Introduction of Newly Developed Level-2 Products from GEMS

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1. Abstract

In this study, retrieval algorithms for bromine monoxide (BrO) and water vapor (Total Column Water Vapor, TCWV) have been newly developed using GEMS measurements. These algorithms follow a typical two-step approach, which comprises spectral fitting (known as direct fitting developed by SAO) and the conversion of SCD into VCD (by calculated AMF). The retrieval window for water vapor is 435.0 – 467.0 nm, while for bromine monoxide it is 326.0 – 356.0 nm. Validation and intercomparison of water vapor are performed using ground-based AERONET Precipitable Water and the TROPOMI pre-operational TCWV product, both showing good agreement (r > 0.9). The spatial distributions of BrO over volcanic eruptions are also compared with other satellite datasets.

2. Retrieval Algorithm of Total Column BrO

2.1. Methodology

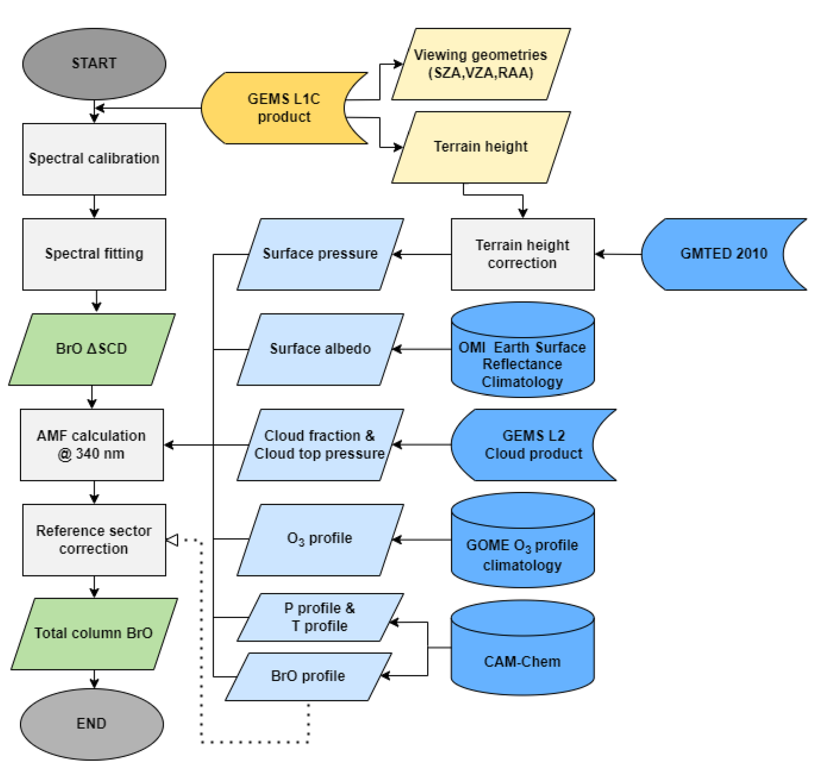
❖Spectral fitting: SAO approach (Chance, 1998)

$$F(\lambda) = \left[\{I_0(\lambda) + x_u b_u(\lambda) + x_r b_r(\lambda)\} \exp\left(-\sum_i SCD_i \sigma_i(\lambda)\right)\right] P_{sc}(\lambda) + P_{bl}(\lambda)$$

$I_0(\lambda)$: source spectrum; $x_u b_u(\lambda)$: undersampling correction; $x_r b_r(\lambda)$: rotational Raman scatt.; SCD_i: slant column amount of a species i; $\sigma_i(\lambda)$: absorption cross section of a species i

- Slant column retrievals of BrO and TCWV are based on a non-linear least squares method by directly fitting the modeled radiance spectrum to the measured spectrum.

