Towards a first ground-based validation of aerosol optical depth from Sentinel-2 over the complex topography of the Alps

Valerio Marinelli*[,1], Edoardo Cremonese[2], Henri Diémoz[2] and Anna Maria Siani[1]

[1] Sapienza University of Rome, Physics Department, 00185 Rome, Italy

[2] ARPA Valle d'Aosta, 11020 Saint-Christophe (AO), Italy

* *valerio.marinelli@uniroma1.it*

1. Introduction

The Copernicus Sentinel-2A/B twin satellites are capable of providing an estimate of the aerosol optical depth (AOD) through an external processing of the L1C level data of atmospheric reflectance. However, adequate validation work lacks at present day. We want to test the actual accuracy of Sentinel-2A AOD estimate in the challenging environment (complex topography, snow-covered surfaces) of the Northwestern European Alps, where the Environmental Protection Agency of Aosta Valley (ARPA VdA) operates an observatory for solar radiation [1]. This site is located at the bottom of the main valley (45.74°N, 7.36°E), and hosts several instruments measuring atmospheric properties, including the AOD. This dataset represents an optimal ground-truth for the corresponding Sentinel-2 estimates.

On the other hand, two different kind of L2A products are publicly available to the scientific community: those processed by the **Sen2Cor** processor (www.step.esa.int/main/third-party-plugins-2/sen2cor/) and those produced by CNES for THEIA Land Data Center (www.theia.cnes.fr/atdistrib/rocket/) with the **MACCS** processor. The former is openly distributed, thus it can be used to reprocess the Sentinel-2 L1C data with configurations defined by the user. Given that, we will verify the AOD estimation accuracy for both products, and test the sensitivity on the Sen2Cor AOD product by varying several configuration parameters.

2. Methods

- Sentinel-2 AOD is a level L2A product (20 m spatial resolution) for both the Sen2Cor and the MACCS (CNES) processors: Sen2Cor provides AOD values from an improved dense dark vegetation (DDV) algorithm [2], while MACCS inverts a cost function computed with a combination of several criteria [3].
- In the ARPA VdA site a Prede POM-02 sun/sky photometer operates within the EuroSkyRad network (ESR, www.euroskyrad.net) and retrieves columnar aerosol optical properties (e.g. AOD) in 11 narrow (10-20 nm) wavelength bands between 315 and 2200 nm, with an accuracy of 0.01-0.02 depending on the wavelength [4]. The POM-02 AOD retrievals at 500 nm were used as a ground reference for the Sentinel-2 AOD measured at the same time (within ±20 min. from the satellite sensing time) and in the same location, considering a 6x3 km area around the ARPA VdA site (larger in the E-W direction due to the peculiar topography of the valley). A total of 11 Sentinel-2 images, captured on days with generally absent or limited cloud covering above the site area, were used in this study.
- Sensitivity tests on the Sen2Cor processing (Section 3.1) were made using a single acquisition (2016-06-24 at 10:37 UTC on tile T32TLR) chosen for the optimal clear sky condition throghout the whole Aosta Valley region.
- Common settings used in the Sen2Cor configuration file (GIPP) for all tests: cirrus and terrain correction (BRDF) were always enabled, while the VIS_Update_Mode (0,1) values were both tested, though giving the same outputs reported in the table in the Results section. For any further details about the GIPP configuration refer to [2].

