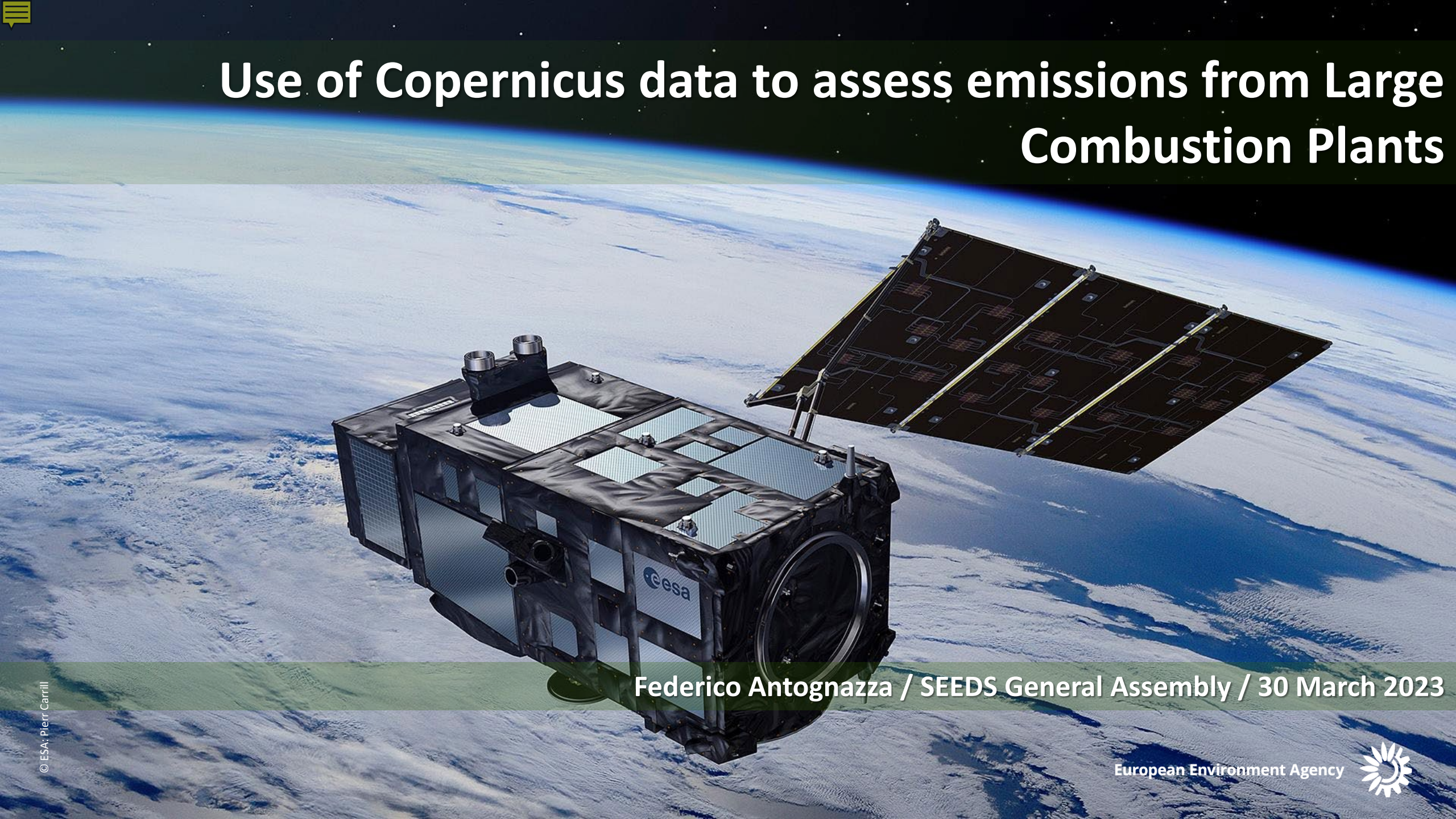
Use of Copernicus data to assess emissions from Large Combustion Plants



