Monitoring shipping fuel sulphur content regulations with in-situ measurements of shipping emissions

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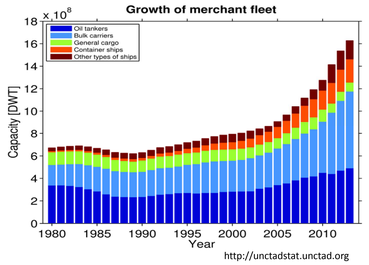
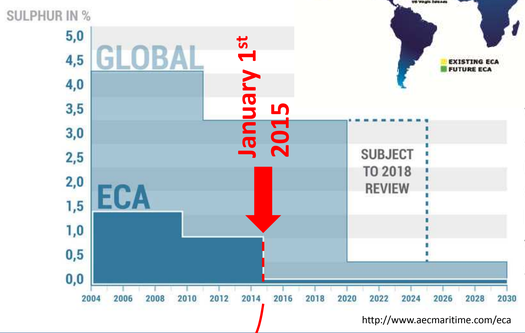
Motivation

- Increase in shipping volume leads to increase in the amount of shipping emissions
- 20% of shipping emission are emitted within the 12-mile-zone near the coast
- Shipping emission can be transported hundreds of kilometers into the inland



Political Measures:
Convention of the International Maritime Organization (IMO) for Prevention of Pollution from Ships (MARPOL 73/78 Annex VI)



When a ship enters an ECA (Emission Control Area), it has to use fuel with a reduced sulphur content

Compliance Monitoring so far:

- No consistent regulations
- Coast guards check fuel log books and collect fuel samples if irregularities occur
- No access to ships offshore

MeSMarT (Measurements of Shipping Emissions in the Marine Troposhpere)
One part of MeSMarT objectives:

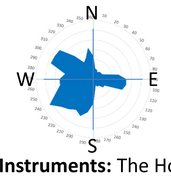
- Testing and implementing in-situ measurements of trace gases to identify ships that do not comply with sulphur fuel content regulations

For further information about MeSMarT activities:
Wed., 15. April, 16:00: EGU2015-6737: A. Seyler et al., „MAX-DOAS measurements of shipping emissions"

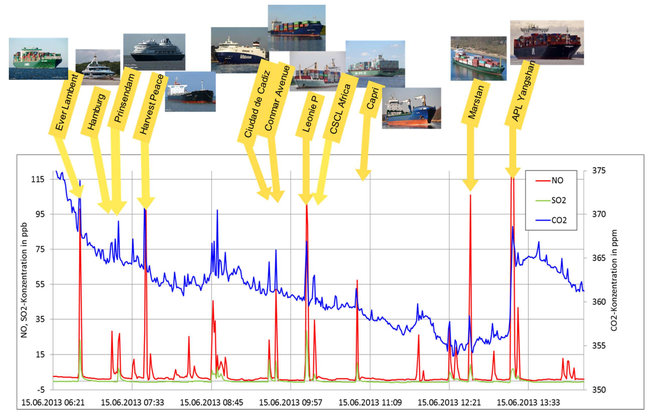
Measurements

	SO_2	NO, NO_2, NO_x	CO_2	O_3
Instrument	APSA-370	APNA-370	Licor 840A	APOA-370
Measurement principle	UV-fluorescence	Chemiluminescence of NO	Non-Dispersive IR spectroscopy	UV-Absorption

- **Measurement location:** in Wedel near Hamburg harbour, about 300 – 500m away from passing ships
- **Main wind direction:**



- **Instruments:** The Horiba system integrates four instruments in a compact, temperature stabilised box



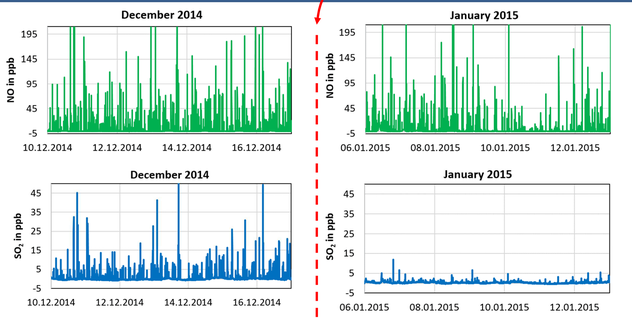
- Ships can be associated with measured emission peaks by combining in-situ data with data about ship positions (AIS – Automatic Identification System), wind direction and speed
- Using a conversion formula, the SO_2/CO_2 ratio can be used to estimate the sulphur content of fuel

$$\%S\ in\ fuel = \frac{S\ [kg]}{fuel\ [kg]} = \frac{\Delta\ SO2\ [ppm] \cdot A(S)}{\Delta\ CO2\ [ppm] \cdot A(C)} \cdot 87\ \% = \frac{\Delta\ SO2}{\Delta\ CO2} \cdot 232$$

with A(S), A(C) = atomic mass of sulphur, carbon

Assumptions:
- 87% of carbon in fuel
- 100% of carbon and sulphur are converted to CO_2 and SO_2

