HUMIDITY SENSORS FOR LAND AND MARITIME STATIONS

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Abstract

In order to find a suitable humidity sensor for the KNMI measuring network, a set of five different sensor types from three different manufacturers has been subjected to a number of tests. Laboratory tests have been performed to test the accuracy and response time of the sensors. Results of the tests on accuracy show a temperature dependence at low temperatures and high humidity for some sensors. Response times vary significantly, but are all within WMO recommendations. Based on these test results, 2 sensor types have been selected for field tests. These field tests take place at a land station and on a North Sea platform and last up to a year in duration. These tests give an indication of condensation effects and of contamination/degradation effects. The progress of these tests is shown.

Introduction

At present, KNMI has Vaisala HMP233 humidity sensors in use in the measurement network in the Netherlands. These sensors have largely worked well, but there is still room for improvement. The new sensor needs to meet the WMO requirements along with additional KNMI requirements. A market survey has resulted in the following pre-selection (see also [1]): Vaisala HMT337 (heated), Vaisala HMT317 (heated), Rotronic HygroClip, E plus E EE31 and E plus E EE33(heated).

All sensors are capacitive sensors and most can be (or are) combined with a temperature sensor. Some of the sensors also give derived products. The sensor accuracies are comparable on paper, as are the time constants. The sensors will be judged by a number of factors, the most important ones being accuracy, time response and calibration interval.

Laboratory tests

Sensors

The sensors tested in the laboratories are the selected sensors, plus the "old" sensors HMP233 and HMP243 in order to make a good comparison with the current situation. There are 2 - 4 sensors for each type. All sensors are used with their factory calibration and the filters recommended by the manufacturer.

Set-up

The sensors are tested in a climate chamber at KNMI. This chamber is humidity and temperature controlled. The humidity of the climate chamber is measured with a Michell S4000 dew-point mirror, and the temperature with a Pt500 element. These measurements are accurate to within 0.13 °C (T_d) and 0.03 °C (T), respectively.

The sensors are placed in the centre of the climate chamber. Because of the limited space and connections available, only 6 sensors can be tested at one time. This means that a number of measurement series are needed. The sensors for each series are selected such that most types are present.

Tests

Two types of tests are performed. The first type tests the accuracy of the sensors for a range of temperature and humidity. The second type tests the time response time of the sensors.

Accuracy

In order to test the accuracy of the sensors, their response is measured for a number of temperatures and humidities. The humidities used are roughly: 17, 27, 37, 47, 57, 67, 77, 87 and 97 %RH. All these values are measured at different temperatures: 2 or 3 temperatures below 0 °C (-15, -10, -5 °C) and at temperatures of 0, 10, 20 and 30 °C. The chamber is set at the required values and the sensors are allowed to stabilize. Then the measurement is taken and the chamber is set at the next value.
The uncertainty of the measurements was determined to be 1 %RH at 20 C, and 1.8 %RH at –10 °C.

Response time

For the time response tests, the sensors are placed in a small box containing a layer of either sillica or water. This box is placed inside the climate chamber. The silica will cause the humidity inside the box to be lower than in the climate chamber, and the water will result in a high humidity (but not yet saturation). Then the sensors are taken out of the box, and the response is measured. Because the box is much smaller than the climate chamber, the effect that is measured can be largely contributed to the time response of the sensor. The measurements are all performed at room temperature and the humidity of the climate chamber is set at about 40 %RH. The time resolution of the measurements is 2 s.

Five types of measurement were performed, which are defined as follows:

1. with silica in the box, and the climate chamber at roughly 40 %RH
2. with silica in the box, and the climate chamber off so that no air flow is present
3. with water in the box, the sensor in the box for 5 minutes and the climate chamber at 40 %RH
4. with water in the box, the sensor in the box for 30 minutes and the climate chamber at 40 %RH
5. with water in the box, the sensor in the box for 30 minutes and the climate chamber off

From the graphs, the response times are determined. Two values are determined: the 1/e time (the RH is about 2/3 of its final value, in accordance with the definition used by WMO) and the 5% time (the RH is 95 % of its final value). The uncertainty of the 1/e time was determined to be 1 – 2 s, the uncertainty of the 5 % time was found to be about 50 % of its value.

