COMPLIANCE MEASUREMENTS OF SHIPS FROM AIRBORNE AND FIXED PLATFORMS WITHIN THE IDENTIFICATION OF GROSS POLLUTING SHIPS PROJECT

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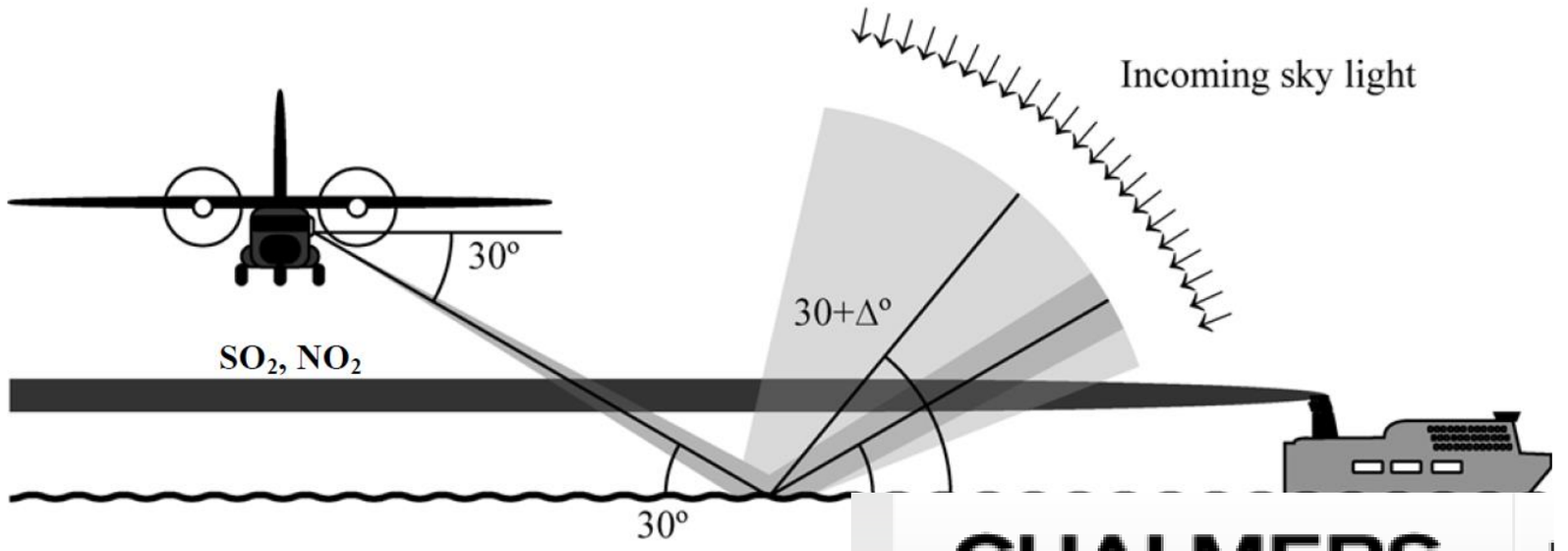
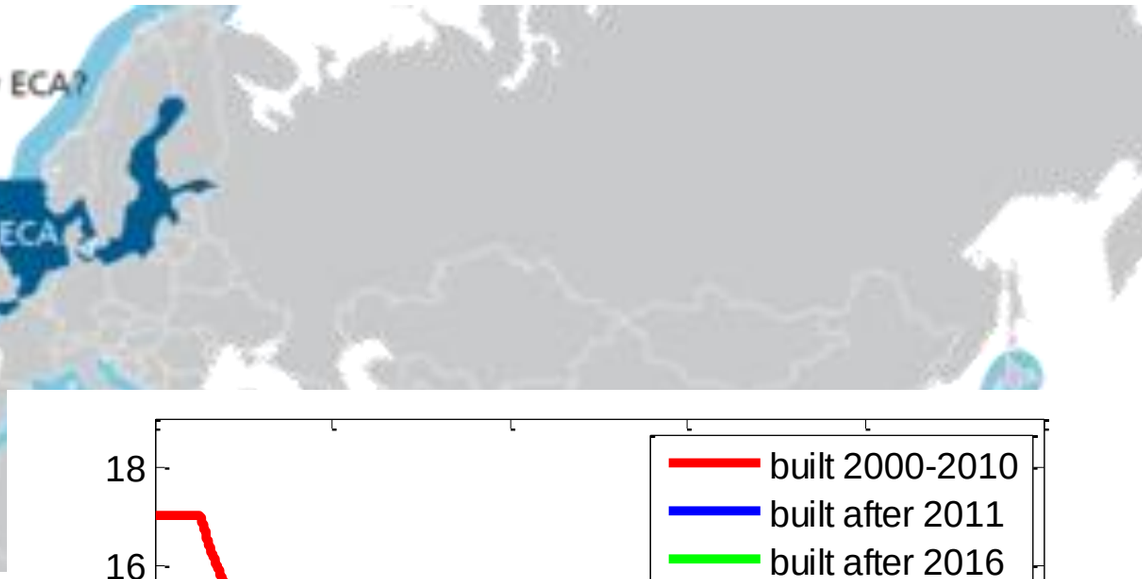
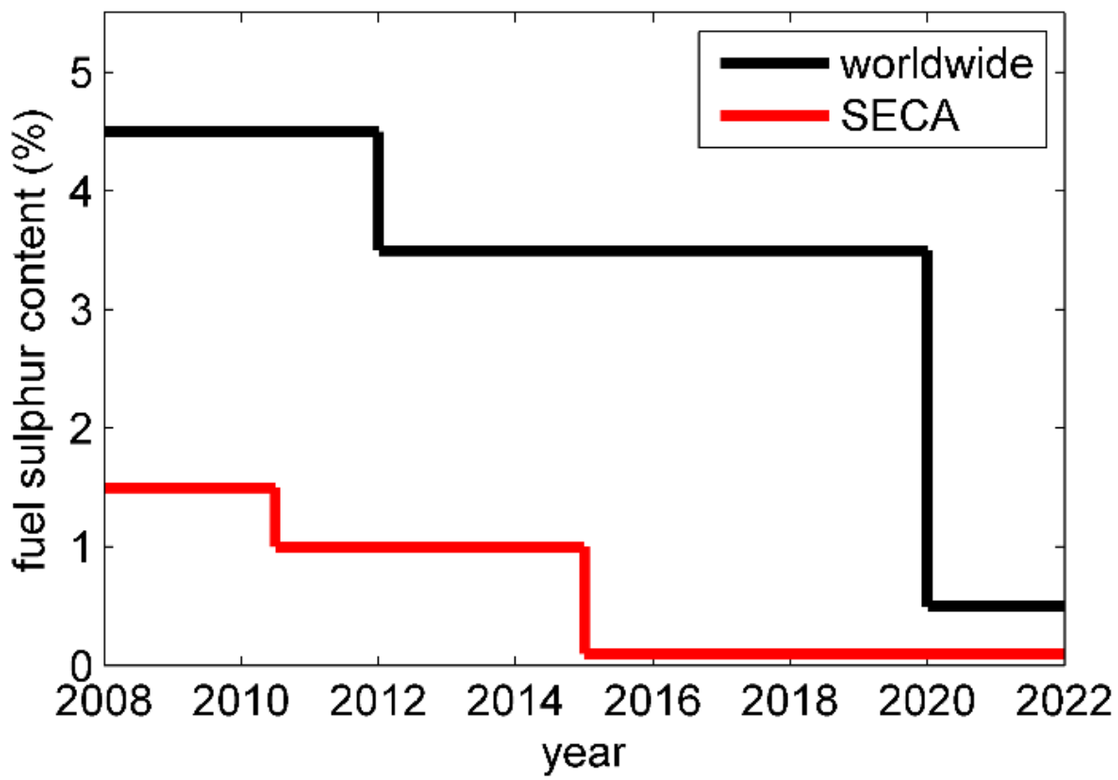
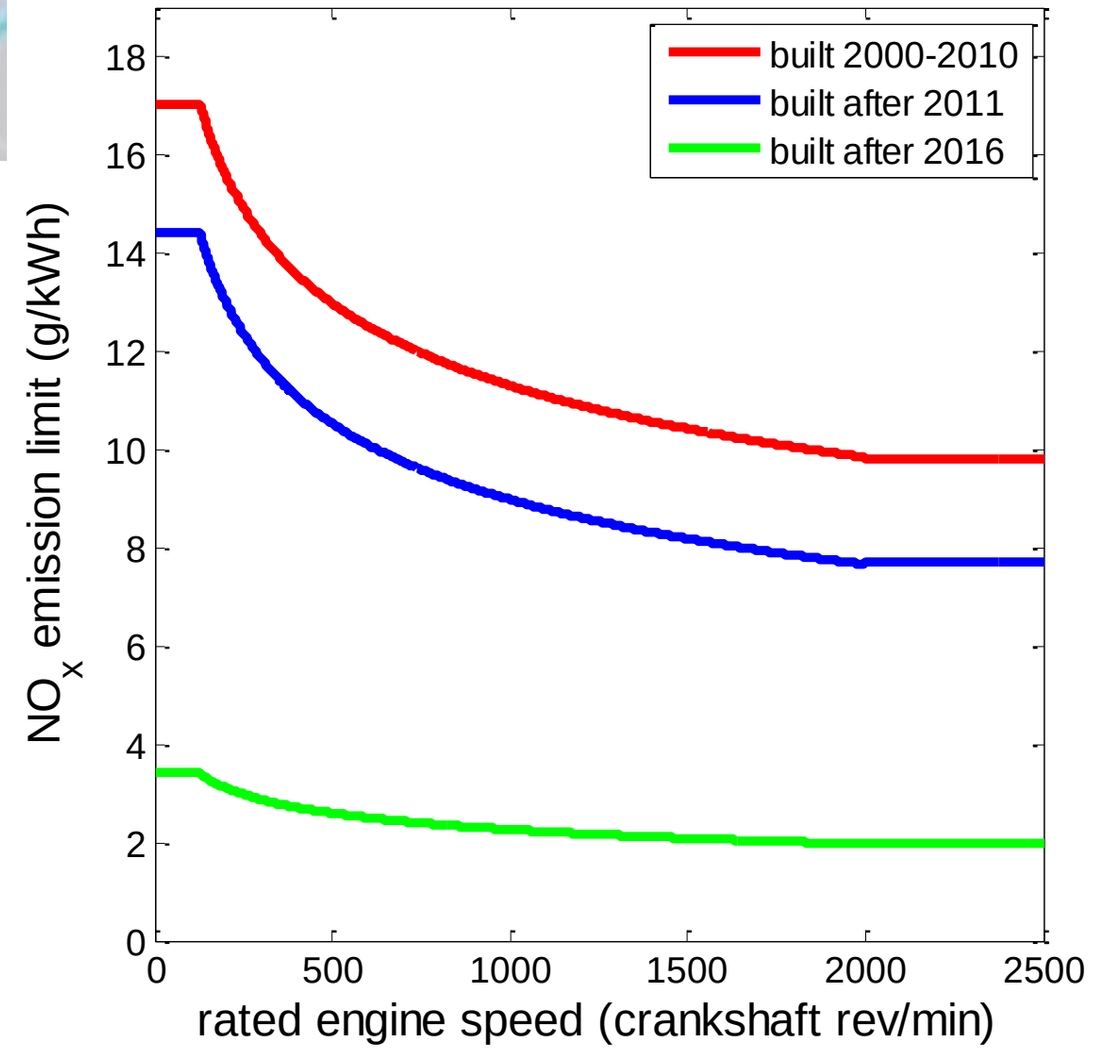


