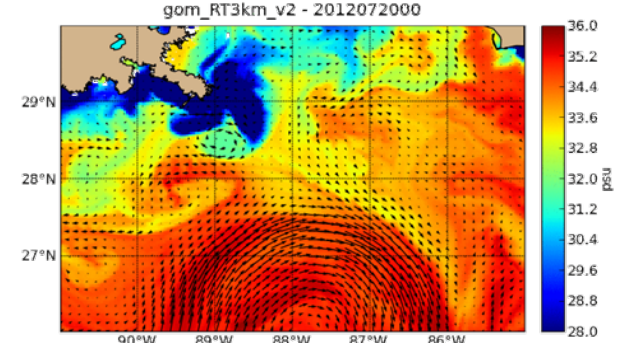
Submesoscale prediction and effects on surface dispersion during the Grand Lagrangian Deployment (GLAD) Experiment



D. Bogucki –Texas A&M Univ., J. Beron-U.Miami, S. Chen-U.Miami, E. Coelho-UNO/NRL, M. Curcic-U.Miami, A. Griffa-U.Miami, M. Gough-U.Miami, B. Haus-U.Miami, A. Haza-U.Miami, P. Hogan-NRL, H. Huntley-U.Delaware, M. Iskandarani-U.Miami, G. Jacobs-NRL, F. Judt-U.Miami, D. Kirwan-U.Miami, N. Laxague-U.Miami, A. Levinson-U.Florida, B. Lipphardt-U.Delaware, A. Mariano-U.Miami, G. Novelli-U.Miami, J. Olascoaga-U.Miami, T. Ozgokmen-U.Miami, T. Prasad-NRL, A. Poje-City Univ.NY, A. Reniers-U.Miami, E. Ryan-U.Miami, C. Smith-U.Miami, M. Wei-NRL

Take home points:

- Ocean time scales and error time scales are long -> altimeter assimilation
- Drifters can supplement satellite altimetry as on scene ‘altimeters’
- Submesoscale effects significantly alter surface particle dispersion

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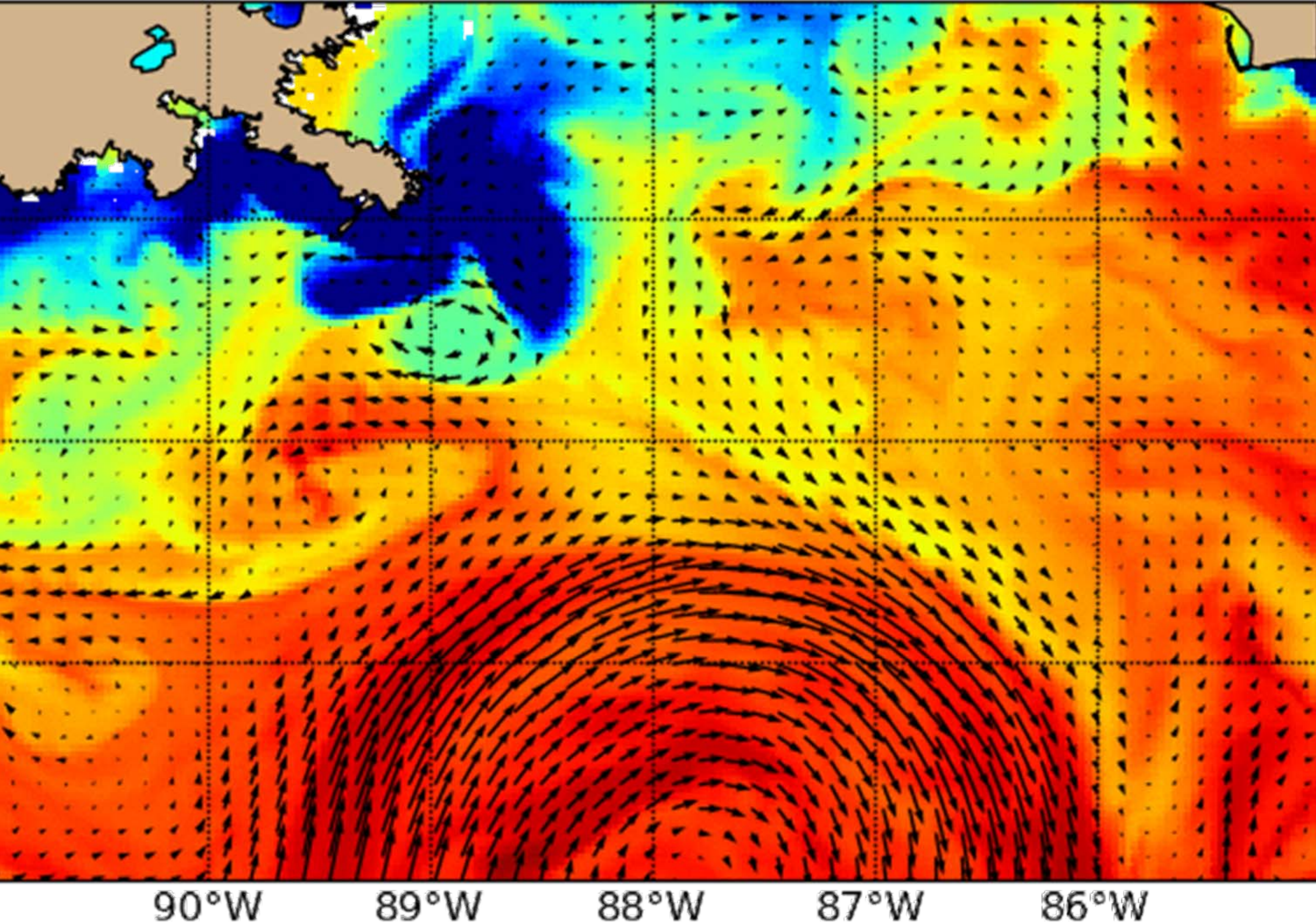
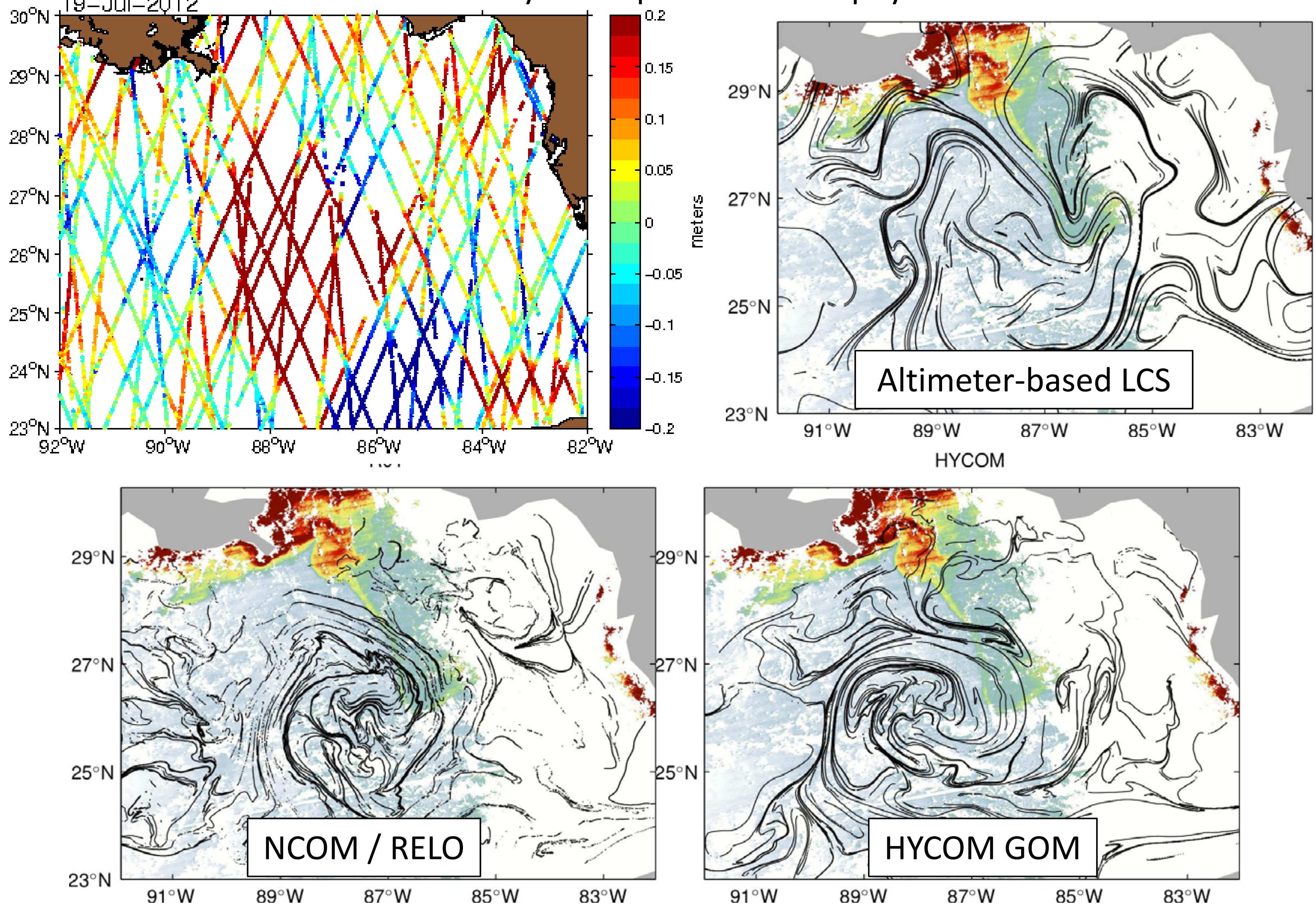

