W O R L D M E T E O R O L O G I C A L O R G A N I Z A T I O N

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COMMISSION FOR BASIC SYSTEMS

OPEN PROGRAMME AREA GROUP ON
INTEGRATED OBSERVING SYSTEMS

EXPERT TEAM ON REQUIREMENTS OF DATA FROM
AUTOMATIC WEATHER STATIONS

GENEVA

2 - 6 SEPTEMBER 2002

FINAL REPORT

WMO General Regulations 42 and 43

Regulation 42

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

Regulation 43

In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation on behalf of the constituent body when the matter is, in his opinion, urgent, and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

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EXECUTIVE SUMMARY

During the week of 2-7 September, 2002, the CBS OPAG on IOS Expert Team on Automatic Weather Stations (ET-AWS) held its meeting in Geneva. The major goals of the session were to review functional specifications for AWSs for BUFR/CREX table driven codes, requirements for automated observations of "present weather" and the "state of the ground," refine practices for reporting instantaneous observations, suggestions on possible replacement of manually observed types of clouds using automated technology and proposals for improving quality control procedures for data from AWSs. The central documents were the new AWS table of functional specifications for BUFR/CREX, the BUFR templates, and the list of AWS descriptors for surface observation data reported by automated weather stations.

During the proceedings a number of suggestions were made to be further submitted to CBS-Ext.(02) for consideration and approval. These recommendations included concerns expressed over inconsistencies between reference documents within WMO as they relate to automatic observing systems and the inclusion of required user parameters currently not reported through BUFR/CREX code. The full list of recommendation is contained in Annex 8 to this document.

1. ORGANIZATION OF THE SESSION

1.1. Opening of the meeting *(Agenda item 1.1*)

The session of the Expert Team (ET) on Requirements of Data from Automatic Weather Stations (ET-AWS) of the Commission for Basic Systems (CBS) Open Programme Area Group (OPAG) on Integrated Observing Systems (IOS) was opened by its Chairman, Mr. Rainer Dombrowsky, at 10 am on Monday 2 September 2002 at WMO Headquarters in Geneva, Switzerland. The list of participants is attached in Annex 1.

On behalf of the WMO Secretariat, Assistant Secretary-General, Mr. Yan Hong welcomed the participants to WMO. He recalled the five Terms of Reference of the Expert Team and commended the members on their qualifications for this important work. He encouraged the session in what he said would be hard work over the coming week.

1.2. Adoption of the agenda *(Agenda item 1.2*)

The agenda adopted by the ET is given in Annex 2.

1.3. Working arrangements *(Agenda item 1.3)*

The ET agreed on working arrangements and adopted a tentative work plan for consideration of the various agenda items. The chairman proposed working hours as early as members felt comfortable with. The meeting agreed to begin each day at 0900 hours and to continue until the work plan for each day was completed. The chairman drew the attention of the session to the fact that there was a holiday on 5 September that would mean that the WMO Canteen would be closed. Hence he proposed that the session, after beginning at 0900 hours, should work straight through until approximately 1400 hours, when they would adjourn for the day. This was agreed.

2. REPORT OF THE CHAIRMAN

The Chairman presented his report. He also reiterated the five revised terms of reference that had been assigned to the Expert Team by CBS. He enumerated the five “core” members of the Team as well as the four representatives of WMO commissions other than CBS and welcomed those who were present. He recalled the five Tasks of the Work Plan that had been established for the Expert Team in the beginning of 2001 and ammended to reflect changes in membership. During the Chairman’s presentation of Other Activities, Annex 2 of the chairman’s report, entitled “Operational Accuracy Requirements and Typical Instrument Performance,” evoked considerable discussion concerning the meaning of ‘typical’ in this context as well as the applicability of some of the ‘required’ parameters.

The representative of CIMO indicated that there are some inconsistencies among the lists of variables used in Documents 3, 4 & 5. He suggested efforts should be made to increase synergy between those lists. Any recommendation to CBS to stimulate such efforts might be helpful. It was agreed to appoint a small group to make a proposal for this and a subgroup of MM van der Meulen, Rudel and Zahumensky presented a revised version of the table from Annex 2 of the report of the chairman. For some variables the ranges and reporting resolution contained in the table are altered to be in line with the functional specifications of AWS to support BUFR/CREX. Moreover, the stated accuracy requirements of some specific variables were modified to conform with the requirements of other TC's. The session approved returning the modified table (Annex 7) to the President of CIMO for further implementation. In addition, in order to eliminate confusion, the Expert Team adopted a recommendation with respect to the units used for reporting radiation intensity (v. radiant exposure). This recommendation is Recommendation 2-1 contained in Annex 8.

3. REVISED FUNCTIONAL SPECIFICATIONS FOR AUTOMATED WEATHER OBSERVING SYSTEMS FOR BUFR/CREX TABLE DRIVEN CODES

The meeting discussed the revised specifications contained in Document 4. The proposed specifications had been drawn up by a sub-group of the ET and were given preliminary approval by CBS XII. Subsequently, they were submitted to all other WMO technical commissions for comment. The CAgM and the CIMO Working Group on Surface Measurement, responding for

CIMO, were the only technical commissions to submit comments. The most recent revision of Document 4 took into account the comments received to date. Considerable discussion took place over the necessity and/or desirability of simplifying the specifications by re-categorising into fewer, simpler categories. The chairman invited members to consider this possibility and it was agreed that a sub-group composed of MM Gmoser and Zahumensky would prepare a proposal. The revised proposal was presented for ET consideration and discussed in detail by the group. During these discussions, several additional changes were recommended and approved. **The final proposal is contained in Annex 3 to this report and will be submitted to CBS Ext. (2002) for consideration and approval.**

The representative of the Commission on Climate (CCl) expressed appreciation for the effect that the proposed specifications would produce in the increased amount and homogeneity of climate data sets. He further submitted a recommendation, which was adopted by the ET, as Recommendation No. 3-1 contained in Annex 8.

3.1. The BUFR Template for AWS Data and New BUFR Descriptors

The BUFR templates and new BUFR descriptors that were developed to facilitate exchange of data from AWS were introduced and discussed (Doc. 4, Rev.1). ET-AWS decided that these templates especially designed to work with Automatic Weather Stations, as well as newly defined descriptors for use by both Automatic Weather Stations and Automated Manned Weather Stations fulfilled the purpose for which they had been requested and developed. Recognising the necessity to have approved BUFR templates in order to achieve the most rigorous assessment – namely that of operational trial – the ET recommended that the proposed templates and descriptors be submitted to CBS by ET/DR&C. After modification to insert changes approved during this week by the chairman of ET/DR&C, the proposed templates and descriptors were approved and are included as Annex 4. **The session agreed that the proposed templates and descriptors be submitted by the ET/DR&C to CBS-Ext. (2002) for consideration and approval.** The Expert Team also felt that the BUFR tables should support reporting of both instrument readings and nominal values. To support this requirement, the group adopted Recommendation 3-2, Annex 8.

