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Program Element: Atmospheric Composition and Climate (ACC)
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Radiative-Climatic Effects of Aerosols and Water Vapor:
Studies in the Context of the North East - North Atlantic Experiment (NENA) with Contributions to Regular Vertical Profiling (RVP)

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Budget requested from NOAA ($K):

Period	Option A AATS-14 Measurements on NOAA P-3	Option B AATS-14 Measurements on Smaller A/C	Option C AATS-6 Measurements on NOAA P-3
October 2003 - September 2004	158.7	141.6	190.0 + TBD
October 2004 - September 2005	151.4	151.4	151.4
October 2005 - September 2006	152.6	152.6	152.6
Three Year Total	462.7	445.6	494.0 +TBD

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ACRONYMS

AATS-6 (14)	6 (14)-channel Ames Airborne Tracking Sunphotometer
ACC	Atmospheric Composition and Climate
ACE	Aerosol Characterization Experiment
ACIP	Aerosol-Climate Interactions Program
ADAM	Asian Dust and Aerosols above Monterey
AERONET	Aerosol Robotic Network
AOD	Aerosol Optical Depth
ARM	Atmospheric Radiation Measurement
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
CCRI	Climate Change Research Initiative
CERES	Clouds and the Earth's Radiant Energy System
CIRPAS	Center for Interdisciplinary Remotely Piloted Aircraft Studies
CLAMS	Chesapeake Lighthouse and Aircraft Measurements for Satellites
CTM	Chemical Transport Model
CWV	Column Water Vapor
DOE	Department of Energy
EOS	Earth Observing System
GMS	Geostationary Meteorological Satellite
GOCART	Global Ozone Chemistry Aerosol Radiation Transport
GOES	Geostationary Operational Environmental Satellite
IDS	Inter-Disciplinary Science
IGAC	International Global Atmospheric Chemistry
INDOEX	Indian Ocean Experiment
INTEX	Intercontinental Chemical Transport Experiment
IOP	Intensive Observation Period
ISCCP	International Satellite Cloud Climatology Project
ITCT	Intercontinental Transport and Chemical Transformation
IUGG	International Union for Geodesy and Geophysics
JOSS	Joint Office for Scientific Studies
MATCH	Model of Atmospheric Transport and CHemistry
MISR	Multi-angle Imaging Spectro-Radiometer
MODIS	Moderate-resolution Imaging Spectroradiometer
NAAPS	Navy Aerosol Analysis and Prediction System
NACIP	National Aerosol-Climate Interactions Program
NAS	National Academy of Sciences
NENA	North East – North Atlantic
ONR	Office of Naval Research
PRIDE	Puerto RIco Dust Experiment
PSAP	Particle Soot Absorption Photometer
RVP	Regular Vertical Profiling
SAFARI	Southern African Regional Science Initiative
SeaWiFS	Sea-viewing Wide-Field-of-view Sensor
SGP	Southern Great Plains
SSA	Single Scattering Albedo
SSFR	Solar Spectral Flux Radiometer
TARFOX	Tropospheric Aerosol Radiative Forcing Observational Experiment
TOMS	Total Ozone Mapping Spectrometer
UCAR	University Corporation for Atmospheric Research

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Proposed Cost, October 2003-September 2006:
Option A: $462.7K. Option B: $445.6K. Option C: $494K + TBD.

Abstract. The overall goal of the proposed research is to advance understanding of the roles that aerosols and water vapor play in determining regional and global climates. Specifically, we will address the following questions:

- What are the distributions, optical properties, and radiative effects of aerosols and water vapor in the continental outflows to be studied in the 2004 North East - North Atlantic (NENA) experiment?
- How do these properties and effects relate to aerosol size, chemistry, mixing state, and the humidity field?
- How do these properties, effects, and relationships evolve during downwind transport in the context of other constituents?
- How consistent are radiometric and in situ determinations of such climatically important variables as aerosol spectral optical depth, single-scattering albedo, and hygroscopic growth factors?
- How can satellite data, especially from recently launched sensors, best be combined with suborbital measurements to address these questions and assess regional radiative forcing?

Of the activities in the proposal solicitation, our proposed research will address primarily Activity 1 (Intercontinental Transport and Chemical Transformation) by making measurements of aerosols and water vapor in NENA using an Ames Airborne Tracking Sunphotometer (AATS). We will also address Activity 2 (Regular Vertical Profiling of Aerosols) by focusing, over the three-year research period, on the issues of marrying smaller aircraft with smaller, lighter, lower-power, automated instruments.

Key elements of our methodology include:

- Making our AATS measurements on an aircraft that simultaneously measures solar spectral flux (with, e.g., the Solar Spectral Flux Radiometers of Peter Pilewskie). Combining the resulting spectra of atmospheric absorption and optical depth permits deriving aerosol-layer single scattering albedo spectra that span the important part of the solar spectrum. This information is critical to determining aerosol climatic effects.
- Executing flight patterns that unambiguously determine radiative effects and their relationship to aerosol properties. Such patterns are essential to achieving a climatically relevant result from NENA. They coordinate with satellites and synergize with other measurements, both in situ and remote, on aircraft, ships, and land.

We present three options for AATS-aircraft combinations in NENA. We show the pros, cons, and costs of each, so that NOAA and/or NASA program managers can make an informed choice as budgets and aircraft possibilities become clearer.

We will deliver our quality-assured NENA data set to an archive accessible to other investigators, so as to facilitate and encourage collaborative analyses. Our integrated analyses of the NENA data set will include (1) Satellite validation, (2) Closure tests among suborbital measurements, (3) Deriving single scattering albedo spectra from radiative flux and aerosol optical depth spectra, (4) Tests of chemical-transport models, and (5) Regional forcing assessments by combining satellite and suborbital results. Our cost estimate assumes that major costs for these integrated analyses will be covered by a NASA EOS-IDS task (proposal pending).

The proposed research will benefit from our extensive experience with airborne sunphotometer measurements and integrated analyses in the aerosol-radiative experiments TARFOX, ACE-2, PRIDE, ACE-Asia, CLAMS, ADAM, and several ARM IOPs—work that has produced ~50 journal papers led or coauthored by the proposing team. It will benefit the general public by reducing the uncertainties about aerosol effects on climate cited by the National Academy of Sciences and by international bodies.

Radiative-Climatic Effects of Aerosols and Water Vapor:
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1. RESULTS FROM PRIOR RESEARCH

As required by the Instructions for Submitting Proposals (http://www.ogp.noaa.gov/c&gc/ao/2004/index.htm), this section summarizes, in two pages or less, results of each relevant research project during the last 3 years. More extensive descriptions of selected results and their relevance to the proposed research are given in Sections 2.2-2.3 of this proposal.

ACE-2 and ACE-Asia Aerosol Radiative Effect Studies Using Airborne Sunphotometer, Satellite and In-Situ Measurements. NOAA Award NA02AANRG0129, NASA RTOP 622-96-00-57-01, 5/2000-4/2003, $466,100. This award supported (a) Acquisition and use of satellite data to plan ACE-Asia; (b) Comparison of aerosol absorption derived by flux-change and other techniques in TARFOX and ACE-2; (c) Contributions to the ACE-Asia Science and Implementation Plan; (d) Development and testing of sunphotometric water vapor analysis techniques; (e) Mission Scientist duties for ACE-Asia C-130 flights addressing aerosol-radiation interactions; (f) Measurements using the 6-channel Ames Airborne Tracking Sunphotometer (AATS-6) on the C-130 in ACE-Asia 2001; (g) Validations and closure analyses combining the AATS-6 data with satellite and other suborbital data; and (h) Aerosol radiative effect calculations that combine satellite and suborbital inputs. Results are described in five journal publications led by our team (Redemann et al., 2001a, 2003a; Bergstrom et al., 2002; Russell et al., 2002; Schmid et al., 2001), plus eight others we coauthored (Huebert et al., 2003a,b; Ingold et al., 2000; Kiedron et al., 2001; Murayama et al., 2003; Revercomb et al., 2003; Wang et al., 2003b; Xu et al., 2003). We have archived our AATS-6 ACE-Asia data set and made it available to the user community via the Ames web site (http://geo.arc.nasa.gov/sgg/AATS-website/AATS_Data.html) and a link from UCAR-JOSS. These data are being used in several ongoing studies that will be published in a 2nd ACE-Asia special issue (e.g. Kahn et al., 2003). Selected results are summarized in Sections 2.2-2.3.

Quantification of aerosol radiative effects by integrated analyses of airborne measurements, satellite retrievals, and radiative transfer models. NOAA Award NA03AANRG0088, NASA RTOPS 622-96-00-58-39, -40, and –41, 3/2003-2/2006, $295,200 received to date. This award, received by Ames four months ago, funds integrated analyses of two data sets: from ACE-Asia and from the DOE SGP Aerosol IOP. It uses a 3-pronged approach to quantifying aerosol radiative effects: A. Aerosol absorption using flux divergence, B. Extinction closure including satellite validation, and C. Regional forcing using satellite and suborbital inputs. Some early results (Bergstrom et al., 2003b) have shown noteworthy similarities in the wavelength dependence of absorption optical depth for different types of aerosol. Other results are from integrated analyses of ACE-Asia data (Redemann et al., 2003b,c) and early analyses of SGP Aerosol IOP data (Schmid et al., 2003c,d).

Solar Spectral Flux, Optical Depth, Water Vapor, and Ozone Measurements and Analyses in the ACE-Asia Spring 2001 Intensive Experiment. Office of Naval Research Award N0001401F0183, NASA RTOP 622-96-00-56-79, 11/2000-9/2002, $163,900. This award supported measurements and analyses of solar spectral fluxes and direct beam transmissions in support of the ACE-Asia Spring 2001 Intensive Experiment. Measurements were made by Solar Spectral Flux Radiometers (SSFRs) and the 14-channel Ames Airborne Tracking Sunphotometer (AATS-14) on the CIRPAS Twin Otter. Data analyses focused on determining the radiative forcing of Asian Pacific aerosols, quantifying the solar spectral radiative energy budget in the presence of elevated aerosol loading, supporting satellite algorithm validation, and providing tests of closure with in situ measurements. Our AATS-14 ACE-Asia data set has been archived and made available to the user community (see above for link). Results are described in Schmid et al. (2003b), Wang et al. (2002) and in several other papers accepted for the ACE-Asia special issue of *J. Geophys. Res.* (e.g., Wang et al., 2003b). Selected results are shown in Sections 2.2-2.3.

Improved Exploitation of Field Data Sets to Address Aerosol Radiative-Climatic Effects and Development of a Global Aerosol Climatology. NASA RTOP 622-44-75-10, 10/98-9/03, $877,000. This award has focused primarily on integrated analyses of data sets from three experiments that studied continental outflow to the North Atlantic (TARFOX, ACE-2, and CLAMS), and one that studied Asian aerosol transport to the Western US (ADAM). Results are described in 10 publications led by the Ames sunphotometer-satellite team (Bergstrom and Russell, 1999; Livingston et al., 2000; Redemann et al., 2000a,b, 2001; Russell and Heintzenberg, 2000; Russell et al., 1999a,b,; Schmid et al., 1999, 2000), plus 12 others we coauthored (Collins et al., 2000; Durkee et al., 2000; Ferrare et al., 2000a,b; Flamant et al., 2000; Gasso et al., 2000; Hartley et al., 2000; Ismail et al., 2000; Pilewskie et al., 2000; Tanre et al., 1999; Veefkind et al., 1999; Welton et al., 2000). About 13 conference papers report early results from CLAMS and ADAM. Examples include Bucholtz et al., 2003; Cairns et al., 2002; Chowdhary et al., 2002; Hobbs et al., 2002; Levy et al., 2002; Martins et al., 2002; Redemann et al., 2001c, 2002a-c; Strawa et al., 2003. Examples of these results are shown in Section 2.3.

Satellite-Sunphotometer Studies of Aerosol, Water Vapor, and Ozone Roles in Climate-Chemistry-Biosphere Interactions. NASA RTOP 291-01-91-45, 2/1999-12/2002, $675,000. This award supported modeling and integrated analyses of suborbital and satellite data primarily from three international multiplatform field campaigns: PRIDE, SAFARI 2000, and ACE Asia. Thirteen journal manuscripts were submitted or accepted (Bergstrom et al., 2003a; Colarco et al., 2003; Gatebe et al., 2003; Kaufman et al., 2003; Levy et al., 2003; Livingston et al., 2003; Magi et al., 2003; McGill et al., 2002; Pilewskie et al., 2003; Reid et al., 2002, 2003a,b; Schmid et al., 2003b; Wang et al., 2003a).

2. PROPOSED RESEARCH (STATEMENT OF WORK)

2.1 Problem Identification, Overall Objectives, and Relevance

Aerosols and chemically active greenhouse gases (including ozone and water vapor) interact in myriad ways to influence atmospheric composition and the climate. Understanding these myriad interactions is essential to understanding climate variability and change, and therefore to enhancing society's ability to respond (NOAA, 2003a). The importance and complexities of aerosol effects on climate have made aerosols one of the top three priorities of the US CCRI (CCSP, 2002).

