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THE STATE-OF-THE-ART OF INSTRUMENTS AND AUTOMATED SURFACE OBSERVING SYSTEMS (ASOS)

Instruments for harsh climatological conditions

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Summary and Purpose of Document

The document contains a proposal for classification of stations regarding icing-induced meteorological conditions and regarding their behaviour as function of the previous stations' icing classification. It also provides requirements for instruments for observations in harsh climatological conditions.

ACTION PROPOSED

The meeting is invited to take into account the document when discussing guidelines on recommended practices for measurements in a harsh environment.

Reference:

1. Improvement of Severe Weather Measurements and Sensors – EUMETNET SWS II Project, B. Tammelin and al., FMI reports 2004:3

INSTRUMENTS FOR HARSH METEOROLOGICAL CONDITIONS

It is recognized that a number of Members are confronted to the consequences of icing on instruments installed at Automatic Weather Stations located in harsh environment.

The following topics should be discussed:

- classification of stations regarding icing-induced meteorological conditions
- classification of instruments regarding their behaviour as function of the previous stations' icing classification

As a result, the user should be able to select the right instrument for the prevailing environmental conditions regarding the icing issue.

REVIEW OF THE STATE OF THE ART FOR MEASUREMENTS UNDER HARSH CONDITIONS

Basis:

WMO/CIMO Wind Instrument Intercomparison, Mont Aigoual, France, 1992-1993

A documented experiment has been conducted at the Mt. Aigoual station, France (within a joint venture between France and Switzerland) in order to analyze the performances of a number of ice-free anemometers under extreme meteorological conditions.

Reference:

WMO Wind Instrument Intercomparison, Mont Aigoual, France
1992-1993 : final report by P. Gregoire and G. Oualid.
Instruments and observing methods report; no. 62
Technical document (WMO); no. 859

EUMETNET/SWS II Experiment (2000-2002):

A documented experiment has been conducted at three sites in Finland, France and Switzerland in the period 2000-2002 in order to analyze the performances of ice-free instruments under extreme meteorological conditions.

Reference:

Improvement of Severe Weather Measurements and Sensors – EUMETNET SWS II Project
B. Tammelin and al.
FMI reports 2004:3

Definitions

Meteorological icing: meteorological event or perturbation which causes icing.

Meteorological icing can be characterized by:

1) the total amount of ice accreted during the icing event, and/or
2) the duration of the icing event, and/or
3) the maximum accretion rate, and
4) the meteorological conditions (simultaneous and following)

Automatic sensors are lacking for the determination of items 1) and 3), while the items 2) and 4) can be more or less achieved with presently available technology.

Instrumental icing: technical perturbation of the instrument due to icing.

Instrumental icing can be defined as the effect of icing on the quality of the measurements. It can be characterized by

1) analyses of video recordings, and/or
2) regular visual observation

The classification of instrumental icing CII during a meteorological icing event can be defined in the following way:

Class	State of instrument	Availability Factor AV
0	Remains free of ice	0
1	Light ice accretion, without obvious effect on the measurement	0
2	Moderate ice accretion, with probable influence on the measurements	1
3	Strong ice accretion, preventing the instrument to deliver data	1

An instrument remaining in classes 0 and 1 is considered as available (Availability Factor AV=0). For higher values of CII, the instrument's results are most probably erroneous and the sensor is considered as unavailable (AV=1).

The Availability Ratio

$$AR = Instrumental - icing \big/ Meteorological - icing$$

can be used for the selection of the instrument as function of the station's classification and can be combined with the above instrumental icing classification. A value of AR smaller or equal to 1 reflects a good behaviour of the instrument in terms of icing (e.g. good heating). Values of AR higher than 1 indicate a sensor which is sensitive to icing (e.g. poor heating) for a time period (much) longer than the meteorological icing.

The performance index PI of an instrument is defined by:

$$PI = AV \times AR$$

An instrument which is not sensitive to icing has a PI value equal to zero. On the contrary, high values of PI reflect a poor behaviour in terms of icing sensitivity.

Further definitions:

- **Incubation time**: delay between the beginning of the meteorological icing and of the instrumental icing.
- **Recovery time**: delay between the end of the meteorological icing and the full recovery of the performance of the instrument

RECOMMENDATIONS

Considering that:

1. Meteorological icing is different than instrumental icing, the latter being the consequence of the former, but with different effects depending on the characteristics of the meteorological conditions and of the instrumental design (instrumental icing can be smaller, equal or longer than meteorological icing due to the sometimes very long recovery time, especially in northern countries with low solar irradiance in winter).

2. Despite relative high human and financial investments, it was recognized that the defined goals of the above mentioned intercomparisons were not completely reached due to the lack of market available adequate instruments for the measurement and characterization of icing accretion.

3. Not only the heating power, but also the design of the instrument and of the heating geometry is of particular importance.

Noting that:

1. The WMO Guide defines meteorological requirements and characteristics for sensors. However, the WMO Guide does not separately consider severe weather conditions like icing, even if low temperature is specified in the requirements. In the same way, manufacturers specify their instruments' performances in severe weather conditions in terms of low temperatures (e.g. operating temperature range), but not icing.

2. There is an increasing demand for accurate meteorological measurements and measurement of icing in cold climate and mountainous regions to improve the information provided by meteorological networks, to produce reliable data for icing forecasting, to produce valuable information for numerous human activities, (esp. energy production) and finally to design structures withstanding such harsh environment.

It is proposed that:

A. The WMO/CIMO Guide is extended in order to include recommendations for the definition of the siting characteristics of the AWS in terms of local icing conditions.

A classification of AWS is introduced indicating the degree of severity of local icing conditions. The following table describes tentatively the frame of such a classification.