Results

Accuracy

An example of the results of the accuracy tests can be seen in Figure 1.

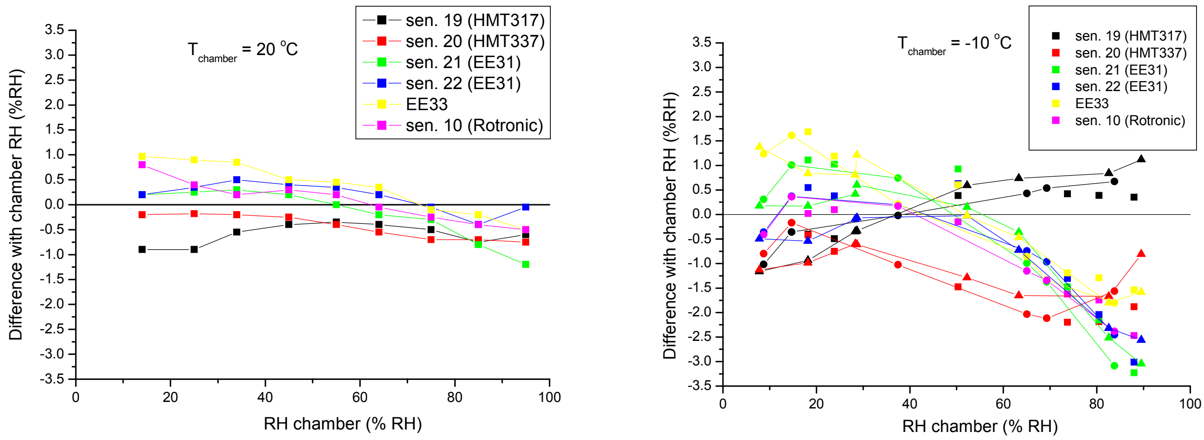


Figure 1. Example of the results from the accuracy lab tests. On the y-axis the difference in Relative Humidity between the sensor and the climate chamber, on the x-axis the humidity of the climate chamber. Left panel: climate chamber at 20 °C, right panel: climate chamber at -10 °C.

Numerous accuracy tests have been performed. A summary of the results by sensor type is given below.

sensor	Max deviation 20 °C (%RH)	Max deviation low temperatures (%RH)
HMT337	±1	-2
HMT317	±1	+3
HygroClip	±1	-3.5
EE31	±1	-3
EE33	±1	-1.5

Table 1. Summary of the accuracy measurements. The maximum deviation from the reference RH is given for all RH values. "low temperatures" are defined as -10 °C and -15 °C.

Response time

An example of the response time measurements is shown in the next figure. The various types of measurement are defined in de previous section.

