Improved Representation of Eddies in Realtime Fine-Resolution Forecasting Systems Using Multi-Scale Data Assimilation of Satellite Altimetry

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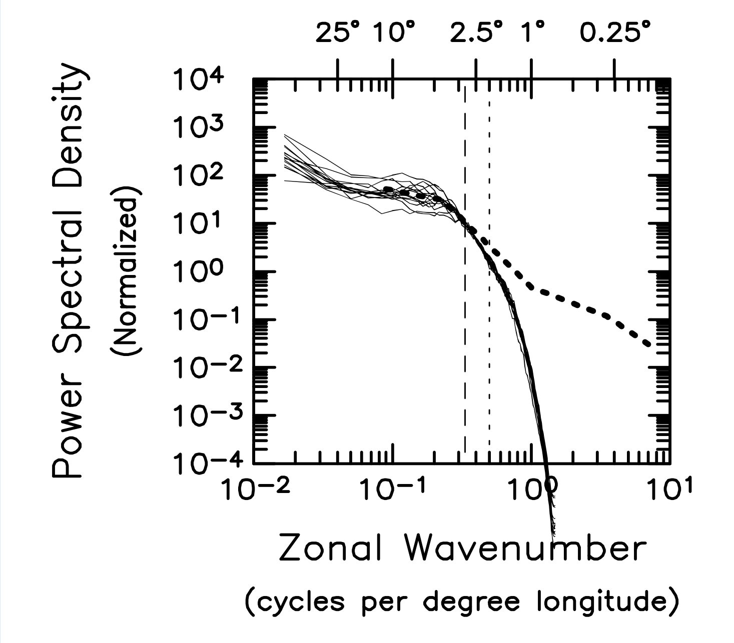
How Does the Altimetry Data Impacts Representation of Meso-Scale Eddies in Data Assimilation?

In Data Analysis

- Eddies down to 100 km along track (?)
- Eddies down to 200 km in 2D maps, with reduced amplitudes approaching 200 km (e.g., Chelton et al., 2011)
- RMS of the difference as large as 10 cm between the OI maps from four and two altimeters (Pascual et al., 2006)

AVISO vs Along Track



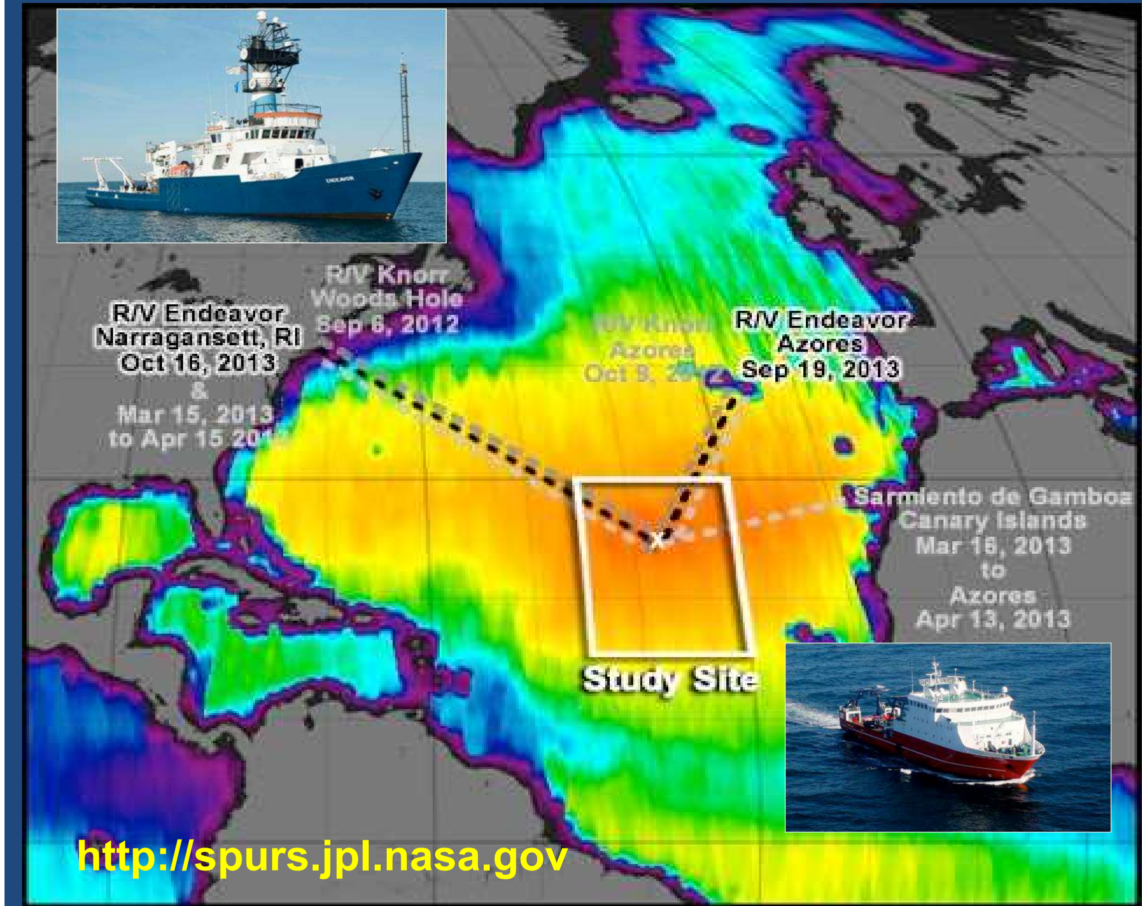
(Chelton et al, 2011)

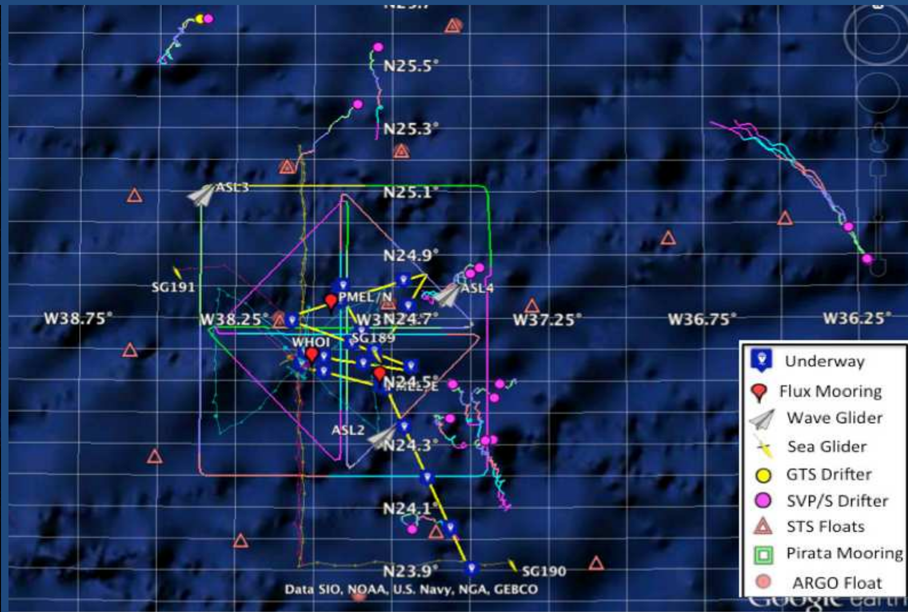
In Data Assimilation

- Frontogenesis deterministic conditioned on the accurate placement of the mesoscale eddies (Jacobs, 2014).

