Libya-4 Rayference Calibration reference: application to S3A/calibration verification

VH-RODA Optical Sensors Sessions

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VH-RODA: Very High-resolution Radar & Optical Data Assessment workshop
and CEOS SAR 2019 workshop
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rayference

Calibration verification method

Definition of a calibration reference
Libya-4 **R**ayference **C**alibration **R**eference (LRCR)
Not (yet) traceable to SI standard!

↓

Determination of our reference accuracy
Not according to GUM recommendations!

↓

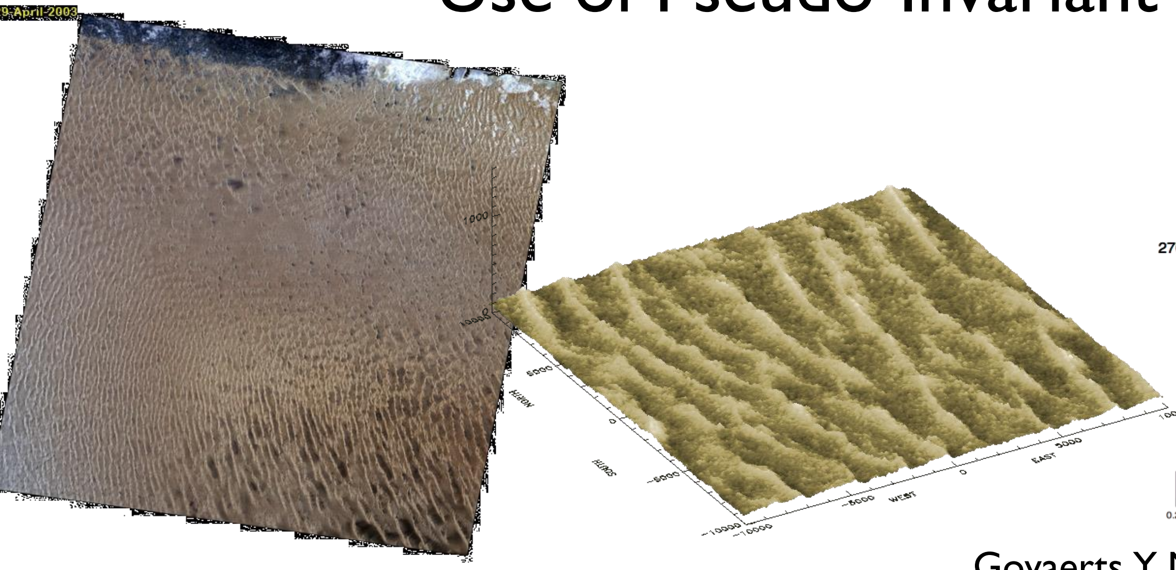
Comparison of our reference with
S3A/SLSTR nadir and oblique observations

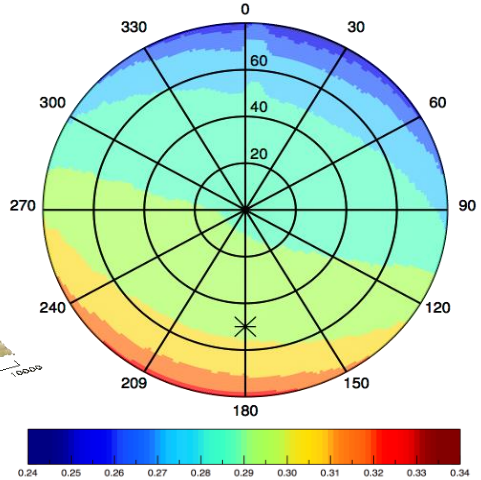
↓

Release correction recommendations

1. Libya-4 Rayference Calibration Reference (LRCR)

Use of Pseudo-Invariant Calibration Site (PICS) (Libya-4);





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1. Libya-4 Rayference Calibration Reference (LRCR)

- Characterisation of surface BRF from 300nm to 2800nm with a 1nm spectral resolution (assuming a flat surface for an area >100km^2);
- Characterization of the atmospheric vertical profile and gas concentrations (H2O, O3, CO2, CH4, …);
- Characterization of aerosol type and concentration;
- Simulation of spectral TOA BRF with 4 different models implementing:
    - Different methods to solve the radiative transfer equation;
    - Different assumptions for molecular absorption and its coupling with scattering;
- Can be used from 300nm to 2800nm at about 1 nm spectral resolution for sun and viewing zenith angles up to 65°.

1. Libya-4 Rayference Calibration Reference (LRCR)

- LRCR uncertainty estimation is difficult to assess following the recommendations of the Guide to the Expression of Uncertainty in Measurement (BIPM 2008) because:

$$\sum_{i=1}^{N}\sum_{j=1}^{N}\left[\frac{1}{2}\left(\frac{\partial^2 f}{\partial x_i \partial x_j}\right)^2 + \frac{\partial f}{\partial x_i}\frac{\partial^3 f}{\partial x_i \partial x_j^2}\right] u^2(x_i) u^2(x_j)$$

  - the uncertainties on the model parameters are difficult to estimate (e.g., aerosol optical type and optical thickness);
  - the radiative transfer models provide different values, i.e., these models have themselves uncertainties;

- The LRCR accuracy has been estimated against "well-calibrated" radiometers observing Libya-4.

2. Acquisition of well-calibrated observations

Platform	Radiometer	Dataset	Version	N_t
AQUA	MODIS	NASA	Collection 5	120
Envisat	MERIS	PICSCAR	Third reprocessing	230
Envisat	AATSR	RAL	Third reprocessing	275 (115)
Landsat-8	OLI	PICSCAR	Collection 1	25
Sentinel-2A	MSI	PICSCAR	Baseline 02.07	35
Sentinel-3A	OLCI	DIMITRI		75

