LPVE23 - WORKSHOP ON LAND PRODUCT VALIDATION AND EVOLUTION

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Inter-comparison of PACO BOA surface reflectance between multi- and hyperspectral sensors: EnMAP overpasses with DESIS, Sentinel-2, Landsat and CalVal sites

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- L2A surface reflectance produced with the same AC: PACO (Python-based Atmospheric Correction) (de los Reyes et al, 2020, Sensors)
- BOA spectral uncertainties: 68% C.L. with RadCalNet as reference
- AOT DDV-algorithms:
    - DESIS (VNIR)
    - EnMAP/Landsat/Sentinel (SWIR)
- WV APDA-algorithms:
    - DESIS (820 nm),
    - EnMAP (945 +1130 nm),
    - Sentinel-2 (945 nm), Landsat (no WV bands)
- No BRDF correction.

PACO uncertainties

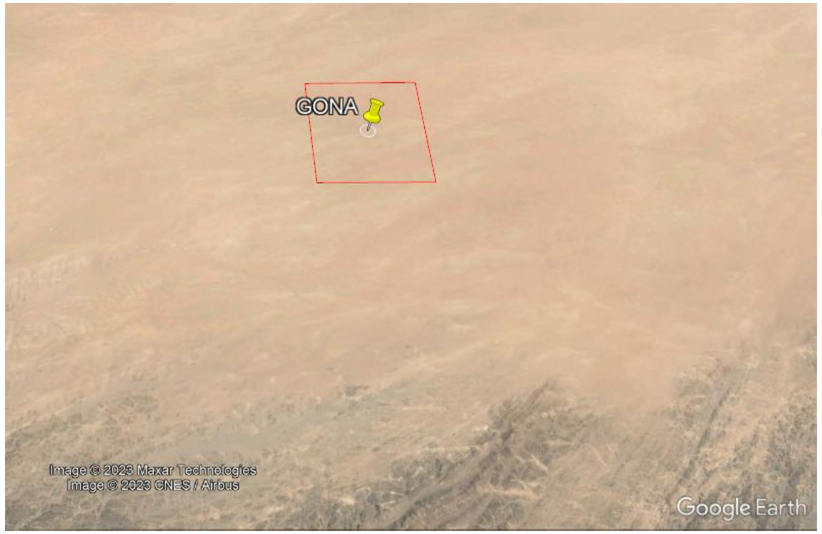
- Overpasses +- 1 hour: similar atmospheric conditions
- Uncertainties (at 68% C.L.) with reference:
  - AOT, WV: AERONET
  - ρ_{BOA} spectral uncertainties: RadCalNet
    - σ_{ROI} (500 x 500 m) < 5% (La Crau), < 3% (Gobabeb)
    - σ_{ROI} (1x1 km) < 1.5% (RailroadValley Playa)

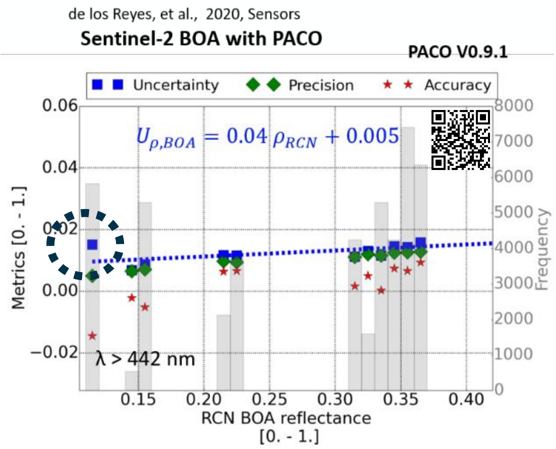
$$U_{PARAM} = U_{slope} * Param + U_{offset}$$

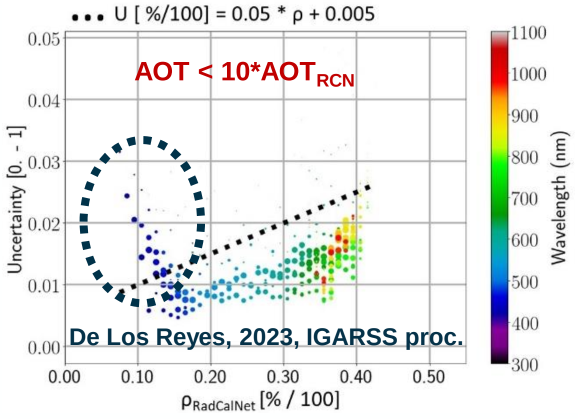
(U_{offset}, U_{slope})	AOT [550 nm]	WV [cm]	ρ_{BOA} [%/100]
Sentinel-2	(0.03, 0.29)	(0.13, 0.02)	(0.005, 0.04)
DESIS	(0.15 , ---)	(0.06, 0.08)	(0.011, 0.05)
EnMAP	(0.04, 0.14)	(0.07, 0.10)	(0.005, 0.05)