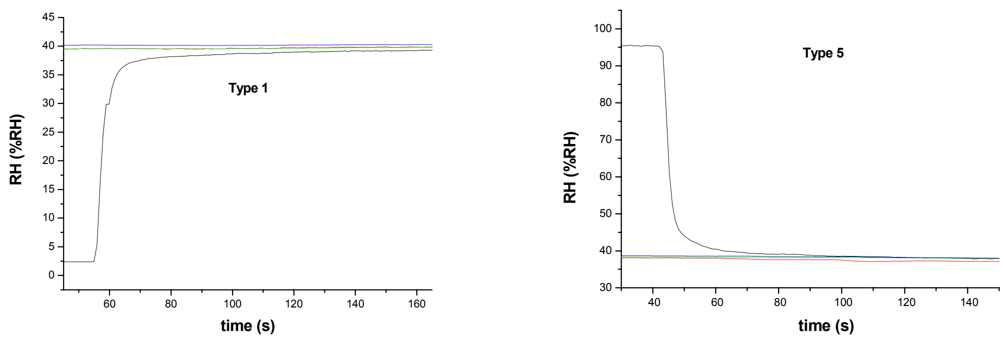
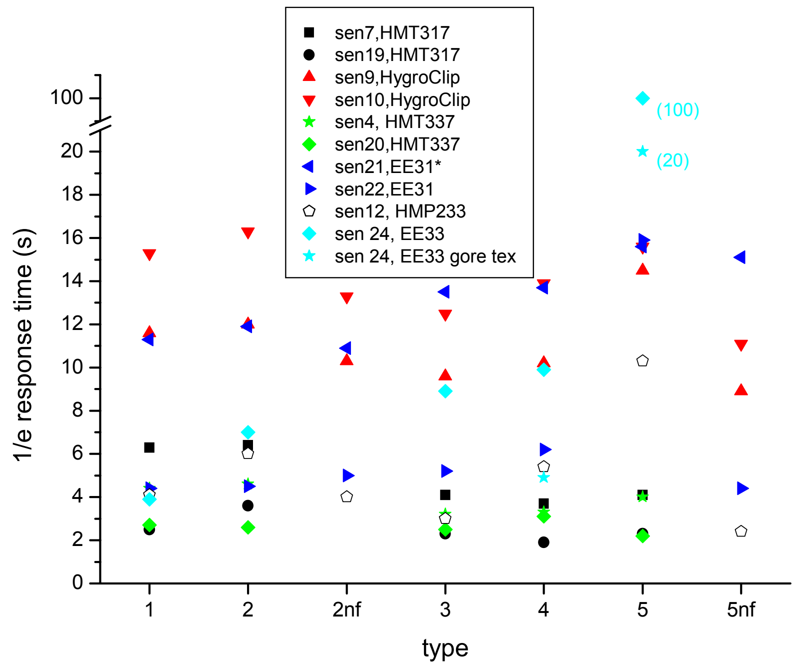


Figure 2. Time response results for a Vaisala HMT317 sensor (black line). On the y-axis the Relative Humidity in %RH derived from the measured dew point temperature and the reference temperature, on the x-axis the time in seconds. The type indication refers to the type of measurement.

These measurements were performed for all sensor types. The resulting 1/e and 5 % response times are summarized in the next figure. The EE33 was tested with its original filter as well as with the gore-tex filter currently in use at KNMI.



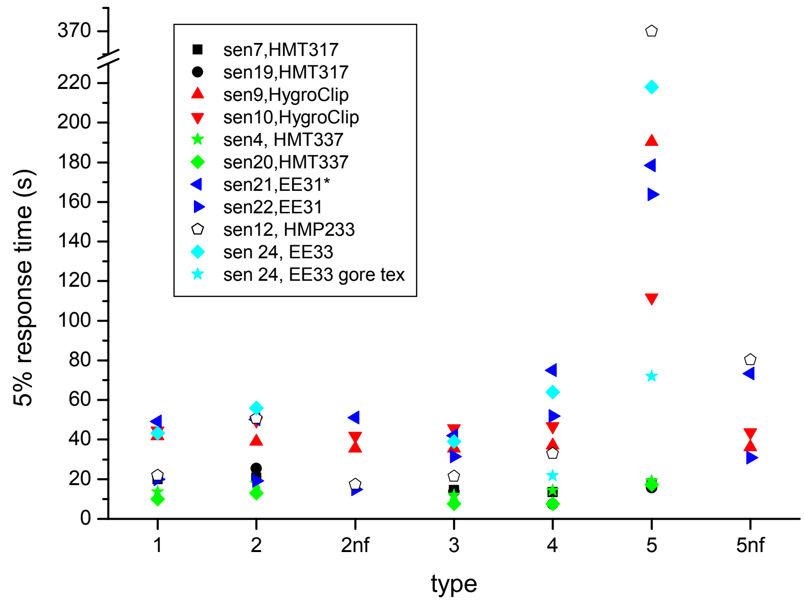


Figure 3. 1/e response times (upper plot) and 5 % response times (lower plot) as a function of measurement type for the sensors indicated. "nf" means no protective filter present (only for the non-heated sensors). Same colour means same sensor type. The EE31* has a special coating.

