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Inertia-gravity wave diffusion by geostrophic turbulence: the impact of flow time dependence

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The scattering of short inertia-gravity waves by large-scale geostrophic turbulence in the atmosphere and ocean can be described as a diffusion of wave action in wavenumber space. When the time dependence of the turbulent flow is neglected, waves conserve their frequency, which restricts the diffusion of energy to the constant-frequency cone. We relax the assumption of time independence and consider scattering by a flow that evolves slowly compared with the wave periods, consistent with a small Rossby number. The weak diffusion across the constant-frequency cone introduced by time dependence leads to a stationary energy spectrum that remains localised around the cone (specifically decaying as $1/\sigma^5$ with σ the angular deviation from the cone) corresponding to a small frequency broadening. We contrast our results with unbounded frequency broadening that arises for surface- or shallow-water waves.