Is NCOM-4DVAR Compatible with HYCOM?

Daniel Uwaifo, SEAP, Naval Research Laboratory, Stennis Space Center, MS

OBJECTIVE: The goal of this project is to demonstrate that the NCOM-4DVAR data assimilation system can be used for HYCOM, that is, the tangent linear and adjoint models of NCOM are good approximations of their HYCOM counterparts.

MOTIVATION: Data assimilation is a critical part of any forecasting. Numerical models that are used for forecasting the ocean usually do not match the observations because they contain errors arising from inaccurate initial conditions and boundary conditions, forcing, parameterization, or unresolved processes. Data assimilation is the process that helps correct the model, i.e. steer it to be in better agreement with the observations. It is important that the models used by the U.S. Navy be equipped with the best data assimilation method possible.

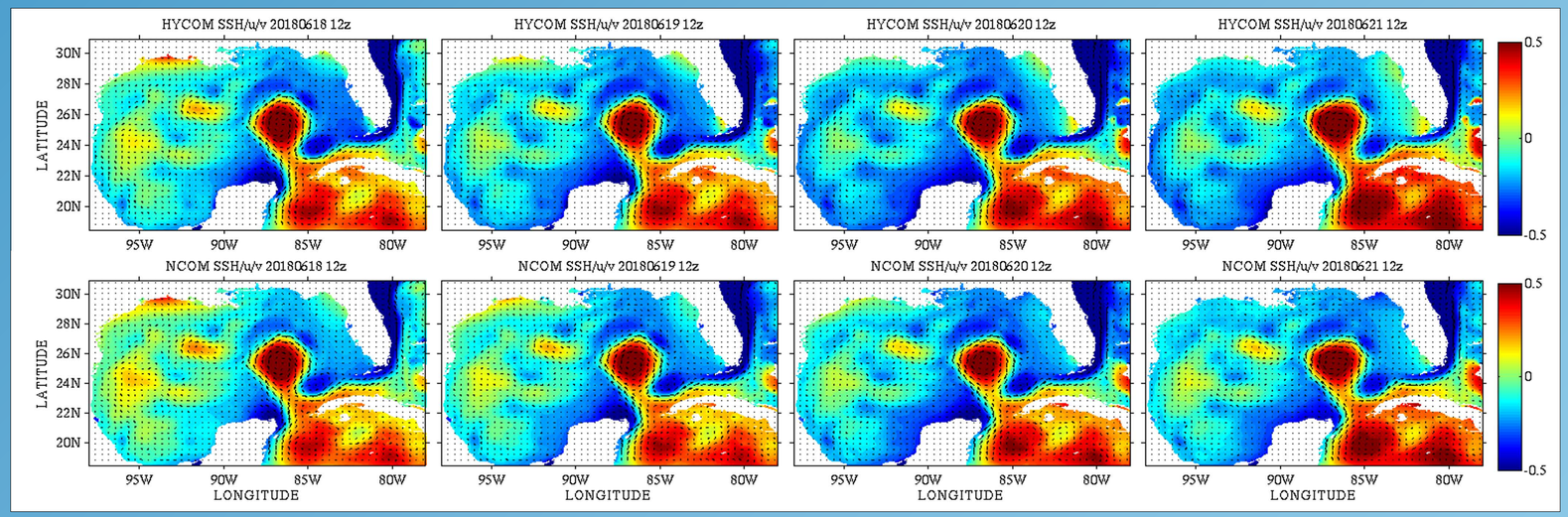
BACKGROUND: The U.S. Navy operates two numerical ocean models: the Hybrid Coordinates Ocean Model (HYCOM) for global analyses and forecasts, and the Navy Coastal Ocean Model (NCOM) for smaller regional domains. NCOM is equipped with the four-dimensional variational (4DVAR) data assimilation system, while HYCOM is only equipped with a three-dimensional variational (3DVAR) data assimilation system. The development of a 4D-Var data assimilation system for any model requires that a tangent linear and adjoint of that model be developed first. It is problematic to develop a 4DVAR system for HYCOM because of HYCOM's complexities and nonlinearities. However, since both HYCOM and NCOM approximate the same Naiver-Stokes equations, it is reasonable to assume that both models represent the same dynamics. In this project we will attempt to demonstrate that the tangent linear model of HYCOM can be approximated by the tangent linear model of NCOM, and by way of consequence, the adjoint model of HYCOM can also be approximated by the adjoint model of NCOM.