$$K = \frac{\rho_{S1} - \rho_{ref}}{\sqrt{\sigma_{S1}^2 + \sigma_{ref}^2}} \leq 1 \qquad \sigma_{ref} = \sqrt{\sigma_{RCN}^2 + \sigma_{ROI}^2}$$

GUM, JCGM 100:2008







De Los Reyes, et al., 2023, IGARSS

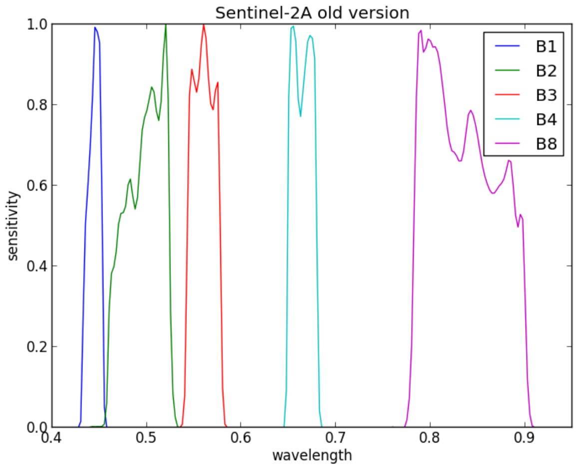
BOA Inter-comparison: ROI and uncertainties

- BOA reflectance (ρ, $U_{\rho,BOA}$): $U_{BOA} = 0.05 * \rho_{BOA} + 0.005$
  - σ_{ROI} : ~ same ROI for both sensors = f(sensor GSD)
    - $\sigma_{ROI,EnMAP} = \sigma_{ROI,DESIS} = \sigma_{ROI,Landsat}$ = 2x2 pix = 60 x 60 m
    - $\sigma_{ROI,Sentinel\text{-}2}$ = 3x3 pix = 60 x 60 m

$$\rho_{si} = \frac{1}{N}\sum_{ROI} \rho_i \qquad \sigma_{si} = \frac{1}{N}\sum_{ROI} U_{BOA} \qquad K = \frac{\rho_{S1} - \rho_{S2}}{\sqrt{\sigma_{S1}^2 + \sigma_{S2}^2}}$$

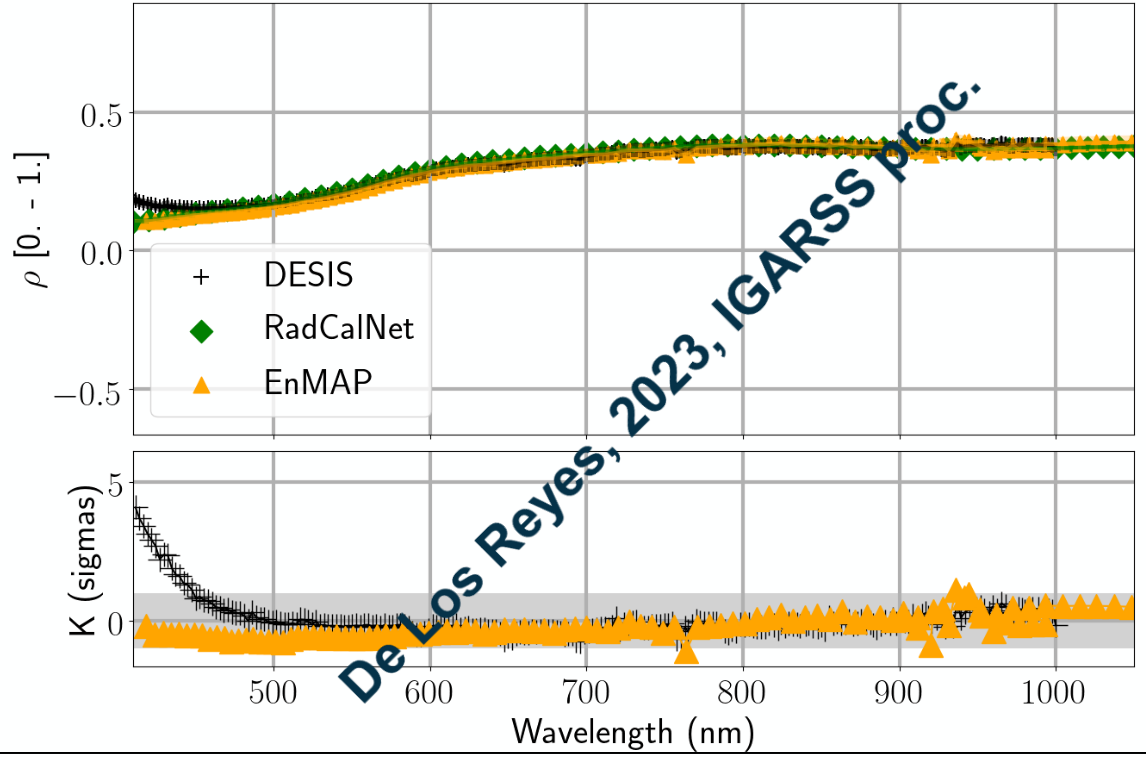
- Band central wavelength (λ_c, $FWHM_\lambda$):

