First year EnMAP radiometric performance based on scenes over RadCalNet and PICS sites

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Hyperspectral/Multispectral Imaging and Sounding of the Environment (HISE)
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Federal Ministry for Economic Affairs and Climate Action

EnMAP (Environmental Mapping and Analysis Program)

www.enmap.org

Mission fact sheet (abbreviated)

EnMAP specification	VNIR	SWIR
Spectral range	420 – 1000 nm	900 – 2445 nm
Number of spectral bands	91	133
Spectral sampling distance	6.5 nm	10 nm
Spectral full width at half maximum	6 – 11 nm	7 – 11 nm
Spectral accuracy	0.5 nm	1 nm
Radiometric accuracy	<5%	
Radiometric stability	<2.5%	
Orbit type, altitude and inclination	Sun-synchronous, 653 km, 97.96°	
Orbit period and repeat cycle	1.6 h, 398 revolutions in 27 days	
Local time descending node	11:00 h ± 18 min	
Revisit time	4 days (±30° off-nadir tilt) 21 days (±5° off-nadir tilt)	
Ground sampling distance	30 m (at nadir; sea level)	
Swath width	30 km (2.63° across track)	
Swath length	1000 km / orbit; 5000 km / day	
Product size	30 km x 30 km	

Mission status:

- Launch: Apr 1, 2022
- Commissioning: Apr – Oct 2022
- Operations started in Nov 2022
- Tasking and download open to global users
- 31756 archived products as of 27.07.2023

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EnMAP talks at HISE:

- Ground Segment (T. Storch) Mon 2:30 PM
- Calibration (D. Marshall) Mon 3:00 PM
- Data QC (M. Bachmann) Wed 3:30 PM

This talk: EnMAP radiometric performance based on RadCalNet and PICS scenes

EnMAP tasking, acquisition and processing

Workflow:

- Task EnMAP over RadCalNet and PICS sites as often as possible.
- Select scenes of acceptable quality, geometry and weather.
- For RadCalNet scenes, select scenes with coincident RadCalNet data.
- L1B process scenes and evaluate based on top-of-atmosphere reflectances.

Challenges:

- Reduced observation opportunities for each site.
- Increased tasking difficulties after start of operations (frequent order conflicts, outage Dec 2022 – Feb 2023).
- Coincident RadCalNet data not always available or reliable.

Note: Detailed list of all RadCalNet and PICS scenes in back-up slides.

EnMAP scenes over RadCalNet sites

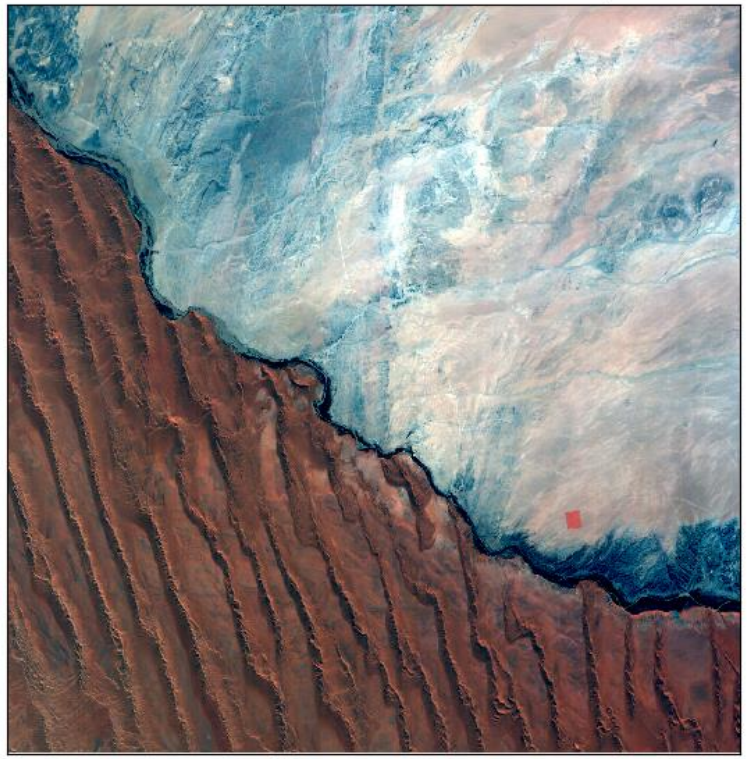
RCN RVUS DT0000001130 TILE2 VNIR QL

Railroad Valley (RVUS):
8 scenes
(6 with off-nadir <20°)

RCN LCFR DT0000001434 TILE33 VNIR QL

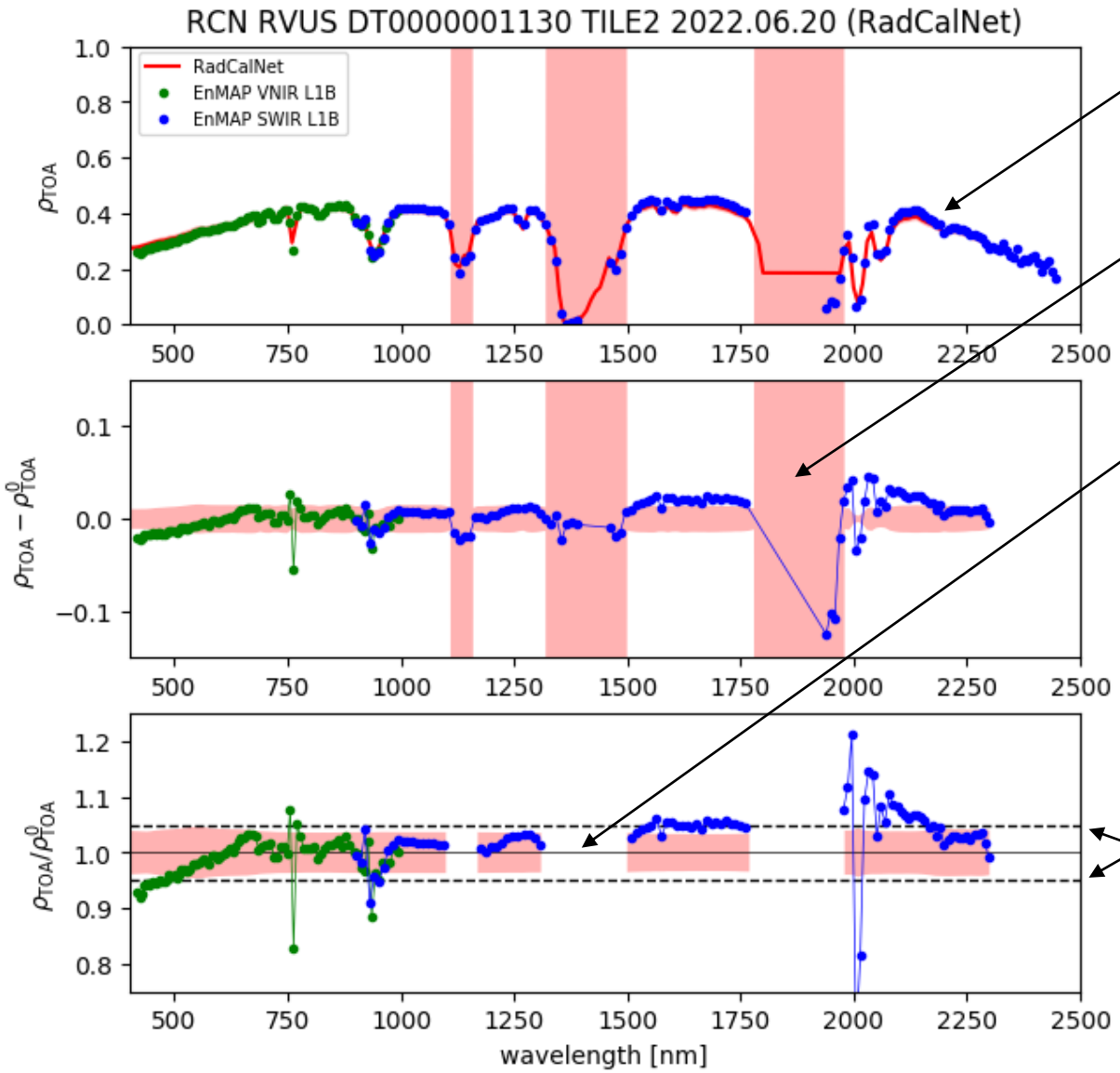
La Crau (LCFR):
1 scene

RCN GONA DT0000000006 TILE16 VNIR QL



Gobabeb (GONA):
9 scenes
(6 with off-nadir <20°)

Radiometric accuracy based on RadCalNet scenes



average EnMAP spectrum over ROI

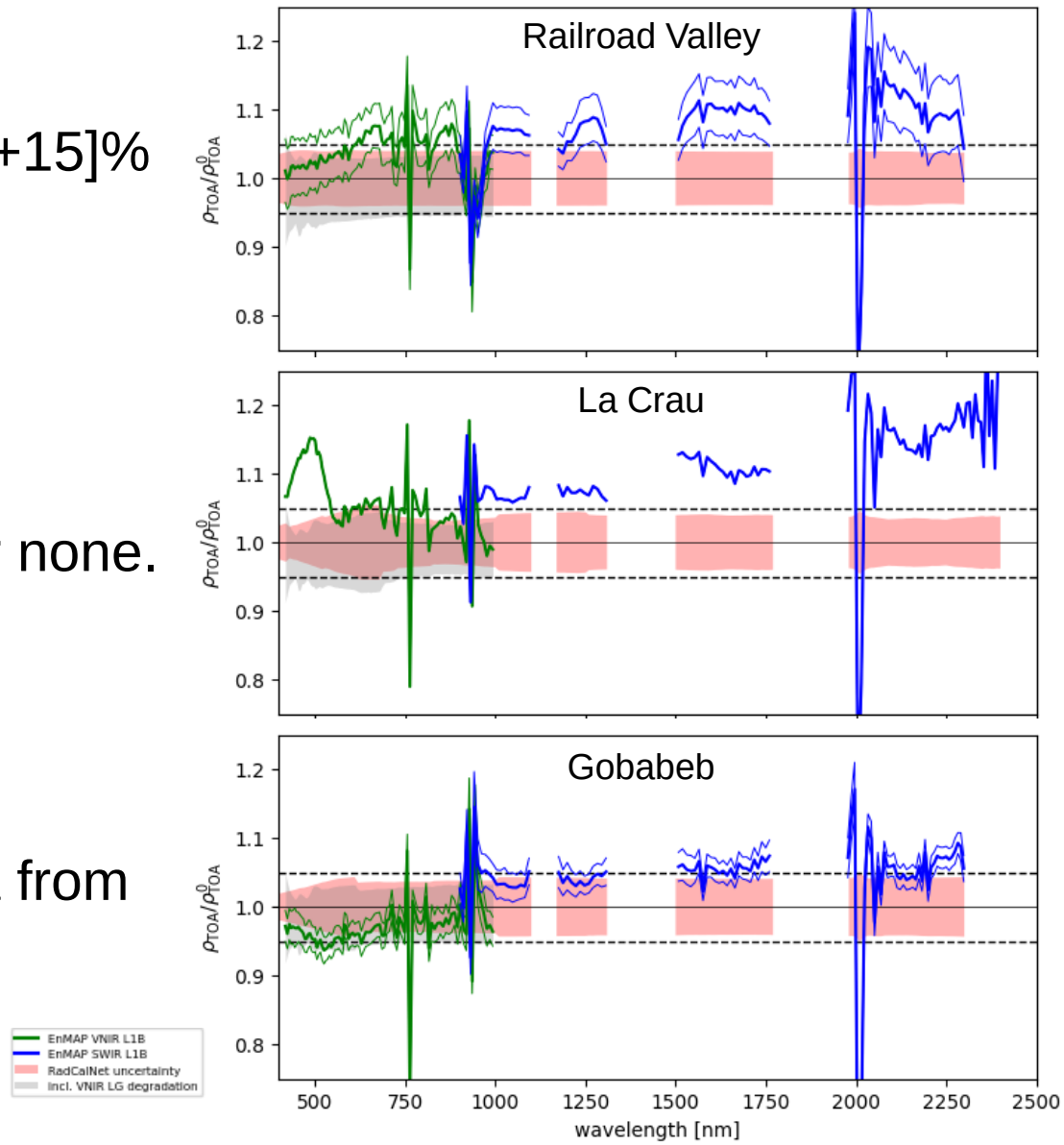
RadCalNet uncertainty

removed SWIR water absorption bands

radiometric accuracy requirement: 5%

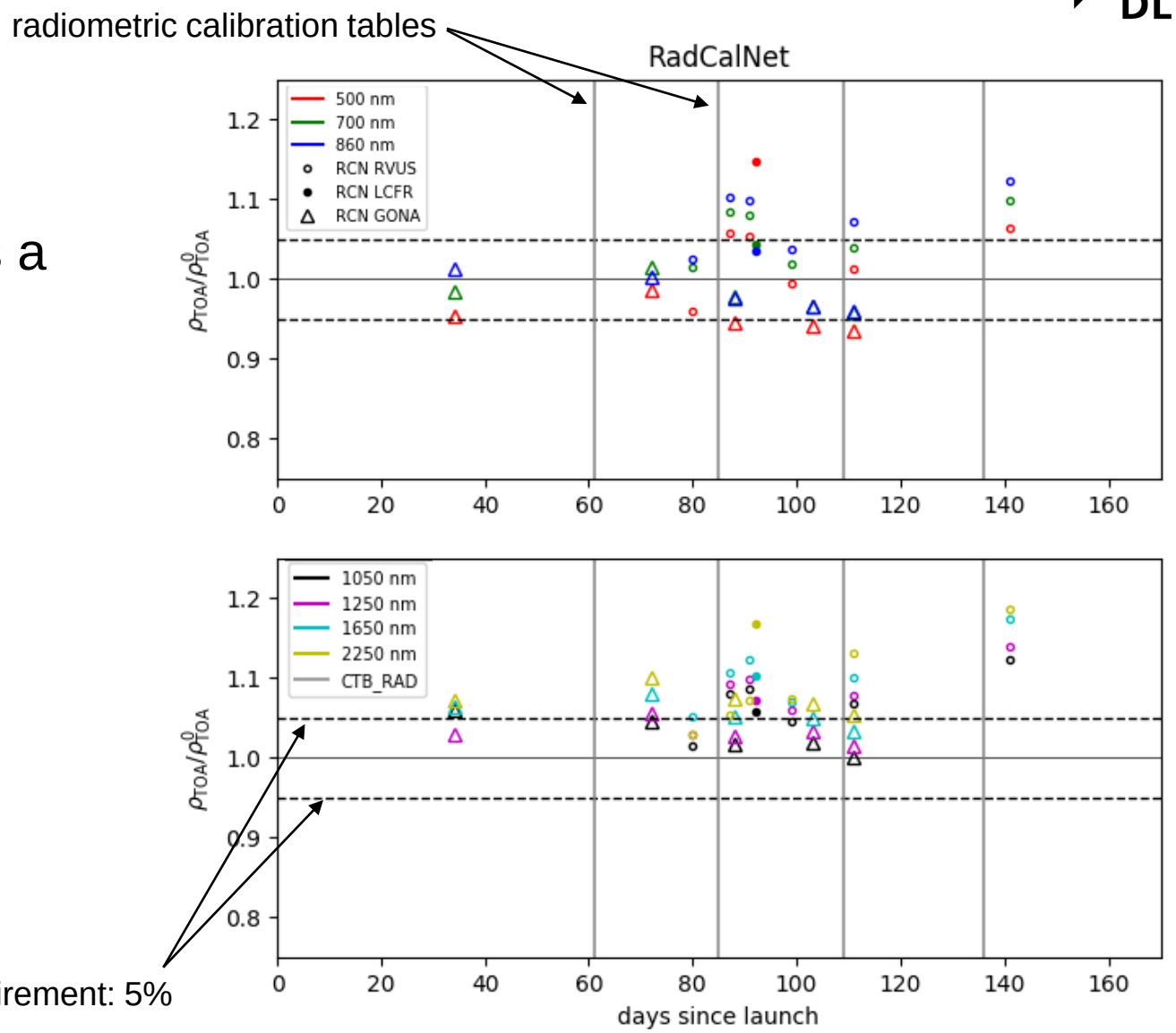
Radiometric accuracy based on RadCalNet scenes

- EnMAP vs RadCalNet TOA (nadir): [–5,+15]%
- Scene variability:
  - Railroad Valley: high
  - La Crau: one scene only
  - Gobabeb: low
- Correlation with off-nadir angle: small or none.
- VNIR/SWIR mismatch:
  - Railroad Valley: small or none
  - La Crau/Gobabeb: 5–10%
- Limited reliability of Railroad Valley data from Aug to Oct 2022.



