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Formation of the double stratopause and elevated stratopause associated with the major stratospheric sudden warming in 2018/19

Haruka Okui[1], Kaoru Sato[1], Dai Koshin[1], and Shingo Watanabe[2]
[1]Department of Earth and Planetary Science, The University of Tokyo, Tokyo, Japan (okui@eps.s.u-tokyo.ac.jp)
[2]Japan Agency for Marine–Earth Science and Technology, Yokohama, Japan

After several recent stratospheric sudden warming (SSW) events, the stratopause disappeared and reformed at a higher altitude, forming an elevated stratopause (ES). The relative roles of atmospheric waves in the mechanism of ES formation are still not fully understood. We performed a hindcast of the 2018/19 SSW event using a gravity-wave (GW) permitting general circulation model containing the mesosphere and lower thermosphere (MLT), and analyzed dynamical phenomena throughout the entire middle atmosphere. An ES formed after the major warming on 1 January 2019. There was a marked temperature maximum in the polar upper mesosphere around 28 December 2018 prior to the disappearance of the descending stratopause associated with the SSW. This temperature structure with two maxima in the vertical is referred to as a double stratopause (DS). We showed that adiabatic heating from the residual circulation driven by GW forcing (GWF) causes barotropic and/or baroclinic instability before DS formation, causing in situ generation of planetary waves (PWs). These PWs propagate into the MLT and exert negative forcing, which contributes to DS formation. Both negative GWF and PWF above the recovered eastward jet play crucial roles in ES formation. The altitude of the recovered eastward jet, which regulates GWF and PWF height, is likely affected by the DS structure. Simple vertical propagation from the lower atmosphere is insufficient to explain the presence of the GWs observed in this event.