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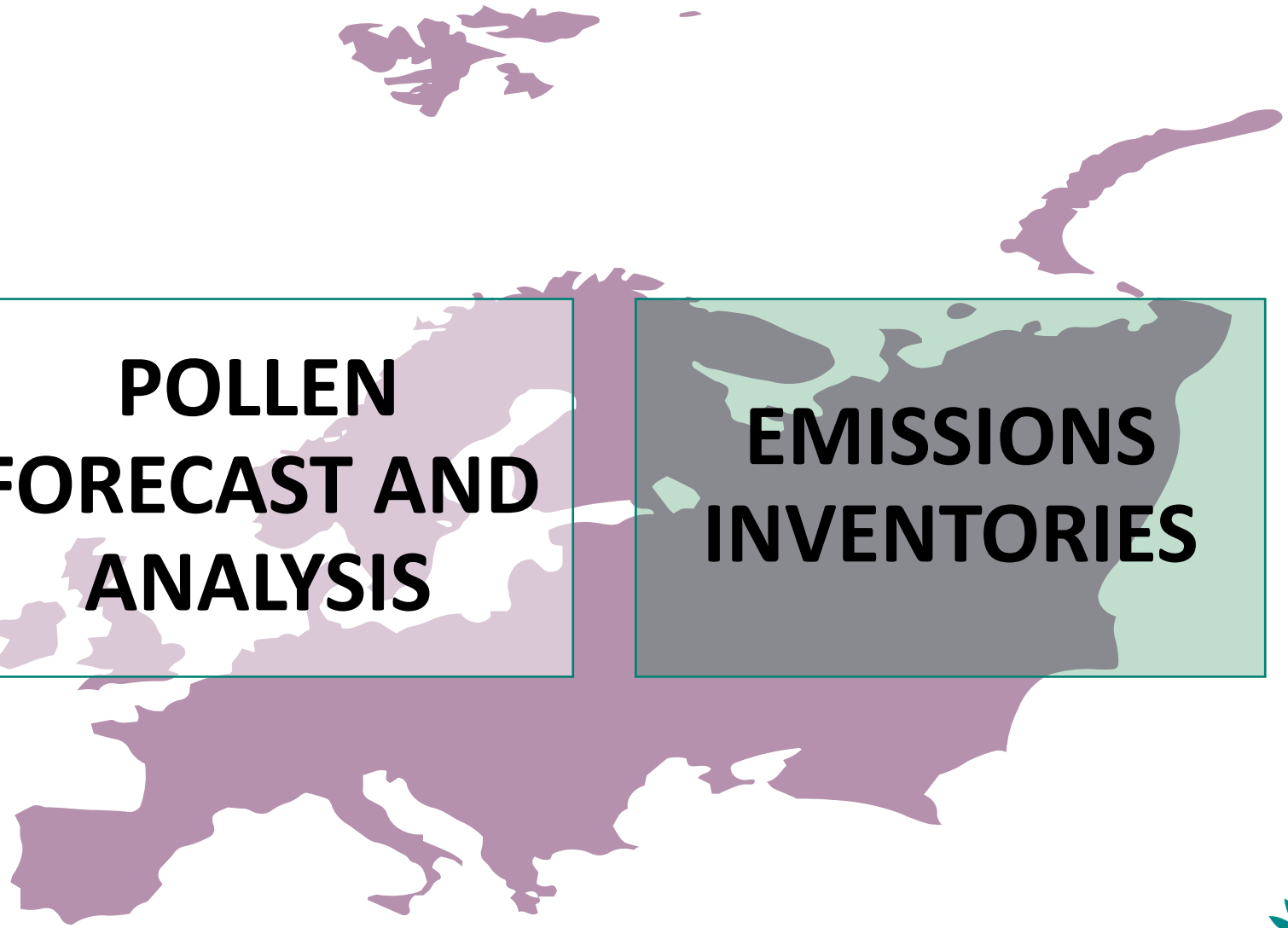
Use of satellite data at EEA



AIR POLLUTION FORECASTS AND ANALYSIS

POLLEN FORECAST AND ANALYSIS

EMISSIONS INVENTORIES

Use of satellite emissions data at EEA

ASSESSMENT OF RELEVANT SOURCES

- NATURAL SOURCES
- FOREST FIRES

SUPPORT ON DATA REPORTING

- QA
- GAP FILLING
- ASSESSMENT

POLICY

- NECD IMPLEMENTATION
- AQ PLANS

Use of Copernicus data for assessing emissions from Large Combustion Plants

European Environment Agency

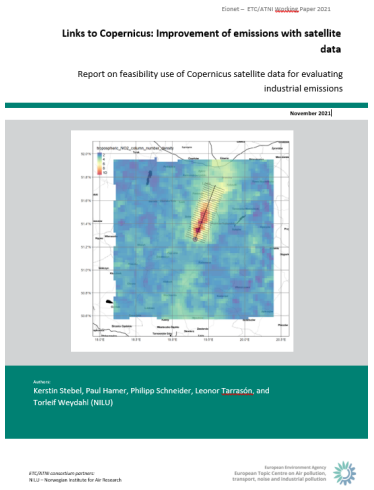
What we have done and what we are doing

2021

Case Study

12 LCPs

Model set-up



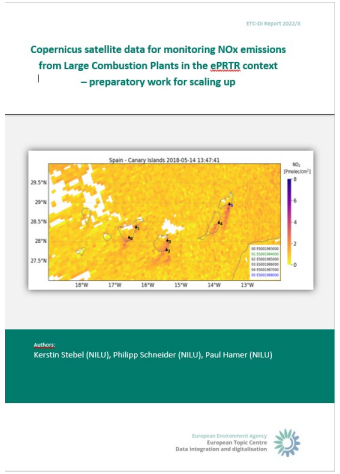
2022

Extensive analysis

Wider number of LCPs

Sensitivity

Evaluation of possible implementation



2023?

Implementation?

