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Development of the CO2M NO_2 Retrieval Algorithm

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EUMETSAT

European Commission

Copernicus Europe's eyes on Earth

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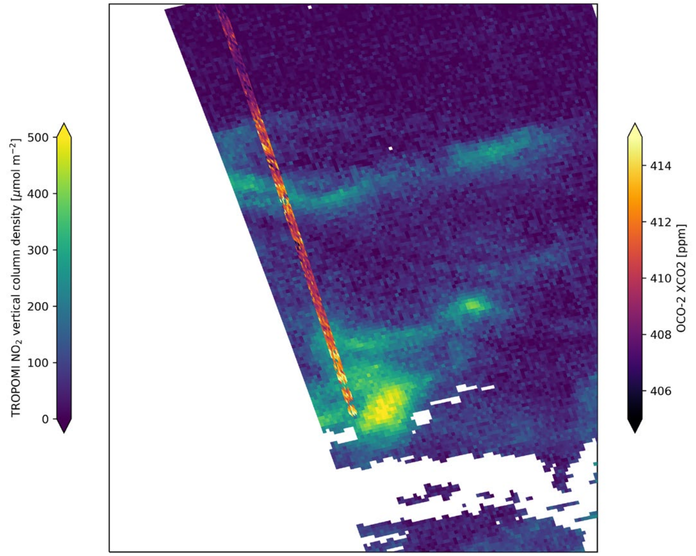
Planned developments for the CO2M NO_2 algorithm

- High resolution surface reflectance / BRDF data (MODIS/VIIRS)
- High resolution a priori NO_2 model data (CAMS global)
- Use of cloud information from CLIM instrument
- Combined O_2-O_2 (VIS) and O_2-A band (NIR) cloud information
- Scattering layer model for cloud and aerosol treatment

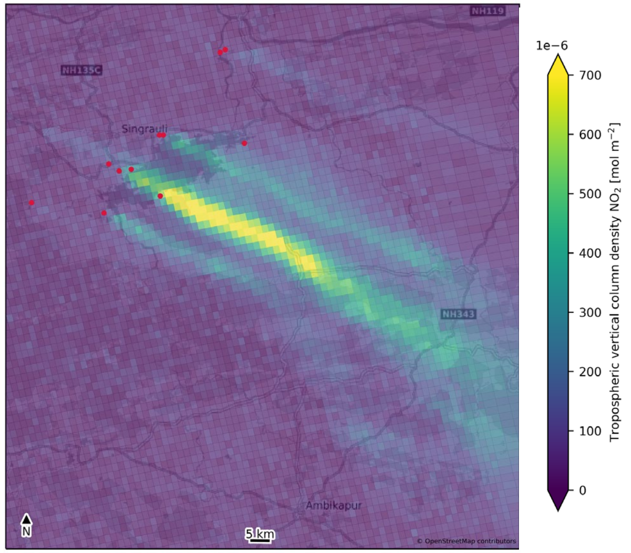
NO_2 as tracer for CO_2

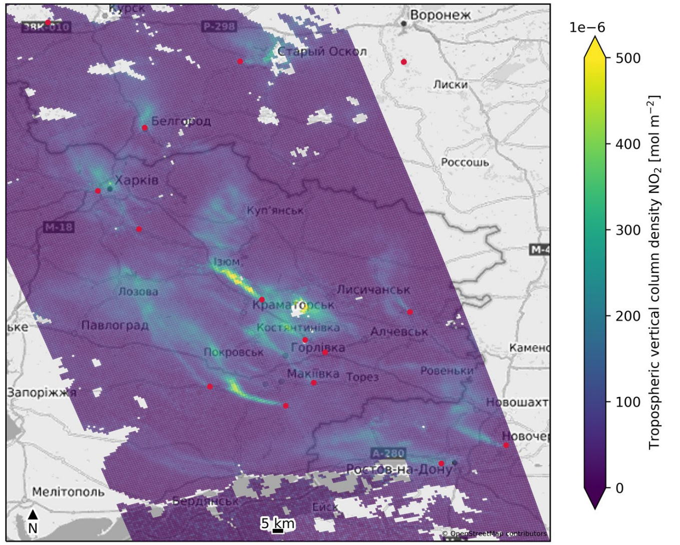
→ Better plume detection
→ Improved hotspot CO_2 emission quantification



