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Verification of TROPOMI NO₂ Product Using OMI NO₂ Algorithm

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Outline



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- Developing Harmonized Multi-satellite NO₂ climate data records
 - OMI NO₂ algorithms: NASA vs QA4ECV
 - OMI NO₂ trends
 - OMI global NO₂ monitoring web site
 - TROPOMI NO₂ algorithms: NASA vs S5P offline
- OMI vs TROPOMI Slant Columns Densities (SCD) comparisons
- OMI vs TROPOMI tropospheric Vertical Columns (VCDs) comparisons
- OMI continuation with TROPOMI
- Validation of OMI and TROPOMI with Pandora NO₂ VCDs
- Summary

Developing Harmonized Multi-satellite NO₂ climate data records



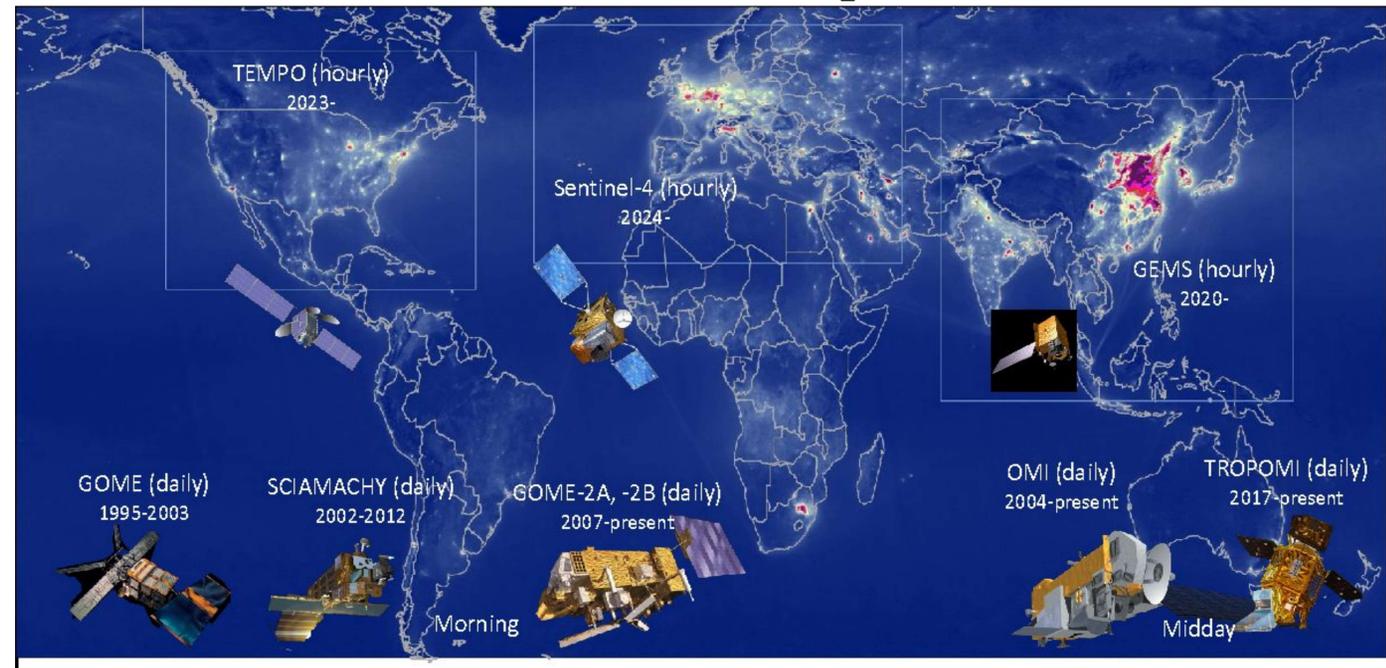
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Satellite Tropospheric NO₂ Observations



These efforts are highly relevant for emerging CEOS Atmospheric Composition Virtual Constellation GEO missions: GEMS (2020-), TEMPO (2023-), and Sentinel-4 (2024-)

- **NASA Program:** Making Earth System Data Records (**ESDRs**) for Use in Research Environments (**MEaSURES**).
- **Project:** Multi-Decadal Nitrogen Dioxide and Derived Products from Satellites (**MINDS**):
<https://www.earthdata.nasa.gov/esds/competitive-programs/measures/minds>. Project PI: Lok Lamsal
- **EU and ESA projects:** Quality Assurance for Essential Climate Variables (**QA4ECV**) and Climate Change Initiative (**CCI**) on Essential Climate Variables precursors for aerosols and ozone (**CCI ECV**):
<https://climate.esa.int/en/projects/precursors-for-aerosols-and-ozone>
Project PI for NO₂: Folkert Boersma

NASA NO₂ Earth System Data Records (ESDRs)



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ESDR name	DOI	Level	Satellite/ Instrument	Period	Data Citation/ release
TROPOMI_MINDS_NO2	10.5067/MEASURES/MINDS/DATA203	L2 pm	S5P/ TROPOMI	2018 -	[Lamsal et al., 2022d]
OMI_MINDS_NO2	10.5067/MEASURES/MINDS/DATA204	L2 pm	Aura/OMI	2005 -	[Lamsal et al., 2022a]
OMI_MINDS_NO2_L2G	10.5067/MEASURES/MINDS/DATA214	L2G pm	Aura/OMI	2005 -	[Lamsal et al., 2022b]
OMI_MINDS_NO2_L3	10.5067/MEASURES/MINDS/DATA304	L3 pm	Aura/OMI	2005 -	[Lamsal et al., 2022c]
GOME_MINDS_NO2	<u>TBA</u>	L2 am	ERS-2/ GOME	1995 - 2003	2023
GOME2A/B_MINDS_NO2	<u>TBA</u>	L2 am	MetOp/ GOME-2A/B	2006-	2023

