

Multi-Satellite Nitrogen Dioxide and Derived Products from Satellites (MINDS): Application to GOME-2 on MetOp-A and -B

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MINDS: AN EFFORT TO UNIFY NO₂ DATA RECORD FROM UV/VIS SATELLITE INSTRUMENTS

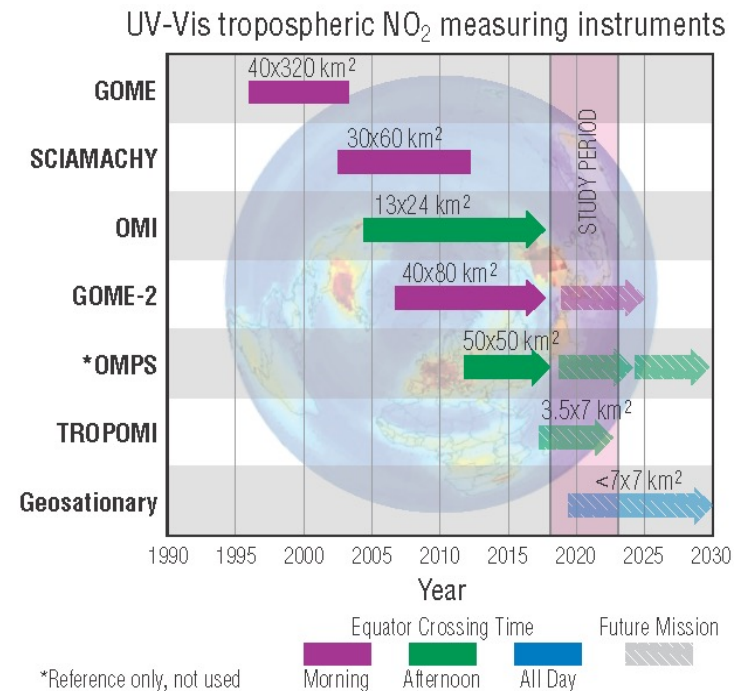
Challenges & motivation: Inconsistency in multi-satellite NO₂ data record

- 1) Difference in instrument & measurement characteristics
- 2) Difference in retrieval algorithms & inputs, affecting data accuracy and inter-satellite data consistency

MINDS: Multi-decadal Nitrogen dioxide and Derived products from Satellites (NASA MEaSUREs-17 program)

Goal: Develop consistent long-term (1995-present) data records of NO₂ products (L2 & L3) from similar satellite measurements (e.g., OMI, TROPOMI, GOME-2 on Metop-series)

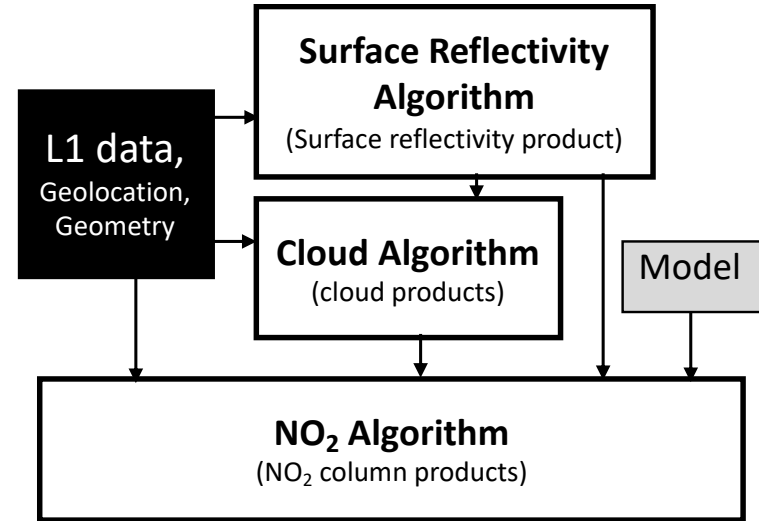
Approach: Apply a consistent algorithm to all sensors and enhance the quality of auxiliary data (surface reflectivity, cloud, etc.), including model-derived a-priori information



