Adjoint-based ensemble prediction in the Mid Atlantic Bight (Northeast US coast)

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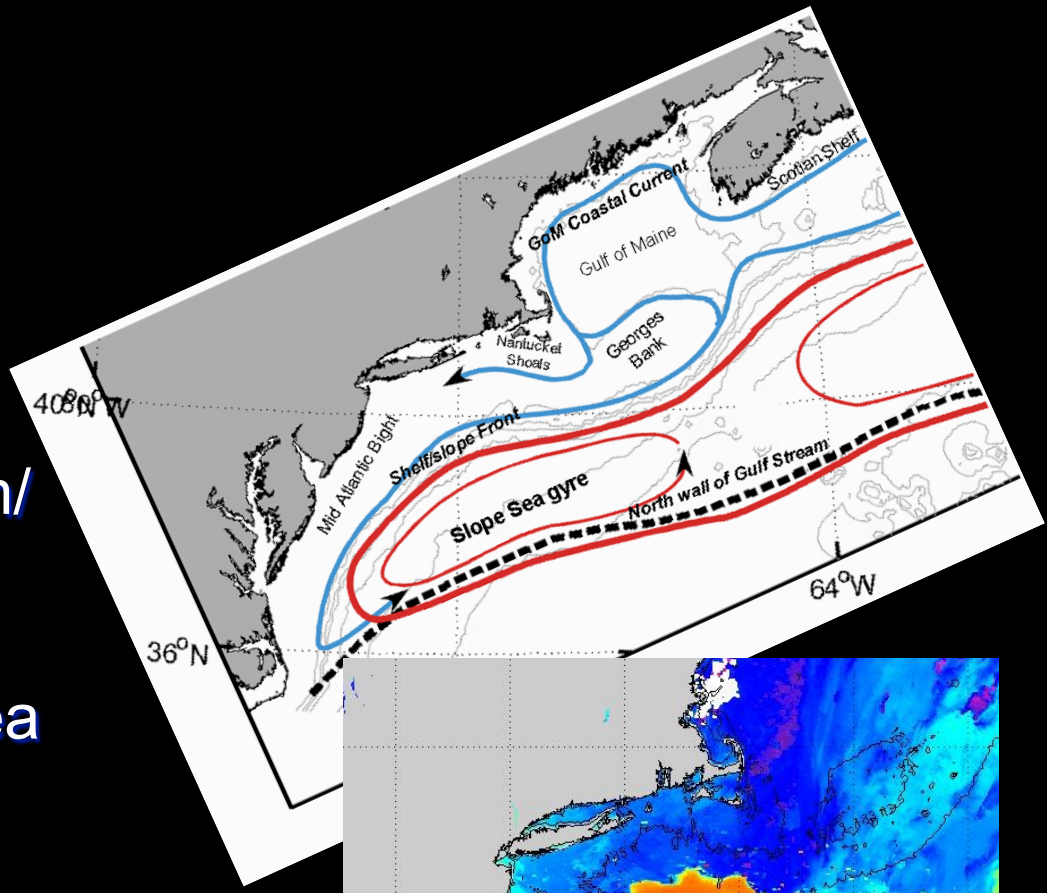
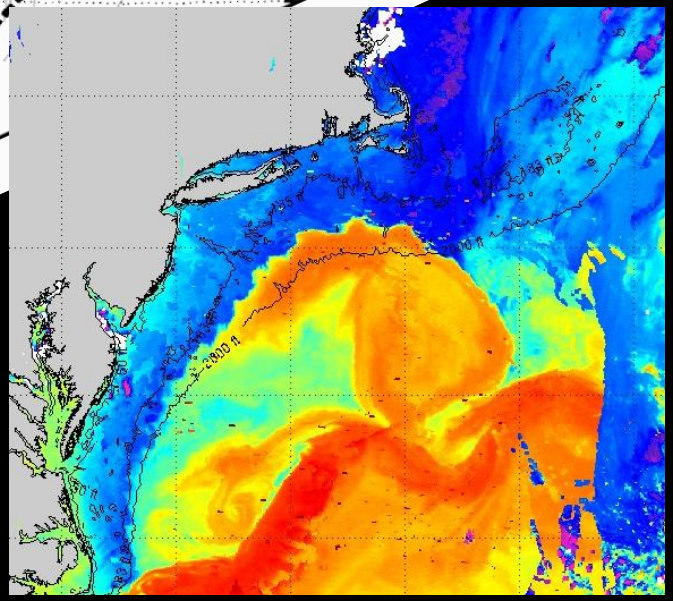
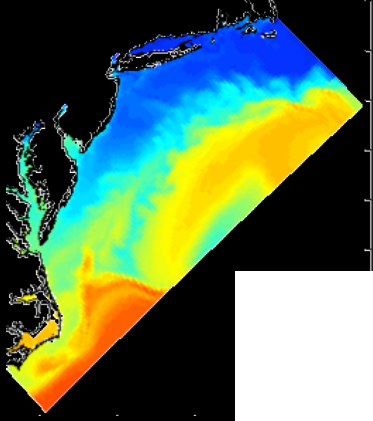
The Mid Atlantic Bight (MAB)

