WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION
OPAG-SURFACE

EXPERT TEAM ON SURFACE TECHNOLOGY AND MEASUREMENT TECHNIQUES
Second Session

(GENEVA, SWITZERLAND, 22-26 SEPTEMBER 2008)

CIMO/OPAG-SURFACE/
ET-ST&MT-2/Doc. 4.1
(5.IX.2008)

ITEM: 4.1

Original: ENGLISH

PROPOSAL FOR UPDATE OF THE GUIDE TO METEOROLOGICAL INSTRUMENTS AND METHODS OF OBSERVATION (WMO-No. 8)

Report Task 4b – Operational Uncertainty Requirements and Instrument Performance

(Submitted by Mr Karl-Heinz Klapheck, Chairperson of ET-ST&MT)

Summary and purpose of document

This document provides a review of uncertainty requirements and operational instrument performance presented in the CIMO Guide and provides a proposal for its update.

ACTION PROPOSED

The meeting is invited to review the proposal for update and make a recommendation towards its inclusion in the CIMO Guide.

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CIMO/ET-A.1/4.1

COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION

(26. VIII. 2008)

CIMO EXPERT TEAM ST&MT
Second meeting

Original: English only

GENEVA, SWITZERLAND, 22-26 September 2008

Report Task 4b
Submitted by K.-H. Klapheck

Operational Uncertainty Requirements and Instrument Performance

The Table Annex B.1 of WMO No. 8, 7th edition, (Guide to Meteorological Instrumentation and Methods of Observation) was reviewed again.
It is sensible to update this table regularly. The continuing improvements in sensor technology make possible to realize changed requirements with economic expenditure. Also new parameters can be collected by instruments. The table keeps information in a condensed and clearly laid out form and therefore it is frequently consulted. On the other hand many operating authorities of measurement networks orientate their requirements on the measurement technique to the recommendations of the WMO Guide No.8.
The participants of the meeting are invited to comment the proposed changes and to agree where appropriate.

The table is presented including the proposed changes and additions red coloured. The following text will give reasons for them.

1.1 Air temperature: in col. (9) it should be added that the achievable uncertainty depends also on the type of the chosen sensor (Quality class of Pt100, PT500, Pt1000, NTC, etc)

1.2 Extremes of air temperature: in col. (5) the required uncertainty should be the same as for 1.1, mostly 1.1 and 1.2 are measured with the same sensor, being in the same range and having the same achievable uncertainty signed to.

1.4 Soil temperature (new parameter) , mostly measured in 5 different depths: 5 cm , 10 cm, 20 cm ,50 cm, 100 cm. Requirements and performance (columns (2) to (9) should be the same as with 1.1 and 1.2. The measurement range could be decreased when increasing the depth.

2.2 Relative humidity: The uncertainty for wet bulb temperature measurement and the solid state sensor depends on the air temperature; especially the 0° C transit is to be considered. Also the time constant of the solid state sensor is dependant on temperature and humidity.
The time constant of the solid sensors is a function of temperature and relative humidity.

3.1 The pressure input pipe opening influences the uncertainty of the measurement: remark in column 9.
Nowadays the time constant is smaller: 2 s is possible.

4.2 Why is the wide range of 0 to 30 km necessary? With a range of 0 to 15 km the cirrus level is reached. The detail of the uncertainty can be examined with a hard target. There is no definition of a cloud base. Algorithms should be made public to allow the comparison of sensors of different manufacturers.

5 With ultrasonic anemometers – widely used meantime – the time constant is not defined, not for wind speed, not for wind direction. Ultrasonic anemometers are acting nearly without inertia.

6.2 Time constant can be set to <10 s and output average time to 1 min. Automatic sensors are available now, for instance ultra sonic sensors. Temperature dependence of about 0.25 cm / K to be compensated for these sensors. Optical sensors without temperature dependence are in test now.

6.3 For ice accretion sensor data can be given, see report COST 727, page 73, from Heimo, A. et al. It should be discussed what information is needed: the specific mass of ice, the time duration of ice accretion or what else. Are there different sensors for different information?

