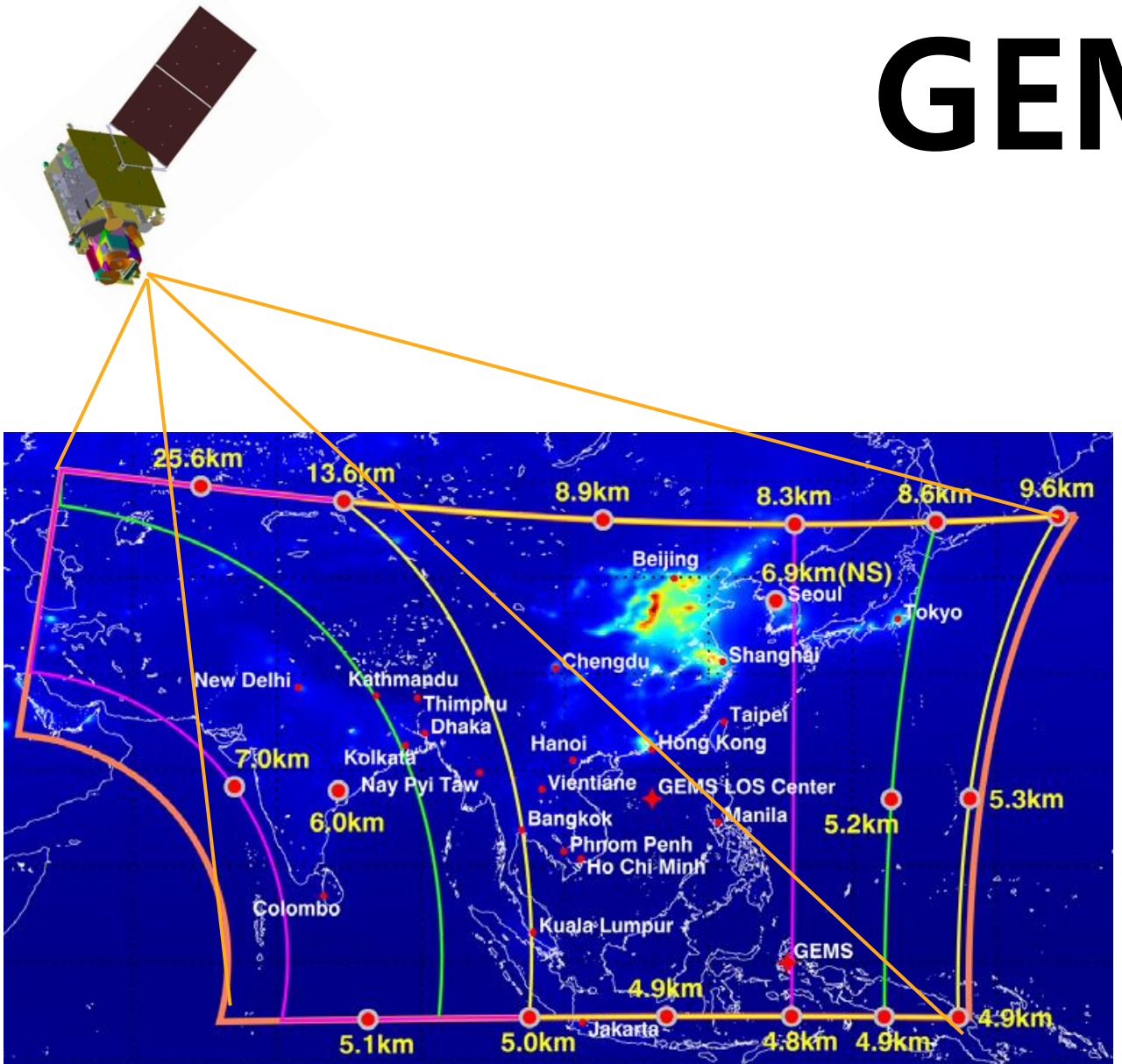


GEMS* Status

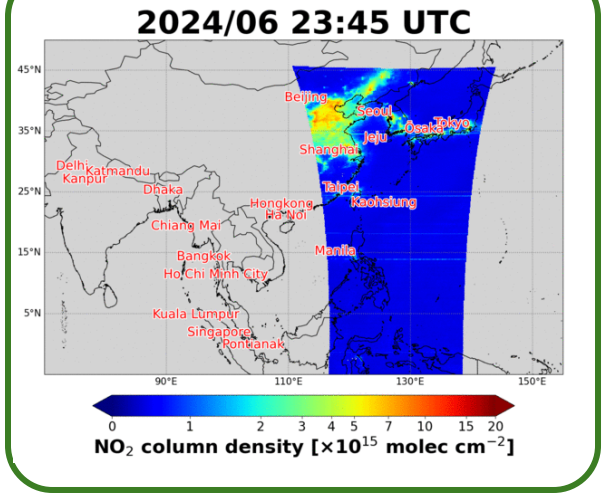
*Geostationary Environment Monitoring Spectrometer

Jhoon Kim*, M.H. Ahn, R. Park, H. Lee, J. H. Kim, K.-S. Han, Y.S. Choi, S. Park; Y. Jung, J. Bak, Y. Lee, K. Kim, M. Kim, H. Chong, J. Park; H. Lee, S. Hong, K. Lee, E. Ha, J. Park, S. Sim, Y. Chung, Y. Chae, H. Cha, Y. Seo, W. Kang, S. Oh, M. Park, S. Lee; H. Shin, W. Lee, S. Shin, H. Hong; J. Crawford, L. Judd, ASIA-AQ Team, N. Theys, PEGASOS Team, NIER ESC Staffs, and GEMS Science Team…

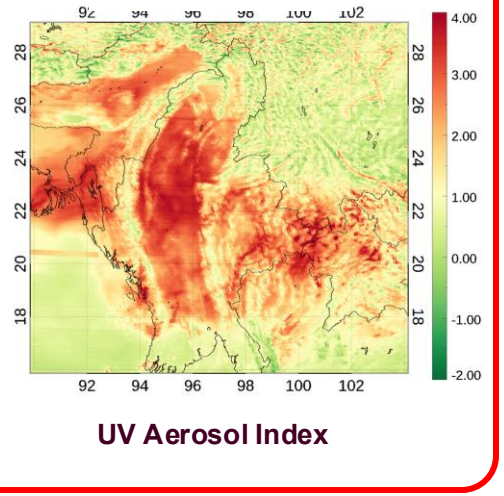
* Lee Youn Jae Fellow Professor of Atmospheric Science
Yonsei University, Seoul, Korea

GEMS Products (Oct. 20 – present)

