



Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure
and Water Management*

Atmospheric composition monitoring with TROPOMI on Sentinel-5P:

high resolution discoveries

Piet Stammes

& TROPOMI Team

led by Pepijn Veefkind

EUMETSAT Atmospheric Composition User
Consultation Workshop, 23-25 June 2020

stammes@knmi.nl

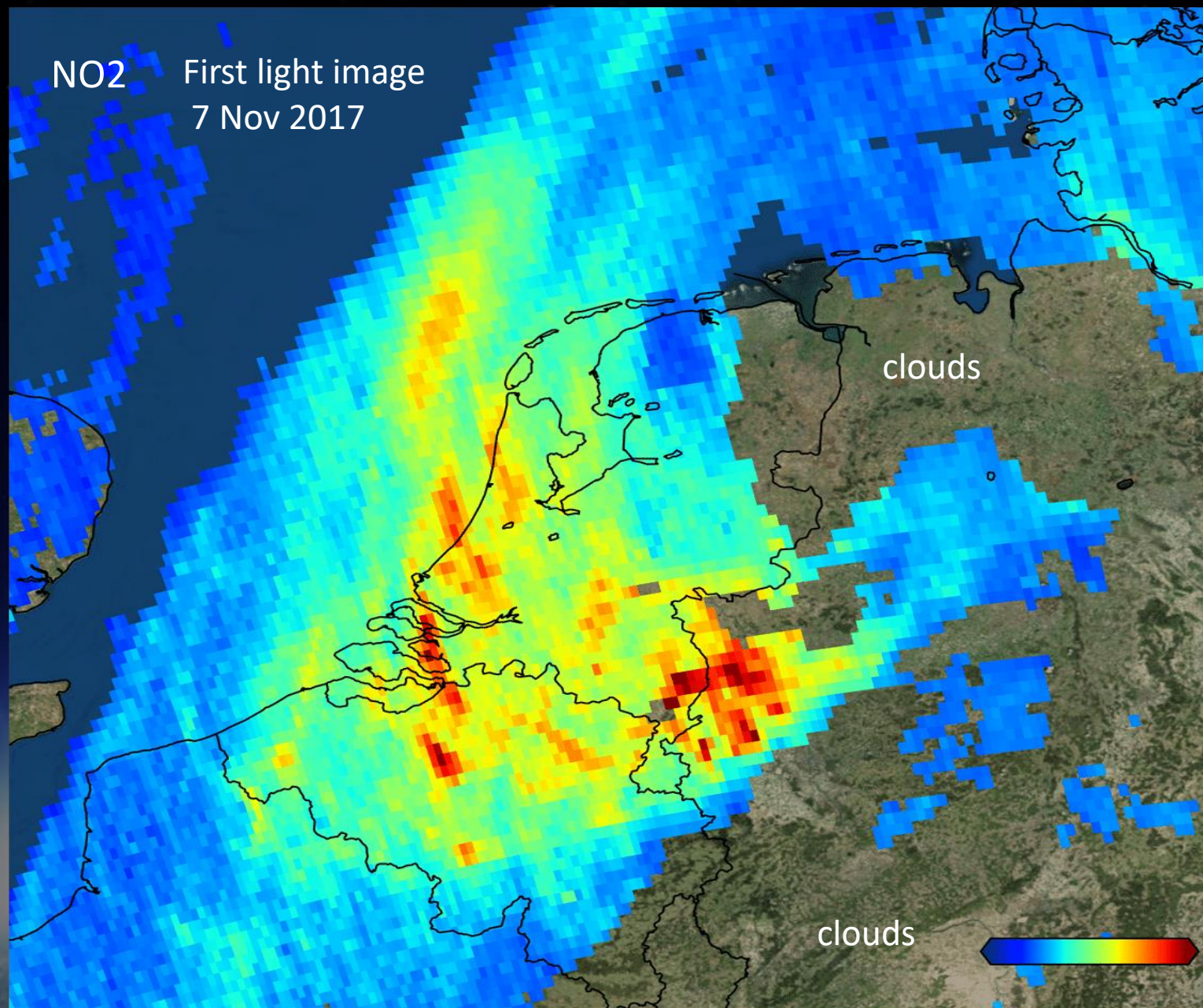
Overview

- TROPOMI on S5P
- Spectrometry of trace gases
- Results
 - NO₂: Covid-19 impacts
 - Ozone layer
 - SO₂ from volcanos
 - Aerosols
 - CO and CH₄
- Conclusions



Launched 13 Oct 2017

TROPOspheric Monitoring
Instrument (TROPOMI)
on board Sentinel-5P satellite
of ESA – EU Copernicus

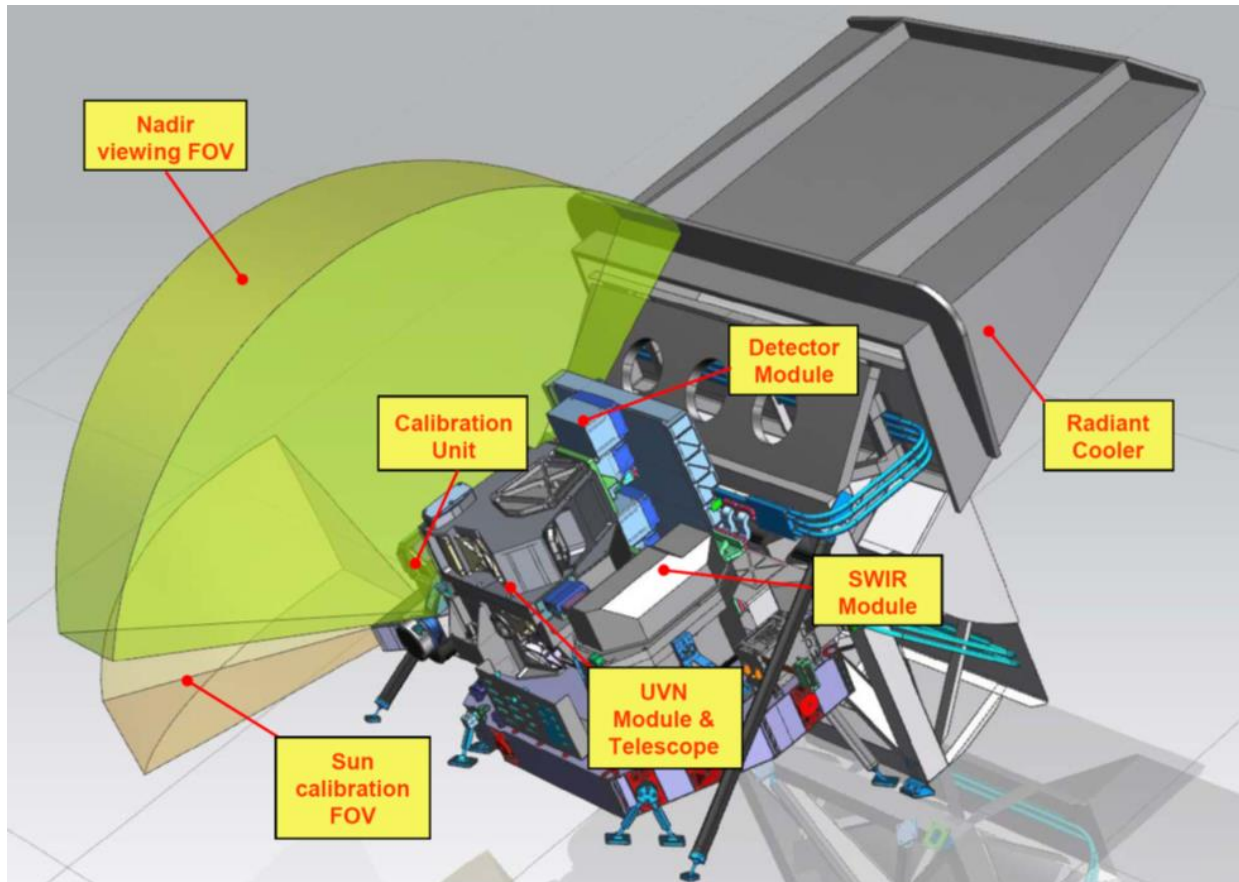


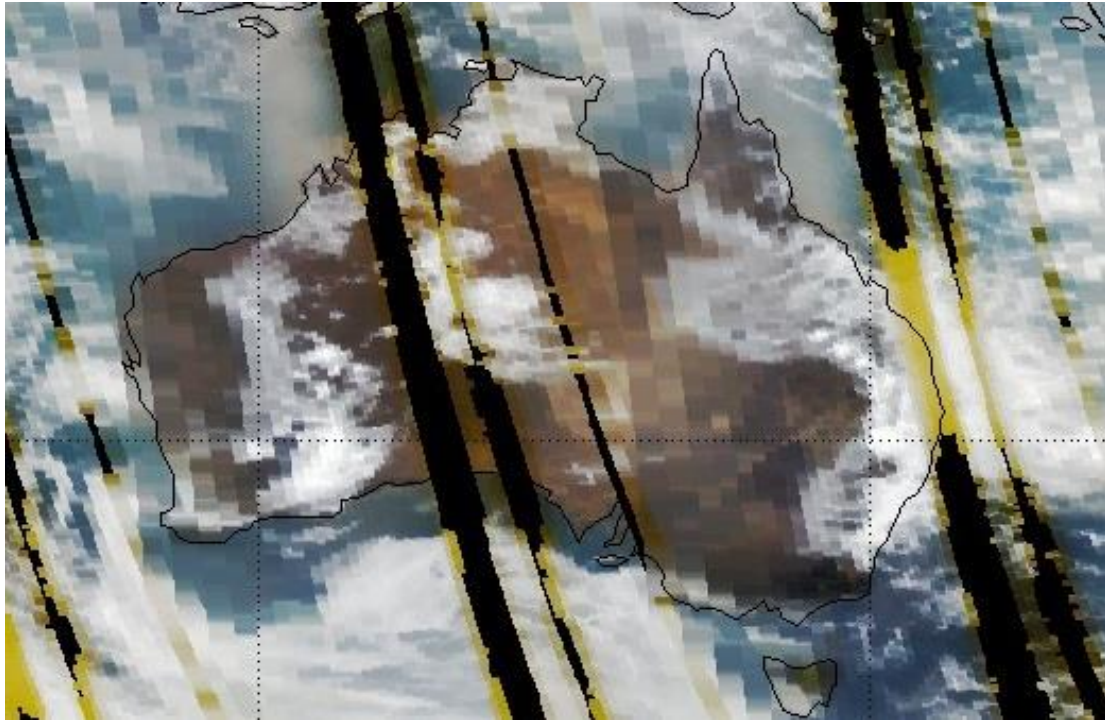


TROPOMI

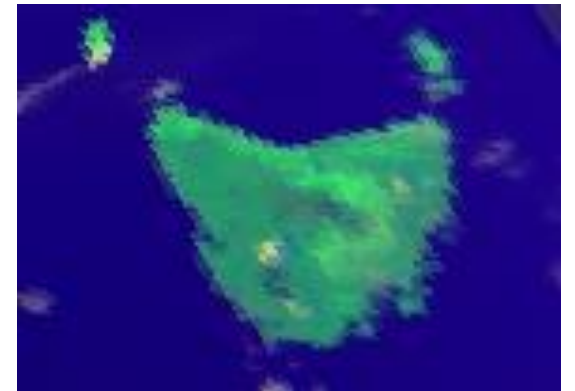
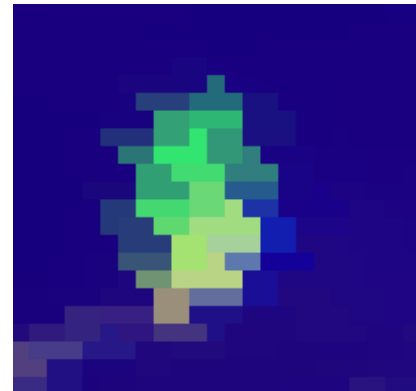
characteristics:

- › UV, Visible, Near-IR, and Shortwave-IR bands
 - **SCIAMACHY/Envisat heritage**
- › 2D detectors
 - **OMI/Aura heritage**
- › Pixel size $3.5 \times 5.5 \text{ km}^2$
 - **Unique**
 - **Before 6 August: $3.5 \times 7 \text{ km}^2$**
 - **Requirement: $7 \times 7 \text{ km}^2$**
- › Daily global coverage
 - **OMI/Aura heritage**
- › High sensitivity (SNR)





