INTERCOMPARISON OF STANDARD CALIBRATION INSTRUMENTS, METHODS AND MEASUREMENTS FOR PRESSURE AND HUMIDITY BETWEEN THE LABORATORIES OF METROLOGY AT THE DEUTSCHER WETTERDIENST AND METEO-FRANCE

Françoise Montariol (i), Eliane Jeanney (i), Holger Dörschel (ii), Richard Seidl (iii)
(i) Météo-France, DSO/LM, 42 avenue Coriolis, 31057 Toulouse, France
(ii) Deuscher Wetterdienst, Referat TI33C3, Frahmredder 95, 22393 Hamburg, Germany
(iii) Deuscher Wetterdienst, Referat TI35C3, August-Schmauß-Straße 1,
85764 Oberschleißheim, Germany
francoise.montariol@meteo.fr, eliane.jeanney@meteo.fr,
holger.doerschel@dwd.de, richard.seidl@dwd.de

1 ABSTRACT

An interlaboratory comparison of standard calibration instruments and methods for humidity and pressure is organised in 2014 between the laboratories of metrology of Meteo-France in Toulouse and the Deutscher Wetterdienst in Hamburg and Munich.
The two German laboratories are equipped and work identically, whereas the French laboratory has very different equipments and methods. All 3 laboratories abides by the ISO 17025:2005 standard and have an unbroken chain of traceability of their standards.
First results are very positive. They show and prove a good agreement between the measurements from the 3 laboratories for both humidity and pressure calibration.

2 ARTICLE

1. General presentation

Both the Deutscher Wetterdienst (DWD) and Meteo-France operate their own laboratories of metrology and calibrate the sensors from the meteorological observation networks.
Meteo-France is Regional Instrument Centre for WMO AR-VI. The Deutscher Wetterdienst is a member of AR-VI too.
As recommended both by the WMO for Regional Instrument Centres and by the ISO 17025 standard for laboratories of metrology, Meteo-France and the DWD have decided to organise interlaboratory comparisons of standard calibration instruments and methods, starting with humidity and pressure in 2014.
The aim of this interlaboratory comparison is to compare the results of the calibration of a test sample of humidity and pressure sensors, carried out by the 3 laboratories.

2. The laboratories

Meteo-France has a laboratory of metrology set in Toulouse and the Deutscher Wetterdienst has two laboratories of metrology installed in Hamburg and Munich.
For pressure and humidity calibration, the two German laboratories are equipped and work identically, whereas the French laboratory has very different equipments and methods.
The traceability chain is unbroken for all 3 laboratories.
The laboratories calibrate the sensors from the meteorological observation networks.
The laboratories can calibrate different sensors measuring different meteorological parameters. The information in this article is limited to humidity and pressure calibration only, as being the two parameters chosen for this interlaboraty comparison.

2.1. **Toulouse laboratory**

Meteo-France laboratory of metrology was recently moved from Trappes near Paris and built back in Toulouse.
The laboratory abides by the ISO 17025:2005 standard.
As a standard, Meteo-France operates all tests and calibration at room temperature 23°C+/- 3°C.

2.1.1. **Humidity calibration in Toulouse**

Meteo-France uses humidity standards HMT333 from Vaisala calibrated yearly at the CETIAT laboratory.
Toulouse laboratory maintains the different humidity environments with relevant saturated salts solutions. The solutions are constantly stirred and stabilised for temperature in Vaisala HMK13B humidity calibrator. Sensors are compared with the standard for calibration.
Measurements can be carried out at 11%, 33%, 54%, 76% and 98% humidity at the laboratory, for up to 14 sensors and standards at the same time.

