THE SCIPPER PROJECT

FMI

EMERGE

Detecting single ship plumes from TROPOMI NO_2 data

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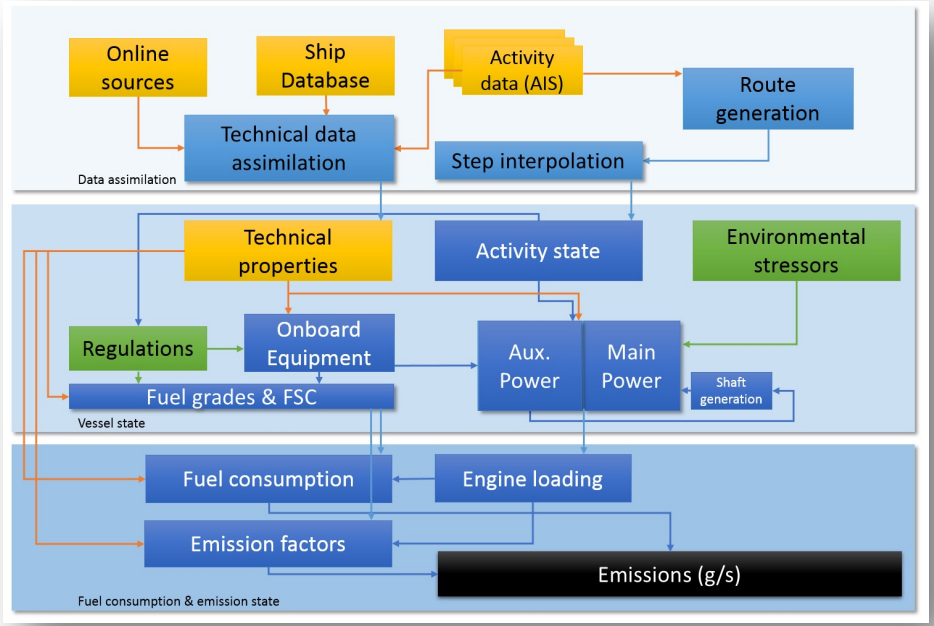
Introduction

- Ships carry about 80 % of the world's trade by volume.
- Atmospheric emissions from ships are mainly from engine fuel combustion.
  - Annually international shipping represents 13-15% of the total anthropogenic NOx emissions
- International standards limit atmospheric NOx, SOx, and PM emissions.
- Stricter regulations in Emission Control Areas (ECAs): in the EU current ECAs are the Baltic and North Sea
- Compliance monitoring is needed, also over open sea areas which is a challenge.
- In this work we investigate the use of TROPOMI NO_2 data to detect signatures from single container ships, and the sensitivity of observations to model NOx emission levels.

Ship Traffic Emission Assessment Model (STEAM)

- Model developed at FMI for shipping emissions.
- Emission estimates for several pollutants: NO_x, SO_x, CO, CO_2, EC, OC, Ash, SO_4
  - Gridded datasets
  - Vessel-specific data / summaries
- Primary source of vessel activity: Automatic Indentification System (AIS)
- Every vessel is a ”unique case”: machinery concepts, hull form, fuels, etc.