- Lamsal et al., 2022a, OMI/Aura NO₂ Tropospheric, Stratospheric & Total Columns MINDS 1-Orbit L2 Swath 13 km x 24 km, NASA Goddard Space Flight Center, Goddard Earth Sciences Data and Information Services Center (GES DISC): https://disc.gsfc.nasa.gov/datasets/OMI_MINDS_NO2_1.1/summary
- Lamsal, et al., 2022b, OMI/Aura NO₂ Tropospheric, Stratospheric & Total Columns MINDS Daily L2 Global Gridded 0.25 degree x 0.25 degree, GES DISC https://disc.gsfc.nasa.gov/datasets/OMI_MINDS_NO2G_1.1/summary
- Lamsal, et al., 2022c, OMI/Aura NO₂ Tropospheric, Stratospheric & Total Columns MINDS Daily L3 Global Gridded 0.25 degree x 0.25 degree, GES DISC: https://disc.gsfc.nasa.gov/datasets/OMI_MINDS_NO2d_1.1/summary
- Lamsal, et al., 2022d, TROPOMI/S5P NO₂ Tropospheric, Stratospheric and Total Columns MINDS 1-Orbit L2 Swath 5.5 km x 3.5 km, GES DISC: https://disc.gsfc.nasa.gov/datasets/TROPOMI_MINDS_NO2_1.1/summary



OMI NO₂ algorithms



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Algorithm	EU QA4ECV	NASA MINDS
Reference	Boersma et al., 2018	Lamsal et al., 2021
NO ₂ slant column density	QDOAS	Modified DOAS (Marchenko et al., 2015)
Surface reflectivity	LER climatology at 0.5°x0.5° (Kleipool et al., 2008)	GLER ^{*)} at OMI FoVs (Qin et al., 2019; Fasnacht et al., 2019)
Cloud correction	KNMI O ₂ -O ₂ algorithm LER climatology-based (Veefkind et al., 2016)	NASA O ₂ -O ₂ algorithm GLER-based (Vasilkov et al., 2018; Lamsal et al., 2021)
A-priori NO ₂ profiles	TM5 at 1° x 1°	GMI ^{**} at 0.25° x 0.25°
Strat-trop NO ₂ separation	TM5 data assimilation	Observation-based (Bucsela et al., 2013)

* Poster: Qin et al., Geometry Dependent Lambertian Equivalent Reflectivity (GLER) **Global Modeling Initiative (GMI)

- Boersma, K. F., et al., 2018, Improving algorithms and uncertainty estimates for satellite NO₂ retrievals: results from the quality assurance for the essential climate variables (QA4ECV) project, Atmos. Meas. Tech., 11, 6651–6678, <https://doi.org/10.5194/amt-11-6651-2018>
- Lamsal, at al., 2021, Ozone Monitoring Instrument (OMI) Aura nitrogen dioxide standard product version 4.0 with improved surface and cloud treatments, Atmos. Meas. Tech., 14, 455–479, <https://doi.org/10.5194/amt-14-455-2021>



