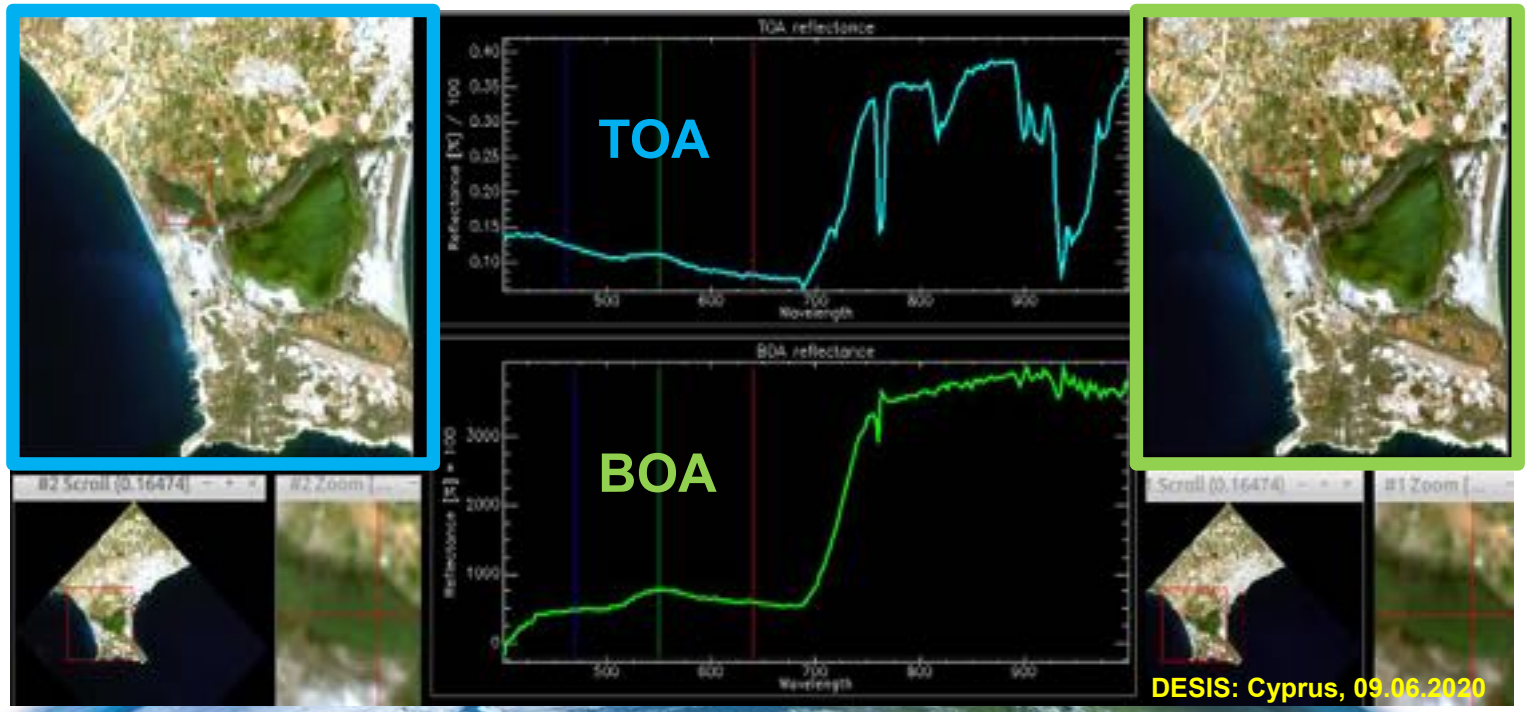
DESIS / EnMAP L2A processor

R. de los Reyes
on behalf the DESIS / EnMAP GS

EOC, DLR



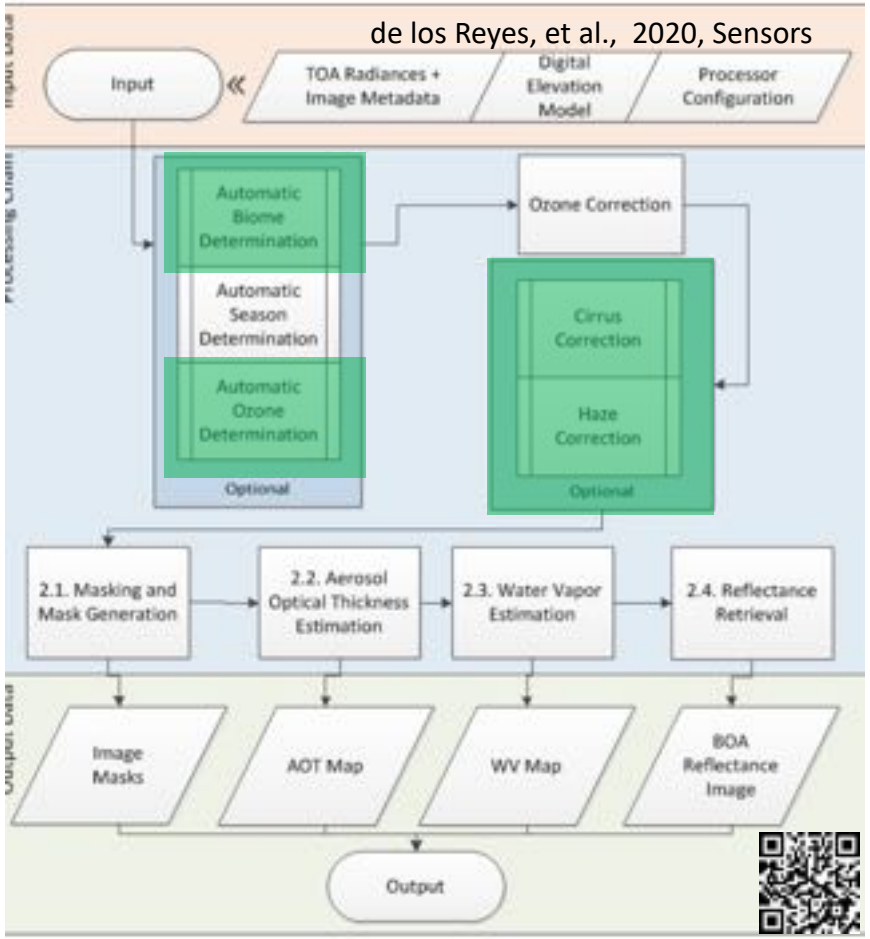
DESIS / EnMAP – L2A processor
PACO – Overview : Atmospheric Correction for Land