Radiometric accuracy based on RadCalNet scenes

- No trend with time observed.
- No sign that VNIR degradation plays a role.



Radiometric accuracy based on RadCalNet scenes

EnMAP vs RadCalNet TOA (nadir): $\rho_{TOA}/\rho^{0}_{TOA}$ (1σ interval)									
VNIR				SWIR					Number of scenes
500 nm	700 nm	860 nm	avg.	1050 nm	1250 nm	1650 nm	2250 nm	avg.	
1.00±0.06	1.02±0.05	1.03±0.05	1.02±0.06	1.05±0.03	1.06±0.04	1.08±0.04	1.09±0.05	1.07±0.04	12

Bottomline: Comparison to RadCalNet is roughly in line with the 5% requirement for VNIR and slightly above for SWIR.

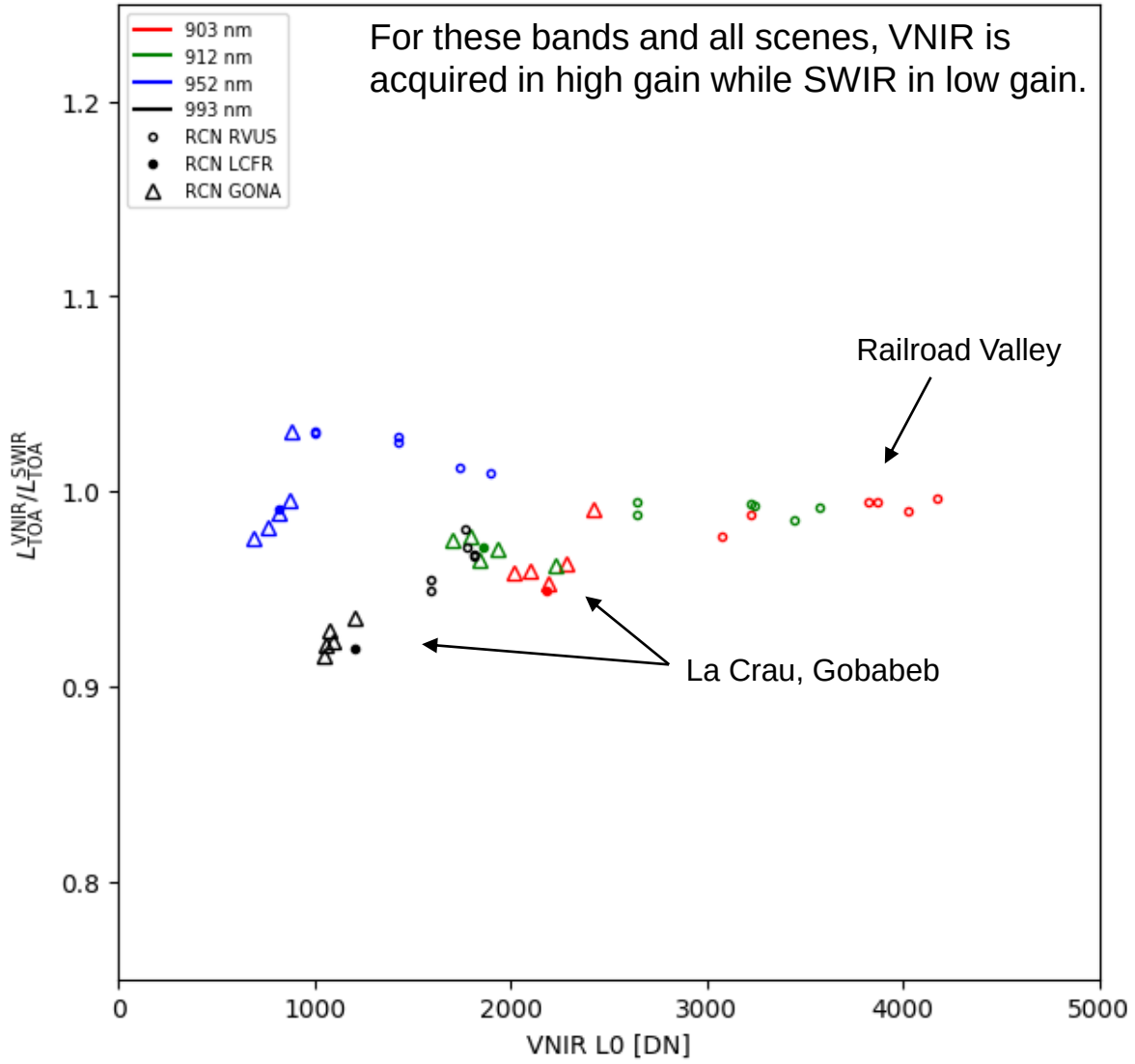
Disclaimer: These numbers are not a direct estimation of EnMAP radiometric accuracy but are due to uncertainties on RadCalNet data, scene and instrument.

Uncertainties:

- RadCalNet data 3–5%
- Scene
  - BRDF variable
  - Path radiance small effect
  - Georeferencing small effect
- Instrument
  - VNIR degradation <1–3%
  - Radiometric accuracy <5% (req.)

VNIR/SWIR mismatch in overlapping spectral range

- Mismatch observed in RadCalNet scenes hints at signal-dependent effect.
- Behaviour clearly confirmed in Moon observations.
- Trend with raw VNIR signal points to non-linearity inconsistencies in VNIR high gain.
- Root cause and calibration-based solution under investigation.



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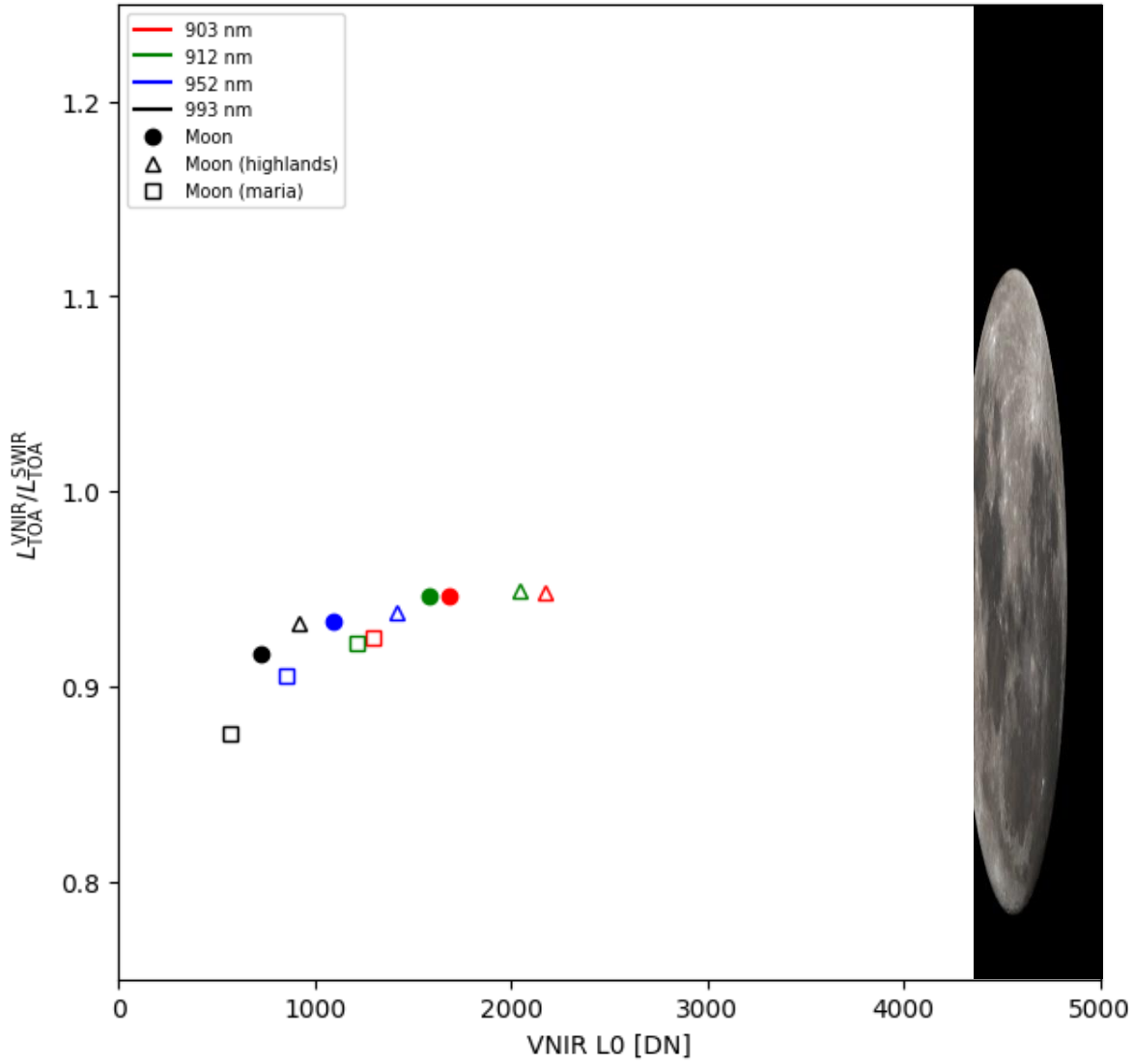
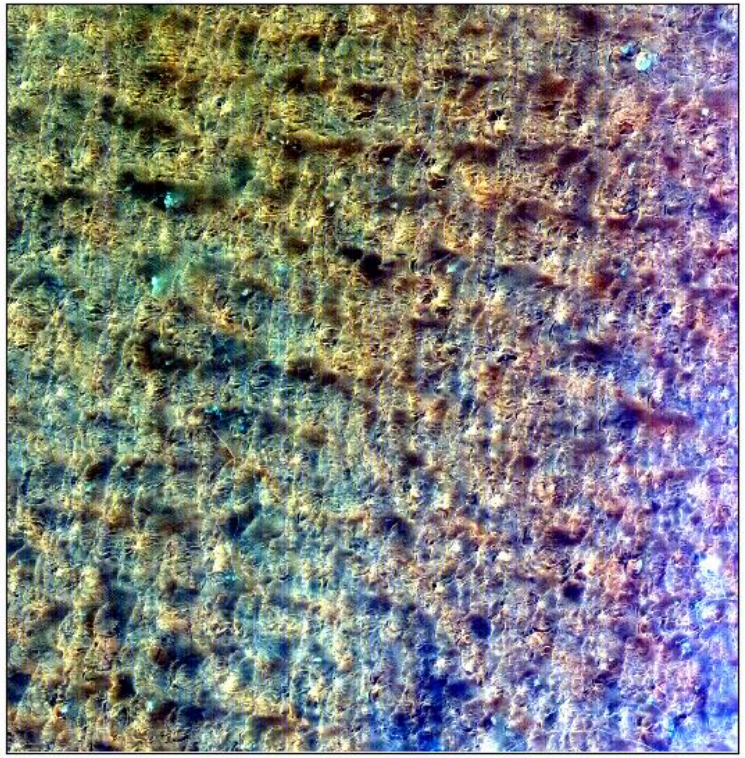
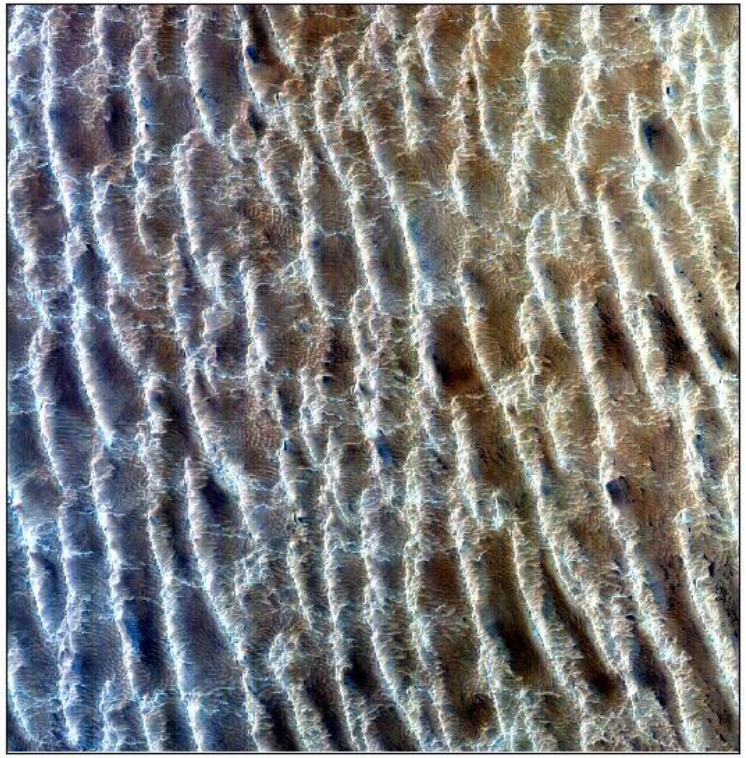


EnMAP scenes over PICS sites

Algeria3 DT0000000005 TILE1 VNIR QL



Libya4 DT0000001969 TILE2 VNIR QL



Niger2 DT0000001387 TILE1 VNIR QL

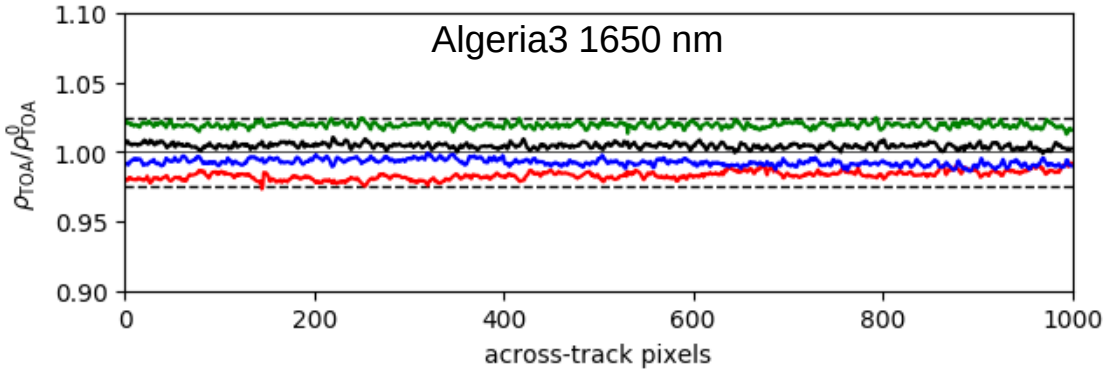
Algeria3:
6 scenes
(4 with off-nadir <20°)

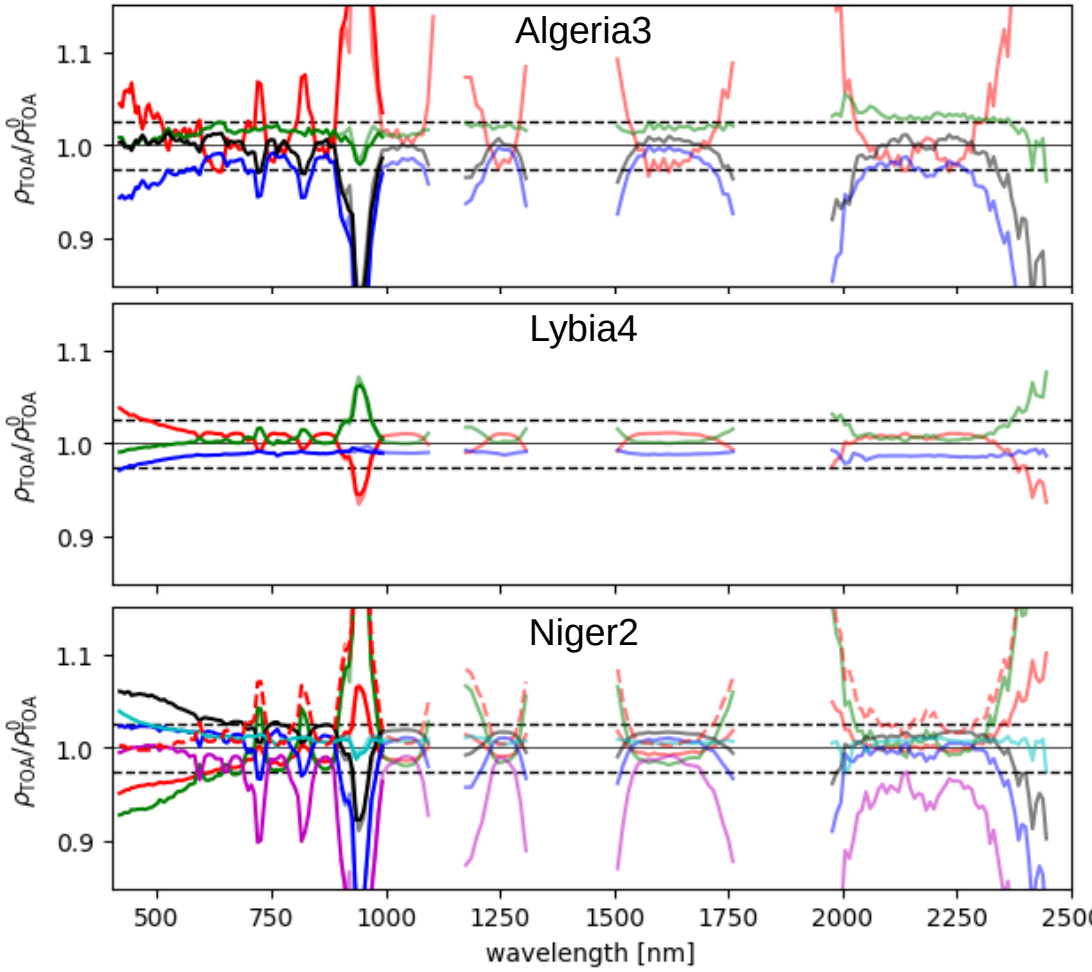
Libya4:
4 scenes
(3 with off-nadir <20°)

