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# SUSTAINED PERFORMANCE CLASSIFICATION FOR SURFACE OBSERVING STATIONS ON LAND

**Summary and purpose of document**

This document provides information on draft sustained performance classification for observing stations on land.

**ACTION PROPOSED**

The Meeting is invited to review the draft, assess its maturity and decide on steps required to finalize this document.

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**Appendices:** None

**SUSTAINED PERFORMANCE CLASSIFICATION FOR SURFACE OBSERVING STATIONS ON LAND**

A primary quality factor of a measurement is the set of "intrinsic" characteristics of the equipment used, maintained over the operational life of the system. They are the characteristics related to the design of the instrument and the field configuration, validated periodically through calibration, field verification, and maintenance. They are known most robustly from laboratory or field tests and sometimes from the manufacturer's documentation Part I, Chapter 1, Annex 1D of WMO-No. 8 (Guide to Meteorological Instruments and Methods of Observation, hereafter called CIMO Guide) includes the users' requirements and the achievable measurement uncertainty, considering the state of the art.

The achievable measurement uncertainty in the CIMO Guide refers to the measuring sensor alone and does not include the contribution of the additional configuration components which enable the installation, e.g. shields/screens, enclosures, pressure heads, data loggers. Each has inherent limitations and are factors contributing to the uncertainty of measurement.

When writing technical specifications for buying equipment, it is necessary to have in mind the achievable measurement uncertainty, as well as all the other configuration components and their contribution to the overall measurement uncertainty: requesting the state-of-the-art achievable uncertainty may result in high costs and/or may not be acheivable within a specified budget. Therefore, it is highly recommended to be aware of the possible performances (with associated costs) before issuing technical specifications. A value analysis may lead to specify lower performances than the "required measurement uncertainty" and the "achievable measurement uncertainty" found in Part I, Chapter 1, Annex 1D of WMO-No. 8. Test and intercomparison reports of instruments are very valuable tools to specify and select an instrument with objective information.

It's important to stress that the uncertainty of a meteorological measurement is a parameter resulting from the combination of the contribution from the measurement system itself, the installation/configuration, and the siting of the measurement system, the definition and knowledge of the measurand, the quantities influencing the measurand and their associated uncertainties. Once an instrument is selected and its performance characteristics known, it is necessary to verify the level of performance during operation. Sometimes it is not physically possible to maintain the stability of an instrument. Preventive maintenance and calibration are therefore necessary and must be performed to maintain the desired measurement uncertainty (such as checking the performance of artificial ventilation of a screen, the screen ageing, heating of sensors, etc.).

**Commenté [AM1]:** A measurement uncertainty is not related to a "user perspective" or "someone's perspective". It's a quantity associated to the measurements that must be the same for the user of the data, the producer of the data,, the manufacture, the post processing phase etc.

When delivering observations for various applications (mainly forecasts and climatology), it should be possible to document the uncertainty of a measurement, typically with a 95% level of confidence. It is not always done and using "by default" the "achievable measurement uncertainty" of WMO-No. 8, Annex 1D is not recommended.

The uncertainty of measurement due to the siting of the measuring system is addressed in a separate standard, and needs to be taken in consideration in conjunction with the performance uncertainly documented here as "sustained performance classification", to fully characterize the measurement reflected in data delivered to the user.

The uncertainty contribution related to the siting must be combined with all other uncertainty components.

In order to document the performance characteristics of the various surface observing networks, this document defines a classification, called "sustained performance classification" with an associated measurement uncertainty, including the uncertainty from the instrument itself and from additional factors such as the associated equipment, the installation, the periodicity of preventive maintenance and calibration. This classification ranges from A (instrument installed and well maintained following the WMO/CIMO required measurement uncertainty and stated achievable measurement uncertainty, in particular Annex 1D of the CIMO Guide) to D (no maintenance and calibration organized), with an additional class E for unknown characteristics and maintenance.

A site as a whole has no single class. Each parameter being measured at a site has its own class, which may be different from the others. If a global classification of a site is required, the maximum value of the parameters' classes can be used.

This classification is related to a network, considering the instruments used and the maintenance organization applied for this network. So, it is a “structural” classification. It doesn’t mention the information of what has been made on a particular day on a particular site.
In practice class A standards are set at high level, for this reason it is most likely that only a subset of stations would be in class A.

