HYCOM Consortium for Data-Assimilation Ocean Modeling

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Award Number: N0001400C0033
http://hycom.rsmas.miami.edu/

LONG-TERM GOALS

The goal of the project is to develop HYCOM (HYbrid Coordinate Ocean Model) with assimilation capability of sea surface height from altimetry, sea surface temperature from MCSST and in-situ data. The ultimate goal is to have an eddy-resolving assimilative global nowcast/forecast system running in real time.

OBJECTIVES

Development and validation of global and basin scale ocean prediction systems which includes assimilation of available data, e.g. satellite altimetry, MCSST and in-situ data. This is a 5-year (FY00-04) National Ocean Partnership Program (NOPP) project and is a collaborative effort between several research groups with Eric Chassignet as the overall lead project PI. The focus will be on an eddy resolving Atlantic domain (with 7 km resolution at mid latitudes) and a coarser resolution global domain.

APPROACH

The approach is to implement several different assimilation techniques starting with simple incremental updating. More sophisticated algorithms such as the parameter matrix objective analysis (PMOA, Mariano and Brown, 1992), the singular evolutive extended Kalman filter (SEEK, Pham et al., 1998), the Markov random field information filter (MRFIF, Chin et al.1999) and the ensemble Kalman filter (Evensen, 1994) will also be implemented by the HYCOM/NOPP consortium. Different vertical projections of the surface information to the deep ocean will be evaluated for the simple techniques, (e.g. Hurlburt et al. 1990, Cooper and Haines, 1996 and Gavart and De Mey, 1996). Synthetic temperature and salinity profiles from the Modular Ocean Data Assimilation System (MODAS) (Fox et al. 2001) will also be tested as an alternative vertical projection technique. The assimilation techniques will be evaluated as a function of computational efficiency and prediction accuracy. The computational requirements will be an important part of the comparison. A real time

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **HYCOM Consortium for Data-Assimilation Ocean Modeling**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Planning Systems Inc.,MSAAP, Bldg. 9121,,Stennis Space Center,,MS, 39529**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

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

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The goal of the project is to develop HYCOM (HYbrid Coordinate Ocean Model) with assimilation capability of sea surface height from altimetry, sea surface temperature from MCSST and in-situ data. The ultimate goal is to have an eddy-resolving assimilative global nowcast/forecast system running in real time.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

system will have a limited amount of computer time available and the model with the data assimilation will have to run within this time limit. The validation of the results from the assimilation experiments is an important part of the project. Data not being assimilated will be used to validate the model solution. A suite of software to do model validation has been developed and is currently being used with the 1/16° global NRL Layered Ocean Model (NLOM) which is running in real time at the Naval Oceanographic Office (NAVOCEANO).

WORK COMPLETED

The effort to determine the "best" mean sea surface height (MSSH) to be added to the satellite anomalies has continued. A MSSH that is consistent with available observations is an important part of an assimilation system. To see the effect of different means when used with satellite altimeter sea surface height anomalies (SSHA), several movies were made for the Gulf of Mexico and Gulf Stream region using the global MODAS SSHA analysis with different MSSH fields added. An example using two different MSSH from MICOM are shown in Figure 1. This figure shows the sea surface height field on 20 July 2000. Figure 1a used the MSSH from a 1/12° Atlantic MICOM experiment with COADS forcing, while Figure 1b shows the results using the MSSH from a MICOM experiment with ECMWF forcing. Having a MSSH with a sharp front (and in the correct position) is essential to get a realistic looking Gulf Stream. This is evident in the eastern part of the Gulf Stream, where the front in Figure 1a is washed out compared to the front in Figure 1b.

