# Calibration status of GOSAT and GOSAT-2

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**and GOSAT team**

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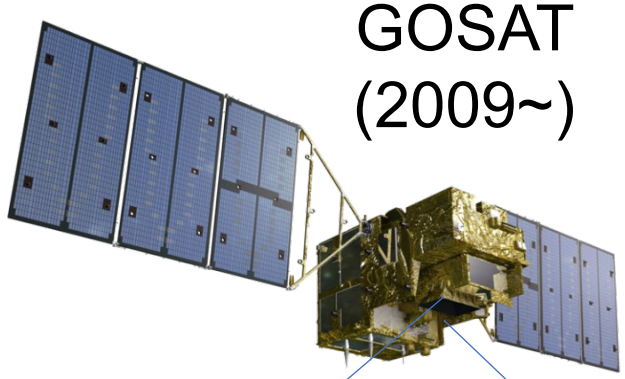
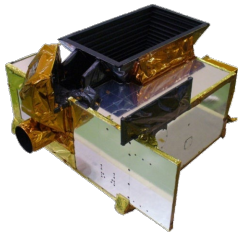
# GOSAT and GOSAT-2 satellites

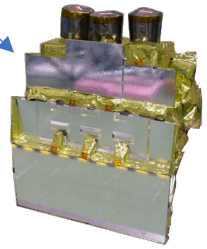
GOSAT
(2009~)





FTS

O2A(0.76μm)
WCO2,CH4(1.6μm)
SCO2(2μm)
TIR (5-15μm)
High spectral resolution 0.2cm$^{-1}$
Pointing mechanism

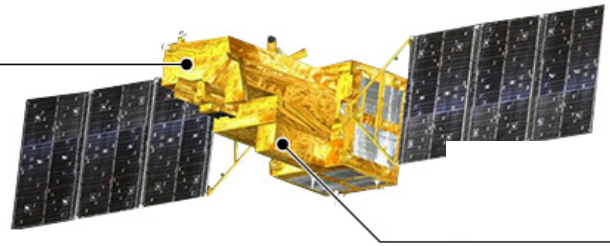


CAI

UV-SWIR
4 bands linear array
Nadir view

GOSAT-2
(2018~)

FTS-2



CAI-2

FTS-2

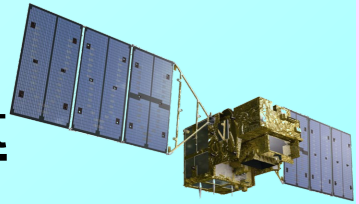
O2A(0.76μm)
WCO2,CH4(1.6μm)
SCO2, CO (2μm)
2 TIR bands (5-15μm)
High spectral resolution 0.2cm$^{-1}$
Enhanced pointing mechanisms

CAI-2

UV-SWIR
10 bands linear array
5 forward view bands, 5 backward view bands (+/-20deg)

# GOSAT and GOSAT-2 status

## Long term (17-year Jan. 2026) calibrated and validated dataset



## Satellite Condition

Enough fuel to operate for at least another 10-year
All four batteries are healthy

Since Jan. 2024, the monthly-used back-side solar diffuser has not been available due to rotation anomaly, but the front-side is in normal operation every orbit.

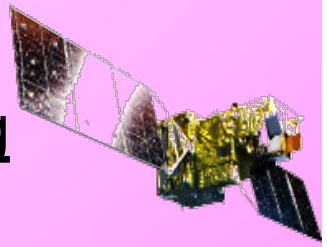
## Level 1 V300.300 (released in March 2023)

Best-estimate SWIR radiance spectra using TSIS-HSRS and long-term vicarious-calibration data.

## Level 1 V300.301 (released in March 2026)

Only TIR update reprocessing data starting from April 2025, Revise the DC offset change of the FTS restart

## Long term (7-year Oct. 2025) Intense target observations using flexible and wide angle pointing



## Oct30,2023, 5-year operation review.

The operation has been extended.

Feb. 2021, anomaly occurred in the solar diffuser plate mechanism. The solar irradiance calibration has been suspended since then, Lunar calibration is normal.

## Level 1 V240.240 (released in March 2026)

SWIR O2A band radiance have recovered since just before 2023 because of the over correction than expected.

# Calibration strategy

| | GOSAT (2009~) | GOSAT-2 (2018~) |
|---|---|---|
| **Relative radiance degradation** | | |
| Solar diffuser | Backside diffuser is only exposed<br>Once per month (2009-2023)<br>Suspended due to the rotation trouble<br>Frontside diffuser operation Once per orbit | Diffuser is only exposed a few minutes<br>Once per orbit (2018-Feb2021)<br>Suspended due to the shutter trouble |
| Lunar calibration | 1-2 times per year (2009-2014)<br>Suspended due to the solar paddles rotation stop | 2 times per month<br>Both before and after full moon |
| Sahara desert | Monitor per 3-day revisit | Monitor per 6-day revisit |
| **Absolute radiance** | | |
| Vicarious Calibration | Field campaign at Railroad Valley (RRV) playa, Nevada conducted annually every summer with OCO team | |
| **Inter-comparison** | | |
| Simultaneous observation with other GHG sensors | Simultaneous observations<br>- At RRV target on the same day<br>- At orbit crossing (SO with BRDF correction) | |

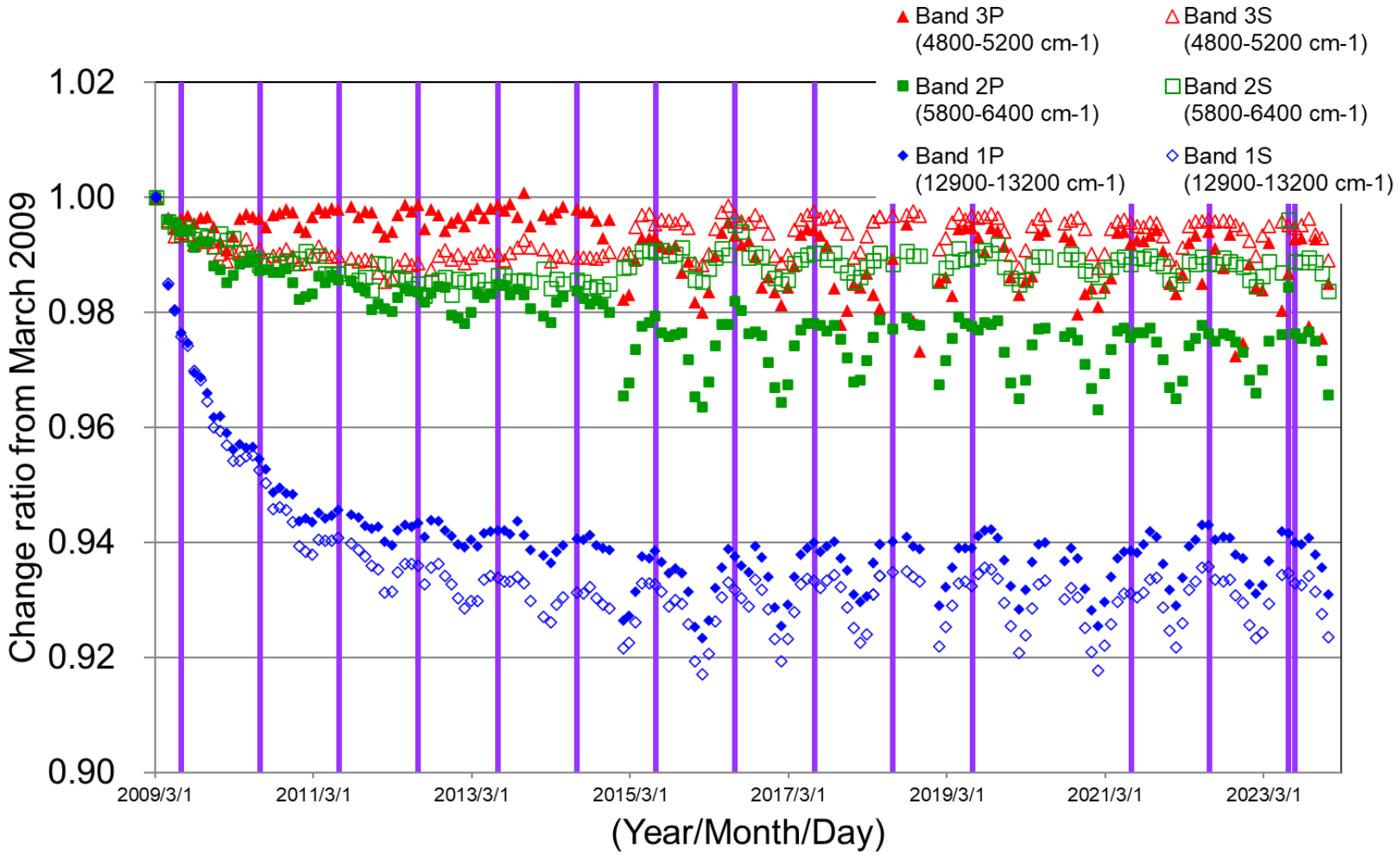
# GOSAT solar diffuser calibration as on-orbit main calibrator

