Subject: Recommendation re QCRC calculation

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3 November 2016

Background

The processing for QCF, leading to QCFC, involves a correction for the "static defect" or difference between true ambient pressure and measured ambient pressure, because the measurement on which QCF is based is the pressure difference between the pressure delivered by a pitot tube and that delivered by the research static buttons on the aircraft. This correction is based on measurements from the Laser Air Motion Sensor (LAMS), as documented in the technical note on Processing Algorithms. Because the same reference source is used for the measurement QCR (the difference in pressure between the center port on the radome and the static pressure delivered by the static buttons), the same correction is being applied (as of the date of this memo) to QCR to obtain QCRC. There are two problems with this:

1. Unlike a pitot tube, which is relatively insensitive to flow angles, the radome port exhibits significant sensitivity to the flow direction. This was investigated in an NCAR Technical Note by E. Brown, where it was argued that an appropriate correction for a radome having hemispherical shape is

$$\mathrm{QCRC} = \frac{\mathrm{QCR} - \Delta p}{1 - 2.25\sin^2\alpha - 2.25\sin^2\beta} \tag{1}$$

   where Δp is the static defect and angle of attack and sideslip are respectively α and β. This worked well for the hemispheric radome, but the GV radome is far from hemispherical so a different correction may apply.

2. The uncorrected measurement QCR often is larger than QCF, while the likely correction for flow angles is to increase it further. This may indicate some difference in transducer calibration, although the observed difference exceeds expected uncertainty limits for the transducers. The reason for this difference is not understood at this time.

These problems make QCRC of questionable value as a backup measurement for QCFC. For that reason, an empirical adjustment is developed in this memo that represents the flow angles in a form similar to (1) while accounting for the difference between measurements of QCR and QCF.

Present Processing Code

The correction (1) is not being applied at this time to either the GV of C-130. Instead, the same correction used for QCF is applied to QCR to find QCRC, on both aircraft. For reference, the code in use is in ".../std/qcrc.c" and "../std/initAC.c" in nimbus.

Proposed Change

The E. Brown analysis and (1) suggest that it may be possible to represent QCR from the GV radome using a formula of the form

$$\{\mathrm{QCRC}\} = b_0 + b_1\{\mathrm{QCR}\} + b_2(\{\mathrm{AKRD}^2\} + b_3\{\mathrm{SSRD}\}^2 - \Delta\mathrm{p} \tag{2}$$

where the coefficients $\{b\}$ can be determined by fitting using the following representation:

$$\{\mathrm{QCF}\} \sim b_0 + b_1\{\mathrm{QCR}\} + b_2\{\mathrm{AKRD}\}^2 + b_3\{\mathrm{SSRD}\}^2\ . \tag{3}$$

Application of the latter empirical representation then leads to an equation that transforms QCR to match, in a fitted sense, QCF, after which inclusion of the static-defect correction gives a value of QCRC that will be similar to QCFC.

The objective of this change is to obtain values of QCRC that, according to the uncertainty analysis contained is the NCAR Technical Note on wind uncertainty, could give wind measurements with similar uncertainty and so could serve as a backup to the standard measurement.

A defect in this chain is that AKRD and SSRD are normally calculated using QCF, so if QCF is unavailable then QCRC cannot be calculated to serve as a backup to QCFC. This could be overcome by using one of these strategies:

1. AKRD and SSRD could be calculated instead using QCR. The normally small difference between QCF and QCR will not affect this calculation significantly because the percentage difference is small.

2. SSRD could be assumed zero and AKRD assumed equal to its zero-vertical-wind value $\alpha^* = \Theta - (w_p/V)(180/\pi)$ where Θ is the pitch angle, w_p the rate of climb of the aircraft, and V the true airspeed.

3. As a last resort, normal mean values of 2.5 and 0 could be used for AKRD and SSRD.

An additional use for QCRC, in addition to being a backup for QCFC, is that agreement between the two is a useful indication of normal opeeration of the measuring system for wind.

