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Jets and geostrophic turbulence: Spherical geometry vs the beta-plane

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We consider the evolution of forced two-dimensional turbulence on the surface of the sphere. In particular, we examine the extent to which the development of flow anisotropy and zonal jets are controlled by two separate effects, (i) the latitudinal variation of the background planetary vorticity gradient and (ii) the latitudinal variation of the Rossby radius of deformation. On the beta-plane, scaling arguments predict a dependence on beta (in conjunction with some form of large-scale friction) of the length scale and intensity of zonal jets, and this dependence has been observed recently in various numerical studies of beta-plane turbulence. These results suggest that in spherical geometry a transition latitude will exist separating an isotropic flow regime at high latitudes from an anisotropic flow regime at low latitudes.

We present the results of high resolution numerical experiments designed to examine the above behavior in more detail. Two systems of equations are considered: (i) the equivalent barotropic system, which is the simplest system in which both beta and Rossby radius vary with latitude; and (ii) the shallow water equations, in which beta and Rossby radius vary in the same way as in the equivalent barotropic model, but which also allows for divergent flows and provides a more realistic representation of the dynamics at low latitudes. The flow is forced stochastically at small scales and energy is dissipated at large scales by a scale-selective hypodiffusion to allow a statistically stationary state to be reached. In addition to the question of the latitudinal dependence of the anisotropy of the stationary flow, we also consider regimes in the two-dimensional parameter space spanned by Rossby and Froude numbers that have been previously unattainable due to prohibitive computational costs.