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BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

MeSmarT – Measurements of Shipping Emissions in the Marine Troposphere





a project of the University of Bremen, supported by BSH

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- Outline of the project “MeSmarT”
- Measurement techniques and sites
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- Outlook

Motivation

What is air pollution?

Pollutant	Sources	Health Effect
NO, NO_2 (Nitrogen Oxides)	Fuel combustion, wood burning	Lung diseases, respiratory symptoms
SO_2 (Sulfur Dioxide)	Fuel combustion (especially high-sulfur fuel), industrial processes, volcanoes	Aggravates asthma, respiratory symptoms
PM (Particulate Matter)	Emitted directly or formed through chemical reactions, fuel combustions, industrial processes	Heart and lung diseases, potentially carcinogenic, premature mortality
O_3 (Ozone)	Formed by chemical reaction	Aggravates lung diseases and asthma, premature death
CO (Carbon Monoxide)	Fuel combustion	Reduces amount of oxygen in body‘s organs and tissues, aggravates heart diseases

EPA-454/R-12-001, February 2012

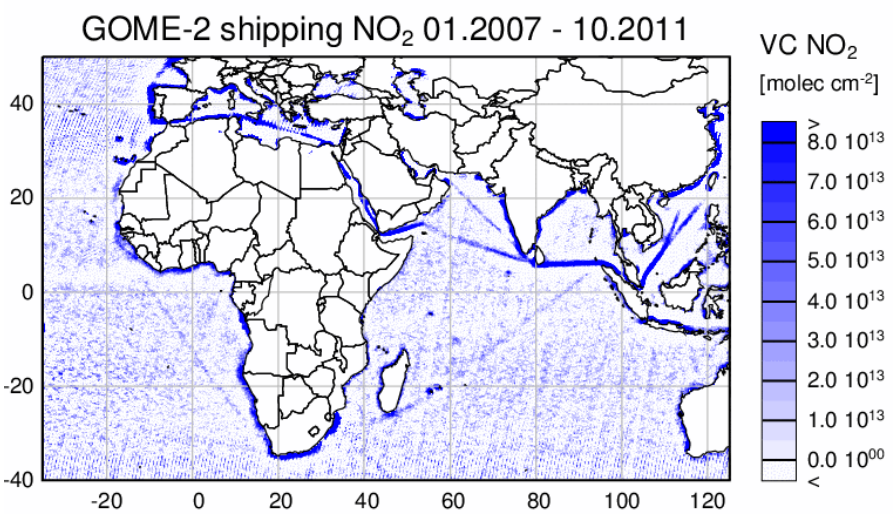
Motivation

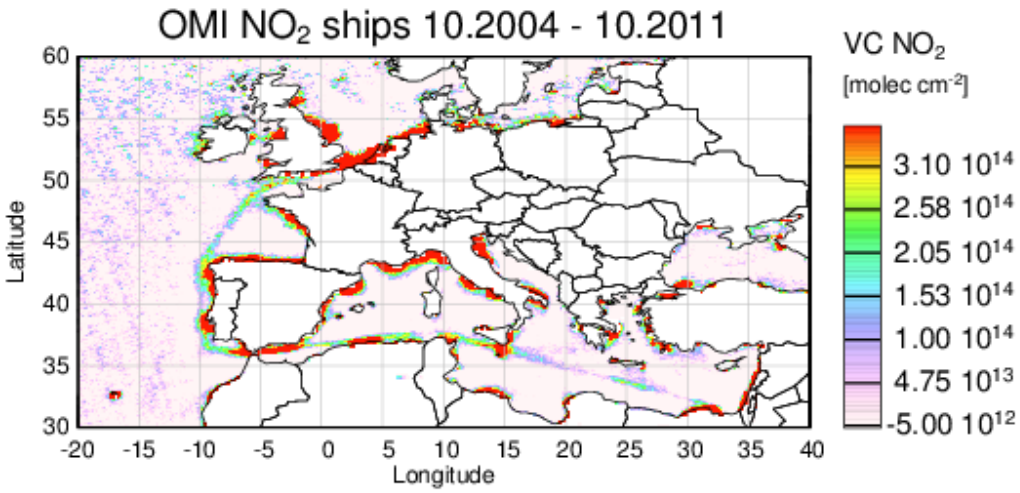
Air pollution caused by shipping emissions:

- Increase of international trade volume and shipping
- Concentration of shipping emissions in coastal areas and harbor cities (20 % within 12 nm – Zone)
- Considerable contribution to local air pollution with severe health effects
    - Corbett et. Al.: “Mortality from Ship Emissions: A Global Assessment“, *Environ. Sci. Technol.* **2007,** *41,* 8512–8518

Motivation

Shipping emission NO_2 - measurements by satellite



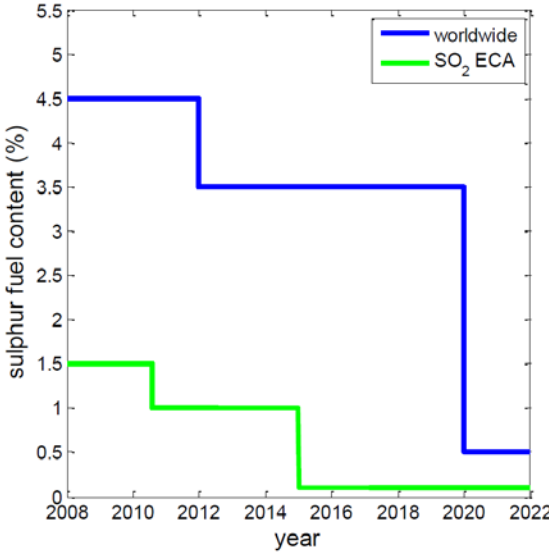


A. Richter et al., Satellite Measurements of NO2 from International Shipping Emissions, *Geophys. Res. Lett.*, 31, 2004
A. Richter et al..: An improved NO2 retrieval for the GOME-2 satellite instrument, *Atmos. Meas. Tech.*4, 1147-1159, 2011