The five levels are:

- Class A: WMO/CIMO required measurement uncertainty or achievable measurement uncertainty when higher. Maintenance and calibration are organized to keep this uncertainty in the field and over time. When the required measurement uncertainty is smaller than the achievable accuracy, the latter is indicated.
- Class B: Measuring system with wider uncertainty interval, often having a good value to money ratio and more affordable in practice. Maintenance and calibration are organized to keep this uncertainty in the field and over time.
- Class C: Specifications and/or maintenance and calibration procedures more relaxed than class B, but known and applied. Maintenance and calibration are organized.
- Class D: Specifications lower than class C or no maintenance and calibration organized.
- Class E: Unknown performances and/or unknown maintenance procedures.

**Commenté [o2]:** JMA
It seems Class A stations are so rare and not practical in real observing stations because their sensors need to be calibrated in laboratory so often. It would be helpful there is some explanation of the usage of such high class stations (for example, as reference?)

**Commenté [o3]:** JMA
We order manufacture for instruments that meet the requirement of Class A (except rain gauges) according to the Annex 1D. However, our maintenance procedures don’t meet Class A, in some cases, even Class B criteria. In that case, most of our stations will fall into Class C. Are we recommended to install lower specification instruments in the first place?

Typical conditions to get and maintain the stated accuracy are indicated in the list below.

For any Class, in order to be compliant with the Class, all criteria must be fulfilled.

This list is meant to cover commonly measured parameters, especially when they are expected to be also provided by third-party networks.

When calibration is mentioned, it has to be understood as calibration against an instrument traceable to SI units and including the uncertainty of the calibration. When calibration is required to be performed in laboratory, it is indicated “in laboratory”. Otherwise, calibration may be performed either in laboratory or in the field if feasible. Calibration is performed over the whole range of measurement. For some classes, it is acceptable to perform field checks or verifications on one or several points.
“Regular” calibration means a calibration with a period consistent with the stability of the instrument.
Redundant measurement approaches act as a continuous check on calibration and allow for longer maintenance intervals.

Depending on the climatological conditions, sensors should be heated to prevent them from being affected by snow, icing and freezing phenomena.
Maintenance related to the retaining a certain measurement uncertainty consists in field verification procedures which are conducted to demonstrate the continuity of the stated performance in the operational environment. The verification is conducted using traceable traveling standards.
Additionally, maintenance may include replacement of certain components, to retain the designed performance (e.g. bearings replacement for wind sensors).

The uncertainties associated to classes A have a clear origin: Annex 1.D of the CIMO Guide, WMO n° 8, with the expression of the operational measurement uncertainty requirements and of the achievable measurement uncertainty.
The uncertainties associated to classes B, C and D haven’t a so direct link to “official” technical documents, nor typical users’ requirements.
Class B uncertainties are derived from the experience of some meteorological services and are a compromise between the best achievable and an affordable system.
Class C uncertainties have been defined mainly by expanding the class B uncertainties by a factor of 2.
Class D uncertainties are by definition larger than class C uncertainties. The criteria indicated deal with the contribution of the instruments to the measurement uncertainty.

| Parameter | Class A | Class B | Class C | Class D |
|---|---|---|---|---|
| Radiation screen | High performance well-maintained radiation screen of known uncertainty | Well-maintained radiation screen with known characteristics and over-estimation of Tx (daily max. temperature) < 0.25°C in 95% of cases when compared with a class A radiation screen | Radiation screen with known characteristics and over-estimation of Tx < 0.7°C in 95% of cases. | Radiation screen with a large influence of solar radiation (for example, over-estimation of Tx ≥ 0.7°C in more than 5% of cases). |
| Air temperature | **0.2°C** (achievable measurement uncertainty). Temperature probe with uncertainty below or equal 0.05 °C (in laboratory conditions, over the measuring range). Uncertainty of the acquisition system < 0.02 °C. Class A radiation screen. Yearly calibration in laboratory against a traceable standard having an uncertainty ≤ 0.02 °C. Redundant measurements can act as a continuous check on drift. | **0.5 °C** Temperature probe with uncertainty below 0.25°C (corresponds of class A of IEC 751 standard, Pt100 platinum probe). Uncertainty of the acquisition system < 0.1°C. Class B radiation screen Regular calibration against a traceable standard having an uncertainty ≤ 0.1 °C. | **1.0°C** Temperature probe with uncertainty < 0.4°C, with good stability, such as Pt100. Acquisition uncertainty < 0.2°C. Class C radiation screen. Temperature probe designed to be calibrated and regular field verification (at least 1-point) | **> 1°C** Temperature probe and/or acquisition system uncertainty lower than for class C. Or Class D radiation screen. Or Temperature probe/system not designed to be calibrated. |
| Relative humidity | **3%** (achievable measurement uncertainty). Performance verified over the full range of humidity and a temperature range typical for the location of the station. Acquisition uncertainty < 0.2%. Class A radiation screen. | **6%** Sensor specified for ± 6%, over a temperature range typical for the location of the station. Acquisition uncertainty < 1%. Class B radiation screen Regular calibration against a traceable standard having an uncertainty ≤ 2%. | **10%** Sensor specified for ± 10%, over a temperature range typical for the location of the station. Acquisition uncertainty < 1%. Class C radiation screen. Regular calibration or field verification (at least, 1 point | **> 10%** Sensor with performances or specifications worse than ± 10% over a temperature range typical of the location of the station or acquisition uncertainty ≥ 1% or Calibration not organized. Or Class D radiation screen. |

