NUMERICAL EXPERIMENTS ON CHARACTERISTICS OF NONLINEAR ENERGY TRANSFER OF OCEAN WAVES

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（海洋波の非線形エネルギー輸送の特性に関する数値実験）

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論 文 内 容 の 要 旨

The nonlinear energy transfer has been shown to play a critical role in the time and space evolution and the establishment of a fully-developed wind sea spectrum by controlling the spectral shape, including the frequency downshift (e.g. Hasselmann et al., 1973). Although the theoretical model equation of these interactions is available, however, most of the existing operational wave models apply a very simplified computation scheme to evaluate these interactions. The method is known as Discrete Interaction Approximation (DIA) developed by Hasselmann et. al., (1985). The strength of DIA is in its preserve of many important physical characteristics of the nonlinear interactions, and its robustness when applied in practical wave model (Tolman, 2003). Nevertheless, the DIA method is considered to have a limitation on accuracy.

Numerous efforts have been made to improve nonlinear energy transfer computation. Up until now, no proper definition has been given how to justify which method is the best. The inter-comparison of those methods is needed in order to direct a suggestion for improvement of nonlinear energy transfer computation.

Theoretically, precise evaluation of nonlinear energy transfer requires a large number of the resonant configurations. Such calculations need huge computational costs which are not suitable for operation of wave model. It is necessary to develop a method, which can provide sufficient accuracy and efficiency, to be practically implemented in the wave model. Hence, the main purpose of this study is to present the efficient number of configurations to nonlinear energy transfer computation, which is better in accuracy and less computational time than the existing methods to be incorporated in the operational wave model.

This dissertation consists of six chapters. Begins with Chapter 1 by introducing and explaining the background of this study. This chapter also clarifying the purposes and the importance of this study. The outline of the dissertation closed this chapter.

Chapter 2 describes some previous methods which can provide high accuracy for calculating nonlinear energy transfer. Descriptions of DIA (Hasselmann et al., 1985), RIAM (Komatsu et al., 1993), SRIAM (Komatsu et al., 1996), EDIA and MDIA (Hashimoto et. al, 2001) in the evaluation of the Boltzmann Integral for nonlinear energy transfer computation in deep

water depth and FD-RIAM (Hashimoto et. al, 1998) for computation in finite water-depth are presented.

As a preliminary of this study, long-term evolution of the gravity wave spectrum due to nonlinear energy transfer is investigated in Chapter 3 by using a third generation wave model, WAM, implemented with DIA, RIAM, and SRIAM in order to understand the fundamental process of wave generation and wave development in deep water depth. The numerical simulations were performed under duration-limited conditions for various initial conditions of directional spectra. Inter-comparisons of those methods were conducted to lead a suggestion which method is the best. The numerical results show that SRIAM seems more superior than the other method. In addition, the characteristics of frequency downshift are investigated by carrying out the WAM model implemented with SRIAM. The relation between frequency downshift with wave steepness, peak frequency, and energy concentration parameters are presented. As a result, interesting characteristics of the frequency downshift of the gravity wave spectrum due to the nonlinear energy transfer are clarified both in frequency and directional domain, especially on the relation between frequency downshift and the energy concentration parameters of directional spectra. This chapter also discussed the characteristics of bimodal directional spectra in the frequency and directional domain.

Chapter 4 focuses on the nonlinear energy transfer computation in finite water depth by a modified WAM implemented with FD-RIAM under duration limited conditions. The evolution of directional spectra in finite water depths due to the nonlinear energy transfer were confirmed to be much faster than those in deep water depth. This chapter also evaluated the enhancement factor R which used in the third generation wave models as well as the downshift factor for various directional spectra in various water depths.

The proposed efficient number of configurations for nonlinear energy transfer computation are presented in Chapter 5. First, we modify SRIAM method, developed by Komatsu and Masuda (1996), by reducing the number of the configurations. This method then called as the Reduced-SRIAM (R-SRIAM). The second method is the Alternative Multiple DIA (AM-DIA) which proposed the efficient configurations by selecting only from the quasi-singular quadruplets. The numerical computation results of R-SRIAM and AM-DIA are compared with RIAM and original SRIAM which has been proven to have the same degree of accuracy with the exact method developed by Masuda (1980) and Komatsu and Masuda (1996). As the outcome, R-SRIAM is less time consuming than the original SRIAM, yet it is still longer than DIA. Meanwhile, the AM-DIA with two configurations is more accurate than DIA and more economical to be incorporated into the operational wave model compared with RIAM, SRIAM, and R-SRIAM.

The last chapter summarizes the results in conclusions and proposes the next step in the near future for a continuation of this study. The major conclusion is that both R-SRIAM and AM-DIA can be considered as the alternative promising method for nonlinear energy transfer computations for gravity wave spectrum in deep water depths.