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Validation of GCOM-C SGLI AOD (aerosol optical depth) using BAQUNIN AERONET and EUROSKYRAD data

Abstract : This TN describes the GCOM-C SGLI AOD validation exercise performed using BAQUNIN instrumental suite.

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Change History

This document shall be amended by releasing a new edition of the document in its entirety. The Amendment Record Sheet below records the history and issue status of this document.

ISSUE	DATE	REASON
1.0	20 Nov 2019	First version

ACRONYMS

Acronym	Definition
APL	Atmospheric Physics Laboratory (at Sapienza)
BAQUNIN	Boundary-layer Air Quality-analysis Using Network of INstruments
ISAC	Institute of Atmospheric Sciences and Climate

1. INTRODUCTION

The aim of this document is to describe the GCOM-C SGLI AOD (aerosol optical depth) validation exercise carried out in the context of the Boundary Layer air Quality Using Network of Instruments (BAQUNIN) ESA project.

The main advantages of using the BAQUNIN instrumental suite are:

1) Use of state-of-art ground based instrumentation and retrieval algorithms
2) Possibility to assess the satellite products quality in urban and semi-rural environments
3) Possibility to check the ground based data quality using different instrument types (independent)
4) Ground based data freely accessible via international network services

These features are of particular relevance for the specific case under discussion. In fact, the quality of AODs retrieved from space is known to be prone to errors when dealing with inhomogeneous Earth' surface, especially for urbanised scenes.

In what follows we demonstrate the importance of operating similar instruments (i.e. AERONET stations) at relatively short distance (about 15 km), embedded in similar atmospheric environments, at least for what concerns the AOD, but surrounded by completely different surface patterns (urban vs. semi-rural).

Finally, the use of instruments based on independent operation and retrieval schemes but retrieving the same quantity (e.g. AOD at 500 nm) such as the CIMEL and the POM-PREDE, allows for cross comparisons and cross checks providing clear indications on the retrieved product quality.

The document is divided in the following main sections:

1) Description of the GCOM-C SGLI instrument and AOD retrieval scheme
2) Description of the BAQUNIN AOD products
3) Data selection and space/time collocation methods
4) Comparison results
5) Outlook
6) References

2. GCOM-C SGLI AOD

Note: the content of this chapter has been extracted from [1].

The GCOM project is consisting of the two series of observation satellites: Global Change Observation Mission-water (GCOM-W) and Global Change Observation Mission-climate (GCOM-C). GCOM-W "SHIZUKU" was launched on May 18, 2012, and is now continuing observation operation with AMSR2 (Advanced Microwave Scanning Radiometer 2) on board. Subsequently, GCOM-C "SHIKISAI" was launched on December 23, 2017, and the initial checkout operation for three months after launch was completed and is continuing observations SGLI (Second-generation Global Imager) on board

SGLI is an optical sensor with 19 spectral channels that can measure light intensity, with high accuracy and wide range, from near-ultraviolet to thermal infrared (380 nm to 12 μm) radiation reflected or emitted from the earth. Using SGLI to conduct global and long-term observations of clouds, aerosols, ocean colour, vegetation, snow and ice, and other components can help elucidate the mechanism behind fluctuations in radiation budget and carbon cycle needed to make accurate projections regarding future temperature rise. SGLI is the next generation model of Ocean Color Temperature Scanner (OCTS) on board the Advanced Earth Observing Satellite (ADEOS), and the Global Imager (GLI) installed on the ADEOS-II. SGLI consists of two radiometer components: Visible and Near Infrared Radiometer (VNR) and Infra-Red Scanning radiometer (IRS). Some of the improvements made over the GLI includes its higher spatial resolution (from 1 km to 250 m), and the polarized and its multi-angle observation capabilities for observing on-land aerosol and other components. The wavelength characteristics are available at JAXA/EORC (http://suzaku.eorc.jaxa.jp/GCOM_C/data/prelaunch/index.html).

The non-polarized (NP) observation sensor has three telescopes having 24° field of view each in the different directions, accordingly with a scanning width of 70° in total (approximately 1,150 km). NP sensor observes the wavelength of 11 channels extracted inside of the sensor in the resolution of 250 m on land and in coastal areas, and in the resolution of 1 km in oceanic regions.

Table 1 GCOM-C SGLI observation modes and related spatial resolutions

Basic observation modes		VN-NP	VN-P		SW1-2, 4	SW3	T1-2	Mbit/s
1	Day-land/coast-T250	250m	1km	+45° / −45°	1km	250m	250m*	23.407
2	Day-land/coast-T500						500m	20.922
3	Twilight-land/coast-T250	1km	1km	+45° / −45°	1km	250m	250m*	7.273
4	Twilight-land/coast-T500						500m	4.788
5	Day-offshore/polar	1km	1km	+45° / −45°	1km	1km	1km	2.612
6	Night-land-T250	OFF	OFF		1km	250m	250m*	5.360
7	Night-land-T500						500m	2.875
8	Night-coast-T250	OFF	OFF		OFF	OFF	250m*	3.353
9	Night-coast-T500						500m	0.868
10	Night-offshore/polar	OFF	OFF		OFF	OFF	1km	0.246

*: 250m mode is limited by downlink data volume per a path

Table 2 GCOM-C SGLI Level 2 atmospheric products

Level2	Parameter	Generation Unit	Temporal Statistics 01D : 1 day 08D : 8 days 01M : 1 month	Product ID	Resolution K : 1 km H : 500 m Q : 250 m F : 1/24 deg C : 1/12 deg		
Atmosphere	Cloud flag	Tile	01D	CLFG	K	Q	
	Cloud properties	Tile	01D	CLPR	K		
	Aerosol by Non-Polarization	Tile	01D	ARNP	K		
	Aerosol by Polarization	Tile	01D	ARPL	K		
Atmosphere (Global)	Top of atmosphere radiance (global)	Global	01D	LTOA	F		
	Top of atmosphere radiance with clear pixels (global)	Global	01D	LCLR	F		
	Cloud flag (global)	Global	01D	CLFG	F		
	Cloud properties (global)	Global	01D	CLPR	F		
	Aerosol by Non-Polarization (global)	Global	01D	ARNP	F		
	Aerosol by Polarization (global)	Global	01D	ARPL	F		

In Table 2, the list of GCOM-C SGLI level 2 atmospheric products is reported. In this work, the ARNP (aerosol from non-polarised measurements) were considered.

The aerosol properties over land consist of aerosol optical thickness, angstrom exponent and single scattering albedo estimations based on the near ultraviolet reflectance.

A common aerosol optical model is used for the retrieval over ocean and land, and the model is determined based on the sky-radiometer observation data. While fixing the particle shape, real part of complex refraction index and size distributions of large and small particle, the fraction of small particle and complex refraction index (in terms of SSA) are assumed to be variable. For retrieval, the algorithm estimates an aerosol parameter suitable to the SGLI observation, and outputs aerosol optical thickness, angstrom exponent and single scattering albedo.

The cloud product, used here to discriminate cloud free scenes, consists of two flags. One is the cloud flag that indicates the existence of cloud within the pixel and the other is the cloud phase flag that indicates whether the cloud particles are water or ice. Both flags are generated from both daytime and night-time observation data with global coverage. In addition, the cloud flag becomes the input of cloud properties/non-polarized aerosol/ polarized aerosol/ clear region composition algorithm.

The cloud identification algorithm CLAUDIA (Cloud and Aerosol Unbiased Decision Intellectual Algorithm) performs multiple threshold tests using the TOA radiance (reflectance/radiance temperature) and their difference or ratio to calculate the confidence level for each threshold test (0.0: cloud – 1.0: clear) and then integrates the calculated confidence level to generate the final clear confidence level as output. Since the selection of the threshold tests is arbitrary, the algorithm has versatility regarding channel configuration of satellite sensors. In addition, even when the data include partially missing, the clear confidence level can be calculated as far as more than one threshold test is performed. Therefore, there is robustness in the processing. The cloud phase identifies whether the cloud particle is water or ice using brightness temperatures at infrared bands.

The SGLI products are provided in form of 2D regular grid fields, with a spatial resolution of about 1 km. This formatting facilitates the data screening and the spatial/temporal selection of the data to be compared with ground based data.

The quality of the GCOM-C SGLI AODs, i.e. the RMS error, is expected to be < 0.15 on global scale. This value is quite “generous”, and should not be considered a valid measure for the data quality. In fact, from the AERONET climatology tables, the average AODs over Rome ranges from 0.1 to 0.3. As a consequence, the target RMS is of the same order of magnitude of the expected AODs. For details on AERONET climatology see https://aeronet.gsfc.nasa.gov/cgi-bin/climo_menu_new_v3.

