Results of the HyperPICS QA4EO study

IDEAS-QA4EO Cal/Val Workshop #5

Yves Govaerts

Rayference

Thessaloniki, 11-13 Jun 2024

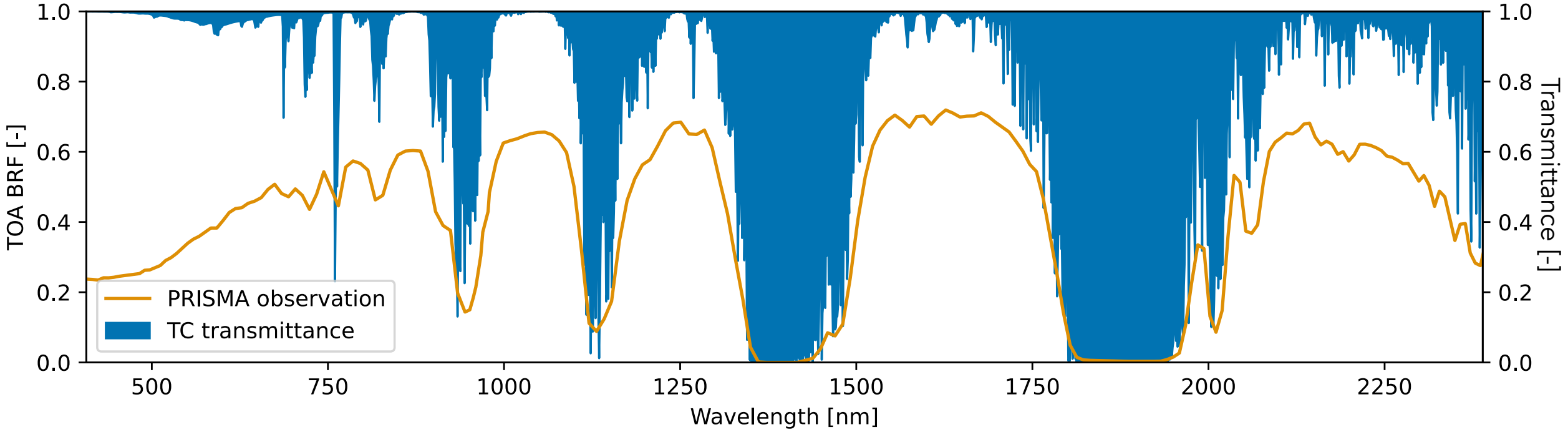
RAYFERENCE

OBJECTIVE

Objectives

The objective of this CalVal study is to assess the accuracy with which hyperspectral observations (top-of-atmosphere reflectance) can be simulated with the Eradiate radiative transfer model over well-established bright desert pseudo-invariant calibration sites

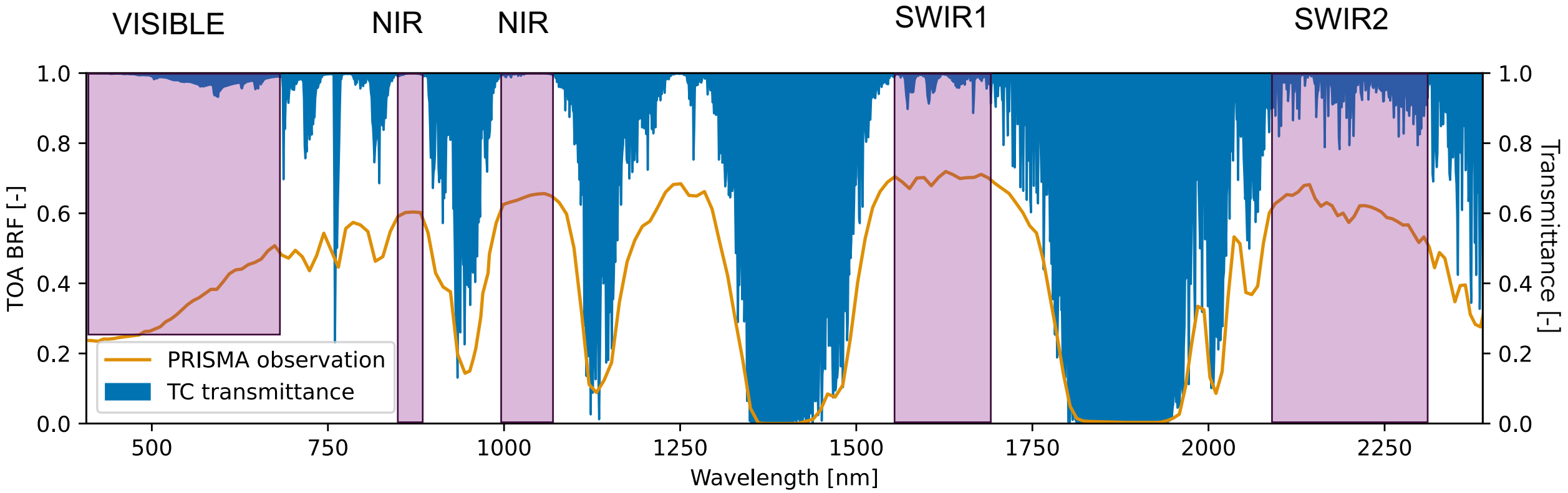
VIS - SWIR spectral domain



Example of PRISMA observation acquired over CEOS Libya4 PICS on 20 March 2020 (orange curve) and molecular transmittance (blue lines) of the AFGL U.S. standard atmosphere

VIS - SWIR spectral domain

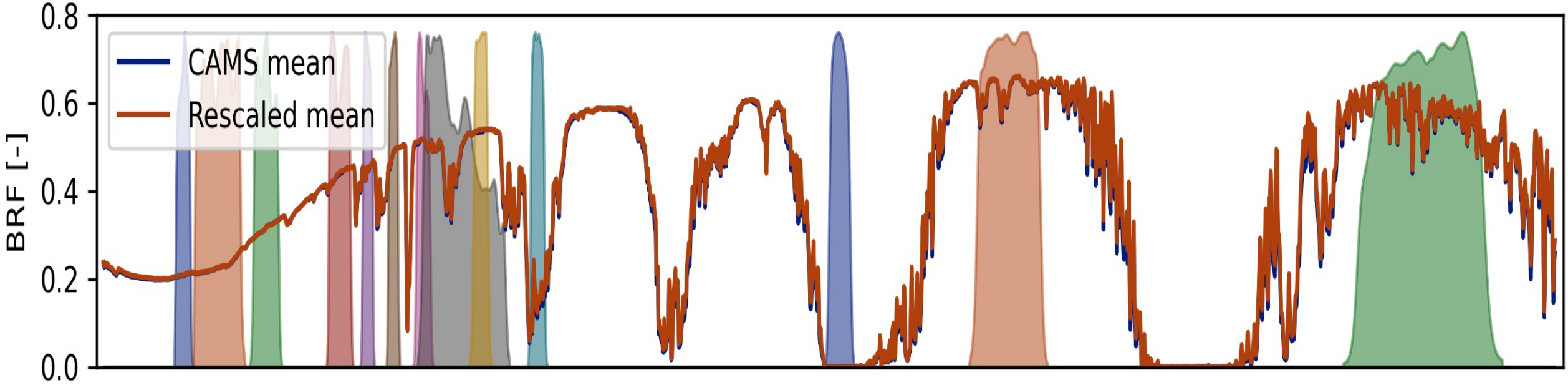
“Window” spectral regions



Example of PRISMA observation acquired over CEOS Libya4 PICS on 20 March 2020 (orange curve) and molecular transmittance (blue lines) of the AFGL U.S. standard atmosphere

VIS - SWIR spectral domain

How good are we outside the “window” spectral regions?



Sentinel-2 MSI spectral bands

ATMOSPHERIC VERTICAL PROFILE

Total Column Band Molecular Transmittance

The heritage : AVHRR

	RED	NIR
Band name	**AVHRR Band 1**	**AVHRR Band 2**
Central wavelength	**636 nm**	**860 nm**
Transmittance (H_2O)	99.06	83.57
Transmittance (O_3)	97.20	99.89
Transmittance (TCBT)	96.14	82.12

Total Column Band Molecular Transmittance

	RED		NIR	
Band name	**OLCI Oa7**	**MODIS B01**	**OLCI Oa17**	**MODIS B02**
Central wavelength	620 nm	645 nm	860 nm	865 nm
Transmittance (H_2O)	99.99	99.47	99.93	99.17
Transmittance (O_3)	96.38	97.53	99.93	99.92
Transmittance (TCBT)	96.38	96.86	99.85	99.09

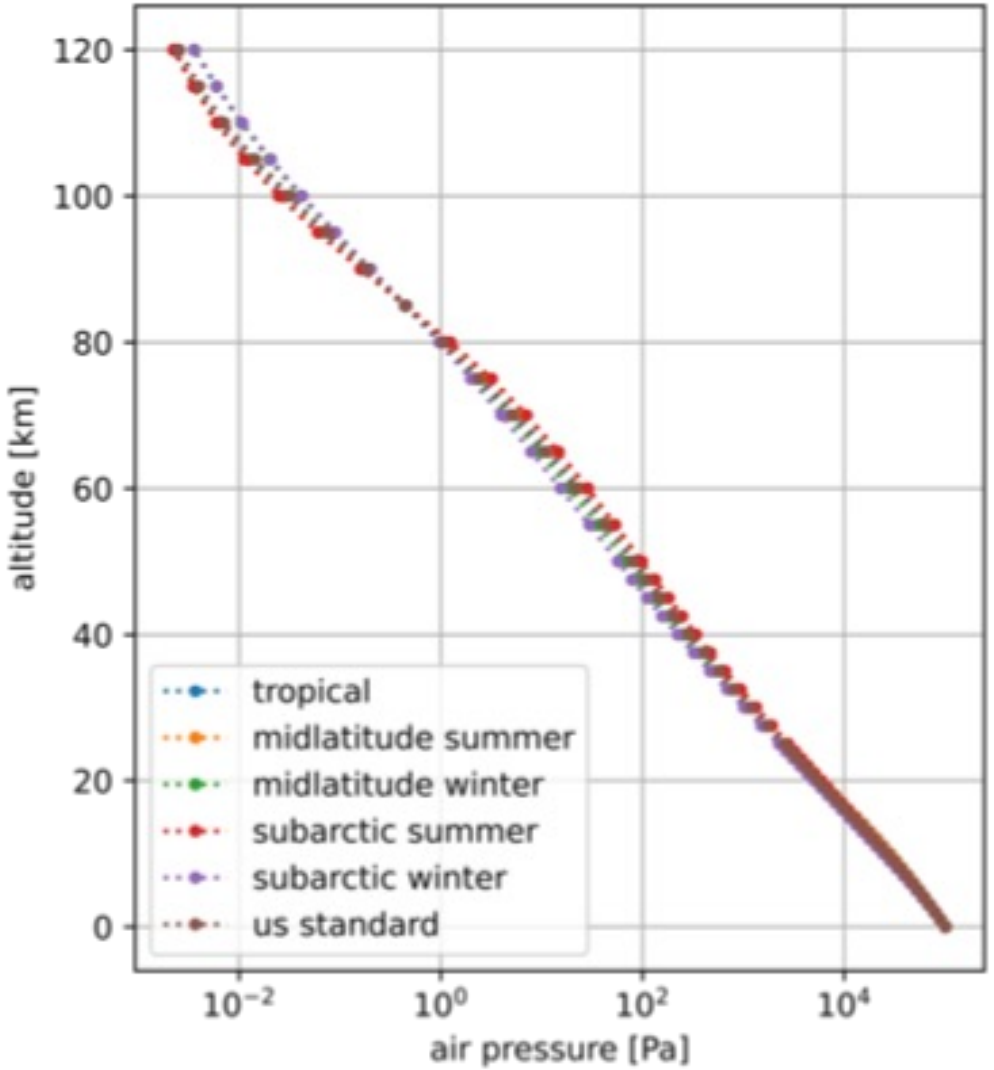
Spectral bands of modern radiometers dedicated to land applications are located in very transparent spectral regions (unlike for AVHRR).

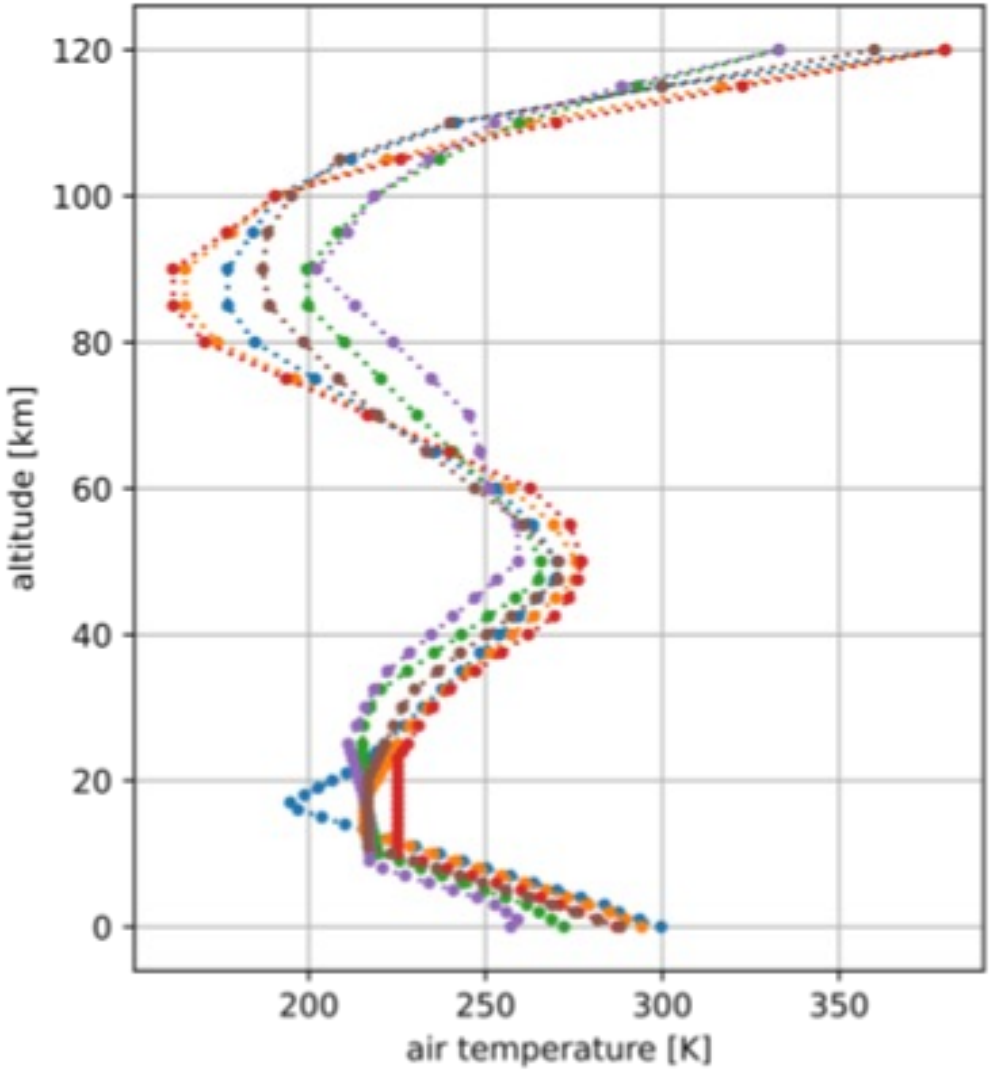
AFGL standard atmospheric profiles (1)

Name	Description	H_2O kg/m^2	O_3 DU	CH_4 ppb	CO_2 ppm
Tropical	15N annual average	41.96	283.7	1700	330
Mid-Latitude summer	45N July	29.84	335.7	1700	330
Mid-latitude winter	45N January	8.65	379.7	1700	330
Sub-artic summer	60N July	21.39	349.1	1700	330
Sub-artic winter	60N Januray	4.23	377.0	1700	330
U.S. standard	U.S. Standard (1976)	14.39	345.7	1700	330

From 1976!

