INSTRUMENTATION ABOARD THE UNIVERSITY OF WASHINGTON'S CONVAIR-580 RESEARCH AIRCRAFT IN SAFARI-2000

(a) Navigational and Flight Characteristics

Parameter	Instrument Type	Manufacturer	Range (and error)	UW Computer Code
Latitude and longitude	Global Positioning System (GPS)	Trimble TANS/Vector	Global (~2-5 m)	tans-lat (deg) tans-lon (deg)
True airspeed	Air computer	Shadin	0 to 250 m s^{-1} (<0.2%)	shadin_tas (m s^{-1})
True airspeed	Variable capacitance	Rosemount Model F2VL 781A	0 to 250 m s^{-1} (<0.2%)	tas (m s^{-1})
Heading	From TANS/Vector	Trimble TANS/Vector	0 to 360˚ (± 1˚)	tans-azimth (0 deg is true north)
Pressure	Variable capacitance	Rosemount Model 830 BA	1100 to 150 mb (<0.2%)	pstat
Pressure altitude	Computed from pstat assuming standard atmosphere	—	0-9 km (Error depends on atmospheric conditions.)	palt (ft)
Altitude	Global Positioning System (GPS)	Trimble TANS/Vector	0-9 km (±15-25 ft)	tans-altft (msl, ft)
Altitude above terrain	Radar altimeter	Bendix Model ALA 51A	Up to 0.75 km	ralt (agl, ft)
Pitch	Differential GPS	Trimble TANS/Vector	–90 to 90˚ (±0.15˚)	Tans-pitch (deg, nose down positive)
Roll	Differential GPS	Trimble TANS/Vector	–90 to 90˚ (±0.15˚)	Tans-roll (deg, right wing up positive)

(b) Communications

Parameter	Instrument Type	Manufacturer	Range (and error)	UW Computer Code
Air-to-ground telephone	Via Iridium satellite	Motorola	Worldwide	—
Air-to-ground e-mail	Via satellite	Magellan	Worldwide	—

(c) General Meteorological

Parameter	Instrument Type	Manufacturer	Range (and error)	UW Computer Code
Weather satellite imagery	HF and satellite	ICOM-R8500	Worldwide	Not recorded
Radar reflectivity	3 cm wavelength (pilot's radar)	Bendix/King (now Allied Signal)	250 km	—
Total air temperature	Platinum wire resistance	Rosemount Model 102CY2CG and 414 L Bridge	-60 to 40˚C (<0.1˚C)	ttot (˚C)
Static air temperature	Calculated from Rosemount total temperature	Rosemount Model 102CY2CG and 414 L Bridge	-60 to 40˚C	tstat (˚C)
Total air temperature	Reverse-flow	In-house	-60 to 40˚C	ttotr (˚C)
Static air temperature	Reverse-flow thermometer	In-house	-60 to 40˚C (<0.5˚C)	tstatr (˚C)
Dew point temperature	Cooled-mirror dew point	Cambridge System Model TH73-244	-40 to 40˚C (<1˚C)	dp (˚C)

(Cont.)

(c) General Meteorological (continued)

Parameter	Instrument Type	Manufacturer	Range (and error)	UW Computer Code
Dew point	IR optical hygrometer	Ophir Corp. Model IR-2000	-40 to 40˚C (~5%)	dp_o = Ophir dew point (degC)
Wind direction	Calculated from TANS/Vector and Shadin	Trimble	0-360˚ (0 deg is magnetic north).	wind_dir
Wind speed	Calculated from TANS/Vector and Shadin	Trimble	—	wind_spd (kts)
Video image	Forward-looking camera and time code	Ocean Systems Splash Cam	—	—

(d) Aerosol

Parameter	Instrument Type	Manufacturer	Range	UW Computer Code
Number concentration of particles (continuous flow)	Condensation particle counter	TSI Model 3022A	$0\text{-}10^7$ cm^{-3} (d>0.003 µm)	cnc1 (/cc)
Number concentration of particles (continuous flow)	Condensation particle counter	TSI Model 3025A	$0\text{-}10^5$ cm^{-3} (d>0.003 µm)	cnc2 (/cc)
Size spectrum of particles (from "baghouse" only)	Differential Mobility Particle Sizing Spectrometer (DMPS)	TSI (modified in-house)	0.01 to 0.6 µm (21 channels)	dmpsdn = DMPS concentration spectrum (/cc).
Size spectrum of particles	35 to 120˚ light-scattering	Particle Measuring Systems Model PCASP-100X	0.12 to 3.0 µm (15 channels)	pcasprt = PCASP 100 total concentration (/cc). pcaspdn = PCASP 100 concentration spectrum (/cc).
Total particle concentration	Forward light-scattering	Particle Measuring Systems Model FSSP-300	0.3 to 20 µm (30 channels)	fsp3rt (/cc).
Size spectrum of particles	Forward light-scattering	Particle Measuring Systems Model FSSP-300	0.3 to 20 µm (30 channels)	fsp3dn = fsp300 concentration spectrum (/cc).
Aerodynamic size spectrum of particles and relative light scattering intensity	"Time-of-flight"	TSI Model 3320 APS	0.5-20 µm (52 channels)	tsirt = TSI 3320 (total concentration (/cc)).
Size spectrum of particles	Forward light-scattering	Particle Measuring Systems Model FSSP-100	2 to 47 µm (15 channels)	fsprt = fssp 100 total concentration (/cc). fspdn = fssp 100 particle concentration spectrum (/cc).

