Calibration of the MICHELL Hygrosmart module (I 7000.1, Pt100 part) at meteoLCD

Francis Massen (francis.massen@education.lu)
Raoul Tholl (raoul.tholl@education.lu)

21 October 2014.   version 1.0

Link to this paper: http://meteo.lcd.lu/papers/Pt100calibration/Pt100calibration.pdf

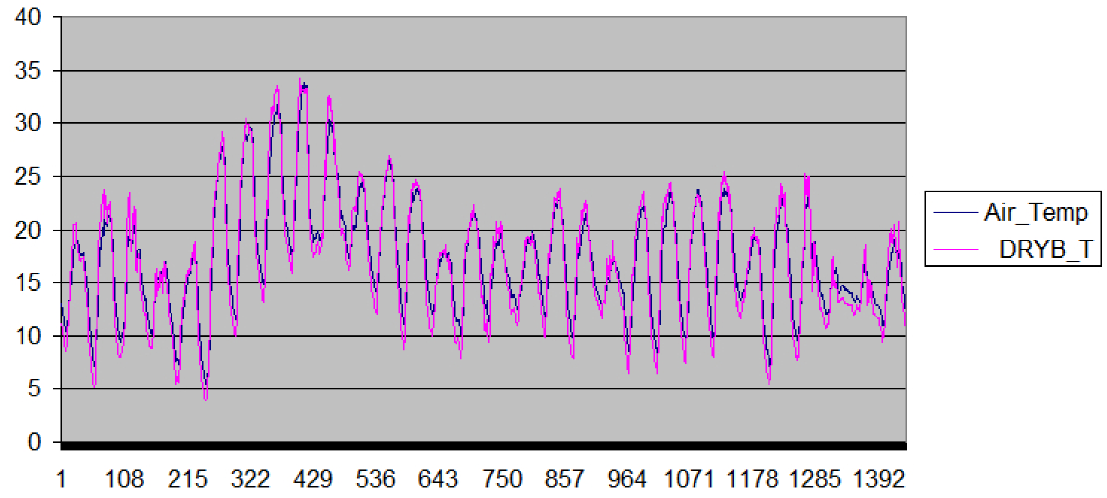
1. History

Air temperature and humidity were measured at meteoLCD (http://meteo.lcd.lu) by an equipment having an integrated hygrosmart module from Michell Instruments (www.michell.com/nl).

The advantage of these modules is that no further calibration is needed, and they can be simply plugged into a socket and replaced in case of malfunction.
The existing sensor went bad in July 2014, and was replaced by a spare one the 23th July 2014. We did not know that the old sensor had a thermistor as its temperature sensing element, and the replacement modules a Pt100 (as the thermistor based hygrosmart module is not available anymore). So the relative humidity readings were ok, but evidently the Pt100 readings way off. As a shortcut, the available Drybulb sensor of the WBGT equipment was used to represent the air temperature in the data and plots; this sensor also is a Pt100 device.
The comparison between the thermistor and Drybulb sensor made using the June 2014 data showed an acceptable linear relationship with a scale factor close to 1 (figure 1)

So despite the somewhat smaller R^2 (0.92 versus 0.96) the decision was made to use the Drybulb sensor as an equivalent to the previous thermistor sensor.

The 12 August 2014, the datalogger was reprogrammed to store Pt100 raw readings (i.e. Ohms), using the best available scale of [0..200] Ohm. The resolution is 0.02 Ohm.
Theoretical calibration factors for Pt100 sensors (e.g. a resistance increase of approx. 0.385 Ohm above 100 Ohm per °C) are of no use. Calibration must be done by comparing the stored Pt100 Ohm readings with a good external thermometer.