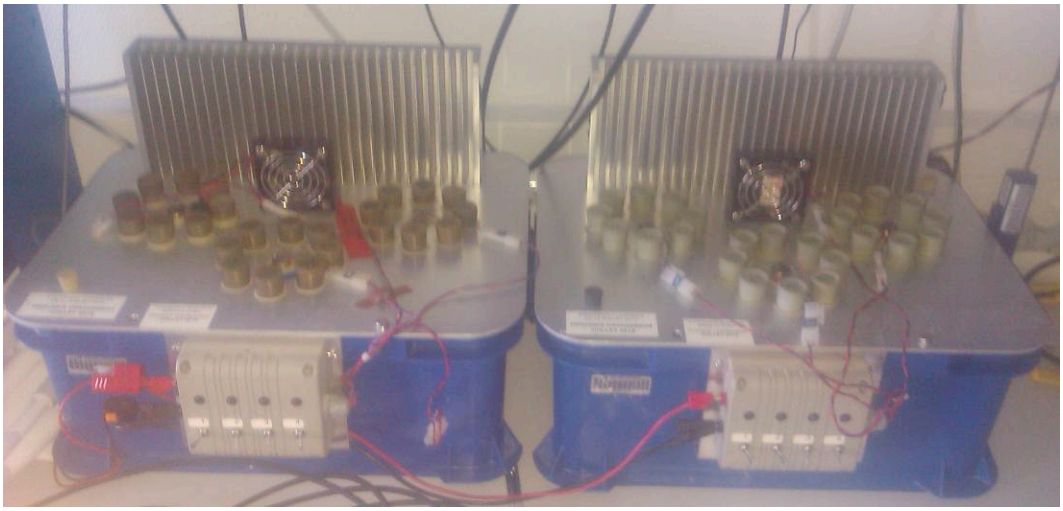


Photo 1: humidity bench at Toulouse laboratory

2.1.2. **Pressure calibration in Toulouse**

The pressure standard is a DHI RPM3 calibrated yearly at the LNE (French National Institute of Metrology).
This primary standard is used to calibrate, at Toulouse laboratory, the secondary standards: currently Ruska 7230 and quartz FPG Instrumentation MPA1000C.
Meteo-France uses a pressure generator PPC1 from Desgranges & Huot to generate the chosen levels of air pressure.
The bench allows to calibrate up to 3 sensors in the same calibration process.
It is possible to calibrate pressure gauges with up to three pressure transducers.
For network sensors, pressure is checked at 11 levels between 1060 and 800hPa. Repeatability is also checked separately.

Photo 2: pressure bench at Toulouse laboratory

2.2. Hamburg and Munich laboratories

The DWD laboratories have got the ISO 17025:2005 accreditation for pressure and humidity. Normally, pressure and humidity calibrations are carried out at temperatures of 23°C +/-5 C.

2.2.1. Humidity calibration in Hamburg and Munich

The humidity standards are two Thunder Scientific 2500 ST humidity generators with dew point mirrors.
The calibration interval used to be five years. This interval will move to two years. The calibration is carried out by MBW from Switzerland.
Up to eight sensors can be calibrated at the same time.
Alternatively, only one humidly sensor can be calibrated with a special manifold.
Measurements are carried out at 20%, 40%, 60%, 80% and 95% humidity.

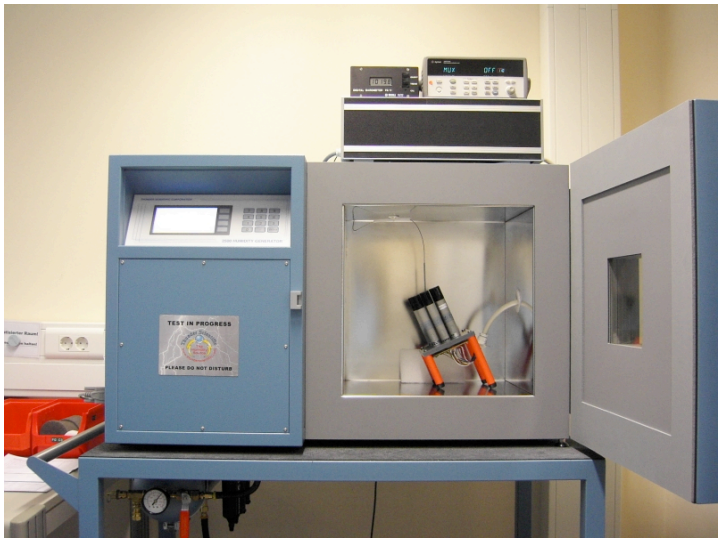


Photo 3: humidity bench at the DWD

2.2.2. Pressure calibration in Hamburg and Munich

The pressure standards are two piston gauges Fluke/DHI PG7601 with automatic mass handler AMH38.
The calibration interval is five years and the standards are calibrated at the PTB (German National Institute of Metrology).
The bench is able to calibrate up to four pressure gauges together. It is possible to calibrate pressure gauges with up to three pressure transducers.
The calibration is done over the entire range from 500 to 1100 hPa at eight pressure levels.

