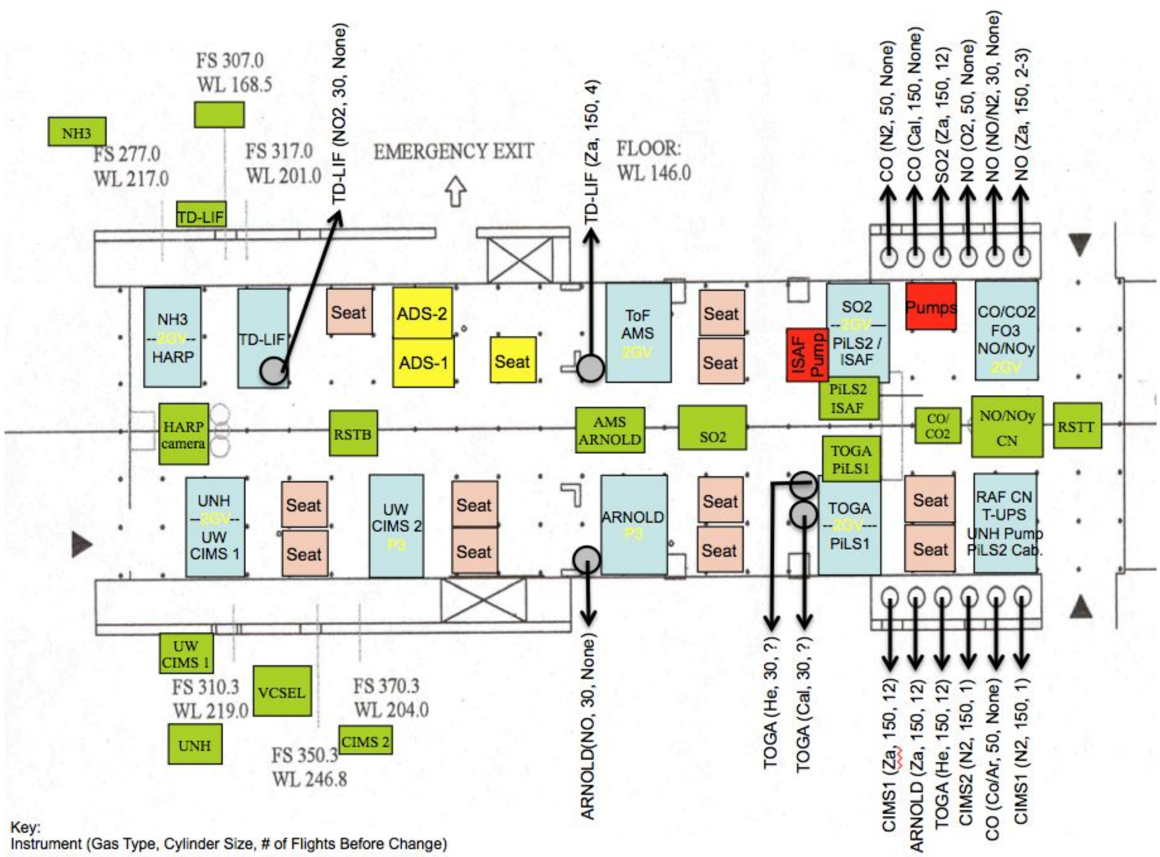
WINTER Project Manager Report

Joel Thornton (University of Washington) & Steve Brown (NOAA)
1 Feb - 15 Mar 2015

C-130 Payload



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.

This summary covers only the RAF supplied instrumentation on the C-130 and is organized into three sections. The first section provides a general overview of the data collected and lists recurring problems, general limitations, and systematic biases in the standard RAF measurements. A discussion of the performance of the RAF chemistry sensors (FO3, CO, CO2, NO, NOy) will be provided separately, as will the respective data sets. The second section describes any issues occurring on a flight-by-flight basis. This includes information from notes provided by the on-board RAF technician that have to do with the quality of the data collected. The third section is a list and description of variables found in the quality controlled netcdf data files.

General Data 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.

1. Position Data. A Novatel Global Positioning System was used for accurate position references during the program. The Novatel System data were good at all times on all flights, except for 4 seconds on RF09. The data have better than 1 meter estimated standard deviation for latitude and longitude, and better than 2 meter estimated standard deviation in altitude. In addition, a blended positional data set is derived from GPS and IRS position to yield a best position (LATC, LONC) that generally removes the GPS spikes.

