COMPARING CALIOP AND AERONET CLOUD OPTICAL DEPTH AT CAMAGÜEY, CUBA.

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ABSTRACT

CALIPSO provide cloud optical depth (COD) values as a product included in the Version 3, Level 2 of data release. AEROsol NEtwork (AERONET) ground−based photometer produce COD values recently, using spectral behavior of the radiation in the site measurements. It is important to evaluate the COD to increment the knowledge about clouds and in turn on the climate system.

In the present work COD measurements below 5 obtained with CALIPSO and AERONET in Camagüey site (21.42º N, 77.85º W, 122 m asl) from June 2010 to December 2011 are compared. In general, comparison shows similar frequencies of occurrence, higher occurrence of COD below 0.3. The frequency decreases with the increase of the COD values. There are slightly differences in the COD's frequency of occurrence below COD of 0.3. The highest occurrence in CALIPSO COD data is in the interval centered in 0.1, by contrast to AERONET the maximum is in the interval centered in 0.2.

A criterion to select collocated measurement of both instruments was search to compare the COD's values. Time and spatial window between both measurements of 6 h and 0.5 degree respectively, were used. Results show not useful correspondence with 2 days of coincident measurements in the analyzed period.

1. INTRODUCTION

Climate system is a complex arrangement of different components. One component, the clouds, acts as a modulator of the Earth's radiation budget. They have effect on the shortwave and longwave radiation involved in radiative transfer processes in the Earth's atmosphere. The information about the optical characteristics of the clouds is crucial to analyze their behavior and the good representation of their role in climatic models. The cloud optical depth (COD) is a variable that describe primarily the interaction between clouds and radiation.

There are some instruments that provide information to obtain the COD. These instruments are placed in the ground, aboard plane and satellite (eg. radiometers, lidar). Cloud−Aerosol LIdar with Orthogonal Polarization (CALIOP) is the primary instrument on the Cloud−Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), launched in April 2006 [1]. CALIOP profile information is used to calculate COD producing a global view of the cloudiness [2]. Recently COD have begun to be derived from the radiometer Cimel CE−318 based in surface [3]. This instrument is used by the AEROsol NEtwork (AERONET) to measure the optical properties of aerosols [4]. When the clouds are in the field of view of the instrument, a "cloud mode" measurement is carried out. Radiance measurements from the zenith are conducted. The algorithm to determine the COD is based in the same spectral response of the cloud properties in the red and near infrared regions of the spectrum. The algorithm uses the zenith radiance measurements and the satellite information combined with radiative transfer model calculations [3].

There are some comparisons or validations of COD from CALIOP with lidar in aircraft [5−7] and ground−based lidar [8,9]. But there had not been reported comparison of COD values estimated with sunphotometer Cimel CE−318 and CALIOP. Here we compare the COD values from the sunphotometer installed in Camagüey and COD from CALIOP in the period between June 2010 and December 2011

2. INSTRUMENTS AND MEASUREMENTS

CALIPSO is part of the Aqua constellation of satellites (A−Train). It have a polar orbit at an altitude of 705 km with a daytime equatorial crossing time around 13:30 hours local time. CALIOP, a two−wavelength (1064 nm and 532 nm (dual−polarization)) elastic−backscatter lidar, together with an Imaging Infrared Radiometer, and a Wide Field Camera is carried in CALIPSO. These three instruments are aligned and have nadir viewing. CALIOP produces one profile every 333 m at each wavelength. To improve the accuracy of the data products, 15 consecutive, profiles are averaged. Then the particulate extinction and optical depths are retrieved at the horizontal resolution of 5 km. More information about instrument and algorithms are detailed in [1,2]. Detection of cloud layers primarily relies on the 532 nm channel. Cloud layers are detected using an adaptive threshold detection technique applied to profiles of attenuated scattering ratio. There is an algorithm for cloud and aerosol discrimination (CAD), to calculate the cloud optical depth. This algorithm is based in a five−dimensional probability density function (PDF) approach [10]. The CALIOP maximum COD value is ~5.