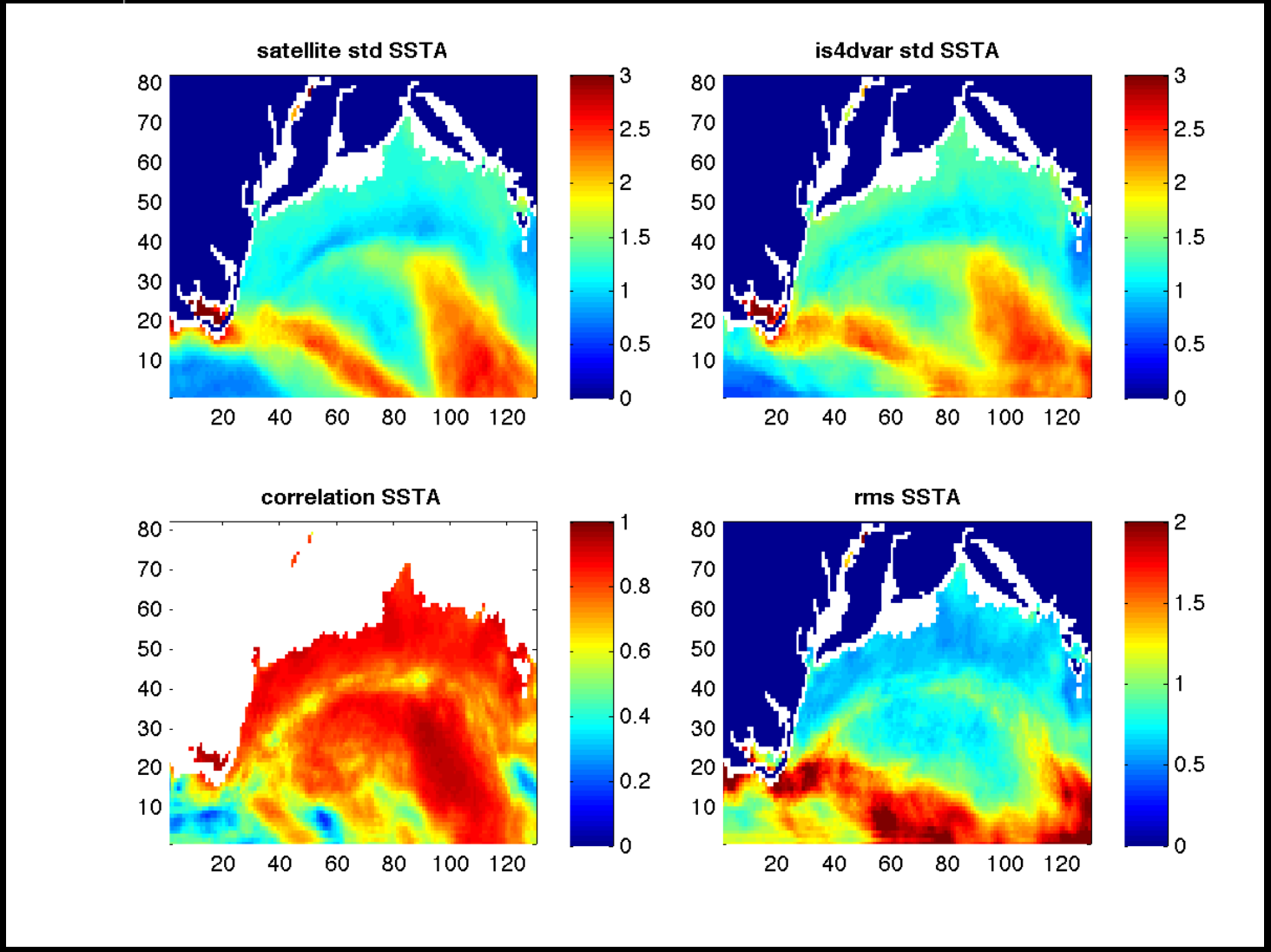
- wide shallow shelf separated from Gulf Stream by the Slope Sea
- Shelf/Slope Front (~0.3 m/s) at shelf edge
- Gulf Stream rings frequently enter Slope Sea and impact shelf
- Strong tides
- Shelf variability highly affected by atmospheric forcing.



