THE SCIPPER PROJECT

EGU21-14623

Detecting single ship plumes from TROPOMI NO_2 data

Anu-Maija Sundström[1], Elisa Majamäki[2], Jukka-Pekka Jalkanen[2], Iolanda Ialongo[1], and Johanna Tamminen[1]

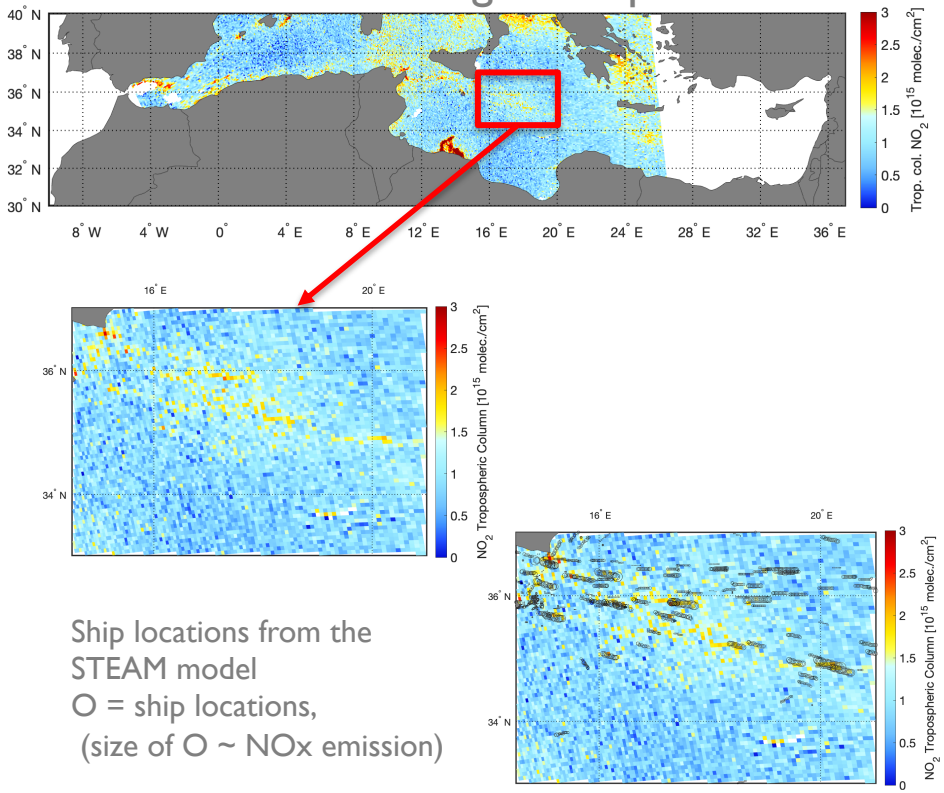
[1] Finnish Meteorological Institute, Space and Earth Observation Centre, Helsinki, Finland
[2] Finnish Meteorological Institute, Atmospheric Composition Research, Helsinki, Finland

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nr.814893

Can we identify signatures of specific ships from TROPOMI NO_2 observations?

- Very high spatial resolution of the TROPOMI instrument allows the detection of smaller NO_2 emission sources than any other satellite instrument before.
- The objective of this work is to study whether emission signatures of specific ships can be indentified from TROPOMI NO_2 observations.

