A West Florida Shelf ROMS model nested into HYCOM, with applications to the 2005 red tide and ensemble-based assimilation of HF-Radar surface currents

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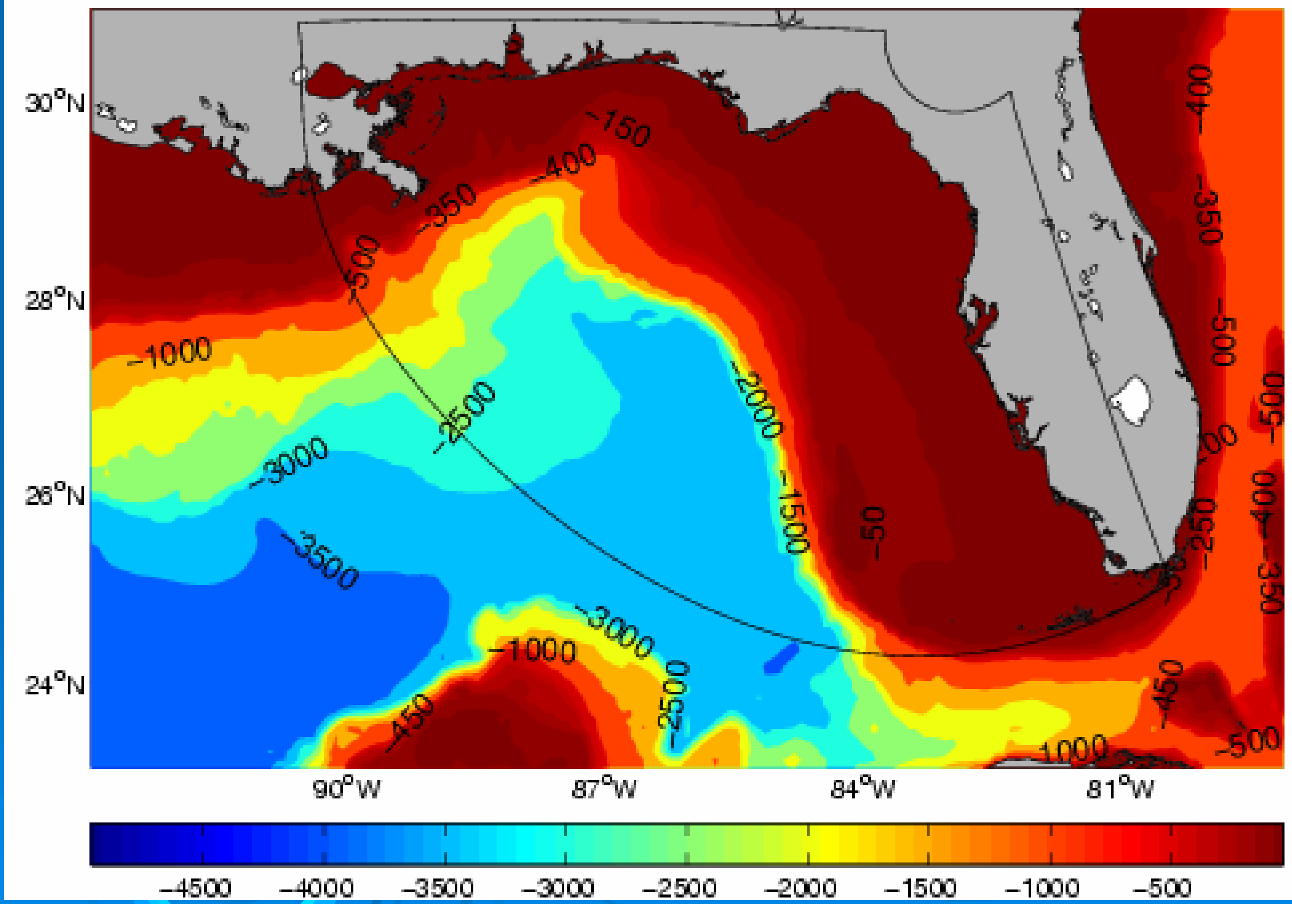
WFS domain

- Black lines show the boundary of the model domain
- Domain is composed by:
  - Broad shelf
  - Deep ocean part
- Both regions are separated by a steep shelf break
- The Loop Current is the dominant large-scale feature



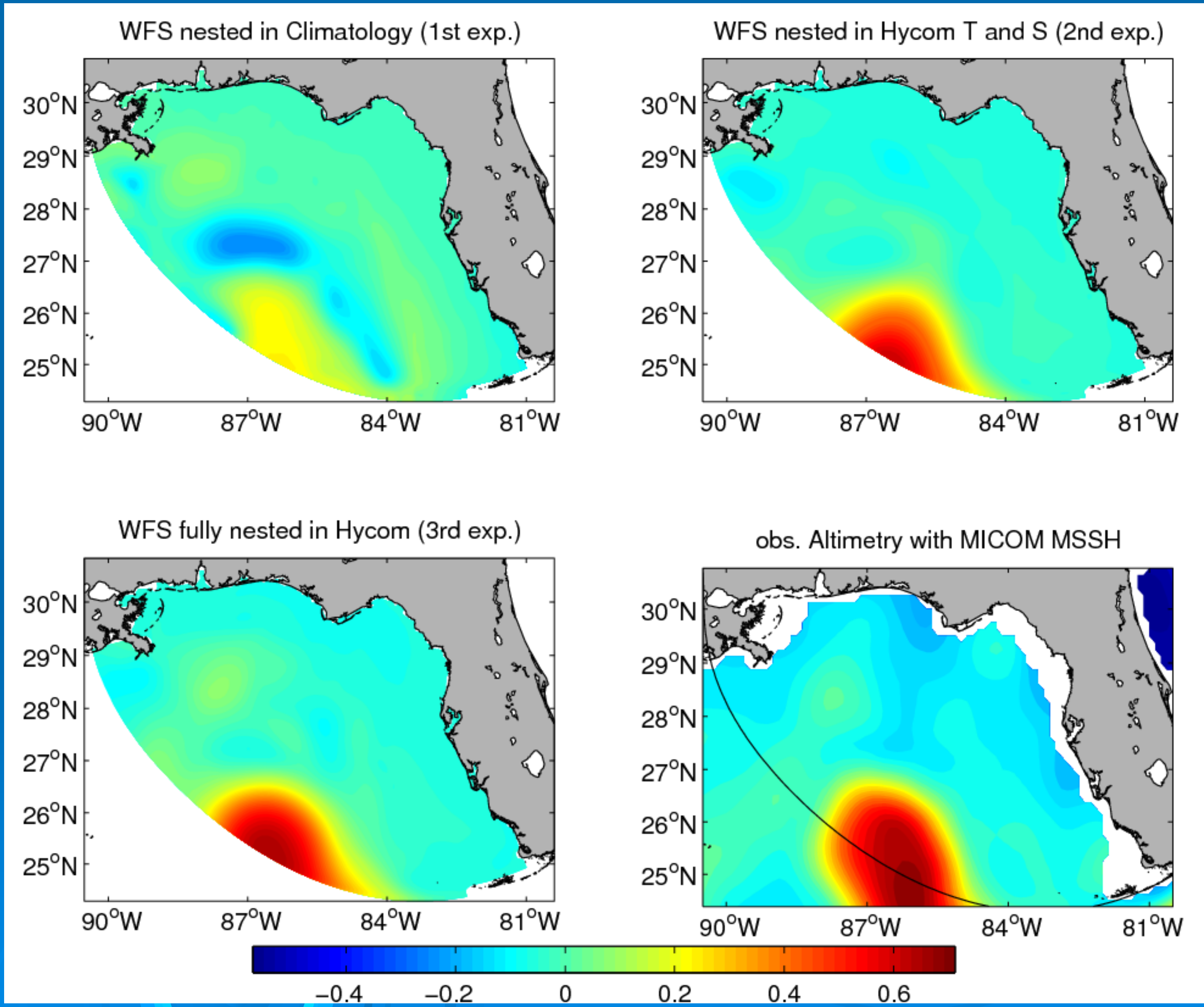
Benefit of using HYCOM boundary conditions compared to climatology

