ARM TR-014

Aerosol Observing System
Handbook

November 2005

Atmospheric Radiation Measurement
Climate Research Facility
U.S. Department of Energy

Work supported by the U.S. Department of Energy
Office of Science, Office of Biological and Environmental Research

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1. General Overview

The aerosol observing system (AOS) is the primary Atmospheric Radiation Measurement (ARM) platform for in situ aerosol measurements at the surface. The principal measurements are those of the aerosol absorption and scattering coefficients as a function of the particle size and radiation wavelength. Additional measurements include those of the particle number concentration, size distribution, hygroscopic growth, and inorganic chemical composition. The AOS measures aerosol optical properties to understand how particles interact with solar radiation and influence the earth's radiation balance. The measurements are useful for calculating parameters used in radiative forcing calculations such as the aerosol single-scattering albedo, asymmetry parameter, mass scattering efficiency, and hygroscopic growth. The system is located at the Southern Great Plains (SGP) site in Oklahoma and has been operational since the beginning of April 1996. Since 1997, the Aerosol Group at the National Oceanic and Atmospheric Administration's (NOAA)/Climate Monitoring and Diagnbostics Laboratory (CMDL), now the Global Monitoring Division (GMD), has had mentorship of the AOS.

In March 2000, a long-term vertical profiling campaign began over the SGP site using a light aircraft. The measurements from the vertical profiles complement the surface measurements because the instrumentation on the airplane is similar to that at the SGP surface site. The aircraft measurements provide information on the aerosol vertical mixing. The AOS system will undergo some major upgrades in 2006 with the addition of two Radiance nephelometers. The sampling inlet was changed in 2005 to allow for sampling of large particles, < 5 *u*m.

2. Contacts

2.1 Mentor

John Ogren
NOAA/GMD
R/GMD -1
325 Broadway
Boulder, CO 80305
Phone: 303-497-6210
john.a.ogren@noaa.gov

Anne Jefferson
NOAA/GMD
Phone: 303-497-6493
Anne.jefferson@noaa.gov

Richard Eagan (data acquisition)
Argonne National Laboratory
Phone: 630-252-3435
dick.eagan@anl.gov

2.2 Instrument Developer

NOAA/GMD Aerosol Group
325 Broadway
Boulder, CO 80305
http://www.cmdl.noaa.gov/aero/

3. Deployment Locations and History

See inst_log_gaw.xls.

4. Near-Real-Time Data Plots

Daily plots of the unedited raw data can be found at http://www.cmdl.noaa.gov/aero/net/sgp/qcplots.html.

5. Data Description and Examples

5.1 Data File Contents

5.1.1 Primary Variables and Expected Uncertainty

Table 1 describes the primary variables of the AOS.

Table 1. Primary Variables: Quantities Found.

Variable Name	Quantity Measured	Unit
Ozone	Ozone concentration	ppm
CPCPartConc	CPC Particle concentration	1/cm^3
BapBlu_I_1µm	1 µm absorption coefficient at 400 nm	1/m
BapBlu_I_10µm	10 µm absorption coefficient at 400 nm	1/m
BapGrn_I_1µm	1 µm absorption coefficient at 500 nm	1/m
BapGrn_I_10µm	10 µm absorption coefficient at 500 nm	1/m
BapRed_I_1µm	1 µm absorption coefficient at 700 nm	1/m
BapRed_I_10µm	10 µm absorption coefficient at 700 nm	1/m
BluTScatCoef_1µm _LRH	Low RH Neph. 450 nm total scat. coef. at 1 µm	1/m
BluTScatCoef_10µm _LRH	Low RH Neph. 450 nm total scat coef. at 10 µm	1/m
GrnTScatCoef_1µm _LRH	Low RH Neph. 550 nm total scat. coef. at 1 µm	1/m
GrnTScatCoef_10µm _LRH	Low RH Neph. 550 nm total scat. coef. at 10 µm	1/m
RedTScatCoef_1µm _LRH	Low RH Neph. 700 nm total scat. coef. at 1 µm	1/m
RedTScatCoef_10µm _LRH	Low RH Neph. 700 nm total scat. coef. at 10 µm	1/m
BluBScatCoef_1µm _LRH	Low RH Neph. 450 nm total backscat. coef. at 1 µm	1/m
BluBScatCoef_10µm _LRH	Low RH Neph. 450 nm total backscat. coef. at 10µm	1/m
GrnBScatCoef_1µm _LRH	Low RH Neph. 550 nm total backscat. coef. at 1 µm	1/m
GrnBScatCoef_10µm _LRH	Low RH Neph. 550 nm total backscat. coef. at 10 µm	1/m