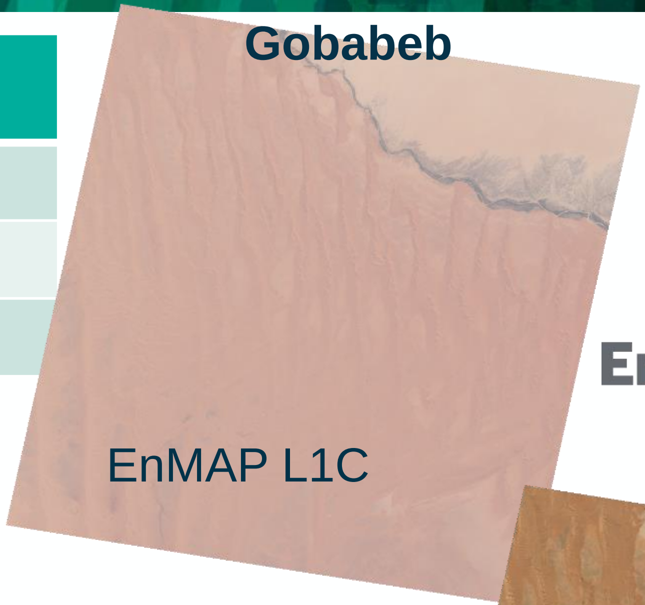
$$\lambda_c = \frac{\sum_i^L SRF \cdot \lambda}{\sum_i^L \lambda}$$

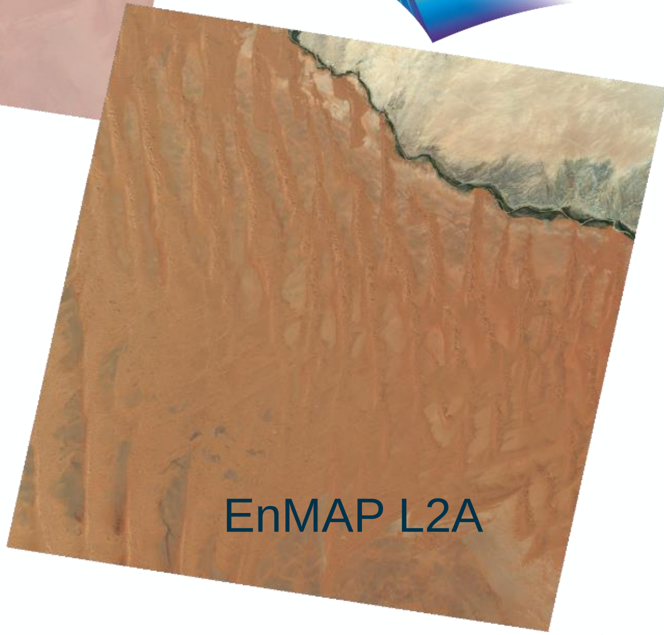


Hyperspectral: EnMAP + DESIS + RadCalNet

02.10.2022	UTC	(θ_s, φ_s)	(θ_v, φ_v)	AOT_{550}	WV (cm)
EnMAP	09:43	(25.6°, 40.9°)	(5.9°, 102.2°)	0.30 ± 0.08	1.6 ± 0.2
DESIS	07:53	(47.6°, 72.3°)	(15.6°,128.9°)	0.30 ± 0.15	1.4 ± 0.2
RadCalNet	08:00	---	(0°, 0°)	**0.31 ± 0.01**	1.7 ± 0.3