Emission Control Areas within IMO Marpol annex VI. Within the dark blue areas the sulfur and NO_x emissions should follow the lower curves for Sulfur and NO_x







Identification of gross polluting ships (IGPS)

- Aim to develop and test technique for remote compliance monitoring of ships with respect to MARPOL annex VI and EU sulfur directive
- Two projects, 2006-2008, and 2009-2014
- Funded by Vinnova and Swedish EPA, Göteborg harbor
- Steering group from the transport agency, maritime administration, EPA, and coastguard.

http://publications.lib.chalmers.se/publication/214636-identification-of-gross-polluting-ships-to-promote-a-level-playing-field-within-the-shipping-sector

Results within the Swedish project IGPS (Identification of gross polluting ships).

- An automatic measurement system has been developed for compliance monitoring of individual ships, remotely with respect to stack emissions of SO_2, NO_x and particulates,
- Parameters measured:

  a) sulfur fuel content (or SO_2 emission per fuel unit),

  b) nitrogen oxide emission per fuel unit (or per kWh)

  c) particulate emission per fuel unit

  d) SO2 and NO2 emission in g/s
- State of the art technique
- Airborne measurements North sea, Baltic sea and Neva Bay for more than 200 ships with 20-25% estimated accuracy
- Automatic measurements of 5000 ships from a fixed station in Göteborg harbor.





Uniqueness

- ✓ innovative combination of techniques,
- ✓ a custom made software that provides automatic real time monitoring
- ✓ Optical method for remote operation from airplanes and to screen ships at berth.
- ✓ 8 year experience with demonstrated measurements and results.
- ✓ A certified installation (EASA, European air safety agency) in Piper Navajo has been carried out and the system is now commercially available for compliance monitoring in Europe.
- ✓ Three products have been developed: 1 system for fixed measurements, one modular system for air surveillance and a software for automatic compliance monitoring..

References

Berg, N., Mellqvist, J. et al., Ship emissions of SO2 and NO2: DOAS measurements from airborne platforms, Atmos. Meas. Tech., 5, 1–14, doi:10.5194/amt-5-1-2012, 2012

Alfoldy B., ..., Mellqvist J., et al., Measurements of air pollution emission factors for marine transportation, Atmos. Meas. Tech. Discuss., 5, 8925–8967, doi:10.5194/amtd-5-8925-2012 2012

Balzani Lööv J M…. J. Mellqvist, et al., Field test of available methods to measure remotely SOx and Nox emissions from ships, Atmos. Meas. Tech. Discuss., 6, 9735-9782, 2013,

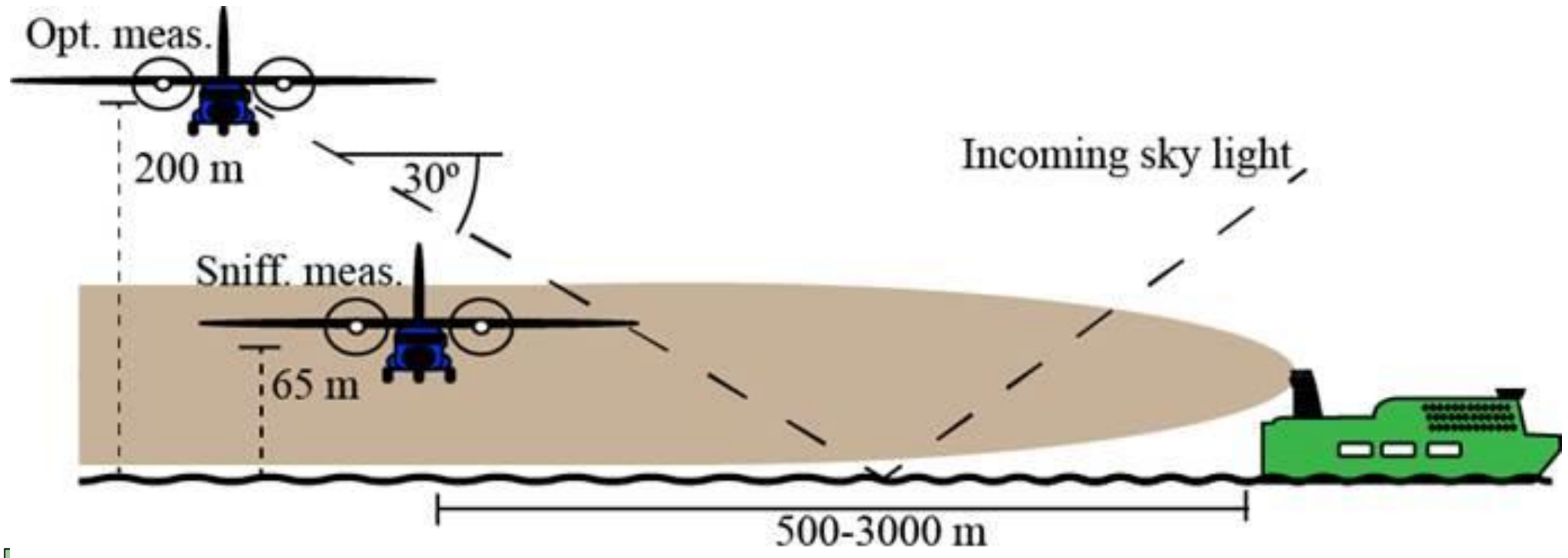
Beecken, J., Mellqvist, J., Salo, K., Ekholm, J., and Jalkanen, J.-P: Airborne emission measurements of SO2, NOx and particles from individual ships using sniffer technique, Atmos. Meas. Tech. Discuss., 6, 10617-10651, doi:10.5194/amtd-6-10617-2013, 2013.

Beecken, Emission Factors of SO2, NOx and Particles from Ships in Neva Bay from Ground-Based and Helicopter-Borne Measurements and AIS-Based Model, ACPD, 2014

Airborne Surveillance

Early warning/Screening

Fly over ships and conduct optical flux measurement (**g SO2/s**), g NO2/s (altitude 300 – 600 m) and model fuel consumption, 40% uncertainty

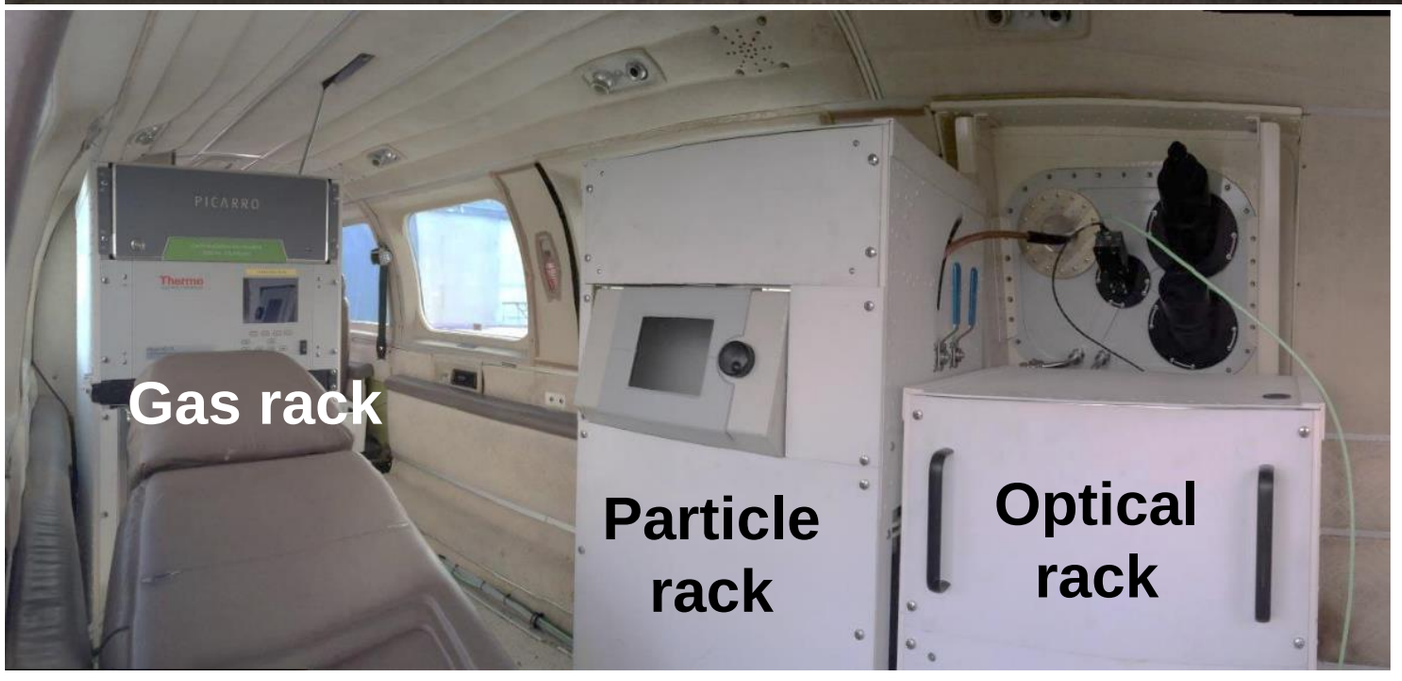


For high emitters fly through the fluegases and conduct sniffer measurements (altitude 60-300 m) to obtain emission factors (**g SO2/kg$_{fuel}$**), 20-25% uncertainty

