A survey of global shipping NOx emission in the S5p / TROPOMI data

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1 Why are we interested in Ship Emissions?

- Nitrogen oxides (NOx = NO_2 + NO) are important trace gases in the troposphere.
- Ships emit large amounts of NOx, which affect the marine boundary layer and human health.
- Global shipping plays a prominent role in transporting goods around the world.

https://stock.adobe.com/de/images/container-ship/65063906

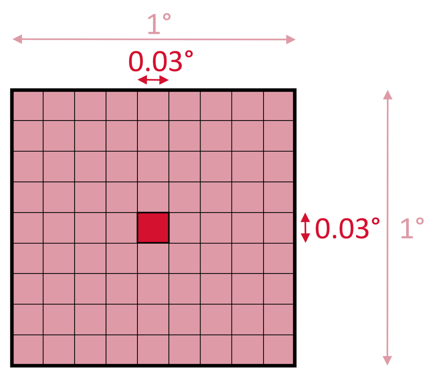
- The aim of this study is to detect shipping signals from global shipping routes in the S5p TROPOMI NO_2 data.

2 Data and Flagging

- S5p TROPOMI PAL and OFFL L2 NO_2 data
- Processor version 2.3.1
- Tropospheric NO_2 Slant Column Density (SCD) (= trop. VCD * trop. AMF) is used, which does not contain model information about shipping routes.
- NO_2 data is averaged on a 0.03 x 0.03 km^2 grid from May 2018 to May 2022.
- The TROPOMI surface classification mask is applied to use only pixels over water.
- Different data flagging is used:
  - Quality: qa value > 0.75
  - Cloud fraction: CF < 0.5
  - Cloud height: CH < 2000 m
  - Wind: wind speed between 0 and 5 m/s
  - Sun glint: "sunglint possible" (TROPOMI variable geolocation_flags = 2)

3 Filtering Method

- Land sources are much larger than shipping sources, therefore we are looking for small signals on a variable background. High pass filtering allows us to highlight the shipping lanes.



- **Step 1:** Filtering the **original NO_2 map** → averaging **the neighbouring pixels** and subtracting this averaged value from **the original pixel value** with a box size of 1° for longitude and latitude => **filtered NO_2 map**
- **Step 2:** Define and apply a threshold (10^{13} molec cm^{-2}) to eliminate values larger than the threshold => **masked filtered NO_2 mask**
- **Step 3:** Masking the original NO_2 map => **masked NO_2 map**
- **Step 4:** Interpolation of the masked NO_2 map => **interpolated NO_2 map**
- **Step 5:** Filtering the original NO_2 map with the interpolated NO_2 map => **final filtered NO_2 map**

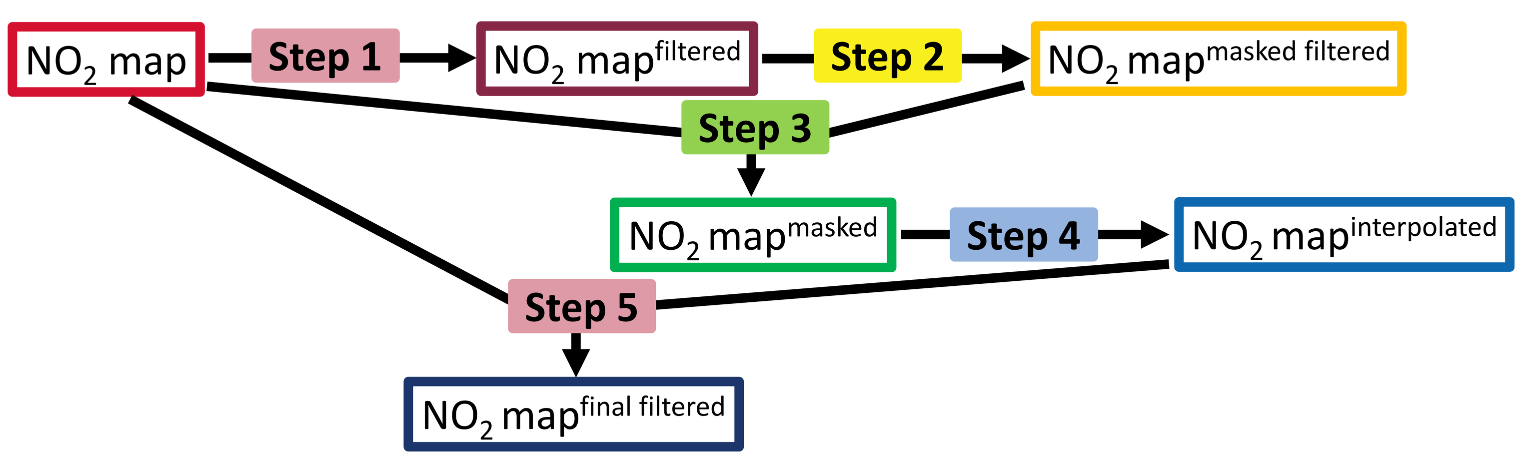


Figure 1: Schematic overview of the filtering method applied to the S5p TROPOMI NO_2 data.

