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Using finite-time Lyapunov exponents to investigate the effect of stratospheric sudden warmings on the polar vortices

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Finite-time Lyapunov exponents are often used to measure mixing in the stratosphere and have been used to investigate the horizontal transport of trace gases near the polar vortices. A better understanding of the dynamics of the polar vortices should provide insight into the circumstances under which odd nitrogen and hydrogen produced by energetic particle precipitation (EPP) in the mesosphere and lower thermosphere (MLT) can be transported to lower levels of the atmosphere.

A climatology of finite-time Lyapunov exponents for isentropic surfaces in the stratosphere ranging from 550-2300K for both the northern and southern hemispheres has been created for the observational period of the EOS-MLS instrument.The Lyapunov exponents are derived by using output from a Lagrangian trajectory model forced by data from the MERRA reanalysis. They are calculated at each point on a 2˚x 4˚ global grid by running trajectories for two neighbouring parcels which are initially 1km apart and measuring their separation after a period of time. In order to ensure that the parcel trajectories remain close enough to each other for the exponents to be a good measure of local mixing, the distance between the parcels is periodically reset to 1km. In order to provide a consistency check Lyapunov exponents and trajectories have also been calculated at 550K using NCEP/NCAR reanalysis data. Initial comparisons suggest that the qualitative agreement is quite good between the results using the two different reanalyses.

Comparison of the variations in the Lyapunov exponents and trace gas distributions using EOS-MLS data during periods where the stratospheric polar vortices are undisturbed and periods which are disturbed by stratospheric sudden warmings are also discussed. Studying how stratospheric sudden warmings (SSWs) affect the atmospheric dynamics in polar regions is particularly worthwhile since recent studies have shown that they have a significant modulating influence upon the EPP indirect effect in the stratosphere. Variations in the impacts of planetary waves on the position and strength of the polar vortices in the middle and upper stratosphere will also be discussed. Differences between the generally undisturbed Southern hemisphere vortices and the dynamically disturbed Northern hemisphere vortices will also be detailed.