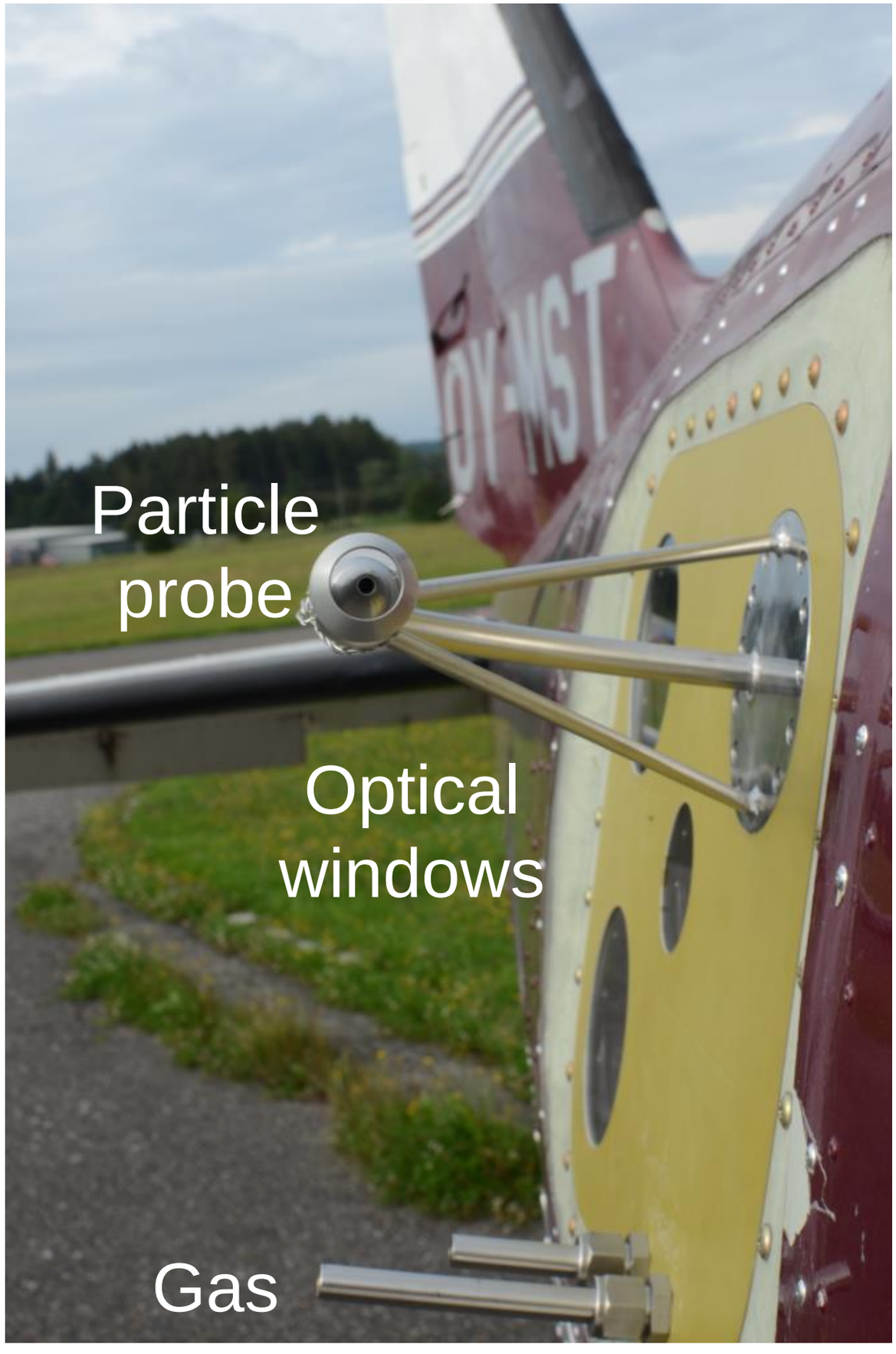
Why airborne measurements

- It is probable that
  - ships on the open sea, with several days before entering harbor will *comply less with the EU sulfur directive* than ships soon entering harbor.
  - ships that leave the SECA region will *comply less* with the EU sulfur directive than ships that soon will enter a SECA harbor.
- Measurements on fixed station (bridges) can be automated but the shipping traffic will fastly adapt
- The airborne measurements from Roskilde has 3-3.5 h endurance. The main shipping lanes to the Baltic and North sea can hence be reached.
- Typically 10 ships per hour can be screened with the optical sensor, or 6 ships per hour investigated with the sniffer.

Navajo Piper from our partner Aircraft ApS



STC-approval for modification from EASA


Particle
probe
Optical
windows
Gas

A ”small” box for compliance measurements of sulfur fuel content has been developed

Sulfur sniffer

Logging Computer
AIS and GPS reciever
Calibration gas
CO2 sensor
SO2 sensor
Power converters,
TCP -IP
47 kg, 15 A @ 28 V DC
19” dimension

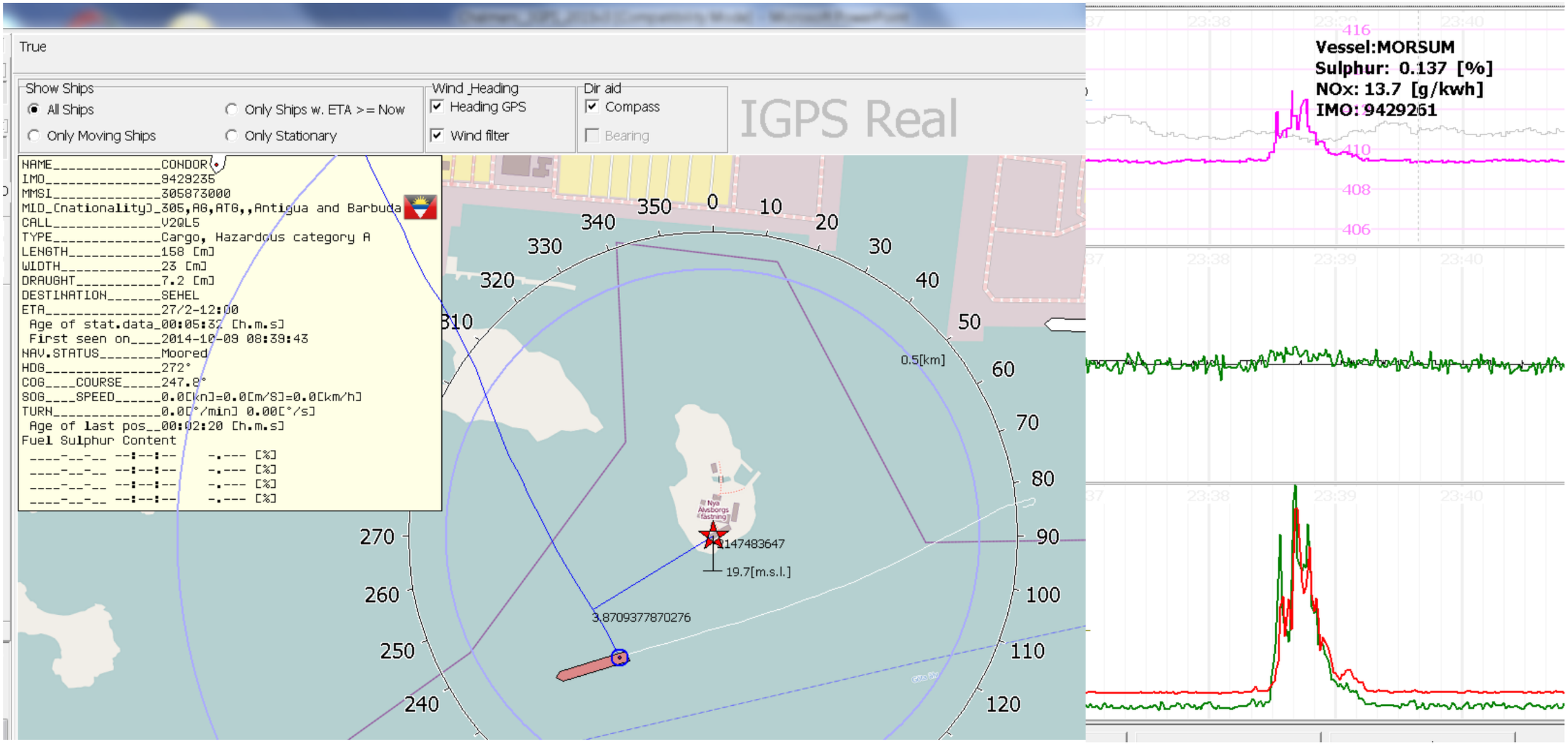
EASA STC approval in Navajor Piper and Navajo Chieftain
EMI tested

Instruments used. (reference technology for ambient and fluegas monitoring)

