

# **Rotronics Humidity Trial**

**C Sloan and D Moore 2008**

**Met Office, Fitzroy Rd, Exeter, EX1 3PB, United Kingdom**

**Tel +44(0)1392 885805 Fax +44(0)870 9005050**

## **1 Abstract**

A trial has been undertaken at Camborne to compare six Rotronics Hygroclip Hygrometers against a pair of Thygan Mirror Dew Point Hygrometers and a screen PRT wet and dry bulb. This has been done to provide a better understanding of the relative performance of wet and dry bulbs and the Rotronics Hygroclip in use within the surface network. The Thygan is recommended by the WMO as a working reference, including its temperature measurements below 0 C. For climate purposes we are looking for an instrument with an accuracy of  $\pm 2\%$  RH.

## **2 The Trial**

Two Thygan Hygrometers were attached to a spare Stevenson screen frame, at the same height and several metres from a naturally aspirated Stevenson Screen housing PRT wet and dry bulbs and 6 Rotronics Hygroclips. The Thygans were orientated north and south approximately 2 metres apart and 5 metres from the screen.

Data was logged on a Campbell Scientific CR3000 logger in a box attached to the screen. Cabling from the logger was routed back to a PC in the main building where it was logged.

Camborne staff changed the wet bulb wicks weekly and later in the trial took photographs of the wicks before and after changing them so that they could be reviewed back at Met Office HQ at Exeter.

Data was sent back to Exeter weekly where it was analysed using Excel. From the Thygan specification, dewpoint accuracy is  $\pm 0.15\text{C}$  between  $-20\text{ C}$  and  $50\text{ C}$ , leading to a humidity accuracy of  $\pm 0.8\%$  C at  $20\text{ C}$ .

## **3 Results**

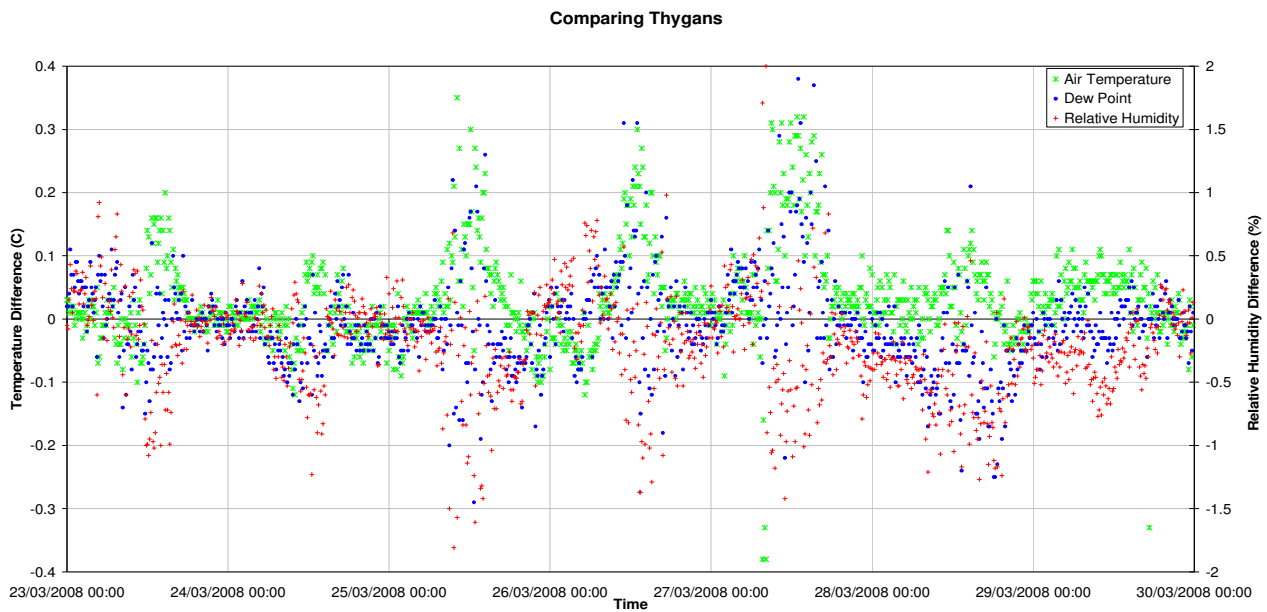
The results were analysed into two parts:-

- Comparisons between instrument of the same type
- Comparisons between different instruments types

### **3.1 Comparison Of Instruments Of The Same Type**

#### **3.1.1 Thygan Mirror Dewpoint Hygrometer**

Figure 1 shows a typical set of data of the temperature and humidity differences between the two Thygans over one week. Comparison of measurements of air temperature, dew point and humidity measurements from the two instruments gave good agreement. Table 1 summarises the correlation.



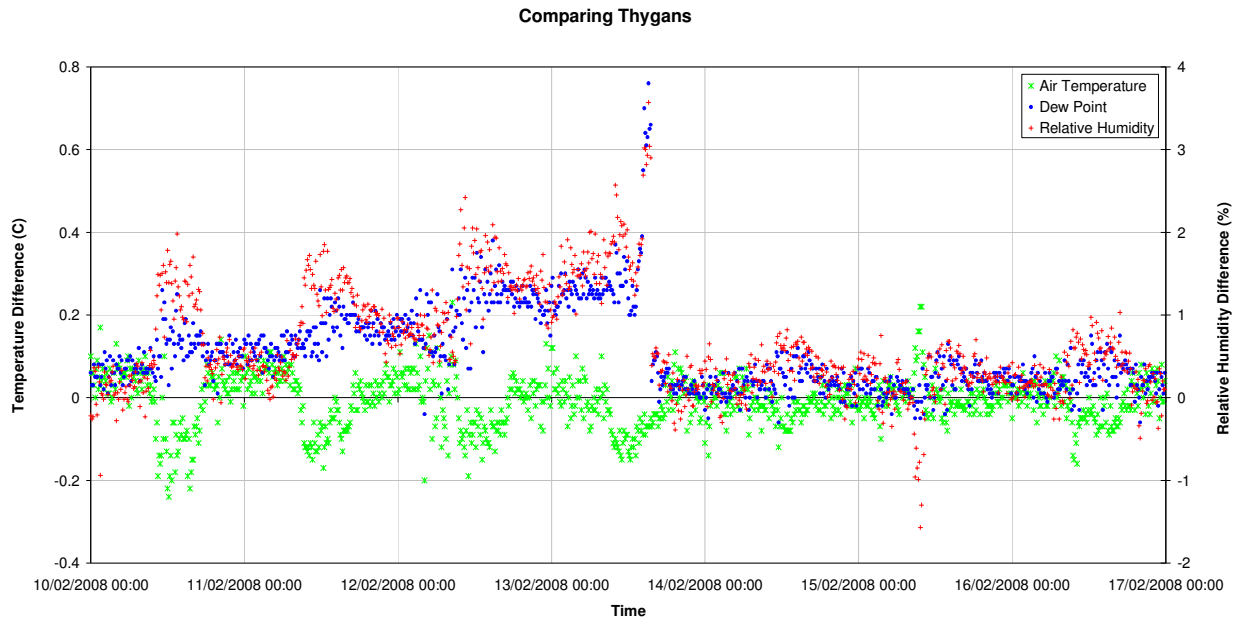
**Figure 1: Instrument comparison data for two Thygans over week 9**