Photo 4: pressure bench at the DWD

3. Purpose, scope and organisation of the intercomparison

In the Annex 1-A of the CIMO guide, the WMO recommends that Regional Instrument Centres "participate in, or organize, interlaboratory comparisons of standard calibration instruments and methods".
The ISO 17025:2005 provides guidance for laboratories of metrology and strongly recommends them to participate in interlaboratory comparisons of calibration instruments and methods.
The DWD and Meteo-France have decided to carry out together in 2014 an interlaboratory comparison between the 3 laboratories in Hamburg, Munich and Toulouse for humidity and pressure calibration instruments and methods.

The ISO 17043, which specifies competences and recommendations to organise and carry out interlaboratory comparisons, was used as a guidance. Toulouse acted as main organiser while Toulouse laboratory was one of the 3 participant laboratories, but with different people involved for each task.

The number of laboratories is relatively small, being three only, but this somehow simplifies the organisation and at the same time allows for more flexibility and additions in the tests.

The 3 laboratories offer an interesting mix, with 2 very similarly equipped laboratories with very similar methods and one very differently equipped laboratory with very different methods.

For humidity calibration, the French and German measurements levels are different. Due to the limitation in capabilities and flexibility of the benches on each side, it was decided that each laboratory would carry out its own usual calibration procedure only. The different measurements and levels would then be used in the results analyses with interpolation, as typically done in interlaboratory comparisons.

On the other hand for pressure, the French and German calibration benches are much more flexible. The French and German calibration procedures have different pressure ranges, levels and patterns. But the bench on each side can carry out the usual measurements procedure from the other. The 3 laboratories agreed to take advantage of this opportunity and to each carry out their own usual procedure and separately in addition the procedure from the other country, except the repeatability part to limit the extra work. This interesting addition extend the usual scope of interlaboratory comparison.

For the test samples for both humidity and pressure, it was decided to use normal available sensors used in the observation networks.
To avoid any possible trouble on the test samples especially due to the many transportation, 2 different models of sensors with different age were chosen and 2 sensors of each model were included in the test samples. The test samples counted 4 sensors for pressure and 4 sensors for humidity.

Initial contact were made in December 2013 and the interlaboratory comparison was decided in January 2014. The method and all the organisation was set up in February with lots of emails to exchange information, propose, make decisions and specify all the details.

All the preparation work is really important. It guarantees a total agreement and understanding between the laboratories, necessary basis to full and well carried out measurements then used in the analyses of the results and the intercomparison.

The rotation of the test samples was organised, taking into account transportation delays. The measurements at the laboratories were carried out throughout March and April, starting from Toulouse, then Hamburg, then Munich. To finish the rotation, a last set of measurements in Toulouse will enable to check on return the test samples. This final step is yet to be carried out as this article is being written.

In the meantime, the analysis for the interlaboratory comparison has begun and the first results are available. More will be for TECO in July.

4. First results

The analyses are based on the calibration certificates provided by each laboratory.
Available information is the measurements data, the deviations, and the expanded global uncertainties, as given by each laboratory.
The deviation is

$$\mathbf{d = V_{sensor} - V_{standard}}$$

where V_{sensor} is the value measured by the sensor and $V_{standard}$ is the value from the standard.
All the expanded global uncertainties given were calculated using a coverage factor k of 2, that is

$$\mathbf{U = 2 \times u_g}$$

where U is the expanded global uncertainty and u_g is the global uncertainty.

As already mentioned, most but not all data are available and the analyses of the available data is not over yet. But so far for both pressure and humidity, results are good and in agreement between the 3 laboratories.