Species	Unit	Method	Sample rate	Detection limit
CO2	Mixing ratio	Cavity ring down spectrometer. Custom software.	2 Hz	0.2 ppm
SO2	Mixing ratio	Fluorescence (modified)	1 Hz	1 ppb
NOx	Mixing ratio	Chemiluminiscence (modified)	1 Hz	0.5 ppb
SO2	Column	Optical meas (DOAS)	1 Hz	20 ppb (over 50 m)
NO2	Column	Optical meas (DOAS)	1 Hz	20 ppb (over 50 m)
PN (PM)	Number size distribution 5-500 nm	Electrostatic mobility	10 Hz	n/a
PN (PM)	Number size distribution 300-10000 nm	Laser scattering	1Hz	n/a

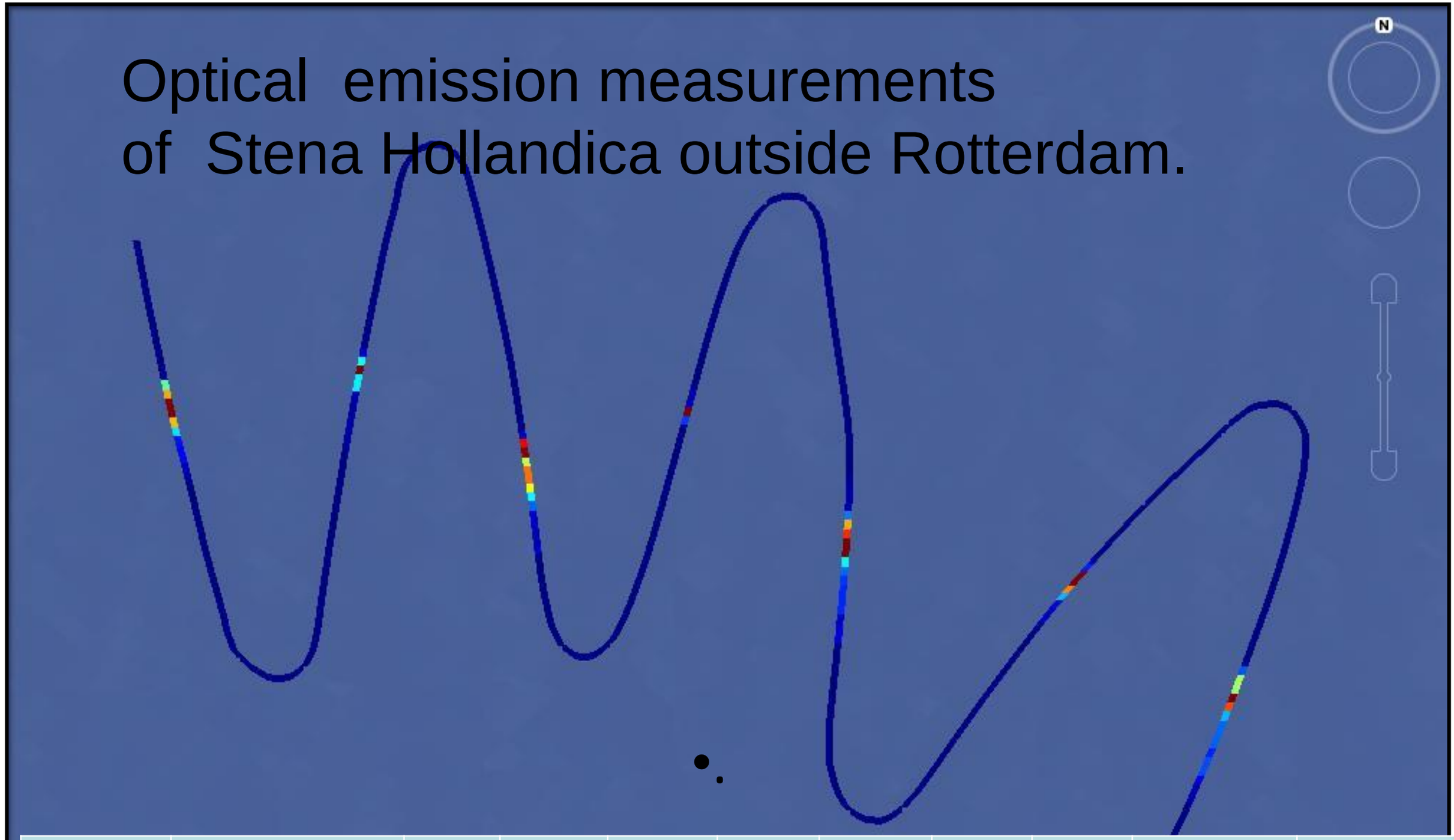
Automatic Software

A view from the custom made realtime program IGPS-real is shown. It identifies ship plumes and calculates the sulfur fuel content and NO_x emission <u>automatically</u> using the SO_2/CO_2 and NO_x/CO_2 ratios.



Airborne SO2 DOAS, obs angle 30o below

Optical emission measurements of Stena Hollandica outside Rotterdam.



Date	Transect	1	2	3	4	5	6	7	DOAS Average	Onboard
0925	SO_2 kg/h	95	83	62	94	97	122	89	87±13	97
	Intensity %	106	105	104	137	124	161	116		

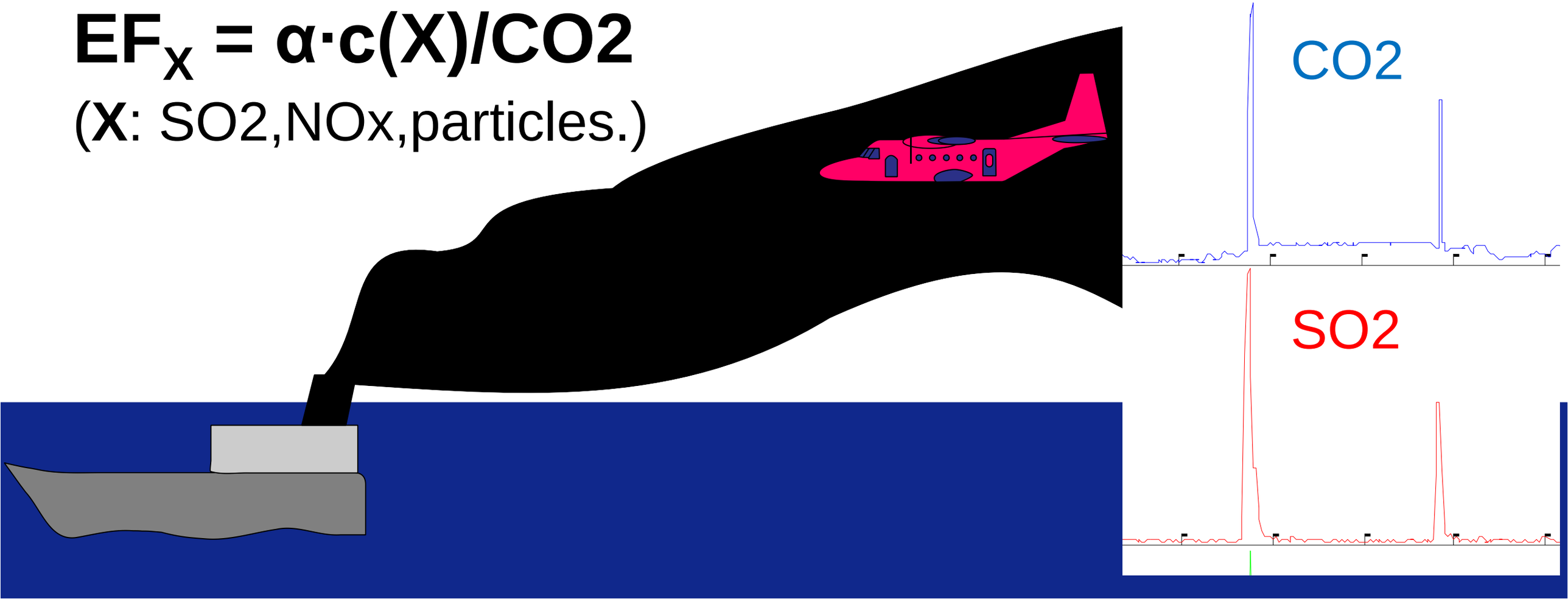
Sniffer measurement

Emission factors in **g/kg$_{fuel}$** are obtained by measuring the ratio of the pollutant **X** versus the concentration of CO_2, downwind of the plume.