Niger2:
11 scenes
(7 with off-nadir <20°)

Radiometric stability based on PICS scenes

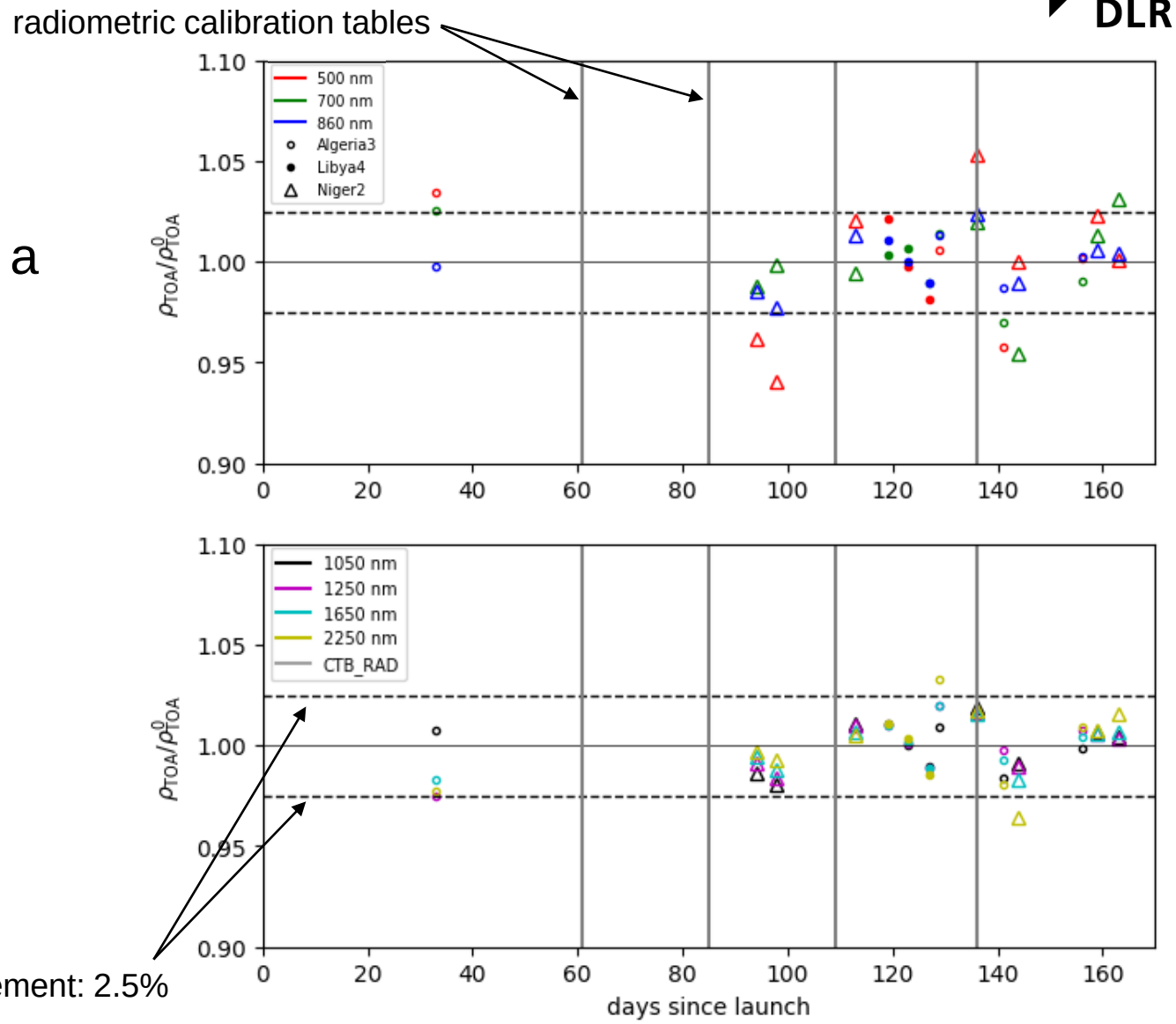
- Scene variability:
  - Algeria3: <5%
  - Lybia4: <2.5%
  - Niger2: <5%
- High stability except for absorption bands and low wavelengths.
- High across-track uniformity.





Radiometric stability based on PICS scenes

- No trend with time observed.
- No sign that VNIR degradation plays a role.



Radiometric stability based on PICS scenes

Scene variability: $\rho_{TOA}/\rho^{0}_{TOA}$ (1σ interval)									
VNIR				SWIR					Number of scenes
500 nm	700 nm	860 nm	avg.	1050 nm	1250 nm	1650 nm	2250 nm	avg.	
1.00±0.03	1.00±0.02	1.00±0.01	1.00±0.02	1.00±0.01	1.00±0.01	1.00±0.01	1.00±0.02	1.00±0.01	14

Bottomline: PICS scene variability is well below the 2.5% requirement for VNIR and especially for SWIR.

Disclaimer: These numbers are not a direct estimation of EnMAP radiometric stability but are due to uncertainties on scene and instrument.

Uncertainties:

- Scene
  - Footprint — small effect
  - BRDF — variable
  - Path radiance — small effect
  - Georeferencing — small effect
- Instrument
  - VNIR degradation — <1–3%
  - Radiometric stability — <2.5% (req.)

Conclusion

- Radiometric accuracy (RadCalNet): VNIR in line and SWIR above 5% requirement, but conclusion not possible due to underlying uncertainties.
- Radiometric stability (PICS): VNIR and SWIR below 2.5% requirement despite underlying uncertainties.
- More data and analysis are needed for solid statistical conclusions.

Ongoing work:

- Extend analysis with additional scenes.
- Include scene-specific TOA simulated data and coincident satellite data.
- Use continously improved processor (VNIR dynamic coefficients, destriping, improved geolocation and co-registration).

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BACKUP SLIDES

EnMAP scenes over RadCalNet sites

RadCalNet site	Datatake ID	Date	Across-track off-nadir [°]	Along-track off-nadir [°]	Scene azimuth [°]	Comment
Railroad Valley (RVUS)	1130	20.06.2022	-13.5°	-1.0°	13.2°	Suspected adverse climate close to time of acquisition.
	1251	27.06.2022	18.9°	0.7°	13.1°	
	1382	01.07.2022	12.7°	0.4°	13.2°	
	1549	09.07.2022	-0.6°	-0.4°	13.2°	Suspected adverse climate close to time of acquisition.
	1727	16.07.2022	29.8°	1.4°	13.1°	Ignored since off-nadir >20°.
	1818	20.07.2022	24.7°	1.0°	13.1°	Ignored since off-nadir >20°.
	1828	21.07.2022	-19.5°	-1.4°	13.1°	
	2707	20.08.2022	19.8°	0.7°	13.1°	
La Crau (LCFR)	1434	02.07.2022	-10.5°	-0.8°	13.8°	
Gobabeb (GONA)	6	05.05.2022	-16.4°	-0.8°	12.1°	
	1048	12.06.2022	13.2°	0.8°	12.2°	
	1253	28.06.2022	-17.4°	-1.0°	12.2°	
	1384	02.07.2022	-24.1°	-1.5°	12.2°	Ignored since off-nadir >20°.
	1665	13.07.2022	5.9°	0.3°	12.2°	
	1728	17.07.2022	29.8°	1.4°	12.2°	Ignored since off-nadir >20°.
	1829	21.07.2022	-9.6°	-0.6°	12.2°	
	2810	24.08.2022	27.9°	1.8°	12.2°	Ignored since off-nadir >20°.
	1119	16.06.2022	5.6°	0.3°	12.2°	Only CNES reference data.

Notes:

- Frequent tasking conflicts
- Outage Dec 2022 – Feb 2023
- Limited RadCalNet LCFR and GONA data availability
- Limited RadCalNet RVUS data reliability Aug – Oct 2022
- New scenes to be added

EnMAP scenes over PICS sites

RadCalNet site	Datatake ID	Date	Across-track off-nadir [°]	Along-track off-nadir [°]	Scene azimuth [°]	Comment
Algeria3	5	04.05.2022	-6.7°	-0.6°	12.5°	
	2038	31.07.2022	28.0°	1.4°	12.5°	Ignored since off-nadir >20°.
	2176	04.08.2022	21.9°	1.0°	12.5°	Ignored since off-nadir >20°.
	2271	08.08.2022	15.5°	0.6°	12.5°	
	2705	20.08.2022	-6.1°	-0.7°	12.5°	
	3165	04.09.2022	15.3°	0.5°	12.5°	
Lybia4	1969	29.07.2022	1.5°	-0.2°	12.4°	
	2032	02.08.2022	-6.0°	-0.6°	12.4°	
	2273	06.08.2022	-13.2°	-1.0°	12.4°	
	3184	05.09.2022	29.1°	1.6°	12.4°	Ignored since off-nadir >20°.
Niger2	1387	04.07.2022	-12.0°	-1.0°	12.1°	
	1544	08.07.2022	-19.3°	-1.5°	12.1°	
	1584	12.07.2022	-25.8°	-2.0°	12.1°	Ignored since off-nadir >20°.
	1585	11.07.2022	25.9°	1.5°	12.1°	Ignored since off-nadir >20°.
	1932	23.07.2022	4.3°	-0.04°	12.1°	
	2401	11.08.2022	20.3°	1.0°	12.1°	Ignored since off-nadir >20°.
	2502	15.08.2022	13.2°	0.5°	12.1°	
	2808	23.08.2022	-12.9°	-0.4°	12.1°	
	3132	03.09.2022	26.6°	1.5°	12.1°	Ignored since off-nadir >20°.
	3244	07.09.2022	19.7°	1.0°	12.1°	
	3262	11.09.2022	12.1°	0.6°	12.1°	

Notes:

- Frequent tasking conflicts
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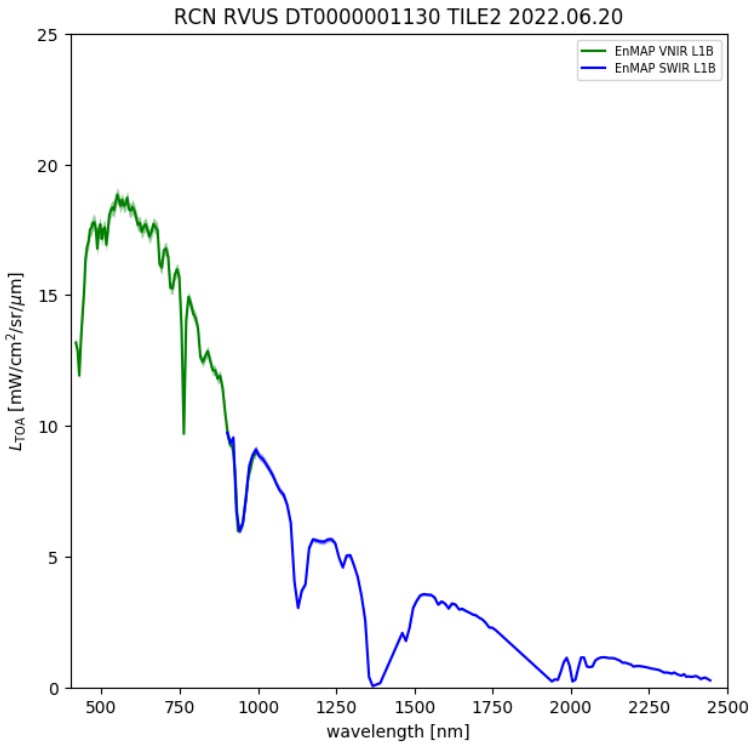
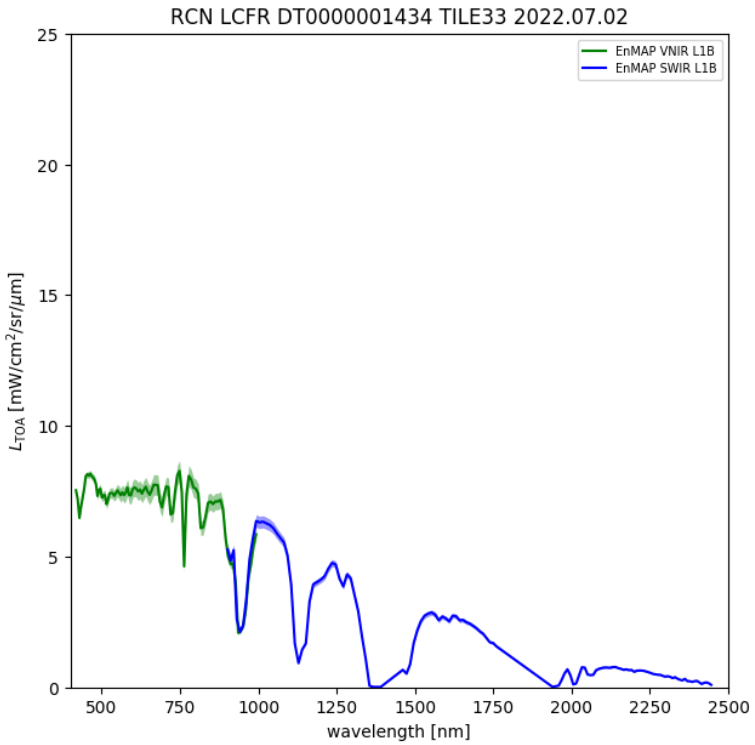
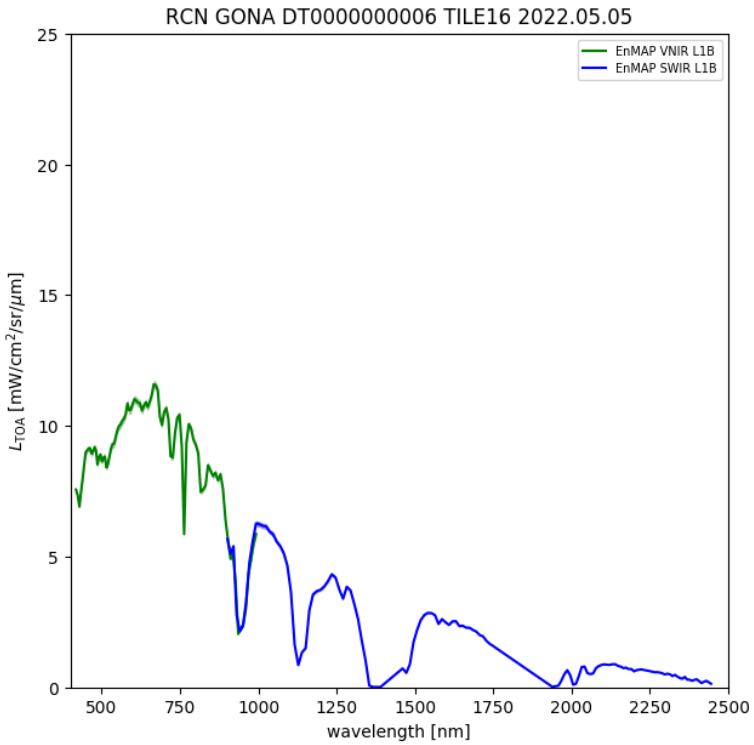
EnMAP scenes over RadCalNet sites