90°W
89°W
88°W
87°W
86°W

Features in altimetry correspond to chlorophyll advection



Real time model forecasts assimilating altimeter data missed features

Understanding the ocean time scales

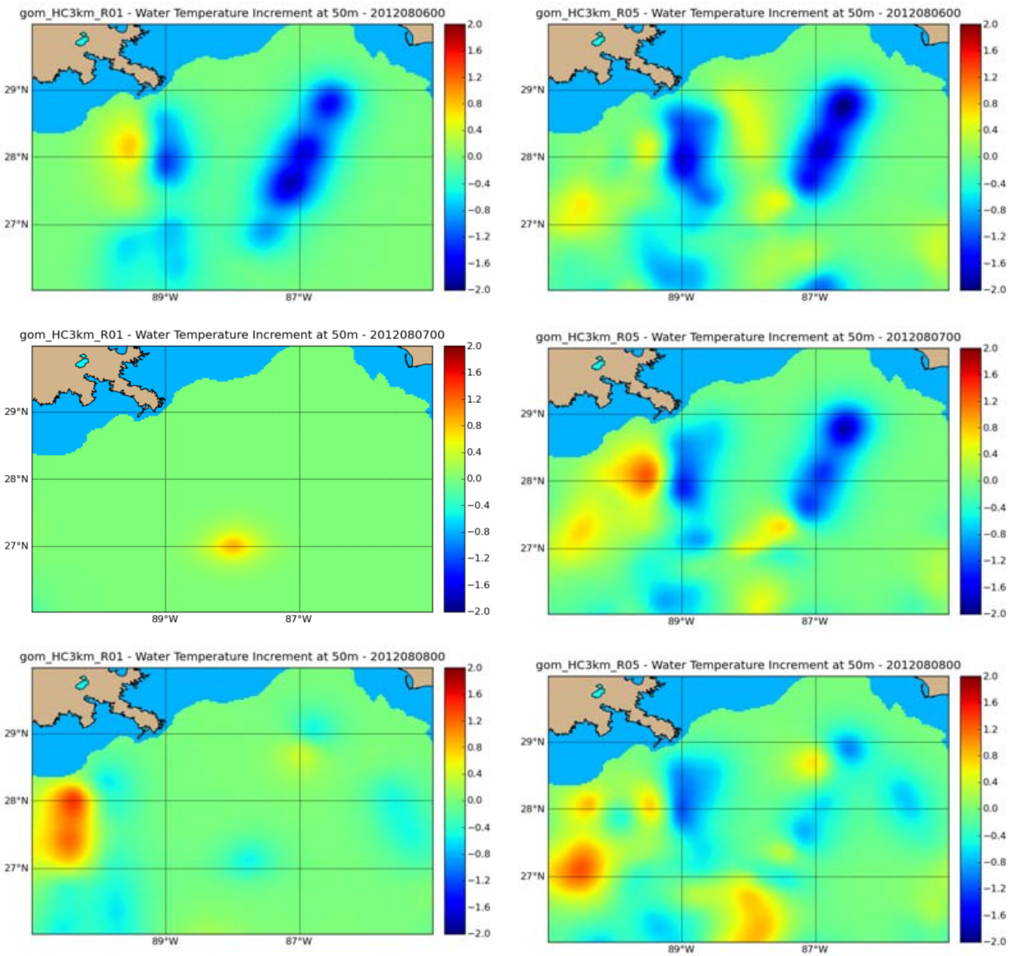
50 m temperature analysis increments

R01, 1 day time scale | R01, 7 day time scale

Aug 6, 2012

Aug 7, 2012

Aug 8, 2012



A series of 12 experiments perturbing the implication of observations

- Background error variance
- Spatial correlation scale
- Temporal correlation scale

R01:

- Use all data received in the last 24 hours
- Construct analysis
- Apply increment over 6 hours

R05:

- Use all data received in the last 7 days
- Construct analysis
- Apply increment over 24 hours