3. BAQUNIN AERONET AND EUROSKYRAD AOD

The BAQUNIN-AERONET station, based at the Atmospheric Physics Laboratory of the Physics Department of Sapienza University (APL, Rome downtown) is active since early 2017. The AERONET instrument is owned by University of Lille and run under BAQUNIN staff responsibility. For details on AERONET algorithms see [2].

In addition, an EUROSKYRAD station (POM-PREDE, as in SKYRAD, PI M. Campanelli) is also based at APL since 2010 [3]. The AOD data provided by this instrument are used here as cross-check for the BAQUNIN-AERONET data.

Finally, a further AERONET station is active at CNR-ISAC (not yet associated to BAQUNIN). This instrument in owned by CNR-ISAC Tor Vergata (PI G. Gobbi) and the related dataset is freely available through the AERONET service. This second AERONET site will be used to assess the quality of SGLI AOD products retrieved in semi-rural environment.

4. DATA SELECTION AND TIME/SPACE COLLOCATION

The following methodology has been applied to the SGLI and ground based data:

1) The time collocation period spans from October 2018 to September 2019
2) Use the BAQUNIN-APL (Rome Sapienza) and the CNR-ISAC (Tor Vergata) AERONET Level 1.5 AODs (500 nm). Uncertainties on AERONET AOD are not available (not produced). The POM-PREDE AODs, used as a second reference for APL, are cloud screened (same as for AERONET 1.5).
3) The time lag between ground based and satellite measurements was set to 10, 20, 30, 40, 50, 60 and 90 minutes. Thus, for any SGLI overpass time the appropriate ground based data are selected according to the above listed time lags. Given that the sun-photometers are operated under different schedules, the number of available data for the three instruments will be also a function of the adopted time selection criteria.
4) The spatial Search Radius was set to 2, 4, 6, 9, 12, 15, 20 and 25 km. This choice allows for the determination of the impact of different land surface types on the SGLI aerosol products.
5) The SGLI AODs are screened using the associated quality flags. For this exercise we **excluded**:
    a. Cloudy pixels
    b. Water pixels
    c. Sun-glint pixels
    d. AOD values > 1.5 (this threshold is based on statistical analysis of AERONET APL and CNR-ISAC AODs)
6) The ground based data are time averaged (within the selected time lag), the satellite data are space averaged within the selected search radius).

Once collocated, the matchups underpass a statistical analysis, as detailed in the next sections.

4.1 SGLI AOD vs. surface reflectance

As a first step, the map of average AOD from SGLI screened measurements was produced and is shown in Figure 1.

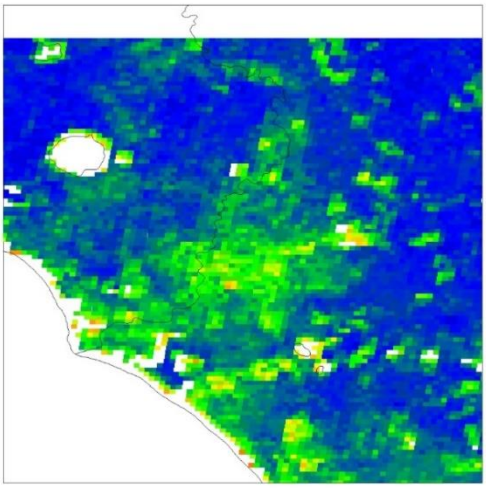

Figure 1: Map of average AOD from SGLI L2 products relative to the period October 2018 – September 2019. AOD colour code: from blue = 0.1 to red = 1.5

The spatial patterns in Figure 1 indicate that the quality of AODs retrieved from SGLI measurements could be significantly affected by the surface type (spectral reflectance). In fact, high AODs are found in areas very close to other areas with very low AODs, which is not likely to happen in the typical conditions of the Tiber valley.

To qualitatively test this hypothesis, the following exercise has been carried out.

i) Select a Sentinel-2 cloud-free RGB image of the area of interest (high spatial resolution)
ii) Interpolate the R, G and B image fields to the SGLI resolution
iii) Correlate the R, G and B values (a.u.) with the SGLI average AODs at pixel scale

In practice, we use the S2 RGB image as a proxy for the spectral surface reflectance, assuming no significant changes of surface characteristics during the period of interest.

Of course, this is a crude approximation and a time dependant surface reflectance will be used in the future developments of this activity.

Despite the above mentioned limitations, the results of this exercise are quite interesting. Figure 2 shows the SGLI AOD as function of the R (red), G (green) and B (blue) S2 channels.

The small dots refer to the whole area of interest shown in Figure 1, the larger symbols refer to the SGLI pixels in a distance from APL < 9 km. As ca be seen, the SGLI AOD show a significant correlation with the “colour” of the surface pixel: for a prevalence of G with respect to R (vegetated areas) the AOD is much lower than for the cases in which R, G and B values are close to each other (i.e. tending to grey => urbanised pixels).

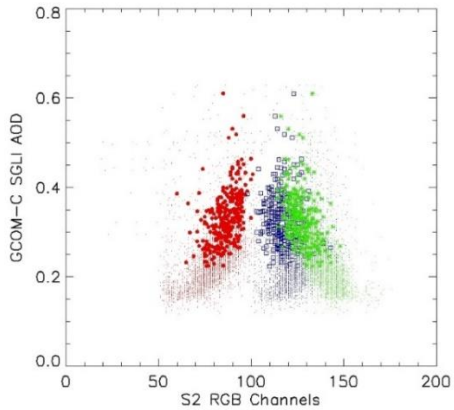

Figure 2 SGLI average AOD vs. Sentinel 2 re-gridded R, G, B channels. Small dots refer to the whole area of interest, larger symbols to SGLI pixels in a 9 km distance from APL

This behaviour becomes more evident when plotting the SGLI AODs against the “green-red” S2 channel values (arbitrary units), as shown in Figure 3. Note that the ordinate axis (AOD) is in logarithmic scale. In this exercise we use the green-to-red contrast as a proxy for vegetated (high G-R values) versus urbanised (small G-R values).

Although the correlation between G-R and AODs is evident, we did not perform any statistical analysis: a more rigorous approach will be adopted in the next phases of this activity (if any).

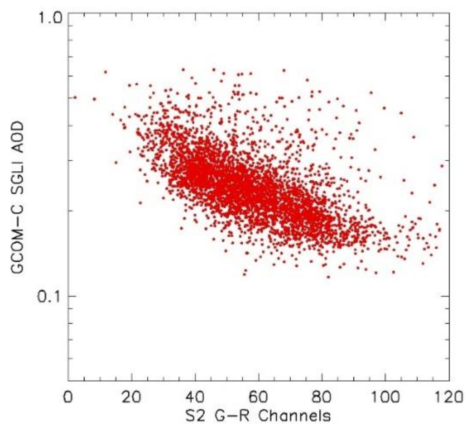

Figure 3 SGLI AOD vs. S2 green-red channel (G-R, arbitrary units)

No rigorous conclusions can be drawn from this exercise, but the above described results suggest that an issue with SGLI AODs is possibly related to the way surface reflactance lookup tables are handled in the SGLI AOD retrieval algorithm. This hypothesis is confirmed by the results of the more rigorous comparison with AERONET and EUROSKYRAD aerosol data, detailed in the next section.

4.2 Comparison with AERONET and EUROSKYRAD

As stated above, for the comparison with ground based data we used **8** search radius (2, 4, 6, 9, 12, 15, 20 and 25 km) and **7** time lag (10, 20, 30, 40, 50, 60 and 90 minutes) values for the two AERONET stations (and the EUROSKYRAD at APL). In total, we analysed **56** datasets and the related results for a subset of these are discussed in this section, which is divided into the following "plotting" categories:

- **Monthly time series**: for each month of the year, the collocated SGLI, AERONET and EUROSKYRAD data are averaged and the related STD is computed. The time series of the various instrument are displayed using the following colour convention: **red** = SGLI, **blue** = AERONET (APL or ISAC), **green** = EUROSKYRAD. The time lag and search radius are indicated in the upper right of the graphs. The aim of this type of plot is to verify if the datasets follow the same seasonal cycle, both qualitatively and quantitatively. Discrepancies would indicate an issue possibly related to a priori assumptions in the satellite retrieval scheme.
- **Scatter plots**: the SGLI (**red**) and EUROSKYRAD (**green**) AODs are plotted against the AERONET data. The time lag and search radius are indicated in the upper left of the graphs. These graphs highlight the degree of correlation between datasets.
- **AOD absolute difference histograms**: the histograms of the AERONET-SGLI (**red**) and AERONET-EUROSKYRAD (**green**) are displayed. The statistical results are reported in the upper left, time lag and search radius are indicated in the upper right of the graphs. Histograms are of fundamental importance for the interpretation of the statistical results. In fact, the degree of asymmetry of the probability density functions (PDF) provide indications on the nature of the deviations between datasets.
- **AOD absolute difference vs. SZA**: the absolute difference between individual SGLI (**red**) or EUROSKYRAD (**blue**) and AERONET are displayed versus the Solar Zenith Angle (SZA) relative to the measurement time. The SZA (elevation of the Sun with respect to Nadir) is a fundamental parameter for any type of instrument measuring sunlight scattered, reflected or absorbed by the Earth atmosphere and surface. Thus, it is common practice in the Cal/Val

community to verify the quality of datasets as function of SZA. In this case, because the measurements refer to the central portion of the day, we would expect a limited sensitivity of the satellite to ground-based difference.

