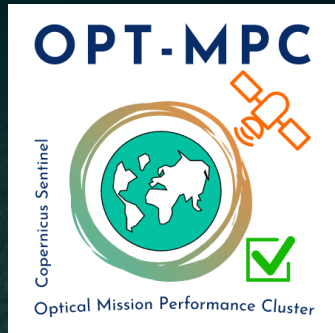




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Validation of Sentinel-2 Collection 1 surface reflectance products with RadCalNet data

R. De Los Reyes, B. Pflug, B. Alhammoud, F. Poustomis, J. Louis, F. C. Pignatale, A. P. Pertiwi, S. Enache, R. Q. Iannone, V. Boccia, F. Gascon

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Sentinel-2 L2A requirements



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Sentinel-2 requirements (S2-SR-ESA-SY-0001, GMES Sentinel-2 System Requirements Document, 16.02.2007).

- All mention “relative accuracy”:

Updated S2 requirements (B. Pflug, B.; Louis, J. et al: “Next updates of atmospheric correction processor Sen2Cor”, 2020, Proc. SPIE (DOI: 10.1117/12.2574035))

Retrieval accuracy requirement

The aimed AOD accuracy is 10% relative for the range between 0.05 and 3.

Parameter name	Unit	Goal Accuracy
AOD	-	10%

$U_{\text{req,AOT}}$

$$|\Delta_{AOT}| \leq 0.1 * AOT (550 \text{ nm}) + 0.03$$

Retrieval accuracy requirement

For water vapour a relative accuracy of 10% is requested for the range between 0.1 and 4 g/cm².

Parameter name	Unit	Goal Accuracy
WV	g/cm ²	10%

$U_{\text{req,WV}}$

$$|\Delta_{WV}| \leq 0.1 * WV (g/cm^2) + 0.2$$

Retrieval accuracy requirement

The requested accuracy for the BOA reflectance is 5% in relative terms.

Parameter name	Unit	Goal Accuracy
ρ_{boa}	-	5%

$$U_{BOA} = 0.05 * \rho (BOA) + 0.005 \quad (1\sigma \text{ c.l.})$$

Vermote, et al, 2008

Sentinel-2 Collection 1 SR validation: RadCalNet in-situ



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Surface reflectance variability across site (uniformity) [QA4EO-WGCV-RadCalNet-{RCNsite}-Q]

ROI (LxL) [m]	LaCrau (LCFR)	Gobabeb (GONA)	Railroad Valley (RVUS)
100 x 100	< 3%	3 – 5%	0.4%
500 x 500	< 5%	< 3%	1%
1000 x 1000	< 5%	< 3%	1.5%

(Bouver, M. et al, 2019)

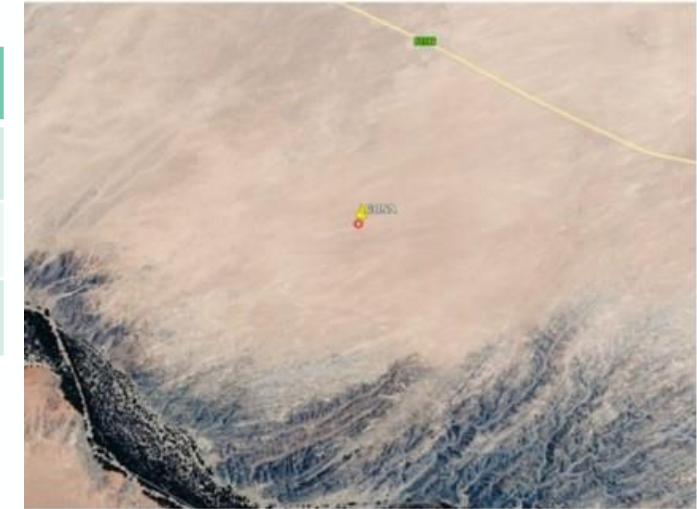


Figure 4: The Gobabeb site and the target for which the RadCalNet top-of-atmosphere reflectance spectra are representative (red circle).

“Quantitative” validation: RadCalNet

- Spatial: ROI of the RadCalNet site
- Temporal:
 - ± 30 min of the overpass
 - Excluded scenes if no/bad RadCalNet data acquisition in $\Delta t > \pm 30$ min.

Coverage factor (GUM, JCGM 100:2008)

$$K = \frac{\rho_{S2} - \rho_{ref}}{\sqrt{U_{S2}^2 + U_{ref}^2}} \leq 1$$

$$U_{S2,BOA} = 0.05 * \rho_{BOA} + 0.005$$

$$U_{ref} = \sqrt{U_{RCN}^2 + U_{ROI}^2}$$

RadCalNet: Gobabeb (BOA)



