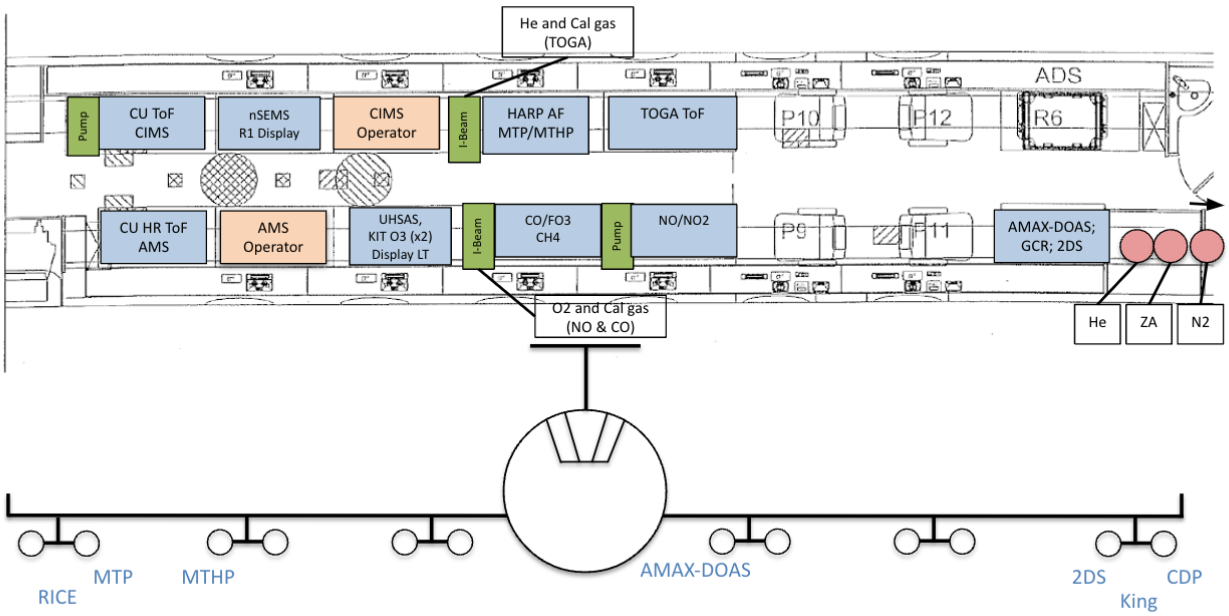
TI3GER (2022) Project Manager Report

Volkamer

I. Aircraft Payload and Layout



Apertures: Lam. Flow Inlet (R1 bottom), nSEMS & CIMS sheath flow (R1 top), AMS (L1 top), KIT O3 (aft bottom VP), VCSEL (middle top), CO/FO3/NOx (L5 top), UHSAS (aft bottom VP), TOGA (P10 top)

Cameras: Side (R5 and L5), Forward (RWO), Downward (B&W; L1 bottom)

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 report covers only the RAF supplied instrumentation on the GV and is organized into the following sections. Section II 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 RAF specialized instrumentation will be provided separately, along with the data. Section III describes issues that occurred on a flight-by-flight basis.

Information on the processing algorithms used to produce the final dataset can be found at:
https://www.eol.ucar.edu/content/raf-bulletins

II. General Data Notes

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 and Altitude Data

The GPS operated well during SPICULE. Terrastar corrections were active most of the time, and only dropped to lesser accuracy during circles. Data were collected at 20 Hz. The horizontal standard deviation was below 0.1 m in most cases and was often below 0.05 m. Vertical standard deviation was less than 0.2 m. These are represented in the GGxxx variables in the dataset.

In RF05 the vertical velocity calculation (GGVSPD) was changed from being based on (change in position) / time (the default for TerraStar mode) to being calculated by measured doppler shifts of satellite signals. This eliminated velocity spikes caused by small position glitches divided by 1/20 seconds, and the spikes propagated through to the vertical wind. The change was made at 17:39:11 in RF05 and was active for the rest of the project.

2. Three Dimensional Winds

Quality-controlled winds for TI3GER are denoted UIC, VIC, and WIX and represent zonal winds, meridional winds, and vertical winds, respectively.

