Use of Ultrasonic Wind sensors in Norway

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ABSTRACT

During the last few years the Norwegian Meteorological Institute (met.no) has mounted several ultrasonic wind sensors (Gill WindObserver and Windsonic) in Norway. The sensor has no moving parts and is almost maintenance free, which makes it suitable for extreme environments as typical along Norway's coastline and in the country's mountainous areas.

Data from all ultrasonic wind sensors in the Norwegian meteorological station network have been analyzed, resulting in a comprehensive study of the sensor characteristics during all kind of weather conditions. Some of the data show unrealistically high gust values. Frost build-up, sleet, and strong precipitation events could be identified as possible reasons. The paper describes the setup and presents the results of this extensive sensor study.

1. INTRODUCTION

The Norwegian Meteorological Institute (met.no) is responsible for collecting data from around 200 automatic weather stations in Norway and Spitsbergen. Most of them observe wind speed and wind direction. Several types of instruments are in use. The conventional cup anemometers and wind vanes require a relatively large amount of maintenance, especially in maritime environments. They occasionally freeze during winter and underestimate the wind speed in heavy snow and sleet. Ultrasonic wind sensors are very robust with no moving parts. Sensors with heating also reduce the risk of icing. These are the main reasons why met.no decided to use ultrasonic wind sensors (Figure 1) on new automatic weather stations. In January 2010, the number of ultrasonic sensors in the Norwegian meteorological station network were 33 Gill WindObserver II and 5 Gill WindSonic (at solar/battery powered stations).

Figure 1: Gill WindObserver II (with de-icing system) to the left and Gill WindSonic (without heating) to the right.

2. DATA ANALYSIS AND DISCUSSIONS

The purpose of this study was to evaluate the reliability of the ultrasonic sensors in the Norwegian weather station network, and to test their performance during the winter season, especially at places where instruments encounter icing-problems. The Gill WindObserver II is equipped with a de-icing system, whereas the Gill WindSonic works without any heating. The WindSonic sensors are used at solar/battery powered stations in Norway.

The data used in the study were collected from 38 automatic weather stations with ultrasonic wind sensors. All stations collect hourly data, and they are situated along the coastline, in the mountains and inland. Ten min mean wind speed (FF), maximum FF during the last hour (FX), maximum 3 second gust (FG), wind direction (DD) and temperature (TA) from the period February to December 2009 were used in the analysis. Just one of the stations had additional wind measurements with another type of wind sensor.

The study focuses on unrealistically high gust values (FG), called outliers, because this is an easy way to evaluate quality of data on stations with just one wind sensor. FG is almost linearly correlated with FX. Depending on the topography, FG is rarely larger than 2.5 times FX. All values with FG/FX > 2.5 are considered as outliers. When FX < 5 m/s, then FG has to be larger than 15 m/s to be considered as outlier. Linear regression has also been used to find outliers. If FG is larger than 5 or 6 times the standard deviation of the linear regression, then it is marked as an outlier. Outliers are marked with red circles in the scatterplots.

Some possible sources of errors:

- Technical problems with the equipment
- Rime, ice or snow on sensor
- Electromagnetic noise from external sources.

2.1 Gill WindObserver II

Thirty-three stations operate Gill WindObserver II. Eight of these stations showed occasionally very high gust values (outliers). For situations with outliers, we analyzed simultaneous measurements of temperature, humidity and precipitation, in order to identify possible reasons for the high gust value. For stations without own precipitation record, data from neighboured stations were used to analyze any correlation with precipitation. At 3 of these stations we found clear indications for icing problems. All three are placed in mountain areas. Also 3 stations placed in coastal areas showed large gust values, but this was not significantly correlated to precipitation, temperature or humidity. Supplementary data is needed to identify a probable cause.