Objective: Assessing the impact of altimetry data on eddies smaller than 200 km

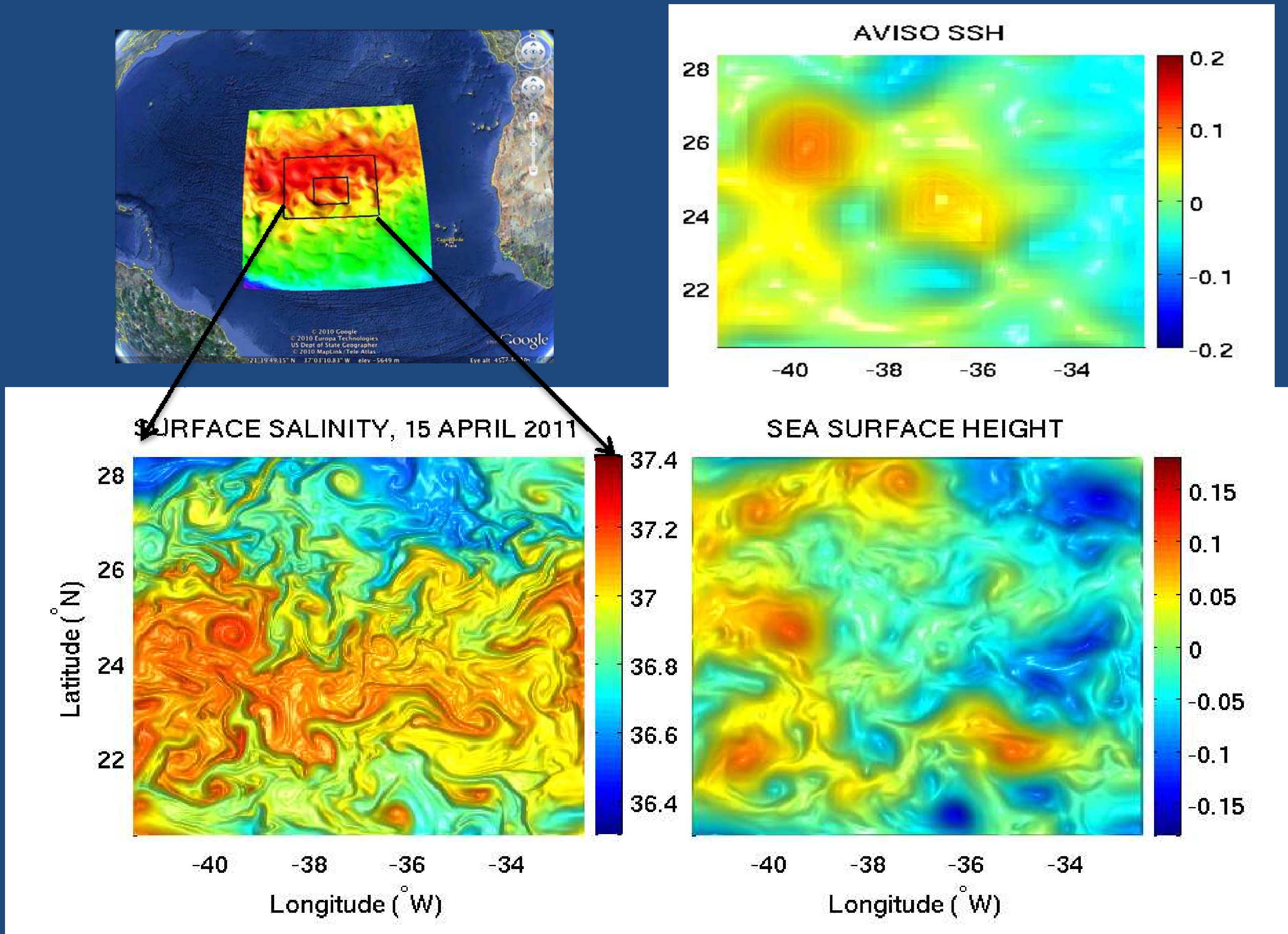
Salinity Processes in the Upper Ocean Regional Study (SPURS) Field Experiment





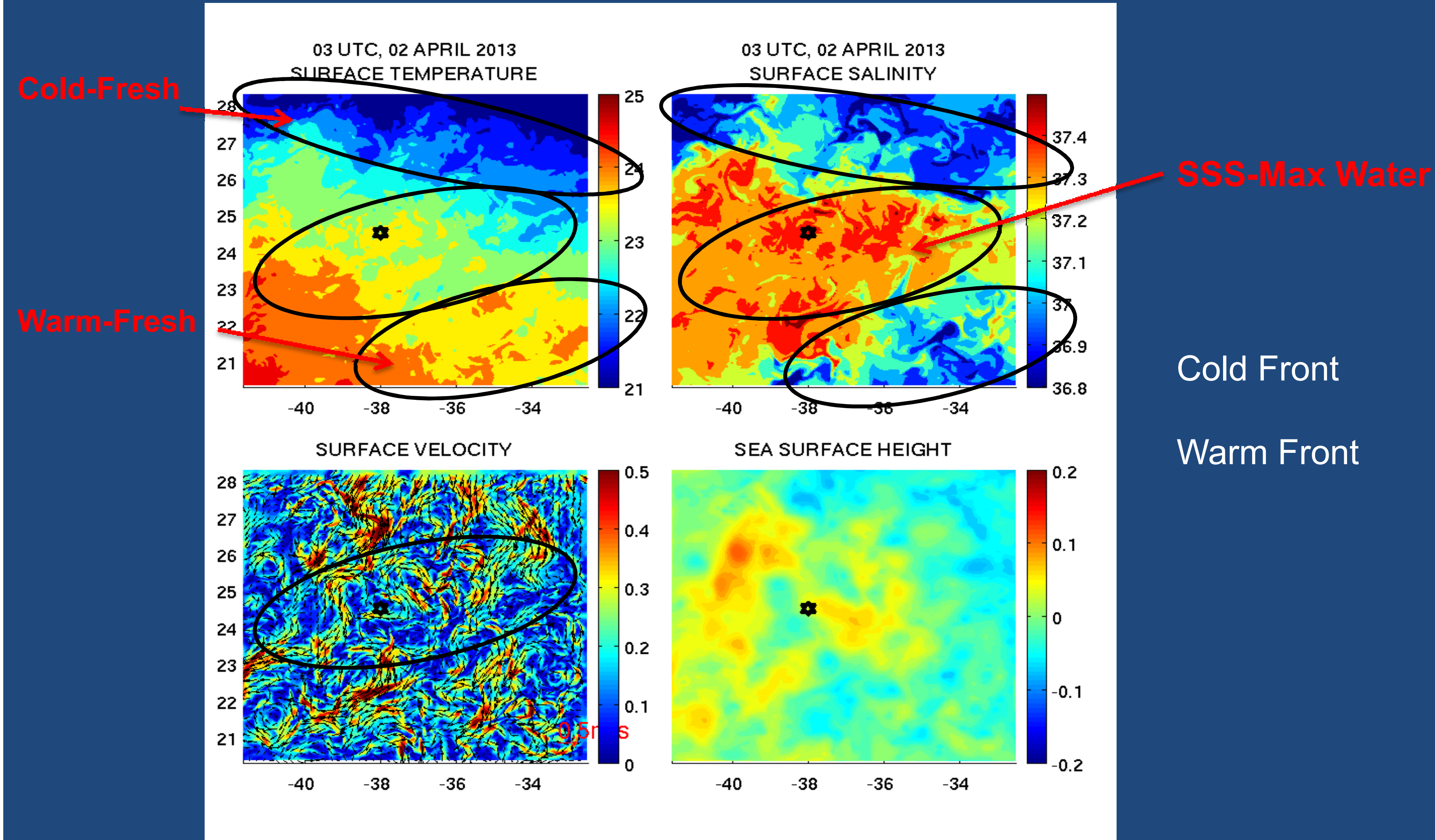
Screen capture showing the locations of all in situ measurements for a given day.

