Data Assimilative Modeling of the U.S. Mid-Atlantic Bight Shelf

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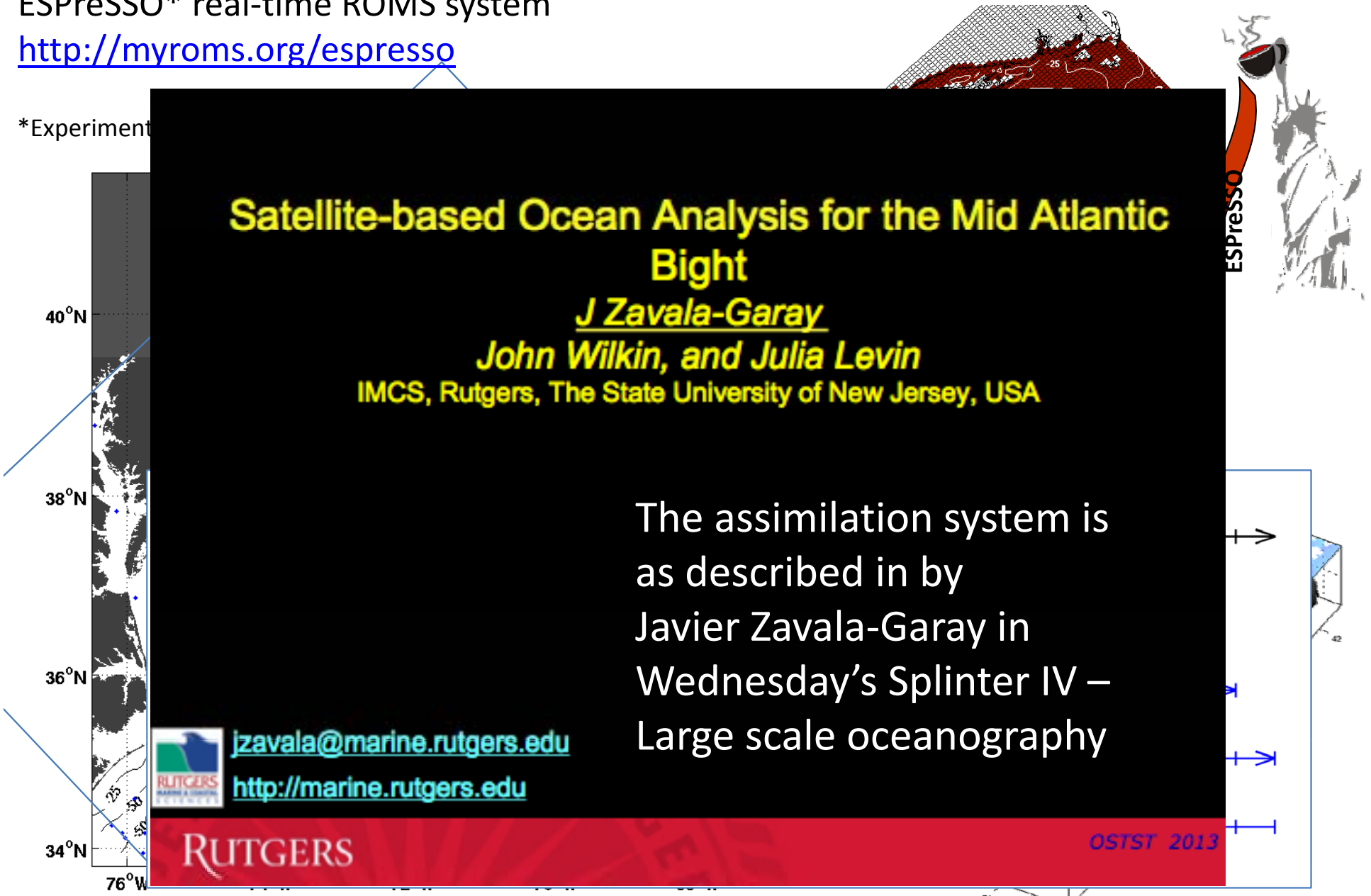
ESPreSSO* real-time ROMS system

http://myroms.org/espresso

*Experiment



Satellite-based Ocean Analysis for the Mid Atlantic Bight

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The assimilation system is as described in by Javier Zavala-Garay in Wednesday's Splinter IV – Large scale oceanography

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RUTGERS

OSTST 2013

http://maracoos.org

Mid-Atlantic Regional Association of Coastal Ocean Observing Systems

Data streams in the NRT system	***NRT real-time data source***
<u>Model surface and boundary forcing:</u>	
• 72-hour forecast NAM 0Z cycle at 2 am EST	*NCEP NOMADS Grads DODS Server*
• USGS daily average flow available 11:00 EST	*waterdata.USGS.gov*
• HYCOM NCODA 7-day forecast updated daily	*Naval Research Laboratory*
<u>Assimilation data sets:</u>	
• Regional CODAR hourly: 4-hour latency delay	*Rutgers TDS**
• RU glider T,S (1 hour delay)	*Rutgers TDS*
• AVHRR IR passes 6-8 per day (2 hour delay)	*U. Delaware via tds.maracoos.org*
• REMSS MW-IR blended SST daily average	*NASA PO-DAAC*
• **<u>Jason-2, CryoSat, AltiKa</u>** along-track OGDR	*RADS*
• SOOP XBT/CTD, Argo floats, on GTS	*OSMC.noaa.gov using ERDDAP*

**THREDDS Data Server unidata.ucar.edu*

Work flow for Near Real Time ESPreSSO 4DVar

Daily schedule for real-time system

All times local U.S. EST

- 03:30: 4D-Var assimilation analysis of last 3 days of observations
- 07:30: Run forecast for next 72 hours
- 09:00: Forecast is complete and transferred to OPeNDAP/THREDDS FMRC

  …
- 10:00: Get HYCOM output for OBC
- 23:00: Get 1-day composite REMSS blended SST (B-SST)
- 00:00: Get daily average river discharge from USGS
- 01:00: Get NAM surface meteorology forcing from NCEP NOMADS
- 03:00: Get IR SST passes; process and combine with B-SST
- 03:00: Get CODAR surface currents; process tide adjustment
- 03:10: Get Jason, Cryosat and AltiKa along-track data from RADS; process tide adjustment, add MDT

Work flow for Near Real Time ESPreSSO 4DVar

Input pre-processing

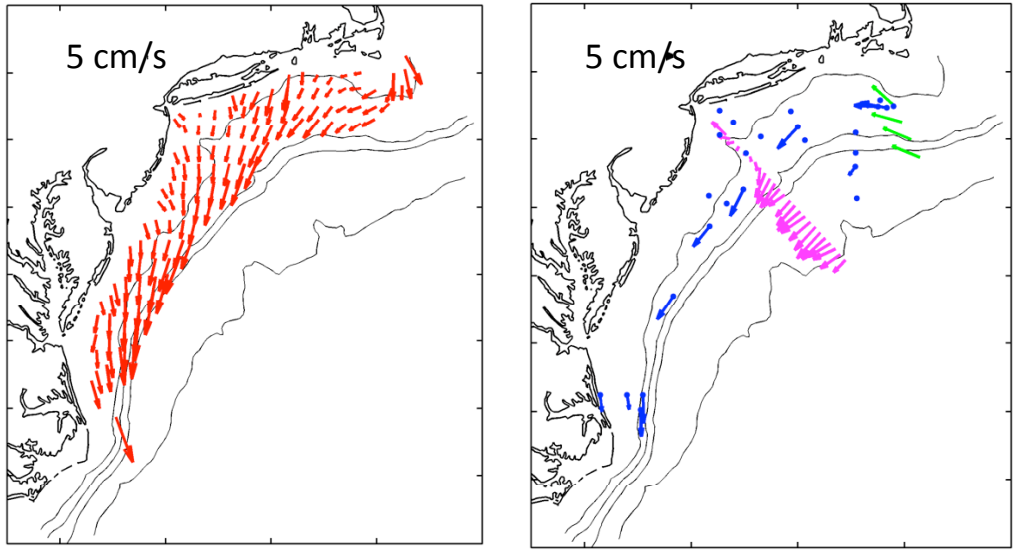
- RU CODAR de-tided (harmonic analysis) and binned to 5km
  - variance within bin & OI combiner expected *u_err* (GDOP) used for QC

    >> ROMS tide added to de-tided CODAR – reduces tide phase error contribution to cost function
- RU glider T,S averaged to ~5 km horiz. and 5 m vertical bins
  - need thermal lag salinity correction to statically unstable profiles
- AVHRR IR individual passes 6-8 per day
  - U. Del cloud mask; bin to 5 km resolution
  - REMSS daily SST OI combination of AVHRR, GOES, and microwave SST
- Altimetry along-track 5 km bins (with coastal corrections) from RADS
  - MDT from 4DVAR on climatological observations: 3D T,S, velocity (moorings, Oleander, *CODAR*), mean τ^{wind}

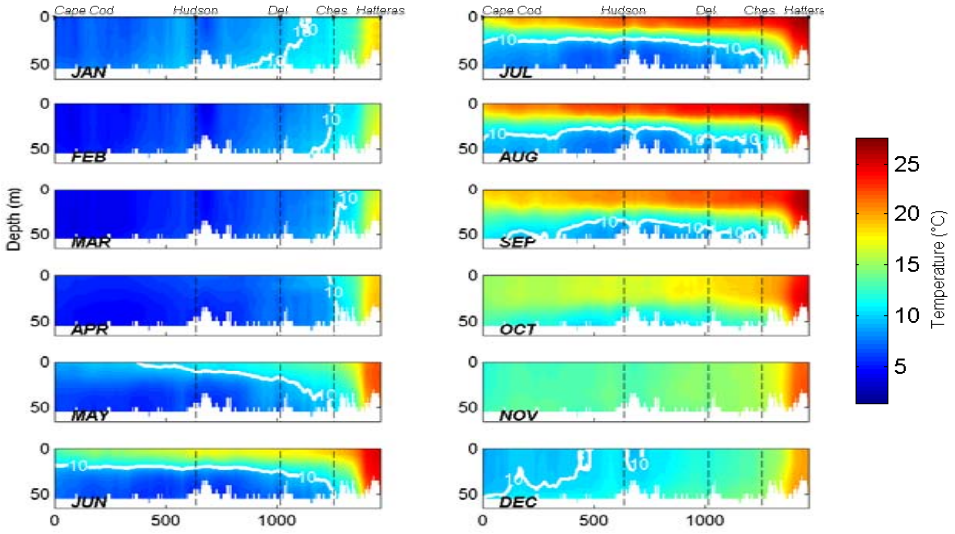
    >> add ROMS tide solution to SSH
- USGS daily river flow is scaled to account for un-gauged watershed
- Open boundary data from HYCOM adjusted to remove mean bias (using 4DVAR climatological analysis)

4DVAR analysis of mean climatological ocean state

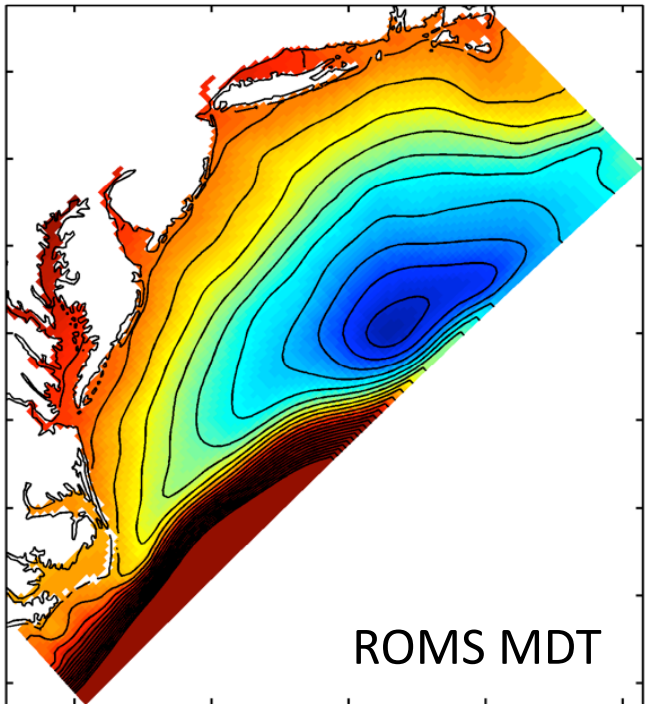
velocity obs. from CODAR (red), moorings (blue, green) and ship ADCP (magenta) …



