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Constraints on Eurasian ship NO_x emissions using OMI NO_2 observations and GEOS-Chem

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Ships emit large quantities of nitrogen oxides (NO_x = NO + NO_2), important precursors for ozone (O_3) and particulate matter formation. Ships burn low-grade marine heavy fuel due to the limited regulations that exist for the maritime sector in international waters. Previous studies showed that global ship NO_x emission inventories amount to 3.0-10.4 Tg N per year (15-30% of total NO_x emissions), with most emissions close to land and affecting air quality in densely populated coastal regions. Bottom-up inventories depend on the extrapolation of a relatively small number of measurements that are often unable to capture annual emission changes and can suffer from large uncertainties. Satellites provide long-term, high-resolution retrievals that can be used to improve emission estimates.

In this study we provide top-down constraints on ship NO_x emissions in major European ship routes, using observed NO_2 columns from the Ozone Monitoring Instrument (OMI) and NO_2 columns simulated with the nested ($0.5^\circ \times 0.67^\circ$) version of the GEOS-Chem chemistry transport model. We use a plume-in-grid treatment of ship NO_x emissions to account for in-plume chemistry in our model. We ensure consistency between the retrievals and model simulations by using the high-resolution GEOS-Chem NO_2 profiles as a priori.

We find evidence that ship emissions in the Mediterranean Sea are geographically misplaced by up to 150 km and biased high by a factor of 4 as compared to the most recent (EMEP) ship emission inventory. Better agreement is found over the shipping lane between Spain and the English Channel. We extend our approach and also provide constraints for major ship routes in the Red Sea and Indian Ocean. Using the full benefit of the long-term retrieval record of OMI, we present a new Eurasian ship emission inventory for the years 2005 to 2010, based on the EMEP and AMVER-ICOADS inventories, and top-down constraints from the satellite retrievals. Our work shows that satellite retrievals can improve the characterization of emission locations, magnitudes and trends over sparsely monitored areas such as seas or oceans.