Internal wave instabilities and transition to turbulence in large aspect ratio wave attractors

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Geophysical turbulence exhibits distinct characteristics compared to conventional turbulence flows, primarily due to the effects of stratification and/or rotations which are different at various scales of flows. We will focus on the small-scale effects where the direct action of buoyancy significantly affects momentum equations and cannot be neglected, as opposed to quasi-hydrostatic modeling at large scales.

Continuous stratification itself profoundly impacts the onset of hydrodynamical instabilities due to a unique dispersion relation. According to this relation, wave beams and wave energy propagate perpendicular to the phase lines. It has also been observed that the dynamics of wave beams (webs of rays) in closed domains differ considerably from conventional ray tracing. In a general case, an attracting trajectory exists for the wave beams, referred to as wave attractors. These trajectories evolve due to the focusing/defocusing of wave packets upon reflection from the walls inclined with respect to gravity or rotation axis [1].

Owing to the high concentration of wave energy along these attracting paths, they are particularly susceptible to instabilities and serve as a source for the propagation of secondary waves. In our previous works, we demonstrated that if the aspect ratio of the motion is of the order of one, the transitions to turbulence can be effectively described using a laboratory toy-box model [2,3]. In such a laboratory model, turbulence originates from cascades of triadic resonances. This model represents an important case of natural flows. Another case involves large aspect ratio motions, where the horizontal scale is much larger than the vertical, yet buoyancy effects cannot be neglected.

Previously, we described the peculiarities of linear regimes of large aspect ratio wave attractors and their instabilities at multiples of half the forcing frequency. Now we complement this scenario with cascades of triadic resonance instabilities in each half-harmonic frequency interval and show the corresponding changes in spatial spectra.

Références

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