TROPOMI NO_2 zoom data set

- Similar resolution as CO2M (≈ 2x2 km^2)
- Scenes with plumes from power plants and cities
- Testing data set for algorithm development



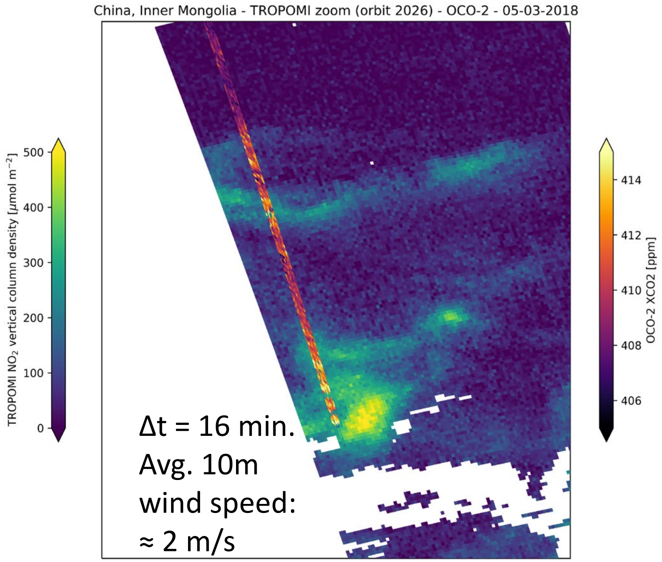


NO_2 as tracer for CO_2 emission plumes

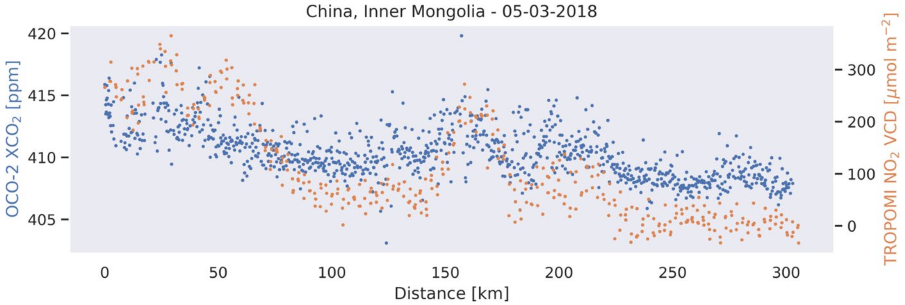
- NO_2 and CO_2 co-emitted in combustion processes
- NO_2 observations have a higher SNR due to shorter lifetime of NO_2 (lower background value), less problems with small cloud cover
- CO_2 emission estimations benefit from additional NO_2 observations:
  - → Better constraint of hotspot emission plume shape and size
  - → CO2M: 3x more CO_2 plumes detectable [Kuhlmann et al., 2019] / SMARTCARB

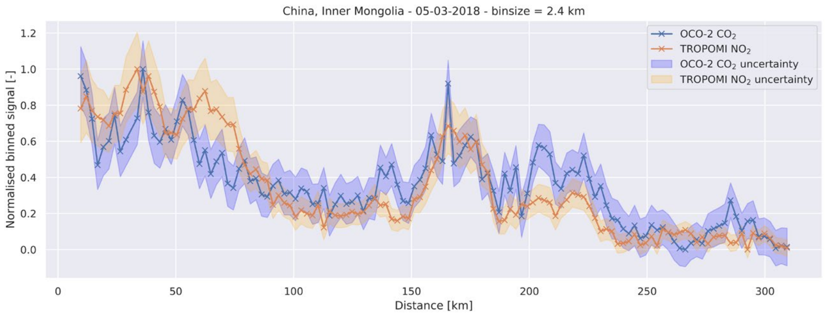
Example: TROPOMI trop. column NO_2 and OCO-2 XCO_2