The STEAM Model



Courtesy of J.-P. Jalkanen, FMI

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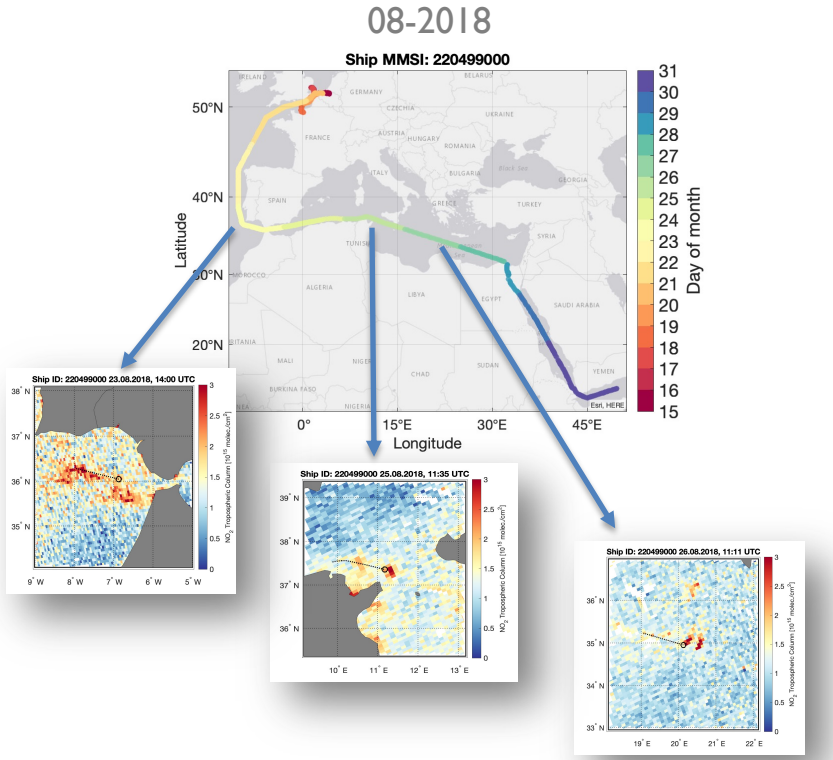
Colocation of TROPOMI NO_2 and STEAM individual container ship data

- For this study large container ships were selected that operate between Europe and Asia, crossing the Mediterranean regularly.
  - Top-NOx emitters -> expected strong signal
- STEAM provides route information and instantaneous emission estimates for these container ships.
- Based on STEAM data TROPOMI NO_2 is sampled along each ships route
  - Max. difference between ship location and TROPOMI overpass 15 mins.
- Additional meteorological data was obtained from ERA5.



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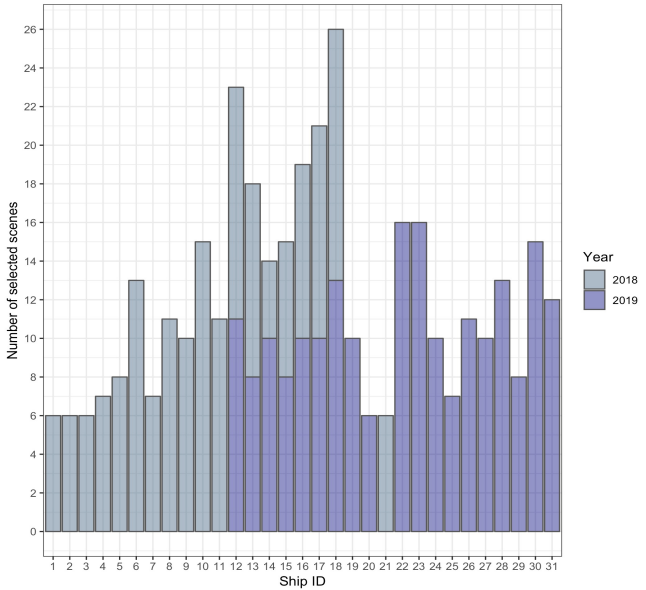
"Average" container ship

Length ~ 400 m
Stack height ~ 50 m

- Alltogether 31 container ships were analysed between May and October 2018 and 2019, 7 of them operated both years.
- Study area: The Mediterranean (lon > 0E)
- In addition to cloudy cases, scenes with strong continental NO_2 outflow were excluded from the analysis.

