ARM Aerosol IOP
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Abstract

Aerosol influences on shortwave radiation are substantial locally and globally. An aerosol optical thickness of 0.1 results in an instantaneous decrease in direct normal surface irradiance of ca 100 watts per square meter, and (depending on particle size and single scattering albedo) a top of atmosphere forcing of ca 30 watts per square meter. Such optical depths are not uncommon at SGP. Aerosols also substantially influence the diffuse downwelling surface irradiance; the magnitude of this influence, and also of the vertical distribution of atmospheric heating, depends sensitively on the aerosol single scattering albedo.

Knowledge of pertinent aerosol properties is required to accurately represent aerosol forcing in models. ARM CART has been systematically measuring aerosol properties at the surface and limited measurements aloft from light aircraft. It is shown by lidar and in-situ measurements that much of the aerosol at SGP is aloft, often in layers that are decoupled from the surface, raising question of the representativeness of surface aerosol properties for these calculations. Vertical profiles of aerosol properties are key parameters required for the computation of radiative flux profiles. Detailed measurements of aerosol optical properties are required to characterize the aerosol optical, microphysical, and chemical properties at the surface and above the SGP site for accurately computing radiative fluxes. Such well-characterized data would permit a more detailed evaluation of the performance of radiative transfer models to compute flux profiles and heating rates.

The planned IOP will carry out a variety of closure experiments on aerosol optical properties and their radiative influence. Additionally, planned measurements of the aerosol chemical composition size distribution, to be conducted by investigators in the DOE Atmospheric Chemistry Program and Tropospheric Aerosol Program, will allow testing of the ability to reconstruct optical properties from these measurements. Additional effort will be directed toward measurement of cloud condensation nucleus concentration as a function of supersaturation and relating to aerosol composition and size distribution. This relation is central to description of the aerosol indirect effect.

Additional participants are sought for this IOP. Contact one of the authors of this Poster.

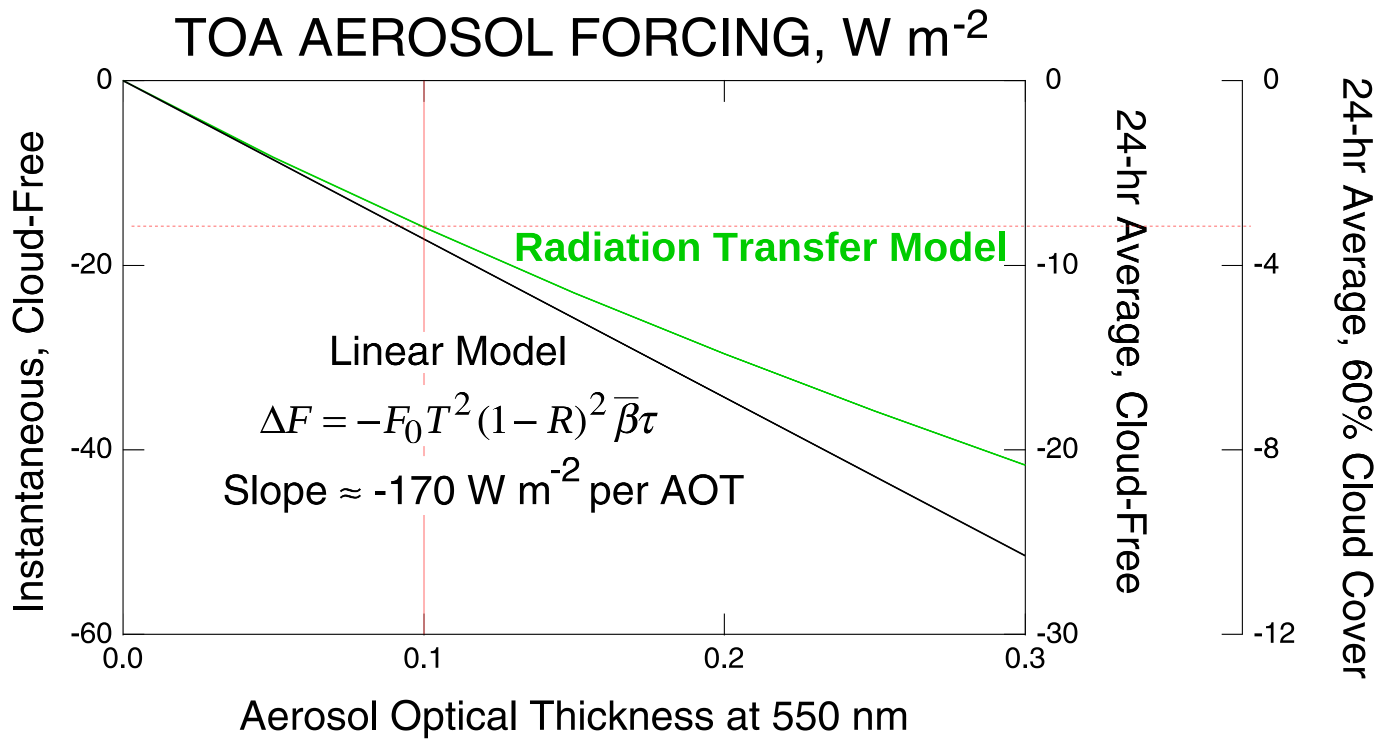
IMPORTANCE . . .

