Atmos. Chem. Phys., 7, 4977-5002, 2007
www.atmos-chem-phys.net/7/4977/2007/

A study of the effect of overshooting deep convection on the water content of the TTL and lower stratosphere from Cloud Resolving Model simulations

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Abstract. Simulations of overshooting, tropical deep convection using a Cloud Resolving Model with bulk microphysics are presented in order to examine the effect on the water content of the TTL (Tropical Tropopause Layer) and lower stratosphere. This case study is a subproject of the HIBISCUS (Impact of tropical convection on the upper troposphere and lower stratosphere at global scale) campaign, which took place in Bauru, Brazil (22° S, 49° W), from the end of January to early March 2004.

Comparisons between 2-D and 3-D simulations suggest that the use of 3-D dynamics is vital in order to capture the mixing between the overshoot and the stratospheric air, which caused evaporation of ice and resulted in an overall moistening of the lower stratosphere. In contrast, a dehydrating effect was predicted by the 2-D simulation due to the extra time, allowed by the lack of mixing, for the ice transported to the region to precipitate out of the overshoot air.

Three different strengths of convection are simulated in 3-D by applying successively lower heating rates (used to initiate the convection) in the boundary layer. Moistening is produced in all cases, indicating that convective vigour is not a factor in whether moistening or dehydration is produced by clouds that penetrate the tropopause, since the weakest case only just did so. An estimate of the moistening effect of these clouds on an air parcel traversing a convective region is made based on the domain mean simulated moistening and the frequency of convective events observed by the IPMet (Instituto de Pesquisas Meteorológicas, Universidade Estadual Paulista) radar (S-band type at 2.8 Ghz) to have the same 10 dBZ echo top height as those simulated. These suggest a fairly significant mean moistening of 0.26, 0.13 and 0.05 ppmv in the strongest, medium and weakest cases, respectively, for heights between 16 and 17 km. Since the cold point and WMO (World Meteorological Organization) tropopause in this region lies at ~15.9 km, this is likely to represent direct stratospheric moistening. Much more moistening is predicted for the 15–16 km height range with increases of 0.85–2.8 ppmv predicted. However, it would be required that this air is lofted through the tropopause via the Brewer Dobson circulation in order for it to have a stratospheric effect. Whether this is likely is uncertain and, in addition, the dehydration of air as it passes through the cold trap and the number of times that trajectories

sample convective regions needs to be taken into account to gauge the overall stratospheric effect. Nevertheless, the results suggest a potentially significant role for convection in determining the stratospheric water content.

Sensitivity tests exploring the impact of increased aerosol numbers in the boundary layer suggest that a corresponding rise in cloud droplet numbers at cloud base would increase the number concentrations of the ice crystals transported to the TTL, which had the effect of reducing the fall speeds of the ice and causing a ~13% rise in the mean vapour increase in both the 15–16 and 16–17 km height ranges, respectively, when compared to the control case. Increases in the total water were much larger, being 34% and 132% higher for the same height ranges, but it is unclear whether the extra ice will be able to evaporate before precipitating from the region. These results suggest a possible impact of natural and anthropogenic aerosols on how convective clouds affect stratospheric moisture levels.

Final Revised Paper (PDF, 2009 KB)   Discussion Paper (ACPD)

Citation: Grosvenor, D. P., Choularton, T. W., Coe, H., and Held, G.: A study of the effect of overshooting deep convection on the water content of the TTL and lower stratosphere from Cloud Resolving Model simulations, Atmos. Chem. Phys., 7, 4977-5002, 2007.   Bibtex   EndNote   Reference Manager