Number of scenes / ship / year



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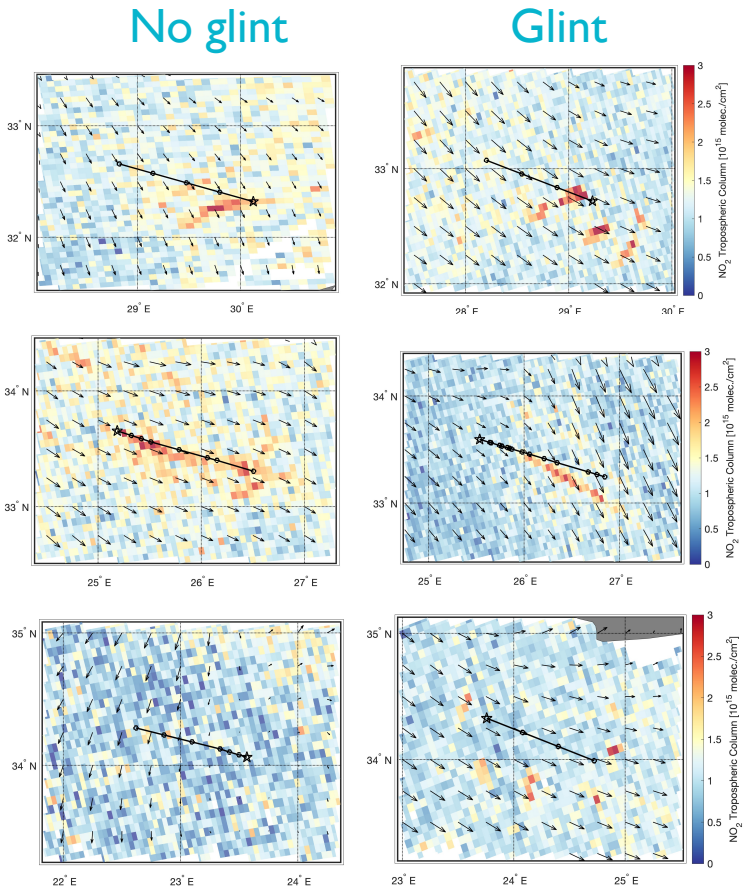
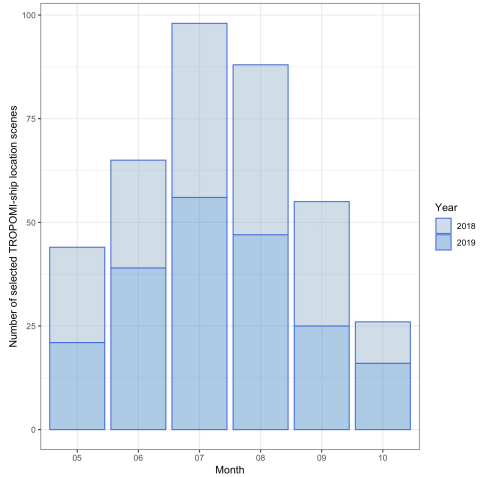


- A total of 376 colocated TROPOMI NO_2 – container ship "scenes" were analysed
  - The number of scenes/ship varied between 6 and 26
  - This represents 40%-60% of the days when a specific vessel has been at the Mediterranean (during daytime, when colocation with TROPOMI possible)
  - In less than 25% of the cases sunglint possible.



