1. Motivation

Shipping emissions:
- Nitrogen oxides (NOx), sulfur oxides (SOx), volatile organic compounds (VOCs), black carbon, NO2, and particulate matter (PM)
- Impact on marine tropospheric chemistry, ecological, and climatic effects (formation of ozone and aerosol, acidification, albedo)
- Health risk (pulmonary/cardiovascular) for people living in harbor cities and close to main shipping routes

Political measures:
- Convention of the International Maritime Organization (IMO) for Prevention of Pollution from Ships (MARPOL 73/78 Annex VI)
- Limitation of sulfur content in heavy oil fuels and in Emission Controlled Areas (ECA), starting Jan 2015
- Establishment of General Emission Controlled Areas (ECA)
- Regulation of NOx emissions from newly built marine engines

2. Objectives

MeSMaRT - Measurements of Emissions in the Marine Troposphere:
- A project coordinated by the University of Bremen with support of the Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH) and the European Space Agency
- Assessment of different measurement systems such as remote sensing, in-situ, and passive sampling measurements as methods for long-term monitoring of shipping emissions in the North and Baltic Sea
- Establishment of remote sensing instruments like MAX-DOAS to support the surveillance of international emission regulations
- Improvement of ship emission data bases by measurements of the actual distribution of trace gases and aerosols related to ship emission
- Validation of satellite measurements and model data
- Description of the influence of ship emissions and its secondary products on the marine environment
- Development of a concept for controlling ship emissions

3. Operational area and platforms

German Bight and Baltic Sea:
- German Exclusive Economic Zone, with 12-nm zone und main shipping routes
- An area already covered with extensive research concerning water quality and oceanography by BSH

Stationary platforms:
- Neuwerk: 6 km to navigation channel of the mouth of Elbe, ~50 km from Flensburg, the biggest German harbor
- Wedel: 30 km to navigation channel of the mouth of Elbe, ~40 km from Cuxhaven and Hamburg

In the near future monitoring car
- Mobile measurement station equipped with MAX-DOAS and in situ devices

4. Methods

A. Passive remote sensing with Differential Optical Absorption Spectroscopy (DOAS) using different platforms (here only MAX-DOAS results from the ground are presented)

Detection:
- Using O3 and H2O as proxies for the effective light path to calculate profile information (VMR) for NOx and SOx
- Detection limits NOx ~100 ppb, SOx ~200 ppb for typical viewing conditions, time resolution to 5 min

Further retrieval:
- Continuous in situ measurements of SOx, NOx, O3, and COx with trace gas monitor in ambient air
- Complementary data: Meteorological data and AIS (Automatic Identification System) ship data

5. Selected Results and Discussion

MAX-DOAS data:
- Figures R1 and R2 show the impact of the shipping lane close to Neuwerk on coastal air quality
- Figure R3 shows single day measurements: Emissions of passing ships are clearly visible as peaks in the data that can mostly be allocated to single ships using AIS and wind data
- Not every NOx peak has a corresponding SO2 peak (app. different sulfur contents in fuel

MAX-DOAS vs. in situ data:
- Figures R4 to R8 show comparisons of MAX-DOAS with in situ NOx volume mixing ratios
- In particular for the Neuwerk site the best agreement was found when using water vapour as a proxy for the effective light path
- A certain time is needed for the emission plumes to travel to the in situ instrument, depending on wind speed -> time delay between MAX-DOAS and in situ measurements (see Figure R6)
- Since ship plumes usually never cover the whole light path very high peaks are usually underestimated (notably for Wedel where the distance to passing ships is ~500m, Figure R5)

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Contact: a.aseyer@iup.physik.uni-bremen.de

www.mesmart.de

Monitoring Shipping Emissions with MAX-DOAS Measurements

André Seyler1, Folkard Wittrock1, Lisa Kattner1,2, Barbara Mathieu-Üffing1,2, Enno Peters3, Andreas Richter3, Stefan Schmolke2, Norbert Theobald2, and John P. Burrows1
1Institute of Environmental Physics (IUP), University of Bremen
2Federal Maritime and Hydrographic Agency (BSH), Hamburg
3German Weather Service (DWD), Hamburg

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MesMaRT – Measurements of Emissions in the Marine Troposphere
Contact: a.aseyer@iup.physik.uni-bremen.de

www.mesmart.de