MAX-DOAS measurements during ASIA-AQ and comparisons with GEMS products

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1. Background & Objective

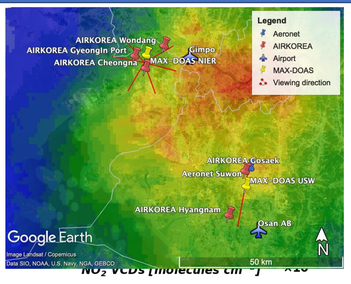
We evaluate MAX-DOAS measurements with in-situ observations during ASIA-AQ and validate GEMS products with MAX-DOAS measurements.

- Multi-axis differential optical absorption spectroscopy (MAX-DOAS) is a remote sensing technique for obtaining aerosol and trace gas vertical information. MAX-DOAS measures scattered sunlight at different elevation angles, leading to retrievals of vertical profiles for aerosol and trace gases as well as total column density.
- During ASIA-AQ, MAX-DOAS measurements were conducted at the University of Suwon (USW) with two azimuth angles (10° and 190°) and at the National Institute of Environmental Research with six azimuth angles (60°, 105°, 160°, 210°, 280°, and 320°).
- This study evaluates MAX-DOAS measurements with ground-based and airborne in-situ observations, and we validate GEMS products with MAX-DOAS measurements.

2. Site & instrument information

Site information

- USW site
  - 37.211°N, 126.980°E
  - Pandora/Skyspec-compact
- NIER site
  - 37.569°N, 126.637°E
  - Pandora/Skyspec-2D/Aeronet



Instrument information

Site	Instrument	Spectral range	Elevation angle (°); Azimuth angle (°)	Retrieved species
USW (Suwon)	Skyspec-compact (1D)	300–460 nm	1, 2, 3, 5, 15, 20, 30; 10, 190	NO_2, HCHO, O_4 (aerosol), etc.
NIER (Incheon)	Skyspec-2D	296–459 nm (UV); 408-554 nm (Vis)	1, 2, 3, 5, 15, 20, 40; 60, 105, 160, 210, 280, 320	NO_2, HCHO, O_4 (aerosol), etc.

3. Data

MAX-DOAS

- NO_2 and aerosol extinction profiles, tropospheric NO_2 vertical column density (VCD), and aerosol optical depth (AOD)
- USW and NIER sites
- Quality check
  - NO_2: degrees of freedom > 2 and relative differences of measured and estimated NO_2 dSCDs < 50%
  - Aerosol extinction: degrees of freedom >1 and relative differences of measured and estimated O_4 dSCDs < 50%

Aeronet

- AOD at 380 nm
- Suwon and NIER sites

Air Korea

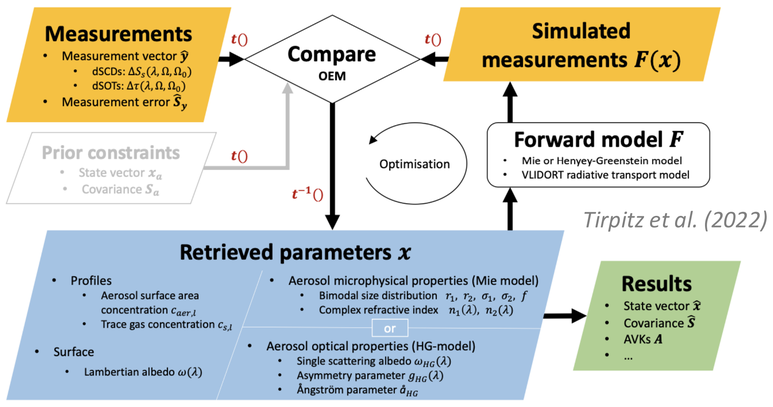
- In-situ NO_2
- Gosaek, Hyangnam near USW
- Wondang, Chengna, Gyeongin Port near NIER

