Recent developments in Lybia-4 spectral and directional characterization

Yves Govaerts

Rayference

Radiometric Calibration Workshop for European Missions

ESRIN, 30 – 31 August 2017

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Genesis ...

176 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 42, NO. 1, JANUARY 2004

Evaluation of Radiative Transfer Simulations Over Bright Desert Calibration Sites

Yves M. Govaerts and Marco Clerici

Abstract—The Spinning Enhanced Visible and Infrared Imager (SEVIRI), the Meteosat Second Generation main radiometer, measures the reflected solar radiation within three spectral bands centered at 0.6, 0.8, and 1.6 μm, and within a broadband. This

TABLE I
SEVIRI SOLAR CHANNEL CHARACTERISTICS. THE DYNAMIC RANGE IS GIVEN IN WATTS PER SQUARE METER PER STERADIAN PER METER. THE SNR IS GIVEN AT 1% OF THE MAXIMUM DYNAMIC RANGE. THE STANDARD

The original idea to use TOA simulated radiance over Libya-4 as an absolute calibration reference dated back to the early 2000s and is still in use since then at EUMETSAT

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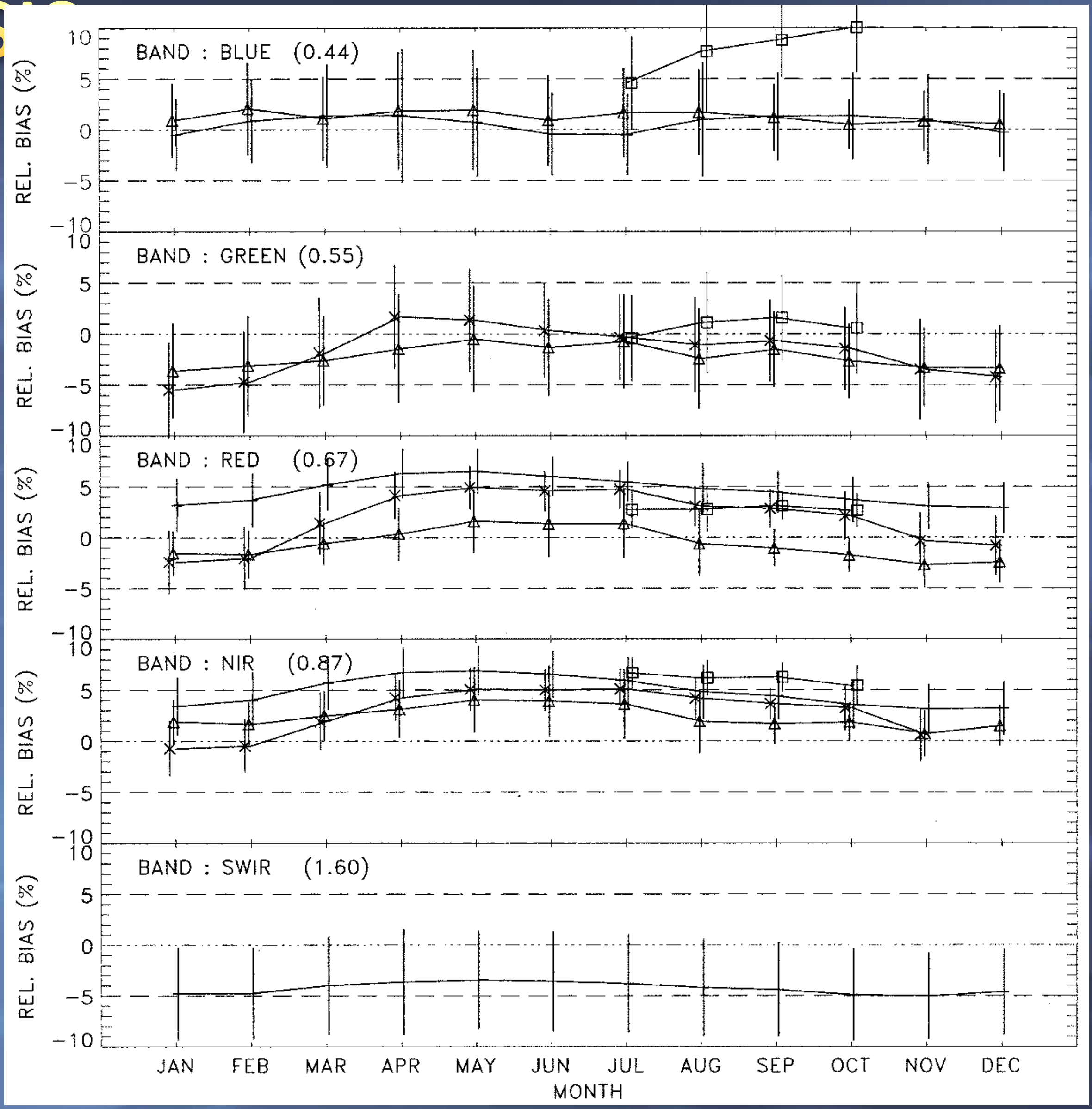
Genesis



The × symbol is for ATSR-2, △ for SeaWiFS, + for VEGETATION and □ for MERIS.

First improvement

Remote Sensing Letters
Vol. 4, No. 6, June 2013, 523–531

Taylor & Francis
Taylor & Francis Group

Use of simulated reflectances over bright desert target as an absolute calibration reference

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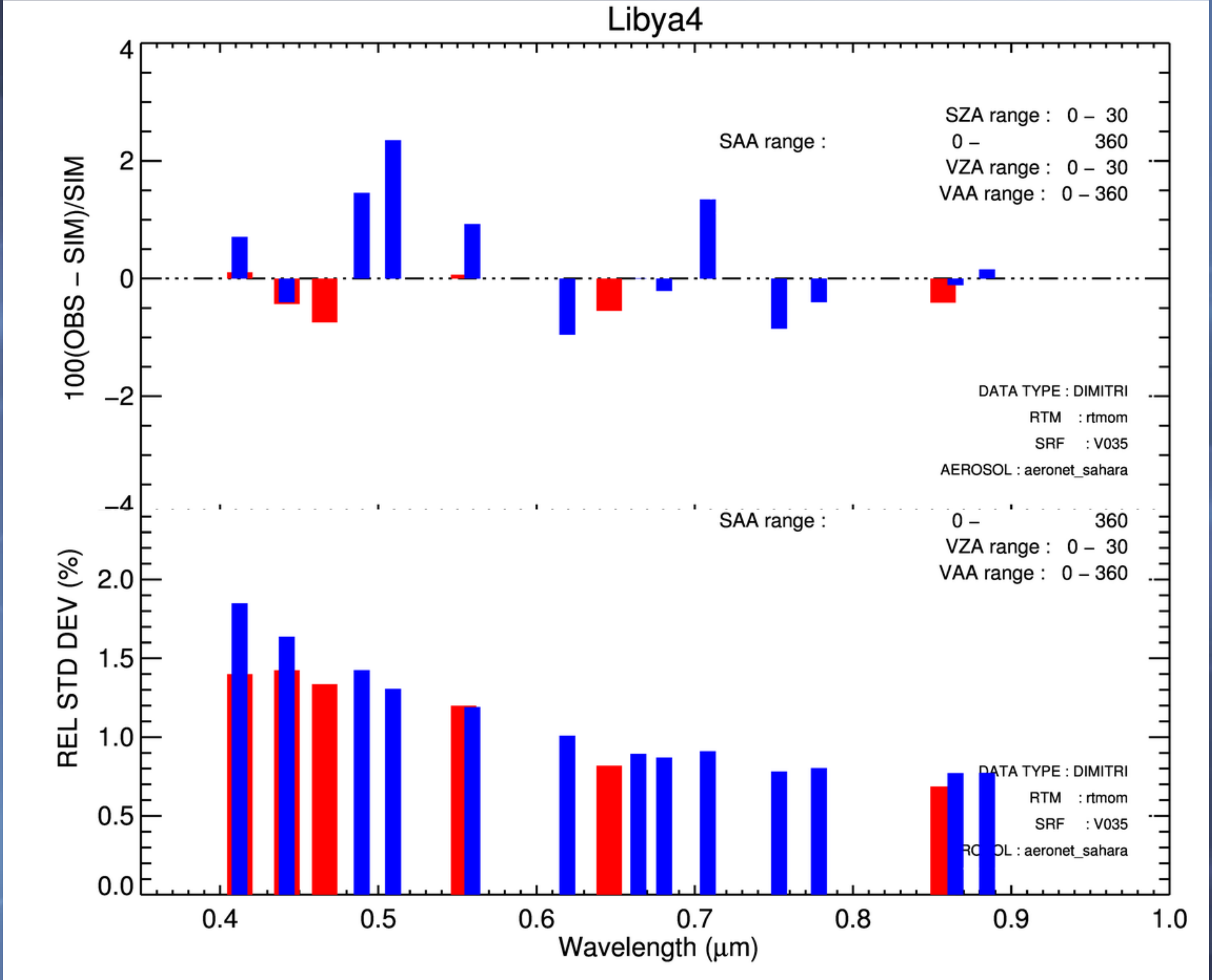
(*Received 10 October 2012; in final form 2 January 2013*)

This letter presents the improvements of an absolute calibration reference system based on simulated top-of-atmosphere bidirectional reflectance factor time series over bright desert targets. The current work highlights a case study performed over Committee on Earth Observation Satellites (CEOS) calibration target Libya4, demonstrating that it is possible to achieve a mean accuracy of 3% when simulation is compared with calibrated observations acquired by polar orbiting satellites.

