THE MISSING LINK: HOW TO OPTIMIZE PRESSURE CALIBRATION USING THE TOWER FLYBY METHOD

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Abstract: The validation of a trailing cone system on a research aircraft using established flight test procedures gave errors which seemed not acceptable for the following calibration experiment. Using new technologies and a detailed analysis of the error sources led to improved procedures and measurement strategies. This new approach was tested on different aircrafts and demonstrated a significant reduction of the residual errors. This paper presents the results of a pitot-static calibration for a meteorological research sensor package mounted on the wing of a Cessna 208B Grand Caravan. The overall error of the static source calibration was shown to be less than 0.25 hPa for the whole aircraft envelope.

INTRODUCTION

In 2011 the German Aerospace Center (DLR) meteorological research aircraft Falcon 20 "D-CMET" (Falcon) [1] was used as a reference to calibrate the static source error of a German Air Force F4. Therefore, it was necessary to install and validate a trailing cone (TC) system on the aircraft similar to the equipment used several years before for calibrating a pressure system connected to the nose boom mounted 5-hole probe (5HP) on the Falcon [2]. The first task in this experiment was the validation of the trailing cone installation in order to prove the accuracy of the reference method itself. A common method for this is the tower flyby, linking the trailing cone pressure to a reference measurement on the ground. This requires accurate measurements of the ground reference pressure and the height of the TC sensor above ground sensors.

The strong geometric height dependency of air pressure becomes obvious looking at the hydrostatic equation

$$dp = -\rho \cdot \mathrm{g} \cdot \mathrm{dh} \qquad \text{(Eq. 1)}$$

where the pressure change (dp) is depending on the height change (dh), air density (ρ) and the gravitational constant (g). The air density is substituted using the ideal gas law

$$\rho = \frac{\mathrm{p}}{R \cdot \mathrm{T_v}} \qquad \text{(Eq. 2)}$$

with the gas constant (R) and the virtual temperature ($\mathrm{T_v}$). $\mathrm{T_v}$ is used in order to account for the impact of humidity on air density instead of the temperature. Integration leads to the well-known barometric height formula

$$p = p_0 \cdot e^{-\frac{g \cdot \Delta h}{R \cdot \overline{T}_v}} \qquad \text{(Eq. 3)}$$

that allows for calculating the pressure difference for a known vertical separation (Δh) [3]. It is important to note, that now the mean virtual Temperature ($\overline{\mathrm{T}}_\mathrm{v}$) is used and that the resulting pressure change is dependent on the absolute value of the reference pressure (p_0). At sea surface 1 hPa corresponds to approximately 8 m vertical distance while in flight level 300 (FL) this value increases to about 25 m.

To measure the exact height of the Falcon during the tower flybys a differential Global Positioning System (DGPS) was installed on the aircraft [4]. Details to the installation and the verification of the trailing cone quality are given in [4] describing the results of 9 tower flyby points conducted during one flight at the Special Airport Oberpfaffenhofen (EDMO). The author determines a static pressure accuracy for the trailing cone system in the order of 1 hPa (corresponding to the 95% confidence interval (CI)) which is similar to the defined accuracy of the Falcon NB pitot-static system [5]. The significant uncertainty in the TC measurement was somehow unexpected and is the result of conservative error calculation accounting for every error source in the calculation chain. For example the uncertainty in the cabin temperature caused a significant error due to the temperature dependency of the TC pressure sensor (95% CI $\sim 0.73\ hPa$). This emphasizes the importance of critical error evaluation and improvement of every component in such a test program.

All necessary steps to realize a successful tower flyby campaign are specified in the next chapter including three important improvements compared to the classic tower flyby method. We propose a best practice resulting in significantly better accuracies than the existing Falcon calibration. This procedure was successfully applied on different DLR research aircraft in the last years. The results of this calibration for the DLR Gulfstream 550 "D-ADLR" (HALO) are described in [7]. In chapter 3 we present the results of the pitot-static calibration of a new experimental sensor package on the DLR Cessna 208B Grand Caravan “D-FDLR” (Caravan) using a 5HP mounted on an underwing container. The last chapter provides the conclusions.