Accuracy 15-20%

$EF_X = \alpha \cdot c(X)/CO2$

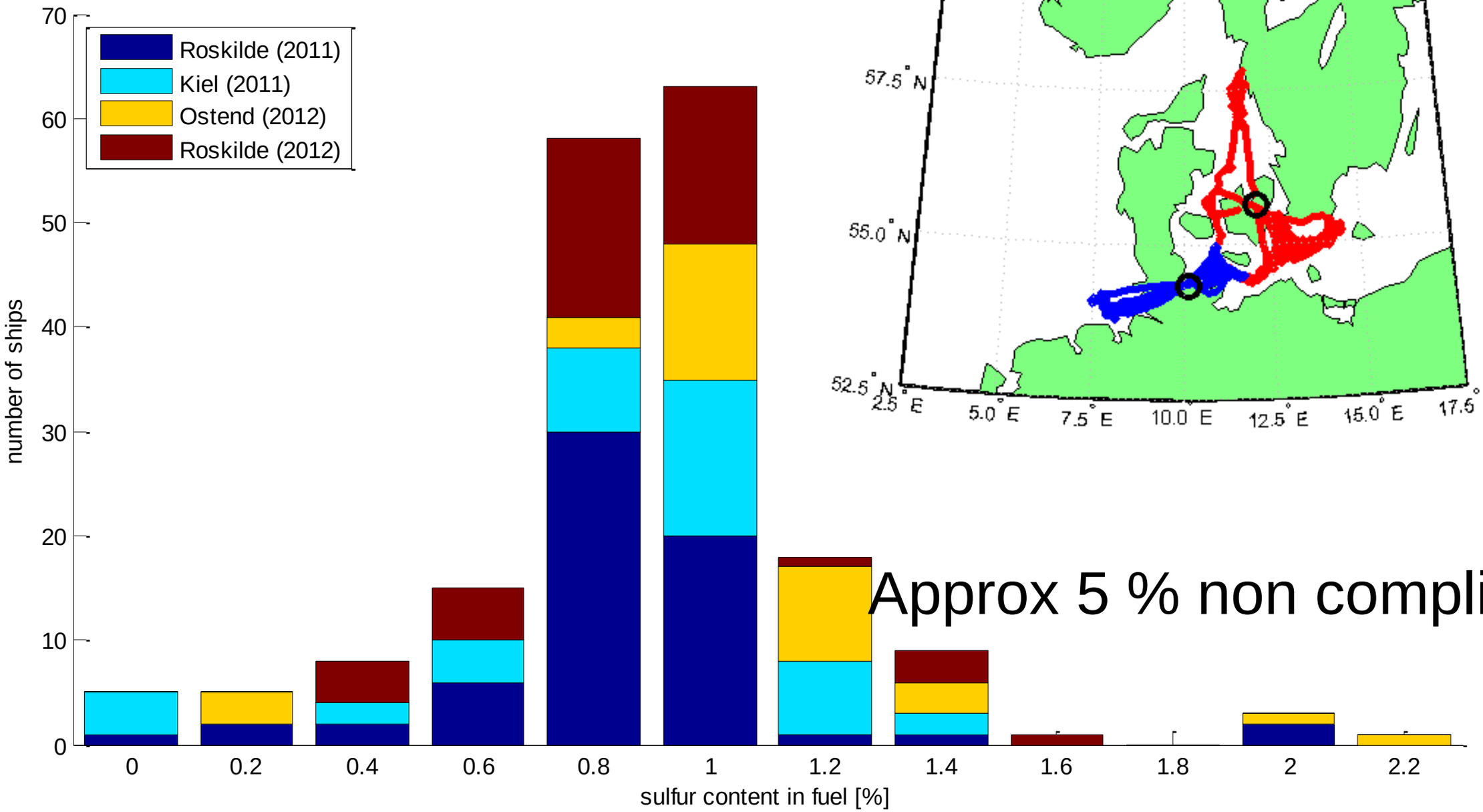
(**X**: SO2,NOx,particles.)



Is there health risks for air crew ?

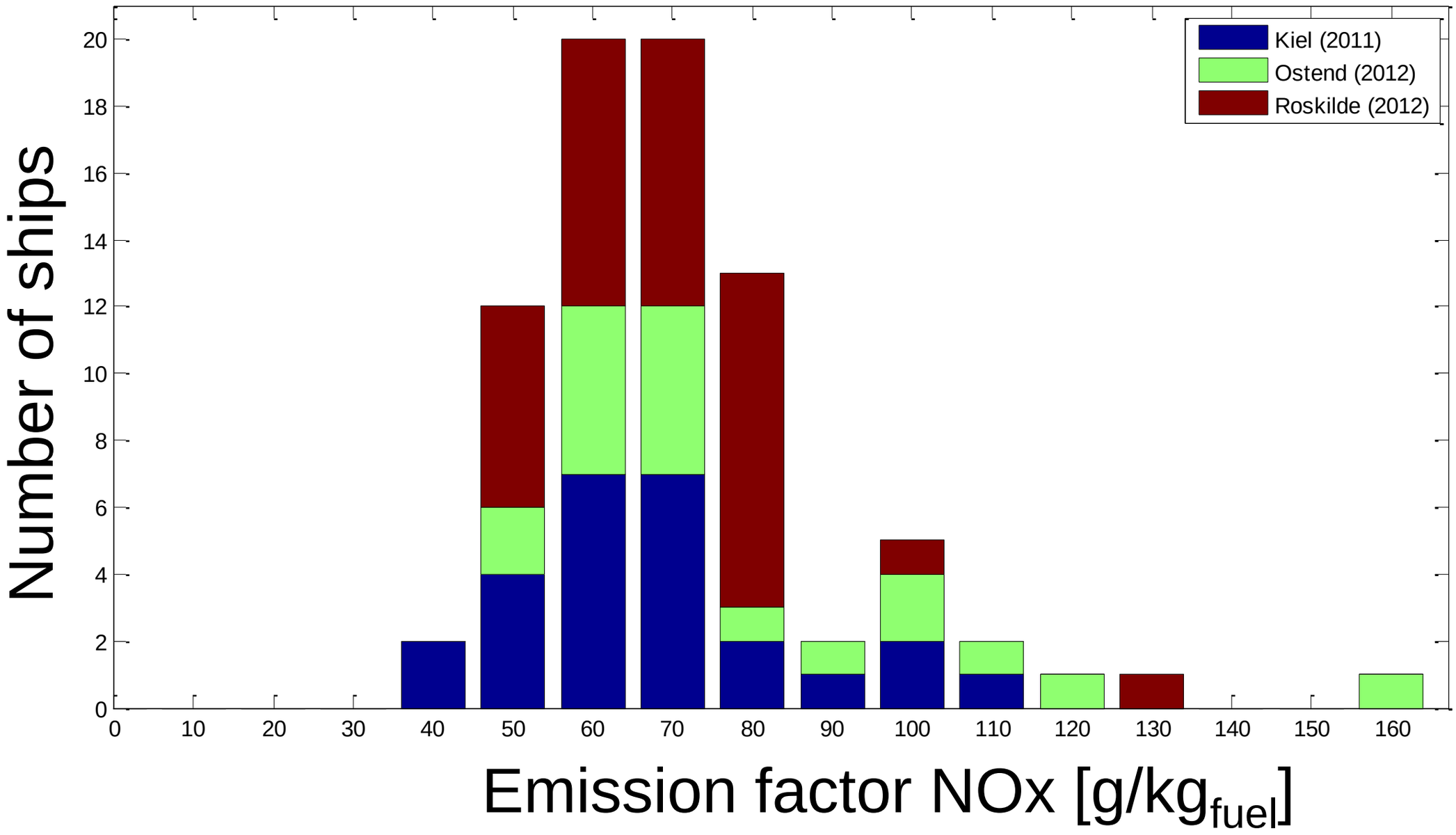
	Comment	NO2	NO	SO2	Particles
Concentrations	Typical level in ship plumes, 1 km awau µg/m3	20	80	100	30
	Typical estimated level in cabine during passage (10 s plume) µg/m3	**2**	**8**	**10**	**3**
	Working limit 15 minutes exposure	13300	NA	9500	NA
	Working limit 8 hours exposure	5000	5000	4000	5000
	Air quality norm, yearly average	20		20	25
	Air quality norm, hourly average	60			35
	Yearly average in Milano, background station,	80	10	32	50
	Yearly average Swedish cities	20-60			30-70
Exposure	**Total typical daily expousre in cabine (µg/m3*min) (10 ships/day)**	**3.3**	**13.3**	**16.7**	**5**
	Total daily allowed expousre, working regulation (µg/m3*min)	2400000	2400000	1920000	2400000
	Total daily exposure threshold, air quality norm µg/m3*min	28800	0	28800	36000
	Total daily exposure in polluted city, i,e. Milano, background levels	115200	14400	46080	72000

Airborne compliance control of the sulfur content in individual ships from 4 campaigns



Approx 5 % non compliers

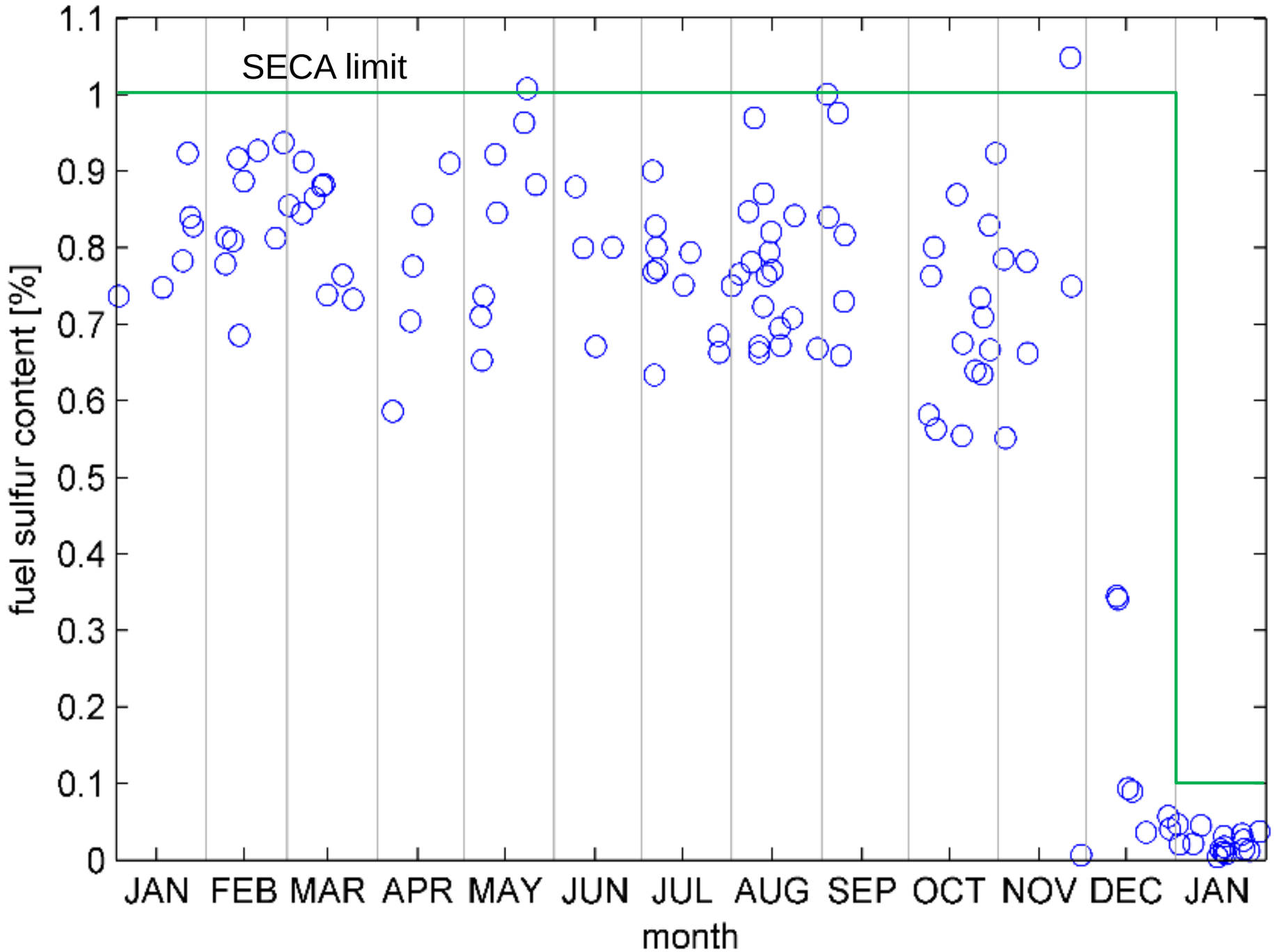
NOx emission factors obtained by airborne studies in the Baltic and North sea 2011/2012 (Beecken 2013)