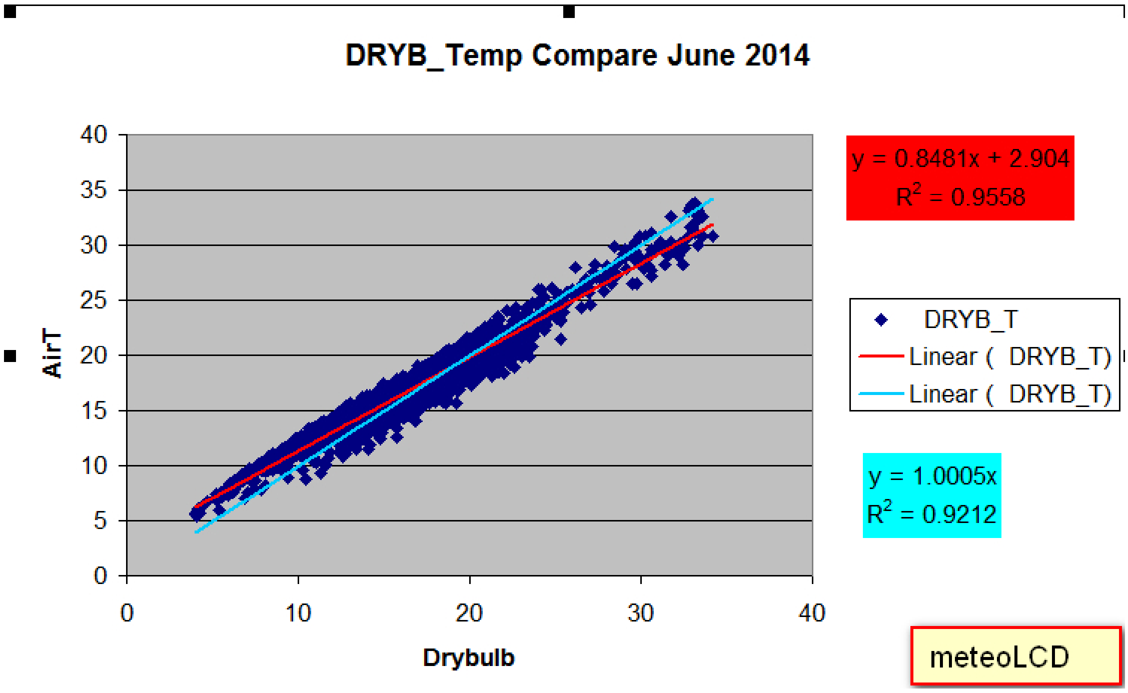


Fig.1. Comparison of Drybulb and thermistor sensor using June 2014 data. A linear function (through the origin) has a scale factor of 1.0005, which is practically 1.

One longer trial using an ONSET micrometeorological station with a 12bit temperature sensor was unsuccessful, due to a sensor malfunction.
A second trial was made using another Onset station with two sensors (type S-TMB-M006), an Omega USB and a Pollin DS100 temperature dataloggers.
These last two inexpensive sensors were put in a waterproof case, whereas the Onset sensors were placed in the open air. All equipment was protected from solar radiation and precipitation.

The next chapter gives the results of a run over the period from 03 to 12 October 2014.

2. Calibration results

2.1. Time series

The 4 sensors used will be named Hobo1, Hobo2 (the Onset sensors), EasyUSB (Omega) and DS100 (Pollin); the two last are the USB sensors. The ONSET datalogger made one reading every 10 minutes, and three readings were averaged to give one reading per half-hour, as is the standard for the meteoLCD data. The USB sensors had shorter reading intervals (e.g. 2 minutes), but these also were averaged into one 30 minute reading.

Fig.2.shows the 4 temperature series and the Drybulb series (left y-axis, Celsius) and the raw Pt100 readings (right axis, Ohm). The series starts the 03 Oct 2014, 12:30 UTC and ends the 12 Oct 2014, 23:30 UTC (455 data points per sensor).