2. Three Dimensional Wind Measurements. 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. A special set of in-flight calibration maneuvers were conducted on WINTER flights TF01 and RF13 to aid in the performance analysis of the wind 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).

3. Pressure Measurements. The C-130 has two independent sets of pressure measurements each consisting of a Paroscientific static pressure system and a pitot tube to measure dynamic pressure. For WINTER, the combination of QCFR (QCFRC) and PSFRD (PSFC) were shown to be more accurate and should be used by anyone requiring pressure information.

4. Ambient Temperature Data. Temperature measurements were made using the standard HARCO heated (ATH1, ATH2) temperature sensors. A fast-response, unheated temperature probe was not included due to the risk of potential icing conditions. Both sensors generally tracked well when compared to each other. ATH2 was chosen as the reference temperature value (ATX) for the project due to some short outages in ATH1.

5. Humidity Data. Humidity measurements were made using two collocated thermoelectric dew point sensors (DP_DPB and DP_DPT) and the VCSEL hygrometer (DP_VXL). In general, DP_DPT had a slower response and tended to oscillate, sometimes as much as 5 C, and was typically 0.5 to 1 C colder than DP_DPB. Several flights exhibited unphysical oscillations in the dewpoint values from the thermoelectric sensors due to overshooting of the sensors on C-130 climbs and descents that were much more suppressed in the VCSEL measurements. Because of this DP_VXL was used as the reference humidity sensor (DPXC), except on flight RF06 because of bad data (noted below). For that flight DP_DPB is the reference humidity sensor.

6. Radiometric Temperature Data. Heimann radiometric sensors were used to remotely measure surface/cloud top temperature (RSTB & RSTB1) and sky/cloud base temperature (RSTT). RSTB and RSTB1 are of good quality. RSTT should be used with caution as it is often pegged at -56 C, the lower limit of the sensor. It is unknown whether the clear, dry sky was often radiometrically colder than the sensor limit or if there were problems due to the sensor not being heated.

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). Data from the radar altimeter (HGM232) is also included. These data can be noisy in places but give the best estimate of the aircraft's height actual above the ground.

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 no instrument failures. 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. Measured total flow, and comparisons with the wing-mounted PCASP & UHSAS, indicate the CN counter lags by 4 +/- 1 seconds, and a constant 4 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 or CONCU are not highly correlated in general due to combined effects of their very different size ranges plus variability in the ambient aerosol size distribution, and at times they are even anticorrelated. For WINTER new flow calibrations were applied that improve these measurements.

10. Aerosol & Cloud Droplet Sizing Data. Four PMS 1D particle probes (SPP300, PCASP, UHSAS, CDP) and one 2D cloud probe were used on the project. The C-130 flew through very few clouds during WINTER, so size histograms from the cloud probes are understandably sparse.

SPP300 (FSSP) -- The FSSP was removed after RF03 and sent to DMT for repairs. It was reinstalled for RF08 and provided good data for the rest of the project.

PCASP -- PCASP had numerous failures that required a power cycle to correct. It is not known whether the issue was in serial communication with ADS or the probe's internal operation.

UHSAS -- UHSAS failed during the second test flight and was sent to DMT for repairs. It returned to service for RF03, but flew with the wrong configuration file for two flights -- successfully in RF03 but not RF04. UHSAS had many failures of the serial link to its control laptop and cabin DSM, leading to considerable data loss. In addition, there were episodes of laser instability when ramp temperatures were unusually low, likely due to an inability to raise the temperature of the optical block once the anti-icing 28V finally came on at takeoff. This problem occurred to varying degrees from RF04 through RF08. Because noise frequently appeared in small-diameter bins, the first eight channels of the histograms are omitted, and channel 9 (75 nm) is the first valid channel.

CDP -- There were no problems with this probe during the project.

2DC -- There were no problems with this probe during the project.

11. Camera Images. Forward facing camera images are available for all flights. Six flights (RF05 - RF10) took place at night. For these flights the cameras were still turned on in order to pick up city lights for help in diagnosing when the C-130 was flying over urban areas.

Please note that 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.

Individual Flight Summary

All times are UTC.

RF01

UHSAS was being repaired and did not fly.

PCASP required two power cycles to correct a data sync problem with its DSM. These outages occurred at 0047 - 0050 and 0112 - 0115.

RF02

An anomaly in ADIFR occurs between 1815 and 1826 associated with a climb out of the boundary layer and a descent to near the surface. All variables dependent on ADIFR should not be used during this time period and include ATTACK, WIC, WDC, WSC, QCX, PSX, and TASX.

