Variable list
http://www.eol.ucar.edu/deployment/field-deployments/field-projects/pacdex/measurements

Instrumentation

Pressure:
Static pressure is available using two different systems: Research and Avionics.

Research static pressure is measured with a Paroscientific (MODEL 1000) with a stated accuracy of 0.01% of full scale. This measurement is output in the netCDF files as:

- PSF (measured): static pressure as measured using the fuselage holes
- PSX (reference): same as PSF. Used to choose reference variable if more than one instrument provides measurement of the same parameter.
- PSFC (measured): static pressure corrected for airflow effects (pcor)
- PSXC (reference): same as PSFC. Used to choose reference variable if more than one instrument provides measurement of the same parameter.

Use PSXC for the normal measure of pressure (e.g., in equation of state or hydrostatic equation).

Avionics static pressure is recorded from the GV avionics. This is slower than the Paroscientific measurement, but it has been corrected for airflow effects and it is certified for 'Reduced vertical separation minimum' (RVSM) through the calculation of pressure altitude. RAF has no documentation on how Gulfstream and Honeywell corrected this pressure measurement, but the measurement has passed very strict FAA certification requirements.

Temperature:
Temperature was measured using four different sensors on the GV:

An unheated Rosemount sensor was used for fast-response measurements. This sensor can be affected by icing, but that did not appear to be a problem in HEFT08. **Two heated Harco sensors** were used to give a slower response temperature, that would also be adequate in icing conditions. A fourth measurement of temperature (slow and with some delay) was provided by the **GV avionics instrumentation**.

The Rosemount and Harco measurements were logged using serial channels and are affected by a variable recovery factor. As a consequence, RAF recommends using the reference temperature, ATX (See below.) for all uses of the HEFT08 data set:

TTFR	Total air temperature from fast Rosemount sensor
TTHR1	Total air temperature from the heated HARCO sensor # 1

TTHR2	Total air temperature from the heated HARCO sensor # 2
TT_A	Total air temperature from the avionics system
ATFR	Ambient air temperature from the Rosemount system
ATHR1	Ambient temperature from the heated HARCO sensor # 1
ATHR2	Ambient temperature from the heated HARCO sensor # 2
AT_A	Ambient temperature from the avionics system
ATX	Ambient temperature reference. This is usually the same as ATFR but can also be replaced by another sensor output if ATFR experiences a problem on a particular flight. In such case a flight-by-flight report will note the change.

RAF recommends using ATX for the temperature in thermodynamic equations, etc.

Dewpoint temperature and vapor density:
Humidity was measured using three different sensors:

Two Buck Research 1011C cooled-mirror hygrometers are used for tropospheric humidity. They have a sandwich of three Peltier elements to cool the mirror, and in comparison to earlier generations of cooled-mirror hygrometers, they have a much-improved capability to measure at low temperatures. These sensors are assumed to measure dewpoint above 0°C and frostpoint below 0°C. The instrument has a quoted accuracy of 0.1 °C over the -75 to +50 °C; however, based on examination of the measurements RAF is not comfortable with accuracies better 0.5 °C for dewpoint and 1 °C for frostpoint. The cooled-mirror sensors are slow, in particular at lower temperatures, and this may give considerable differences between the measurements from the two units or when comparing with faster instruments. Their cooling rates depend in part on the airflow through the sensor, and this may depend on the angle of the external stub relative to the airflow. The angle may differ between the two sensors, and this may contribute to response-time differences between the sensors. At very low temperatures the sensors may jump ("rail") to even lower temperatures. The cooled-mirror temperatures are included even when they are outside the sensor operating range; this is caused by the need to use values of water vapor in other calculations (e.g., true airspeed). However, the impact of these out of bounds conditions on derived calculations that depend on humidity correction is very small since they occur at extremely low dew points.