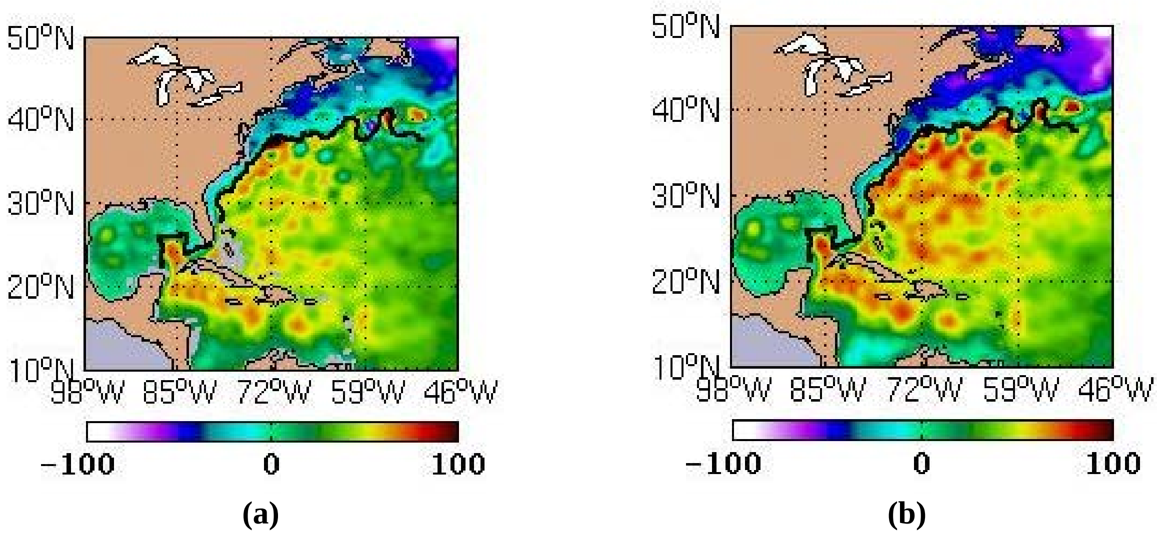
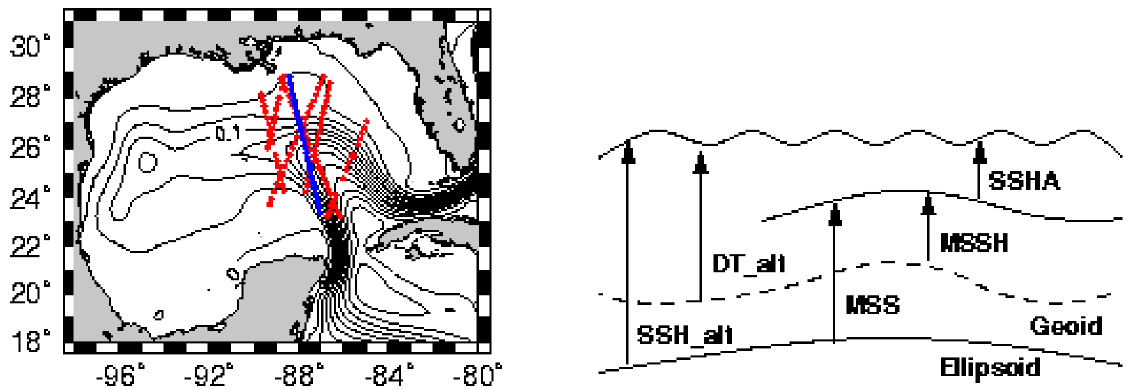


FIGURE 1 The sea surface height for 20 July, 2000 in the Gulf of Mexico and Gulf Stream region. Two different MSSH fields from the 1/12° Atlantic MICOM were added to the MODAS altimeter SSHA analysis. Figure 1a shows the results using the mean from the experiment with COADS forcing while Figure 1b shows the results using the mean from the experiment with ECMWF forcing. The NAVOCEANO frontal analysis (black line) is overlayed on the field. This is an independent analysis using MCSST satellite data to determine the frontal position of the Gulf Stream.

