Improved Representation of Submesoscale Flows Using Multiscale Data Assimilation of Satellite Altimetry

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Ocean Surface Topography Science Team Meeting

La Rochelle, November 2, 2016

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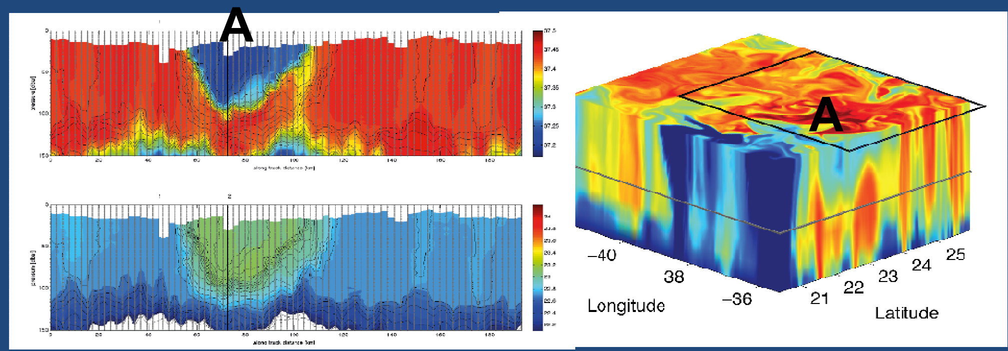
Impact of Altimetry Data in Real-Time Mesoscale Prediction during the SPURS Field Campaigns

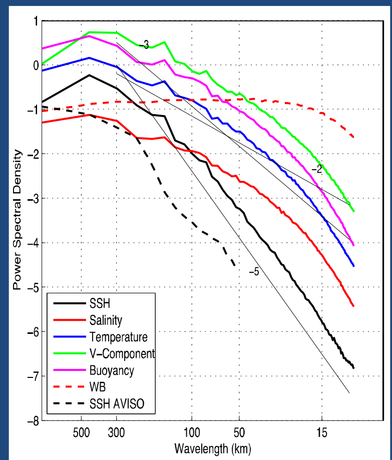
- The model encouragingly showed some ability of predicting submesoscale features during SPURS-1 (OSTST 2014)

- Why the assimilation altimetry data improves representation of eddies down to tens of km (2015)

- **Today's topic: Results from SPURS-2 and some new results on submesoscale analyses**



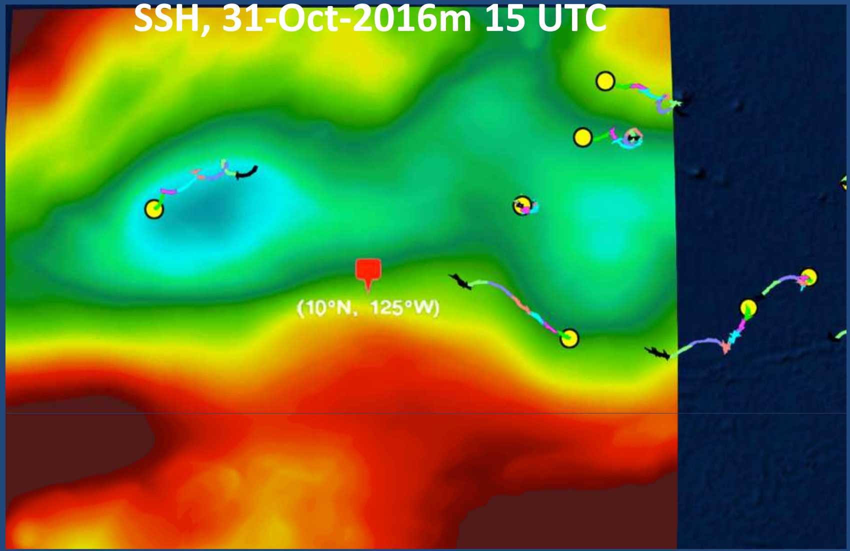
2013 Spring, Model Predicted Sub-mesoscale features

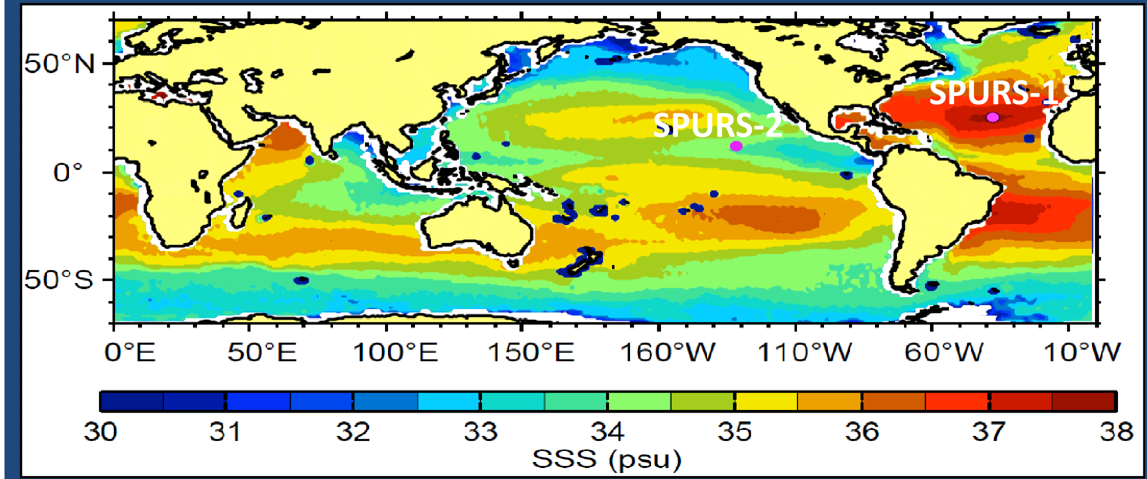


Assimilation of multi-satellite altimetry measurements improved the representation of submesoscale but partially.

