



## **The interaction between synoptic-scale balanced flow and a finite-amplitude mesoscale wave field throughout all atmospheric layers: Weak and moderately strong stratification**

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The interaction between locally monochromatic finite-amplitude mesoscale waves, their nonlinearly induced higher harmonics, and a synoptic-scale flow is reconsidered, both in the tropospheric regime of weak stratification and in the stratospheric regime of moderately strong stratification. A review of the basic assumptions of quasi-geostrophic theory on an  $f$ -plane yields all synoptic scales in terms of a minimal number of natural variables, i.e. two out of the speed of sound, gravitational acceleration and Coriolis parameter. The wave scaling is defined so that all spatial and temporal scales are shorter by one order in the Rossby number, and by assuming their buoyancy field to be close to static instability. WKB theory is applied, with the Rossby number as scale separation parameter, combined with a systematic Rossby-number expansion of all fields. Classic results for synoptic-scale-flow balances and inertia-gravity wave (IGW) dynamics are recovered. These are supplemented by explicit expressions for the interaction between mesoscale geostrophic modes (GM), a possibly somewhat overlooked agent of horizontal coupling in the atmosphere, and the synoptic-scale flow. It is shown that IGW higher harmonics are slaved to the basic IGW, and that their amplitude is one order of magnitude smaller than the basic-wave amplitude. GM higher harmonics are not that weak and they are in intense nonlinear interaction between themselves and the basic GM. Compressible dynamics plays a significant role in the stratospheric stratification regime, where anelastic theory would yield insufficient results. Supplementing classic derivations, it is moreover shown that in the absence of mesoscale waves quasi-geostrophic theory holds also in the stratospheric stratification regime.