- Input:
  - L1C (ortho-rectified)
  - DEM (Digital Elevation Model) (rugged-terrain) (automatic) (SRTM_1ARC/COPERNICUS_30m)
  - Solar model: Fontenla 2011 (Fontenla, 2011, doi:10.1029/2011JD016032)
  - Season: MOD11C3.006 (Wan, Z., doi:105067/MODIS/MYD11A2.006)
  - RTM: MODTRAN 5.4 (Mid-Latitude Summer/Winter)
  - Aerosol = rural / continental

- Atmospheric correction functionalities
  - Masking -> masks
  - AOT estimation (DDV based, Kaufmann 1997) -> AOT
  - WV estimation (APDA, Schlaepfer, 1998) -> WV
  - Rugged / Flat-terrain AC (Richter, R., 1998) -> BOA reflectance
  - No BRDF correction (Lambertian surface)

- Output products:

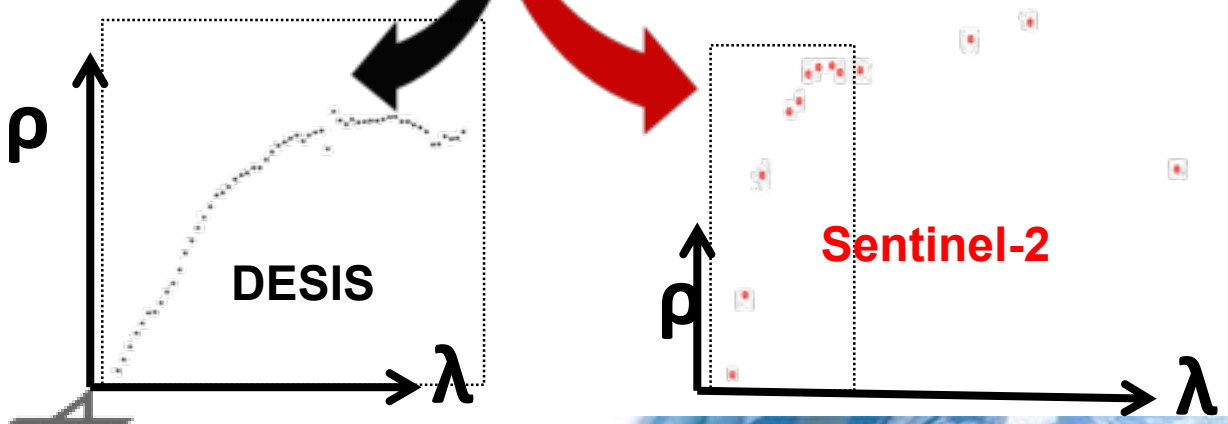
Product	DESIS	EnMAP (PACO / MIP)
Masks (clouds, haze, land, water,…)	QL_QUALITY-2	QL_QUALITY_ [CLASSES, HAZE, CIRRUS, SNOW, CLOUDS, CLOUDSHADOWS]
AOT / WV	QL_QUALITY-2	(Scene mean in metadata)
BOA ground reflectance	SPECTRAL_IMAGE	SPECTRAL_IMAGE (land_mode)
Water leaving reflectance	---	SPECTRAL_IMAGE (water_mode)
Subsurface reflectance	---	SPECTRAL_IMAGE (water_mode)

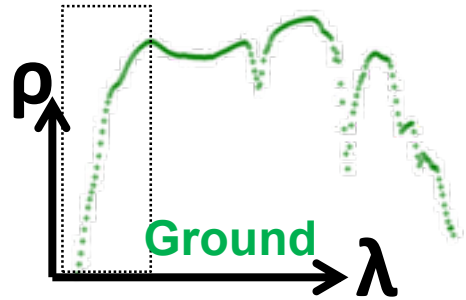


Validation of Bottom-Of-Atmosphere (BOA)

- Illumination/acquisition conditions:
  - SZA < 30°
  - Off-nadir < 10°
- **RadCalNet sites** (Bouver, M. et al, 2019):
  - La Crau (DDV available)
  - Gobabeb and Railroad Valley (*L2AF*)
- *Qualitative* validation (±30 min):
  - Sentinel-2: A/B
  - Landsat-8

