Improving Surface Forcing of the Marginal Seas

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LONG-TERM GOAL

The PI's long-term goal is to understand the physical processes of the air-sea interaction and coupling of the ocean and the atmosphere on the regional scale and to predict the variability of the coupled ocean-atmosphere system.

OBJECTIVES

The main objectives of this study are (1) to better understand the diurnal and synoptic variability of the surface forcing in the Arabian Gulf-Strait of Hormuz region and (2) to examine the influence of complex coastal terrain and the atmospheric aerosols on the surface winds, radiative and air-sea fluxes in the Arabian Marginal Seas and Gulfs (AMSG).

APPROACH

The complex coastline and coastal topography in AMSG contribute to a large uncertainty in the global analysis of the surface forcing fields, which are not resolved by relatively low-resolution global models. As a result, these model analysis fields cannot capture the strong diurnal cycle in surface wind and temperature fields. Another challenging problem is the abundant aerosol in the region and its impact on the radiative fluxes is largely unknown. To explore these science issues, we use the Penn State University/National Center for Atmospheric Research atmospheric nonhydrostatic mesoscale model (MM5) to characterize the small scale and mesoscale structures of atmospheric forcing in AMSG. Our general approach is to use multi-nested grids model to cover a large area in the outer domain and still resolve the fine mesoscale features in the inner domains. We use a triple-nest with 45, 15, and 5 km grid spacing for the outer and two inner domains, respectively. The outer domain covers the entire AMSG (including the Red Sea) and the northern Indian Ocean. The 5-km grid inner-most domain is centered over the Arabian Gulf. The ECMWF global analysis fields and the NCEP global SST analysis are used to initialize MM5 and provide continuous lateral boundary conditions. The outer domain is run in a four-dimensional data assimilation (FDDA) mode to provide the best possible boundary conditions for the inner domains. The two inner nested domains are run in a forecast mode with no FDDA. To further explore the potential impact of aerosols on the radiative fluxes, we will use the NOGAPS and Navy Aerosol Analysis and Prediction System output fields as initial and lateral boundary conditions for the regional models (MM5 and Navy COAMPS) in AMSG.

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WORK COMPLETED

We have completed a two-week long MM5 simulation of June 2000 to examine the diurnal variability in model simulated surface forcing fields. The model simulation has been validated with both the satellite and in situ observations including the METEOSAT-7 cloud top temperature and water vapor images, the NASA QuikSCAT surface winds, and the surface measurements from the stations near the coastal regions. We have also conducted number of sensitivity simulations using various atmospheric boundary layer schemes to examine the validity of the currently physical parameterizations in the atmospheric models.

In addition to model simulations and data analyses, we have developed a real-time meteorological data archive and display system online at RSMAS/UM for the AMSG region (http://orca.rsmas.miami.edu/amsg) . This web site has been used by the PIs to aid the ONR supported field program in AMSG (two recent cruises in February and August-September 2001).

RESULTS

The initial MM5 simulations captured the observed diurnal cycle in surface winds in the Arabian Gulf region. To evaluate the model simulated surface wind, we first compared the MM5 surface wind with the in situ measurement from a number of coastal surface stations. Fig. 1 shows the complex coastal topography and locations of the surface stations we used for the model evaluations. Fig. 2 shows observed surface winds from a coastal surface station OIKB indicated in Fig. 1. These histograms of the wind direction and speed demonstrated clearly that there are very strong diurnal variations at OIKB (and all other coastal stations we examined) during both summer (July) and winter (January) seasons. During the day, the on-shore winds (sea breeze) from north/northwest are about 5-10 m s^{-1}. During the night the off-shore winds (land breeze) are weaker than the daytime, which decrease to less than 3 m s^{-1}. The model captures the diurnal cycle of the surface winds quite well as shown in Fig. 3. The daytime sea breeze is very prominent around the entire coastal region of the Arabian Gulf (lower panel of Fig. 3). The nighttime winds are mostly in the off-shore direction (upper panel in Fig. 3). There is a strong, north-northwesterly, large-scale nocturnal jet over the Arabian Gulf. It seems to be forced by the high mountains, similar to the nocturnal jet observed in the Great Plains in the United States. This model simulated nocturnal jet is confirmed by the QuikSCAT surface wind data in AMSG (Olson el al., 2001). We are in the process of examing model simulated surface heat and momentum fluxes. A number of sensitivity experiments are conducted to test various boundary layer and surface flux parameterizations in the model.

