dodsC/projects/wilkin/ioda/yojo/his_esp_nstd017_0050.nc
TEMP - Date 19-Aug-2006 - MeanLon -72.91



file: http://tds.marine.rutgers.edu:8080/thredds/dodsC/projects/wilkin/ioda/yojo/his_ioda_nstd017_0050.nc
TEMP - Date 19-Aug-2006 - MeanLon -72.73





Black box outlines PIONEER nest
Red box outlines Pioneer operations

Doppio model

- *MDT by 4DVAR (hydro, CODAR, drifters, moorings)*
- *Mercator OBC*
- *NARR met forcing*
- *Rivers UNH surface water model*

- *Reanalysis 2006- with all altimeters (MSS problems), SST (LEO and GEO IR + MW), CODAR, in situ T/S (Argo, glider, XBT)*

DATA ASSIMILATIVE REANALYSIS OF THE U.S. MID ATLANTIC BIGHT SHELF

John Wilkin, Julia Levin, Javier Zavala-Garay, Naomi Fleming: *Rutgers University*

- Rutgers ROMS ESPreSSO 4DVAR reanalysis 2006-2014 uses **all available data** from a modern coastal ocean observing system
  - Satellite SSH and SST, HF-radar, gliders, Argo, GTS XBT/CTD
  - More and diverse data is better; Bias removal essential
- Useful skill for real-time forecast applications
  - 4 days for temperature and salinity; 1-2 days for velocity
- Reanalysis output of full model solution on THREDDS: 3 versions …
  - Satellite data only
  - Satellites plus CODAR and in situ CTD
  - Sat/ CODAR/in situ plus Craig and Banner wave breaking parameterization

- Development path [for IODA]
  - 2-way nesting for enhanced resolution of internal tide generation and propagation
  - Nested 4DVAR assimilation: (1) downscaling increments in “parent” grid to “child” grid background trajectory, then (2) independent 4DVAR in child