Commonalities in aerosols, ozone, and water vapor—e.g., their short lifetimes and strong variability, their mutual chemical, physical, and radiative interactions—mean that research projects can successfully focus on these species in concert. An example is the coordinated group of experiments, including NENA, that will study intercontinental transport and chemical transformations (ITCT) in Summer 2004 as part of the IGAC activity that bears the name ITCT. The dependence of aerosol, ozone, and water vapor radiative and chemical effects on their individual and mutual vertical profiles is another commonality that argues for their coordinated study.

The FY 2004 solicitation of the NOAA Atmospheric Composition and Climate (ACC) Program reflects these scientific relationships and national research priorities by focusing on three Activities:

1. <u>The North-East/North Atlantic (NENA) Experiment</u>, NOAA's Summer 2004 ITCT study that will coordinate with NASA's INTEX and with other studies led by Canadian and European agencies. NENA aims to provide data and studies needed to evaluate and improve model estimates of the outflow of chemicals from North America across the Atlantic Ocean and to evaluate their impact on the radiative balance and chemistry of the Eastern US and North Atlantic (NOAA, 2003b). By synthesizing observations from the surface, aircraft, and space, NENA will address a suite of NOAA objectives that include:

- Quantify the export, evolution, and transformations of radiatively and chemically important trace gases and aerosols from North America to the western Atlantic.

- Relate the optical properties of aerosols to their microphysical and chemical properties and identify the processes that determine those properties.

- Evaluate and improve the capabilities of current models in simulating the observed distributions of ozone and distributions and properties of aerosols.

2. <u>Regular Vertical Profiling (RVP)</u> of aerosols. This activity supplements ITCT/NENA by using small aircraft at selected sites to provide systematic monitoring of aerosols and their effects on radiation budgets. Flights made several times weekly over several years will provide data to test chemical transport models (CTMs) and satellite retrieval algorithms, as well as enable an observationally based calculation of aerosol radiative forcing. This activity requires instrumentation optimized for small size and weight, low power, and automated operation.

3. <u>Aerosol Indirect Effects</u>. This activity builds on the preceding two and includes components directed at cloud microphysical and radiation measurements. It aims to benefit from NENA in 2004 by taking advantage of the multiple aircraft and RV Brown in the context of continental outflows of pollution and a variety of clouds to obtain a useful data set on indirect effects.

This proposal addresses primarily ACC Activity 1 by proposing measurements in NENA using an Ames Airborne Tracking Sunphotometer (AATS). It also addresses ACC Activity 2 by proposing to focus, over the three-year research period, on the issues of marrying smaller aircraft with smaller, lighter, lower-power, automated instruments that measure aerosol properties and radiative effects. The proposed NENA measurements will also support ACC Activity 3 by providing aerosol optical depth (AOD) spectra above and/or adjacent to clouds that are susceptible to aerosol indirect effects. (See Section 2.2, flight pattern (4).)

The overall scientific goal of the proposed research is to advance understanding of the roles that aerosols and water vapor play in determining regional and global climates. Specifically, we will address the following questions:

- What are the distributions, optical properties, and radiative effects of aerosols and water vapor in the continental outflows to be studied in NENA?
- How do these properties and effects relate to aerosol size, chemistry, mixing state, and the humidity field?
- How do these properties, effects, and relationships evolve during downwind transport in the context of other constituents?
- How consistent are radiometric and in situ determinations of such climatically important variables as aerosol spectral optical depth, single-scattering albedo, and hygroscopic growth factors?
- How can satellite data, especially from recently launched sensors, best be combined with suborbital measurements to address the above questions and assess regional radiative forcing?
- What approaches to RVP (in terms of aircraft and instrument adaptations and developments) are likely to have the highest scientific payoff per dollar of investment, in the short term and in the longer run?

2.2 Methodology and Introduction to Previous Results

Figures 1 and 2 give an overview of our general methodology for studying aerosol and gas properties and radiative effects in the context of continental outflows. Since 1996 we have evolved and applied this methodology in studies of outflows from North America, Europe, Africa, and Asia, in the locations shown in Figure 3.

Some of these continental outflows, which include urban-industrial pollution, biomass smokes, and desert dust, are illustrated schematically in the left frame of Figure 1. Episodic outbreaks of these aerosols form features recognizable from space on regional to intercontinental scales (e.g., Husar et al., 1997; Kaufman et al., 2002). These aerosols can change the climate by perturbing energy exchange between the sun, Earth, and space, as well as by redistributing energy within the atmosphere. Two gas-phase constituents, water vapor and ozone, are also relevant to these processes, because they interact with aerosols both chemically and physically, and they are themselves major players in the Earth's radiation budget. All three constituents—aerosols, water vapor, and ozone—can be retrieved quantitatively from spaceborne measurements. However, retrieval accuracy is still being determined,

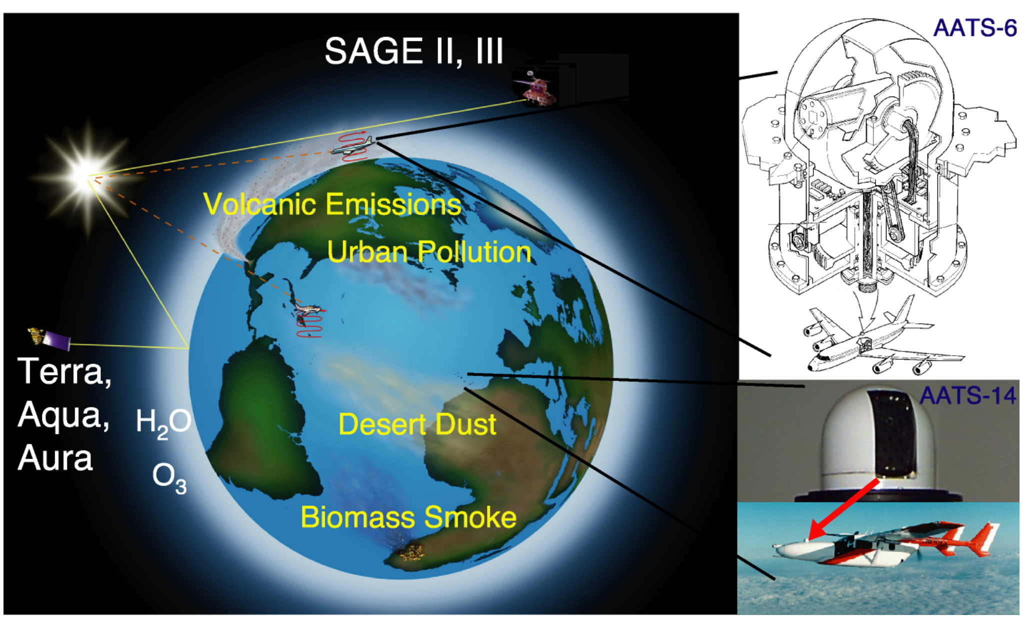

Figure 1. Schematic illustration of the types of continental outflows previously studied by the Ames Airborne Tracking Sunphotometers (AATS-6 and AATS-14), and the general method.

because it depends strongly on constituent type, measurement conditions (e.g., over land vs. water, in or out of sun glint, in or out of cirrus or other cloud fields), and spaceborne measurement technique (e.g., multiangle, multiwavelength, polarization, nadir- vs. limb-viewing, passive vs. active, etc.)

The three constituent types can also be measured by airborne sunphotometry (see note below on ozone sunphotometry). Our previous research has emphasized the use of airborne sunphotometry as a unique link between space-based retrievals and a diversity of suborbital measurements. These include in situ, vertically resolved measurements of radiative fluxes and of aerosol physico-chemical microproperties, as well as remote sensing by lidar and surface-based radiometers. A key theme has been combining satellite and suborbital measurements to develop more complete and realistic descriptions of the regional and seasonal distributions of aerosol and gas properties as well as their effects.

(Note on ozone sunphotometry: Our ozone measurements, which use the Chappuis band (wavelengths ~500-700 nm), require relatively small AOD (<~0.03). Hence, they are usually restricted to the free troposphere or nonvolcanic stratosphere. In NENA our ozone retrievals will likely be restricted to profile tops and near tops.)

An essential element of these previous studies (e.g., TARFOX, ACE-2, PRIDE, SAFARI 2000, ACE-Asia, CLAMS, ADAM, ARM Aerosol IOP) has been the flight patterns shown schematically in Figure 2. These flight patterns have been carefully designed, in concert with a wide variety of collaborators, to maximize the synergy between the different types of measurements, both satellite and suborbital. The basic types are:

(1) Survey Vertical Profile (typically a spiral). This profile, usually flown when first arriving at the location of interest, identifies aerosol layers to be measured more thoroughly in a subsequent profile pattern (often called a "parking garage"—see below). The survey profile's bottom is at the minimum safe altitude (typically 30-50 m over water), and its top altitude aims to reduce the overlying aerosol optical depth (AOD) to a small fraction of surface AOD. Ascent or descent rate is typically ~500 ft/min, chosen as a compromise between the desire to minimize time between profile top and bottom and the need to permit measurements by one or more continuous-readout aerosol sampling instruments, such as an optical size spectrometer or a nephelometer. In addition to locating layers for investigation in the subsequent "parking garage", this survey profile provides data for studies of the consistency (or closure--see Section 2.3.2) among radiometric and in situ measurements on the profiling aircraft. If the profile is flown over a land site or ship equipped with a lidar or sunphotometer, further closure studies are possible (see examples in Section 2.3.2). The continuous surface-site measurements also provide a record of any temporal changes that occur during the profile.

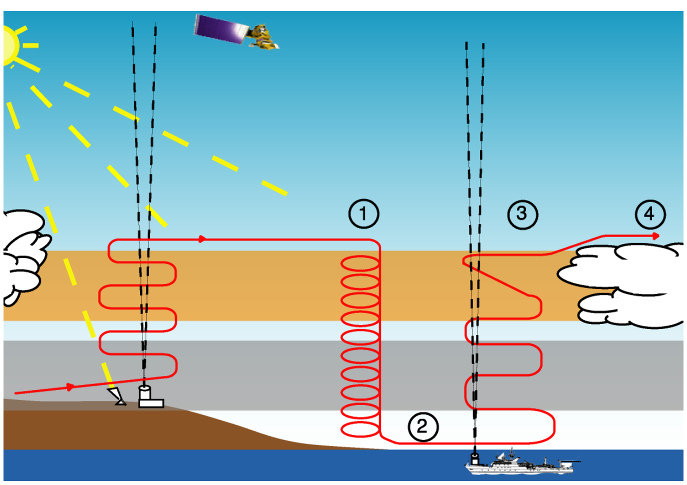

Figure 2. Illustration of the flight patterns used to reveal aerosol radiative effects and relate them to aerosol properties determined from space, air, land and sea. (1) Survey Vertical Profile. (2) Minimum-Altitude Transect. (3) Parking Garage. (4) Above-Cloud Transect.

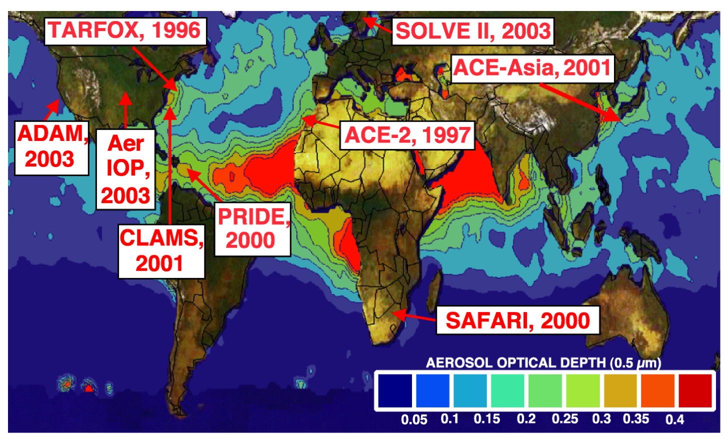

Figure 3. Major aerosol field campaigns in which the NASA Ames Airborne Sunphotometers participated, 1996-2003. Background shows June-August aerosol optical depth (AOD) for July 1989 to June 1991, as retrieved from upscattered solar radiance detected by AVHRR/NOAA 11 (Husar et al., 1997). Patterns of continental outflow are evident in the AOD contours.

(2) Minimum-Altitude Transect. Goals here are to measure the full-column AOD and to enable comparisons to measurements—both radiometric and in situ—at the ship or land site. Typically these transects are scheduled to include the time(s) of one or more satellite overpasses, thus yielding data to test satellite AOD retrievals (see Section 2.3.1). In turn, the satellite-retrieved spatial structure shows the context of the aircraft-sampled transect. Minimum-altitude transects often last for only a few minutes. However, longer transects, if safe, can span gradients in AOD, water vapor, or surface characteristics, affording more extensive tests of the consistency between aircraft and satellite results. An example is the ATSR-2/AVHRR/AATS-6 comparison summarized in Section 2.3.1.

(3) Parking Garage. This profile's name stems from its combination of near-level legs with linking ramps. The near-level legs, flown at heights chosen on the basis of a survey profile or lidar data, permit accurate flux radiometry and also aerosol measurements by instruments that need long sampling times or have inlets sensitive to aircraft pitch or turns (as is often the case). The in situ measurements provide tests of the aerosol-characteristic assumptions made in satellite retrievals. Combining (in a radiative transfer model) spectra of radiative flux and AOD measured above and below an aerosol layer permits derivation of the spectrum of aerosol single scattering albedo (SSA, see section 2.3.3).

