Predictability of Submesoscale Flows Using Multiscale Data Assimilation of Satellite Altimetry

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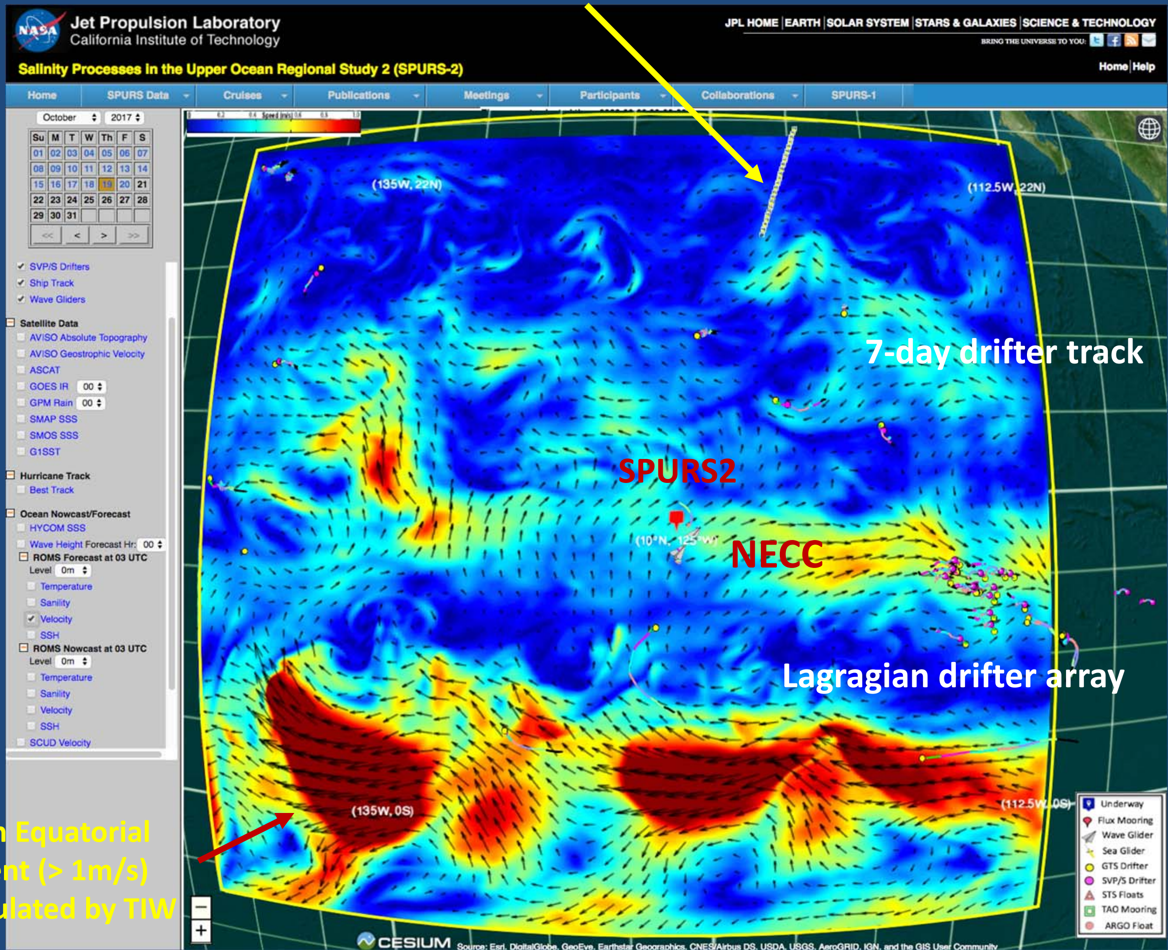
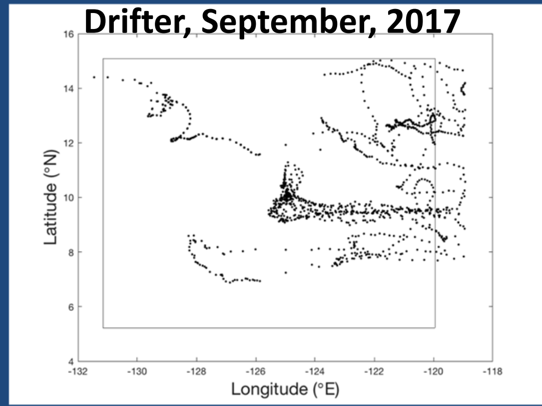
Salinity Processes in the Upper Ocean Regional Study (SPURS) Phase 2

