Demonstration and Comparison of Sequential Approaches for Altimeter Data Assimilation in HYCOM

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Outline:

Assimilation Schemes

Twin Experiments

Results/Diagnostics

Sequential assimilation schemes for HYCOM

1. Optimal Interpolation
2. Multivariate Optimal Interpolation

   (J. Cummings, O.M. Smedstad –NRL)
3. Ensemble Optimal Interpolation & Kalman Filter

   (F. Counillon, L. Bertino – NERSC)
4. Ensemble Reduced Order Information Filter

   (T. M. Chin, Univ of Miami/JPL)
5. Singular Evolutive Extended Kalman Filter

   (P. Brasseur – LEGI, Grenoble)

Multivariate Optimal Interpolation
NRL Coupled Data Assimilation System (NCODA)

- Oceanographic version of MVOI method used in NWP systems (Daley, 1991)
- Simultaneous analysis of five ocean variables: temperature, salinity, geopotential, and u-v velocity components (T, S, Φ, u, v)

$$x_a = x_b + P_b H^T (H P_b H^T + R)^{-1} [y - H(x_b)]$$

Observation Space Formulation

where $\mathbf{x_a}$ is the analysis
$\mathbf{x_b}$ is the background
$\mathbf{P_b}$ is the background error covariance
R is the observation error covariance
H is the forward operator (spatial interpolation)
$(\mathbf{x_a} - \mathbf{x_b})$ is the analyzed increment
$[\mathbf{y}-\mathbf{H}(\mathbf{x_b})]$ is the innovation vector (synoptic T, S, u, v observations)

Ensemble Optimal Interpolation (ENOI)

- Covariance are based on an historical ensemble composed of 3 year 10 day model output (106 members) without assimilation
- Covariance are 3D multivariate
- Conservation of the dynamical balance of the model since the update is a linear combination of model state
- Temporal invariance of the covariance matrix, computationally cheap

$$X^a = X^f + \alpha A'A'^T H^T (\alpha HA'A'^T H^T + \varepsilon^0 \varepsilon^0)^{-1} (Y - HX^f)$$

Kalman Gain obs-model

X : model state (η, t, s, u, v, thk); (a: analysis; f: forecast)
A’: centered collection of model states (A’=A-A)
Y : observations
H : interpolates from model grid to observation
ε^0 : Observation error
α : rebalance ensemble variability to realistic level

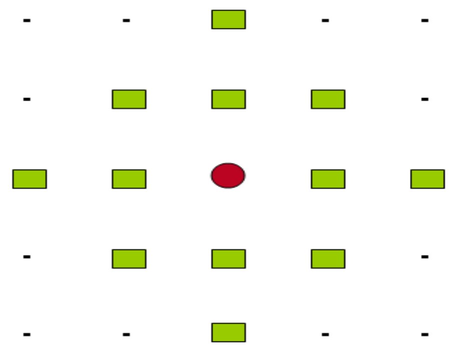
Ensemble Reduced Order Information Filter (ENROIF)

- The ROIF assimilation scheme parameterizes the covariance matrix using a second-order Gaussian Markov Random Field (GMRF) model

- A sparse auto-regression operator operates on the error in the MRF neighborhood

$$e_j = \Sigma_{i \in Z} \; \alpha_{ij} e_{j-i} + v_j$$

- The square of the regression operator is the Information Matrix which is the inverse of the covariance Matrix



MRF order 2 Neighborhood

- Recently replaced the extended KF with ensemble methods to propagate the information matrix.

- Uses a static Information matrix generated using 55 members in all experiments shown here

Gulf of Mexico Model Configuration

Configuration:

• 89° to 98°W Longitude and 8° to 31°N Latitude

•1/12° horizontal grid (258x175 pts; 6.5km average spacing)