IMPACT/APPLICATIONS

This project has provided the first high spatial and temporal resolution surface forcing (heat and momentum fluxes) associate with the diurnal variability in AMSG. The model simulated

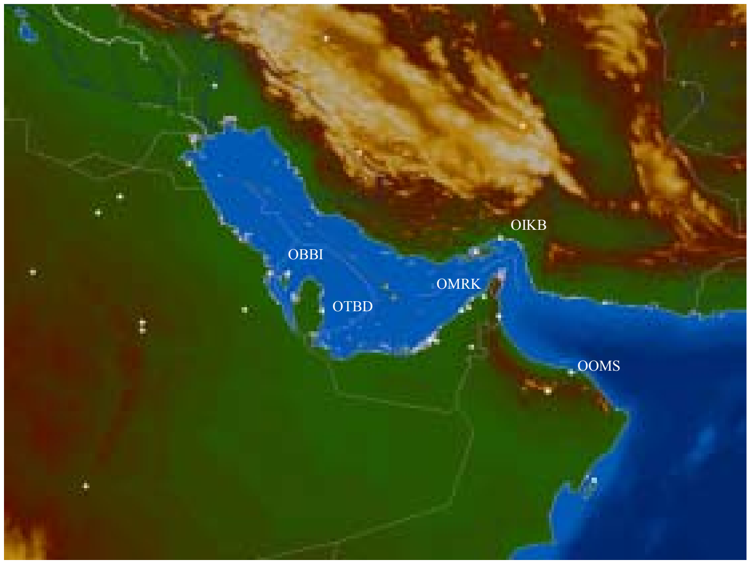

Figure 1. Topography of the Arabian Gulf region.

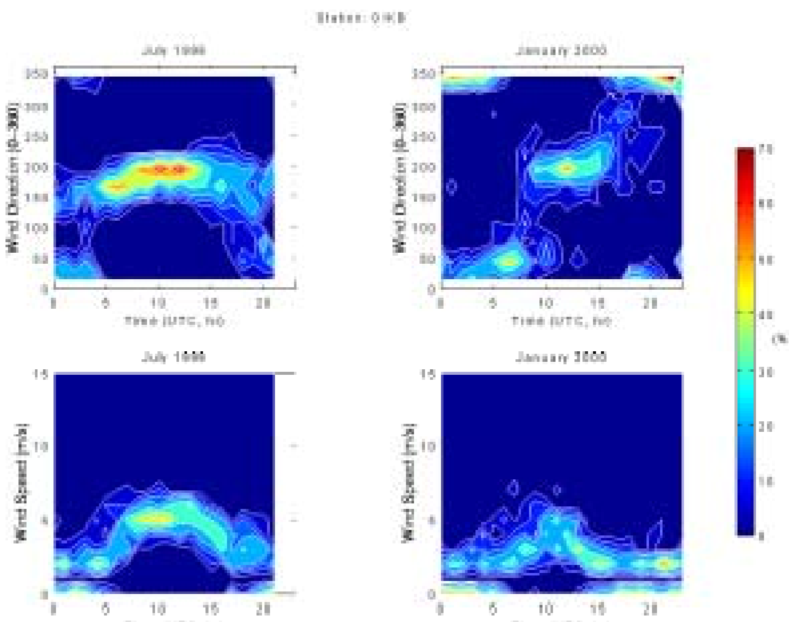

Figure 2. Frequency occurrence of the diurnal surface wind direction and speed observed at the station OMRK (marked in Fig. 1) for July 1999 and January 2000.

