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Residual Circulation and Temperature Changes during the Evolution of Stratospheric Sudden Warmings Revealed in MERRA

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A composite analysis for 21 stratospheric sudden warming (SSW) cases in 1979–2012 northern winter is performed using the MERRA reanalysis in order to investigate the changes in residual circulation and temperature during the SSW evolution. The SSW cases are classified as Type-1 and Type-2, based on the relative amplitude of planetary waves with zonal wavenumbers 1 and 2. The residual circulation induced by each forcing term in the transformed Eulerian mean (TEM) equation and the temperature advection associated with the circulation are calculated for both types of SSW. It is found that strong poleward and downward motion exists in the polar stratosphere just before the central date of SSW, which is induced primarily by the Eliassen–Palm flux divergence forcing (EPD). Gravity-wave drag (GWD) induces strong poleward and downward motion in the lower mesosphere. The temperature advection is significantly increased in the stratosphere before the central date of the SSW, as a result of the strong downward motion due to the EPD. However, the temperature change in the lower mesosphere is small despite the strong downward motion, because the vertical gradient of the potential temperature is relatively small at these altitudes. The temperature change in the stratosphere before the SSW is more rapid for Type-2 than Type-1. After the central date of SSW, the polar stratospheric temperature is recovered primarily by diabatic heating rather than by the residual circulation associated with wave forcing. Difference in the speed of temperature recovery between the two types of SSW is not significant.