Railroad Valley (RVUS):
8 scenes
(6 with off-nadir <20°)

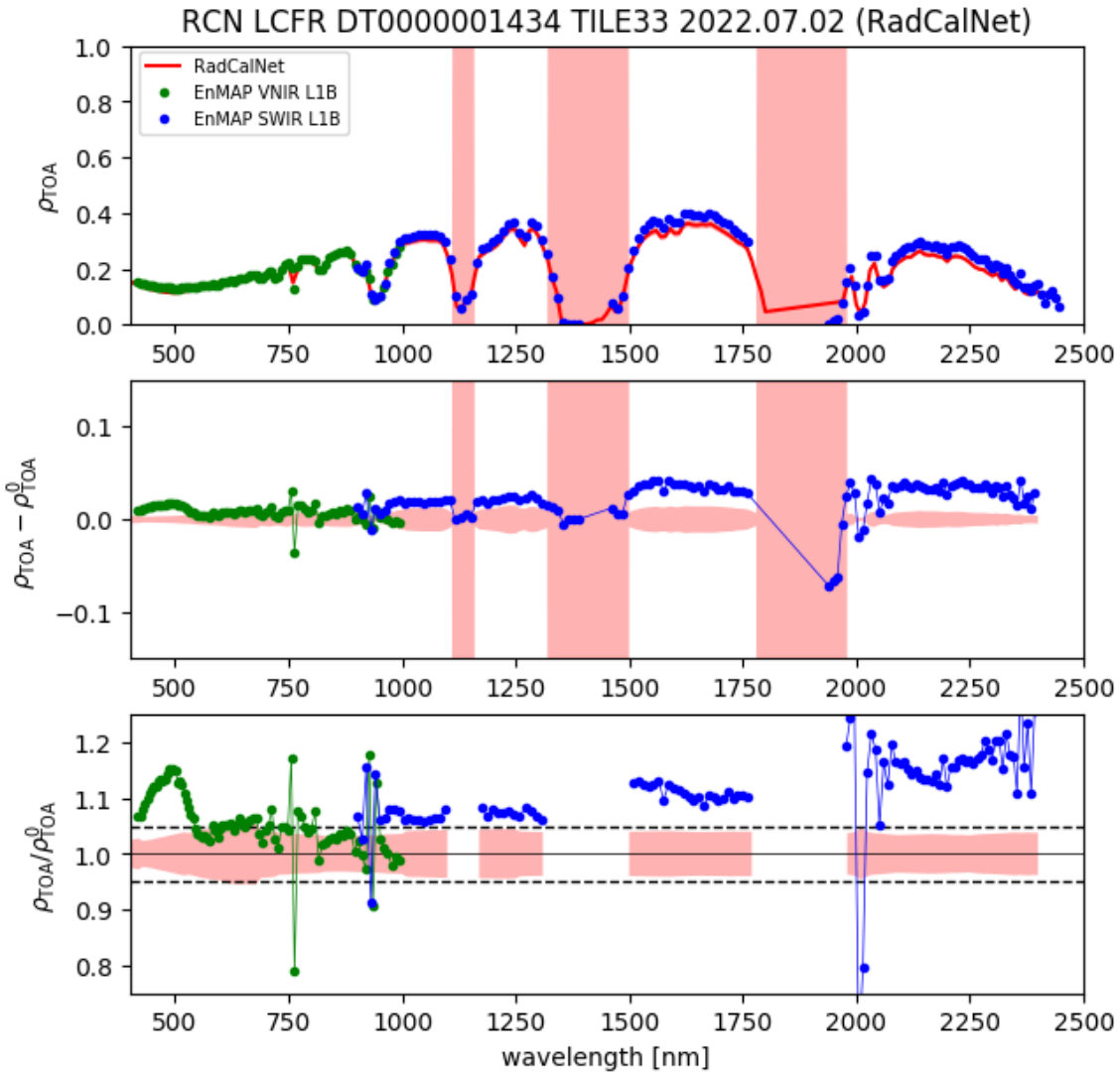


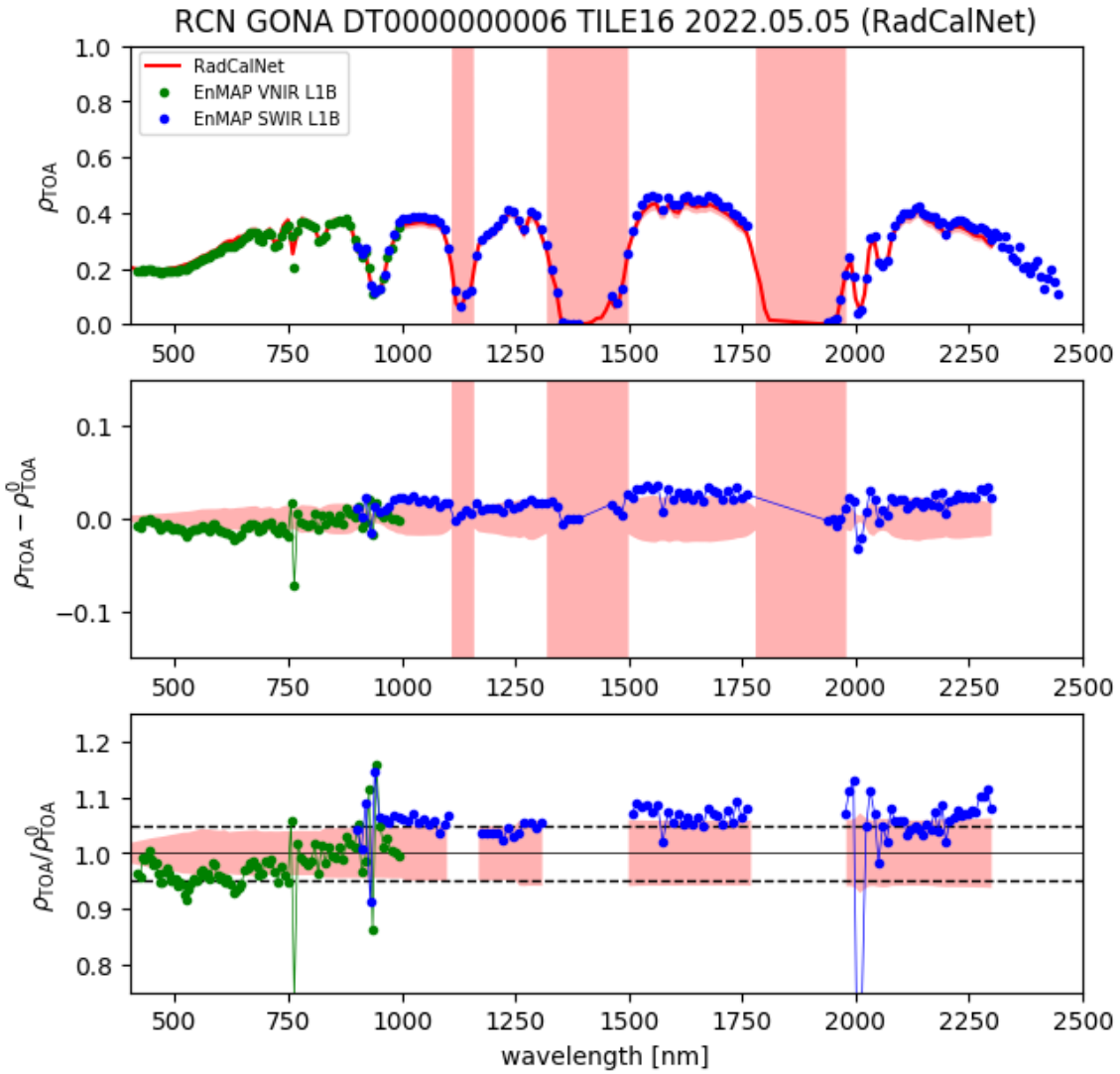
La Crau (LCFR):
1 scene



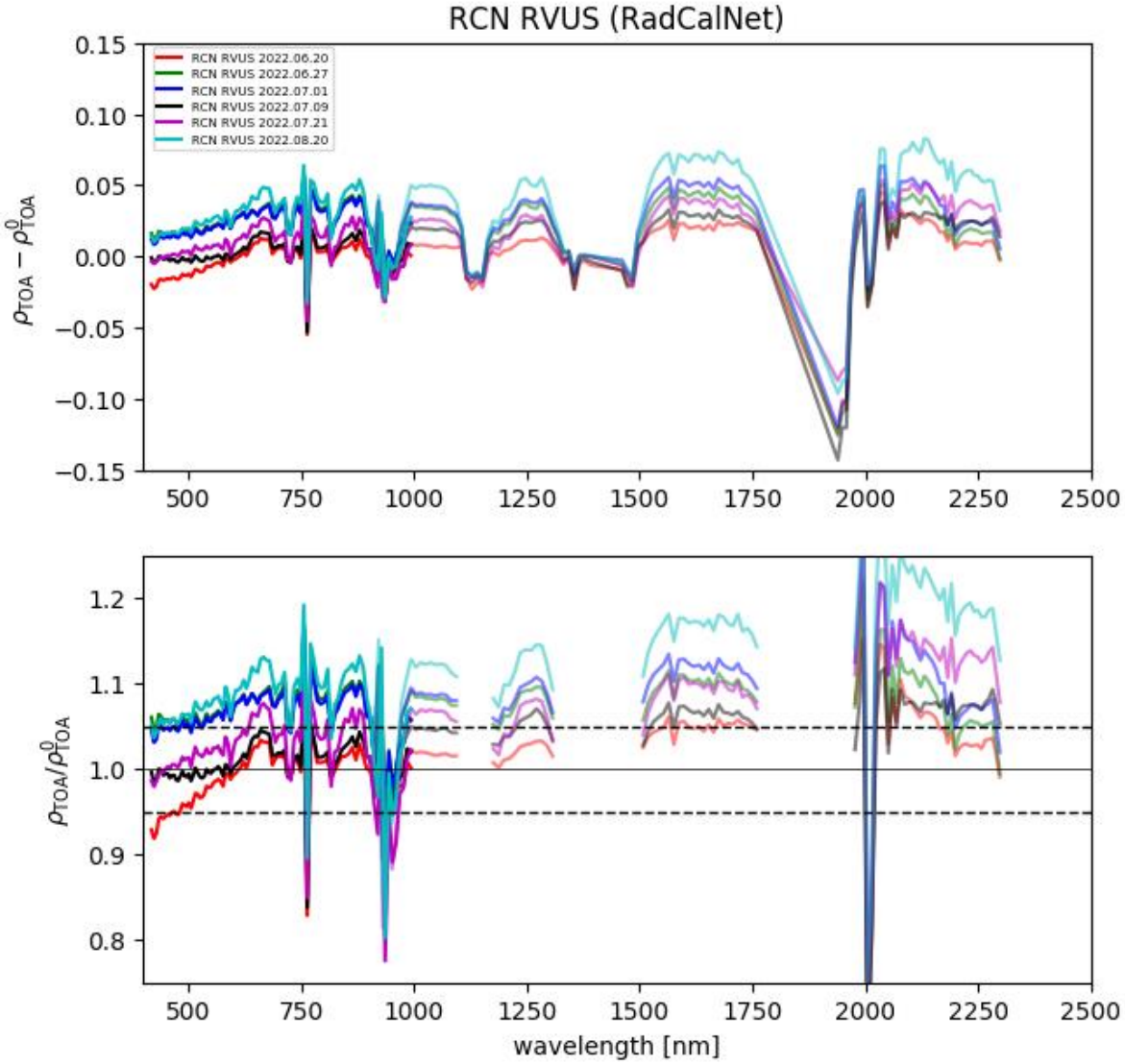
Gobabeb (GONA):
9 scenes
(6 with off-nadir <20°)

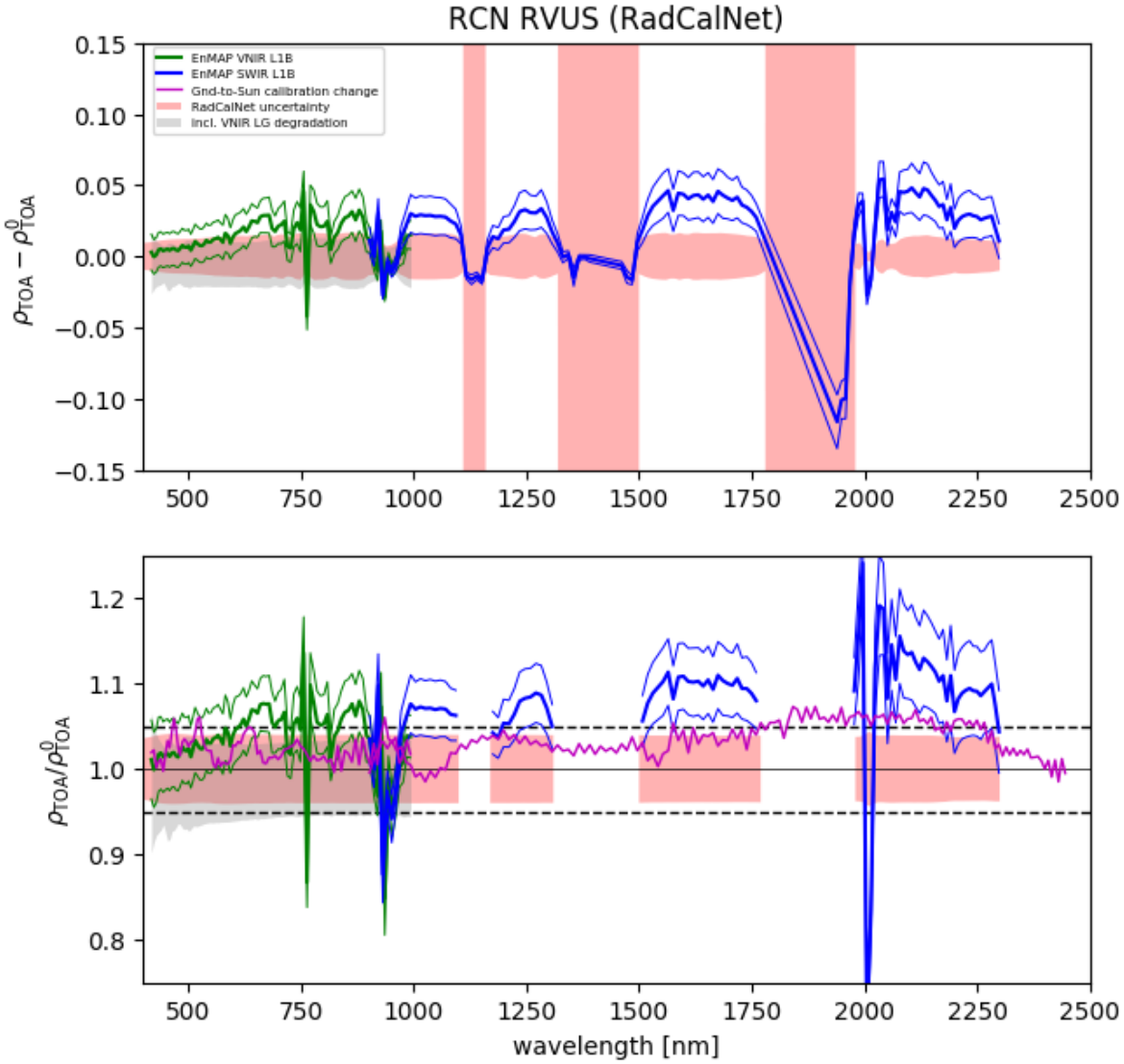
Radiometric accuracy based on RadCalNet scenes