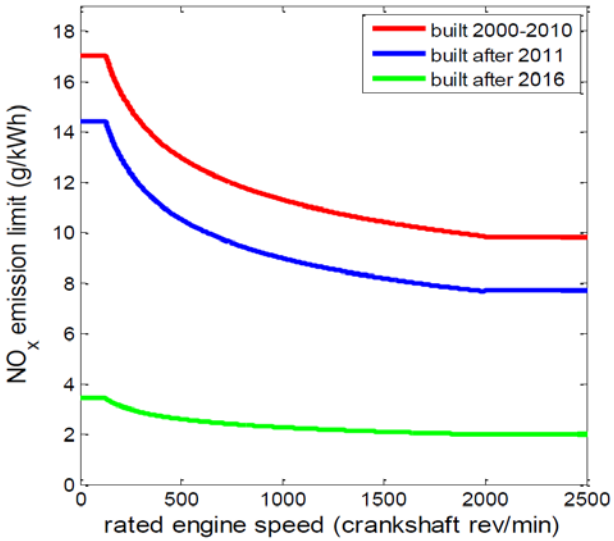
Motivation

Political measures:
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*

Sulfur fuel content regulation



Nitrogen oxides emission regulation



SECA zones Europe and worldwide

© Lloyd's Register June 2012

Outline of the project MeSmarT

- How is the actual situation of air pollution over the North and Baltic Sea and what is the contribution of shipping emissions?
- How do the political regulations influence the air quality?
- How can we assure the quality of our measurements?
- Is it possible to reproduce measured data with state-of-the-art modelling?

Outline of the project MeSmarT

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- How is the actual situation of air pollution over the North and Baltic Sea and what is the contribution of shipping emissions?
- How do the political regulations influence the air quality?
- How can we assure the quality of our measurements?
- Is it possible to reproduce measured data with state-of-the-art modelling?

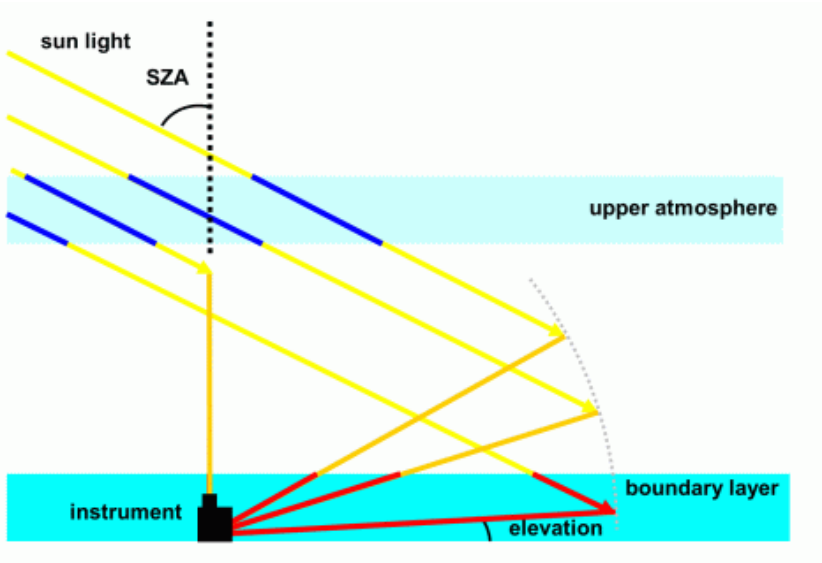
- How can we observe and controll the compliance of the shipping emission regulations?
- Which measurement methods are suitable for this?

Measurement methods

Remote sensing: MAX-DOAS

Multi-**Ax**is **D**ifferential **O**ptical **A**bsorption **S**pectroscopy

- Detection of column densities of trace gases for different optical paths
- Vis spectrometer (400 – 570 nm) for NO_2 measurements
- UV spectrometer (315 – 385 nm) for SO_2 measurements



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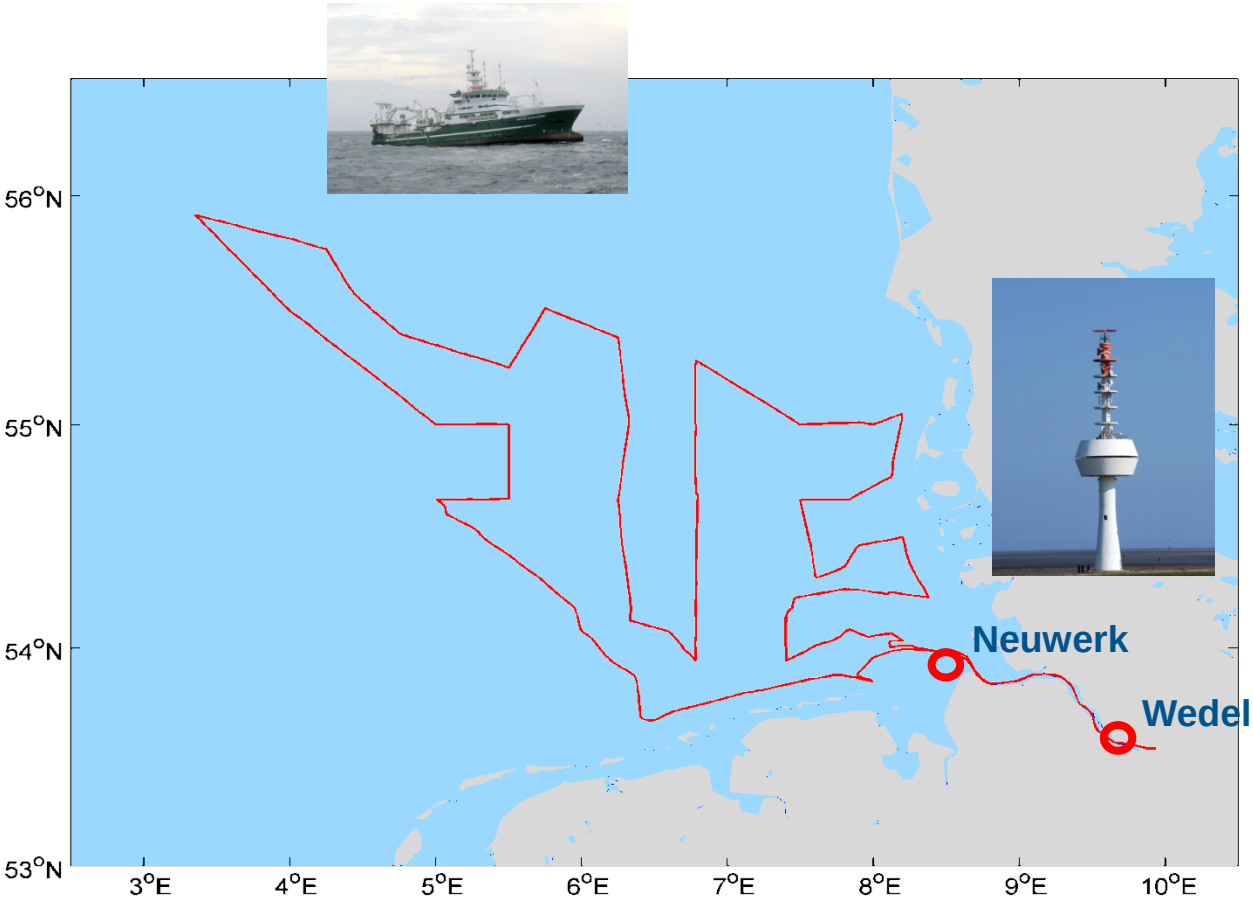
Measurement methods