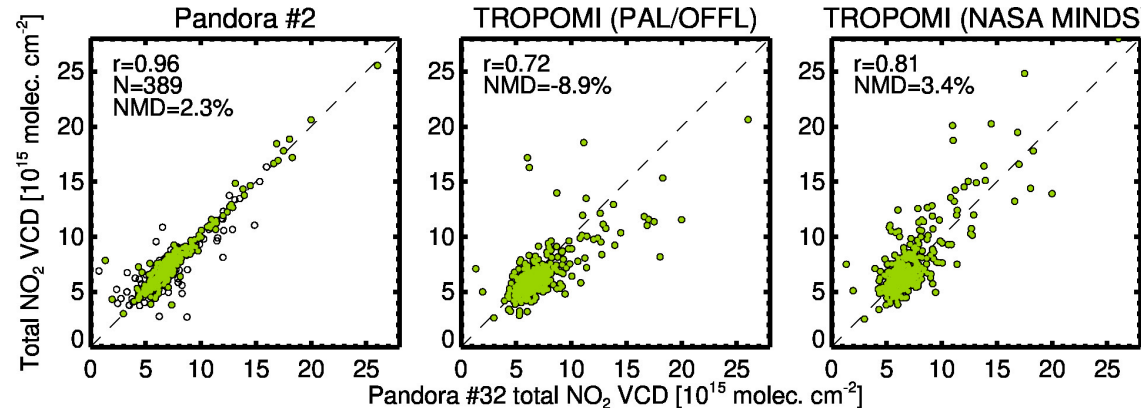
MINDS IMPLEMENTATION TO OMI, TROPOMI, AND GOME

- Foundation: NASA OMI NO₂ Standard Product Algorithm
- New features:
 - Accounting for surface reflectance anisotropy in cloud and NO₂ retrievals using **MODIS-based geometry-dependent surface reflectivity product (GLER)**
 - **GLER-based cloud retrievals**
 - Satellite field-of-view specific auxiliary information and improved treatment over snow/ice surfaces
 - A-priori NO₂ profiles from high-resolution (~25 km) global GEOS GMI simulation
- Significant change in tropospheric NO₂ retrievals (seasonal variation and trends), and Improved agreement with independent observations

MINDS approach



TROPOMI-Pandora comparison at Greenbelt, MD



DATA LINKS AND FUTURE UPDATES FOR OMI, TROPOMI, AND GOME

<https://measures.gesdisc.eosdis.nasa.gov/data/MINDS/>

OMI: current version is based on Col3 L1 data and will be updated in 2023 with Col4 L1 data

disc.gsfc.nasa.gov/datasets?keywords=MINDS&page=1

Refine By

Subject Sort ▾

Atmospheric Chemistry (5)

Measurement Sort ▾

Atmospheric Nitric Acid (5)

Nitric Oxide (5)

Nitrogen Dioxide (5)

Nitrogen Oxides (5)

Nitrous Oxide (5)

Source Sort ▾

Aura OMI (3)

ERS-2 GOME (1)

Sentinel-5P TROPOMI (1)

Processing Level Sort ▾

2 (3) 3 (1)

2G (1)

Project Sort ▾

MEaSUREs (5)

Temporal Resolution Sort ▾

98.8 minutes (1)

101.5 minutes (1)

1 day (2)

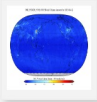
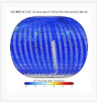
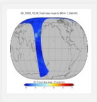
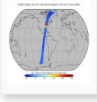
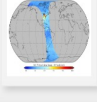
Spatial Resolution Sort ▾

5.5 km x 3.5 km (1)

13 km x 24 km (1)

0.25 ° x 0.25 ° (2)

