

GEMS Status

- Operation over 5 years

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GEMS L2 Version History

Products	2020	2021	2023	2024	2025	2026 (Version scheduled for release)
O3 Total	Δ Launch IOT Δ First light Image	V1.0	V2.0	V2.1.0	→	V2.2.0
O3 Profile				V3.0.0		-
NO2				V3.0.0	V4.0.1	→ V4.1.0
SO2				V2.1.0	V3.0.1	→ V3.1.0
HCHO				V3.0.0		V4.0.0
CHOCHO				V2.1.0	V3.0.1	→ V3.1.0
AOD				V2.1.0		V3.0.0
AEH				V2.1.0		V3.0.0
CLD				V3.0.0		V3.0.2
SFC				V3.0.0		V3.2.0
BrO, H2O		-	R&D		V1.0 (research product)	→ V1.1.0
HONO		-	R&D			

Algorithm improvements in the 2026 release version

L1	- Improved de-stripping processes and north-south variability - Improved diffuser degradation correction	Compared to TROPOMI: 17.9% → -3.2%
O3T	Improvement of the cloud processing module	R=0.97 → 0.97
O3P	The ISRF derivation optimization method in the GEMS O3P wavelength region has been validated	(Tropo) R=0.87 → 0.92 (Strato) R=0.80 → 0.67
NO2	- Incorporating monthly mean tropopause climatology derived from FNL reanalysis data - Improved scattering weight LUT by considering aerosol type information	2024/06 (Trop) R=0.66 → 0.67 (Strat) R=0.92 → 0.91 2024/12 (Trop) R=0.87 → 0.87 (Strat) R=0.89 → 0.87
SO2	- Improved retrieval noise characteristics - Improved issues related to anomalous positive/negative stripe patterns and missing retrievals - Replaced the SO₂ profile data used in AMF calculations - Applied fitting window options used for volcanic SO₂ retrievals	R = 0.85~0.88 → 0.89~0.91
HCHO	- Improved the polarization correction methodology Reduced model dependence by improving reference spectrum sampling	R=0.58 → 0.70 (When using polarization-corrected L1C, R = 0.60 → 0.77)

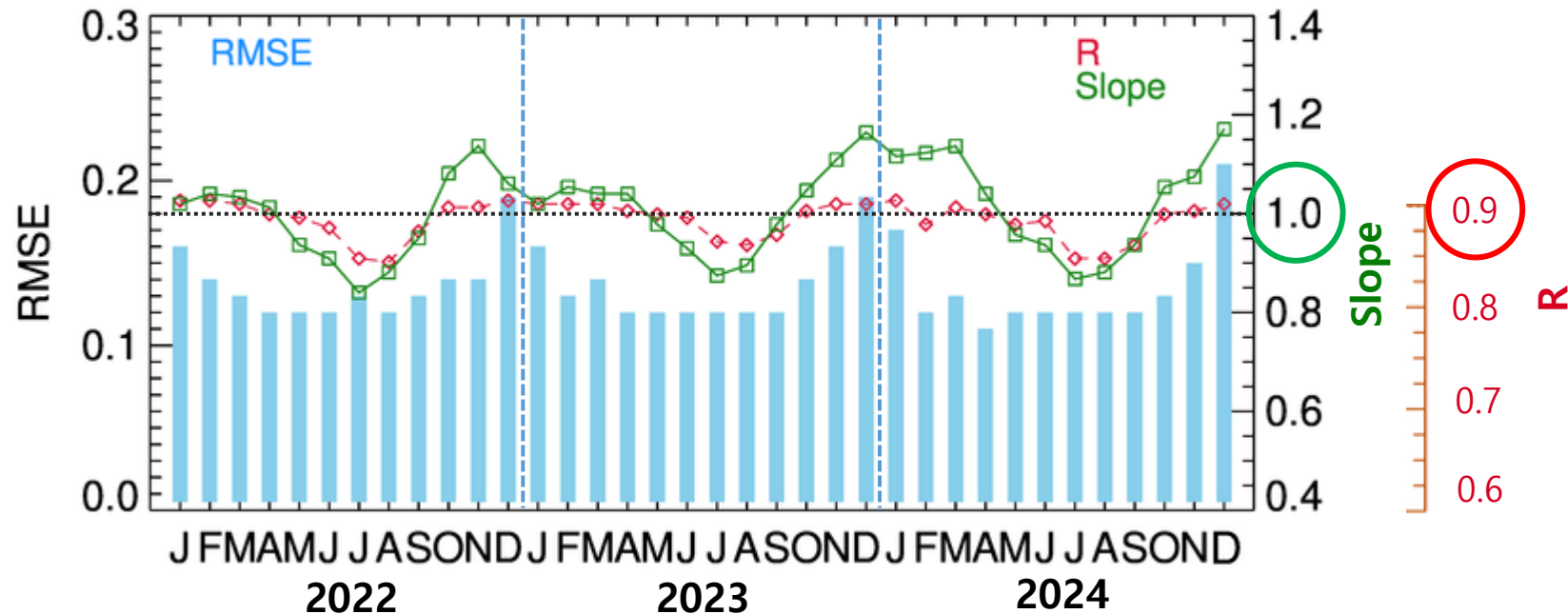
Algorithm improvements in the next release version

