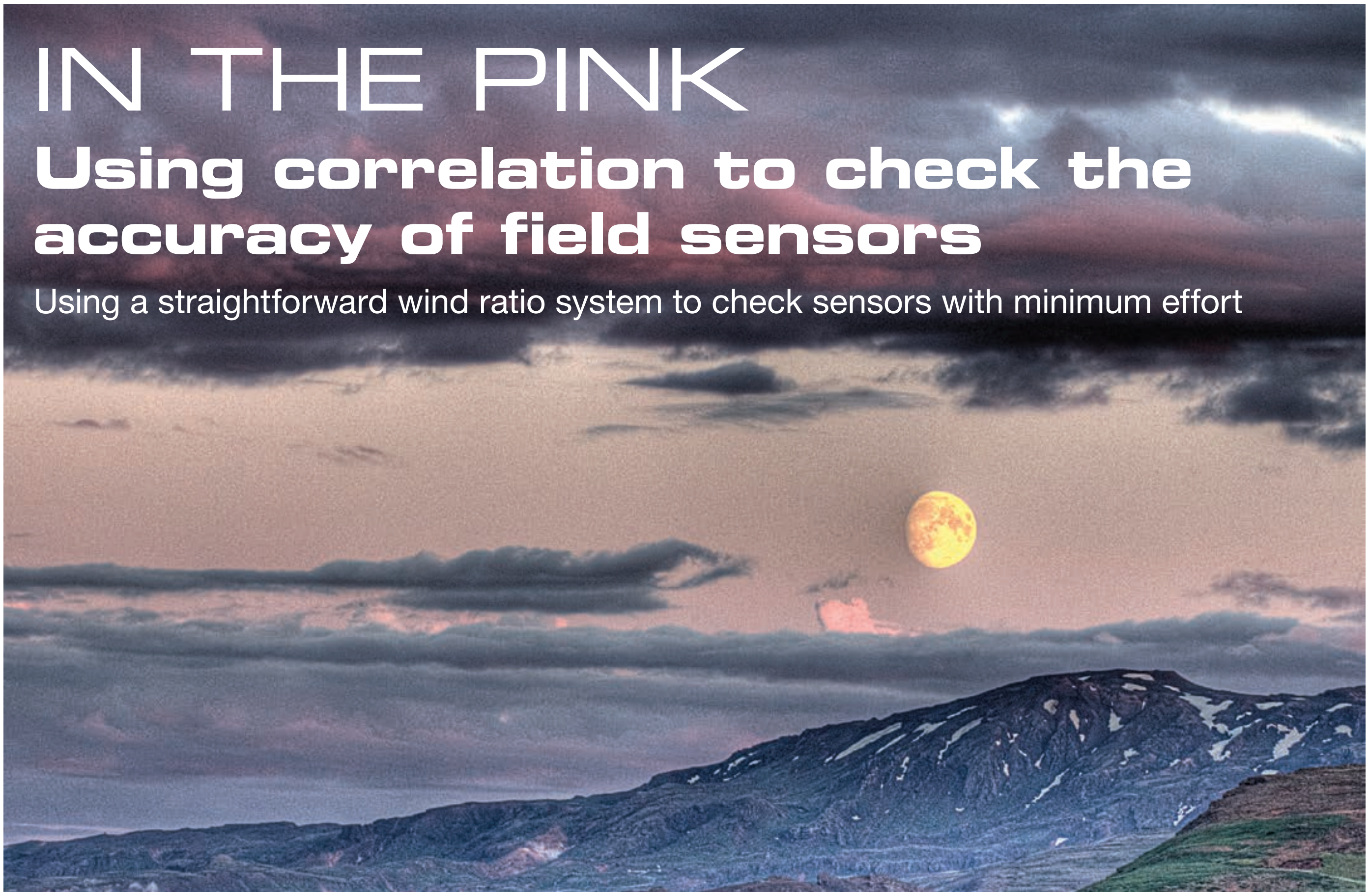
by Andres Thorarinsson

IN THE PINK

Using correlation to check the accuracy of field sensors

Using a straightforward wind ratio system to check sensors with minimum effort



Field sensors, such as those that measure weather elements, are vital pieces of technology, and it is essential that readings can be totally trusted to be accurate. However, it is not uncommon that readings from field sensors are not quite as accurate as they should be, and various methods of checking sensor accuracy with minimum effort are being explored.