QA4EO-WGCV-IVO-CSP-002_RVUS

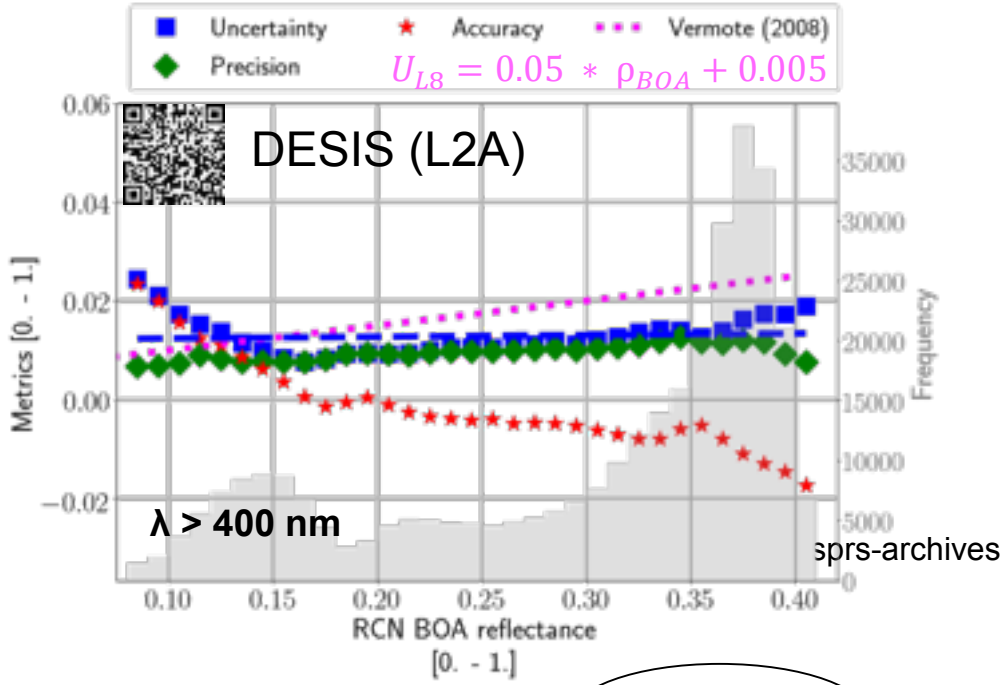




DLR

L2A – BOA validation: Gobabeb

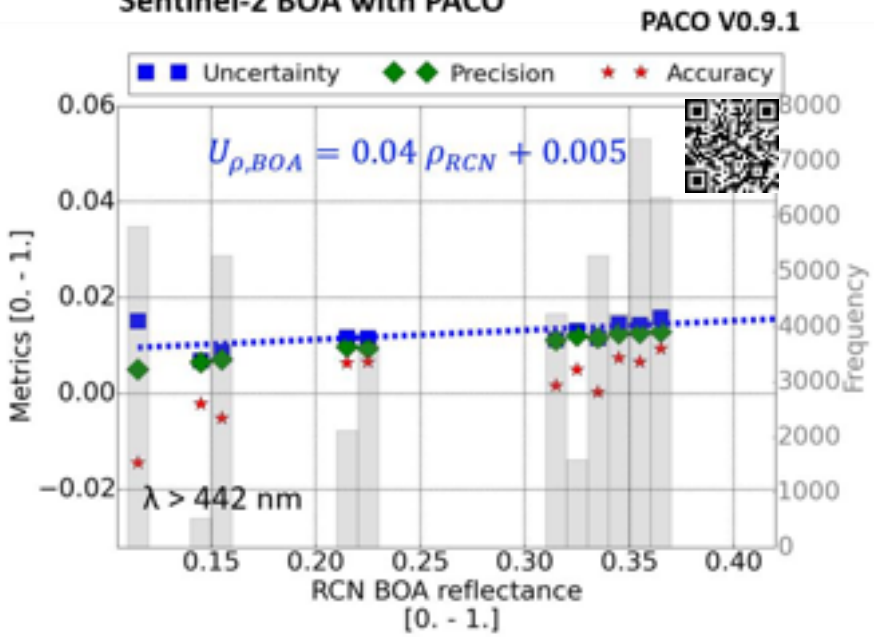
- BOA reflectance after atmospheric correction: processor **consistency** through **multi- and hyper-spectral** sensors
- 7 scenes for SZA < 30°, off-nadir < 10°
- ROI = 500 m (U_{RCN} < 3%) **< 5% (requirement)**



sprs-archives

$U_{\rho,RCN} = (\mathbf{0.04} \pm 0.02) * \rho_{RCN} + (\mathbf{0.011} \pm 0.006)$

de los Reyes, et al., 2020, Sensors

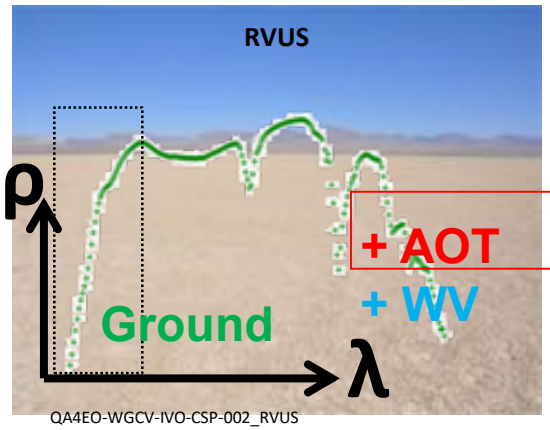


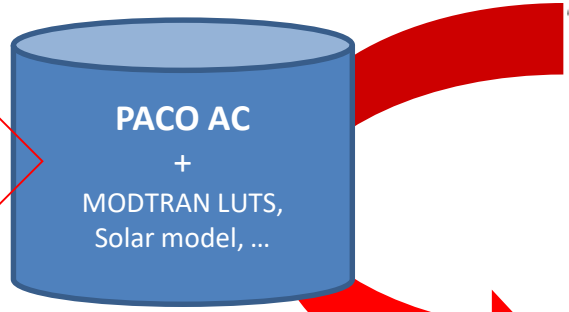
AOT DESIS in **arid sites** (no DDV):
AOT_{DESIS} < 10 * AOT_{RCN}

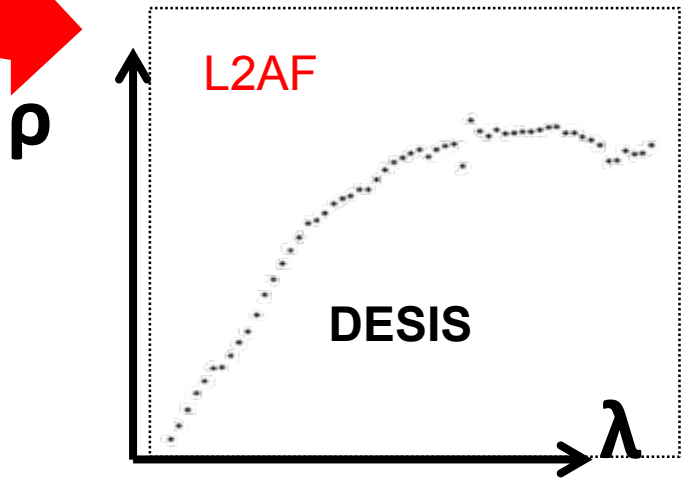
Dominated by the blue wavelengths (AOT)

Validation of Bottom-Of-Atmosphere (L2AF)

