CARG Aerosol and Cloud Data from the Convair-580

Abstract

The Cloud and Aerosol Research Group (CARG) of the University of Washington participated in the SAFARI-2000 Dry Season Aircraft campaign with their Convair-580 research aircraft. This campaign covered five countries in southern Africa from 10 August through 18 September, 2000. Various types of measurements were obtained on the thirty-one research flights of the Convair-580 in SAFARI-2000, to study their relationships to simultaneous measurements from satellites (particularly Terra), other research aircraft, and SAFARI-2000 ground-based measurements and activities.

The main goals of the University of Washington's Convair-580 research aircraft were to:

- Measure the physical and chemical properties of aerosols and trace gases in ambient air, and from various sources, in southern Africa.
- Obtain measurements on aerosols, trace gases, clouds, and surface properties for comparisons with simultaneous remote sensing measurements from the NASA ER-2 aircraft and Terra satellite and from SAFARI-2000 ground stations.
- Carry out comparative studies using in situ and remote sensing measurements made aboard the Convair-580.
- Compare aerosol and trace gas measurements aloft at various locations in Southern Africa.
- Measure the nature and concentrations of aerosols and trace gases, and their emission factors, in smoke from prescribed fires and non-prescribed fires of biomass in southern Africa.
- Measure the spectral albedo and bidirectional reflection distribution function (BRDF) of various surfaces and clouds in southern Africa.
- Measure the microstructures of clouds off the Atlantic Coast of southern Africa.
- Investigate aerosol-cloud interactions.

For a complete detailed guide to the extensive measurements obtained aboard the UW Convair-580 aircraft in support of SAFARI 2000, see the companion file UW Technical Report for the SAFARI 2000 Project [SAFARI-MASTER.pdf].

Background Information

Investigators:
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The University of Washington Convair-580 aircraft

Project: SAFARI 2000
Data Set Title: CARG Aerosol and Cloud Data from the Convair-580

Site: Southern Africa
Westernmost Longitude: 11
Easternmost Longitude: 36
Northernmost Latitude: -14
Southernmost Latitude: -26

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Data File Information

The data are stored in ASCII files of space separated values, each containing descriptive header information. Within each directory, the following files (#### is the 4 digit flight number) exist:

```
carg_####_aer.txt   (aerosol data)
carg_####_chm.txt   (chemistry data)
carg_####_cld.txt   (cloud physics data)
carg_####_met.txt   (meteorological data)
carg_####_nav.txt   (navigation & flight characteristics)
carg_####_rad.txt   (radiation data)
```

The data files contain descriptive header information and are tab-delimited text files. The data is output at 1-second resolution. The first column in all data files is the UTC time that the data were collected. All values use -999.99 to denote missing or bad data.

The column headings, units, instruments, data processing notes, data availability and quality notes, and example data records for the respective data file types are shown below. References to similar data collected on the CV-580 by other investigators are also listed.

Aerosol data (aer)

Column Name	Definition	Units	Instrument	Processing	Notes
nepred_c	Red (770nm) total light-scattering coefficient	per m	Integrating 3-wavelength nephelometer with backscatter shutter (MS Electron 3W-02)	Linear scaling from voltage to units	This value is corrected for the angular truncation problem and for the non-isotropic light source problem. Correction information can be found in Appendix A.

nepgrn_c	Green (550nm) total light-scattering coefficient	per m	Integrating 3-wavelength nephelometer with backscatter shutter (MS Electron 3W-02)	Linear scaling from voltage to units	This value is corrected for the angular truncation problem and for the non-isotropic light source problem. Correction information can be found in Appendix A.
nepblu_c	Blue (450nm) total light-scattering coefficient	per m	Integrating 3-wavelength nephelometer with backscatter shutter (MS Electron 3W-02)	Linear scaling from voltage to units	This value is corrected for the angular truncation problem and for the non-isotropic light source problem. Correction information can be found in Appendix A.
bksprd_c	Red (700nm) back scattering coefficient	per m	Integrating 3-wavelength nephelometer with backscatter shutter (MS Electron 3W-02)	Linear scaling from voltage to units	Correction information can be found in Appendix A.
bkspgr_c	Green (550nm) back scattering coefficient	per m	Integrating 3-wavelength nephelometer with backscatter shutter (MS Electron 3W-02)	Linear scaling from voltage to units	Correction information can be found in Appendix A.
bkspbl_c	Blue (450nm) back scattering coefficient	per m	Integrating 3-wavelength nephelometer with backscatter shutter (MS Electron 3W-02)	Linear scaling from voltage to units	Correction information can be found in Appendix A.
rams550_amb_c	(550nm) Particle soot/absorption photometer	per m	Radiance Research	Linear scaling from voltage to units	Adjusted from 567nm to 550nm, and adjusted to ambient pressure and temperature for easier comparison to

					nephelometer values. Correction information can be found in Appendix A.
cnc1	Condensation particle counter	#/cc	TSI Model 3022A	None	None
cnc2	Condensation particle counter	#/cc	Civil Engineering Nephelometer	Linear scaling from voltage to units	None
cetspgr	Integrating nephelometer	per m	Civil Engineering Nephelometer	Linear scaling from voltage to units	None
rhhum	Relative Humidity from the Humidograph	percent	Scanning Humidograph	Linear scaling from voltage to units	Value of relative humidity during humidograph scan. There are no measurements for UW flights 1810 through 1823.
pcaspdnc	Particle concentration between 0.1 and 3.0 µm in 15 channels (corrected per micron)	#/cc	Particle Measuring Systems Model PCASP-100X	Calculated from raw counts and sample time	Channel Limits are: 0.10, 0.12, 0.14, 0.17, 0.20, 0.25, 0.30, 0.40, 0.50, 0.70, 0.90, 1.20, 1.50, 2.00, 2.50, 3.00 µm
tsidnc	Particle concentration between 0.5 and 20 µm in 52 channels (corrected per micron)	#/cc	TSI Model 3320 APS	Calculated from raw counts and sample time	There is no data from this instrument on UW flights 1815, 1818, 1820, and 1830. Channel Limits are: 0.487, 0.523, 0.562, 0.604, 0.649, 0.698, 0.750, 0.806, 0.866, 0.931, 1.000, 1.075, 1.155, 1.241, 1.334, 1.433, 1.540, 1.655, 1.778, 1.911, 2.054, 2.207, 2.371, 2.548, 2.738, 2.943, 3.162, 3.398, 3.652, 3.924, 4.217, 4.532, 4.870, 5.233, 5.623, 6.043, 6.494, 6.978, 7.499, 8.058, 8.660, 9.306, 10.000, 10.746, 11.548, 12.409, 13.335, 14.330, 15.399, 16.548, 17.783, 19.110, 20.535 µm
oecext	Light-extinction coefficient of smoke	per m	Optical extinction cell (6m path length)	Scaling from voltage to units	This measurement is available only for certain time periods during UW flights

	at 538nm				1816, 1819, 1825, 1826, 1831, and 1834 when penetrating smoke plumes. Where as all other data is archived at 1 Hz, this instrument sampled at approximately 5 Hz and only in plumes. Thus, the data for these flights are appended to the aerosol flight data files after the 1 Hz data.
oecscat	Light-scattering coefficient of smoke at 538nm	per m	Optical extinction cell (6m path length)	Scaling from voltage to units	This measurement is available only for certain time periods during UW flights 1816, 1819, 1825, 1826, 1831, and 1834 when penetrating smoke plumes. Where as all other data is archived at 1 Hz, this instrument sampled at approximately 5 Hz and only in plumes. Thus, the data for these flights are appended to the aerosol flight data files after the 1 Hz data.

Example aerosol data records

carg_1810_aer.txt

Flt 1810 - 2000-08-10 pcasp concentration corrected per micron tsi3320 concentration corrected per micron (tsidnc)

Time nepred_c nepgrn_c nepblu_c bksprd_c bkspgr_c bkspbl_c rams550_amb_c cnc1 cnc2 cetspgr 0.10-0.12um 0.12-0.14 0.14-0.17um 0.17-0.20um 0.20-0.25um 0.25-0.30um 0.3-0.4um 0.4-0.5um 0.5-0.7um 0.7-0.9um 0.9-1.2um 1.2-1.5um 1.5-2.0um 2.0-2.5um 2.5-3.0um 0.487-0.523um 0.523-0.562um 0.562-0.604um 0.604-0.649um 0.649-0.698um 0.698-0.750um 0.750-0.806um 0.806-0.866um 0.866-0.931um 0.931-1.000um 1.000-1.075um 1.075-1.155um 1.155-1.241um 1.241-1.334um 1.334-1.433um 1.433-1.540um 1.540-1.655um 1.655-1.778um 1.778-1.911um 1.911-2.054um 2.054-2.207um 2.207-2.371um 2.371-2.548um 2.548-2.738um 2.738-2.943um 2.943-3.162um 3.162-3.398um 3.398-3.652um 3.652-3.924um 3.924-4.217um 4.217-4.532um 4.532-4.870um 4.870-5.233um 5.233-5.623um 5.623-6.043um 6.043-6.494um 6.494-6.978um 6.978-7.499um 7.499-8.058um 8.058-8.660um 8.660-9.306um 9.306-10.000um 10.000-10.746um 10.746-11.548um 11.548-12.409um 12.409-13.335um 13.335-14.330um 14.330-15.399um 15.399-16.548um 16.548-17.783um 17.783-19.110um 19.110-20.535um

UTC /m /m /m /m /m /m /m /cc /cc /m /um/cc

11:27:00 -999.99

11:27:01 -999.99

Related aerosol data collected on the CV-580 during SAFARI 2000

- Discrete measurements of particle size, shape, elemental composition, crystallographic structure and aggregation were obtained from electron-beam techniques. For information on times of samples see Table 5.6 in the SAFARI-MASTER.pdf. For actual measurements, contact Prof. P. Buseck (pbuseck@asu.edu).

  Pósfai, M., R. Simonics, J. Li, P. V. Hobbs, and P. R. Buseck, Individual aerosol particles from biomass burning in southern Africa: 1. Compositions and size distributions of carbonaceous particles, J. Geophys. Res., 108(D13), 8483, doi:10.1029/2002JD002291, 2003.

Particles, Dry Season 2000.

- For information on cloud condensation nucleus spectra, measured in Namibia only, contact Dr. R. Bruitjes (roelof@rap.ucar.edu).

  Data neither part of S2K JRG Special Issue nor CD-ROM Series.

Chemistry data (chm)

Column Name	Definition	Units	Instrument	Processing	Notes
co2	CO_2 concentration	ppm	LICOR Li 6262 - Infrared correlation spectrometer	Scaling from voltage to units	Calibration information can be found in Appendix A.
co2bag	CO_2 concentration from the bag house	ppm	LICOR Li 6262 - Infrared correlation spectrometer	Scaling from voltage to units	Calibration information can be found in Appendix A.
co	CO concentration	ppm	Teco Model 48 - Infrared correlation spectrometer	Scaling from voltage to units	Calibration information can be found in Appendix A.
no	NO concentration	ppb	Modified Monitor Labs Model 8840 -- Chemiluminescence	Scaling from voltage to units	Calibration information can be found in Appendix A.
so2	SO_2 concentration	ppb	Teco 43S (modified in-house) - Pulsed fluorescence	Scaling from voltage to units	Calibration information can be found in Appendix A.
o3	O_3 concentration	ppb	TEI Model 49C - UV absorption	Scaling from voltage to units	Calibration information can be found in Appendix A.

Example chemistry data records

carg_1810_chm.txt

Flt 1810 - 2000-08-10

Time co2 co2bag co no so2 o3

UTC ppm ppm ppb ppb ppb ppb

11:27:00 -999.99 -999.99 -999.99 -999.99 -999.99 -999.99

11:27:01 -999.99 -999.99 -999.99 -999.99 -999.99 -999.99

Related chemistry data collected on the CV-580 during SAFARI 2000

- Reactive and stable gaseous combustion emissions from Fourier Transforms IR spectrometer: Contact Prof. Robert Yokelson (byok@selway.umt.edu).

    Yokelson, R. J., I. T. Bertschi, T. J. Christian, P. V. Hobbs, D. E. Ward, and W. M. Hao, Trace gas measurements in nascent, aged, and cloud-processed smoke from African savanna fires by airborne Fourier transform infrared spectroscopy (AFTIR), *J. Geophys. Res.*, *108*(D13), 8478, 108, doi:10.1029/2002JD002322, 2003.

    Yokelson, R. J., et al. 2004 SAFARI 2000 Emission Factors and Emission Ratios from Savana Fires. Data set. Available on-line [http://www.daac.ornl.gov] from ORNL DAAC.

- The following discrete measurements data were also obtained aboard the Convair-580. For information on times of samples, see Tables 5.8 and 5.11 in the SAFARI-MASTER.pdf document and for actual measurements, contact phobbs@atmos.washington.edu:
    1. Total particulate mass and concentrations of SO_4, NO_3, Cl, Na^+, K^+, NHM_4^+ Ca^{++}, and Mg^{++} from ion exchange chromatography.
    2. Carbonaceous particles (black or organic carbon). From Thermal Evolution Techniques.
    3. Hydrocarbons, CO or CO_2 from gas chromatography.

