Study of the possible benefits of cloud products of EUMETSAT in solar energy

Zhipeng Qu, Philippe Blanc, Mireille Lefèvre, Lucien Wald, Marion Schroedter Homscheidt, Gerhard Gesell

Study of the possible benefits of cloud products of EUMETSAT in solar energy

Zhipeng Qu, Philippe Blanc, Mireille Lefèvre, Lucien Wald
MINES ParisTech, Centre for Energy and Processes, BP 207 – 06904, Sophia Antipolis, France
Marion Schroedter-Homscheidt, Gerhard Gesell
German Remote Sensing Data Center, German Aerospace Center (DLR), Postfach 1116, D-82234 Wessling, Germany

Abstract

Satellite-derived assessments of surface downwelling solar irradiance are more and more used by engineering companies in solar energy. To increase performances, work is on going in the framework of the MACC project funded by the European commission, to improve both the modeling of the radiative transfer and the quality of the inputs describing the optical state of the atmosphere. The present study focuses on the cloudy atmosphere. EUMETSAT provides a range of products which could be potentially used for a proper description of cloud properties: cloud analysis, cloud analysis image, cloud mask. According to our study, the cloud products of EUMETSAT show a noticeable correlation with the ground measurements of solar irradiance. Nevertheless, these products are not suitable for an accurate assessment of the surface downwelling solar irradiance.

INTRODUCTION

Satellite-derived assessments of surface downwelling solar irradiance received on a horizontal plane (SSI) are more and more used by engineering companies in solar energy. Performances are judged satisfactory for the time being. Nevertheless, requests for more accuracy are increasing, in particular in the spectral definition and in the decomposition of the global radiation into its direct and diffuse components. One approach to reach this goal is to improve both the modelling of the radiative transfer and the quality of the inputs describing the optical state of the atmosphere (Oumbe et al. 2009). MINES ParisTech and German Aerospace Center (DLR) are involved in the development of methods for computing SSI. In particular, they jointly develop the Heliosat-4 method. This method makes use of optical parameters for clear-sky (Fig. 1). Cloud properties are also input to Heliosat-4 and Fig. 1 shows a number of possible candidates for such input.

Actually, there are several cloud products available, like that of DLR, CM SAF and EUMETSAT. Their temporal and spatial resolutions are different. The range of spatial resolution varies from 1x1 MSG pixel (about 5 km in Europe) to 16x16 MSG pixels; the range of temporal resolution is from 15 min to 24 h. These different resolutions could have an important impact to the usage of calculating the SSI. Also, different algorithms are used to obtain these cloud products. Furthermore, use cloud properties to calculate SSI depends on the product. To conclude, the properties of cloud products are different from one to another. The object of this study is to understand the influence of all these factors mentions above.

We firstly analyze the correlations between the cloud products of EUMETSAT and measurements of solar irradiance made by stations within the Baseline Surface Radiation Network in order to evaluate their potential in SSI calculation. Secondly, we compare the cloud products from EUMESAT with that of DLR (APOLLO, Kriebel et al. 1989, 2003) in order to better understand the characteristics of each product.

