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Studies of Mixing Barriers in the Stratosphere using Renyi Entropy

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This study examines how the Renyi entropy (RE) statistical measure can, by application to long-lived atmospheric tracer data, be used to understand stratospheric mixing processes. Combining a high number of dynamical degrees-of freedom with non-linear feedbacks, predicting such atmospheric evolution has traditionally presented a significant signal-to-noise challenge. Due to the significant impact of the Antarctic polar vortex, we focus on the southern hemisphere stratosphere as a suitable test case for the new technique. Daily gridded data, for the years 1980 and 1981, are obtained from a control integration of the chemistry-climate-model (CCM) SOCOL. Methane (CH4) is chosen as a representative long-lived tracer. The analysis is repeated using Earth Observing System Microwave Limb Sounder (EOS MLS) satellite measurements of nitrous oxide (N2O) for the same period.

RE can be considered to be a measure of the inhomogeneity of a dynamical system. The strong polar vortex in the southern hemisphere leads to significant inhomogeneity in the distribution of stratospheric tracers. It separates the cold polar winter air from warmer mid-latitude air. Its intensification in austral autumn severely restricts meridional mixing, thereby creating a gradient in tracer concentrations. This ultimately also contributes to the magnitude of the Antarctic Ozone Hole. Our RE methane analysis successfully identifies the seasonal build up and breakdown of the barrier to meridional, stratospheric mixing. Compared to previous work, RE has the significant benefit that it is data driven and requires considerably less computational effort. Application of the technique to observed MSL N2O data show qualitatively similar, though less distinct, high-entropy mixing barriers. The increased signal strength in the CCM data is attributed to an artificially strong, modelled meridional temperature gradient (common "cold pole" problem). This initial study suggests that RE has a significant potential as a quantitative measure for analyzing mixing in the atmosphere.