# L2A processor

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EOC, DLR

# Contents

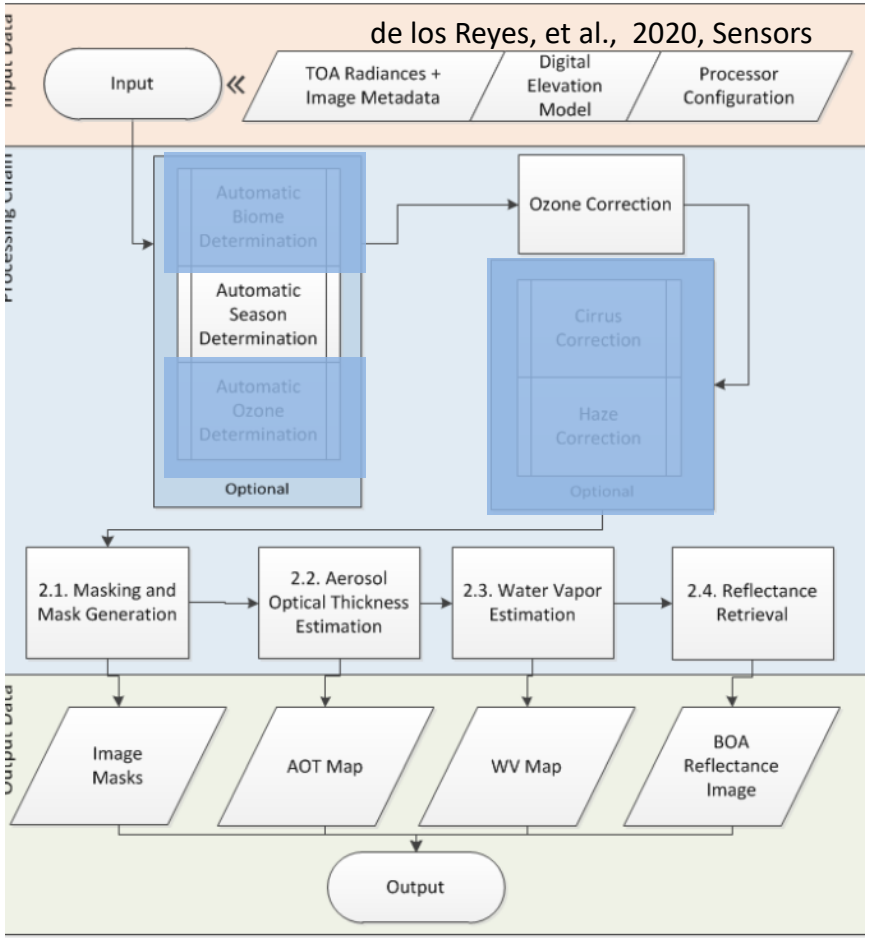
- L2A processor: atmospheric correction
- Validation of L2A products

# DESIS – L2A processor
# PACO – Overview : Atmospheric Correction for Land

- Input:
  - L1C (ortho-rectified)
  - DEM (Digital Elevation Model) (rugged-terrain) (automatic) (SRTM_1ARC)
  - 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:
  - **BOA reflectance** (*SPECTRAL_IMAGE*)
  - *QL_QUALITY-2*:
    - Masks: (clouds, haze, land, water,..)
    - **Aerosol Optical Thickness** (AOT) map
    - **Water Vapor** (WV) map

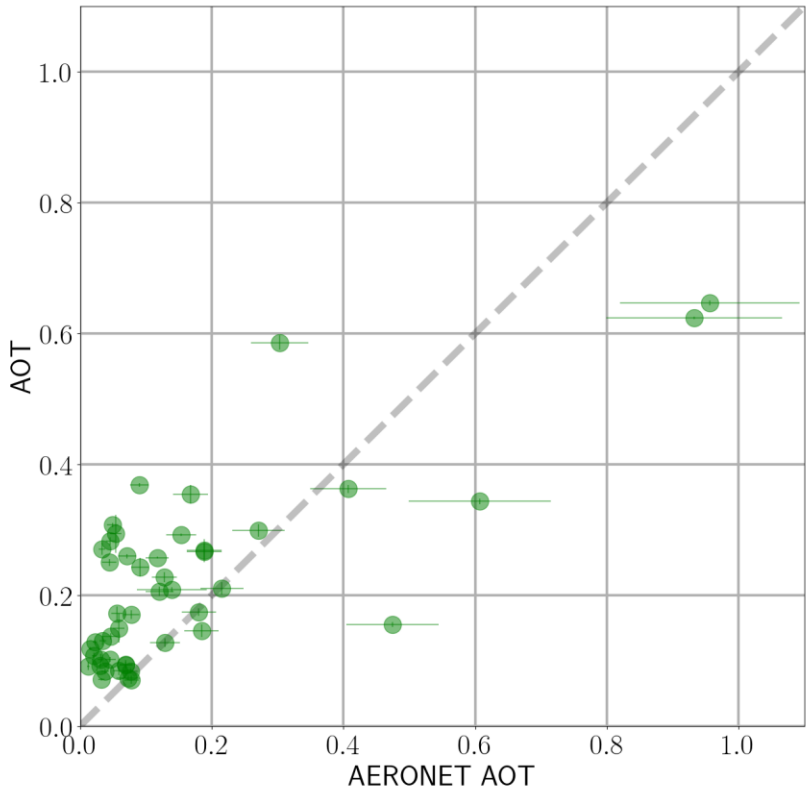



***https://www.dlr.de/eoc/desktopdefault.aspx/tabid-13624/23669_read-54281***

# DESIS L2A processor – Validation

- DESIS processors: V02.13
- Reference data:
  - AOT / WV -> AERONET stations (Holben, B., 1998, doi:10.1016/S0034-4257(98)00031-5)
  - BOA -> RadCalNet sites (Bouvet, M., 2019, doi:10.3390/rs11202401)

