Remote Sensing Technology Institute (IMF)

Photogrammetry and Image Analysis (PBA)

Validation of a new atmospheric correction software using AERONET reference data

PACO: Python-based Atmospheric COrrection

PACO: Python-based Atmospheric COrrection library

PACO is the Python (2.7) parallel development of the atmospheric correction SW package ATCOR [2], developed by DLR.
Being Python-based has several advantages:

- Maintenance: extensive support libraries and participation in the global maintenance effort using other python libraries (e.g. usage of Cython for faster performance and memory extensive tasks).
- Interoperability: interact with most other languages and platforms through 3rd party modules.

It uses the Python library of *XDIBIAS* satimport [3], as API with the different sensing optical sensors supported:

- Spaceborne sensors: Sentinel-2, Landsat-8, DESIS, EnMAP, etc.
- Airborne sensors: HySpex, etc.

PACO is designed as 3rd party module itself for Big-Data solution (e.g. DLR processing chain CATENA [3]) or to any other product pipeline (e.g. L3A products, time-series, hyperspectral analysis, etc.)

Validation Data Set

The present validation only concerns the atmosphere characterization products: **Aerosol Optical Thickness (AOT)** at 550 nm and the **Water Vapour (WV)** column.
The validation has been designed using L2A products produced with PACO SW from Sentinel-2 scenes [5], using as reference AERONET data [1].

Sentinel-2 L1C products.

- Only one sensor (S2A): discarded possible sensor inter-calibration issues.

155 random AERONET sites, covering:

- (Lat., Long.) = ([-40, 60], [-124, 146]) deg
- Altitude = [0.01 – 3.57] km
- Level = 1.5 and 2.0.
- AOT (550 nm) = [0.01 – 1.36]
- WV = [0.15 – 5.96] cm

SW PACO (release branch 0.9):

- Terrain correction (DEM REF "SRTM C1ARC")
- AOT algorithm: Dark Dense Vegetation (DDV)
- WV algorithm: Atmospheric Precorrected Differential Absorption (APDA) [9]
- RT LUTs database:
    - Monochromatic LUTs (MODTRAN 5.4.0) [8]
    - Thuillier 2003 solar model [7]
    - Last Sentinel-2 sensor RSPs [6].

References:

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Data Quality cuts: study about co-location dependencies

The satellite and AERONET station measurements are not necessarily acquired at the same time. Therefore:

- AERONET data are linearly interpolated to scene acquisition time.
- Both "see" the same atmosphere:
    - **ROI** = 8km-square box around AERONET station coordinates .
    - Cloudiness in ROI < 5%.

Under these conditions, the correlation between satellite and AERONET measurements shows no evident dependency on the angular distance (**co-location angle**) between the sun and the satellite (Fig. 1 squares), and neither on the time difference between the closest AERONET measurement and the satellite acquisition time (**co-location time**) (Fig. 1, red circles).
In addition, the following AERONET and PACO quality thresholds are applied to exclude problematic scenes:

- AERONET data stable over a 2h time window:
    - Interpolated scene value < 3 σ_{2h} .
- PACO algorithms:
    - Number DDV pixels in scene > 5%

A total of **81 scenes** (52%) will remain for the study.

Validation study

Here we define K as the ratio of the difference between AERONET and PACO measurements results, where **X** is the AOT (550 nm) or WV variable, and the total uncertainty.
The total uncertainty includes the uncertainties of AERONET (**u1**) and PACO (**u2**).
The AERONET uncertainty comprises the measurements standard deviation plus a 10% precision. The PACO uncertainty is calculated as the sum of the statistical uncertainty (σ_{stat}) over the ROI and the systematic uncertainty (σ_X) derived from the corresponding variable calculation method:

- the AOT (σ_{AOT}) is the systematic uncertainty over the visibility standard deviation over the full scene.
- the WV (σ_{WV}) is considered as 10% of the WV mean value over the ROI [4].

Fig.2 shows the distributions results (top) for the AOT, with mean $\langle K \rangle_{AOT}$ = 0.6 ± 0.3 and WV $\langle K \rangle_{WV}$ = 0.30 ± 0.06.
The correlation results are shown at the bottom of Fig.2, yielding Pearson's correlation coefficients (r) for AOT and WV of 0.75 and 0.99, respectively.