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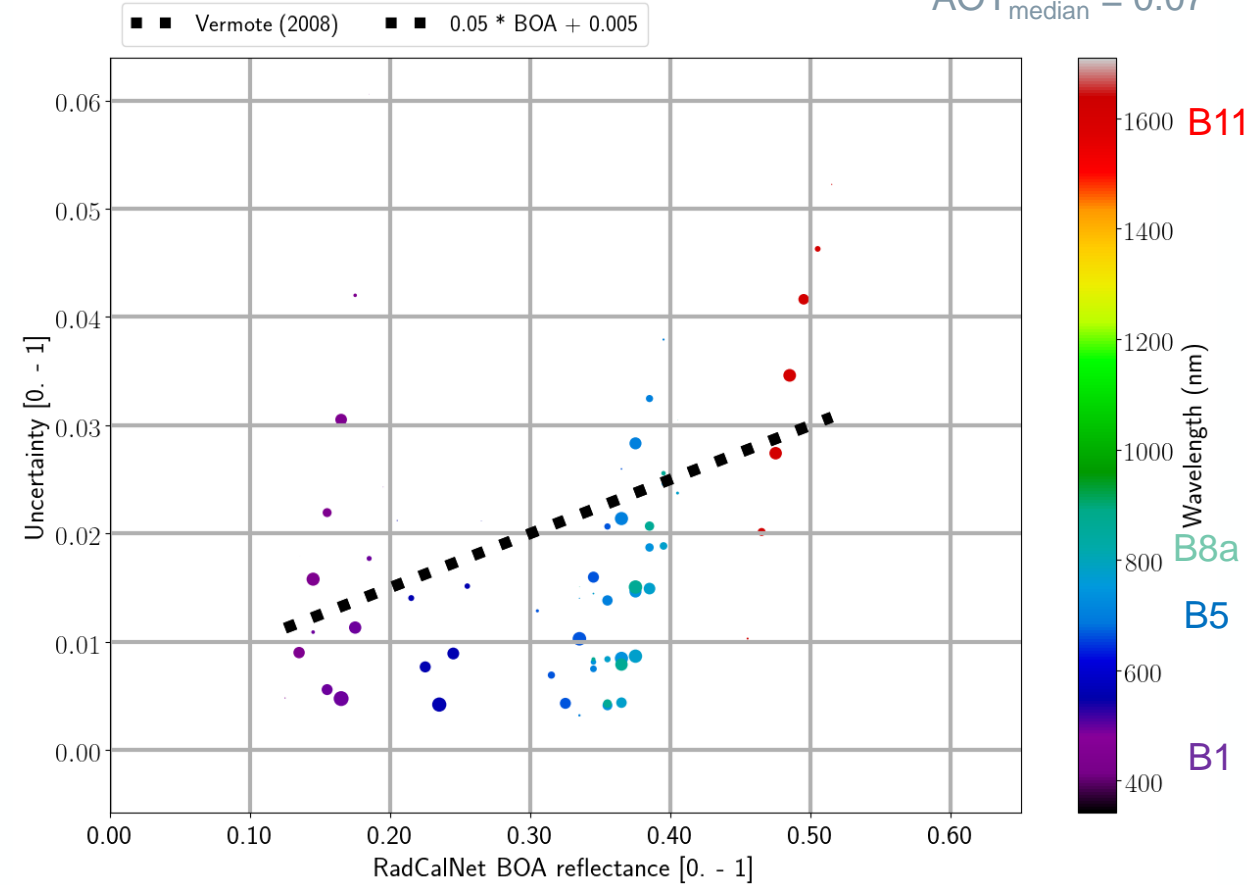
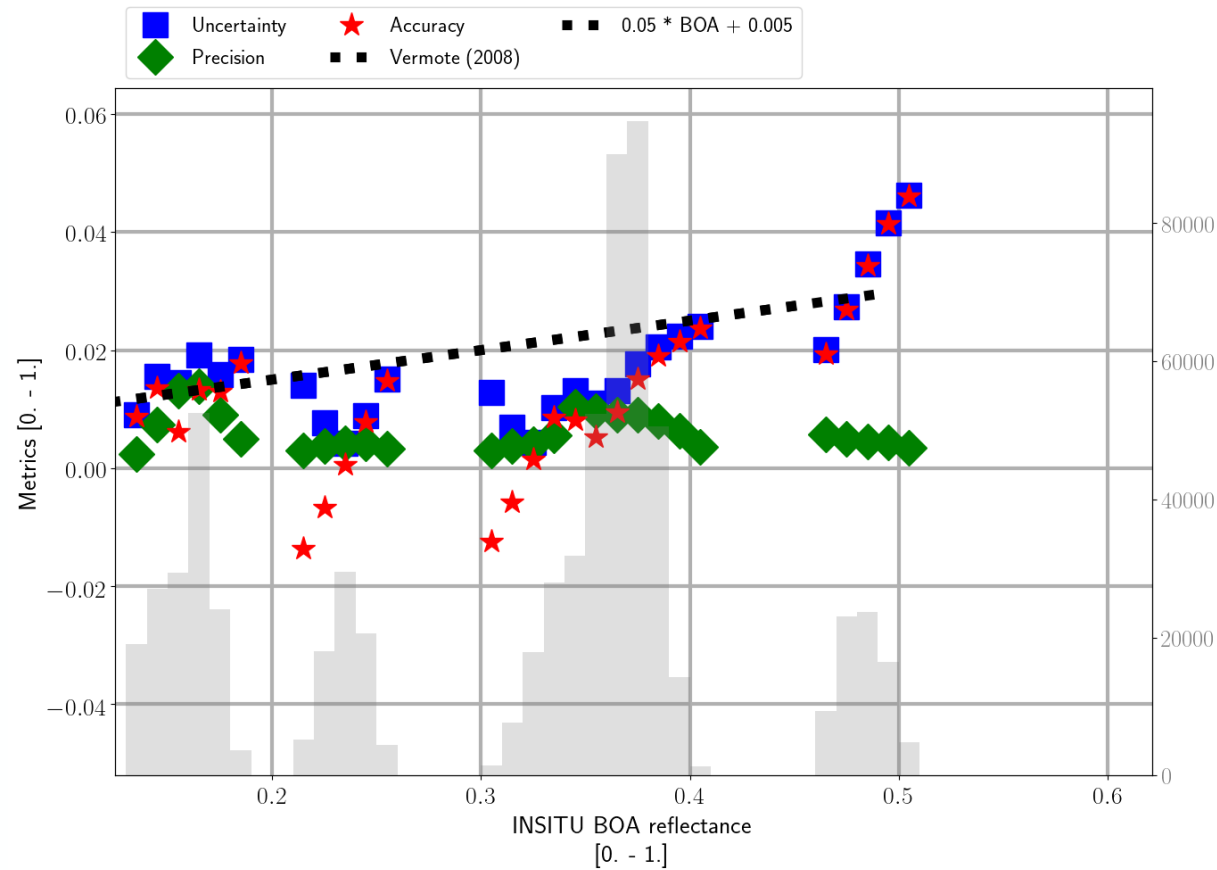
30 scenes of Sentinel-2 overpasses with Gobabeb (GRI tile 33KWP)

