TPB No. 494

Subject: Ocean Surface Waves

SIGNIFICANT CHANGES FROM LAST BULLETIN ON THIS SUBJECT NO. 453

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This bulletin, prepared by H. S. Chen, L. D. Burroughs, and H. L. Tolman of the Marine Modeling and Analysis Branch (MMAB), Environmental Modeling Center (EMC), National Centers for Environmental Prediction (NCEP), describes automated global ocean wave guidance provided in graphic, alphanumeric, and GRIB formats.

The NOAA WAVEWATCH III (NWW3) was implemented in March 2000. It is a third generation model which accounts for wave dispersion within discrete spectral bins by adding diffusion terms to the propagation equation (Booij and Holthuijsen 1987); it uses the Chalikov and Belevich (1993) formulation for wave generation and the Tolman and Chalikov (1996) formulation for wave dissipation; it employs a third order finite difference method by utilizing a split-mode scheme with a Total Variance Diminishing limiter to solve wave propagation; its computer code has been optimized to fully utilize the MPP structure of the IBM mainframe computer and all the power of FORTRAN 90; it uses a spatial resolution of 1.25^{o} x 1.00^{o}on a lon./lat. grid, a domain from 78^{o}N to 78^{o}S, and a directional resolution of 24 directions.

The bulletins and graphics of the new guidance follow the same formats shown in TPB No. 453 (Chen et al., 1999), except for changes to the spectral text bulletins now being sent to AWIPS and the following model improvements :

- The model has been re-coded in FORTRAN 90 to utilize modular concepts and allocatable data structures. No noticeable changes have resulted in the guidance.

- Improved source term integration schemes have been used with no perceptible changes to the guidance.

- A new propagation scheme to eliminate the Garden Sprinkler Effect more efficiently and to account for unresolved islands and sea ice.

- Re-tuning to eliminate model biases induced by changes above.

- Spectral text bulletins for the NWW3 are available at

  http://polar.ncep.noaa.gov/waves .

  These files are in ASCII and are available by anonymous ftp at

  ftp://polar.ncep.noaa.gov/pub/waves/date.cycle,

where date represents the date in yyyymmdd format and cycle represents the run cycle identifier (t00z, t06z, t12z or t18z, respectively). These bulletins have been implemented on AWIPS, but with a condensed format necessitated by the capabilities of the communications gateway and display capabilities of AWIPS.

The ocean wave guidance is generated four times daily out to 168 hours based on the 0000, 0600, 1200 and 1800 UTC cycles of the of the Global Forecast System (GFS).

Technical Procedures Bulletin No. 453 is now operationally obsolete.

OCEAN SURFACE WAVES[(1)]

by H. S. Chen, L. D. Burroughs, and H. L. Tolman[(2)]

1. INTRODUCTION

During the last five decades, wind wave forecasts have improved significantly from the empirical approaches based on Sverdrup and Munk (1947) and Bretschneider (1958) to the spectral approaches based on the radiative transport equation (e.g. SWAMP Group 1985). At present, the most advanced spectral model for research and forecast is the so-called third generation wave[(3)] model (WAMDI Group 1988) of which the NWW3 is an example (Tolman 2002). The Marine Modeling and Analysis Branch (MMAB) has made systematic efforts to test and develop models based on prediction accuracy, computational efficiency and sound wave dynamics and to employ them to produce operational forecasts.

The NWW3, as noted above, is a third generation model; it accounts for wave dispersion within discrete spectral bins by adding diffusion terms to the propagation equation (Booij and Holthuijsen 1987); it uses the Chalikov and Belevich (1993) formulation for wave generation and the Tolman and Chalikov (1996) formulation for wave dissipation; it employs a third order finite difference method by utilizing a split-mode scheme with a Total Variance Diminishing limiter to solve wave propagation; its computer code has been optimized to fully utilize the Massively Parallel Processing (MPP) structure of the IBM computer; it uses a spacial resolution of 1.25^{o} x 1.00^{o} lon./lat. grid, a domain north-south from 78^{o}N to 78^{o}S, and a directional resolution of 24 directions.

This TPB briefly describes the NWW3 and the wave guidance products which are being disseminated. This guidance consists of significant wave height (H_s), which combines sea and swell; mean wave direction (D_m); mean wave period (T_m); and directional wave spectra at selected grid points. Guidance is available in graphic, alphanumeric, and GRIB formats. Note that other wave and wind parameters are also available in GRIB format, i.e., peak wave period and direction, wind sea peak wave period and direction, wind speed and direction, and u and v wind components, and are posted at http://polar.ncep.noaa.gov/waves on the web. The reader is referred to World Meteorological Organization (WMO) Report No.702 (second edition; 1998) for wave definitions, measurements and modeling.

The bulletins and graphics of the new guidance follow the same formats shown in TPB No. 453 (Chen et al., 1999), except for changes to the spectral text bulletins now being sent to AWIPS and the following model improvements :

- The model was originally coded in FORTRAN 77 to assure portability in the early 1990s. It has been re-coded in FORTRAN 90 to utilize modular concepts and allocatable data structures. The conversion greatly

simplifies the maintenance of the NWW3 family of wave models at NCEP. To simplify the code further, some minor changes of operations were adopted. No noticeable changes have resulted in the guidance.

- The source term integration scheme has been changed to forward in time since the time scales are comparable to the time step (Hargreaves and Annan 2001). This results in a smoother spectra with little impact on guidance. The parameters of dynamic time stepping have been reset to get slightly faster initial growth again with no noticeable changes in the guidance.