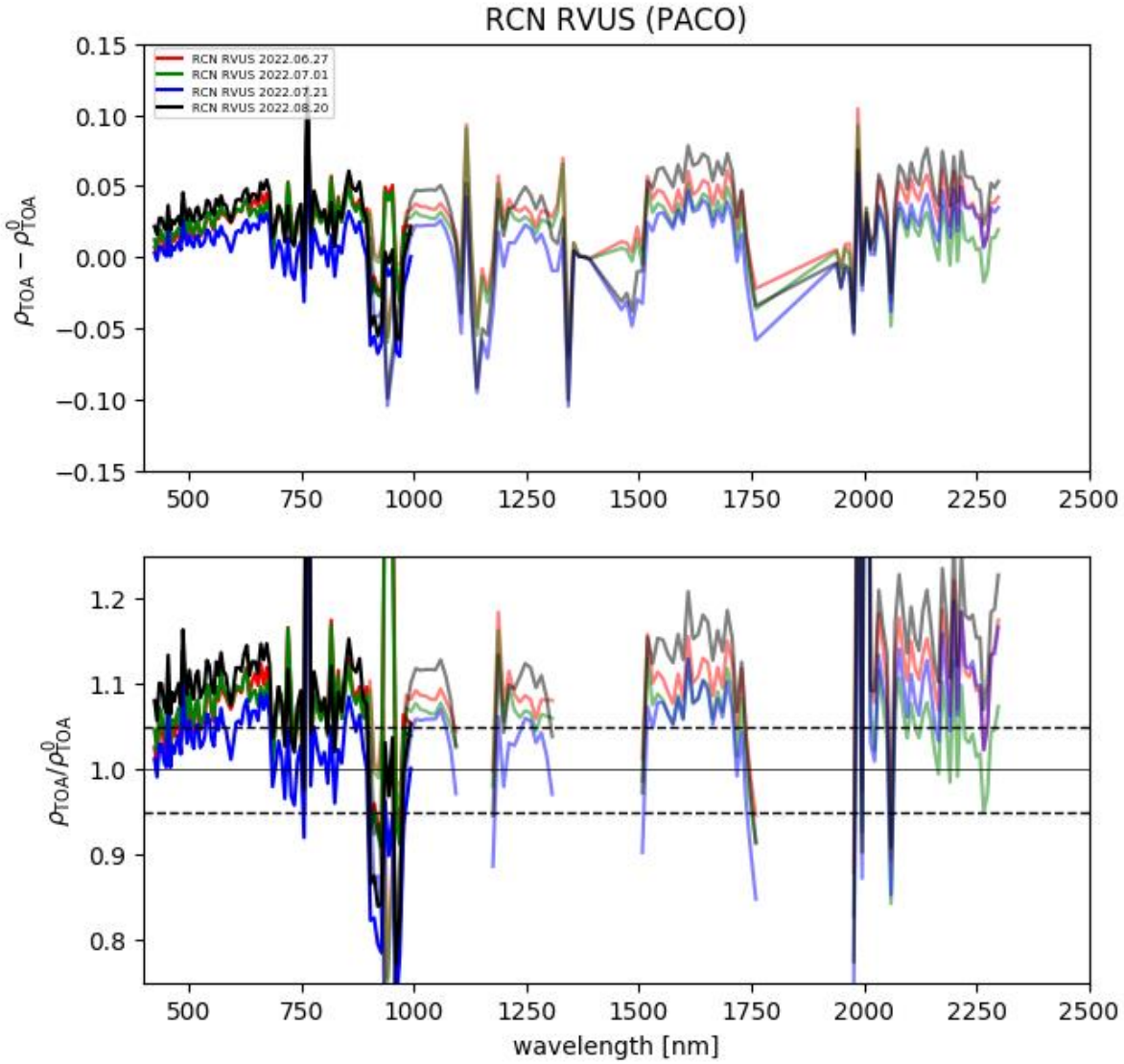


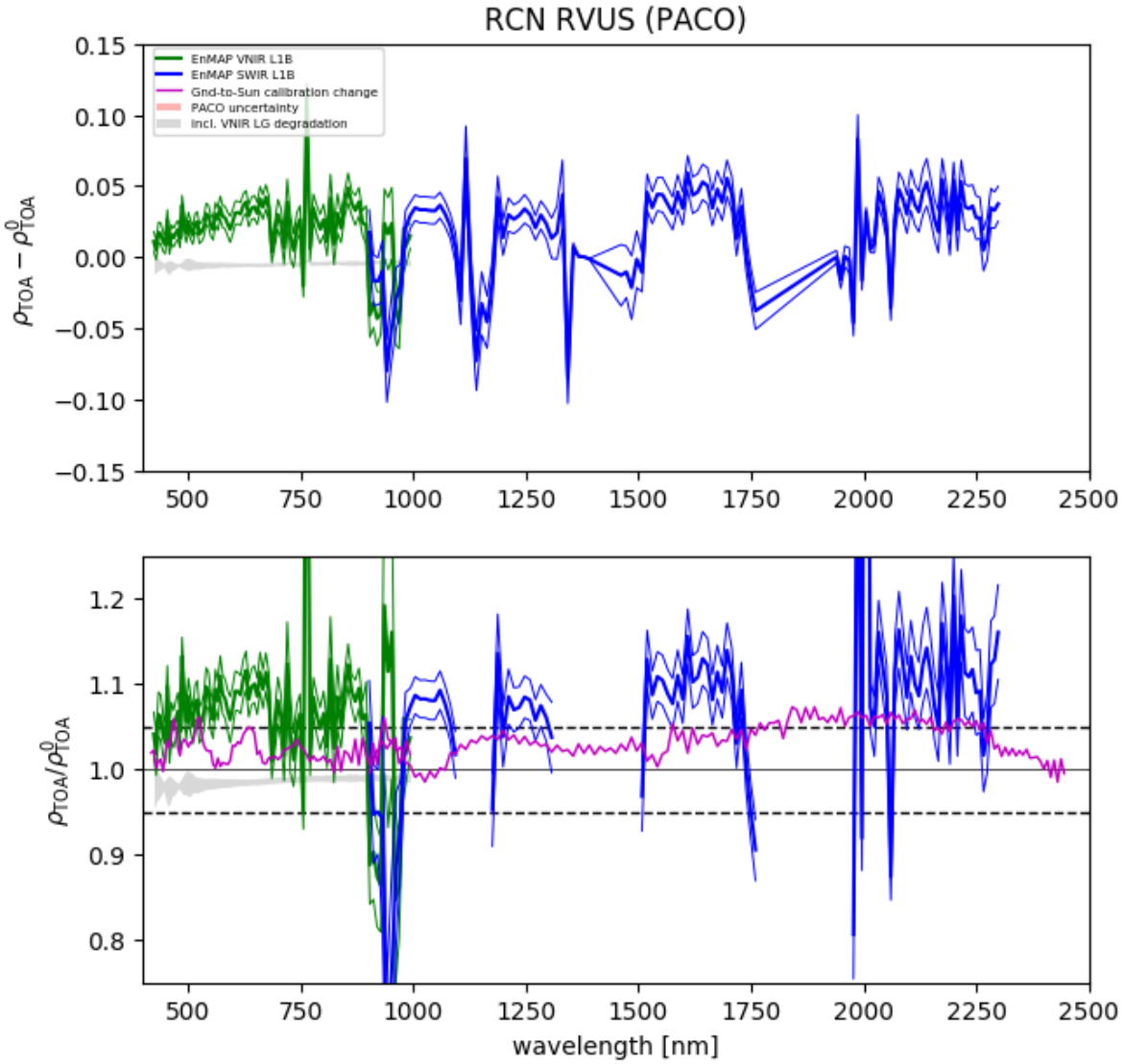
Radiometric accuracy based on RadCalNet scenes



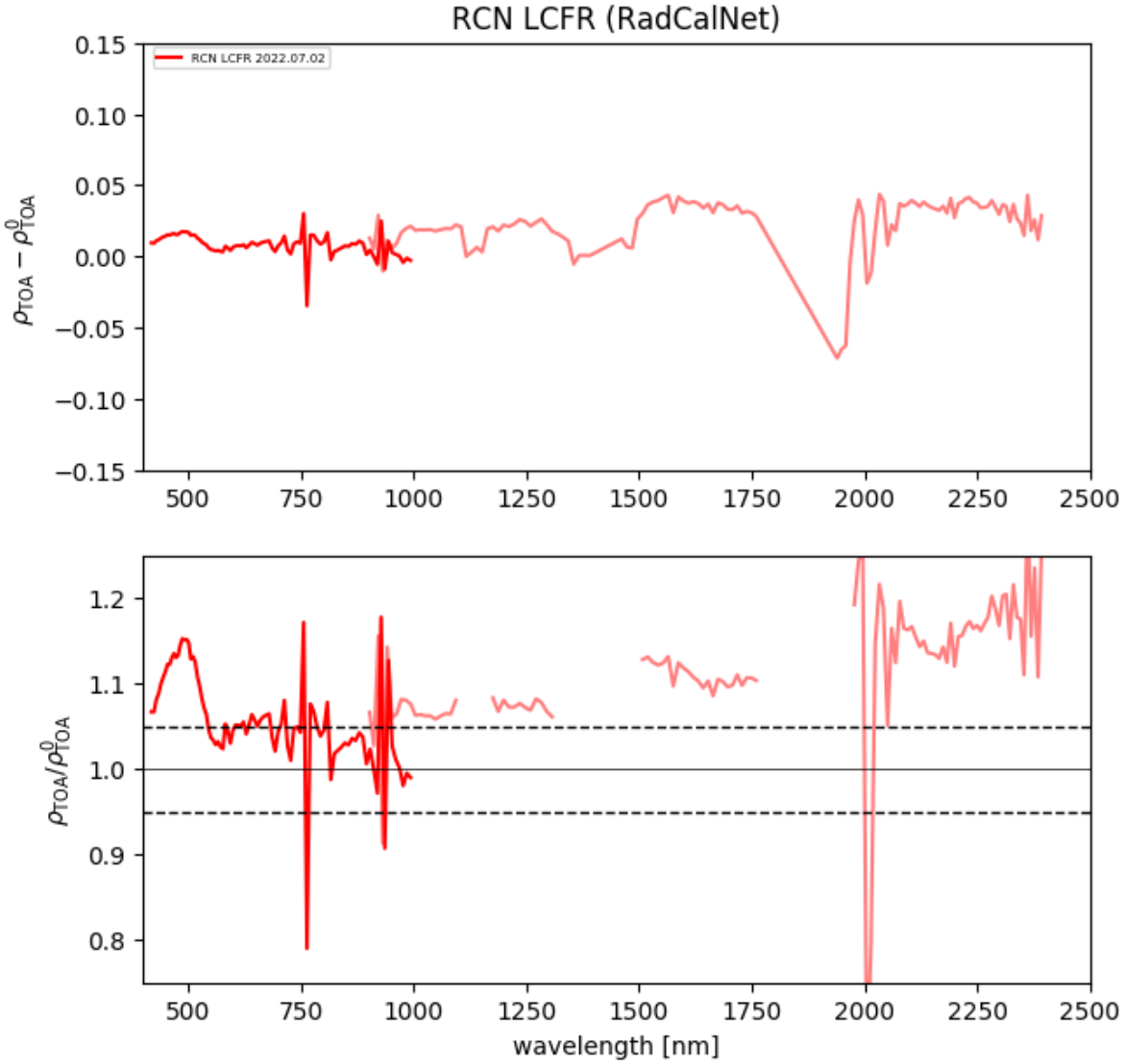


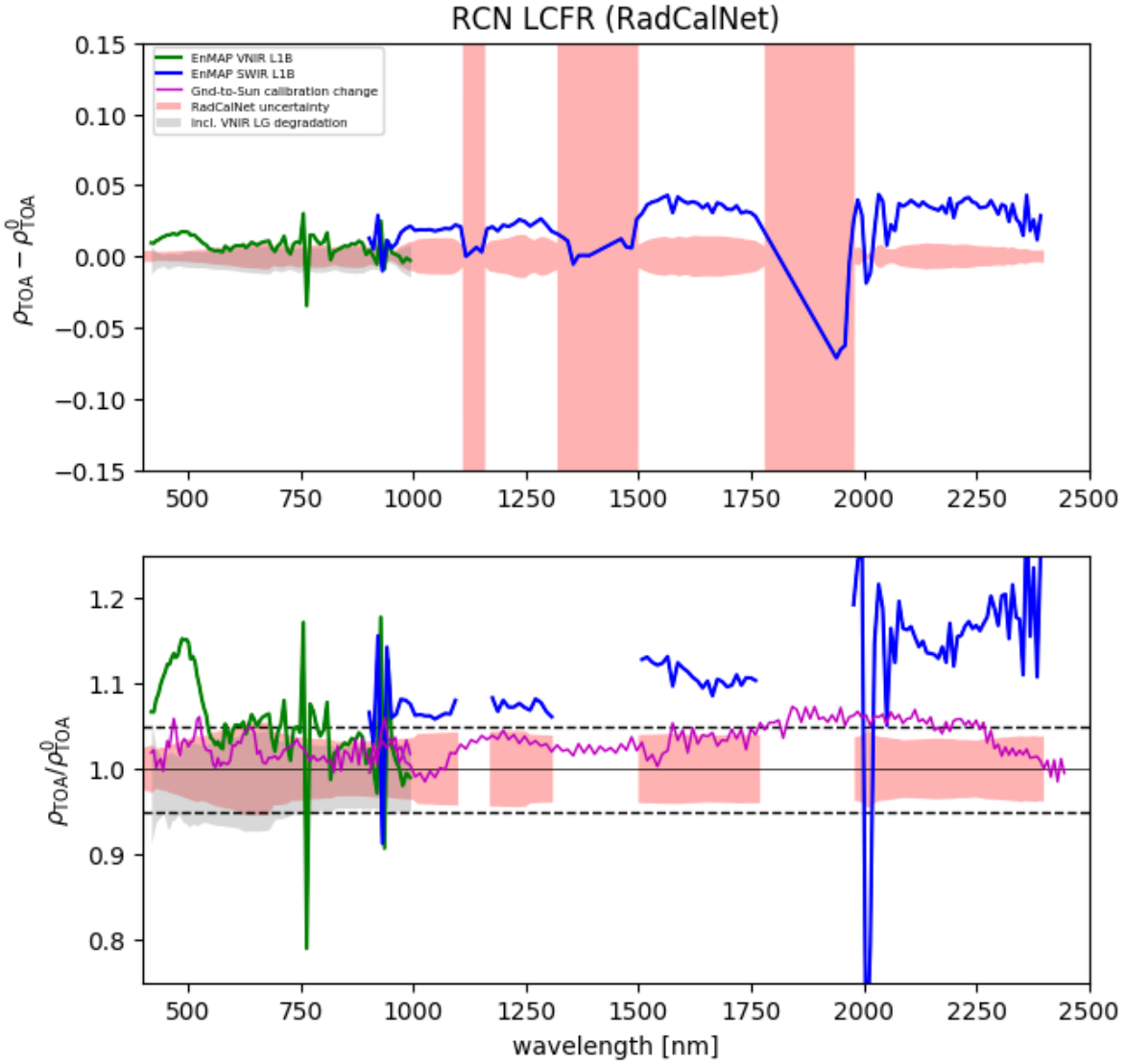
Radiometric accuracy based on RadCalNet scenes





Radiometric accuracy based on RadCalNet scenes





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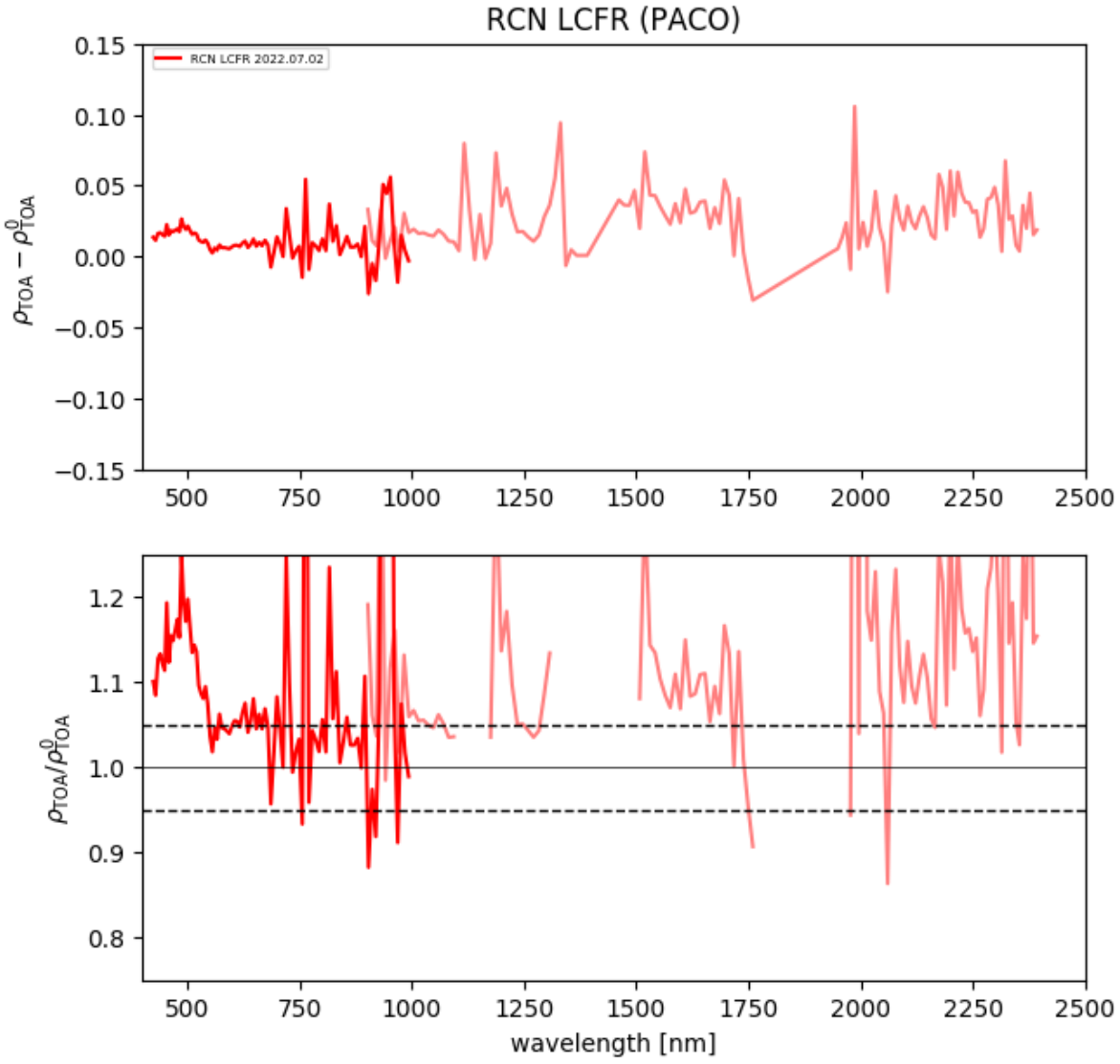

