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Global surface NO_x emission estimation with a resolution of 0.56° derived from multi-constituent satellite data assimilation

Takashi Sekiya (1), Kazuyuki Miyazaki (1,2), Koji Ogochi (1), Kengo Sudo (1,3), Masayuki Takigawa (1), Henk Eskes (4), and Folkert Boersma (4)

(1) Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan, (2) Jet Propulsion Laboratory/California Institute for Technology, Pasadena, CA, USA, (3) Graduate School of Environmental Studies, Nagoya University, Nagoya, Japan, (4) Royal Netherlands Meteorological Institute (KNMI), De Bilt, the Netherlands

Nitrogen oxides (NO_x) emitted from anthropogenic, biomass burning, and natural sources are a precursor of ozone (O_3) and nitrate aerosols, which are important to human health, ecosystems, and the climate. Previous studies have demonstrated the capability of advanced multi-species satellite data assimilation as a mean of optimizing the global distributions of NO_x and other ozone precursor emissions at relatively low resolutions (1°–4°). In the present study, we examined a high-resolution global NO_x emission estimates (with a resolution of 0.56°) derived from multi-species satellite data assimilation using an ensemble Kalman filter approach (Miyazaki et al., 2015) and a high-resolution global chemical transport model (Sekiya et al., 2018). Assimilated data were obtained from the OMI, GOME-2, and SCIAMACHY for tropospheric NO_2 column, the TES for O_3 profile, the MOPITT for total CO column, the MLS for O_3 and HNO_3 profiles, and the OMI for total SO_2 column (all of which were for July 2008). Multi-species data assimilation plays an important role in improving NO_x emission estimates by constraining the photochemical environment, including the NO_x chemical lifetime. Data assimilation with a resolution of 0.56° was found to offer an effective means of estimating global surface NO_x emissions at the megacity scale in a consistent way. Data assimilation reduced the root mean square errors (RMSEs) of the surface NO_2 concentrations relative to in-situ measuring networks (AirBase, AQS, Hong Kong EPD, and NIES) by 33% for European cities, by 67% for U.S. cities, and by 75% for East Asian cities, relative to the results of model simulations. Substantial differences in the estimated emissions were obtained by increasing the model resolution from 2.8° to 0.56°. The global emission estimates fell by 10% mainly because of the effects of non-linear O_3-HO_x-NO_x chemistry, in contrast to the increase in emissions for most of megacities by a factor of 4-5 through the representation of emission contrasts between megacities and their surrounding areas. These emission changes, in addition to resolving different ozone chemical regimes, led to obvious improvements in the surface O_3 concentrations at both the megacity and regional scales with data assimilation at a resolution of 0.56°. These results demonstrate the potential of the data assimilation with a resolution of 0.56° for making better use of the more advanced high-resolution satellite retrievals provided by TROPOMI and geostationary satellites, which will benefit studies of the atmospheric environment at various spatial scales.