QA input to reporting data validation

Gap-filling of late or not reported dataset

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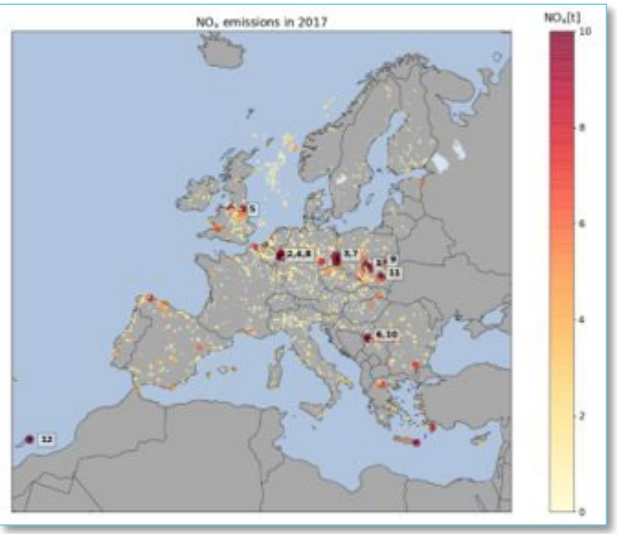
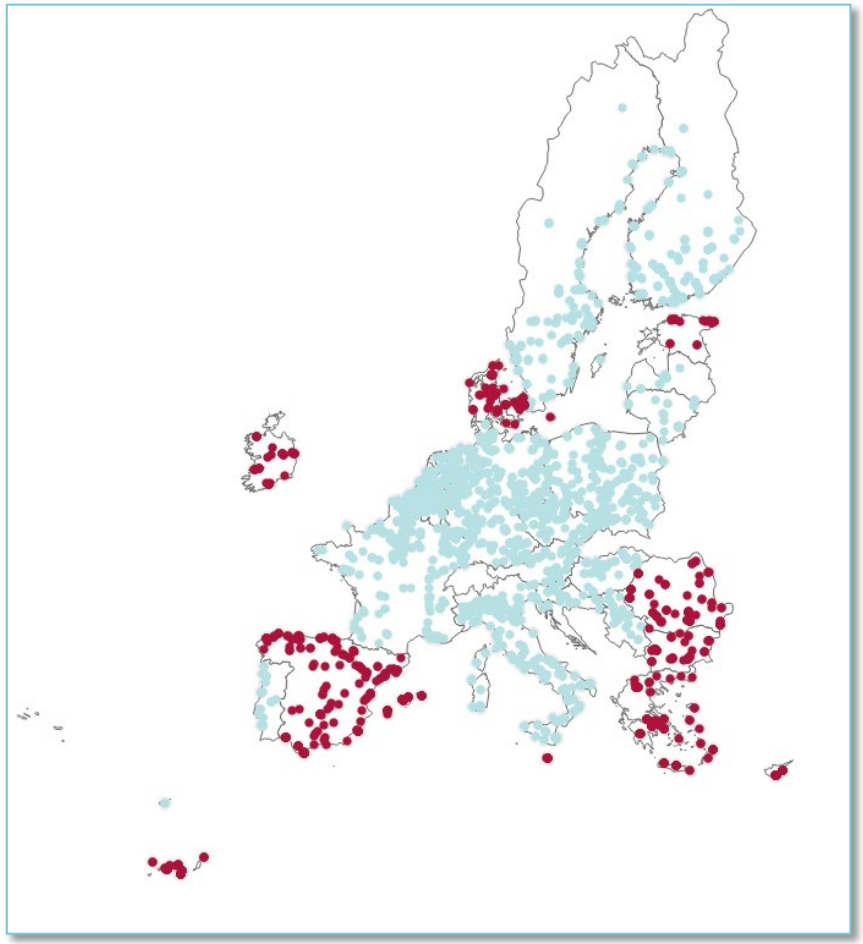
Assessing LCPs emissions from satellite





SENSITIVITY ANALYSIS

UNCERTAINTY ESTIMATION

+600 LCPS

ON/OFF DETECTION

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General concept of work

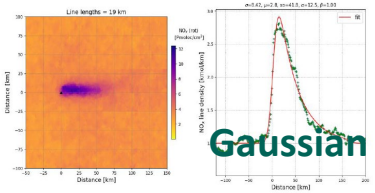
2021 Feasibility study for 12 LCPs **2022 Country BG, CY, DK, EE, ES, GR, IE, MT, RO**

TROPOMI / Sentinel-5P (~2.5TB/y)
NO_2 overpasses (Level 2 data)
2021: 2018 – 2020
2022: 2018 – 2021 reprocessed data

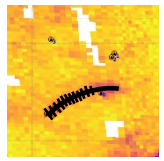
E-PRTR LCP
latitudes, longitudes

ECMWF ERA5 model
0.25° x 0.25° x 12 level
wind, temperature, ozone,
cloud fraction
2022: Boundary Layer Altitude

- REGRIDDING, OVERSAMPLING (0.01°)
- NO_2 DATA LISTINGS ON COUNTRY LEVEL
- FIND WIND MATCHING PLUME DIRECTION (LEVEL)
- $[NO_2]$ -> $[NO_X]$ CONVERSION

