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A New Global Wave Forecast System at NCEP [1]

Hendrik L. Tolman [2]

Abstract

This paper describes a new ocean wave prediction system which is presently being developed at the National Centers for Environmental Prediction (NCEP). The wave model is briefly described together with its global application in the forecast system. The validation of the wind fields and the wave model are discussed. NCEP's wind fields include a moderate systematic bias, which has reduced significantly with recent upgrades of NCEP's model suite. The new wave model (WAVEWATCH-III) required some modifications in its first practical application. With these modifications, the new model outperforms the WAM model in the tropics, and gives similar results at higher latitudes in a three-month hindcast study. A parallel comparison with NCEP's present operational WAM model has recently started.

1. Introduction

In the past five years a new wave model has been developed at Ocean Modeling Branch (OMB) of he National Centers for Environmental Prediction (NCEP). This model is called WAVEWATCH-III and is based on the WAM model (WAMDIG 1988, Komen et al. 1994) and on previous versions of WAVEWATCH (Tolman 1989, 1991, 1992). It nevertheless differs from its predecessors in all important aspects, i.e., the governing equations, model structure, numerical approaches and physics parameterizations. This model is extensively described in Tolman (1997), and a brief description presented here in section 2.

To test this model in practical conditions, a global application has been made, using NCEP's operational products as input. This global application is described

[1] OMB Contribution Nr. 152.

[2] UCAR Visiting Scientist, Ocean Modeling Branch, National Centers for Environmental Prediction, NOAA/NWS, 5200 Auth Road Room 209, Camp Springs, MD 21746, USA. E-mail: Hendrik.Tolman@NOAA.gov

in section 3. Validation of this forecast system is performed in three stages. (i) Validation of wind fields. (ii) Validation of the wave model in hindcast mode using the best possible winds. (iii) Validation of the entire system (wind and wave models) in forecast mode and parallel comparison with NCEP's operational WAM model. Stages (i) and (ii) consider hindcasts for the period of December 1994 through February 1995.

Presently (December 1997), the first two stages of the validation study are completed or nearing completion. The results of the wind validation are described briefly in section 4. The wind speeds show moderate systematic biases both against buoy data and satellite data. Because the operational weather models are continually being updated and improved, the wind speed biases also have to be monitored continuously, and bias corrections have to be updated when necessary. The validation of the wave model in hindcast mode is nearing completion and the results are briefly described in section 5. It is shown that the model required some modification to the parameterizations of the physics regarding aspects not covered by the previous testing in idealized conditions (e.g., Tolman and Chalikov, 1996). With these modification, WAVEWATCH-III shows similar model behavior as WAM at high latitudes, but better behavior at low latitudes. The parallel forecast model comparison has started December 1, 1997, and its results will be presented elsewhere. Results of the parallel model runs can be inspected on the OMB home page at http://polar.wwb.noaa.gov under the experimental products section (NOAA Experimental Wave model).

2. Model description

A detailed description of version 1.15 of WAVEWATCH-III as used in NCEP's new wave forecast system can be found in its manual (Tolman 1997)[3]. Here, only a brief description will be presented.

WAVEWATCH-III solves the spectral balance equation for the action density spectrum N as a function of the wavenumber k and the direction θ

$$\frac{D\,N(k,\theta)}{D\,t} = \frac{S}{\sigma} \,, \qquad (1)$$

where S represent the net source term for the conventional variance ('energy') spectrum $F = N\,\sigma$, and σ represents the intrinsic frequency

$$\sigma = \sqrt{gk\,\tanh(kd)} \,, \qquad (2)$$

and where d represents the mean water depth.

The left side of Eq. (1) describes linear propagation, including shoaling, depth refraction, and wave-current interactions. For the present global application, wave-current interactions are not considered, and shallow water effects are fairly irrelevant (although the model is formally run as a shallow water model). Effects of propagation are calculated using the third-order accurate ULTIMATE

[3] Available as a postscript file on http://polar.wwb.noaa.gov (OMB home page) .

QUICKEST scheme (Leonard 1979, 1991; Tolman 1995), using time steps that scale with the frequency or wavenumber of the spectral component considered. To avoid reduced resolution in shallow water implicit to the use of the wavenumber spectrum for the description of the wave field, a variable wavenumber grid corresponding to an invariant frequency grid is used (Tolman and Booij, 1998).

The right side of Eq. (1) represents sources and sinks in the balance equation, including relevant nonlinear propagation effects. The net source S is generally considered to consist of several constituents,

$$S = S_{wind} + S_{nl} + S_{ds} + S_{bot} \,, \qquad (3)$$

where the terms on the right side represent wind-wave interactions, resonant wave-wave interactions, dissipation ('whitecapping') and wave-bottom interactions. In WAVEWATCH-III these terms are modelled according to Chalikov and Belevich (1993), Hasselmann et al. (1985), Tolman and Chalikov (1996) and JONSWAP (1973), respectively. The source terms are integrated in time using a semi-implicit numerical scheme (WAMDIG, 1988), with a dynamically adjusted time step (Tolman 1992, 1997), which concentrates computation effort in locations where spectra are subject to rapid changes.

3. A global application

For testing purposes, WAVEWATCH-III has been run on a global grid with a longitude-latitude resolution of $1.25^o \times 1^o$. The grid covers an area from 78^o S to 78^o N. The spectrum is discretized using 24 equally spaced directions and 25 logarithmically distributed frequencies ranging from 0.041 Hz to 0.42 Hz. This model runs twice daily, performing a 12h hindcast and a 72h forecast.

The wind fields driving the wave model are obtained from NCEP's operational Global Data Assimilation Scheme (GDAS) and the aviation cycle of the Medium Range Forecast model (AVN) (Kanamitsu 1989, Kanamitsu et al. 1991, Derber et al., 1991, Caplan et al., 1997). The winds are converted from the lowest model level to 10m height assuming neutral stability. These wind fields are available at 6h intervals for the hindcast studies of stages (i) and (ii) of the validation, and at 3h intervals for the parallel forecast comparison (using analyses and 3h forecasts in the hindcast part of the wave model run). The wind speeds are corrected statistically as described in section 4.

As is described in section 5, WAVEWATCH-III accounts for effects of atmospheric stability on wave growth. The wave model therefore also requires stability information. This information is obtained from the lowest level air temperatures of the above wind models, and sea surface temperatures from the 50km SST analysis provided by NESDIS (updated two times per week).

Finally, the wave model incorporates a dynamically updated ice coverage in polar regions. These data are obtained from NCEP's operational automated passive microwave sea ice concentration analysis (Grumbine 1996) (updated daily).