REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
23-08-2018	NRL Publication	

4. TITLE AND SUBTITLE
Variational Data Assimilation

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
0602435N

6. AUTHOR(S)
S. Smith, C. Amerault, C.N. Banon, T. Campbell, M. Carrier,1 J.M. Dastugue, S. deRada, E. Douglas, P. Martin, J.C. May, H. Ngodock, C.D. Rowley, J.F. Shriver, O. Smedstad, P.J. Spence, and M. Y aremchuk

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
73-6764-06-5

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Research Laboratory
Oceanography Division
Stennis Space Center, MS 39529-5004

8. PERFORMING ORGANIZATION REPORT NUMBER
NRL/PU/7320--17-3684

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
One Liberty Center
875 North Randolph Street, Suite 1425
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The scope of this project is to advance the analysis and prediction capability of the Navy's environmental modeling and forecasting systems through the improvement of the assimilation software. This project used three different variational assimilation systems: (1) Relo NCOM (3DVAR), (2) the adjointless 4DV AR, and (3) the NCOM-4DV AR. There were 8 funded NRL projects that focused on either adding or improving capabilities of 4DVAR in FYI 7, and the experiments performed under this HPC project went towards satisfying these efforts.

15. SUBJECT TERMS
environmental modeling, forecasting systems

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Scott Smith
Unclassified	Unclassified	Unclassified	UU	03	19b. TELEPHONE NUMBER *(Include area code)* (228) 688-4630

Reset

Title: Variational Data Assimilation
Author(s): S. Smith,[1] C. Amerault,[2] C.N. Barron,[1] T. Campbell,[1] M. Carrier,[1] J.M. Dastugue,[1] S. deRada,[1] E. Douglas,[1] P. Martin,[1] J.C. May,[1] H. Ngodock,[1] C.D. Rowley,[1] J.F. Shriver,[1] O. Smedstad,[3] P.J. Spence,[3] and M. Yaremchuk[1]
Affiliation(s): [1]Naval Research Laboratory, Stennis Space Center, MS; [2]Naval Research Laboratory, Monterey, CA; [3]QinetiQ North America, Stennis Space Center, MS
CTA: CWO

Computer Resources: Cray XC30, Cray XC40, IBM iDataPlex [NAVY, MS]

Research Objectives: The scope of this project is to advance the analysis and prediction capability of the Navy's environmental modeling and forecasting systems through the improvement of the assimilation software. This project used three different variational assimilation systems: (1) Relo NCOM (3DVAR), (2) the adjointless 4DVAR, and (3) the NCOM-4DVAR. There were 8 funded NRL projects that focused on either adding or improving capabilities of 4DVAR in FY17, and the experiments performed under this HPC project went towards satisfying these efforts.

Methodology: This HPC project helped advance the NCOM-4DVAR assimilation system in FY17 through the following funded NRL projects: (1) The 6.4 Ocean Data Assimilation (ODA) project was tasked to test the NCOM-4DVAR within the operational COAMPS5 system and in the highly nonlinear regimes of the US East Coast and Agulhas. (2) The 6.2 Coupled Ocean-Atmosphere Variational Assimilation and Prediction System project merged the 4DVAR capabilities of the atmospheric and oceanic components of the Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS) to create a coupled 4DVAR capability. (3) In the 6.2 Coupled Ocean-Acoustic Assimilative Model project, a number of validation experiments were performed of the coupled 4DVAR-NCOM and 4DVAR-RAM system. (4) The 6.2 Smart Glider Teams for Rapid Update of Local Analysis project tested a new capability for accurate and rapid characterization of the local ocean battlespace using coordinated teams of gliders and preserving the fidelity of their collective observations through innovative 4DVAR assimilation. (5) The 6.2 Calibration of Ocean Forcing with satellite Flux Estimates project, continued NCOM-4DVAR experiments to quantify ocean error covariance. (6) The 6.1 Adjointless 4dVar for operational Navy ocean models project performed experiments with this developed adjointless system in the Okinawa Trough and RIMPAC regions. (7) The 6.1 Propagation and Dissipation of Internal Tides on Coastal Shelves project continued the study of the year-long NCOM-4DVAR experiment on the Northwest Australia Shelf. (8) The 6.2 Submesoscale Prediction of Eddies through Altimeter Retrieval (SPEAR) project performed 3DVAR and 4DVAR experiments to test high-resolution assimilation to resolve submesoscale features.