Discussion and Conclusions Laboratory tests

Accuracy

The accuracy measurements show that all tested sensors are within 1 %RH from the reference at 20 °C. At lower temperatures (-10, -15 °C), the deviation is larger, as can be expected, especially at high humidities. The HMT337 and EE33 have the smallest deviations.

Response time

In the response time results, there are clear differences (see Figure 3). Generally speaking, the heated sensors have fast response times, as can be expected. All sensors are within WMO recommendations. In near saturation conditions (measurement type 5) response times increase significantly, especially the 5% response time. All in all, the HMT337 and HMT317 are the fastest sensors.

Conclusions
In order to keep the number of sensors in the field tests manageable, only a selection of the sensors was chosen to continue in the field tests. This selection is based on the results and experiences of the lab tests.
The two sensor types that show the smallest deviation at low temperatures in the lab tests are the HMT337 and EE33. Both these sensors are heated and thus have relatively fast response times, if supplied with a proper filter. The experiences with these sensors so far have not yielded any major problems. Therefore, these two sensor types are tested in the field.

Field tests

Set up

In the field tests, 2 locations are used. One in the centre of The Netherlands (De Bilt) and one on a platform in the North Sea. The sensors are placed in KNMI radiation screens. The test at sea contains only two sensors, one HMT337 and one EE33. The test in De Bilt is the more elaborate one, with two sensors of each type. These sensor types are: HMT337 and EE33, and the HMP233 and HMP243 for comparison. Figure 4 shows the set-up in De Bilt.

Figure 4. The field test in De Bilt. Shown are the radiation screens containing the humidity sensors.

Tests

The field tests consist of monitoring the response of the sensors to the outdoor environment. In order to keep track the sensors' stability, the sensors in De Bilt are checked in the climate chamber once every 2 months. This check is a reduced version of the laboratory accuracy tests. Unfortunately, this is not possible for the sensors at the North Sea platform. The test in De Bilt started in February 2008. Therefore, the complete results are not yet available.

Results

Figure 5 shows examples of the results of the checks in the climate chamber, for one HMT337 sensor and one EE33 sensor, along with the results of the initial lab tests. The latter are called “dec” measurements for convenience.

