A minimal model of stratospheric vacillations

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A new, low-order model of the variability of the Arctic polar vortex has been derived in the context of a shallow-water contour dynamics representation of quasigeostrophic shallow water flow on a polar f-plane. The model consists of a single linear wave mode propagating on a near-circular patch of constant potential vorticity (PV). The PV jump at the vortex edge serves as an additional degree of freedom. The wave is forced by surface topography, and interacts with the vortex through a simplified parameterization of diabatic wave/mean flow interaction.

The resulting system of three coupled ODEs depends on four non-dimensional parameters, and the structure of the steady state solutions can be determined analytically in some detail. The system exhibits a range of dynamical behaviour closely related to that of the Holton-Mass model, including multiple steady states corresponding to weak and strong vortex states, and dynamically active limit cycles.

One key insight from the model is that, in dynamically active parameter regimes, the time-mean state of the vortex is predominantly controlled by the properties of the Rossby wave mode, while the strength of the topographic forcing plays a far weaker role.