Mr. van der Meulen commented some algorithms are mentioned in the new BUFR descriptors. He felt that links should be provided for users on the specific algorithms used at the source. The chairman assured him that the ET will take steps to ensure that algorithm information is available to those users who need it. Accordingly, the group formulated Recommendation 3-3 to address this problem. The recommendation is contained in Annex 8.

4. REQUIREMENTS FOR AUTOMATED OBSERVATIONS OF "PRESENT WEATHER", CLOUDS, WATER VAPOUR AND THE "STATE OF THE GROUND" IN ORDER TO IDENTIFY THE NECESSITY TO DEVELOP OR REFINE QUANTITATIVE DEFINITIONS

Because of the illness of a key contributor to this agenda item, there was insufficient information for discussion. The chairman recommended that this item be carried over into the ET/AWS future work plan. (See §10 of this report.)

5. REVIEW AND REFINE PRACTICES FOR REPORTING THE INSTANTANEOUS PRECIPITATION INTENSITY, TOTAL CLOUD AMOUNT AND CLOUD HEIGHT

Mr. van der Meulen presented Document 7 dealing with reporting of precipitation intensity (PI), overcast conditions, and cloud height as well as some general considerations on reporting observations. Since for PI no appropriate measurement range and accuracy requirements are recommended by WMO, an expert meeting [Expert Meeting on Rainfall Measurements (Bratislava, Slovakia, 23-25 April 2001)] produced recommendations on this issue to be adopted by CIMO-XIII (September 2002). He noted that PI is only part of $7wwW_1W_2$ group in the SYNOP code, referring to *light, moderate* and *heavy*, and that CBS has recommended reporting PI in quantitative terms. As a result PI will be a new variable for BUFR encoded reports. Van der Meulen informed that with new technologies it is possible to report instantaneously the intensity of solid precipitation as well.

For more than 10 years cloud height has been determined automatically using ceilometers and applied algorithms. Mr. Van der Meulen recommended making time series extinction profiles in reporting cloud amount. These profiles, produced by ceilometers, should be reported as a

primary parameter. Cloud base and cloudiness can then be derived by simple calculations. The meeting endorsed this recommendation and it is included as Recommendation No. 5-1 contained in Annex 8.

6. SUGGESTIONS ON POSSIBLE REPLACEMENT OF MANUALLY OBSERVED TYPES OF CLOUDS USING AUTOMATED TECHNOLOGY

Mr. Lynch presented Document 8, describing the ongoing developments in automatic measurement of cloud cover. He pointed out that developments of automated measurement techniques have in general attempted to replicate the observations made by a human observer. He suggested that a more reasoned approach would be to gather data which could be practically achieved and which could provide the best possible information to the user. In this regard, he postulated that a complete automated sky observation, based on point data, could consist of measurements of base height, top height and *persistence.* Following further discussion, Mr. Lynch drafted Recommendation 6-1, contained in Annex 8, which were agreed by the ET after discussion.

7. PROPOSALS FOR IMPROVED QUALITY CONTROL PROCEDURES FOR DATA FROM AUTOMATIC WEATHER STATIONS

Mr. Zahumensky introduced Document 9, providing suggested quality control procedures for AWS. The recommended procedures are contained in Annex 5. The ET-AWS discussed the procedures and recommended their adoption. Mr. Gmoser recommended that WMO Members operating AWS be solicited to contribute to a compendium of AWS quality control procedures. **The ET agreed to submit the Basic Quality Control procedures for AWS to CBS-Ext. (2002) for consideration and approval for publication in the WMO Guide on GDPS (WMO No. 305).** The recommendation is contained in Annex 8, Recommendation 7-1.

The ET-AWS is of the opinion that additional work is required in the area of extended quality control for AWS. An element of this activity would involve bringing consistency between the GDPS and CIMO guides. The ET-AWS underlined that all Technical Commissions must be engaged in this effort.

Mr. Gmoser introduced Document 9(2). The chairman requested he add a brief description of the procedures used in administering the tables contained in the annex. Mr. Gmoser agreed to do this. The group agreed that it would be appropriate to include both reports in the ET's recommendations. Annex 6 reproduces the information from those tables. In presenting this information, however, a framework document would be required. This document would provide an overview of the proposed quality control process *i.e.,* describe the three levels of quality control, and identify the types of QC that would be carried out within each level. Within this framework, the paper would therefore present specific criteria that could be used for station-level QC. It would also present the concept of areal checks carried out at a central processing centre and provide examples of how such checks have been applied in a region with specific terrain.

8. ANY OTHER BUSINESS

8.1. Information on EUMETNET PWS-GTS Project

Mr. Zahumensky introduced Document 10, an information document that gave some information on the EUMETNET PWS-GTS (Present Weather Systems - Global Telecommunications System) pilot project for exchange of observations from AWS via the GTS using BUFR. The participants welcomed this information and took note that the Czech Republic (CHMI), The Netherlands (KNMI), France (Météo France), and the Slovak Republic (SHMI) were participating. The group felt that this pilot demonstration should provide useful information for all countries as they transition to BUFR.

9. RECOMMENDATIONS TO BE SUBMITTED TO CBS-EXT. (4-12 December 2002)

During the course of this Meeting, the ET-AWS formulated seven recommendations, which it proposes for consideration by CBS Ext. (02) in December 2002. These recommendations are collected in Annex 8.

10. FUTURE WORK PLAN

The chairman requested participants to consider whether they were aware of any necessary required work that would fall under the purview of the Expert Team on Data Requirements from Automatic Weather Stations (ET-AWS). He reminded the ET that the previous Work Plan included an analysis of "Requirements for Automated Observations of 'Present Weather', Clouds, Water Vapour and the 'State Of The Ground'" in order to identify the necessity to develop or refine quantitative definitions of these parameters. Since this subject had not been adequately addressed in this period, he recommended that it reappear in the future work plan. Two additional items that, in the opinion of the ET-AWS, are required: (1) Production of comprehensive guidelines on Extended Quality Control Procedures for Data from AWS. These should lead to a standard suitable for publication as mentioned in item 7 above and Annex 5; and (2) A review of the requirements for provision and reporting of metadata from AWS. The session agreed to further recommend that reporting of metadata must be possible using table-driven codes.

11. CLOSURE OF THE SESSION

There being no other business, the chairman closed the session of the Expert Team on Automatic Weather Stations at 12:00 noon on 6 September 2002.

