Data Quality Report

ICE-T

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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, TDL) and the University of Wyoming Cloud Radar (WCR) and Cloud Lidar (WCL) will be provided separately, as will the respective data sets.

Section I: General Discussion

1. 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.

2. **Position Data**. Both a Garmin Global Positioning System (_GMN) and a Novatel Global Positioning System (GGPS) were used as more accurate position references during the program. The systems generally performed well. With no real differences between the two sets of data, it was decided to only output the Novatel variables in order to avoid confusion in the data analysis. The algorithm referred to in (3) below also blends the GPS and IRS position to yield a best position (LATC, LONC) that generally removes the GPS spikes.

3. **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 ICE-T flights TF01, and RF11 to aid in the performance analysis of the wind gust measurements. The calibration data identified a systematic bias in the pitch and sideslip parameters. These offsets have been removed from the final data set. The time intervals for each set of maneuvers have been documented in both the flight-by-flight data quality review and on the individual Research Flight Forms prepared for each flight. Drift in the IRS accelerometers are removed using an algorithm that employs a complementary high-pass/low-pass filter that removes the long term drift with the accurate GPS reference and preserves the shorter term fluctuations measured by the IRS.

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).

4. **SPECIAL NOTE**: RAF flies redundant sensors to assure data quality. Performance characteristics differ from sensor to sensor with certain units being more susceptible to various thermal and dynamic effects than others. Good comparisons were typically obtained between the two static pressures (PSFDC,PSFC), the three standard temperatures (ATRL, ATHR1, ATHR2), three dynamic pressures (QCRC, QCFC, QCFRC), and the two dew pointers (DPT,DPB). Exceptions are noted in the flight-by-flight summary. The two remote surface temperature sensors (RSTB, RSTB1) generally functioned well and also showed good agreement. The backup static pressure system showed smaller turbulent fluctuations in the signal (PSFRD) and therefore was selected as the reference pressure (PSXC) used in all of the derived parameters.

5. **Ambient Temperature Data**. Temperature measurements were made using the standard HARCO heated (ATHR1, ATHR2) and unheated (ATRL) Rosemount temperature sensors and an OPHIR-III radiometric temperature sensor. Performance of all three "insitu" sensors remained stable throughout the project and showed excellent agreement. Due to significant wetting errors in the fast response sensor ATRL during cloud passes, ATHR1 was selected as the reference value (ATX) used in calculating the derived parameters.

The OPHIR-III sensor (OAT) was flown because it is not sensitive to interference from sensor wetting or icing. Measurements are derived from near field radiometric emissions in an infrared frequency band. The integrated sample volume of the unit is designed to extend roughly 10 meters out from the aircraft. While the unit performed quite well and its output was generally well correlated to the in-situ temperature sensors, it is susceptible to in-flight calibration drift. The instrument is calibrated by statistical comparison against the reference in-situ sensor ATX over the term of the deployment. Because OAT is not an independent, stand alone measurement, use of the OPHIR data should be strictly limited to the direct cloud penetrations where the standard sensors have a problem with sensor wetting.

6.**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 (DPBC, DPTC) yielded good correlation in instrument signatures during the largest portions of the flights when both instruments were functioning normally. Under conditions where the units had been cold soaked at high altitude or experienced a rapid transition into a moist environment, both units showed a tendency to overshoot. DPTC was used as the reference humidity sensor (DPXC).

Note: Even at their best, the response of the thermoelectric dew point sensors is roughly 2 seconds. Response times are dependent upon ambient dew point depression and can exceed 10-15 seconds under very dry conditions.

The experimental fast response humidity sensor (XUVI) provides a logarithmic response and is electrically unstable during the early portions of each flight and thermally unstable at higher altitudes. Typically the data are unusable for the first 15 minutes of flight. While slightly less accurate overall, the high rate response of this system is clearly more characteristic in mapping the sudden changes in humidity associated with the ICE-T conditions. Therefore it has been used in the calculation of the derived humidity variables (RHOUV, DPUV, MRUV, RHUM, THETAE). It is also adequate for flux calculations.