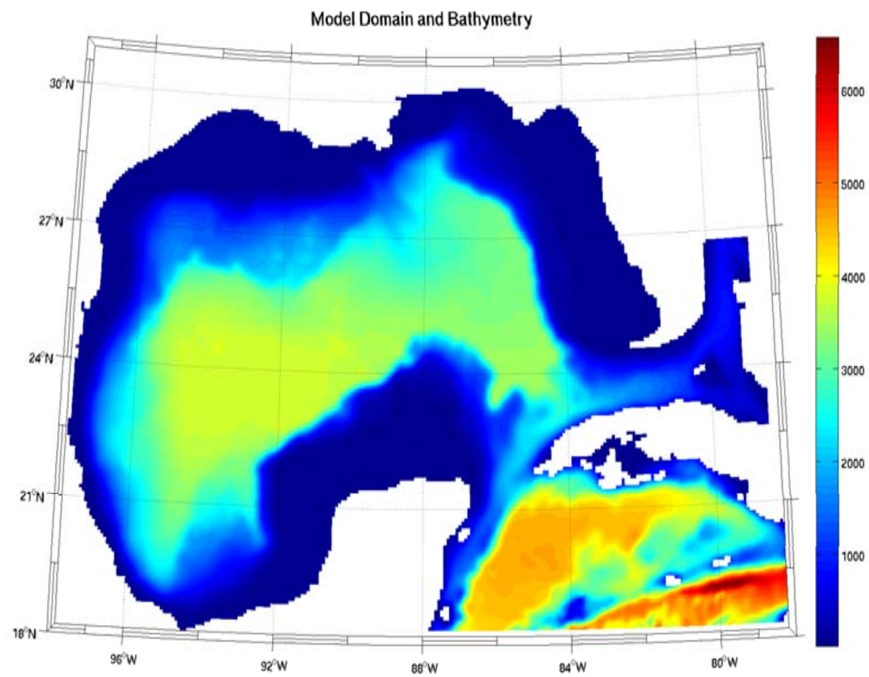
• 20 vertical layers

• Forcing from NOGAPS/FNMOC 1999-2000

• Monthly River Runoff

• Nested within 1/12 N. Atlantic domain

• HYCOM V. 2.1.36

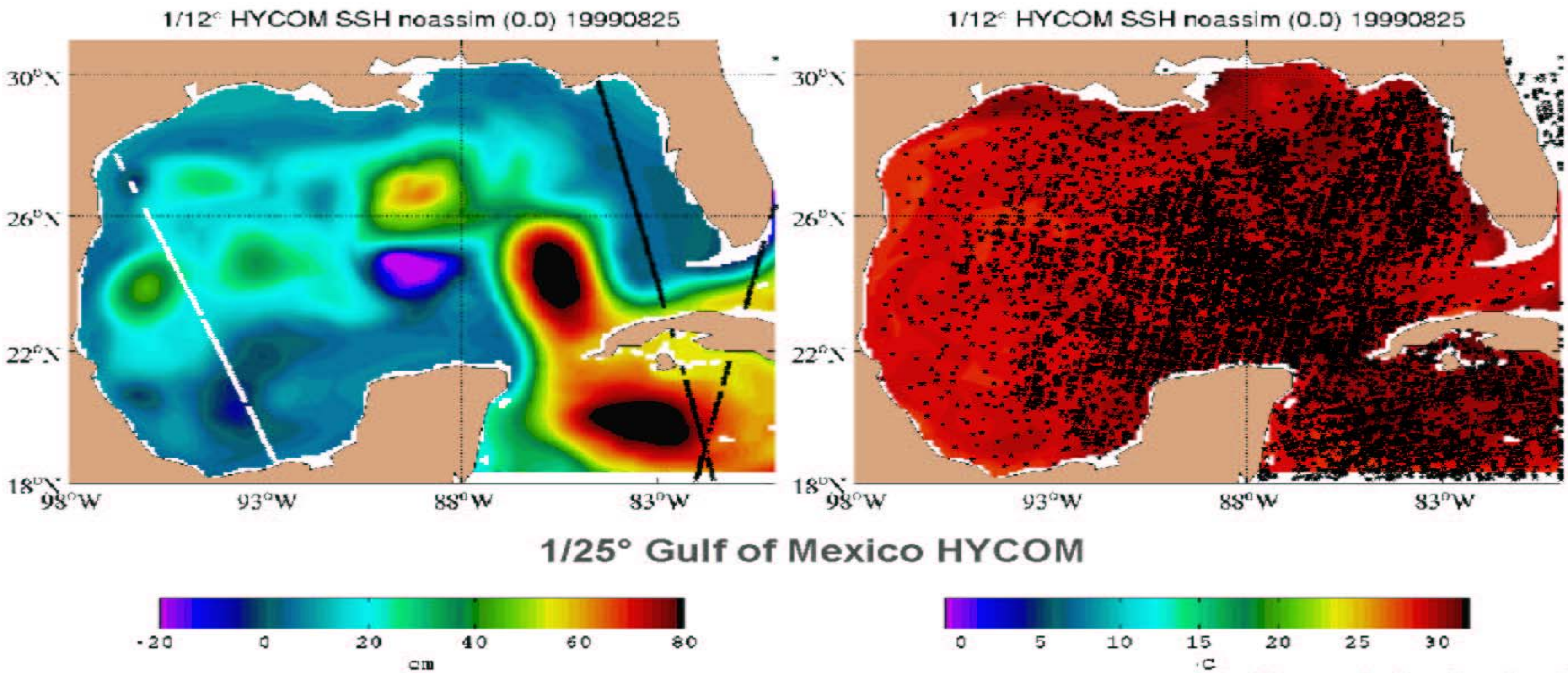


Synthetic Data Used in the Experimants

HYCOM Identical Twin SSH and SST Data

Ocean model sampled along observed tracks

Ocean model sampled at observed MCSST locations



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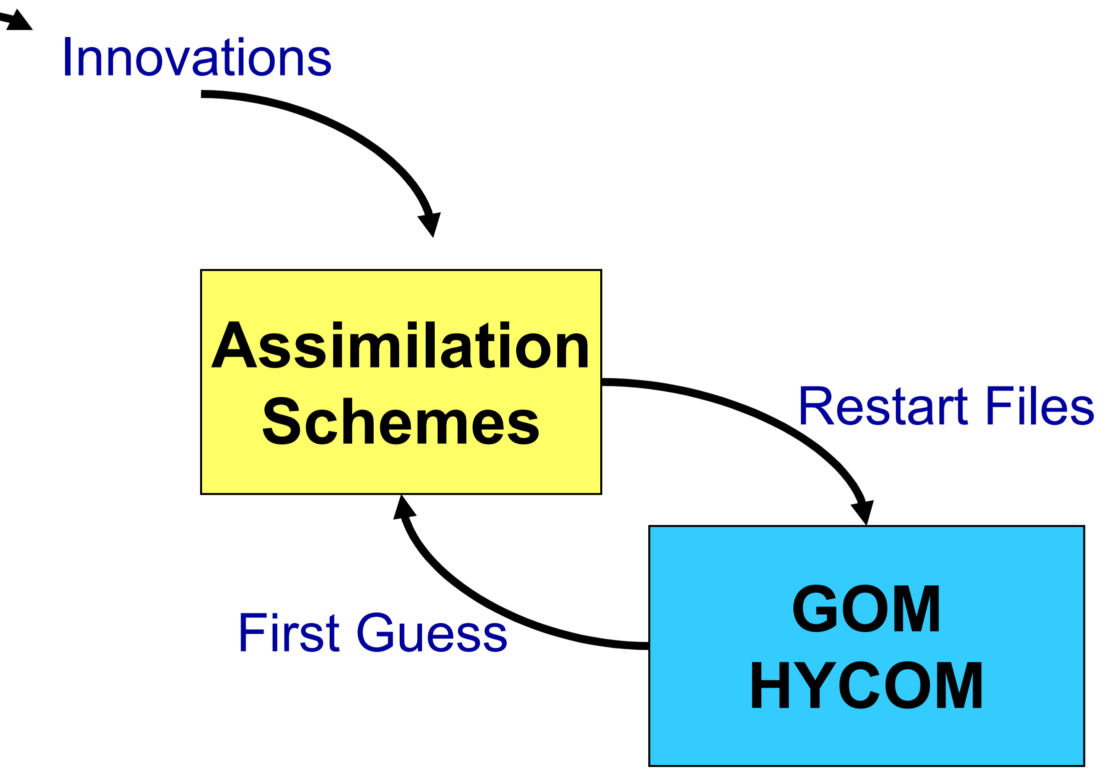
Sequential Analysis-Forecast-Analysis Cycle