Table 1. (contd)

Variable Name	Quantity Measured	Unit
RedBScatCoef_1µm _LRH	Low RH Neph. 700 nm total backscat. coef. at 1 µm	1/m
RedBScatCoef_10µm _LRH	Low RH Neph. 700 nm total backscat. coef. at 10 µm	1/m
BluTScatCoef_1µm _HRH	High RH Neph. 450 nm total scat. coef. at 1 µm	1/m
BluTScatCoef_10µm _HRH	High RH Neph.450 nm total scat coef. at 10 µm	1/m
GrnTScatCoef_1µm _HRH	High RH Neph. 550 nm total scat. coef. at 1 µm	1/m
GrnTScatCoef_10µm _HRH	High RH Neph. 550 nm total scat. coef. at 10 µm	1/m
RedTScatCoef_1µm _HRH	High RH Neph. 700 nm total scat. coef. at 1 µm	1/m
RedTScatCoef_10µm _HH	High RH Neph. 700 nm total scat. coef. at 10 µm	1/m
BluBScatCoef_1µm _HRH	High RH Neph. 450 nm total backscat. coef. at 1 µm	1/m
BluBScatCoef_10µm _HRH	High RH Neph. 450 nm total backscat. coef. at 10 µm	1/m
GrnBScatCoef_1µm _HRH	High RH Neph. 550 nm total backscat. coef. at 1 µm	1/m
GrnBScatCoef_10µm _HRH	High RH Neph. 550 nm total backscat. coef. at 10 µm	1/m
RedBScatCoef_1µm _HRH	High RH Neph. 700 nm total backscat. coef. at 1 µm	1/m
RedBScatCoef_10µm _HRH	High RH Neph. 700 nm total backscat. coef. at 10 µm	1/m
Pa1000Conc	PCASP Chan. 0 (Dp > 10 micrometers)	1/cm^3
pa10_p12conc	PCASP Chan. 1 (0.10 micrometers < Dp < 0.12)	1/cm^3
pa12_p14conc	PCASP Chan. 2 (0.12 micrometers < Dp < 0.14)	1/cm^3
pa14_p16conc	PCASP Chan. 3 (0.14 micrometers < Dp < 0.16)	1/cm^3
pa16_p18conc	PCASP Chan. 4 (0.16 micrometers < Dp < 0.18)	1/cm^3
pa18_p20conc	PCASP Chan. 5 (0.18 micrometers < Dp < 0.20)	1/cm^3
pa20_p23conc	PCASP Chan. 6 (0.20 micrometers < Dp < 0.23)	1/cm^3
pa23_p26conc	PCASP Chan. 7 (0.23 micrometers < Dp < 0.26)	1/cm^3
pa26_p30conc	PCASP Chan. 8 (0.26 micrometers < Dp < 0.30)	1/cm^3
pa30_p35conc	PCASP Chan. 9 (0.30 micrometers < Dp < 0.35)	1/cm^3
pa35_p40conc	PCASP Chan. 10 (0.35 micrometers < Dp < 0.40)	1/cm^3
pa40_p45conc	PCASP Chan. 11 (0.40 micrometers < Dp < 0.45)	1/cm^3
pa45_p50conc	PCASP Chan. 12 (0.45 micrometers < Dp < 0.50)	1/cm^3
pa50_p60conc	PCASP Chan. 13 (0.50 micrometers < Dp < 0.60)	1/cm^3
pa60_p70conc	PCASP Chan. 14 (0.60 micrometers < Dp < 0.70)	1/cm^3
pa70_p80conc	PCASP Chan. 15 (0.70 micrometers < Dp < 0.80)	1/cm^3
pa80_p90conc	PCASP Chan. 16 (0.80 micrometers < Dp < 0.90)	1/cm^3
pa90_p100conc	PCASP Chan. 17 (0.90 micrometers < Dp < 1.00)	1/cm^3
pa100_p130conc	PCASP Chan. 18 (1.00 micrometers < Dp < 1.30)	1/cm^3
pa130_p140conc	PCASP Chan. 19 (1.30 micrometers < Dp < 1.40)	1/cm^3
pa140_p160conc	PCASP Chan. 20 (1.40 micrometers < Dp < 1.60)	1/cm^3
pa160_p180conc	PCASP Chan. 21 (1.60 micrometers < Dp < 1.80)	1/cm^3
pa180_p200conc	PCASP Chan. 22 (1.80 micrometers < Dp < 2.00)	1/cm^3
pa200_p230conc	PCASP Chan. 23 (2.00 micrometers < Dp < 2.30)	1/cm^3