A similar anomaly occurs between 2244 and 2314 associated with pitch variations. The same variables should not be used during this time period either.

VCSEL had a delayed mode change that resulted in bad data. The outage occurred at 1654 - 1708.

UHSAS was being repaired and did not fly.

PCASP required a power cycle with an outage at 1718 - 1736.

RF03

VCSEL had a bad laser temp control and peak position drift that resulted in an outage at 0226 - 0235.

PCASP required a power cycle which was delayed due to research requirements. The outage was at 0037 - 0153.

During the power cycle all power was lost to probes on the left side, with multiple restarts required to get them back up. The 2DC, FSSP, and CDP were out at 0153 - 0212.

RF04

UHSAS flew with the wrong configuration file, and incorrect laser settings caused optical instability. There is no valid data for this flight as a result.

PCASP required four power cycles. Data outages are at 2035 - 2039, 2243 - 2249, 0029 - 0031, and 0236 - 0238.

FSSP was being repaired and did not fly.

RF05

VCSEL had a bad laser temp control and peak position drift that resulted in two outages at 0625 - 0633 and 0849 - 0853.

UHSAS laser was unstable for the entire flight. No valid data were obtained.

FSSP was being repaired and did not fly.

RF06

DP_DPB and DP_DPT had invalid values from startup until they recovered at 0421 and were good for the rest of the flight.

VCSEL was missing ATX data 0814 - 1021. VCSEL depends on ATX in flight and therefore has no valid data for the same time period. DPXC is set to DP_DBP for this flight because the chilled mirror dewpointers were missing during the ferry and not the research portion of the flight.

QCR and QCRC are bad at 1108 - 1113. This affected downstream variables such as TASR and MACHR.

UHSAS had laser instability from startup until 0427, with no valid data during this time.

FSSP was being repaired and did not fly.

RF07

PCASP required three power cycles, with data outages 0506 - 0513, 0547 - 0601, and 0816 - 0827.

UHSAS had a period of laser instability with no valid data at 0512 - 0534. The PCASP restarts also caused brief outages at 0601 - 0602, 0827 - 0828, and 0830 - 0832.

FSSP was being repaired and did not fly.

RF08

VCSEL was bad on startup and has invalid data from the beginning of the flight until 0903.

UHSAS has no valid data from the beginning of the flight until 1001 due to optical instability.

PCASP had data sync failures requiring power cycling causing outages at 0916 - 0954 and 1132 - 1133.

RF09

A four second GPS dropout caused outages in GGLAT, GGLON, and GGALT at 100756 - 100800.

VCSEL was missing ATX data 0614 - 0618 and 0620 - 0622, and ATH1 (used as ATX during the project) was bad 1250 - 1325. VCSEL depends on ATX in flight and therefore has no valid data for the same time periods.

UHSAS lost serial communication with the control laptop and the cabin DSM following power switch, and connection could not be established until return approach. There are no valid data for this flight.

RF10

VCSEL had a bad startup sequence resulting in lost data from the beginning of the flight until 0408.

UHSAS had several serial communication failures during the flight and has no data at 0403 - 0426, 0638 - 0639, 0649 - 0650, 0719 - 0720, 0912 - 0956, 1015 - 1023, and 1034 - 1036.

PCASP had two failures requiring power cycling and has no data at 0415 - 0425 and 0717 - 0756.

A number of variables are missing at 0415 - 0425 due to a DSM problem requiring a reboot. The variables impacted are QCF, ATTACK, PSFDC, DP_DPB, and all data from the INS (LAT, LON, VEW, VNS, ALT, VSPD, PITCH, ROLL, THDG, IWS, IWD).

RF11

UHSAS had multiple serial communication failures this flight with data outages at 1819 - 1820, 1822 - 1827, 1938 - 1942, 1944 - 1959, 2008 - 2019, 2022 - 2027, 2036 - 2154, 2207 - 2211, 2223 - 2224, 2237 - 2243, and 0037 - 0055.

PCASP had many data sync failures this flight. A total of about 1.5 hours of data were lost. The largest outages are at 1826 - 1834, 1855 - 1903, 1950 - 2107 (intermittently up), and 2155 - 2202.

RF12

DP_DPT and DP_DPB are bad from the beginning of the flight until 1414.

UHSAS had serial communication failures for much of the flight, although data were recorded intermittently at 1455 - 1543 and 1955 - 2058.