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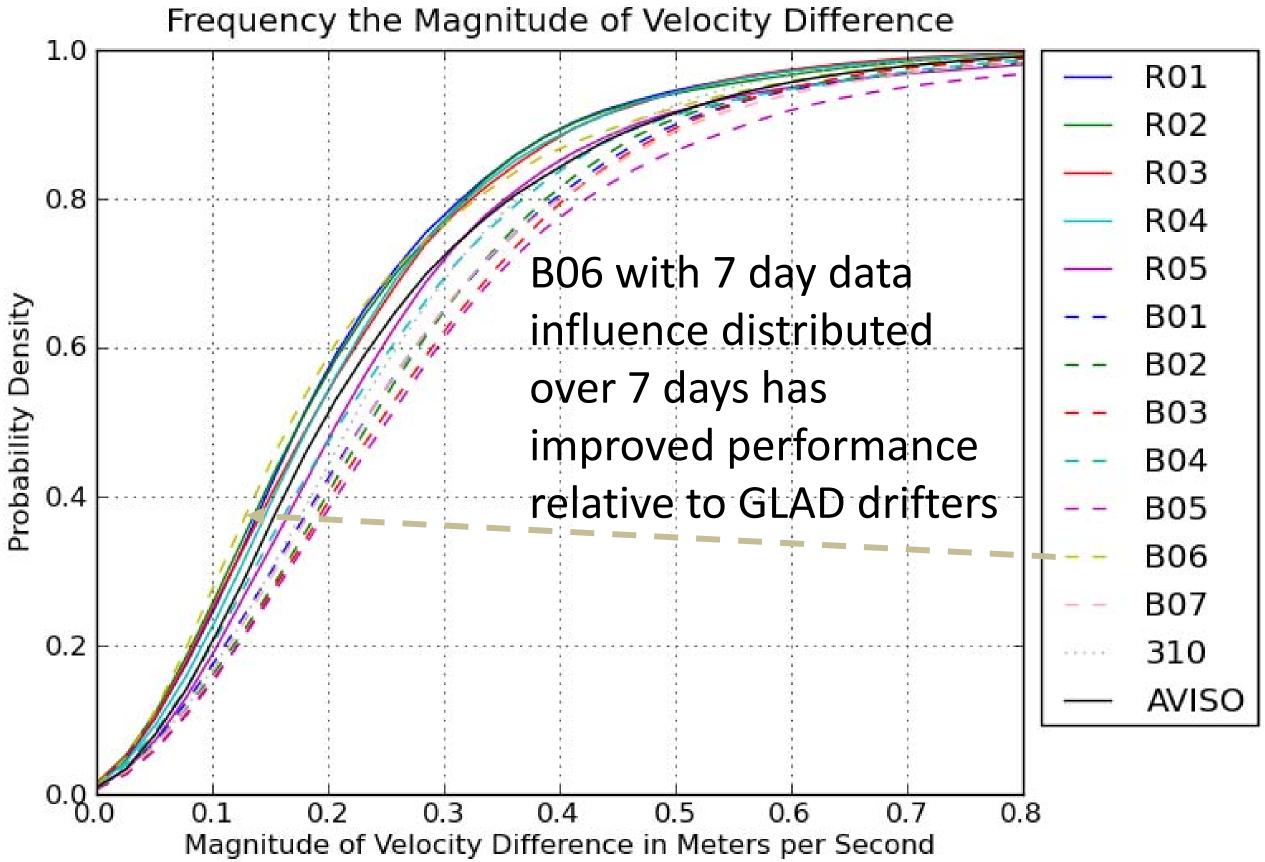
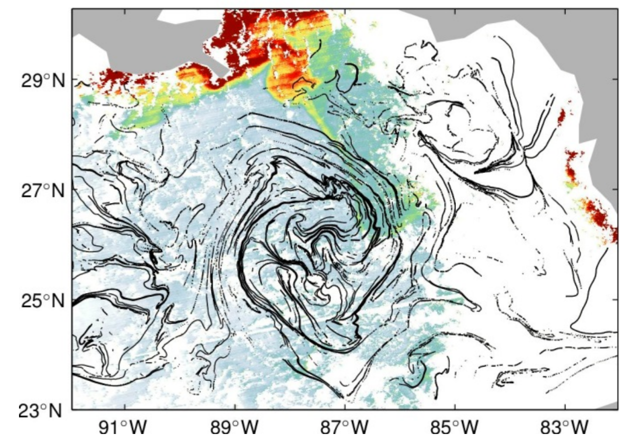
Observed corrections to forecasts have long time scales, just as do ocean processes

Understanding the implications of data relative to the ocean

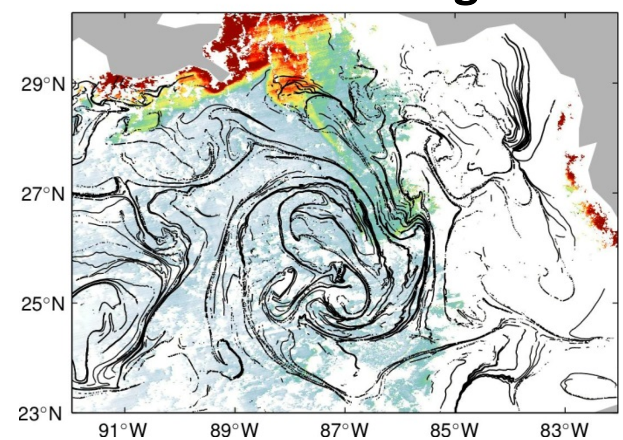
- LCS and GLAD data are definitive in showing shortcomings
- Features are in data but not forecasts
- A series of controlled reanalysis experiments with perturbations in assimilation parameters reveals new information



LCS real time during GLAD



LCS with new understanding



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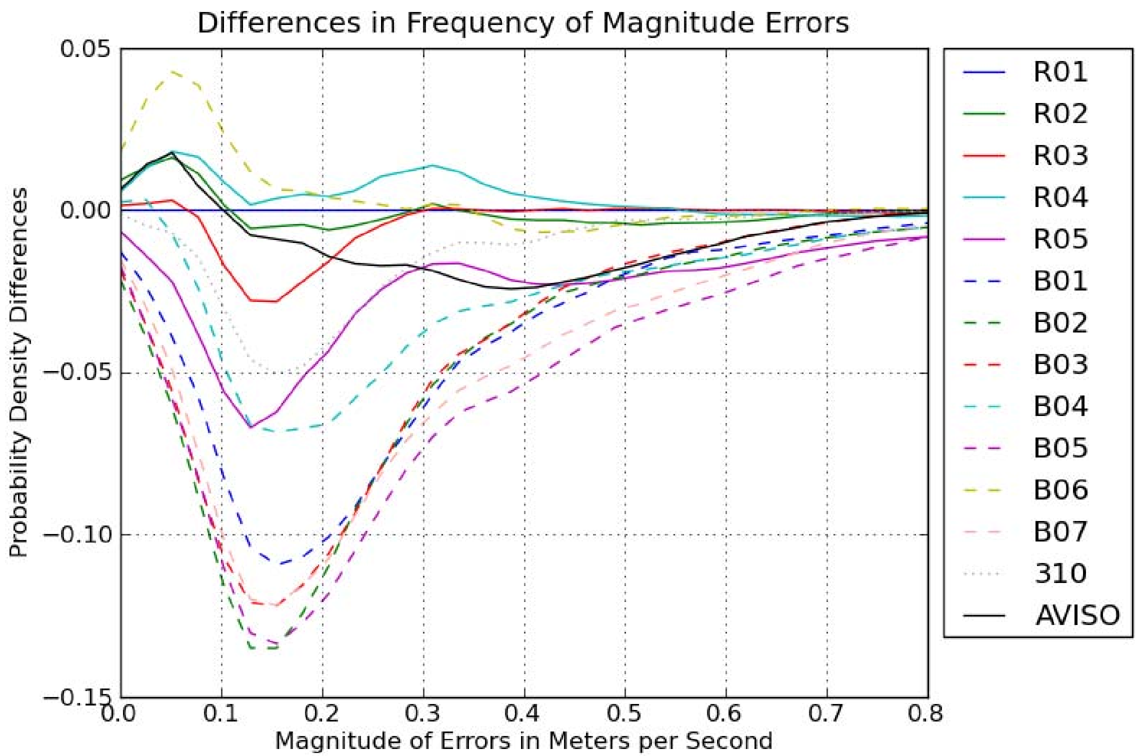
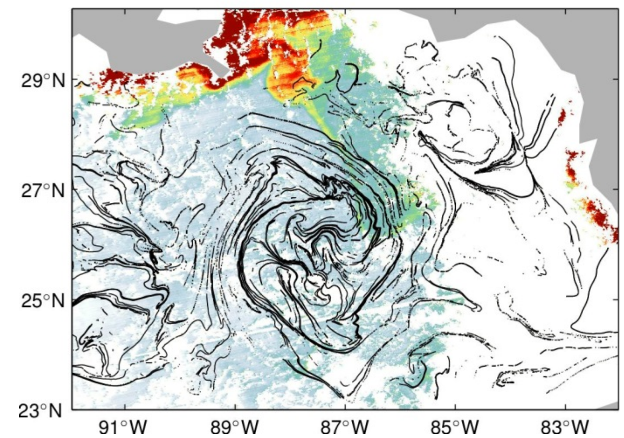
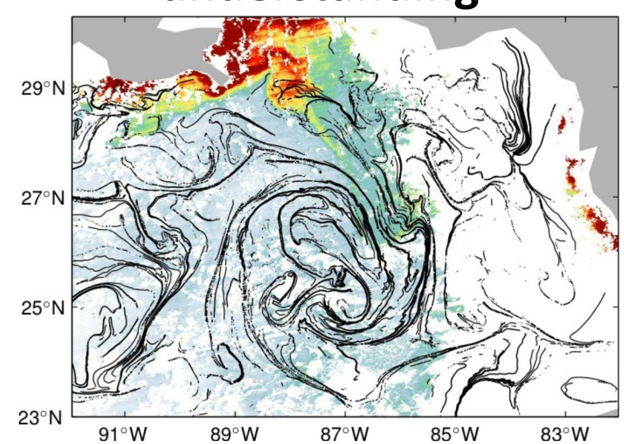


