SPICULE (2021) Project Manager Report

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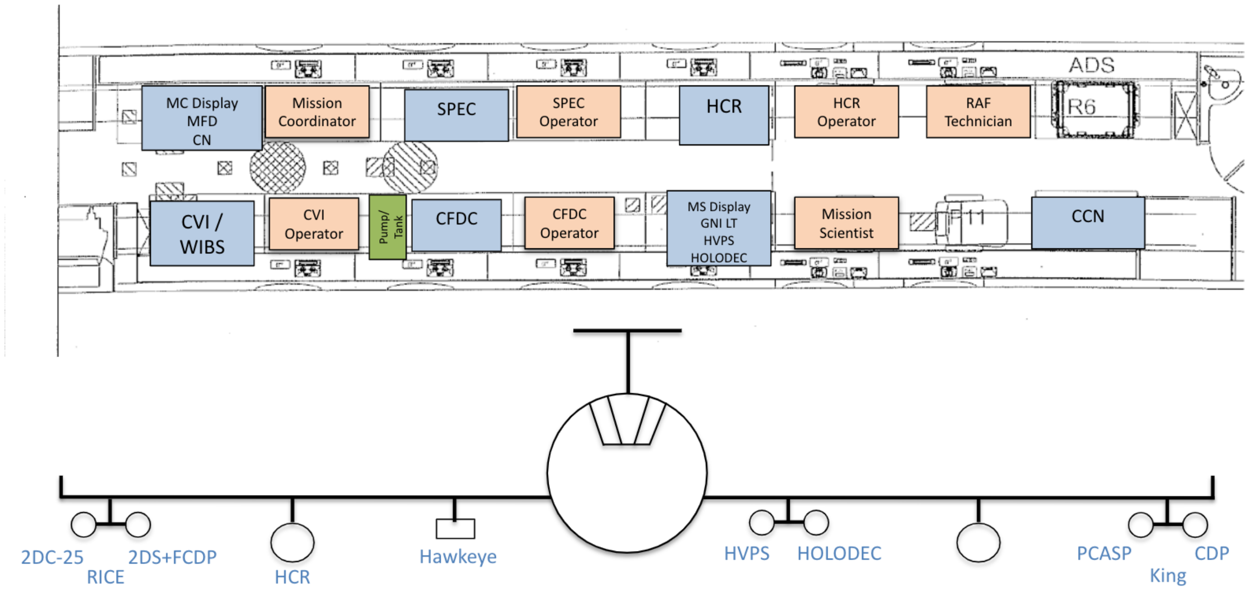
I. Aircraft Payload and Layout



Apertures: CVI (L1 Bottom), CFDC (L1 Top), VCSEL (R1 Bottom), CN (R1 top), GNI (Aft Bottom Viewport), CCN (P11 top)
Cameras: Forward

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 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 on all flights except RF04. (See flight specific QC for RF04 for more details.) Data were collected at 20 Hz. The horizontal standard deviation was below 0.1 m in all 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.

2. Three Dimensional Winds

Vertical wind (and specifically the angle of attack calibration) has been optimized for cloud sampling periods at altitudes below 8000m. Angle of attack was calibrated using a linear model based on two predictors: the ratio of the vertical differential pressure (on the radome) to the dynamic pressure and the dynamic pressure alone. The model was fit to near-level legs, in clear sky conditions and with minimal roll. WIY is the preferred variable for vertical wind during SPICULE. WIY should not be used during climbs and descents.

High altitude ferries exhibit a positive bias in vertical wind (RF08 is a good example of this). Landing periods and the preceding approaches also tend to exhibit positive biases. In addition, because SPICULE targeted clouds, wetting of the radome ports occurred frequently, influencing the accuracy of the measurements used to estimate 3-D winds.

The reference horizontal wind variables are WDC and WSC.

