Air Temperature Sensor Siting Classification in Nordic Countries

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Introduction

Air temperature is one of the most important climate parameter and is measured by almost all standard automatic weather stations around the world. The accuracy of the measurement is determined by the instrument quality, its uncertainty and overall performance as well as calibration and maintenance routines. Furthermore, the temperature measurements are influenced by their immediate vicinity. The distance to artificial and natural heat sources or sinks, topography, vegetation and shading effects are all factors which may affect the representativeness of the measurements. The World Meteorological Organization's Commission for Instruments and Methods of Observation (WMO CIMO) gives suggestions on the siting of a temperature sensor (WMO, 2008) and also recommends a siting classification system to classify those stations which are not perfectly located for easier evaluation of the expected data quality (CIMO/WMO, 2010). The CIMO siting classification system is adapted from a scheme developed at Meteo France (Leroy, 1998 and Leroy, 2006).

Within the co-operation between the Nordic national meteorological services in the field of Observations (NordObs), a working group was established to work towards a common approach of metadata collection and site classification of their networks.
First experiences with the WMO CIMO siting classification by the participating countries had shown a couple of common challenges when implementing it for stations at higher latitudes. For example, the combination of low elevation and very varying azimuth angles of the sun throughout a year, typical landscape forms and vegetation types often result in a siting class unsuited for climatological assessment of the temperature.

Twenty-five stations in Estonia, Finland, Iceland, Norway, and Sweden were evaluated and classified applying a common metadata scheme. The four criteria of the WMO CIMO siting classification (slope, vegetation, distance to heat sources and water bodies and shading) were analysed separately for those stations. Sites were additionally evaluated based on the experiences of the station holders and the entire Nordobs-team. For a few selected stations, more detailed analyses were performed.
This paper summarizes and concludes on the evaluation results. The common metadata schemes for all stations, the detailed analyses of the selected stations and an extended discussion of the

results will be published in a report by the NordObs co-operation in autumn 2016 and will also be provided to the WMO/CIMO expert team currently working on that topic.

Results

During summer 2015, 25 stations in all five countries were evaluated, applying the common metadata scheme. For each station, the CIMO classification was performed. The results are shown in the histogram in Figure 1. The first four bars for each class indicate the number of stations separately for each criterion.

At 20 of 25 stations, the vegetation was evaluated as class 1 (green bars). Two stations were classified as class 3 and three stations were classified as class 4. All 25 stations are situated on flat terrain or slopes with an angle less than 19 ° (yellow bars). The distance to heat sources and water bodies is large enough for class 1 (> 100 m) at 11 stations (red bars), about 30 m (class 2) at 8 stations and about 10 m (class 3) at 5 stations. Only 1 station is closer than 10 m to heat sources, justifying a class 4.

The shade criterion is the only criterion for which a significant amount of high classes (class 4 and 5) were given. At 15 stations in total, shade on the temperature sensor is experienced if the sun is higher than 7° or 20° (purple bar).

The last (blue) bar shows the overall evaluation. The site class is equal to the highest class number given for any criterion. For most stations receiving class 4 or 5, the shade criterion was determining the high class. No station was classified as class 3. Five stations were classified as class 1 and four as class 2.