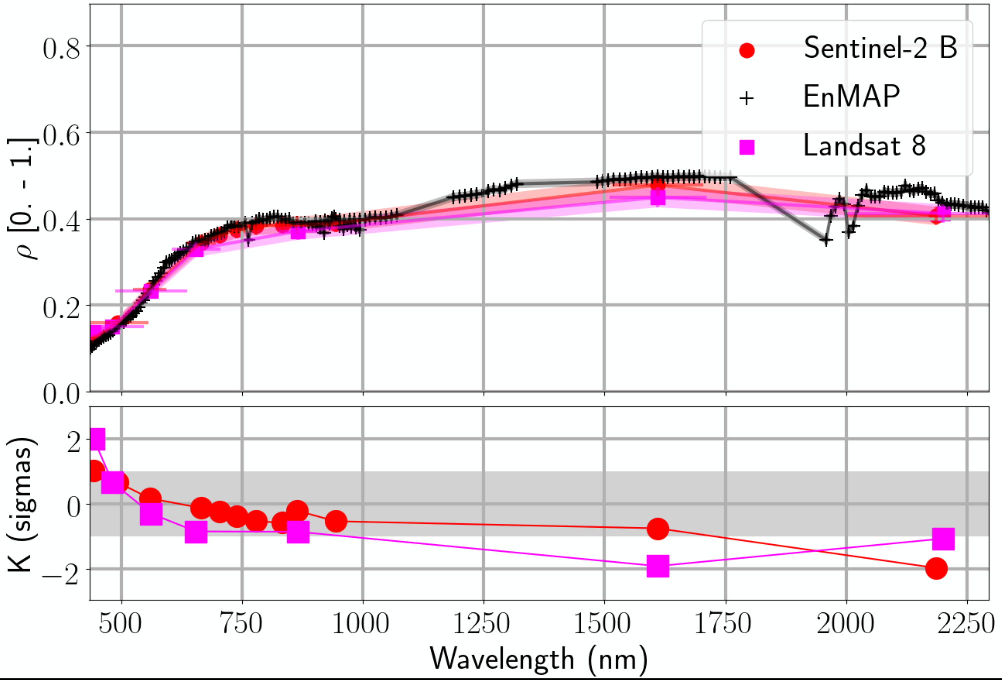


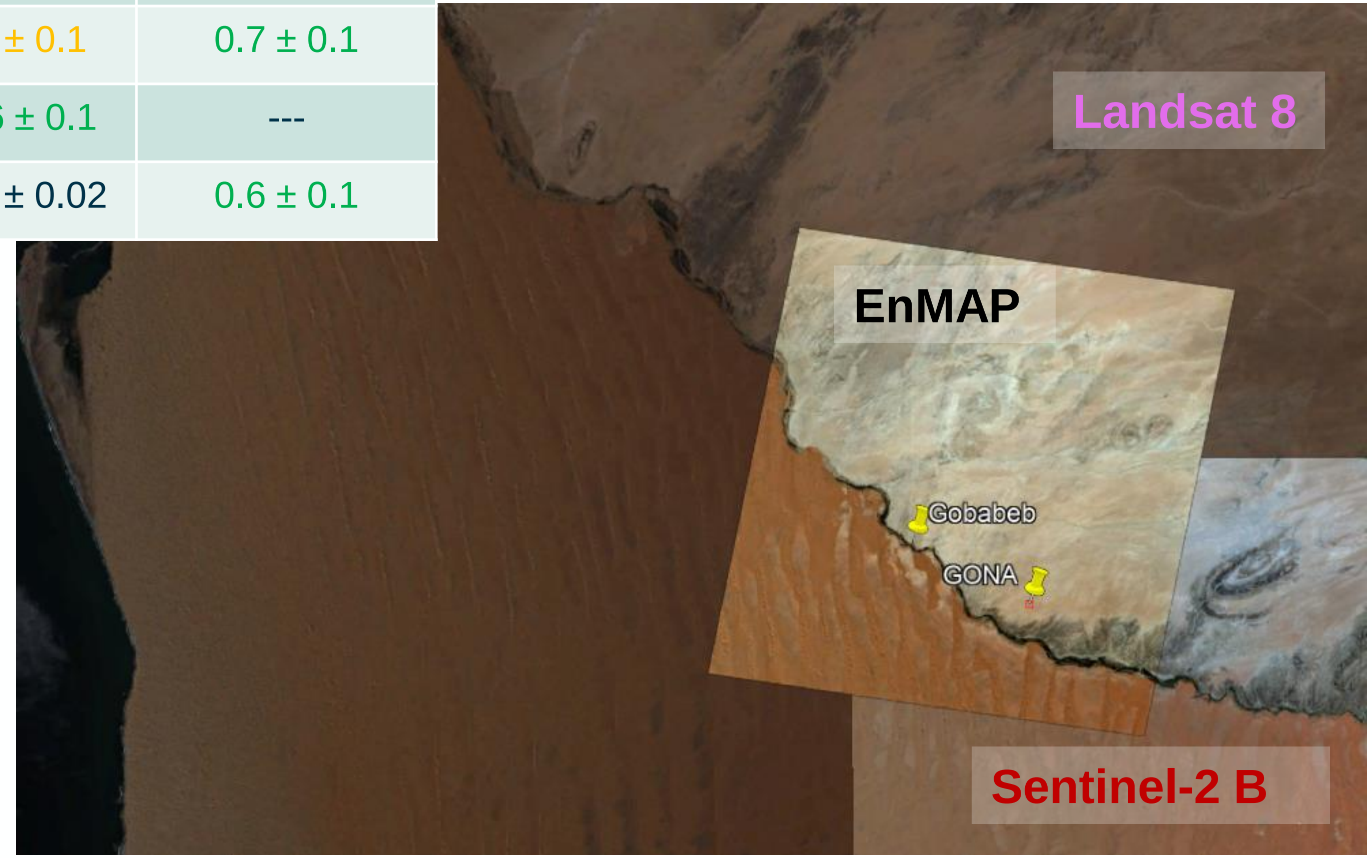




Multi-/Hyperspectral:
EnMAP + Sentinel-2 B + Landsat 8

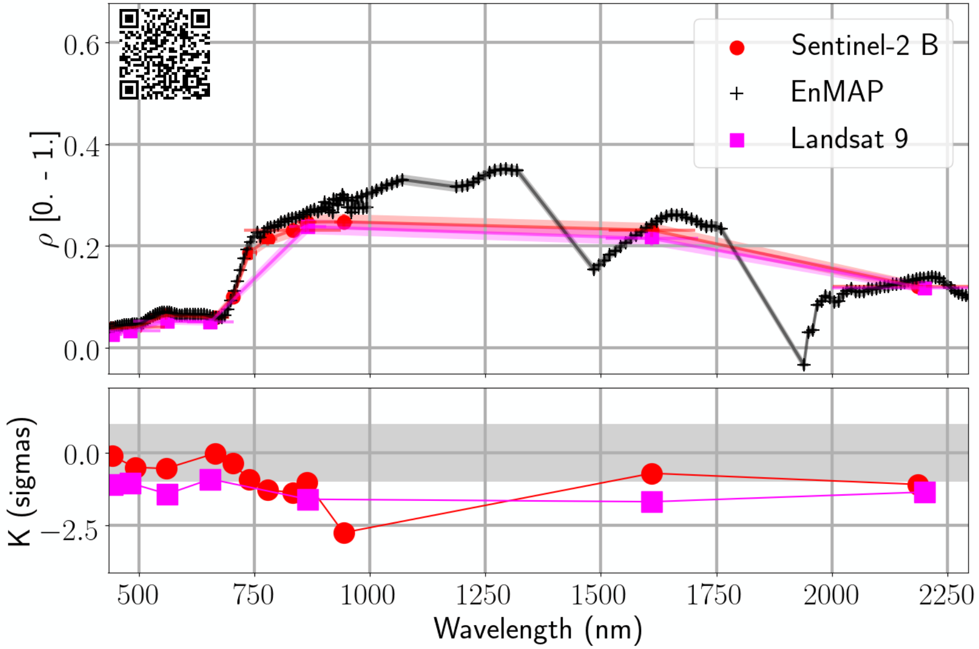
17.08.2022	UTC	(θ_s,φ_s)	(θ_v,φ_v)	AOT_{550}	WV (cm)
EnMAP	09:35	(41.1°, 28.1°)	(9.4°, 282.1°)	0.30 ± 0.08	0.7 ± 0.2
Sentinel-2 B	08:46	(45.3°, 37.2°)	(8.3°, 285.8°)	0.2 ± 0.1	0.7 ± 0.1
Landsat 8	08:58	(47.7°,43.2°)	(0°, 0°)	0.06 ± 0.1	---
AERONET	09:35±1^h	---	---	0.04 ± 0.02	0.6 ± 0.1