GEMS v2.0

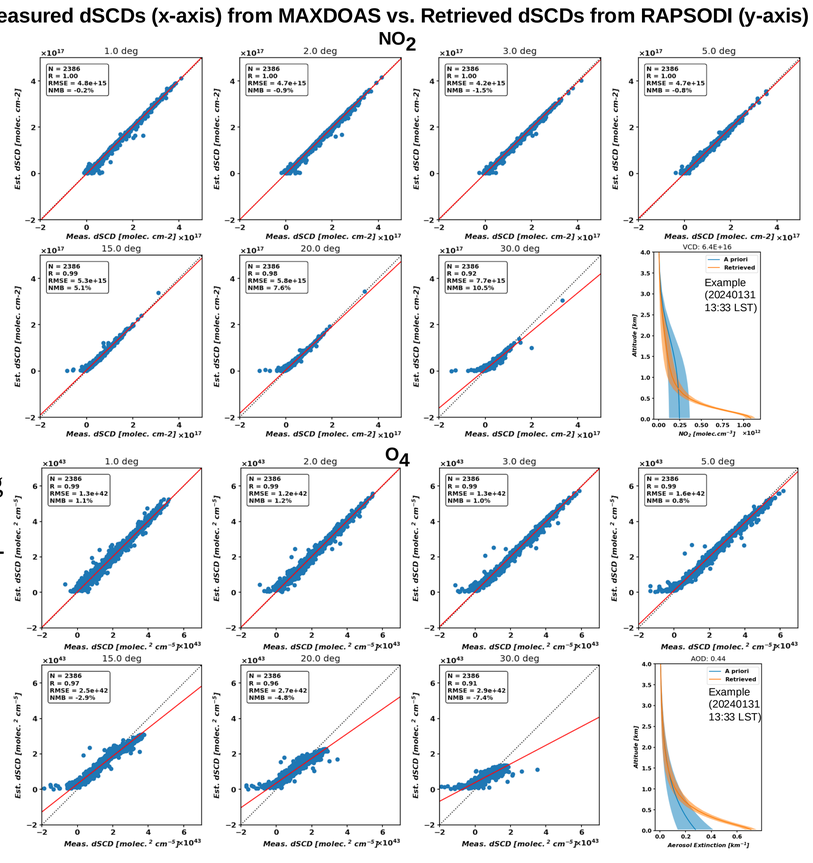
- NO_2 and AOD at 354 nm

4. Retrieval method

RAPSODI (Retrieval of Atmospheric Parameters from Spectroscopic Observations using DOAS Instruments)



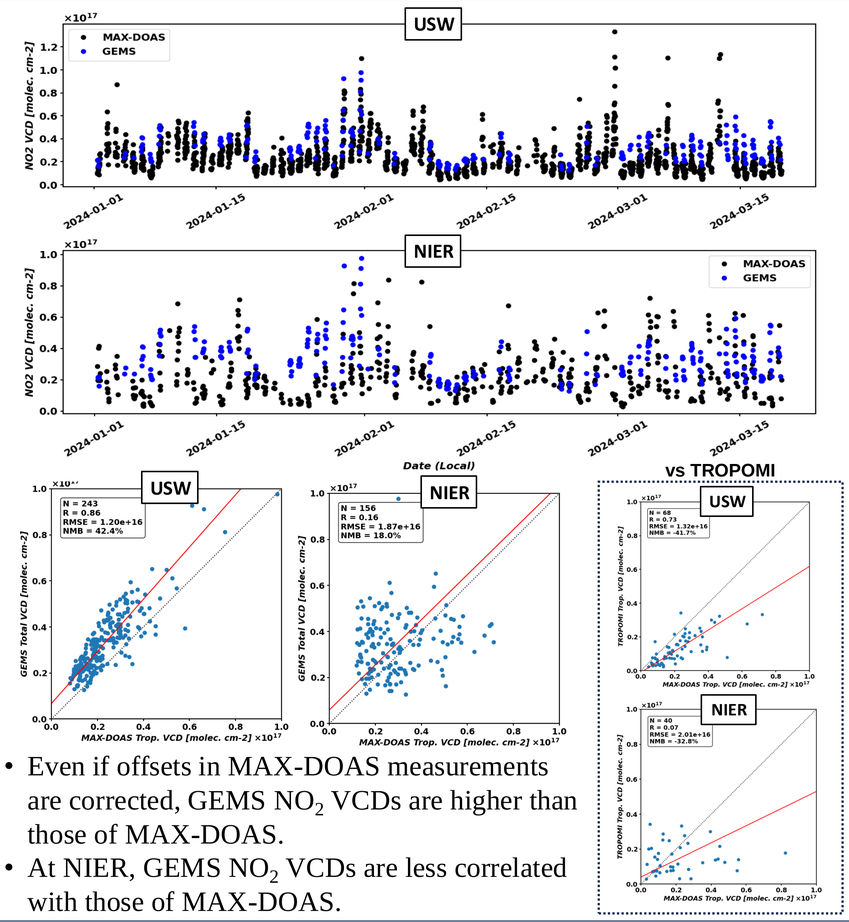
Tirpitz et al. (2022)



- RAPSODI is an optimal estimation tool with a radiative transfer model (VLIDORT) to retrieve trace gases and aerosol extinction profiles using measured dSCDs at different elevation angles (Tirpitz et al., 2022).
- The Henyey-Greenstein parameterization of aerosols and a wavelength-independent surface albedo are assumed.
- Fermi and exponential a priori profiles are applied for NO_2 and aerosol extinction, respectively.