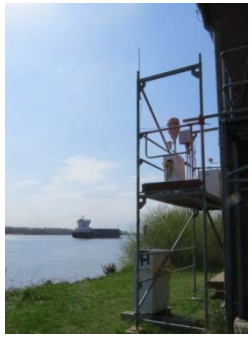
In-situ-measurements : Airpointer (MLU)

	SO_2	NO, NO_2, NO_x	O_3	CO_2
Messprinzip:	UV-Fluoreszenz (EN 14212)	Chemi-luminesz von NO (EN 14211)	UV-Absorption (EN 14625)	Non-Dispersive IR-Spectroscopy LI-COR LI820
Detection limit	0.25 ppb	0.4 ppb	0.5 ppb	1 ppm
Measuring range	< 10 ppm	< 20ppm	< 200 ppm	< 20000 ppm
Time period	< 90 s	< 60 s	< 30 s	1 s

B. Mathieu-Üffing

Measurement sites





Resarch vessel cruises

CE12015: 3.11.2012 – 9.11.2012

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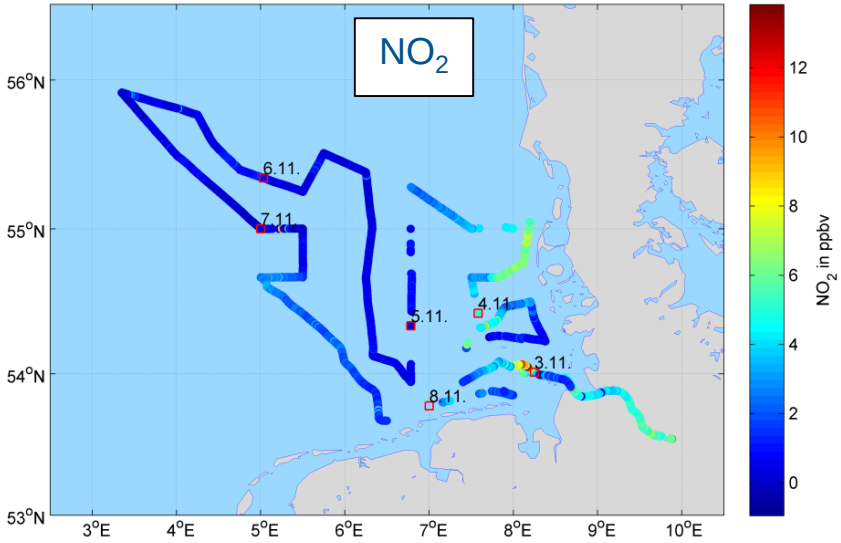

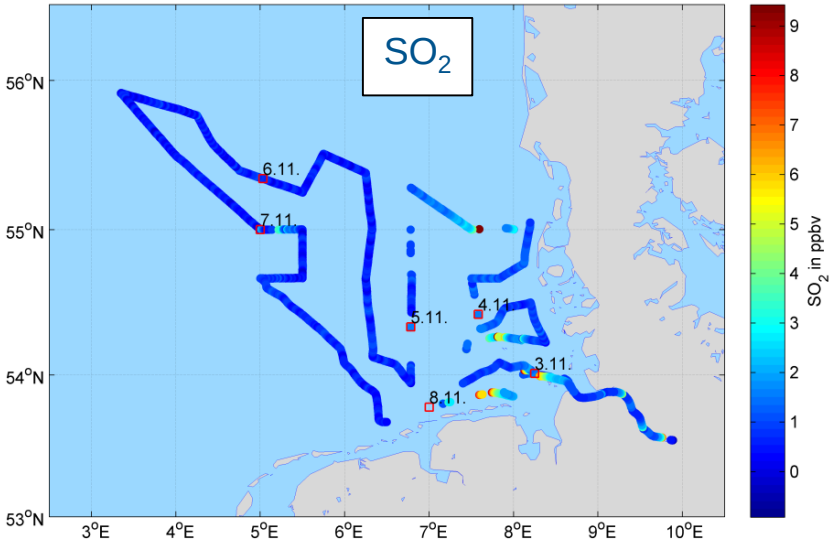

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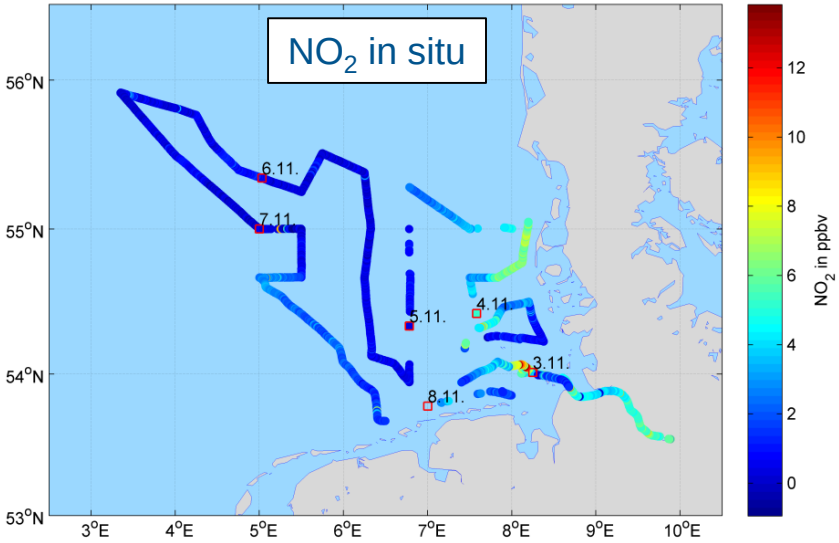