7. **Surface Temperature Data**. Heimann radiometric sensors were used to remotely measure surface temperature (RSTB & RSTB1) and cloud base temperature (RSTT). Both down looking units functioned well through out the project although RSTB1 showed some thermal drift in the later stages of the deployment. RSTB was selected as the reference system for this measurement and in the calculation of "corrected" sea surface temperature (TSURF). RSTT also functioned well. Note that when no clouds are present above the aircraft the RSTT signal will be pegged at its maximum "cold" limit of roughly -60 oC.

8. **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 K.

The GPS positioning systems also provide altitude readouts (GGALT & GGALT_NTL). These outputs normally provide a fairly accurate MSL altitude based on a ellipsoid model of the Earth (WGS-84).

9. **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 some of the optical particle probes. 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. Increasing voltage indicates an accumulation of ice on the sensing element. The system is designed to shed ice at a maximum threshold by flash heating the element. Rapid cycles of the sensor are associated with significant levels of super-cooled water.

10. **CN Concentration Data (0.01 to 3 um)**. The calculation of CN sized aerosol particle concentrations (CONCN) is dependent upon total particle counts (CNTS) and the measurement of sample flow (FCN,FCNC). The internal sample flow (FCN) has been corrected (FCNC) to ambient conditions, only, and not to STP for the calculation of

particle concentration. The special inlet for this measurement is not as susceptible to the normal droplet splashing effects typically noted in all clouds. Some residual shattering effects can still be seen in clouds containing drizzle sized precipitation (<200 um).

Note: The location of the inlet on the aircraft and length of the tubing connecting the inlet to the counter will induce a lag in the system response to changes in particle concentration. Based on a comparison against the wing mounted SPP200 optical probe, the lag in CONCN for the PASE experiment is 3 seconds. The data in the production data files have been corrected for this time lag.

11. **Aerosol & Cloud Droplet Sizing Data**. Four PMS 1D particle probes (SPP300, SPP100, SPP200, CDP) were used on the project. Some specific details on each of the probes are summarized below:

SPP200 - The SPP200 aerosol particle probe functioned well for most of the flights during the project. The probe being flown has been modified in order to directly measure the sample flow through the instrument. These data, recorded as PFLWC_RWO, have been used in the calculation of particle concentrations to provide a more accurate measurement of aerosol concentrations. Counts in the lowest bin size were contaminated by excessive electronic noise. Data from that channel have been removed from the calculation of total particle concentration (CONCP). Note that the sampling range of this probe is a sub-set of the sampling range of the CN counter. The values of CONCP should therefore always be less that the CONCN values. During cloud penetrations splashing effects can reverse this trend due to false counts in CONCP. **Due to the sampling technique employed by this probe it is not suitable for use in clouds.**

SPP100(FSSP) – The probe is the standard model FSSP with the flow straightening shroud. This unit seemed to function well under all conditions, particularly in the ice clouds encountered at higher altitudes. In liquid precipitation, some droplets shattering likely shifts the size spectra toward higher concentrations of small particles. It is recommended that the cloud size particle data from this system be used as a better representation of the conditions than the other two 1-D probes.

SPP300(FSSP) - The SPP300 aerosol probe covers a range of particle sizes that bridges the gap between the true aerosols and the smaller droplets (0.3 - 20 mm). Like all 1-D optical probes, however, the SSP300 has no way to distinguish between aerosols, ice or water. Due to difficulties in determining the sample volume for this probe, this measurement is the least accurate of the aerosol probes.

CDP - This probe basically matches the same cloud particle size distribution as covered by the SPP100 probes but has difficulty in sampling ice particles. Under the conditions targeted by the ICE-T flights, the CDP particle concentration data and calculated liquid water content will under estimate the true values of these variables. Direct comparisons against the SPP100 will vary from cloud to cloud depending on the type of cloud particles (ice crystals, water drops or mixed phase) encountered. During the project the primary unit failed due to a static discharge from the wing pylon. This event occurred on flight rf05. A replacement probe was installed and operated for the remainder of the project. While it appeared to function, the RAF was unable to confirm the true sample volume for the probe and thus considered the resulting data to be unreliable. These data have been removed from updated data archive.

