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Physical interpretation using wave dynamics of leaky tropospheric modes

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Many idealised studies of internal gravity waves in the lower atmosphere assume two-dimensional linearised non-rotating hydrostatic dynamics, with piecewise constant buoyancy frequency to represent the troposphere and stratosphere. In a recent study for such a setting, Chumakova, Rosales and Tabak (2013) proposed the existence of dissipative internal gravity wave modes in the troposphere, with typical decay time scales from an hour to a week. These modes were found by solving the governing equations in the troposphere alone, and applying an effective boundary condition at the tropopause to allow for upward radiation of internal gravity waves into a stratosphere of higher buoyancy frequency. However, when these solutions are continued upwards into the stratosphere, it can be shown that their amplitudes increase exponentially (at a rate faster than that normally expected due to the exponential decrease of the background density), in such a way that the upwards energy flux also increases exponentially with height. This strange behaviour goes against standard thinking in geophysical fluid dynamics, in which solutions are usually sought with spatial exponential decay or bounded energy fluxes. However, here we show how the exponential increase of the energy flux with height may be understood (and perhaps accepted) physically, and how it is linked quantitatively to the temporal decay scale of the tropospheric modes. A separate argument in terms of the successive (partial) reflection of vertically propagating waves between the ground and the tropopause can also be used to understand and estimate the temporal decay scale. This argument is similar to those sometimes used to understand instabilities via over-reflection, except here the resulting solution is decaying in time.