1 THE TOWER FLYBY CALIBRATION

Measuring static and dynamic pressure with an aircraft is not trivial due to an unavoidable flow distortion around the aircraft that leads to a static source error at the particular pressure ports. This effect can be minimized by placing the pressure ports at the right position. Since it is not possible to find a completely undisturbed region near the aircraft there is always a residual static source error (Δp_s) which is characteristic for any specific aircraft and pressure port location. It is defined as

$$\Delta p_s = p_{si} - \mathrm{p_{ref}} \qquad \text{(Eq. 4)}$$

, the difference between the indicated (measured) value (p_{si}) and the ‘real’ reference pressure of the undisturbed atmosphere ($\mathrm{p_{ref}}$) . The measurement of the static source error is necessary in order to parameterize the effect and correct the measured pressure for an exact pressure determination. One option to calculate the static source error is the tower flyby method [2], which can be applied for any air data reference system including scientific systems like the trailing cone or a boom mounted pitot-static probe.

1.1 Tower flyby method

The principle of the pitot-static calibration using the tower flyby method is rather simple. An aircraft flies at 100 ft to 300 ft height in stable flight conditions above the runway and measures the indicated pressure. The aircraft must fly with constant speed and height for several (10-20) seconds to get representative data for an averaging interval. Steady flight conditions and minimum turbulence are crucial for a successful test point. Therefore, it is recommended to plan a respective flight in the early morning on days with low wind conditions preferably in winter. The flight pattern is repeated with different speeds and aircraft configurations to calibrate the system for the entire envelope of the aircraft possible at this level.

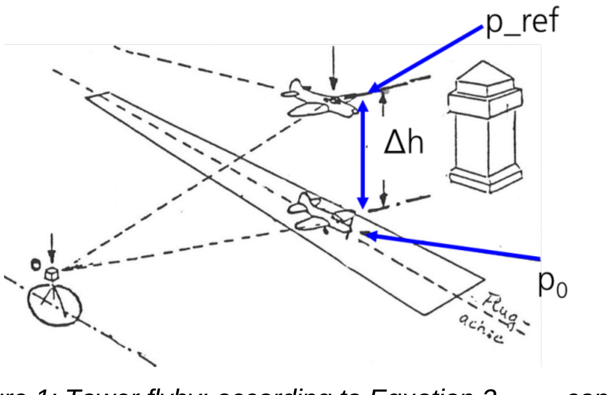

Figure 1: Tower flyby: according to Equation 3, p_{ref} can be calculated from the surface pressure p_0 and the vertical separation Δh

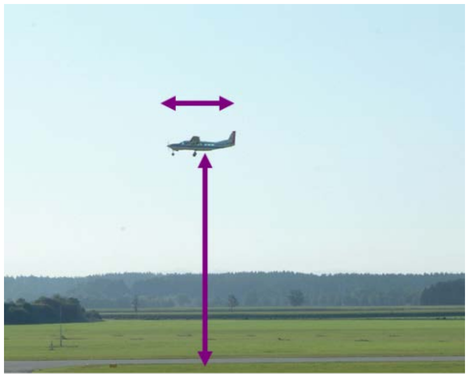

Figure 2: Height estimation using the photo method. The ratio of the aircraft length and height above runway is the same in the photo and in real.

The pressure reading of the aircraft is compared to a reference pressure (p_{ref}) of the undisturbed air, which can easily be calculated from a reference ground pressure (p_0) and the vertical separation (Δh) as sketched in Figure 1 using Equation 3. The mean virtual temperature is usually not differing significantly from the measured values at the height of the aircraft when Δh is small. An estimation of the error introduced with this assumption can be made during takeoff and landing, where the vertical profiles of temperature and humidity are measured. The acceleration of gravity can be calculated from the position information.

1.2 Best practice: relative pressure measurement and DGPS

A much better way to measure p_0 is using the aircraft sensor instead of an independent reference sensor on the ground. Therefore, before and after the test flight a "ground block" is performed where the aircraft is placed on the runway measuring the ground pressure. The blue dotted line in Figure 3 shows the linear trend for p_0 calculated for 14 tower flyby points during one flight with the Caravan in 2011. To account for ground pressure variations between different tower flyby points, another sensor near the runway (red line) is providing the needed information. It is important to note that the absolute accuracy of this sensor is of no importance because it just monitors pressure variations. The black line and the crosses in Figure 3 show the corrected signal adding the pressure fluctuations of this ground sensor to the original data of the ground blocks giving the final values of p_0. For good results the pressure should not change significantly during the measurement period. Even if the accuracy of the ground sensor is better than the sensor of the aircraft, p_0 should be taken from the aircraft sensor to interlink these two measurements. As a result both values on the right hand side of Equation 4 are measured with the same sensor and the static source error determination becomes a relative measurement. With this approach possible calibration errors and slow drifts of the sensor will be eliminated and the result becomes independent of many errors which contribute to a classical tower flyby experiment.

