VIIRS Bias Analysis using Hyperion

Sirish Uprety and Changyong Cao

CIRA, Colorado State University and NOAA/NESDIS/STAR

Outline

- Objective
- Introduction
- S-NPP VIIRS on-orbit radiometric performance
  - Calibration Sites used:
    - Libya-4 and Sudan-1 Desert sites
    - Antarctica Dome C
  - Methodology
  - Results and Analysis
- GOSAT TANSO-FTS comparison with EO-1 Hyperion
- Summary

Objective

- Assess the radiometric performance of Suomi NPP VIIRS

Introduction

- Radiometric performance can be independently analyzed through:
  - Onboard calibration system
  - calibration 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 radiometric bias is analyzed through intercomparison with AQUA MODIS over
  - Libya-4 and Sudan-1
  - Antarctica Dome C
- Spectral differences analyzed using EO-1 Hyperion.
- In addition, GOSAT FTS is compared with Hyperion over CO_2 absorption region to analyze radiometric differences.

Methodology

Collect L1B Data of VIIRS and AQUA MODIS over Libya-4, Sudan-1 and Dome C
http://www.nsof.class.noaa.gov/
http://ladsweb.nascom.nasa.gov/

Extract TOA Reflectance

Extract ROI (30*30 km) and calculate Mean and Stdev of pixels within ROI

Derive reflectance time series and analyze Radiometric Stability and Bias

Collect L1Gst Data of EO-1 Hyperion
http://glovis.usgs.gov/

Extract Reflectance for ROI over Libya-4, Sudan-1 and Dome C

Extract ROI (3km * 3km) and calculate Mean and Stdev of all pixels within ROI for all channels

Extract reflectance mean as a function of wavelength and analyze spectral characteristics and Bias

