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The Emission of Inertia-Gravity Waves from Fronts and Jets

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Experience suggests that unsteady, stratified flows inevitably generate internal gravity waves, although the amplitudes of such waves may be exceedingly small. An important question yet to be answered in full is: under what conditions are large amplitude waves are generated? Inertia-gravity waves are often observed in connection with fronts at both the surface and tropopause, and consequently unsteady, large-amplitude perturbations on the mean flow such as upper level jets and fronts are thought to be important sites for their generation.

This paper examines the emission of inertia-gravity waves from fronts and jets using a combination of idealized numerical modelling and simple theory. In particular, the calculations follow the development of upper level and lower level fronts in a time dependent deformation field. Prominent low-frequency, long-wavelength inertia gravity waves are generated in certain cases even though the deformation varies on a time scale which is long compared with the period of the waves.

The effect of two mathematical approximations on the wave solutions are investigated. The first approximation is a linearization about the balanced solution for the front and jet (where balance is defined by the geostrophic momentum approximation). This approximation amounts to neglecting advection of wave field by the wave field and results in a set of equations identical to that investigated by Snyder et al. (1993). The second approximation is commonly called the Lighthill approximation. In this case the equations are written in flux form and the fluxes approximated by their balanced equivalents. The theoretical motivation for this approximation is the work by Ford (1994), which is itself closely related to Lighthillś theory for the aerodynamic generation of sound (Lighthill, 1952).

The main results are as follows. (i) Like those commonly observed in the atmosphere, the modelled waves have frequencies close to the inertial frequency, horizontal wavelengths of order 200 – 400 km and vertical wavelengths in the range 2 – 10 km. (ii) Inertia gravity waves are generated by cross-front parcel accelerations provided by the balanced part of the solution. (iii) Both the linear and Lighthill approximations give very accurate solutions to the wave field. (iv) As a surface discontinuity forms, standing waves are generated at the leading edge of the front by the strong cross-frontal accelerations that develop.

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