Monthly distribution of analysed scenes

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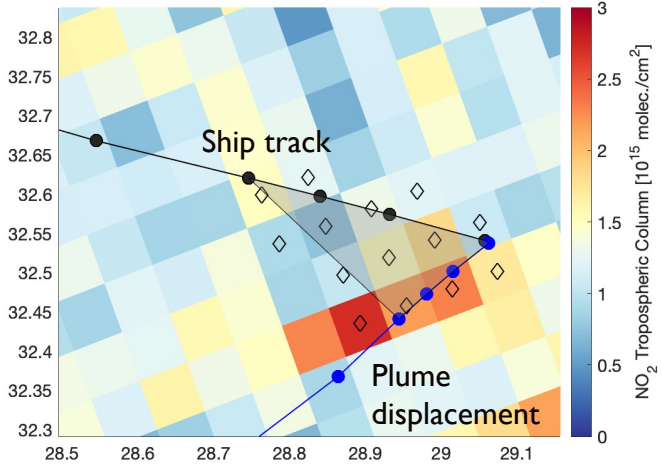
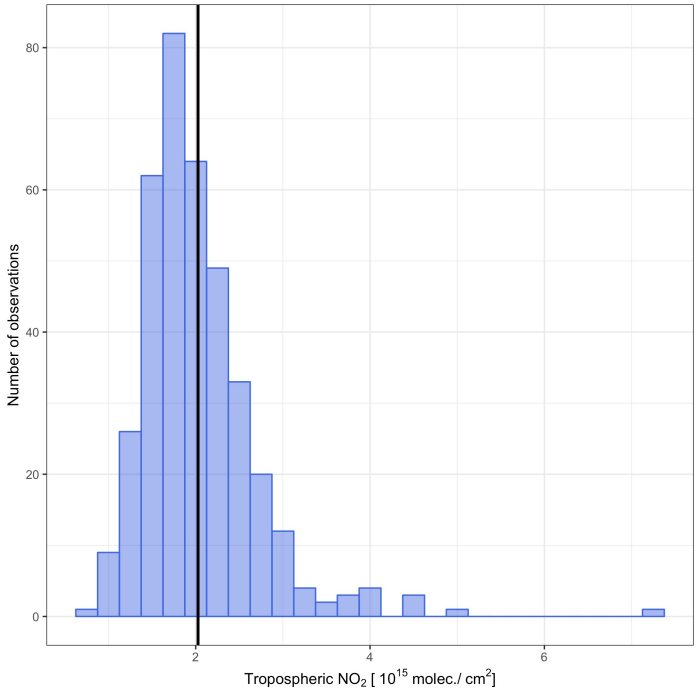
TROPOMI NO_2 value for ship plume

- Defined using ship track data and estimated plume displacement 1.5 h prior to TROPOMI overpass
  - Plume displacement estimated from ERA5 100m wind
- "Ship NO_2" = Mean of three maximum values within the polygon (diamond)



Distribution of "plume" NO_2 values



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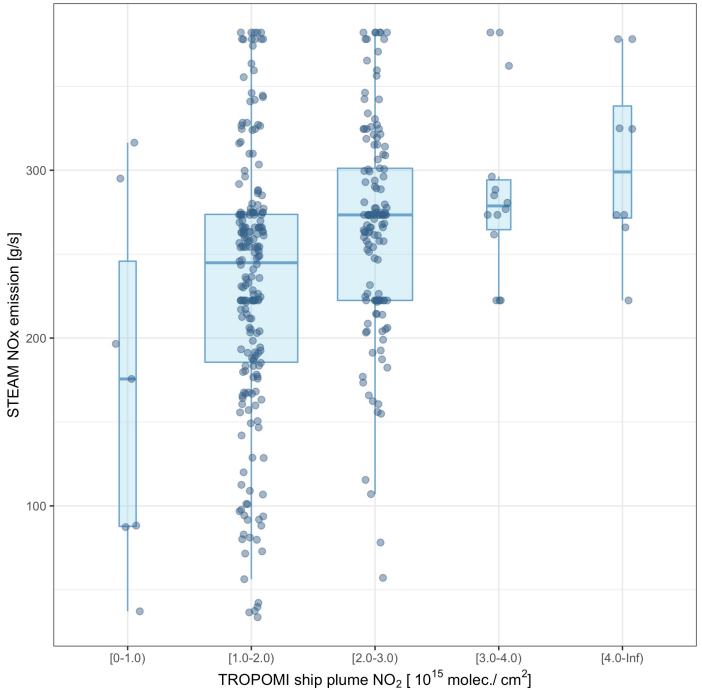
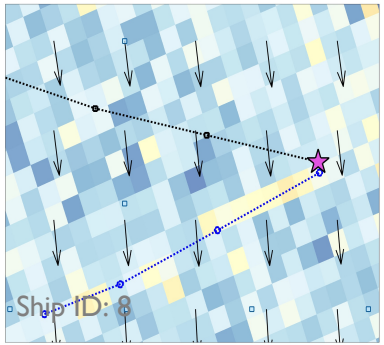
Comparison of TROPOMI NO_2 and STEAM NOx emission estimates



