Atmospheric Modeling Support For CREAMS II: Simulations of Mesoscale Atmospheric Circulation and Forcing in the Japan/East Sea

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

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http://orca.rsmas.miami.edu/jes

LONG-TERM GOAL

The PI's long-range 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 influence of the wintertime Siberian cold-air outbreaks and their interaction with the complex coastal terrain on the surface forcing in the JES region and (2) to investigate the effects of the surface winds and air-sea fluxes on the ocean circulations and surface waves in JES.

APPROACH

We use the Penn State University/National Center for Atmospheric Research atmospheric nonhydrostatic mesoscale model (MM5) to characterize the mesoscale structures of atmospheric synoptic forcing, especially for the wintertime Siberian cold-air near Vladivostok and in the vicinity of the subpolar SST front in JES, where oceanic deep convection occurs. 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 a large portion of the Asian Continent and the northwest Pacific Ocean. The 15-km grid inner domain covers the JES region. The 5-km grid inner-most domain is centered near Vladivostok where the strong, persistent valley winds were observed. The ECMWF global analysis fields are used to initialize MM5 and provide continuous lateral boundary conditions. To investigate the impact of the SST front on the winter storms we use both the high-resolution (~9 km) AVHRR Pathfinder SST and the NCEP global SST analysis (2.5) as model lower boundary conditions to examine the sensitivity to SST patterns. 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 explore the impact of the high-resolution model simulated surface forcing on surface waves and coastal storm surges, we use WAVEWATCH III model with the MM5 surface wind as the

forcing field. The wave model grid spacing is 1/12 degree (~7 km). In addition, we have collaborated with Dr. Cheryl Ann Blain at the NRL/Stennis using the NRL version of the ADCIRC-2DDI hydrodynamic model to simulate tides and storm surges in JES. In collaboration with Dr. Mooers' ocean modeling group at RSMAS/University of Miami, we use the MM5 surface wind and fluxes to test the impact of the high spatial and temporal resolution forcing on the ocean circulation using POM.

WORK COMPLETED

We have completed two month-long MM5 simulations for January 1997 and January 2000. The model simulation has been validated with both the satellite and in situ observations including the Japanese Geosynchronous Meteorological Satellite (GMS-5) infrared cloud top temperature and water vapor images, the NASA Scatterometer (NSCAT) surface winds, and the surface measurements from the stations near the coastal regions and the JMA buoy at (39^{o}N, 138^{o}E). We have conduct two sensitivity runs to investigate the impact of the subpolar SST front on winter storms in JAS. The results are summarized Chen et al. (2001) and Chen and Zhao (2001).

We conducted a month-long simulation of ocean surface waves, tides, and storm surges using WAVEWATCH III and NRL/Stennis hydrodynamic model with the grid spacing of 1/12 degree (~7 km). The model results have been validated with observations taken at the JMA moored buoy in JES. A manuscript (Zhao, et al., 2001) has been submitted to JGR.

In addition to model simulations and data analyses, we have developed and maintained a real-time meteorological data archive and display system online at RSMAS/UM for the JES region (http://orca.rsmas.miami.edu/jes). This website has been used by many ONR JES PIs. We have used this interactive display system to provide field program summaries on meteorological conditions for both summer 1999 and winter 2000 JES field programs. The PI and two research associates at RSMAS/UM also provided real-time weather forecasts for both the R/V *Revelle* and the CIRPAS Twin Otter missions during January-February 2000. We have provided meteorological data to ONR PI's to aid their oceanic data analysis.

RESULTS

The main results have been summarized in several manuscripts (Chen et al., 2001, GRL, Chen and Zhao, 2001, JGR, Zhao et al., 2001, JGR, and Mooers et al., 2001). We present a few highlights in this report. Chen et al. (2001) shows that the subpolar SST front observed by the high-resolution AVHRR Pathfinder SST (PFSST) has a significant impact on the atmospheric circulation in JES. We use two different SST products to examine the sensitivity to SST forcing. The atmospheric properties near the ocean surface including mean sea-level pressure, surface winds, and turbulent heat fluxes show a significant difference using PFSST and NCEPSST as lower boundary conditions in the atmospheric model (Figs. 2 and 3). The high spatial resolution PFSST improves model simulation of winter storms in JES, especially those developed in JES, and has a significant impact on the atmospheric forcing on the monthly time scale.

