Effects of Coastal Topography and Atmospheric Aerosol on the Surface Forcing of Marginal Seas

Dr. Shuyi S. Chen
Division of Meteorology and Physical Oceanography
Rosenstiel School of Marine and Atmospheric Science, University of Miami
4600 Rickenbacker Causeway Miami, FL 33149-1098, USA
Phone: (305) 361-4048, FAX: (305) 361-4696, E-mail: schen@rsmas.miami.edu

Grant Number: N00014-03-1-0680
http://orca.rsmas.miami.edu/amsg

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 variability of the surface forcing from diurnal-to-seasonal time scales in the Red Sea, the Gulf of Aden, and the Arabian Gulf-Strait of Hormuz regions 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 3 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 NCEP global analysis fields 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. The initial model simulations indicate that the NECP SST analysis field is generally too cold and lack of spatial structure near the coastal regions. It is inadequate to use as model lower boundary conditions in this kind of study. So we first have to generate a merged satellite SST data for the region using the AVHRR and TRMM/TMI measurements, similar to that of Chen et al. (2001). To

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2003		**00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE	
Effects of Coastal Topography and Atmospheric Aerosol on the Surface Forcing of Marginal Seas	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) **Division of Meteorology and Physical Oceanography,,Rosenstiel School of Marine and Atmospheric Science,,University of Miami,4600 Rickenbacker Causeway,,Miami,,FL, 33149**	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 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.

15. SUBJECT TERMS

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

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

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.

WORK COMPLETED

During the past year (FY2002-2003), we have developed modeling capability of including the dust and other atmospheric aerosols and investigating their impact on the radiative heat fluxes in the AMSG regions. We have also completed two new month-long MM5 simulations with the new modeling capability for February and August 2001, respectively, during which the ONR/NSF-supported REDSOX1 and REDSOX2 research cruises have been in AMSG taking observations. The model simulation has been evaluated/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. The model reproduces the strong diurnal cycle of the surface wind and temperature fields very well. We have generated a merged satellite SST data for the region using the AVHRR and TRMM/TMI measurements, similar to that of Chen et al. (2001). The satellite-based SST fields are proved to be crucial in reproducing the observed seasonal changes in surface heat fluxes. In addition to model simulations and data analyses, we have developed a real-time meteorological data archive and display system online at RSMAS/University of Miami 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 (REDSOX1 and REDSOX2 in February and August 2001).

RESULTS

One of the uncertainties in estimating the total heat flux of the marginal seas, especially in the AMSG region is the contribution of the dust to the shortwave radiative flux. Fig. 1 shows an example of the observed dust in the region.

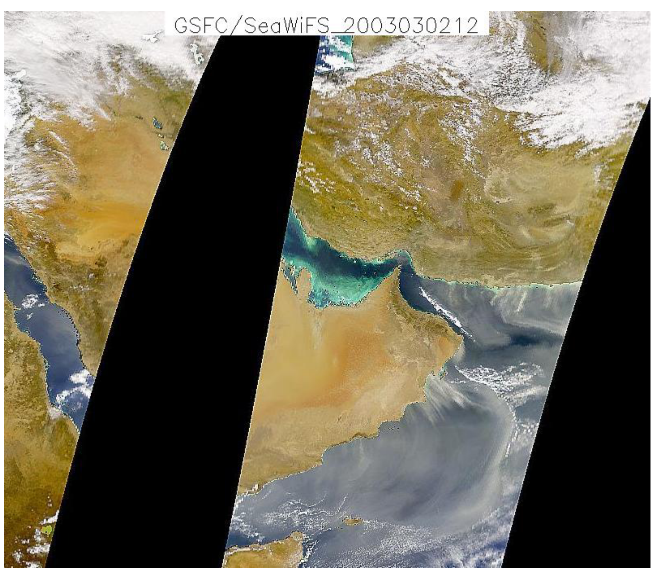

Fig. 1 Satellite observed dust event on 2 March 2003 in AMSG region.

The dust and atmospheric aerosol transported over the marginal seas in the region can affect the radiative flux significantly. First we use the high-resolution model to capture the characteristics of the transport in the topographically complex region. Fig. 2 shows the model simulated wind and dust fields.