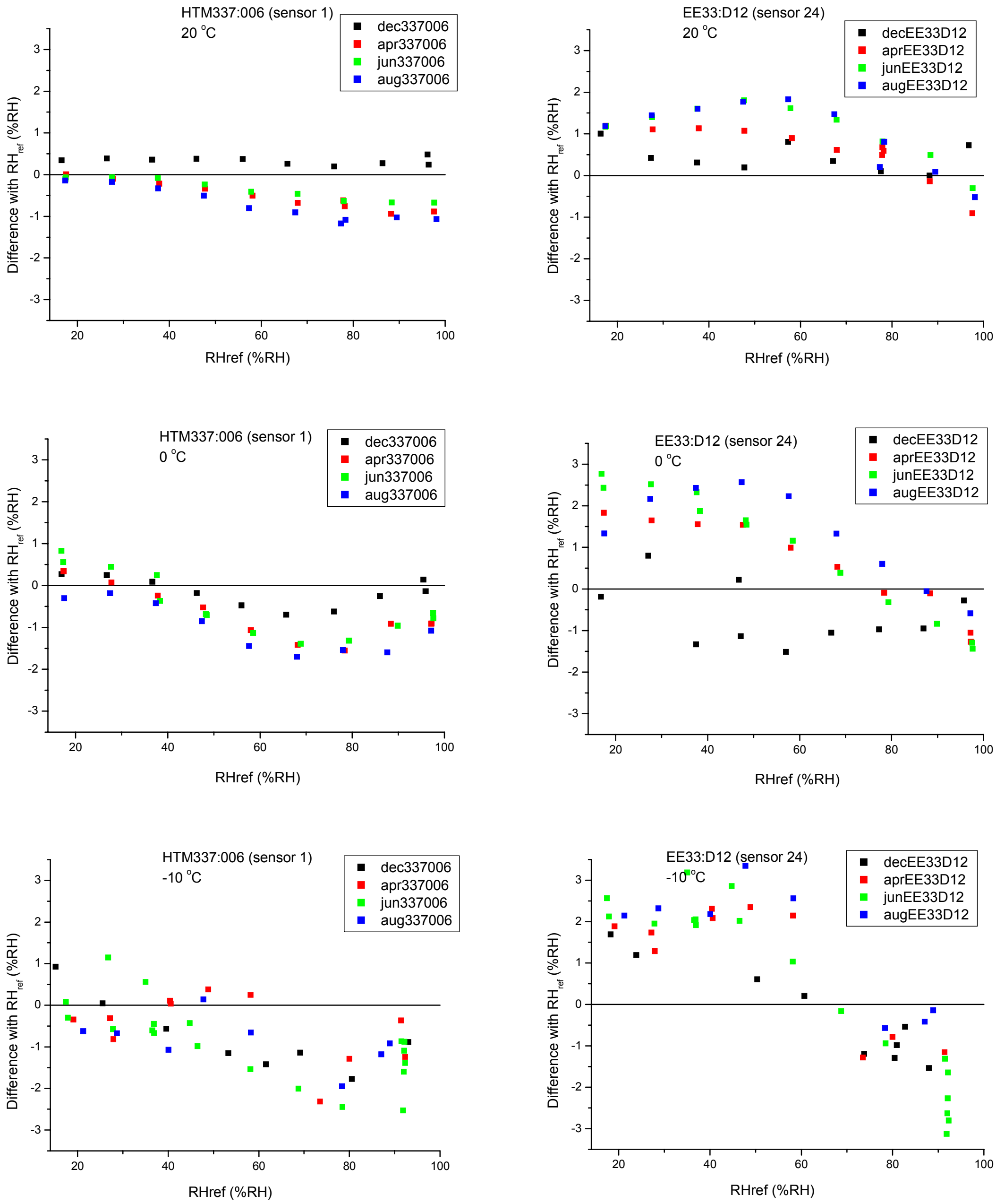


Figure 5. Example of the results of the lab checks during the field test for one HMT337 sensor (left figures) and 1 EE33 sensor (right figures), including the earlier calibrations (“dec”, black symbols). “apr” is after 2 months of field test (red), “jun” after 4 months (green) and “aug” after 6 months (blue). For each measurement, the temperature is indicated. On the y-axis the difference in Relative Humidity between the sensor and the climate chamber is indicated (in %RH), on the x-axis the humidity of the climate chamber (in %RH).

For each sensor, temperature and series, an average and standard deviation is calculated. These results are summarized in Figure 6.

