THE SCIPPER PROJECT

# Technical possibilities to monitor vessel emissions explored in the SCIPPER project and their impact

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Posidonia Ποσειδώνια
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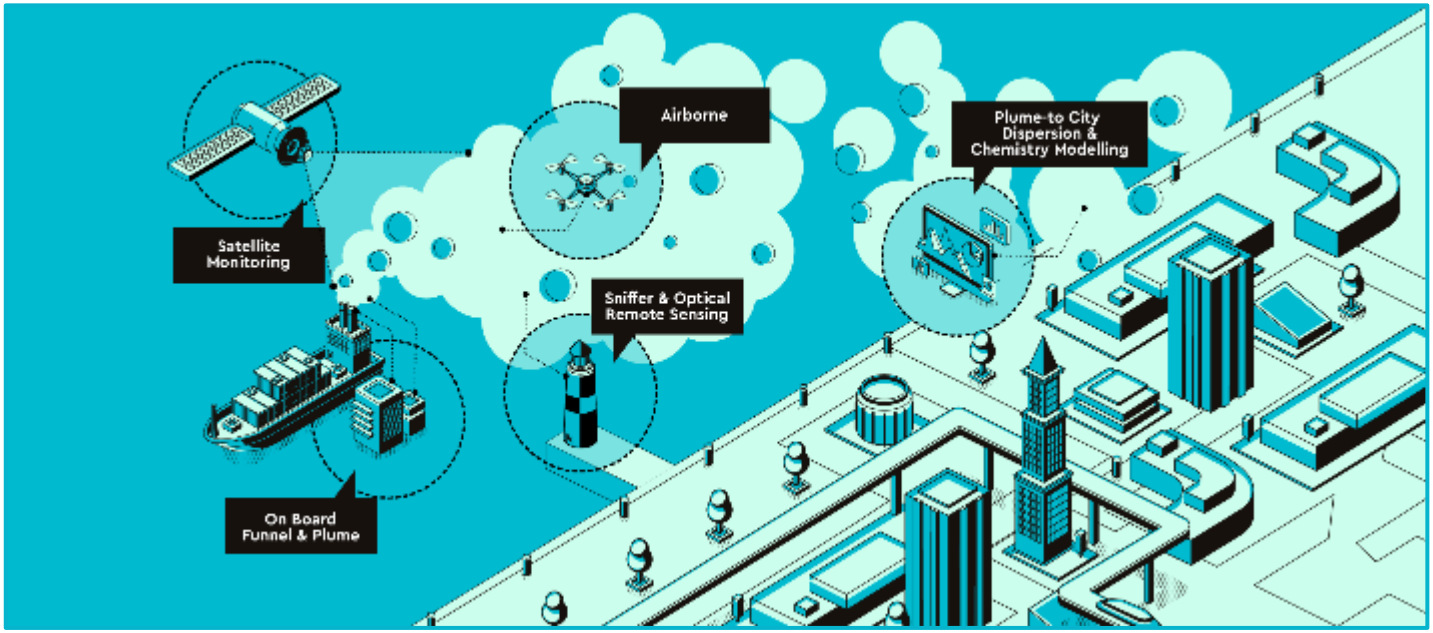
# Concept

Real-world deployment of various monitoring techniques

Implementation of 5 experimental campaigns at different locations

Runs from 5.2019-1.2023




- ❑ Application / validation / comparison of various emission measurement and monitoring techniques for emission standards compliance checking purposes
- ❑ Determination of the impact of shipping on air quality at coastal and harbor level

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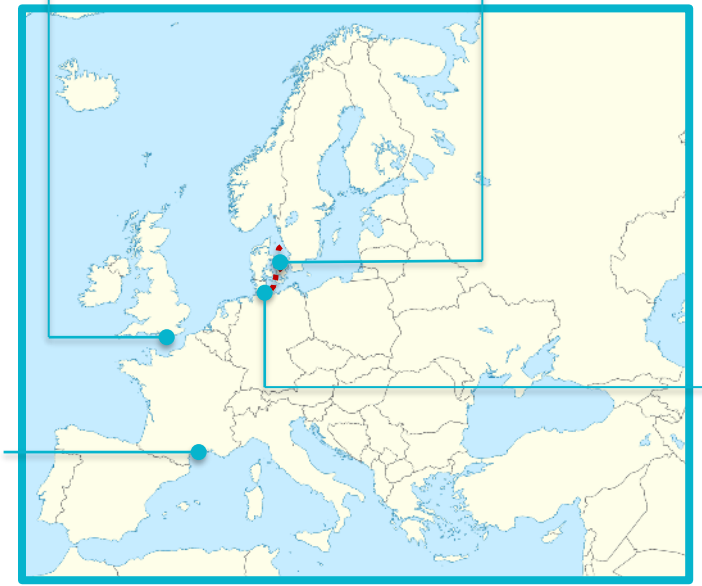
# Experimental Campaigns Locations