OMI NO₂ trends: 2005 - 2021



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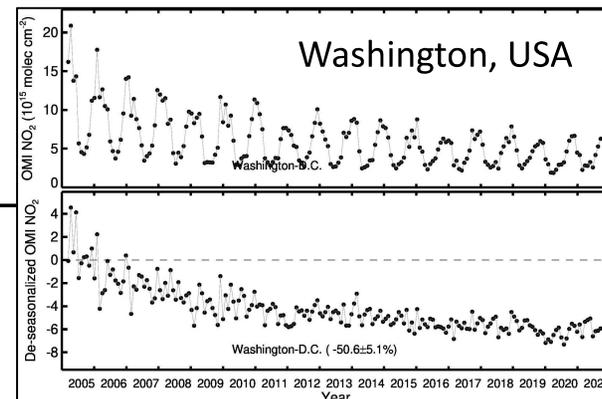
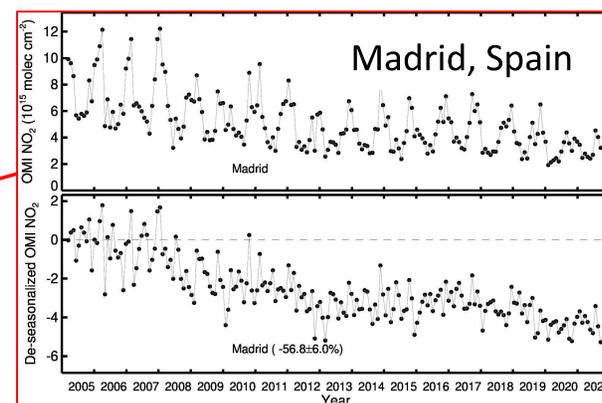
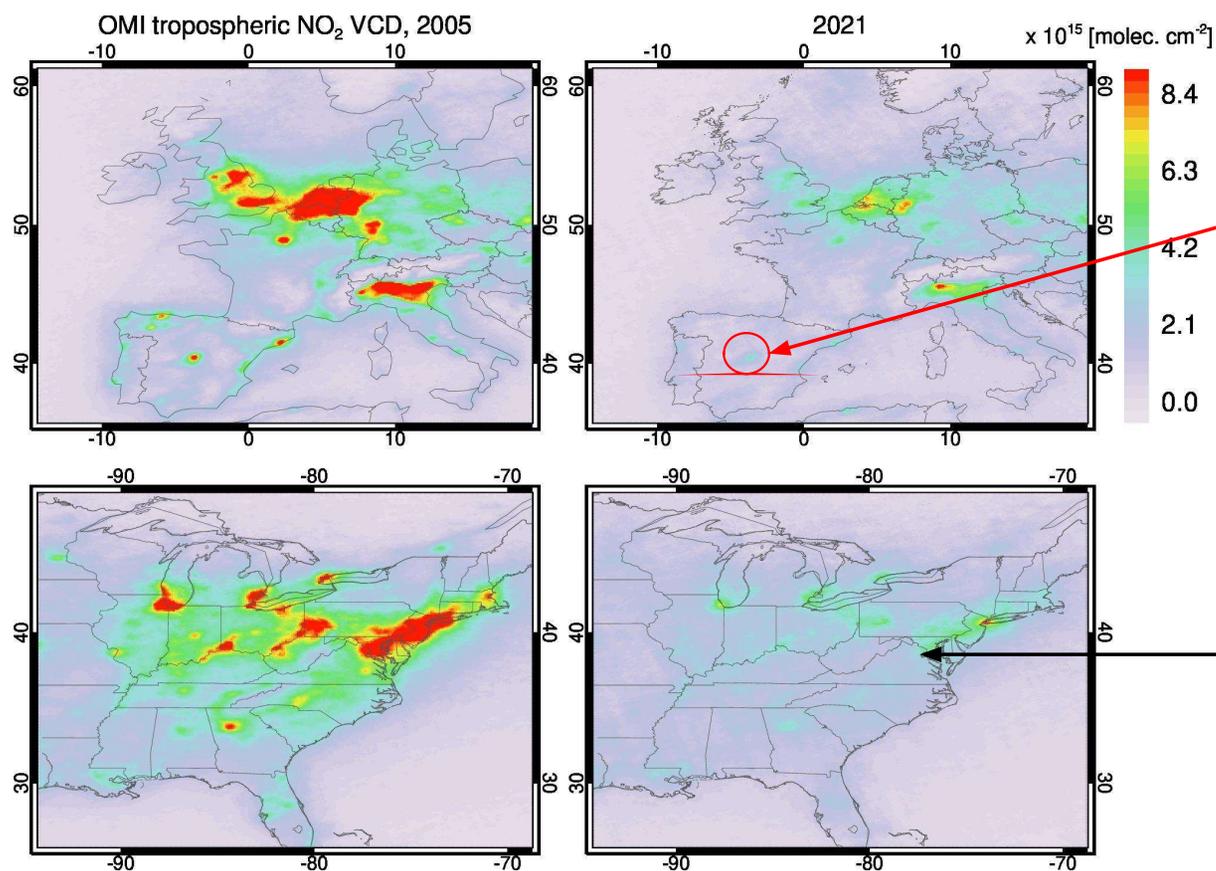


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<https://avdc.gsfc.nasa.gov>

<https://airquality.gsfc.nasa.gov/no2>





OMI Global NO₂ monitoring web site: COVID-19 anomalies



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https://so2.gsfc.nasa.gov/no2/no2_index.html

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AURA OMI average tropospheric NO₂ maps

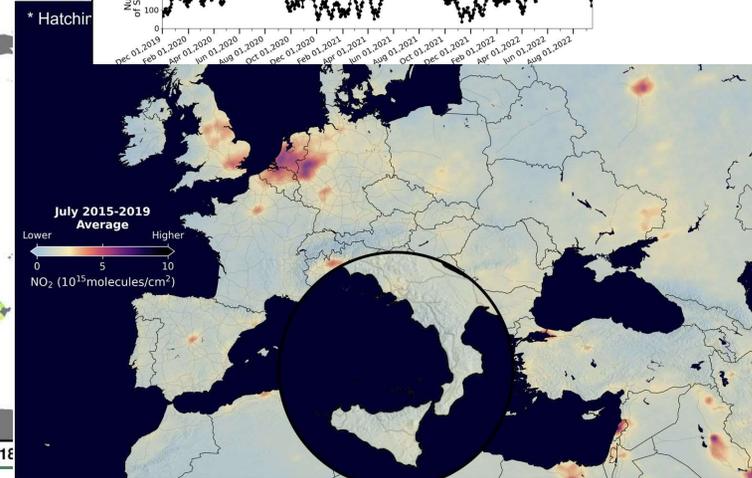
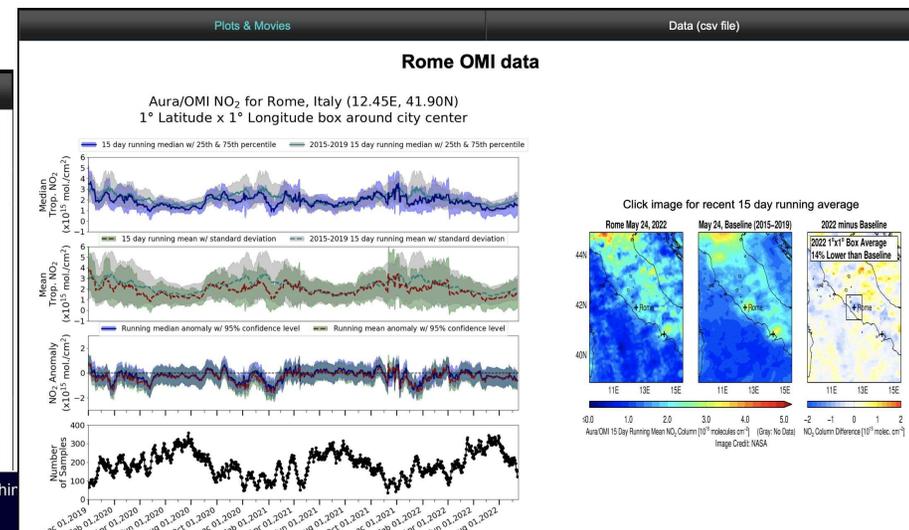
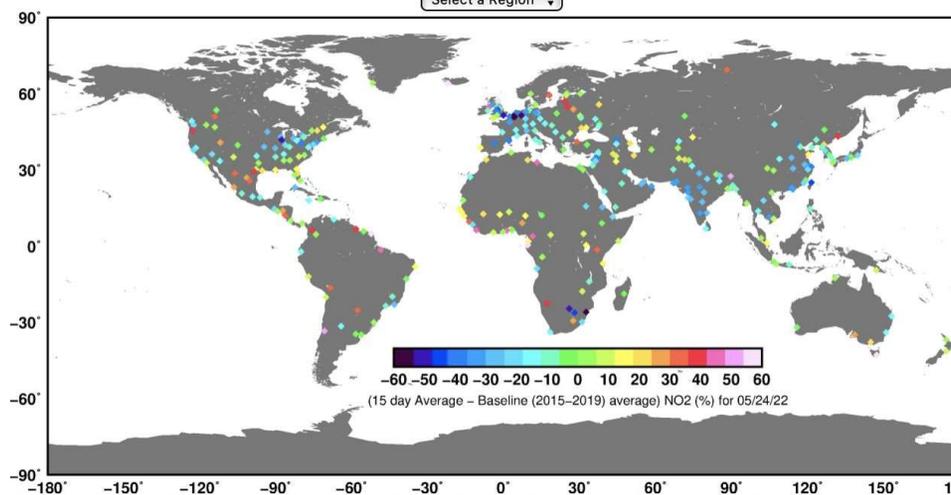
Please **README** to better understand the data
(You may need to enable popups on your browser)