4 Results

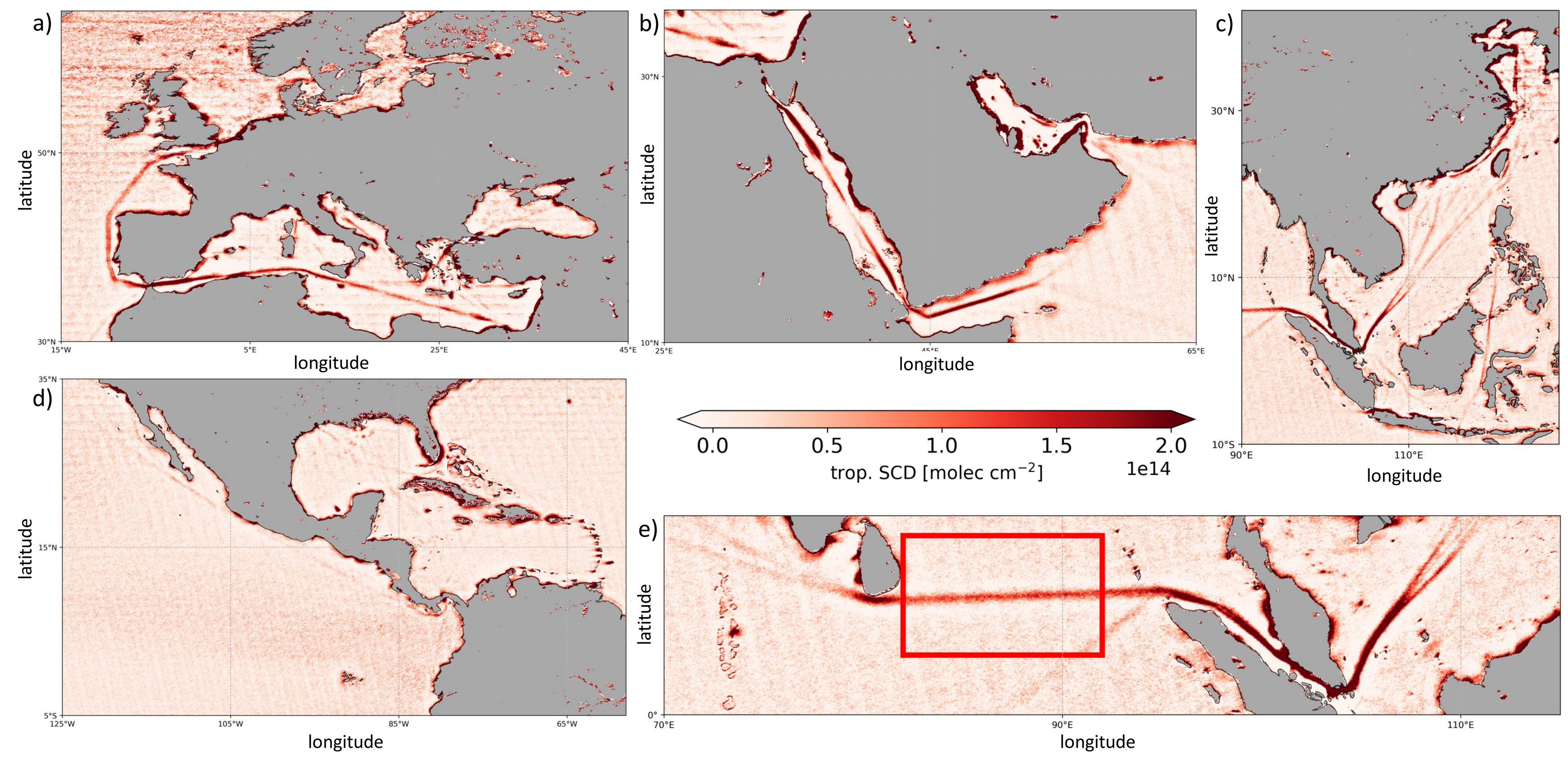


Figure 2: Examples for final filtered S5P TROPOMI NO_2 maps for different regions (flagged for quality and cloud fraction).