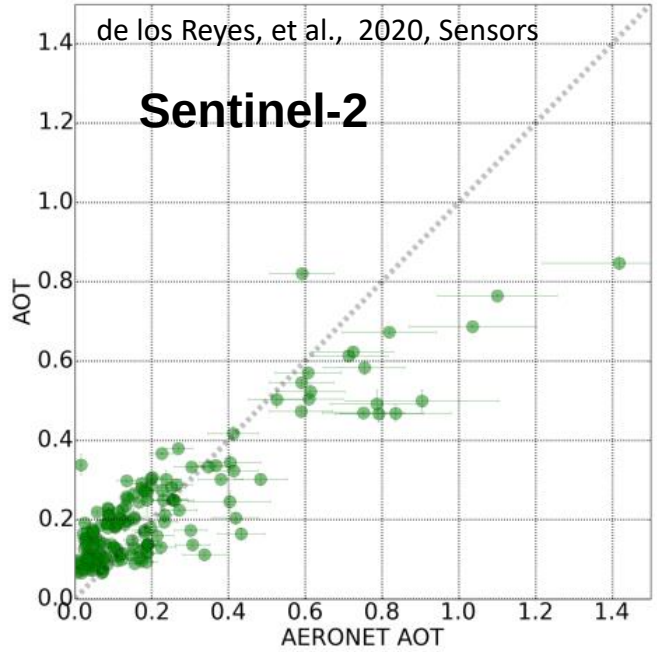
# L2A – AOT validation




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

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

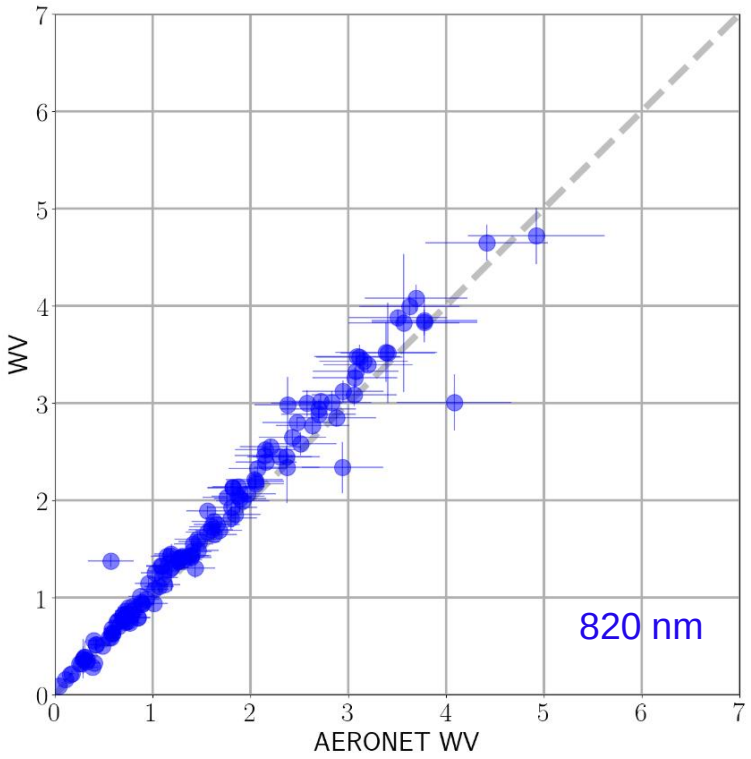
- Higher uncertainty in VNIR sensors.
- **RMSE ~ 0.15 (preliminary)**