GOSAT backside diffuser was exposed only once a month until Jan. 2024

Over 15 years

High-spectral resolution

Collaborated with TSIS team

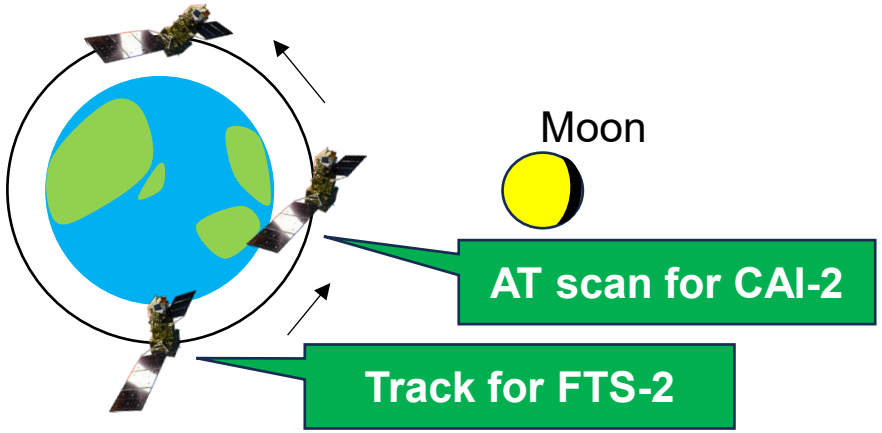


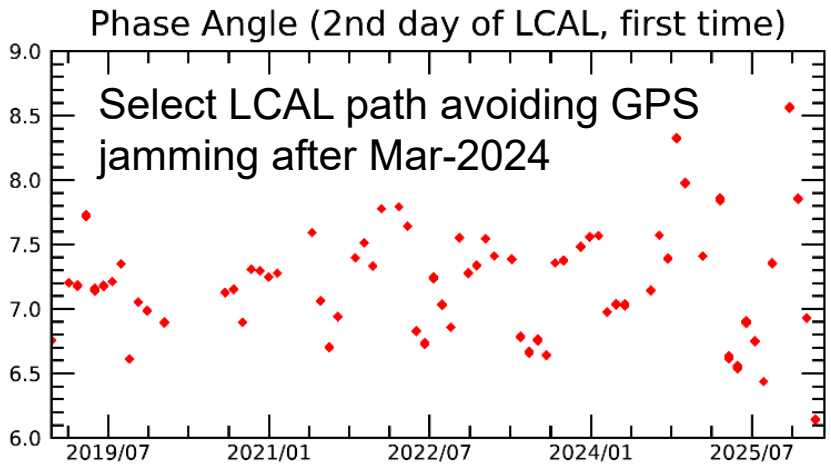

- The GOSAT radiance degradation curve was estimated from solar diffuser calibration.
- This curve will be scaled to the Railroad Valley Vicarious Calibration results over 15 years.

# GOSAT-2/FTS-2 lunar calibration as on-orbit main calibrator

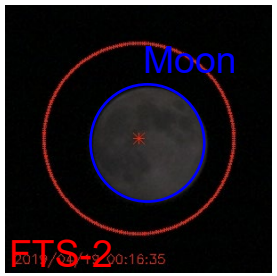
GOSAT-2 Lunar Calibrations are operated in both waxing and waning gibbous moon (phase angle ~ ±7-8 [deg]). The LCAL operation path is carefully selected avoiding GPS jamming after Mar-2024.

**■day2 : Waning gibbous moon**



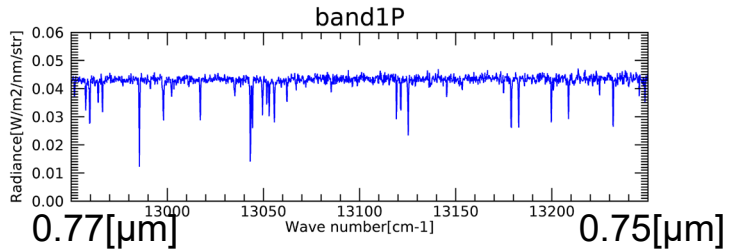




- Keep tracking the moon, integrate for 4 [sec] per sounding and observes 10-30 soundings.
- Used for the evaluation of radiometric degradation.
- FTS-2 modulation efficiency depends on orbital ambient temperature. We use initial LCAL data after earth observation.




footprint

integrate 4 [sec] each sounding

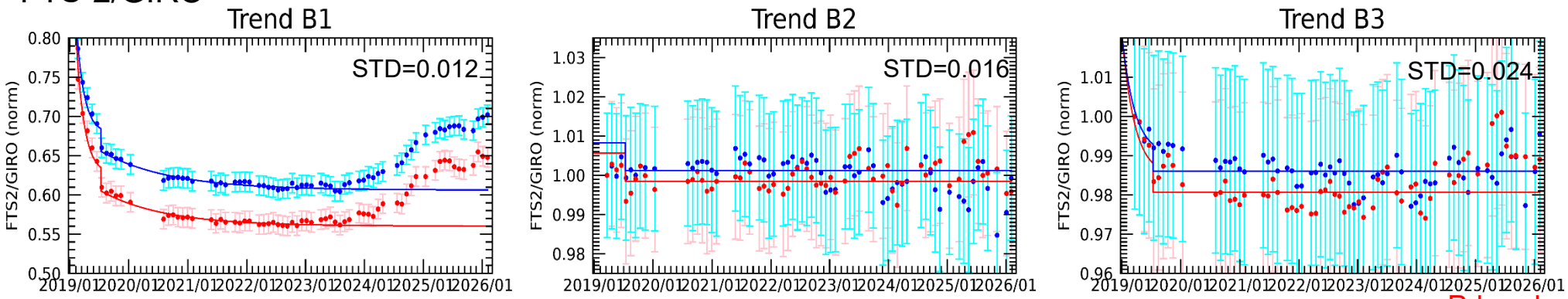



**The advantage of FTS-2 lunar calibration data**

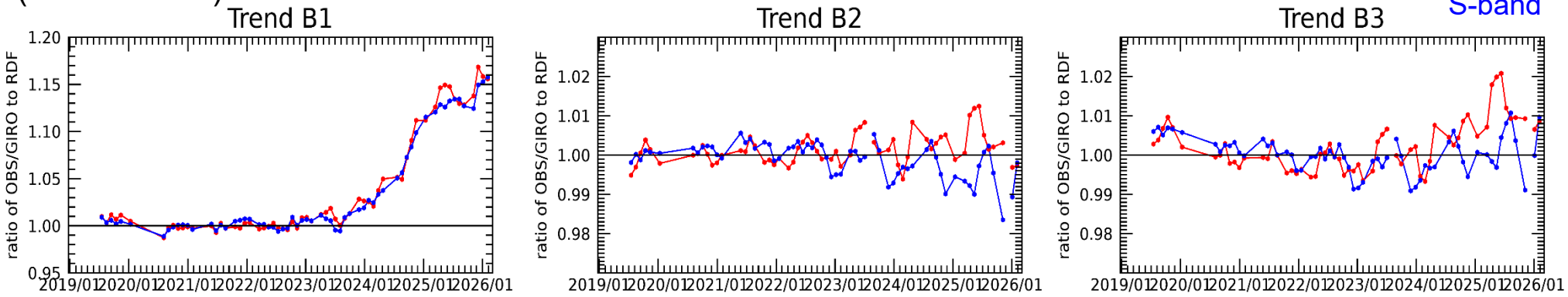
- High-frequency observation (almost every month)
- Long-term dataset (over 7 years)
- phase angle around ±7-8[deg], less lunar polarization (Coyne and Pellicori, 1969, Toledano et al., 2023)

# GOSAT/FTS-2 radiometric degradation from lunar calibration

FTS-2/GIRO




(FTS-2/GIRO) /RDF2024



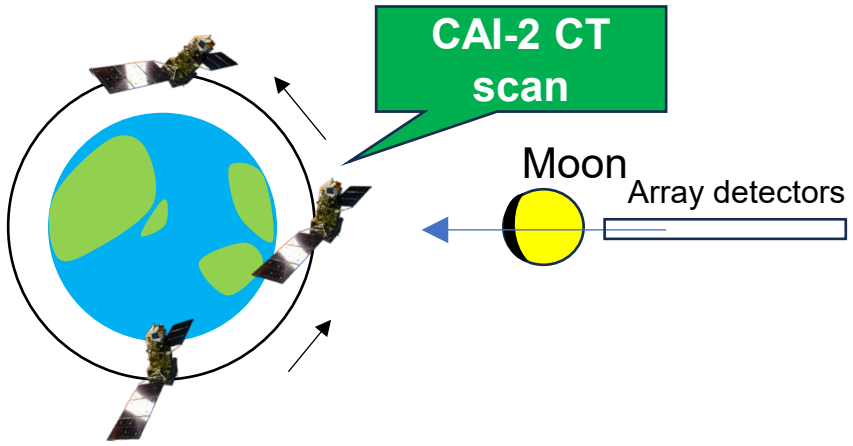

P-band
S-band

- The GOSAT-2 radiance degradation curve was estimated from solar diffuser calibration before. (RDF2021)
- Radiance degradation curve was estimated from 5-year lunar calibration and scaled to the Railroad Valley vicarious calibration results.(RDF2024)
- After that, the B1(O2A) radiometric response has recovered up to 15 % as shown by lunar calibration.

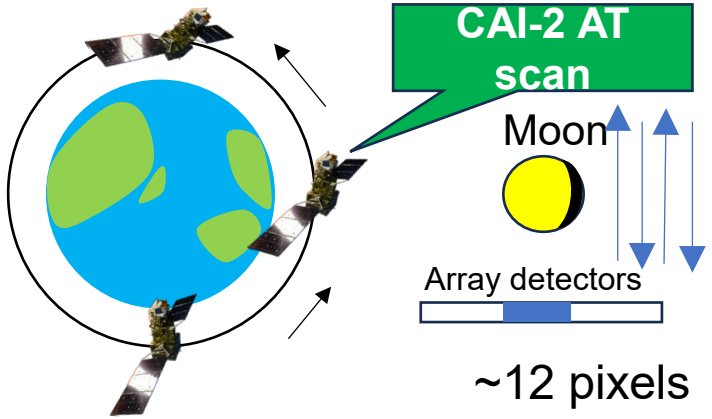
# GOSAT-2/CAI-2 lunar calibration

GOSAT-2 Lunar Calibrations are operated in two days around full moon (phase angle ~ ±7-8 [deg]).