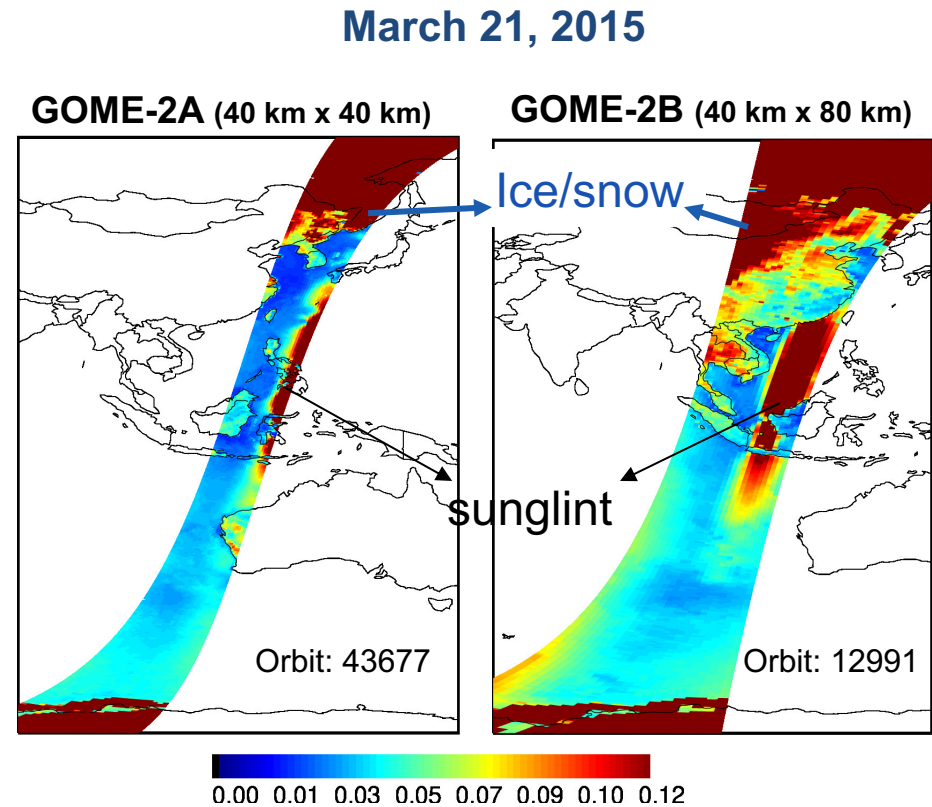
40 km x 320 km (1)

Dataset	Source	Version	Time Res.	Spatial Res.	Process Level	Begin Date	End Date
 OMI/Aura NO2 Tropospheric, Stratospheric & Total Columns MINDS Daily L3 Global Gridded 0.25 degree x 0.25 degree (OMI_MINDS_NO2d 1.1) Subset / Get Data	Aura OMI	1.1	1 day	0.25 ° x 0.25 °	3	2004-10-01	2021-12-30
 OMI/Aura NO2 Tropospheric, Stratospheric & Total Columns MINDS Daily L2 Global Gridded 0.25 degree x 0.25 degree (OMI_MINDS_NO2G 1.1) Get Data	Aura OMI	1.1	1 day	0.25 ° x 0.25 °	2G	2004-10-01	2022-11-29
 OMI/Aura NO2 Tropospheric, Stratospheric & Total Columns MINDS 1-Orbit L2 Swath 13 km x 24 km (OMI_MINDS_NO2 1.1) Get Data	Aura OMI	1.1	98.8 minutes	13 km x 24 km	2	2004-10-01	2022-01-01
 GOME/ERS-2 NO2 Tropospheric, Stratospheric and Total Columns MINDS 1-Orbit L2 Swath 40 km x 320 km (GOME_MINDS_NO2 1.1) Get Data	ERS-2 GOME	1.1		40 km x 320 km	2	1996-01-01	2003-06-22
 TROPOMI/S5P NO2 Tropospheric, Stratospheric and Total Columns MINDS 1-Orbit L2 Swath 5.5 km x 3.5 km (TROPOMI_MINDS_NO2 1.1) Get Data	Sentinel-5P TROPOMI	1.1	101.5 minutes	5.5 km x 3.5 km	2	2018-05-01	2022-01-01

TROPOMI: current version is based on V1-V2 L1 and V2.3.1 L2 NO₂ slant column data, and will be updated in 2023 following official release of L1 and L2 data

DEVELOPMENT OF SURFACE REFLECTIVITY PRODUCT FOR GOME-2 ON METOP-A (2006-2021) AND METOP-B (2012-)

- Current GOME-2 trace-gas and cloud retrievals use **climatological LER** for surface reflectivity
- We develop **Geometry-dependent surface LER (GLER)** product for GOME-2; it is more accurate and captures the solar and satellite viewing angle dependence as well as seasonal changes
- GLER is based on MODIS BRDF products over land and Cox-Munk surface wave slope distribution with a contribution from water-leaving radiance over water