6.4 Actual achievable uncertainty for precipitation could be taken from the latest WMO-comparison results.

6.5 A new variable should be added: precipitation duration. Optical sensors and electrical conductivity sensors are in use. In analogy to sunshine duration a threshold condition is to be defined for precipitation yes/no. The threshold could be: drop size > 0.2 mm and intensity > 0.02 mm/h, this is the control resolution of a laser precipitation monitor. The uncertainty of an electrical sensor may be a few minutes due to delay at the end of a precipitation event.

7 Radiation

Different radiation components are frequently measured and the corresponding sensors are connected to an AWOS. So it would be practical to have the sensor specifications in an overview like this table, for more details see chapter 7, part I of WMO no. 8. Short wave global and diffuse radiation is used for expertises about solar energy and the operation of solar power systems.

Information on long wave atmospheric radiation is needed in agricultural meteorology amongst others. The physical quantity is calculated in the AWOS and an additional device temperature sensor (Pt100 or NTC resistor) is needed and to be connected to the AWOS. Chapter 7, esp. table 7.7, could be modified, because actually no more pyrradiometers are used but only pyrgeometers (hint to ET 'radiation).

7.3 to be added: global / diffuse radiation

7.4 to be added: long wave atmospheric radiation

8.2 Runway visual range: the range is now 10 to 2000 m according to ICAO Annex 3, 15th edition, 2004.

8.3 To be added: Background luminance that is measured with a separate sensor and needed for the computation of RVR.

9 no comment

10 no comment

to discuss: adding further measurement quantities to the Table ?
e. g.: soil state, road state, soil humidity, present weather

ANNEX 1.B

OPERATIONAL UNCERTAINTY REQUIREMENTS AND INSTRUMENT PERFORMANCE

(1) Variable	(2) *Range*	(3) *Reported resolution*	(4) *Mode of measurement /observation*	(5) *Required measurement uncertainty*	(6) *Sensor time constant*	(7) *Output averaging time*	(8) *Achievable measurement uncertainty*	(9) *Remarks*
1. Temperature								
1.1 Air temperature	-80 - +60℃	0.1K	I	0.3 K for =-40℃ 0.1 K for >-40℃ and =+40℃ 0.3 K for >+40℃	20 s	1 min	0.2 K	Achievable uncertainty and effective time constant may be affected by the design of thermometer solar radiation screen. Time constant depends on the air flow over the sensor.
1.2 Extremes of air temperature	-80 - +60℃	0.1 K	I	0.5 K for =-40℃ 0.3 K for > -40℃ and =+40℃ 0.5 K for >+40℃ see 1.1	20 s	1 min	0.2 K	
1.3 Sea-surface temperature	-2 - +40℃	0.1 K	I	0.1 K	20 s	1 min	0.2 K	
1.4 Soil temperature	-50 - +50℃	0.1 K	I	see 1.1	20 s	1 m in	0.2 K	Measurement at different depths, typically 5 cm, 10 cm, 20 cm, 50 cm, 100 cm. Range can be decreased with increased depth.

2. Humidity								
2.1 Dew-point temperature	-80 - +35℃	0.1 K	I	0.1 K	20 s	1 min	0.5 K	
					Wet-bulb temperature (psychrometer)			
2.2 Relative humidity	0 - 100%	1 %	I	1%	20 s	1 min	0.2 K	If measured directly and in combination with air temperature (dry bulb). Large errors are possible due to aspiration and cleanliness problems. (see also note 11). Threshold of 0℃ to be noticed with wet bulb.
					Solid state and others			
					40 s	1min	3% for 0 - +45℃ and 0 - 100%rh, 5% for -10°- 0℃ and 0 - 95%rh, 8% for -20°- -10℃ and 0 - 85%rh	solid state sensors may show significant temperature and humidity dependence on achievable uncertainty and time constant
3. Atmospheric pressure								
3.1 Pressure	500 - 1080 hPa	0.1 hPa	I	0.1 hPa	20 s 2 s	1 min	0.3 hPa 0.15 hPa	Both station pressure and MSL pressure. Measurement uncertainty seriously affected by dynamic pressure due to wind if no precautions are taken. Inadequate temperature compensation of the transducer may affect the measurement uncertainty significantly.
3.2 Tendency	Not specified	0.1 hPa	I	0.2 hPa			0.2 hPa	Difference between instantaneous values
4. Clouds								
4.1 Cloud amount	0/8 - 8/8	1/8	I	1/8	n/a		2/8	Period (30 s min) clustering algorithms may be used to estimate low cloud amount automatically
4.2 Height of cloud base	0 m - 30 km 0 - 15 km	10 m	I	10 m for <= 100 m 10% for > 100 m	n/a		~10 m	Achievable measurement uncertainty can be determined with a hard target. undetermined because no clear definition exists for instrumentally measured cloud base height (e.g. based on penetration depth or significant discontinuity in the extinction profile)