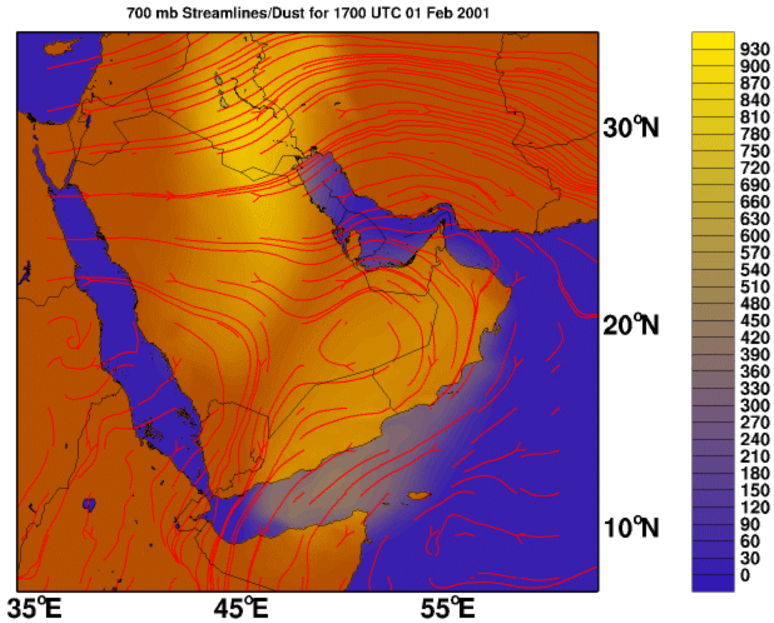

Fig. 2 Model simulated streamlines (red) and dust (mixing ratio, blue-yellow) transport in the AMSG region.

We also compare the model results with the available ship observations from the REDSOX2 along the ship track (Fig. 3). The surface meteorological conditions are well simulated by the model.

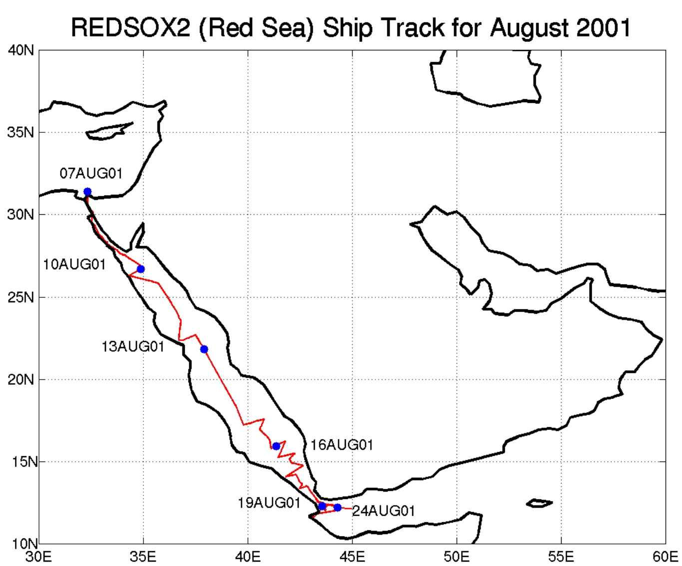

Fig. 3 REDSOX2 ship track.

Fig. 4 shows an example of the MM5 simulated surface shortwave and longwave radiative fluxes compared with the shipborne radiometer observations during the REDSOX2. The model seems to overestimate shortwave flux due to the lack of the influence from the dust and atmospheric aerosol while the research cruise was in the Gulf of Aden in late August 2001.