Expert Team on Requirements of Data from Automatic Weather Stations (ET-AWS)
Geneva, 2 - 6 September 2002

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AGENDA

1. ORGANIZATION OF THE SESSION

1.1. Opening of the session
1.2. Adoption of the agenda
1.3. Working arrangements for the session

2. REPORT OF THE CHAIRMAN

3. REVISED FUNCTIONAL SPECIFICATIONS FOR AUTOMATED WEATHER OBSERVING SYSTEMS FOR BUFR/CREX TABLE DRIVEN CODES

3.1. The BUFR Template for AWS data and recommended new BUFR descriptors

4. REQUIREMENTS FOR AUTOMATED OBSERVATIONS OF "PRESENT WEATHER", CLOUDS, WATER VAPOUR AND THE "STATE OF THE GROUND" IN ORDER TO IDENTIFY THE NECESSITY TO DEVELOP OR REFINE QUANTITATIVE DEFINITIONS

5. REVIEW AND REFINE PRACTICES FOR REPORTING THE INSTANTANEOUS PRECIPITATION INTENSITY, TOTAL CLOUD AMOUNT AND CLOUD HEIGHT

6. SUGGESTIONS ON POSSIBLE REPLACEMENT OF MANUALLY OBSERVED TYPES OF CLOUDS USING AUTOMATED TECHNOLOGY

7. PROPOSALS FOR IMPROVED QUALITY CONTROL PROCEDURES FOR DATA FROM AUTOMATIC WEATHER STATIONS

8. ANY OTHER BUSINESS

8.1. Information on EUMETNET PWS-GTS project

9. RECOMMENDATIONS TO BE SUBMITTED TO CBS-EXT. (4-12 December 2002)

10. FUTURE WORK PLAN

11. CLOSURE OF THE SESSION

Revised Functional Specifications for Automatic Weather Stations

(to support BUFR/CREX)

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	1 – 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	0 – 400 mmh^{-1}	0.1 kg $m^{-2}s^{-1}$, 0.1 mm h^{-1}	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}	1hydrometeor 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
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

VARIABLE [1)]	Maximum Effective Range [2)]	Minimum Reported Resolution [3)]	Mode of Observation [4)]	BUFR / CREX [5)]
AIR QUALITY				
TSP (dust)	$1 \cdot 10^{-7}$ – 10 g m^{-3}	$1 \cdot 10^{-7}$ gm^{-3}	A	N
PM1, PM2.5, PM10	0.1 – 20 000 ppb	0.1 ppb	A	N
BTEX	0.1 – 20 000 ppb	0.1 ppb	A	N
NO	0.1 – 20 000 ppb	0.1 ppb	A	N
Nox	0.1 – 20 000 ppb	0.1 ppb	A	N
CO	10 – 100 000 ppb	1 ppb	A	N
H_2S	0.1 – 20 000 ppb	0.1 ppb	A	N
HC (Hydrocarbons)	0.1 – 20 000 ppb	0.1 ppb	A	N
NMHC (Non methan hydrocarbons)	0.1 – 20 000 ppb	0.1 ppb	A	N

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.

BUFR templates

BUFR template for AWS data from n-minute period

This template is proposed to be used for representation of surface observation data from both automatic stations and automated manned stations.

3 01 004		Surface station identification	
	0 01 001	WMO block number	Numeric
	0 01 002	WMO station number	Numeric
	0 01 015	Station or site name	CCITT IA5
	0 02 001	Type of station	Code table
3 01 011	0 04 001	Year	Year
	0 04 002	Month	Month
	0 04 003	Day	Day
3 01 012	0 04 004	Hour	Hour
	0 04 005	Minute	Minute
3 01 021	0 05 001	Latitude (high accuracy)	Degree, scale 5
	0 06 001	Longitude (high accuracy)	Degree, scale 5
0 07 030		Height of station ground above mean sea level	m, scale 1
0 07 031		Height of barometer above mean sea level	m, scale 1
0 08 010		Surface qualifier (for temperature data)	Code table
3 01 091		**Surface station instrumentation**	
	0 02 180	Main present weather detecting system	Code table
	0 02 181	Supplementary present weather sensor	Flag table
	0 02 182	Visibility measurement system	Code table
	0 02 183	Cloud detection system	Code table
	0 02 184	Type of lightning detection sensor	Code table
	0 02 179	Type of sky condition algorithm	Code table
	0 02 186	Capability to detect precipitation phenomena	Flag table
	0 02 187	Capability to detect other weather phenomena	Flag table
	0 02 188	Capability to detect obscuration	Flag table
	0 02 189	Capability to discriminate lightning strikes	Flag table
0 04 025		Time displacement (= - n minutes)	Minute
0 04 065		Short time increment (= 1 minute)	Minute
1 14 n		Replicate 14 descriptors n-times	
		E.g.: 1 14 005 in case of 5-minute period, *1 14 010 in case of 10-minute period*	
0 10 004		Pressure	Pa, scale -1
3 02 070		**Wind data**	
	0 07 032	Height of sensor above local ground	m, scale 2
	0 07 033	Height of sensor above water surface	m, scale 1
	0 11 001	Wind direction	Degree true
	0 11 002	Wind speed	m s^{-1}
	0 11 043	Maximum wind gust direction	Degree true
	0 11 041	Maximum wind gust speed	m s^{-1}
	0 11 016	Extreme counterclockwise wind direction of a variable wind	Degree true
	0 11 017	Extreme clockwise wind direction of a variable wind	Degree true
3 02 072		**Temperature and humidity data**	
	0 07 032	Height of sensor above local ground	m, scale 2
	0 07 033	Height of sensor above water surface	m, scale 1
	0 12 101	Temperature/dry-bulb temperature (scale 2)	K, scale 2
	0 12 103	Dew-point temperature (scale 2)	K, scale 2
	0 13 003	Relative humidity	%

