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COMMISSION FOR INSTRUMENT AND METHODS OF OBSERVATION
OPAG-SURFACE

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ITEM: 4.1

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

Development of Instruments and ASOS

Submitted by Chairman

Summary and Purpose of Document

The document contains an overview of tables with functional requirements of surface observations and operational measurement uncertainties.

ACTION PROPOSED

The meeting is invited to take notice of the attachments of this document and to supply comments or recommendations.

References:

1. CBS Expert Team On Requirements For Data From Automatic Weather Stations (ET-AWS), 3rd meeting, Geneva, 28 June - 2 July 2004, Final Report.[1]
2. WMO Technical Regulations, Vol. I (WMO-No.49), Suppl. No. 3 (II.1998)
3. WMO Manual on the Global Data Processing and Forecasting System (WMO No. 485)

[1] see WMO's website at http://www.wmo.ch/web/www/OSY/Reports/ET-AWS3_Geneva2004.pdf

INFORMATION

The Guide to Meteorological Instruments and Methods of Observations (WMO-No. 8) contains a table (Vol. I, Chap. I, Annex 1.B) containing for each variable (or element) the required maximum measurement uncertainties and the minimum achievable measurement uncertainties. For WMO this table is of principle importance for the further design and implementation of instrument measurements in terms of accuracy requirements and attainable uncertainty. In the forthcoming revision of this Guide an updated table will be inserted. The 'requirements' part of this table is revised recently by the ET-AWS 3 (June 2003) - a request for confirmation to the President of TCs has been send (deadline 15 November 2004). It is up to the ET ST&MT now to discuss and advise for the update of the attainable uncertainties. This table, already prepared for insertion into the CIMO Guide, is attached as ANNEX I.

On request by EC, ET AWS-3 also produced an updated table with Functional Specifications for Automatic Weather Stations. Because of the need and trend to automate observations, human observations, which are hardly to automate (visual and subjective observations) and suffer from subjectivity had to be defined in more detail. Such observations must be represented by numerical quantities rather than subjective descriptors like 'light' or 'severe' (The requirement *"To report observed quantities rather than qualitative parameters for present weather in observation from automatic stations in FM 94 BUFR and FM 95 CREX"* stated in Rec. 3 (CBS-XII) is reconfirmed by Res. 4 (EC-LIII). This table on Functional Specifications therefore contains a large set of measurable variables to be reported quantitatively in BUFR format by AWS. This table is attached as ANNEX II.

Other WMO/WWW documents containing tables with requirements on surface data are the Technical Regulations, Vol. I (WMO-No. 49) and its Annex IV, the Manual on the Global Data Processing and Forecasting System (WMO-No. 485). In both documents two relevant and rather similar tables on surface data are presented which are in terms of measurable variables [see also footnote 2]. Both tables relate to the Requirements for International Exchange of International Data (Requirements for the International Exchange of Observational Data and Products to Meet the Needs of WMO Programmes (*in* WMO-No. 49, 1988 edition, Suppl. No. 3 (II.1998)) and Observational Data Requirements for GDPS Centres for Global and Regional Exchange (*in* WMO-No. 485, 1992 edition, Suppl. No. 4 (VIII.1997))). Both tables are attached as ANNEX III and give a brief overview of the required variables used for international dissemination.

REQUEST

The ET ST&MT is invited to take notice of the tables in the Annexes. The ET ST&MT is requested to comment and approve the *Achievable measurement uncertainties* presented in the table of Annex I. Within the context of *Instrument Development* and the *Automation of Observations*, any comment on the variables presented in the other tables will be appreciated.

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[2] Note on *Variables,* stated in the *Technical Regulations* [1992 edition, Suppl. No. 4 (VIII.1997)]

Following past convention, the observational requirements for data assimilation are stated in terms of geophysical variables. This is thought to be useful since, from a user's perspective, these are the variables on which information is required. However, it is important to note that these variables are not always observed directly (satellite systems observe none of them directly, with the exception of top-of-the-atmosphere radiation and a Doppler wind lidar). Also, it is no longer true that the users need their data exclusively in the form of geophysical parameters; recent developments in data assimilation have demonstrated the potential and the benefits of using data at the engineering level (e.g. radiances, brightness temperatures).

