EGU24-687, updated on 27 Jul 2024
https://doi.org/10.5194/egusphere-egu24-687
EGU General Assembly 2024

3D modelling of internal tide generation

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Internal tides, generated by the interaction of tidal flows with underwater topographies, play a pivotal role in ocean dynamics. They significantly contribute to energy transport in the oceans and can lead to deep-ocean mixing, influencing large-scale ocean circulation and ecosystems through nutrient transport. Their accurate representation in large-scale numerical models is essential to improve our understanding of oceanic processes and assess their impact on climate scenarios. However, implementing internal tide generation is challenging due to the variety of spatial and temporal scales involved. It cannot be tackled by estimations from observations and/or numerically expensive regional models alone. In this context, analytical methods offer insights to accurately describe the internal tide wavefield, enabling more precise parameterizations in global ocean models. Existing analytical approaches are based on specific (limiting) assumptions, often considering two-dimensional situations or weak amplitude topographies.

Here, we present a boundary element method to compute the internal tide radiated for a prescribed barotropic tidal flow over any arbitrary localized three-dimensional topography. This method, based on a Green's functions approach, assumes linear Boussinesq generation for harmonic tidal forcing (hence with a weak-amplitude excursion) and uses vertical mode decomposition to express the wave velocity field and the energy flux of the internal waves radiated in all directions. The properties of the internal tide generated by an axisymmetric Gaussian topography for constant stratification are discussed in detail. Results for the sub-critical regime (internal wave slopes larger than the topography) are consistent with the Weak Topography Approximation in the limit of small seamounts and when the influence of the Coriolis frequency is negligible. A specific discussion is made regarding the influence of the Coriolis frequency on the direction of emission for the internal tide radiated by axisymmetric seamounts. An important result is that the direction where the internal tide flux is maximum is controlled by the relative importance of the Coriolis frequency with respect to the tidal frequency, the orientation of the tidal flow, and the geometrical properties of the topography. Interestingly, for topographies elongated in one specific direction, the role of the Coriolis effect becomes negligible; the orientation of the tidal forcing and the one associated with the topography alone control the angular dependency of the energy flux radiated.

Our work is a first approach to realistic analytical modeling of internal tide generation. It emphasizes the importance of considering the 3D effects for this problem.