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Verification of TROPOMI NO_2 Product Using OMI NO_2 Algorithm

Nickolay A. Krotkov[1], Lok N. Lamsal [2,1], Bradford Fisher[3,1], Sungyeon Choi[3,1], Luke Oman[1], Wenhan Qin[3,1], Eun-Su Yang[3,1], Zachary Fasnacht[3,1], Joanna Joiner[1], Alexander Vasilkov[3,1], Sergey Marchenko[3,1], David Haffner[3,1], Peter J. T. Leonard [4,1], Henk Eskes[5], Jos van Geffen[5], Pepijn Veefkind[5], Folkert Boersma[5], William H. Swartz[6]

[1]NASA Goddard Space Flight Center, Greenbelt, MD 20770, USA

[2]University of Maryland Baltimore County, Baltimore, MD 20770, USA

[3]Science Systems and Application Inc., Lanham, MD 20706, USA

[4]ADNET Systems, Inc., Lanham, MD 20706, USA

[5]The Royal Netherlands Meteorological Institute, De Bilt, The Netherlands

[6]Johns Hopkins University, Applied Physics Laboratory, Laurel, MD 20723, USA

Outline

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- Developing Harmonized Multi-satellite NO_2 climate data records
  - OMI NO_2 algorithms: NASA and QA4ECV
  - OMI NO_2 trends
  - OMI global NO_2 monitoring web site
  - TROPOMI NO_2 algorithms: NASA and S5P offline
- OMI and TROPOMI Slant Columns Densities (SCD) comparisons
- OMI and TROPOMI tropospheric Vertical Columns (VCDs) comparisons
- OMI continuation with TROPOMI
- Validation of OMI and TROPOMI with Pandora NO_2 VCDs
- Summary

Developing Harmonized Multi-satellite NO_2 climate data records

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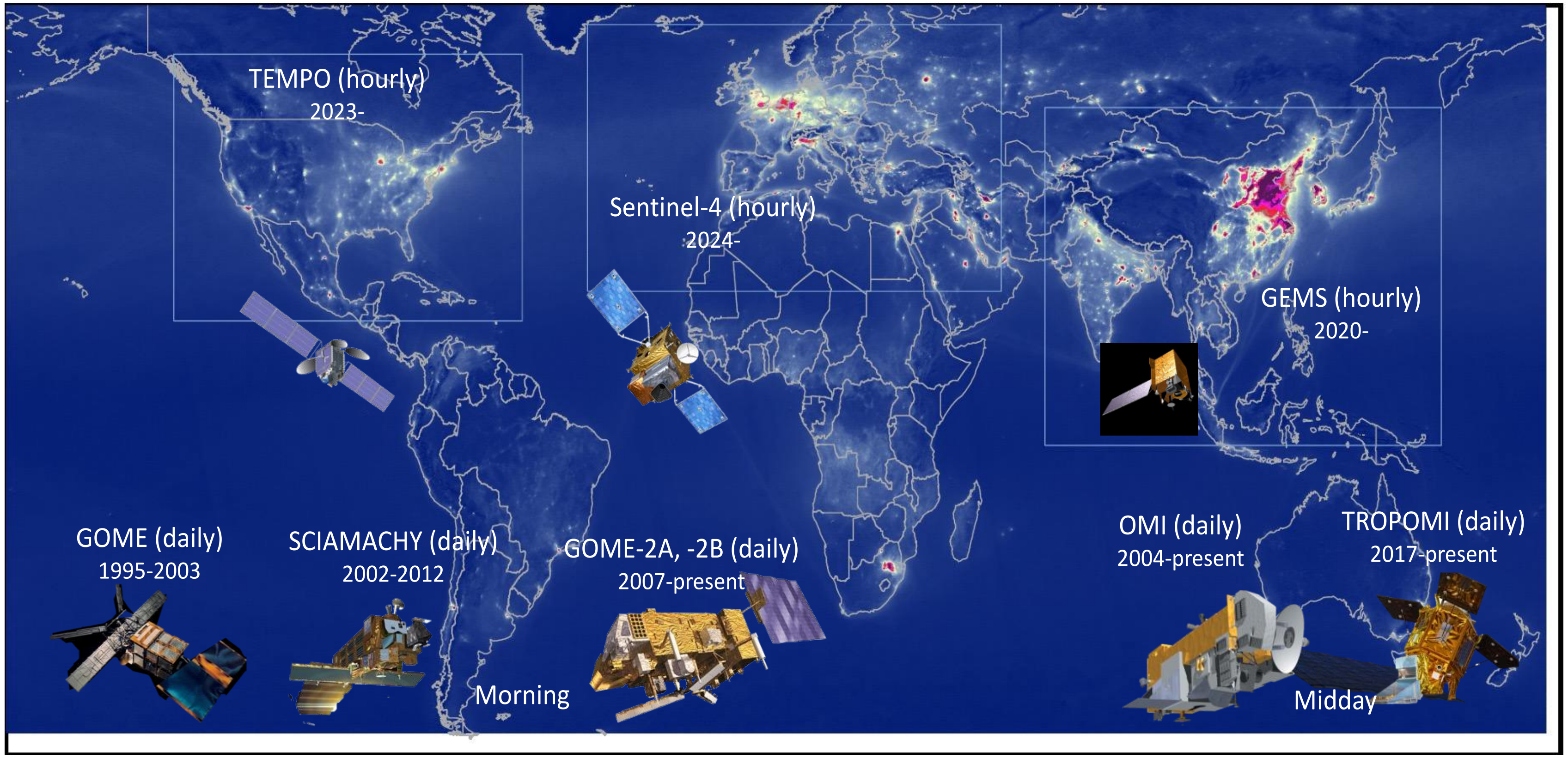
- **NASA Program**: Making Earth System Data Records (**ESDRs**) for Use in Research Environments (**MEaSUREs**).
- **Project:** Multi-Decadal Nitrogen Dioxide and Derived Products from Satellites (**MINDS):** **https://www.earthdata.nasa.gov/esds/competitive-programs/measures/minds.** Project PI: Lok 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 NO_2: Folkert Boersma