NO₂ images will be displayed by clicking on a diamond or

NO₂ time series data (csv files) are **now** available

For a bigger picture, select a region

Or a video of a region





Applying OMI NO₂ algorithm to TROPOMI



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Algorithm	ESA/KNMI (Operational)	NASA
NO ₂ algorithm heritage	QA4ECV [Boersma et al., 2018]	OMI MINDS NO ₂ [Lamsal et al., 2021,2022]
NO ₂ slant columns	ESA/KNMI (Operational)	Same
Surface reflectivity	OMLER climatology*** at 0.5° x 0.5°	GLER at TROPOMI FoV [see Poster: Wenhan et al.]
Cloud products	OMLER climatology-based	GLER-based
A-priori NO ₂ profiles	TM5 at 1° x 1°	*GMI-Replay at 0.25° x 0.25°
Snow/ice flag	ECMWF weather data	IMS** (NISE in SH)

*Global Modeling Initiative (GMI) model – see presentation by Brad Fisher

** Interactive Multisensor Snow and Ice Mapping System (IMS) – U.S. National Ice Center

*** Will be replaced with the S5P Directional Lambertian Equivalent Reflectivity (DLER) in new version

Lamsal, et al., 2022, TROPOMI/S5P NO₂ Tropospheric, Stratospheric and Total Columns MINDS 1-Orbit L2 Swath 5.5 km x 3.5 km, NASA Goddard Space Flight Center, Goddard Earth Sciences Data and Information Services Center (GES DISC), https://disc.gsfc.nasa.gov/datasets/TROPOMI_MINDS_NO2_1.1/summary, DOI: [10.5067/MEASURES/MINDS/DATA203](https://doi.org/10.5067/MEASURES/MINDS/DATA203)

OMI vs TROPOMI Slant Column Densities (SCD)



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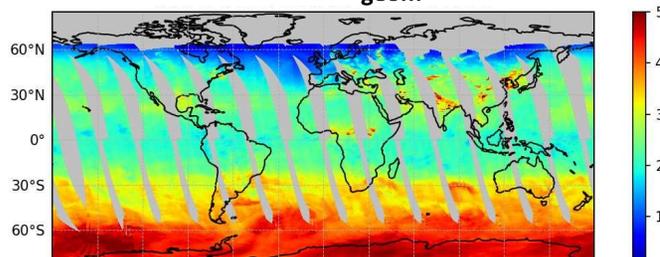


- Compared normalized SCDs from TROPOMI (S5P-PAL) with OMI (both QA4ECV & NASA retrievals)

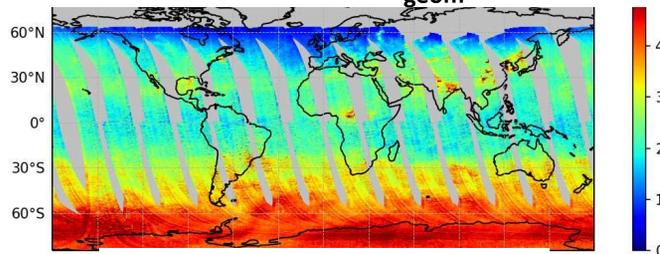
- TROPOMI SCDs were averaged over OMI footprints for comparison

- TROPOMI NO₂ SCDs are less noisy than OMI, but appear little higher than two independent OMI NO₂ retrievals