Nesting experiments

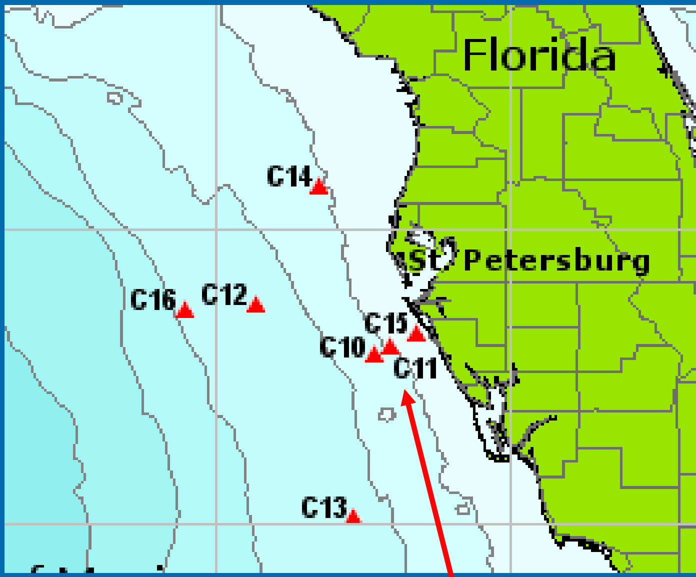
- 1. WFS ROMS nested in climatological temperature and salinity
- 2. WFS ROMS nested in temperature and salinity from HYCOM
- 3. WFS ROMS fully nested in HYCOM, i.e. temperature, salinity, elevation and currents from HYCOM are used
- Additional configurations to come in collaboration with George Halliwell.

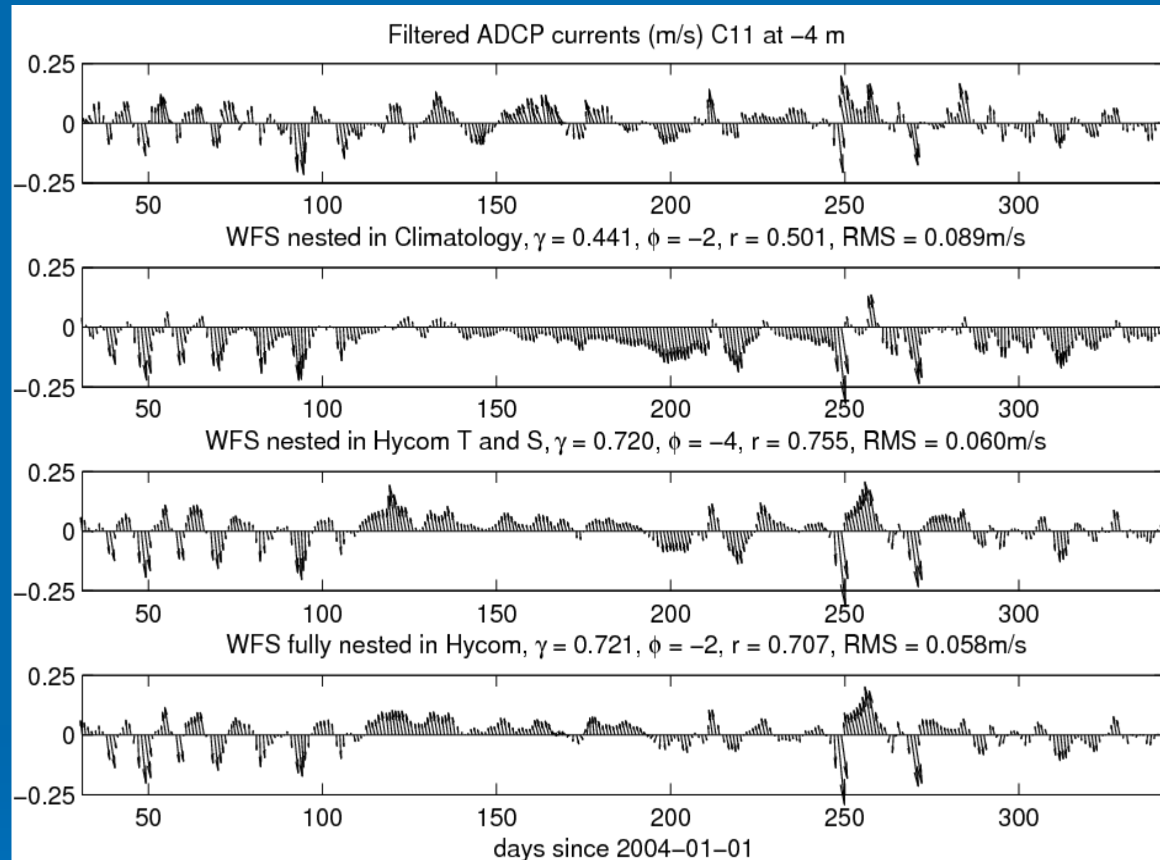
Sea surface height

- With climatology,the LC is too weak and a spurious cyclonic frontal eddy has formed.
- With HYCOM T and S, LC path is better. Intensity is slightly underestimated.
- Intensity of the LC is best when the WFS model is fully nested in HYCOM.