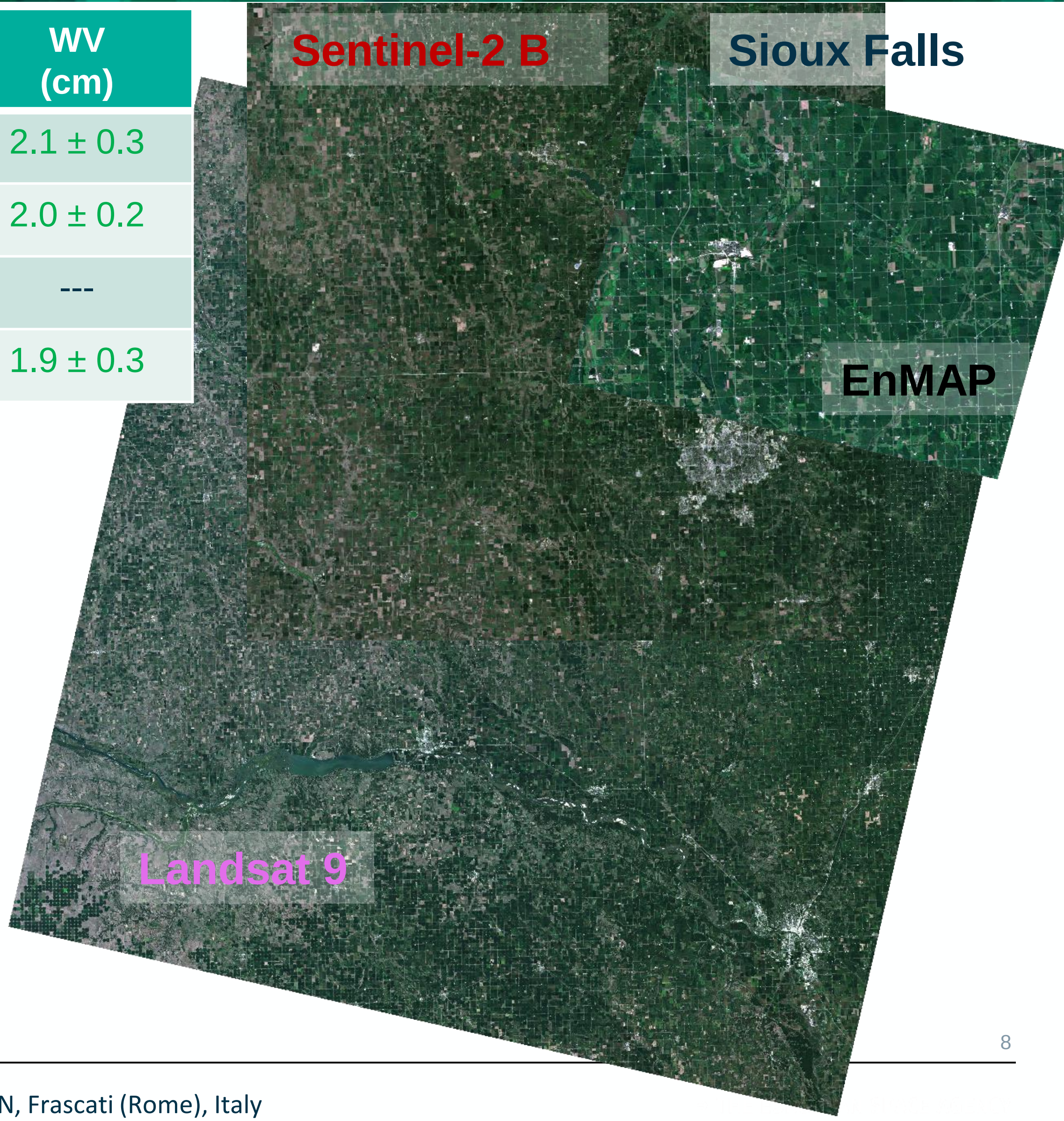




Multi-/Hyperspectral: EnMAP + Sentinel-2 B + Landsat 9

30.08.2022	UTC	(θ_s,φ_s)	(θ_v,φ_v)	AOT_{550}	WV (cm)
EnMAP	18:16	(35.1°, 175.3°)	(32.7°, 282.9°)	0.10 ± 0.05	2.1 ± 0.3
Sentinel-2 B	17:19	(37.1°, 156.1°)	(0.6°, 251.5°)	0.06 ± 0.05	2.0 ± 0.2
Landsat 9	17:12	(38.3°, 148.2°)	(0°, 0°)	0.06 ± 0.05	---
AERONET	$18{:}16\pm1^h$	---	---	0.036 ± 0.006	1.9 ± 0.3