Several grids of MSSH are compared to try to determine the "best" mean in some quantitative sense. One such quantitative measure involves using the MSSH grids to correct SSHA from altimetry, and comparing the result to actual dynamic heights (DHT) computed from AXBT's and CTD's. In order to perform this analysis we need collinear tracks of 1) the measured sea surface height from the satellite altimeters relative to the ellipsoid (SSH_alt), 2) a mean sea-surface (MSS) from the altimeter data (relative to the ellipsoid), 3) MSSH from a model or data and 4) dynamic height (DHT) from in situ measurements, see Figure 2a. The satellite data were obtained from the GSFC Pathfinder collinear data set, Koblinsky et al. (1999). The MSS used is GSFC00.1 from Wang (2000).

The MSSH grids to be compared are several different model and data grids including: a 1/16° global NLOM mean, a 1/16° global NLOM rubber sheeted mean (see below), a 1/32° NLOM North Atlantic model mean, a 1/12° Atlantic MICOM mean with COADS forcing, a 1/12° Atlantic MICOM mean with ECMWF forcing and two means based on data, a climatological mean from MODAS and the MSSH in the Gulf Stream region from Kelly and Gille (1991) modified by the Lozier et al. (1996) climatology.

The DHT are courtesy of John Blaha (NAVOCEANO) and Mike Gilligan (PSI). These DHT were obtained from AXBT and CTD measurements during a survey along groundtracks of the TOPEX and ERS-2 satellites during April and May 1998, see Figure 2a. The data were taken within a few hours of the overflight of the satellites. The DHT computations used salinity information obtained from the CTD data. They are computed relative to the 1500 dB pressure surface, following the method of Blaha and Lunde (1992).



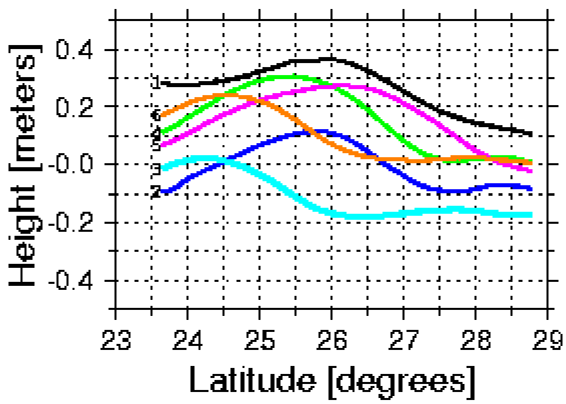
(a) **(b)**

FIGURE 2 (a) The satellite tracks overlayed on the mean sea surface height from the 1/12° Atlantic MICOM experiment using the COADS forcing, and (b) the definition of the height measurements used.

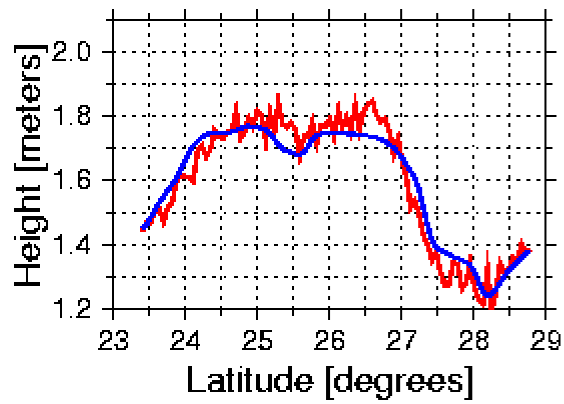
The dynamic ocean topography (DT) from in situ measurements (DT_dht) is to be compared with that obtained from altimetry (DT_alt). To obtain the dynamic topography from altimetry, the following relationship is used see Figure 2b

DT_alt = SSH_alt - MSS + MSSH

Although the MSSH reference level is arbitrary, the reference level is parallel to that of the geoid. Most of the items that lead to a difference between DT_alt and DT_dht are of long wavelength, and can be modeled as linear trends. Thus, to compare the short wavelength signals of DT_alt and DT_dht, a linear regression can be done to remove the unwanted signals. Then an assessment can be made of how well the DT_alt matches DT_dht.