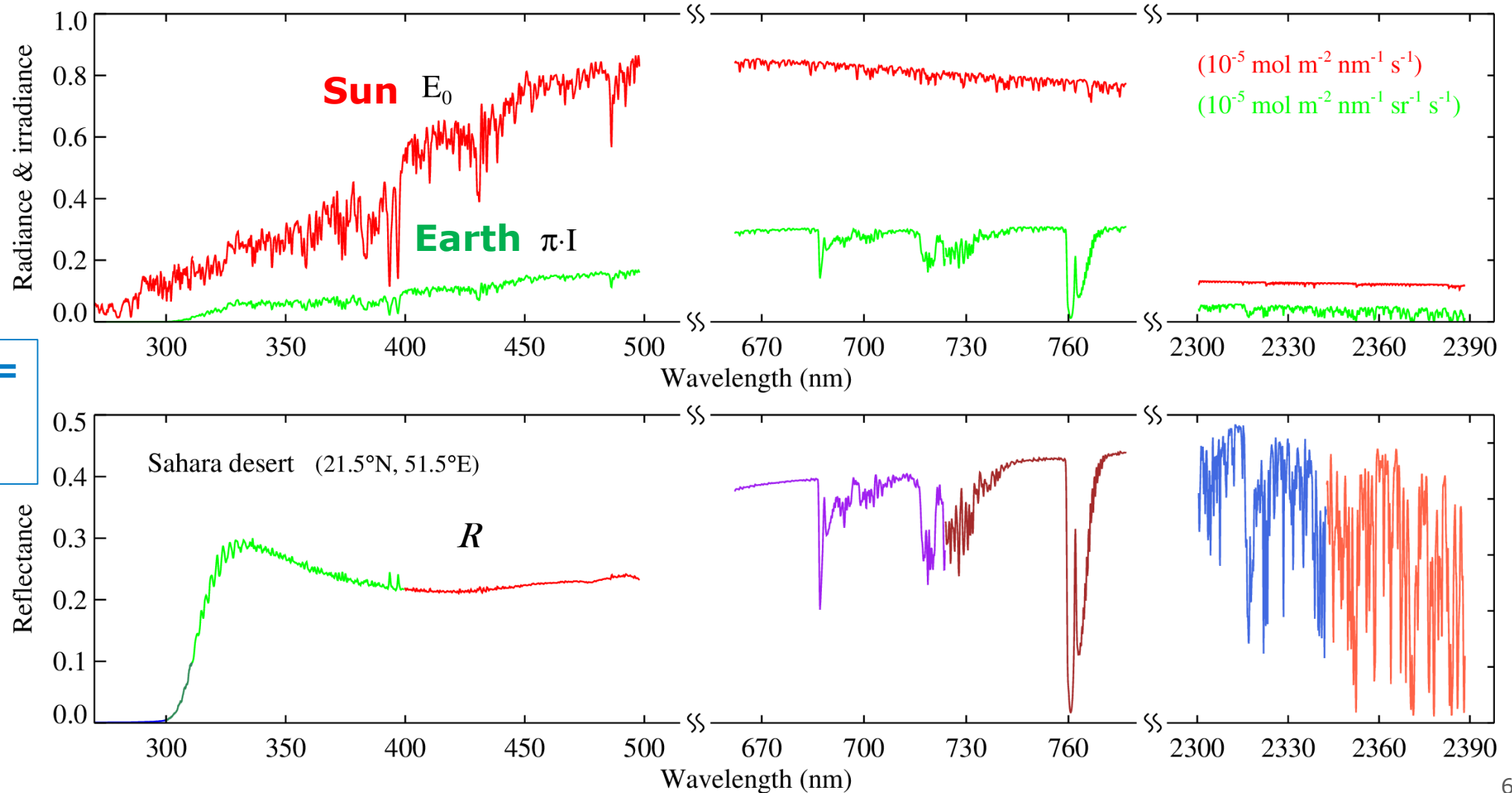
OMI 13x24 km²



TROPOMI 3.5x7 km²



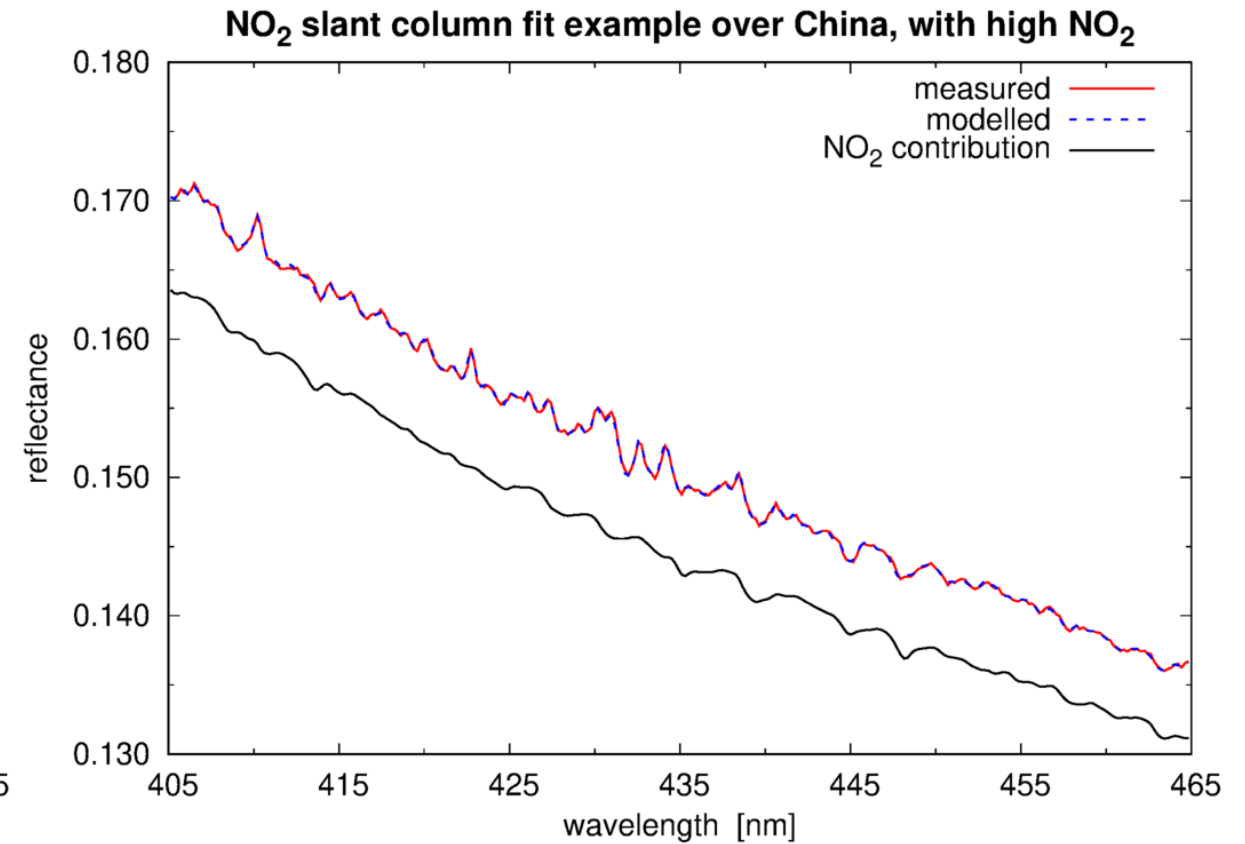
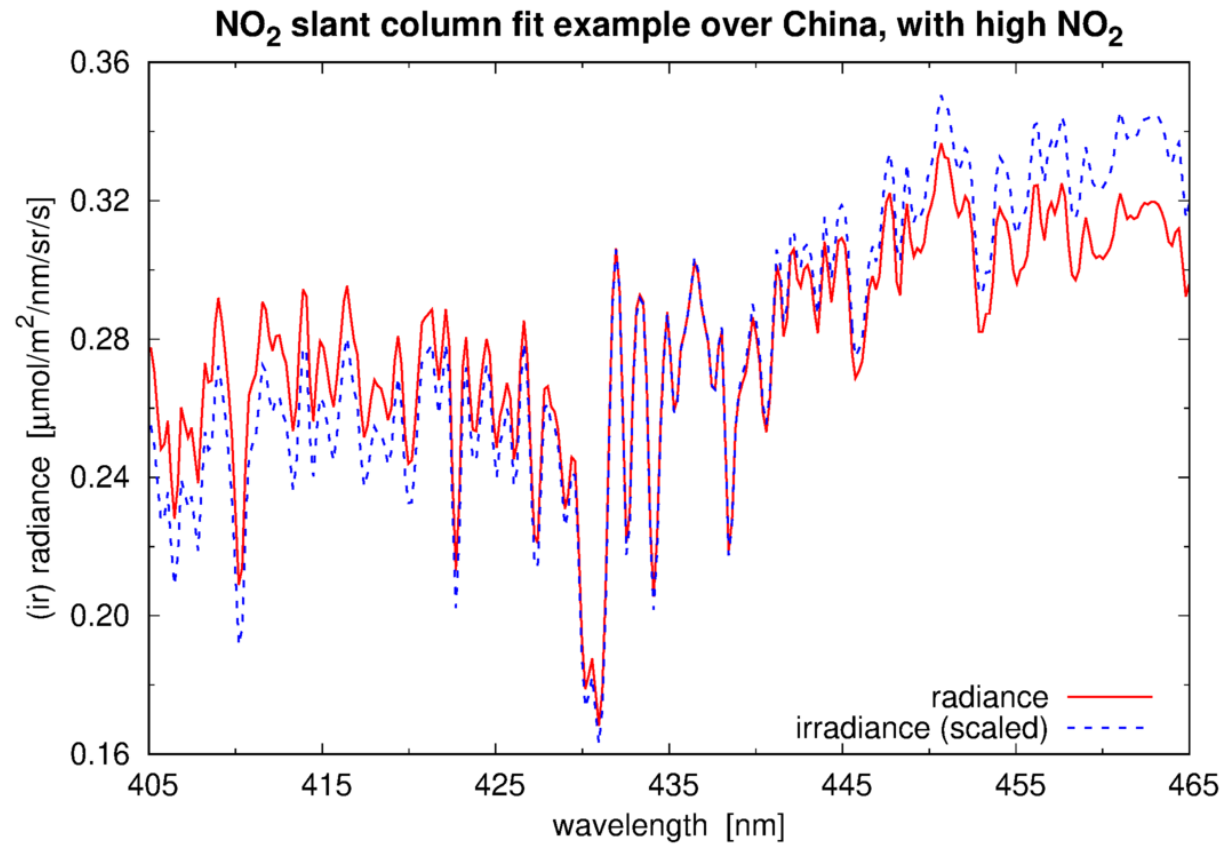
L1b spectra from TROPOMI's 8 spectral bands



Spectrum of one pixel



Fitting the atmospheric spectrum in the NO₂ range



NO₂ in Europe (2019)