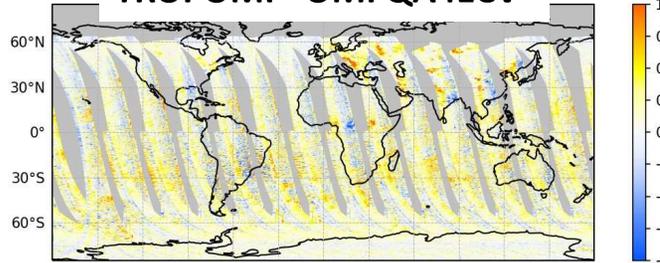
TROPOMI SCD/AMF_{geom} 2018-12-20



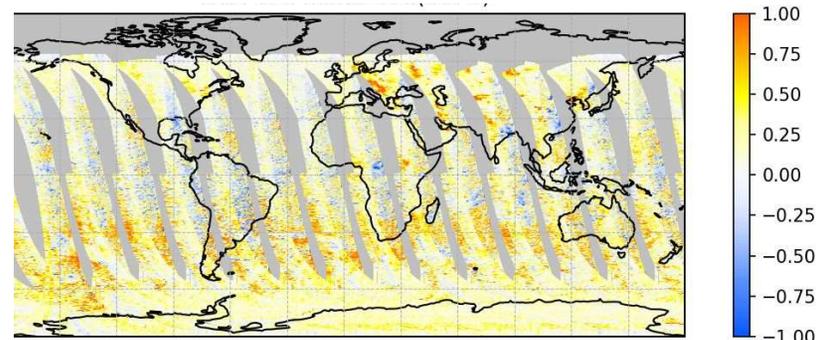
OMI QA4ECV SCD/AMF_{geom} 2018-12-20



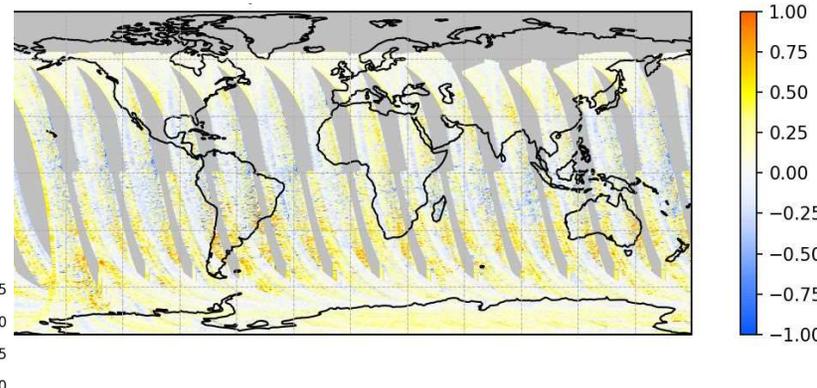
TROPOMI - OMI QA4ECV



TROPOMI PAL - OMI NASA



OMI QA4ECV - OMI NASA





OMI vs TROPOMI Tropospheric NO₂



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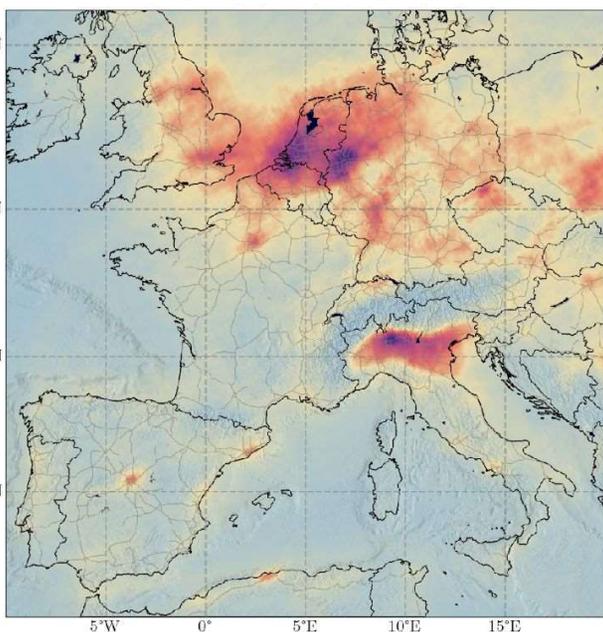


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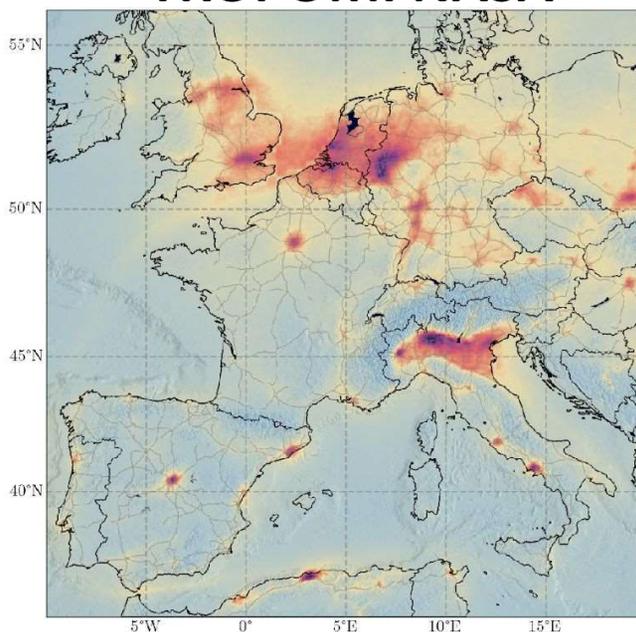