0 07 032		Height of sensor above local ground	m, scale 2
0 12 101		Temperature/dry-bulb temperature (scale 2) (for ground temperature)	K, scale 2
1 01 005		Replicate one descriptors five times	
3 07 063	0 07 061	Depth below land surface	m, scale 2
	0 12 130	Soil temperature (scale 2)	K, scale 2
3 02 069		**Visibility data**	
	0 07 032	Height of sensor above local ground	m, scale 2
	0 07 033	Height of sensor above water surface	m, scale 1
	0 33 041	Attribute of following value	Code table
	0 20 001	Horizontal visibility	m, scale -1
0 07 032		Height of sensor above local ground (set to missing to cancel the previous value)	m, scale 2
0 07 033		Height of sensor above water surface (set to missing to cancel the previous value)	m, scale 1
3 02 073		**Cloud data**	
	0 20 010	Cloud cover (total)	%
	1 05 004	Replicate 5 descriptors four times	
	0 08 002	Vertical significance	Code table
	0 20 011	Cloud amount	Code table
	0 20 012	Cloud type	Code table
	0 33 041	Attribute of following value	Code table
	0 20 013	Height of base of cloud	m, scale -1
3 02 076		**Precipitation, obscuration and other phenomena**	
	0 20 021	Type of precipitation	Flag table
	0 20 022	Character of precipitation	Code table
	0 26 020	Duration of precipitation	Minute
	0 20 023	Other weather phenomena	Flag table
	0 20 024	Intensity of phenomena	Code table
	0 20 025	Obscuration	Flag table
	0 20 026	Character of obscuration	Code table
0 13 055		Intensity of precipitation	$kgm^{-2}s^{-1}$,scale 4
0 13 058		Size of precipitation element	m, scale 4
		(end of the replicated sequence)	
0 20 031		Ice deposit (thickness)	m, scale 2
0 20 032		Rate of ice accretion	Code table
3 02 078		**State of ground and snow depth measurement**	
	0 02 176	Method of state of ground measurement	Code table
	0 20 062	State of ground (with or without snow)	Code table
	0 02 177	Method of snow depth measurement	Code table
	0 13 013	Total snow depth	m, scale 2
3 02 079		**Precipitation measurement**	
	0 07 032	Height of sensor above local ground	m, scale 2
	0 02 175	Method of precipitation measurement	Code table
	0 02 178	Method of liquid water content measurement of precipitation	Code table
	0 04 025	Time period (= - n minutes)	Minute
	0 13 011	Total precipitation / total water equivalent of snow	$kg\ m^{-2}$, scale 1
0 07 032		Height of sensor above local ground (set to missing to cancel the previous value)	m, scale 2
3 02 080		**Evaporation measurement**	
	0 02 185	Method of evaporation measurement	Code table
	0 04 025	Time period or displacement (= - n minutes)	Minute
	0 13 033	Evaporation/evapotranpiration	$kg\ m^{-2}$

3 02 081		**Total sunshine data**	
	0 04 025	Time period (= - n minutes)	Minute
	0 14 031	Total sunshine	Minute
3 02 082		**Radiation data**	
	0 04 025	Time period (= - n minutes)	Minute
	0 14 002	Long-wave radiation, integrated over period specified	J m^{-2}, scale -3
	0 14 004	Short-wave radiation, integrated over period specified	J m^{-2}, scale -3
	0 14 016	Net radiation, integrated over period specified	J m^{-2}, scale -4
	0 14 028	Global solar radiation (high accuracy), integrated over period specified	J m^{-2}, scale -4
	0 14 029	Diffuse solar radiation (high accuracy), integrated over period specified	J m^{-2}, scale -4
	0 14 030	Direct solar radiation (high accuracy), integrated over period specified	J m^{-2}, scale -4
0 04 025		Time period (= - n minutes)	Minute
0 13 059		Number of flashes	Numeric
3 02 083		**First order statistics of P, W, T, U data**	
	0 04 025	Time period (= - n minutes)	Minute
	0 08 023	First order statistics (= 9; best estimate of standard deviation)	Code table
	0 10 004	Pressure	Pa, scale -1
	0 11 001	Wind direction	Degree true
	0 11 002	Wind speed	m s^{-1}
	0 12 101	Temperature/dry-bulb temperature (scale 2)	K, scale 2
	0 13 003	Relative humidity	%
	0 08 023	First order statistics (= missing value)	Code table
0 33 005		Quality information (AWS data)	Flag table
0 33 006		Internal measurement status information (AWS)	Code table

Notes:

1) The time identification refers to the end of the n-minute period.
2) Duration of precipitation (in minutes) represents number of minutes in which precipitation was registered.
3) Best estimate of standard deviation is counted out of a set of samples (signal measurements) recorded within the period specified; it should be reported as a missing value, if the measurements of the relevant element are not available from a part of the period specified by 0 04 025.

BUFR template for surface observations from one-hour period

This template is proposed to be used for representation of surface observation data from both automatic stations and manned stations.

3 01 004		**Surface station identification**	
	0 01 001	WMO block number	Numeric
	0 01 002	WMO station number	Numeric
	0 01 015	Station or site name	CCITT IA5
	0 02 001	Type of station	Code table
3 01 011	0 04 001	Year	Year
	0 04 002	Month	Month
	0 04 003	Day	Day
3 01 012	0 04 004	Hour	Hour
	0 04 005	Minute	Minute
3 01 021	0 05 001	Latitude (high accuracy)	Degree, scale 5
	0 06 001	Longitude (high accuracy)	Degree, scale 5
0 07 030		Height of station ground above mean sea level	m, scale 1
0 07 031		Height of barometer above mean sea level	m, scale 1
0 08 010		Surface qualifier (for temperature data)	Code table
3 01 091		**Surface station instrumentation**	
	0 02 180	Main present weather detecting system	Code table
	0 02 181	Supplementary present weather sensor	Flag table
	0 02 182	Visibility measurement system	Code table
	0 02 183	Cloud detection system	Code table
	0 02 184	Type of lightning detection sensor	Code table
	0 02 179	Type of sky condition algorithm	Code table
	0 02 186	Capability to detect precipitation phenomena	Flag table
	0 02 187	Capability to detect other weather phenomena	Flag table
	0 02 188	Capability to detect obscuration	Flag table
	0 02 189	Capability to discriminate lightning strikes	Flag table
3 02 001	0 10 004	Pressure	Pa, scale -1
	0 10 051	Pressure reduced to mean sea level	Pa, scale -1
	0 10 061	3-hour pressure change[(2)]	Pa, scale -1
	0 10 063	Characteristic of pressure tendency[(2)]	Code table
0 07 004		Pressure (standard level)	Pa, scale -1
0 10 009		Geopotential height of the standard level	gpm
3 02 072		**Temperature and humidity data**	
	0 07 032	Height of sensor above local ground	m, scale 2
	0 07 033	Height of sensor above water surface	m, scale 1
	0 12 101	Temperature/dry-bulb temperature (scale 2)	K, scale 2
	0 12 103	Dew-point temperature (scale 2)	K, scale 2
	0 13 003	Relative humidity	%
1 01 005		Replicate one descriptor five times	
3 07 063	0 07 061	Depth below land surface	m, scale 2
	0 12 130	Soil temperature (scale 2)	K, scale 2
3 02 069		**Visibility data**	
	0 07 032	Height of sensor above local ground	m, scale 2
	0 07 033	Height of sensor above water surface	m, scale 1
	0 33 041	Attribute of following value	Code table
	0 20 001	Horizontal visibility	m, scale -1
0 07 032		Height of sensor above local ground (set to missing to cancel the previous value)	m, scale 2
0 07 033		Height of sensor above water surface (set to missing to cancel the previous value)	m, scale 1