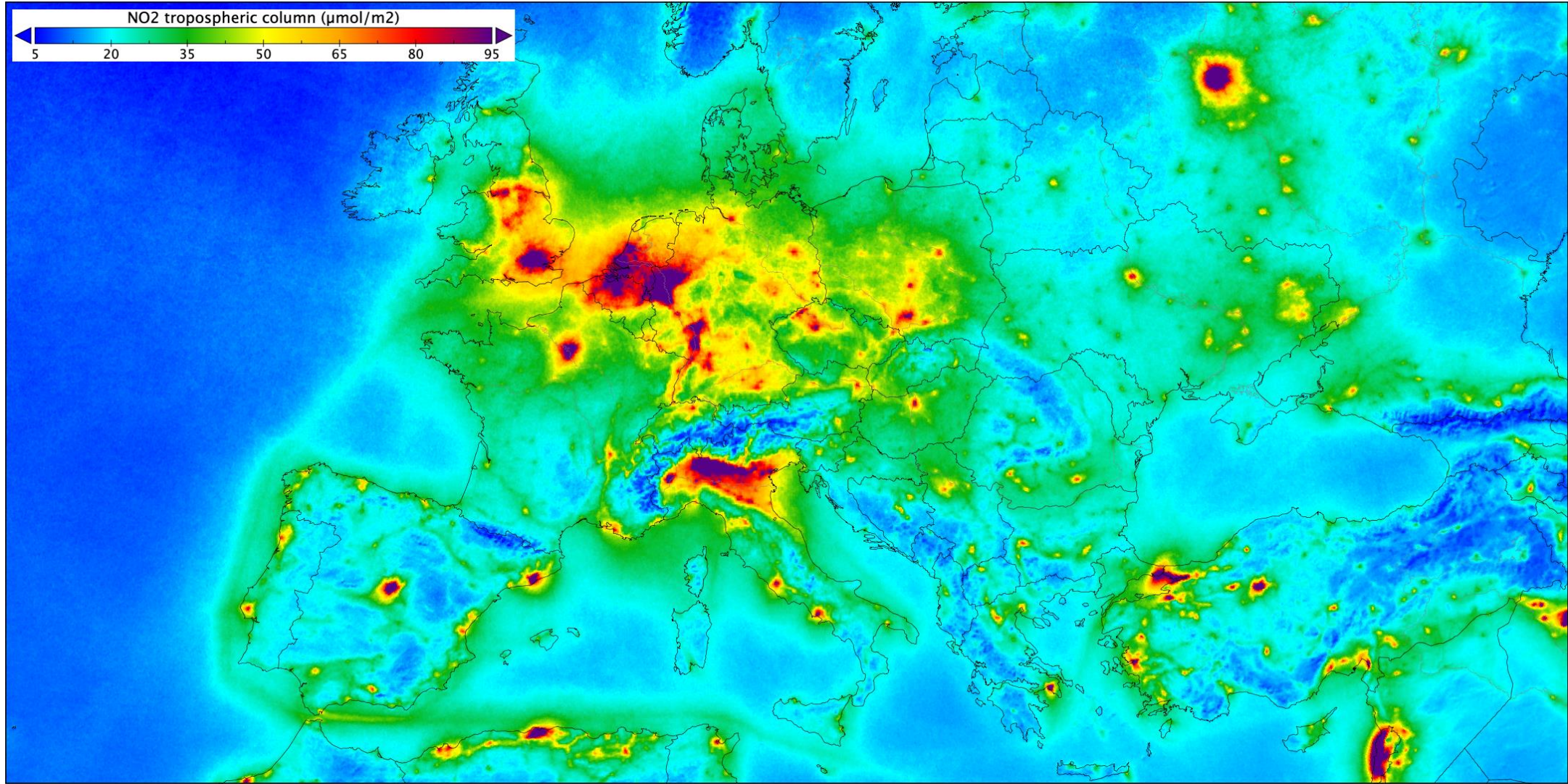


Figure: Henk Eskes, KNMI



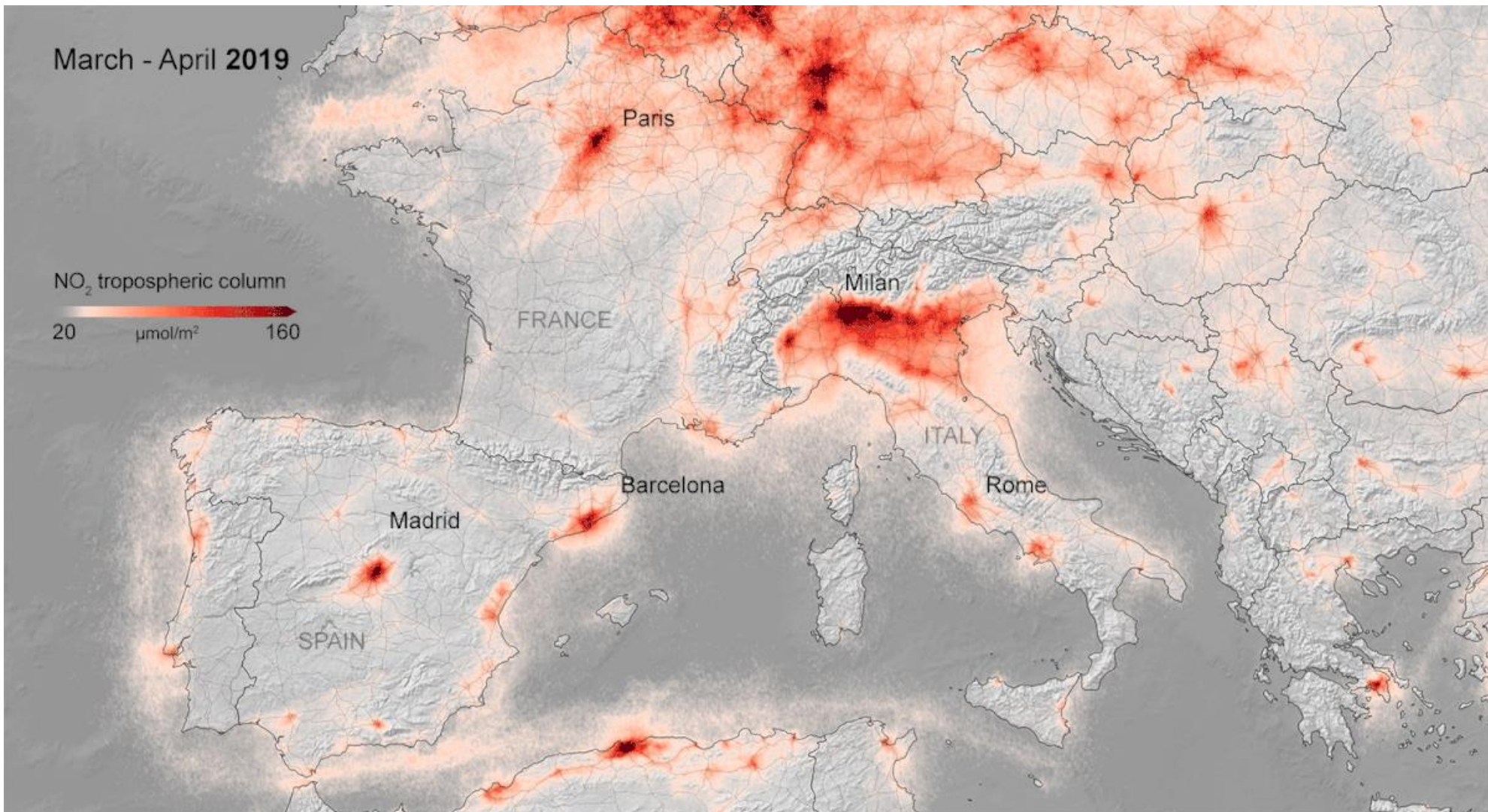
TROPOMI/S5P Operational L2 Data Products

Product	Main Parameter	Developers	(Planned) Release
UV Aerosol Index	absorbing aerosol index	KNMI	Released
Aerosol Layer Height	mid-level pressure	KNMI	Released
Carbon monoxide (CO)	total column	SRON	Released
Cloud	fraction, albedo, top pressure	DLR	Released
Formaldehyde (HCHO)	total column	BIRA-IASB	Released
Methane (CH₄)	total column	SRON	Released
Nitrogen dioxide (NO₂)	total column	KNMI	Released
Ozone profiles	total and tropospheric profiles	KNMI	2020
Sulphur dioxide (SO₂)	total column	BIRA-IASB	Released
Ozone (O₃)	total column	DLR	Released
Tropospheric Ozone (O₃)	tropospheric column	DLR	Released
UV ¹	surface irradiance, erythemal dose	FMI	-----

Mission Performance Center (MPC): QA, Validation, Evolution; see www.tropomi.eu



Impact of Covid-19 lock-downs: NO₂ in Southern Europe



Source:
ESA-EU/
KNMI

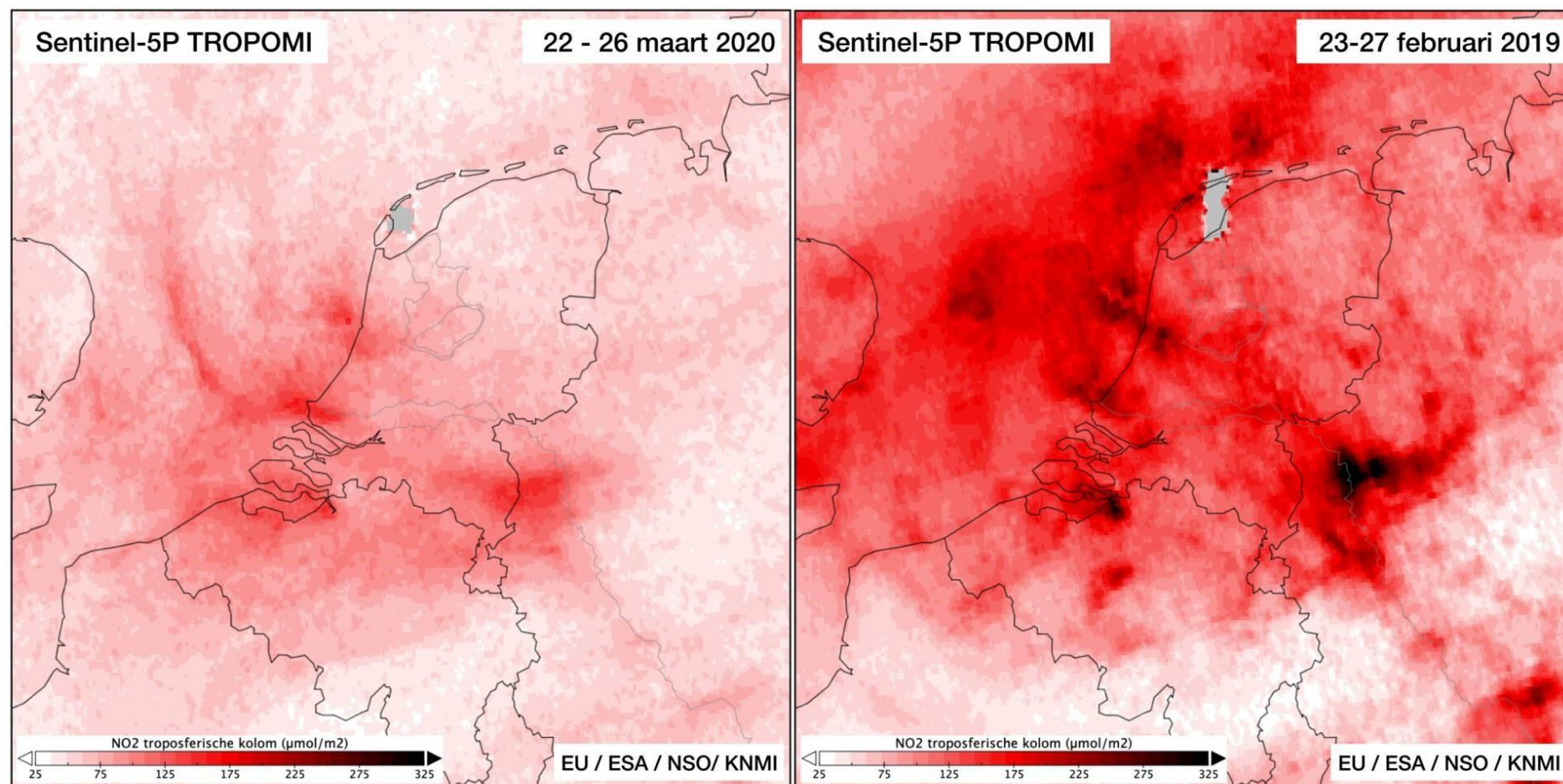
NO₂ in the Netherlands/Western Europe



Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the
Environment

Year-to-year changeable weather. Therefore
comparison is done with similar weather conditions.