Eddies Spanning a Spectrum of Meso-Scales



- Eddies smaller the 100 km are energetic
- The spatial structures are finer in salinity

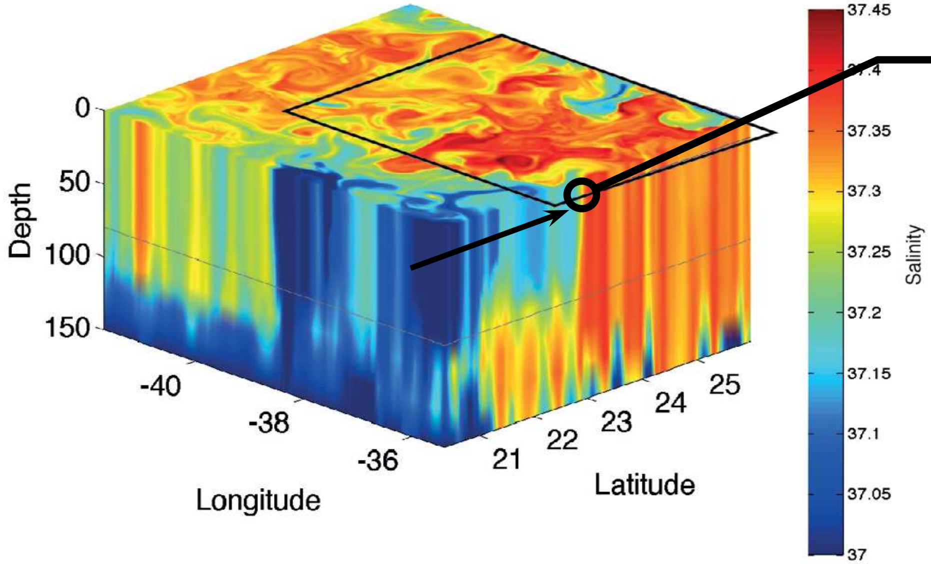
Maximum SSS and Convergence of Water Masses from Data Assimilation



Cold Front

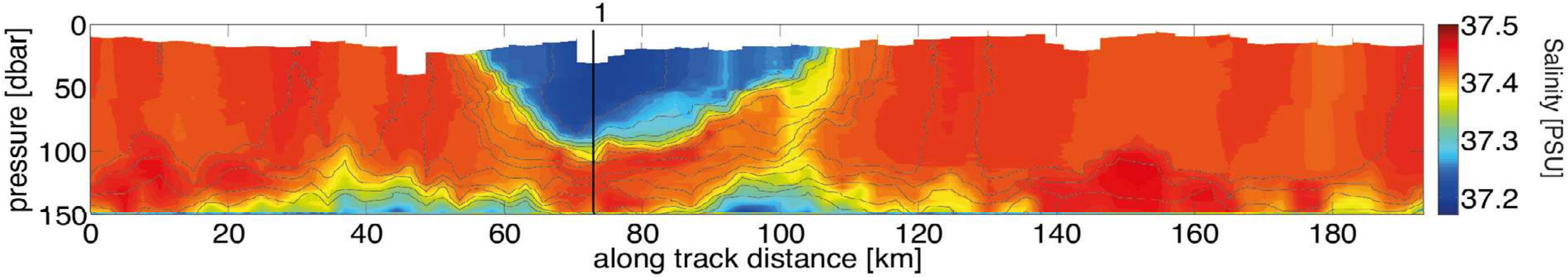
Warm Front

Data Assimilation Analysis and Observations



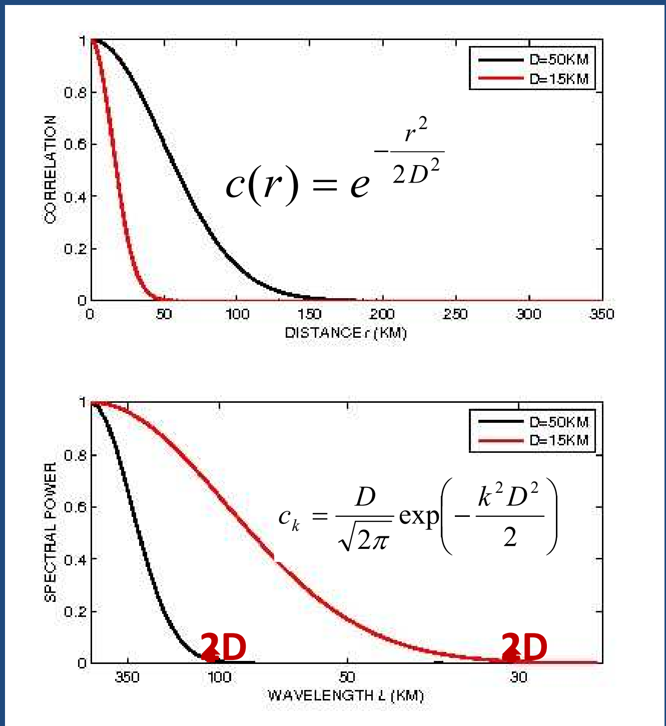
Comparison with survey data

- ROMS (2km resolution) reproduces an abundance of similar fresh features
- Lateral/vertical dimensions and surface characteristics are very similar to the in-situ data
- Northward advection from a fresh/warm body of water
- Fresh feature is dissipated on comparable time scale (~14-18 days)



(Busecke et al., 2014, JGR)

Multi-Scale Three-Dimensional Variational Data Assimilation Scheme and Experiments



$$x = x_L + x_S$$
$$B = B_L + B_S$$

Assimilate long-track altimetry, high and low resolution satellite SSTs and SSSs, and sparse in-situ data

$$\min_x J(\delta x) = \frac{1}{2}\delta x^T \left(B_L + B_S\right)^{-1}\delta x + \frac{1}{2}(H\delta x - \delta y)^T R^{-1}(H\delta x - \delta y)$$

Low resolution obs

$$\min_{\delta x_L} J(\delta x_L) = \frac{1}{2}\delta x_L{}^T B_L^{-1}\delta x_L + \frac{1}{2}(H\delta x_L - \delta y)^T\left(HB_S H^T + R\right)^{-1}(H\delta x_L - \delta y)$$
$$\min_{\delta x_S} J(\delta x_S) = \frac{1}{2}\delta x_S{}^T B_S^{-1}\delta x_S + \frac{1}{2}(H\delta x_S - \delta y)^T\left(HB_L H^T + R\right)^{-1}(H\delta x_S - \delta y)$$