For both pressure and humidity, and overall for the laboratories, the first results show a similar behaviour of the measurements results of the 2 sensors of the same model, with slight differences. But the pattern of the results is different between the 2 models of sensors.
Results with graphs, tables and analyses are presented here for one typical sensor from the test sample of first humidity and then pressure.

The different graphs show the deviations for the 3 laboratories. The deviations are plotted in a different colour for each laboratory: yellow for Munich, red for Hamburg and blue for Toulouse.

In adition on some graphs, vertical coloured bars represent the expanded global uncertainties on the measurements.

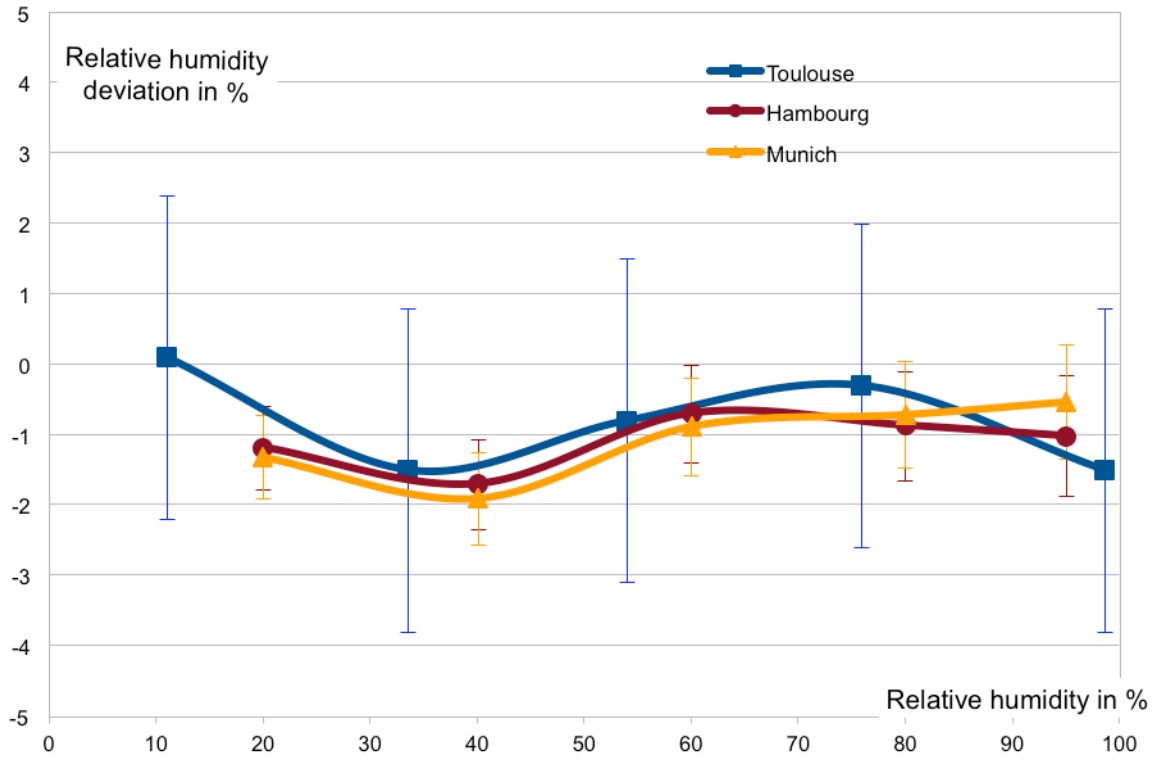
Good agreement between 2 laboratories A and B is confirmed when $\mathbf{X_{LB} \in [X_{LA} - U_{LA} ; X_{LA} + U_{LA}]}$ and vice-versa, where
X_{LA} and X_{LB} are the deviations respectively measured by laboratories A and B for level L,
U_{LA} is the expanded global uncertainty on the measurement, calculated by laboratory A for level L.