Result:
20-60% reduction
in NO₂

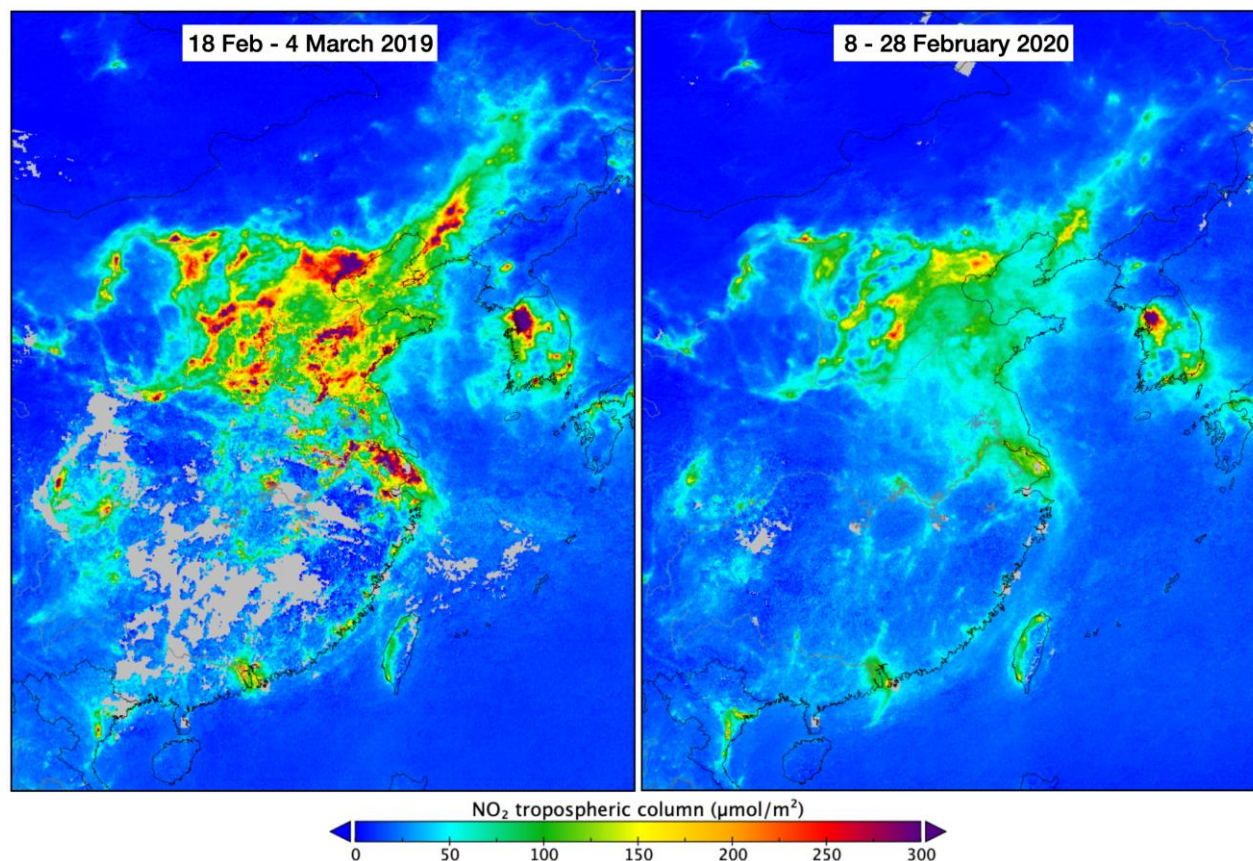


Work by Henk Eskes

NO₂ reduction in China

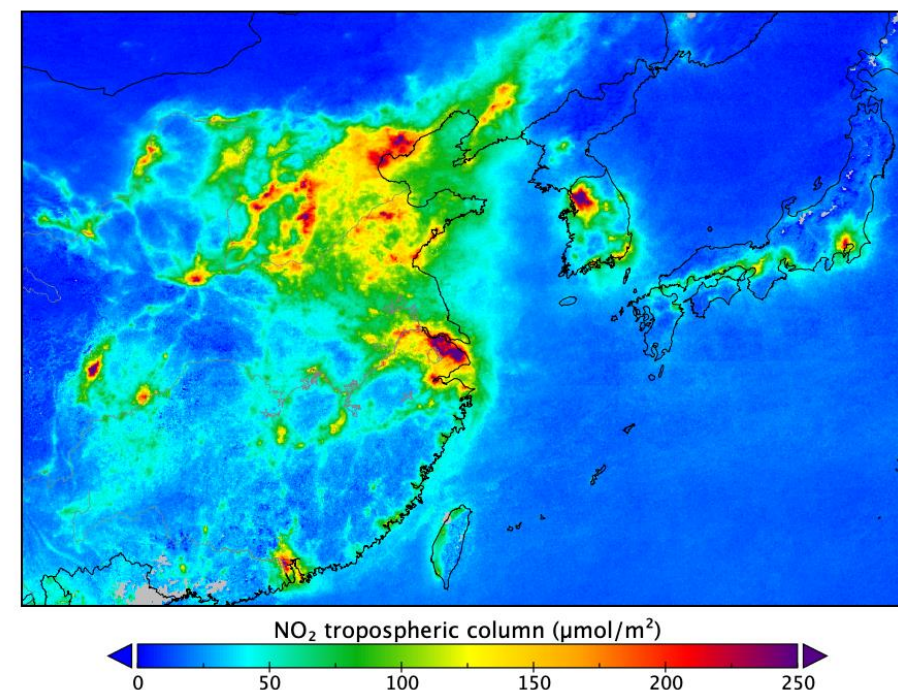
Normal situation Feb 2019

Lockdown Feb 2020



China back to work in March 2020

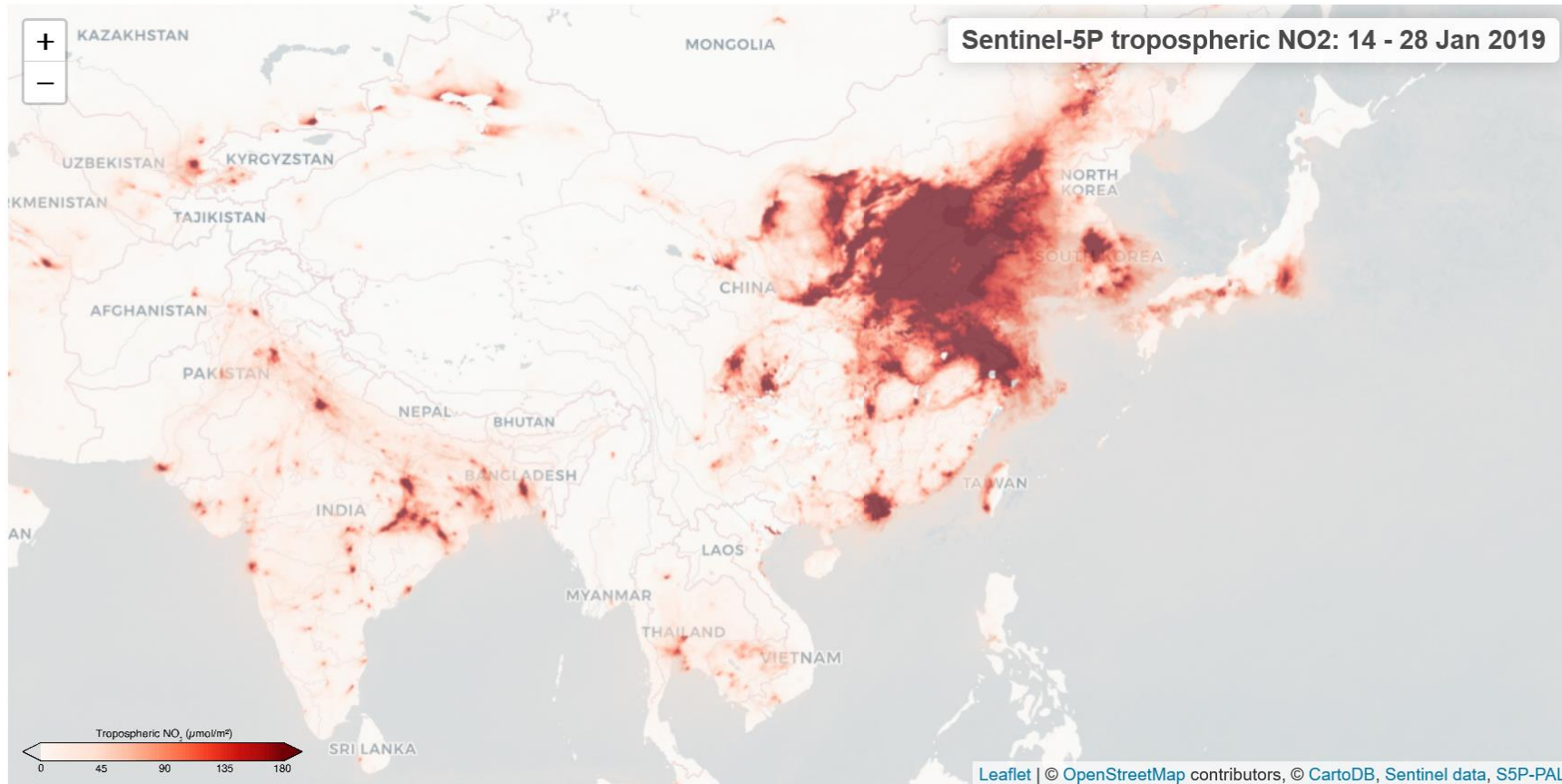
Sentinel-5P NO₂, 13 March - 13 April 2020