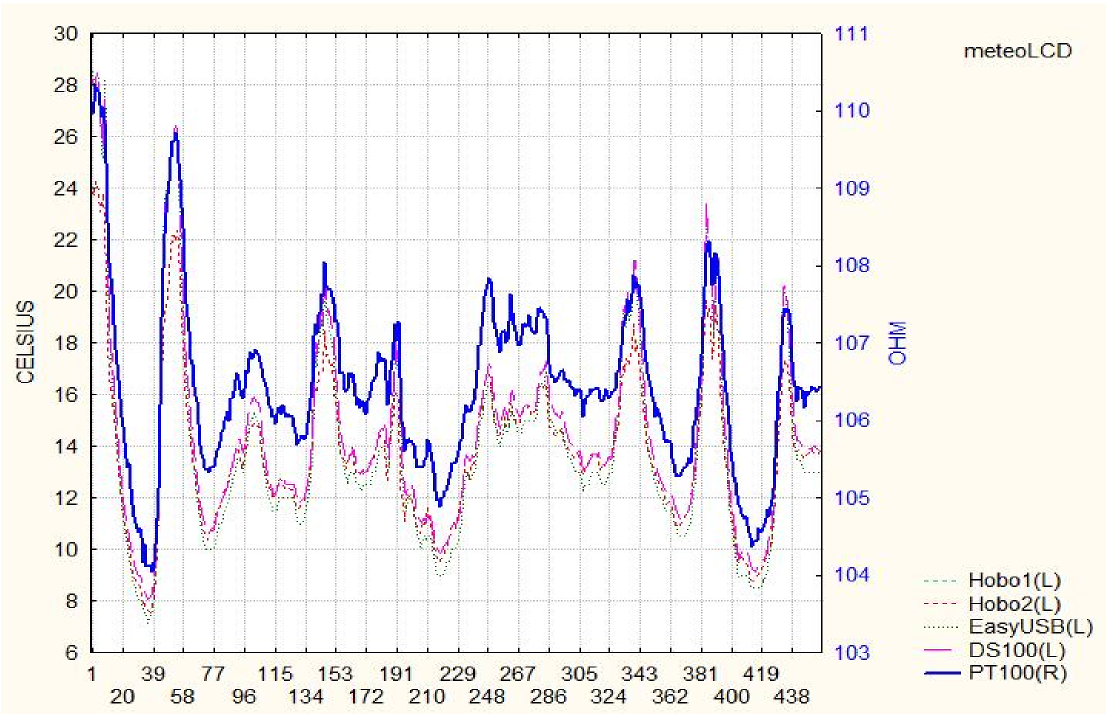


Fig.2. Series of all temperature sensors (left axis) and Pt100 (heavy blue line, right axis)

The two Hobo lines overlap and can not be visibly distinguished. Clearly the Pt100 curve lies higher than the temperature sensors curves; this offset forbids a simple calibration multiplier. Inspection shows that after data point 438 (12 Oct

2014, 15:00 UTC) there is a large diversion between Pt100 and the temperature sensors. On the following analysis, we will truncate the data series to 438 lines.