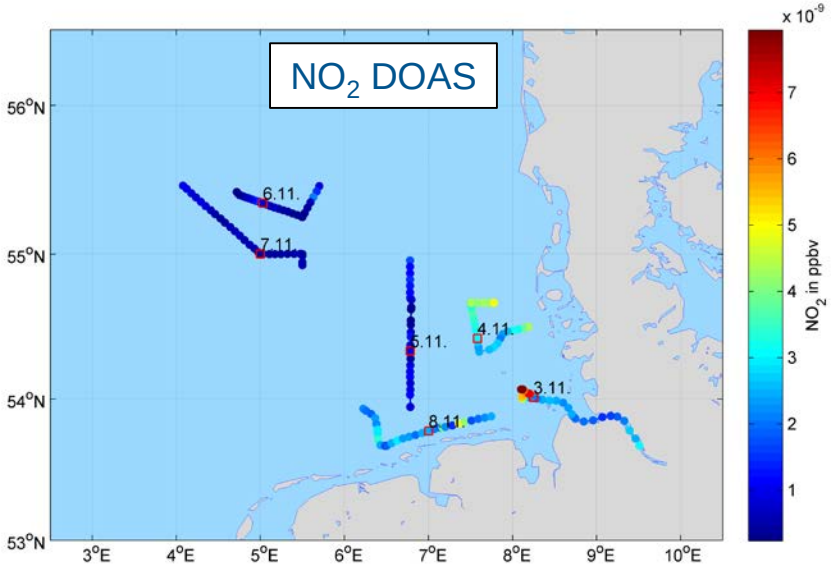

Resarch vessel cruises

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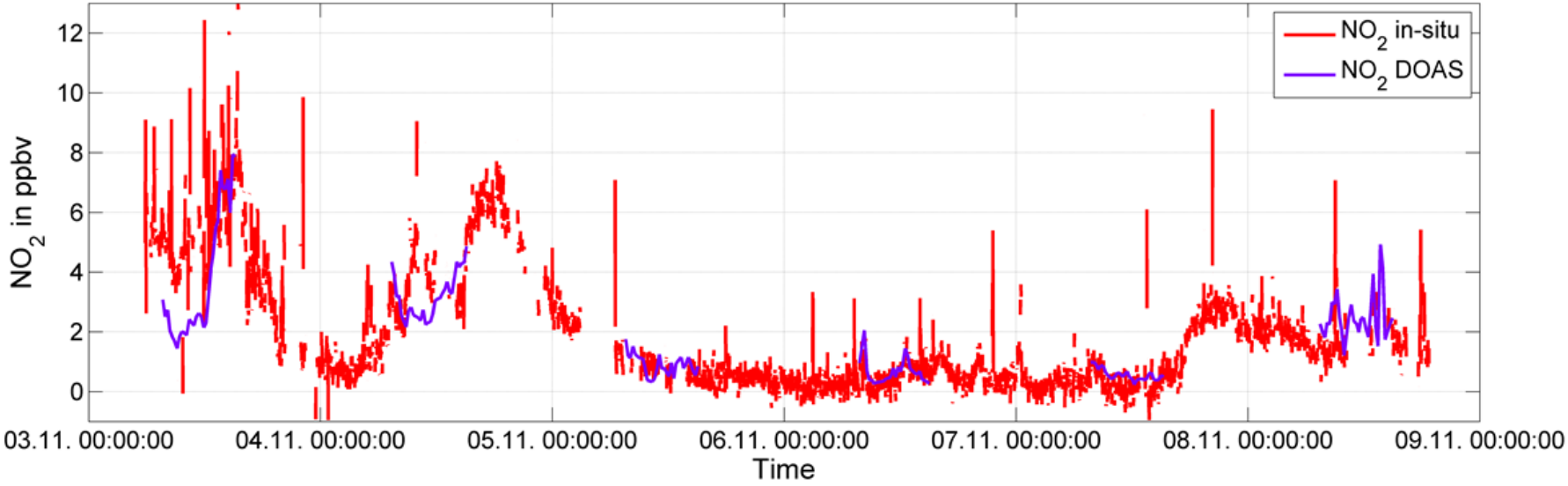
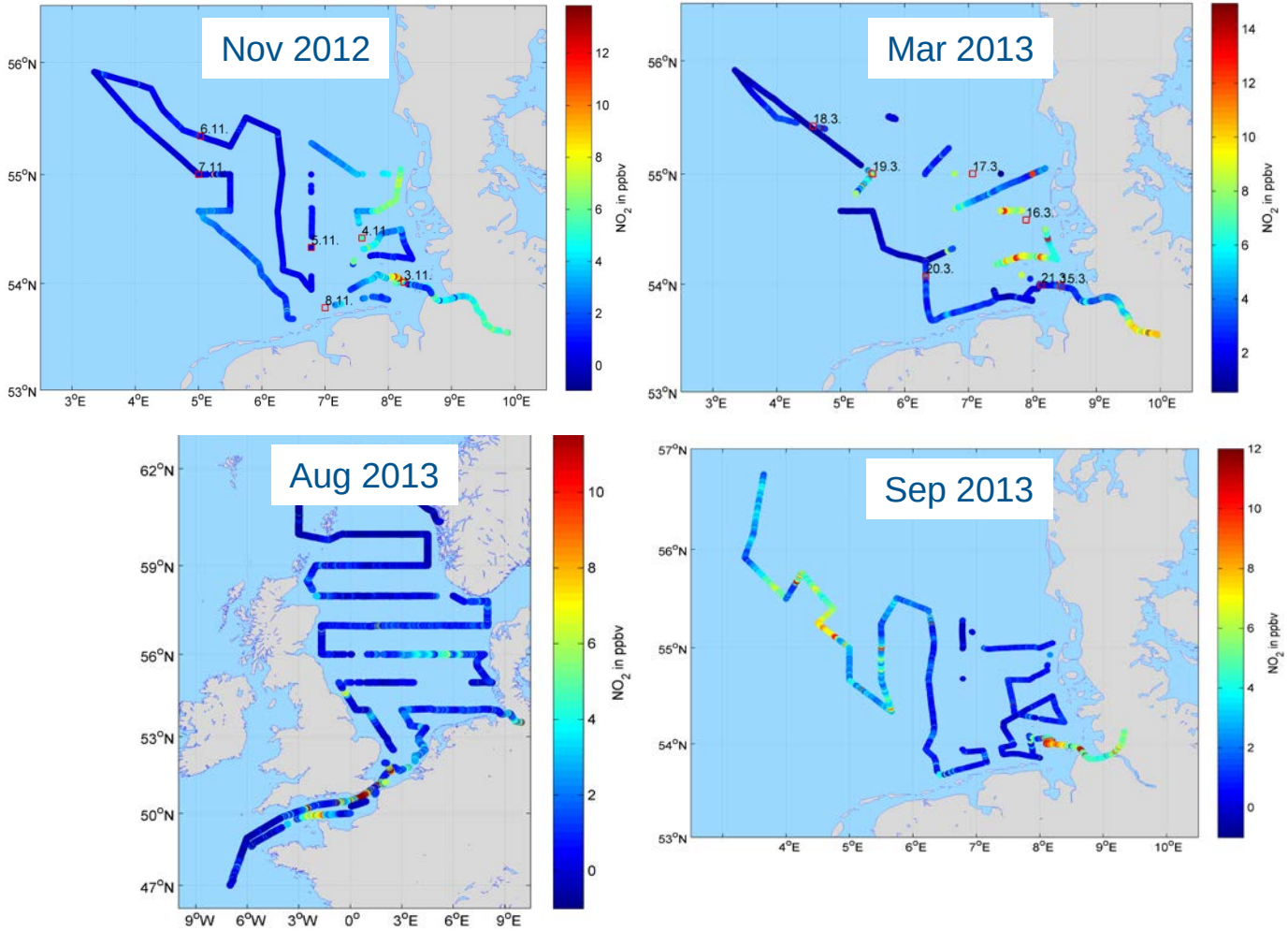


