Data Quality Report

FRAPPE

Flocke & Pfister

V2 – Updated 23 Jul 15

This summary has been written to outline basic instrumentation problems affecting the quality of the data set and is not intended to point out every bit of questionable data. It is hoped that this information will facilitate use of the data as the research concentrates on specific flights and times.

The following report covers only the RAF supplied instrumentation and is organized into two sections. The first section lists recurring problems, general limitations, and systematic biases in the standard RAF measurements. The second section lists isolated problems occurring on a flight-by-flight basis. A discussion of the performance of the RAF chemistry sensors (FO3, CO, CO2, CH4, NO, NO2) will be provided separately, as will the respective data sets.

Section I: General Discussion

RAF staff have reviewed the data set for instrumentation problems. When an instrument has been found to be malfunctioning, specific time intervals are noted. In those instances the bad data intervals have been filled in the netCDF data files with the missing data code of -32767. In some cases a system will be out for an entire flight. A direct intercomparison mission was flown with the NASA P-3. Those data appear in flight number RF10.

1. Position Data. Both a Garmin Global Positioning System and a Novatel Global Positioning System (_NVTL) were used for accurate position references during the program. The Novatel System, has superior position data, but had periodic outages throughout the project. Because of these dropouts, the Garmin System was used as the input to all derived parameters requiring GPS output. Data from both GPS systems are provided in the final data set. In addition, a blended positional data set derived from GPS and IRS position to yields a best position (LATC, LONC) that generally removes the GPS spikes. OMNISTAR data was not available for RF01-RF05, therefore position accuracy is on the order of 1 m.

2. **3D- Wind Data**. The wind data for this project were derived from measurements taken with the radome wind gust package. As is normally the case with all wind gust systems, the ambient wind calculations can be adversely affected by either sharp changes in the aircraft's flight attitude or excessive drift in the onboard inertial reference system (IRS). Turns, or more importantly, climbing turns are particularly disruptive to this type of measurement technique. Wind data reported for these conditions should be used with

caution. Special sets of in-flight calibration maneuvers were conducted on FRAPPE flight RF09 to aid in the performance analysis of the wind gust measurements.

Both the GPS corrected and basic uncorrected values are included in the final data set for the purpose of data quality review. RAF strongly recommends that the GPS corrected inertial winds be used for all research efforts (WSC, WDC, UXC, VYC, WIC, UIC, VIC). Detailed information on the wind processing algorithms used during FRAPPE can be found at the below link:

3. **Pressure Measurements.** The C130 has two independent sets of pressure measurements each consisting of a Paroscientific static pressure system and a pitot tube to measure dynamic pressure. For FRAPPE, the combination of QCFR (QCFRC) and PSFRD (PSFC) were shown to be more accurate and should be used by anyone requiring pressure information.

Links to Al Cooper's Papers

4. **Ambient Temperature Data**. Temperature measurements were made using the standard HARCO heated (ATHL1, ATHL2) and unheated (ATRL) Rosemount temperature sensors. All sensors generally tracked well when compared to each other. On several flights ATHL1 and ATHL2 exhibited difference of 2-4 degrees for long periods. ATRL was chosen as the reference temperature value (ATX) for the project.

5. **Humidity Data**. Humidity measurements were made using two collocated thermoelectric dew point sensors and one experimental fast response hygrometer. A comparison of the dew point sensors (DP_DPB, DP_DPT) yielded good correlation in instrument signatures during the largest portions of the flights when both instruments were functioning normally. Several flights (noted below) exhibited unphysical oscillations in the dewpoint values due to overshooting of the sensors on C130 climbs and descents. DP_DPT experienced these oscillations less frequently and was used as the reference humidity sensor (DPX).

The performance of the fast response humidity sensor (_UVH) was unreliable throughout the project. UV hygrometer data is only available for research flights 7, 9, 11, and 12.

6. **Surface Temperature Data**. Heimann radiometric sensors were used to remotely measure surface temperature (RSTB & RSTB1). Both units had short-lived, intermittent discontinuities/missing data on several flights. RSTB exhibited poor pre- and post-project calibrations, therefore these data were not included in the final release of the data.

