CGMS XXVII
Prepared by USA
Agenda Item: H.6
USA-WP-14.1

AERONET-A Federated Instrument Network and Data Archive for Aerosol Characterization

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Summary and Conclusions:

AERONET is a remote sensing aerosol monitoring network initiated by NASA and developed to support and validate satellite aerosol retrievals from NASA, CNES and NASDA's earth satellite missions, aid understanding of aerosol optical properties and develop a detailed ground based climatology of those properties. The program has expanded by national and international collaboration with NGOs, government institutions and universities. The combination of identical weather resistant automatic sun and sky scanning spectral radiometers, transmission of automatic measurements via the geostationary satellites GOES, GMS and METEOSAT's Data Collection System, advanced processing algorithms, internet access to the data and strong institutional support have resulted in an internationally federated globally distributed network of quality assured aerosol optical properties. Information on the system is available on the project homepage, http://aeronet.gsfc.nasa.gov:8080/. The philosophy of an open access data base, centralized processing and a user friendly graphical interface has contributed to the growth of international cooperation for ground-based aerosol monitoring and imposes a standardization for these measurements. The following paper presents a brief description of the processing system, operational monitoring, and examples of the data products. The CGMS Data collection system is a fundamental element of AERONET's success allowing globally distributed measurements and near real time analysis of the observations. Implementation of the international channels will greatly facilitate network expansion in Asia, Europe and Africa.

Action Requested: Members to consider allowing use of the IDCS for AERONET

AERONET-A Federated Instrument Network and Data Archive for Aerosol Characterization

Introduction

Accurate knowledge of the spatial and temporal extent of aerosol concentrations and properties has been a limitation for assessing their influence on satellite remotely sensed data (Holben et al., 1992) and climate forcing (Hansen and Lacis, 1990). With the advent of the EOS era of laboratory quality orbiting spectral radiometers, new algorithms for global scale aerosol retrievals and their application for correction of remotely sensed data will be implemented (Kaufman and Tanré, 1996). However the prospect of fully understanding aerosols influence on climate forcing is small without validation and augmentation by ancillary ground-based observations as can be provided by radiometers historically known as sun photometers. The Aerosol Robotic Network (AERONET) program standardizes ground-based aerosol measurements and processing, provides much of the ground-based validation data required for current and future remote sensing programs and may provide basic information necessary for improved assessment of aerosols impact on climate forcing and public health.

Automatic Sun and Sky Scanning Spectral Radiometer

The CIMEL Electronique 318A is a solar powered weather hardy robotically pointed sun and sky spectral radiometer. This instrument has a 1.2 degree full angle field of view and two detectors for measurement of direct sun, aureole and sky radiance. The robot mounted sensor head is parked pointed nadir when idle to prevent contamination of the optical windows from rain and foreign particles. The sun/aureole collimator is protected by a quartz window allowing spectral observations between 300 and 1020 nm. The sky collimator has the same field of view but an order of magnitude larger aperture-lens system allows better dynamic range for the sky radiances.

The sensor head is pointed by microprocessor controlled robot with a precision of 0.05 degrees. After the routine measurement is completed the instrument returns to the "park" position awaiting the next measurement sequence.

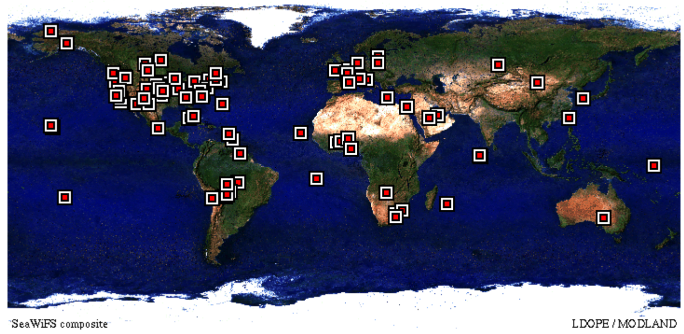

Fig. 1 (left)Tower mounted sun & sky scanning spectral radiometer. Figure 1 (right), The approximate location of instruments is represented by the red squares. Measurements are made at permanent sites year round. Data are taken seasonally at high latitudes and/or when cloud cover permits. In 1999 over 65 locations contributed to the data base.

The radiometer makes only two basic measurements, direct sun and sky, both within several programmed sequences. The direct sun measurements are made in eight spectral bands 340 380, 440, 500 675, 870, 940 and 1020 nm are standard) to retrieve aerosol optical thickness, AOT, and precipitable water. Observations are made during morning and afternoon Langley calibration sequences and at standard 15-minute intervals in between. The time variation of clouds are typically greater than that of aerosols causing an observable variation in the data that can be used to screen clouds in many cases. Additionally the 15-minute interval allows a longer temporal frequency check for cloud contamination.