WIX is accompanied by ancillary variables WIX_FLAG, WIX_SCALE, and WIX_OFFSET. WIX_FLAG values are 0=good quality, 1=quality uncertain, 2=requires scale and offset.

Vertical wind data quality may be flagged as uncertain (WIX_FLAG=1) if the aircraft is ascending or descending at a steep rate, turning sharply, or traveling slower than normal (e.g. near takeoff, landing), since the angle of attack is not well characterized under these extreme conditions. Data quality can also be affected by wetting or icing of the radome, which can occur under high relative humidity conditions, when passing through clouds, or when descending rapidly such that the pressure lines in the nose of the aircraft cold-soak. Vertical winds were severely compromised during TI3GER RF04, when evidence of liquid condensation and debris blocking the radome pressure lines was found. They were also compromised during most of the second ferry flight (FF02), after it appears liquid entered the radome ports during takeoff, causing a positive bias in WIX until about 2252 UTC.

The vertical wind accuracy is especially sensitive to the accuracy of the angle of attack, which is calibrated by defining an attack reference value as

$$a_{\mathrm{ref}} = \theta - (v_z/v_h) \times C,$$

where θ is the aircraft's pitch, v_z and v_h represent the aircraft's vertical and horizontal air speeds, respectively, and C is a conversion factor (180/π).

We then identify the coefficients (c) that minimize the least-squares error in the following equality:

$$a_{ref} = c_0 + c_1 \times \alpha/q + c_2 \times \alpha/q \times M,$$

where α is the differential pressure between the top and bottom ports of the aircraft radome, q is the dynamic pressure, and M is Mach.

Historically, RAF has used a single set of coefficients to correct the angle of attack for all flights in a campaign. However, continued investigations over the past few years have revealed that the angle of attack exhibits a time-variant response to the aircraft's time in air, relative to the duration of a flight, which manifests more sensitively at lower (compared to higher) altitudes. To work to address this sensitivity, scale (unitless) and offset (m/s) variables are provided alongside WIX, which users should consider applying when WIX_FLAG is 2. These provide a bulk offset or a time-varying adjustment to WIX for select low-altitude portions of various TI3GER flights. The scale and offset values are derived by bias-correcting large residuals in the angle of attack. The bias corrections are then translated from degrees attack to m/s wind.

The reference horizontal wind variables are WDC and WSC.

Wind variables take a few minutes to recover after long descents and should be used with caution during these times.

3. Pressure

Static pressure (PSF) on the GV is measured using a static port on the fuselage and then corrected (PSFC) using the angle of attack and dynamic pressure. This sensor worked well through the entire project and its measurements are the reference for TI3GER (PSX, PSXC). There are two traditional measurements for dynamic pressure: a heated pitot tube on the fuselage (QCF) and the forward hole on the radome (QCR), which is unheated. Both are also then corrected (QCFC and QCRC) using the static pressure and angle of attack. Water can sometimes get into the radome tubing and cause poor measurements. QCF and QCFC are chosen as the reference raw and corrected dynamic pressures (QCX, QCXC), respectively, for TI3GER. The corrected measurements from the pitot-static sensor mounted on the nose of the GV (QCTFC and PSTFC) track well with the traditional variables described above but are not used as the reference measurements here.

4. Ambient Temperature

Temperature measurements were made using heated (ATH1 & ATH2) and fast response (ATF1) sensors. The temperature sensors generally tracked well throughout the project. There were occurrences where ATF1 cooled up to 0.5 degrees in clouds with large drops, precipitation, or high liquid water content due to wetting and evaporative cooling on the sensor. This causes what appears to be large areas of supersaturation and may result in the appearance of instability in a well mixed cloud. The probe recovered after every instance, but users should use caution when interpreting the fast response temperature data when in cloud.

ATH1 is chosen as the reference temperature (ATX) for TI3GER.

5. Humidity

Humidity is measured by two collocated thermoelectric dew point sensors and the VCSEL hygrometer. The chilled mirror dewpointers (_DPL, _DPR) typically perform poorly in the flight profiles of the GV as they flood on descent and take time to restabilize. There are also non-physical oscillations that occur occasionally in the chilled mirror sensors. The chilled mirror dewpointers should only be used when VSCEL data are missing and even in these situations, should be used with caution. The left dew pointer tended to oscillate at dew points above -20 °C and was slower to respond so DPR is usually the better choice in these cases.