For this “visual” inspection of the results, in each figure the SGLI vs. APL panels are displayed on the left, the SGLI vs. ISAC panels are displayed on the right.

4.2.1 AOD monthly time series

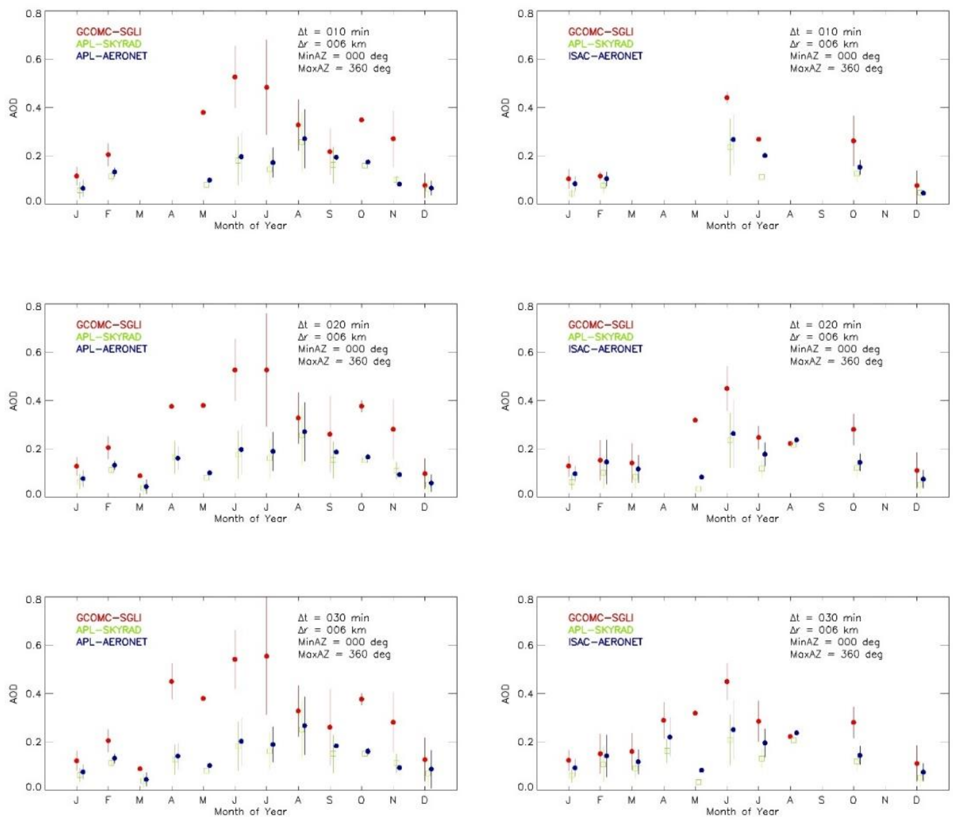

Figure 4 Monthly average time series for the collocated datasets. The time lag is 10, 20 and 30 minutes, the search radius is set to 6 km. The left panels refer to APL, the right panels to ISAC collocations

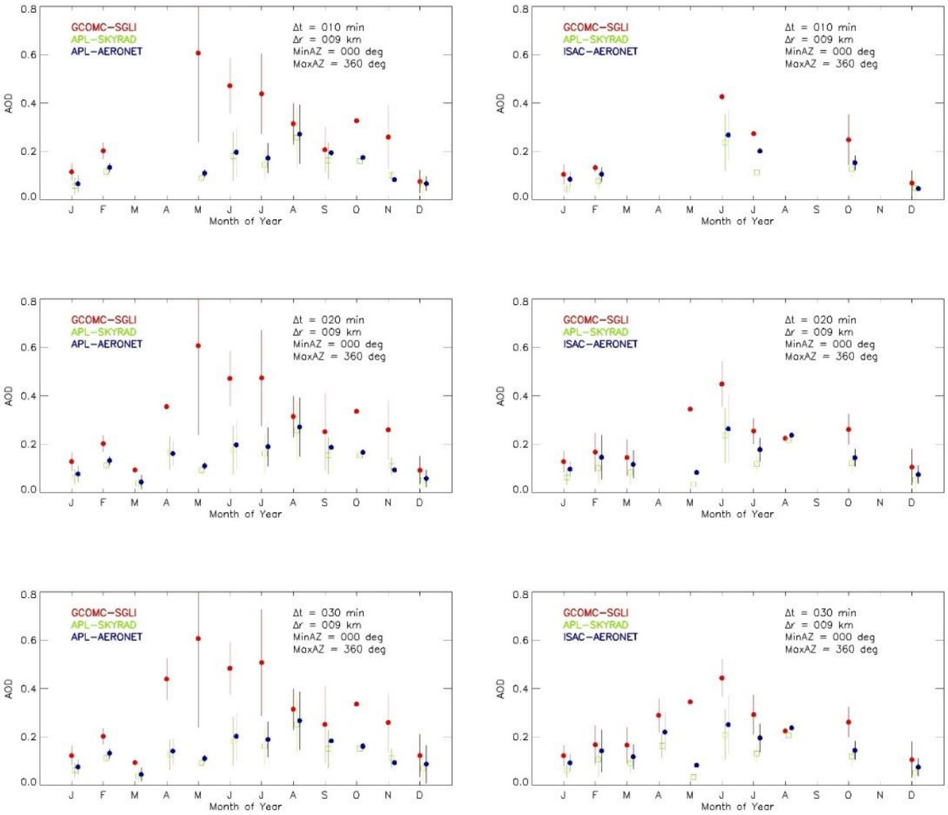

Figure 5 same as Figure 4 but for search radius = 9 km

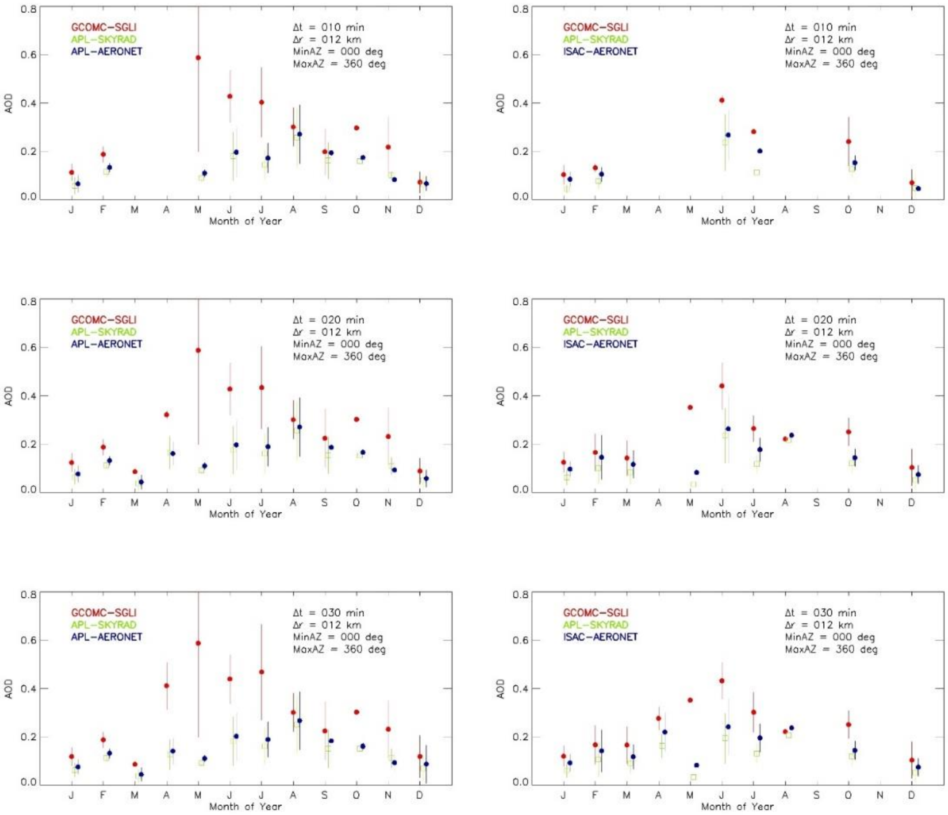

Figure 6 same as Figure 4 but for search radius = 12 km

From the analysis of Figures 4-6 it evident that the time evolution of the SGLI AODs show significant differences with respect to APL AERONET and EUROSKYRAD data (this two are perfectly aligned), especially for the April, May, June and July months. This suggests that the SGLI retrieval could be impacted by an insufficient quality of the a priori information about the aerosol type and load that can be expected in the area of interest.