❖Flow chart

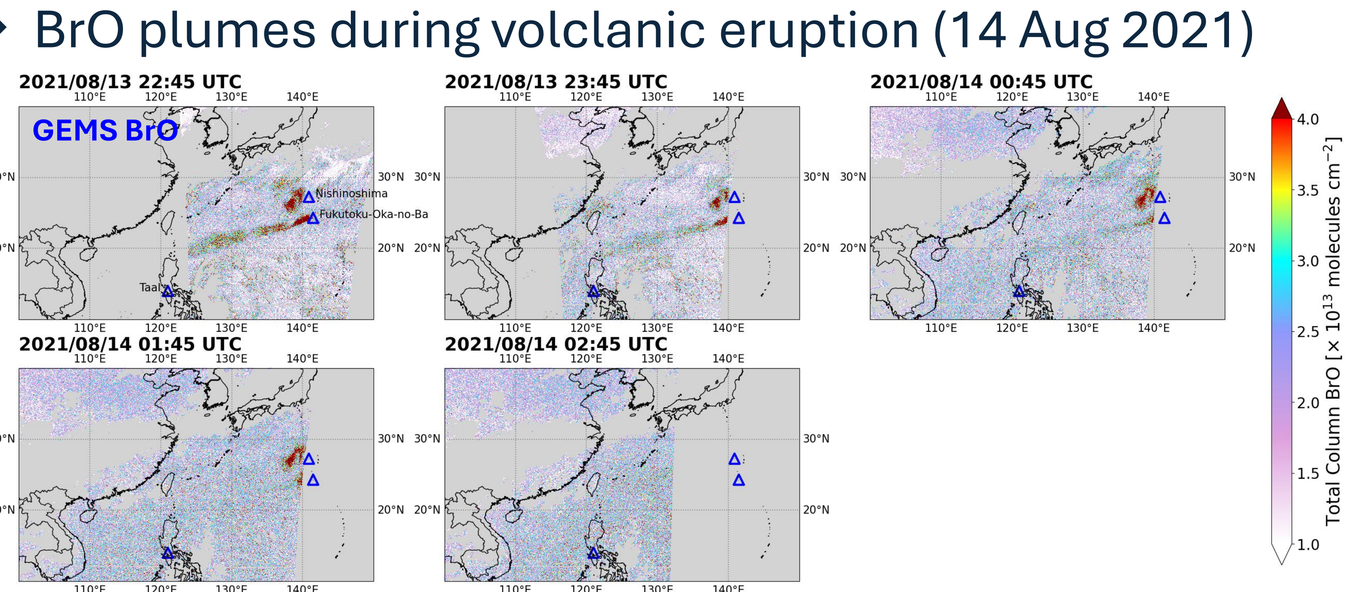


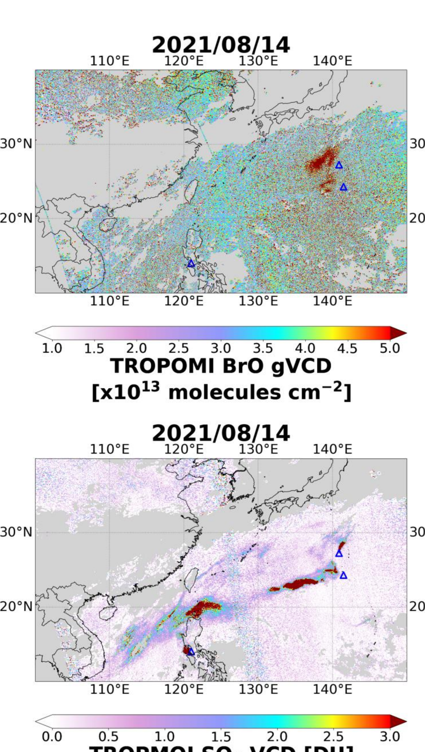
❖Retrieval configuration

Parameter	Note
Fitting window	326.0–356.0 nm
Radiance reference spectrum	Spectrum averaged over the whole domain for each CCD pixel
Solar reference spectrum	Chance and Kurucz (2010)
Undersampling correction spectrum	Chance et al. (2005)
Rotational Raman scattering spectrum	Chance and Spurr (1997)
Vibrational Raman scattering spectrum	Chance and Spurr (1997)
BrO cross section	Wilmouth et al. (1999), 228K
O_3 cross section	Serdyuchenko et al. (2014), 243 & 273 K
The first-order Taylor series expansion for O_3 absorption (243 and 273 K)	Puķīte et al. (2010)
O_2–O_2 cross section	Finkenzeller and Volkamer (2022), 293K
NO_2 cross section	Vandaele et al. (1998), 220 K
SO_2 cross section	Birk and Wagner (2018), 293 K
HCHO cross section	Chance and Orphal (2011), 300 K
Scaling polynomial	Fourth order
Super-Gaussian slit function	Beirle et al. (2017)
Wavelength shift	

