This note documents what I think I have learned from the trailing-cone flight of the GV.

I assumed that the variable TCONE is the pressure of the trailing-cone referenced to the research static sources; i.e., TCONE positive means the trailing-cone system provides a higher pressure than the static buttons. The flight (from 14 Sept 2006) was long because it apparently included over-ocean segments to reach levels near sea level. It also extended to very high levels, FL490 near the end of the flight. There are a range of airspeeds and angles-of-attack at each altitude, so the flight has very good information for this study.

If the measurements from the trailing cone are considered reference values, the measured difference is then a correction to be applied to the measured pressure. A fit to the measurements revealed a complicated dependence, with all the terms in the following table making significant contributions to the fit when expressed non-dimensionally as $\Delta p/p = a_i y_i$ where Δp is the measured difference between the trailing-cone pressure and the static-port pressure, p is the static-port pressure, and the contributing terms (y_i) and coefficients a_i are given in the following table.:

Term y_i	Coefficient a_i	Standard Error of Fit
(intercept, factor=1)	0.01015	0.00035
M = Mach Number	-0.0495	0.0020
M^2	0.0877	0.0034
M^3	-0.0441	0.0019
$\Delta p_\alpha/q_r$	0.02432	0.00032
$(\Delta p_\alpha/q_r)^4$	0.707	0.017
$(\Delta p_\alpha/q_r)M^4$	0.18200	0.00092

In this table, Δp_α is the pressure difference measured between radome ports that reflects the angle of attack and is normalized by the pressure q_r measured at the center port of the radome; this is the ratio normally used to determine the angle of attack. The standard error of this fit was about 0.0006, corresponding to a pressure error of about 0.3 hPa at 500 hPa ambient pressure. The correlation coefficient between the trailing-cone measurements and this fit was 0.98 for all the measurements on this flight. The results are shown in the Fig. 1.

There are some subtleties involved in this calculation: q and p are corrected first by use of the trailing-cone measurements and Mach No is calculated from the corrected values. In a practical application, this correction is not available except as a function of variables like M and q, initially known only in uncorrected form, so an iteration will be necessary. In addition, the revision in airspeed resulting from assuming that the change in measured dynamic pressure is the same, except for reversed sign, as the change in measured ambient pressure results in a mean increase in temperature of about 0.3°C (because of the change in calculated airspeed), compared to the processed file.

With the trailing-cone values for P_c, it is possible to determine temperature directly from the LAMS measurements with no reference to any temperature sensor on the aircraft. I did this for PREDICT ferry flight #1 (from Colorado to St.l Croix, 12 Aug 2010). That flight also had a good series of flight legs at various altitudes and airspeeds with LAMS operational and so provides a good dataset for LAMS analyses. The procedure to obtain temperatures for this flight were as follows:

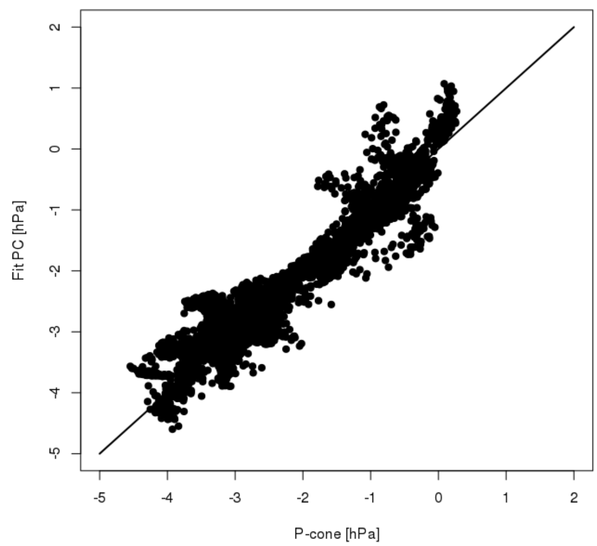

Figure 1: The fit result (P_c=$p\sum a_i y_i$) plotted against the corresponding pressure difference measured between the trailing-cone source and the static-pressure source on the GV.

1. Calculate Mach number M from the uncorrected measurements of pressure and total pressure (p and $p_t = p+q$ where PSF is used for p and QCF for q:

$$M = \left\{ \left(\frac{2c_v}{R_a} \right) \left[\left(\frac{p_t}{\mathrm{p}} \right)^{R_a/c_p} - 1 \right] \right\}^{1/2} . \tag{1}$$

   Use humidity-corrected values of the specific heats and gas constant because, especially at low levels, the effect is significant at the accuracy level of these calculations. The assumption made here (with good justification, which I have documented separately) is that $p_t$is measured accurately and does not need correction, to a level of 0.1 mb.

2. Use the above fit for P_c (which also depends on ADIFR and QCR) to find the correction factor to be applied to pressure, and calculate a new estimate of the correct pressure $p' = p + P_c$.