(4) Above-Cloud Transect. This pattern provides measurements of (a) above-cloud AOD spectra (needed to test assumptions in satellite retrievals of cloud properties), (b) above-cloud radiative flux and cloud-top albedo spectra (needed to quantify an important aerosol indirect effect), and (c) properties of the aerosols entrained into the cloud top—a prime driver of aerosol-induced cloud modifications. This pattern thus addresses ACC solicitation Activity 3, Aerosol Indirect Effects.

2.3 Examples of Previous Results

In the measurement and analysis phases of our previous experiments (e.g., Figure 3), we typically devote efforts to many or all of the following: (1) Satellite validation including satellite scene classification, (2) Closure tests among suborbital measurements, (3) Deriving single scattering albedo spectra from radiative flux and AOD spectra, (4) Tests of chemical-transport models,

Table 1. Satellite validation studies using measurements by the Ames Airborne Tracking Sunphotometers (AATS-6 and AATS-14)

Sensor	Campaign	Region	Surface	Period	Publication
ATSR-2	TARFOX	US East Coast	Ocean	July 1996	Veefkind et al., 1999
ATSR-2	SAFARI 2000	Namibian Coast	Ocean	September 2000	Schmid et al., 2003a
AVHRR	TARFOX	US East Coast	Ocean	July 1996	Veefkind et al., 1999
AVHRR	ACE 2	Canary Islands	Ocean	June/July 1997	Durkee et al., 2000 Livingston et al., 2000 Schmid et al., 2000
GMS-5	ACE-Asia	Eastern Asia	Ocean	April 2001	Wang et al, 2003b
GOES-8	PRIDE	Puerto Rico	Ocean	June/July 2000	Livingston et al., 2003 Wang et al., 2003a
MAS	TARFOX	US East Coast	Ocean	July 1996	Tanré et al. 1999
MISR	SAFARI-2000	Southern Africa	Ocean & Land	September 2000	Schmid et al., 2003a
MISR	ACE-Asia	Eastern Asia	Ocean	April 2001	Kahn et al., 2003
MISR	CLAMS	US East Coast	Ocean	July/August 2001	Redemann et al., 2001c
MODIS	PRIDE	Puerto Rico	Ocean	June/July 2000	Livingston et al., 2003 Levy et al., 2003
MODIS	SAFARI-2000	Southern Africa	Ocean & Land	September 2000	Schmid et al., 2003a
MODIS	CLAMS	US East Coast	Ocean	July/August 2001	Levy et al., 2002
MODIS	ACE-Asia	Eastern Asia	Ocean	April 2001	Chu et al., in prep.
POAM	SOLVE-2	Arctic	Ocean & Land	Jan/Feb 2003	Livingston et al., 2003b
SAGE 3	SOLVE-2	Arctic	Ocean & Land	Jan/Feb 2003	Livingston et al., 2003b
SeaWiFS	ACE-Asia	Eastern Asia	Ocean	April 2001	Hsu et al, in prep.
TOMS	PRIDE	Puerto Rico	Ocean	June/July 2000	Livingston et al., 2003
TOMS	SAFARI-2000	Southern Africa	Land	September 2000	Schmid et al., 2003a

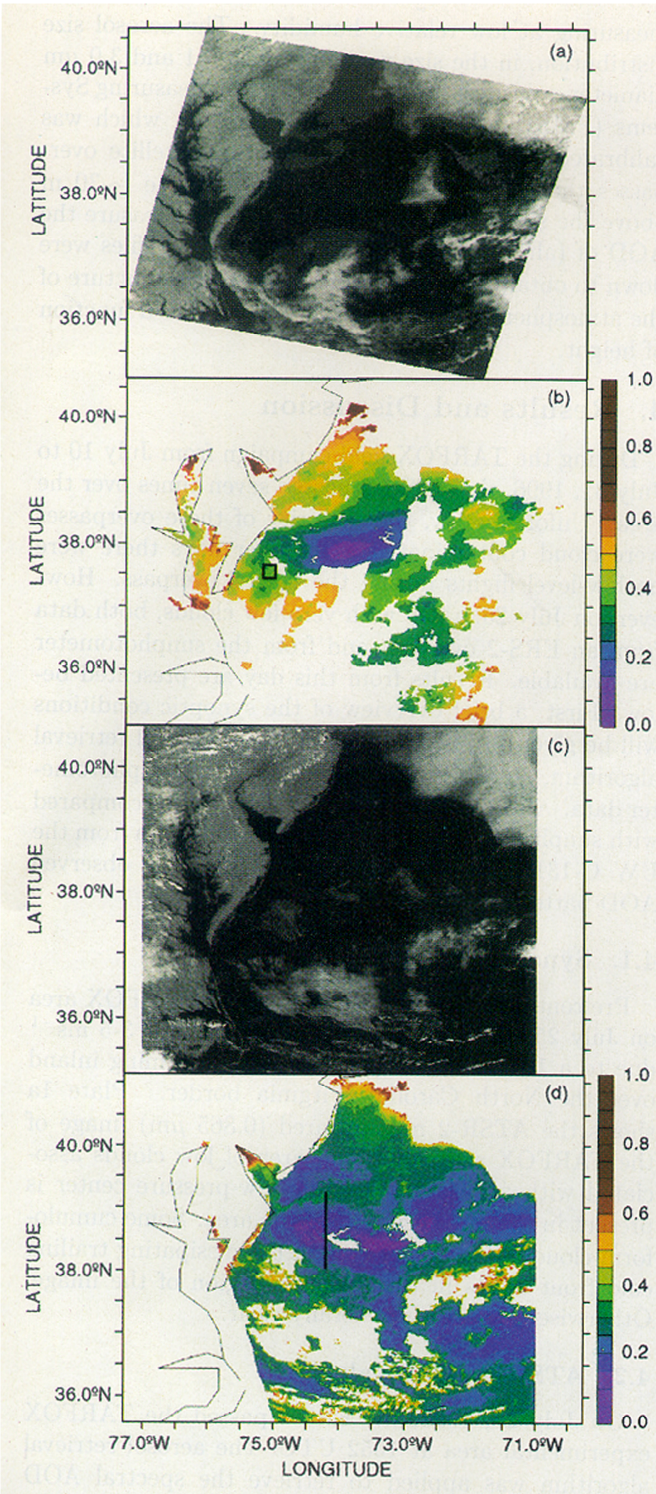

Figure 4. (a) ATSR-2 0.865 µm image for July 25, 1996, 15:52 UTC; (b) ATSR-2 retrieved AOD(0.659 µm); box is UW-C131A position during overpass; (c) AVHRR 0.84 µm image for same date at 18:45 UTC; (d) AVHRR retrieved AOD(0.64 µm); S-N line at 74.2 W is UW-C131A flight track (Veefkind et al., 1999).

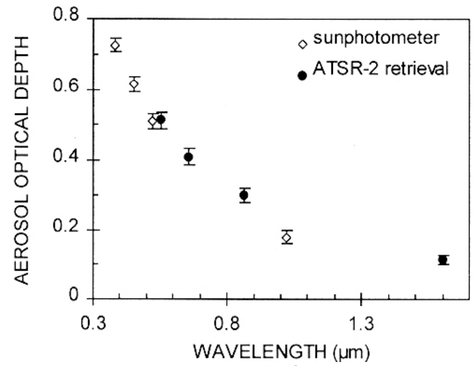

Figure 5. Comparison of AOD spectra from ATSR-2 and AATS-6, both at 15:52 UTC in the square shown in Figure 4b.

and (5) Regional forcing assessments by combining satellite and suborbital results. In this section we show some examples, as an introduction to our proposed tasks.

2.3.1 Satellite Validation

In the experiments shown in Figure 3, major efforts were devoted to coordinating aircraft measurements with satellite overpasses. Table 1 lists the satellite sensors whose retrievals were compared to AATS measurements. Here we show a representative sampling of results.

ATSR-2 and AVHRR Retrievals off the US East Coast in TARFOX. In TARFOX we flew AATS-6 on the UW C-131A and made underflights of both ATSR-2 and AVHRR. Figure 4a shows the ATSR-2 image of clouds and aerosols off the US East Coast at 15:52 UTC on 25 July 1996. Figure 4b shows the corresponding map of retrieved AOD(0.66 µm), and also the location of the C-131A at ATSR-2 overpass time. Figure 5 compares the AATS-6 and ATSR-2 spectra of AOD(λ), showing agreement within the eror bars of ~0.02.

About 3 hours later, at 18:45, AVHRR overflew the same area, yielding the cloud/aerosol image and corresponding AOD retrieval in Figures 4c,d. From 18:42 to 19:06 UTC the C-131 flew the transect shown in Figure 4d, across the AOD gradient in the AVHRR retrieval. (This AOD gradient had been found, and the path planned, using AOD retrievals from half-hourly GOES Imager data [e.g., Durkee et al., 2000].) Comparisons (Veefkind et al., 1999, not shown for brevity) showed that ATSR-2 matched the strength of the AATS-6-measured AOD gradient and Angstrom exponent better than AVHRR did. These differences reflect the success of ATSR-2's use of two view angles and 4 wavelengths, compared to AVHRR's one view angle, two wavelengths, and poorer calibration.

MISR Retrievals in SAFARI-2000. Figure 6A compares AOD spectra retrieved by MISR and measured by AATS-14 in SAFARI-2000. The MISR retrieval (e.g., Kahn et al., 2003) seeks the closest match between the radiances measured by MISR and those calculated from a set of mixed-aerosol models. In the case of Figure 6A, the MISR best-fit model gives AOD(λ) with a slope similar to the AATS-14 slope, but with MISR AOD > AATS AOD at all λ. The larger MISR AODs are caused by the relatively strong absorption in the MISR best-fit model, which results from its 20% black carbon content, and which requires relatively large AOD to reproduce the MISR-measured radiances.

The MISR 2nd-best-fit model has no black carbon, and hence yields smaller AOD. However, it also has a relatively strong component of coarse sea salt, producing a small slope that doesn't match the AATS-14 slope well. This and other comparisons showed that the MISR retrieval needed to restore a model including small, spherical, non-absorbing particles, which had been deleted early in the mission to reduce computer demands.

MODIS Retrievals in SAFARI 2000. Figure 6B compares MODIS and AATS AOD spectra for a biomass-smoke haze in SAFARI 2000. The original MODIS retrieval, labeled MODIS 9:02 UT, has AOD < AATS and Cimel AOD for all λ. Such comparisons helped confirm that the biomass smoke single scattering albedo (SSA) assumed in the original retrieval (SSA ~0.9, based on results from South America) was too large (i.e., absorption was too weak). Adopting a new model SSA (~0.85) has now produced retrieved AODs (V4 MODIS in Figure 6B) that agree with AATS, AERONET, and other AODs in regions with strong biomass burning such as in Zambia.

SeaWiFS Retrievals in ACE-Asia. Comparisons (e.g., Figure 7) between AATS measurements and SeaWiFS retrieved AOD yield good agreement if the new 4-wavelength Hsu et al. (2002) algorithm is used, but disagreement if using the standard SeaWiFS algorithm.

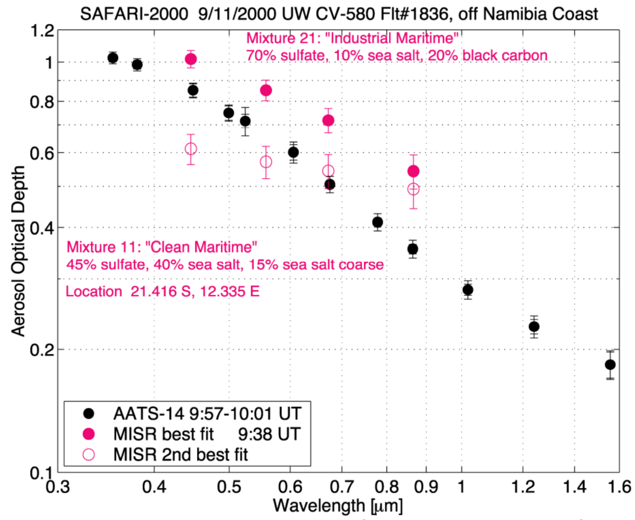

Figure 6A. Comparison of AOD spectra from MISR retrievals and AATS-14 measurements in SAFARI 2000.