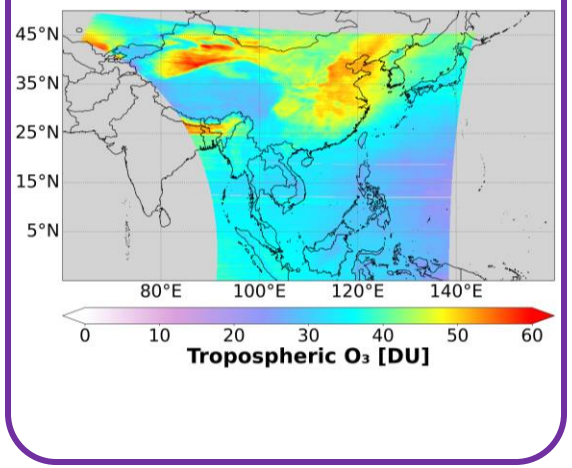
Urban Emission



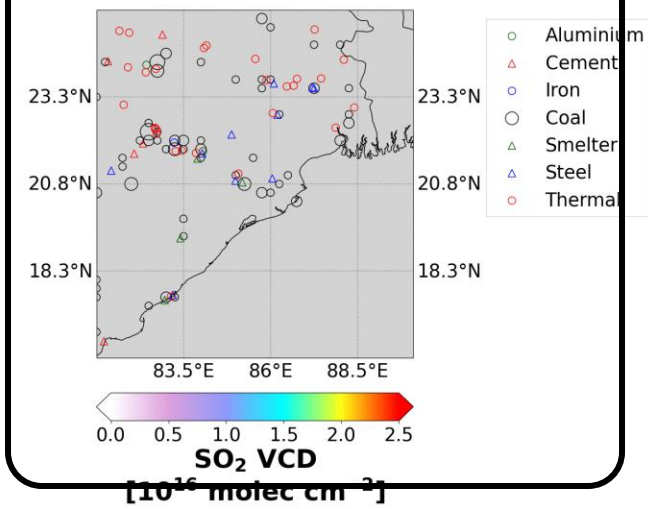
Wildfires



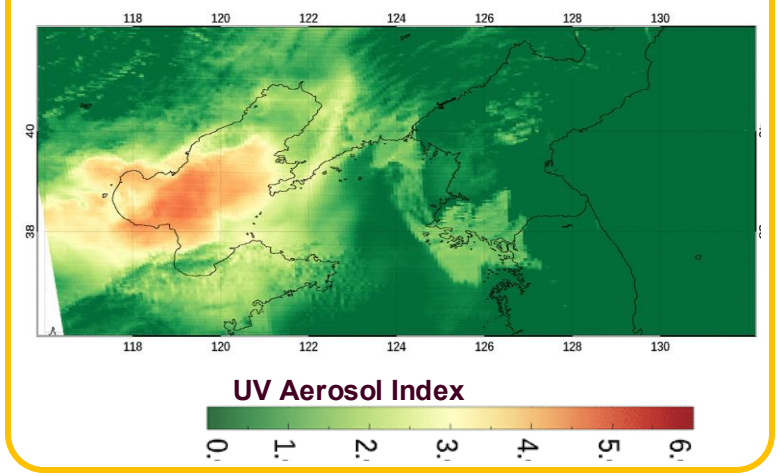
Trop Ozone



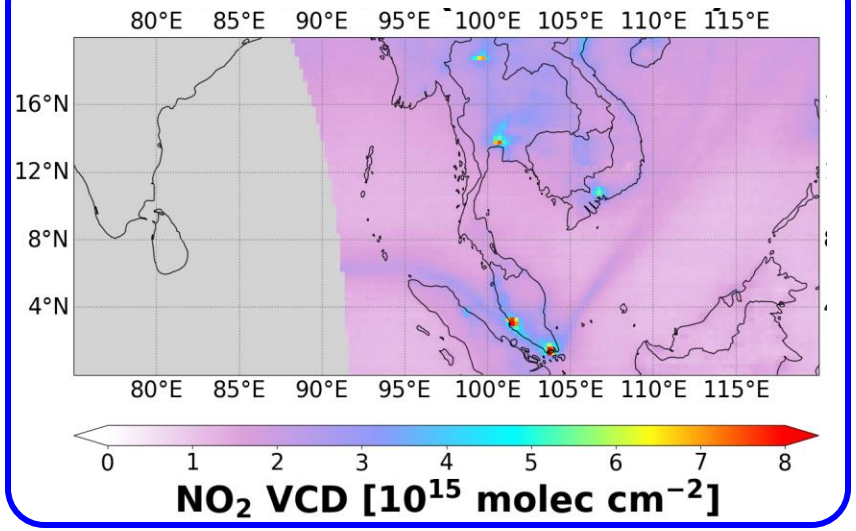
Coal PP & Smelters



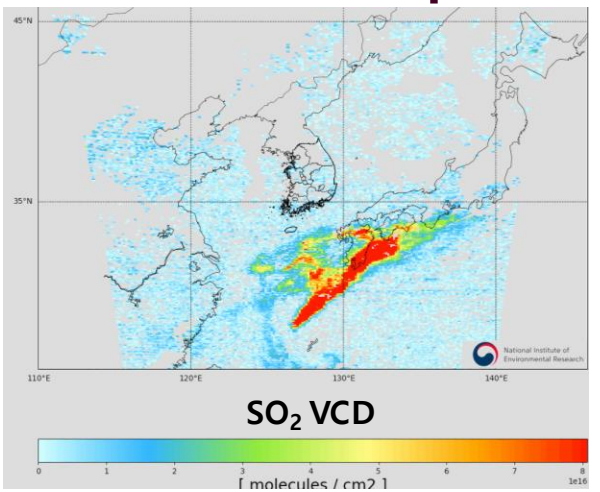
Dust & Wildfires



Ship Track Emission



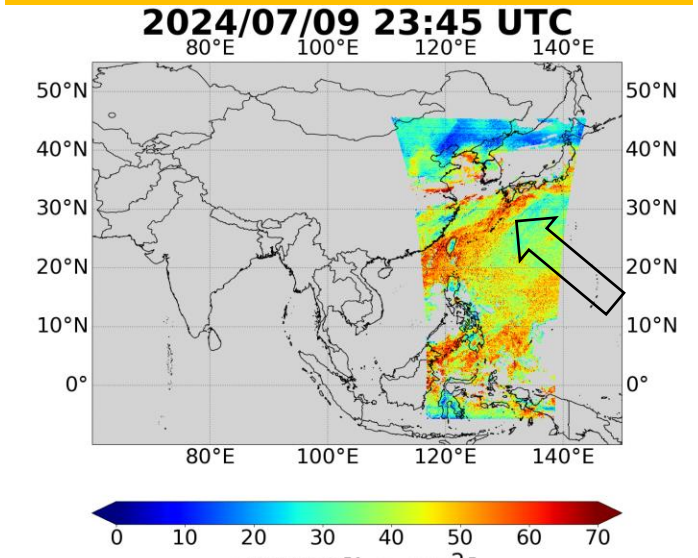
Volcanic Eruption



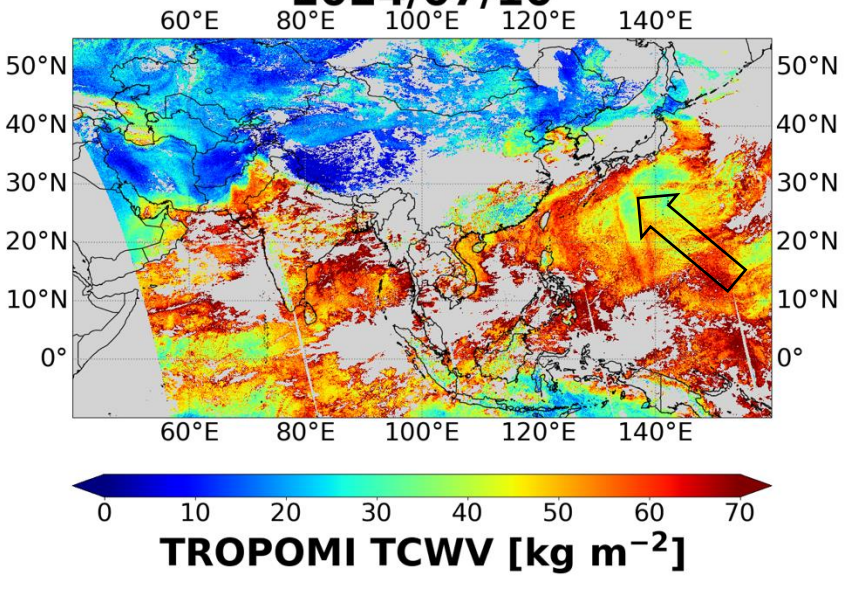
New products of GEMS

H_2O

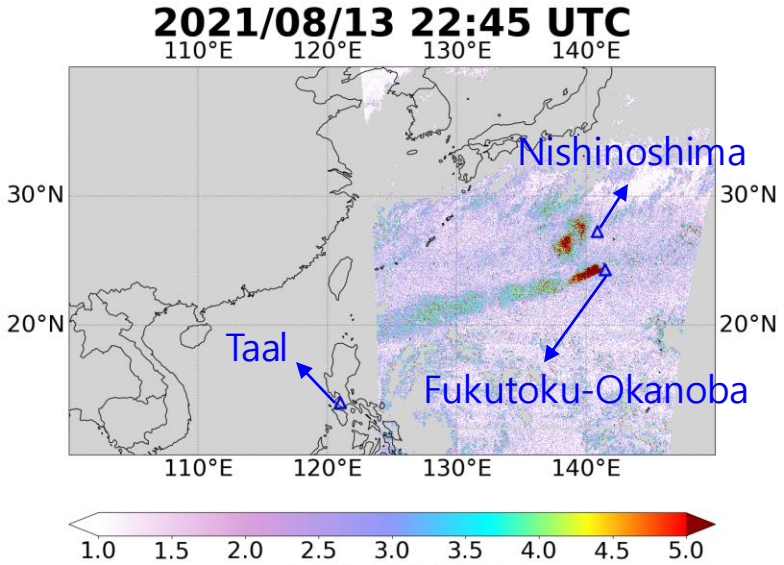
GEMS

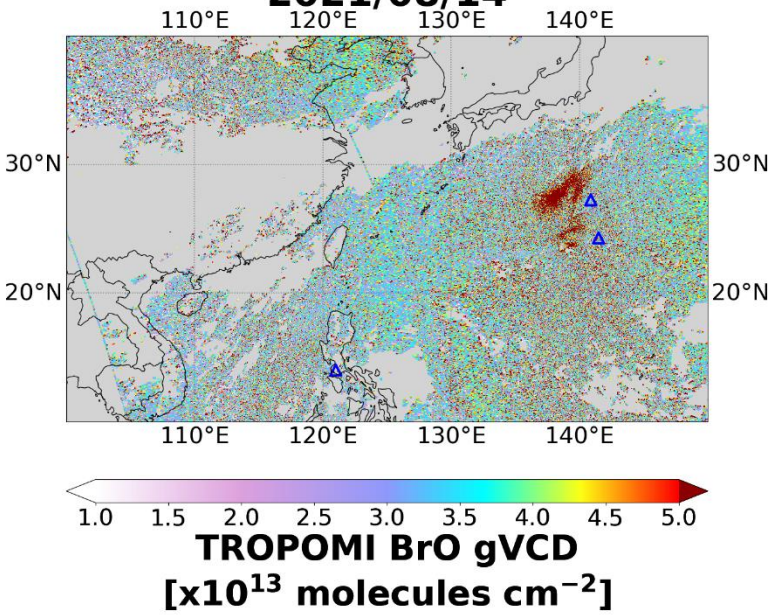


TROPOMI



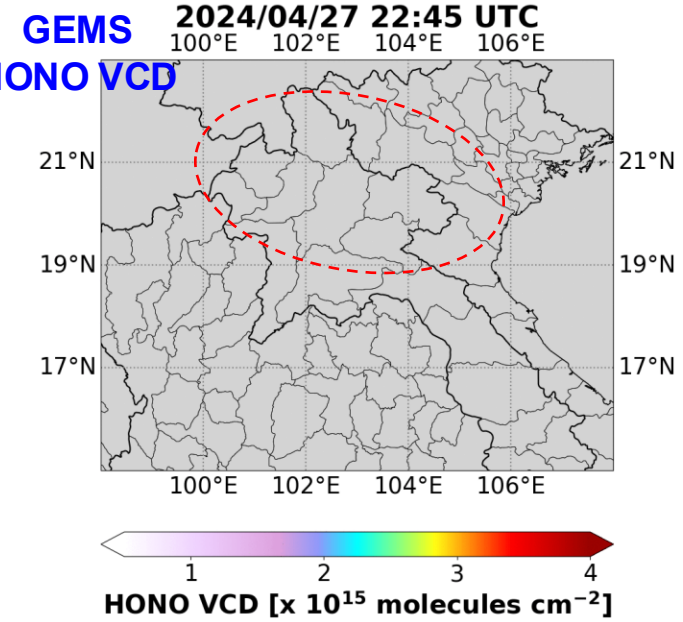
BrO



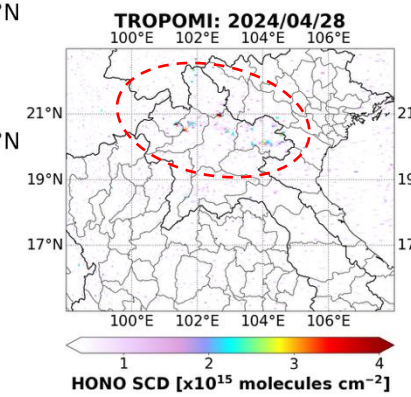


HONO

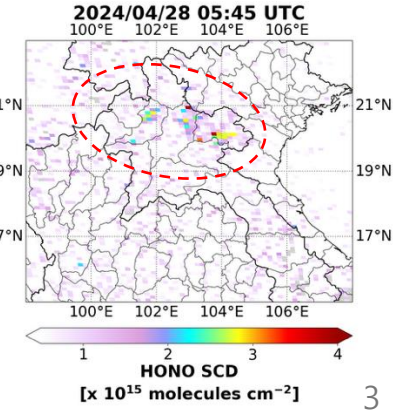
GEMS HONO VCD



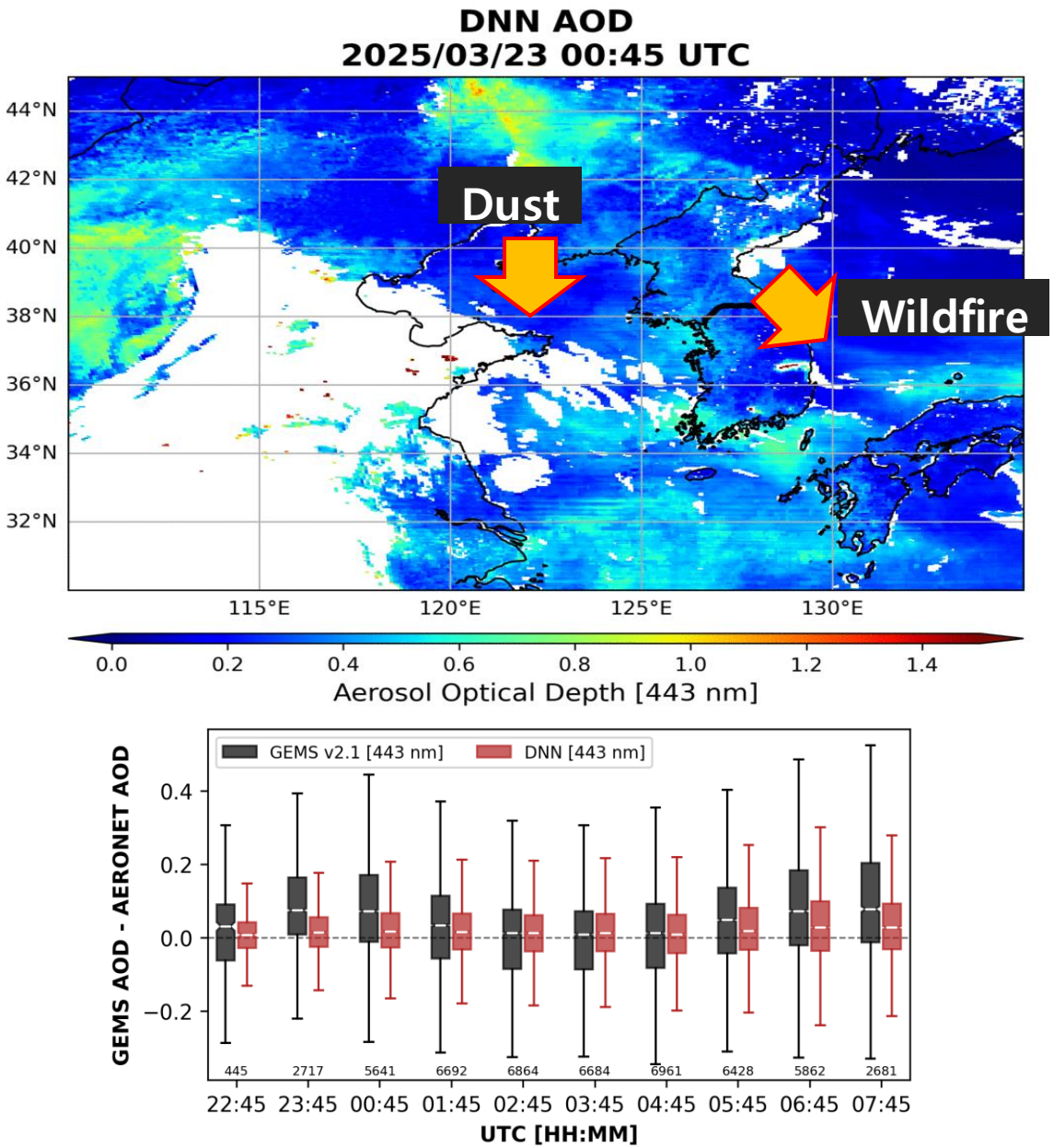