Cause of error	Stations in mountain area	Stations in coastal area	Stations inland	Total number
Icing, rime, snow	3	0	0	3
Technical problems	1	0	1	2
Unknown problems	0	3	0	3
Total	4 (of 6)	3 (of 13)	1 (of 14)	8 (of 33)

Examples of stations with icing problems:

Finsevatn (1210 m.a.s.l. in Southern Norway) showed large gust values in two cases during autumn/winter 2009 (Figure 2 and 3). In both cases the temperature was below 0 ºC and the humidity was high. This is a typical situation where riming occurs. Finsevatn is located nearby a river and the area is known for sudden occurrence of frost and rime especially during autumns.

Hasvik – Sluskfjellet (438 m.a.s.l. in Northern Norway) also experienced icing problems (Figure 4). This station is located on top of a small mountain near the coast. The temperature was below 0 ºC in all cases (Figure 5), and other surrounding stations observed precipitation. Data occasionally dropped out during such situations. A picture taken in October 2009 shows an ice-layer covering the sensor.

As a result of this study, met.no will replace the wind sensor at these stations with another Gill model with more powerful heating.

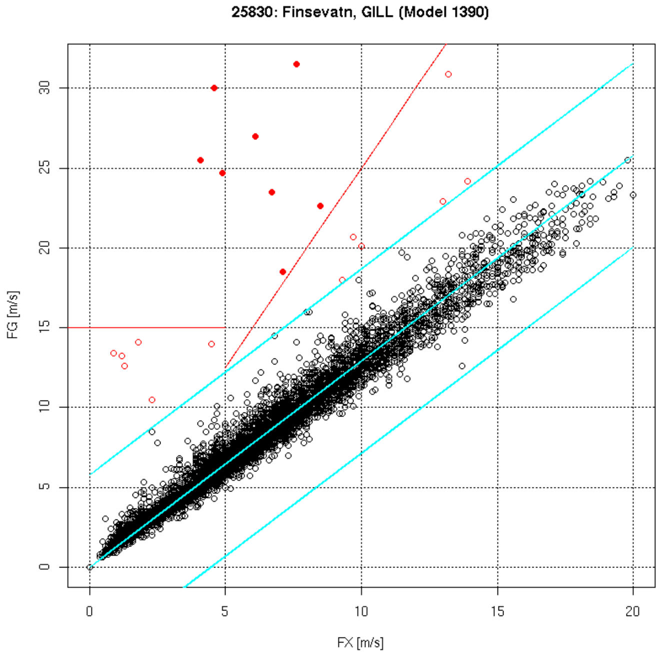

Figure 2: Scatter plot, maximum gust (FG) versus maximum wind speed (FX) for Finsevatn station (1210 m.a.s.l). Linear regression line with 5 times its standard deviation (blue lines) and FG = 2.5·FX (red line). Red marks indicate outliers.