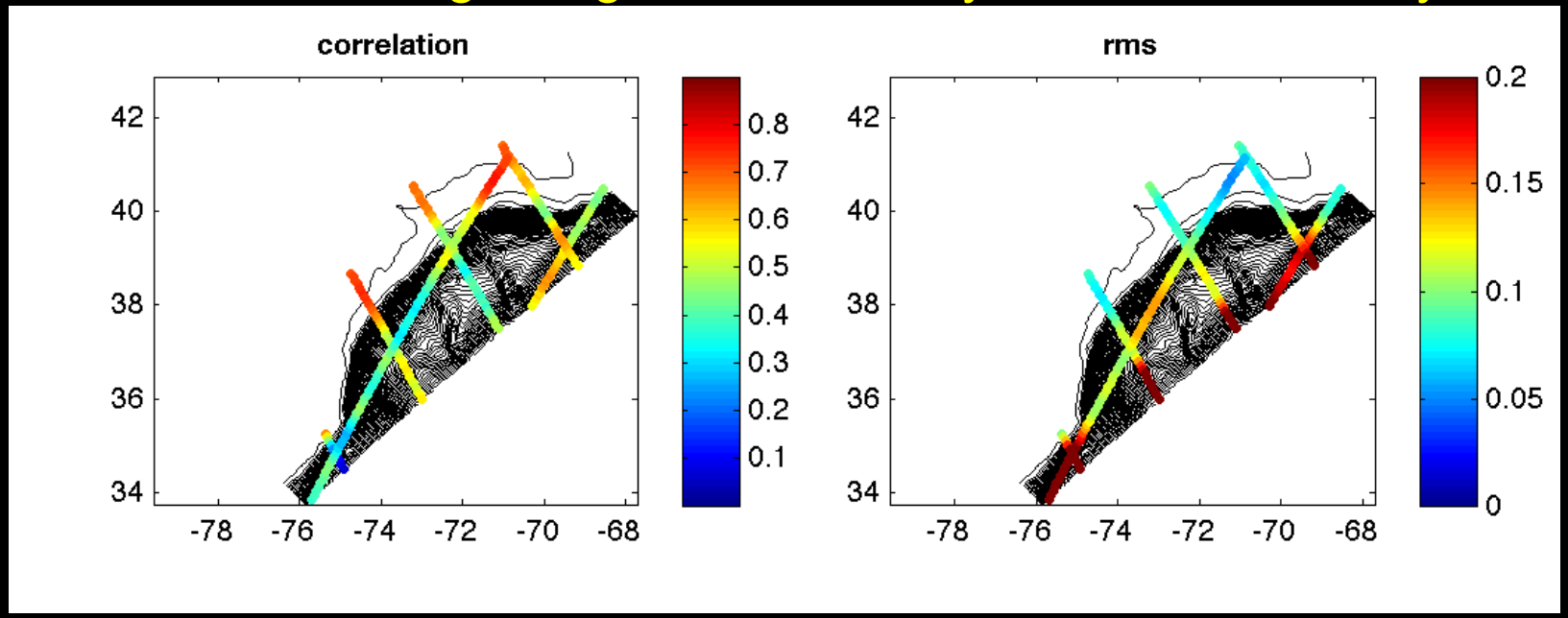


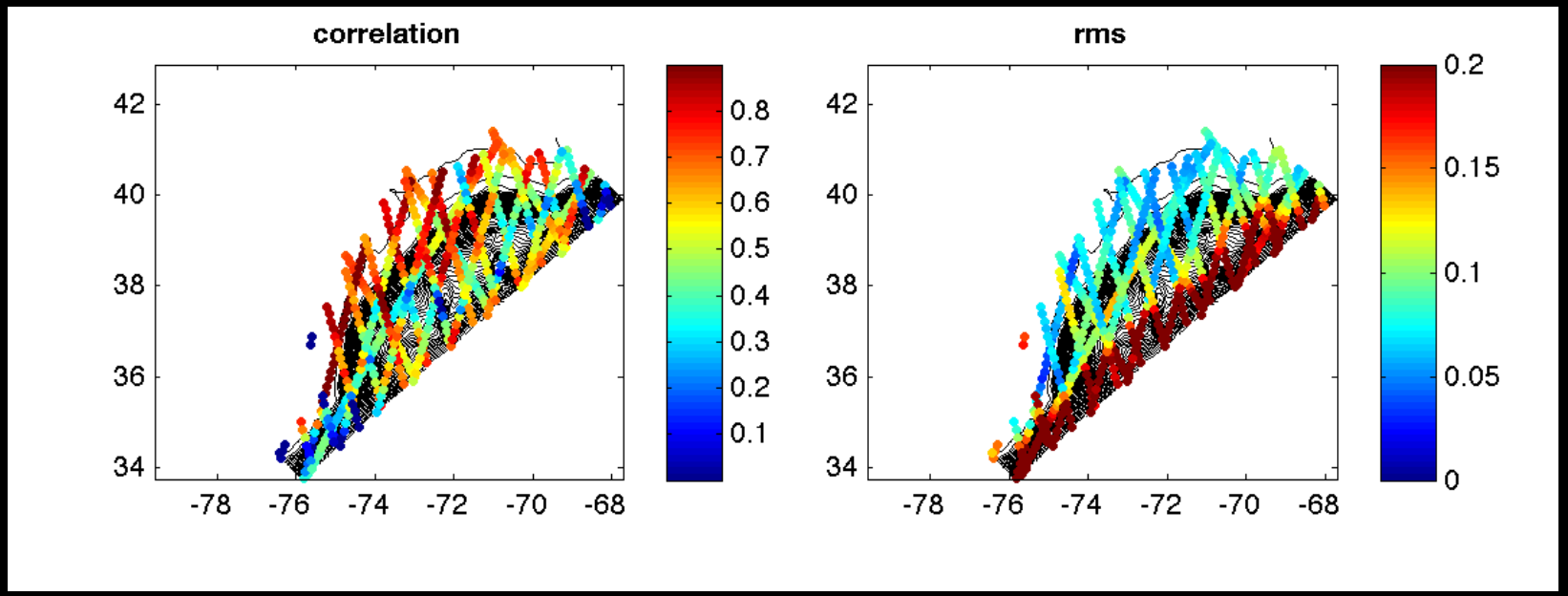


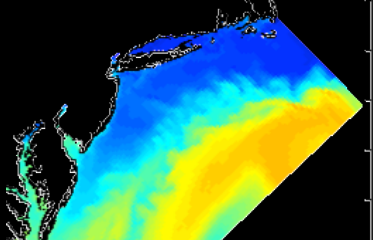
Skill in hindcasting mesoscale SST by the assimilation system



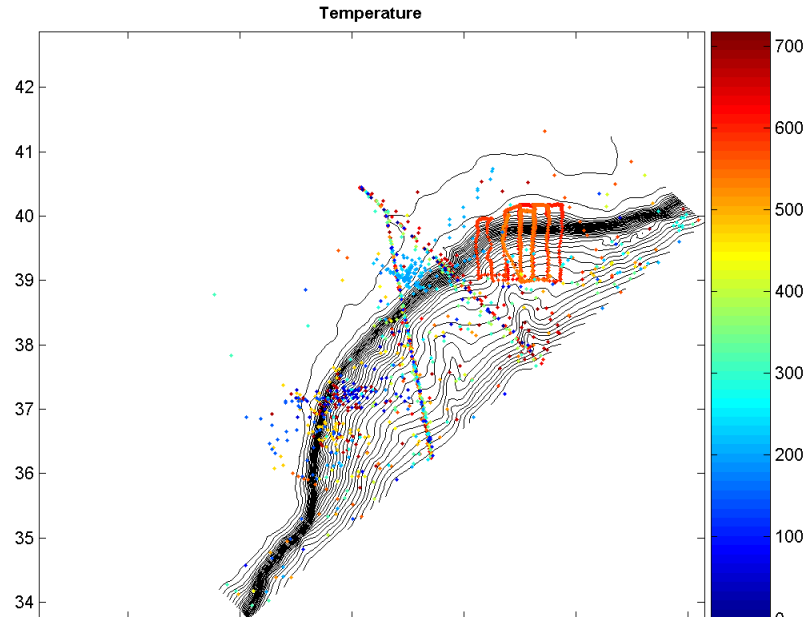
Skill in hindcasting along-track SSHA by the assimilation system