Resarch vessel cruises



Unique data set:

- Different seasons
- different weather conditions
- different air mass origins

Measurements in Wedel

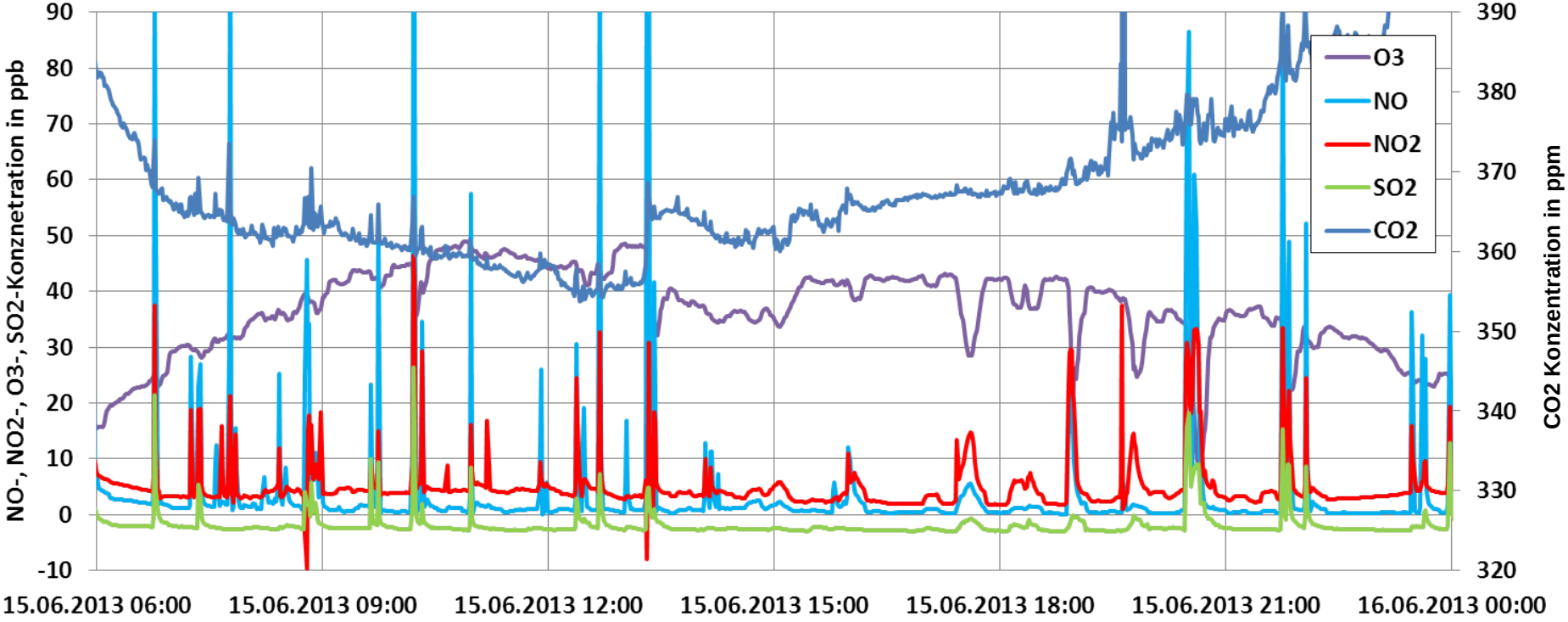
29.4.2013 – 3.7.2013

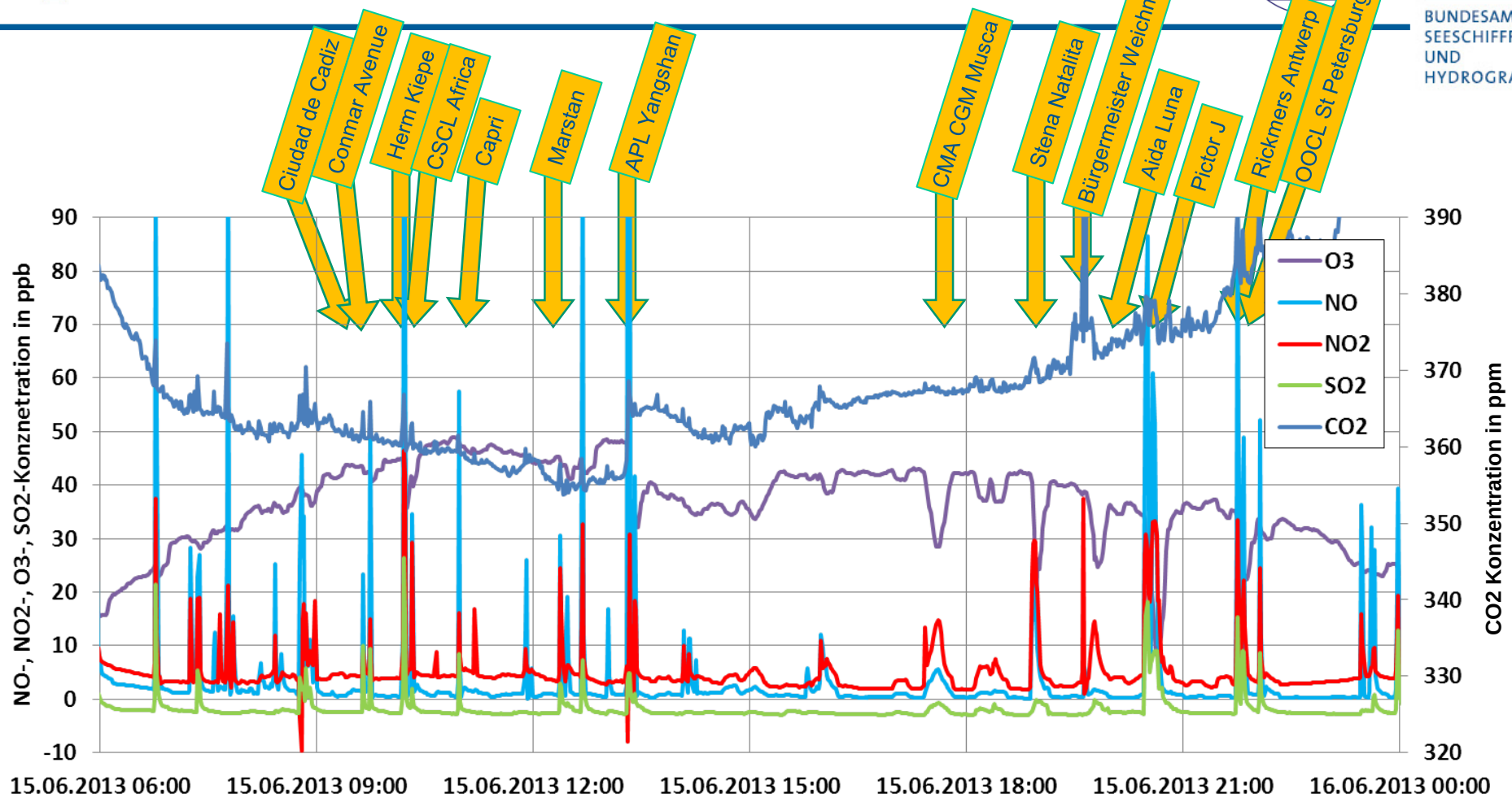
With contribution of WSA Wedel

Folkard Wittrock

Measurements in Wedel

15.6.2013 – 16.6.2013 – obvious shipping emission peaks




Ciudad de Cadiz
Conmar Avenue
Herm Kiepe
CSCL Africa
Capri
Marstan
APL Yangshan
CMA CGM Musca
Stena Natalita
Bürgermeister Weichmann
Aida Luna
Pictor J
Rickmers Antwerp
OOCL St Petersburg
O3
NO
NO2
SO2
CO2