Next steps and conclusions

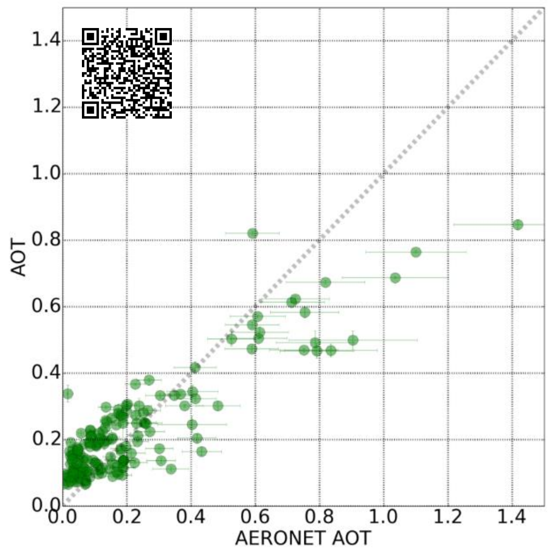
- Next steps:
  - DESIS “recover” in the blue wavelengths (?)
  - BRDF correction from RadCalNet sites: sites LUTs for sensors (θ_v, φ_v, AOT,…) (talk B. Pflug et al).
  - L0 V01.03.01: improved EnMAP VNIR/SWIR co-registration
  - Investigate how to add $FWHM_\lambda$ in K estimation.
- Conclusions:
  - Low quality (no DDV) -> $\Delta\rho_{BOA}$ ~ 2 – 3 %.
  - Sensor/AC requirements -> approximation **upper limit of the uncertainty**.
  - L2A CalVal sites have $U_{ROI} < 3\text{-}5\ \%$ ~ U_{BOA} (L2A): not significant validation results.
  - Redefinition of the L2A requirements to cope with U_{AOT} ($\lambda < 500$ nm): $U_{BOA,\lambda<500} > 0.05 * \rho_{BOA} + 0.005$
  - K < 1-> sensors L2A retrievals from inter-comparison are compatible with random errors.

Backup slides

AOT uncertainties

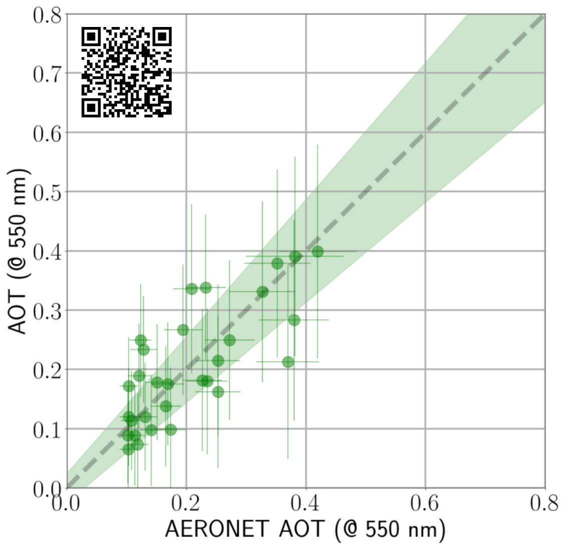
SWIR

$$U_{AOT} = 0.29 * AOT_{550} + 0.03$$



Sentinel-2 (de los Reyes, R. et al, 2020)

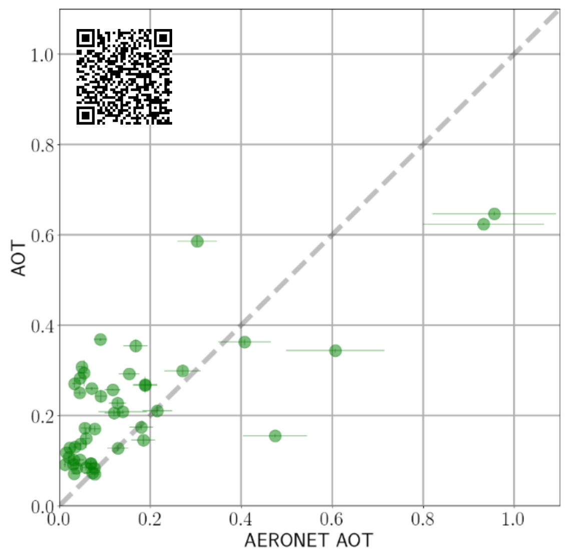
$$U_{AOT} = 0.14 * AOT_{550} + 0.04$$



EnMAP (Storch, T. et al, 2023)

