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Stable flows that maximize or minimize energy

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In general, flows that maximize or minimize the energy in a set of isovortical flows are stationary and stable. (Two flows are isovortical if one can be obtained from the other by an incompressible deformation of the PV-field.) For example, in ideal, two-dimensional flow, a circular vortex with a monotonic vorticity profile is a maximum energy flow, and therefore stable.

This analysis can be extended to localized vortices in more complex flows. Rigorous proofs have been found for the existence of large classes of stable and localized vortex solutions in external shear flows, both for ideal two-dimensional flow and for three-dimensional quasigeostrophic flow. The vorticity anomaly of the vortex must have the same sign as the background shear, in agreement with numerous observations in nature, in laboratory experiments, and in numerical simulations.

More recent applications concern flows above nonuniform topography. For barotropic flow at an isolated seamount, it has been shown that a large class of stable and stationary attached anticyclones exists. Those with positive potential vorticity (PV) are maximum energy flows, while those with negative PV are minimum energy flows. If the seamount is circular there are also stable cyclones, but these are destabilized by noncircularities in the topographic shape, unlike the anticyclones. Analogous results also hold for basin-scale flows, with possible applications to the circulation in the Arctic basin.