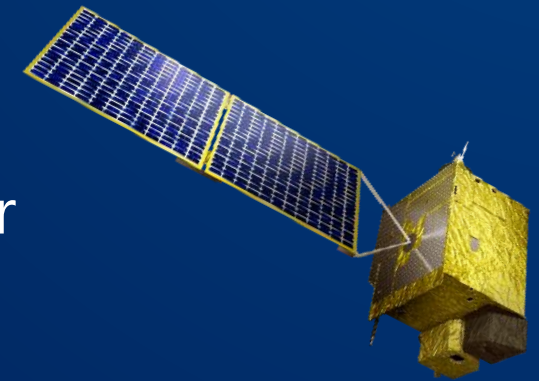


GEMS Validation Activities

Geostationary Environmental Monitoring Spectrometer

Wonjin Lee, NIER
2 June, 2026



GEMS GEMS GEMS



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Environmental Satellite Center

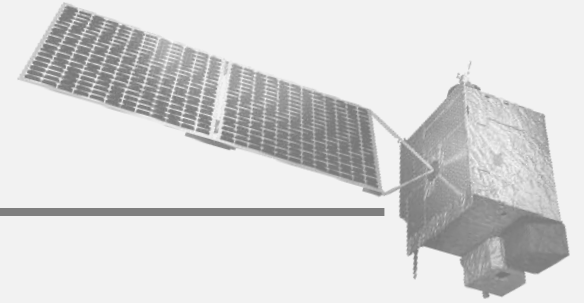
Contents

1. GEMS Validation Activities
2. Validation Results(L0, L1, L2, L4)
3. GEMS-AQ



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1. GEMS Validation Activities



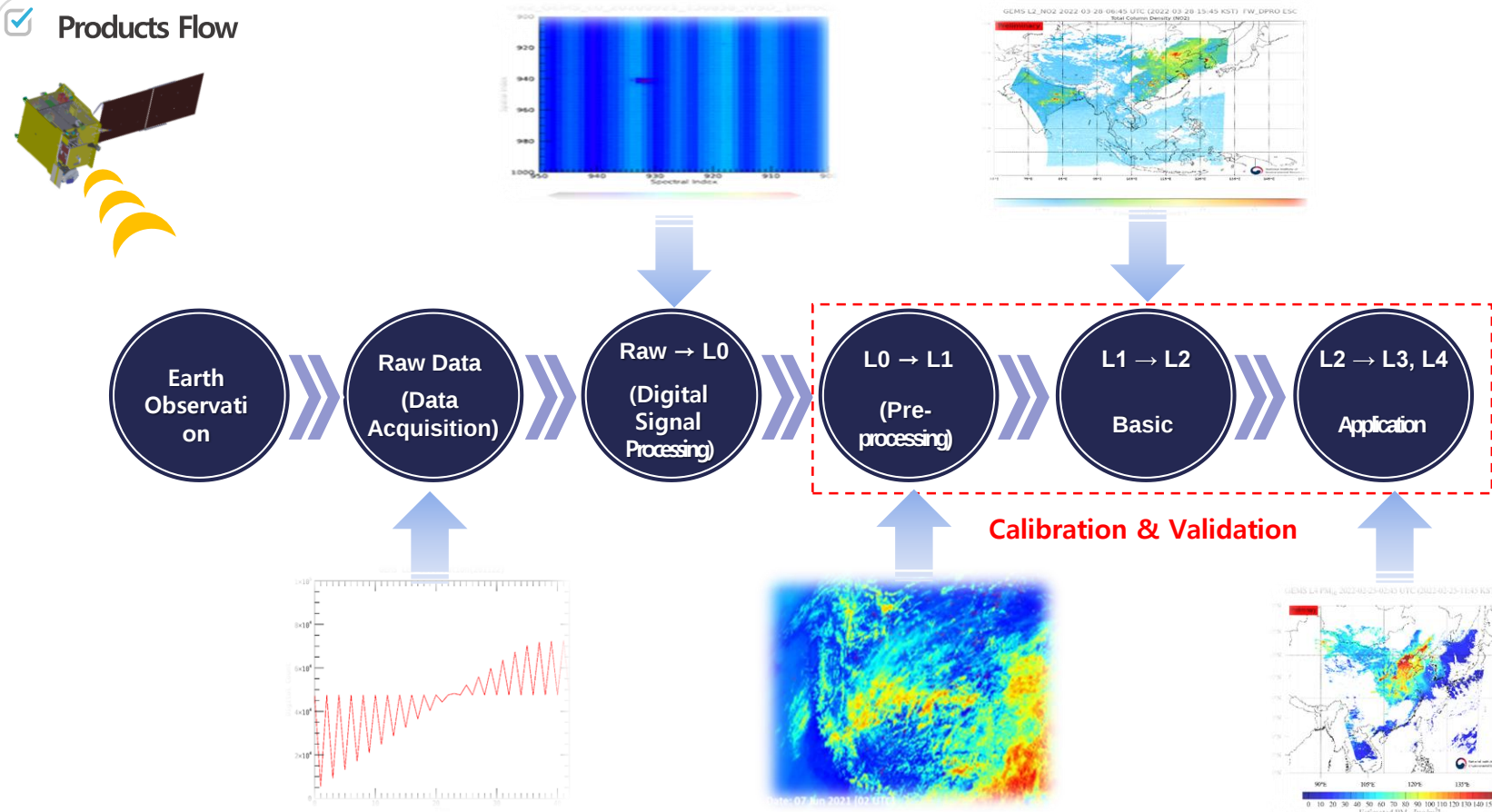
Ministry of Climate, Energy and Environment

National Institute of Environmental Research
Environmental Satellite Center

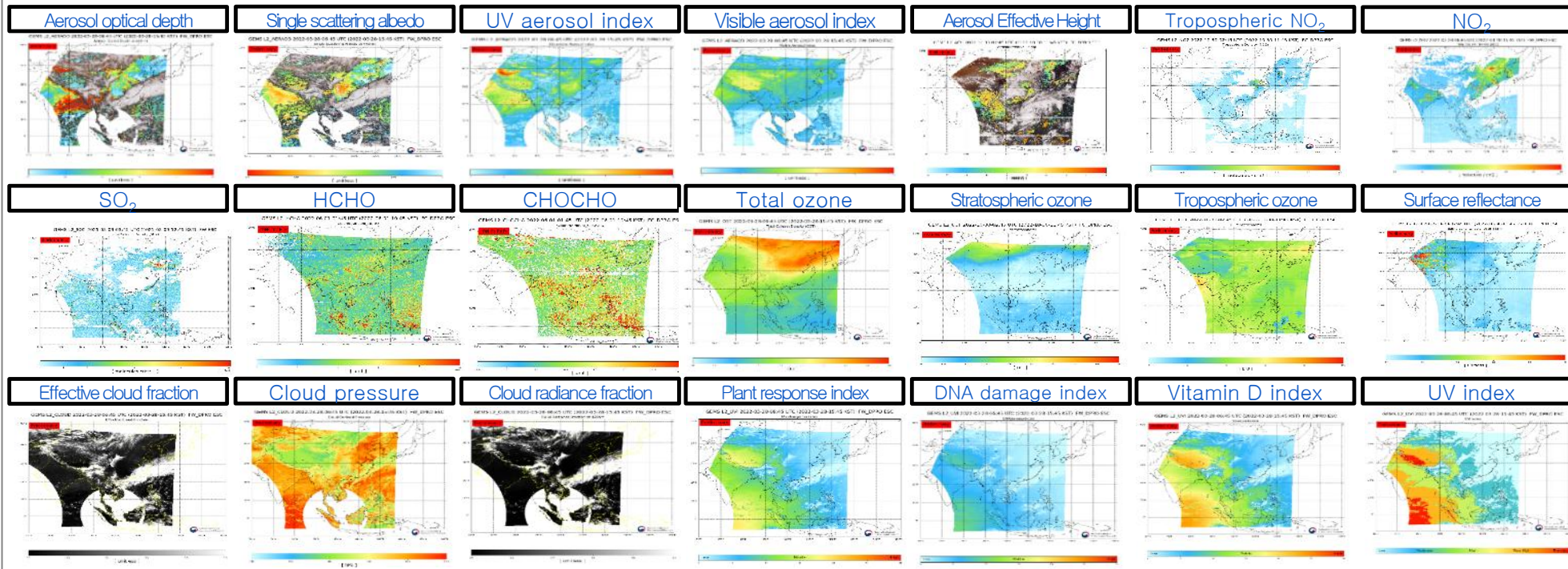
Establishment of a ground segment operation system for stable production and release of GEMS products

- High-quality satellite products through data reception, preprocessing, product generation and validation.
- Implementation of a redundant system based on high-performance computing (HPC) to ensure stable data service, mission continuity

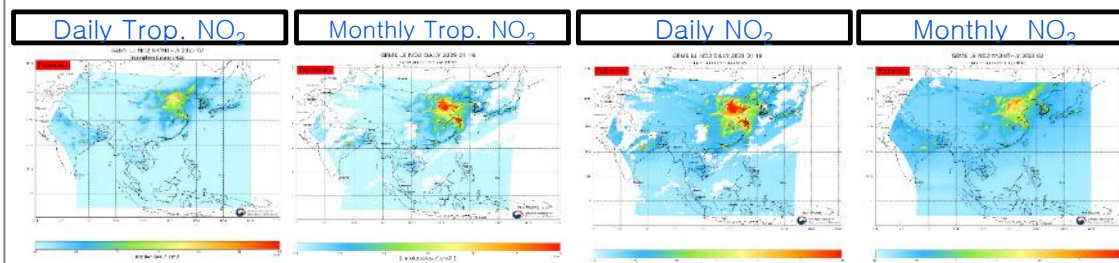
✓ Products Flow



Basic Products (L2)