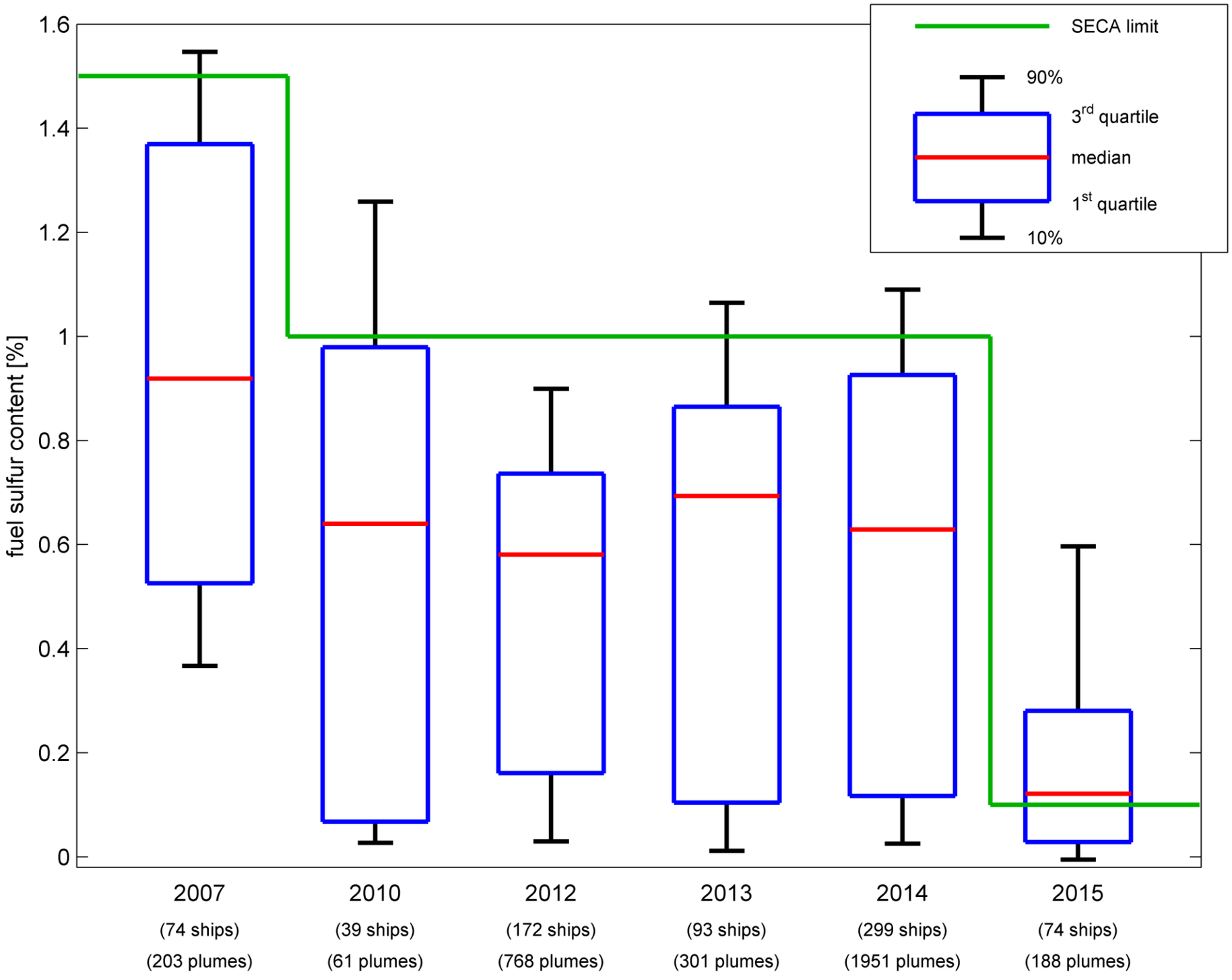
Fixed measurements

- Sniffer instruments, AIS-, GPS reciever, computer etc has been built into a water tight box.
- Automatic measurements and retrieval of emission factors.
- Continous sniffer measurements at Göteborg Harbor since 2012 (> 5000 remote inspections so far)
- Monitoring of voluntary sulfur program.
- Scientific campaign in Göteborg harbor 22 Sep-30 October with focus on chemical composition of particles

Measured FSC at Gothenburg of the same ferry boat



Measured FSC at Gothenburg, first month



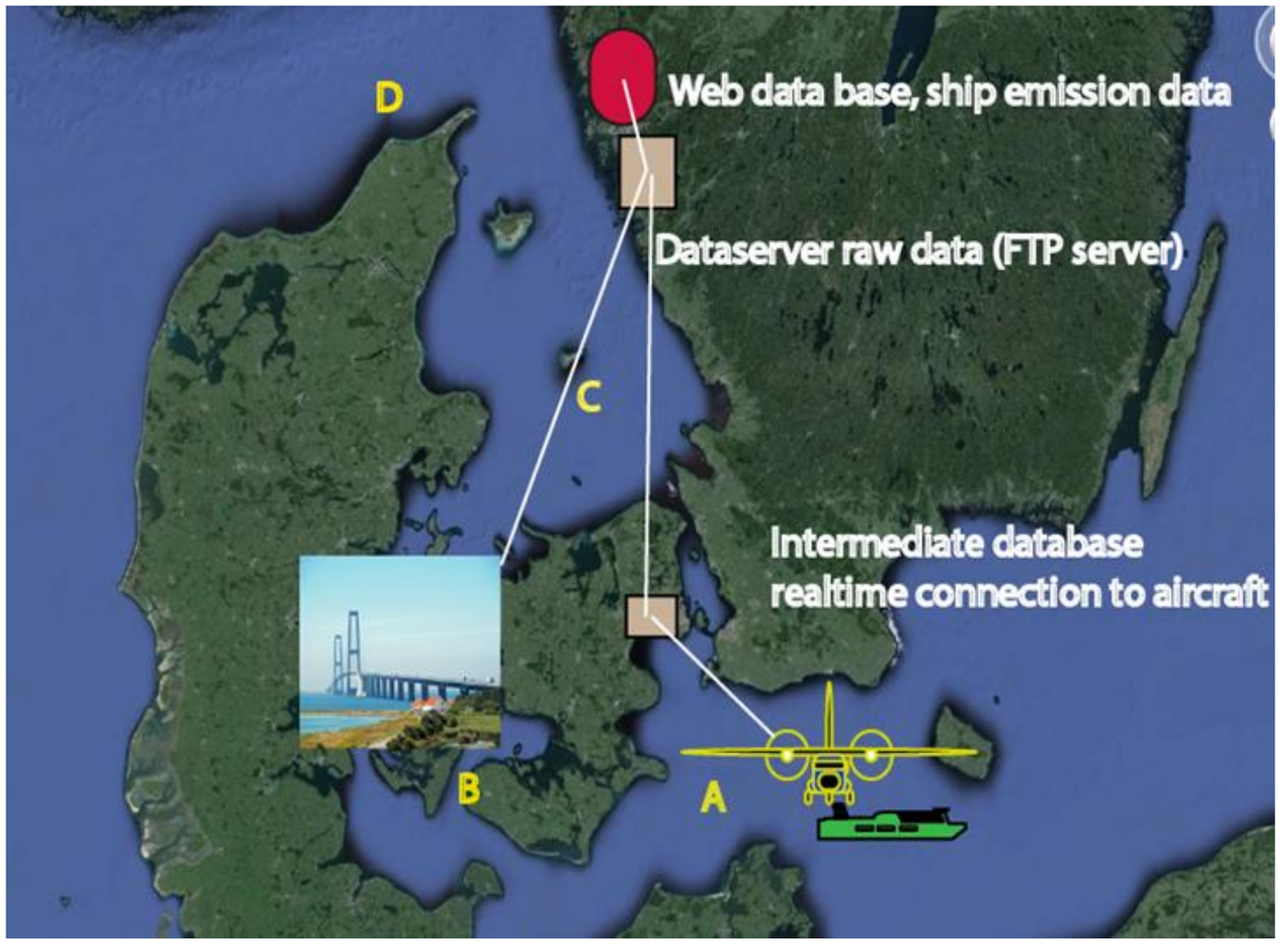
System sends a mail when ships are running high sulfur fuel