3. Results

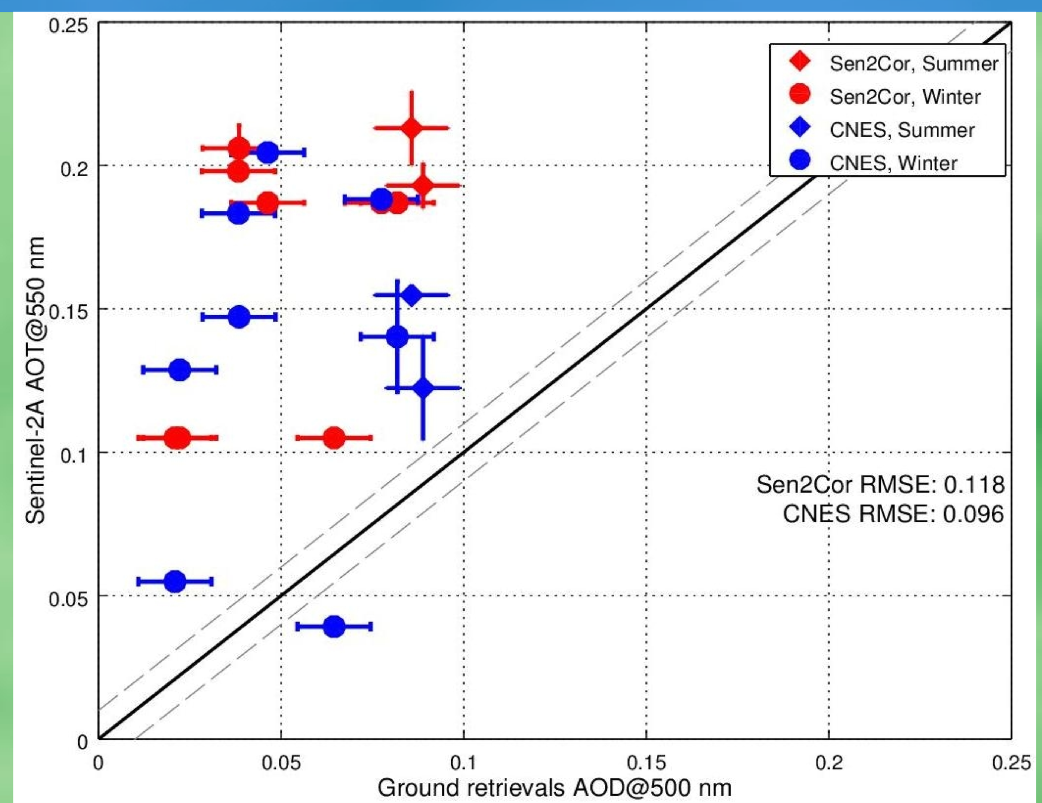
3.1 Impact of Sen2Cor parameterisation

Test run #	O_3 Content	Visibility	<AOD>	Std. Dev. ([6x3]km area)
1	0	40	0,193	0,008
2	0	80	0,193	0,008
3	0	120	0,193	0,008
4	0	100	0,193	0,008
5	0	80	0,193	0,008
6	g	120	0,193	0,008
7	g	5	0,193	0,008
8	f	120	0,193	0,008
9	f	5	0,193	0,008
10	k	5	0,193	0,008

Tests made by altering parameters on the Sen2Cor GIPP file lead to an absolute stability between the variuos configurations: the AOD values remained unchanged throughout the whole map extension. For the O_3 content parameter, "0" (automatic ozone retrieval from map metadata) or "g" ([O_3]=290 DU) should represent better the actual ozone depth as measured by the ARPA VdA Brewer spectrophotometer [5]. "f" and "k" correspond to 250 and 450 DU respectively.

3.2 Validation

Fig. 1: Sen2Cor and MACCS (CNES) AOD estimates for the ARPA VdA ground station proved to be both generally overestimating the AOD from the POM-02 photometer by a factor of ~1.5-2, though the CNES dataset has a lower root mean square error (RMSE). This is verified in general for both "winter" (October-April, circles) and "summer" (May-September, diamonds) acquisitions. The Alpine area is characterized by a diffuse snow-cover that partly lasts in the summer, and valleys are often shadowed by the mountains during part of the day, especially during the winter. These two factors could contribute to the overestimation of the Sentinel-2 AOD.