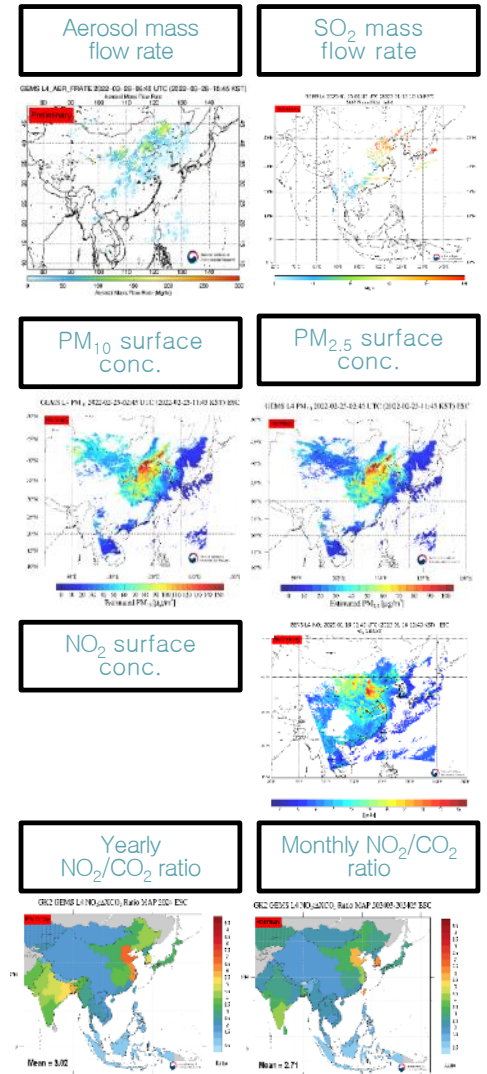
Averaged Fields (L3)



GEMS data download:

- 1) <http://nesc.nier.go.kr>
- 2) FTP
- 3) API

Value-added Products (L4)

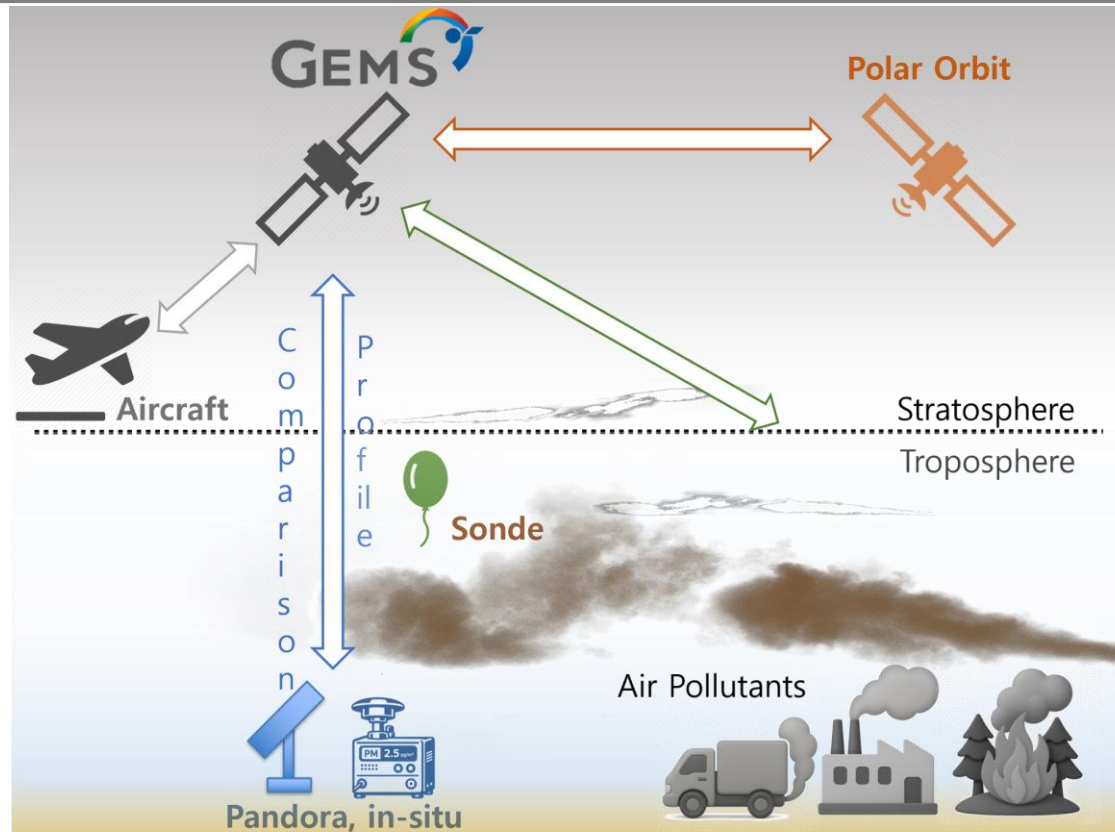


Ensure High Accuracy, Data Consistency, Reliability for policy decision-making

International satellite validation campaigns

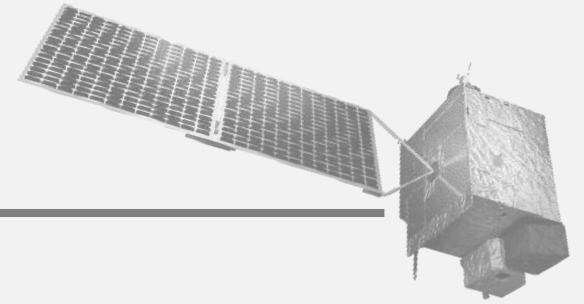
- (On going) **Geo-Ring** (2025~, Korea, U.S., Europe), **PEGASOS** (2021~, Europe), **PAN**(2021~, Asia), **GEMS-AQ** (2025~, Asia Countries)
- (Finish) CINDI (2024, Europe), PAN (2024, Asia), ASIA-AQ (2024, U.S.), ACCLIP (2023, U.S.) etc.

Validation Framework



Validation Method

	Method	Products
L0	Solar (WSD, RSD), Dark etc.	Degradation, Bad Pixel
L1	GEO, LEO Satellite	INR
L2	Remote (PM, AERONET)	AOD, SSA, Type
	Remote (Gases, Pandora)	NO ₂ , O ₃ , SO ₂
	Sonde	Profile NO ₂ , Profile O ₃
	LEO, Aircraft	HCHO, SO ₂ , NO ₂
L4	In-situ	Surface PM-2.5, PM-10, O ₃



2. Validation Results



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Established Pandora Asia Network (`21~`24)

Operation



Sites



Cooperation

- Atmospheric composition monitoring and data provision across 20 Asian Countries
 - PAN (Pandora Asia Network) Training through PAN workshop
- ※ (PGN) 235 sites worldwide, including 55 sites within the GEMS FOR (NIER-KOICA 29 sites)



Established Pandora Asia Network ('21~'24)

✓ Operation

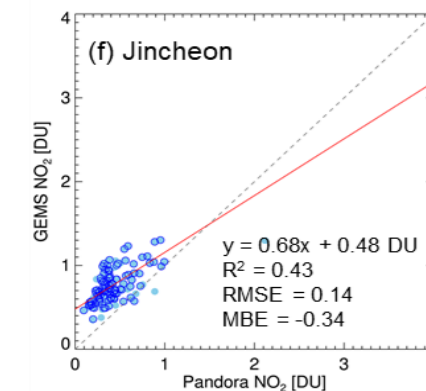
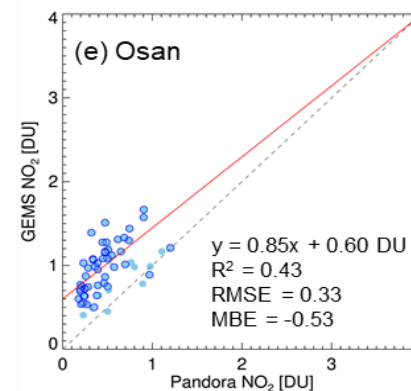
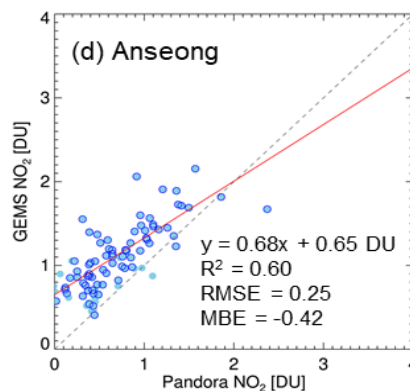
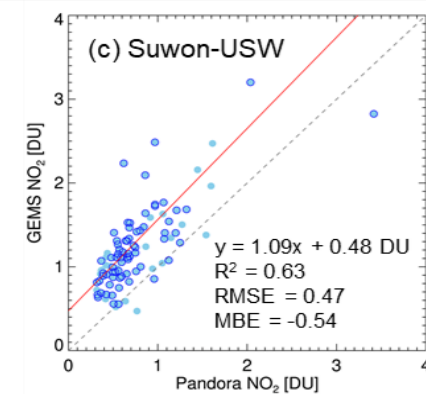
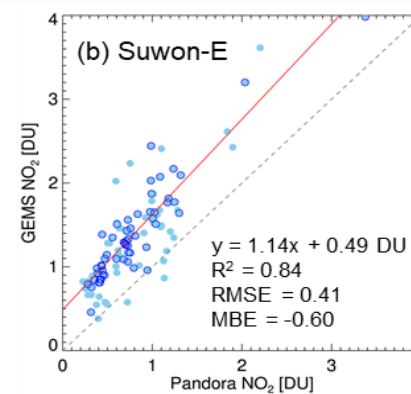
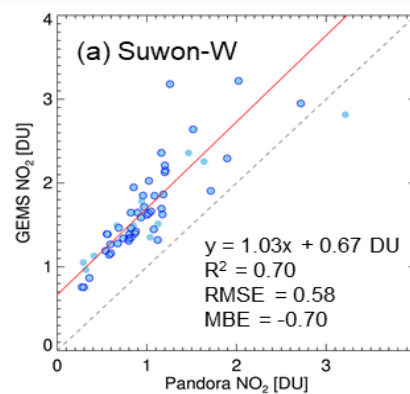


✓ Sites

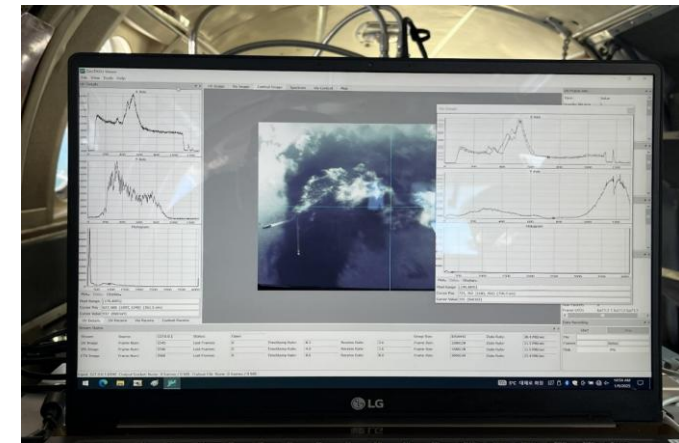


Results

- Through comparison with Pandora, we can investigate regional characteristics. GEMS generally shows higher values in urban areas, whereas Pandora tends to show higher values in relatively non-urban areas.



