Dynamical characteristics of the middle atmosphere associated with the Antarctic sudden stratospheric warming in 2019.

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In September 2019, a strong sudden stratospheric warming (SSW) occurred in the Antarctic. The size of the ozone hole, which is greatly affected by the temperature in the lower stratosphere, was as small as in the 1980s, and its maximum area was smaller than that of Antarctica for the first time in 30 years. We report the dynamical characteristics of this SSW.

First, planetary waves with strong heat fluxes entered into the stratosphere after around August 20. This heat flux intrusion was followed by a sudden increase in the zonal mean temperature averaged over 60 S-90 S at 10 hPa (corresponding to an altitude of about 30 km) around August 22. The temperature was maximized around September 16. Simultaneously, the zonal mean zonal wind at 60 S was significantly weakened to 15 m/s at 10 hPa. The zonal mean zonal wind did not become negative, and hence did not meet the criteria for the major SSW. However, as the zonal mean zonal wind averaged over the past 40 years is about 74 m/s there, the decrease in the zonal wind amounts to nearly 60 m/s. If the same zonal wind weakening occurred around October 1, the criteria for the major SSW would have been met.

What is interesting about this event is that barotropic instability had frequently occurred around 10 hPa since mid-September. Barotropic instability is a phenomenon that is sometimes seen in the upper stratosphere and mesosphere, but rarely occurs at 10 hPa. The characteristics are described by using Ertel's potential vorticity (PV). The maximum of the zonal mean |PV| (absolute value of PV) was frequently observed in the range of 70 S to 80 S in the middle stratosphere, and often extended down to the 850 K isentropic surface corresponding to 10 hPa. Time evolution of the horizontal structure of the PV in the polar stereo maps was examined. It is seen that the high |PV| of the polar vortex was strongly deformed by the planetary waves and stretched like a string surrounding the polar vortex and toward low latitudes. Then, the string-like high |PV| was split into many vortices which subsequently developed. These features are a typical barotropic instability.

Next we examined the EP flux in the meridional cross section. The upward EP flux from the troposphere did not converge around 60 S, which is the central latitude of the polar night jet, but went toward low latitudes and converged in a pressure level of 30 hPa (~23 km) to 5 hPa (~35 km). It is considered that the EP flux toward low latitudes is accompanied by the barotropic instability. At 10 hPa, 30 S, which is the center of the EP flux convergence area, a strong westward jet exceeding 20 m/s was formed.

As such, this Antarctic SSW event exhibits an interesting time evolution: Due to the barotropic instability that frequently occurred during the SSW event, the planetary waves did not efficiently decelerate the polar night jet and then the stratospheric condition did not reach the major SSW. Instead, a strong westward jet was formed in the mid-latitudes of the middle stratosphere.

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