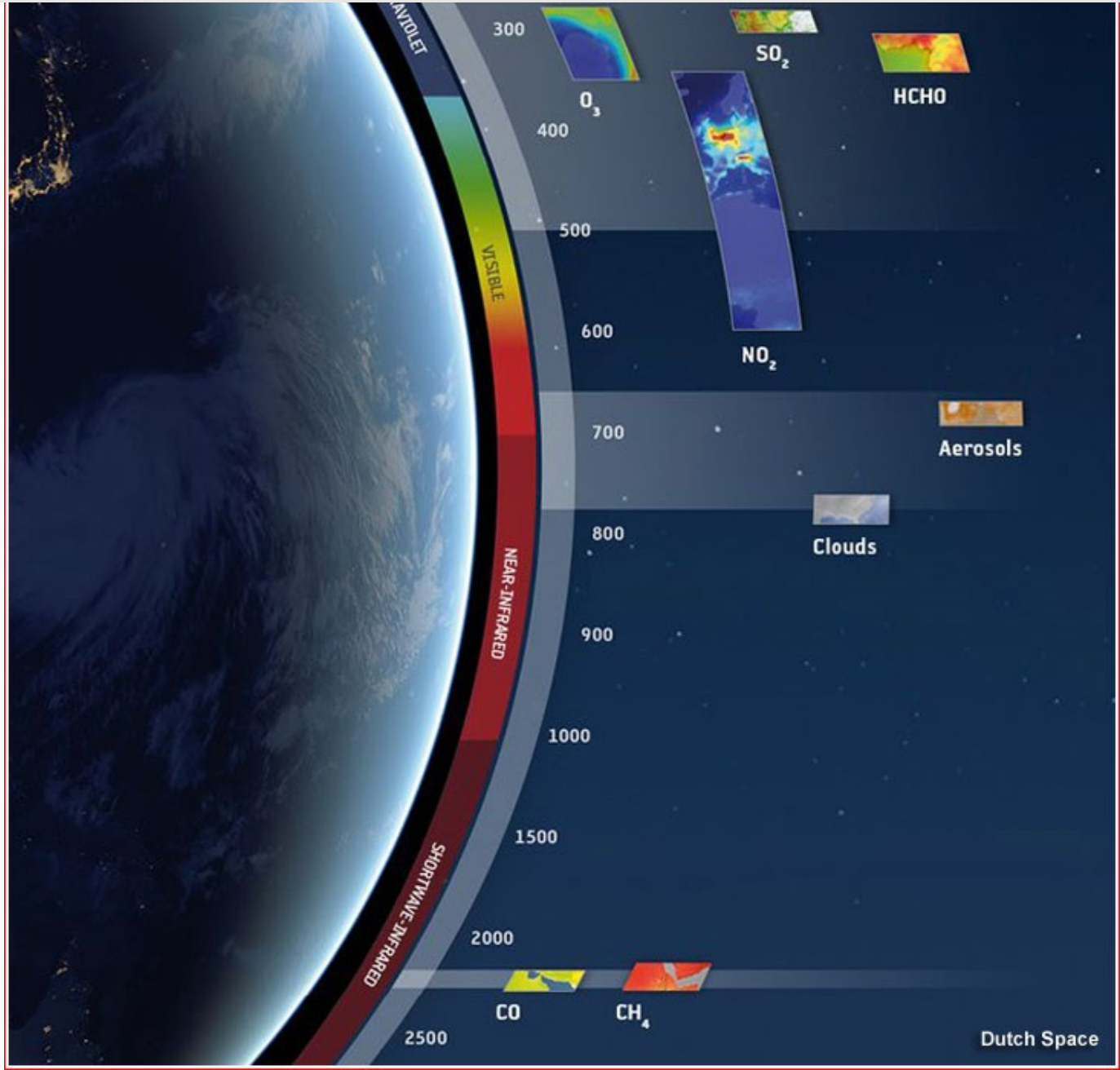


2021: Exponentially Modified Gaussian (EMG) fit of rotated plumes



2022: Image processing revised, LCP on/off, EMG fit for lifetime and NOx emissions

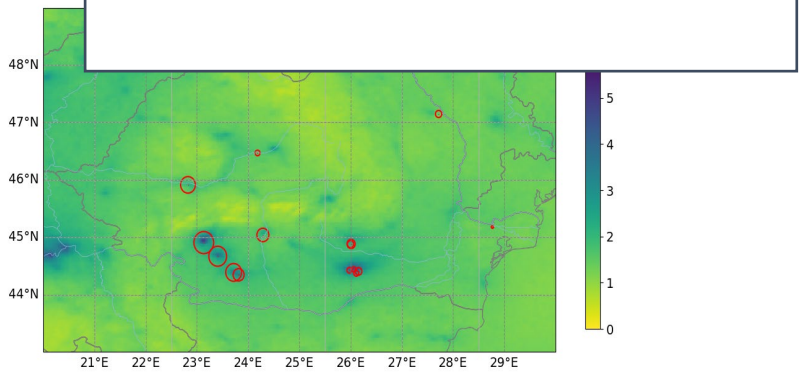
TROPOspheric Monitoring Instrument (TROPOMI) on the Sentinel-5 Precursor (S-5P) satellite

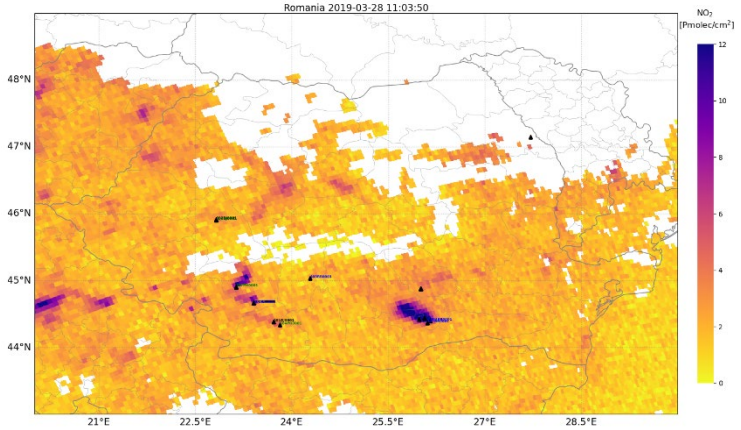


- Launched on 13th October, 2017
- Sun-synchronous orbit at 824 km altitude
- Initial pixel size of 7 km x 3.5 km at nadir
- Reduced to 5.5 km x 3.5 km on 6th August 2019
- Equator crossing time at around 13:30 LT (ascending node)
- Across-track swath width 2600 km, thus obtaining daily global coverage

Input data

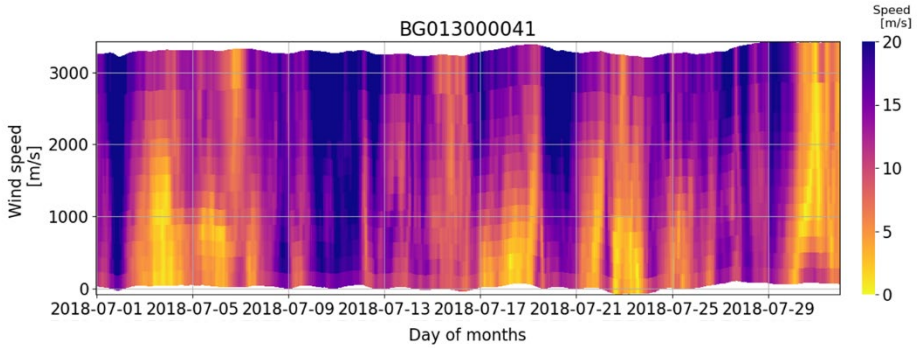
TROPOMI NO2





ERA5 meteorological data from ECMWF

- (hourly data have a spatial horizontal resolution of 0.25° x 0.25°)



