Stratospheric front-like structure and characteristics of gravity waves during a stratospheric sudden warming event in 2016

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A large-scale front-like structure, a boundary where the horizontal gradient of temperature is significantly large, is observed in the Arctic stratosphere during a stratospheric sudden warming (SSW). Previous studies report that the stratospheric front is formed near the polar vortex edge and vertically tilts westward (Fairlie and O'Neill 1988; Manney et al. 1994, 2005). It is also shown by a numerical simulation that upward-propagating gravity waves (GWs) are generated near the front (Fairlie et al. 1990). However, a mechanism for the frontogenesis and how GWs are generated near the front are poorly understood, partly due to the lack of observational studies. In order to reveal the behavior and formation mechanism for the stratospheric fronts, we investigate the case observed during wavenumber-1 SSW event in 2016. We also examine the characteristics of GWs in the Arctic winter stratosphere and discuss the relationship between the front and the GWs.

First, a synoptic-scale structure in the stratosphere is analyzed by using MERRA-2 reanalysis data. A few days prior to the major warming, the stratospheric front is the strongest in the pressure range between 30 and 3 hPa, namely with a depth of about 15 km (i.e. 24–39 km). An elongated region with a quite high temperature appears in the boundary between the cyclone and the anticyclone. A strong front is formed in the polar vortex side of the boundary. In the middle to upper stratosphere, quasi-geostrophic potential vorticity (PV) has a characteristic structure in which an elongated low PV anomaly is located close to a high PV anomaly surrounded by the polar vortex edge. The high PV anomaly is maximized near the polar vortex edge rather than the vortex core. This narrow PV structure may be associated with a large horizontal gradient of temperature. It seems that the low PV anomaly results from an intrusion of low PV air into the higher latitude region from the lower latitude region due to planetary wave breaking. Second, temperature perturbations associated with GWs are extracted by applying a highpass filter to individual vertical profiles of dry temperature data from FORMOSAT-3/COSMIC satellite. The cutoff wavelength of 6 km is used for the highpass filter to avoid the contamination from the front-like structure with the vertical scale of about 15 km. The GW amplitude averaged between 25 and 35 km is maximized a few days prior to the major warming. It is also shown that the GW amplitudes are larger near the front and rather smaller in the vortex core. The vertical wavelength of the GW is estimated from 1D-Stockwell transform (S-transform) for the temperature data, indicating that the S-transform spectra have a peak around 4–7 km in the vertical range between 25 and 35 km. These results indicate that the GW activity in the Arctic stratosphere is enhanced when the front-like temperature structure associated with SSW event is strongest.

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