2.2. Retrieved Results

❖ BrO plumes during volclanic eruption (14 Aug 2021)



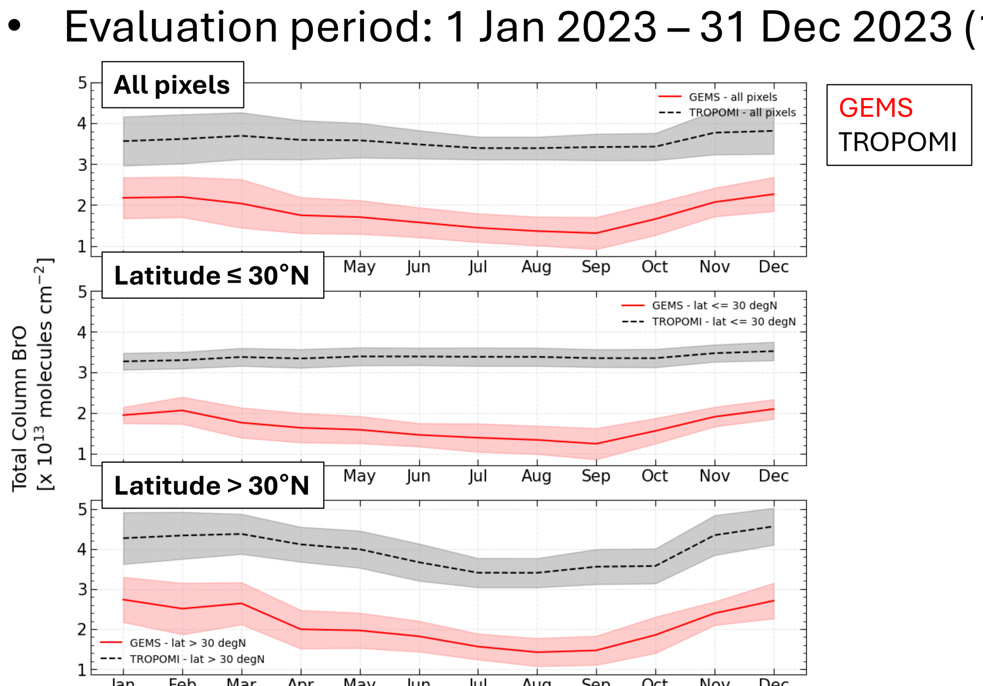


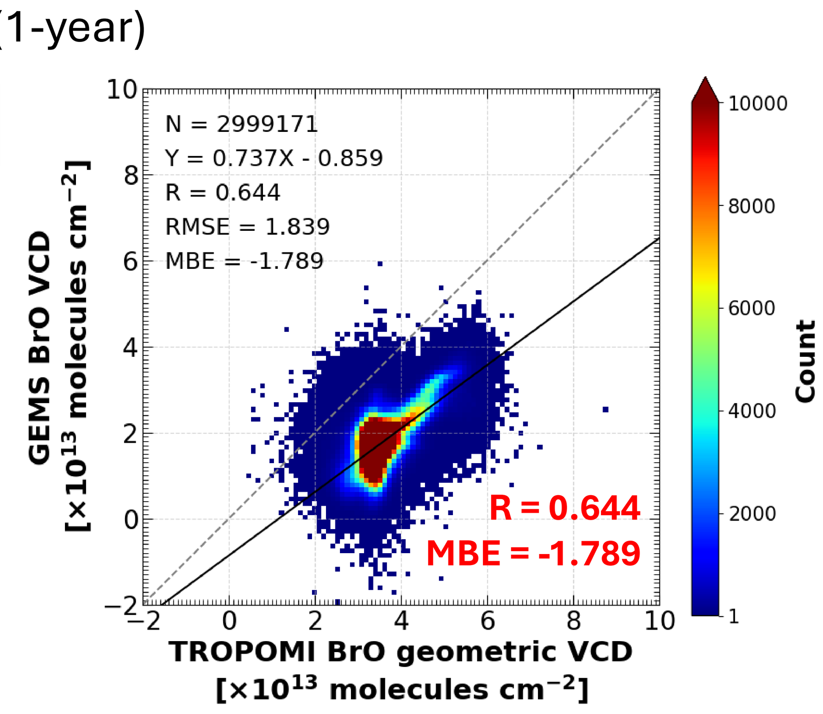
- BrO plumes were co-detected with SO_2 from both GEMS and TROPOMI over Japanese volcanoes (Nishinoshima, Fukutoku-OkaNoba), although BrO was not detected over Taal volcano.
- GEMS BrO VCD has systematically lower than those from TROPOMI, due to the background correction (reference sector correction) scheme.

