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The subtropical pathway of water vapor into the lower stratosphere linked to Asian monsoon and horizontal transport

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We compare global water vapor observations in the lower stratosphere from MLS with global simulations with the Lagrangian chemical transport model CLaMS to investigate the pathways of water vapor into the lower stratosphere during northern hemisphere (NH) summer. Model simulations and observations both show that the Asian and American monsoons are main regions of upward transport of water vapor into the upper troposphere during summer, moistening the NH subtropics. In NH mid- and high-latitudes, a clear anticorrelation between water vapor and ozone tendencies reveals a large region influenced by frequent horizontal transport from low latitudes, extending up to about 430-450K during summer and fall. Close to the subtropics, this horizontal transport is caused by the shallow Brewer-Dobson circulation branch. In contrast, at higher latitudes polewards of about 50°, horizontal transport is caused by eddy mixing, related to Rossby-wave breaking. Additional sensitivity simulations with transport barriers in the model confirm that the entire annual cycle of water vapor mixing ratios in NH extratropics at altitudes above the subtropical jet core is caused by horizontal transport from the subtropics. Hence, NH water vapor between about 370-430K during summer and fall appears to be 'subtropically controlled'. In the model, highest water vapor mixing ratios in this region are closely linked to horizontal transport from the subtropics rather than to mid-latitude convection. Further, an asymmetry exists in lower stratospheric water vapor, with a significantly moister NH than SH. This asymmetry is largely caused by processes at high latitudes, like strong dehydration within the Antarctic vortex and hemispheric differences in downwelling, and is only weakly affected by horizontal transport from low latitudes.