DIRECT AEROSOL FORCING AT TOP OF ATMOSPHERE

Dependence on Aerosol Optical Thickness

Comparison of Linear Formula and Radiation Transfer Model

Particle radius r = 85 nm; surface reflectance R = 0.15; single scatter albedo $\omega_0 = 1$.

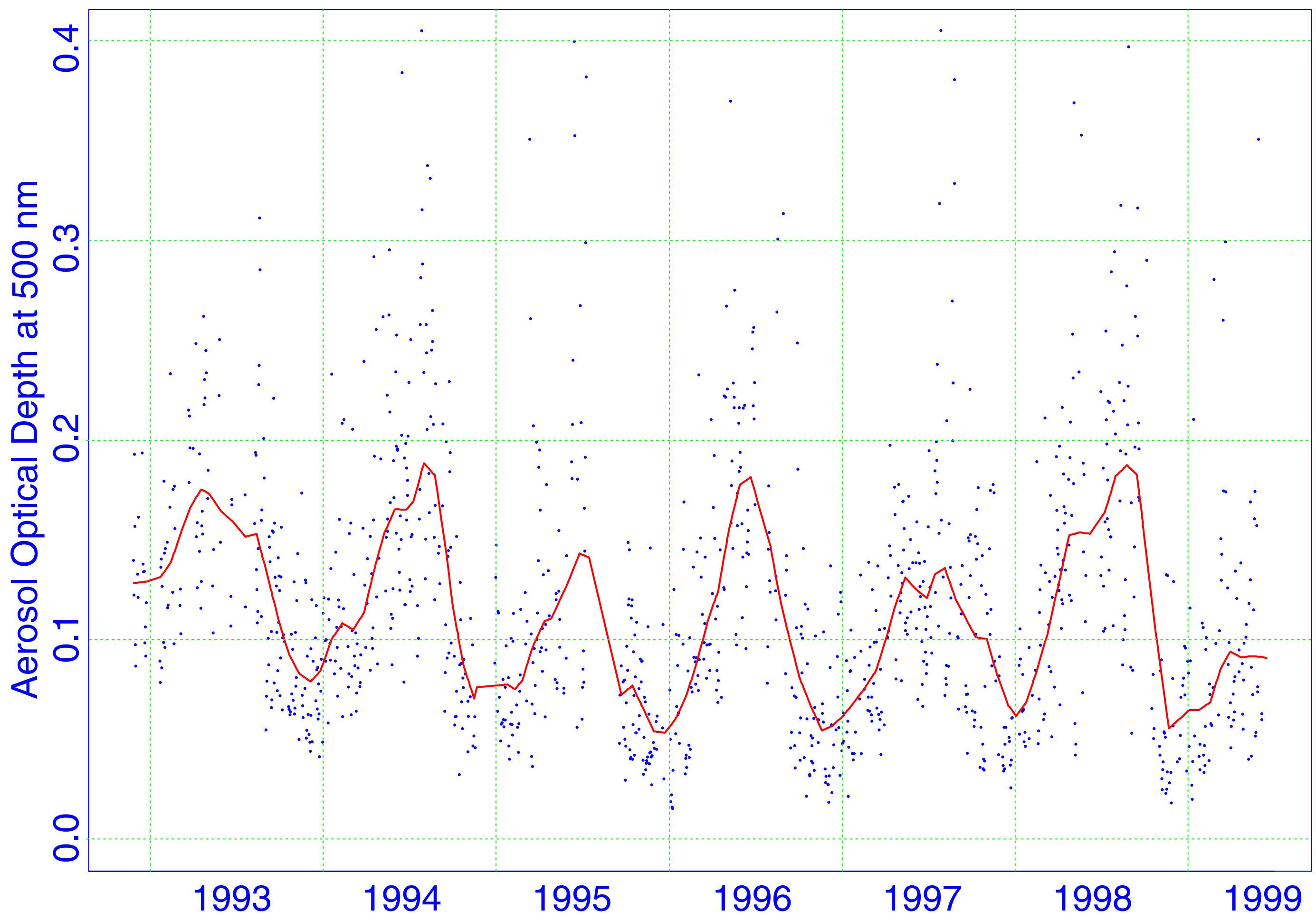


Global-average AOT 0.1 corresponds to global-average forcing -3.2 W m^{-2}.

AEROSOL OPTICAL DEPTH

Determined by Sunphotometry

North Central Oklahoma



J. Michalsky et al., JGR, 2001

Closure Experiments

ARM Aerosol Observing System

ARM Radiometric Instruments

Measured Aerosol Properties → Model → Calculated Observable Geophysical Quantity ?= Observed Geophysical Quantity

A New Paradigm in Studying Climate Influences of Atmospheric Aerosols

CLOSURE OF IRRADIANCES AND FLUXES

Closure between measurements and models of ***diffuse radiation*** under low AOT conditions (cloud free sky) with accurate measurements of the aerosol single scattering albedo?

Specific closure experiments and measurement comparisons - See measurement requirements

Aerosol absorption (surface, dry) - 1, 2

PSAP (AOS) vs. Aethelometer vs. photoacoustic

Aerosol absorption profiles from SGP routine measurements - 1, 16, 23, 2, 11, 25

IAP (dry) vs. PSAP (airborne) vs. photoacoustic (airborne)

Comparison of in-situ profiles (IAP, PSAP, photoacoustic) vs. AOT from Cimel, MFRSR, and/or polarization

Diffuse Downwelling (broadband) - 16, 17, 18, 10, 6, 14, 15, 16, 27

Measured (shaded pyranometer) vs. Model (aerosol + gas) input

Diffuse Downwelling (spectral) - 16, 17, 9, 10, 7, 14, 15, 16, 27

Measured (RSS, SSFR) vs. Model (aerosol + gas) input

Diffuse/Direct Ratio (spectral) - 16, 17, 9, 10, 7, 14, 15, 16, 27

Measured (RSS, SSFR) vs. Modeled (aerosol + gas) input

Note fan-out of measurement streams. Individual measurements are used in multiple experiments.

CLOSURE OF AEROSOL OPTICAL THICKNESS