2.2. Individual scatterplots and linear regression

Hobo1 (Hobo2) versus Pt100

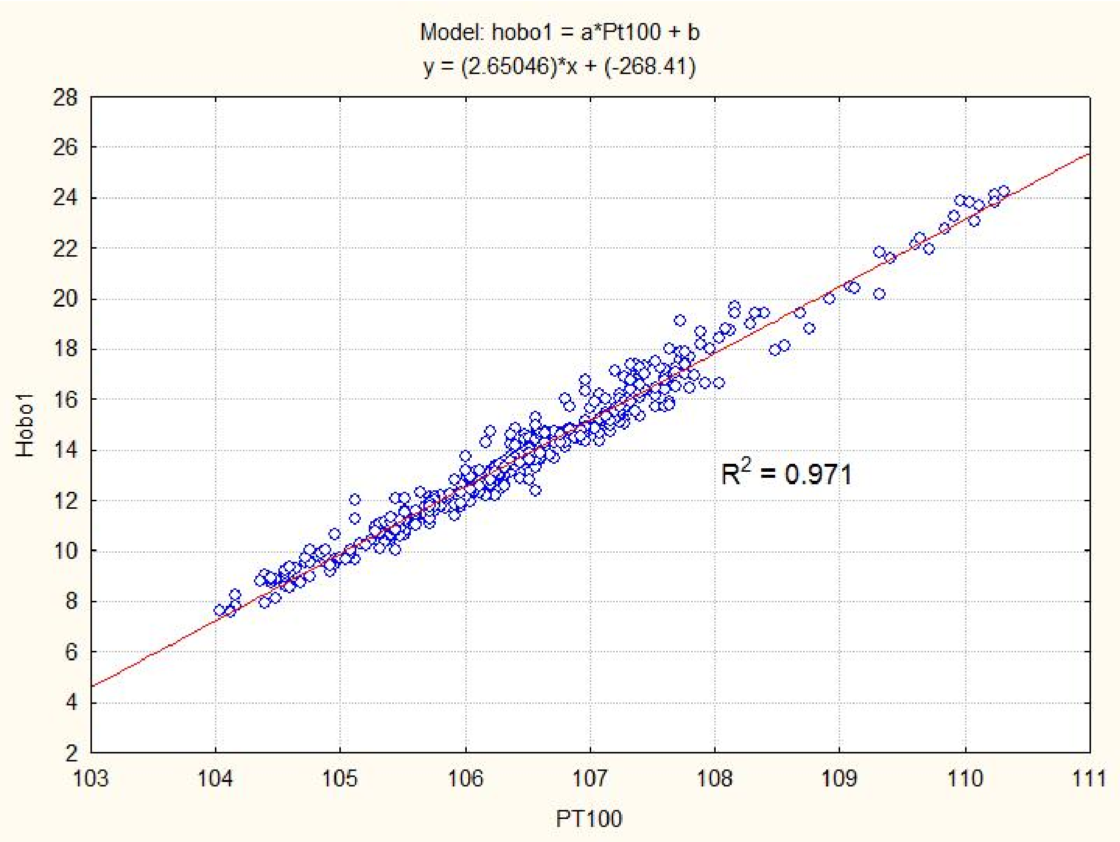


Fig.3. Hobo1 versus Pt100; the linear regression parameters give the calibration parameters to apply to the Pt100 readings to give a good result, assuming the Hobo1 readings represent the correct temperature.

Using the readings of the second Onset sensor (Hobo2) gives identical results.

Drybulb versus Pt100

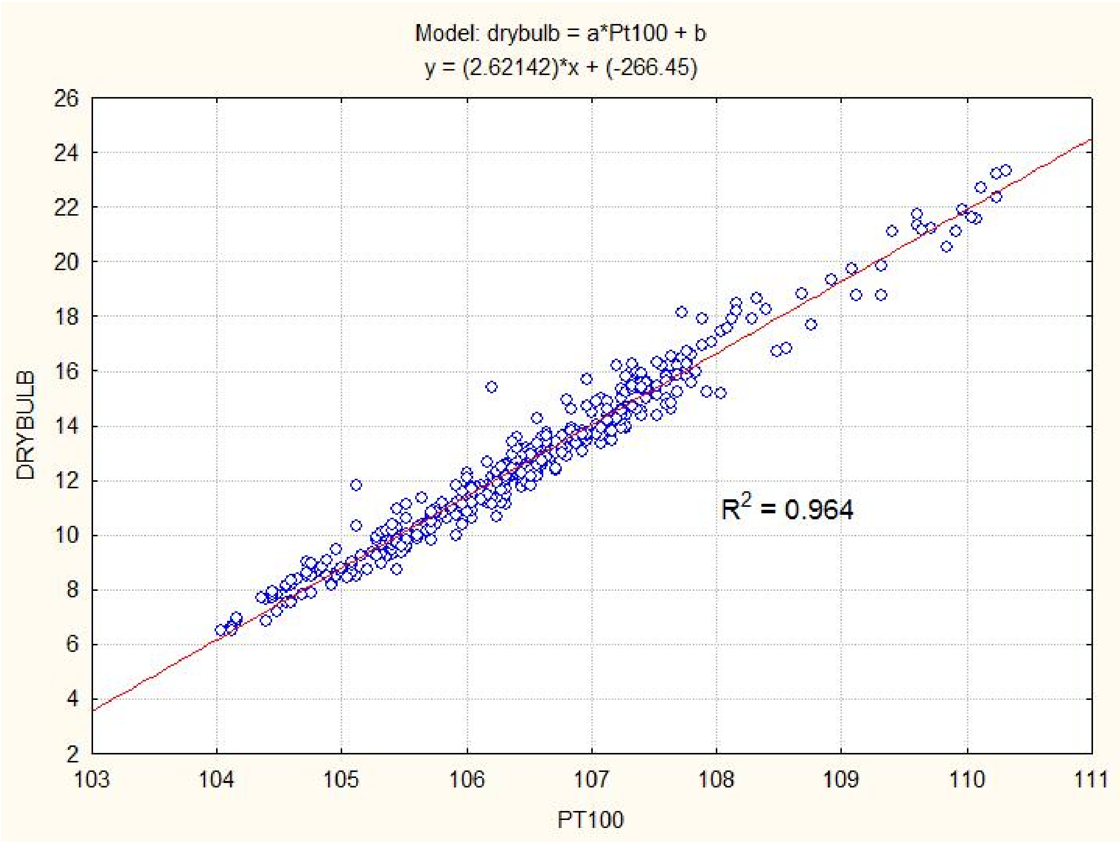


Fig.4. Drybulb sensor versus Pt100. The goodness of fit is very close to the preceding one

Note the existence of a couple of visible outliers!