- A new cheaper propagation scheme has been included in the model to eliminate the 'Garden Sprinkler' Effect (see figs. 1 , 2 , 3, 4, and 5). A new way to account for unresolved islands and sea ice has also been included in the model (see figs. 6, 7, and 8). Dramatic improvements in model guidance have occurred in the vicinity of island groups world wide (see figs. 9, 10, 11, and 12).

- Re-tuning to eliminate model biases induced by changes above has also been done.

- Spectral text bulletins for the NWW3 are available at

  http://polar.ncep.noaa.gov/waves .

  These files are in ASCII and are available by anonymous ftp at

  ftp://polar.ncep.noaa.gov/pub/waves/date.cycle,

  where date represents the date in yyyymmdd format and cycle represents the run cycle identifier (t00z, t06z, t12z or t18z, respectively). These bulletins have been implemented on AWIPS, but with a condensed format necessitated by the capabilities of the communications gateway and display capabilities of AWIPS. See fig. 13 for a sample bulletin and Table 1 for the list of points having spectral wave bulletins, their locations, and their bulletin headers.

The ocean wave guidance is generated four times daily out to 168 hours based on the 0000, 0600, 1200 and 1800 UTC cycles of the of the Global Forecast System (GFS).

2. NOAA WAVEWATCH III (NWW3) OCEAN WAVE FORECAST MODEL

Global ocean wave forecasts are operationally generated at the NCEP by using the NWW3 model. Fields of directional frequency spectra in 24 directions and 25 frequencies are generated at hourly intervals up to 168 hours. The 24 directions begin at 90 degrees to the east and have a directional resolution of 15 degrees. The 25 frequencies used by the NWW3 are given by bin in Table 2.

Wave spectral data are computed on a 1.25 by 1.00 degree longitude/latitude grid for ocean points between latitude 78.0 degrees North to 78.0 degrees South. Wind fields are the only driving force used in the model. They are constructed from spectral coefficients of the lowest sigma layer winds from the NCEP analysis and forecasts of the GFS (Kanamitsu et al. 1991; Caplan et al. 1997) with no interpolation to the model grid required. The winds are then adjusted to a height of 10 m by using a logarithmic profile corrected for stability with air- sea temperature differences. Analyzed wind fields from the previous 12 hours at 3-h intervals are used for a 12-h wave hindcast. Winds from the GAFS at 3-h intervals out to 168 hours are used to produce wave forecasts out to 168-h which are produced four times daily from the 0000, 0600, 1200 and 1800 UTC cycles.

3. AVAILABLE PRODUCTS AND DISSEMINATION

The ocean surface waves are calculated for grid points covering the whole globe, excluding land, the North and South pole areas, and inland water bodies, such as Great Lakes, Chesapeake Bay, Mediterranean Sea,etc. The calculated waves are disseminated graphically via AWIPS and NAWIPS, in alphanumeric format via AWIPS for selected grid points, and in GRIB format via AWIPS.

a. Spectral text bulletins on the web

Spectral text bulletins are presented for numerous points of NWW3. These bulletins are in ASCII and are available on the INTERNET at present. The line length of the table is 130 characters by 160 lines (see Fig. 14). The header of the table identifies the output location, the generating model and the run date and cycle of the data presented. At the bottom of the table, a legend is printed. The table consists of 8 columns. The first column gives the time of the model results with a day and hour (the corresponding month and year can be deduced from the header information). The second column presents the overall significant wave height (H_s, the number of individual wave fields identified with a wave height greater that 0.05 m (n), and the number of such fields with a wave height over 0.15 m that could not be tracked in the remainder of the table (x). Individual wave fields in the spectrum are identified using a partitioning scheme similar to that of Gerling (1992). In the remaining six columns individual wave fields are tracked with their height (H_s), peak wave period (T_p) and mean wave direction (dir, direction in which waves travel relative to North). Generally, each separate wave field is tracked in its own column. Such tracking, however, is not guaranteed to work all the time. An asterisk in a column identifies that the wave field is at least partially under the influence of the local wind, and, therefore, most likely part of the local wind sea. All other individual wave fields are pure swell.

b. Spectral text bulletins for AWIPS

The format for the spectral text bulletins sent to AWIPS is generally the same as that for the web, except that the period is to the nearest second, the wave heights are to the nearest foot, the direction is from (meteorological, rather than oceanographic), the number of fields that couldn't be tracked is not given, and the asterisk indicating when a wave field is, at least, partially under the influence of the local wind is not shown. The bulletin width is 69 characters, which is a legacy of the teletype era and the display capability of AWIPS. A sample bulletin is shown in fig. 13, and the list of points for the NWW3 is given in Table 1.

d. GRIB bulletins

GRIB bulletins are available for use in AWIPS. Table 3 gives the bulletin headers and their meaning. Bulletins are available at 6-h intervals from 00- through 72-h and at 12-h intervals from 72- through 168-h. Available parameters are H_s, D_m, T_m, peak wave direction and period, wind sea peak wave direction and period, and u and v components of the wind velocity. A 1.25 ^{o} x 1.00^o lon./lat. grid is used with a domain from 0 ^{o} - 360^{o}E and 78^{o}N to 78^{o}S.

4. EVALUATION

Extensive evaluation of the NWW3 model has been carried out by comparing with buoy data and ERS2 altimeter data. These results are available at http://polar.ncep.noaa.gov/waves/ .

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