Table 1. (contd)

Variable Name	Quantity Measured	Unit
pa230_p260conc	PCASP Chan. 24 (2.30 micrometers < Dp < 2.60)	1/cm^3
pa260_p300conc	PCASP Chan. 25 (2.60 micrometers < Dp < 3.00)	1/cm^3
pa300_p350conc	PCASP Chan. 26 (2.60 micrometers < Dp < 3.00)	1/cm^3
pa350_p400conc	PCASP Chan. 27 (3.50 micrometers < Dp < 4.00)	1/cm^3
pa400_p500conc	PCASP Chan. 28 (4.00 micrometers < Dp < 5.00)	1/cm^3
pa500_p650conc	PCASP Chan. 29 (5.00 micrometers < Dp < 6.50)	1/cm^3
pa650_p800conc	PCASP Chan. 30 (6.50 micrometers < Dp < 8.00)	1/cm^3
pa800_p1000conc	PCASP Chan. 31 (8.00 micrometers < Dp < 10.0)	1/cm^3

5.1.1.1 Definition of Uncertainty

The calculation of the measurement uncertainty of each nephelometer follows the protocol of Anderson et al. (1999). The measurement uncertainty associated with the TSI 3563 nephelometer was calculated from five known sources and is expressed as a linear combination of the following terms: $du_{total}^2 = du_{noise}^2 + du_{drift}^2 + du_{cal}^2 + du_{trunc}^2 + du_{stp}^2$. Here, du_p designates the uncertainty in u associated with the parameter, p. These arise from the following:

- instrument noise in the filtered air scattering coefficient
- instrument drift in the calibration
- uncertainty in the instrument calibration to Rayleigh scattering of dry air and CO_2
- instrument truncation of near forward scattered light
- uncertainty in the instrument pressure and temperature in conversion of the data to STP. The associated uncertainties for each parameter for one-minute averages are listed in Table 2 as a function of the scattering coefficient magnitude.

Table 2. Instrument Noise, Drift, and Uncertainty Factors.

bsp	noise	drift	calibration	truncation	Stp	**total**
1	1.25	0.44	0.08	0.02	0.003	**1.33**
10	1.56	0.80	0.75	0.22	0.03	**1.92**
20	1.84	1.20	1.50	0.44	0.07	**2.70**
50	2.50	2.40	3.75	1.10	0.17	**5.23**
100	3.32	4.40	7.51	2.20	0.34	**9.58**

Uncertainty associated with differences in the aerosol inlets and tubing is expected to be insignificant for submicron aerosol. Losses within the nephelometer itself were found to be negligible for submicron particles and are 5%-10% for super micrometer particles (Anderson and Ogren 1998). The variation in particle size with relative humidity (RH) and hence, the particle transmission through a submicron impactor, operating upstream of the nephelometer, will vary with the particle type. For an RH below 50%, we estimate this uncertainty to be less than 5% based on Berner impactor efficiency curves and estimates of the scattering size distribution. In addition to RH, the flow rate affects the 50% aerodynamic cut off diameter of the impactor. Running the Berner-type impactors at a flow 10% lower than 30 lpm yields a 5% change in cut size. Typically, flows are within 1%-2% of the expected flow rate.

For low-scattering values, instrument noise is the prevalent source of uncertainty, while for higher scattering coefficients both noise and instrument truncation uncertainties dominate. Uncertainty for low signal values can be greatly reduced by increasing the signal averaging time. For a 10-min averaging time, the uncertainty associated with noise for a bsp of 1 Mm^{-1} is 0.40 Mm^{-1}.

Uncertainties in the particle soot absorption photometer (PSAP), have been described by Bond et al. (2001) and the appropriate corrections have been applied to PSAP measurements made at the SGP site. Corrections have been made for spot size, flow rate, interpretation of scattering as absorption and instrument response to absorption. Uncertainty in the measurements also stems from the variability of each PSAP unit and from instrument noise. Bond et al. found instrumental variability to be 6% of the measured absorption. Instrument noise (i.e., detection limit), determined by measuring particle-free air, is 0.1 Mm^{-1} for hourly averaged data and 0.9 Mm^{-1} for minute-averaged data. The total uncertainty in aerosol absorption coefficient from the PSAP usually varies from 1 to 4 Mm^{-1} for one minute average data and depends on the magnitudes of the absorption and scattering coefficients.