Table 1: Classification of sites according to severity of icing. It is assumed that the sensors operate at the given accuracy (WMO or manufacturer) minimum 95% of the time per month.

Site class	Icing days / year	Duration of icing events %/year	Max. load per day g/100 cm^2 (95%)	Intensity of icing g/100 cm^2/h (95%)	Icing type
S5	> 60	> 20	> 100	> 50	Heavy
S4	31-60	10-20	50	25	Strong
S3	10-30	5-10	35	10	Moderate
S2	3-10	< 5	20	5	Light
S1	0-2	0-0.5	0-10	0-5	Occasional

B. The WMO/CIMO Guide is extended in order to include recommendations for the definition of the requirements for measurements in severe icing conditions:

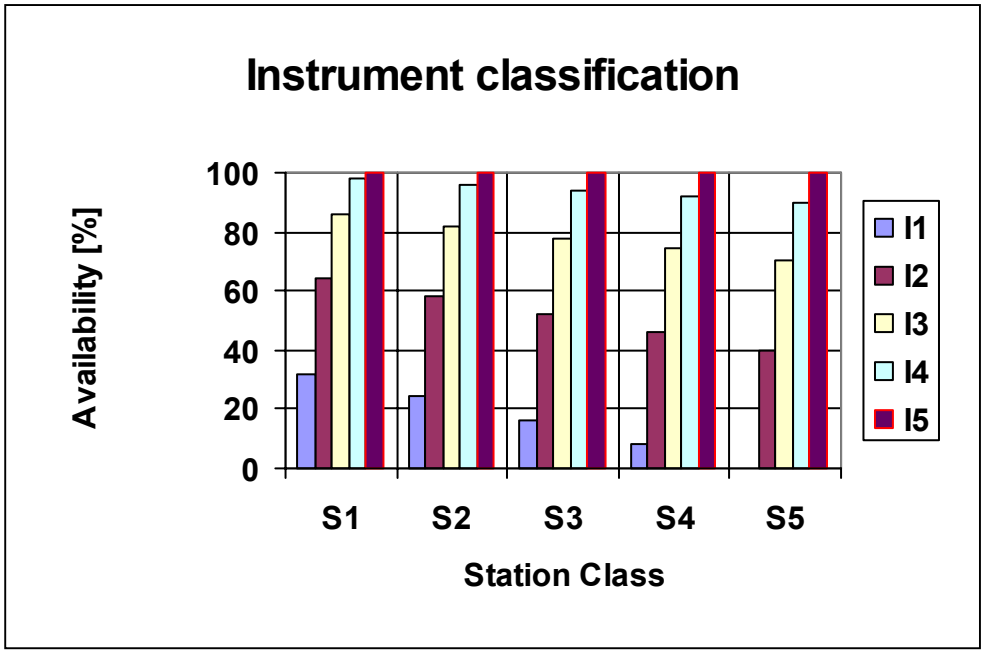
A classification for meteorological sensors taking into account accuracy and required reliability of data combined with climatic conditions is difficult to achieve. A good indicator may be given by **In, the mean availability index of the instrument against the different site classes S1 to S5** (see below).

The range of this classification extends from I5 (PI = 0; availability = 100 % → perfect icing non-sensitive instruments) to I1 (PI = very high values; availability ≤40 % → instruments which could remain frozen for a very long period after the meteorological icing period, e.g. long recovery time for high latitude stations without sun during whole seasons). The classification of the instrument could therefore look like:

Table 2: Classification of instruments in terms of mean performance depending on the station's classification *(the availability values displayed in italic are purely hypothetical)*

Mean Availability Index	PI for S1→ S5	Mean availability in % for S1 → S5	Remarks
I5	0	*100 %*	Excellent instrument not sensitive to icing
I4	0 → 1	*99 → 90 %*	Good instrument, little sensitivity to icing
I3	1 → 5	*89 → 70 %*	Good instrument but during icing events
I2	5 → 20	*69 → 40 %*	Instrument to be used only with separate icing detection
I1	20 → ∞	*39 → 0 %*	Instrument not recommended for such applications

This index **In** is strongly dependant on the station's class ($S_{n,\ n=1-5}$). Furthermore, the effect of icing on the results' quality (see AV definition above) is taken into account. This leads to the possible following graphical representation where the user can select the class of instruments needed to fulfil his requirements depending on the location (e.g. classification) of his station.



This availability is dependant on the instrument type (anemometer, thermometer, etc.), design (e.g. rotating parts), heating (power, design/geometry), but also on the meteorological conditions prevailing at the selected site (AWS classification). However, it should be determined independently of the site's meteorological characteristics, e.g. under laboratory conditions and/or at selected regional centers (RICs) representative of the stations' classification.

The goal is that the user can determine approximately if the selected instruments fulfils the required specifications for his station.

Example: A potential user is located at a station with classification S4. He intends to perform wind measurements of high quality. But, due to financial restrictions, he will choose an instrument of class I3, which guarantees that his measurements will be performing correctly 74% of the time for a station of class S4. However, when installing the same instrument at a station of type S2, the mean availability of the instrument would increase to 82%.

Requirements:

1. The development of reliable sensors to measure the duration and loads of icing is sponsored by WMO. This information is necessary to determine the above mentioned meteorological icing periods.
2. Test sites for ice-free sensors are promoted by WMO (e.g. RICs for S1 to S5), equipped for the determination of the meteorological icing periods as well as for the characterization of the instrumental icing.

CONCLUSIONS:

With this new WMO/CIMO recommendation for measurements performed under icing conditions:

1) The user knows in a unique way how the acquired instrument will perform at his station.
2) The manufacturer has a unique definition to characterize the performance of his product (ISO certification ?)