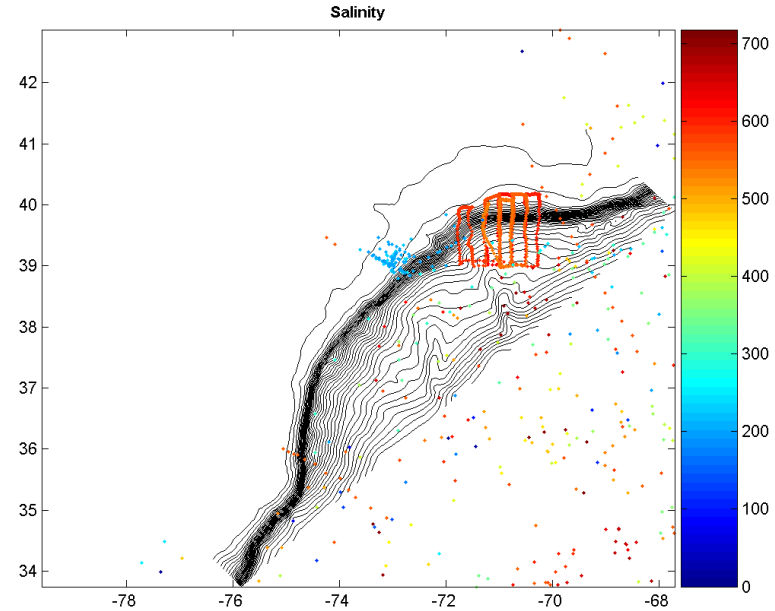


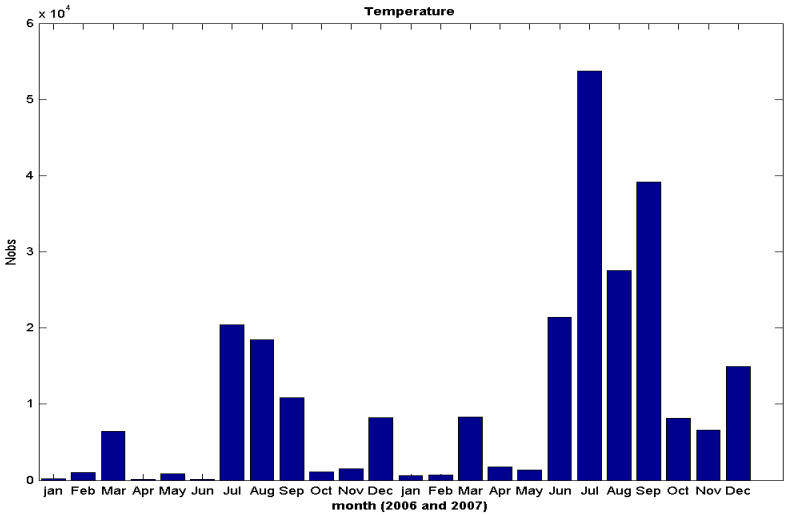


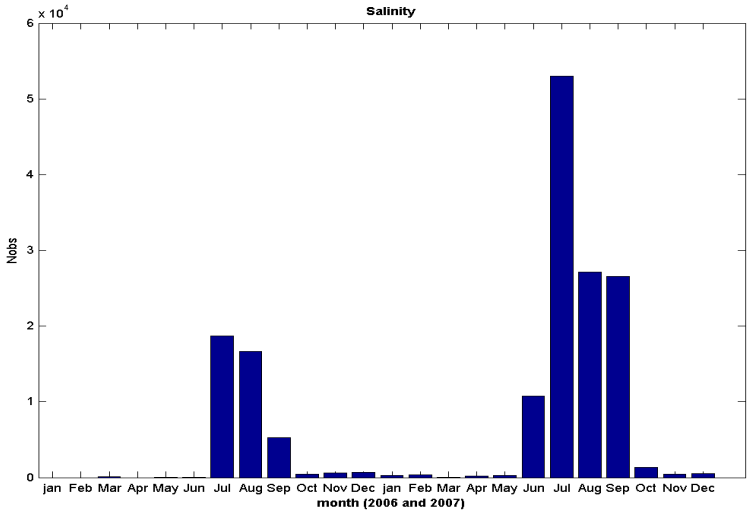


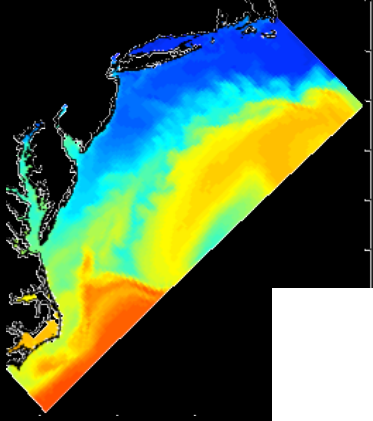
Large set of T and S observations from CTD, gliders, XBTs for 2006 (SW06) and 2007



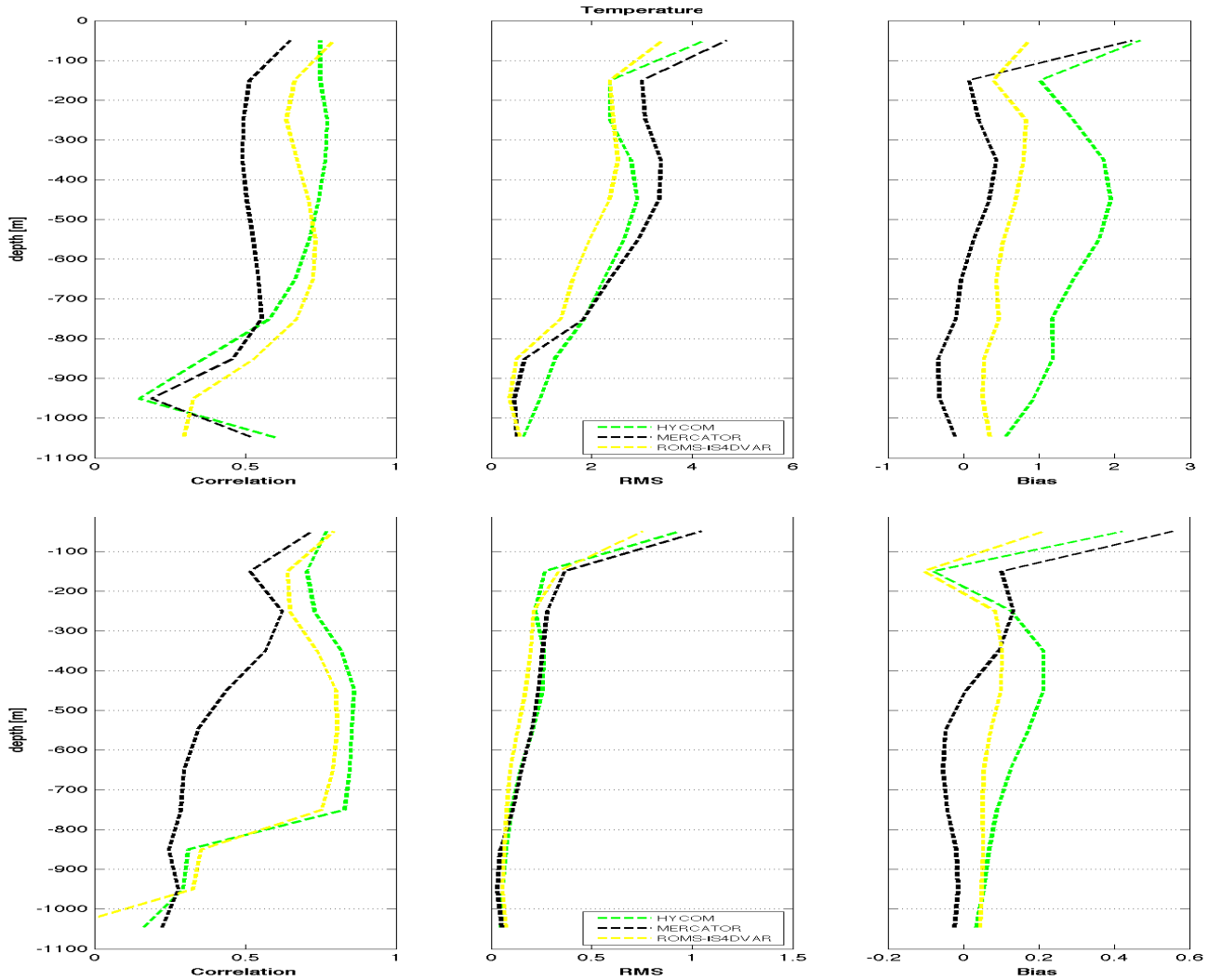


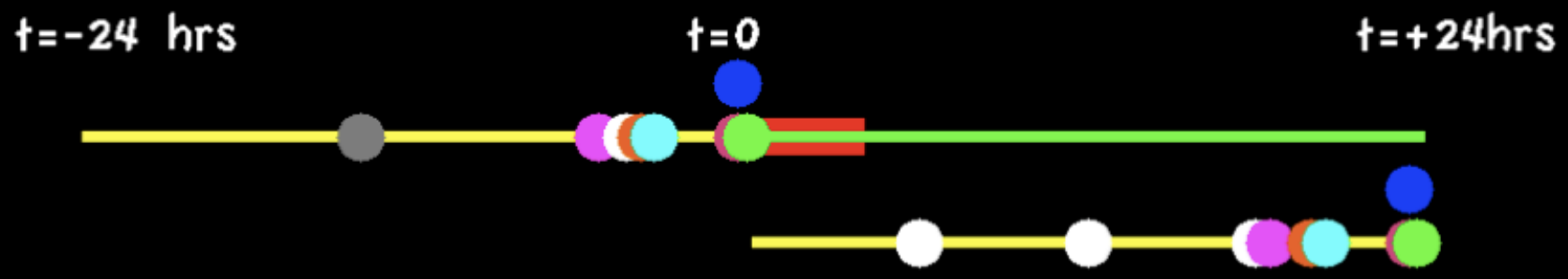






Correlation, rms error and bias in hindcasting the vertical structure of temperature and salinity. Note: these variables were not assimilated.





