Monitoring shipping emissions in the German Bight using MAX-DOAS

André Seyler1, Folkard Wittrock1, Lisa Kattner1,2, Barbara Mathieu-Uffing1,2, Enno Peters1, Andreas Richter1, Stefan Schmolke2, Andreas Weigelt2, and John PD Burrows1

1Institute of Environmental Physics (IUP), University of Bremen, Germany
2German Maritime and Hydrographic Agency (BSH), Hamburg, Germany

Contact: aseyler@iup.physik.uni-bremen.de

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MeshMarT project
• "Measurements of Shipping Emissions in the Marine Troposphere" – a project coordinated by the University of Bremen with support of the German Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH) and the Helmholtz Zentrum Geesthacht (HZG)
• MeshMarT permanent measurement sites and platforms for campaigns:
  - DOAS
  - Slant column densities of NO2
  - Green
  - Blue
  - Red
  - Enhanced

Background values of 0.5

Slant column densities of NO2 to NO2 signal:

• MesMedA permanent measurement sites and platforms for campaigns:
  - DOAS
  - Slant column densities of NO2

Retrieved quantity

NO2

Seeschifffahrt

Global scale: changing atmospheric composition and impact on climate

Since 2005, the capacity of the global merchant fleet doubled in the last decade

Significantly

Enlargement of NO2 and SO2 pollution levels on wind direction:

• Red curve: before 1 January 2015
• Blue curve: after 1 January 2015
• Volume mixing ratios calculated using O2 as a tracer for the effective horizontal light path length (Gomez, 2014)
• NO2: No regulations → no significant change in emission
• SO2: Allowed fuel sulfur content dropped from 1.0 % to 0.1 % → significantly lower SO2 emissions, especially from the open North Sea

Wind sector classification

• Blue sector: wind from the open North Sea, shipping is the only pollution source
• Green sector: mainly land-based air pollution (traffic, industry, ...)
• Yellow sector: air mass contains shipping emissions as well as land-based air pollution (mixed origin)

Regulations

• International Maritime Organisation (IMO): Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78 Annex VI)
• Establishment of general Emission Controlled Areas (ECA)
• Regulation for new built ships
• Limitation of sulfur content in heavy oils and marine fuel

Since January 2015 only 0.1% sulfur is allowed (before: 1%) in ECA like North Sea and Baltic Sea

Dependence of NO2 and SO2 pollution levels on wind direction:

Shipment

• Shipping is generally the most efficient energy transportation mode (per t per km)
• Shipping accounts for ≈ 80% of total merchandise worldwide trade volume
• Seaborne trade grows fast, despite the economic crisis
• Capacity of global ship fleet doubled in the last decade
• Shipping accounts for a significant part of the emissions from the transportation sector
• Emissions of NOx from high temperature combustion (nitrogen and oxygen from ambient air)
• Emissions of SOx directly linked to fuel sulfur content
• Local scale: affecting air quality and harmful for human health
• Global scale: changing atmospheric composition and impact on climate

Contribution of ships vs. land-based pollution sources on coastal air quality on Neukower: NOx

• To trade ship emissions off against land-based emissions (e.g. industry, road transport), two representative sectors of wind directions have been chosen
• Excluding data with mixed air mass origin, the contribution of shipping sources to pollution on Neukower is around 40% for both NO2 and SO2 in the years 2013 and 2014, a significant, but surprisingly small fraction
• Since 2015, the recent contribution of shipping sources was reduced to 14%, the absolute amount decreased by about 0.8, even though the wind was coincidentally blowing more often from the open sea in this time period
• Since 2015, the vast majority of SO2 emissions can be attributed to land sources, ships play only a negligible role

MAX-DOAS measurement geometry

• DOAS: Differential Optical Absorption Spectroscopy
• Idea: Measure spectra of back-scattered sunlight from the atmosphere, fit absorption cross sections of multiple absorbers (e.g. NO2, O3, NO, O3) simultaneously to measured optical depth
• Retrieved quantity: Slant column density (SCD)
• Concentration of the absorber integrated along the light path

Enhanced HCHO downwind of oil rigs

• MAX-DOAS measurements of formaldehydes (HCHO) onboard the Irish research vessel Celtic Explorer during the annual BSH summer survey in North and Baltic Sea in August 2015
• Background values of 0.5-11.6 molec/cm in agreement with GOE2A satellite measurements of HCHO
• Measurements indicate that some oil rigs are important sources of HCHO precursors

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