ACTRIS TNA Activity Report

Intercomparison of tropical aerosols properties measurements conducted by sunphotometer and CALIPSO, VALIDATION

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- **Introduction and motivation**

  It has been pointed out, by many researchers, the important role of Saharan dust on climate, chemical, physical and biological processes, health and human activities. The variability of the optical properties of the Saharan dust transported, across the Atlantic to the Caribbean, has been poorly studied. From the end of 2008 a sun-photometer has been operating at Camagüey, Cuba, operated by Atmospheric Optics Group of Camagüey (GOAC, in Spanish). This site belongs to RIMA (Iberian Network for Aerosols Measurements) under GOA-UVA leadership, and its measurements are contributed to AERONET. The collected information has been used for preliminary studies and new studies are under way by GOAC, including the characterization of the variability of the optical properties of Saharan dust during the transport from its sources to the Caribbean.

  The GOAC has been acquired knowledge in the intercomparisons of aerosols optical properties derived from sunphotometer and MODIS as well as its model forecasts at the NASA Goddard Space Flight Center [1]. To complete the required knowledge of the GOAC team for conducting further research, it was necessary to acquire the necessary knowledge on the use and reliability of CALIPSO lidar information, and comparing data with ground-based sunphotometer, MODIS data and ground-based lidar EARLINET measurements.

- **Scientific objectives**

  The research to be conducted consists of on characterizing the variability of the Saharan dust in its way from the source in Africa through the Atlantic until reaching the Caribbean. A sunphotometer belonging to RIMA, installed in Camagüey, Cuba, allow understanding the spatio-temporal distribution of the aerosols optical properties and comparing it with ground-based measurements carried out at the same time in Europe. Measurements in both sides could be compared with CALIPSO [2, 3], however the lack of knowledge about this instrument inhibited this The TNA access to CIAO facility allowed to fill this gap through the training from CIAO personnel about using multi-platform data and in particular CALIPSO and EARLINET ones.

- **Reason for choosing station**

  The widely well-known expertise in the field of atmospheric studies and also in the exploitation of a wide variety of instruments, was the main reason for selecting CNR-IMAA Atmospheric Observatory (CIAO), Potenza, Italy, for this ACTRIS action. An important aspect related with the objective of this action, is associated with the experience of CIAO in the instrument intercomparison and synergistic use such as ground based and satellite-borne instruments as CALIPSO and MODIS. The TNA access to CIAO also provides the access to a specific geographical CALIPSO subset and to EARLINET database.

- **Method and experimental set-up**

  The facilities access and personnel experience capabilities were offered by the CIAO personnel. All the necessary knowledge and know-how in the synergistic use of multi-platform data was transferred during the training period. Access to CIAO datasets and infrastructure was granted during the action.

  A case study was selected for investigating variability of aerosol properties during their transport over the Atlantic Ocean. During July 2009 several Saharan Dust events affected the Camagüey measurement site, where a CIMEL CE-318 sunphotometer [5, 6] is operated by the GOAC. Along lasting event was observed for the 15-20 July period. Multi-instrumental data were analyzed with the main aim of understanding the variability of aerosol mass, from their source on West Africa coast to the Caribbean. For such a goal, a spatial coincident criterion between different instruments (mainly sunphotometer and CALIPSO) of 40 km was used.

  European Lidar Network (EARLINET) data are used for investigating the potential presence of dust aerosol over Europe at the same time than in Caribbean and analyzing differences in aerosol mass concentration and optical properties for dust particles coming from the same source region. This would allow us to investigate mixing and modification processes for aerosol with different traveled paths. The CIAO facilities were used for accessing, extracting and handling CALIPSO and EARLINET data.

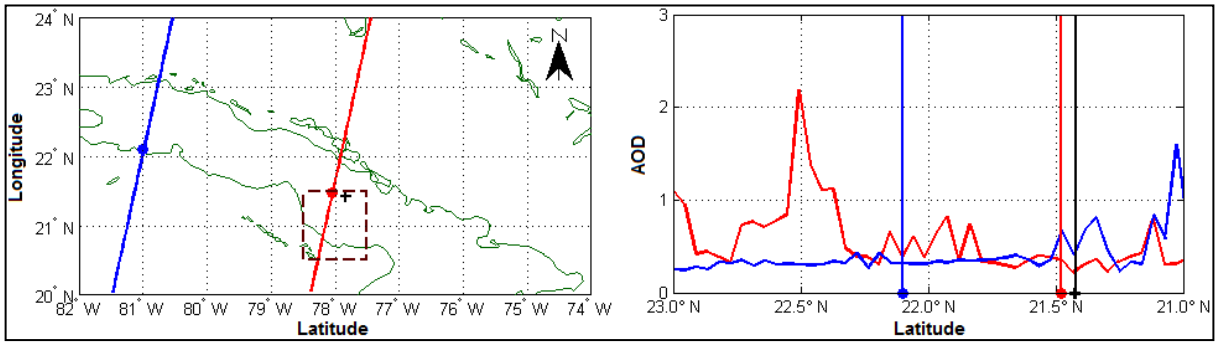
  The combination of all information collected in the framework of this TNA project could represent a show case of the CALIPSO performances in Saharan dust detection and optical properties retrieval. EARLINET Granada data on Angstrom Parameter and Depolarization Ratio collected on July 13 were used to determine the characteristics of such desert dust aerosols.