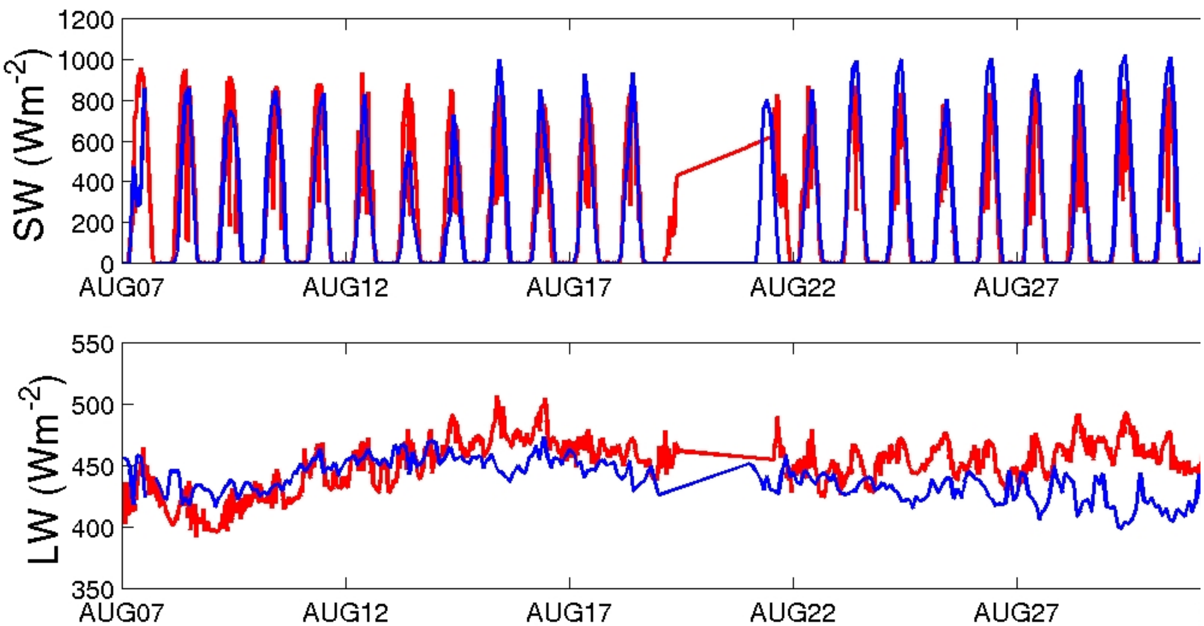

Fig. 4 Comparison of MM5 simulated (blue) and observed (red) surface shortwave and longwave radiative fluxes from the REDSOX2 research cruise during August 2001.

The monthly mean net surface heat fluxes from the MM5 simulation are compared with the NCEP, ECMWF, and the SOC analyses for August 2001 (Fig. 5). During the summer month (August), two local maxima of ocean heat loss are in the central-southern Red Sea and in the Gulf of Aden, respectively, where orographically induced strong local wind maxima are located. Over the open ocean region of the Arabian Sea the net surface heat flux changes from a moderate heat loss in February to a relatively strong heat gain in August. MM5 produced net surface heat fluxes are very similar to the observations of Weller et al. (1998) from the IMET buoy deployed in the Arabian Sea (61.5E, 15.5N) during October 1994-October 1995. In contrast, the net surface heat flux from the NCEP, ECMWF, and SOC analyses has no coastal features, partly because of the lack of spatial resolution to resolve the coastal mountains. The maximum heat flux in the Gulf of Aden during the summer, well simulated by MM5, is related to the warm SST and an extremely strong nocturnal wind jet channeled through a valley in the high mountains in the northern Ethiopia. This feature is also absent in the global analysis.