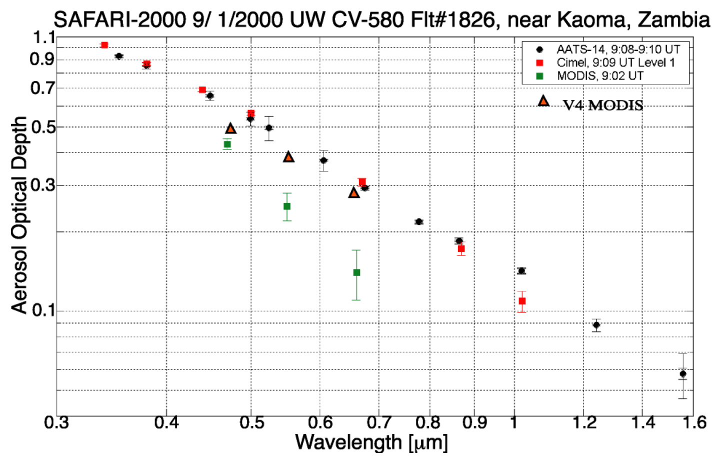

Figure 6B. Comparison of AOD spectra from MODIS retrievals and AATS-14 measurements in SAFARI 2000

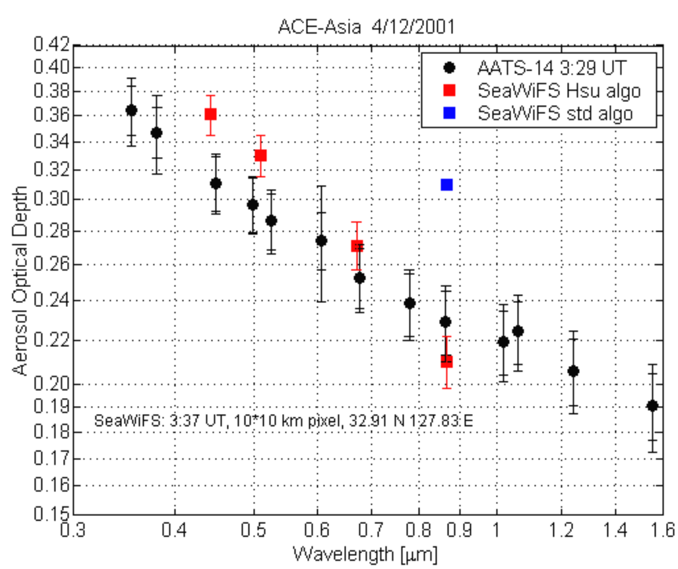

Figure 7. Comparison of AOD spectra on April 12, 2001 between AATS-14 and SeaWiFS, using standard and Hsu et al. (2002) algorithms.

MISR Retrievals in ACE-Asia. MISR-AATS comparisons in ACE-Asia (not shown for brevity) confirmed that early MISR-derived AODs were skewed high for some low-light-level scenes. Subsequent experiments demonstrated that scattered light played a key role in this phenomenon, and led to a revision of the MISR low-light-level calibration (that significantly affects MISR-derived AOD over dark water) (R. Kahn, personal communication).

MODIS Dust Retrievals in PRIDE. Extensive comparisons in the Puerto Rico Dust Experiment (PRIDE; see Reid et al., 2003a,b; Livingston et al., 2003, not shown for brevity) demonstrated that when Saharan dust was dominant (typically for AOD >0.2), MODIS-retrieved AOD spectra sloped more steeply than AATS AOD spectra. The likely cause is dust nonsphericity, which causes the MODIS retrieval to substitute more small mode aerosol for nonspherical large mode dust dust (Remer et al., 2002). An updated MODIS algorithm that adds nonspherical phase functions is being developed to address this.

2.3.2 Closure Tests Among Suborbital Measurements

Closure studies test the consistency of different measurements that are linked by one or more models. Because the linking models (e.g., of aerosol growth in humidity, of light scattering by mixed aerosols) are often used as components of the chemical transport models or general circulation models that predict aerosol effects on climate, closure studies provide important assessments of both the measurements and the models that undergird our current understanding of aerosol effects on climate.

An important class of closure studies addresses 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 have revealed important insights about aerosol sampling and inadvertent modification in such previous experiments as TARFOX (Hegg et al., 1997; Hartley et al. 2000), ACE-2 (Collins et al., 2000; Schmid et al., 2000), SAFARI 2000 (Magi et al., 2003), and ACE-Asia (Redemann et al., 2003a; Schmid et al., 2003b).

Key to these studies is the measurement of AOD and columnar water vapor with an Ames Airborne Tracking Sunphotometer (AATS-14 or AATS-6). This is because inlet effects (e.g., loss or enhancement of large particles, shrinkage by evaporation of water, organics, or nitrates) and filter effects are avoided. The AATS direct solar beam transmission measurements yield spectral aerosol optical depths AOD(λ), columnar water vapor CWV, and (when AOD is <~0.03) columnar ozone. Flying at different altitudes over a fixed location allows derivation of AOD(λ) or CWV in a given layer. Data obtained in vertical profiles allow derivation of spectral aerosol extinction $E_a(\lambda)$ (see Figure 8) and water vapor density ρ_w.

Measuring solar beam attenuation by an AATS on the same aircraft as in situ sensors allows an exact match in the altitudes spanned by the attenuation and in situ measurements (see, e.g., Figure 2). Such a match allows the best-defined comparison between attenuation and in situ results. It avoids the ambiguity that occurred in previous experiments when the only sunphotometer was on the surface and thus provided no information on what fraction of column optical depth was above the aircraft's maximum sampling height. Figure 9 shows

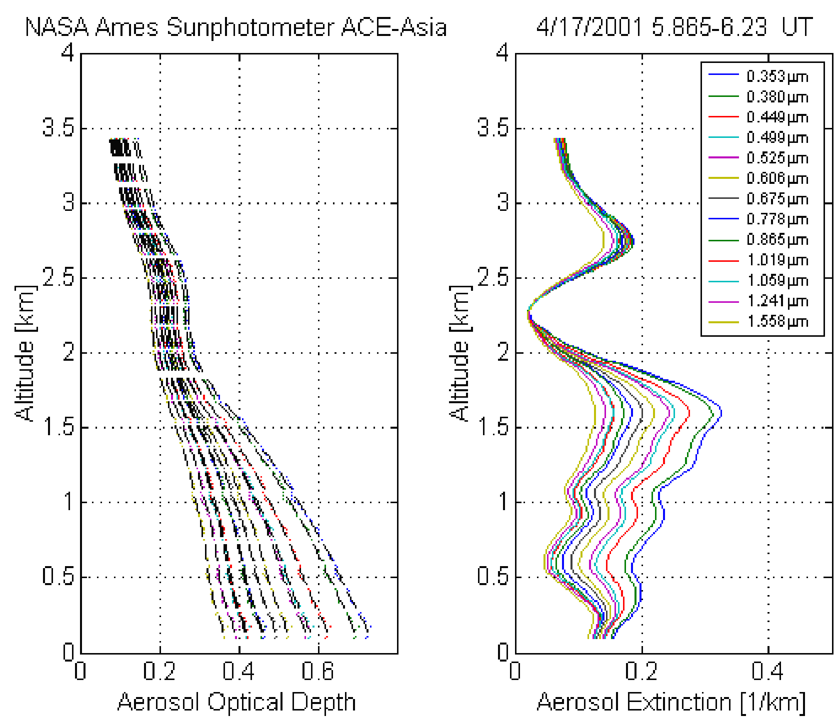

Figure 8. Left: AOD profiles at 13 wavelengths, 354-1558 nm, calculated from AATS-14 measurements acquired during an aircraft ascent south of Korea, 17 April 2001 in ACE-Asia. Right: Corresponding aerosol extinction profiles derived by differentiating spline fits (dashed lines in left panel) to the optical depth profiles.

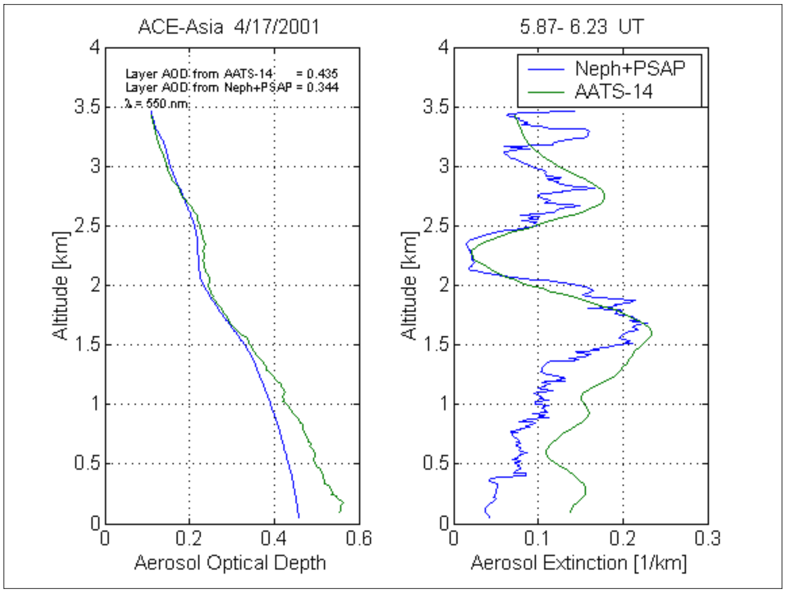

Figure 9. AOD (left) and extinction (right) profile at 550 nm measured by AATS-14 and computed as the sum of scattering (from humidified nephelometry) and absorption (PSAP instrument) during aircraft ascent shown in Figure 8.

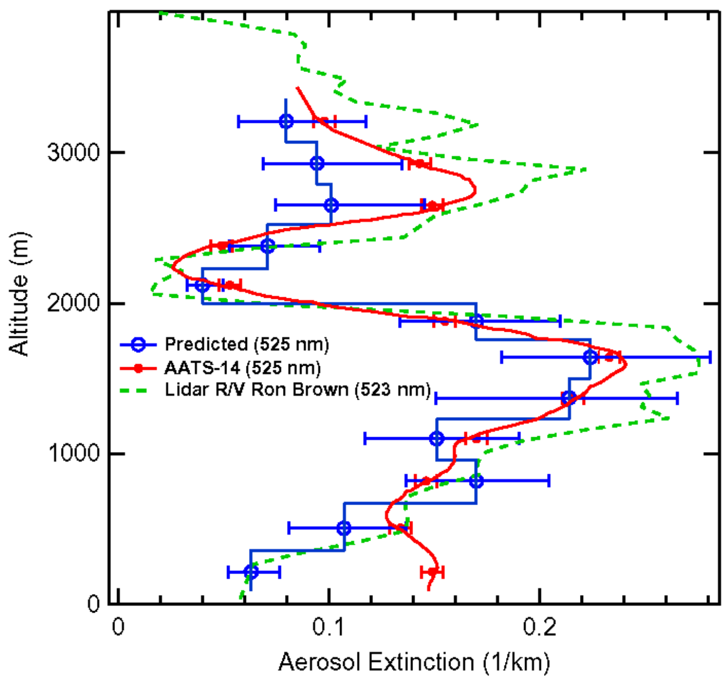

Figure 10. Comparison of aerosol extinction derived from AATS-14 measurement, from aerosol size distributions, and from lidar measurements on R/V Ron Brown during the ascent shown in Figure 8 (Wang et al., 2002a).

an example from ACE-Asia where the in situ extinction is computed as the sum of scattering (from humidified nephelometry) and absorption (from a PSAP instrument).

Figure 10 shows an example result from an ACE-Asia closure study (Wang et al., 2002) that compares aerosol extinction from AATS-14 with values calculated from Mie theory using measured size distributions and size-resolved composition (used to determine the complex refractive indices). In the uppermost layer, the underestimate of Mie-predicted extinction compared to the AATS-14 result is attributed to nonspherical dust particles there. Treating these nonspherical particles as spheres causes underestimation of their size as determined by the in situ mobility analyzer, and underestimation of their extinction-to-volume ratio (Wang et al., 2002).

Our extinction closure analyses have also included comparisons with the numerous lidars deployed during TARFOX, ACE-2, SAFARI-2000, and ACE-Asia on land, ships and aircraft. Figure 10 includes an example using the ACE-Asia ship lidar (e.g., Welton et al., 2001) during the same flight as shown in Figures 8 and 9.

AATS-6 and AATS-14 measure the overlying column water vapor (CWV) using a channel in the 940-nm water vapor absorption band. Vertical differentiation of AATS CWV profiles in aircraft ascents or descents yields profiles of water vapor concentration. Our closure studies have included many comparisons between the AATS water vapor results and those from a variety of other measurement techniques (e.g., Schmid et al., 2000, 2001). Figure 11 shows examples for AATS-14 in ACE-Asia. The continuously measured CWV results are useful in radiative transfer calculations (e.g., Section 2.3.3) and in assessing the CWV associated with AOD aloft.