S5P tropo. NO_2 column

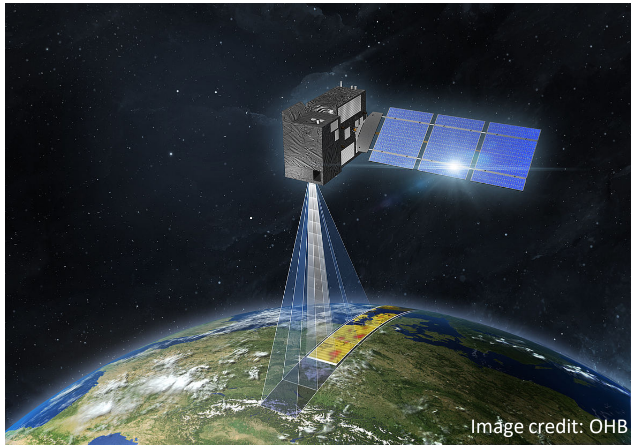


OCO-2 XCO_2





NO_2 observations on CO2M



CO2M NO2I instrument:

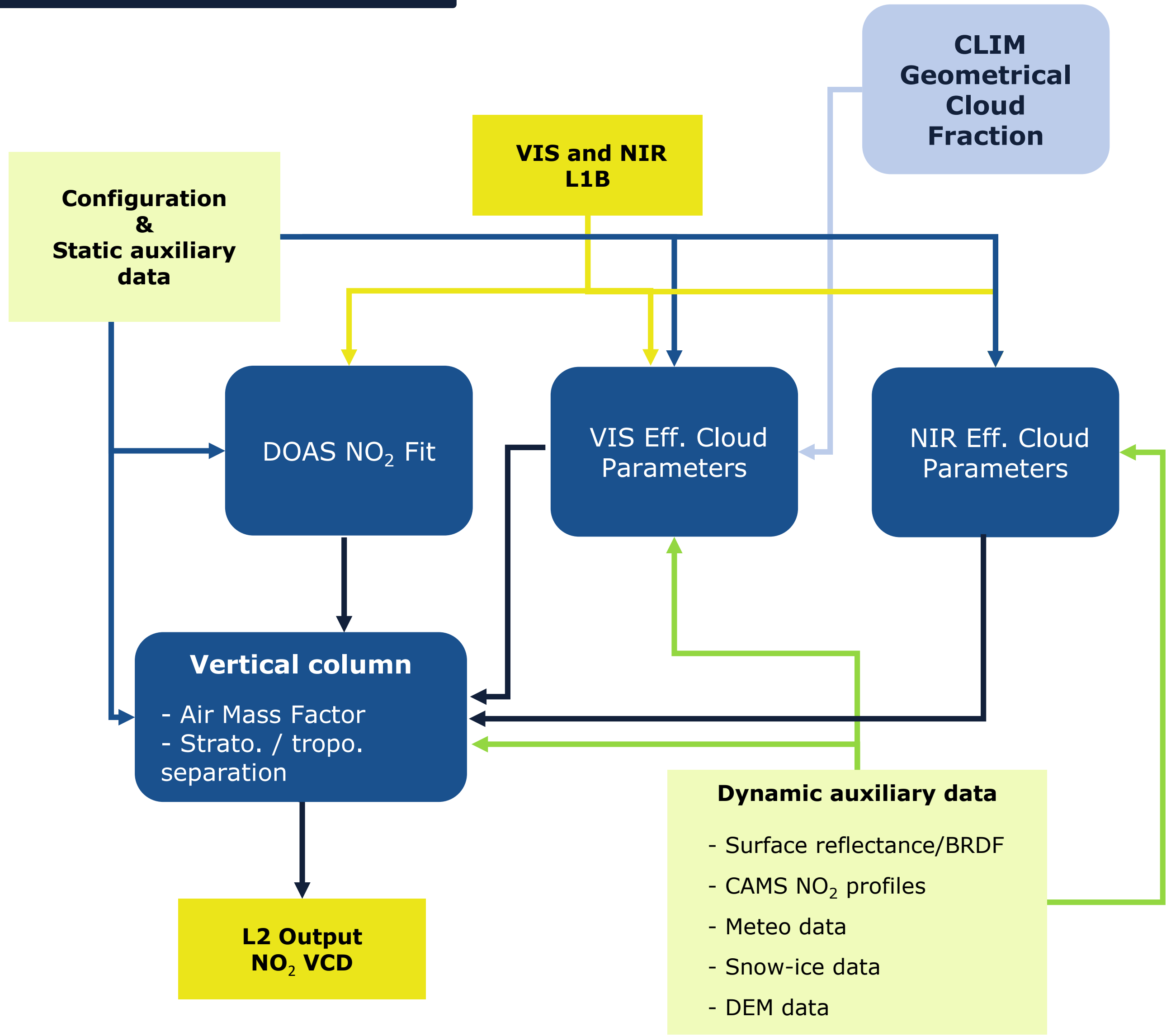
- → VIS imaging spectrometer with high spectral resolution
- → **Co-located** NO_2 and CO_2 observations
- → High spatial resolution: **2x2 km²**