- RadCalNet sites:
  - Gobabeb and Railroad Valley





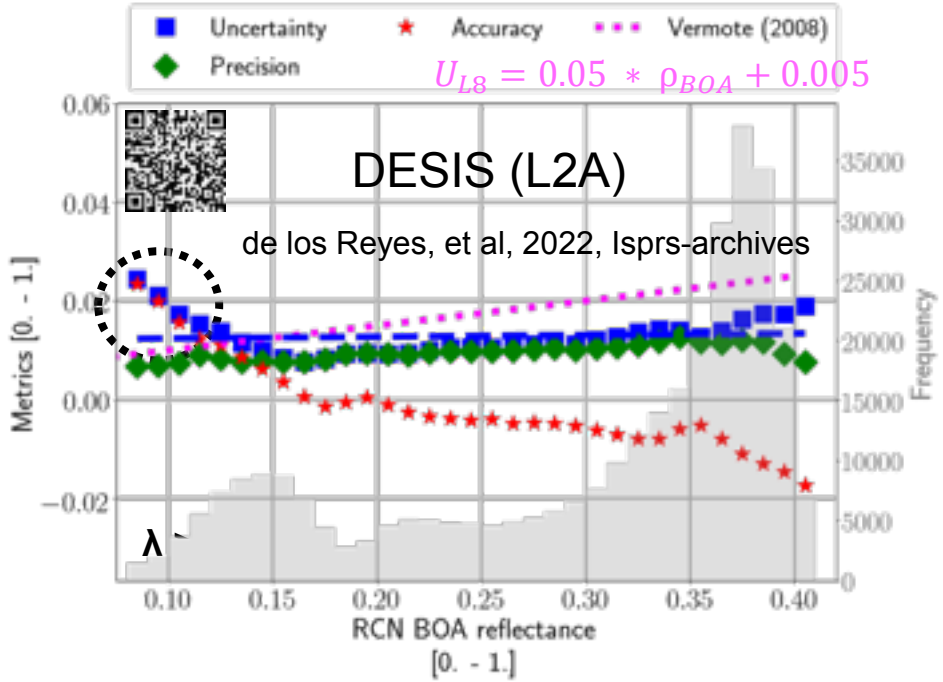


- Only for arid scenes (no DDV information possible)
- No DDV -> no accurate AOT estimation:
  - $AOT_{DESIS} < 10 * AOT_{RCN}$

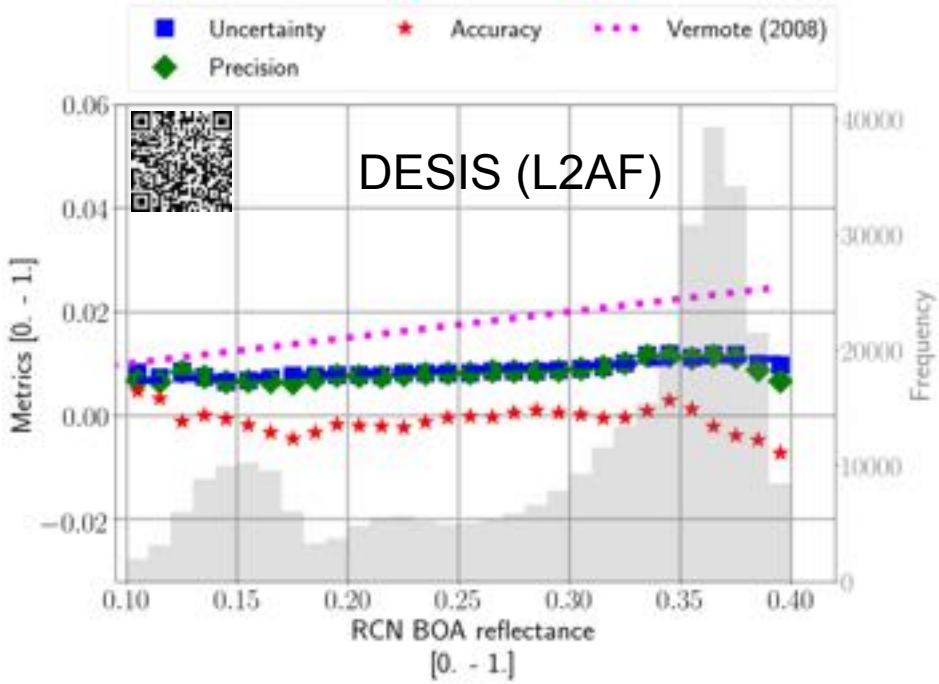
L2AF – BOA validation (*AOT Forced*): Gobabeb

- 7 scenes for SZA < 30°, off-nadir < 10°
- BOA uncertainty (ρ < 10%) comes from AOT uncertainty

New reformulation of the BOA requirements: <u>no linear fit</u>



$U_{\rho,RCN} = (\mathbf{0.04} \pm 0.02) * \rho_{RCN} + (\mathbf{0.011} \pm 0.006)$