NO-, NO2-, O3-, SO2-Konzentration in ppb
CO2 Konzentration in ppm
90
80
70
60
50
40
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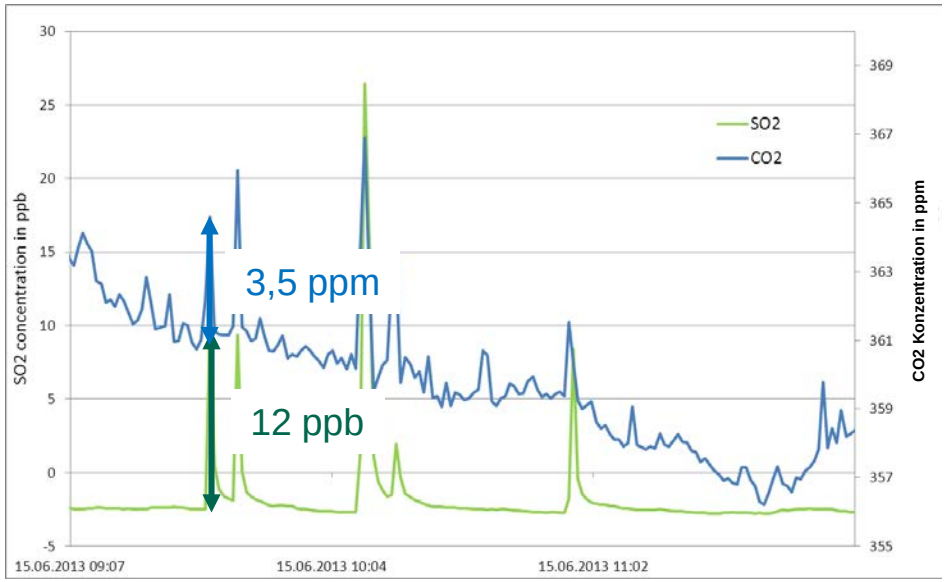
Measurements in Wedel

Analysis of sulfur content in fuel



Formula for Sulphur content in fuel:

$$\% \, S \; in \; fuel = \frac{\Delta SO_2}{\Delta CO_2} \cdot 0{,}232$$

Tuttle et. al., 1995
Williams et. al., 2006
Moldanova et. al., 2009

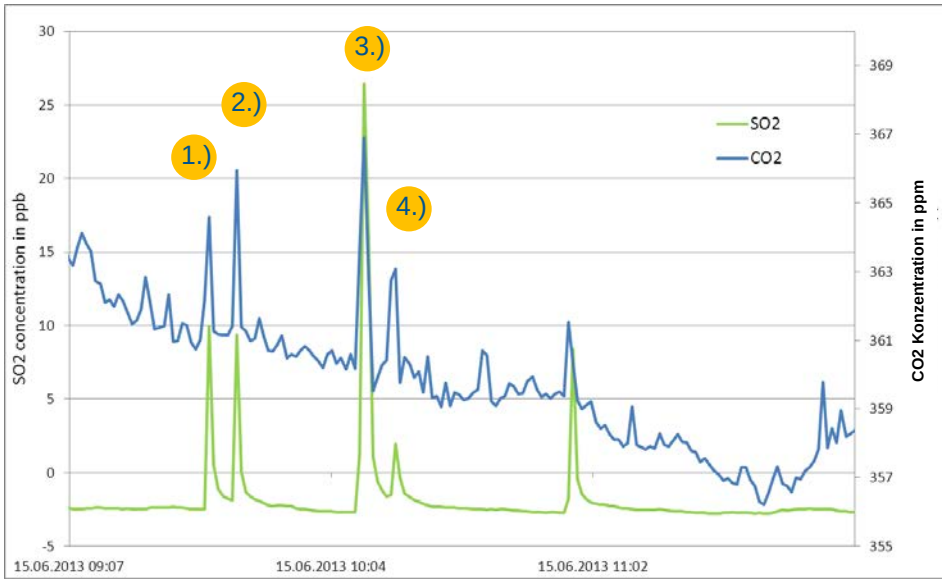
Example:
For first ship emission peak shown:

$$\% \, S \; in \; fuel = \frac{12 \; ppb}{3{,}5 \; ppm} \cdot 0{,}232 = 0{,}79 \; \pm 0{,}11\%$$

