Aerosol influences on radiative heating rates in the Asian tropopause aerosol layer

Jie Gao\textsuperscript{1} and Jonathon Wright\textsuperscript{2}

\textsuperscript{1}Department of Earth System Science, Tsinghua University, Beijing, China (gaojie20@mails.tsinghua.edu.cn)
\textsuperscript{2}Department of Earth System Science, Tsinghua University, Beijing, China (jswright@tsinghua.edu.cn)

The Asian Tropopause Aerosol Layer (ATAL) has emerged over recent decades to play an increasingly prominent role in the upper troposphere and lower stratosphere above the Asian monsoon region. Although the effects of the ATAL on the surface and top-of-atmosphere radiation budget have been examined by several studies, the processes and effects by which the ATAL alters radiative transfer within the tropopause layer have been much less discussed. We have used a conditional composite approach to investigate aerosol mixing ratios and their impacts on radiative heating rates in the Asian monsoon tropopause layer in MERRA-2. We have then subsampled in time based on known volcanic eruptions and the evolution of emission and data assimilation inputs to the MERRA-2 aerosol analysis to isolate the ATAL contribution and compare it to radiative heating signatures in the monsoon anticyclone region after volcanic eruptions. The results indicate that the ATAL impact on radiative heating rates in this region is on the order of 0.1 K/day, similar to that associated with ozone variability in MERRA-2 but weaker than cloud radiative effects at these altitudes. We have validated these results and tested their sensitivity to variations in the vertical structure and composition of ATAL aerosols using offline radiative transfer simulations. The idealized simulations produce similar but slightly stronger responses of radiative heating rates to the ATAL and are in good agreement with previous estimates of the top-of-atmosphere radiative forcing. Although the ATAL perturbations inferred from MERRA-2 are only about 10% of mean heating rates at these levels, their spatial distribution suggests potential implications for both isentropic and diabatic transport within the monsoon anticyclone, which should be examined in future work. Our results are limited by uncertainties in the composition and spatiotemporal variability of the ATAL, and reflect only the conditions in this layer as represented by MERRA-2. Targeted observations and model simulations are needed to adequately constrain the uncertainties, particularly with respect to the relative proportions and contributions of nitrate aerosols, which are not included in the MERRA-2 aerosol analysis.