2.3. Intercomparison

❖ Intercomparison results against TROPOMI (s5p-pal) BrO product

- Evaluation period: 1 Jan 2023 – 31 Dec 2023 (1-year)



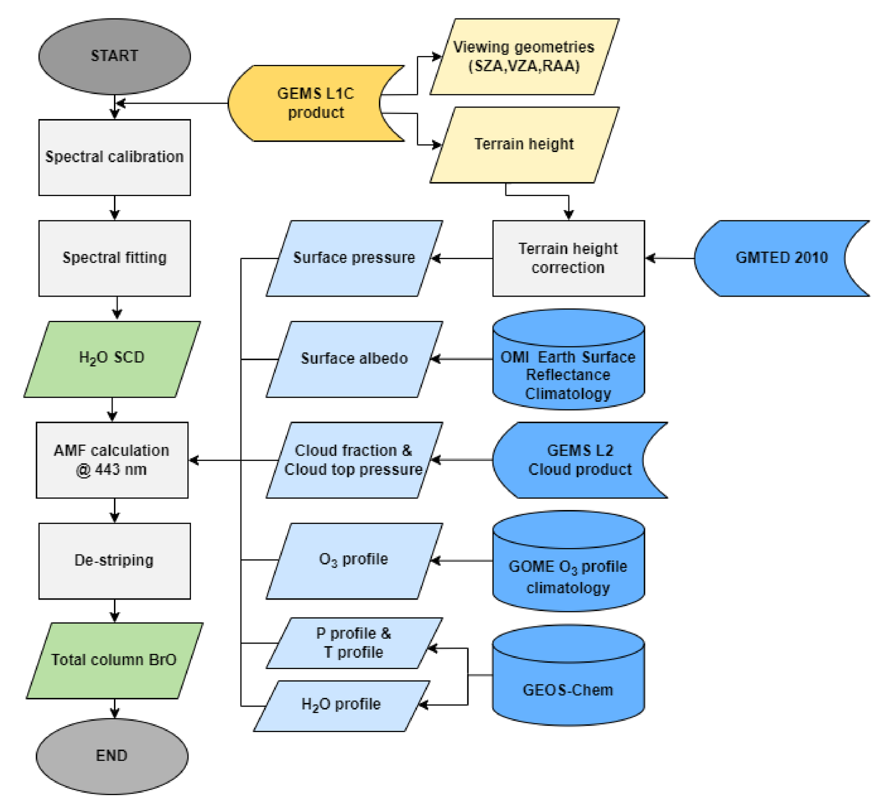


- From the timeseries of monthly mean BrO (0.1° x 0.1°), GEMS showed similar variability but systematically lower values.
- From the scatter plot, GEMS and TROPOMI showed moderate agreement (R=0.64).