$$U_{BOA} [\%/100] = (0.06 \pm 0.01) \rho_{RCN} + (0.000 \pm 0.005)$$

$$U_T = \sqrt{U_{req,S2}^2 + U_{ROI}^2} = 0.06$$

$U_{ROI < 500m} = 3\%$

RMSE_{AOT} = 0.04
AOT_{mean} = 0.08
AOT_{median} = 0.07



RadCalNet: LaCrau (BOA)



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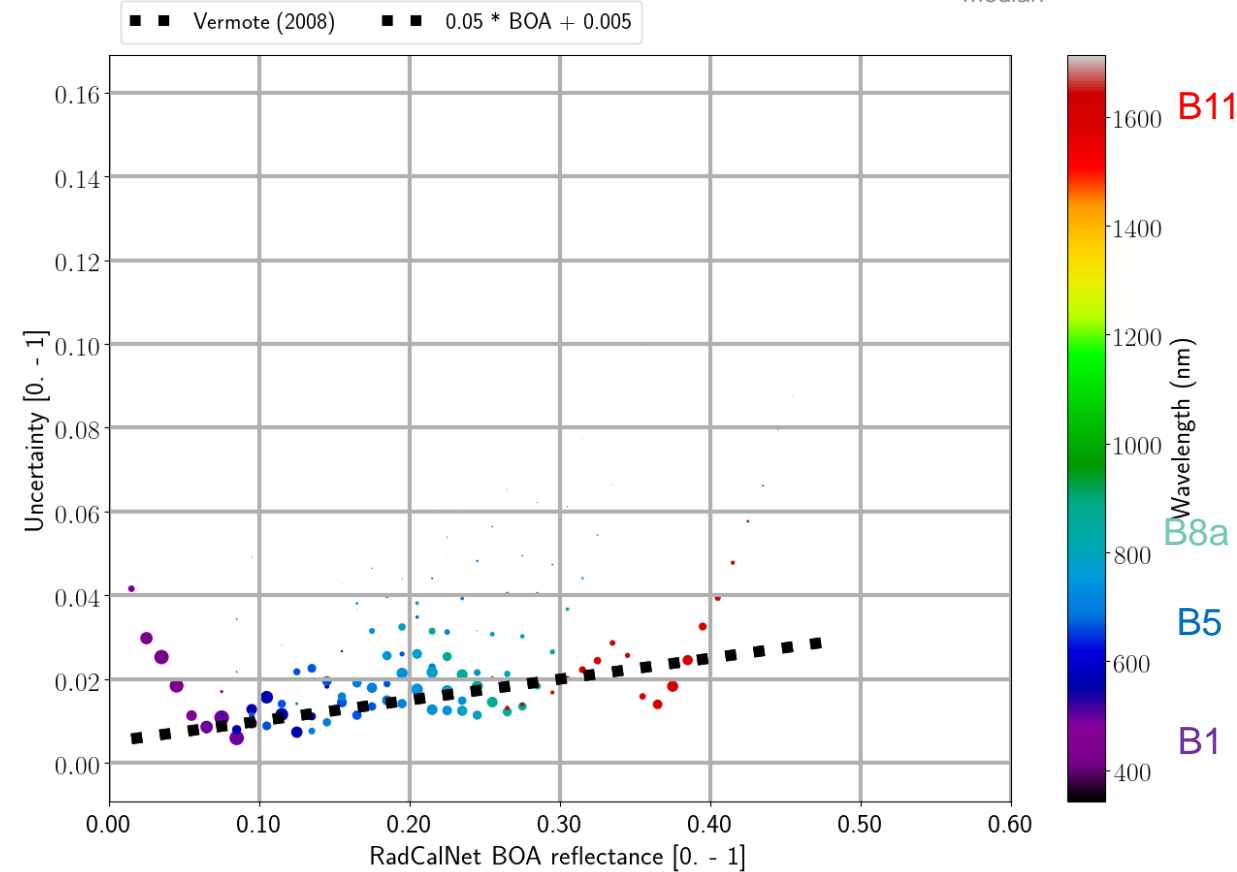
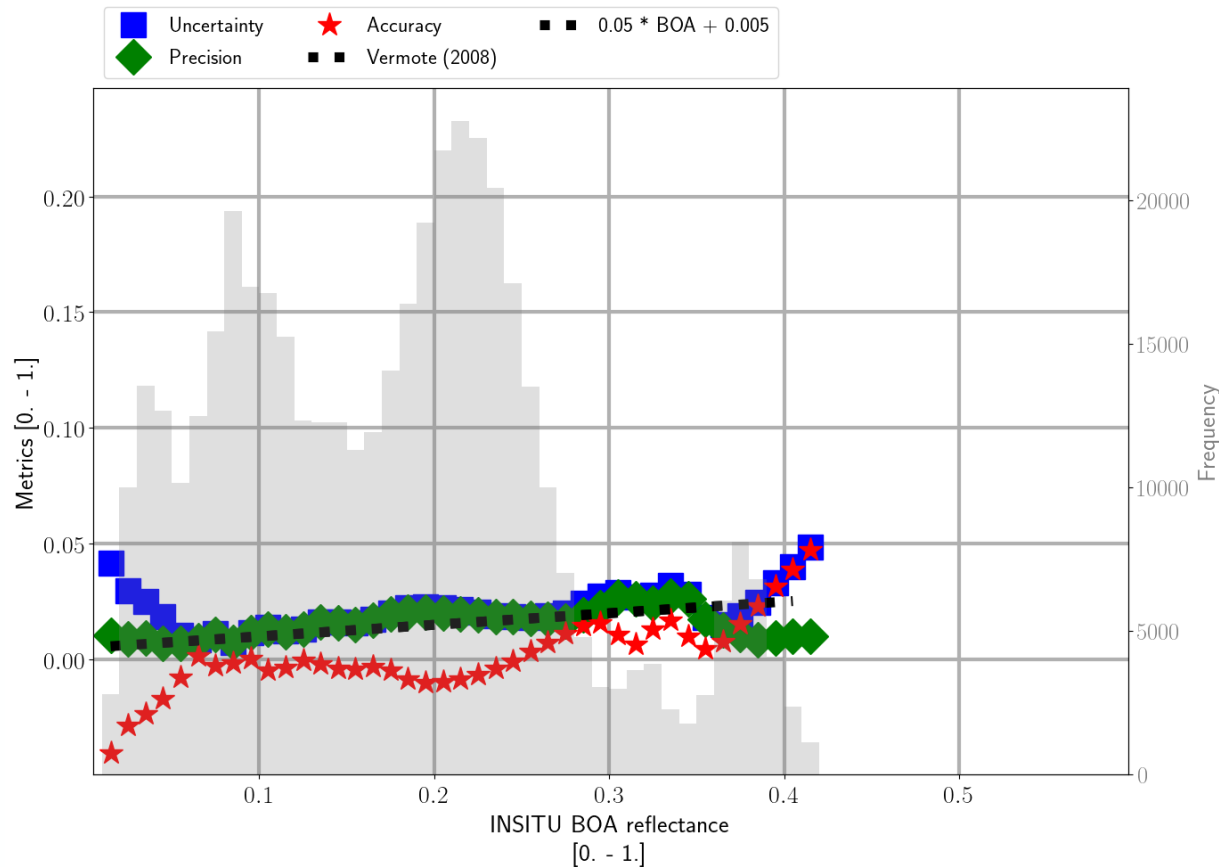
19 scenes of Sentinel-2 overpasses with La Crau (GRI tile 31TFJ)

