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# Tropical Intercontinental Optical Measurement Network of Aerosol, Precipitable Water and Total Column Ozone

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## ABSTRACT

A new generation of automatic sunphotometers will be used to systematically monitor clear sky total column aerosol concentration and optical properties, precipitable water and total column ozone diurnally and annually in West Africa and South America beginning in 1992. The instruments are designed to measure direct beam sun, solar aureole and sky radiances in 9 narrow spectral bands from the UV to the near infrared on an hourly basis. This paper describes the projects participating in the networks, the instrumentation, and the algorithms required to reduce the data for subsequent analysis.

## INTRODUCTION

The atmosphere overlying the tropical belt from Africa to South America is highly perturbed by seasonal variations in dust outbreaks [3,6] and emissions due to biomass burning [9,13,16] resulting in substantial impacts to visible and near infrared remote sensing, [15]. Specifically much of the Amazon basin including the forested and cerrado lands are subject to extensive anthropogenic biomass burning and subsequent smoke and trace gas emissions including elevated levels of ozone. Aeolian erosion in the Sahara and West African Sahel is the greatest source of naturally occurring aerosols on earth. Saharan aerosol transport has been modeled [3] and outbreaks over Europe, the North Atlantic [2,11] and South America [14] are common. Furthermore Hanson and Lacis have stated that aerosols, particularly anthropogenic aerosols, are the greatest unknown factor in climate forcing<sup>7</sup>.

This report describes a network designed to provide a more comprehensive understanding of the spatial and temporal distribution of aerosols over land. The network is comprised of automatic ground stations to optically measure sun, aureole and sky radiances for computing aerosol optical thickness and aerosol properties, water vapor and ozone which will allow climatological analysis of temporal and spatial patterns of these variables. The relationships between aerosol size distributions, total ozone and water vapor will be studied as they relate to the burning and non burning seasons and/or to dust events and background conditions. The data will be prepared to make atmospheric corrections on satellite imagery and aircraft measurements. The data base will also be used in support of ground truth for satellite and/or aircraft derived smoke, trace gas emission measurements, dust and graphitic carbon transport and for verification of algorithms which automatically correct satellite images and aircraft data. It is expected that the success of the project will have strong implications for routine aerosol, water vapor, and ozone monitoring as a part of standard meteorological observations.

## NETWORK DESIGN

In the Amazon Basin, a network of 8 automatic sunphotometers/radiometers, (sponsored by NASA to study carbon sources, sinks and transport associated with biomass burning), will be spaced across the Amazon basin from 45° to 65° West by 0° to 15° south encompassing forest regions largely unaffected by biomass burning in the north, forested areas highly affected by biomass burning in the central Amazon and the cerrado areas to the south and east. The instruments will be located with the cooperation of the Brazilian Instituto de Pesquisas Espaciais, (INPE) and the environmental agency Instituto Brasileiro do

Meio Ambiente e Recursos Naturais Renováveis (IBAMA) in areas removed from local aerosol sources such as cities such that sites are representative of regional aerosol conditions. The overall network is designed to cover the counter clockwise tropospheric circulation entering the eastern Amazon basin and exiting the southern Amazon.

The West African network will initially have 5 automatic sunphotometers (in support of HAPEX-Niger, an investigation to study the land-atmosphere interactions in August and September 1992) selectively spaced from 5°N to 15°N and from 15°E to 15°W. Both networks will be augmented by simpler handheld instruments and periodically three automatic instruments will be used for short periods of time to investigate the small scale distribution of the aerosol properties in a moveable network. Two handheld instruments will be used for calibration.

## INSTRUMENTATION

The automatic instruments used for this investigation will embody the simplicity and durability of traditional sunphotometry with the precision of laboratory type radiometry. Physically the instrument is a compact tri-collimator sensor head mounted on a programmable tracker and powered by a solar charged lead-acid storage battery. The sensor head is cabled to a controller box containing a microprocessor for controlling data acquisition. A second microprocessor transmits the data via the geostationary satellite environmental Data Collection System (DCS) and it is received in near real time at the designated data collection center.