AFGL standard atmospheric profiles (2)





Comparison of two approaches for absorption

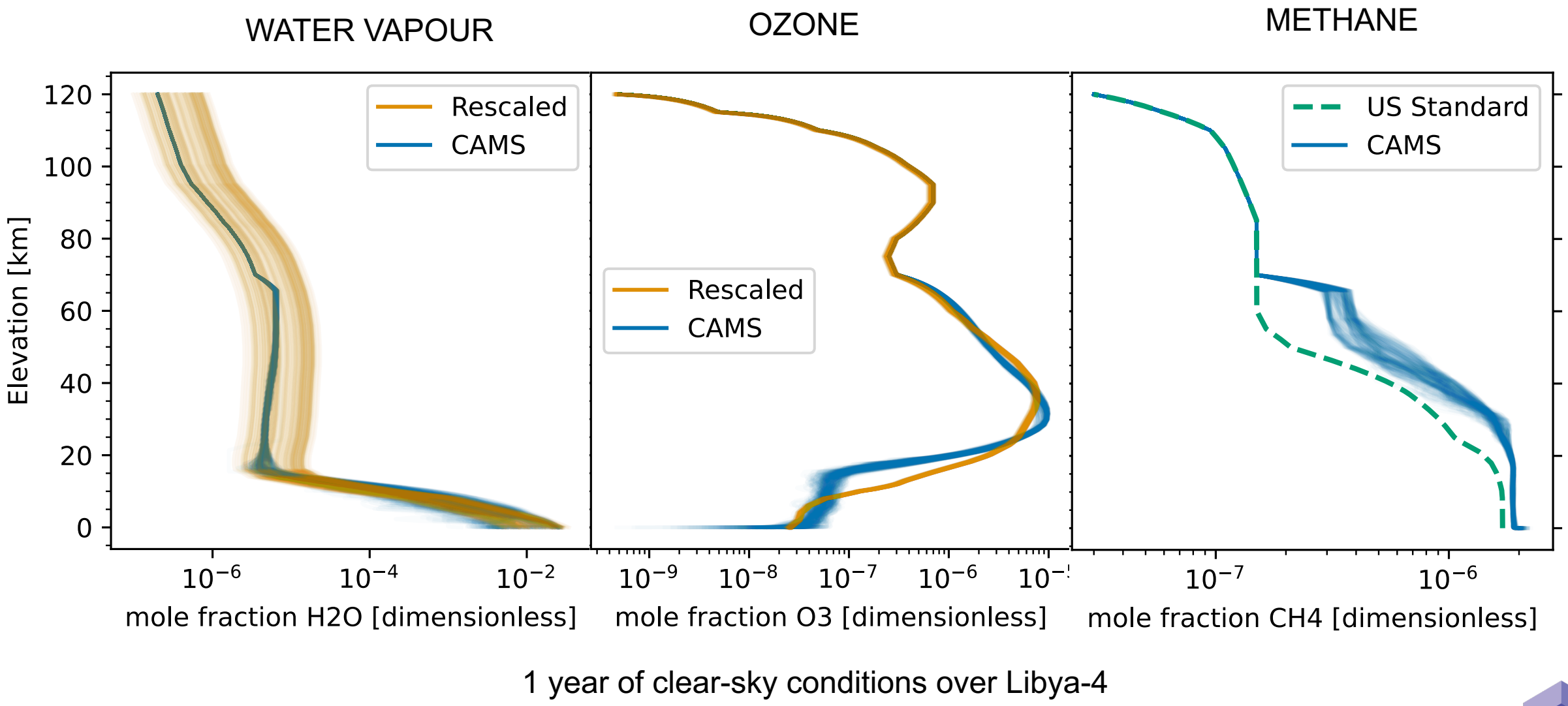
1. **Conventional approach**: use the AFGL US standard atmospheric profile and rescale the total column concentration of water vapour and ozone.

Comparison of two approaches

1. **Conventional approach**: use the AFGL standard atmospheric profile and rescale the total column concentration of water vapour and ozone.

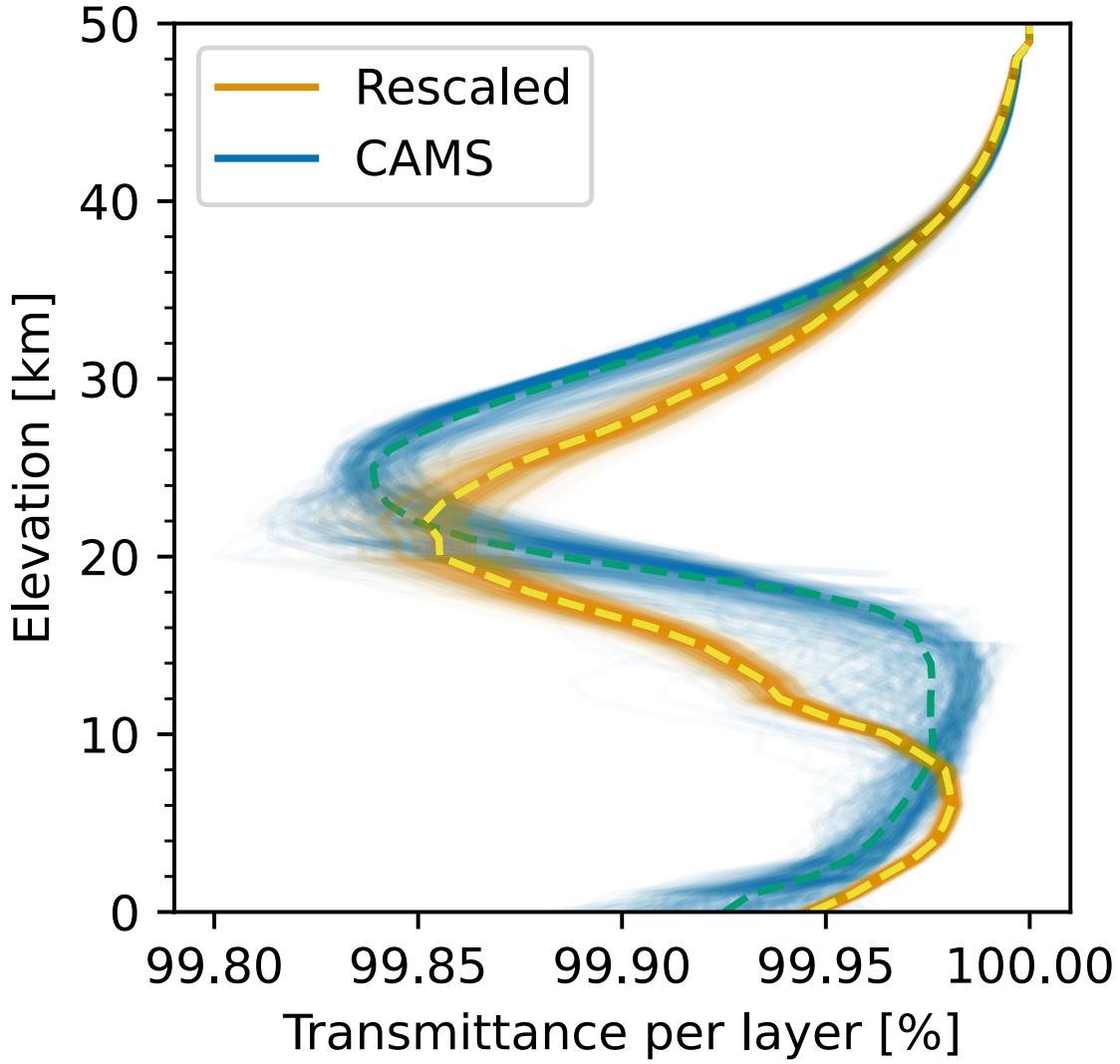
2. **New approach**: use CAMS reprocessed data to generate a customised atmospheric profile at the place and time of observation over PICS
   - Pressure and temperature profiles
   - Vertical concentration of CO, NO_2, NO, O_3, H_2O, SO_2, N_2O, O_2, CH_4, CO_2

H2O, O3 and CH4 profiles over Libya-4



1 year of clear-sky conditions over Libya-4

Effect on molecular transmittance



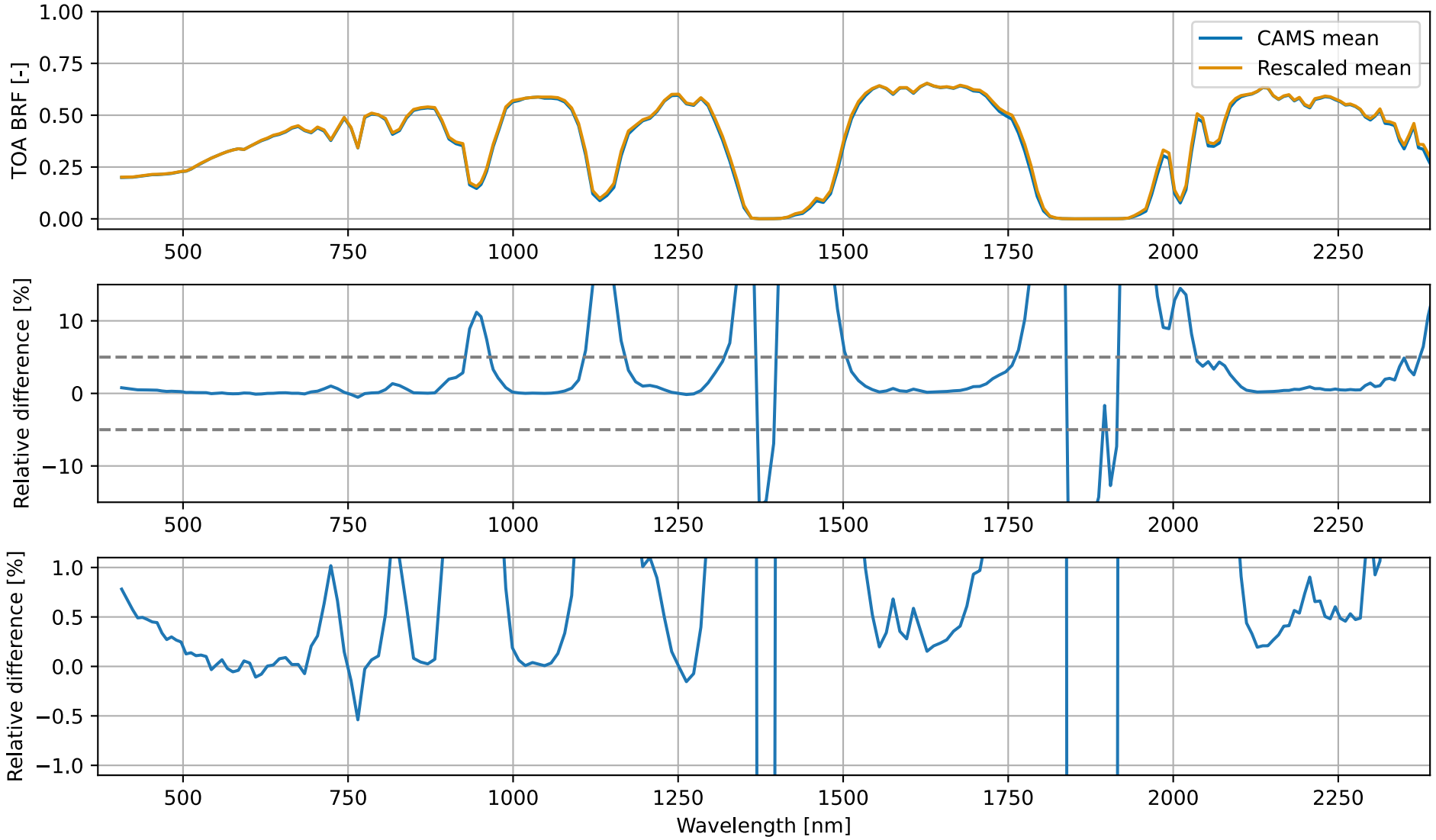
Ozone vertical profile

PRISMA observations over Libya-4

Experimental plan

- Acquisition of 27 clear-sky PRISMA observations over Libya-4;
- Simulation of the observations with
  1. the conventional approach (rescaling water vapour and ozone)
  2. the new approach (CAMS profiles)
- Comparisons of the two types of simulations (1 and 2).