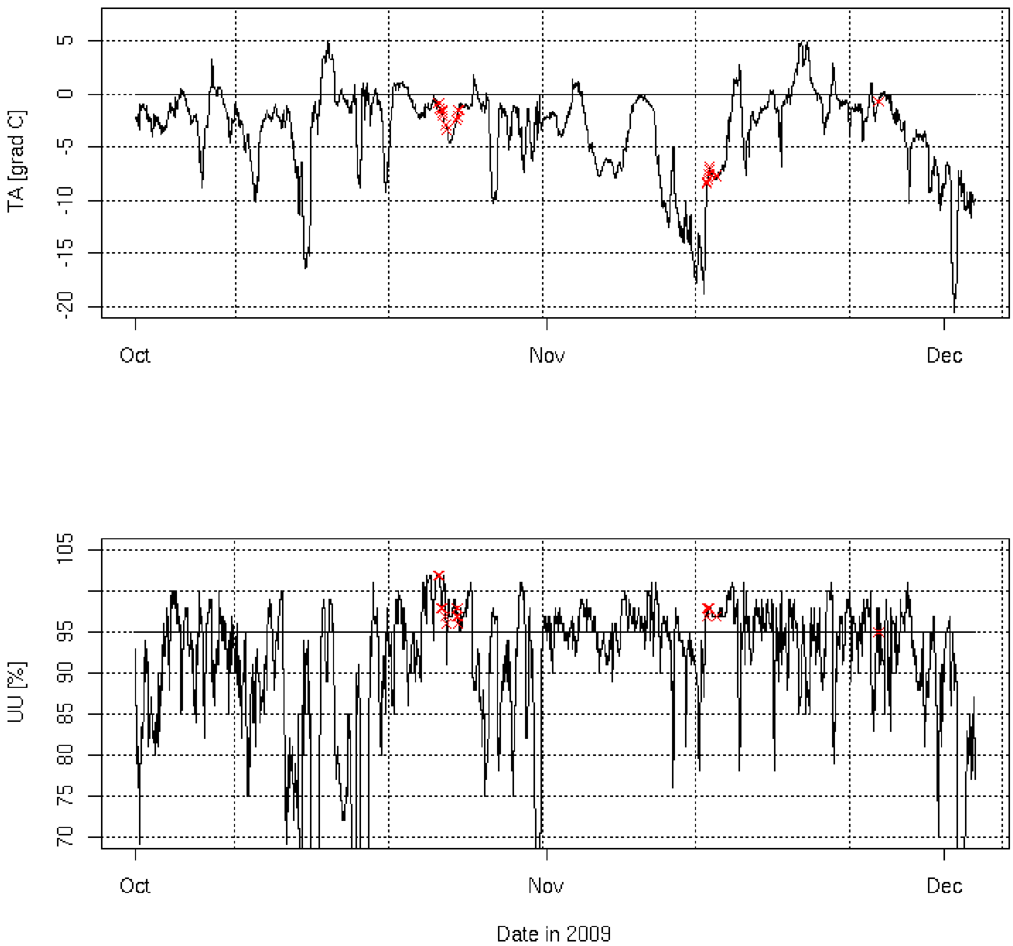

Figure 3: Temperature (TA) and humidity (UU) at Finsevatn station from October to December 2009. Periods with outliers are marked with red crosses.

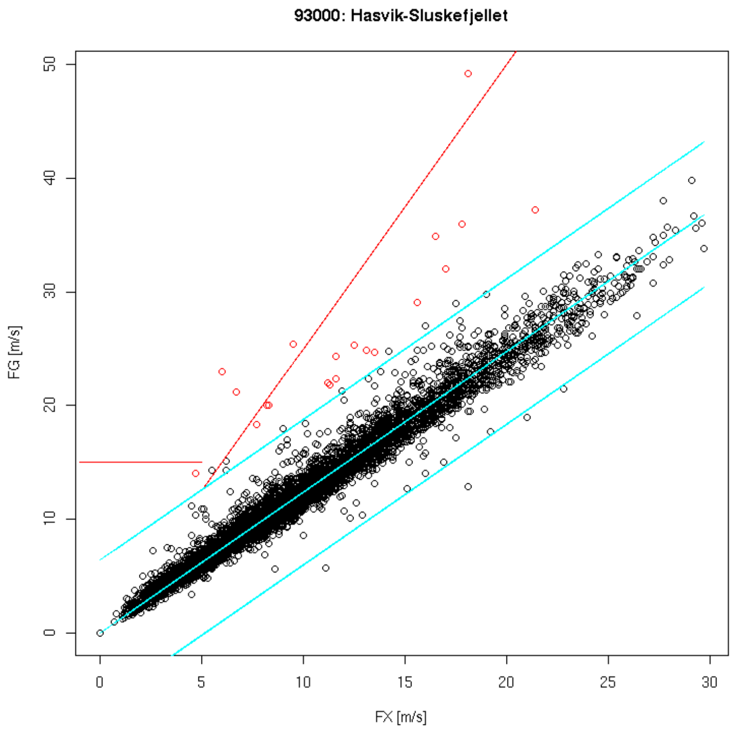

Figure 4: Scatter plot, maximum gust (FG) versus maximum wind speed (FX) at Hasvik – Sluskfjellet (438 m.a.s.l in Northern Norway). Linear regression line with 5 times its standard deviation (blue lines) and FG = 2.5·FX (red line). Red marks indicate outliers.

