Improved Representation of Eddies in Regional Real-Time Forecasting Systems Using Multi-Scale Data Assimilation of Satellite Altimetry

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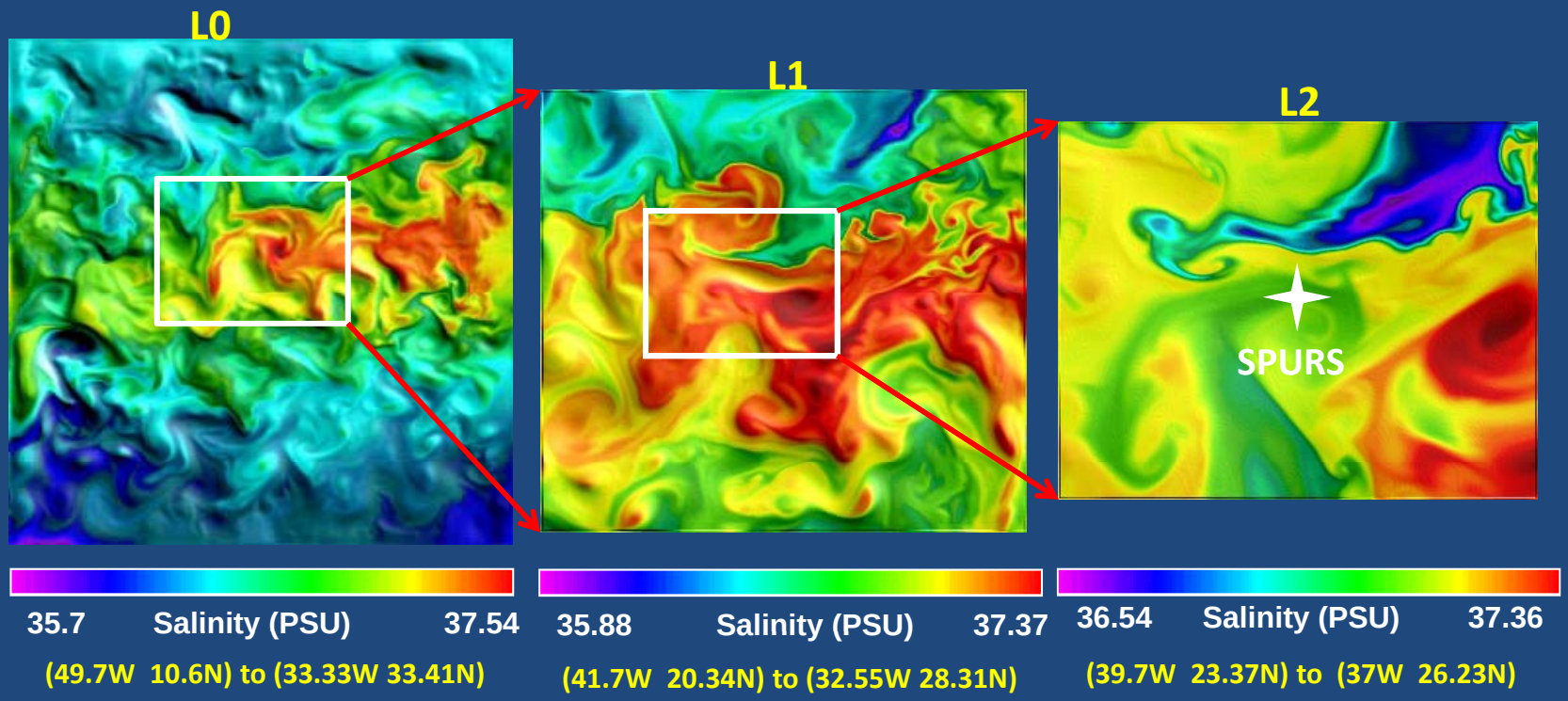
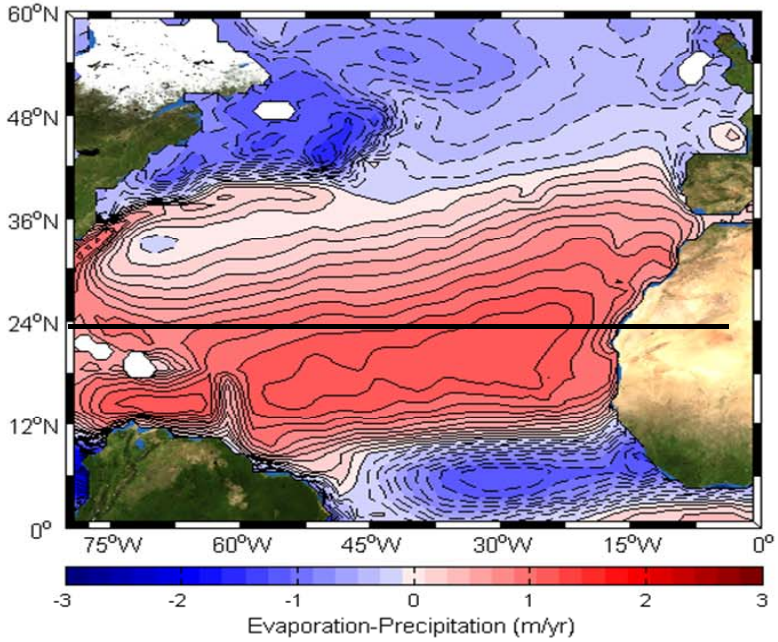
Three-Domain ROMS Model in Support of SPURS