3. Iterate steps 1 and 2 using successive approximations to the corrected pressure p' to improve the estimate of the Mach number. (Five iterations give machine-precision convergence in the examples that I checked, so I used five iterations. This is much more precision than is needed for these results but at least obtains results consistent with the calibration derived from the trailing-cone data.

4. Once a final corrected value for pressure (p') is obtained, calculate the temperature from the following equation, derived by re-arranging the standard equation for obtaining TAS from p, q and T:

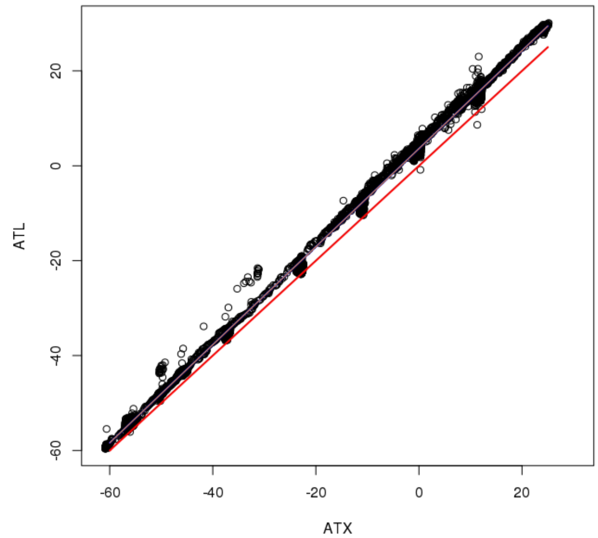

Figure 2: The temperature calculated using the LAMS-measured airspeed in (2), plotted as a function of the corresponding direct temperature measurement 'ATX', for PREDICT flight from Colorado to St. Croix on 12 August 2010. The best linear fit is ATL=3.61+1.033 ATX (orange line, hard to see over black dots). A 1:1 reference line (red) is also shown.

$$T_L = \frac{v_L^2}{2c_p\left[\left(\frac{p_t}{p}\right)^{Ra/cp} - 1\right]} \tag{2}$$

where v_L is the airspeed measured by LAMS.

If ATL=$T_L - 273.15$, the result is a temperature that can be compared to ATX. The following figure shows the result. The temperature obtained in this way is significantly different from that in the archived file for this flight. It is surprising that this result differs so much from the standard processing, and this is worth more investigation. I don't know what cals were used for this original processing, but it will be worth determining best values for this flight and reprocessing if they differ from those used originally.

It is worth mentioning that I have applied one correction to the file that I have for this flight. The pressure was apparently processed with an incorrect calibration, and I have re-calculated all values of PSF with cal coefficients of (0.,1.) instead as is appropriate for a digital sensor. I don't know why the processing used (-0.809, 1.0014) instead, but that appears to be an error in calibration that was inserted into processing. It is very unlikely that this sensor changed calibration by this much.

Here is an addition from Feb 20 2013:

Comments from Jorgen and Dick reminded me that the ATX value was the avionics value for this flight and that there were some problems with the temperature sensors. Nevertheless, I repeated the

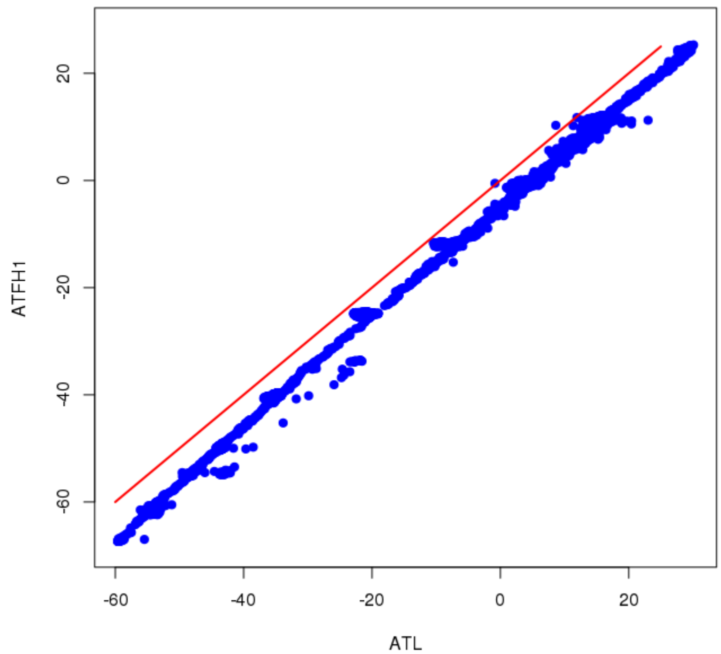

Figure 3: ATFH1 vs ATL

above for each of the four sensors available, finding that all looked quite bad in comparison to the deduced ATL. The only values that looked reasonable were the ATA values at low T (perhaps consistent with the analysis of MJ Mahoney and Julie that argued for the validity of that measurement in PREDICT). The plots for each sensor are below:

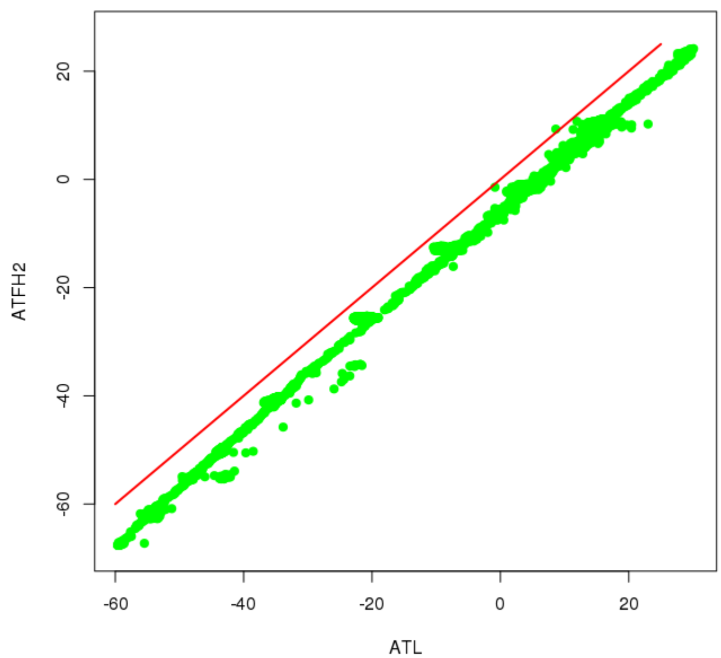

Figure 4: ATFH2 vs ATL

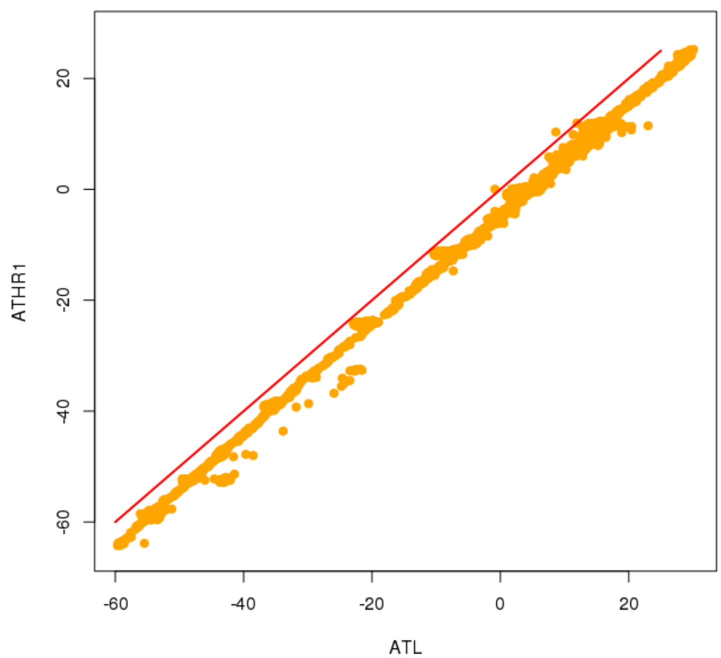

Figure 5: ATHR1 vs ATL

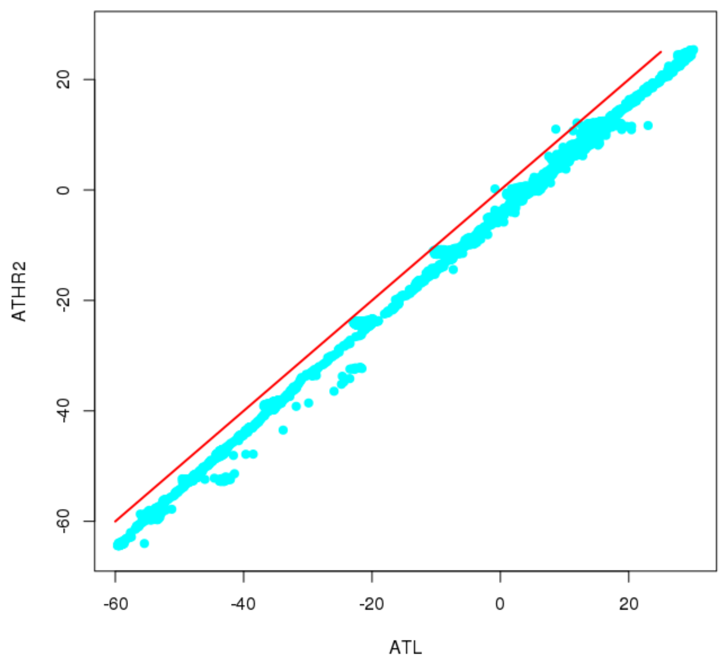

Figure 6: ATHR2 vs ATL