Geophysical Research Abstracts
Vol. 19, EGU2017-10, 2017
EGU General Assembly 2017

On the interaction of small-scale linear waves with nonlinear solitary waves

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In the study of environmental and geophysical fluid flows, linear wave theory is well developed and its application has been considered for phenomena of various length and time scales. However, due to the nonlinear nature of fluid flows, in many cases results predicted by linear theory do not agree with observations. One of such cases is internal wave dynamics. While small-amplitude wave motion may be approximated by linear theory, large amplitude waves tend to be solitary-like. In some cases, when the wave is highly nonlinear, even weakly nonlinear theories fail to predict the wave properties correctly. We study the interaction of small-scale linear waves with nonlinear solitary waves using highly accurate pseudo spectral simulations that begin with a fully nonlinear solitary wave and a train of small-amplitude waves initialized from linear waves. The solitary wave then interacts with the linear waves through either an overtaking collision or a head-on collision. During the collision, there is a net energy transfer from the linear wave train to the solitary wave, resulting in an increase in the kinetic energy carried by the solitary wave and a phase shift of the solitary wave with respect to a freely propagating solitary wave. At the same time the linear waves are greatly reduced in amplitude. The percentage of energy transferred depends primarily on the wavelength of the linear waves. We found that after one full collision cycle, the longest waves may retain as much as 90% of the kinetic energy they had initially, while the shortest waves lose almost all of their initial energy. We also found that a head-on collision is more efficient in destroying the linear waves than an overtaking collision. On the other hand, the initial amplitude of the linear waves has very little impact on the percentage of energy that can be transferred to the solitary wave. Because of the nonlinearity of the solitary wave, these results provide us some insight into wave-mean flow interaction in a fully nonlinear framework.