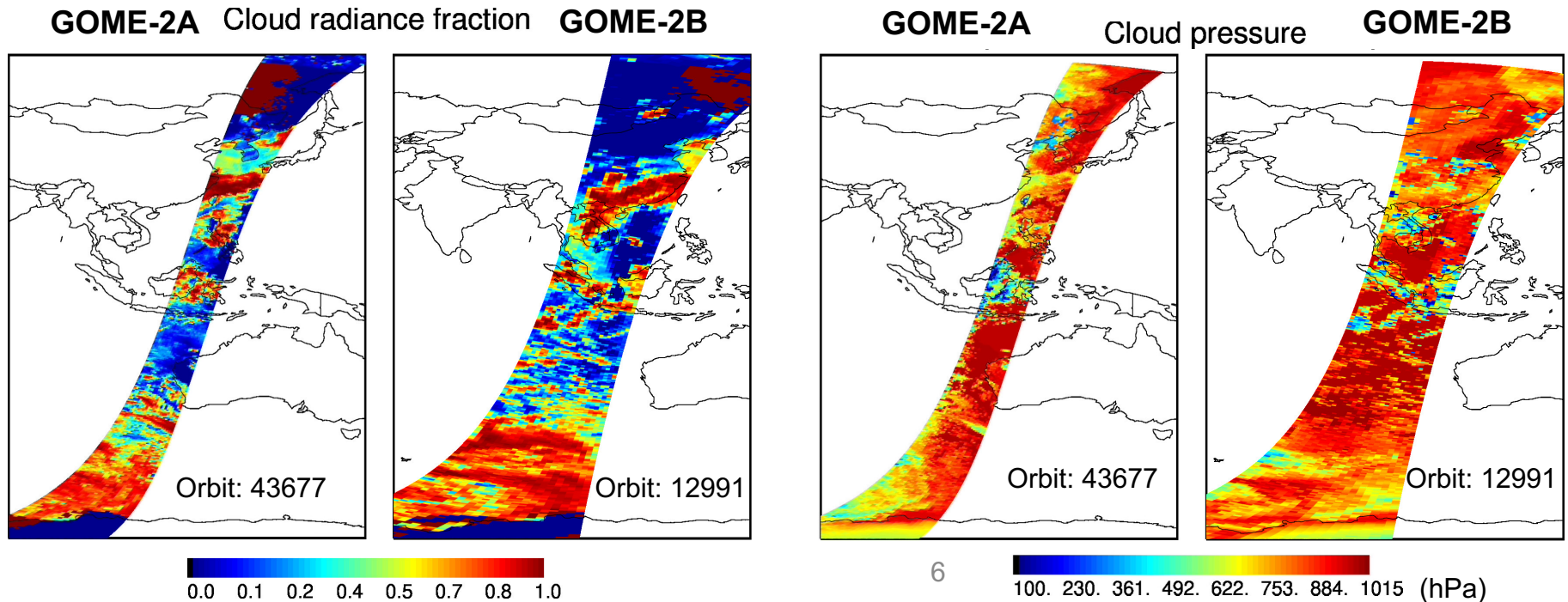


*Since 2013, GOME-2A and GOME-2B operate in tandem with GOME-2A in narrower swath and higher ground resolution mode

NEW CLOUD PRODUCT DEVELOPMENT FOR GOME-2A AND GOME-2B: MOTIVATION & APPROACH

- Cloud parameters (cloud fraction & pressure) are important error source for NO₂ retrievals, and retrievals of NO₂ and cloud are highly sensitive to surface reflectivity
- Our retrievals of cloud products
 - ✓ are based on O₂-O₂ absorption at 477 nm
 - ✓ use the auxiliary information (e.g., GLER, surface pressure) that are used by NO₂ algorithm