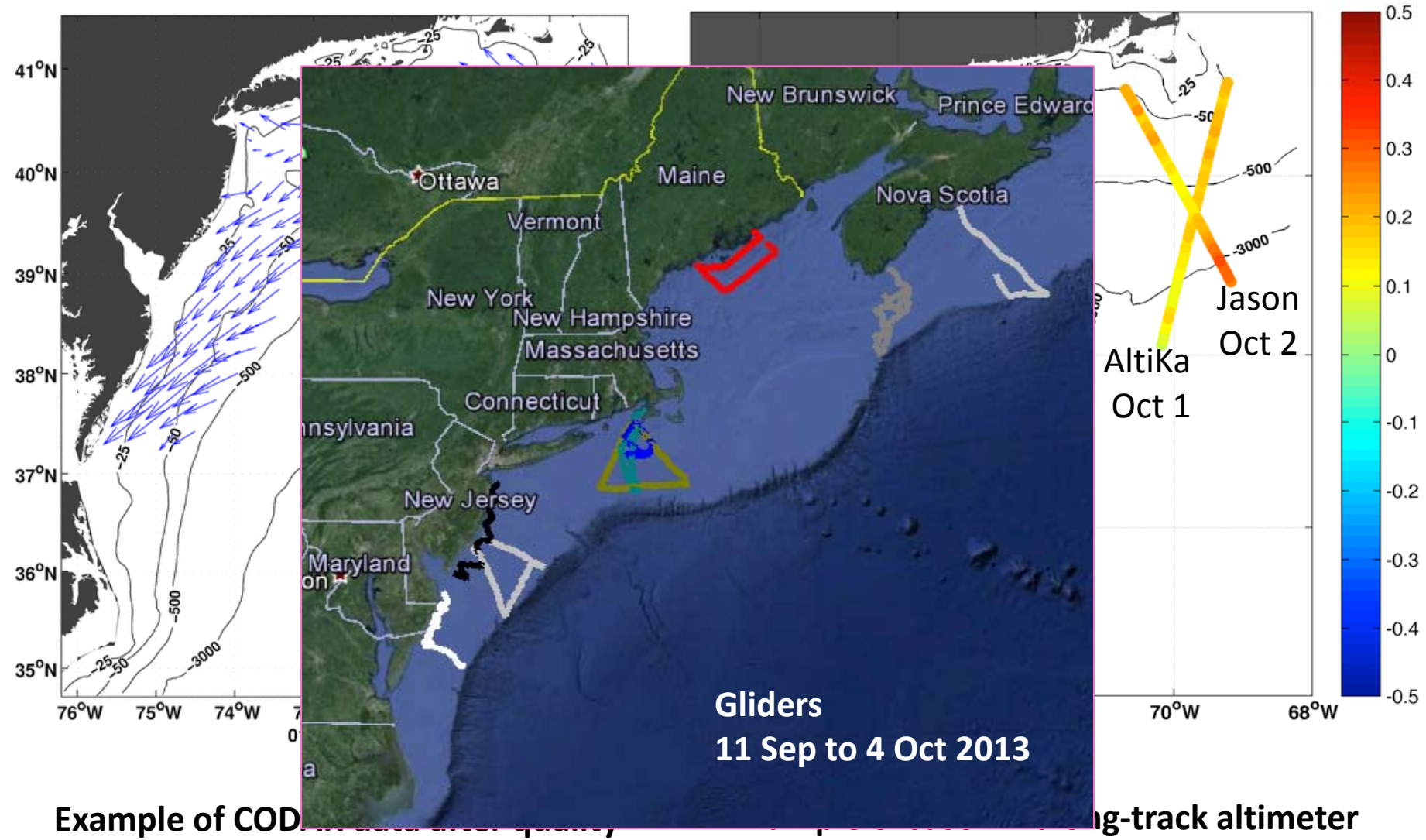
+ high-res regional T/S climatology



4DVAR seasonal and annual mean



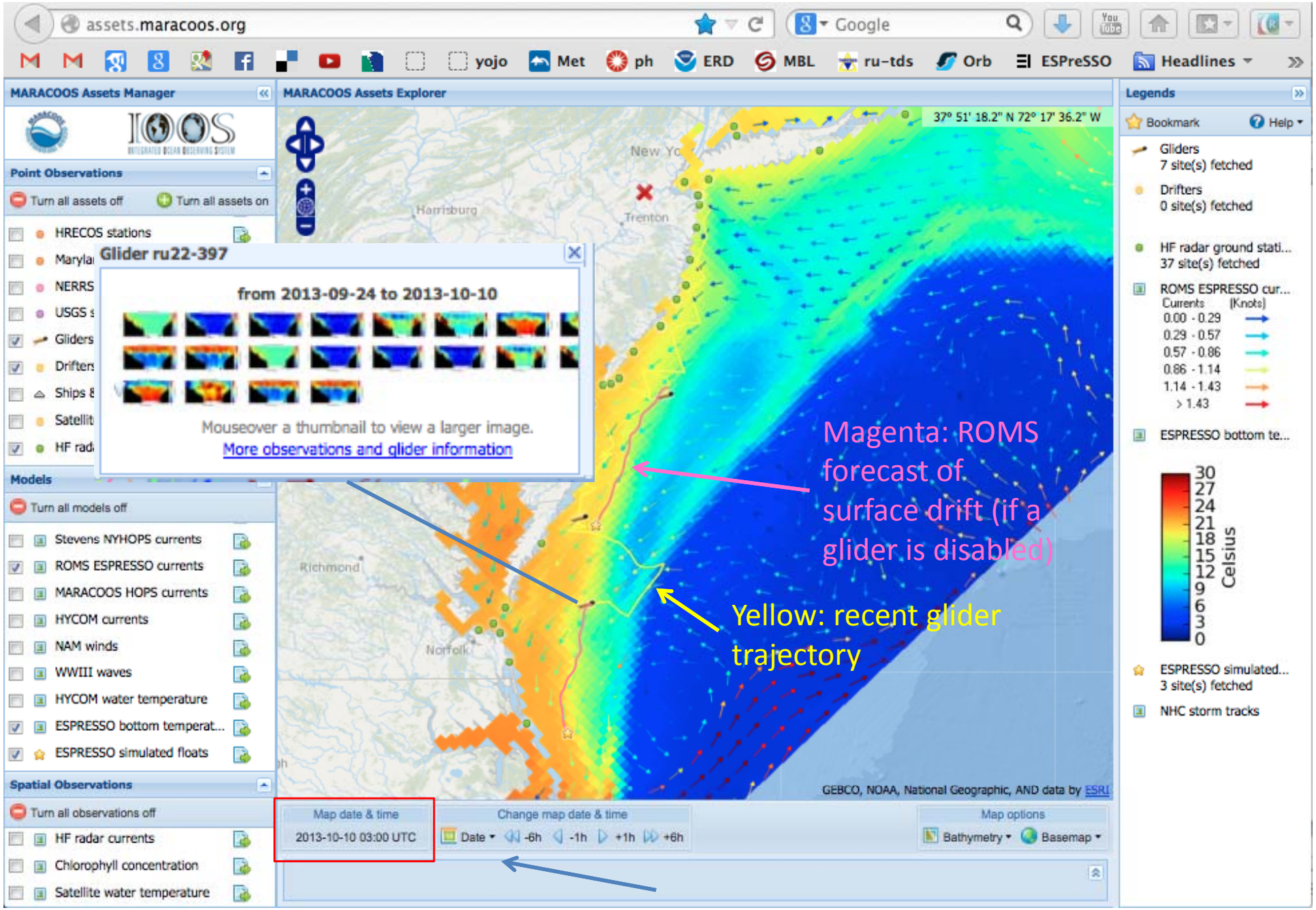
Dynamically & kinematically adjusted MDT, and seasonal T,S,u,v for OBC bias removal



Example of COD[illegible] control, binning and decimation to a set of independent observations.

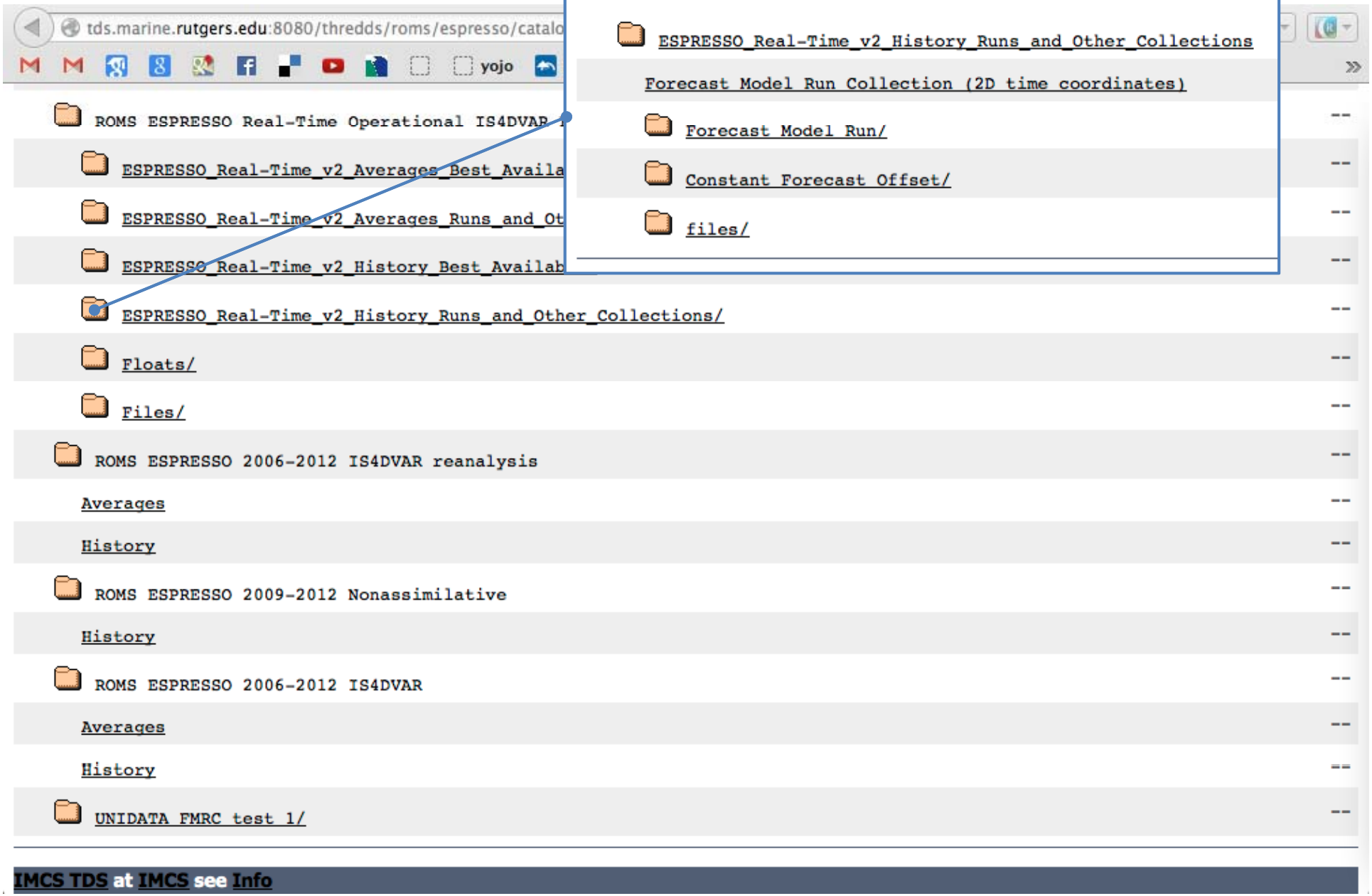
[illegible]g-track altimeter sea level anomaly data during a single 3-day analysis window.