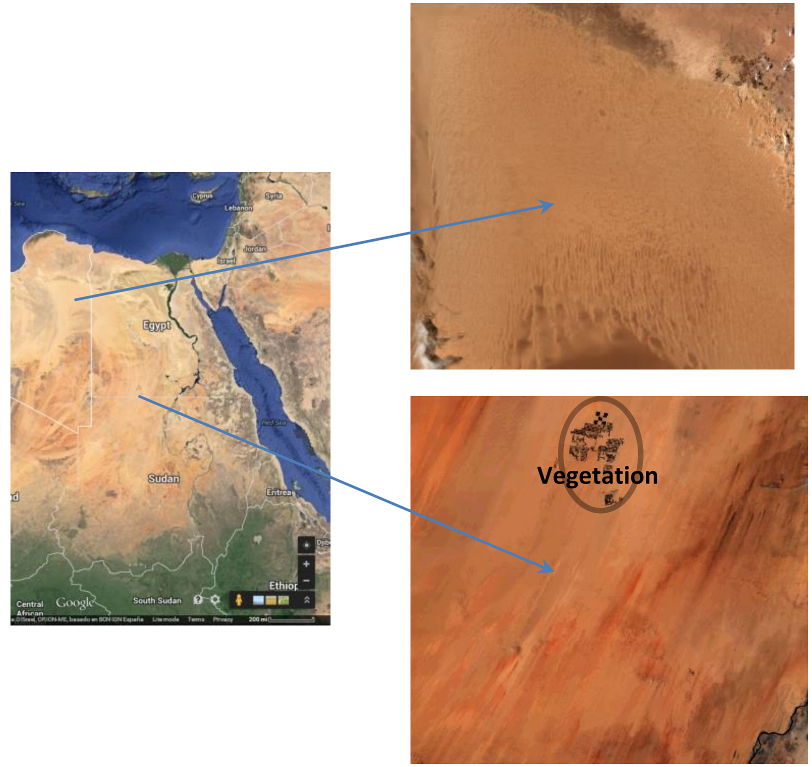
Calibration Sites Used

Libya-4 and Sudan-1

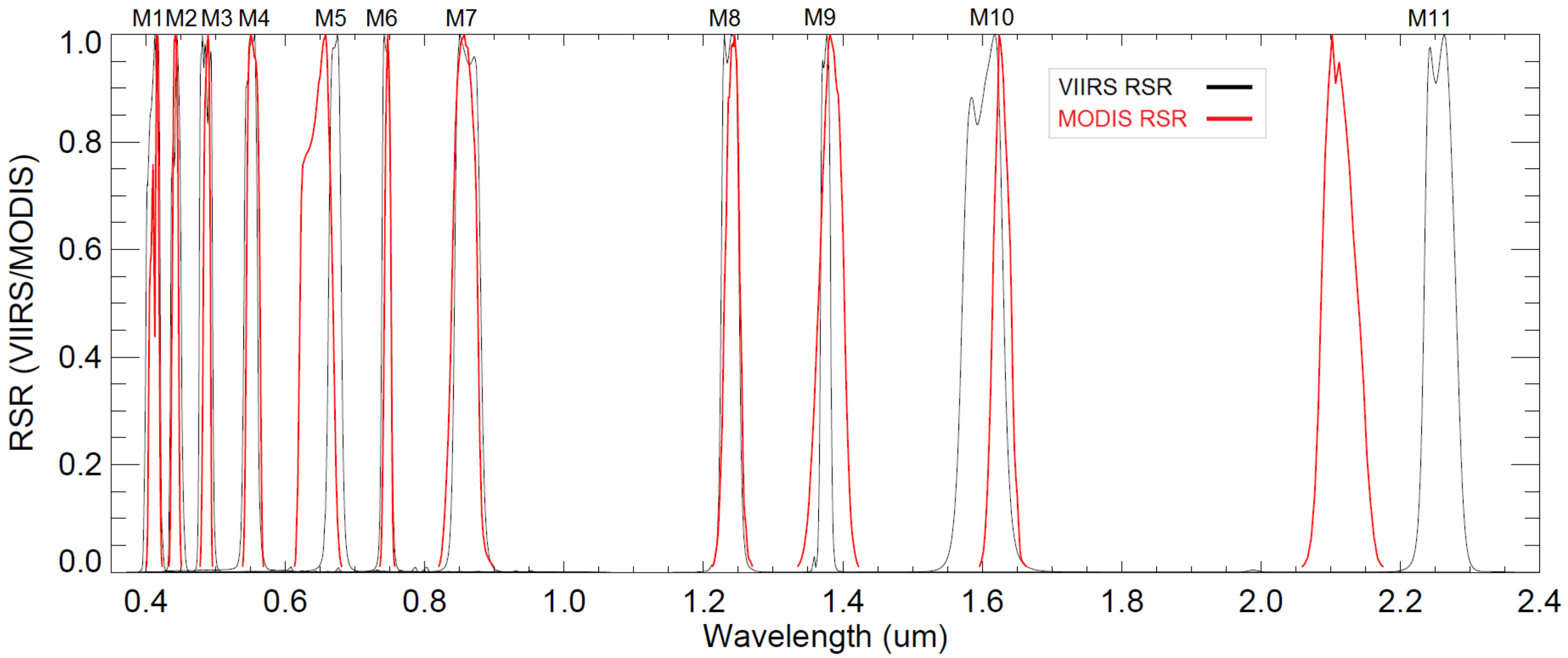
- Libya-4 (28.55, 23.39) is a CEOS endorsed cal/val site.
- Both Libya-4 and Sudan-1 are Saharan desert sites used mostly for on-orbit cal/val of VNIR radiometers.
- Sudan-1 (21.74, 28.22) is used by NOAA series AVHRR for post-launch relative calibration.
- VIIRS nadir observations are collected to study the radiometric performance.

Antractica Dome C

- Dome C (-75.102°, 123.395°) is also a CEOS cal/val site.
- Large homogenous snow field in Antarctica at an altitude of 3.2 km
- high altitude; high reflectance; > 75% of cloud-free time; low water vapor content; very cold and dry climate; low aerosol and dust etc.
- Limitations: accessibility, availability of data only during austral summer, high BRDF, not visible by GOES/GOES-R instruments etc.