Satellite Tropospheric NO_2 Observations



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

NASA NO_2 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	TBA	L2 am	ERS-2/ GOME	1995 - 2003	2023
GOME2A/B_MINDS_ NO2	TBA	L2 am	MetOp/ GOME-2A/B	2006-	2023

- Lamsal at 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, at 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, at 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, at 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 NO_2 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 NO_2 trends: 2005 - 2021

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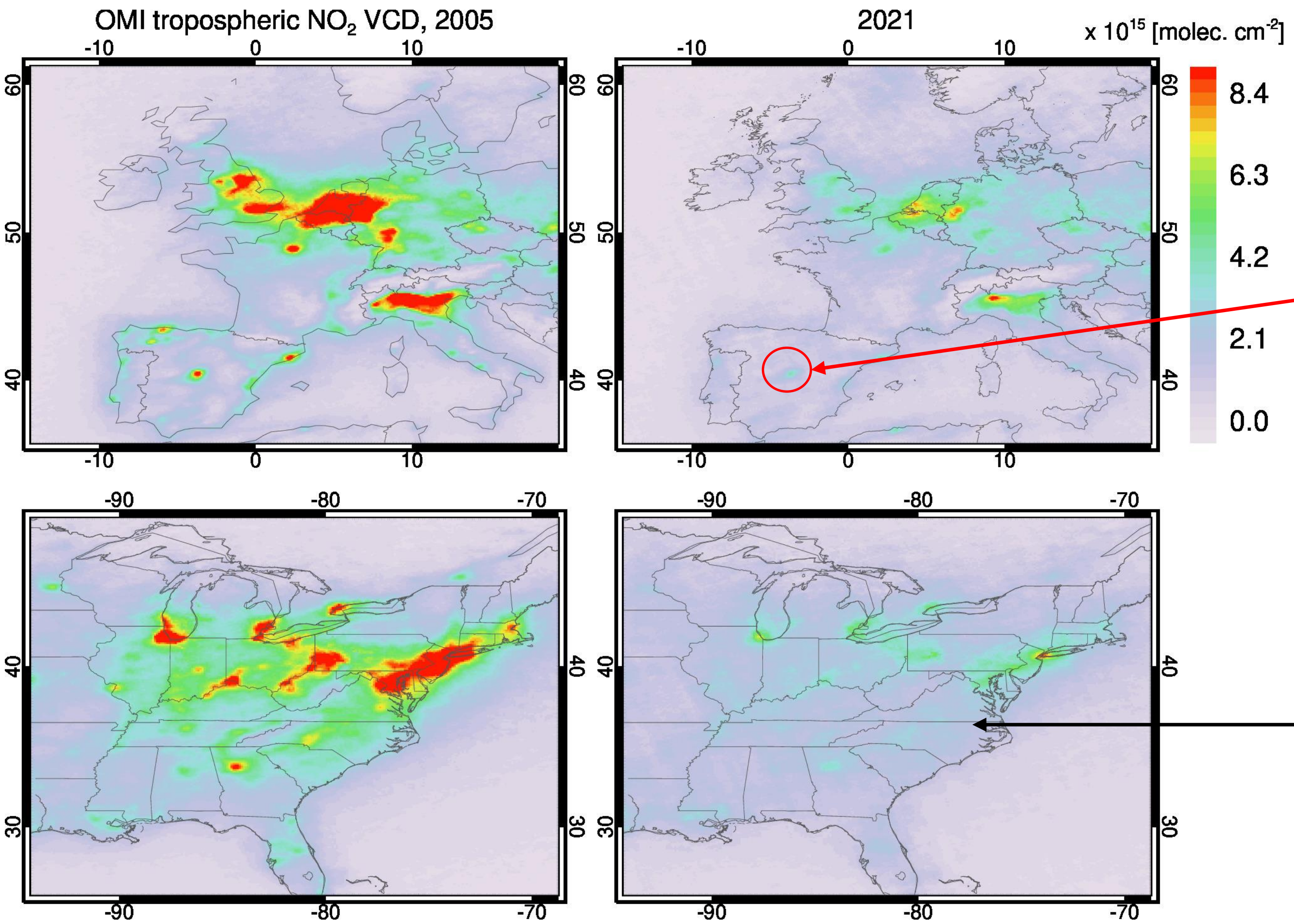
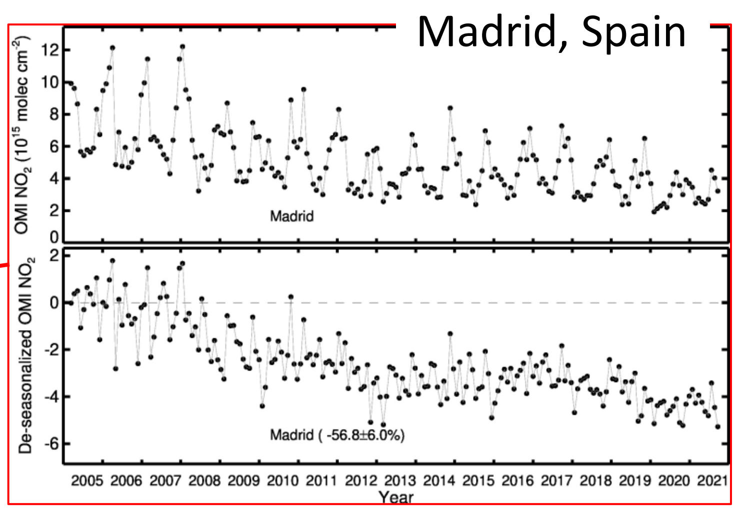
OMI NO_2 global and regional maps

