A pollutant emission model for ships and its application in air quality modelling

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INTRODUCTION

Pollutant exhaust from ships is an important factor influencing the air quality in cities with large ports like the city of Hamburg, Germany. Therefore, municipalities are concerned with measures aimed at mitigating air pollution by ships, in particular with NOx and PM. For planning these measures and evaluating their effectiveness, it is essential to have an emission model that can be run in any temporal and spatial resolution, and above all, is able to simulate different emission scenarios. Knowing emission fluxes, however, does not allow for sound conclusions about the air quality because the dispersion of pollutants depends on the weather conditions, radiation and the chemical composition of the atmosphere. Therefore, the emission model is embedded in a modelling system that comprises also weather and chemical transport simulation models.

SHIP EMISSION MODEL

At Helmholtz-Zentrum Geesthacht we developed a ship emission model that simulates the activities sailing, manoeuvring and berthing of every single registered ship in the port of Hamburg and calculates their emissions of NOx, SO2, sulfuric acid, CO, CO2, VOC, PM10, black carbon and primary organic carbon. As different emission factors apply for the different activities, it is at first necessary to reconstruct the activities of the ship during their stay within the port. This can be achieved by evaluating Automatic Identification System (AIS) signals that are broadcast by the ships every six seconds and contain at least the coordinates and time stamp. Alternatively, data gathered by the port authorities could be used. In our current development, we use such data in the form of arrival-departure tables. This means that the least that must be known is time of entry into the port, arrival at the quay, departure from the quay and time of leaving the port.

The emission factors for moving ships are energy specific (denoted in g/kWh) and defined as a function of the engine load. We used different functions for different engine types and ship sizes (Aulinger et al., 2016). The actual load while sailing is calculated from the actual speed and the maximum speed of the vessel whereas for the activity manoeuvring fixed loads are assumed per ship type. The emissions of the auxiliary engines are calculated assuming fixed loads, too. Ship emissions at berth are calculated with fuel specific emission factors (denoted in g/kg). The method for calculating the fuel consumption of auxiliary engines and boilers was derived from an on board survey comprising 175 ships (Clean North Sea Shipping Project Consortium, 2014; Hulskotte and van der Gon, 2010).

RESULTS AND DISCUSSION

Based on a simple arrival-departure table, the emissions model is able to quickly calculate ship emissions in any desired spatial and temporal resolution. Due to its bottom-up nature it is simple to set up a different ship traffic scheme and calculate scenario emissions. If the routes and activities of the ships in ports were reconstructed from AIS signals – a module for this is in preparation – the model would be easily portable to other port areas.

After conversion of the line emissions to gridded emissions they can be used in air quality simulation frameworks like US-EPAs Community-Multiscale-Air-Quality modelling system. Showing the emissions as raster maps allows for identifying hot spots, which are in the case of the port of Hamburg the cruise terminals at the northern banks of the River Elbe and, most of all, the container terminals. Container ships have by far the largest share in the total ship emissions because they are both the most abundant ship type in Hamburg and they belong to the largest ships with the highest engine power. As an example, container and general cargo ships emitted about 3500 tons NOx in the year 2013 in contrast to less than 500 tons NOx emitted by all the other vessels. The emissions from ships constitute 20-36% of the total NOx emissions in the city of Hamburg. Results of air quality simulations revealed that shipping emissions are accountable for an increase of nitrogen oxides of up to 40% close to the harbour and to 15% in living areas that are about 10 km away from the harbour.

References

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