TROPOMI HONO SCD



GEMS HONO SCD

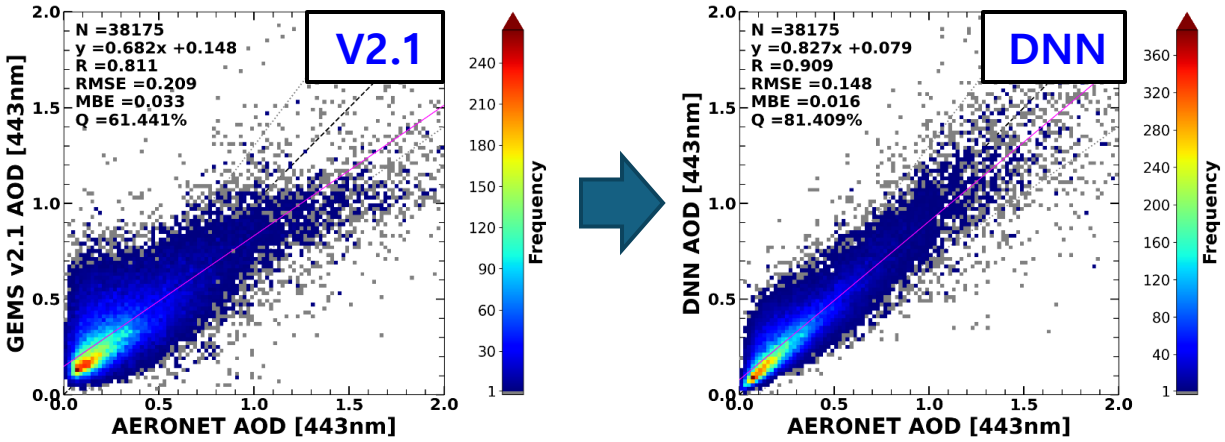


Post-processing of GEMS AOD



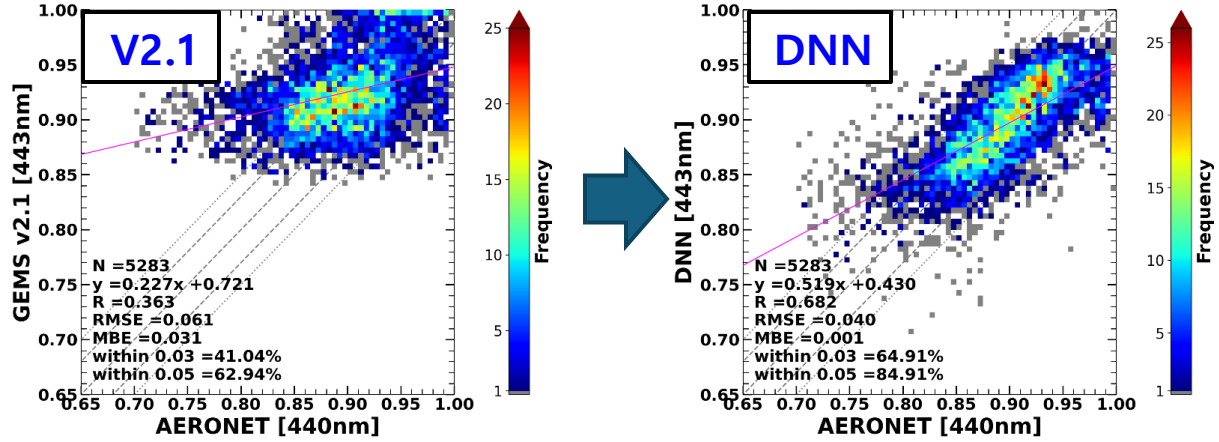
AOD

Validation Period: 2024/05 – 2025/04



SSA

Validation Period: 2025/01 – 2025/04

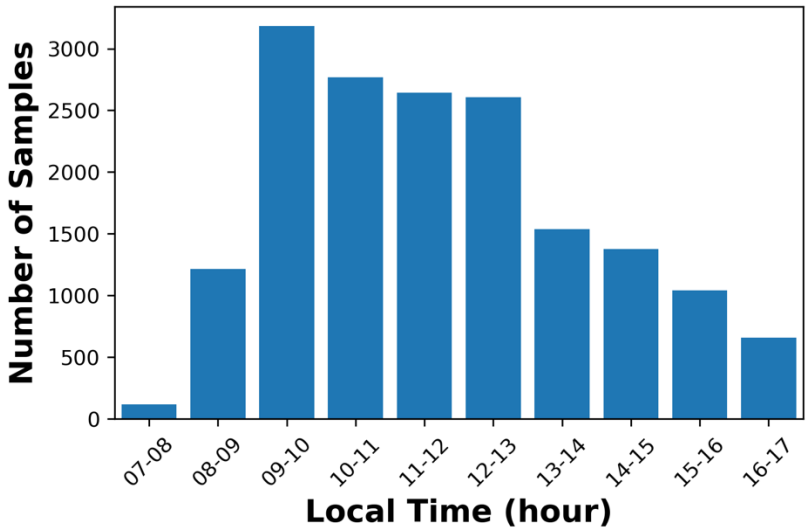


GEMS Total NO_2 V4.0b Annual Validation wrt PANDORA in terms of

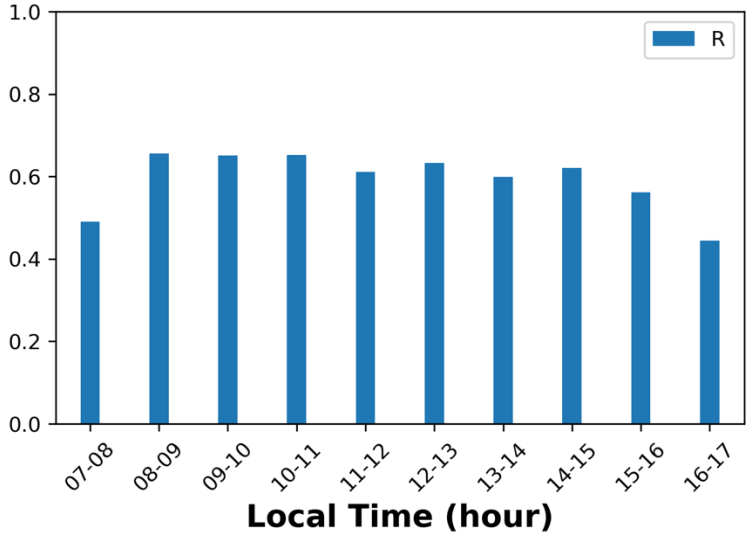
Cloud fraction, Concentration, Local time, Solar zenith angle, Month of the year, station , TROPOMI

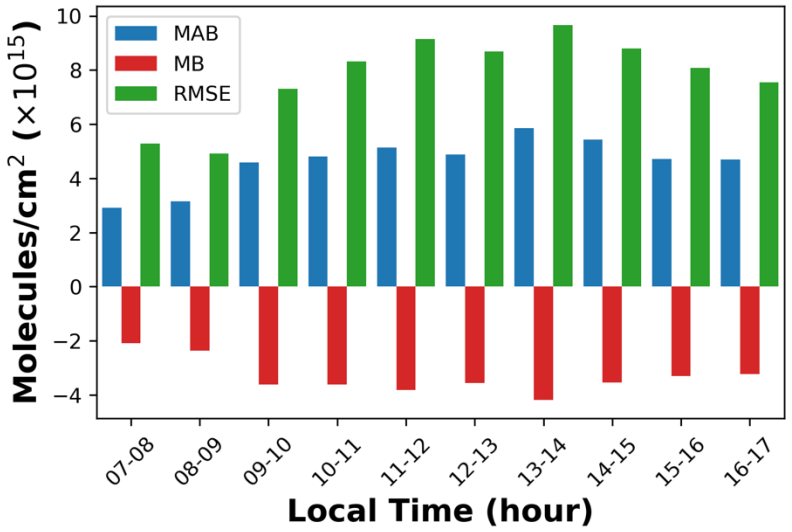
Data period: Jan 2024 – Dec 2024

No of Data



R





- Because many Pandora sites lie toward the eastern part of the GEMS domain, grouping by local time yields more observations in the morning.