Coordinates of LCP from E-PRTR/LCP Database

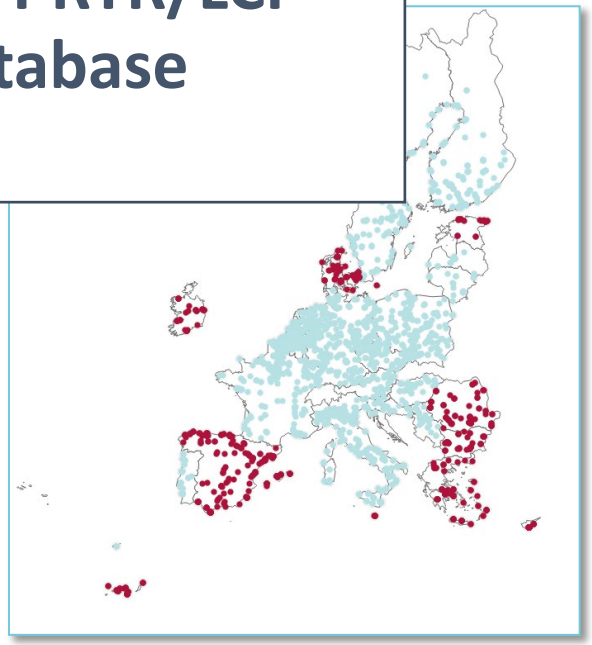


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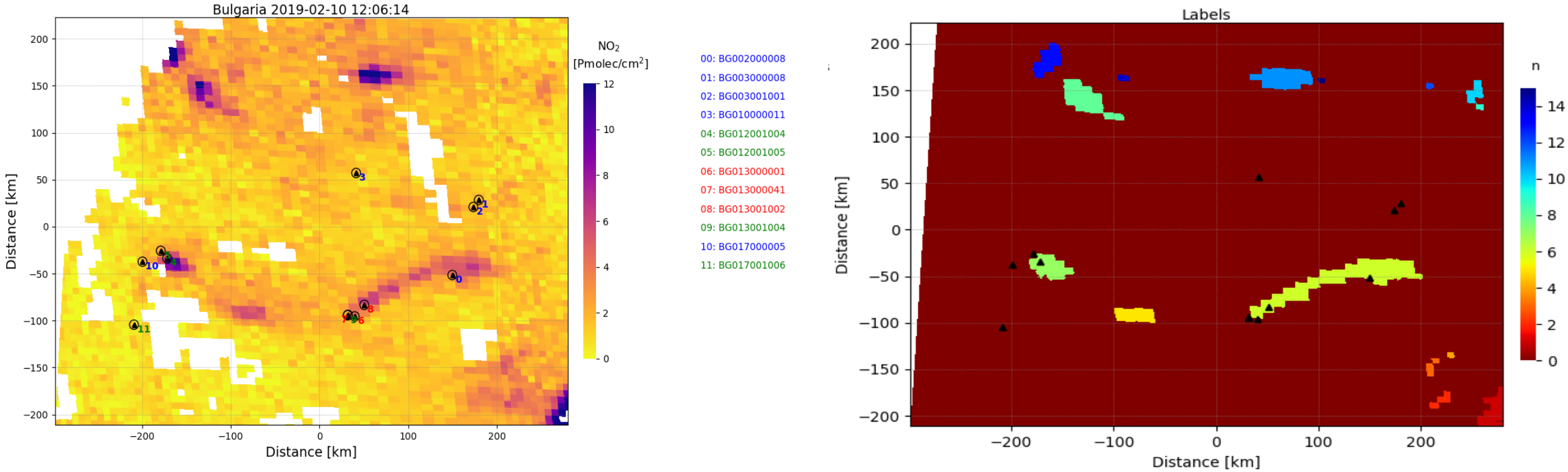
Image processing

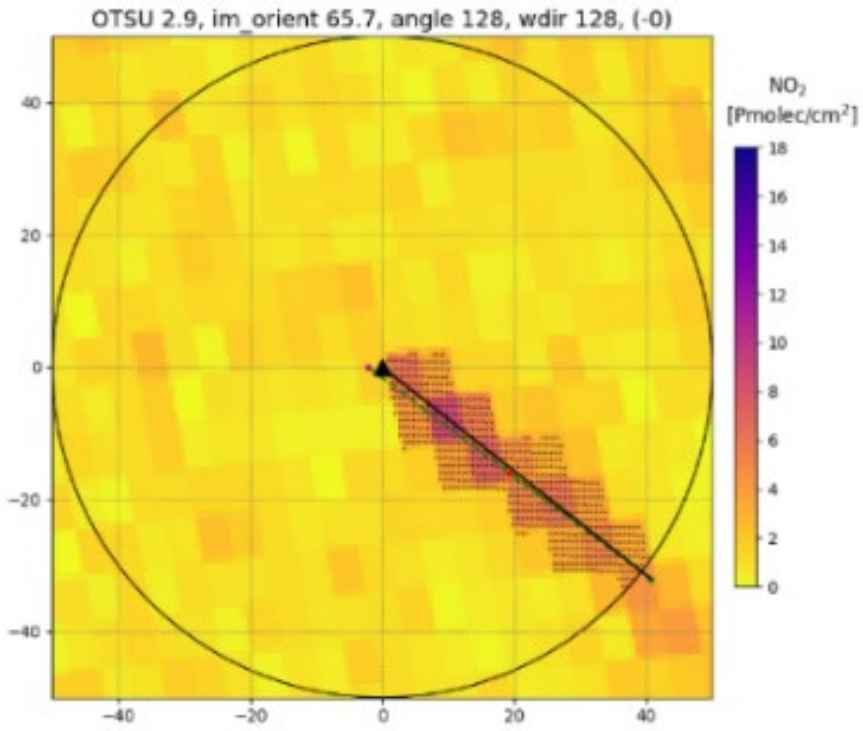


Example of plume detection and plume sequencing for a single overpass over Bulgaria. The left panel shows the NO_2 observations and the location of the different facilities (color code represents emissions below 0.5 kt (blue), between 0.5 – 1 kt (green) and above 1 kt (red)). The right panel shows the plume segmentation