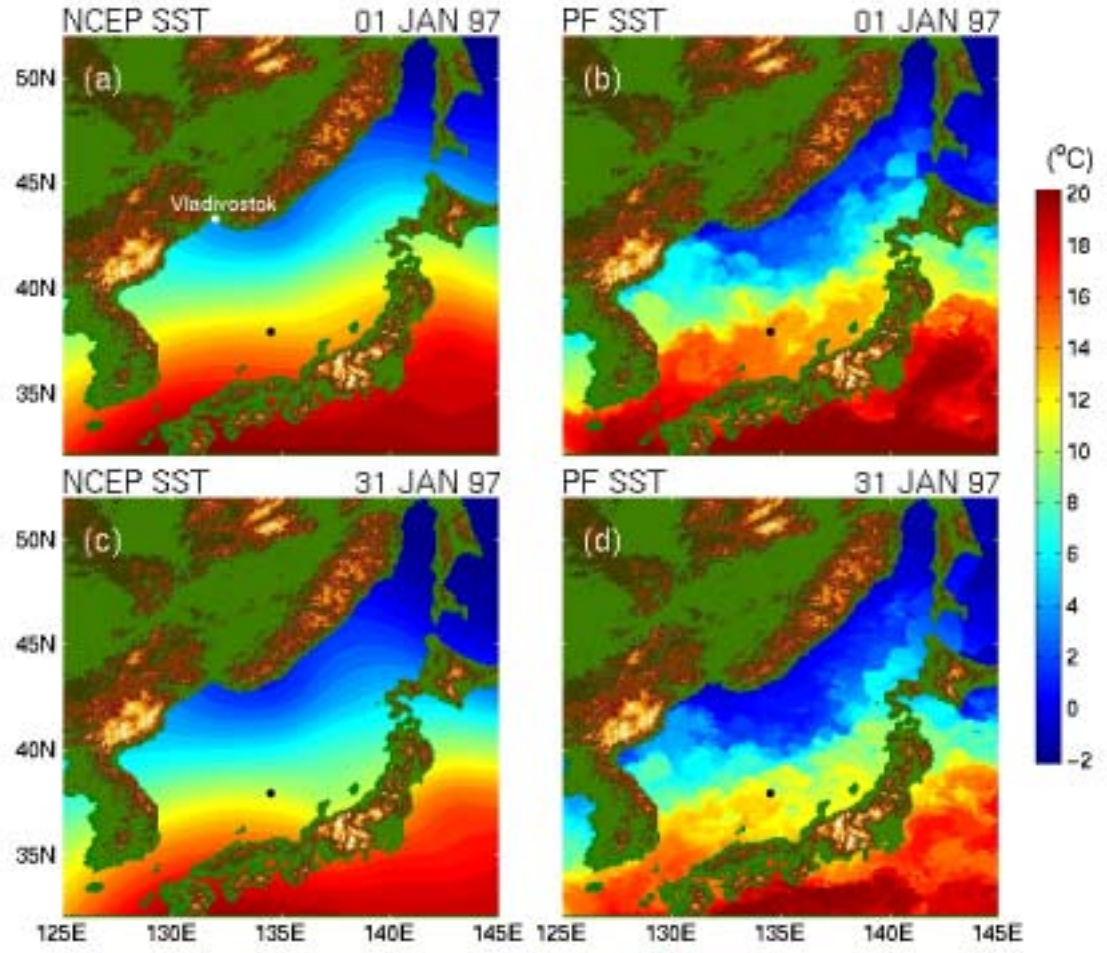

Figure 1. The NCEP global SST analysis (NCEPSST) and AVHRR Pathfinder SST (PFSST) for 1 January 1997 (a and b) and 31 January 1997 (c and d), respectively. The PFSST images are 10-day composites centered on the dates indicated. The black dot indicates the location of the JMA moored buoy (21002) in JES.

Ocean surface waves are strongly forced by high wind conditions associated with winter storms the Japan/East Sea (JES). They are also modulated by tides and storm surges, especially near the coasts. Zhao et al. (2001) investigate the effects of the variability in surface wind forcing, tides, and storm surges on the waves using a wave model, a high-resolution atmospheric mesoscale model, and a hydrodynamic ocean circulation model with MM5 surface forcing. Comparing with observed mean wave parameters (i.e., significant wave heights and wave periods), our results indicate that the variation in the wave fields is mainly caused by the variability of wind forcing. Tides and storm surges seem to have a significant impact on the waves near shores when mean water depth decreases sharply from a few hundreds of meters to less than 10 m along the west coast of Japan.

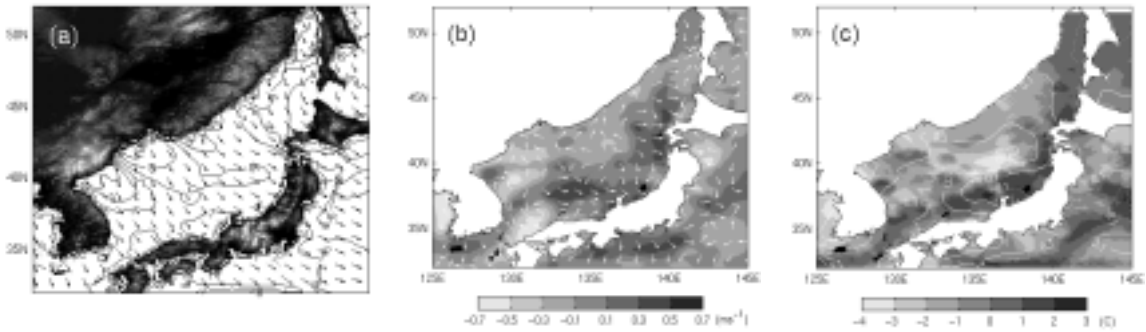

Figure 2. (a) Model simulated monthly mean surface wind speed (contours) and direction (arrows) using PFSST, (b) difference (PFSST-NCEPSST) fields of wind speed (shaded) and direction (arrows), and (c) difference fields of SST (shaded) and SLP (contours).

