

## Decay rates of internal tides estimated by an improved wave-wave interaction analysis

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Recent numerical and observational studies have reported that resonant wave-wave interaction may be a crucial process for the energy loss of internal tides and the associated vertical water mixing in the mid-latitude deep ocean. Special attention has been directed to the remarkable latitudinal dependence of the resonant interaction intensity; semi-diurnal internal tides promptly lose their energy to near-inertial motions through parametric subharmonic instability equatorward of the *critical latitudes* 29°N/S, where half the tidal frequency coincides with the local inertial frequency. This feature contradicts the classical theoretical prediction that resonant wave-wave interaction does not play a major role in the tidal energy loss in the open ocean.

In this study, by reformulating the kinetic equation for long internal waves and developing its calculation method, we estimate the energy decay rates of the low-vertical-mode semi-diurnal internal tides interacting with the "ubiquitous" oceanic internal wave field. The result shows rapid energy decay of the internal tides, typically within  $O(10)$  days for the lowest-mode component, near their critical latitudes. Energy lost from the internal tides is then transferred to high-mode near-inertial components in the upper ocean. The decay time of internal tides obtained here is several-fold shorter than those in the classical studies and, additionally, varies by a factor of two depending on the local depth and density structure.

We suggest from this study that the numerical integration of the kinetic equation is a more effective approach than recognized to determine the decay parameter of wave energy, which is indispensable for the global ocean models.

Keywords: Internal tides, wave dynamics, parametric subharmonic instability