LIBYA-4 : SPECTRAL SIMULATIONS

Latest improvements

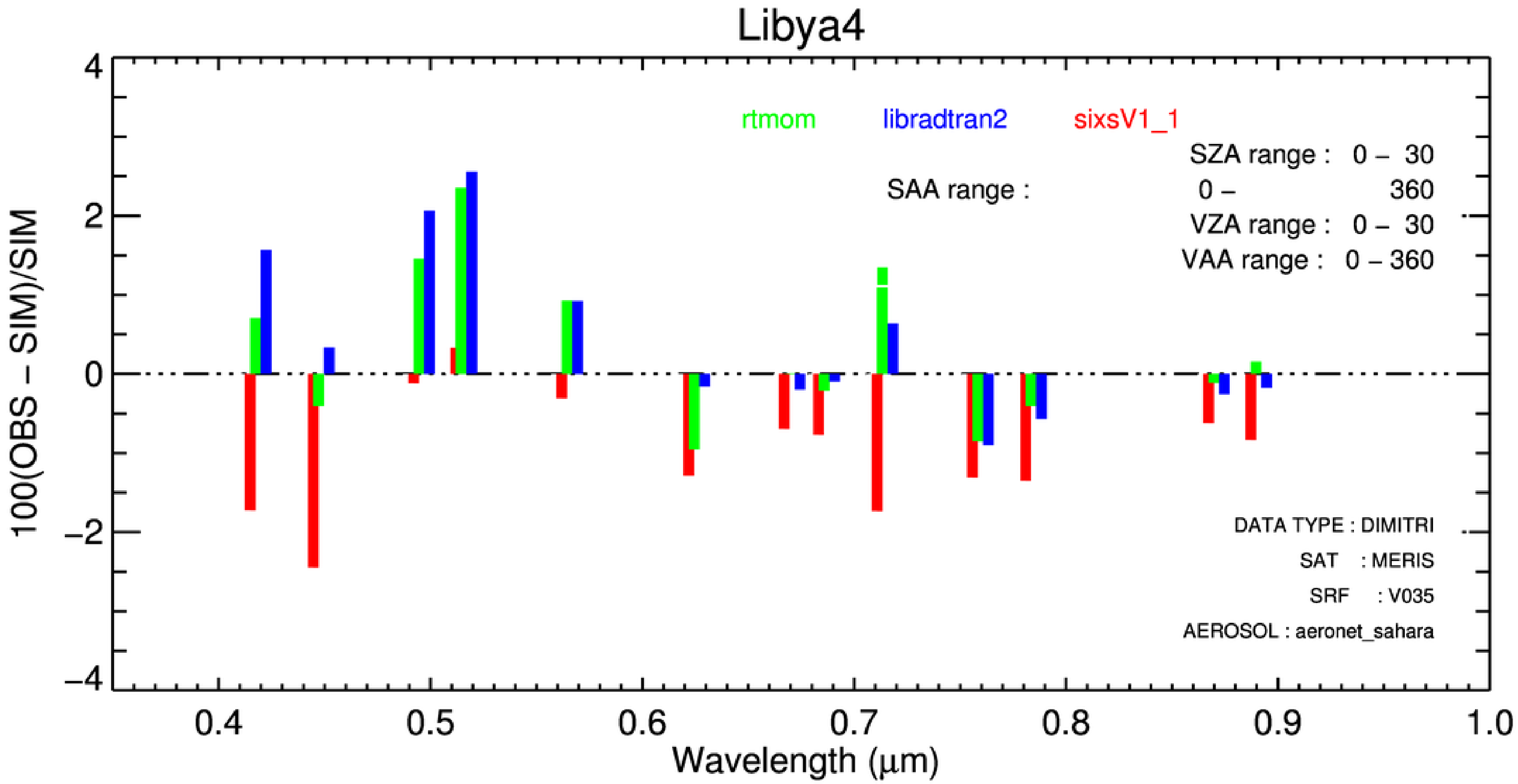
- Comparison of 3 RTMs in the VIS spectral range over Libya-4 wrt MODIS, MERIS, GOME-2 data;
- **6SV**: RTE -> Successive Order of scattering. Widely used in the "land" community for atmospheric correction (HITRAN96)
- **RTMOM**: RTE -> MOM (HITRAN96)
- **LibRadTranV2beta**: RTE -> MC (<u>**REPTRAN**</u>, HITRAN 2004)



Comparison between RTM simulations and observations over Libya-4

RED: ~600 MODIS observations

BLUE : ~350 MERIS observations



Simulation of 350 MERIS DATA with:

- RTMOM
- SIXSV
- LibRadTranV2

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GOME-2 DATA

- Provided by EUMETSAT
- Extraction of one "pixel" centered over Libya-4
- SZA and VZA restricted to 0-30 degrees
- ~70 observations, band-3 and -4

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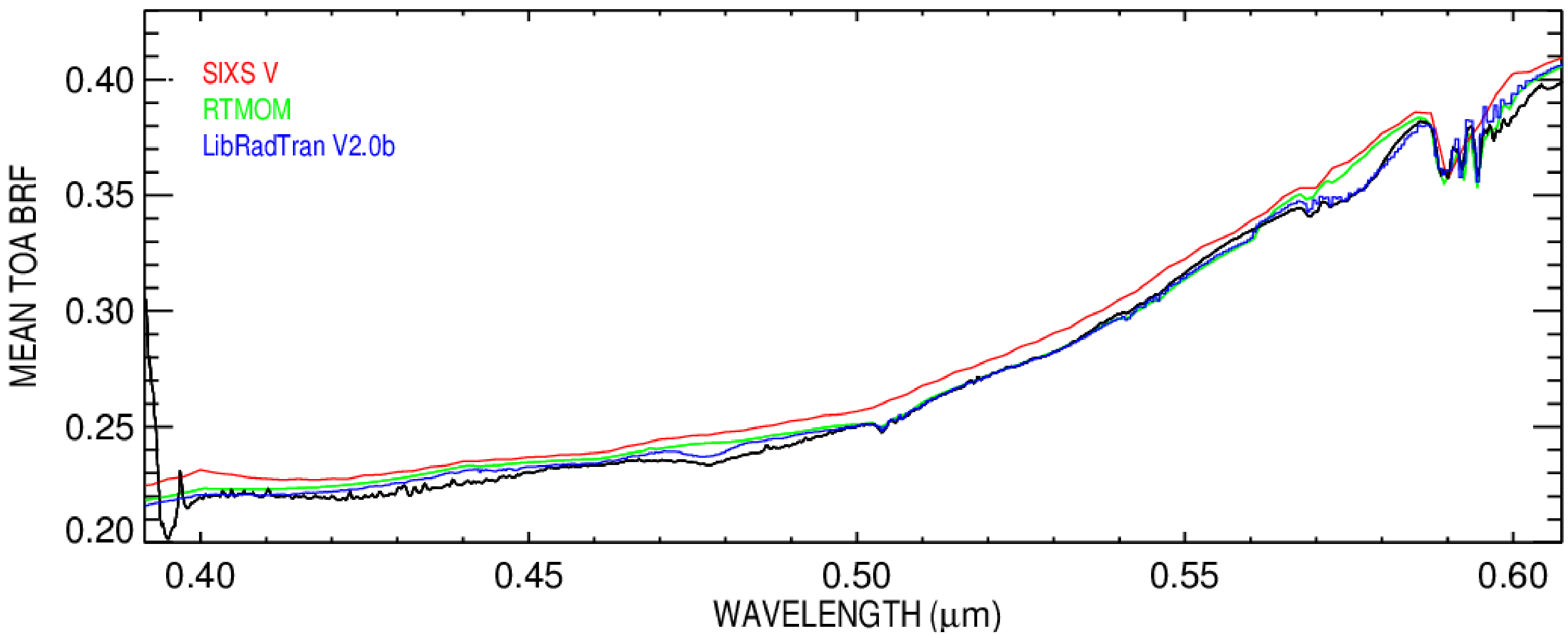
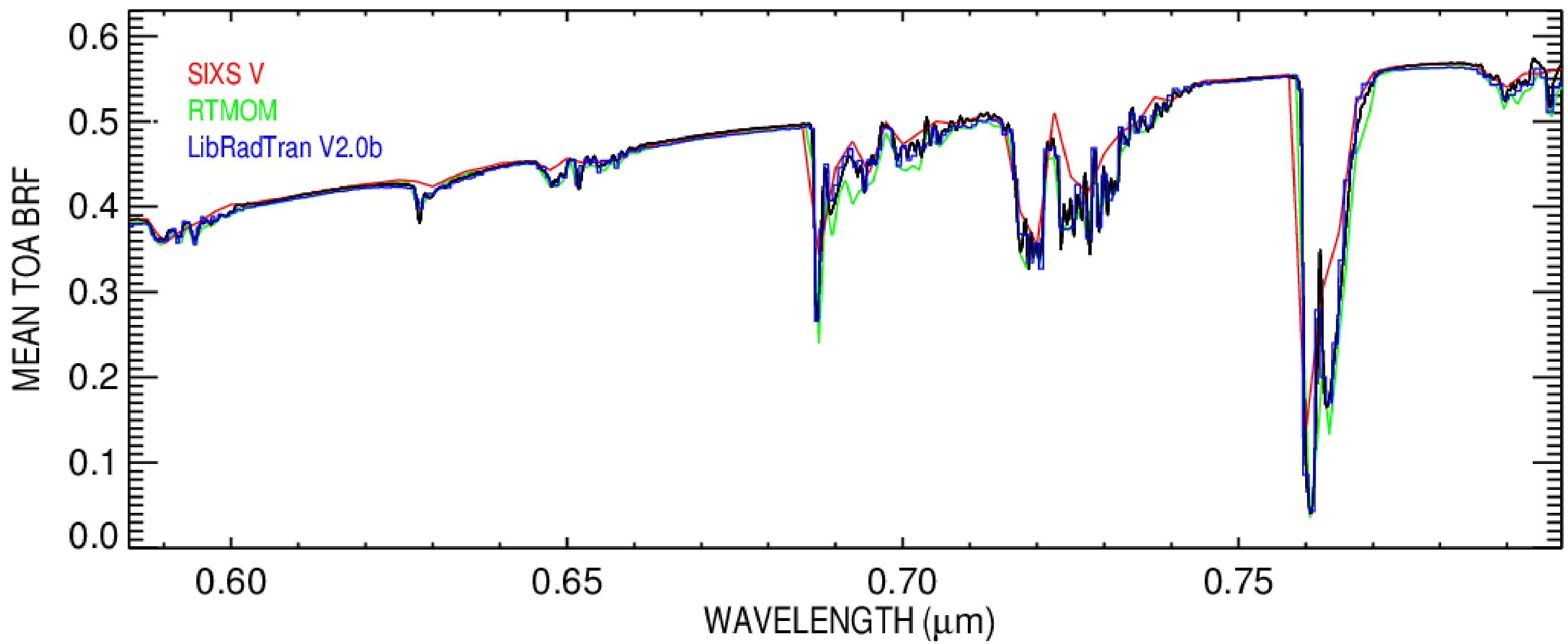
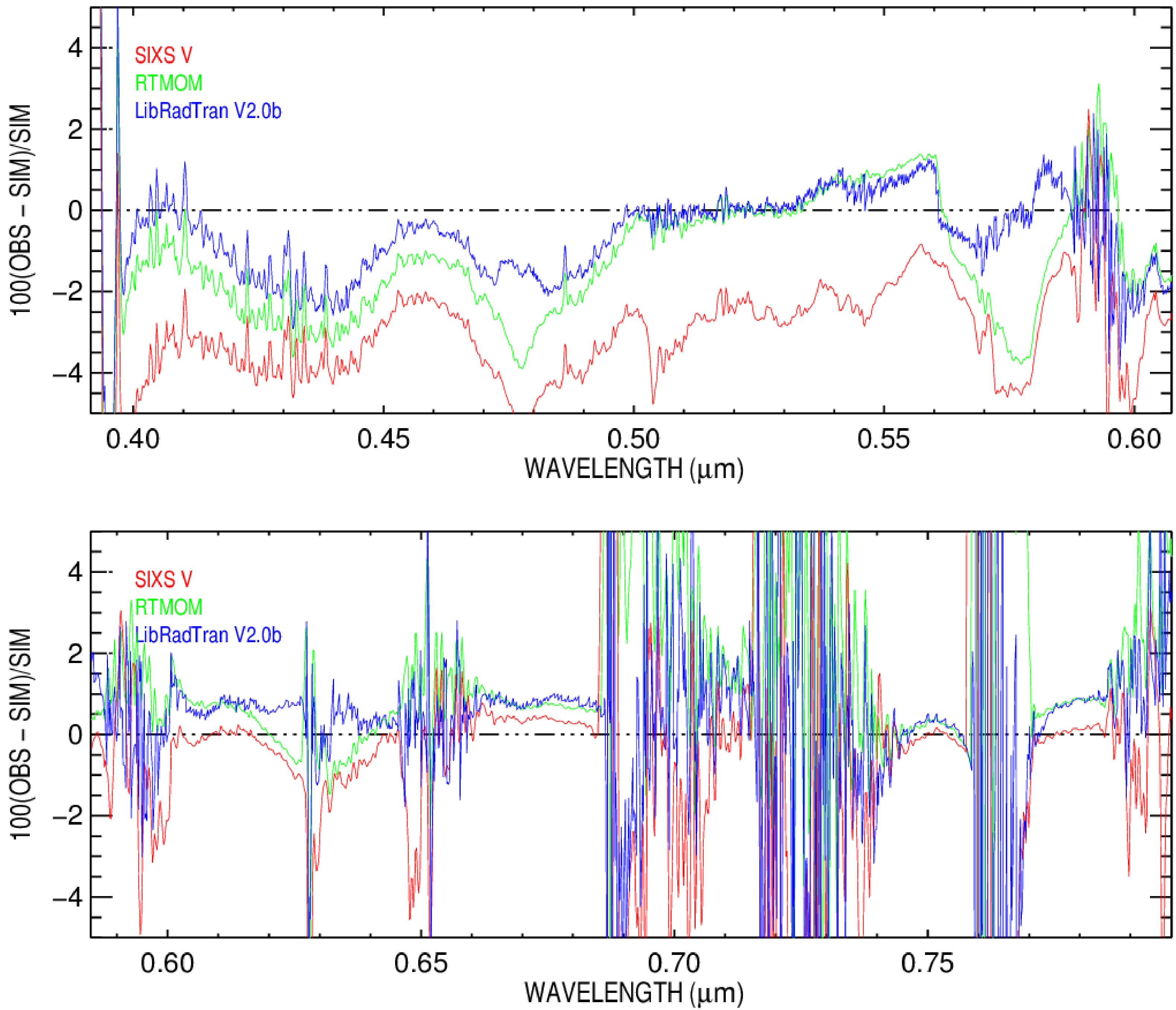