LCS real time during GLAD



LCS with new understanding



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Observed corrections to forecasts have long time scales, just as do ocean processes

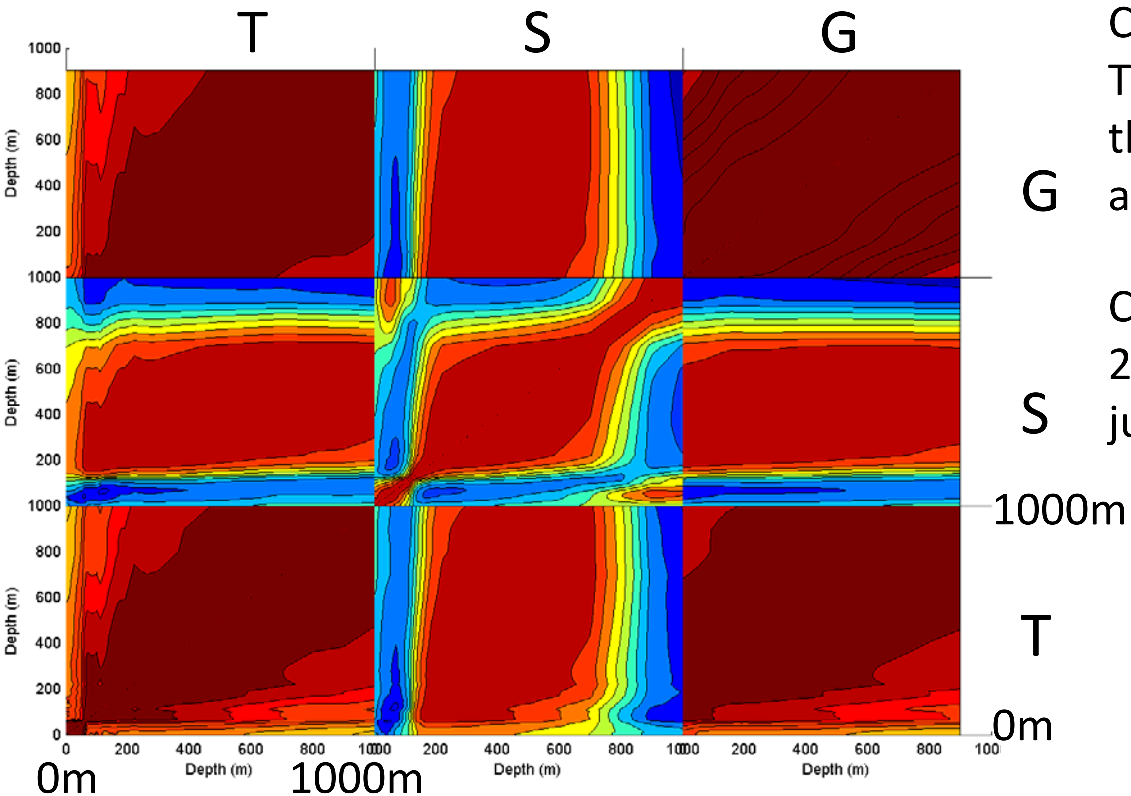
Understanding the implications of GLAD relative to the ocean T&S

- Surface currents are inferred from drifters
- How are currents related to subsurface T&S?

Forward problem: T&S produces pressure (geopotential anomalies), which imply geostrophic currents
Inverse problem: Given velocities, must infer geopotential anomalies and then T&S
Solved through historical data covariances

$$B = \langle \acute{Y}\acute{Y}^T \rangle = \begin{bmatrix} \acute{X}\acute{X}^T & \acute{X}\acute{X}^T \delta^T G \\ G^T \delta^T \acute{X}^T \acute{X} & \delta G X \acute{X}^T G^T \end{bmatrix}$$

$$\acute{X} = [\acute{T}_1 \quad \cdots \quad \acute{T}_N \quad \acute{S}_1 \quad \cdots \quad \acute{S}_1]$$



Cross Correlation matrix extended T&S (X’) to include geopotential (Y’) through linearized specific volume anomaly (δ) and vertical integral (G)

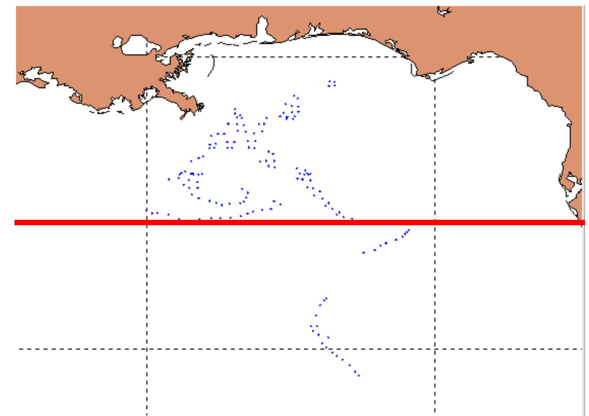
Cross Correlation February, 275°E, 24°N, Gulf of Mexico in Loop Current just off Cuba

S Smith, et al., The Impact of Velocity Data Assimilation from Drifters using the Navy Coupled Ocean 3d Variational Data Assimilation System (NCODA-VAR), in preparation