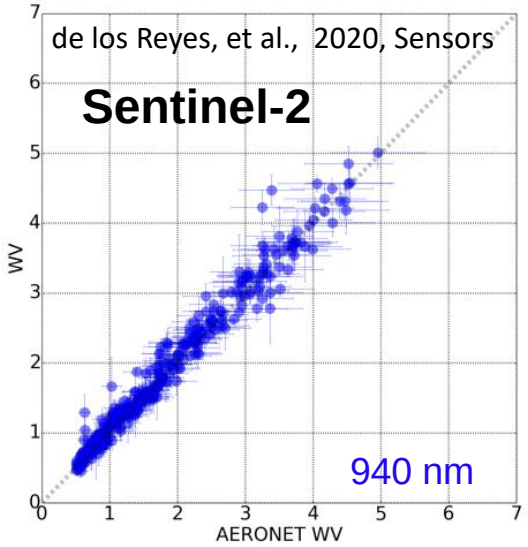



$$U_{AOT} = 0.29 \ * AOT\ (550\ nm) + 0.03$$

Not as many scenes as for Sentinel-2

# L2A – WV validation



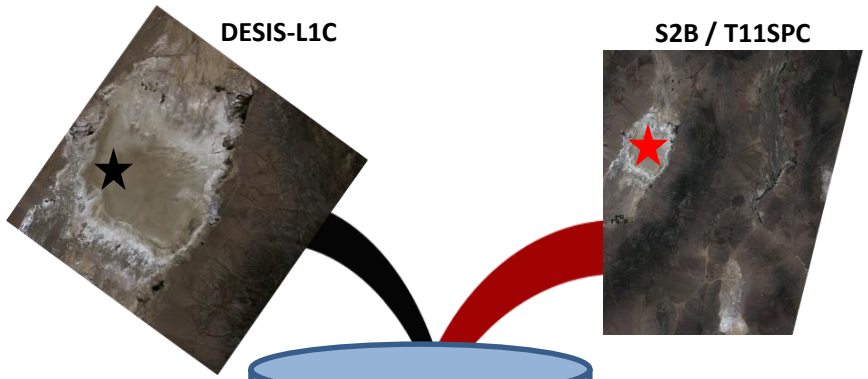

$$U_{WV} = 0.02 * WV\ (cm) + 0.13$$

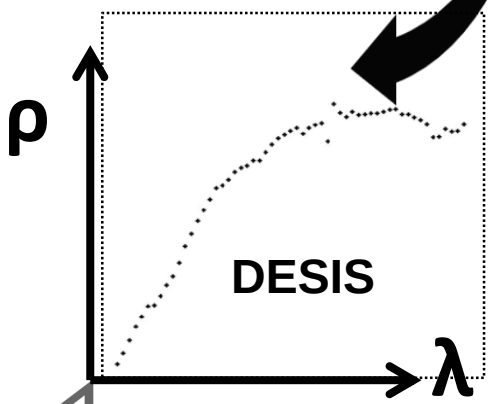
- N=141
- ROI: 9 km
- Mean over clear land pixels

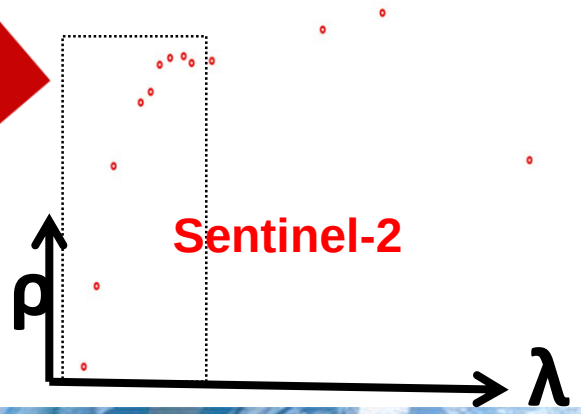
- Improvement in estimation in hyperspectral vs multispectral.

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

# Validation of Bottom-Of-Atmosphere (BOA)

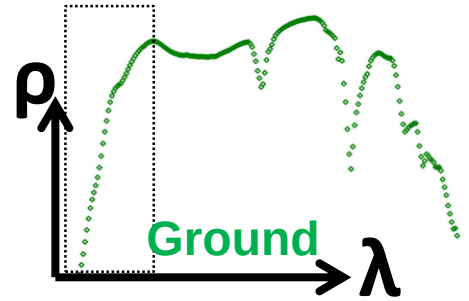



- Illumination/acquisition conditions:
  - SZA < 30°
  - Off-nadir < 10°
- **RadCalNet sites** (Bouver, M. et al, 2019):
  - La Crau (DDV available)
  - Gobabeb and Railroad Valley (*L2A**F***)
- *Qualitative* validation (±30 min):
  - Sentinel-2: A/B
  - Landsat-8