Sunphotometer Cimel CE−318 is the standard radiometer used by AERONET for the measurement of sun direct irradiance and sky radiance with a field of view of 1.2º in the wavelengths of 340 nm, 380 nm, 440 nm, 675 nm 870 nm, y 1020 nm [4]. Under the condition when a cloud is in the instrument field of view, was proposed recently by [3] to conduct 10 radiance measurements in the zenith direction with each wavelength. This mode of the instrument operation is named "cloud mode". It is based in the similar radiative behavior of the cloud at the two wavelength measurements at red and near infrared wavelengths to retrieve COD values over the vegetated surface [3].

The algorithm for the COD determination implemented in AERONET is detailed in [3]. There is no one to one relationship between zenith radiances and COD. Thus, two wavelengths radiance measurements (470 nm and 870 nm) are used to reduce the ambiguity. Combining the radiance in these two wavelengths, radiative transfer calculations, and satellite data the COD value is obtained [3]. The reported COD value is the 1.5 minutes average of the 10 instantaneous values.

The datasets used in the present study are COD values in the period between June 2010 and December 2011 from the sunphotometer Cimel CE−318 installed in Camagüey (21.42º N, 77.84º W, 128 m asl), Cuba and the CALIOP in the spatial window of one degree in latitude and longitude centered in the site coordinates. Threshold COD value of 5 is selected to compare both dataset.

In order to compare collocated measurements the criterion of the spatial window is reduced to 0.5 degree centered in the site coordinates. The temporal window between measurements is a critical variable. We start with exact coincidence in time and increase the time in order to find out any collocated measurements of AERONET and CALIOP in the analyzed period.

3. RESULTS

Figure 1 show the COD frequency distribution for the values obtained with both instruments in the studied period. Frequency distributions are shown in intervals of 0.1 optical depth units. There are little differences between COD frequency distributions. COD frequency distribution from the Cimel CE 318, AERONET has a maximum of 24 % in the interval centered in 0.2, figure 1a. Frequency distribution decreases monotonically with the increase of the COD, after this maximum.

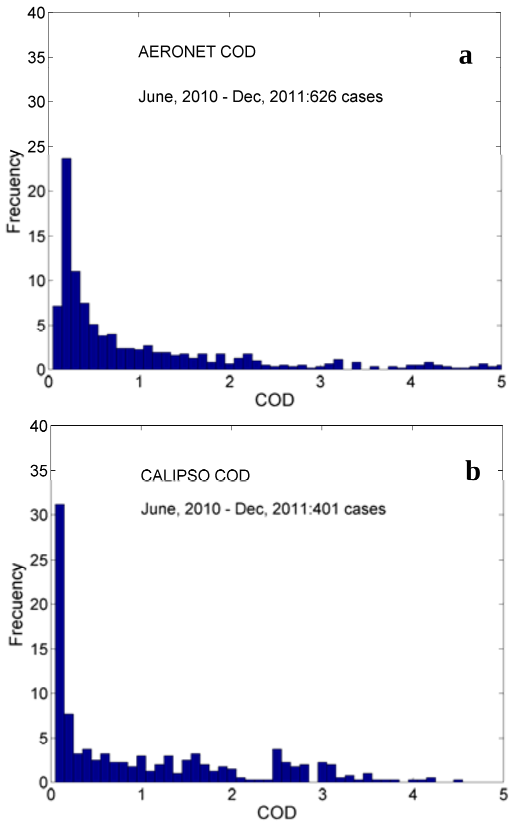

Figure 1. COD frequency distribution for the period from June 2010 to December 2011, in Camagüey, for the values below 5, a) with sunphotometer, AERONET, b) lidar CALIOP onboard CALIPSO in the spatial window of one degree centered in the site coordinates.