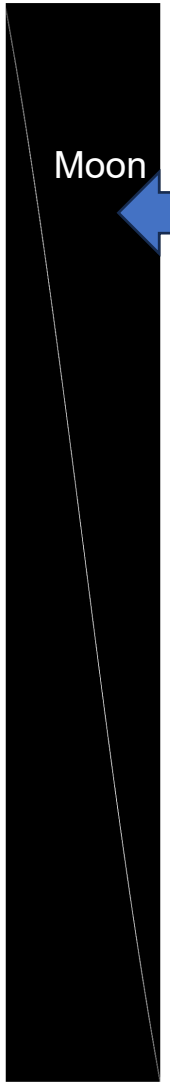
## ■day1 : Waxing gibbous moon




## ■day2 : Waning gibbous moon




~12 pixels




## ■CAI-2 Lunar Calibration

●Cross Track(CT) Scan in day1 path

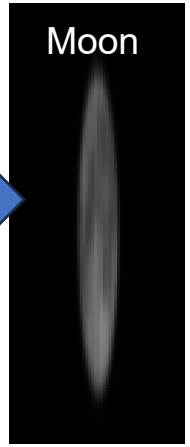
・Scanning in the CT direction only once.

・Used for the evaluation of pixel-to-pixel sensitivity difference.

●Along Track(AT) Scan in day2 path

・Scanning in the AT direction 4 times

・Used for the evaluation of radiometric degradation.

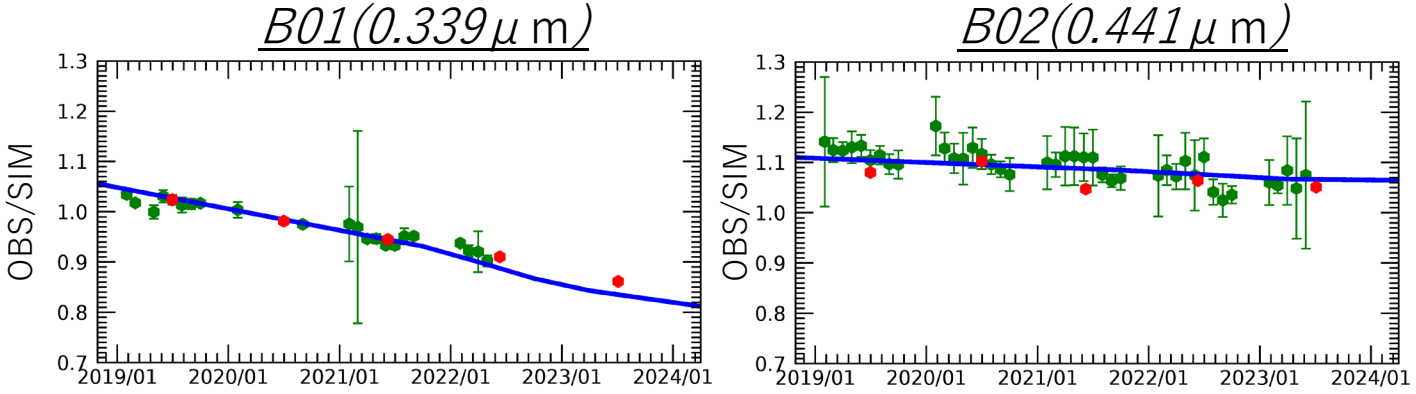



**The advantage of CAI-2 lunar calibration data**

- High-frequency observation (almost every month)
- Long-term dataset (over 7 years)

# GOSAT-2/CAI-2 radiometric degradation from lunar calibration combined with vicarious methods

## ■Radiance degradation factor combined with Lunar calibration and Vicarious calibrations

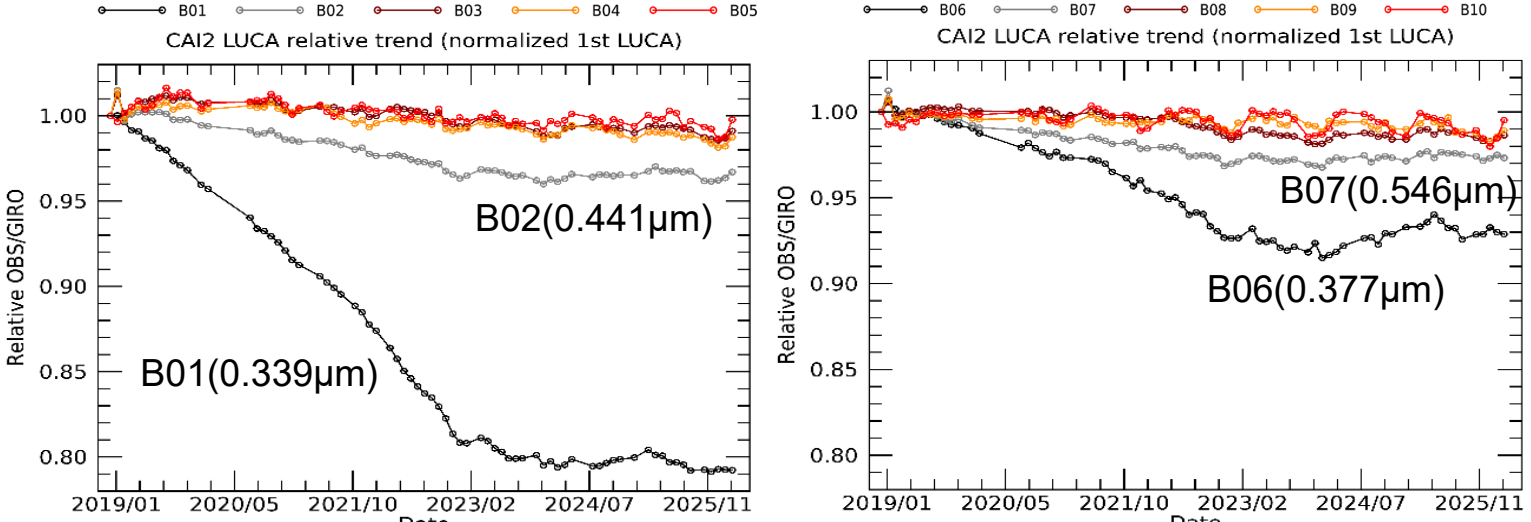



① Vicarious calibration results that evaluated at the Railroad Valley, USA

② Cross-calibration results using other satellite data (ex. VIIRS)

③ Degradation curve estimated from Lunar Calibration results

## ■Radiance degradation curve estimated from Lunar calibration




B01-B05(Forward-view)




B06-B10(Backward-view)

- The shorter wavelength bands have larger degradation.
- After Jan. 2023, the degradation curve has changed and became slowly.
- The changing looks the same between forward-view and backward-view bands. B1/B6 use the common before-optics as well as B2/B7.

