

Fundamental Problems of Internal Gravity Waves Dynamics in Ocean

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Abstract: In paper fundamental problems of internal gravity waves dynamics are considered. The solution of this problem is expressed in terms of the Green's function and the asymptotic representations of the solutions are considered. The uniform asymptotic forms of the internal gravity waves in horizontally inhomogeneous and non-stationary stratified ocean are obtained. A modified spatio-temporal ray method is proposed, which belongs to the class of geometrical optics methods (WKB method). Analytical and numerical algorithms of internal gravity wave calculations for the real ocean parameters are presented.

Keywords: Stratified ocean, internal gravity waves, asymptotic methods.

INTRODUCTION

Internal gravity waves are an important feature of ocean dynamics and they may be found almost everywhere in the ocean. Internal gravity waves are supported in a stably stratified medium. Vertical motion is then suppressed by gravitational forces. A vertical displacement of a fluid parcel will result in a buoyancy force opposite in direction to the displacement and as a result the fluid parcel will undergo vertical oscillations with a frequency which is determined by the density stratification of the medium. The essential characteristic of internal gravity waves is that they can propagate over large distance practically without dissipation losses and with almost unchanged structure. There are many works devoted to theoretical, numerical and experimental investigations of the internal gravity waves fields, but our aim is not to discuss these results. The reader is referred to, among others, the papers [1-19].

There are several types of energy source for internal gravity waves. One possibility is generation through atmospheric winds. Another is tidal flow over bottom topography. To generate an internal wave field with an organized structure it is necessary to have a coherent localized source. One example of this is a moving vessel. Both surface and underwater vessels generate internal gravity waves which have a well organized structure. Just as for surface ship waves, the internal wave field has a V-shaped structure, but in contradistinction to ship waves here the opening angle of the V depends on the stratification and the speed of the vessel. A self-propelled moving underwater object

will create a turbulent wake. The wake will form behind the body and it will expand in time, both horizontally and vertically. Further this wake collapses at a certain distance downstream of the moving object and produces a significant internal wave field. The numerical modeling of such wake collapse is difficult, and requires a large amount of computer capacity. Such a model is outside the scope of our investigation [14, 15].

For an arbitrary ocean density distribution it is possible to solve the internal wave generation and propagation problems numerically. The shortcoming of this approach is the boundness of the space region in which the problem can be solved. For example, numerical Fourier method is used usually. In accordance with this method it is necessary to sum over about 10^6 Fourier components. Moreover, the numerical method does not readily lead to a qualitative description of internal waves in real ocean. In this paper we will examine the linear internal gravity waves generated by a source in stratified medium. This problem is solved by using Green's function method. The solution thus obtained is a sum of triple quadratures which expressed in terms of eigenfunctions and eigenvalues of corresponding vertical spectral problems. This method makes it possible to obtain the simple asymptotic forms of solution and easy-to-interpret qualitative description of field structure [6, 9, 11, 12].

The internal gravity waves are the oscillations of a stratified medium in the gravity force field. The stratified medium is such a medium where the density increases with the depth. Suppose that a volume element of the medium is not at the equilibrium, for example it could be displaced upward, then it will be heavier than the surrounding medium and therefore Archimedean forces will make it move back to the equilibrium. The essential parameter of any oscillating system is the frequency. It is determined by the correlation of two factors:

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