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An evaluation of a high-resolution operational wave forecasting system in the Adriatic Sea

J.D. Dykes *, D.W. Wang, J.W. Book

Oceanography Division, Naval Research Laboratory, 1009 Balch Blvd, Stennis Space Center, Mississippi, 39529, USA

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ABSTRACT

The SWAN (Simulating Waves Nearshore) wave model using wind inputs generated by the ALADIN 8-km, operational high-resolution, atmospheric model was run in real-time to provide surface waves forecast for the semi-enclosed Adriatic Sea in support of the "Dynamics of the Adriatic in Real-Time" (DART) field experiments. Together with predictions from other wave and wind models, the successful prediction of a high sea-state event by this model led to a real-time shifting of planned operations while at sea, allowing five ADCP moorings to be deployed just before a bora storm and associated storm waves arrived. The model was also able to simulate the spatial gradients in significant wave height observed by in-situ and remote-sensing measurements for a particular sirocco storm case study, providing an additional perspective in aiding interpretation of the model output of features. To further quantify prediction skill, the wave forecast performance over a 12-month period was evaluated against in-situ and altimeter measurements over the region. Correlation coefficients between forecast and in-situ measured significant wave heights were from 0.82 to 0.91 for the 24-h forecast and from 0.78 to 0.88 for the 48-h forecast. However, best-fit slope comparisons with in-situ wave data at five coastal locations show the forecast wave heights were underpredicted by 10% to 30%. Best-fit slope comparisons between modeled wind speeds, U_{10}, and significant wave heights, H_s, and altimeter-derived measurements show that model U_{10} was about 4% underpredicted, but H_s was underpredicted by an average of 30%. The underprediction of SWAN H_s has a very significant location-dependent geographical variation ranging from 10% to over 50%. In addition, the wave model comparison with altimeter H_s shows a broad region of scatter index exceeding 0.4 along and offshore of the central Croatian coast. Elsewhere the scatter index is generally around 0.3. Compared to previous studies we found that using higher-resolution wind forcing with realistic orography decreased the U_{10} underestimation bias, but the magnitude of H_s underestimation bias did not correspondingly decrease, suggesting that wave model dynamics or wind–wave coupling deserves further investigation.

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1. Introduction

Operational requirements for nowcast/forecast wave models include the ability to predict the spatial locations and arrival times of sharp significant wave height (H_s) gradients and thus be able to assure the planning of safe ship operations before or after the arrival of high seas or at locations with low H_s during times when there are strong spatial H_s gradients. It was partially for such operational reasons that the Naval Research Laboratory (NRL) ran a forecast SWAN (Simulating Waves Nearshore) wave model in real-time for the Adriatic Sea in 2006. At the time, NRL was participating in an internationally collaborative project, "Dynamics of the Adriatic in Real-Time" (DART), jointly with the NATO Undersea Research Centre (NURC) and many other partners. One of the main goals of the effort was to evaluate monitoring and prediction capabilities for vigorous, swiftly-evolving fronts and eddies in a topographically controlled coastal environment. To accomplish this, mooring measurements; drifter data; towed Conductivity–Temperature–Depth (CTD) measurements; turbulence profile measurements; numerous standard CTD profiles; surface wave measurements; remote sensing of temperature, optics, and roughness; high-resolution atmospheric models; high-resolution ocean models; and wave models were all utilized (see various other manuscripts in this special issue). A key part of the logistics of the project was the deployments and recoveries of 16 different bottom moorings, at various times over the 12-month period, October 2005 through September 2006. Due to limits on deployment time from corrosion or battery life, all of these moorings were deployed and recovered twice, typically with a deployment in October, recovery and redeployment in March, and a final recovery in September. With such a large number of deployments and recoveries (especially in March 2006) and limited ship time for these and other DART objectives, the wave model forecasts were very useful in efficiently planning the timing and order of mooring operations and avoiding sea-state conditions that were too severe to permit mooring work.

* Corresponding author. Tel.: +1 228 688 5787; fax: +1 228 688 4759.
E-mail address: james.dykes@nrlssc.navy.mil (J.D. Dykes).

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In addition to practical needs, the DART international project was also generally focused on evaluating rapid environmental assessment (REA) capability using multiple models. Therefore, NURC encouraged various partners to run operational models of various processes, including waves, during the two focused REA experiments in March and September 2006. Thus, in total, four different state-of-the-art operational wave forecast models were run and used during the experiments. These were: (1) a 1/12 degree or 8-km SWAN model forced by LAMI (Limited Area Model Italy) (Signell et al., 2005), a 7-km Italian operational model for medium- and small-scale weather prediction based on a model developed by the German Meteorological Service (Deutscher Wetterdienst) (Steppler et al., 2003); (2) a 1/20-degree or 5-km WAve Model Cycle 4 (WAM, (WAMDI group, 1988; Komen et al., 1994)) forced by SKIRON, a 1/20-degree modified version of the Eta/NCEP model (Kallos et al., 1997, 2006); (3) a 1/12-degree or 8-km WAM forced by the ECMWF (European Centre for Medium Range Weather Forecasting) model (Janssen et al., 1997); and (4) a 5-km SWAN model forced by 8-km ALADIN wind model (see Sections 2 and 3 for details). Model (1) was run by Servizio Idro-Meteo-Clima ARPA-SIMC of Emilia Romagna Region, Bologna, Italy; model (2) was run by the University of Athens; model (3) was run by the Marine Science Institute of the Italian National Research Council; and model (4) was run by NRL as first mentioned above.