CO2M NO_2 algorithm development

Based on TROPOMI (S5P) / Sentinel 5 NO_2 algorithm

Planned improvements

- High-resolution surface reflectance/BRDF information over land.
- Modelled surface reflectance over oceans.
- Use of the CO2M cloud imager (CLIM) geometric cloud fraction
- Combined O_2-O_2 (VIS) and O_2-A band (NIR) cloud information
- Use scattering layer model to represent scattering by aerosols and clouds
  - Simplified phase function (most likely Henyey-Greenstein)
  - Single layer with fixed pressure thickness
  - Determine cloud pressure and optical thickness
  - Consistent cloud model for VIS cloud retrieval and NO_2 AMF calculation
- Use of high spatial resolution NO_2 model information.



Testbed data: TROPOMI NO_2 zoom

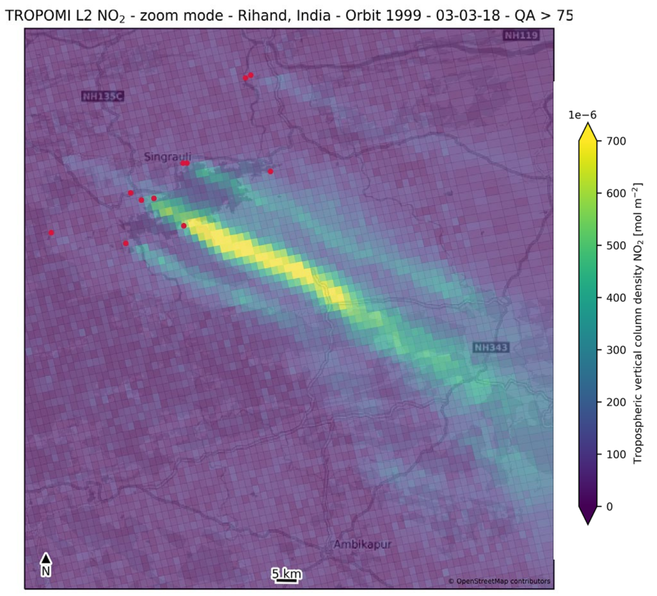
- During the TROPOMI commissioning phase measurement were done with extra high spatial sampling (**2.4 x 1.8 km²**), current nominal sampling is 5.6 x 3.6 km²
- The spatial zoom measurement mode was used during **1st week of March 2018**.
- Integration time was reduced by factor 3 and the binning was disabled (factor 2) for the very center of the swath (310 out of 2700 km). To further compensate for the high data volume, only half of the detector channels were used.

Several interesting scenes captured with high resolution resulting in detailled mapping of **NO_2 plumes**.