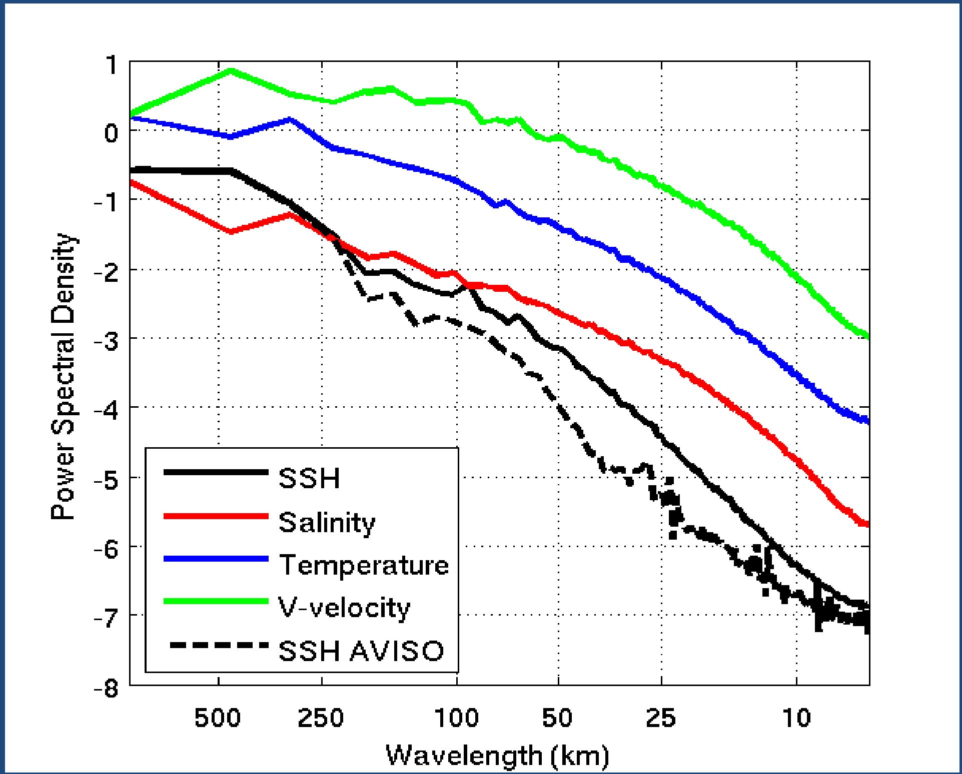
High resolution obs

(Li et al., 2012, CSR; 2014, JGR)

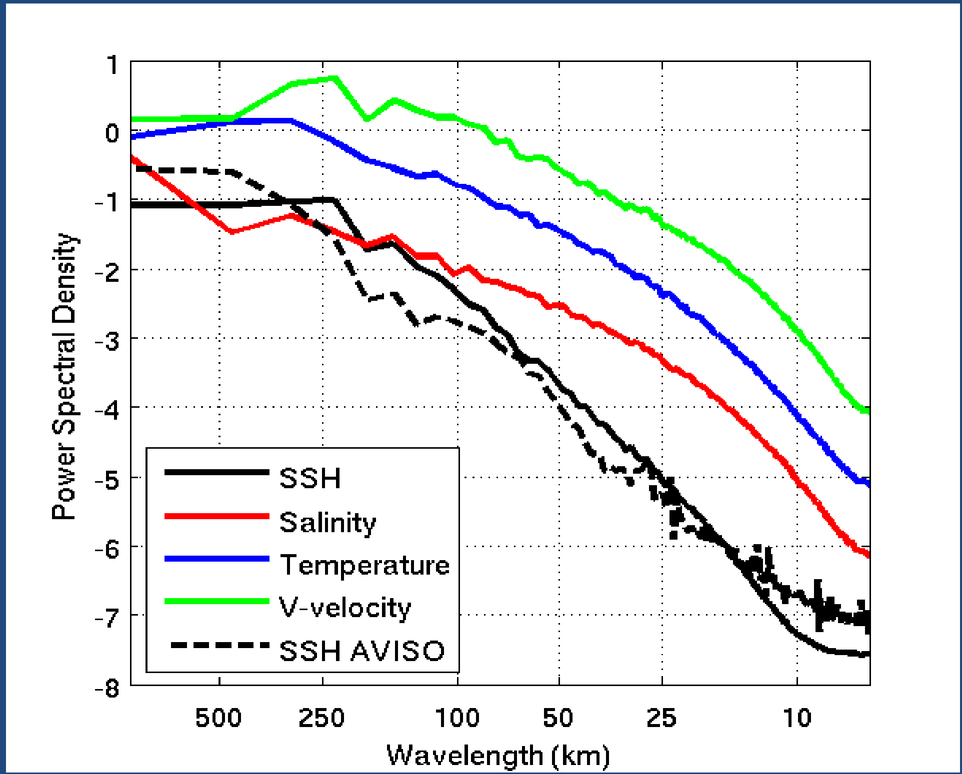
All observations are assimilated, including processed SPURS observations, ARGO profiles, and satellite altimetry and SST data. Data assimilated is performed twice a day.

Impact of Altimetry Data: Spectral Analyses

DA (SST and SSH only)



NO DA (After March 5)



March 18 through April 12, 2013, 23.0ºN to 26.0ºN

Data assimilation 1) effectively constraining the scales larger than 200 km

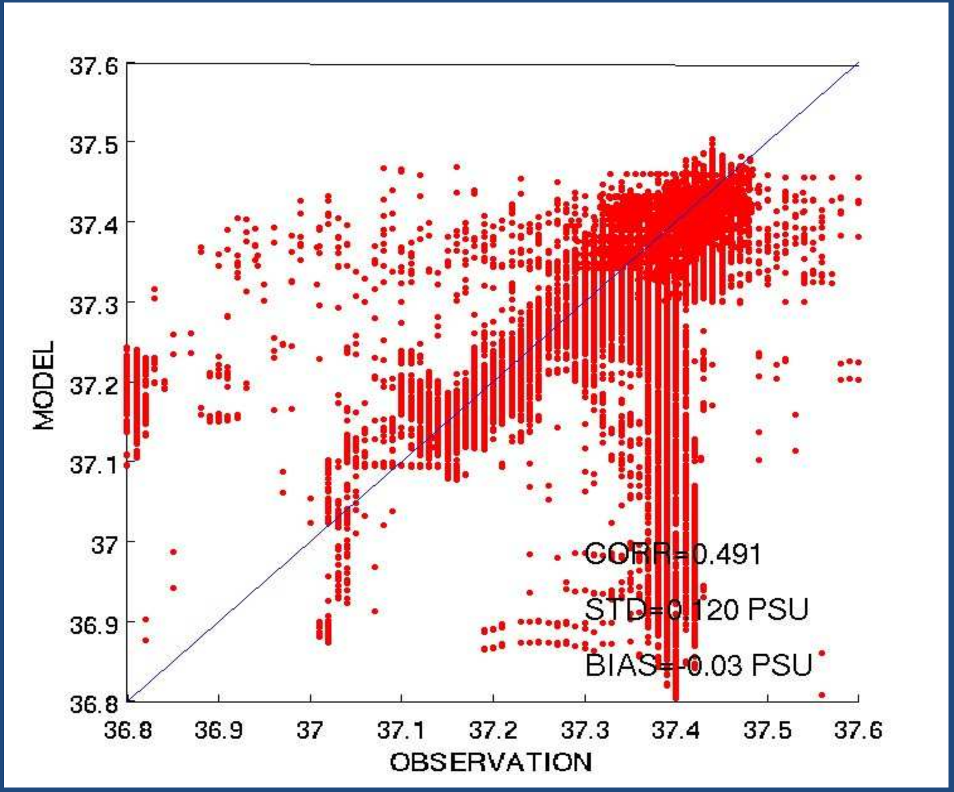
2) reducing the energy for scales from 200 km to 100km

