Phase II Option 3rd quarterly progress report for the SBIR project on

An Ensemble Kalman Filtering Approach for Regional Ocean Data Assimilation

Contract N00039-08-C-0017
Amount: $747,336; awarded by Space and Naval Warfare Systems Command

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23 March 2011

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PHASE II Option – QUARTERLY PROGRESS REPORT (period ending 23 March 2011)
CONTRACT NO. N00039-08-C-0017

Administrative narrative.

Weekly telecons on Tuesdays, 3:30 pm ET have continued to be the focal point for progress reporting and project discussions.

Two staff have who have worked on prior phases of the project actively participated with research team during the last quarter: (1) Eric Kostelich, a mathematics professor at Arizona State University, resumed support of the project as a subcontractor to AER starting in December; and (2) Sergey Vinogradov, an oceanographer and Staff Scientist at AER, began working on the project again in February. Eric wrote much of the LETKF preprocessor, solver and postprocessor, and has advised us on approaches to parallelize NCOM inputs/outputs. Sergey is visualizing LETKF analysis increments and observation locations with MatLab.

Technical progress.

Mark Leidner has made the following technical progress during the third quarter:

- got LETKF running at Stennis on a single processor using a modest ensemble (6 members), essentially reproducing prior results at AER;
- verified that two Fortran compilers at Stennis produce the same answers to within machine precision (g95/gfortran);
- performed LETKF sensitivity tests, changing observation standard deviation and localization parameters (Sergey Vinogradov provided visualization);
- wrote new LETKF software to accommodate parallel reading of an ensemble of NCOM outputs (background), and parallel writing of NCOM inputs (analyses; Eric Kotselich consulted on software changes);
- initiated a 36-member, 12-processor cycling experiment.

Parallelizing LETKF NCOM model i/o was an essential step to allow for larger ensembles (> 20) that will produce more credible background error estimates.

We also found that the assumed observation error for multi-channel sea surface temperatures (MCSST) was too small ($\sigma_{SST} = 0.2C$) and produced unrealistic increments in surface height and velocity. Using such a small observation standard deviation also reduced the analysis errors at the observation locations to unrealistically small values. It also had the side effect of producing NCOM inputs (i.e., LETKF analyses) that immediately violated thresholds for stable model time stepping.

After settling on a more substantiated value of MCSST observation error standard deviation (0.7 C), the magnitude of the analysis increments are more physically reasonable and reduce the analysis errors to a level consistent with the documented accuracy of MCSST observations (statistics not show here, but compare the left and right columns of Fig. 1). The results shown in Fig. 1 are valid at 12 UT July 1, 2007, the first analysis time in each experiment for the Okinawa Trough region. Only SST observations are available at this analysis time. Experiment cy6g (left column) uses $\sigma_{SST} = 0.2$ C and experiment sgfo (right column) uses $\sigma_{SST} = 0.7$ C. Even with a more realistic SST observation standard deviation (sgfo), there are still large height increments (> 1 m) near the Chinese coast that do not seem reasonable. This may be a product of a small ensemble or of near-coastline assimilation in shallow water. We are still investigating the cause and resolution.

The earliest results at Stennis (reproducing earlier 6-member results at AER) also showed that the localization did not confine the influence of the observations sufficiently. LETKF uses an analysis patch radius (R_P) to define the influence region of observations. Experiment cy6g uses $R_P = 80$ km, which is not appropriate for either the 9 km MCSST observation density or the 3 km NCOM model grid. Experiment sgfo uses a localization patch radius of 18 km, a more appropriate choice for the resolution of the observations and NCOM model grid.

Finally, a 36-member cycling experiment was initiated at Stennis, but immediately ran into computer allocation/resource issues: the 12-processor analysis tried to allocate nearly all available memory on the computer on which the analysis was runnning and could not complete. There are many ways to bring more computers and resources to bear on the problem, and we will be exploring this next.

Planned activities.

Now that multi-processor LETKF is working at Stennis, larger-scale experiments will be conducted. In the near future, we would like to run analysis experiments that parallel current NCODA-MVOI/NCODA-3dVAR comparisons. That is, spin up the analysis during the month of July 2007 and continue cycling for the months of August-October 2007 when special ocean observations were collected by the Navy in the Okinawa Trough area.

These larger-scale tests will eventually involve the use of NCODA observation pre-processing to ensure that LETKF is being fed the same set of observations and observation errors that NCODA-MVOI/3dVAR are using.