Currents on the Shelf





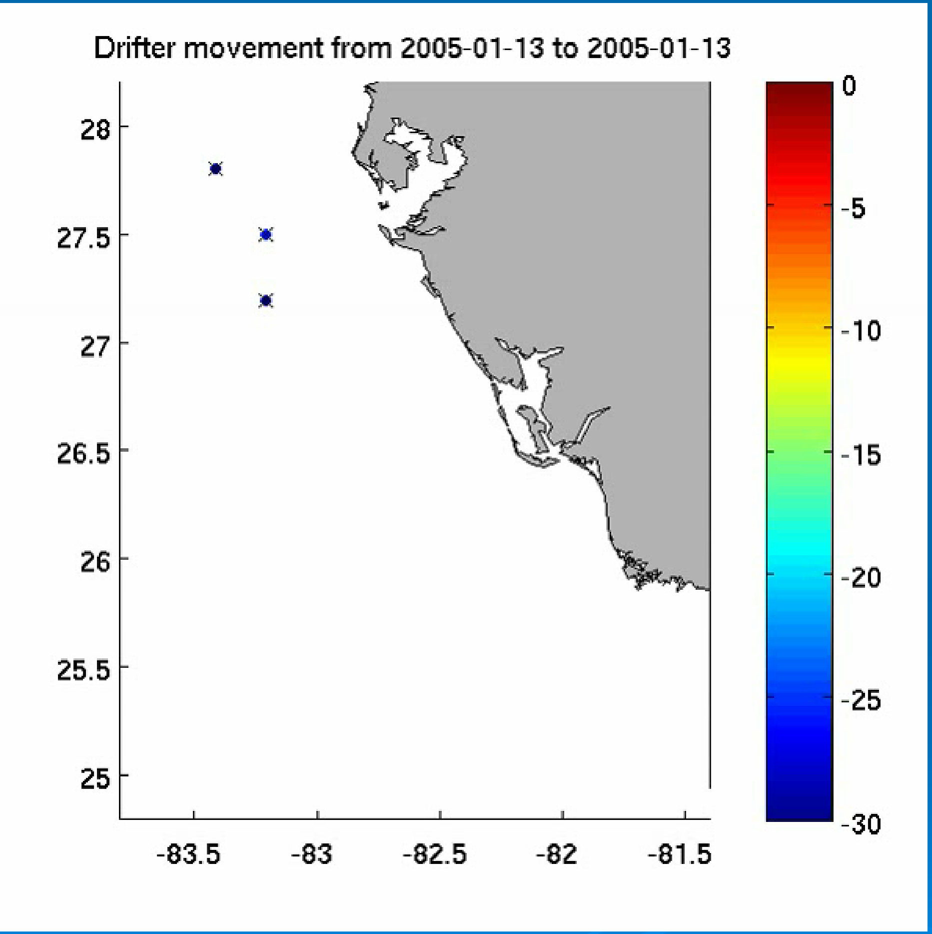
- High-frequency variations in all model simulations are close to the observed ones.
- The largest differences are observed in summer (190-220, July 2004) with climatological forcings.
- The velocity RMS error is reduced by 3 cm/s when NAT HYCOM boundary conditions are used instead of climatology.
- The currents are further improved with full nesting instead of only temperature and salinity.

2005 Red Tide

Objectives

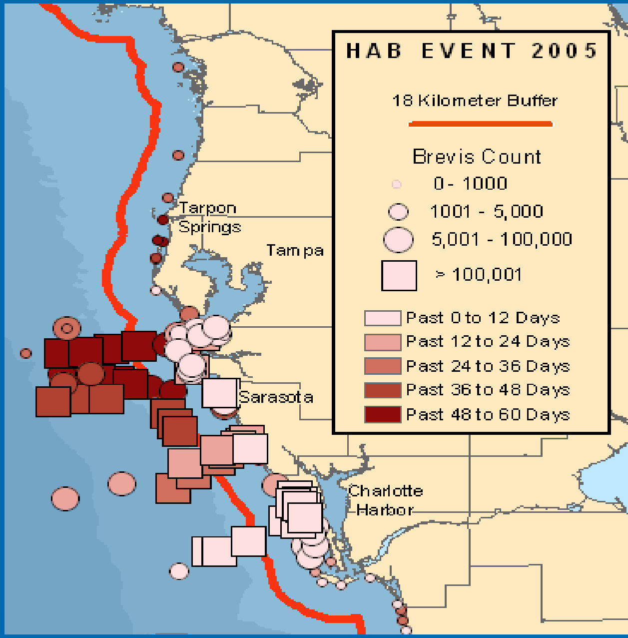
- Anomalous high concentration of Karenia Brevis from November 2004 to end of 2005.
- Little is known about initiation and termination of these HAB
- Is the observed evolution of the red tide a result of advection or biological growth?
- Are the model currents able to explain the observed patterns of high concentration of K. Brevis?