N_t is the number of processed clear sky observations

3. Nadir view LRCR verification

Nadir view : SZA < 30° VZA < 30°

Satellite observation

$$\tilde{O}_{\lambda_k}(\Omega, t; q_j)$$

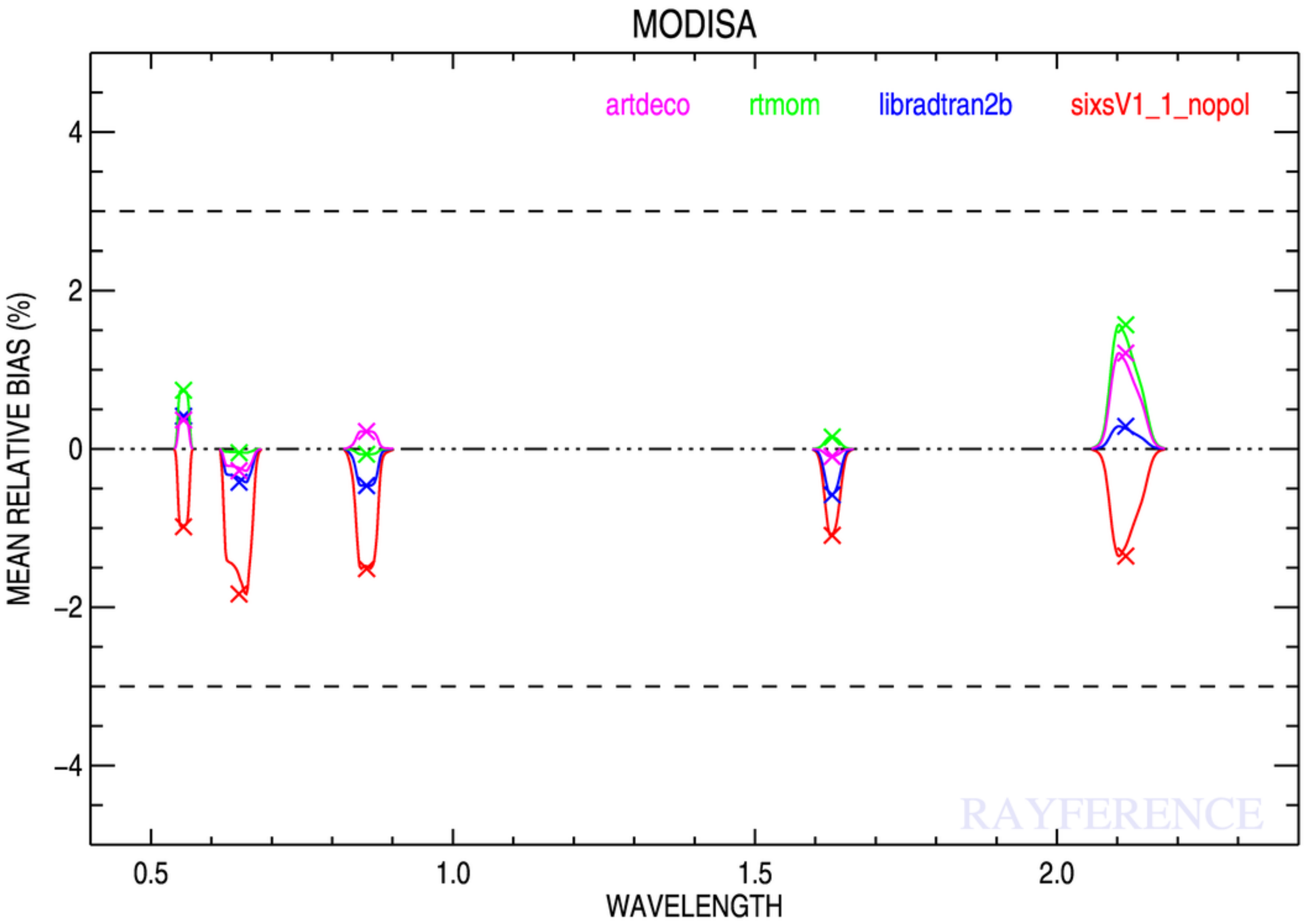
Corresponding LRCR

$$\tilde{R}_{\lambda_k}(\Omega, t; q_j) = \frac{\int_\lambda R(\Omega, \lambda, t; q_j)\, \xi_k(\lambda) \mathrm{d}\lambda}{\int_\lambda \xi_k(\lambda) \mathrm{d}\lambda}$$

Mean relative bias

$$\bar{B}_k = \frac{1}{N_t} \sum_{N_t} \frac{\left(\tilde{O}_{\lambda_k}(\Omega, t; q_j) - \tilde{R}_{\lambda_k}(\Omega, t; q_j)\right)}{\tilde{R}_{\lambda_k}(\Omega, t; q_j)}$$