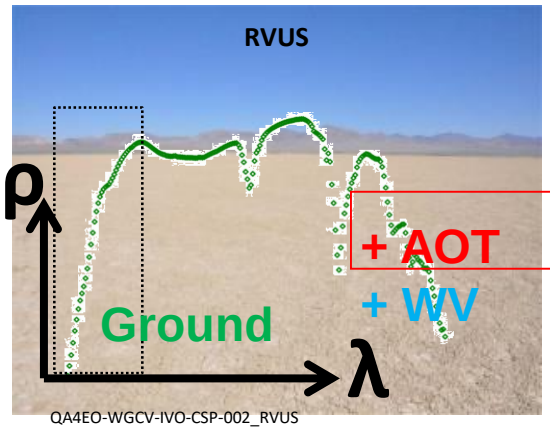

QA4EO-WGCV-IVO-CSP-002_RVUS

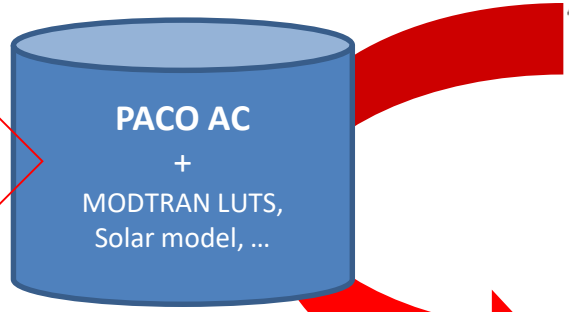



DLR

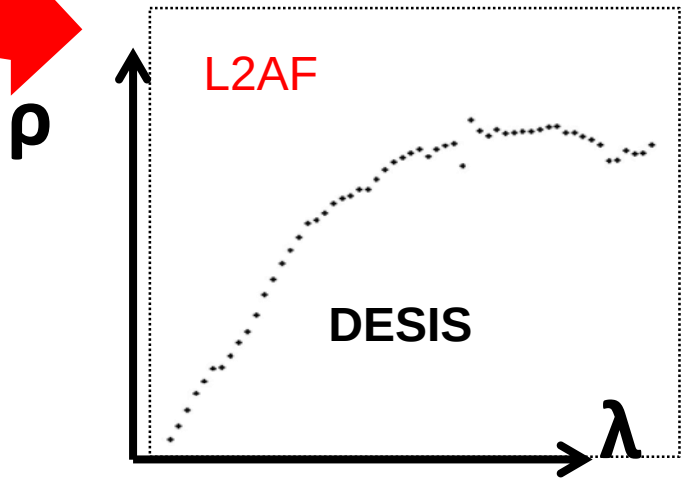
# Validation of Bottom-Of-Atmosphere (L2AF)

- RadCalNet sites:
  - Gobabeb and Railroad Valley



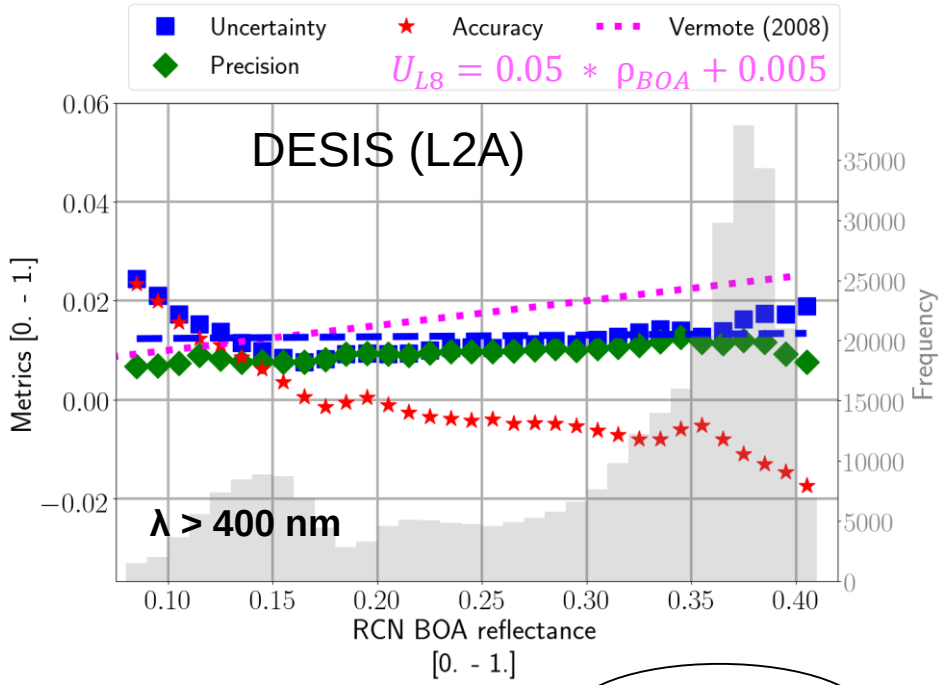





- Only for arid scenes (no DDV information possible)
- No DDV -> no accurate AOT estimation:
  - $AOT_{DESIS} < 10 * AOT_{RCN}$

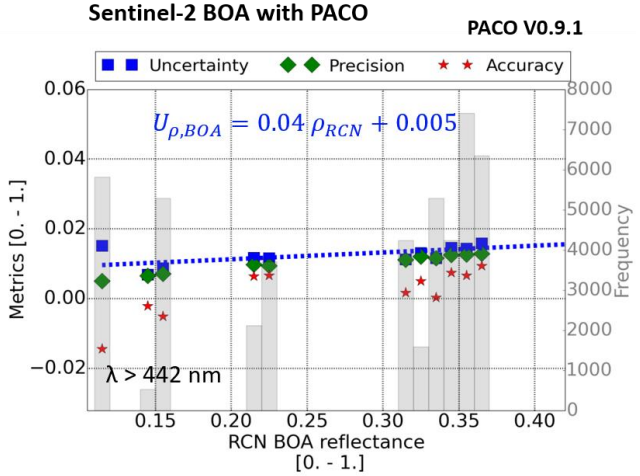
# L2A – BOA validation: Gobabeb

- 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%)