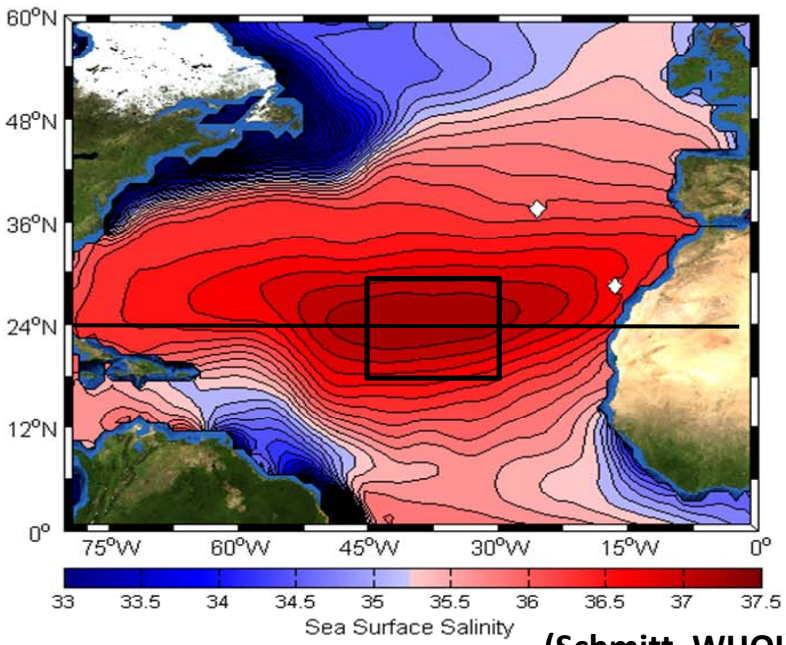
- Three domain nested Regional Ocean Modeling System (ROMS) model
- A horizontal resolution of 9 km (L0), 3 km (L1) and 1 km (L2), with 50 vertical levels
- Three-hourly atmospheric forcing derived from the NCEP Global Forecasting System (NFS) products



Evaporation-Precipitation



Surface Salinity

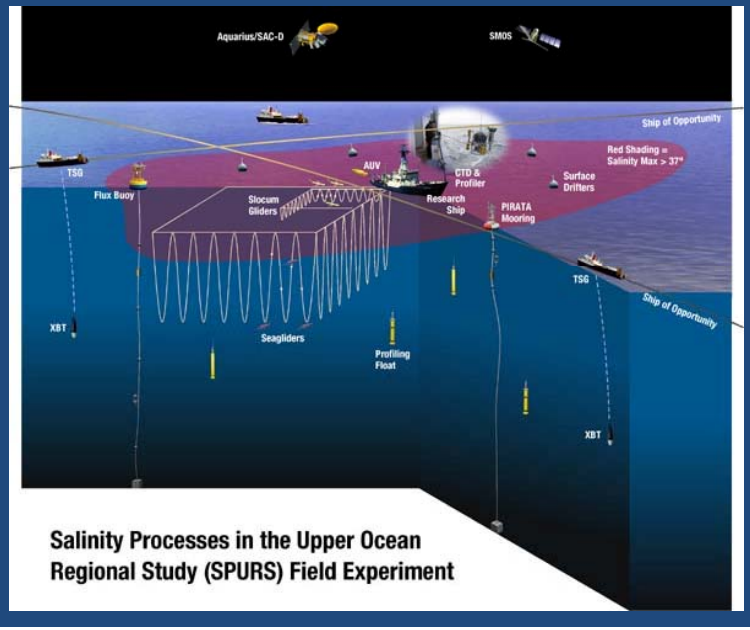


(Schmitt, WHOI)

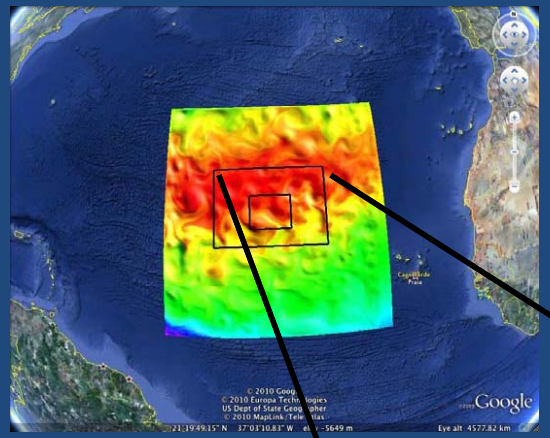
The maximum SSS is located a couple of degrees north of the maximum E-P.

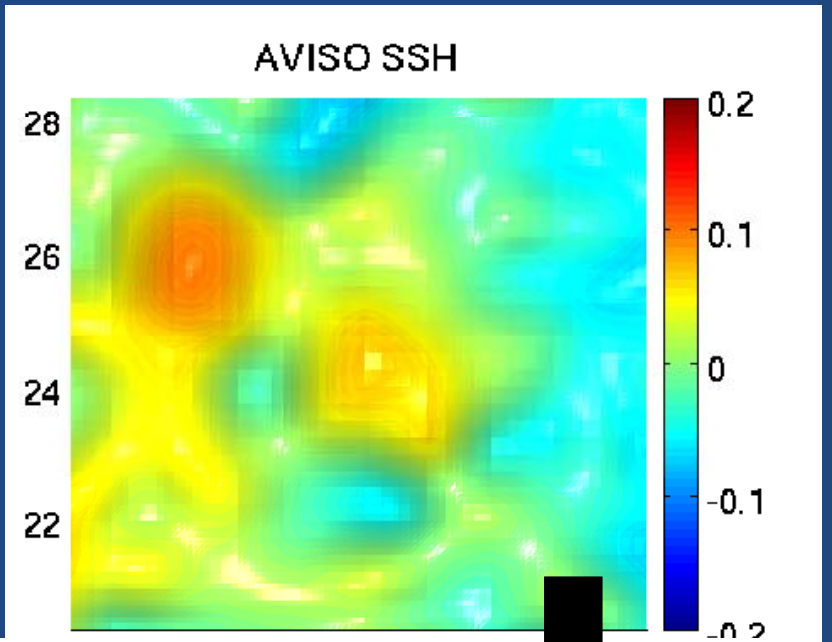
Oceanic processes that may be responsible for: 1) Large scale circulation; 2) Eddy fluxes; 3) Vertical mixing; 4) …