5.1.2 Secondary/Underlying Variables

The secondary variables are value-added products (VAPs) calculated from the primary variables. These aerosol-intensive parameters depend on the intrinsic aerosol properties and not on the aerosol quantity. Further information on the AOS VAPs is located at http://science.arm.gov/vaps/aip1ogren.stm. The AOS VAP is as follows:

> f(RH) or aerosol hygroscopic growth factor is the ratio of the scattering coefficient at 85% RH to that at 40% RH. f(RH) provides an indication of the amount of water absorbed by the aerosol, which depends on the aerosol size and chemical composition. This factor is necessary to calculate the scattering coefficient at ambient RH. f(RH) data are available in the AOS ARM archive data stream under the filename: sgpcmdlaosfitrhC1.c1.

5.1.3 Diagnostic Variables

The diagnostic variables in the AOS data stream include those of the instrument temperature, pressure, and RH. A description of each parameter is given in Table 3.

Table 3. Diagnostic Variables in the AOS Data Stream.

Variable Name	Quantity Measured	Unit
SampTemp	Sample temperature at base of inlet heater	C
SampRH	Sample RH at base of inlet heater	%
AmbTemp	Outdoor air temperature	C
TSINephTin_HRH	High RH Neph. inlet temperature	C
TSINephPres_HRH	High RH Neph. Pressure	hPa
TSINephTSamp_HRH	High RH Neph. Sample Temperature	C
TSINephRHSamp_HRH	High RH Neph. Relative humidity	%
HGdownstream_RH	RH downstream of humidograph	%
HGupstream_RH	RH upstream of humidograph	%

Table 3. (contd)

Variable Name	Quantity Measured	Unit
HGupstream_T	Temp. upstream of humidograph	C
HGdownstream_T	Temp. downstream of humidograph	C
TSINephTin_LRH	Low RH Neph. inlet temperature	C
TSINephPres_LRH	Low RH Neph. Pressure	hPa
TSINephTSamp_LRH	Low RH Neph. Sample Temperature	C
TSINephRHSamp_LRH	Low RH Neph. Relative humidity	%

5.1.4 Data Quality Flags

The data quality flags are set below. Of particular note are flags 4 and 12. Every hour the system is in a ‘zero’ mode for 6 min. During this time, filtered air passes through the instruments. The aerosol size alternates between submicron and sub 10-micron size cuts every 6 min.

0 => 'Local contamination (Not set by ingest)
1 => 'Wind speed < min (Not set by ingest)
2 => 'Wind direction out of sector (Not set by ingest)
3 => 'CN spike (Not set by ingest)
4 => 'System Zero Mode
5 => 'Stack offline (tilted)
6 => 'Zero/Stack flow > max
7 => 'Zero/Stack flow < min
8 => 'Value > max
9 => 'Value < min
10 => 'Std. Dev. > max (Not set by ingest)
11 => 'Std. Dev. < min (Not set by ingest)
12 => '1-um impactor
13 => 'Instrument Zero mode
14 => 'Calibration mode
15 => 'Offline/inop/no data
16 => 'Power Off, Flow Out of Range
17 => 'Dependant Min/Max Field Out of Range (not set by ingest)
18 => 'Incorrect Valve Position
19 => 'Instrument Bypass
20 => 'TSI lamp power out/CPC Low Vacuum
21 => 'TSI valve fault/CPC Low Liquid
22 => 'TSI chopper fault
23 => 'TSI shutter fault
24 => 'TSI cal air
25 => 'TSI span gas (CO_2)
26 => 'Not Used
27 => 'Not Used
28 => 'Data not flagged, but invalid
29 => 'Data not flagged, judged suspicious
30 => 'Data flagged, judged valid

5.1.5 Dimension Variables

This section is not applicable to this instrument.

5.2 Annotated Examples

The AOS data contain both the aerosol-scattering and absorption coefficients measured at the SGP surface site as well as vertical aircraft profiles of these values over the site. The data below show typical values of the aerosol-scattering and absorption coefficients for the two aerosol size cuts as well as the calculated intensive parameters of the single-scattering albedo at 550 nm and the Angstrom exponent, calculated for the 550 and 700 nm wavelength pair.