PRISMA observations over Libya-4

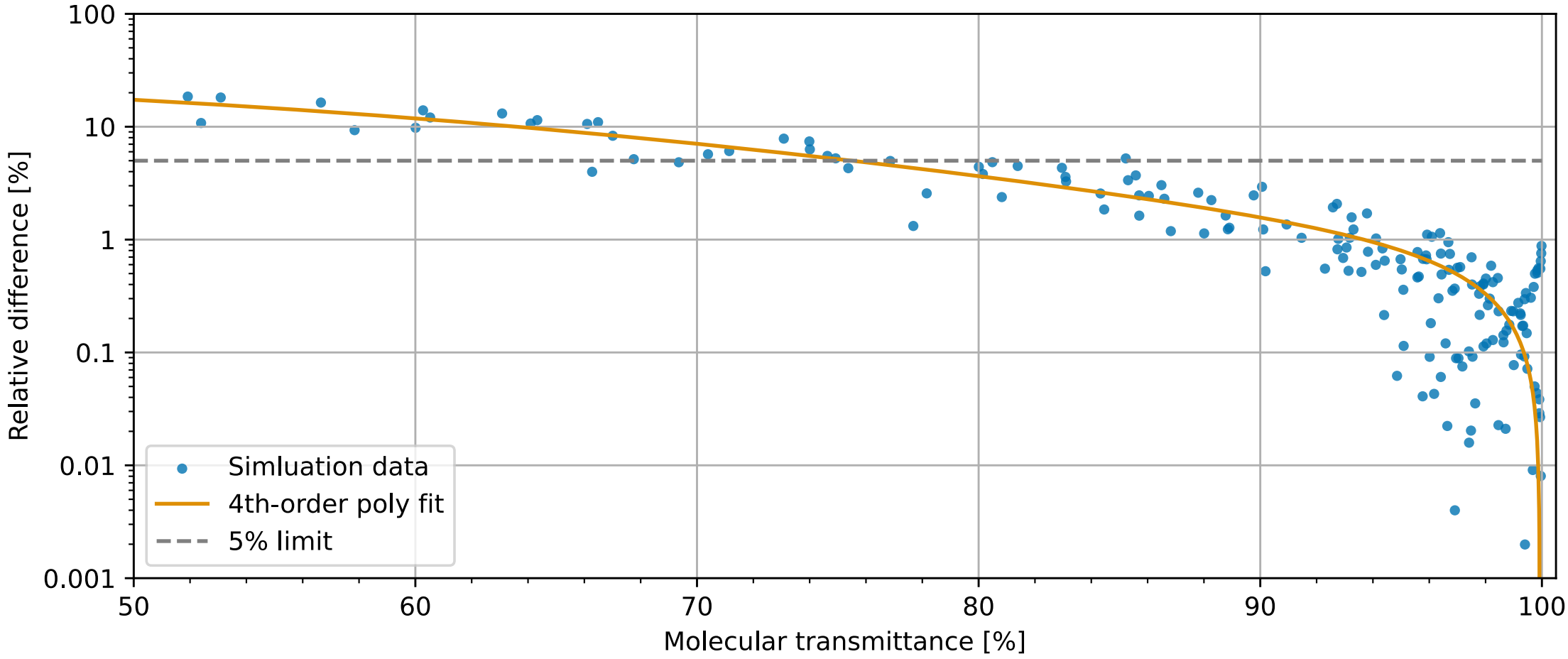


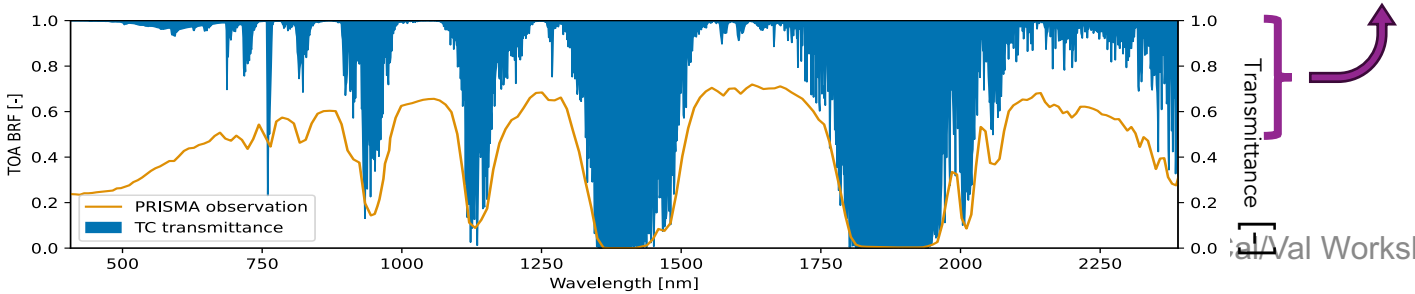
Mean value of the 27 simulations

Mean relative difference

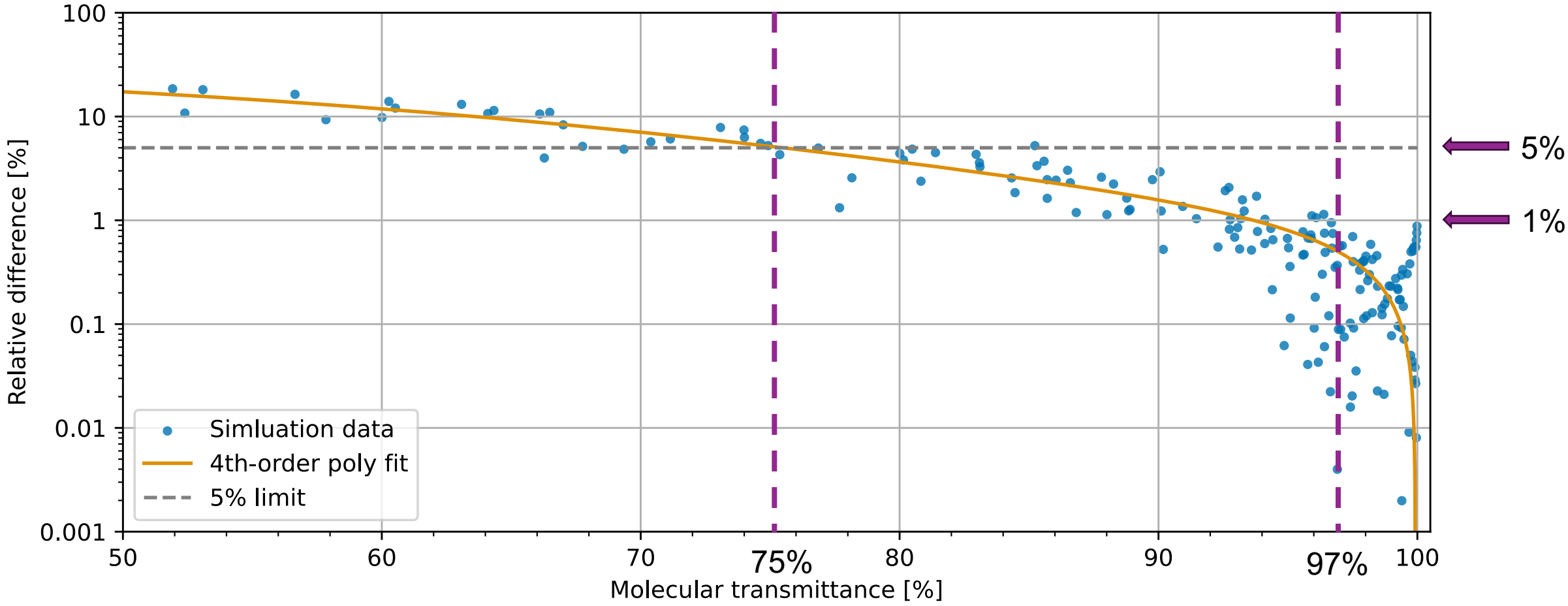
TRUTHS uncertainty range

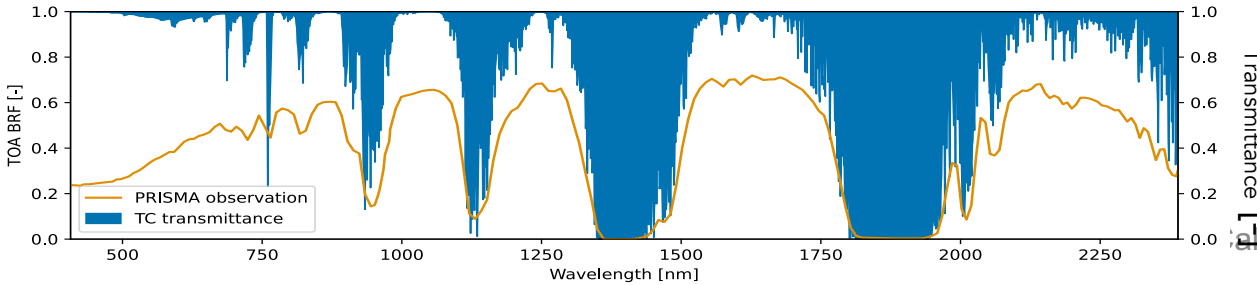
Relative difference versus molecular transmittance



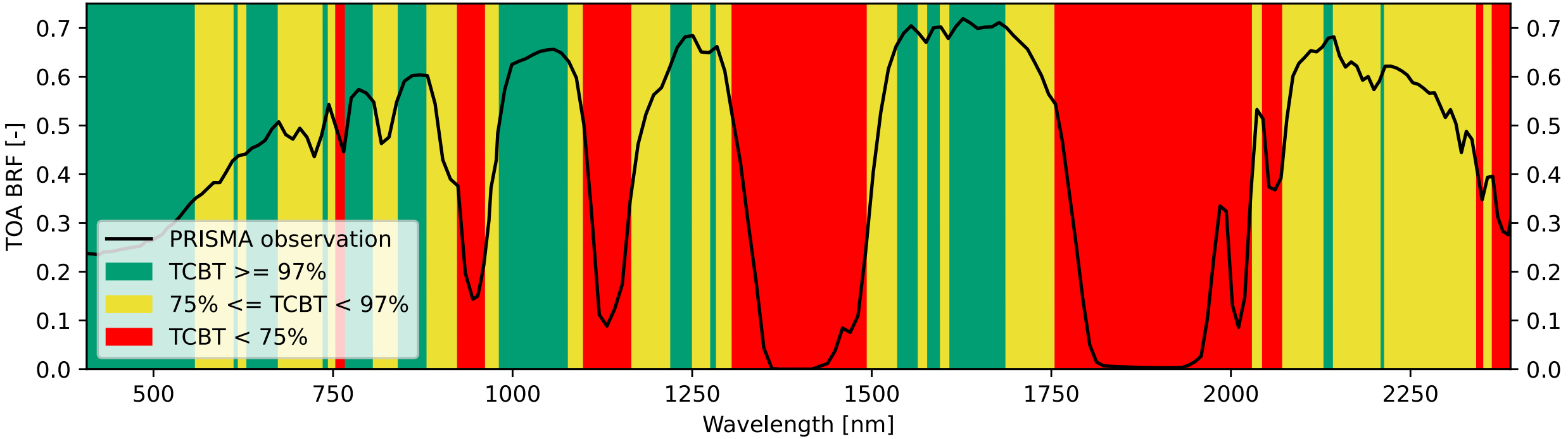


Relative difference versus molecular transmittance





Simulation uncertainty



Mean PRISMA TOA BRF values from the 27 observations acquired over Libya-4 (solid black line).

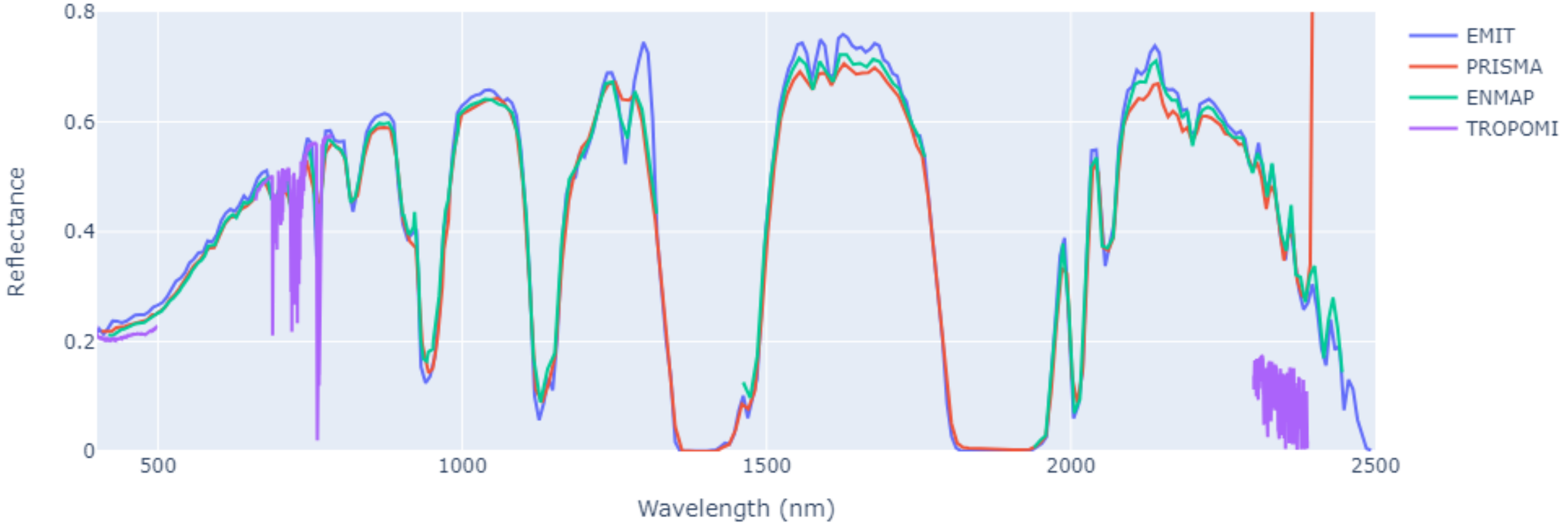
- The green background colour shows the spectral regions where TCBT > 97 % and d_r < 1 %.
- The yellow background colour shows the spectral regions where 75 % < TCBT < 97 % and 5 % > d_r > 1 %.
- The red background colour shows the spectral regions where TCBT < 75 % and d_r > 5 %.