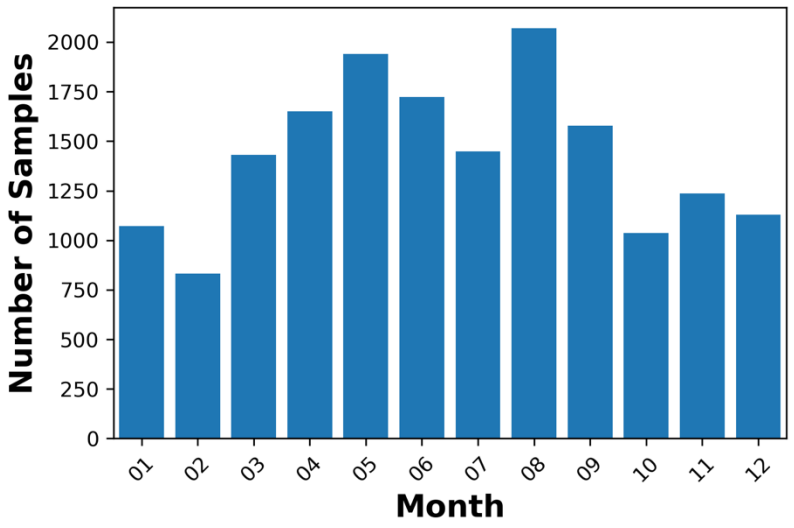
- GEMS NO_2 v4 shows an overall negative bias with respect to Pandora, and MAB/MB/RMSE decrease in the morning and evening. This behavior has been linked to planetary boundary layer (PBL) effects on retrieval accuracy (Ghahremanloo et al., 2025).

GEMS Total NO_2 V4.0b Annual Validation wrt PANDORA in terms of

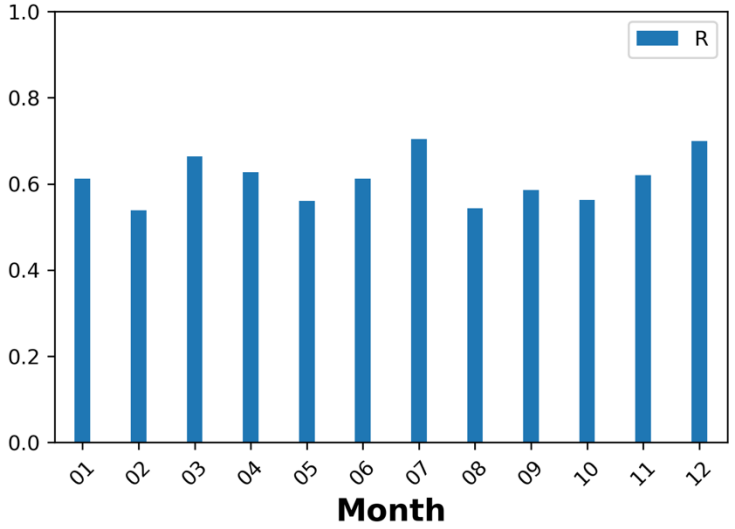
Cloud fraction, Concentration, Local time, Solar zenith angle, Month of the year, station , TROPOMI

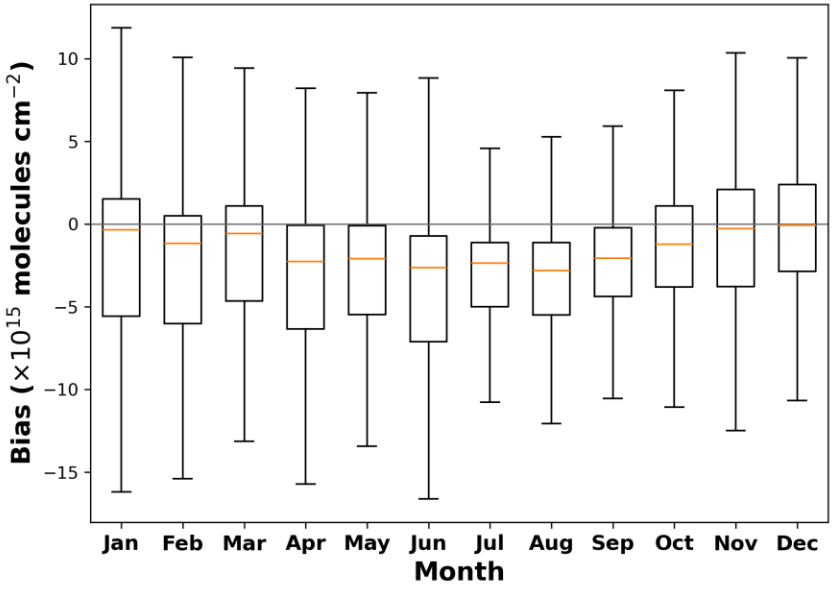
Data period: Jan 2024 – Dec 2024

No of Data



R





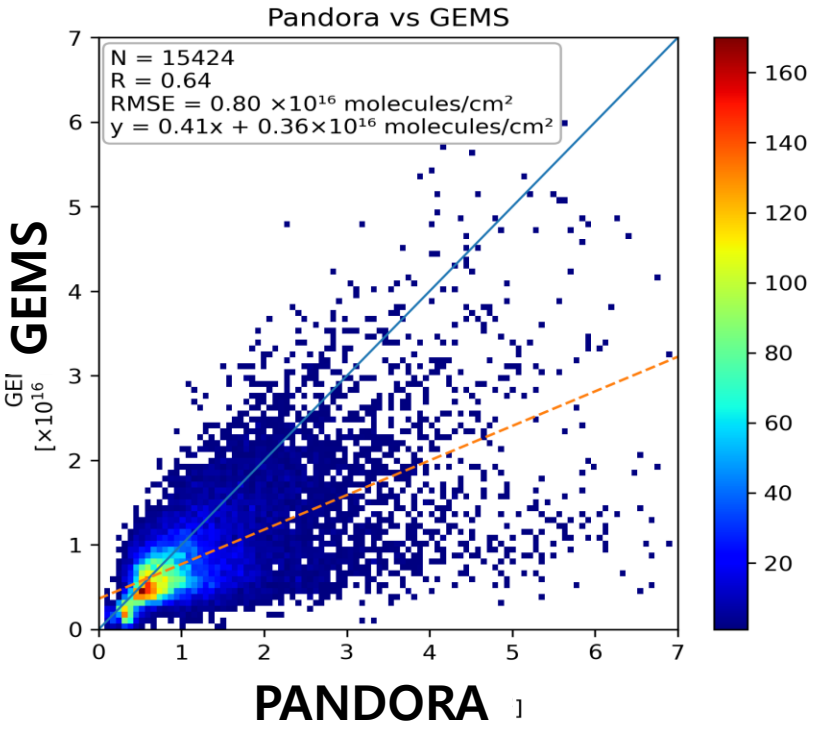
- Negative bias in summer and better agreement in winter.
- Consistent with this, **most stations show lower retrieved NO_2 in summer**.

GEMS NO_2 V4.0b Annual Validation wrt PANDORA in terms of

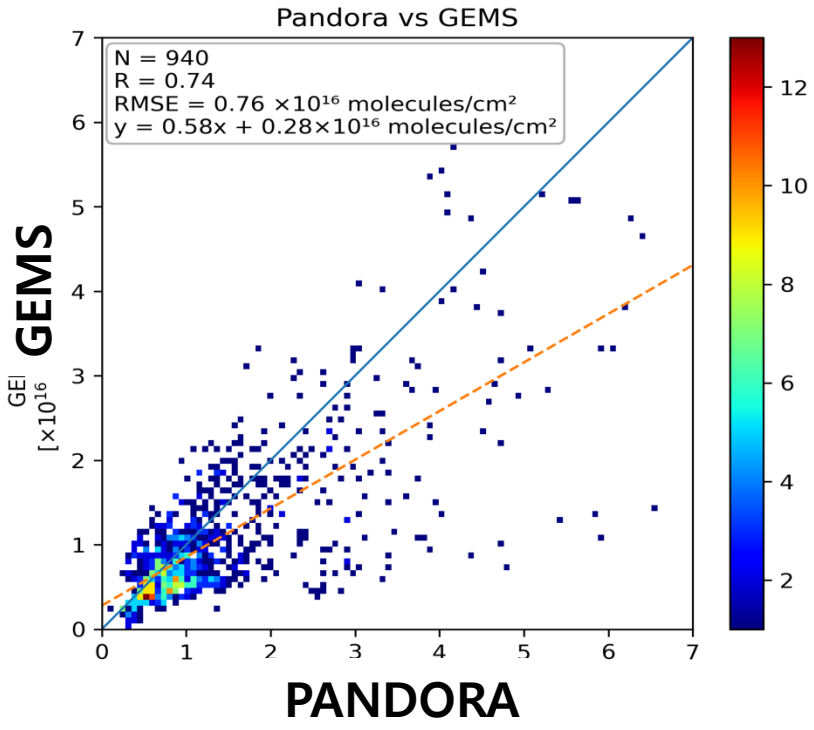
Cloud fraction, Concentration, Local time, Solar zenith angle, Month of the year, Station, TROPOMI