- For information on discrete samples of PM2-5 SO_4, NO_3, NH_4^+, pH, and carbonaceous aerosol, contact Prof. D. Eatough (deatough@chemdept.byu.edu).

Eatough, D. J., N. L. Eatough, Y. Pang, S. Sizemore, T. W. Kirchstetter, T. Novakov, and P. V. Hobbs, Semivolatile particulate organic material in southern Africa during SAFARI 2000, *J. Geophys. Res.*, *108*(D13), 8479, doi:10.1029/2002JD002296, 2003.

Cloud data (cld)

Column Name	Definition	Units	Instrument	Processing	Notes
fsprt	Total cloud particle concentration	#/cc	Particle Measuring Systems Model FSSP-100	Calculated from raw counts and sample time	The several cloud penetrations prior to UW flight 1836 were impacted by an alignment problem. Droplet concentrations are considered reliable during these flights, but droplet spectra and integrated liquid water content (LWC) are not. The latter were only about 10-20% of the Johnson Williams hot wire and Particle Volume Monitor LWCs in the few clouds sampled prior to UW flight 1836. The FSSP was cleaned and aligned and calibrated prior to UW flight 1836.
reff	Effective particle radius	µm	None	Calculated from combined "fspdn"and "cpdn" size	Not reliable prior to UW flight 1836 (see above), nor after UW flight 1837 due to spurious counting of "particles" in clear air by the PMS-1-D Model OAP-200 cloud probe.
erpvm	Effective particle radius	µm	Gerber Scientific Instruments PVM-100A	calculated from "lwpvm" and "psapvm"	Impacted by numerous large noise spikes randomly and when threshold LWCs occurred throughout SAFARI. Thes have been assigned the missing/bad value of -999.99.
fspcs	Cumulative Surface Area	cm^2/m^3	Particle Measuring Systems Model FSSP-100	Calculated from raw counts and sample time	Values not reliable in the several clouds sampled prior to UW flight 1836
sapvm	Particle surface area concentration	cm^2/m^3	Gerber Scientific Instruments PVM-100A	Linear scaling from voltage to units	Impacted by numerous large noise spikes randomly and when threshold LWCs occurred throughout SAFARI. Thes have been assigned the missing/bad value of -999.99.

lwfsp	Liquid water content	g/m^3	Particle Measuring Systems Model FSSP-100	calculated from fssp concentration values	Not reliable prior to UW flight 1836 (see above).
lwpvm0	Liquid water content	g/m^3	Gerber Scientific Instruments PVM-100A	Linear scaling from voltage to units	Impacted by numerous large noise spikes randomly and when threshold LWCs occurred throughout SAFARI. Thes have been assigned the missing/bad value of -999.99. Valu is set to 0 if fsprt is less than 10 cm-3 in the continental clouds of South Africa, and less than 5 cm-3 in the maritime clouds off the coast of Namibia.
lwjw0	Liquid water content	g/m^3	Johnson-Williams hot wire	Linear scaling from voltage to units	Impacted by numerous large noise spikes randomly and when threshold LWCs occurred throughout SAFARI. Thes have been assigned the missing/bad value of -999.99. Valu is set to 0 if fsprt is less than 10 cm-3 in the continental clouds of South Africa, and less than 5 cm-3 in the maritime clouds off the coast of Namibia.
fspdn	Cloud particle concentration between 1.7 and 47.0 µm in 15 channels	#/cc	Particle Measuring Systems Model FSSP-100	Calculated from raw counts and sample time	The several cloud penetrations prior to UW flight 1836 were impacted by an alignment problem. Droplet concentrations are considered reliable during these flights, but droplet spectra and integrated liquid water content (LWC) are not. The latter were only about 10-20% of the Johnson Williams hot wire and Particle Volume Monitor LWCs in the few clouds sampled prior to UW flight 1836. The FSSP was cleaned and aligned and calibrated prior to UW flight 1836.

Example cloud data records

carg_1810_cld.txt

Flt 1810 - 2000-08-10 fssp concentration (fspdn)

Time fsprt erpvm reff sapvm fspcs lwfsp lwpvm0 lwjw0 1.70-4.05um 4.05-6.80um 6.80-9.72um 9.72-12.00um

12.00-14.32um 14.32-16.77um 16.77-19.69um 19.69-22.93um 22.93-26.46um 26.46-30.10um 30.10-33.38um 33.38-36.59um 36.59-39.75um 39.75-43.33um 43.33-47.00um

UTC /cc um um cm2/m3 cm2/m3 g/m3 g/m3 g/m3 /cc /cc /cc /cc /cc /cc /cc /cc /cc /cc /cc /cc /cc /cc

11:27:00 -999.99

11:27:01 -999.99

Meteorological data (met)

Column Name	Definition	Units	Instrument	Processing	Notes
tstatr	air temperature	deg C	Reverse flow thermometer	Linear scaling from voltage to units, corrected	This parameter was impacted by large noise spikes during SAFARI and "top hat" shaped temperature deviations mainly associated with pilot-to-air-traffic control communications. These have been replaced with the missing/bad data value of -999.99. Pre-, mid-, and post-SAFARI calibration information for this instrument can be found in Appendix A.
dp	air dew point temperature	deg C	Cambridge System Model TH73-244	Linear scaling from voltage to units	Nature of instrument causes very small oscillation around "true" value. This parameter was also impacted by large noise spikes during SAFARI and "top hat" shaped temperature deviations mainly associated with pilot-to-air-traffic control communications. These have been replaced with the missing/bad data value of -999.99. Values are not considered reliable when dewpoints are indicated to approach about -25 C. Slow response (several seconds) to changes in humidity. Most accurate values are those averaged over 10 s or more. Pre-, mid-, and post-SAFARI calibration information for this instrument can be found in Appendix A.
dp_o	IR optical hygrometer dew point	deg C	Ophir Corp. Model IR-2000	Derived from the Ophir absolute	This parameter was also impacted by noise spikes during SAFARI and "top hat" shaped temperature deviations mainly associated with pilot-to-air-traffic control communications. These have been replaced with

	temperature			humidity	the missing/bad data value of -999.99 wherever they were obviously present. However, the normal "noisy" output by this device made eliminating smaller scale spikes moot. Values are not considered reliable when dew points approach about -25 C. Values below -50 C have been replaced by the missing/bad data value of -999.99. Some values, particularly those between UW flights 1830 and 1838, often deviated substantially (more than a few degrees) from values indicated by the Cambridge chilled mirror system. It is believed that, although swabbed periodically during SAFARI, smoke/dirt buildup may have degraded the Ophir instrument operation during this period and the Cambridge system should be favored in retrieving humidity data for these flights. Pre-, mid-, and post-SAFARI calibration information for this instrument can be found in Appendix A.
wind_dir	Wind Direction	deg from true north	Trimble TANS/Vector GPS & Shadin Aircraft Computer	Calculated from shadin_tas and GPS data	Values are not considered reliable during turns (aircraft roll values greater than +/-3 deg) and in those cases have been assigned the missing/bad data value of -999.99.
wind_spd	Wind Speed	m/s	Trimble TANS/Vector GPS & Shadin Aircraft Computer	Calculated from shadin_tas and GPS data	Values are not considered reliable during turns (aircraft roll values greater than +/-3 deg) and in those cases have been assigned the missing/bad data value of -999.99.

Example meteorological data records

carg_1810_met.txt

Flt 1810 - 2000-08-10

time tstatr dp dp_o wind_dir wind_spd

UTC degC degC degC deg from true N m/s

11:27:00 -999.99 -999.99 -999.99 -999.99 -999.99

11:27:01 -999.99 -999.99 -999.99 -999.99 -999.99

Navigation data (nav)

Column Name	Definition	Units	Instrument	Processing	Notes
tans-lat	aircraft latitude	deg N	Trimble TANS/Vector GPS	None	Position is updated every 3 to 10 seconds.
tans-lon	aircraft longitude	deg E	Trimble TANS/Vector GPS	None	Position is updated every 3 to 10 seconds.
tans-altft	aircraft altitude	feet ASL	Trimble TANS/Vector GPS	None	Position is updated every 3 to 10 seconds. On a few occasions, the loss of one or more of the satellites used to determine the GPS altitude causes the indicated altitude to remain constant while the aircraft may be in a climb or descent.
palt	aircraft altitude	feet ASL	Rosemount Model 830 BA	Uses surface pressure of 1013 hPa	Spurious slight flight level changes of up to 10s of meters due to noise in the pstat measurement (see below). Data should be averaged or median value used to obtain the most reliable altitude.
ralt	radar altimeter	feet AGL	Bendix Model ALA 51A	Scaling from voltage to units	Range is up to 2500 feet above ground level
pstat	air pressure	mb	Rosemount Model 830 BA	Linear scaling from voltage to units	Spurious second-to-second deviations in pressure of one to a few hPa. Data should be averaged or median value used to obtain the most reliable pressure. Pre-, mid-, and post-SAFARI calibration information for this instrument can be found in Appendix A.

shadin_tas	Shadin True Airspeed	m/s	Shadin Aircraft Computer	None.	No data for UW flight 1822. For UW flight 1822, see instrument tas below.
tas	True Airspeed	m/s	Rosemount Model F2VL 781A	Scaling from voltage to units	Data only for flight UW 1822. For all other flights, see shadin_tas above.
tans-azimth	aircraft azimuth angle	deg clockwise from true north	Trimble TANS/Vector GPS	None	None
tans-roll	aircraft roll angle	deg - positive is right wing up	Trimble TANS/Vector GPS	None	None
tans-pitch	aircraft pitch angle	deg - positive is nose down	Trimble TANS/Vector GPS	None	None

Example navigation data records

carg_1810_nav.txt

Flt 1810 - 2000-08-10

time tans-lat tans-lon tans-altft palt ralt pstat shadin_tas tans-azimth tans-roll tans-pitch

UTC deg deg ft feet ft mb m/s deg from true N deg right wing up deg nose down

11:27:00 -999.99 -999.99 -999.99 -999.99 -999.99 -999.99 80 -999.99 -999.99 -999.99

11:27:01 -999.99 -999.99 -999.99 -999.99 -999.99 -999.99 80 -999.99 -999.99 -999.99

Radiation data (rad)

Column Name	Definition	Units	Instrument	Processing	Notes
irtemp	IR radiometer - surface radiative temperature	deg C	Omega Engineering OS3701	None	Absolute values are not considered accurate, but accuracy increases when within about 600 m of the surface. Useful for detecting the widths of fires overflown in low elevation passes and cloud width when just above cloud top.
pyrdo	hemispheric downward radiance from 0.3 to 3µm wavelengths (visible and near-infrared)	W/m^2	Eppley Lab Inc. Model PSP	Linear scaling from voltage to units	No data available for UW flights 1810 through 181
pyrup	hemispheric upward radiance from 0.3 to 3µm wavelengths (visible and near-infrared)	W/m^2	Eppley Lab Inc. Model PSP	Linear scaling from voltage to units	No data available for UW flights 1810 through 181
uvdo	hemispheric downward radiance from 0.295 to 0.390 µm wavelengths (ultraviolet)	W/m^2	Eppley Lab Inc. Model PSP	Linear scaling from voltage to units	Data available for US flights 1821 and 1828 only.
uvup	hemispheric upward radiance from 0.295 to 0.390 µm wavelengths (ultraviolet)	W/m^2	Eppley Lab Inc. Model PSP	Linear scaling from voltage to units	No data available for UW flights 1810 through 181

Example radiation data records

carg_1810_rad.txt

Flt 1810 - 2000-08-10

time irtemp pyrdo pyrup uvdo uvup

UTC degC W/m2 W/m2 W/m2 W/m2

11:27:00 -999.99 -999.99 -999.99 -999.99 -999.99

11:27:01 -999.99 -999.99 -999.99 -999.99 -999.99

Related radiation data collected on the CV-580 during SAFARI 2000

- Absorption and scattering of solar radiation by clouds and aerosols and reflectivity of surfaces from NASA-Goddard 14 wavelength scanning radiometer - contact Dr. M. King (king@climate.gsfc.nasa.gov).

  Gatebe, C. K., M. D. King, S. Platnick, G. T. Arnold, E. F. Vermote, and B. Schmid, Airborne spectral measurements of surface atmosphere anisotropy for several surfaces and ecosystems over southern Africa, *J. Geophys. Res.*, *108*(D13), 8489, doi:10.1029/2002JD002397, 2003.

  Gatebe, C.K., et al. 2004. SAFARI 2000 Cloud Absorption Radiometer BRDF, Dry Season 2000 (CARG CV-580). Data set. Available on-line [http://www.daac.ornl.gov] from ORNL DAAC.

- Solar spectral irradiance or radiance; spectral transmission and reflection - Contact Dr. P. Pilewskie (ppilewskie@mail.arc.nasa.gov).