(Caution: Measurement uncertainity : 15%
according to Berg et. al. 2012)

Measurements in Wedel

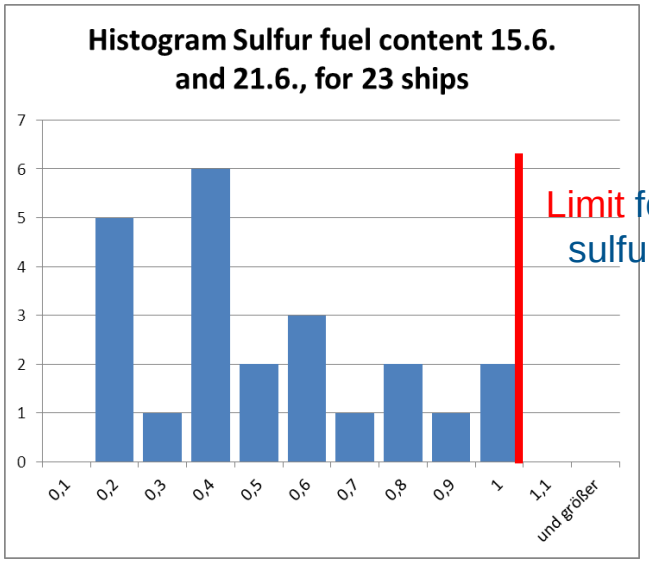
Analysis of sulfur content in fuel



Example for 4 Peaks shown in graph:

1.): (0,79 ± 0,11) %S in fuel
2.): (0,56 ± 0,08) %S in fuel
3.): (0,92 ± 0,13) %S in fuel
4.): (0,29 ± 0,04) %S in fuel

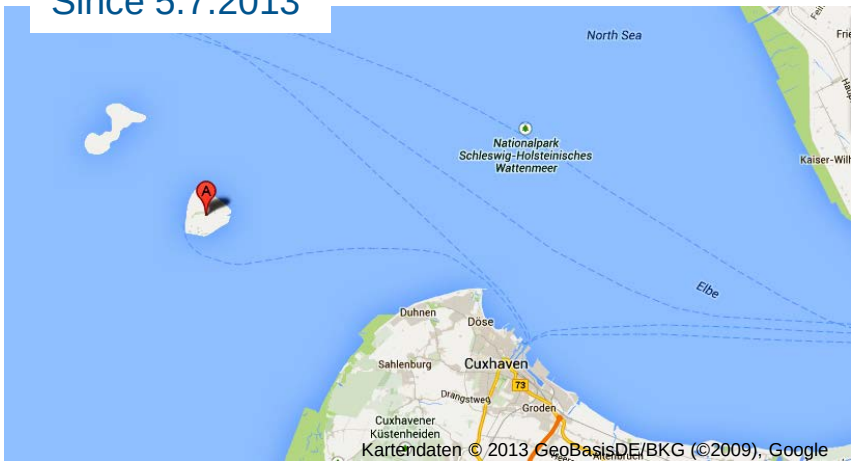
Example for 23 Peaks of 2 days:



Limit for allowed sulfur content

Measurements on the island Neuwerk

Since 5.7.2013



www.maps.google.de

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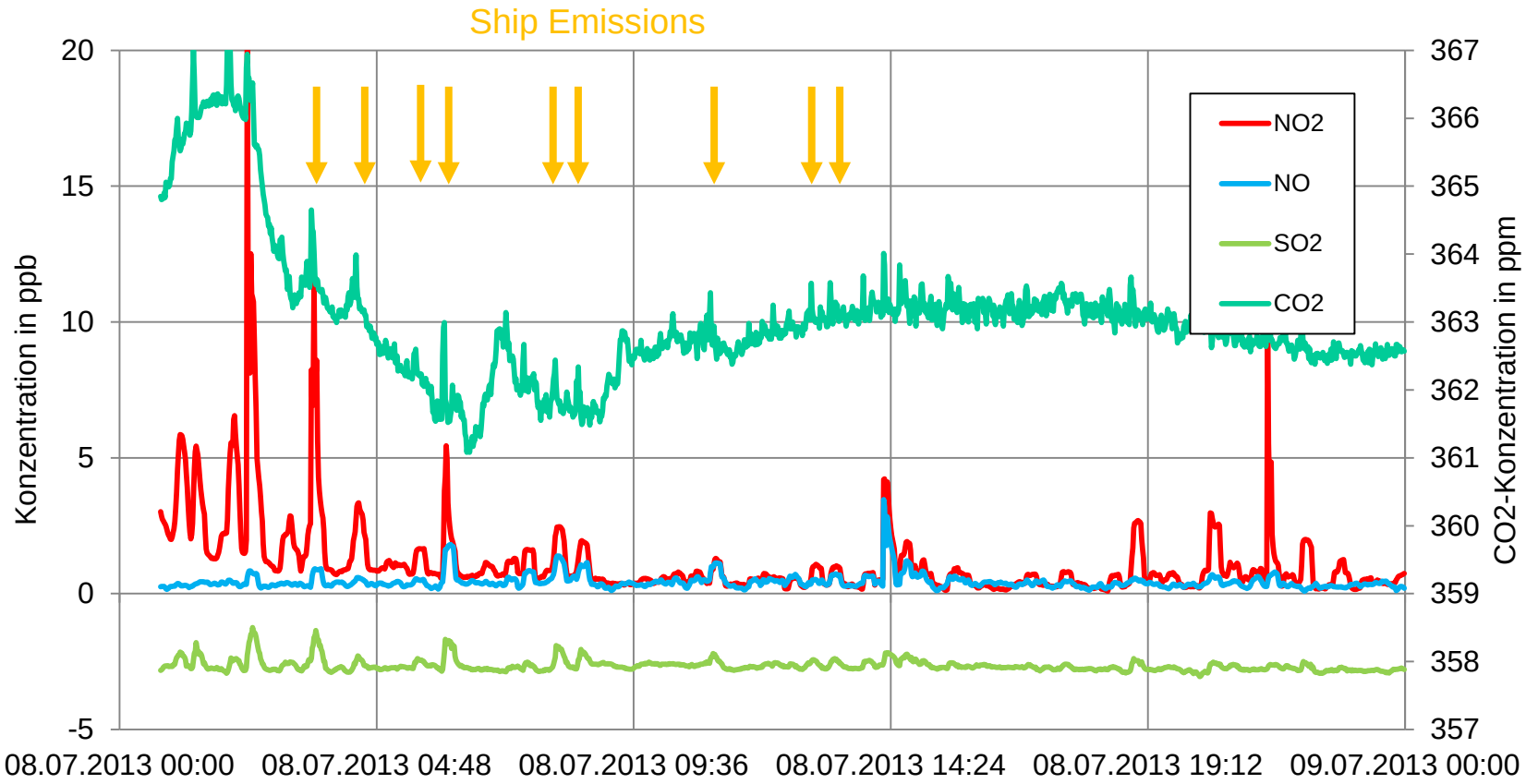
Measurements on the island Neuwerk