$$U_{BOA} [\%/100] = (0.04 \pm 0.01) \rho_{RCN} + (0.014 \pm 0.003)$$

$$U_{ROI < 500m} = 5\%$$

$$U_T = \sqrt{U_{req,S2}^2 + U_{ROI}^2} = 0.07$$

RMSE_{AOT} = 0.06
 AOT_{mean} = 0.1
 AOT_{median} = 0.08



RadCalNet AOT and WV validation La Crau and Gobabeb



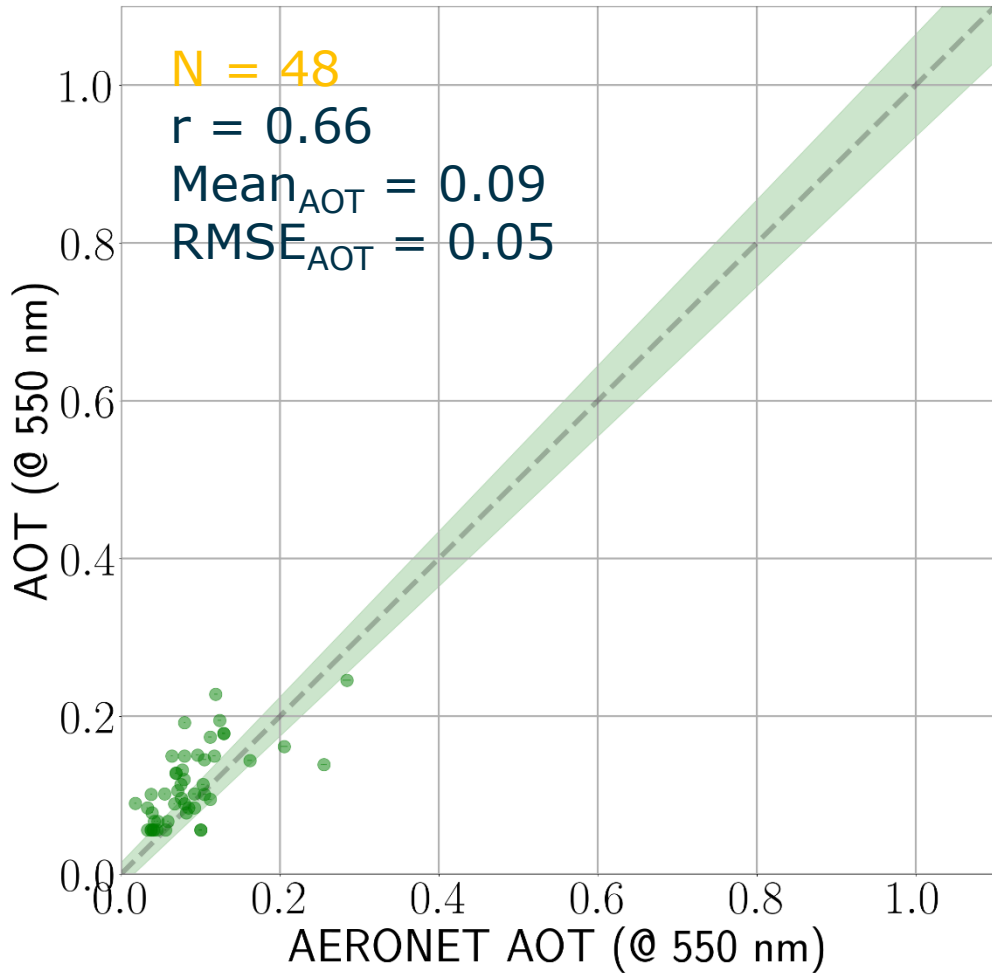
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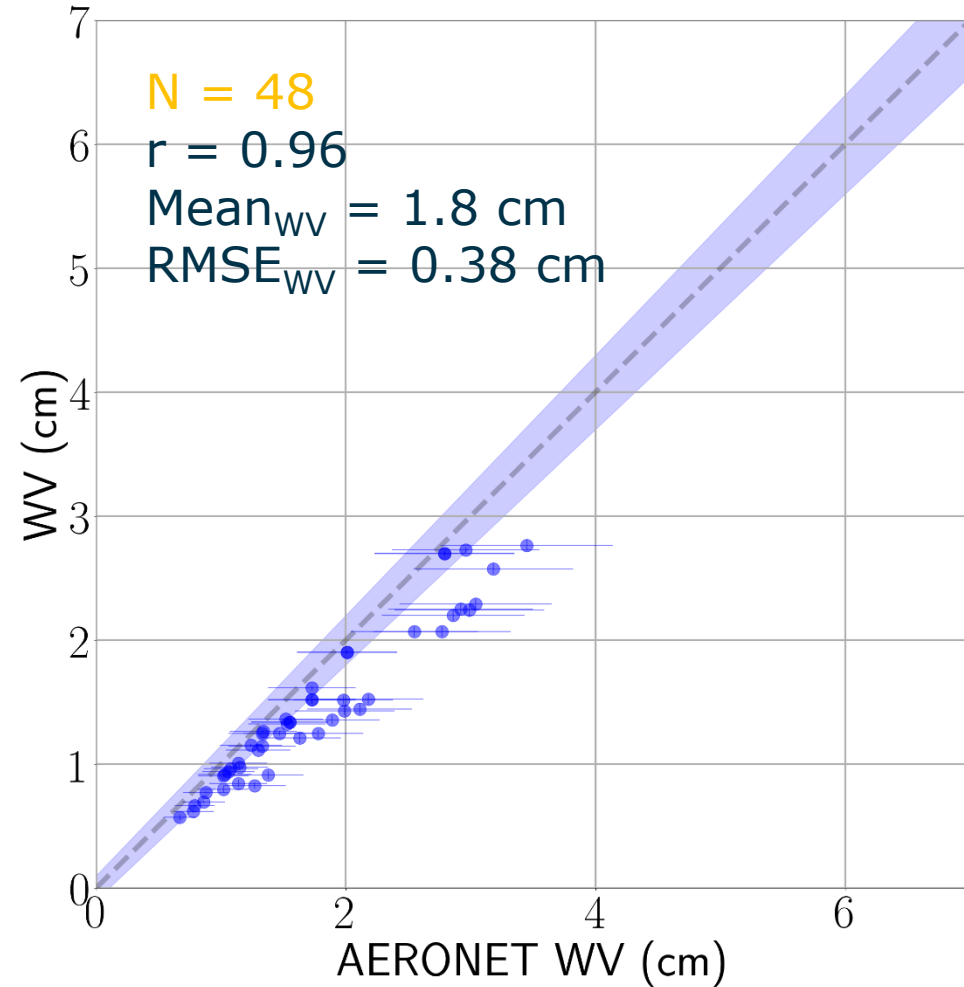
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$$U_{\text{req,AOT}} < 0.1 * \text{AOT} + 0.03$$



$$U_{\text{req,WV}} (\text{cm}) = 0.1 * \text{WV} (\text{cm}) + 0.2$$



Sentinel-2 Collection 1 SR validation: inter-comparison with Landsat



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“Qualitative” validation: satellite inter-comparison (ρ_{si} : BOA extracted with PACO (DLR AC SW))

- Spatial: 2x2 and 3x3 pixels depending on sensor GSD.
- Temporal: overpasses (± 1 hour) with Landsat 8/9.

