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# Horseshoe-shaped temperature structure around the tropical tropopause, and its relationship to deep convection

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Tropical tropopause temperature is one of the most important factors which control the dehydration mechanism of air entering the lower stratosphere from the upper troposphere. Around the tropical tropopause during Northern Hemisphere (NH) summer and Southern Hemisphere (SH) summer, we usually see a 'horseshoe' shaped zonally asymmetric structure in the equatorial temperature field; cold anomalies on the equator extend to north-west and south-west, surrounding warm anomalies in the west of it. They are theoretically interpreted as the Matsuno-Gill pattern, which is induced by near equatorial diabatic heating such as due to convective activity (Highwood and Hoskins, 1998).

In spite of possible influence of such a horseshoe-shaped temperature structure on stratosphere-troposphere exchange, its longitude and time variations have not clearly documented yet. In this study, using the ERA-40 temperature data at 100hPa and the outgoing longwave radiation (OLR) data for the proxy of deep convection for about 23 years, we have investigated the variability of such a horseshoe-shaped temperature structure, and its relationship to deep convection.

Paying attention to this structure, we define two indices: the HorseShoe Index (HSI) as the meridional temperature difference between the subtropics and the equator, and the zonal gradient index of temperature (Tgrad) as the longitudinal temperature difference on the equator. When a negative Tgrad locates in the east of a negative HSI, the horizontal distribution of cold anomalies would represent a horseshoe shape. Longitude-time sections for each of HSI and Tgrad averaged over 23 years for each month show two prominent minima in NH summer (June-October) around the Indian Ocean and in SH summer (December-May) around the western Pacific.

Using 5-20 day and 20-80 day band-pass filtered daily data, we calculated correlation coefficients between each of HSI, Tgrad and OLR, because Kelvin waves with periods of around 10-20 days and intraseasonal oscillations (ISOs) with periods of around 20-90 days have large amplitude in the Eastern Hemisphere at 100hPa (Suzuki and Shiotani, 2008). We also used 365 day low-pass filtered daily data for examining interannual variation. In the frequency range with 5-20 day and 2 0-80 day oscillations, HSI and Tgrad are correlated very well in NH and SH summer. In SH summer, interannual variation of OLR is associated with HSI and Tgrad, and it is related to El Nino-Southern Oscillation cycle.

We can conclude that in NH summer (June-October) around the Indian Ocean and in SH summer (December-May) around the western pacific, there are prominent horseshoe-shaped temperature structures around the tropical tropopause, and the short-time variation is not strongly coupled with deep convection, but in SH summer its interannual variation associated with deep convection is seen.

Keywords: Tropical Tropopause Layer, Stratosphere-troposphere exchange