	Average Difference	Standard Deviation
Air Temperature (C)	0.03	0.08
Dew Point (C)	-0.01	0.08
Relative Humidity (%)	-0.2	0.4

**Table 1: Summary of Thygan Comparison Results**

Instrument differences have been seen to correlate with solar radiation. In Figure 1 data for 25-27 March 2008 showed a diurnal variation in instrument air temperature and dew point differences, which in turn caused differences and increased scatter in relative humidity. Solar radiation was high on these three days compared to the rest of the period covered in Figure 1. These differences could have been due to exposure differences as the instruments were mounted on the north and south side of a screen stand.

Occasionally the dew point measurements drifted off over a period of time and the mirror cleaning system did not detect this. Figure 2 shows a typical occurrence. The dew point differences and hence relative humidity differences can be seen to steadily increase over the course of several days.



**Figure 2: Dew point drift error**

The error accumulated until a mirror clean was triggered for another reason. (The mirror clean comprised a leather coated disk being wiped across the mirror.) In Figure 2 mirror cleans occurred at 15:20 and 15:40 on the 13<sup>th</sup> February. Afterwards both instruments were back in good agreement with each other. There were other occasions when the mirror cleans occurred at significantly different times on the two instruments. These difference data collected at these times showed that both instruments were susceptible to this problem, though one was greater than the other and caused the dew point to drift in the opposite direction. However, once both mirrors were cleaned there was good correlation between the instruments again. It should be noted that these differences were fairly small and air temperature measurements were unaffected.

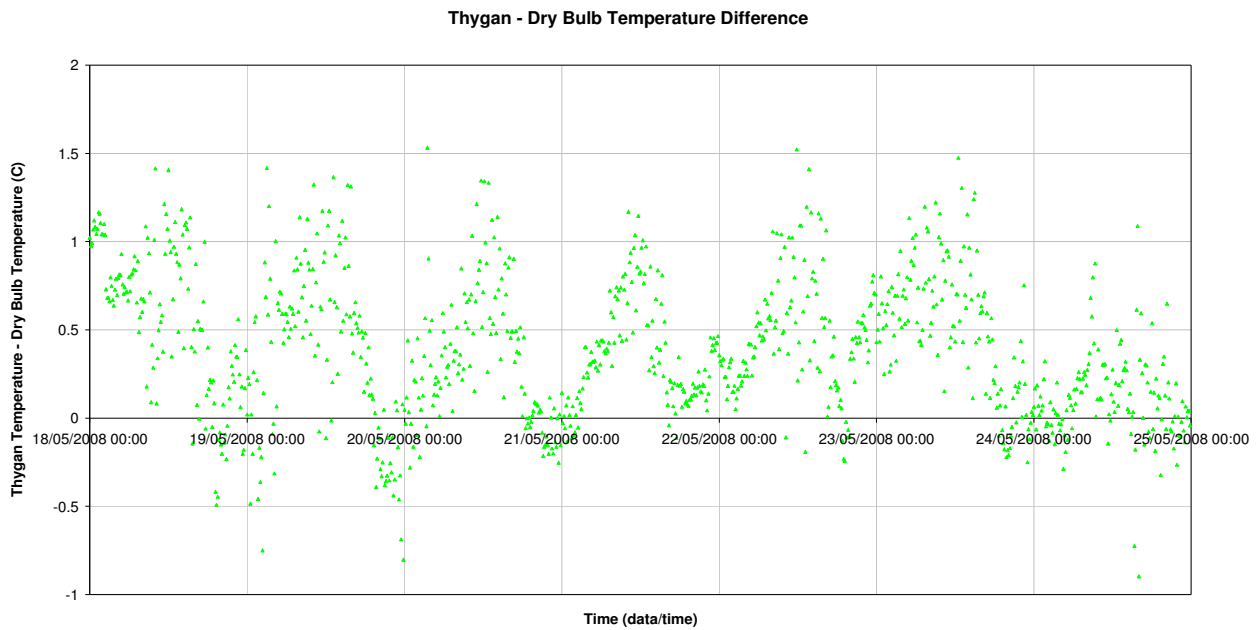
An automatic mirror clean currently occurred around once per week. However, it is possible to make this more frequent and a daily clean would be frequent enough to ensure the dew point error never reached a significant level, as long as this would not shorten the life of the instrument.

### 3.1.2 Thygan Air Temperature Measurement

The Thygan air temperature measurement did not always correlate well with the screen temperature from the dry bulb.

Figure 3 indicates a temperature comparison between the Thygan and the screen dry bulb temperatures. The difference here has a strong diurnal component, with the Thygan reading up to 1.5C warmer than the screen in the middle of the day and up to 0.5C colder at night. This was a surprise as the Thygan is an aspirated instrument. It is intended to investigate this effect further by comparing against an aspirated air temperature thermometer.

The temperatures from this screen and another one nearby were compared and agreed well.