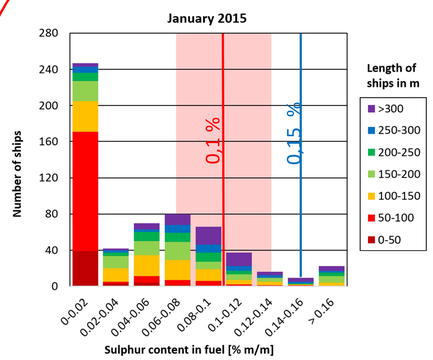
Results



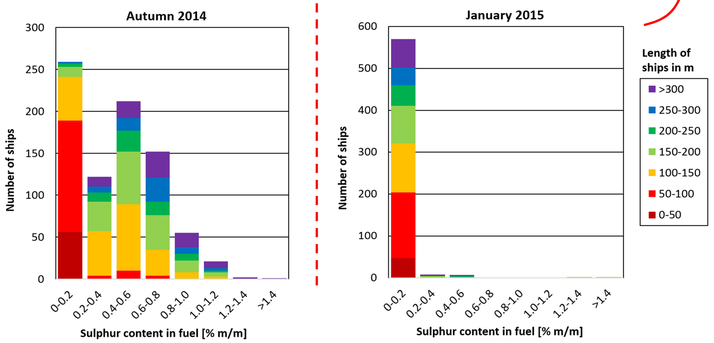
Comparison of absolute NO and SO_2 volume mixing ratio values in December 2014 and in January 2015 under comparable wind conditions

- Each peak belongs to one emission plume of an individual ship
- Obvious SO_2 reduction in 2015, while for NO no reduction can be observed

Detailed view of January 2015 data:



- With respect to an error of 15 – 30% of the sulphur content (red shaded area), we suggest to use the value 0.15 % to discuss compliance of ships with sulphur regulations
- 95.4 % of all ships in January comply with the new, much stricter sulphur content regulations
- Small ships still have the lowest sulphur fuel contents, possibly because of the even stricter regulations for inland water vessels



Sulphur fuel content of 824 ships in autumn 2014 and of 589 ships in January 2015

- While in 2014 only small ships had fuel sulphur contents below 0.2%, nearly all ships fell into this category in January 2015

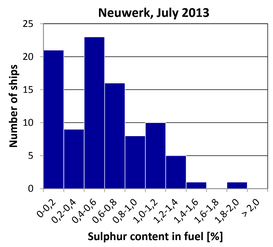
Summary and Conclusion

- With the presented method it is possible to determine the sulphur fuel content of ships passing downwind of the measurement station
- At the measurement station in Wedel near Hamburg harbour up to 40 % of all ships entering and leaving the harbour per month can be checked when weather conditions are good
- We have analysed the sulphur fuel content of 1413 ships in total
- The compliance rate to the 1 %-sulphur limit in 2014 was 99% and to the 0.1%-sulphur limit in 2015 it was 95.4 %
- Government agencies in charge of controlling SECAs could use this method to efficiently check suspicious ships

Outlook

Using the method at different locations, further away and on the open sea:

- Measurement site Neuwerk, a small island at the German Coast, 5-10 km away from passing ships
- Preliminary results of 94 ships in July 2013, comparable to Wedel 2014 data



Operation of the system on research vessels on the North Sea:
Data have been collected on several cruises with the RV „Celtic Explorer" in 2012 - 2014

Acknowledgements

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- The authors thank the staff of the BSH Laboratory in Hamburg-Sülldorf, Institut für Hygiene und Umwelt, Wasser- und Schiffahrtsamt Cuxhaven and Hamburg for their help and support

Selected References

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- International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI Prevention of Air Pollution from Ships (entered into force 19 May 2005), http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution
- Balzani Lööv et al., Field test of available methods to measure remotely SOx and NOx emissions from ships, AMT, 7, 2597 – 2613, 2014