## Western English channel (GB)


## Gothenburg (SE) to Kiel (DE)

## Marseille (FR)



## Hamburg - Wedel (DE)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# Instrumentation on Sniffer Systems

| Partner/Group | Instrument |
|---|---|
| BSH | 3 sniffers ($CO_2$, $SO_2$, NO, $NO_2$, $O_3$)<br>2 particle size classifiers (5.6 nm – 10µm)<br>1 LP-DOAS ($SO_2$, $NO_2$) * |
| Chalmers | 1 sniffer ($CO_2$, $SO_2$, $NO_x$)<br>1 laser spectrometer ($CO_2$, $SO_2$)<br>1 particle size classifier (5.6 nm – 10 µm)<br>1 aethalometer (BC)<br>1 zenith-sky DOAS ($SO_2$, $NO_2$)<br>1 mini-Sniffer on UAV ($CO_2$, $SO_2$, NO, $NO_2$, PM) |
| Explicit | 1 mini-Sniffer on UAV ($CO_2$, $SO_2$, NO, $NO_2$) |
| TNO | 1 sniffer ($CO_2$, $SO_2$, NO, $NO_2$)<br>1 CPC<br>1 particle size classifier (90 nm – 7.5 µm)<br>1 aethalometer (BC) |

gaseous emission (in plume)
gaseous emission, (optical, remote)
particle emission (in plume)

* operated by University of Bremen

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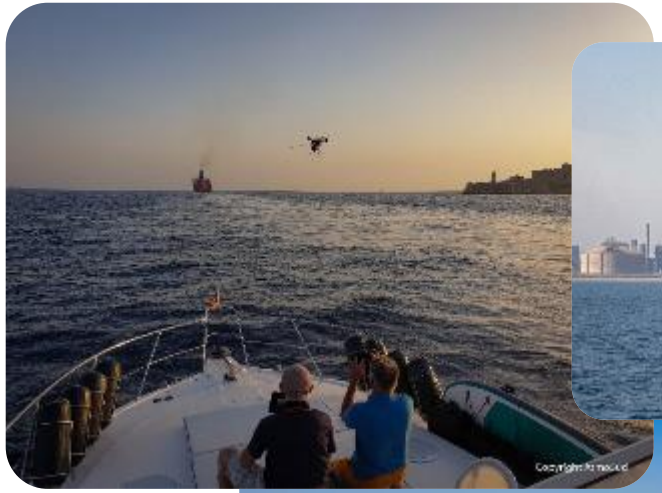
# Overview of CI

## CI Marseille, September 2019



- Remote compliance monitoring of FSC in ships in and outside the port before global FSC regulations
- First assessment of state-of-art remote and UAS comparability
- Assessment of state-of-art remote techniques including uncertainty characterization
- Input to AQ emissions before global FSC regulation

21 plumes measured by drones

30 plumes measured by a sniffer boat & 17 for intercomparison on $SO_2$ and $NO_x$