EasyUSB versus Pt100

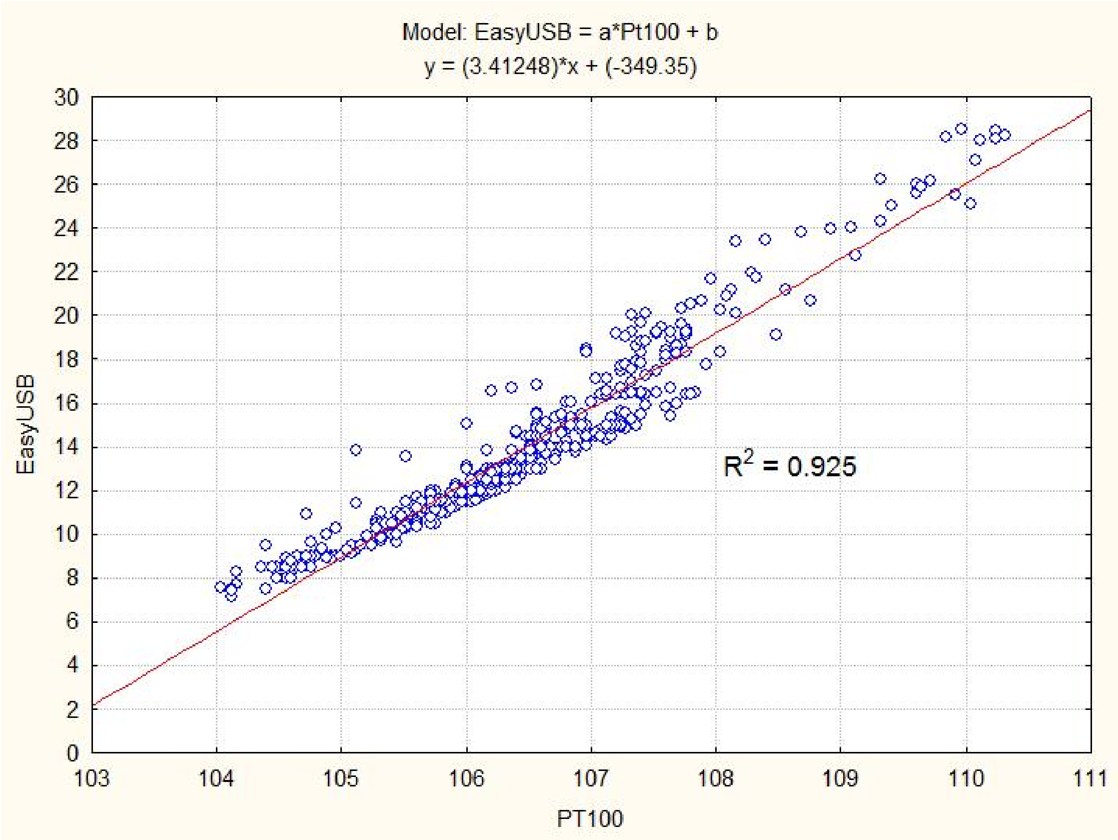


Fig.5. EasyUSB sensor versus Pt100.

This scatterplot shows a quite visible deviation from linearity, and a goodness of fit parameter R2 visible smaller than the two previous ones.

The outliers are numerous and important in magnitude.