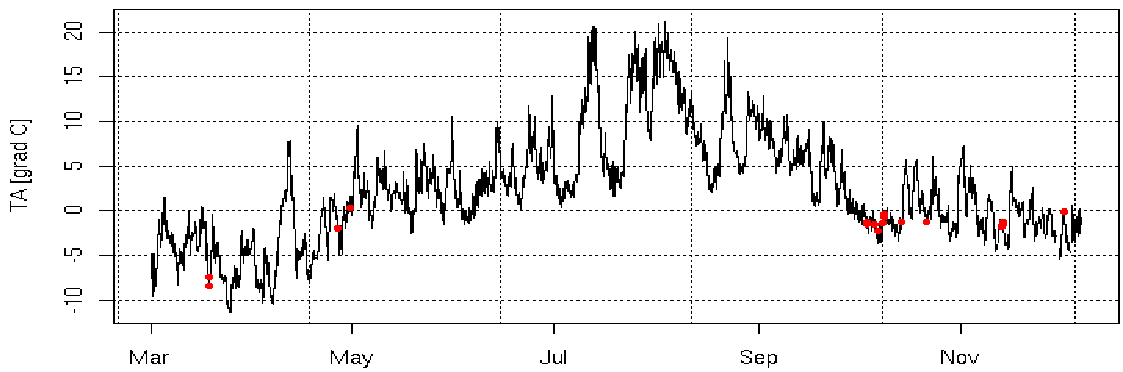

Figure 5: Temperature (TA) at Hasvik – Sluskfjellet from March to November 2009. Periods with outliers are marked with red dots.

Example of one station without problems:
Fokstugu is placed in the mountains in Southern Norway. The wind observations do not show any outliers. The climate at Fokstugu is relatively dry and situations with riming on the sensor are rare.