Air quality measurements at harbor sites

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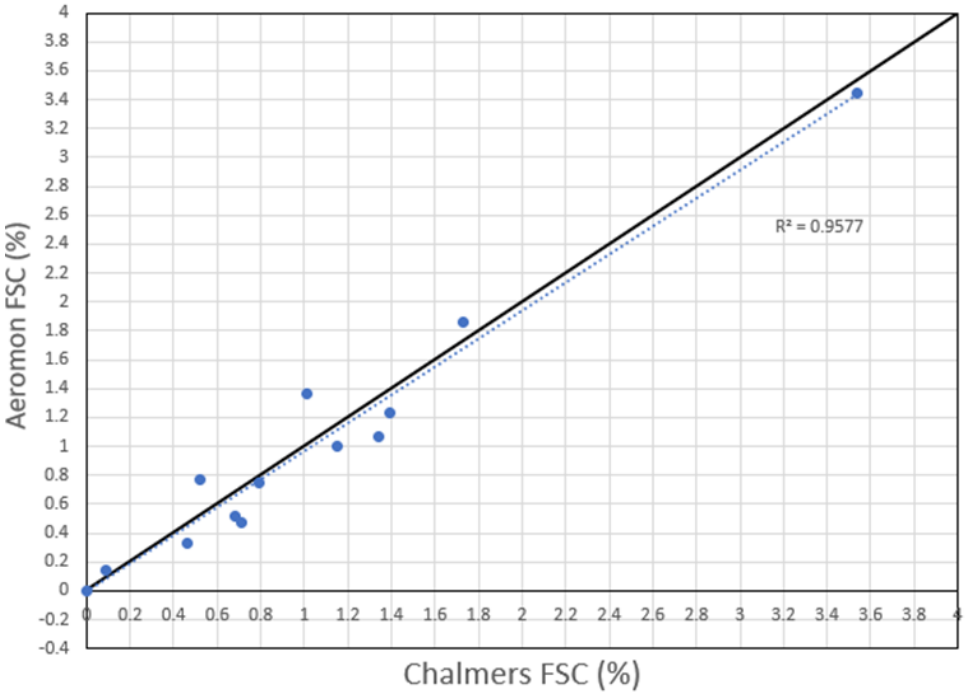
# Highlight of CI




- Mini-sniffer (Aeromon BH-12) drone with $SO_2$, $CO_2$, NO, $NO_2$, $PM_1$, $PM_{2.5}$ and $PM_{10}$ sensors.
  - Calibrated daily with certified calibration gases for traceability and quality control.
- In comparison with the Chalmers reference method, achieved a good linear fit between FSC% results from same plumes.
- Comparison between NOx and PM is ongoing and full comparison with all parameters will be published later this year.

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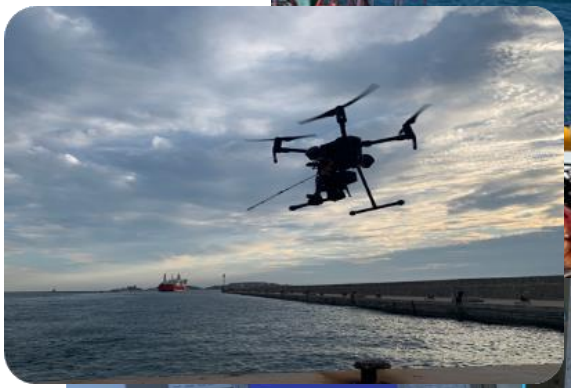
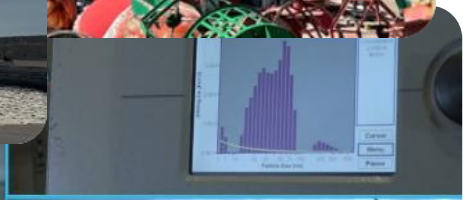
# Overview of C4

## C4 Marseille, July 2022

Harbor based stations

Drone remote

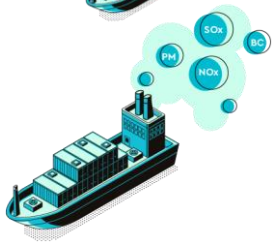




Equipped vessel

- Remote compliance check **after global sulphur cap**
- Characterization of fresh ship plumes and evaluation of atmospheric transformations
- Shipping emissions impact on urban AQ

Equipped vessel – Drones - Harbor based stations – Network of AQ microsensors in the city




38 different vessels measured

126 plumes

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# Comparison C1 C4

## FSC and NOx emissions detection (2019)

### Sniffer boat



- Measurements were repeated after the new limits enforcement
- C4 – Two vessels found to exceed 0,5% FSC in 2021

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# C3 Objectives

C3 Wedel, September 2021

- Intercomparison of different remote measurement techniques and strategies
- Originally planned for 07 Sept – 02 Oct, and extended to 15 Oct, 2020
- The objectives of the campaign are:
  - demonstration of state-of-the-art and novel measurement techniques,
  - performance assessment of remote measurement techniques, including uncertainty characterisation for $SO_2$, $NO_x$ and particulate matter monitoring,
  - harmonization of compliance monitoring measurement and reporting procedures,
  - implementation and validation as input for air quality simulations,
  - sulphur emission compliance monitoring during the campaign.