DS100 versus Pt100

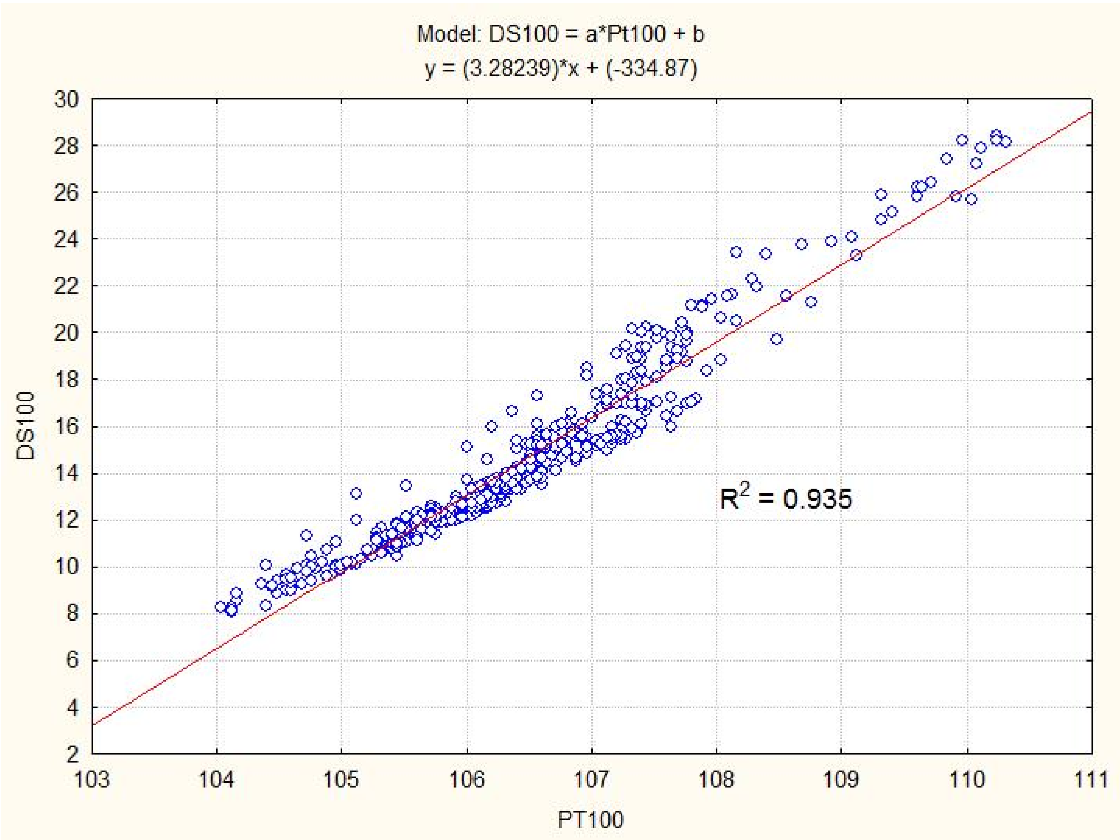


Fig. 6. DS100 sensor versus Pt100

Again a strong non-linearity, but an R^2 slightly better than the previous one.

Let us summarize the various relationships versus Pt100 (the x parameter) and give them according to decreasing R^2:

Hobo sensors	y = 2.65046*x -268.41	R^2 = 0.971
Drybulb	y = 2.62142*x -266.45	R^2 = 0.964
DS100	y = 3.28269*x – 334.92	R^2 = 0.935
EasyUSB	y = 3.41248*x – 349.35	R^2 = 0.925

The conclusion seems to be clear: use the Hobo parameters as calibration factors!

2.3. Differences between temperature sensors and calibrated Pt100

Let us call deltaXYZ the difference between the sensor reading and the calibrated Pt100, where the calibration function is the linear regression given in the preceding graphs.

