The validation and uncertainty of DESIS L2A products using AERONET and RadCalNet data

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Introduction

The hyperspectral instrument **"DLR Earth Sensing Imaging Spectrometer" (DESIS)** is a **VNIR** sensor on-board of the International Space Station (ISS) and operational since October 2019. DESIS acquires images of Earth on user request with a swath of about 30 km and 235 bands with a Full Width at Half Maximum (FWHM) of 3.5 nm in the spectral range of 400 to 1000 nm. The DESIS Ground Segment L2A processor corrects the at sensor received terrestrial reflection of the incident solar radiation from the effect of the atmospheric constituents. Implemented within the **L2A processor**, the **PACO** atmospheric correction software processes ortho-rectified Top-Of-Atmosphere (TOA) radiance scenes and generates the Bottom-Of-Atmosphere (BOA) ground reflectance spectral image cube, together with pixel-classification masks, Aerosol Optical Thickness (AOT at 550 nm) and Water Vapor (WV) maps. In this contribution we present the validation of the DESIS atmospheric (AOT550 and WV) and spectral products (BOA reflectance) using independent in-situ measurements.

Method

The aerosol optical thickness and water vapor are compared with the **Aerosol Robotic Network (AERONET)**[4] measurements (level 1.5). The surface reflectance is validated with the **Radiometric Calibration Network (RadCalNet)** data[3].

The validation results are expressed in terms of uncertainty, which we propose to be used as the **DESIS error estimation**.

AOT and WV validation

Remote sensing AOT and WV values per scene are extracted from a region around the location of the AERONET site:

- Region of Interest (ROI): 9km
- Clear land mask areas
- AOT:
  - > 5% DDV in scene
- The hyperspectral nature of the DESIS sensor allows the estimation of the **water vapor uncertainty (U_{WV})** by using *the 820 nm water absorption region* in the Atmospheric Pre-corrected Differential Algorithm (APDA).

There is a lower uncertainty for WV < 1 cm, compared to the one derived from Sentinel-2 data using 945 nm water vapor absorption region (U_{WV} = 0.02 * WV (in cm) + 0.13 cm)[1]. Not much statistics available for high AOT and WV values.