For what concerns the comparison with ISAC AODs, results are significantly better, with still some inconsistency for May and June.

4.2.2 AOD scatter plots

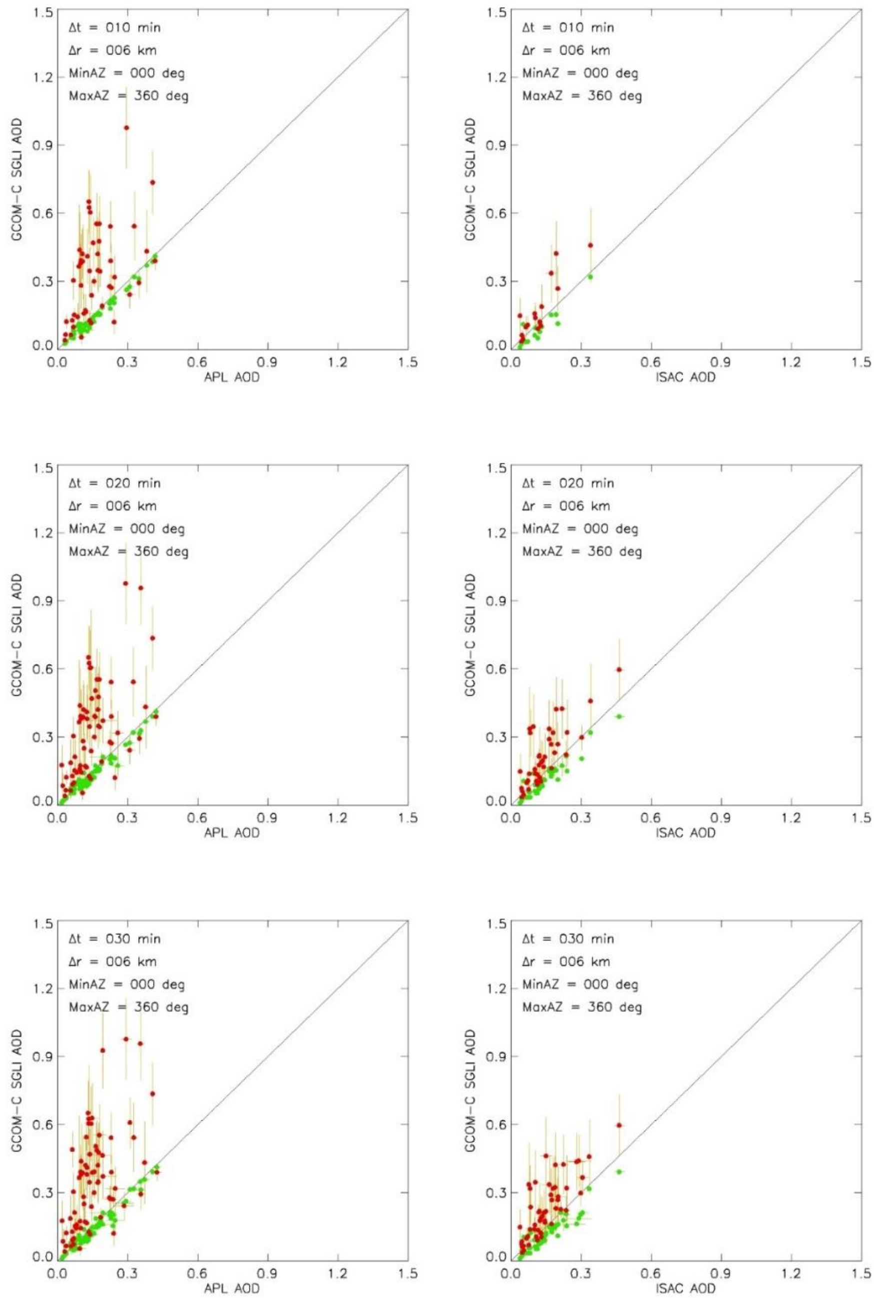

Figure 7: GCOM-C SGLI (red) and EUROSKYRAD (green) vs. collocated AERONET AODs. The vertical and horizontal thin lines indicate the variability of the data within the integration time (ground-based) and search radius (satellite). The time lag is 10, 20 and 30 minutes, the search radius is set to 6 km. The left panels refer to APL, the right panels to ISAC collocations