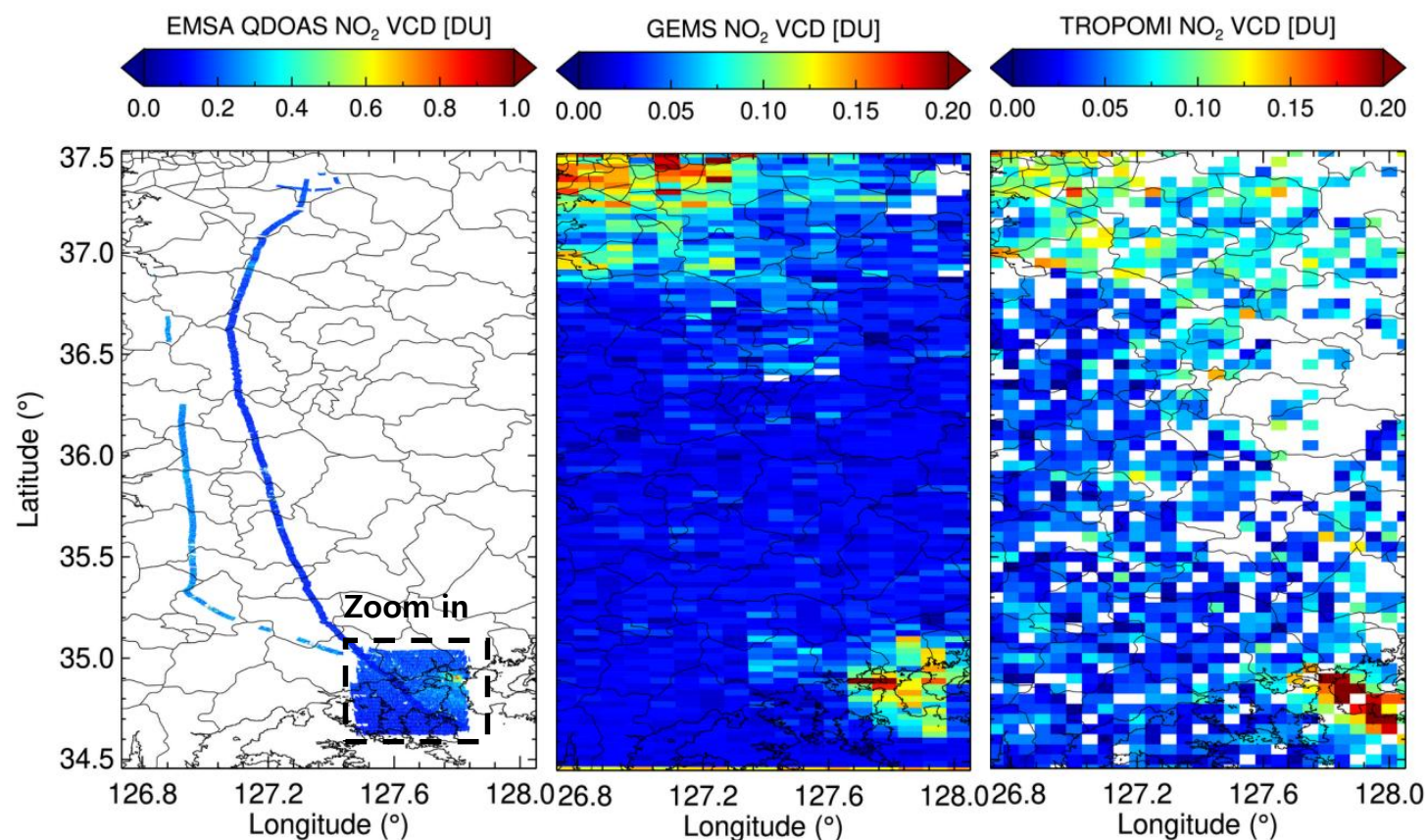
EMSA (Environment Monitoring Spectrometer for Aircraft platform) : A high-resolution aircraft observation system used to precisely validate the spatial accuracy and retrieval performance of GEMS satellite products.





Satellite can observe a very large area at once.

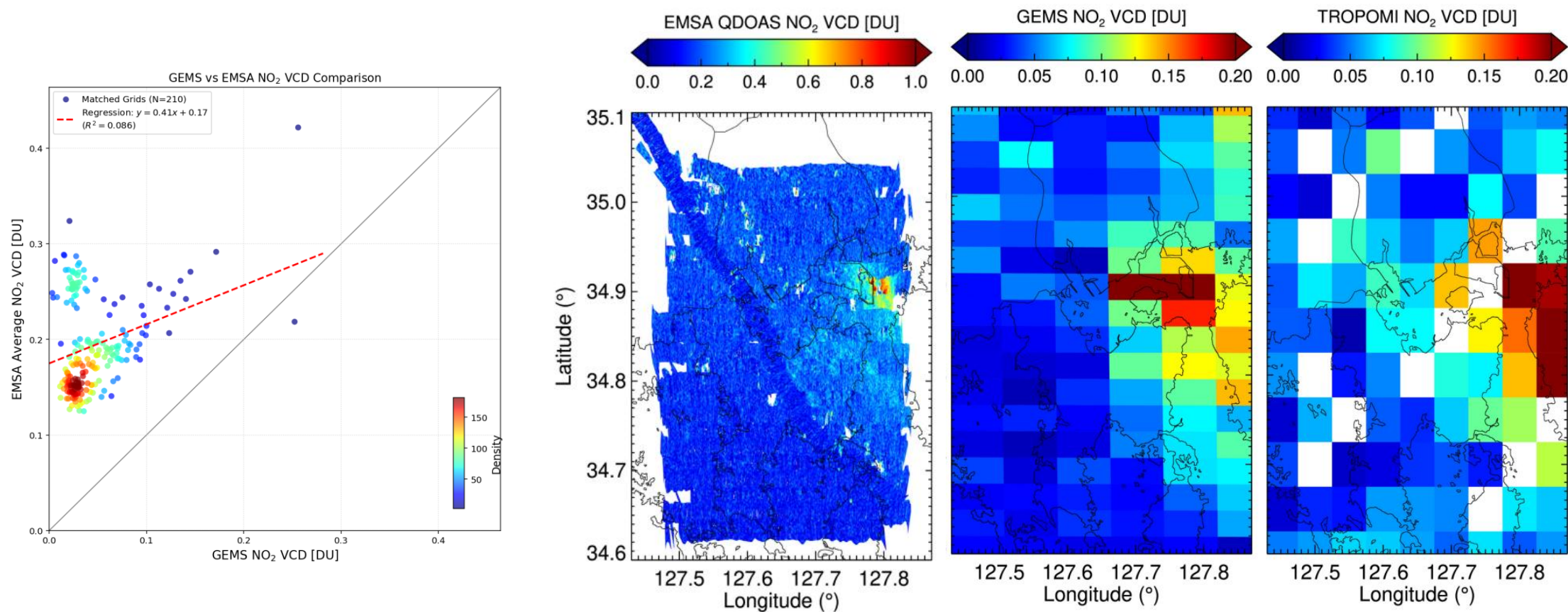
In contrast, EMSA needs much longer flight time and observe only a relatively narrow area.



