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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Influence of meteorological variability on interannual variations of the springtime boundary layer ozone over Japan during 1981–2005" *by* J. Kurokawa et al.

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The authors would like to thank Anonymous Referee #1 for taking his or her time to review our manuscript and for giving very constructive and informative comments. These comments helped us improve the quality and clarity of the manuscript. We revised our manuscript based on them. Below are our detailed responses to the comments.

Reply to specific comments:

> Comment: 1. Model evaluation: one major weakness of this paper is that the authors

evaluate the model results only over WCJ. The authors need to use other sources of observations (such as EANET observational data) to evaluate model results over a broader area, particularly for the upwind regions from WCJ (e.g., continental Asia or western Pacific).

Reply:

In order to evaluate the general model performance for O3 over East Asia, we compared the springtime averaged O3 simulated by EyyMyy with observations of the EANET and the WDCGG, and with several measurements taken from published research papers. As presented in Fig. 1 and Table 2 in the revised manuscript, these monitoring stations are located at remote Japanese sites and in the western Pacific and continental Asia. Although there are several discrepancies between simulated and observed results, our modeling system generally reproduced the observations, so we considered that it was validated for the analysis of springtime O3 over East Asia. We have added a new section to the revised manuscript where we describe the above results.

> Comment: 2. 20ppbv overestimation of ozone: the authors did not discuss in detail on the causes of this significant overestimation. Does this overestimation appear in both urban and rural sites? Is there any overestimation outside Japan (e.g., the continental Asia, or western Pacific)? One way the authors may want to do is to compare the ozone concentrations at several key sites (in both urban and rural areas) to further investigate the reason. Lacking a more careful evaluation it is difficult to determine what level of confidence we believe these results.

Reply:

We agree that we did not adequately address the large overestimation of simulated O3 compared with the observations of air quality monitoring stations over Japan in the previous manuscript. First, we compared the simulated springtime O3 with EANET observation data at remote sites of Japan as mentioned in the reply to the first comment.

ACPD

9, C2654–C2660, 2009

Interactive Comment

We found that simulated results were not systematically larger than the observations. With respect to the air quality monitoring stations managed and operated by the Ministry of the Environment of Japan and by local governments, there is unfortunately no information about site characteristics. Thus, we classified the sites as urban, suburban, or rural using the 21-year average (during 1985–2005) of springtime NOx concentrations observed at each station. As expected, observed Ox were smallest over urban areas and largest over rural areas. However, simulated O3 values over WCJ were still about 5–10 ppbv larger than observed Ox over rural areas, which suggests that even stations defined as rural might be affected greatly by neighboring urban or suburban areas. In order to further investigate the cause of differences between observed and simulated results, we compared concentrations of Ox' (the sum of simulated O3 or observed Ox and NO2 generated secondarily by the oxidation of NO in the atmosphere) and found that simulated Ox' values and the interannual variation of them agreed well with observations. From these results, we inferred that differences of observed Ox and simulated O3 over WCJ were caused mainly by the dilution of NOx emissions in the coarse model grid of this study. In addition, all observation types, namely, Ox at urban, suburban, and rural areas and Ox' over WCJ, showed very similar trends, which suggests that the interannual variability of O3 over WCJ is influenced by large-scale factors rather than by local ones. We have added these results and discussion to the revised manuscript.

> Comment: 3. Page 7567: the region that the authors choose to calculate the ASPA is based on the significance of surface pressure anomalies. However, from Fig. 4ef, the largest surface pressure anomalies could appear in the central Pacific. The authors should provide more information on the basis they choose to calculate ASPA.

Reply:

We agree that the largest surface pressure anomalies appear in the central Pacific. In fact, we investigated global springtime surface pressure anomalies using the NCEP/NCAR Reanalysis 1 data sets and found that the largest anomalies appeared

ACPD

9, C2654–C2660, 2009

around the region 30–45°N, 180–150°W. However, that region is outside the model domain of CMAQ designed for this study. Therefore, we examined the relationship between ASPA and the anomalies averaged over 30–45°N, 180–150°W. We found positive correlations between them (r = 0.83) and thus chose ASPA as a reference parameter for O3 over WCJ in this study. We have added this explanation to the definition of ASPA.

> Comment: 4. Page 7570: the authors compared the ASPA with ENSO, I wonder if you have compared the results with NPI (North Pacific Index). The location of ASPA is quite close to the major surface pressure anomalies over the North Pacific, which are mostly captured by NPI.

Reply:

We have compared the simulated springtime BL O3 anomalies over WCJ with not only Niño3 index but also NPI during 1981–2005. However, we did not find any significant relationship between O3 over WCJ and NPI.

Reply to minor comments:

> Comment: 1. Page 7561, line 20: "biomass-burning emissions . . . has some impact on IAV of O3 . . .", "some impact" is unclear. Since you are using climatological biomass burning emissions, can you comment on the relative importance of IAV of biomass burning emissions on the IAV of O3 over WCJ?