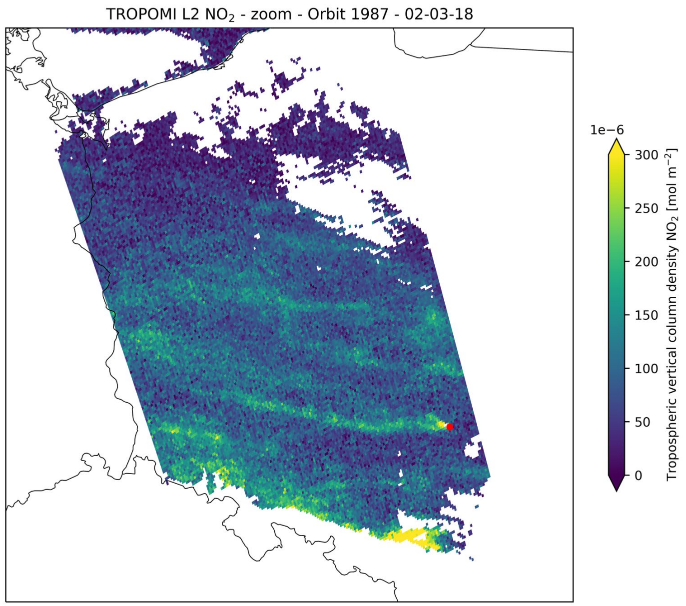
Similar spatial sampling as CO2M NO_2

→ **Good testbed data set for NO_2 algorithm development**

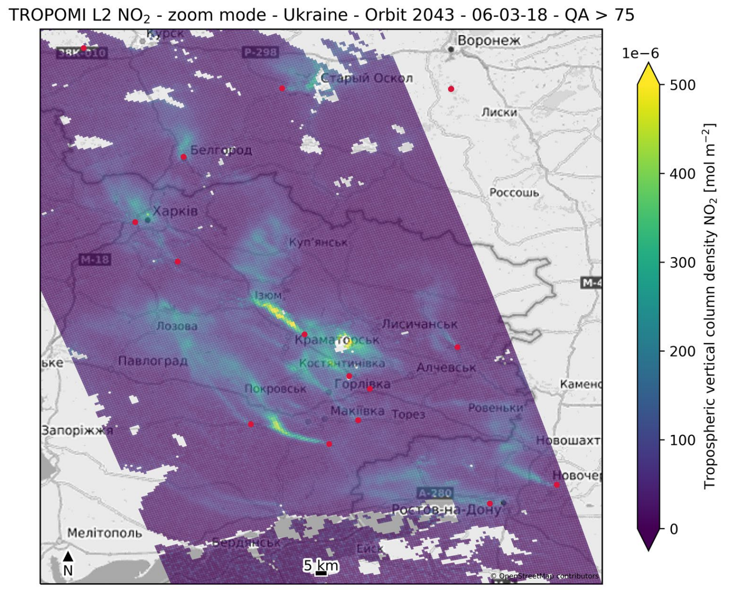
Power plant plumes



Rihand Lake, India



Bełchatów, Poland



Donetsk, Ukraine

High resolution surface reflectance database

The CO2M high spatial resolution requires the use of **km-scale surface information** for accurate air-mass factor calculation and cloud parameter retrieval.

CO2M will have a **Sun glint pointing mode**, utilizing the Sun glint spot over the ocean.

Over land: MODIS/VIIRS surface reflectance and/or BRDF products, visible band

Over water: BRDF model accounting for water-leaving radiance and specular reflection by sea surface roughness

