Collaborative Proposal: Ocean Currents Forecasts Using Multi-model, Multi-scale Assimilation

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LONG-TERM GOALS

1. Examine the effects of unresolved model physics captured by observations in the assimilation

2. Understand the influence of the mesoscale on the internal tide spectrum and vice-versa

3. Determine the effects of increased physics on the Kalman Gain Matrix

4. Identify the temporal and spatial variability of the observational error of representativeness

OBJECTIVES

The primary objectives of this project are to: (i) build a suite of ocean models of the Philippine Sea (PS) of varying resolutions and dynamical representations; ii) perform “twin” experiments to examine how assimilation of full-spectra observations (including scales not resolved by the models) into simplified models impacts predictability; iii) generate covariance data from a suite of models to generate new Kalman gain matrix estimates; iv) use the Kalman estimate with the Green's function assimilation (as opposed to an adjoint) to compare different assimilation efforts; v) examine scale-selective error in the observations; vi) transition the results and methodology to NRL for further examination and possible inclusion into NRL operations.

APPROACH

We propose to investigate the two aspects of the multiscale assimilation: effects of physics on the Kalman Gain matrix and the temporal and spatial variability of the error of representativeness for observations. This work will be done in the Philippine Sea in hindcast for the year 2010, when we have a significant number of observations available.

Prof. Brian Powell at the University of Hawaii will run a suite of ROMS models of the region using varying resolutions with and without tides enabled. The varying resolutions will allow for selective sampling of physics at varying lengthscales, while tides will enable/disable the important contribution of the internal tide energy flux. By examining a ``twin" experiment case with and without the M2 (semi-diurnal) tide component, we can analyze and compare the baroclinic energy flux importance to predictability and how the observations impacted twin members with and without tidal physics. These twins will serve as the basis for the rest of the experiments.

Using the suite of ROMS models of the region along with the MITgcm which SIO will supply, HOPS from Dr. Lermusiaux, and NCOM from Dr. Coelho, we will examine the covariant structure that provides a new estimate of the Kalman gain matrix, **K,** which captures the variety of physics and scales present within the model ensemble. We intend to examine whether the Green's function method (along with the input statistics required to employ them) as compared to an adjoint will provide a significant improvement of the model forecasts. One issue is the generation of the covariances used to generate the ensemble members.

If only variability from a single model is used, the biases between the model and observations will be misconstrued by the reduced basis set used for inversion; therefore, utilizing multiple models in the basic research will provide a robust test of the method. Using the multi-model ensemble mean, we may be able to generate ensemble members constrained by the T-S relation. Another possibility would be to include differences with other models as well as climatology, and informing the covariance estimation with forecast error statistics archived from the operational runs.

Secondly, SIO will work in collaboration with Prof. Powell to experiment with incorporating scale-selective representational error, **R**, in the observations. There are two errors present in the formulation of **R**: (i) the error of representativeness due to missing model physics; and, (ii) the time-varying error due to the growth of uncertainty in the original background circulation. For (i), we will examine the twin experiments to understand the effect of the internal tides on the regional ocean circulation, which will allow us to build a covariance matrix of the uncertainty. For (ii), the **R** matrix needs to vary as a function of time since prediction (as model error grows, the representational error grows) and space (baroclinic energy fluxes vary spatially, but are limited in their variations). Incorporating these ideas into the minimization procedure may provide a way to estimate the Kalman Gain Matrix while accounting for unresolved physics.

A major goal of this proposal to provide useful techniques, ideas, and methodologies to the Navy that can be integrated into the operational context. Drs. Coelho and Heaney are well experienced in transitioning research into operations, and the work under this proposal will be in collaboration with those teams. While the work within this proposal is of basic research, results and experimental design will be shared with the NRL team throughout the period of this proposal.

WORK COMPLETED

The project milestones for year one were identified as:

- Develop and Integrate ``twin'' experiments.
- Compute space and time scales of internal tide energy flux.
- Exchange model solutions with collaborating teams to begin multi-model ensemble **K** calculations.
- Meet with collaborators to discuss progress and coordinate efforts of multi-model ensembles.

We are currently four months into year one, and UH have built a twin experiment and examined the space and time scales of the internal tide energy flux. SIO has an assimilating model of the PS running for 2010 to supply alternative large-scale ensemble elements. SIO has also met with Heaney to discuss the use of ensemble methods.

RESULTS

The PS 2010 state estimates computed so far have been for 1 and 2-month time windows, and fit the observations within prescribed error bars. Huge adjoint sensitivities due to intrinsic variability have been suppressed using increased viscosity in the adjoint model runs.

IMPACT/APPLICATIONS

This is an important multi-institute, multi-investigator team including MIT, NRL, SIO, and UH. In collaboration with Dr. Heaney and Dr. Coelho working on behalf of NRL, the results from this collaborative proposal will be made available with the expectation that they will be incorporated into NRL operational systems that utilize a wide variety of oceanographic observations.

RELATED PROJECTS

This project is a collaboration with a number of ONR sponsored investigators:

Brian Powell, UH: ONR N00014-13-1-0514
Pierre Lermusiaux, MIT: ONR N00014-13-1-0518
Emanuele Coelho, NRL and Kevin Heaney, Oasis: ONR N0001413-WX21102/RX20289

REFERENCES

PUBLICATIONS

None