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On jet sharpening and the equilibration of meridional-asymmetric barotropic instability

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Jet sharpening is a robust and persistent process which is inherent to jet formation and maintenance in a wide range of geophysical flows. Its resilience against the action of vortices stems from a positive feedback of the potential vorticity-flow invertibility relation. Most idealized studies of jet sharpening have examined jet sharpening in the presence of prescribed potential vorticity (PV) anomalies, in which this positive feedback is most easily understood. This study examines the equilibration and sharpening of a barotropically unstable jet, by eddies which arise spontaneously on it. We construct the simplest model of an unstable jet in which sharpening can occur - a beta- plane QG barotropic fluid with a zonal strip of negative vorticity, alongside a two-step increase of vorticity to its north. This configuration can be sharpened by the narrowing of the gap in the positive vorticity jump. An extensive parameter sweep allows us to determine how the basic state vorticity and jet structure, in particular the gap structure, and the eddy kinetic energy and wavenumber, depend on the initial negative PV jump and gap width and on beta. We find three evolution states: The initial barotropic instability ends in the breakup-up of the negative PV strip into vortices. In the second stage, the vortices drift away from the remaining adjacent positive PV jumps, and while they deform and break up due to vortex shearing/colliding/merging, the vorticity interfaces becomes wavy, with increasing wavelength and the gap between them narrows. This stage nicely shows the upscale energy cascade in the waves, alongside the downscale vorticity cascades in the vortices. In the final stage, the remaining interface waves evolve forming intricate PV filamentation patterns. Furthermore, we make use of the simplicity of the problem to develop a theory relating the properties of the equilibrated flow to the initial flow state, making use of marginal stability together with conservation of circulation and wave activity.