7. **Altitude Data**. The altitude of the aircraft was measured in several ways. A pressure based altitude (PALT, PALTF) is derived from the static pressure using the hydrostatic equation and normally using the U.S. Standard Atmosphere, which assumes a constant surface pressure of 1013mb and a mean surface temperature of 288.15 K. The GPS positioning system also provides an altitude readout (GGALT). This output normally

provides a fairly accurate MSL altitude based on an ellipsoid model of the Earth (WGS-84).

Two variables, SFC_SRTM and ALTG_SRTM (respectively, surface elevation and altitude above the ground) were added to the low rate (1Hz) data files. These values were calculated using data fromhttp://www.viewfinderpanoramas.org/dem3.html, an improved dataset that is largely based on the Shuttle Radar Topography Mission (SRTM) database, but has been edited extensively to fill in missing values. SRTM, flown in 2000, mapped the altitude of the Earth's surface from 56S to 60N with resolution of 3 arc-sec or about 90 m at the equator, and 1 arc-sec or about 30 m for the US and its Territories. The improved database is constructed and maintained by Jonathan de Ferranti BA, Lochmill Farm, Newburgh, Fife, KY14 6EX, United Kingdom. The database values give the height in meters above the WGS84/EGM96 geoid. The measurement uncertainty is about 9 m at 90% confidence but there are some biases. The SAR radar used by the SRTM did not always penetrate fully through vegetation and so might reflect the top of the vegetation canopy or some level intermediate between the canopy and the surface. In other cases the radar penetrated a few meters into snow so measured a height between the snow cover and the terrain. Aircraft altitude above terrain (ALTG_SRTM) was calculated by subtracting the surface altitude (SFC_STRM) from GGALT.

8. **Liquid Water Content Data**. One hot wire liquid water sensor (King Probe: PLWCC) was mounted on the C-130 for the program. Liquid water content is also derived from the concentration and size distributions measured by the CDP cloud probe. The presence of super-cooled liquid water can be monitored using the Rosemount Icing Rate Detector (RICE). This is a qualitative measurement output in Vdc.

9. **CN Concentration Data**. The calculation of CN sized aerosol particle concentrations (CONCN) is dependent upon total particle counts (CNTS) and the measurement of sample flow (FCN, FCNC). CN ran very well this project, with minor data loss due only to dropouts of ADS and none from instrument failure. The length of sample tubing between the external inlet and the CN counter induces a time lag in the instrument response to changes in particle concentration. Comparisons with the wing-mounted PCASP indicate the CN counter lags by 10 +/- 1 seconds, and a constant 10 second correction has been applied to the CN data. Two factors contribute to the uncertainty in this time lag. First, the sample flow rate varies slightly with ambient pressure and other state parameters. More importantly, CONCN and CONCP are not highly correlated in general due to combined effects of their very different size ranges and variability in the ambient aerosol size distribution. For FRAPPE, the time lag was determined from selected aerosol plume events in which the cross-correlation as a function of time lag produced a definitive peak with a reasonable correlation value

10. **Aerosol & Cloud Droplet Sizing Data**. Four PMS 1D particle probes (SPP300, PCASP, SPP200, CDP) and one 2D cloud probe were used on the project. Some specific details on each of the probes are available on the EOL web page.

SPP100 – The FSSP100 did not function properly throughout the entire project. These data have not been included in the final release of the data set.

SPP300 (FSSP) - The FSSP300 shared power on the wing with PCASP, most of the dropouts in FSSP300 data are primarily due to PCASP power cycles.

PCASP – Had numerous failures throughout the project resulting in power cycle to bring the probe back online.

2DC – There was heavy raking in the particle images on all flights. Diode bit 49 was constantly stuck in a shaded state except on RF01, 11, 15. The C130 did not fly through clouds on most flights, therefore size histograms are typically sparse.