Ocean Obs



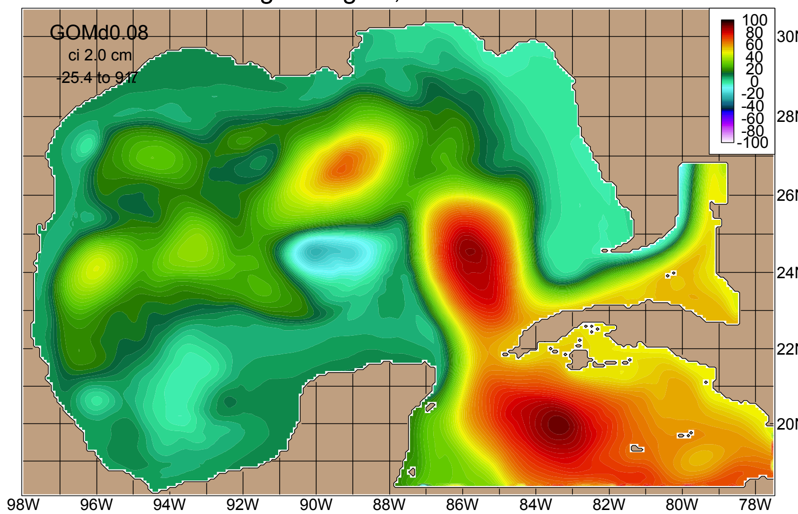
SST: Ship, Buoy, AVHRR(GAC/LAC), GOES, AMSR-E, AATSR, MSG