ANNEX I

Operational Uncertainty ~~Accuracy~~[3] [1] Requirements and Typical[4] [2] Instrument Performance

Present values [from the Guide to Meteorological Instruments and Methods of Observations, 6th edition (WMO No. 8, 1996)] are given by "(**old:...**)". Further explanation and remarks to the data by ET/AWS are given as footnotes at the bottom of each page. The endnotes are part of the table and are as published in WMO-No. 8.

(1) Variable	*(2) Range*	*(3) Reported resolution*	*(4) Mode of measurement observation*	*(5) Required Uncertainty ~~accuracy~~*[5]	*(6) Sensor time constant*[6]	*(7) Output averaging time*	*(8) Achievable operational Uncertainty ~~accuracy~~*[7]	*(9) Remarks*
1. Temperature								
1.1 Air temperature	-80 – +60 ºC **(old: -60 – +60 ºC)**	0.1 K	I	0.3 K for ≤ -40ºC 0.1 K for >–40C and ≤ +40ºC 0.3 K for > +40ºC **(old: ±0.1 K)**	20 s	1 min	0.1 K **(old: ±0.2 K)**	Achievable ~~accuracy~~ uncertainty and effective time constant may be affected by the design of thermometer solar radiation screen.
1.2 Extremes of air temperature	-80 – +60 ºC **(old: -60 – +60 ºC)**	0.1 K	I	0.5 K for ≤ -40ºC 0.3 K for > -40 ºC and ≤ +40ºC 0.5 K for > +40ºC **(old: ±0.5 K)**	20 s	1 min	0.1 K **(old: ±0.2 K)**	
1.3 Sea-surface temperature	-2 – +40 ºC	0.1 K	I	0.1 K	20 s	1 min	0.1 K **(old: ±0.2 K)**	

[3] The term *accuracy* is replaced by *uncertainty* to be in accordance with ISO standards on *uncertainty of measurements*
[4] To be removed
[5] ± sign should be removed to be in accordance with ISO standards on *uncertainty of measurements*
[6] n/a: not applicable.
[7] Suggestions.

(1) Variable	*(2) Range*	*(3) Reported resolution*	*(4) Mode of measurement observation*	*(5) Required Uncertainty ~~accuracy~~[5]*	*(6) Sensor time constant[6]*	*(7) Output averaging time*	*(8) Achievable operational Uncertainty ~~accuracy~~[7]*	*(9) Remarks*
2. Humidity								*If measured directly. Tending to ±0.1 K when (relative humidity)[10] nears saturation.*
2.1 Dew point temperature	-80 – +35 ºC **(old: -60 – +35 ºC)[9]**	0.1 K	I	0.1 K **(old: ±0.5 K)**	20 s	1 min	0.5 K	
					Wet-bulb temperature			
2.2 Relative humidity	0 – 100 %	1 %	I	1 % **(old: ±3%)**	20 s	1 min	0.2 K	If measured directly. Tending to ±1% when relative humidity[9] nears saturation. Large errors are possible due to aspiration and cleanliness problems.
					Solid state and others			
					40 s	1 min	1 % **(old: ± 2– 5 %)**	Solid-state sensors may show significant temperature and humidity dependence.
3. Atmospheric pressure								
3.1 Pressure[11]	500 – 1080 hPa **(old: 920 - 1080 hPa)**	0.1 hPa	I	0.1 hPa	20 s	1 min	0.1 hPa **(old: ±0.3 hPa)**	***(Range to sea-level)[12].*** Accuracy seriously affected by dynamic pressure due to wind and temperature coefficient of transducer.
3.2 Tendency	Not specified	0.1 hPa	I	0.2 hPa			0.1 hPa **(old: ±0.2 hPa)**	Differences between instantaneous values.

