IMPROVING THE PREDICTION OF AN OCEAN MODEL USING NOVEL REMOTE SENSING DATA

Charles Galdies

International Ocean Institute, University of Malta, Msida, Malta

Abstract

Novel satellite SST is assimilated into a high-resolution primitive-equation ocean model to improve the simulation of surface ocean processes linked to the air-sea interactions at sub-mesoscale level. A high-resolution ocean model over the Ionian basin is used to provide short-range forecasts of the ocean state. The model is initialised using high-resolution air-sea fluxes generated by a high-resolution atmospheric model. An assimilation scheme using SST derived from the Tropical Microwave Imager is optimised to improve the ocean forecasting skill. Validation is performed over a 15-day model integration window.

Keywords : Tropical Microwave Imager, Newtonian nudging, Sea surface temperature, Princeton Ocean Model

Introduction

Free surface, sigma coordinate ocean models are being used for a variety of applications, ranging from small-scale process studies and coastal and estuarine modelling and prediction to basin-scale ocean circulation and climate change modelling. It is important to evaluate the sensitivity of the model and enhance its predictive capability as to help users choose the best parameters for their particular applications. This study uses independent information collected from satellite platforms to improve and spatially verify the forecasting accuracy of small-scale predicted oceanic fields.

Method

The ocean model is the Princeton Ocean Model (POM) with a domain starting from 15.8°E and 33.24°N with 82 grid points in the east-west direction, and 61 grid points in the north-south direction. The grid spacing in degrees is 0.042° with 24 sigma levels. The model bathymetry used is the US Navy Digital Bathymetric Base. The lateral boundary conditions were from MODB MED4. Sets of daily, 3-hourly surface fields were generated from a high-resolution atmospheric model working over the same domain and horizontal resolution and used to force the ocean model at the surface. SST was derived from the Tropical Microwave Imager at a nominal resolution of 0.25° and re-interpolated over the model's domain grid.

A hind-cast forecasting sequence was started with zero velocity on 1st July 1999 and continued in forecasting mode for an additional 20 days. No forcing of the surface boundary conditions was performed. The 3-D oceanic fields were dynamically adjusted to a constant SST field derived by the TMI on the 22nd of July 1999 at approximately 00UT. The actual model forecasts started on July 22nd at 1200 hrs with daily atmospheric forcing and consecutively every integration day until the 5th of August. The model was initialised using remotely-sensed SST. This information was propagated down to the vertical model prognostic fields. Two data assimilation (DA) experiments were performed to assess the effectiveness on the accuracy of the forecasted SST:

1. varying the nudging period during which the model fields are dynamically nudged towards the SST observations. Three scales were tested: 06, 12 and 24 hours.
2. including a second forcing, nudging coefficient, to nudge the model fields towards the SST observations. Four coefficients were tested $5x10^{-3}$, $5x10^{-4}$, $5x10^{-5}$ and $5x10^{-6}$ for each of three nudging periods.

Results and discussion

The first data assimilation scheme leads to the most accurate predictions of the SST. The best nudging period is 24 hours, giving a mean bias over the entire 15-day model integration of only –0.05°C against remotely sensed data. It is interesting to note that Horton *et. al.,* applied a similar DA scheme for their ocean forecasting system that assimilated AVHRR MCSST [1]. The new SST values were assimilated by the model using a nudging period of only 4 hrs.

The inclusion of an additional coefficient in the equation leads to strong nudging towards the initial observations. The optimal nudging coefficient is found to be $5x10^{-4}$ for 06 hours, giving a mean bias of –0.08°C.

Despite the small period of evaluation, some general remarks can be made. What is evident from this study is that an active data assimilation scheme tends to dampen the fluctuating bias tendency. The temporal fluctuation in the bias trend is caused by the model's attempt to equilibrate the model dynamics towards the prognostic SST values. However, its resilience or degree of damping is seen to be dependent on the two factors that regulate the extent of this fluctuation: the relaxation time $\frac{\partial q^{model}}{\partial t}$ and nudging coefficient K^q.

This treatment leads the model to show a better performance than other ocean forecasting systems used in the region. Nittis *et. al.,* for example, obtained a bias of 0.1 to 0.8°C when their 24-hour POM-forecasted SST was compared to collocated *in situ* buoy measurements [2].

High-resolution sea surface thermal signature observed by AVHRR confirmed the ability of the improved ocean model to predict sub-basin surface circulation. The small-scale SST pattern is shown to be set by a balance of atmospheric (provided by the high resolution, atmospheric model) and oceanic processes (provided by the high resolution POM), including wind-driven mixing, atmospheric heating and cooling, and horizontal and vertical advection in the ocean. Predicted ocean fronts are found to be collocated with atmospheric convergences as predicted by the atmospheric momentum stress over the geographical area. The AVHRR sensor reveals filaments and jets near these fronts.

The use of one-way atmosphere-ocean coupling offers distinct advantages over current basin-wide forecasting systems. Recent studies in the Mediterranean utilise bulk formulae to compute the surface boundary conditions of the ocean models [3]. Atmospheric variables, such as wind field, air temperature and relative humidity are derived from coarse, monthly averages of 12-hour NCEP analyses for the period 1980-1988.

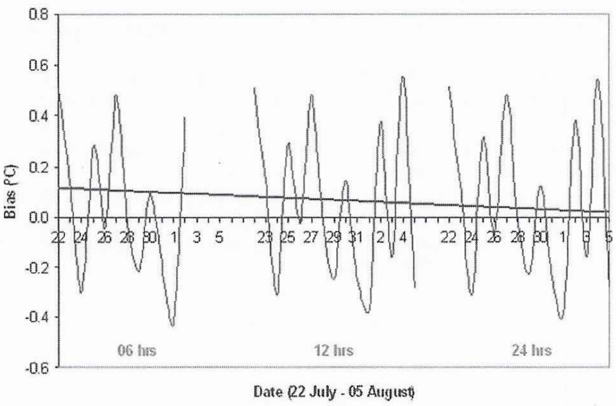

Fig. 1. Bias trends of 24-hr predicted SST using a varying nudging period (lower text in graph).

References

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