SSH: Altimeter (Jason, Envisat, GFO), *in situ* Temp/Salt profiles

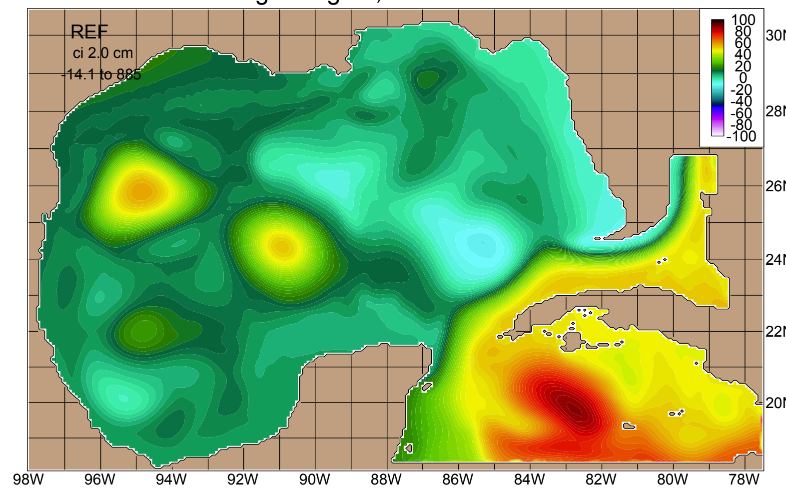
Communication via restart files

Truth and Initial State of Assimilative Runs

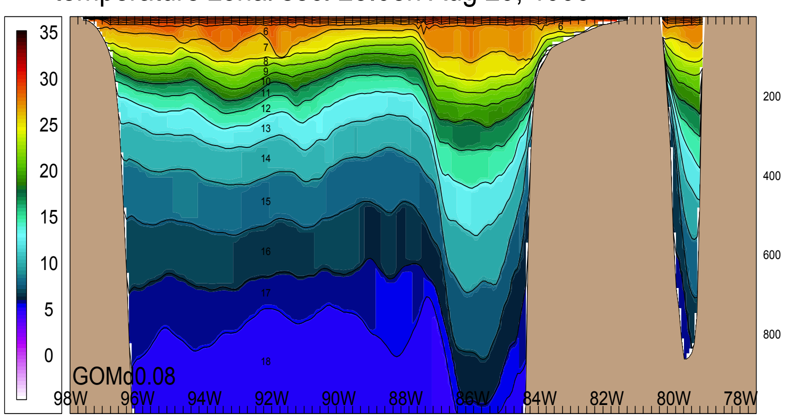
sea surf. height Aug 29, 1999



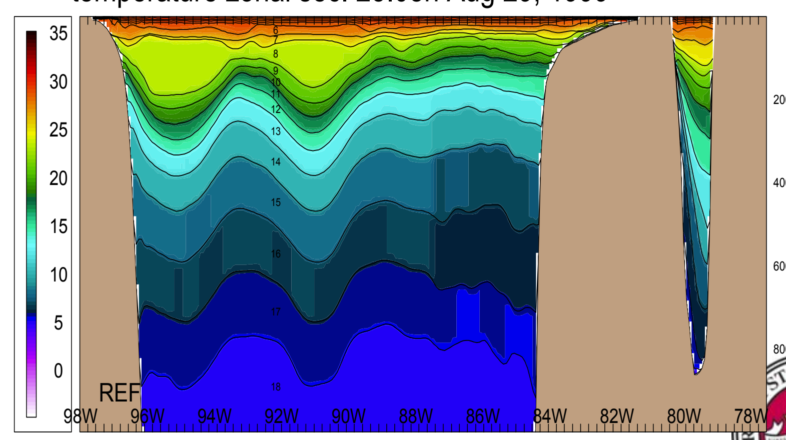
sea surf. height Aug 29,1999



temperature zonal sec. 25.08n Aug 29, 1999

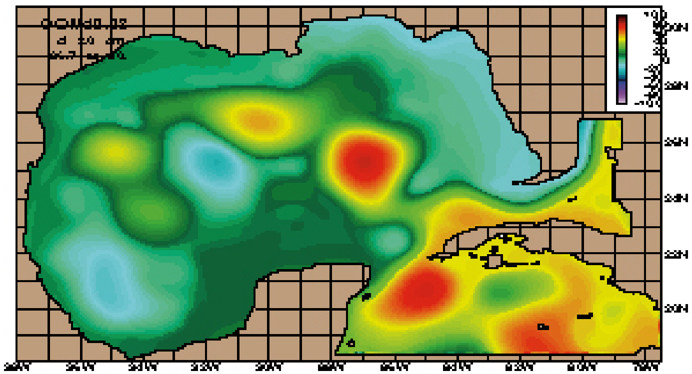


temperature zonal sec. 25.08n Aug 29, 1999



Truth and Forecast Day 50

TRUTH



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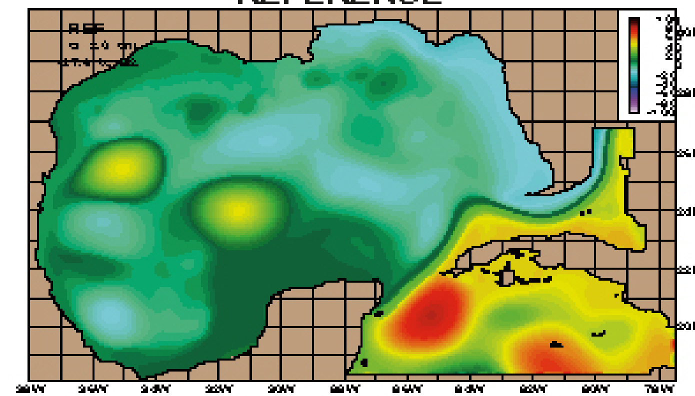
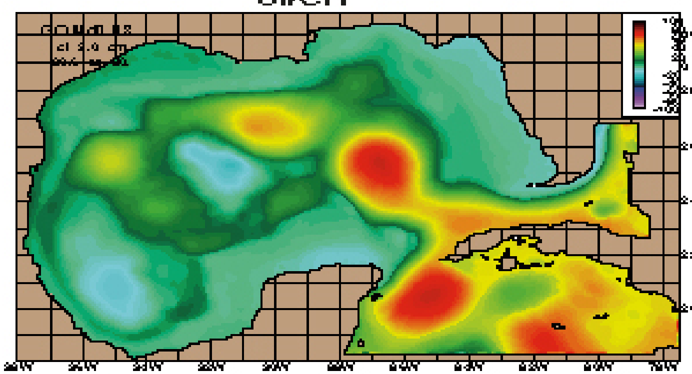
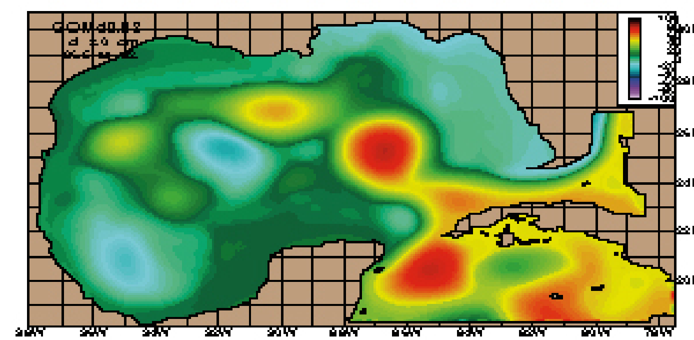


