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Optimally coherent sets in geophysical flows, with an application to delimiting the stratospheric polar vortex

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We present a new numerical method of transport analysis for time-dependent dynamical systems, based upon ergodic-theoretic considerations. Our new approach can detect and track coherent structures: global minimum transport structures that disperse much more slowly than one might expect from the average rate of chaotic local trajectory sepration. We apply our new technique to European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-40 three-dimensional velocity data and produce an improved three-dimensional estimate of the location and internal structure of the Antarctic polar vortex. This novel computational approach has wide potential application in detecting and analysing mixing structures in a variety of atmospheric, oceanographic, and general fluid dynamical settings.