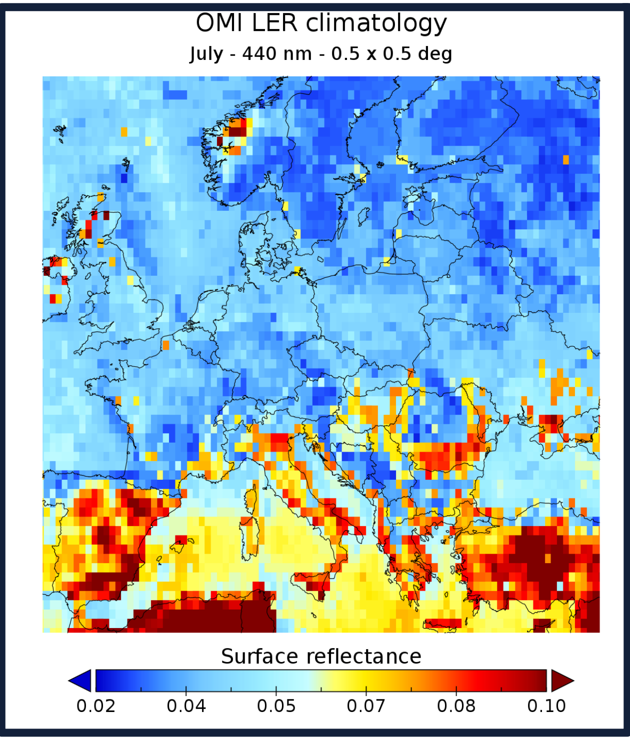
Cloud retrievals and NO_2 retrievals require a **consistent approach** w.r.t. surface reflectance

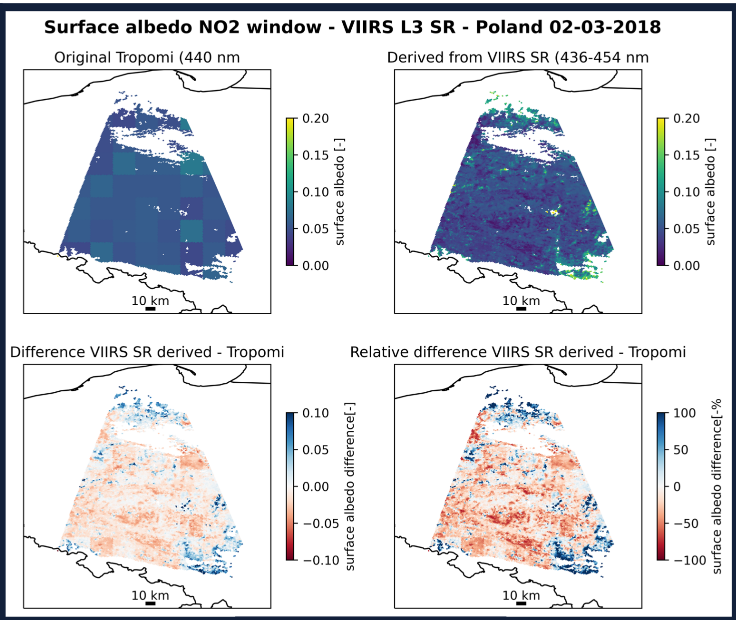
Surface reflectance data can be **dynamic,** using a static fallback (climatology)

BRDF surface treatment in radiative transfer models instead of Lambertian surface assumption.

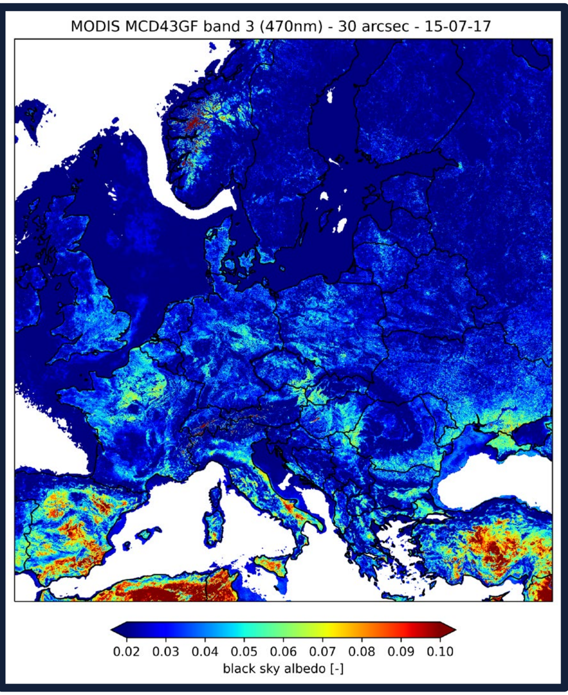
Air-mass factors stored in look-up table or neural network.