HYPERSPECTRAL SIMULATIONS

Hyperspectral data

Property	PRISMA	EnMAP	EMIT - ISS
Launching date	22/03/2019	01/04/2024	14/07/2022
Spectral Range	400 – 2500 nm	420 – 2450 nm	381 – 2493 nm
Detectors VNIR SWIR	400 – 1100 900 - 2500	420 – 1000 900 - 2450	
Number of Bands	239	246	285
Spectral Resolution	≤14.5 nm	~7.4 nm	~7.4 nm
Ground sampling distance (nadir)	30 m	30 m	60 m (L1B)
Nbr. Obs. over Libya-4	27	34	6
Nbr. Obs. over Niger-2	2	0	9

Hyperspectral observations (Libya-4)

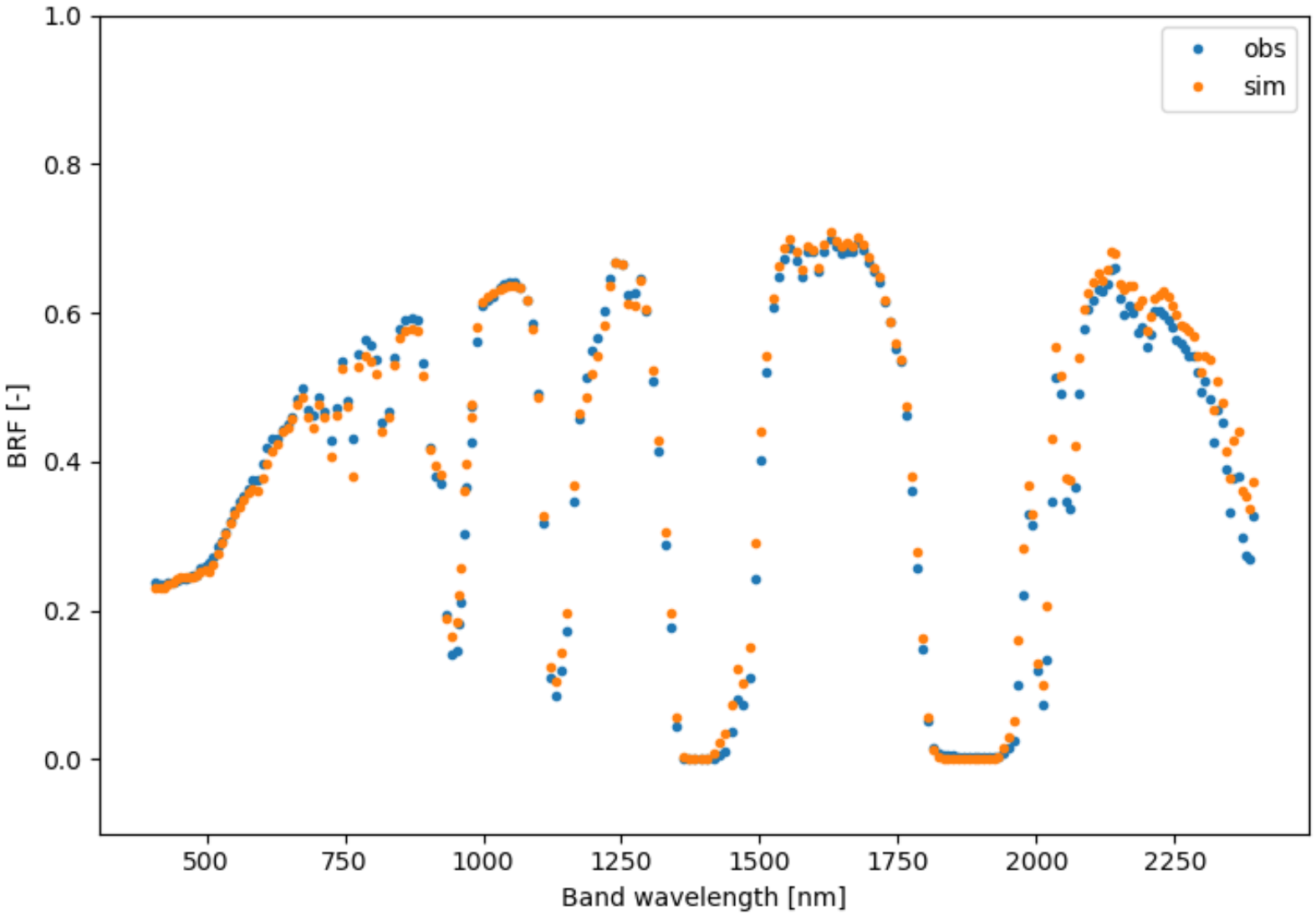


Hyperspectral calibration reference

Rayference Radiometric Calibration Reference (RRCR)

- RPV model for surface BRF at 1 nm spectral resolution;
- CAMS data for the atmospheric profile;
- CAMS data for aerosol optical thickness;
- Aerosol model based on various sources of information;
- Spherical Earth;
- TOA simulation performed with Eradiate at 1 nm spectral resolution;
- Illumination and viewing geometries from the simulated observation.

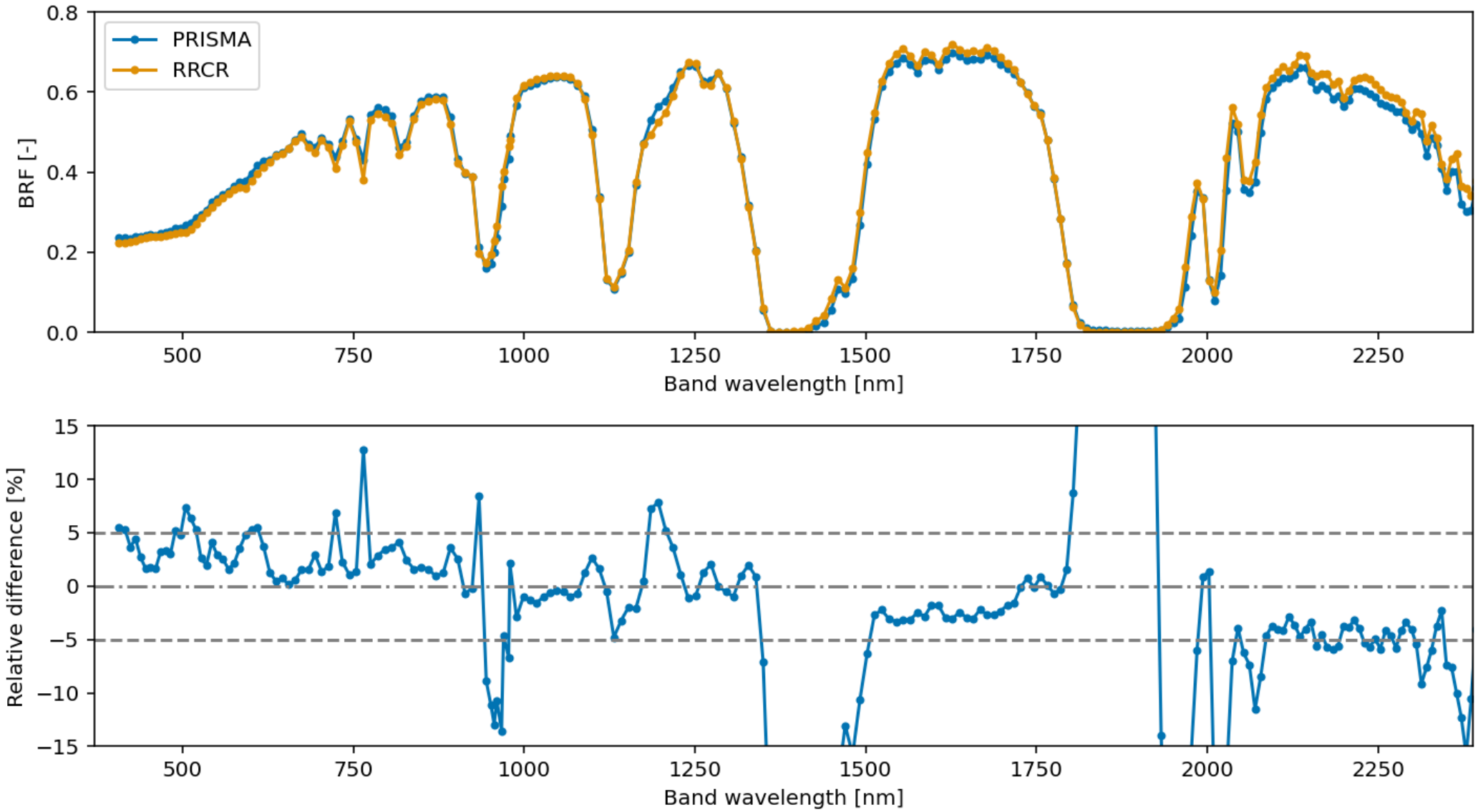
Example of PRISMA simulation over Libya-4



Simulation of one PRISMA clear sky observation acquired over Libya-4 on 17-10-2022
SZA : 41
VZA : 13
AOT : 0.075

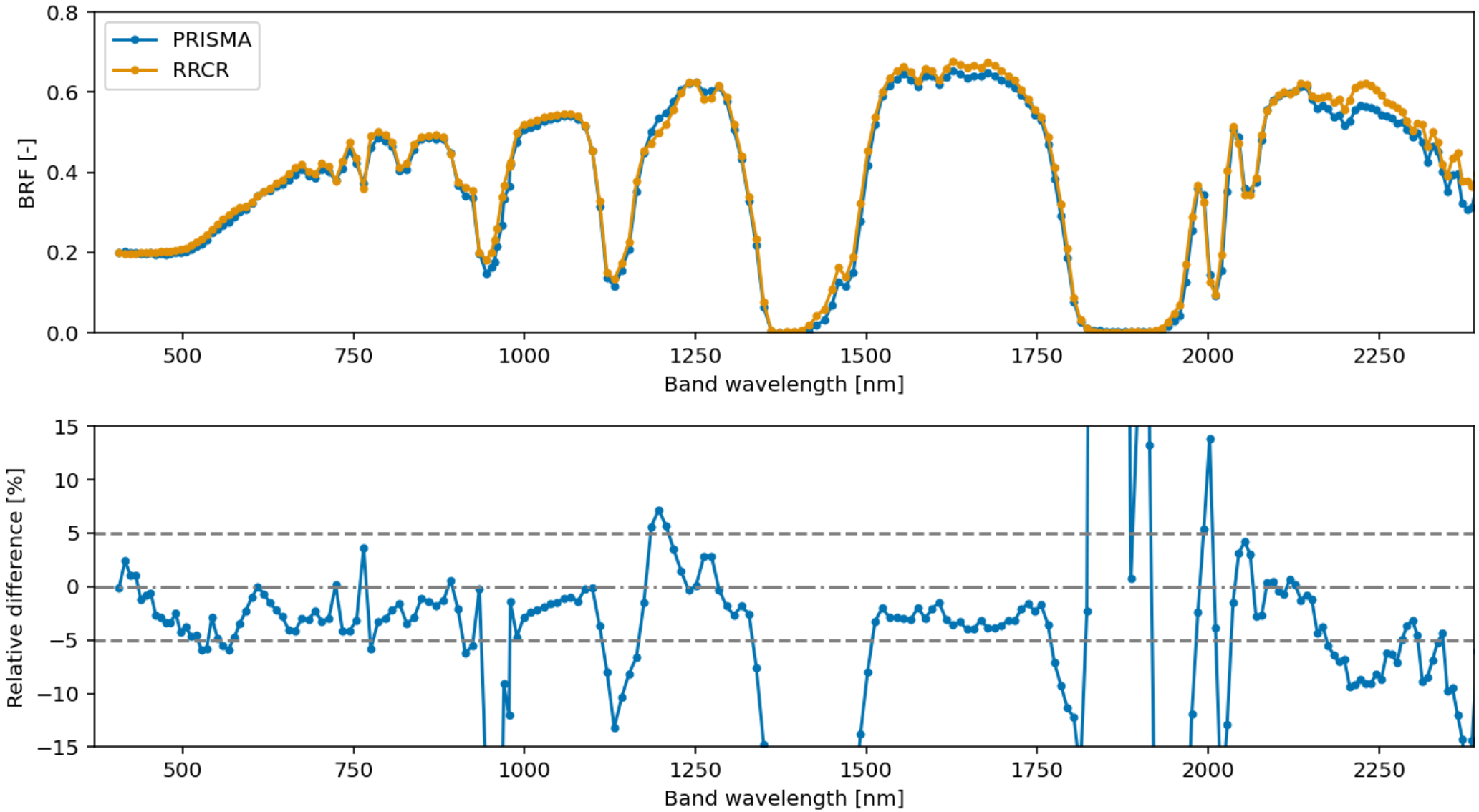
PRISMA results (26 clear sky observations)

Libya-4



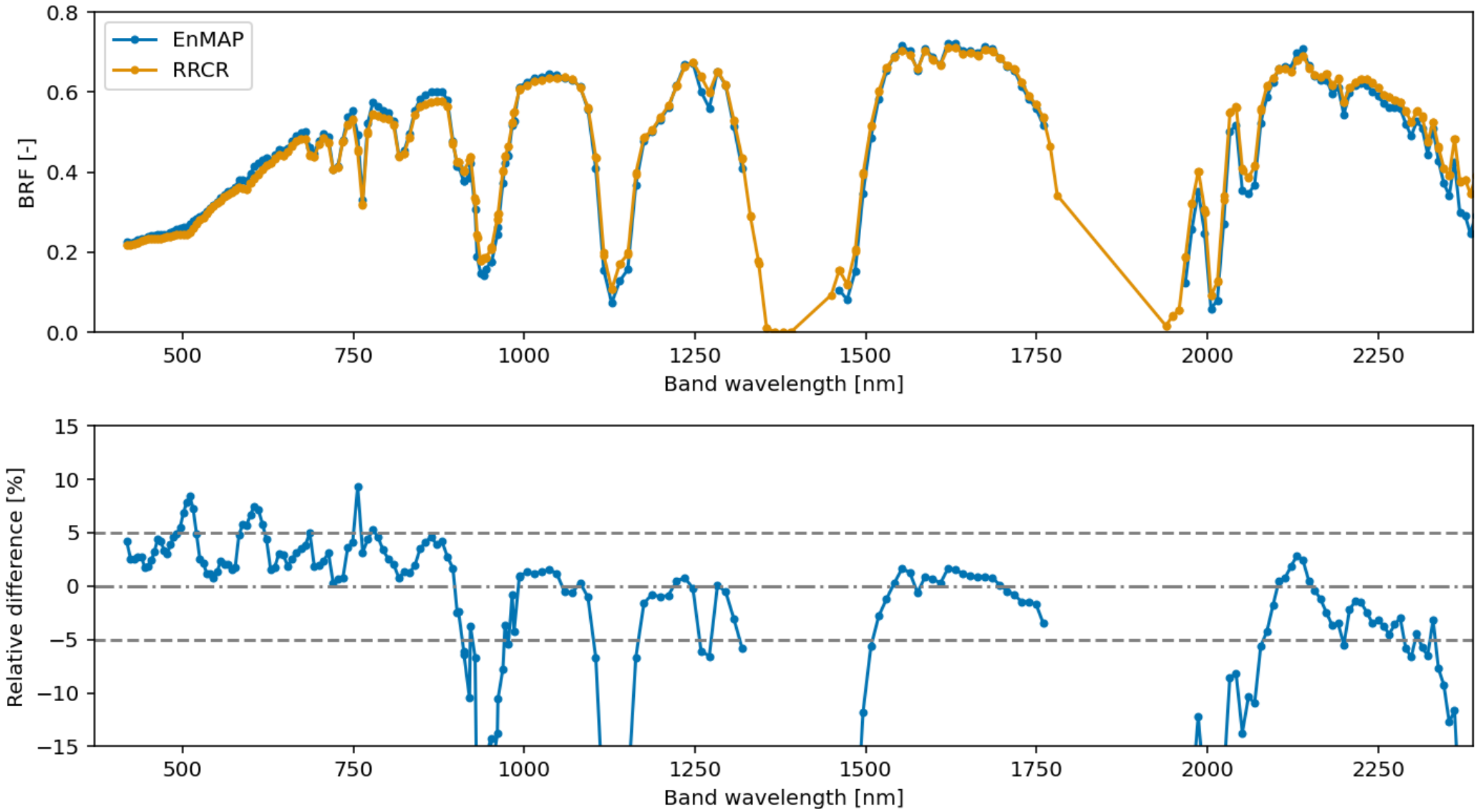
PRISMA results (2 clear sky observations)

