Appendix to DC3 Project Manager's Report: Reprocessing

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The NCAR/EOL Research Aviation Facility has recently completed a review and upgrade of its existing algorithms for data processing to incorporate recent improvements that have become available for specific instruments. The complete documentation of RAF's standard algorithms can be found in the RAF Technical Note on Processing Algorithms (Cooper, 2016) and is available at https://www.eol.ucar.edu/content/raf-processing-algorithms. These are living documents and changes may be made at any time in the future.

Recently RAF reprocessed all GV projects between 2008 and 2014 to incorporate many updates to the processing code. This reprocessing provided consistency across all projects with earlier projects having more changes than later ones. Many of the changes do not have a large effect on the data, but the processing updates are presented here for transparency and to provide background information on data quality issues.

RAF has performed quality control on the reprocessed flight data and is releasing it with this addendum to the project manager's report. Section I in the present document provides a description of the specific upgrades to the processing code made for DC3. In most cases the changed variables supersede those described in the original project manager's report. The modifications to the data and impacts on individual flights will be described in Section II.

Section I - Summary of Changes to the Processing Code

Temperature

Soon after the GV entered service, comparisons were made between the various on board temperature measurements and dropsondes, utilizing flight maneuvers that followed the descent of dropsondes so that the measurements could be made in the same airmass at nearly the same time and near the same location as the dropsonde. These studies revealed a problem with the standard calibration of research temperature probes and indicated that the temperature data that matched the sonde data best was the avionics temperature (which is taken from the onboard avionics system and used for aircraft flight data and avionics control systems). Consequently, until recently the reference temperature (ATX) for projects was taken from the avionics temperature (AT_A). Now that the problems with the calibration system have been resolved, the data are reprocessed to use the measurements from the research temperature instruments as the reference temperature, which provides better accuracy and time response than is available from the avionics temperature.

A large-scale effort to understand the calibration issue found that there were two primary problems with the bath calibrations: (i) inadequate immersion and stirring to hold them to the bath temperature at the low end of the calibration range, followed by heat conducted from the room to the sensor through the mounting stem, and (ii) the ability to now have calibration data at much colder temperatures than what was possible earlier. This combination of factors biased the results at cold temperatures by an amount that varied from calibration to calibration. This became an issue because of the lower temperatures sampled by the GV compared with the C-130, for which the bath calibration techniques were adequate. Re-calibration of the sensors using the bath chamber at EOL's In-situ Sensing Facility (ISF) resolved the bath calibration problem and this calibration data is now applied to projects where the avionics temperature was previously used as a reference.

Variable names for the measurements have also changed. Historically, variables like TTHR1 denoted the direct measurement from the sensors and was referred to as the total temperature. This direct measurement is more accurately known as the recovery temperature so all 'TT' prefixes have been changed to 'RT'. The reason is that air flowing towards the surface of the sensing element may not be decelerated to 0 m/s (which would give the total temperature) but only to a very low air speed (which gives the recovery temperature). Additionally, names have been simplified by removing some of the letters formerly used to denote location so that the variables for the (up to) four heated sensors are RTH1, RTH2, RTH3, and RTH4. The associated ambient temperature variables are ATH1, ATH2, ATH3, and ATH4. RTF1 and ATF1 are used for the recovery and ambient temperatures from the unheated (fast-response) sensors.

King Liquid Water Content

The method for calculating LWC from the King Probe has been revised to include a variety of corrections. The formulas used for the thermal conductivity of air and for relating the Nusselt number to the Reynolds number for heat transfer when out of cloud have been updated. The boiling point of water is now dependent on the pressure and the latent heat of vaporization is now dependent on temperature. Finally, the filtering to give zero LWC values in clear air have been updated, which is especially important for the GV. All of these changes have resulted in a more accurate LWC measurement (PLWCC).

Pressure Corrections

The Laser Air Motion Sensor (LAMS) presented an opportunity to determine the "static defect" (or difference between the true ambient pressure and that delivered by the static-button pressure ports) with reduced uncertainty. The key assumption was that the measurement of dynamic pressure obtained by comparing the pressure at a pitot tube to that at the static buttons is in error primarily because of the error at the static buttons. If that is the case, a prediction of the true dynamic pressure calculated from the LAMS-based airspeed can be used to determine the error in the measured dynamic pressure, and that error (with reversed sign) is also the static defect (Cooper et al, 2014). A parameterized representation of the correction was developed for projects in which LAMS was not involved (which is almost all of them) and is applied to the pressure measurements. This allows for better determination of the longitudinal component of airspeed and a reduction in the uncertainty of wind measurements.

Vertical Winds
Adjustments have been made to the sensitivity coefficients that relate pressure measurements on the radome and at the entrance to a pitot tube to the angle of attack that is used to calculate the vertical wind. An effort was made to find project-wide sensitivity coefficients that produced reasonable measurements of vertical wind for all flights, but for some projects that was not possible and some special steps were taken.

Attack Angle
The ATTACK variable has been updated with revised coefficients for its calculation from the radome pressure-port measurements.

Humidity Mach Number and True Air Speed
Moist-air properties are used to calculate the Mach number and subsequent true airspeed (TAS), resulting in more accurate values. MACHF and TASF now represent the humidity adjusted speeds. The old, dry air calculation is represented by TASDRY. MACHX is set to MACHF and TASX is set to TASF.

