Global surface NO$_x$ emission estimation with a resolution of 0.56° derived from multi-constituent satellite data assimilation

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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.