TROPOMI single overpass

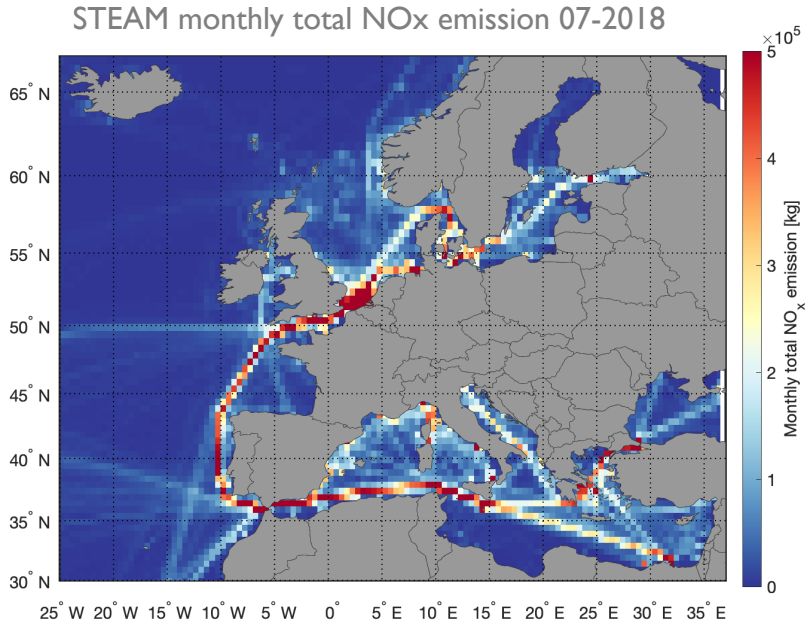


Ship locations from the STEAM model
O = ship locations,
(size of O ~ NOx emission)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nr.814893

Ship Traffic Emission Assessment Model (STEAM)

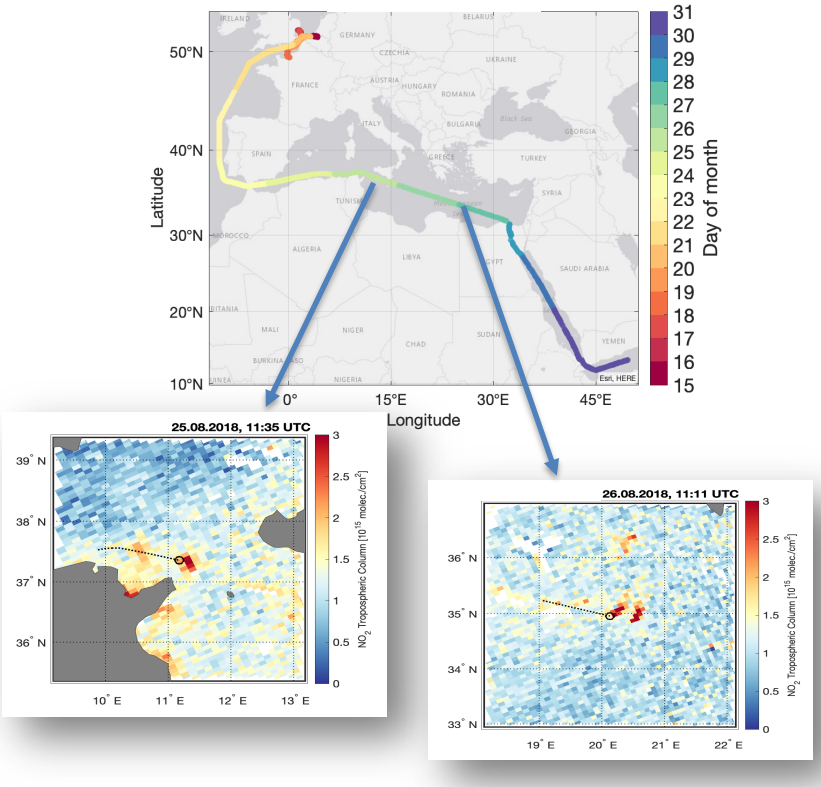
- Model developed at FMI for shipping emissions (Jalkanen et. al, 2009).
- Emission estimates for several pollutants: NO_x, SO_x, CO, CO_2, EC, OC, Ash, SO_4
  - Gridded datasets
  - Vessel-specific data / summaries
- Primary source of vessel activity: Automatic Indentification System (AIS)
- Every vessel is a ”unique case”: machinery concepts, hull form, fuels, etc.



