**Autonomous Airborne Sun/Sky-Scanning Spectrometer**

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## 1 Problem

Atmospheric aerosols play a crucial role in the Earth's radiation balance. Recent publications debate whether reducing the emission of light-absorbing aerosol into the Earth's atmosphere may be the most feasible way to combat global warming (*Hansen et al*., 2000, *Jacobson*, 2002, *Penner et al*., 2003) and point to the large uncertainties in the sources, distribution and properties of absorbing aerosol (*Sato et al*., 2003).

To monitor the distribution of aerosols globally requires the combination of continuous observations from satellites, networks of ground-based instruments, and dedicated field experiments.

The AErosol RObotic NETwork (AERONET) of ~200 identical globally distributed Sun and sky-scanning ground-based automated radiometers provides measurements of aerosol optical properties, including ten years of observations in some locations (*Holben et al*., 2001). In-situ measurements of aerosol optical properties and composition are made by numerous ground-based networks around the world. In addition, ground-based lidar networks, monitoring the vertical distribution of aerosols, are emerging.

Coordinated field campaigns that include in-situ and remote sensing measurements of aerosols aboard airborne platforms have proven to be a very valuable tool to extend the temporally continuous land-based point observations of such networks to a larger geographical area that includes the oceans and the vertical dimension.

The use of the NASA Ames Airborne Tracking Sunphotometers (AATS) in many such campaigns (e.g., TARFOX, ACE-2, PRIDE, SAFARI 2000, ACE-Asia, CLAMS, ARM AIOP) has proven to be a unique link between space-based retrievals of aerosols (plus also $O_3$ and $H_2O$) and a diversity of suborbital measurements. To date AATS data have contributed to validating aerosol and $O_3$ retrievals from 11 different satellite sensors. AATS data have been used extensively to address the question: "Can in situ measurements of aerosol properties account for the solar beam attenuation (extinction) by an aerosol layer or column?" Such closure studies reveal important insights about airborne aerosol sampling because with the AATS instrument inlet effects (e.g., loss or enhancement of large particles, shrinkage by evaporation of water, organics, or nitrates) and filter effects are avoided.

The Ames airborne sunphotometers measure the transmission of the direct solar beam in several channels from UV to near-IR wavelengths. However, unlike the ground-based AERONET instruments mentioned above, they do not measure scattered sunlight as a function of angular distance from the sun. As demonstrated by the ground-based AERONET (*Dubovik et al*., 2002), adding skylight measurements to transmission measurements yields improved accuracy in the large-particle region of retrieved aerosol size distributions and permits retrievals of aerosol absorption. Note that transmission measurements alone, as provided by the AATS instruments, yield aerosol extinction, i.e. the sum of scattering and absorption, but no information on their relative contributions.

*An airborne instrument that measures the direct solar beam and the skylight as a function of scattering angle, and hence allows derivation of absorption of the aerosol in its ambient state, does not currently exist. We propose to build such an instrument targeted for autonomous operation on small or unmanned aircraft.*

## 2 Approach

Since August 2003 we have made considerable progress in designing the envisioned instrument. Our design work benefits from synergism with a recent successful proposal to NOAA's Atmospheric Composition and Climate program. Hence the DOE ASP would not bear the full cost of designing and building the envisioned instrument.

Analogous to the existing AATS instruments, the sun tracking head of the envisioned instrument is mounted external to the aircraft skin. However, light is not detected by photo-diodes in the tracking head but guided by optical fibers into two rack-mounted spectrometers covering the wavelength range from 350 to 1700 nm.

Azimuth and elevation motors point the entrance optics at the sun using tracking-error signals from a quad-cell photodiode. Position feedback signals and power are transported through cables to the rack-mounted power supply, motor amplifiers, motion-control unit and data acquisition computer.

The main challenges lie in the dynamic range of the detection system (direct Sun vs. sky radiance) and in the suppression of unwanted stray light when measuring sky radiance a few degrees away from Sun.

We will use the inversion procedure used for AERONET (*Dubovik and King*, 2000) with alterations specifically tailored to the planned airborne instrument. The current AERONET inversion algorithm was developed by Dr. Oleg Dubovik (Co-I of this proposal). The accuracy of individual AERONET retrievals was analyzed by extensive sensitivity simulations (*Dubovik et al.,* 2000).

We plan to adhere to the AERONET sky observation sequences, almucantar and principal plane, when taking measurements aboard the aircraft (in addition to the direct beam measurements of course). Due to the aircraft's movement, however, the sky observations will not fall exactly on the almucantar or principal plane. Information on aircraft attitude will then be used to compute the scattering angle for each observation. It should be noted that the inversion procedure does not require the observations to follow any specific geometrical pattern. It merely requires the observations to be carried out over a sufficient range and number of scattering angles, and that the scattering angles be accurately determined.

The proposing team combines the capabilities of the NASA Ames Airborne Sunphotometer Team with the expertise on measurement and inversion of sky-radiances within the AERONET group. It is thus uniquely qualified to develop a new instrument to perform airborne sky-radiance measurements. The observations of such a new instrument will give new insights into the spatial distributions of absorbing aerosols and hence aerosol-climate interactions.

## 3 References

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