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Modelling the emissions from ships in ports and their impact on air quality in the metropolitan area of Hamburg

Martin Ramacher, Matthias Karl, Armin Aulinger, Johannes Bieser, Volker Matthias, and Markus Quante
Helmholtz Zentrum Geesthacht, Chemistry Transport Modelling, Germany (martin.ramacher@hzg.de)

Exhaust emissions from shipping contribute significantly to the anthropogenic burden of air pollutants such as nitrogen oxides (NOX) and particulate matter (PM). Ships emit not only when sailing on open sea, but also when approaching harbors, during port manoeuvers and at berth to produce electricity and heat for the ship's operations. This affects the population of harbor cities because long-term exposure to PM and NOX has significant effects on human health. The European Union has therefore has set air quality standards for air pollutants. Many port cities have problems meeting these standards. The port of Hamburg with around 10.000 ship calls per year is Germany's largest seaport and Europe's second largest container port. Air quality standard reporting in Hamburg has revealed problems in meeting limits for NO_2 and PM10. The amount and contribution of port related ship emissions (38% for NO_x and 17% for PM10) to the overall emissions in the metropolitan area in 2005 [BSU Hamburg (2012): Luftreinhalteplan für Hamburg. 1. Fortschreibung 2012] has been modelled with a bottom up approach by using statistical data of ship activities in the harbor, technical vessel information and specific emission algorithms [GAUSS (2008): Quantifizierung von gasförmigen Emissionen durch Maschinenanlagen der Seeschiffart an der deutschen Küste]. However, knowledge about the spatial distribution of the harbor ship emissions over the city area is crucial when it comes to air quality standards and policy decisions to protect human health. Hence, this model study examines the spatial distribution of harbor ship emissions (NOX, PM10) and their deposition in the Hamburg metropolitan area. The transport and chemical transformation of atmospheric pollutants is calculated with the well-established chemistry transport model TAPM (The Air Pollution Model). TAPM is a three-dimensional coupled prognostic meteorological and air pollution model with a condensed chemistry scheme including photochemistry. The model was applied to the Hamburg metropolitan area with a setup of 30 x 30 grid cells of 1 km^2 each and 30 vertical grid levels from 10 to 8,000 m, for a time period of one year. Emission inventories for traffic, industry, households and ships in 2013 were generated. To investigate the dispersion of ship emissions to air pollution two different model runs for 2013 were performed; one model run including land-based emissions and the ship emissions and a model run just including the land-based emissions. The modelling results were evaluated with air quality data from the monitoring station network of Hamburg (luft.hamburg.de). The results are presented in form of spatial distribution maps for the Hamburg metropolitan area highlighting the pollutants (PM and NOX) originating from harbor residential ships.