Figure 1 shows the aerosol absorption coefficient at 550 nm (top frame) and the aerosol-scattering coefficient at three wavelengths, 450, 550, and 700 nm for six days in September 2004. Both size cuts, submicron (dark colors) and sub 10 micron (light colors) are plotted, but because most of the aerosol resides in the submicron size mode there is little difference in the scattering and absorption coefficients of these size modes. On September 23 (day 267), a sharp decline occurred in the aerosol scattering that accompanied rain. The single-scattering albedo at 550 nm (Figure 2) was relatively high during the rain and substantially declined after the rain episode. The aerosol Ångstrom exponent (550/700 nm pair) initially declined at the onset of rain, indicating the presence of large particles, and subsequently increased during the rain to high values. On days 269 and 270, a low abundance of relatively large and dark aerosols was present as indicated by the low single-scattering albedo and low values of the Ångstrom exponent.

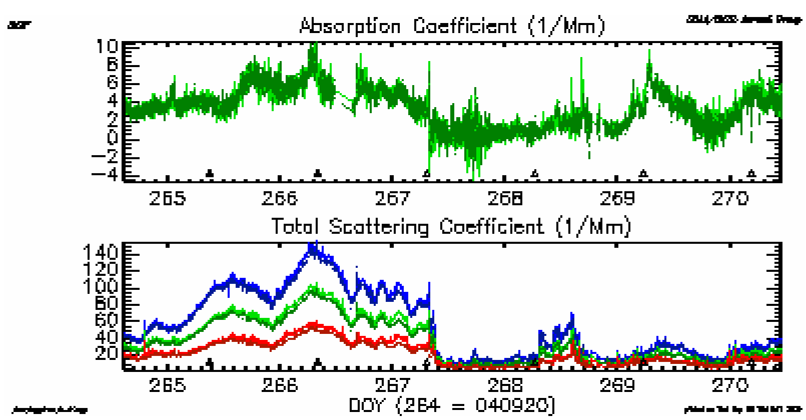

Figure 1. Aerosol Absorption and Scattering Coefficients at Three Wavelengths.

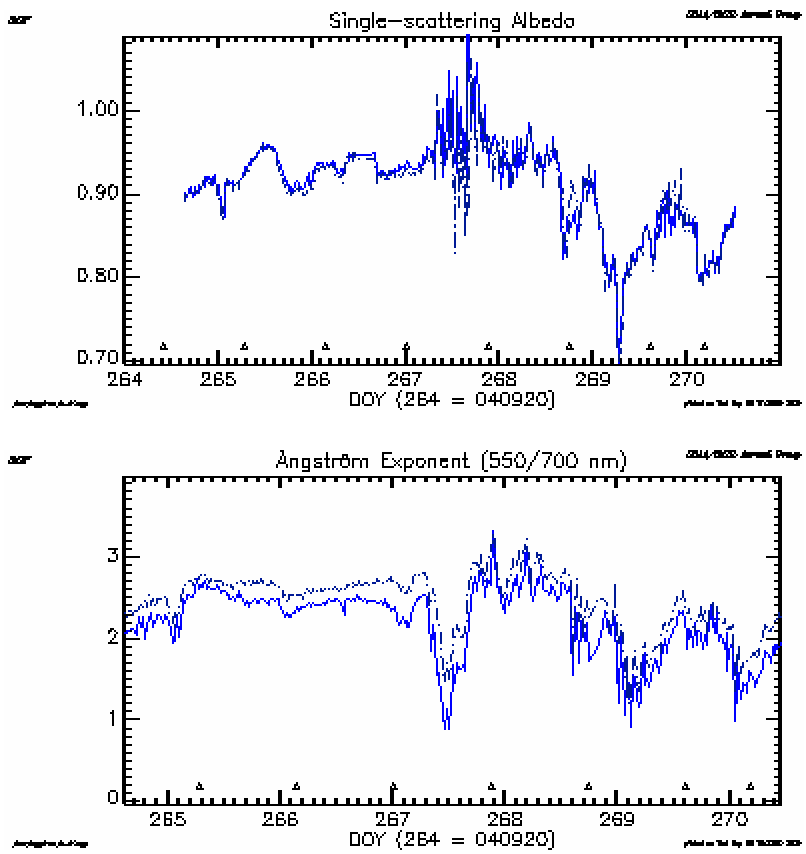

Figure 2. Single-Scattering Albedo Before and After Rain Episode.

