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A (not so) empirical definition of the stratospheric polar vortex boundary

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The stratospheric polar vortex (SPV) is a major feature of the winter and early-sprig circulation of the middle atmosphere. Strong mixing and filamentation occurs around the SPV, in a region which is referred to as the surf-zone. Recent work has indicated that similar processes also occur in the SPV core. The location of the boundary between the SPV and the surf-zone has been estimated by using several methods with results that have been very useful. In general, however, the methods have been justified by using empirical arguments.

The present paper introduces a definition of the kinematic boundary of the SPV based on Lagrangian properties of the flow. These properties are represented by a Lagrangian Descriptor (hereafter "M"), which is defined at every point and time t as the length of the trajectory that a fluid parcel passing through the point at time t travels in the interval (t-τ, t+τ). Binning the parcels on an isentropic (or constant height) surface according to their values of M gives a probability density function (pfd) of which the highest values correspond to the jet. Numerical experimentation reveals that filamentation is minimum in the region corresponding to values of M approximately in the upper 94 per cent of the pdf. The contours in a map of M that limit this region can, therefore, be defined as the SPV vortex boundary at time t with the outer boundary representing the poleward edge of the surf zone.

Moreover, working in the idealized framework of a kinematic model (KM) that aims at emulating the behavior of the longest planetary waves on an isentropic (or constant height) surface reveals a remarkable property: The values of M/2τ for a periodic flow converge when τ-$\longrightarrow \infty$ if the parcels are selected within the vortex boundary defined as above. According to the Birkhoff ergodic theorem, this convergence means that contours of M within the vortex boundary are formed by the same parcels as the flow evolves in time, and that therefore the special contours that bound such a boundary are barriers to the flow. The outer contour, therefore, provides a location of the poleward edge of the surf zone that can be rigorously justified albeit some uncertainty remains from the choice based on the pdf of M. Fluid parcel and filamentation at this edge will be illustrated in the framework of the KM model.

The Birkhoff ergodic theorem has not been proven for aperiodically time dependent velocity fields. Therefore, for realistic cases, there is not rigorous support at the present time for the definition of kinematic vortex boundary as given by contours of M and associated pdf. However, trajectories and filaments computed by using Reanalysis data show that the methodology is useful in the time scales of interest to middle atmosphere dynamics.