Current albedo database for TROPOMI NO_2





Example comparison case



Example of MODIS product

A-priori NO_2 information

- For tropospheric – stratospheric separation of the measured columns, model stratospheric NO_2 columns are used.
- For the calculation of the air-mass factor, tropospheric NO_2 profile shapes are required.
- Using a model with **higher horizontal spatial resolution** for the NO_2 profile shape increases spatial representativeness of the air-mass factor and reduces NO_2 column bias.
- **NO_2 stratospheric columns from CAMS global**, optionally scaled in clean background regions to remove model bias.
- **NO_2 tropospheric profile shapes from CAMS global**, optionally in combination with CAMS regional for Europe.

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EUMETSAT

CAMS global model

- 0.4 x 0.4°
- 137 levels up to 0.01 hPa
- 1 hour resolution
- integrated into the ECMWF IFS

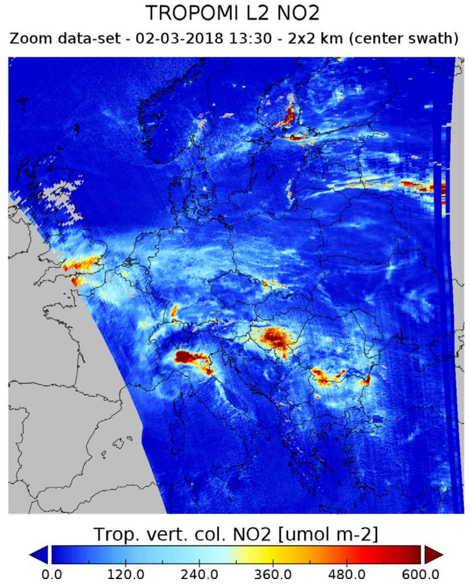
CAMS regional European model

- 0.1 x 0.1°
- 8 levels up to 5 km altitude
- 1 hour resolution
- Ensemble of 7 models

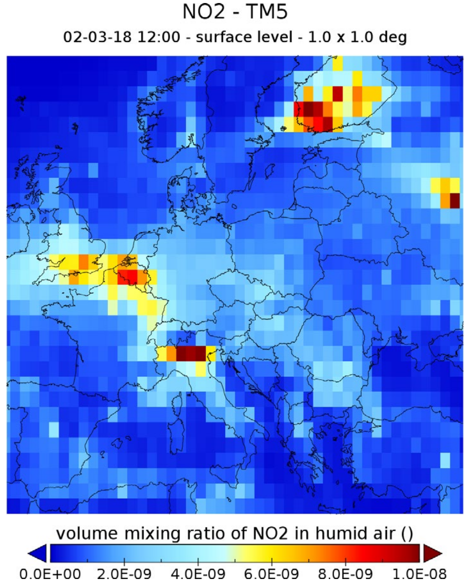
Atmosphere Monitoring Service
atmosphere.copernicus.eu

Comparison of horizontal resolution

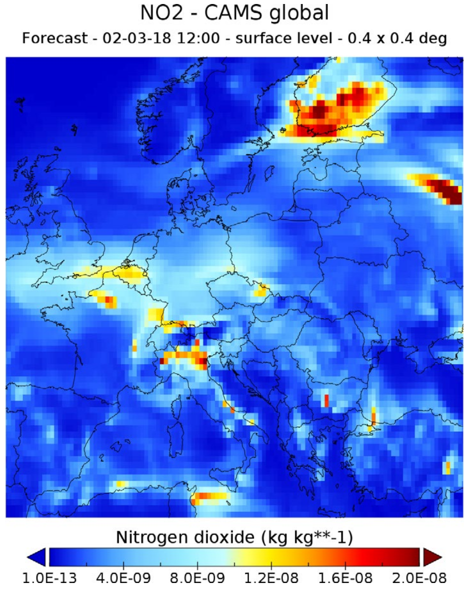
TROPOMI zoom observations



TM5 model, used in TROPOMI NO_2



CAMS global model



CAMS regional model