CHOCHO	Reduced model dependence by improving reference spectrum sampling	R=0.51 → 0.51
AOD	Reconstructed the LUT by incorporating updated aerosol microphysical and optical properties, and added a Mixture LUT - Modified the threshold for aerosol type selection - Applied DNN-based post-processing for AOD	R=0.70 → 0.81 (After post-processing, 0.91)
AEH	Case analysis of AEH variability	-
SFC	Improved overestimated BSR values over the Southeast Asia region - Addressed errors causing BSR discontinuities arising from scan scenarios - Reconstructed the application of an atmospheric correction LUT based on VLIDORT	(440 nm) Bias=-0.02 → 0.003
CLD	Snow-covered pixels were identified using the GEMS L1C GPQF-snow index	(ECF) R=0.70~0.78 → 0.75~0.78 (CCP) R=0.73~0.87 → 0.71~0.84
BrO	Modified the AMF calculation module and updated input data (CLD, albedo) : introduced BSR and CRF	R=0.58 → 0.59
TCWV	Modified the AMF calculation module and updated input data (CLD, albedo): introduced BSR and implemented a configurable CRF option in the code	R=0.95 → R=0.93

GEMS NO₂ V4.0 Comparison with TROPOMI

Data period: Jan 2022 – Dec 2024 04:45 UTC

Total NO₂

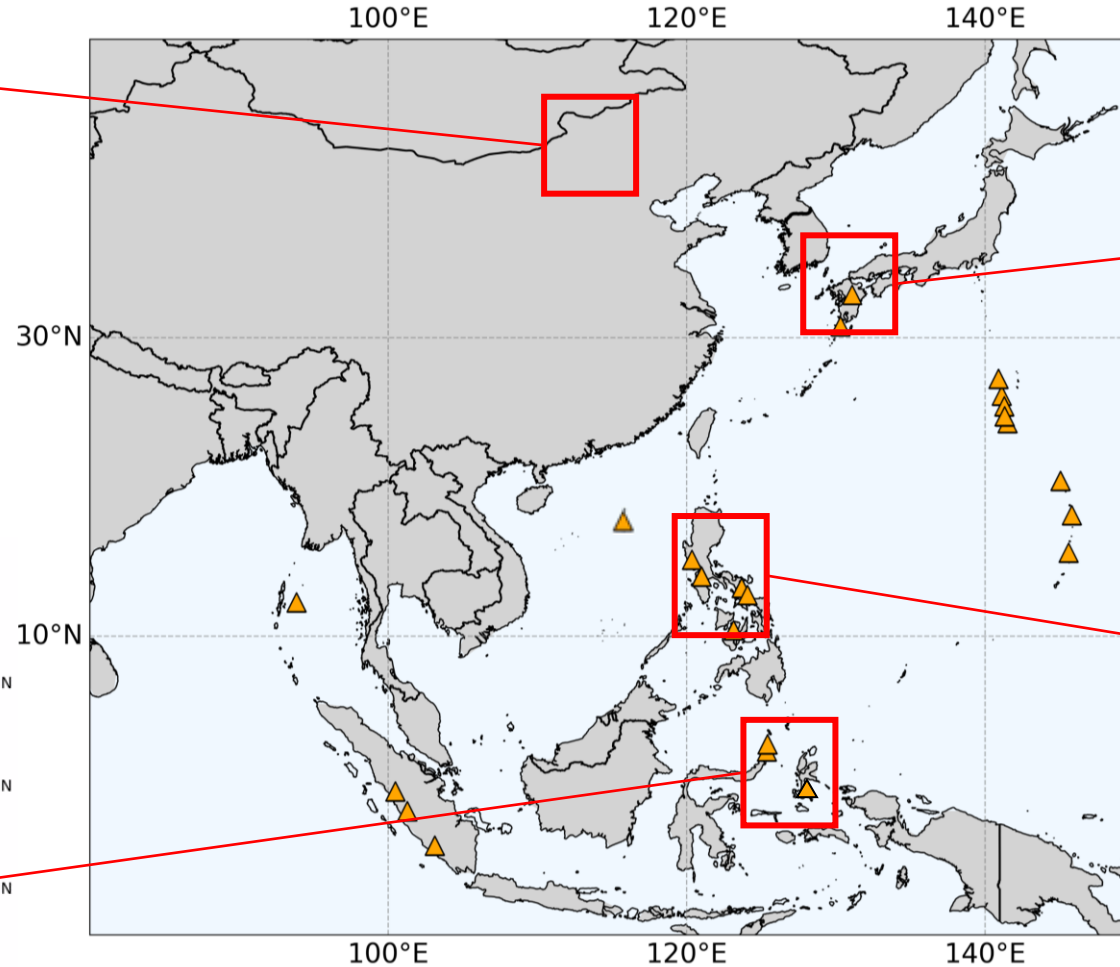
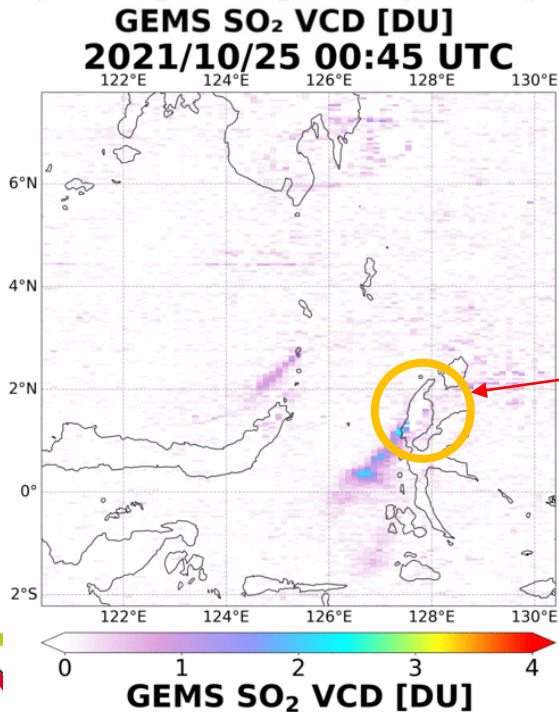
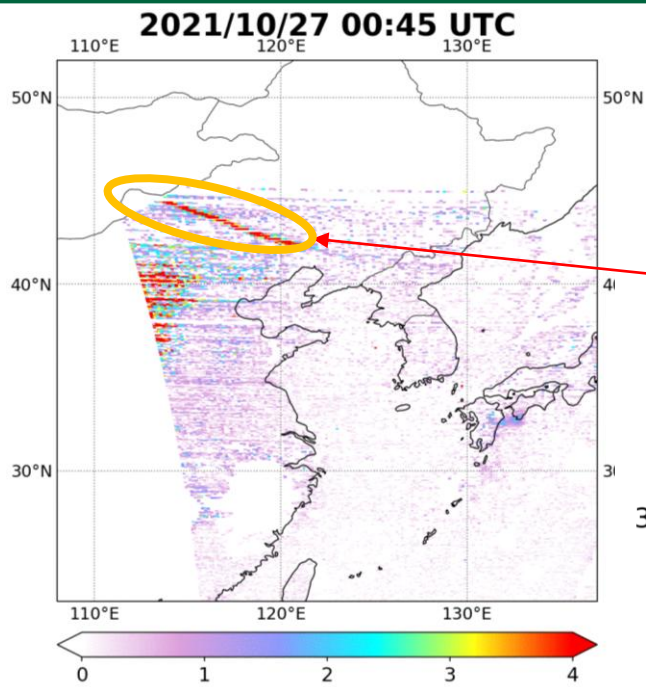


- RMSE values of 0.12–0.20 and correlation coefficients (R) greater than 0.8 indicate stable performance.
- The GEMS NO₂ VCD exhibits pronounced seasonal variability, with underestimation in summer and overestimation in winter.

