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Experimental observations of spontaneously-emitted gravity waves: a challenge for theorists

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Orthodox explanations of gravity wave generation in the ocean and atmosphere include dynamical instability and topographic forcing. We report on an alternative possibility: spontaneous Lighthill-like emission from balanced mesoscale flow. In a laboratory study using a rotating two-layer annulus, we find that all evolving baroclinically-unstable flows emit inertia-gravity waves, as proposed by Ford, McIntyre and Norton (2000). The spatial locations of the waves are well-predicted by the radiation term derived by Ford (1994), following Lighthill (1952).

Two important issues arise from this study. First, the amplitude of the laboratory inertia-gravity waves displays a roughly linear variation with Rossby number. This finding is in disagreement with several dynamical theories and needs to be better understood. Specifically, quasi-geostrophic theory predicts that loss of balance can enter only at second order in Rossby number, and thus we might expect the amplitude to scale as Rossby number squared. Other theories predict that the amplitude should decay exponentially with decreasing Rossby number, which fits the laboratory observations even worse. This mismatch presents an important challenge to slow manifold theorists.

Second, we estimate that the balanced large-scale waves in the laboratory lose roughly one per cent of their energy per rotation period into the inertia-gravity waves. Extrapolation of this result suggests that the spontaneous-emission mechanism might make a significant contribution to the energy budgets of the ocean and atmosphere. For example, we crudely estimate that O(1TW) is being lost from balanced mesoscale ocean

eddies into the internal wave field, suggesting that this mechanism might be a significant player in maintaining the deep ocean stratification.