One straightforward method is to check how well a sensor reading is correlated with other nearby sensors. This may not be the most accurate method, but it will at least indicate how the questionable sensor behaves relative to others in the area. If the sensor behaves like those sensors nearby, and the other sensors have not given any reason to doubt their own readings, then at least it is unlikely that the sensor in question has faults that the others do not have. If the others are found to be accurate, then the sensor in question can also be considered to be okay. An additional benefit of such a correlation is that sensor faults that were unknown before can be discovered. This way of thinking does not replace regular maintenance work or sensor calibration, but it may make maintenance work easier.

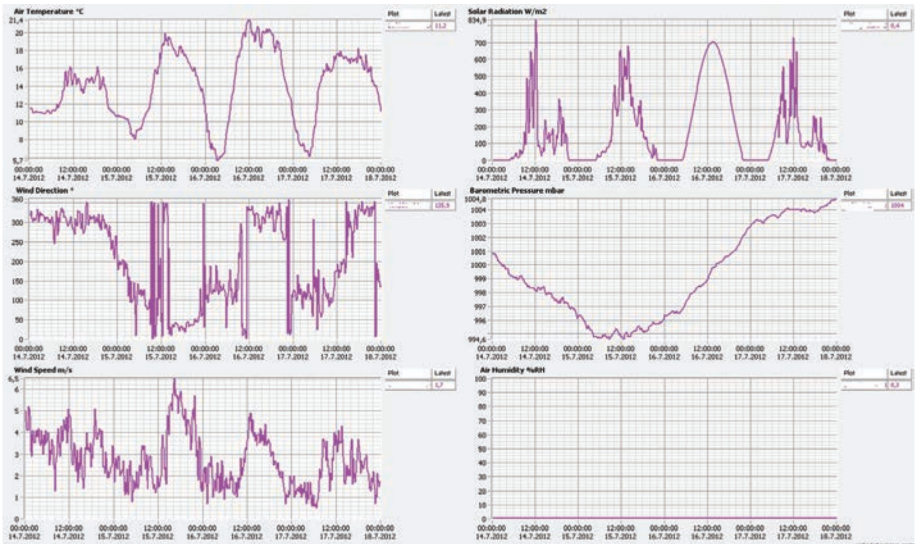


Figure 1: Weather station equipped with classical instruments, showing measured data for a few days in July 2012

Iceland case study

A case study has been conducted at a weather station in Iceland located some 5km from the seashore and 90m above sea level, with the aim of finding out if its sensors are trustworthy. With regard to reference sensors, there is access to data from other weather stations in the nearby area.

The first step is to check the wind directional sensor, which has a built-in amplifier that will convert the direction

> "The sensor at 90m ASL shows 10-15% higher wind speed than the one at sea level"

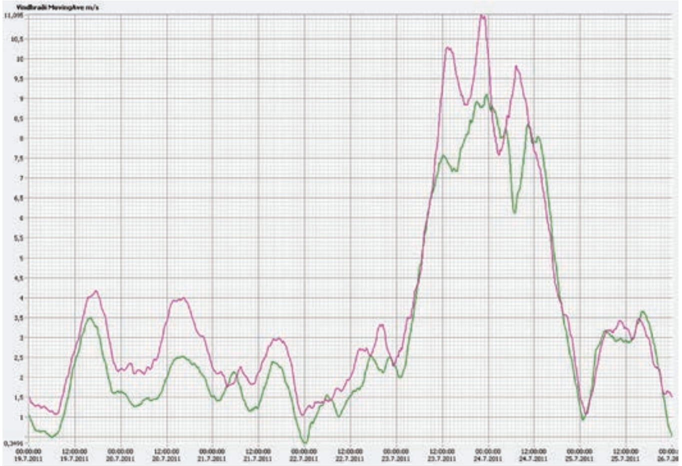


Figure 2: Wind directional data from four sensors for a week in February 2012. Our sensor is the pink one. Blue is 30km away, orange is 15km away, and green is 5km away

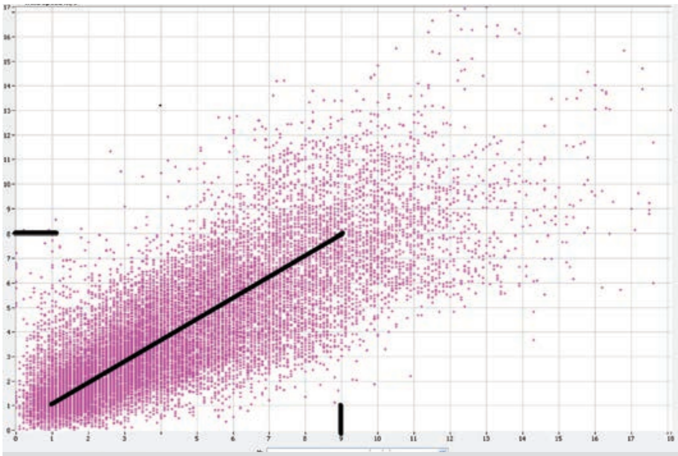


Figure 3: Windspeed data from the two windspeed sensors for a week in July 2011. Our station is the pink one. The pink trend line is always indicating higher windspeed than the green one

0-360° into 0-2.5V DC voltage output before connecting to a 0-2.5V input of a data logger to be rescaled in the data logger's program, therefore doubling the risk of calibration error in hardware and software.