< 2025/06/03, KST 12-15, (GEMS, TROPOMI, EMSA) >

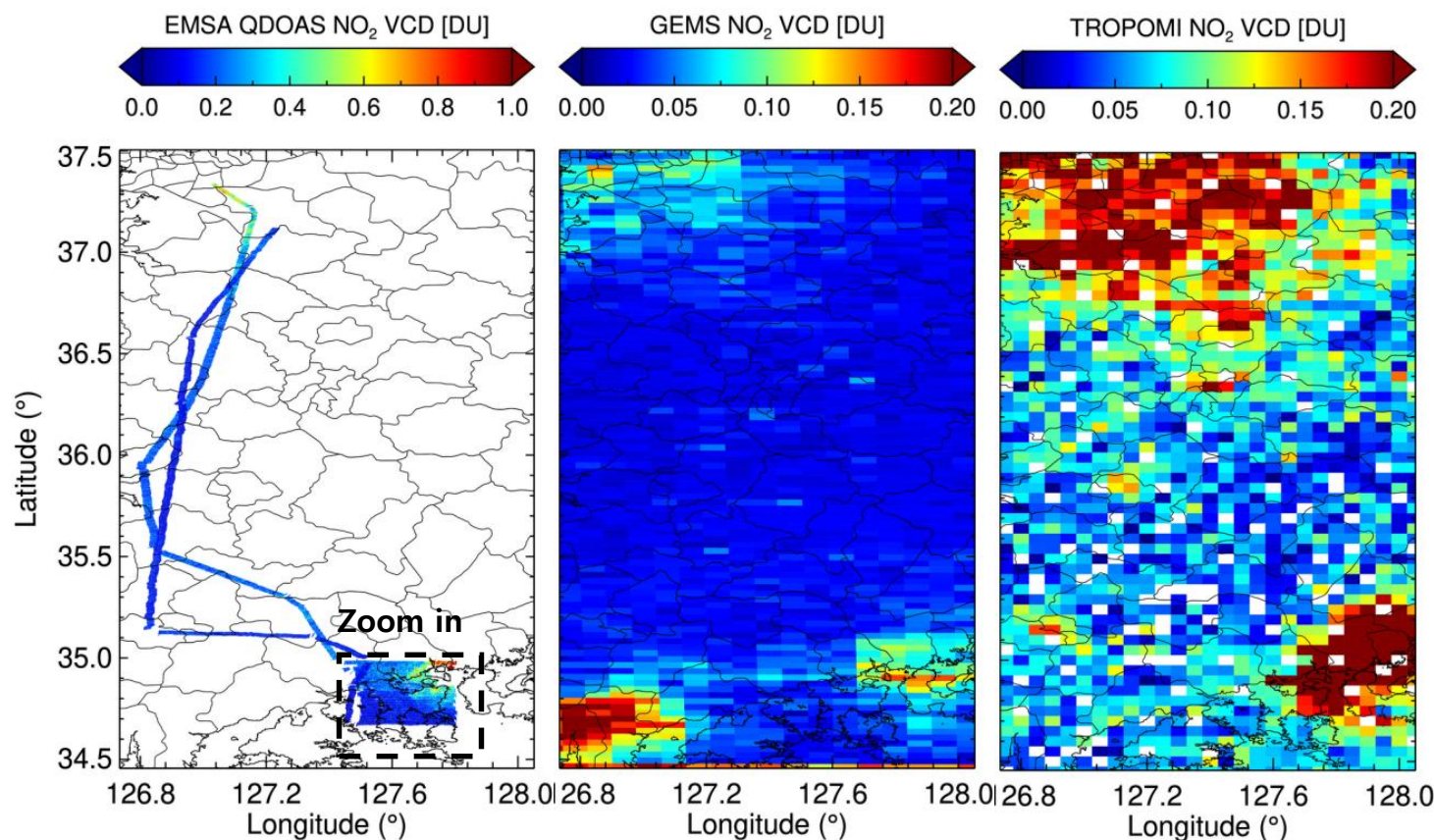


However, EMSA Provide much higher spatial resolution than satellite. Shows detailed local-scale pollution patterns
Satellites show the broad regional distribution, while EMSA shows fine local structures.





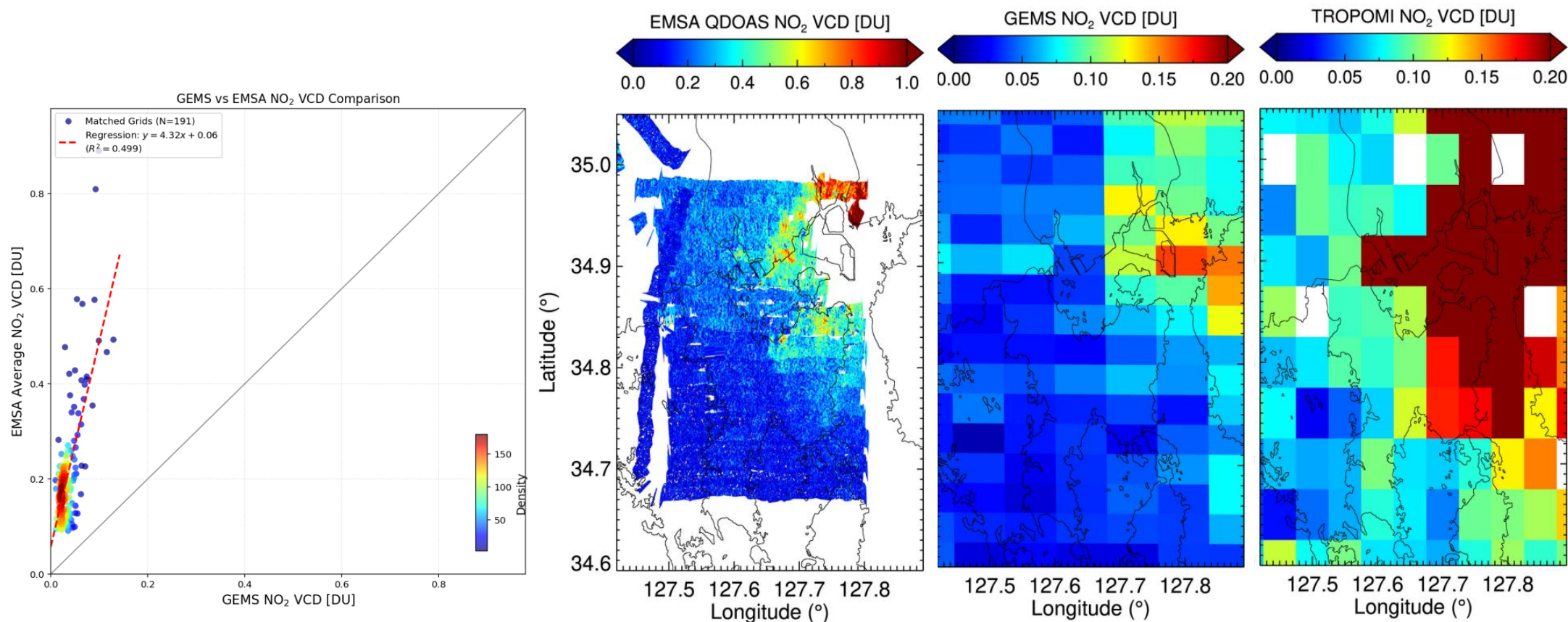
The purpose is to check the consistency between satellite observations and aircraft measurements.



< 2025/06/05, KST 10-14, (GEMS, TROPOMI, EMSA) >

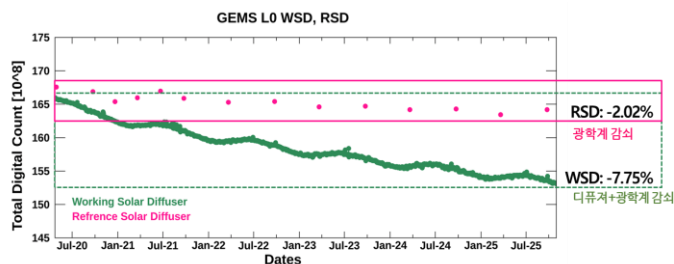
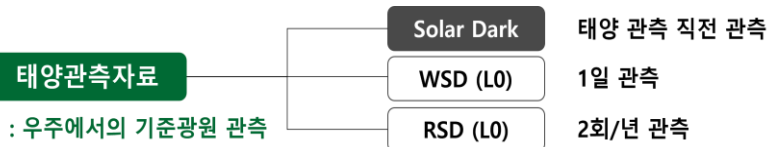


EMSA generally shows good spatial distribution but higher values than GEMS. We will further compare Pandora, aircraft, and GEMS data to better understand these differences.

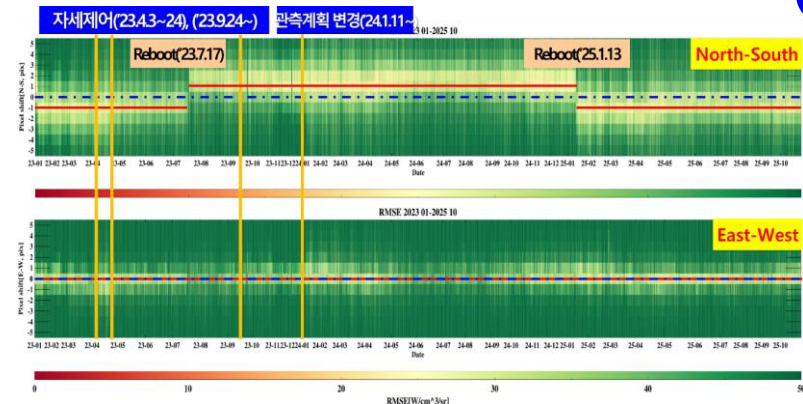


Results example – ESC Internal validation

L0



L1

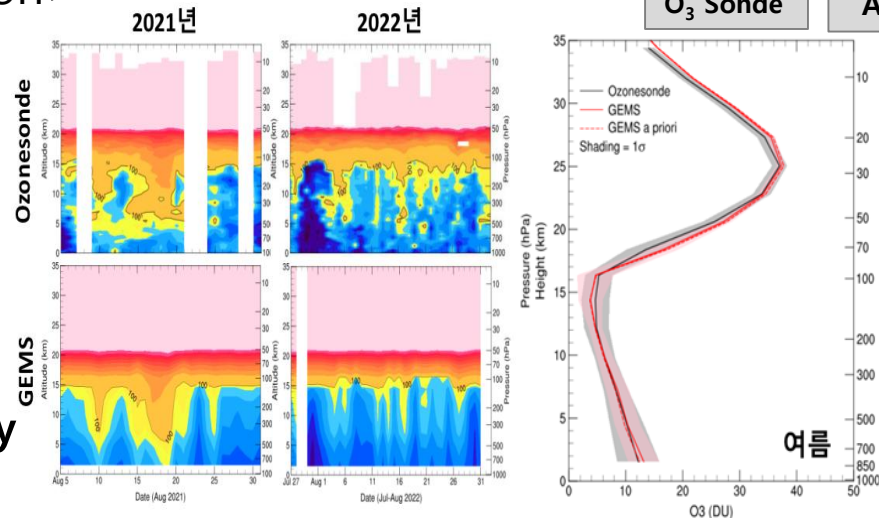


Results example – Part of GEMS FOV

Products Validation

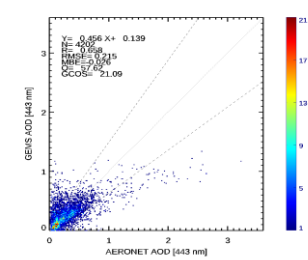
L2~L4

<Korea Region>

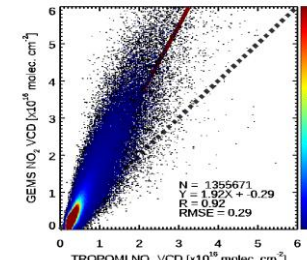


<See Presentation 3.1 (Prof. Kim)>

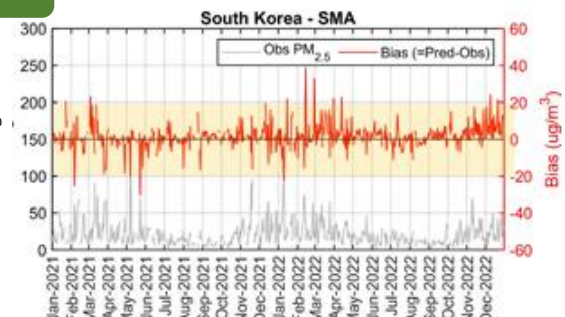
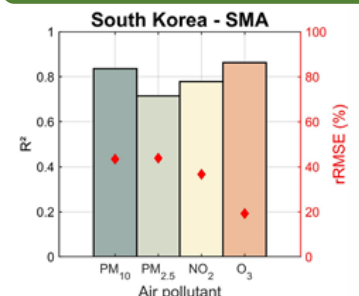
AOD