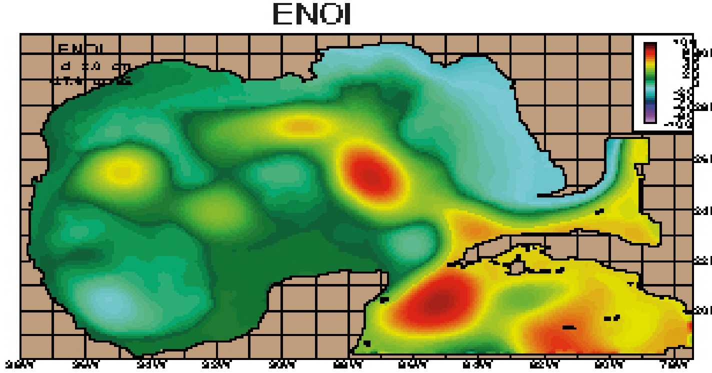
OI/CH



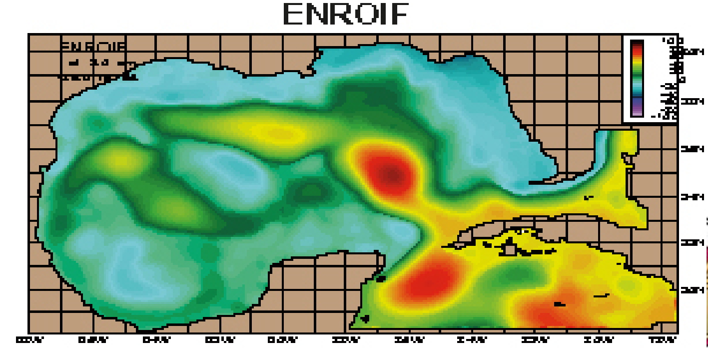
MVOI



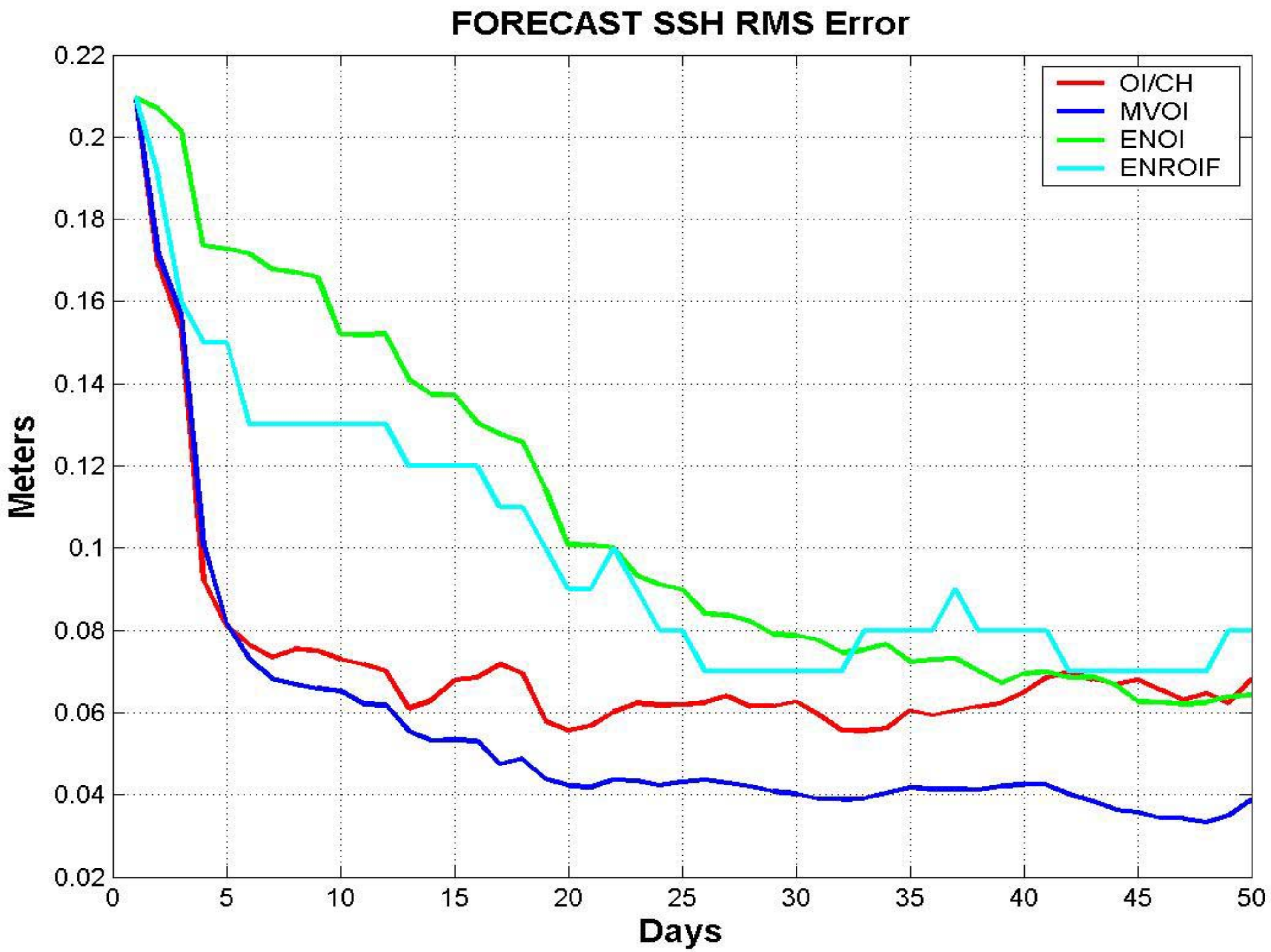
ENOI