Our closure studies have also included comparisons of aerosol absorption and single scattering albedo (SSA) derived by different techniques. In Russell et al. (2002) we compared aerosol absorption derived by diverse techniques in TARFOX and ACE-2, and found that absorption derived from broadband solar irradiance measure-

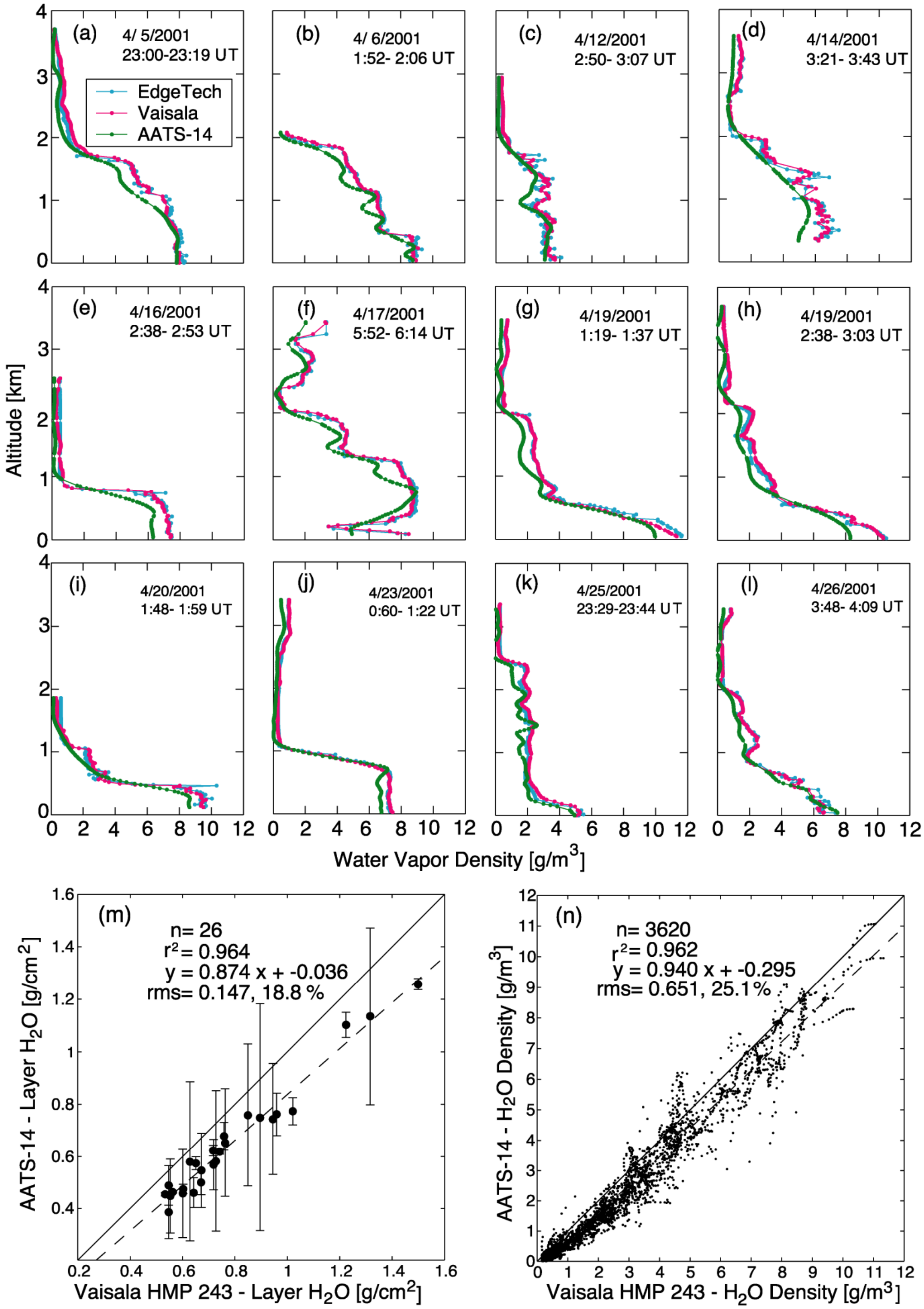

Figure 11. Comparison of water vapor measurements on the Twin Otter in ACE-Asia by AATS-14 and in situ sensors. (a-l) Representative vertical profiles. (m) Comparison of layer water vapor for 26 profiles. Error bars are based on horizontal distance spanned by a profile, combined with average horizontal variability of CWV in ACE-Asia flights. (n) Comparison of water vapor density for the 26 profiles.

ments (~300-700 and 300-4000 nm) was larger than that derived from other techniques. As shown in the next section, using spectrally resolved irradiance measurements can yield absorption spectra and, when combined with AOD spectra, SSA spectra.

2.3.3 Aerosol Absorbing Fraction from Radiative Flux and AOD Spectra

Results in this section are from a collaboration with Dr. Peter Pilewskie of NASA Ames, who flew Solar Spectral Flux Radiometers (SSFRs) on the same aircraft as our AATS-6 or -14 in PRIDE, SAFARI-2000, ACE-Asia, and ARM 2003 Aersol IOP. The SSFRs measured downwelling and upwelling solar radiative flux spectra, from which the net (downwelling minus upwelling) flux spectrum was derived. The difference between net flux spectra at two altitudes is the absorption spectrum of the included atmospheric layer (gases and particles). Combining this SSFR-measured absorption with AATS-measured AOD in a radiative tranfser model yields spectra of SSA in the layer.

Figure 12 illustrates this type of analysis for an ACE-Asia flight of the Twin Otter, which included level legs at altitudes 43 and 2277 m. The measured absorption spectrum (blue curve in frame a) is shown in frame b as a fraction of the downwelling radiation at the upper level. Frame c shows AOD spectra measured by AATS-14 at the same altitudes. The radiative transfer model of Bergstrom et al. (2003a) used these measured AOD spectra with an assumed wavelength-independent SSA to calculate the model absorption

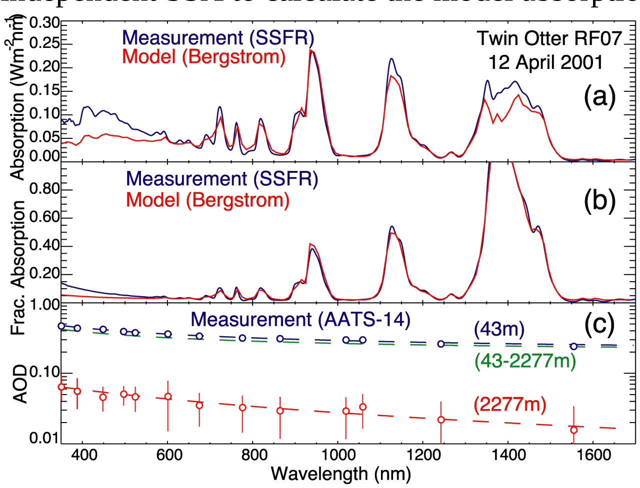

Figure 12. (a) Measured and modeled absorption spectra for Twin Otter Flight RF07, ACE-Asia, 12 April 2001. (b) As in (a), shown as fraction of downwelling flux on 2277 m leg. (c) AOD spectra measured simultaneously on the same aircraft.

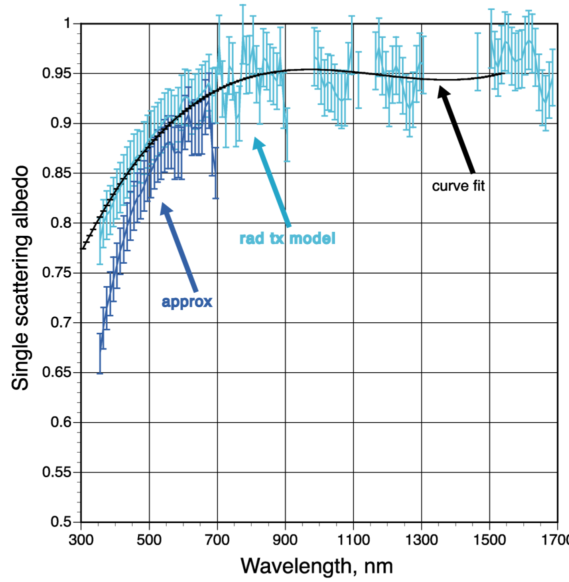

Figure 13. Aerosol single scattering albedo spectra derived from the measured flux and AOD spectra in Figure 12.

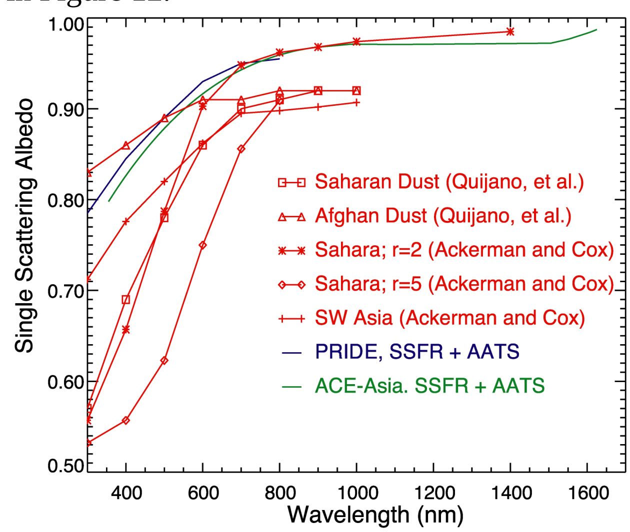

Figure 14. Derived dust single scattering albedo from PRIDE (blue curve) and ACE-Asia (green curve). Five aerosol models are shown for comparison (Quijano et al., 2000; Ackerman and Cox, 1988)

spectra (red curves) shown in frames a and b. Note that this assumed SSA clearly underestimates absorption for wavelengths <600 nm.

Adjusting model SSA to produce a match between modeled and measured absorption yields the SSA values shown in Figure 13 with the wavelength regions dominated by gaseous absorption removed. Figure 14 compares the SSA spectra derived for this ACE- Asia case and an analogous PRIDE case to published results for Saharan, Afghan and SW Asian dusts (Quijano et al., 2000; Ackerman and Cox, 1988).

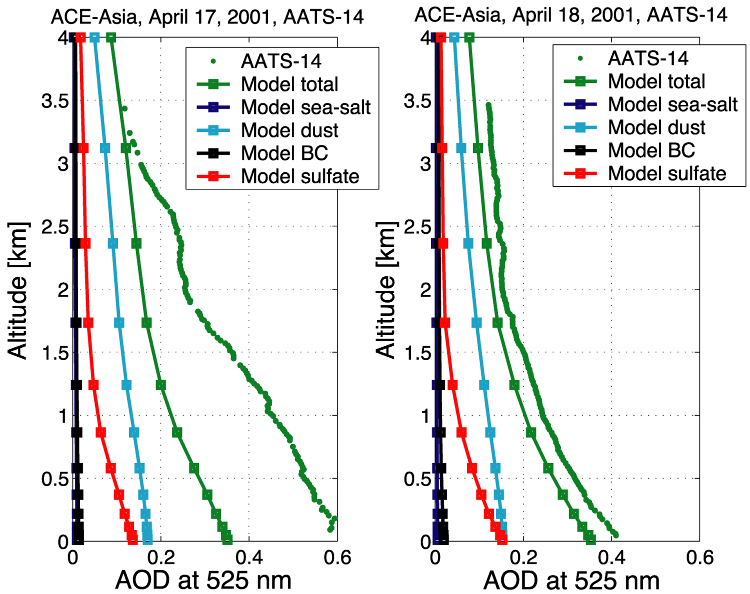

Figure 15. Comparison of AOD profiles measured by airborne sunphotometer (AATS-14) and computed by the GOCART model (e.g., Chin et al., 2002).

2.3.4 Tests of Chemical-Transport Models

International comparisons (e.g., Penner et al., 2001) of the chemical-transport models (CTMs) that predict aerosol spatial distributions show that vertical distributions often differ markedly from model to model. Hence, the vertical profiles of AOD and extinction measured by our airborne sunphotometers (AATS-6 and -14) can provide a key performance test for such CTMs. We have participated in such tests of the models GOCART (e.g., Chin et al., 2002), CARMA/MATCH (Colarco et al., 2003), and MATCH (e.g., Rasch and Collins, 2001).

As an example, Figure 15 shows comparisons between AOD profiles simulated by GOCART and measured by AATS-14 in ACE-Asia. Both days, April 17 and 18, 2001, are cases of mixed aerosols, treated in GOCART as height-dependent profiles of sulfate, soil dust, black carbon (BC), and sea salt. The April 18 case shows good agreement between measured and modeled total AOD profiles, especially in profile shape. In contrast, the April 17 case indicates that the model is underestimating one or more AOD components at the measurement time and location. Comparisons such as this are helping to guide GOCART improvements.

Other comparisons (Colarco et al., 2003, not shown for brevity) between Sahara dust AOD profiles simulated by CARMA/MATCH and AOD profiles measured by AATS-6 in PRIDE (Reid et al., 2002, 2003a,b; Livingston et al., 2003) have helped to test that model's treatment of dust transport and precipitation scavenging.

2.3.5 Regional Forcing Assessments by Combining Satellite and Suborbital Results

Our first regional assessment of aerosol radiative forcing (Bergstrom and Russell, 1999) combined single-wavelength seasonal AOD maps of the North Atlantic region with aerosol intensive properties derived from the TARFOX and ACE-2 field programs. The AOD maps were derived by Husar et al. (1997) from AVHRR reflectances; an example is shown in Figure 3. The aerosol intensive properties included optical depth wavelength dependence across the solar spectrum, single scattering albedo, hemispheric upscatter fraction, and relative vertical profile, all synthesized from suborbital measurements by aircraft and ground sites (including lidars). The satellite and suborbital inputs were combined in a radiative transfer model (Bergstrom et al., 2003a) to derive maps of cloud-free and all-sky radiative forcing; an example for cloud-free conditions is shown in Figure 16. As shown in Bergstrom and Russell (1999), cloud effects, estimated from ISCCP data, greatly reduce the regional annual average, because of the large cloud fractions in the North Atlantic.