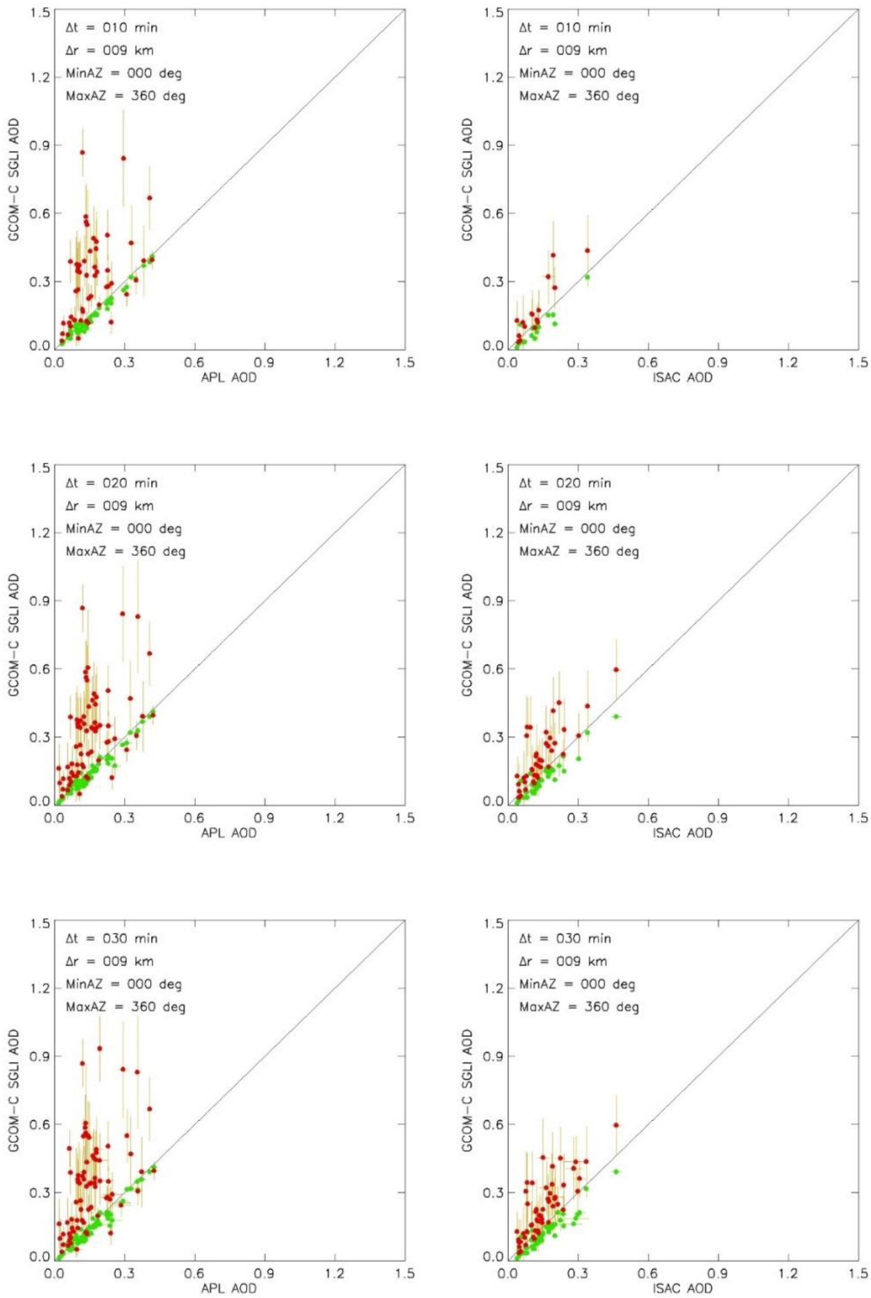

Figure 8 Same as Figure 7 but for search radius = 9 km

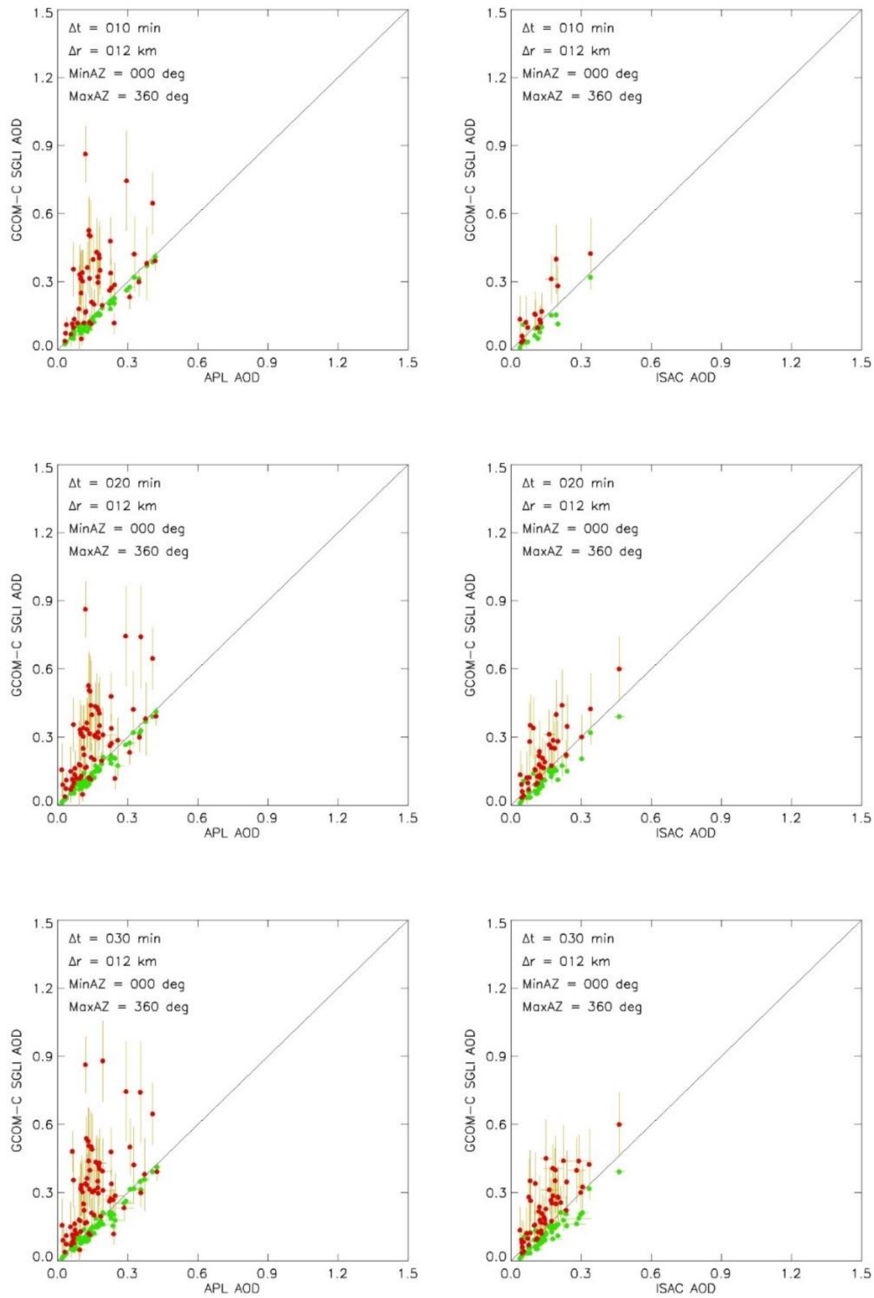

Figure 9 Same as Figure 7 but for search radius = 12 km

The comparison with APL-AERONET (left panels) reveals the inconsistency of SGLI AODs for urban areas. Some SGLI values are very close to that from APL instrument, but the majority of them is clearly not in line with the "ground truth". The SGLI extreme values are found for the above mentioned period between April and July. The situation is much better for the ISAC station.

4.2.3 AOD absolute difference histograms

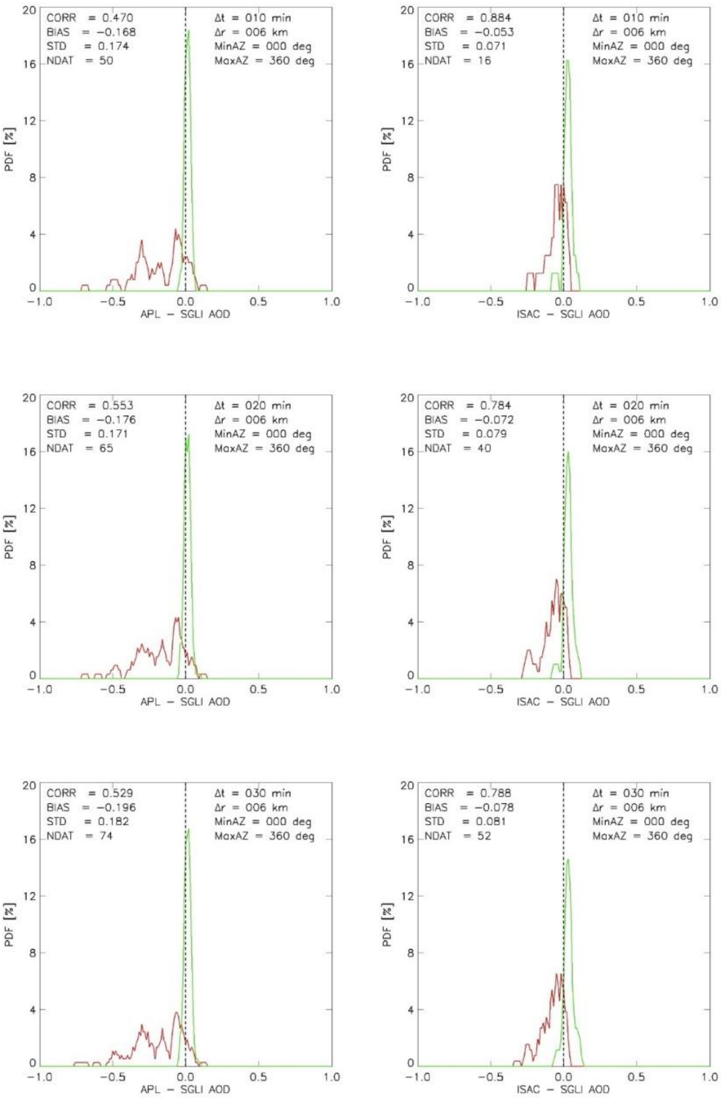

Figure 10 AERONET – SGLI (red) and AERONET – EUROSKYRAD (green) difference histograms. The time lag is 10, 20 and 30 minutes, the search radius is set to 6 km. In each panel, the values of the statistical parameters are reported. The left panels refer to APL, the right panels to ISAC collocations