On average, biweekly in situ aerosol profiles are measured over the SGP site with a Cessna 172 aircraft. Seasonal and annual averages of the aerosol submicron scattering and absorption coefficients for these flights are shown in Figure 3.

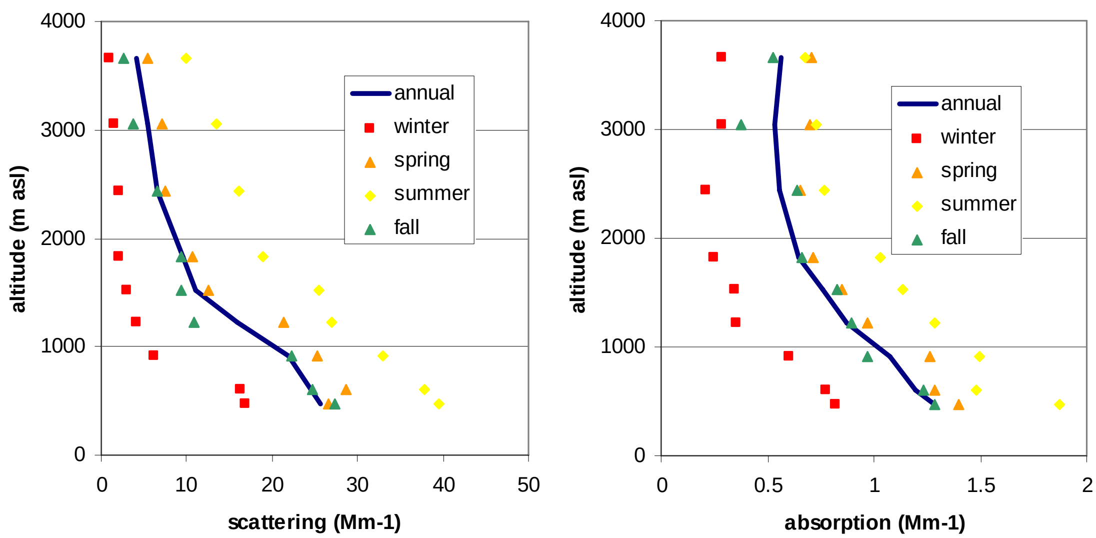

Figure 3. Seasonal and Annual Aerosol Submicron Scattering and Absorption Coefficient Averages.

5.3 User Notes and Known Problems

This section is not applicable to this instrument.

5.4 Frequently Asked Questions

This section is not applicable to this instrument.

6. Data Quality

6.1 Data Quality Health and Status

The following links go to current data quality health and status results.

DQ HandS (Data Quality Health and Status)
NCVweb for interactive data plotting using

The tables and graphs shown contain the techniques used by ARM's data quality analysts, instrument mentors, and site scientists to monitor and diagnose data quality.

6.2 Data Reviews by Instrument Mentor

Monthly reports on the data and instrument performance are provided by the mentor and can be found at www.db.arm.gov/IMMS/

6.3 Data Assessments by Site Scientist/Data Quality Office

This section is not applicable to this instrument.

6.4 Value-Added Procedures and Quality Measurement Experiments

See Section 5.1.2 on Secondary/Underlying Variables.

7. Instrument Details

7.1 Detailed Description

7.1.1 List of Components

Aerosol instrumentation inside the trailer consists of the following:

1. Two nephelometers. These are 3-wavelength (450, 550, and 700 nm) TSI (Model 3563) nephelometers that measure total angular scattering and hemispheric backscattering coefficients from 90° to 170°. The second TSI nephelometer is connected to a humidity scanning system to provide measurements of the scattering coefficients as a function of RH. Calibration with CO_2 gas

for the nephelometers is done weekly. Until summer 2001, there also was a 1-wavelength (at 545 nm) Radiance Research (Model M-903) nephelometer that measured the total light-scattering coefficient.

2. Light absorption photometer. The Radiance Research (Model PSAP) Particle Soot Absorption Photometer measures the particle absorption coefficient at the wavelength of 550 nm. In April 2005, this instrument was upgraded to a 3-wavelength instrument.

3. One condensation nuclei counter. The TSI (Model 3010) measures the total number concentration of condensation particles of diameter in the size range of 10 nm to 3 μm.

4. Optical particle counter (OPC). The PMS (Model PCASP-X) OPC measures the particle number concentration in 31 size channels from 0.1 to 10 μm. This instrument was inoperable and removed in 2004 because of poor instrument reliability.