Niger-2



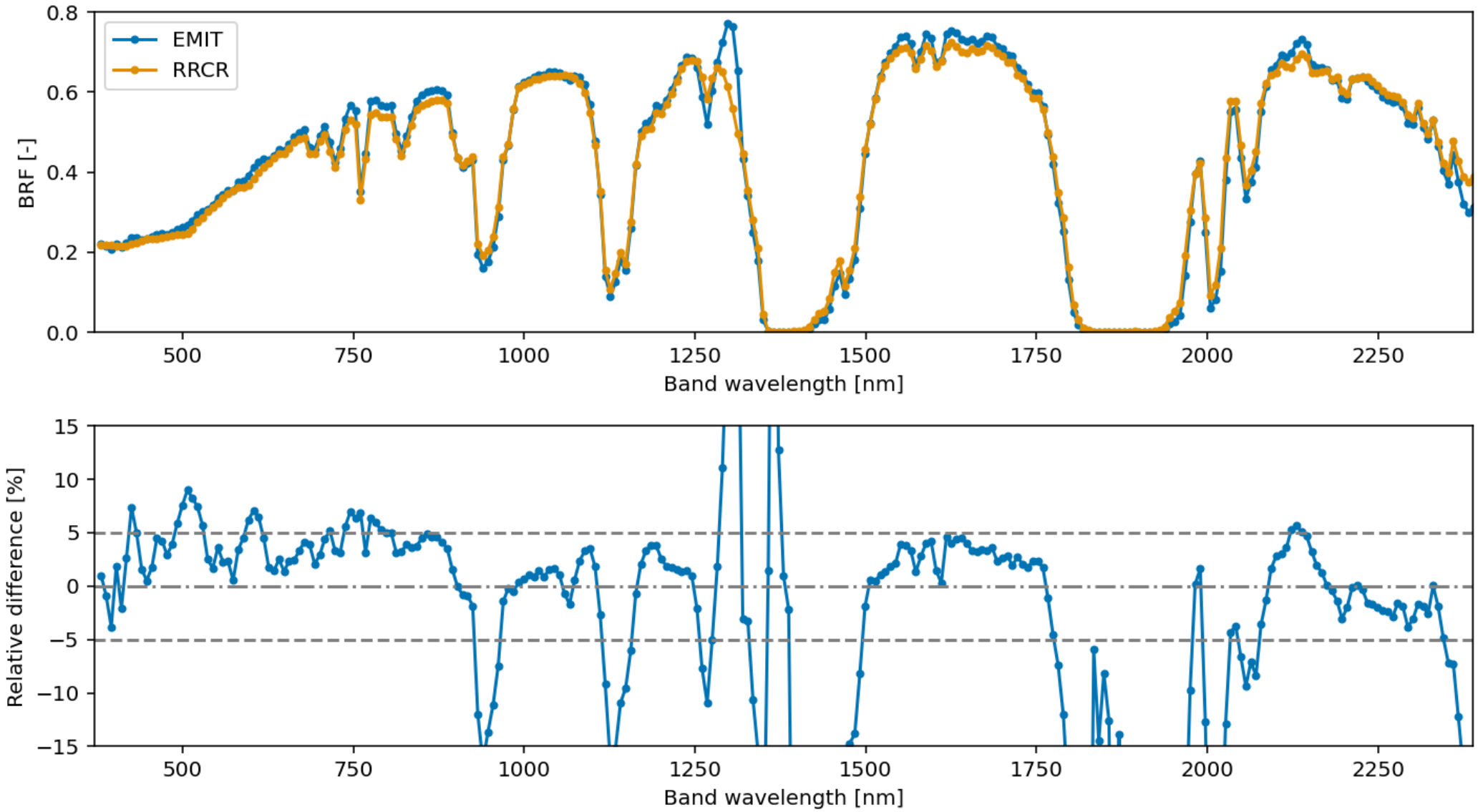
EnMAP results (32 clear sky observations)

Libya-4



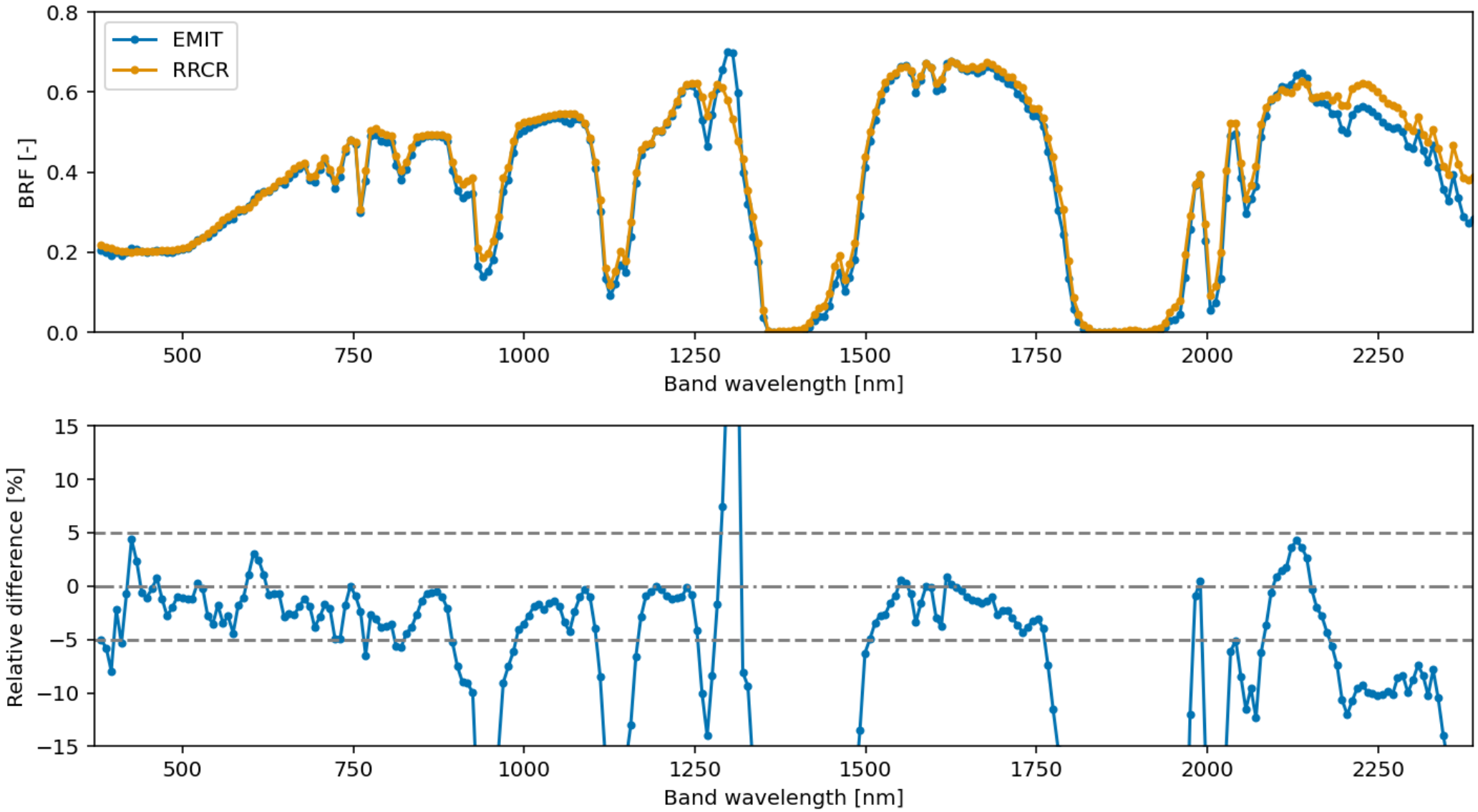
EMIT results (6 clear sky observations)

Libya-4

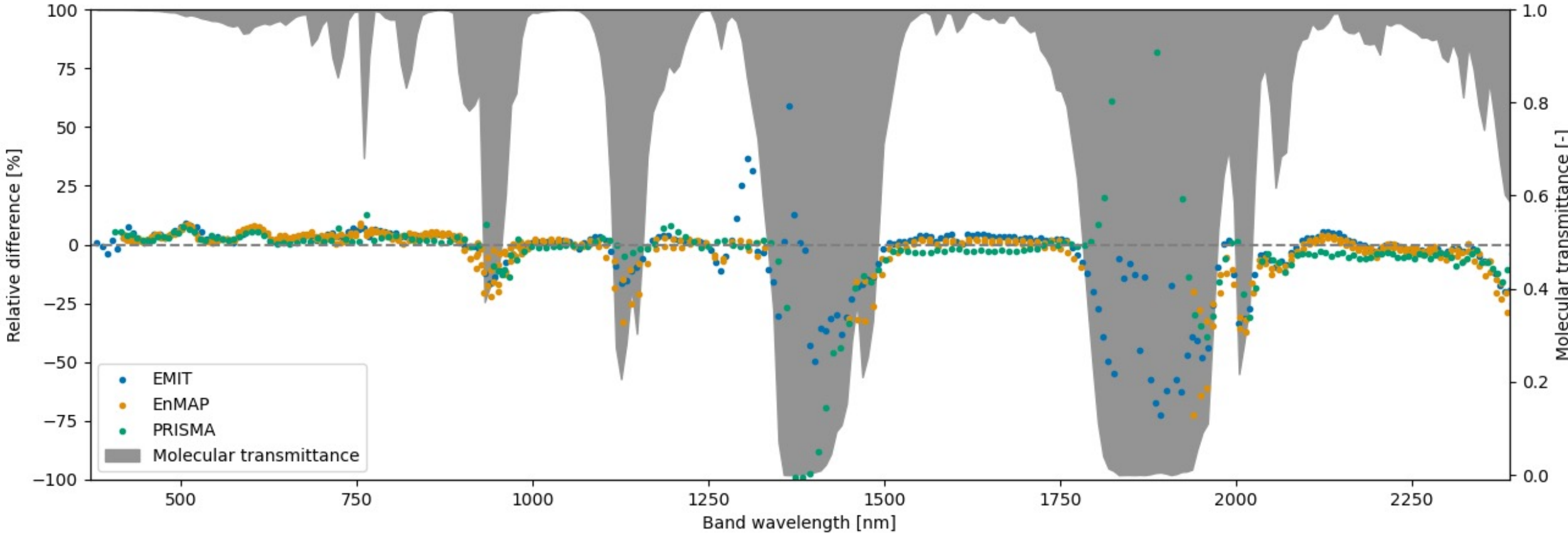


EMIT results (9 clear sky observations)