http://spurs.jpl.nasa.gov

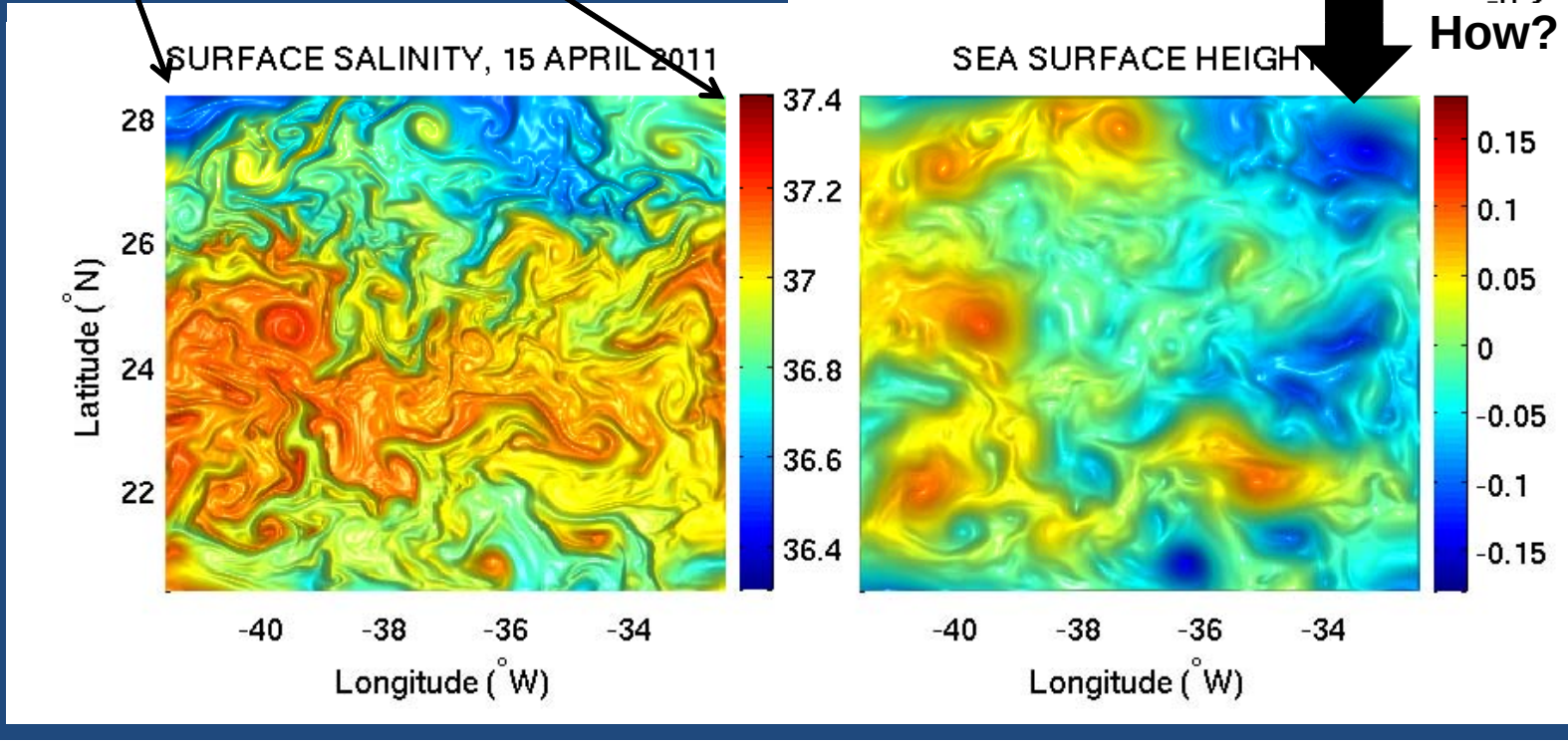


Eddies spanning a Spectrum of Meso-Scales: Missing Bands





How?



Three-Dimensional Variational Data Assimilation (3DVAR)