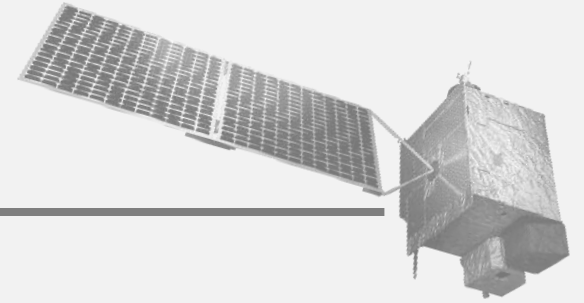
Total NO₂



Surface PM



< PI: Prof. Kim,
KNU, Supported by
NIER >



3. GEMS-AQ

(PI: Yongju Choi, HUFS, supported by NIER)



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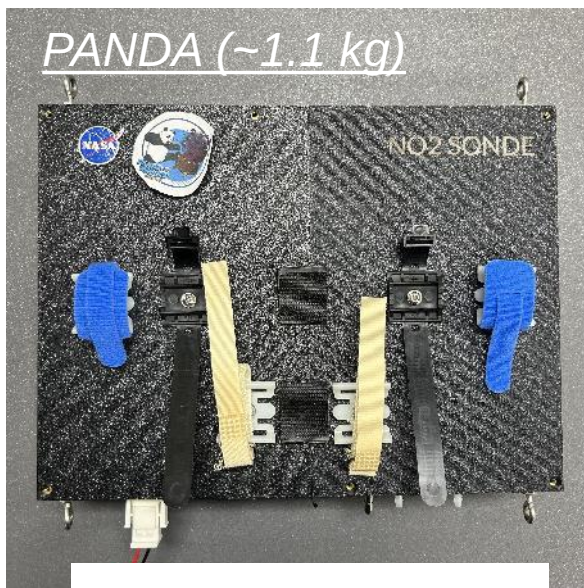
GEMS-AQ: Integrated Observations for Southeast Asian Air Quality and Improved GEMS accuracy

Category	SIJAQ-1	SIJAQ-2/ASIA-AQ	GEMS-AQ
Full Name	<u>S</u> atellite <u>I</u> ntegrated <u>J</u> oint monitoring of <u>A</u> ir <u>Q</u> uality	<u>A</u> irborne and <u>S</u> atellite <u>I</u> nterpretation of <u>A</u> ir <u>Q</u> uality	<u>GEMS</u> <u>A</u> ir <u>Q</u> uality Campaign
Period	2022 (Pre ASIA-AQ)	Feb-Mar. 2024	2025~2029
Organized by	NIER	NASA, NIER	NIER, GISTDA
Target Region	Korean Peninsula	Korean Peninsula, Philippines, Thailand	2025: Thailand Bangkok 2026: Thailand Chiang Mai 2027: (Under discussion) Candidate: Indonesia, Laos, Philippines, Mongolia etc.
Key Components	Ground-based remote sensing + Satellite (GEMS)	DC-8-G-III Aircraft + <i>in-situ</i> + Ground-based remote sensing + model + Satellite (GEMS)	<i>in-situ</i> + Ground-based remote sensing + model + Satellite (GEMS)

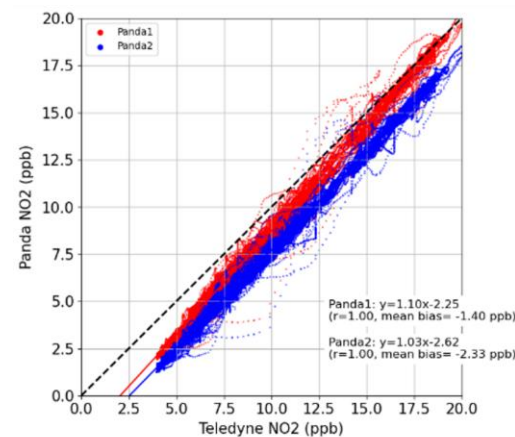
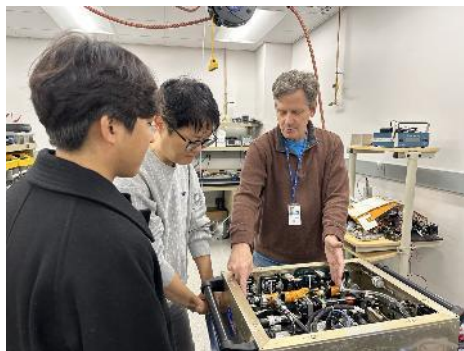
Portable cavity-enhanced Absorption of Nitrogen Dioxide Analyzer (PANDA)

• 16m³ (~3 x ~4 m) Skyhook Helikite

- Payload: 8 kg (including instrument and tether)
- Maximum altitude: < 1.3 km (depends on payload and weather condition)



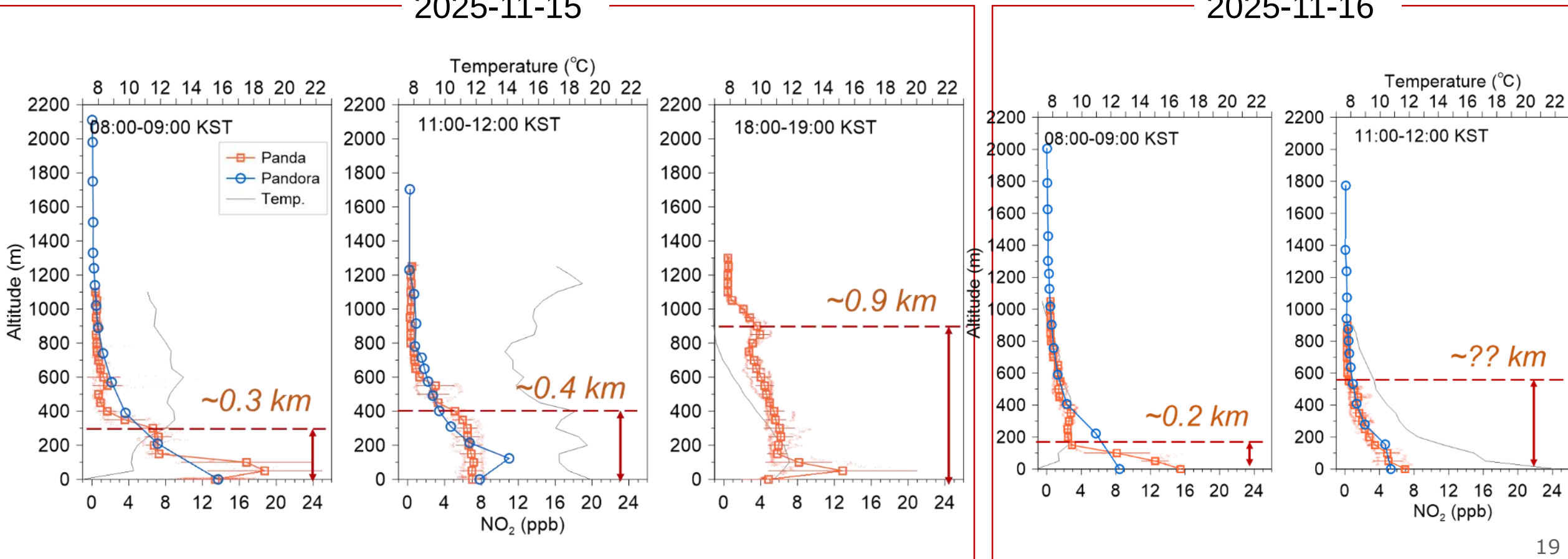
Courtesy of T. Hanisco



An-sung site in Korea, pre-launch(~1km), 3 times/per day, (AM, Noon, PM)
Found that the NO₂ layer gradually moved upward with time.

2025-11-15

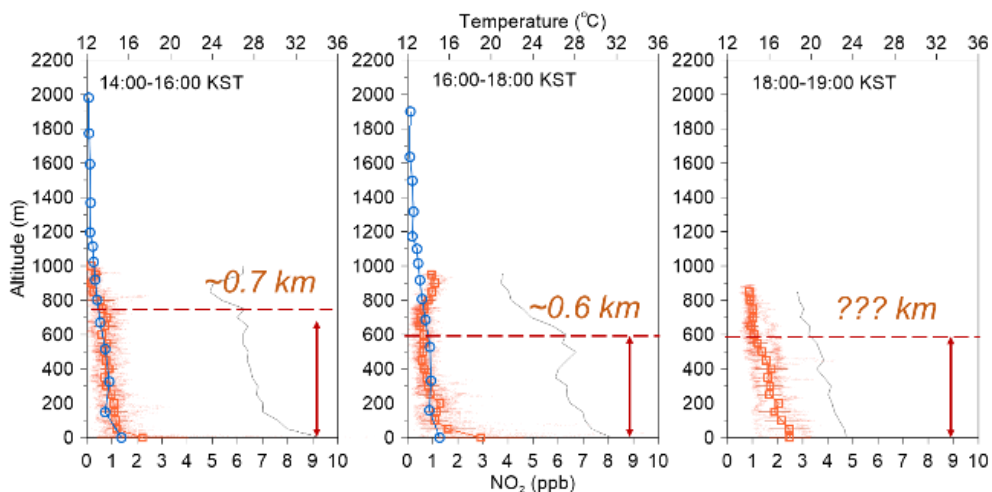
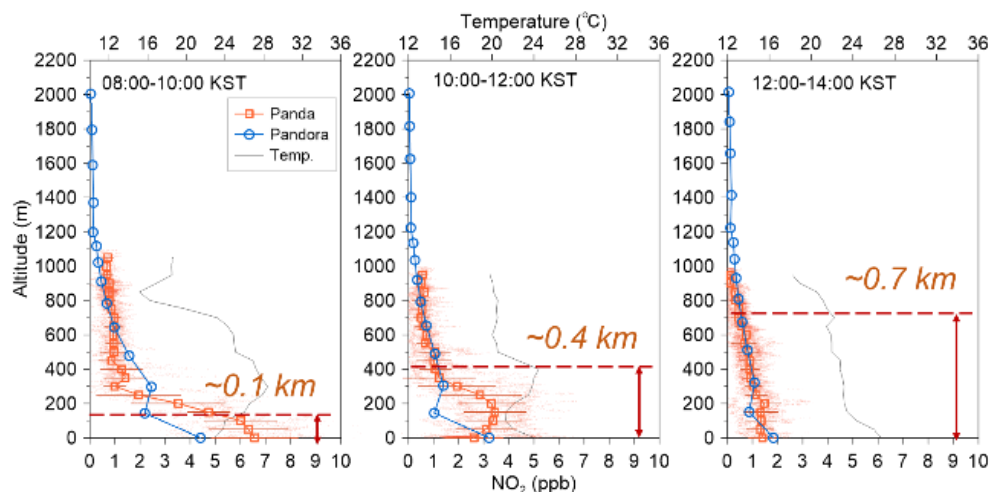
2025-11-16



