Geophysical Research Abstracts
Vol. 16, EGU2014-5031, 2014
EGU General Assembly 2014

Dynamics of 2009 Stratospheric Major Warming and its Impact on Composition of Stratosphere

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In a case study of a remarkable stratospheric Major Warming (MW) during the boreal winter 2008-09, we investigate how transport and mixing triggered by this event affect the composition of the whole stratosphere in the northern hemisphere. We simulate this event with the Chemical Lagrangian Model of the Stratosphere (CLaMS), which allows quantifying the effect of small-scale atmospheric mixing by varying the mixing intensity in the model (optimized mixing versus no mixing). The results are investigated by using the tracer-tracer correlation technique and by applying the Transformed Eulerian Mean formalism (TEM).

The CLaMS simulation of N2O and O_3 with optimized mixing parameters shows a good agreement with MLS observations. The comparison with CLaMS simulation without mixing shows that after the MW, i.e. around 23rd of January 2009, mixing of tracers increases at the polar vortex edge and at the extra-tropical transport barrier. The spatial distribution of the mixing intensity in CLaMS correlates fairly well with the EP flux convergence and illustrates that planetary waves drive mixing between the vortex and mid-latitude air as well as between the mid-latitude and tropical air under weak polar vortex condition. Moreover, the MW event also accelerates polar descent and tropical ascent of the Brewer-Dobson circulation. The accelerated ascent in the tropics and descent at high latitudes firstly occurs in the upper stratosphere and then propagates downward to the lower stratosphere. This downward propagation takes about one month from 1000K to 400K.

In addition, as a consequence of the MW, negative anomalies of water vapor are found at low and mid latitudes of lower stratosphere during late winter and spring 2009 in MLS data counteracting the moistening effect of the westerly phase of the Quasi-Biennial Oscillation (QBO). The water vapor at the tropical tropopause is about 0.5 ppm lower than during the years with westerly QBO phase. This highly dehydrated air ascends into the lower stratosphere in late February of 2009, i.e. one month after the MW, and is consistent with accelerated upwelling branch of the Brewer-Dobson circulation due to intensified extratropical wave forcing during the MW.