0 20 031		Ice deposit (thickness)	m, scale 2
0 20 032		Rate of ice accretion	Code table
0 02 038		Method of sea surface temperature measurement	Code table
0 22 043		Sea/water temperature (scale 2)	K, scale 2
3 02 021	0 22 001	Direction of waves	Degree true
	0 22 011	Period of waves	s
	0 22 021	Height of waves	m, scale 1
3 02 078		**State of ground and snow depth measurement**	
	0 02 176	Method of state of ground measurement	Code table
	0 20 062	State of ground (with or without snow)	Code table
	0 02 177	Method of snow depth measurement	Code table
	0 13 013	Total snow depth	m, scale 2
3 02 073		**Cloud data**	
	0 20 010	Cloud cover (total)	%
	1 05 004	Replicate 5 descriptors four times	
	0 08 002	Vertical significance	Code table
	0 20 011	Cloud amount	Code table
	0 20 012	Cloud type	Code table
	0 33 041	Attribute of following value	Code table
	0 20 013	Height of base of cloud	m, scale -1
3 02 074		**Present and past weather**	
	0 20 003	Present weather[3]	Code table
	0 04 025	Time period (= - 60 minutes)	Minute
	0 20 004	Past weather (1) [3]	Code table
	0 20 005	Past weather (2) [3]	Code table
3 02 075		**Intensity of precipitation, size of precipitation element**	
	0 08 021	Time significance (= 2 (time averaged))	Code table
	0 04 025	Time period (= - 10 minutes)	Minute
	0 13 055	Intensity of precipitation	$kgm^{-2}s^{-1}$,scale 4
	0 13 058	Size of precipitation element	m, scale 4
	0 08 021	Time significance (= missing value)	Code table
0 04 025		Time period (= - 10 minutes)	Minute
3 02 076		**Precipitation, obscuration and other phenomena**	
	0 20 021	Type of precipitation	Flag table
	0 20 022	Character of precipitation	Code table
	0 26 020	Duration of precipitation [4]	Minute
	0 20 023	Other weather phenomena	Flag table
	0 20 024	Intensity of phenomena	Code table
	0 20 025	Obscuration	Flag table
	0 20 026	Character of obscuration	Code table

3 02 071		**Wind data from one-hour period**	
	0 07 032	Height of sensor above local ground	m, scale 2
	0 07 033	Height of sensor above water surface	m, scale 1
	0 08 021	Time significance (= 2 (time averaged))	Code table
	0 04 025	Time period (= - 10 minutes, or number of minutes after a significant change of wind, if any)	Minute
	0 11 001	Wind direction	Degree true
	0 11 002	Wind speed	$m\ s^{-1}$
	0 08 021	Time significance (= missing value)	Code table
	1 03 002	Replicate next 3 descriptors 2 times	
	0 04 025	Time period	Minute

		(= - 10 minutes in the first replication, = - 60 minutes in the second replication)	
	0 11 043	Maximum wind gust direction	Degree true
	0 11 041	Maximum wind gust speed	m s^{-1}
	0 04 025	Time period (= - 10 minutes)	Minute
	0 11 016	Extreme counterclockwise wind direction of a variable wind	Degree true
	0 11 017	Extreme clockwise wind direction of a variable wind	Degree true
3 02 077		**Extreme temperature data**	
	0 07 032	Height of sensor above local ground	m, scale 2
	0 07 033	Height of sensor above water surface	m, scale 1
	0 04 025	Time period (= - 60 minutes)	Minute
	0 12 111	Maximum temperature (scale 2) at height and over period specified	K, scale 2
	0 12 112	Minimum temperature (scale 2) at height and over period specified	K, scale 2
	0 07 032	Height of sensor above local ground (for ground temperature)	m, scale 2
	0 04 025	Time period (= - 60 minutes)	Minute
	0 12 112	Minimum temperature (scale 2) at height and over period specified (for ground temperature)	K, scale 2
0 07 033		Height of sensor above water surface (set to missing to cancel the previous value)	m, scale 1
3 02 079		**Precipitation measurement**	
	0 07 032	Height of sensor above local ground	m, scale 2
	0 02 175	Method of precipitation measurement	Code table
	0 02 178	Method of liquid water content measurement of precipitation	Code table
	0 04 025	Time period (= - 60 minutes)	Minute
	0 13 011	Total precipitation / total water equivalent of snow	kg m^{-2}, scale 1
0 07 032		Height of sensor above local ground (set to missing to cancel the previous value)	m, scale 2
3 02 080		**Evaporation measurement**	
	0 02 185	Method of evaporation measurement	Code table
	0 04 025	Time period (= - 60 minutes)	Minute
	0 13 033	Evaporation /evapotranspiration	kg m^{-2}
3 02 081		**Total sunshine data**	
	0 04 025	Time period (= - 60 minutes)	Minute
	0 14 031	Total sunshine	Minute

3 02 082		**Radiation data**	
	0 04 025	Time period (= - 60 minutes)	Minute
	0 14 002	Long-wave radiation, integrated over period specified	J m^{-2}, scale -3
	0 14 004	Short-wave radiation, integrated over period specified	J m^{-2}, scale -3
	0 14 016	Net radiation, integrated over period specified	J m^{-2}, scale -4
	0 14 028	Global solar radiation (high accuracy), integrated over period specified	J m^{-2}, scale -4
	0 14 029	Diffuse solar radiation (high accuracy), integrated over period specified	J m^{-2}, scale -4
	0 14 030	Direct solar radiation (high accuracy), integrated over period specified	J m^{-2}, scale -4
0 04 025		Time period (= - 10 minutes)	Minute
0 13 059		Number of flashes	Numeric
3 02 083		**First order statistics of P, W, T, U data**	
	0 04 025	Time period (= -10 minutes)	Minute
	0 08 023	First order statistics (= 9 (best estimate of standard deviation) (5)	Code table
	0 10 004	Pressure	Pa, scale -1
	0 11 001	Wind direction	Degree true
	0 11 002	Wind speed	m s^{-1}
	0 12 101	Temperature/dry-bulb temperature (scale 2)	K, scale 2
	0 13 003	Relative humidity	%
	0 08 023	First order statistics (= missing value)	Code table
0 33 005		Quality information (AWS data)	Flag table
0 33 006		Internal measurement status information (AWS)	Code table

Notes:

1) The time identification refers to the end of the one-hour period.
2) 0 10 061 (3-hour pressure change) and 0 10 063 (Characteristic of pressure tendency) are included in this template, although they refer to 3-hour period preceding the time of observation.
3) Present weather may be represented only by 0 20 003, especially if reported from a manned non-automated station. When encoding present weather reported from an automatic weather station, the sequence of descriptors (proposed under 3 02 076) should be used, if applicable.
4) Duration of precipitation (in minutes) represents number of minutes in which precipitation was registered.
5) Best estimate of standard deviation is counted out of a set of samples (signal measurements) recorded within the period specified; it should be reported as a missing value, if the measurements of the relevant element are not available from a part of the period specified by 0 04 025.

