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Cloud system resolving model study of the roles of deep convection for photo-chemistry in the TOGA COARE/CEPEX region

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Abstract. A cloud system resolving model including photo-chemistry (CSRMC) has been developed based on a prototype version of the Weather Research and Forecasting (WRF) model and is used to study influences of deep convection on chemistry in the TOGA COARE/CEPEX region. Lateral boundary conditions for trace gases are prescribed from global chemistry-transport simulations, and the vertical advection of trace gases by large scale dynamics, which is not reproduced in a limited area cloud system resolving model, is taken into account. The influences of deep convective transport and of lightning on NO_x, O_3, and HO_x(=HO_2+OH), in the vicinity of the deep convective systems are investigated in a 7-day 3-D 248×248 km^2 horizontal domain simulation and several 2-D sensitivity runs with a 500 km horizontal domain. Mid-tropospheric entrainment is more important on average for the upward transport of O_3 in the 3-D run than in the 2-D runs, but at the same time undiluted O_3-poor air from the marine boundary layer reaches the upper troposphere more frequently in the 3-D run than in the 2-D runs, indicating the presence of undiluted convective cores. In all runs, in situ lightning is found to have only minor impacts on the local O_3 budget. Near zero O_3 volume mixing ratios due to the reaction with lightning-produced NO are only simulated in a 2-D sensitivity run with an extremely high number of NO molecules per flash, which is outside the range of current estimates. The fraction of NO_x chemically lost within the domain varies between 20 and 24% in the 2-D runs, but is negligible in the 3-D run, in agreement with a lower average NO_x concentration in the 3-D run despite a greater number of flashes. Stratosphere to troposphere transport of O_3 is simulated to occur episodically in thin filaments in the 2-D runs, but on average net upward transport of O_3 from below ~16 km is simulated in association with mean large scale ascent in the region. Ozone profiles in the TOGA COARE/CEPEX region are suggested to be strongly influenced by the intra-seasonal (Madden-Julian) oscillation.

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