Shipping Signals in S5P NO_2 data

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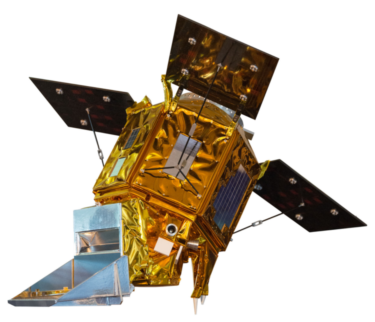
Why measure shipping NOx?

http://www.hapag-loyd.com/images/press_and_media/photo_library/BremenExpress01_print.jpg

- Nitrogen oxides (NOx = NO_2 + NO) are important trace gases in the troposphere.
- They are a key component in tropospheric ozone formation.
- Through reaction with OH, they form HNO_3 contributing to acidification.

- Ships emit large amounts of nitrogen oxides into the marine boundary layer.
- They change the chemistry in remote regions and create health hazards when operating close to coasts.
- As the amount of goods transported increases, so do emissions from ships.
- NOx emissions from ships are currently not strongly regulated but legislation will change in the coming years, in particular in selected emission control areas.

Instrument and Retrieval



https://commons.wikimedia.org/w/index.php?curid=45634546

TROPOMI on Sentinel 5 Precursor:
- launched October 2017
- early afternoon 13:30 LT orbit
- 3.5 x 7 km^2 pixel size at nadir
- daily global coverage
- data from April - October 2018 has been used

DOAS Analysis:
- 425 - 465 nm, IUP-UB fits, destriped

Stratospheric Correction:
- reference sector over the Pacific (180° - 220° E)

Airmass Factors:
- assumption of a 600 m well mixed boundary layer with No_2
- no correction for aerosol impacts

Cloud treatment:
- filtering for cloud radiances < 50% unless noted otherwise

Filtering:
- masked to include data over water only
- high pass filter using boxcar smoothing over +/- 1° latitude and longitude unless noted otherwise

Data selection effects

Clouds:
Cloud screening reduces values only slightly, but increases noise as less measurements are averaged.

Wind speed:
Low wind speed observations result in higher signal and slightly narrower distribution, but have much higher noise (smaller number of observations).

Sun glint:
As expected, the sensitivity increases under sun glint geometry (larger surface reflection) but noise increases because less observations contribute.