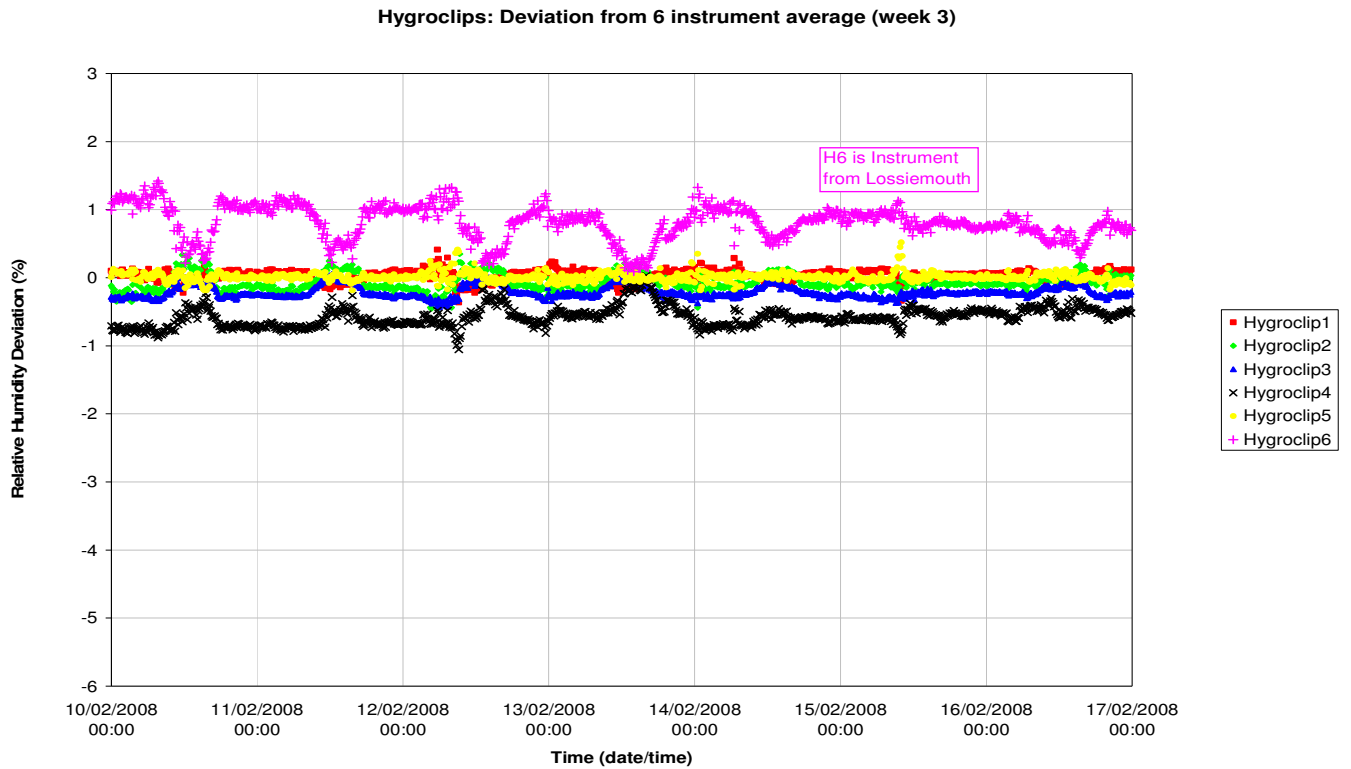
**Figure 3: Thygan Dry Bulb Temperature Difference (May)**

The Thygan measures dew point directly and then calculates humidity using the measured air temperature. Since there is such a large difference between Thygan air temperature and the screen temperature the humidity data will be significantly different and cannot be directly compared. The solution was to use the screen temperature to calculate the humidity.

### 3.1.3 Hygroclips

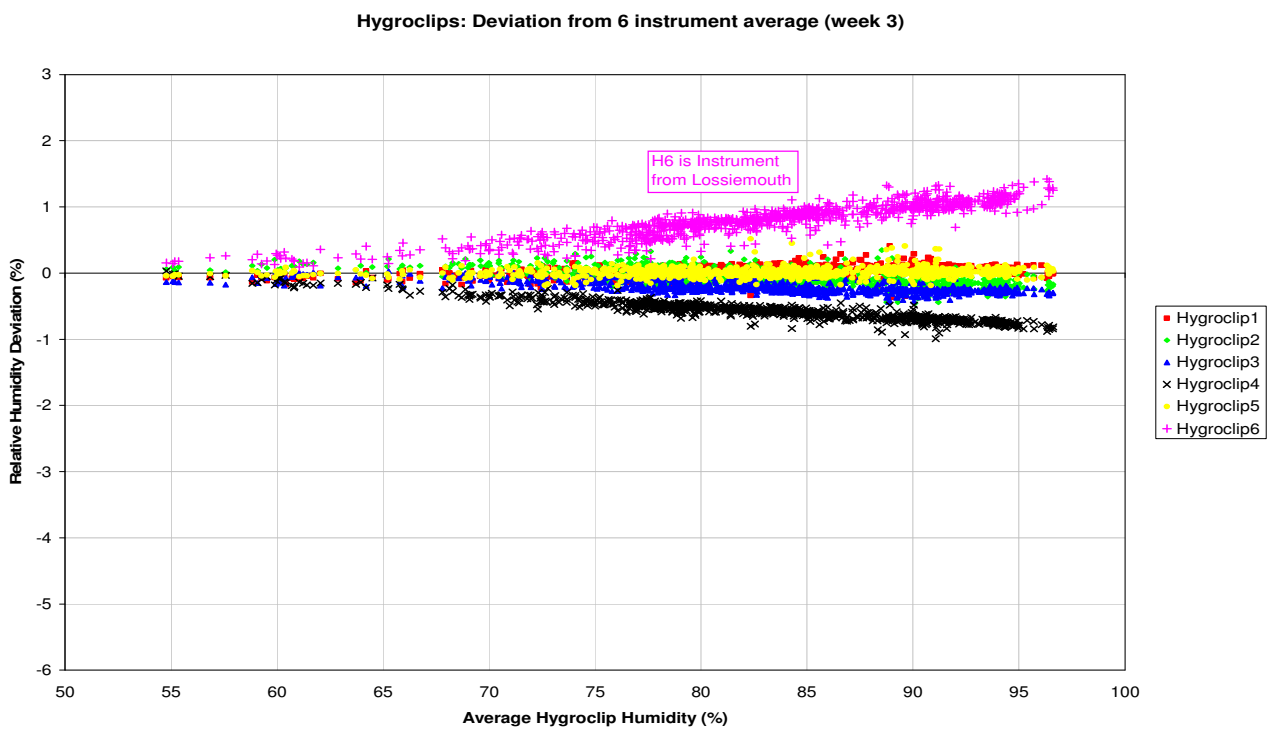
The Hygroclip performance in isolation could be assessed by comparing the humidity measured by each instrument with the average of all six instruments acting as a virtual instrument. This form of comparison indicates the consistency of the instruments.