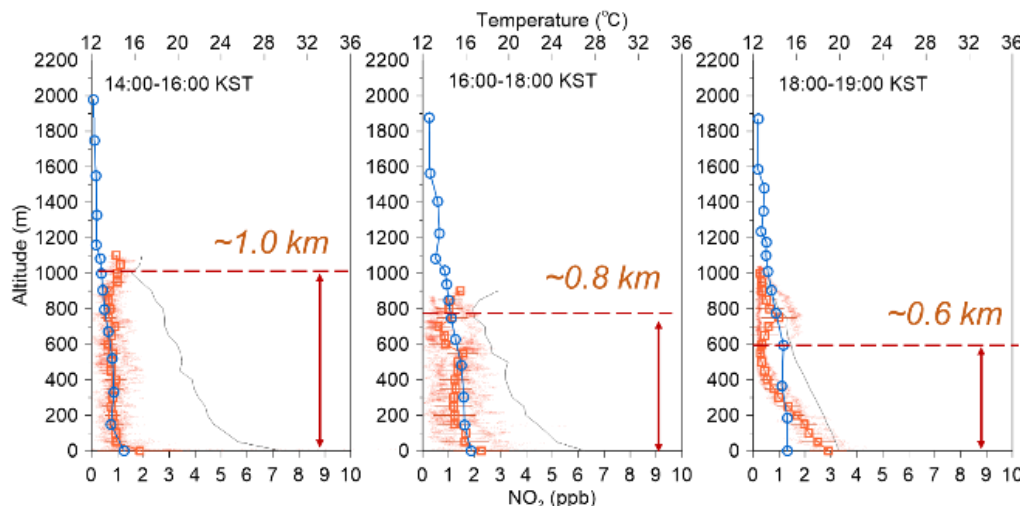
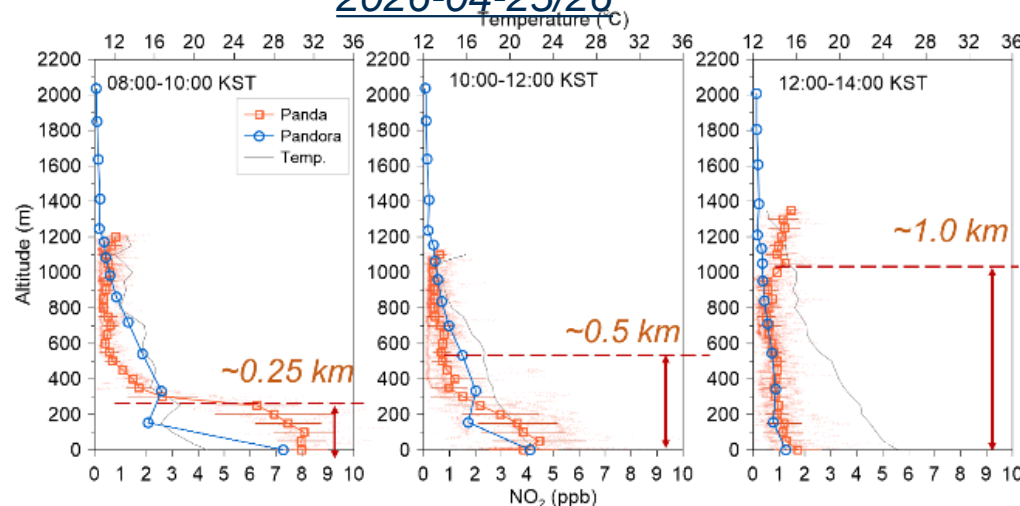
Divided the observation time more finely and conducted measurements six times a day
The NO₂ layer gradually moved upward during the day, and then came back down again in the evening.

@Chun Cheon

2026-04-18/19



2026-04-25/26



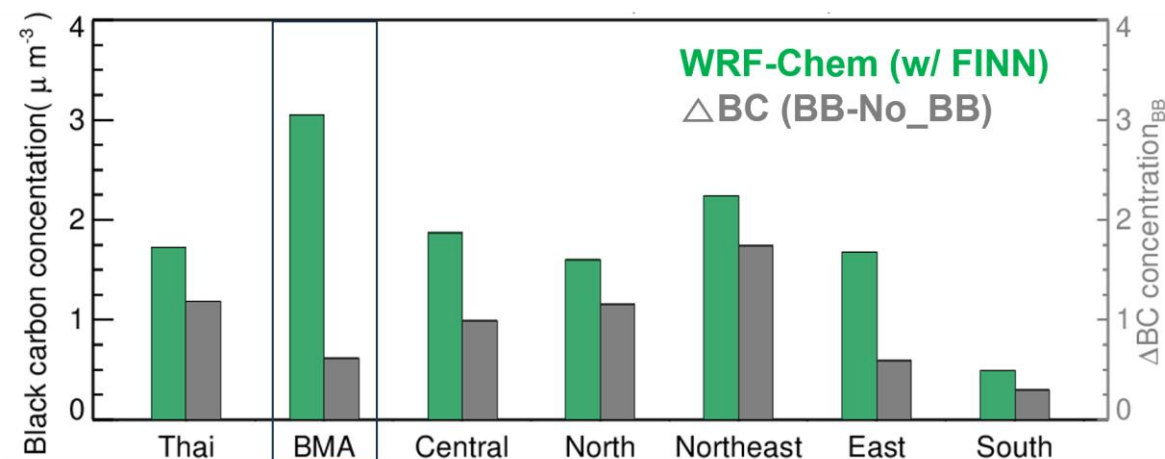
N₂O vertical distribution can change significantly within a day



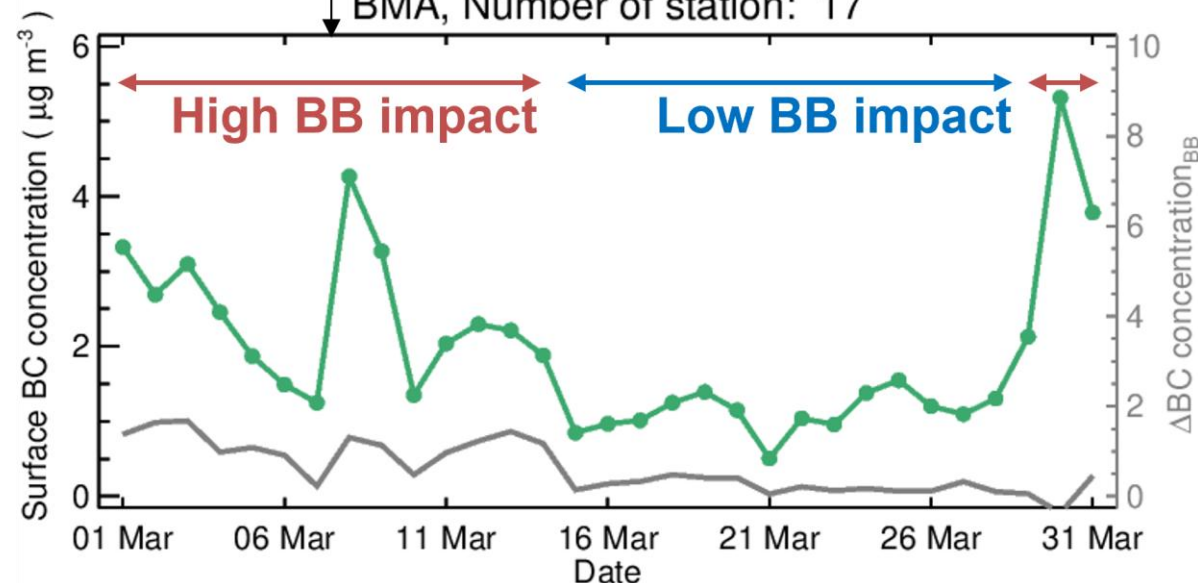
< period: 2026-02-16 to 2026-03-12 >

- Increase in Surface Black Carbon Due to Biomass Burning Emissions
- Increase in BB Due to Biomass Burning
 - **BB increment** : 1.0~4.0 $\mu\text{g m}^{-3}$