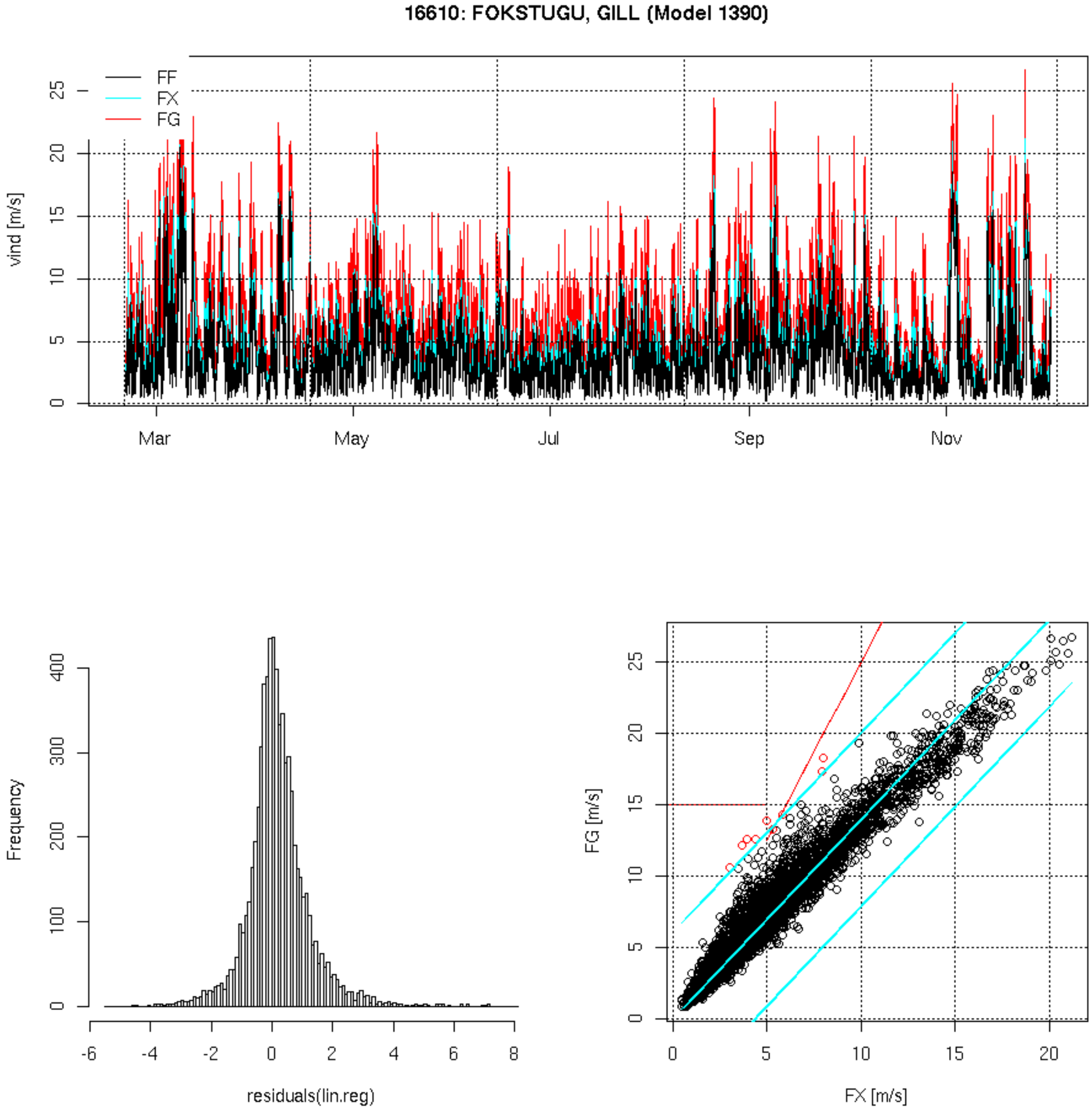

Figure 6: Fokstugu. Wind data from March to November, histogram of residuals and scatter plot of FG versus FX.

2.2 Gill WindSonic

Met.no has 5 Gill WindSonic in the meteorological station network. Two of them are placed inland and have no problems. The other three in mountainous or coastal areas show occasionally very high gust values (outliers).

Sandhaug is situated 1250 m.a.s.l. in the mountains in southern Norway. This station has additional wind measurements with a mechanical Young wind sensor. The observation record of the Gill WindSonic shows very high gust values (outliers) in two periods during autumn 2009 (Figure 7 and 9). Surrounding stations measured heavy precipitation, and the temperature was below 0 ºC during these periods (Figure 8). Occasionally, data also dropped out.

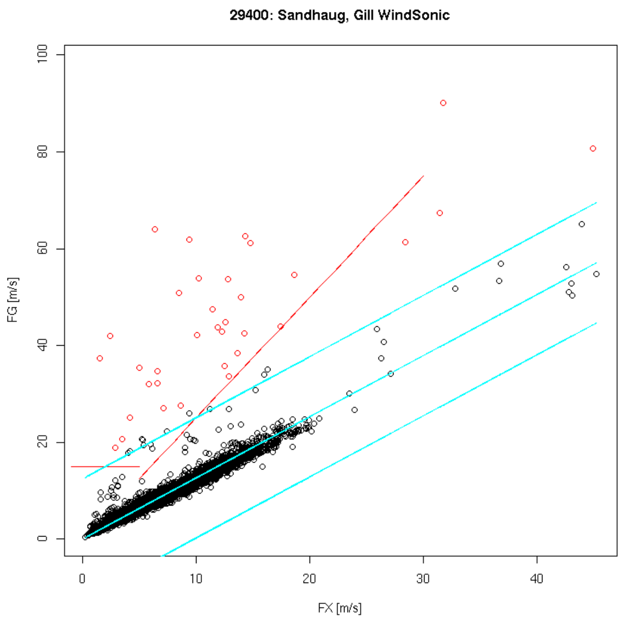

Figure 7: Scatter plot of maximum gust (FG) versus maximum wind speed (FX) at Sandhaug (1250 m.a.s.l in Southern Norway). Linear regression line with 5 times its standard deviation (blue lines) and FG = 2.5·FX (red line). Outliers are marked with red circles.