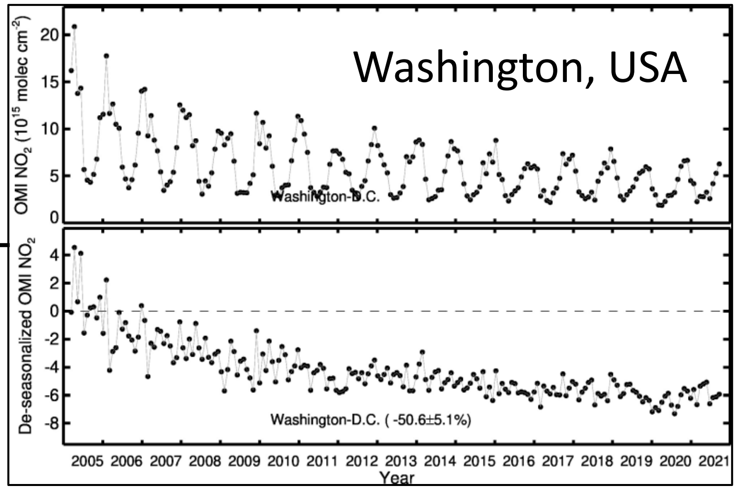
https://avdc.gsfc.nasa.gov



OMI NO_2 timeseries for 300+ cities and 300+ power plants

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





OMI Global NO_2 monitoring web site: COVID-19 anomalies

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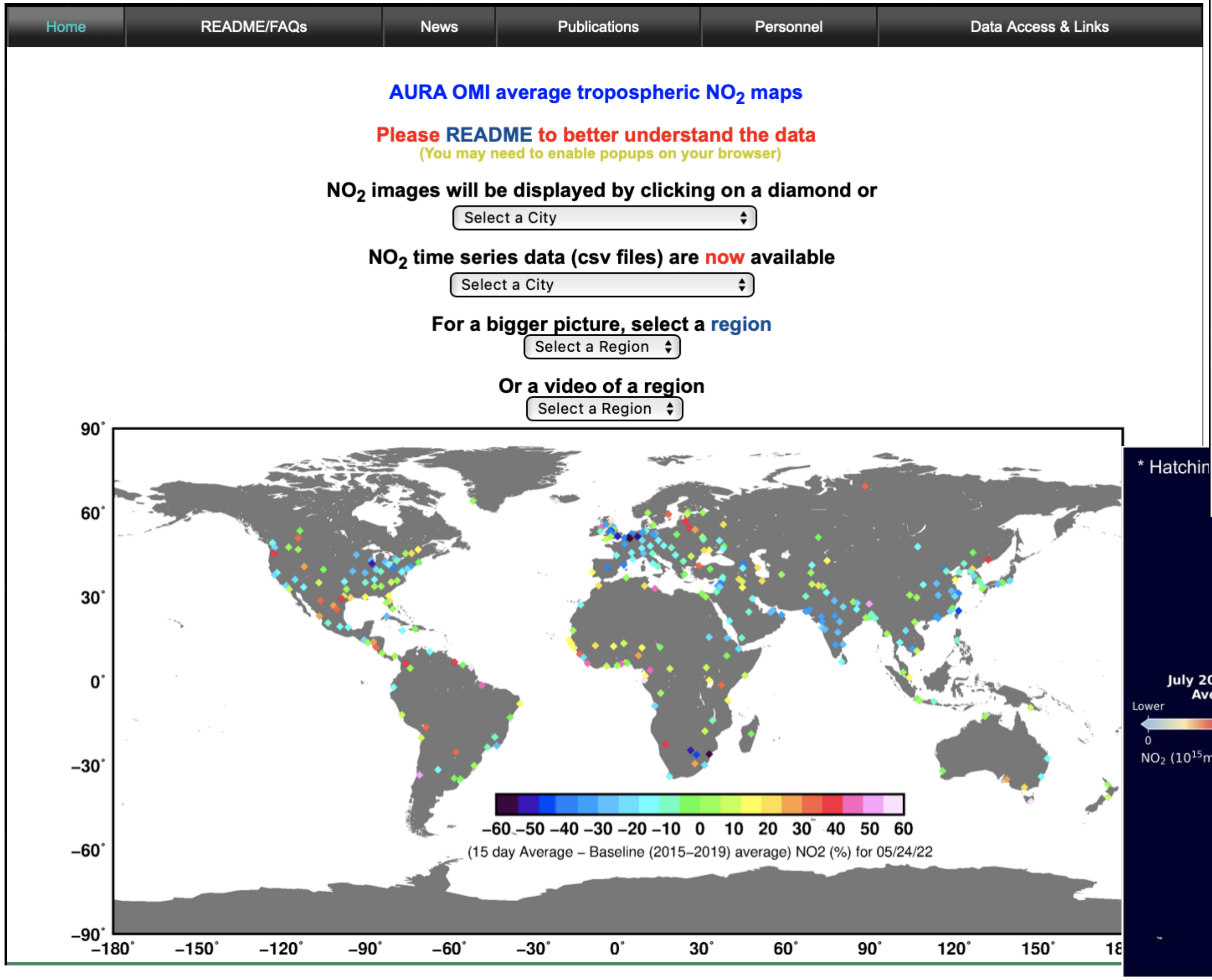
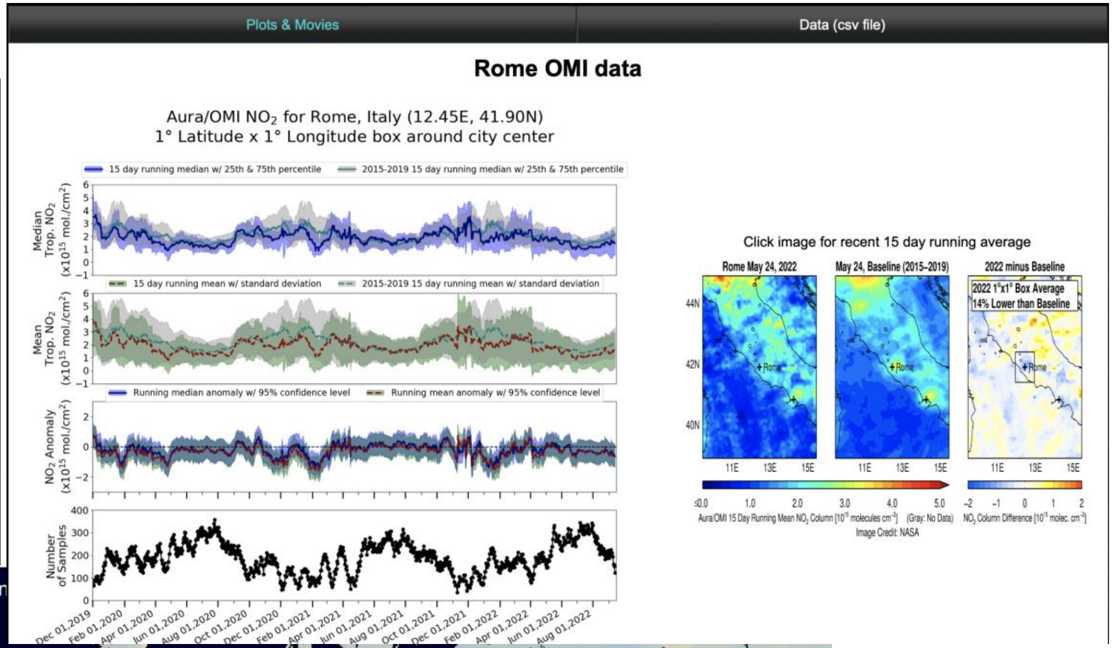
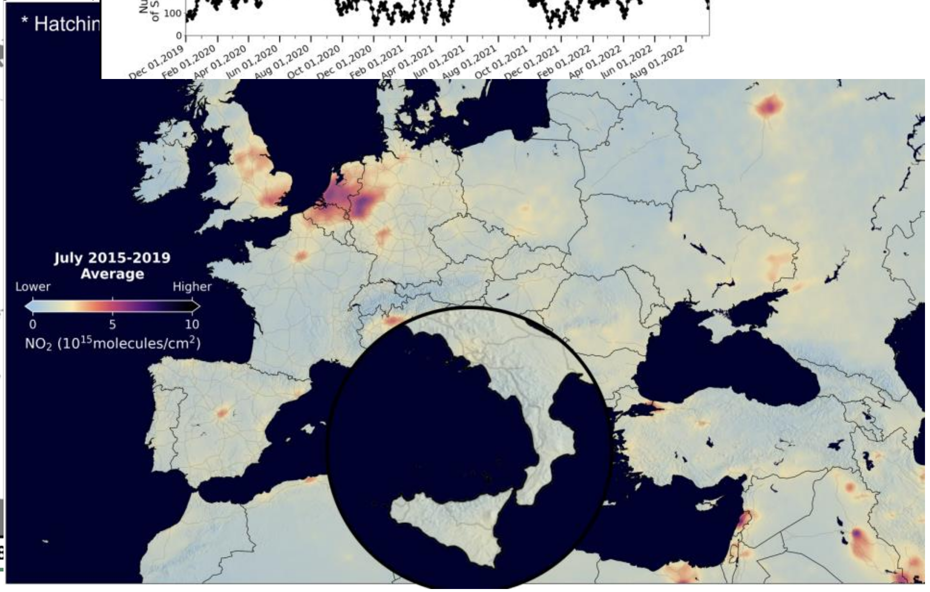
https://so2.gsfc.nasa.gov/no2/no2_index.html