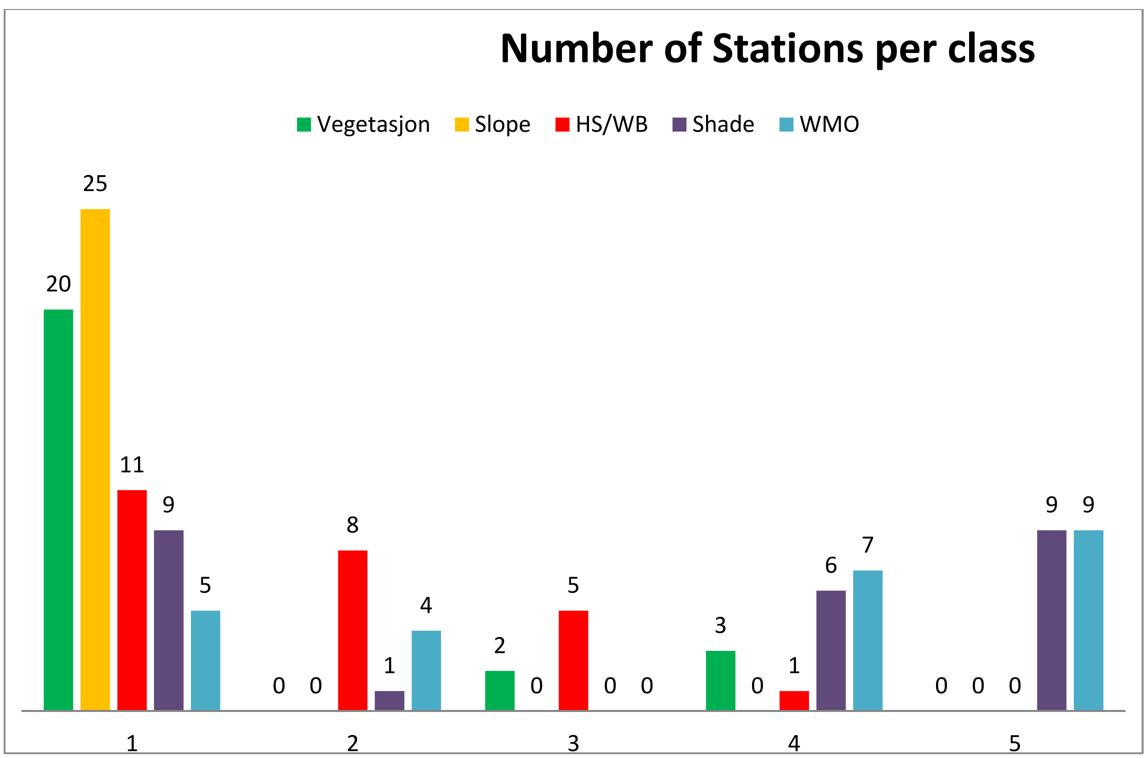

Figure 1. Site classification results for Nordobs stations. The bars/numbers indicate the number of stations per class for each criterion and for the overall site classification, see colored legend. Totally, 25 stations were classified.

Figure 2 compares the results of the CIMO site classification with the evaluation of each station, based on the opinion and experiences from the NordObs group. Colors are used for indicating the influence of the exposure on temperature measurements. Only three colors are used for simplicity, indicating no influence (green=class 1), little influence (yellow=classes 2 and 3) and a lot of influence (red= classes 4 and 5).

While the siting classification classifies high influence on temperature measurements on 16 stations, the Nordobs group evaluates only temperature measurements at five stations to be highly influenced.