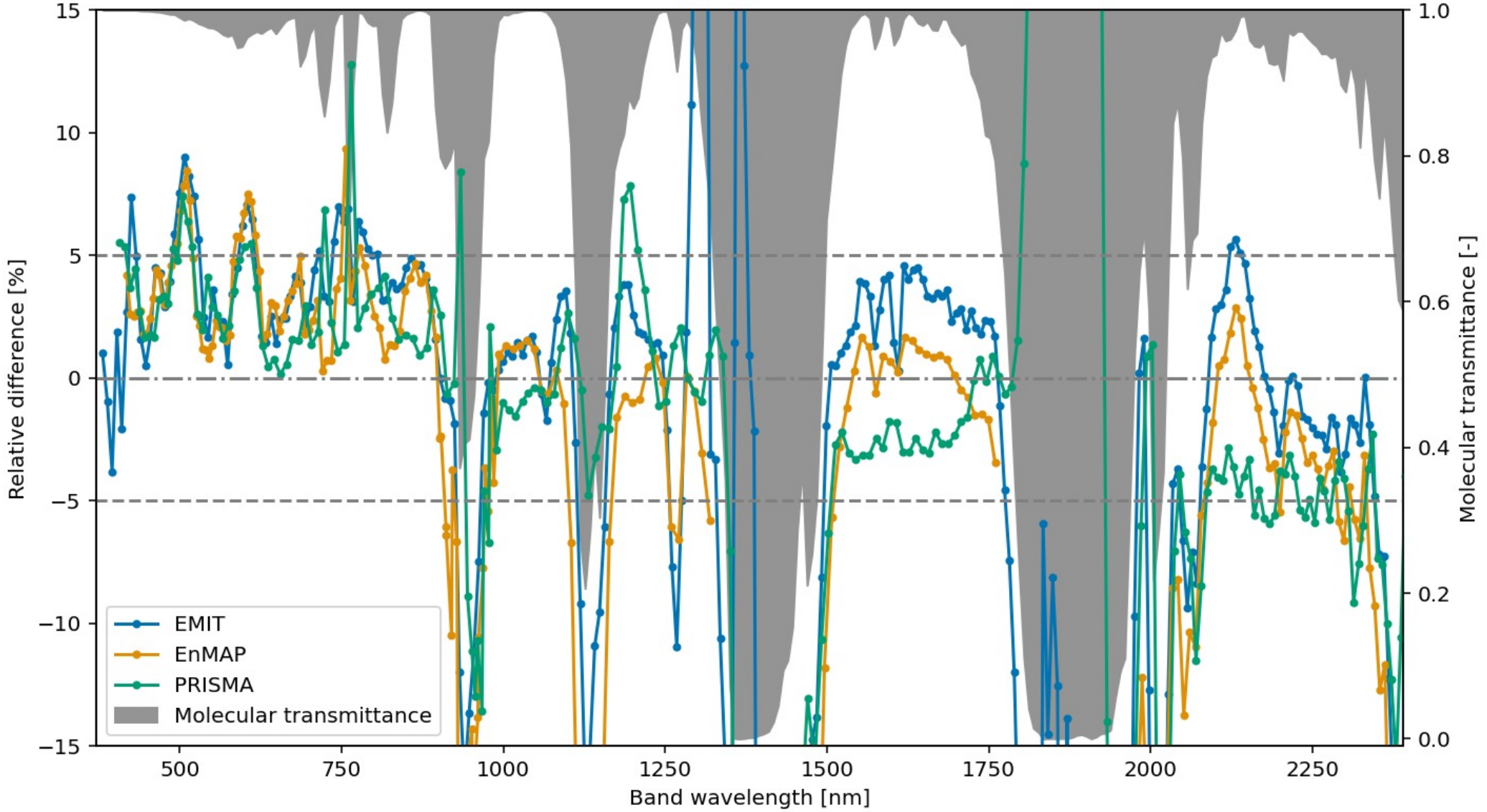
Niger-2



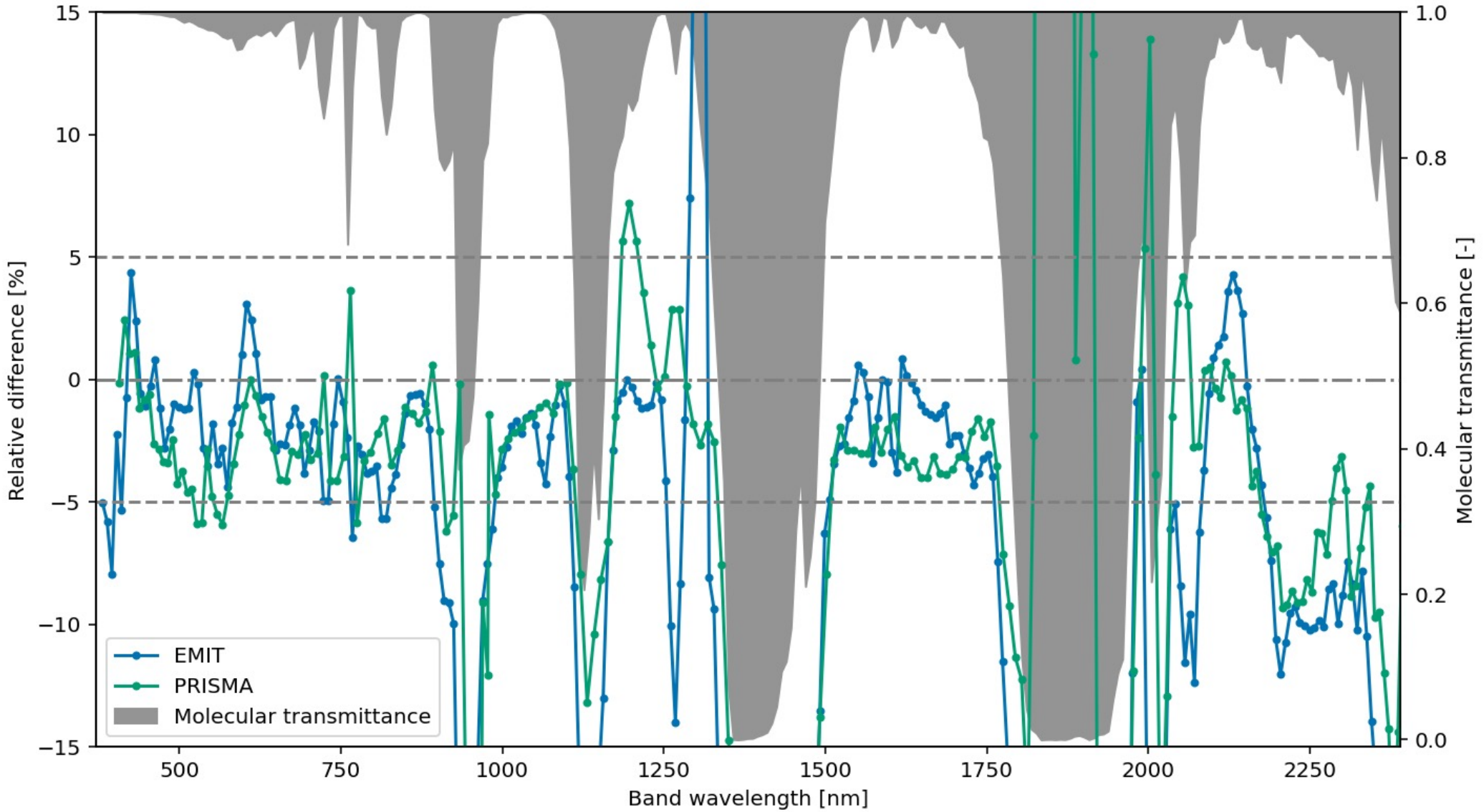
Libya-4 hyperspectral overall results



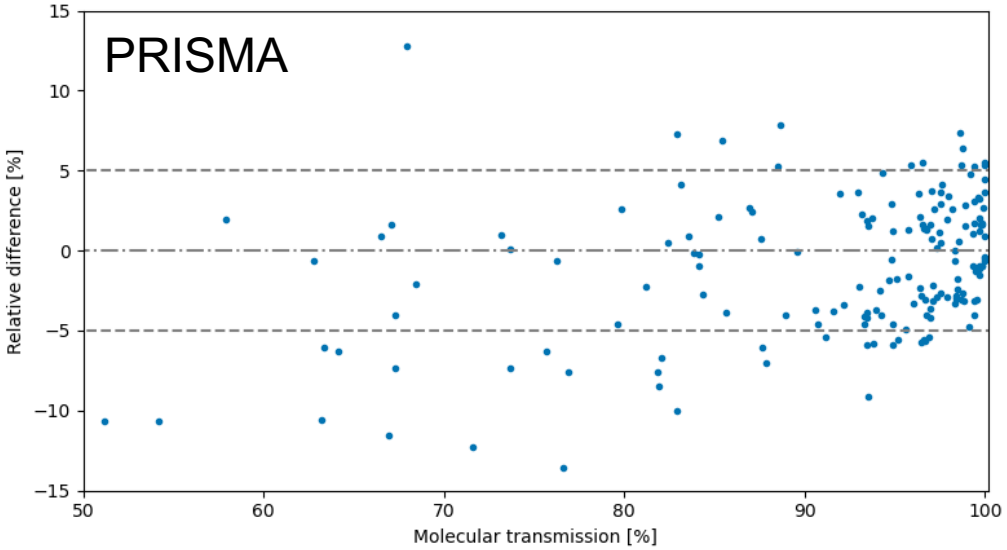
Libya-4 overall results



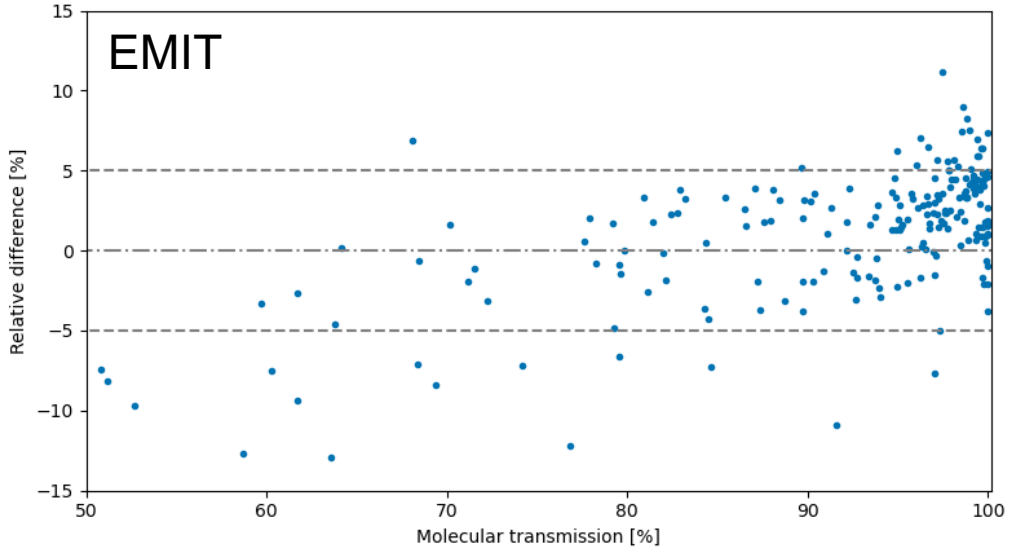
Niger-2 overall results

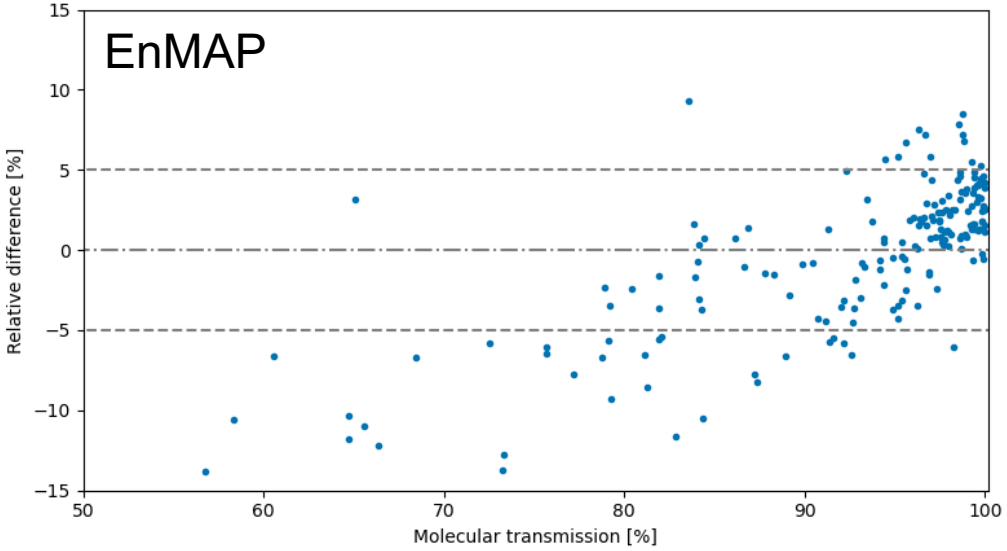


Relative differences versus molecular transmittance

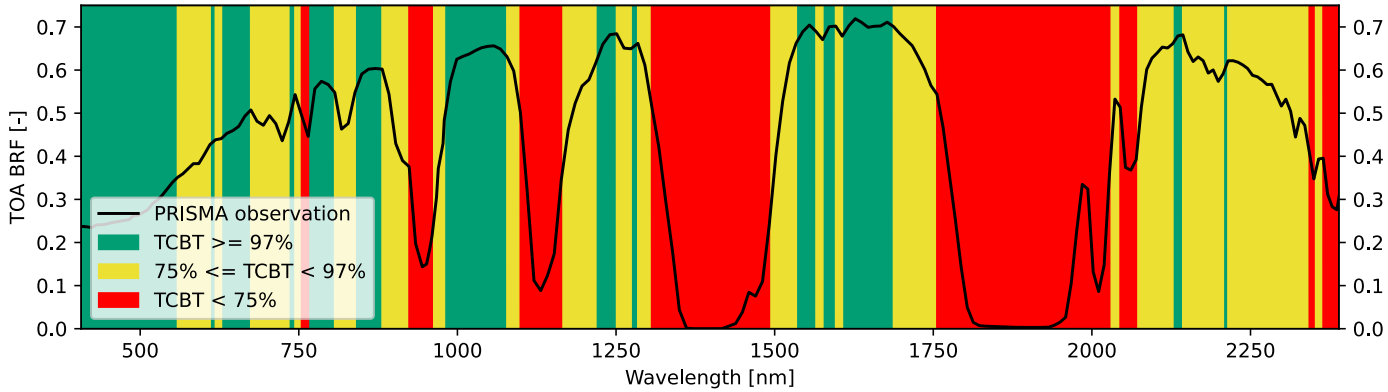


Libya-4

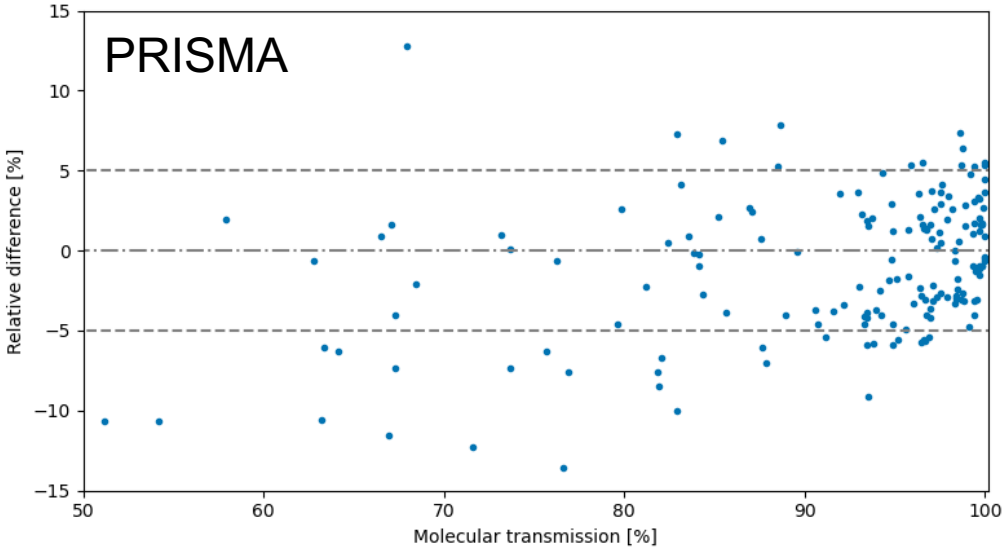




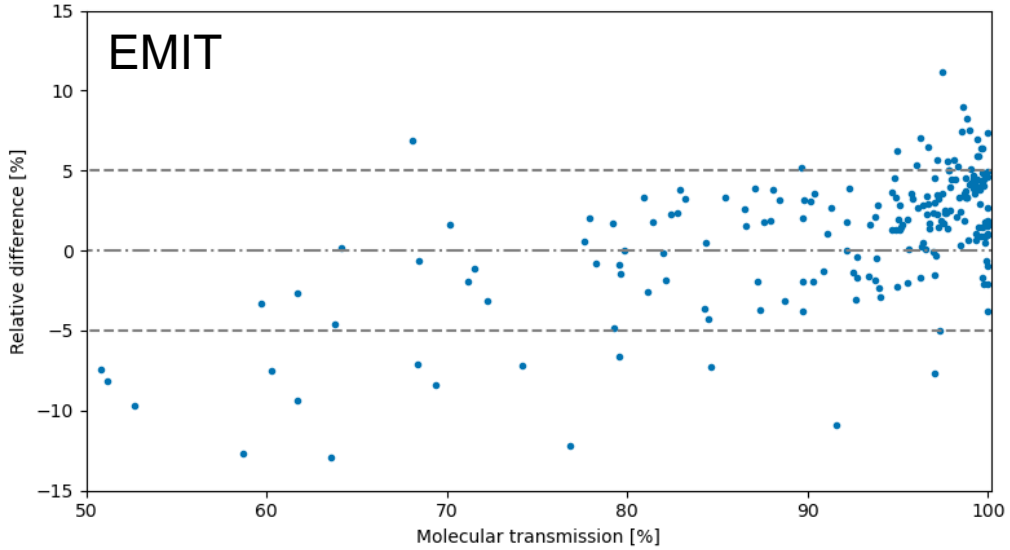
Mean relative bias

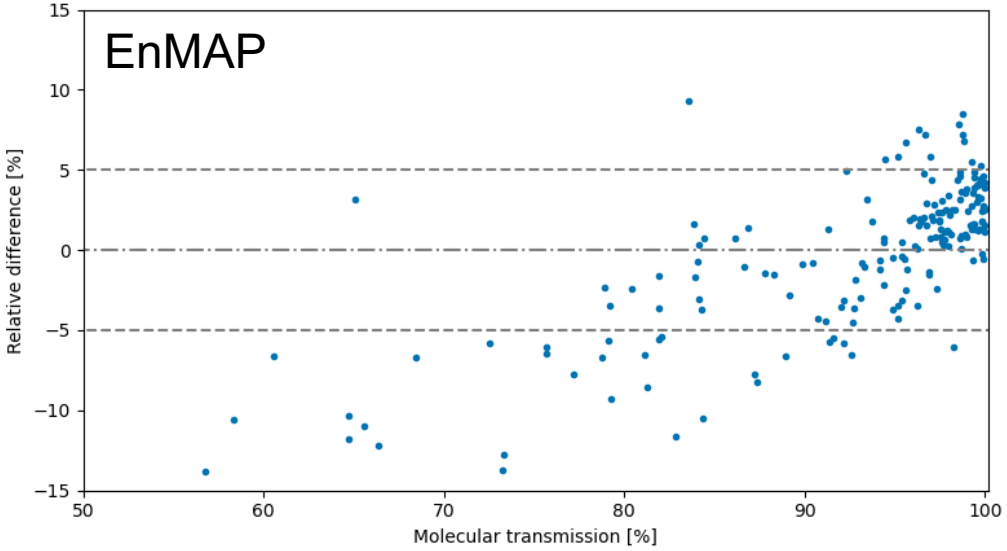


Relative differences versus molecular transmittance



Libya-4





Mean relative bias

	Molecular transmittance		
Instrument	**>97%**	**97 – 75%**	**< 50%**
EMIT	+3.0%	+1.55%	-15.41%
EnMAP	+2.75%	-0.28%	-16.62%
PRISMA	+0.69%	-1.7%	-10.4%

