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The generation of gravity waves in unbalanced jet streams

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Recent studies using both simulations from numerical weather prediction models and idealized models of baroclinically unstable atmospheres have shed light on the problem of gravity wave generation in dynamically unbalanced flow regimes. The cascade of energy from gravity-inertia waves generated by an unbalanced jet streak to smaller-scale, but more energetic, gravity waves has been both simulated and observed with high-resolution dropwindsonde and in-situ measurements collected by research aircraft. The idealized model simulates packets of upward propagating gravity-inertia waves shed by an increasingly unbalanced jet streak as it approaches a ridge in the upper-level height field. Using nested horizontal grid resolutions from 100 km down to 4 km, the model produces wave sharpening and energy cascade down to smaller scales, where sub-grid scale turbulent kinetic energy is generated due to wave breaking.

In-depth analysis of high-resolution aircraft data and model simulations have been performed of an event in which gravity waves (horizontal wavelengths of ˜100-200 km) were generated in the vicinity of a complex tropopause fold. Analysis suggests that the waves were generated by geostrophic ("balance") adjustment associated with highly unbalanced streamwise ageostrophic frontogenesis. The waves emanated from a secondary tropopause fold that formed along a stable lamina above the primary fold. This same region was also the source for a wide spectrum of higher-frequency gravity waves displaying wavelengths of 1-20 km that were detected in the spectral and wavelet analyses of the 25-Hz in-flight data. These smaller-scale gravity wave packets perturbed the background wind shear and stability, promoting the development of bands of reduced Richardson number conducive to the generation of the observed turbulence.