Evolution of the 2005 Red Tide: Advection toward Charlotte Harbor



Jan.13th

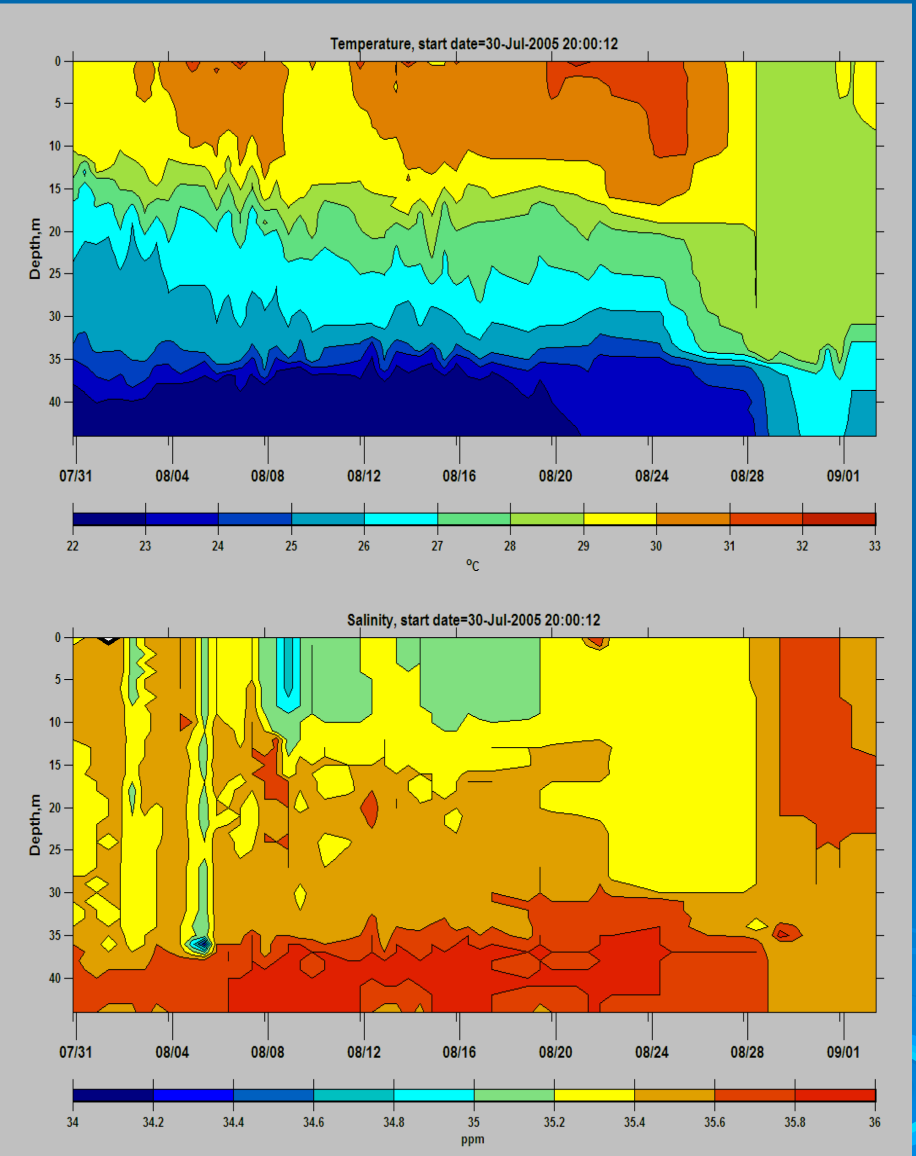
Feb.18th

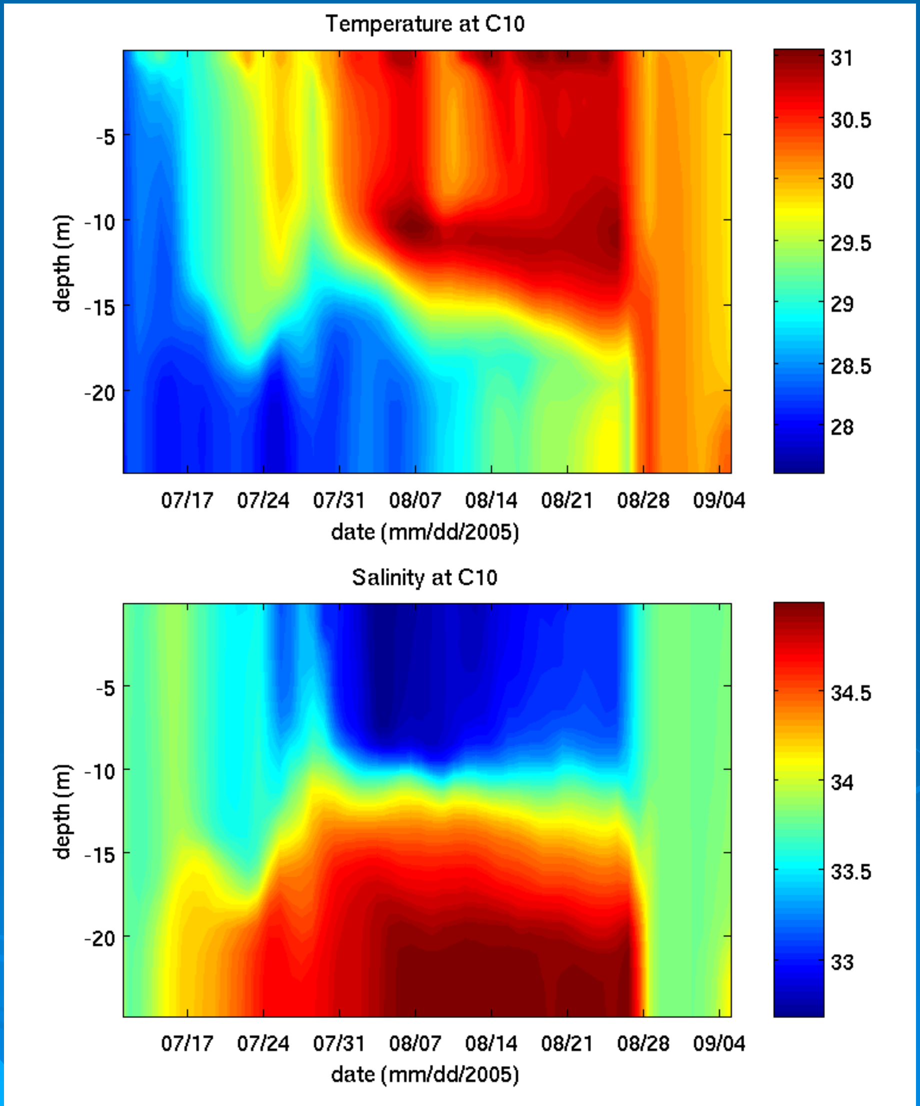


Courtesy FWRI

Drifter colors represent depth

T and S time series modeled at the C10 location showing the BSOP observed stratification