# International collaboration for GHG sensors calibration

2008 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

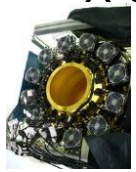
Radiometric calibration

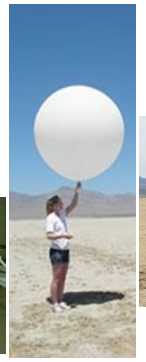
Prelaunch X-CAL

Annual Vicarious Calibration at the desert playa in Nevada

$CO_2$ & $CH_4$ profile

In situ $CO_2$ and $CH_4$ on AJAX



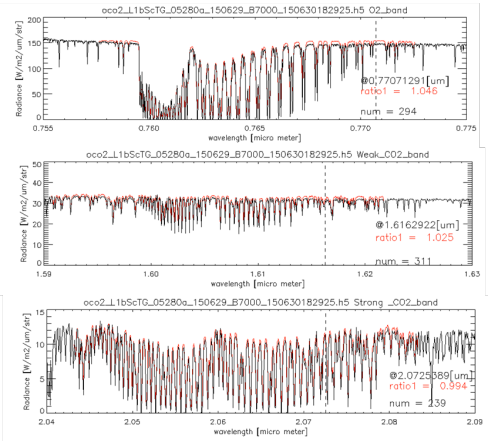




$XCO_2$ & $XCH_4$

Column with EM-27 FTS

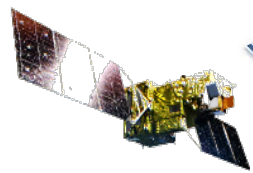
GOSAT OCO-2



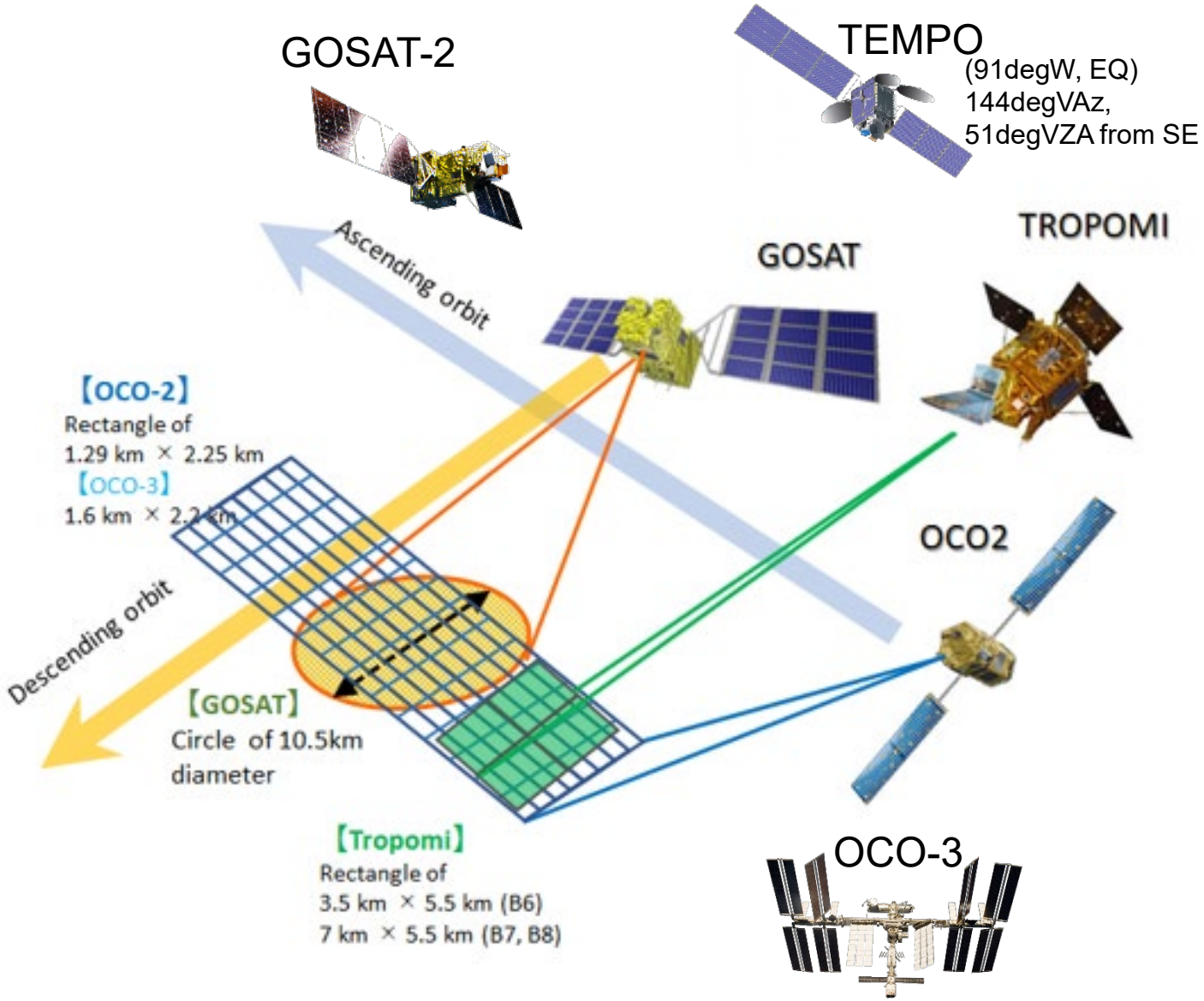

Calibrated GOSAT and OCO-2 radiance spectra agrees within 5% for all bands.



Coincident Target



# Railroad Valley target by multiple GHG & AQ sensors



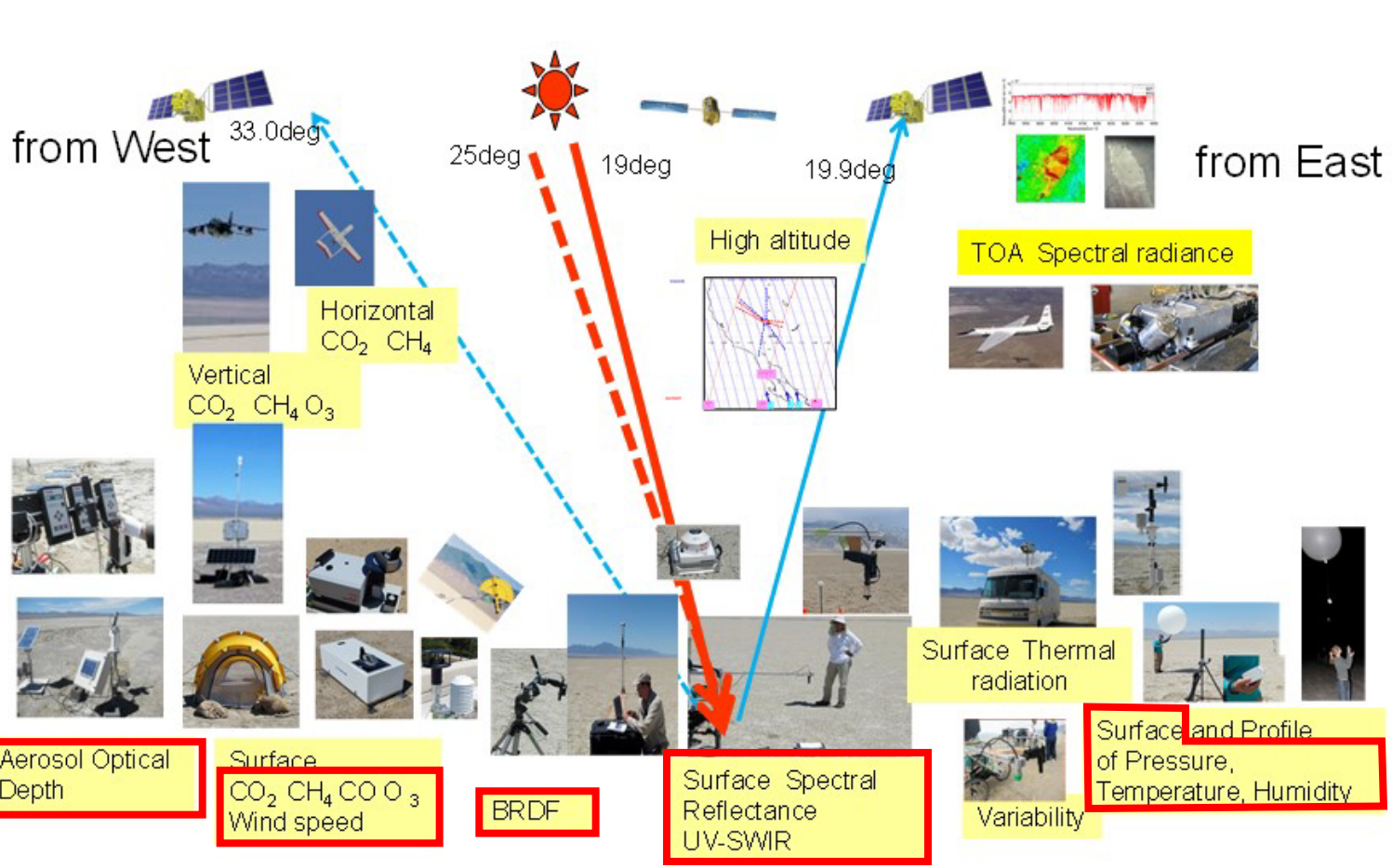

## RRV 2024 Summer Campaign Schedule

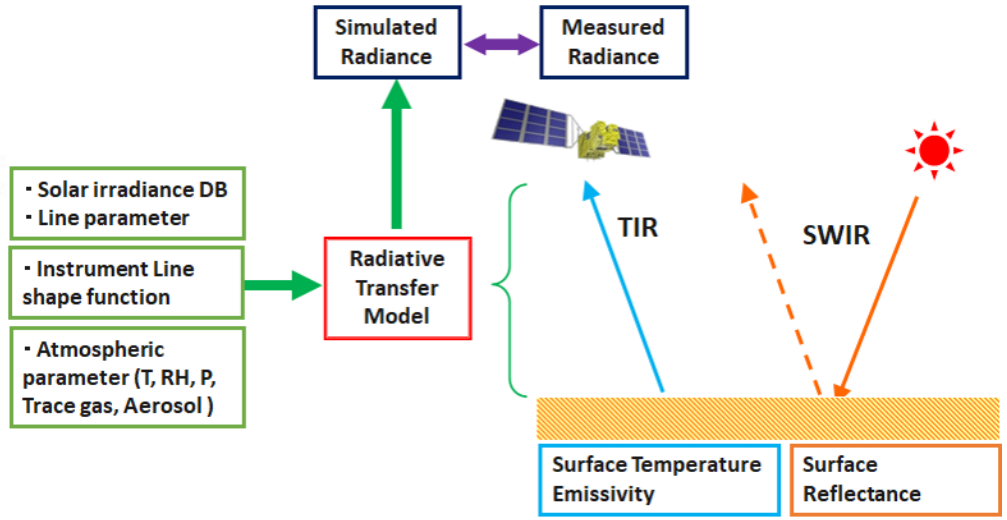
| Date | DoW | OCO-2 path | GOSAT path | GOSAT-2 path | TROPOMI InstZA [deg] | |
|---|---|---|---|---|---|---|
| 12-Jun-24 | Wed | | | 74 | 28.0 | RRV |
| 13-Jun-24 | Thu | | 36 | | 53.6 | RRV |
| 14-Jun-24 | Fri | 138 | 37 | | 8.1 | RRV |
| 15-Jun-24 | Sat | | | | 6.9 | RRV |
| 16-Jun-24 | Sun | 136 | 36 | 72 | 46.3 | RRV |
| 17-Jun-24 | Mon | | 37 | 73 | 31.7 | RRV |
| 18-Jun-24 | Tue | | | 74 | 46.6 | RRV |

Good conditions for all sensors come every 48 days.

| | Nadir footprint size |
|---|---|
| GOSAT | Circle of 10.5km diameter |
| GOSAT-2 | Circle of 9.6km diameter |
| OCO-2 | Rectangle of 1.3 km * 2.3 km |
| OCO-3 | Rectangle of 1.6 km * 2.2 km |
| TROPOMI | Rectangle of 3.5 km * 5.5 km (B6)<br>7 km * 5.5 km (B7, B8) |

