OPTICAL PROPERTIES OF AEROSOLS FROM LONG TERM GROUND-BASED AERONET MEASUREMENTS

B.N. Holben (1), D. Tanré (2), A. Smirnov (1,3), T.F. Eck (1,4)I .Slutsker (1,3), O. Dubovik (1,3) , F. Lavenu (5), N. Abuhassen (1,3), and B. Chatenet (2)

1. Biospheric Sciences Branch, code 923, NASA/GSFC, Greenbelt, MD 20771, USA
2. Laboratoire d'Optique Atmosphérique, U.S.T. de Lille, Villeneuve d'Ascq, France
3. Also at Science Systems and Applications, Inc., Lanham, MD 29706, USA
4. Also at Raytheon STX, Lanham, MD 20771, USA
5. CESBIO (CNRS) 18 avenue E. Belin 31401 Toulouse Cedex 4 France

The AERONET federated measurement network

AERONET is an optical ground-based aerosol monitoring network and data archive supported by NASA's Earth Observing System and expanded by federation with many non-NASA institutions including AEROCAN (AERONET CANada) and PHOTON (PHOtometrie pour le Traitement Operationnel de Normalisation Satellitaire). The network hardware consists of identical automatic sun-sky scanning spectral radiometers owned by national agencies and universities purchased for their own monitoring and research objectives. Data are transmitted hourly through the data collection system (DCS) on board the geostationary meteorological satellites GMS, GOES and METEOSAT and received in a common archive for daily processing utilizing a peer reviewed series of algorithms thus imposing a standardization and quality control of the product data base. Data from this collaboration provides globally distributed near real time observations of aerosol spectral optical depths, aerosol size distributions, and precipitable water in diverse aerosol regimes. The data undergo preliminary processing (real time data), reprocessing (final calibration ~6 mo. after data collection), quality assurance and cloud screening (Smirnov et al., 1999), archiving and distribution from NASA's Goddard Space Flight Center master archive and several identical data bases maintained globally. The AERONET website (http://aeronet.gsfc.nasa.gov:8080/), provides access to the preliminary data in near real time for quality control analysis also provides access to the quality assured data. Further operational details are available in Holben et al. (1998) however several significant new details require further elaboration.

Access to the AERONET data base has shifted from the interactive program 'demonstrat' (reserved for PI's) to the AERONET homepage allowing faster access and greater development for GIS object oriented retrievals and analysis with companion geocoded data sets from satellites, LIDAR and solar flux measurements for example. To achieve development of this objective certain systems are co-located with existing in situ and ground based measurement programs including some BSRN and SURFRAD sites, LIDAR sites, satellite cal/val sites and well instrumented long term measurement sites. AERONET has and will continue to participate in intensive field programs such as ACE-2, TARFOX, SCAR, ZIBBEE, CAMEX, BOREAS, LBA, and INDOEX, ACE-ASIA and SIMBIOS. The approach has resulted in a combined network of approximately 100 instruments world wide and an anticipated distribution of about 70 active sites by mid 1999 (Fig. to left). The current distribution, which fluctuates seasonally due to calibration and local deployment decisions, may be observed from the AERONET homepage.

We feel that a significant yet under utilized component of the AERONET data base are inversion products made from hourly principal plane and almucanter measurements. The current inversions are based on Nakajima et al., (1996) and have been shown to successfully retrieve aerosol volume size distributions (Remer et al. 1997). Limitations in the code and/or method of implementation have restricted inversions to light to moderate aerosol loading levels and prevented full exploitation of the retrieval products. A significant enhancement to the inversion code has been developed and is presented in these proceedings (Dubovik et al., 1999). The Dubovik code retrieves a wider particle size range and for much higher aerosol loading conditions than was possible with the Nakajima code. Additionally defensible retrievals of real and imaginary index of refraction and single scattering albedo are possible. The code requires validation and assessment which is currently underway.