The chilled mirror sensors are sensitive to flooding on rapid descents of the aircraft into the humid boundary layer. This results in temporary loss of the instruments ability to measure the dewpoint, which may last from 3 to 15 minutes, depending on conditions. This problem can be seen in the form of "ringing", or a decaying sinusoidal oscillation of the signal, that appears after altitude changes, especially those following a period of cold soaking at high altitudes. During these periods it is advised to compare the data from both chilled mirrors and choose the one that recovers faster.

Humidity was also measured using a MayComm Open-path Laser Hygrometer. This dual-channel hygrometer detects optical absorption of water vapor at 1.37 µm. The sensor has an estimated accuracy of 5-10% of ambient specific humidity (in ppbv). The sensor has two spectral channels that are used to determine high and low values of humidity, and they are combined to give a single value of humidity. (See below.)

DPLS	Dewpoint/frostpoint for left fuselage cooled-mirror sensor
DPLC	Dewpoint for left cooled-mirror sensor
DPRS	Dewpoint/frostpoint for right cooled-mirror sensor
DPRC	Dewpoint for right cooled-mirror sensor
DPXC	Dewpoint, from either right or left cooled-mirror sensor. The project manager has chosen the best performing of either DPLC or DPRC for a given flight.
MR	Mixing ratio (g/kg) based on DPXC

RAF recommends using DPXC as a slow 'tropospheric' variable, and RAF recommends using MRTDL as a fast-response 'tropospheric' variable. MRTDL is also recommended for all 'stratospheric' use.

Attack and Sideslip:
Measurements of attack and sideslip were done using the 5-hole nose cone pressure sensors, primarily ADIFR and BDIFR. Although sampled at 50 sps, internal filtering in the Mensor pressure sensors (model 6100) limits usefulness of high-rate analysis to about 5 Hz.

ADIFR	Attack angle pressure sensor
AKRD	Attack angle. Determined from the vertical differential pressure of the radome gust probe.
BDIFR	Sideslip angle pressure sensor
SSLIP	Sideslip angle. Determined from the horizontal differential pressure of the radome gust probe.

Both AKRD and SSLIP were calibrated using in-flight maneuvers.

True airspeed:
True airspeed was also measured primarily using a Mensor 6100 sensor, thus limiting the effective response to 5 Hz.
The radome pitot tube system uses the center hole of the 5-hole nose cone in conjunction with the research static pressure ports on the fuselage aft of the entrance door. A standard avionics pitot tube is also mounted on the fuselage aft of the radome, and this system is also referenced to the fuselage static ports aft of the main entrance door. It was found during empirical analysis that the fuselage pitot system gave more consistent results in reverse-heading maneuvers; it is suspected that this is due to random pressure

changes at the radome center hole as has been suggested by modeling. The fuselage system is used for the calculation of the aircraft true airspeed, as well as for attack and sideslip angles. True airspeed is also provided from the aircraft avionics system, but this system is considered of slower response. Measurements using the radome and fuselage pitot systems were corrected using in-flight maneuvers.

TASR	True airspeed using the radome system
TASF	True airspeed from the fuselage pitot system
TASHC	True airspeed using the fuselage pitot system and adding humidity corrections to the calculations; this is mainly of benefit in tropical low-altitude flight
TAS_A	True airspeed from the avionics system
TASX	Reference true air speed. This is normally equal to TASF but TASR may be substituted in cases where TASF is compromised for any reason. This would be noted in the individual flight reports.

RAF recommends using TASX as the aircraft true air speed.

Position and ground speed:
The measurement of aircraft position (latitude, longitude and geometric altitude) and aircraft velocities relative to the ground are done using several sensors onboard the GV.

Garmin GPS (Reference): These data are sampled at 10 sps and averaged to 1 sps. This is a simple GPS unit with a serial output, and the measurements are available in real-time. The values from this sensor start with a "G"; e.g.:

GGLAT	Latitude
GGLON	Longitude
GGALT	Geometric altitude
GGSPD	Ground speed
GGVNS	Ground speed in north direction
GGVEW	Ground speed in east direction

These are good values to use for cases where the highest accuracy is not needed. These variables are subsequently used to constrain the INS drift for the calculations of the GV winds; more about this below.