@ 3:30am: Assimilation of last 3 days of observations (~4 hrs)

@ 7:30am: Forecast for the next 58 hrs

@ 1:15pm and 10:15pm: UNH pushes via ftp the RADS data to RU

@ 10:00pm: get BF from HYCOM, interpolate, and correct T and S

@ 11:00am: get NAM surface forcing from NCEP

@ 11:30pm get 1-day composite RSS blended SST (B-SST) from CW

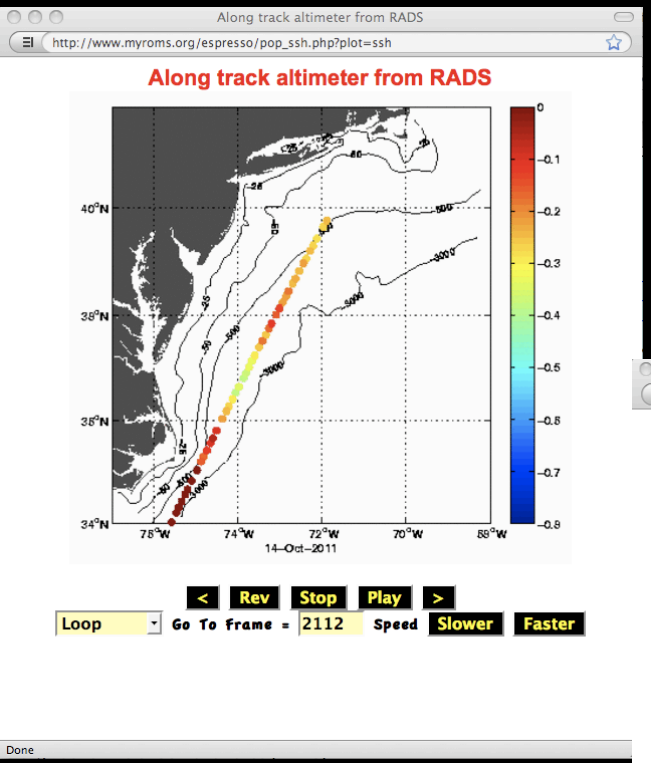
@ 12:00am get river discarge from USGS

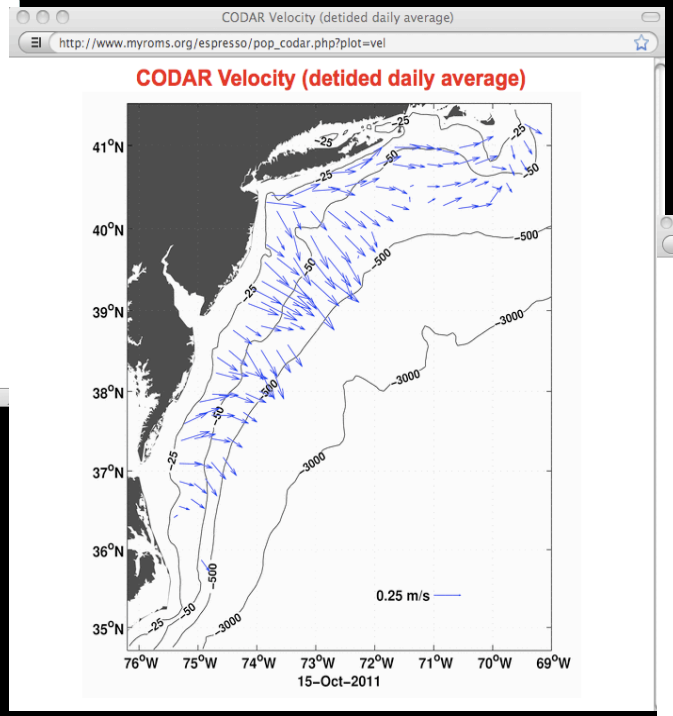
@ 3:00am get IR SST passes, proc. errors, and combine with B-SST

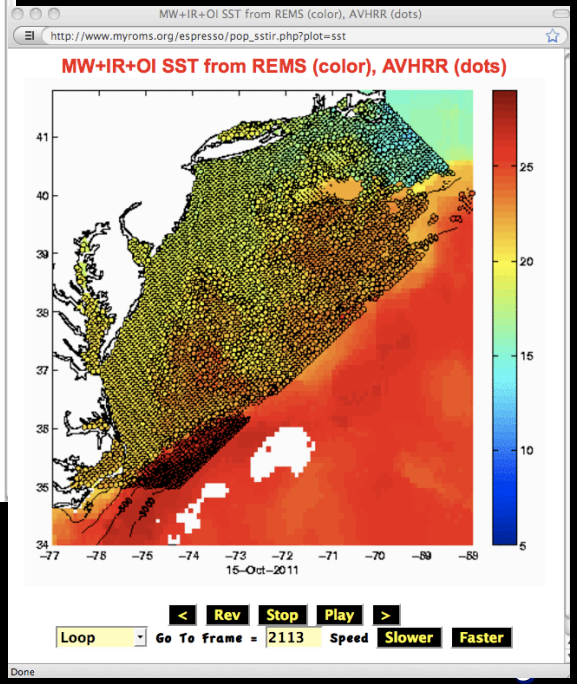
@ 3:00am get and process CODAR

@ 3:10am prepare the Jason-1 along track data

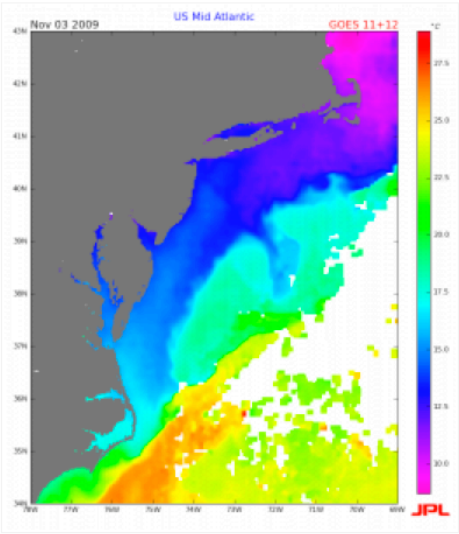
Operational forecast assimilates SSH, SST, and CODAR data