Performance of the SPURS-2 Data Assimilation and Forecasting System

- Nested ROMS model
- Multiscale 3DVAR (Li et al, 2015a, b)
- Three-hourly Bulk atmospheric forcing from NCEP GFS forecasts
- http://spurs2.jpl.nasa.gov/
- The forecasting system has strong capability of predicting mesoscale eddies

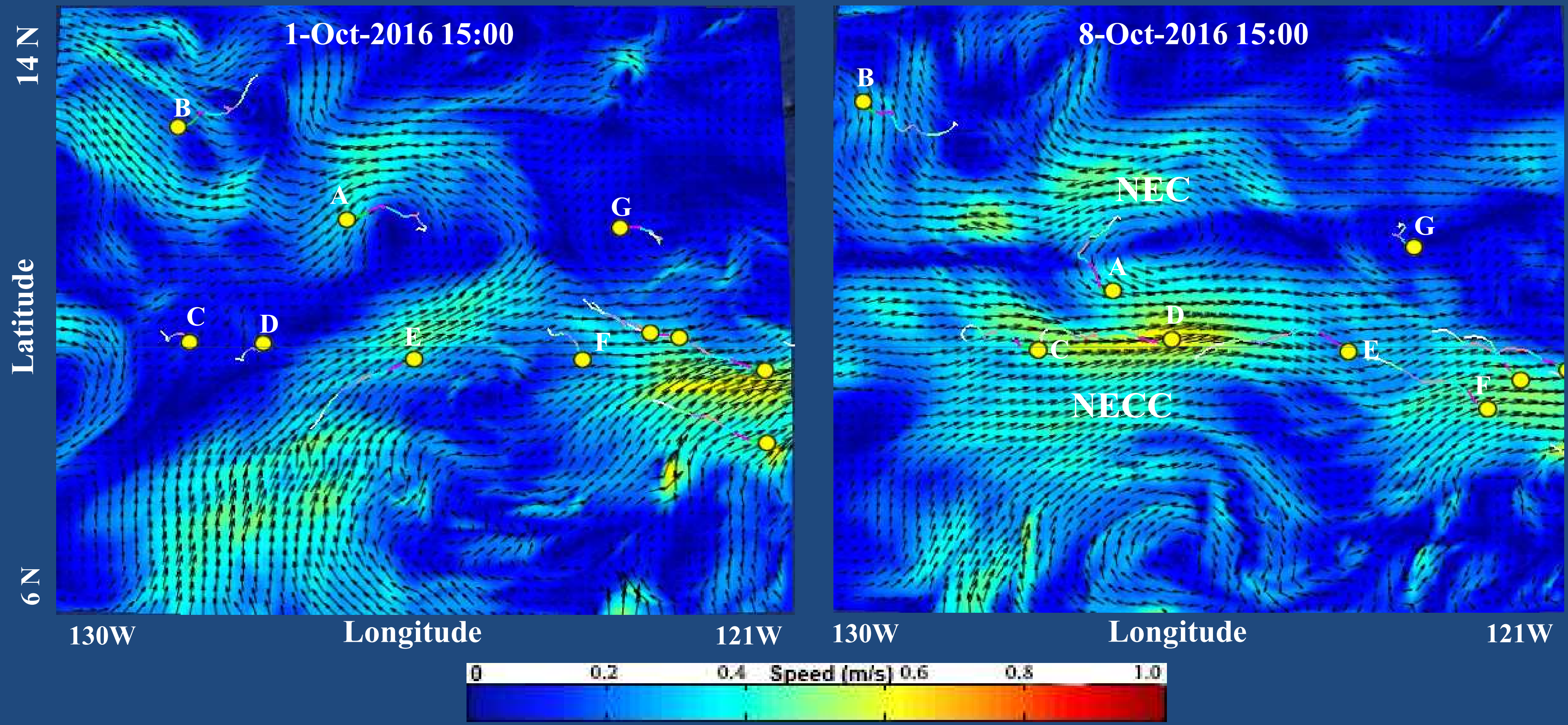




The NASA-sponsored SPURS(the Salinity Processes in the Upper Ocean Regional Study) field campaign studies the salinity balance in the upper ocean:

- First phase (SPURS-1 2012-2013) focused on the salinity maximum of the North Atlantic.
- Second phase (SPURS-2, 2016-2017) focused on the low- salinity region of the eastern tropical Pacific

Model Currents and Observed Drifter Trajectories



A yellow bullet indicates the current locations of an AOML's GTS drifter
The tail is the trajectory for the past 7 days

Drifter trajectories are not assimilated

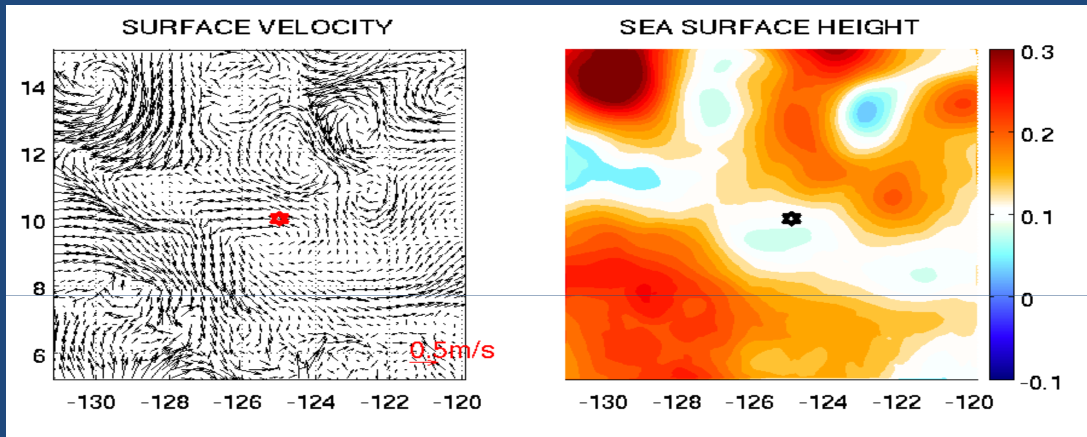
NECC=North Equatorial Countercurrent
NEC =North Equatorial Current