Moreover, there is maximum value of 31 % in the interval centered at 0.1 for the COD frequency distribution in the case of the CALIPSO, figure 1b. After this maximum the frequency distribution decreases with the increase of the COD. In the interval centered at 2.5 there are a slightly increase in the frequency to 4 %.

Differences in the maximums intervals between both dataset are due the measurement method. Sunphotometer instrument made a measurement of sun radiances to estimate aerosol optical depth still in the case that is present some subvisual clouds. In that situation the cloud mode is not carried out. The result is that the COD for this cloud type is not obtained. These aerosol measurements are "cloud contaminated". AERONET current algorithm do not allows to derive COD values from all subvisual cirrus clouds present in the sky.

Mean (standard deviation) values of the COD are 0.97 (1.11) and 1.04 (1.11) for AERONET and CALIPSO data respectively. There are no differences in the frequency distribution for the COD calculated from Cimel when the mean and standard deviation values are compared. There are not statistically significant differences at the 1 % significance level between both samples.

In the process to obtain collocated measurements of the sunphotometer and CALIOP in Camagüey, the minimum time interval for any collocated measurement was 6 hours. Latitude and longitude interval were 0.5º centered in the site coordinates (21.42º N, 77.84º W). Two days have collocated measurements with values of COD less than 5. The information of these collocated measurements is summarized in Table 1. First day, July 6, 2010 has 2 measurements of Cimel. The second day, January 29, 2011, has 1 measurement of Cimel. Each day has 11 collocated measurements of CALIPSO. The first day had similar values of COD with both instruments. The mean (standard deviation) values are 0.91 (0.90) and 1.45 (0.05) for CALIPSO and Cimel, respectively. In the second day there are differences with COD mean (standard deviation) values of 1.64 (0.19) for CALIPSO, Cimel has 1 measurement with COD of 5.50.

There are reports of cirrus clouds presence in the actinometric and weather observations for both days. In the second day there are reported an altocumulus cloud type in the zenith ten minutes after the Cimel COD measurements. There is no information about cloud in the zenith to the first day.

Differences between collocated measurements are attributed primarily, of course, to the time separation in the measurements, near to 5 hours. But we have similarity between the COD values to the first day. The second day the measured cloud by Cimel was an altocumulus cloud type. Other aspect is that CALIPSO measurement for this day was in the night (near to 2 hours Local Time, -5 hours from Greenwich meridian) and Cimel measurements early in the morning.

4. CONCLUSIONS

This work is the first attempt to compare measurement of COD obtained with Cimel and CALIOP in Camagüey site. The results show a general agreement between the COD values both instruments, in the period studied. There are slightly differences in the maximum of frequency of occurrence in different interval of COD. These differences are attributed to the method of operation of the Cimel in the "cloud mode". Some subvisual cirrus clouds optical depths are measured as "contaminated aerosol optical depth".

Table 1. Characteristics for the collocated measurements of Cimel and CALIPSO in Camagüey.

***Cimel* 21.42, −77.84**		***CALIOP−CALIPSO***		
Hour (GMT) hh:mm:ss	**COD**	**Hour (GMT) hh:mm:ss.ff**	**Latitude, Longitude**	**COD**
2010/07/06				
12:20:41	1.41	07:10:28.16	21.64, −77.97	0.15
12:43:54	1.49	07:10:28.91	21.60, −77.98	0.07
		07:10:29.65	21.55, −77.99	0.09
		07:10:30.39	21.51, −78.01	0.53
		07:10:31.14	21.46, −78.02	0.99
		07:10:31.88	21.42, −78.03	0.74
		07:10:32.63	21.37, −78.04	0.69
		07:10:33.37	21.33, −78.05	1.66
		07:10:34.11	21.28, −78.06	2.99
		07:10:34.86	21.24, −78.07	1.77
		07:10:35.60	21.19, −78.08	0.34
2011/10/29				
13:02:21	5.50	07:08:54.36	21.65, −77.97	1.80
		07:08:55.10	21.60, −77.98	1.59
		07:08:55.85	21.56, −77.99	1.58
		07:08:56.59	21.51, −78.00	1.89
		07:08:57.34	21.47, −78.01	1.90
		07:08:58.08	21.42, −78.02	1.47
		07:08:58.82	21.38, −78.03	1.45
		07:08:59.57	21.33, −78.04	1.54
		07:09:00.31	21.29, −78.05	1.84
		07:09:01.06	21.24, −78.06	1.36
		07:09:01.80	21.20, −78.07	1.56