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement Nr.814893

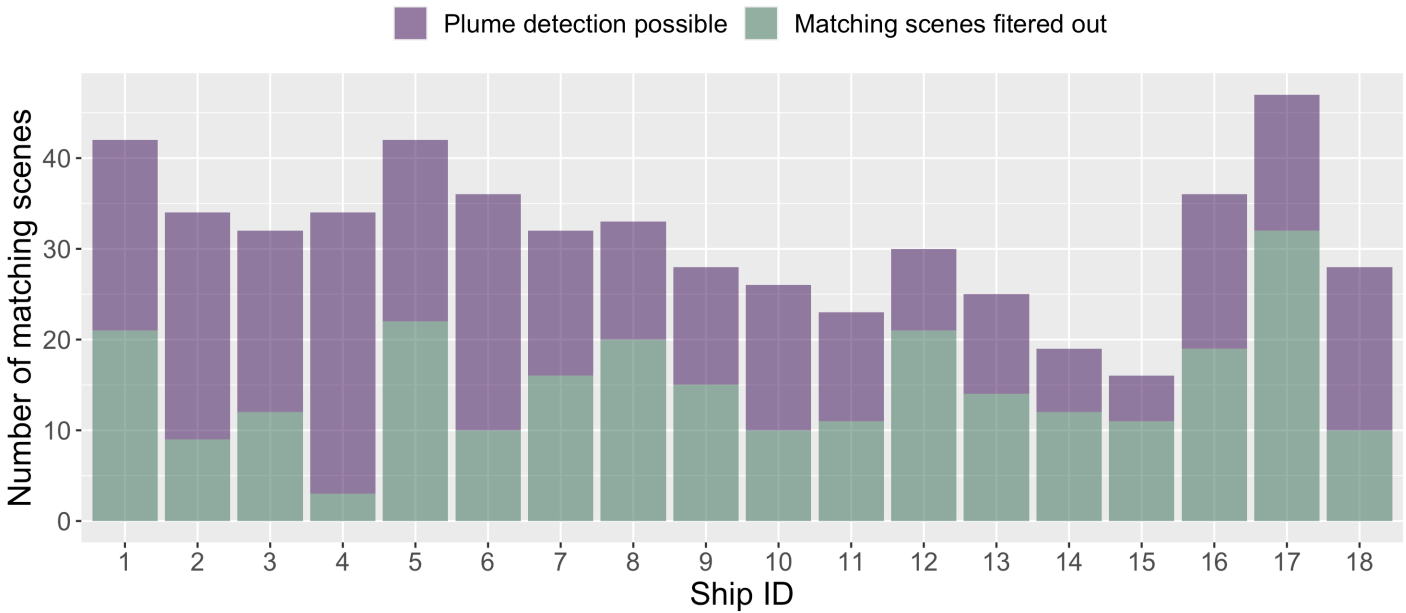
Comparison of TROPOMI and container ship data

- In this work the focus is on large container ships, that operate between Europe and Asia.
- The information on these individual ships are obtained from the STEAM model.
- Sample TROPOMI NO_2 data along the ships route
- Study period: May-October 2018 and 2019 over the Mediterranean
- STEAM shipping routes for 33 single vessels have been analyzed (7 ships have data for both years)
- Meteorological data is obtained from ERA5.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nr.814893

Number of matching TROPOMI NO_2 scenes and ship locations in May-Oct 2019



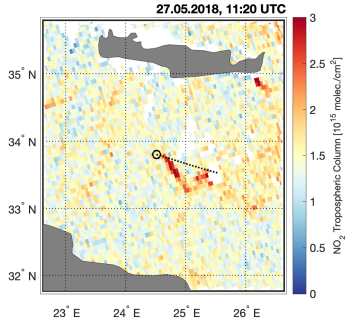
- For the possible signature detection matching scenes were further filtered:
  - Cloudy scenes were excluded
  - Cases when ships were at the port or close to the coast under continental outflow were excluded