Honeywell inertial reference system 1 and 2: The GV is equipped with three inertial systems. Data from the first two of these are logged on the main aircraft data logger, with subscripts the latter having variable names with suffix "_IRS2". The advantage of the IRS values is that they typically have very high sample rates and very little noise from measurement to measurement. However, since they are based on accelerometers and gyroscopes, their values may drift with time. The drift is corrected for by filtering the

INS positions towards the GPS positions with a long time-constant filter; the filtered values have a "C" added to the end.

LAT	latitude from IRS 1, no GPS filtering
LATC	latitude from IRS 1, filtered towards GPS values
LAT_IRS2	latitude from IRS 2, no GPS filtering
LON	longitude from IRS 1, no GPS filtering
LONC	longitude from IRS 1, filtered towards GPS values
LON_IRS2	longitude from IRS 2, no GPS filtering
GSF	ground speed from IRS 1, no GPS filtering
GSF_IRS2	ground speed from IRS 2, no GPS filtering

The choice of variables for position analysis depends on the type of analysis; in general the Garmin GPS is sufficiently accurate.

Not all INS variables are output in the final data set. If you require more detailed INS data please contact RAF.

- **Attitude angles:**

Aircraft attitude angles are measured by the two Honeywell IRS units.

PITCH	Pitch of the aircraft
PITCH_IRS2	Pitch of the aircraft from the second IRS
ROLL	Roll of the aircraft
ROLL_IRS2	Roll of the aircraft from the second IRS
THDG	True heading of the aircraft
THDG_IRS2	True heading of the aircraft from the second IRS

The values of pitch angle (PITCH) have been corrected using in-flight measurements to give approximately the same values as the aircraft attack angle (AKRD) for long parts of each flight; this correction is performed to give a near-zero mean updraft over extended flight legs. The variation from flight to flight of this offset is caused by small differences in the pre-flight alignment of the inertial navigation system. No alignment correction has been applied to PITCH_IRS2.

- **Wind speeds:**

Wind speeds are derived from the 5-hole radome gust probe, other pressure measurements, temperature and inertial measurements supported by GPS data. The use of the Mensor 6100 pressure sensors for ADIFR, BDIFR and QCF results in the following limitations on the wind data: these pressure measurements were sampled at 50 sps and thus resulting in power spectra to 25 Hz. Examination of power spectra and specifications from Mensor indicate that the sensors have internal filters with a -3dB (half-power) cutoff at 12 Hz, resulting in a noticeable roll-off in the spectra beginning approximately at 6 to 7 Hz. Users of wind data should be aware that contributions to covariances and dissipation calculations will be affected at and above these frequencies. The following lists the most commonly used wind variables:

UI	Wind vector, east component
UIC	Wind vector, east component, GPS corrected for INS drift
VI	Wind vector, north component
VIC	Wind vector, north component, GPS corrected
UX	Wind vector, longitudinal component
UXC	Wind vector, longitudinal component, GPS corrected
VY	Wind vector, lateral component
VYC	Wind vector, lateral component, GPS corrected
WI	Wind vector, vertical gust component
WIC	Wind vector, vertical gust component, GPS corrected
WS	Wind speed, horizontal component
WSC	Wind speed, horizontal component, GPS corrected
WD	Horizontal wind direction
WDC	Horizontal wind direction, GPS corrected

RAF recommends using the GPS corrected wind components, i.e., the variables ending in "C".

Liquid water content:
A PMS-King type liquid water content sensor was installed on the GV. The probe did not operate properly due to a hardware problem and the data are not reported.

Icing rate indicator

Rosemount Model 871FA Icing Rate Detector - Right Wing pylon Access Plate (RICE). The instrument was operational but repoerted essentially no data due to the absense of supercooled liquid water cloud penetrations.