Collocated measurements in suitable time interval are very scarce. In the analyzed period only two days were selected with near of 5 hours of differences. This time interval is not useful for comparing clouds with different instrument. There would be necessary to increment the points of comparisons or extending the analyzed period of time to obtain better criterion of coincidence between measurements.

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6. REFERENCES

[1] Winker, D. M., W. H. Hunt, and M. J. McGill, 2007: Initial performance assessment of CALIOP, Geophys. Res. Lett., 34, L19803.

[2] Winker, D. M., et al., 2010: The CALIPSO Mission: A Global 3D View of Aerosols and Clouds. Bull. Amer. Meteor. Soc., 91 (July 2010).

[3] Chiu, J. C., C.−H. Huang, A. Marshak, I. Slutsker, D. M. Giles, B. N. Holben, Y. Knyazikhin, and W. J. Wiscombe, 2010: Cloud optical depth retrievals from the Aerosol Robotic Network (AERONET) cloud mode observations, J. Geophys. Res., 115, D14202, doi:10.1029/2009JD013121.

[4] Holben, B. N., Eck, T. F., Slutsker, I., Tanré, D., Buis, J. P., Setzer, A., Vermote, E. F., Reagan, J. A., Kaufman, Y. J., Nakajima, T., Lavenu, F., Jankowiak, I., and Smirnov, A., 1998: AERONET: A federated instrument network and data archive for aerosol characterization, *Remote Sens. Environ*., **66**, 1–16 .

[5] McGill, M. J., *et al.*, 2007: Airborne validation of spatial properties measured by the CALIPSO lidar, *J. Geophys.Res.***112,**D20201, doi:10.1029/2007JD008768.

[6] Vaughan, M., R. Kuehn, S. Young, M. McGill, Z. Liu, Yongxiang Hu, 2008: Validating cirrus cloud optical properties retrieved by CALIPSO. *Proceedings of the 24th International Laser Radar Conference (ILRC 24)*, 23−27 June 2008, Boulder, Colorado(USA).,

[7] Young, S. A., D. L. Hlavka, M. A. Vaughan, M. J. McGill, 2010: A comparison of space−borne and airborne lidar observations of complex, high cloud fields during CLASIC. *Proceedings of the 25rd International Laser Radar Conference (ILRC 25)*, (St. Petersburg, Rusia

[8] Thorsen, T. J., Q. Fu, and J. M. Comstock, 2011: Comparison of the CALIPSO satellite and ground−based observations of cirrus clouds at the ARM TWP sites, *J. Geophys. Res.*, **116**, D21203, doi:10.1029/2011JD015970.

[9] Dupont, J.−C., M. Haeffelin, Y. Morille, V. Noel, P. Keckhut, D. Winker, J. Comstock, P. Chervet, and A. Roblin, 2010: Macrophysical and optical properties of midlatitude cirrus clouds from 4 ground−based lidars and collocated CALIOP observations, *J. Geophys. Res.*, **115**, D00H24, doi:10.1029/2009JD011943.

[10] Liu, Z., R. Kuehn, M. Vaughan, D. Winker, A. Omar, K. Powell, C. Trepte, Y. Hu, and C. Hostetler, 2010:, The CALIPSO Cloud And Aerosol Discrimination: Version 3 Algorithm and Test Results, *Proceeding of 25th International Laser Radar Conference (ILRC)*, St. Petersburg, Russia, 4 pp..