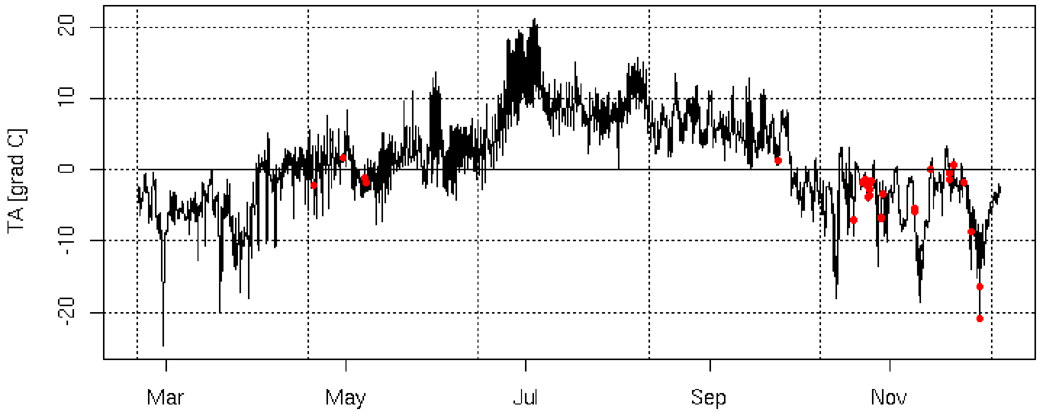

Figure 8: Temperature TA from March to November 2009 at Sandhaug. Cases with outliers have red markings.

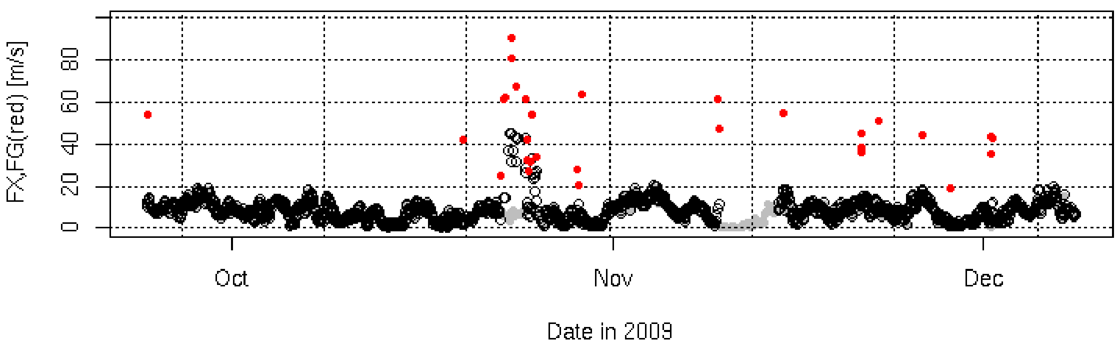

Figure 9: Maximum wind speed (FX) and maximum gust (FG) from Gill WindSonic (black) and Young (grey). Very high gust values (outliers) are marked with red dots.

Rotvær is situated at the coast near Lofoten in Northern Norway. In all cases with outliers (Figure 10 and 11), the surrounding stations measured precipitation, mostly snow and sleet.