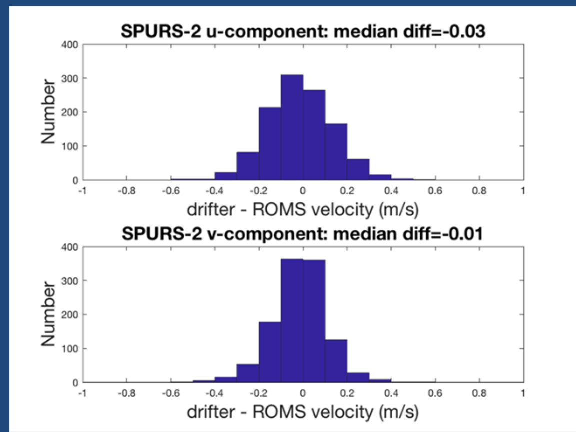
R/V Revelle Track



South Equatorial Current (> 1m/s) Modulated by TIW

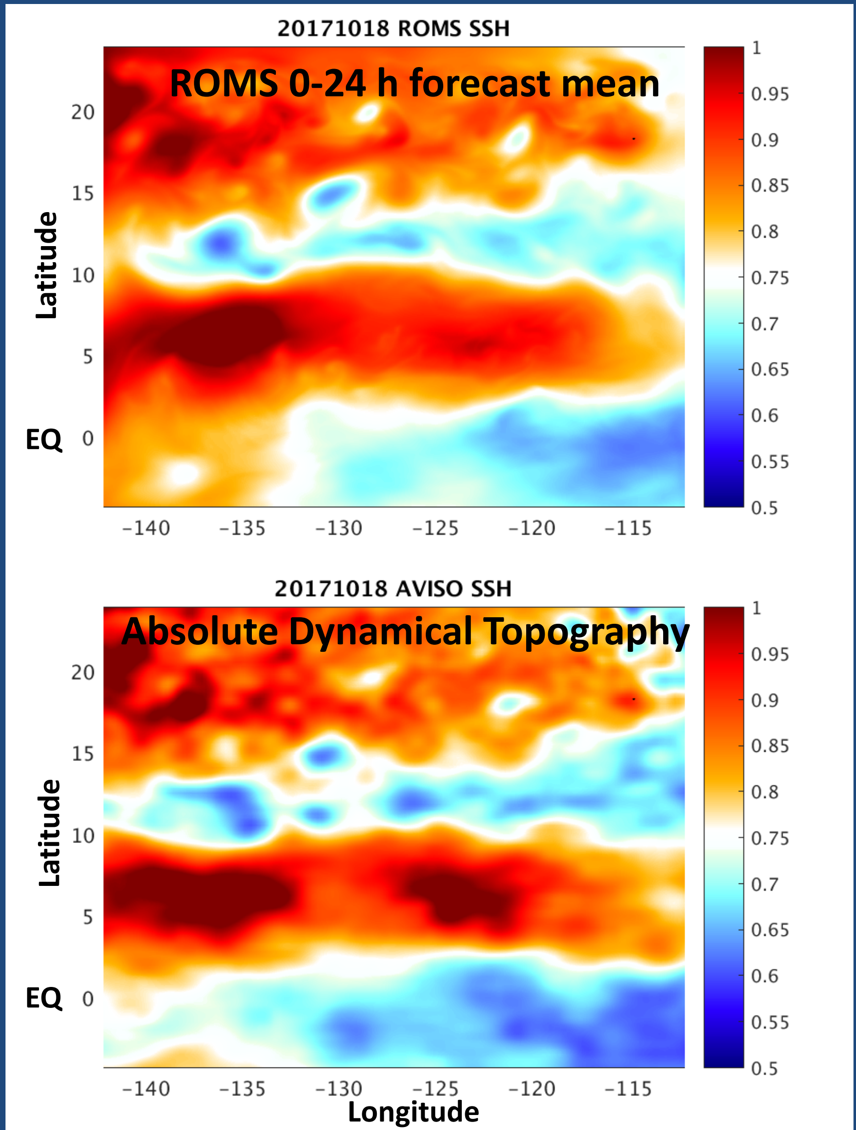
https://ourocean3.jpl.nasa.gov/spurs2/visual.php#

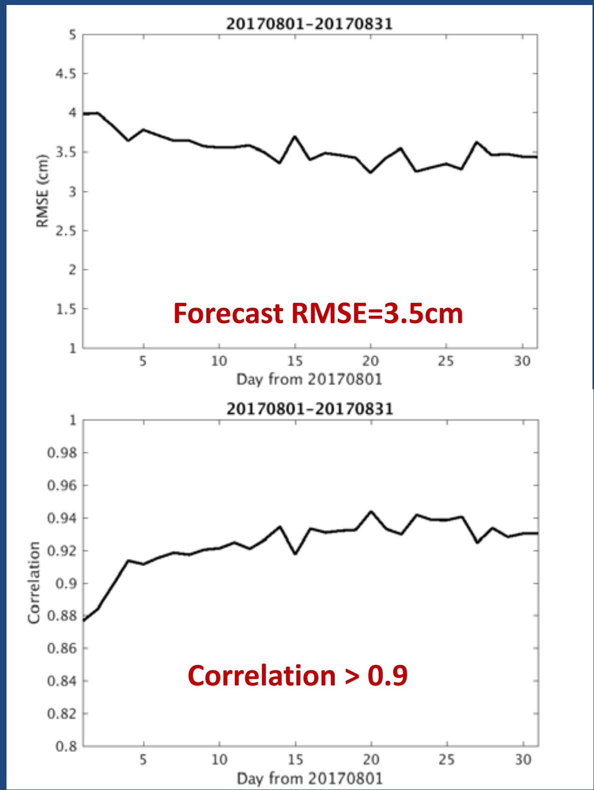




RMS of the difference between the model and drifter velocity 0.12 m/s (due to forcing error, geostrophic velocity error, etc)