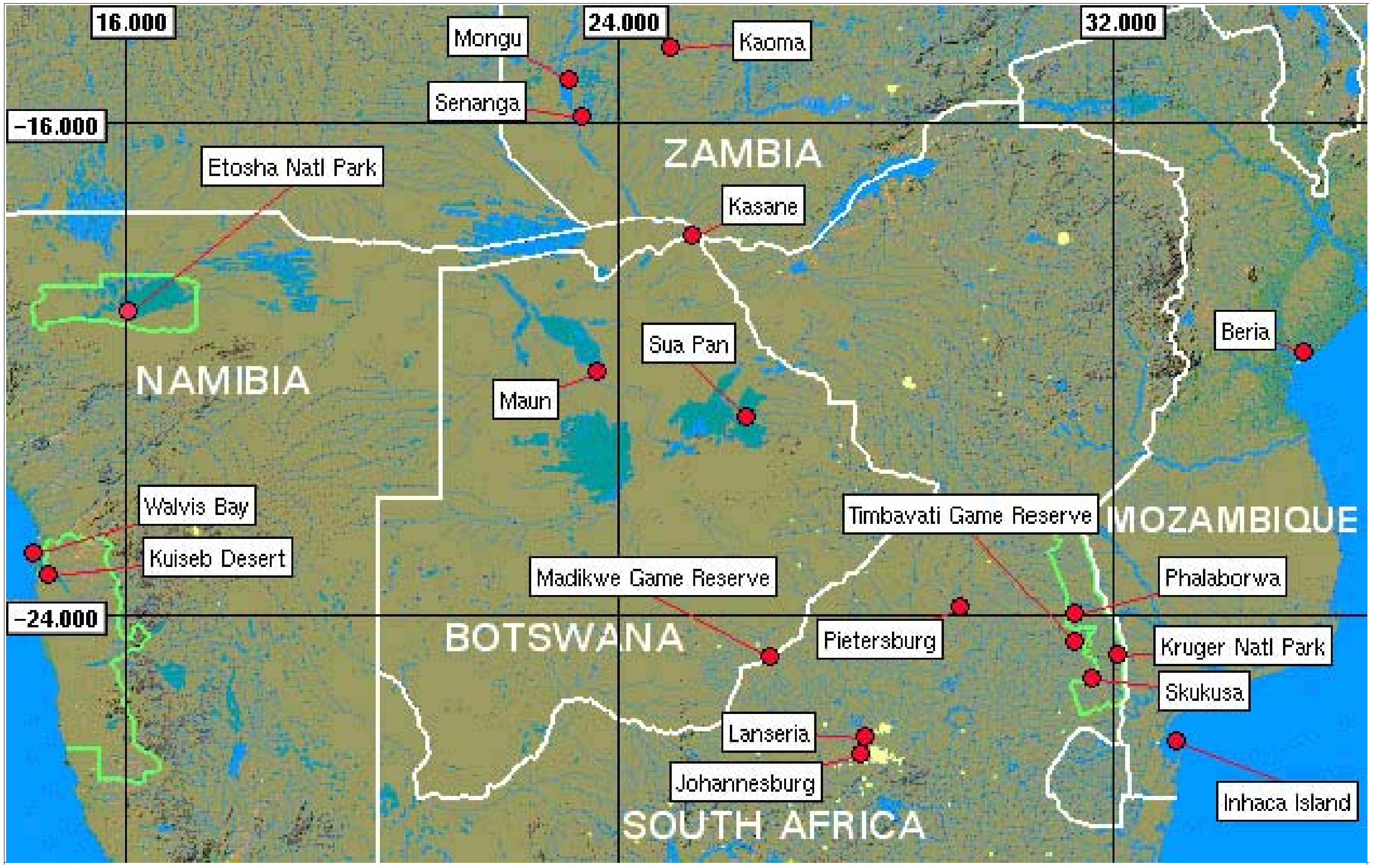
  Pilewskie, P., J. Pommier, R. Bergstrom, W. Gore, S. Howard, M. Rabbette, B. Schmid, P. V. Hobbs, and S. C. Tsay, Solar spectral radiative forcing during the Southern African Regional Science Initiative, *J. Geophys. Res.*, *108*(D13), 8486, doi:10.1029/2002JD002411, 2003.

- Aerosol optical depths, water vapor and ozone - contact Dr. P. Russell (prussell@mail.arc.nasa.gov).

  Bergstrom, R. W., P. Pilewskie, B. Schmid, and P. B. Russell, Estimates of the spectral aerosol single scattering albedo and aerosol radiative effects during SAFARI 2000, *J. Geophys. Res.*, *108*(D13), 8474, doi:10.1029/2002JD002435, 2003.

Overview of Convair-580 Flights

The Cloud and Aerosol Research Group (CARG) of the University of Washington participated in SAFARI 2000 from 13 August through 18 September, 2000. The Convair-580 was based out of Pietersburg (South Africa) from 7 August through 9 September, and out of Walvis Bay (Namibia) from 12-18 September. The flights were numbered from UW #1810 (10 August) to UW #1840 (18 September). The following map shows the bases of the Convair-580 within the SAFARI 2000 study area. For maps of individual flight lines, see the UW Technical Report for the SAFARI 2000 Project [link to SAFARI-MASTER.pdf].



Overview of University of Washington Convair-580 Research Fligths for SAFARI 2000
(10 August-18 September, 2000)

Date (2000)	U.W. Flight #	Period (UTC)	General Location	Main Measurements
10 Aug.	1810	1127-1522 (3.92 hr)	In quadrant northwest of Pietersburg, South Africa, out to about 90 miles from Pietersburg.	• Physical and chemical measurements above and in boundary layer.
14 Aug.	1811	1026-1132 (1.10 hr)	Pietersburg to Lanseria, South Africa.	• Measurements en route.
14 Aug.	1812	1216-1505 (2.82 hr)	About 80 miles northwest of Johannesburg, South Africa.	• Physical and chemical measurements in boundary layer.
14 Aug.	1813	1551-1649 (0.97 hr)	Lanseria to Pietersburg, South Africa.	• Measurements en route.
15 Aug.	1814	0655-1115 (4.33 hr)	Pietersburg to Skukusa (in Kruger National Park), South Africa. Then to about 30 miles west of Skukusa. Return to Pietersburg.	• Measurements en route in free troposphere (at 9,000 ft). • 100 ft runs beneath TERRA overpass (at 0823 UTC) at Skukuza. • Physical and chemical measurements at 3,000 ft just west of Skukuza. • Measurements of smoke from two grass fires and some cumulus sampling 30 nm west of Skukusa.
17 Aug.	1815	0701-1213 (5.20 hr)	Pietersburg to south and central Kruger National Park, South Africa. Return to Pietersburg.	• Measurements en route at 10,000 ft. • Vertical profile from 10,000 ft to 100 ft in Kruger National Park. • Physical and chemical measurements at 4,000 ft. • Measurements in two smoke plumes (flaming and smoldering combustion). • Measurements on return to Pietersburg.
18 Aug.	1816	0802-1339 (5.62 hr)	Pietersburg to Medikwe Game Reserve on border of South Africa and Botswana, and return.	• Measurements en route. • Physical and chemical measurements of smoke from prescribed fire in Medikwe Game Reserve.

20 Aug.	1817	0657-0705 (0.13 hr)	Flight cancelled on Pietersburg runway.	N/A
20 Aug.	1818	0713-0819 (1.10 hr)	Pietersburg toward South Africa-Botswana border and return. (Flight terminated prematurely due to radio communication problem with ATC.)	• Physical and chemical measurements in ambient haze en route.
20 Aug.	1819	1124-1541 (4.28 hr)	Pietersburg to Medikwe Game Reserve on border of South Africa and Botswana, and return.	• Physical and chemical measurements in smoke from prescribed fire in Medikwe. • Measurements of ambient smoke and haze near Botswana/South Africa border.
22 Aug.	1820	0658-1235 (5.62 hr)	Pietersburg to Skukusa (in Kruger National Park), South Africa, and return to Pietersburg via Phalaborwa.	• Vertical profile over Skukuza Airport with ER-2 and TERRA overpasses. • BRDF near Skukuza. • BRDF near Mopane trees (??) in northern Kruger National Park.
23 Aug.	1821	1138-1448 (3.17 hr)	In vicinity of Pietersburg.	• Intercomparisons of aerosol and state parameters with South African Aerocommanders and with rawinsonde launched from Pietersburg Gateway Airport.
24 Aug.	1822	0638-1130 (4.87 hr)	Pietersburg, South Africa, to Inhaca Island, Mozambique.	• Detailed vertical profile over Inhaca Island, Mozambique, with Terra and ER-2 overpasses.
29 Aug.	1823	0822-1114 (2.87)	Pietersburg to border between South Africa and Zimbabwe, and return.	• Measurements en route during outbound and return legs. • Physical and chemical measurements in well mixed boundary layer at 9,500 ft and • BRDF of uniform shrub near South Africa/Zimbabwe border. • Vertical profile near South Africa/Zimbabwe border. • Some cloud penetrations near South Africa-Zimbabwe border.
29 Aug.	1824	1245-1540 (2.92 hr)	Pietersburg to Skukusa, Kruger National Park, South Africa, and return.	• BRDF centered on Skukuza tower. • Measurements of smoke from smoldering fire in Kruger National Park.

				• 200 ft agl run over plantations on high veldt.
31 Aug.	1825	0842-1421 (5.65 hr)	Pietersburg, South Africa, to central Mozambique coast. North along Mozambique coastline to west of Beria. Return to Pietersburg.	• Measurements at several levels on transit legs. • Run at 100 ft along Mozambique coastline. • Measurements of smoke at several distances downwind from smoldering fire west of Beria. • Good measurements in haze and smoke on return flight.
1 Sept.	1826	0532-1108 (5.60 hr)	Pietersburg, South Africa, to Kaoma, Zambia, to Kasane, Botswana.	• Measurements en route to Kaoma. • Detailed measurements on prescribed Miombo burn near Kaoma, Zambia. • Measurements en route from Kaoma to Kasane.
1 Sept.	1827	1229-1241 (0.20 hr)	Did not take off from Kasane, Botswana, due to recall by ATC.	--
1 Sept.	1828	1329-1551 (2.37 hr)	Kasane, Botswana, to Pietersburg, South Africa.	• Measurements en route from Kasane to Pietersburg.
2 Sept.	1829	0736-1334 (5.97 hr)	Pietersburg, South Africa, to Maun, Botswana, and return to Pietersburg.	• BRDF centered on Maun tower. • Vertical profile under TOMS at Maun tower.
3 Sept.	1830	0702-1238 (5.60 hr)	Pietersburg, South Africa, to Sua Pan, Botswana, and return.	• BRDF over Sua Pan and grass. • Vertical profile over Sua Pan parabola with TERRA overpass. • Measurements at several altitudes on transit legs.
5 Sept.	1831	0838-1413 (5.58 hr)	Pietersburg, South Africa, to Kaoma, Zambia, to Kasane, Botswana, via Senanga, Zambia.	• Measurements from Pietersburg to Kaoma, Zambia. • Measurements on smoke from prescribed burn of Diombo near Kaoma, Zambia. • Measurements en route to Kasane with low-level pass over Senanga, Zambia.
6 Sept.	1832	0700-1058 (3.97 hr)	Kasane, Botswana, to about 20 miles north of Mongu, Zambia. Return to Kasane.	• Low-level run from Senanga to Mongu to about 20 nm north of Mongu. • Measurements en route back to Kasane. • BRDF over Mongu tower.

				• Vertical profile over Mongu airport.
6 Sept.	1833	1133-1354 (2.35 hr)	Kasane, Botswana, to Pietersburg, South Africa.	• Measurements in boundary layer from Kasane to Pietersburg.
7 Sept.	1834	0755-1220 (4.42 hr)	Pietersburg to Timbavati Game Reserve, near Kruger National Park, South Africa, to Phalaborwa, and return to Pietersburg.	• Extensive measurements on large prescribed fire at Timbavati, South Africa, with TERRA and ER-2 overflights (see AirMISR imagery). • Two intercepts of plume from Phalaborwa copper mine. • Two sets of BRDFs on Mopane trees.
10 Sept.	1835	0558-1025 (4.45 hr)	Pietersburg, South Africa, to Walvis Bay, Namibia.	• Measurements en route.
11 Sept.	1836	0835-1222 (3.78 hr)	Walvis Bay, Namibia, to off central Namibian coast; then to Kuiseb Desert. Return to Walvis Bay.	• Underflew Terra and ER-2 in thin, broken stratus off central Namibia coast. • Vertical profile to 12,200 ft off central Namibia coast for sunphotometer and in situ comparisons. • Two sets of five CAR turns for BRDF measurements of "red" sand in Kuisab Desert, south of Walvis Bay.
13 Sept.	1837	0826-1416 (5.83 hr)	Walvis Bay, Namibia, to off Namibian coast. Return to Walvis Bay.	• Measurements below, above and in stratus off Namibian coast under Terra and ER-2. • Vertical profile, with physical and chemical measurements, from cloud top to 16,800 ft.
14 Sept.	1838	0800-1232 (4.53 hr)	Walvis Bay, Namibia, to off west coast of South Africa. Return to Walvis Bay.	• Measurements on post-frontal cumulus congestus, including inflow, outflow, and below cloud base measurements. • Measurements of effluents from two freighter ships. • Vertical profile to 12,200 ft for sunphotometer and in situ measurements. • Measurements through dust storm on descent into Walvis Bay.
16 Sept.	1839	0709-1245 (5.60 hr)	Walvis Bay, Namibia, to Etosha National Park, Namibia. Return to Walvis Bay.	• BRDF of white Etosha pan (at 19.05°/15.96°) and of Mopane trees (at 19.18°/15.66°) in Etosha National Park. • Vertical profile from 200 ft to 15,750 ft over ground-based sunphotometer site in Etosha (at 19°11'/15°55').