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

y observation

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

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

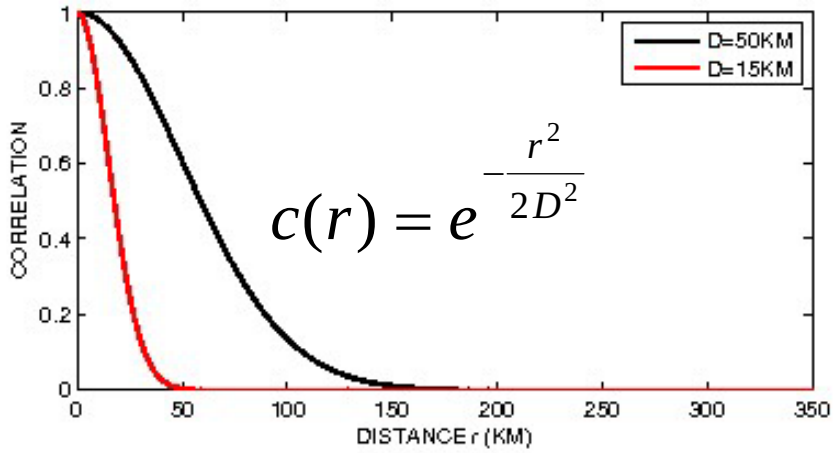
Fit to Background + Fit to Observation

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

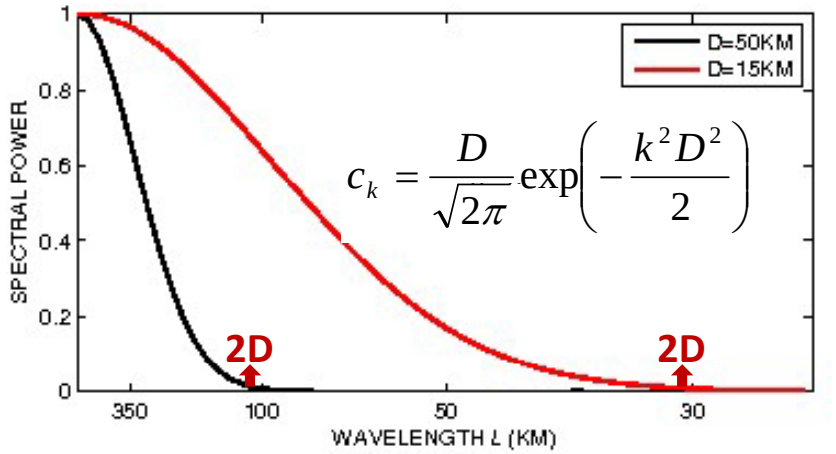
Two requirements

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

Multi-Scale 3DVAR with Background Error Covariance of Multi-Decorrelation Length Scales



$$c(r) = e^{-\frac{r^2}{2D^2}}$$



$$c_k = \frac{D}{\sqrt{2\pi}} \exp\left(-\frac{k^2 D^2}{2}\right)$$

$$x = x_L + x_S$$

$$B = B_L + B_S$$

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

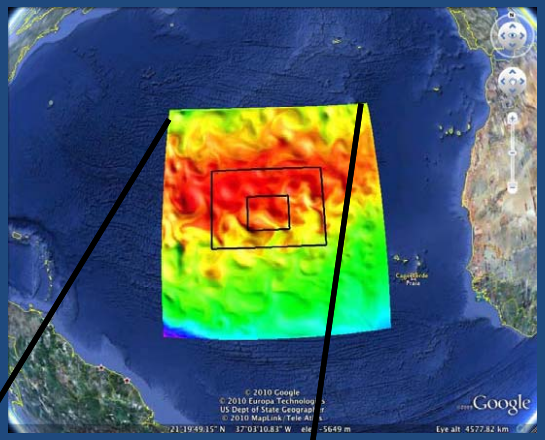
Low resolution obs

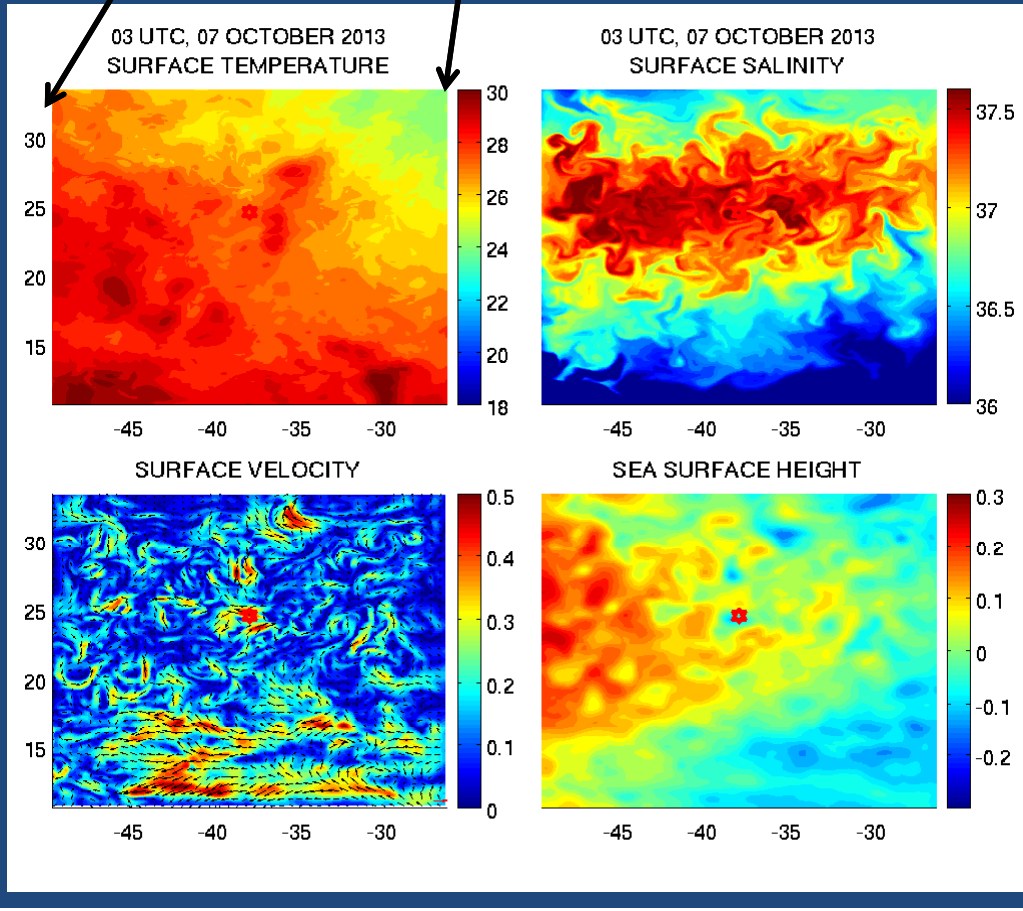
$$\min_{\delta x_L} J(\delta x_L) = \frac{1}{2}\delta x_L{}^T B_L^{-1} \delta x_L + \frac{1}{2}(H\delta x_L - \delta y)^T \left(HB_S H^T + R\right)^{-1}(H\delta x_L - \delta y)$$