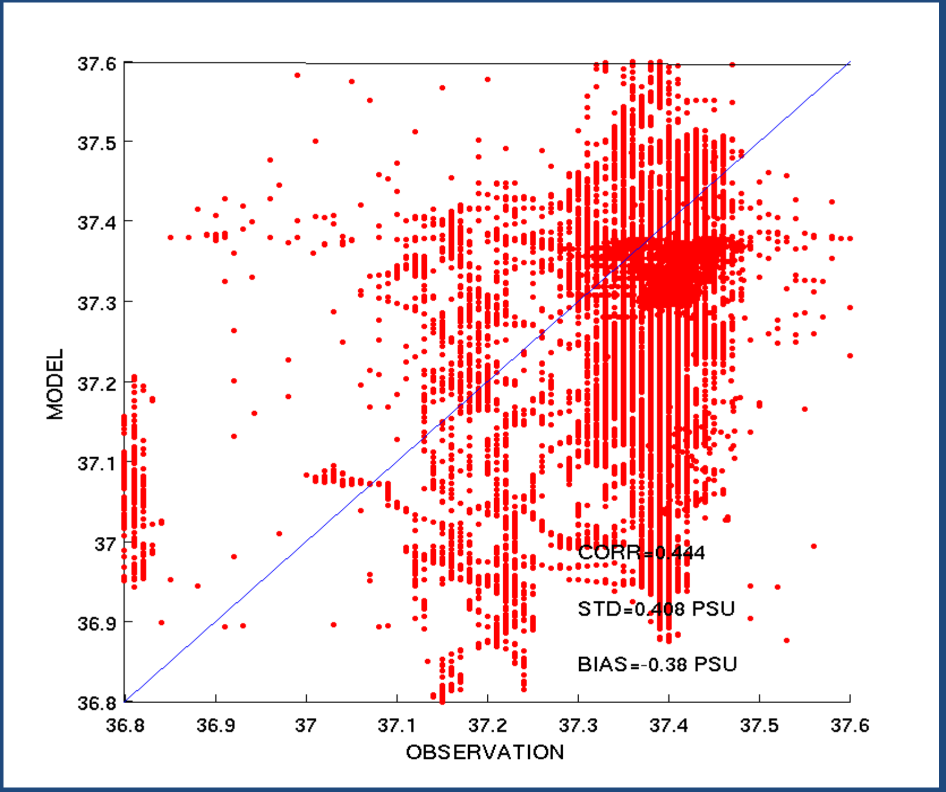
3) increasing the energy for the scales smaller than 100 km

Impact of Altimetry Data: Surface Salinity Evaluation

DA

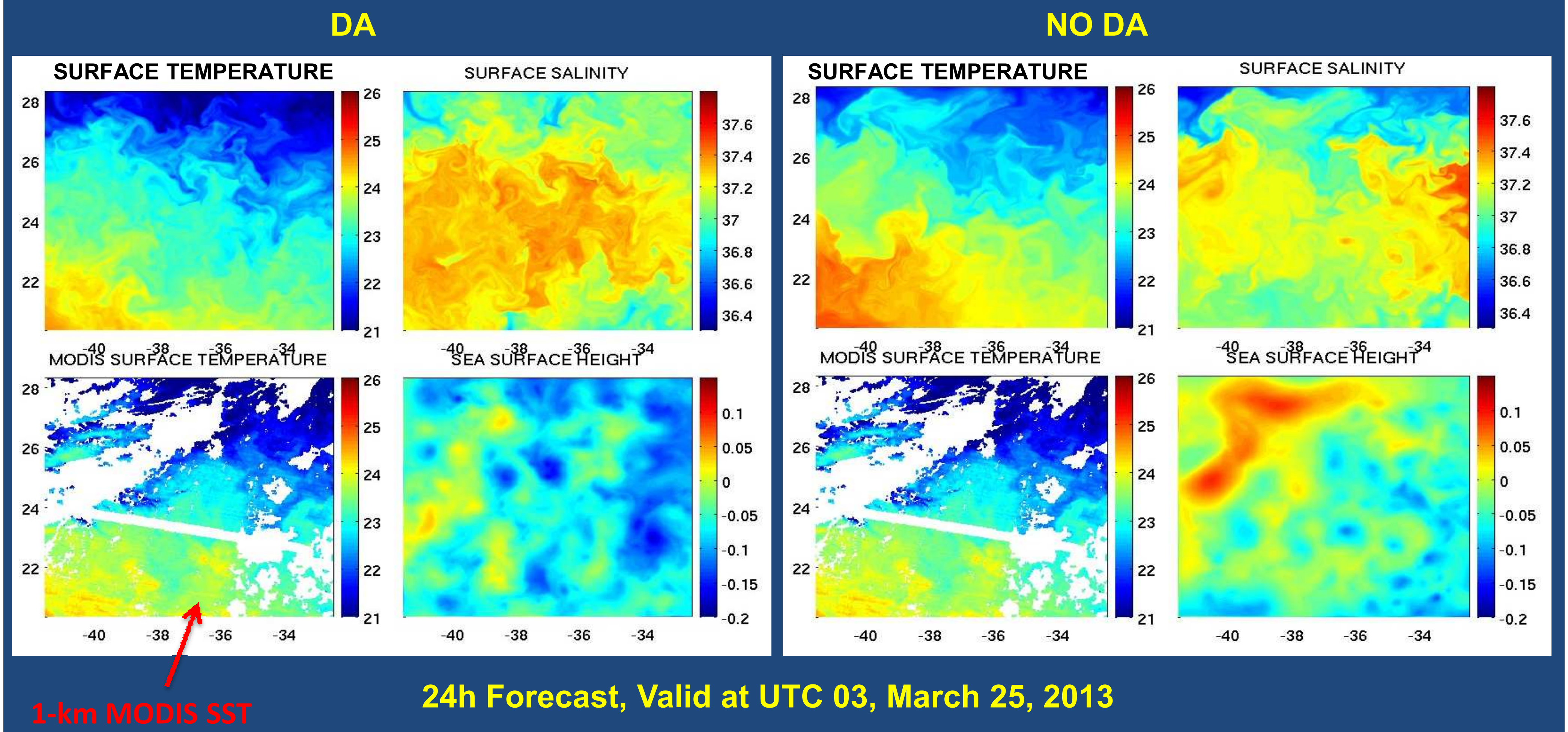
NO DA





March 18 through April 12, 2013, surface salinity observations from surface drifters and underway measurements

Impact of Altimetry Data: Spatial Pattern Consistency among Surface Temperature, Salinity and Height

