

Open Ocean Data Assimilation

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LONG-TERM GOALS

Development of data assimilation, not only for data analysis, but as a rigorous framework for the testing of numerical models of ocean circulation to be used in hindcasting, forecasting and array assessment.

OBJECTIVES

1. Construction of a regional, reduced-gravity model in fully Lagrangian coordinates, and assimilation of float data variationally.
2. Optimization and parallelization of a global primitive equation model in Eulerian coordinates, for variational assimilation of Eulerian data.
3. Transition, from NAVO to FNMOC, of graphics for visualizing ocean model output.

APPROACH

1. Regional primitive equation models are ill-posed, if the domain is Eulerian. However, they are well-posed if the domain is Lagrangian. It is therefore feasible to find solutions of the inverse or variational data assimilation problem in Lagrangian domains, using the methods developed here in the last decade. Prof. Jodi Mead was contracted to compute solutions of the inverse problem for a shallow water model in a Lagrangian domain.
2. The standard, robust primitive equation model in Eulerian coordinates needs new coding for efficiency. Derived models (tangent-linear and adjoint) need constructing, coding and embedding in a new modular system for variational data assimilation. Mr Boon Chua (supported by NOAA) was tasked with developing the derived models in collaboration with the PI, and coding them for single processors. Dr Richard Loft was contracted to perform the optimization and parallelization.
3. Graphics recently developed at NAVO need to be installed and demonstrated at FNMOC. Contractors located at FNMOC assumed these tasks.

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WORK COMPLETED

1. The tangent linear form of the viscous shallow water equations in Lagrangian coordinates has been coded and test for consistency. The adjoint model has been coded and is being tested for consistency. They are being implemented iteratively in a fully nonlinear assimilation scheme.
2. The B-grid, free-surface primitive-equation model of Bryan & Cox (and subsequent developers) has been recoded for optimal performance on new microprocessors, and then parallelized using OpenMP, MPI and custom communication libraries coded in C. The code has been tested on SGI and IBM computers at FNMOC and at NCAR respectively. The derived models have been constructed, coded for single processors and tested for consistency. They are undergoing optimization and then parallelization.
3. SEAFLOW software developed at NAVO has been installed on SGI systems in the VIP Theatre at FNMOC, and demonstrated to Division 400 (Models and Data Department). FAST software is also being obtained form NASA Ames and installed at FNMOC.

RESULTS

1. The solution method for the nonlinear equations of variational assimilation involves functional or Picard iteration. This technique should be tested first on the nonlinear forward model: numerical solutions of the iterated, linear models should converge to numerical solutions of the nonlinear model.

The solutions have been found to converge, for choices of parameters appropriate to mesoscale variability in the N. Atlantic , so long as the first iterate is not far wrong. Otherwise convergence obtains if the mean phase speed of the first iterate is less than that of the nonlinear model. The adjoint of the iterated forward model has been coded; the pair is being tested for adjoint symmetry.

2. The recoded, explicit barotropic solver for the free-surface Bryan & Cox model has been tested at 1/10 degree resolution globally. It scales well in OpenMP on SGI and well in MPI on IBM, attaining computational speeds of 80Gflops on 192 IBM processors (48 four-way four-pipe 375mhz nodes) or 27% of peak. Sustained performance, including communications, is 48 Gflops. The optimized, parallelized baroclinic solver matches the unoptimized single processor code, bit-for-bit, and is now being tested for performance. The unoptimized, single-processor tangent linear and adjoint models pass consistency checks, also to machine precision.

3. A demonstration of SEAFLOW to the Command at FNMOC is being scheduled.

IMPACT/APPLICATIONS

1. Even though regional primitive equation models are well-posed if the domain is Lagrangian, solutions of equations of fluid dynamics in Lagrangian coordinates are not well studied. Along with the advent of new Lagrangian observing platforms, Lagrangian dynamics will give new insight into ocean circulation, both as a forward model and as a basis for assimilating data.
2. The inverse or weak 4DVAR version of the optimized primitive equation model permits the testing of parameterization schemes and external forcings, using ocean data in quantity; a succesful inverse

model may be used to initialize forecasts of the forward model, to generate synoptic covariances for existing 3DVAR schemes, and to assess observing systems.

3. Effective visualization is essential to the development, maintenance and operation of realistic, high-resolution ocean forecasting systems.

TRANSITIONS

1. n/a

2. The optimized forward and inverse codes for the primitive-equation model are being made available to FNMOC , with support in the form of growing documentation and also regular meetings of a code study group.

3. The visualization tools are being installed and demonstrated on FNMOC computers.

RELATED PROJECTS

n/a

PUBLICATIONS

J.L. Mead and A.F. Bennett, "Towards regional assimilation of Lagrangian data: the Lagrangian form of the shallow water model and its inverse", Journal of Marine Systems 29 (2001) 365-384.