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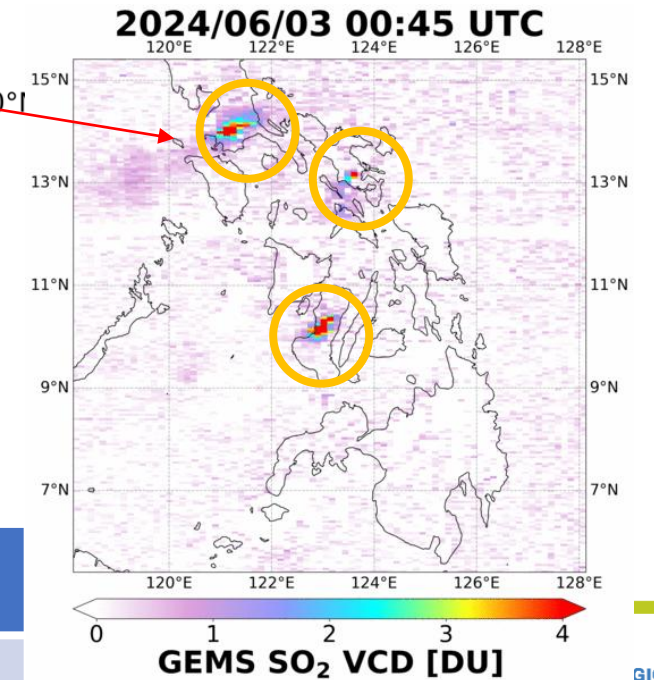
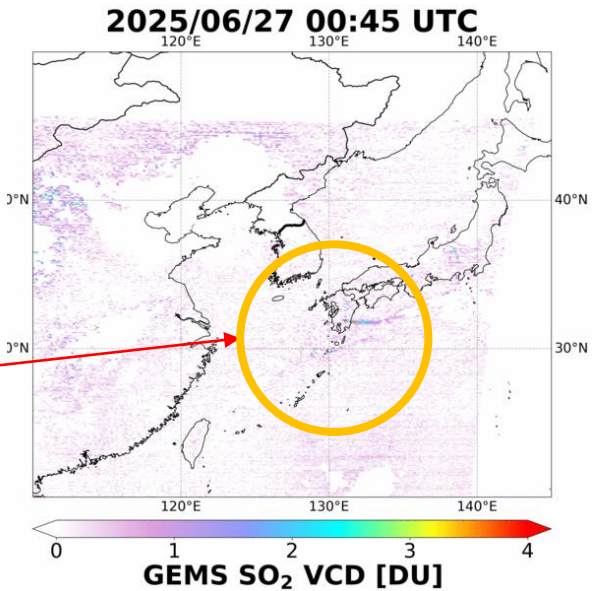
Volcanoes within the GEMS domain

GEMS SO₂ V3.0



Number of Volcanic Eruptions from 2021 to 2025 within the GEMS domain(60-150°E, -5~50°N)

Philippines	Indonesia	Japan	United States	India	Total
12	12	14	5	3	46

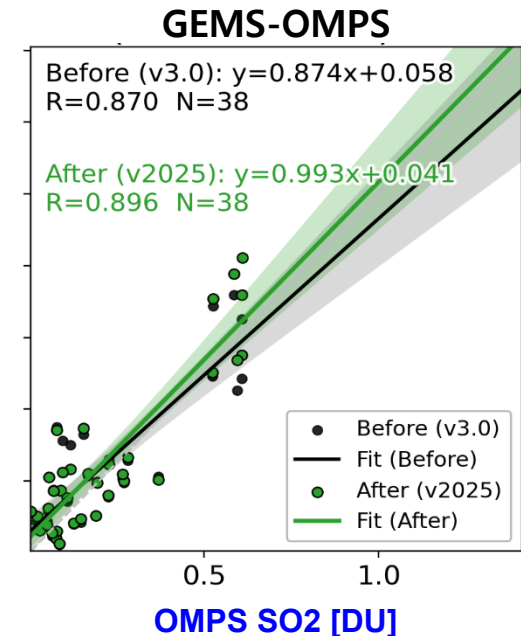
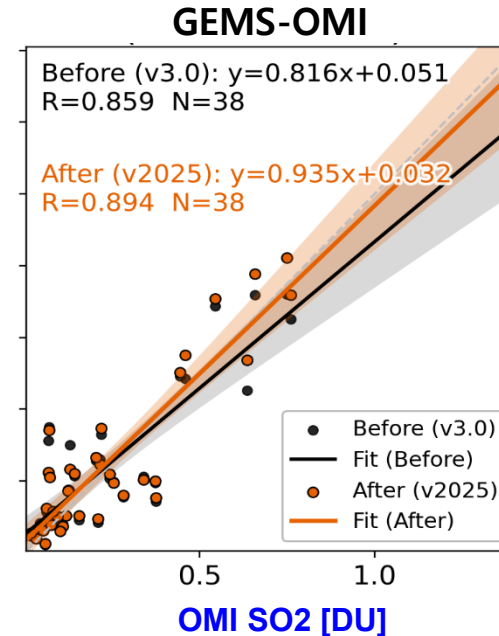
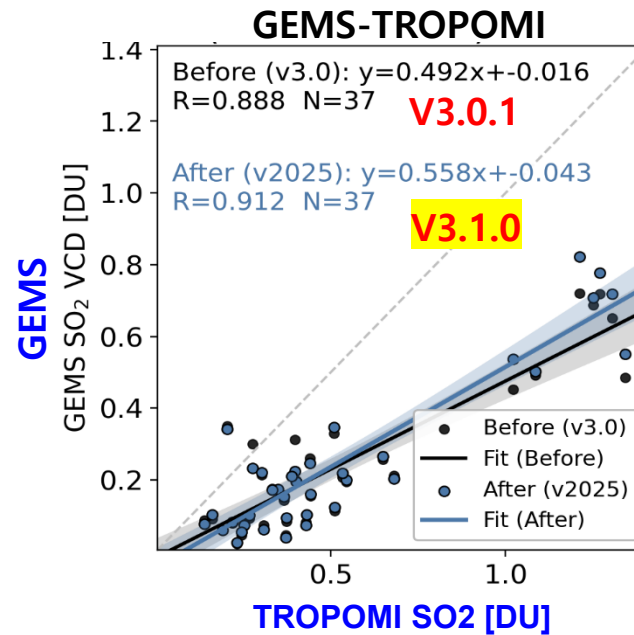