# RRV vicarious calibration for GHG and AQ sensors




Key parameters

(1) Surface reflectance inhomogeneity correction

(2) Surface BRF correction

(3) Solar database

(4) Atmospheric parameter

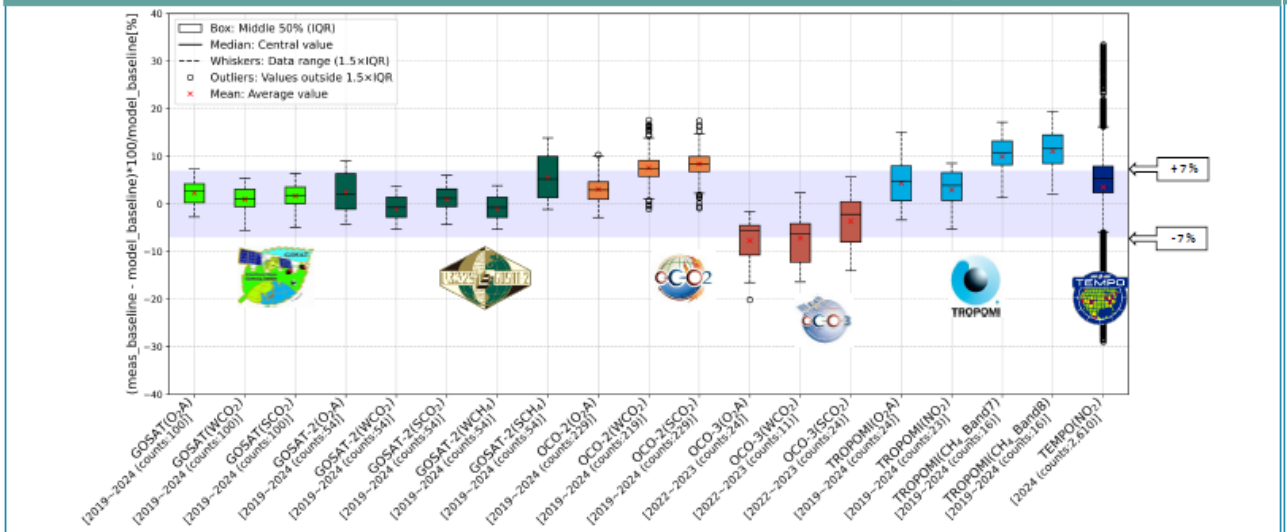
*currently operating

We will calculate all sensors for validating radiometric calibration accuracy by the same target.

# Multiple sensors VCAL results for RRV2025 and averaged all RRV campaigns (Latest result)

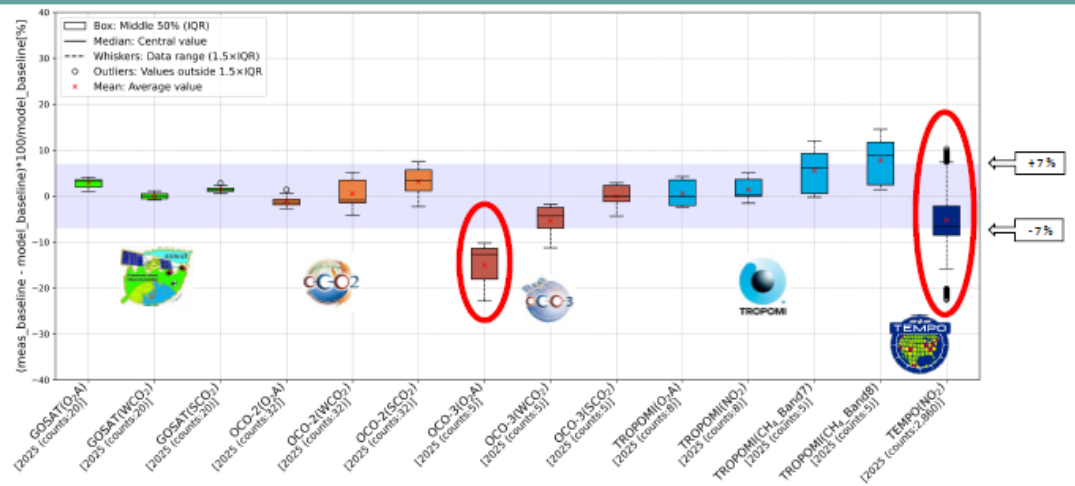
- All sensors are in good agreement within 5-7 % through the long-term campaign.
- OCO-3 late afternoon observation is affected by large BRDF correction uncertainty in RRV2025.
- TEMPO outliers decrease by using L1 ver.4 data in RRV2025.

## Chart 1. Result for RRV 2019-2024 campaigns




**GOSAT**, **GOSAT-2**, and **OCO-2** show good agreement with median residuals within **about±5%. OCO-3** has a wider spread and **more outliers (values outside 1.5×IQR)**, reflecting the variability of ISS viewing geometry. **TROPOMI** is generally stable, with a slight positive bias where observed radiance exceeds the model. **TEMPO's** geostationary sampling results in far more observations, making outliers more noticeable, although most values remain within roughly −5% to +15%.

## Chart 3. Result for RRV 2025 fall campaign

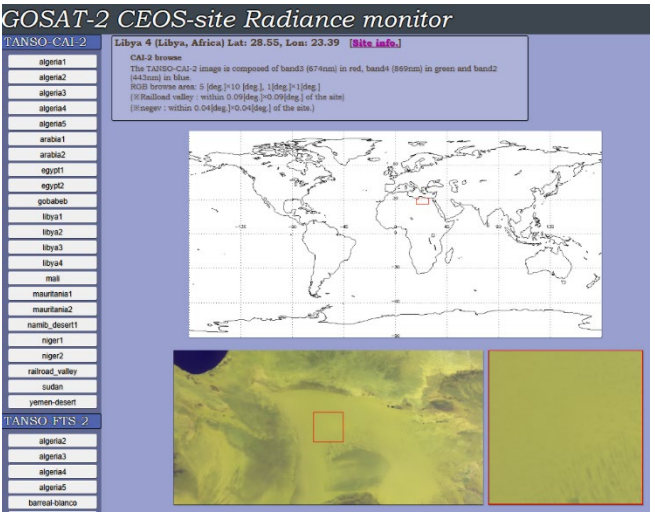



The **September 2025** update to **TEMPO's Level-1 processing (Version 4) significantly reduced the number of outliers**, indicating improved radiometric stability. However, sensitivity differences between **detector elements (or viewing sectors) still appear to remain**; further details will be discussed later. **GOSAT-2** is not included here because its overpass during this period was **cloud-contaminated**. In addition, **OCO-3's late-afternoon observations** resulted in **larger solar zenith angles**, which may increase BRDF and/or radiative-transfer uncertainties.

*Ishida et al., AGU25*

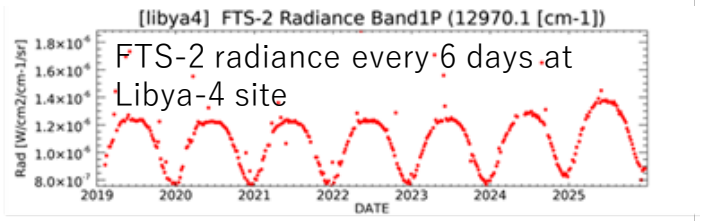
# GOSAT-2/FTS-2 radiometric degradation from Sahara desert site monitoring