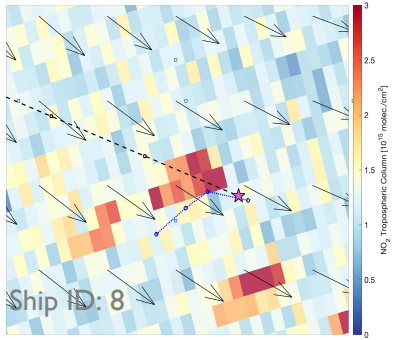
- Large scatter of STEAM NOx emission estimates in TROPOMI NO_2 bins

Example: same ship, consecutive days

22.7.2019



23.7.2019



- For both days STEAM NOx emission estimate is 266 g/s, but signature of TROPOMI NO_2 is different.

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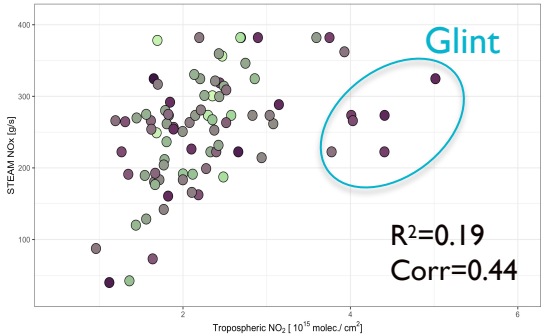
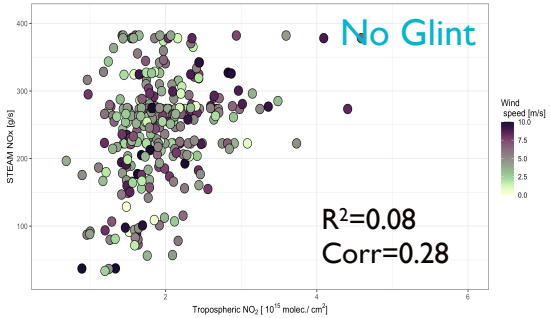
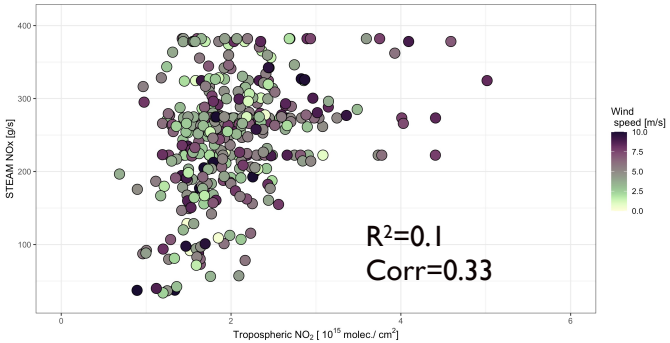
Comparison of TROPOMI NO_2 and STEAM NOx emission estimates

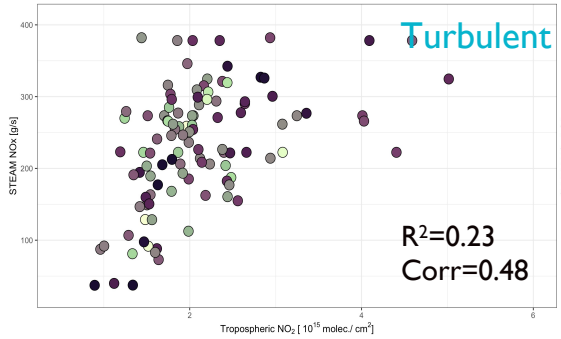
- Subsetting dataset by
  - sun glint /no glint
  - atmospheric stability
    - Bulk Ri calculated between two lowest ERA5 levels