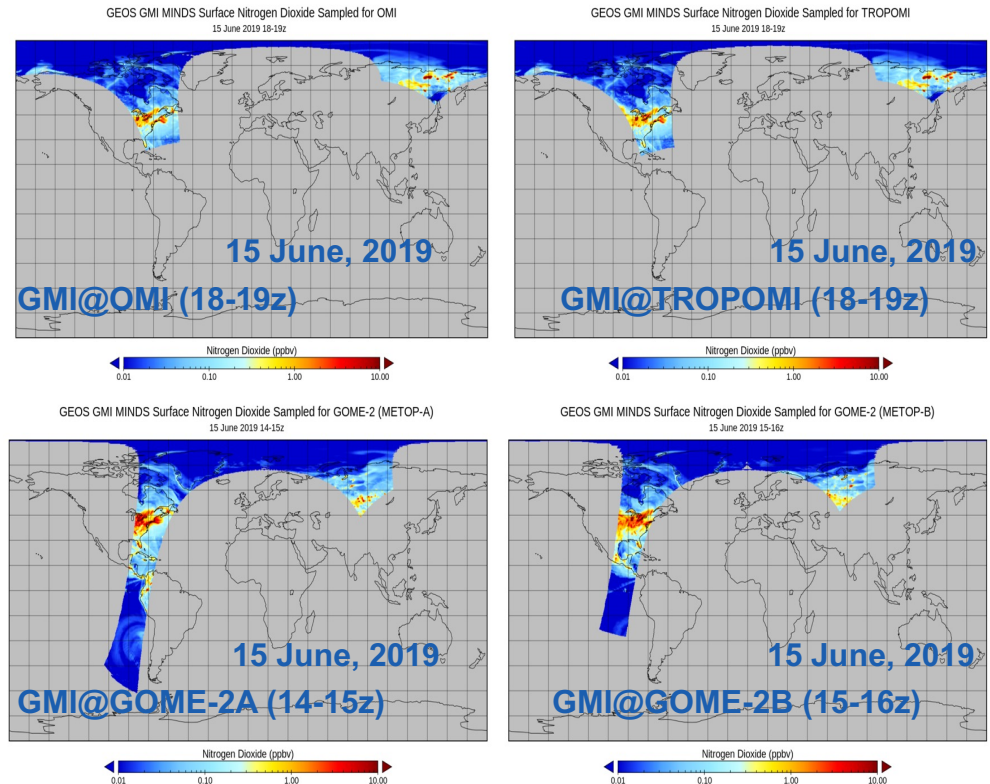
March 21, 2015



MODEL-BASED AUXILIARY INFORMATION FROM HIGH-RESOLUTION GEOS GMI (MINDS) SIMULATION

- A new GMI-Replay simulation for improved a-priori (profile shape) and data interpretation
 - High-resolution ($0.25^\circ \times 0.25^\circ$) **vs.** much coarser ($>1^\circ \times 1^\circ$) data by current operational algorithms
 - Includes full stratospheric and tropospheric chemistry from GMI
 - Based on updated emissions (**including COVID-driven emissions for 2020-2021**)
 - Simulation period: 1995-present
- Simulates the actual instrument swath width as satellite travels **vs.** current fixed local time approach (e.g. 9-10 AM for GOME-2)
- Model output sampled for GOME, SCIAMACHY, GOME-2 (on METOP-A, -B, -C), OMI, OMPS (on SNPP and NOAA-20), and TropOMI

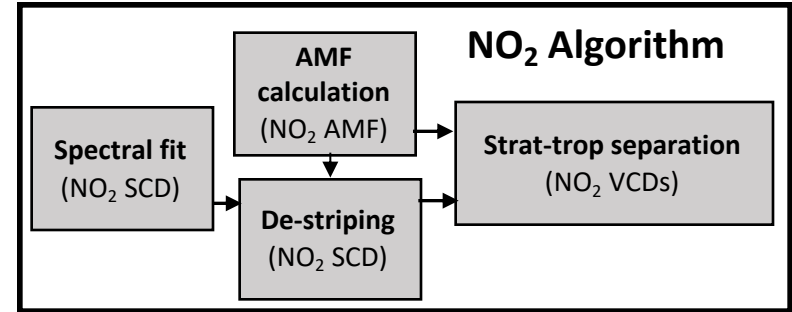
GMI-Replay simulation with satellite simulator



DEVELOPING MINDS GOME-2A AND GOME-2B TROPOSPHERIC AND STRATOSPHERIC NO₂ PRODUCTS

Applying NASA NO₂ algorithm to GOME-2

- 1) Spectral fit (DOAS) and de-stripping
- 2) Air mass factor (AMF) calculation
- 3) Observation-based stratosphere-troposphere separation



