

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

Bruce D. Cornuelle
Scripps Institution of Oceanography
University of California San Diego
Mail Code 0230
La Jolla, CA 92093-0230
Phone: (858) 534-4021 Fax: (858) 534-9820 Email: bcornuelle@ucsd.edu

Award Number: N00014-13-1-0520

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

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 2013		2. REPORT TYPE		3. DATES COVERED 00-00-2013 to 00-00-2013	
4. TITLE AND SUBTITLE Collaborative Proposal: Ocean Currents Forecasts Using Multi-model, Multi-scale Assimilation				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of California, San Diego, Scripps Institution of Oceanography, 9500 Gilman Drive, San Diego, CA, 92093				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 3	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

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, $\mathbf{K}$, 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, $\mathbf{R}$, in the observations. There are two errors present in the formulation of $\mathbf{R}$: (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 $\mathbf{R}$ 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 $\mathbf{K}$ 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