3. Nadir view verification: AQUA/MODIS



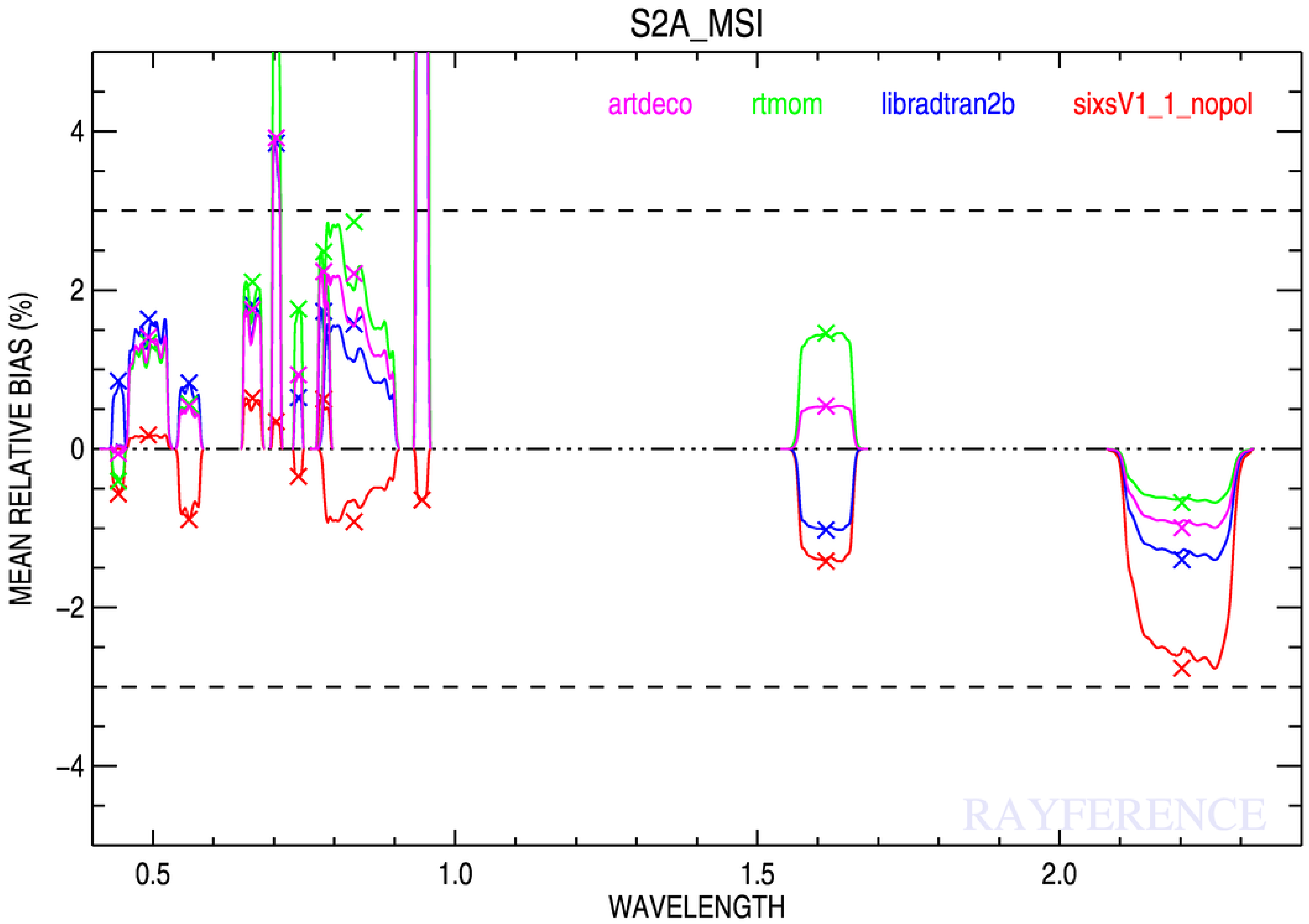
3. Nadir view verification: AQUA/MODIS

AQUA/MODIS					
BAND	$0.55\mu m$	$0.66\mu m$	$0.84\mu m$	$1.62\mu m$	$2.20\mu m$
	B4	B1	B2	B6	B7
6SV	-0.98±1.03%	-1.83±0.75%	-1.51±0.77%	-1.09±0.47%	-1.35±1.22%
LibRadtran	+0.41±1.06%	-0.42±0.78%	-0.46±0.81%	-0.58±0.57%	+0.28±1.34%
RTMOM	+0.74±1.09%	-0.05±0.80%	-0.07±0.78%	+0.15±0.50%	+1.57±1.27%
ARTDECO	+0.36±0.99%	-0.28±0.74%	+0.22±0.66%	-0.09±0.37%	+1.21±1.01%
RTM range	1.72%	1.78%	1.44%	1.24%	2.92%

Mean relative bias (120 obs.) and its standard deviation

The RTMs are a major source of uncertainty

3. Nadir view verification: Sentinel-2A/MSI



3. Nadir view verification: Sentinel-2A/MSI

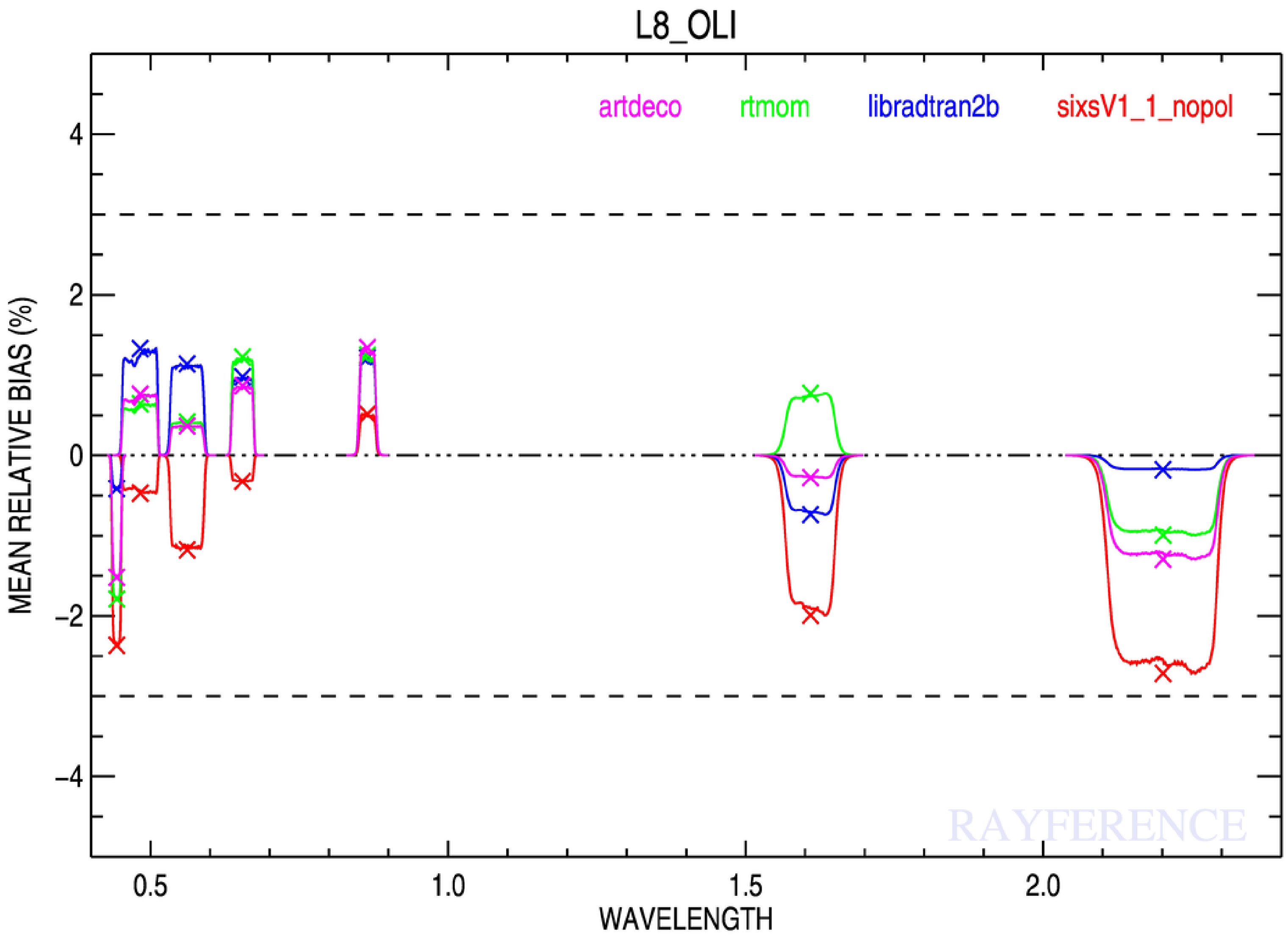
BAND	0.55μm	0.66μm	0.84μm	1.62μm	2.20μm
Sentinel-2A/MSI					
	B3	B4	B8	B11	B12
6SV	-0.89±0.67%	+0.64±0.50%	-0.92±0.83%	-1.42±0.30%	-2.77±0.79%
LibRadtran	+0.83±0.67%	+1.81±0.43%	+1.57±0.67%	-1.02±0.26%	-1.40±0.62%
RTMOM	+0.56±0.59%	+2.10±0.35%	+2.86±0.58%	+1.46±0.21%	-0.68±0.56%
ARTDECO	+0.54±0.73%	+1.75±0.52%	+2.21±0.86%	+0.54±0.29%	-0.99±0.83%
RTM range	1.72%	1.46%	3.78%	2.88%	2.09%