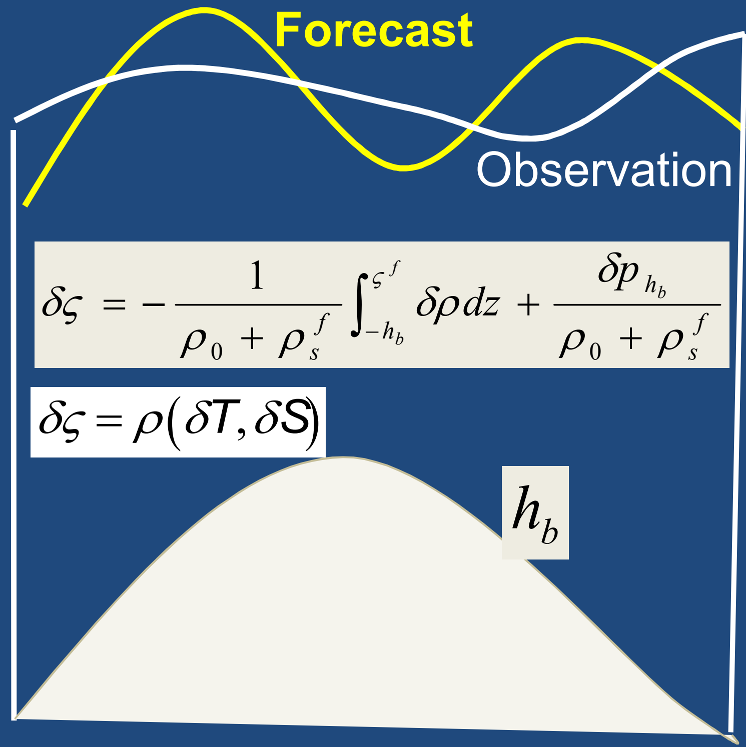


24h Forecast, Valid at UTC 03, March 25, 2013

How the Altimetry Data Impacts Small Meso-Scale Eddies?

$$\delta x = x - x^f$$

$$\delta x = \begin{pmatrix} \delta\varsigma \\ \delta u \\ \delta v \\ \delta T \\ \delta S \end{pmatrix}$$

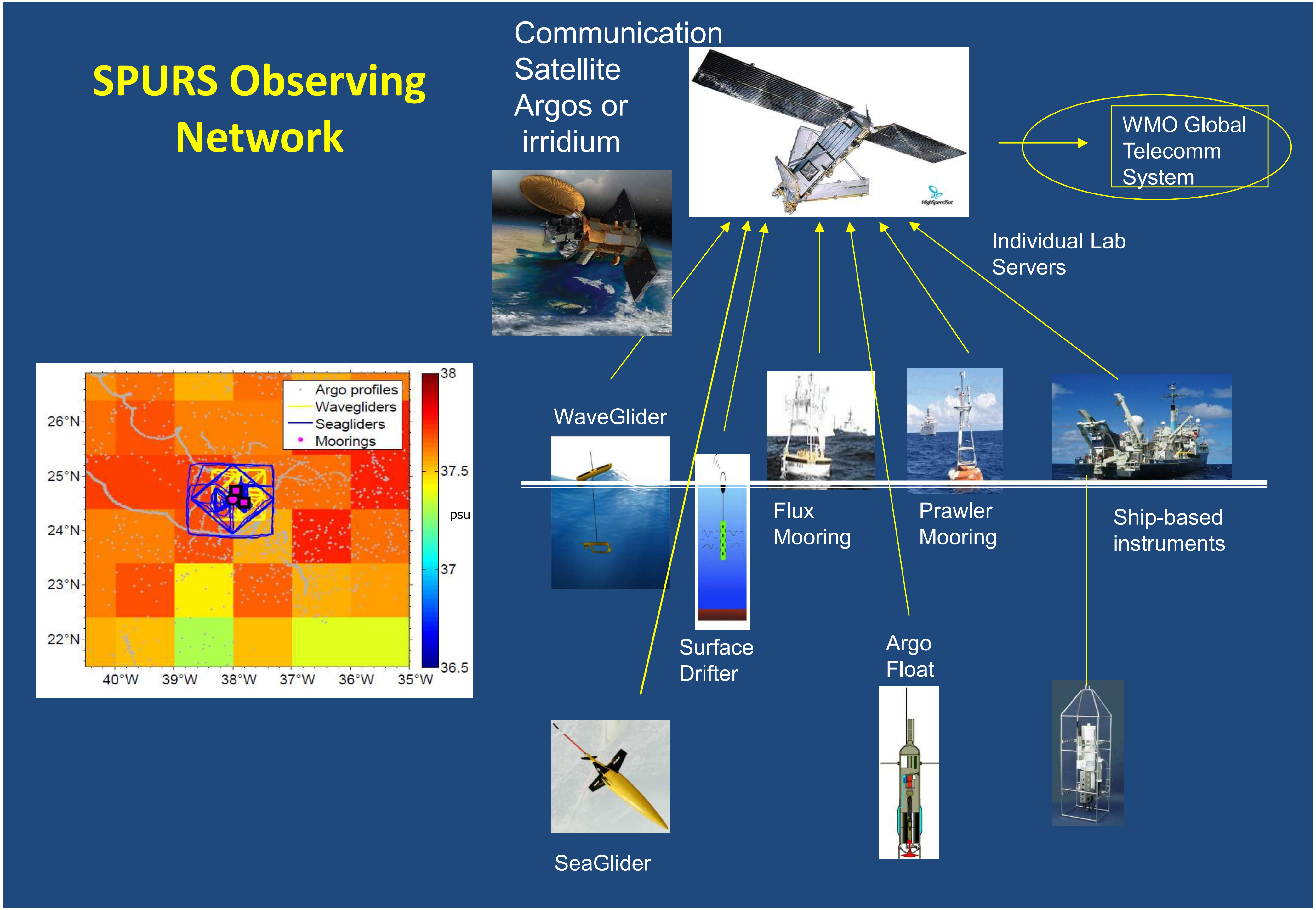


1. **Directly constrain the scales larger than 200 km**
2. **Indirectly constrain the small meos-scale eddies through the model dynamics due to the corrected eddies and thus advection**

