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

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Contributions of planetary and gravity waves to the meridional circulation and temperature change during the evolution of stratospheric major sudden warming (SSW) are investigated by composite analyses of 22 SSW events in 1979–2012 during the northern hemisphere winter (November–March) using the MERRA reanalysis data. The SSW events are classified as Type-1 and Type-2, based on the relative amplitude of planetary waves with zonal wavenumbers 1 and 2. The residual mean meridional circulation induced by each forcing term in the transformed Eulerian mean (TEM) momentum 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 just before the central date of SSW, which is induced primarily by the Eliassen–Palm flux divergence forcing (EPD). Gravity wave drag (GWD) and residual term of the TEM momentum equation induce smaller contribution to the residual circulation than EPD. The circulation induced by wind acceleration term partially cancels the effects of the EPD. The downward motion in the polar stratosphere is stronger for Type-2 than Type-1 around lag = 0, and it is primarily due to EPD. GWD is enhanced during lag = -15 day and -8 day exclusively for Type-2 SSW, and it leads to increase downward motion in the upper stratosphere before the onset of SSW. Adiabatic warming induced by mean downward motion owing to EPD increases the temperature in the polar stratosphere significantly before lag = 0, while adiabatic warming in the lower mesosphere is not large, despite the strong downward motion, because of relatively weak static stability. During lag = -15 day and -8 day, Type-1 SSWs show sharp temperature rise, compared with Type-2 SSWs, due to stronger temperature advection by EPD, while it is opposite during lag = -5 day and 0. After lag = 0, the polar stratospheric temperature is recovered primarily by diabatic heating rather than by the residual circulation associated with wave forcing.

Key words: stratospheric sudden warming, planetary wave, gravity wave