The VCSEL hygrometer had issues with noise and high laser intensity during RF01 and RF02. See the flight specific QC notes below for more information. For FF01, FF02, and RF03 - RF10 there were no issues with VCSEL, and it should be used as the reference humidity measurement.

6. Liquid Water Content

LWC is measured by the King probe (PLWCC) and the CDP (PLWCD_LWOO). PLWCC should not be used for a few minutes after takeoff as it often has spurious, high values during that time and has been blanked out. PLWCC also often shows non-zero values on descent after high-altitude ferry and sometimes during descents in dry air while profiling. At times these values reach up to 0.05 g m^{-3}. No outages were reported for either probe, so PLWCD_LWOO should be compared with PLWCC for all liquid cloud penetrations.

7. Supercooled Liquid Water Indicator

RICE should be used only as a qualitative indicator of the presence of icing. It functioned well during TI3GER.

8. UHSAS-G

The UHSAS-G generally ran well during TI3GER. The exception was RF01, for which no data were collected due to a flow problem. Also, most flights had one to three random data gaps of several minutes each. These gaps were the result of the control program freezing, requiring it to be stopped and restarted by the onboard technician. The cause could not be determined during TI3GER, but has since been eliminated by computer upgrade.

Users should note the following limitations of the UHSAS-G data:

a) The reported size distributions are for dry aerosol. This results from ram heating in the HIMIL, thermalization of the sample air to cabin temperature along the sample line, and the elevated temperature in the UHSAS-G enclosure.

b) Data have not been filtered for clouds. Cloud particles may shatter on the leading edge of the inlet, producing elevated counts over the aerosol background, and possibly skewing the size distribution. Partly due to the difficulty of determining a cloud threshold, and because TI3GER is an experimental project, cloud passes are retained in the data set.

c) Due to relative drifts between multiple gain stages in flight, the size distributions at times exhibit 'stitching' errors, in which bumps or dips occur at the overlaps between four stages in the UHSAS-G. This is most prominent where the mid-low and mid-high gains join near 0.22 micron, as these are independent detector circuits. Stitching errors typically involve 1-3 channels, and though not affecting total concentration, they may be significant for calculations of total surface area and volume. A two-channel shift of the distribution above 0.22 micron, for example, would introduce an error of ~12% in aerosol surface area and ~19% in volume.

d) The length and total bend angle of the sample line from the bottom HIMIL resulted in some size-dependent particle losses, primarily reducing transport efficiency for particles larger than about 0.3 micron. While it is possible to estimate these losses, no adjustments have been made to the data. Users who are interested in such a correction are encouraged to contact the RAF to discuss their needs.

9. Cloud Particle Size

One 1D particle probes (CDP) and one 2D cloud/precipitation probe (2DS) were used for TI3GER.

CDP: The CDP worked very well during the project with only small issues that are discussed in the flight specific notes.
Based on calibrations done during the project the bin edges for the CDP are set as follows: 2.12, 3.14, 4.16, 5.18, 6.20, 7.22, 8.24, 9.26, 10.29, 11.31, 12.33, 13.35, 14.37, 16.41, 18.46, 20.50, 22.54, 24.58, 26.63, 28.67, 30.71, 32.75, 34.80, 36.84, 38.88, 40.92, 42.97, 45.01, 47.05, 49.10, 51.14

2DS: TI3GER was the first project to use the newly purchased RAF 2DS. The data from this probe are considered experimental and should be used with caution as TI3GER did not target clouds for scientific purposes.

10. Camera Images

The NSF/NCAR GV HIAPER flew forward, left, right, and downward facing digital cameras for in-flight image capture.

The forward camera is a Point Grey Research Hi-Res Flea Hi-Color, 1024x768 resolution. The Navitar DO-412 lens has a focal length of 4 mm and the field of view is about 62 x 48 degrees with some barrel distortion. This camera is located on the right wing pylon. Exposure time is automatically controlled by the camera. The image gamma is 1.0 (linear response), resulting in high-contrast images when viewed on ordinary displays.

The left-facing camera is a Point Grey Research Scorpion SCOR-20SO - Color, 1600 x 1200 resolution resolution equipped with an Edmund Optics 6mm lens (#67-709). The field of view is 75 x 54 degrees with approximately 7% barrel distortion. Exposure time is automatically controlled by the camera. The image gamma is 1.0 (linear response), resulting in high-contrast images when viewed on ordinary displays.