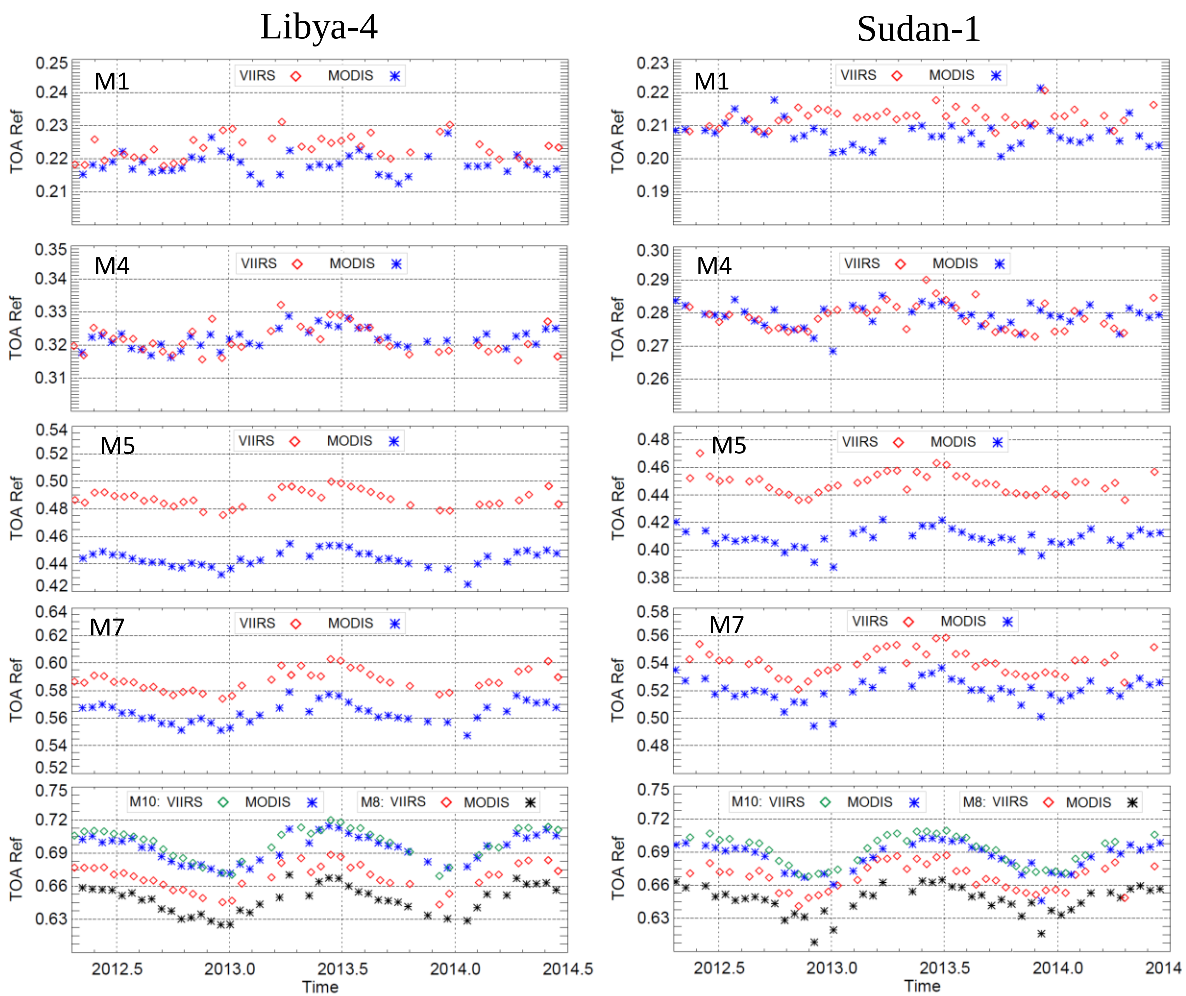


VIIRS and MODIS RSR



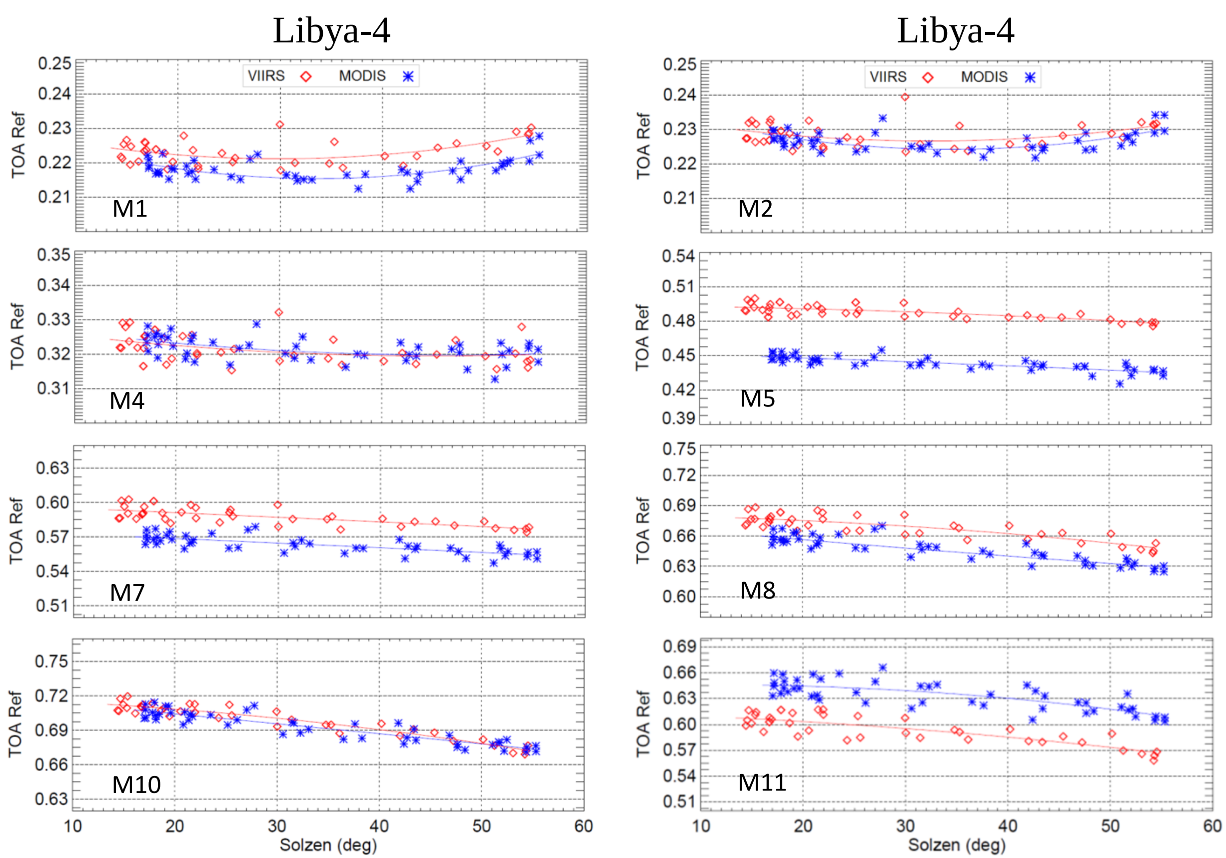
VIIRS		MODIS	
Band	Wavelength (µm)	Band	Wavelength (µm)
M1	0.402 - 0.422	8	0.405 - 0.420
M2	0.436 - 0.454	9	0.438 - 0.448
M3	0.478 - 0.498	10	0.483 - 0.493
M4	0.545 - 0.565	4	0.545 - 0.565
M5	0.662 - 0.682	1	0.620 - 0.670
M7	0.846 - 0.885	2	0.841 - 0.876
M8	1.230 - 1.250	5	1.230 - 1.250
M10	1.580 - 1.640	7	1.628 - 1.652
M11	2.225 - 2.275	6	2.105 - 2.155