Sky measurements are performed at 440, 670, 870 and 1020 nm. Two basic sky observation sequences are made, the "almucantar" and "principal plane". The philosophy is to acquire aureole and sky radiances observations through a large range of scattering angles from the sun through a constant aerosol profile to retrieve size distribution, phase function and AOT. An almucantar is a series of measurements taken at the elevation angle of the sun for specified azimuth angles relative to the position of the sun.

The standard principle plane sequence measures in much the same manner as the almucantar but in the principal plane of the sun where all angular distances from the sun are scattering angles regardless of solar zenith angle. Principal plane observations are made hourly when the optical airmass is less than 2 to minimize the variations in radiance due to the change in optical airmass.

Polarization measurements of the sky at 870 nm are an option with this instrument. The sequence is made in the principal plane at 5 degree increments between zenith angles of -85 and +85 degrees. The configuration of the filter wheel requires that a near-IR polarization sheet be attached to the filter wheel. Three spectrally matched 870 nm filters are positioned in the filter wheel exactly 120 degrees apart. Each angular observation is a measurement of the three polarization filter positions. An observation takes approximately 5 seconds and the entire sequence completed in about 3 minutes.

Data Transmission and distribution

Data are transmitted from the memory of the sun photometer via the Data Collection Systems (DCS) to either of geosynchronus satellites GOES-E, GOES-W, GMS or METEOSAT and then retransmitted to the appropriate ground receiving station. The data are retrieved for processing either by internet resulting in near real-time acquisition globally.

Each station on the GOES, GMS and METEOSAT networks has been assigned a regional or international user ID and transmission time window passing up to 30 kbytes per day in 24 and 48 individual transmissions at hourly and half-hourly intervals respectively. During each transmission, a packet of data and status information are time stamped by the radiometer, the transmitter and the central receiving station (Wallops Island, VA, USA for GOES; Darmstadt, Germany for METEOSAT; and Tokyo, Japan for GMS). Typically the data are maintained in the receiving station computers for 3 to 5 days before they are overwritten. The data are retrieved daily from the central receiving station which we term near real-time.

Approximately 100 network instruments are in AERONET, which is growing by approximately 15 to 20 sites per year. Acquisition from approximately 65 instruments world wide has provided a long-term globally distributed database of aerosol optical properties encompassing a variety of aerosol conditions (Fig. 1 right).

Data Results

There is an historic lack of agreement between investigators on corrections, calibration procedures, data analysis procedures etc. often caused by divergent error tolerances or specific requirements of various researchers. We have implemented a series of processing algorithms on a UNIX server that have been published in the open literature and/or are generally accepted by the scientific community (Holben et al, 1998, Nakajima et al., 1996 and Dubovik et al., 1999). These algorithms impose a processing standardization on all of the data taken in the network facilitating comparison of spatial and temporal data between instruments. We present here examples of data collected from four unique aerosol types and the resulting data products.

Biomass burning from the world tropical forests is a significant landcover, human health and air quality problem and a major regional impact on the radiation balance however quantification of the emissions is very sparse. Fig. 2 is a time dependent plot of the daily averaged aerosol optical thickness during the dry and burning season as measured by AERONET at Cuiaba, Brazil. Note that beginning in August to Early October the AOT is dramatically elevated over background levels from forest clearing activities. Analysis shows the mean burning season AOT is 1.4 at 440 nm where as background levels are 0.15. This pattern has now been measured by AERONET since 1993.