SID-2H (Small Ice Detector, version 2)
SID-2H measures the intensity and pattern of near-forward light scattering to determine the size, shape, and concentration of cloud particles. The estimate of particle size is based on the integrated scattering intensity, not the peak. Scattered light falls on multi-anode photomultiplier detector so that the scattering pattern of each particle is measured in 28 pie-shaped wedges. Spherical particles will produce symmetric patterns. Asymmetry in the scattering pattern indicates non-sphericity (snow crystals). This is a single-particle instrument. The scattering intensity patterns and time of arrival are logged for each particle. SID-2H was custom-built for use on HIAPER by having very fast electronics to keep up with the fast airspeeds.

size range	~1 – 60 nm diameter
concentration range	0 – 200 cm^{-3}
sample area	~0.3 mm^2
volume sample rate	~50 cm^3/s
data interface	custom, ten serial pairs
data rate	max ~9,000 particles per second

more information: *http://strc.herts.ac.uk/pi/proj.html*

UHSAS (Ultra-High Sensitivity Aerosol Spectrometer)
The UHSAS is a single-particle light scattering instrument. It uses a CW high energy laser diode, wide angle collection optics centered at 90°, and four stages of amplification to size aerosol particles according to their scattered light. It assigns bins to individual particles and outputs a histogram of particle size and concentration. The RAF version of this instrument has been highly modified from the commercially-available lab bench version. It uses volume flow controllers to keep the flow constant over a wide range of operating pressures and temperatures. It mounts in a PMS canister.

size range	75 – 1000 nm diameter
concentration range	0 – 18,000 cm^{-3}
number of size bins	99
volume sample rate	1 cm^3/s
data interface	serial RS-232
data rate	10 histograms per second

more information: *http://www.dropletmeasurement.com/products/UHSAS.htm*

CDP (Cloud Droplet Probe)
The CDP is a commercial instrument from Droplet Measuring Technologies (DMT). It measures the intensity of forward light scattering (4 – 12°) to determine the sizes of

individual cloud droplets. An internal multi-channel analyzer assigns to individual particles to bins, and the data interface outputs a histogram of particle size and concentration. On the NSF/NCAR C-130 and HIAPER, it is mounted in a PMS canister.

size range	2 – 50 µm diameter
concentration range	0 – 5,000 cm^{-3}
number of size bins	10, 20, 30, or 40
sample area	200µm x 1.5mm
volume sample rate	30 cm^3/s at airspeed 100 m/s
airspeed range	10 – 200 m/s
data interface	serial RS-232 or RS-422
data rate	10 histograms per second

more information: *http://www.dropletmeasurement.com/products/CDP.htm*

2D-C (Two-Dimensional Optical Array Probe)
RAF's 2DC probe is a highly modified version of the original Particle Measuring Systems (PMS) instrument. It detects shadow images of cloud particles that pass through a laser beam. The beam illuminates a linear diode array, and each diode state changes to shadowed when a particle passes through the arms of the probe and interrupts its part of the beam. The diode array is sampled at a rate proportional to the airspeed, and this allows the shadow image to be reconstructed.
The recent (2007) modifications include using a laser diode instead of gas laser, changing from a 32-element diode array to a 64-element array, faster electronics, and a high speed USB-2 data interface. From the shadow image records, RAF software derives the particle concentration and size distribution.

size range	25 – 1600 µm diameter
concentration range	0 – ~5,000 L^{-1}
number of size bins	64 diodes @ 25 µm spacing
sample area	1600 µm x 6.1 cm
volume sample rate	10 L/s at airspeed 100 m/s
airspeed range	10 – 240 m/s
data interface	USB-2

Data logging and averaging:

Analog data were logged at 500 sps and averaged to 1 sps. Serial data (e.g., RS-232), ARINC data (IRS units), etc. were recorded at the instrument-specific output rate.

The recordings listed for a given second contains measurements logged at e.g., 12:00:00.000 and until 12:00:01. The value of "Time" corresponding to this interval is given a 12:00:00 in the released data set.

All measurements are "time-tagged" at the time of logging. Subsequently these measurements are interpolated onto a regular grid and averaged.

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 may be out for an entire flight.