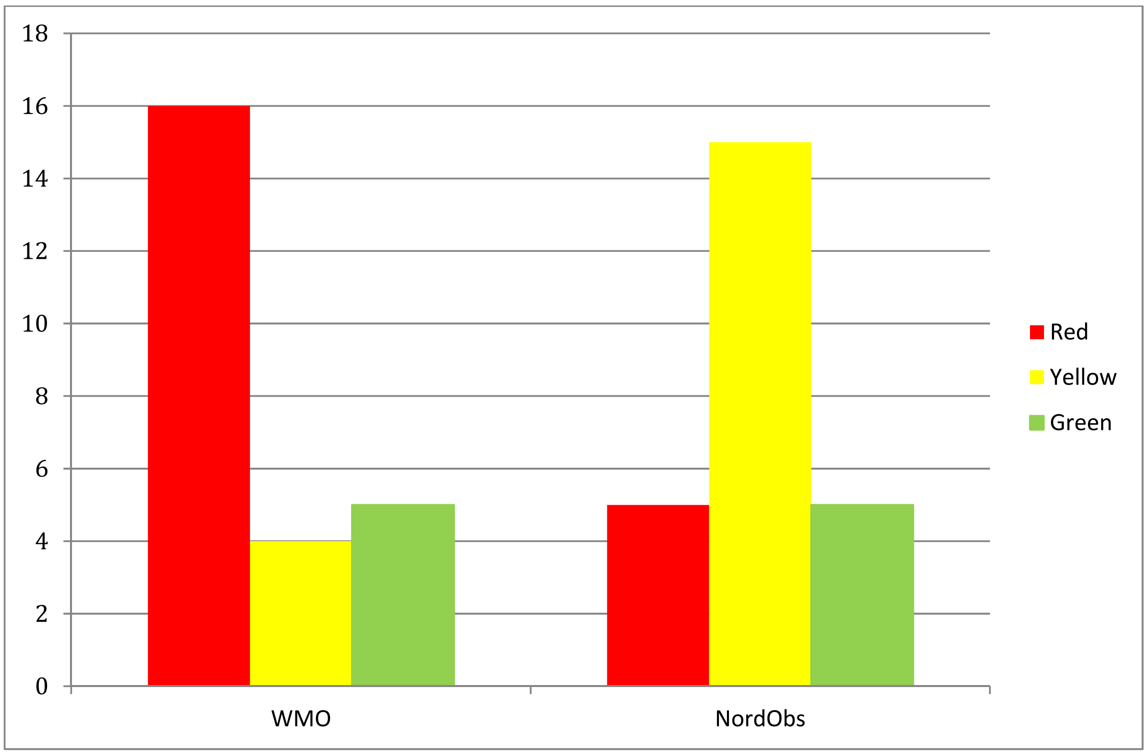

Figure 2: Evaluation of temperature influence of siting exposure on temperature measurements by WMO siting classification and by Nordobs

Conclusions

Generally, the implementation of a classification of siting is very useful. Currently, the available metadata about sites differ a lot for different countries as they have been developed individually and often reflect very local characteristics of the typical landscapes and even cultural aspects.

The used vocabulary may be understood differently, i.e. the term "suburban" is very dependent on the typical size and density of the cities in each country.

Being able to characterize the siting of a sensor by one or several numbers makes it possible to compare the influence of the siting within the network, between different networks and over time. Sites can be more objectively assessed and it is easy to identify possible improvements and their impact. Last but not least, communication about the importance of siting both internal and external was noticeable simplified by the suggested classification system.

Estimated uncertainty

The estimated uncertainty of the temperature measurement due to siting is given for classes 3, 4 and 5 in the WMO Siting classification for temperature. The additional estimated uncertainty added by siting is up to 1 °C for class 3, up to 2 °C for class 4 and up to 5 °C for class 5, CIMO/WMO 2010.

For a specific class, the influence on temperature due to slope, vegetation, heat sources/water bodies or shadow should give the same estimated uncertainty, but this does not seem correct for all cases.

A lot of stations in the Nordic countries get class 4 or 5 due to shadow during a short period of the year. According to the siting classification this is expected to give the same estimated uncertainty as a nearby heat source that will give an influence on the temperature most of the year. Without doubt, shade has an influence on the temperature and the comparison between two neighbored Norwegian stations showed a temperature difference possibly caused by a prolonged period with shade on the sensor of about 2 °C, categorized as class 5. However, results from the same study and similar studies from Finland and Estonia also showed that a significant effect on temperature could not be seen for short shading periods.

Both from literature research (i. e. Kumamoto, 2012; Jinaxia, 2014) and own studies it could also been shown, that different kind of heat sources may have very different impacts on the air temperature nearby:

- Water bodies seem to have a larger impact than flat heat sources during day.
- The influence of elevated heat sources depends very much on the direction of the site – an obstacle in the North of the sensors can change the temperature of the sensor by several degrees (for classes 4 and 5), while an obstacle in the South hardly have any effect.
- Lots of heat sources acts as heat sinks during night and that effect seems to be larger than the warming effect during day.

A more reliable quantification of the estimated added uncertainty of the temperature measurements and a possible adjustment of the class-limits are required. Both would raise the value of the siting classification scheme tremendously.