SSH Forecast Performance





Major Progress: Assimilation of Absolute Dynamic Topographies

SSH anomalies, thus pseudo SSH observations, have been assimilated in most data assimilation systems

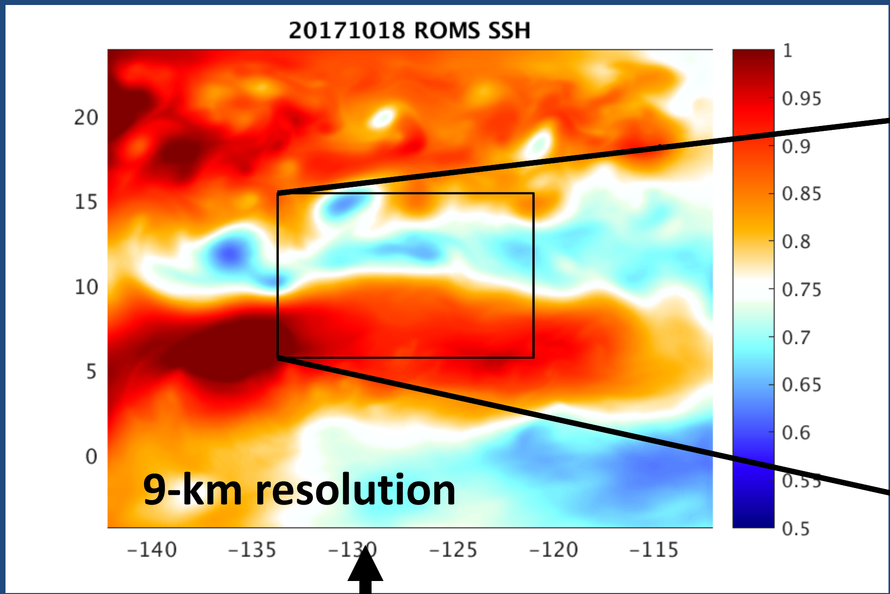
$$ssh^o = ssh_{climate} + ssha$$

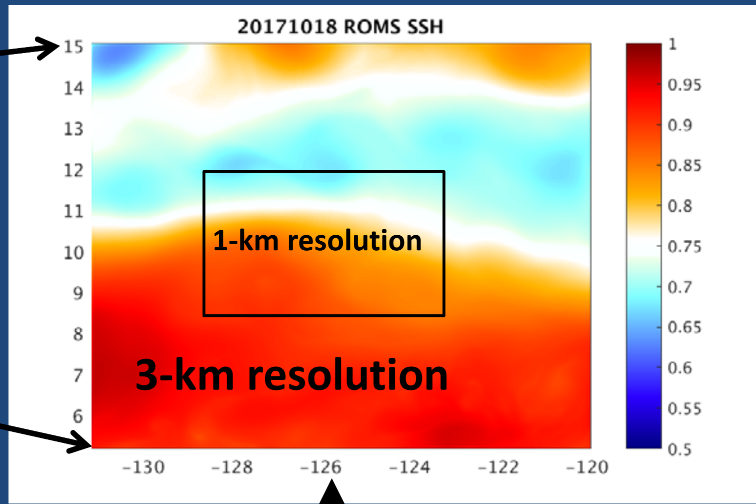
Pseudo observation   Model climate   Altimetry data

When the model has a bias in $ssh_{climate}$, the consequences could be

1. The model bias cannot effectively be reduced by assimilating T/S profiles
2. Altimetry data is difficult to be assimilated effectively with T/S profiles
3. The assimilation of T/S vertical profiles often creates “bull eyes” in T/S and SSH fields
4. The localized and dense measurements, such as those from field campaigns, can not be fully assimilated
5. …

SPURS-2 Model Configuration
The Outer Boundary Condition from Observations



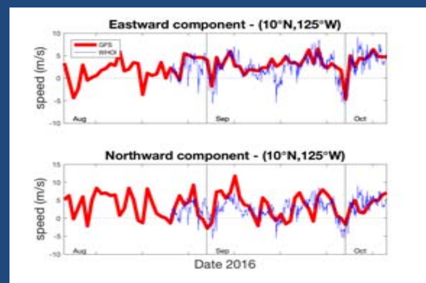


Climatological WOA13 + monthly anomaly T/S and geostrophic velocities from gridded Argo. Thus,