Rad. Performance over Desert



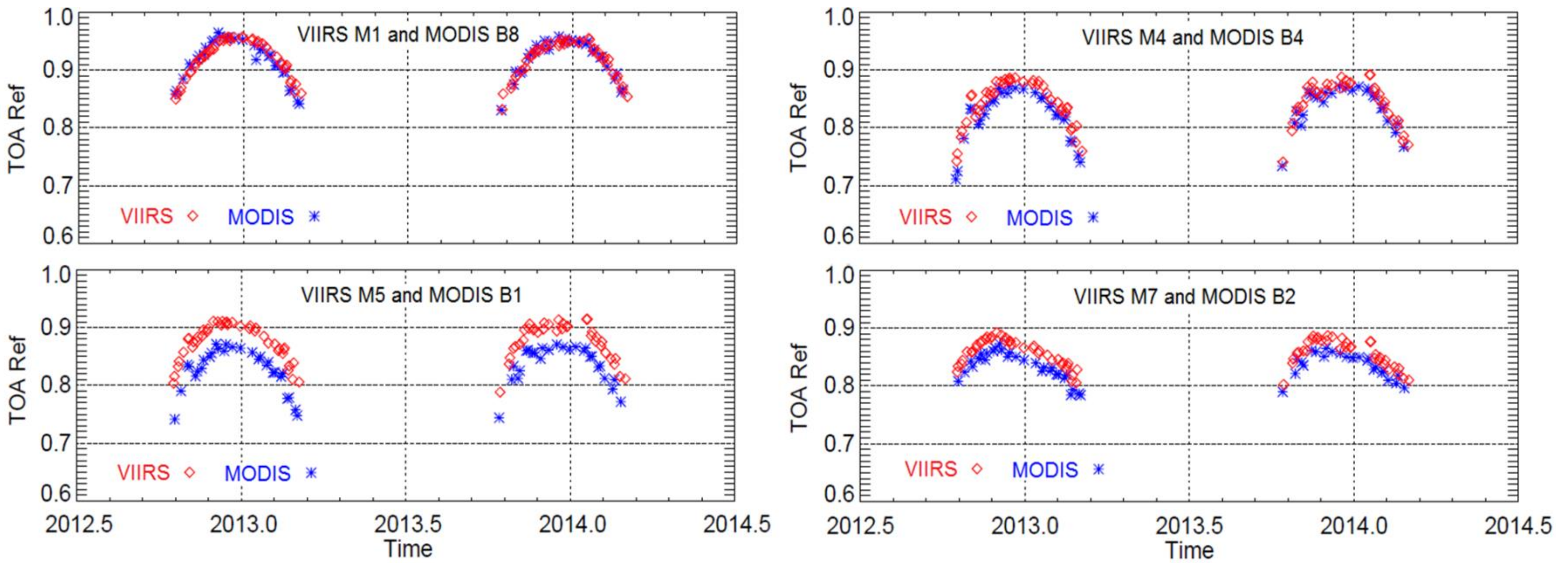
- Doesn’t indicate long-term upward or downward trends over the period.
- Seasonal oscillation is mainly due to annual solar zenith change
- Calibration stability is better than 1%

VIIRS Bias Relative to MODIS



VIIRS		MODIS		Libya-4	Sudan-1
Band	Wavelength (μm)	Band	Wavelength (μm)	Bias @ solzen=18°	
M1	0.402 - 0.422	8	0.405 - 0.420	1.65% ± 0.31%	1.54% ± 0.24%
M2	0.436 - 0.454	9	0.438 - 0.448	0.31% ± 0.42%	0.15% ± 0.27%
M3	0.478 - 0.498	10	0.483 - 0.493	1.32% ± 0.42%	1.36% ± 0.28%
M4	0.545 - 0.565	4	0.545 - 0.565	-0.23% ± 0.39%	-0.04% ± 0.35%
M5	0.662 - 0.682	1	0.620 - 0.670	9.5% ± 0.40%	10.05% ± 0.54%
M7	0.846 - 0.885	2	0.841 - 0.876	3.95% ± 0.53%	3.99% ± 0.64%
M8	1.230 - 1.250	5	1.230 - 1.250	2.74% ± 0.64%	2.96% ± 0.84%
M10	1.580 - 1.640	7	1.628 - 1.652	0.54% ± 0.41%	0.85% ± 0.39%
M11	2.225 - 2.275	6	2.105 - 2.155	-6.3% ± 0.96%	-5.61% ± 0.98%