Work by Henk Eskes, Pieternel Levelt

Copernicus Sentinel-5P Mapping Portal

14-day running-mean maps of NO₂: <https://maps.s5p-pal.com/>



Source:
ESA/EU,
S[&]T / KNMI



O₃

Ozone hole over Northern Hemisphere in Spring 2020

TROPOMI S5P, total ozone, DLR, BIRA, ESA

2020-03-10

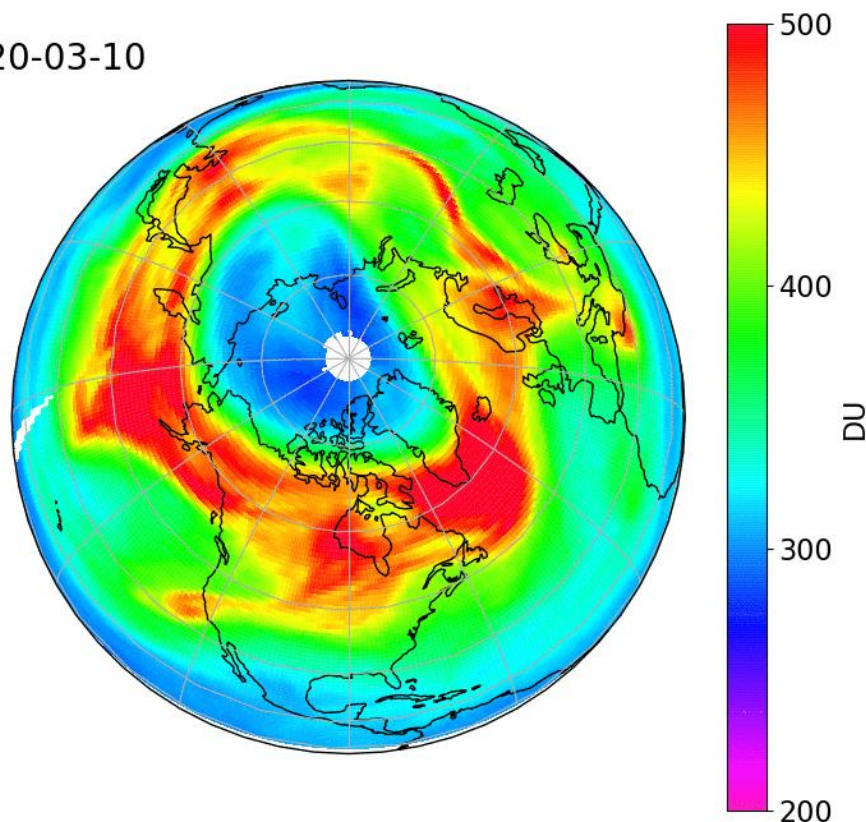


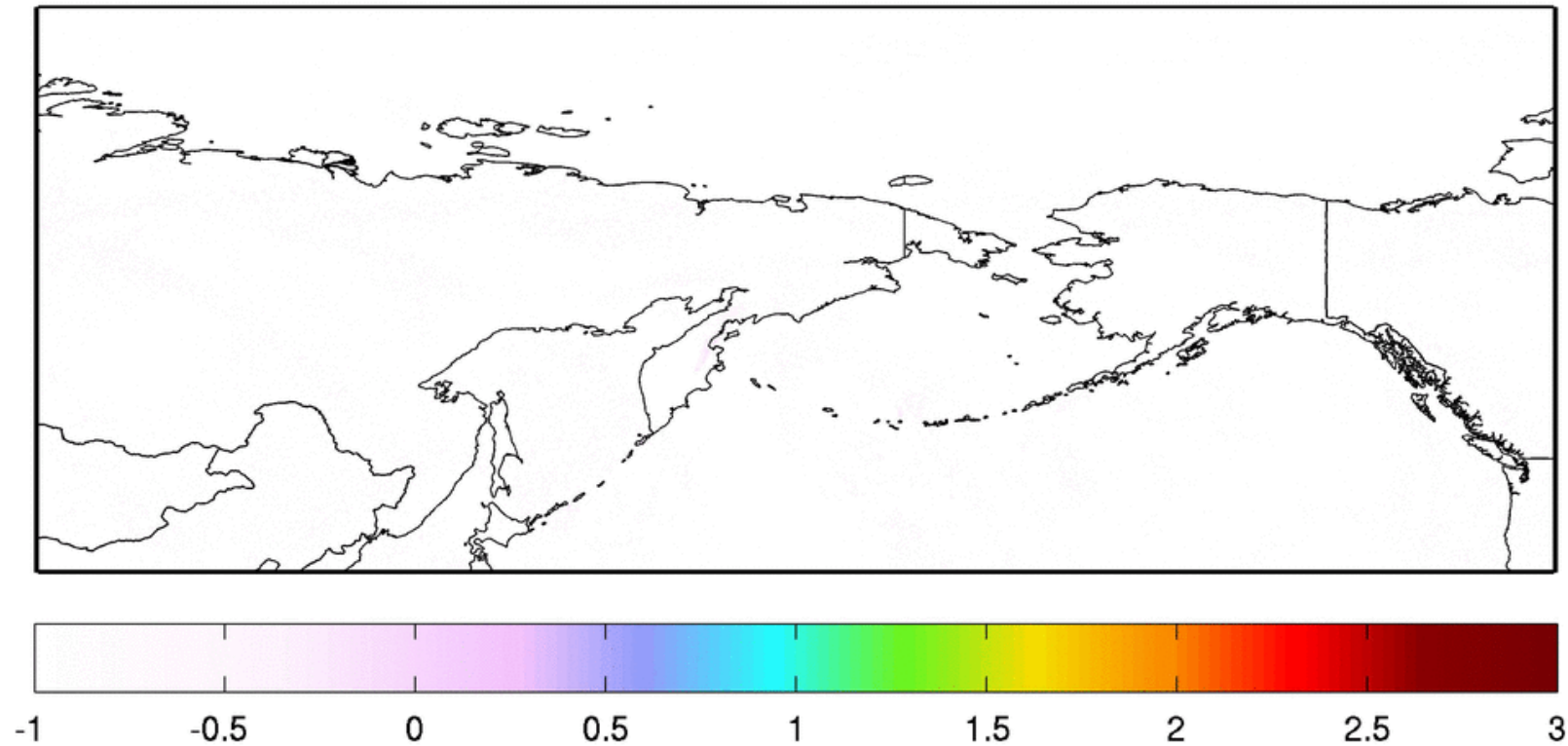
Figure: Loyola et al., DLR

SO₂

Raikoke eruption in June 2019 observed by TROPOMI



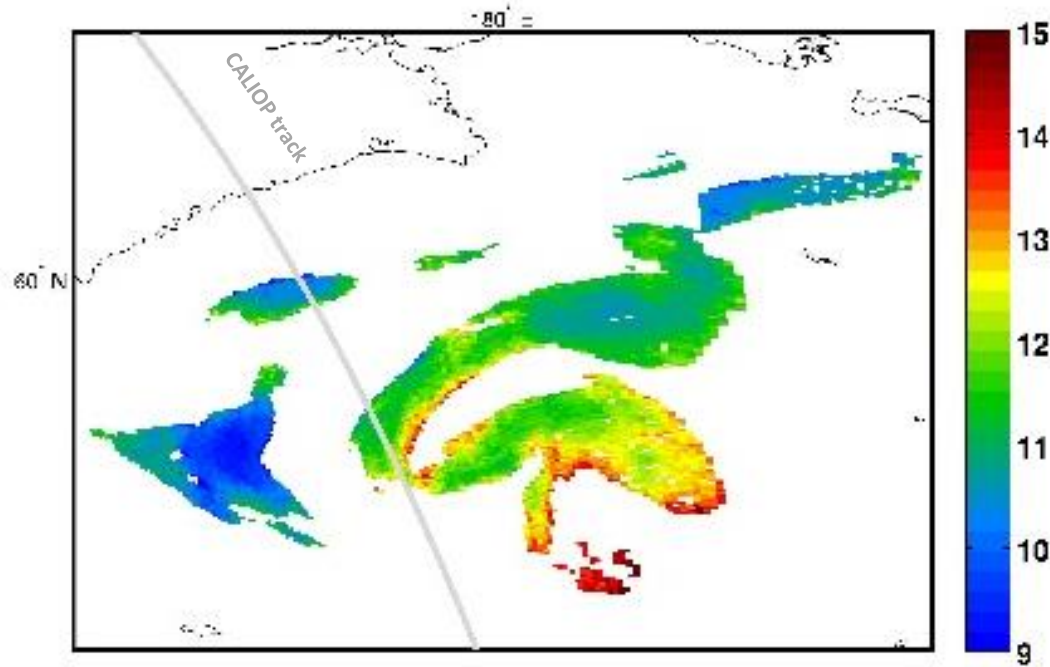
log(SO₂ (DU)) 21.06.2019



SO₂

SO₂ plume height retrievals

Raikoke eruption (25.06.2019)



Experimental product

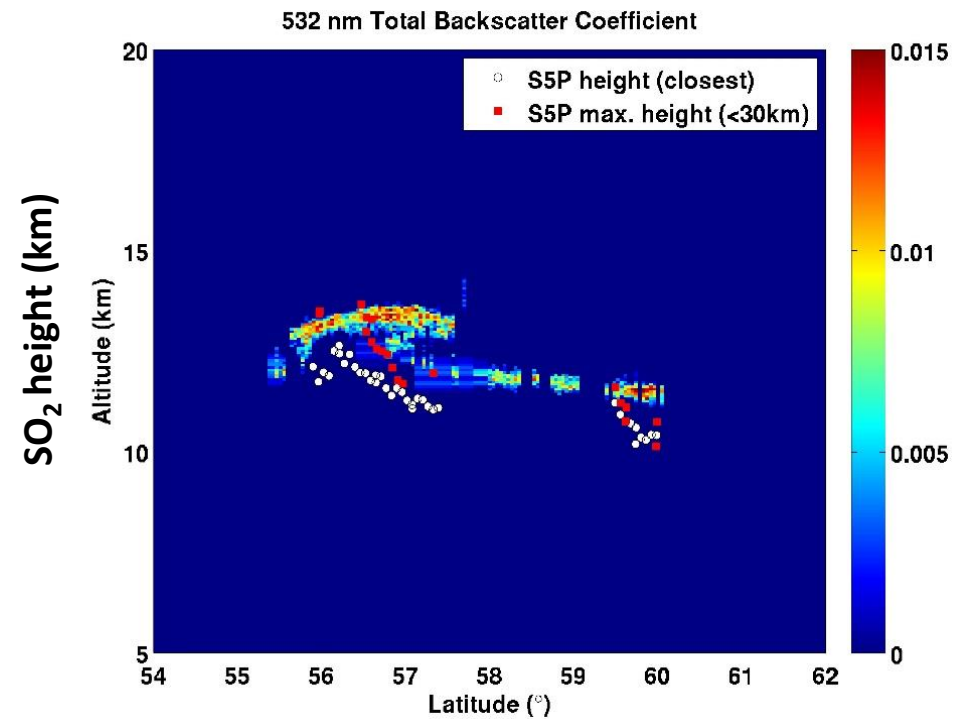
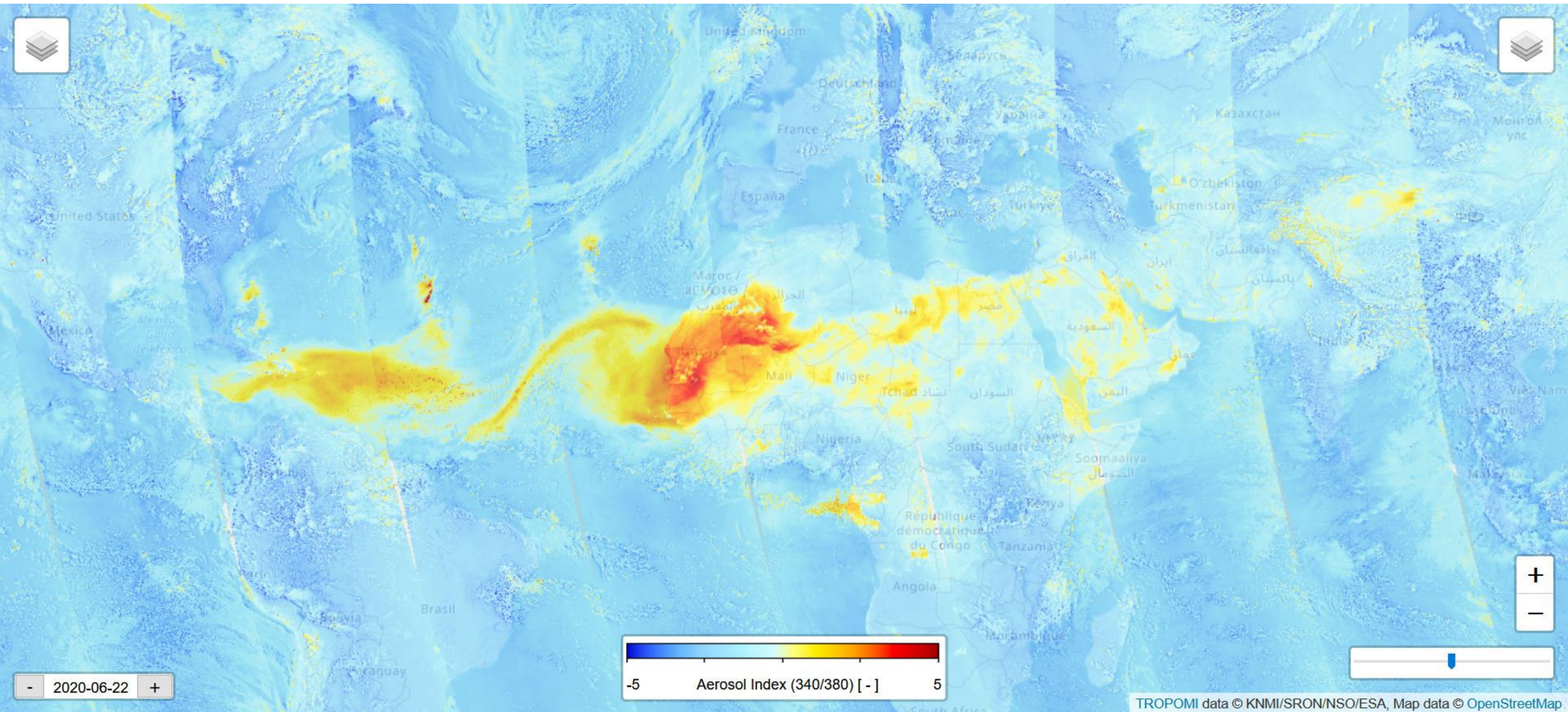


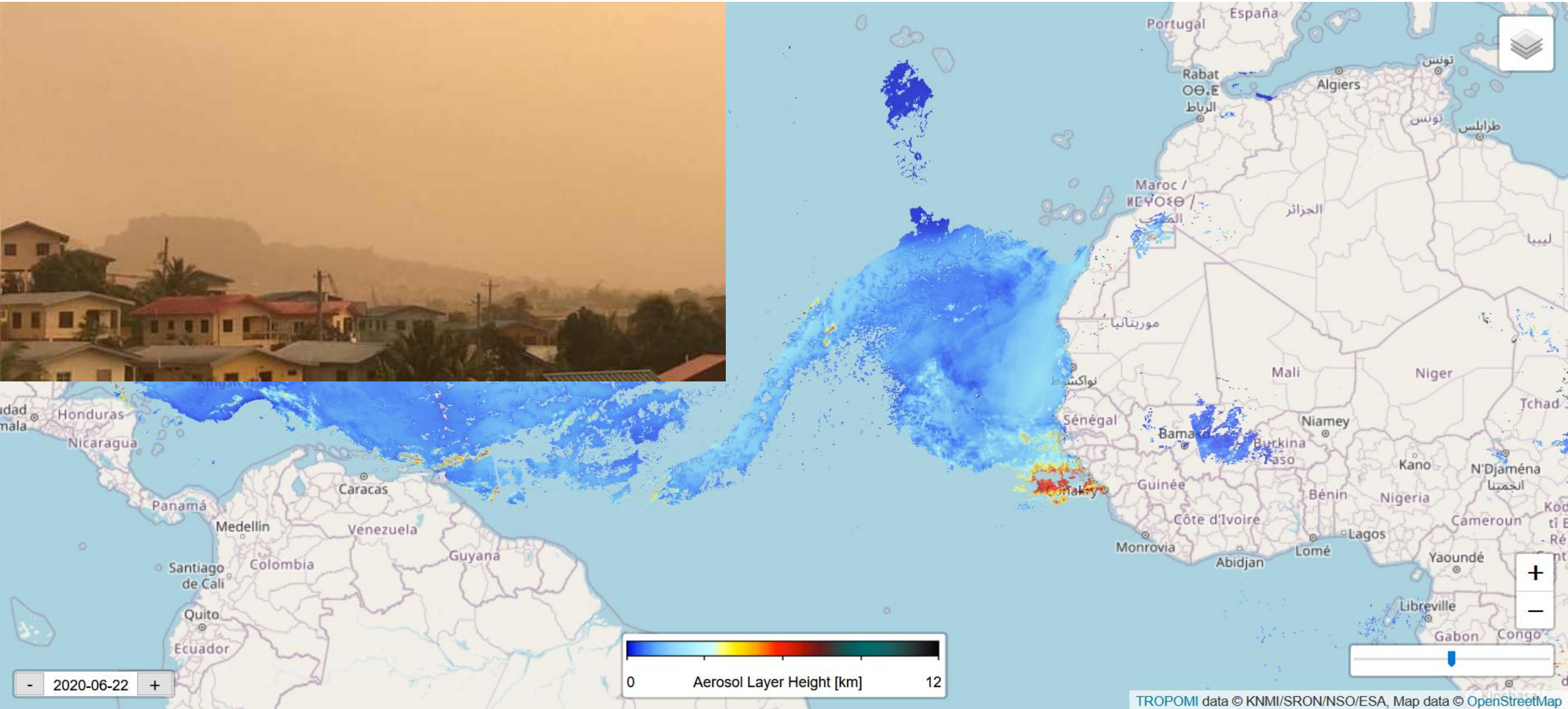
Figure: Nicolas Theys, BIRA

Sahara desert dust outbreak - Absorbing Aerosol Index (AAI) from 13 – 22 June 2020