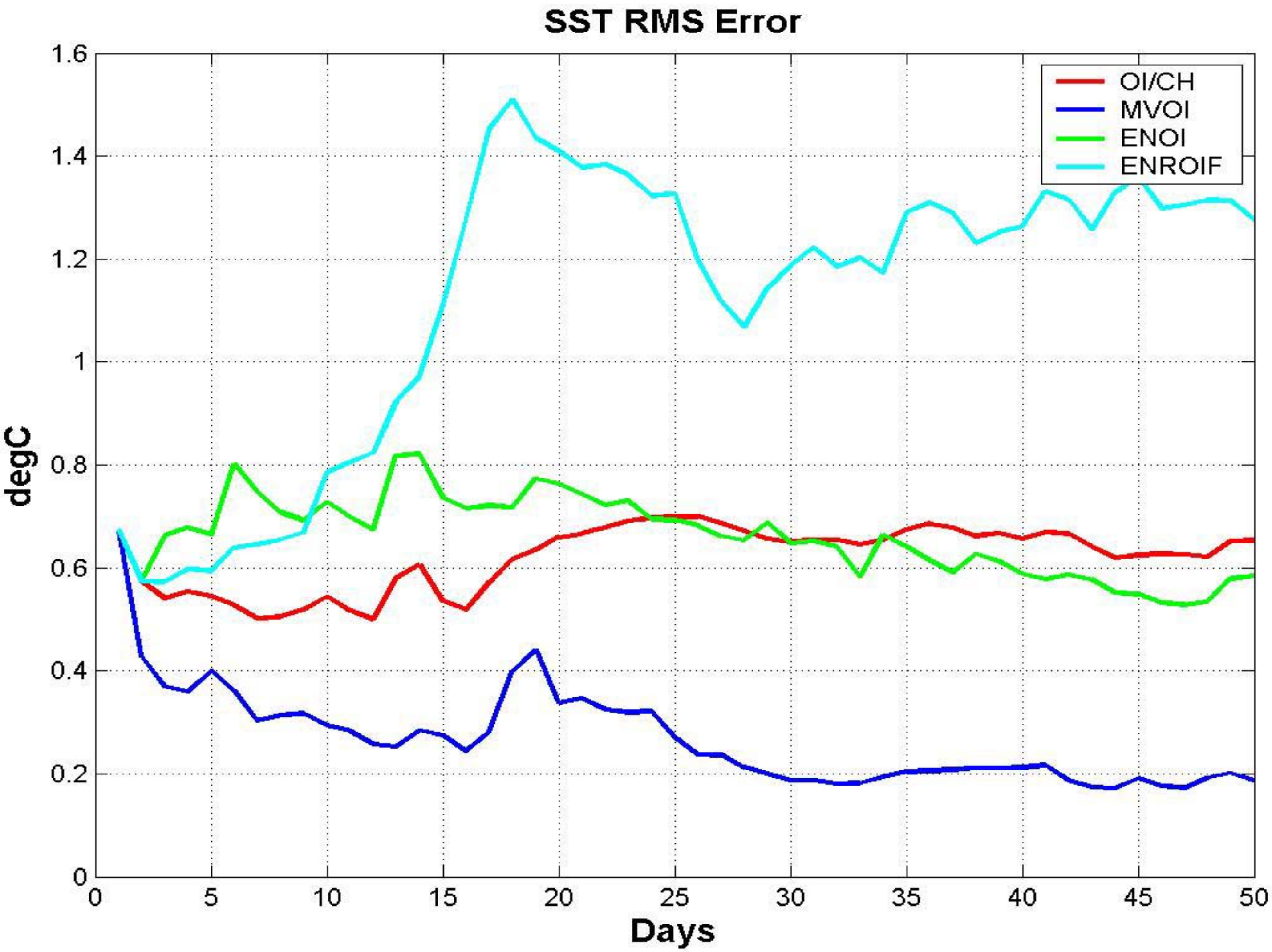
ENROIF



RMS Error in SSH Forecasts

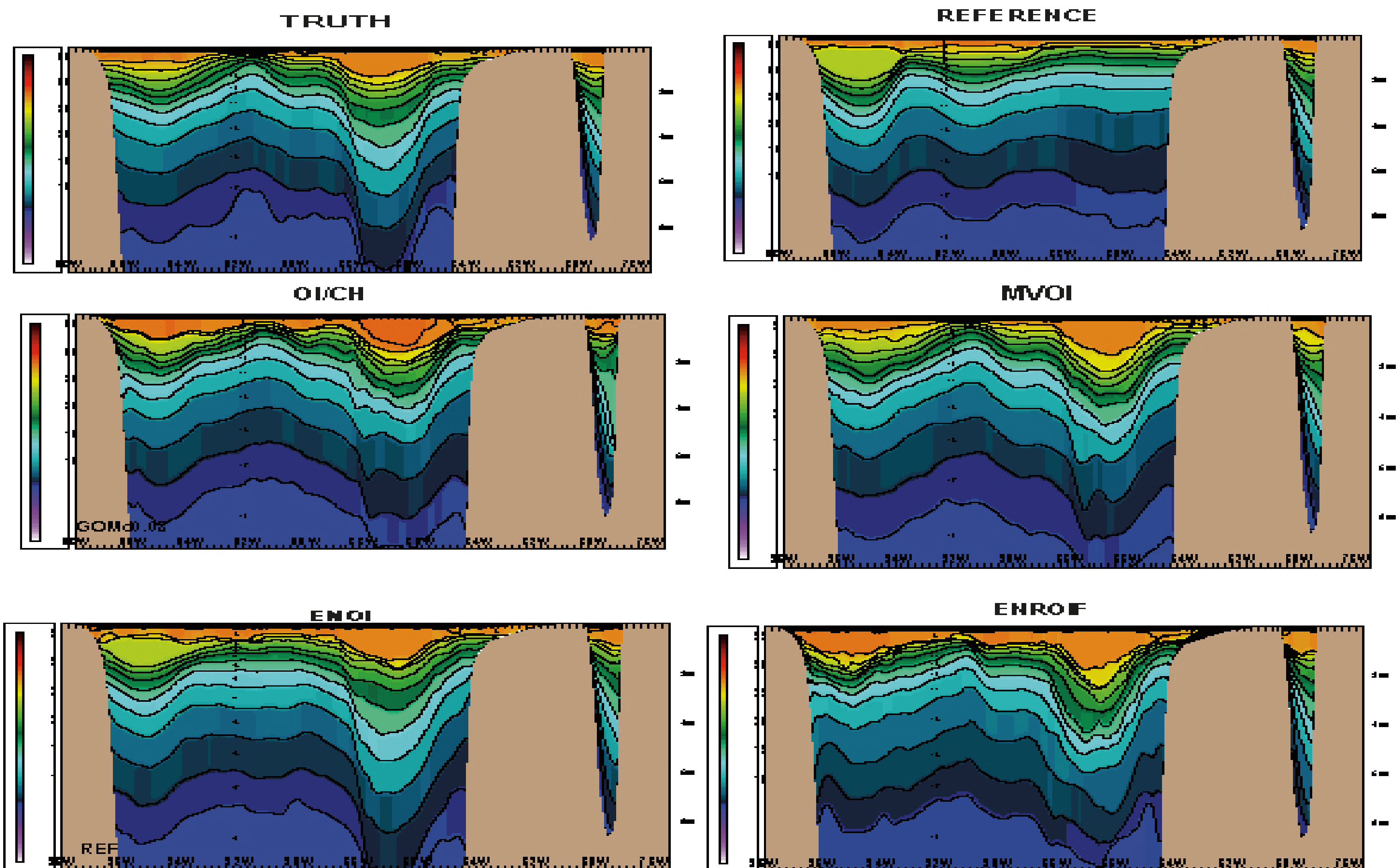


SST RMS Error

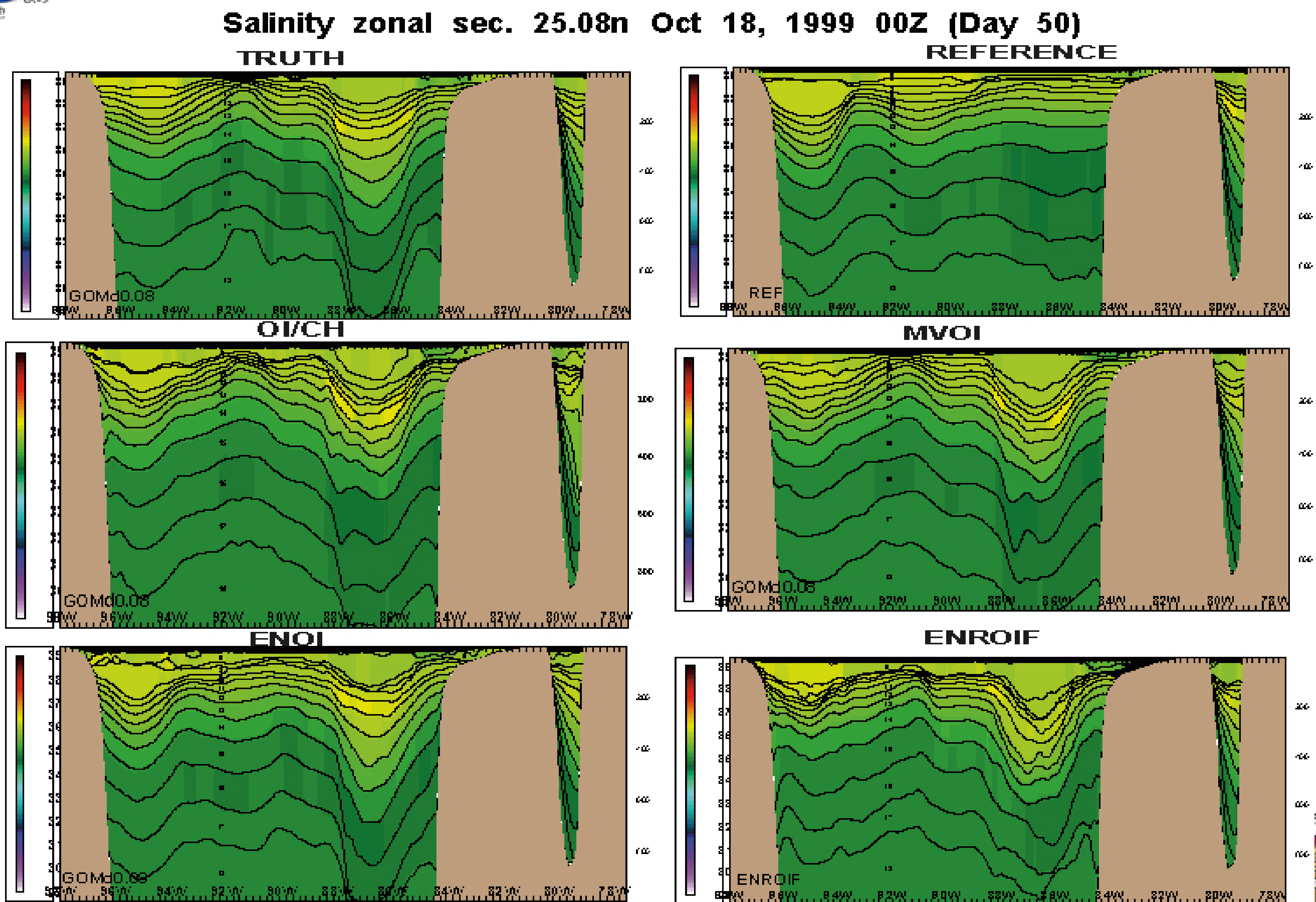