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# C3 Campaign Setup

- All systems are operated side-by-side to make them comparable under the same environmental conditions

- >910 allocated plumes from >420 individual ships have been analysed for FSC by all systems
- thereof 70 different plumes from 58 different vessels with UAV borne mini-sniffer

- Intercomparison to fuel samples and bunker delivery notes from passing ships

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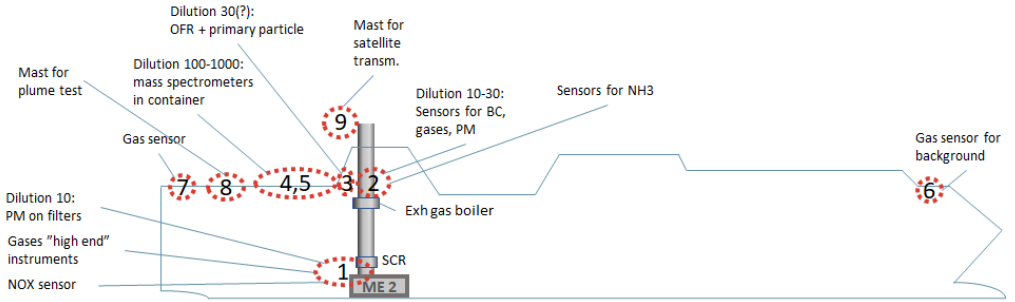
# C2 Sensor Systems on-board

| Partner | Instrumentation/sensor List | Placement | Measurement period |
|---|---|---|---|
| AUTH | BC Optoacoustic sensor | eDiluter, deck 7 | 2 weeks |
| TNO | Automotive sensors: $NO_x/O_2$, $NH_3$, temperature sensor (thermocouple) | 2 raw (deck 2, deck 7) | 4 months |
| AEROMON | $CO_2$ (NDIR), $SO_2$ (EC), $NO_2$ (EC), NO (EC), $NH_3$ (EC), CO (EC) and PM (OPC) | eDiluter, deck 7 | 1 week |
| TAU | Dilution system for particle measurement | deck 7 | 2 weeks |
| TAU | PN sensors, BC sensors (from FMI) and reference CPC | deck 7 | 2 weeks |
| TAU | Reference aethalometer | Deck 7 after WP3 sampling | 1 week |
| CML | $PM_{2.5}$, $PM_{10}$, NO, $NO_2$, $CO_2$, $SO_2$ | deck 7 / 10: (one box aft and one box stern) | 1 week |

**C2** Gothenburg (SE) to Kiel (DE), September 2021

+ high-end reference measurements by IVL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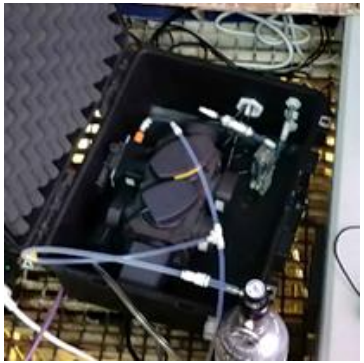
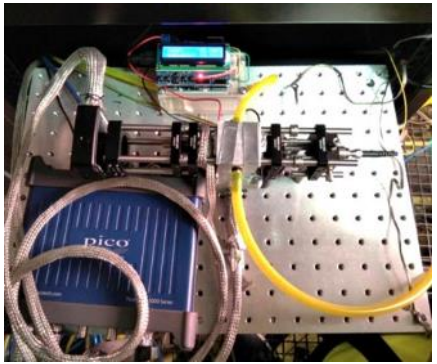
# C2 Sensor Systems Setup



