Validation of Atmospheric correction of DESIS L2A products: comparison of hyperspectral and Sentinel-2-like multi-spectral sensors

DESIS web page @ DLR

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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. These results are complemented and compared with a simulated DESIS multi-spectral sensor characterized by the Sentinel-2 spectral response functions and atmospherically corrected by the same software.

Method

The aerosol optical thickness and water vapor are compared with the **Aerosol Robotic Network (AERONET)**[4] measurements (level 1.5). 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 (@ 550 nm):
  - > 5% DDV in scene
  - AOT_{DESIS} = 0.1 ± 0.2[2]; $AOT_{DESIS\text{-}S2}$ = 0.09 ± 0.06[1]
- 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 (Fig. 1, left), compared to the one derived from Sentinel-2 data (Fig. 1, right).

Possible influence of ground vegetation water content in WV estimation (see Fig. 2).

WV uncertainty estimation: 820 nm versus 940 nm

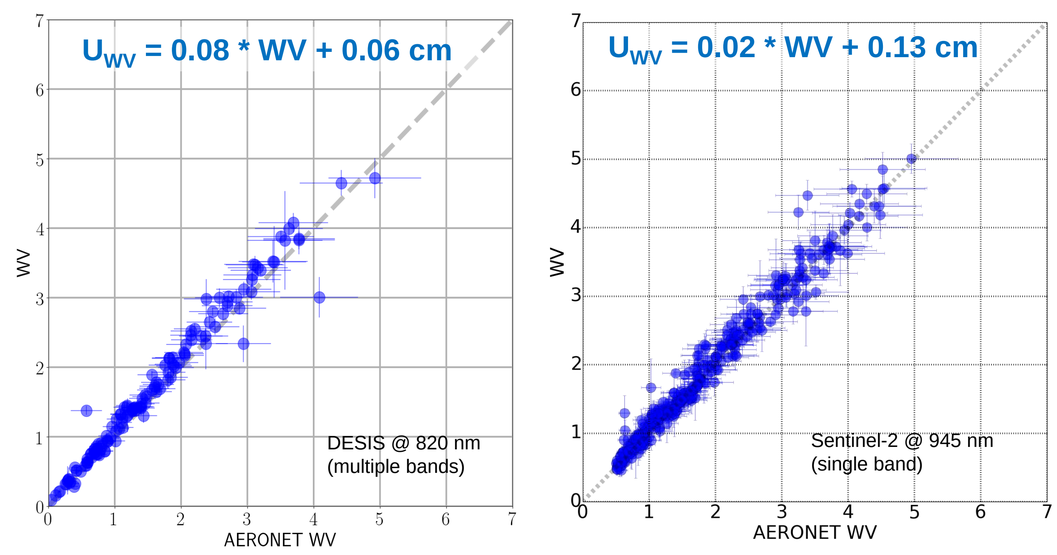

Fig1: WV uncertainty (in cm) of DESIS (left) and Sentinel-2 versus AERONET WV. The 1:1 line is represented by a grey dashed line. [1],[2]

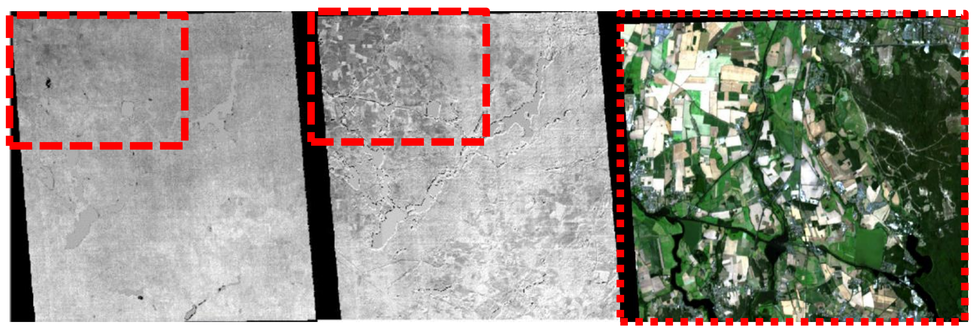

Fig2: WV map (in cm) of DESIS (left) and Sentinel-2 (center). On the right a zoom of the quick look. The ground composition is not visible in the DESIS WV map but it does in the Sentinel-2 one.

BOA validation

❖ Data set: DESIS and Sentinel-2 overpass over Berlin (Germany).

The simulated Sentinel-2 (◊) L1C data (Fig.3, left) is created convolving the DESIS spectra to the SRF of Sentinel-2 and adding the co-registered SWIR bands from the original Sentinel-2.

L2A surface reflectance is compared for two different processing depending on the wavelength range: VNIR and VNIR-SWIR.