11. **SPECIAL NOTE:** Virtually all measurements made on the aircraft require some sort of airspeed correction or the systems simply do not become active while the aircraft remains on the ground. None of the data collected while the aircraft is on the ground should be considered as valid. Please be advised that RFs 12, 13, and 15 were "double headers" with two flights on each day. The data for both flights is in the same data file with a period of time on the ground in between the two flights.

Section II: Flight-by-Flight Summary

RF01

There were several prolonged outages due to DSM restarts. The longest data outages affect mainly QCF and DPB, these outages occurred at: 1637-1800 and 1812-1928.

Shorter outages affecting most every variable occurred at: 1642-1644, 1651-1653, 1703-1705, and 1748-1800.

UV Hygrometer: Instrument failure, no data available for flight.

Radiometric Temperatures: Both sensors missing data (~1748-1800) due to DSM failure.

Forward looking camera: No data for entire flight.

Time: Spike in data 174819.

RF02

UV Hygrometer: Instrument failure, no data available for flight.

Radiometric temperatures: RSTB1 exhibited several brief, intermittent spikes and discontinuities.

RF03

Research power failure from approximately 1827-1836 – all variables missing.

UV Hygrometer: Instrument failure, no data available for flight.

Radiometric temperatures: RSTB1 exhibited two spikes from 183900-183920.

Time: Spike in data 182730.

RF04

UV Hygrometer: Instrument failure, no data available for flight.

Radiometric temperatures: RSTB1 missing data from 1836-1838.

Forward looking camera: No data prior to 2050.

Dewpoint: Flooded on descent, bad data from 1659-1728

CDP: Diode bit 49 stuck in shaded state, heavy raking.

RF05

UV Hygrometer: Instrument failure, no data available for flight.

Temperature: ATHL1 is several degrees lower than ATHL2 and ATRL for the entire flight.

2DC: Cause of concentrations is unknown as there are no 2D particle images.

RF06

UV Hygrometer: Instrument failure, no data available for flight.

Dewpoint: DPB indicates several instances of unphysical oscillations between approximately 2200-0024.

Radiometric temperatures: RSTB1 both exhibit multiple brief discontinuities.

RF07

Radiometric temperatures: RSTB1 both exhibit multiple brief discontinuities.

RF08

UV Hygrometer: Instrument failure, no data available for flight.

Temperature: ATHL2 is bad the entire flight.

A2D Restart: Occurred approximately 1702-1707 leaving to outages in several avionics, position, temperature, wind, and moisture variables.

Dewpoint: DPB has issues with overshooting and unphysical oscillations during the flight.

RF09

Temperature: ATHL1 is approximately 4 degrees too low until approximately 1919.

Dewpoint: Both DPB and DPT flood 1959-2007. DPB exhibits unphysical oscillations from 1926-1956.

2DC: Bottom three bins do not have good data.

RF10

UV Hygrometer: Instrument failure, no data available for flight.

Dewpoint: DPB exhibits unphysical oscillations 1543-1556.

RF11

Temperature: ATHL1 is 2-3 degrees too low until 2231.

Dewpoint: DPB exhibits several periods of unphysical oscillations between 2133-2211.

RF12 (Double header, time on ground ~ 2142-2240)

Radiometric temperatures: RSTB1 not functional for the first flight (until 2151).

RF13 (Double header, time on ground ~ 1941-2033)

UV Hygrometer: Instrument failure, no data available for flight.

Temperature: ATHL1 is 3 degrees too low for the entire flight.

2DC: Shattering and poor sensitivity observed near 1825.

RF14

UV Hygrometer: Instrument failure, no data available for flight.

Radiometric temperatures: Short periods of missing and/or discontinuous data in RSTB1 throughout the flight.

Dewpoint: Unphysical oscillations in DPB (2119-2125) and DPT (2118-2128).

RF15 (Double header, time on ground ~ 1943-2218)

UV Hygrometer: Instrument failure, no data available for flight.

Temperature: ATHL1 is 1-2 degrees lower than the other two temperatures throughout the flight.

Radiometric temperature: Data spike in RSTB1 at 1944.