Air quality sensor




Proto BC sensor

Automotive sensors

Plume air quality sensors

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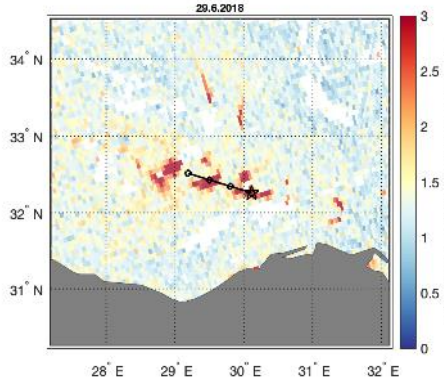
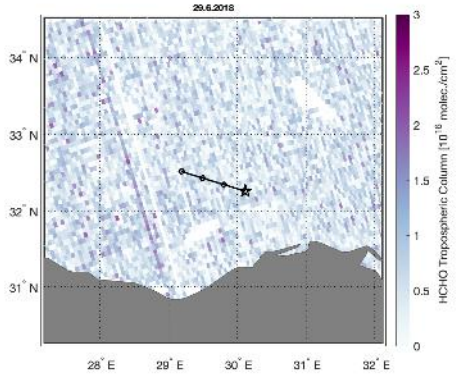
# Simultaneous Satellite Observations

(black line indicates route of a large container ship 2h prior to satellite overpass)

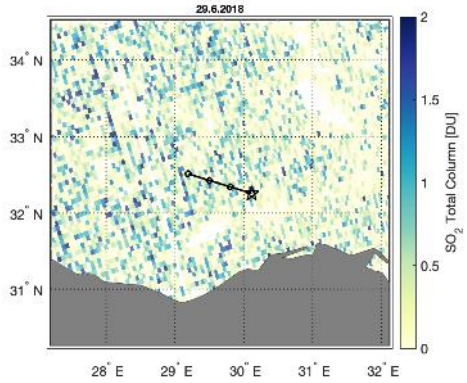
$NO_2$




HCHO




$SO_2$




- In optimal satellite viewing conditions (cloudfree, sun glint) $NO_2$ signal from single ships is clearly visible, while for other trace gases signal seems to be too weak and below satellite detection limit.
- With long temporal averaging and data filtering (e.g. account for winds) some elevated signal of $SO_2$ and HCHO could be detected over busiest shipping routes.

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# Methods Overview (On-going assessment)

| Technique | On-Board | Small UAV | Patrol-Vessel | Aircraft/Large UAV | Fixed Station | Fixed station | Optical - Satellite |
|---|---|---|---|---|---|---|---|
| **Method** | **Sensors** | **Sniffers** | | | | **Remote Optical** | |
| **Most widespread detection techniques** | $SO_x$ (IR or DOAS)<br>NO, $NO_2$ (Electrochem.)<br>$CO_2$ (NDIR)<br>BC/PN (various) | $SO_2$ (Electrochem., DOAS)<br>NO, $NO_2$ (Electrochem.)<br>$CO_2$ (NDIR)<br>New concepts | $SO_2$ (UV Fluorescence)<br>NO, $NO_2$ (CLD)<br>PN (CPC)<br>$CO_2$ (NDIR, CRDS) | | | $SO_2$ (DOAS, IR Iradiance)<br>$NO_2$ (DOAS) | $NO_2$, $SO_2$ (DOAS) |
| **Experience** | Yes, Scrubber vessels | DK, FI, EMSA | DE, FR, SE | EMSA, BE, FI, (SE) | DE, NL, SE, DK, FI | DE | FI, GR, NL |
| **Flexibility in terms of monitoring location** | On-board | Yes (restrictions) | Yes (restrictions) | Yes (restrictions) | No | No | No (5.5×3.5 $km^2$, depends on pass) |
| **Open Sea surveillance** | Yes | No | Yes | Yes | No | No | Yes |
| **Availability of results** | Can be on-line | Immediately | Immediately | After landing | Immediately | Immediately | Post-processing |
| **Suitable sites** | vessels | line of sight (smaller harbour, canal, …) | ports, busy lanes | coast and open sea | major shipping lane (harbour, canal, pole, bridge,…) | | Away from other major sources |
| **Operation time** | 24/7 (automated) | daylight | 24/7 | daylight | 24/7 (automated) | 24/7 (automated) | daylight/weather |
| **Resources (cost, personnel)/vessel** | High | Low-Medium | Medium | High | Low | Low | Medium (currently processing-tedious) |

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# Summary and conclusions

- A large number of possibilities in measuring vessel emissions locally and remotely
- The potential of different techniques demonstrated in five field campaigns
- The selection of the most appropriate method is case specific; no silver bullet method
- SCIPPER project can provide more specific support to local authorities in selecting their approach

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# Thank You

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