BOA reflectance (ρ , $U_{\rho,BOA}$):

$$U_{BOA} = 0.05 * \rho_{BOA} + 0.005$$

σ_{ROI} : ~ same ROI for both sensors = f(sensor GSD)

$$K = \frac{\rho_{S2} - \rho_{Si}}{\sqrt{U_{S2}^2 + U_{Si}^2}}$$

$$\sigma_{ROI,Landsat} = 2x2 \text{ pix} = 60 \times 60 \text{ m}$$

$$\sigma_{ROI,Sentinel-2} = 3x3 \text{ pix} = 60 \times 60 \text{ m}$$

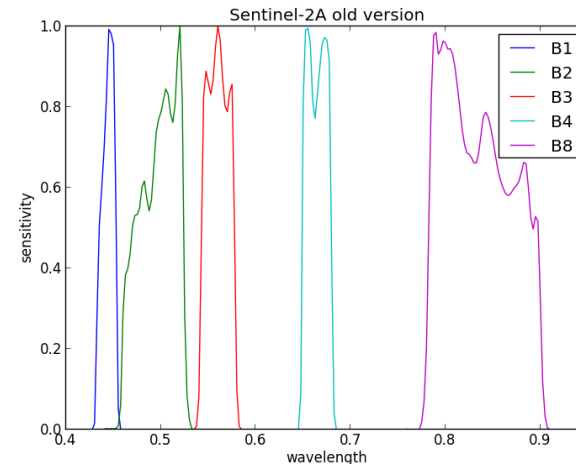
Coverage factor (GUM, JCGM 100:2008)

$$\rho_{si} = \frac{1}{N} \sum_{ROI} \rho_i$$

$$U_{si} = \frac{1}{N} \sum_{ROI} U_{BOA}$$

Band central wavelength (λ_c , $FWHM_{\lambda}$):

$$\lambda_c = \frac{\sum_i^L SRF \cdot \lambda}{\sum_i^L SRF}$$



Inter-comparison: Gobabeb Sentinel-2 and PACO-Landsat 8/9



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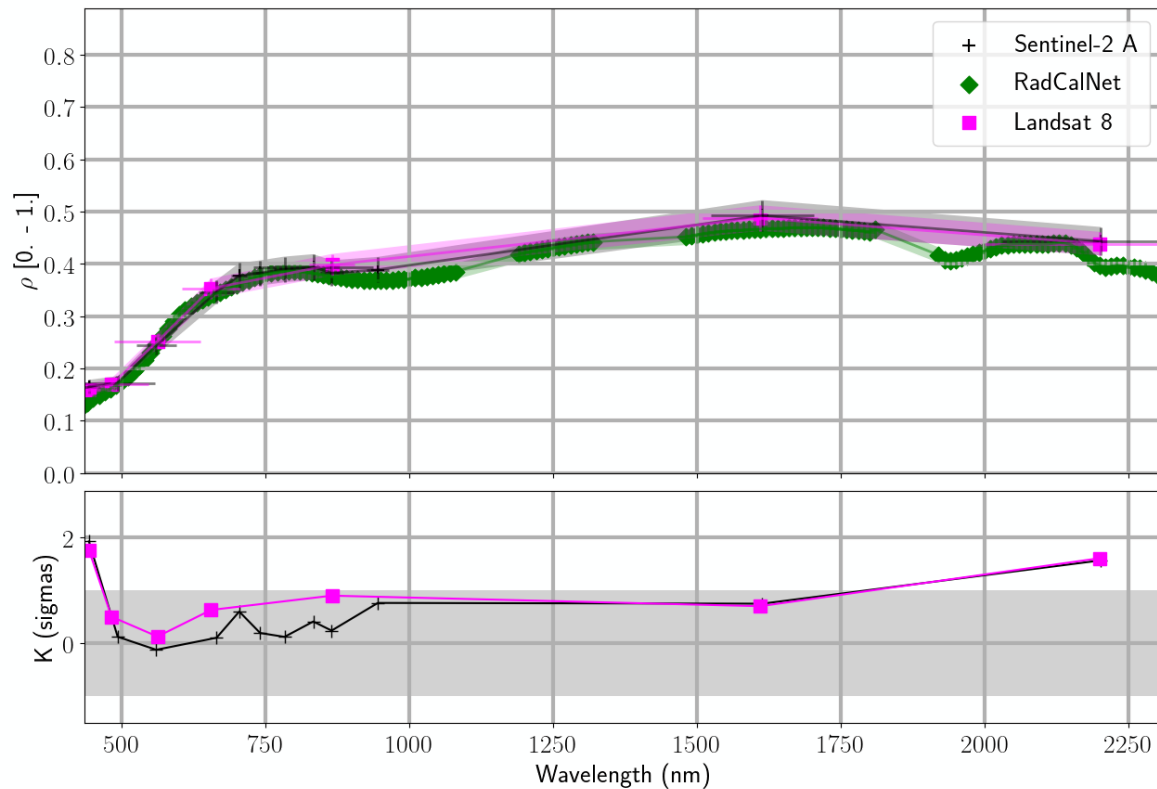