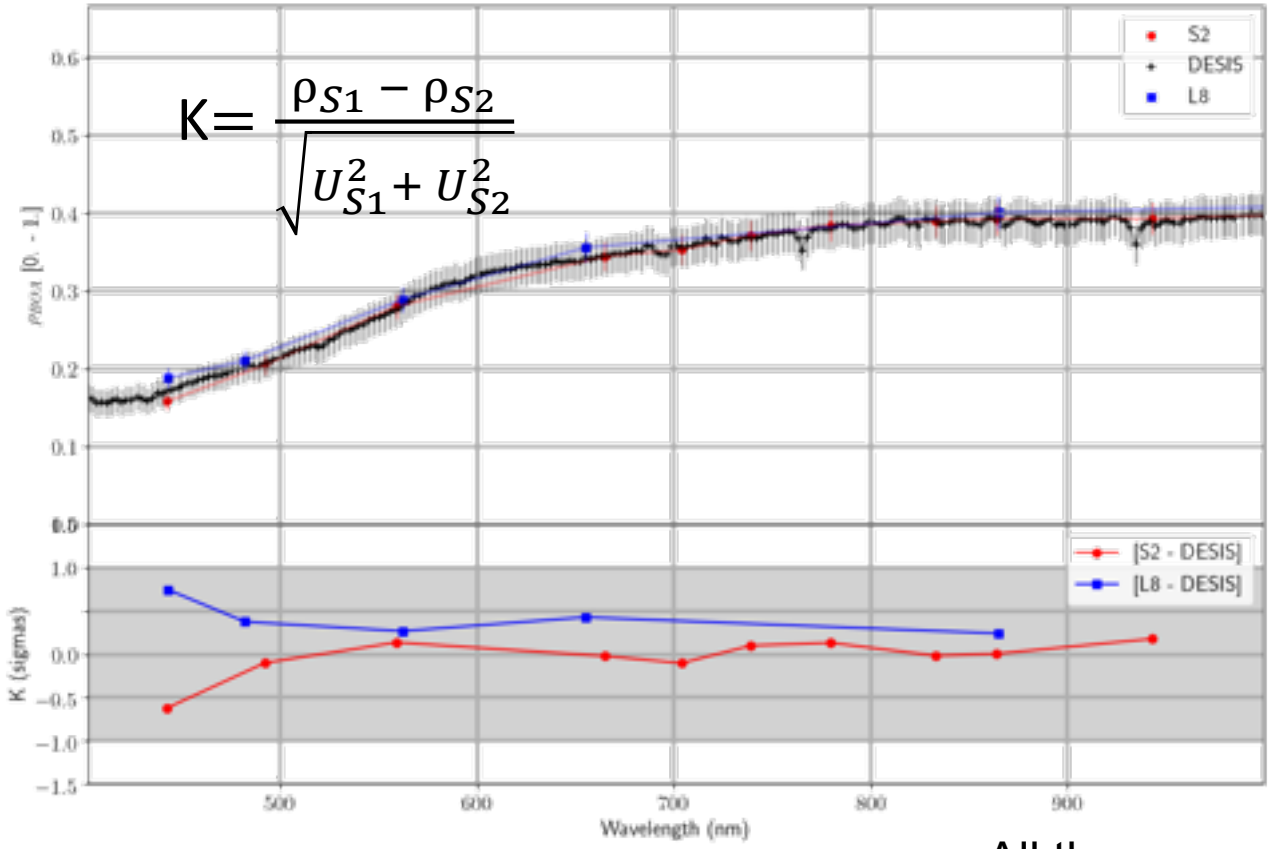


$U_{\rho,RCN} = (0.014 \pm 0.002) * \rho_{RCN} + (0.005 \pm 0.000)$

L2A – comparison with other sensors

- Cross-comparison between sensors ground reflectance (ρ) (PACO products):
  - Minimization of uncertainties due to difference in processors and LUTs
  - *Qualitative* evaluation < 1 σ.

$$K = \frac{\rho_{S1} - \rho_{S2}}{\sqrt{U_{S1}^2 + U_{S2}^2}}$$



Barreal Blanco (PICS)
12.03.2019
Δt ~ 50 min.
Θ_{sun} ~ 40°
$\theta_{S2,L8,\ DESIS}$ < 10 °

All three sensors processed with PACO: $\mathbf{U_{Si} = 0.04 * \rho_{BOA} + 0.011}$

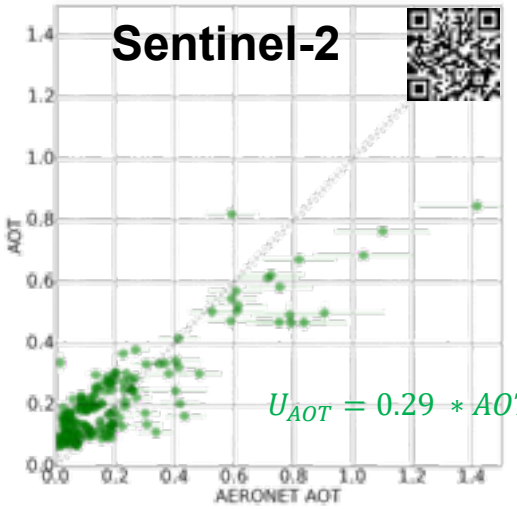
Conclusions from DESIS / EnMAP L2A validation

- DESIS / EnMAP L2A in agreement with ground measurements and other sensors.
- *Atmosphere characterization*: linear function (AOT/WV) + **OFFSET** is still possible
- *Surface reflectance (BOA)*:
  - RadCalNet Gobabeb: U_{BOA} < 5% (AOT < 0.1, SZA < 30° and off-nadir < 10 °)
  - **Consistent results with multi-spectral sensors**:
    - Uncertanties of Sentinel-2 with RadCalNet
    - Cross-validation with sensors (Landsat-8, Sentinel-2): PICs sites.
  - **U_{BOA} (1σ) = 0.04 * ρ_{BOA} + 0.011 -> non-linear fit needed for BOA requirements**.
- **More in-situ data** (AOT, ρ_{BOA}) will help in the uncertainty estimation.

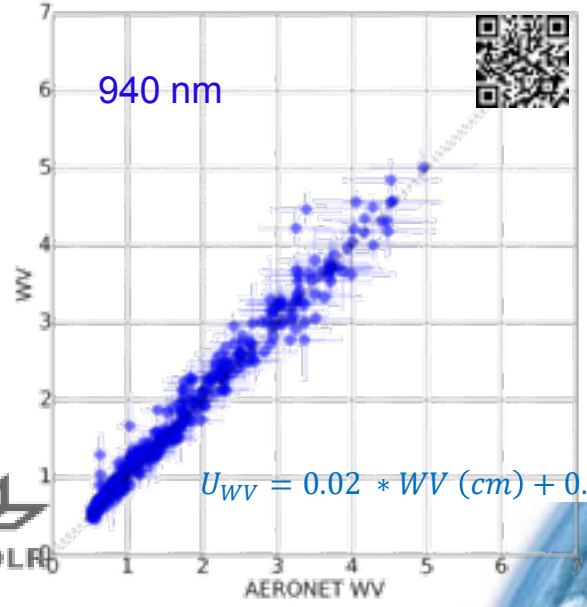
Backup slides

L2A – AOT / WV validation

de los Reyes, et al., 2020, Sensors



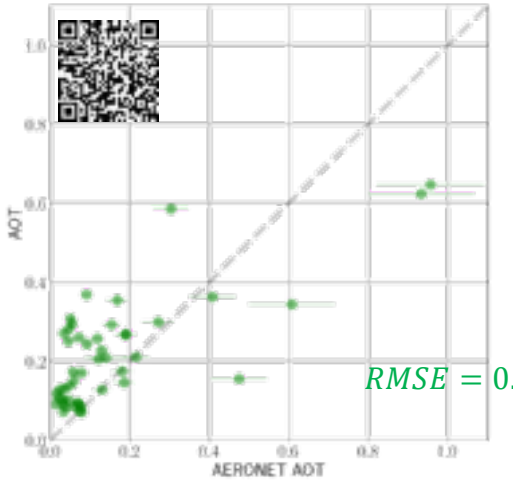
$$U_{AOT} = 0.29 * AOT\ (550\ nm) + 0.03$$