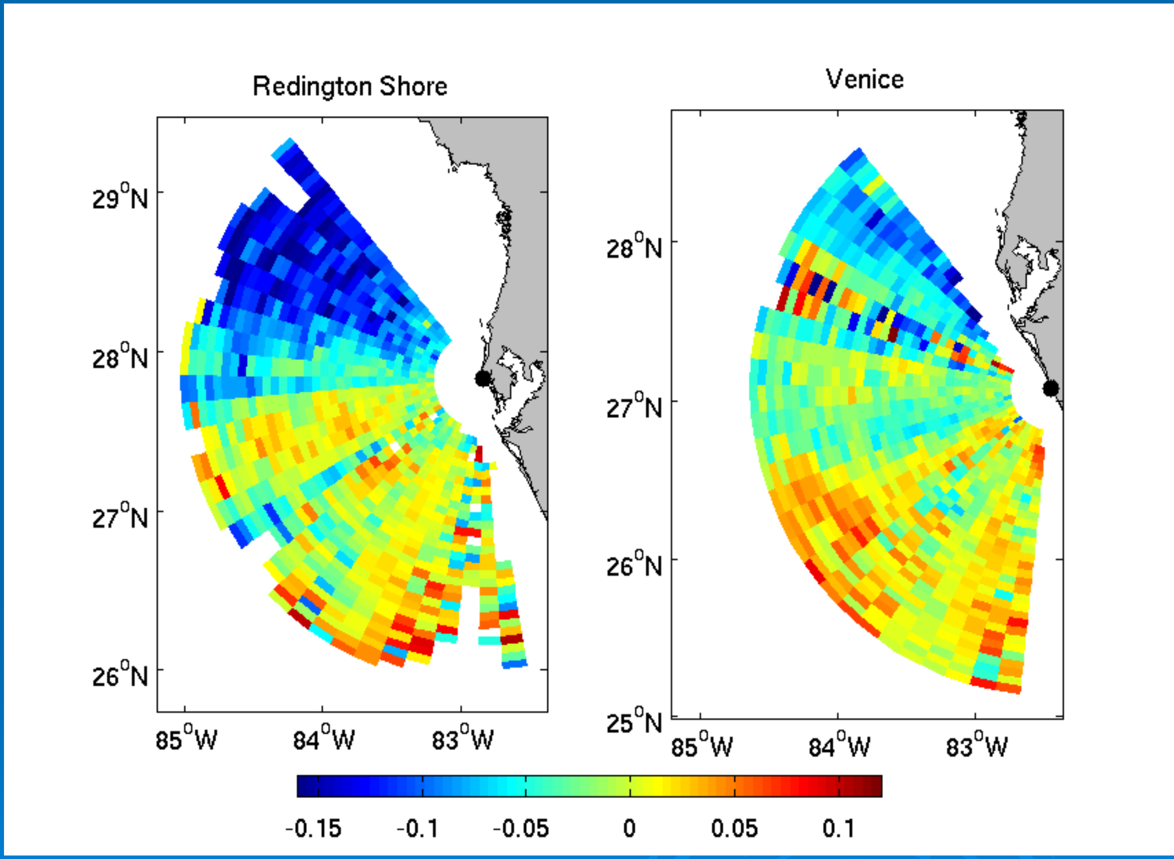




Data Assimilation

Data assimilation: Observations

- HF-Radar radial surface currents maps
- detided
- 2-day averaged, but still “noisy”
- error estimate provided by instrument



Radial velocities measured from the Redington and Venice sites on December, 9 2005. Positive values represent current towards the antenna.

Model error covariance

- 100-member ensemble of wind fields
  - EOF analysis of the u and v wind components
  - random perturbations proportional to spatial EOFs
- For each wind field, the WFS ROMS model was integrated for 30 days
- The resulting ensemble was used for the assimilation of HF Radar currents
- Error covariance assumed constant in time -> “OI-approximation”.

SEEK analysis

Analysis: $$\mathbf{x}^a = \mathbf{x}^f + \mathbf{K}\left(\mathbf{y}^o - \mathbf{H}\mathbf{x}^f\right)$$

Kalman gain: $$\mathbf{K} = \mathbf{P}^f\mathbf{H}^T\left(\mathbf{H}\mathbf{P}^f\mathbf{H}^T + \mathbf{R}\right)^{-1}$$

For a reduced rank-error covariance:

$$\mathbf{P}^f = \mathbf{S}^f{\mathbf{S}^f}^T$$

Eigenvalue decomposition:

$$(\mathbf{H}\mathbf{S}^f)^T\mathbf{R}^{-1}(\mathbf{H}\mathbf{S}^f) = \mathbf{U}\mathbf{\Lambda}\mathbf{U}^T$$

Kalman gain can be written as:

$$\mathbf{K} = \mathbf{S}^f\mathbf{U}(\mathbf{I} + \mathbf{\Lambda})^{-1}\mathbf{U}^T(\mathbf{H}\mathbf{S}^f)^T\mathbf{R}^{-1}$$

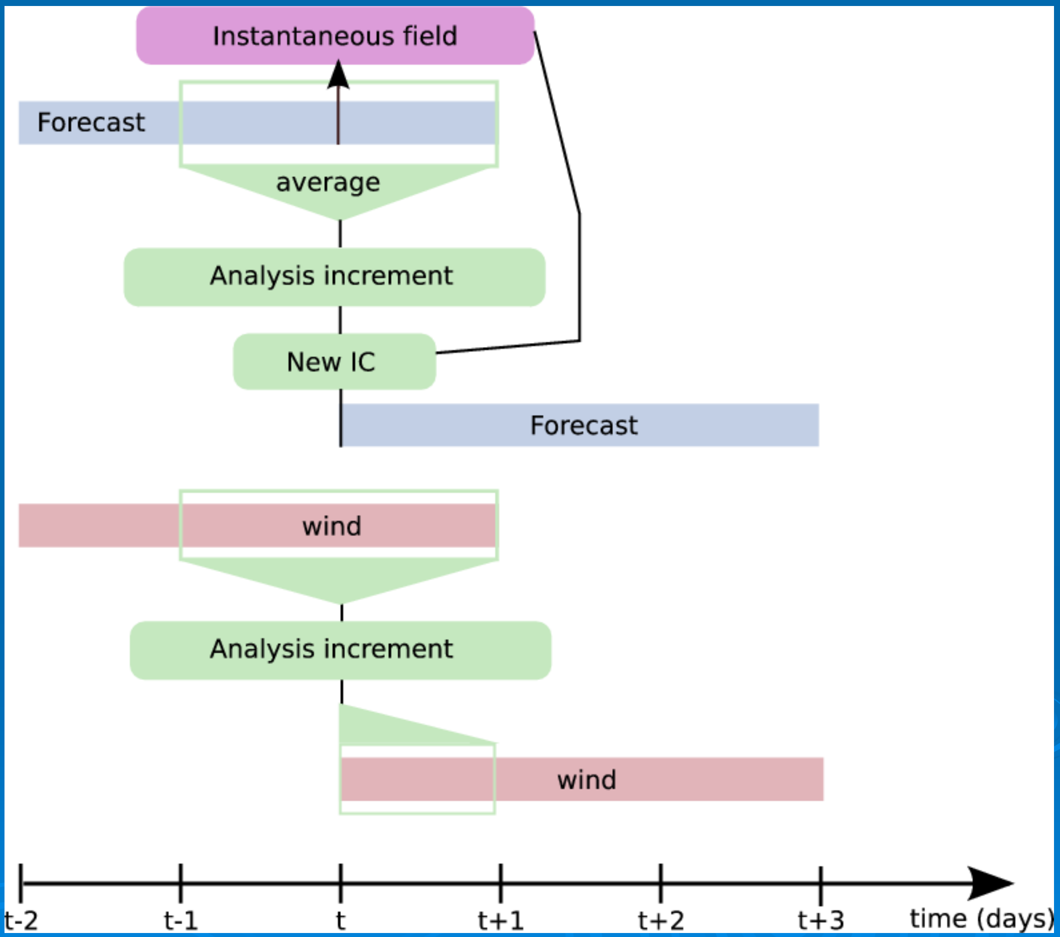
State vector

- The state vector includes:
  - elevation
  - horizontal velocity
  - temperature and salinity
  - 2-day averaged wind stress
- All variables are at the model native grid (curvilinear, Arakawa C).
- Why wind stress and not wind speed?