[8] Note that dewpoint temperature, relative humidity and air-temperature are linked, and thus their uncertainties are linked.
[9] Primary standards for dewpoint available for t-dew > -60ºC
[10] The string "relative humidity" can be removed.'
[11] Both station pressure and MSL pressure.
[12] To be removed (also station pressure involved)

(1) Variable	*(2) Range*	*(3) Reported resolution*	*(4) Mode of measurement observation*	*(5) Required Uncertainty ~~accuracy~~*[5]	*(6) Sensor time constant*[6]	*(7) Output averaging time*	*(8) Achievable operational Uncertainty ~~accuracy~~*[7]	*(9) Remarks*
4. Clouds								
4.1 Cloud amount	0 – 8/8	1/8	I	1/8	n/a[14]		1/8 to 2/8 (**old: ±1/8**)	Period (30s) clustering algorithms may be used to estimate low cloud amount automatically.
4.2 Height of cloud base	0 m – 30 km **(old: 30 m - 30 km)**	10 m (**old: 30 m**)	I	10 m for ≤ 100 m 10 % for > 100 m	n/a		≈ 10 m repeatability*	* Accuracy difficult to determine since no definitions exists for instrumentally measured cloud base height.
4.3 Height of cloud top (to be introduced)	not available[13]							
5. Wind								
5.1 Speed	0 – 75 m s^{-1}	0.1 m s^{-1}	A	0.5 m s^{-1} for ≤ 5 m s^{-1} 10 % for > 5 m s^{-1}	Dist. cont.[15] 2–5 m	2 and/or 10 min	0.5 m s^{-1}	Average over 2 and/or 10 minutes. Non-linear devices. Care needed in design of averaging process.
5.2 Direction	0 – 360º	1º	A	5 %		2 and/or 10 min	5 º	
5.3 Gust	0.1 – 150 m s^{-1} **(old: 5 - 75 m/s)**	0.1 m s^{-1} (old: 0.5 m/s)	A	10 %		3 s	0.5 m s^{-1}	Highest 3s average should be recorded.

[13] to be determined.
[14] To be determined for instrument measurements
[15] Distant constant; for anemometers: *response length*

(1) Variable	*(2) Range*	*(3) Reported resolution*	*(4) Mode of measurement observation*	*(5) Required Uncertainty ~~accuracy~~*[5]	*(6) Sensor time constant*[6]	*(7) Output averaging time*	*(8) Achievable operational Uncertainty ~~accuracy~~*[7]	*(9) Remarks*
6. Precipitation								
6.1 Amount (daily)	0 – 500 mm **(old: 0 - > 400 mm)**	0.1 mm	T	0.1 mm for ≤ 5 mm 2 % for > 5 mm	n/a [17]	n/a	5 %	Accuracy depends on aerodynamic collection efficiency of gauges and evaporation losses in heated gauges.
6.2 Depth of snow	0 – 25 m **(old: 0 – 10 m)**	1 cm	A	1 cm for ≤ 20 cm 5 % for > 20 cm				Average depth over an area representative of the observing site
6.3 Thickness of ice accretion	Not specified	1 cm	I	1 cm for ≤ 10 cm 10 % for > 10 cm				Accuracy seriously affected by wind. Sensors may show significant non linear behavior
6.4 Precipitation intensity[16] (new variable)	0.02 mm/h - 2000 mm/h to be implemented	0.1 mm/h to be implemented	I	0.02 - 0.2 mm/h (trace): n/a 0.2 - 2 mm/h: 0.1 mm/h > 2 mm/h: 5% to be implemented		1 min to be implemented		
7. Radiation								
7.1 Sunshine duration (daily)	0 – 24 h	60 s (old: 0.1 h)	T	0.1 h	20 s	n/a	2 %	
7.2 Net radiation – radiant exposure [18] (daily)	Not specified	1 J m^{-2} (old: 1MJ m^{-2} d^{-1}; see footnote 18 on change in units)	T	0.4 MJ m^{-2} for ≤ 8 MJ m^{-2} 5 % for > 8 MJ m^{-2} **(old: ±0.4 MJ m^{-2} d^{-1} for ≤ 8 MJ m^{-2} d^{-1} ;±5 % for > 8 MJ m^{-2} d^{-1}; see footnote 18 on change in units)**	20 s	n/a	5 %	