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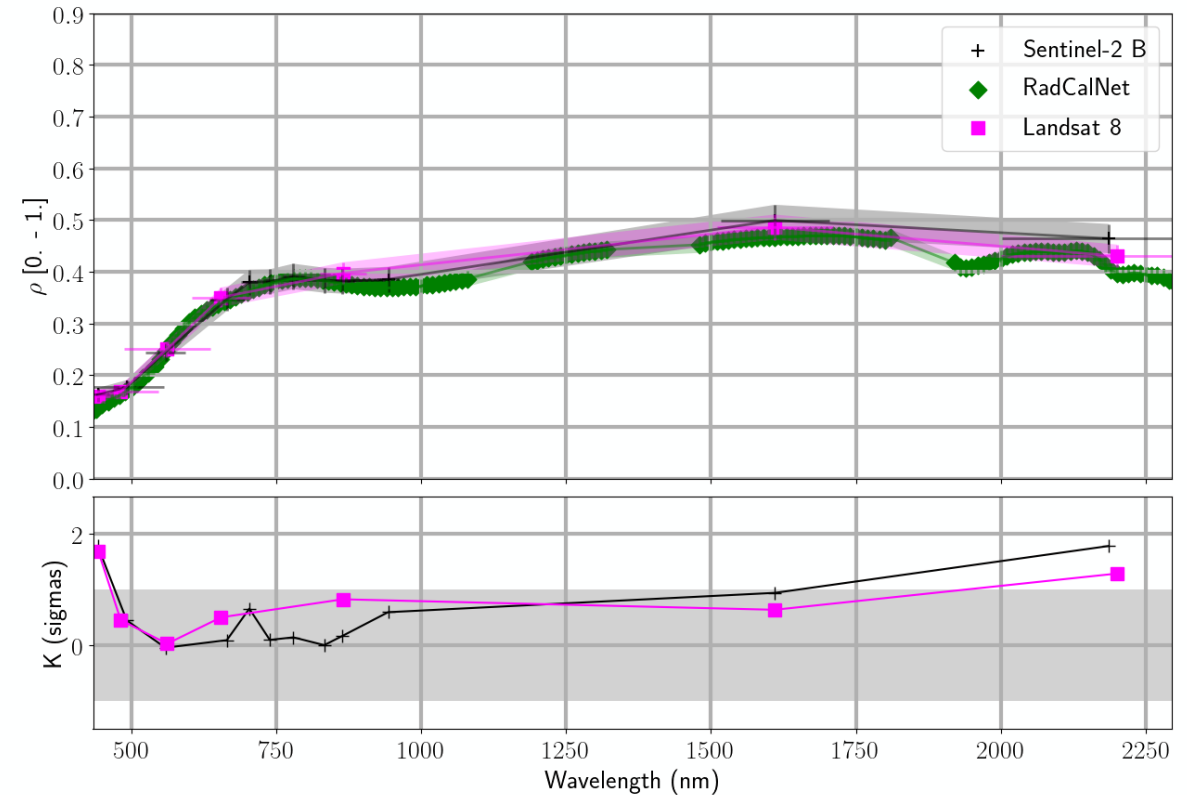
Satellite	Sensor	View angles (θ, ϕ)	Sun angles (θ, ϕ)
Sentinel-2	A	(8°, 287°)	(21°, 90°)
Landsat	8	(0°, 0°)	(26°, 94°)

2021-12-05



Satellite	Sensor	View angles (θ, ϕ)	Sun angles (θ, ϕ)
Sentinel-2	B	(8°, 286°)	(22°, 94°)
Landsat	8	(0°, 0°)	(27°, 97°)