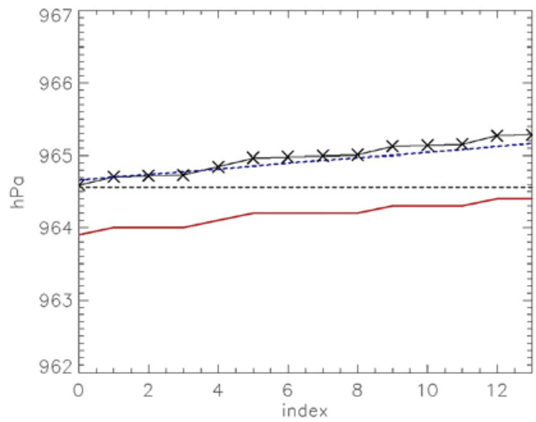

Figure 3: Corrected values of p_0 (black line and crosses) for tower fly by points estimated from the linear trend of ground block pressure values (blue dots) corrected with pressure fluctuations from reference sensor (red line). Grey dots: Pressure value from 1st ground block.

Typically optical methods have been used to determine the height difference (Δh). An example is shown in Figure 2 where the height is estimated by measuring the length of the aircraft and its height above the runway directly in the picture. Knowing the true length of the aircraft, the aircrafts height above the runway can be calculated from this data. According to [2] this traditional height estimation is the major source of uncertainty in the calculation of Δp_s. Using DGPS data for the tower flyby reduces both the effort and the measurement error in an effective way. The reference height of the ground measurement is again taken during the two "ground blocks" and Δh is determined as a relative height measurement of the DGPS. The height accuracy of a modern DGPS system is better than 10 cm and allows for an almost perfect pressure correction ($0.1\ hPa\ \cong 0.8\ m$).

Using a reference pressure system positioned on a nearby tower is inferior to this relative measurement method for several reasons. In this case the errors of the two pressure sensors and the different height determinations (height of tower, height of aircraft and height of a common reference point) will contribute to the overall error, while for the relative method the error of just two sensors (one pressure device and the DGPS) are involved. A possible offset of these sensors due to a calibration error or long-term drift effects will even cancel out when the difference of two measurement points is calculated. Determining the reference points on the runway avoids negative influence on the measurement due to big distances or nearby buildings.

1.3 Data evaluation

A thorough examination of the data of the test points is the key to a maximum of accuracy. Figure 4 shows an example of a successful tower flyby point realized with the DLR Caravan in 2011. The black line in the upper panel is the height measurement of the DGPS and the blue line the calibrated airspeed reading of the avionic system. For each test point an optimum

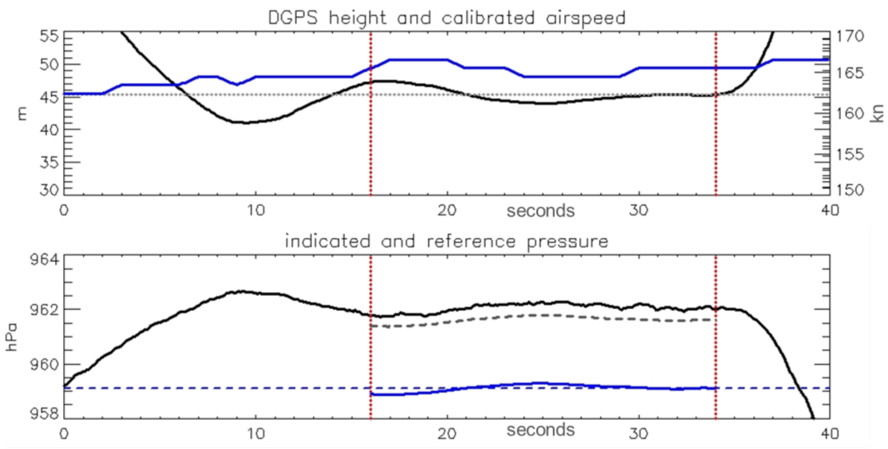

Figure 4: Time series of a successful tower flyby test point with the DLR Caravan. The red dotted lines mark the start and the end of the 18 seconds period chosen for data evaluation. The upper plot shows the DGPS height (black line) above ground and calibrated airspeed (blue line), grey dots are the mean height during this period. Lower panel: the black line shows p_{si}, the blue line the calculated p_{ref}, blue dots represent a mean $\overline{p_{ref}}$ and the grey dots are the shifted p_{ref} data for comparison purposes.