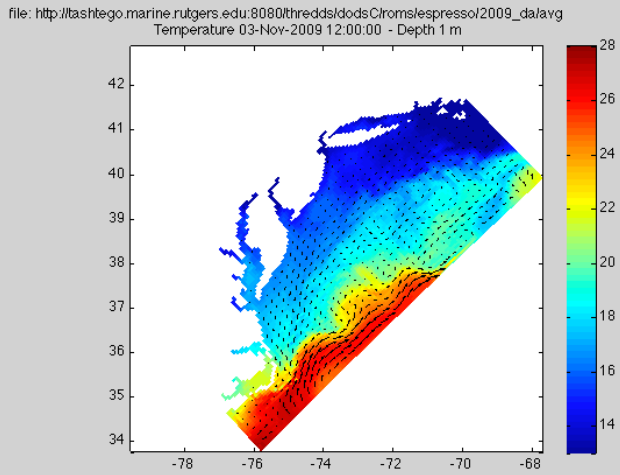


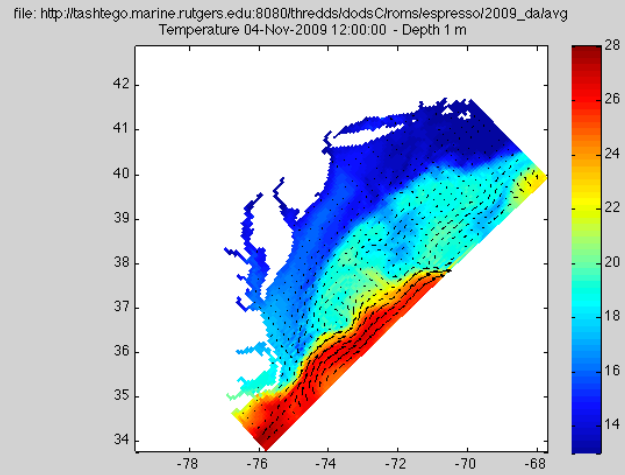




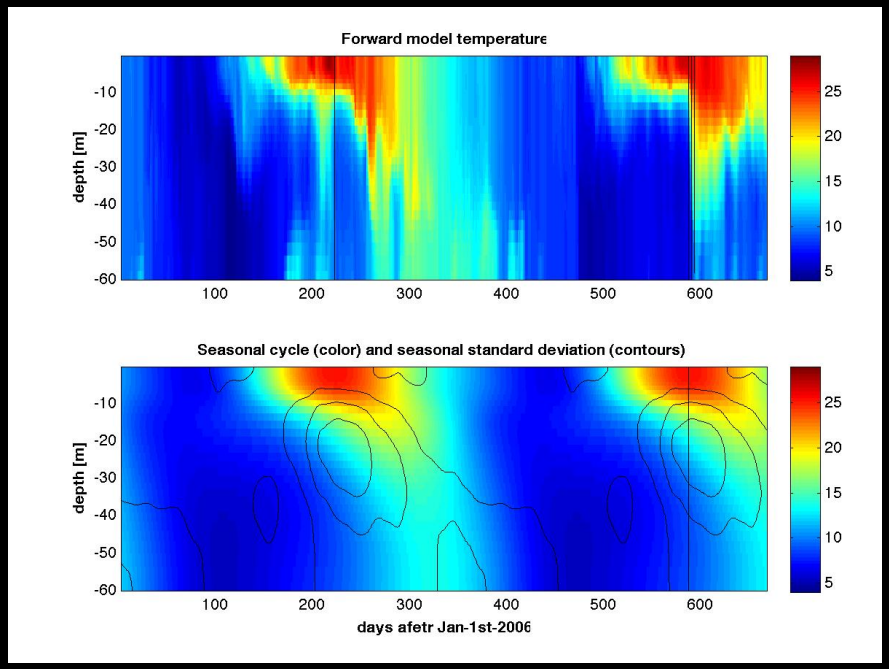
Impact of individual passes of AVHRR vs 1-day SST composites

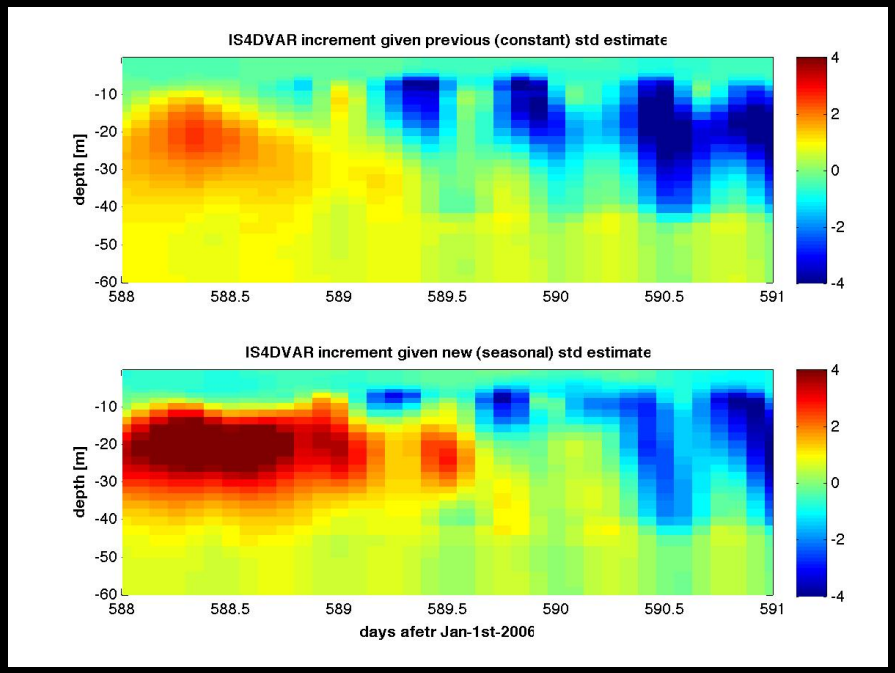






Impact of seasonality of the modeling of the background standard deviation





In the shelf the evolution is governed by the surface forcing at short led times (days) …

In an operational framework a forecast never will exactly verify because of the chaotic nature of the atmospheric variability

How to generate realistic atmospheric forcing?