Figures 4 and 5 show typical data from week 3, with the difference from the 6-instrument average plotted against time and average relative humidity. Hygroclips 1-5 were new instruments. Hygroclip 6 was the instrument previously deployed at Lossiemouth outstation.



**Figure 4: Individual Hygroclip deviation from average relative humidity as time series(week 3)**

Figure 4 indicates that all the instruments differ from the average by less  $\leq \pm 1.5\%$  and by  $\leq \pm 1\%$  without the Lossiemouth instrument.

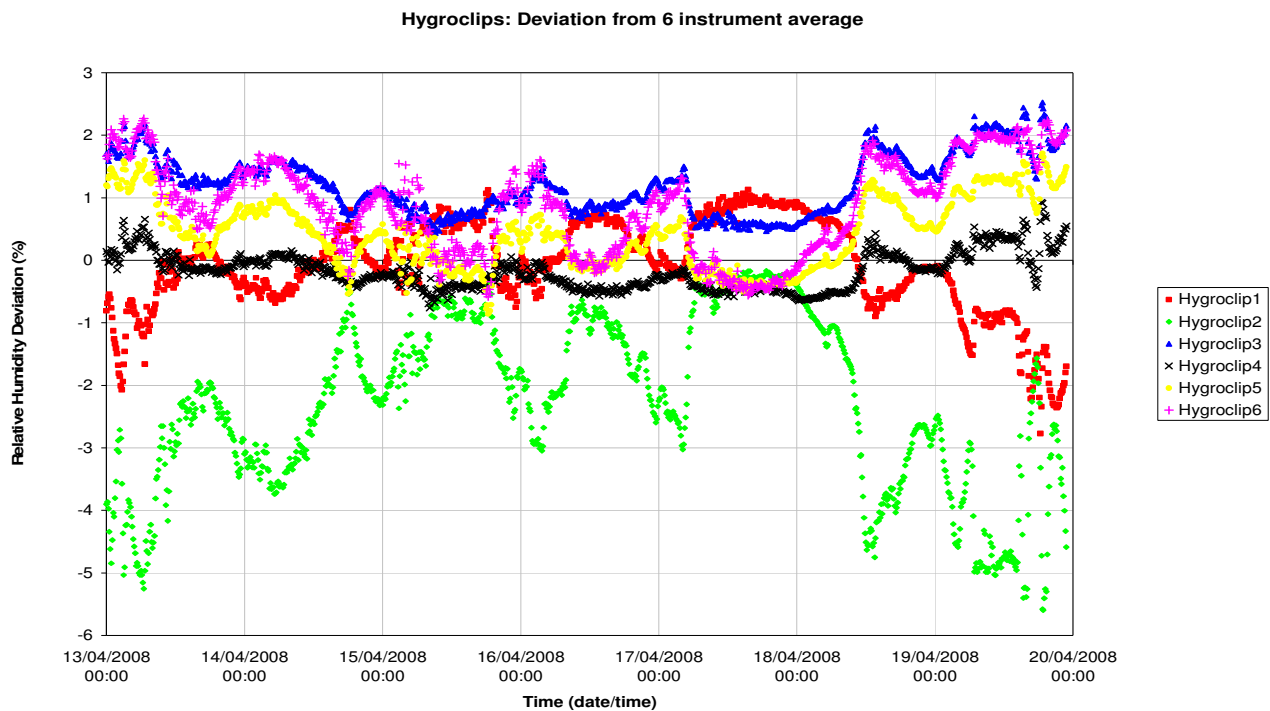


**Figure 5: Individual Hygroclip deviation from average relative humidity plotted against average relative humidity (week 3)**

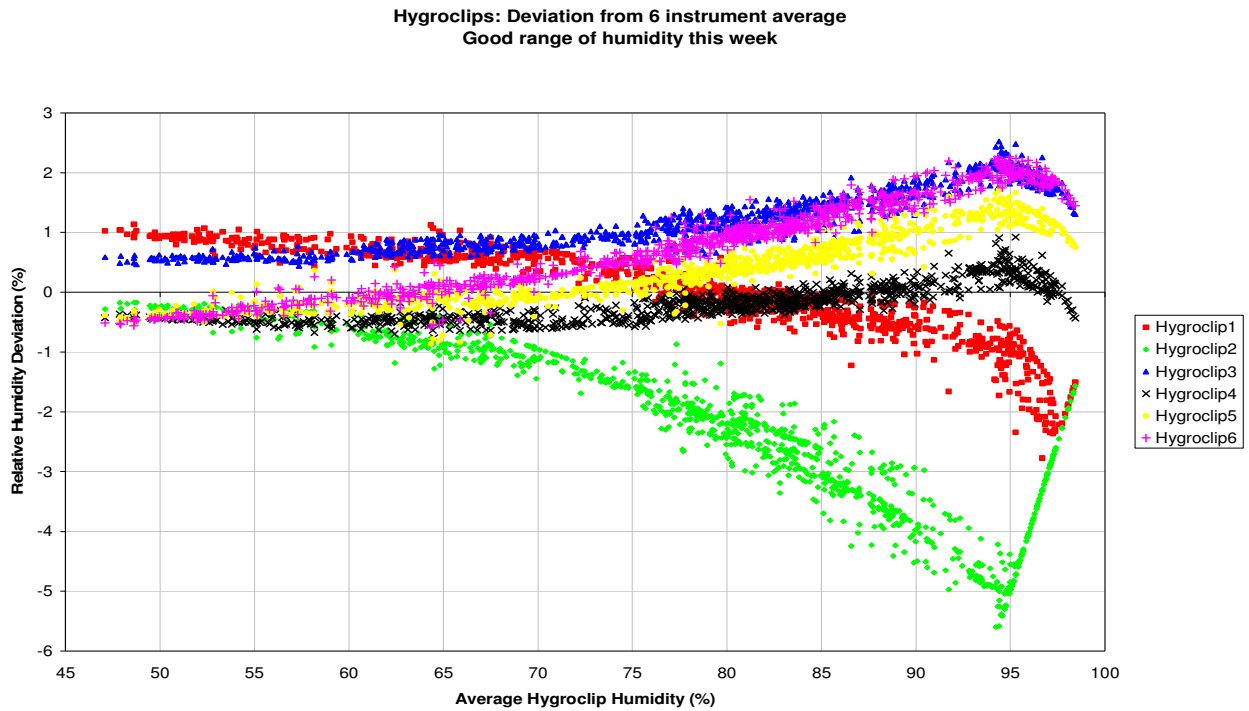
Figure 5 indicates that there is a clear correlation between relative humidity and the variation between sensors. The greatest spread was at high humidities and the best correlation at low humidities, when all the instruments tended to a single asymptote. Four of the Hygroclips were very consistent; better than  $\pm 0.5\%$  and the other two were still within  $\pm 1.5\%$ . The instrument from Lossiemouth was most different, but not significantly so. There was no change in this relative performance during the first five weeks of the trial when these six instruments were deployed together. It should be remembered that at this stage that the instruments were only being compared against each other.