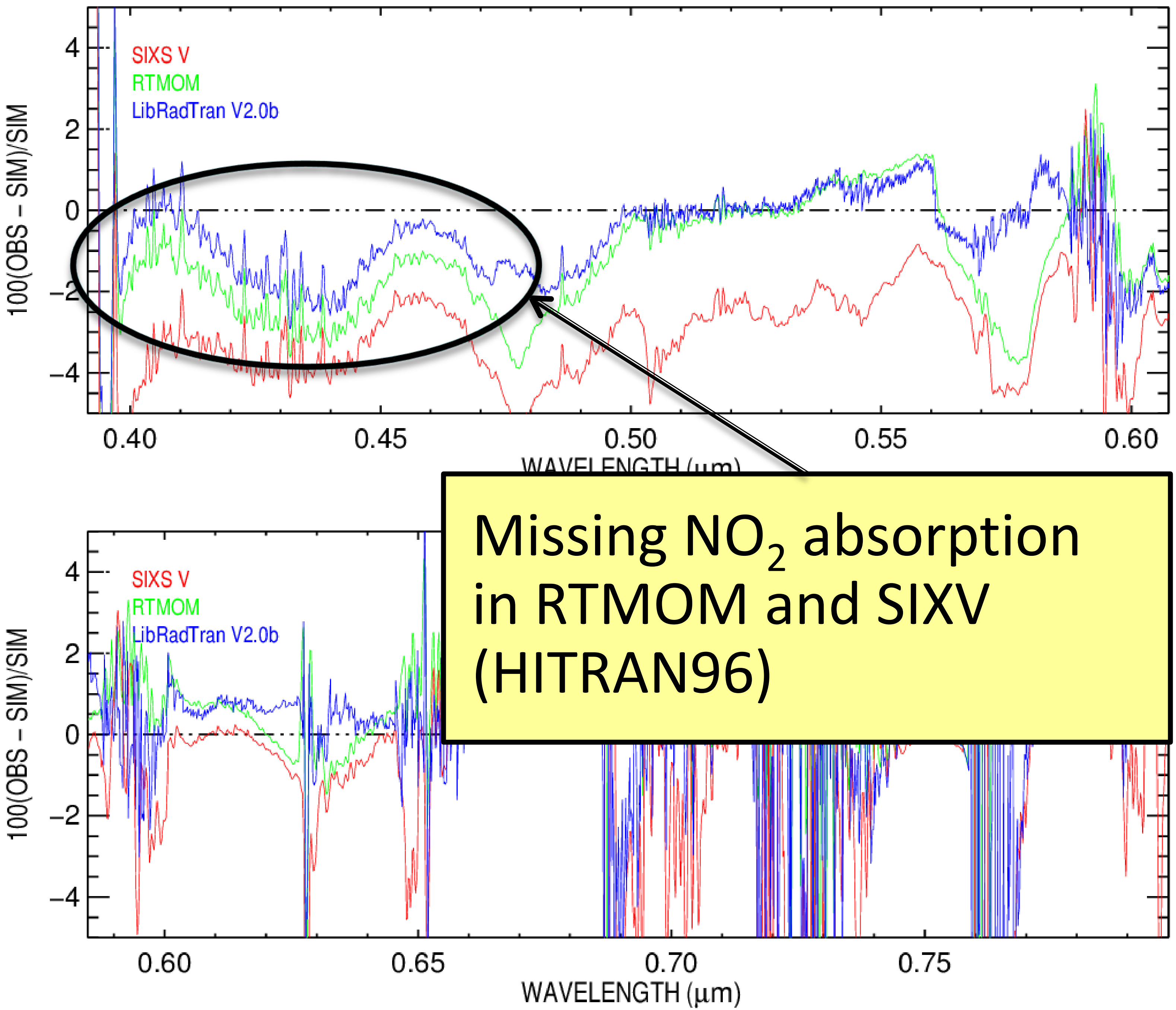
SIXS V
RTMOM
LibRadTran V2.0b
MEAN TOA BRF
0.40
0.35
0.30
0.25
0.20
0.40
0.45
0.50
0.55
0.60
WAVELENGTH (μm)



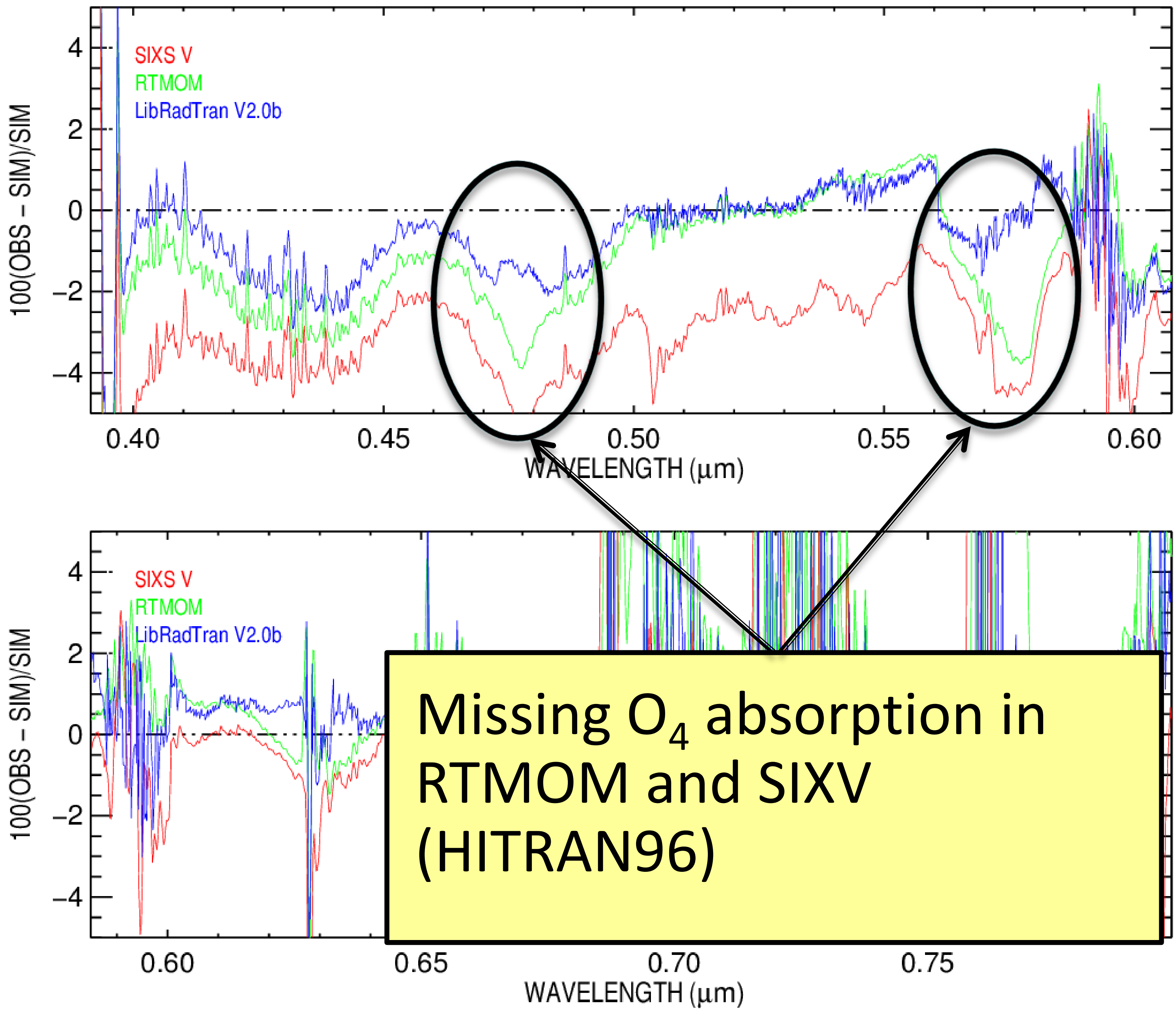
SIXS V
RTMOM
LibRadTran V2.0b
MEAN TOA BRF
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.60
0.65
0.70
0.75
WAVELENGTH (μm)

