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Constraints on ship NO_x emissions in Europe using OMI NO_2 observations

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About 90% of world trade is transported by oceangoing ships, and seaborne trade has been shown to have increased by about 5% per year in the past decade. Global ship traffic is currently not regulated under international treaties (e.g. Kyoto protocol) and ships are still allowed to burn low-grade bunker fuel. As a result, ships emit large quantities of nitrogen oxides (NO_x = NO + NO_2), important precursors for ozone (O_3) and particulate matter formation. Previous studies indicated that the global NO_x emissions from shipping are in the range 3.0-10.4 Tg N per year (15-30% of total global NO_x emissions). Because most ships sail within 400 km of the coast, it is important to understand the contribution of ship emissions to atmospheric composition in the densely populated coastal regions. Chemistry Transport Models (CTMs), in combination with emission inventories, are used to simulate atmospheric concentrations of air pollutants to assess the impact of ship emissions. However, these bottom-up inventories, based on extrapolation of a few engine measurements and strong assumptions, suffer from large uncertainties. In this study we provide top-down constraints on ship NO_x emissions in Europe using satellite observations of NO_2 columns.

We use the nested version of the GEOS-Chem model ($0.5^\circ \times 0.667^\circ$) to simulate tropospheric NO_2 columns over Europe for the years 2005-2006, using our plume-in-grid treatment of ship NO_x emissions. We improve the NO_2 retrievals from the Ozone Monitoring Instrument (OMI v2.0) by replacing the coarse a priori (TM4) vertical NO_2 profiles ($2^\circ \times 3^\circ$) with the high-resolution GEOS-Chem profiles. This ensures consistency between the retrievals and model simulations. GEOS-Chem simulations of tropospheric NO_2 columns show remarkable quantitative agreement with the observed OMI columns over Europe (R^2=0.89, RMS difference < 0.2×10^{15} molec. cm^{-2}), providing confidence in the ability of the model to simulate NO_2 pollution over the European mainland. We proceed and show quantitative comparisons of simulated and observed columns over two distinct ship tracks in Europe (west of France and Mediterranean Sea). Our comparisons suggest that both the AMVER-ICOADS and EMEP inventories provide too low NO_x emissions for these ship tracks, with important implications for exceedances of air quality standards in coastal regions.