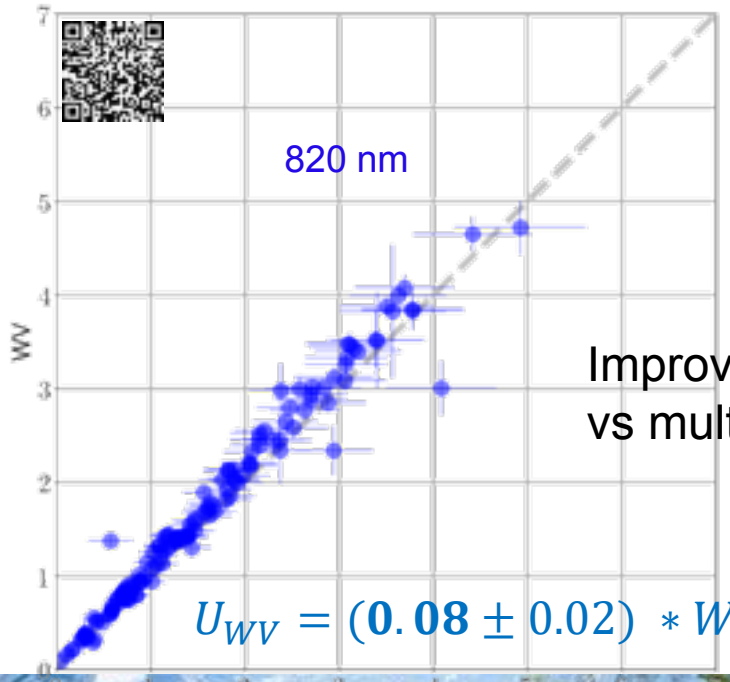
$$U_{WV} = 0.02 * WV\ (cm) + 0.13$$

de los Reyes, et al, 2022, Isprs-archives

DESIS



$$RMSE = 0.15\ (VNIR)$$

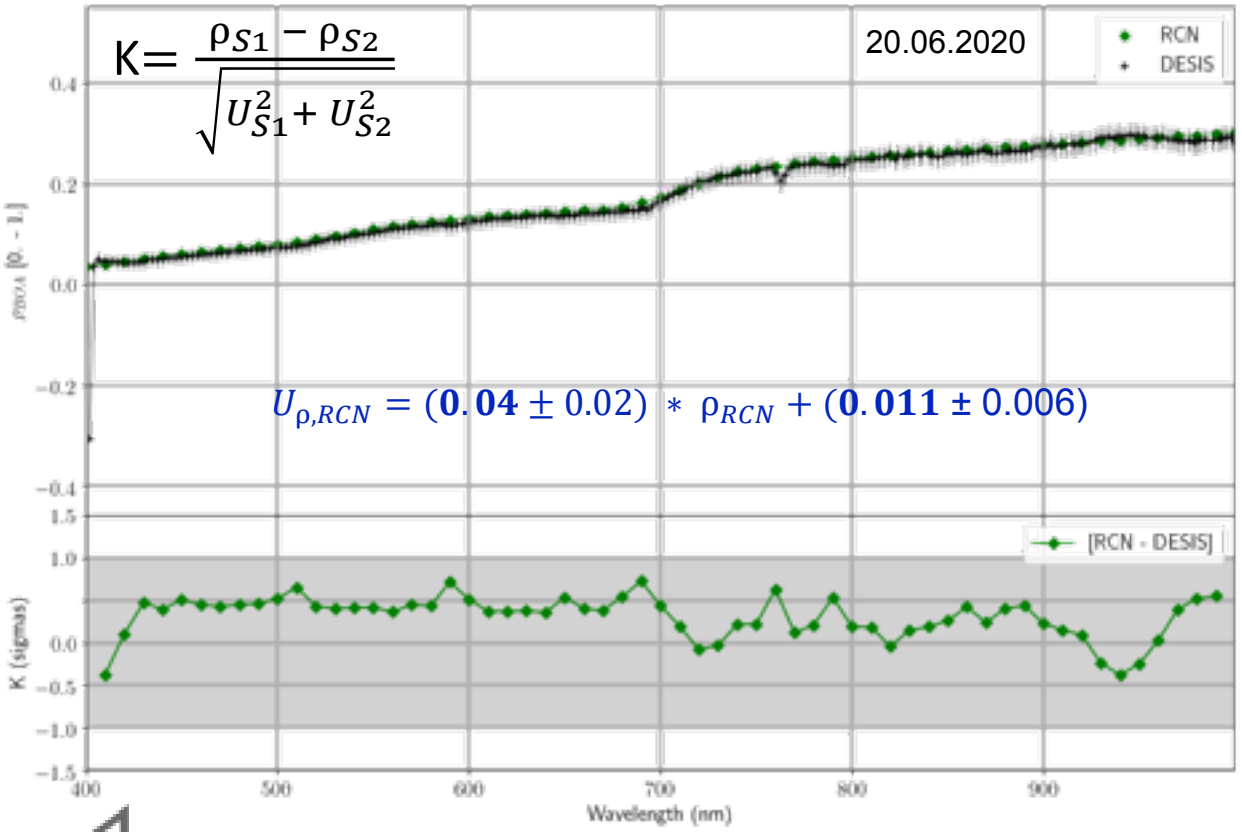


$$U_{WV} = (\mathbf{0.08} \pm 0.02) * WV\ (cm) + (\mathbf{0.06} \pm 0.03)$$

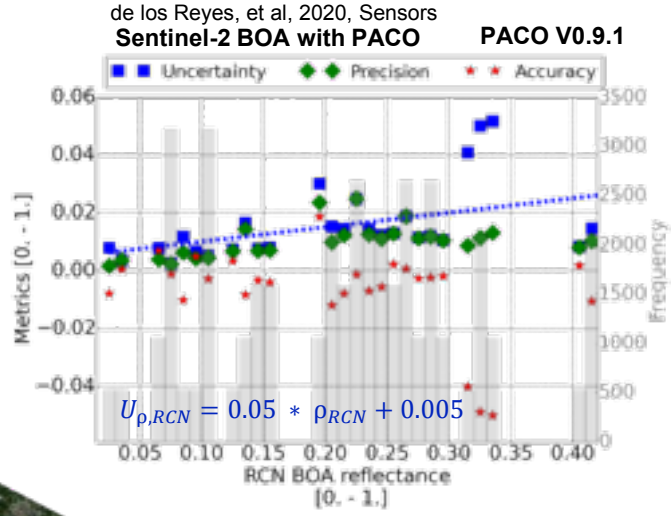
Improvement in estimation in hyperspectral vs multispectral.

