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Release of tracers from freezing hydrometeors as a transport pathway to the UT: model sensitivity studies

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Deep convection can rapidly transport trace gases to the upper troposphere (UT). Highly soluble gases, on the other hand, are efficiently scavenged by precipitation. A few recent model studies have, however, suggested that even highly soluble gases could reach the UT if they are released from freezing hydrometeors. In this study, the role of the retention coefficient R (i.e. the fraction of a dissolved gas which is retained in hydrometeors during freezing) is discussed based on a number of cloud resolving model (CRM) sensitivity runs. Results from runs in which deep convection is initiated by small random perturbations in association with so-called "large scale forcings (LSF)" for a tropical oceanic (TOGA COARE) and a mid-latitude continental case (ARM) are compared to two runs in which bubbles are used to initiate deep convection (STERAO, ARM). In the LSF runs scavenging is found to almost entirely prevent a highly soluble tracer initially located in the lowest 1.5 km of the troposphere from reaching the UT, independent of R. The release of gases from freezing hydrometeors leads to mixing ratio increases in the UT comparable to those calculated for insoluble gases only in the two runs in which bubbles are used to initiate deep convection, indicating that previous CRM studies using bubbles may possibly have over-estimated the influence of R on the vertical transport of highly soluble tracers. R is, however, found to play an important role for the scavenging and redistribution of highly soluble gases with a (chemical) source in the free troposphere, and also for gases for which even relatively inefficient transport may be important. The large difference between LSF and bubble runs is attributed to differences in dynamics and micophysics in the inflow regions of the simulated storms, highlighting the need for further model studies with a more realistic initiation of deep convection, e.g. considering orographic effects in a nested model setup.