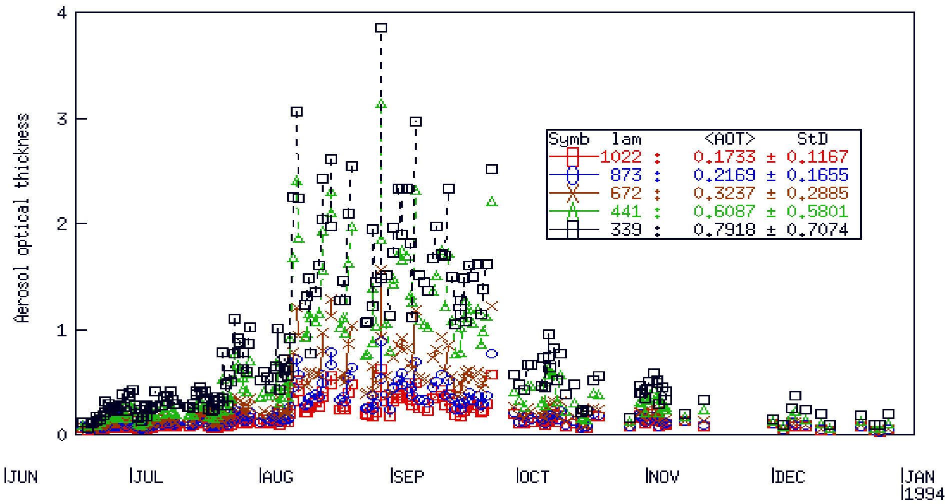

Figure 2, The aerosol optical thickness dry season record for Cuiaba, Brazil showing a large increase in August and September 1993 due to region wide burning.

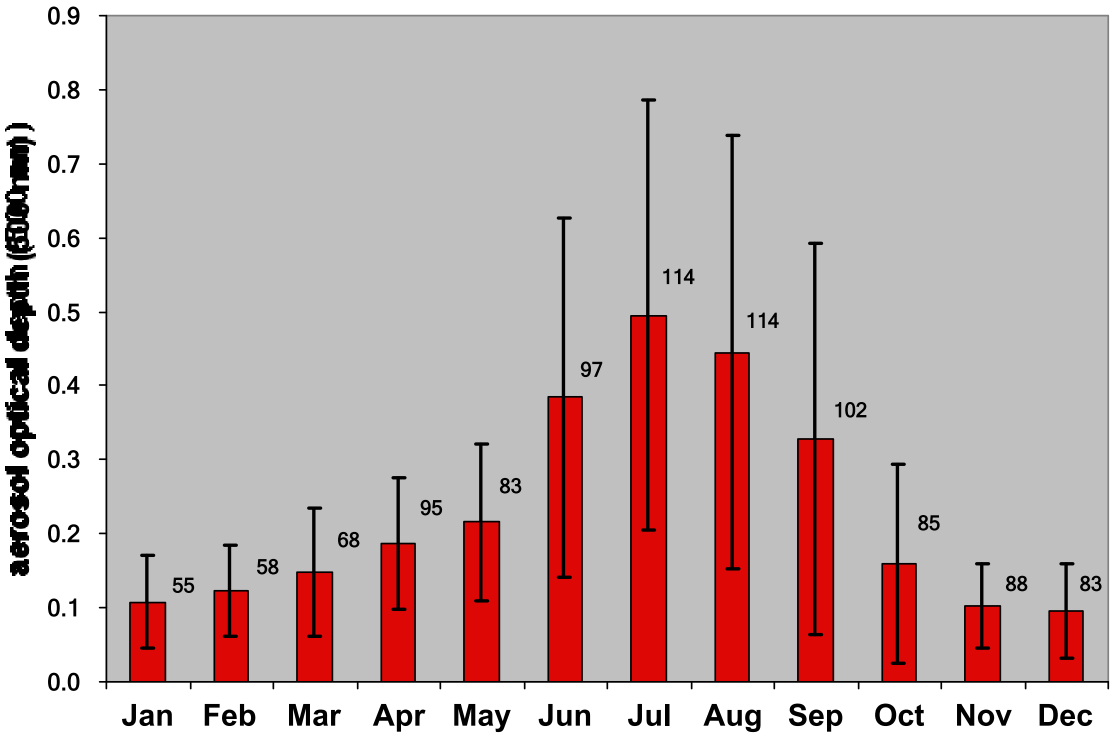

Figure 3, Monthly averaged AOT measured at GSFC since 1993. The numbers are the daily means used to compute the monthly averages and the bars are the first standard deviation of the means

Data have been collected almost continuously at GSFC since 1993. Fig. 3 shows the mean Monthly average of AOT peaking in July and August with a mean value of 0.50. Wintertime values drop to 0.1 at 500 nm due to the frequent passage of clean Canadian airmasses and increase circulation of the midlatitude westerlies. The annual mean AOT for GSFC is 0.26 at 500 nm.

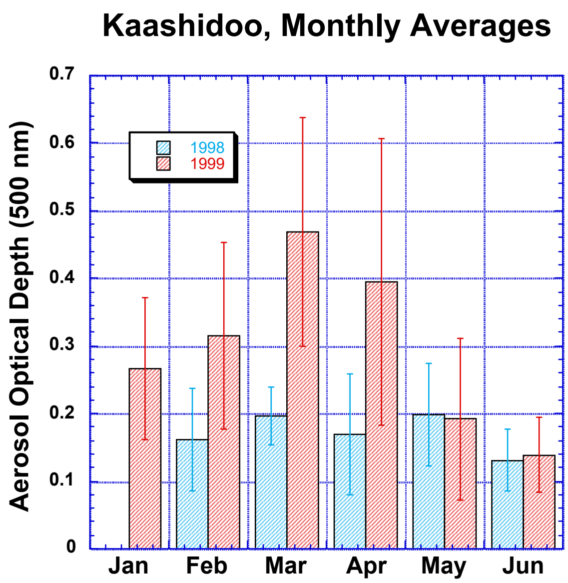

Figure 4, Monthly averaged AOT from Kaashidoo AERONET site during NE monsoon.