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(d) Aerosol (continued)				
Parameter	Instrument Type	Manufacturer	Range	UW Computer Code
Light-scattering coefficient ("continuous" measurements on ambient air, but interrupted on occasions for "baghouse" measurements).	Integrating 3-wavelength nephelometer with backscatter shutter	MS Electron 3W-02	1.0×10^{-7} m^{-1} to 1.0×10^{-3} m^{-1} for 550 (green) and 700 (red) nm channels. 2.0×10^{-7} m^{-1} to 1.0×10^{-3} m^{-1} for 450 nm channel (blue)	nepblu_c = total scatter blue (/m). nepgrn_c = total scatter green (/m). nepred_c = total scatter red (/m). bkspbl_c = backscatter blue (/m). bkspgr_c = backscatter green (/m). bksprd_c = backscatter red (/m).
Light-scattering coefficient (for "baghouse" samples only) at 530 nm	Integrating nephelometer	Radiance Research Model M903	1.0×10^{-6} m^{-1} to 2.0×10^{-4} m^{-1} or 1.0×10^{-6} m^{-1} to 1.0×10^{-3} m^{-1}	nephbag (m^{-1})
Light-scattering coefficient (ambient and extinction cell)	Integrating nephelometer	CE	10^{-7} to 10^{-2} m^{-1} at 537 nm	cetspgr (/m)
Light absorption and graphitic carbon	Particle soot absorption photometer (PSAP)	Radiance Research	Absorption coefficient at 550 nm: 10^{-7} to 10^{-2} m^{-1}. Carbon: 0.1 mg m^{-3} to 10 mg m^{-3} ($\pm 5\%$)	rams550_amb_c (m^{-1})
Humidification factor for aerosol light-scattering (occasionally interrupted for measurements on "baghouse" sample)	Scanning humidogram	In house	b_{sp} (RH) for 30% £ RH £ 85%	rhhum
Light-extinction coefficient of smoke (in plumes only) at 538 nm	Optical extinction cell OEC (6 m path length)	In-house	5×10^{-5} to 10^{-2} m^{-1}	oecext (m^{-1}) = oec extinction coefficient. oecscat (m^{-1}) = oec scattering coefficient.
Aerosol-shape	Change in light-scattering with applied electric field–Aerosol Asymmetry Analyzer (A^3)	In-house	Detects 2% deviation from sphericity	rras
Particle size, shape, elemental composition, crystallographic structure, aggregation, etc.	Individual particle analysis using electron-beam techniques (e.g., TEM, EDS, EELS, SAED)	P. Buseck (Arizona State Univ.)	Down to a few nanometers	—
Cloud condensation nucleus (CCN) spectrum[†] (for Namibia flights only)	Thermal diffusion chamber	Univ. of Wyoming (operated by R. Bruintjes, NCAR)	CCN concentrations at 0.1, 0.3, 0.6 and 1%	—

[†] Guest instrument.

(Cont.)

TABLE (continued)

(e) Cloud Physics

Parameter	Instrument Type	Manufacturer	Range (resolution)	UW Computer Code
Liquid water content	Hot wire resistance	Johnson-Williams	0 to 2 or 0 to g m^{-3}	lwjw0 = cloud liquid water content from JW (g/m^3)
Liquid water content	Hot wire resistance	DMT	0 to 5 g m^{-3}	lwdmt = cloud liquid water content from DMT (g/m^3)
Total particle concentration	Forward light-scattering	Particle Measuring Systems Model FSSP-300	0.3 to 20 μm (30 channels)	fsp3rt (/cc).
Size spectrum of particles	Forward light-scattering	Particle Measuring Systems Model FSSP-300	0.3 to 20 μm (30 channels)	fsp3dn = fsp300 concentration spectrum (/cc).
Size spectrum of particles	Forward light-scattering	Particle Measuring Systems Model FSSP-100	2 to 47 μm (15 channels)	fsprt = fssp 100 total concentration (/cc).
				fspdn = fssp 100 particle concentration spectrum (/cc).
Liquid water content; effective droplet radius; particle surface area	Optical sensor	Gerber Scientific Ins. PVM-100A	LWC = 0.001-10 g m^{-3}	lwpvm = cloud liquid water from PVM (g/m^3).
				erpvm = PVM100A effective radius (μm).
				psapvm = PVM100A raw surface area (cm^2/m^3).
				sapvm = PVM100A surface area [corrected using fssp100 drop rate] (cm^2/m^3).