2020 annual average Tropospheric NO₂

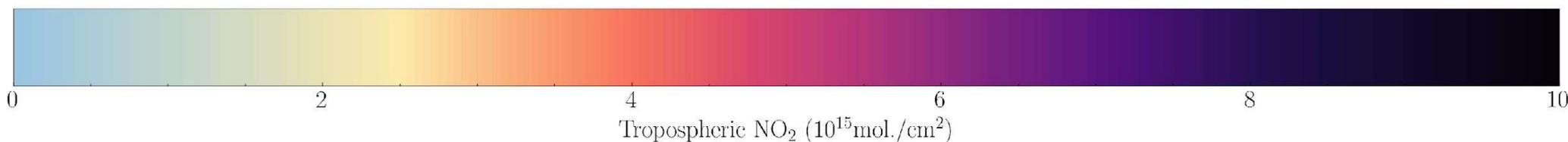
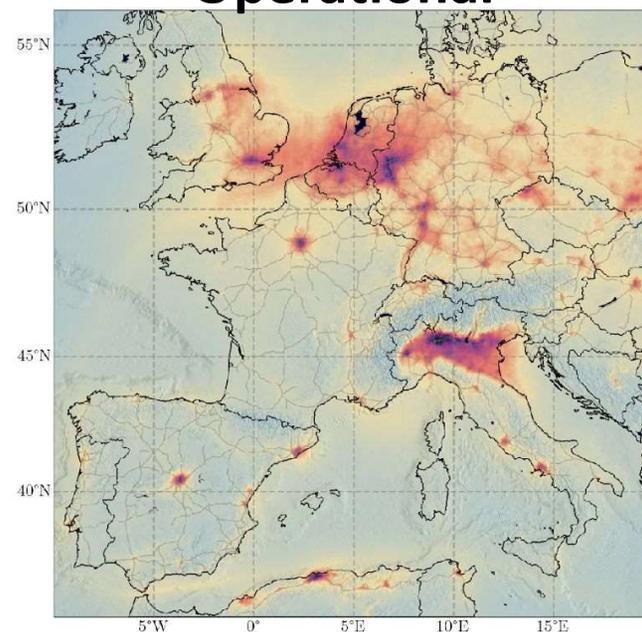
OMI NASA



TROPOMI NASA



TROPOMI Operational





TROPOMI tropospheric NO₂ NASA vs Operational



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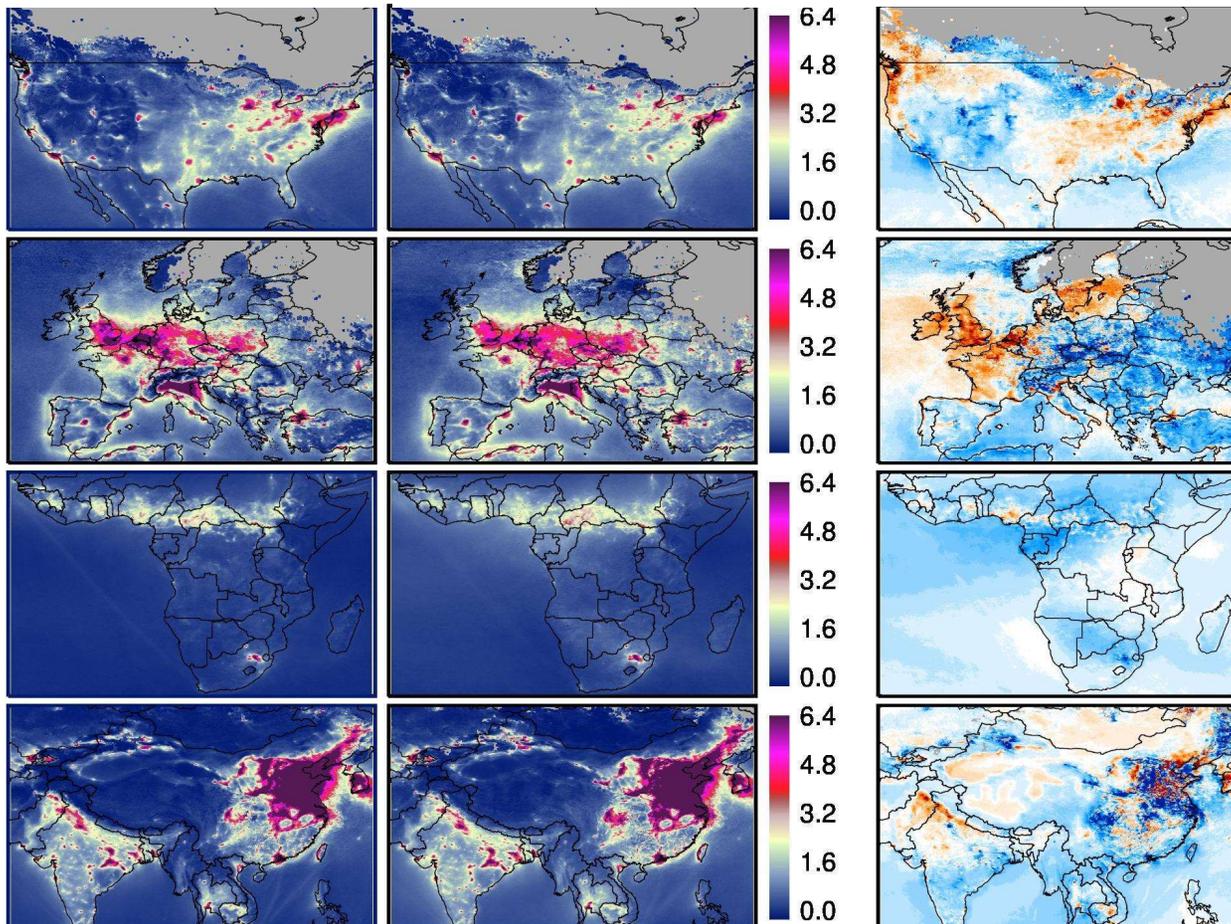
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TROPOMI NASA

TROPOMI Operational

NASA - Operational



- In polluted areas NASA tropospheric AMFs are smaller and VCDs are higher because of the use of GLER and *a priori* inputs.
- In background areas, operational product is higher primarily due to the difference in stratospheric NO₂ columns.