During the next ten weeks of the trial, the instruments in positions Hygroclips 1 and Hygroclip 2 were replaced with two instruments previously deployed at outstations. These two had also exhibited significant humidity differences from the operational psychrometer.

Figures 6 and 7 showed how these instruments performed during week 12.



**Figure 6: Individual Hygroclip deviation from average humidity as time series (week 12)**



**Figure 7: Individual Hygroclip deviation from average relative humidity against average humidity (week 12)**

Hygroclips 1 and 2 response was significantly different to the other sensors at high humidities. At low humidities, Hygroclip 1 also tended to a different value than the other instruments. Due to the significantly different performance of these two instruments the performance of the other instruments must be interpreted with care when comparing with the average of six instruments.

Hygroclips 1, 2 and 6 which have been previously deployed at Aberporth, St Mawgan and Lossiemouth, drifted away from the rest of the batch during their year at these locations. Rotronics have commented that periods of saturation can change the calibration and this limits the time the instruments can be left in field before having their calibration checked. It should be noted that the change in calibration is most pronounced at higher humidities.

Hygroclips 3-6 were still broadly similar and only varied over a  $\pm 2\%$  range.

There was little change in the relative performance of the Hygroclips over the 10 weeks.

By week 12, Hygroclip 3 had started to show a change in the performance. At low humidities, it tended to a different asymptote to Hygroclips 4-6. Also as the trial progressed this particular instrument began to output more and more data that was different to the other Hygroclips. Hygroclip 3 was also found to have a temperature offset of around  $-1^{\circ}\text{C}$  and another had significant scatter.

Rather than failing completely, Hygroclip 3 partially failed by outputting apparently valid humidity and temperature data, but which were significantly different to those from the other Hygroclips. When returned to QA Lab, the connector between the sensor and the handle was found to be damaged. During retest by QA Lab, the connector broke completely. However, by using an improvised connection, humidity and temperature performance were able to be retested and were found to be within specification. Therefore the connector was likely to be the cause of the failure.

The Hygroclip instrument comprises two parts, a sensor and a handle. Previous investigations by QA Lab have found that although the two parts are supposed to be interchangeable with no impact on performance, this was not always the case. Met Office operational procedure is to calibrate a

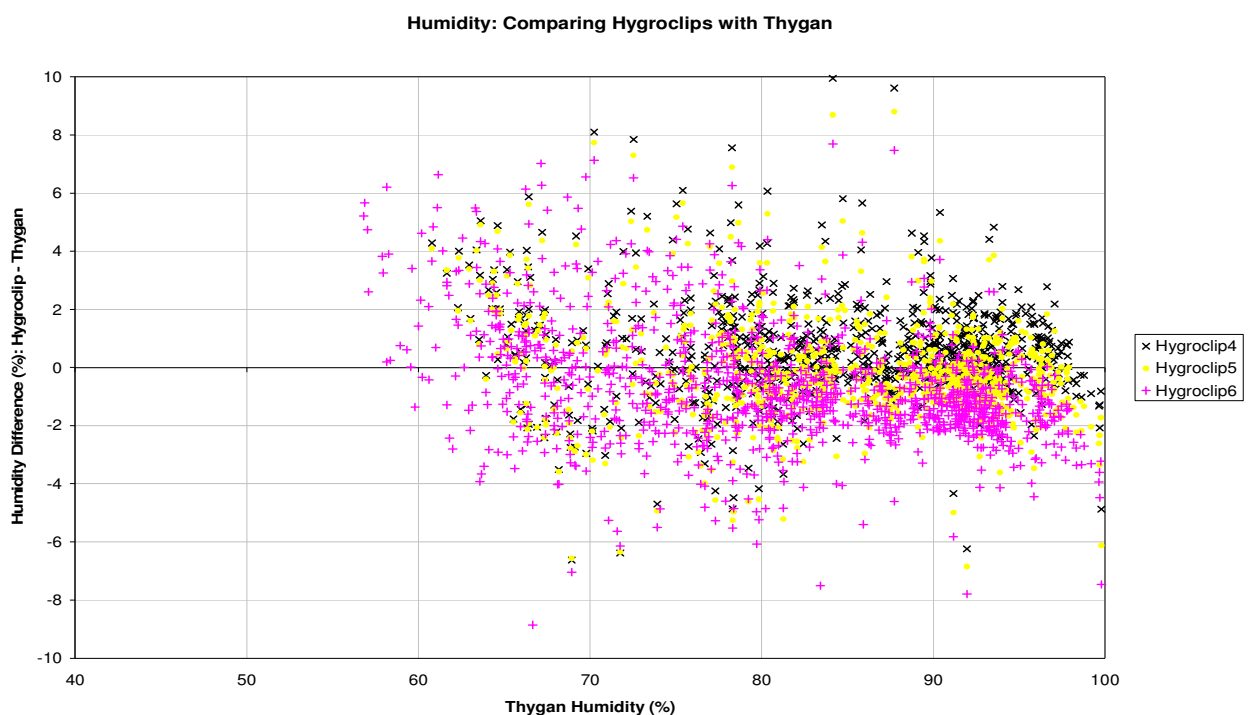
handle and sensor as a pair and deploy them as a single instrument. No interchanging of sensors and handles occurs. During this trial it was found that during installation that two sensors were connected to the wrong handles. This was rectified during a later check of instrument pairs. However, this did mean that data was obtained for both sensor/handle combinations. The results showed that as would be expected, the sensor performance was mainly linked to the sensor.

Due to the erratic behaviour of Hygroclip 3, the instrument was replaced with a new instrument during week 16. Both instruments in position 3 were found to perform very similarly. Particularly unusual was that at low humidities, both instruments tended to a value around 1% higher than the other Hygroclips.