Applying OMI NO_2 algorithm to TROPOMI

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^o x0.5^o	GLER at TROPOMI FoV [see Poster: Wenhan et al.]
Cloud products	OMLER climatology-based	GLER-based
A-priori NO_2 profiles	TM5 at 1^o x 1^o	*GMI-Replay at 0.25^o x 0.25^o
Strat-trop NO_2 separation	TM5 data assimilation	Observation-based (Bucsela et al., 2013)

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

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

OMI vs TROPOMI Slant Column Densities (SCD)

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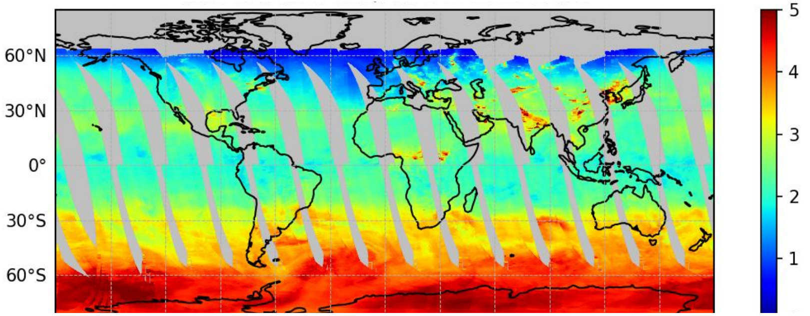
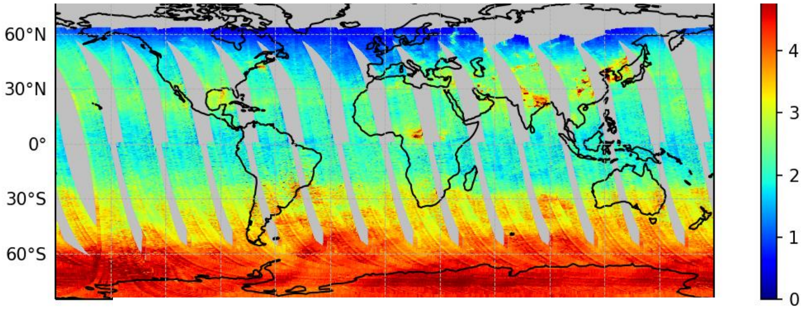
- Compared normalized SCDs from TROPOMI (S5P-PAL) with OMI (both QA4ECV & NASA retrievals)
- TROPOMI SCDs were averaged over OMI footprints for comparison
- TROPOMI NO_2 SCDs are less noisy than OMI, but appear little higher than two independent OMI NO_2 retrievals