New BUFR descriptors

ET/DR&C recommended the following new descriptors for approval by CBS-Ext. (2002):

Descriptors for vertical co-ordinates of a station and sensors

0 07 030	Height of station ground above mean sea level	M	1	- 4000	17
0 07 031	Height of barometer above mean sea level	M	1	- 4000	17
0 07 032	Height of sensor above local ground (or deck of marine platform)	M	2	0	14
0 07 033	Height of sensor above water surface	m	1	0	12

with notes added under Table B, Class 7, referring to 0 07 030, 0 07 031, 0 07 032 and 0 07 033:

- Height of station ground above mean sea level is defined as the height above mean sea-level of the ground on which the rain gauge stands or, if there is no rain gauge, the ground beneath the thermometer screen. If there is neither rain gauge nor screen, it is the average level of terrain in the vicinity of the station (Reference: Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8. 1996).
- Height of barometer above mean sea level, referring to the location of barometer of a station, does not redefine the descriptor 0 07 030.
- Height of sensor above local ground (or deck of marine platform) is the actual height of sensor above ground (or deck of marine platform) at the point where the sensor is located. This descriptor does not redefine the descriptor either 0 07 030 or 0 07 033.
- Height of sensor above water surface is the height of sensor above water surface of sea or lake. This descriptor does not redefine the descriptor either 0 07 030 or 0 07 032.

A note to be added to the existing descriptor 0 07 001:

“This descriptor should be used for archived data only. Descriptors 0 07 030 and 0 07 031 should be used and preferred to represent ground elevation and elevation of barometer, respectively, as defined in Observing Stations, WMO Publication No. 9, Volume A1.”

Descriptors (needed particularly for the AWS)

0 02 175	Method of precipitation measurement	Code table	0	0	4
0 02 176	Method of state of ground measurement	Code table	0	0	4
0 02 177	Method of snow depth measurement	Code table	0	0	4
0 02 178	Method of liquid content measurement of precipitation	Code table	0	0	4
0 02 179	Type of sky condition algorithm	Code table	0	0	4
0 02 180	Main present weather detecting system	Code table	0	0	4
0 02 181	Supplementary present weather sensor	Flag table	0	0	21
0 02 182	Visibility measurement system	Code table	0	0	4
0 02 183	Cloud detection system	Code table	0	0	4
0 02 184	Type of lightning detection sensor	Code table	0	0	4
0 02 185	Method of evaporation measurement	Code table	0	0	4
0 02 186	Capability to detect precipitation phenomena	Flag table	0	0	30
0 02 187	Capability to detect other weather phenomena	Flag table	0	0	18
0 02 188	Capability to detect obscuration	Flag table	0	0	21
0 02 189	Capability to discriminate lightning strikes	Flag table	0	0	12
0 08 010	Surface qualifier (temperature data)	Code table	0	0	5
0 26 020	Duration of precipitation	Minute	0	0	11
0 33 005	Quality information (AWS data)	Flag table	0	0	30
0 33 006	Internal measurement status information (AWS)	Code table	0	0	3

Sequence descriptors

The following new sequence descriptors are proposed for approval by CBS-Ext.(2002):

3 01 004, 3 01 090, 3 01 091, 3 02 069, 3 02 070, 3 02 071, 3 02 072, 3 02 073, 3 02 074, 3 02 075, 3 02 076, 3 02 077, 3 02 078, 3 02 079, 3 02 080, 3 02 081, 3 02 082, 3 02 083.

3 01 004		**Surface station identification**
	0 01 001	WMO block number
	0 01 002	WMO station number
	0 01 015	Station or site name
	0 02 001	Type of station
3 01 090		**Surface station identification; time, horizontal and vertical co-ordinates**
3 01 004		Surface station identification
	0 01 001	WMO block number
	0 01 002	WMO station number
	0 01 015	Station or site name
	0 02 001	Type of station
3 01 011	0 04 001	Year
	0 04 002	Month
	0 04 003	Day
3 01 012	0 04 004	Hour
	0 04 005	Minute
3 01 021	0 05 001	Latitude (high accuracy)
	0 06 001	Longitude (high accuracy)
0 07 030		Height of station ground above mean sea level
0 07 031		Height of barometer above mean sea level
3 01 091		**Surface station instrumentation**
	0 02 180	Main present weather detecting system
	0 02 181	Supplementary present weather sensor
	0 02 182	Visibility measurement system
	0 02 183	Cloud detection system
	0 02 184	Type of lightning detection sensor
	0 02 179	Type of sky condition algorithm
	0 02 186	Capability to detect precipitation phenomena
	0 02 187	Capability to detect other weather phenomena
	0 02 188	Capability to detect obscuration
	0 02 189	Capability to discriminate lightning strikes
3 02 069		**Visibility data**
	0 07 032	Height of sensor above local ground
	0 07 033	Height of sensor above water surface
	0 33 041	Attribute of following value
	0 20 001	Horizontal visibility
3 02 070		**Wind data**
	0 07 032	Height of sensor above local ground
	0 07 033	Height of sensor above water surface
	0 11 001	Wind direction
	0 11 002	Wind speed
	0 11 043	Maximum wind gust direction
	0 11 041	Maximum wind gust speed
	0 11 016	Extreme counterclockwise wind direction of a variable wind
	0 11 017	Extreme clockwise wind direction of a variable wind