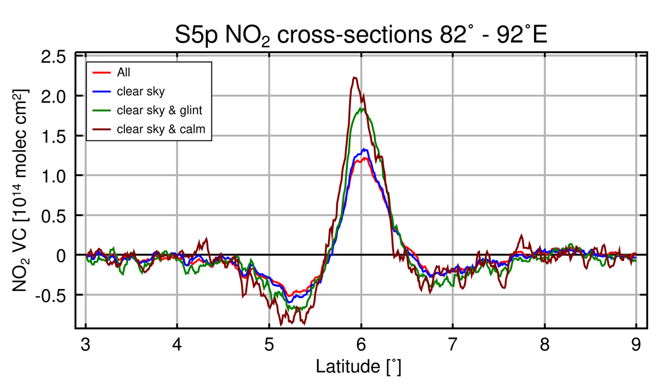


Figure 2: Cross-section through the shipping lane shown in Figure 1

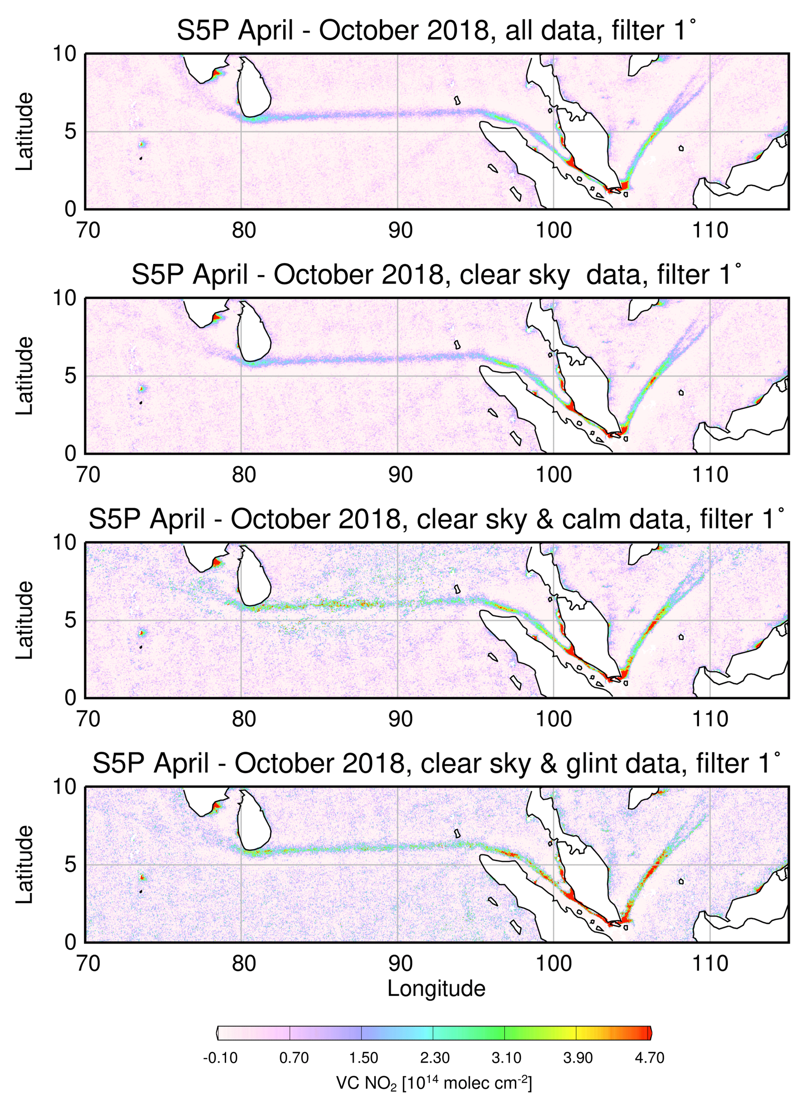


Figure 1: NO_2 shipping signal between India and Indonesia for different selection criteria of the data included in the mean. From top to bottom: All da, only clear sky data, only clear sky data with wind speeds < 7m/s, only clear sky data taken under sun glint geometry

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Universität Bremen

Results

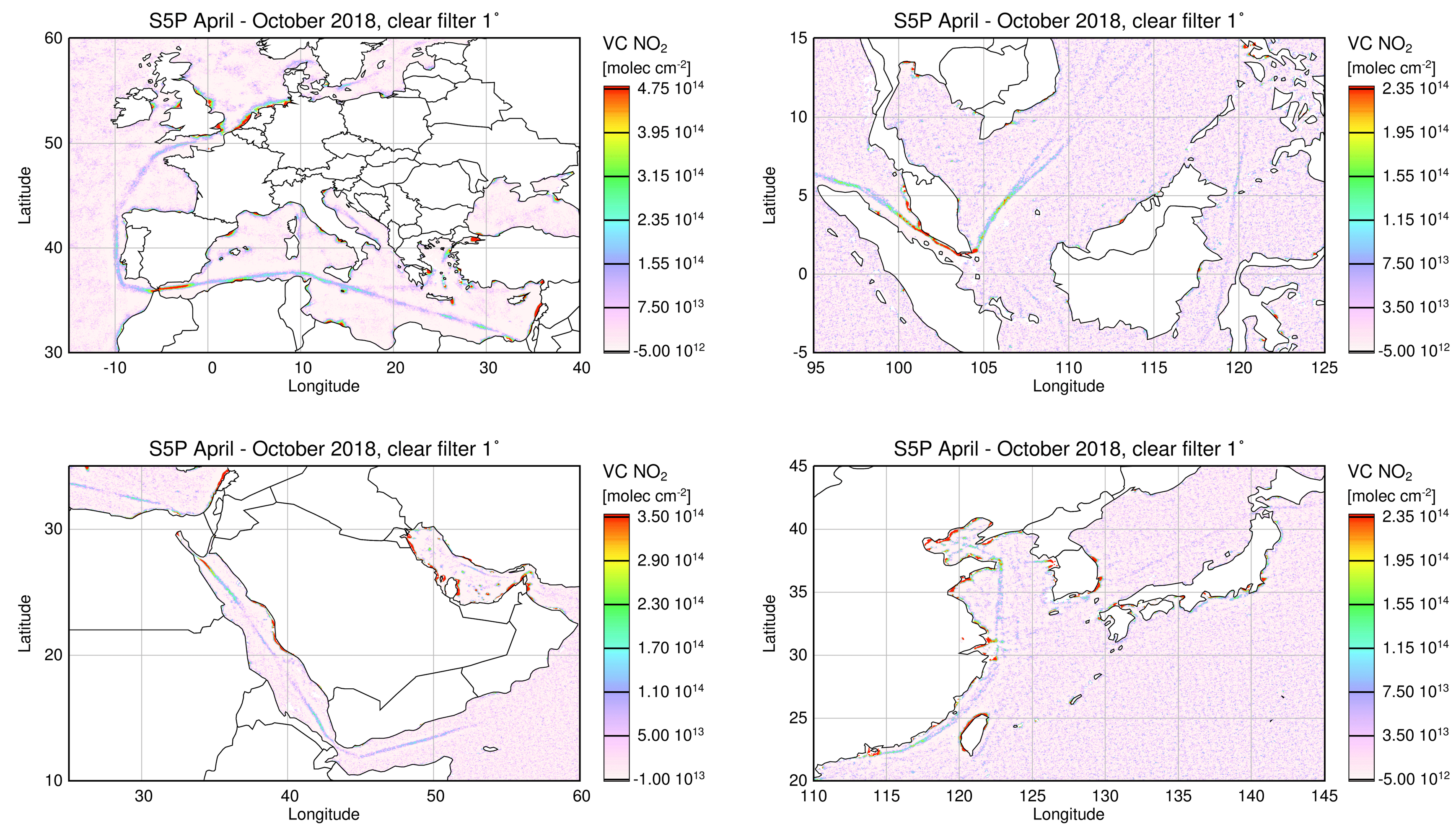

Figure 3: Examples for filtered S5P NO_2 maps for different regions. Different colour scales have been used to highlight shipping lanes