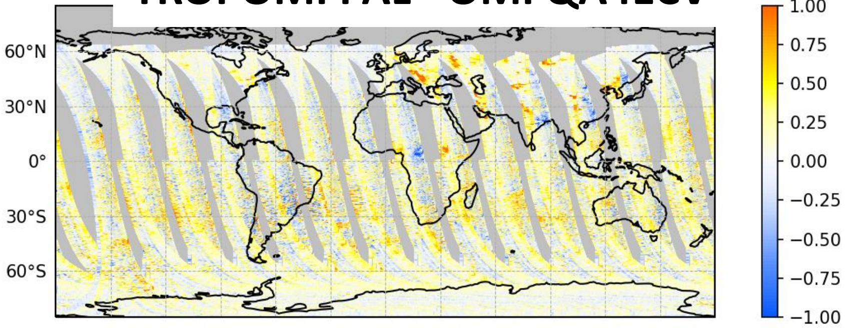
TROPOMI SCD/AMF$_{geom}$ 2018-12-20



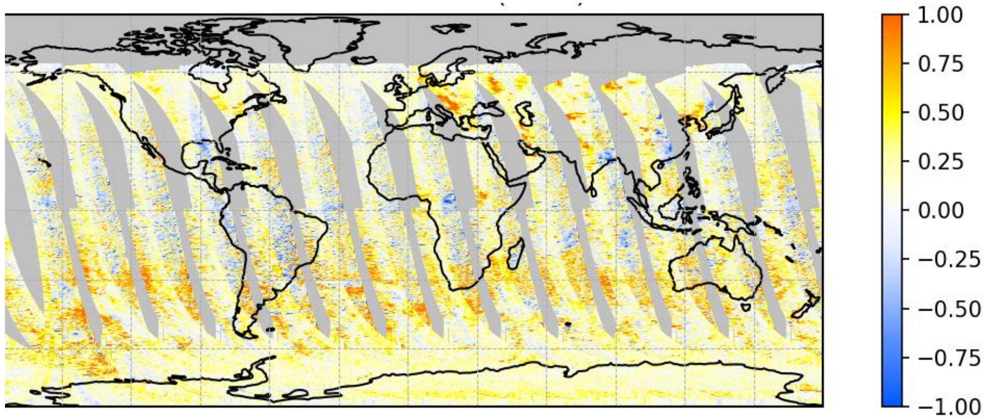
OMI QA4ECV SCD/AMF$_{geom}$ 2018-12-20



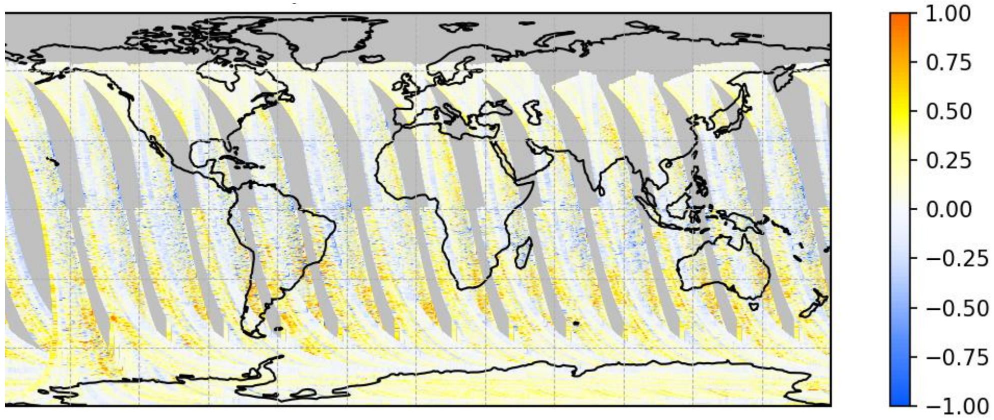
TROPOMI PAL - OMI QA4ECV



TROPOMI PAL - OMI NASA



OMI QA4ECV - OMI NASA



OMI vs TROPOMI Tropospheric NO_2

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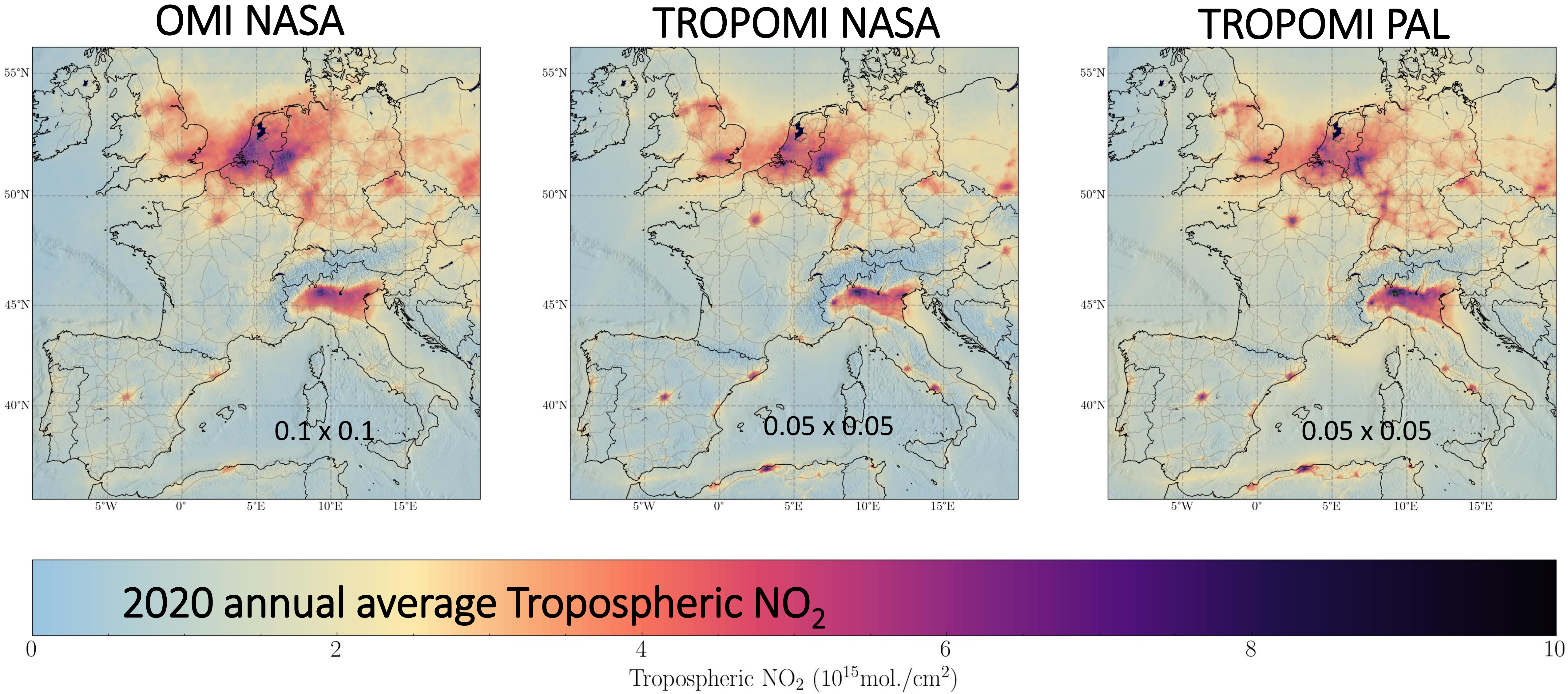