MARACOOS assets.maracoos.org map server displays Near Real Time data and models

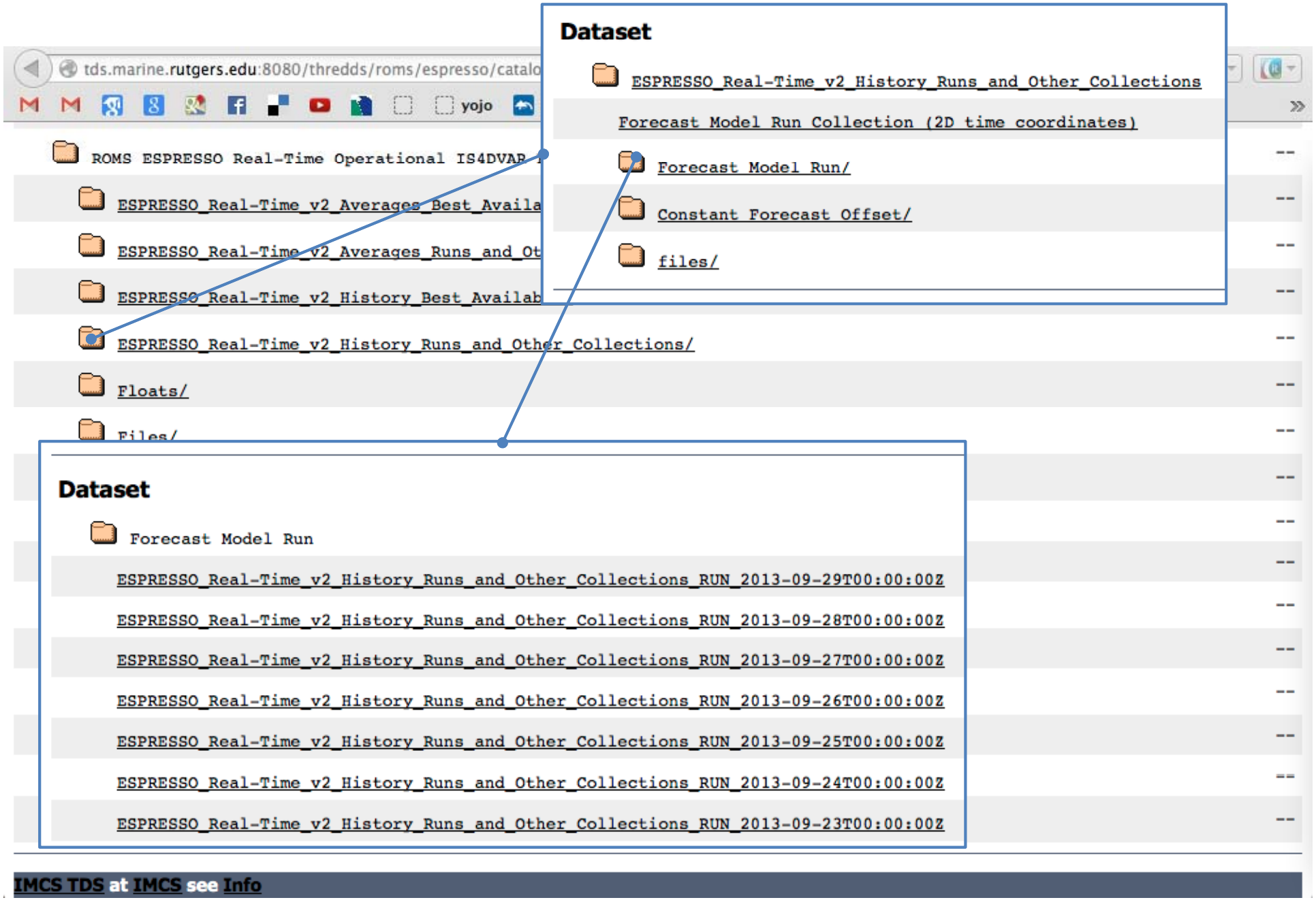


Output goes to THREDDS server Forecast Model Run Collection* (FMRC) at tds.marine.rutgers.edu/thredds