As a check, it is critical to compare the pink wind directional sensor readings with three nearby weather stations located 5km, 15km, and 30km away.

Considering the distance between the sensors, the correlation between them is a lot better than expected, and this indicates that the wind direction in the open area is quite steady. This demonstrates that the pink wind directional sensor is just as good as the others and is working as expected.

Windspeed

It would be easy to think that windspeed as measured by two nearby sensors would be almost the same. In this study, the windspeed sensor is 90m above sea level (ASL) and the windspeed reference sensor is 5km away and close to the seashore.

As expected, the windspeed sensor at 90m ASL indicates higher windspeed than the one at sea level. In order to see if that is always the case, an XY diagram is useful.

In general, and as expected, the sensor at 90m ASL shows 10-15% higher windspeed than the one at sea level, but there are large variations. This research is aimed at establishing whether the windspeed sensor is working as expected and the results here offer no reason to believe otherwise.

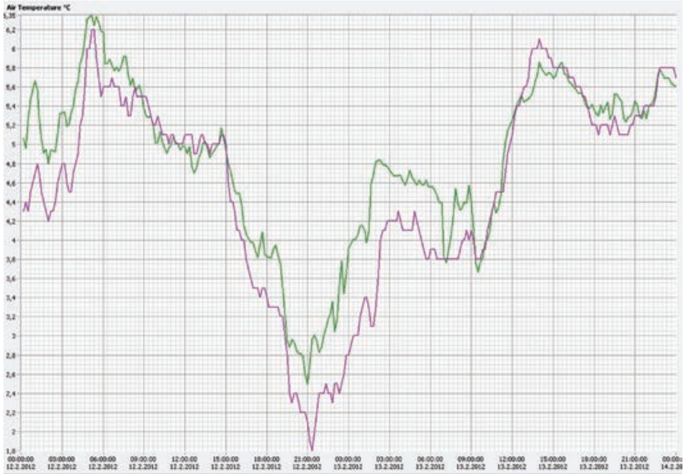


Figure 4: Correlation between temperature sensor at 80m ASL (pink line) and a temperature sensor at sea level (green line) during winter weather of three days in February 2012. Correlation is very good

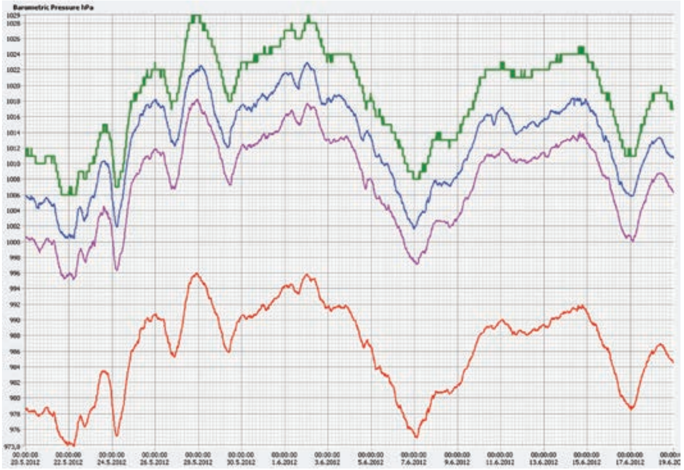


Figure 5: Barometric pressure at four locations at different height and spread over 40km for one month of the summer of 2012. The green line is readings from the sensor located at sea level