- Improved consistency between the inner solution and boundary conditions, since Argo T/S profiles are assimilated
- Effective assimilation of altimetry data

Online nesting

Updating the boundary condition every time step

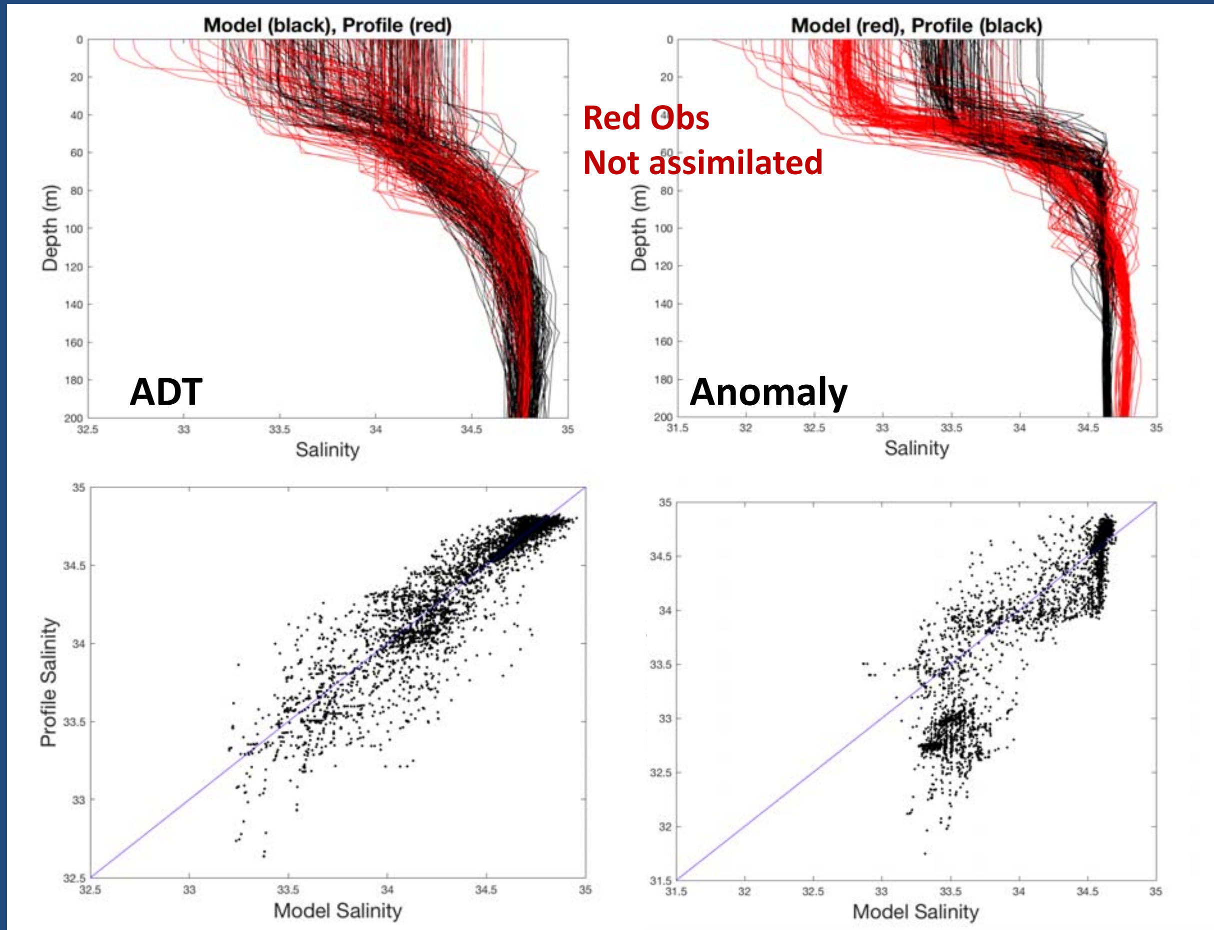


NCEP GFS Forcing