[16] Specified for rainfall intensity by the expert team on rainfall intensity measurements (Bratislava, Slovakia, 23 to 25 April 2001)
[17] Totals reading
[18] According to the Guide to Instruments and Methods of Observation (WMO No. 8), Vol. I, Ch. 7, "Measurement of Radiation" to be *Radiant exposure"*, symbol *H*, to be used for daily sums of (net) radiation. In Annex 7.A of this Guide, the unit for *H* is J m^{-2} and not W m^{-2}. Although it is common practice to regard radiation as an *intensity* variable like *irradiance* in W m^{-2} or J m^{-2} d^{-1}, daily amounts of radiation, expressed in J m^{-2} are in use as well. Obviously, confusion may arise and a better definition of *radiation* should be endorsed.

(1) Variable	*(2) Range*	*(3) Reported resolution*	*(4) Mode of measurement observation*	*(5) Required Uncertainty ~~accuracy~~*[5]	*(6) Sensor time constant*[6]	*(7) Output averaging time*	*(8) Achievable operational Uncertainty ~~accuracy~~*[7]	*(9) Remarks*
8. Visibility								
8.1 MOR	10 m – 100 km **(old: <50 m – 70 km)**	1 m (**old: 50 m**)	I, A[19]	[20]50 m for ≤ 600 m 10 % for > 600 – ≤ 1500 m 20% for > 1500 m **(old: ±50 m for ≤ 500 m ±10 % for > 500 m)**		1 and 10 min **(old: 3 min)**	10 – 20 %	Achievable instrumental accuracy may depend on the cause of obscuration.
8.2 RVR	10 m – 1 500 m **(old: 50 m 1500 m)**	1 m (old: 50 m)	A	[20]10 m for ≤400 m 25 m for >400-≤800 m 10 % m for >800 m **(old: ±25 m for ≤150 m ±50 m for >150 – ≤500 m ±100 m for >500 – ≤ 1000 m ±200 m for > 1000 m)**		1 and 10 min		[20])
9. Waves								
9.1 Wave height	0 – 50 m **(old: 0 – 30 m)**	0.1 m	A	0.5 m for ≤ 5 m 10 % for > 5 m	0.5 s	20 min	10 %	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 – 360º	1º (old: 10º)	A	10º	0.5 s	20 min	20º	Average over 20 minutes for instrumental measurements.
10. Evaporation								
10.1 Amount of pan evaporation	0 – 100 mm (**old: 0 – 10 mm**)	0.1 mm	T	±0.1 mm for ≤ 5 mm ±2 % for 5 mm				

NOTES:
1. Column 1 gives the basic variable.
2. Column 2 gives the common range for most variables; limits depend on local climatological conditions.
3. Column 3 gives the most stringent resolution as determined by the *Manual on Codes (WMO-No. 306)*
4. In column 4:

[19] A: For 10 min intervals, averaging over logarithmic values is advised.
[20] In accordance with WMO Technical Regulations (WMO No. 49) - Vol. II, Attachment B

I: Instantaneous. In order to exclude natural small-scale variability and noise, an average value over a period of one minute is considered as a minimum and most suitable; averages over periods of up to 10 minutes are acceptable.
A: Averaging. Average values over a fixed time period, as specified by the users' requirements.
T: Totals. Totals over a fixed time period(s), as specified by the users' requirements.

5. Column 5 gives the recommended accuracy requirement for general operational use. Individual applications may have less stringent requirements. The stated value of required accuracy 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 probability level is 95 %, which corresponds to the 2σ-level for a normal (Gaussian) distribution of the variable. The assumption that all known corrections are taken into account implies that the errors in reported values will have a mean value (or bias) close to zero. Any residual bias should be small compared with the stated accuracy 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 account siting and exposure.
6. Columns 2 to 5 refer to the requirements stated by the Meeting of Experts on Operational Accuracy Requirements, held in 1991.
7. Columns 6 to 8 refer to the typical operational performance stated by the CIMO Working Group on Surface Measurements in 1993.