**Commenté [o4]:** JMA
Because this radiation screen classification is new (not in the Annex 1D), the reference material is needed. "Dictionary" that was developed last year?

**Commenté [o5]:** JMA
Does this mean "against Class A radiation"?

**Commenté [o6]:** JMA
Is it possible to add field verification here? (for Class B of humidity and atmospheric pressure, too)
In "Dictionary", field verification may be alternative for calibration. Based on experience in operation and some research in the past, we use regular field verification for maintenance instead of calibration and maintain good quality.

**Commenté [o7]:** JMA
The meaning of this expression is not easy to understand. Is it different from just stating "regular calibration" or "calibration organized"?

**Commenté [o8]:** JMA
Different expressions regarding field verification appear in the chart, "field verification", "point field verification", "1-point field verification", and the y are rather confusing. Do they need to be used differently? Or does the definition of field verification include point verification?

**Commenté [o9]:** JMA
Add "or point field verification" as like as temperature.

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| | Yearly calibration in laboratory against a traceable standard having an uncertainty ≤ 1%. | | | |
| Atmospheric pressure | **0.15 hPa** (achievable measurement uncertainty). Yearly calibration in laboratory against a traceable standard having an uncertainty ≤ 0.05 hPa, over the full range of operational conditions. | **0.5 hPa** Sensor specified for ± 0.5 hPa, including possible drift between calibrations. Regular calibration against a traceable standard having an uncertainty ≤ 0.15 hPa. | **1 hPa** Sensor specified for ± 1 hPa, including possible drift between calibrations. Regular calibration or field verification (at least 1 point). | > 1 hPa<br>Sensor specifications lower than for class C<br>or<br>no regular calibration organized. |
| Wind | Wind speed: **10% (or 0.5 m/s)** Starting threshold (for wind speed) ≤ **0.5 m/s** wind direction: **5°** Calculation of wind parameters following WMO recommendations: 4 Hz samples, gust over a 3 seconds period. Yearly check of bearings, and wind vane for rotating anemometers. Yearly field verification of static anemometers (i.e. sonic). Yearly check of the north alignment. Sensor heated (if the climatological conditions require it) | Wind speed: **10% (or 0.5 m/s)** Starting threshold (for wind speed) ≤ **1 m/s** wind direction: **10°** Calculation of wind parameters following WMO recommendations, with the possible difference concerning gust calculation: min. 1 Hz sampling, gust calculated over a period ≤ 3 s. Regular check of bearings, and wind vane for rotating anemometers. Regular field verification of static anemometers (i.e. sonic). Regular check of the north alignment. Maximum intervals between checks should be 2 years. | Wind speed: **15% (or 0.5 m/s)** Starting threshold (for wind speed) ≤ **2 m/s** wind direction: **10°** Regular check of bearings, and wind vane for rotating anemometers. Regular field verification of static anemometers (i.e. sonic). Regular check of the north alignment. Maximum intervals between checks should be 3 years. | Wind speed: > **15%** (or **1 m/s**)<br>Wind Direction: > 20°<br>Starting threshold (for wind speed) > 2 m/s.<br>Or no regular maintenance organized. |