UHSAS Aerosol Particles
In the UHSAS data processing, the raw sample flow measurement is adjusted to a “corrected” value to determine an equivalent ambient sample volume for the calculation of ambient particle concentration. This correction algorithm had presumed the output of the flow controller to be a *mass flow* measurement requiring correction to standard conditions in order to determine the actual volumetric flow. In fact, the flow controller both controls and reports *volumetric* flow at laser conditions, so the existing adjustment to standard conditions introduced an error that scales roughly with ambient pressure. A new algorithm for calculating the correct flow was developed and results in new concentrations that are roughly unchanged at sea level but are increasingly larger at altitude.

Height Above Terrain
Two variables have been added to the data files. SFC_SRTM represents the height of the terrain under the coordinates of the flight track of the research aircraft. ALTG_SRTM represents the aircraft’s altitude above ground along the flight track. Both variables are in meters above the WGS84/EGM96 geoid. Terrain height is determined using data from the Shuttle Radar Topography Mission (SRTM) of 2000, which mapped the altitude of the Earth’s surface from 56S to 60N latitude with resolution of 3 arcsec or about 90 m at the equator. For the US and territories, the resolution is 1 arcsec or about 30 m. The measurement uncertainty is about 9 m at 90% confidence, but there are some biases. The SAR-radar technique did not penetrate fully through vegetation and so might reflect the top of the vegetation canopy or some level intermediate between the canopy and the surface. The radar also penetrated a few meters into snow and so measured a height between the snow cover and the terrain (as measured in Feb. 2000). There are also some gaps, especially in mountainous areas.

When there is no terrain but only ocean, terrain height has been set to zero. Remaining missing-value regions after interpolation to fill small gaps are mostly over ocean and are replaced by zeros as well.

Section II - Project and Individual Flight Summary

The following comments apply to the entire project.

- All temperatures are based on new coefficients. ATF1 is selected as the primary temperature (ATX) for all flights except RF22. This temperature measurement may suffer from cooling errors of a few tenths of a degree caused by wetting in warm clouds. This is rare, but temperature measurements taken in warm clouds should be used carefully.
- EW_VXL is the primary water vapor measurement (EWX) for all flights and feeds into the primary dewpoint measurement (DPXC). The VCSEL did suffer from some dropout periods where no data were recorded due to a bug that caused lockups when the mode changed quickly. Humidity measurements from the chilled mirror dew pointers (*DPL and *DPR) should be used in those cases.
- The UHSAS ran reasonably well in DC3, with some notable exceptions flagged in the individual flight reports. There were occasional drifts of relative gains between the four detector gain stages causing "stitching" errors that appear as bumps or gaps in the histograms. Such errors are minor and largely cosmetic. At other times the UHSAS laser shifted to an unstable mode, leading to spurious noise counts in the smallest few diameter bins, and in more severe cases, no valid particle size or count information at all. These episodes have been blanked in the data files. The original PM Data Quality report, both in the general comments and specific flight notes, ascribed some UHSAS problems to a failure of one or more gain stages. Although the histograms have that appearance, the actual cause is laser instability, specifically failing to hold its tuning and jumping to a bad mode. In this state the probe neither sizes nor counts properly, and large gaps develop in the histograms. The particle pulse processing electronics were not affected. The distinction is important, since gain stage problems might have been cured by a simple board replacement, while laser instability under flight conditions is a far more difficult problem to overcome.
- The previously applied correction for particle coincidence is specific to RAF's butanol CN counter, and not the Water CN Counter (WCN). For this reprocessing, the appropriate coincidence correction using the WCN's measured live time has been applied. This is a more robust method as well, being more accurate and working to even higher concentrations. The change from previous processing becomes significant only at higher concentrations, where new values exceed the old. The length of sample line for the WCN introduces a delay in its measurement time series, and comparisons with the wing-mounted UHSAS show this to be about 1 second. The WCN data are therefore shifted 1 second.

- A satisfactory solution for calculating a consistent vertical wind (WIC) for these flights could not always be found due to variation in the sensitivity coefficients from flight to flight. Even though WIC is good in most cases a low-pass filter has been applied to correct the vertical wind measurements. WIF is the new variable representing these corrected measurements and often has less bias than WIC. WIX has also been added as the primary vertical wind and is set to WIF for all flights.
- The variables IRT and IRB have been changed to IRTV and IRBV, respectively. These represent the raw infrared irradiances from the pyrgeometers on the top and bottom of the aircraft, and the "V" designates the units, which is volts for both measurements.

Not all flights have significant changes beyond what is described above. Only the flights with large differences from the previous dataset are referenced below.

RF08
The GPS suffered some drop outs between 21:50 and 22:00. ALT, LATC, and LONC should be used for position information during those times.

RF17
ATF1 is blanked out 21:06:57 - 21:08:12.
ATH1 and ATH2 are blanked out 01:58:20 - 02:14:20.

RF18
ATF1 is blanked out 01:18:52 - 01:19:10 and 01:22:00 - 01:23:15.
WIC has no usable data until the end of the flight due to a problem with AKRD. WIF should be used for vertical winds for this flight.

RF19
ATF1 is blanked out 14:53:13 - 14:54:58 and 21:23:39 - 21:31:00.

RF20
ATF1 is blanked out 02:08:10 - 02:17:00.

RF22
ATH1 is used as the primary temperature measurement for this flight due to a long period of bad measurements by the fast response probe.

References:

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