ANNEX II

Functional Specifications for Automatic Weather Stations

(changes marked in red)

VARIABLE [1]	Maximum Effective Range [2]	Minimum Reported Resolution [3]	Mode of Observation [4]	BUFR / CREX [5]
ATMOSPHERIC PRESSURE				
Pressure	500 – 1080 hPa	10 Pa	I, V	0 10 004
TEMPERATURE				
Ambient air temperature (over specified surface)	-80 °C – +60 °C	0.1 K	I, V	0 12 101
Dew-point temperature	-80 °C – +60 °C	0.1 K	I, V	0 12 103
Ground (*surface*) temperature (*over specified surface*)	-80 °C – +80 °C	0.1 K	I, V	0 12 113
Soil temperature	-50 °C – +50 °C	0.1 K	I, V	0 12 130
Snow temperature	-80 °C – 0 °C	0.1 K	I, V	N
Water temperature - river, lake, sea, well	-2 °C – +100 °C	0.1 K	I, V	0 13 082
HUMIDITY				
Relative humidity	0 – 100%	1%	I, V	0 13 003
Mass mixing ratio	0 – 100%	1%	I, V	N
Soil moisture, volumetric or water potential	0 – 10^3 g kg^{-1}	1 g kg^{-1}	I, V	N
Water vapour pressure	0 – 1000 hPa	10 Pa	I, V	N
Evaporation / evapotranspiration	0 – 0.1 m	0.1 kg m^{-2}, 0.0001 m	T	0 13 033
Object wetness duration	0 – 86 400 s	1 s	T	N
WIND				
Direction	0 – 360 degrees	1 degree	I, V	0 11 001
Speed	0 – 75 m s^{-1}	0.1 m s^{-1}	I, V	0 11 002
Gust Speed	0 – 150 m s^{-1}	0.1 m s^{-1}	I, V	0 11 041
X,Y,Z component of wind vector (horizontal and vertical profile)	0 – 150 m s^{-1}	0.1 m s^{-1}	I, V	N
Turbulence type (Low levels and wake vortex)	up to 15 types	BUFR Table	I, V	N
Turbulence intensity	up to 15 types	BUFR Table	I, V	N
RADIATION [6]				
Sunshine duration	0 – 86 400 s	60 s	T	0 14 031
Background luminance	$1 \cdot 10^{-6}$ – $2 \cdot 10^4$ Cd m^{-2}	$1 \cdot 10^{-6}$ Cd m^{-2}	I, V	N
Global downward solar radiation	0 – $6 \cdot 10^6$ J m^{-2}	1 J m^{-2}	I, T, V	N
Global upward solar radiation	0 – $4 \cdot 10^6$ J m^{-2}	1 J m^{-2}	I, T, V	N
Diffuse solar radiation	0 – $4 \cdot 10^6$ J m^{-2}	1 J m^{-2}	I, T, V	0 14 023
Direct solar radiation	0 – $5 \cdot 10^6$ J m^{-2}	1 J m^{-2}	I, T, V	0 14 025
Downward long-wave radiation	0 – $3 \cdot 10^6$ J m^{-2}	1 J m^{-2}	I, T, V	0 14 002
Upward long-wave radiation	0 – $3 \cdot 10^6$ J m^{-2}	1 J m^{-2}	I, T, V	0 14 002
Net radiation	0 – $6 \cdot 10^6$ J m^{-2}	1 J m^{-2}	I, T, V	0 14 016
UV-B radiation	0 – $1.2 \cdot 10^3$ J m^{-2}	1 J m^{-2}	I, T, V	N
Photosynthetically active radiation	0 – $3 \cdot 10^6$ J m^{-2}	1 J m^{-2}	I, T, V	N
Surface albedo	1 – 100%	1%	I, V	0 14 019