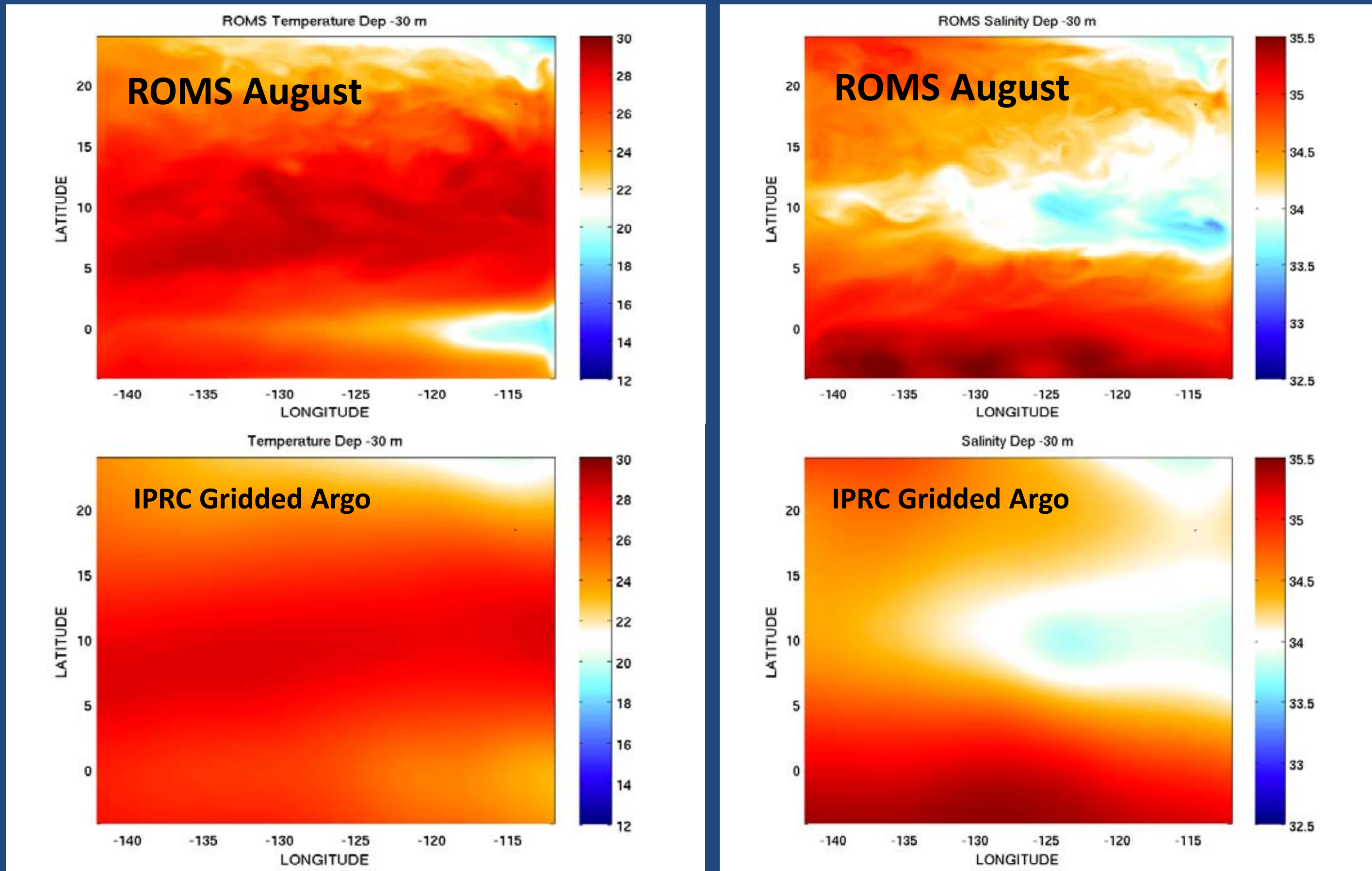
Impact of Absolute Dynamical Topographies

Observations Assimilated

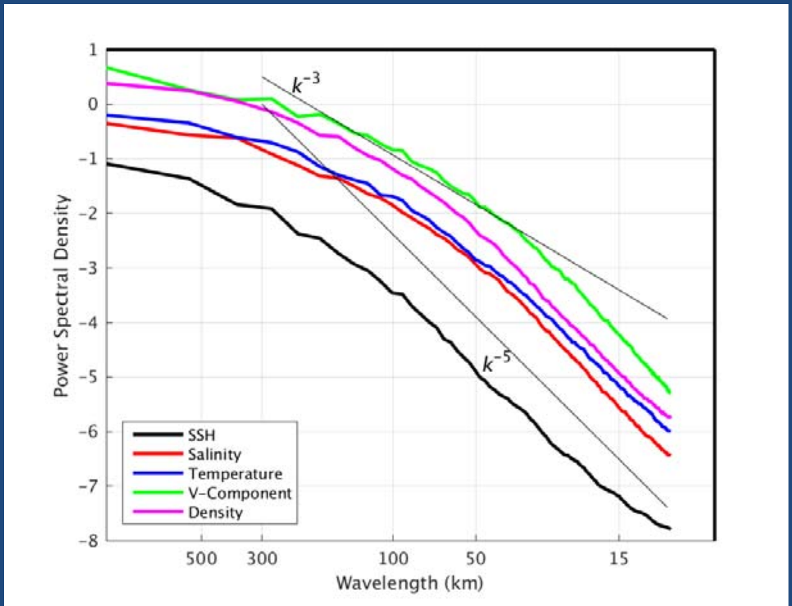
1. Satellite MV AMSR2 SST
2. Satellite IR MODIS and VIIRS SST
3. AVSIO ADT
4. Argo and TOGA-TAO mooring T/S profiles
5. Satellite SMAP SSS
6. Drifter SST