3. Retrieval Algorithm of Total Column Water Vapor

3.1. Methodology

❖Flow chart



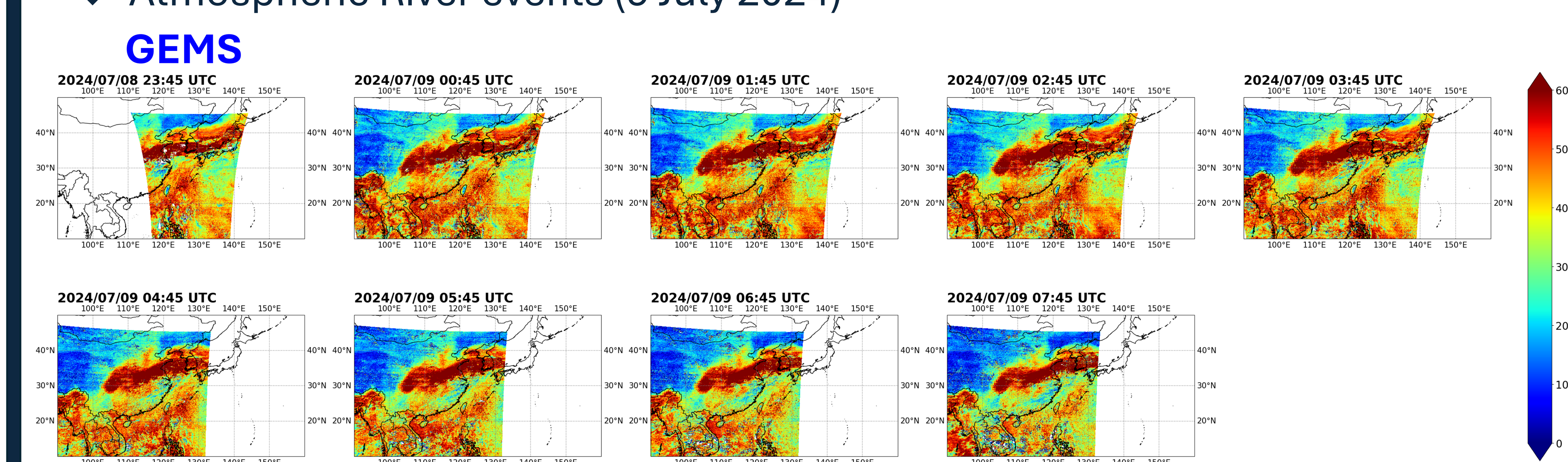
❖Retrieval configuration

Parameter	Note
Fitting window	435.0 – 467.0 nm
Source spectrum	Daily Solar Irradiance measured from GEMS
Solar reference spectrum	Chance and Kurucz (2010)
Undersampling correction spectrum	Chance et al. (2005)
Rotational Raman scattering spectrum	Chance and Spurr (1997)
Vibrational Raman scattering spectrum	Chance and Spurr (1997)
H_2O cross section	Gordan et al. (2022), 293K
NO_2 cross section	Vandaele et al. (1998), 220K
O_2-O_2 cross section	Finkenzeller and Volkamer (2022), 293K
Liquid H_2O cross section	Manson et al. (2016), 296K
O_3 cross section	Serdyuchenko et al. (2014), 233K
Scaling polynomial	Second order
Baseline polynomial	-
Super-Gaussian slit function	Beirle et al. (2017)
Wavelength shift	

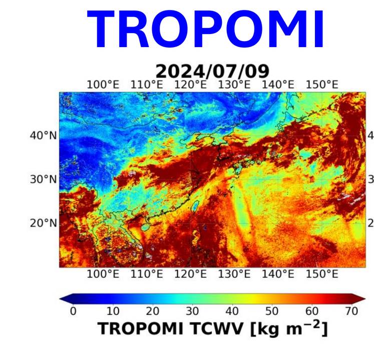
3.2. Results

❖ Atmospheric River events (9 July 2024)