CONCLUSIONS
AND
WAY FORWARD

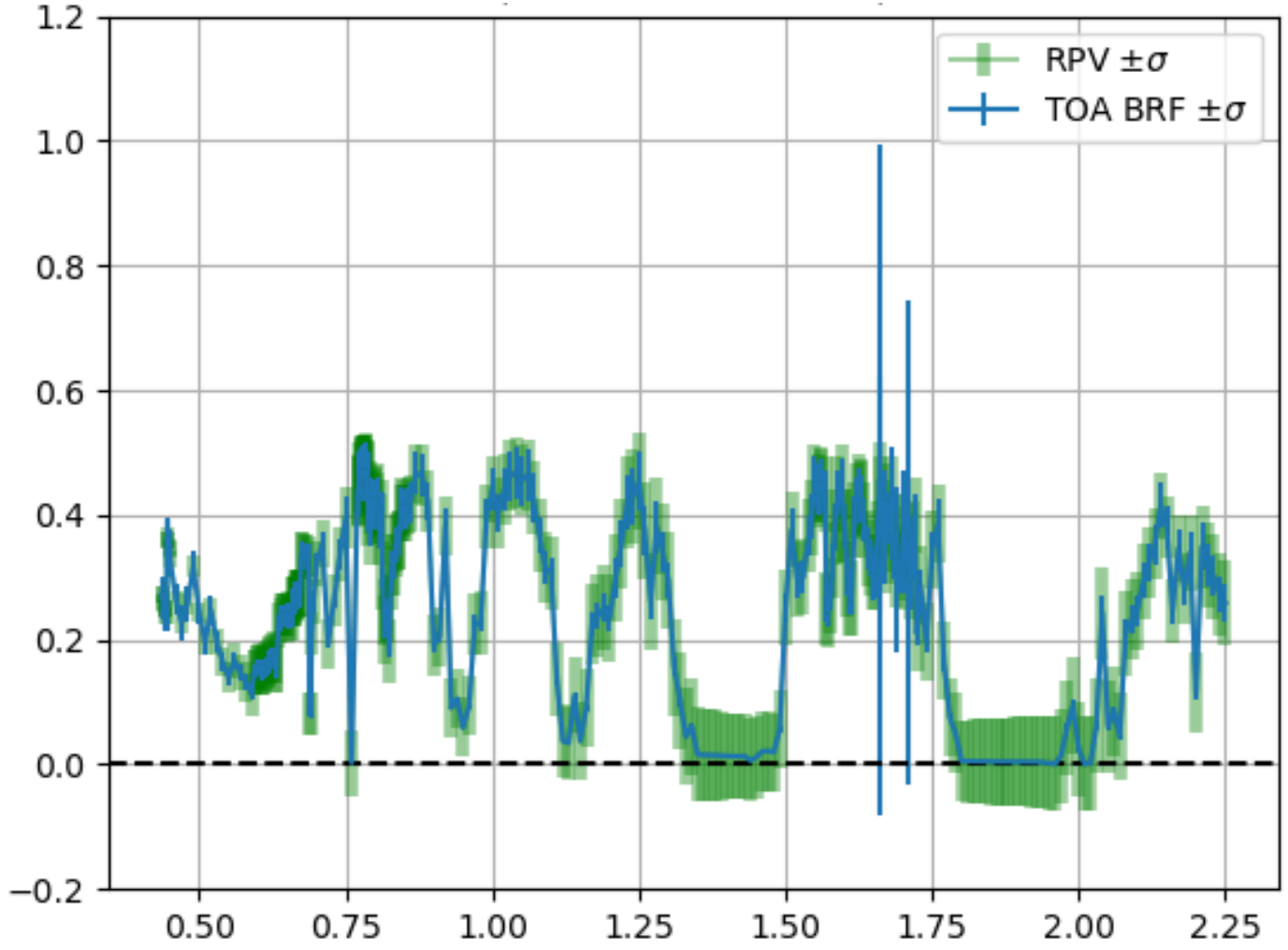
Conclusions

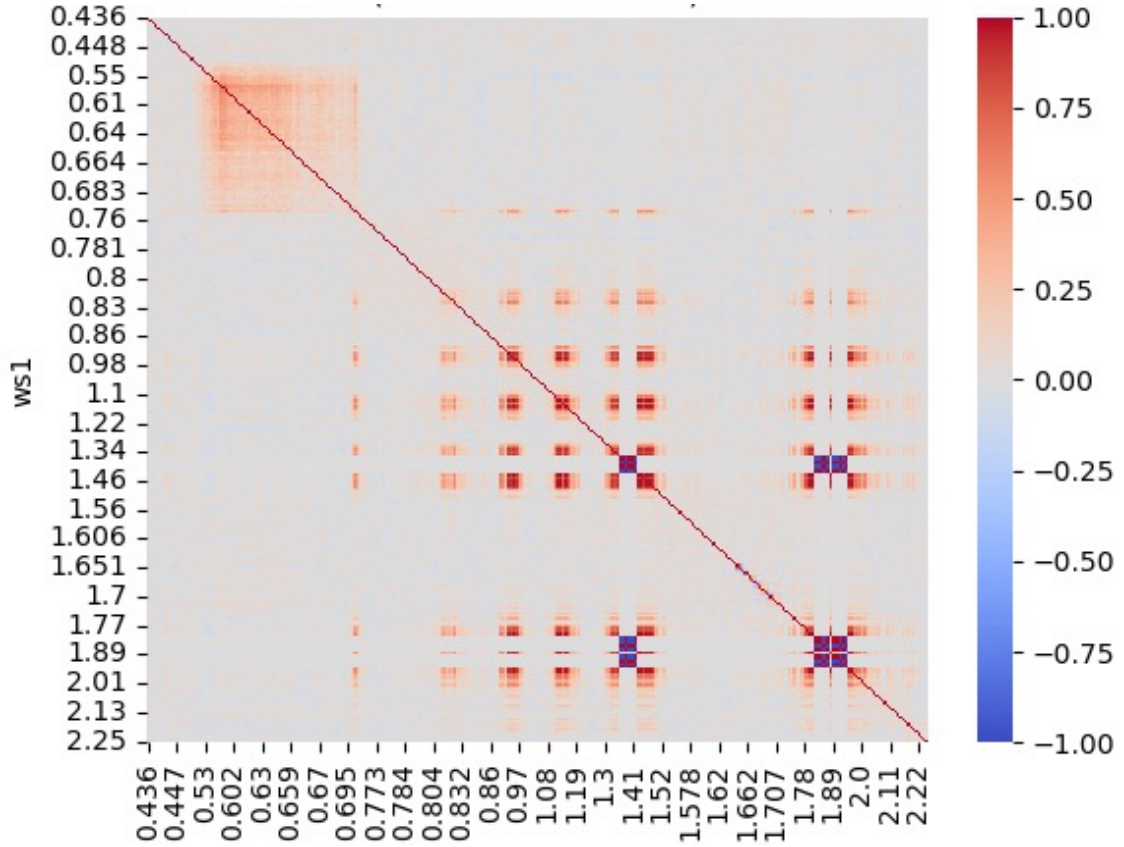
- Preliminary results!!
- Generation of a 1 nm resolution hyperspectral radiometric calibration reference;
- First comparison of PRISMA, EnMAP and EMIT with our hyperspectral radiometric calibration reference generated with Eradiate;
- The use of CAMS profile is recommended when the total column molecular transmittance is lower than 97% to secure accurate results;
- Current accuracy is within [-5%,+5%] across most of the VIS – SWIR spectral domain.

Way forward

- Long-term objective is to reduce the uncertainty to ±1% to support the TRUTHS/HIS observations.
- Perform some minor improvements to our calibration reference;
- Process more PRISMA, EnMAP and EMIT observations acquired over different PICS;
- Additional work is needed for spectral regions where the molecular transmittance is lower than 75% (our reference is too bright);
- Rayference Radiometric Calibration reference uncertainty estimation;

Uncertainty estimation





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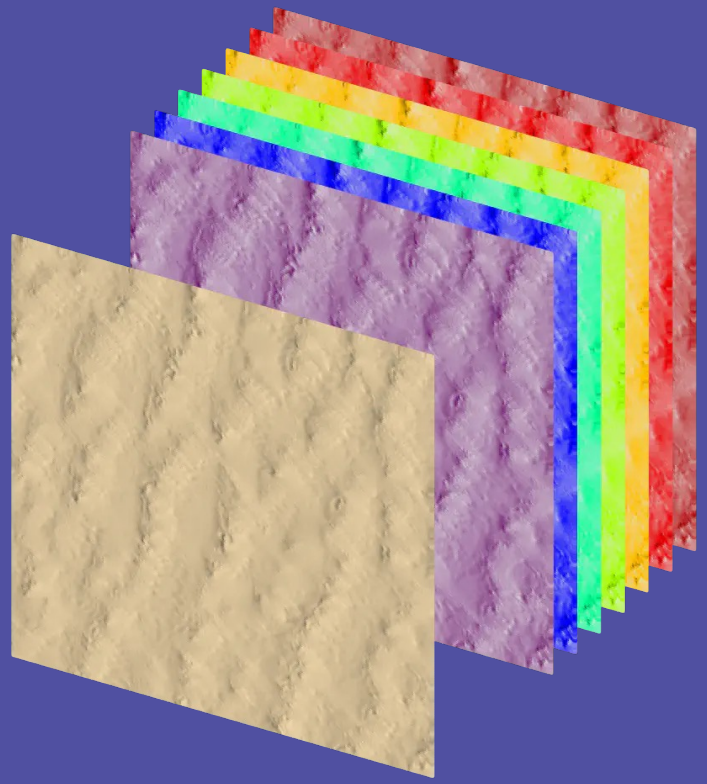

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Training session

12th Nov 2024

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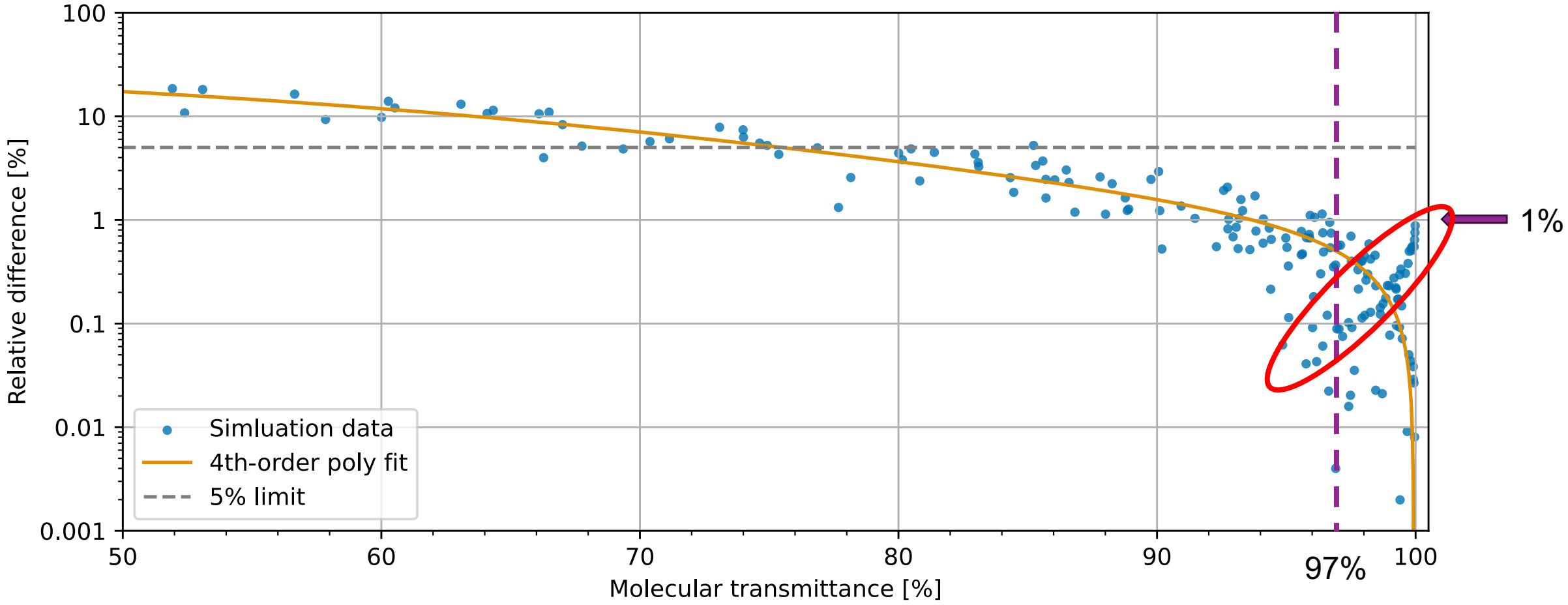
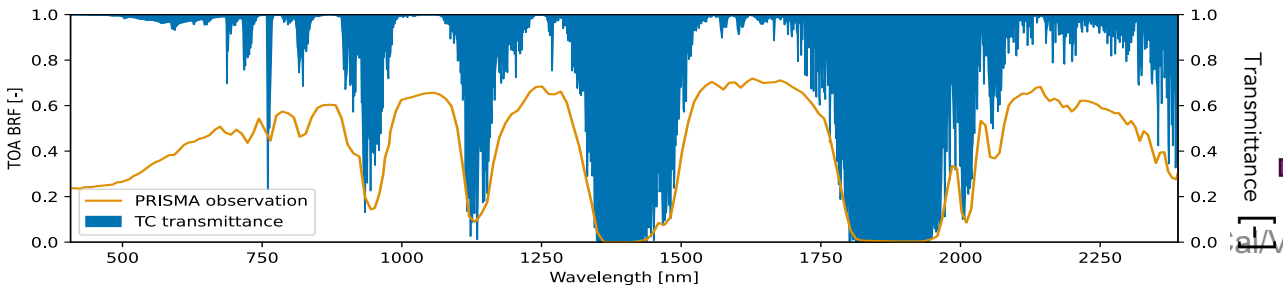
Relative difference versus molecular transmittance