L2A – BOA validation: La Crau

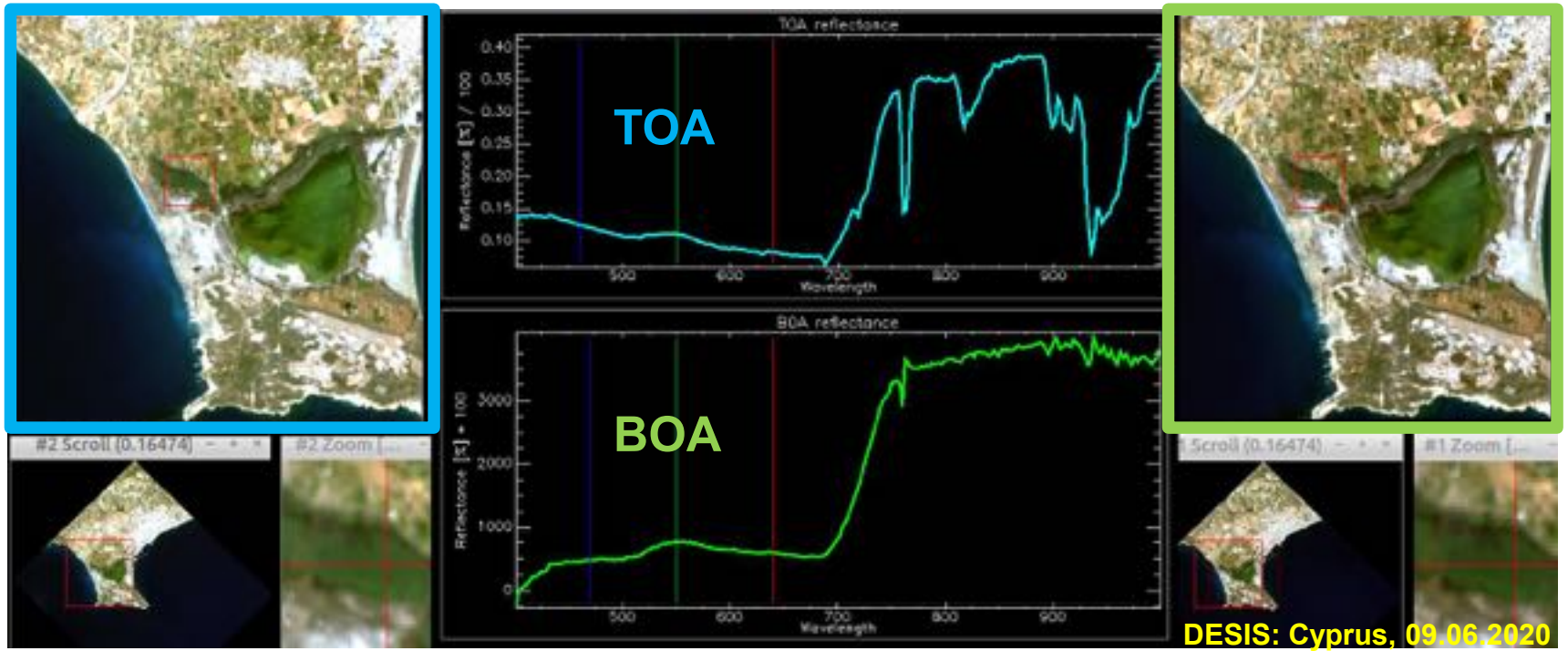
- BOA reflectance after atmospheric correction with N_{DDV} > 5%
- SZA < 30° and off-nadir < 10°
- ROI = 500 m (U_{RCN} < 5%)