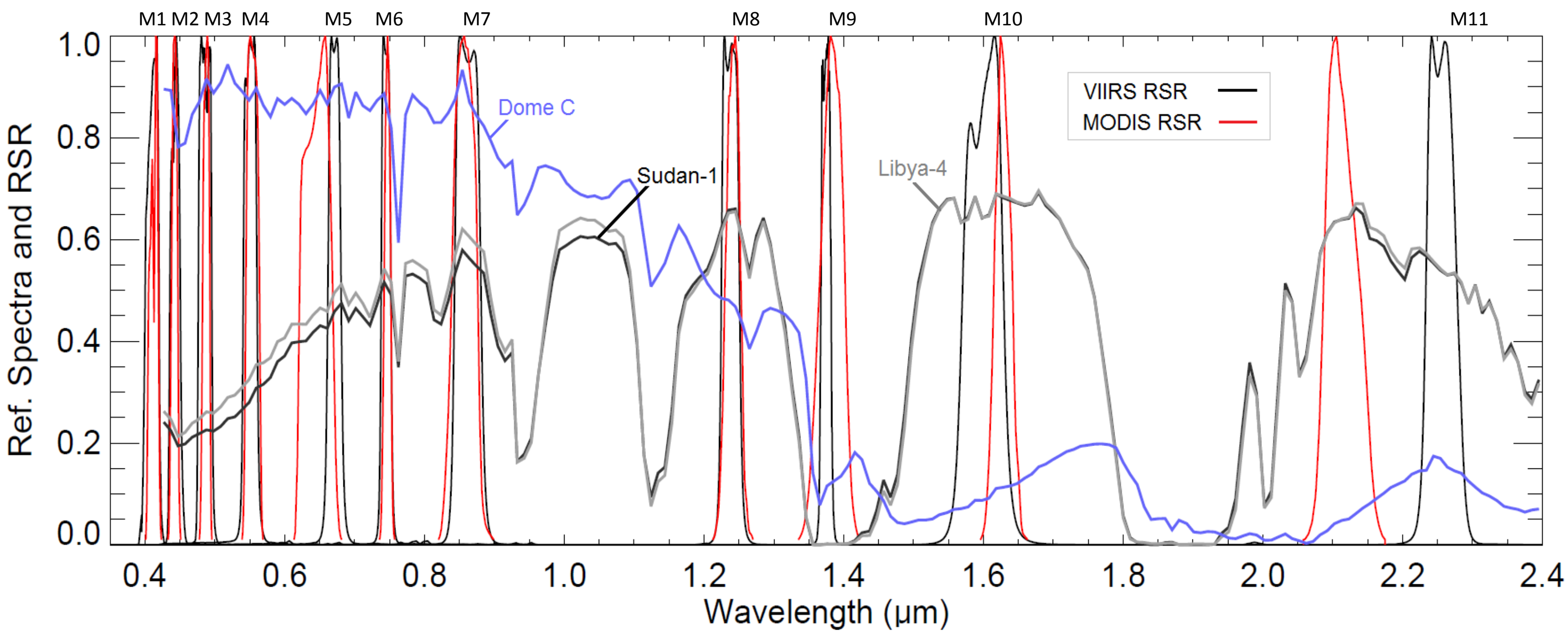
Dome C TOA Reflectance



- Large BRDF
- Some VIIRS bands agree well with MODIS and some suggest large bias.
- MODIS matching bands for M2 and M3 are saturated at larger solar elevation.

VIIRS		MODIS		Dome C
Band	Wavelength (µm)	Band	Wavelength (µm)	Bias @ solzen=18°
M1	0.402 - 0.422	8	0.405 - 0.420	-0.14% ± 0.65%
M2	0.436 - 0.454	9	0.438 - 0.448	-0.50% ± 0.67%
M3	0.478 - 0.498	10	0.483 - 0.493	-0.20% ± 0.79%
M4	0.545 - 0.565	4	0.545 - 0.565	1.62% ± 1.64%
M5	0.662 - 0.682	1	0.620 - 0.670	5.00% ± 1.28%
M7	0.846 - 0.885	2	0.841 - 0.876	2.93% ± 1.44%

Spectral Characteristics Using Hyperion



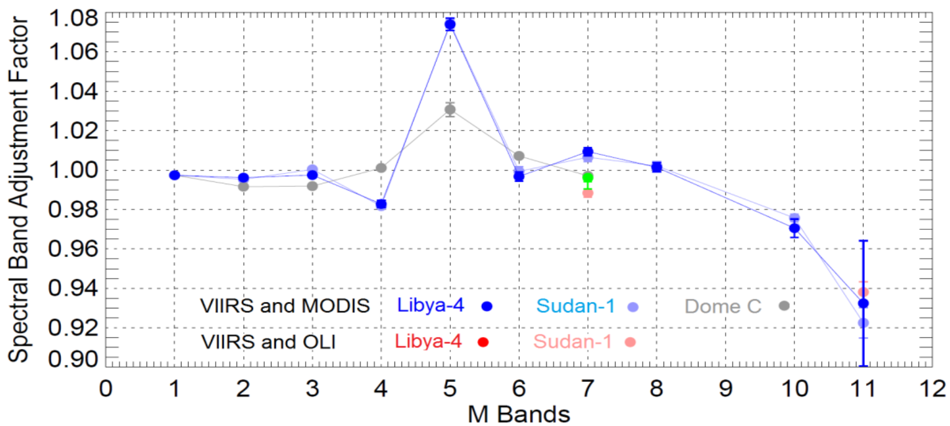
- Dome C is more flat in VNIR region whereas desert sites are better for longer wavelengths.
- Observed bias depends on target spectral characteristics and RSR differences.
- Large bias for some VIIRS bands exists mainly due to the differences in spectral response functions of instruments.
- If the spectral characteristics of the sites are well characterized, the impact of spectral differences in inter-comparison can be accounted.

Bias Induced due to Spectral Differences

- Residual bias (RB): Observed bias - **Spectral bias**
- Residual bias exists mainly due to uncertainties in calibration, spectral bias estimation, atmospheric absorption variability, collocation error, BRDF.
- In an ideal case, the residual bias should be close to zero regardless of the target chosen.
- Simulated reflectance for VIIRS and MODIS is estimated by convolving Hyperion measurements with instrument RSRs.

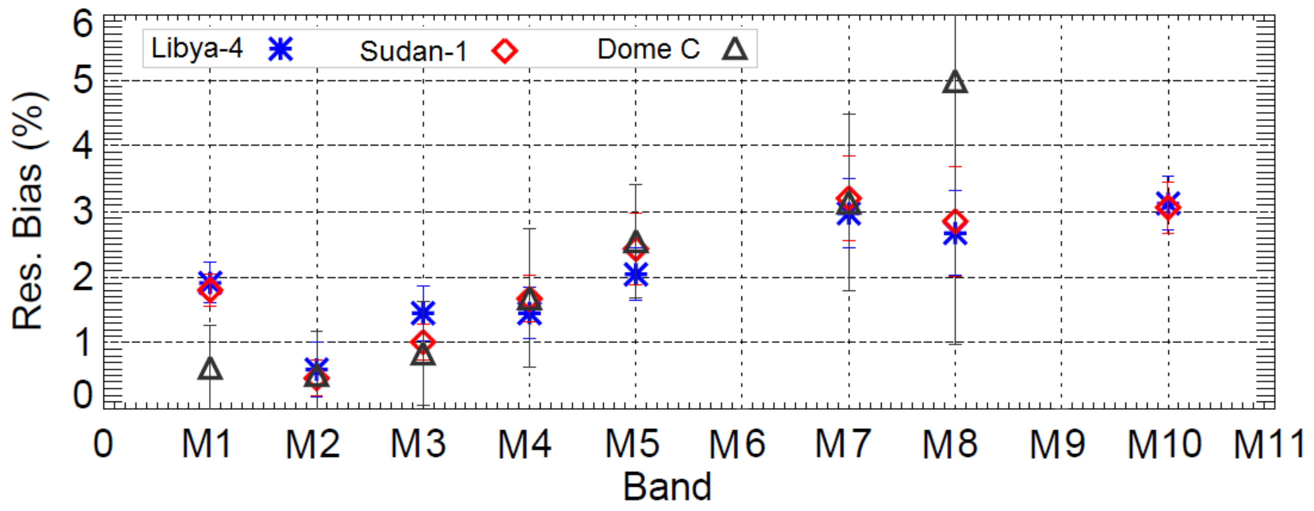
$$\boldsymbol{Conv_i = \frac{\int Hyp_{ref(\lambda)} . SRF_i(\lambda) . d\lambda}{\int SRF_i(\lambda) . d\lambda}}$$

