1. Motivation

Shipping emissions:
- Pollution components: carbon dioxide (CO₂), carbon monoxide (CO), nitrogen oxides (NOₓ), sulfur oxides (SO₂), volatile organic compounds (VOCs), black carbon (BC), polyaromatic hydrocarbons (PAHs), particulate matter (PM) impact on marine trophic chains, ecological and climatic effects (formation of zones of aerosol, acidification, albedo)
- Health risk (pulmonary/cardiovascular) in harbor cities and coastal regions
- Especially dangerous due to combustion products from heavy oil fuels with high sulfur content and strong soot emission
- Capacity of global merchant fleet has doubled since 2000

2. Objectives

McSmarT — Measurements of Shipping Emissions in the Marine Troposphere — a project coordinated by the University of Bremen with support of the Federal Maritime and Hydrographic Agency (BSH), Hamburg and the Helmholtz Zentrum Geesthacht

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 emissions
- 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

Operational area: German Bight and Baltic Sea

Ship monitoring: 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 different DOAS results from the ground are presented)

Influence of fuel sulfur content regulations:
- On the 1st of January 2015, the allowed sulfur fuel content inside ECA decreased from 1.5% to 0.5%
- SO₂ emissions since then: no ship emission peaks visible anymore (see Fig. R5)
- SO₂ values below the MAX-DOAS detection limit (<0.2 ppb)
- Wind direction dependence: much less SO₂ from shipping lane (see Fig. R6)

3rd International DOAS Workshop (Brussels, 2015)
McSmarT — Measurements of Shipping Emissions in the Marine Troposphere
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5. Selected Results and discussions:

Figures R1 and R2 show the impact of the shipping lane close to Neuwerk on coastal air quality
- Enhanced background pollution from the shoreline and the city of Cuxhaven and Bremerhaven
- In sector from W to N: wind from the open North Sea → all ships are coming from ships
- The fraction of shipping emissions on the overall emissions is much higher for SO₂ than for NO₂
- Figures R3 and R4 show single day measurements: emissions of passing ships are visible as peaks
- Scanning horizontally: movement of ships and ship plumes can be studied (see Fig. R3)
- Using AIS and wind data → peaks can mostly be allocated to individualships (see Fig. R4)
- Not every NO₂ peak has a corresponding SO₂ peak → different sulfur content in fuel

Comparison in-situ data:
- Figures R7 to R9 show comparisons of MAX-DOAS with in situ volume mixing ratios
- In particular for the Neuwerk site the best agreement for NO₂ was found when using water vapour as a proxy for the effective light path length
- 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 (Fig. R7)
- Since ship plumes usually never cover the whole light path very high peaks are usually underestimated

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Selected references