de los Reyes, et al, 2020, Sensors

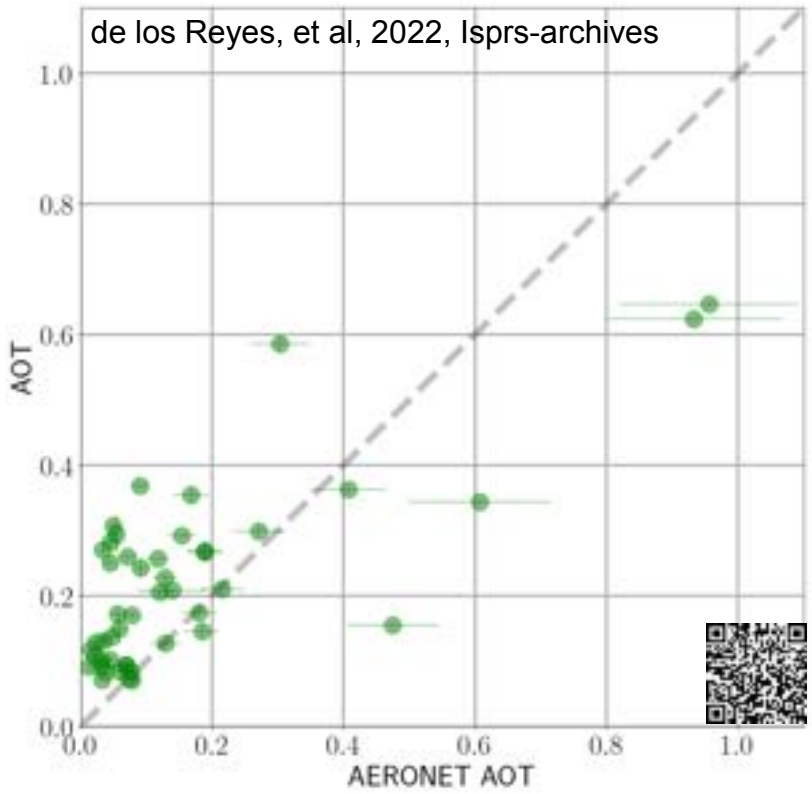


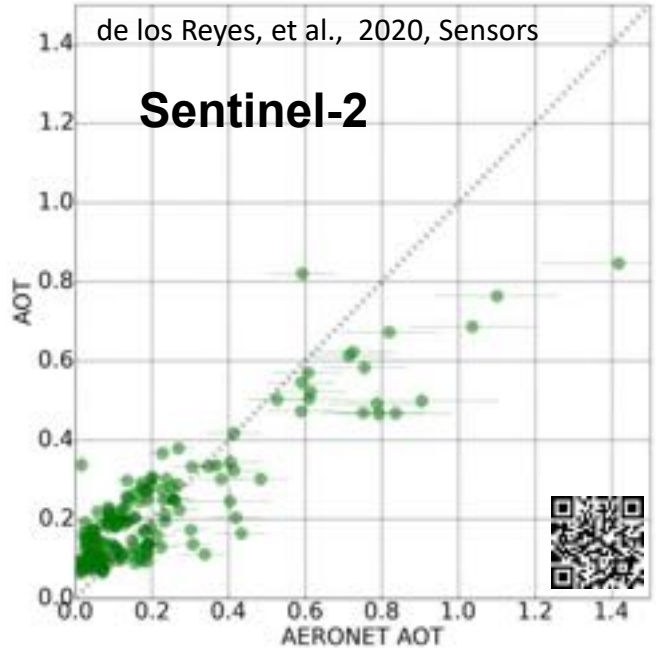
PACO: Python-based Atmospheric Correction



- Correct the Earth's atmosphere effects (i.e. absorption and scattering) in the data from a remote sensing sensor (**T**op-**O**f-**A**tmosphere, L1C)
- Result: **B**ottom-**O**f-**A**tmosphere (L2A) reflectance, i.e. percentage or fraction of sun light reflected by the Earth ground.

L2A – AOT validation





$U_{AOT} = 0.29 * AOT\ (550\ nm) + 0.03$

- N=47
- > 5% DDV pixel
- ROI: 9km

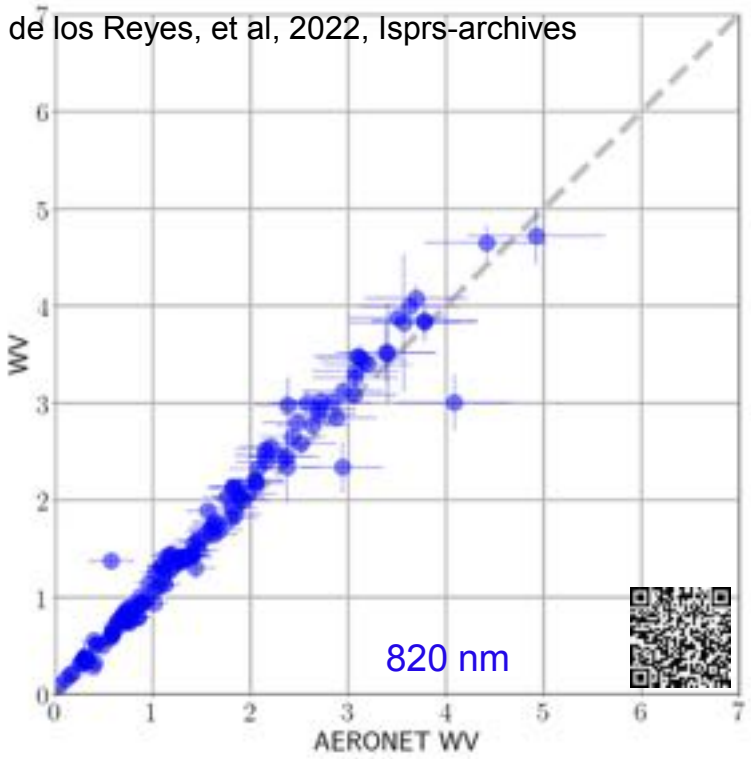
- Higher uncertainty in VNIR sensors.
- **RMSE ~ 0.15 (preliminary)**

$U_{AOT} = -(0.6 \pm 0.3) * AOT\ (550\ nm) + (0.2 \pm 0.0)$

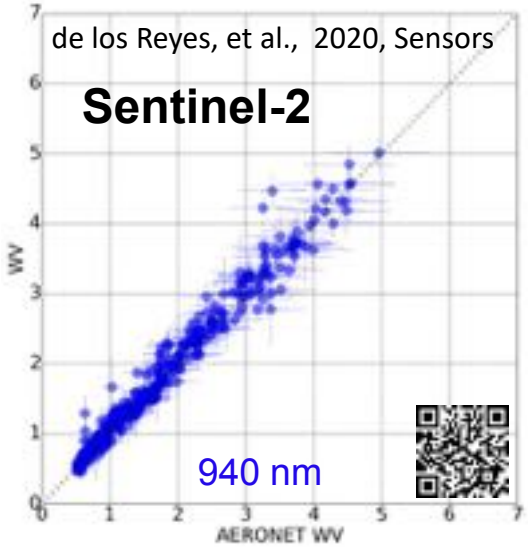
Not as many scenes as for Sentinel-2

L2A – WV validation

de los Reyes, et al, 2022, Isprs-archives



de los Reyes, et al., 2020, Sensors



$U_{WV} = 0.02 * WV\ (cm) + 0.13$

- N=141
- ROI: 9 km
- Mean over clear land pixels

- Improvement in estimation in hyperspectral vs multispectral.

$$U_{WV} = (\mathbf{0.08} \pm 0.02) * WV\ (cm) + (\mathbf{0.06} \pm 0.03)$$

Conclusions from DESIS / EnMAP L2A validation

- DESIS / EnMAP L2A in agreement with ground measurements and other sensors.
- *Atmosphere characterization*:
  - **$RMSE_{AOT}$ ~ 0.15** (DDV > 5%) (preliminary)
  - **U_{WV} (1σ) < (8 ± 2) %,** with an offset of (0.06 ± 0.03) cm
- *Surface reflectance (BOA)*:
  - RadCalNet Gobabeb: U_{BOA} < 5% (AOT < 0.1, SZA < 30° and off-nadir < 10 °)
  - **Consistent results with multi-spectral sensors**:
    - Uncertanties of Sentinel-2 with RadCalNet
    - Cross-validation with sensors (Landsat-8, Sentinel-2): PICs sites.
  - **U_{BOA} (1σ) = 0.04 * ρ_{BOA} + 0.011** (preliminary) gives < 1σ difference in La Crau, including AOT estimation with DDV pixels.
- **More in-situ data** (AOT, ρ_{BOA}) will help in the uncertainty estimation.