(f) Chemistry

Parameter	Instrument Type	Manufacturer	Range (and error)	UW Computer Code
SO$_2$ (occasionally interrupted for measurements on "baghouse" sample)	Pulsed fluorescence	Teco 43S (modified in-house)	0.1 to 200 ppb	so2 (ppb) = Teco 43S

(Cont.)

TABLE (continued)

(f) Chemistry (continued)				
Parameter	Instrument Type	Manufacturer	Range (and error)	UW Computer Code
O_3 (occasionally interrupted for measurements on "baghouse" sample)	UV absorption	TEI Model 49C	1-1000 ppbv (<0.5 ppbv)	o3 = Pressure corrected TEI49C ozone concentration (ppb).
CO_2 (occasionally interrupted for measurements on "baghouse" sample)	Infrared correlation spectrometer	LI-COR Li-6262	0 to 300 ppmv (0.2 ppmv at 350 ppmv)	co2 (ppm) = Licor 6262
CO (occasionally interrupted for measurements on "baghouse" sample)	IR correlation spectrometer	Teco Model 48	0-50 ppb (~0.1 ppmv)	co (ppb) = Teco 48 (ppb)
NO	Chemiluminescence	Modified Monitor Labs. Model 8840	0-5 ppmv (~1 ppb)	no (ppb)
NO_x (occasionally interrupted for measurements on "baghouse" sample)	Chemiluminescence	Modified Monitor Labs. Model 8840	0-5 ppmv (~1 ppb)	nox (ppb)
Total particulate mass and species $SO_4^=$, NO_3^-, Cl^-, Na^+, K^+, NH_4^+, Ca^{++}, Mg^{++}	37 Teflon filters, gravimetric analysis and ion exchange chromatography	Gelman Dionix (UW)	0.1 to 50 μg m^{-3} (for 500 liter air sample)	—
Carbonaceous particles (black and organic carbon)[†]	Quartz filters (Thermal Evolution Techniques)	T. Novakov and T. Kirchstetter (LBNL)	4-160 μg m^{-3} (±1.6 μg m^{-3}) for 1 m^3 sample	—
Hydrocarbons CO, CO_2[†]	Collected in stainless steel canisters; analysis by GC/FID	D. Blake (U.C. Irvine)	Variable	—
$PM_{2.5}$, $SO_4^=$, NO_3^-, NH_4^+, pH, carbonaceous aerosol[†]	Particle concentrator, organic sampling system (BC-BOSS sampling system)	D. Eatough (Brigham Young University)	—	—
Reactive and stable gaseous combustion emissions[†]	Fourier transform IR spectrometer (FTIR)	R. Yokelson (U. of Montana)	ppt-ppb	—

(g) Radiation				
Parameter	Instrument Type	Manufacturer	Range (and error)	UW Computer Code
UV hemispheric radiation, one upward, one downward	Diffuser, filter photo-cell (0.295 to 0.390 μm)	Eppley Lab. Inc. Model TUVR	0 to 70 W m-2 (±3 W m-2)	uvup = uv upward looking (W m-2) uvdo = uv downward looking (W m-2)
VIS-NIR hemispheric radiation (one downward and one upward viewing)	Eppley thermopile (0.3 to 3 μm)	Eppley Lab. Inc. Model PSP	0 to 1400 W m-2 (±10 W m-2)	pyrup = vis-nir upward looking (W m-2) pyrdo = vis-nir downward looking (W m-2)

[†] Guest instrument.

(g) Radiation (continued)

Parameter	Instrument Type	Manufacturer	Range (and error)	UW Computer Code
Surface radiative temperature	IR radiometer 1.5˚ FOV (8 to 14 μm)	Omega Engineering OS3701	-50˚ to 1000˚C ±0.8% or reading	irtemp (degC) = surface temp. (˚C)
Absorption and scattering of solar radiation by clouds and aerosols; reflectivity of surfaces	Fourteen wavelength all-directions scanning radiometer	NASA-Goddard/ University of Washington	14 discrete wavelengths between 340 and 2300 nm	—
Solar Spectral irradiance or radiance; Spectral transmission and reflectance[†]	Upward and downward pointed hemispherical signal collectors	NASA Ames Solar Spectral Flux Radiometer (SSFR) (P. Pilewskie)	300-2500 nm (5-10 nm resolution). FOV 1 mrad. 1 Hz spectral sampling rate.	—
Aerosol optical depth, water vapor, and ozone[†]	14-channel Sun-tracking photometer	NASA Ames (P. Russell)	14 discrete wavelengths, 350-1558 nm	—

[†] Guest instrument