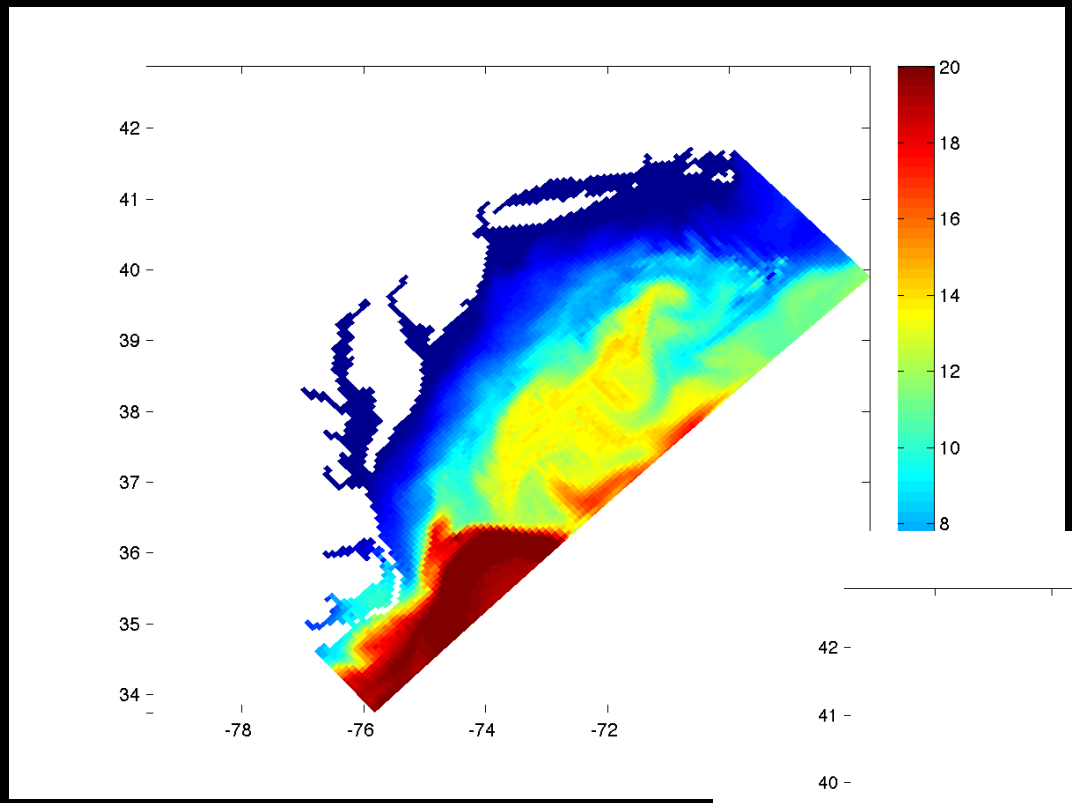
Given an atmospheric forecats and a collection of historical data an ensemble of atmospheric realizations can be created

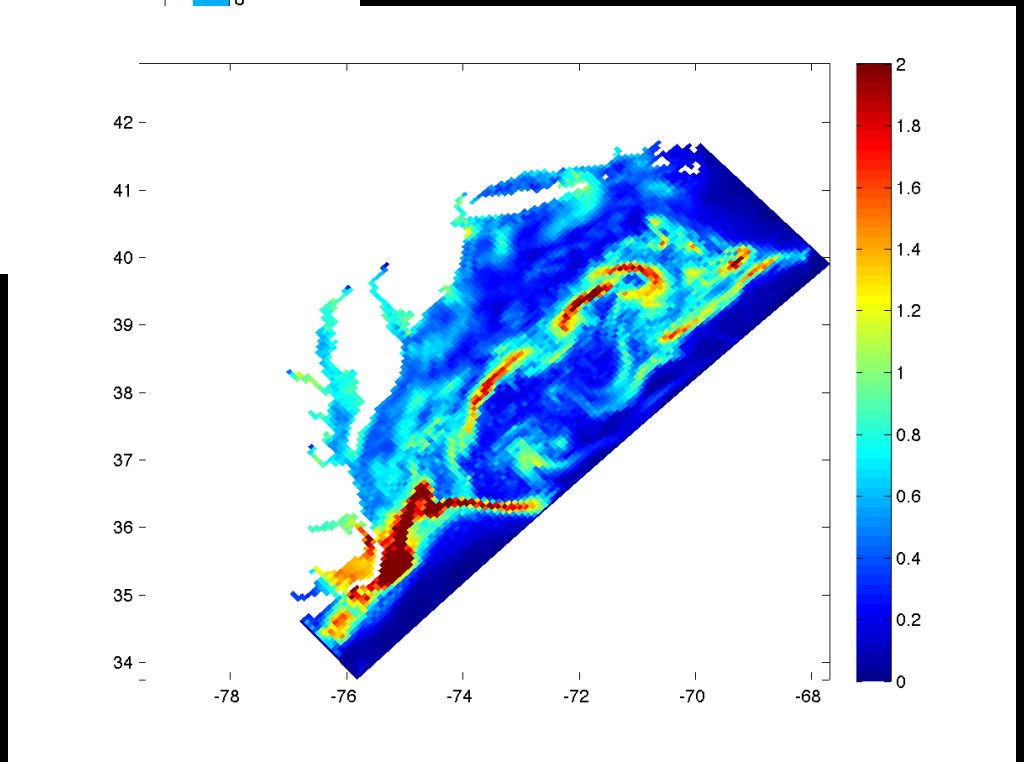
$$\text{ensemble}(t) = c(t)*\text{forecast}(t) + (1-c(t))*\text{historical}(t)$$

where $c(t) = \exp(t/Tau)$ is the "credibility"