Dec2019-Jan2020-Feb2020



OMI continuation by TROPOMI: power plants



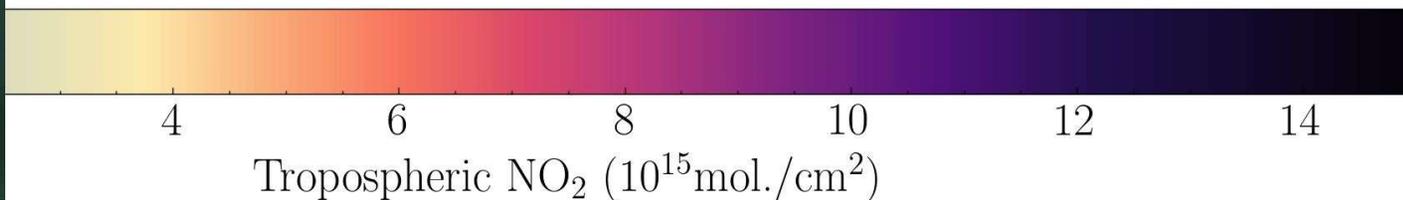
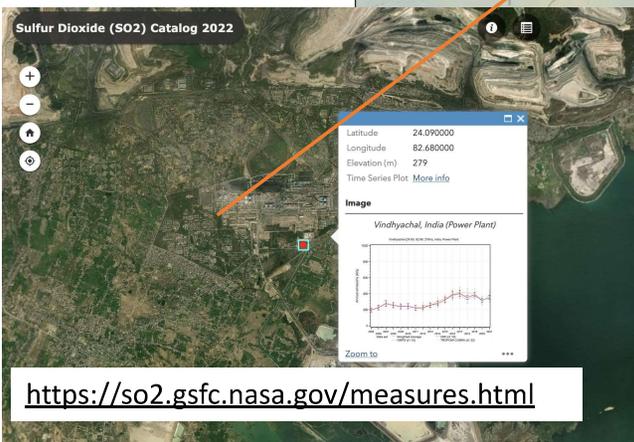
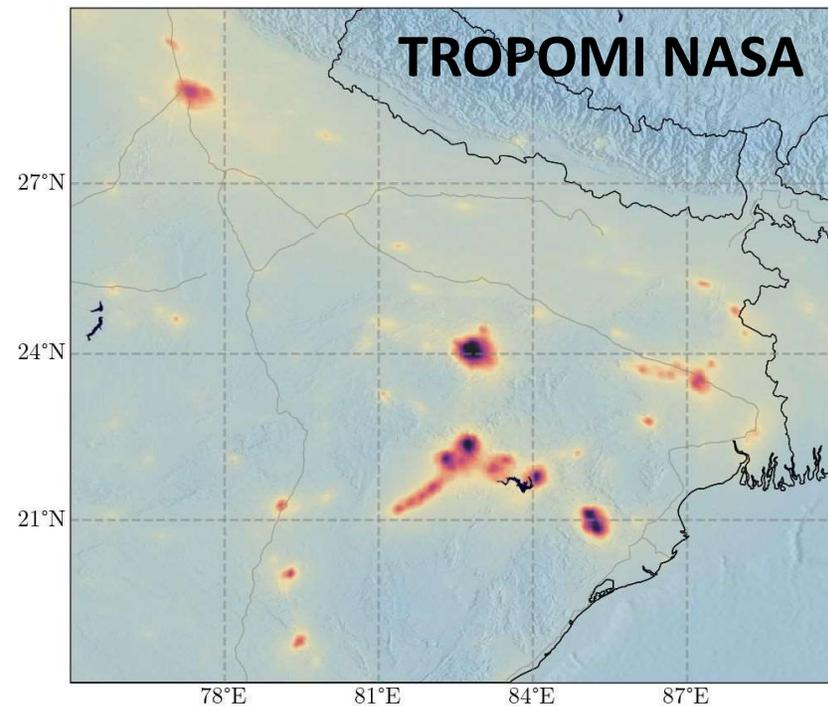
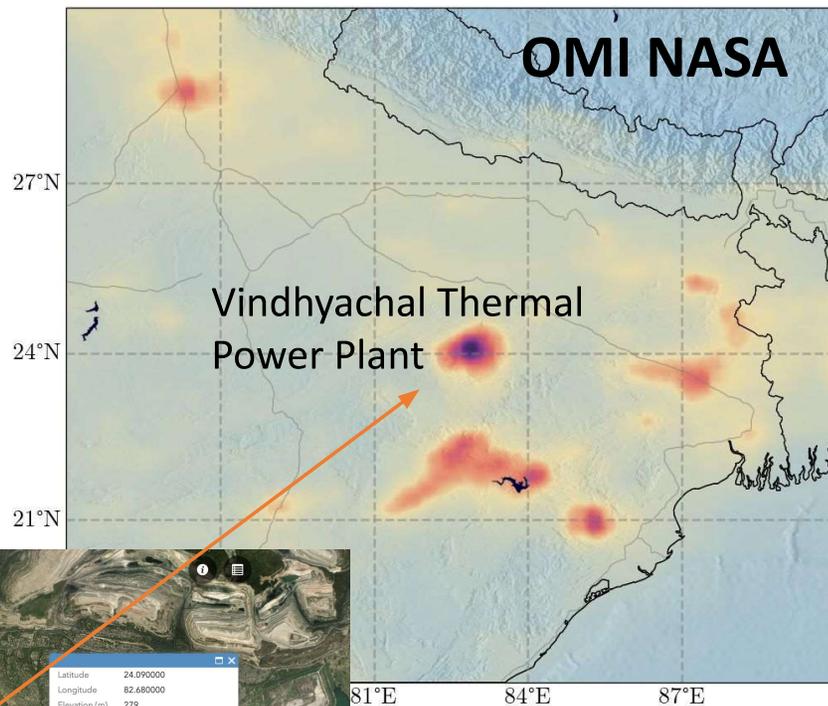
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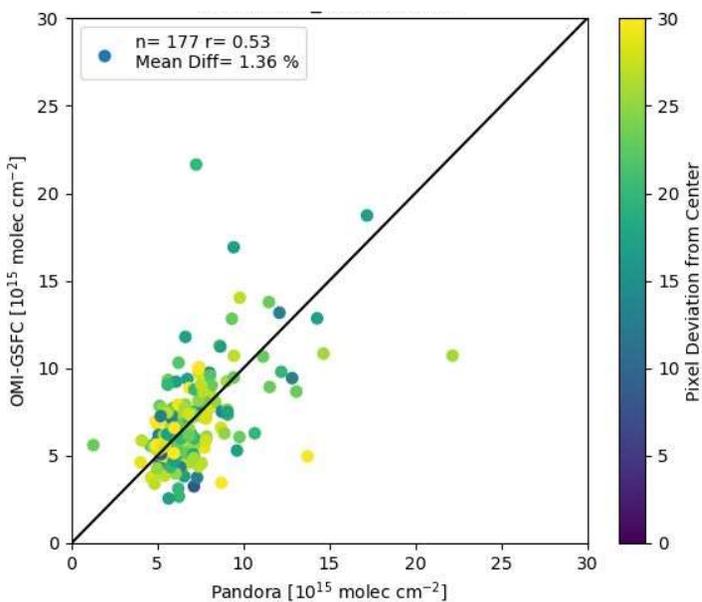
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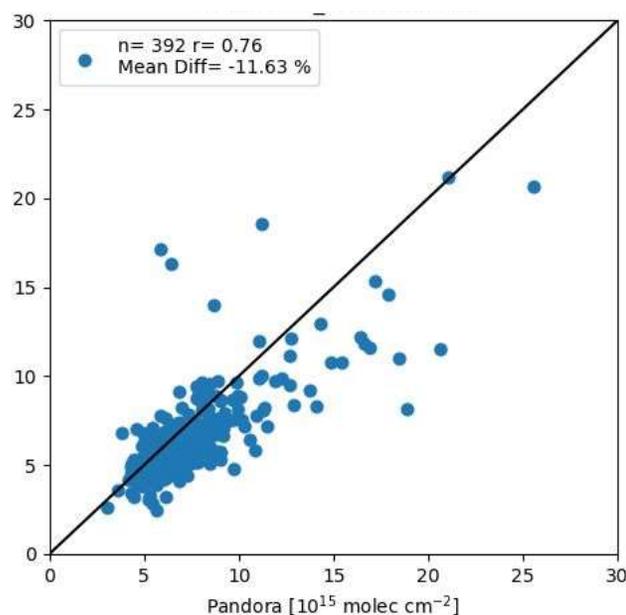
2020