$$\mathrm{SBAF} = \frac{\mathrm{Conv}_{\mathrm{VIIRS}}}{\mathrm{Conv}_{\mathrm{MODIS}}} \times 100\%$$



Band	Modeled Bias		
	Libya-4	Sudan-1	Dome C
M1	-0.26%	-0.26%	-0.76%
M2	-0.28%	-0.31%	-1.01%
M3	-0.13%	0.35%	-1.04%
M4	-1.68%	-1.71%	-0.06%
M5	**7.46%**	**7.62%**	2.31%
M7	0.98%	0.79%	-0.38%
M8	0.07%	0.11%	0.81%
M10	-2.58%	-2.21%	-
M11	**~7%**		-

VIIRS Bias



- VIIRS residual bias at three sites (Libya-4, Sudan-1 and Dome C) agree to within 1% for bands M1 to M7 and M10.
- M8 indicate larger bias and uncertainty over Dome C.
- After accounting for spectral differences, VIIRS and MODIS agree to within 2% ± 1% for bands M1 through M5.
- M7-8 and M10 indicate bias on the order of 3%.

GOSAT TANSO-FTS

- The Greenhouse gases Observing SATellite (GOSAT) was launched on January 23, 2009
- TANSO-FTS (Fourier Transform Spectrometer):
  - RSB bands: 0.76, 1.64, and 2.00 um
  - Spectral resolution: 0.2 wavenumbers (about 0.05 nm at 1.6 μm)
  - Spatial Resolution: ~10.5 km
- Incoming light splits into two orthogonally polarized components (P and S components) and measured independently.
- FTS Calibration: Solar Irradiance, Deep Space, Moon, Diode Laser.

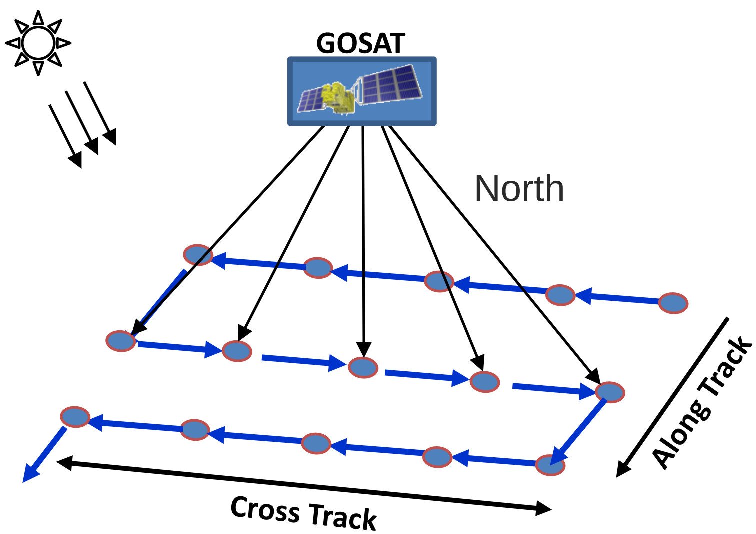


Figure 1. TANSO-FTS operation

	GOSAT FTS	VIIRS
B1	0.757-0.775 μm	-
B2	***1.562 -1.724 μm***	***1.58-1.64 μm***
B3	1.923-2.083 μm	-