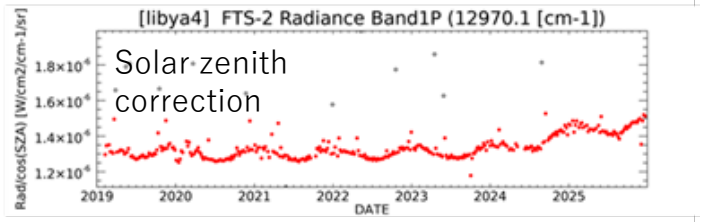
GOSAT-2 CEOS-site monitor

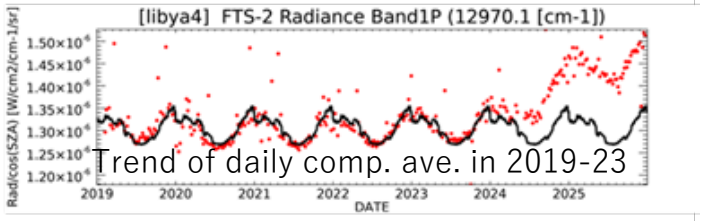


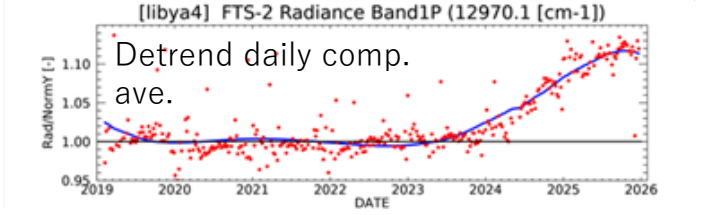

CEOS PICS

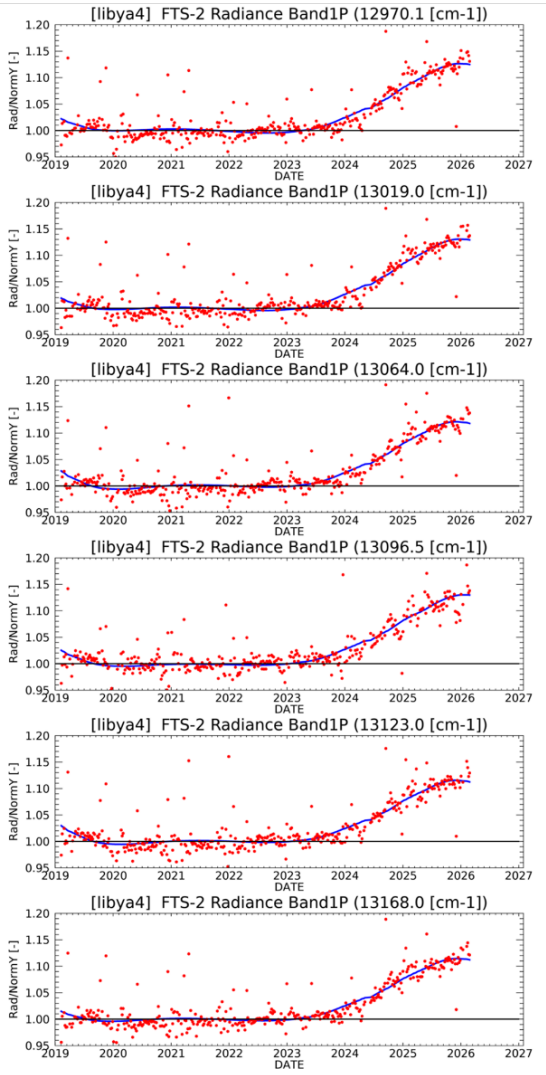

Period：2019/2/8—2026/2/27
Site：Libya4 Sensor: FTS-2 B1

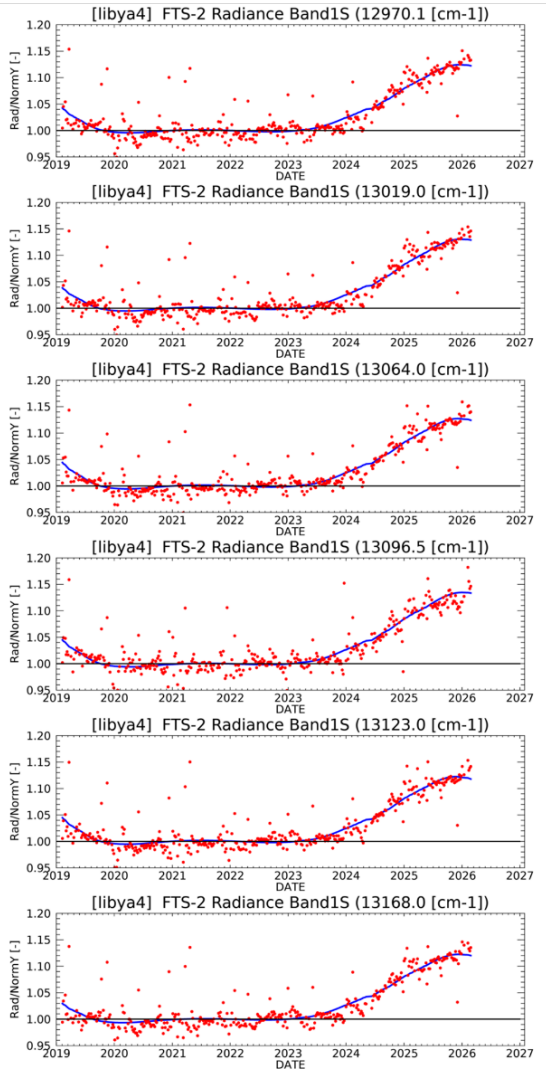


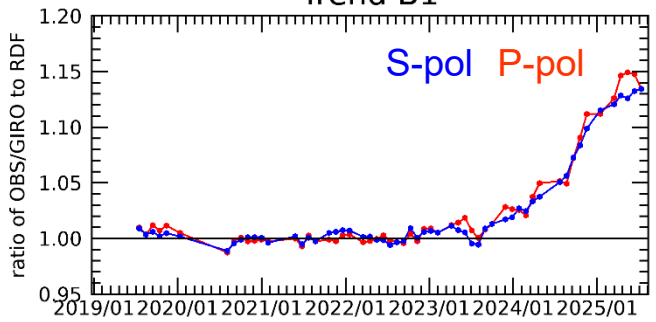

Sahara desert site monitoring supported the other calibration method results.

# GOSAT-2/FTS-2 radiometric response change evaluated with 3 methods

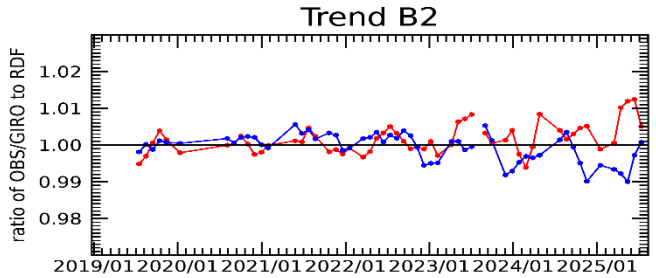
## LunarCAL

**monthly**

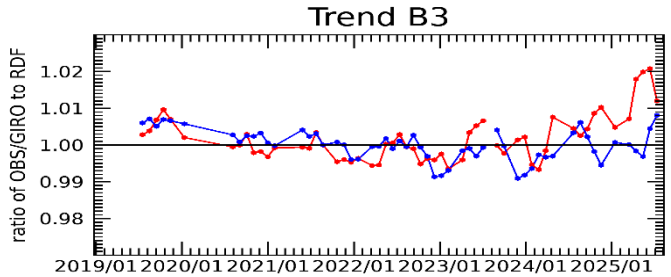
Trend B1




Trend B2

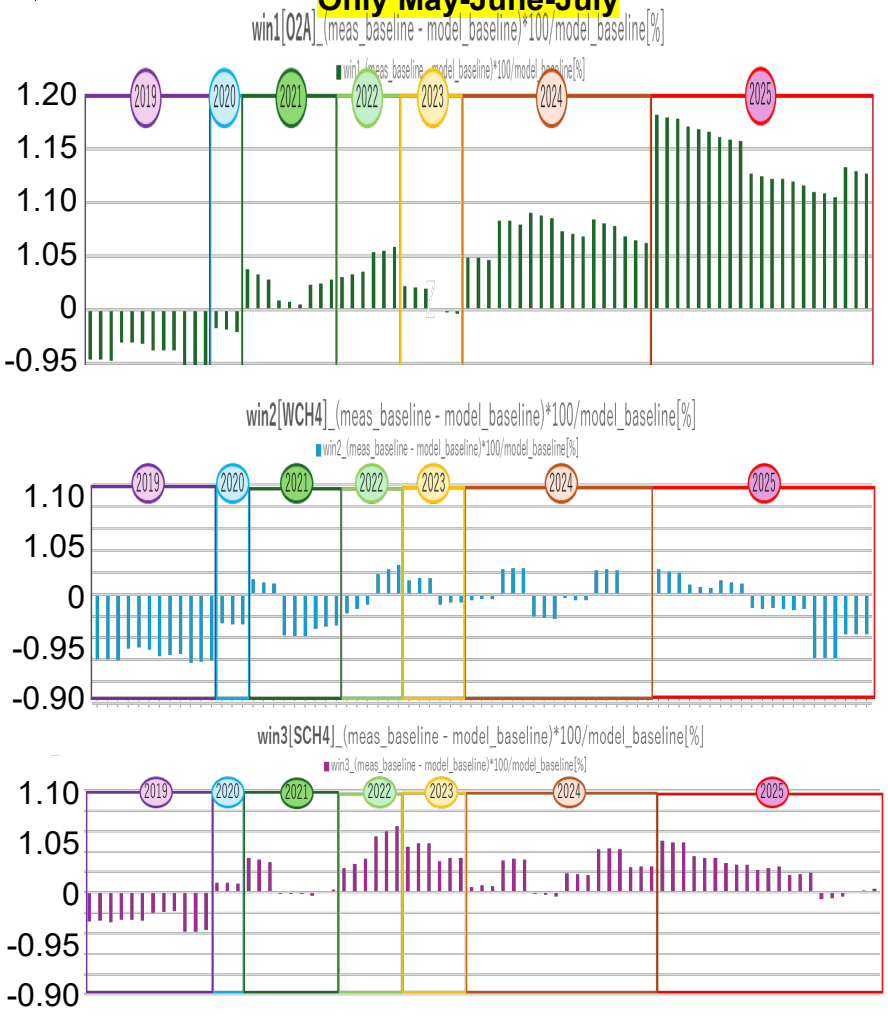



Trend B3



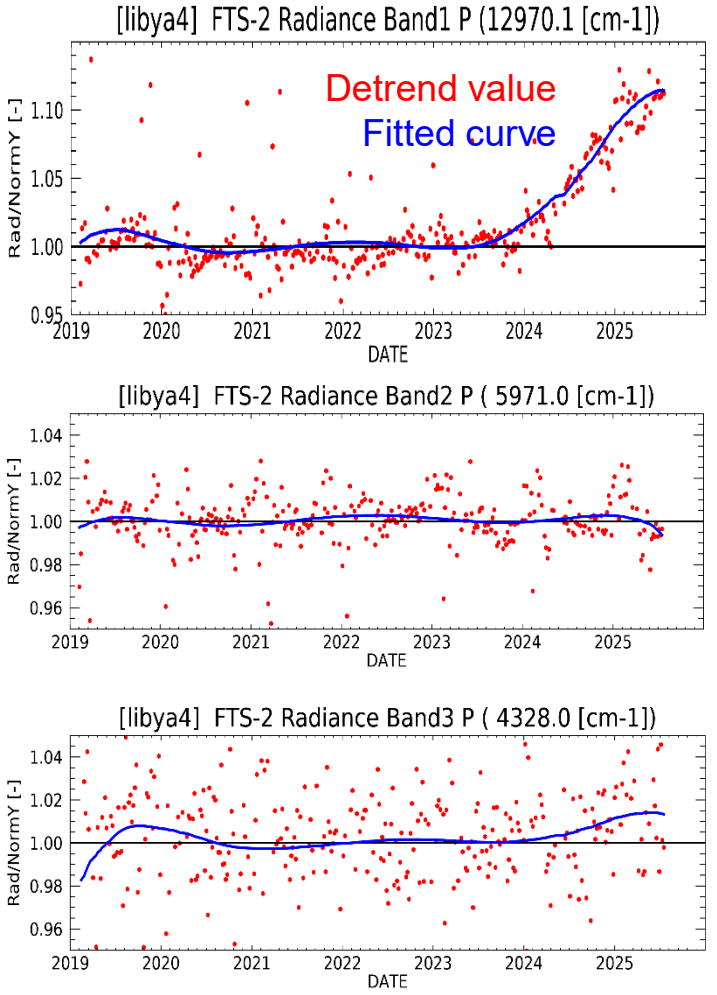

## RRV ViCAL

**Only May-June-July**




## Sahara desert

**After detrend**



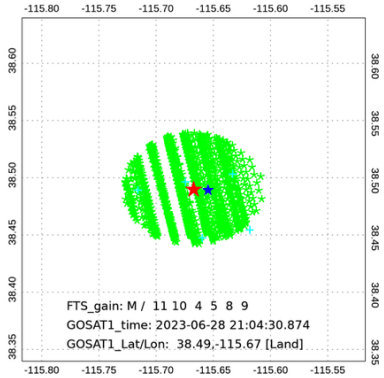

Radiometric response change ratios to the current L1B RDF between 3 methods almost agree.