During the March experiment, all available wave model forecast data were transferred to R/V Alliance while at sea, and displayed together with the same graphics and scales to provide a simple planning tool for the chief scientist to potentially change daily activities. Through this process it became immediately clear that all four models were often displaying quite different spatial H_s patterns for the same wind events. Fig. 1 shows one example of this; the 48-h H_s forecasts greatly differ between SWAN-LAMI (model 1), WAM-SKIRON (model 2), and SWAN-ALADIN (model 4). In other instances the patterns disagree in different ways but to the same extent with, e.g., in a different snapshot (not shown) SWAN-LAMI (model 1) and SWAN-ALADIN (model 4) were similar to each other but different than the other two models. Given the complexity of the Adriatic orography and winds (Pasarić et al., 2009-this issue), this is perhaps not surprising, but it also suggests that there is a need for validating spatial accuracy for operational wave modeling in such coastal environments so that confidence can be placed in more complex predicted spatial patterns of H_s and operations can be optimized with respect to wave conditions. For example, in this forecast snapshot (Fig. 1), the predicted H_s values with respect to the southern DART moorings (solid circles) are not consistent and therefore it would be unclear if the sea-state conditions would have allowed for recovery or deployment operations at that time.

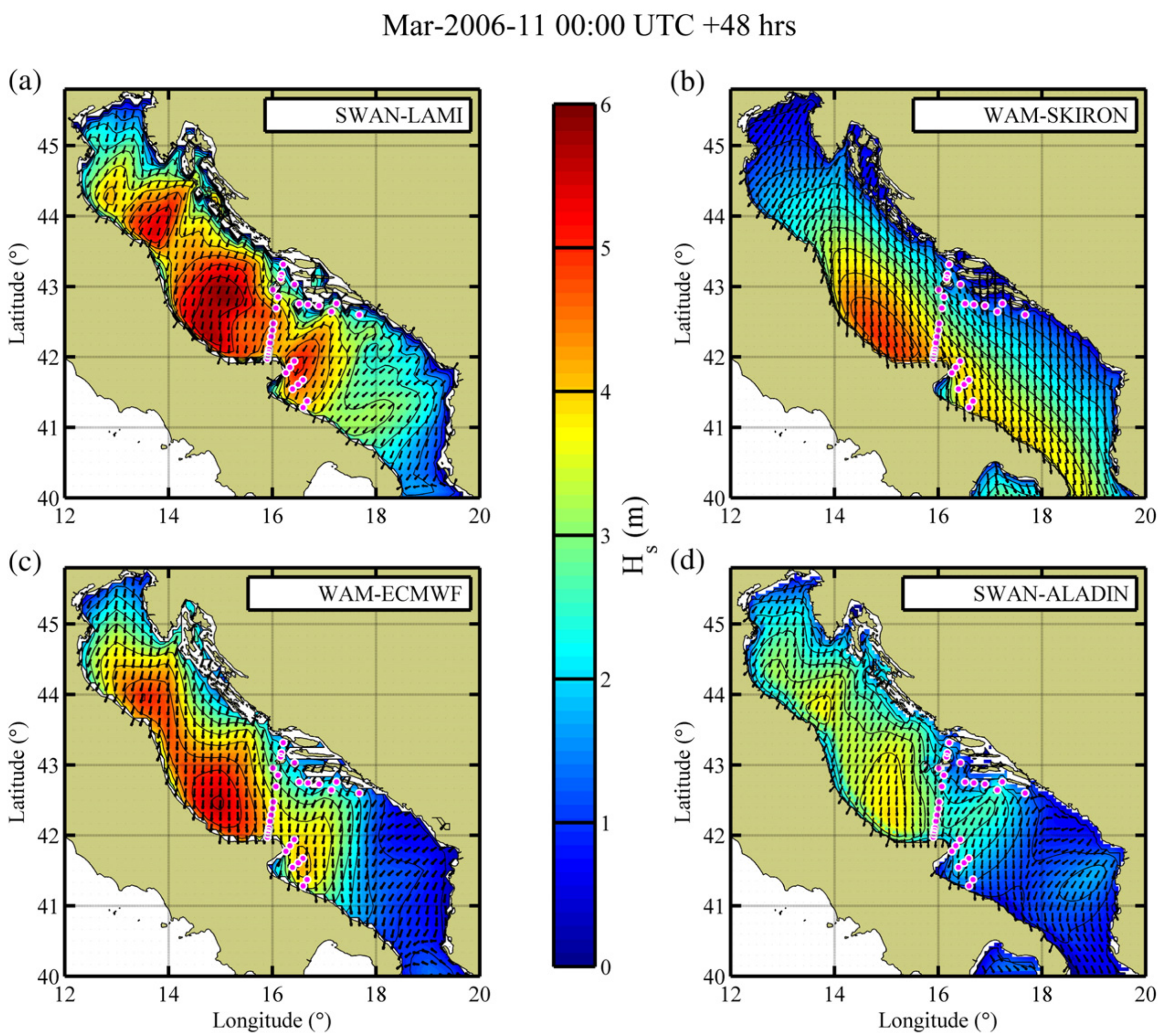

Fig. 1. 48-h forecast wave field valid for 00 UTC, March 13, 2006 by the four models forced by their associated wind models indicated in the hyphenated names: (a) SWAN by LAMI, (b) WAM by SKIRON, (c) WAM by ECMWF, and (d) SWAN by ALADIN. DART observation network is shown as solid circles.