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The latitudinal dependence of atmospheric jet scales and macroturbulent energy cascades

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The latitudinal width of atmospheric eddy driven jets and scales of macroturbulence are examined latitude-by-latitude. In order to isolate the eddy-driven jets, we use a high resolution idealized GCM and systematically vary the rotation rate of the planet up to 16 times Earth's rotation rate. We find that for each latitude through all rotation rates the jet spacing scales with the Rhines scale. These simulations show the presence of a "supercritical latitude" within the baroclinic zone, where poleward (equatorward) to this latitude the Rhines scale is larger (smaller) than the Rossby deformation radius. Poleward to this latitude a classic 2D turbulence picture appears: the zonal spectrum of the barotropic eddy kinetic energy shows a -5/3 slope of inverse cascade from the deformation radius up to the Rhines scale. A shallower slope than the -3 slope of enstrophy cascade is found from the deformation radius down to the viscosity scale, due to the broad input of baroclinic eddy kinetic energy. At these latitudes eddy-eddy interactions play a major role in transferring barotropic eddy kinetic energy from the scales where baroclinic eddy kinetic energy is converted to barotropic eddy kinetic energy, up to the jet scale and down to the viscosity scale. Furthermore, at these latitudes, the length scale of the energy-containing zonal wavenumber coincides with the jet scale. For the Earth case, this latitude is outside the baroclinic zone and therefore often an inverse cascade does not appear, but for higher rotation rates this latitude is placed inside the baroclinic zone and hence can be examined in our model. Equatorward to the "supercritical latitude" the -5/3 slope of inverse cascade vanishes, eddy-mean interactions play an important role in the balance, and the spectrum follows a -3 slope from the Rhines scale down to the viscosity scale, similar to what is observed on Earth. Moreover, the length scale of the energy-containing zonal wavenumber is larger than the jet scale at these latitudes. Thus, other mechanisms than turbulence cascade should explain why the jet and the Rhines scales coincide even at these latitudes. In addition, even though the Rossby deformation radius plays a major role in predicting the latitude where inverse cascade does and does not occur, it does not coincide with the scale of conversion from baroclinic to barotropic eddy kinetic energy.