Multivariate Global Ocean Assimilation Studies

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LONG-TERM GOALS

Our long-term goal is to exploit developments in meteorology and computer sciences and well as oceanography to construct highly accurate representations of the four dimensional circulation of the ocean using data assimilation methods. We intend these representations to be applied in a variety of military, academic, as well as commercial applications.

Note: this grant evolved from a grant entitled, "Diagnose Large Scale Circulation in the South China Sea" (PI: Li Ping Wang) and it shares the same agency number.

OBJECTIVES

Among the most straightforward, efficient, and widely applied approaches to data assimilation is called Optimal Interpolation. The Naval Research Laboratory has implemented a version of OI called 3D MVOI, which was originally developed for meteorological applications. Here at University of Maryland we have independently developed another implementation called SODA. This grant explores the differences between these implementations with the goal of combining the best qualities of each. We begin with an examination of the performance of 3D MVOI in comparison with independent observations such as sea level and surface velocity. We then focus on improving that analysis by improving the error covariance models. In brief, technical objectives are:

1) compare initialization schemes

2) compare error covariance scales including geographic, vertical, covariance of temperature and salinity errors, and flow-dependent covariance

3) evaluate model

4) develop the algorithms for basin-scale error covariances (includes handling model bias).

APPROACH

This is the first grant the PI has received from ONR and the beginning of a collaboration with ONR and NPS scientists (Cummings, McClean). Thus a key aspect of the first year has been to become familiar with the people, technical and scientific problems, and software. The tasking as outlined in the proposal specifically focuses on the need in Year 1 has been to obtain and become familiar with the NRL software and computers. Next, we were to begin comparison of our results with those of MVOI

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14. ABSTRACT

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15. SUBJECT TERMS

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and in particular to evaluate the advantages/disadvantages of different algorithms. We were asked by a program manager (Terry Paluszkiewicz) to begin by comparing the two different initialization schemes used in MVOI and SODA.

Key individuals:

Ms. Xianhe Cao will carry out porting of the code to our local computers. She will also be responsible for comparing the data sets available at NRL and UMD and providing NRL with additional observations such as subsurface float and surface drifter observations, tide gauge observations, TMI SST, etc.

Dr. Grodsky (Research Scientist) has been responsible for examination of the data sets and in particular, the nearsurface drifters.

Dr. Chepurin (Research Scientist) has been responsible for the examination and comparison of filters (see the annual report Enclosure (1) for our comparison). He has also been responsible for development of bias correction algorithms.

WORK COMPLETED

1) Examination of digital filter and IAU initialization schemes (item #1 under objectives).

2) Port of the 0.4degx0.4degx40level POP model to NCAR where it is now running on Blackforest (an SP2, similar to our Navy target machines). This falls under item #3 of our objectives. We have submitted a request for computer time there. We submitted a Grand Challenge proposal with Dr. Julie McClean to get computer time, although it seems that that proposal will not provide sufficient time for us. We have filled out security clearance forms and are waiting approval. We have ported one of the assimilation schemes we intend to work with, but not the other yet. Getting sufficient computer time remains a problem.

3) We are about 2/3s of the way toward implementing basin-scale error covariances (see item #4 under objectives). We believe this work will have wide applicability.

RESULTS

This has been a very active year thanks in large part to all the help we have gotten from Dr. Julie McClean at the Naval Postgraduate School. We have completed a comparison of different initialization schemes used throughout the world. We are working with the POP code now, but still have a long way to go in terms of detailed comparison of results.

Comparing initialization schemes

Data assimilation requires combining a model forecast with an estimate of the corrections based on an observation set. Simply combining the two at intermittent intervals causes generation of spurious gravity waves and also may lead to data rejection. A number of strategies have been developed to eliminate these spurious waves based on some kind of filtering. Here we compare two time-filtering procedures that have been suggested for application to ocean data assimilation, Digital Filtering Initialization (DFI) used at NRL and Incremental Analysis Update (IAU) used, for example at NASA/Goddard (Schubert et al., 1993). The basic approach of DFI was introduced by Lynch and

Huang (1992). In that first version an adiabatic version of the forecast model is integrated backward and forward in time from the analysis time to produce a time series at each grid point spanning several inertial periods. These grid point time series are then low-pass filtered. IAU, in contrast involves a predictor/corrector set of model integrations. We conclude that the IAU is really just a specific application of DFI as long as the system is linear. Even for a fully nonlinear system the results are very similar.

Comparison To IAU

To understand the differences in these two approaches we first consider a linear system. To illustrate we represent the ocean by the function f(t) as a simple 1^{st} order process forced by Q(t).

$$\frac{\partial f}{\partial t} = -af + Q(t)\,; \quad f(t=0) = 0 \tag{1}$$

where the analysis increments look like: $Q(t) = c\delta(t - t_j)$. The solution is:

$$\begin{aligned} f &= 0 \qquad t < t_j \\ f &= ce^{-at} \quad t > t_j \end{aligned} \tag{2}$$

which shows a dramatic shock. If Q is smoothed with a boxcar filter of width L then the solution becomes

$$\begin{aligned} f &= \frac{C}{La}(1 - e^{-a(t - t_j + L/2)}) \quad t_j - L/2 < t < t_j + L/2 \\ f &= \frac{C}{La} e^{-a(t - t_j - L/2)} \qquad\qquad t_j + L/2 < t \end{aligned} \tag{3}$$

Notice that f, although smoothed, is phase-shifted roughly L/2 in time because of the filter. If the analysis is evaluated at $t = t_j$ this is the digital filter (with a boxcar window), if at $t = t_j + L/2$ it is incremental update analysis. Thus, we see for the linear case that IAU is simply an application of digital filtering, but with s somewhat different analysis time. Because of the phase-shifting inherent in the filtering operation the IAU approach is probably superior in this linear case.

