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The Seasonal Timing of Stratospheric Sudden Warmings

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We aim to diagnose causes for the differences in the seasonal distribution of stratospheric sudden warmings (SSWs) between reanalysis and models. Observations over the past 60 years indicate that most SSWs occur during mid-winter (January), but climate models tend to simulate the maximum number of SSWs during late-winter or early-spring. This discrepancy has led to the speculation that models might be flawed and that the simulation of a January maximum represents a measure of model performance. However, the relatively short observational record and rare occurrence of SSWs also implies considerable uncertainty in the observation derived result. The goal of this work is to understand the seasonal distribution of SSWs using a simple statistical model, to test the model using a variety of data sets, and to answer the questions when SSWs are most likely to occur and what the reasons for it are. Our analysis is based on Charlton and Polvani's (2007) criteria for SSWs and on the assumption that the polar vortex wind approximately follows a normal distribution. The statistical model successfully predicts the day-to-day variations in the empirically derived occurrence frequency of SSWs, demonstrating that the seasonal distribution of SSWs can be almost entirely understood in terms of the climatological seasonal cycle of the polar vortex wind. The statistical model indicates that the maximum frequency of SSWs in climate models and reanalysis occurs during late-winter, and not during mid-winter as implied by the observations. This strongly suggests that sampling uncertainty is responsible for the January maximum seen in the reanalysis and that the simulation of a January maximum does not represent a metric of model performance. The reason for the late-winter maximum is the decreasing strength of the polar vortex, making it more likely that the winds of the polar vortex reach the zero-threshold required by the WMO definition for SSWs. This further suggests that climatological January maximum of planetary wave propagation from the troposphere into the stratosphere does not explain the seasonal distribution of SSWs.