Hyperion and GOSAT FTS over Libya-4

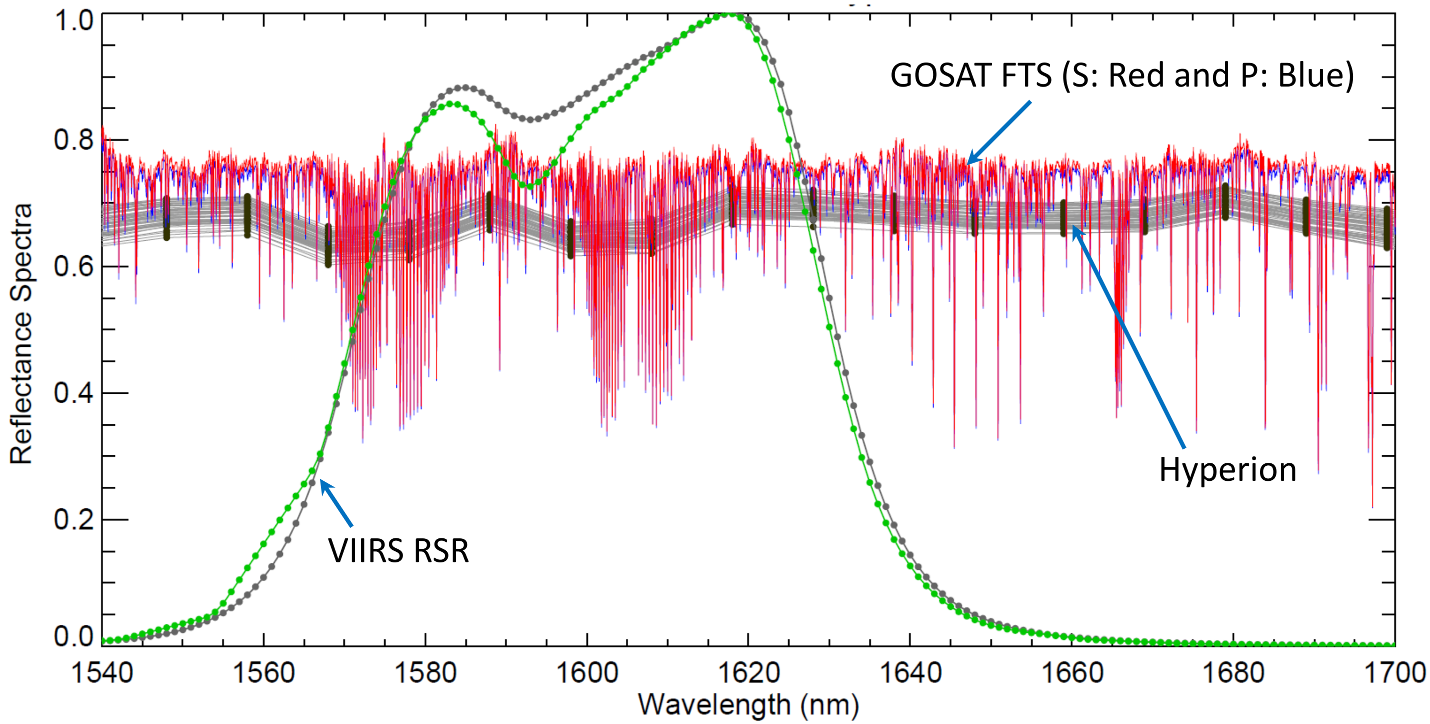
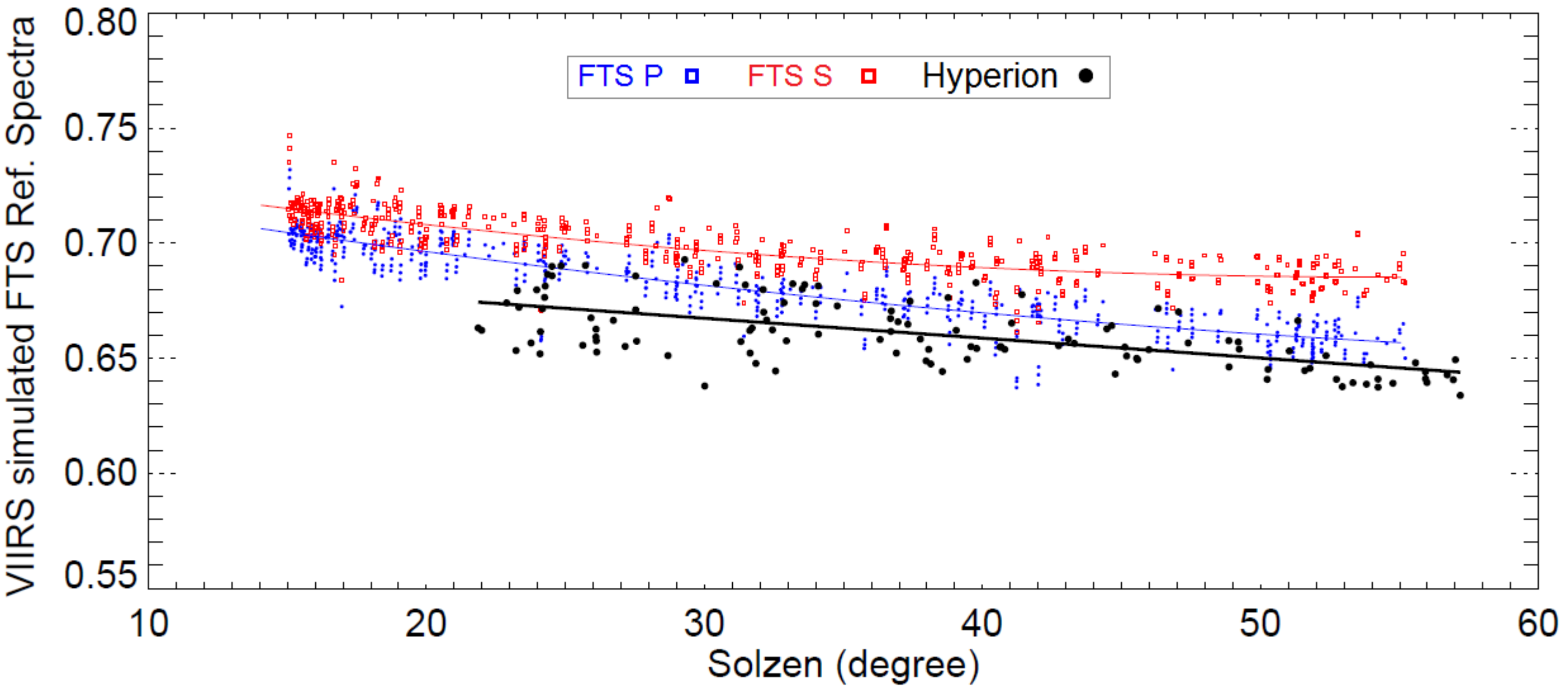


Figure. GOSAT FTS Band 2 (1.6 µm) along with Hyperion reflectance (57 observations) over Libya-4. VIIRS M and I bands are completely covered by FTS L1b spectra.

