The analysis of extreme tropopause fold events at Syowa Station in the Antarctic

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Rapid and deep descent in the tropopause (the so-called tropopause folding) is often observed in association with the strong cyclonic disturbances in the extra-tropics. It is considered that such tropopause fold significantly contributes to the stratosphere-troposphere exchange (Sprenger et al., 2003). The frequency of deep tropopause folds (TF) is maximized along the coast of Antarctica from reanalysis data in previous studies (Škerlak et al., 2015). However, the dynamical processes of TF in the Antarctic region have not yet been studied adequately. In the present study, the dynamics of TF around Syowa Station (39.6°E, 69.0°S) are examined using the state-of-art reanalysis data (ERA5) for January 2000 to December 2018.

The dynamical tropopause defined as the potential vorticity (PV) surface of -2 PVU is examined in this study. We focused on extreme TF events at Syowa Station, which were defined as the time periods during which the tropopause height descends to less than 4 km. To remove ambiguity of the tropopause height owing to possible multiple tropopause structure, the lowest altitude of the PV surface connected to the stratosphere is regarded as the tropopause height in the present study. It is found that, in more than 80% cases of the extreme TF events at Syowa Station, the tropopause descends from the southeast of Syowa Station. To obtain statistically significant characteristics of the extreme TF events, we performed composite analyses of the extreme TF events. Each TF event is aligned in time such that T=0 corresponds to the timing of the lowest tropopause height. Fluctuations associated with transient eddies are extracted with a high-pass filter with a cut-off period of 10 days.

Figure 1a shows a latitude-height section of a composite of PV fluctuation components at 39.5°E at T=0 together with the dynamical tropopause height (z_{PV}). The negative anomaly ranges from 2 km to 12 km altitude and from 68°S to 75°S, which corresponds to the folding structure of the tropopause. Figure 1b shows the horizontal cross-section of a composite of z_{PV} fluctuation component. It is found that TF extends from 32°E to 55°E along the coast of Antarctica. Figure 2a shows a composite map of geopotential height and zonal wind at 500hPa at T=0. A local westerly jet is observed along with a low-pressure system centered at 70°S. Figure 2b shows a map of Q vector and its divergence at 500hPa at T=0. It is clear that the Q vector is equatorward on the northwest side of the center of the low-pressure system. The divergence field of the Q vector in 69-71°S, 36-41°E indicates the existence of downward ageostrophic flow, which accords well with the location of the minimum of z_{PV} at 70°S, 35-40°E. Therefore, the development of TF can be explained, at least qualitatively, in the framework of quasi-geostrophic flows.

We will also show the results of a quantification of downward flow associated with dynamical processes and diabatic processes using a quasi-geostrophic omega equation.

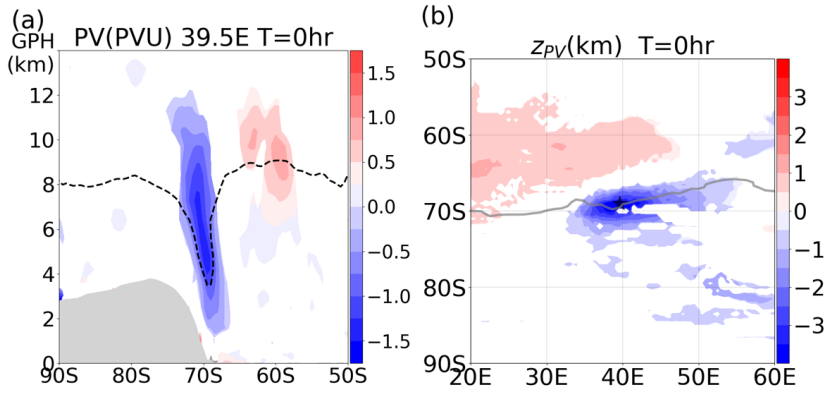

Fig. 1 Composites at T=0h. (a) Latitude-height section of PV fluctuations (color; PVU) at 39.5°E. The dashed line indicates z_{PV}. The grey hatch indicates the Antarctic continent. (b) The horizontal cross-section of fluctuations of z_{PV}. The gray curve denotes the coast of Antarctica. The shading is statistically significant at a 95% confidence level.

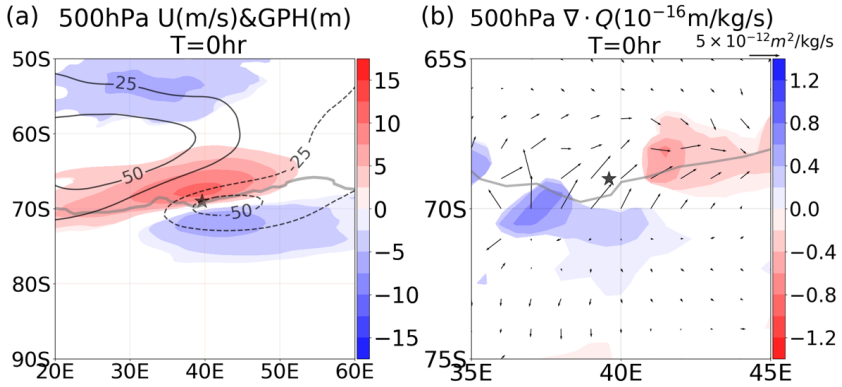

Fig.2 Composites at 500hPa, T=0h. (a) wind speed (colored ; m/s) and geopotential height (contour ; m), and (b) Q vector (vector) and its divergence (colored ; 10^{-16} m/kg/s). Gray curves indicate the coast of Antarctica. Stars mark denotes the location of Showa Station. The shading is statistically significant at a 95% confidence level.

References

Sprenger, M., Croci Maspoli, M., and Wernli, H., Tropopause folds and cross-tropopause exchange: A global investigation based upon ECMWF analyses for the time period March 2000 to February 2001, J. Geophys. Res., 108, 8518, 2003, doi:10.1029/2002JD002587, D12.

Škerlak, B., Sprenger, M., Pfahl, S., Tyrlis, E., and Wernli, H., Tropopause folds in ERA-Interim: Global climatology and relation to extreme weather events. J. Geophys. Res. Atmos., 120, 4860–4877, 2015, doi:10.1002/2014JD022787.