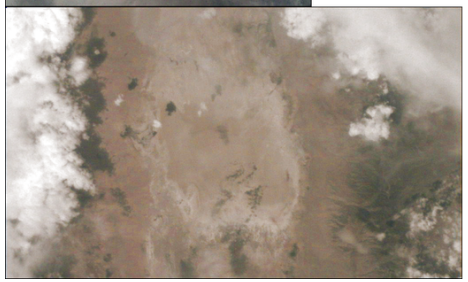
# Intercomparison of GHG sensors simultaneous measurements at RRV target

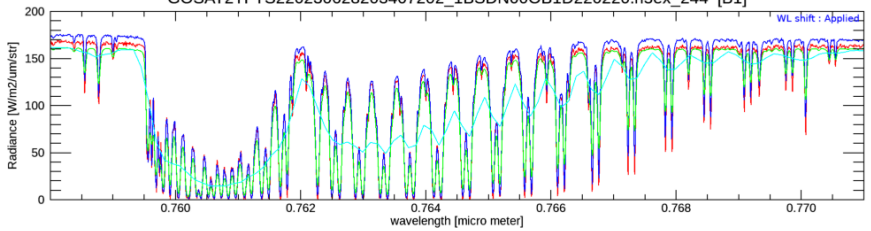
GOSATTFTS2023062821040360242_1BSPOD300300.01_ex3 / GOSAT2TFTS220230628203407202_1BSDN00OB1D220220.h5_ex244

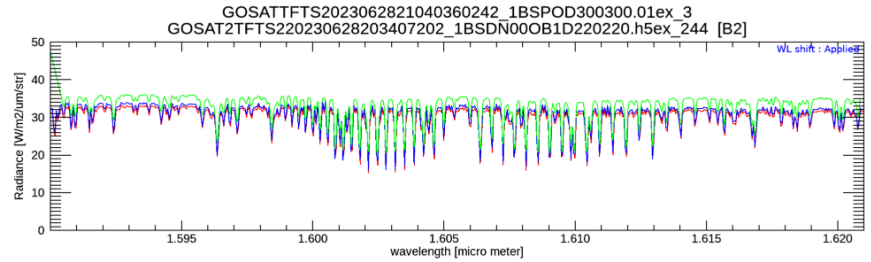
SensorZn [deg.]: 21.923 / 21.212 SensorAz [deg.]: 91.376 / 94.360 Cloud check: 3 / 0.001022
SolarZn [deg.]: 22.615 / 21.073 SolarAz [deg.]: 233.347 / 228.663 BT(892-905[cm-1]) Average [K]: 313.707 / 315.237
Matchup_time [min.]: 10.199 Matchup_dist [km]: 1.095 QualityFlag: 000000 / Good

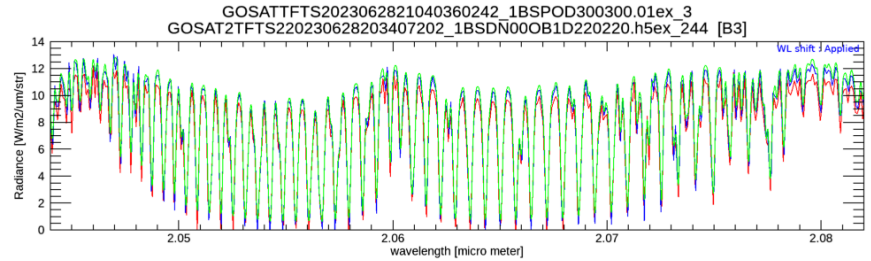
BRDF applied

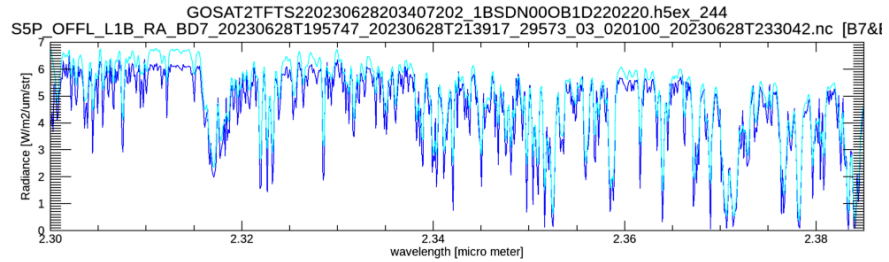


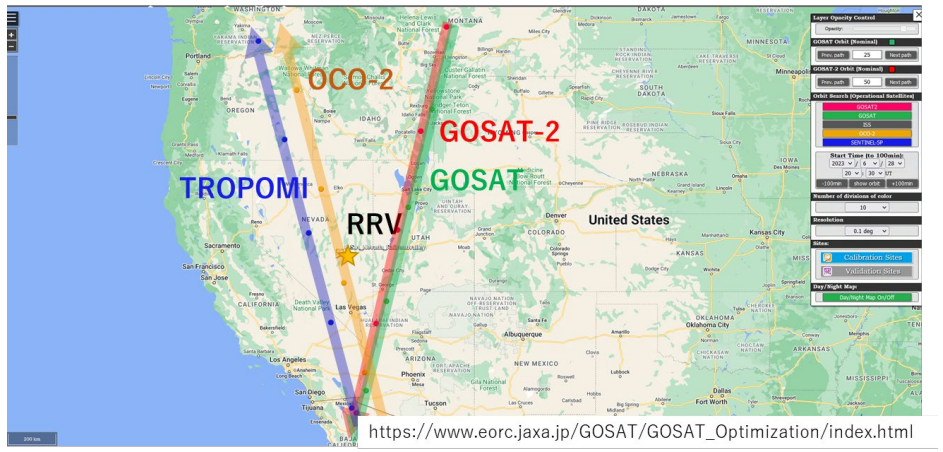



2023/06/28
GOSAT (21:04) V300
GOSAT-2 (20:54) V200
OCO-2 (20:53) B11r
OCO-3
TROPOMI(20:51)
All sensors SatZA=20-23deg