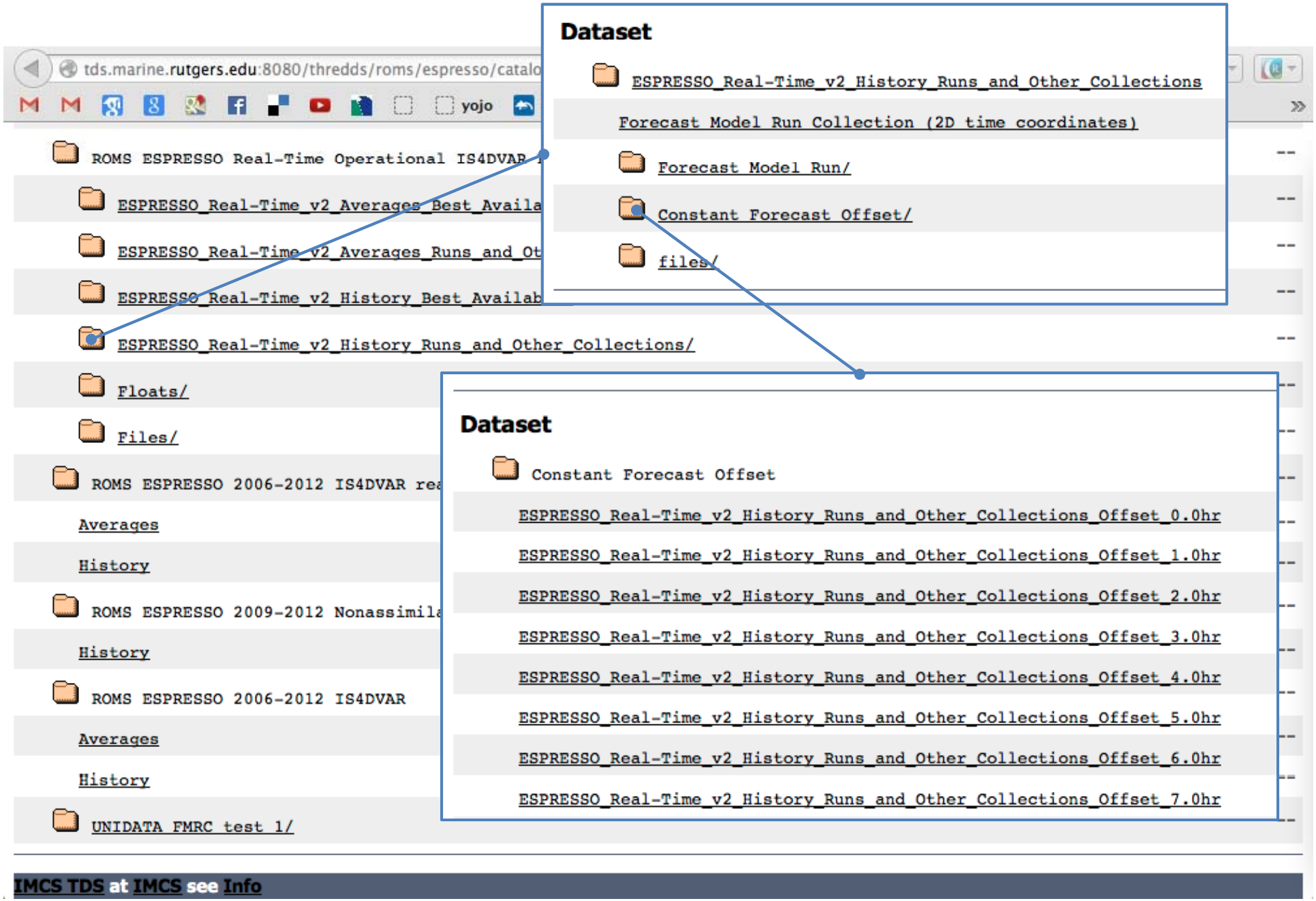
*unidata.ucar.edu

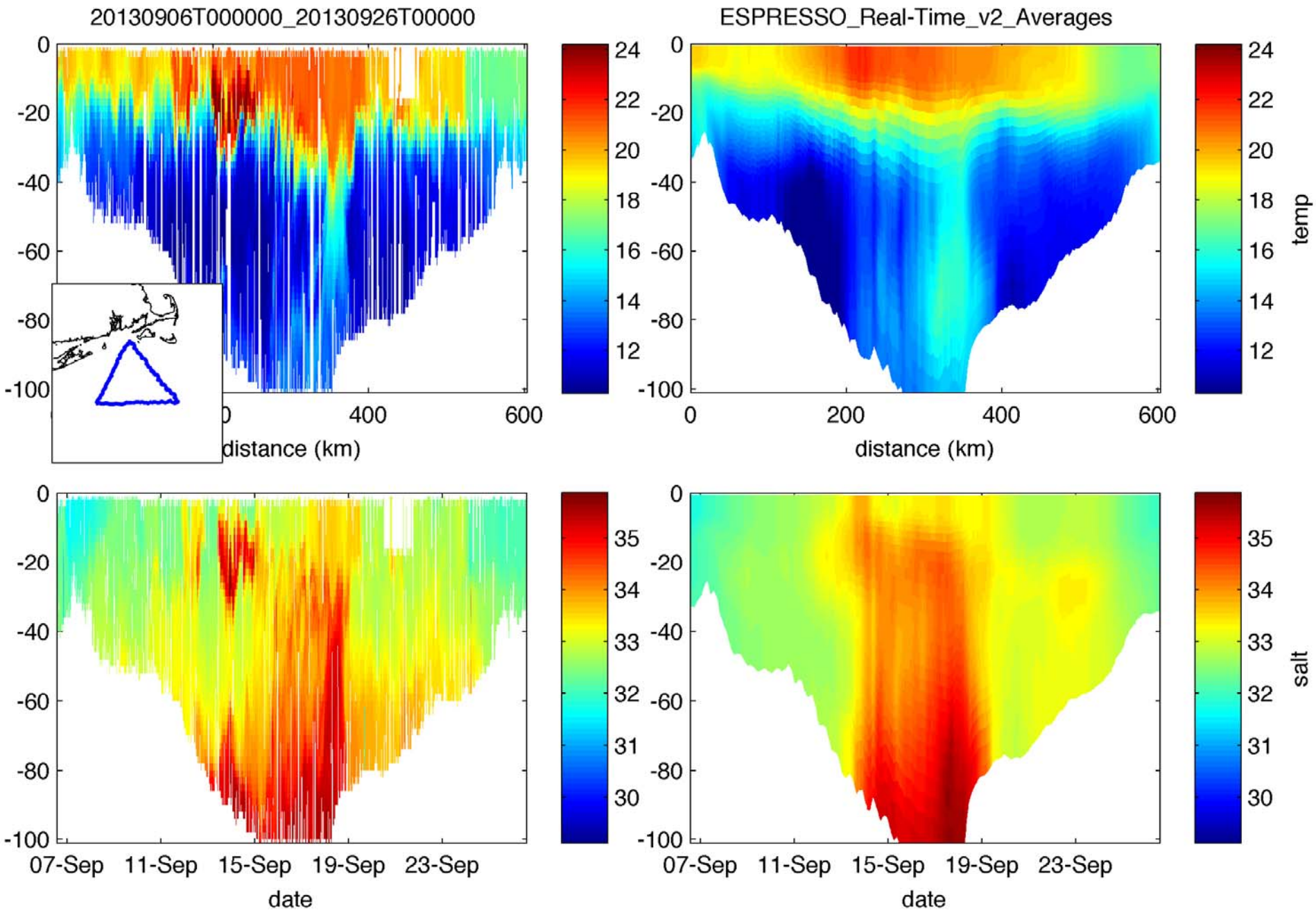


Forecast Model Run: Output from a single analysis and forecast

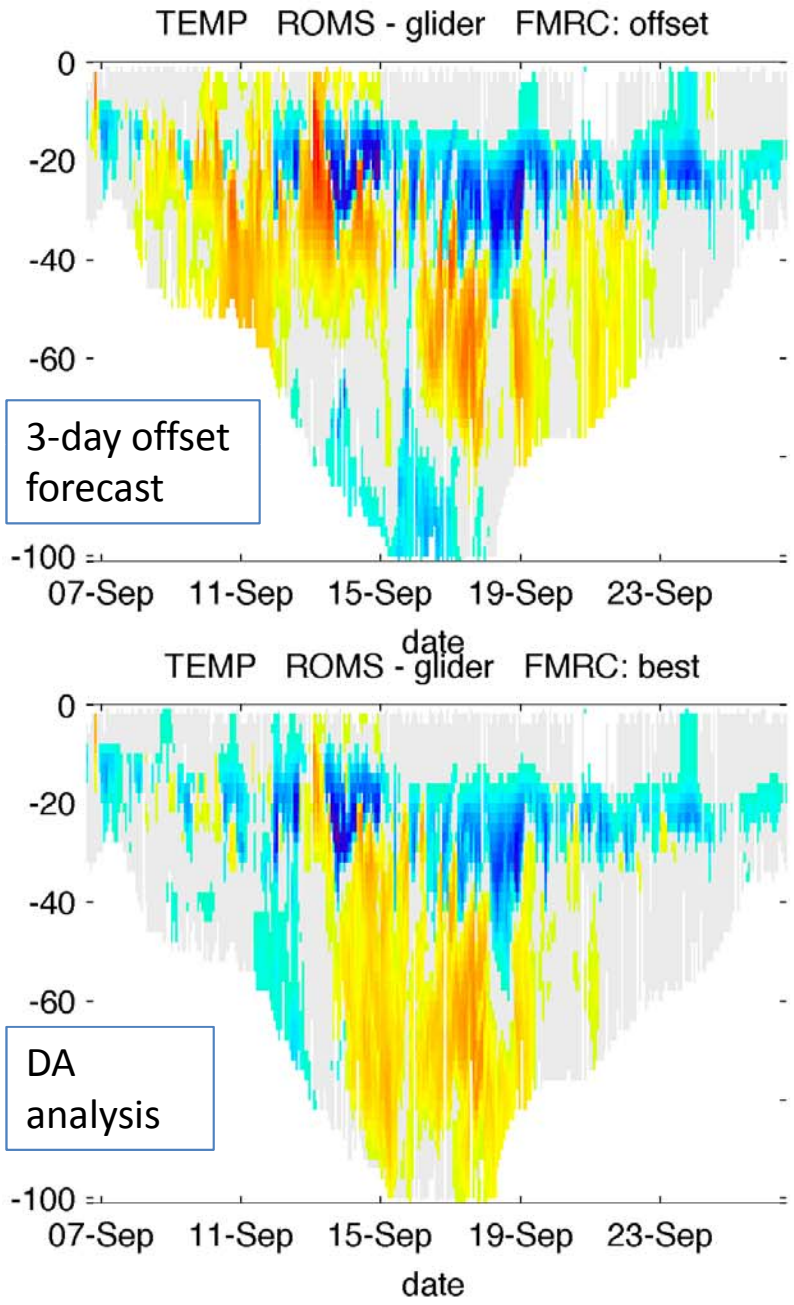


Constant Forecast Offset: Every realization of a given date from all forecasts

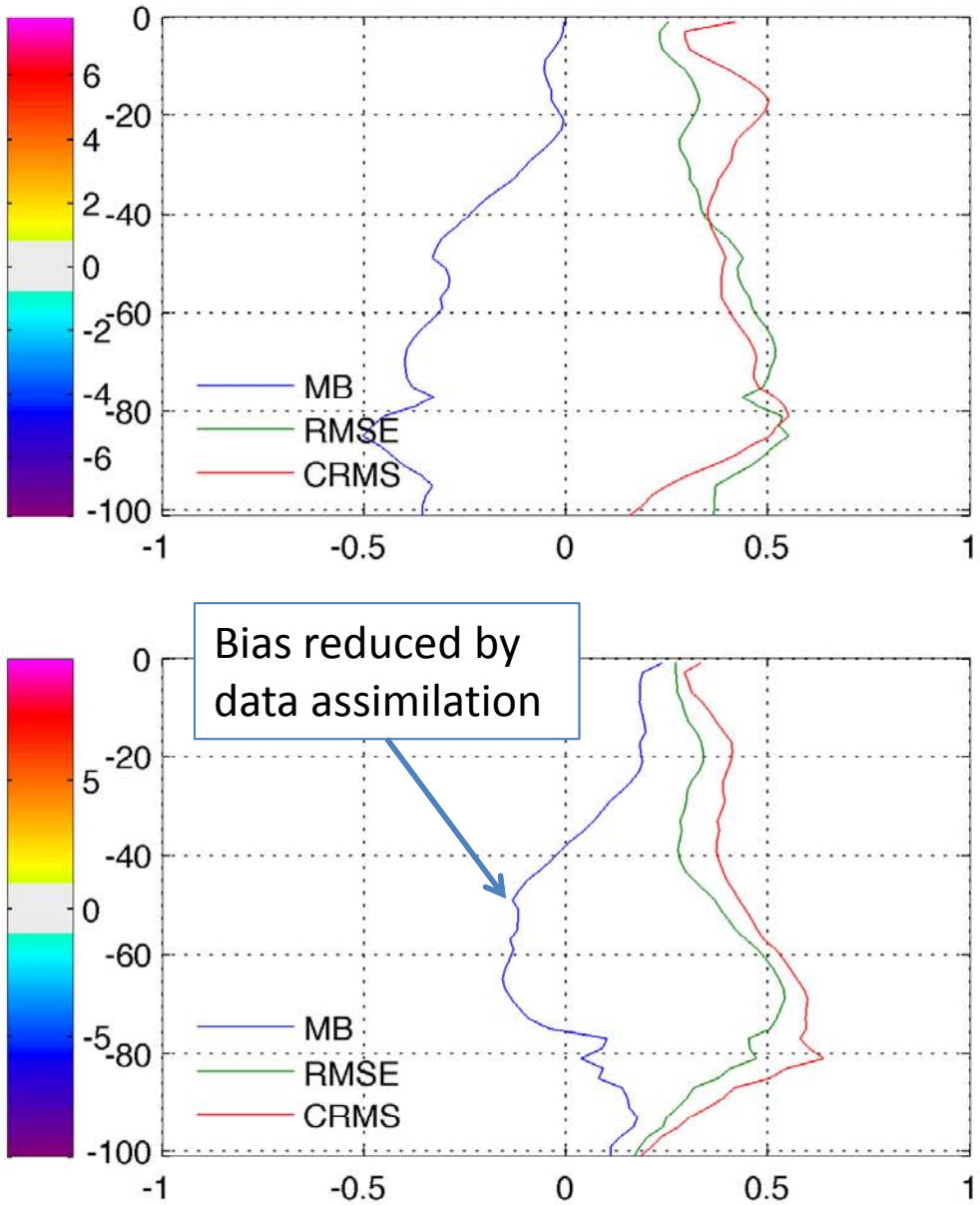



Glider observations
ROMS IS4DVAR analysis
20130906T000000_20130926T00000
ESPRESSO_Real-Time_v2_Averages
0
-20
-40
-60
-80
-100
0
200
400
600
distance (km)
24
22
20
18
16
14
12
temp
35
34
33
32
31
30
salt
07-Sep
11-Sep
15-Sep
19-Sep
23-Sep
date

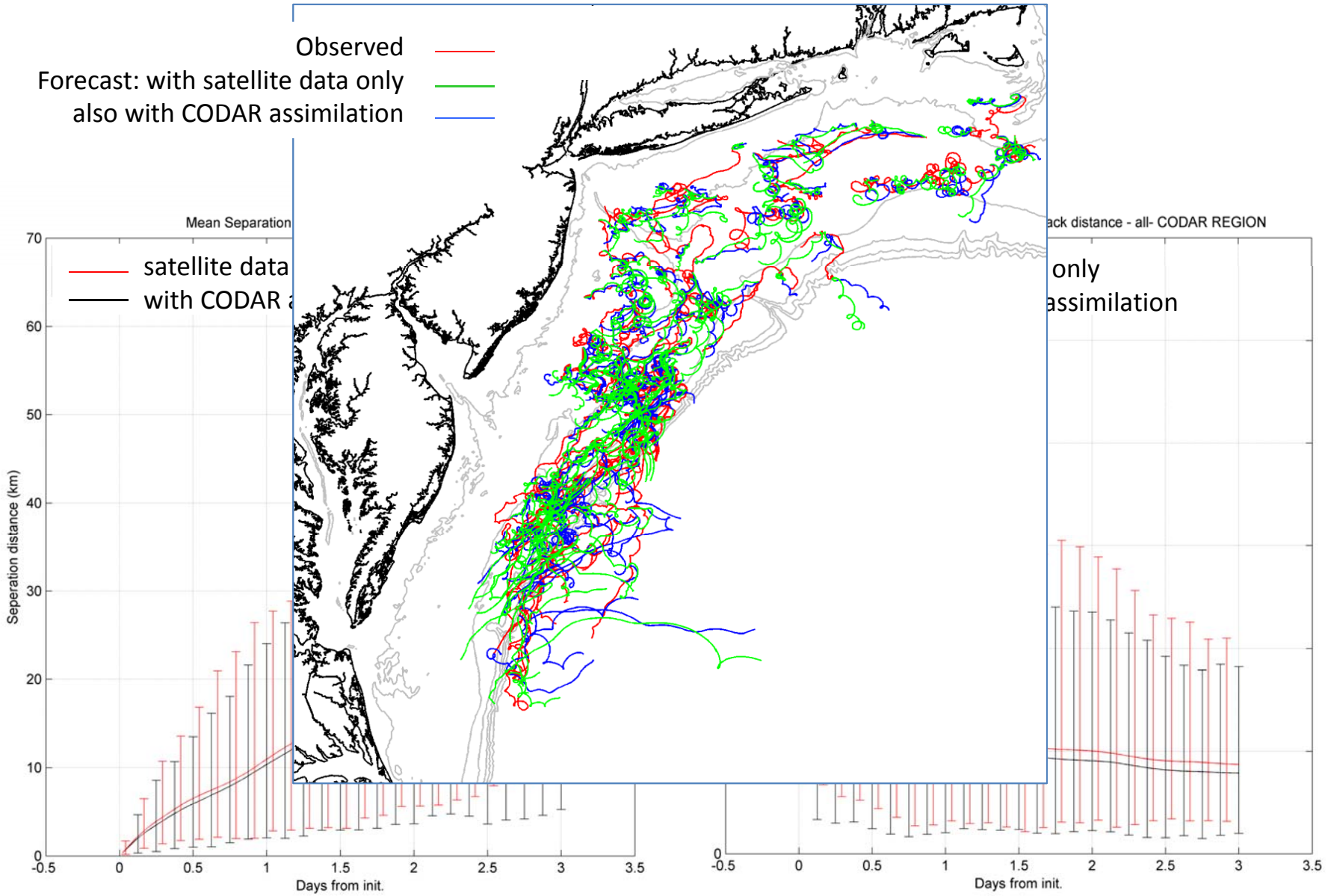
Model minus glider obs.