- **Preliminary results and conclusions**

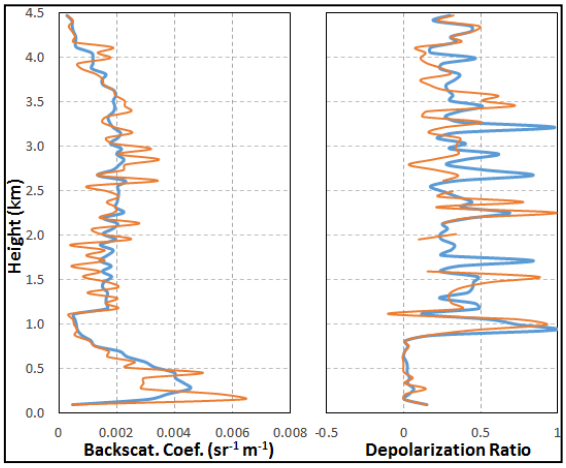
  The Aerosol Optical Depth (AOD_{500nm}) ground-based measurements, carried out by the GOAC CIMEL sunphotometer, have permitted to characterize the Camagüey site as maritime mixed [7]. Nevertheless, the occurrence of dust events during the North hemisphere summer disrupts the normal pattern of the background condition of tropospheric aerosols concentrations.

  The closest CALIPSO trajectory, for the maximum AOD_{500nm} value in the case study (July 17), took place to 334.9 km westward of the GOAC site, at 7:25:35 UTC (figure below, blue line on left panel). That means 4:54:38 hours earlier than the sunphotometer measurement, with CALIPSO AOD (AOD_{532nm}) value of 0.32, almost the half of CIMEL value for the same day. A better space-temporal coincidence with CALIPSO was recorded on July 19. The sunphotometer measurement was made at 11:49:39 UTC, with AOD_{500nm} = 0.34. The nearest CALIPSO overpass took place 04:36:18 hours before than the sunphotometer measurement, to a distance of 22.61 km to west northwest of CIMEL site, with an AOD_{532nm} value of 0.35 (figure below,, right panel, red line). For this second case, there is a good agreement between the two observations.

  This good agreement could be corroborated by MODIS Terra instrument, which was also used as reference for the surface measurements. The interpolated AOD value at 550 nm (AOD_{550nm}), for GOAC coordinates for the July 19 MODIS Terra overpass is 0.32, for MODIS Aqua the interpolated value is 0.21. The disagreement between the two satellites is due, firstly, to the difference in the time overpass, and secondly to the different viewing geometries, returning in different distributions of scattering angles.



CALIPSO coincident measurements, nighttime, for July 17 (blue line) and July 19 (red line). Overpass trajectories are represented on the left panel, as well as the nearest point (filled circles) to Camagüey coordinates (black cross). Also in this panel is represented by a brown dashed line box the grid formed by MODIS retrievals for July 19. On right panel the AOD_{532nm} values corresponding to the two CALIPSO overpass cross section, the closest point are represented by vertical lines for both cases.



Aerosol Backscatter Coefficient at 532 nm (left panel) and Depolarization Ratio (right panel) for CALIPSO nearest point on July 19 (orange line). Blue line represents the average values up to ±15 km before and after the coincident point.

The aerosol optical characteristics are investigated through the aerosol backscatter coefficient and the depolarization ratio profiles (left and right panel, respectively). The blue line represents the average profiles calculated from 15 km before and after CALIPSO overpass on July 19. CALIPSO profile is reported as orange line. The presence of Saharan dust can be seen from ≈ 1.1 km of altitude for both backscatter profiles, average (smoothed) and the coincident point (noisy). Then the aerosol dust layer is clearly shown from ≈ 1.1 km to ≈ 4.1 km, with the maximum concentration between 2.5 and 3.0 km in both cases.