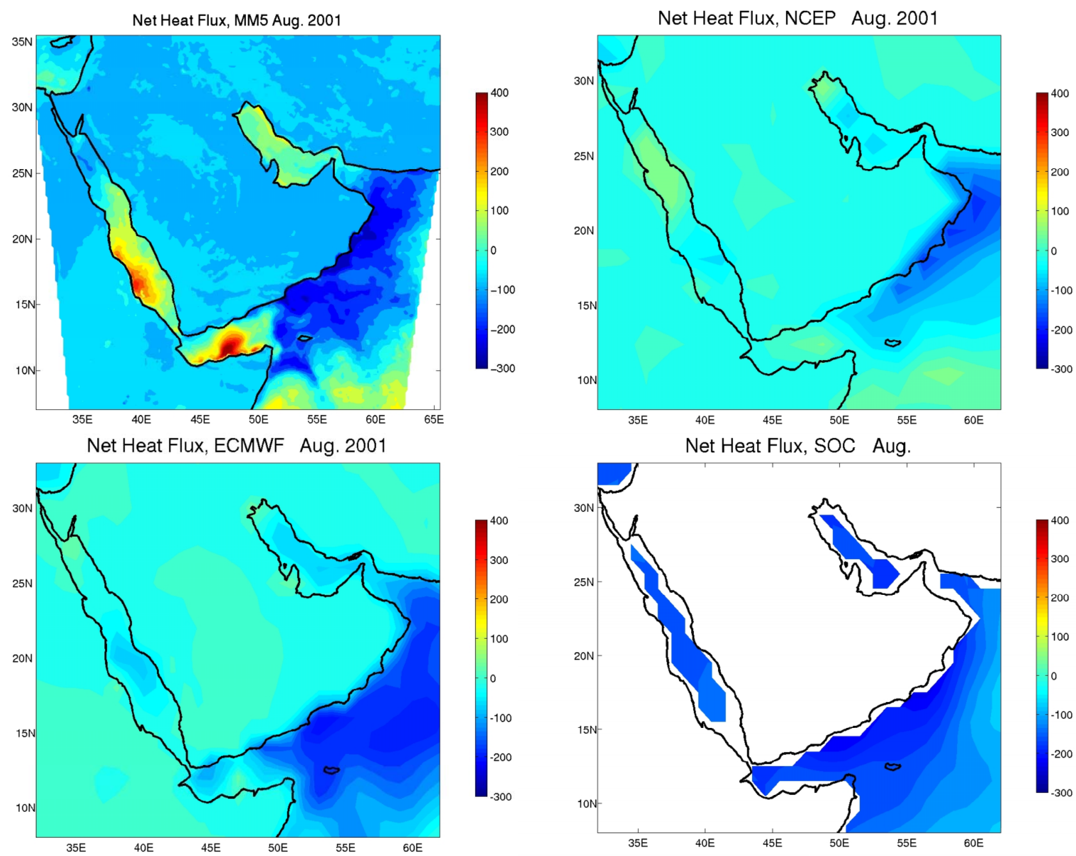

Fig. 3 Net surface heat fluxes (color scale in W m^{-2}) from the MM5 simulation and the NCEP, ECMWF, and SOC analyses for August 2001, respectively. The positive (negative) value indicates the net ocean heat loss (gain).

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 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 in JES 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 of REDSOX1 and REDSOX2 in AMSG and to the ocean modeling groups at NRL Stennis 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 as we conduct similar simulations using COAPMS in AMSG.

RELATED PROJECTS

Related projects include the ONR DRI of the Japan/East Sea (S. Chen), the NASA/JPL QuikSCAT (S. Chen), ONR Arabian Marginal Seas and Gulfs (W. Johns, D. Olson).

PUBLICATIONS (2001-2003)

Chen, S. S., W. Zhao, J. E. Tenerelli, R. H. Evans, and V. Halliwell, 2001: Impact of the AVHRR sea surface temperature on atmospheric forcing in the Japan/East Sea, *Geophys. Res. Lett.*, **28**, 4539-4542.

Chen, S. S., and W. Zhao, 2003: A high-resolution model simulation of winter storms in the Japan/East Sea. *J. Geophys. Res.*, in review.

Mooers, C. N. K., H. Kang, S. S. Chen, 2001: Several aspects of the simulated response of the Japan/East Sea to synoptic atmospheric forcing due to Siberian cold air outbreaks, *La Mer,* **38**, 233-243.

Olson, D., S. S. Chen, and W. Johns, 2001: Sea-land breezes in the Indian Ocean from scatterometer data, preprint, AGU 2001 fall meeting, San Francisco.

Zhao, W., S. S. Chen, and C. A. Blain, 2003: Effects of winds, tides, and storm surges on ocean surface waves in the Japan/East Sea, *J. Geophys. Res.,* submitted.