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Tropospheric impact of Sudden Stratospheric Warmings in Central and Eastern Europe

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The North Hemisphere winter stratosphere is frequently affected by large and rapid temperature increases, known as Sudden Stratospheric Warmings (SSWs). The strongest and most spectacular events, known as the Major Mid-Winter Warmings, cause a temporary reversal of climatological westerly zonal mean winds and, in some cases, even the breakup of the stratospheric polar vortex into several smaller vortices. The following downward propagation of stratospheric anomalies to the upper and middle troposphere has been associated with significant weather anomalies resembling a negative Northern Annular Mode (NAM) regime over Eurasia and North America. These events are often involved in winter weather extremes in Northern Hemisphere, therefore a better understanding of their occurrence and development could be helpful for the improvement of medium term forecast of extreme meteorological conditions.

In order to assess the impact of Sudden Stratospheric Warmings on surface weather conditions in central and eastern Europe, all major SSW events identified in the period 1979 – 2020 were classified in 5 major types using a k-means cluster analysis method. Then, in order to determine the changes in tropospheric circulation as an effect of each SSW, we identified the main weather circulation types in Europe by performing a cluster analysis of 500 hPa geopotential height and sea level pressure. After that, the changes in frequencies of these types, as well as the mean composite anomalies of the two aforementioned parameters were assessed. This has been done for three intervals: one month before and two months after a SSW event. The surface and lower troposphere impact was studied using the mean composite anomalies of several parameters: 2 m temperature, total precipitation amount, snowfall and snow depth, for the same intervals.

The results show a great deal of variability in the surface effects of SSW events. The general impact of SSW events consisted in a tendency towards a diminishing of the frequency of westerlies, and a subsequent increase in the frequency of both Mediterranean cyclones and high latitude blocking conditions, with their associated temperature and precipitation anomalies. Also, a second major output of the study indicates that in central and eastern Europe these SSW events lead to harsh winter conditions in 30% of cases, but also to abnormal warm winters intervals in other 25% of cases, depending on the type of the SSW. However, some events show a less marked impact on tropospheric weather, while other SSW do not propagate from the stratosphere to the upper and middle troposphere. Taking into account the type and characteristics of each SSW might significantly increase the predictability of their tropospheric effects.