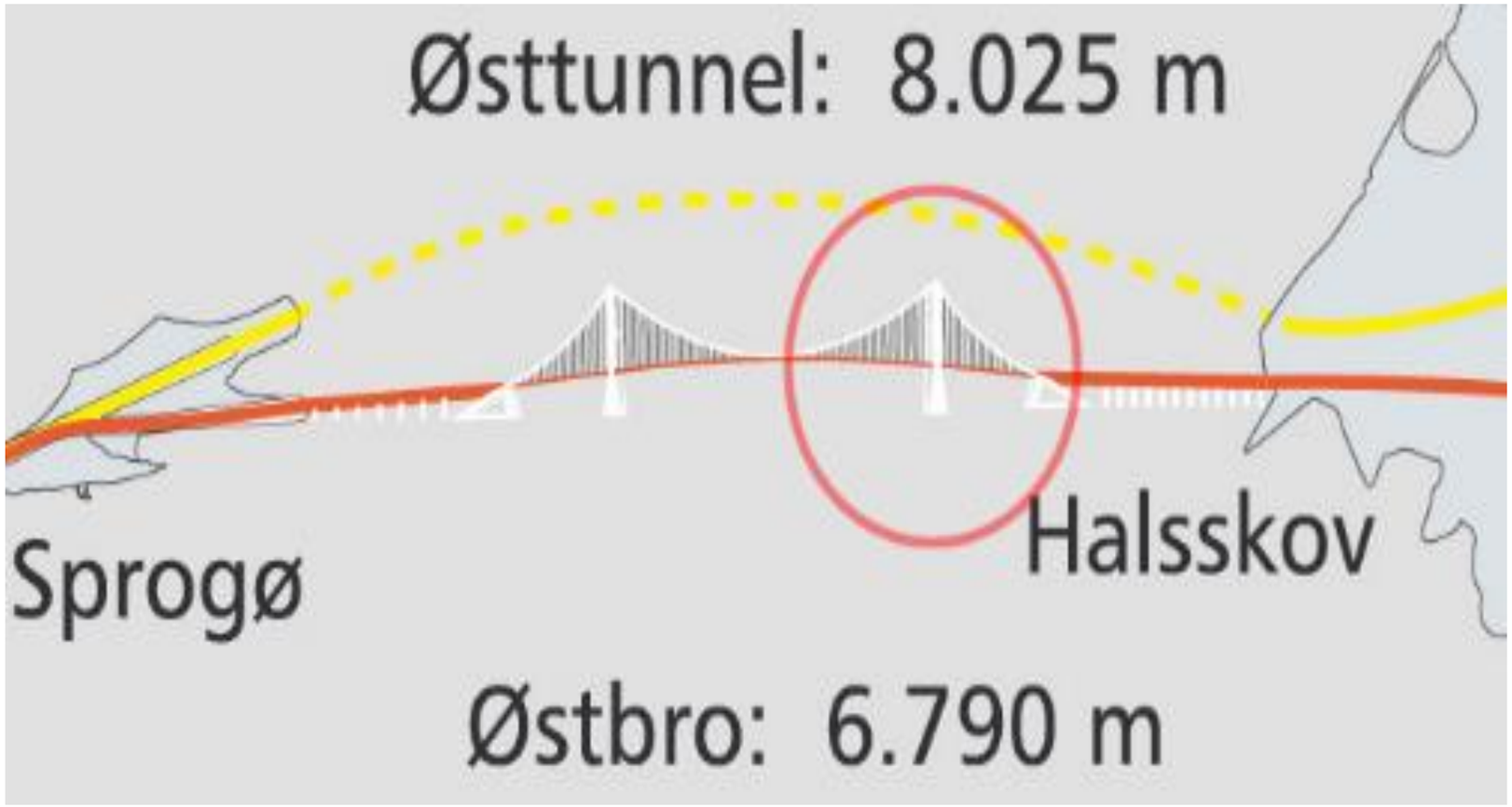
UTC: 2015-03-26 17:33:34
Vessel: Name
IMO: 9373644
MMSI: 249246000
Nat: 249,MT,MLT,,Malta
Lat: 57.681083
Long: 11.823533
Sulphur: NNNN [%]
NOx: 15.8 [g/kwh]
%inPlm: 100
#inPlm: 1

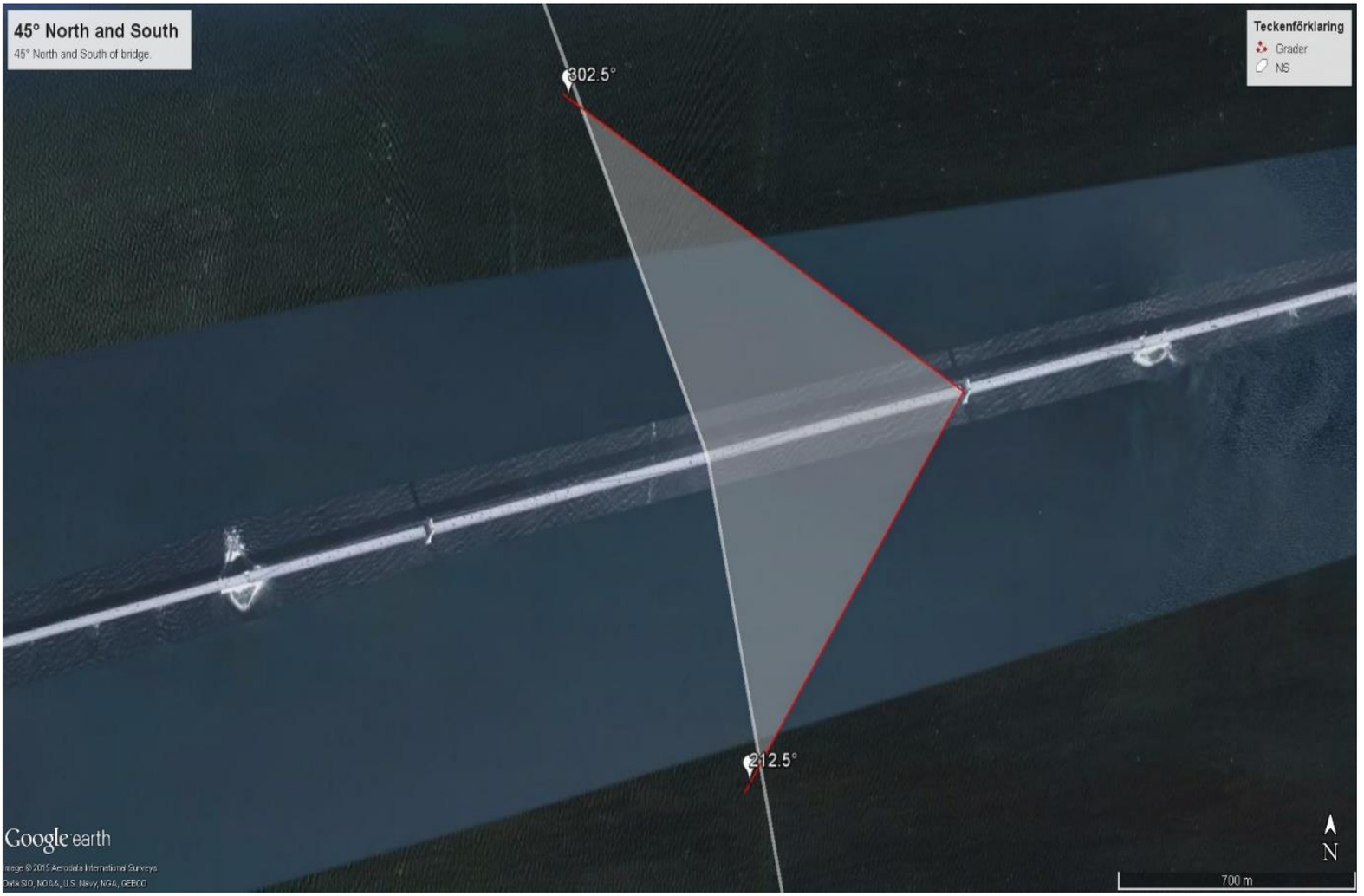
Pending Danish EPA project

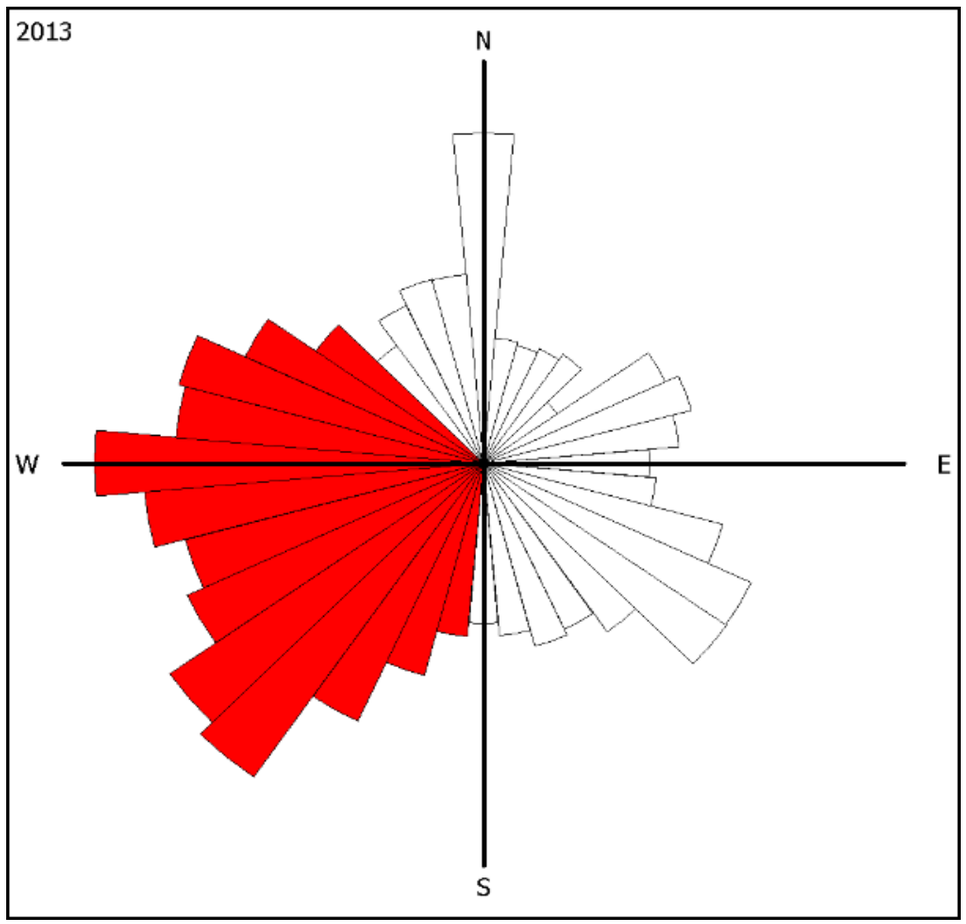
1. Airborne measurements of 100 ships per month