3 02 071		**Wind data from one-hour period**
	0 07 032	Height of sensor above local ground
	0 07 033	Height of sensor above water surface
	0 08 021	Time significance (= 2 (time averaged))
	0 04 025	Time period (= - 10 minutes, or number of minutes after a significant change of wind, if any)
	0 11 001	Wind direction
	0 11 002	Wind speed
	0 08 021	Time significance (= missing value)
	1 03 002	Replicate next 3 descriptors 2 times
	0 04 025	Time period (= - 10 minutes in the first replication, = - 60 minutes in the second replication)
	0 11 043	Maximum wind gust direction
	0 11 041	Maximum wind gust speed
	0 04 025	Time period (= - 10 minutes)
	0 11 016	Extreme counterclockwise wind direction of a variable wind
	0 11 017	Extreme clockwise wind direction of a variable wind
3 02 072		**Temperature and humidity data**
	0 07 032	Height of sensor above local ground
	0 07 033	Height of sensor above water surface
	0 12 101	Temperature/dry-bulb temperature (scale 2)
	0 12 103	Dew-point temperature (scale 2)
	0 13 003	Relative humidity
3 02 073		**Cloud data**
	0 20 010	Cloud cover (total)
	1 05 004	Replicate 5 descriptors four times
	0 08 002	Vertical significance
	0 20 011	Cloud amount
	0 20 012	Cloud type
	0 33 041	Attribute of following value
	0 20 013	Height of base of cloud
3 02 074		**Present and past weather**
	0 20 003	Present weather
	0 04 025	Time period
	0 20 004	Past weather (1)
	0 20 005	Past weather (2)
3 02 075		**Intensity of precipitation, size of precipitation element**
	0 08 021	Time significance (= 2 (time averaged))
	0 04 025	Time period (= - 10 minutes)
	0 13 055	Intensity of precipitation
	0 13 058	Size of precipitation element
	0 08 021	Time significance (= missing value)
3 02 076		**Precipitation, obscuration and other phenomena**
	0 20 021	Type of precipitation
	0 20 022	Character of precipitation
	0 26 020	Duration of precipitation
	0 20 023	Other weather phenomena
	0 20 024	Intensity of phenomena
	0 20 025	Obscuration
	0 20 026	Character of obscuration

3 02 077 **Extreme temperature data**

0 07 032	Height of sensor above local ground
0 07 033	Height of sensor above water surface
0 04 025	Time period
0 12 111	Maximum temperature (scale 2) at height and over period specified
0 12 112	Minimum temperature (scale 2) at height and over period specified
0 07 032	Height of sensor above local ground (for ground temperature)
0 04 025	Time period
0 12 112	Minimum temperature (scale 2) at height and over period specified (for ground temperature)

3 02 078 **State of ground and snow depth measurement**

0 02 176	Method of state of ground measurement
0 20 062	State of ground (with or without snow)
0 02 177	Method of snow depth measurement
0 13 013	Total snow depth

3 02 079 **Precipitation measurement**

0 07 032	Height of sensor above local ground
0 02 175	Method of precipitation measurement
0 02 178	Method of liquid water content measurement of precipitation
0 04 025	Time period
0 13 011	Total precipitation / total water equivalent of snow

3 02 080 **Evaporation measurement**

0 02 185	Method of evaporation measurement
0 04 025	Time period
0 13 033	Evaporation /evapotranspiration

3 02 081 **Total sunshine data**

0 04 025	Time period
0 14 031	Total sunshine

3 02 082 **Radiation data**

0 04 025	Time period
0 14 002	Long-wave radiation, integrated over period specified
0 14 004	Short-wave radiation, integrated over period specified
0 14 016	Net radiation, integrated over period specified
0 14 028	Global solar radiation (high accuracy), integrated over period specified
0 14 029	Diffuse solar radiation (high accuracy), integrated over period specified
0 14 030	Direct solar radiation (high accuracy), integrated over period specified

3 02 083 **First order statistics of P, W, T, U data**

0 04 025	Time period
0 08 023	First order statistics
0 10 004	Pressure
0 11 001	Wind direction
0 11 002	Wind speed
0 12 101	Temperature/dry-bulb temperature (scale 2)
0 13 003	Relative humidity
0 08 023	First order statistics (= missing value)

New BUFR Code Tables or Flag Tables

ET/DR&C recommended the following Code Tables or Flag Tables for approval by CBS-Ext. (2002):

0 02 175
Method of precipitation measurement

Code figure	
0	Manual measurement
1	Tipping bucket method
2	Weighing method
3	Optical method
4	Pressure method
5	Float method
6	Drop counter method
7-13	Reserved
14	Others
15	Missing value

0 02 176
Method of state of ground measurement

Code figure	
0	Manual observation
1	Video camera method
2	Infra-red method
3	Laser method
4-13	Reserved
14	Others
15	Missing value

0 02 177
Method of snow depth measurement

Code figure	
0	Manual observation
1	Ultrasonic method
2	Video camera method
3-13	Reserved
14	Others
15	Missing value

0 02 178
Method of liquid content measurement of precipitation

Code figure	
0	Manual observation
1	Optical method
2	Capacitive method
3-13	Reserved
14	Others
15	Missing value

0 02 179

Type of sky condition algorithm

Code figure	
0	Manual observation
1	VAISALA algorithm
2	ASOS (USA) algorithm
3	AWOS (Canada) algorithm
4-13	Reserved
14	Others
15	Missing value

0 02 180

Main present weather detecting system

Code Figure	
0	Manual observation
1	Optical scatter system combined with precipitation occurrence sensing system
2	Forward and/or back-scatter system of visible light
3	Forward and/or back-scatter system of infrared light
4	Infrared light emitting diode (IRED) system
5	Doppler radar system
6-13	Reserved
14	Others
15	Missing value

0 02 181

Supplementary present weather sensor

Bit No.	
1	Rain detector
2	Freezing rain sensor
3	Ice detection sensor
4	Hail and ice pellet sensor
5-19	Reserved
20	Others
All 21	Missing value

0 02 182

Visibility measurement system

Code figure	
0	Manual measurement
1	Transmissometer system (base 25 m)
2	Transmissometer system (base < 25 m)
3	Forward scatter system
4	Back scatter system
5-13	Reserved
14	Others
15	Missing value

0 02 183
Cloud detection system

Code figure	
0	Manual observation
1	Ceilometer system
2	Infrared camera system
3	Microwave visual camera system
4	Sky imager system
5	Video time lapsed camera system
6	Micro pulse lidar (MPL) system
7-13	Reserved
14	Others
15	Missing value

0 02 184
Type of lightning detection sensor

Code figure	
0	Manual observation
1	Lightning imaging sensor
2	Electrical storm identification sensor
3	Magnetic finder sensor
4	Lightning strike sensor
5	Flash counter
6-13	Reserved
14	Others
15	Missing value

0 02 185
Method of evaporation measurement

Code Figure	
0	Manual measurement
1	Balanced floating method
2	Pressure method
3	Ultrasonic method
4	Hydraulic method
5-13	Reserved
14	Others
15	Missing value

0 02 186

Capability to detect precipitation phenomena

Bit No.	
1	Precipitation-unknown type
2	Liquid precipitation not freezing
3	Liquid freezing precipitation
4	Drizzle
5	Rain
6	Solid precipitation
7	Snow
8	Snow grains
9	Snow pellets
10	Ice pellets
11	Ice crystals
12	Diamond dust
13	Small hail
14	Hail
15	Glaze
16	Rime
17	Soft rime
18	Hard rime
19	Clear ice
20	Wet snow
21	Hoar frost
22	Dew
23	White dew
24-29	Reserved
All 30	Missing value