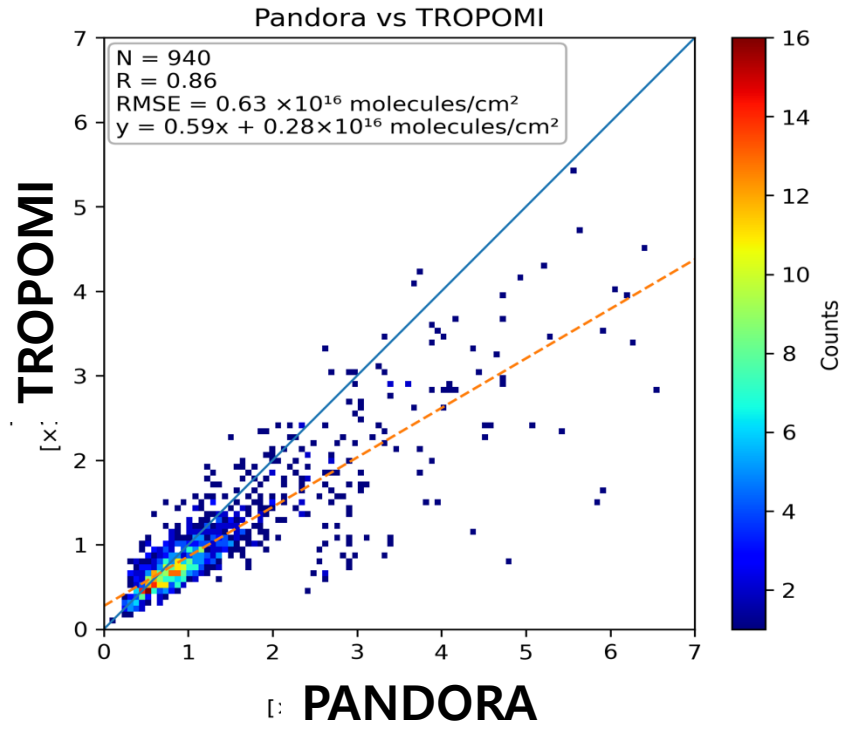
Data period: Jan 2024 – Dec 2024

All hours



1300-1400 LT



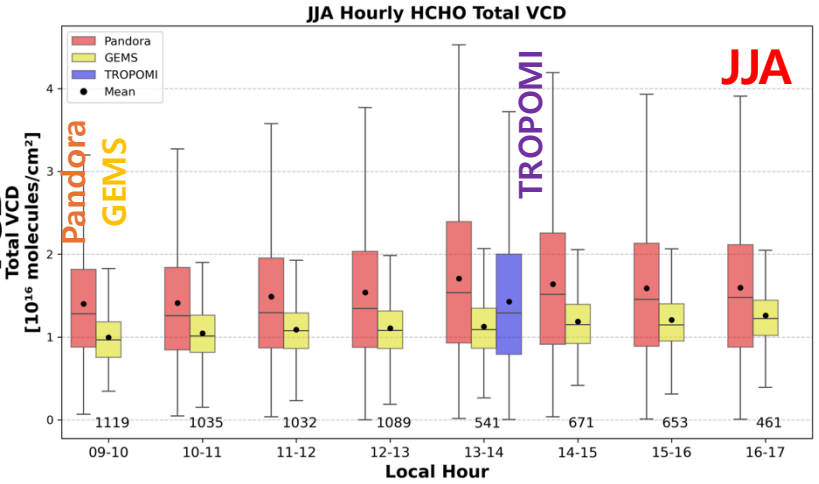


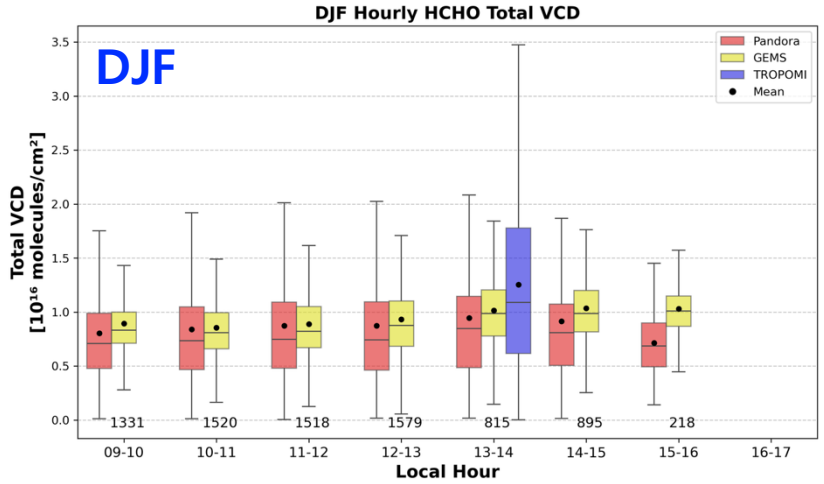
- At 13-14 LT, TROPOMI and GEMS show similar slope and offset.
- However, TROPOMI shows better performance than GEMS.
- GEMS R = 0.74, RMSE = 0.76 × 10^{16} molecules cm^{-2}; TROPOMI R = 0.86, RMSE = 0.63 × 10^{16} molecules cm^{-2}.

GEMS HCHO Annual Validation wrt PANDORA in terms of Seasons

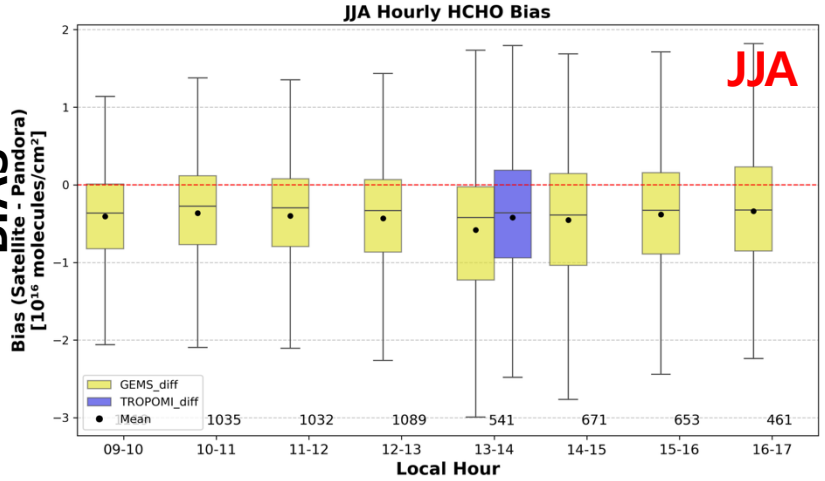
Data period
Summer : Jun 2024 – Aug 2024
Winter : Dec 2024 – Feb 2025

