UTLS structure and tracer distributions in the Asian Summer Monsoon Anticyclone inferred from balloon measurements during StratoClim 2016-2017

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The Asian summer monsoon anticyclone (ASMA) is a major meteorological system of the upper troposphere-lower stratosphere (UTLS) during boreal summer. It is enriched in tropospheric trace species and aerosols, due to rapid lifting from the boundary layer by deep convection, and subsequent horizontal confinement. Given its dynamical structure, the ASMA offers a very efficient pathway for the transport of these gases and aerosols to the global stratosphere. For a detailed understanding of the ASMA structure and processes, accurate in-situ measurements are required. To this end, high-precision balloon-borne measurements of temperature, water vapor, ozone and aerosol backscatter were conducted within the *StratoClim* project from two stations at the southern slopes of the Himalayas. In particular, we performed 58 balloon soundings during two monsoon campaigns, one in August 2016 in Nainital, India (NT16) and one in July-August 2017 in Dhulikhel, Nepal (DK17). These measurements provide unprecedented insights into the ASMA thermal structure, its relations to the vertical distributions of water vapor, ozone and aerosols, and interannual variability. Here, we adopt the concept of the tropical tropopause layer (TTL), and define the region of altitudes between the lapse rate minimum (LRM) and the cold-point tropopause (CPT) as the Asian Tropopause Transition Layer (ATTL). Further, based on air mass trajectories, we define the Top of Confinement (TOC) level of ASMA, which divides the lower stratosphere (LS) into a Confined LS (CLS), below TOC and above CPT, and a Free LS (FLS) above the TOC. Our analysis reveals that the composition of ATTL and CLS are strongly affected by convection, whose influence extends 1.5-2 km above the CPT. This is shown by enhanced water vapor in the Confined LS compared to background stratospheric values in the Free LS, observed in both the NT16 and DK17 measurements. Enhanced aerosol backscatter of the Asian tropopause aerosol layer (ATAL) was found to extend across both the ATTL and CLS in NT16, suggesting that the LRM coincides with the onset of the horizontal confinement by ASMA, while the polluted convective outflow penetrates into the Confined LS. The CPT was significantly higher and colder in DK17 compared to NT16, suggesting that the convective activity of the monsoon season 2017 was stronger than in 2016. This is corroborated by strong ozone depletion in the ATTL and CLS in DK17, which was not observed in NT16. Finally, an isolated water vapor maximum in the Confined LS was found in DK17, which we argue is due to overshooting convection injecting ice crystals directly above the CPT, and hence hydrating the CLS. This evidence suggests that the ASMA contributes to moistening the global stratosphere.

Key words: Asian summer monsoon anticyclone (ASMA), Upper troposphere lower stratosphere (UTLS), In-situ measurements, Water vapor, Asian Tropopause Aerosol Layer (ATAL)