More recently we have been using ACE-Asia satellite and suborbital data to estimate the radiative impact of the Asian Pacific plume of desert dust and pollution. Our initial studies have used SeaWiFS-derived maps of aerosol optical depth and Angstrom exponent, as well as in situ data obtained during ACE-Asia. Figure 17a shows a map of the April 2001 monthly mean AOD(865 nm), derived from SeaWiFS-measured radiances using the algorithm of Hsu et al. (2002). We computed corresponding maps of shortwave direct aerosol radiative forcing of climate at the surface and at the top of the atmosphere (TOA) by using the map in Figure 17a in conjunction with profiles of a model dust over a model pollution aerosol, each constrained by ACE-Asia measurements. We adjusted the relative amounts of dust and pollution in each pixel to produce a model Angstrom exponent that matches the SeaWiFS-retrieved Angstrom exponent in that pixel. An example result for surface radiative forcing in cloud-free conditions is shown in Figure 17b.

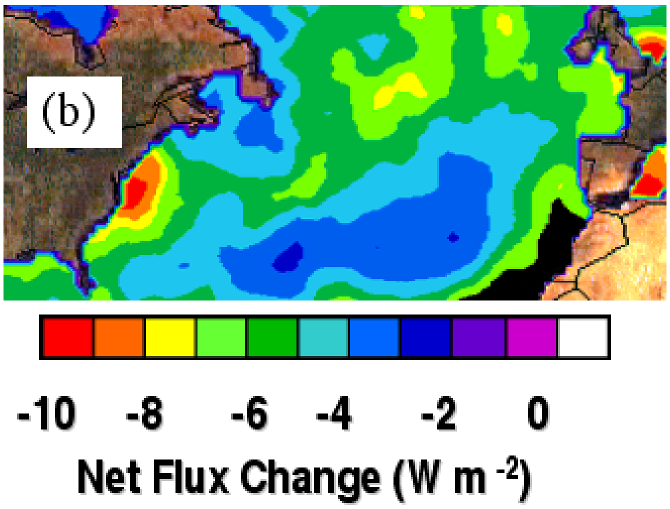

Figure 16. 24h-average, cloud-free direct shortwave aerosol radiative forcing at the tropopause derived from the June-August mean AOD map of Husar et al. (1997). The radiative calculation (Bergstrom and Russell, 1999) assumes an aerosol model based on suborbital measurements in TARFOX and ACE-2. The choice of SSA shown here, ω_a=0.9, is based on radiative flux measurements; other measurements yielded larger SSA (ω_a~0.92 to 0.98) (Russell et al., 2002). Bergstrom and Russell (1999) show results for ω_a=1 and ω_a=0.9.

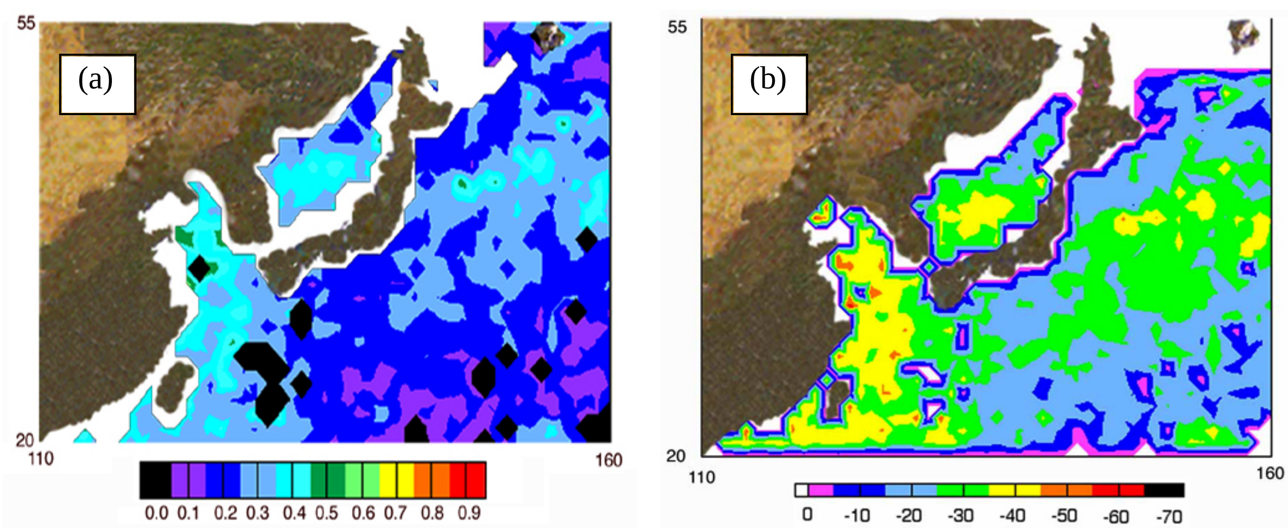

Figure 17. (a) April 2001 monthly mean AOD at 865 nm derived from SeaWiFS radiances using the algorithm of Hsu et al. (2002). (b) 24h-average, cloud-free direct shortwave aerosol radiative forcing at the surface in Wm^{-2}, derived from total aerosol optical depth shown in (a). The calculation assumes an aerosol model of dust over pollution. The relative amounts of dust and pollution aerosols are adjusted pixel-by-pixel to force model Angstrom exponent to equal the Angstrom exponent derived from the 4-wavelength SeaWiFS radiances by Hsu et al. (2002).

In another approach, presented by Redemann et al. (2002d), we have made more explicit use of ACE-Asia aerosol intensive properties derived in closure-study vertical profiles and obtained a cloud-free surface radiative forcing map similar to that in Figure 17b.

2.4 Proposed Tasks and Timing

For the funding requested in Section 3 we propose to provide the necessary personnel, equipment, and supplies to accomplish the following tasks.

2.4.1 Year 1 (Oct 2003 - Sep 2004)

We propose to make measurements in NENA using an Ames Airborne Tracking Sunphotometer (AATS) on flight paths like those shown in Figure 2, acquiring aerosol and water vapor data like those shown in Figures 5-12 and 15. We will coordinate our AATS measurements with those by satellites and by a variety of investigators making suborbital measurements (remote and in situ, from land, sea and air) thus enabling closure studies and integrated analyses like those described in Sections 2.3.1-2.3.5.

At the current stage of planning and funding for NENA, INTEX, and associated experiments it is not clear which combination of an AATS (-14 or -6) and an aircraft platform will provide the highest scientific return per cost, or even which combinations are feasible. Therefore, in the following sections we describe the three options that currently look most promising. These options

Table 2. Summary of proposed options

Instrument/Aircraft Combination	Pros	Cons
Option A. AATS-14 on NOAA P-3 (with SSFR)	• Best Ames airborne sunphotometer capability. - $\lambda = 0.35$ _o2.1 μm - Automated sun-searching; compatible with NOAA shared operator. - No limit on number of turns. • P-3 plans strong coordination with NOAA ship. • Complementary aerosol sensors on board.	• Very difficult for NOAA to accommodate AATS-14 on P-3. Cost or structural limits may be prohibitive.
Option B. AATS-14 on relatively small radiation/aerosol aircraft (e.g., Sky Research Caravan or Jetstream), with SSFR, based at Pease International Tradeport with the NOAA P-3 during NENA	• More flexibility to fly patterns addressing radiation-climate objectives. • May provide best coordination opportunities with NOAA ship and NOAA lidar Aircraft. • Integration period (shorter & at Ames) reduces travel costs & moves pre-mission calibration closer to mission. • Likely to be best way of addressing climate and radiation in NENA/INTEX.	• Requires NASA funding of instrument integration, flight hours, and related aircraft deployment costs. • Complement of onboard aerosol in situ instrumentation not clear yet.
Option C. AATS-6 on NOAA P-3 (with SSFR)	• AATS-6 accomplished a lot of science in ACE-Asia, TARFOX, etc. • P-3 plans strong coordination with NOAA ship. • Complementary aerosol sensors on board.	• AATS-6 needs repair, also mod to make more compatible with NOAA shared operator. Amount of work & \$ to do this currently TBD. May not be compati- ble with short time frame available. • AATS-6 wavelength range limited (λ<~1 μm). • AATS-6 cable limits number or type of A/C turns in spirals

are also summarized briefly in Table 2. The intent of Table 2 and the following sections is to show the pros, cons, and (to the extent possible) the costs of each, so that program managers can make an informed choice on how to maximize scientific return as budgets and aircraft possibilities become clearer.

Option A: AATS-14 Measurements on NOAA P-3. (See Table 2 for summary of pros and cons.) Since Fall 2002 our group has been consulting with Gerd Hubler of the NOAA Aeronomy Lab to help determine whether AATS-14 can be accommodated on the NOAA P-3. This is still being determined. We will continue to work with NOAA Aeronomy Lab and aircraft personnel to determine feasibility and if this is the best way to go. A consideration is the location (including elevation) of the AATS-14 optical head relative to the P-3 external fuselage, and resulting sunlight reflections into AATS-14's tracking detector. If reflected sunlight is likely to create a significant tracking problem, narrowing the tracking detector field of view is a potential fix, though this would require more tracking head turns and time in AATS-14's automated sun-seeking routine. We will continue to assess this as the feasible AATS-14 head elevation on the NOAA P-3 becomes clearer.

Option B: AATS-14 Measurements on Smaller Aircraft (based at Pease International Tradeport with the NOAA P-3 during NENA). As noted in Table 2, this combination may provide the best way to contribute a strong aerosol-radiation component to NENA, including the most frequent opportunities to coordinate airborne radiation-aerosol measurements with the NOAA R/V Brown and NOAA lidar aircraft. Though this option requires NASA funding for the aircraft hours and integration, the use of such aircraft is consistent with NASA's new paradigm of reducing the use of large, NASA-owned aircraft in favor of contracted aircraft that offer more flexibility and cost savings. This new paradigm is reflected in NASA's solicitation of flight requests for FY 2004, which lists the Sky Research Caravan as an available aircraft.

Recently Sky Research has acquired a twin-engine Jetstream-31 (J-31) that would offer flight safety advantages over the Caravan for flight patterns over water (cf. Figure 2). The J-31's range is 850 nm, which would provide many opportunities for coordinated flights with the RV Ron Brown while it is <~300 nm from shore in the Gulf of Maine. (See Figure 14 of NOAA 2003b for possible RV Brown cruise tracks in NENA.) During other times, coordination with satellites and with lidars, radiometers, and in situ sensors on land and other aircraft (including the NOAA P-3) would provide opportunities for many collaborative studies. Because of the many objectives of the NOAA P-3 flights in NENA (many stemming from its longstanding commitment to studies of gas-phase chemistry, air quality, and long-range transport) the P-3's opportunities to fly the patterns shown in Figure 2 will be limited. Prioritizing P-3 flight hours to include sufficient patterns that address aerosol-radiation interactions could well be a difficult and contentious process, played out daily during NENA as weather and aerosol conditions change. Having AATS-14 and complementary instruments on a smaller aircraft like the J-31 at Pease could greatly ease this process.

Currently we are pursuing with NASA program management the use of the J-31 or similar aircraft in NENA and INTEX. Our goal is to have NASA cover the integration, flight-hour, and other deployment costs of such an aircraft, and for it to carry AATS-14, Dr. Peter Pilewskie's SSFRs, and in situ aerosol sensors provided by one or more collaborating investigators. Initial response from NASA program management has been favorable, in part because the planned INTEX call for proposals will include a strong radiative-climatic component. We will keep NOAA managers apprised on the status of these efforts as they evaluate the options in this proposal.

As shown by the budgets in Section 3, this option also offers cost savings to NOAA, mainly because we could integrate and test-fly at NASA Ames, rather than MacDill AFB in Florida. In addition to the scientific and flight-planning advantages mentioned above, it also has the scientific advantage of allowing the pre-mission calibration at Mauna Loa Observatory to be scheduled closer to the NENA mission.

Option C: AATS-6 Measurements on NOAA P-3. For the reasons summarized in Table 2, this option is least favored by our group. In sum, it would require a significant investment to repair and modify an old instrument that would still have less capability than AATS-14. However, as also noted in Table 2, if the other options prove infeasible, this option offers the prospect of yielding the kind of scientific productivity that AATS-6 provided in TARFOX, ACE-Asia, and other experiments.

This option would also be more costly to NOAA than the others, though we won't be able to estimate how much more costly until we complete tests and designs for the necessary repairs and modifications. We expect to start these tests and designs in September 2003, which will probably be while this proposal is still being evaluated. We will keep NOAA program management apprised of the outcome of these tests and designs, and of their cost implications.

2.4.2 Years 2 and 3 (Oct 2004 – Sep 2006)

2.4.2.1 Task 1: AATS Data Reduction and Archival. We will analyze the AATS data set collected in NENA to produce quality-assured transects and profiles of multiwavelength AOD and aerosol extinction, as well as of water vapor columns and densities. We will present the results at NENA data workshops and at scientific conferences. We will deliver quality-assured AATS data to an archive accessible to other investigators, thus encouraging and facilitating their use in collaborative studies. (See, e.g., our previous archives at http://geo.arc.nasa.gov/sgg/AATS-website/AATS_Data.html.)

2.4.2.2 Task 2: Integrated Analyses and Collaborative Studies. This task includes (1) Satellite validation including satellite scene classification, (2) Closure tests among suborbital measurements, (3) Deriving single scattering albedo spectra from radiative flux and AOD spectra, (4) Tests of chemical-transport models, and (5) Regional forcing assessments by combining satellite and suborbital results, as exemplified by Sections 2.3.1–2.3.5. We have proposed these types of studies, for experiments like NENA and INTEX, to NASA as a renewal of our recent tasks in the EOS Inter-Disciplinary Science (IDS) and Radiation Science programs (see bottom row of table in Section 5). We have informal indications that that proposal is expected to be funded. The budget for this proposal to NOAA assumes that we will conduct this task for NENA using NASA funding, without cost to NOAA.