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 SPICULE (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 SPICULE. 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 iced up due to flight segments in clouds with supercooled liquid water. Though it always recovered it should be used with caution and compared with ATH1/2 as slight damage may have occurred. There were also 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. Again, the probe recovered after every instance, but users should use caution when interpreting the fast response temperature data when in cloud.

ATH1 showed a deviation from ATH2 and ATF1 at times during the project, usually during high altitude ferries. Therefore, ATH2 is chosen as the reference temperature (ATX) for SPICULE, and ATH1 should be used with caution.

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. DPL is the best option in these cases as it has fewer oscillations and less noise than DPR during the project.

The VCSEL hygrometer began failing at about 19:20 in RF01. See flight specific QC for RF01. Fixes were tried unsuccessfully during RF02, RF03, and RF04 and no VCSEL data exists for these flights. For RF05 - RF10 the uncalibrated board was used and calibrated by comparison to the chilled mirror dew-pointers. These post-project processed values are reported as XDP_VXL and are merged into the NetCDF files. This calibration is only valid for the high humidity mode. In mid and low humidity modes the data is reported as missing.

6. Liquid Water Content

LWC is measured by the King probe (PLWCC) and the CDP (PLWCD_LWOO). PLWCC should be used with for the first 15 minutes after takeoff as it sometimes has spurious, high values during that time. 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 SPICULE.

8. CN Concentration

The CN performed well during SPICULE. Note that particle counts from cloud passes are contaminated by splash and shatter artifacts, but these events have not been filtered and the data are retained for informational purposes. The length of sample line for the CN introduces a delay of about 1 second in its measurement time series, as determined by comparisons with the wing-mounted PCASP. Although this delay time varies somewhat with changes in altitude and airspeed, the CN data have been shifted by a constant 1 second.

9. Aerosol and Cloud Particle Size

Two 1D particle probes (PCASP, CDP) and one 2D cloud/precipitation probe (2DC-25μm) were used for SPICULE, with complementary measurements provided by the CVI. The HOLODEC as well as three probes provided by SPEC, Inc. (2DS+FCDP, HVPS, and Hawkeye) were also flown on SPICULE. These datasets will be released separately by the responsible teams and are not part of this dataset.

PCASP: The PCASP generally ran well during SPICULE, with no failures. However, the probe experienced frequent optical instability at altitudes above approximately 6 km, causing spurious counts in the small-diameter size bins. Such altitudes were reached only on ferry legs, so data from those portions of the flights were simply blanked. If there is a need for PCASP data in specific cases during those times, the data can be combed more finely to extract valid values, though the coverage may be sparse. The user is also cautioned that PCASP sampling during cloud passes is contaminated by splash or shatter artifacts and residual (not fully evaporated) larger particles. These have not been filtered and are retained for informational purposes.

CDP: The CDP worked very well during the project with only small issues that are discussed in the flight specific notes.

2DC: The 2DC generally ran well during SPICULE. There are some issues with true airspeed and low diode voltages, especially after descents from high altitude, which are discussed in the flight specific notes. Post project processing with in-house software has added new variables to the dataset. These variables contain the string 2DCA or 2DCR where 2DC refers to the 2D cloud probe. "A" represents all counted particles while "R" represents only those that are identified as round. The "round particle" population is intended to represent liquid water particles. The "all particle" population follows the more traditional method of processing 2D image data, placing both round and irregularly shaped particles together into the same particle size distribution. More information on this post processing step can be found at this webpage.

CVI: CVI variables of interest are CWC, FACT, and FACT2. Cloud water content (CWC) from the CVI has been calculated using a Picarro water vapor isotopic analyzer (WVISO) and is reported in g/m^3 of moist air.

The CVI enhancement factor has been calculated in two ways. The first way (FACT1), considered the more reliable, is done by comparing the mole fraction of water measured by the WVISO in the CVI system to the mole fraction equivalent of the cloud water content. The second (more approximate) way (FACT2) is done by comparing the volume swept by the CVI inlet vs. the volumetric flow through the CVI, which is estimated by using the pressure and assumed temperature (40 C) of the ambient sample within the CVI inlet line.

