Geophysical Research Abstracts, Vol. 7, 02663, 2005
SRef-ID: 1607-7962/gra/EGU05-A-02663

Adiabatic behavior of strongly nonlinear internal solitary waves in slope-shelf areas

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Transformation of large-amplitude internal solitary waves (ISW) propagating over slope-shelf topography is studied theoretically and with the use of the experimental data collected during the Coastal Ocean Probing Experiment. Taking into account a very strong nonlinearity of observed waves (the ratio of isotherm displacement to their initial depth reached a value of 5), two different approaches were employed for the theoretical investigations of the wave evolution: numerical simulations in the framework of a fully nonlinear nonhydrostatic system of equations, and estimations based on a long-wave equation derived for a two-layer fluid without any restrictions on the wave amplitude. Special attention is paid to the adiabatic stage of the wave evolution over a gently sloping bottom when the ISW conserves its energy in the course of propagation and preserves the parameters close to a steady solitary wave corresponding to each local depth. Strong ISWs vary adiabatically along the trace of propagation until their vertical scale (amplitude) becomes comparable with the total water depth. This adiabatic process typically ends when a soliton reaches its limiting amplitude, after which the breaking process occurs that leads to the generation of turbulence. For a sharp pycnocline, simplified two-layer models are applicable for the study of the shoaling process roughly within the same limits as for steady solitons over a flat bottom. Even for a relatively smooth stratification, some soliton parameters, such as its velocity and the peak particle velocity, can be satisfactorily evaluated from simplified models.