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Enhancement of aerosols in monsoon anticyclone over the Tibetan Plateau: Balloon-borne measurements at Lhasa, China

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Impact of the Asian summer monsoon activities on the global/regional climate system and geochemical cycle becomes a great concern, especially in terms of interactions between the Tibetan Plateau atmosphere and the monsoon activities. Recent investigations have suggested that not only natural aerosols but also anthropogenic aerosols (e.g., sulfate, soot, and organics) largely have characterized the atmosphere over the Tibetan Plateau during the Asian summer monsoon periods.

The Asian summer monsoon forms deep circulation associated with upper-level monsoon anticyclone (South Asia High or Tibetan anticyclone) between the upper troposphere and lower stratosphere due to rapid increase in heating rate of the atmosphere over the Tibetan Plateau in summer (e.g., Yanai et al., 1992). Therefore, the summer monsoon circulation certainly gives a large impact on distributions of atmospheric constituents including water vapor, ozone, and anthropogenic aerosols in the upper troposphere and lower stratosphere in the northern hemisphere. Li et al. (2005) suggested, on the basis of the simulation made by a global chemical transport model, that the Tibetan anticyclone could trap anthropogenic aerosols which were transported from the lower atmosphere in the anticyclone region.

However, few investigations have been made concerning aerosol behaviors over the Tibetan plateau, even though the aerosols may have affect the radiation balance, heterogeneous chemistry and so on in the atmosphere, and have altered the atmospheric compositions.

We present here the results of the balloon-borne measurements of tropospheric and stratospheric aerosols which were made during the late summer and early fall of 1999 at Lhasa, China in order to investigate temporal and spatial changes of particle number-size distributions in the Tibetan Plateau atmosphere. These measurements were conducted from the Tibet Meteorological Observatory in Lhasa using the Optical Particle Counters (OPC) during August and October 1999 (**Figure 1**). The results indicated that characteristic enhancement of aerosols was found in the vicinity of the tropopause, especially in August. The enhanced layer gradually diminished in September and November.

Aerosols suspended in the upper troposphere and lower stratosphere are believed to be mainly composed of sulfuric acid and water. Aqueous sulfuric acid aerosols can take up ambient gaseous species (e.g., nitric acid and water vapor) under low temperature and change the composition. The measured aerosol volumes clearly depended upon the air temperatures, and increased under the atmospheric condition of the cold-temperature. We examined the possibility for uptake of HNO_3 and H_2O by liquid aerosols. As shown in **Figure 2**, the measured aerosols changed their volumes referred to the calculated growth curves. Also, the thermo-dynamical theory of aerosol growth indicated the

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presence of NAT-saturated condition near the tropopause (not shown here).

The measured cold-temperature in summertime would be caused by adiabatic expansions of air parcels from the lower-atmosphere over the Tibetan Plateau. Also, early investigations suggested slightly higher water vapor content over the Tibetan Plateau in summer. Hence we speculate the enhanced aerosols near the tropopause may have been growth aerosols in the form of ternary $HNO_3/H_2SO_4/H_2O$ system droplets, and/or nitric acid trihydrate (NAT) under slightly humid and cold temperature condition.

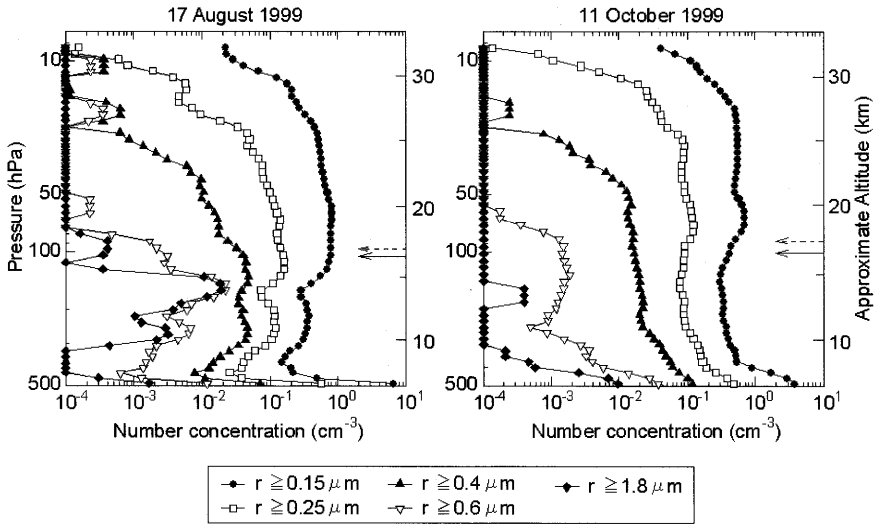

Figure 1 Vertical profiles of aerosols with radii ≥ 0.15, 0.25, 0.4, 0.6, and 1.8 μm at Lhasa (29.4°N, 91.1°E) on 17 August and 11 October 1999. The dots on the profiles are 0.5 km average values. The arrows indicate the positions of the local tropopause (solid arrow) and the coldest height (dashed arrow).

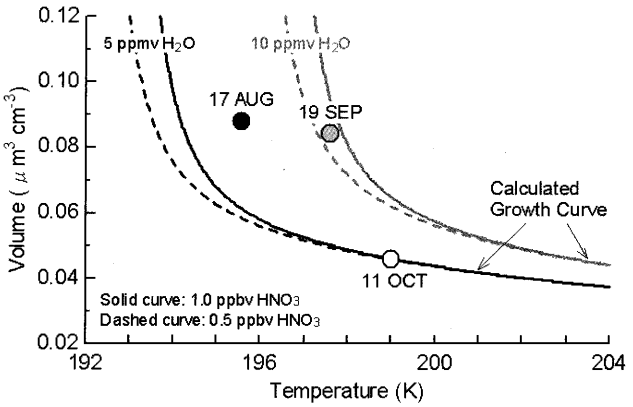

Figure 2 Aerosol volume concentrations from the OPC measurements compared with model calculations for the growth of liquid particles. The points are the assumed volume concentrations from the measurements at 16.5 km altitude. The growth curves are for 0.5-1.0 ppbv total HNO_3 and 5-10 ppmv total H_2O at 105 hPa altitude, assuming that the aerosols on 11 October 1999 are almost binary H_2SO_4/H_2O systems for 5 ppmv H_2O. These calculations are given by a chemical model of Carslaw et al. (1995).

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