In order to facilitate large-scale LETKF tests, diagnostic software to compute ensemble statistics (o-a, o-b, ensemble variance, etc.) that was written for and used during analysis cycling of the single-processor version of LETKF also needs to be parallelized. This work will be completed before larger-scale testing commences.

Fig. 1:

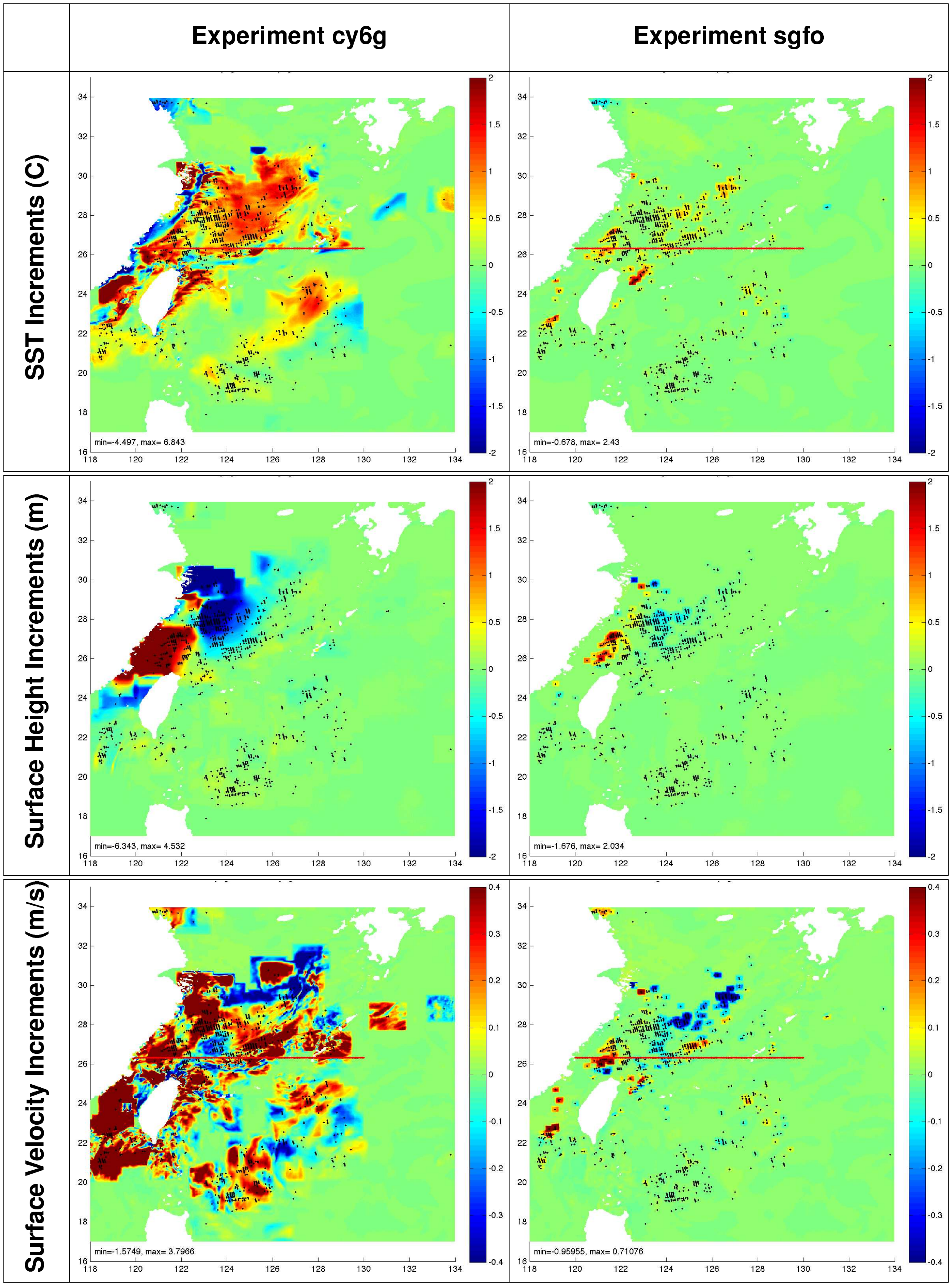
Experiment cy6g
Experiment sgfo
SST Increments (C)
Surface Height Increments (m)
Surface Velocity Increments (m/s)
min=-4.497, max= 6.843
min=-0.678, max= 2.43
min=-6.343, max= 4.532
min=-1.676, max= 2.034
min=-1.5749, max= 3.7966
min=-0.95955, max= 0.71076

Figure 1. LETKF sea surface analysis increments for two experiments: cy6g (left column; $\sigma_{SST} = 0.2$ C, $R_P = 80$ km) and sgfo (right column; $\sigma_{SST} = 0.7$ C, $R_P = 18$ km). MCSST (n=988) and ship SST (n=15) observation locations are plotted as black dots. The top and bottom rows also show east-west cross section locators (red; see Fig. 2 for cross sections.)