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

de los Reyes, et al., 2020, Sensors

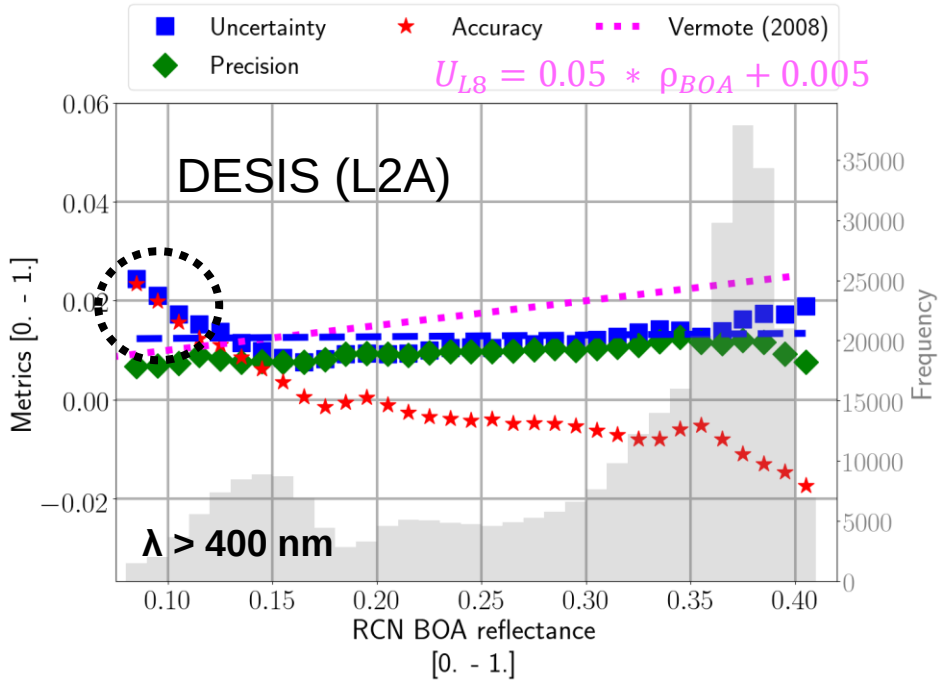



AOT DESIS in **arid sites** (no DDV):
$AOT_{DESIS} < 10 * AOT_{RCN}$

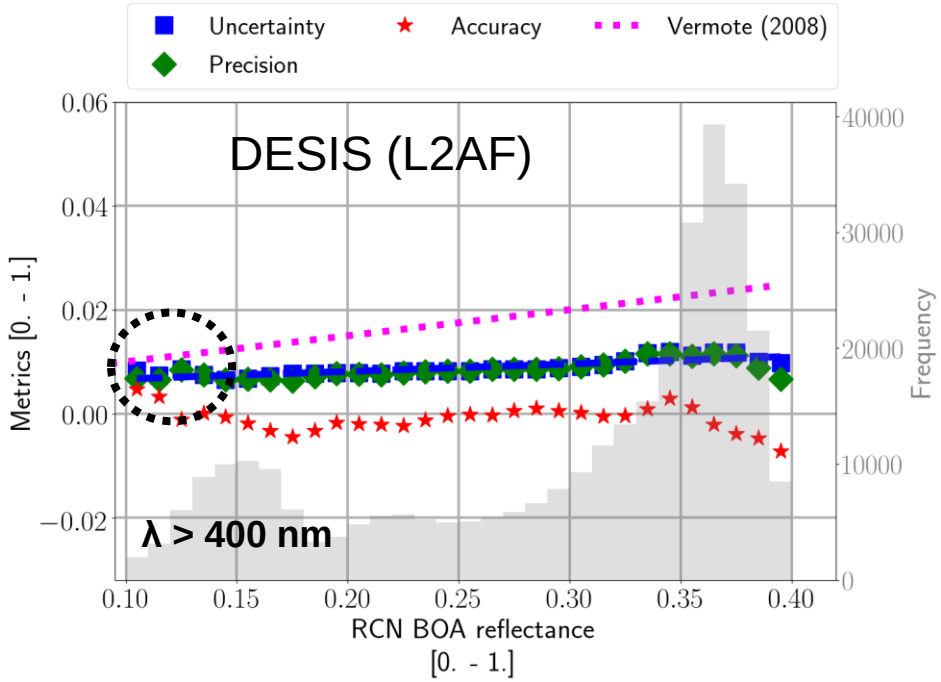
Dominated by the blue wavelengths (AOT)