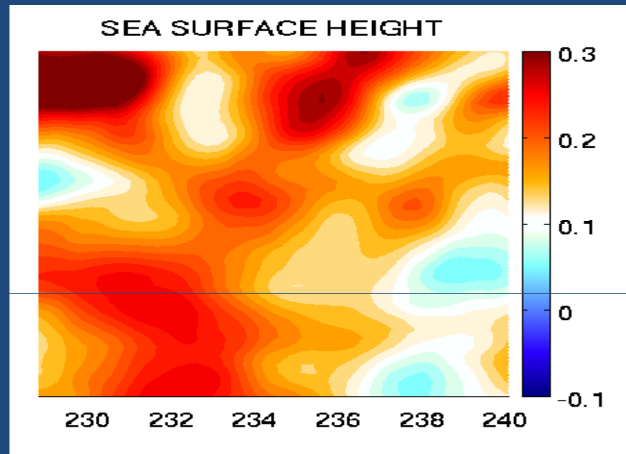
Impact of Multi-Satellite Altimetry

17-Aug-2016, 03 UTC

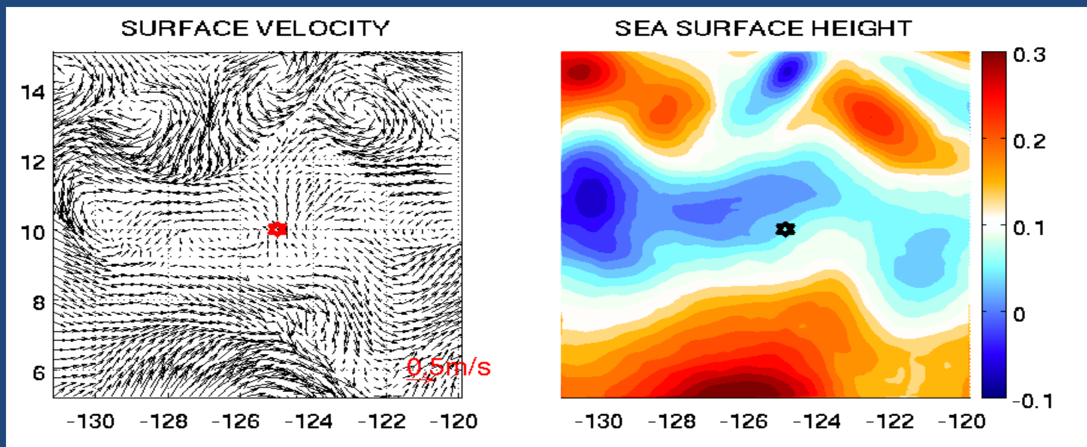
AVISO

With Altimetry





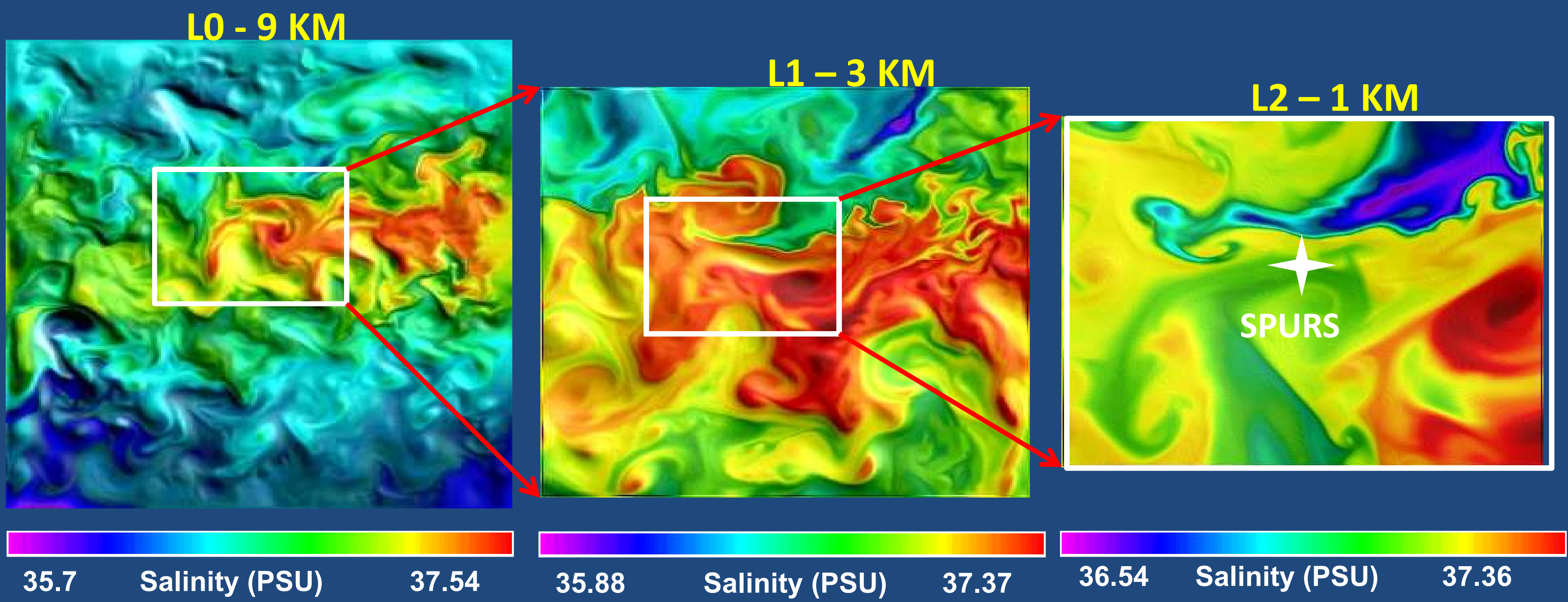
Without Altimetry



With the assimilation of multi-satellite altimetry measurements, the mesoscale eddies that could be identified by drafter trajectories were predicted

Three-Domain ROMS Model in Support of SPURS-1

- 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



(49.7W 10.6N) to (33.33W 33.41N)

(41.7W 20.34N) to (32.55W 28.31N)

(39.7W 23.37N) to (37W 26.23N)