VARIABLE [1]	Maximum Effective Range [2]	Minimum Reported Resolution [3]	Mode of Observation [4]	BUFR / CREX [5]
CLOUDS				
Cloud base height	0 – 30 km	10 m	I, V	0 20 013
Cloud top height	0 – 30 km	10 m	I, V	0 20 014
Cloud type, convective vs. other types	up to 30 classes	BUFR Table	I	0 20 012
Cloud hydrometeor concentration	1 – 700 hydrometeors dm^{-3}	1 hydrometeor dm^{-3}	I, V	N
Effective radius of cloud hydrometeors	$2 \cdot 10^{-5}$ – $32 \cdot 10^{-5}$ m	$2 \cdot 10^{-5}$ m	I, V	N
Cloud liquid water content	$1 \cdot 10^{-5}$–$1.4 \cdot 10^{-2}$ kg m^{-3}	$1 \cdot 10^{-5}$ kg m^{-3}	I, V	N
Optical depth within each layer	Not specified yet	Not specified yet	I, V	N
Optical depth of fog	Not specified yet	Not specified yet	I, V	N
Height of inversion	0 – 1 000 m	10 m	I, V	N
Cloud cover	0 – 100%	1%	I, V	0 20 010
Cloud amount	0 – 8/8	1/8	I, V	0 20 011
PRECIPITATION				
Accumulation	0 – 500 mm	0.1 kg m^{-2}, 0.0001 m	T	0 13 011
Duration	up to 86 400 s	60 s	T	0 26 020
Size of precipitating element	$1 \cdot 10^{-3}$ – 0.5 m	$1 \cdot 10^{-3}$ m	I, V	N
Intensity - quantitative	0 – 2000 mm h^{-1}	0.1 kg m^{-2} s^{-1}, 0.1 mm h^{-1}	I, V	0 13 055
Type	up to 30 types	BUFR Table	I, V	0 20 021
Rate of ice accretion	0 – 1 kg dm^{-2} h^{-1}	$1 \cdot 10^{-3}$ kg dm^{-2} h^{-1}	I, V	N
OBSCURATIONS				
Obscuration type	up to 30 types	BUFR Table	I, V	0 20 025
Hydrometeor type	up to 30 types	BUFR Table	I, V	0 20 025
Lithometeor type	up to 30 types	BUFR Table	I, V	0 20 025
Hydrometeor radius	$2 \cdot 10^{-5}$ – $32 \cdot 10^{-5}$ m	$2 \cdot 10^{-5}$ m	I, V	N
Horizontal - extinction coefficient	0 – 1 m^{-1}	0.001 m^{-1}	I, V	N
Slant - extinction coefficient	0 – 1 m^{-1}	0.001 m^{-1}	I, V	N
Meteorological Optical Range	1 – 100 000 m	1 m	I, V	N
Runway visual range	1 – 4 000 m	1 m	I, V	0 20 061
Other weather type	up to 18 types	BUFR Table	I, V	0 20 023
LIGHTNING				
Lightning rates of discharge	0 – 100 000	Number h^{-1}	I, V	0 13 059
Lightning discharge type (cloud to cloud, cloud to surface)	up to 10 types	BUFR Table	I, V	N
Lightning discharge polarity	2 types	BUFR Table	I, V	N
Lightning discharge energy	Not specified yet	Not specified yet	I, V	N
Lightning - distance from station	0 – $3 \cdot 10^{4}$ m	10^{3} m	I, V	N
Lightning - direction from station	1 – 360 degrees	1 degree	I, V	N