2. Fixed measurements at Great belt bridge 1000 ships per month,

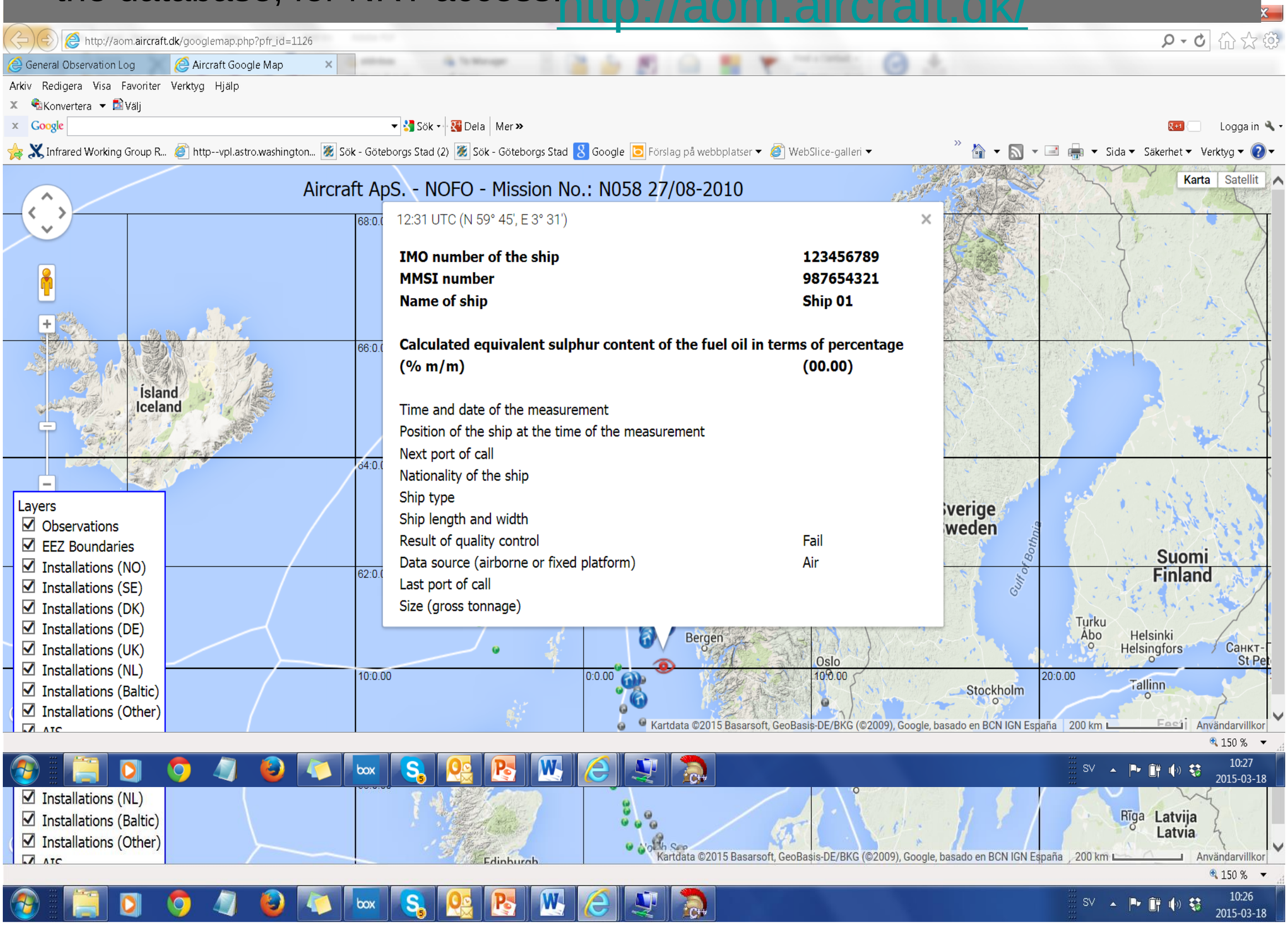



Østtunnel: 8.025 m
Sprogø
Halsskov
Østbro: 6.790 m


45° North and South
45° North and South of bridge.
Teckenförklaring
Grader
NS
302.5°
212.5°
Google earth
700 m
N

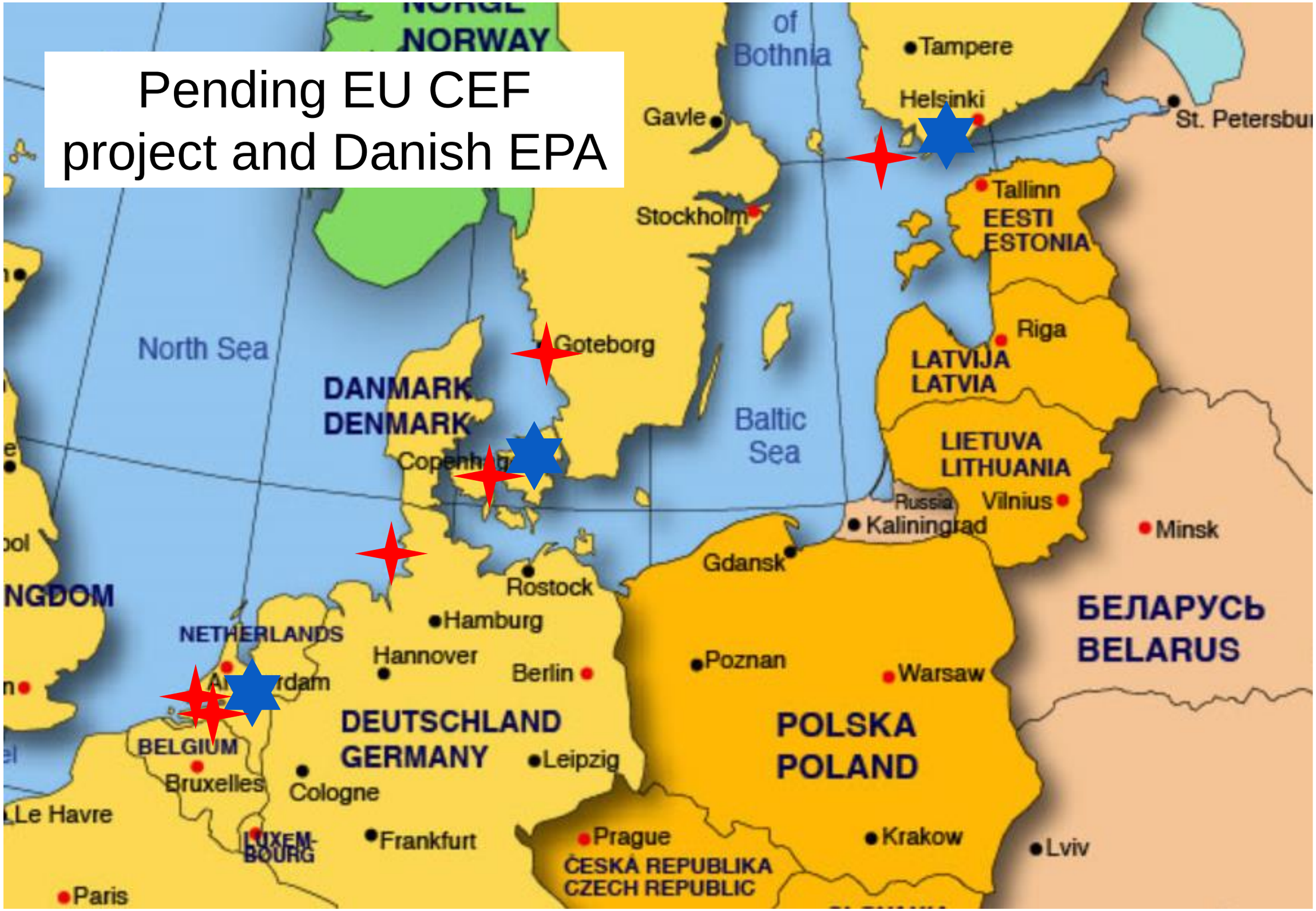

2013
N
W
E
S

- Database by aircraft Aps. High polluter will be reported thru GSM to the database, for NRT access. http://aom.aircraft.dk/



Surveillance Aircraft

Fixed sites



Outlook

- Measurements at Älvsborg funded by Göteborg harbor and Chalmers for 2015. Cooperation with transport agency.
- Study in Long beach and LA harbor in Sep 2015 funded by South Coast Air Quality management district
- Campaign in June with Belgian “coast guard”, in Belgian Britten Islander
- Pending EU and Danish applications on compliance monitoring

Conclusion

- The sniffer measurements combined with optical methods works in practice and can be carried out from airplanes, ships and stationary sites close to shipping lanes.
- Such measurements can be used to flag suspect ships, to direct the port state control authorities for further control
- The Swedish transport agency has made a governmental report where they conclude that IGPS measurement will make the future compliance control of the EU sulfur directive more effective and recommend it’s use. **Future activities are however pending on governmental decisions**. At present all measurements are therefore carried out as R&D activities
-