The performed analyses of selected stations showed the difficulties of just comparing data from existing stations. Firstly, it is hard to find suitable sites in close enough vicinity that homogenous temperature data series can be assumed. Further, influences are often combined: A heat source might also give shade and slopes are often connected to changes in elevation which have a much higher impact on temperature.

Therefore, The Nordic countries highly recommend further studies with existing and especially with dedicated stations and sensor configurations to quantify the effect of different type of heat sources, shade, slopes and vegetation. One initiative performing currently such studies is the METEOMET-project which also collaborates with the the WMO/CIMO expert team.

Further, model studies can be a very helpful and complimentary tool to this effort. Different influences can be assessed independently from each other and the distance to the sensor or the size of the feature can be changed step less. For example, Kinoshita (2014) have successfully applied the model ENVI-met for site exposure studies.

Additional effects not yet considered

Several aspects of the exposure of a sensor are not yet considered in the siting classification. Based on the general literature in micrometeorology (i.e. Geiger, 1995) and more focused studies within forest/agricultural (i.e. Dobrowski, 2009) and urban climatology (Eliasson and Svennson, 2003; Grimmond, 2001; Oke, 1981; Oke, 2006; Shudo, 1997; Sailor, 1995), it is suggested that the following features may have significant influence on temperature sensors:

- The direction of the slope
- The position of the sensor on the slope (within or without cold-air drainage area or rather on top of the hill)
- Night-time effects:
    - Reduction of long wave radiation from the ground due to obstacles reducing the sky view
    - Stronger cooling of typical flat heat sources (parking lot, etc)
- Obstacles (natural and artificial) in the North which change the radiation balance of the area and thus may influence the temperature measurements nearby
- Changes in snow height and thus the changing distance between the sensor and the ground.

Off course, it is important to not overload the siting scheme to guarantee its application. The Nordic countries suggest to cooperate with related scientific communities (as forest/agricultural and urban climatology) when developing further categories.

Adaption of the site classification in the Nordic countries

The Nordic countries will continue using the developed common metadata scheme for evaluating their sites. By that, additional information is collected in a comparable way which may allow adapting the siting classification to future modifications.

Instead of reporting only one number as a result of the WMO/CIMO siting classification, the Nordic countries will report all four numbers for the four categories allowing for a more balanced evaluation of the site.

The Nordic countries will apply the WMO/CIMO siting classification with the following adaptions:

1. A simple time-parameter will be used additional to the sun elevation in the shade-criterion. The Nordic countries will neglect shadowing from obstacles which lasts less than 1 hour (equal to an obstacle width of 30 °). Consequently, the separation between shade on sensor when the sun is higher than 5 ° and 7 ° is not necessary.

Class 1	Class 2	Class 3	Class 4	Class 5
Away from projected shade when the sun is higher than 7 ° or shade on sensor for less than 1 hour per day.	Away from projected shade when the sun is higher than 7 ° or shade on sensor for less than 1 hour per day.	Away from projected shade when the sun is higher than 7 ° or shade on sensor for less than 1 hour per day.	Away from all projected shade when the sun is higher than 20° or shade on sensor for less than 1 hour per day.	Site not meeting requirements for class 4

2. Because of the wide spread typical heathland vegetation in the Nordic countries, which is sparse and often reaches a natural low height of about 40 cm, the vegetation criterion will be relaxed. Especially, when the temperature sensor is mounted in 2 m height, the slightly higher vegetation is not expected to have an impact on the temperature measurements.

Class 1	Class 2	Class 3	Class 4	Class 5
Ground covered with natural and low vegetation (<10 cm) representative of the region	Ground covered with natural and low vegetation (<10 cm) representative of the region	Ground covered with natural and low vegetation (<45 cm) representative of the region	-	-

3. Following the practice in Finland, for areas where the abundance of water increases 30% within a radius of 1 km, water bodies between 10 and 100 m away from to the sensor are not considered for the siting classification.

Further, if a low vegetation area needs to be maintained, i.e. within a field of crops or in an urban area, a plot size of 6 m times 9 m is recommended, in accordance with the Guide to Climatological Practices (WMO, 2011).

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