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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Quantifying pollution inflow and outflow over East Asia through coupling regional and global models" *by* M. Lin et al.

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Response to Anonymous Referee 2

We are grateful to the reviewers for their constructive comments that we believe have helped us to strengthen the manuscript.

*Below we include the original reviews, and we respond to each comment line-by-line. Original reviewers' comments are shown in black, and **our responses in bold**.*

General comments: The authors use two high-resolution regional models (WRF-Chem and WRF-CMAQ) and one global model (MOZART-2) to examine the pollution outflow

(to the western Pacific) and inflow (from Europe) over East Asia. The results emphasize the capability of regional models (in contrast with the MOZART global model) to capture the pollution outflow episodes in the upper troposphere, as observed during the TRACE-P aircraft campaign. The authors attribute it to the global model's inability to capture deep convection along the leading edge of the cold fronts as well as the coarse resolution. The results are original and well presented. This reviewer recommends publication after some minor revisions.

Co-author G.R. Carmichael's group used the STEM regional model to provide chemical forecast during the TRACE-P field campaign and also to conduct post-mission analysis (Carmichael et al. 2003). Was the STEM model able to capture the deep convection events discussed in this paper? This should be discussed in the text, especially in terms of convective parameterization vs. model resolution.

» We have added the discussion of STEM model results (Page 12, L34-43):

"In addition, high-resolution meteorological fields calculated using the mesoscale meteorological models (e.g., MM5, RAMS and WRF), as opposed to the coarse reanalysis data (e.g., NCEP/NCAR, ECMWF) for driving offline global CTMs, further support the improved simulation of tracer vertical transport in the regional scale CTMs. For example, prior TRACE-P post-campaign analysis showed that the STEM regional model driven with RAMS meteorology (80x80km2, hourly) was also able to capture the elevated CO outflow extending to the upper troposphere for the 7 March episode discussed above [Carmichael et al., 2003], while the global GEOS-Chem model driven with 3-hourly assimilated meteorology misplaced the plume in the lower free troposphere similar to the distribution in MOZART [Liu et al., 2003]."

Specific comments: Title – This paper did not address pollution inflow/outflow over East Asia in the seasons other than spring (March). Please clarify this in the title. On the other hand, how about replacing "through coupling" by "with"?

» Agreed. The title is now changed to: "Quantifying pollution inflow and outflow over East Asia in spring with regional and global models"

Abstract – "Episodic outflow of CO,: : :.is twice as great in the WRF-Chem model : : :.". Not sure where this was mentioned in the text or Summary/Conclusions. Line 1, Page 121 – How large are "the striking discrepancies in the episodic outflow in the upper troposphere"?

» We have rewtritten the abstract:

"Our analysis indicates the importance of rapid venting through deep convection that develops along the leading edge of frontal system convergence bands, which are not adequately resolved in either of two global models compared with TRACE-P aircraft observations during a frontal event. Both the aircraft measurements and regional model simulations show that, during frontal outflow episodes, elevated CO, O3 and PAN can extend to the upper troposphere (6-9 km). Pollution plumes in MOZART are typically diluted and insufficiently lofted to higher altitudes where they can undergo more efficient transport in stronger winds.".

Abstract – P111, L2: please clarify "compensating effects".

» The sentence has been cut from the abstract.

P112, L9: reference Stohl et al., 2007 is missing from the list.

» We have added Stohl et al. [2007] to the reference list: Stohl, A., Forster, C., Huntrieser, H., Mannstein, H., McMillan, W. W., Petzold, A., Schlager, H., and Weinzierl, B.: Aircraft measurements over Europe of an air pollution plume from Southeast Asia aerosol and chemical characterization, Atmos. Chem. Phys., 7, 913–937, 2007, http://www.atmos-chem-phys.net/7/913/2007/.

P116, L24: It is worth mentioning specifically which convective parameterization(s) is (are) used in the driving meteorology of MOZART. As the authors pointed out, convec-

tive parameterization may play an important role in the (regional vs. global) model skill differences.

» Good point. We have added the description of convective schemes used in MOZART to section 2 (Page, L36-38): "For MOZART convective mass fluxes are diagnosed by the model using the shallow and midlevel convective transport of Hack [1994] and deep convection scheme of Zhang and McFarlane [1995]."