Mean relative bias (35 obs.) and its standard deviation

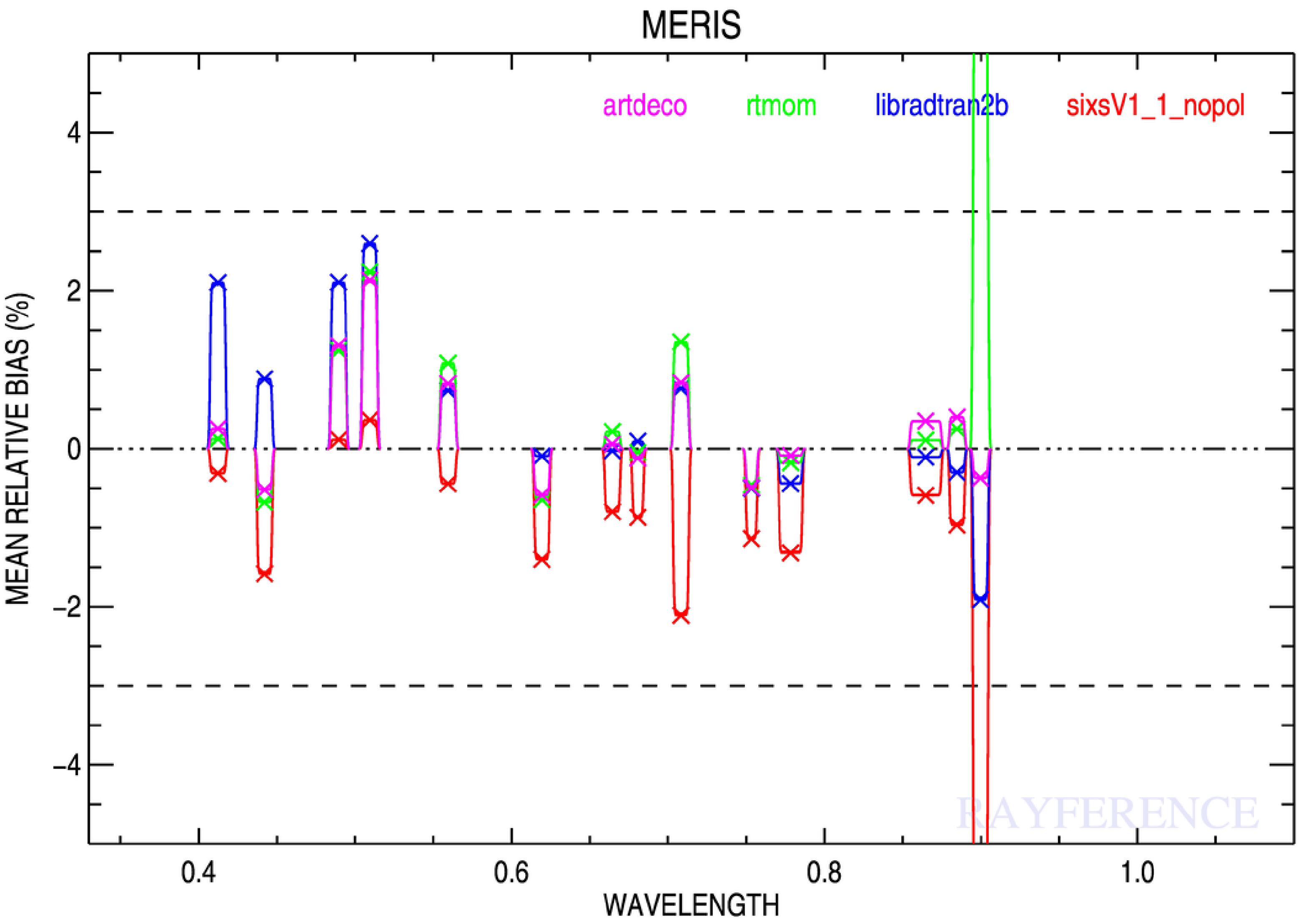
The mean bias does not exceed ±3%

The RTM differences are noticeable but not significant

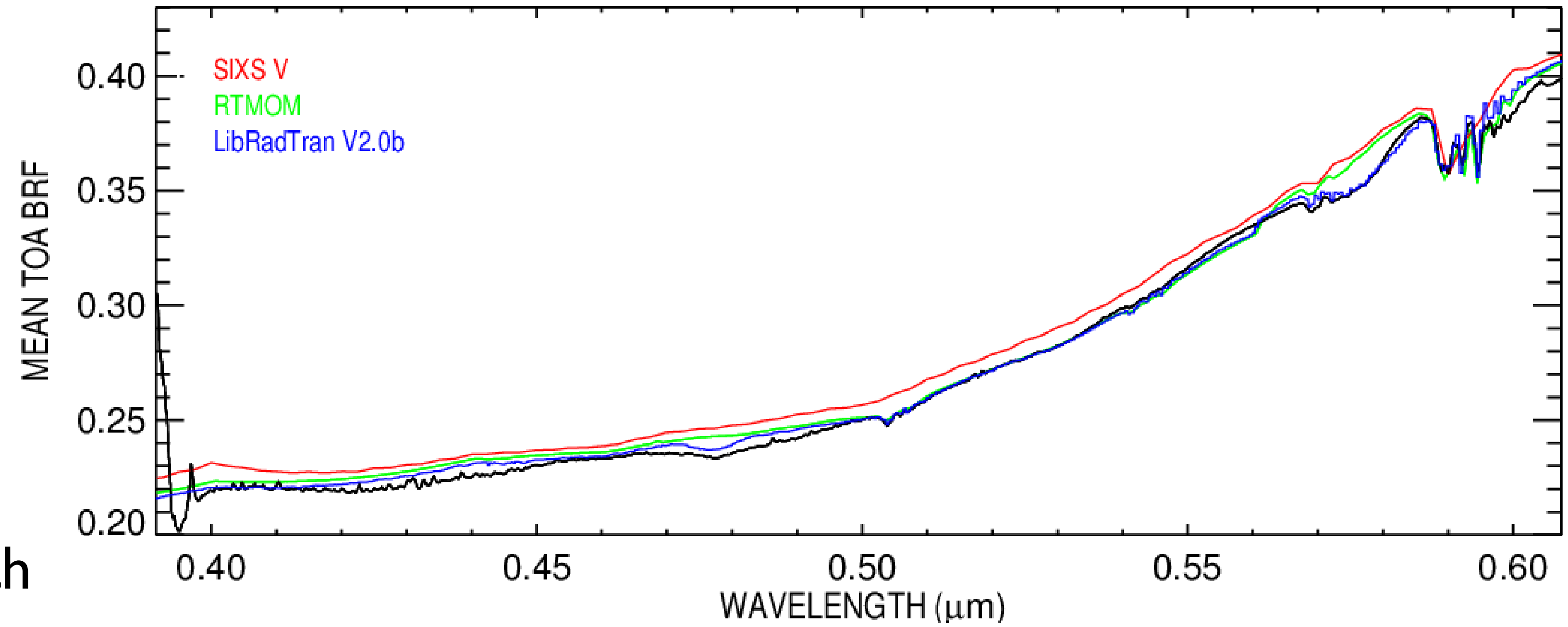
3. Nadir view verification: Landsat-8/OLI