Extensions to ocean property relations connects velocity to T&S

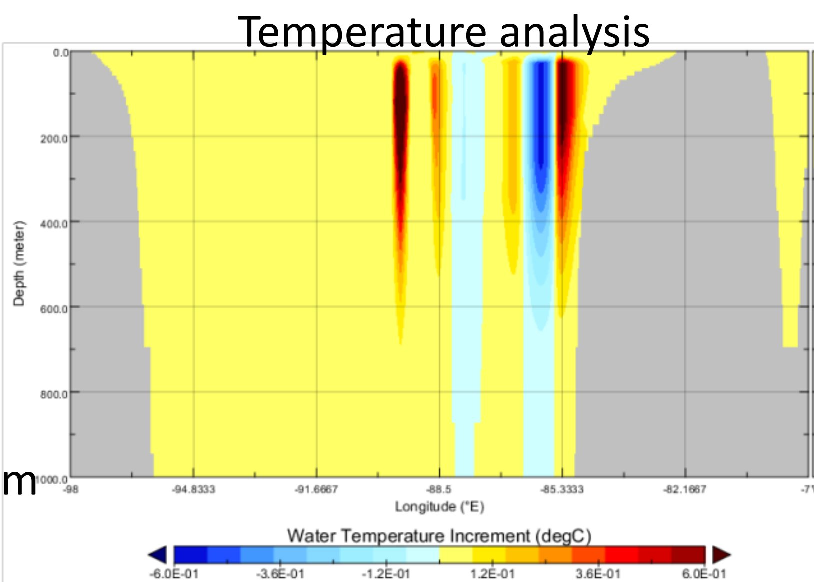
Understanding the implications of GLAD relative to the ocean

- Surface currents are inferred from drifters
- How are currents related to subsurface T&S?



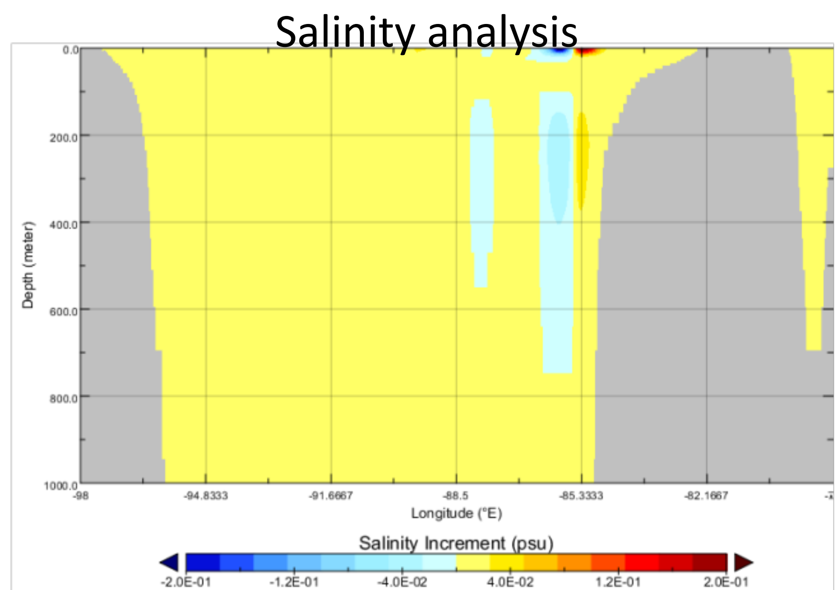
Example, 1 Aug 2012
Analysis increments across 27°N
Using drifter velocities only
Surface velocities are extended to T&S throughout the water column

0m



1000m

-0.6°C 0.6°C



-0.2 psu 0.2 psu

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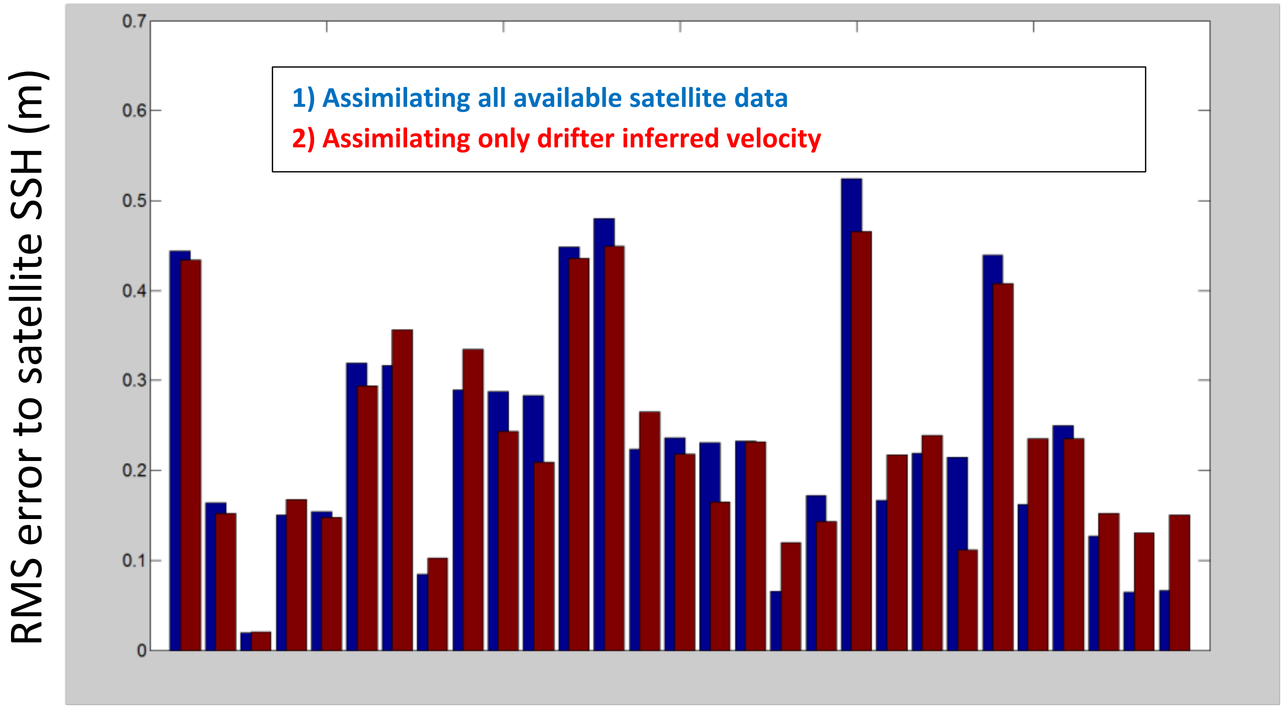
Surface drifters can now affect the deep ocean T&S

Understanding the implications of GLAD relative to the ocean

Two experiments split at the drifter deployment time:

1) Assimilate only satellite SSH and synthetics
2) Assimilate only surface drifter obs