From both analysis (Fig.4), the following L2A products are obtained:

- **VNIR** analysis: **DESIS** versus **DESIS-S2-VNIR (□)**
- **VNIR-SWIR** analysis: **DESIS-S2 (◊)**

DESIS-S2-VNIR is the result of processing Sentinel-2 data using only the VNIR bands. DESIS-S2 is the normal processing of Sentinel-2 data.

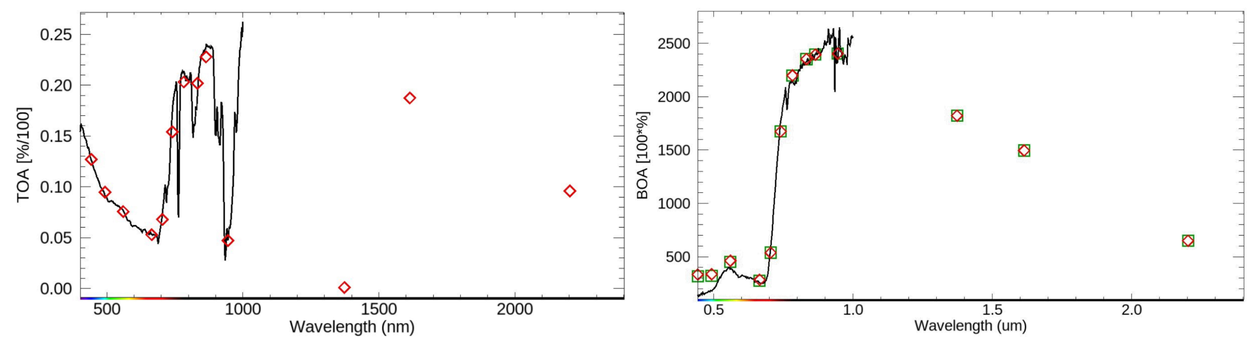

Fig3: Top-Of-Atmosphere (TOA) (left) and Bottom-Of-Atmosphere (BOA) (right) of the DESIS (black line), DESIS-S2 (◊) and DESIS-S2-VNIR (□). DESIS-S2-VNIR is a L2A product using DESIS-S2 L1C as input.

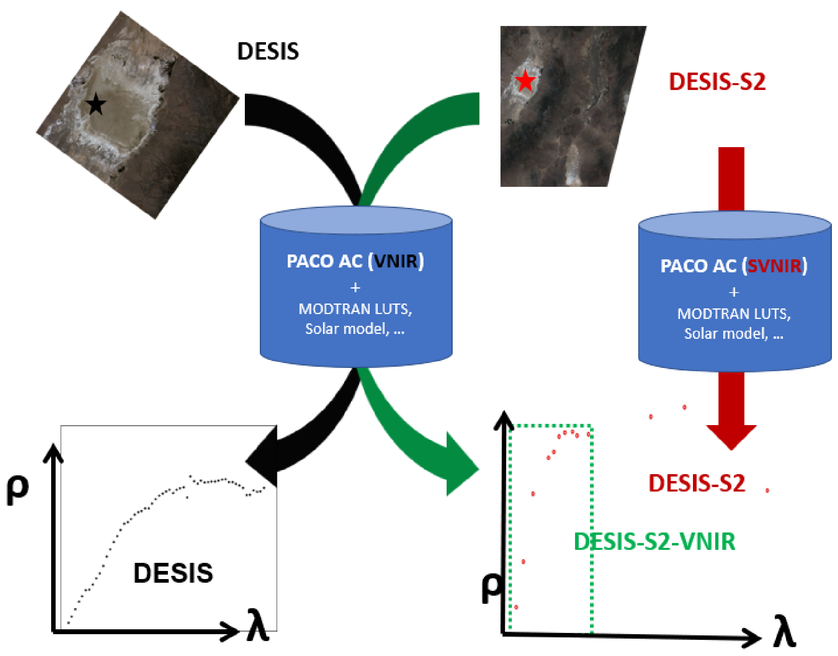

Fig4: PACO processing schema for the DESIS data and the two simulated Sen2Like data sets: DESIS-S2-VNIR and DESIS-S2.

The L2A results show no difference between the VNIR and the VNIR-SWIR analysis. A negligible difference might happen for some pixels when they are affected by haze.

Also, the availability of short wavelengths in DESIS hyperspectral data is visible in the different scale of the blue-path radiance (see Fig. 3, right, for λ < 500 nm): 1.2 (DESIS-S2) versus 1.1 (DESIS)

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.
- Possible influence of the ground type into the water vapor map when using the 945 nm bands.
- No significant differences in Sen2Like L2A products.
- Recommended hyperspectral AC processing and convolve to multi-spectral at L2A level. Also minimum re-computing to convolve to different multi-spectral SRF.

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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