averaging interval has to be selected where the change in height and calibrated airspeed are small. In Figure 4 the red lines indicate the chosen interval. Also the time series of pitch, roll or the vertical acceleration are adding useful information to this decision as they are indicators for steady flight conditions. The grey dotted line in the upper panel of Figure 4 represents the mean of the DGPS height during the selected period. Thus the height variation is less than 2 m for the chosen example which corresponds to a pressure change of 0.25 hPa. Applying Equation 3 using the measured values of Δh for the test interval and the calculated ground pressure value p_0, the reference pressure (p_{ref}) can be estimated and compared to the indicated pressure value (p_{si}) on the aircraft. These timeseries are displayed in the lower panel of Figure 4 with the black line representing p_{si} and the blue line p_{ref}. Following Equation 4 the static source error (Δp_s) for this test point is about 3 hPa. It is important to note that p_{ref} is calculated for all recorded points in the selected period according to the temporal variation of Δh. This is necessary because the relation in Equation 3 is nonlinear; therefore averaging the input parameters on the right hand side of the equation before calculating a mean reference pressure ($\overline{p_{ref}}$) would introduce an error. The correct $\overline{p_{ref}}$ (blue dotted line in Figure 4) is then determined from the calculated timeseries of p_{ref}. As mentioned above the fluctuations of the indicated pressure are mainly due to the small height variations during the chosen interval. This becomes clear shifting the line of p_{ref} (grey dotted line in Figure 4) up to the values of p_{si}. With the accurate height measurement of the DGPS and the demonstrated evaluation method the uncertainties due to small height variations during the test point time interval can be minimized.

Measuring the attitude rates of the aircraft during the tower flyby allows for correcting another source of uncertainty. Usually the pressure sensor in the aircraft is separated from the DGPS. Due to the lever arm and the aircraft attitude variations the relative height between DGPS reference location (antenna) and pressure sensor will change. For the Caravan the respective corrections are in the order of 0.2 m resulting from a horizontal distance of the sensors of about 4 m and an observed smooth roll oscillation. With an increasing horizontal distance this effect becomes gradually more important. For all of these calculations an exact time synchronization of the involved measures is crucial.
After completing the static source error calculation for all successful tower flybys a parameterization must be found to correct the indicated static pressure. It is recommended to parameterize $\Delta p_s / q_{ci}$ as a function of the Mach number using the indicated dynamic pressure (q_{ci}) as scaling parameter [6]. Usually the tower flyby maneuver is just the first part in validating a pressure reference system, because only the low Mach number range can be covered near the ground. For this it is necessary to expand the calibration to higher levels flying racetrack patterns with increasing speeds and height [7]. For slow flying propeller aircraft, like the Cessna Caravan, it is possible to test the entire speed envelope during the low flight patterns of the tower flyby. In this case an expansion of the test program to higher flight levels is only performed to check on possible height dependences of the pitot-static calibration.

2 EXAMPLE OF A PITOT-STATIC CALIBRATION

The Flight Facility Oberpfaffenhofen of the German Aerospace Center (DLR) is operating several aircraft for atmospheric research. As the static and the dynamic pressure are used in the calculation of almost every meteorological parameter it becomes obvious that the accuracy of these units plays a critical role. Calculating the static source error allows for correcting both of these quantities measured with a 5HP. It is assumed that

$$p_s = p_{si} - \Delta p_s \ \ and \ \ q_c = q_{ci} + \Delta p_s \qquad \text{(Eq. 5)}$$

i.e. that the total pressure ($p_s + q_c$) is conserved. In the beginning of 2011 four tower flyby test flights were performed with the DLR Cessna 208B Grand Caravan to realize the calibration of the pitot-static system mounted on an under wing container.