Focus on this Domain

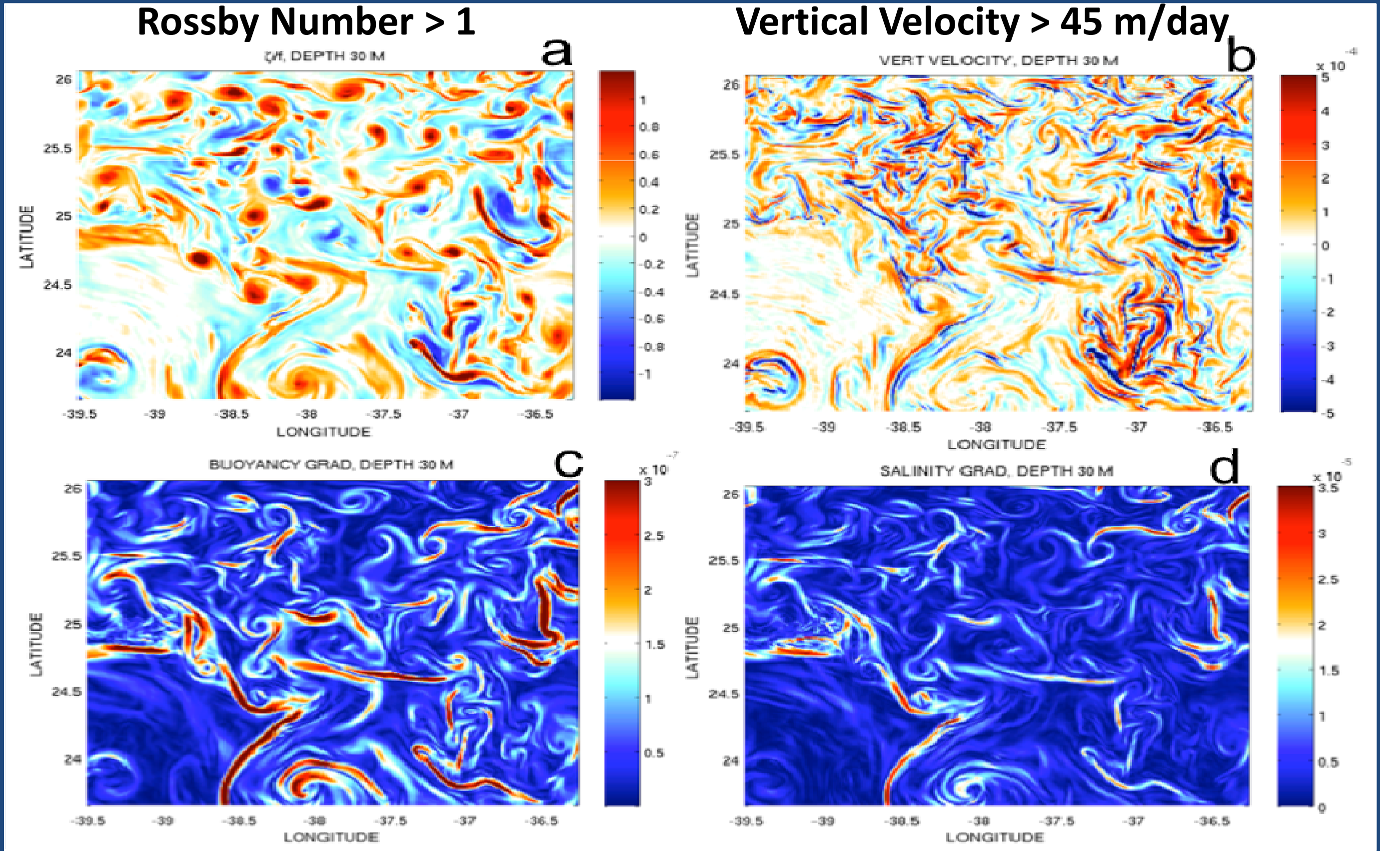
Submesoscale Flows

No commonly accepted definition

1 Spatial scale < 50 km (SWOT definition)

2 Rossby number > 1 (ageostrophic and nonlinear)

3 Vertical velocity of order of 10 m /day(one to two order of magnitude larger than those of mesoscale



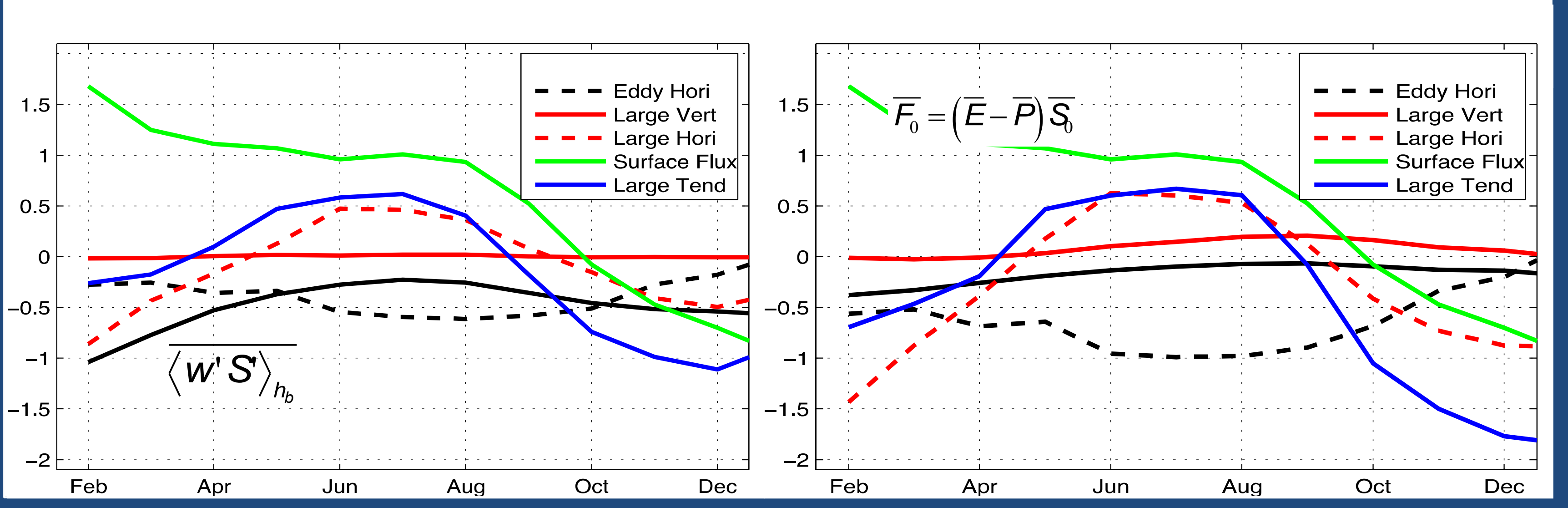
The SSS-max region in the subtropical North Atlantic was previously considered an “eddy desert”, but submesoscale flows are as energetic as known submesoscale active regions