Closure between routine CART Raman lidar and In-situ Aerosol Profiling of aerosol scattering and extinction profiles and AOT?

Specific closure experiments - See measurement requirements

Aerosol extinction (surface, dry) - 1, 2, 3

Nephelometer (AOS) + absorption {PSAP (AOS) or photoacoustic or Aethelometer} vs. cavity ringdown

Aerosol extinction (surface, ambient RH) - 1, 2, 3, 4, 6, 14

Nephelometer (AOS) + absorption + humidification factor (AOS) vs. differential sun photometers (surface + airborne)

Cavity ringdown + humidification factor (AOS) vs. differential sun photometers (surface + airborne)

Aerosol humidification factor (profile) - 15, 13, 23

AOS (surface) + IAP (single elevated RH) vs. aircraft humidigraph

Aerosol scattering, absorption, and extinction profiles from SGP routine measurements - 15, 11, 23, 25

IAP (dry) vs. nephelometer (airborne)

Aerosol absorption profiles from SGP routine measurements - 1, 16, 23, 2, 11, 25

IAP (dry) vs. PSAP (airborne) vs. photoacoustic (airborne)

Aerosol Extinction Profiles from SGP Routine Measurements - 14, 15, 16, 23, 1, 4, 11, 12, 25

Raman/MPL lidars vs. sun photometer (airborne) vs. nephelometer + PSAP + humidification factor (airborne)

CLOUD CONDENSATION NUCLEI (CCN) AND CLOUDS

Key questions to be answered

- Confirm relationship between CCN number concentration (at several supersaturations in the range ~0.1 - 1%) and aerosol size distribution, at the surface and at cloud base?
- How well can the cloud nucleating properties of particles just below cloud base be represented using surface measurements of cloud nucleating properties of particles along with profiles of relative humidity and aerosol extinction?
- What is the relationship between the cloud base CCN number concentrations and size distributions, cloud base turbulence, and cloud droplet number concentrations and size distributions?

