Improved Parameterizations of Nonlinear Four Wave Interactions for Application in Operational Wave Prediction Models

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LONG-TERM GOAL

The long-term goal of this project is to improve spectral wave prediction models by providing an accurate and fast method for computing the nonlinear quadruplet wave-wave interactions in deep and shallow water. Although an accurate integral description of these interactions exists for more than 28 years (Hasselmann 1962, see also Zakharov, 1998), the computation thereof is hampered by the complexity of its functional form and its computational demands. In 1985 the Discrete Interaction Approximation (Hasselmann et al., 1985) was developed which enabled the development of third generation wave prediction models. The DIA, however, has some shortcomings which hamper the further development of third generation wave prediction models. These models all use the action balance equation for describing the time and space evolution of wave spectra. By providing an accurate and fast method for computing these interactions, wave evolution characteristics will improve and more attention can be given to the development of the other source terms.

OBJECTIVES

The objective of this project is obtain a fast and accurate method for computing the nonlinear four wave interactions in deep and shallow water, such that this method can be applied in operational wave prediction models.

APPROACH

To develop improved methods for computing the nonlinear four wave interactions, a bench mark model will be developed for comparing any approximation for correctness and/or calibration. This benchmark model will be based on the method of Resio and Tracy (Resio and Perrie, 1991). The software for computing the nonlinear quadruplet wave-wave interactions will be rewritten such that it can easily be included into any spectral wave prediction model. At the same time, approximate methods will be developed by following two paths. The first path is based on stripping down the method of Resio and Tracy by reducing the integration space and developing smart integration techniques. The second path is based on extending the DIA by including more basic interacting wave number configurations. In the development of these approximations attention will be given to the following aspects:

- improve the depth scaling (Herterich and Hasselmann, 1980),
- swell-sea interaction,

- effect on the width of spectrum, both in frequency and direction space,
- short and long time scale behavior,
- fetch and time evolution of spectra,
- directional response to turning winds.
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For testing the time and fetch behavior of the evolution of wave spectra a one-dimensional (time or space) transect wave model will be used. This model will be used for the analysis of wave transformation of idealized cases but also to study the evolution of wave spectra on the continental shelf near Duck as observed in the SHOWEX experiment.

WORK COMPLETED

The AWPP Snl group (Herbers, Jensen, Resio, Tracy, Van Vledder and Zakharov) met two times during the year for in-depth discussions, and to plan continued collaborative work. In March 2000 a full AWPP meeting was held in Delft, The Netherlands in which the Snl group met for 2 days. The second meeting was in June 2000 at the WISE meeting in Reykjavik, Iceland. In these meetings the progress and coordination was discussed of the various parties involved in the AWPP Snl program.

In November 1999, Van Vledder finished the first version of a subroutine version of the Webb/Resio/Tracy (WRT) method for the computation of the nonlinear transfer. Subsequently this subroutine version was implemented in the WAM model during a visit of Van Vledder to Bob Jensen of CHL, Vicksburg in November 1999. In February 2000 Van Vledder visited Hendrik Tolman of NCEP/NOAA Washington DC to implement these routines in the WaveWatch III wave model. In addition, the routines were handed over to Dimitry Chalikov of NCEP/NOAA for use in training a neural network approach being developed by Vladimir Krasnopolsky of NCEP/NOAA. The routines were also implemented in the SWAN model together with IJsbrand Haagsma of Delft University of Technology, The Netherlands.

An explicit method was developed to compute the 'loci' in wave number space. The loci are a key element in the WRT method for computing the nonlinear interactions. This method works both for deep and finite depth water, and for directions defined in a limited sector on a full circle.. In addition some improvements for the computation of the gradient term were realized. These results were shared with the developers (Resio and Tracy) of the original RT source code.

A first extension has been made to the original DIA by adding a second interaction wave number configuration. The coefficients of two wave number configurations were obtained by fitting the approximate model to exact results obtained with WRT method.

Developments of the AWPP Snl group were presented during the Int. Conf. on Coastal Engineering, Sydney Australia, July 2000. The related paper is in press.

The new method for computing the interaction space, viz. the loci has been reported in a paper to be presented at the 6th International Workshop on Wave Hindcasting and Forecasting, 6-10 November, Monterey, Ca., United States of America.

RESULTS

A set of subroutines has been developed for the exact computation of the nonlinear interactions in an arbitrary discrete wave spectrum. The subroutine version of Xnl has been implemented in the WAM, SWAN and WAVEWATCH III model.

An explicit method for the computation of the loci has been developed.

An extension to the DIA has been developed by adding a second wavenumber configuration and optimizing the coefficients for a range of target spectra.

The transect model has been further developed for modeling the evolution of the wave field along a one-dimensional fetch.

IMPACT/APPLICATION

A fast and accurate method for computing the nonlinear four wave interactions will improve the quality of operational third generation wave prediction models. By providing an accurate method for computing these interactions, the basic growth behavior improves and more attention can be given to the other source terms in third generation wave prediction models. Since the source term balance will change by replacing the DIA with better methods, third generation wave prediction model need to be re-calibrated.

TRANSITIONS

The set of subroutines for computing the nonlinear four wave interactions is available to the wave modeling community to be included in wave prediction models. The only model dependent part will be the interface subroutine, which also ensures that future versions can easily be included in the wave models. In addition, the one dimensional transect model can be used by researchers who want to study the fetch or time evolution of wave spectra. The new explicit method for computing the position of the loci has been described in detail in the paper ... to be presented at the waves meeting to be held in November 2000, Monterey, CA, USA.