Submesoscale Contribution to Salinity Balance

$$\int_{h_b}^{0}\langle\frac{\partial\bar{S}}{\partial t}\rangle\,dz = -\int_{h_b}^{0}\langle\bar{v}\cdot\nabla_H\bar{S}\rangle dz - \int_{h_b}^{0}\langle\bar{w}\,\frac{\partial\bar{S}}{\partial z}\rangle\,dz - \int_{h_b}^{0}\langle\nabla_H\cdot\overline{v'S'}\rangle dz + \langle\overline{w'S'}\rangle_{h_b} + \langle\overline{F_0}\rangle + \int_{h_b}^{0}\langle\bar{D}\rangle dz$$

Mesoscale

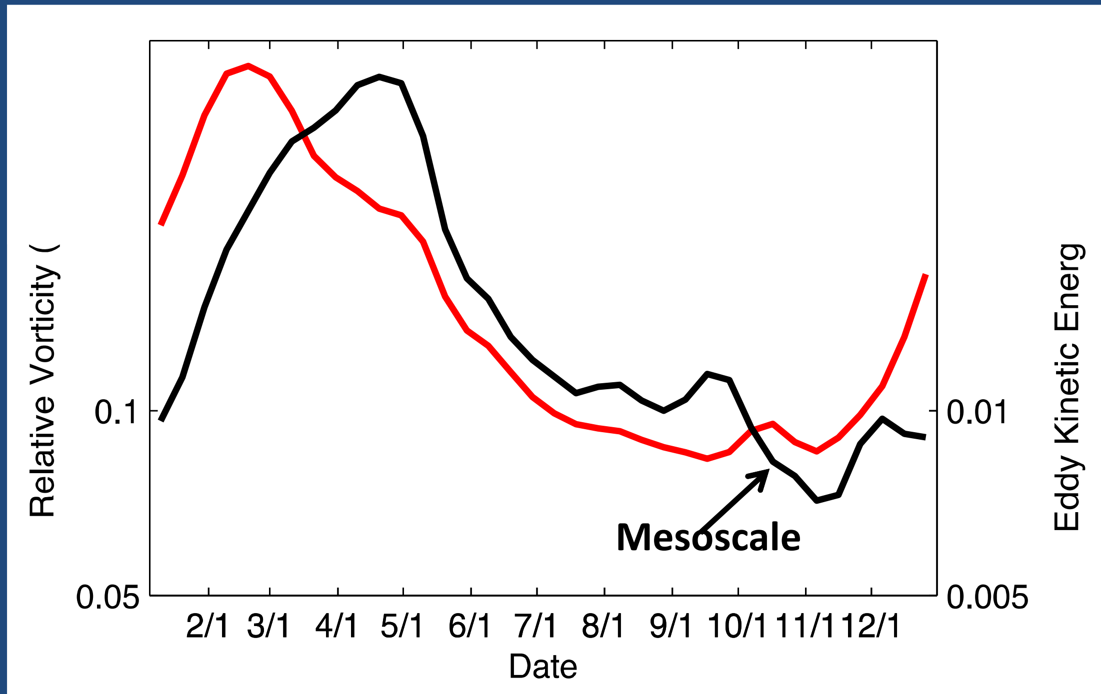
Submesoscale



The magnitude of the salinity reduction due to submesoscale vertical mixing can reach 60% of the effect of surface freshwater flux near the surface and 25% within the mixed layer as a whole

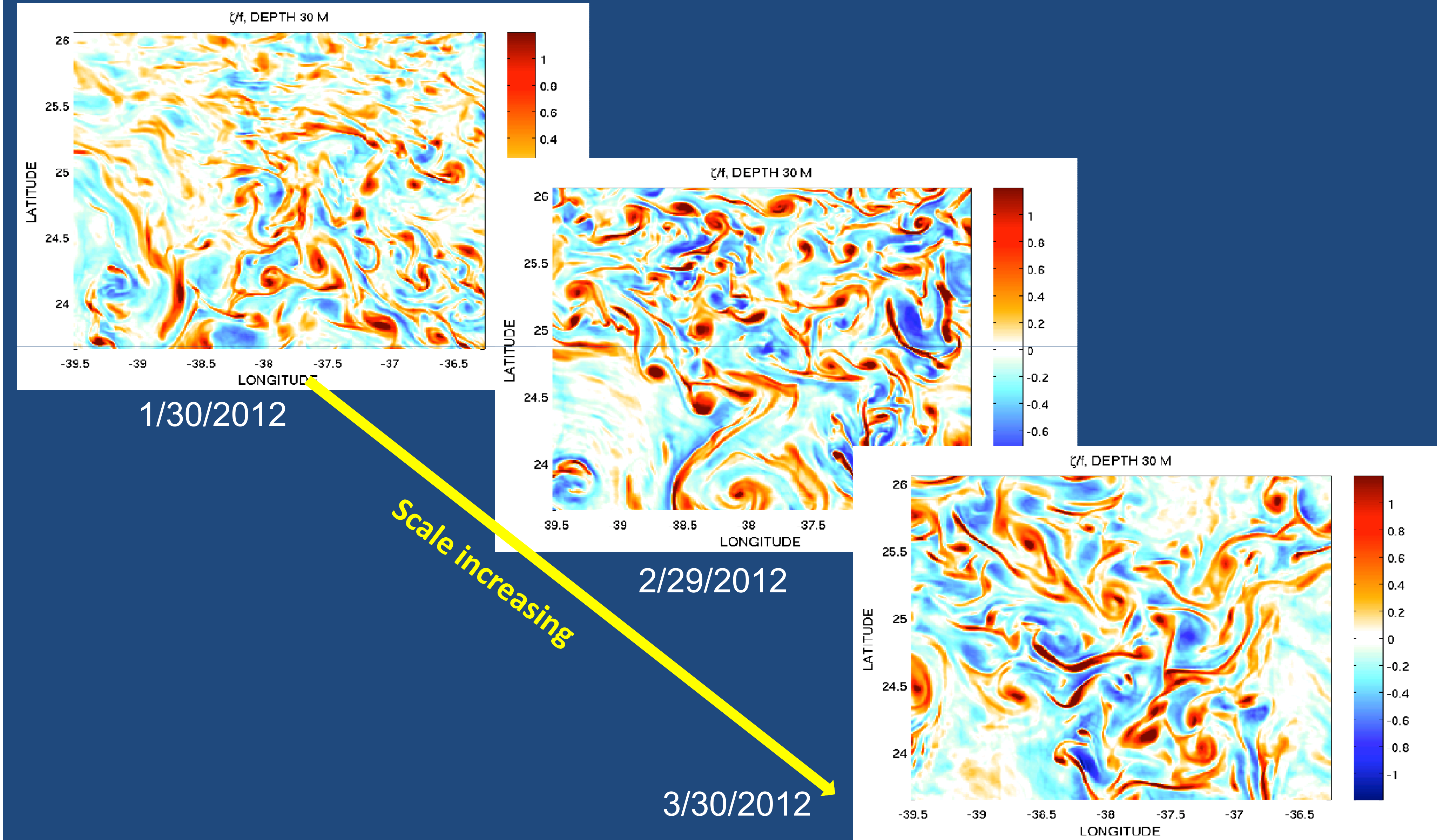
Seasonal Variability of Mesoscale and Submesoscale Activities and Energy Cascade