CLOUD CONDENSATION NUCLEI (CCN) AND CLOUDS

Specific experiments - See measurement requirements

CCN spectrum (surface) - 7, 8, 26

measured vs. modeled

CCN spectrum (cloud base) - 7, 8, 19, 20, 21, 23

measured vs. modeled

CCN (profile) - 7, 8, 15, 23

CCN (surface) + lidar aerosol extinction + humidification + RH vs. CCN aircraft

Cloud liquid water path - 21, 22, 23

In-situ (vertical integral of LWC from Johnson probe, Gerber probe) vs. remote (MWR, radar)

In-situ (vertical integral of cloud drop conc.) vs. in-situ (vertical integral of LWC from Johnson probe, Gerber probe)

Cloud transmittance - 20, 21, 22, 23

Surface measurements of optical depth (RSS) vs. Model + LWP + drop concentration

Cloud drop concentration - 7, 8, 20, 21, 23, 24

Model from radar vs. aircraft in situ

Model from radar vs. Model + CCN spectrum + vertical velocity

MEASUREMENT REQUIREMENTS AND INSTRUMENTS

	Measurement	Instrument	Possible PI/team	Sfc ● (green)	Air ● (blue)
1	Aerosol absorption (532 nm)	Photoacoustic	Arnott, Moosmueller DRI	●	●
2	Aerosol absorption (450, 550, 700 nm)	Modified Aethelometer	Ogren CMDL	●	
3	Aerosol extinction (532 nm)	Cavity Ringdown (CRD)	Arnott, Moosmueller DRI	●	
4	Aerosol extinction (700 nm)	Cavity Ringdown (CRD)	Strawa NASA-Ames		●
5	Broadband irradiance	Broadband cavity radiometer	Michalsky PNNL	●	
6	Aerosol optical thickness (0.3-2.5 μm), sky radiance, polarization, BRDF	Sun-sky-surface sensor	Tsay NASA-GSFC	●	
7	CCN	CCN spectrometer	Hudson DRI	●	●
8	CCN	CCN spectrometer	Seinfeld Cal Tech		●
9	Diffuse/direct radiance (300-380 nm)	UVRSS	Michalsky SUNY-Albany	●	
10	Column ozone	UVRSS or CSU- MFRSR	Michalsky SUNY-Albany	●	
11	Aerosol extinction profiles, aerosol mean radius, refractive index, single scatter albedo (nighttime)	Multi-wavelength Raman/Rayleigh-Mie Lidar	Ansmann, Wandlinger IfT	●	

MEASUREMENT REQUIREMENTS AND INSTRUMENTS (cont'd)

	Measurement	Instrument	Possible PI/team	Air ● Sfc ●
12	Aerosol extinction (horizontal profile) (355 nm)	Scanning Raman Lidar	NASA-GSFC	●
13	Aerosol size distribution 10 nm - 1 µm at 2 RH	TDMA	Cal Tech	●
14	Aerosol optical thickness, extinction profiles	Airborne AATS-14 Sun photometer	Russell, Schmid NASA-Ames	●
15	Aerosol hygroscopic scattering	Humidified Neph, humidigraph	Covert U. Wash	●
16	Aerosol absorption	PSAP	Covert U. Wash	●
17	Up- and downwelling SW spectral irradiance/radiance, surface albedo 300-2500 nm	Solar Spectral Flux Radiometers (SSFR)	Pilewskie NASA-Ames	●
18	Total upward and downward fluxes	Kipp and Zonen CM-22 pyranometers, CG-4 pyrgeometers	A. Bucholtz NRL and/or McCoy Sandia	●
19	Aerosol Size Distribution 0.3-2.5 µm	PCASP (0.1-2.5 µm) >0.3 µm (CAPS)	CIRPAS	●