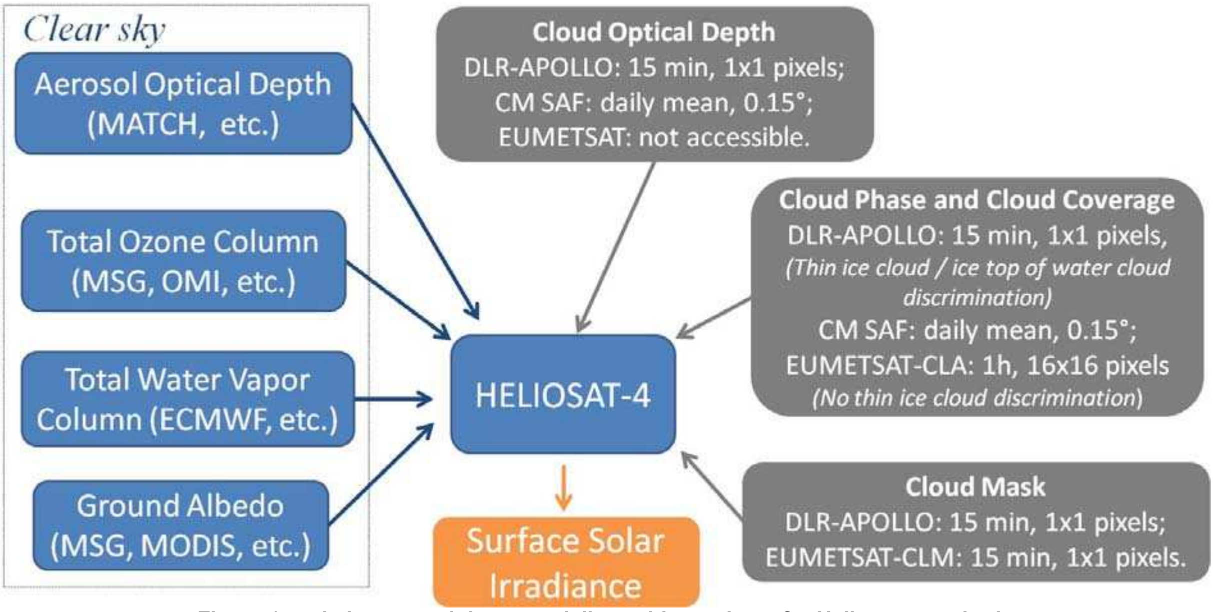

Figure 1: **main inputs and the potentially usable products for Heliosat-4 method**.

CORRELATION: CLOUD PRODUCTS AND SSI

There are many different methods to calculate SSI, from relatively simple and quick empirical methods to more complicated methods which include more physical parameters in the calculation. The first part of the study is to analyze the correlation between the cloud products and the ground measurement of SSI in order to see their potential. Here, we focus on the available cloud parameters from EUMETSAT: Cloud analysis (CLA), Cloud analysis images (CLAI) and Cloud mask (CLM). The SSI measured at BSRN sites is composed of the direct component, i.e. in the direction of the sun, and the diffuse component. The sum of these two components is called global SSI. In order to remove seasonal and latitudinal effects, SSI is converted to clearness index which defined as the ratio of SSI to the irradiance received on a horizontal plane at the top of atmosphere. Four BRSN stations are tested in this study:

Site name	Country	Latitude	Longitude	Elevation (m)
Carpentras	France	44.083°N	5.059°E	100
Payerne	Switzerland	46.815°N	6.944°E	491
Sede Boqer	Israel	30.905°N	34.782°E	500
Tamanrasset	Algeria	22.780°N	5.510°E	1385

Table 1: **tested BSRN stations**.

The cloud analysis (CLA) offers information about cloud amount for different types of cloud (low, middle, high cloud amount) and for total cloud amount as well as the associated cloud phase for each segment of 16x16 MSG pixels. Fig. 2 shows the correlation coefficient between the clearness index Kt of global SSI and the cloud amount for the year 2009. Generally, the total cloud amount shows the best correlation with the ground measurements for all the four stations though this correlation is not high. Middle and high cloud amount show a lower correlation. The low cloud amount shows a fairly bad score, especially for the stations not located in desert like Carpentras and Payerne. We can find a similar conclusion for the direct irradiance (not shown), but generally the correlation is slightly higher than that of global SSI.

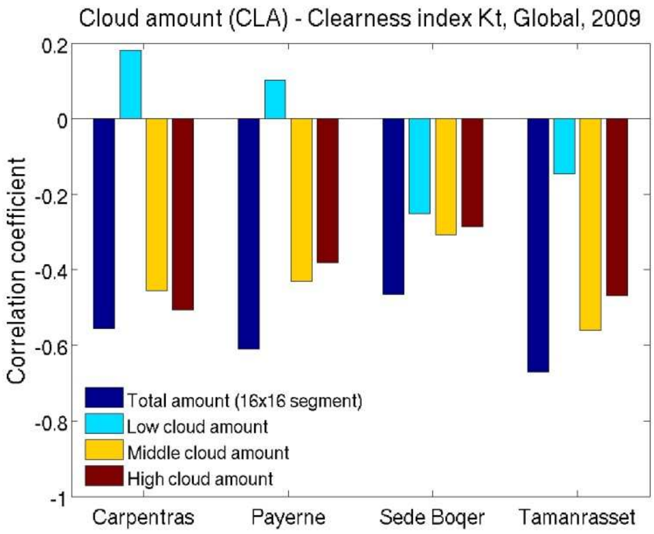

Figure 2: **correlation between clearness index and cloud amount (CLA)**.