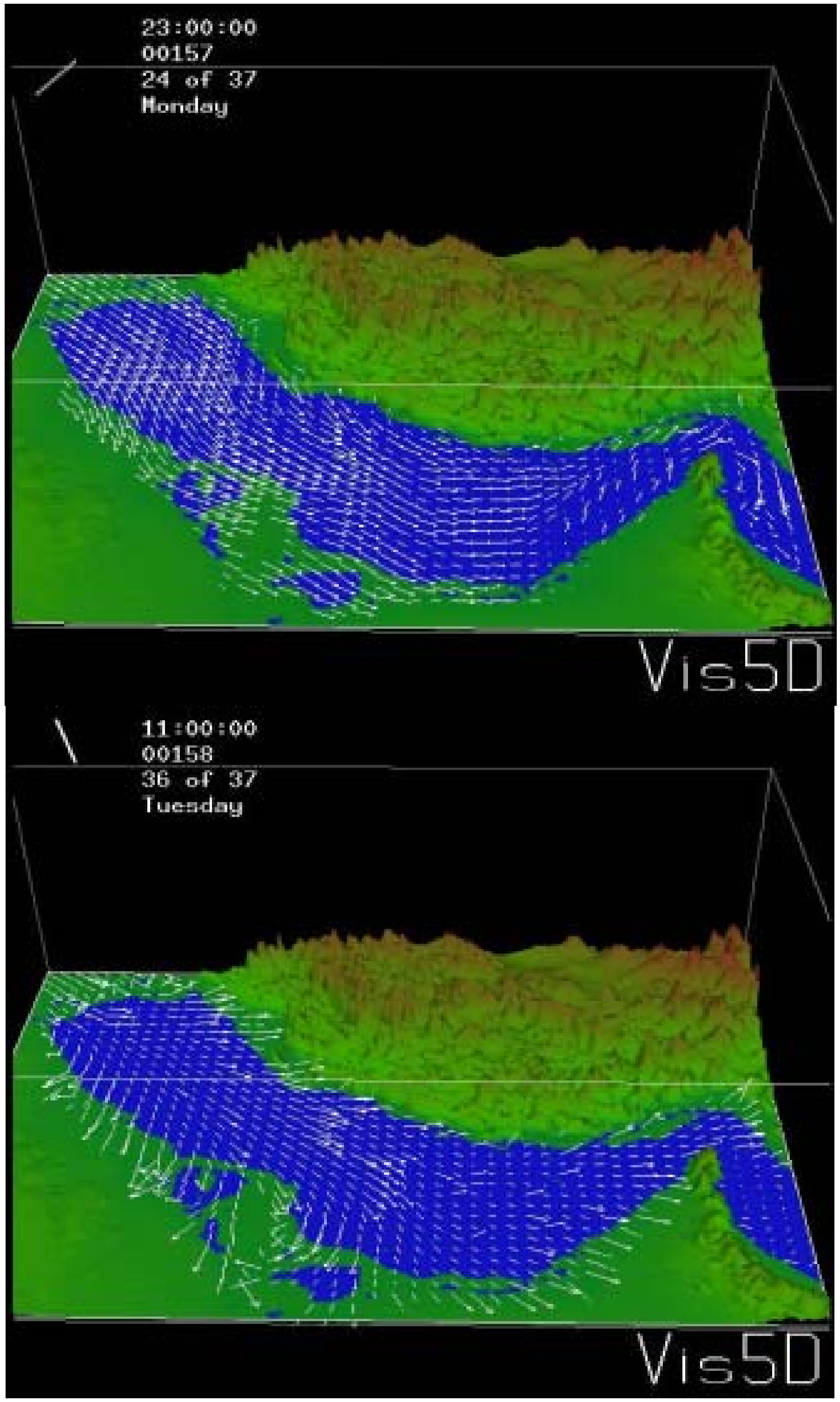

Figure 3. Model simulated surface wind during the nighttime (upper panel) and during the daytime (lower panel) for the Arabian Gulf region.

surface forcing fields will be used compare with the observations from in situ measurements from various cruises in AMSG and to drive the ocean circulation and surface wave models.

Recent ocean circulation and wave model simulations using MM5 surface forcing have show a great sensitivity in ocean response to the high-resolution atmospheric forcing which is very different from that climatological mean forcing and the ECMWF global (Mooers et al., 2001, Zhao et al., 2001).

TRANSITIONS

The full three-dimensional, high-resolution atmospheric forcing fields (including all surface fluxes) will be made available to all ONR PIs for their data analysis in AMSG and to the ocean modeling groups at NRL and UM as well other ONR supported modeling efforts. The results on the sensitivity to different boundary layer and surface flux parameterizations will be tested in COAMPS during the second year (2002) as we conduct similar simulations using COAPMS in AMSG.

RELATED PROJECTS

Related projects include the ONR DRI of the Japan/East Sea, the NASA/JPL QuikSCAT.

PUBLICATIONS (2001)

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