2.1 The Aircraft: DLR Cessna 208B Grand Caravan “D-FDLR” (Caravan)

The Cessna 208B Grand Caravan is operated by DLR since 1998. The aircraft was significantly modified in order to meet the requirements of an atmospheric research aircraft. This includes an independent experimental power system, several openings in the fuselage and hard points on the wing. An under wing container, carrying a meteorological sensor package (METPOD), was constructed and certified. Figure 5 shows the aircraft with the METPOD mounted under the left wing dominated by the 2m long boom equipped with a 5-hole probe (Rosemount Model 858AJ [8]) at the tip which is used to determine the 3-dimensional wind vector along the flight path. The pressure signals are measured with temperature stabilized pressure transducers (DRUCK 4000 series). The sensor package includes temperature, humidity and accelera-

Figure 5: DLR Cessna 208B Grand Caravan with the MET-POD mounted underneath the left wing.

tion measurements. In the cabin a combined system of DGPS and experimental inertial reference system (IRS) provides high accuracy position and attitude data. Real time DGPS accuracy can be achieved receiving satellite based correction signals allowing for accuracies of up to 0.05 m and 0.01° for position and attitude data respectively [7]. A custom built data acquisition system "**M**easurement **A**cquisition for **M**eteorological **B**asics" (blackMAMBA) allows for data recording, time management and provides the real time visualization.

Table 1: Summary of the 4 tower flyby test flights (Times in UTC)

	date	takeoff	landing	points clean	points flaps 10	comment
TFB #1	15.03.2011	07:35	08:45	7	6	
TFB #2	21.03.2011	07:13	08:00	7	2	flight aborted due to turbulence
TFB #3	22.03.2011	06:24	07:34	7	7	
TFB #4	23.03.2011	06:25	07:35	6	6	heavy aircraft (~ +500 kg)

2.2 The Test Program

Table 1 summarizes the dates, times and test points conducted during the 4 tower flyby flights in March 2011 at the special airport EDMO. All flights were performed in the early mornings during a stable weather period to get calm atmospheric conditions, only for the second flight the turbulence started earlier as expected. Therefore the test program was aborted and repeated the next day starting one hour earlier. The fourth flight was conducted with the maximum takeoff weight of almost 4 tons while for the other flights the weight was reduced by about 500 kg corresponding to half the fuel capacity.
Overall, 48 tower flyby points were successfully performed, 27 of them with aircraft clean

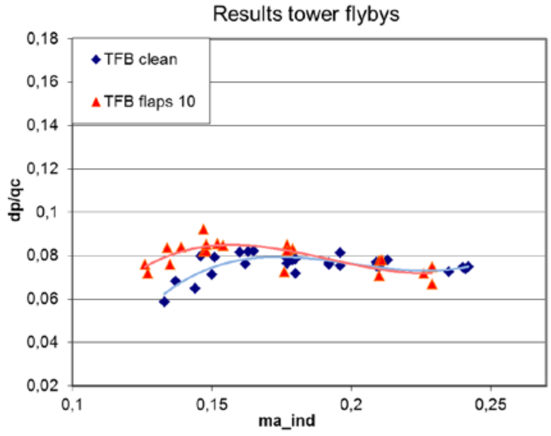

Figure 6 Results of 4 TFB flights for the Caravan pitot-static calibration. The points show $\Delta p_s/q_{ci}$ over Ma for clean and flaps 10 configurations. The lines represent 3rd order polynomial fits for these two configurations.

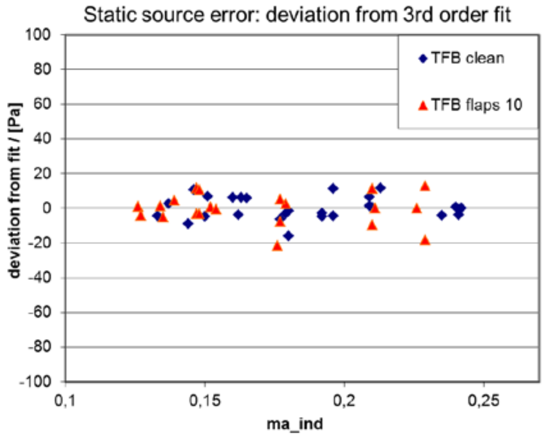

Figure 7: Deviation of the static source error of the 3rd order polynomial fits. Due to the differential measurement principle the relevant instrument error is very small.