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| Precipitation (rainfall) with tipping bucket rain gauges | The larger of **5 %** or **0.1 mm.** (achievable measurement uncertainty).<br>Reported resolution better than or equal to 0.1 mm.<br>Error related to precipitation intensity corrected.<br>Daily monitoring of the collecting funnel<br>Yearly calibration. | The larger of **5 %** or **0.2 mm.**<br>Reported resolution better than or equal to 0.2 mm.<br>Error related to precipitation intensity corrected or at least known.<br>Regular calibration or point field verification.<br>Regular monitoring of the collecting funnel. | The larger of **10 %** or **0.5 mm.**<br>Unknown error related to precipitation intensity.<br>Regular calibration or point field verification.<br>Preventive maintenance planned and applied. | > 10%<br>or<br>no control and adjustment methods defined<br>or<br>no regular maintenance organized. |
| Precipitation (rainfall) with weighing rain gauges | The larger of **5 %** or **0.1 mm.** (achievable measurement uncertainty).<br>Reported resolution better than or equal to 0.1 mm.<br>Yearly calibration. | The larger of **5 %** or **0.2 mm.**<br>Reported resolution better than or equal to 0.2 mm.<br>Regular calibration or point field verification | The larger of **10 %** or **0.5 mm.**<br>Regular maintenance. | > 10%<br>or<br>no regular maintenance organized. |
| Global solar radiation | **2 %** for daily total (achievable measurement uncertainty).<br>Pyranometer of high quality (acc. to CIMO Guide).<br>Ventilated sensor.<br>Calibration every two years.<br>Daily control of the sensor (including cleaning if necessary).<br>Sensor heated (if the climatological conditions require it) | **5 %** for daily total.<br>Pyranometer of good quality (acc. to CIMO Guide).<br>Ventilation may be omitted.<br>Regular calibration<br>Regular control of the sensor (including cleaning if necessary). | **10 %** for daily total.<br>Pyranometer of moderate quality (acc. to CIMO Guide)<br>Ventilation may be omitted.<br>Regular calibration.<br>No regular cleaning of the sensor. | Uncertainty > 10% for daily total or sensor not using a thermopile.<br>Or<br>Calibration not organized |
| Sunshine duration<br><br>To be checked by experts | The larger of 0.1 h or 2% for daily totals (achievable measurement uncertainty).<br>120 W.m$^{-2}$ threshold applied to pyrheliometer's measurements. | The larger of 0.5 h or 5% for daily totals.<br>2% for yearly totals.<br>Use of a sunshine recorder or | The larger of 1 h or 10% for daily totals.<br>4% for yearly totals. | Uncertainty > 1h or > 10% for daily totals or<br>Uncertainty > 4% for yearly totals |

**Commenté [o11]:** JMA
There is no difference on instrument performance between Class B and Class C. We think Class C instruments should be somewhat downgraded as that is the case in other elements.
We suggest like below:
Class B :
Regular calibration
Regular control of the sensor (including cleaning if necessary)
Class C:
10% for daily total .
Pyranometer of moderate quality ( acc. to CIMO Guide).
Regular calibration
Regular control of the sensor (including cleaning if necessary)

**Commenté [o10]:** JMA
Calibration intervals may be different depending on the environment of sensors or other factors, so they need not be specified.
For example, we maintain Class A pyranometers with a calibration interval of five years and weekly cleaning that have shown good enough quality for years (maybe equal to Class B if not Class A )

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| | Calibration every two years. | calculation of direct radiation from the direct measurement of global and diffuse solar radiation.<br>Regular calibration (if use of pyranometers) or regular control of the sunshine recorder. | Use of a sunshine recorder or calculation of sunshine from the measurement of global solar radiation of at least class B. | |
| Visibility (MOR) | The larger of **20 m** and **20%** (achievable measurement uncertainty).<br>In 95% of cases in homogenous visibility conditions (ratio of standard deviation to mean value over 10 minutes < 0.1).<br>Regular calibration.<br>For forward scatter meters, full control of the calibration chain: reference transmissometer, transfer control forward scatter meter, calibration plates.<br>Weekly cleaning of the optics or automatic calibration to ensure sustained accuracy.<br>Sensor heated (if the climatological conditions require it) | The larger of **30%** and **50 m**, up to 10000 m.<br>In 90% of cases in homogenous visibility conditions.<br>Regular calibration.<br>For forward scatter meters, full control of the calibration chain: reference transmissometer, transfer control forward scatter meter, calibration plates.<br>Use of internal warning from the sensor to clean the optics. | The larger of 40% and 100 m, up to 10000 m.<br>In 90% of cases in homogenous visibility conditions.<br>Regular calibration.<br>Defined calibration chain. | Specifications lower than for class C<br>or<br>No control and adjustment methods defined<br>or<br>No regular maintenance organized. |
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**Note**

A classification for All Weather precipitation (including solid precipitation) and snow depth is not yet defined, due to the lack of shared knowledge on the subject. The WMO SPICE - Solid Precipitation Intercomparison Experiment should allow a further definition of a sustained performance classification.

A classification for Present Weather is not defined. As there is no real reference (apart from human observer) for present weather and the sensor performance is known to be type and technology dependent, a classification of the performance is not easily feasible. And maintenance practices would also be dependent on sensor technology and design.

A classification for soil temperature is not defined because any physical move of the probe for calibration generates large step changes in the time series. The only realistic way to control the metrology is to use stable temperature probes such as platinum probes, and/or to use multiple measurements, to ensure long term stability.

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