Representation Error in Ocean Data Assimilation

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Abstract

- Data assimilation works by using model-data misfits to correct the model state of the system
- The causes of some of the observed variability are not reflected in the model, and that portion of the observed variability cannot be usefully assimilated
- We propose a method for constructing statistical error estimates that account for representation error explicitly
- We describe the results of our first implementation of our methods within the framework of the operational climate forecast system.

Representation Error

- The *model-data misfit* $\mathbf{y}^o - H\mathbf{x}^f$ contains all the information we have about model errors

$$\begin{aligned}\mathbf{y}^o - H\mathbf{x}^f &= (\mathbf{y}^o - \mathbf{y}^t) + (\mathbf{y}^t - H\mathbf{x}^t) + \\ &\quad H(\mathbf{x}^t - \mathbf{x}^f) \\ &= \epsilon^o + \epsilon^R + H\epsilon^f\end{aligned}$$

- ϵ^o, ϵ^R, and $H\epsilon^f$ are the *instrument error*, the *representation error* and the *forecast error* mapped into observation space
- Only $H\epsilon^f$ contains information that can be usefully assimilated. The other components must be treated as noise
- We characterize ϵ^f in terms of the significant EOFs of a long run of the model. Significance is determined by the Preisendorfer test. The model space $\mathbf{X}$ is the span of the significant EOFs.
- ϵ^o and ϵ^R make up the orthogonal complement, in observation space, of $H\mathbf{X}$.
- The Preisendorfer test is used to distinguish ϵ^R from ϵ^o. This amounts to a scale assumption.

Representation Error EOFs

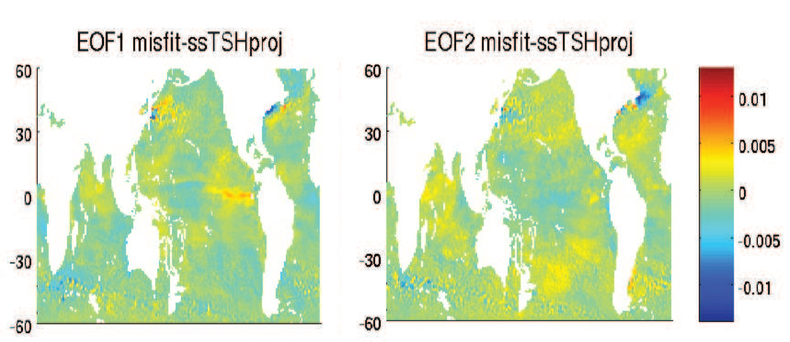


FIGURE 1: Lead EOFs of Representation Error

Example: MOM4 and SST Observations

- MOM4 on a $1/2^o$ horizontal grid (finer in the tropics) 40 levels in the vertical
- Data: Gridded SST analyses based on satellite observations, assimilated every 5 days
- ENSO is the strongest interannual signal in the model and observed SST.
- In the new scheme, only that part of the misfit that lies in $H\mathbf{X}$ participates in the assimilation process