Indoex was an international campaign to investigate the influence of aerosols on radiative forcing in the Indian Ocean during the NE monsoon from January to April. An aeronet site has operated at the Kaashidoo Climate Observatory on this extremely isolated island in the Maldives about 500 km off the SW coast of India. Results clearly show the variation in aerosol loading between the two years and points to the need for long term measurements to add perspective to short term field campaigns (Fig. 4)

Saharan dust is a major component of the global aerosol environment. Since 1994 and AERONET site has been located in the Cape Verde Islands 200 km West of Senegal. This is well known as a major transport region of Saharan dust. Dust events are highly variable in their loading yet their particle size distribution can be related to the aerosol loading as retrieved from satellite data over oceans. This strategy was developed from AERONET retrievals for the satellite aerosol algorithms prepared for MODIS on board NASA's TERA satellite. An example of this size distribution retrieval is presented in Fig.5 (left) showing the coarse particle mode dominates the particle volume. Additionally AERONET retrievals are made for the absorption of aerosol known as the single scattering albedo. Figure 5 (right) shows the wavelength dependence of dust single scattering albedo from Cape Verde is very absorptive at shorter wavelengths. This property is opposite or neutral for most other aerosol types and represents the first a routine retrieval of such measurements on a global scale. The retrieved properties are particularly important to insert realistic aerosol optical properties into regional and global climate models.

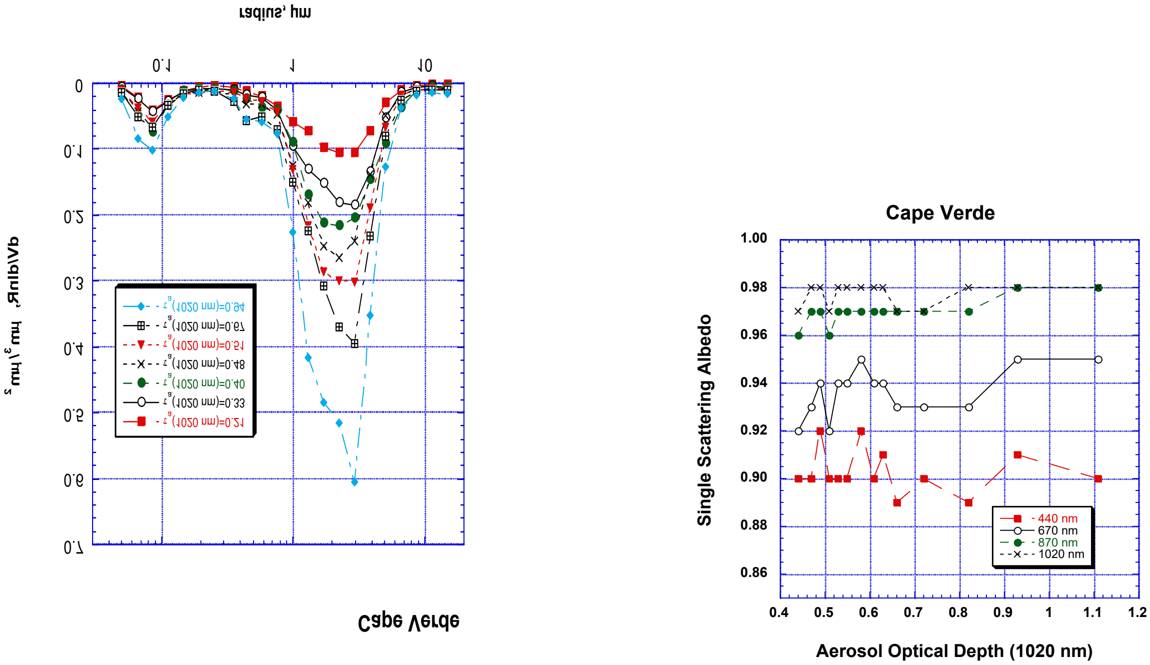

Figure 5, The volume size distribution (left) from AERONET Cape Verde measurements clearly shows the dominace of the coarse particle volume increases as the particle loading increases. Fig. 5 (right) illustrates the wavelength dependence of the dust aerosols as retrieved from AERONET sky scan observations at Cape Verde Islands.