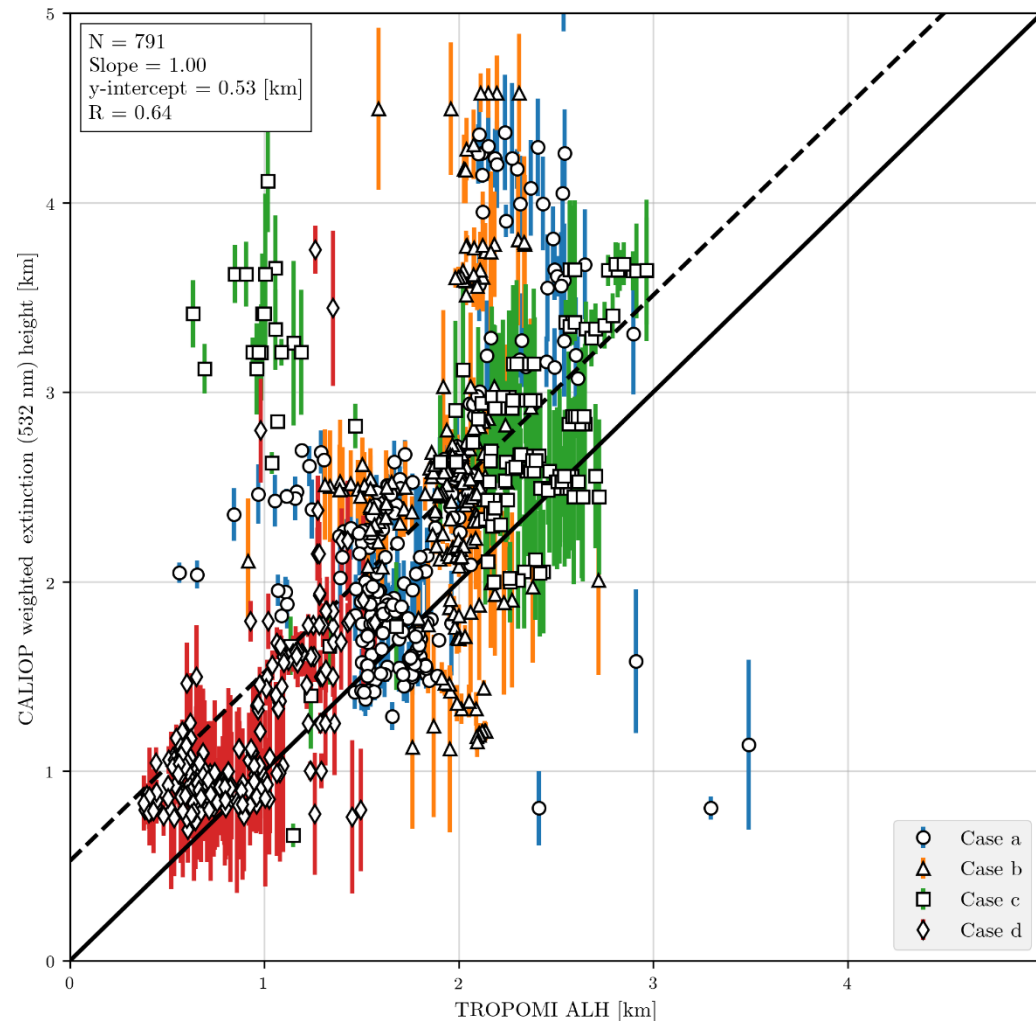
TROPOMI data © KNMI/SRON/NSO/ESA, Map data © OpenStreetMap

Sahara desert dust outbreak - Aerosol Layer Height (ALH) from 13 – 22 June 2020





Validation of TROPOMI Aerosol Layer Height with Caliop lidar



ALH over ocean:
About 0.5 km lower than lidar

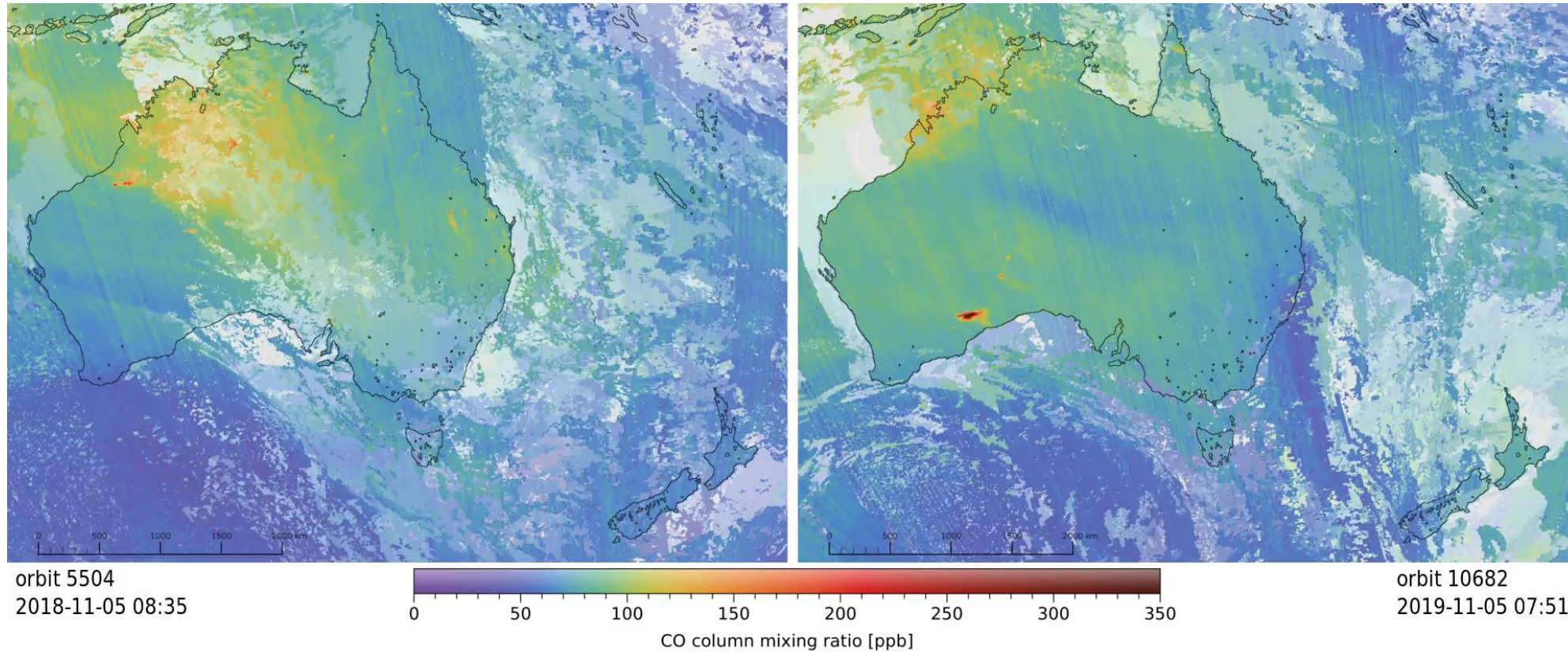
ALH over land:
1 km or more lower than lidar

CO

AUSTRALIAN Wild fires in Nov 2019 - Jan 2020

2018

2019



Vd Velde et al, 2020

Figure: Ilse Aben, SRON

CH₄

Accidental & short but huge source detected by TROPOMI : the Ohio blow-out case



Satellite observations reveal extreme methane leakage from a natural gas well blowout

ib Sudhanshu Pandey, Ritesh Gautam, Sander Houweling, Hugo Denier van der Gon, Pankaj Sadavarte, Tobias Borsdorff, Otto Hasekamp, Jochen Landgraf, Paul Tol, Tim van Kempen, Ruud Hoogeveen, Richard van Hees, Steven P. Hamburg, Joannes D. Maasackers, and Ilse Aben

Feb-March 2018 (~3 weeks)

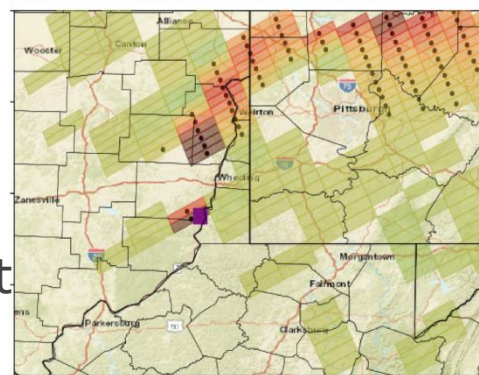
Newly drilled well exploded

$120 \pm 32 \text{ ton hr}^{-1}$

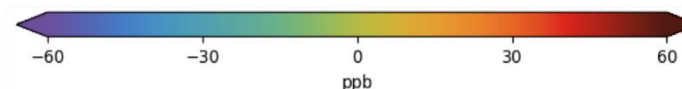
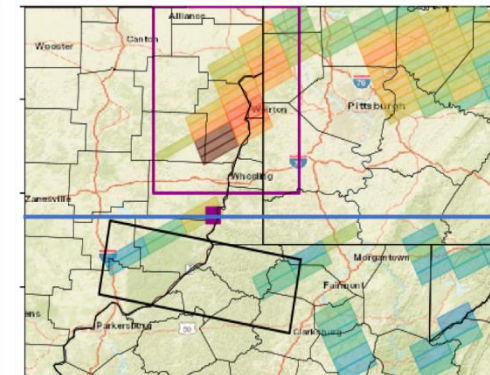
TROPOMI the only CH₄ measurement