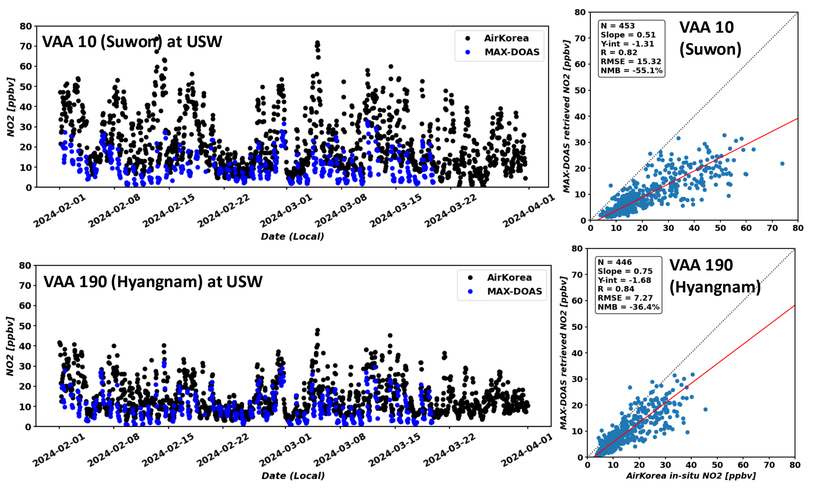
Parameters	A priori profile	
Species	NO_2	Aerosol extinction
Profile shape	Fermi profile (Layer height: 2km)	Exponential (Scale height: 1km)
Total column	5×10^{16} molec. cm^{-2}	0.25
A priori error	100%	100%

7. MAX-DOAS vs GEMS NO_2 VCD



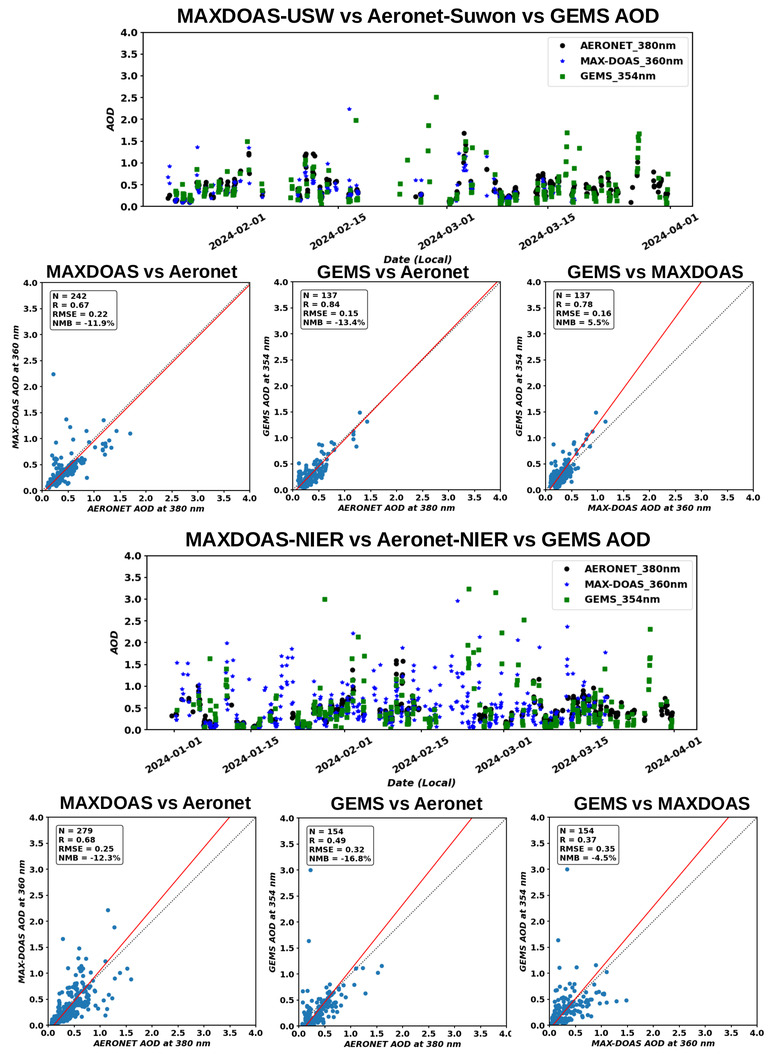
- Even if offsets in MAX-DOAS measurements are corrected, GEMS NO_2 VCDs are higher than those of MAX-DOAS.
- At NIER, GEMS NO_2 VCDs are less correlated with those of MAX-DOAS.