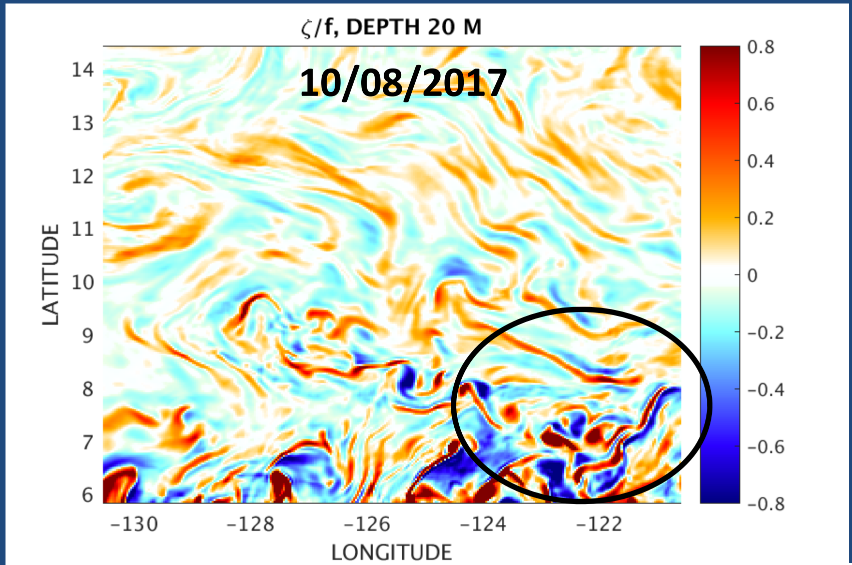


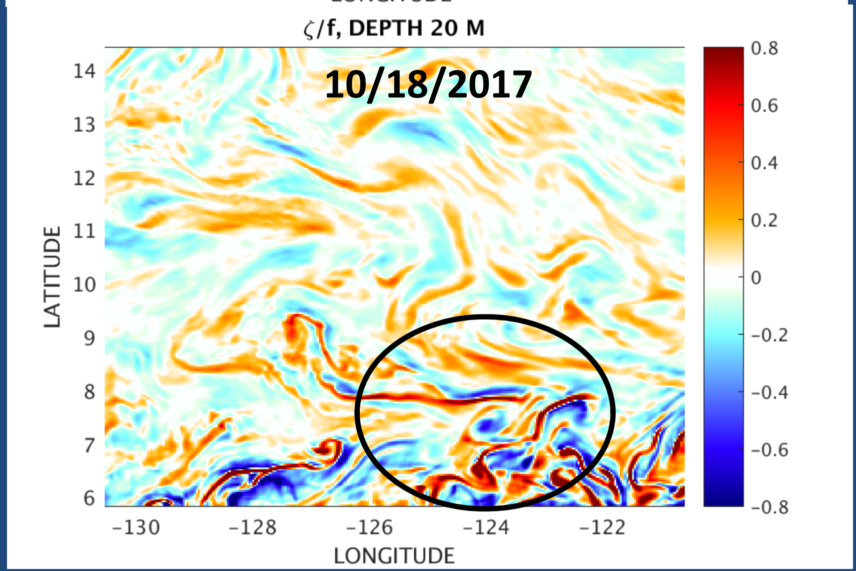
Monthly Mean



Prediction of Submesoscale Flows

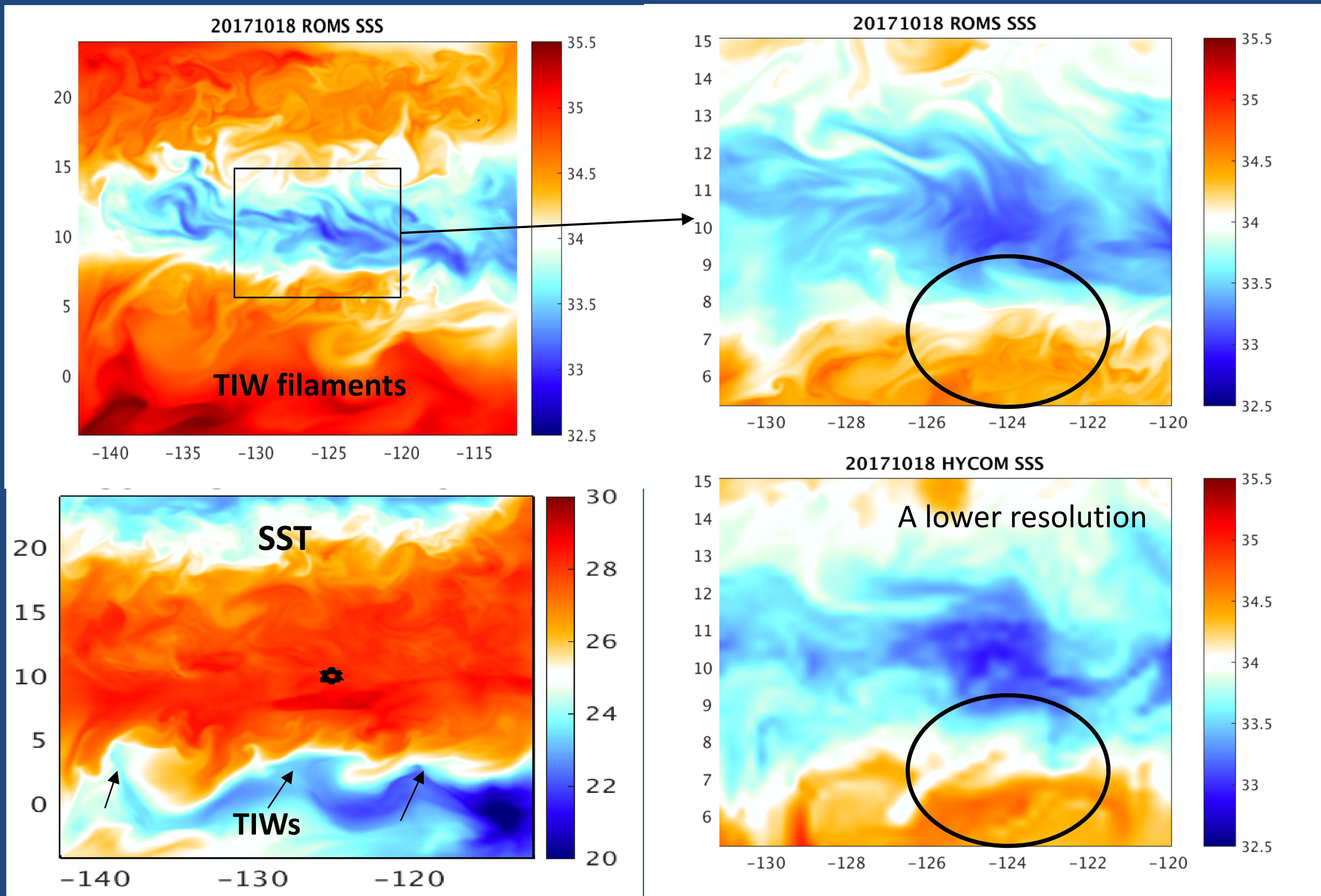






SPURS Question: what contribution of submesoscale flows to salinity budgets?

Major Submesoscale Flows Associated with TIW Filaments?



A Multi-Scale Data Assimilation (MS-DA) System for Submesoscales