AOT and WV uncertainty estimation

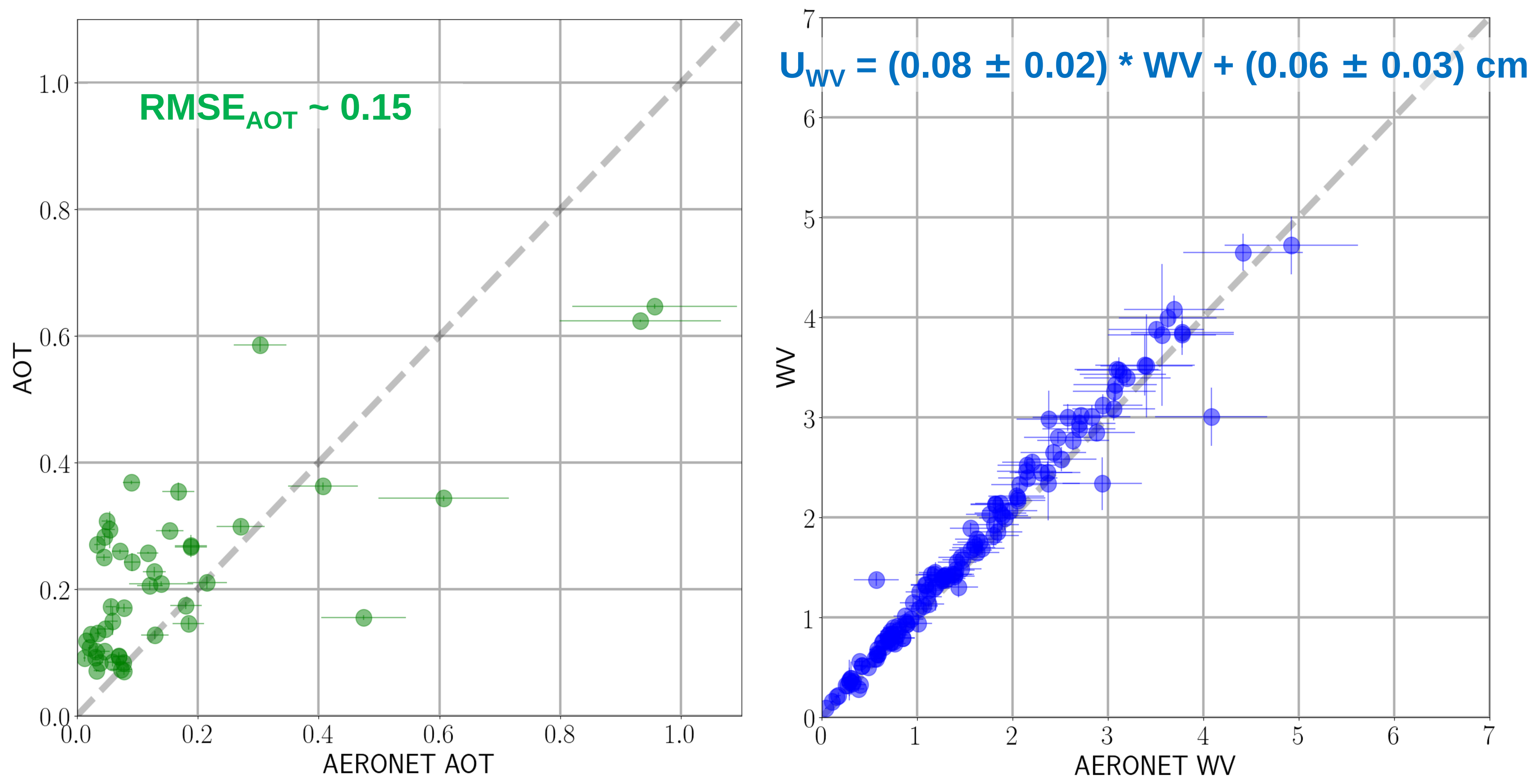


Fig1: DESIS AOT (@ 550 nm) (left) and WV (in cm) (right) versus AERONET AOT (550 nm) and WV (in cm), respectively. The 1:1 line is represented by a grey dashed line. [2]