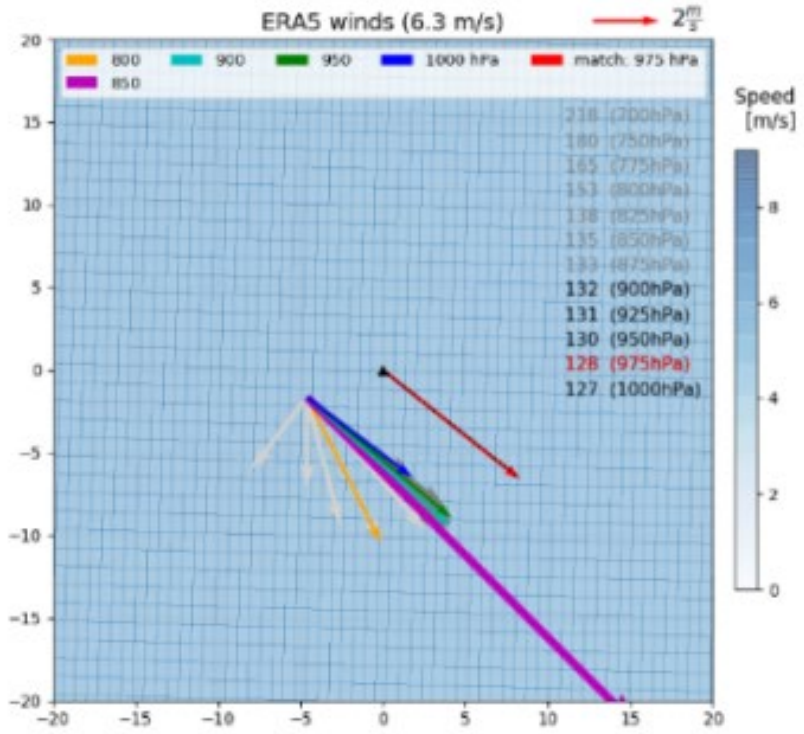
$$\frac{X_p - X_{\mathrm{bg}}}{\sqrt{\frac{s_{ssp}^2}{n_p} + s_{bg}^2}} > z(q),$$

Eurc

Matching plume direction with winds



TROPOMI NO_2 plume (20 km circle around LCP site)



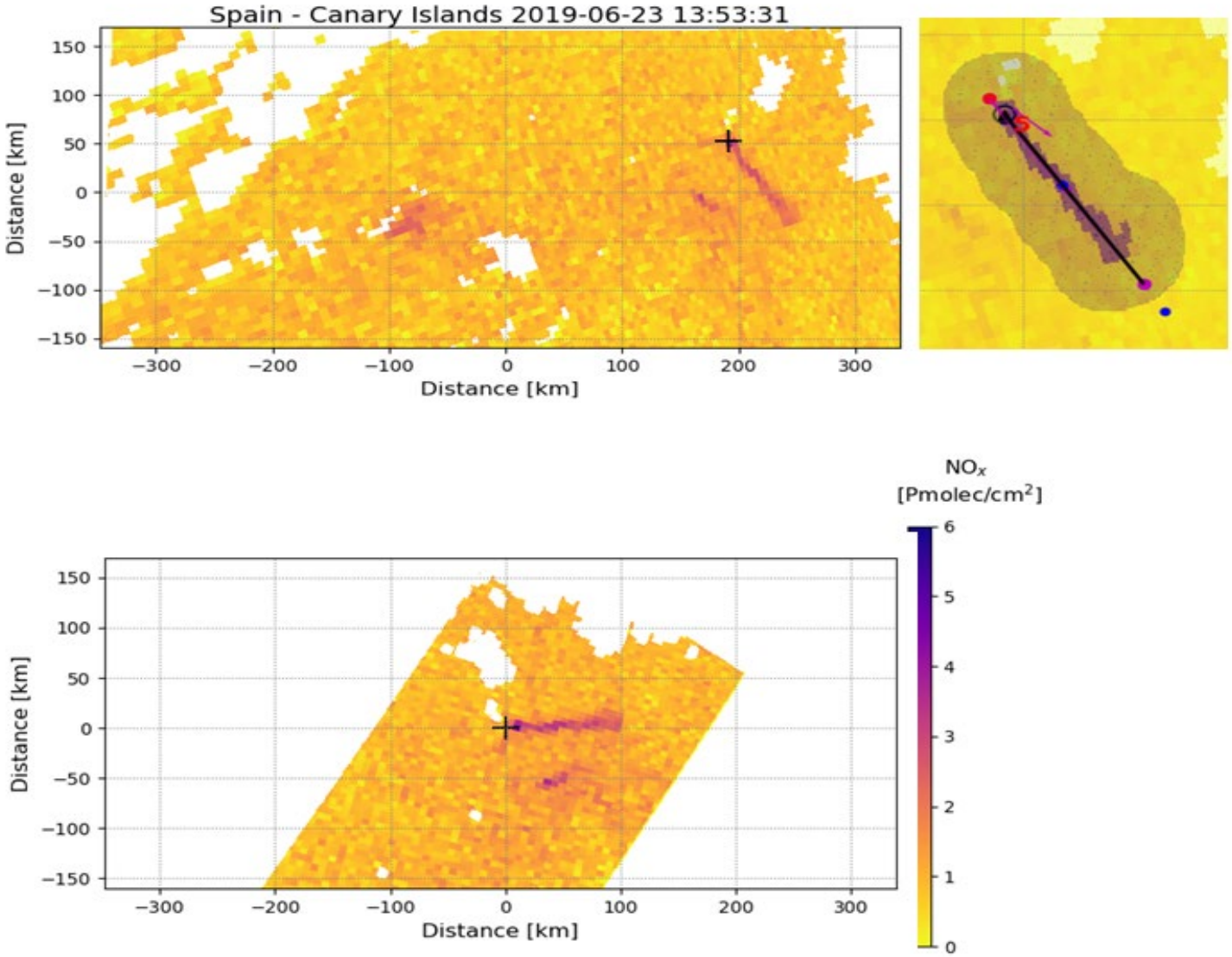
ECMWF winds at different pressure levels

Determination of pressure level (ERA5 winds and O_3) to be used for the NO_2 to NO_x conversion and wind-speed for the emission estimates.