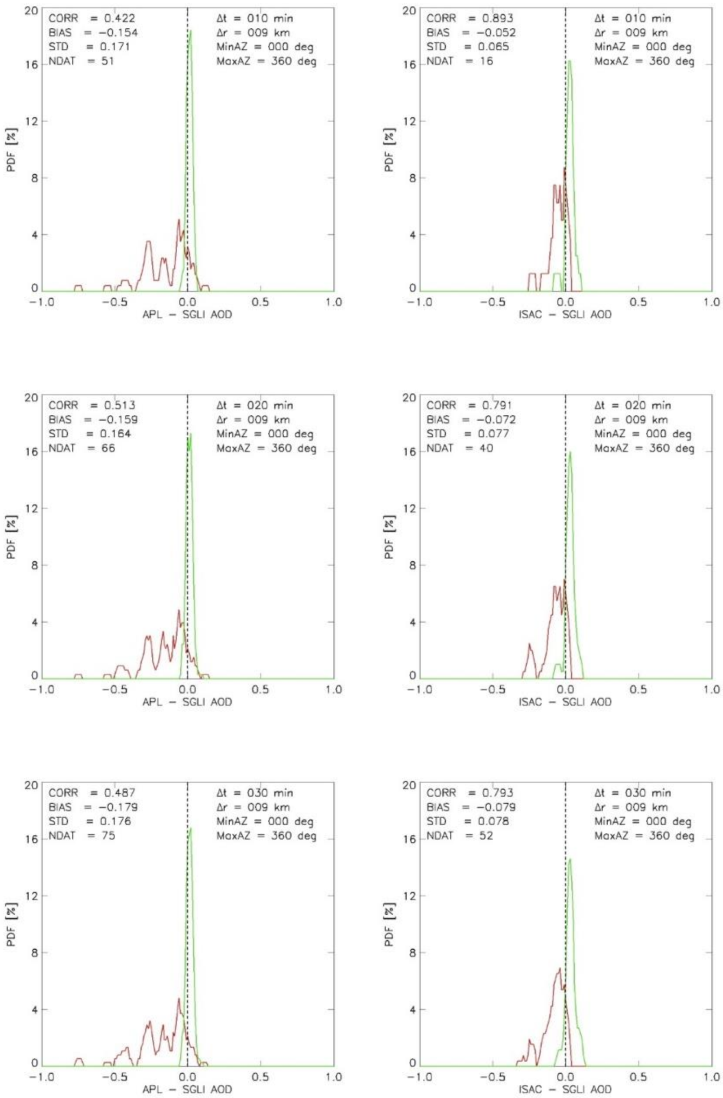

Figure 11 Same as Figure 10 but for search radius = 9 km

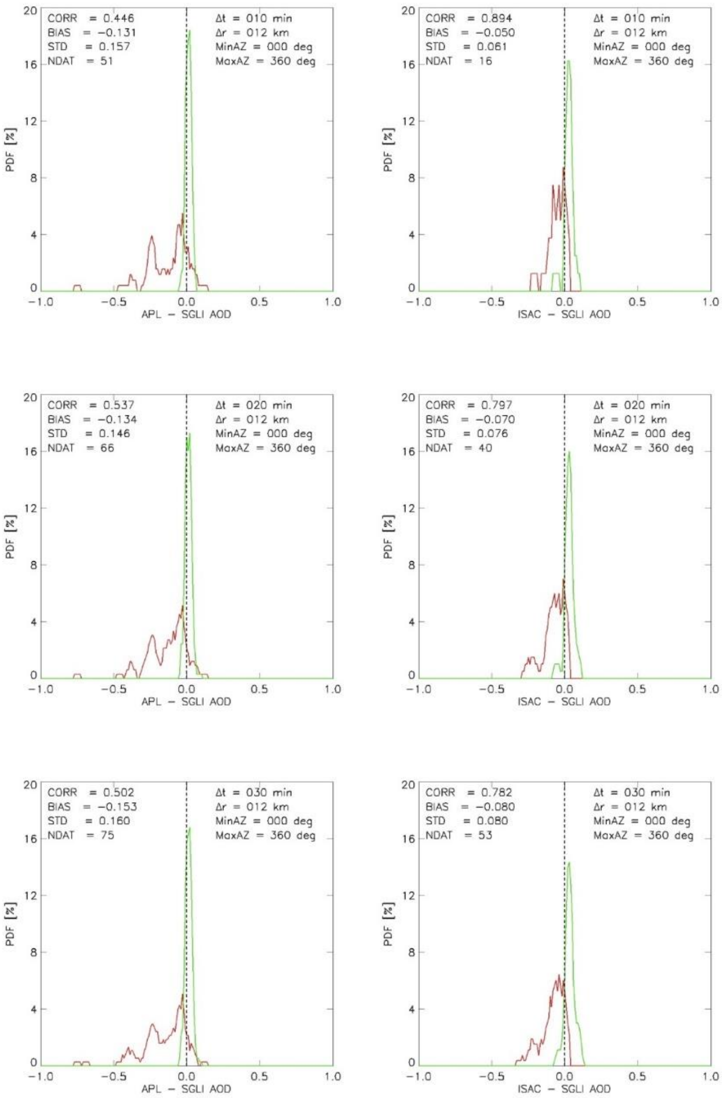

Figure 12 Same as Figure 10 but for search radius = 12 km

The APL-SGLI difference histograms reveal that this difference can be divided in three main groups, with modal △AOD values at around 0, -0.3 and -0.45, independently from time lag or search radius. A similar behaviour is found for ISAC, with modal values at around 0 and -0.3.

This could indicate, again, a “problematic” choice in the aerosol type and load for the urbanised areas.

4.2.4 AOD absolute difference vs. Solar Zenith Angle

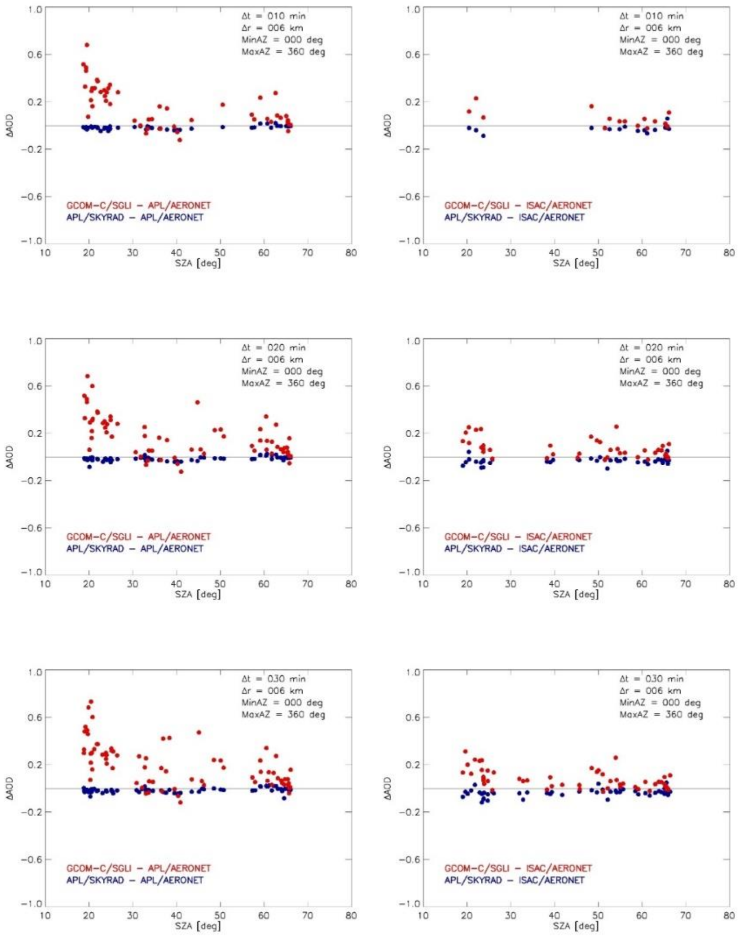

Figure 13 GCOM-C SGLI – AERONET (red) and EUROSKYRAD – AERONET (blue) AOD differences vs. SZA. The time lag is 10, 20 and 30 minutes, the search radius is set to 6 km. The left panels refer to APL, the right panels to ISAC collocations