- Using the filtering method, signals from international shipping can be detected as separated distinct lines of enhanced NO_2 in European seas (Fig. 2a), in the Red Sea and Persian Gulf (Fig. 2b), in the Asian seas (Fig. 2c), and in Central America, e.g., in the Caribbean Sea and near the Panama Canal (Fig. 2d).

- The distribution and width of the signal from India to Indonesia (mean of the red box in Fig. 2e) depends on the flagging used (Fig. 3):
  - considering only small cloud fractions has the smallest effect on the signal
  - for low cloud heights the peak increases strongly
  - low wind speed results in a high signal with the largest width, and the peak is slightly shifted to smaller latitudes
  - under sun glint geometry, the distribution lies in between the peak with cloud fraction and quality flagging
- The background noise is clearly separated for the different flagging options (needs to be further investigated).

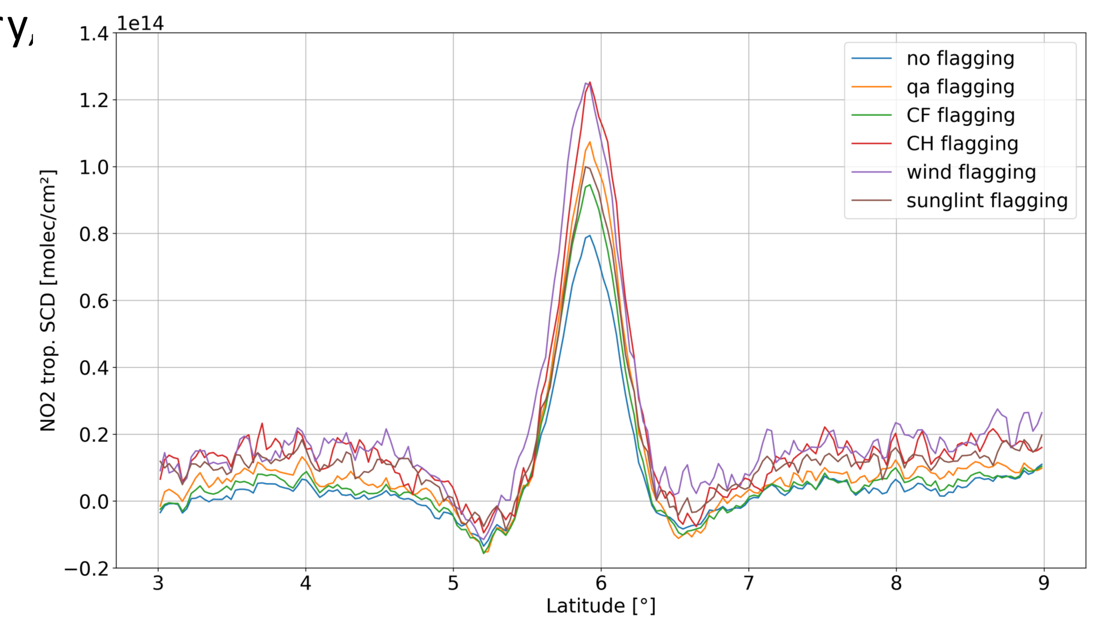


Figure 3: Cross-section through the shipping lane shown in Figure 2e (red box). For each curve one different flagging is applied.

5 Conclusions and Outlook

- The filtering method can highlight large global shipping lanes in the S5p TROPOMI NO_2 data.
- All flags used increased the shipping signal:
  - excluding scenes with large cloud fraction has the smallest effect, similar to including only scenes under sun glint conditions
  - quality filtering leads to even larger shipping signals
  - the largest signals are found for low cloud heights and low wind speeds

- Future work will be to test some additional filtering methods, and to quantify the NO_2 shipping emissions by using scene dependent appropriate air mass factors and comparison with model simulations.

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Selected References

Georgoulias, A. K., et al.: Detection of NO_2 pollution plumes from individual ships with the TROPOMI/S5P satellite sensor, Environ. Res. Lett., 15(12), 124037, doi:10.1088/1748-9326/abc445, 2020.

Richter, A., et al.: Satellite measurements of NO_2 from international shipping emissions, Geophys. Res. Lett., 31, L23110, doi:10.1029/2004GL020822, 2004.

Richter, A., et al.: Shipping Signals in S5P NO_2 data, ATMOS 2018, 2018.

Riess, T. C. V. W., et al.: Improved monitoring of shipping NO2 with TROPOMI: decreasing NOx emissions in European seas during the COVID-19 pandemic, Atmos. Meas. Tech., 15, 1415–1438, doi:10.5194/amt-15-1415-2022, 2022.

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