- **EKE: captured by mesoscale eddies**
- **Relative vorticity: highlights the energy of smaller scale structures**



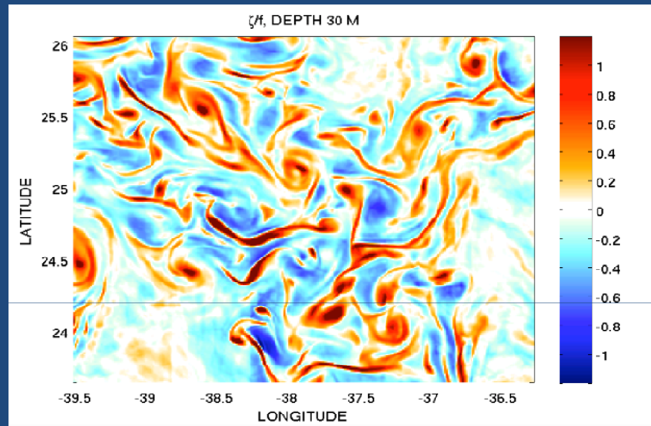
The time lag of two months in these regions suggests the existence of an inverse energy cascade from small scales to larger scales

Submesoscale Energy Inverse Cascade

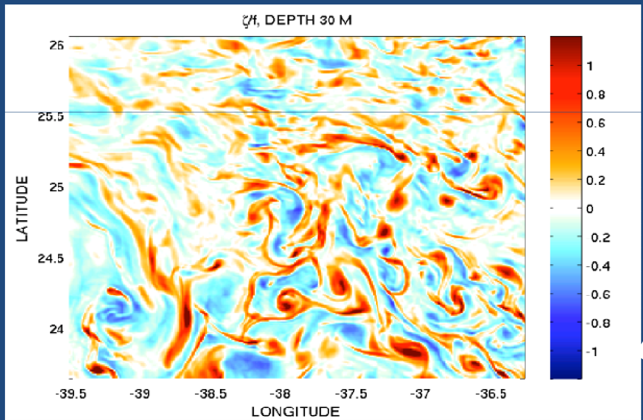


Dynamical Routes of Submesoscale Flows: Growth or Dissipation ?

Mesoscale



Submesoscale



Inverse Cascade

Forward Cascade

Microscale

Dissipation

1 Growing to mesoscale ?

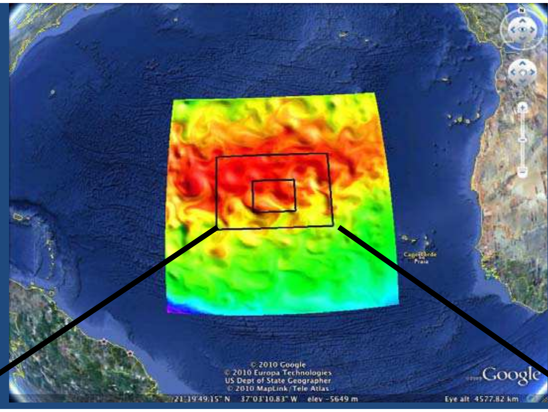
2 Merged ?