12**. Precipitation Sizing Data.** Two OAP probes were flown during the project. Unit one was a standard 2D-C probe with 25 um resolution. This system functioned well though out the entire project. A newly modified 2D-P with 150 um resolution was added to the payload just prior to departure. The system functioned well but needed some re-characterization for data processing due to changes in the basic optics of the probe.

13. **Small Ice Detector (SID-2H).** The SID II performed well throughout ICE-T. For the purposes of particle sizing in the first release of data from the SID II, the SID II was calibrated to agree with the CDP in warm clouds. To accomplish this the gain in the processing software was adjusted so that the peak in the SID II size distribution matched that of the CDP for the same time period in a warm, low precipitation, cloud. Thus the size calibration (and other variables, such as water content, that are related the computed particle size from the instrument) is most appropriate for measurements in warm, liquid only, clouds, consisting of spherical water droplets. A small correction to particle sizes is needed when converting the SID II scattering signal to represent spherical ice particles. However, since most of the ice encountered during ICE-T was unlikely to be sperical, with poorly known scattering properties, and many clouds contained both ice and water, we have not included more sophisticated size calibrations; these are left for future releases of data from the instrument, or for more elaborate analysis by investigators focusing on specific cloud regions where the characteristics of the ice particles are better known.

14. **Three Dimensional Particle Imager (3V-CPI).**

Contact Jorgen Jensen (jbj@ucar.edu) with questions about the 3V-CPI data**.**

15. **HOLODEC-2.** This 3D holographic particle imaging system is currently under development and was flown in the Experimental Category. Some images were obtained on selected flights, but troublesome optics limited the collection and quality of the data. Michigan Tech University is responsible for the data.

16.**CVI Data Report: ICE-T (C. Twohy, Date)**

Contact Cynthia Twohy (twohy@coas.oregonstate.edu) with questions about the CVI data or for residual nuclei size distributions not available in the netcdf file.

17. **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.

Section II: Flight-by-Flight Summary

RF01 Uncharacteristic response in heated temperature sensor. ATHR1 & ATHR2 data bad from 154120 to 154930 UTC. Reference temperature (ATX) set to ATRL for this flight.

CN Counter pump not turned on. CONCN data are bad for the entire flight.

Communications to King Probe are non-functional. Liquid water content data from this sensor (PLWCC) are bad for the entire flight.

Liquid water likely in bottom dew pointer sample cavity. DPBC data bad from 1541 to 1613 UTC.

In-cloud temperature sensor exhibiting excessive drift. OAT data bad from 1639 to 1651 UTC.

Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC & DPBC data bad from 1637 to 1706 UTC.

RF02 Bad communications with in-cloud temperature sensor. OAT data bad for the entire flight.

Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC & DPBC data bad from 1645 to 1809 UTC.

Communications with SPP200 aerosol probe lost at ground power switch. CONCP data missing for the entire flight.

Excessive drift in UH Hygrometer sensor. Humidity data are bad from 1552 to 1610 UTC. Use dew point alternates for this interval.

RF03 Signal recording error in the nose DSM. ATRL and 3-D wind data are missing from 1915 to 1956 UTC.

Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC & DPBC data bad from 1858 to 1923 UTC.

RF04 In-cloud temperature sensor exhibiting excessive drift. OAT data bad from 2007 to 2035 UTC.

Excessive drift in UH Hygrometer sensor. Humidity data are bad from 1556 to 1625 and 200545 to 201235 UTC. Use dew point alternates for this interval.

Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC & DPBC data bad from 1654 to 1705, 1730 to 1756 and 2002 to 2023 UTC.

RF05 Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC & DPBC data bad from 1943 to 2001 UTC.