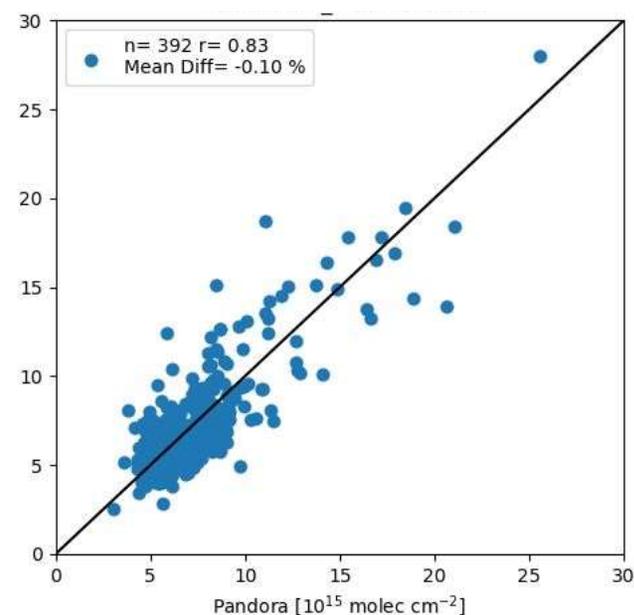
OMI vs Pandora



TROPOMI operational S5P-PAL/OFFLINE, v2.3.1



TROPOMI NASA S5P-PAL/OFFLINE, v2.3.1



Greenbelt, Maryland



Summary



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- ✓ Updated NASA AQ NO₂ web site – <https://airquality.gsfc.nasa.gov/no2>
- ✓ NASA COVID-19 NO₂ monitoring web site continues and will include TROPOMI data:
https://so2.gsfc.nasa.gov/no2/no2_index.html
- ✓ Compared OMI with TROPOMI NO₂:
 - TROPOMI **SCDs are higher** than OMI over background areas
 - TROPOMI tropospheric NO₂ is lower than OMI over background areas (land and water), but higher over pollution sources.
 - Considering spatial resolution is important for merging OMI and TROPOMI timeseries
- ✓ Publicly released OMI-continuation TROPOMI NO₂ Level 2 product:
https://disc.gsfc.nasa.gov/datasets/TROPOMI_MINDS_NO2_1.1/summary
- ✓ TROPOMI NASA product is lower than S5P operational product over background regions but reverses over polluted areas.
- ✓ NASA TROPOMI NO₂ data agree better with PANDORA NO₂ measurements