Both experiments compared to satellite SSH



August 1 – 30, 2012

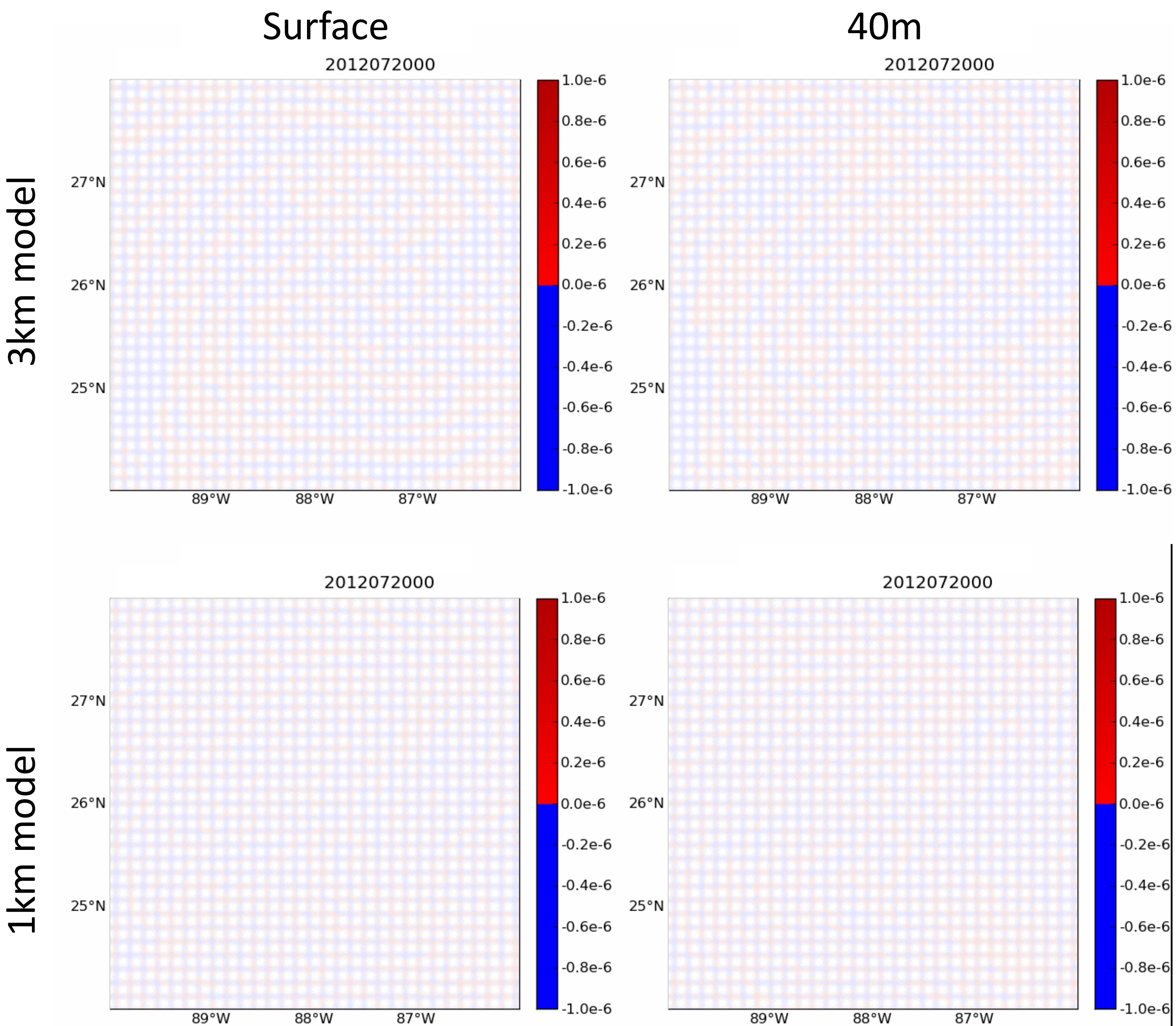
1) Assimilate only satellite SSH and synthetics **<- compares less well to satellite SSH**
2) Assimilate only surface drifter obs **<- compares better to satellite SSH**

Drifters are concentrated on scene, providing continuous observations

S Smith, et al., The Impact of Velocity Data Assimilation from Drifters using the Navy Coupled Ocean 3d Variational Data Assimilation System (NCODA-VAR), in preparation

Drifters are equivalent to miniature satellites, observing SSH slope

Revealing the processes involved in surface dispersion



In the absence of divergence, an initial uniform concentration will stay constant

Surface contains stronger divergence that 40m

What are the relative impacts to a local group at different time scales due to divergence, strain, shear, rotation?

Gregg Jacobs, Francisco Javier Baron , Angelique Haza , Helga Huntley , Bruce Lipphardt , Josefina Olascoaga , Andrew Poje , Ed Ryan, Ocean Surface Process Effects on Buoyant Particle Distributions , in preparation

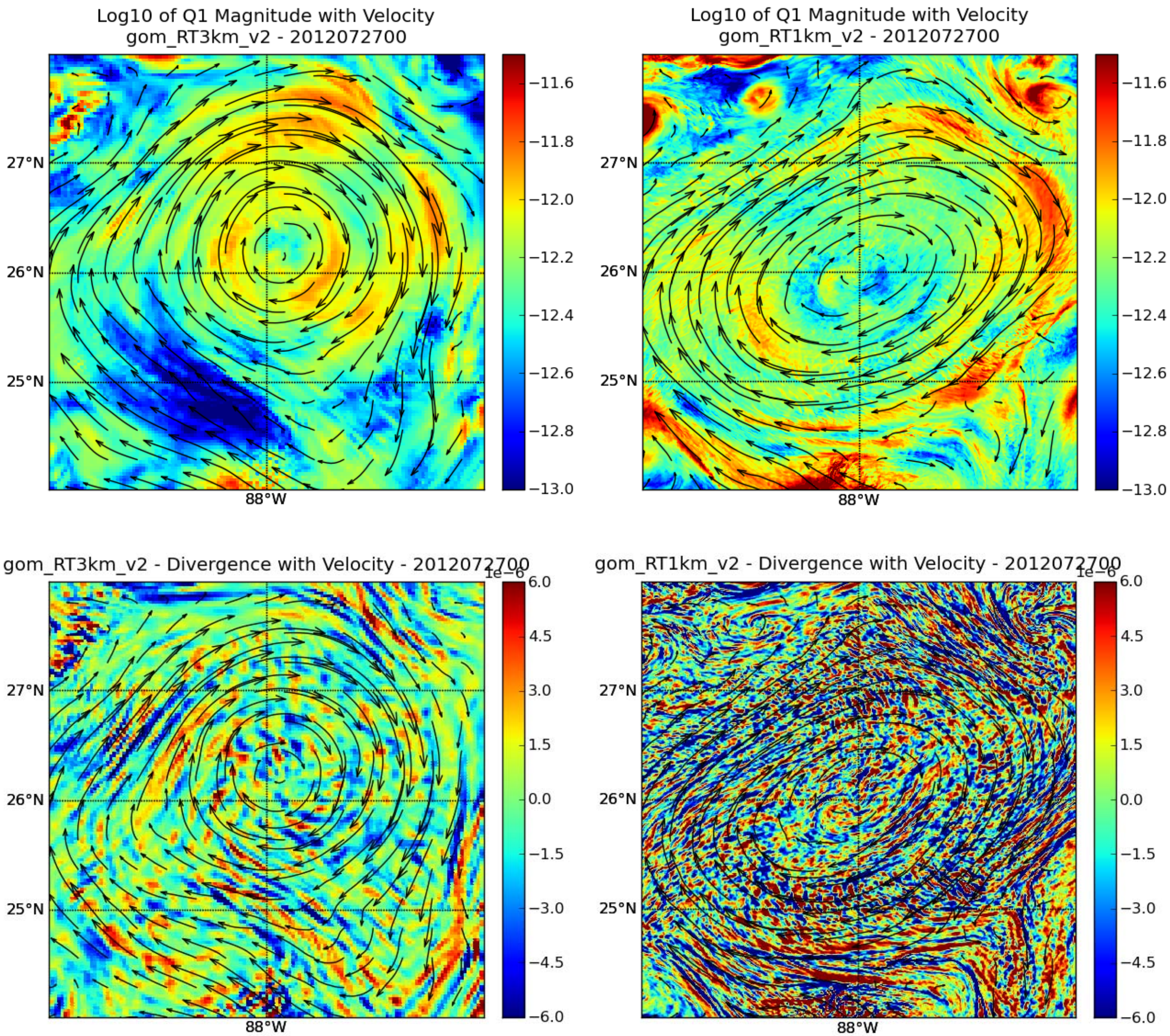
Divergence has an effect on particle evolution, but how much?