Tropospheric NO₂ VCD

March 21, 2015

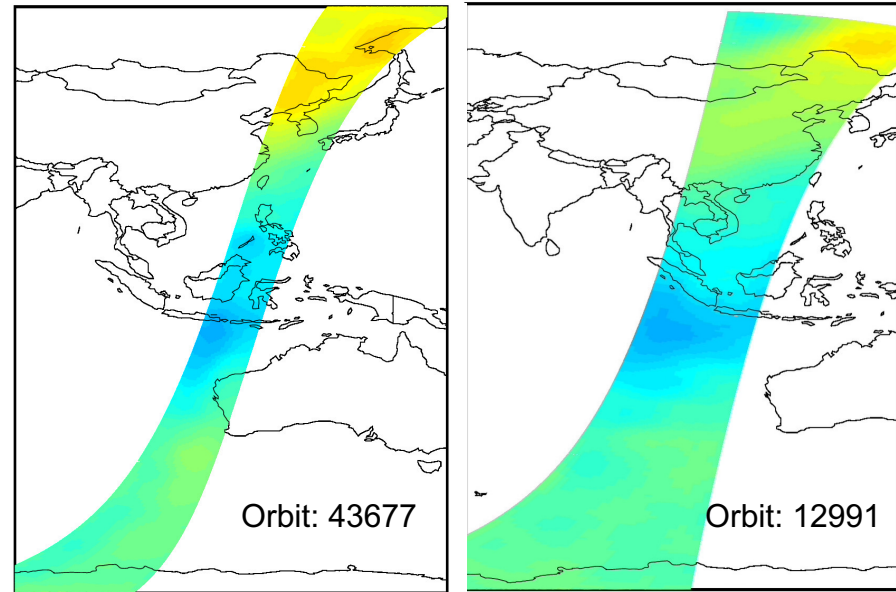
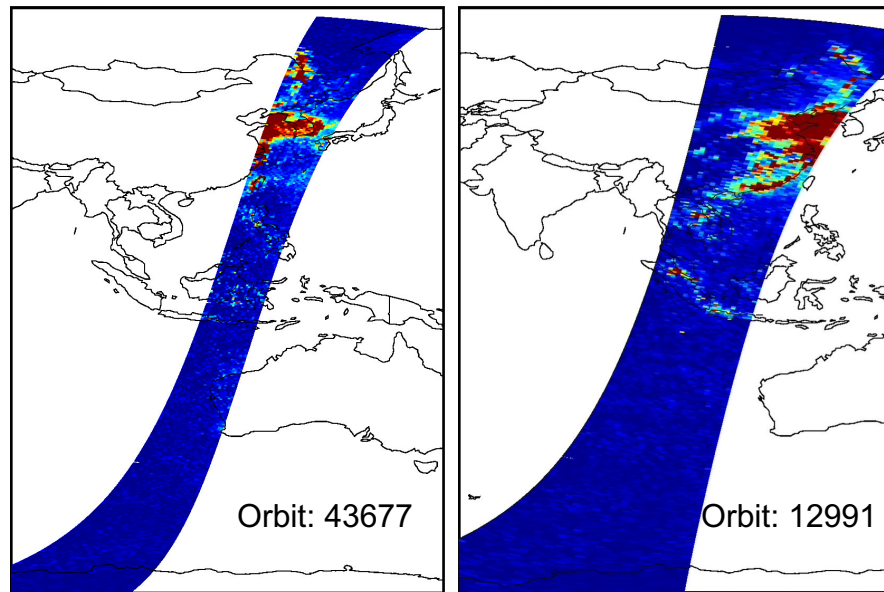
Stratospheric NO₂ VCD