The tables display the standardized differences computed with the results of the couples of laboratories. The formula used is

$$\mathbf{D_L = | X_{LB} - X_{LA} | / (U_{LA}^2 + U_{LB}^2)^{1/2}}$$

where D_L is the standardized difference for level L computed for laboratories A and B,
X_{LA} and X_{LB} are the deviations respectively measured by laboratories A and B for level L,
U_{LA} and U_{LB} are the expanded global uncertainties on the measurements, calculated by laboratories A and B for level L.
The agreement between the measurements of 2 laboratories A and B is satisfactory for $D_L < 1$. And the lower the value of D_L, the better the agreement.

4.1. **First results of the interlaboratory comparison for humidity**



Graph 5: relative humidity deviations for the 3 laboratories

We note a really great agreement between the measurements values and overall patterns of the 3 laboratories, with an excellent maximum difference of roughly 1% of humidity. Due to the very different methods between Germany and France, the agreement in the pattern is slightly altered in the higher and lower range of humidity.
The very good agreement is confirmed by the calculation of the standardized difference computed for each couple of laboratories as shown in table 6 hereafter.
French uncertainties are larger than German ones, due to differences in the benches.

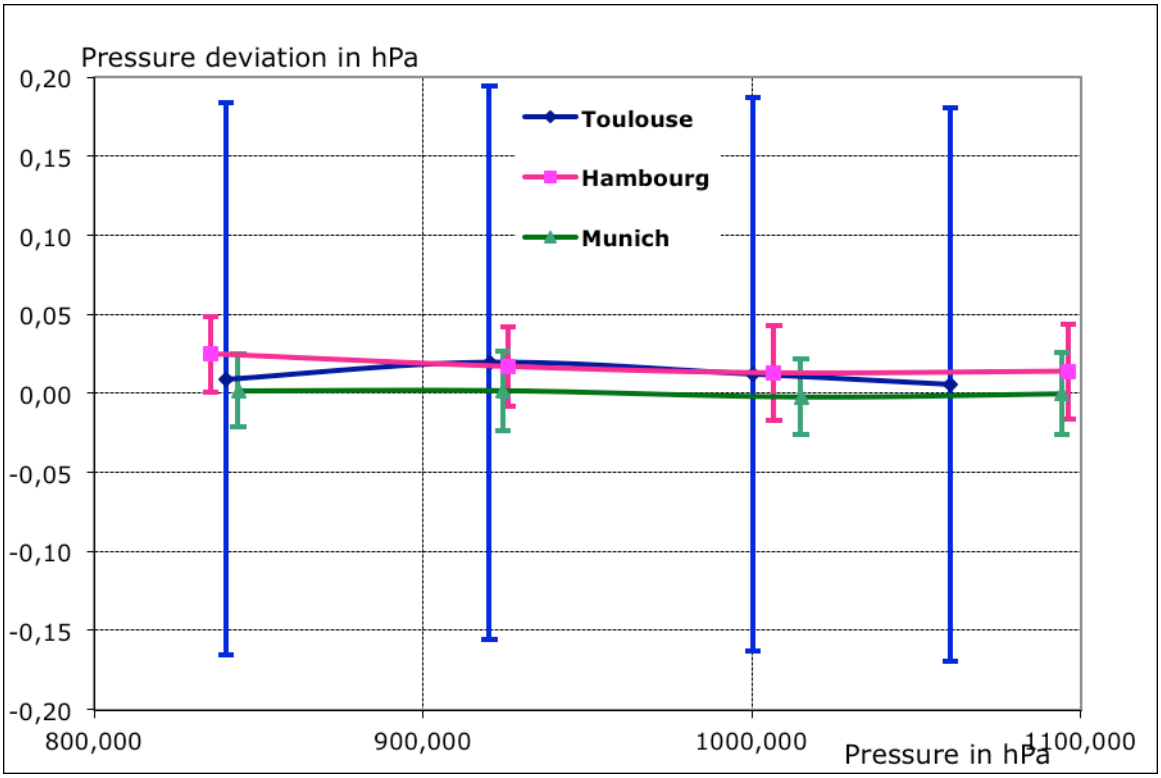
standardized differences for each couple of laboratories			
Humidity levels in %	Hamburg Toulouse	Munich Toulouse	Munich Hamburg
20	0.54	0.60	0.15
40	0.08	0.17	0.22
60	0.04	0.03	0.18
80	0.23	0.17	0.15
95	0.20	0.40	0.41

Table 6: standardized differences for humidity

4.2. First results of the interlaboratory comparison for pressure

All the different results presented here come from the analyses of measurements made with the same pressure sensor from the test sample. Results using another pressure sensor from the test sample are similar.