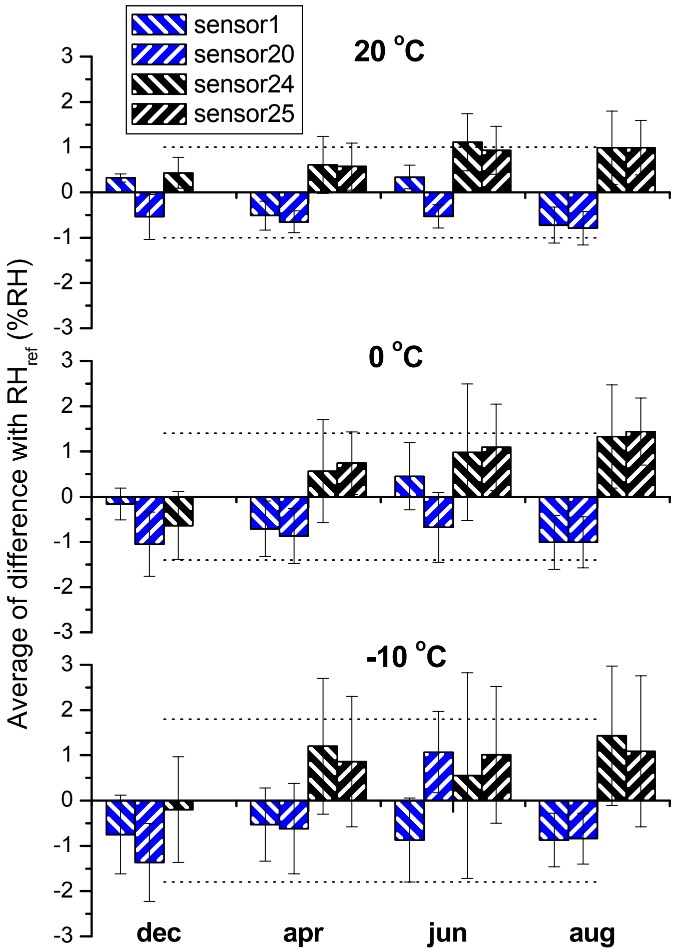


Figure 6. On the y-axes: average deviation of the difference between the sensor and the reference (in %RH) of the sensors indicated (blue: HMT337, black: EE33) for the different temperatures (20, 0 and -10 °C) and series (dec, apr, jun and aug). The standard deviation for each series is indicated by the error bar, the dashes line the uncertainty of the measurement for the temperature in question.

In order to detect possible trends, a linear fit through these data for each sensor type was performed, using the standard deviation as error margin for the fit. The fits are shown in Figure 7, and the results of the fits in Table 2.

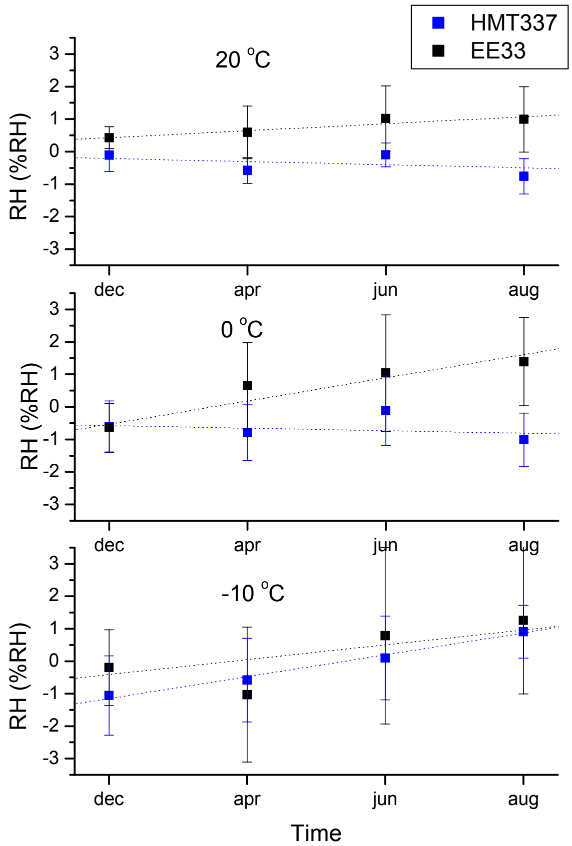


Figure 7. Fits based on the data of Figure 6, where the data for the two sensors of each type are combined. On the y-axes: average deviation of the difference between the sensor and the reference (in %RH) of the sensors indicated (blue: HMT337, black: EE33) for the different temperatures (20, 0 and -10 °C) and series (dec, apr, jun and aug). The standard deviation for each series is indicated by the error bar.

	HMT337		**EE33**	
	slope	*err*	*slope*	*err*
20 °C	-0.09	0.22	0.21	0.30
0 °C	-0.08	0.39	0.71	0.49
-10 °C	0.67	0.46	0.45	0.79

Table 2. Results of the fits of Figure 7. Shown are the slope (in (%RH/2 months)) and the error therein.

