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The emergence of jets and vortices in freely evolving, shallow-water turbulence on a sphere. (English) Zbl 1087.76057

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Summary: Results from a series of simulations of unforced turbulence evolving within a shallow layer of fluid on a rotating sphere are presented. Simulations show that the turbulent evolution in the spherical domain is strongly dependent on numerical and physical conditions. The independent effects of (1) (hyper)dissipation and initial spectrum, (2) rotation rate, and (3) Rossby deformation radius are carefully isolated and studied in detail. In the nondivergent and nonrotating case, an initially turbulent flow evolves into a vorticity quadrupole at long times, a direct consequence of angular momentum conservation. In the presence of sufficiently strong rotation, the nondivergent long-time behavior yields a field dominated by polar vortices – as previously reported by *S. Yoden* and *M. Yamada*. In contrast, the case with a finite deformation radius (i.e., the full spherical shallow-water system) spontaneously evolves toward a banded configuration, the number of bands increasing with the rotation rate. A direct application of this shallow-water model to the Jovian atmosphere is discussed. Using standard values for the planetary radius and rotation, we show how the initially turbulent flow self-organizes into a potential vorticity field containing zonal structures, where regions of steep potential vorticity gradients (jets) separate relatively homogenized bands. Moreover, Jovian parameter values in our simulations lead to a strong vorticity asymmetry, favoring anticyclonic vortices-in further agreement with observations.

MSC:

76F99 Turbulence
76U05 General theory of rotating fluids
85A20 Planetary atmospheres

Keywords:

dissipation; Rossby deformation radius; Jovian atmosphere

Full Text: DOI

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