Temperature Vertical Section Forecast Day 50

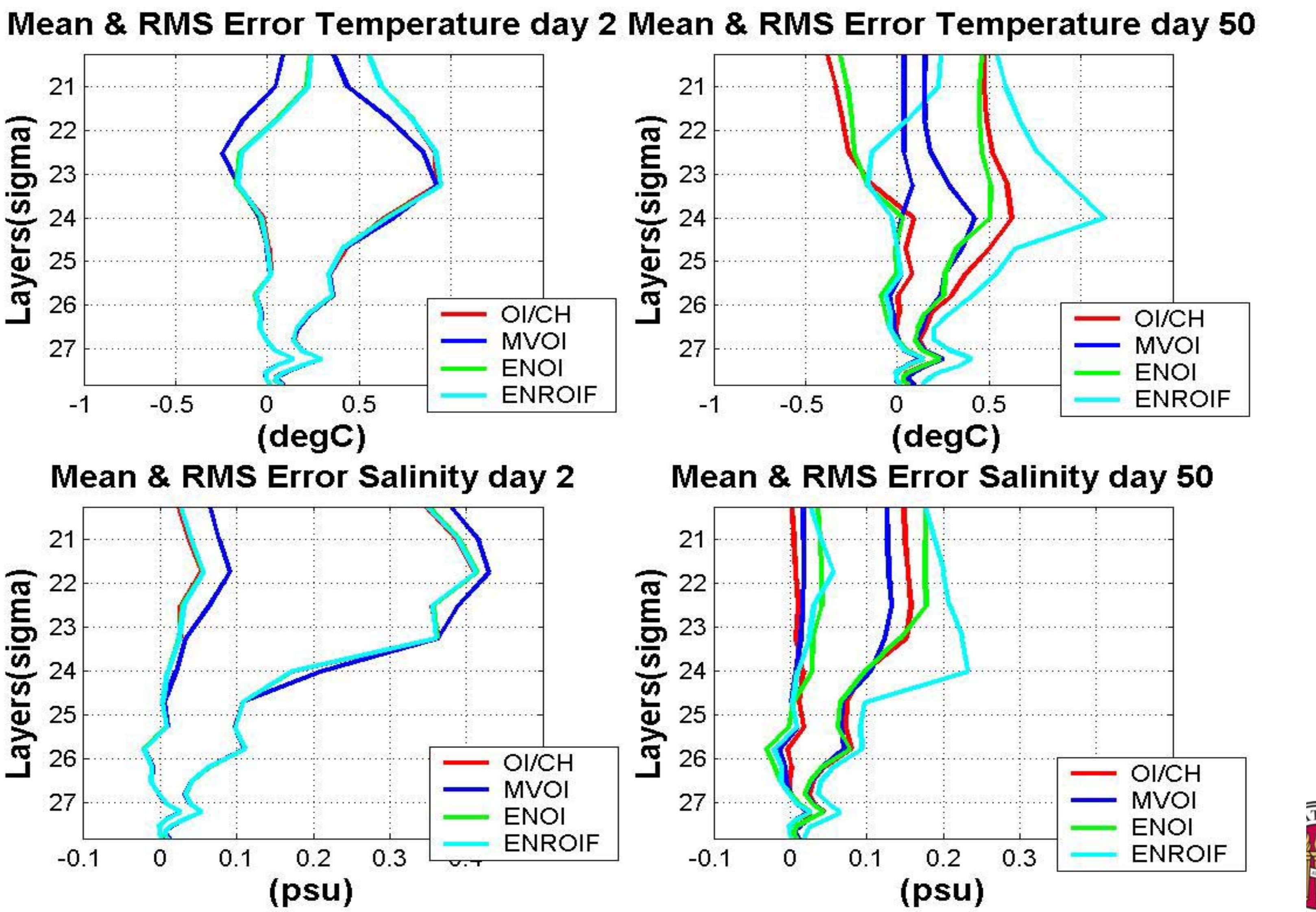
Temperature zonal sec. 25.08n Oct 18,1999 (Day 50)



