

AN OPERATIONAL SPECTRAL WAVE FORECASTING MODEL
FOR THE GULF OF MEXICO¹

Yung Y. Chao

National Meteorological Center, NWS/NMC, NOAA
Washington D.C., U.S.A.

1. INTRODUCTION

Until recently, the NWS has been issuing wave forecast guidance for the Gulf of Mexico using a model developed by the Techniques Development Laboratory (TDL). The model empirically relates the significant wave height and period to wind speed, fetch and duration. The model performance was found to be inadequate in terms of accuracy and consistency of forecasted wave fields. Furthermore, wave forecasts are needed for both the deep (offshore) and shallow (coastal) areas of the Gulf. In each of these areas the dynamics of the wave physics are quite different and the empirical model cannot take these effects into account.

There are two operational global models which also routinely forecast wave conditions for the Gulf. They are the Fleet Numerical Oceanography Center Global Spectral Ocean-Wave Model (GSOWM) and the NOAA Ocean Wave (NOW) model. These models employ dynamical spectral wave forecasting techniques. However, in addition to being global scale models with coarse horizontal resolution, they are only applicable to deep water cases. The effects of bottom conditions on the modification of the wave spectrum are not considered in these models.

In order to improve and extend NMC's wave forecasting capability over the coastal areas of the Gulf of Mexico, a regional spectral ocean wave model, applicable for both deep and shallow waters of the gulf has been implemented recently. Model performance has been evaluated by means of statistical error analysis of the significant wave height forecasts against measurements at NDBC buoys in both deep and shallow water of the gulf. The result of evaluation along with an intercomparison with other deep water wave models forecasts are presented in this paper.

¹OPC Contribution No.30

2. WAVE MODEL CHARACTERISTICS

The present model is an adaptation of the model developed by Duffy and Atlas (1984) to the Gulf of Mexico. The essential governing equations and computational procedures follow the model described by Golding (1983). The model solves the energy balance equation of the form

$$\partial E/\partial t = -\nabla \cdot (VE) - \partial\{(V \cdot \nabla\theta)E\}/\partial\theta + I + D + N \quad (1)$$

where $E(f, \theta)$ is the spectral density of the wave field, V the group velocity and θ is the wave direction, and where I represents energy input from winds, D energy loss due to whitecapping and bottom effects and N the redistribution of energy within the wave spectrum due to conservative nonlinear wave-wave interactions. The equation is solved in four stages in the following order: propagation, refraction, growth and dissipation, and nonlinear interaction.

In computing wave propagation, Golding (1983) used a modified Lax-Wendroff integration scheme while Duffy and Atlas have chosen a two-step, third order scheme suggested by Takacs (1984) to minimize numerical dissipation and dispersion. At grid points adjacent to the coast, this scheme, however, cannot be used because it uses values from two grid points away from the central grid. At these points, simple upstream differencing scheme is used assuming that no waves would be reflected from the shore. The wave refraction effect in shoaling water of varying depth is computed according to Golding (1983). The procedure involves using centered differences to compute the water depth derivatives and using upstream difference to solve the refraction portion of the wave energy equation in flux form.

The growth of waves driven by input surface winds, I , is modelled according to conventional linear and exponential terms representing, respectively, an excitation by turbulence fluctuation in the surface wind and the coupling of existing waves with mean shear flow in the marine boundary layer.

The wave energy dissipation in deep water due to whitecapping is determined according to a formulation involving the entire spectrum as described by Hasselmann (1974). In shallow water, in addition to the calculation of bottom friction loss of wave energy formulated by Collins (1972), a computation of energy loss due to bottom percolation proposed by Shemdin et al. (1980) is included in the present model.

The nonlinear wave-wave energy transfer is considered in a parameterized and empirical manner. Firstly, a wind-sea spectrum is defined as that part of a spectrum that is : (1) above 0.8 of the peak frequency and (2) within 90 degrees of direction of wave propagation and wind direction. This wind-sea spectrum is then forced to conform to a modified JONSWAP spectrum based on the assumption that nonlinear interactions will always act to bring the wind-sea spectrum back to the modified JONSWAP-shape spectrum. This modified JONSWAP spectrum incorporates the saturation range in water of arbitrary depth suggested by Thornton (1977) and a cosine square angular spreading function with the original JONSWAP spectrum (Hasselmann et al., 1973).