Geophysical Research Abstracts
Vol. 19, EGU2017-18871, 2017
EGU General Assembly 2017

Impact of viscous boundary layers on the emission of lee-waves

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Oceans large-scale structures such as jets and vortices can lose their energy into small-scale turbulence. Understanding the physical mechanisms underlying those energy transfers remains a major theoretical challenge. Here we propose an approach that shed new light on the role of bottom topography in this problem. At a linear level, one efficient way of extracting energy and momentum from the mean-flow above topography undulations is the radiation of lee-waves. The generated lee-waves are well described by inviscid theory which gives a prediction for the energy-loss rate at short time [1].
Using a quasi-linear approach we describe the feedback of waves on the mean-flow occurring mostly close to the bottom topography. This can thereafter impact the lee-waves radiation and thus modify the energy-loss rate for the mean-flow. In this work, we consider the Boussinesq equations with periodic boundary conditions in the zonal direction. Taking advantage of this idealized geometry, we apply zonally-symmetric wave-mean interaction theory [2,3]. The novelty of our work is to discuss the crucial role of dissipative effects, such as molecular or turbulent viscosities, together with the importance of the boundary conditions (free-slip vs no-slip). We provide explicite computations in the case of the free evolution of an initially barotropic flow above a sinusoidal topography with free-slip bottom boundary condition. We show how the existence of the boundary layer for the wave-field can enhance the streaming close to the topography. This leads to the emergence of boundary layer for the mean-flow impacting the energy-loss rate through lee-wave emissions. Our results are compared against direct numerical simulations using the MIT general circulation model and are found to be in good agreement.

References

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