				• Measurements in and below small cumulus clouds near Walvis Bay.
18 Sept.	1840	????	Walvis Bay, Namibia, to Pietersburg, South Africa.	• No measurements en route.

Additional Sources of Information

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The CARG Home page:
http://cargsun2.atmos.washington.edu/

Instrumentation aboard the Convair-580 for SAFARI 2000:
http://cargsun2.atmos.washington.edu/sys/research/safari/instrumentation/TabSAFARI.htm

Overview of U of W Convair-580 Research Flights for SAFARI-2000:
http://cargsun2.atmos.washington.edu/sys/research/safari/SumS2KFlts.html

S**ummary Reports and Flight Tracks for the University of Washington's Convair-580 Flights in SAFARI 2000:**
http://cargsun2.atmos.washington.edu/sys/research/safari/SumTracks/S2Ksum.html

Photographs taken aboard the Convair-580 during the SAFARI 2000 Field Project by Peter V. Hobbs:
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Appendix A

Containing SAFARI 2000 Convair-580 research aircraft instrument calibration and data correction information for:

- Aerosol Data
- Chemistry Data
- Meteorological Data (Pre-, Mid-, and Post-SAFARI)

Aerosol Corrections for Safari 2000

Prepared by Brian Magi, June 2002.

MS Electron 3 wavelength nephelometer

These formulas correct the MS 3 wavelength nephelometer for the angular truncation problem and for the non-isotropic light source problem. The equations for the total scattering parameter corrections are from Seth Hartley's Masters thesis equations 3.6, 3.7a, 3.7b, and 3.7c. The equations for the backscatter parameter corrections are from Seth Hartley's Masters thesis equations 4.5a, 4.5b, and 4.5c. Errors associated with these corrections are discussed in the thesis and, although they are small, should be examined.

```
alphabg = -log(nepblu/nepgrn)/log(450/550)
cblu = 1.238-0.080*alphabg
nepblu_c = nepblu*cblu

alphabr = -log(nepblu/nepred)/log(450/700)
cgrn = 1.233-0.077*alphabr
nepgrn_c = nepgrn*cgrn

alphagr = -log(nepgrn/nepred)/log(550/700)
cred = 1.204-0.064*alphagr
nepred_c = nepred*cred

bkspbl_c = bkspbl*0.935
bkspgr_c = bkspgr*0.955
bksprd_c = bksprd*0.979
```

Particle soot/absorption photometer

The original PSAP measurements are made at 567 nm (confirmed with Ray Weiss May 2002 and stated in Bond et al, Calibration and Intercomparison of Filter-based Measurements of Visible Light Absorption by Aerosols, *Aerosol Science and Technology*, v.30, 582-600, 1999). Thus, the first correction is to adjust the PSAP measurements to 550 nm wavelength so they can be directly compared with the 3 wavelength nephelometer scattering values at 550 nm. The correction is based on the assumption of a 1/wavelength dependence for absorption coefficient in the visible (discussed in Hartley et al, Properties of aerosols aloft relevant to direct radiative forcing off the mid-Atlantic coast of the United States, *JGR*, v. 105, 9859-9885, 2000). Since the correction is small, the assumption should be valid.

Since the flow meter on the PSAP reduces all flow rates to STP (standard temperature of 288K and pressure of 1013.25 hPa), the absorption coefficient values are first converted to ambient pressure and temperature (using pstat and tstatr) via the Perfect Gas law equation. This is done because the nephelometer makes measurements at ambient pressure and temperature.

The next formula corrects the PSAP absorption coefficient measurements for the errors and inconsistencies discussed in the Bond et al 1999 paper mentioned above. The Bond et al 1999 corrections are all stated for 550 nm, which we have already adjusted our measurements to. Important values for the PSAP used to complete the Bond et al 1999 correction are the measured filter spot size of 4.7mm (smaller than the calibrated 5.1mm) and a 30 second averaging time. The internal PSAP flow meter was not checked and thus no correction for the flow meter is applied (inaccuracies in the flow meter are thought to introduce no more than 10% inaccuracy in the PSAP measurements, although Bond et al note that flow meters were up to 20% inaccurate).

rams550 = rams*567/550
rams550_amb = rams550*(pstat/1013.25)*[288/(tstatr+273.15)]
rams550_amb_c = rams550_amb*(4.7/5.1)^2
rams550_amb_c = [rams550_amb_c – 0.02*nepgrn + 0.06*rams550_amb_c +
0.18*sqrt(24/0.5)*1e-6]/1.22

Summary of SAFARI Gas Instrument Calibrations
(UW Flights 1810-1840: 10 Aug-18 Sept 2000)

TECO 43S Pulsed Flourescence SO_2 analyzer

UW Flights 1810-1814 (10 Aug-15 Aug):

Instrument was configured with a 200 ppbv range and 2 minute averaging time.

$$SO_2\ [ppbv] = 40.5(volts) - 1.6$$

standard error (σ) = 2%

UW Flights 1815-1840 (17 Aug-18 Sept):

Instrument was configured with a 100 ppbv range and 2 minute averaging time.

$$SO_2[ppbv] = 1 + \frac{(180-1)[volts - [3.7\times10^{-2} + 7.2\times10^{-4}(tstatr) - 4.2\times10^{-6}(pstat)]]}{[3.7 + 1.7\times10^{-2}(tstatr) + 3.6\times10^{-4}(pstat)] - [3.7\times10^{-2} + 7.2\times10^{-4}(tstatr) - 4.2\times10^{-6}(pstat)]}$$

standard error (σ) = 7%

where "volts" is the voltage output of the TECO 43S (in volts).
where "tstatr" is the static air temperature measured by the reverse flow thermometer (in °C).
where "pstat" is the pressure measured by the Rosemount Model 830 BA (in mb).

TEI Model 49C UV Absorption O_3 analyzer

UW Flights 1810-1840 (10 Aug-18 Sept):

Instrument was configured with a 60 second averaging time, 1000 ppbv range, and automatic pressure and temperature corrections.

$$O_3\ [ppbv] = -0.7 + 94.5(volts)$$

standard error (σ) = 1%

where "volts" is the voltage output of the TEI 49C (in volts).

LI-COR LI-6262 Infrared Correlation Spectrometer CO_2 analyzer

UW Flights 1810-1840 (10 Aug-18 Sept):

Instrument was configured with 1 second averaging time, a 1 ppmv range, and a metal bellows pump pulling sample air through the instrument.

$$CO_2[ppmv] = 1 + \frac{(205-1)[volts-[8.2\times10^{-1}+1.4\times10^{-2}(tstatr)-4.5\times10^{-4}(pstat)]]}{[1.4+5.6\times10^{-3}(tstatr)+5.9\times10^{-7}(pstat)]-[8.2\times10^{-1}+1.4\times10^{-2}(tstatr)-4.5\times10^{-4}(pstat)]}$$

standard error (σ) = 15%

where “volts” is the voltage output of the LI-COR LI-6262 (in volts).
where “tstatr” is the static air temperature measured by the reverse flow thermometer (in °C).
where “pstat” is the pressure measured by the Rosemount Model 830 BA (in mb).

TECO Model 48 Infrared Correlation Spectrometer CO analyzer

UW Flight 1816 (18 Aug)

Instrument range malfunctioned: no measurements

UW Flights 1810-1815 (10 Aug-17 Aug) and UW Flights 1817-1818 (20 Aug):

Instrument was configured with 2 ppmv range and 10 second averaging time.

$$CO\ [ppbv] = 362.0(volts)-1.7$$

standard error (σ) = 3%

UW Flights 1819-1822 (20 Aug-24 Aug):

Instrument was configured with 2 ppmv range and 10 second averaging time.

$$CO\ [ppbv] = 5 + [(1424-5)(volts + 1.2\times10^{-1})/(5.6\times10^{-1}+1.2\times10^{-1}]$$

standard error (σ) = 7%

UW Flights 1823-1840 (29 Aug-18 Sept):

Instrument was configured with 2 ppmv range and 10 second averaging time, and the zero was raised to reduce noise at low concentrations.

$$CO\ [ppbv] = 5+[1424-5)(volt-.4)/(1.3-.4)]$$

standard error (σ) = 21%

where “volts” is the voltage output of the TECO Model 48 (in volts).

Monitor Labs Model 8840 Chemiluminescence NO/NO_x analyzer

UW Flights 1810-1821 (10 Aug-23 Aug):

Vacuum pump not operational : no measurements

UW Flights 1822-1840 (24 Aug-18 Sept):

Instrument was configured with 1 ppmv range and 60 second averaging time, and vacuum pump was operational.

$$NO[ppbv] = 1 + \frac{(1004-1)[volts-[8.3+8.3\times10^{-2}(tstatr)-1.0\times10^{-2}(pstat)]]}{[5.8+1.1\times10^{-2}(tstatr)-4.1\times^{-3}(pstat)]-[8.3+8.3\times10^{-2}(tstatr)-1.0\times10^{-2}(pstat)]}$$

standard error (σ) = 37%

$$NO_x[ppbv] = 1 + \frac{(1004-1)[volts-[3.7-2.0\times^{-2}(tstatr)-2.1\times10^{-3}(pstat)]]}{[8.2+2.5\times10^{-2}(tstatr)+5.6\times10^{-3}(pstat)]-[3.7+2.0\times10^{-2}(tstatr)-2.1\times10^{-3}(pstat)]}$$

standard error (σ) = 30%

where “volts” is the voltage output of the Monitor Labs Model 8840 (in volts).
where “tstatr” is the static air temperature measured by the reverse flow thermometer (in °C).
where “pstat” is the pressure measured by the Rosemount Model 830 BA (in mb).

CONVAIR-580 STATE PARAMETER CALIBRATIONS FOR PRE-SAFARI 2000

Name of Instrument and Parameter: Rosemount (Model 830BA) pressure

Date of Calibration: None

Method of Calibration: None. Normally calibrated via flyby of the Paine Field tower using a calibrated aneroid barometer in the tower and the aircraft flies by at the same level as the barometer. However, no flyby was done prior to the SAFARI project. A mid-SAFARI check of the Rosemount sensor revealed no discrepancies (see appropriate form).

Person Carrying Out Calibration:

Copy of this form given to PVH on __9 July 2002_(insert date).

Completed form distributed by PVH to CARG Faculty, Students, Engineers, and Computer Programmers on ____6 August 2002_________.

RESULTS OF CALIBRATION

Conclusions: No action required.

Name of Instrument and Parameter: Reverse flow temperature (in- house manufactured)

Dates of Calibrations: 25 July 2000 (Local Daylight Time/Date), UW flight 1809

Method of Calibration: Two coordinated flights with NWS rawinsondes launched from Quillayute, Washington, were carried out. The first, on 20 July 2000 (Flight 1808), and the second was on 25 July 2000 (Flight 1809). Due to a faulty rawinsonde or faulty data transmission, no data were available from the rawinsonde at 0000 UTC on 21 July 2000. Therefore, only data from the second comparison on 25 July (the 0000 UTC 26 July sounding) are discussed. This comparison uses those data acquired in the ascent from the surface to 700 hPa, the top of the coordinated ascent.

Person Carrying Out Calibration: CARG crew

Updated copy of this form given to PVH on ____9 July 2002___ (insert date).

Completed form distributed by PVH to CARG Faculty, Students, Engineers, and Computer Programmers on _____6 August 2002_____.

RESULTS OF CALIBRATION

A comparison of the raw reverse flow temperature (tstatr) and the NWS rawinsonde temperatures at mandatory and “significant” levels shows that the CV-580 reverse flow temperature was generally lower than the rawinsonde temperature from the surface through 700 hPa. The regression equation that best adjusts the negative offset in the temperature, in degrees Celsius, is:

$$tstatr_{corrected} = 0.9\,(tstatr_{raw}) + 1.8 \qquad (1)$$

Conclusion: For UW flights 1810 (beginning of SAFARI 2000) through 1820 apply Eqn (1) to obtain the most accurate values of the reverse flow temperature. (A coordinated ascent with a rawinsonde took place in Pietersburg, South Africa, on flight 1821; adjustments to Eqn (1) based on this comparisonare addressed in the MID-SAFARI calibration forms.)

The effect of the adjustment factor is demonstrated by comparing Figures 1 and 2.

