Intraseasonal to interannual variability in the tropical tropopause temperature and its relationship with convective activity

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Temperature around the tropical tropopause layer (TTL) is one of the most important factors controlling the aridity of air in the stratosphere. Low temperatures generally occur over the equator and extend northwestward and southwestward in the subtropics to form a horseshoe-shaped structure. This structure resembles a stationary wave response known as the Matsuno–Gill pattern, which is induced by the heating generated by the convective activities near the equator. This study investigates the intraseasonal to interannual variability in the horseshoe-shaped temperature structure and its relationship with convective activity by using ECMWF reanalysis and NOAA/OLR data.

The horseshoe-shaped structure index is first established to quantitatively capture its variability. Then, by using this index we find the significant relationship with the climatological convective activities in the monsoon regions over the Indian Ocean and Pacific with the seasonal and interannual timescale. During the southern summer the horseshoe-shaped structure index is also related to convective anomalies associated with the El Niño-Southern Oscillation (ENSO) cycle, shifting eastward in El Niño years. After that, we investigate the relationship with the eastward propagating convection with the intraseasonal oscillation (ISO) such as the Madden-Julian Oscillation, which is observed predominantly over the Indian Ocean and Pacific during the southern summer. The various types of the eastward propagation features are observed in the unfiltered OLR field. Because of this, cluster analysis is performed according to the propagation features of the convective activity, and then the 72 ISO events selected from 1979–2011 are grouped into five clusters. Each cluster shows different features in the distribution of sea surface temperature in associated with the ENSO cycle. The horseshoe-shaped temperature structure is observed to be accompanied by the convective activity in every cluster, and both the ISO life cycle and event-to-event variation are significantly correlated. We also find that the strength and location of the minimum temperature at 100 hPa differ among the clusters. These results imply that the different MJOs will have different impacts on the dehydration process depending on their type.

Finally, we could conclude from the above results that the horseshoe-shaped temperature structure around the tropical tropopause is induced by the heating generated by the convective activities.