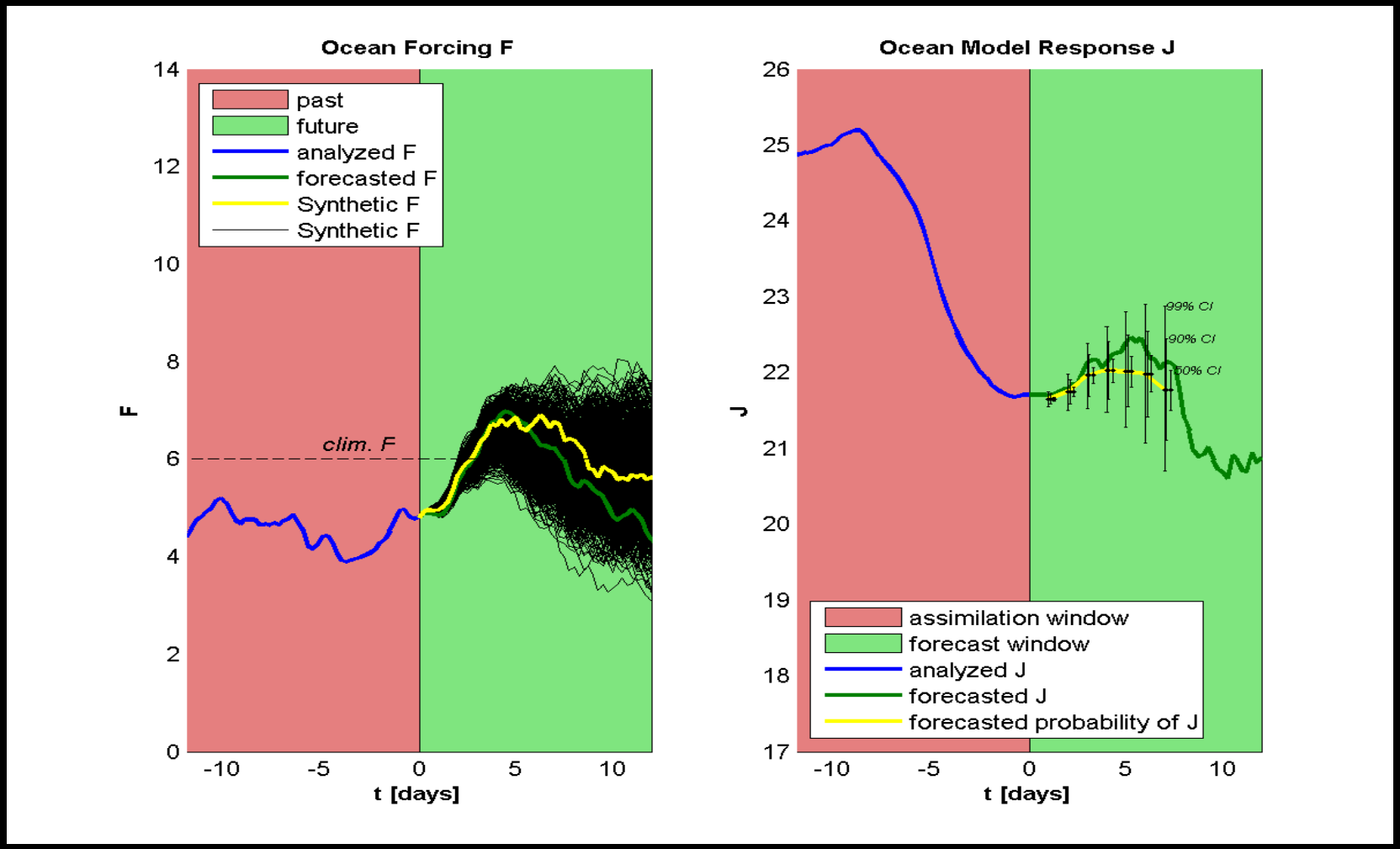
We use statistics from NAM atmospheric analysis from years 2007-2010 and Tau = 3 days.

SST forecast for Feb 14 initialized Feb 10:





We can avoid hundreds of non-linear integrations if we characterize the state of the ocean by an index of interest



Alternative approach:

- The adjoint model provides the sensitivity to a given index J
- In the assimilation stage the sensitivity to changes in initial conditions is used to find the best fit to observations
- It also provides the sensitivity to changes of the atmospheric forcing. Therefore the model response (quantified by J) to different atmospheric realizations can be found without having to integrate the model hundreds of times!

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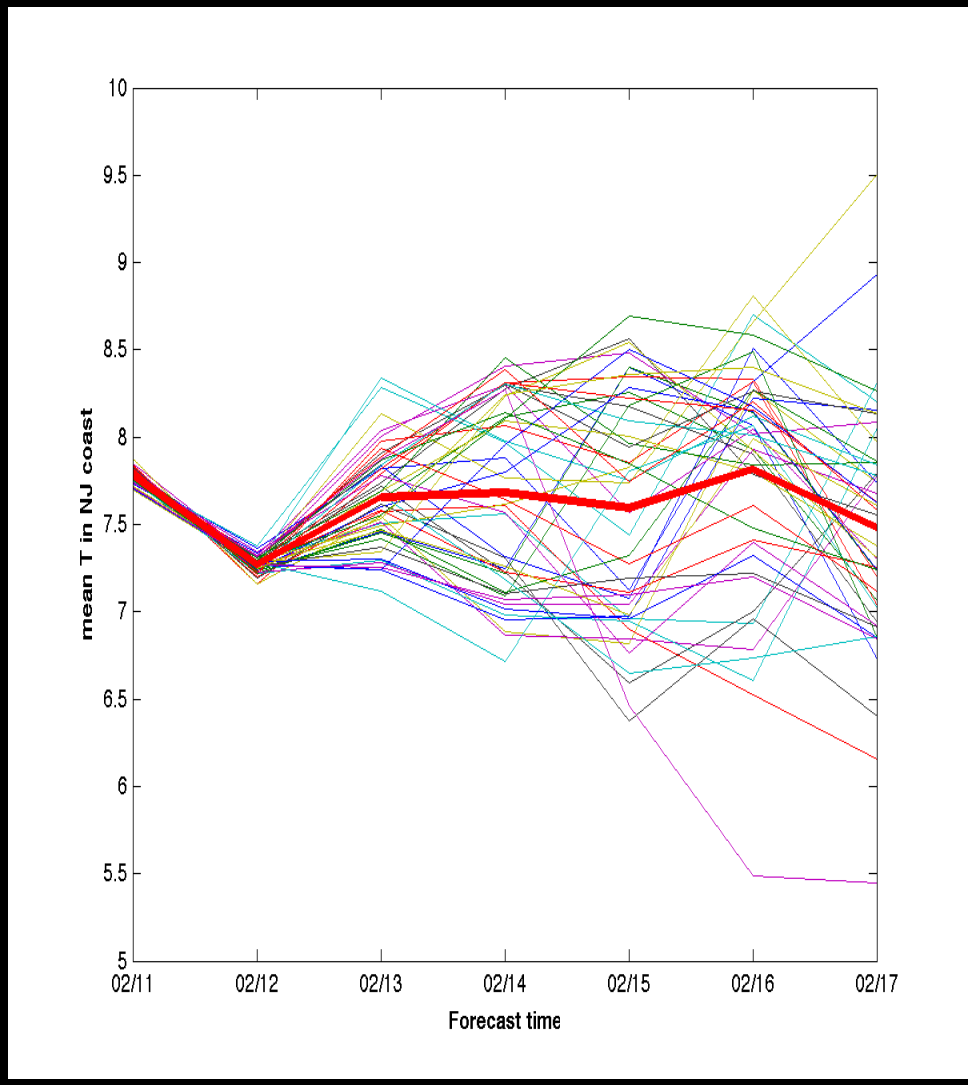

Summary

The operational version of ESPRESSO uses 4-dimensional variational (4DVAR) data assimilation to integrate a 3-dimensional coastal model (ROMS) with near real-time along track SSHA from Jason-2, SST from different satellite sensors, and high frequency radar surface currents.

Comparison with not assimilated ENVISAT SSH data, and insitu temperature and salinity observations suggest good skill in nowcasting the 3D ocean state.

In an operational framework we need to propagate the error inherent in the forecasted atmospheric flow into the forecasted ocean state.

The property of the adjoint model to act as a sensitivity operator allow us to measure the divergence of model trajectories (quantified by an index) without having to perform multiple integrations of the full nonlinear model.

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