3.3 Spatial patterns

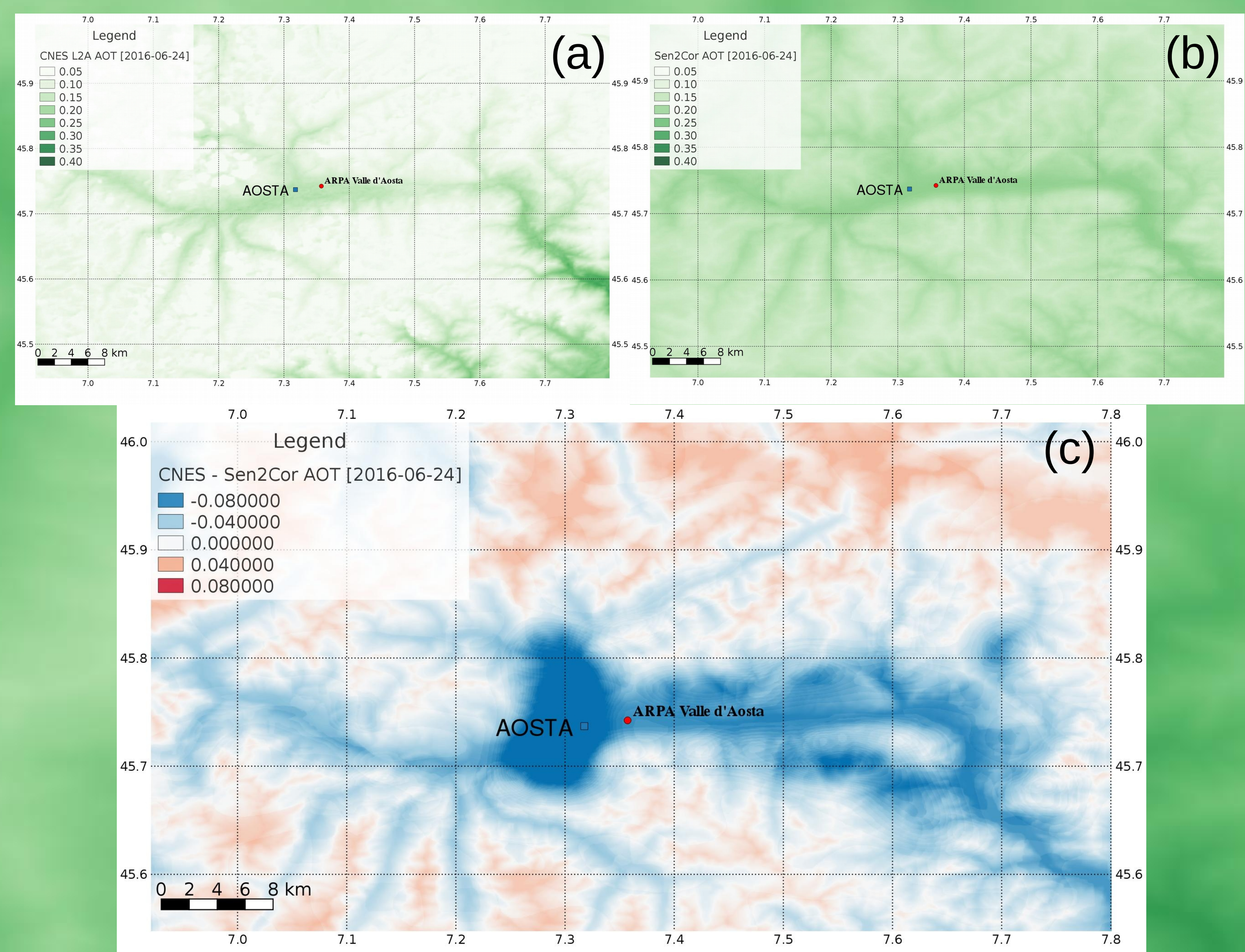


Fig. 2(a,b): CNES (left) and Sen2Cor (right) AOD maps on the Aosta Valley region for the same day used in the Section 3.1. For the latter in particular, there is a correlation with the terrain elevation. Anyway, 3 of the CNES products for the same area showed a uniform AOD value across the whole Alpine region, probably a fictitious effect due to issues in the processing.

(c): AOD map obtained by subtracting Sen2Cor estimates to those retrieved by the CNES product for 2016-06-24.

Conclusions and remarks

Sentinel-2 L2A products proved to have potential to retrieve AOD with an unprecedented spatial resolution, though it is necessary to improve processing algorithms to solve some side-effect apparently related to terrains with high slopes. As of our knowledge, a sistematic validation campaign has not yet been undertaken to address these problems, hence we propose the ARPA VdA site as a privileged ground-truth site, thanks to its favorable position and the availability of several remote-sensing instrumens.

References

[1] Poster EGU2017-**12818**, session AS3.19, board **X5.291**

[2] Sen2Cor Configuration and User Manual, S2-PDGS-MPC-L2A-SUM-V2.3

[3] B. Petrucci, M. Huc, T. Feuvrier, C. Ruffel, O. Hagolle, V. Lonjou, and C. Desjardins, SPIE Remote Sensing, 964307-964307 (2015)

[4] M. Campanelli, T. Nakajima, and B. Olivieri, Appl. Opt., 43, 651–659 (2004)

[5] H. Diémoz et al., Atm. Meas. Tech., 4(8), 1689-1703 (2011)