Calibrations

The following table identifies the sensors serial numbers and calibrations that were used on the GV during HEFT-08:

Sensor	Type	DSM	S/N			
				A	B*x	C*x2
PCAB	Absolute	307		-4.350	108.196	-0.015
PDUMPPL	Absolute	307		0	103.42	0
PDUMPPR	Absolute	307		0	103.42	0
PSF	Absolute	304		0	1.000	0
TTFR	Rosemont	305	3245	-80.2	22.272	0.1383
TTHR1	Harco	305	630393	-82.76	23.572	0.0091
TTHR2	Harco	305	?????	-83.22	23.836	0.0093
QCR	Mensor	305	590684	-0.4629	1.0006	0
QCF	Mensor	305	590682	-0.5612	1.0014	0
ADIFR	Mensor	305	590688	-0.75019	1.0004	0
BDIFR	Mensor	305	590686	-0.50418	1.0003	0

Data Quality Control

General:

- There are interruptions in the data system recording when the GV crosses the UTC midnight. These interruptions may be as long as 5 minutes.
- DPRS, DPLS, DPRC, DPLC: dewpointers tend to overshoot and oscillate after rapid temperature increase on aircraft descents. Using best judgment, these overshoots are removed from DPXC, which is the recommended reference dewpoint variable, but are left in DPLC, which is the source variable for DPXC, for comparison. The operating range for both DPLC and DPRC is down to approximately -70C and values below that should not be used for quantitative analyses.
- LONC, LATC deviate where there is the 5 min interruption in data after midnight on all flights crossing UTC midnight. It is recommended that direct GPS position is used in referencing the data (GGLAT, GGLON, GGALT).
- Vertical wind speed (WIC) can deviate on steep climbs and descents. This is due to imperfections in the calculation algorithm.
- PLWC (King probe liquid water content) was part of the project but did not operate properly due to a hardware problem. The instrument did not respond correctly to changing airflow and did not output proper background signal. Although there is response from the instrument to the liquid water in clouds, it is not quantitative. Use CDP liquid water instead (PLWCD_LWI).
- Exhaust line pressures (PDUMP*) and PCAB exhibit occasional narrow (1-3 s) spikes. These spikes are believed to be a recording system artifact, not actual pressure spikes, and were removed from the final data set.
- UHSAS data sometimes are noisy and unusable during rapid descents. Additionally, there are unrealistic gaps in size distributions where the four instrument gain stages overlap. The total concentration produced by the instrument is believed to be correct. The concentrations of particles in 0.17 um and 0.2 um size ranges is affected by gain stages overlap, which is manifested as a "gap" in the first case and a "hump" in the second, which corresponds to bins 20-22 and 45-50. Depending on the research needs users may wish to average across these sections or increase bin sizes to include adjacent bins.

Flight specific notes:

TF01:
DPRC is noisy from 17:16 to 17:54 and should not be used. The noise is during the period that is below the reliable

TF03:
Chilled mirrors did not come online until 19:58.

RF03:

The analog board that records air temperatures experienced spiking in electronics. This resulted in repeated spikes in all three research temperature measurements, which have been removed in post processing and resulted in about 23 short data gaps.
DPXC is blanked out from 15:13:30 to 15:14:48 and from 15:18:42 to 15:19:39 due to oveshooting. The missing data can still be seen in DPLC and DPRC but should not be used for research. Also, the dewpointers show "ringing" on the rapid descent at the end of flight caused by their trying to reach balance in rapidly changing conditions.

RF04:
The dewpointers show some overshooting and "ringing" on the rapid descent at the end of flight caused by their trying to reach balance in rapidly changing conditions.

RF05:
DPXS is blanked out from 17:32:07 to 17:34:03 due to overshooting. Data from this period should not be used. Also, the dewpointers show overshooting and "ringing" on the rapid descent at the end of flight caused by their trying to reach balance in rapidly changing conditions. Do not use data from these periods for research.

RF06:
DPXC is blanked out from 00:19:01 to 00:20:12 due to overshooting on descent. Also, pronounced ringing is observed at the rapid descent at the intermediate landing and the end of flight. It is recommended to refer to DPRC for this period.