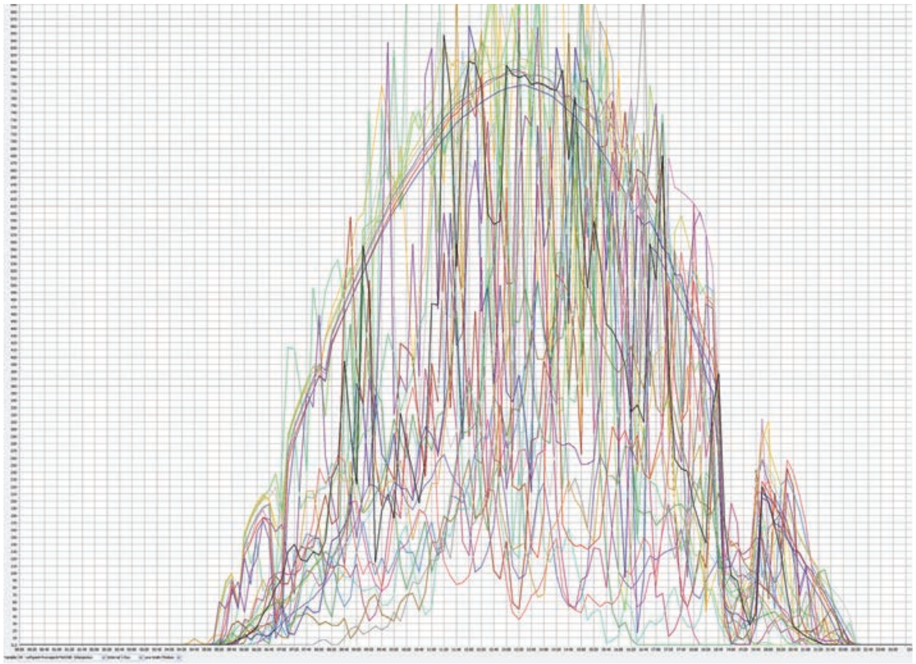


Figure 6: The solar radiation drops every night at 7pm because of the shadow by the sensor pole itself

Solar radiation

Solar radiation sensors are straightforward instruments with no moving parts, which, if correctly mounted, should show the same readings under the same conditions. Identical conditions are easiest to find on sunny days with no clouds. If there are any clouds in the sky, the radiation level drops fast, so it should be easy to see if calibration of all solar radiation sensors is the same.

In the figure on the previous page (top left, figure 2), the Vista Data station is indicated by the pink trend line. Its readings are 8-10% lower than those of the other two. As the shape of the pink line is normal, it would be tempting to think that the pink sensor should be recalibrated (i.e. have its magnification factor in the data logger increased by 8-10%). It is, however, quite possible that the pink sensor is the correct one and the others show readings that are too high. The lower blue readings in the afternoon may be caused by the nearby roof to the west. The result of this has been to dismount one of the radiation sensors, compare it with a newly factory calibrated sensor, and then correct the others as well.

This exercise did reveal weakness in the installation of the blue sensor as the drop at 19.00hrs is not caused by clouds but by the shadow of the sensor pole itself, which is badly situated; this becomes clear on an overlay graph of the readings, (see figure 6 above). This error adds to the fault of the 'close-by roof' to the west which lifts the horizon by 15°. The graphs then show other obstacles affecting the sensor in early morning.

Air temperature

When comparing the air temperature readings of the observational weather stations (pink line) to the readings of the reference station at sea level 5km away (green line), it might appear that the pattern is similar but days are warmer and nights are colder at 80m ASL than at sea level. But this knowledge does not help in terms of finding out if the temperature sensor is likely to be correct.

When visiting the sensor sites, it becomes clear that while the (green) air temperature sensor at sea level is mounted in a ventilation grill on a free-standing mast, the (pink) temperature sensor in its ventilated grill is actually located only 1.5m above the roof of the instrumentation hut, therefore being affected by the warm air of the roof when the sun is shining. Therefore, for the sake of checking the correlation between temperature sensors, one could pick a period of time in the winter with no sunshine and at least a light breeze.

The conclusion of this is that the temperature sensor is working fine, but the installation needs to be modified in order not to be affected by the hot roof of the instrumentation hut on sunny days.

Barometric pressure

There are four barometric sensors in the area: the sensor to be checked at 90m ASL (pink); the one at sea level (green); the one that is 30km away and 45m above sea level (blue); and the one that is 15km away and 280m ASL (red). The trend lines all have similar shape, but are shifted vertically. However, are all the sensor readings correct or is it possible that one or more are faulty?

For the most part, the solution discovered has been the height difference between the barometric sensors. One is at sea level, one at 45m ASL, one at 90m ASL, and finally one at 280m ASL. By calculating the change in air pressure as function of height, it turns out that, relative to sea level, the barometric pressure should be lower by 5.3hPa at 45m ASL, by 10.6hPa at 90m ASL, and by 32.6hPa at 280m ASL. Therefore, by subtracting the sensor readings from the green one at sea level, the difference should indicate this air pressure drop. What is most interesting is that the average difference is exactly as expected – 5.6hPa, 11hPa, and 33hPa, which is 5% or closer to the calculated difference.

The conclusion of this study is that it may not be possible to know if the barometric pressure sensor is correct or not, but it does seem that it correlates perfectly with the others. Therefore, either all are wrong, or all are correct. ∎

Andres Thorarinsson is the CEO of Vista Data Vision based in Reykjavik, Iceland.