Observations:
- NO_2 from international shipping can be detected as distinct lines of enhanced NO_2 in many regions of the world
- in addition to shipping lanes already detected in earlier satellite measurements, more lines become visible such as in the Mediterranean Sea east of Italy, around Greece, in the Baltic sea, east of Borneo, from Korea towards the passage south of Hokkaido and the shipping lane off the coast of China and towards Beijing (Fig. 3)
- In the Persian Gulf, NO_2 from flaring is apparent as localised NO_2 spots
- although this is just 7 months of S5P data, the noise is already very low
- absolute values and the width of the retrieved lanes depends critically on the width of the filter used (see Fig. 5)
- smaller filter width results in more narrow lines and detection of additional signals (see Figure 4), but NO_2 columns decrease as more background signal is removed

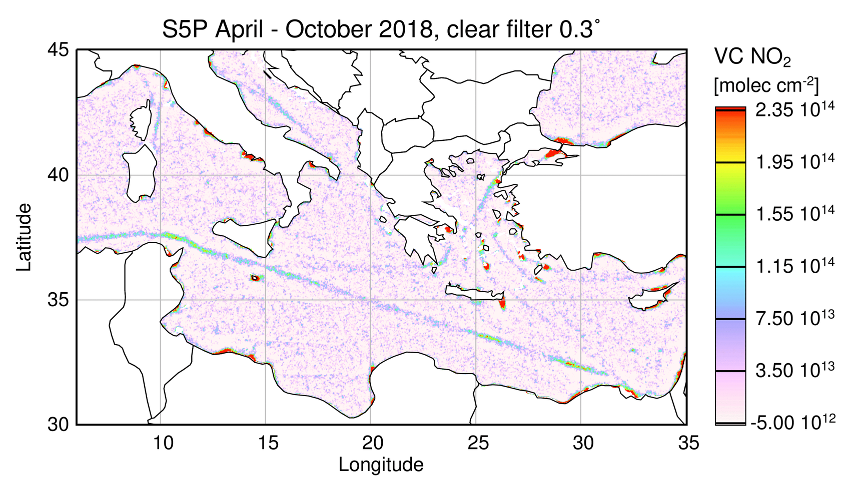

Figure 4: S5P NO_2 map over the Mediterranean Sea using a more narrow filtering (0.3°). Additional shipping lanes towards Greece and the Bosporus appear, as well as a lane east of Corsica. However, NO_2 columns decrease (see also Fig. 5).

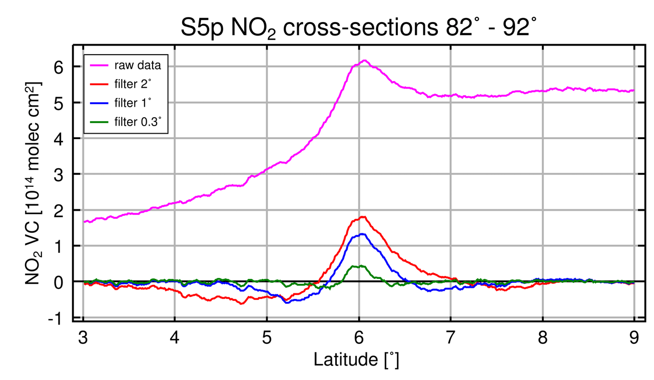

Figure 5: Effect of different filter widths on the NO_2 signal found for the cross-section through shown in Figure 1. Which part of the enhancement around 6°N is due to shipping emissions and which is part of teh background variation cannot be unambiguously determined.

Conclusions

Conclusions

- High pass filtered NO_2 columns from TROPOMI on Sentinel 5 Precursor show many clear signals of emissions from international shipping.
- The signal to noise ratio is excellent, facilitating detection of many additional shipping lanes already in a 7 month average.
- Clouds have a surprisingly small effect on the magnitude of the detected NO_2 signal.
- Using only observations in glint geometry increases the NO_2 signal by more than 30%, but reduced number of observations increases the noise.
- Excluding observations at high wind speed increases the signal even more, and slightly narrows the observed lanes, but much less data can be averaged, resulting in higher noise.
- Selection of the right filter width is difficult and probably no value can be found which is optimum for all regions.

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see also: www.doas-bremen.de