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nr.814893

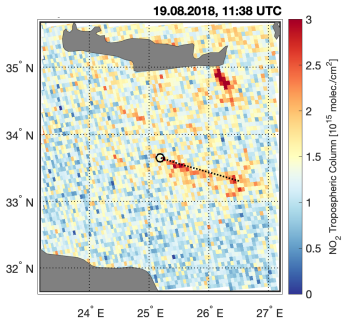
- For all 33 container ships scenes are found over the Mediterranean, where locally elevated TROPOMI NO_2 is most likely related to the specific ship.
- TROPOMI NO2 values in the ship plumes vary typically around $2 \cdot 10^{15}$ molec./cm^2 (enhancement of about $1 \cdot 10^{15}$ molec./cm^2)
- Signatures of large ships in TROPOMI NO_2 seem to be visible both under glint and no glint conditions, but with glint the signature is often more clear.

(same ship, different dates)

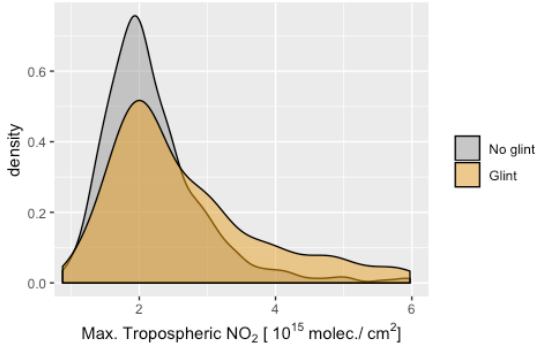
Glint



No glint



"Maximum" TROPOMI NO_2 in the vicinity of ship location (all ships)

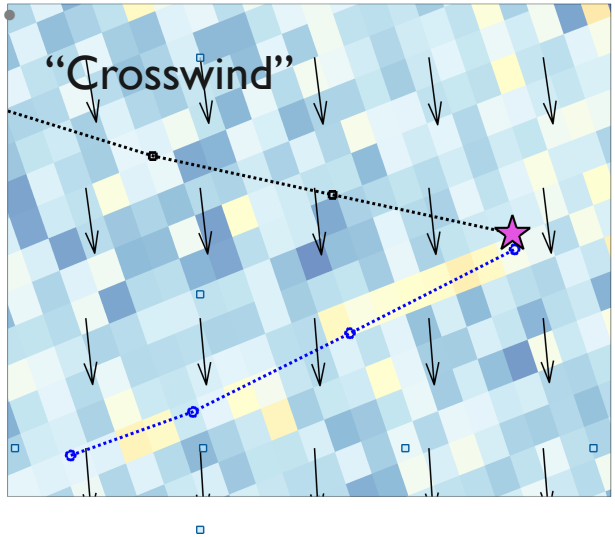


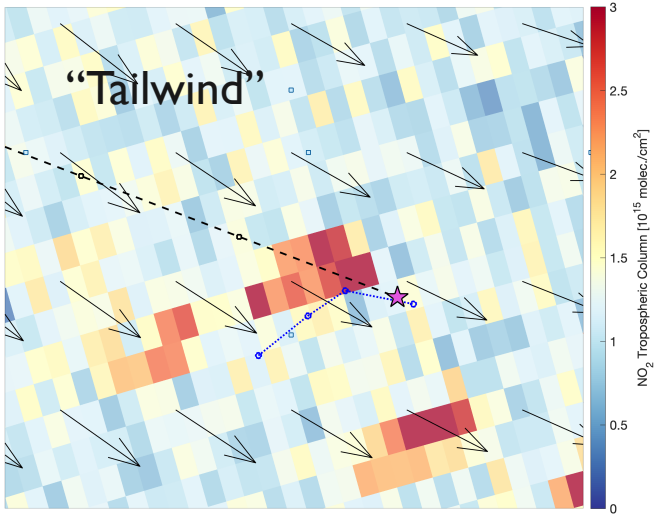
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nr.814893

- The observed signatures are affected by the prevailing meteorological and/or viewing conditions, e.g. wind speed, direction, sun glint /no glint.