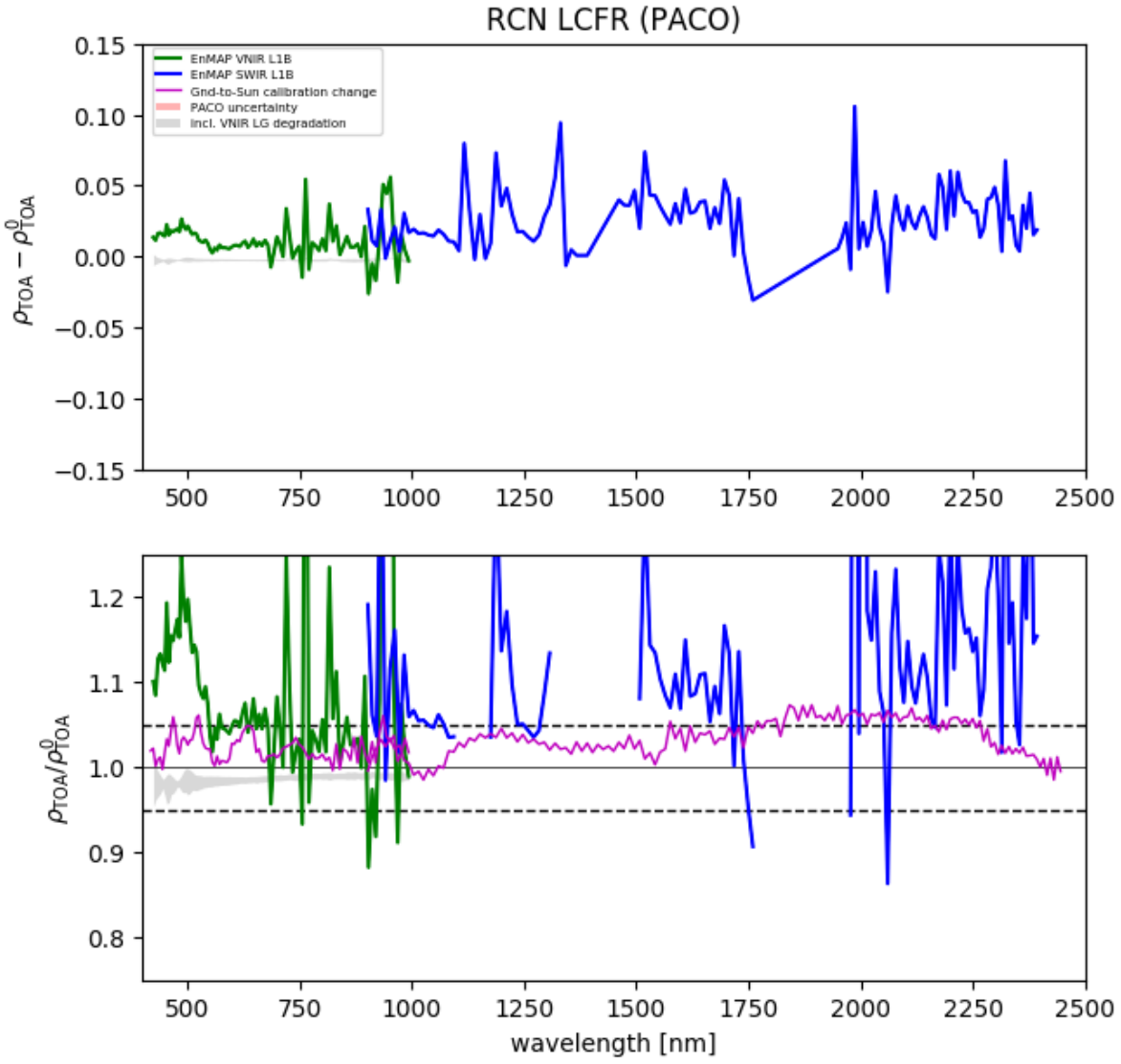

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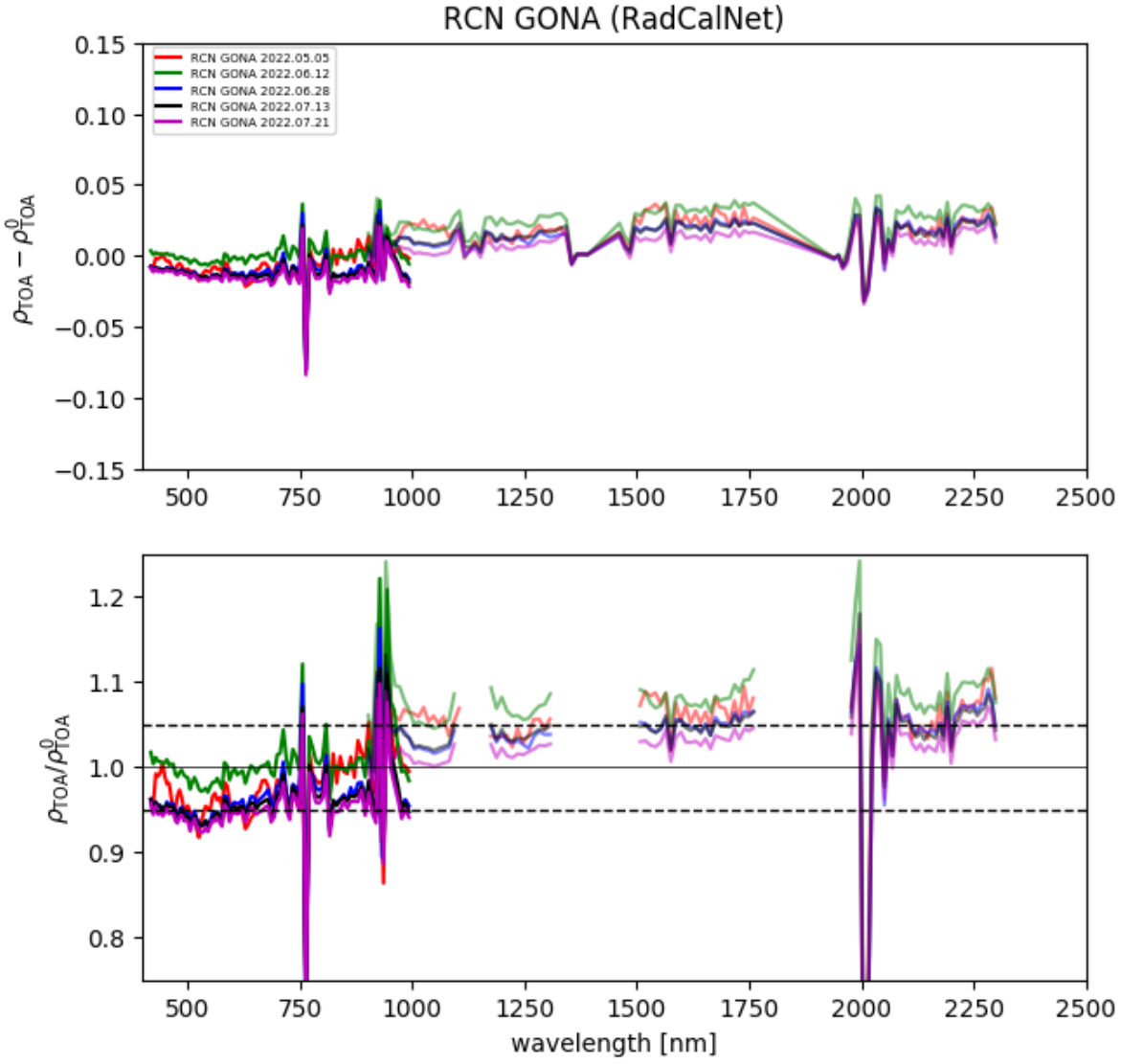