Rotation of all plumes to increase SNR

Eur

Plume rotation



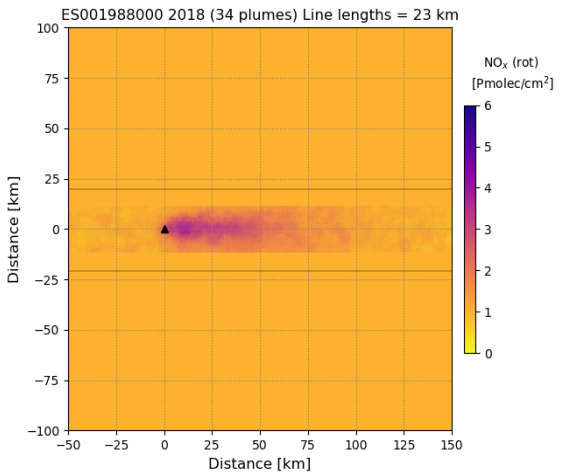
Example for plume rotation. The upper left panel shows the NOx column densities for an overpass on June 23rd, 2019. The upper right panel gives an example of the plume direction (black line) and wind direction for the Punta Grande *power station on Lanzarote. The triangle marks the location of the facility, with a five km circle around the site. Note the dots indicating centre and endpoints of the plume and an area around. The lower panel shows the rotated plume.*

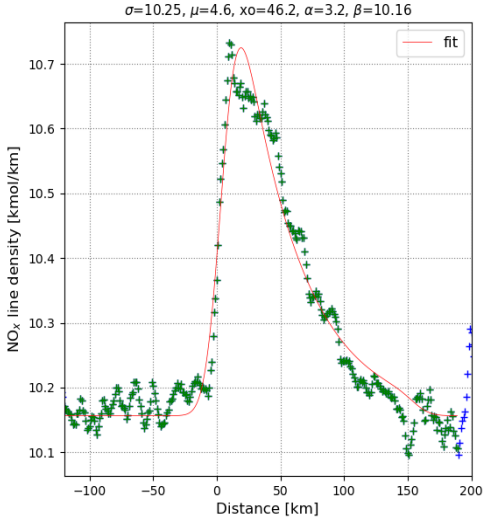
Conversion of NOx and TROPOMI line density

NO_x / NO_2 conversion factor for the photochemical steady state

$$\frac{[NO_x]}{[NO_2]} = 1 + \frac{[NO]}{[NO_2]} = 1 + \frac{J_{NO_2}}{k_{NO+O_3} * n_{O_3}}$$

TROPOMI NO_2 line density (S)





w = 6.4 m/s

τ = 2.0 h

E = 266.4 g/s (8402 t/year)

From Exponentially Modified Gaussian fit determine:

$\tau = x0\ w$ effective lifetime

$E = \alpha\ /\ \tau$ NOx emission rate

Illustration of EMG fit procedure. Left panel: Visualization of the averaged rotated plume and the determined width for the line-density calculation for the LCP facility ES00198000, which is located on the Canary Islands for the year 2018. Right panel: line density (green points) and EMG fit (red line). α, the total number of NOx observed near the power plant, $x0$ is the e-folding time, w is wind-speed

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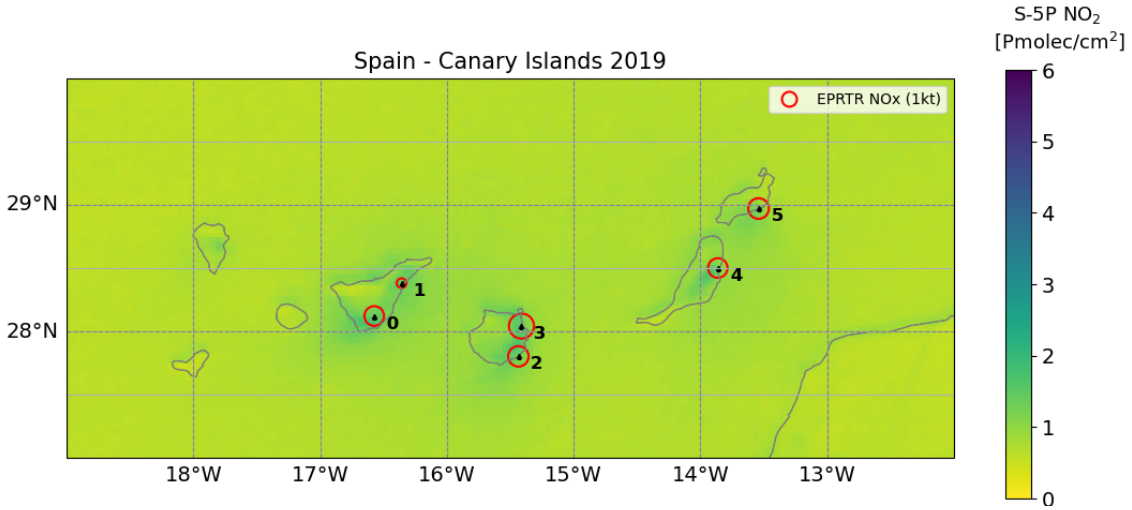
Best vs Worst case