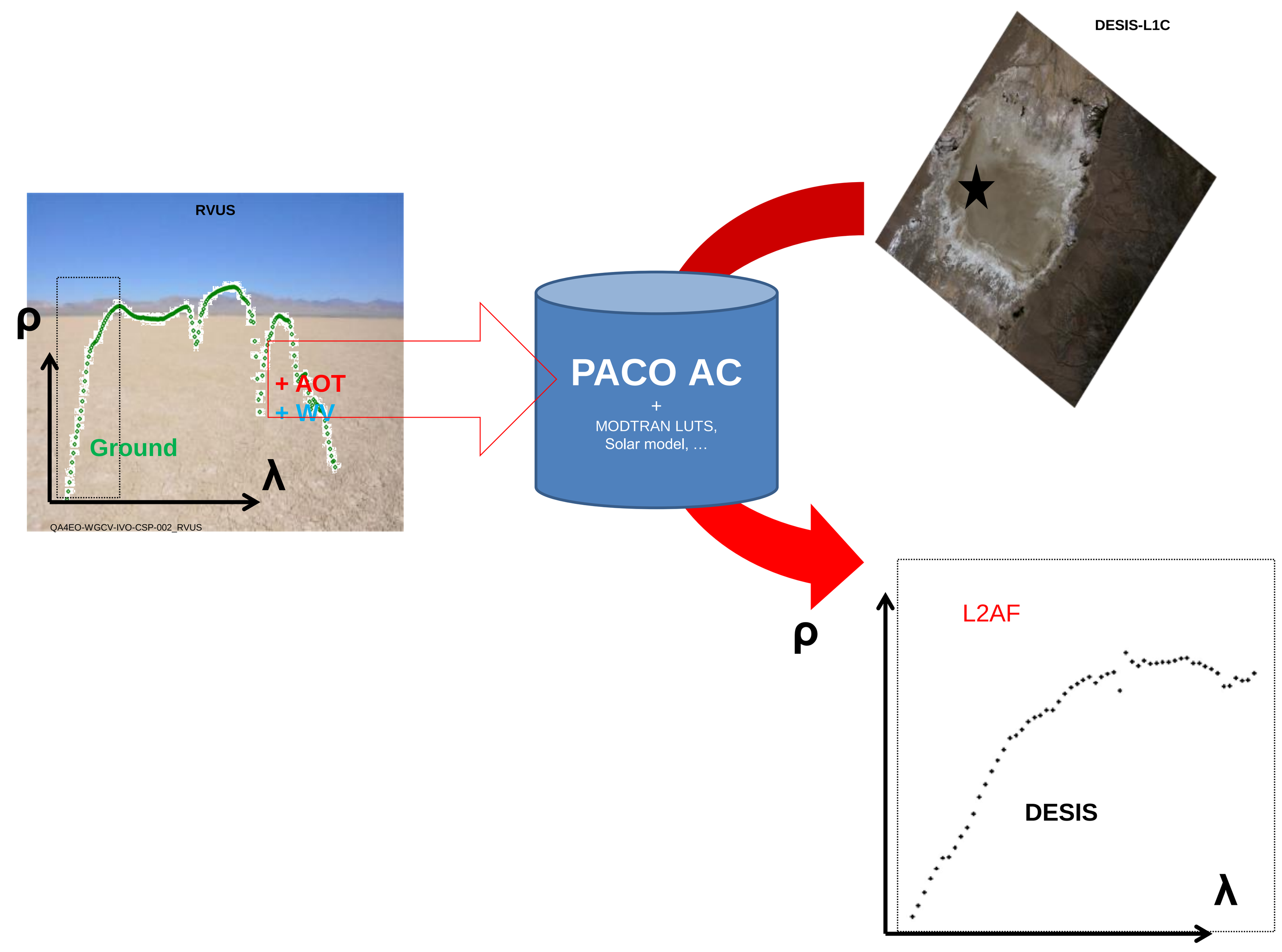
BOA validation

Limited in-situ measurements for BOA uncertainty studies. RadCalNet sites have typically AOT < 0.1

Large $U_{PACO,AOT}$ for arid sites

- Arid sites: PACO visibility = 23 km
- ➢ For Gobabeb (arid site): $PACO_{AOT} \leq 10 * AOT_{RCN}$ for clear days

The hyperspectral sampling range of DESIS starting at 400 nm opens the possibility to **study the uncertainty trend towards lower wavelengths**.