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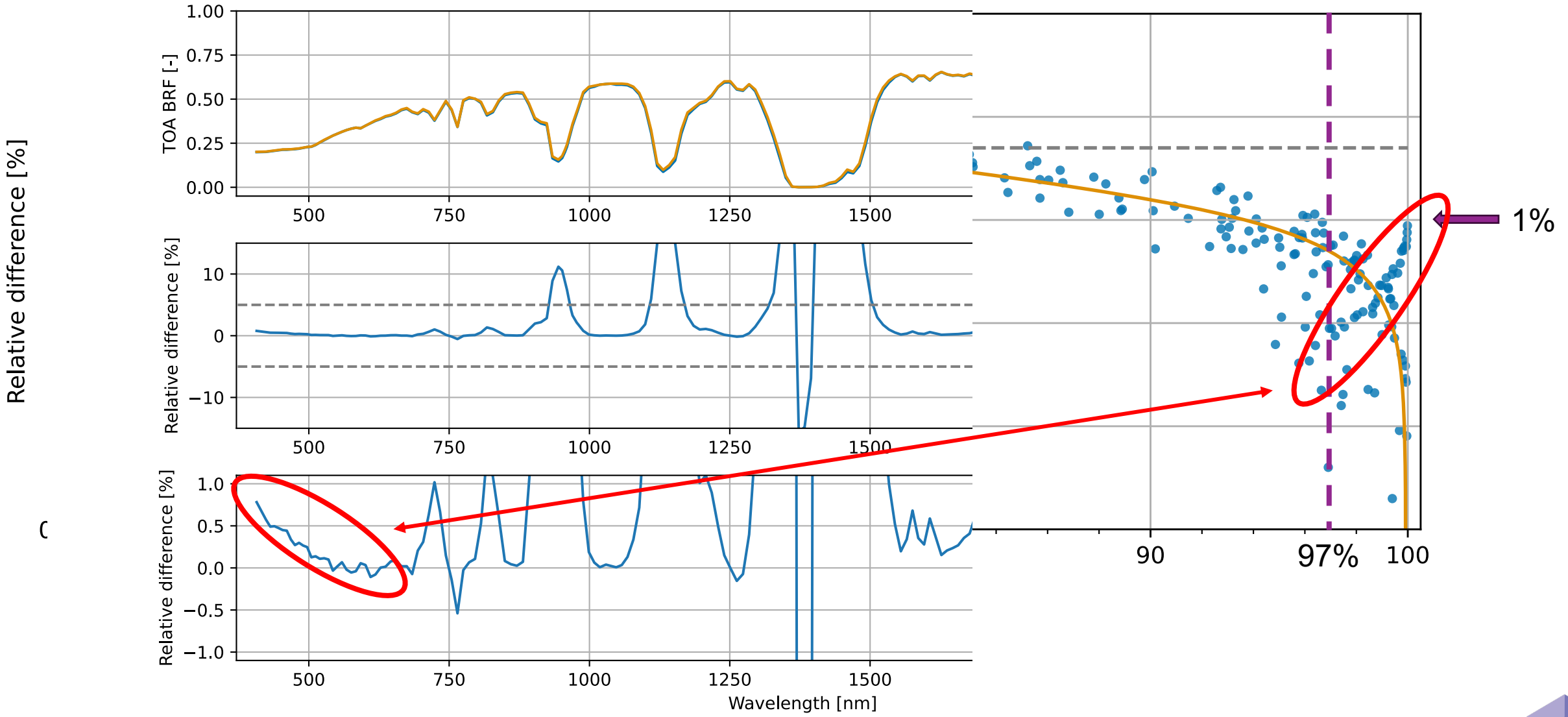
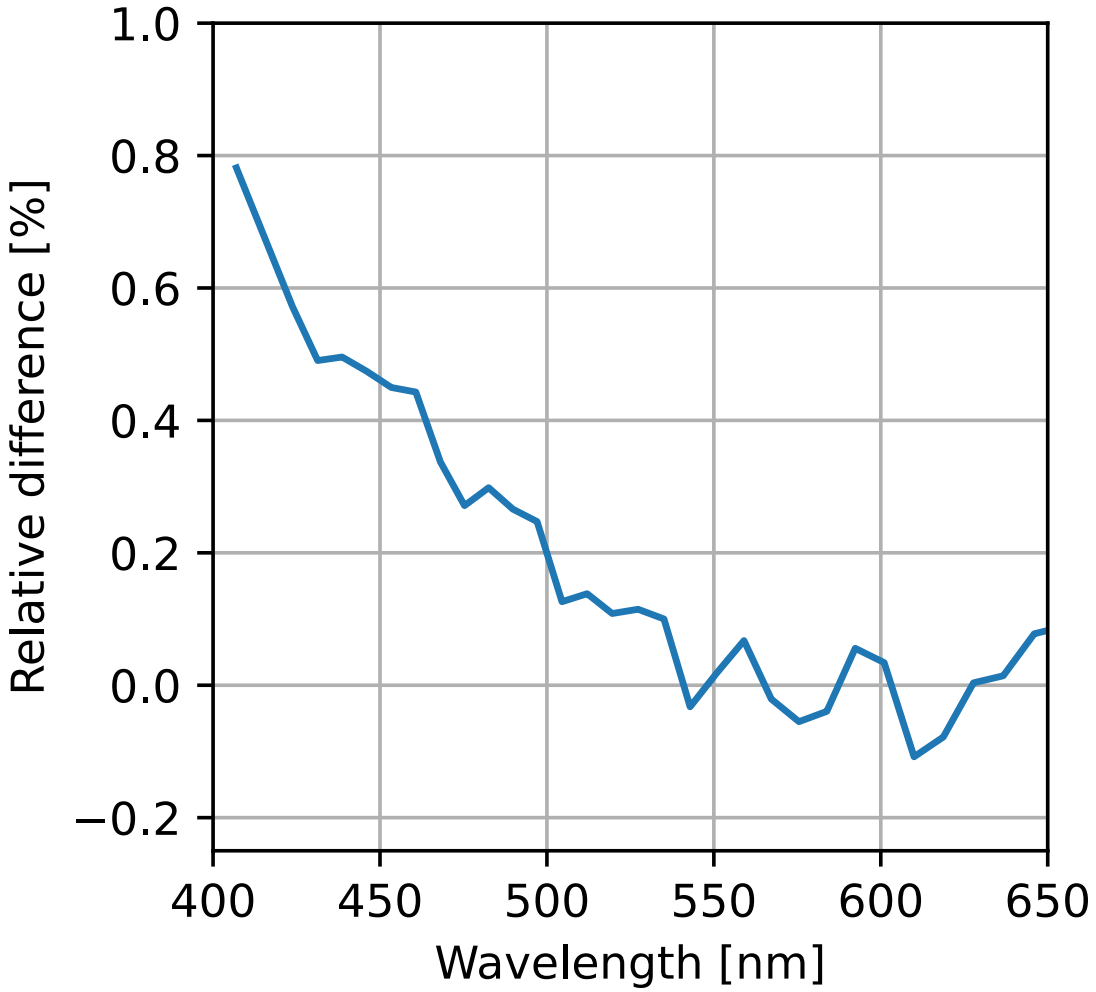
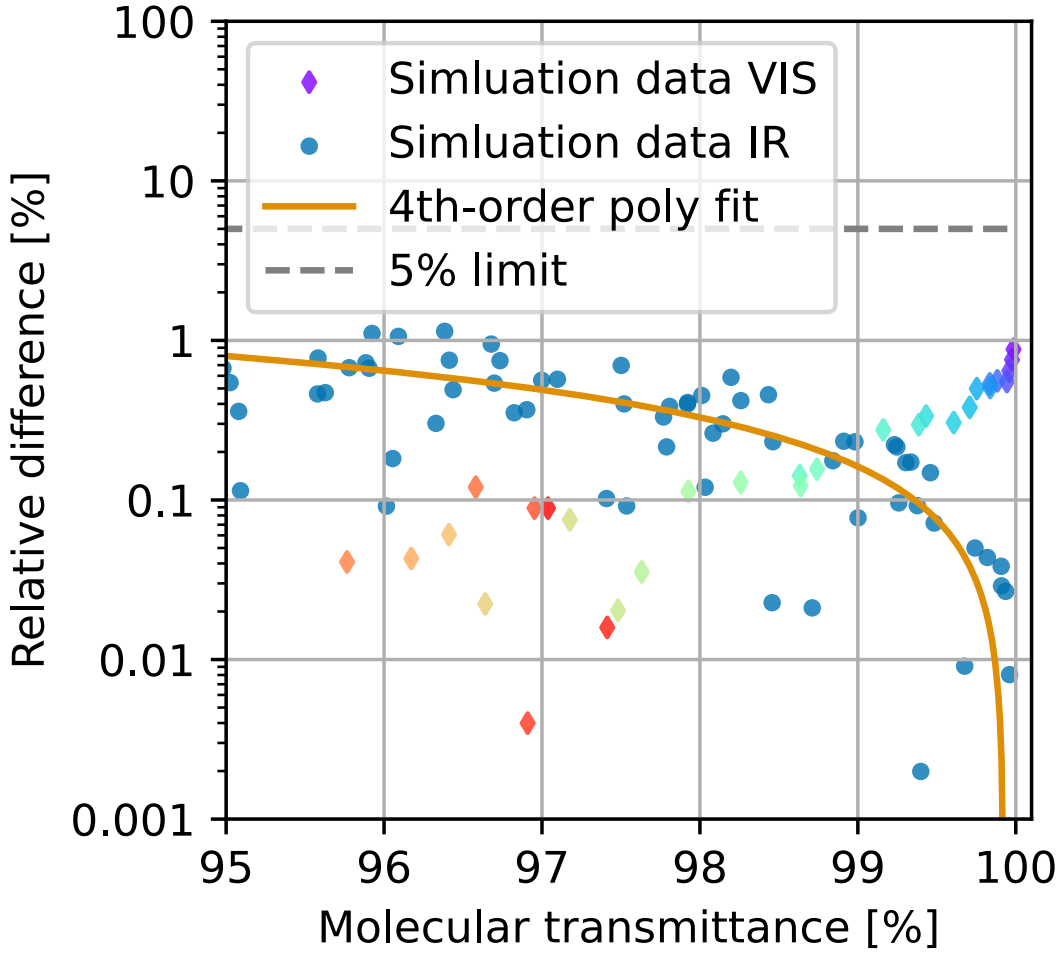
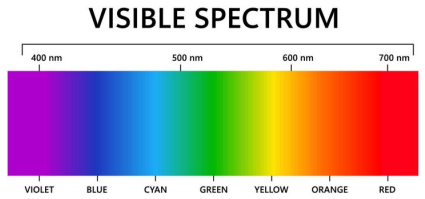


Rayleigh scattering



Rayleigh scattering depends on the pressure and temperature





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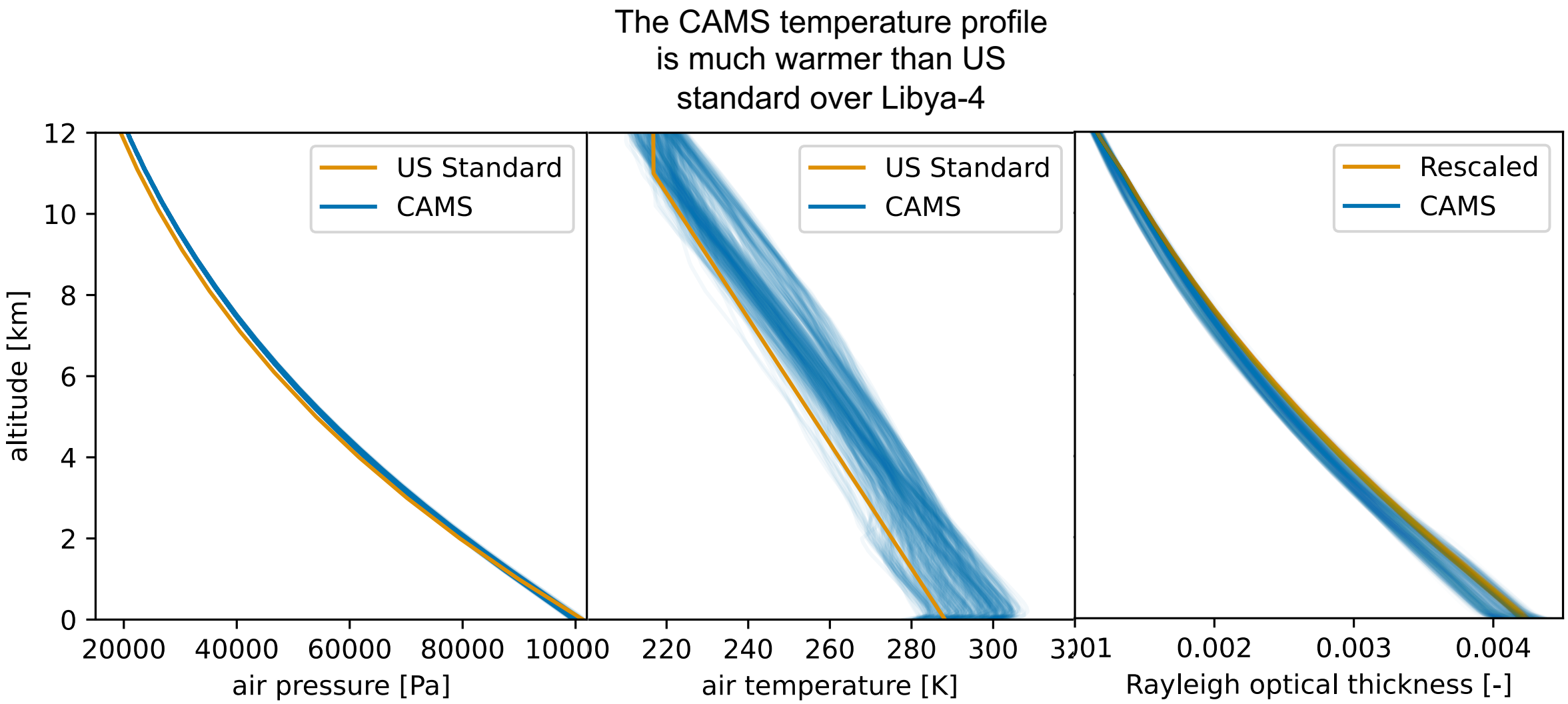

Why bright desert PICS?