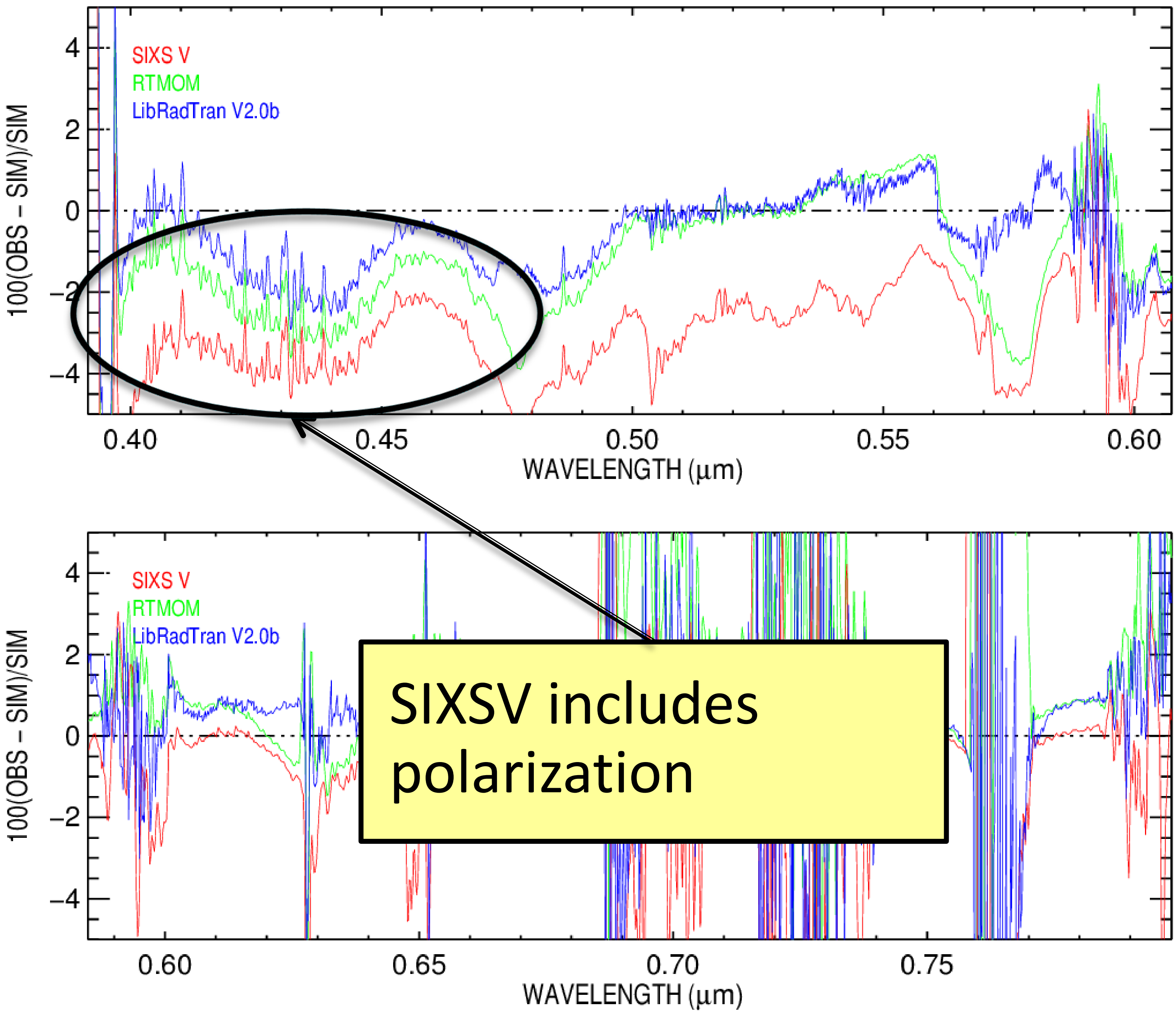


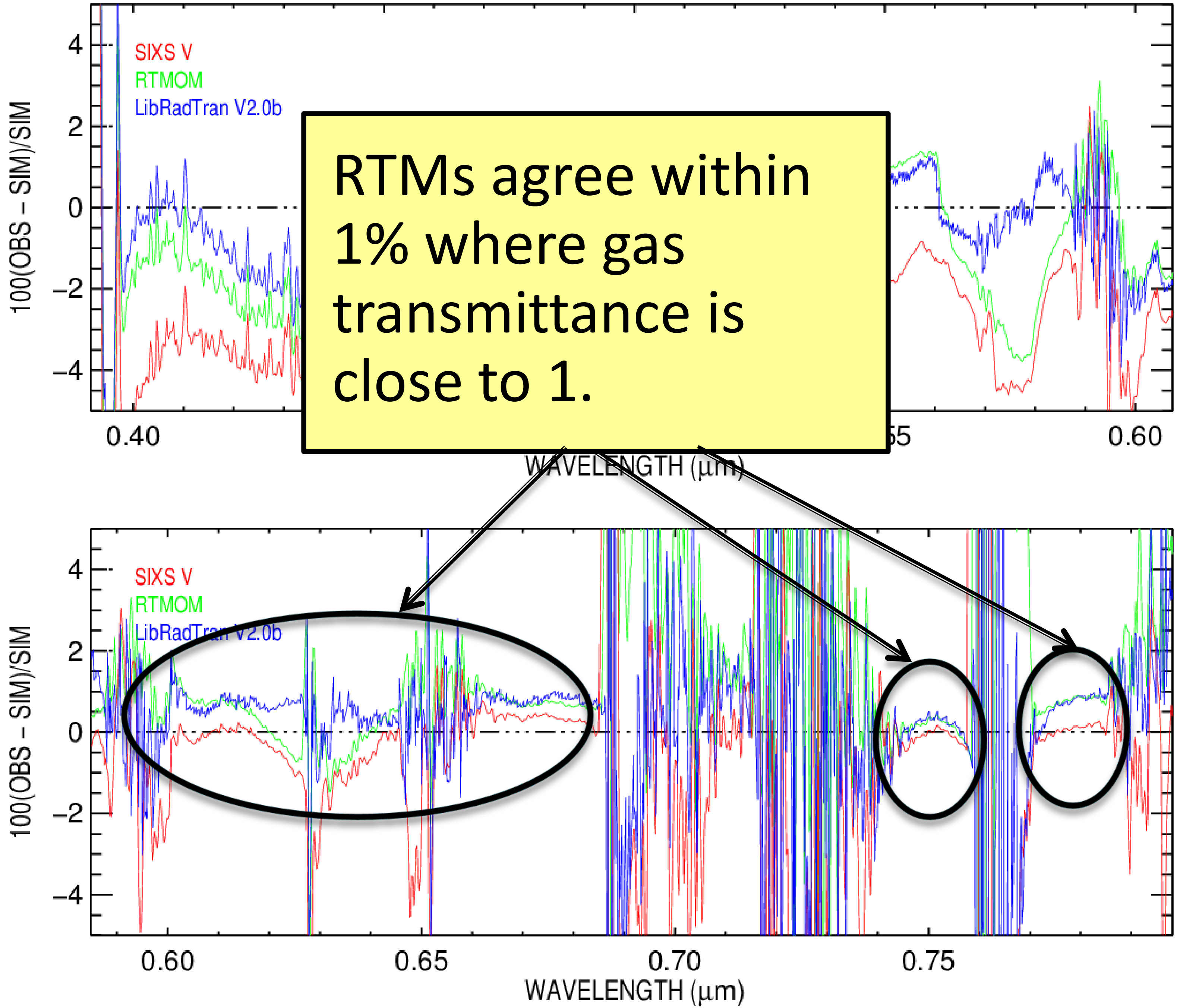
SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
4
2
0
−2
−4
0.40
0.45
0.50
0.55
0.60
WAVELENGTH (μm)
SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
4
2
0
−2
−4
0.60
0.65
0.70
0.75
WAVELENGTH (μm)



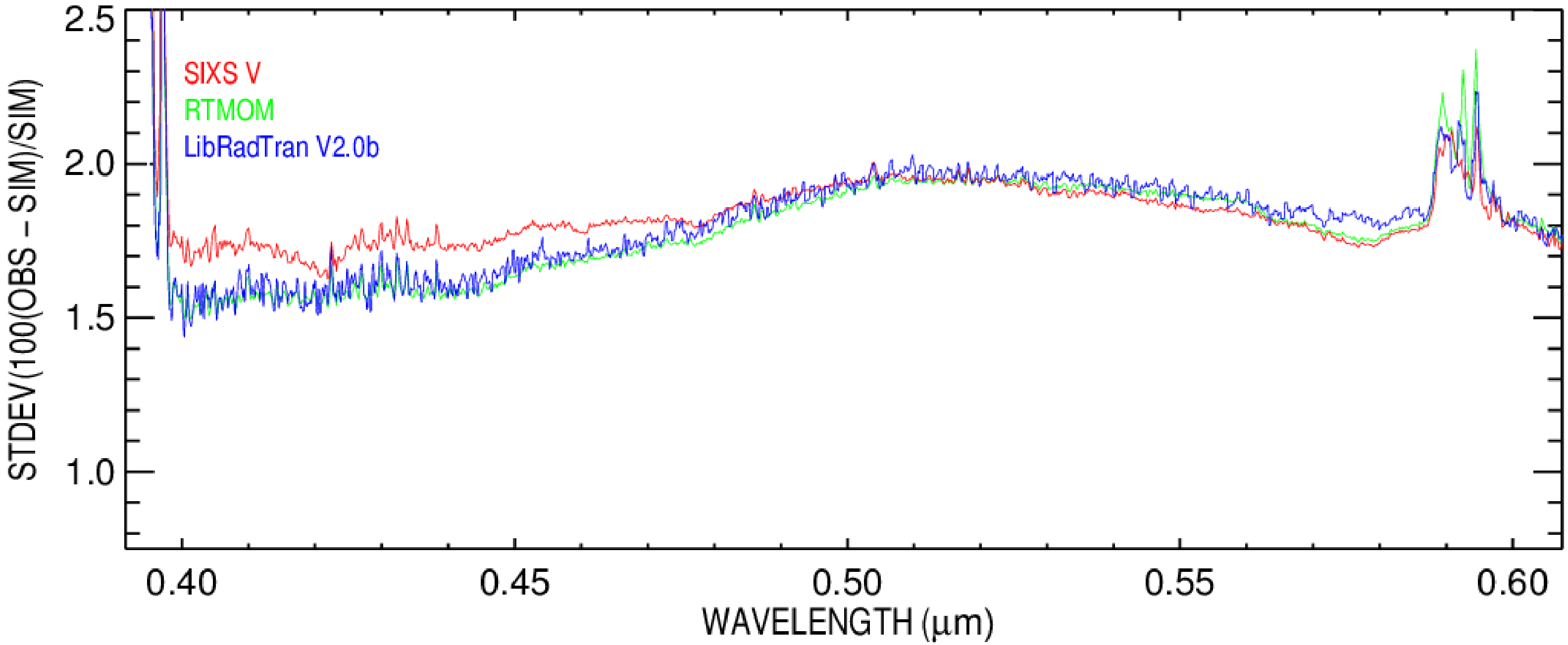
SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
4
2
0
−2
−4
0.40
0.45
0.50
0.55
0.60
Missing NO_2 absorption in RTMOM and SIXV (HITRAN96)
SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
4
2
0
−2
−4
0.60
0.65
0.70
0.75
WAVELENGTH (µm)


SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
WAVELENGTH (μm)
0.40
0.45
0.50
0.55
0.60
SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
WAVELENGTH (μm)
0.60
0.65
0.70
0.75
Missing O4 absorption in RTMOM and SIXV (HITRAN96)

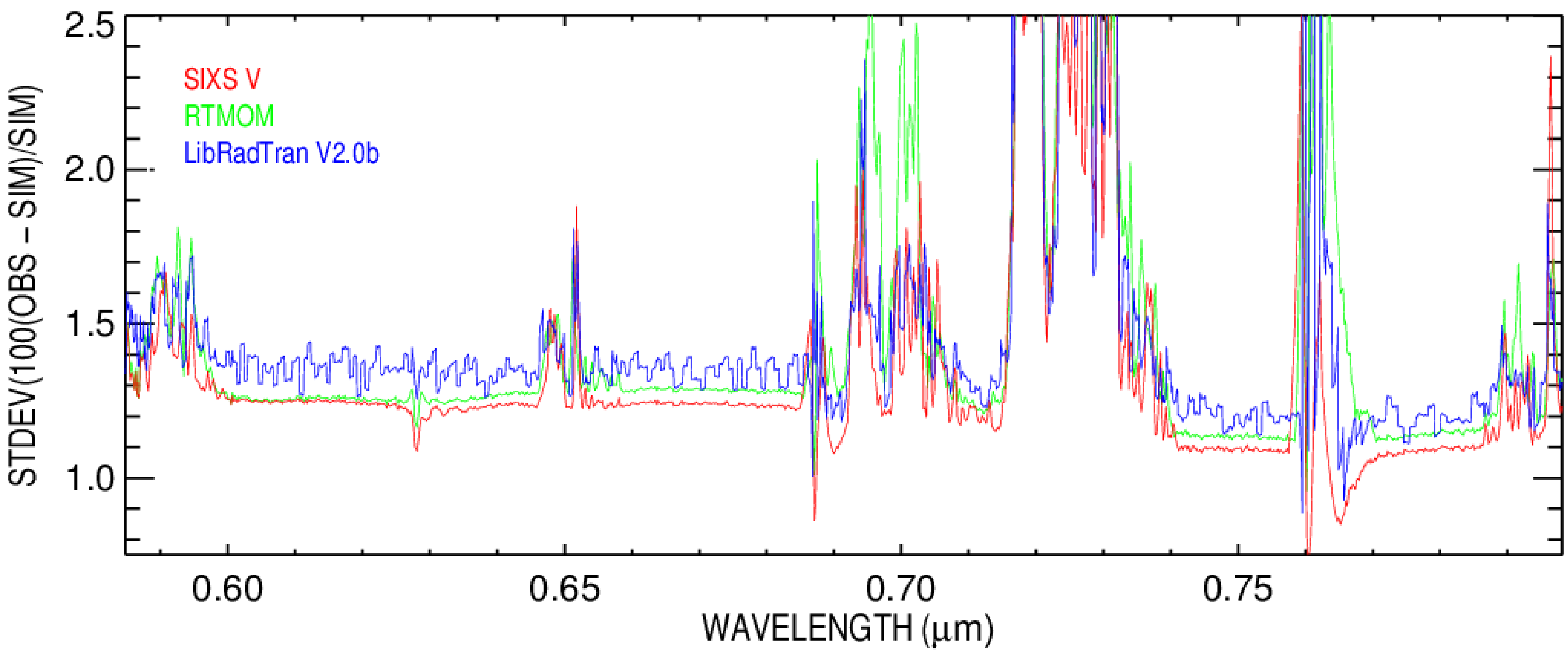

SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
4
2
0
−2
−4
0.40
0.45
0.50
0.55
0.60
WAVELENGTH (μm)
SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
0.60
0.65
0.70
0.75
WAVELENGTH (μm)
SIXSV includes polarization