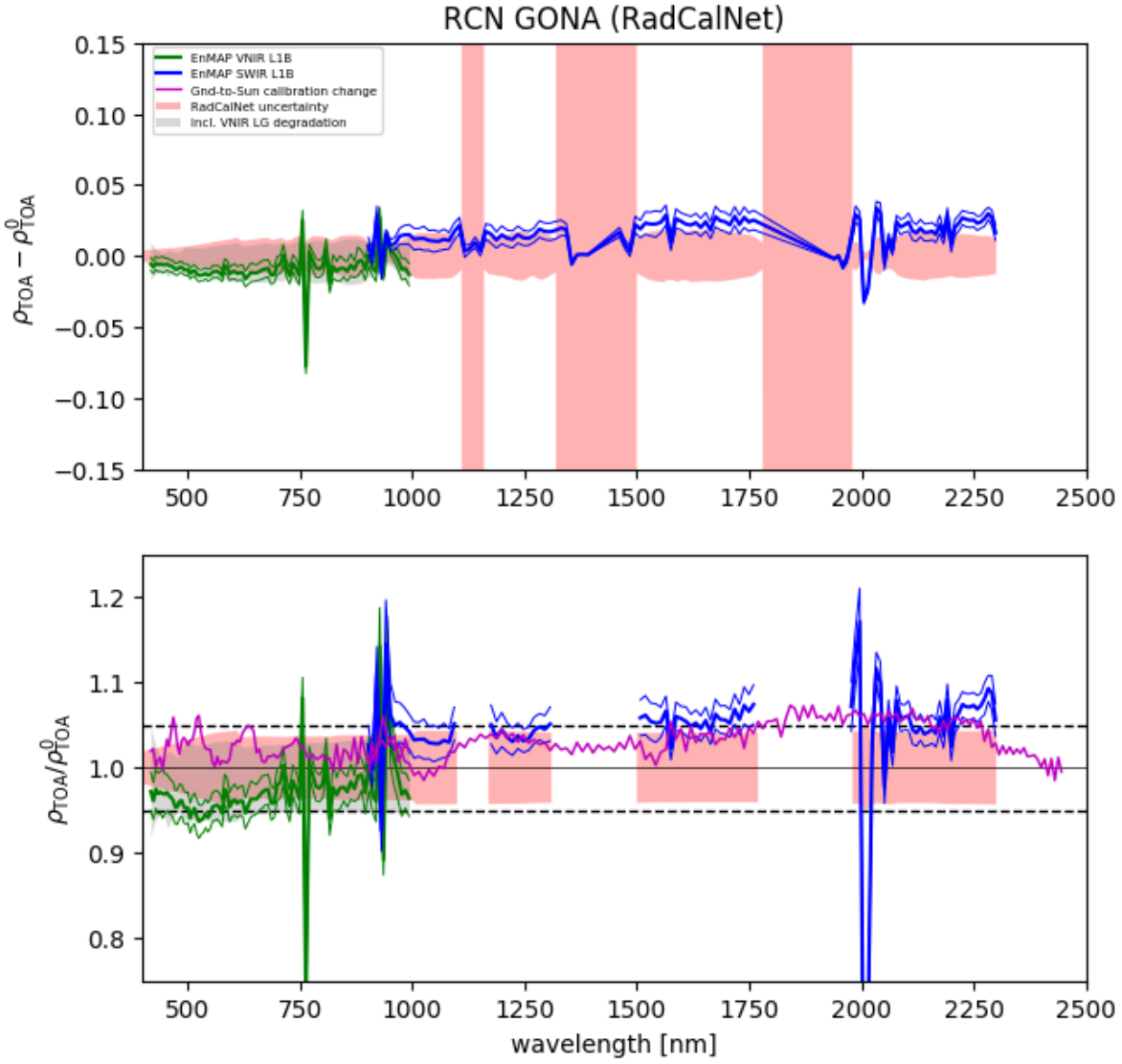

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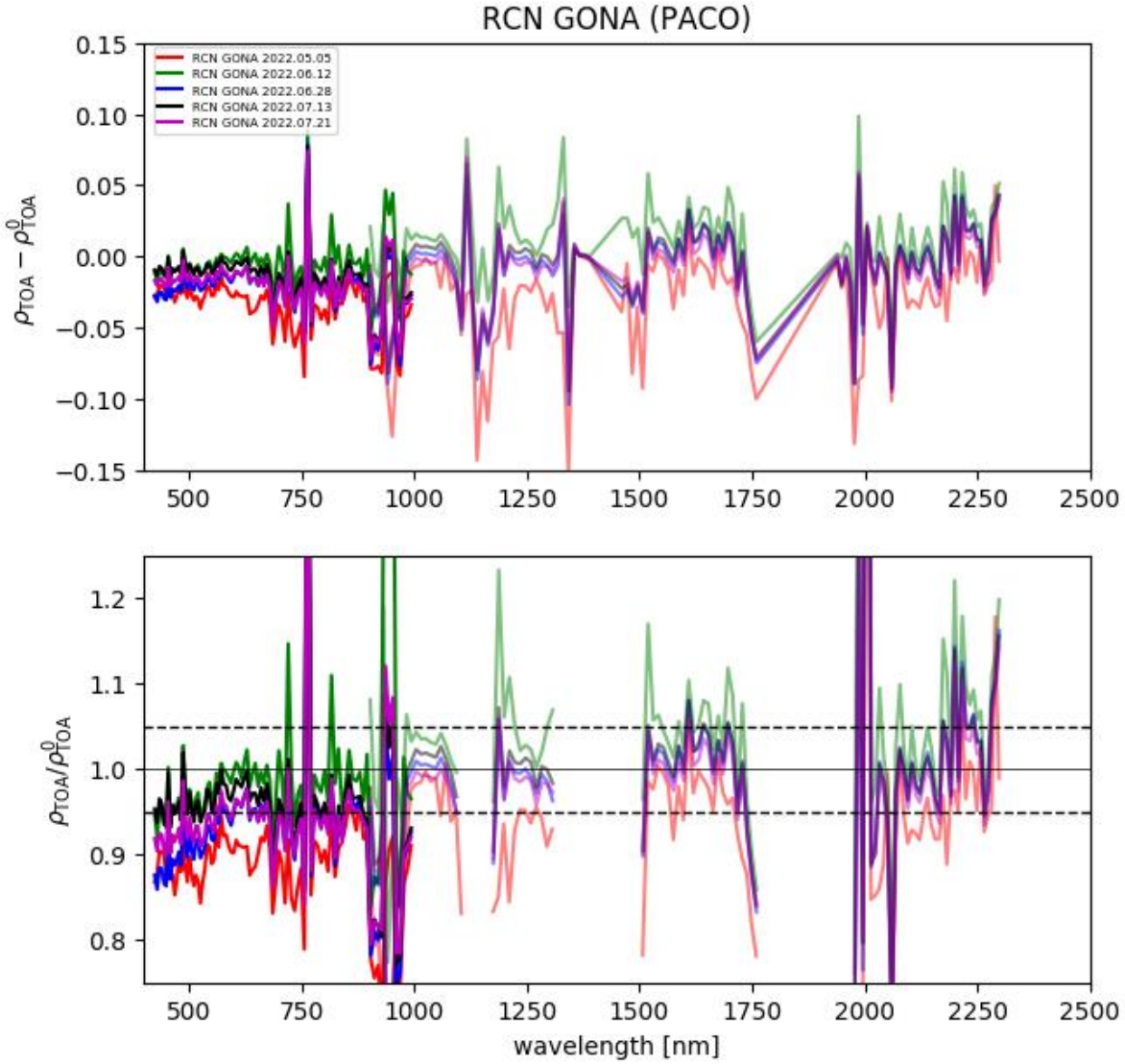
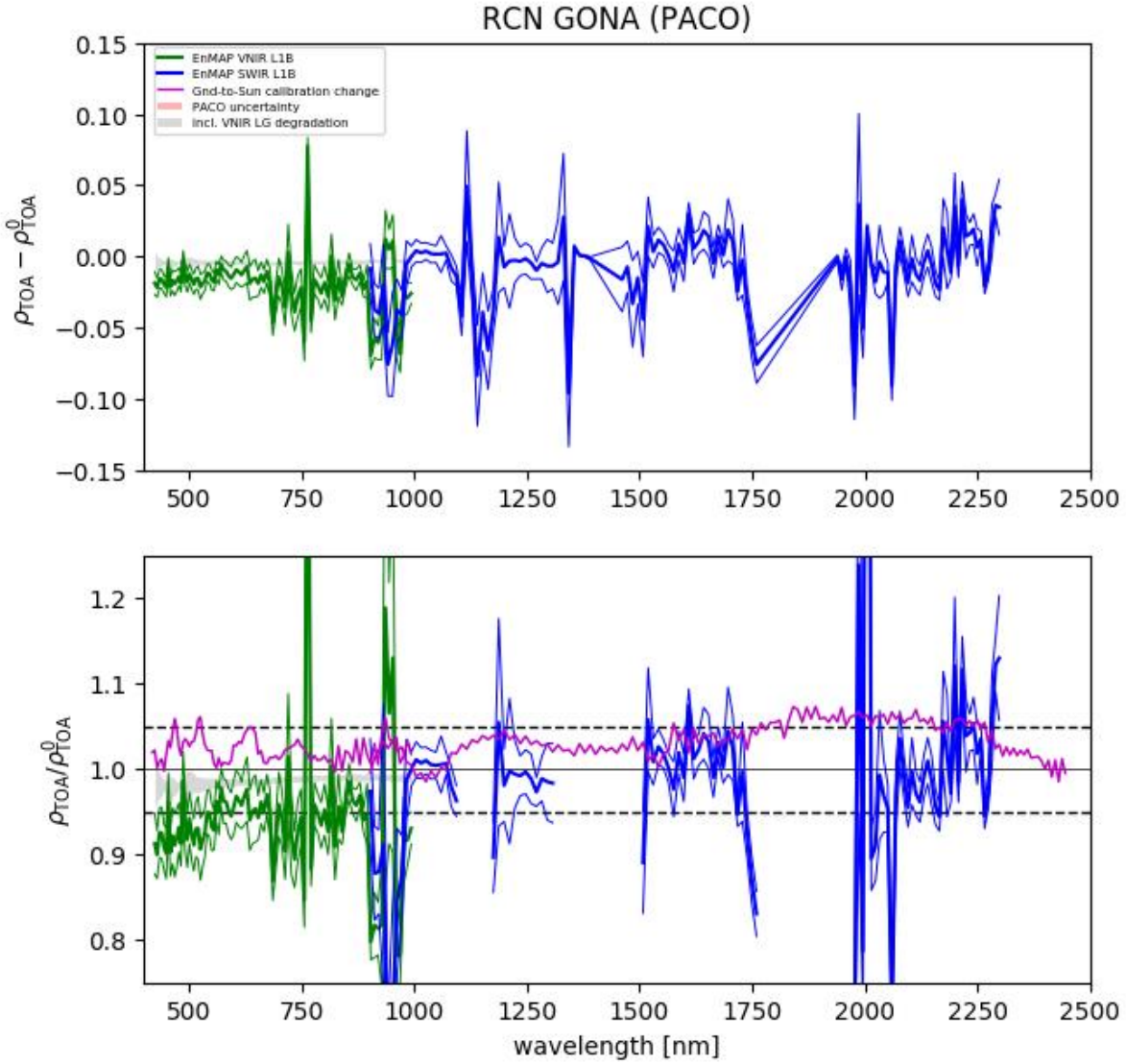
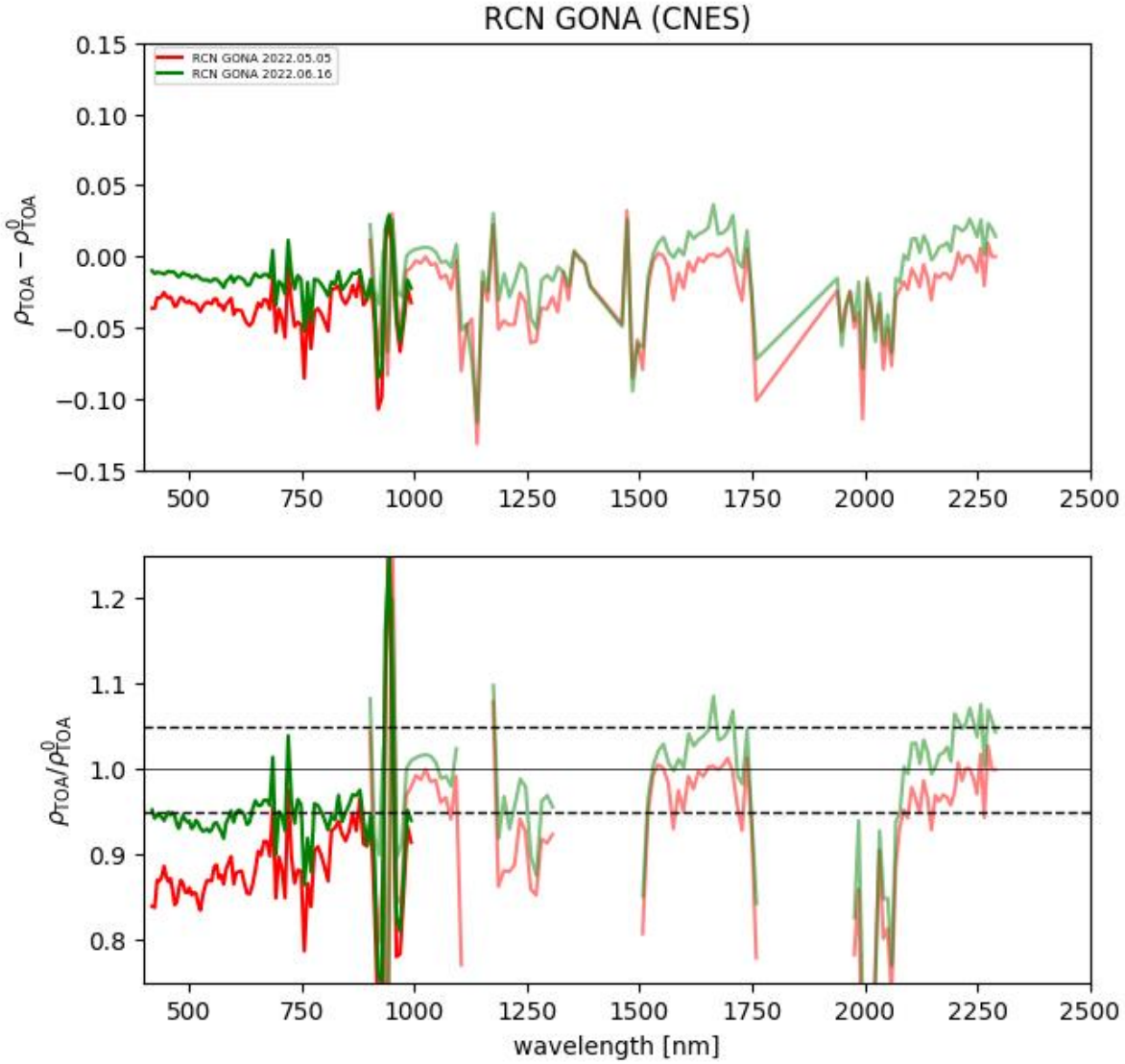
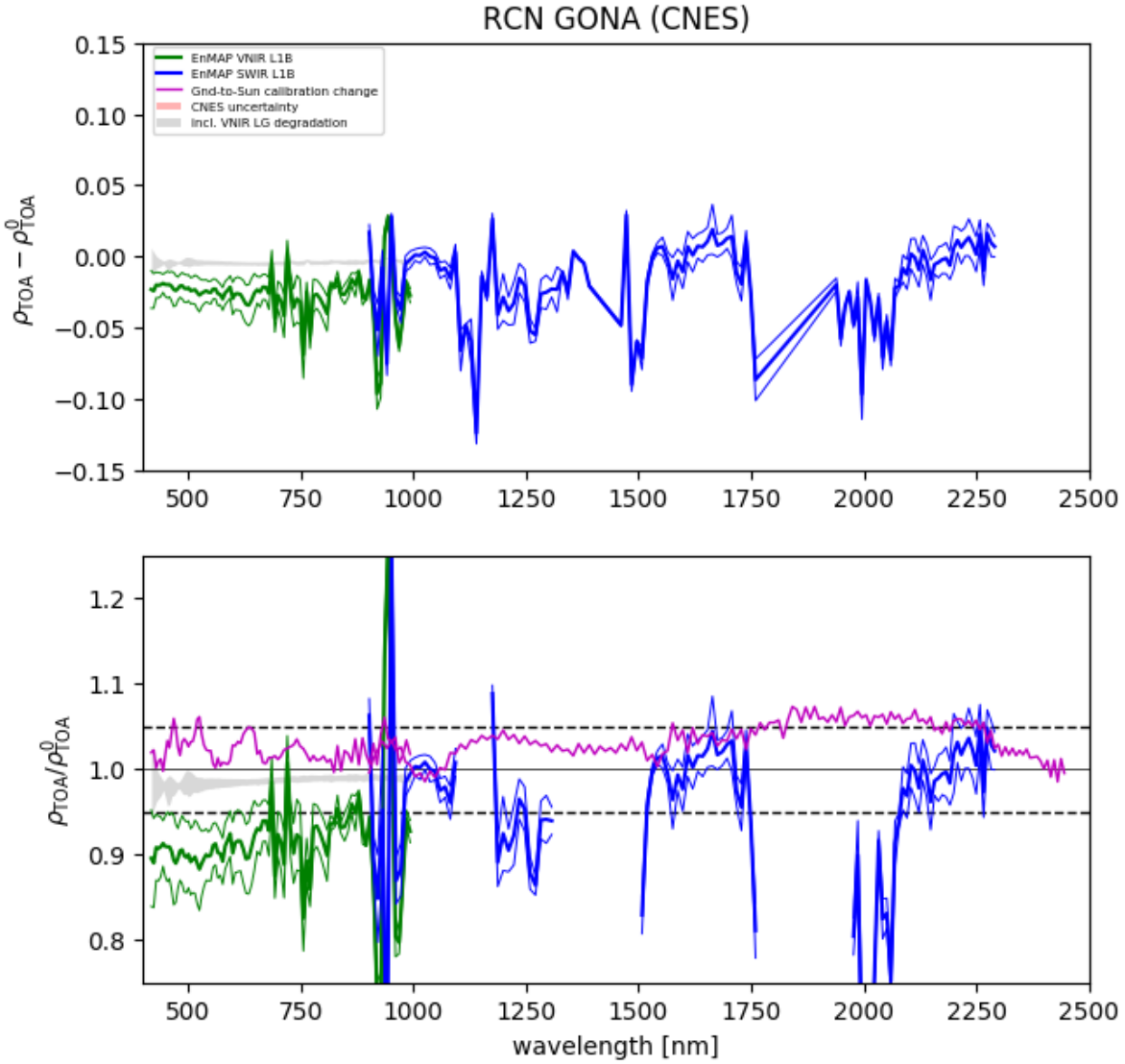


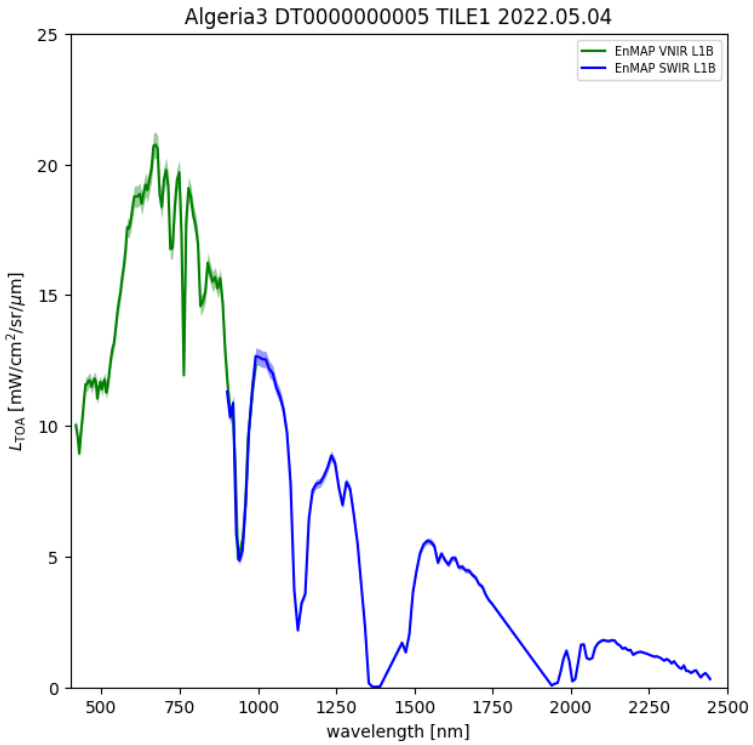


Radiometric accuracy based on RadCalNet scenes

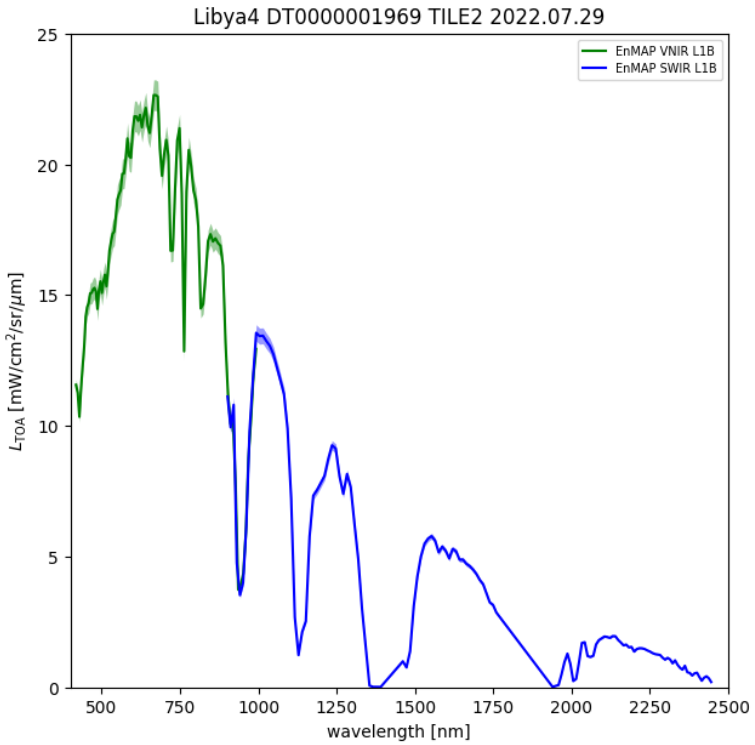




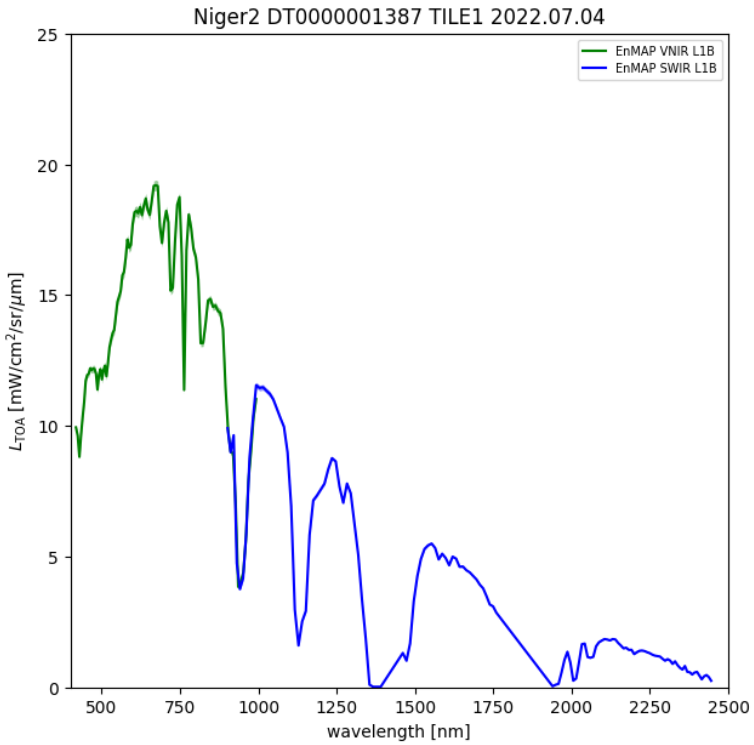
EnMAP scenes over PICS sites



Algeria3:
6 scenes
(4 with off-nadir <20°)

