An improved tropospheric NO_2 product for the GEMS instrument

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1 Introduction

NO_2 in the troposphere

- key pollutant, produced by combustion processes, lightning, soil bacteria
- harmful for human health
- precursor of tropospheric ozone
- leads to aerosol formation and acid rain

Satellite retrievals of tropospheric NO_2

- long time series from GOME, SCIAMACHY, OMI, TROPOMI
- provide spatial distribution, trends, emissions, transport patterns
- so far only from sun-synchronous orbits => one measurement per day

The GEMS instrument

- first in a constellation of geostationary instruments (with TEMPO and S4)
- up to 12 measurements per day, 1 hour time resolution
- measurements over Asia, spatial resolution up to 4 x 7 km^2
- launched in February 2020

2 IUP-UB NO_2 retrieval

IUP GEMS NO_2 retrieval

- DOAS retrieval in a large fitting window (405 - 485 nm)
- Polarisation correction, destriping
- Stratosphere from STREAM (Beirle et al., 2016)
- NO_2 a priori profiles from TM5
- OMI surface reflectivity
- Cloud correction using GEMS V1 lv2 cloud data
- No aerosol correction
- No BRDF correction

3 Seasonal variation

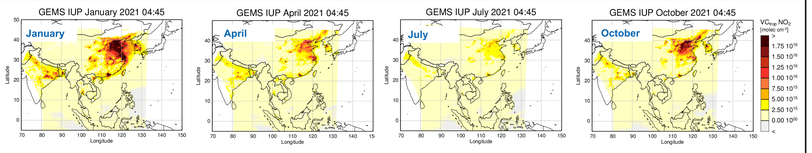

Figure 1: Seasonal variation of IUP GEMS tropospheric NO_2 columns at 04:45 UTC. No cloud correction has been applied (see discussion in box #4).

Seasonal variation of GEMS IUP tropospheric NO_2 columns is as expected:

- higher values in winter, lower values in summer
- low background values outside anthropogenic pollution regions

Acknowledgements

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- TROPOMI lv1 and lv2 data provided by Copernicus
- GEMS lv1 and lv2 data provided by NIER

4 Comparison to TROPOMI data

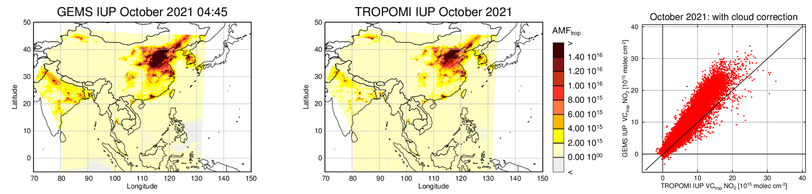


Figure 2: Comparison of monthly mean tropospheric NO_2 columns for October 2021 between GEMS IUP data at 04:45 UTC (left) and TROPOMI IUP data (middle). Cloud screening and cloud correction is applied. The scatter plot (right) shows good correlation but some scatter and systematic overestimation by IUP GEMS.

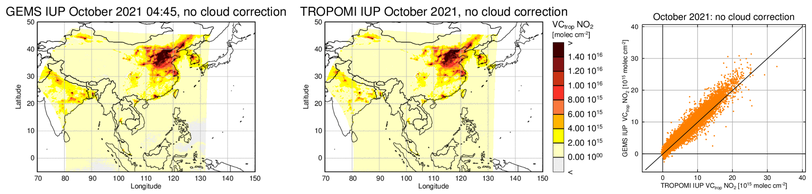


Figure 3: As Figure 2, but without cloud correction. Only cloud screening is applied. As seen from the scatter plot (right), both the correlation and the scatter improve considerably. However, absolute values may be biased low without cloud correction.

Cloud problems in GEMS data

- applying consistent settings to GEMS and TROPOMI results in very similar but not identical results
- only difference is use of different cloud products
- analysis without cloud correction leads to much better agreement
- GEMS lv2 cloud product appears to still have problems

Oversampling

- when averaged over one month, TROPOMI data appears smoother and GEMS data more rasterized
- TROPOMI's changing orbits lead to better oversampling of the scene

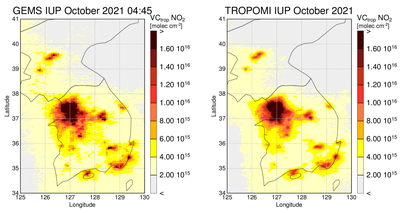


Figure 4: Monthly average of IUP GEMS (left) and IUP TROPOMI (right) tropospheric NO_2 for October 2021. Measurement pattern remains visible in GEMS data because there is less oversampling than in TROPOMI observations.

5 Diurnal variation

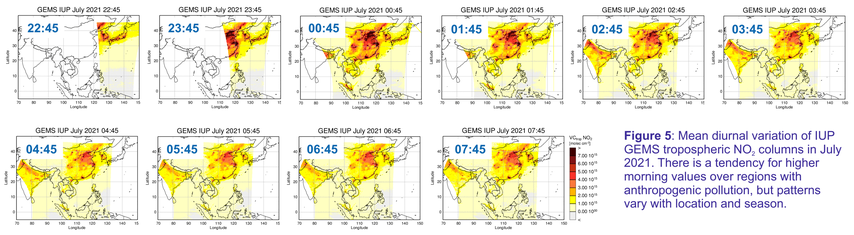
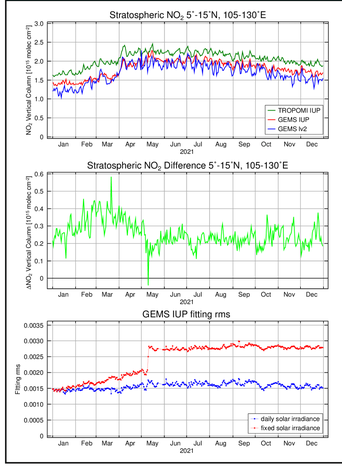


Figure 5: Mean diurnal variation of IUP GEMS tropospheric NO_2 columns in July 2021. There is a tendency for higher morning values over regions with anthropogenic pollution, but patterns vary with location and season.

6 Stability of retrieval



Longterm evolution of NO_2 fit

- time series of NO_2 vertical columns with stratospheric AMF over the Pacific background region is very similar for operational lv2 and IUP GEMS products
- operational product shows larger variability
- TROPOMI IUP columns are systematically larger
- Difference between GEMS and TROPOMI is mostly constant but larger in February - April
- fitting residuals remain relatively stable over time with daily irradiance
- with fixed irradiance, something changes in early May => lv1 change?

Figure 6: Top: Time series of GEMS IUP, GEMS lv2, and TROPOMI NO_2 data computed from slant columns by applying a stratospheric AMF over a Pacific background region. Middle: Difference between TROPOMI and GEMS IUP time series. Bottom: Fitting residuals of GEMS IUP NO_2 retrieval using a daily solar irradiance (blue) or a fixed irradiance (red) as background spectrum.

7 Summary & Outlook

Summary

- GEMS is the first geostationary satellite providing hourly tropospheric NO_2 data from space
- The IUP GEMS tropospheric NO_2 product shows
  - low noise
  - the expected seasonal variation
  - clear diurnal patterns, depending on season and location
  - good agreement with the IUP TROPOMI product, but only without cloud correction
  - more impact of measurement pixels than TROPOMI because of less oversampling
  - good consistency over a full year

Outlook

- More tests with cloud correction are needed
- BRDF effects need to be implemented
- Effects of different a priori NO_2 profiles need to be evaluated

Selected references

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Photography encouraged

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