To compare the two approaches in the full nonlinear context of data assimilation we have implemented both in our optimal assimilation algorithm. The results summarized in **Figs.** 1 and 2 reveal that the two approaches give strikingly similar results even when applied to full assimilation systems.

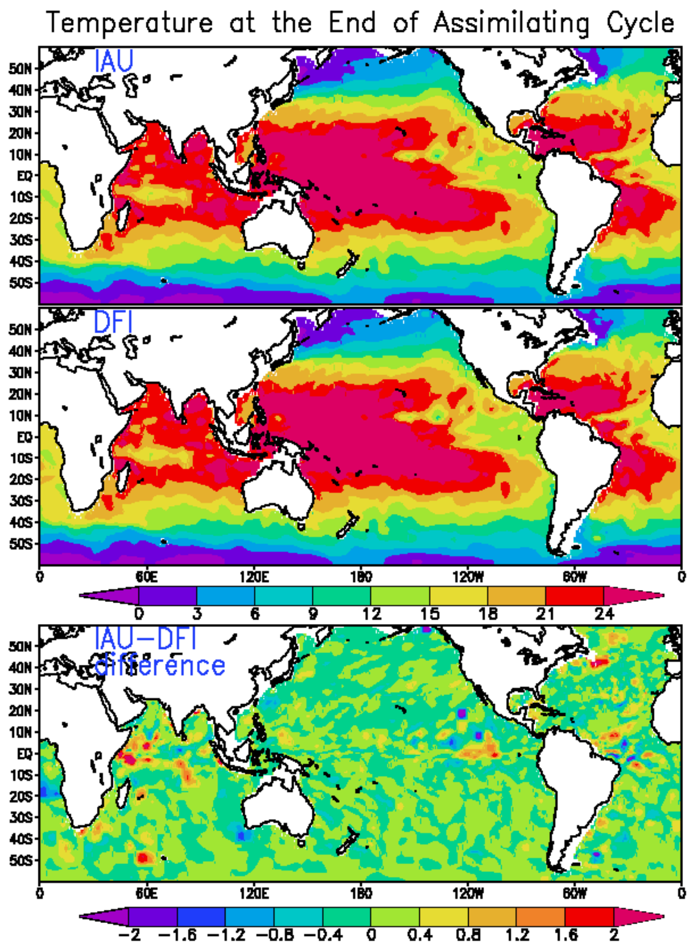

Fig. 1 Comparison of SST from two analyses, one using IAU and the other using digital filtering (DFI) with a boxcar window. The data assimilation analysis and general circulation models for both experiments are based on SODA (Carton et al., 2000). The filter window width and updating period are 10 days for both. The differences between the two initialization schemes are generally within the error.

IMPACT/APPLICATIONS

As indicated under long-term goals, we believe work on assimilation algorithms has very wide-spread implications, touching on commercial and environmental systems as well as military applications.

TRANSITIONS

We make our data assimilation analyses available to the scientific community through a variety of web servers. We have no statistics on usage, but are receiving email regularly about them.

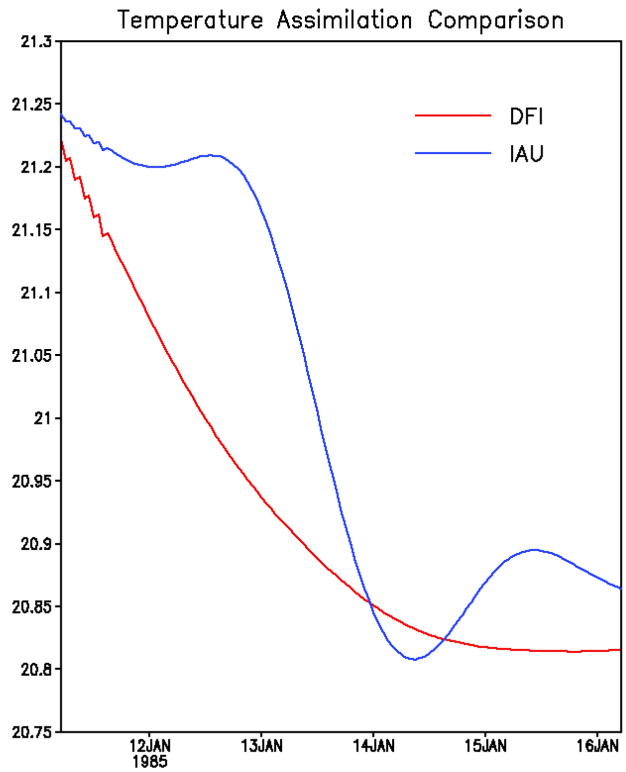

Fig. 2 SST at one representative location in the tropical Atlantic (6N, 50W) for the two experiments shown in Fig. 1. The time series show that the temperature analysis using a digital filter is smoother the one using the IAU filter. The latter appears to retain more high frequency variability. However, the weekly averaged SST from the two time series is very similar.

RELATED PROJECTS

I have two related project, both of which are directed toward development and exploration of the data assimilation algorithms. The first is a grant from the NSF ITR program to develop methods of dealing with bias in ocean models. As mentioned above, forecast model bias is the worst problem we currently face and must be addressed in advance of application of more sophisticated methodologies (in my opinion). The second grant from NASA is directed toward examination of the behavior of current assimilation schemes.

Table 1

NASA	Role of satellites in detecting decadal change in the oceans
NSF	ITR/AP+IM (GEO) Reanalysis of the Climate of the Global Ocean

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PUBLICATIONS

The grant has produced no publications in the first year, which has been devoted to getting codes and computers ready.