Revealing the processes involved in surface dispersion

3km resolution model | 1km resolution model

Frontogenesis forcing

Surface divergence



Frontogenesis forcing characteristics (scales, strength) do not change significantly from 3km to 1km resolution.

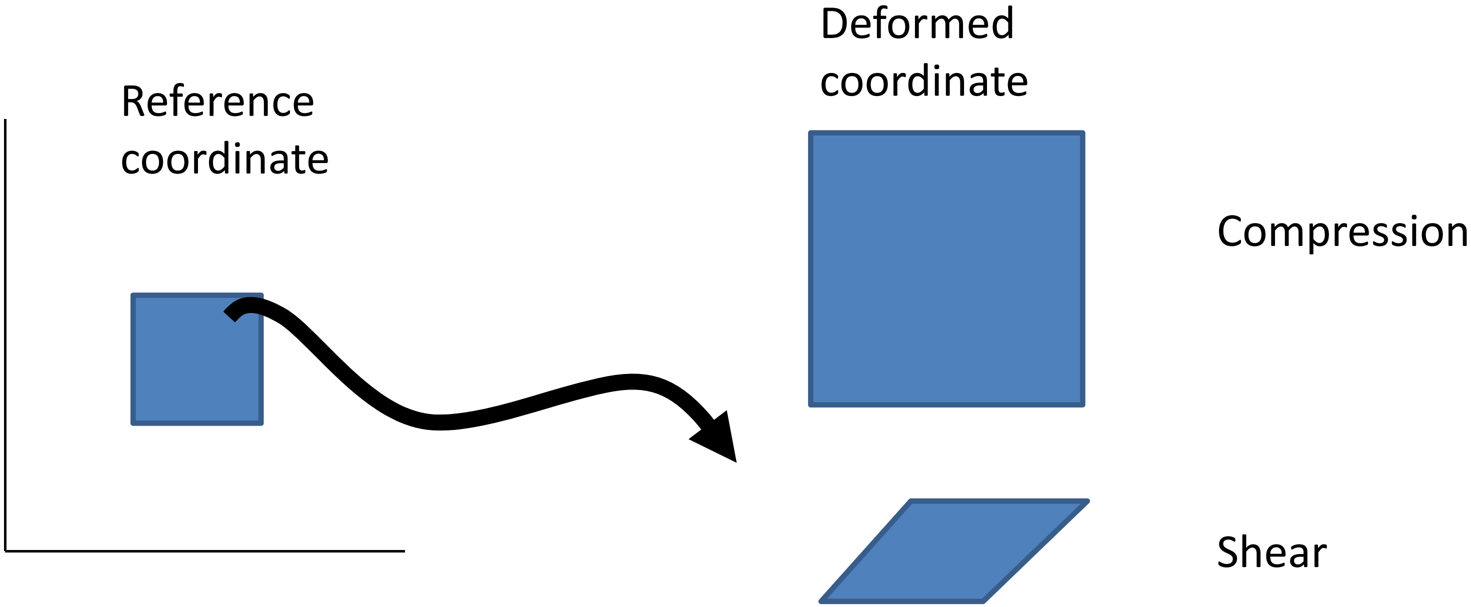
Surface divergence changes substantially as submesoscale instability in the mixed layer becomes resolved at 1km and to resolved at 3km.

What is the impact on surface transport?

Gregg Jacobs, Francisco Javier Baron , Angelique Haza , Helga Huntley , Bruce Lipphardt , Josefina Olascoaga , Andrew Poje , Ed Ryan, Ocean Surface Process Effects on Buoyant Particle Distributions, in preparation

Submesoscale physics are the source of the surface divergence difference

Shear versus compression



Material deformation tensor $$F_{ij} = \frac{\partial x_i}{\partial X_i}$$

Material deformation tensor rate of change $$\dot{F}_{ij} = \frac{\partial v_i}{\partial x_j} F_{ij}$$

Deformation through time is integrated in material elements through velocity gradient field

Right Cauchy Green tensor $$C = F^T F$$

Rotation deformation is removed

Eigenvalues and eigenvectors of C provide compression and shear

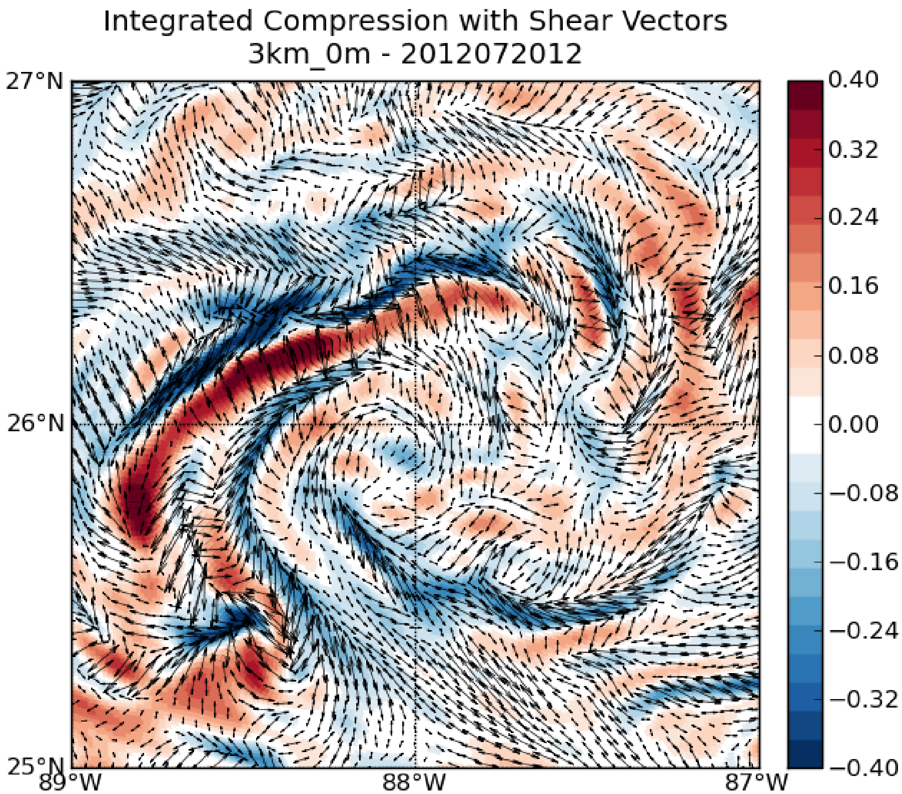
Shear and compression effects are separable by integrating deformation