OMI continuation by TROPOMI: power plants

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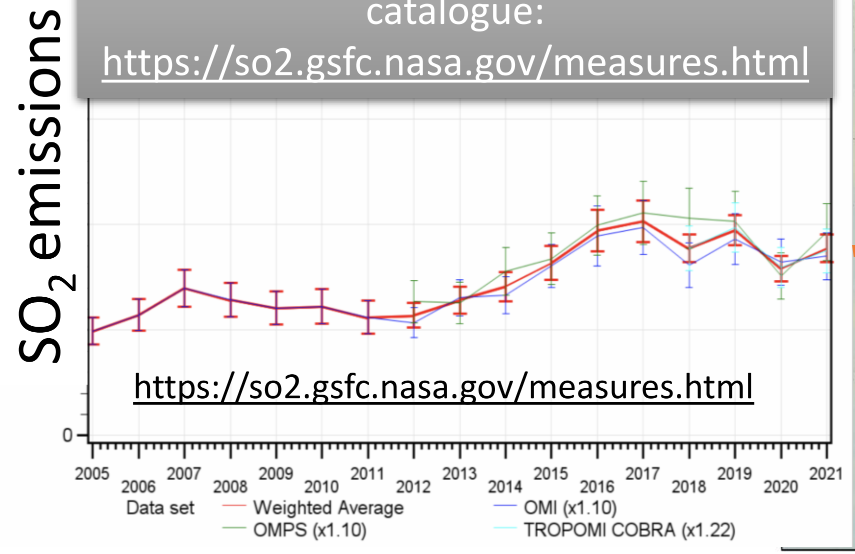
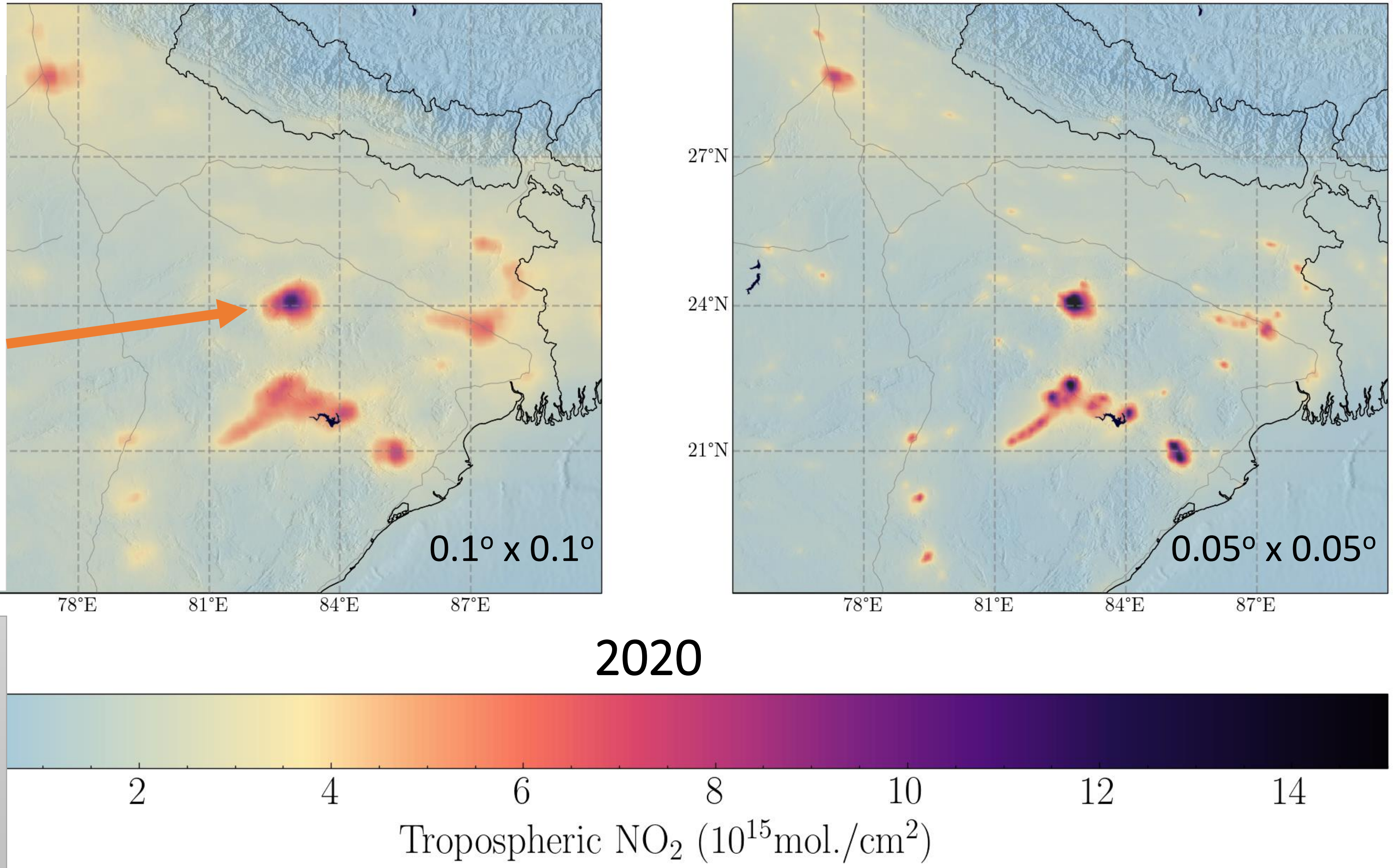
Vindhyachal Thermal Power Station, India

