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Atmospheric Measurement Techniques
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Interactive comment on "Calibrating airborne measurements of airspeed, pressure and temperature using a Doppler laser air-motion sensor" *by* W. A. Cooper et al.

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General Comments:

A very interesting paper which addresses two important issues in the field of airborne atmospheric measurement techniques: the determination of the static source error and the determination of the accuracy of temperature measurements. Accurate temperature and pressure measurements are the most critical parameters in airborne atmospheric science since virtually every parameter measured on an aircraft is based on these two parameters. Therefore, this paper is extremely interesting for all operators of atmospheric research aircraft The instrumentation which has been developed is innovative and allows for a measurement of these units which is independent of the

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classical methods being commonly used. A great strength of the paper is the fact that it shows a lot of experimental results and actual measurements including many details which indicate where further investigations are needed. Many of the presented methods seem to be right on the edge of what one can do with the available data set. However, the great potential of the instrument becomes visible from this work.

Specific comments

1) The strategy behind the static source determination and its consequences should be discussed more precise in order to understand the observed results: The whole experiment is based on the assumption that the total pressure Pt around an aircraft is constant which is true as long as Pt is measured outside the boundary layer around the aircraft fuselage. This assumption which has been demonstrated in this paper for the available sensor locations on both aircraft is well accepted in flight testing (compare for example to NASA Technical Memorandum 104316, Airdata Measurement and Calibration, Edward A. Haering, Jr., 1995). As a consequence the sum of the LOCAL static (Ps) and dynamic (Qc) pressure at each location on the aircraft is constant and the static source error delta_p for the measured values of Ps and Qc has the same value but a different sign. The presented experiment uses for the GV two different locations to determine Pt (Pitot tube on the aircraft nose) and a Ps (from connected static ports on each side of the fuselage aft of the entrance door). The connection between the two Ps ports is supposed to compensate for a possible non-symmetric lateral pressure distribution around the aircraft as caused by yaw maneuvers. It is important to understand that the correction delta_p which is applied to Ps and QS always refers to the location where Ps has been measured. The corrected Qc as found in this paper is the true (mean) QC but with properties referring to the Ps port location: It represents a mean Qc between the two static pressure ports. In other words: When Ps is measured in a way which is insensitive to yaw maneuvers, the calculated Qc will also be insensitive to beta and this is exactly what equation (8) shows. However, this result does not prove that a qc measurement by the turbulence system on the aircraft nose is also insensitive

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to yaw maneuvers. The separated measurements of Pt and Ps have another possible effect: Changes in the airflow around the aircraft (as caused by wind, turbulence or just maneuvers) might lead to different signatures in the pressure signals, since the local flow typically reacts differently to these perturbations. Therefore, I would recommend to include a short discussion on these issues in the paper and to also describe the exact location of the sensors on both aircraft.

2) The static source error is usually expressed in terms of delta_p/Qc and plotted as a function of Machnumber. A great advantage of this parameterization is the possibility to compare the results to other experiments or theoretical predictions (as given for example in NASA Reference Publication 1046, Measurement of Aircraft Speed and Attitude, S083A). The correction terms given in equation (8) and (10) in their present form cannot be assessed by the reader. The shape and order of magnitude of a delta_p/Qc plot would help a lot to get a feeling for the quality of the results. The problem becomes obvious on page 2599, line 17. What is meant by ‘better’? When the available data does not cover the complete flight envelope and when there is no idea about a principal parameterization of the static source error it is not clear what a ‘better extrapolation’ means. The only way to treat the problem is to exclude flight data outside the investigated flight envelope from the correction. I would propose to present a plot of delta_p/Qc as a function of Machnumber and to treat the observed dependencies from airflow-angles as correction terms to this parameterization.

3) Page 2589, line 22, Page 2595 line 12, Page 2603, line 19, Page 2617, line 9: The information on attitude correction, coordinate systems and ‘airspeed’ is a bit confusing. During yaw maneuvers LAMS definitely doesn’t measure airspeed. It would help to briefly introduce the aerodynamic coordinate system in relation to the aircraft axes (how are these defined?), the definition of airspeed and to explain the adjustment of the beam-orientation (errors?) and the LAMS-IRS. It is also not clear how the data from the two IRS and flow angle measurements (what source? which errors?) are used in order to correct the offsets caused by the fixed laser beam orientation. A GV

will change alpha during a 10 h flight by more than 1 degree which makes up a 3cm/s offset at 200m/s airspeed.