BOA uncertainty estimation with Gobabeb: L2A and *L2AF*

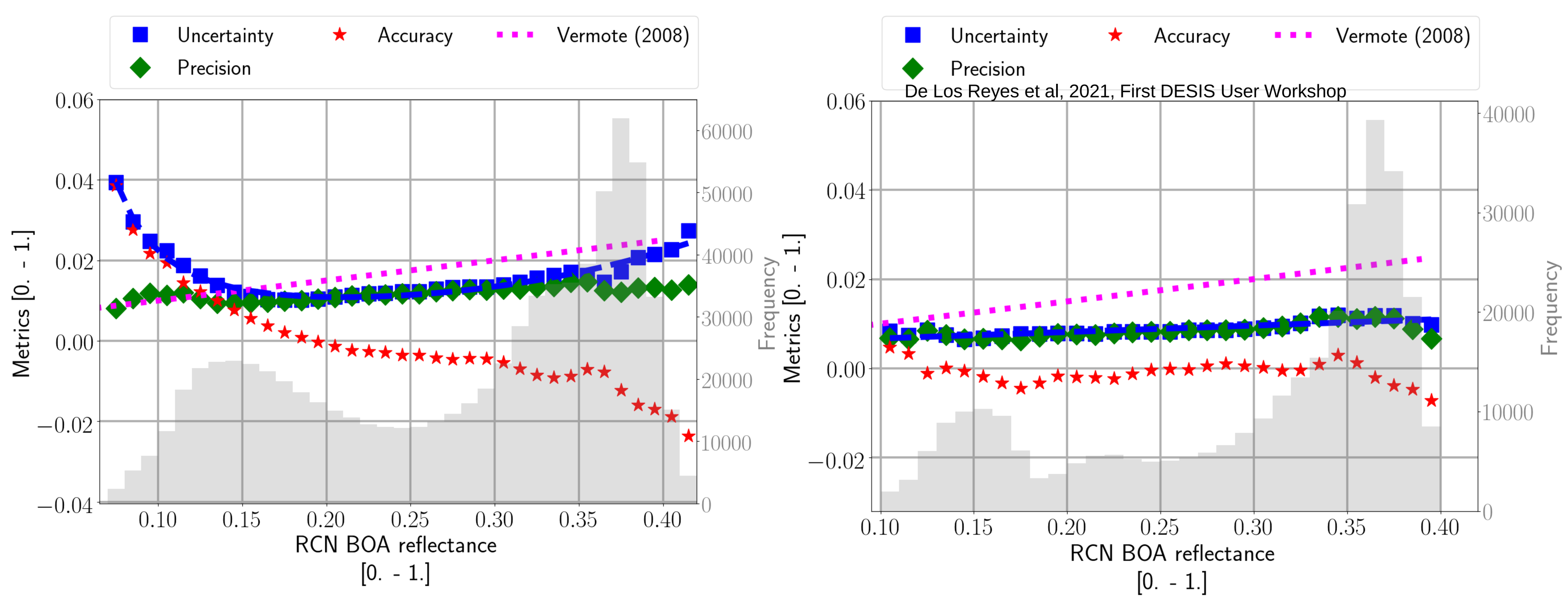


Fig. 3: Accuracy (red star), precision (green diamond) and uncertainty (blue square) as a function of the reference value of DESIS surface reflectance [% / 100] for Gobabeb RadCalNet site. **L2A** (left), **L2AF** (right). The number of pixels included in each bin are shown in the shadow histogram. Uncertainty fit is displayed as dotted blue line and Landsat-8 reference as a pink dotted line. [2]

Forcing the PACO atmospheric correction using the AOT of Gobabeb measured by each overpass DESIS scene, we create the so called **L2AF** (F=forced AOT) (Figure 3, right). The effect of the AOT uncertainty is visible when comparing with the L2A BOA uncertainty (Figure 3, left).

For L2AF (with U_{AOT} = o(AOT)), a linear regression seems correct to fit the uncertainty (with $U_{L2AF} = (0.014 \pm 0.002) * \rho_{BOA,RCN} + (0.005 \pm 0.000)$), but not for the L2A with AOT uncertainties (Figure 3, left).

For L2A products, new non-linear models seems more correct (blue dotted line in Figure 3, left).

Other possibility is express the BOA remote sensing uncertainty requirements as a step function for different BOA reflectance intervals.

Conclusion

- Results show a **lower WV uncertainty** in hyperspectral data when using several bands in the algorithm and with a shorter wavelength distance between them.
- The DESIS BOA validation results show that the approach of **a linear dependency is not sufficient** to represent the influence of the AOT uncertainty in the BOA uncertainty.
- Future missions requirements in BOA reflectance, specially hyperspectral, should change the multi-spectral requirements formulation.

Knowledge for Tomorrow

[1] de los Reyes, R. et al, 2020, PACO: Python-Based Atmospheric Correction, Sensors, 20, 1428

[2] de los Reyes, R. et al, 2022, The DESIS L2A processor and validation of L2A products using AERONET and RadCalNet data, The international Archives of the Photogrammetry, Remote Sensing and Spatial Information, XLVI-1/W1-2021, 9-12.

[3] Bouvet, M. et al, 2019, RadCalNet: A Radiometric Calibration Network for Earth Observing Imagers Operating in the Visible to Shortwave Infrared Spectral Range, Remote Sensing, 11.

[4] Holben, B. N., et al, 1998, AERONET-A Federated Instrument Network and Data Archive for Aerosol Characterization, Remove Sensing Environment, 66, 1, 1-16.

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