Summary

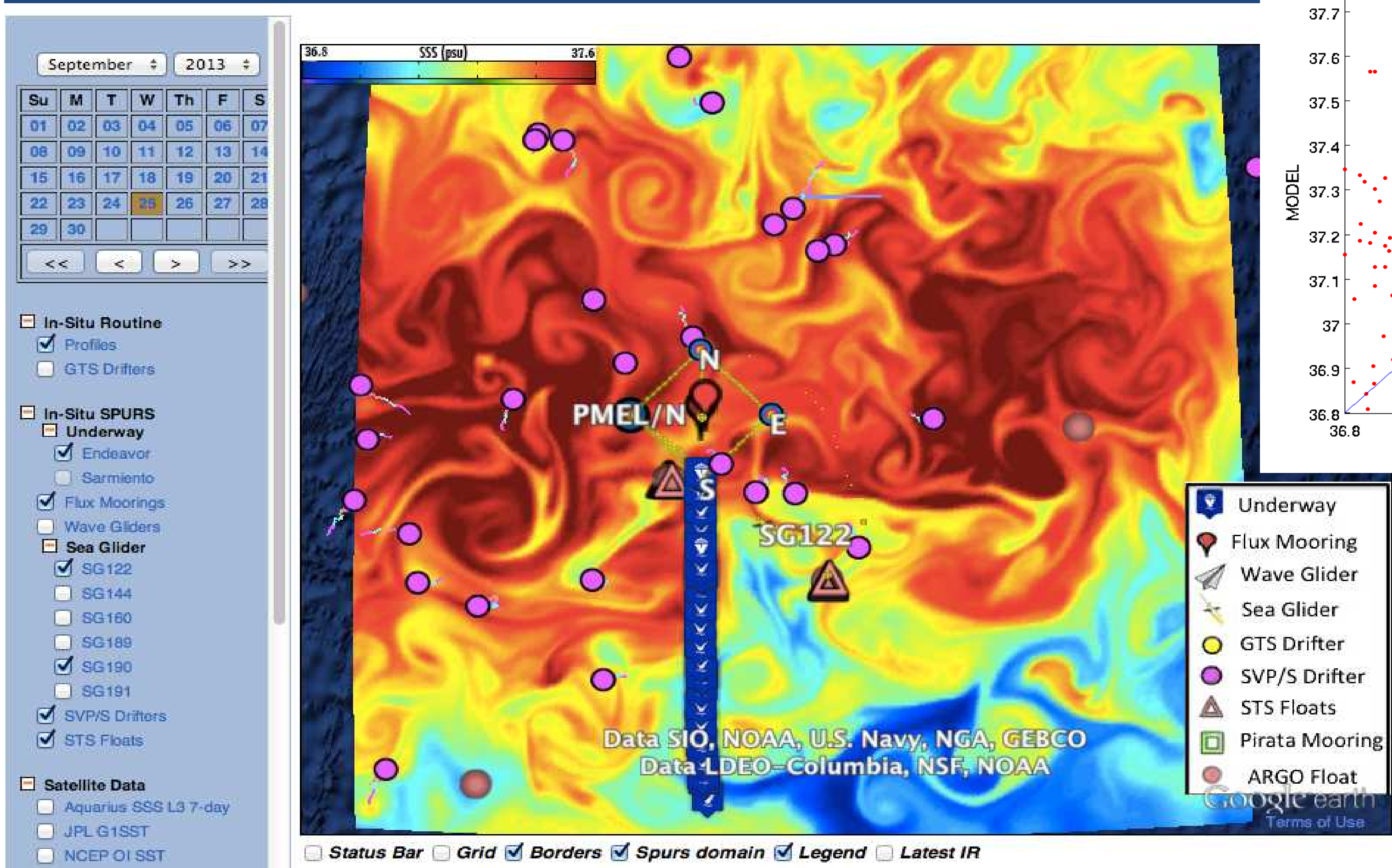
1. The assimilation of the multi-satellite altimetry data effectively constrains eddies larger than 200 km.
2. The results show positive impacts on the representation of mesoscale eddies whose scales are smaller than 200 km, but the impact is limited.
3. More quantitative assessments of the impact on the representation of mesoscale eddies smaller than 200 km are needed
    - Air SWOT?
    - Denser T/S profiles?

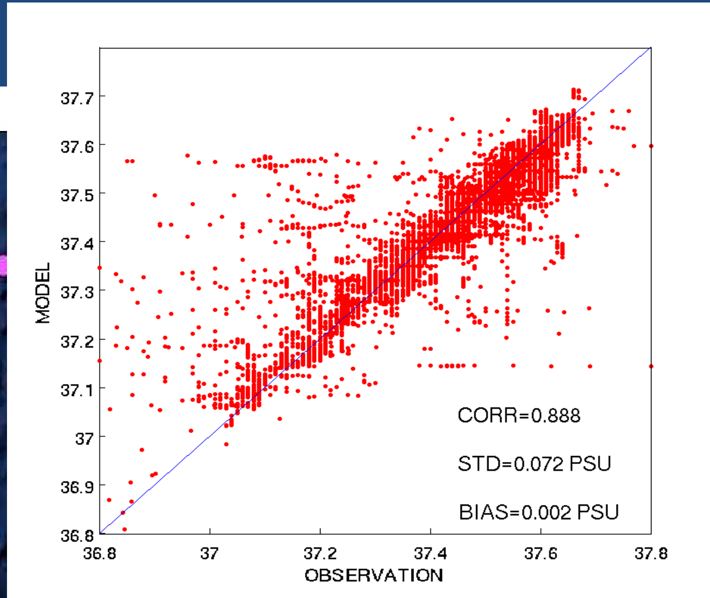
Backup



SPURS Observing Network
Communication Satellite Argos or irridium
WMO Global Telecomm System
Individual Lab Servers
Argo profiles
Wavegliders
Seagliders
Moorings
26°N
25°N
24°N
23°N
22°N
40°W
39°W
38°W
37°W
36°W
35°W
38
37.5
psu
37
36.5
WaveGlider
Surface Drifter
Flux Mooring
Prawler Mooring
Ship-based instruments
Argo Float
SeaGlider