$$\left[\nu \frac{\partial \mathbf{u}}{\partial z}\right]_{z=0} = \tau_s = C_d \|\mathbf{u}_a\| \mathbf{u}_a$$

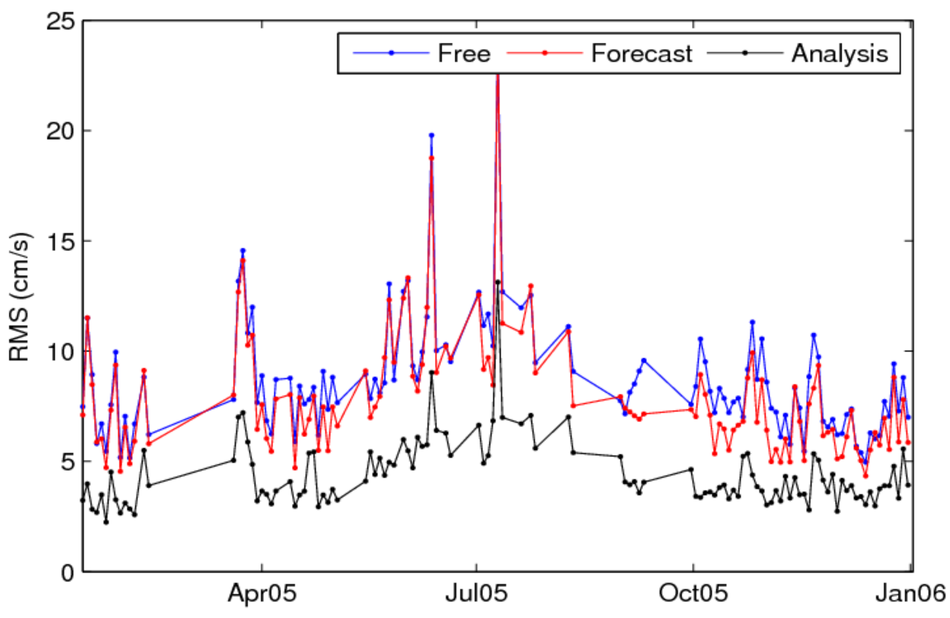
Sequential algorithm

- Data is assimilated every 2 days
- Model is started at t-2 and run for 3 days
- Currents are averaged over t-1 and t+1
- Wind stress are also averaged over t-1 and t+1
- Analysis increment is computed based on the model error covariance expressed as an ensemble
- This correction is added to the instantaneous model field at t to produce a new initial condition (IC)
- The wind stress correction is applied uniformly to the wind forcing between t and t+1

