Towards high-resolution operational ocean forecasting

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A system for producing high-resolution real-time analyses and three-to-ten-day forecasts of the ocean's temperature, salinity and current structure is being developed. It assimilates in-situ profile data, surface temperature and surface height data and is driven by surface fluxes from the UK Met Office's numerical weather prediction system. Model configurations with 10-km and 30-km horizontal grid spacing are nested within larger-area, lower-resolution configurations. Three-year trial integrations of the system have been performed. We will study the statistics of the differences between the observations and the model and make appropriate improvements to the assimilation methods.

Introduction

Numerical models of the dynamical evolution of the temperature, salinity and current structures of the ocean covering entire ocean basins can now be run with 40 or more vertical levels and gridpoints separated by 10 kilometres or less in the horizontal [Smith et al. 2000]. Such models are able to represent the evolution of the meanders of the Gulf Stream and Kuroshio fronts and the other energetic "mesoscale" motions in the ocean whose natural horizontal length-scales are of the order of 50 to 150 kilometres.

Major improvements have been made in the 1990s and will be made in the next five years to measurements, available within a day or two of real time, of the ocean and its interaction with the atmosphere. Only within the last five years have adequate orbital corrections to the mean surface height data from altimeters been available within two days of measurement. The in-situ network of measurements of temperature and salinity as a function of depth will be significantly improved in the next five years by the ARGO project [Roemmich et al. 1999], which will deploy and then maintain 3,000 autonomous profiling floats across the global ocean. Each float will transmit in real time, once every 10 to 15 days, a profile of temperature and salinity to 2,000-meter depth. Wide swath surface wind stresses from advanced scatterometer instruments [Milliff et al. 1999] and high-resolution surface temperature data from both geostationary and polar-orbiting satellites will also be available. Satellite information on other surface flux and sea-ice fields is also becoming more accurate and extensive [EUMETSAT 2000].

Objectives

Our main objectives are to combine these models and measurements to produce high-resolution real-time analyses and three-to-ten-day forecasts of ocean temperature, salinity and current fields, and to build a community of users who find our products useful. These are the main objectives of the Global Ocean Data Assimilation Experiment [GODAE, 2000] in which we will participate. Examples of products which could be of value include: surface currents for search and rescue, near-bottom currents for oil drilling, the locations and strength of upwelling in fronts for fisheries, and sound speed structure for naval operations. Our models also provide boundary data for models forecasting the waters of the continental shelves. Coupled models of the atmosphere and ocean for seasonal forecasting also benefit from using ocean measurements to set their initial conditions, but usually have coarser horizontal resolution.

Approach

The system we are developing for making analyses and forecasts is built around an ocean and sea-ice model which is also developed for climate simulation [Gordon et al. 2000]. We usually drive it using six-hourly average surface fluxes of momentum, heat and moisture from the Met Office's numerical weather prediction (NWP) system. Thermal profile and surface temperature measurements are assimilated into the model as described in Bell et al. [2000]. Sea-ice concentration data from the Canadian Met Center are also assimilated into the sea-ice model. A global configuration of this system with a one-degree grid spacing has produced five-day forecasts daily since 1997.

Our recent work has focused on three configurations of the model: the global model with a one-degree grid spacing; a model covering the Atlantic and Arctic with a 30-kilometer grid; and one covering the Gulf of Mexico and Caribbean with a 10-kilometer grid. The areas covered by the higher-resolution models will be increased in future. The higher-resolution models are nested in the lower-resolution ones using the Flow Relaxation Scheme [Davies 1976]. Altimeter data are assimilated (Hines 2001) using along-track data and a method based on Cooper & Haines [1994]. A set of three year integrations (1997-1999) of these models has been performed and is being assessed. Some integrations assimilated all available data, and others only subsets of the measurements. Figure 1 illustrates

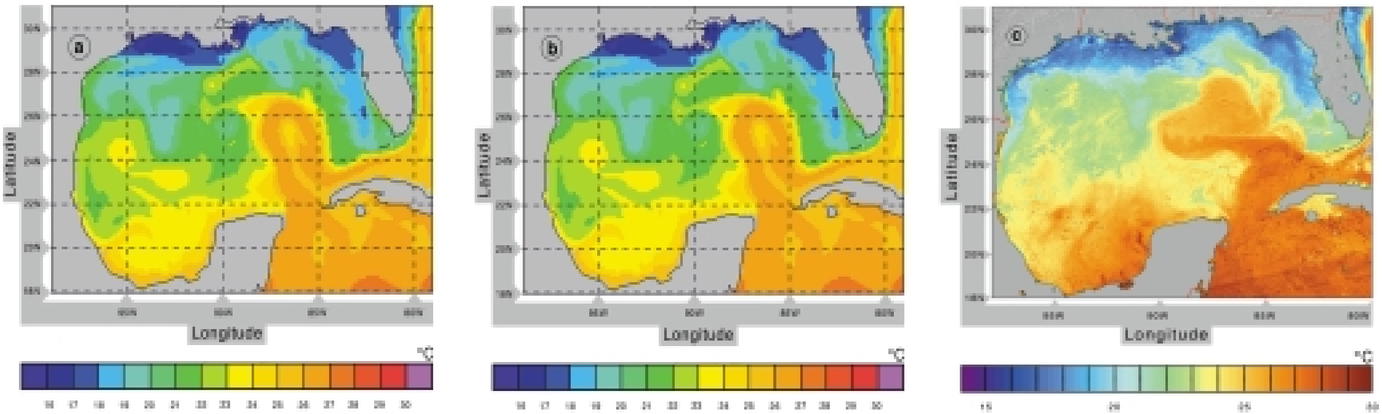

Figure 1: Surface temperature (°C) for March 14-19, 1998 in the Gulf of Mexico (a) in 1/9° model assimilating in-situ temperature profiles and coarse resolution surface temperature data (b) as in (a) except that altimeter data were also assimilated (c) corresponding seven-day composite from AVHRR data processed by John Hopkins University APL (http://fermi.jhuapl.edu/avhrr/gm/averages/index.html).

the improvement to the surface temperature field of the model with 10-kilometer resolution in the Gulf of Mexico resulting from assimilation of altimeter data.

Anticipated results

We will assess our analyses and forecasts using measurements before they influence the system. We will also use independent sources of information, such as surface drifter data (which are not assimilated), to assess the results. To improve the information extracted from the measurements we will calculate statistics on the variances and correlations of differences between the measurements and the analyses, compare them with the statistics used in the data assimilation schemes and amend the statistics and methods used to assimilate the measurements into the model fields appropriately. We will also seek to gain access to better data sources. In particular, the surface temperature data we presently assimilate has very coarse (2.5°) horizontal resolution. Global satellite data at 50-kilometer resolution and data for the Atlantic at five-kilometer resolution will be investigated.

Near the Equator, most ocean model systems presently have significant temperature biases. Assimilation of thermal profile data significantly reduces the biases but drives unrealistic vertical overturning circulations. Bell et al. [2001] presents a technique for analyzing the model system's bias and reducing the unrealistic circulations. The use of this technique with altimeter data will be explored both along the equator and in the western boundary currents of the coarser-resolution models (where there are also major biases).

Significance

Demonstrations of the practical value of altimeter data are vital to facilitate the transfer of the funding of satellite altimeters from research organisations like NASA and CNES to operational agencies such as EUMETSAT and NOAA. Our work is a contribution to this effort and to GODAE.

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