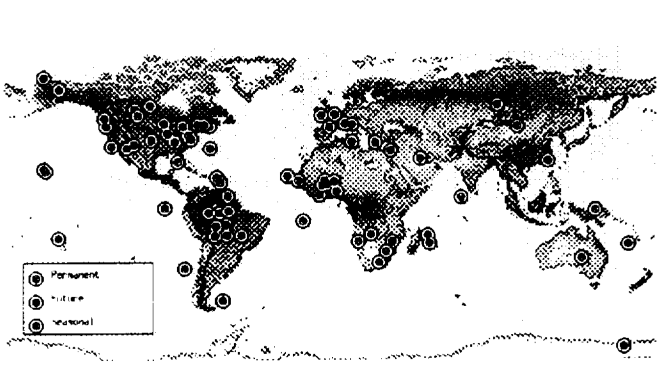
Aerosol Climatology

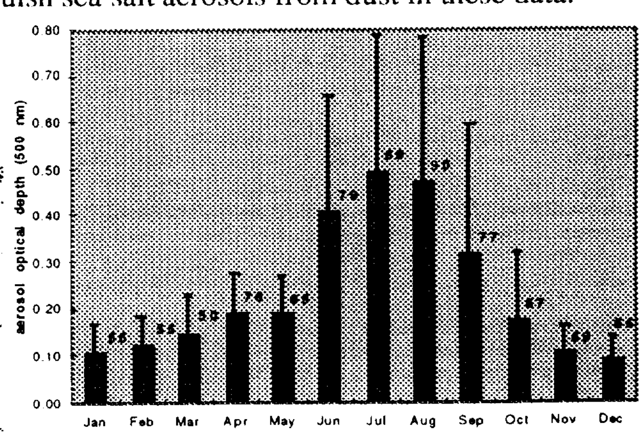
approximately twenty other sites allows development of an emerging aerosol climatolgoy based on cloud free observations for a wide variety of globally distributed aerosol types. We present here the mean monthly optical depths and Angstrom exponents for three sites: GSFC, Cape Verde, and Mongu, Zambia representing carbonaceous and sulfate aerosols, desert dust and biomass burning respectively. A full paper on this work is in preparation. We also present case studies of the new sky radiance inversions at the biomass burning site.

The aerosol optical depth at 500 nm and Angstrom exponent computed from four wavelengths (440, 500, 675, and 870 nm)were averaged daily from the cloud screened data base and from that monthly averages computed with standard deviations. The resultant monthly values were plotted to illustrate the monthly climatology of the aerosol optical depth. Precipitable water retrieved from the network were averaged in the same manner.

Goddard Space Flight Center (39 N, 79 E, 50 m elev.), located in suburban Washington, D.C. and approximately 30 Km south of industrial Baltimore, is influenced by a synoptic scale southeasterly flow due to the Bermuda high from late spring through early fall months and a west and northwesterly flow during the other months. Some episodes of each may occur at any time of year and be regionally modified by cold fronts with a strong southerly flow in advance of the front and a northwesterly flow behind. Most heavy industry is located to the north and local emissions are dominated by automobiles owned by the 2.3 million metropolitan area residents. The landscape is dominated by deciduous trees leafed out from late April through October. Fig. (top right) illustrates the monthly averaged aerosol optical depth (AOD) for the six year record (1993-1997) at Goddard. The AOD is dominated by marked increase in optical depth from June through September which peaks during July and August. The six year mean July AOD is 0.50. In contrast, the AOD decreases to a minimum during the winter months to 0.10 during December. The Angstrom exponent has a annual range from 0.3 to 2.3, typically associated with low and high aerosol loading events respectively. The summer high Angstrom values indicate a significant shift in particle size distribution toward smaller particles. Analysis of the Pw shows a peak water vapor content in the summer, 4.5 cm (August) and a minimum of 1.2 cm for January. The dramatic increase in summer aerosol loading over the eastern US is a dynamic mixture of natural and anthropogenic sources, processed by convection within water laden stagnant airmasses. As these processes and components are reduced the aerosol loading will necessarily decrease.

Sal Island, Cape Verde (17 N by 23 W) is located approximately 500 km west of Mauritania in the outflow area of Saharan dust from west Africa. The nearest town of ~25,000 residents is about 7 km away the measurement site. The island's limestone formation and dry climate supports xerophitic vegetation and the Island's primary industry salt extraction from evaporation ponds. The dominant easterly wind direction is well known to be influenced by easterly waves, Saharan storms and associated dust outbreaks, (Carlson and Prospero, 1972). A four year measurement record has been collected as part of the PHOTON network and cloud screened. The AOD for this site is high throughout the year with elevated values in June and July and secondary peaks in Feb., Sept. and Nov. Monthly means range between 0.2 (Oct) to 0.7 (July) (Fig. bottom left). The angstrom exponent is typically below 0.5. Pw is also relatively constant throughout the year. The aerosol types for Sal Island are probably marine sea salt and dust. High aerosol loading indicates that dust dominates the aerosol regime associated with frequent dust outbreaks. The lowest Angstrom exponents are associated with elevated AOD as would be expected for coarse particles from Saharan dust events. There is no obvious method to distinguish sea salt aerosols from dust in these data.