GEMS SO₂ V3.1 Comparison with LEO

Data period: Jan 2024 – Dec 2024

SO₂ V3.1 updates

- Improved **retrieval noise**
 - Improved issues related to **stripe patterns** and **missing retrievals**
 - Replaced the **SO₂ profile data** used in AMF calculations
 - Applied **fitting window options** used for **volcanic SO₂ retrievals**
- Increase in **correlation** with LEO satellites by **2.7–4.1%**

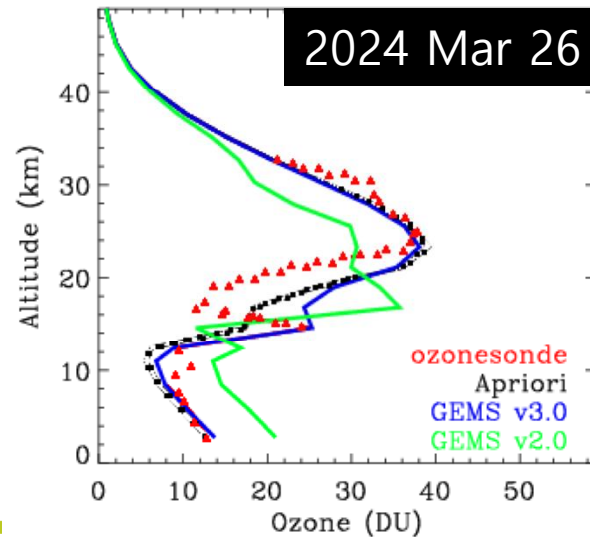
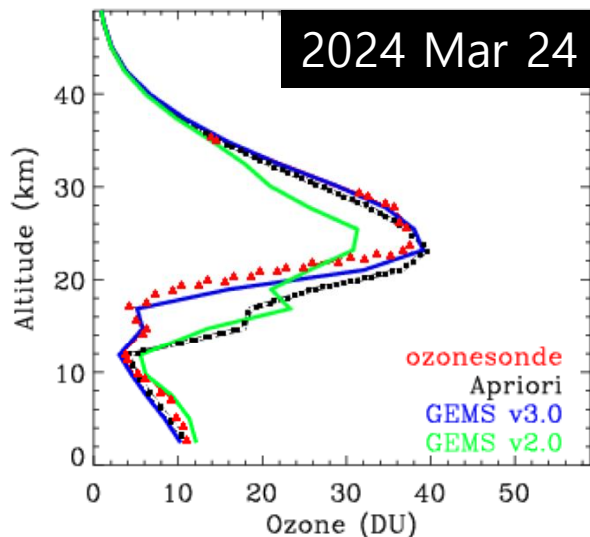
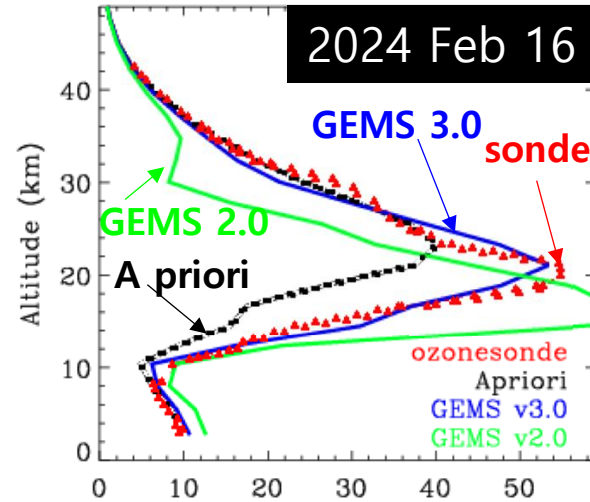
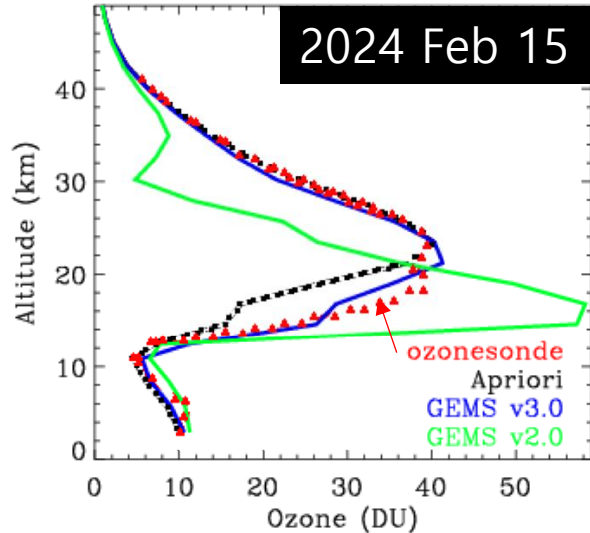