Regional & BMA BC Concentration

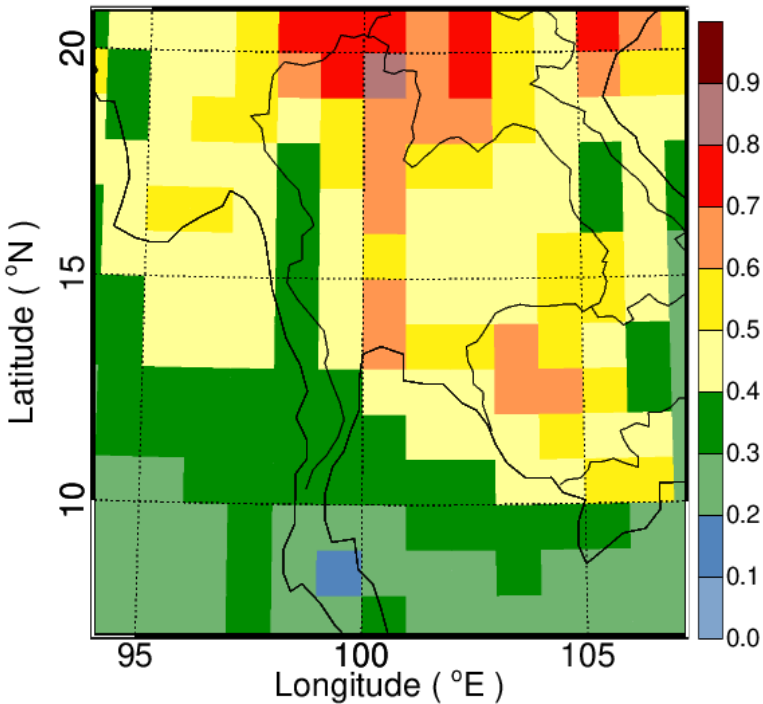


BMA, Number of station: 17

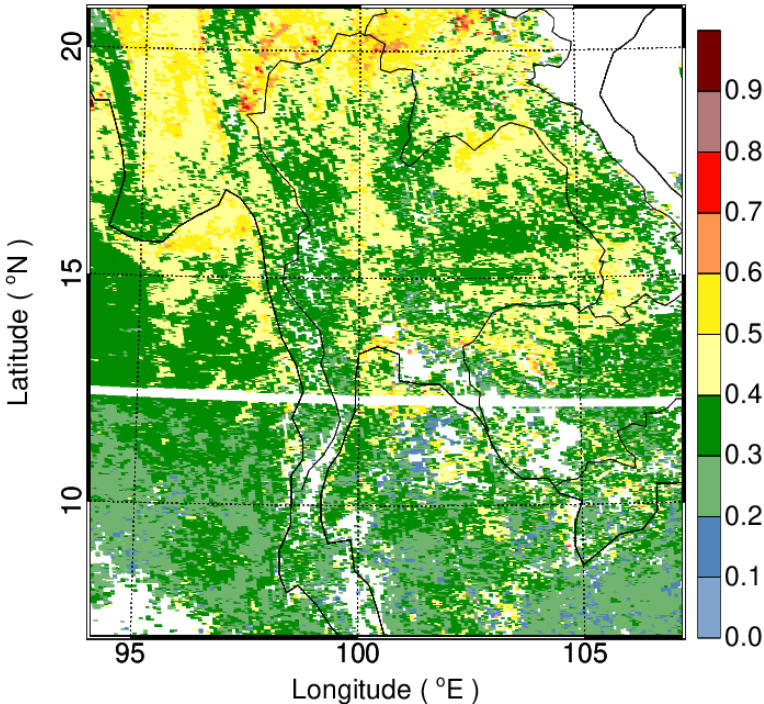


Compare AOD from MODIS, GEMS and WRF-Chem. GEMS shows values comparable to MODIS; however, further investigation is needed to better understand the spatial distribution.

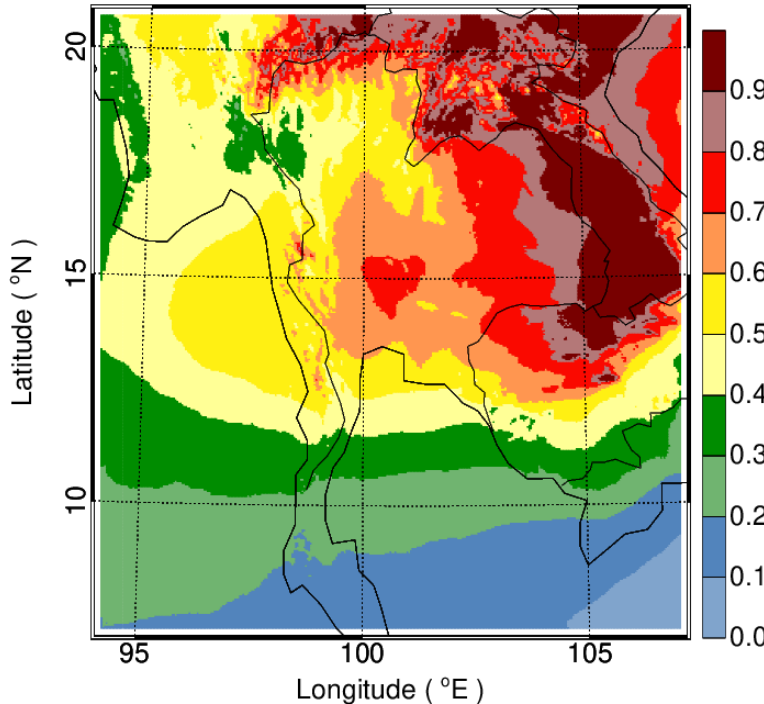
MODIS



GEMS



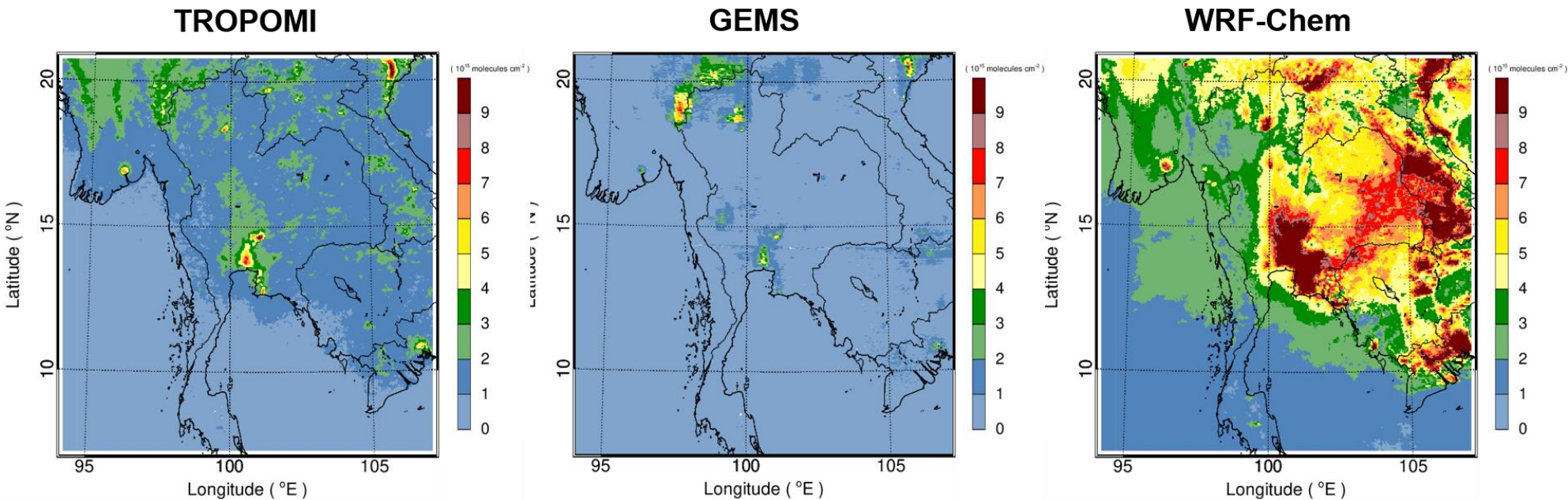
WRF-Chem



*Time
GEMS: 0445, 0545 UTC
WRF-Chem: 04, 05 UTC

	MODIS	GEMS	WRF-Chem
Domain Avg	0.41±0.14	0.38±0.10	0.50±0.27

For NO₂, the retrieved values were lower than those from the CTM. In the comparison with Pandora, TROPOMI also showed lower values. GEMS produced even lower values than TROPOMI



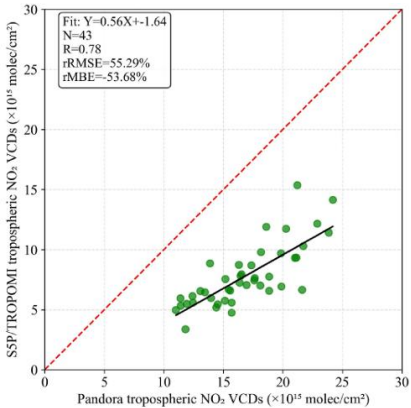
	($\times 10^{15}$ molec. cm^{-2})		
	TROPOMI	GEMS	WRF-Chem
BMA	4.6 ± 2.6	2.4 ± 1.1	14.2 ± 8.6

TROPOMI v.s. Pandora @ BMA

(Kanchanachat, AE, 2026)

Table 3
Summary statistics of tropospheric NO₂ VCDs corresponding to Fig. 3 (seasonal).

Season	NO ₂ ($\times 10^{15}$ molec/ cm^2)
Winter	13.95 ± 8.39
Summer	13.43 ± 7.53
Rainy	10.98 ± 6.53



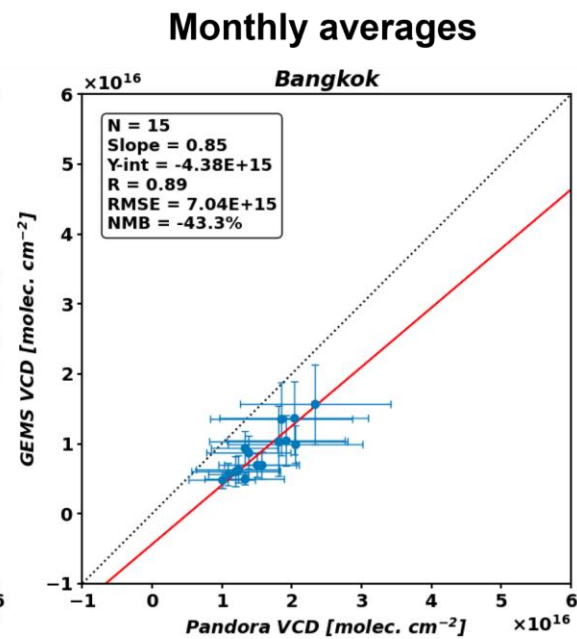
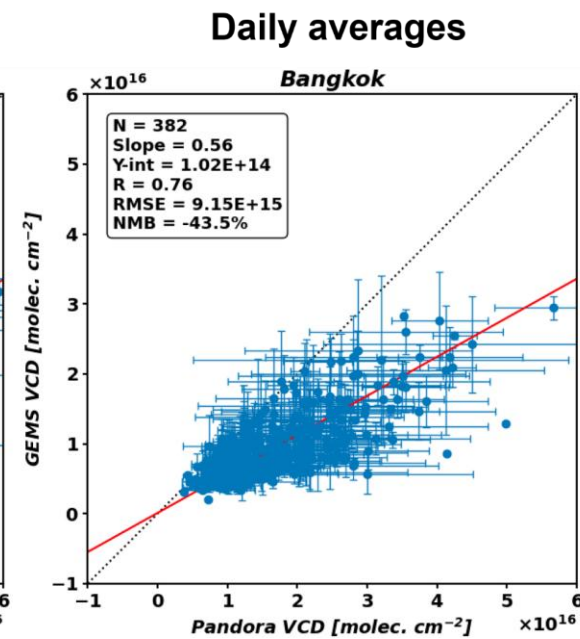
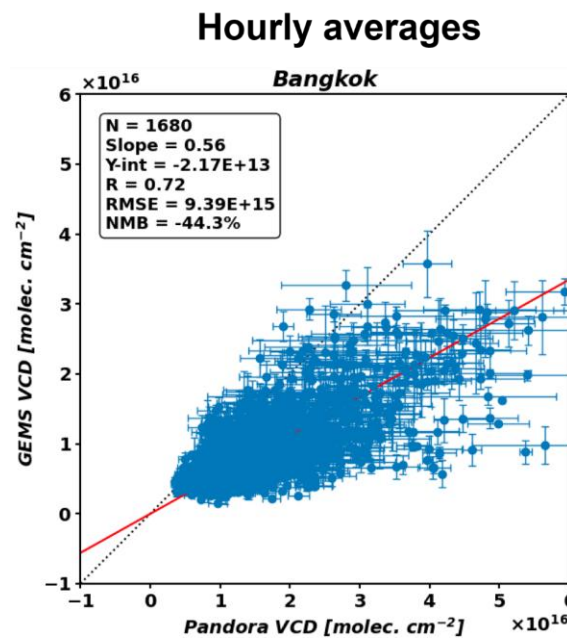
TROPOMI underestimates Pandora by -54% at Bangkok