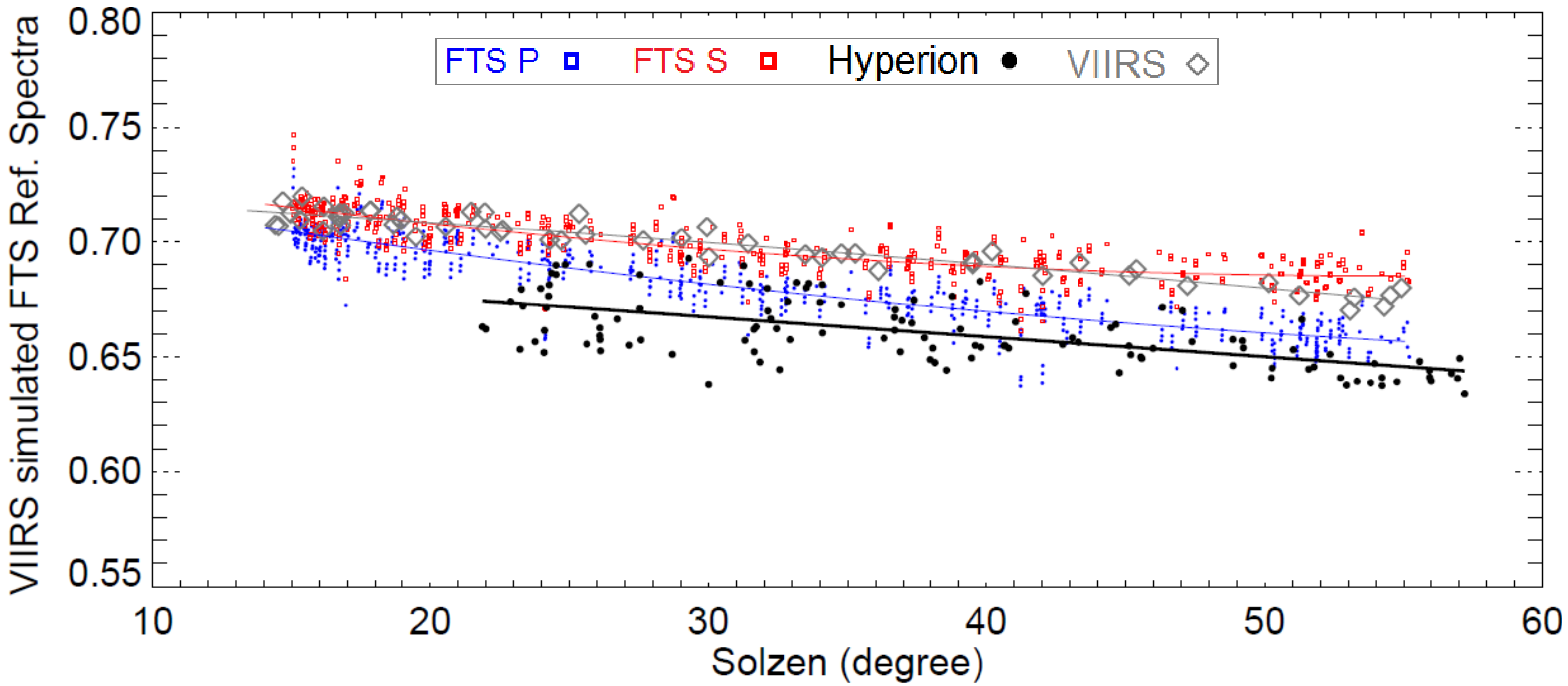
- *GOSAT FTS measurements near Libya-4 are higher than Hyperion*

Hyperion and GOSAT FTS Comparison



- Hyperion and FTS measurements are convolved with VIIRS.
- Bias is clearly observed: larger inconsistency with S polarized light compared to P polarization.
- Inconsistency between S and P polarized measurements ranges from about 1.2% @ 16° solzen to nearly 3% at 55° solzen.
- Larger discrepancy between Hyperion and FTS could be due to a number of reasons such as use of different solar models (Hyperion: CHKUR and FTS: Kurucz), collocation error, BRDF, low spectral resolution of Hyperion and calibration uncertainties.

Hyperion and GOSAT FTS Comparison



- Hyperion and FTS measurements are convolved with VIIRS and plotted.
- Larger bias with S polarized light compared to P polarization.
- Inconsistency between S and P polarized measurements ranges from about 1.2% to nearly 3%.
- Larger discrepancy between Hyperion and FTS could be due to a number of reasons such as use of different solar models (Hyperion: CHKUR and FTS: Kurucz), collocation error, BRDF, low spectral resolution of Hyperion and calibration uncertainties.

Summary

- VIIRS bias over Libya-4, Sudan-1 and Dome C suggest bias on the order of 2% ± 1% or less for most of the bands analyzed.
- VIIRS calibration stability and radiometric accuracy computed at Libya-4 and Sudan-1 sites agree very well to within 1%.
- Hyperion observations are used to quantify the impact due to spectral differences between matching bands.
- Hyperion relative radiometric accuracy is also analyzed using GOSAT FTS for CO_2 absorption band near 1.6 μm.
- Preliminary results indicate that FTS measurements are higher than Hyperion. Further investigation needed!