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Tropospheric Precursors of Sudden Stratospheric Warmings: Data-Constrained Simulations

Lisa Neef and Katja Matthes

Helmholtz Centre for Ocean Research Kiel GEOMAR, Ocean Circulation and Climate Dynamics – Marine Meteorology, Kiel, Germany (lneef@geomar.de, +49 331 288-1163)

The external factors that cause sudden stratospheric warmings to occur in the Northern Hemisphere are not yet entirely understood. For example, recent studies have found that the Madden Julian Oscillation in tropical weather influences the occurence of sudden warmings, but the number of observed warmings is so small that it is difficult to establish statistical significance. Studies that focus on single sudden warming events generally rely on reanalysis data and are therefore unable to separate the different factors influencing sudden warmings. On the other hand, studies that composite over many warming events in a climate model simulation can be difficult to interpret because individual events vary greatly from one another in their precursors, magnitude, downward-propagation, and lifecycle.

We present a modeling framework that makes it possible to study individual winters by constraining the model's dynamical variables to observations using an Ensemble Kalman Filter. The ensemble filter is advantageous because it gives not just an estimate of the atmospheric state, but also of the probability distribution of the state variables, conditioned upon the available meteorological observations. We show that the tropical precursors of sudden warmings can be observed in variations in the rotation rate of the Earth, while extratropical precursors can be observed in variations in polar motion. This makes it possible to evaluate the degree to which observations are able to truly constrain the winter precurors of sudden warmings, by comparing the model's atmospheric angular momentum to observations of Earth rotation parameters.