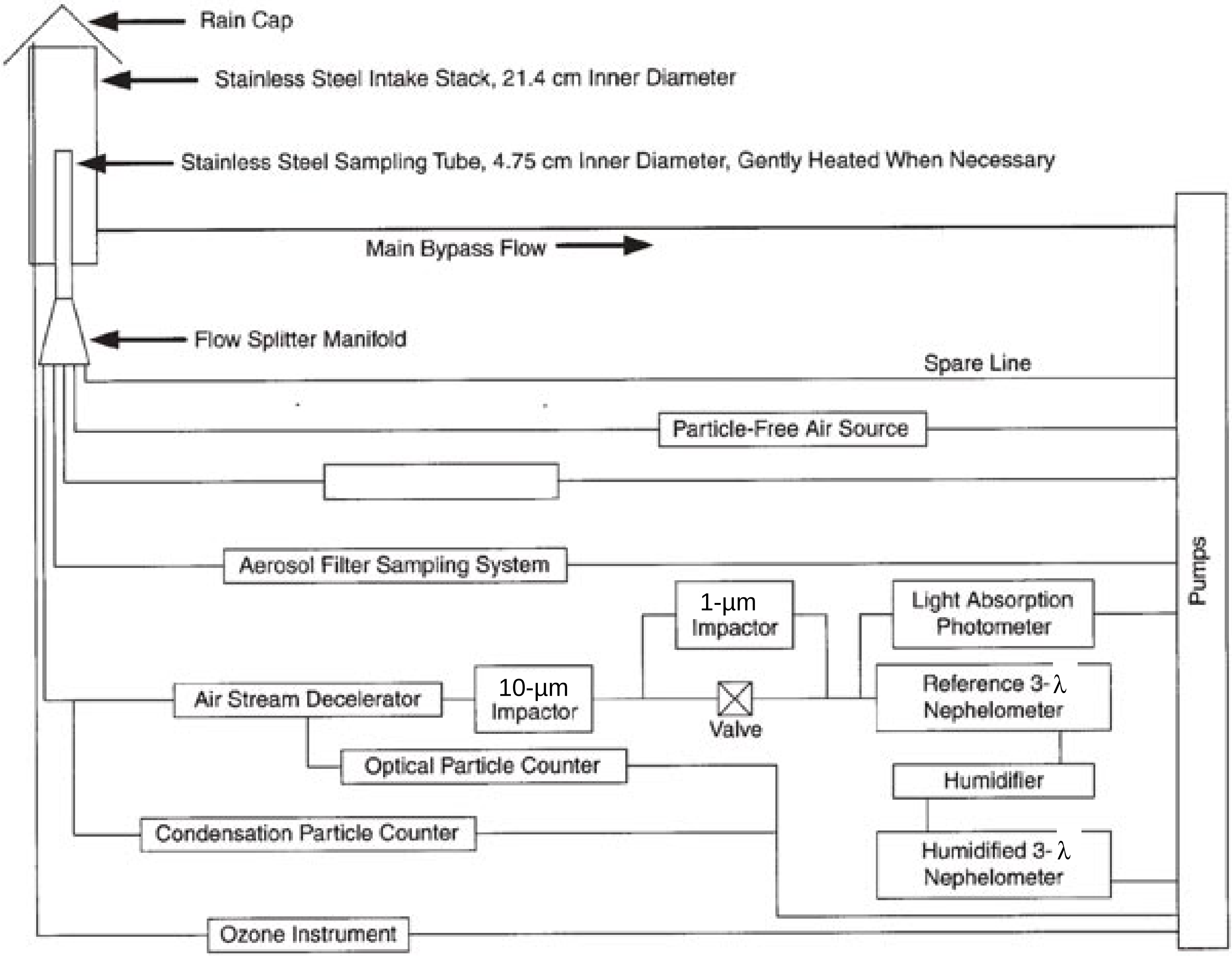
MEASUREMENT REQUIREMENTS AND INSTRUMENTS (cont'd)

	Measurement	Instrument	Possible PI/team	Air ● Sfc ●
20	Aerosol Size Distribution >0.5 μm	TSI aerodynamic particle sizer	CIRPAS	●
21	Aerosol/Cloud Drop Size Distribution 0.5-50 μm	CAPS, FSSP	CIRPAS	●
22	Cloud liquid water	Johnson probe, Gerber PVM probe	CIRPAS	●
23	Meteorological state	Standard instruments	CIRPAS	●
24	Turbulence, updraft velocity	Analysis	CIRPAS	●
25	Polarization measurements of radiance (aerosol refractive index), BRDF	Research Scanning Polarimeter (RSP) or Cimel	Cairns NASA-GISS	●
26	Aerosol Size Distribution (20 - 500 nm)	SMPS	Hudson DRI	●
27	Reflectance, radiance or irradiance spectra (350-2500 nm)	ASD spectroradiometer	??	●