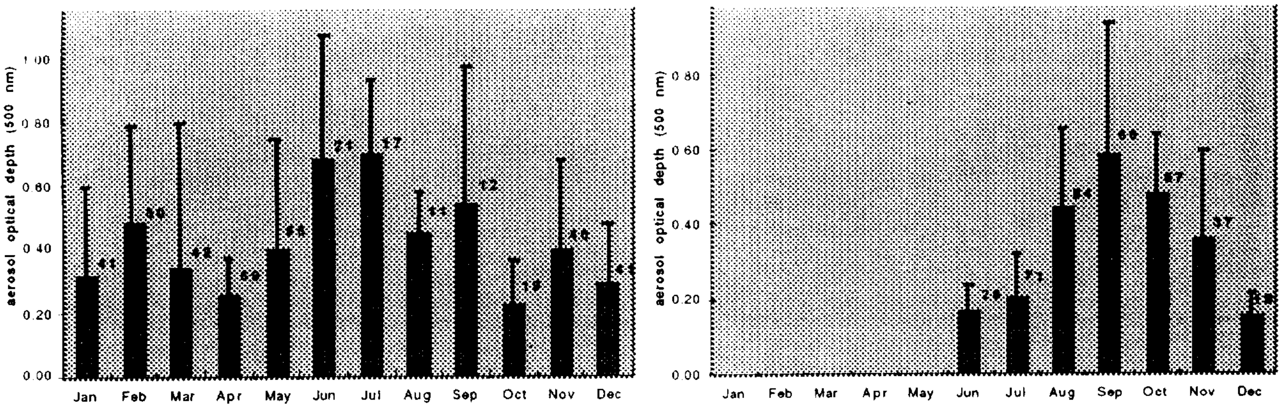


Figure 1, Top Row: (left) AERONET federated site distribution anticipated by June 1999.; (right) Monthly AOD (500 nm) for GSFC are shown with standard deviations and the number of observation days. Bottom row: Cape Verde (left) and Mongu, Zambia (right).

Mongu, Zambia, (15°S by 23° E elevation 1107 m), is located in Zambia's Western province, on the edge of the Zambezi flood plain. The dominant cover type is a wooded Savannah growing on the Kalahari sands and maintained through anthropogenic and natural fires. During the dry season grasses growing on the numerous dambos and extensive flood plains to the west of Mongu burn largely due to agricultural activities. The dominant wind direction is east largely associated with the south African Gyre centered over northern Republic of South Africa. As a result, the aerosols observed at Mongu are a combination of the ubiquitous sources of local and regional biomass burning emissions entrained and advected from several tens to over a thousand km upwind. The strength and duration of the gyre largely dictates the duration of the burning season which will typically last from July through November. Satellite images from Justice et al., 1996 clearly indicate the fire sources are in Zambia and the Democratic Republic of Congo as well as adjacent countries to the east and west. Weather records from the Zambian Met Service indicate precipitation is less than 5 mm on average during August and September. AERONET data have been collected at Mongu since 1995 largely during the dry season. The AOD measurements show the peak aerosol loading in September of 0.58 and a gradual reduction to preburning levels in November of 0.15. (Fig. right). Our observations show that there is significant inter annual and seasonal variability largely dictated by local burning which can be episodic as well as circulation patterns passing over source regions. As the wet season is approached, precipitable water and atmospheric instability increases until frequent rains effectively end the burning season. The Angstrom exponent shows a classic biomass burning value throughout the burning season, 1.7 to 1.8. Angstrom values of 1.8 have been observed in other regions of intense biomass burning from Brazil (Holben et al., 1996) and central Canada (Markham et al., 1997) representing different fuel types and environmental conditions. Smoke particles with these Angstrom exponents typically have accumulation modal radii of 0.13 to 0.15 based on log-normal volume size distributions (Remer et al., 1998 and Reid et al., 1998). Sky radiances were selected for inversion with the Dubovik code which represent the wide range of aerosol loading during the burning season. The size distributions indicated an accumulation mode radii of ~0.15 with a weak coarse particle mode radii of ~5 um (see Dubovik et al. 1999 in this issue). The single scattering albedo retrievals indicate a decreasing spectral dependence for those cases selected. The mean value for 500 nm is approximately 0.85 which matches closely (±0.03) to other determinations made in Zambia and Brazil, (Eck et al., 1998). A more extensive discussion of Climatology of aerosol optical properties will be presented at the conference.

Conclusion

An on-line data base of aerosol optical properties with sufficient geographic and temporal distribution has developed by collaboration with international partners to provide a focus for comparison and evaluation of aerosol transport models, satellite aerosol retrieval algorithms and an emerging alerosol climatology.

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