Same ship, different days

- Both days under glint conditions, wind speed is 6 and 8 m/s
- For both cases STEAM emission estimate is 266 g/s, but NO_2 values within the plume areas differ.





Ship location at TROPOMI overp.

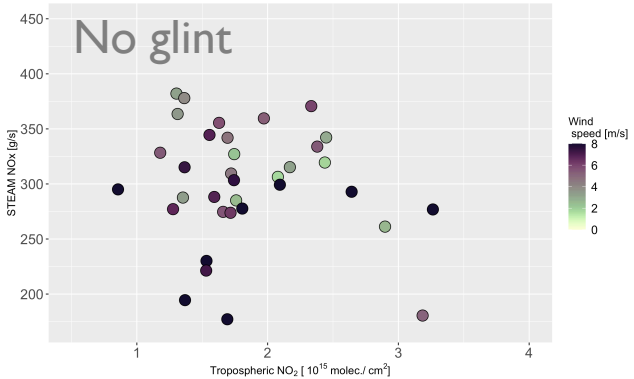
Ship track from STEAM

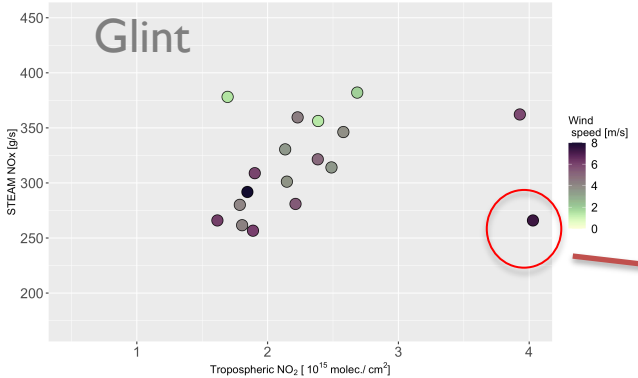
Plume displacement estimated from ERA5 10 m wind

10m wind from ERA5

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nr.814893

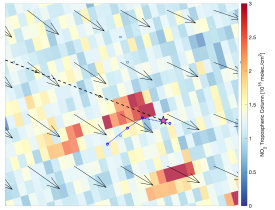
Comparison of STEAM NOx emissions vs. TROPOMI NO_2



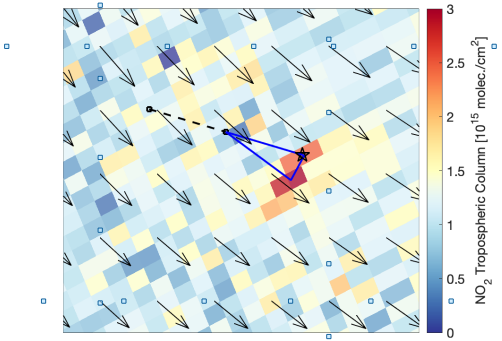


- Defining TROPOMI NO_2 values for comparison is not straightforward, different colocation methods affect the results.
- In these examples the TROPOMI value is defined as the mean of 3 highest NO_2 observations, that are found within the area bordered by the ship track (1 hour backwards) and the plume displacement.

"Outlier": high TROPOMI NO_2, "lower" STEAM NOx



Strong tailwind



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nr.814893

Reference:
J.-P. Jalkanen, A. Brink, J. Kalli, H. Pettersson, J. Kukkonen, and T. Stipa: A modelling system for the exhaust emissions of marine traffic and its application in the Baltic Sea area, Atmos. Chem. Phys., 9, 9209–9223, 2009.

Acknowledgements:

This work is funded by the SCIPPER project (H2020 grant agreement Nr. 814893)