Figure 3 shows the correlation between clearness index and cloud mask (binary value, 1x1 MSG pixel, 15 min). The correlation coefficients are around 0.5 and 0.6 for global and direct SSI respectively. As for the cloud amount product, the direct irradiance shows a better correlation than that of the global irradiance. Nevertheless, these coefficients are still low.

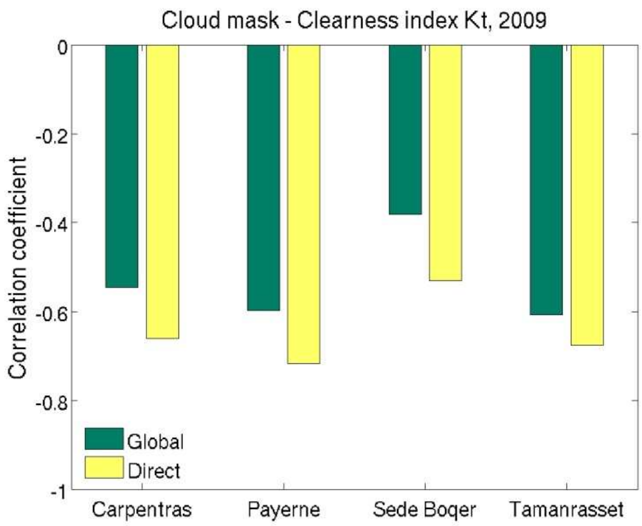

Figure 3: **correlation between clearness index and cloud mask (CLM).**

In order to illustrate the influence of the spatial resolution, the cloud analysis images (CLAI) are used like the cloud mask (binary value, 3x3 MSG pixels instead of 1x1 pixel of CLM). Fig. 4 shows the results for CLAI. It is very clear that the correlation is significantly reduced compared to the cloud mask results. There is an important influence of spatial resolution of cloud products for the application of SSI calculation.

According to the results presented above, we can observe a noticable correlation between the ground measurements and the cloud products (CLA, CLM and CLAI). However, the correlation is still not good enough (around 0.7 maximal) for the accurate surface solar irradiance calculation.

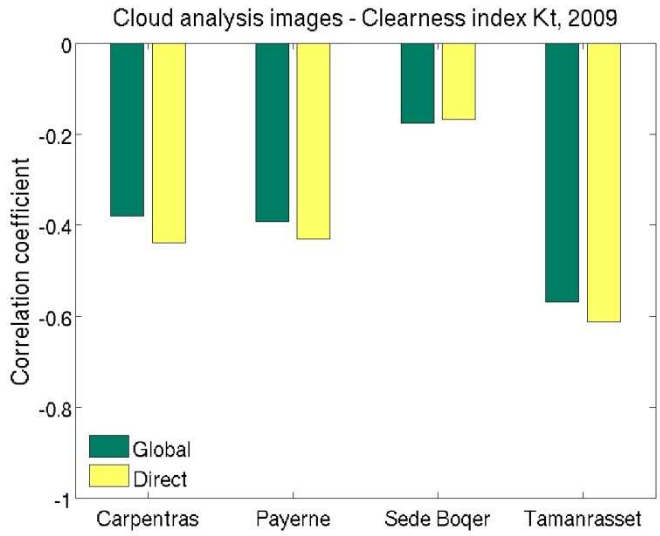

Figure 4: **correlation between clearness index and cloud analysis images (CLAI).**

COMPARISON: APOLLO AND THE CLOUD PRODUCTS OF EUMETSAT

The cloud product APOLLO offered by German Aerospace Center (DLR), provide abundant information about the cloud properties, such as cloud optical depth, type, classification, fraction, mask and cloud top temperature. In this part, we compare the existing products from EUMETSAT with that of APOLLO in order to better understand the characteristics of each product.