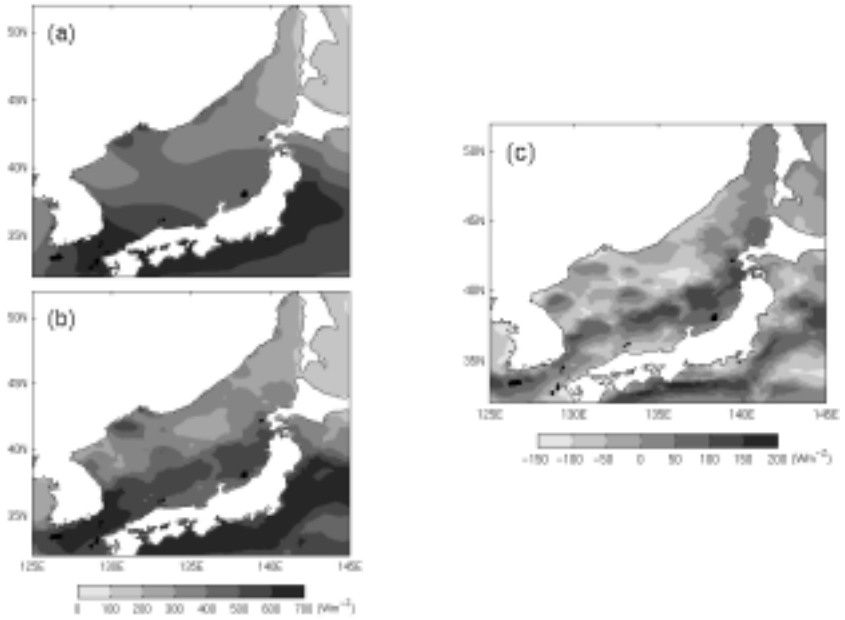

Figure 3. Model simulated monthly mean surface turbulent (sensible + latent) heat fluxes for (a) NCEPSST, (b) PFSST, and (c) difference (PFSST-NCEPSST) field.

The MM5 simulated surface wind and fluxes are used to investigate the impact of the relatively high-frequency synoptic winter storms on the ocean circulation in the Princeton Ocean Model (POM). A series POM simulations with various atmospheric forcing fields, including the ECMWF analysis, the NSCAT gridded data, and MM5 high-resolution simulations, indicate that the ocean model is very sensitive to the high-resolution synoptic-scale surface forcing. The results are summarized in Mooers et al. (2001).

IMPACT/APPLICATIONS

This project has provided the first high spatial and temporal resolution surface forcing (heat and momentum fluxes) associated with the wintertime Siberian cold-air outbreaks in JES. The MM5 simulated surface forcing fields have been used to drive the ocean circulation, hydrodynamic, and surface wave models. Recent ocean circulation, hydrodynamic, and wave model simulations using this 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. Future coupled atmosphere-ocean modeling work can provide some insights of the air-sea interaction and its potential impact on the deep ocean ventilation processes in JES.

TRANSITIONS

The full three-dimensional, high-resolution atmospheric forcing fields (including all surface fluxes) has been made available to all ONR JES PIs for their data analysis in JES and to the ocean modeling groups at NRL and UM as well other ONR supported modeling efforts. We are also comparing the MM5 simulation with the COAMPS simulation in JES from Dr. Q. Wang of NPS. The results will be communicated with Drs. J. Doyle and S.-P. Wang at NRL/Monterey.

RELATED PROJECTS

Related projects include the ONR Arabian Marginal Seas and Gulfs, ONR CBLAST, ONR Air-Sea Interactions, and the NASA QuikSCAT.

PUBLICATIONS (2001)

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. Letters*, in press.

Chen, S. S., and W. Zhao, 2001: A high-resolution model simulation of winter storms in the Japan/East Sea. *J. Geophys. Res.*, submitted.

Chen, S. S., R. C. Foster, J. Tenerelli, W. T. Liu, and C. N. K., Mooers, 2001: Comparison of surface winds from NSCAT swath and gridded data and an atmospheric mesoscale model, *J. Geophys. Res.*, submitted.

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, *Proceedings of the 5th International Marine Science Symposium on the Physical, Biological, Chemical, and Geological Processes in the Pacific Ocean and Asian Marginal Seas*, in press.

Zhao, W., S. S. Chen, and C. A. Blain, 2001: Effects of winds, tides, and storm surges on ocean surface waves in the Japan/East Sea, *J. Geophys. Res.,* submitted.