Shear versus compression

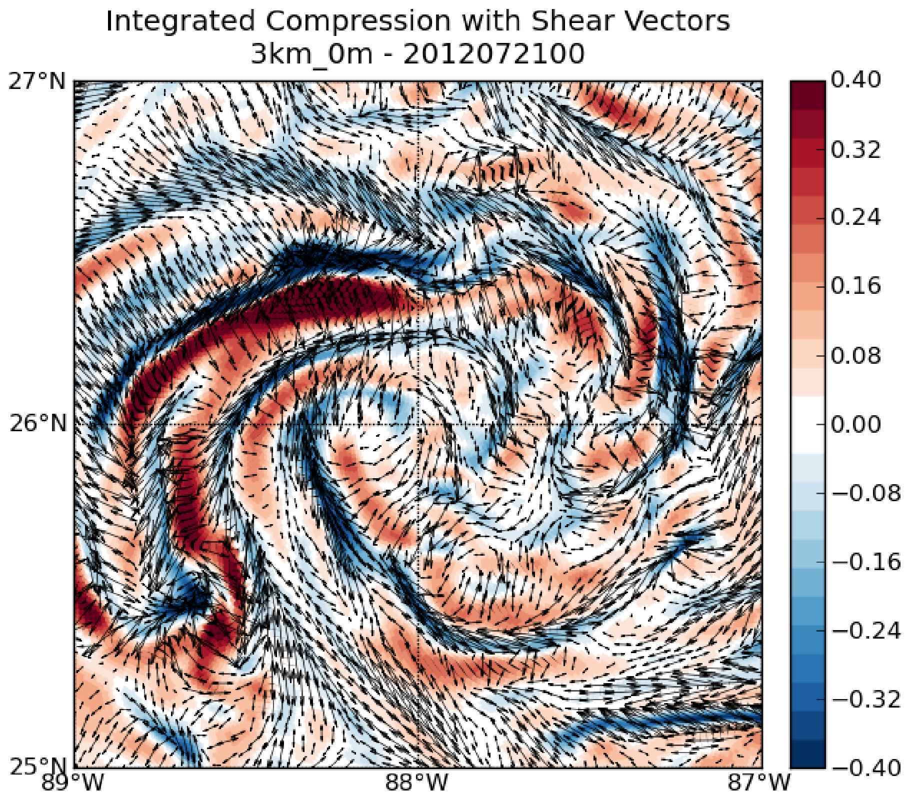
3km model, surface analysis
Color is 1/T*ln(compression)
Vectors are direction of primary shear eigenvector
Length of vectors is 1/T*ln(shear)

These are compressed filaments in which surface material is being stretched out by shear and simultaneously pulled in from the surrounding areas

+12 hours

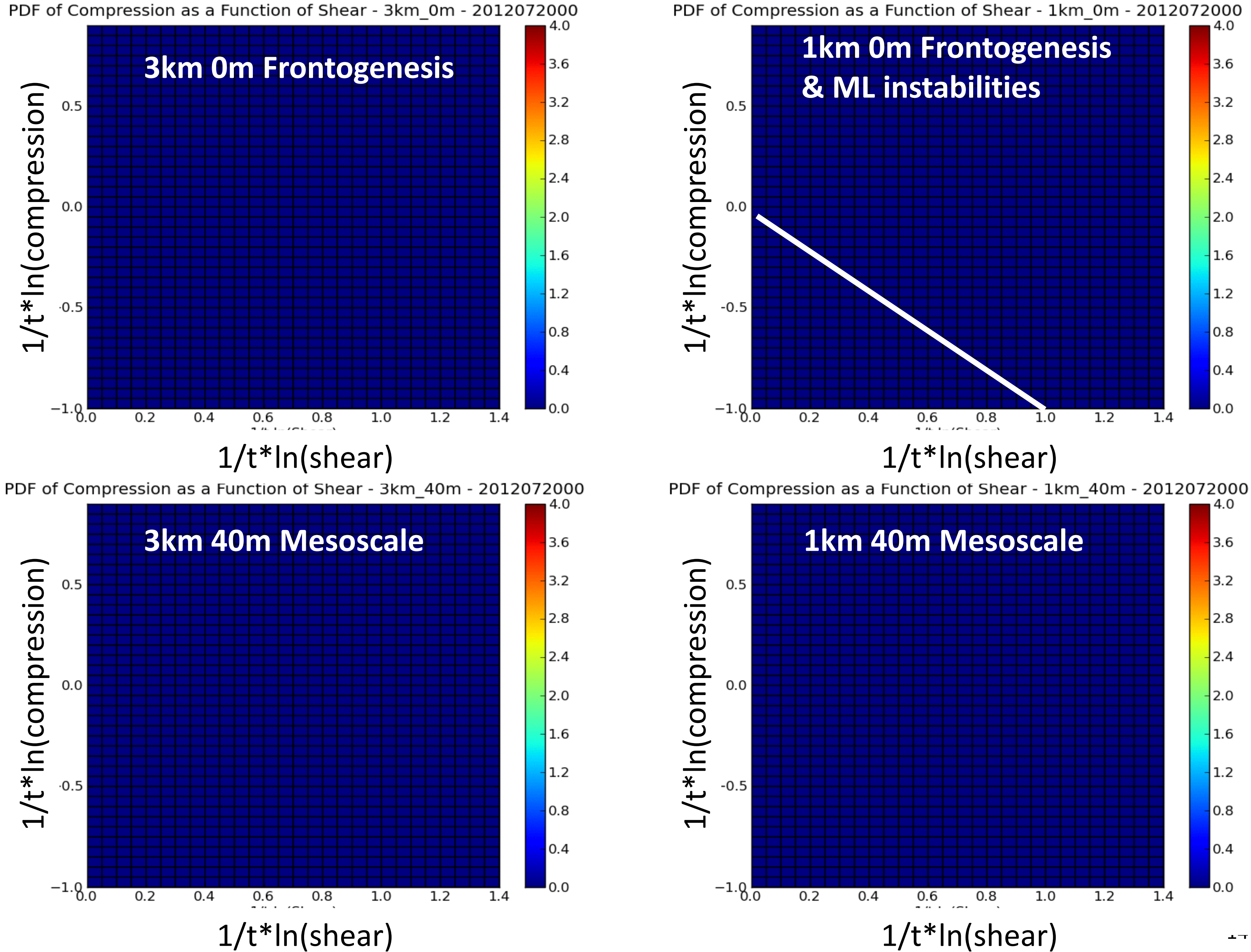


+24 hours



Filaments are sheared out and compressed

How are shear and compression changed under dynamical conditions?



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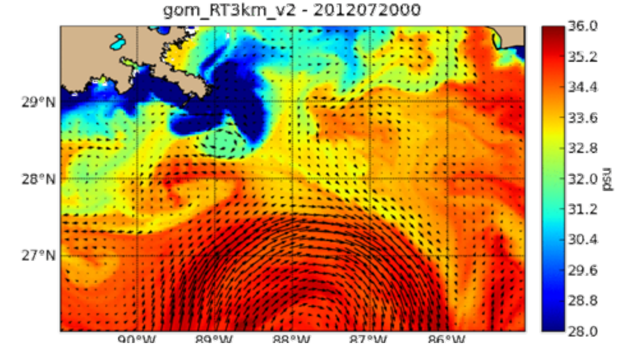

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Original blob of particles in compression. These particles are identifiable in the reference frame which shows they compress over time

In the deformed frame, the blue compressed blob is sheared out into a narrow filament

All the blue blobs in the reference frame turn into blue filaments. These are compressed filaments. Their area is less than the original area

Reference frame | Deformed frame

Shear | Compression | Compression | Shear