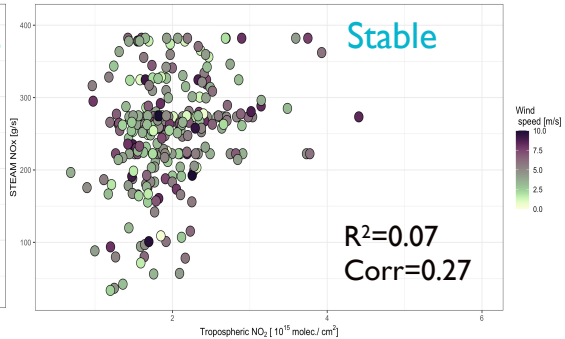




All scenes







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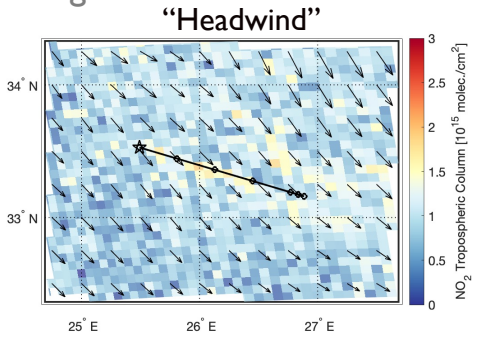
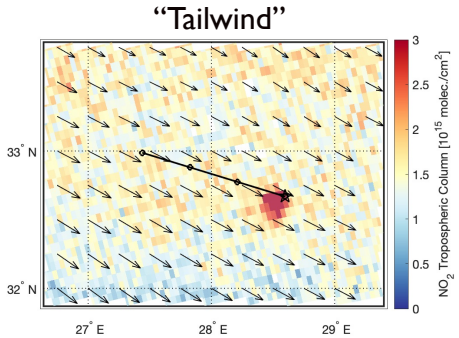
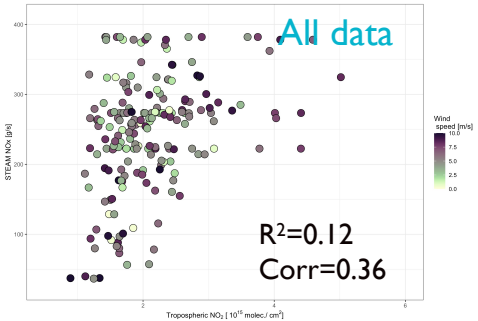
Comparison of TROPOMI NO_2 and STEAM NOx emission estimates

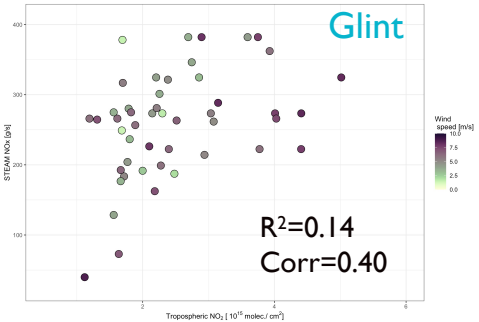
- wind speed and direction relative to ships heading