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GEMS O₃P Validation



Data period: Feb 2024 – Mar 2024



	V2.0	V3.0
Fitting range	310 – 340nm	310 – 330nm
Input data	UM, SAO, BDM	GFS, TSIS, BW

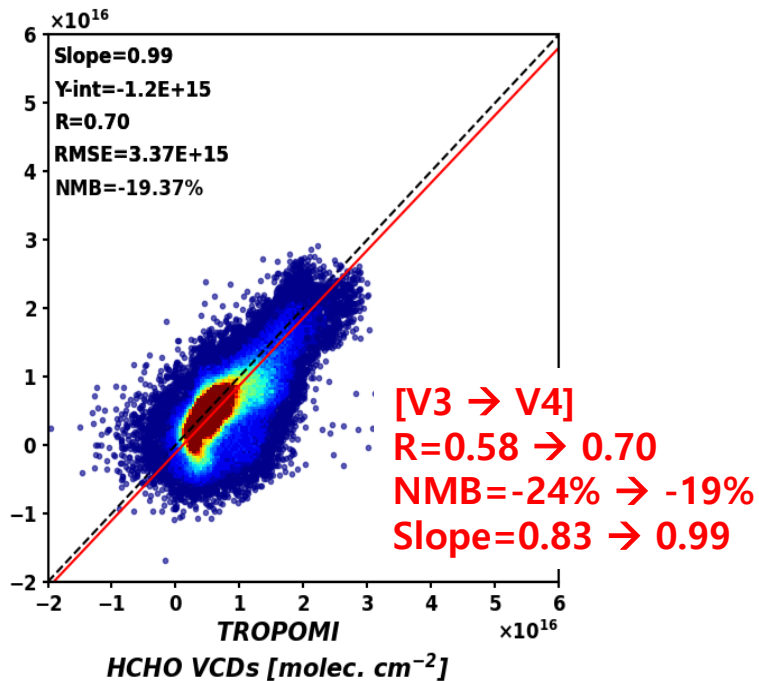
- GEMS v2.0 (green) overestimated lower stratospheric ozone and underestimated upper stratospheric ozone in February cases.
→ GEMS v3.0 (blue) produces data with high consistency with ozone sondes, independent of a priori.
- Seasonal changes in the vertical distribution of stratospheric ozone from February to March were also captured in GEMS v3.0.
- While GEMS v2.0 showed a high bias of approximately +9.5 DU compared to ozone sondes, GEMS v3.0 significantly improved, demonstrating consistency within **-1 ± 2.35 DU**.



GEMS VOCs Comparison

GEMS HCHO

Data period: Mar 2024

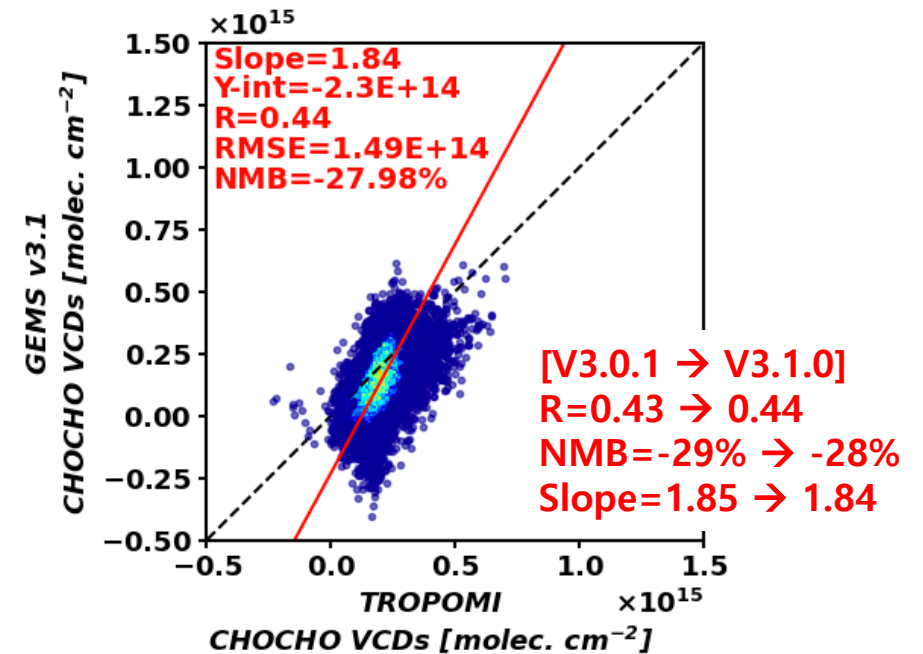


HCHO V4.0 updates

- Improved the **polarization correction** methodology
- Reduced model dependence** by improving reference spectrum sampling