IOP WILL MAKE EXTENSIVE USE OF ROUTINE MEASUREMENTS AT CART SITE

Instrument	*Primary Measurement*	*Derived quantities*
AOS (Surface)	*Aerosol light scattering at 3 λ* *Aerosol absorption coefficient (RH ≤ 40%), (< 1, 10 µm)* *Light scattering (green) as f(RH)* *Aerosol number distribution (0.1 to 10 µm)* *Total condensation particle concentration* *Ozone*	*Aerosol extinction coefficient* *Aerosol single scattering albedo* *Angstrom exponent* *Hemispheric backscatter fraction*
CSPOT (Cimel) Sun and sky photometer	*AOT (6 λ)* *Sky radiance in principal plane and almucantar*	*Angstrom exponents* *Aerosol size distribution* *Refractive index* *Single scatter albedo*
MFRSR	*AOT (5 λ)*	*Angstrom exponent* *Direct/diffuse ratio*
RSS	*Direct spectral irradiance* *Diffuse spectral irradiance*	*AOT ƒ(λ)*

AEROSOL SAMPLING SYSTEM AT SGP SITE



Sheridan, Delene & Ogren, JGR, 2001

ROUTINE MEASUREMENTS AT CART SITE (cont'd)

Instrument	*Primary Measurement*	*Derived quantities*
CART Raman Lidar	*Aerosol backscatter profiles* *Aerosol extinction profiles* *Aerosol optical thickness profiles* *Water vapor mixing ratio profiles*	*Relative humidity (z)*
MPL	*Relative aerosol backscatter*	*Aerosol backscatter profiles* *Aerosol extinction profiles*
In-situ Aerosol Profiling (IAP)	*Aerosol scattering (3 λ) (dry)* *Aerosol absorption (1 λ) (dry)* *Hemispheric backscatter fraction (dry)* *Aerosol scattering (1 λ) (high RH) (future)*	*Single scatter albedo* *AOT* *Angstrom exponents*
Aerosol Sample	*Aerosol mass concentration* *Aerosol ionic composition*	

Use of routine measurements at CART site will enhance future utility of those measurements.

KEY AEROSOL PROPERTIES TO BE MEASURED AT SURFACE

- Scattering coefficient (450, 550, 700 nm)
  - Total (7-170˚) and backscatter (90-170˚)
  - Dry (RH < 40%) and *f*(RH) (40 - 90%)
  - Aerodynamic diameter < 10 µm and < 1 µm
- Aerosol absorption coefficient (PSAP, 550 nm)
- CCN spectrum 0.1 - 1% supersaturation
- Aerosol extinction (Cavity ringdown)
- Aerosol absorption (Photoacoustic)
- Optical particle counter, 0.1 - 10 µm, 31 channels, RH < 40%
- CNC (total count, diameter > *ca* 10 nm)

How well can these aerosol properties be reproduced from the measured chemical composition and size distribution?

POTENTIAL MEASUREMENTS BY INVESTIGATORS FROM DOE'S ATMOSPHERIC SCIENCE PROGRAM

Major inorganic and organic aerosol species by real-time rapid-response instruments.

Semivolatile organic vapors and aerosols.

Size distributed composition of particles (single-particle time-of-flight mass spectrometry). Also provides information on the on the extent to which particles in a given size range exhibit similar or disparate composition.

Size distributions from a few nanometers to about 1 µm and of size-dependent hygroscopic growth will allow examination of the relations between size distribution, composition, and hygroscopic growth.

^{7}Be and ^{210}Bi/^{210}Po/^{210}Pb on aerosols permits examination of particle age and relative contributions from air aloft.

It is anticipated that these measurements will be available for closure experiments on aerosol properties.

PARTICIPANTS WANTED . . .

ARM Investigators and others interested in participating in this IOP please contact one of the authors of this poster.

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www.tap.bnl.gov/arm_aerosol_iop.html