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Some statistics of sudden stratospheric warmings and effects of the warmings on stratospheric NO_2 and total ozone

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NCEP-NCAR, ERA 40 and ERA-Interim reanalysis data of temperature and wind velocity are used to identify major and minor sudden stratospheric warmings (SSWs) in the Northern hemisphere and derive statistics of SSW for 1958-2015. Data of ground-based spectrometric measurements of stratospheric column NO_2 contents (SC NO_2) at a few mid- and high-latitude NDACC stations, data of OMI total ozone (TO) measurements, and ERA-Interim reanalysis data of stratospheric temperature for the last two decades are analyzed jointly to study effects of major SSWs on these parameters. The dependence of major and minor SSWs on the phase of the quasi-biennial oscillation (QBO) in the equatorial stratospheric wind and the phase of solar activity is analyzed. The occurrence of the major SSWs of split stratospheric vortex type do not depend on QBO or solar activity, while the major SSWs of displacement vortex type are more frequent during the east phase of the QBO and during enhanced solar activity. Contrary to the latter, minor SSWs are more frequent for the west QBO phase and for low solar activity. Major SSWs affect significantly the stratospheric polar vortex. During major SSWs of displacement vortex type, the vortex is usually shifted toward the longitudinal sector 60°W–120°E. During major SSWs of split vortex type, the fragments of the polar vortex are more frequently located in longitudinal sectors 120°W–30°W and 0°–120°E. Analysis of SC NO_2, TO and stratospheric temperature during major SSWs shows that: (1) The shift of the polar vortex aside from the pole during SSWs can result in significant negative anomalies in SC NO_2, TO and stratospheric temperature over West Europe. For example, the SC NO_2 decreased by 40 percent during the SSW on February 9, 2010. (2) Significant increase in SC NO_2, TO and stratospheric temperature can be also observed during SSWs, which is caused by transport of stratospheric air from lower latitudes. For example, TO and the SC NO_2 over Zvenigorod (Moscow region) increased by 85 percent and 50 percent respectively during the 2010 SSW. (3) If the border of the vortex is above a measurement site, no significant changes in SC NO_2, TO and stratospheric temperature are usually observed, and the changes in the three parameters may differ in sign. NO_2 observations at Zvenigorod allow retrieving NO_2 vertical profiles. In particular, analysis of changes in the NO_2 profiles during SSWs shows altitude-dependent variations of NO_2 concentration related to highly changeable vertical structure of the Arctic polar vortex during major SSWs, feature of denitrification inside the vortex, and arrival of NO_2-rich stratospheric air from the low latitudes.