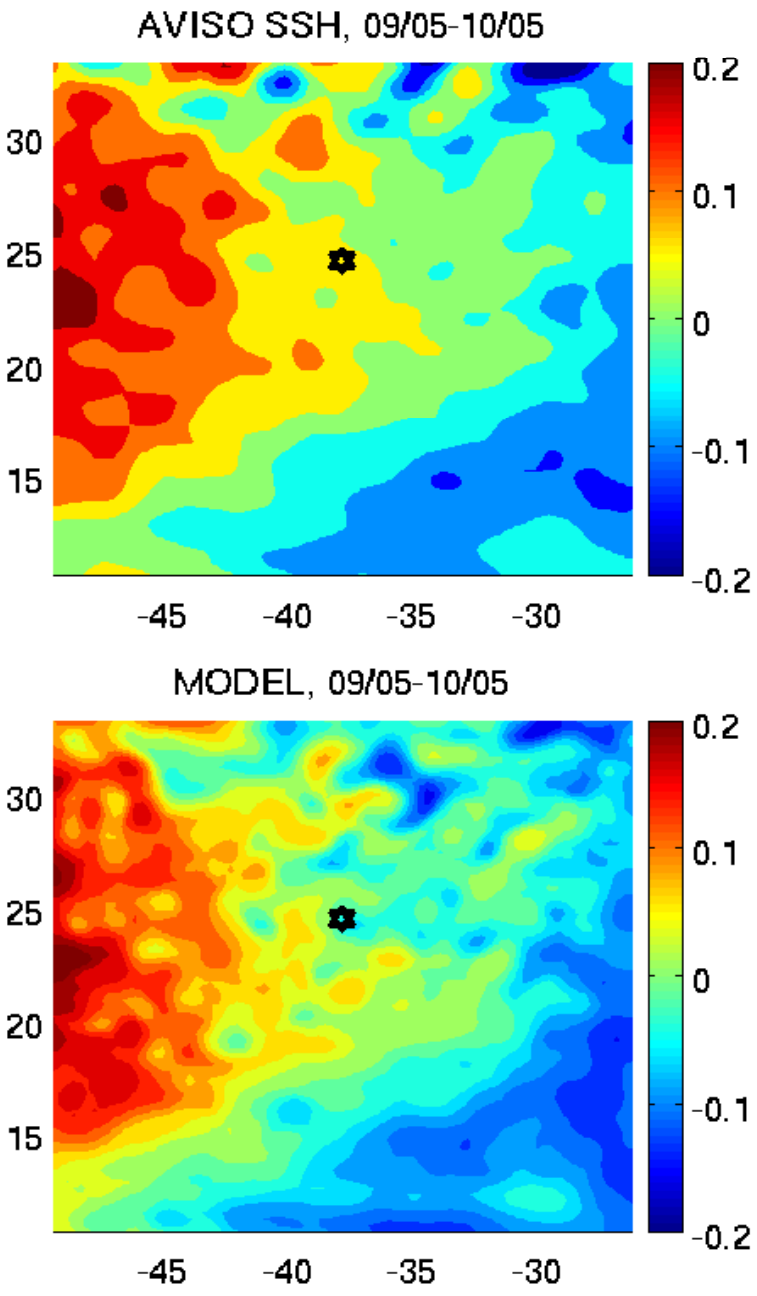
$$\min_{\delta x_S} J(\delta x_S) = \frac{1}{2}\delta x_S{}^T B_S^{-1} \delta x_S + \frac{1}{2}(H\delta x_S - \delta y)^T \left(HB_L H^T + R\right)^{-1}(H\delta x_S - \delta y)$$