2.4.2.3 Task 3: Concepts and Designs that Address Regular Vertical Profiling of Aerosols. In this task we will produce concepts and designs that address the issues of marrying smaller aircraft with smaller, lighter, lower-power, automated instruments. Possible directions under consideration include miniaturized instruments with the capabilities of AATS-14, as well as instruments with increased capabilities. The miniaturization effort will explore the use of an optical fiber with direct solar beam optics (e.g. offered by Metcon Inc., Boulder) aimed at significantly reducing the size of the instrument and the size of the port required for its installation. Reducing instrument size and weight will yield easier, more cost-efficient integration of the instrument onto smaller aircraft. The effort to enhance the instrument's capabilities will investigate the ability to perform airborne sky radiance measurements to derive aerosol size distribution and absorption much like the retrieval of those parameters from ground-based AERONET sun/sky-radiometers (Holben et al., 1998). In addition, we intend to study the feasibility of performing spectrally continuous direct solar beam measurements by means of a spectrometer (rather than using optical filters at discrete wavelengths as done currently with AATS-14). This task will benefit not only from our previous experience on a wide variety of aircraft (from Cessna Pelican to DC-8), but also our experience in NENA, especially if we do Option B (AATS-14 measurements on a smaller aircraft).

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3. BUDGET

	FY04							FY05			FY06		
	$K	Option A: AATS-14 on NOAA P-3		Option B: AATS-14 on Smaller A/C		Option C: AATS-14 on NOAA P-3		$K			$K		
	/WY	WY	$K	WY	$K	WY	$K	/WY	WY	$K	/WY	WY	$K
Civil Service+Contractors													
P. Russell (Co-PI)		0.10		0.10		0.10			0.10			0.10	
J. Eilers		0.50		0.45		0.80			0.30			0.30	
Secty/Admin (SGG,SG,S,F, etc.)		0.10		0.10		0.10			0.10			0.10	
Total		**0.70**		**0.65**		**1.00**			**0.50**			**0.50**	
F&A costs* **	43.0	0.70	30.1	0.65	28.0	1.00	43.0	45.0	0.50	21.5	47.0	0.50	21.5
Co-op													
B. Schmid, Co-PI (BAERI)	155	0.10	15.5	0.10	15.5	0.10	15.5	169	0.15	23.2	184	0.15	23.2
J. Redemann, Co-PI (BAERI)	141	0.10	14.1	0.10	14.1	0.10	14.1	153	0.15	21.1	167	0.15	21.1
T. Meriam (BAERI)	112	0.08	9.0	0.07	7.8	0.08	9.0	121	0.20	22.4	133	0.20	22.4
S. Ramirez (BAERI)	71	0.02	1.4	0.02	1.4	0.02	1.4	76	0.02	1.4	83	0.02	1.4
J. Livingston, Co-I (SRI)	247	0.09	22.2	0.08	19.8	0.16	39.5	259	0.09	22.2	272	0.08	19.8
Total		**0.39**	**62.1**	**0.37**	**58.5**	**0.46**	**79.4**		**0.61**	**90.3**		**0.60**	**87.9**
F&A costs* **	11.5	0.39	4.5	0.37	4.3	0.46	5.3	9.1	0.61	7.0	9.5	0.60	6.9
Parts (including A/C Interface)			1.0		1.0	TBD				1.0			1.0
Instrument Mods			1.0		1.0	TBD				1.0			1.0
Computation & Lab Support													
Network and computer support			2.0		2.0		2.0			2.0			2.0
Computer/Peripheral Repairs			1.0		1.0		1.0			1.0			1.0
Computer Hardware			3.0		3.0		3.0			3.0			3.0
Bldg 245 Journal Subscriptions			0.3		0.3		0.3			0.3			0.3
Travel			35.9 *		28.1 *		35.9 *			5.0			7.7
Publications			0.0		0.0		0.0			2.0			3.0
Shipping			6.0		4.0		6.0			6.0			6.0
Division Reserve (1.5%)			2.2		2.0		2.7			2.1			2.2
NASA Reimbursible Taxes (6%)			9.5		8.5		11.4			9.1			9.2
Total			**158.7**		**141.6**		**190.0 +**			**151.4**			**152.6**
							& TBD						

*Asssumes NASA pays for Civil Servant travel for deployments & planning (VT travel)

***Explanation for Facilities & Administrative (F&A) Costs

For Civil Servants F&A =G&A +ASP+Directorate Reserve (see below)
For Co-op F&A =0.5*ASP

Directorate Reserve of $2K per workyear is currently not charged on reimbursable tasks and is excluded from rates above.

General and Administrative (G&A) Costs are those not attributable to any one project, but benefiting the entire organization. G&A is calculated by dividing the ARC Institutional costs by the assigned direct workforce. Functions funded from G&A include Safety, Mail Services, Fire, Security, Environomental, Center Management and Staff, Medical Services, and Administrative ADP.

Allocated Service Pool (ASP) charges are not immediately identified to a project but can be assigned based on usage or comsumption. Functions funded include Computer Security, Network Replacement, ISO 9000, Utilities, Photo & Imaging, Maintenance, Data Communications, and Instrumentation.

Travel

FY2004

Option A (AATS-14 Measurements on NOAA P-3)	Airfare Trips	Airfare $/trip	Airfare Total	Per Diem Days	Per Diem $/day	Per Diem Total	Car Days	Car $/day	Car Total	Misc	Total	Total incl. co-op agreement travel burden
P-3 PI Meeting, Boulder, November 2003												
Russell*	1	350	350	1	139	139	1	50	50	200	$739	$739
Planning Meeting, Durham, NH, Spring 2004												
Schmid**	1	350	350	3	123	369	5	50	250	200	$1,169	$1,374
AATS Calibration, Mauna Loa Observatory, HI, April 2004												
Scientist**	1	740	740	10	180	1,800	10	50	500	200	$3,240	$3,807
Engineer**	1	740	740	10	180	1,800			0	200	$2,740	$3,220
AATS-14 Integration on NOAA P-3, MacDill AFB, FL, May 2004												
Includes training NOAA operator												
Engineer*	1	500	500	5	135	675	5	50	250	200	$1,625	$1,625
Test flights, MacDill AFB, FL, June 2004												
Scientist**	1	500	500	5	135	675	5	50	250	200	$1,625	$1,909
Engineer**	1	500	500	5	135	675				200	$1,375	$1,616
NOAA P-3 Deployment, Portsmouth, NH, 1 July - 15 August 2004												
Scientist 1*	1	670	670	18	127	2,286	18	50	900	200	$4,056	$4,056
Engineer*	1	670	670	9	127	1,143				200	$2,013	$2,013
Scientist 2**	1	350	350	17	127	2,159				200	$2,709	$3,522
Scientist 3**	1	350	350	20	127	2,540	20	50	1000	200	$4,090	$4,806
Engineer**	1	350	350	15	127	1,905	15	51	765	201	$3,221	$3,785
Scientist 4**	1	350	350	15	127	1,905				202	$2,457	$2,887
AATS-14 download from NOAA P-3, MacDill AFB, FL, August 2004												
Engineer**	1	500	500	3	135	405	5	50	250	200	$1,355	$1,592
AATS Calibration, Mauna Loa Observatory, HI, September 2004												
Scientist 1**	1	740	740	10	180	1,800	10	50	500	200	$3,240	$4,212
Scientist 2**	1	740	740	10	180	1,800			0	200	$2,740	$3,220
*Civil Servant											Civil Servant Total:	$8,433
**Co-op											Co-op Total:	$35,948
											FY2004 Option A Total:	$44,381

Option C (AATS-6 Measurements on NOAA P-3)		
Same FY04 travel costs as Option A	Civil Servant Total:	$8,433
	Co-op Total:	$35,948
	FY2004 Option C Total:	$44,381

Option B (AATS-14 Measurements on Smaller A/C)	Airfare Trips	Airfare $/trip	Airfare Total	Per Diem Days	Per Diem $/day	Per Diem Total	Car Days	Car $/day	Car Total	Misc	Total	Total incl. co-op agreement travel burden
Planning Meeting, Durham, NH, Spring 2004												
Russell*	1	670	670	3	123	369	5	50	250	200	$1,489	$1,489
AATS Calibration, Mauna Loa Observatory, HI, May 2004												
Scientist**	1	740	740	10	180	1,800	10	50	500	200	$3,240	$3,807
Engineer**	1	740	740	10	180	1,800			0	200	$2,740	$3,220
AATS-14 Integration on Jetstream or Caravan, Moffett Field, CA, May 2004												
No travel cost												
Test flights, Moffett Field, CA, June 2004												
No travel cost												
Jetstream or Caravan Deployment, Portsmouth, NH, 5 weeks in July - August 2004 (to coincide with RV Brown deployment to Gulf of Maine)												
Scientist 1*	1	670	670	20	127	2,540	20	50	1000	200	$4,410	$4,410
Engineer*	1	670	670	9	127	1,143				200	$2,013	$2,013
Scientist 2**	1	350	350	13	127	1,651				200	$2,201	$2,861
Scientist 3**	1	350	350	13	127	1,651	13	50	650	200	$2,851	$3,350
Engineer**	1	350	350	15	127	1,905	15	51	765	201	$3,221	$3,785
Scientist 4**	1	350	350	20	127	2,540				202	$3,092	$3,633
AATS-14 download, Moffett Field, CA, August 2004												
No travel cost												
AATS Calibration, Mauna Loa Observatory, HI, September 2004												
Scientist 1	1	740	740	10	180	1,800	10	50	500	200	$3,240	$4,212
Scientist 2	1	740	740	10	180	1,800			0	200	$2,740	$3,220
*Civil Servant											Civil Servant Total:	$7,912
**Co-op											Co-op Total:	$28,087
											FY2004 Option B Total:	$35,999

FY2005

	Airfare Trips	Airfare $/trip	Airfare Total	Per Diem Days	Per Diem $/day	Per Diem Total	Car Days	Car $/day	Car Total	Misc	Total	Total incl. co-op agreement travel burden
NENA Data Workshop, assumed Boulder, CO												
Russell	1	550	550	4	145	580	4	55	220	300	$1,650	$1,650
Redemann	1	400	400	4	145	580			0	300	$1,280	$1,504
Science Meeting assumed Europe												
Livingston	1	600	600	5	205	1,025			0	200	$1,825	$1,825
											FY2005 Total:	$4,979

FY2006

	Airfare Trips	Airfare $/trip	Airfare Total	Per Diem Days	Per Diem $/day	Per Diem Total	Car Days	Car $/day	Car Total	Misc	Total	Total incl. co-op agreement travel burden
NENA/INTEX Integrated Science Workshop, assumed Durham, NH												
Russell	1	550	550	4	130	520	4	55	220	300	$1,590	$1,590
Schmid	1	400	400	4	130	520			0	300	$1,220	$1,434
AGU, San Francisco, December 2005												
Russell										300	$300	$300
Livingston										300	$300	$390
Redemann										300	$300	$353
Schmid										300	$300	$353
Science Meeting assumed Europe												
Russell	1	1,300	1,300	5	259	1,295			0	300	$2,895	$2,895
Redemann	1	1,300	1,300	5	259	1,295			0	300	$2,895	$3,402
											FY2006 Total:	$7,692

4. STAFFING, RESPONSIBILITIES, AND VITAE

Drs. Philip Russell, Beat Schmid, and Jens Redemann will be Co-Principal Investigators. They will supervise the work, lead the planning, and participate in the measurements and analyses, as well as in selected presentations and publications. They will be responsible for the completion of the work within budget and schedule. Drs. Schmid and Redemann will have primary responsibility for the work in Years 2 and 3 on concepts and designs addressing Regular Vertical Profiling of aerosols. Mr. John Livingston will be Co-Investigator. He will participate in the planning, measurements, analyses and publications, Ames will furnish additional personnel necessary to accomplish the research.

(a) Philip B. Russell
Abbreviated Curriculum Vitae

B.A., Physics, Wesleyan University (1965, Magna cum Laude; Highest Honors). M.S. and Ph.D., Physics, Stanford University (1967 and 1971, Atomic Energy Commission Fellow). M.S., Management, Stanford University (1990, NASA Sloan Fellow).

Postdoctoral Appointee, National Center for Atmospheric Research (1971-72, at University of Chicago and NCAR). Physicist to Senior Physicist, Atmospheric Science Center, SRI International (1972-82). Chief, Atmospheric Experiments Branch (1982-89), Acting Chief, Earth System Science Division (1988-89), Chief, Atmospheric Chemistry and Dynamics Branch (1989-95), Research Scientist (1995-present), NASA Ames Research Center.

NASA Ames Honor Award (2002, for excellence in scientific research). NASA Ames Associate Fellow (1995, for excellence in atmospheric science). NASA Space Act Award (1989, for invention of Airborne Autotracking Sunphotometer). NASA Exceptional Service Medal (1988, for managing Stratosphere-Troposphere Exchange Project). Member, Phi Beta Kappa and Sigma Xi.