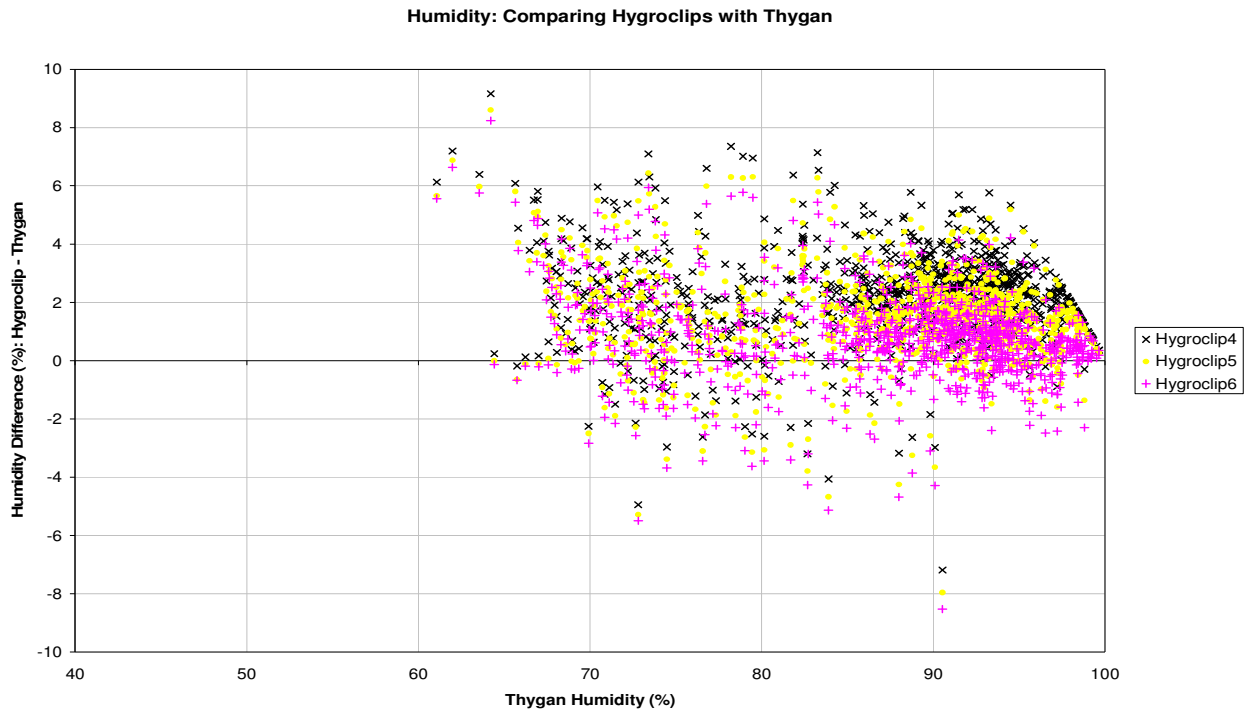
### 3.2.1 Hygroclip vs. Thygan

This is another instrument comparison which must be made with care. The Hygroclips are screen-exposed and non-aspirated whereas the Thygan have their own radiation screen and are aspirated instruments. The options were to compare dew point, or calculate Thygan humidity using Thygan dew point and screen dry bulb temperatures. For consistency, humidity comparisons have been chosen here.

Given that the Thygans have consistent performance throughout the trial, this instrument comparison was the best way to show if there had been any gradual changes in the Hygroclip performance. For this comparison, only Hygroclips 4-6 were considered as these have been deployed for the longest period of time. Figures 8 and 9. Indicate Thygan, Hygroclip differences for weeks 1 and 29 for these three Hygroclips.



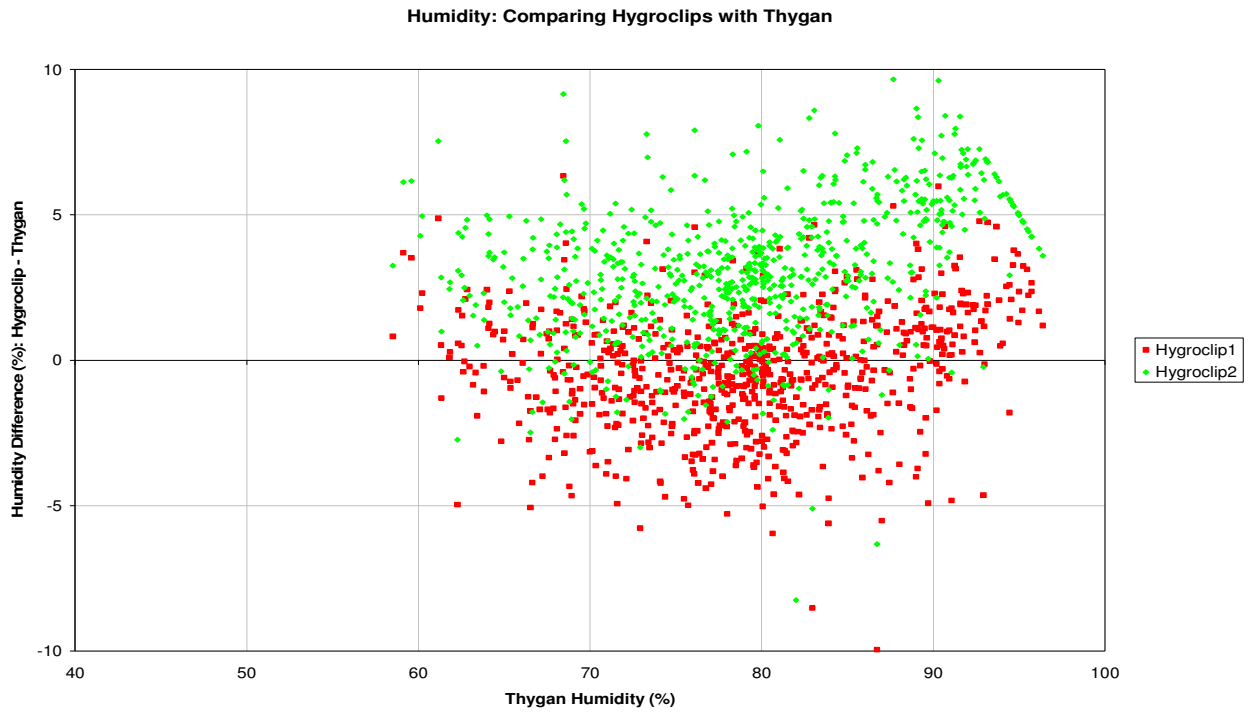
**Figure 8: Hygroclip Thygan Humidity Difference vs. Humidity (week 1)**