The OMI-OMPS-TROPOMI SO_2 emissions catalogue: https://so2.gsfc.nasa.gov/measures.html



OMI NASA NO_2 | TROPOMI NASA NO_2



See poster by Fioletov, V. et al.: Version 2 of the global catalogue of large anthropogenic and volcanic SO_2 sources and emissions derived from satellite measurements, Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2022-281

Comparison with Pandora NO_2 data

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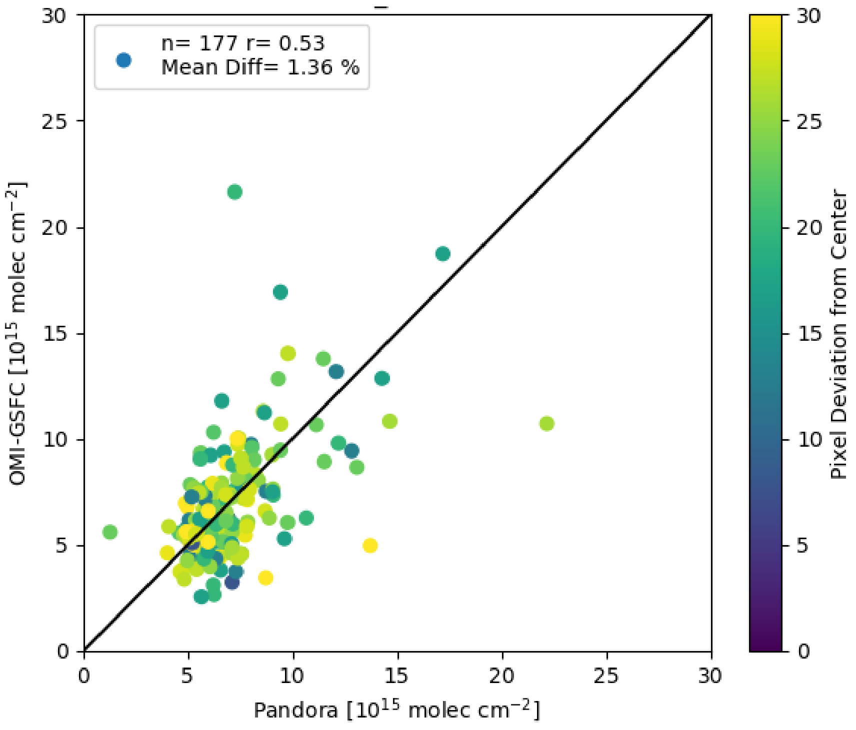
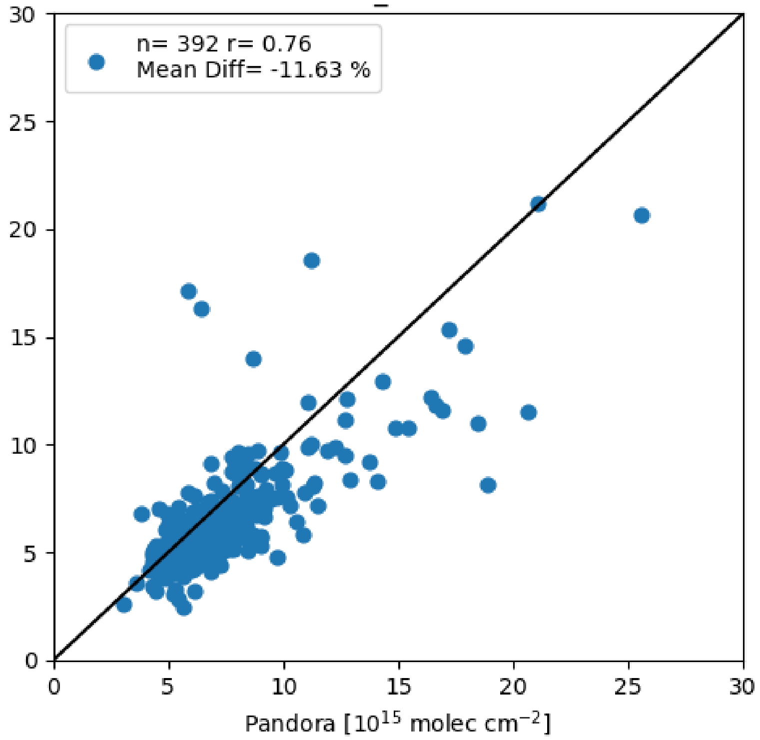
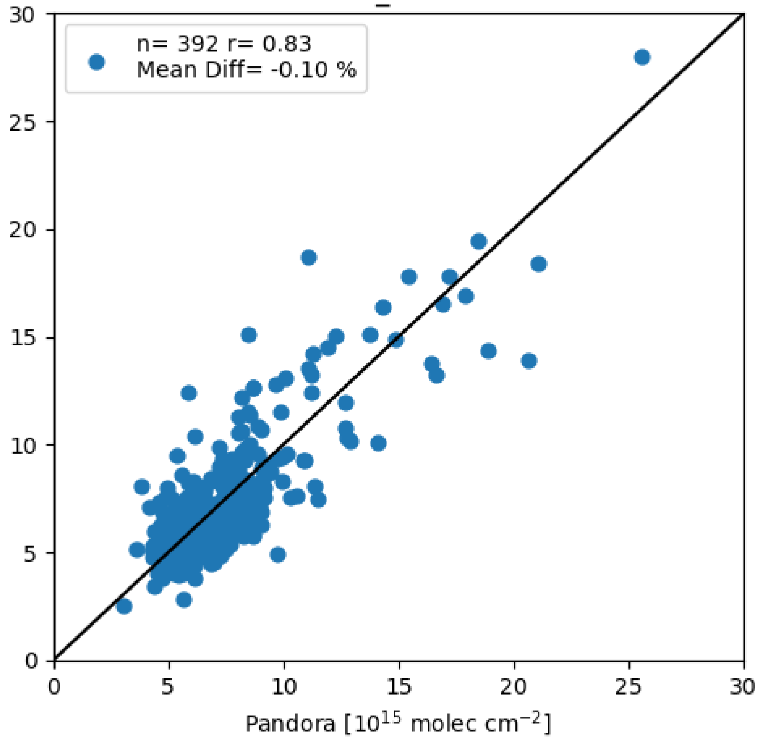
OMI vs Pandora