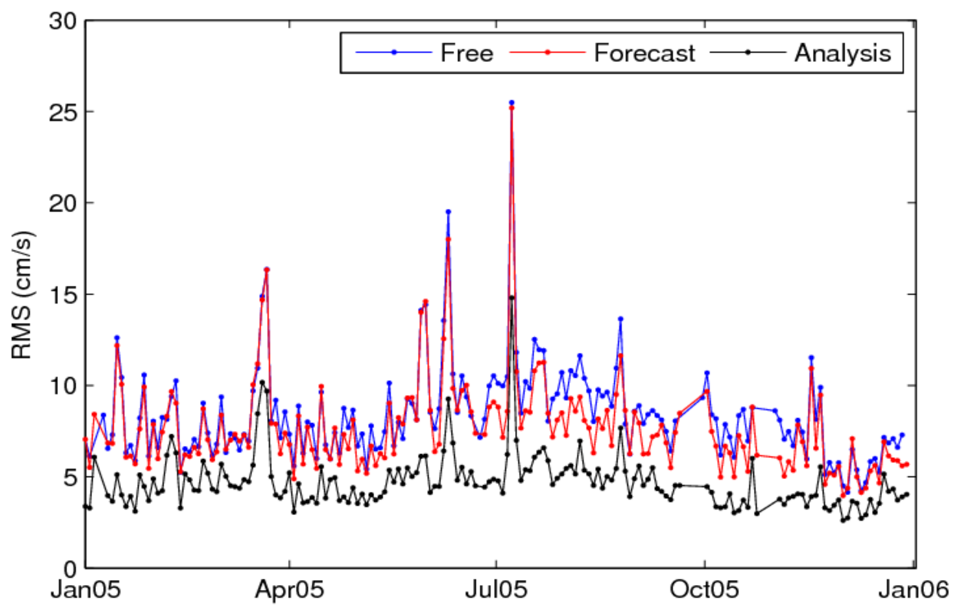


RMS error relative the HF Radar currents

Redington



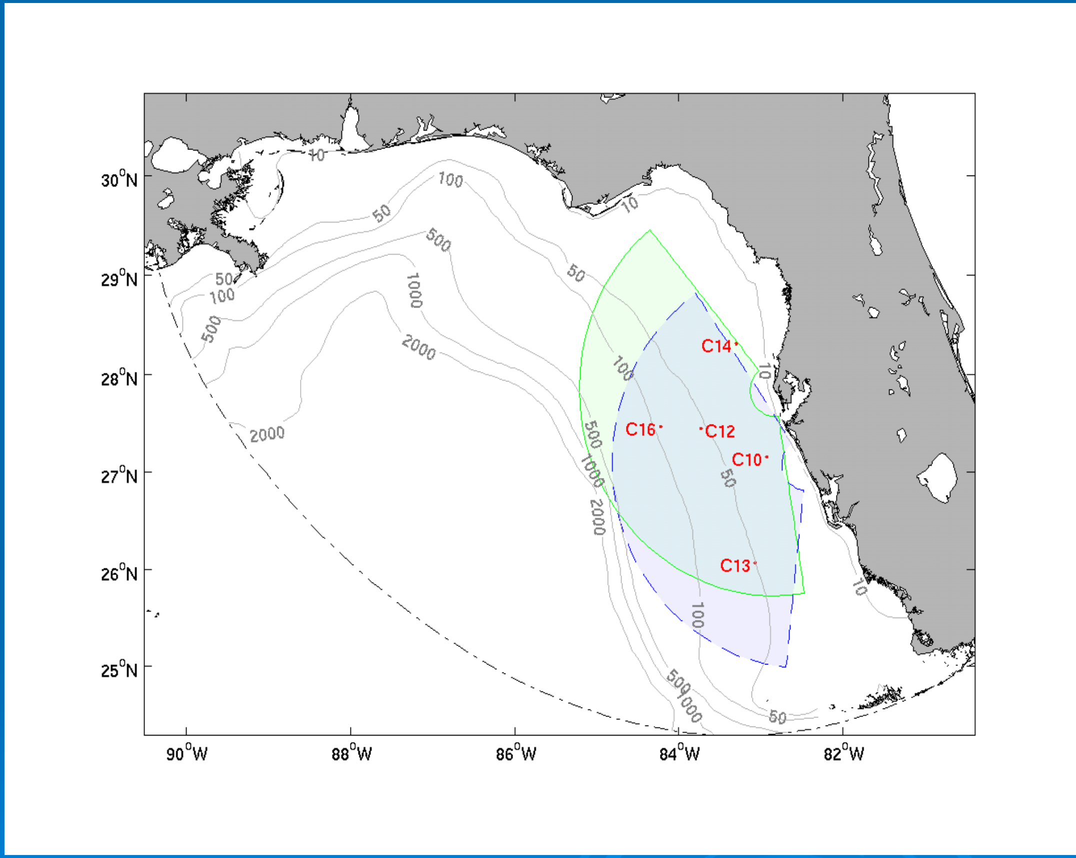
Venice



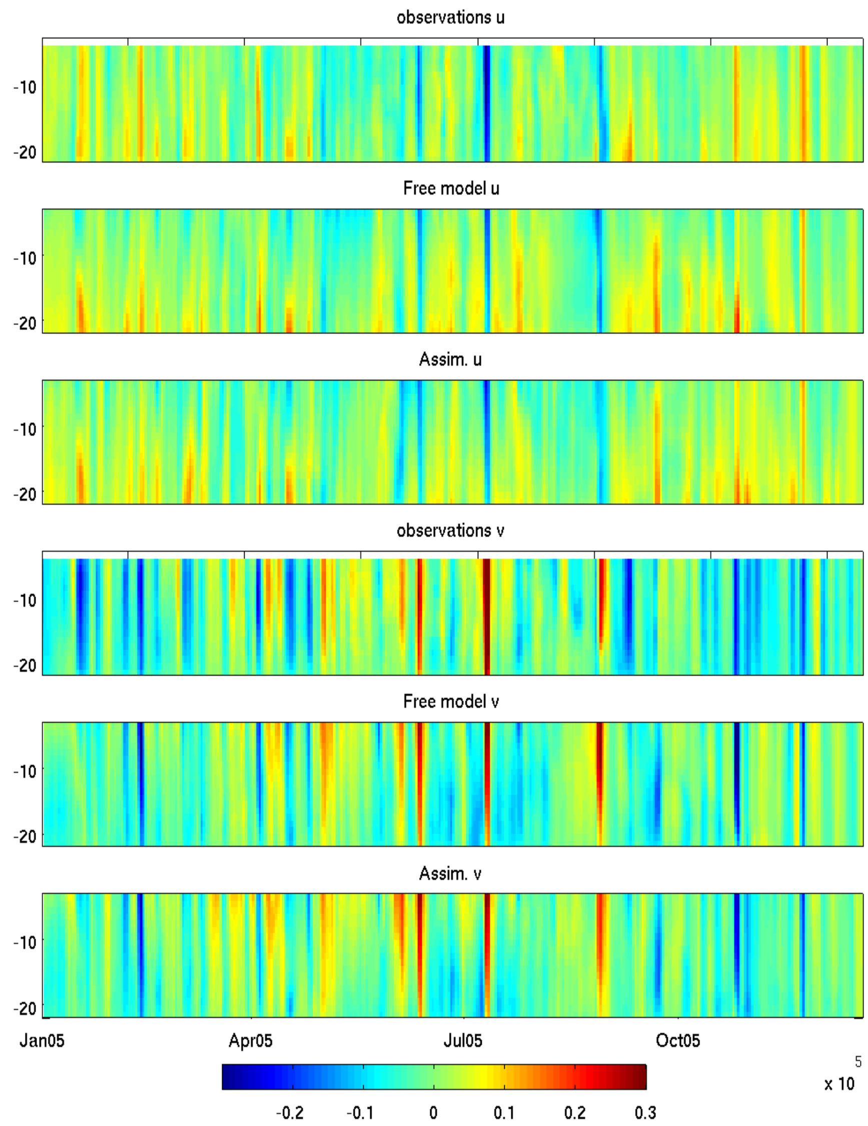
The RMS time series for the model run without assimilation (free model), the model forecast (before assimilation of CODAR data) and the model analysis (after assimilation) are shown.

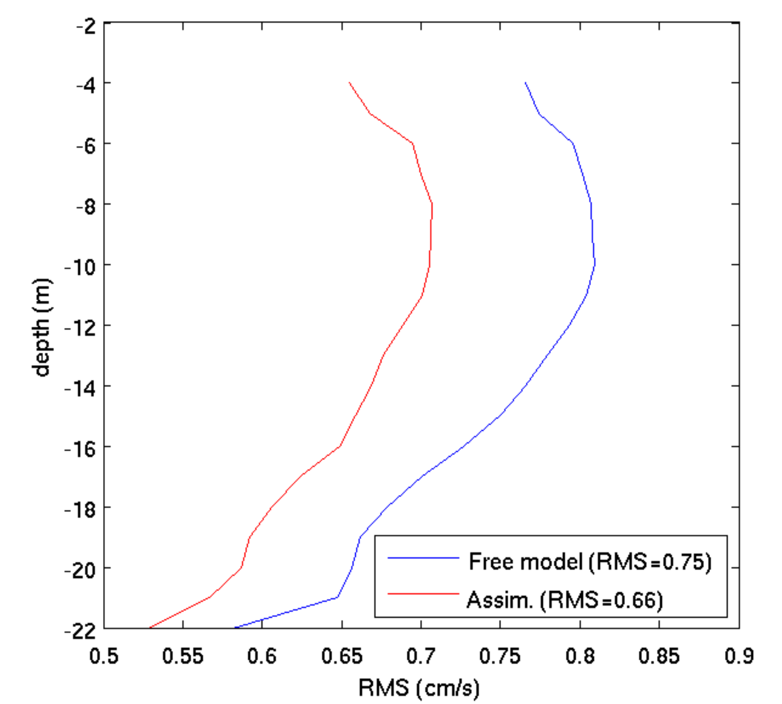
Comparison with independent observations

- Several ADCP sites on WFS shelf
- Error reduction at the surface is expected, but
- how does the error behave at depth?