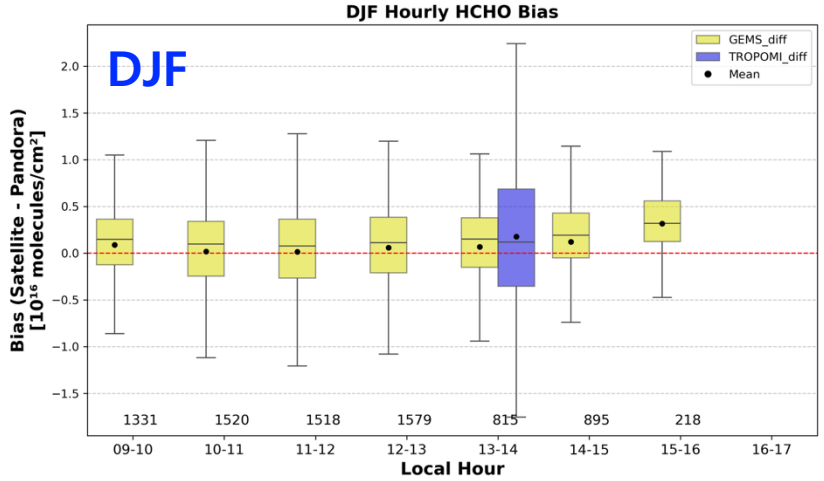
VCD



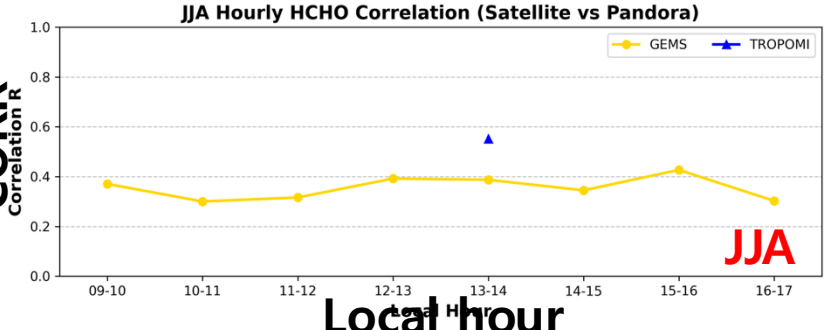


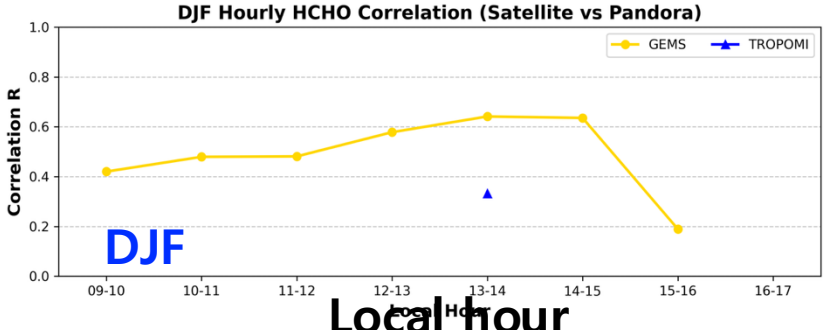
BIAS





CORR



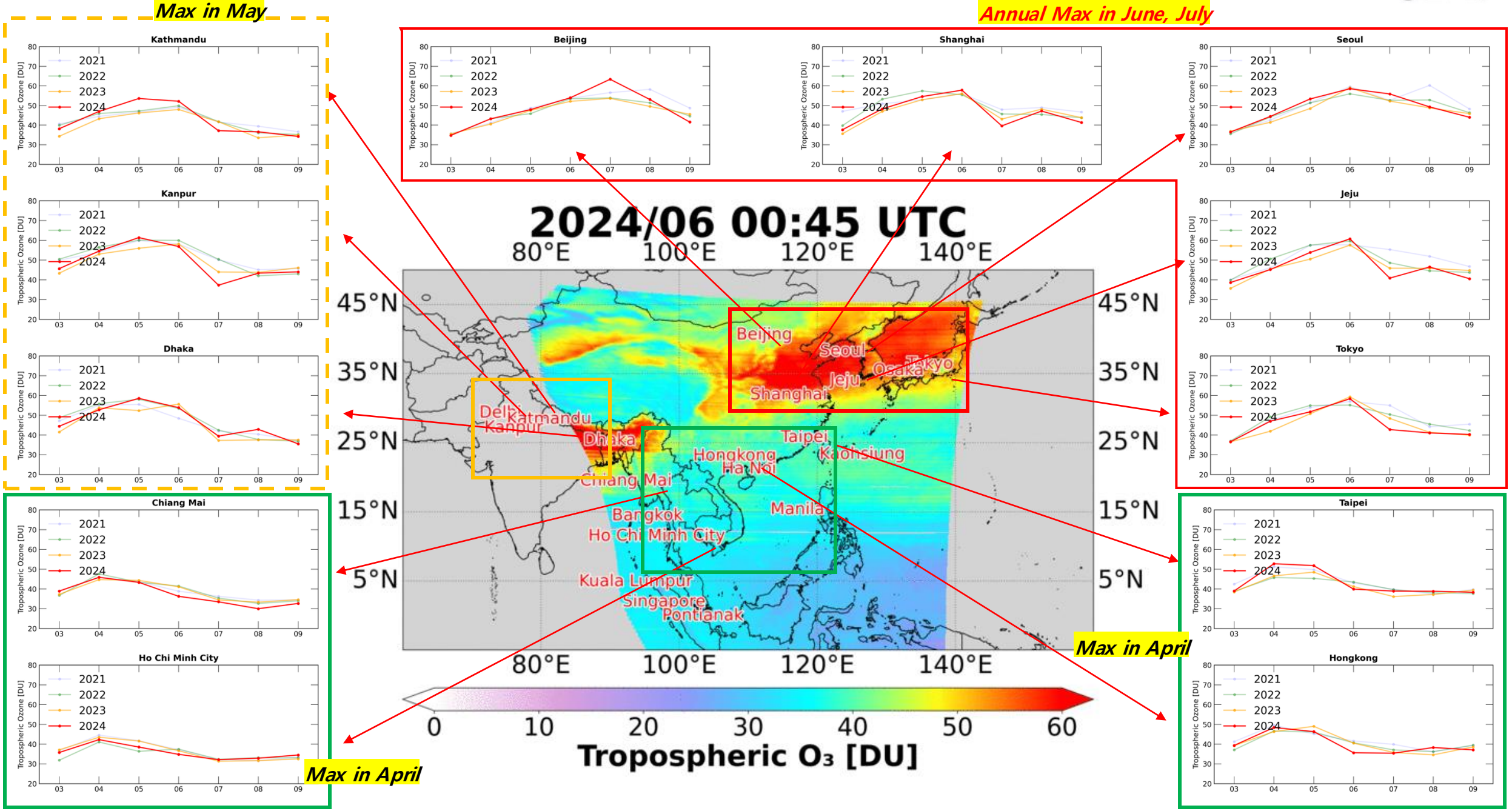


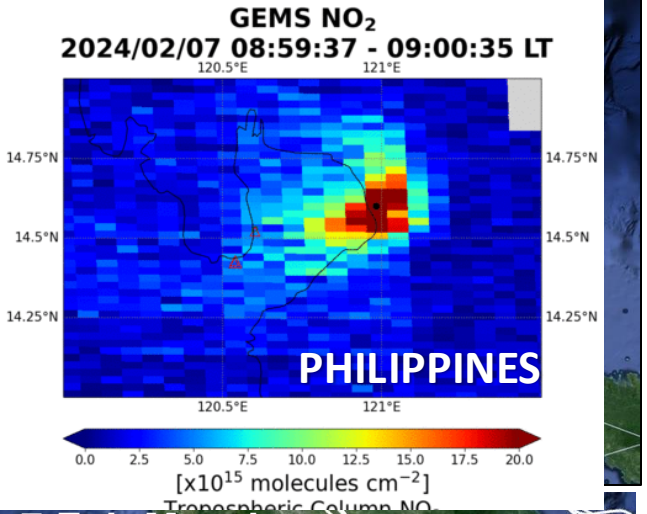
Local hour

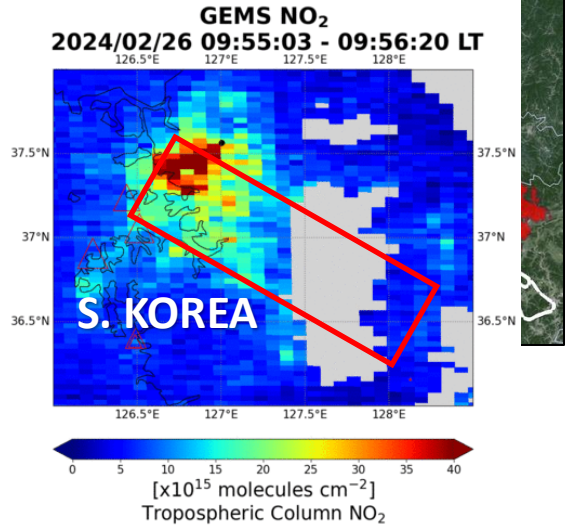
Local hour

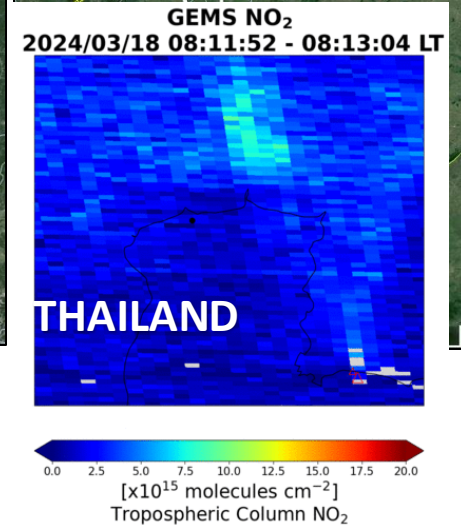
- HCHO total columns are higher in summer than in winter because of biogenic sources
- Negative bias (Satellite – Pandora) in summer but slightly positive in winter
- Correlation (R) is generally higher in winter than in summer.

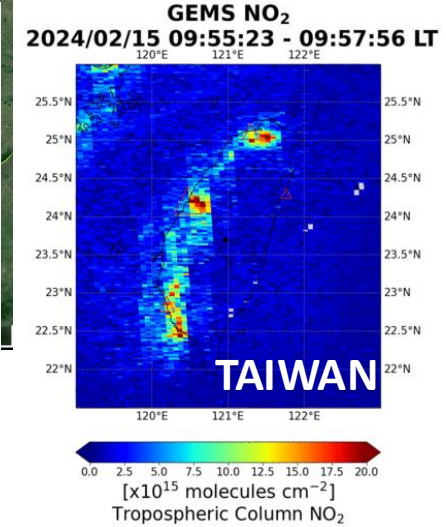
GEMS v3.0 Tropospheric Ozone trends for 4-years (Jan 21 – Dec 24)