2021-12-20



Inter-comparison: La Crau Sentinel-2 and PACO-Landsat 8/9



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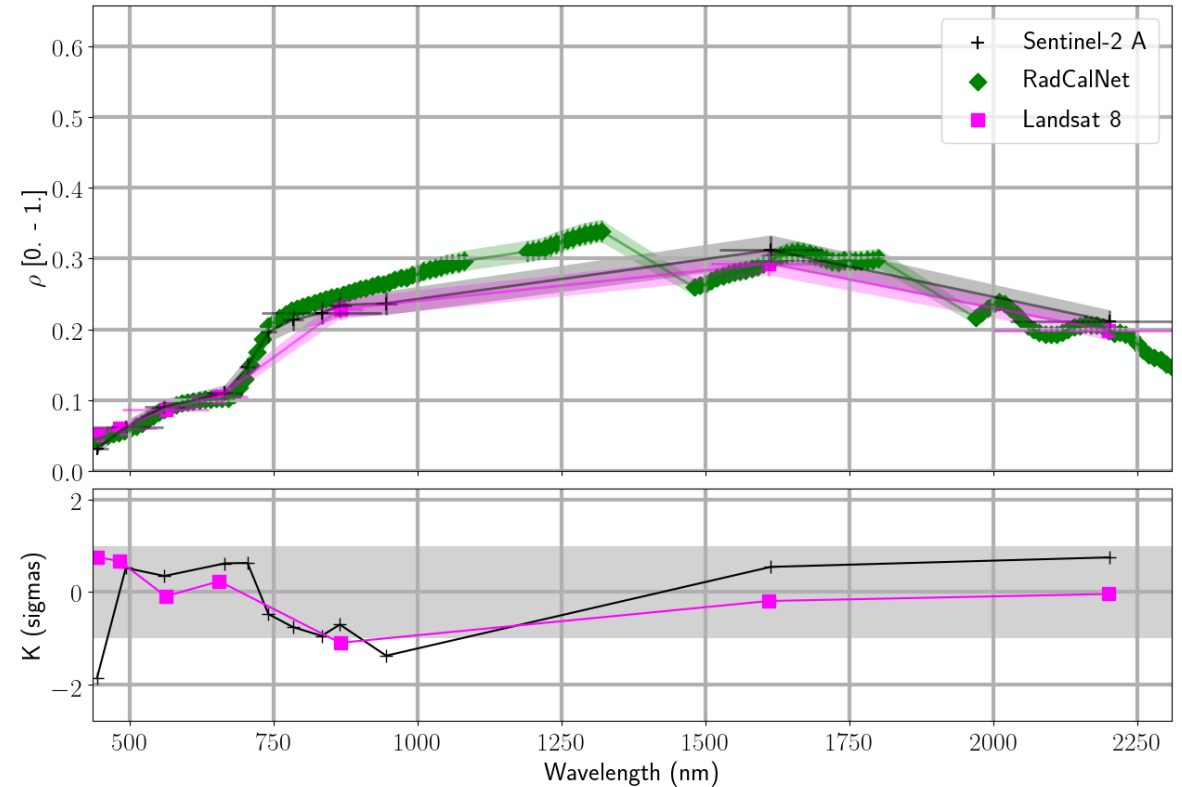
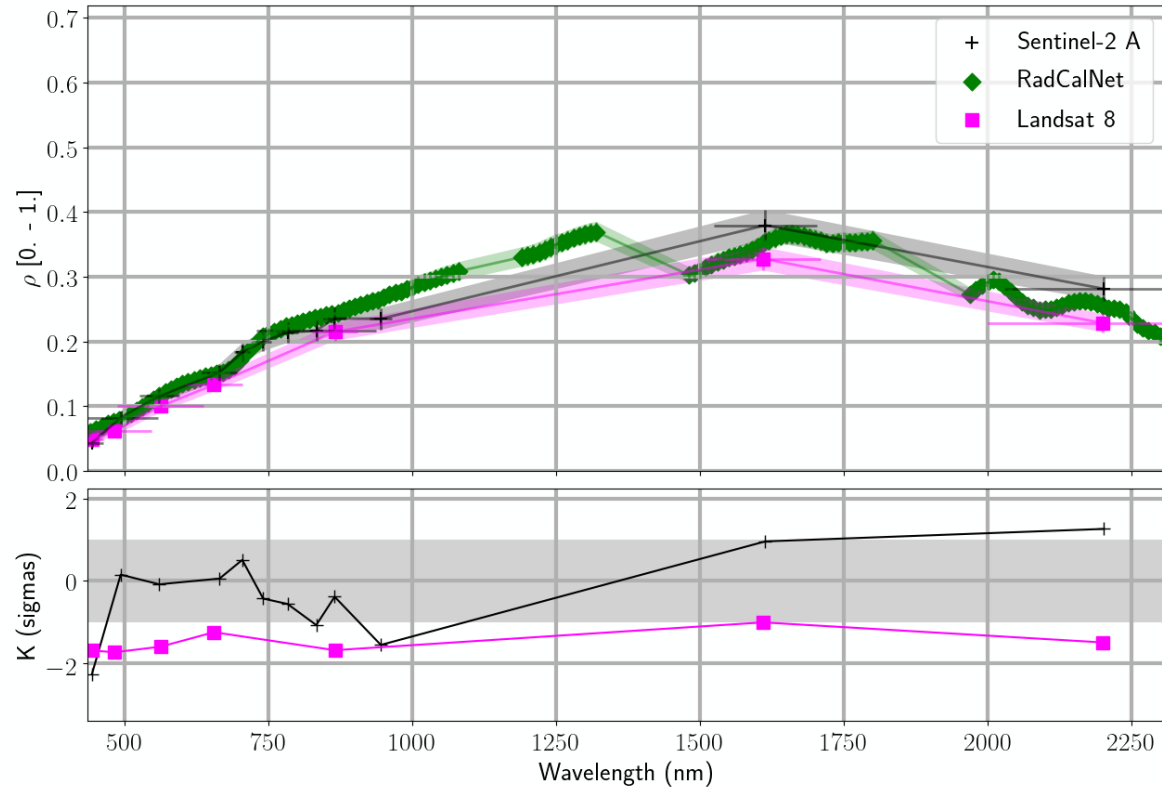


Satellite	Sensor	View angles (θ, ϕ)	Sun angles (θ, ϕ)
Sentinel-2	A	(7°, 105°)	(39°, 156°)
Landsat	8	(0°, 0°)	(40°, 151°)

2021-09-06

Satellite	Sensor	View angles (θ, ϕ)	Sun angles (θ, ϕ)
Sentinel-2	A	(8°, 287°)	(51°, 168°)
Landsat	8	(0°, 0°)	(51°, 160°)

2021-10-09



Conclusions



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Validation with reference in-situ measurements:

- ✓ Sentinel-2 Collection -1 SR (2021) is within L2A ground reflectance requirements.
- ✓ Consistent results in all bands with operational products (May 2023 DQR ; Pflug, B. et al, 2022, IGARSS)
- ✓ Consistent results for AOT with operation products and validation with AERONET sites.
- ✓ Outliers in the water vapor estimation currently under investigation.
- ✓ More statistics required over the RadCalNet sites. More Sentinel-2 scenes to be downloaded.

Validation with other sensors:

- ✓ Consistent ($|k| < 1$) results with Landsat 8: both sensors measure *the same*.
- ✓ Other sensors to be added: searching for DESIS overpasses.

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