CLOUD MASK

Both EUMETSAT and DLR provide cloud mask product with the same spatial (1x1 MSG pixel) and temporal (15 min) resolution. The algorithms are different, therefore in different situations, the data qualities are different.

Carpentras 2009 (%)		CLM		Total	**Payerne 2009 (%)**		CLM		Total
		Yes	No				Yes	No	
APOLLO	Yes	39	5	44	APOLLO	Yes	62	8	70
	No	3	53	56		No	2	28	30
Total		42	58	100	Total		64	36	100

Sede Boqer 2009 (%)		CLM		Total	**Tamanrasset 2009 (%)**		CLM		Total
		Yes	No				Yes	No	
APOLLO	Yes	22	10	32	APOLLO	Yes	24	4	28
	No	17	51	68		No	6	66	72
Total		39	61	100	Total		30	70	100

Table 2: **comparison of cloud mask between APOLLO of DLR and CLM of EUMETSAT**.

Table 2 shows the comparison of cloud mask between APOLLO and CLM. For three out of four stations (Carpentras, Payerne and Tamanrasset), APOLLO agrees in most of the cases with CLM with disagreement cases less than 10%. Nevertheless, the disagreement cases appear more often for the station Sede Boqer with around 27% of all cases. When looking in to the details, the differences between the two products happen frequently for hours after sunrise and before sunset. This problem is probably caused by the confusion between cloud and ground in a region with high albedo (>0.3) combined with large solar zenithal angle and low temperature conditions.

CLOUD AMOUNT

The spatial and temporal resolutions of cloud amount are different for APOLLO (1x1 MSG pixel, 15 min) and CLA (16x16 pixels, 1 h). Fig. 5 shows the comparison of daily mean cloud amount values.

Even though the spatial resolution is different between APOLLO and CLA, we can still observe a relatively good correlation for the station Tamanrasset, as well as for the other three stations (not shown). However, when using the hourly values, the correlation becomes fairly bad (Fig. 6). APOLLO (1x1 MSG pixel) has more cases of 100% and 0% value due to its high spatial resolution. The values of CLA are averaged in the 16x16 MSG pixels segment, therefore there are much less extreme cases. This characteristic limits the usage of CLA for the high temporal resolution calculation of the SSI.

