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HCHO seasonal characteristics and inconsistency between CMAQ-predicted and GOME-retrieved HCHO columns in East Asia

Kyung M. Han (1), Chul H. Song (1), Chul K. Lee (1,2), and Folkard Wittrock (3)

(1) Department of Environmental Science and Engineering, Gwangju Institute of Science and Technology (GIST), Gwangju, Republic Of Korea (chsong@gist.ac.kr/+82-62-970-3404), (2) Department of Physics and Atmospheric Science, Dalhousie University, Halifax, Nova Scotia, Canada, (3) Institute of Environmental Physics, University of Bremen, Otto-Hahn-Allee 1, 28359, Bremen, Germany

In this study, US EPA Models-3/CMAQ (Community Multi-scale Air Quality) v4.5.1 model simulations, using the ACE-ASIA (Asia Pacific Regional Aerosol Characterization Experiment), CAPSS (Clean Air Policy Support System), REAS (Regional Emission Inventory in Asia) and GEIA (Global Emissions Inventory Activity) emission inventories, were carried out for four seasonal episodes in order to examine seasonal variations and characteristics of formaldehyde (HCHO) columns over East Asia. Tropospheric HCHO columns were retrieved from the GOME (Global Ozone Monitoring Experiment) instrument over East Asia. For the consideration of possibly overestimated GEIA biogenic emission fluxes in East Asia, reduced isoprene and mono-terpene emission fluxes were used. There is a seasonally distinctive distribution of tropospheric HCHO columns from the GOME observations in East Asia where large amounts of NMVOCs are emitted from several major sources such as anthropogenic, biogenic, and biomass burning emissions. On the contrary, seasonal variations of the HCHO columns from the CMAQ simulation are not definitely clear except during summer due to the possible effect of biogenic emissions. In addition, there are seasonally large discrepancies between the CMAQ-predicted and GOME-retried HCHO columns, particularly over South China. The tropospheric HCHO columns from the CMAQ simulations have 97.1% and 13.6% larger values than those from the GOME observations during the fall and summer episodes, respectively, whereas the HCHO columns from the GOME observations have 131.3% and 59.9% larger values than those from the CMAQ simulations during the spring and winter episodes, respectively over South China. In the statistical analyses between both HCHO columns, absolute difference (Mean Bias) are also much more biased over South China than over North China, Korea, and Japan and relative differences (Mean Normalized Bias) are biased by 385.2% and -53.9% during the fall and spring seasons over South China. These large discrepancies between the CMAQ-predicted and GOME-retrieved HCHO columns could be caused mainly by missing BB (biomass burning) emission (whose fluxes have been not well quantified at present) in the CMAQ simulation, particularly for the spring episode and large uncertainties of the isoprene and mono-terpene emission fluxes. In order to examine these large differences, the HCHO chemical production/loss rates were calculated using 26 photo-chemical reactions obtained from the CMAQ simulation. The HCHO chemical production/loss rate has the highest positive values during the winter season and the highest negative values during the summer season. The negative values of the HCHO chemical production/loss rate indicate that the radical species (i.e. OH and O3) actively or dominantly react with the VOC species, particularly isoprene during the summer season. In addition, the seasonal distributions of the HCHO chemical production/loss rate are almost consistent with the isoprene emission fluxes considered in this CMAQ simulation. Again, this indicates that isoprene is a major species to determine the distribution of the HCHO columns over East Asia in this CMAQ simulation.