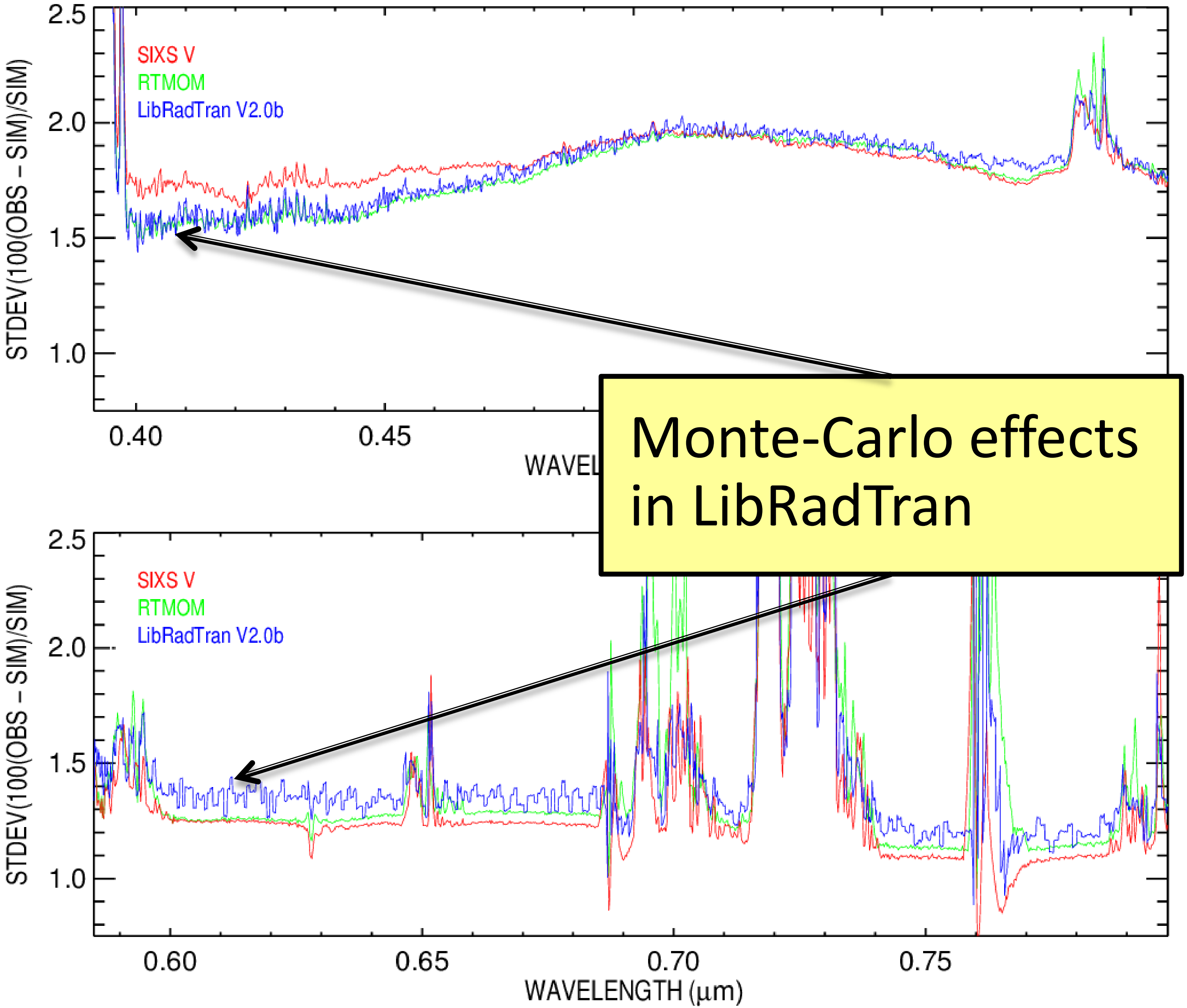
RTMs agree within 1% where gas transmittance is close to 1.
SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
WAVELENGTH (μm)
SIXS V
RTMOM
LibRadTran V2.0b
100(OBS – SIM)/SIM
WAVELENGTH (μm)

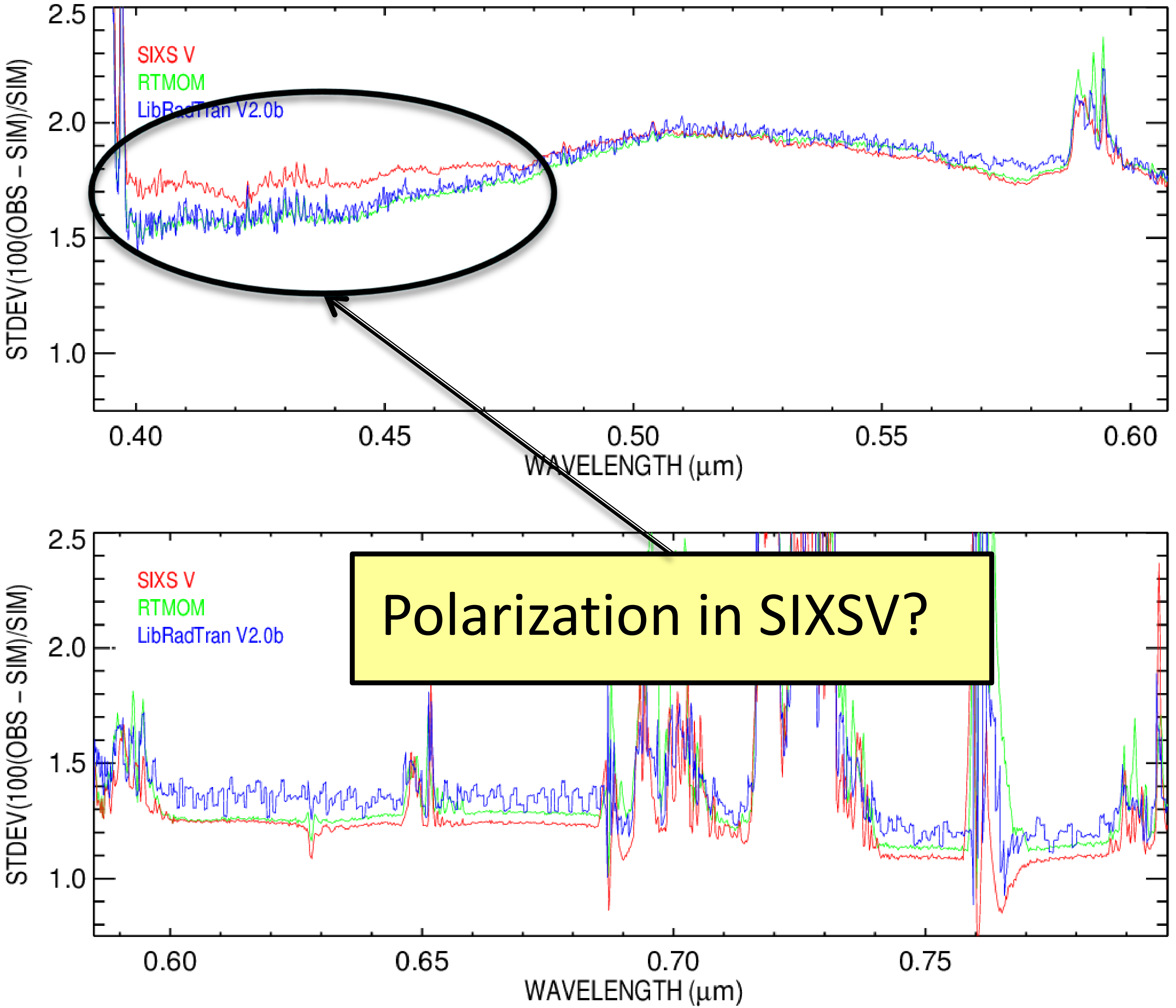


SIXS V
RTMOM
LibRadTran V2.0b
STDEV(100(OBS – SIM)/SIM)
2.5
2.0
1.5
1.0
0.40
0.45
0.50
0.55
0.60
WAVELENGTH (µm)



SIXS V
RTMOM
LibRadTran V2.0b
STDEV(100(OBS – SIM)/SIM)
2.5
2.0
1.5
1.0
0.60
0.65
0.70
0.75
WAVELENGTH (µm)


SIXS V
RTMOM
LibRadTran V2.0b
STDEV(100(OBS – SIM)/SIM)
2.5
2.0
1.5
1.0
0.40
0.45
Monte-Carlo effects in LibRadTran
SIXS V
RTMOM
LibRadTran V2.0b
STDEV(100(OBS – SIM)/SIM)
2.5
2.0
1.5
1.0
0.60
0.65
0.70
0.75
WAVELENGTH (µm)



2.5
2.0
1.5
1.0
STDEV(100(OBS – SIM)/SIM)
SIXS V
RTMOM
LibRadTran V2.0b
0.40
0.45
0.50
0.55
0.60
WAVELENGTH (µm)
2.5
2.0
1.5
1.0
STDEV(100(OBS – SIM)/SIM)
SIXS V
RTMOM
LibRadTran V2.0b
0.60
0.65
0.70
0.75
WAVELENGTH (µm)
Polarization in SIXSV?

LIBYA-4 : BRF SIMULATIONS

OBJECTIVE:

Analyze surface reflectance azimuthal dependencies due to sand dune organization for different regions-of-interest (ROIs) sizes using a 3D Monte Carlo ray-tracing RTM.

The global 30m digital elevation model (DEM) derived from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) observations has been used for this analysis.

