A Lagrangian model diagnosis of stratospheric contributions to tropical mid-tropospheric air

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Tropical tropospheric ozone is controlled by a number of atmospheric chemical and dynamical processes. This work presents a Lagrangian model transport diagnosis to examine the contribution from two plausible processes to the mid-tropospheric elevated ozone layers, which are (1) transport from the mid-latitude upper troposphere and lower stratosphere (UTLS) through isentropic mixing, and (2) photochemical production from biomass burning-influenced air masses which are transported by convective lofting and the Hadley circulation. Based on the in situ observations during the Convective Transport of Active Species in the Tropics (CONTRAST) campaign in January-February 2014 over the tropical western Pacific (TWP) ocean, we use the isentropic (2D) version of Chemical Lagrangian Model of the Stratosphere (CLaMS) to quantitatively characterize the contribution of stratospheric air to the mid-troposphere through isentropic mixing and use the 3D back-trajectory calculations to diagnose the connections between tropics and extra-tropics.

A good agreement between stratospheric tracers from the Lagrangian isentropic (2D) run and from a Eulerian chemistry-climate model run suggests that the isentropic transport run sufficiently reproduced the stratospheric contribution to the mid-tropospheric layer at the 320-330 K level for this season. A 3D back-trajectory calculation from the times and locations of observed HOLW identified interesting differences in the background flow experienced by the two groups of air masses, one with, and one without significant stratospheric influence based on the stratospheric tracer distribution from the CLaMS isentropic run. 60% of the observed HOLW air masses contained a significant mid-latitude stratospheric influence, which experienced equatorward flow near the subtropical jet. The background flow experienced by the remaining 40% HOLW air masses without significant stratospheric influence is consistent with the Hadley circulation, which involves upward lofting from tropics, followed by cross-equator or poleward flow and descent near the jet. Furthermore, clear chemical signatures of biomass burning ozone production, identified by positive correlations among O_3, HCN and CO, are found in approximately 8% of the air masses, primarily from the group that did not have a significant stratospheric influence.

This analysis provides the first quantitative diagnosis of the transport pathways and contributions from the two leading mechanisms. These results also highlight the importance of mixing in chemical transport and the limitations of pure Lagrangian trajectory calculations in quantifying transport.

Key words: tropospheric ozone, isentropic mixing, Stratospheric-Tropospheric Exchange, biomass burning