Radiometric comparison of GOSAT TANSO-FTS and Suomi NPP VIIRS 1.6 µm CO₂ absorption band

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Objective and Background

• Evaluate the radiometric consistency between S-NPP VIIRS M10 (1.61 µm) and GOSAT TANSO-FTS band 2 (1.64 µm) that helps to better understand the calibration accuracy of the instruments.

• Radiometric performance can be independently analyzed through:
  – Onboard calibration system
  – Stable sites such as desert, ocean, snow, DCC.
  – Exo-terrestrial targets such as moon, stars etc.
  – Inter-calibration with other well calibrated radiometers (SNO/SNO-x, stable desert targets etc).

• VIIRS and TANSO-FTS radiometric consistency is analyzed using
  – TOA reflectance trending near Libya-4 desert site and
  – Extended SNOs based intercomparison over low latitudes (SNOx)
  – Radiometric comparison is performed between matching VIIRS band M10 with FTS band 2.
GOSAT

- The Greenhouse gases Observing SATellite (GOSAT) was launched on January 23, 2009
- GOSAT also called “IBUKI” is a cooperative project among JAXA, the National Institute for Environmental Studies (NIES) and the Ministry of the Environment (MOE).
- Payloads: Thermal and Near Infrared Sensor for Carbon Observation - Fourier Transform Spectrometer (TANSO-FTS) and a Cloud and Aerosol Imager (TANSO-CAI)
- 100 minute/orbit and 3 day repeat cycle
- Carbon Dioxide and methane are the primary retrieved greenhouse gases data product.

Ref: http://www.gosat.nies.go.jp

Figure 1. GOSAT TANSO-FTS operation
VIIRS and TANSO-FTS

**VIIRS**
- is a Sun-synchronous polar orbiting instrument launched in October 2011.
- Multispectral scanning radiometer with 16 moderate resolution bands (0.4 µm to 12 µm), 5 Imagery bands (0.6 µm to 12 µm) and 1 day night band (DNB).
- Wide-swath: 3,000 km, spatial resolution: 750m for moderate resolution bands and DNB, 375 m for imagery bands.
- Equipped with solar diffuser (SD) and black body as onboard calibrators.

**TANSO-FTS**
- **RSB bands:** 0.76, 1.64, and 2.00 um with Spatial Resolution: ~10.5 km
- **Spectral resolution:** 0.2 wavenumbers (about 0.05 nm at 1.6 µm)
- Takes 56,000 measurements over 3-day period.
- Incoming light splits into two orthogonally polarized components (P and S components) and measured independently.

➢ VIIRS M10 is covered by FTS band 2
FTS Radiance Spectra

Radiance @ Libya-4 desert

Radiance Spectra W/(m²sr-um)

Wavelength (nm)

CO₂, CH₄

Libya-4

CO₂

Radiance Spectra W/(m²sr-um)

Wavelength (nm)

Libya-4

O₂
VIIRS/FTS Comparison Methodology

**VIIRS**

1. Collect L1b Data of VIIRS over Libya-4
   - [http://www.nsof.class.noaa.gov/](http://www.nsof.class.noaa.gov/)

2. Read TOA Reflectance (near nadir only)

3. Extract circular ROI (~10.5 km) and calculate Mean and Stdev of pixels within ROI

4. Derive reflectance time series and compare with FTS

**TANSO-FTS**

1. Collect L1b Data (V/cm) of FTS over Libya-4
   - [http://www.gosat.nies.go.jp](http://www.gosat.nies.go.jp)

2. Apply prelaunch calibration coeffs.

3. Convert radiance (wavenumber) to reflectance (wavelength)
   - Solar model: Kurucz spectrum

4. Find FTS point near Libya-4 region

5. Apply degradation correction (Kuze et al. 2014) factor and derive reflectance time series
GOSAT FTS ROIs used in Time Series

- FTS reflectance time series over Libya-4 is based on above observations.
- Since the ROIs are located at different lat/lon, the reflectance can be different and constructing a time series without properly adjusting for the target-dependent reflectance can add bias among these ROIs and also add larger variability.
Since desert spectra is in general flat for most of the wavelength coverage of M10 from 1540 to 1562 nm, the convolution suggest:

- By using VIIRS RSR=0 for wavelength < 1562 nm, convolved Reflectance= 61.422%
- By using all VIIRS RSR values, convolved Reflectance= 61.379%
- Using convolved radiance, the difference with/without cutoff at 1562nm is about 0.2%. eg. 47.28 vs 47.18 w/m2sr/um at Libya-4

The impact is insignificant over desert!
Preliminary Result

TOA Reflectance Comparison

- Figure shows the near-nadir TOA reflectance time series for VIIRS and FTS observations over Libya-4 region.
- Annual seasonal variation mainly due to the changing solar geometry.
- Relative bias for P polarization measurements is larger than that of S polarization.
- VIIRS and S polarized observations agree very well to within 0.3% with uncertainty less than 1%.
- Larger radiometric inconsistency exist between VIIRS and P polarized measurements ranging from about 1.2% @ 16° solar zenith to nearly 3% at 55° solar zenith.
• Up to 1% uncertainty is added due to the variation in location of FTS observation near Libya-4 region
• Scaling factors can be estimated and applied to account for the differences and reduce the uncertainty.
Extended Simultaneous Nadir Overpass
NPP and GOSAT SNO

Total SNO-x: 8085 with Time Difference=10 minutes

- SNO events at low latitudes
- Only North African Deserts are used in this study
- SNO time difference of few minutes causes the movement of clouds and its shadows.
- Latitude limits: ±40°. $\text{Bias} = (\text{VIIRS} - \text{FTS}) \times 100\% / \text{VIIRS}$

➤ SNO-x Comparison:
  - Diamond shaped overlapping region
Preliminary Results

- Relative bias between VIIRS and FTS is less than 1% for S polarization.
- Bias for P polarization ranges from nearly 2% to 4% with varying solar zenith angles.
- Bias time series is very noisy with 1-sigma uncertainty larger than 2% for both P and S polarized measurements.
- Collocation errors and cloud contamination can be primary sources of uncertainty.
- Needs more investigation.
Summary

• VIIRS and TANSO-FTS compared using TOA reflectance trending and extended SNOs over low latitudes.
• Intercomaprison over Libya-4 desert suggest that VIIRS and S polarized FTS measurements are radiometrically consistent to within 0.5% ± 0.9%.
• For VIIRS and P polarized light, estimated bias ranges from about 1.5% at smallest solar zenith angle that increases to nearly 3% at largest solar zenith angle observed.
• The result over Libya-4 agree in general with the SNO-x results however, SNO-x suggest much larger uncertainty of more than 2% for both P and S polarized light.
• Bias estimated using SNO-x is within 1% for S polarization whereas it ranges from 2-4% for P polarized light.
• CAI product will be used in future for cloud masking of FTS observations to reduce the uncertainty.