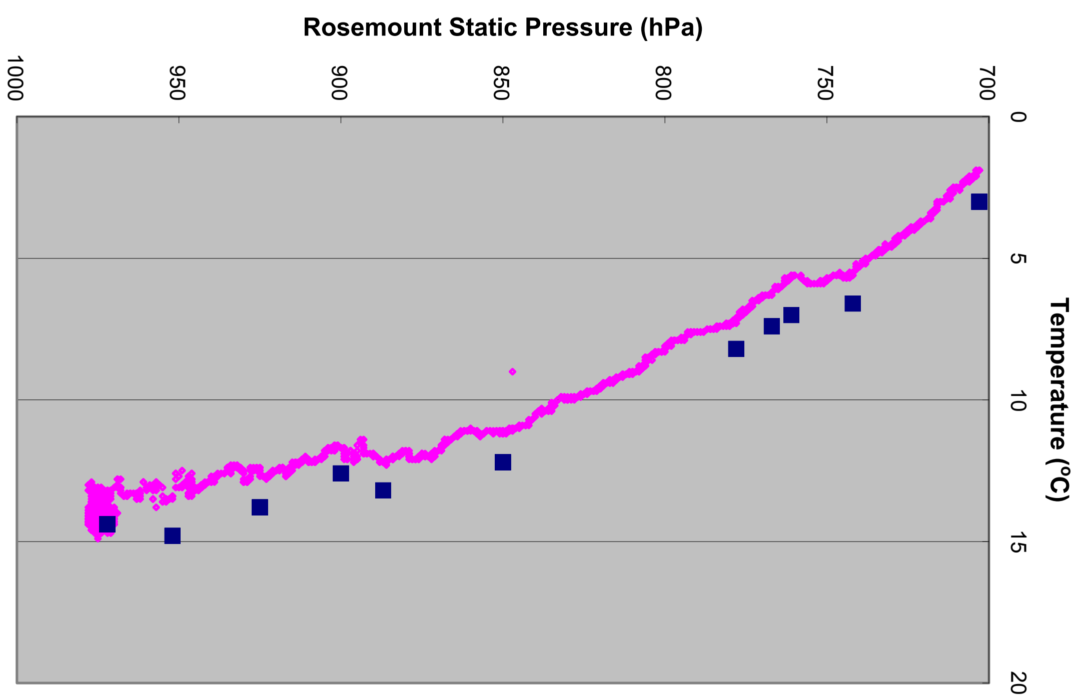

Figure 1. A comparison of the NWS Quillayute, Washington, rawinsonde temperatures (solid squares) and the raw reverse flow static temperatures (light gray line). The rawinsonde was launched at 0000 UTC, 26 July 2000.

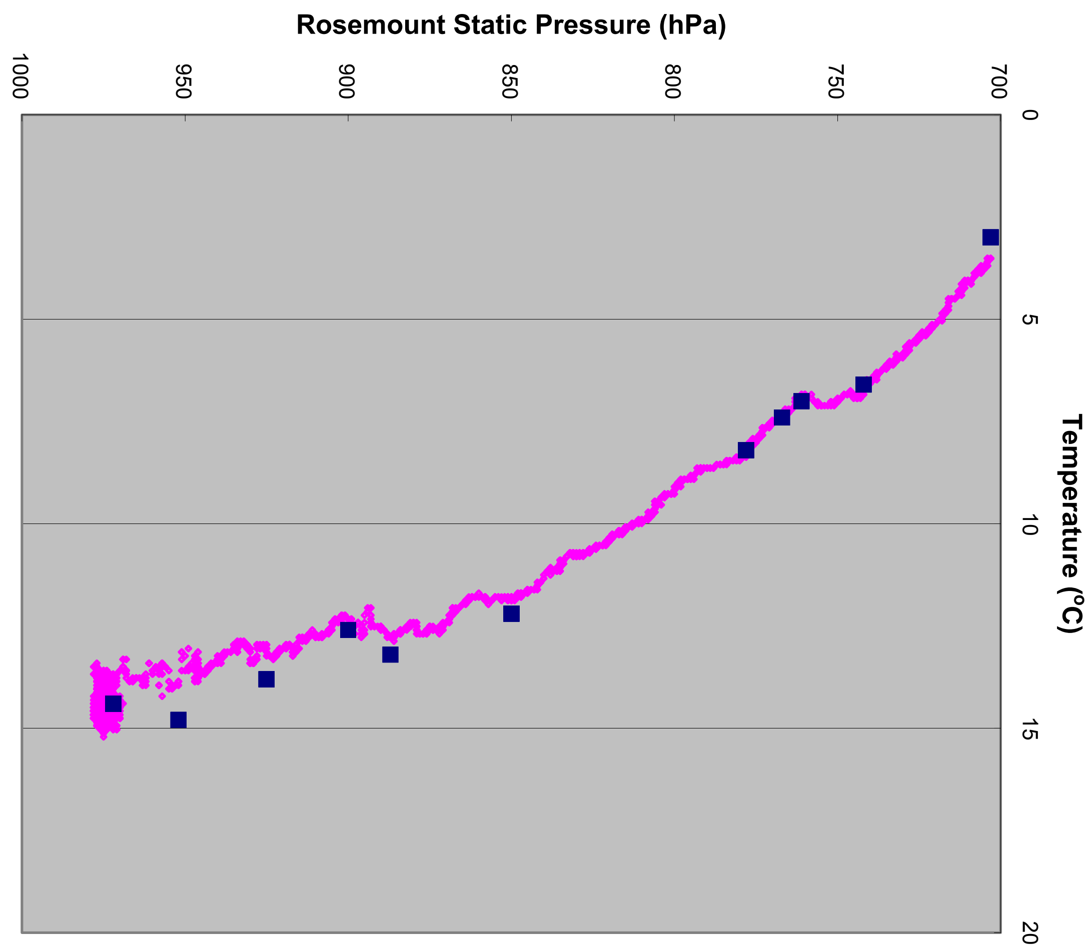

Figure 2. A comparison of the NWS Quillayute, Washington, rawinsonde temperatures (solid squares) and the adjusted reverse flow static temperatures (light gray line) from Eqn (1). The rawinsonde was launched at 0000 UTC, 26 July 2000.

Name of Instrument and Parameter: Rosemount (Model 102CY2CG) static temperature

Dates of Calibration: 25 July 2000 (Local Daylight Time/Date), UW flight 1809

Method of Calibration: Coordinated ascent with the NWS Quillayute, Washington rawinsonde on 26 July, 0000 UTC.

Person Carrying Out Calibration: CARG personnel

Updated copy of this form given to PVH on ___9 July 2002______(insert date).

Completed form distributed by PVH to CARG Faculty, Students, Engineers, and Computer Programmers on ___6 August 2002_____.

RESULTS OF CALIBRATION

The Rosemount temperature (tstat) was about 6-7 deg C higher than the rawinsonde and reverse flow temperatures (tstatr). The cause of this sudden large discrepancy between tstat and the rawinsonde temperatures has not been determined (the sensor was apparently damaged sometime in the ferrying of the aircraft from Kwajalein, Marshall Islands, to Seattle, USA (D. Spurgeon, private communication). The Rosemount sensor had always been the source of our most accurate temperature measurements. Further, it does not appear to be correctable since the discrepant temperature drifted in level flight.

Conclusion: The Rosemount temperature data should not be used in SAFARI 2000.

Name of Instrument and Parameter: Cambridge (Model TH73-244) dew point temperature

Dates of Calibrations: 25 July 2000 (Local Daylight Time/Date), UW flight 1809

Method of Calibration: Coordinated ascent with the NWS Quillayute, Washington, rawinsonde at 0000 UTC 26 July 2000.

Person Carrying Out Calibration: CARG personnel

Updated copy of this form given to PVH on ____9 July 2002______ (insert date).

Completed form distributed by PVH to CARG Faculty, Students, Engineers, and Computer Programmers on _____6 August 2002_________.

RESULTS OF CALIBRATION

A comparison between temperatures measured by the NWS rawinsonde launched at 0000 UTC on 26 July 2000 and the Cambridge chilled mirror dewpoint temperatures showed extremely high correlation (r=0.99) but the Cambridge dewpoints were lower by about 1.5° to 2° C, although larger dewpoint temperature differences were occasionally observed. Some of the larger offsets can be attributed to differences in the path of the aircraft from the path taken by the balloon, particularly near the top of moist layers.

The equation that best adjusts the Cambridge dewpoints to the rawinsonde dewpoints, in degrees Celsius, is given by:

$$dp_{corrected} = 0.86(dp_{raw})+1.6 \qquad (2)$$

Conclusion: For UW flight 1810 (beginning of SAFARI 2000) through UW flight 1820, apply Eqn (2) to obtain the most accurate values of the Cambridge chilled mirror dewpoint temperatures. The effect of the adjustment factor is demonstrated by comparing Figures 3 and 4.

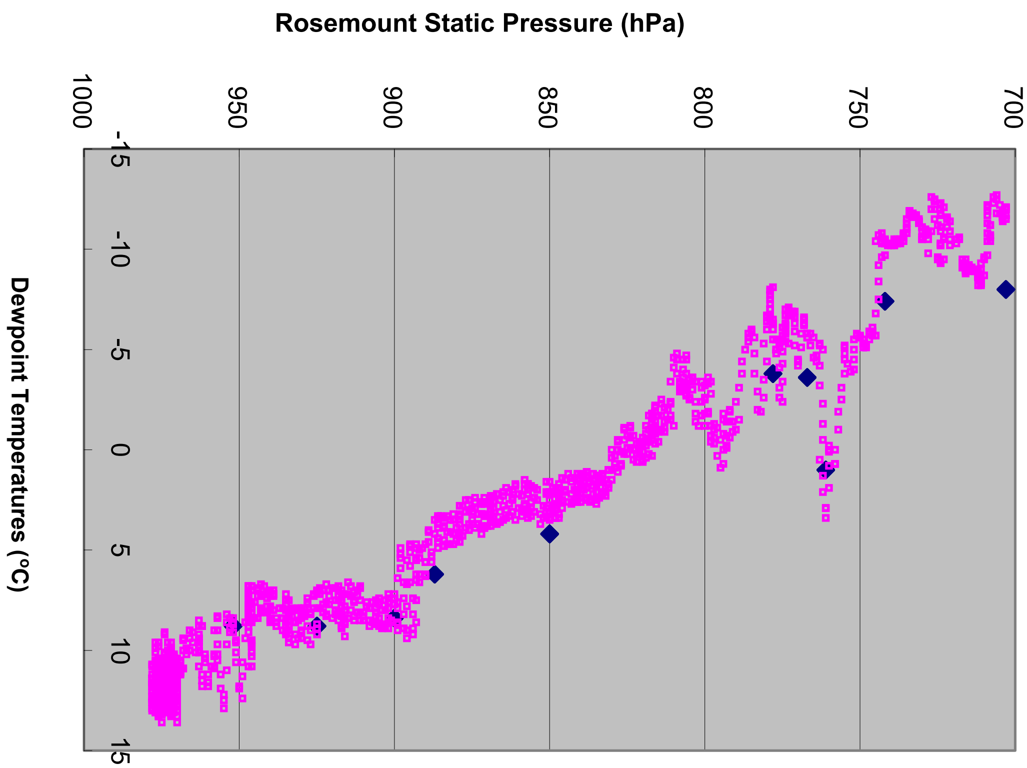

Figure 3. A comparison of the NWS Quillayute, Washington, rawinsonde dewpoints (solid diamonds) and the raw Cambridge chilled mirror dewpoint temperatures (light gray line). The rawinsonde was launched at 0000 UTC, 26 July 2000.