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

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



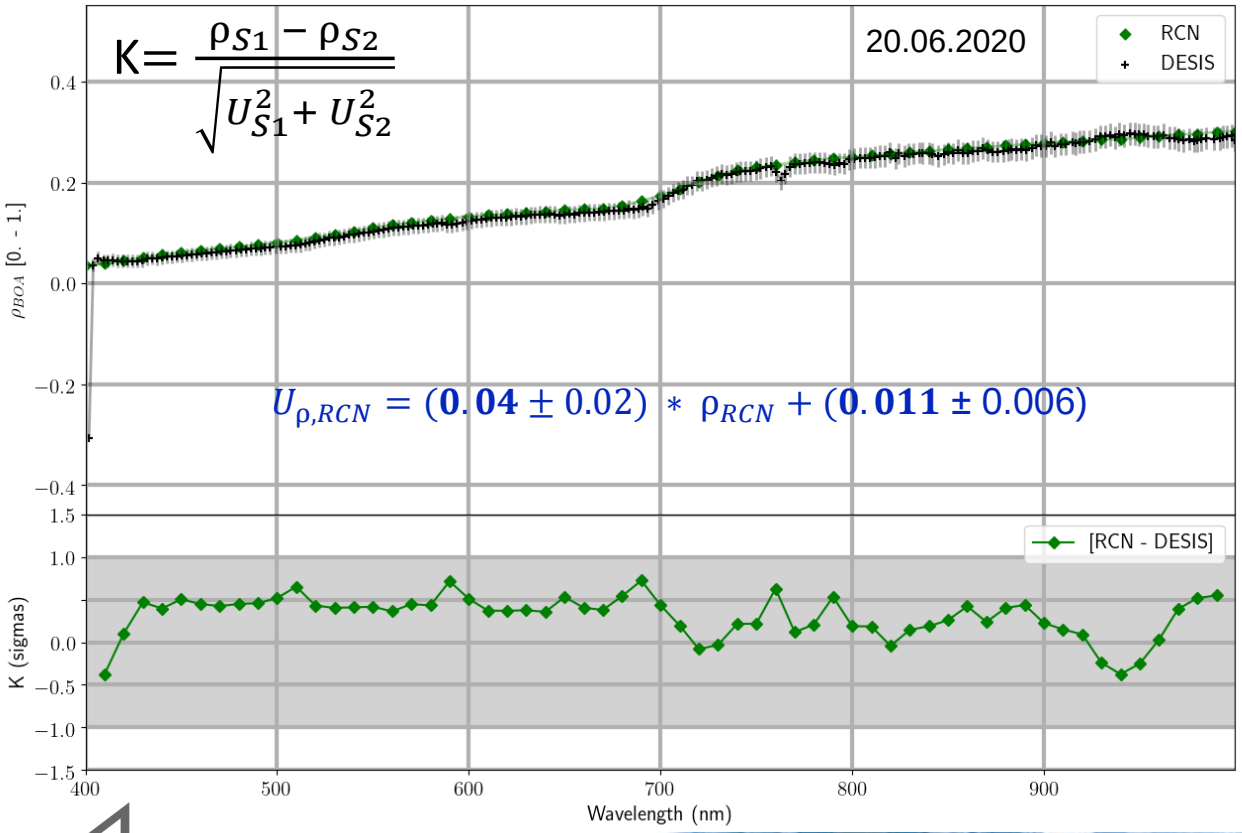

$U_{\rho,RCN} = (\mathbf{0.04} \pm 0.02) * \rho_{RCN} + (\mathbf{0.011} \pm 0.006)$