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Article

Sand Dune Ridge Alignment Effects on Surface BRF over the Libya-4 CEOS Calibration Site

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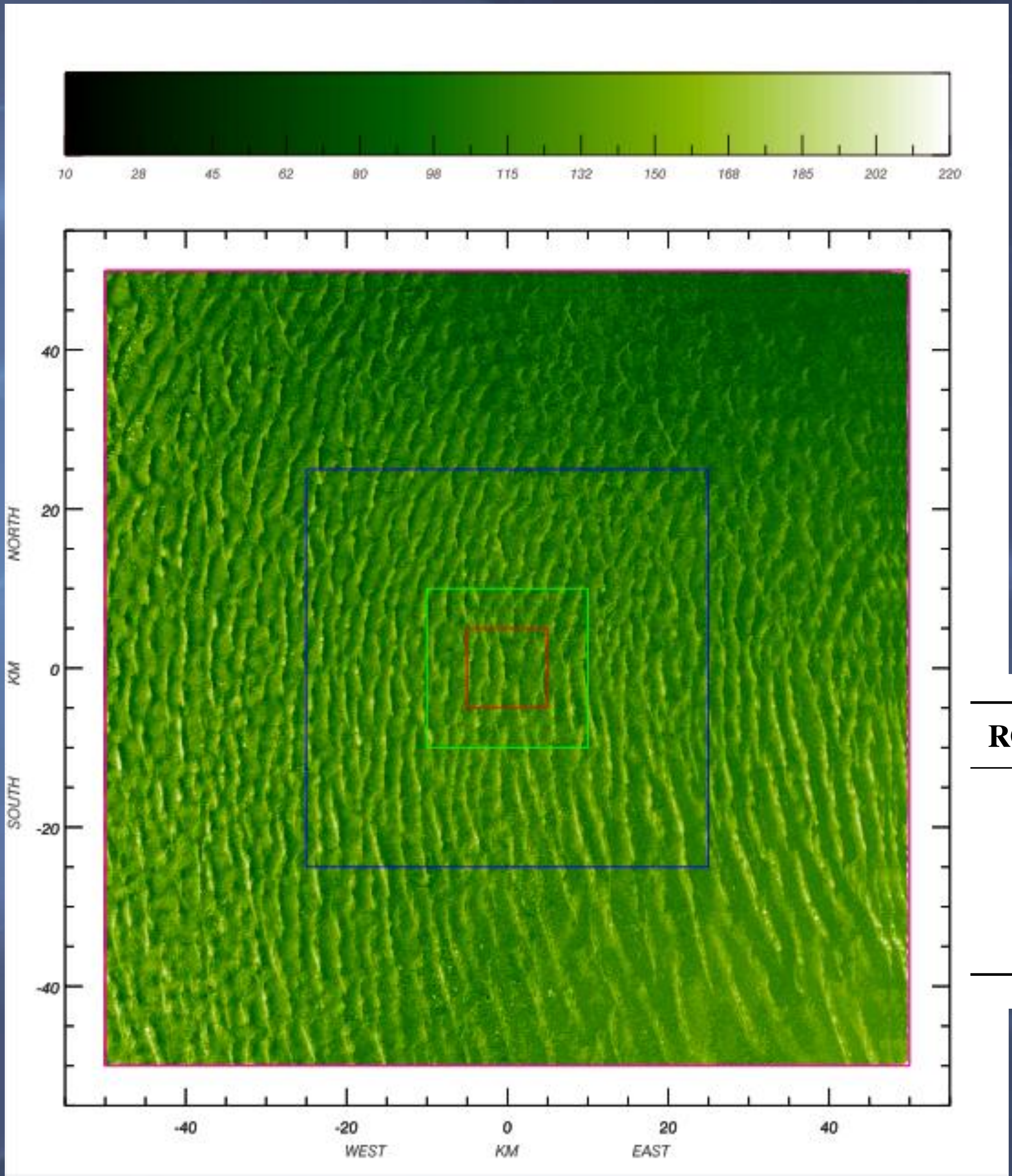
Libya-4 morphology



ASTER DEM over the Libya-4

10 km

20 km

50 km

100 km

ROI Size (km)	Min (m)	Max (m)	Mean (m)	SD (m)
10	73	184	124	14
20	68	208	123	14
50	56	215	122	16
100	11	222	120	19

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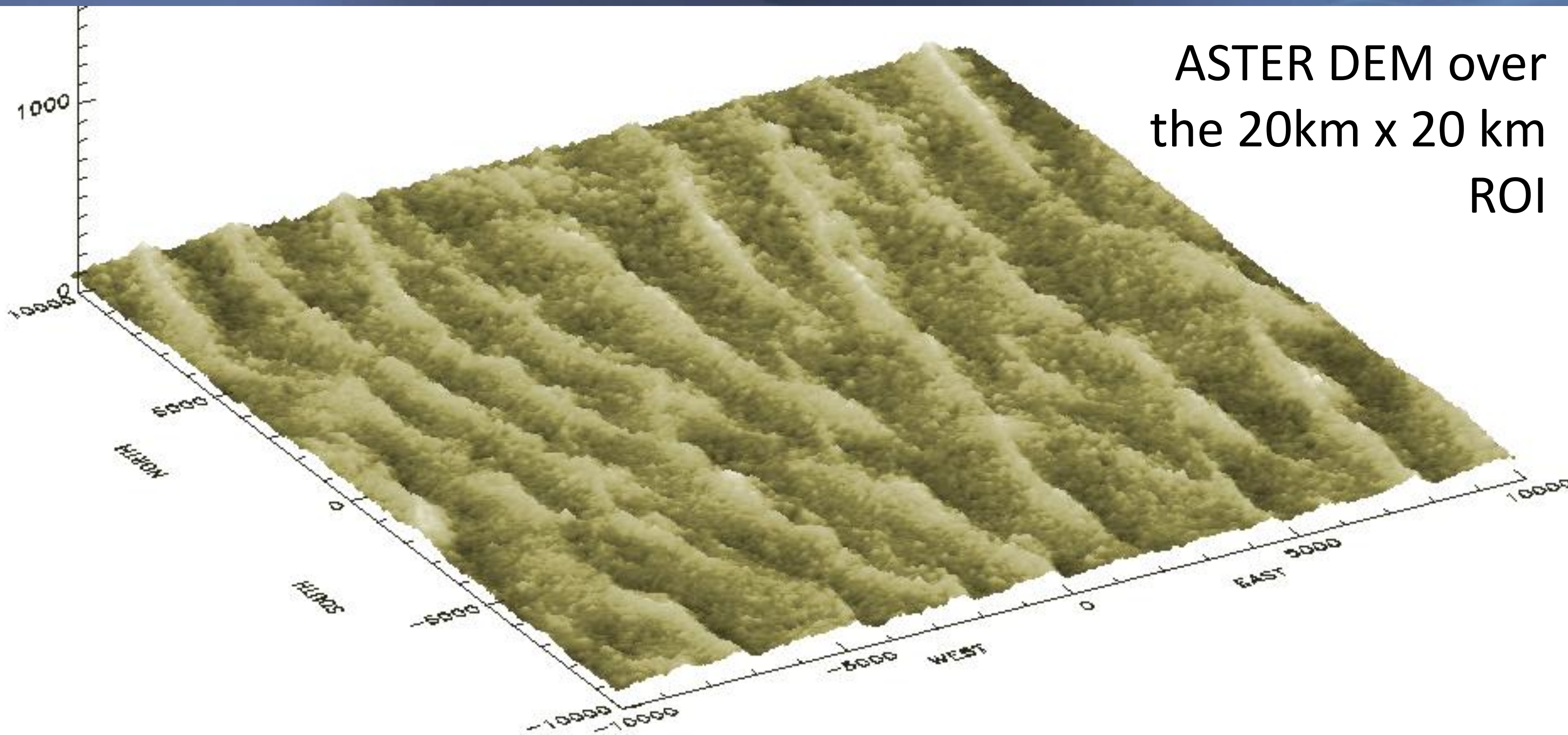
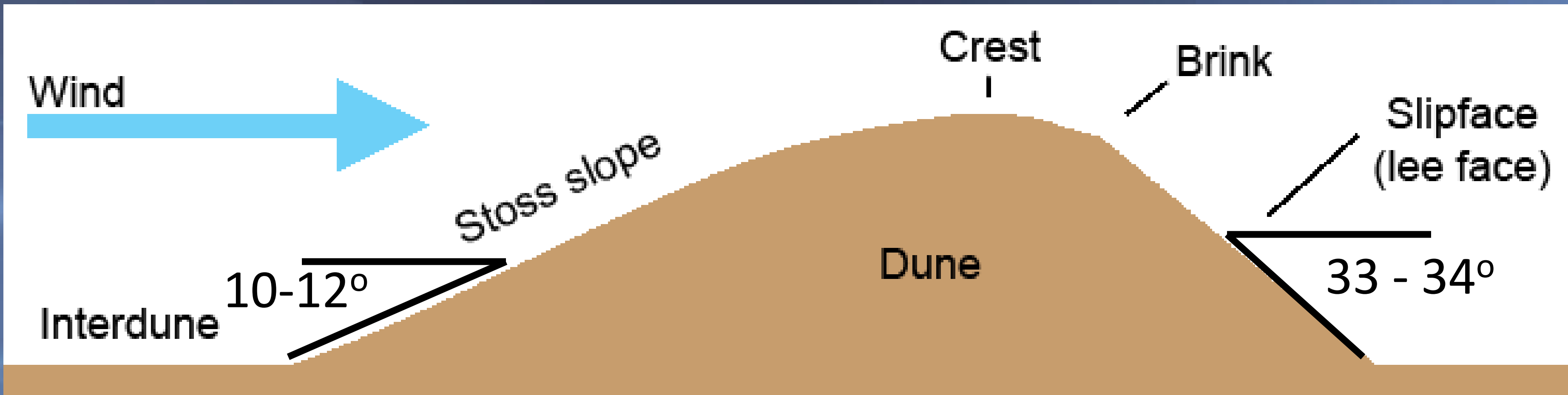
Libya-4 morphology