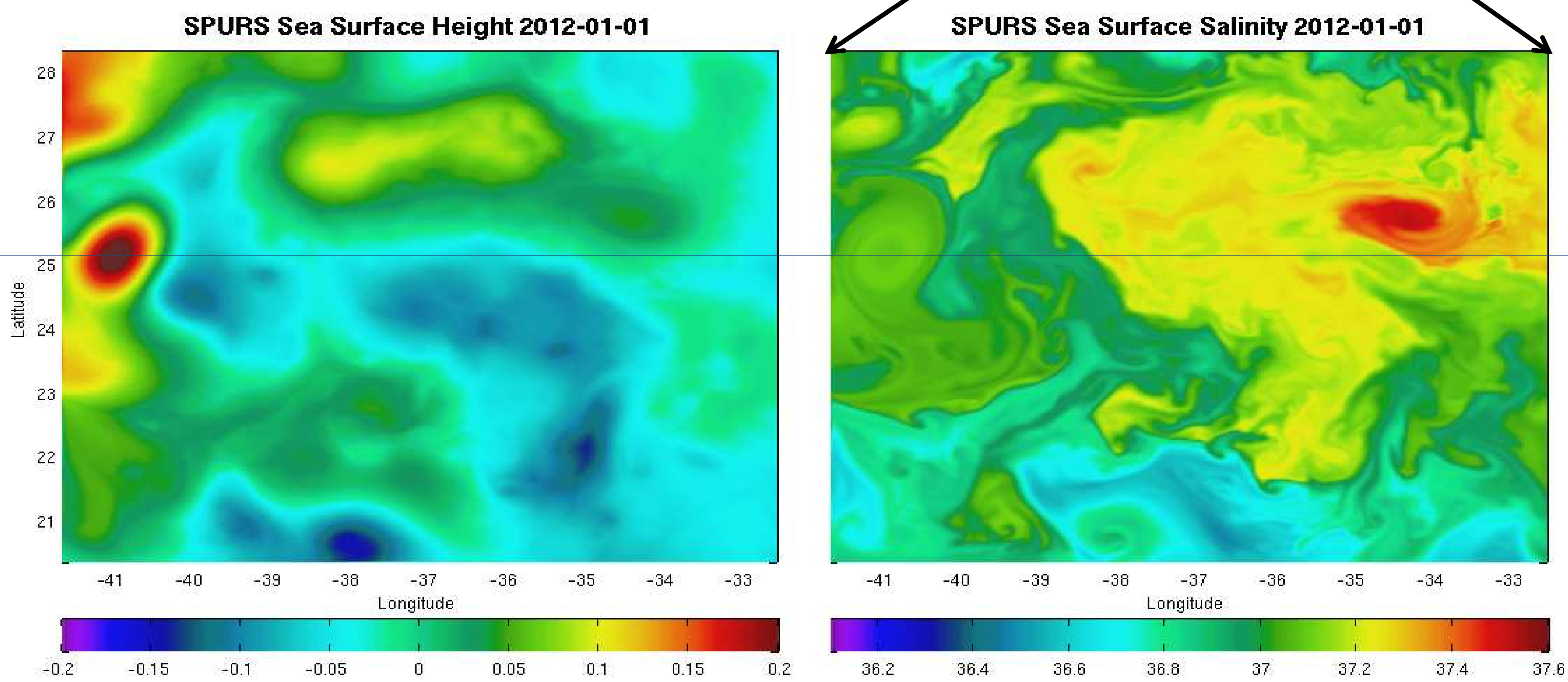
3 Dissipated ?

Summary

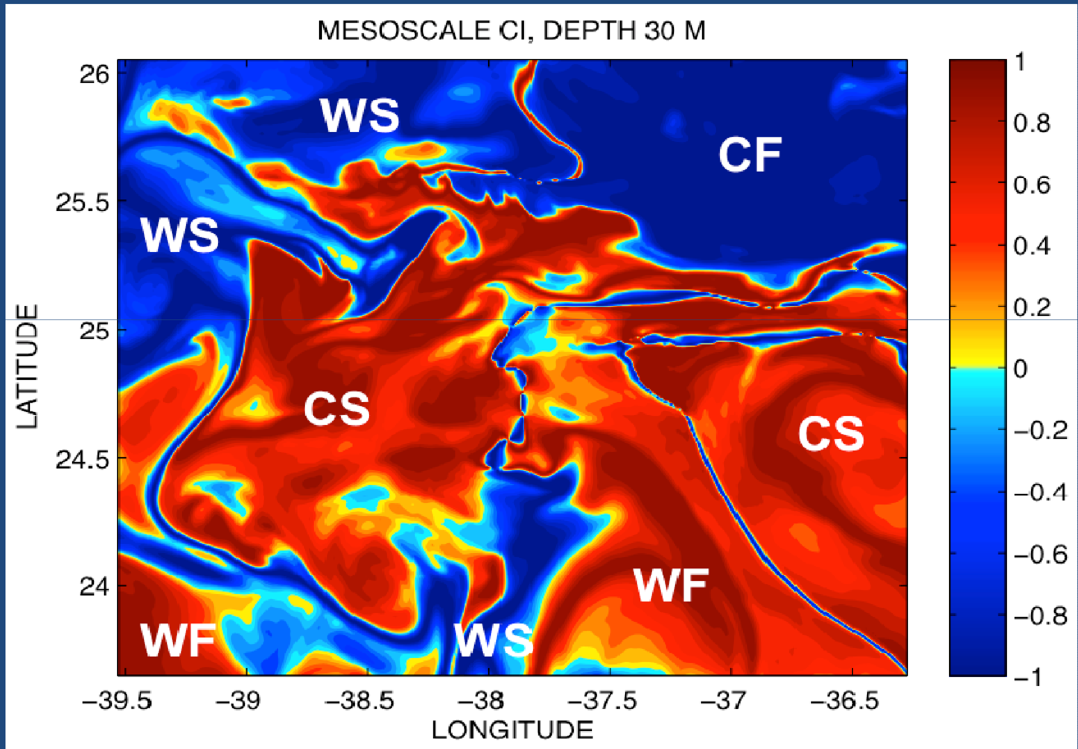
1. The SPURS-2 data assimilation and forecasting system predicted observed mesoscale eddies due to the assimilation of multi-satellite altimetry measurements
2. The assimilation of multi-satellite altimetry measurements constrains model biases
3. Submesoscale flows make a major contribution to near-surface salinity balance
4. Submesoscale flows of the same scale may grow (inverse cascade), merge (?) or dissipate (forward cascade)
5. Higher resolution simulations needed?

Eddy Activities and Energy Cascade





Density Compensation



$$\Delta\rho = -\alpha\Delta T + \beta\Delta S$$

$$CI = \frac{-2\beta\alpha\Delta S\Delta T}{|\beta\Delta S|^2 + |\alpha\Delta T|^2}$$