4) Page 2595, line 16: ‘a correction is needed… if the airflow angle is not along the centerline of the pitot tube’. According to Appendix B (Page 2617, line 15) no correction is necessary for Pt.

5) Page 2596, equation (7) : It makes sense to use the LAMS data for the temperature calculation, but the largest error contribution in the temperature calculation is expected from the uncertainty in the recovery correction. Therefore, this error should be specified.

6) Page 2598, line 17 : When the measurements represent 1s averages it is difficult to discuss scatter from displaced air parcels. The aircraft is moving at 150-200 m/s and the LAMS measurement takes place 16m ahead of the aircraft. Has a respective time delay of 0.1s ever been observed in the data?

7) Page 2598, line 20 : ‘Because the fit…..’ I don’t understand the sentence and the reason for the error reduction.

8) Page 2603, line 6 and Fig.3: Again: A plot of D-value over Machnumber would help to analyze the data. The systematic offset in D-value for Machnumbers above 0.67 indicates that the parameterization of the pressure error is erroneous for this part of the flight envelope. The large deviations seem to be associated with aircraft acceleration and could be due to time delay problems, since the part between these accelerations looks much better. This causes a problem when LAMS data is taken during ‘speed variations’ (Page 2597, line 25!). The red line represents a pressure gradient along the flight track as described in section 5.2, right?

9) Page 2603, line 21: see 6) : It is hard to believe that measurements taken within 0.1 s differ so much from each other. Furthermore, at typical GV flight altitudes turbulence should be fairly weak. The arguments to use the nose data instead of LAMS are weak

(see also the discussion under 1))

10) Page 2605, line 4 and section 5.1: An accurate comparison based on 1Hz measurements seems to be difficult when temperature changes caused by the climb and high frequency atmospheric variability are superimposed. Does one expect systematic errors caused by averaging effects and atmospheric variance?

11) Page 2609, line 6 : Not all of the ‘data quality restrictions’ are obvious: While ‘ice accumulation’ and ‘flaps’ are clear the ‘climb restrictions (too fast, too slow)’ require further explanation.

12) Page 2609, line 28 : It is not clear where the recovery factor formula comes from.

13) Page 2610, line 11 : see 12) What is the criterion to categorize a measurement as ‘questionable or erroneous’?

14) Section 6: The claim that the temperature calculation using equation (23) is ‘without any reference to temperature sensors on the aircraft’ seems to be wrong. The equation uses the fitted pressure corrections (equation (8) and (10)), which are based on results calculated with equation (2). Equation (2) uses the in situ temperature, i.e. an offset in T would be ‘translated’ by equation (5) into an erroneous pressure correction value. If these corrections are used in equation (23) the error would be transferred back into a temperature offset.

15) Page 2611, line 21 : According to 6) ‘high rate’ is something in the order of 0.1s. But the plot in Fig 5 is based on 1Hz data. Since open wire thermometers as used for ‘standard measurements’ on aircraft have a temporal resolution definitively better than that, the line width from the standard thermometer can be seen as the real atmospheric variance at 1Hz. Therefore, there must be a different explanation for the large variability of the LAMS based measurement. A spectral analysis would help to see whether this ‘noise’ is white or shows a specific spectrum.

16) Figure 6 The upper plot should show the difference between both temperature

measurements in order to allow for some analysis of the measurement and to check for possible correlations. Most interesting is the fact that LAMS seems to have systematic positive and negative offsets to the conventional temperature for certain time periods. Is there any obvious correlation of this offset to any flight parameter?

17) Figure B1: 'The total pressure (from the sum of the ambient...)' : Is Pt calculated from a Ps and a OC on the C-130 or directly measured using a Pitot tube? Compare to 1): Show the sensors and their location on both aircraft.

Corrections

1) Page 2606, line 10: Tp=-S2/S1 instead of Tp=-S1/S2

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