Section III: FRAPPE Calibrations for RAF Instruments

Variable	Date	Cal File		
ADIFR	20-Jun-14	0.0265582	6.99825	0.00506988
BDIFR	23-Jun-14	-0.164478	5.16347	-1.20E-05
FCN	25-Mar-13	0.007	0.1349	0.15291
PCAB	19-Jun-14	-1.56948	109.049	-0.0418767
PCN	9-May-13	3.11005	108.47	-0.0234438
QCF	20-Jun-14	1.18249	17.2991	-0.00421515
QCFR	2-Jun-14	-0.300948	13.8181	-0.00388295
QCR	19-Jun-14	-1.32029	17.3661	-0.00422356
RSTB1	15-May-13	-46.9984	8.64588	0.122765
RSTB	15-May-13	-55.7497	10.7629	-0.0164283
RTHL1	24-Jun-14	-81.4095	22.6258	0.309925
RTHL2	24-Jun-14	-81.4653	22.6027	0.306075
RTRL	24-Jun-14	-60.2054	23.8186	0.0133449

Section IV: Variable List

RAF Reference Parameters

Reference Ambient Temperature (C) - ATX
Reference Recovery Temperature (C) – RTX
Reference Dew Point Temperature (C) - DPXC
Reference Ambient Saturation Vapor Pressure (mb) - EWX
Reference Ambient Static Pressure, Corrected (mb) – PSXC
Reference Ambient Static Pressure (mb) - PSX
Reference Corrected Dynamic Pressure (mb) - QCXC
Reference Raw Dynamic Pressure (mb) - QCX
Reference True Air Speed (m/s) – TASX
Reference Mach Number - MACHX
GPS Corrected Inertial Latitude (deg) - LATC
GPS Corrected Inertial Longitude (deg) - LONC
GPS Corrected Horizontal Wind Speed (m/s) - WSC
GPS Corrected Horizontal Wind Direction (deg) - WDC
GPS Corrected Wind Vector, East Component (m/s) - UIC
GPS Corrected Wind Vector, North Component (m/s) - VIC
GPS Corrected Wind Vector, Longitudinal Component (m/s) - UXC
GPS Corrected Wind Vector, Latitudinal Component (m/s) - VYC
GPS Corrected Wind Vector, Vertical Gust Component (m/s) - WIC
GPS Corrected IRS Ground Speed Vector, East Comp, (m/s) - VEWC
GPS Corrected IRS Ground Speed Vector, North Comp, (m/s) - VNSC

RAF Standard Parameters

GPS Altitude : MSL (m) - GGALT
GPS Latitude (deg) - GGLAT
GPS Longitude (deg) – GGLON
*** Novatel GPS values include the suffix _NVTL ***
Corrected Static Pressure (digital) Fuselage (mb) - PSFDC
Corrected Static Pressure (digital) Fuselage (mb) - PSFC
Cabin Pressure (mb) - PCAB
Ambient Temperature: Radome Left Side(C) - ATRL
Ambient Temperature: HARCO Heated, Fuselage (C) - ATHL1
Ambient Temperature: HARCO Heated, Fuselage (C) - ATHL2
Corrected Dew Point Temperature, Top Fuselage (C) – DP_DPT
Corrected Dew Point Temperature, Bot Fuselage (C) – DP_DPB
Corrected Dew Point Temperature, Fast Hygrometer (C) – DP_UV

Pressure Altitude : MSL (m) - PALT
Pressure Altitude : MSL (ft) - PALTF

Potential Temperature (K) - THETA
Equivalent Potential Temperature (K) – THETAE
Pseudo-Adiabatic Potential Temperature (K) - THETAP
Virtual Potential Temperature (K) – THETAV
Wet Equivalent Potential Temperature (K) - THETAQ
Absolute Humidity, Top (g/m3) - RHODT

Relative Humidity, Reference (%) - RHUM
Mixing Ratio, Chilled Mirror (g/kg) – MR
Saturation Vapor Pressure, Chilled Mirror (mb) – EW_DPT
Saturation Vapor Pressure, Chilled Mirror (mb) – EW_DPB
Saturation Vapor Pressure, Fast Hygrometer (mb) – EW_UVH