Illustrating the strength of routine satellite measurements in detecting and quantifying CH₄ emissions unpredictable events

b. WRF XCH₄ at TROPOMI pixels



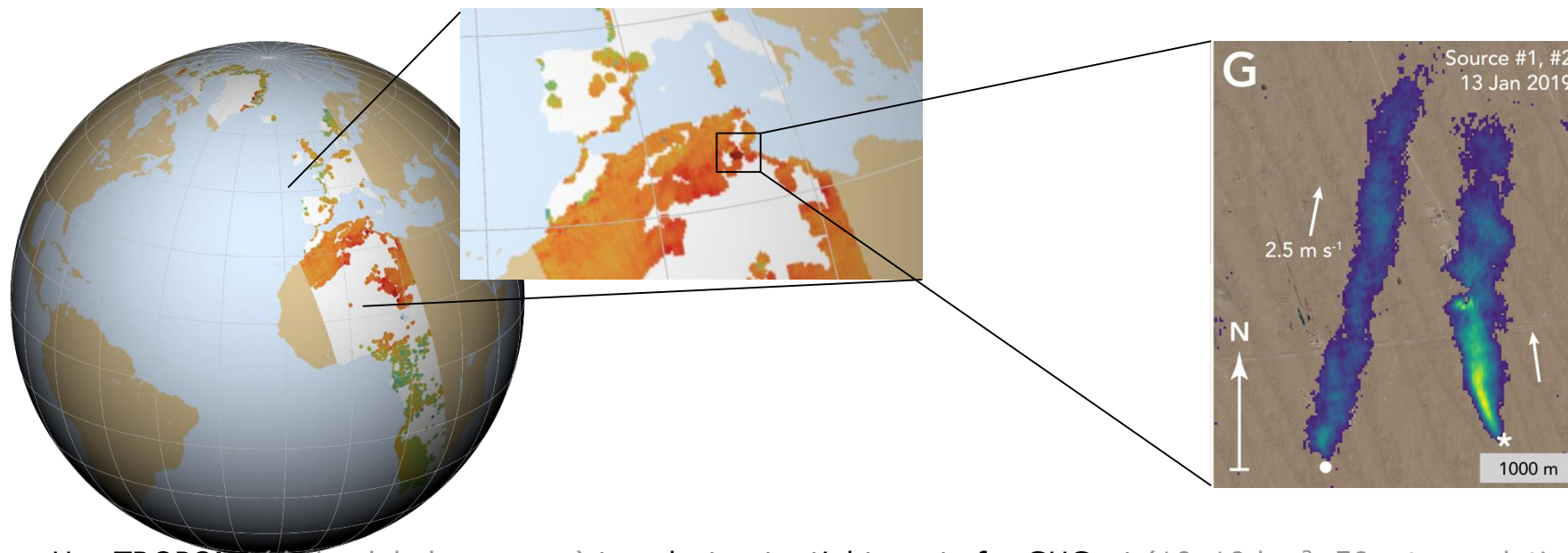
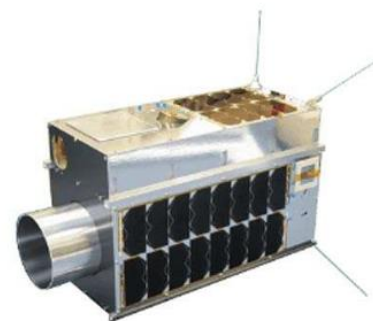
c. TROPOMI XCH₄



Pandey et al, PNAS 2019

CH₄

TROPOMI guiding GHGsat observations

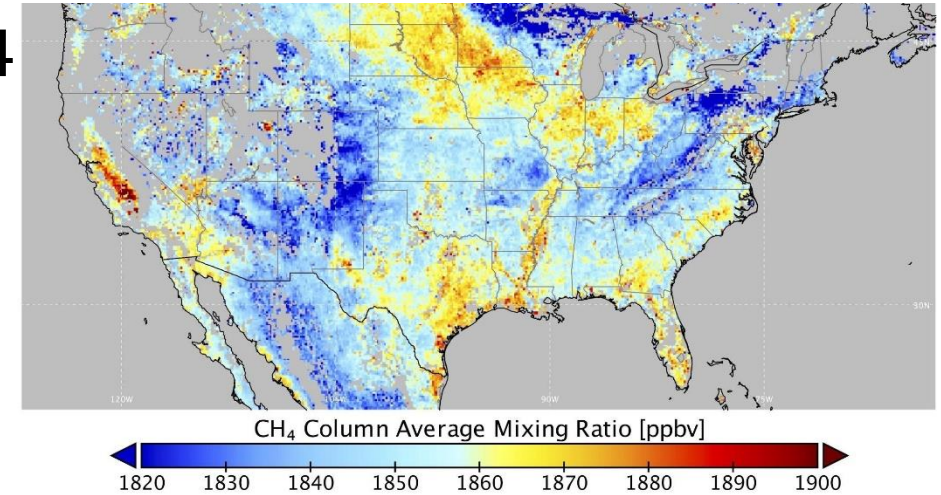


Use TROPOMI (daily global coverage) to select potential targets for GHGsat (10x10 km², 50 mtr resolution) to map CH₄ emission hot spots at facility scale

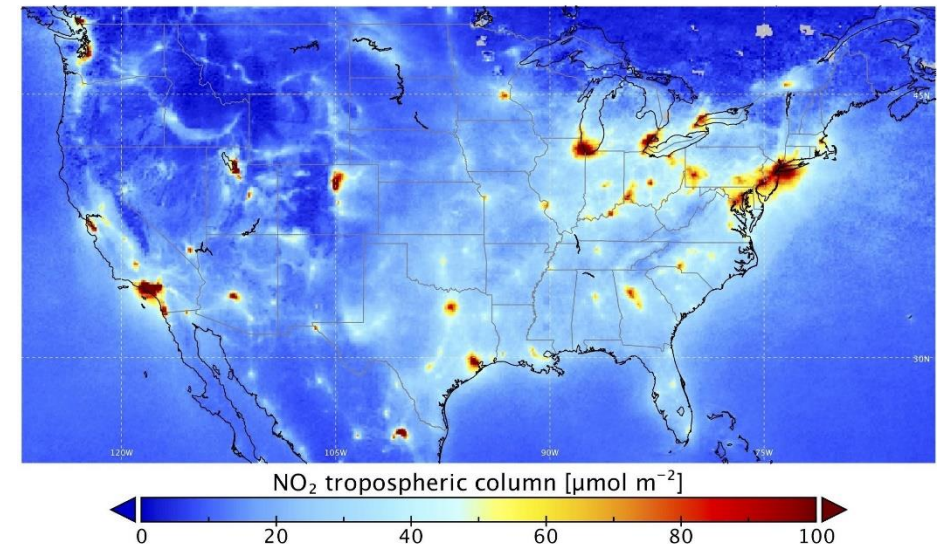
CH₄ enhancements from Oil and Gas production observed by TROPOMI



CH₄



NO₂



de Gouw, Veefkind et al., Nature Scientific Reports, 2020

Average TROPOMI columns for (top) methane and (bottom) tropospheric NO₂ over the contiguous United States between 1 December 2018 and 31 March 2019. Retrieved columns have been binned on a 0.1°×0.125° grid.

Conclusions



- The TROPOMI mission is its operational phase and sets new standards for UVNS instruments for atmospheric composition monitoring: *game changer*.
- The data products are of high quality, are continuously monitored and are freely available.
- Released products will be further improved and the entire dataset will be reprocessed.
- New data products are being developed, based on user needs.
- Use of TROPOMI data in CAMS air quality forecasts, just like weather forecasts.
- **Future: use of satellite data in environmental regulations.**

veefkind@knmi.nl

www.tropomi.eu

sentinels.copernicus.eu

[#tropomi](https://twitter.com/tropomi)



[HOME](#)[MISSION STATUS](#)[DATA PRODUCTS](#)[MORE](#)[FEATURED RESULTS](#)[ABOUT](#)

> <http://www.tropomi.eu/>

OBSERVING OUR FUTURE



Ozone



Ozone
profile



Nitrogen
dioxide



Sulfur
dioxide



Clouds



Surface
UV-B



Clouds



TROPOMI
TROPOspheric Monitoring Instrument

SCIENCE WEBSITE

[VISIT PUBLIC TROPOMI WEBSITE](#)

The TROPOspheric Monitoring Instrument (TROPOMI) is the satellite instrument on board the Copernicus Sentinel-5 Precursor satellite. The Sentinel-5 Precursor (SSP) is the first of the atmospheric composition Sentinels, launched on 13 October 2017, planned for a mission of seven years.

[Tropomi on Twitter](#)

Tweets by @tropomi

TROPOMI



Back-up slides

> <http://mpc-vdaf.tropomi.eu/>

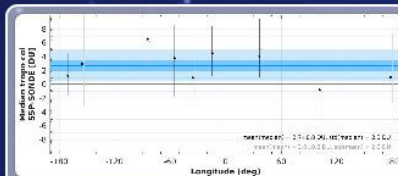


VALIDATION FACILITY

SENTINEL 5P MISSION PERFORMANCE CENTER



Most recent contributions



Validation against SHADOZ ozonesonde data confirms that the TROPOMI/S5p OFFL tropospheric O3 (L2_O3_TCL) data product meets mission requirements. This web article summarizes the results of the validation of the first year of S5p OFFL tropospheric ozone column data products (v01.01.05, v01.01.06 and v01.01.07) against co-

First comparison results for the S5P CH4 product based on correlative reference measurements acquired by FTIR instruments contributing to NDACC and TCCON networks.

First validation results for Sentinel-5p NO2 column data. This report describes initial validation results for Sentinel-5p TROPOMI L2_NO2 tropospheric column, stratospheric

A first validation against NDACC and WUOCC ground-based data confirms that the TROPOMI/S5p NRTI total O3 (L2_O3) product meets mission requirements. Initial Sentinel-5p TROPOMI

Preliminary comparison of TROPOMI/S5p RPRO CLOUD CAL cloud top height and CRB cloud height against ground-based CLOUDNET data. From the Sentinel-5p TROPOMI L2_CLOUD

First comparison results for the S5P CO product based on correlative reference measurements acquired by FTIR instruments contributing to NDACC and TCCON networks.

ROCVR REPORTS

- Quarterly Validation Report of the Sentinel-5 Precursor Operational
- Quarterly Validation Report of the Sentinel-5 Precursor Operational
- Quarterly Validation Report of the Sentinel-5 Precursor Operational
- Quarterly Validation Report of the Sentinel-5 Precursor Operational



Orbit 10531.132

Orbit

Calendar

Engineering

Monitoring

Earth View

Quicklook

Life Limited Items

Trends

Reporting

Help

Status of instrument

<http://mps.tropomi.eu>

TROPOMI portal

Instrument and Calibration





Outlook to upcoming missions

- **GEO-Ring** of geostationary air quality satellites:
GEMS (S-Korea, 2020) + TEMPO (USA, 2022) + **Sentinel-4** (EU, 2023)
- **Sentinel-5** on Metop-SG in 09:30 orbit (*Note: S-5P is in 13:30 orbit*)
- **CO2M**: CO2 monitoring High Priority Candidate Mission
 - Needs **NO2 sensor** for anthropogenic plume tracking
 - Needs **aerosol sensor** for light path correction.

TROPOMI/S-5P is useful for all these missions.