Real-Time Feature Observation and Evaluation



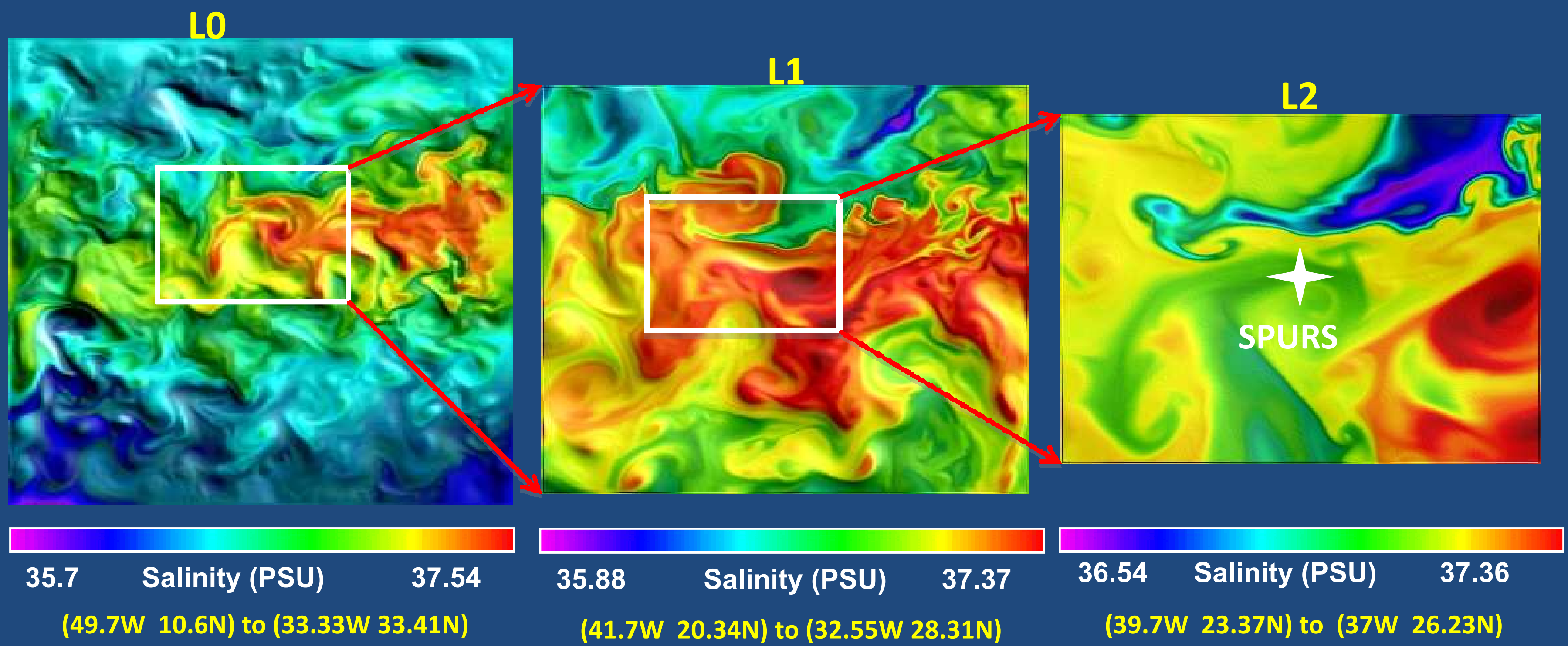


R/V Endeavor, 9/19-10/15, 2013

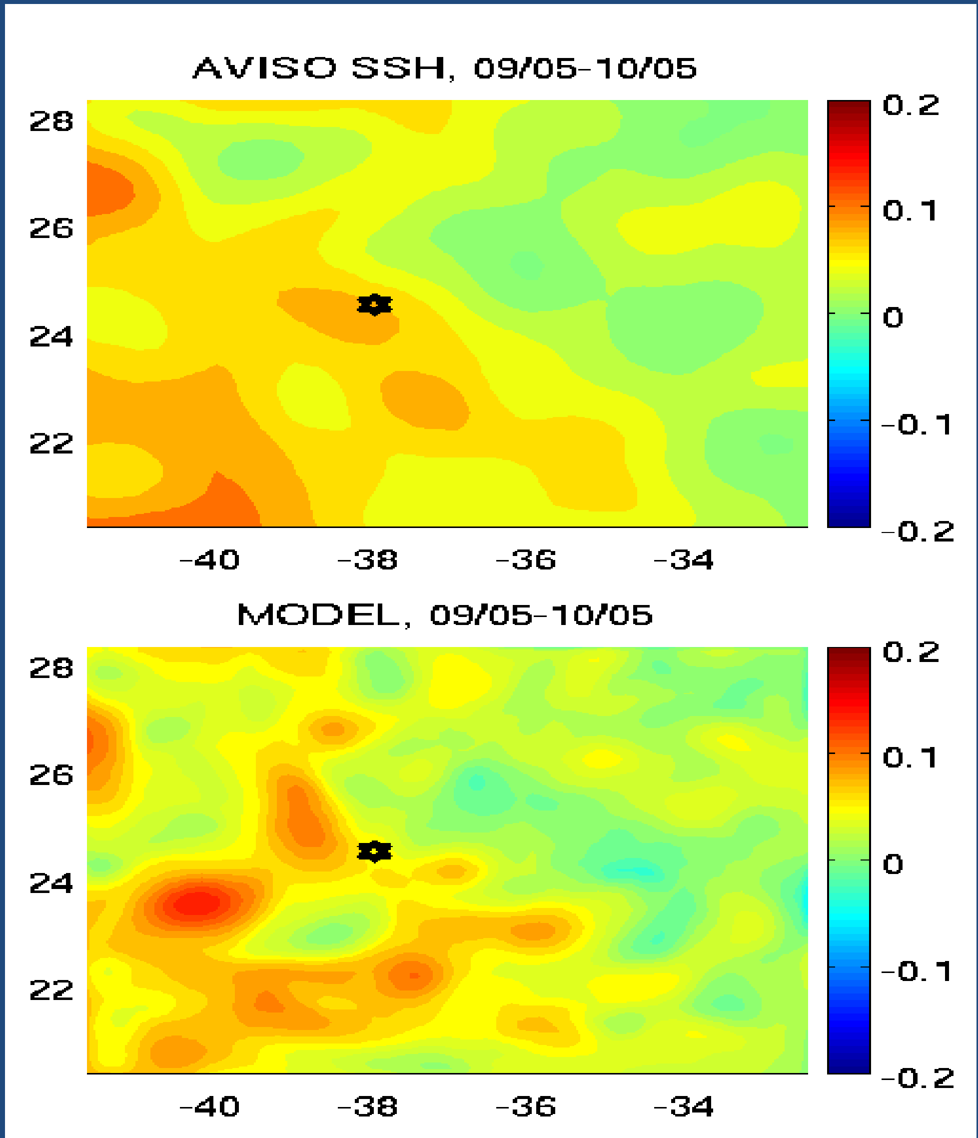
http://spurs.jpl.nasa.gov

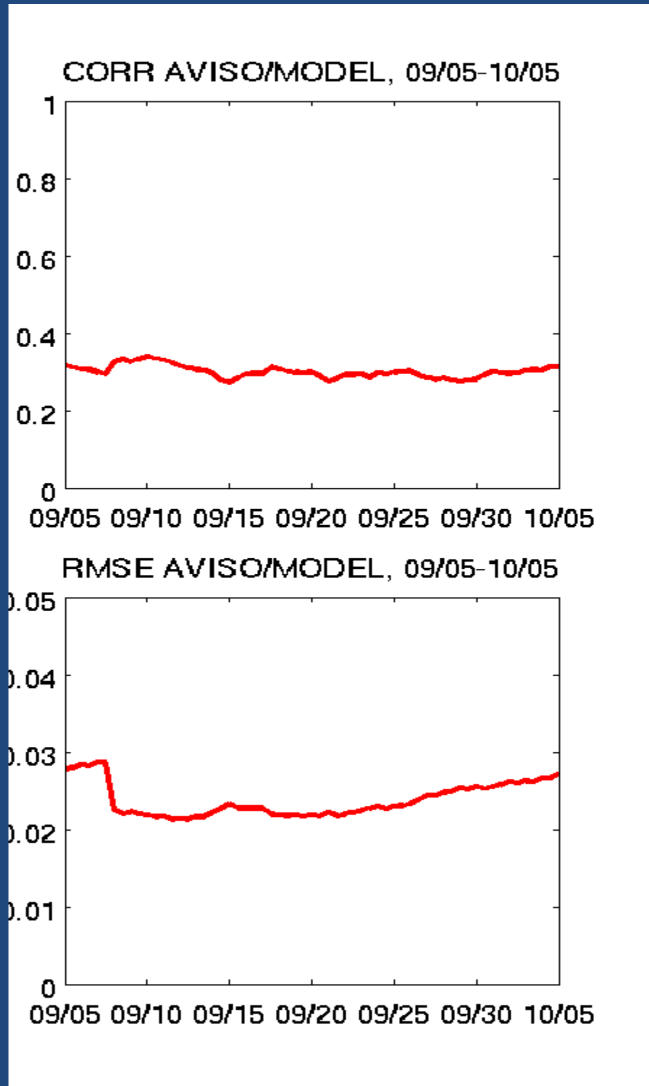
Three-Domain ROMS Model in Support of SPURS

- Three domain nested Regional Ocean Modeling System (ROMS) model
- A horizontal resolution of 9 km (L0), 3 km (L1) and 1 km (L2), with 50 vertical levels
- Three-hourly atmospheric forcing derived from the NCEP Global Forecasting System (NFS) products



AVISO vs ROMS 24-Hour Forecast





Three-Dimensional Variational Data Assimilation (3DVAR)

$$x^a = x^f + K(Hx^f - y)$$

y observation

$$\min_x J(x) = \frac{1}{2}(x - x^f)^T B^{-1}(x - x^f) + \frac{1}{2}(Hx - y)^T R^{-1}(Hx - y)$$

$$\min_x J(\delta x) = \frac{1}{2}\delta x^T B^{-1}\delta x + \frac{1}{2}(H\delta x - \delta y)^T R^{-1}(H\delta x - \delta y)$$

Fit to Background + Fit to Observation

$$\delta y = y - Hx^f$$

Two requirements

1. **Dynamic balance**
2. **Decorrelation length scale**