The Saharan dust layer is well identified above 1 km, from the analysis of the depolarization ratio profiles (right panel). Both depolarization ratio profiles are very noise, however around the inflection point a good agree can be appreciated. The mean value of depolarization ratio starting from 1 km is about 39 %, value that correspond to non-spherical particles, as Saharan dust particles. The analysis of both, CIMEL and CALIPSO datasets for July 19, 2009 have corroborated the presence of Saharan dust aerosols over Camagüey for July 19, 2009. The optical parameters analysis for both instruments, provide a good insight of the dust particles layering and properties.

- **Outcome and future studies**

  Activities and results of this TNA activity are well suited within the general ACTRIS objectives of integrating different atmospheric observations (in the specific case sun-photometer and lidar, both ground-based as satellite borne) for a better insight of the atmospheric state.

  The complementarities between ground-based measurements, carried out with sun-photometer, and satellite measurements (CALIPSO and MODIS), have been evidenced for Saharan dust events here analyzed. In this case study, the spatial criteria has been determinant for selecting appropriate CALIPSO overpass, despite the temporal criteria. During the transport of Saharan dust cloud over Atlantic Ocean, different process cause the transformation of the original mass, from the physical point of view, as well as, optical and chemical. The mixing of dust mass with pollutants and marine aerosols is an example of

this, evidenced through backtrajectories analysis, not shown in this report, as well as the CALIPSO subtypes profiles analysis, between the origin (Africa) and the other side of the ocean (Cuba).

As result of this ACTRIS action, the Atmospheric Optics Group of Camagüey, Cuba, has been acquired the necessary knowledge for design and development of a Saharan dust Alert and Tracking Service for Cuba and the Caribbean. It will be based on the regular checking of the area of Saharan dust origin (combining mainly the instruments CALIPSO, MODIS and sunphotometers, as well as, all the instruments available) in conjunction with model forecasts to provide individual alerts and its regular updates to the local Meteorological Offices in Cuba and the Wider Caribbean.

All the results derived from this action and the subsequent collaboration with the CIAO was presented during the VII Workshop on Lidar Measurements in Latin-America, which held in Pucón, Chile, during November 11 – 15, 2013. An extended abstract derived from this workshop is under a peer review process, by the Journal of Pure and Applied Optics from Spanish Optical Society. Enhanced results will be reported, in poster format, at the International Conference on Atmospheric Dust (DUST 2014) to be held in Italy, June 1 - 6, 2014.

In collaboration with CIAO personnel, further analysis about differences in CALIPSO vs ground-based measurements agreement will be carried out for understanding the effect of the desert dust mixing and modification processes on CALIPSO retrieval reliability. Results of this study will be reported in a further publication.

- **References**

[1] Antuña, J. C. V. Cachorro, R. Estevan, Á. de Frutos, B. Barja, Y. Benouna, B.Torres, D. Fuertes, R. González, C. Toledano, G. Kallos and S. Cristos, “Characterizing AOD measurements and forecasts of Saharan dust events at Camagüey, Cuba, during July 2009”. Optica Pura y Aplicada, Vol. 46, No. 4, pp 415-421. DOI: 10.7149/OPA.45.4.415, 2012.

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

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

[4] Mona, L, Z. Liu, D.M¨uller, A. Omar, A. Papayannis, G. Pappalardo, N. Sugimoto, and M. Vaughan, “LidarMeasurements for Desert Dust Characterization: An Overview”, Advances in Meteorology, Volume 2012, Article ID 356265, pp. 36, doi:10.1155/2012/356265, 2012.

[5] 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., “AERONET: A federated instrument network and data archive for aerosol characterization”, Remote Sens. Environ., 66, 1–16, 1998.

[6] Holben, B. N., D. Tanré, A. Smirnov, T. F. Eck, I. Slutsker, N. Abuhassan, W. W. Newcomb, J. S. Schafer, B. Chatenet, F. Lavenu, Y. J. Kaufman, J. Vande Castle, A. Setzer, B. Markham, D. Clark, R. Frouin, R. Halthore, A. Karneli, N. T. O'Neill, C. Pietras, R. T. Pinker, K. Voss, G. Zibordi, “An emerging ground-based aerosol climatology: Aerosol Optical Depth from AERONET”, J. Geophys. Res., 106, 12067-12097, 2001.

[7] Estevan, R., J.C. Antuña, B. Barja, V.E. Cachorro, A.M. de Frutos, A. Berjón, C. Toledano, B. Torres, R. Rodrígo, T.A. Hernández, C.E. Hernández, “Preliminary results of aerosols measurements with sun photometer at Camagüey, Cuba”, Opt. Pura Apl., 44 (1) 99-106, 2011.