Decomposition of large and small scales

$$X = X_L + X_S$$

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

Large scale data assimilation

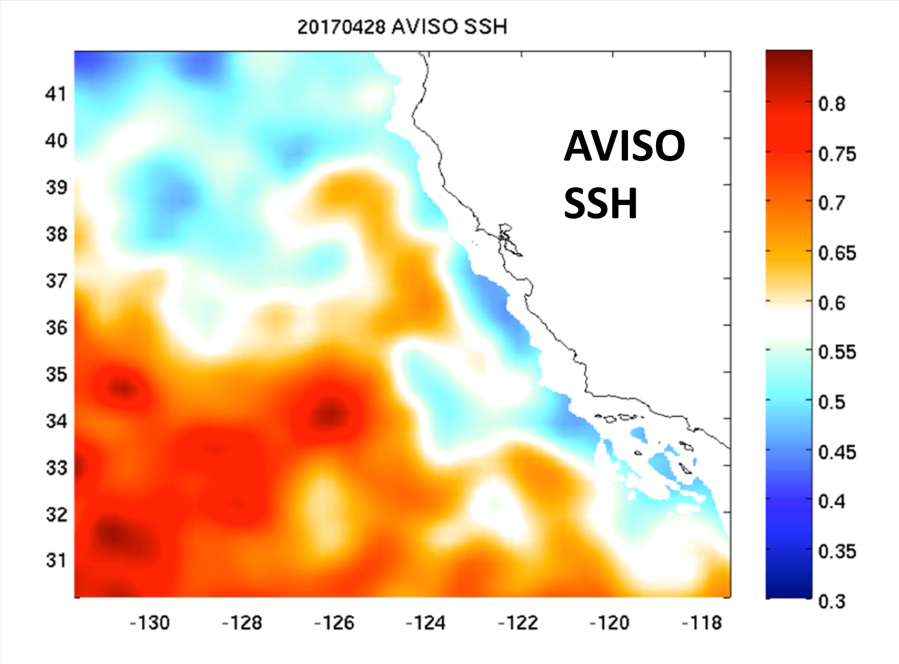
$$\min_{\delta x_L} J(\delta x_L) = \frac{1}{2}\delta x_L{}^T B_L^{-1}\delta x_L + \frac{1}{2}(H\delta x_L - \delta y)^T \left(H B_S H^T + R\right)^{-1}(H\delta x_L - \delta y)$$