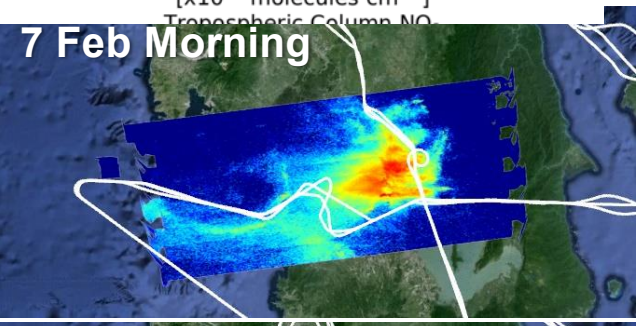


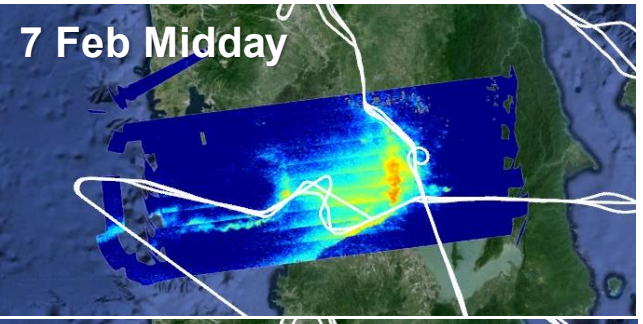
GEMS

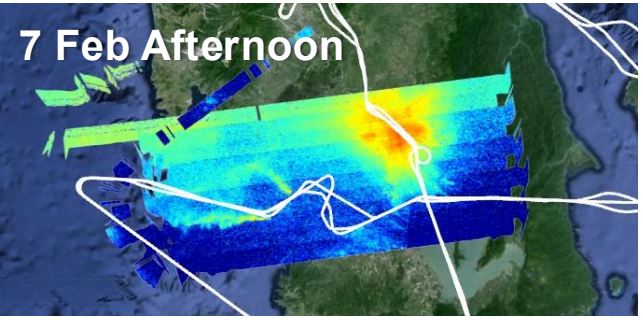
NO_2

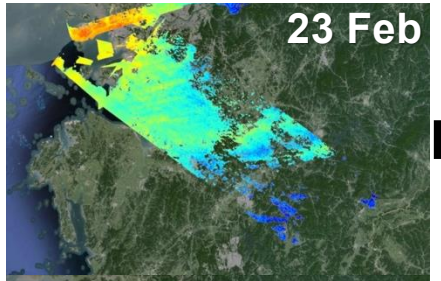
GEMS

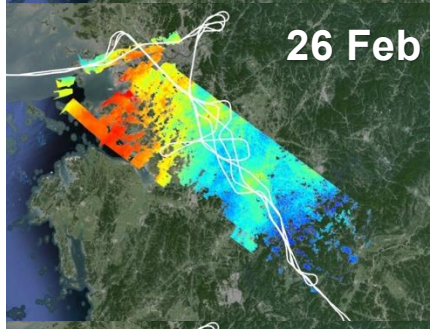
GCAS

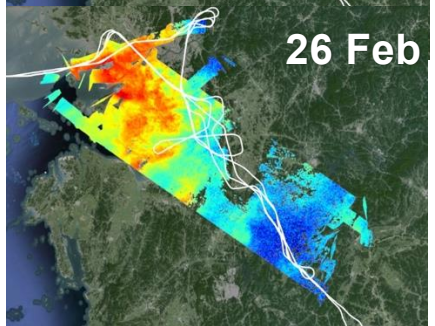








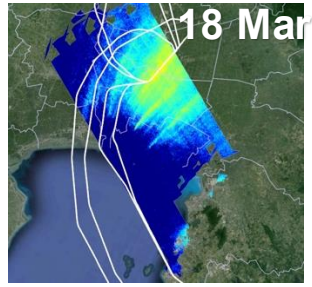


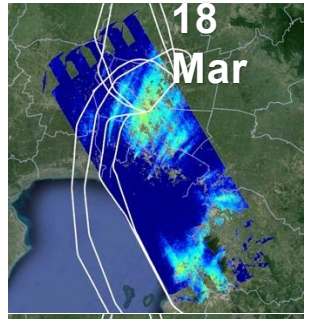


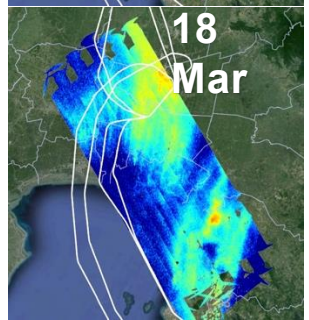
Morning

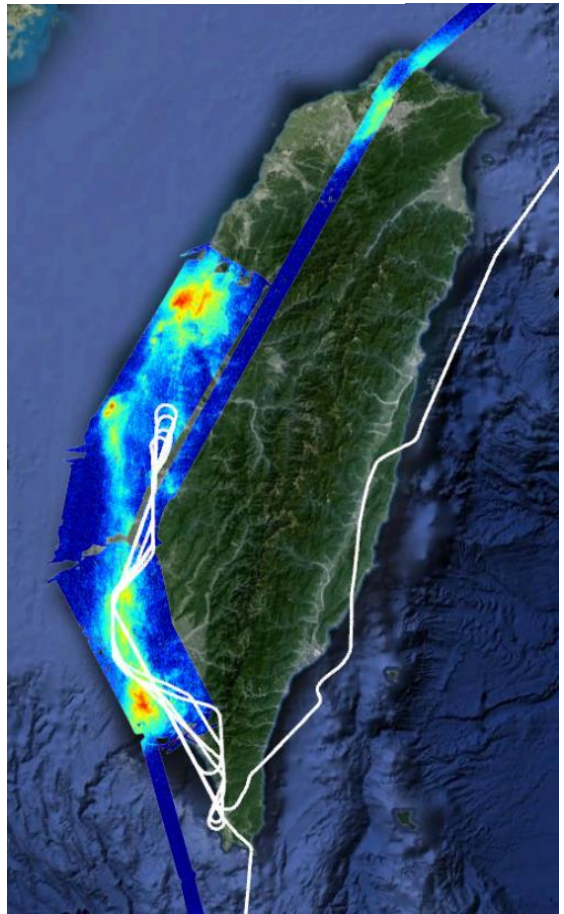
Midday

After-noon





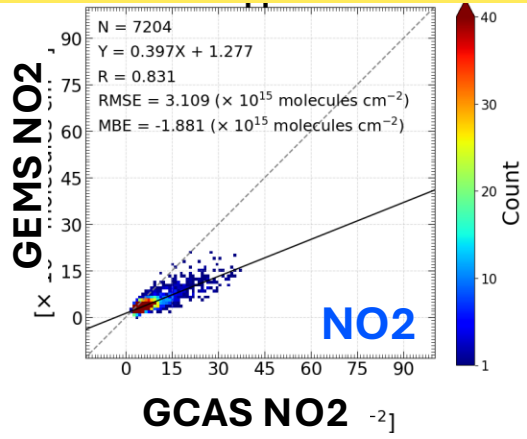


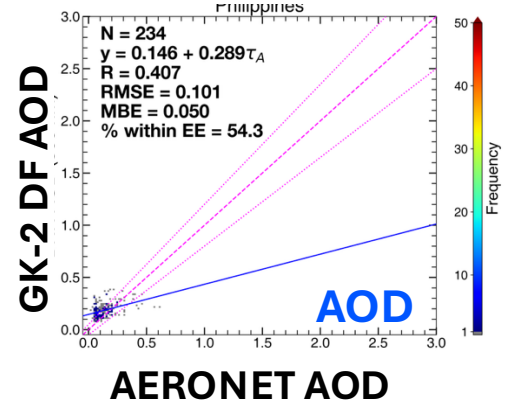


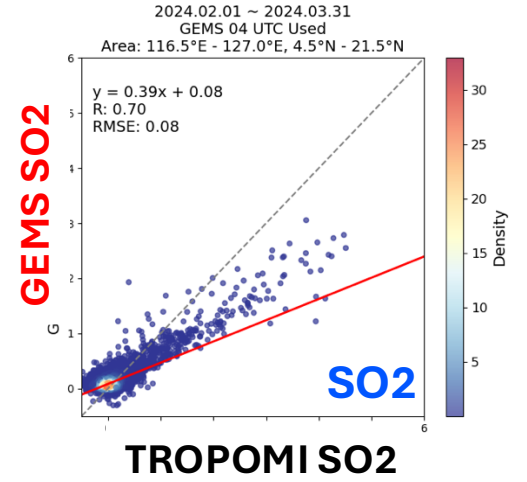
Feb-Mar, 2024

Credit: J. Crawford, Laura Judd, Scott Janz, Jhoon Kim, Hanlim Lee

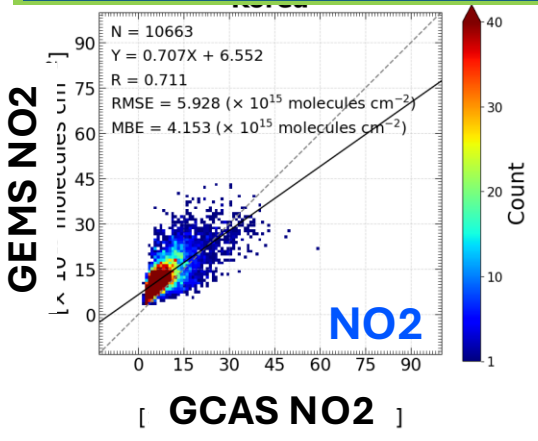
1. Philippines

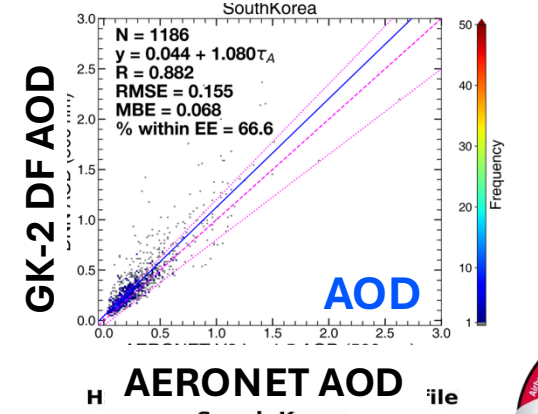


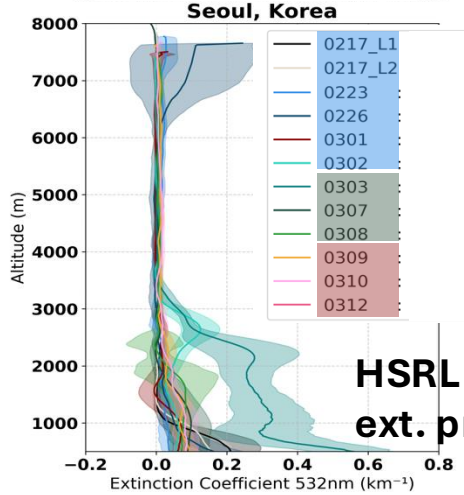




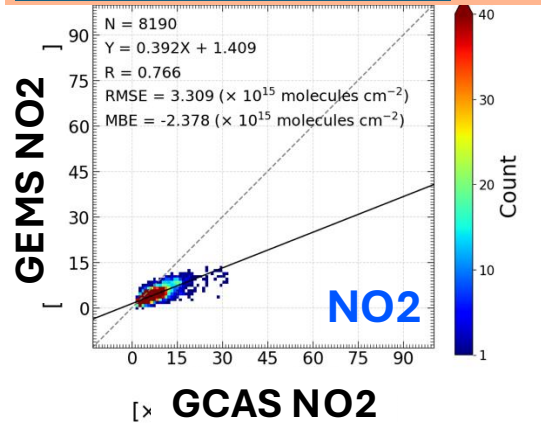
2. Korea

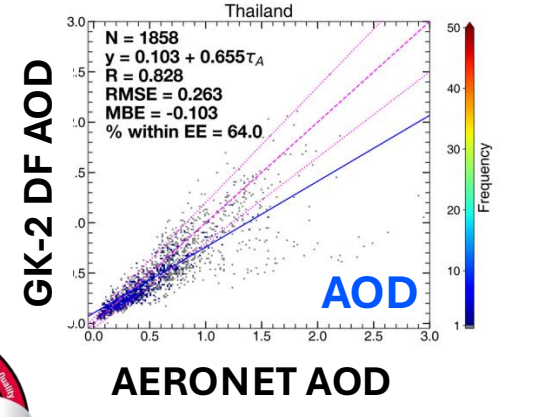


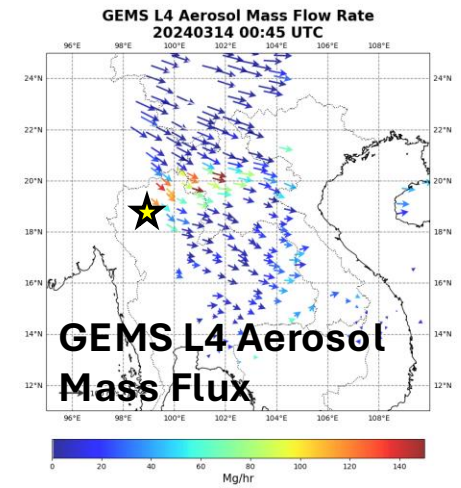




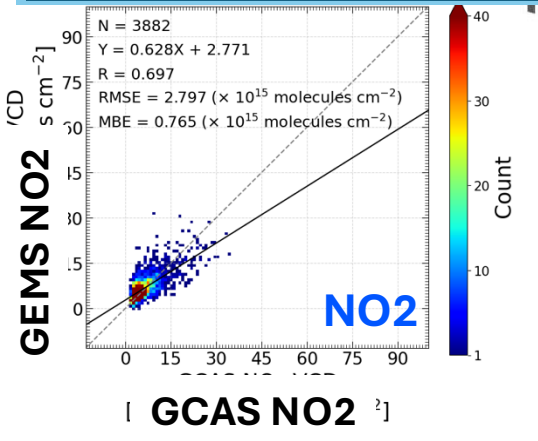
3. Thailand

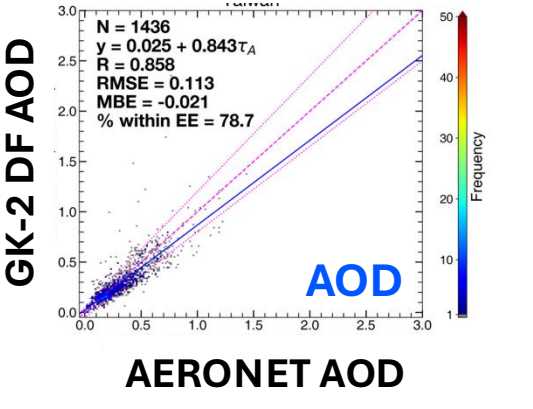




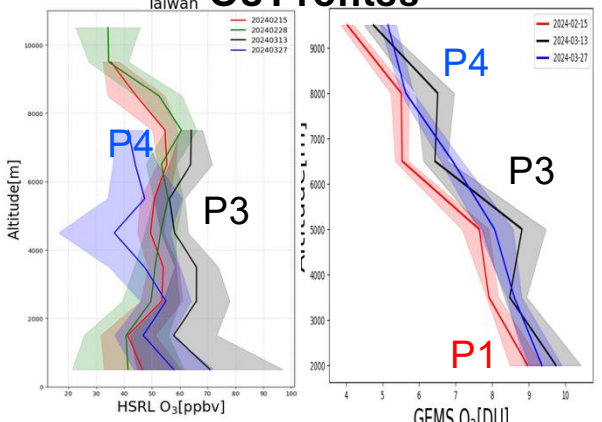


4. Taiwan

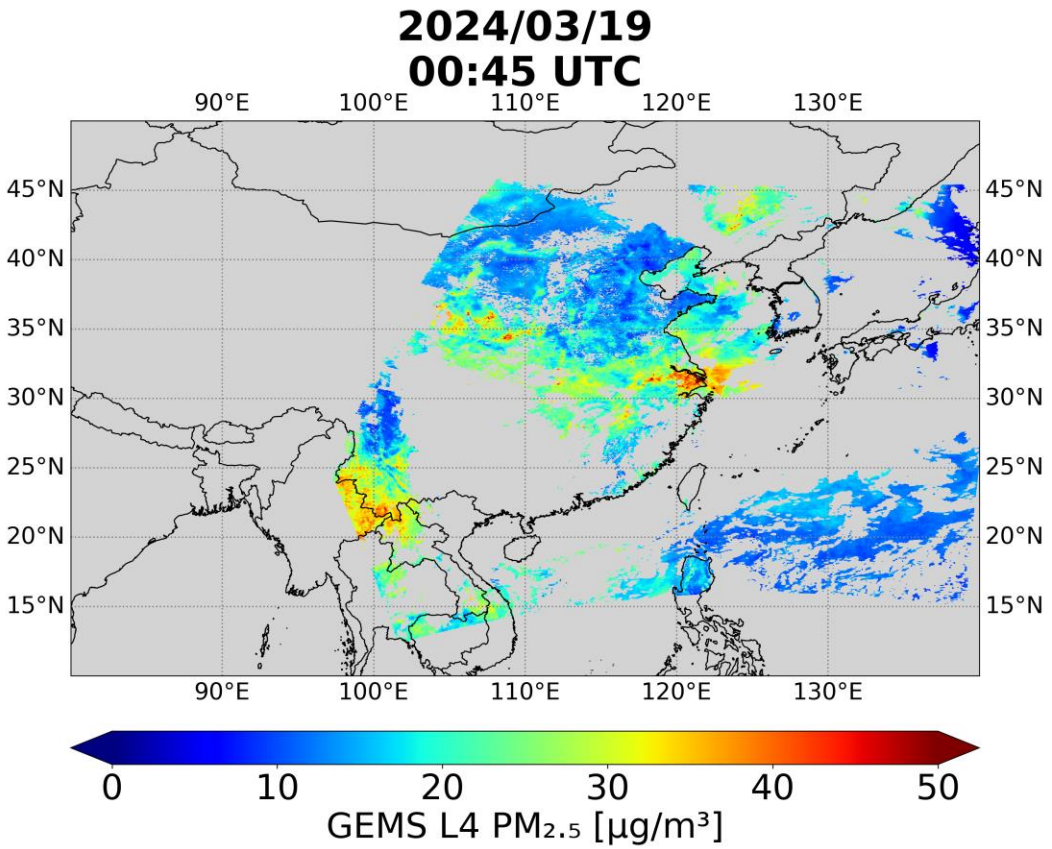


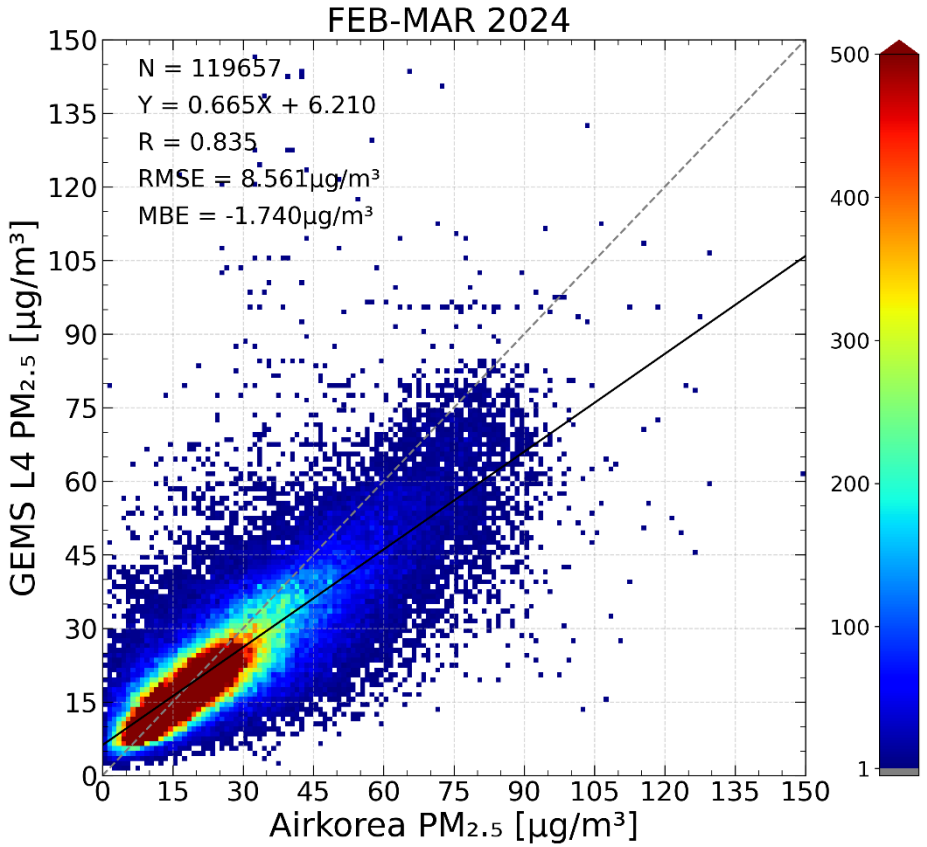


O3 Profiles



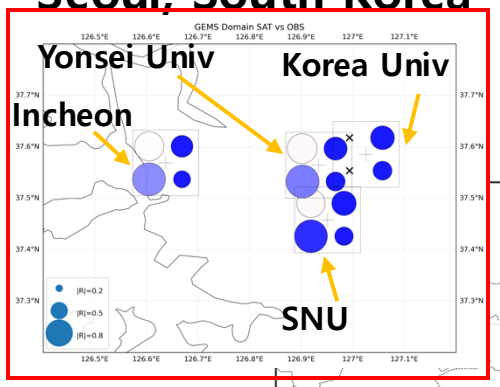
GEMS L4 Surface $PM_{2.5}$ vs. AirKorea $PM_{2.5}$ (Ground-based) during ASIA-AQ

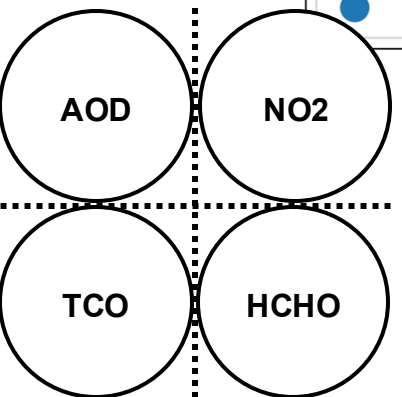




- GEMS provides surface PM2.5 concentrations using AI-based algorithm using Aerosol Optical Properties(AOPs).
- On March 19, the long-range transport of PM was observed.
- The GEMS Level 4 $PM_{2.5}$ product exhibits a slight underestimation relative to ground-based data.

GEMS Ground Validation





Radius : Correlation Coefficient
Color : Mean Bias

AOD : May 2024 – Apr 2025
Gases : Jan 2024 – Dec 2024

Used product(GEMS)	Used product(Ground)
AOD v2.1post-processed	AERONET AOD V3.0 Lev1.5
NO_2 v4.0 Total VCD	Pandora NO2 Direct sun mode
HCHO v3.0 Total VCD	Pandora HCHO Multi-axis mode