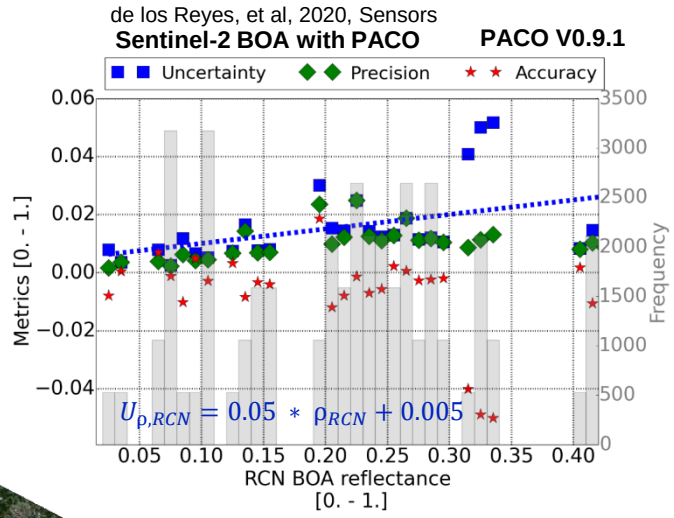


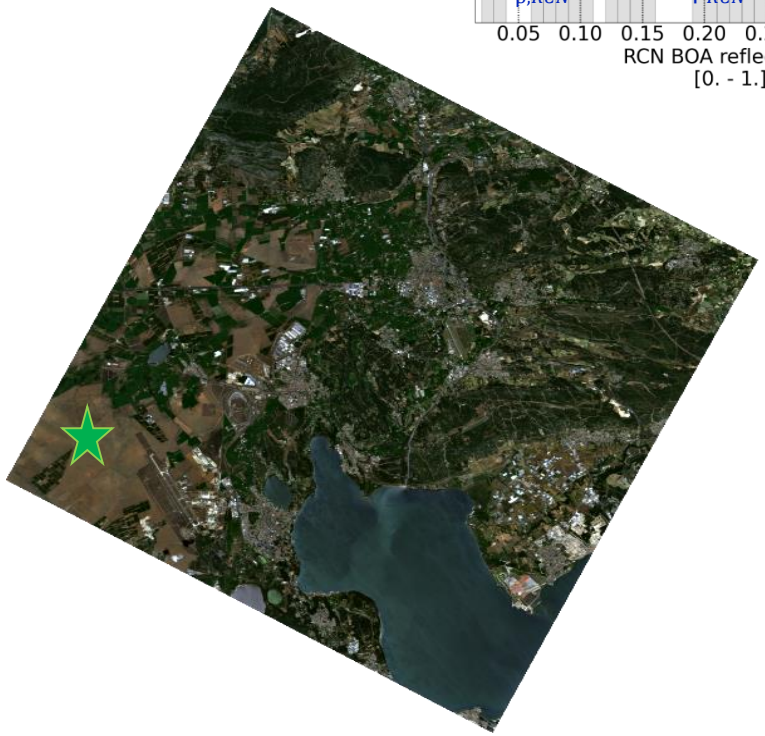

$U_{\rho,RCN} = (0.014 \pm 0.002) * \rho_{RCN} + (0.005 \pm 0.000)$

# L2A – 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%)

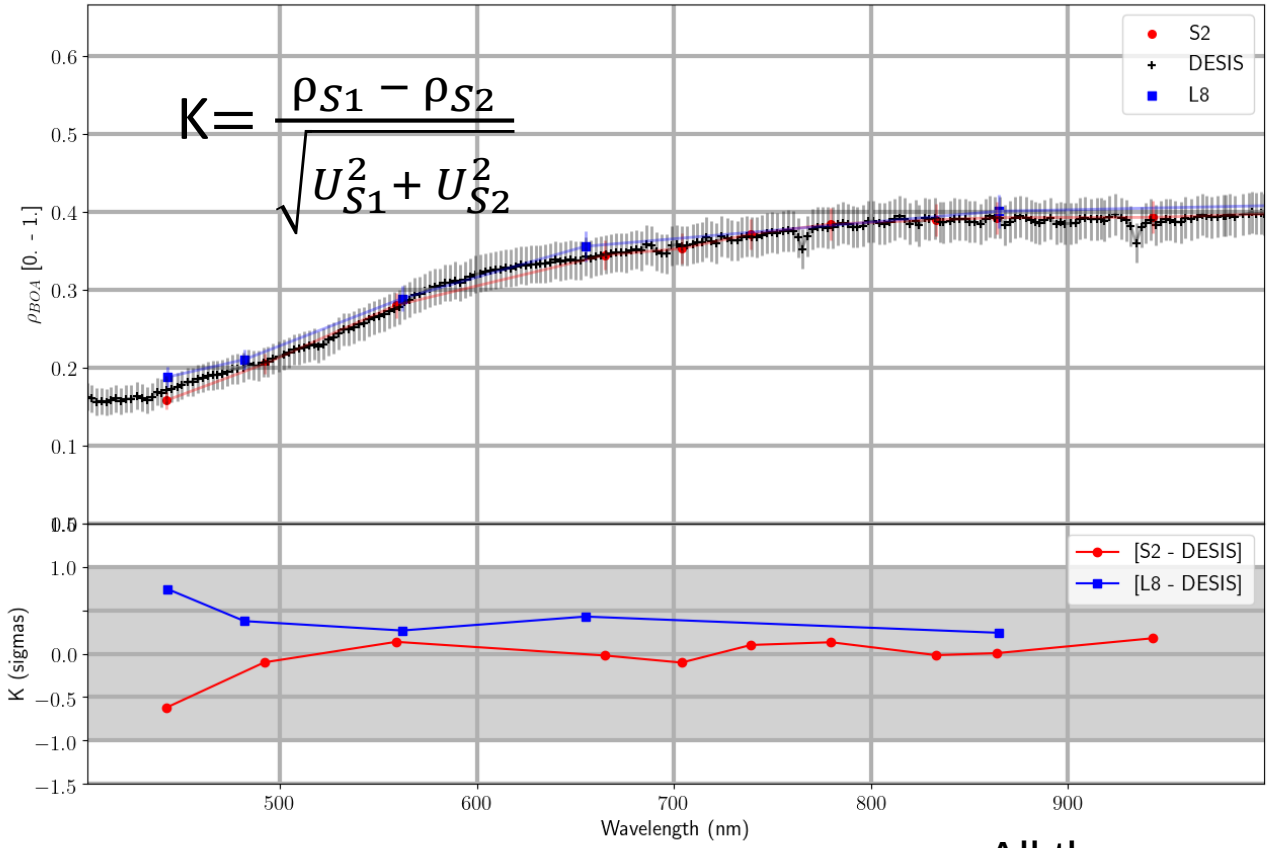


# L2A – comparison with other sensors

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




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

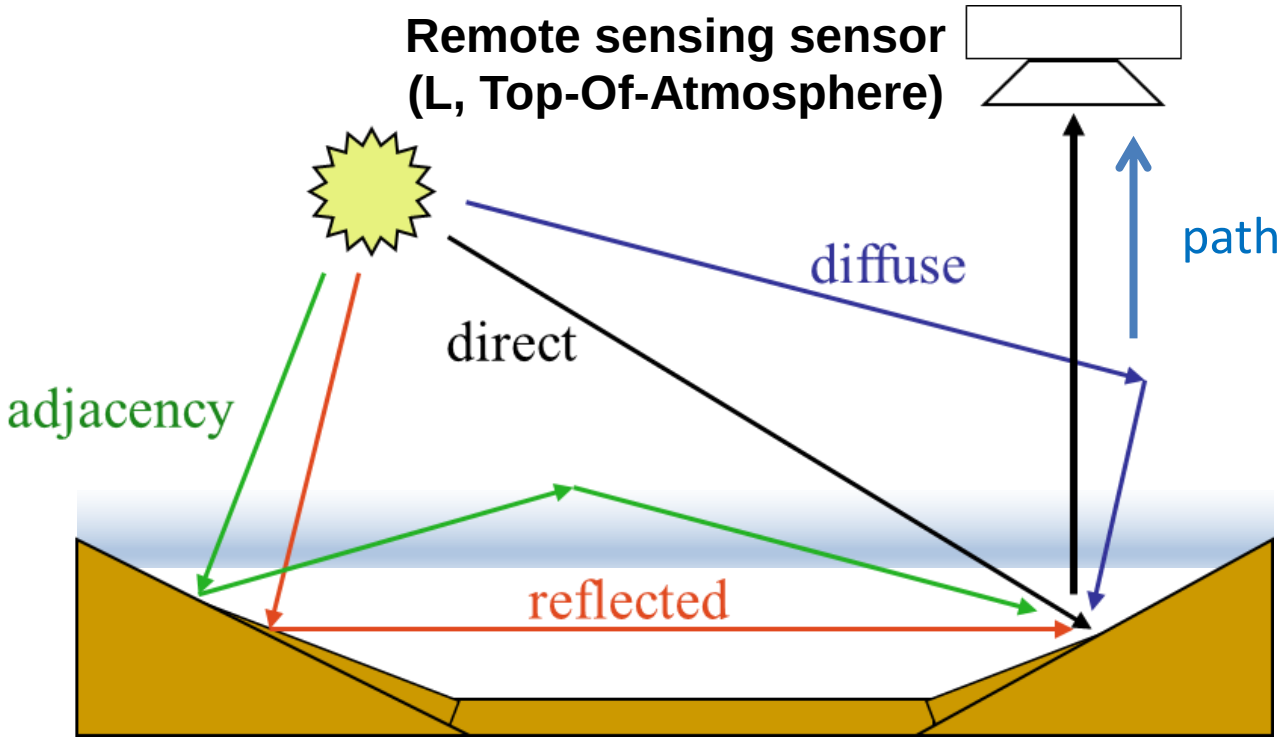
All three sensors processed with PACO: $U_{Si} = 0.04 * \rho_{BOA} + 0.011$