GEMS



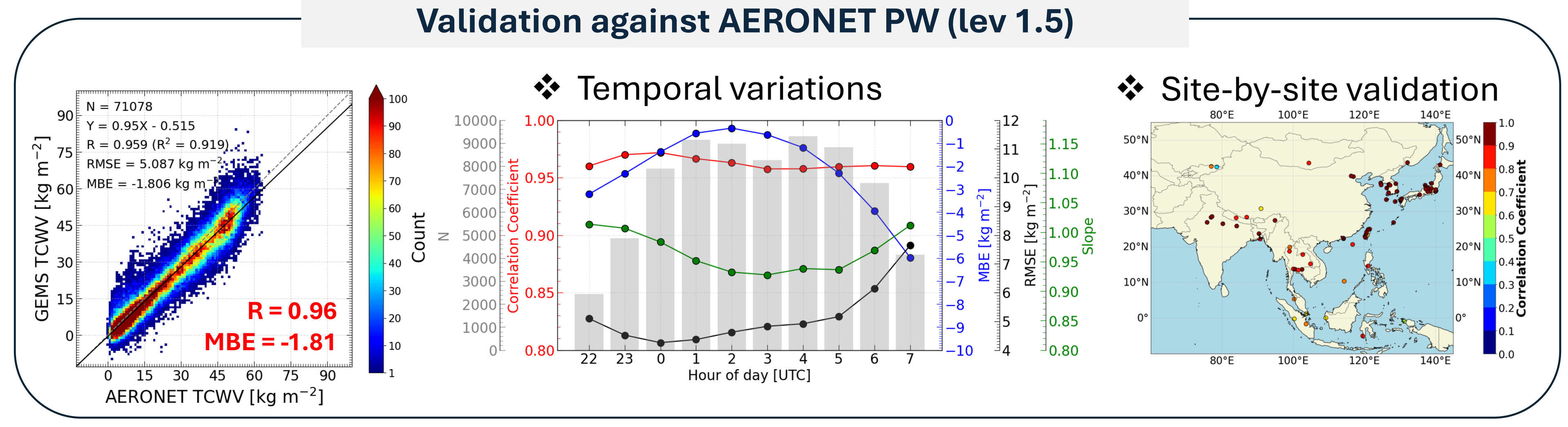
TROPOMI



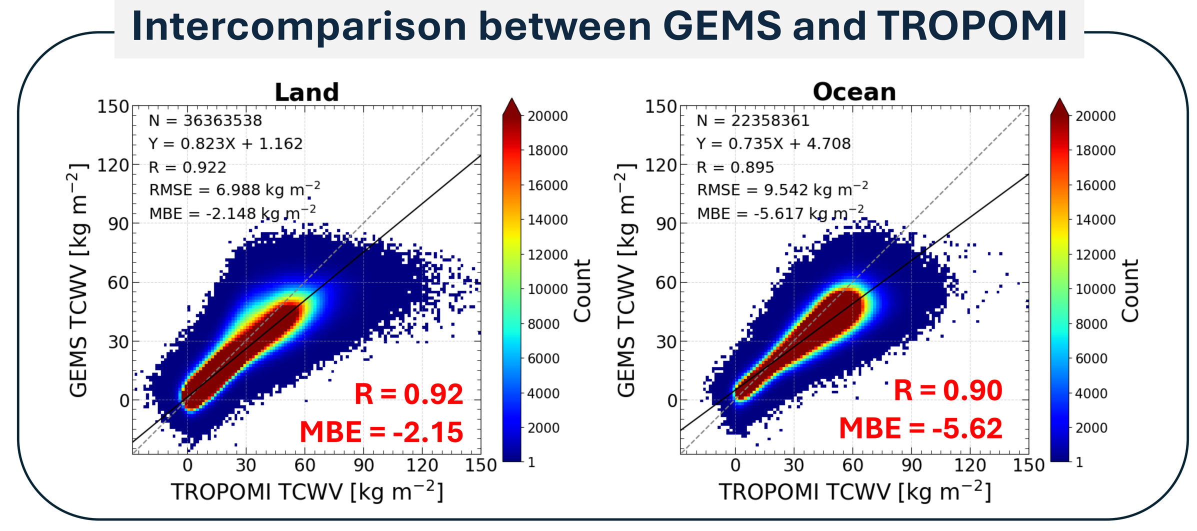
- Both GEMS and TROPOMI detected atmospheric river evens passing through South Korea on 9 July 2024, resulting in extreme rain.
- GEMS and TROPOMI showed similar spatial distribution, but GEMS TCWV values showed lower value than TROPOMI.
  - mainly due to the **combined effects of input data difference for AMF calculation (surface albedo, cloud fraction, and cloud top pressure)**

3.3. Validation/Intercomparison

Validation against AERONET PW (lev 1.5)



Intercomparison between GEMS and TROPOMI



- GEMS TCWV show excellent correlation with AERONET Preicipitable datasets (R = 0.959, MBE = -1.806 kg m-2) for 2-year period (Mar 2021 – Feb 2023).
  - no temporal dependency for correlation coefficient (R), but MBE has diurnal variation.
  - GEMS TCWV has lower R value over low latitudes.
- Intercomparison between GEMS and TROPOMI TCWV show good agreement, but underestimation issue is amplified over the ocean.
  - due to the difference in surface albedo, cloud properties input data

4. Conclusion

- Total Column BrO and TCWV are successfully retrieved by using GEMS measurements with applying different fitting window (326.0 – 356.0 nm for BrO, 435.0 – 467.0 nm for TCWV)
- GEMS BrO and TCWV both show reasonable correlations, but they both show underestimation compared to those of TROPOMI due to the different reasons (different background correction scheme, difference in input data for AMF calculation).

Reference

Kim et al., 2020. "New Era of Air Quality Monitoring from Space: Geostationary Environment Monitoring Spectrometer (GEMS)". Bulletin of the American Meteorological Society, 101

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