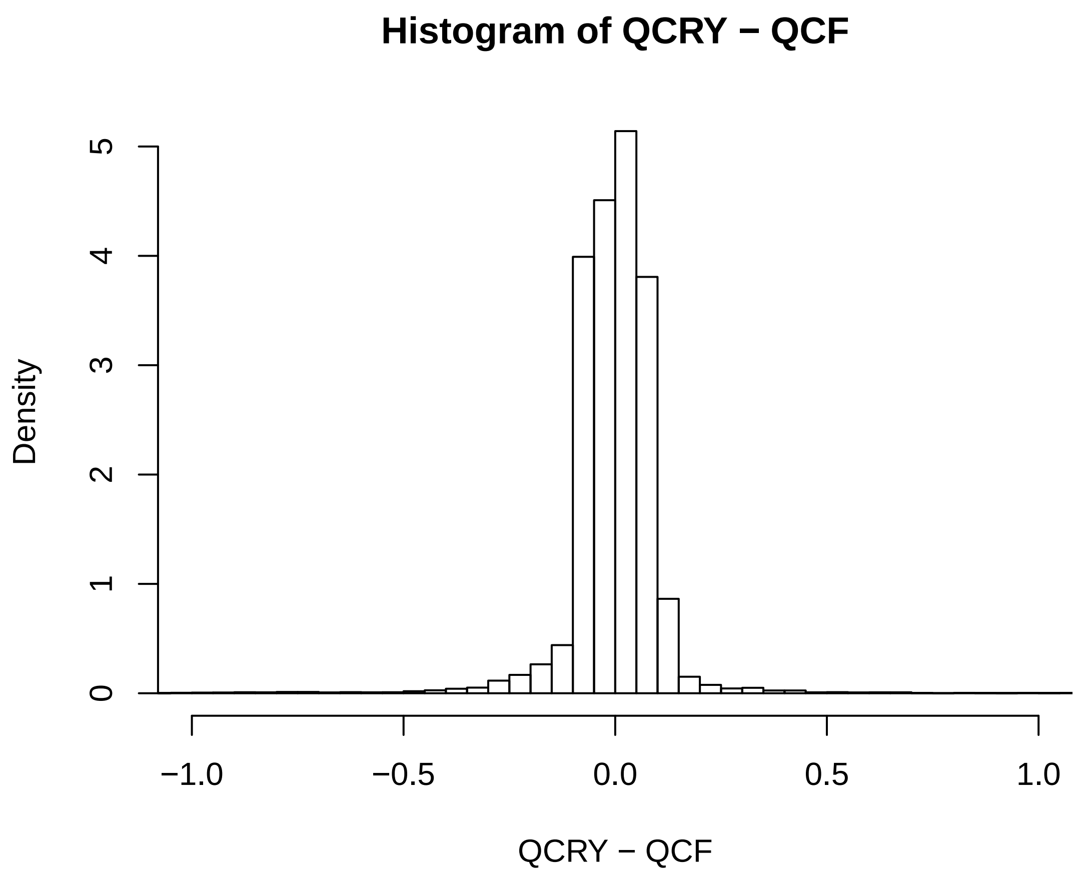

Figure 1: Distribution of the difference between the result of the fit (here, QCRY, as given by (3)) and the measured value of QCF, for CSET flight 16.

Analysis

To find an appropriate empirical correction, data from flight 16 of CSET were used. This flight had advantages that a large altitude range was covered, with many level legs at various altitudes. Several other flights and projects were checked also to see that consistent results were obtained. For the fit, measurements were constrained to have valid measurements of both QCR and QCF with both larger than 20 hPa, to avoid regions with very slow flight at the start and end of the flight. The representation (3) provided a reasonable representation of the relationship so more complicated equations were not explored. The residual standard deviation from the fit was 0.13 hPa and the fit left only 0.002% of the variance unexplained. On this basis, the fit provides a representation of QCF within about 0.1 hPa by using QCR, so this new value of QCRC has essentially the same uncertainty as normal measurements of QCFC. The coefficients obtained are contained in the recommendation below.

For the C-130, measurements from WINTER flights 1–8 and 10–12, combined with FRAPPE flights 1–3 and 4–7, were used for a similar fit, after exclusion of many regions where it appeared possible that some port on the radome was blocked, had an obstruction in the pressure line, or otherwise was not operating normally. For that data set, the fit resulted in a residual standard deviation of 0.15 hPa. However, in that case QCR and QCF were usually in quite good agreement, with a mean difference of 0.02 hPa and standard deviation of 0.17 for the entire data set, so it does not appear useful to apply a similar correction to the C-130 measurements. The correction would not produce any significant improvement.

Recommendations

For the GV, add the following empirical correction to QCR when calculating QCRC:

$$\Delta\{\mathrm{QCRC}\} = b_0 + (b_1 - 1)\,\{\mathrm{QCR}\} + b_2\{\mathrm{AKRD}\}^2 + b_3\{\mathrm{SSRD}\}^2 \tag{4}$$

where $\{b_{0-3}\}$ are {-0.5635, 0.9982, 0.0273, 0.0562}. The full equation for QCRC is (2). For the C-130, leave the processing as it is.

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