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Cold Trap Dehydration in the Tropical Tropopause Layer Estimated from the Water Vapor Match

Yoichi Inai[1*], Fumio Hasebe[1], Masatomo Fujiwara[1], Masato Shiotani[2], Noriyuki Nishi[2], Shin-Ya Ogino[3], holger Voemel[4], Suginori Iwasaki[5], Takashi Shibata[6]

[1]Hokkaido univ., [2]Kyoto univ., [3]JAMSTEC, [4]German Weather Service, [5]National Defense Academy, [6]Nagoya univ.

Stratospheric water amount is controlled by the degree of dehydration the air parcels experienced on their entry into the stratosphere. The dehydration takes place in the tropical tropopause layer (TTL) over the western Pacific, where the air parcels are exposed to the lowest temperature during horizontal advection (cold trap dehydration; Holton and Gettelman, 2001; Hatsushika and Yamazaki, 2003). We have been conducting the project Soundings of Ozone and Water in the Equatorial Region (SOWER) using frostpoint hygrometers in the western Pacific. To quantify the efficiency of dehydration, it is necessary to estimate the changed amount of water vapor by repeated observation of the same air parcel, the water vapor match.
For this purpose, the isentropic coordinate system is conveniently used (e.g., Hasebe et al., 2007) because the air parcels stay on an isentrope even when they are displaced by transient waves. For this purpose, it is important to reduce the pressure and temperature errors in radiosonde data. Consequently, a method of correction for radiosonde pressure and temperature data by using simultaneous global positioning system ellipsoidal height is proposed. The analyses in the present study are conducted after these biases are corrected.
The match pairs are sought from the SOWER network observations with the use of isentropic trajectories calculated from the ECMWF operational analysis data. For those pairs identified, extensive screening procedures are performed to verify the representativeness of the air parcel and the validity of isentropic treatment, and to check possible water injection by deep convection. The match pairs are rejected when the sonde-observed temperature does not agree with spatio-temporary interpolated temperature of the ECMWF analysis field within a reasonable range, or the ozone mixing ratio is not conserved between the paired sonde observations.
Among those pairs survived, we found some cases corresponding to the first direct evidence of the cold trap dehydration in the TTL. From the detailed case studies, we found that the match air masses at about 370 K potential temperature are not dehydrated effectively even though they are exposed to supersaturation with the maximum relative humidity with respect to ice (RHice) of about 135%. On the other hand, on the isentropes between 350 and 360 K, those cases indicating dehydration show that the ice nucleation must have started before RHice reaches about 130% and that the air masses are dehydrated until the RHice reaches about 90%. There also found some cases in which the water vapor amount increases by unknown reason. The statistical features on the dehydration for the air parcels advected in the TTL are derived from the match pairs. It is indicated from the ratio of the observed water mixing ratios to the minimum value of the saturation mixing ratio (SMR) during the advection (SMRmin) that the ice nucleation must have started before RHice reaches the value of 167 +/-54% (1sigma) and the air mass is dehydrated until the RHice reaches 84 +/-27% (1sigma). The latter suggests that the sub-grid scale temperature fluctuations unresolved in the analysis field may have some influence on the cold trap dehydration.
The efficiency of dehydration is modeled from match analysis in two terms; the critical value of RHice initiating the ice nucleation (RHcri), and the relaxation time (e-folding time: tau) of the

relative humidity for the supersaturated air parcel to approach saturation state. Tau is empirically estimated for each given value of RHcri as the quantity that reproduce the 1st and the 2nd observed water vapor amount given the sequence of SMR exposed to during the advection. The values of tau are found to be 1 - 1.5 hours, which are much shorter than the typical time scale of horizontal advection in the TTL. Therefore, it is suggested the cold trap dehydration functions quite efficient in the lower levels of the TTL once ice nucleation is initiated.

Keywords: TTL, stratosphere, water vapor, dehydration, match, SOWER