GEMS CHOCHO

Data period: Aug 2022



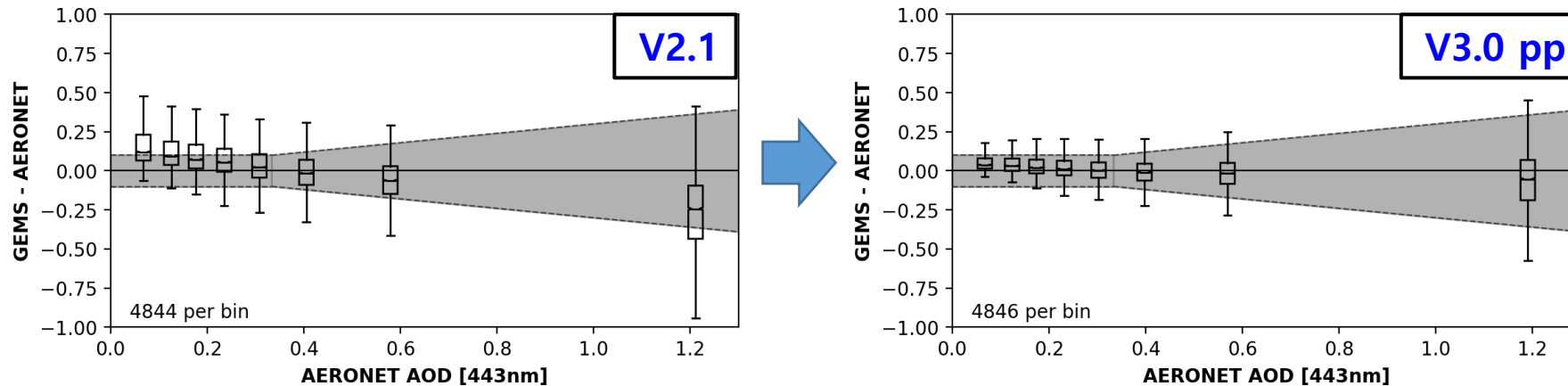
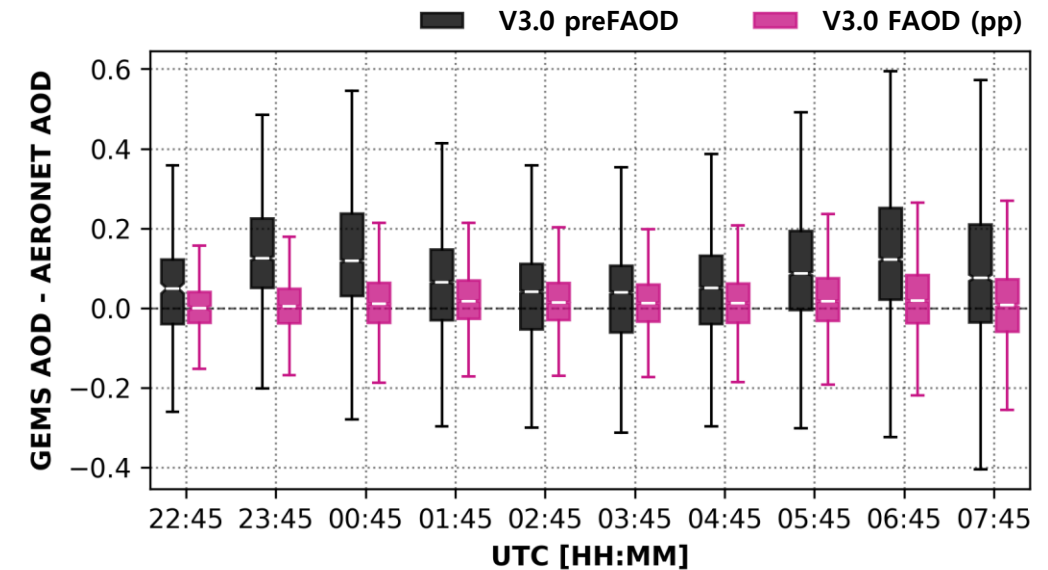
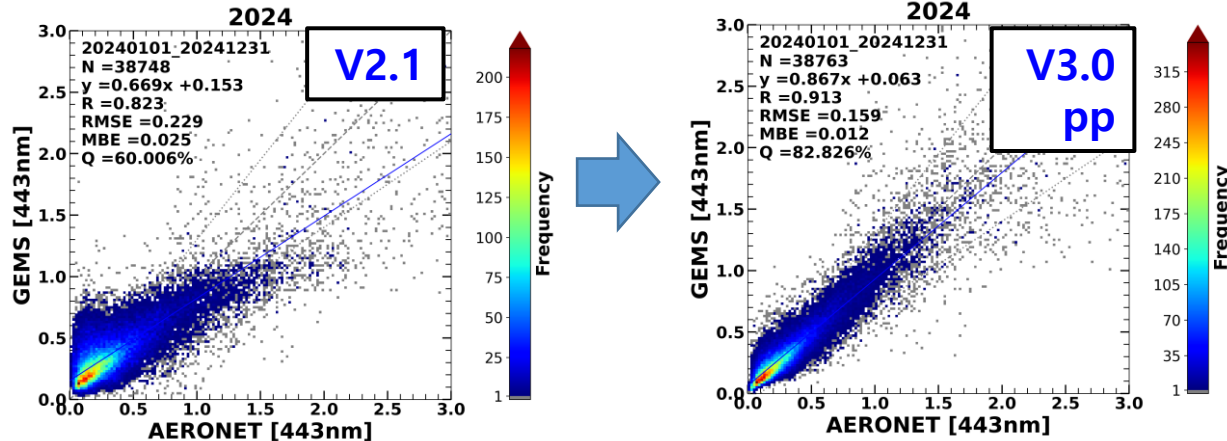
CHOCHO V3.1 updates