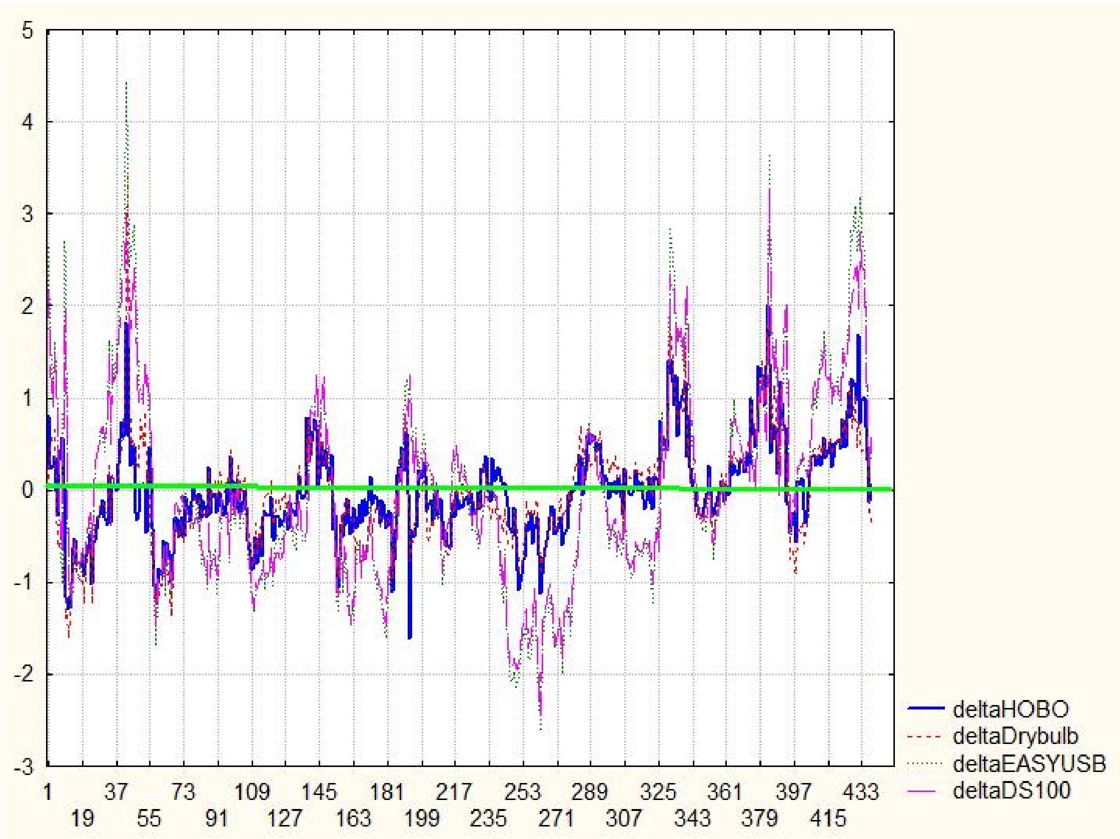


Fig.7: Plot of the differences between sensor and model.

The emphasized blue line (Hobo sensor) shows that usually the differences are lower than approx. +/- 0.5 °C. Out of the 438 deltaHOBO readings, 33 (i.e. 7.5%) show a difference exceeding +/- 1 °C, **but nearly 96% (419 cases out of 438) have a difference lower than +/- 0.5 °C**.

The following table gives the mean and standard-deviations of the deltas:

delta with	mean	standard deviation
Hobo	+0.000163	0.518884
Drybulb	-0.003210	0.573582
DS100	+0.004975	0.985673
EasyUSB	+0.002424	1.104932

The Hobo deltas have by far the lowest average and also the lowest standard deviation.

3. Conclusion

In the future, meteoLCD will use the calibration function **y= 2.65046*x -268.41** to convert raw Pt100 readings into degrees Celsius. As the resolution of the datalogger is 0.04 Ohm, this gives a temperature resolution of 0.1 °C.

To avoid further degradation due to limited precision of the logger parameters, air temperature (channel 2, sensor code PTL, label AIR_PT1, unit Ohm) will be recorded as raw Pt100 readings, and the metadata given in the data header will restate this in every monthly data file.

Fig. 8 shows the location of the raw Pt100 readings in the standard meteoLCD data file

air temperature Pt100 raw Ohm readings in the meteoLCD data file

```
"DELTA-T LOGGER"
"lcd_UV   "
"12/08 09:26:54"
"21/10 00:02:13"
"TIMED"
"Channel number    ",25," ",          61," ",          62," ",           1," ",          2," ",           3," ",
"Sensor code       ",25," "," AN1"," "," RG1"," "," TM1"," "," PLT"," "," %RH"," ",
"Label             ",25," ","AirSpeed"," ","Rainfall"," ","Logger_T"," "," AIR_PT1"," ","Air_Humi"," ",
"Unit              ",25," "," m/s"," "," mmRain"," "," deg C"," "," Ohm"," "," %RH"," ",
"Minimum value     ",25," ",        0.00," ",         0.0," ",       25.29," ",     102.04," ",       33.02," ",
"Maximum value     ",25," ",       19.98," ",         4.8," ",       30.70," ",     111.56," ",       99.38," ",
"21/10 00:00:39    ",25," ",        0.31," ",         0.0," ",       25.49," ",     104.16," ",       95.13,"$",
"21/10 00:30:39    ",25," ",        0.33," ",         0.0," ",       25.45," ",     104.28," ",       94.52,"$",
"21/10 01:00:39    ",25," ",        0.46," ",         0.0," ",       25.39," ",     104.56," ",       94.62,"$",
```

Fig. 8. Raw Pt100 readings in standard data file.

History:

21 Oct 2014: original version 1.0