BOUNDARY EFFECTS IN POTENTIAL VORTICITY DYNAMICS

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ABSTRACT

Many aspects of geophysical flows can be described compactly in terms of potential vorticity dynamics. Since potential temperature can fluctuate at boundaries, however, the boundary conditions for potential vorticity dynamics are inhomogeneous, which complicates considerations of potential vorticity dynamics when boundary effects are dynamically significant.

A formulation of potential vorticity dynamics is presented that encompasses boundary effects. It is shown that, for arbitrary flows as for quasigeostrophic flows, the generalization of the potential vorticity concept to a sum of the conventional interior potential vorticity and a singular surface potential vorticity allows one to replace the inhomogeneous boundary conditions for potential vorticity dynamics by simpler homogeneous boundary conditions (of constant potential temperature). Functional forms of the surface potential vorticity are derived from field equations in which the potential vorticity and a potential vorticity flux appear as sources of flow quantities in the same way in which an electric charge and an electric current appear as sources of fields in electrodynamics. For the generalized potential vorticity of flows that need be neither balanced nor hydrostatic and that can be influenced by diabatic processes and friction, a conservation law holds that is similar to the conservation law for the conventional interior potential vorticity. The conservation law for generalized potential vorticity contains, in the quasigeostrophic limit, the wellknown dual relationship between fluctuations of potential temperature at boundaries and fluctuations of potential vorticity in the interior of quasigeostrophic flows. A non-geostrophic effect described by the conservation law is the induction of generalized potential vorticity by baroclinicity at boundaries, an effect that plays a role, for example, in mesoscale flows past topographic obstacles.

The generalized potential vorticity allows one to consider a mean potential vorticity balance in isentropic coordinates, including the surface layer of isentropes that sometimes intersect the surface. We discuss the relation between the mean potential vorticity balance and the momentum balance on near-surface isentropes, as well as fundamental differences between the mean potential vorticity balance in isentropic coordinates and the mean balance of potential vorticity in guasigeostrophic theory.

REFERENCES

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