O3T v2.1 Total VCD	Pandora Total Ozone Direct-sun mode

Summary

- In successful operation since 2020.
- Oct. 2024: **Level 4** data Release (sfc conc.)
- Dec. 2024: **Version 3** data Release
- **Version 4** data in R&D phase
- L2 data: R > 0.9 (O3T),
  > 0.8 (volcanic SO2, H2O, CCP, BSR),
  > 0.7 (AOD, ECF),
  > 0.6 (NO2, PBL SO2, BrO),
  > 0.5 (HCHO, CHOCHO)

- **Issues**:
  - Degradation : 19% @320 nm, 1% @470 nm
  - BTDF corr. residuals, Degradation corr.
  - L1 updates and impact to L2
  - Underestimation: trop NO_2 in summer, volcanic SO_2, strat O_3, trop O_3, VOCs, AOD, ALH, ECF
  - Overestimation: PBL SO_2, AEH
  - E-W contrast (bias): HCHO
  - Latitudinal dependency: O3T
  - Diurnal variation of retrieval accuracy

- **Application studies**:
  - Diurnal variation : Edward et al.(ACP, 2024)…
  - Trend analysis : Oak et al. (ACP, 2024) …
  - Surface concentrations using AI : Yang et al. (npj CAS, 2023), S. Park et al. (EP, 2022) …
  - Top-down emission : J. Park et al. (npjCEE, 2025). J. Park et al. (AMT, 2023), …
  - Public health : Li et al. (Ncomm, 2025), …

GEMS Achievement Summary

Publications

GEMS SI (ACP/AMT): 22 Papers
Total: 105 Papers

Citations

1,742
(‘25.7.16)

Patent/SW

Total 35
(Patent 12, SW 23)

Data Downloads

accumulated 1.6M+
50 Countries

Employments

47+
faculty, civil servants, physicist,
research scientist, …

Startup Foundations

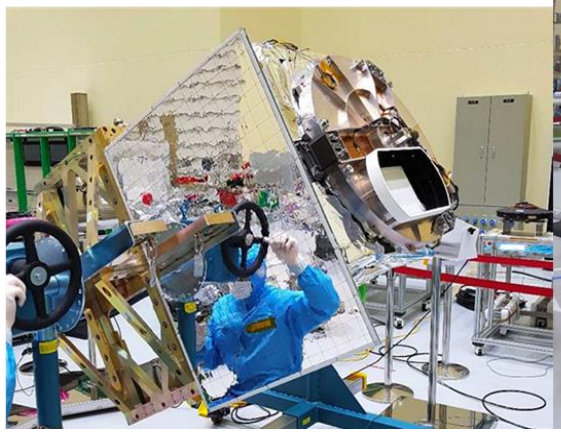
3 Cases
(CEO, CTO)

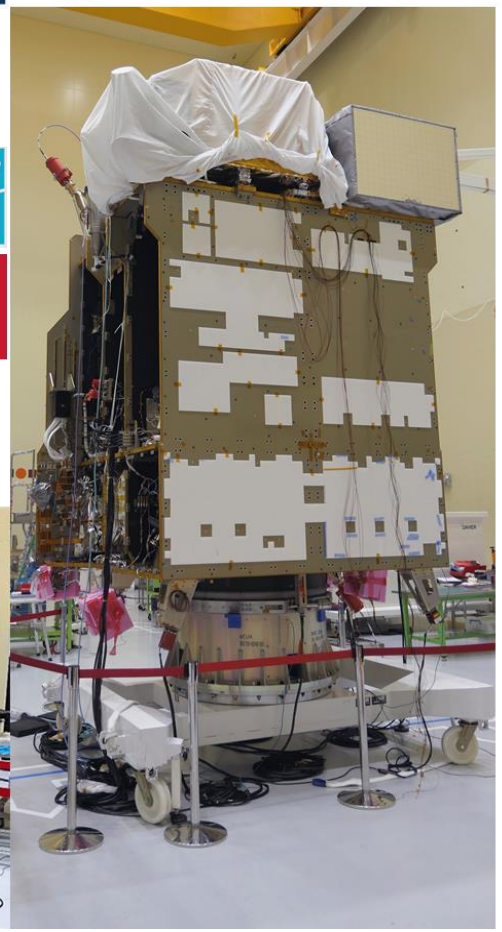
News

’20-’25.6 Total 656

Acknowledgements

National Institute of Environmental Research
Republic of Korea
환경부 Ministry of Environment
Ministry of Science and ICT
KARI
KEITI
GEMS
TEMPO
EU | ESA | EUMETSAT sentinel-4 COPERNICUS
CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN
NASA
Royal Netherlands Meteorological Institute Ministry of Infrastructure and the Environment
esa
EPA
Ball
JPL
JAXA
NCAR UCAR
UH
CEOS
NICT
JAMSTEC





Thanks for all your contribution, dedication, and support !