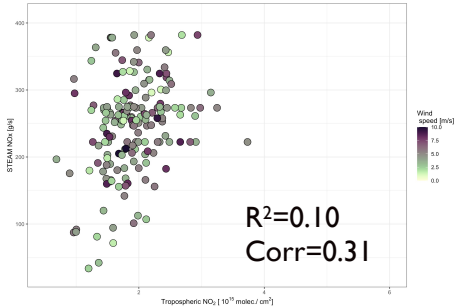


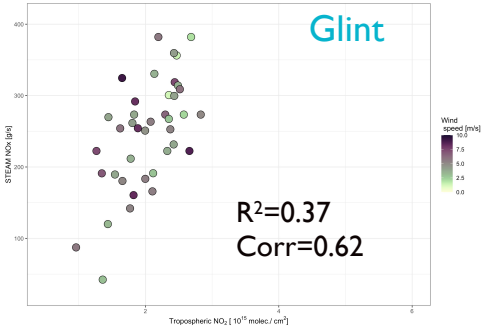
Tailwind





Headwind





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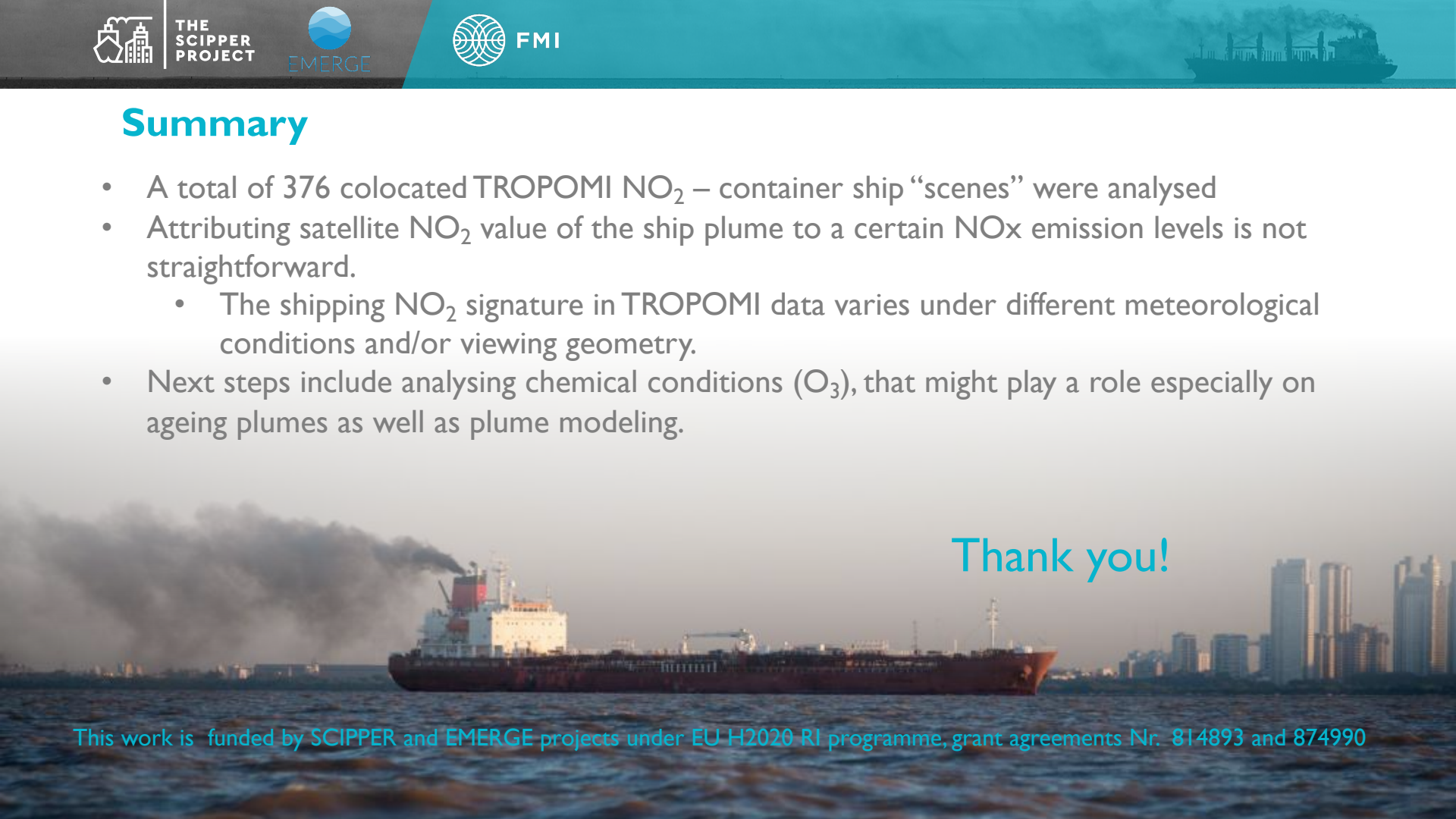
Summary

- A total of 376 colocated TROPOMI NO_2 – container ship "scenes" were analysed
- Attributing satellite NO_2 value of the ship plume to a certain NOx emission levels is not straightforward.
  - The shipping NO_2 signature in TROPOMI data varies under different meteorological conditions and/or viewing geometry.
- Next steps include analysing chemical conditions (O_3), that might play a role especially on ageing plumes as well as plume modeling.



Thank you!

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