4. Comparison of monthly average tropospheric NO₂ VCDs between SSP/ TROPOMI and Pandora (June 2021-December 2024).

Satellite validation can be more challenging in Southeast Asia.

Results

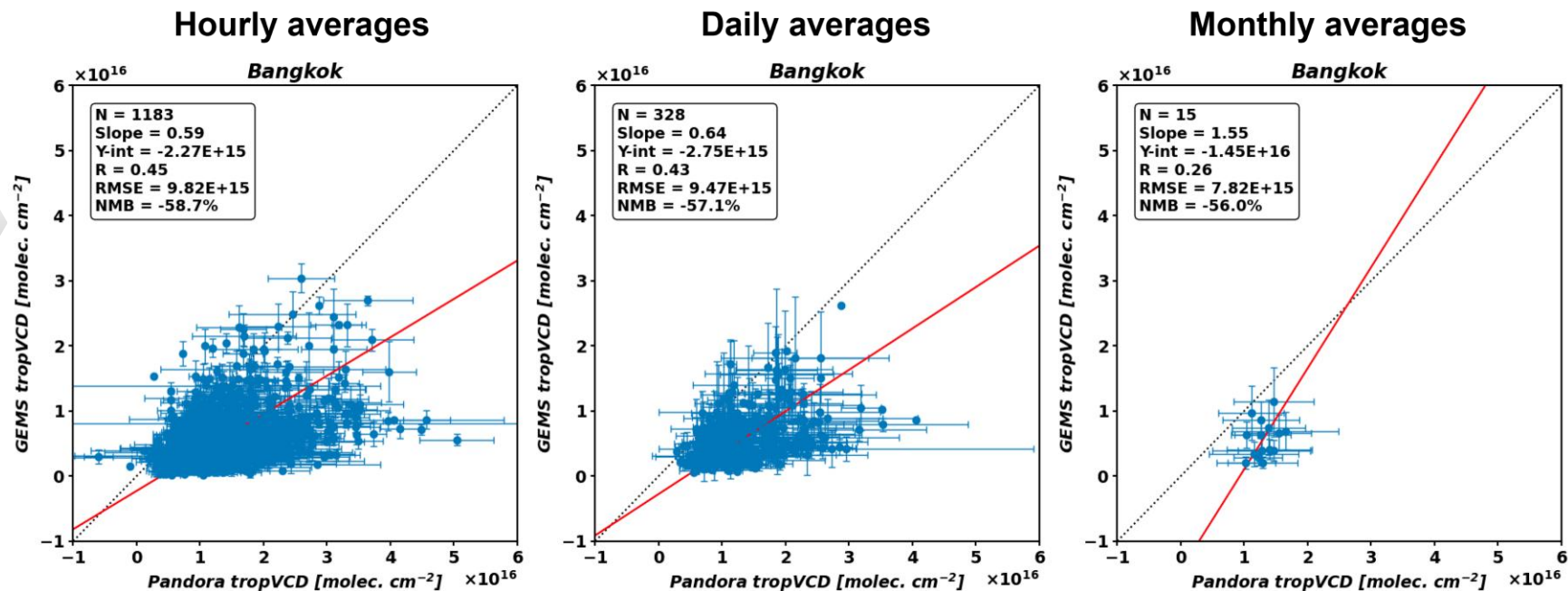
- For the NO₂ total column, Pandora observes lower values than GEMS.
- More local validation data are needed to better understand GEMS performance in SouthEast Asia



Agreement between GEMS and Pandora is weaker for tropospheric NO₂ than for total column NO₂.

Results

- Compared with the total column result, the difference becomes larger in terms of the correlation coefficient, or R value.



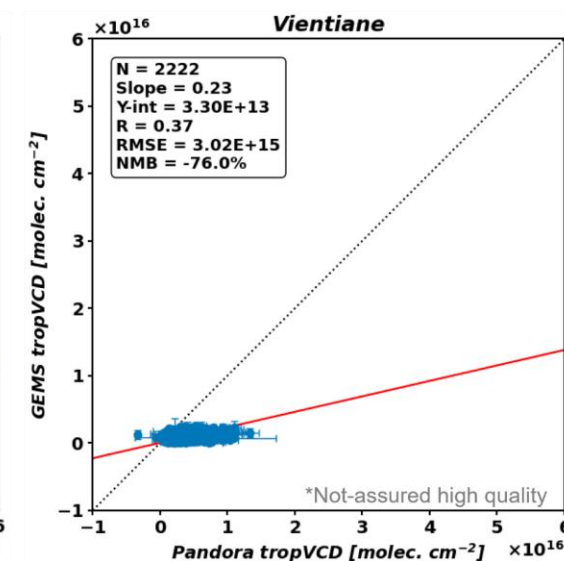
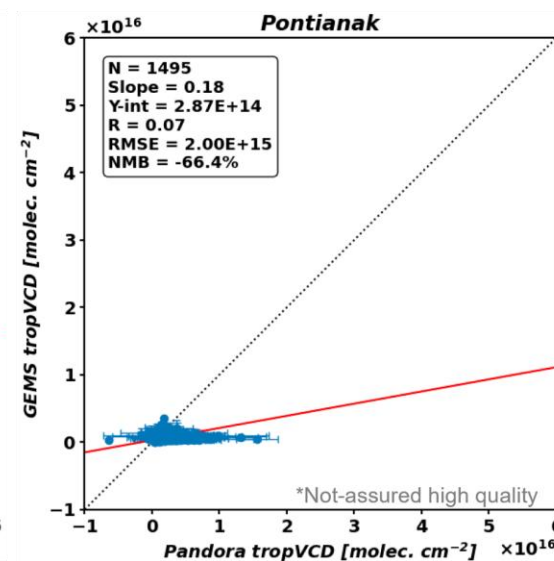
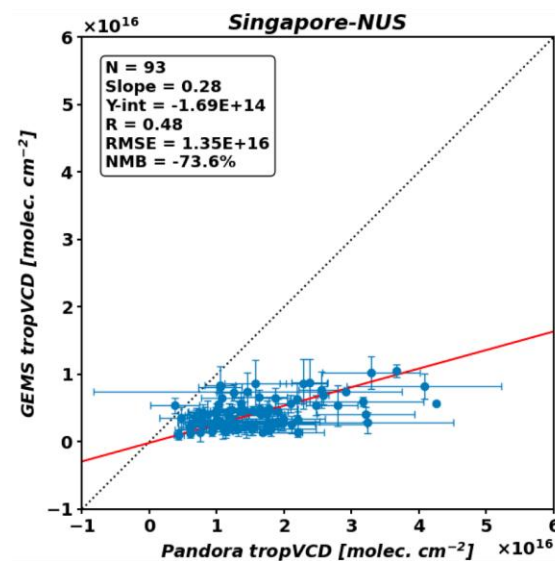
GEMS validation in Southeast Asia is more challenging than in Korea

Results

- Compared with the Bangkok case, the difference between GEMS and Pandora becomes even larger.
- Pandora data themselves may need additional quality control and further checking.



Hourly averages



- Bangkok BMA (same site) and **Chiang Mai** (strong biomass burning)
- **planning to January 2027**
 - will launch the tethered sonde up to ~1 km along with installation of *in-situ* instruments



Skyhook Helikite



Pandora

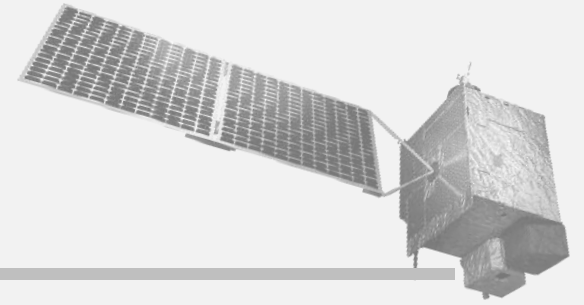
PM_{2.5} samplers

GEMS-AQ (Air Quality) campaign in Bangkok

โครงการรณรงค์ GEMS-AQ (คุณภาพอากาศ) ในกรุงเทพฯ



- **GEMS has established a comprehensive validation framework** covering L0, L1, L2, and L4 products.
- **Multi-platform validation**, including Pandora, aircraft, in-situ measurements, sondes, and other satellites, enhances the reliability of GEMS data.
- **PAN, EMSA, and GEMS-AQ expand validation capability across Asia**, especially in regions with limited ground-based observations.
- **GEMS-AQ will improve our understanding of regional air pollution**, including biomass burning impacts and urban air quality in Southeast Asia.
- **GEMS will continue to provide reliable satellite information** for air quality management, policy support, and climate resilience in Asia.



“

We will continue to strengthen
GEMS operations and utilization
for better air quality and climate resilience in Asia.”



Thank you



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