5. MAX-DOAS vs Air Korea NO_2 surface concentration

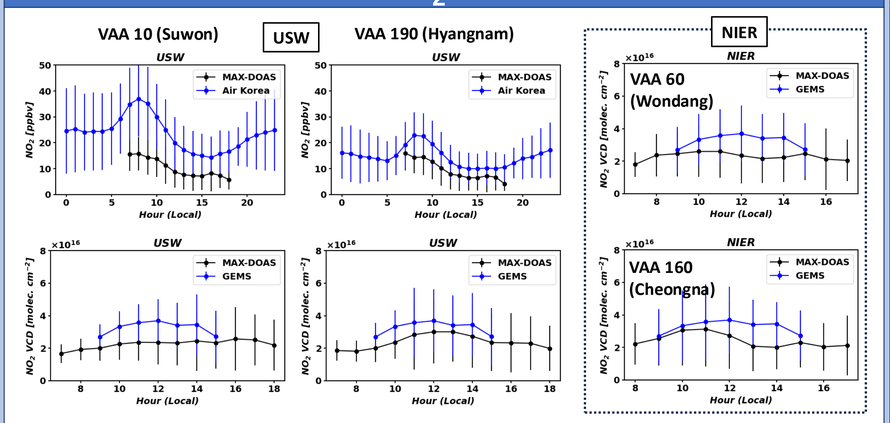


- Retrieved NO_2 mixing ratios at the surface have good agreement with those of in-situ measurements from Air Korea.
- Lower NO_2 values from MAX-DOAS are likely due to differences in measurement locations. (See the number 2 panel)
- However, there are some offsets (y-intercept) in MAX-DOAS measurements, ranging from –1.7 to –1.3 ppbv at USW and –4.3 to –3.1 ppbv at NIER, respectively.

8. MAX-DOAS vs Aeronet vs GEMS AOD

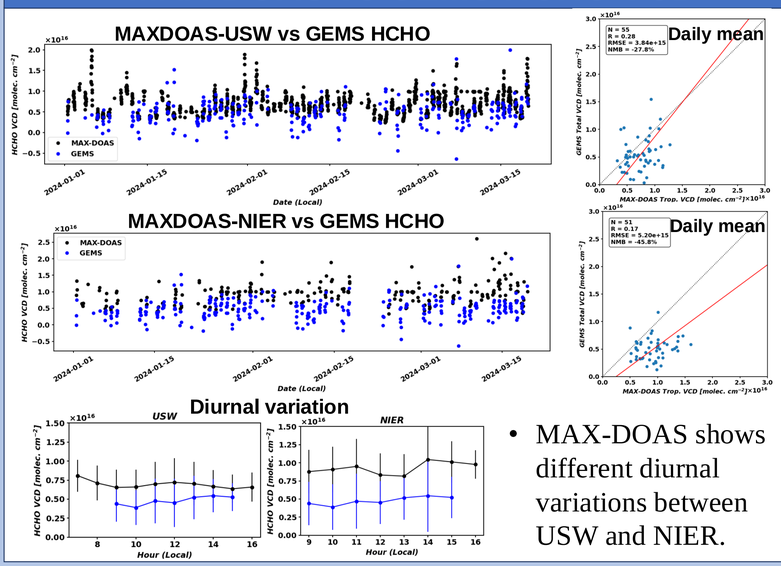


6. MAX-DOAS NO_2 diurnal variations



- NO_2 diurnal variations from MAX-DOAS show a peak in the early morning and a decrease during the day, consistent with those of Air Korea.
- However, NO_2 VCD diurnal variations depend on viewing directions.

+ *MAX-DOAS vs GEMS HCHO VCD*



- MAX-DOAS shows different diurnal variations between USW and NIER.

9. Summary

- NO_2 mixing ratios from MAX-DOAS have good agreement with in-situ measurements from Air Korea despite negative biases and offsets.
- MAX-DOAS AOD products are well correlated with those of Aeronet.
- GEMS NO_2 VCDs have the offset of ~6.8 $\times10^{15}$ molecules cm^{-2} despite corrections of MAX-DOAS offsets. GEMS AOD shows good agreement with MAX-DOAS measurements.

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