5. Ozone monitor. The Dasibi (Model 1008) ozone monitor measures ozone mixing ratios between 1 and 1000 ppbv using monochromatic ultraviolet (UV) absorption spectrophotometry.

7.1.2 System Configuration and Measurement Methods

Figure 4 shows a flow schematic for the AOS. Atmospheric aerosol is sampled at a volumetric flow rate of 1,000 m^3 min^{-1}. The main flow into the sampling stack is split into five lines:

- Three spare lines
- Condensation nuclei counter (CNC)
- TSI nephelometers and PSAP
- Chemical sampling.

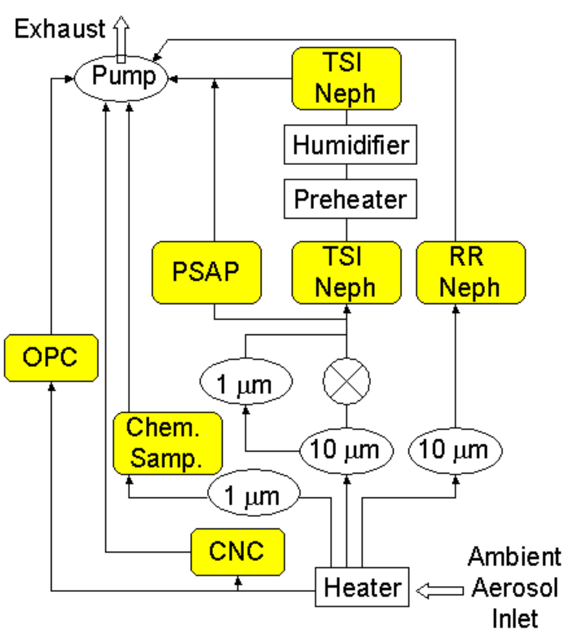

Figure 4. Flow Schematic for AOS.

The flow rate through each of these five instrument lines is 30 l min^{-1}. Ozone is sampled from a separate line coated with Teflon and the ozone sample line is mounted on the main aerosol sampling stack. The Dasibi ozone monitor is preceded by a particle filter because particles interfere with the ozone measurement. The aerosol inlet stack can be tilted down for regular maintenance and periodic filtered air checks. Note that the RR Neph and OPC are no longer in the sample line.

The aerosol sample stream is heated to an RH of 40% or less, depending on ambient conditions, before it enters the sample lines. The sample air is dried to measure the aerosol optical properties with minimal influence from water vapor. Care is taken not to over heat the aerosol and evaporate semi-volatile compounds such as nitric acid or organics. An RH control unit conditions the air stream before it enters the second 3-wavelength nephelometer to provide a measurement of scattering coefficient as a function of RH. The ambient scattering coefficients can be derived from the measured dry scattering coefficients and the hygroscopic growth factor, fRH.

7.1.3 Specifications

The following describes the observational specifications of the AOS.

- **AOS Size Cuts**

  The TSI nephelometers and Radiance Research absorption photometer are preceded by two switched impactors; a 10-um impactor removes particles with aerodynamic diameter > 10 μm and a 1-μm impactor removes super micron size particles. The size cut switches every 6 min.

  The chemical sampling instrumentation has a 10-um size cut before the weekly sample and a 1-μm size cut before the daily filter samples.

- **TSI (Model 3563) nephelometer**

  wavelengths: 450 nm, 550 nm, 700 nm

  sensitivity (TSI specs): 1.0 x 10-7 m-1 for 450 & 550 nm; 3.0 x 10-7 m-1 for 700 nm

- **Radiance Research (Model PSAP) absorption photometer**

  wavelength: 550 nm

- **TSI (Model 3010) condensation particle counter**

  wavelength: 780 nm

  concentration range: 0.0001 to 10000 particles cm-3 particle size range: 0.01 μm to 3 μm particles

- **PMS (Model PCASP-X) optical particle counter**

  wavelength: 633 nm

particle size range: 31 size channels from 0.1 to 10 µm and 1 channel for diameter >10 µm

maximum counting rate: 10,000 particles sec-1

- **Dasibi (Model 1008) ozone monitor**

  mixing ratio range: 1 to 1000 ppbv

  UV light source wavelength: 253.7 nm

7.2 Theory of Operation

The individual instruments are described on their own web pages at Nephelometers and Absorption Photometer.