								Internal algorithms for determination of cloud base should be public for comparison. Significant bias during precipitation
4.3 Height of cloud top	Not available							
5. Wind								
5.1 Speed	0 - 75 ms^{-1}	0.5 ms-1	A	0.5ms^{-1} for <=5ms^{-1} 10% for >5 ms^{-1}	Distance constant 2 - 5 m	2 and/or 10 min	0.5 ms^{-1} for <=5 ms^{-1} 10% for >5 ms^{-1}	Average over 2 and/or 10 minutes. Non-linear devices. Care needed in design of averaging process. Distance constant is usually expressed as response length. Averages computed over Cartesian components (see this Guide, Part III, chapter 2, section 2.6).
5.2 Direction	0- 360 ℃	1°	A	5°	1 s	2 and/or 10 min	5°	
5.3 Gusts	0.1 - 150 ms^{-1}	0.1 ms^{-1}	A	10%		3 s	0.5 ms^{-1} for <=5 ms^{-1} 10% for >5 ms^{-1}	Highest 3 s average should be recorded When using ultrasonic anemometers no distant constant or time constant is defined , they are nearly without inertia.
6. Precipitation								
6.1 Amount (daily)	0 - 500 mm	0.1 mm	T	0,1 mm for ≤5 mm 2 % for >5 mm	n/a	n/a	The larger of 5 % or 0.1 mm	Quantity based on daily amounts. Measurement uncertainty depends on aerodynamic collection efficiency of gauges and evaporation losses in heated gauges.
6.2 Depth of snow	0 - 25 m	1 cm	A	1 cm for ≤20 cm 5 % for >20 cm	< 10 s	1 min	1 % of range	Average depth over an aera area representative of the observing site.
6.3 Thickness of ice accretion on ships	Not specified	1 cm	I	1 cm for ≤10 cm 10 % for >10 cm				
6.4 Precipitation intensity	0.02 mm h^{-1} - 2000 mm h^{-1}	0.1 mm h^{-1}	I	for 0.02 - 0.2 mm h^{-1} (trace) : n/a 0.1 mm h^{-1} for 0.2 - 2 mm h^{-1} 5 % for > 2 mm h^{-1}	<30 s	1 min		Uncertainty values for liquid precipitation only. Uncertainty seriously affected by wind. Sensors may show significant non-linear behaviour. For <0.2 mm h^{-1}: detection only (yes/no) Sensor time constant significantly affected during solid precipitation using catchment type of gauges.