VARIABLE [1)]	Maximum Effective Range [2)]	Minimum Reported Resolution [3)]	Mode of Observation [4)]	BUFR / CREX [5)]
HYDROLOGIC OBSERVATIONS				
Flow discharge - river	0 – $2.5 \cdot 10^5$ $m^3 s^{-1}$	0.1 $m^3 s^{-1}$	I, V	0 23 017
Flow discharge - well	0 – 50 $m^3 s^{-1}$	0.001 $m^3 s^{-1}$	I, V	0 23 017
Ground water level	0 – 1 800 m	0.01 m	I, V	N
Ice surface temperature	-80 °C – +0 °C	0.5 K	I, V	N
Ice thickness - river, lake	0 – 50 m	0.01 m	I, V	N
Ice thickness - glacier, sea	0 – 4 270 m	1 m	I, V	0 20 031
Water level	0 – 100 m	0.01 m	I, V	0 13 071 0 13 072
Wave height	0 – 50 m	0.1 m	I, V	0 22 021
Wave period	0 – 100 s	1 s	I, V	0 22 011
Wave direction	0 – 360 degrees	1 degrees	I, V	0 22 001
Sea salinity	0 – $50 \cdot 10^{-3}$ %	10^{-3} %	I, V	0 22 062
Ice thickness	0 – 3 m	0.015 m	T	0 20 031
Ice mass	0 – 50 kg m^{-1}	0.5 kg m^{-1} (on 32 mm rod)	T	N
Snow density (liquid water content)	100 – 700 kg m^{-3}	1 kg m^{-3}	T	N
OTHER SURFACE VARIABLES				
Runway conditions	up to 10 types	BUFR Table	I, V	N
Braking action/friction coefficient	up to 7 types	BUFR Table	I, V	N
State of ground	up to 30 types	BUFR Table	I, V	0 20 062
Type of surface specified	up to 15 types	BUFR Table	I, V	0 08 010
Snow depth	0 – 25 m	0.01 m	T	0 13 013
OTHER				
Gamma radiation dose	1 – 10 nSv h^{-1}	1 nSv h^{-1}	I, T	N
Categories of stability	9 types	BUFR Table	I, V	0 13 041

Notes:

1. Name of variable;
2. Maximum Effective Range – Maximum range of measuring capability;
3. Minimum Reported Resolution –Lower resolution of reporting is not permitted;
4. Mode of Observation – Type of data being reported:
   I: Instantaneous – 1-minute value (instantaneous as defined in WMO-No.8, Part II, paragraph 1.3.2.4);
   V: Variability – Average (mean), Standard Deviation, Maximum, Minimum, Range, Median, etc. of samples – those reported depend upon meteorological variable;
   T: Total – Integrated value during defined period (over a fixed period(s)); maximum 24 hours for all parameters except radiation which requires a maximum of one hour.
   A: Average (mean) value.
5. BUFR/CREX – Present ability to represent variable by BUFR Tables, N = not existing.
6. Radiation energy amounts are given over a 24-hour period.

ANNEX III

[reference: **Technical Regulations**, Volume I (WMO-No. 49;1988 edition, Suppl. No. 3 (II.1998)), p. XV, *Requirements for the International Exchange of Observational Data and Products to Meet the Needs of WMO Programmes*]

Table 2 – Surface data

	Horizontal resolution (km)	*Temporal resolution*	*Source of requirement*
Pressure	100	1h	Most programmes
Wind	100	1h	Most programmes
Temperature (air)	100	1h	Most programmes
Relative humidity	100	1h	Most programmes
Visibility	100	1h	Most programmes
Present weather	100	1h	Most programmes
Accumulated precipitation	100	1h	Most programmes
Precipitation rate	100	1h	Most programmes
Sea-surface temperature	100	1 day	Most programmes
Land-surface temperature	100	3h	Most programmes
Sea-ice cover	100	1 day	Most programmes
Snow and ice cover	100	1 day	Most programmes
Snow equivalent-water depth	100	1 day	Most programmes
River runoff	250	1 day	GCOS, OHP
Lake water levels	Variable	1 week	GCOS, OHP
Water quality	250	1 week	OHP
Sediment	250	1 week	OHP
Percentage of vegetation	100	1 week	Most programmes
Phenological data	Variable	10 days	GCOS, AgM
Soil temperature, 20 cm	100	6h	GCOS, AgM
Deep soil temperature, 100 cm	100	1 day	GCOS, AgM
Surface roughness	50	1 month	GCOS, AgM
Albedo, visible	100	1 day	Most programmes
Albedo, near infrared	100	1 day	Most programmes
Long-wave emissivity	100	1 day	Most programmes
Multipurpose imagery	1 or 4	6h	Most programmes
Surface net radiation	50	6h	GCOS, AgM
UV incoming	50	1h	PWS, AREP, WCP
Wave spectra	100	1h	WWW, MM
Salinity	100	6h	GCOS
Sea level	50	12h	GCOS
Ocean current	100	6h	IGOSS, GCOS, GOOS
Greenhouse gas concentrations	Variable	Variable	GCOS, WCP, AREP
Ozone	Variable	Variable	GCOS, GAW
Precipitation chemistry	Variable	Variable	GAW, GCOS
Aerosols — chemical and physical properties	Variable	Variable	GAW, GCOS
Reactive gases	Variable	Variable	PWS,CCl,GAW
Radionuclides	Variable	Variable	EER, GAW
Volcanic activity	Variable	Variable	PWS, AeM