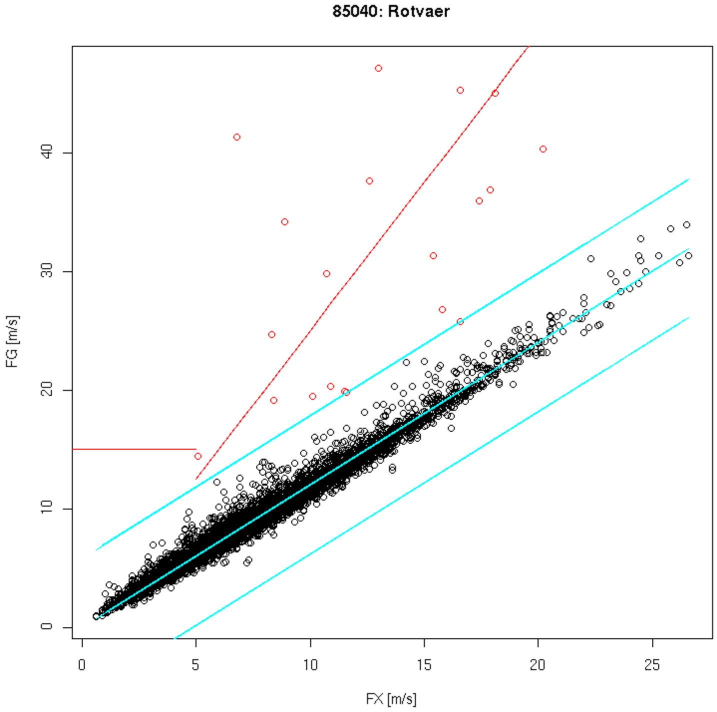

Figure 10: Scatter plot of maximum gust (FG) versus maximum wind speed (FX) at Rotvær (in Northern Norway). Linear regression line with 5 times its standard deviation (blue lines) and FG = 2.5·FX (red line). Outliers are marked with red circles.

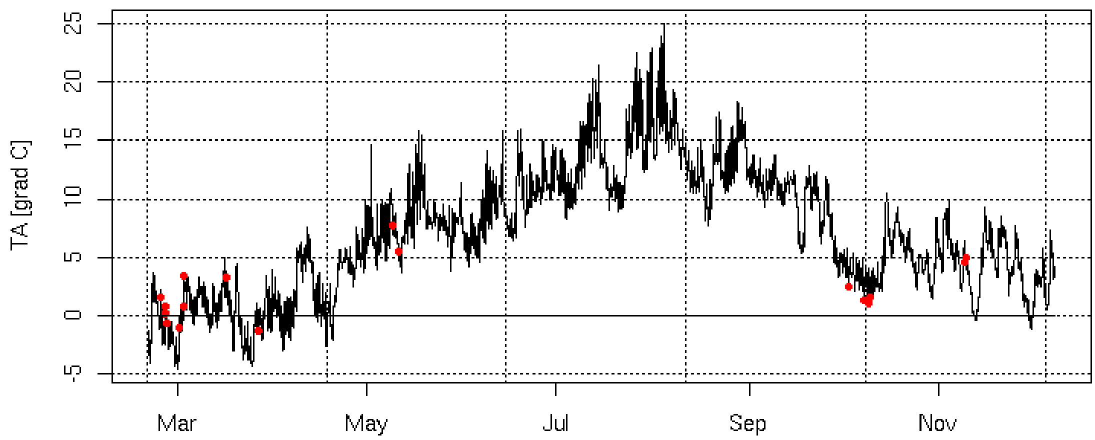

Figure 11: Temperature TA from March to November 2009 at Rotvær. Cases with outliers are marked with red dots.

3. SUMMARY

The study showed some cases with unrealistically high gust values from the ultrasonic wind sensors. Most of these high values seem to be due to icing/riming or snow/sleet covering the sensor. For Gill WindObserver II, this occurred on stations in mountainous areas with high risk of icing. In some cases the cause is unknown due to lack of supplementary data. About 75 % of all the stations with Gill WindObserver II did not have any problems with high gust values. In areas with low temperatures and risk of icing, met.no has started to use another Gill sensor with more powerful heating.

Gill WindSonic is not suitable for use in areas with low temperatures due to risk of icing. Figure 12 illustrates this. The sensor shown in the picture is mounted on a test station that is not included in this study. It also seems that this type of sensor occasionally show unrealistically high gust values in heavy snow and sleet. Data also drop out in such situations. But Gill WindSonic is suitable at weather stations with minimal risk of icing and rarely heavy snow and sleet. This sensor is only in use at solar/battery powered stations in the Norwegian station network.

Figure 12: Gill WindSonic with icing. Data from this test site is not included in this study.

REFERENCES

Gill: Gill WindObserver II Ultrasonic Anemometer. User Manual. Doc No. 1390-PS-0004. Issue 19. Gill Instruments, England 2009.

Gill: Gill WindSonic User Manual. Doc.no. 1405-PS-0019. Issue 18. Gill Instruments, England, 2009.

WMO: Guide to Meteorological Instruments and Methods of Observation, WMO No. 8 (seventh edition), WMO, Geneva 2008.