7.3 Calibration

7.3.1 Theory and Procedures

Nephelometers: The instrument calibration is checked weekly using low-span and high-span gases (filtered air and CO_2, respectively). Rayleigh scattering from these gases is a known quantity, and the performance characteristics of each nephelometer are derived from these calibrations. The instrument calibration values are readjusted annually or more frequently, if needed. A weekly span check is performed where the instruments are filled first with filtered air and then CO_2, and the agreement between measured and calculated CO_2 Rayleigh scatter is determined. As long as the span checks show good agreement, the calibration is believed to be good.

Light Absorption Photometer: Calibration of this instrument absorption measurement can be done using an extinction cell and a nephelometer to provide an independent measure of suspended state aerosol absorption. This calibration and the resulting instrument corrections are found in Bond et al. 2001. CMDL calibrates the volumetric flow rate through the instrument with a gilibrator or Bios flowmeter, and does not attempt to calibrate the absorption measurement.

Optical Particle Counter: The optical particle counter is calibrated using polystyrene latex spheres of known size and index of refraction. The calibration is performed once a year or as needed.

Ozone Monitor: The ozone monitor is periodically shipped back to our laboratory and calibrated with a National Institute of Standards and Technology (NIST)-certified standard ozone calibration source.

7.3.2 History

Calibration data are available from NOAA/CMDL upon request.

7.4 Operation and Maintenance

7.4.1 User Manual

This section is not applicable to this instrument.

7.4.2 Routine and Corrective Maintenance Documentation

Daily Maintenance

System - Check system variables to see within range.
Humidity System - Check water level and add water if necessary.
PSAP - Change aerosol sample filter.

Weekly Maintenance

PSAP - Change reference filter.
Nephelometer - CO_2 calibration span check.
Impactors - Change impactor films.
Leak test - Test for leaks in stack/tubing/fittings.
Chemical Filters – change filters in aerosol chemical filter sampler.

Annual Maintenance

Instrument maintenance and calibration is done annually; further maintenance is done on an as-needed basis. The annual maintenance includes:

- Pumpbox - Replace carbon vanes and diaphragms in various pumps; check and calibrate pitot tube, replace or clean the pump exhaust filter.
- Stack - Leak test with HEPA filter; clean flow splitter; check T/RH probes; inspect tubing.
- PSAP - Check tubing and connectors; check internal filter; calibrate flow.
- CNC - Replace drier tube; fill with butanol; flush aerosol line, compare counts to another TSI 3010 CNC.
- Impactors - Clean impactor surfaces; regrease with high vacuum grease; replace impactor films.
- Nephelometer - Perform CO_2 calibration; do zero air test over night, replace filters.
- Pressure Sensors - Check pressures and calibrate.
- Mass Flow Meters - Change upstream filters; calibrate with flow calibrator.
- Miscellaneous - Check wind vane direction; clean solenoid valves; update station inventory log.

7.4.3 Software Documentation

ARM netCDF file header descriptions may be found at AOS Data Object Design Changes.

7.4.4 Additional Documentation

This section is not applicable to this instrument.

7.5 Glossary

See the ARM Glossary at http://www.arm.gov/about/glossary.stm.

7.6 Acronyms

AOS	aerosol observing system
ARM	Atmospheric Radiation Measurement (Program)
CMDL	Climate Monitoring and Diagnostics Laboratory
CNC	condensation nuclei counter
CPC	condensation particle counter
IAP	in situ aerosol profiling
Lpm	liters per minute
MFC	mass flow controller
NOAA	National Oceanic and Atmospheric Administration
OPC	optical particle counter
Ppbv	parts per billion by volume
PSAP	particle soot absorption photometer
PSL	polystyrene latex spheres
RH	relative humidity
SGP	Southern Great Plains
VAP	value-added product

7.7 Citable References

Anderson, TL, and JA Ogren. 1998. “Determining aerosol radiative properties using the TSI 3563 integrating nephelometer.” *Aerosol Science and Technology* 29, 57-69.

Anderson, TL, DS Covert, JD Wheeler, JM Harris, KD Perry, BE Trost, DJ Jaffe, and JA Ogren. 1999. “Aerosol backscatter fraction and single-scattering albedo: Measured values and uncertainties at a coastal station in the Pacific Northwest.” *Journal of Geophysical Research* 104, 26793-26807.

Bond, TC, TL Anderson, and D Campbell. 2001. “Calibration and intercomparison of filter-based measurements of visible light absorption by aerosols.” *Aeroso Science and Technology* 30, 582-600.