# Conclusions

- DESIS 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 * $\rho_{BOA}$ + 0.011** (preliminary) gives < 1σ difference in La Crau, including AOT estimation with DDV pixels.
- **More in-situ data** (AOT, $\rho_{BOA}$) will help in the uncertainty estimation.

# Backup slides

# Atmospheric correction (AC) over land: Rugged Terrain

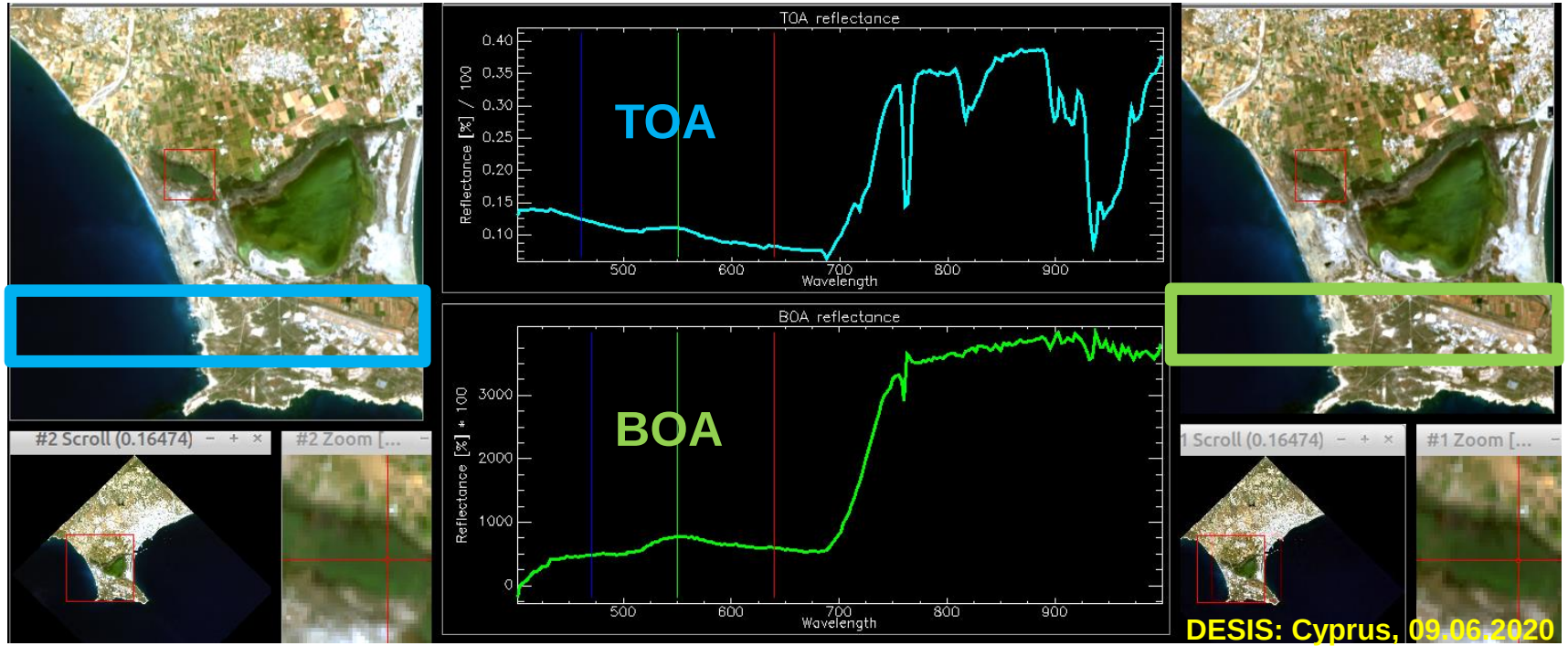



$$L = L_p + L_{direct} + L_{diffuse} + L_{reflected} + L_{adj}$$

Result: Bottom-Of-Atmosphere (**ρ**) or ground reflectance (unitless, in % or [0 – 1])

$\rho = f(L, L_p, E_{dir}, \tau, E_{diff}, \text{DEM}, \ldots)$

# 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.