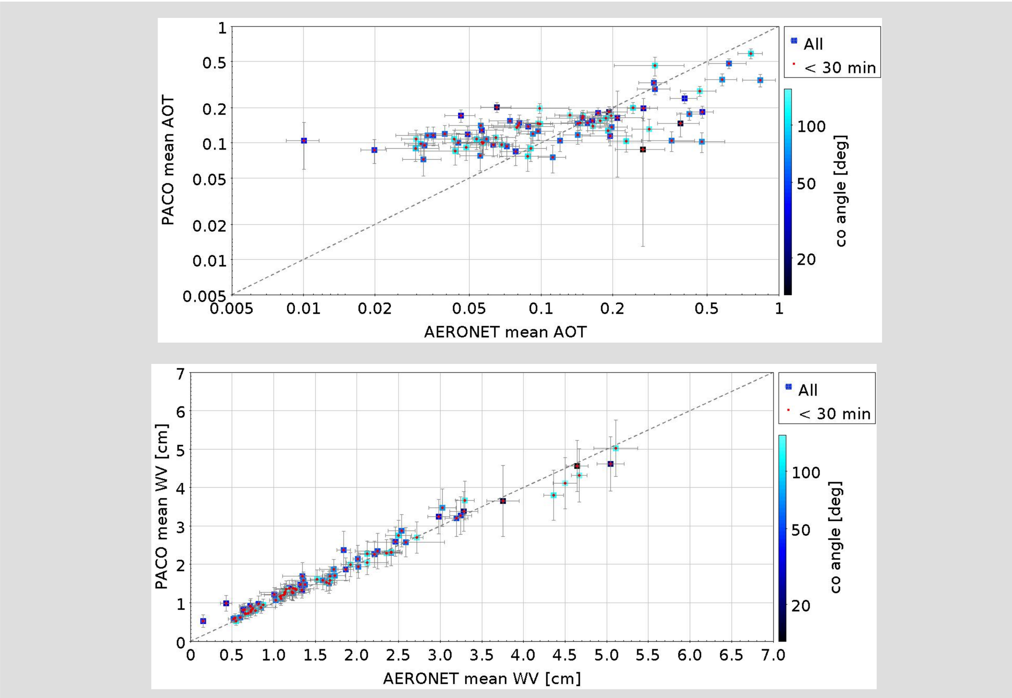

Fig. 1: Scattered plots of the AOT (top) and WV (bottom) of AERONET versus PACO versus the co-location angle (color z-axis) for all final scenes (filled squares) and those with a time difference of 30 min of co-location time (filled red circles).

Results

The mean value of K is < 1 for both distributions, which is rather promising as a first approach.
The dispersion of the distributions show that PACO results are in agreement, within the total estimated uncertainty, for ~30% and ~90% of the scenes for the AOT and WV values, respectively.
The large disagreement for the AOT values suggests the lack of other possible uncertainty sources.
For the water vapour the results indicate a better estimation, in agreement with [4]. A detailed error propagation study is on going.

Nevertheless both results show a good correlation with AERONET data, although for the AOT estimation further studies could improve the result.

Therefore, these datasets can also be used in future validations studies of remote sensing L2A products, especially to **validate major PACO releases**.

Conclusions

- No evident spatial or temporal co-location dependencies found ($\sigma_{co}^2 \ll u1^2 + u2^2$).
- PACO results are in agreement with AERONET in-situ measurements.
- Further improvements on-going:
    - More statistics: more sites and data sets.
    - Addition of other sources of uncertainties (e.g. masking, aerosol models, site altitude, season, etc.)
    - Include cirrus/haze scenes.

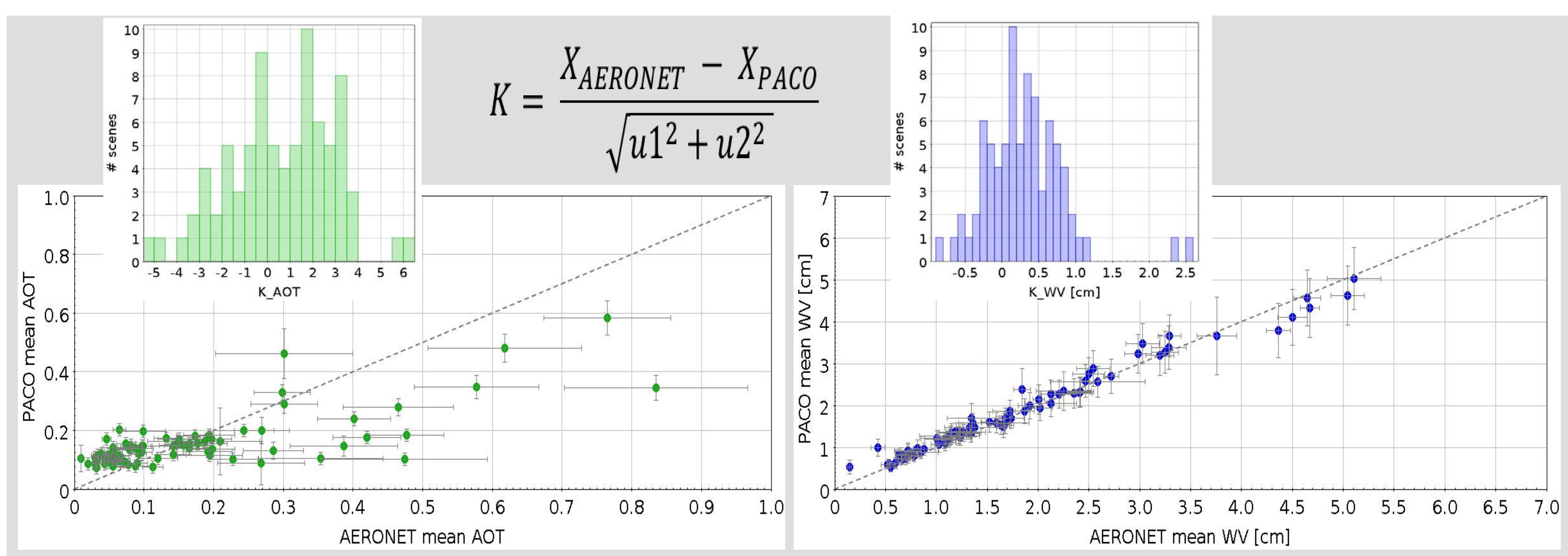

Fig. 2: Top: Distribution of K parameter (top) and correlation plots of PACO versus AERONET (bottom) for aerosol optical thickness (AOT) at 550 nm (left) and water vapor (WV) (right).

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