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Instabilities and turbulence arising from multi-scale gravity wave interactions

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Superpositions of larger-scale mid-frequency gravity waves (GWs) and smaller-scale low-frequency GWs or mean shears are common throughout the atmosphere and the oceans. Such superpositions exhibit strong interactions and instabilities due to mutual deformation of their respective fields. Wave-wave interactions are strong when velocity perturbations are fully or partially aligned. Instability dynamics accompanying such multi-scale superpositions depart in significant ways from those due to monochromatic GWs. When smaller-scale GWs or mean motions contribute significantly to the shear variance, they can have profound effects on both the evolution and the energetics of the larger- and smaller-scale flows. Consequences include 1) the occurrence of instabilities at smaller vertical scales than accompanying a single larger-scale GW, 2) strong wave-wave interactions, 3) a surprising dependence of GW and turbulence evolutions on the form and orientation of the small-scale GW or mean motion, and 4) formation of "sheet and layer" structures similar to those often seen in high-resolution atmospheric and oceanic measurements.