Results: Numerous 4DVAR-NCOM experiments were performed under this FY17 HPC project with the overall result of further improving the analysis accuracy, prediction skill, portability and robustness of the system in various regions of interest and at different resolutions. A few of the specific advancements that were made include: how to operate the system at very high resolution (Fig. 1), the understanding of the modeling and prediction of internal tides, the coupling of assimilation systems from different models, and glider control.

DoD Impact/Significance: The 3D and 4D variational systems that were tested under this project went towards improving the Navy's capability of forecasting the ocean environment. Various validation studies for the 4DVAR-NCOM were performed and they showed more accurate analyses and model forecast fields than its predecessor, NCODA_VAR. Additionally, the work on coupling the assimilation systems for the ocean, atmosphere, and acoustic models made significant progress this fiscal year and these coupled systems will ultimately further improve the forecast skill of all three environments.

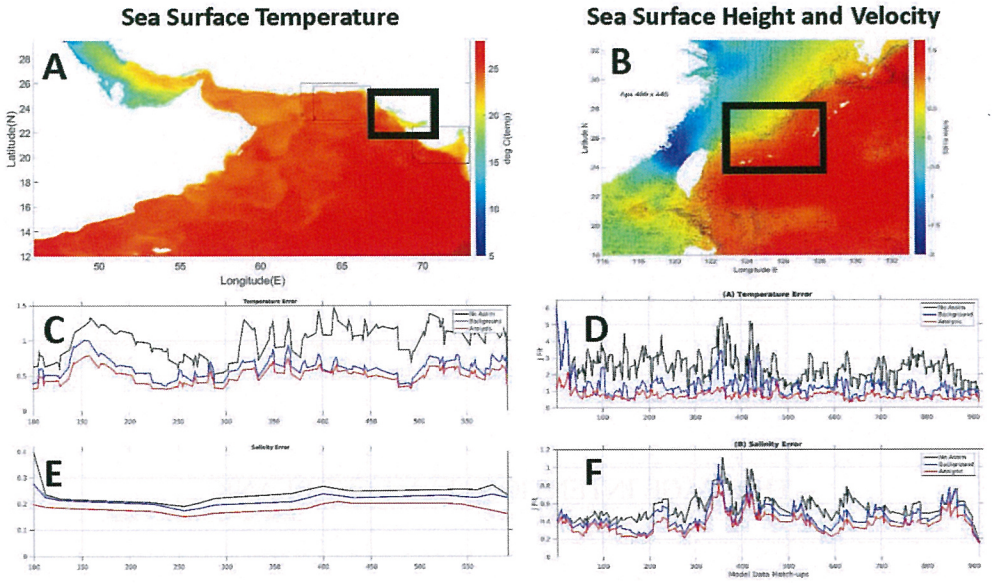

Figure 1. High resolution (1-km) ocean assimilation experiments were performed with the NCOM-4DVAR analysis/prediction system for subdomains (solid black squares) in the North Arabian Sea (Panel A) and the Western Pacific Ocean (Panel B) for the months of February and March, 2016. The resulting temperature (Panels C and D) and salinity (Panels E and F) error statics are compared between the free run (no assimilation) (black line), the previous 24-hr forecast (blue line), and the 4DVAR analysis (red line). These results verify that the NCOM-4DVAR software is performing well at a high resolution. Since this system is computationally expensive to operate, these experiments could not have been performed on anything other than HPC resources.

U.S. NAVAL RESEARCH LABORATORY

FY17 NRL DoD High Performance Computing Modernization Program Annual Reports

Prepared by
Portia A. Shingler
and
Beth A. Howell

Center for Computational Science
Information Technology Division

August 15, 2018