- Reduced model dependence** by improving reference spectrum sampling

R. Park

GEMS AOD V3.0 bias after post-processing

- Deep Neural Network-based **post-processing** of GEMS AOD



- ✓ Underestimation at high AOD and overestimation at low AOD have been reduced
- ✓ Diurnal bias has been reduced
- ✓ Bias falls well within the expected error

After applying BTDF-corrected Irradiance

	Stripe issue	Overestimation/Underestimation	Note
O ₃ Total	X	-	- The negative bias has shifted to a positive bias - Absolute value of the bias has decreased
O ₃ Profile	O	overestimation	Stripe issue in the 10-30° N - If the irradiance offset is not applied, it results in an overestimation of tropospheric O₃
SO ₂	O	-	The stripe issue has increased in the ranges of 15-30° N and around 0° N
NO ₂	O	-	- The stripe issue still exists NO₂ VCDs have decreased over high NO₂ areas
HCHO	X	-	Increase in HCHO VCDs of over 8% in Jan and Fab is expected to improve the underestimated winter values Decrease in HCHO VCDs in the south and increase in the north
CHOCHO	O	overestimation	Stripe issue Increase in winter, where there was an issue of CHOCHO overestimation
AOD	X	bias	Overestimation of AOD due to a degradation issue
AEH	X	-	Overestimation of AEH has decreased - AEH output range is more stable
SFC	X	-	- The stripe issue that occurred when using KNMI has been reduced - The low BSR calculated with KNMI has stabilized to reliable values when using BTDF IRR
CLD	O	-	Stripe issue does not occur with ECF, but occurs with CCP - Stripe issue in CCP mainly occurs in the lower layers and appears regardless of latitude

Summary

- GEMS has been in successful operation, providing column density of key air quality components, with AI-based surface concentrations and application L4 products.
- The accuracy of GEMS products has improved with the NIER's continued support, a progress that will be directly carried over to GEMS-2.
- The ongoing product updates will be available in 2026 at the ESC of NIER.
- Now L1 updates including BTDF correction, detrending, and CKD updates are needed after review and evaluation for operational products.

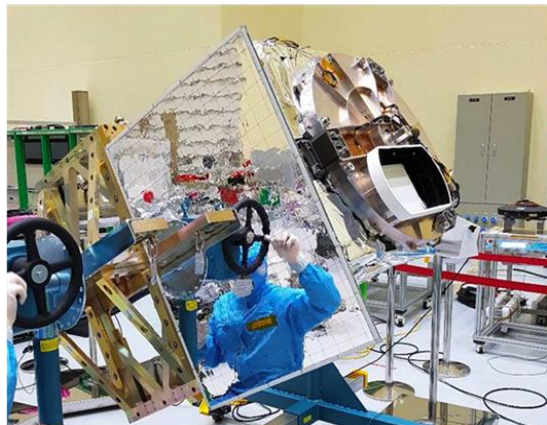
✓ **Data download:**

- **GEMS** : <https://nesc.nier.go.kr/product/view>

Acknowledgements



***Thank you
for all your
contribution,
dedication,
and
support !***



국립환경과학원

National Institute of Environmental Research