SENTINEL 5 PRECURSOR

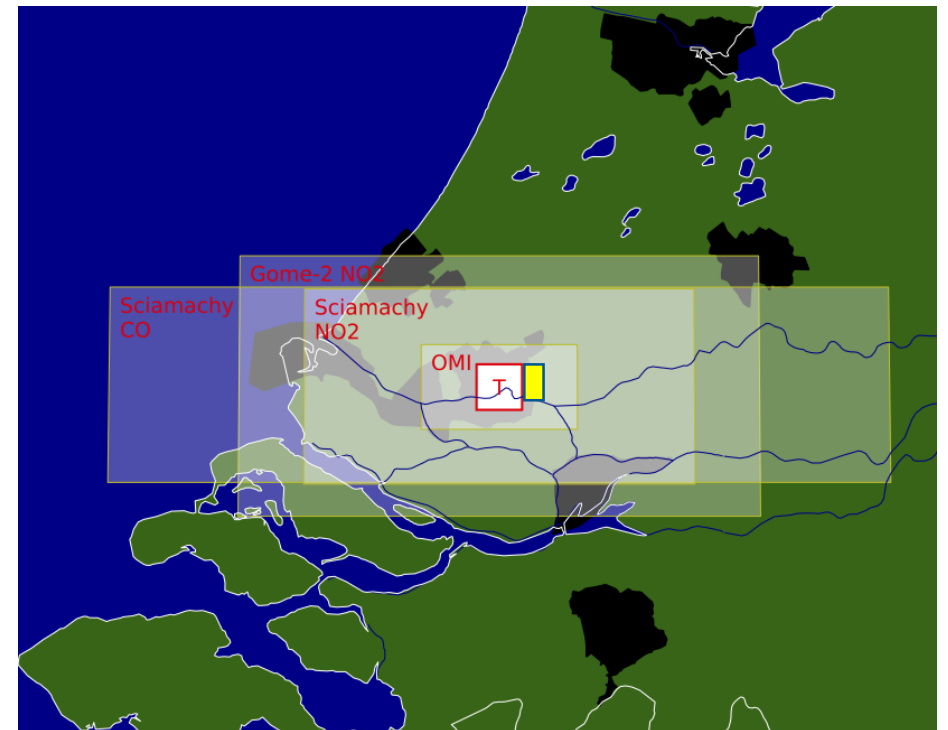
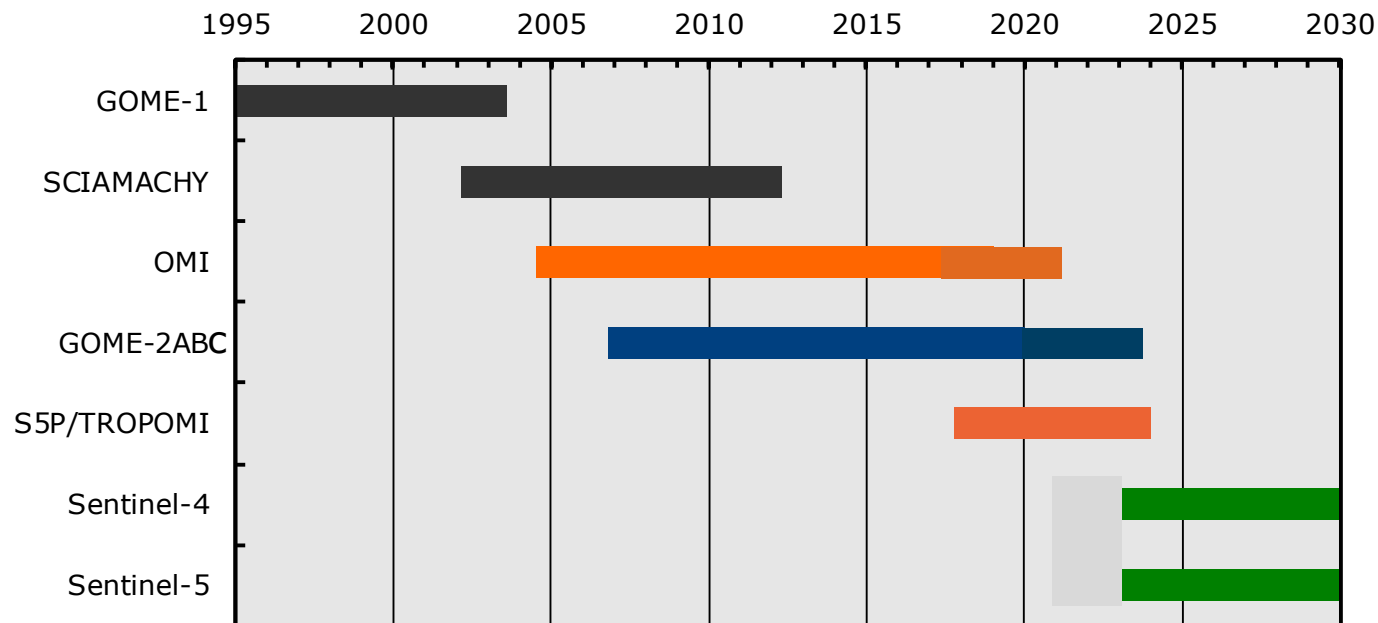
Launch	13 October 2017
Launcher	Rockot from Plesetsk Russia
Orbit	Polar Sun synchronous, altitude 824 km
In formation with	USA's Suomi-NPP (VIIRS), 3.5 min difference
Overpass time	13:30 local time
Mission duration	7 year
Satellite	Airbus Astrobus-M, height 3.55 m, 5.63 m diameter, mass 820 kg
Payload	Tropospheric Monitoring Instrument (TROPOMI)
Ground stations	Svalbard (Norway), Inuvik (Canada) and Kiruna (Sweden)
Data processing	DLR Oberpfaffenhofen (Germany) KNMI De Bilt, The Netherlands





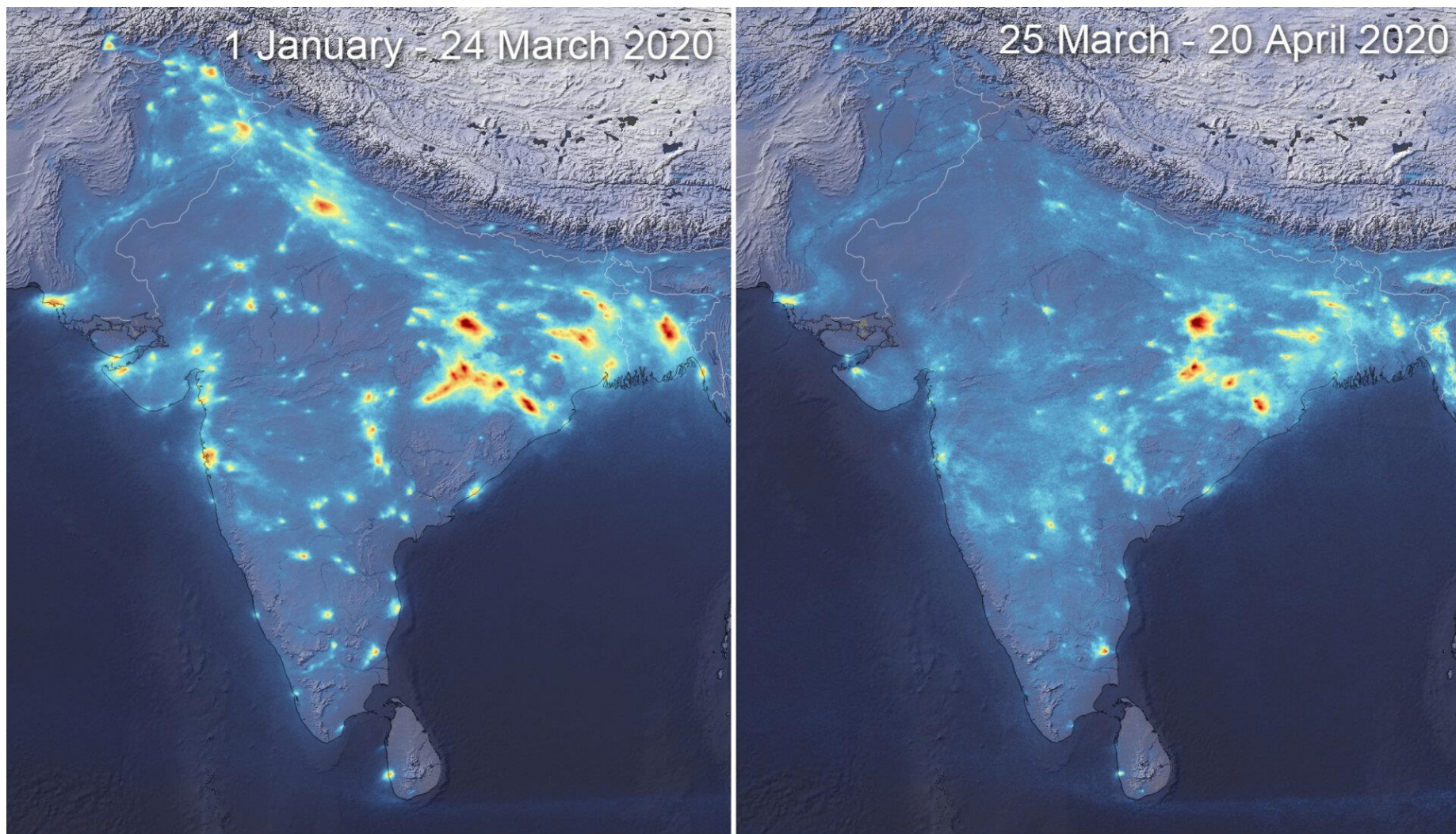
Heritage of TROPOMI

- > Heritage instruments since 1995: GOME, SCIAMACHY, OMI & GOME-2
- > Now 25 years of European satellite spectrometers in the solar spectral range





India



Source:
ESA-EU/
KNMI

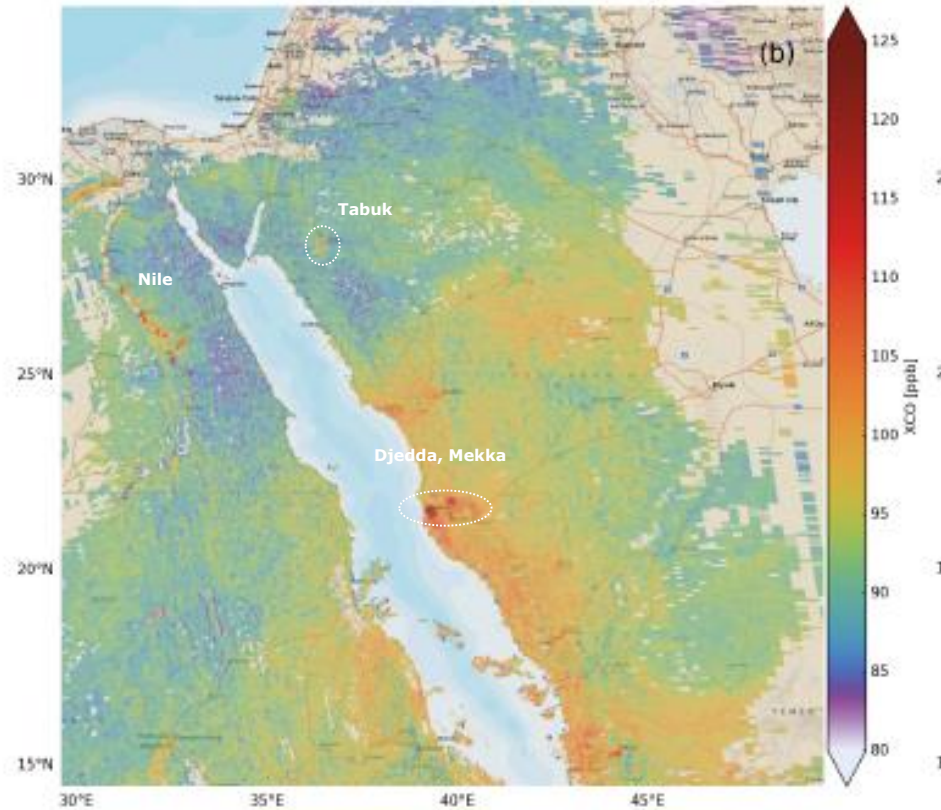
Sentinel-5P Nitrogen Dioxide tropospheric column



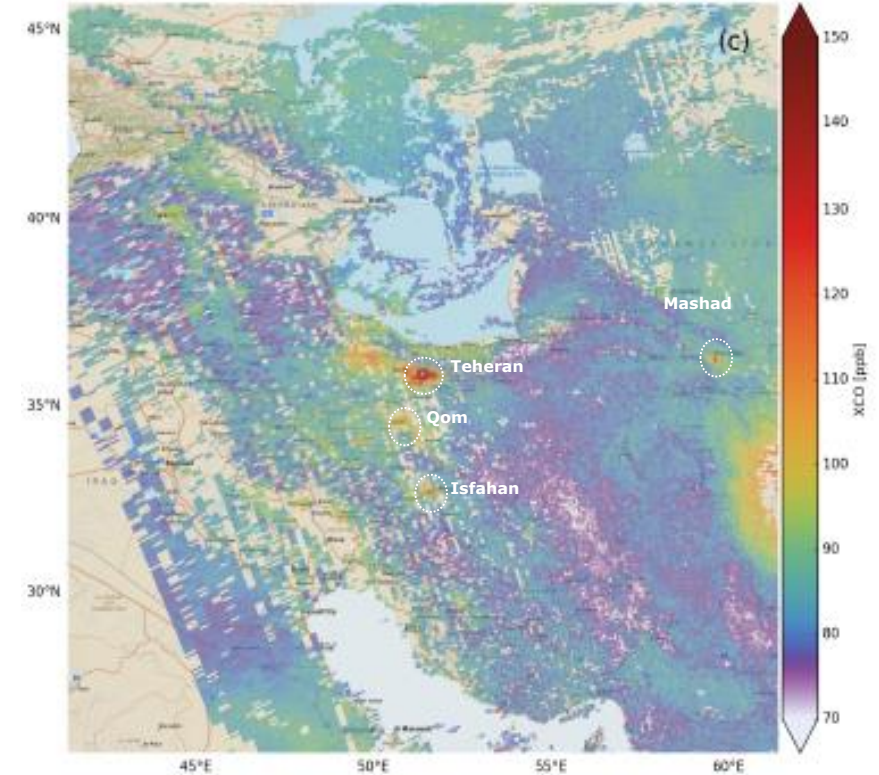
CO

High spatial resolution (7x7 km²),
estimate emissions from individual cities

single orbits



Saudi Arabia & Egypt



Iran

Lifetime of CO is ~ 2 weeks – 2 months

Estimate emissions from individual cities

Borsdorff et al., AMT, 2018

String of NO₂ hot spots point to natural gas field in Siberia

(van der A et al., 2020)