10. Camera Images

Forward looking camera images and movies from the right wing pylon are available for all flights except RF02 and RF03. The camera lens was damaged during RF01, and the camera was removed while a new lens was ordered. Images are available from RF04 on. The images are taken at one second intervals and then combined at 15 fps to create the movies.

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. SPICULE had a number of flights with refueling stops. None of the data collected while the aircraft is on the ground should be considered valid.

III. Individual Flight Summary

All times are UTC.

RF01

The forward camera was inoperable until 15:57.
The data system goes down just before landing. All data are lost starting at 19:58:39.
VCSEL becomes unstable at 19:19. Data have been deleted after this time.

RF02

DPL shows strong oscillation starting around 18:58.

RF03

DPR oscillates more than DPL during this flight
ATF1 differs from ATH1/2 starting around 2330 due to wetting from very high LWC (> 0.75 g/m3). It comes back after exiting the cloud around 2336.

RF04

Terrastar corrections are not available for most of the flight for unknown reasons. Horizontal and vertical standard deviations are about 0.5 m and 1.0 m, respectively.
Data system down due to a spontaneous reboot of the data system computer 20:14:03-20:16:56 and 20:27:48-20:32:38. No data are available during these times.

ATF1 wetting issues noted 1802-1807, 1809, 1848-1849, 1852-1855, 1900-1904, 1908-1914, 1953-2006, 2011-2014, 2018-2020, 2024-2026, 2032-2034, 2040.
Narrow images on the 2DC due to anomalously low TAS values at 20:32:48

RF05
ATF1 wetting issues noted 2135-2137, 2143, 2152, 2154, 2159, 2202.
The aircraft descended rapidly from 13,000 m to 1600 m to begin research. On descent, the diode voltages for the 2DC decreased dramatically due to cold soaking, taking about 10 minutes to recover. The 2DC is blanked out 21:14:00-21:24:30.

RF06
The data system stopped recording and lost all data at 17:57:51, just before takeoff. Flight start time in the file is when it came back after takeoff. It also went down on landing. Flight end time in the file is when data acquisition stopped just before landing.
The 2DC probe was cycled at 18:55 and took several minutes to come back.
DPR entered ‘Service Mirror’ mode at 19:09 and DPL followed at 19:14. This was due to flooding of the sensors after a descent from high altitude. Both recovered at 19:50.
DPR and DLP were also out of service 22:13 - 22:25 due to a similar issue.
The aircraft descended rapidly from 10,000 m to 1600 m to begin research. On descent, the diode voltages for the 2DC decreased dramatically, taking about 14 minutes to recover. The 2DC is blanked out 18:52:00-19:06:00.

RF07
The data system went down just before takeoff (18:28:12). Flight start time in the file is when it came back on climbout.
Couple of minor deviations in ATF1 due to wetting.
The 2DC is off from 19:40 to 21:37 and is blanked out during this time.

RF08
DPL and DPR were both power cycled at 2141 to clear out mirrors.
There is a gap in data on both DPR and DPL at 2144 during climb to 6000 ft.
ATF1 wetting issues noted 2203-2205, 2210, 2226-2228, 2239, 2246, 2251-2252, 2321-2324, 2359-0000, 0004, 0006-0009, 0134-0138, 0141-0142, 0145-0147, 0149, 0158-0159.
The 2DC is off from 19:54 to 21:09 and is blanked out during this time.

RF09
When ferrying back VCSEL, DPL and DPR reported unreliable data above 20K feet.
There are some odd oscillations in temperature, altitude, and some other variables starting at around 22:54:35 for a minute to 90 seconds. Data should be used with caution during this time period.

RF10
DPL and DPR have issues at various times between 19:27 and 19:52.
ATF1 stops tracking the other temperature probes at 22:02, likely due to an icing encounter. The probe may have been damaged and should not be used for the rest of this flight. Some slight wetting issues were noted before this time.
QCR is bad 22:09-22:17 due to an icing event.