Comparison New Scheme vs. Original

Assimilation Cycles for the Kuroshio, 6/25/03 - 6/30/03

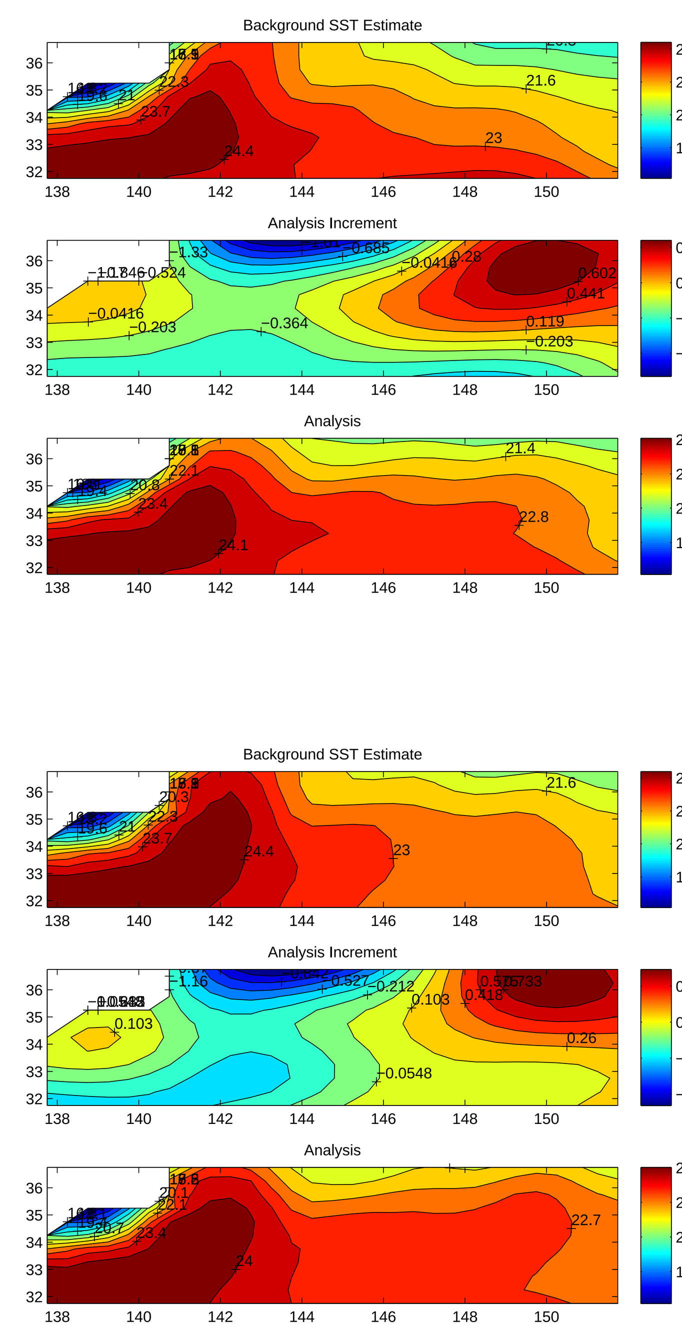


FIGURE 2: Original Scheme

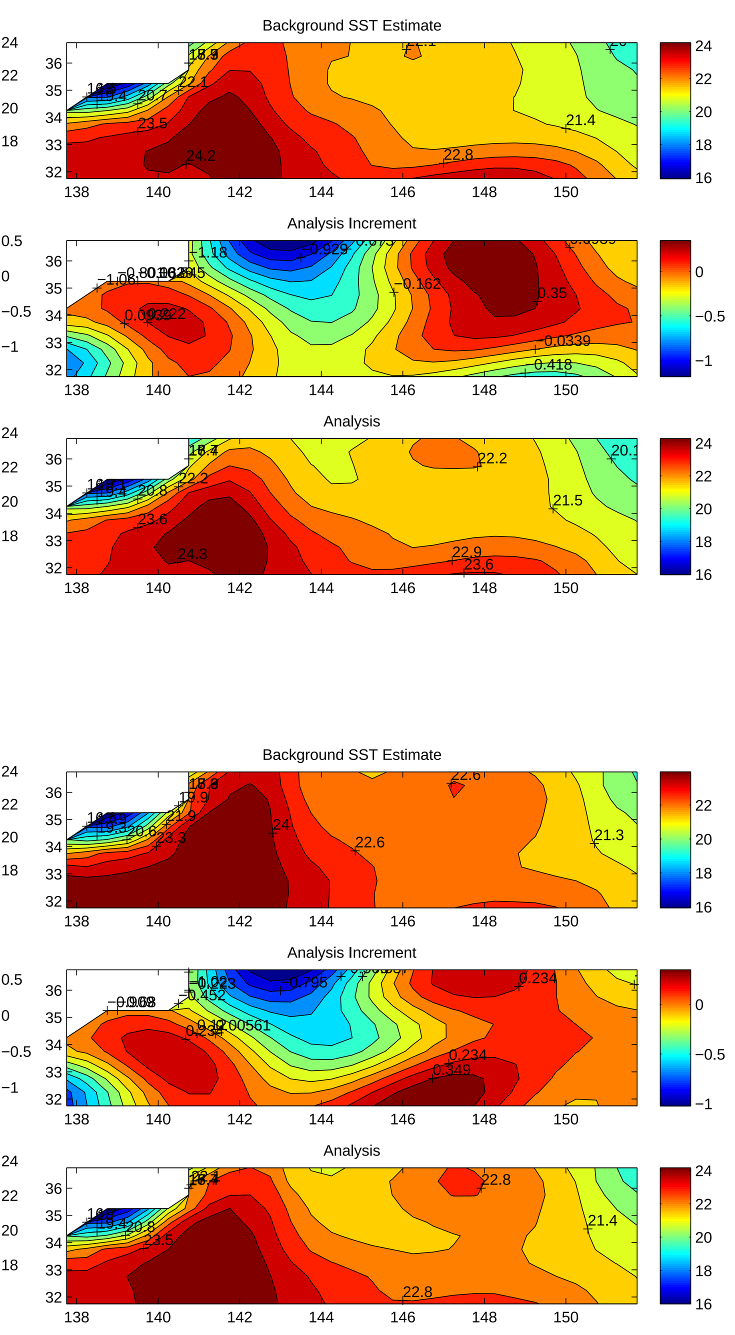
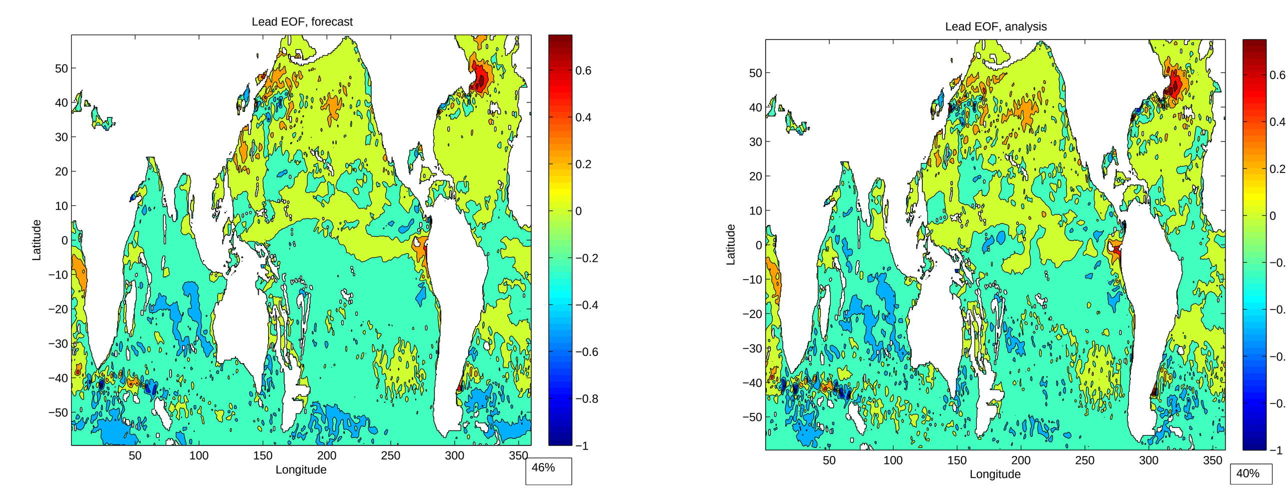


FIGURE 3: New scheme

Top to bottom: 6/25/2003, background, increment analysis; 6/30/2003 background, increment, analysis

Lead Misfit EOFs, New Assimilation Scheme



EOFs of model-data misfit for forecast (left) and analysis (right).

- Both show seasonal pattern. Principal components are dominated by annual signal.
- Analysis shows finer scale features, as expected.
- Representation error accounts for a greater proportion of analysis misfit than it does for forecast misfit.

Discussion

- The new scheme works as designed, i.e., misfits from representation error do not participate in the assimilation process
- In practice, with a 5 day assimilation cycle, large scale spatial patterns appear in the misfits in both the old and new schemes, with temporal variability dominated by annual cycle. This suggests two possibilities
  - Systematic seasonal bias in the surface forcing
  - Inefficiency in the assimilation scheme
- The estimated representation error also has significant seasonal cycle, arising from seasonal cycle in the un-modeled phenomena.
- Useful ensembles consisting of model output + simulated representation error will have to account for seasonal cycle, even with a more efficient assimilation scheme and improved surface forcing

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