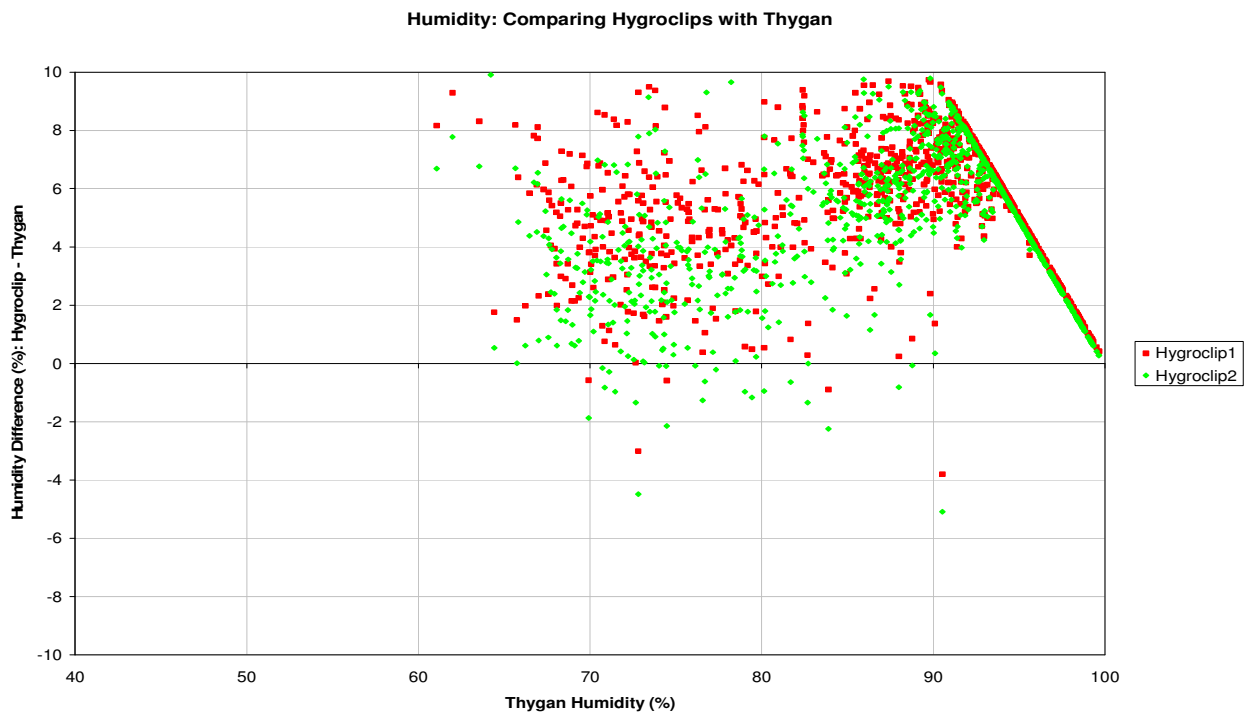
**Figure 9: Hygroclip Thygan Humidity Difference vs. Humidity (week 29)**

There is a clear change in the instrument differences over this 29 week period, as can be seen by the upward drift of the Hygroclips in Figs 8 and 9 above. Assuming that the Thygans have remained consistent during the trial, the Hygroclips must have drifted by +1% to +2%. Although the data is not shown here, data for weeks 3 and 28 indicates the same change. Similar behaviour was seen in previous work and in QA lab tests. This means that if an instrument was already 1% high when it was deployed and then drifted high 2% during deployment then it would end up 3% high and out of specification. This was the case for Hygroclip 4 which was already approximately 1% too high in week 1, and approximately 3% too high by week 29 and therefore outside the acceptance limit of 2%. An instrument that started its deployment 1% low in relative humidity, would not suffer from this problem.

Figures 10 and 11 indicates the change in performance of Hygroclips 1 and 2 between weeks 6 and 29.



**Figure 10: Thygan Hygroclip Instrument Differences (week 6)**



**Figure 11: Thygan Hygroclip Instrument Differences (week 29)**

Hygroclip 1 and 2 had a much poorer correlation with Thygan humidity in the first place, especially at high humidities. The correlation can be seen to have become worse throughout the duration of the trial. There is a particularly large increase in offset for Hygroclip 1.

These sensors were seriously out of specification at most values of relative humidity by the end of the trial. Indeed Hygroclip 2 was out of specification at higher humidities at the beginning of the trial.

### 3.3 Saturation

Performance of the Hygroclips during and after saturation was a particular area of concern. Previous trials had found that the Hygroclips were slow to recover in these circumstances.

There were several occasions of prolonged saturation. Figures 12 and 13 indicate the onset of saturation and the end of saturation in more detail. The graphs shows data from the psychrometer, and average of the two Thygans and six Hygroclips. The correlation between the two Thygans has been shown to be good enough that the average is representative of both instruments.