VNIR

$$U_{AOT} = 0.05 * AOT_{550} + 0.005$$



DESIS (de los Reyes, R. et al, 2021)

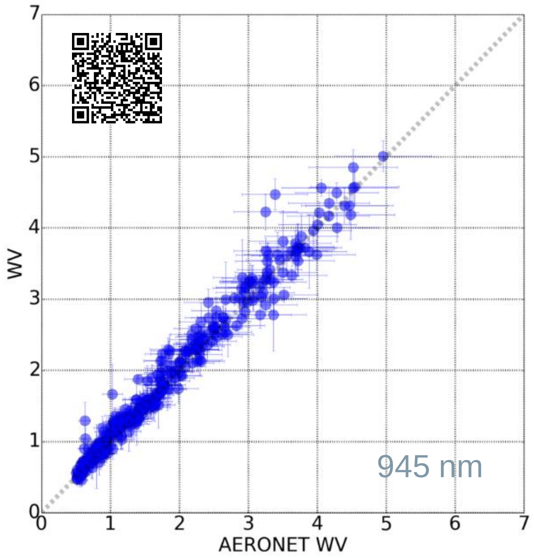
For AOT estimation with DDV (Kaufmann et al, 1997):

- $\Delta\rho \sim 0.1 * \Delta\tau$ (for $\tau < 0.2$)
- $\Delta\tau \sim 0.06$ for $\langle\tau\rangle \sim 0.1$

WV uncertainties

1 band

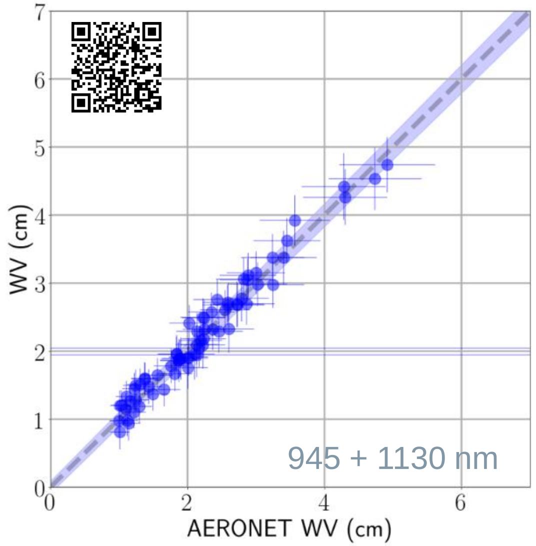
$$U_{WV} = 0.02 * WV + 0.13$$



Sentinel-2 (de los Reyes, R. et al, 2020)

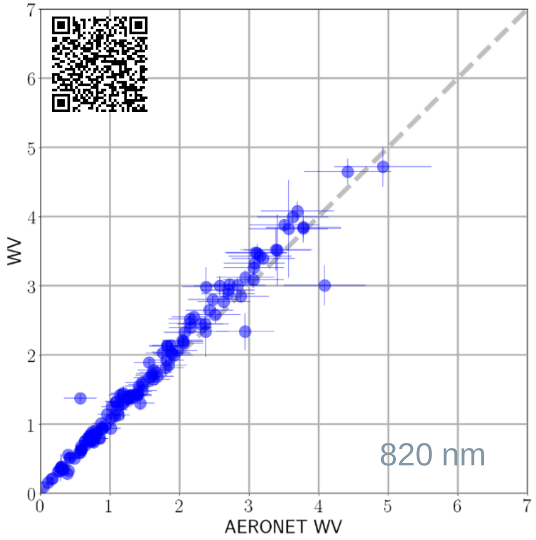
Band regression

$$U_{WV} = 0.10 * WV + 0.07$$



EnMAP (Storch, T. et al, 2023)

$$U_{WV} = 0.08 * WV + 0.06$$



DESIS (de los Reyes, R. et al, 2021)