configuration and 21 points with flaps 10 configuration. These two configurations were tested, because they represent the usual configuration during research flights. Due to the mounting point of the 5HP near the wing a significant influence of the configuration was expected. Following the procedure described in the previous chapter a ground block was performed on the runway before and after the flight. The reference pressure sensor (RUSKA 7750i), monitoring the ground pressure trend, was measuring in the nearby hangar. The instrument is periodically calibrated by an authorized calibration laboratory which is accredited by the Deutscher Kalibrierdienst (DKD) and thus traceable to national standards with an accuracy of 0.05 hPa [4]. It is the same instrument that is also used as the reference to calibrate the pressure transducers in the METPOD. During the flights the onboard real time visualization allowed for monitoring the real time DGPS height, calibrated airspeed, vertical acceleration and roll angle for the test points to support the subjective test point's evaluation of the pilots and flight test engineer. An extensive quality check including automatic and manual tests was performed for every single test point to choose the optimal test interval for each tower flyby and reject insufficient steady test points (e.g. height change > 10 m, CAS change > 4 kn). The calculated static source errors for the above listed 48 tower flyby points scaled with the indicated dynamic pressure over the Mach number are depicted in Figure 6. The different results for the two configurations are obvious in the lower Mach number range, thus a separated polynomial fit for the configurations is performed. The deviations of the static source errors of the 3rd order polynomial fits are shown in Figure 7 resulting in a standard deviation of $\sigma < 0.1\ hPa$. This result is significantly better than the earlier TC validation on the Falcon with $\sigma \sim 0.4\ hPa$ [2] where the major source of uncertainty was found to be the height estimation.

2.3 Evaluation, Results and Accuracy

Following the results of [6] a height dependency of the static source error, especially for wing mounted systems in the lower Mach range, cannot be excluded. To account for this possibility three more flights as listed in Table 2 were performed flying a racetrack pattern (RTR) similar

Table 2: Summary of the 3 racetrack flights (Times in UTC).

	date	takeoff	landing	points clean	points flaps 10	comment
RTR #1	21.03.2011	6:54	8:53	11	8	FL 100
RTR #2	22.08.2011	7:17	9:32	7	9	FL 100
RTR #3	31.08.2011	5:06	7:08	5	8	FL 140

to the method described in [7]. During this maneuver test points at different CAS are performed with steady flight conditions. The indicated static pressure is compared to a height and attitude corrected reference pressure. These corrections are equivalent to those discussed with the tower flyby. For the TC validation in [7] the test program is expanded to higher levels and higher Mach number ranges measuring the reference pressure at an already validated Mach number. Thus the reference pressure in the higher level is estimated flying the racetrack pattern at a low Mach number and the test points performed with higher speeds are compared to this reference pressure. For the Caravan the whole speed range was covered with the tower flyby and with this an intermediate CAS of 120kn and clean configuration were chosen for the "reference run". According to [6] the lower speed range could be more sensitive to any height dependencies. During the three flights 48 test points were performed, 23 of them with clean configuration and 25 with flaps 10 configuration. For calm conditions the flight legs were flown in the morning above the residual boundary layer of the day before. To avoid horizontal pressure gradients the patterns were aligned along the wind direction. In order to minimize effects of vertical wind and gradients in temperature regions of high static stability were omitted. The results are shown in Figure 8 combining the tower flyby and racetrack test points plotting $\Delta p_s/q_{ci}$ over Ma. For the clean configuration systematic deviations at lower Mach