Currently, Member, Science Teams for NASA's Earth Observing System Inter-Disciplinary Science (EOS-IDS) and Solar Occultation Satellites (SOSST)

Previously, Mission Scientist for C-130 flights addressing aerosol-radiation interactions in the Asian Pacific Regional Aerosol Characterization Experiment (ACE-Asia) of the International Global Atmospheric Chemistry (IGAC) Project. Co-coordinator for the CLEARCOLUMN component of IGAC's Second Aerosol Characterization Experiment (ACE-2). Coordinator for IGAC's Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX). Member, Science Teams for SAGE II and SAGE III (satellite sensors of stratospheric aerosols, ozone, nitrogen dioxide, and water vapor). Member, Science Team for Global Aerosol Climatology Project (GACP).

Previously, Editor-in-Chief (1994-95) and Editor (1993, 1996), *Geophysical Research Letters*. Chair, American Meteorological Society Committee on Laser Atmospheric Studies (1979-82). Member, AMS Committee on Radiation Energy (1979-81). Member, National Research Council Committee on Army Basic Research (1979-81).

Previously, Project Scientist, Small High-Altitude Science Aircraft (SHASA) Project to develop the Perseus A Remotely Piloted Aircraft (RPA, 1992-94). Member, NASA Red Team on Remote Sensing and Environmental Monitoring of Planet Earth (1992-3). Leader, NASA Ames Earth Science Advanced Aircraft (ESAA) Team (1990-94).

PUBLICATIONS (Over 110 peer-reviewed publications. Per the guidelines, this list is limited to all publications in the last three years—the allowance for up to five other relevant papers is not used to save space. See Section 2.5, References for complete citations.**)**

Bergstrom et al., 2002, 2003; Colarco et al., 2003; Collins et al., 2000; Durkee et al., 2000; Ferrare et al., 2000a,b; Gasso et al., 2000; Hartley et al., 2000; Huebert et al., 2003a,b; Ismail et al., 2000; Levy et al., 2003; Livingston et al., 2000, 2003; Murayama et al., 2003; Pilewskie et al., 2000; Redemann et al., 2000a,b, 2001, 2003; Reid et al., 2003; Russell and Heintzenberg, 2000; Russell et al., 2002;

Schmid et al., 2000, 2001, 2003a,b; Wang [Jian] et al., 2002; Wang [Jun] et al., 2003a,b; Welton et al., 2000; Xu et al., 2003

Plus 2 others in 2003 not cited in this proposal.

(b) Beat Schmid
Abbreviated Curriculum Vitae

Education

M.S.	1991	Institute of Applied Physics, University of Bern, Switzerland
Ph.D.	1995	Institute of Applied Physics, University of Bern, Switzerland
Postdoctoral Fellowship	1995-97	Institute of Applied Physics, University of Bern, Switzerland

Professional Experience
Bay Area Environmental Research Institute, Sonoma, CA (1997-Present)
Senior Research Scientist, Principal Investigator, Group Leader (since July 2003)

University of Arizona, Tucson, AZ (Oct. 1995 -Jan. 1996)
Visiting Scientist

University of Bern, Switzerland (1989-1997)
Research Assistant (1989-1995)
Postdoctoral Researcher (1995-1997)

Scientific Contributions

- Conducted 10 years of leading studies in ground-based and airborne sun photometry: instrument design and calibration, development and validation of algorithms to retrieve aerosol optical depth and size distribution, H_2O and O_3.
- Participated with the NASA Ames Airborne Sun photometers in ACE-2 (North Atlantic Regional Aerosol Characterization Experiment, 1997, Tenerife). Extensive comparison of results (closure studies) with other techniques: lidar, optical particle counters, nephelometers, and satellites.
- Employed NASA Ames Airborne Sun photometers in the US Dept. of Energy, Atmospheric Radiation Measurement (ARM) program integrated fall 1997 and fall 2000 intensive observation periods in Oklahoma. Led sun photometer intercomparison. Extensive comparison of water vapor results with radiosondes, microwave radiometers, lidar, and Global Positioning System.
- Operated NASA Ames Airborne Sun photometers in SAFARI 2000 (Southern African Regional Science Initiative; August/September 2000). Validation of lidar and satellite retrievals.
- Participated with the NASA Ames Airborne Sun photometers in ACE-Asia (Asian Pacific Regional Aerosol Characterization Experiment; April 2001). Closure studies, satellite and lidar validation.
- Operated the NASA Ames Cavity Ringdown instrument in Reno Aerosol Optics Study (June, 2002). Comparison of aerosol extinction, scattering and absorption from various methods (cavitiy ring down, photo-acoustic, nephelometer, filter based)
- Participated with the NASA Ames Airborne Sun photometers in SAGE III Ozone Loss and Validation Experiment (SOLVE2, January 2002) and Asian Dust above Monterey (ADAM, April 2003) experiment.
- Led planning of DOE ARM May 2003 Aerosol Intensive Observation Period. Responsible for defining airborne payload on the CIRPAS Twin Otter aircraft. Led Twin Otter investigators (10 PI's) during field campaign as platform scientist.
- Applied NOAA/AVHRR satellite data to monitor vegetation growth in Switzerland

Scientific Societies/Editorships

- Associate Editor, *Journal Geophysical Research* (2002-)
- Member, American Geophysical Union and American Meteorological Society

Grants

- Principal Investigator, DOE ARM Science Team.
- Principal Investigator on two Cooperative Agreements between Bay Area Environmental Research Institute and NASA Ames Research Center since 2000. Responsible for research and financial administration of 4 fulltime scientist positions.
- Co-PI and Co-I on numerous research grants funded by NASA, NOAA, Office of Naval Research (ONR) and National Science Foundation (NSF).

PUBLICATIONS (33 peer-reviewed publications. Per the guidelines, this list is limited to all publications in the last three years—the allowance for up to five other relevant papers is not used to save space. See Section 2.5, References for complete citations.**)**

Bergstrom et al., 2003; Colarco et al., 2003; Collins et al., 2000; Durkee et al., 2000; Ferrare et al., 2000a; Gasso et al., 2000; Gatebe et al., 2003; Ingold et al., 2000; Kaufman et al., 2003; Keidron et al., 2001; Livingston et al., 2000, 2003; Magi et al., 2003; McGill et al., 2002; Murayama et al., 2003; Pilewskie et al., 2000, 2003; Redemann et al., 2000a, 2003; Revercomb et al., 2003; Russell et al., 2002; Schmid et al., 2000, 2001, 2003a,b; Wang [Jian] et al., 2002; Wang [Jun] et al., 2003b; Welton et al., 2000

(c) Jens Redemann
Abbreviated Curriculum Vitae

PROFESSIONAL EXPERIENCE

Senior Research Scientist	BAERI, Sonoma, CA	**April 1999 to present**
Research Assistant	UCLA, CA	**May 1995 to March 1999**
Lecturer	UCLA, CA	**Jan. 1999 to present**
Research Assistant	FU Berlin, Germany	**June 1994 to April 1995**

EDUCATION

Ph.D. in Atmospheric Sciences, UCLA.	**1999**
M.S. in Atmospheric Sciences, UCLA.	**1997**
M.S. in Physics, FU Berlin, Germany.	**1995**

RELEVANT RESEARCH EXPERIENCE

- Principal Investigator, NASA New Investigator Program, 2002-2005.
- Principal Investigator for the participation of AATS-14 (a narrow-band tracking sunphotometer) in the CLAMS satellite validation study (July 2001). Responsible for proposal writing and experiment design, instrument integration, as well as scheduling and supervision of three group members.
- Developed a coupled aerosol microphysics and chemistry model to study the dependence of the aerosol single scattering albedo on ambient relative humidity.
- Related airborne measurements using a sunphotometer, a lidar (light detection and ranging) system and a spectral solar flux radiometer to in situ measurements of atmospheric (mineral dust) aerosols and gases and modeled the local radiative transfer in Earth's atmosphere.
- Participated in the SAFARI-2000, ACE-Asia, PRIDE and CLAMS field experiments aimed at investigating atmospheric aerosols. Member of CLAMS (Chesapeake Lighthouse Aerosol Measurements for Satellites) science team.

- Utilized satellite derived aerosol optical depth fields and aerosol properties from the ACE-Asia campaign to determine the aerosol radiative forcing of climate in the Pacific Basin troposphere.

HONORS / ORGANIZATIONS

Invited Presentation at the 5th International APEX workshop, Miyazaki, Japan.	**July 2002**
Invited Presentation at the Atmospheric Chemistry Colloquium for Emerging Senic Scientists (ACCESS V).	**1999**
Outstanding Student Paper Award, AGU Fall meeting.	**1998**
NASA Global Change Research Fellowship Awards.	**1995-1998**
UCLA Neiburger Award for excellence in teaching of the atmospheric sciences.	**1997**

PUBLICATIONS (17 peer-reviewed publications. Per the guidelines, this list is limited to all publications in the last three years—the allowance for up to five other relevant papers is not used to save space. See Section 2.5, References for complete citations.**)**

Colarco et al., 2003; Livingston et al., 2003; Magi et al., 2003; Murayama et al., 2003; Redemann et al., 2000a,b, 2001, 2003; Russell et al., 2002; Schmid et al., 2003a,b; Wang [Jian] et al., 2002; Wang [Jun] et al., 2003b

Plus 1 in 2001 not cited in this proposal.

(d) **John M. Livingston**

SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025

Education

Notre Dame Year-in-Japan Program	1971-72	Sophia University, Tokyo, Japan
B.S., earth sciences	1974	University of Notre Dame, Notre Dame, IN
M.S., atmospheric sciences	1977	University of Arizona, Tucson, AZ
M.B.A.	1992	Santa Clara University, Santa Clara, CA

Professional Experience

SRI International (formerly Stanford Research Institute), Menlo Park, CA (1978-present)
- Senior Research Meteorologist, Center for Geospace Studies, Engineering and Systems Division

University of Arizona,Tucson, AZ (1974-1977)
- Research assistant, Institute of Atmospheric Physics
- NASA Kennedy Space Center (1975-1976): thunderstorm electrification studies

Scientific Contributions

- Acquisition and analysis of ground-based, airborne, and shipboard sunphotometer measurements in a variety of coordinated international field campaigns to study the radiative impact on climate of anthropogenic pollution, volcanic aerosol, and African and Asian dust
- Validation of satellite aerosol extinction measurements (SAM II, SAGE I, SAGE II, SAGE III), and corresponding studies of the global distribution of stratospheric aerosols
- Analysis of in situ measurements of stratospheric and tropospheric aerosols

- Analysis of ground-based lidar measurements obtained at Sondrestrom, Greenland to retrieve atmospheric density and temperature profiles in the polar stratosphere and mesosphere and to characterize the physical properties of noctilucent clouds
- Acquisition, modeling and analysis of Differential Absorption Lidar measurements of tropospheric ozone
- Simulation of passive sensor radiance measurements to infer range to an absorbing gas
- Error analysis and simulation of lidar aerosol measurements
- Analysis of lidar propagation through fog, smoke, and dust clouds
- Weather forecasting for large-scale air pollution field study
- Testing and evaluation of an offshore coastal dispersion computer model
- Application of objective wind field/trajectory models to meteorological measurements

Honors and Awards
- 1997 NASA Ames Research Center Contractor of the Year

Scientific Societies
- American Geophysical Union

Publications (Over 45 scientific publications. Per the guidelines, this list is limited to all publications in the last three years—the allowance for up to five other relevant papers is not used to save space. See Section 2.5, References for complete citations.**)**

Colarco et al., 2003; Collins et al., 2003; Durkee et al., 2000; Ferrare et al., 2000a,b; Flamant et al., 2000; Levy et al., 2003; Livingston et al., 2000, 2003; Murayama et al., 2003; Redemann et al., 2000a, 2003; Reid et al., 2002, 2003a,b; Russell et al., 2002; Schmid et al., 2003b; Wang [Jian] et al., 2002; Wang [Jun] et al., 2003a

5. CURRENT AND PENDING SUPPORT

Short Title	Agency/Task No.	Investigator Months per Year				Dollar Value	Duration	Status
		PBR	BS	JR	JML			
Global Aerosol Climatology	NASA RTOP 622-44-75-10	3	2	2	2	$202,000 in FY03	10/1998-9/2003	Funded
Quantification of Aerosol Radiative Effects (Prongs B & C)	NOAA Interagency Transfer of Funds NA03AANRG0088	2	3	2	1	$195,000 in FY03	4/2003-3/2006	Funded
NASA New Investigator Program: "Validating EOS Terra sensor retrievals"	NASA HQ / NAG5-12573			3		$107,600 in FY03	11/2002-10/2005	Funded
Vertically resolved aerosol optical properties over the ARM SGP site	DOE ARM Science Team DE-AI03-03ER63535		2	1		$115,000 in FY03	11/2002-10/2005	Funded
AATS-14 in 2003 Aerosol IOP	DOE ARM IOP funds ITF 355506-A		2	1		$34,500 in FY03	2/2003-12/200	Funded
Solar Occultation Satellite Science Team (SOSST)	NASA RTOP 229-10-32-00	1	1		1	$75,000 in FY03	7/2003-6/2006	Funded
Satellite-Sunphotometer Studies of Aerosol,…	NASA RTOP 291-01-91-45	5	1	2	2	$227,000 in FY03	2/2000-12/2002	Pending