4.2.1. Results when each laboratory uses its own series of levels for calibration



Graph 7: pressure deviations when each laboratory uses its own series of levels for calibration

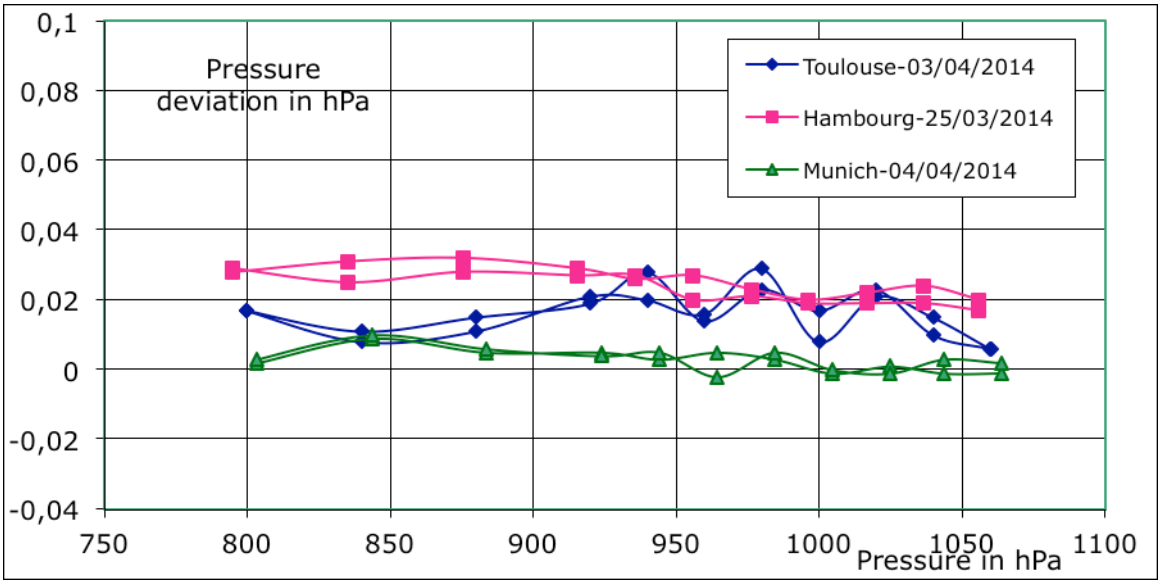
Graph 7 is here limited to the pressure range and levels common to the German and the French methods, that is 4 pressure levels in the range of 800hPa to 1060hPa.
Both graph 7 and the below table 8 of standardized differences boast an excellent agreement.

Expanded global uncertainties are added on graph 7.
French method uses a secondary standard for sensor calibration. In addition, French primary and secondary standards are good but relatively old and the uncertainty due to their individual drift over their whole lifetime is included in the global uncertainty. This explains the large uncertainties displayed for Toulouse, contrary to those from the German laboratories.

standardized differences for each couple of laboratories			
Pressure levels in hPa	Hamburg Toulouse	Munich Toulouse	Hamburg Munich
840	0.09	0.04	0.69
920	0.02	0.10	0.42
1000	0.00	0.08	0.39
1060	0.05	0.03	0.35

Table 8: standardized differences for pressure when each laboratory uses its own series of levels.