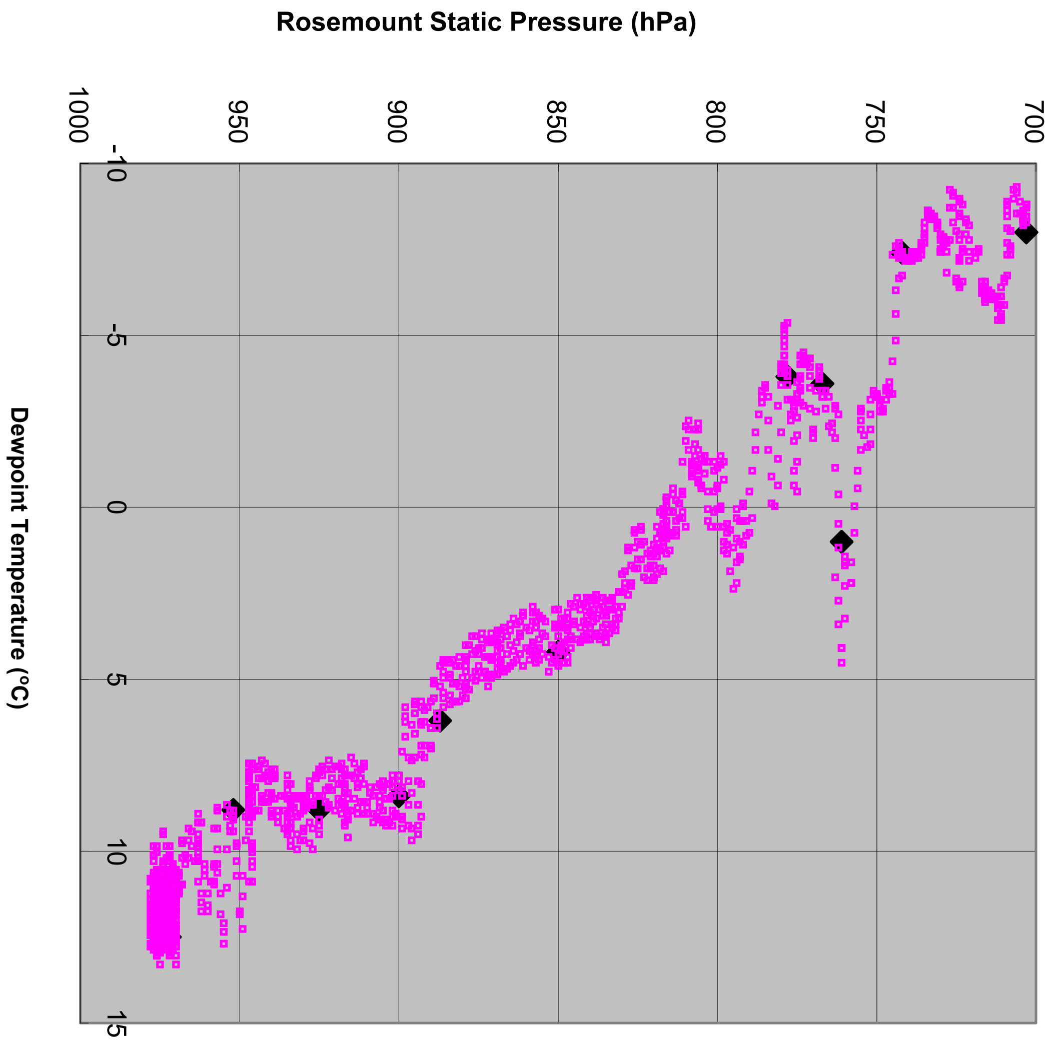

Figure 4. A comparison of the NWS Quillayute, Washington, rawinsonde dewpoints (solid diamonds) and the adjusted Cambridge chilled mirror dewpoint temperatures from Eqn (2) (light gray line). The rawinsonde was launched at 0000 UTC, 26 July 2000.

Name of Instrument and Parameter: Ophir (Model IR-2000) absolute humidity

Dates of Calibrations: 29 July 2000, UW flight 1809

Method of Calibration: Coordinated ascent with the NWS Quillayute, Washington, rawinsonde at 0000 UTC 26 July 2000.

Person Carrying Out Calibration: CARG personnel

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RESULTS OF CALIBRATION

A comparison between the rawinsonde launched from Quillayute, Washington, at 0000 UTC 26 July 2000 and dewpoints derived from the Ophir-measured absolute humidity showed a high correlation (r=0.98) and good agreement. The difference between the two dewpoints was less than 2 deg C overall—considered excellent. Larger point differences were observed in the comparison, but these were likely due to differences in the location where the aircraft flew and the path taken by the balloon. The Ophir-derived dewpoints were slightly higher than the rawinsonde dewpoints at higher temperatures, and slightly lower than the Ophir-derived dewpoints at lower temperatures. Also contributing variance to this comparison of unsmoothed dewpoints is low frequency

(<1 Hz) cyclical electrical noise in the Ophir data. A least squares fit between the rawinsonde and Ophir-derived dewpoints produced:

$$dp\_o_{adjusted} = 1.09(dp\_o_{raw}) - 0.1 \qquad (3)$$

Conclusion: The above correction is minimal (compare Figures 5 and 6) and is not likely to appreciably improve the raw Ophir-derived dewpoint values. Thus, it is recommended that no corrections be applied to the Ophir-derived dewpoint temperatures from UW flight 1810 (beginning of SAFARI 2000) through UW flight 1820 in SAFARI 2000.

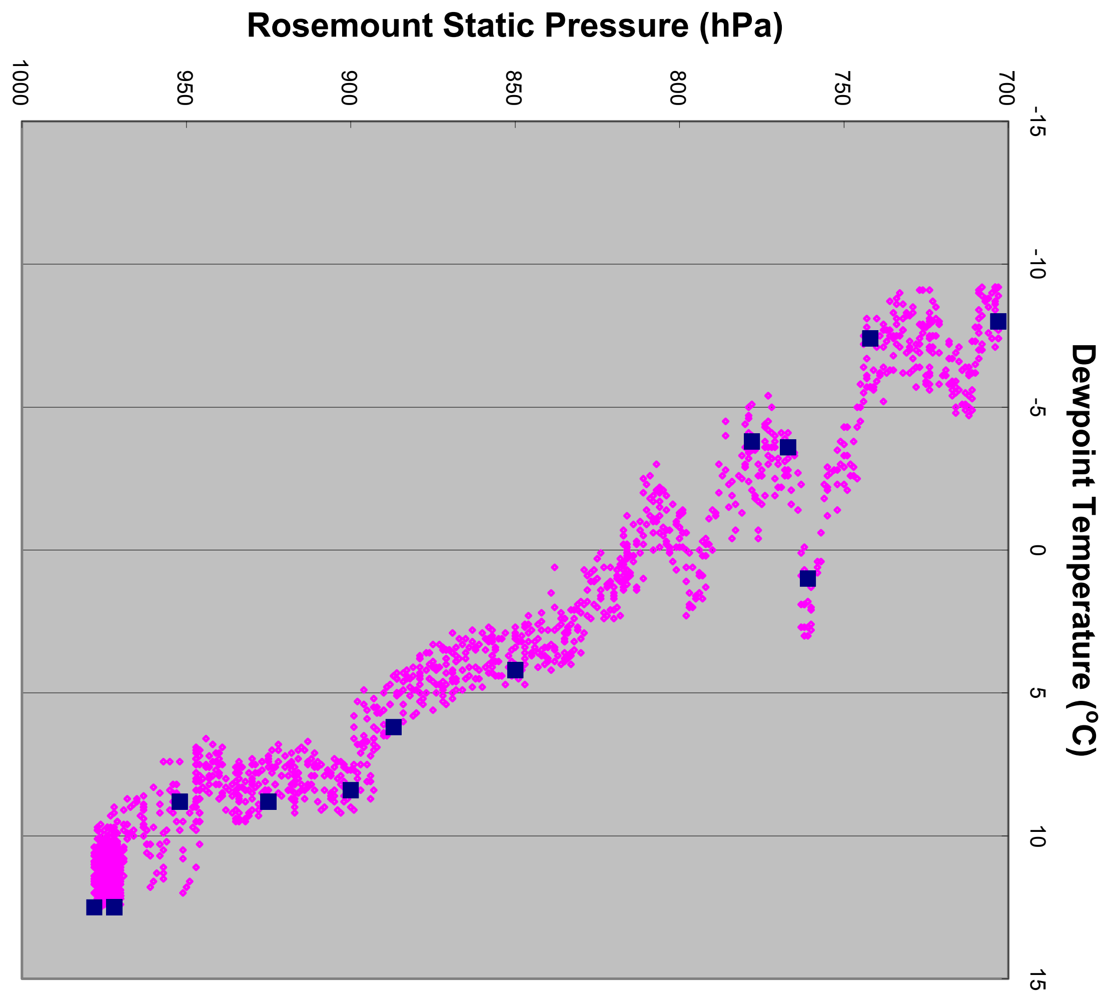

Figure 5. A comparison of the NWS Quillayute, Washington, rawinsonde dewpoints (solid squares) and raw Ophir-derived dewpoints (small light gray dots). The rawinsonde was launched at 0000 UTC 26 July 2000.

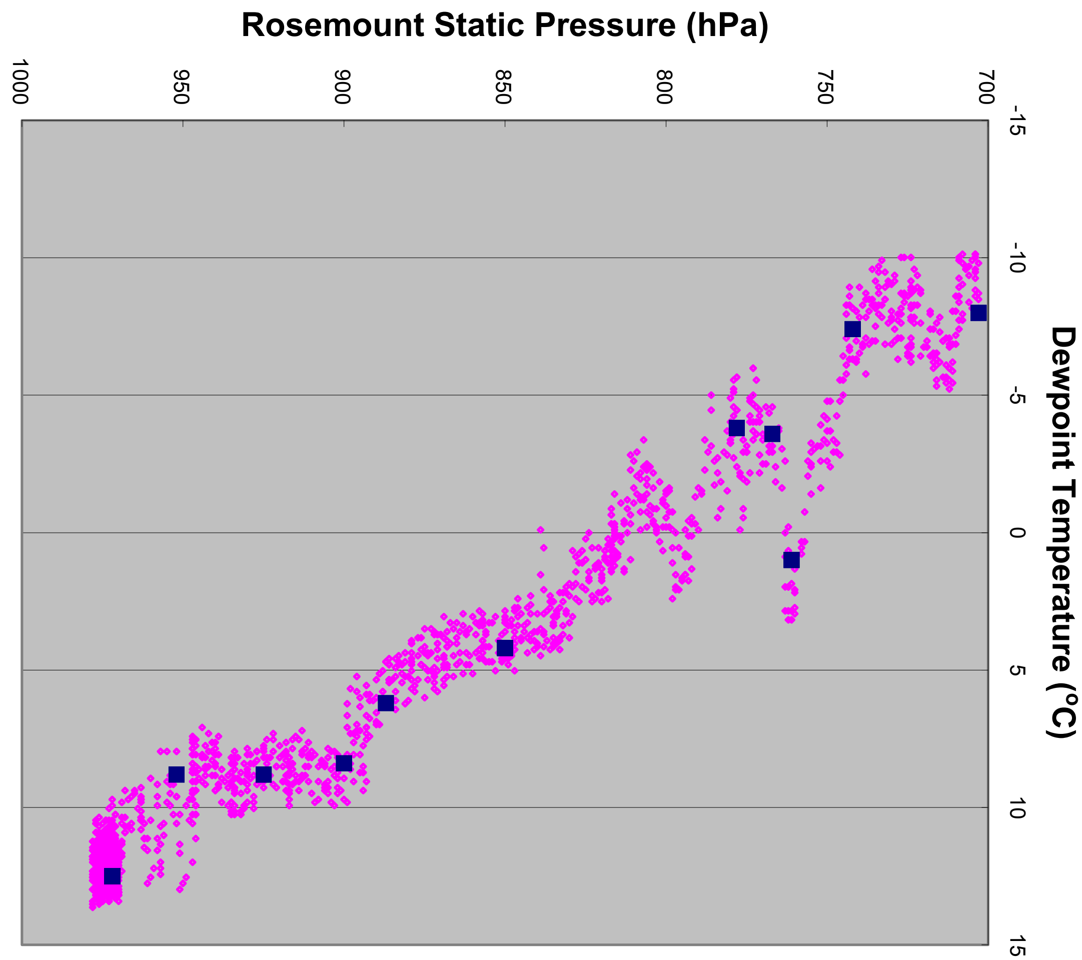

Figure 6. A comparison of the NWS Quillayute, Washington, rawinsonde dewpoints (solid squares) and adjusted Ophir-derived dewpoints from Eqn. (3) (small light gray dots). The rawinsonde was launched at 0000 UTC 26 July 2000.

Name of Instrument and Parameter: Omega Engineering (Model 0S3701) surface temperature

Date of Calibration: None

Method of Calibration: NA

Person Carrying Out Calibration: NA

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RESULTS OF CALIBRATION

Calibration of this instrument was not carried out. While not calibrated, the qualitative temperature trends when the aircraft was flying within about 500 m of the surface appear reliable. Can also be used for fire, cloud or smoke width estimates on some occasions when the aircraft is close to the surface or the top of the cloud/dense smoke was just below the aircraft.

Name of Instrument and Parameter: Rosemount (Model 830BA) pressure

Date of Calibration: 23 August 2000

Method of Calibration: Calibrated against station pressure at the South African Weather Bureau Pietersburg station. Also conducted wing-tip-to-wing-tip flight with the South African Aerocommanders.

Person Carrying Out Calibration: CARG personnel

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RESULTS OF CALIBRATION

The Pietersburg station pressure at sounding release time (1100 UTC) was 885.9 hPa. The Convair-580 static pressure from the Rosemount 830BA sensor rolling down the runway (and nearest the SAWB station) was 885.3 hPa, a difference of just 0.6 hPa. This is within the Rosemount manufacturer's error bar of 0.1%.

On 23 August 2000 (UW Flt 1821) the Aerocommanders and the Convair-580 targeted 700 hPa static pressure as the level for an in-flight comparison of data. Both aircraft were within about 50-100 m horizontal distance of each other while flying at this level. No other flight levels were flown for this purpose, and no data has been exchanged as of this date.

Conclusions: No corrective action required.

Name of Instrument and Parameter: Reverse flow temperature (in-house manufactured)

Date of Calibration: 23 August 2000

Method of Calibration: Comparison against the South African Weather Bureau rawinsonde launched from Pietersburg, SA, at 1100 UTC on 23 August 2000.