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 OMI NO_2 web site – https://airquality.gsfc.nasa.gov/no2
- ✓ Continued NASA COVID-19 NO_2 monitoring web site: https://so2.gsfc.nasa.gov/no2/no2_index.html

- ✓ Released NASA OMI-continuation TROPOMI NO_2 data: https://disc.gsfc.nasa.gov/datasets/TROPOMI_MINDS_NO2_1.1/summary

- ✓ Compared OMI with TROPOMI NO_2:
  - ➢ TROPOMI **SCDs are higher** than OMI over background areas
  - ➢ TROPOMI trop. **VCDs are lower** over background areas, but higher over pollution sources.
  - ➢ Merging OMI and TROPOMI trop. VCDs requires accounting for different background.

- ✓ TROPOMI NO_2 data agree better with PANDORA NO_2 measurements

TROPOMI tropospheric NO_2 NASA vs Operational

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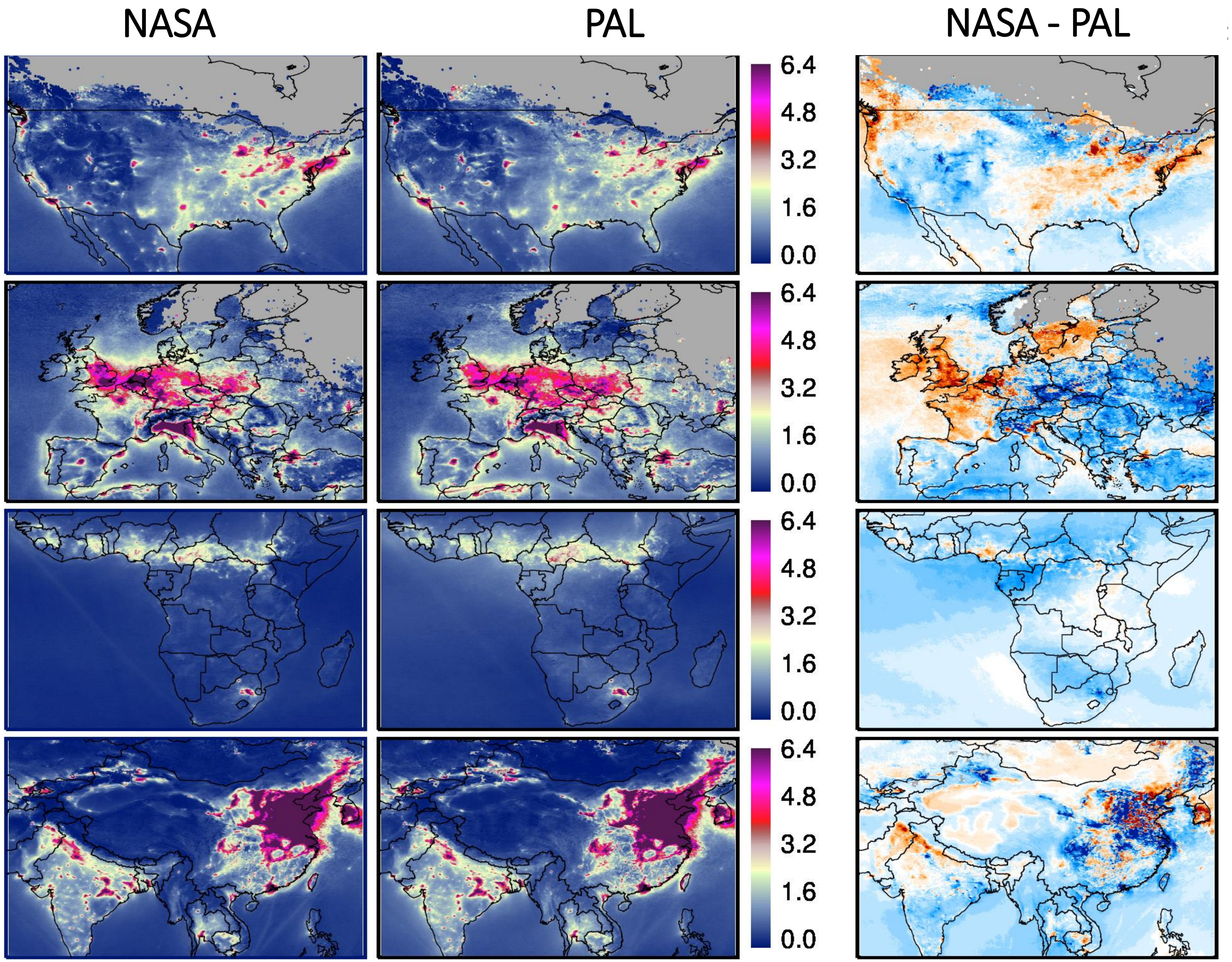

- In polluted areas NASA tropospheric AMFs are smaller and VCDs are higher because of the use of GLER and *a priori* inputs.
- In background areas, PAL VCDs are higher primarily due to the difference in stratospheric NO_2 columns.

Dec2019-Jan2020-Feb2020