Lightning strike to the aircraft took out selected channels on 2 DSM's. Icing rate (RICE), King Probe Liquid Water (PLWCC) and Cloud Droplet spectra from the CDP probe (CONCD) are missing from 173922 to 202600 UTC.

RF06 Unable to recover CDP Cloud Particle probe function. CONCD data bad for the entire flight.

Community aerosol pump turned off for sensor leak testing. INFLOW data affected from 1326 to 1356 UTC. Affect on down stream sampling systems is unknown.

RF07 Unable to recover CDP Cloud Particle probe function. CONCD data bad for the entire flight.

Short data gaps in all DSM's. Data affected from 184919 to 185552 UTC.

Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC & DPBC data bad from 1847 to 1911, 1849 to 1905 and 1921 to 1925 UTC.

Loss of communication with in-cloud temperature sensor. OAT data bad from 1744 to 1745 and 1849 to 1853 UTC.

Intermittent data spikes removed from all three remote temperature sensor data (RSTB, RSTB1, RSTT).

RF08 CARI chemistry instruments were intentionally not turned on due to limited warm-up opportunity. FO3, CO, CO2 and CH4 data missing for the entire flight.

Poor response from OPHIR temperature sensor. OAT data considered bad for the entire flight.

Sample volume for the replacement CDP probe cannot be directly determined. CONCD data have been judged to be unreliable and have been removed from the data archive.

RF09 Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC & DPBC data bad from 1741 to 1800 UTC.

Excessive drift in OPHIR temperature response. OAT data questionable from 190555 to 190700 UTC.

Fast ozone instrument rebooted in flight. FO3 data missing from 1326 to 1442 UTC.

No raw counts (ShadowOre) from PMS 2D-P probe recorded for the entire flight. Images appear to be fine.

Uncharacteristic response from the remote cloud base temperature sensor. RSTT data bad from 1712 to 1713 UTC.

Sample volume for the replacement CDP probe cannot be directly determined. CONCD data have been judged to be unreliable and have been removed from the data archive.

RF10 Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC data bad from 2023 to 2042 UTC. DPBC data bad from 2023 to 2059 and 2300 to 2309 UTC.

Uncharacteristic response from the remote cloud base temperature sensor. RSTT data bad from 1629 to 1647 UTC.

Sample volume for the replacement CDP probe cannot be directly determined. CONCD data have been judged to be unreliable and have been removed from the data archive.

RF11 Excessive drift in UV hygrometer response. Humidity data questionable from 1425 to 1458 UTC.

Uncharacteristic response from the remote cloud base temperature sensor. RSTT data intermittent from 1639 to 1720 UTC.

Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC data bad from 1702 to 1713 and 1959 to 2021UTC. DPBC data bad from 1701 to 1729 and 2011 to 2021 UTC.

Sample volume for the replacement CDP probe cannot be directly determined. CONCD data have been judged to be unreliable and have been removed from the data archive.

RF12 Short data gap in forward DSM. All State parameters missing from 143020 to 143320 UTC.

Loss of avionics GPS data from 1946 to 1952 UTC. Use WI as the vertical wind speed reference for this flight.

Uncharacteristic response from all of the remote surface temperature sensors. RSTT, RSTB and RSTB1 data bad from 163435 to 163505 UTC.

Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC data bad from 1617 to 1637 and 1926 to 1939UTC. DPBC data bad from 1506 to1553, 1617 to 1637 and 1926 to 1939UTC.

Sample volume for the replacement CDP probe cannot be directly determined. CONCD data have been judged to be unreliable and have been removed from the data archive.

RF13 Loss of avionics GPS data from 1839 to 1845 UTC. Use WI as the vertical wind speed reference for this flight.

OPHIR radiometric temperature sensor is not communicating with the ADS system. OAT data missing for the entire flight.

Dew point sensor heaters unable to respond to rapid increases in humidity. DPTC & DPBC data bad from 1908 to 1919 UTC.

Sample volume for the replacement CDP probe cannot be directly determined. CONCD data have been judged to be unreliable and have been removed from the data archive.