Outdoor results

Some preliminary general statistical results from the outdoor measurements are (based on 1-minute data of approximately 90 days):

- difference in RH between 2 HMT337 sensors: -0.19 %RH
- difference in RH between 2 EE33 sensors: +0.22 %RH
- difference in RH between average of 2 HMT337 and average of 2 EE33 sensors: +1.48 %RH

Figure 8 shows an example of data from the sensors taken during the field test. A number of similar cases were present. However, in order to produce relevant statistics for various situations, more measurements are necessary.

Results from the tests at the North Sea are not yet available. Please contact the author if you wish to receive an update on these, or any other tests.

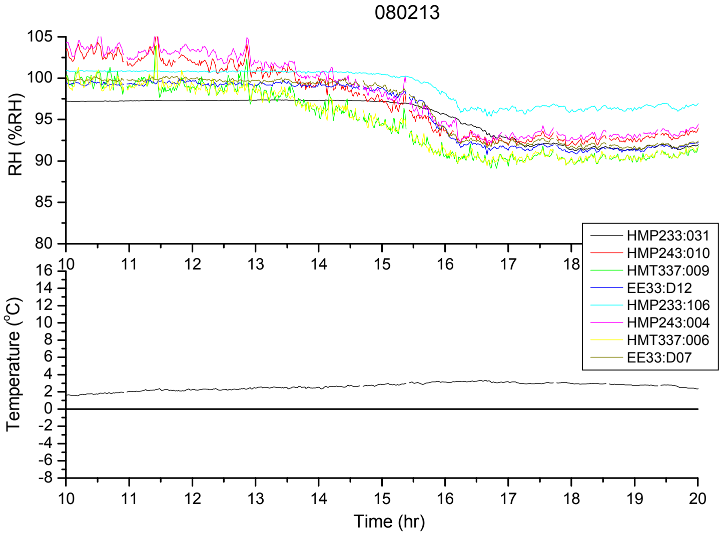


Figure 8. Results from the field test in De Bilt. Date: 13 February 2008. Upper panel: the RH from the 8 sensors (in %RH); lower panel: the average temperature of the external temperature elements (in °C). Additional measurements show that fog was present until about 13:00 when it lifted slowly. Precipitation and wind were not present.

Discussion

The lab tests have resulted in a pre-selection of two sensor types, the HMT337 and EE33. These two sensor types have shown the smallest deviations at low temperatures in the lab tests, and both these sensors are heated and thus have relatively fast response times, if supplied with a proper filter.

The lab results during the first six months of field testing are shown in Figure 5 - Figure 7 and Table 2. As the figures show, the initial lab tests result in small deviations from the reference at 20 °C (about 1 %RH), and larger deviations at -10 °C (about 2 – 3 %RH). Over time, the deviations from the reference appear to become larger (see Figure 6). The standard deviation in the data from the EE33 is larger than for the HMT337 (see for example Figure 6). However, Figure 7 and Table 2 show that significant trends are not yet observed in the first six months of testing. Therefore, contamination and/or degradation effects on the sensors cannot yet be determined for this location. As the area of De Bilt is a relatively clean environment, the contamination effects at other locations may well be larger.

The preliminary statistical outdoor results show that the sensors of the same type deviate very little from each other, about 0.2 %RH. This indicates that the sensors of the same type behave very similarly, as expected, and that the measurement set-up is sufficiently uniform to allow detailed measurements.

Figure 8, finally, shows that some sensors respond much faster than others in the case of condensation/fog. This was observed on various occasions. However, more fog cases are needed in order to make a proper analysis.

As this is work in progress, no final conclusions can be drawn yet.

References

1. Bloemink, H.I. and R. van Krimpen, *KNMI humidity sensor test*, paper presented at WMO Technical Conference on Instrumentation and Methods of Observation (TECO) 2006, Geneva, Switzerland, WMO-IOM-94, WMO-TD No. 1354.