Radiometric Surface Temperature-2 - RSTB1

TSI CN Particle Concentration (n/cm3) – CONCN
2DC Cloud Particle Concentration (n/cm3) – CONC1DC_LPI
2DC Cloud Particle Concentration 100um and larger (n/cm3) – CONC1DC100_LPI
2DC Cloud Particle Concentration 150um and larger (n/cm3) – CONC1DC150_LPI

PCASP/200 Aerosol Particle Concentration (n/cm3) - CONCP_RPI
FSSP/300 Aerosol Particle Concentration (n/cm3) - CONC3_RPO
CDP Cloud Particle Concentration (n/cm3) - CONCD_LPC

2DC Mean Particle Diameter (um) – DBAR1DC_LPI
PCASP/200 Mean Particle Diameter (um) - DBARP_RPI
FSSP/300 Mean Particle Diameter (um) - DBAR3_RPO
CDP Mean Particle Diameter (um) - DBARD_LPC

King Probe Liquid Water Content (g/m3) - PLWCC
CDP Water/Ice Content (g/m3) - PLWCD_LPC

Aircraft True Heading (deg) - THDG
Aircraft Roll Attitude Angle (deg) - ROLL
Aircraft Pitch Attitude Angle (deg) - PITCH
Aircraft IRS Vertical Velocity (m/s) - VSPD

GPS Ground Speed Vector, East Comp (m/s) - GGVEW
GPS Ground Speed Vector, North Comp (m/s) - GGVNS
GPS Ground Speed (m/s) - GGSPD

Aircraft True Airspeed, Fuselage (m/s) - TASF
Aircraft True Airspeed, Radome (m/s) – TASR

Aircraft True Airspeed, Right Fuselage (m/s) - TASFR
Aircraft True Airspeed, Humidity Corrected (m/s) - TASHC
Corrected Dynamic Pressure, Left Fuselage (mb) - QCFC
Corrected Dynamic Pressure, Radome (mb) - QCRC
Corrected Dynamic Pressure, Right Fuselage (mb) - QCFRC
Raw Dynamic Pressure, Radome (mb) - QCR
Raw Dynamic Pressure, Left Fuselage (mb) - QCF
Raw Dynamic Pressure, Left Fuselage (mb) - QCFR
Attack Angle, Radome Diff. Pressure (deg) - AKRD

Sideslip Angle, Radome Diff. Pressure (deg) - SSRD
Vertical Differential Pressure, Radome (mb) - ADIFR
Horizontal Differential Pressure, Radome (mb) - BDIFR
Raw Static Pressure, (digital) Fuselage (mb) - PSFD
Raw Static Pressure, (digital) Fuselage (mb) - PSFRD

Recovery Temperature: Radome Left (C) - RTRL
Recovery Temperature: HARCO Heated, Fuselage (C) - RTHL1
Recovery Temperature: HARCO Heated, Fuselage (C) - RTHL2
Raw Dew Point Temperature, Fuselage Top (C) – MIRRTMP_DPT
Raw Dew Point Temperature, Fuselage Bot (C) – MIRRTMP_DPB

Raw King Probe Liquid Water Content (watts) - PLWC
Icing Rate (Vdc) - RICE
TSI 3760 CN Counter Output (N) - CNTS
TSI 3760 CN Counter Flow: Raw (slpm) - FCN
TSI 3760 CN Counter Sampling Pressure (mb) - PCN
TSI 3760 CN Counter Sampling Temperature (C) - CNTEMP
TSI 3760 CN Counter Corrected Flow (slpm) - FCNC

RAF Fast Humidity Signal (Vdc)- XSIGV_UVH
RAF Fast Humidity Sample Pressure (hPa) – XCELLPRES_UVH
RAF Fast Humidity Sample Temperature (C) – XCELLTEMP_UVH

SFC_SRTM – Derived surface elevation (m)
ALTG_SRTM – Derived elevation of aircraft above the surface (m)