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

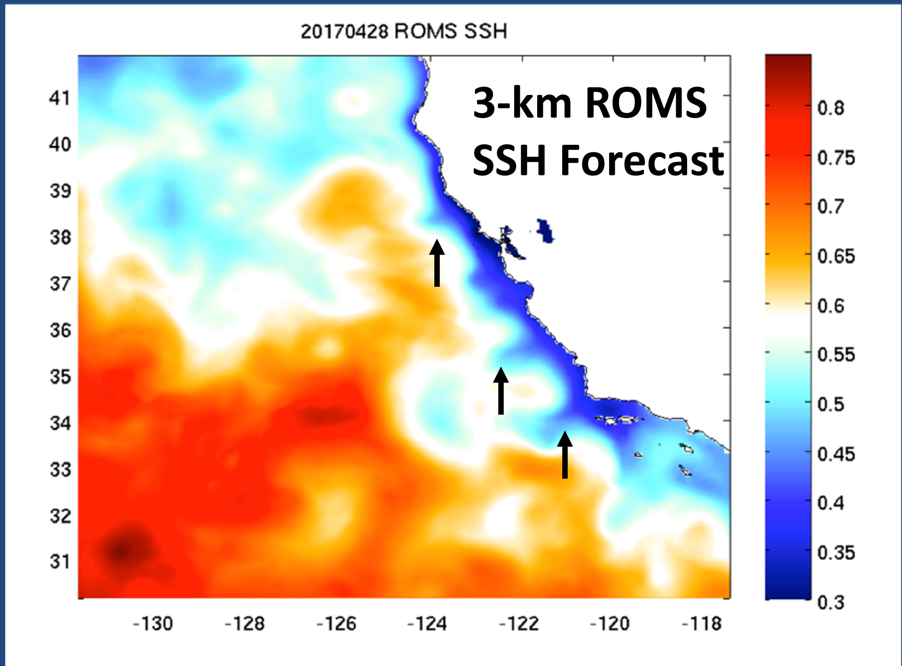
Small scale data assimilation (reduced nonlinearity?)

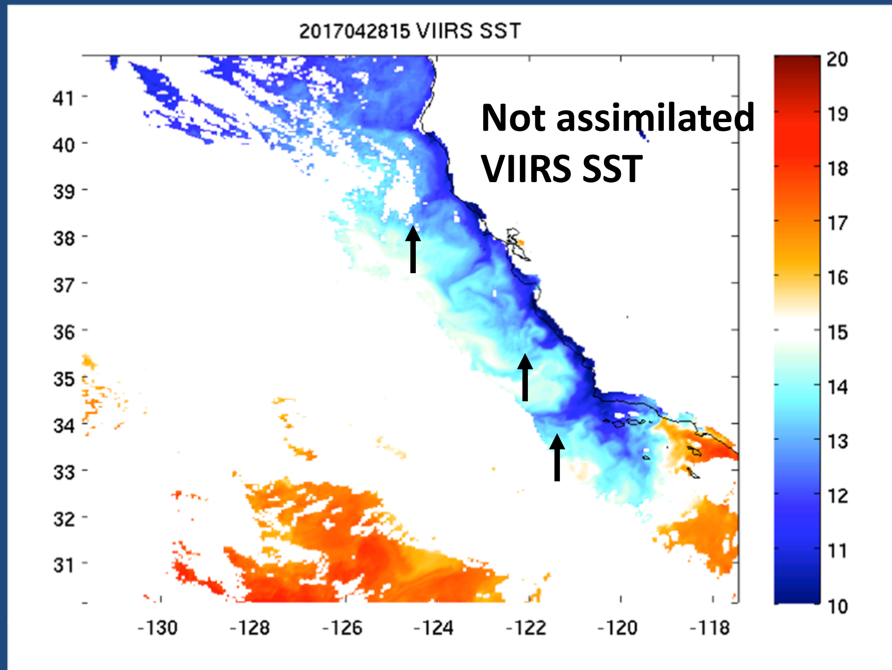
1. Small-scale DA for enhanced effectiveness of assimilating dense observations
2. Large–scale DA for low-resolution observations
3. Developed on top of the existing DA system

(Li et al. 2016 MWR; 2015, JGR)



- Smoothed upwelling filaments in AVISO ADT
- Effectively constraining large and mesoscale scales by AVISO ADT
- The multiscale data assimilation not smoothed submesoscale upwelling filaments





Summary

1. The SPURS-2 data assimilation and forecasting system demonstrated reliable forecast skill for mesoscale systems
2. The assimilation of absolute dynamical topographies (ADT) along with vertical T/S profiles from the routine observing network allows effectively constraining model biases
3. Submesoscale flows could be better simulated with the assimilation of the low resolution observations and sparse vertical profiles.
   - How much?
   - What submesoscale observations needed to predict submesoscale flows to a given accuracy?