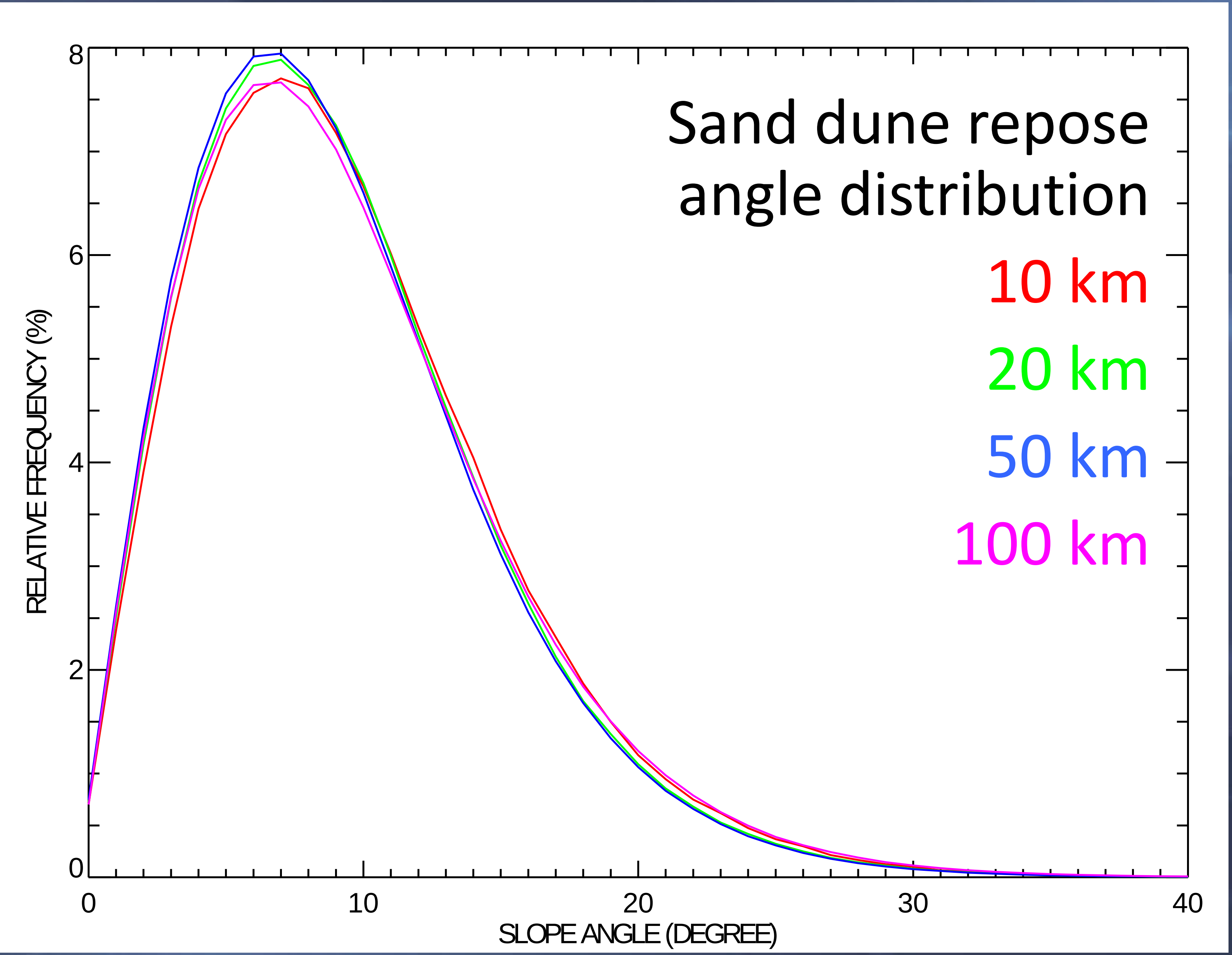


ASTER DEM over the 20km x 20 km ROI

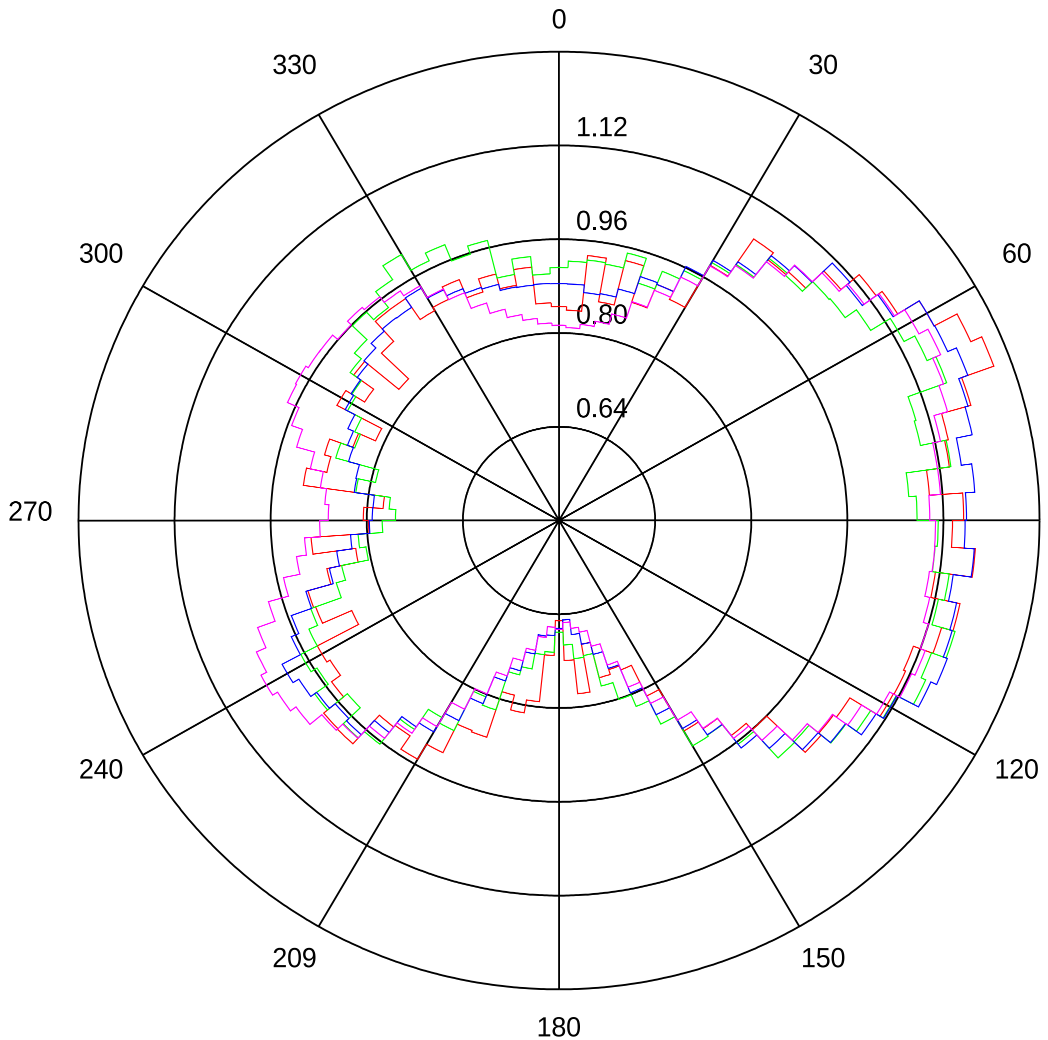

Wind
Crest
Brink
Slipface
(lee face)
Stoss slope
Dune
10-12°
33 - 34°
Interdune


Google Earth
s: 489 m, -482 m
Max Slope: 18.4%, -26.8%
Avg Slope: 4.1%, -5.5%
60m
2,500m
2.5 km
5 km
7.5 km
10 km
12.5 km
15 km

Libya-4 morphology



Libya-4 morphology



Sand dune azimuth angle distribution

10 km

20 km

50 km

100 km

Experimental set-up

- Simulation performed with Raytran, a 3D ray-tracing Monte-Carlo radiative transfer model;
- Surface topography represented with ASTER DEM;
- Sand reflectance is assumed Lambertian (0.3), *i.e.*, BRF effects are only due to the topography.

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Example of nadir-looking Raytran surface reflectance simulation over the 100 km × 100 km ROI acquired with a 250 m pixel resolution CCD camera for a sand reflectance value of 0.3