The sensor head is composed of three one degree field of view parallel collimators used for tracking the sun and making sun and sky measurements. The tracking collimator simply allows a narrow beam of direct radiation to fall on a four quadrant detector yielding precise tracking information for the controller. A single filter wheel activated by a stepping motor and designed to accommodate 9 narrow band interference filters intercepts the collimated beam from the base of the sun and sky collimators. The filter wheel assembly is followed by one silicon detector for each of the sun and sky collimators. The sky collimator is extended to 50 cm and baffled to reject 6 orders of magnitude of stray light allowing aureole measurements as close as 2 degrees from the sun. To accommodate four orders of magnitude of intensity change, an automatic gain switching is incorporated in the electronic system and a lens is used in the sky collimator. The sun collimator has no optics, minimal baffles and a quartz window which seals the internal components from the degrading effects of humidity and dust.

Nine spectral filters will be used in this investigation including two in the UV for ozone, five in the visible and near-IR for aerosols and two in the near-IR for water vapor, (Table 1).

Table 1. Spectral characteristics of the nine interference filters used in the automatic sunphotometer.

APPLICATION	CENTRAL $\lambda$ (nm)	BANDWIDTH (nm)
Ozone	305	2
Ozone	317	2
Aerosol	440	10
Aerosol	500	10
Aerosol	660	10
Aerosol	870	10
Water Vapor	940	10
Water Vapor	940	50
Aerosol	1020	10

The 305 and 317 nm bands are experimental at this point however comparisons of a filter instrument to Dobson's results demonstrated that total column ozone should be possible with this type of instrument with an accuracy of  $\pm 7\%$  [1]. The 440, 500, 660, 870 and 1020 nm bands are fairly standard in sunphotometry. The two 940 nm bands, a narrow band and a broad band, account for the broadening of energy absorption by water vapor as the water vapor amount increases therefore the ratio of the two can be related to the total column water vapor. The 870 and 940 proximity also allows computation of the water vapor by the modified Langley plot method [12] which has been shown to be accurate to within  $\pm 0.5$  cm of radiosonde observations [5].

The instrument is designed to shut down in the event of rain and remain in a resting position which protects the optics from rain and dust contamination. It is expected that only routine examination of the equipment will be required for a few minutes daily thereby making it largely independent of human intervention.

### DATA ACQUISITION

The instruments have two measurement modes termed sun and sky. In the sun mode, the instrument will find from a resting position, the sun based on a stored ephemeris and track it for the duration of a spectral cycle, approximately 10 seconds, with a four quadrant detector housed at the base of collimator number 1. A filter wheel rotates nine spectral interference filters through collimator number 2 and the signal measured from a UV enhanced silicon detector. Immediately after, the instrument switches to the sky mode in which the solar aureole and almucantar are measured from 2 to 180 degrees in increasing step sizes. Three selected aerosol bands (440, 660 and 870) will be used to measure sky radiances and aureole through collimator number 3 which will take approximately 20 seconds. The instrument returns to the sun takes a second sun reading then completes a second aureole and almucantar reading in the opposite azimuthal direction. The instrument returns to the sun for a third measurement then completes a sky measurement sequence in the principle plane of the sun in 30 degree increments before returning to a resting position. An entire measurement sequence takes approximately two minutes.

Sky, aureole and sun data will be taken hourly at all sites for nine spectral wavelengths (from the UV to the near infrared). A further measurement sequence for a Langley plot calibration (sun mode only) will be attempted every morning for airmasses 7 through 2. Current levels of funding will provide for a minimum of two years of data acquisition.

### DATA REDUCTION ALGORITHMS and EXPECTED RESULTS

All data will be transmitted to the data collection and processing center. Aerosol optical thickness, total column precipitable water, and total column ozone content will be computed from the sun data. The aureole and almucantar data will be used in inversion routines developed by Nakajima et al [10] and implemented by Kaufman et al. [8] to compute aerosol phase function and size distributions. The results of this preprocessing will be used to screen for cloud contamination before being entered into a clear sky data base. Langley plots will be computed from the standard Lambert-Beers law method, precipitable water from the modified Langley method [12] and total column ozone [1,4].

We expect a comprehensive data base will be developed of the optical properties of aerosols, water vapor and ozone such that temporal and spatial distributions of these variables develop into a regional climatology useful for remote sensing and radiation transfer applications. Additionally we believe the data will be extremely useful for understanding and quantifying aerosol transport within a region and between continents.

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