The right-facing camera is a Point Grey Research Flea 3 (FL3-FW-14S3C-C) - Color, 1384x1032 resolution equipped with an Navitar 3.5 mm lens (DO-3514). The field of view is 94 x 73 degrees. Exposure time is automatically controlled by the camera. The image gamma is 1.0 (linear response), resulting in high-contrast images when viewed on ordinary displays.

The downward-facing camera is a Allied Vision ProSilica GT4907 monochrome camera with Zeiss ZF.2 100mm F/2 lens stopped down to F/8. Field of view is 20 x 15 degree. The camera was mounted such that the long ('horizontal') dimension is fore-aft to the plane. The images were taken with 3x3 binning giving a resolution of 1621 x 1076 pixels. Exposure time is automatically controlled by the camera. The images were recorded with 8-bit pixel depth. The gamma was set to 0.5, so that the scene contrast is approximately normal when viewed on ordinary displays. The sensor has significant response to wavelengths longer than 700 nm so the image brightness may not match visual brightness.

For all cameras, images were acquired once per second and stored as JPEG-compressed files. No image processing was performed beyond converting the raw pixel data from the color cameras to 24 bit/pixel color images. Applying a sharpening filter as is ordinarily done by consumer digital cameras will considerably improve the appearance. The UTC date and time are encoded in the filename as YYMMDD-HHMMSS.jpg.

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 valid.

III. Individual Flight Summary

All times are UTC.

FF01
The aircraft was on the ground for refueling 1811 - 1944. Data should not be used during this time.

RF01
VCSEL was very noisy in the high-humidity (MODE_VXL = 87) and the lowest humidity mode (MODE_VXL = 83), due to a grounding issue on the aircraft. The mid-range (MODE_VXL = 68) was not affected. For the high-humidity mode it is recommended to use DPR as a substitution. For the low-humidity mode, the Picarro or Aerodyne humidities might be usable.
The UHSAS-G did not collect any particle data this flight because the passive sample flow configuration was overwhelmed by other pump-driven instrument exhaust at a shared dump port. Prior to RF02, a pump was added to isolate the UHSAS-G from the exhaust line, as well as increase the bypass flow to reduce sample line delay.
The 2DS was restarted at 1657

RF02
VCSEL: Excessive laser light resulted in detector saturation in low-humidity mode (high altitude). These times have been blanked out, and either DPR, the Picarro, or Aerodyne should be used here. The blankout times are 1623-1634 and 1756-1855.

RF03
The multiple and large altitude changes during this flight caused the dewpointers (DPL and DPR) to be unstable for much of it. VCSEL worked properly and should be used for all moisture measurements.
The UHSAS was restarted at 1840 and 2020.

RF04
DP_DPR went into service mode at 0056 and no data are available after that time.
WIC contains spikes and dropouts at various times that were later tied to GGVSPD, described above. This is fixed during the next flight.
Moisture in the radome lines affected measurements of QCR and possibly ADIFR. Winds show large deviations for the first three hours of flight, with sudden changes aligning with cloud passes at 2043 and 2112. WIC appears to correct around 2130, but then veers "high" again after a cloud pass at 0039. It remains about 0.5 m/s high for the remainder of flight.

RF05

The change to the GPS velocity calculation (GGVSPD) described above was made at 17:39:11.
The UHSAS was restarted at 1811
VCSEL dropped out 23:10:42 - 23:24:44 due to rapid shifts in the humidity mode causing the instrument to hang, which required a reboot.

RF06

The UHSAS was restarted at 1957 and 2132
The King probe (PLWCC) element went out at 2000 and no measurements are available after this. Liquid water content from the CDP should be used during this time.

RF07

The King probe was out for this flight while awaiting the arrival of a new element.
DP_DPR went into service mode at 2150 and no data are available after that time.

RF08

Large deviations between QCR and QCF start at 2222 and last until 0018, likely due to moisture in the lines. QCF and QCFC should be used after this time. This has impacts on WIC as well.
ATH1 and ATH2 show large jumps due to ice condensate in the top of a convective cloud and should not be used from 2224 to 2226. ATF1 is unaffected during this time.

FF02

WIX has a positive bias until about 2252 UTC due to moisture in the radome line.