A New Generation of Spectral Wave Models

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Over the last decade, considerable effort has been spent on the evaluation of operational wave models such as the WAM, WAVEWATCH III, and SWAN third-generation (3G) model. Most recent effort has focused on a "wholistic" approach to model evaluation, rather than on related comparisons directly to physics-based processes. In such an approach, model coefficients are tuned to maximize the global fit to integrated wave parameters such as wave height, mean/peak period, mean direction and directional spreading [1]. However, these coefficients do not ensure a universal "best-fit" to observation. Also, comparisons to spectra are omitted from the model evaluations since they tend to be generally poor [2]. Since overall spectral shape and its directional distribution are very important to modeling nearshore wave conditions, this can be critical to many coastal operations. In this paper, we will show a new approach to solutions which enables a fourth-generation (4G) model to run approximately an order of magnitude faster than third-generation models and which provides improved estimates of swell arrival time and spectral shape for coastal areas.

The primary motivation to transition from second-generation models to third-generation models was the need to improved details in the nonlinear wave-wave interaction source term, S_{nl}. However, the operational approximation still used in operational models, the Discrete Interaction Approximation (DIA). has consistently been found to yield large deviations when compared to the full integral solution for S_{nl} for any number of specific spectra. New research has now shown that this deficiency leads to spectral shapes which develop significantly different forms than the DIA and which produce significant errors used in many operations.

Figure 1 from [3] shows that the evolution of swell emanating from a storm produced by 3G models is not consistent with that produce by 4G models. In particular, differences in spectral shape in 3G models fail to capture the magnitude of the swell and the arrival time for swell compared to the actual physics of the processes. In operational models some of the arrival-time problem is obscured by the inherent diffusion in the propagation, and recently 3G models have added empirical dissipation into operational modes but since their method does not shift and enhance energy levels at lower frequencies, as seen in Figure 1), the result cannot capture large swell trains propagating into a coast. Naval operations, entrances into LNG ports, and emergency managers all need this information for various applications.

A second problem, although not as immediately apparent, is the fact that wind and breaking source terms needed to balance the overall wave growth in 3G models have to

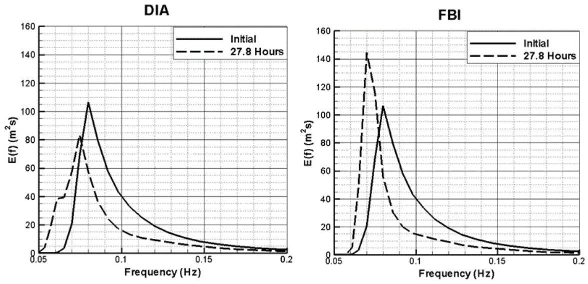

Figure 1. Comparison of results of 28.7 hours with an initial Pierson-Moskowitz spectrum with a peak period of 12.5 seconds for DIA and Full Boltzmann Integral (FBI).

contain artificial shapes and magnitudes that compensate for the misspecification of S_{nl}. Since these processes are important for many other types of applications, it will be very important to examine these differences in detail.

A significant obstacle to transitioning from a 3G to a 4G model is considered to be the expected computer time needed to perform simulations with this class of model. However, ongoing research at the University of North Florida has developed and alternative solution method which is quite general and in the case of spectral wave models could actually result in significantly decreased run times. This method is loosely based on the same principle as used in transitioning from analogue to digital representation of audio and optical recordings, using sufficiently small solution increments that, combined with physics-based interpolation functions, the entire set of possible combinations of spectra and forcing functions are used to map the spectrum at one time into the predicted spectrum at the next. In a general sense this approach considers the initial spectrum as a representation of the state of the wave surface at a given time and estimates the next state from an interpolation within a stochastic transition space.

The concept of digital solution is also being adapted for applications to surge forecasting and improved circulation modeling, including highly resolved vertical structure even near/at the coast. Unfortunately, there is little or no way for innovations such as these to be merged into existing operational systems at present.

References

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