4.2.2. Results when using Meteo-France series of levels for calibration



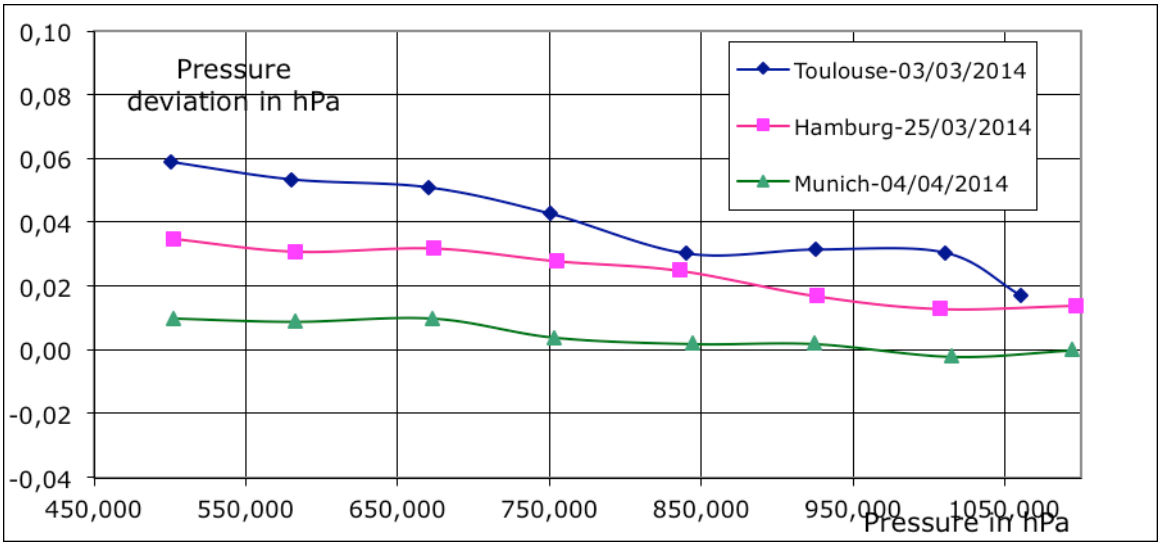
Graph 9: pressure deviations when using Meteo-France series of levels for calibration

Graph 9 plots separately measurement deviations going up and going down the pressure range, this helps display here the hysteresis but draws rougher curves.
All 3 laboratories have deviations in good agreement, which is confirmed by the below table 10 of standardized differences.

standardized differences for each couple of laboratories			
Pressure levels in hPa	Hamburg Toulouse	Munich Toulouse	Hamburg Munich
1060	0.08	0.04	0.30
1040	0.05	0.09	0.35
1020	0.01	0.11	0.30
1000	0.07	0.05	0.30
980	0.03	0.14	0.28
960	0.06	0.06	0.31
940	0.03	0.09	0.33
920	0.04	0.09	0.34
880	0.12	0.03	0.38
840	0.13	0.01	0.31
800	0.06	0.08	0.37
800	0.07	0.08	0.37
840	0.08	0.01	0.21
880	0.07	0.05	0.31
920	0.04	0.08	0.33
940	0.01	0.13	0.31
960	0.03	0.09	0.31
980	0.01	0.10	0.23
1000	0.01	0.09	0.27
1020	0.02	0.13	0.28
1040	0.05	0.04	0.23
1060	0.06	0.02	0.21

Table 10: standardized differences when using Meteo-France series of levels for calibration.

4.2.3. Results when using the DWD series of levels for calibration



Graph 11: pressure deviations when using the DWD series of levels for calibration

On graph 11, the plotted deviations are averaged over four values, thus explaining the overall smoother curves. Agreement between the laboratories is again excellent, as corroborated in the below table 12 of standardized differences.

standardized differences for each couple of laboratories			
Pressure levels in hPa	Hamburg Toulouse	Munich Toulouse	Hamburg Munich
500	0.14	0.28	0.91
580	0.13	0.25	0.78
670	0.11	0.23	0.44
750	0.08	0.22	0.75
840	0.03	0.16	0.69
925	0.08	0.17	0.42
1010	0.10	0.18	0.26
1060	0.02	0.10	0.30

Table 12: standardized differences when using the DWD series of levels for calibration.

5. Conclusion

First results are very positive. They show that the calibration measurements from the 3 laboratories are equivalent for both humidity and pressure calibration.
The French and German laboratories equipments are different, the local calibration processes are different. But all 3 laboratories have unbroken traceability chains for humidity and pressure and their calibration results are in good agreement.

Full results will be available at TECO2014 in July after the last set of measurements and the comprehensive analyses of all the calibration results.