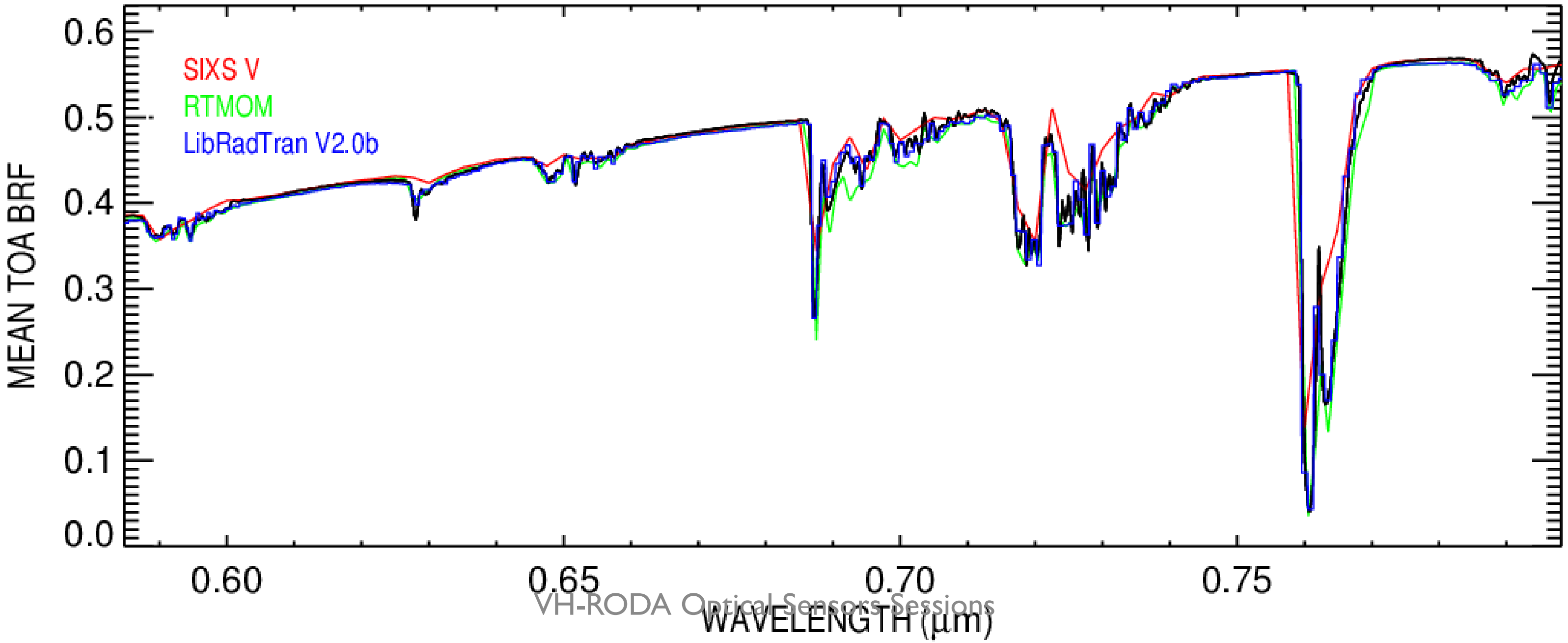


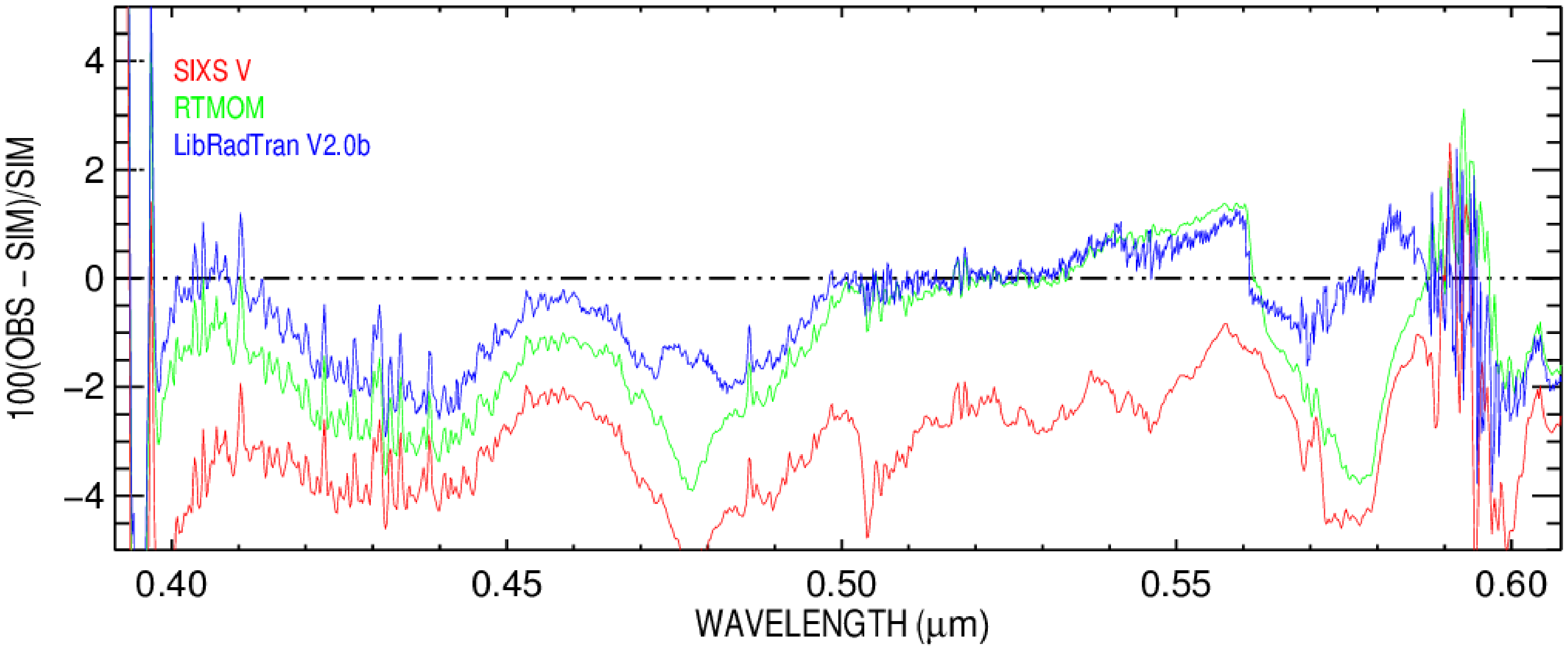
3. Nadir view verification: Envisat/MERIS