Skill score vs. depth

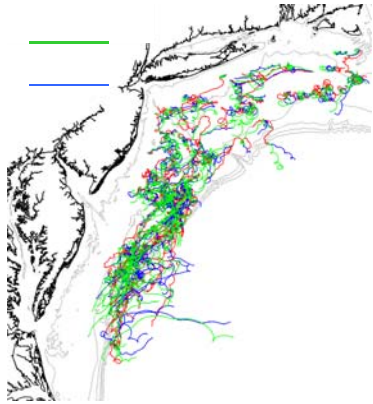


Lagrangian forecast skill w.r.t.
U.S. Coast Guard (SLDMB) drifters

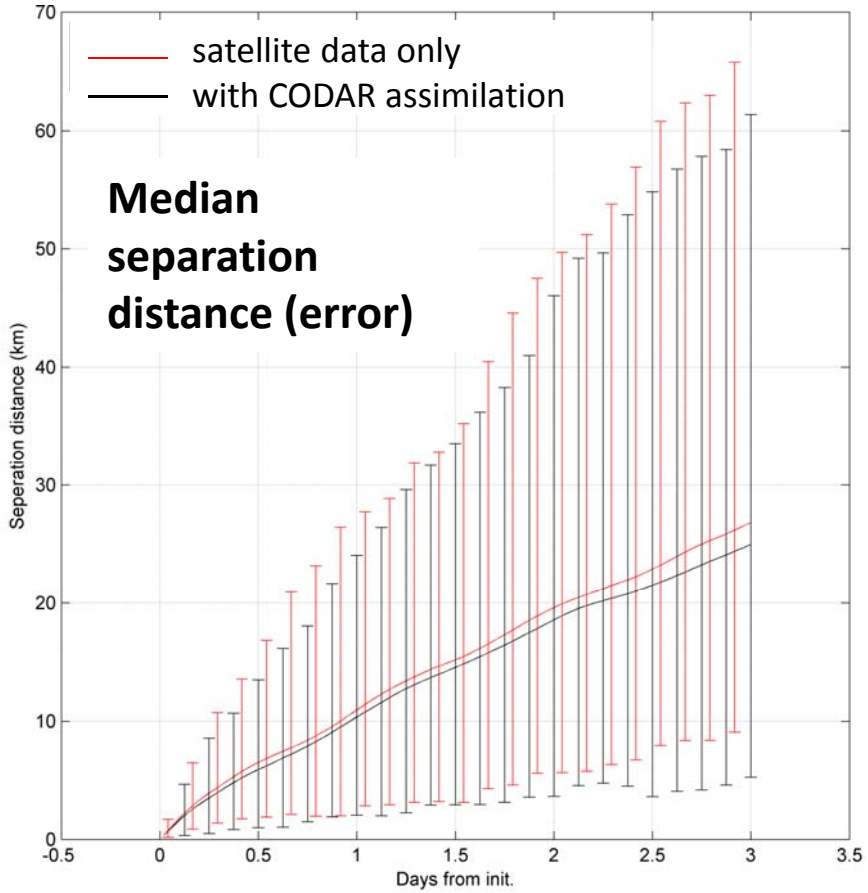


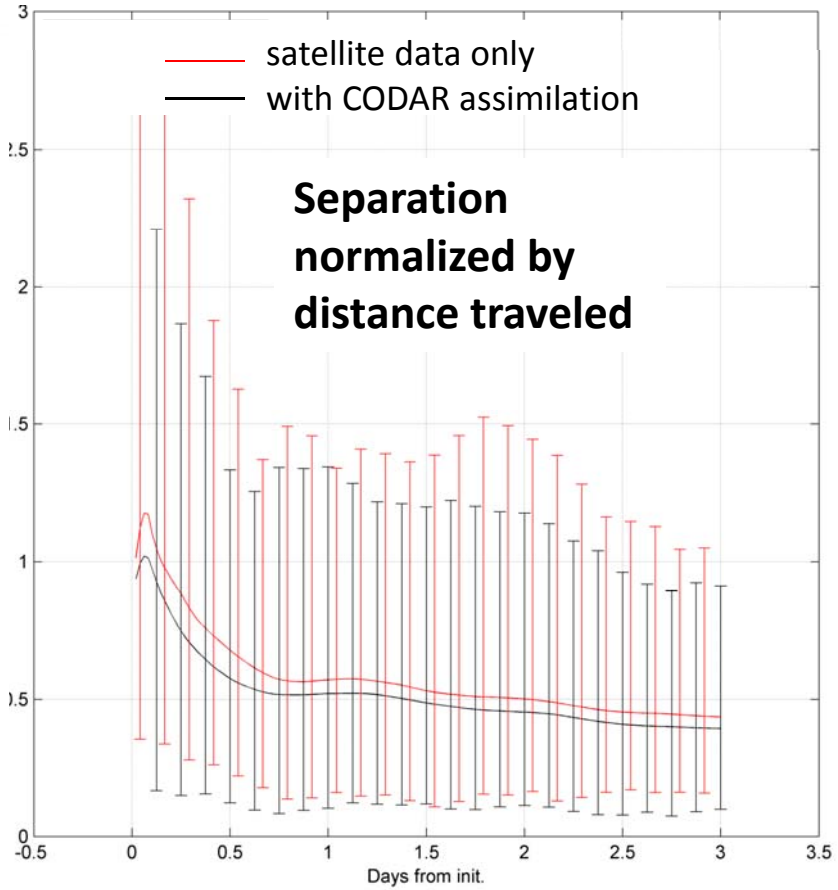
Lagrangian forecast skill w.r.t. U.S. Coast Guard (SLDMB) drifters

Observed
Forecast: with satellite data only
also with CODAR assimilation



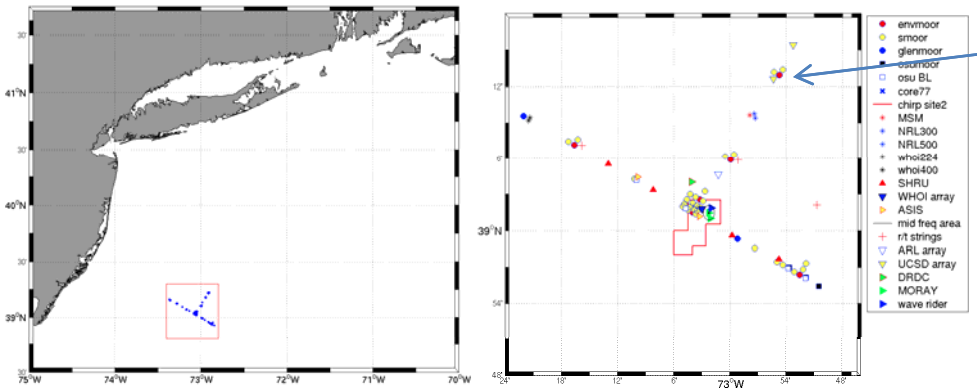
Addition of HF-radar (CODAR) to assimilation system gives modest error reduction, but more significant reduction in uncertainty (error bars are 5% and 95%)





Sub-surface velocity analysis skill

Shallow Water 2006



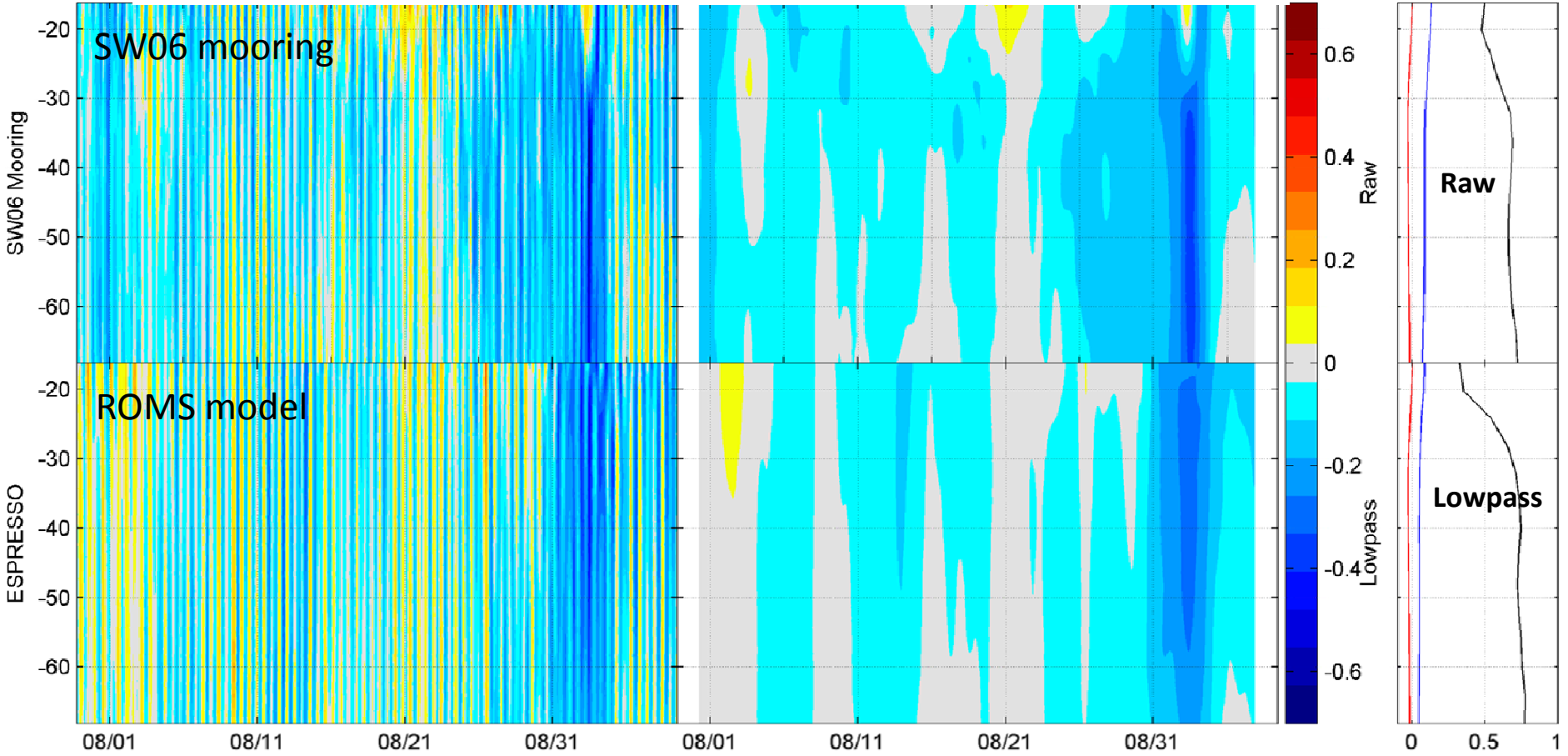
SW06 mooring 32 N-S velocity skill scores

R (corr. coeff.)

BIAS (m s^{-1})

CRMS (m s^{-1})

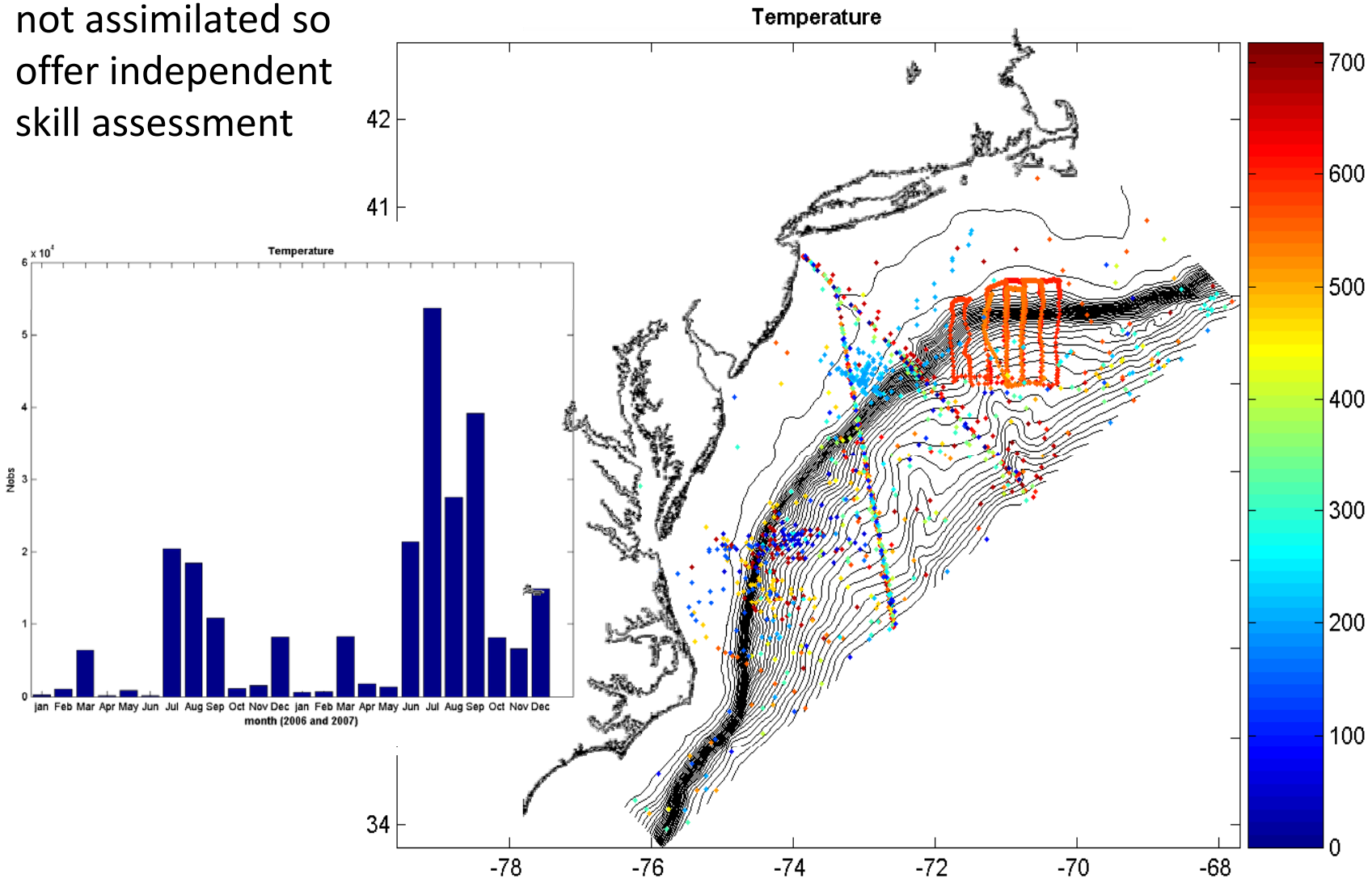
Raw (hourly) **Lowpass (33-hr cutoff)**



Sub-surface T/S analysis and forecast skill

In situ T and S observations are not assimilated so offer independent skill assessment