PCASP had a few data sync problems this flight, but data loss was limited to about 10 minutes total.

RF13

VCSEL had a laser light blockage resulting in bad data at 1753 - 1757.

PSFRD goes bad temporarily at 1650 and 1756. Because this is the reference pressure PSX and PSXC are impacted. These and any dependent measurements should be used with care at these times.

UHSAS serial communication failed for approximately the first half of flight, with no data recorded from takeoff until 1626. Data are good after that.

PCASP data sync failures led to lost data at 1259 - 1320 and 1329 -1332.

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
Reference Attack Angle - ATTACK
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
Corrected Static Pressure (digital) Fuselage (mb) - PSFDC
Corrected Static Pressure (digital) Fuselage (mb) - PSFC
Cabin Pressure (mb) - PCAB
Ambient Temperature: HARCO Heated, Fuselage (C) - ATH1
Ambient Temperature: HARCO Heated, Fuselage (C) - ATH2
Corrected Dew Point Temperature, VCSEL (C) - DP_VXL
Corrected Dew Point Temperature, Top Fuselage (C) – DP_DPT
Corrected Dew Point Temperature, Bot Fuselage (C) – DP_DPB
Pressure Altitude : MSL (m) - PALT
Pressure Altitude : MSL (ft) - PALTF
Radar Altitude : AGL (ft) - HGM232

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/m^3) - RHODT

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

Radiometric Surface Temperature - RSTB
Radiometric Surface Temperature-2 - RSTB1
Radiometric Sky/Cloud Base Temperature - RSTT

TSI CN Particle Concentration (n/cm^3) – CONCN
2DC Cloud Particle Concentration (n/cm^3) – CONC1DC_LPB
2DC Cloud Particle Concentration 100 μm and larger (n/cm^3) – CONC1DC100_LPB
2DC Cloud Particle Concentration 150 μm and larger (n/cm^3) – CONC1DC150_LPB

PCASP/200 Aerosol Particle Concentration (n/cm^3) - CONCP_RPT
FSSP/100 Particle Concentration (n/cm^3) - CONCF_LPT
CDP Cloud Particle Concentration (n/cm^3) - CONCD_LPC
UHSAS Aerosol Particle Concentration (n/cm^3) - CONCU_RPC
UHSAS Aerosol Particle Concentration 100 μm and larger (n/cm^3) - CONCU100_RPC
UHSAS Aerosol Particle Concentration 500 μm and larger (n/cm^3) - CONCU500_RPC

2DC Mean Particle Diameter (μm) – DBAR1DC_LPB
PCASP/200 Mean Particle Diameter (μm) - DBARP_RPT
FSSP/100 Mean Particle Diameter (μm) - DBARF_LPT
CDP Mean Particle Diameter (μm) - DBARD_LPC
UHSAS Mean Particle Diameter (μm) - DBARU_RPC

King Probe Liquid Water Content (g/m^3) - PLWCC
CDP Water/Ice Content (g/m^3) - PLWCD_LPC
FSSP/100 Liquid Water Content (g/m^3) - PLWCF_LPT
Icing Rate (Vdc) - RICE

Aircraft True Heading (deg) - THDG
Aircraft Roll Attitude Angle (deg) - ROLL
Aircraft Pitch Attitude Angle (deg) - PITCH

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

GPS Ground Speed Vector, North Comp (m/s) - GGVNS
GPS Ground Speed (m/s) - GGSPD
GPS Vertical Speed (m/s) - GGVSPD

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) - TASDRY
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: HARCO Heated, Fuselage (C) - RTH1
Recovery Temperature: HARCO Heated, Fuselage (C) - RTH2
Raw Dew Point Temperature, Fuselage Top (C) – MIRRTMP_DPT
Raw Dew Point Temperature, Fuselage Bot (C) – MIRRTMP_DPB

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
UHSAS Corrected Flow (cm^3/s) - UFLWC_RPC

2DC Concentration per Cell (n/cm^3) - C1DC_LPB
PCASP Concentration per Cell (n/cm^3) - CS200_RPT
FSSP/100 Concentration per Cell (n/cm^3) - CS100_LPT
CDP Concentration per Cell (n/cm^3) - CCDP_LPC
UHSAS Concentration per Cell (n/cm^3) - CUHSAS_RPC

VCSEL Average Laser Intensity (mV) - LSRINT_VXL
VCSEL Number Moisture Density (n/cm^3) - CONCV_VXL

Weight on Wheels - WOW_A