Since 5.7.2013



Measurements on the island Neuwerk

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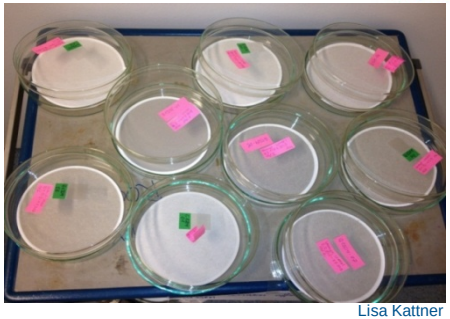
Outlook

Filter analysis

- Gravimetric analysis of PM10
- Ion chromatography for anions (SO42-, NO3- , Cl-) and cations (NH4+ , Na+, K+, Ca++, Mg++)
- ICP-MS (Inductively Coupled Plasma Mass Spectrometry) for elemental analysis, especially V, Ni, Fe (tracer for shipping emissions)
- Organic carbon (TOC) und elemental carbon (EC)
- GC-MS (gas chromatography mass spectroscopy) for Polycyclic aromatic hydrocarbons (PAH)



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B. Mathieu-Uffing

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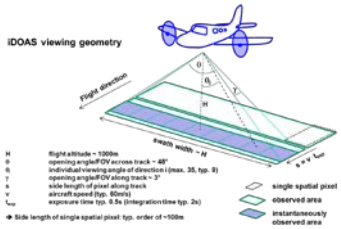
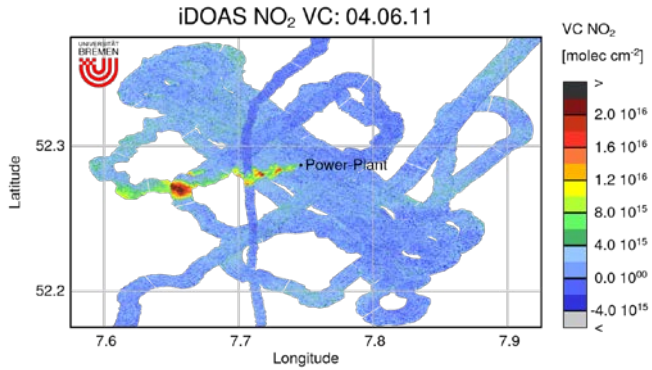
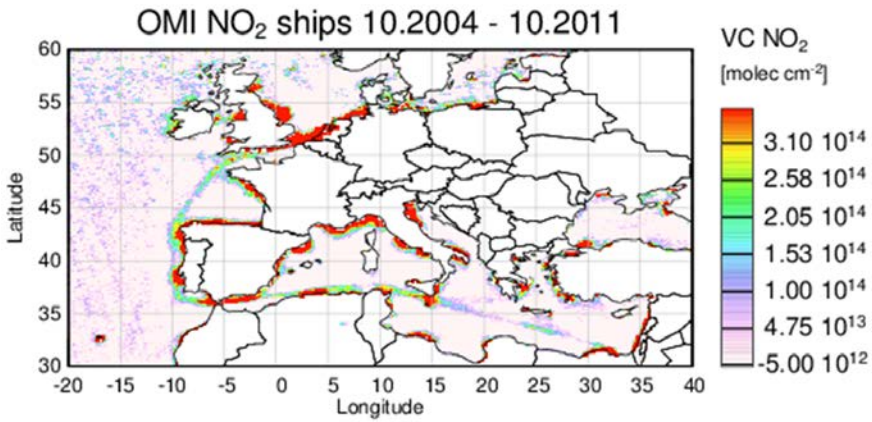
Outlook

- Aircraft measurements Uni Bremen:

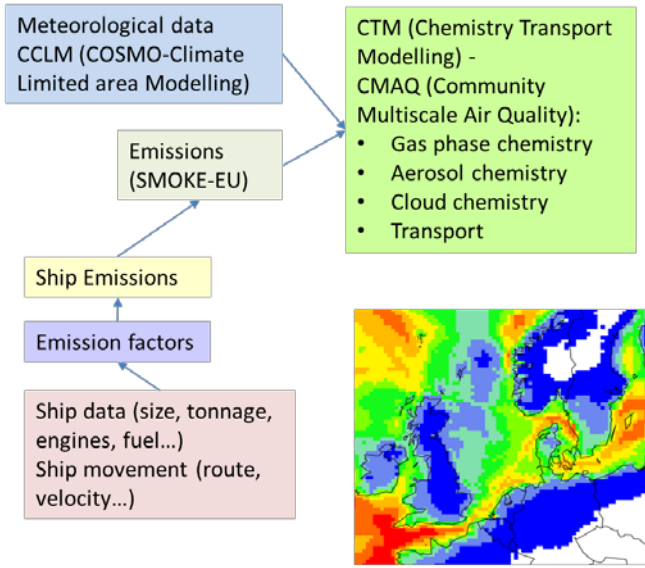


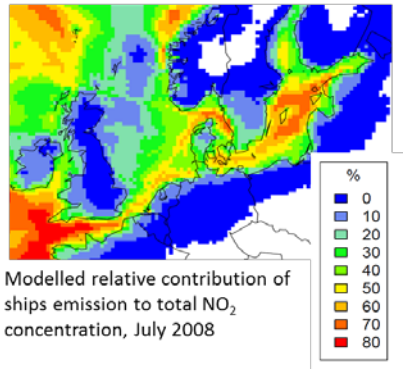


- comparison with Satellite data



- Modelling
(Volker Matthias, HZG Geesthacht)





Modelled relative contribution of ships emission to total NO_2 concentration, July 2008

Summary

- MeSmarT project objectives:
  - Examine the influence of shipping emissions on the marine atmosphere over the North and Baltic Sea
  - Find a way to controll the emission regulations
- Two methods: remote sensing and in-situ measurements
- First results of research cruises: mapping air pollution
- Measurements in Wedel: Investigating single ship plumes and determining sulfur content in ship fuel
- Measurements in Neuwerk: Combining measurements of clean marine background air and single ship plumes

Thank you!

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