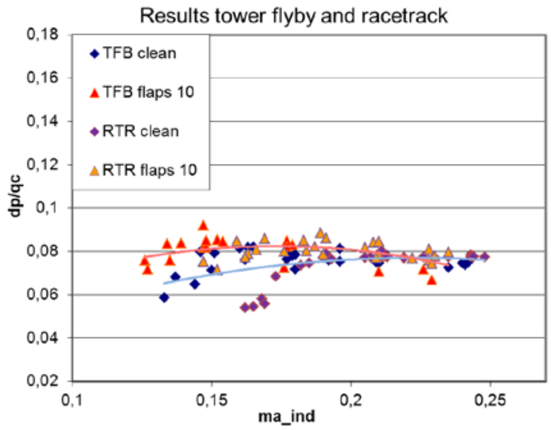

Figure 8 Same as Figure 6 including the 48 RTR test points

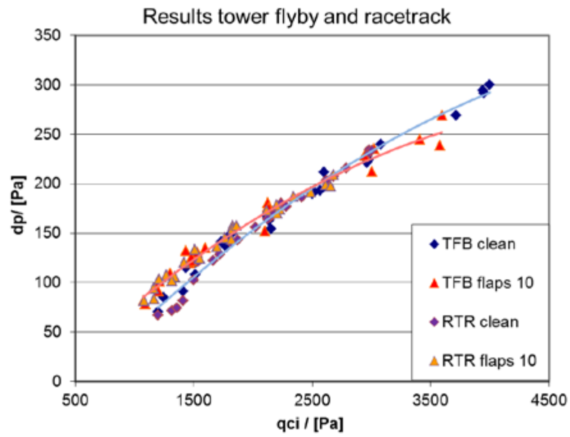

Figure 9: Same as Figure 8 for Δp_s over q_{ci}. The height dependency in the signal due to Mach number vanishes.

numbers can be found for the RTR data at FL 100 (violet diamonds) compared to the TFB results (blue diamonds). The data taken at the highest level (FL 140) are lying all above Ma 0.2 and don't show any significant deviations. This effect seems to be less dominant with flaps 10 configuration. The results indicate that in this case the Mach number is not a good choice for the parameterization.
Plotting the absolute static source error directly over the dynamic pressure reveals significantly better results (see Figure 9). The height dependency vanishes completely and all data points line up on two curves for clean and flaps 10 configurations respectively. A possible explanation for the success of this scaling is given in [6]. The authors find the lift coefficient (C_l) applicable to account for the height dependency of the static source error in the low Mach range. For an aircraft with a constant weight flying horizontally in steady state conditions this coefficient is inverse proportional to the dynamic pressure.

In Figure 10 the deviations for all TFB and RTR points from a 3rd order polynomial fit are shown. With this choice for the parameterization the height dependence of the static source error is completely removed. The cross validation for the results of Δp_s , excluding 6 randomly chosen cases of the clean and the flaps 10 configuration respectively, converges to a standard deviation of $\sigma = 0.095\ hPa$.
The variation of the test points is the sum of the implied uncertainties in the method such as sensor errors, atmospheric fluctuations and the accepted unsteadiness in the test points. The errors introduced to the measurement by g and T_v are of minor impact [4] while the errors in pressure and height measurements are minimized by the differential method described above. The absolute accuracy of the NB pressure sensor is limited by the accuracies of the static source error and the sensor error itself. The error of the pressure sensor caused by offsets, non-linearity, hysteresis and repeatability are determined by calibra-

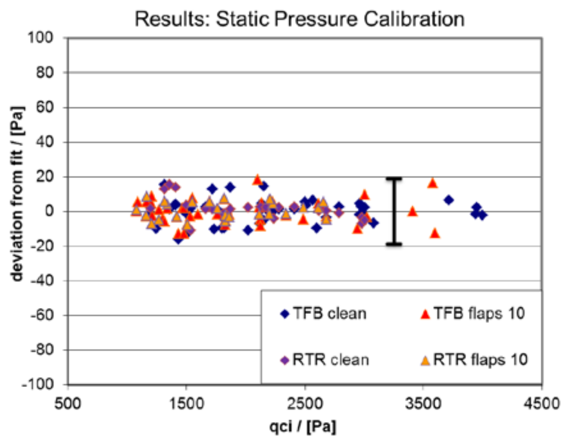

Figure 10: Results of pitot-static calibration: deviation of the static source error of the 3rd order polynomial fit for all TFB and RTR points. The black error bar represents the estimated accuracy of the pressure sensor (σ<0.2 hPa)

tions with the above mentioned reference sensor (RUSKA 7750i). These calibrations are performed in preparation of each measurement campaign. The sensor is contained in a temperature stabilized housing which reduces the temperature variation to less than 2 °K and thus minimizes the related sensor error. Including a long term drift of the sensor of 0.1 hPa per month the error of the sensor adds up to $\sigma < 0.2\ hPa$. The calibration covers the whole measurement chain since it is performed at the aircraft. However, an additional source of uncertainty is introduced by the temperature sensitivity of the 16 bit analogue/digital device installed in the METPOD. A heating system within the METPOD reduces this effect during flight and the pod internal temperature is monitored by 5 housekeeping sensors. Therefore, the temperature variation is less than 10 °K during an average flight which contributes to the static pressure error with $\sigma < 0.1\ hPa$. Combining the discussed error sources the overall accuracy of the static pressure measurement on the Caravan is limited to

$$\sigma < 0.25\ \mathrm{hPa} \qquad \text{(Eq. 6)}$$

. The same estimation is true for the accuracy of the dynamic pressure, which is measured directly at the 5HP as the difference of total and static indicated pressures and corrected according to Equation 5. Due to the smaller full scale range of $q_{ci}$the sensor error is even smaller compared to p_{si}. It is important to note that the height dependence of this static source error has been validated to a maximum height of FL140 only. However, the concerned low speeds cannot be reached above these heights.