6.5 Precip. duration (daily)	0 - 24 h	60 s	T	?		n/a		uncertainty depending on threshold definition
7. Radiation								
7.1 Sunshine duration (daily)	0 - 24 h	60 s	T	0.1 h	20 s	n/a	The larger of 0.1 h or 2 %	
7.2 Net radiation, radiant exposure (daily)	Not specified	1 J m^{-2}	T	0.4 MJ m^{-2} for ≤ 8 MJ m^{-2} 5 % for > 8 MJ m^{-2}	20 s	n/a	0.4 MJ m^{-2} for ≤ 8 MJ m^{-2} 5 % for > 8 MJ m^{-2}	Radiant exposure expressed as daily sums (amount) of (net) radiation.
7.3 Global and diffuse radiation	0 - 1400 Wm^{-2}	1 Wm^{-2}	I	?	< 15 s	1 min	2% of daily sum	free horizon from elevation >5° needed, uncertainty for 'high quality', see table 7.5
7.4 Atmospheric radiation	100 - 600 Wm^{-2}	1 Wm^{-2}	I	?	< 20 s	1 min	5 % of daily sum	free horizon from elevation >5° needed
8. Visibility								
8.1 Meteorological Optical Range (MOR)	10 m - 100 km	1 m	I	50 m for ≤600 mm 10 % for >600 mm ≤ 1500 m 20 % for >1500 m	<30 s	1 and 10 min	The larger of 20 m or 20 %	Achievable measurement uncertainty may depend on the cause of obscuration. Quantity to be averaged: extinction coefficient (see this *Guide* , Part III, Chapter 2, section 2.6). Preference for averaging logarithmic values.
8.2 Runway Visual Range (RVR)	10 m - 1 500 m 10 m - 2000 m	1 m	A	10 m for ≤400 m 25 m for >400 m - ≤800 m 10 % for > 800 m	<30 s	1 and 10 min	The larger of 20 m or 20 %	In accordance with WMO-No. 49, Volume II, Attachment A (2004 ed.) and ICAO Doc 9328-AN/908 (Second ed., 2000)
8.3 Background luminance	0 - 40000 cdm^{-2}	1 cdm^{-2}	I	10% of actual value	30 s	1 min	10%	
9. Waves								
9.1 Signifcant wWave height	0 - 50 m	0.1 m	A	0.5 m for ≤5 m 10 % for >5 m	0.5 s	20 min	0.5 m for ≤5 m 10 % for >5 m	Average over 20 minutes for instrumental measurements.
9.2 Wave period	0 - 100 s	1 s	A	0.5 s	0.5 s	20 min	0.5 s	Average over 20 minutes for instrumental measurements.
9.3 Wave direction	0 -360°	1°	A	10°	0.5 s	20 min	20°	Averag e over 20 minutes for instrumental measurements.
10. Evaporation								
10.1 Amount of pan evaporation	0 - 100 mm	0.1 mm	T	0.1 mm for ≤5 mm 2 % for >5 mm	n/a			

NOTES:

1. Column 1 gives the basic variable.

2. Column 2 gives the common range for most variables; limits dpend on local climatological conditions.

3. Cloumn 3 gives the most stringent resolution as determined by the *Manual on Codes* (WMO-No. 306)

4. In column 4:

   I: Instantaneous. In order to exclude the natural small scale variability and the noise, an average value oder a period of one minute is considered as a minimum and most suitable; averages over periods of up to ten10 minutes are acceptable.

   A: Averaging. Average values over a fixed time period, as specified by the coding requirements

   T: Totals. Totals over a fixed time period, as specified by coding require-ments.

5. Column 5 gives the recommended measurement uncertainty requirements for general operational use, i.e. of Level II Data according to FM 12, 13, 14, 15 and ist BUFR equivalents. It is adopted by all eight technical commissions and is applicable for synoptic, aeronautical, agricultural, marine meteorology, hydrology, climatology, etc. These requirments are applicable for both manned and automatic weather stations as defined in the *Manual on the Global Observing System* (WMO.-No. 544). Individual applications may have less stringent requirements. The stated value of required measurement uncertainty represents the uncertainty of the reported value with respect to the true value and indicates the interval in which the true value lies with a stated probability. The recommended probaility level ist 95 per cent (k = 2), which corresponds to the 2δ level for a normal (Gaussian) distribution of the variable. The assumption that all known corrections are taken into account implies that ehe errors in reported values will have a mean value (or bias) close to zero. Any residual bias should be small compared with the stated measurement uncertainty requirement. The true value is that value which, under operational conditions, perfectly characterizes the variable to be measured/observed over the representative time interval, area and/or volume required, taking into acount siting and exposure.

6. Columns 2 to 5 refer to the requirements stated by the CBS Expert Team on Requirements of Data from Automatic Weather Statioons, in 2004.

7. Columns 6 to 8 refer to the typical operational performance stated by the CIMO Expert Team on Surface Technology and Measurement Techniques in 2004.

8. Achievable measurement uncertainty (coumn 8) based on sensor performance under nominal and recommended exposure that can be achieved in operational practice. It should be regarded as a practical aid to users in defining achievable and affordable requirements.

9. n/a = not applicable

10. The term uncertainty has preference over accuracy (i.e. uncertainty is in accordance with ISO standards on uncertainty of measurements , ISO, 1995).

11. Dewpoint temperature, relative humidity and air-temperature are linkes, and thus their uncertainties are linked. In case of averaging, preference is given for the absolute humidity as principal variable.