High resolution obs

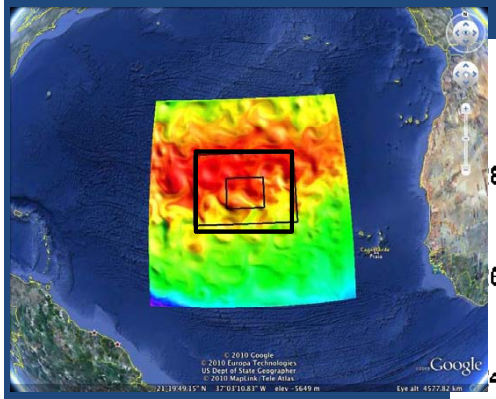
One Month, 2013 Fall SPURS

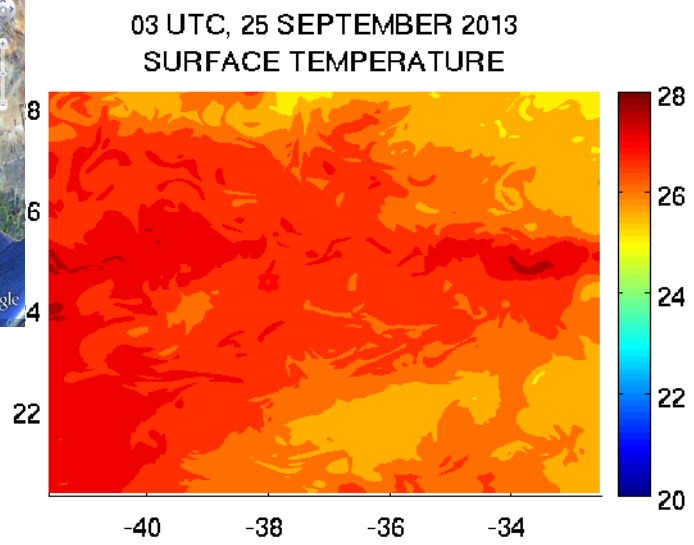


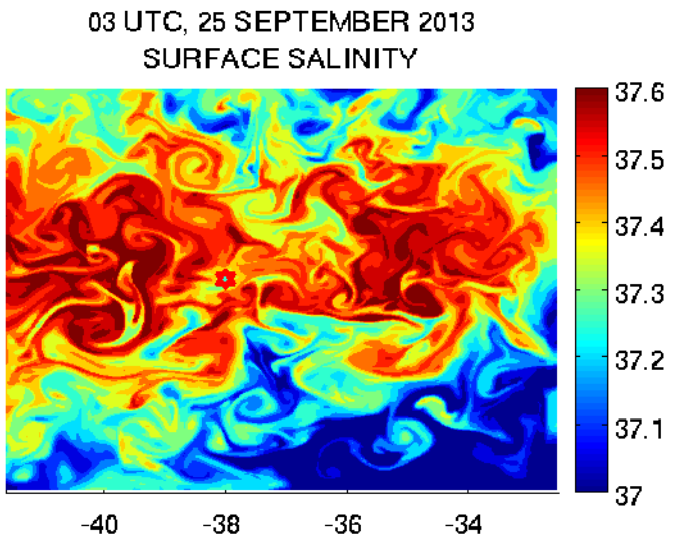


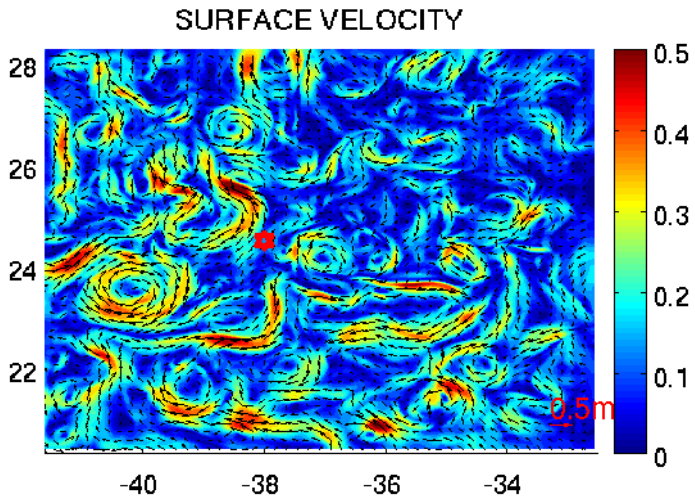


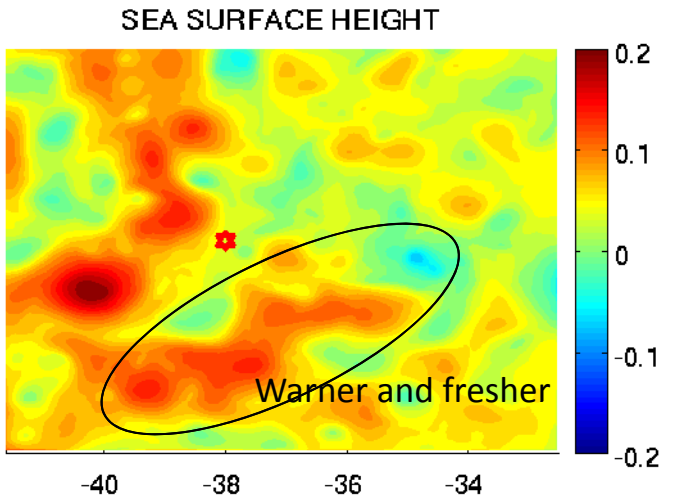
Real-Time High Resolution Forecast



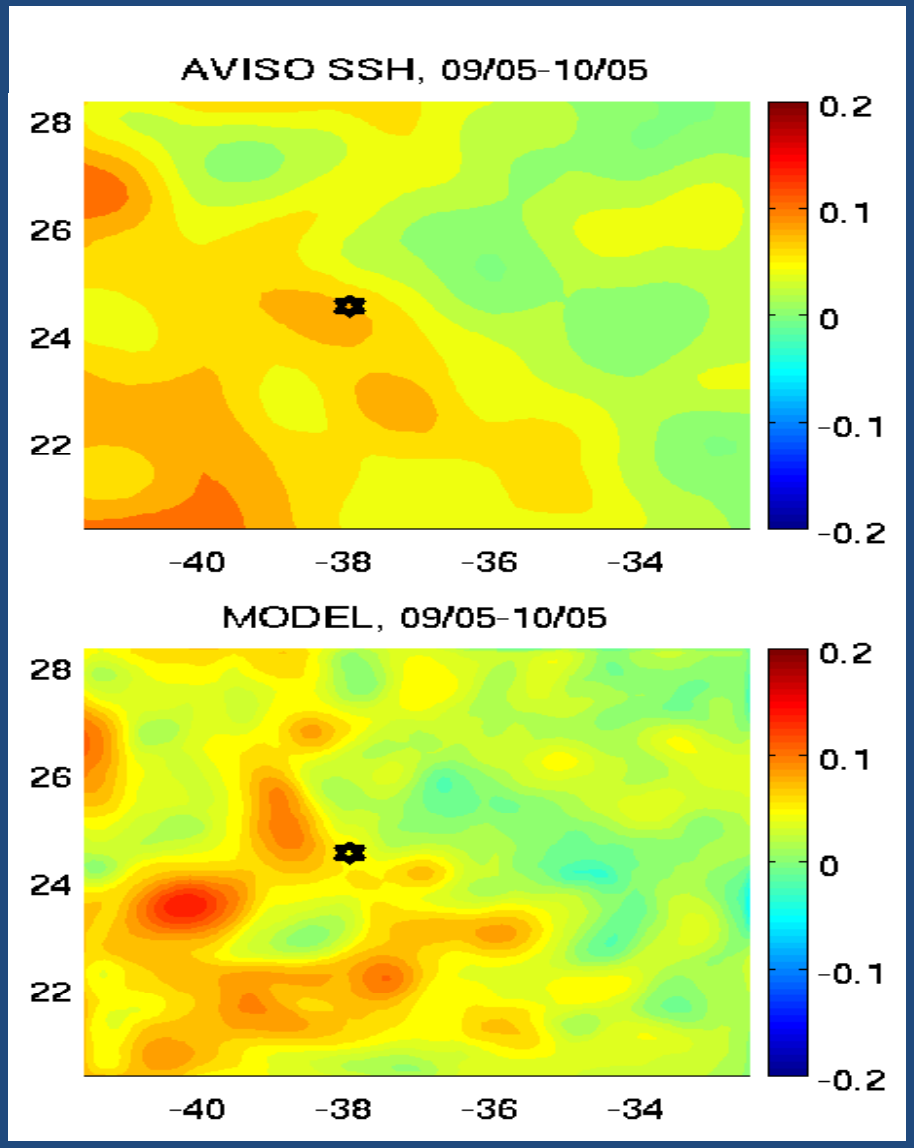


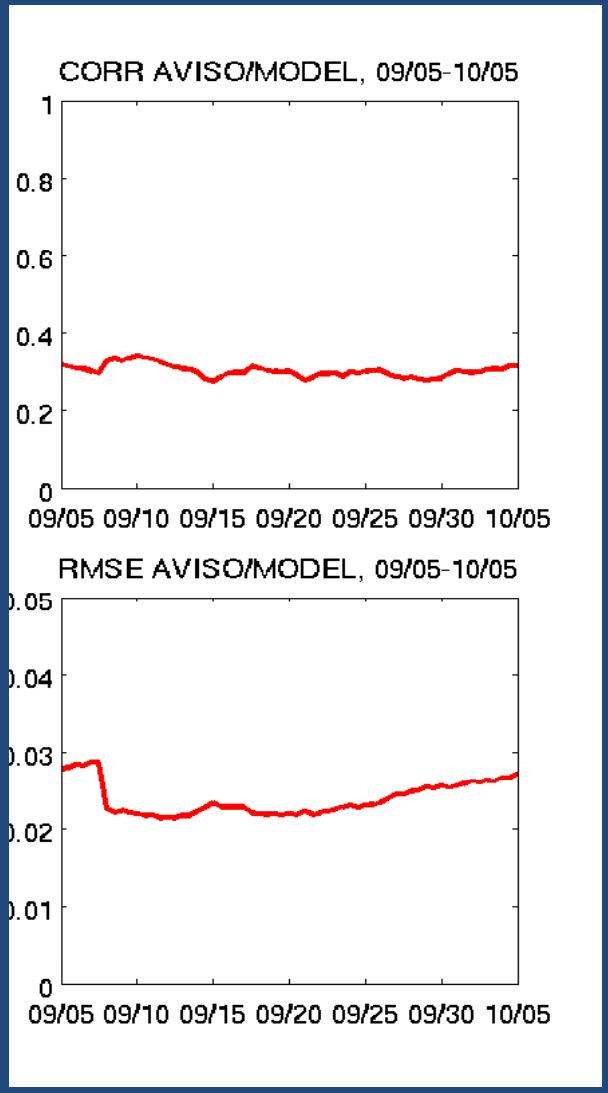




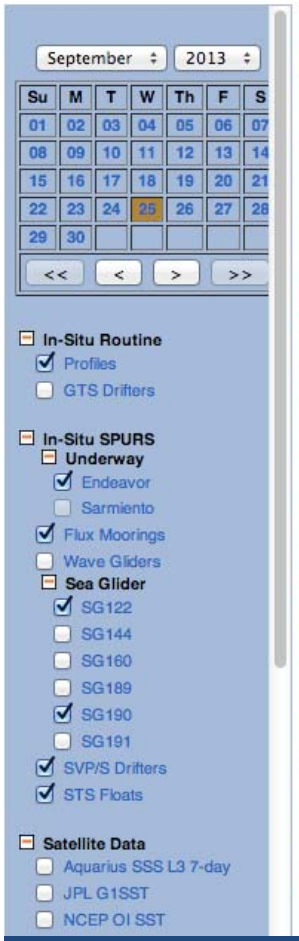


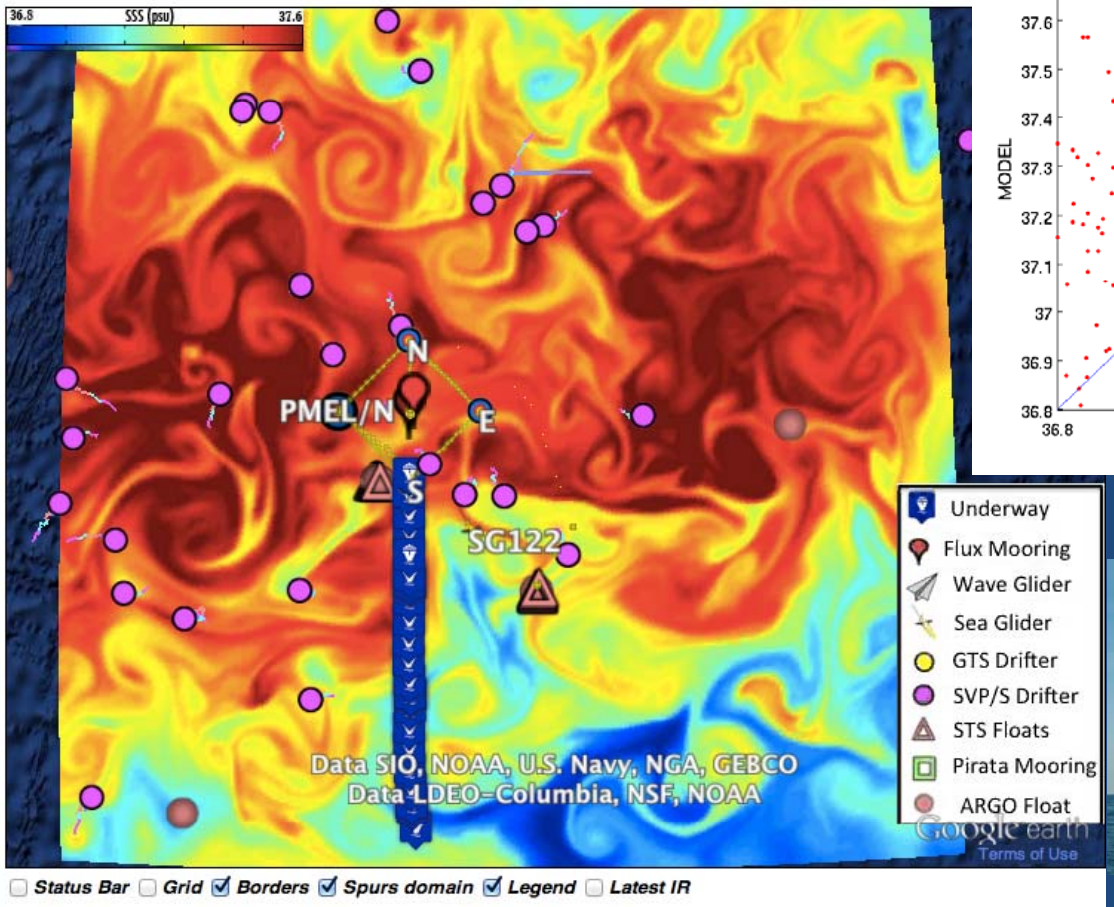