RELATED PROJECTS

Delft University of Technology: The continued development of the third-generation shallow water wave model SWAN.

Naval Postgraduate School, Monterey: Improved parameterization of nonlinear wave interactions for application in operational wave prediction models.

USAE Waterways Experiment Station, Coastal and Hydraulics Laboratory: Accurate representation of arbitrary depth source terms in coastal wave prediction models.

REFERENCES

Booij, N., L.H. Holthuijsen and R.C. Ris, 1999: A third-generation wave model for coastal regions. 1. Model description and validation. J. Geophys. Res., Vol. 104, No. C4, 7649-7666.

Hasselmann, K., 1962: On the non-linear transfer in a gravity wave spectrum, 2, Conservation theory, wave-particle correspondence, irreversibility, J. *Fluid Mechanics*, Vol. 15, No. 385-398.

Hasselmann, S., and K. Hasselmann, 1981: A symmetric method of computing the nonlinear transfer in a gravity wave spectrum, Hamburger. Geophys. Einzelschr., A, 52, 138 pp.

Herterich, K., and K. Hasselmann, 1980: A similarity relation for the nonlinear energy transfer in a finite-depth gravity-wave spectrum. J. Fluid. Mech., Vol. 97, 215-224.

Hasselmann, S., K. Hasselmann, J.H. Allender and T.P. Barnett, 1985: Computations and parameterisations of the nonlinear energy transfer in a gravity wave spectrum. Part 2: Parameterisations of the nonlinear energy transfer for application in wave models. J. Phys. Oceanogr., Vol. 15, 1378-1391.

Resio, R.T., and W. Perrie, 1991: A numerical study of nonlinear energy fluxes due to wave-wave interactions. Part 1: Methodology and basic results. J. Fluid Mech., Vol. 223, 609-629.

Zakharov, V.E, 1998: Statistical theory of gravity and capillary waves on the surface of the finite-depth fluid. Proc. UITAM symposium (Nice, 1998), special issue of the European Journal Mechanics.

PUBLICATIONS

Vledder, van, 1999a: Source term investigation SWAN, ALKYON report A162.

Vledder, G.Ph. van, T.H.C. Herbers, R. Jensen, D. Resio and B. Tracy, 2000: Modeling of nonlinear quadruplet wave-wave interactions in operational coastal wave models. Paper presented at Int. Conf. on Coastal Engineering, Syndey Australia, July 2000.

Vledder, G.Ph. van, 2000: Improved method for obtaining the integration space for the computation of nonlinear quadruplet wave-wave interactions. To be presented at the 6th International Workshop on Wave Hindcasting and Forecasting, 6-10 November, Monterey, Ca., United States of America.

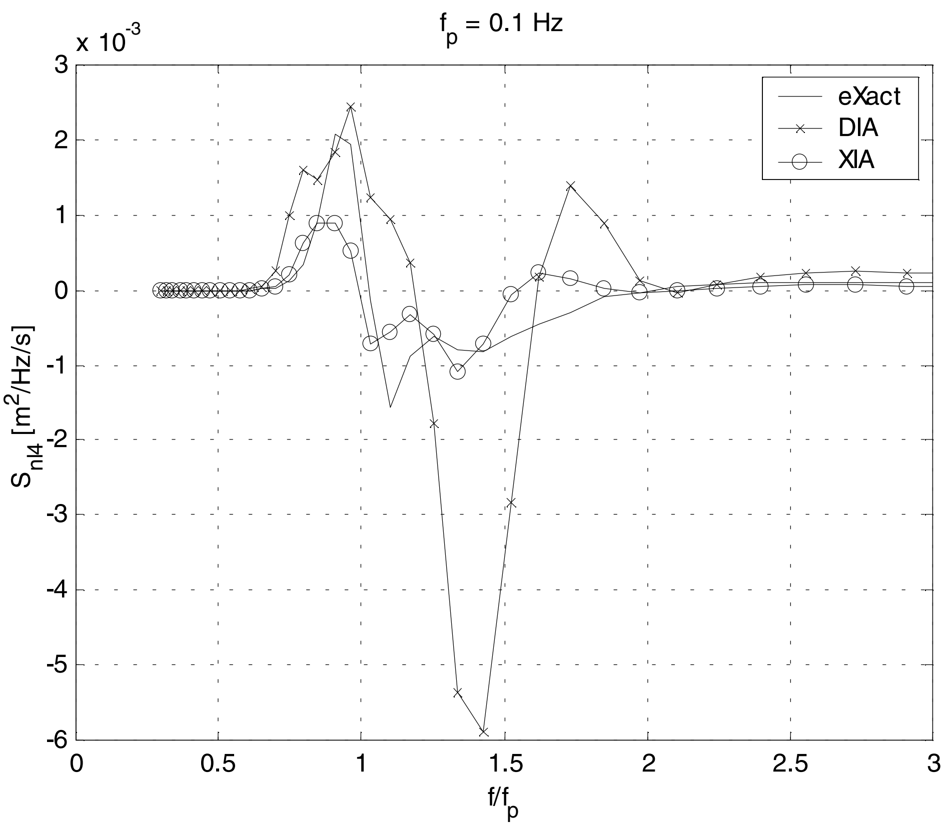

Figure 1: Example of the extended Discrete Interaction Approximation (XIA) with two wave number configurations and comparison with the DIA and an eXact method.