Reply:

We removed the comments for Koumoutsaris et al. (2008) and instead, added those for Tanimoto et al (2008) which reported the impact of boreal biomass burning on O3 at Rishiri, the northern island of Japan, in 1998, 2002, and 2003. According to their results, two episodes observed in 2002 and 2003 suggested that at Rishiri, O3 in wildfire-polluted plumes was comparable to the magnitude typically observed in industrially-polluted air masses from the Asian continent. In this study, our focus was not on the

ACPD
9, C2654–C2660, 2009

effects of year-to-year changes in wildfire emission. We will examine the influences of interannual variation of biomass burning on O3 concentrations over WCJ as well as northern Japan in a future study.

> Comment: 2. Page 7562, lines 18-20: “Thus . . . is appropriate”, why? You can use 25-year averaged emissions instead.

Reply:

We removed this sentence, because it was not logical or essential, as Referee #1 suggested.

> Comment: 3. Page 7563: again the authors discussed how ozone is measured in Japan. However, they did not show enough information on model evaluation. The authors should discuss more on model evaluation.

Reply:

Please see our reply to specific comments 1 and 2.

> Comment: 4. Page 7564, bottom: the trend of O3 in WCJ is âĹij0.4ppbv/year, I am wondering the trends of ozone precursors emissions in both WCJ and CEC.

Reply:

In Fig. 5b of the revised manuscript (Fig. 3a in the previous manuscript), we have plotted emissions of NOx and NMVOC over WCJ and CEC calculated from input emissions for EyyMyy. We found no long-term increasing trend in either the simulated results by E00Myy or emissions over WCJ, whereas both NOx and NMVOC emissions over CEC increased clearly during 1985–2005. These results suggest that the increase in the observed Ox anomalies was caused by the recent increase in anthropogenic emissions in East Asia, especially in China. We have added this information to the revised manuscript.

> Comment: 5. Page 7568 lines 6-8: “when the O3 flux anomaly along LSJ is large,

ACPD

9, C2654–C2660, 2009

Interactive Comment

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Interactive Discussion

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low O_3 air masses are transported to WCJ. . .", !? what are the directions of the O_3 flux along LSJ?

Reply:

The directions of the O_3 flux along LSJ are northward. Thus, when the O_3 flux anomaly along LSJ (FASJ) is large, the O_3 mixing ratio over WCJ is decreased by clean maritime air transported from the Pacific Ocean. On the other hand, when FASJ is small, O_3 over WCJ is not influenced by the low-O_3 air masses. We have rewritten the indicated sentence to avoid confusion.

> Comment: 6. Page 7569 line 16-19, "Our examination . . . This finding indicates that the IAV of FAWJ is determined mostly by the IAV of westerly winds over LWJ", this seems obvious. How about LSJ?

Reply:

The point that we wanted to emphasize in the indicated sentence was that the interannual variation of FAWJ was not determined by that of O_3 over CEC. The corresponding sentence has been rewritten. In addition, we also investigated the relationship between FASJ and springtime southerly winds in the BL averaged over LSJ. The results showed that the correlation coefficient of the relationship between them was also almost 1, which indicates that the interannual variability of FASJ is determined by that of southerly winds over LSJ. We have added this description to the revised manuscript.

> Comment: 7. Page 7580, Fig. 1, since most of the analysis is based on E00Myy, why not show NO_x emissions for 2000?

Reply:

We agree with Referee #1. We replaced NO_x emissions for 2005 shown in Fig. 1 with those for 2000 and changed the legend for Fig. 1.

> Comment 8. Fig. 3, Fig 3a is mostly repeating Figure 3b. For figure 3b, both left

ACPD

9, C2654–C2660, 2009

Interactive Comment

and right axes should keep the same. Add E00Myy line and show the error bars for observations data in Figure 3b. In addition, the authors may add a plot to show the time-series of ozone precursors' emissions (i.e., NOx or VOCs) from WCJ and CEC.

Reply:

We made major revisions to section 3.2 and Fig. 3 of the previous manuscript. In the revised manuscript, the corresponding figure is Fig. 5, and the discussion is in section 3.3.2. We believe that the essential points indicated in this comment are satisfied in the modified Fig. 5.

References

Koumoutsaris, S., Bey, I., Generoso, S., and Thouret, V.: Influence of El Niño-Southern Oscillation on the interannual variability of tropospheric ozone in the northern midlatitudes, J. Geophys. Res., 113, D19301, doi:10.1029/2007JD009753, 2008.

Tanimoto, H., Matsumoto, K., and Uematsu, M.: Ozone-CO correlations in Siberian wildfire plumes observed at Rishiri Island, SOLA, 4, 65-68, doi:10.2151/sola.2008-017, 2008.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 7555, 2009.