AVISO vs ROMS 24-Hour Forecast

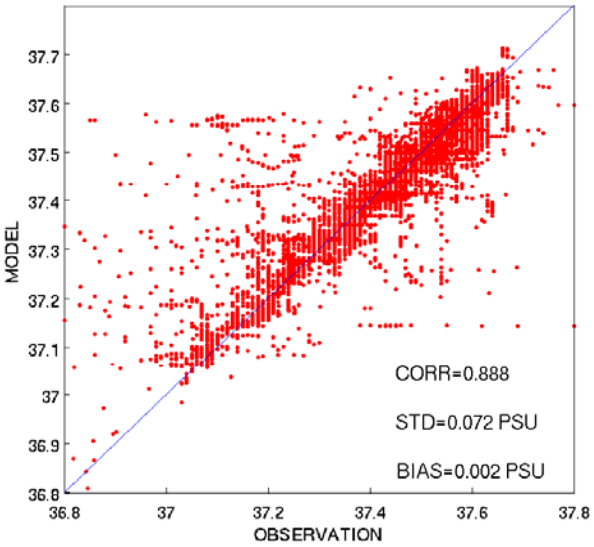




Real-Time Feature Observation and Evaluation







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

http://spurs.jpl.nasa.gov

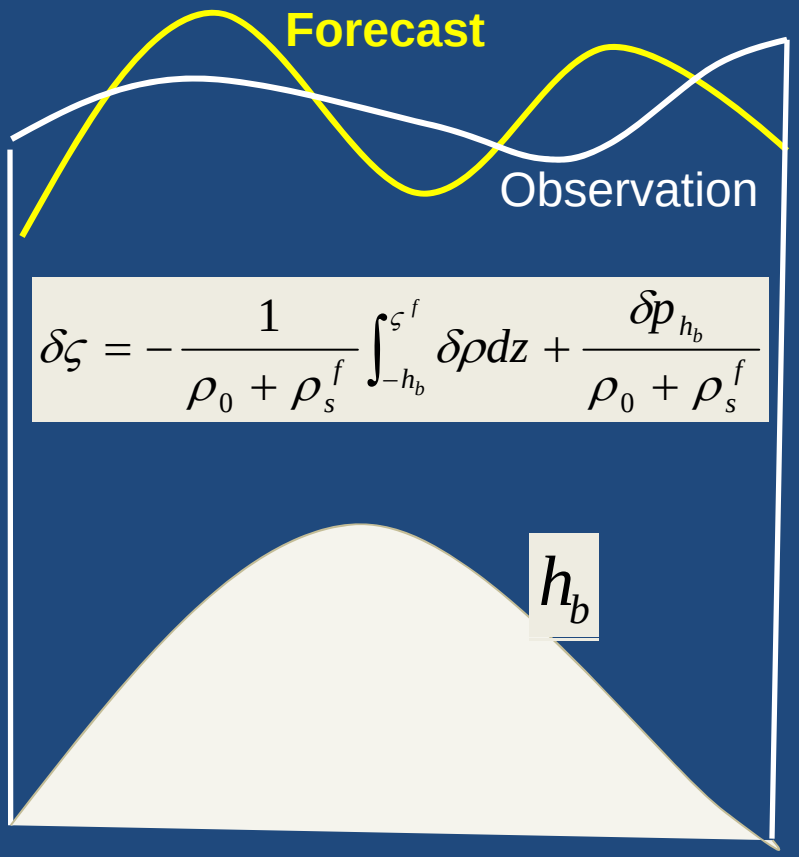
Summary

1. Assimilation of multi-satellite altimetry data significantly improved the representation of meso-scale eddies during SPURS
2. The multi-scale data assimilation scheme is effective to assimilate existing altimetry data into high resolution models
3. Extension of the constraint on the low end of meso-scales and submeso-scales is on-going investigation
    - Steric vs non-steric
    - Baroclinic vs barotropic
    - Geostrophic vs ageostrophic

Hydrostatic Balance and Assimilation of Altimetry Data

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

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



OSTM/Jason-2

Challenges: shallow depths density as the function of T/S