GOME-2A

GOME-2B

GOME-2A

GOME-2B



0.0 1.4 2.8 4.2 5.6 7.0 8.4 9.8 x 10¹⁵ molec cm⁻²

0.0 0.6 1.2 1.8 2.4 3.0 3.6 4.2 x 10¹⁵ molec cm⁻²

CONCLUSIONS

- **MEaSURES NO₂ (MINDS)**
 - **Goal:** Develop consistent long-term (1995-present) global trend-quality data records of NO₂ products from similar satellite measurements (GOME, SCIAMACHY, OMI, GOME-2, TROPOMI)
 - **Approach:** Apply coupled surface reflectivity-cloud-NO₂ algorithm & high-resolution auxiliary data in both cloud and NO₂ retrievals
- **Algorithm development and product release status**
 - OMI, TROPOMI, and GOME NO₂ products developed and released
 - Algorithm implementations for GOME-2 on both Metop-A and –B are complete, and data processing and evaluation are ongoing. Release plan: summer of 2023.
 - Updates are planned for OMI and TROPOMI next year due to changes in L1 data

Contact: Lok Lamsal, UMBC & NASA GSFC (lok.lamsal@nasa.gov)

Acknowledgment: NASA MEaSURES, ACMAP, and Aura programs for funding

EXTRA SLIDES

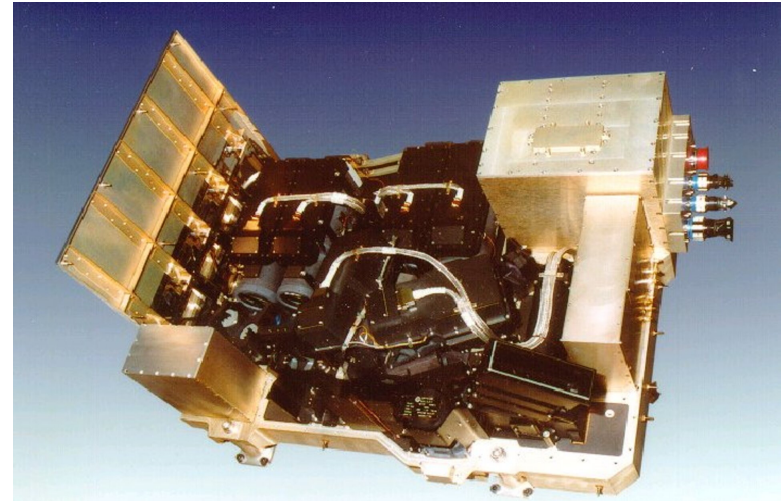
STATUS OF MINDS WORK & DATA RELEASE PLANS

MINDS work		OMI	GOME	TROPOMI	GOME-2A	GOME-2B
GLER algorithm		✓	✓	✓	✓	✓
Cloud algorithm		✓	✓	✓	✓	✓
MINDS simulation implementation		X	✓	✓	✓	✓
NASA NO ₂ algorithms	SCD	✓	✓	X	✓	✓
	AMF	✓	✓	✓	✓	✓
	VCD	✓	✓	✓	✓	✓
Data processing & evaluation		✓	✓	✓	*	*
Data release		2020	2022	2022	Mid-2023	Mid-2023

- Public release of MINDS products for OMI, GOME, and TROPOMI in CF-compliant netCDF file format
- Currently focusing on GOME-2A and -2B instruments, and data products evaluation phase

GOME-2 ON METOP-A AND -B

- Nadir-viewing scanning spectrometer with higher ground resolution (40 km x 80 km) than GOME (40 km x 320 km)
- GOME-2 on Metop-A (GOME-2A; 2006-2021), Metop-B (GOME-2B; 2012-present), and Metop-C (GOME-2C; 2018-present)
- Since 2013, GOME-2A and GOME-2B operate in tandem with GOME-2A in narrower swath and higher ground resolution (40 km x 40 km) mode



GOME-2

<i>Item</i>	<i>Budget</i>
Spectral band (nm)	240 nm – 790 nm
Spectral resolution (nm)	0.26 - 0.51
Spatial resolution Metop-A (km ²) before 15 July 2013	40 × 80 (main channels) 40 × 10 (PMD)
Spatial resolution Metop-A (km ²) after 15 July 2013	40 × 40 (main channels) 40 × 5 (PMD) after 15 July 2013
Spatial resolution Metop-B (km ²)	40 × 80 (main channels) 40 × 10 (PMD)
Swath width Metop-A (km) before 15 July 2013	1920
Swath width Metop-A (km) after 15 July 2013	960
Swath width Metop-B (km)	1920
Spectral channels	4096
Polarization channels	30
Calibration system	Spectral lamp, white lamp, solar diffuser