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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Cloud system resolving model study of the roles of deep convection for photo-chemistry in the TOGA COARE/CEPEX region" *by* M. Salzmann et al.

M. Salzmann et al.

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We appreciate the review by this referee.

Major comments:

The following sentences have been added on p.407, line 8 of the original manuscript:

"Unfortunately, chemistry and flash rate observations are not available for the episode (19–26 December 1992) simulated in this model sensitivity study. In order to constrain the simulated flash rates and for the discussion of our chemistry results, we instead rely on observations from nearby regions and/or at other times." Please note that here we simulate a 7-day episode while most chemistry observations have concentrated on outflow from a single isolated storm or MCS. Please note also that we are currently setting up another version of the same model for studying a recent field campaign for which direct observations of chemistry and meteorology will be available.

It is correct that our study does not provide any new insights on the NO production from lightning. (We have neither claimed nor expected that it would.) Instead, we have focused on studying the impacts of lightning and ozone transport in the domain. The much smaller impact of NO on ozone in our study compared to the pioneering study of Wang and Prinn is in a large part due to the lower NO production per flash and the lower time and space average number of flashes in our 3-D run. NO_x residence times also vary strongly between the 2-D runs of Wang and Prinn (who have used periodic boundary conditions) and our runs with specified boundary conditions. In our simulations, the residence time of NO_x in the domain varies strongly with altitude and time and also depends strongly on deep convective vertical transport due to strong vertical wind shear during most of the episode. Neglecting the effects of deep convective transport, the residence time could roughly be estimated from Fig. S3a for the 2-D runs and Figs. S3a and b for the 3-D runs. This would, however, not yield a very accurate estimate, since the vertical redistribution is very important for the residence time (compare discussions in Salzmann et al., 2004). The lightning NO_x residence time for the specific (2-D) mesoscale convective system in Fig. 7 can roughly be estimated to be as little as 2.5-3 h, i.e. this plume is rapidly advected out of the domain. (We added the sentence "Note that this NO_x plume is almost completely advected out of the domain in $\sim$2.5–3 hours" at the end of the 2nd paragraph of Sect. 3.2.)

A sentence stating that the chemistry tendencies in Fig. 10b "reflect the influence of lightning on ozone within the domain not taking into account ozone production further downwind." has been added in the first paragraph of Sect. 4. Note also, that in several other places we have stressed that we are studying the effects of in-situ lightning on the chemistry in the vicinity of the clouds (local chemistry).

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Specific comments:

p. 406, line 20: The dates have been indicated in the sentence added on p. 407, line 8 (see above) in the same paragraph.

p. 410, lines 16-22: The pressure dependence of the NO production is included in both cases. We have added the sentence "The pressure dependence of the NO production is taken into account" to the description of the lightning NO parameterization on p. 410, line 20.

p. 410, lines 22-26: The assumptions used in the placement of the flashes are still rather crude (as has also been the case in most previous cloud resolving studies including lightning and chemistry). They nevertheless do not appear inconsistent with the findings of Dye et al. (2000). Dye et al. state that while lightning discharges extend into portions of the diverging and spreading anvil, they "remain close to the cell cores and rarely extend extensively into the downwind anvil". Referring to their Plate 2d, they also note that "very few sources were detected in the region of the main downdraft. Some sources were located in the active updraft core, but not many. The majority of the sources are located in the moderate updrafts and downdrafts, and downshear of the main udraft/downdraft couplet, with a tendency to be located in the downshear portion of higher reflectivities." The latter is for a time in which they found almost all flashes to be IC flashes. In the present study, IC flashes are placed (horizontally) inside the previously identified anvil area in the vertical column where q_{totm} above $z_{(-15)}$ is largest and which is still located within 80 km of the maximum updraft. The upper mode of the IC distribution is assumed to be centered at $z = z_{(-15)} + 0.8 \cdot (z_{ctw} - z_{(-15)})$, where $z_{(-15)}$ is the altitude of the -15°C isotherm, thus allowing the altitude of the upper mode to vary depending on the growth stage of the cloud. This has been clarified in the revised manuscript by adding the words "horizontally" and "inside the previously identified .... area" to the sentences above.

Note that in the LTN3D run, more than 90% of all flashes are IC flashes, accounting for

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more than 80% of the total NO production (for additional comments on this issue see also response to Anonymous Referee#1, specific point 3).

Although we do not take into account branching, the simulated grid box average NO maxima due to lightning can still be expected to be below local maxima occurring in reality since in the model lightning produced NO is assumed to be instantaneously mixed over the size of a grid box (base area: 2 x 2 km^2). To include a parameterization of branching into our model would nevertheless be highly desirable. Unfortunately, its implementation in a massive parallel model requires a major technical effort. The (to our knowledge) novel aspect of the lightning parameterization in the present study is the way updrafts and anvils are identified prior to computing the flash rates. This allows us to study multiple mesoscale convective systems and isolated storms in a model which resolves cloud systems.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 403, 2008.

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