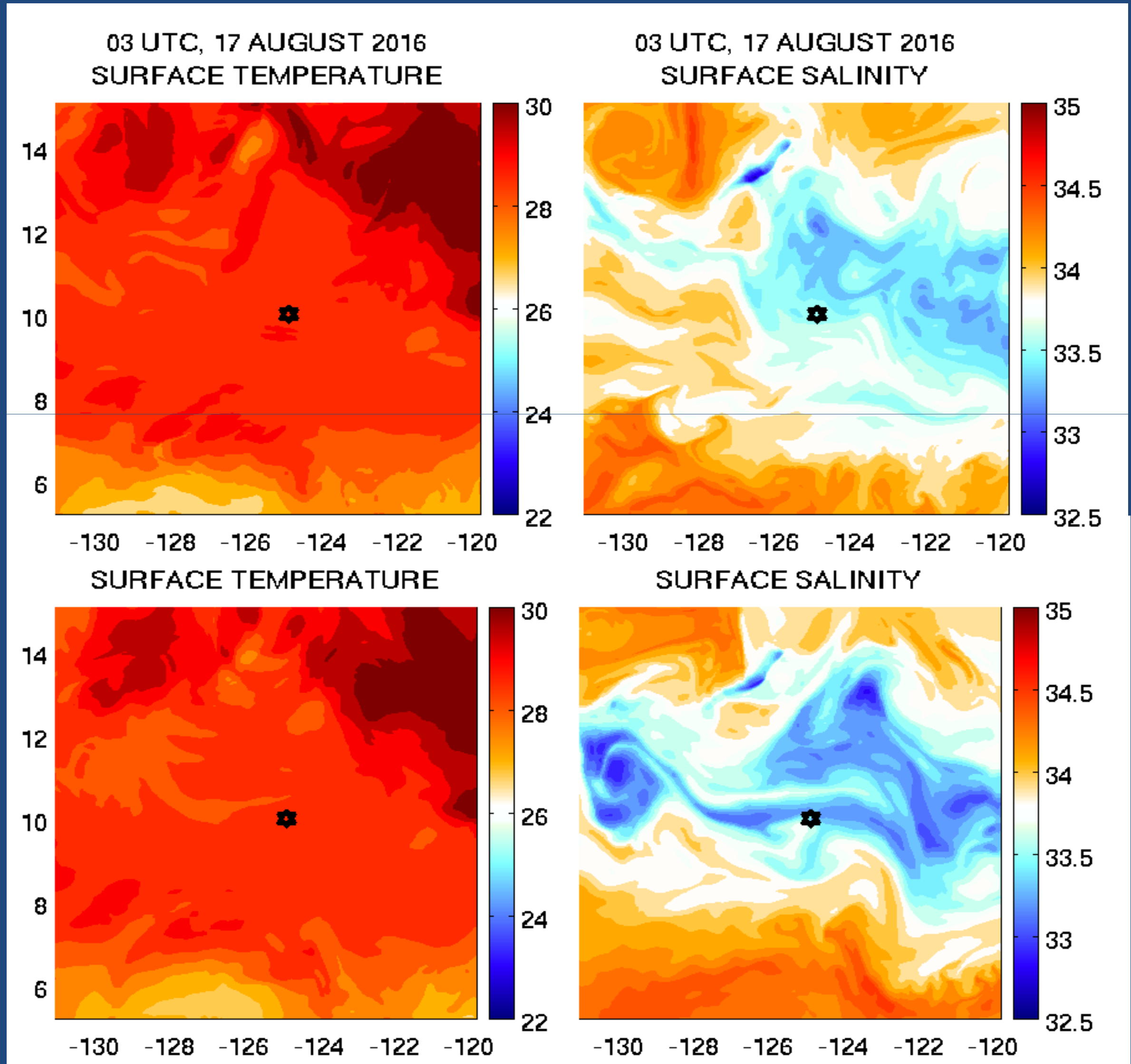
$$-1 \le CI \le 1$$

Water masses of different density compensation property create density gradients

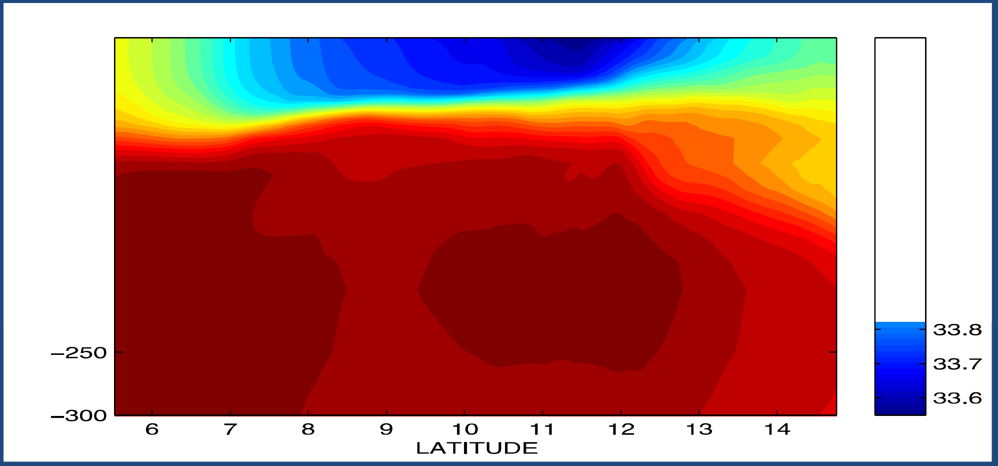
Impact of Multi-Satellite Altimetry on Temperature and Salinity Fields

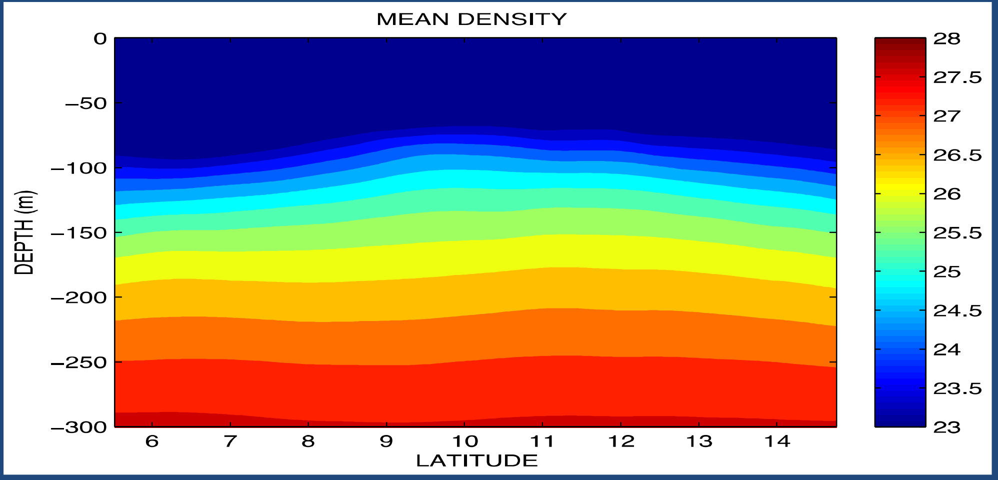
With Altimetry

Without Altimetry



Improved the Representation of the Barrier Layer





Sprintall et al.