(a)



(b)

FIGURE 3. (a) The variation in MSSH along the ERS-2 track marked in blue in Figure 2a. The black line is the MODAS climatology, the blue line is the 1/16° rubber sheeted (see text below) NLOM mean, the cyan line is the 1/32° Atlantic NLOM mean, the green line is the 1/12° Atlantic MICOM mean with COADS forcing, the magenta line is the 1/12° Atlantic MICOM mean with ECMF forcing, while the orange line is the 1/16° NLOM mean. (b) shows the comparison between the dynamic height calculated from the in situ observations (blue line) taken along the track and the satellite data (red line) using the "best" mean which turned out to be the 1/12° Atlantic MICOM mean with COADS forcing in this case.

We have so far done a comparison in the Gulf of Mexico. The MSSHs compared are the means described above, except for the Kelly and Gille (1991) mean that has no data in the Gulf of Mexico. When the regression analyses was performed for the MSSH grids in the Gulf of Mexico, it was found that the 1/12° Atlantic MICOM mean using COADS forcing produced the best result in 3 out of 7 cases. These results should be considered preliminary. In fact the 1/12° Atlantic MICOM mean with ECMWF forcing seems to be better in the Gulf Stream region as indicated by the results in Figure 1. The method will be extended to the Gulf Stream region and set up so that when a new mean becomes available it can easily be tested for consistency with available observations. If necessary the final mean to be used in the assimilation can be modified using the rubber sheeting technique tested last year. The rubber-sheeting application suite is a collection of MATLAB scripts specifically designed to operate on SSH fields. It includes methods to move masses of water in an elastic way (hence rubber-sheeting), merge data, overlay contours from a second reference field and raise or lower the values of a region.

Version 2.0 of HYCOM was released in July 2001. This is the version of the code that will be used to test the different assimilation techniques. Remy Baraille (LEGOS/BRESM) has implemented the Cooper and Haines (1996) technique for downward projection of sea surface height data into HYCOM and he provided the code to us in the middle of September 2001. This baseline assimilation technique will be tested in a .32° Atlantic version of HYCOM.

The development of a suite of software tools to verify both nowcast and forecast skills of a data assimilative ocean model has continued. Several applications have been developed and are currently being used in the operational data assimilative 1/16° global NLOM nowcast/forecast system running in real time at NAVOCEANO. The statistics calculated includes RMS error, anomaly correlation and a skill score for the forecast and also calculation of an error in the forecasted frontal location of the Kuroshio and the Gulf Stream. Examples of these types of statistics can be found on the public NRL web page http://www7300.nrlssc.navy.mil/global_nlom

RESULTS

The necessary components are now available to implement the baseline data assimilation capability in HYCOM. A technique has been developed to help determine the best possible mean sea surface height that can be used in the assimilation of the satellite altimeter anomalies. Several different mean sea surface heights both from models and data can be compared to available observations from both satellite altimetry and independent in situ observations taken along the satellite tracks. This information and additional observations such as the standard deviation fields from satellite altimetry and the mean position of fronts determined from MCSST data can then be combined. The rubber sheeting technique can combine this information into one coherent picture of the mean sea surface height. A suite of verification software has been developed and is currently being used in the real time NLOM system. This will be an important part of the verification of the results from the data assimilation effort with HYCOM.

IMPACT/APPLICATIONS

The results from the project is relevant to the Global Ocean Data Assimilation Experiment (GODAE), the multinational project designed to help justify a global ocean observing system by demonstrating useful real-time operational ocean products. The model developed in this project is planned for transition to NAVOCEANO as a replacement for their operational ocean model.

TRANSITIONS

None

RELATED PROJECTS

The results described here are a part of a NOPP project with participation from several different research groups, E.P. Chassignet (Coordinator), A. Mariano and G. Halliwell, T.M. Chin (University of Miami), R. Bleck (LANL), H. Hurlburt, P. Hogan, R. Rhodes, C. Barron, A. Wallcraft and G. Jacobs (Naval Research Laboratory), O.M. Smedstad and B. Lunde (Planning Systems Inc.), W.C. Thacker (NOAA/AOML), M. O'Keefe (University of Minnesota).

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