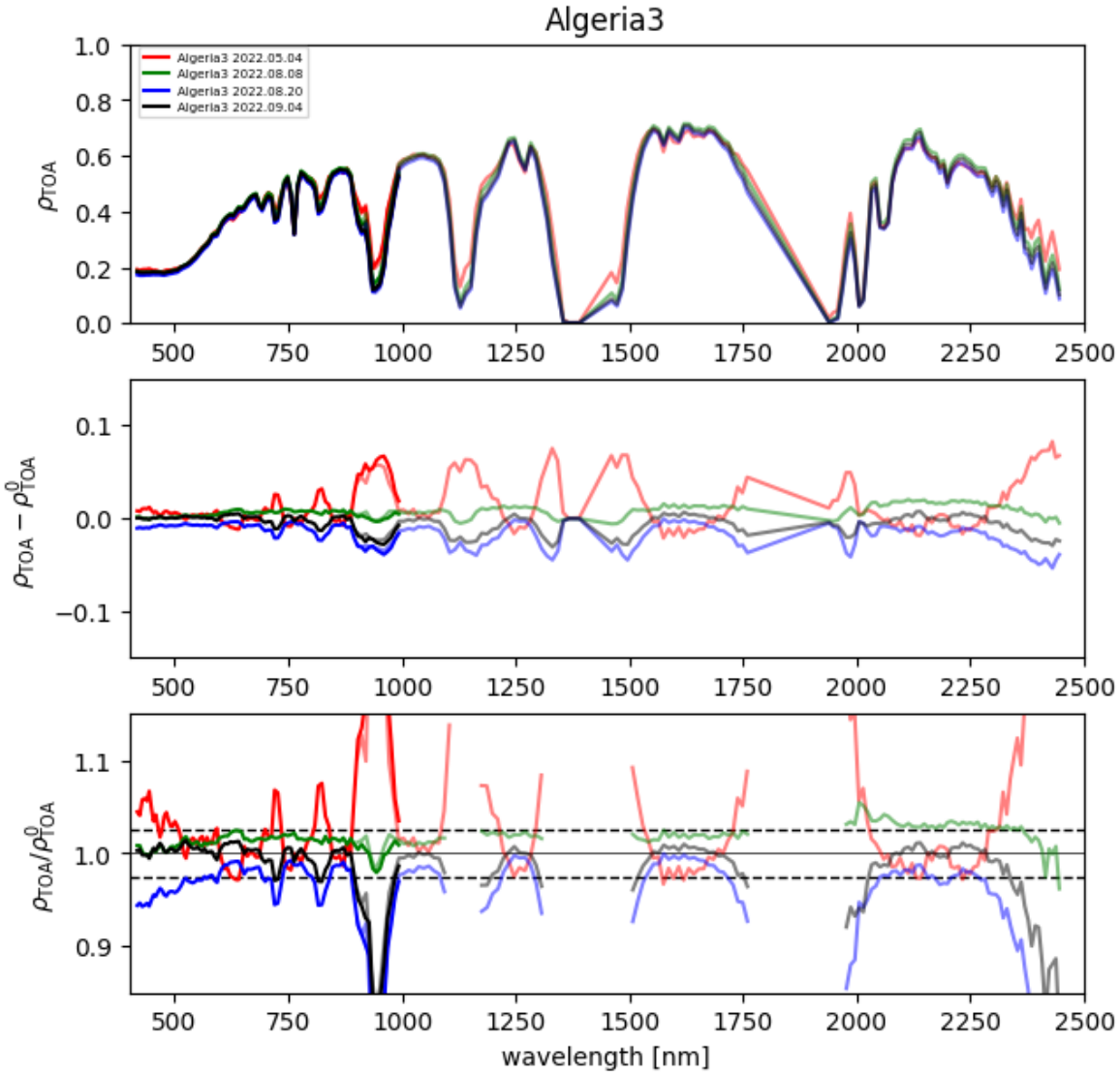


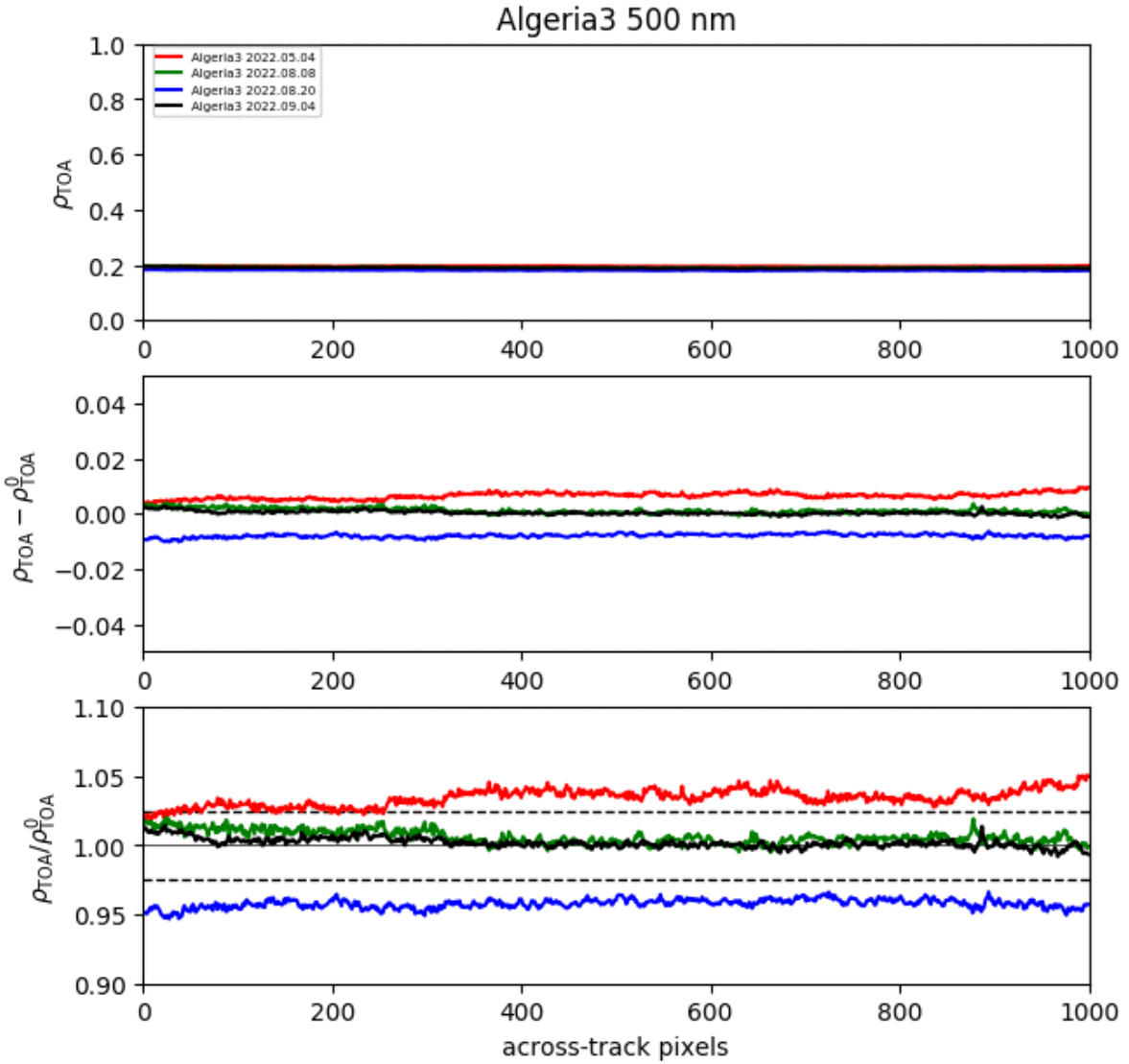
Libya4:
4 scenes
(3 with off-nadir <20°)



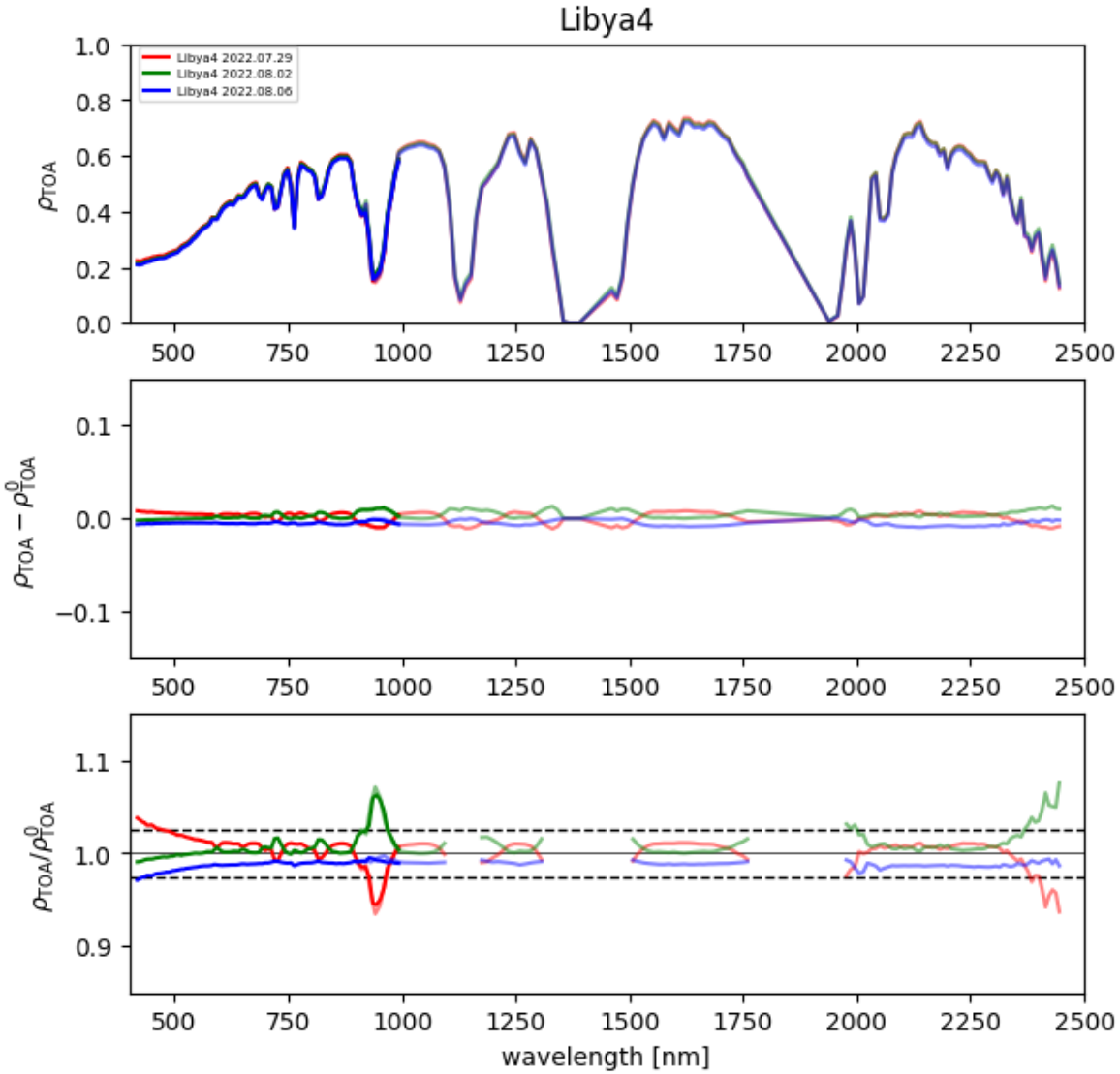
Niger2:
11 scenes
(7 with off-nadir <20°)

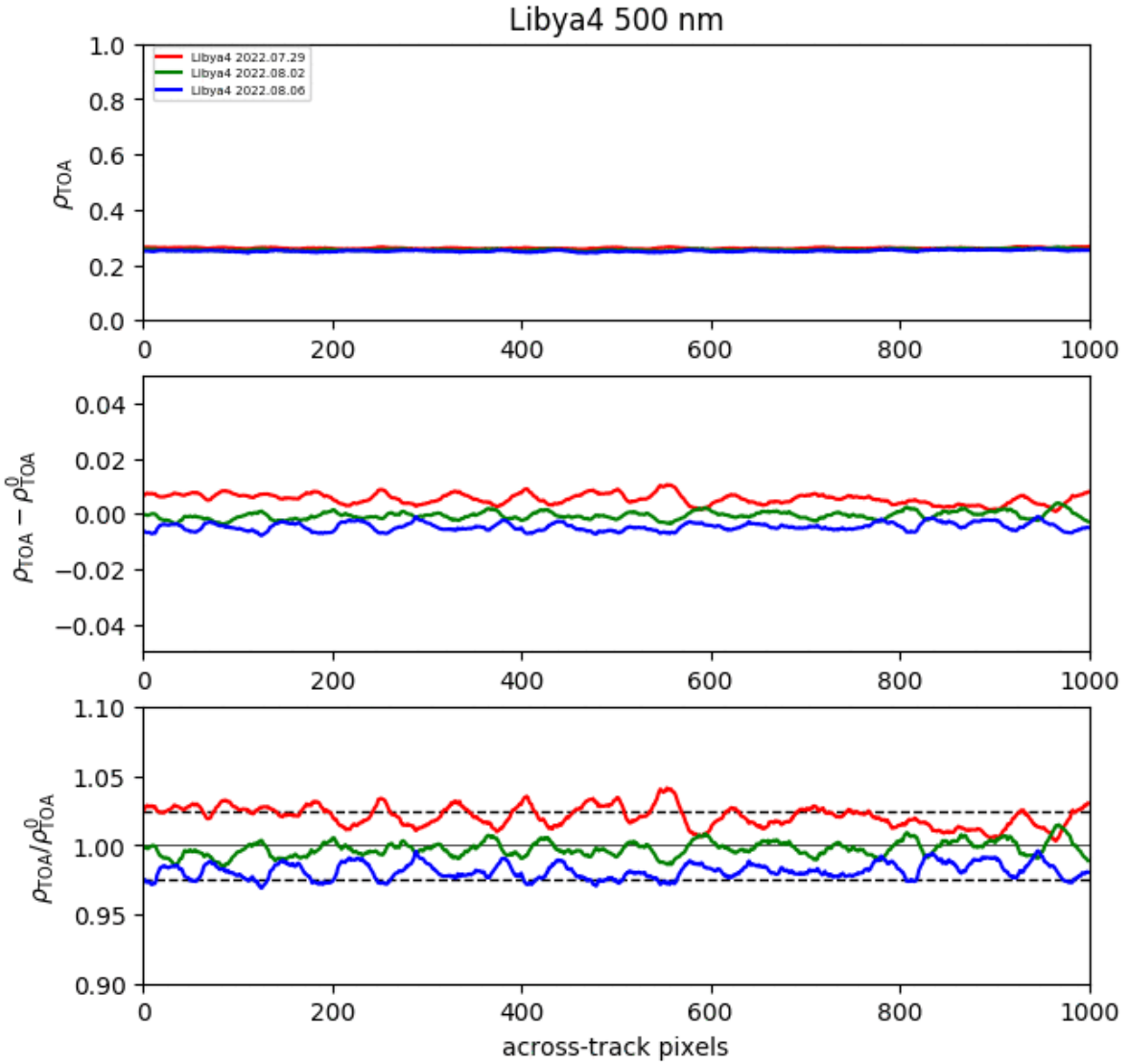
Radiometric stability based on PICS scenes





Radiometric stability based on PICS scenes





Radiometric stability based on PICS scenes