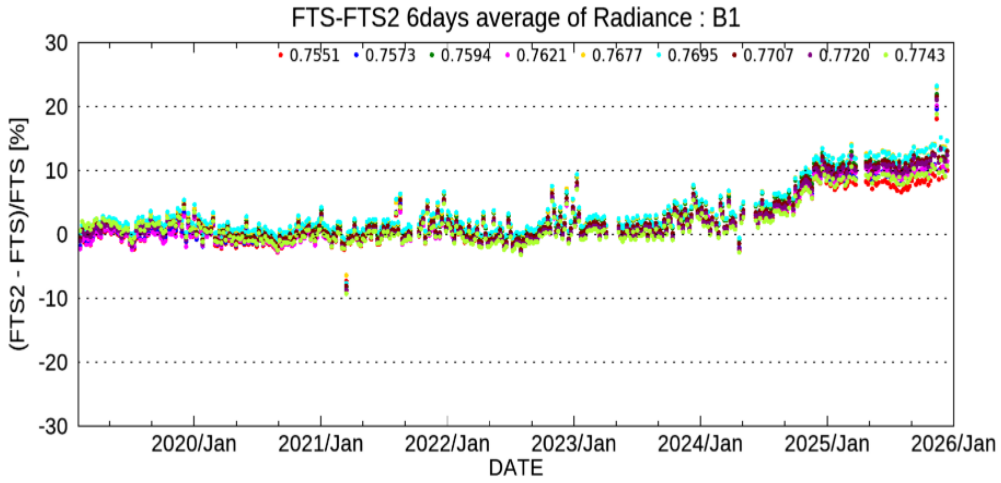


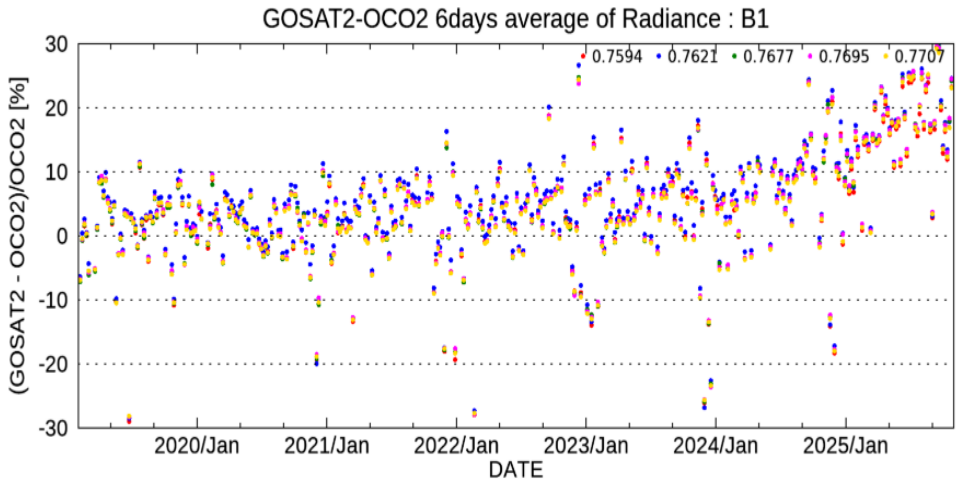

https://www.eorc.jaxa.jp/GOSAT/GOSAT_Optimization/index.html

# Inter-comparison of GOSAT-2/GOSAT/OCO-2 global simultaneous observation

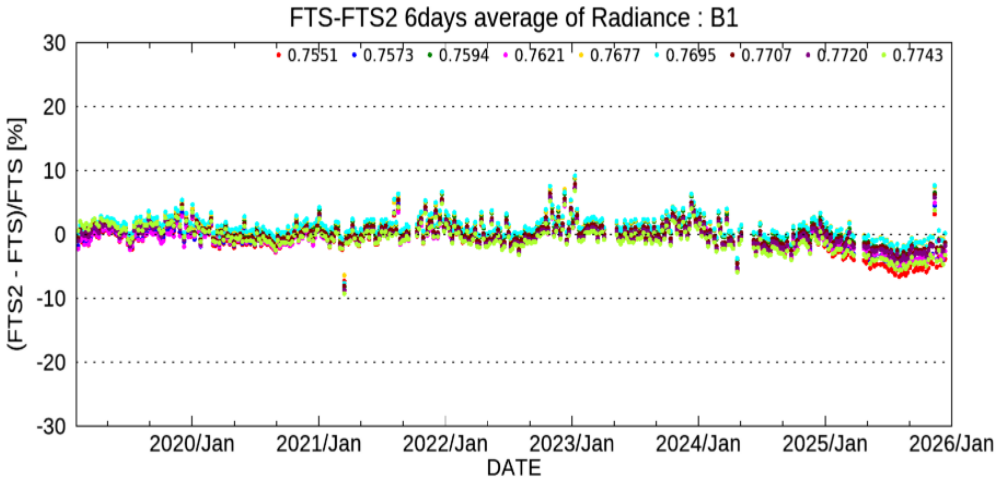
GOSAT-2 L1B applied new RDF is compared with GOSAT and OCO-2 for radiometric validation by using simultaneous observations applied BRDF correction.

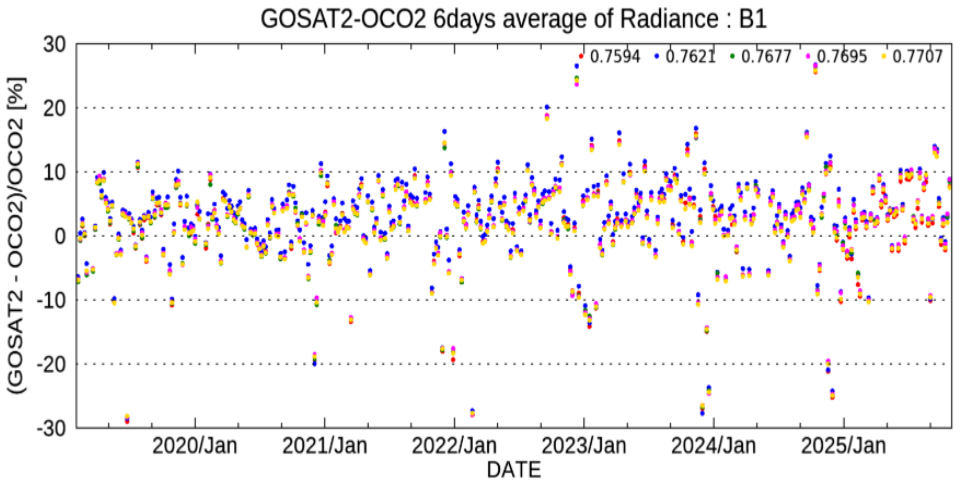
V230.230 (old RDF)



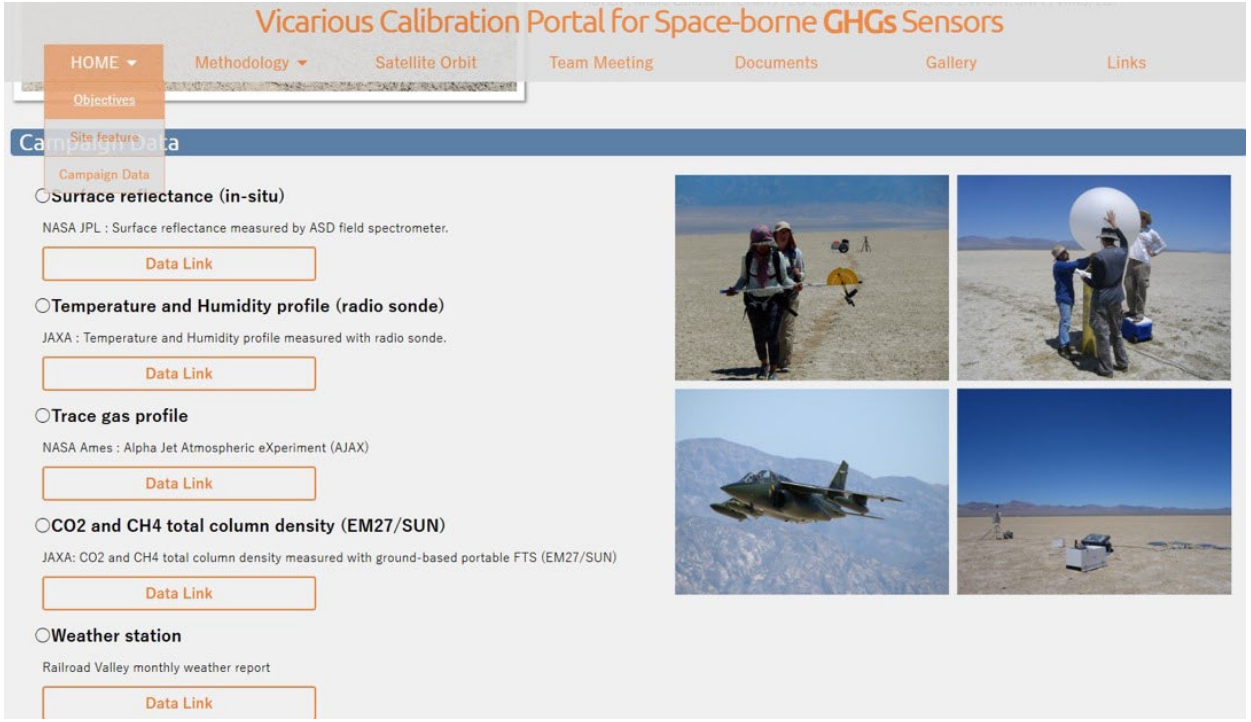

V240.240 (new RDF from Nov2022)



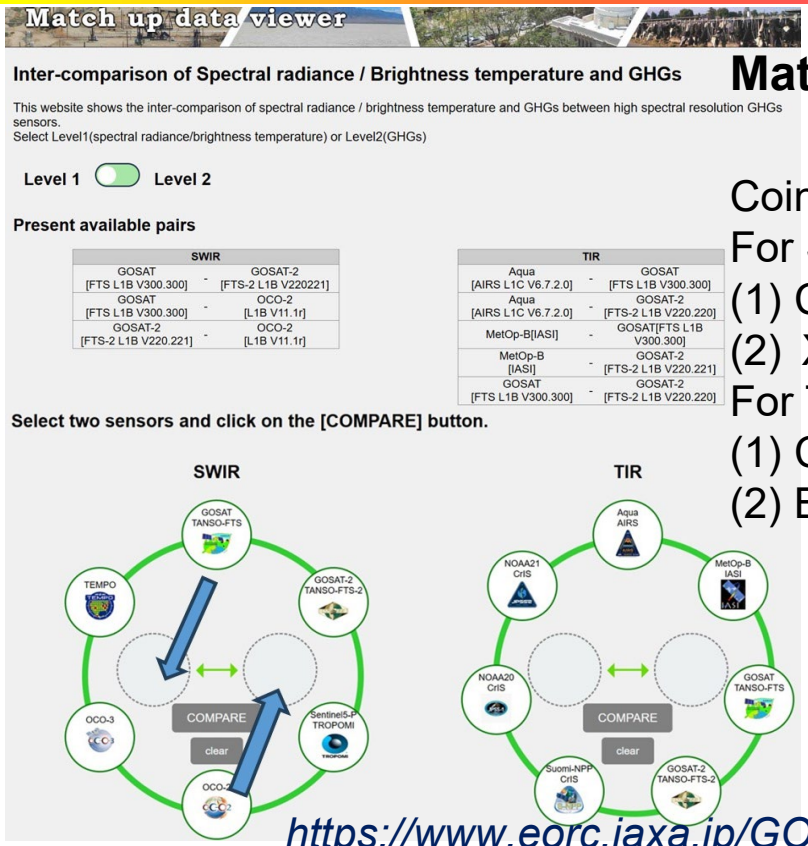
# Summary

## VCAL portal site




https://www.eorc.jaxa.jp/GOSAT/GHGs_Vical/index.html

## Match-up data viewer




**Match-up data viewer**

Coincident match-ups
For SWIR
(1) Calibrated radiance
(2) XCO2, XCH4, SIF, AOT
For TIR
(1) Calibrated radiance
(2) Brightness temperature

https://www.eorc.jaxa.jp/GOSAT/Matchup_forCal/top_matchup_viewer.html

- The Railroad Valley field data are available from VCAL portal site.
- VCAL team meeting is held every 3-4 months. Next meeting: 12-13UTC, Friday, May 22, 2026.
- RRV2026 summer (Jun18-22 + 1day): 1st year of GOSAT-GW, MicroCARB, Sentinel-5