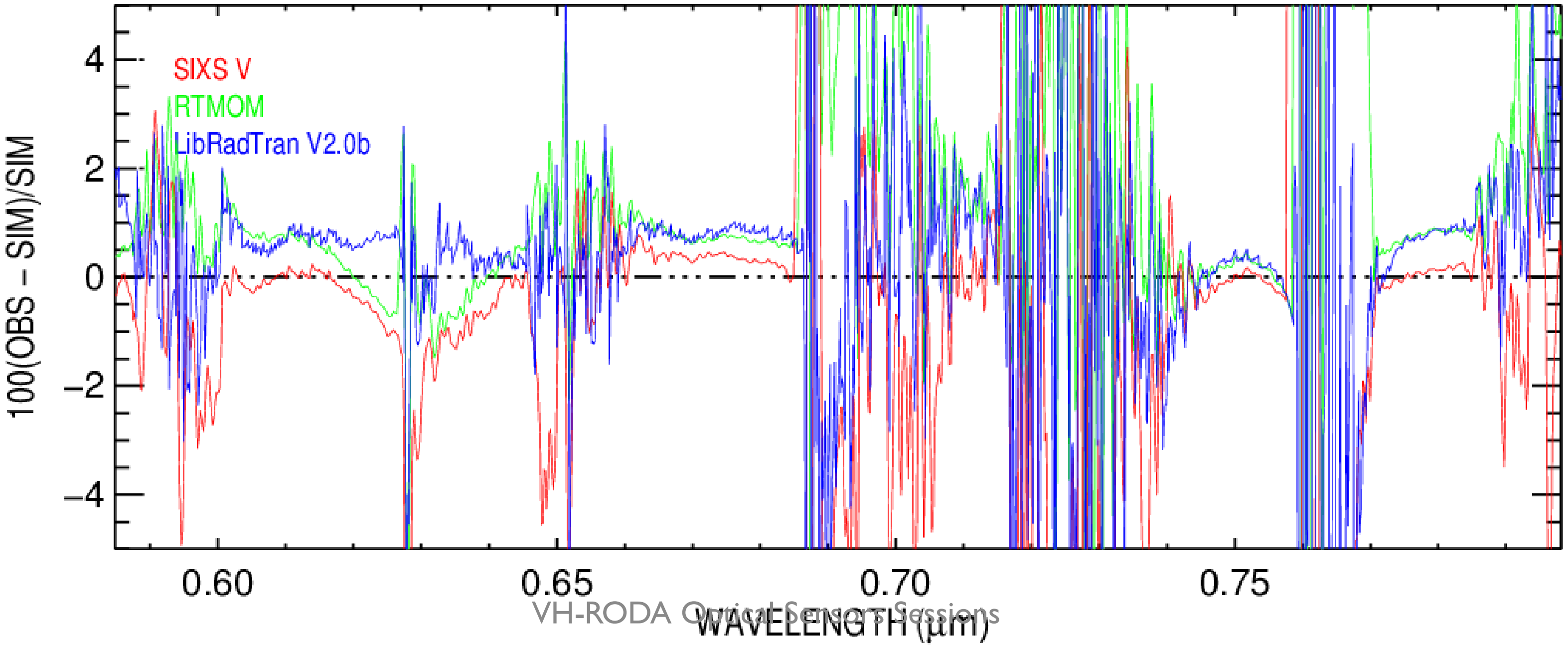
Comparison with GOME-2







SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
WAVELENGTH (μm)



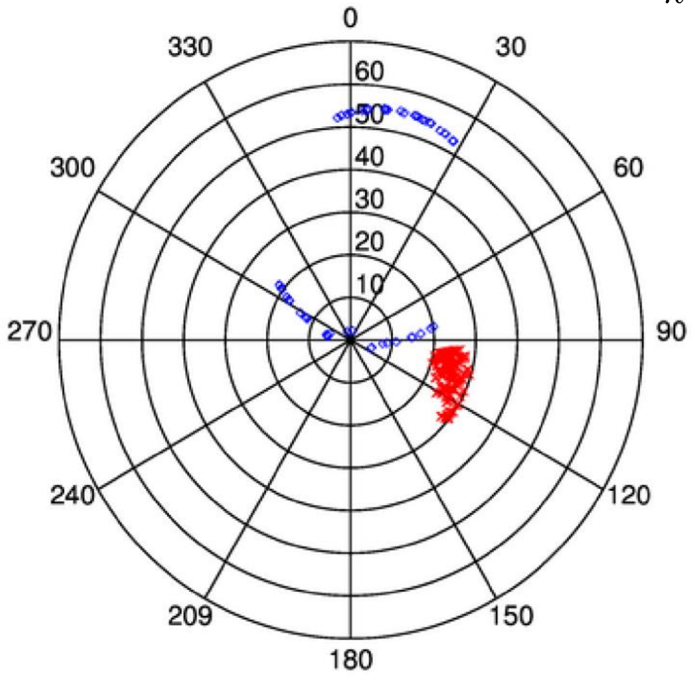
SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
WAVELENGTH (μm)

4. Oblique view verification : Envisat/AATSR

Envisat/AATSR instrument is acquiring the nadir and oblique view with the same radiometer.

The difference between the mean relative biases with respect to LRCR provides an indication of the angular reliability of our calibration reference.