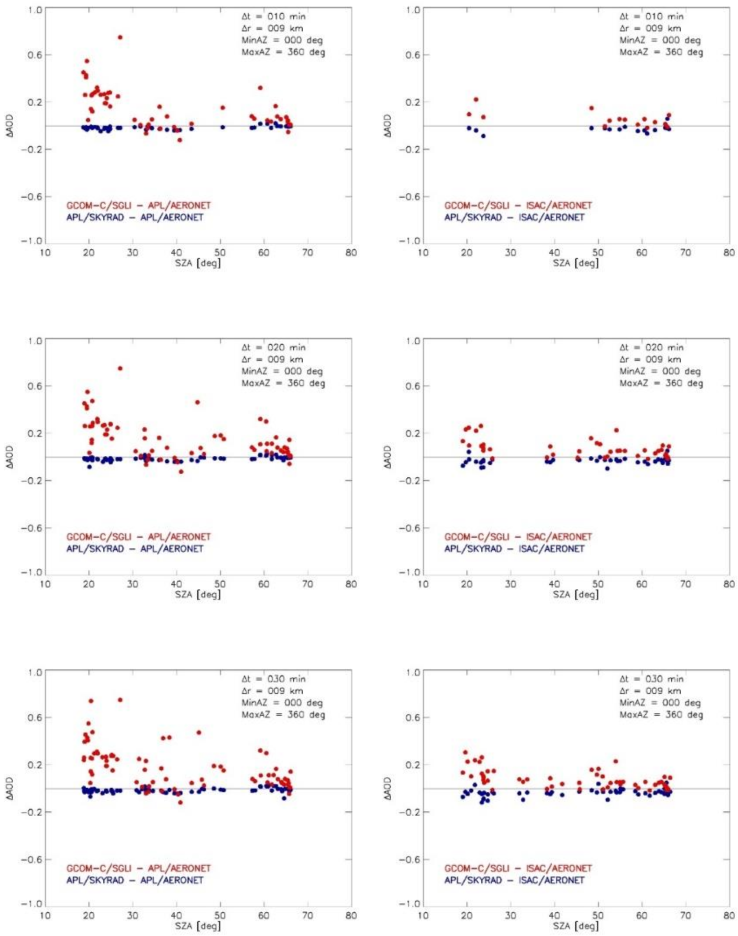

Figure 14 Same as Figure 13 but for search radius = 9 km

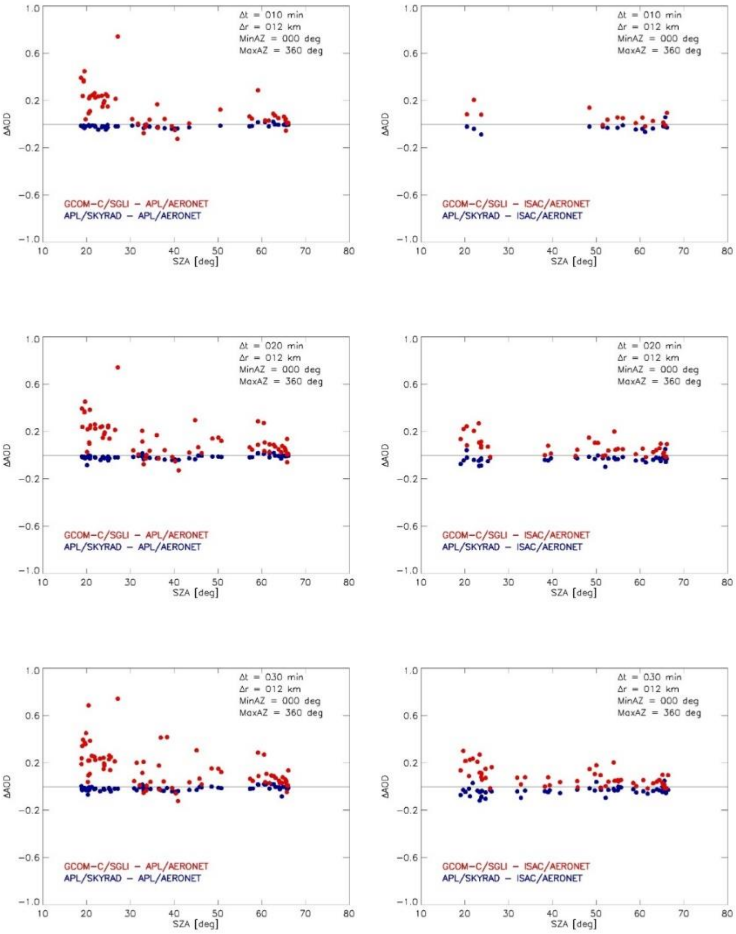

Figure 15 Same as Figure 13 but for search radius = 12 km

The larger △AOD values are found for low SZA (summer months, in line with above findings). This is particularly interesting, as the quality of the AODs from space-borne measurements is generally decreasing with SZA, while here we observe the opposite behaviour. In particular, the SZA value of 30 degrees seems to play an important role in the SGLI retrieval scheme: for both APL and ISAC comparisons the larger differences are found for SZA < 30 deg.

4.3 Summary of comparison results

The Table 3 summarises the results of the inter-comparison statistical analysis for a subset of selected time lags and search radius values. For sake of readability, it was decided to report only the results for typical search radius and time lags values. However, the statistical results for the complete dataset can be made readily available under request.

Table 3 columns (10) report the values for:

1. Site: the name of the AERONE site (APL or ISAC)
2. Rad: the search radius for the SGLI data around each site
3. Dt: the time lag expressed in hour fractions (10, 20 30 minutes)
4. Ndat: the number of matchups
5. A-S Bias: AERONET-SGLI AOD mean difference
6. A-S STD: AERONET-SGLI AOD standard deviation
7. A-E Bias: AERONET-EUROSKYRAD AOD mean difference
8. A-E STD: AERONET- EUROSKYRAD AOD standard deviation
9. AS Corr: AERONET vs. SGLI correlation coefficient
10. AE Corr: AERONET vs. EUROSKYRAD correlation coefficient

The values in RED indicate significant inconsistency with respect AERONET data.

Table 3 Summary statistical results for a subset of time lags and search radius values

Site	Rad	Dt	Ndat	A-S Bias	A-S STD	A-E Bias	A-E STD	AS Corr	AE Corr
APL	6	0.1667	50	**-0.1679**	**0.1741**	0.0169	0.0146	**0.4700**	0.9889
APL	6	0.3333	65	**-0.1761**	**0.1707**	0.0151	0.0182	**0.5534**	0.9819
APL	6	0.5000	74	**-0.1961**	**0.1823**	0.0163	0.0190	**0.5293**	0.9787
APL	9	0.1667	51	**-0.1541**	**0.1711**	0.0170	0.0144	**0.4223**	0.9889
APL	9	0.3333	66	**-0.1594**	**0.1637**	0.0151	0.0180	**0.5128**	0.9820
APL	9	0.5000	75	**-0.1788**	**0.1760**	0.0164	0.0188	**0.4875**	0.9787
APL	12	0.1667	51	**-0.1310**	**0.1573**	0.0170	0.0144	**0.4462**	0.9889
APL	12	0.3333	66	**-0.1340**	**0.1464**	0.0151	0.0180	**0.5370**	0.9820
APL	12	0.5000	75	**-0.1531**	**0.1602**	0.0164	0.0188	**0.5019**	0.9787
ISAC	6	0.1667	16	-0.0531	0.0709	0.0291	0.0302	0.8837	0.9229
ISAC	6	0.3333	40	-0.0720	0.0794	0.0342	0.0282	0.7840	0.9455
ISAC	6	0.5000	52	-0.0780	0.0811	0.0371	0.0316	0.7881	0.9344
ISAC	9	0.1667	16	-0.0521	0.0645	0.0291	0.0302	0.8928	0.9229
ISAC	9	0.3333	40	-0.0720	0.0772	0.0342	0.0282	0.7915	0.9455
ISAC	9	0.5000	52	-0.0786	0.0782	0.0371	0.0316	0.7930	0.9344
ISAC	12	0.1667	16	-0.0498	0.0610	0.0291	0.0302	0.8938	0.9229
ISAC	12	0.3333	40	-0.0698	0.0755	0.0342	0.0282	0.7970	0.9455
ISAC	12	0.5000	53	-0.0795	0.0798	0.0380	0.0320	0.7823	0.9313

From the results reported in the previous sections and in Table 3, two completely different behaviours are detected for the SGLI AOD. It is of relatively good quality for rural environments (mostly vegetated surfaces), while for urbanised areas the values are basically inconsistent with respect the AERONET and EUROSKYRAD data. Note that, the AERONET-EUROSKYRAD statistics are exceptionally good, as a further demonstration of the very high quality of these AOD products.

The AERONET vs. SGLI results are further confirmed by the variation of the fundamental statistical parameters (**Bias**, **STD** and **Corr**) as function of all the 8x7 selected Search Radius and the Time Lag. For consistent AOD data, we expect the STD to increase with Time Lag and the Bias to be substantially independent from the Search Radius. In fact, this is what we find for the ISAC site, contrarily to what happens for the APL site. Also, when varying the Search Radius and the Time Lag, the correlation coefficient (Corr) behaves in opposite ways for the two sites.

This clearly indicates that the GCOMC-SLGI AODs for urban areas are affected by large systematic errors, probably due to insufficient quality of the a priori information about the surface properties and the aerosol types that are to be expected in these environments.

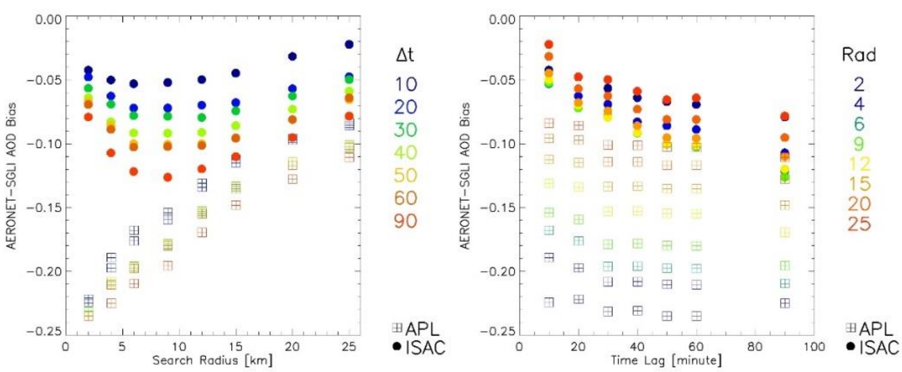

Figure 16 AERONET-SGLI mean bias vs. search radius for differen time lags (left), and vs. time lag for different search radius (right). In the left panel, time lag = Δt; in the right panel, search radius = Rad

In Figure 16, the mean AERONET-SGLI AOD bias is displayed vs. the search radius as function of time lag (left panel), and vs. the time lag as function of the search radius (right panel). It is evident that the search radius plays a relevant role for the selection of the urban data than for the semirurlal. This is a clear indication that, by increasing the search radius around APL, more vegetated "pixels" are considered and the quality of results for the space-averaged AOD increases.