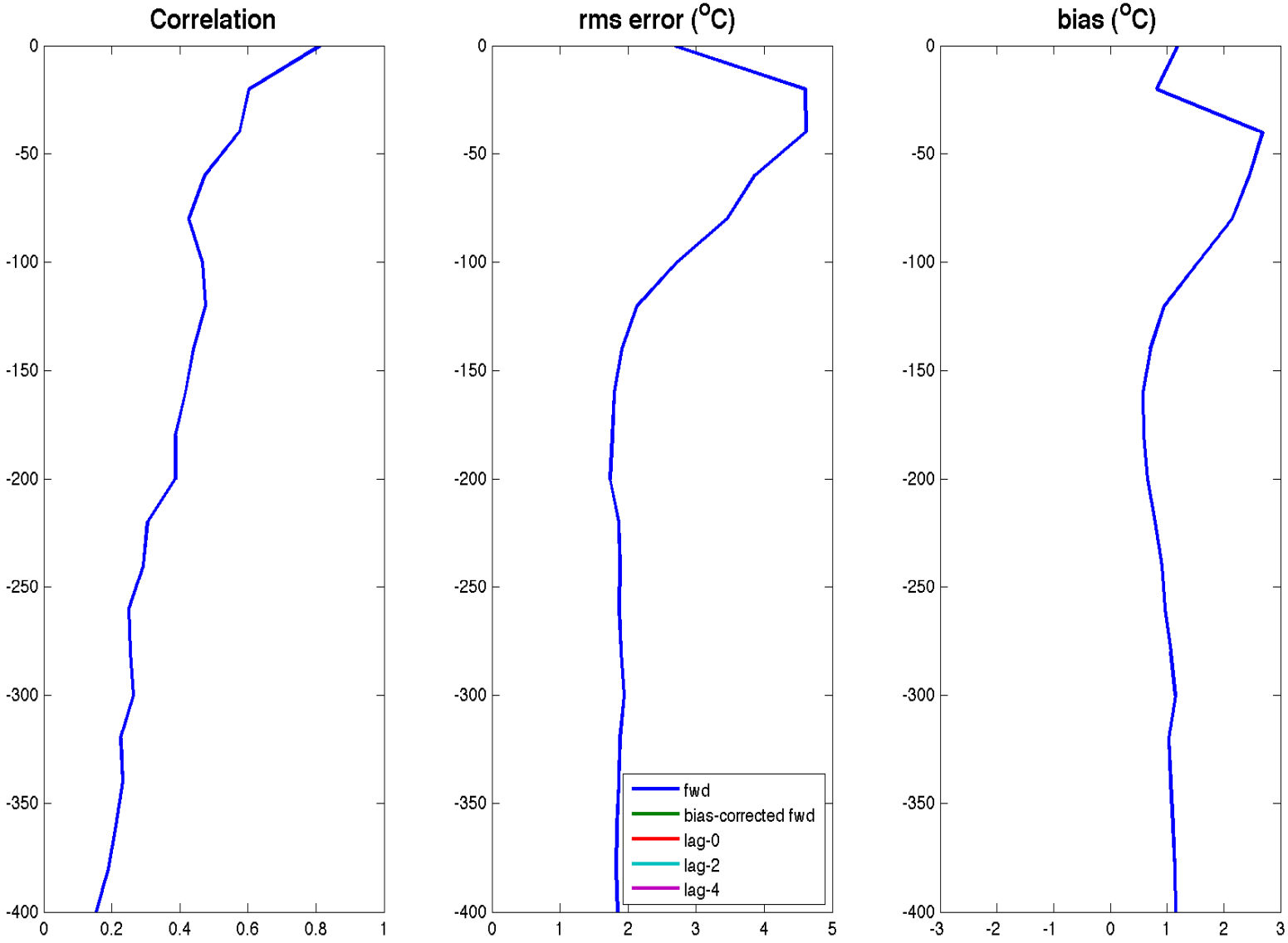
There is a sizeable archive of observatory data from CTD, gliders and XBTs for 2006 (SW06) and 2007