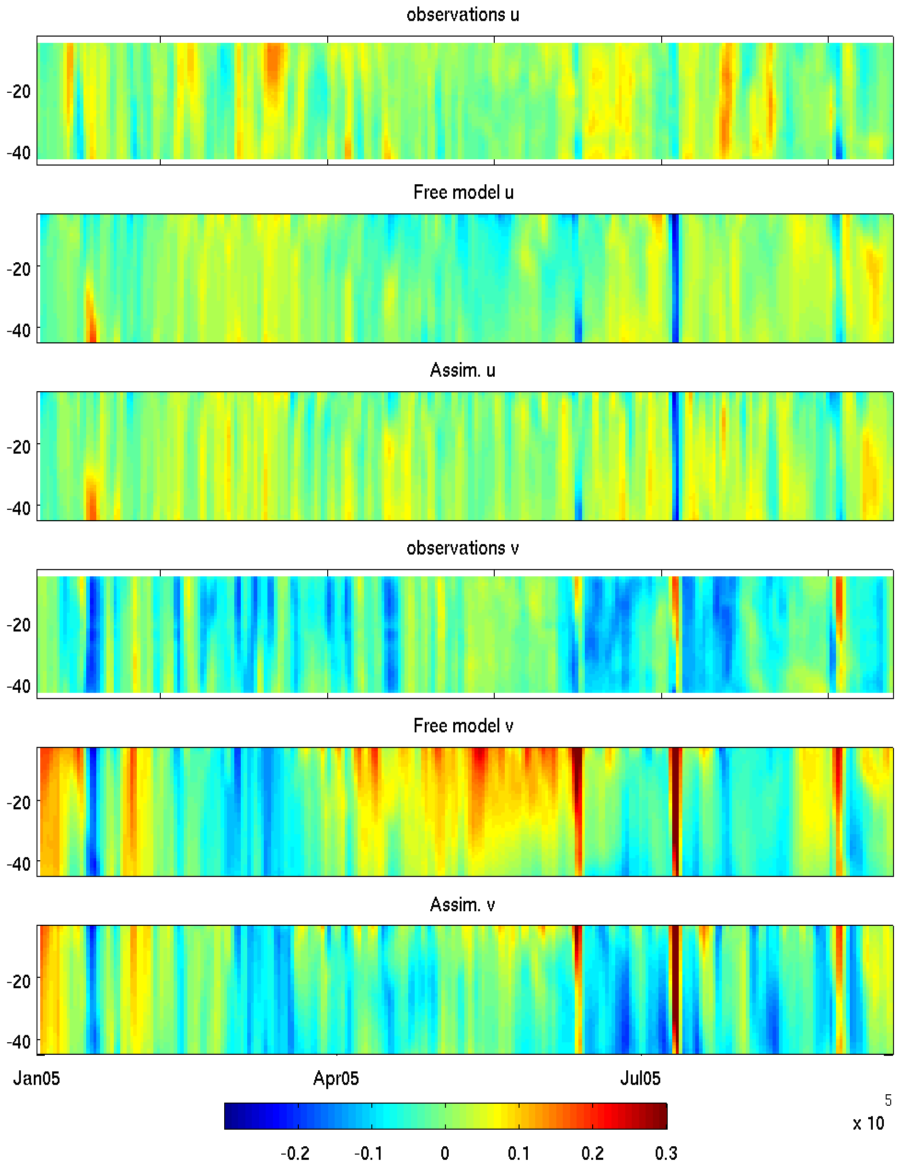
ADCP observations from C10

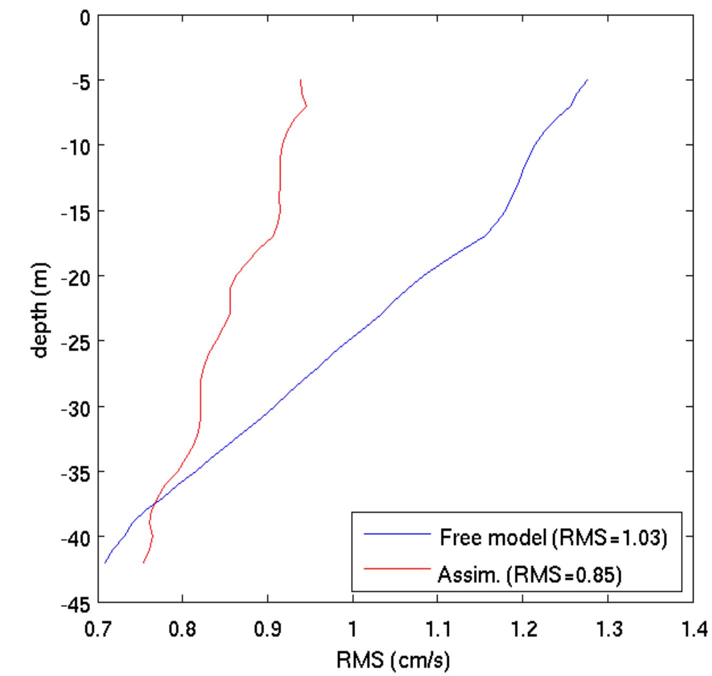




- Free model already very close to observations.
- Time averaged RMS shows however that error is reduced.

ADCP observations from C12





- Free model shows an unrealistic Northwestward current during summer which is corrected through the assimilation
- Except at the bottom, the time averaged RMS error is reduced.

Conclusions

- WFS ROMS model produces better results on the shelf when HYCOM boundary values are used instead of climatology
- The model LC is more realistic if current and velocity boundary values are used in addition to temperature and salinity
- Model bottom currents are able to explain the evolution of the 2005 Red Tide.
- The proposed CODAR assimilation scheme is able to improve:
  - The 2-day velocity forecast
  - The velocity at depth

Future work

- New WFS simulation nested in NCODA HYCOM GoM.
- Comparison to in situ observations
- Compare WFS ROMS 2004-2005 experiments to WFS HYCOM of George Halliwell
- More validation of the model results with surface current assimilation