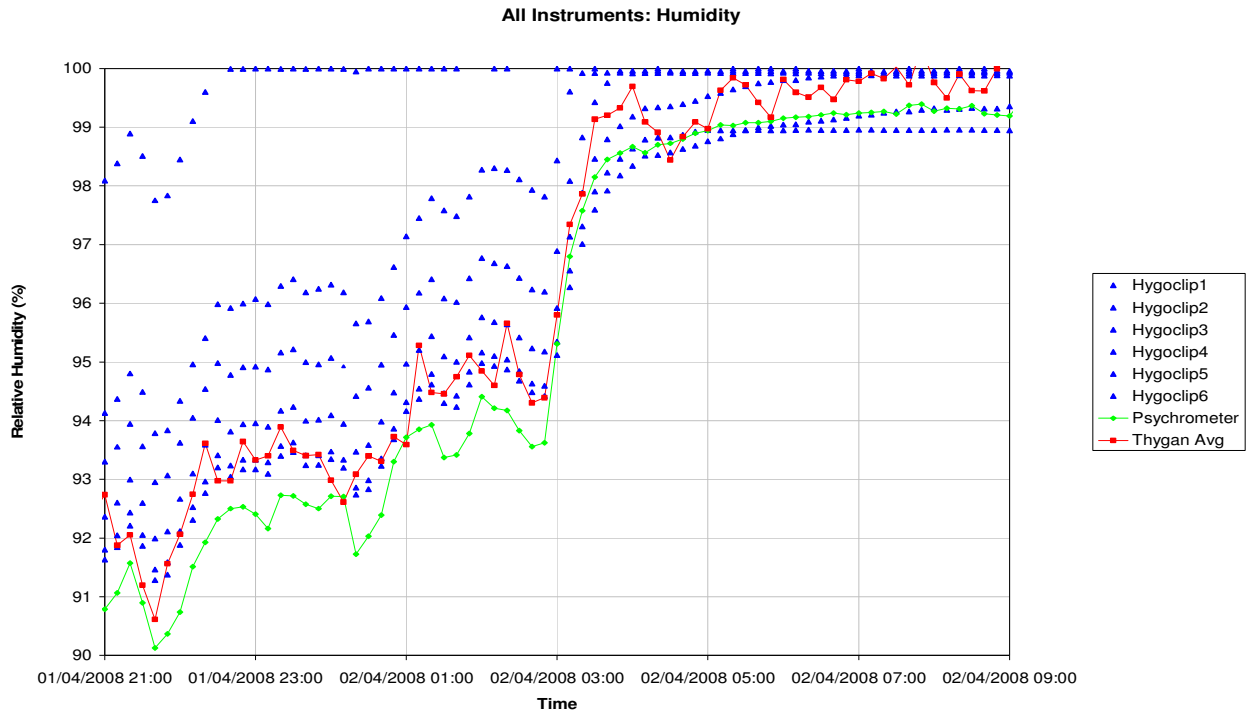
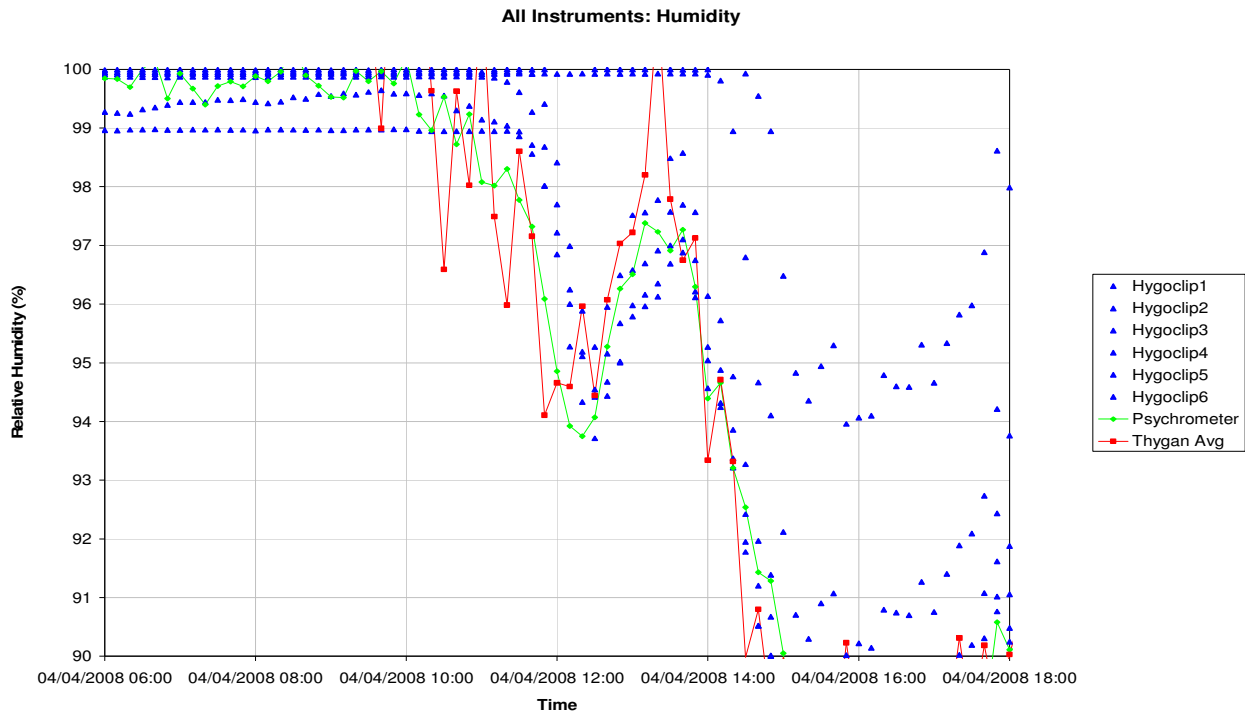


Figure 12: All Instruments Humidity Output Approaching Saturation



**Figure 13: All Instruments Humidity Output Approaching Saturation**

Hygroclip 1 reached saturation 5 hours earlier than any other instrument and Hygroclips 1 and 2 both took 4 hours longer to recover from saturation. However, earlier results have already shown that the performance of these two instruments was significantly different to the other Hygroclips. The other Hygroclips recovered from saturation approximately 1 hour after the Thygans and the wet and dry bulbs.

## 4 Conclusions

Thygans have already been selected as a WMO working reference instrument. The two instruments generally correlated well with each other. However, at the moment, a few outstanding issues remain. A small dew point error occurred over time and at the moment the cause is unknown. A daily mirror clean would stop this error developing to a significant level as long as this does not shorten instrument life.

The Rotronics tend to drift high with time, in the case of this trial by 1% to 2% with the newly deployed instruments and by approximately 5% in the case of Hygroclip 1.

Increasing amounts of solar radiation has an impact on the Thygan air temperature measurement compared with that of the screen. This needs to be further investigated in comparison with an aspirated air temperature thermometer.

Five Hygroclips drawn from stores initially agreed within  $\pm 2\%$  of each other. During the trial it has been shown that their greatest divergence between themselves was at high humidities and their least at low humidities.

Of the three Hygroclips returned to HQ from outstations, two performed badly, mainly at high humidities. The third Hygroclip performed similarly to the other Hygroclips which were new at deployment and within specification at that time.

Temperatures derived from the Hygroclip were similar to those from the dry bulb. However, one instrument gave a temperature around 2C below the others. Another instrument produced temperatures with a significant amount of scatter.

One Hygroclip failed due to broken connector. The failure may have been difficult to detect if this instrument had been deployed without another instrument to measure humidity.

Instrument performance after saturation was a particular area of concern. The Hygroclips lagged behind the Thygans by between 1 and 4 hours, recovering from saturation. This confirms earlier work done.