Person Carrying Out Calibration: CARG personnel

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RESULTS OF CALIBRATION

The radiosonde-aircraft comparison extended from near the surface to above 16,000 feet ASL and a temperature range from 23° C to -7° C. The correlation between the radiosonde and the Convair-580 reverse flow static temperature (tstatr) was 0.98. However, the Convair-580 reverse flow temperature was generally **lower** than the Pietersburg rawinsonde temperature by about 2° C (see Figure 1). This temperature offset was little affected by pressure, the magnitude of the temperature, or true airspeed. Thus, it appears that the offset is fairly constant in value. The most accurate adjustment of the Convair-580 tstatr relative to the Pietersburg sounding can be obtained by applying the following equation to the raw tstatr temperatures:

$$\mathrm{tstatr}_{\mathrm{corrected}} = 0.98(\mathrm{tstatr}_{\mathrm{raw}}) + 2.2 \qquad (1)$$

The effect of this correction is shown in Figure 2.

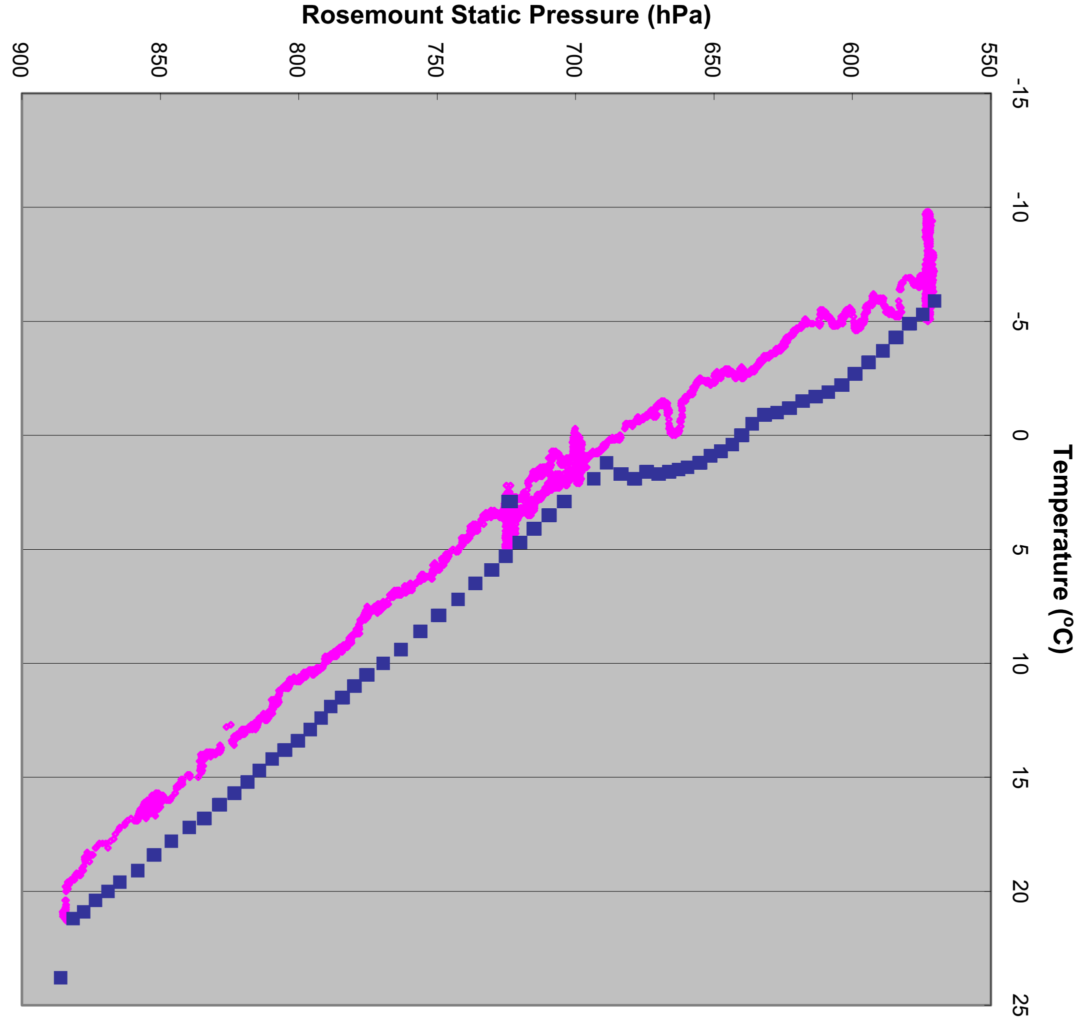

Figure 1. A comparison of the Pietersburg, South African Weather Bureau, rawinsonde temperatures (solid squares) and the raw reverse flow static temperatures (light gray line) The rawinsonde was launched from Pietersburg, South Africa, at 1100 UTC, 23 August 2000.

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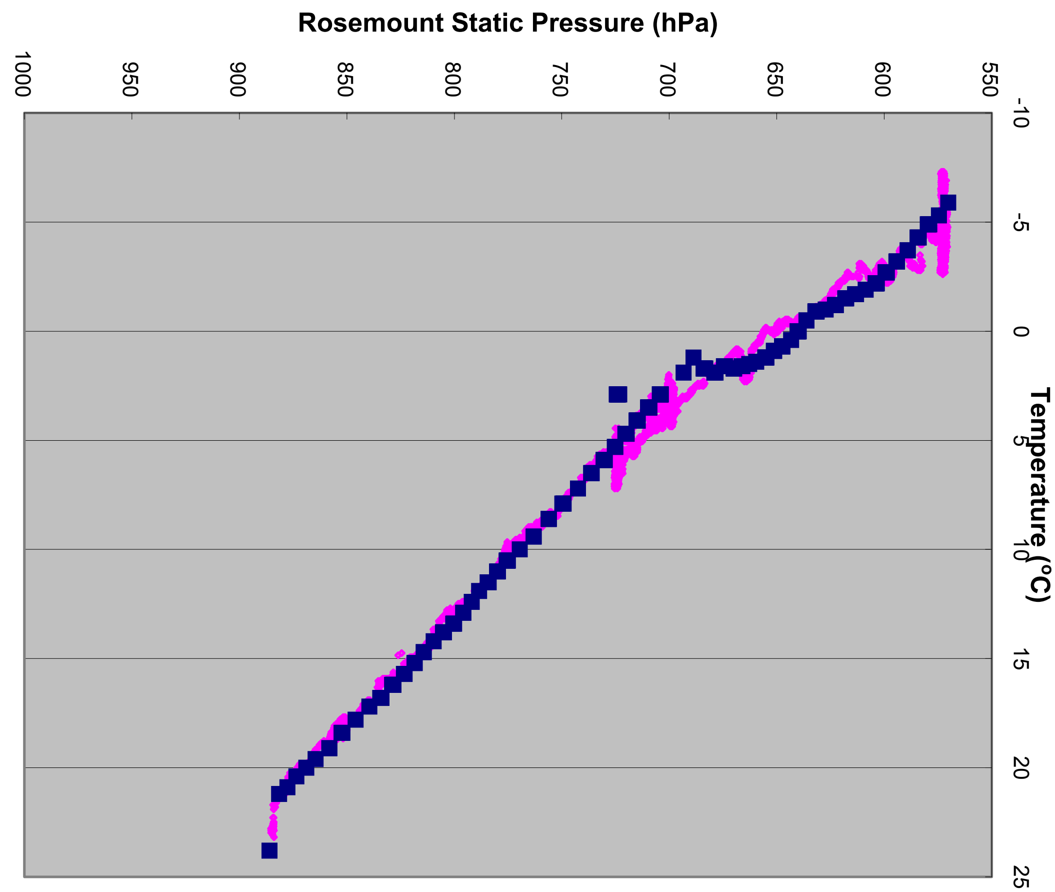

Figure 2. A comparison of the Pietersburg, South African Weather Bureau, rawinsonde temperatures (solid squares) and the adjusted reverse flow static temperatures using Eqn (1) (light gray line). The rawinsonde was launched from Pietersburg, South Africa, at 1100 UTC, 23 August 2000.

Conclusion: For UW flights 1821 through 1839 (end of SAFARI 2000), apply Eqn (1) to obtain the most accurate values of static temperatures from the raw values of tstatr.

Name of Instrument and Parameter: Rosemount (Model 102CY2CG) temperatures

Date of Calibration: This instrument is no longer usable due to a malfunction that occurred during the ferry of the aircraft from Kwajalein, Marshall Islands, to Seattle, Washington, in 1999. The malfunction causes the Rosemount temperature to drift between 5 and 15 ° higher than the true temperature and sometimes this occurs in level flight at constant true airspeed. The fluctuations have not been correlated with any existing parameter that might allow for a correction.

Method of Calibration: None

Person Carrying Out Calibration:

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RESULTS OF CALIBRATION

No calibration performed.

Conclusion: The Rosemount temperature data should <u>not</u> be used in SAFARI 2000.

Name of Instrument and Parameter: Cambridge (Model TH 83-244) dewpoint temperature

Date of Calibration: 23 August 2000

Method of Calibration: Comparison against the South African Weather Bureau rawinsonde launched from Pietersburg, South Africa, at 1100 UTC on 23 August 2000.

Person Carrying Out Calibration: CARG personnel

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RESULTS OF CALIBRATION

The Cambridge chilled mirror dewpoint temperature (dp_{raw}) exhibited a high correlation (r=0.93) with the Pietersburg rawinsonde dewpoint temperature. However, an offset was present, with dp_{raw} higher than the rawinsonde dewpoint over most of the altitude range that the rawinsonde was tracked. Some of the scatter in the data is most likely due to real fluctuations in humidity. The balloon was launched on a partly cloudy day consisting of scattered small cumulus clouds, indicating considerable inhomogeneities in the humidity field. The aircraft and the balloon did not travel the exact same path. Some of the scatter is also due to the heating and cooling cycle that the Cambridge sensor undergoes in order to produce condensation and then evaporation of water on the mirror's surface. These cycles cannot be completely eliminated in this type of comparison. Regions where the dewpoint is indicated to be below about -20° C are not considered reliable data.

Based on a best fit least squares method, the Cambridge raw dewpoint temperatures (dp_{raw}) should be adjusted by the following factors to retrieve the most accurate dewpoints:

$$dp_{corrected} = 1.1(dp_{raw}) - 1.43 \qquad (2)$$

The effect of applying Eqn. (2) is shown in Figure 4.

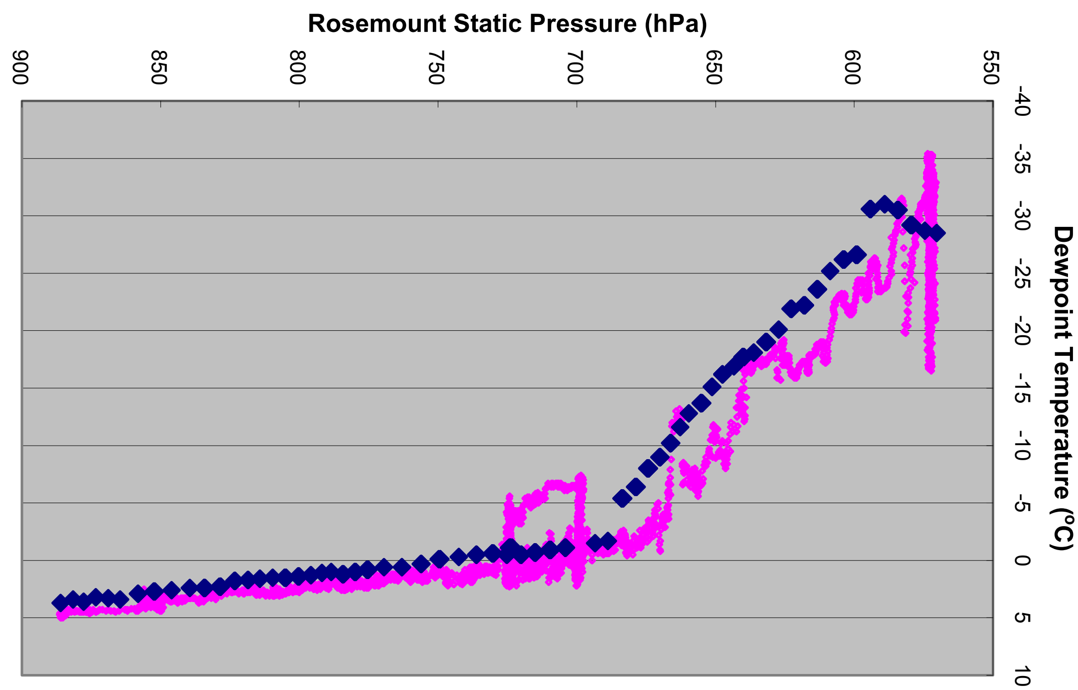

Figure 3. A comparison of the Pietersburg, South African Weather Bureau rawinsonde dewpoints (solid diamonds) and the raw Cambridge chilled mirror dewpoint temperatures (light gray line). The rawinsonde was released from Pietersburg, South Africa, at 1100 UTC, 23 August 2000.