3 CONCLUSION

The tower flyby method is a common way to measure the static source error of an air data reference system such as a trailing cone or a 5HP on a nose boom. We suggested a best practice method for the tower flyby introducing three major improvements compared to the classic approach.

1) The height determination can significantly be improved at less effort by using a DGPS and aircraft attitude data.

2) Using the same sensor for the reference ground pressure and the indicated static pressure on the aircraft interlinks these measurements and thus the major errors of the involved sensors are canceled out.

3) The correction of pressure errors caused by aircraft height variations during the selected test point time interval eliminates averaging errors.

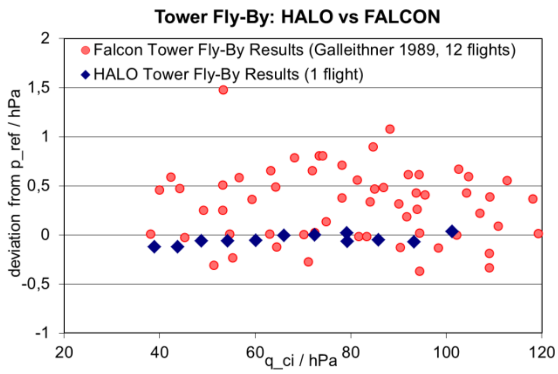

Figure 11: Results of trailing cone validation with HALO [7] (blue diamonds) compared to the results from the Falcon [2] (red circles). The latter is performed with the classic method while the HALO TC validation is following the method described in chapter 2.

In this paper the results of the pitot-static calibration for the DLR Cessna 208B Grand Caravan were discussed. The accuracy for the static source error is better than $\sigma < 0.1\ hPa$ leading to an overall accuracy for the NB pitot-static system of $\sigma < 0.25\ hPa$. The presented parameterization of the absolute static source error with the dynamic pressure accounts for the observed systematic height dependencies in the lower Mach range. The same method was also applied to validate a trailing cone system on the DLR research aircraft HALO [7]. In Figure 11 the results of this tower flyby flight are compared to the outcome of the Falcon TC validation described in [2]. The variation of the HALO is significantly smaller compared to the Falcon data and it is obvious that the new method is superior to the classic approach.

4 ABBREVIATIONS

4.1 Parameters

g	(m/s²)	Acceleration of Gravity
h	(m)	WGS 84 Elliptical Height
Δh	(m)	Height Difference
Ma	(-)	Mach Number
q_{ci}	(hPa)	indicated Dynamic Pressure
p_s	(hPa)	Static Pressure
p_{ref}	(hPa)	Reference Pressure
p_{si}	(hPa)	Indicated Static Pressure
R	(J/(kg·K))	Gas Constant of dry Air
ρ	(kg/m³)	Density of Air
σ	(-)	Standard Deviation
Ts	(K)	Static Temperature
Tv	(K)	Virtual Temperature

4.2 Abbreviations

blackMAMBA	Measurement Acquisition for Meteorological Basics
Caravan	DLR Cessna 208B Grand Caravan "D-FDLR"
CAS	Calibrated Air Speed
CI	Confidence Interval
DGPS	Differential Global Positioning System
DLR	German Aerospace Center
EDMO	Special Airport Oberpfaffenhofen (Germany)
Falcon	DLR Dassault Falcon20 "D-CMET"
5HP	Five hole probe: Rosemount Model 858AJ
FL	Flight Level
HALO	DLR Gulfstream 550 "D-ADLR"
METPOD	Meteorological Sensor Package in an underwing Container
NB	Nose Boom carrying pitot-static Probe
RTR	Racetrack Flight
TC	Trailing Cone
TFB	Tower Flyby Flight
UTC	Coordinated Universal Time

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