Progress of the study on MICS-Asia phase II --- Ozone and its relevant gases

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Model simulations for MICS-Asia phase II were generally carried out after the 6th workshop held in IIASA on 9-10 February, 2004. By now, 7 groups have submitted their model results. A general review and preliminary analysis of model intercomparison in regard to 4 topics had been introduced in the 1st meeting of the Working Group on MICS-Asia Phase II, which was held on 18-20 November 2004 in Kyoto University. Due to large discrepancies among model groups and with observations, some comments and suggestions were proposed for further study. Firstly, model groups were asked to check their model results carefully to avoid occasional mistakes in the data output for submission; secondly, modelers are requested to examine their model structure, processes and parameters detailedly to clarify the inherent problems or errors within the model, followed by necessary model improvement ; thirdly, additional model output are requested to assist us in exploring in detail the evolutionary features of species in the atmosphere and investigating possible reasons which are responsible for the discrepancies. These data include model results on meteorological field, dry deposition velocity, afternoon ozone profiles at 4 specific locations where ozone sonde data are available, as well as 3-d hourly concentrations of ozone and relevant species over west Pacific Ocean in a few days of March 2001. For the case of March 2002, all model groups show large differences with aircraft observations from LTP project, especially for NOx. The reasons are supposed to be the uncertainty in emission inventory, poor model capability, as well as observation accuracy itself. The analysis of additional data set together with intense observations will not only help to reveal the mechanism of transport and chemical processes, but also to examine model capability comprehensively. The study results are briefly introduced as following.

1. Spatial distribution of monthly average concentration

The spatial patterns of SO_2 and NO_x are similar among model groups, with high level in or in the vicinity of big cities or industrial regions. However, the magnitude of simulated concentrations differs from each other due in part to the various prescription of the height of first model layer, near-surface meteorological field and vertical diffusivity coefficient. Ozone behavior is of much concern because it is one of the key pollutants in the lower troposphere and it involves a complex interplay of chemical and dynamic processes. Figure 1 presents the monthly average ozone concentrations of first model layer derived from 7 groups. Most of model results (M1,M3,M5,M6,M7) exhibit an elevated ozone level over a wide area from the China East Sea to the south of Japan, which is mainly resulted from the outflow transport from the continent. The patterns from M1, M3 and M7 are quite alike, showing a high ozone center to the south of Japan, whereas M5 and M6 simulate a clear belt, extending from the China East Sea to the south of Japan. Ozone over southeastern China are found higher in M1, M3 and M5, and relatively lower in M4, M6 and M7; these differences are partly due to the various simulation of cloud process in each model which has a strong influence on photolysis. M2 yields a very high ozone level with the maximum exceeding 300 ppb over west Pacific Rim, which implies serious errors in modeling. For July case (not shown), high ozone concentration mainly occurs in northeast Asia. Ozone transport under southwester can be clearly identified, showing an evident gradient over the China Yellow Sea, Baohai Bay, east of Korean peninsula and the Sea of Japan. This feature is similarly reflected in M1,M3,M5 and M6. The model results from M3 and M6 are in a good agreement in terms of spatial pattern. Ozone transport is also prominent in wintertime; in M1,M3,M6 and M7, elevated ozone is found over the area from the East China Sea to south and southeast of Japan. M1,M6 and M7 show a level of 50~60 ppb, whereas M3 show a level of 40~45 ppb. The ozone pattern in March 2002 is similar to that of March 2001, despite more or less difference occur in each model. For March case, all the models reproduce the high HNO_3 concentration in the west Pacific rim, including the coastal area of eastern China, Korean peninsula and southern Japan. In July, similar pattern is found in most of model results except for M4, showing higher level in northeast Asia than southern China. For March case, an apparent pattern of PAN is obtained by almost all models, showing a long band extending from southern China to Japan island, with concentration generally decreasing from southwest to northeast. The difference between each model is generally within a factor of 2 in March. Relatively large difference occurs in July and December case.

2. Comparison with monthly and daily average observations

Comparison of monthly average concentration with EANET observation is conducted to generally evaluate the model performance (Figure 2). For SO_2 and NO_2, model results show a good correlation with each other at different locations, reflecting the influence of emission strength and meteorology. Model results for ozone differ largely at the sites in China, eastern Russia and Vietnam, due to a combined influence of boundary conditions, meteorological field and chemical process. Ozone observation is relatively limited, several sites in Japan have data for comparison. The consistence between model and observation varies seasonally, with better agreement in March case and relatively poor in December case. It is found that M1 and M7 systematically overpredict ozone level at most of Japanese sites in December, whereas other model results show somewhat underprediction. The comparison for daily averages clearly display the synoptic and transport processes. Model results agree with observations better in March case than that in other cases, transport process can be well reproduced by most of models.

3. Comparison with ozone sonde data

Afternoon ozone production and its vertical profile is studied by using sonde data from JMA. 4 monitoring sites Naha (26.2 N, 127.7 E), Kagoshima (31.6 N, 130.6 E), Tateno (36.1 N,140.1 E) and Sapporo (43.1 N,141.3 E) spread over a wide region of west Pacific rim and represent various characteristics of sub-urban, rural and remote areas. Figure 3 shows a part of comparison results at 4 sites for March 2001. At saporro site, ozone shows an increasing trend with height, M3-M6 reproduce observation reasonably well below 6km, but much differences appear above 6km due to poor solution of top boundary condition and subsidence of stratospheric air in the model. High ozone production is found in boundary layer at Tateno, with a peak around 2km. M6 matchs the sonde date quite well. At Kagoshima, there is a strong mixing within the boundary layer; all the models reproduce a similar pattern as observation except for larger magnitude. At the remote site Naha, high concentration above 70 ppb occur in boundary layer, with a peak appearing at a height around 1 km, implying possible transport process from the upwind area. M3-M6 generally exhibit a good agreement with observation, with the exception of higher altitude where ozone maximum appears.

4. Comparison with aircraft observation from Trace-P

In March 2001, Trace-P mission has been conducted over a wide region of west Pacific ocean including northern portion of the South China Sea, East China Sea, Yellow Sea and the south of Japan. For this study, 4 DC-8 flights (11,12,13,15) were chosen for comparison with model results. These flights are generally characterized by Asian continental outflow. 5 model results (M1,M3-M6) are adequate for comparison with Trace-P observations. Figure 4. shows the comparison results of SO_2, NO_2, CO and O_3 for DC-8 flight 15 (27 March,2001). Almost all the models can reproduce the evolution of trace species reasonably well, with the outflow feature being reflected, such as the high concentration of SO_2 and NO_2 at about 06:00-07:00 UTC over the China yellow Sea in the lower troposphere. The modeled ozone concentration shows a relatively good consistence with observation in trend, with the exception of the altitude around 10 km where the observation shows much higher than simulation. This sharp peak is resulted from a strong stratospheric intrusion. Although models appear to simulate somewhat increasing trend at this time period, there exist large differences in terms of magnitude and detail structure, which implies that neither the application of global top boundary condition nor the assumption of PV-O_3 relationship can well reproduce the stratospheric intrusion process. For carbon monoxide, M1, M4 and M6 show lower concentration and less variability compared with observations, while M5 show a good agreement with observation except for the underprediction of sharp peak.

The comparison of model results with ozone sonde data and Trace-P aircraft observations indicate that most of the participating models are capable of modeling the major processes of trace species in the troposphere of east Asia. Model intercomparison study does yield some common features of concerned species. Further investigation of the evolutionary features of trace species and possible reasons for the discrepancy among models and with observations are to be continued and more study results will be introduced in detail in the following relevant papers.