$$\vartheta_k = \bar{B}_k\{\theta_v > 50°\} - \bar{B}_k\{\theta_v < 25°\}$$

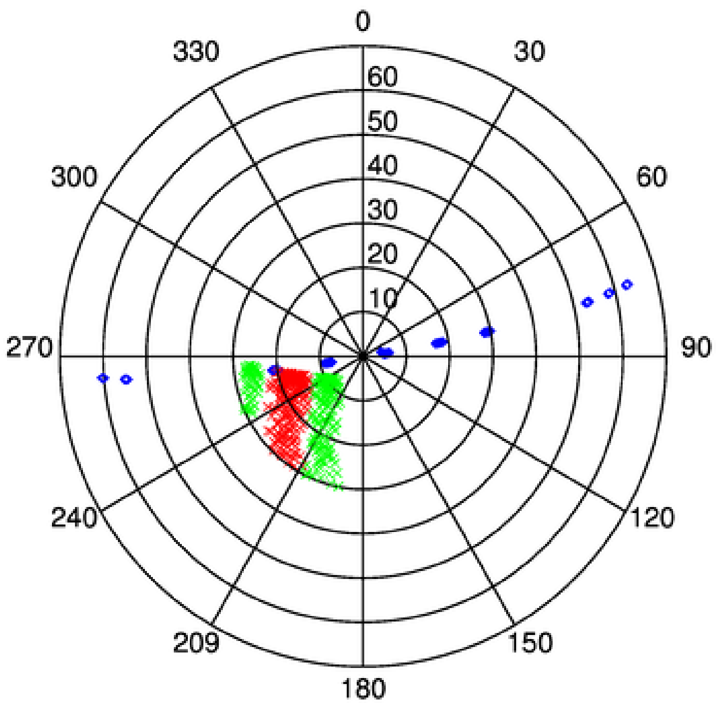


BAND	$0.55\mu m$	$0.66\mu m$	$0.84\mu m$	$1.62\mu m$	$2.20\mu m$
AATSR					
RTM	B1	B2	B3	B4	–
6SV	+0.96%	+1.66%	+1.00%	+0.28%	–
LibRadtran	+0.59%	+1.47%	+0.73%	+0.23%	–
RTMOM	+0.45%	+1.35%	+0.55%	+0.91%	–
ARTDECO	-0.41%	-1.02%	-0.83%	-2.71%	–

4. Oblique view verification : AQUA/MODIS

AQUA/MODIS is acquiring observation with a VZA > 55°.

The difference between the mean relative biases with respect to LRCR provides an indication of the angular reliability of our calibration reference.



$$\vartheta_k = \bar{B}_k\{\theta_v > 50°\} - \bar{B}_k\{\theta_v < 25°\}$$

BAND	0.55μm	0.66μm	0.84μm	1.62μm	2.20μm
			MODIS		
RTM	B4	B1	B2	B6	B7
6SV	+0.43%	+1.06%	+0.62%	+0.54%	-1.34%
LibRadtran	-0.25%	+1.03%	+0.38%	+0.29%	-1.09%
RTMOM	-0.21%	+0.80%	+0.30%	+0.39%	-0.89%
ARTDECO	-0.17%	+0.51%	+0.03%	+0.08%	-1.24%

LRCR accuracy estimation statement

For nadir view, LRCR agrees within ±1.5% with well-calibrated radiometers over Libya-4 when both Sun and view zenith angles < 30° and gaseous transmittance > 0.95.

Large viewing angles introduce an additional ±1.4% uncertainty based on AATSR and MODIS results.

The total LRCR uncertainty is estimated to ±2.1% (in clear atmosphere).

The cloud filtering might introduce some (unknown) bias that might affect the mean relative bias standard deviation.

Only relative differences with respect to LRCR larger than ±3% should be considered.

S3A/SLSTR calibration verification

S3A/SLSTR NADIR VIEW					
RTM	S1	S2	S3	S5	S6
6SV	+3.66±1.33%	+2.15±0.90%	+1.62±1.00%	-10.79±0.69%	-11.29±1.05%
LibRadtran	+5.38±1.37%	+3.11±0.87%	+2.35±1.14%	-10.25±0.73%	-10.02±0.97%
RTMOM	+5.48±1.46%	+3.89±1.11%	+2.42±1.14%	-8.38±0.78%	-9.23±1.15%
ARTDECO	+5.37±1.37%	+3.52±0.85%	+2.42±0.90%	-9.23±0.66%	-9.13±0.91%
S3A/SLSTR OBLIQUE VIEW					
6SV	+7.88±1.51%	+6.04±1.16%	+7.03±1.21%	-2.87±0.80%	-5.96±1.50%
LibRadtran	+9.41±1.83%	+7.22±1.31%	+7.35±1.25%	-2.24±0.84%	-3.90±1.27%
RTMOM	+9.66±1.71%	+7.96±1.23%	+7.66±1.17%	+0.33±0.70%	-2.88±1.06%
ARTDECO	+8.82±1.60%	+6.95±1.22%	+7.43±1.25%	-1.19±0.80%	-3.62±1.35%

Values with a mean relative bias larger than 3% for all RTMs are shown in red

S3A/SLSTR Rayference calibration recommendations

	S1	S2	S3	S5	S6
S3A/SLSTR NADIR VIEW					
Correction	0.95	–	–	1.10	1.10
S3A/SLSTR OBLIQUE VIEW					
Correction	0.91	0.93	0.93	–	–