Global Perspective

Through 1997 approximately 100 instruments have been included in the network and 60 instruments were deployed world wide on various Islands, North America, South America, Europe, Africa, and the Middle East, fostered by collaboration between international, national, and local agencies, private foundations and individuals (Fig. 2). As the data base continues to expand, the processing system becomes more sophisticated and more users have access to the data base, the need to provide better access to and quality assurance of the data base becomes more critical. To aid in that effort, the reference data base is located on 'spamer.gsfc.nasa.gov' at Goddard Space flight Center in Greenbelt, MD, USA or ‘loaser.univ-lille1.fr’ (IP number is 134.206.50.10) at Lab. d'Optique Atmosphérique, U.S.T. de Lille, 59655-Villeneuve d'Ascq, France for European access. A third supported data base will be established in Tokyo, Japan to support access to the data from eastern Asia. Identical clones of these systems have been established at various locations to facilitate access to the data for local activities. All processing changes are made to the entire spamer reference data base to maintain uniform processing.

An automatic, computerized quality assured data base is available and is continuing to be improved providing a screened data set to the scientific community. It is accessed by a simplified version of the ‘demonstrat’ browser, ‘demonstrat II’, available through the AERONET homepage. The data must exceed specified optical, radiometric and calibrational specifications as well as incorporating screening algorithms for cloud contamination that are functionally related to temporal and spectral behavior of the aerosol optical depth. Further details will be included in the homepage.

The network is expected to provide characterization of aerosol optical properties, a data base for atmospheric correction, validation of satellite based aerosol retrievals, and satellite observations of ocean color. The simple technology and international collaboration that has produced AERONET can be expanded to complimentary data sets of BRDF, automatic lidar systems, and radiation networks.

Conclusion

We believe that a successful system for long term monitoring and characterization of aerosols requires automatic low maintenance radiometers, real time data reception through the geostationary meteorology satellites Data Collection Systems, imposing standardized processing internet access of the data base by the scientific community. We have combined commercially available hardware, international agency collaborations, a public domain software and a collaborative philosophy among investigators to form a network that has yielded regionally based aerosol amounts and properties in North and South America, Africa, the Middle East and various Atlantic and Pacific islands. More systems will come on-line in the years ahead that will provide greater spatial coverage and synergism between and satellite measurements to achieve the objectives of specific intensive field campaigns, global climate change assessment and public health. The philosophy of an open interactive data base is expected to promote research and collaboration among investigators.

References

Dubovik O., A. Smirnov, B. N. Holben, M. D. King, Y. J. Kaufman, T. F. Eck, and I. Slutsker, Accuracy assesments of aerosol optical properties retrieved from AERONET Sun and sky-radiance measurements, submitted to *J. Geophys. Res.*, 1999.

Hansen, J.E. and A.A. Lacis, 1990, Sun and dust versus greenhouse gases: an assessment of their relative roles in global climate change, Nature, vol. 346: 713-719.

Holben,B.N., T.F. Eck, I. Slutsker, D. Tanre, J.P. Buis, A. Setzer, E. Vermote, J.A. Reagan, Y.J. Kaufman, T. Nakajima, F. Lavenu, I. Jankowiak, and A. Smirnov, 1998. AERONET – A Federated Instrument Network and Data Archive for Aerosol Characterization, Remote Sens. Environ, 66:1-16.

Kaufman, Y.J. and D. Tanré, 1996. Strategy for direct and indirect methods for correcting the aerosol effect on remote sensing: From AVHRR to EOS-MODIS, RSE, 55:65-79.

Nakajima, T, T. Glauco, R. Rao, P. Boi, Y. Kaufman and B. Holben, 1996. Use of sky brightness measurements from Ground for Remote Sensing of Particulate Polydispersions, Appl. Opt., 35:2672-2686.

NOAA/NESDIS, 1990, User Interface Manual version 1.1 for the GOES, Data Collection System Automatic Processing System (DAPS), Prepared by Integral Systems, Inc. for NOAA/NESDIS Contract No. 50-DDNE-7-00037.

Smirnov, A., B.N.Holben, T.F.Eck, O.Dubovik, and I.Slutsker, Cloud screening and quality control algorithms for the AERONET database, submitted to Remote Sensing of Environment, 1999.

Twitty, J.T., 1975. The Inversion of Aureole Measurements to Derive Aerosol Size Distributions, Journal of Atmospheric Sciences, 32: 584-591.

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