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

Temperature

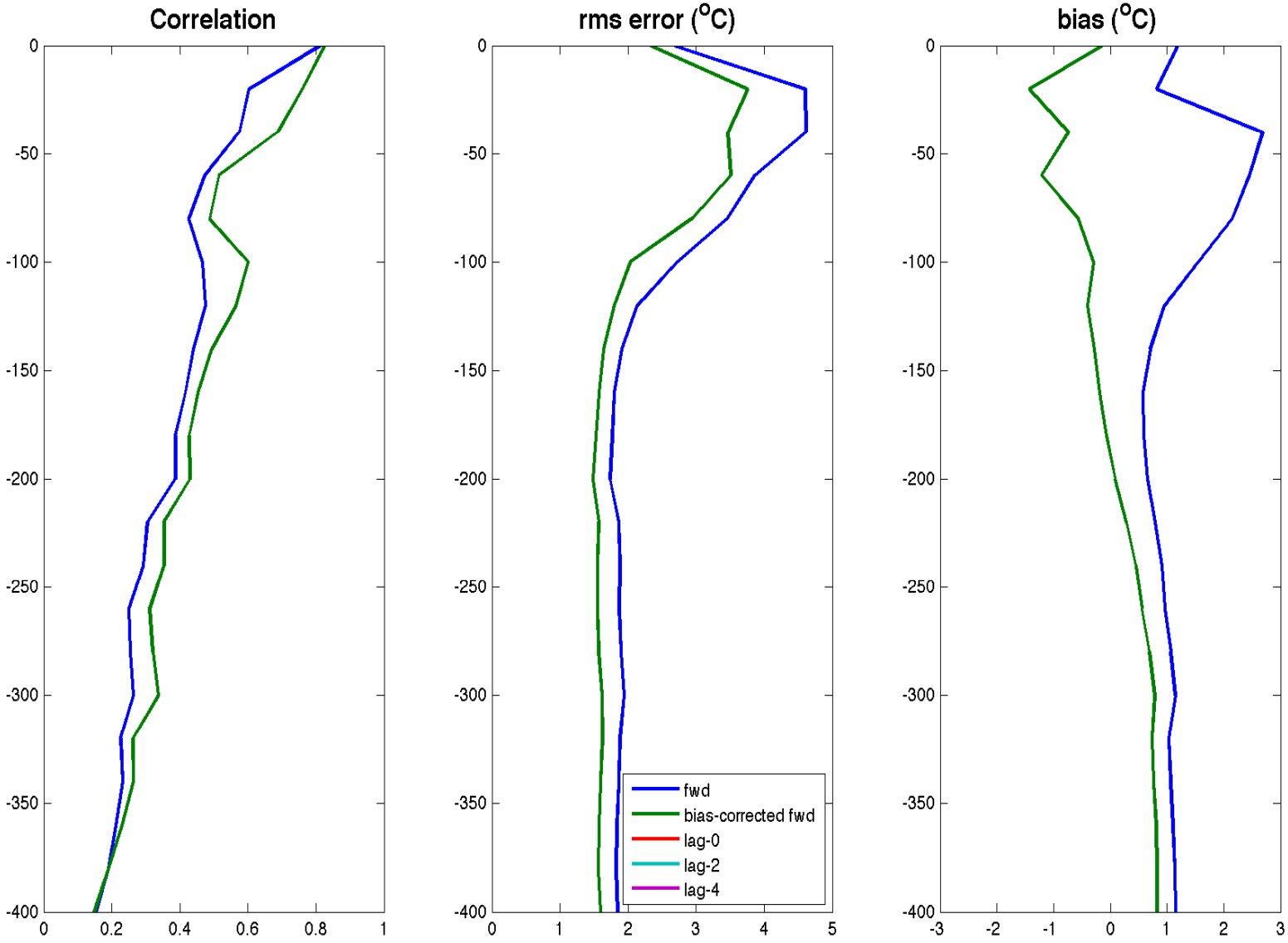
Forward model



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

Temperature

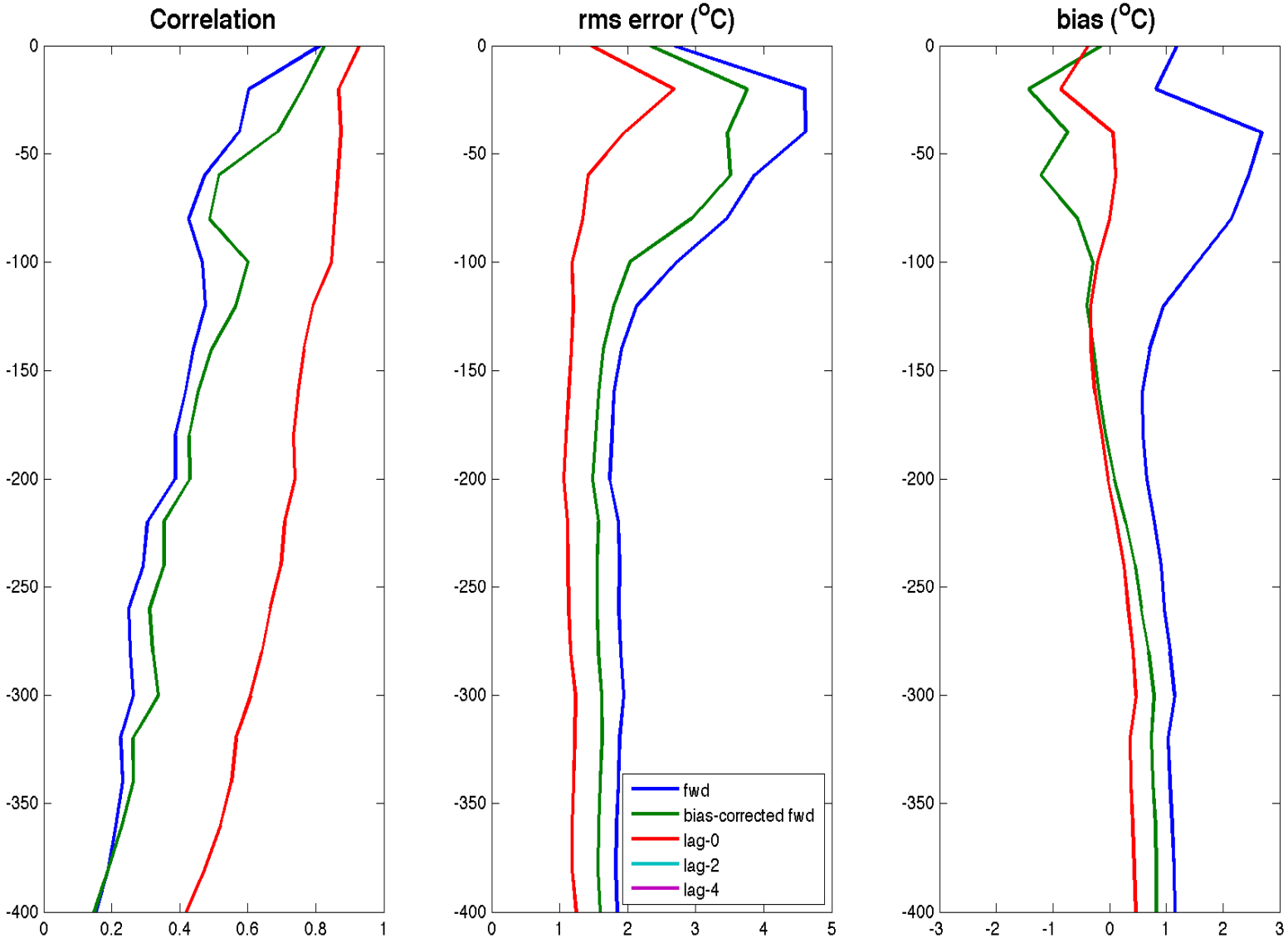
Forward model after bias removal



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

Temperature

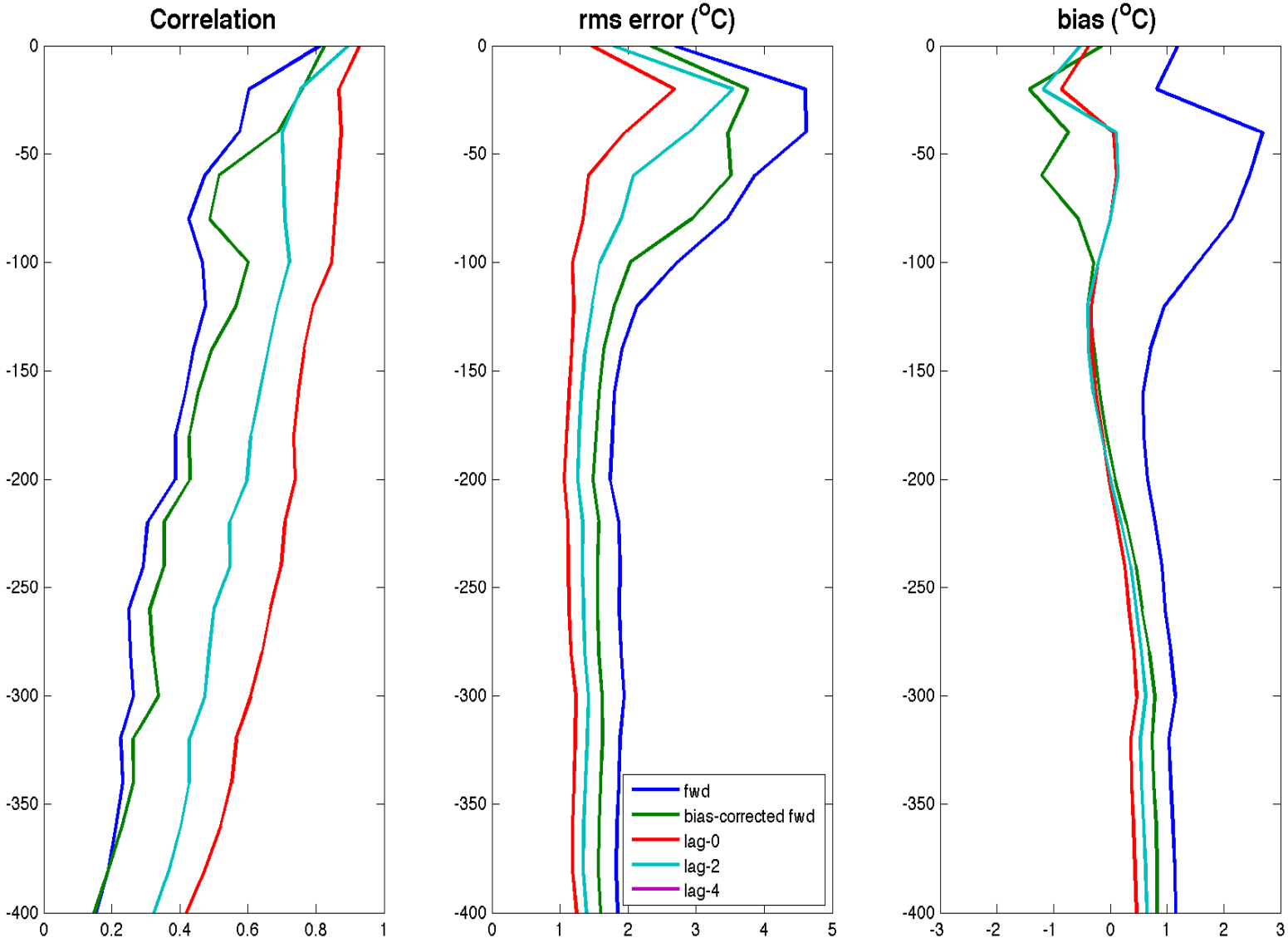
Data assimilation analysis/hindcast



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

Temperature

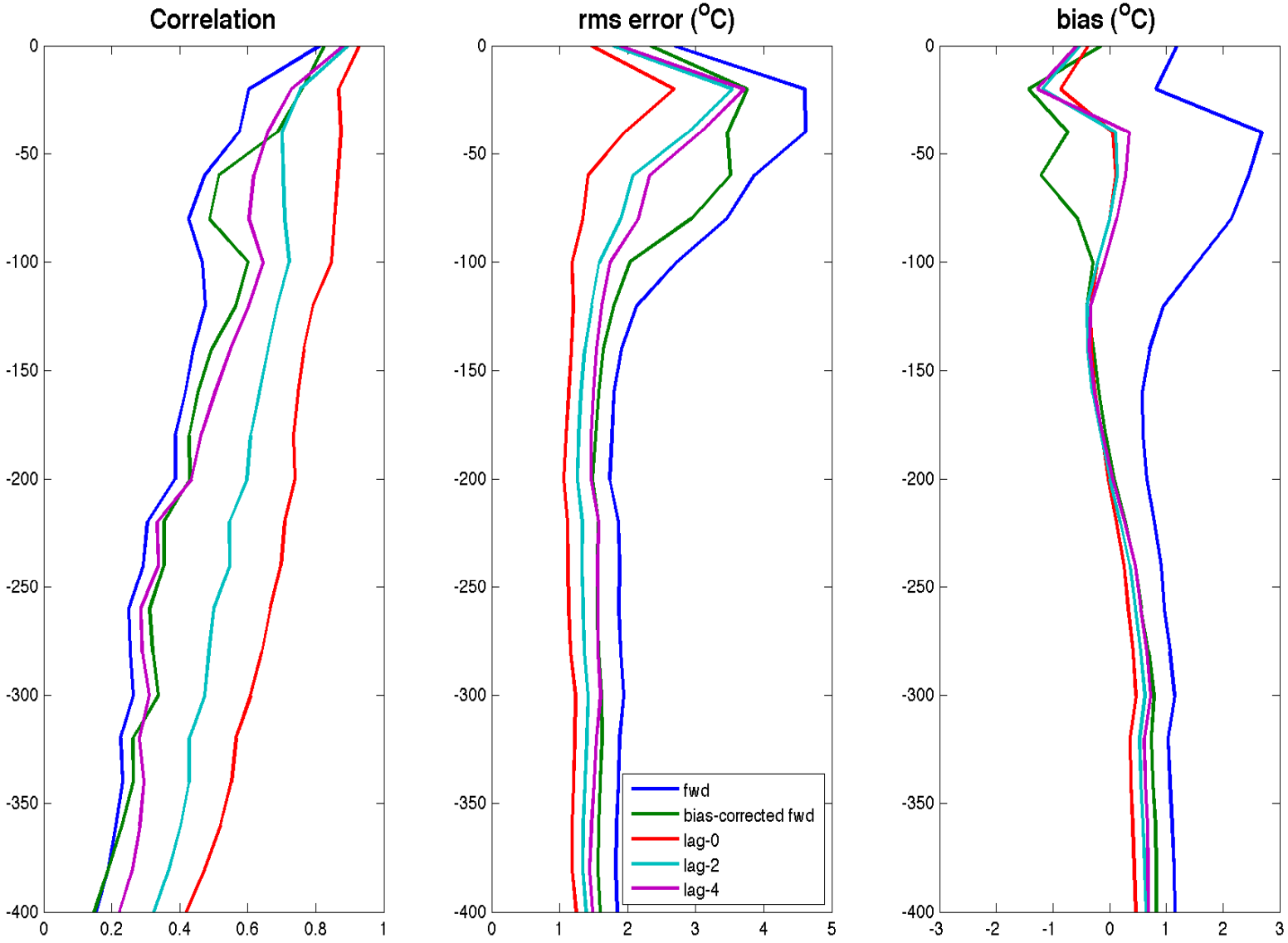
2-day forecast



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

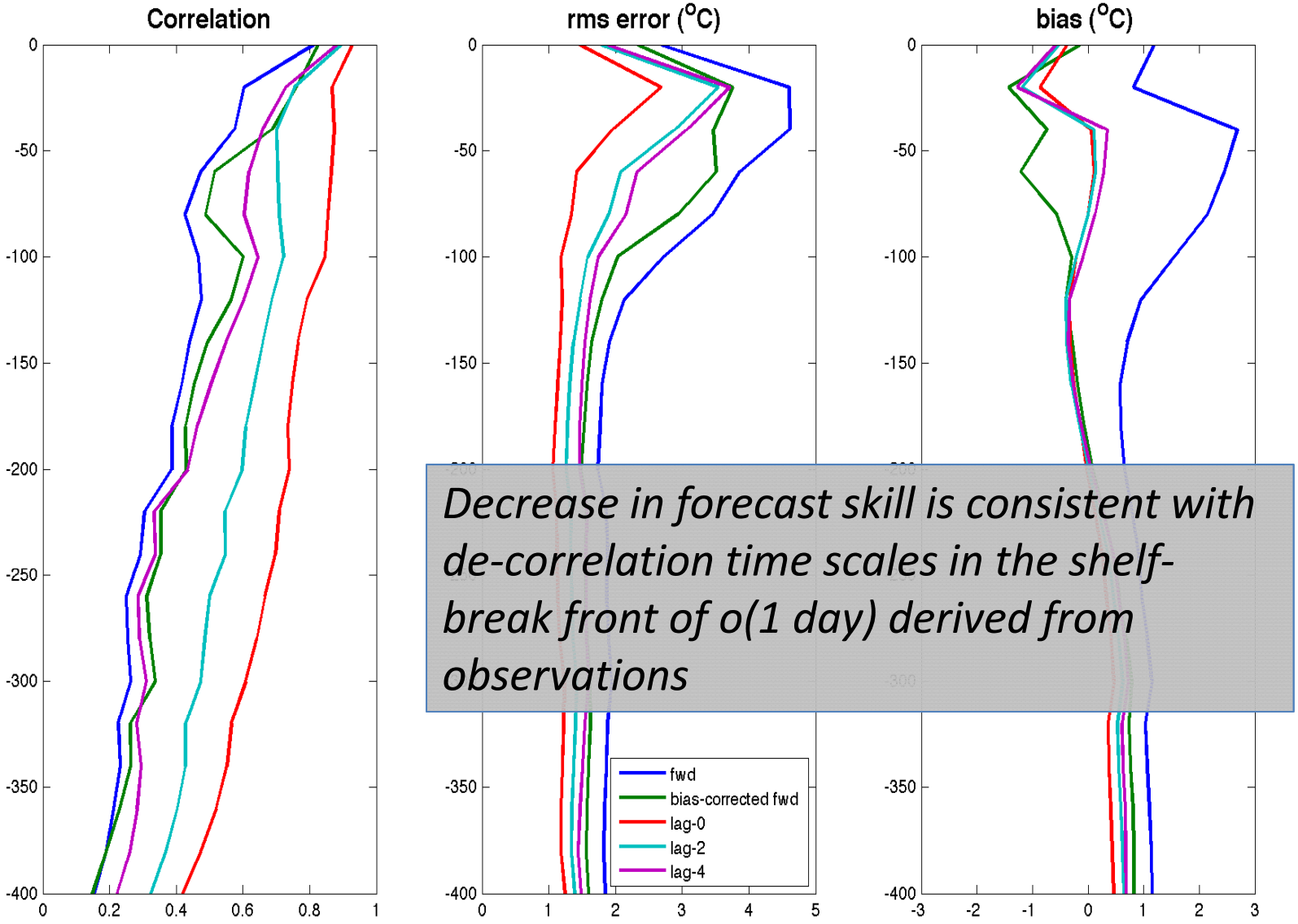
Temperature

4-day forecast



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

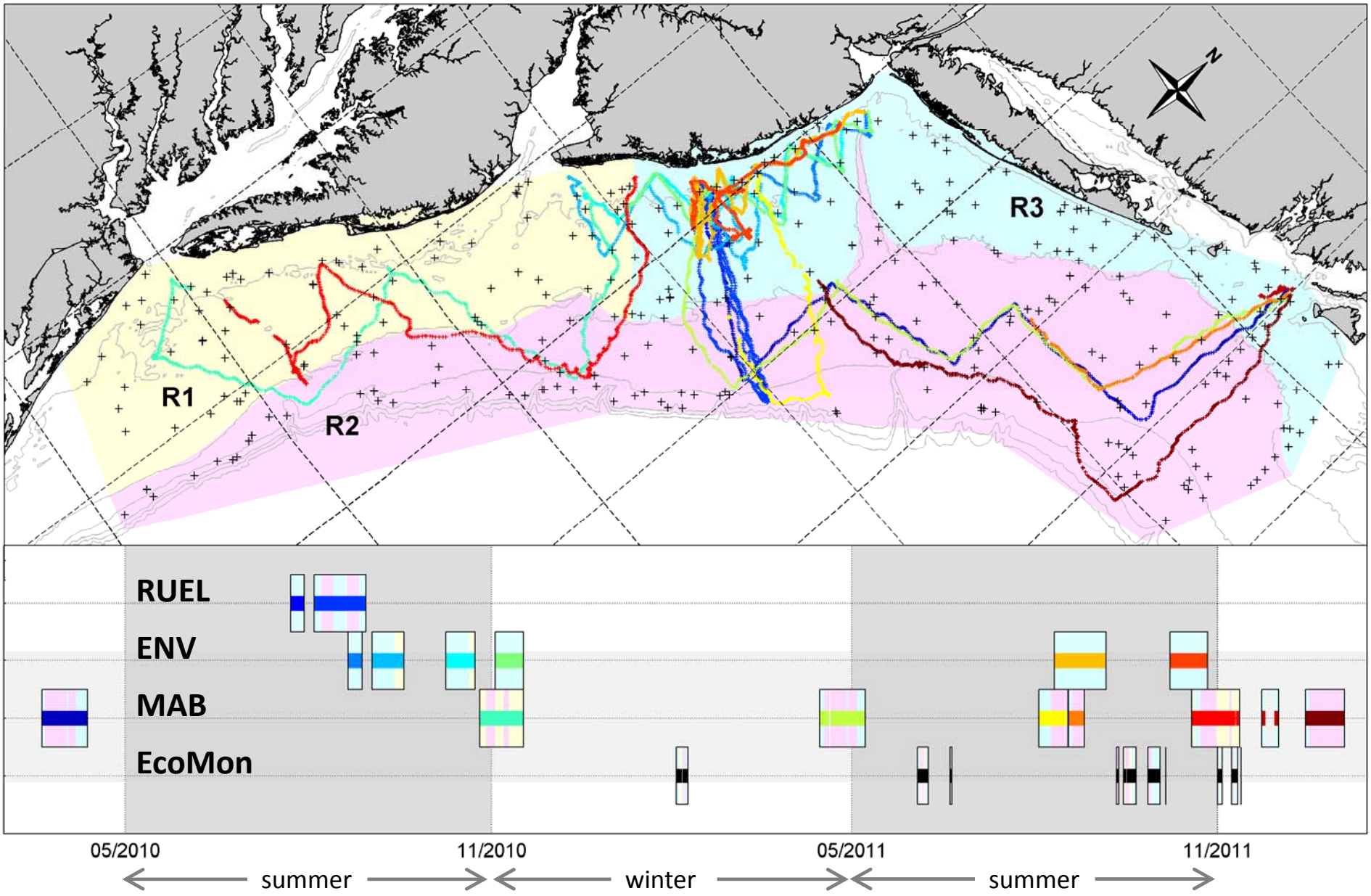
Temperature



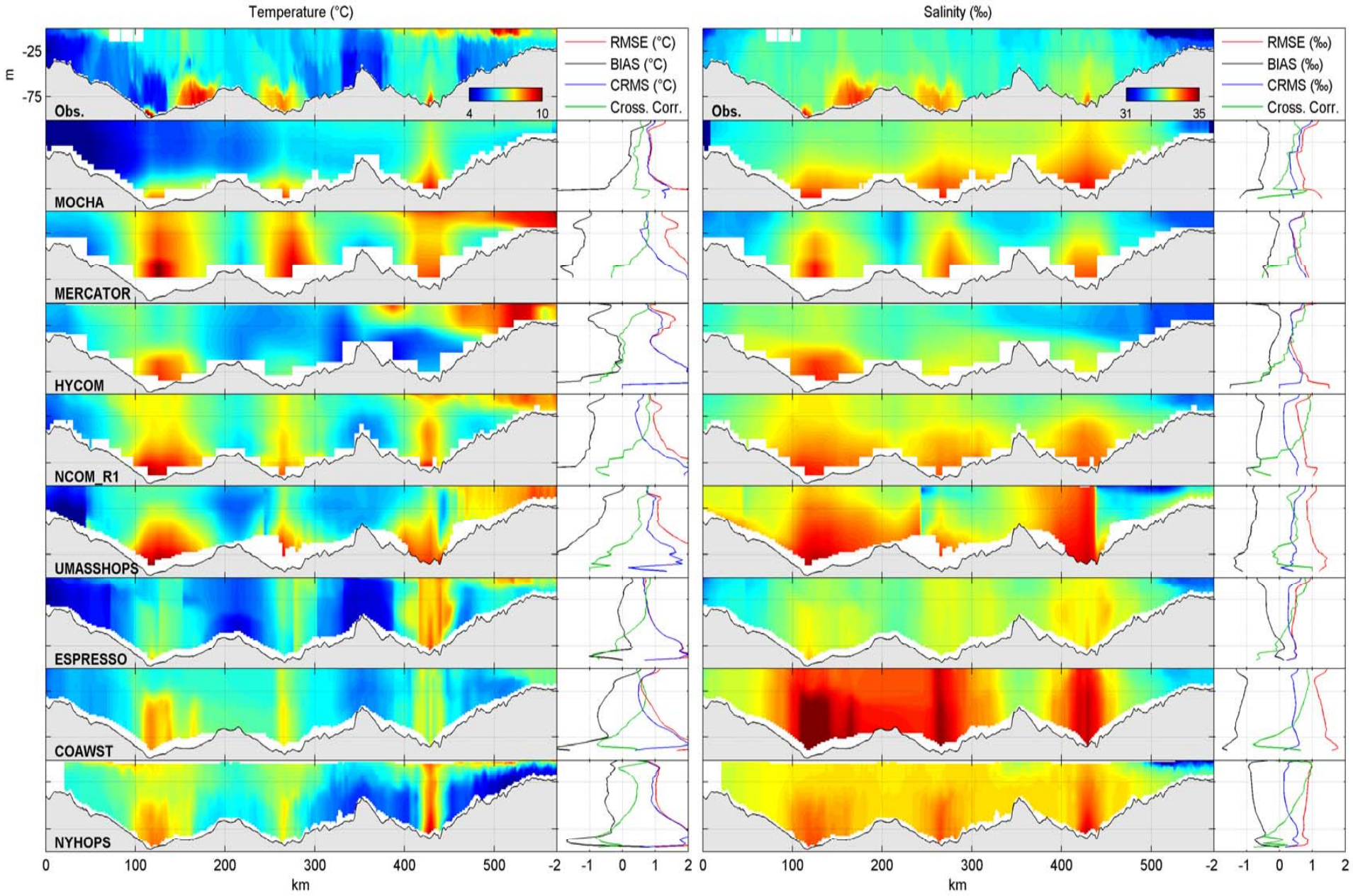
Decrease in forecast skill is consistent with de-correlation time scales in the shelf-break front of o(1 day) derived from observations

Multi-model skill assessment: 7 real time models of the Mid-Atlantic Bight