Recommended calibration corrections

$$SLSTS_{new} = SLSTR_{orig} * corr$$

Recommendation uncertainty: ±2.6%

S3A/SLSTR Rayference calibration recommendations


ASSESSMENT OF S3A/SLSTR NADIR AND OBLIQUE SOLAR BAND CALIBRATION OVER LIBYA-4

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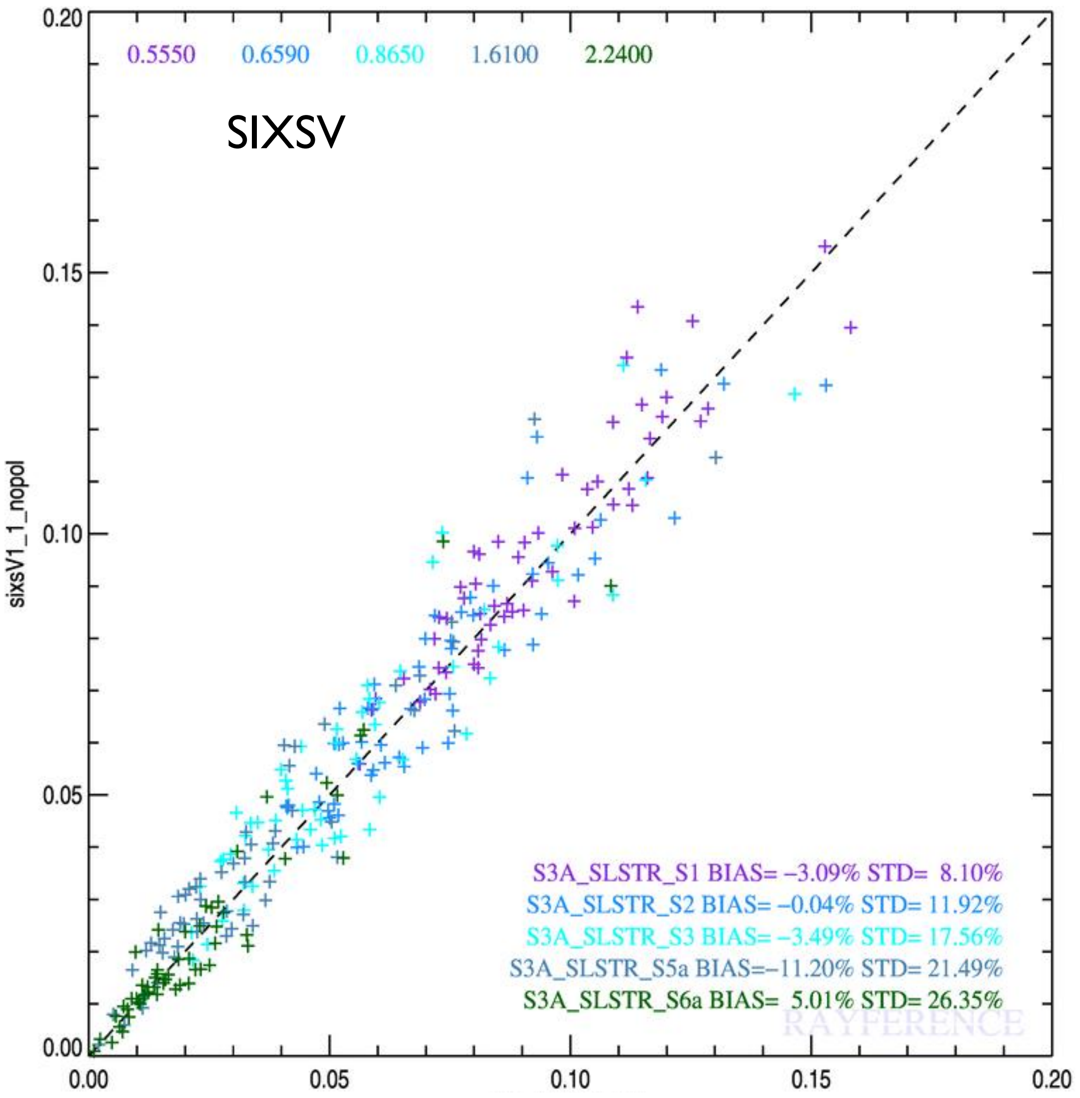
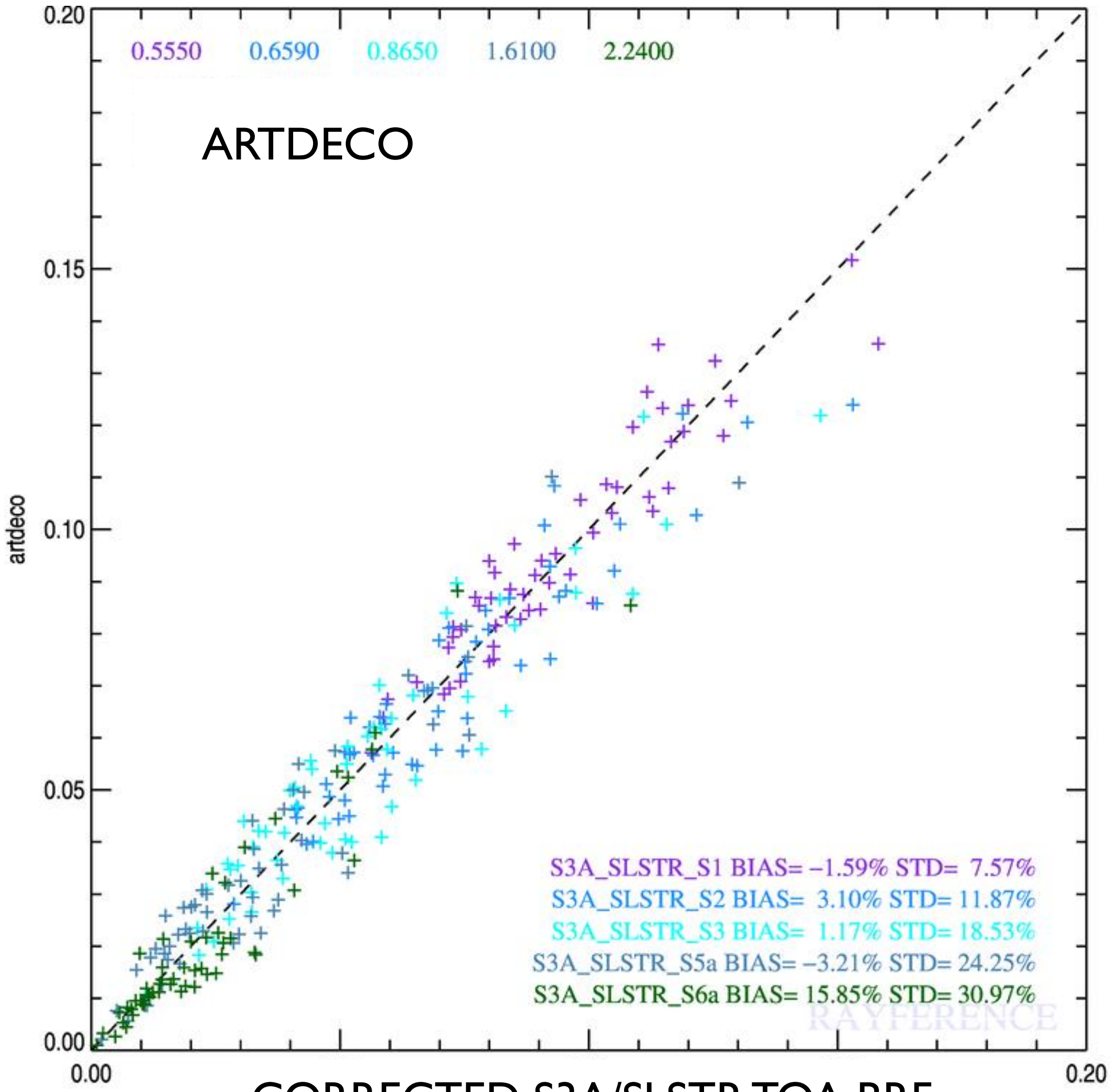
Correction verification over sea water (on-going)

- Acquisition of cloud-free S3A/SLSTR over sea water close to AERONET stations;
- Simulation of TOA BRF assuming
  - AERONET AOT;
  - ECMWF surface wind speed;
  - Open ocean colour (case-I);

Correction verification over sea water (on-going)



CORRECTED S3A/SLSTR TOA BRF



CORRECTED S3A/SLSTR TOA BRF

Conclusions (1)

- Rayference has developed its own **absolute** calibration reference over Libya-4 based on simulated spectral reflectance at the satellite-level;
- It is currently possible to simulate TOA BRF over Libya-4 with a **mean** relative accuracy of about ±2% in spectral regions where the molecular transmittance is > 0.95;
- Radiative transfer model numerical assumptions and approximations are responsible for most of these uncertainties;
- Our calibration reference has been used to propose calibration correction for S3A/SLSTR solar channels for both nadir and oblique views.

Conclusions (2)

SI traceable vicarious calibration methods proposing an accuracy below 3% will require:

- SI traceable reference measurements (<1%) such as those that will be delivered by TRUTHS or CLARREO;
- the use of a new generation of radiative transfer model capable of coping with this accuracy level: **www.eradiate.eu**