SZA = 50^{o}
SAA = 270^{o}

The ROI size has limited impact on the mean reflectance value

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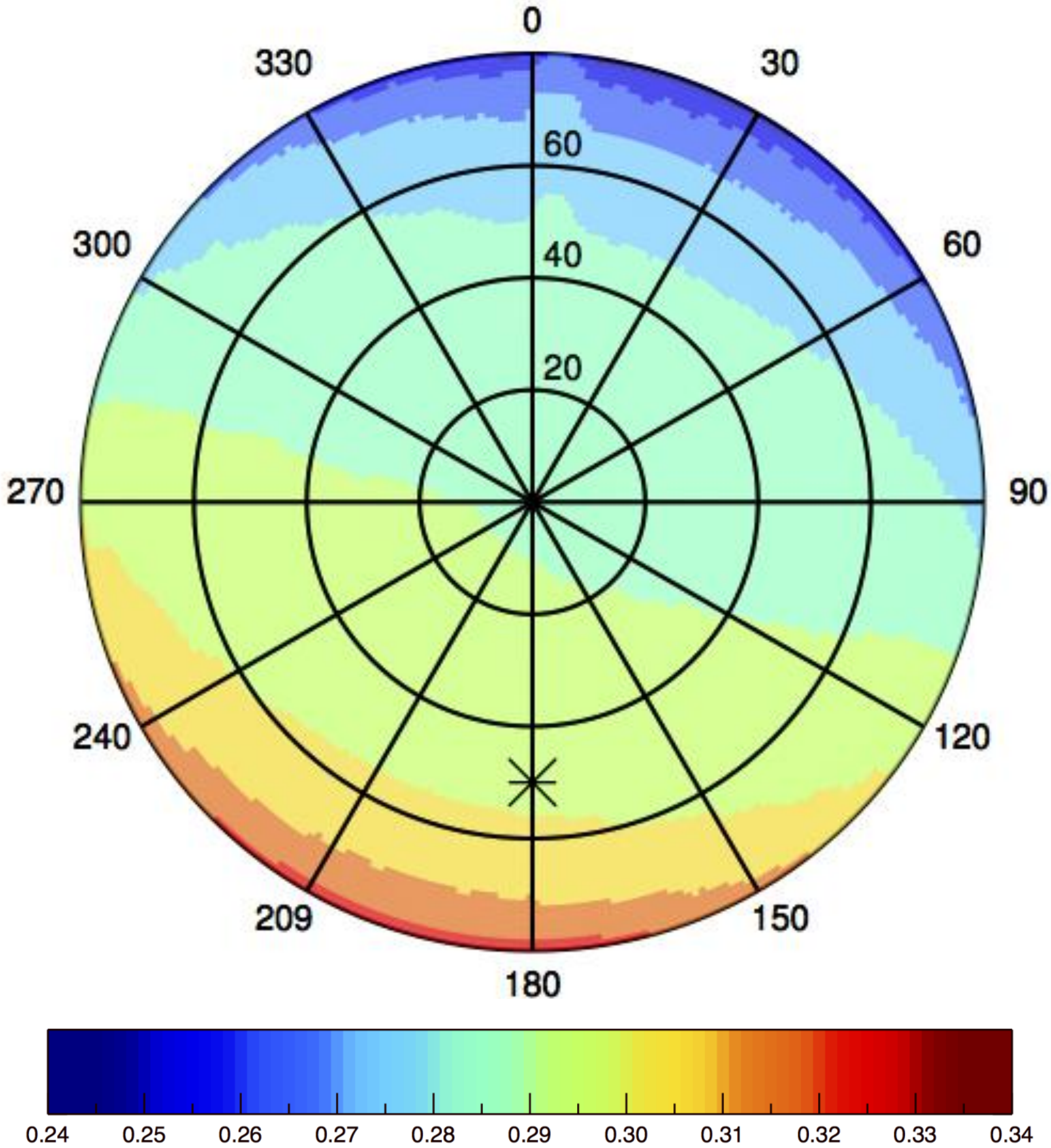
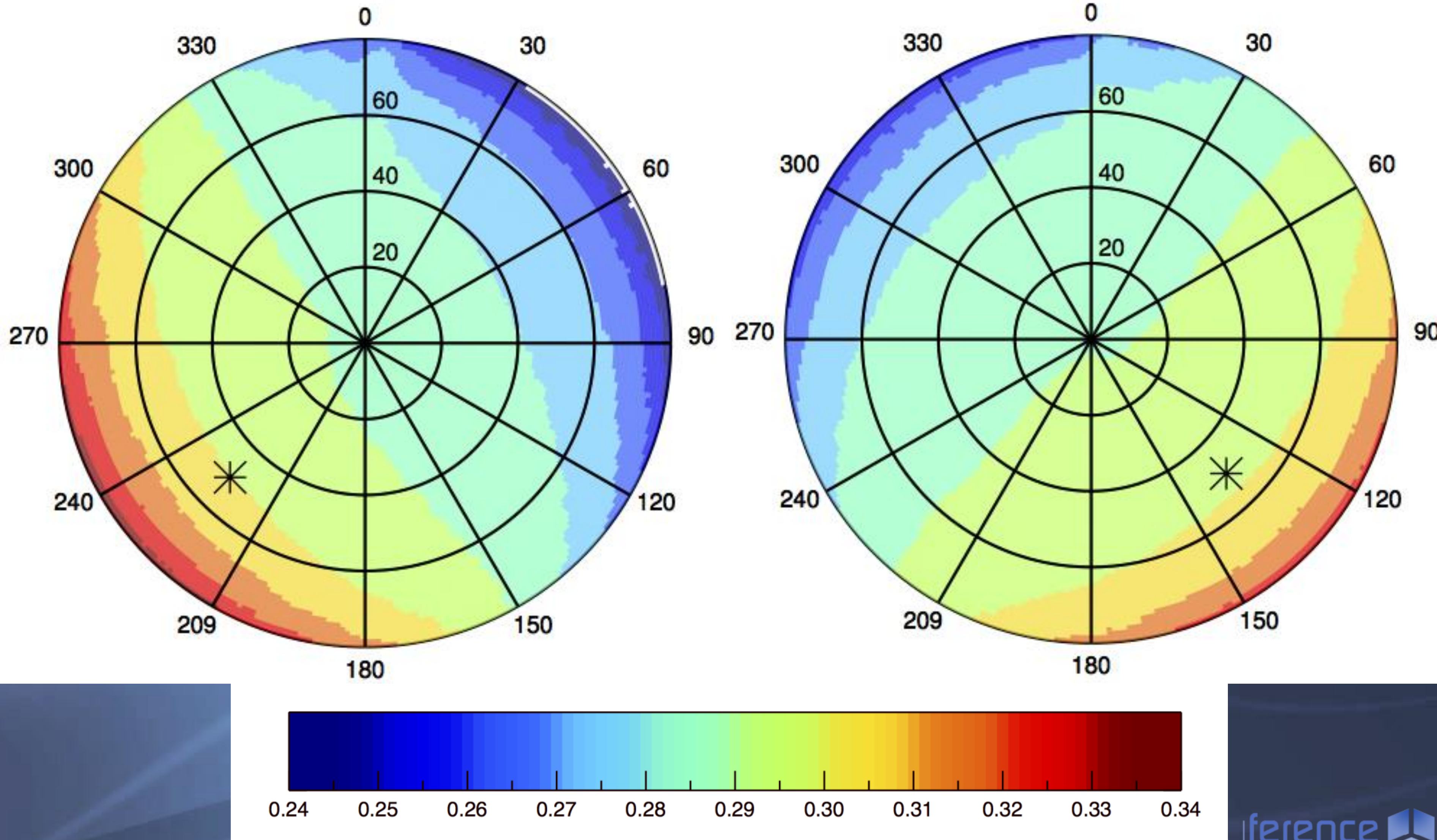
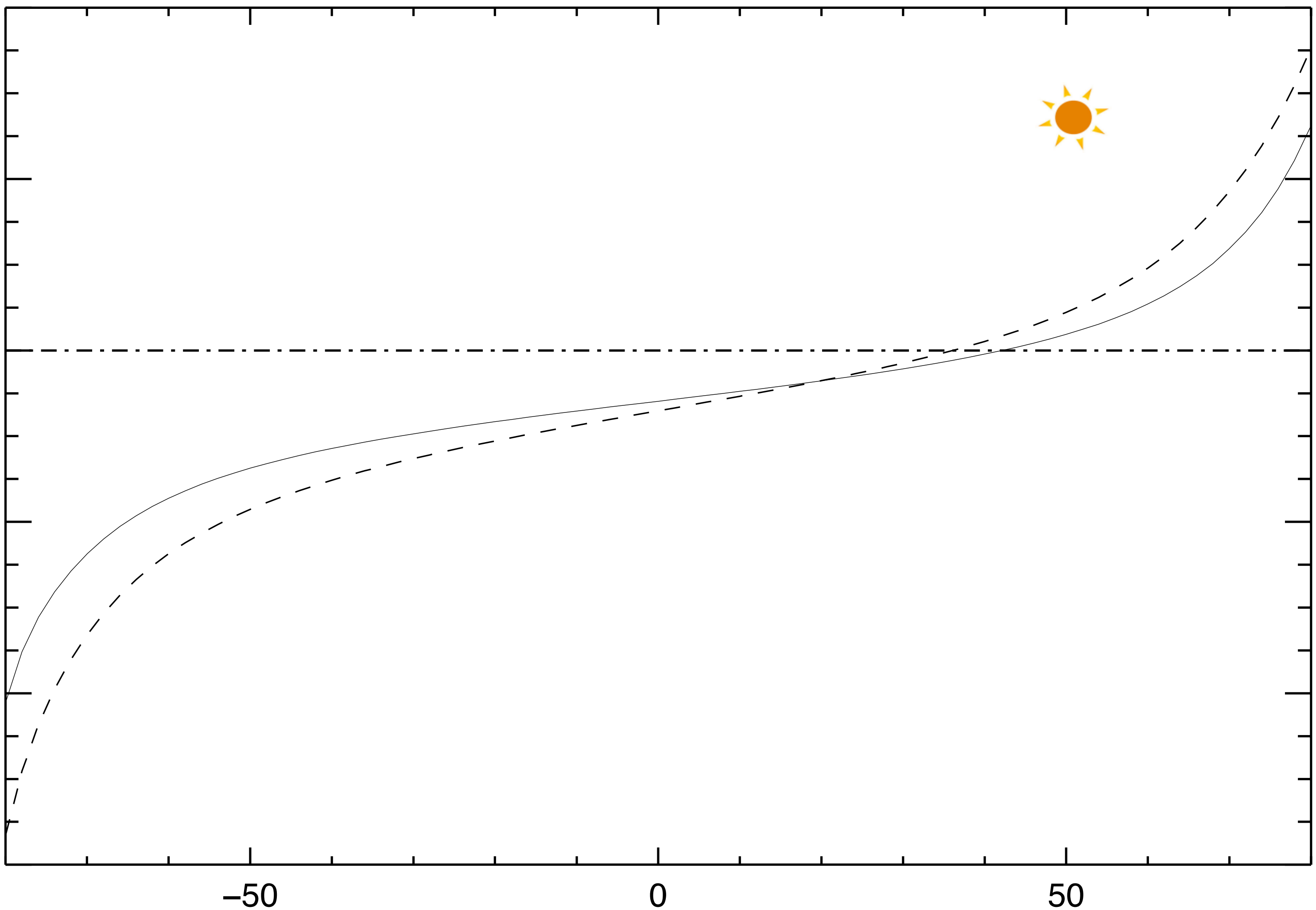
Sand reflectance = 0.3



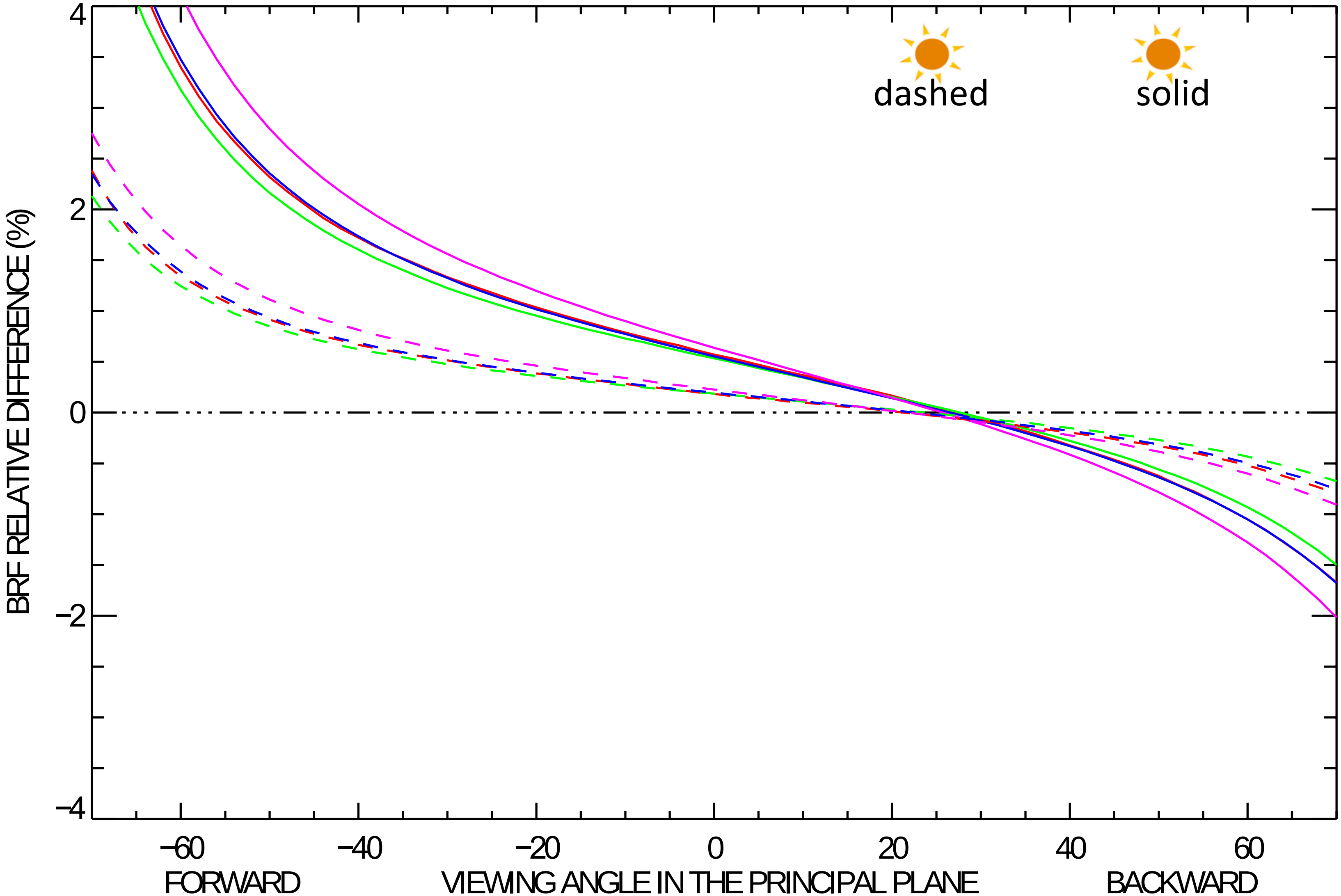
Comparison of morning and afternoon overpasses





Raytran surface reflectance simulation in the principal plane
over the 20 × 20 km ROI for SZA = 50◦.
Morning pass : solid line
Afternoon pass : dashed line

Surface reflectance relative difference in the principal plane between morning and afternoon overpasses



ROI : 10 km 20 km 50 km 100 km

TOWARD A NEW 3D RTM

The new required RTM accuracy driven by vicarious calibration of Sentinel satellites better than 3% will necessitate the development of a new generation of RTM:

- Non flat earth;
- 3D effects of any complexity and scales;
- Accurate simulation over land surfaces, water bodies and atmospheric media;
- Full radiative coupling between these media;
- Polarization and IR emission;
- Moon.

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CONCLUSIONS (1)

- The major simulated TOA BRF differences between RTMs over Libya-4 are due to the way gas transmittance is handled;
- In the 350nm – 500nm spectral interval, the exact contribution of polarization is yet to be estimated;

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CONCLUSIONS (2)

- Analysis of the effects of sand dune ridge alignments and ROI size on surface BRF over CEOS PICS Libya-4;
- 3D scene construction relies on the 30-m resolution ASTER DEM;
- ROI size has a pretty limited impact on the mean BRF averaged over a large number of illumination and viewing conditions;
- 50 km ROI has the most homogeneous surface reflectance.

CONCLUSIONS (3)

- Relative difference of surface reflectance in the principal plane between morning and afternoon illumination can exceed 1%;
- It is recommended to account for these effects when comparing these two illumination conditions with a required accuracy better than 3%;
- Future works should include sand BRF for accurate TOA BRF simulations et would necessitate the development of a new generation of RTM.

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