APPROACH:

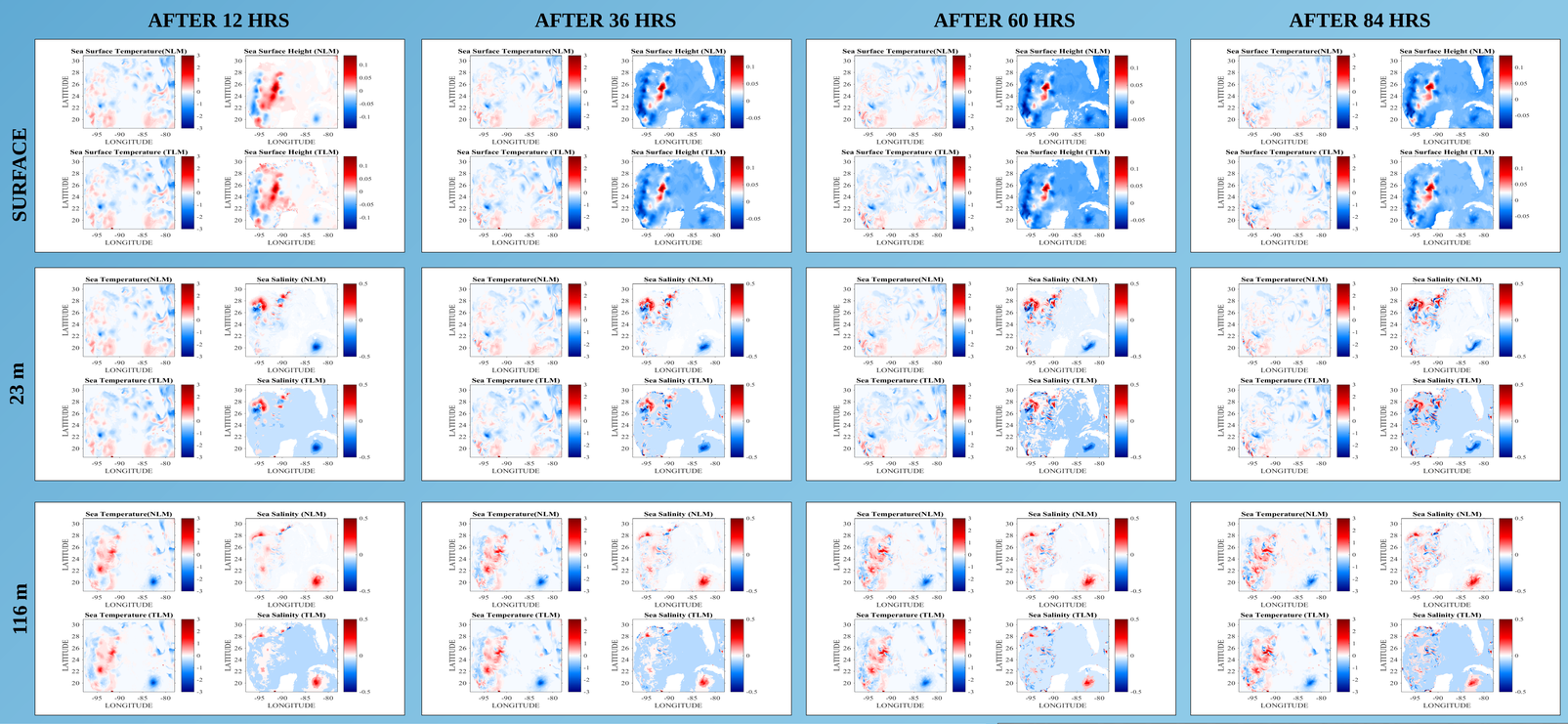
1. Unperturbed runs: set up an NCOM run with the same initial boundary and forcing conditions as in HYCOM. Ensure both solutions are similar.
2. Use the analysis increments as initial perturbations for a second HYCOM run, the perturbed run.
3. Use the analysis increments from the initial perturbation of HYCOM for the NCOM TLM.
4. Compare the difference between the two HYCOM runs (perturbed minus unperturbed) and the NCOM TLM.
5. Differences should be within the range of typical discrepancies between models and observations.

EXPERIMENT SETUP: Gulf of Mexico HYCOM is run from June 17, 2018 to June 22, 2018 at 4km resolution. The initial condition for the unperturbed run is the 24-hr forecast from June 21, while the perturbed run starts from the analysis on June 22. The initial condition of unperturbed HYCOM run is also the initial condition for the NCOM background that the NCOM TLM requires.

Comparison of sea surface height and currents from both HYCOM and NCOM solutions after 4.5 days, showing that NCOM replicates HYCOM with minor differences.



Comparison of the difference between two perturbed HYCOM nonlinear solutions with the NCOM tangent linear model at surface and depth, and over time. These figures show that NCOM TLM approximates the HYCOM TLM very well.



ANALYSIS AND CONCLUSION: The experiment shows that not only does NCOM replicate HYCOM given the same initial and boundary conditions and forcing, but also the evolution of small initial perturbations with the NCOM TLM are similar in shape and magnitude after 84 hrs, to the difference between two HYCOM nonlinear solutions that differ initially only by the same initial perturbation given to the NCOM TLM. The differences were examined both at the ocean's surface and subsurface. Because the adjoint model is the transpose of the tangent linear model, we can conclude that since NCOM TLM approximates HYCOM TLM, NCOM adjoint will also approximate HYCOM adjoint. Therefore, NCOM-4DVAR can be used in place of a HYCOM 4DVAR, since the latter is difficult to develop.

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