Fig. 2:

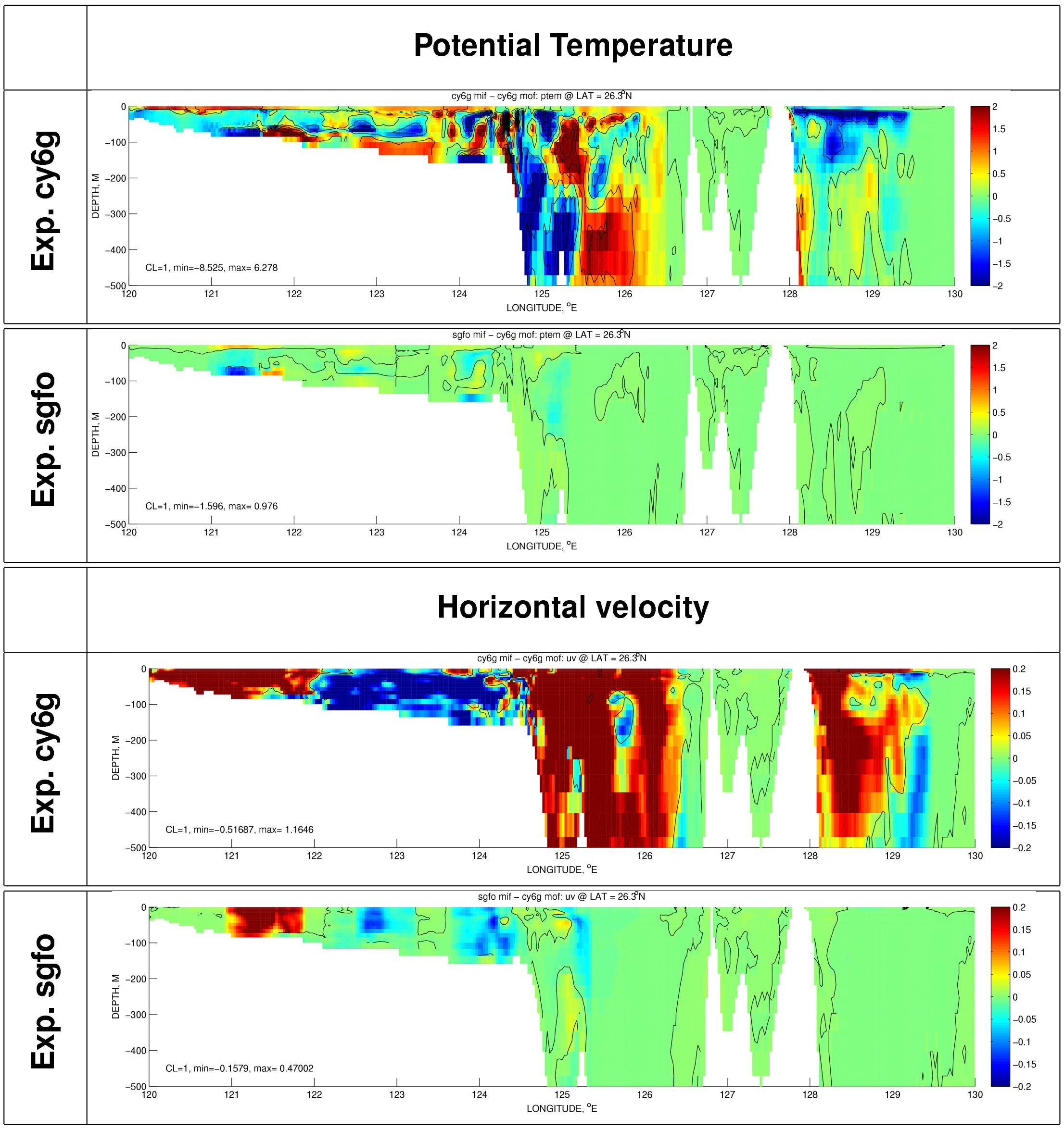

Figure 2. Vertical cross sections (0-500 m) of LETKF analysis increments for two experiments:cy6g ($\sigma_{SST} = 0.2$ C, $R_P = 80$ km) and sgfo ($\sigma_{SST} = 0.7$ C, $R_P = 18$ km). See Fig. 1 for cross section location.