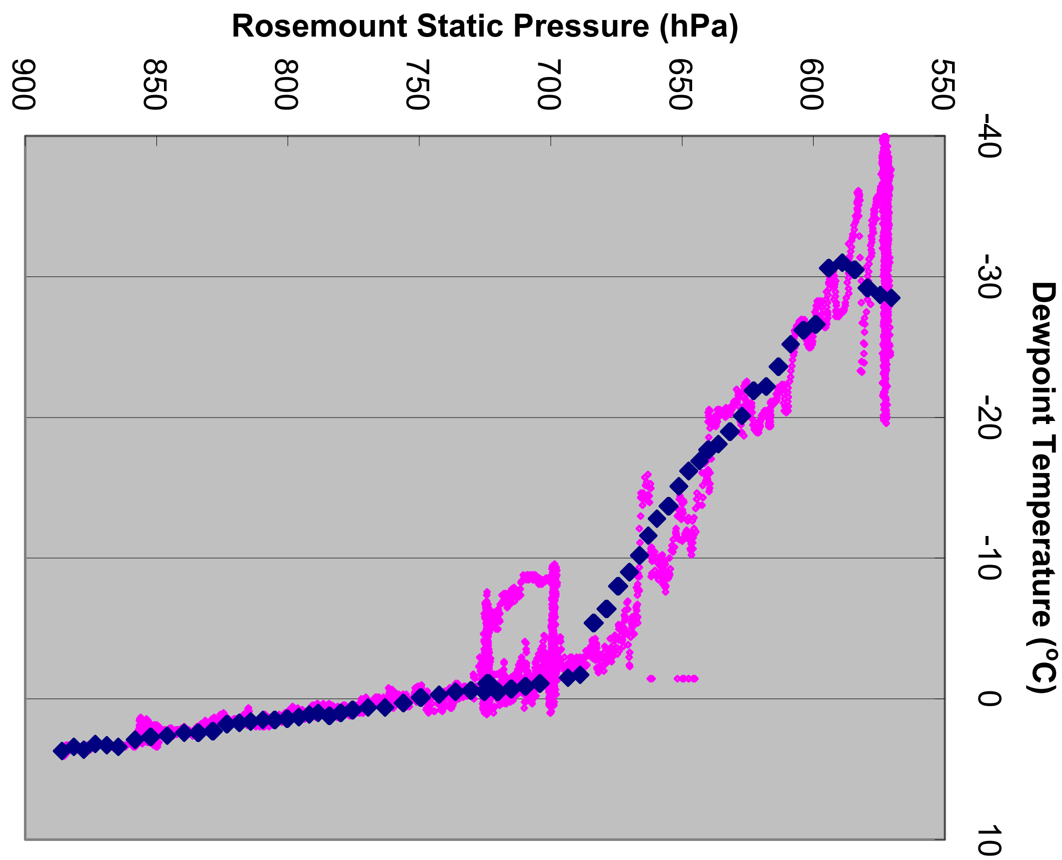

Figure 4. A comparison of the Pietersburg, South African Weather Bureau rawinsonde dewpoints (solid diamonds) and the adjusted Cambridge chilled mirror dewpoint temperatures using Eqn. (2) (light gray line). The rawinsonde was released from Pietersburg, South Africa, at 1100 UTC, 23 August 2000.

Conclusion: For UW flights 1821 through 1839 (end of SAFARI 2000), apply Eqn (2) to obtain the most accurate values of Cambridge chilled mirror dewpoint temperatures from values of dp_{raw}.

Name of Instrument and Parameter: Ophir (Model IR-2000) absolute humidity

Date of Calibration: 23 August 2000

Method of Calibration: Comparison against the South African Weather Bureau rawinsonde launched from Pietersburg, South Africa, at 1100 UTC on 23 August 2000.

Person Carrying Out Calibration: CARG personnel

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RESULTS OF CALIBRATION

The Ophir-derived dewpoints and Pietersburg rawinsonde dewpoint temperatures were highly correlated (r^2=0.91). Some of the scatter between the two is undoubtedly due to real inhomogeneities in humidity on a partly cloudy day with scattered cumulus clouds. Also, the aircraft and the balloon did not travel identical paths. However, the magnitude of the scatter in the regions where the ambient dewpoint is less than -25° C is large and is thought to be a limitation of the Ophir probe in measuring extremely low values of absolute humidity. Dewpoints below about -20° C from the Ophir sensor should not be used.

Apart from the limitation noted above, the most noticeable difference between the raw Ophir-derived dewpoints (dp_o_{raw}) and those indicated by the rawinsonde was that dp_o_{raw} was slightly lower than the rawinsonde dewpoint temperature at lower altitudes, higher than the rawinsonde at mid-levels, and lower again than the rawinsonde dewpoint temperature in the upper portion of the sounding.

A least squares fit to the two data sets yielded:

$$dp\_o_{corrected} = 0.83(dp\_o_{raw}) + 0.4 \qquad (3)$$

Comparisons of Figure 5 and Figure 6 shows the effects of using Eqn. (3).

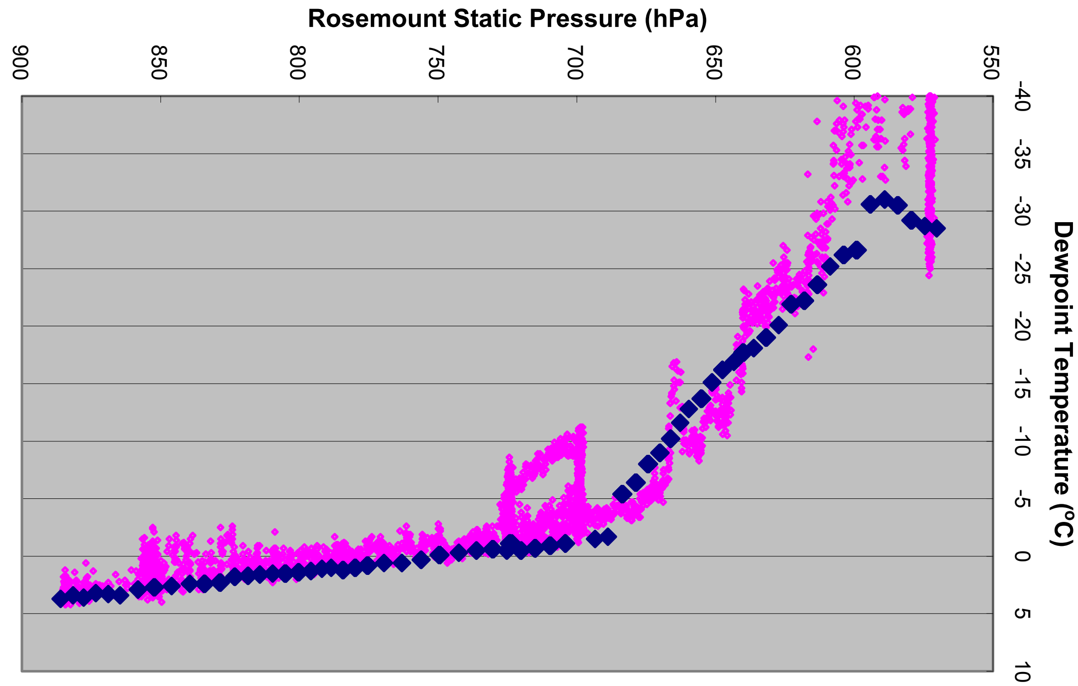

Figure 5. A comparison of the Pietersburg, South African Weather Bureau rawinsonde dewpoints (solid diamonds) and the raw Ophir-derived dewpoint temperatures (light gray line). The rawinsonde was released from Pietersburg, South Africa, at 1100 UTC, 23 August 2000.

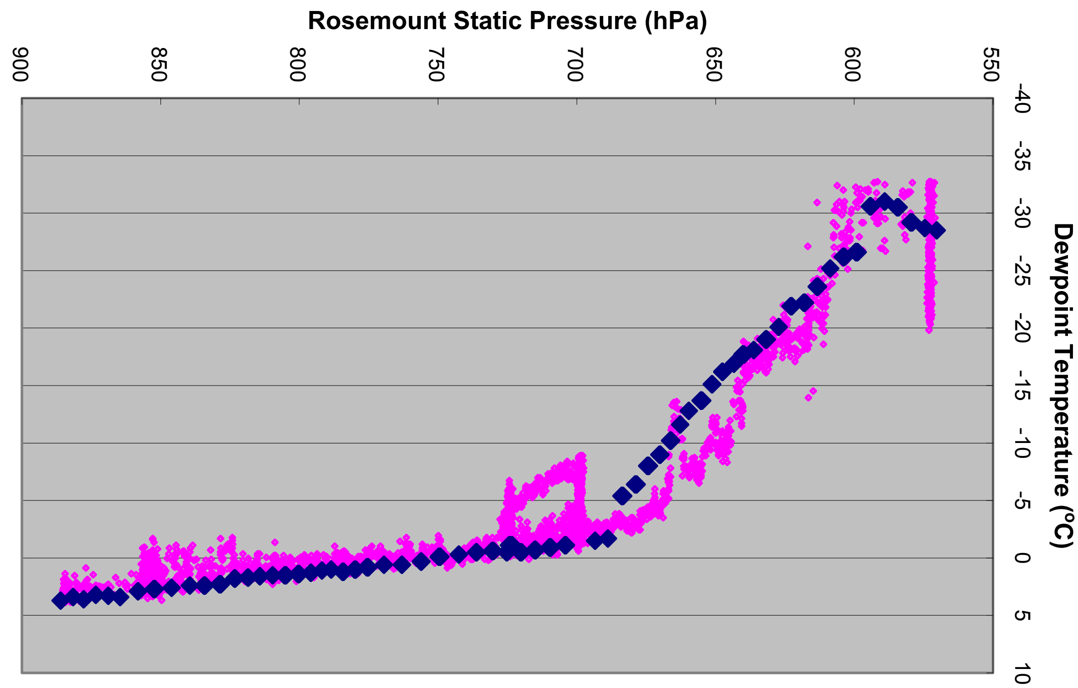

Figure 6. A comparison of the Pietersburg, South African Weather Bureau rawinsonde dewpoints (solid diamonds) and the adjusted Ophir-derived dewpoint temperatures using Eqn. (3) (light gray line). The rawinsonde was released from Pietersburg, South Africa, at 1100 UTC, 23 August 2000.

Conclusion: For UW flights 1821 through 1830 apply Eqn (3) to obtain the most accurate dewpoint temperatures from the raw Ophir-derived dewpoint temperatures (dp_o_{raw}). However, for reasons possibly related to smoke sampling and perhaps lack of a regular cleaning routine, the Ophir began to indicate significantly lower dewpoints compared with the Cambridge chilled mirror device from UW flight 1830 through UW flight 1838, a period in which there were no calibrations. From the clouds that were sampled in a few of those flights, it is clear that the Ophir was indicating dewpoint values that were low by several °C to as much as 10° C. However, there were also periods during these same flights when the Ophir dewpoint was too high and indicated saturated conditions when the absence of clouds at flight level suggested otherwise.

The performance of the Ophir improved considerably on UW Flight 1839, when the Ophir-derived and Cambridge dewpoints were in good agreement for much of the flight. We attribute this to the likelihood (not documented) that the Ophir was cleaned after flight 1838. Thus, for the UW flights 1830 through 1839, the Cambridge dewpoints should be used instead of the Ophir dewpoints.

Name of Instrument and Parameter: Omega Engineering (Model 0S3701) surface temperature

Date of Calibration: None

Method of Calibration: None

Person Carrying Out Calibration: NA

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RESULTS OF CALIBRATION

This instrument was not calibrated. However, the qualitative temperature trends when the aircraft was flying within about 500 m of the surface appear reliable. (Can also be used to estimate widths of those portions of fires, clouds, or dense smoke when the aircraft is just above them.)

CONVAIR-580 STATE PARAMETER CALIBRATIONS FOR POST-SAFARI 2000

Due to an engine problem during the last few days of the SAFARI 2000 project in Namibia, a post-SAFARI calibration flight using a rawinsonde as an independent measure of state parameters was not carried out. The next such calibration flight, using a National Weather Service rawinsonde as an independent measure of state parameters, was conducted about one year later on 14 July 2001 (UW flight 1872) as a MID-CLAMS project calibration flight. This calibration flight showed that tstatr was in substantial agreement with the Pietersburg, South Africa, 23 August 2000 comparison, while the Cambridge and Ophir-derived dewpoints required no corrections according to the MID-CLAMS comparisons. Thus, the MID-SAFARI calibrations can probably be used from UW Flight 1821 through the end of SAFARI (UW Flt 1839). A comparison of the correction factors required for tstatr from the two rawinsonde comparisons are shown below.

$$tstatr_{corrected} = 0.98(tstatr_{raw}) + 2.2 \qquad \text{(MID-SAFARI)}$$

$$tstatr\_{}_{corrected} = 0.98(tstatr_{\_raw}) + 0.9 \qquad \text{(MID-CLAMS)}$$