NOTE: For some programmes, e.g. environmental monitoring/agriculture/hydrology/environmental emergency response and public weather services, much higher resolution data are needed operationally

[reference: **Manual on the Global Data Processing and Forecasting System** (WMO-No. 485;1992 edition, Suppl. No. 4 (VIII.1997)), pp. II-2-5, Appendix II-2, *Observational Data Requirements for GDPS Centres For Global And Regional Exchange*]

TABLE 2
Surface fields

	Horizontal resolution (km)	*Temporal resolution*	*Accuracy (RMS error)*	*Notes*
Pressure	100	1h	0.5 hPa	
Wind	100	1h	2 m s^{-1}	(1)
Temperature	100	1h	1 K	
Relative humidity	100	1h	5%	
Visibility	100			
Accumulated precipitation	100	1h	0.1 mm	(2)
Precipitation rate	100	1h	0.1 mm h^{-1}	
Sea and lake surface temperature	100	1 day	0.5 K	
Soil temperature	100	3h	0.5 K	
Sea-ice and lake ice cover	100	1 day	10%	
Snow cover	100	1 day	10%	
Snow equivalent-water depth	100	1 day	5 mm	
River runoff	250	1 week		
Lake water level	Variable	1 week		
Water quality	250	1 week		
Sediments	250	1 week		
Percentage of vegetation	100	1 week	10% (relative)	
Phenomological data	Variable	10 days		
Soil temperature, 20 cm	100	6h	0.5 K	
Deep soil temperature, 100 cm	100	1 day	0.5 K	
Surface roughness	50	1 month		
Albedo, visible	100	1 day	1%	
Albedo, near infrared	100	1 day	1%	
Long-wave emissivity	100	1 day	1%	
Multipurpose imagery	1 or 4	6h	–	
Surface net radiation	50	6h	1%	
UV incoming	50	1h	1–5%	
Waves spectra	100	1h	0.01 m	
Salinity	100	6h	1%	
Sea level	50	12h	0.01m	
Ocean current	100	6h	2 cm s^{-1}	
Greenhouse gas concentrations	Variable	Variable	2–10% (1pptv–1ppmv)	(3)
Ozone	Variable	Variable	1–5%	
Precipitation chemistry	Variable	Variable	–	
Aerosols-chemical and physical properties	Variable	Variable	–	
Reactive gases	Variable	Variable	2–10% (1pptv–1ppmv)	
Radionuclides	Variable	Variable		
Volcanic activity	Variable	Variable		(3)

NOTES:
(1) Wind at 10 metres over land;
Over sea, height in the range 1 to 40 metres (to be transmitted with the observations)
(2) Required principally for model validation, not time critical.
(3) For some programmes, *e.g.* environmental monitoring, environmental emergency response and public weather services, much higher resolution data are needed

Accuracy
The values given are intended to represent the RMS of the observation errors. The assessment of accuracy should include not only the true instrumental error but also the representativeness error (i.e. the characteristics of some observing systems, particularly *in situ* systems, which sample spatial and temporal scales that are not represented by the models). For NWP applications, such effects appear as though they were observation errors.