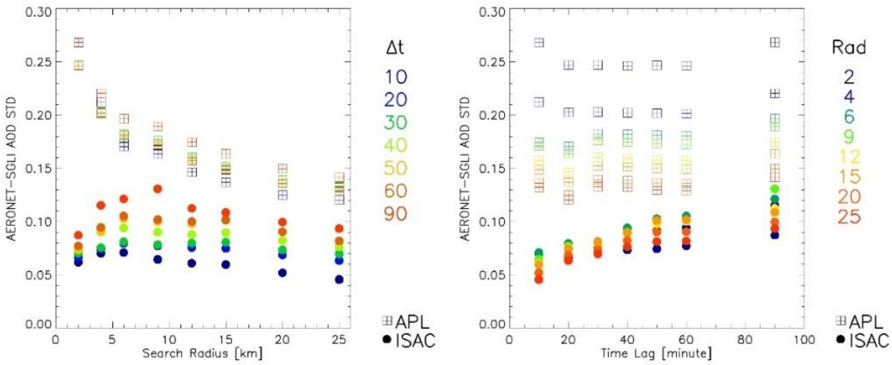

Figure 17 Same as Figure 16 but for AERONET-SGLI STD

The AERONET-SGLI AOD standard deviation (STD) vs. search radius and time lag is displayed in Figure 17 (same notation as in Figure 16). As can be noticed in the left panel, the STD for APL decreases for increasing search radius, while is substantially independent from time lag. Again, as a larger number of vegetated pixels are included in the analysis, the quality of the satellite data appear to increase.

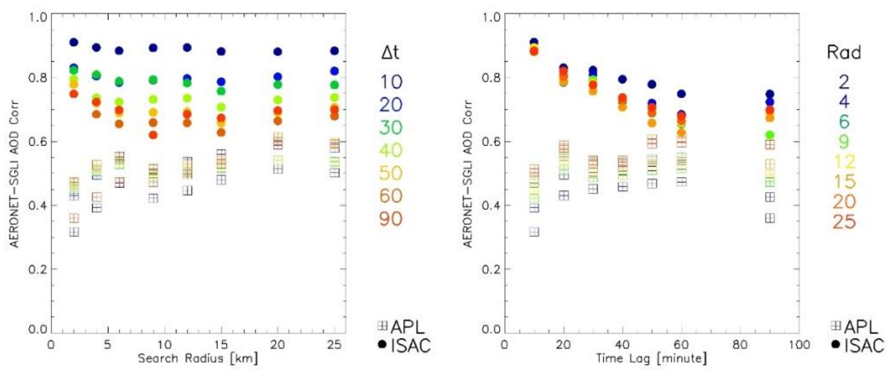

Figure 18 Same as Figure 16 but for AERONET-SGLI Corr

The behaviour of the correlation coefficient (Corr) vs. search radius and time lag is shown in Figure 18 (same notation as in Figure 16). In this case, the importance of selecting small time lags for aerosol inter-comparison exercises is evident for the ISAC results: the smaller the time lag, the higher the correlation coefficient. For the APL site, the correlation between AERONET and SGLI AODs is largely insufficient and substantially independent from any space/time selection criteria.

4.4 Sun-photometers time series (2018-2020)

Finally, Figure 19 shows how consistent are the AOD products are for the three sun-photometers used in this work. Evidently, it is correct to use this dataset as "ground truth" for satellite validation.

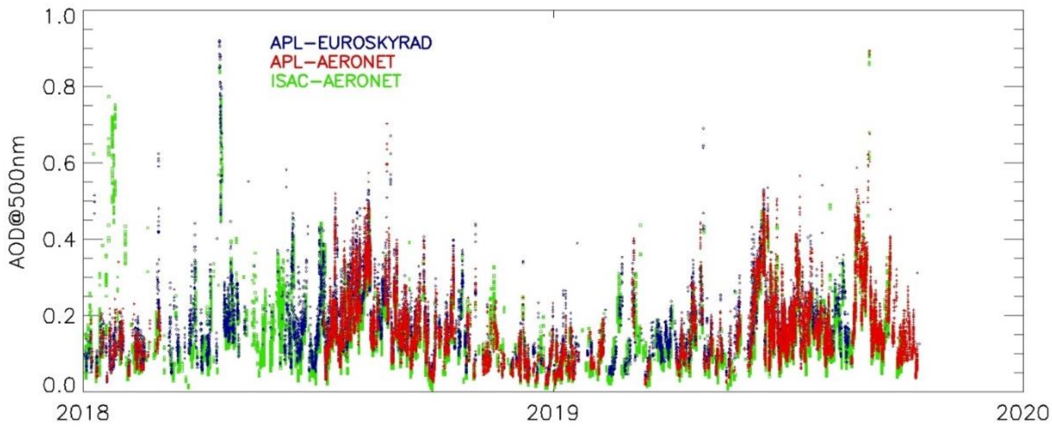

Figure 19 Time series of AOD (500 nm) for AERONET-APL (red), AERONET-ISAC (green) and EUROSKYRAD (blue) for the period January 2018 – September 2019. All available AERONET Lev1.5 and EUROSKYRAD (cloud screened) data are used

5. CONCLUSIONS AND OUTLOOK

The results of the AERONET – SGLI AOD validation exercise show that:

a) The SGLI AOD for vegetated areas are of good quality (see results for AERONET-ISAC)
b) The SGLI AOD for urbanised areas of extremely poor quality (AERONET-APL)
c) Possible cause for b) is the insufficient quality of the a priori information used in the SGLI AOD inversion scheme

These results are relative to one complete year of data: if requested by ESA, the analysis could be extended to other periods and to the SGLI AOD from polarised measurements.

5.1 Relevance of BAQUNIN super-site for GCOM-C SGLI validation

The validation of satellite derived AODs is not trivial and prone to misinterpretation of results, due to the complexity of the retrieval schemes and to the diversity in viewing geometries between ground based and satellite instruments. One of the most impacting factors for the AOD retrieval from space is the quality of the a priori information about the Earth's surface and the handling of this information in the AOD retrieval scheme. In addition, the validation of satellite AOD products for urban areas is by far the most complex, as the surface characteristic variations are of very small spatial scales and extremely complex to parametrise. This implies that even if a high quality ground based station is operating in the urbanised area, no specific conclusions could be drawn from the inter-comparison exercise.

In this context, the BAQUNIN super site provides a close-to-optimal solution, as it includes high quality instruments operating in urban, semi-rural and rural environments in a relatively small distance. In addition, the same atmospheric parameters are estimated instruments using independent retrieval schemes, as in this case AODs are estimated from AERONET and EUROSKYRAD sites. This allows for:

a) Satellite to Ground-based AOD data inter-comparison under different surface conditions
b) Ground-based to Ground-based data inter comparison for consistency checks

With the BAQUNIN supersite setup, the validation results provide deeper and unambiguous insights on the satellite data quality and on the possible sources of errors or weaknesses in the satellite retrieval schemes.

6. REFERENCES

1) GCOM-C "SHIKISAI" Data Users Handbook, December, 2018, SGC-180025
2) Giles, D. M., Sinyuk, A., Sorokin, M. G., Schafer, J. S., Smirnov, A., Slutsker, I., Eck, T. F., Holben, B. N., Lewis, J. R., Campbell, J. R., Welton, E. J., Korkin, S. V., and Lyapustin, A. I. (2019): Advancements in the Aerosol Robotic Network (AERONET) Version 3 database – automated near-real-time quality control algorithm with improved cloud screening for Sun photometer aerosol optical depth (AOD) measurements, Atmos. Meas. Tech., 12, 169-209, https://doi.org/10.5194/amt-12-169-2019
3) Campanelli, M., Siani, A. M., di Sarra, A., Iannarelli, A. M., Sanò, P., Diémoz, H., Casasanta, G., Cacciani, M., Tofful, L., and Dietrich, S.: Aerosol optical characteristics in the urban area of Rome, Italy, and their impact on the UV index, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2019-300, under review, 2019

6.1 Web sites

EUROSKYRAD: http://www.euroskyrad.net/index.html (with credentials)

AERONET: https://aeronet.gsfc.nasa.gov/new_web/aerosols.html (free download)

GCOM-C SGLI product description: https://suzaku.eorc.jaxa.jp/GCOM_C/data/product_std.html

GCOM-C SGLI data selection/download: https://gportal.jaxa.jp/gpr/search?tab=0 (with credentials)

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