Comparison to MARACOOS gliders and NMFS CTD surveys in 2010-2011

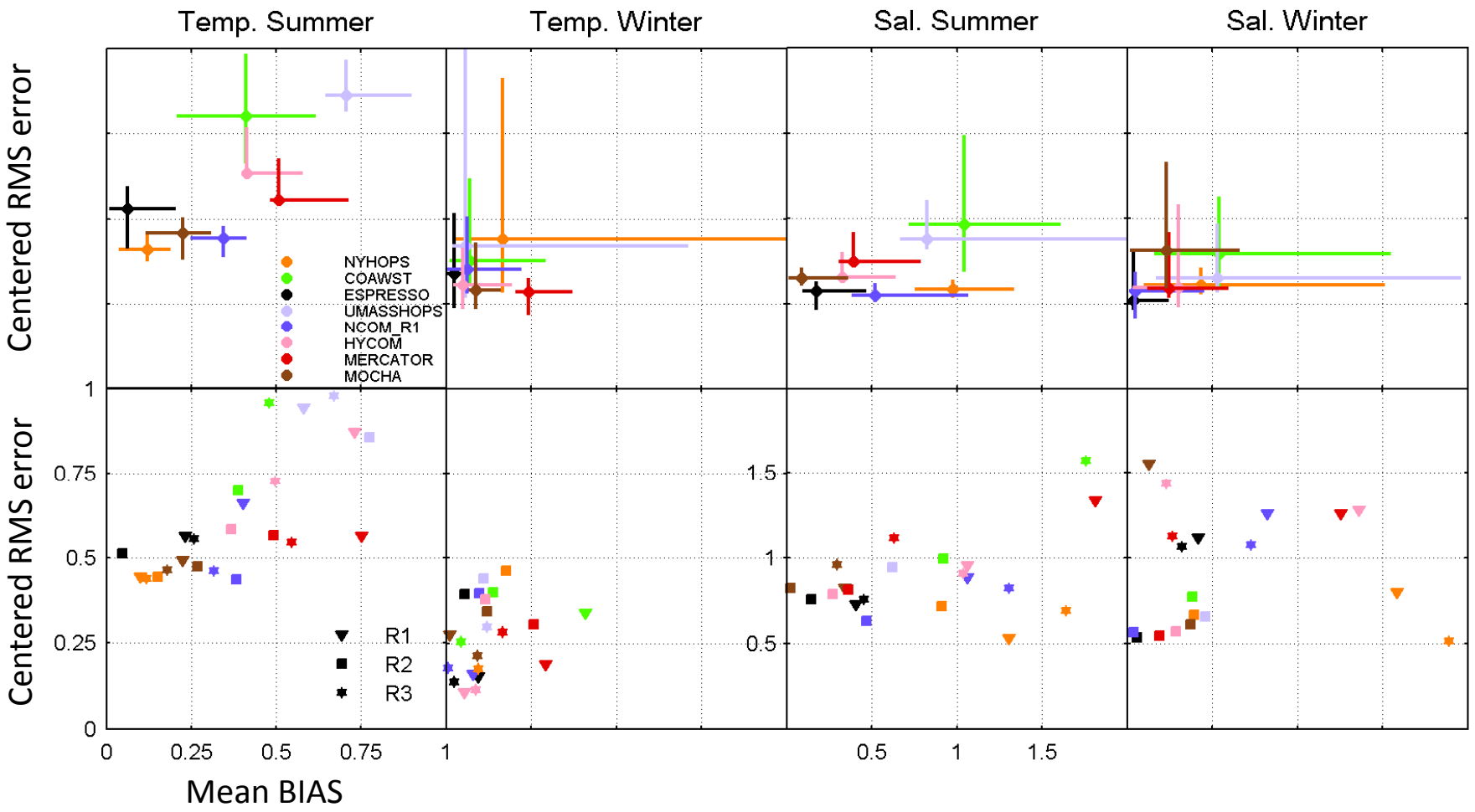


MAB March 2010



Multi-model Skill Assessment: 7 real time models of the Mid-Atlantic Bight

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



Summary

- Rutgers ROMS ESPreSSO 4DVAR 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
  - *Modest pre-processing for QC, binning to independent obs.*
  - *Bias removal essential: use mean ocean state from 4DVAR-based climatology*
  - *Data ingest exploits web services (OPeNDAP/THREDDS) and interoperability of data conventions (CDM, CF-conventions, NetCDF/HDF)*
- Useful skill for real-time applications
  - 4 days for temperature and salinity; 1-2 days for velocity
- *Output of full model solution to THREDDS/FMRC Forecast Model Run Collection*
  - Available to high-level users servicing numerous end-users
- Future developments
  - Adjoint sensitivity and Observation Impact analysis using variational tools
  - representer-based observing system design/operation
  - Nested 4DVAR; Coupling to waves and meteorology