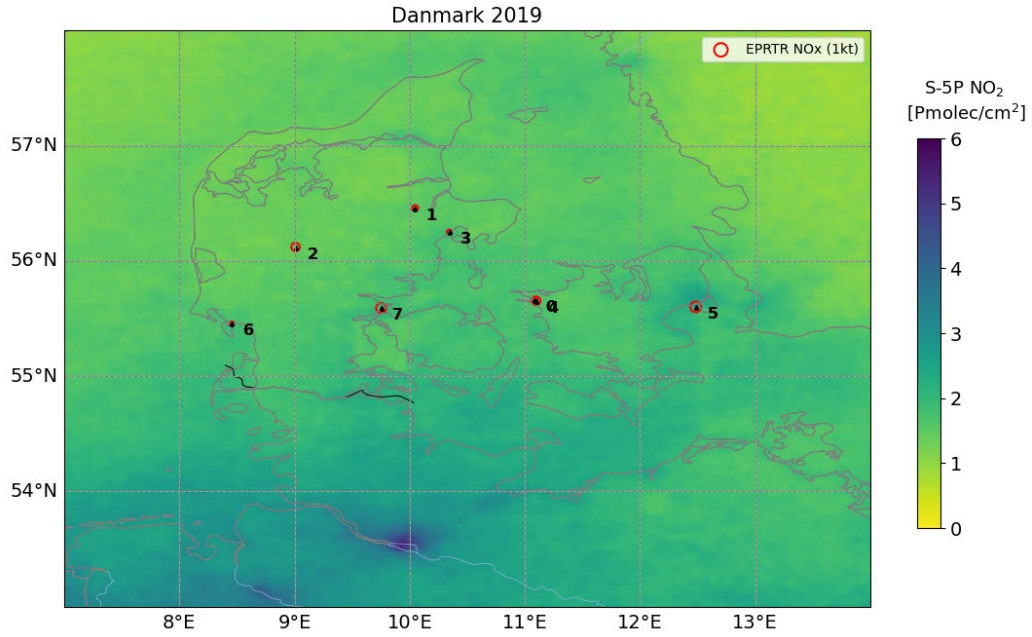


Canary Islands (Spain)

- No overlap between plumes
- Good visibility
- Wind
- Contrast

Denmark

- LCP too close to each other
- High NO2 pollution
- Low emission from LCP
- Low detection

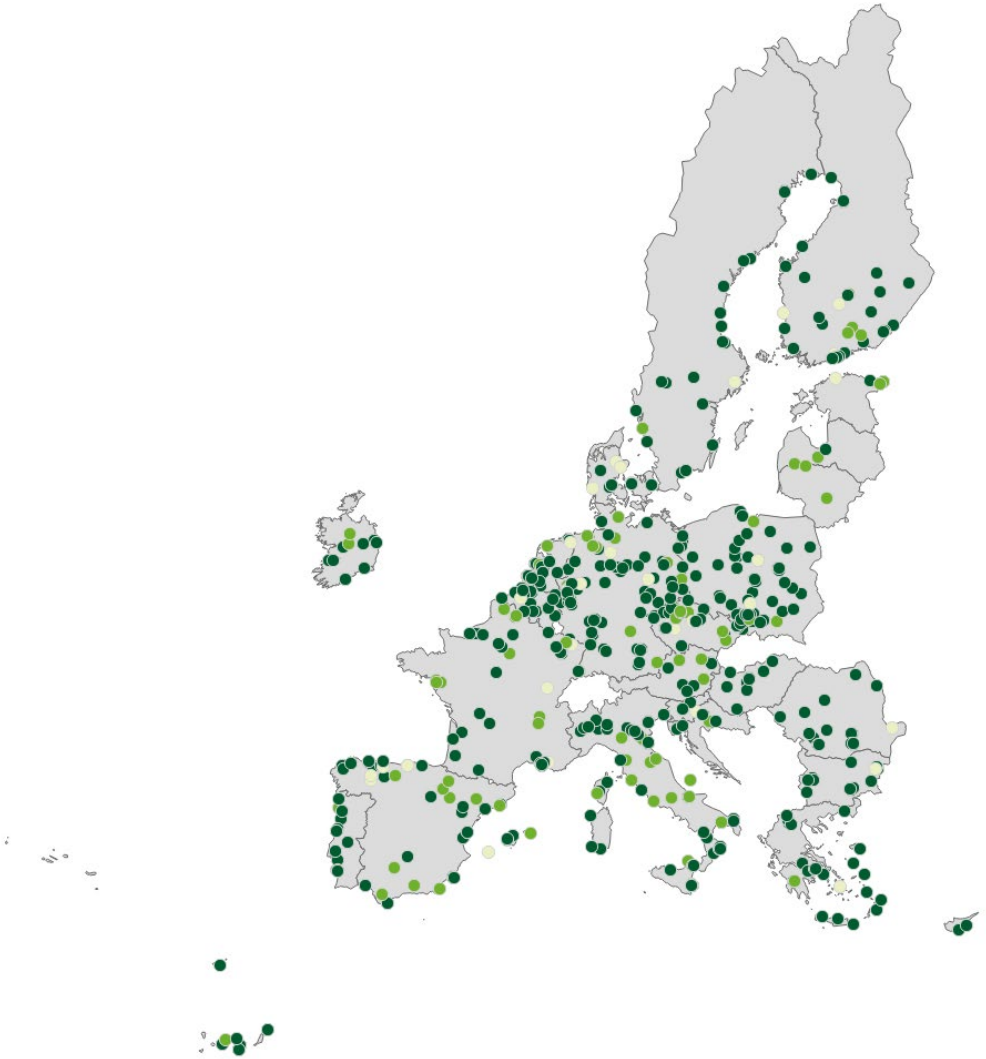


Summary

- **Denmark, Estonia and Ireland**: lower NOx emissions, cloud-coverage, emission from urban area. **The process is inhibited**
- **Malta**: emissions are below the detection limit
- **Canary islands, Romania and Bulgaria**: good results to further investigate
- **Spain and Greece**: fewer results for some LCPs
- **Cyprus**: feasible but hampered by strong sources in the north of the country

Ongoing study

Facilities with NOx > 250 tonnes



- Cover time period **May 2018 – December 2022**
- All facilities with LCPs with aggregated annual NOx emission > 250t
- Comprehensive **assessment report on usability of Sentinel-5P** to estimate status of emissions from LCPs in Europe

Thank you

Federico Antognazza / SEEDS Assembly / 30 March 2023

With the contribution of: Kerstin Stebel, Philipp Schneider, Arve Kylling, Paul Hamer (NILU)

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