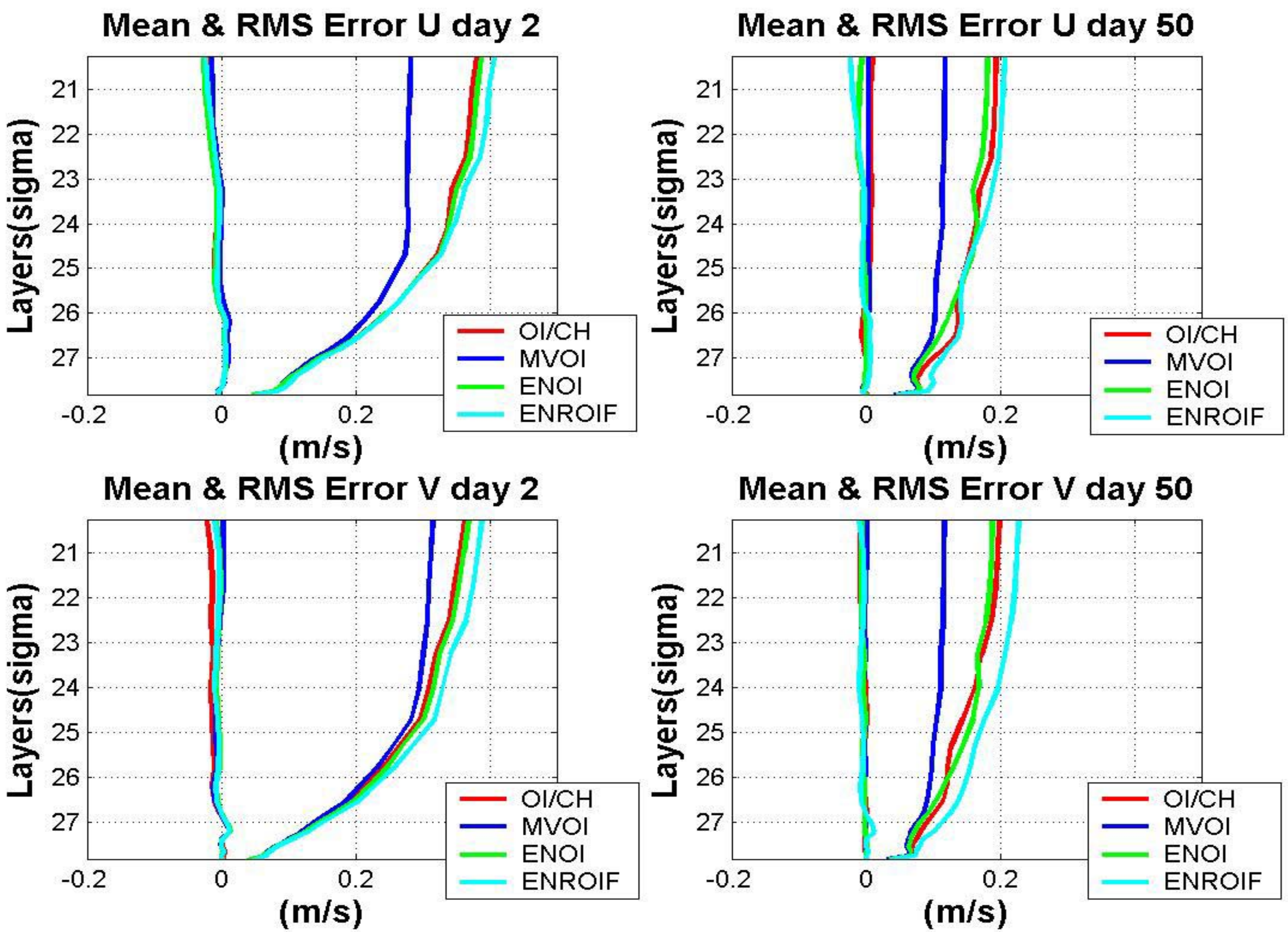
Salinity Vertical Section Forecast Day 50



Mean and RMS Error Profiles (T &S)

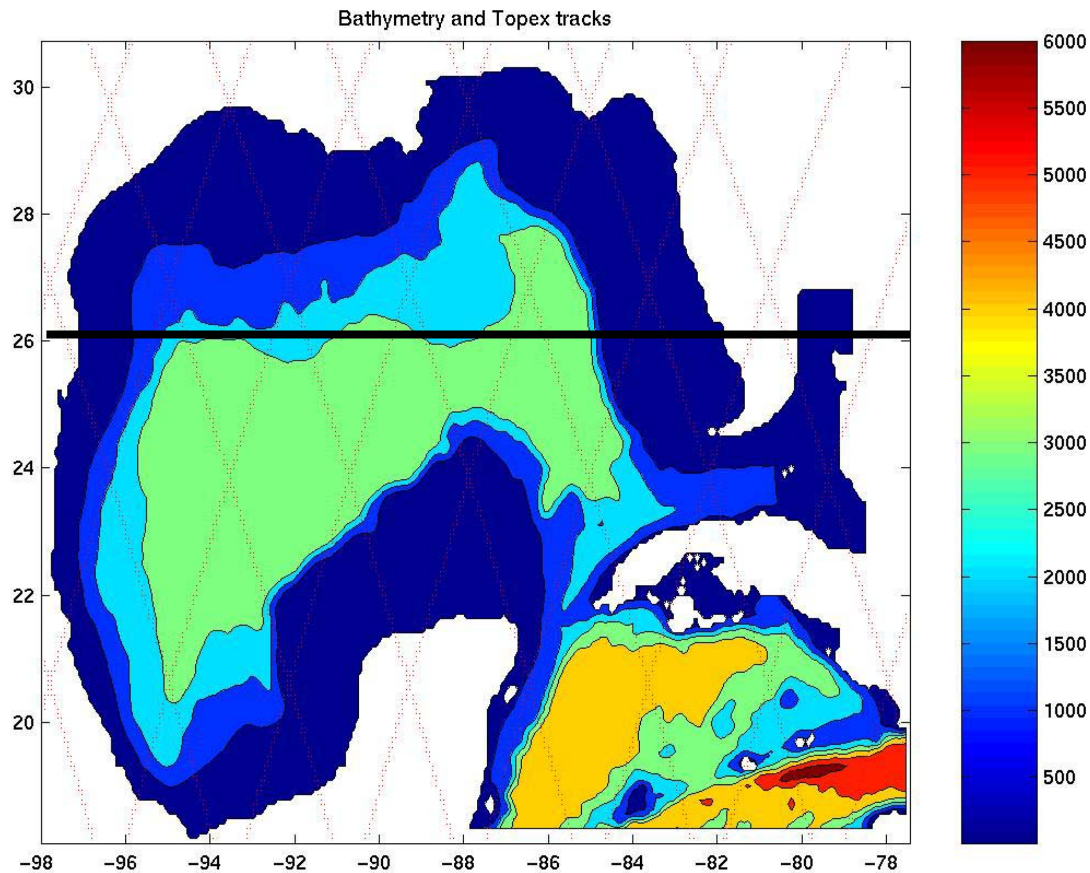


Mean and RMS Error Profiles (u & v)



Basin Averaged Layer Thickness

Transports across a closed section



Transports across a closed section