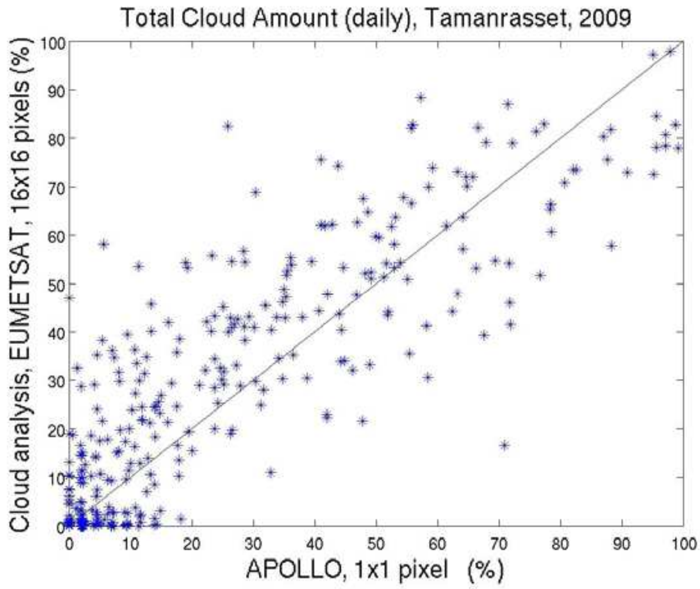

Figure 5: **total cloud amount: APOLLO and CLA (daily mean).**

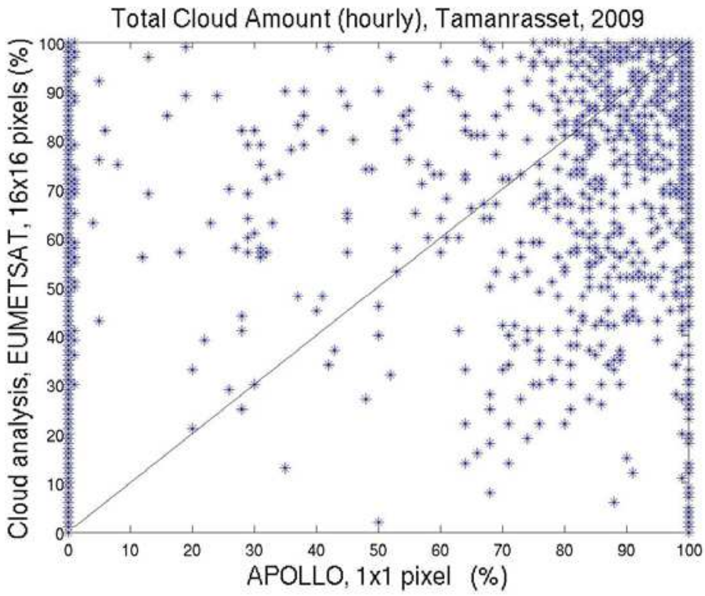

Figure 6: **total cloud amount: APOLLO and CLA (hourly).**

CLOUD PHASE

The way to define the cloud phase between APOLLO and CLA is quite different. For CLA, the cloud phases are associated to 8 types of cloud: 1st, 2nd, 3rd low and middle clouds, 1st and 2nd high clouds. For a segment, the ice and water clouds are present with different percentage in different levels (8 types of cloud). APOLLO defines the cloud phase in another way. There are four types of cloud in APOLLO: low, middle, high and thin cloud. The first three types of clouds are generally considered as water cloud. In this case, the middle and high clouds with ice top are also considered as water cloud, because, in radiative transfer application, the lower part of middle and high cloud are often water cloud which are the main contributor of the attenuation of the solar irradiance. The thin cloud in APOLLO is considered as ice cloud due to its high altitude, low temperature and thin structure. In this case, there is no presence of water cloud below. The extinction of irradiance is solely due to the ice cloud.

CONCLUSION

The cloud products of EUMETSAT show a noticeable correlation with the ground measurements of solar irradiance. Nevertheless, these products are not suitable for an accurate assessment of the SSI. There is a well developed algorithm from EUMETSAT to calculate the cloud optical depth (Watts et al. 2011). However, the product is not operational. Therefore, in this study, there is no cloud optical depth product available from EUMETSAT which is crucial for accurate surface solar irradiance calculation. The comparison between EUMETSAT products and that of DLR shows that there are impacts of the methods/algorithm (cloud mask) spatial and temporal resolution (cloud amount). The existing EUMETSAT cloud products are of restricted use for solar energy application due to their temporal and spatial characteristics and missing parameters being crucial for accurate solar irradiance calculation.

ACKNOWLEDGMENTS

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement no. 218793 (MACC project). This work was done while the author Zhipeng Qu was a visiting scientist at Germen Aerospace Centre (DLR).

REFERENCES

Kriebel, K. T., Gesell, G., Kästner, M., and Mannstein, H., (2003) The cloud analysis tool APOLLO: Improvements and validations, International Journal of Remote Sensing, 24:12, 2389-2408

Kriebel, K. T., Saunders R. W., and Gesell, G., (1989) Optical properties of clouds derived from fully cloudy AVHRR pixels. Beitr. Phys. Atmosph., **62,** 3, pp 165-171

Oumbe, A., Blanc, Ph., Ranchin, T., Schroedter-Homscheidt, M., and Wald, L., (2009) A new method for estimating solar energy resource. In Proceedings of the ISRSE 33, held in Stresa, Italy, 4-9 May 2009. Published by Joint Research Center, Ispra, Italy, USBKey, paper 773.

Watts, P. D., Bennartz, R., and Fell, F., (2011) Retrieval of two-layer cloud properties from multispectral observations using optimal estimation. J. Geophys. Res., **116,** D16203, 10.1029/2011JD015883