We have rewritten the discussion on the influence of convective parameterization schemes in the regional vs. global model difference (P11, L41-P13, L2):

"The WRF simulations in this study employed the new Grell-3d scheme for convective parameterization [Grell et al., 2002], and evaluation of chemical compositions presented here illustrates the capability of the Grell-3d convective scheme to closely simulate vertical exchanges of air masses. The convective transport schemes of Hack [1994] and Zhang and McFarlane [1995] were applied in both MOZART version 2 [Horowitz et al., 2003] and version 4 [Emmons, et al., 2010]. Our results suggest further in-depth evaluation and development needed for the parameterizations of convective transport processes in the MOZART model. "

P120, L14-16: say a few words here explaining why you are showing total zonal fluxes at the 4-8.5km altitude range (vs. 2-4km).

»We have added text explaining why the 4-8.5 km altitude band is selected (P9, L14-16): "The 4-8.5 km altitude band is selected to examine the relative strength of upward vertical transport flux from the boundary layer to the middle and upper troposphere in global and regional models."

P121, L8-9: "Calculated total zonal fluxes of CO are approximately 50% higher in WRFChem than in MOZART for the two episodes." - It appears that Figure 2 (4-8.5km) does not show this large difference. How about the zonal fluxes of CO at 0-4km?

» The sentence has been cut, and we added a new figure showing the vertical

distribution of CO fluxes along 140E for selected frontal events (now Figure 2 in the manuscript). The plume can appear in the different location and time in the models. The vertical distribution in Figure 2 clearly shows that the CO zonal fluxes in the upper troposphere can differ by a factor of two between WRF-Chem and MOZART.

P121, L27: Wuhang or Wuhan?

» **Corrected**

P123, L16: It is inappropriate to cite here Duncan et al. 2003, which is about the impact of the Indonesian fire emissions. In the context of the present study, Southeast Asia biomass burning includes mainly those fire activities over continental SE Asia (Indochina) and the Indian subcontinent, instead of those over the maritime continent (Indonesia). They occur in different seasons of the year.

» **We have rephrased the sentence (P11, L15-20) :**

"Deep convection is an important mechanism for vertically transporting tropical and subtropical biomass burning emissions out of the atmospheric boundary layer into the middle and upper troposphere [Duncan et al, 2003; Hess, 2005]."

P123, L25-27: consider citing this paper: Lin, C.-Y., et al., A new transport mechanism of biomass burning from Indochina as identified by modeling studies, ACP, 9, 7901-7911, 2009.

» **We have added the above paper to the discussion on the influence of orographic forcing on pollution export (P11, L30-45):**

"We find that the export of biomass burning emissions from Southeast Asia for some episodes is likely enhanced by orographic forcing over the complex terrains in Myanmar and southwest China. A tracer modeling study by Lin et al. [2010] suggests that the trough (low) formed on the lee side of Tibetan Plateau and Indochina mountains, is an important transport mechanism for uplifting

biomass-burning emissions from Indochina."

P128, section 4.1: How was the European region defined (latitude/longitude ranges)?

» **Clarified**

Reference: Guenther A. et al., 1994 is misplaced in the list.

»**Corrected**

Fig.1: the legends are too small to read, at least in the printer friendly version.

» **Changed**

Fig. 5: please indicate the latitudes/longitudes of the flight track.

» **The flight track in both Figure 4 and Figure 6 is now labeled with UTC times, corresponding to the geographical location of the flight track shown in Figure 4. To clarify, we have added the text below to the captions:**

"Figure 4: The thick black line labeled with UTC denotes the flight track of the NASA DC8 along which the chemical distributions are illustrated in Figure 6"

"Figure 6: The black line denotes the flight path shown in Figure 4 with corresponding UTC labels"

Fig. 7 caption: The sentence "Note that : : :." needs a reference – is the linearity valid?

» **The sentence has been cut. We re-made Figure 7, 8 and 9, and restricted our discusson to the response to a 20% decrease in European emissions.**

Fig. S5: remove "NO2 (middle panel)".

» **Removed.**

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 109, 2010.