0 02 187

Capability to detect other weather phenomena

Bit No.	
1	Dust/sand whirl
2	Squalls
3	Sand storm
4	Dust storm
5	Lightning - cloud to surface
6	Lightning - cloud to cloud
7	Lightning – distant
8	Thunderstorm
9	Funnel Cloud not touching surface
10	Funnel cloud touching surface
11	Spray
12-17	Reserved
All 18	Missing value

0 02 188
Capability to detect obscuration

Bit No.	
1	Fog
2	Ice fog
3	Steam fog
4-6	Reserved
7	Mist
8	Haze
9	Smoke
10	Volcanic ash
11	Dust
12	Sand
13	Snow
14-20	Reserved
All 21	Missing value

0 02 189
Capability to discriminate lightning strikes

Bit No.	
1	Manual observation
2	All lightning strikes without discrimination
3	Lightning strikes cloud to ground only
4	All lightning strikes with discrimination between cloud to ground and cloud to cloud
5-11	Reserved
All 12	Missing value

0 08 010
Surface qualifier (for temperature data)

Code Figure	
0	Reserved
1	Bare soil
2	Bare rock
3	Land grass cover
4	Water (lake, sea)
5	Flood water underneath
6	Snow
7	Ice
8	Runway or road
9	Ship or platform (steel)
10	Ship or platform (wood)
11	Ship or platform (at least partly covered by rubber mat)
12-30	Reserved
31	Missing value

0 33 005

Quality Information (AWS data)

Bit No.	
1	No automated meteorological data checks performed
2	Pressure data suspect
3	Wind data suspect
4	Dry-bulb temperature data suspect
5	Wet-bulb temperature data suspect
6	Humidity data suspect
7	Ground temperature data suspect
8	Soil temperature (depth 1) data suspect
9	Soil temperature (depth 2) data suspect
10	Soil temperature (depth 3) data suspect
11	Soil temperature (depth 4) data suspect
12	Soil temperature (depth 5) data suspect
13	Cloud data suspect
14	Visibility data suspect
15	Present weather data suspect
16	Lightning data suspect
17	Ice deposit data suspect
18	Precipitation data suspect
19	State of ground data suspect
20	Snow data suspect
21	Water content data suspect
22	Evaporation/evapotranspiration data suspect
23	Sunshine data suspect
24-29	Reserved
All 30	Missing value

0 33 006

Internal measurement status information (AWS)

Code figure	
0	Self-check OK
1	At least one Warning active, no Alarms
2	At least one Alarm active
3	Sensor failure
4-6	Reserved
7	Missing value

Basic Quality Control (B-QC)

Basic Quality Control procedures (automatic data validity checking) should be applied at all Automatic Weather Stations (AWSs) to monitor the quality of sensors' data prior to their use in computation of weather parameter values. B-QC is designed to remove erroneous sensor information while retaining valid sensor data.

A comprehensive documentation on B-QC, including the specification of basic data processing procedures for the calculation of instantaneous (i.e. one minute) data and sums should be a part of AWS' standard documentation. The range of B-QC strongly depends on the type of AWS and a level of its sophistication. The outputs of B-QC would be included inside every AWS BUFR message (BUFR descriptor 0 33 005 - Quality Information (AWS data)).

Five types of B-QC procedures are suggested:

1) **The technical monitoring** of all crucial parts of AWS including all sensors. Most of the manufactures already provide technical monitoring for intelligent sensors, however result of the monitoring is not distributed to users. The technical monitoring provides an information on quality of data through the technical status of instrument and an information on the internal measurement status. Those would be represented in BUFR descriptor 033 006 - Internal measurement status information (AWS).

2) **The monitoring of measurement range** (gross error check). Measurement ranges of different parameters depend on longitude, latitude and height of AWS above mean see level (i.e. climatological conditions of an AWS' site). Limit values for surface wind speed, air temperature, dew-point temperature, station pressure are listed in the WMO Guide on GDPS, WMO-No. 305. In addition, there is a need to define limit values for other measured parameters, e.g. ground and soil temperatures, amount of precipitation, radiation parameters etc. The limit values are used for checking both signal measurement data (samples) and 1-minute average, in case of wind 2- and 10-minute averages.

3) **The time variance of the signal** (temporal consistency of measured values). The samples are checked every 3 seconds in case of wind speed and direction and every 10 seconds in case of temperature, humidity, pressure and global radiation. After each signal measurement the current (actual) sample is compared to the previous one. If the difference of these two samples is more then specified limit then the current sample is identified as a suspected and not used for computation of an average. However, it is still used for checking of the temporal consistency of samples. It means that new sample is still checked with the suspected one. The result of this procedure is that in case of a large noise one or two successive samples are not used for the computation of an average.

   There must be at least 4 of 6 samples available in order to compute 1-minute average in case of temperature, humidity, pressure, or sum in case of global radiation and at least 75 % of samples to compute 2- or 10-minute average in case of wind direction and speed.

4) **Internal consistency of data**. The range of this control depends on the capacity of AWS' processing unit and on sensors used. The basic algorithms used for Internal consistency of data are based on relation of two or more parameters (the following conditions should be true):

   (a) dew-point temperature $\leq$ dry bulb temperature;

   (b) wind speed = 00 and wind direction = 00;
   wind speed $\neq$ 00 and wind direction $\neq$ 00;
   wind gust speed $\geq$ wind speed;

   (c) both elements are suspected[1] in case of "clear (sky condition)" and "total precipitation > 0"

   (d) both elements are suspected[1] in case of "overcast (sky condition)" and "sunshine duration > 0";

[1] For data from a period not longer then 10 minutes

(e) both elements are suspected[1] if “total precipitation > 0” and “duration of precipitation = 0”;

(f) both elements are suspected[1] if “duration of precipitation > 0” and “weather phenomenon is different from precipitation”;

(g) both elements are suspected[1] if “visibility < 10 000 m” and “weather phenomenon is missing”.

5) The calculation of a **standard deviation** of some basic variables such as temperature, pressure, humidity, wind etc. should be optional but strongly suggested. The formula for standard deviation (SD) is as follows:

$$\mathrm{SD} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(X - X_i)^2}\ ,$$

where:

N means a number of signal measurements (sampling) over period of the last XY minute;

X means average value;

X_i means values of individual samples.

In case of small number of samples (less then 20) the calculation of the best estimation of standard deviation should be done using the formula as follows:

$$\mathrm{SD}^* = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(X - X_i)^2}\ .$$

The SD or SD* will not be calculated in case of small number of samples (less then 10) and the value will be missing in the corresponding BUFR message.

Extended Quality Control (E-QC)

Extended Quality Control procedures should be applied at the national Data Processing or Data Management Centers. This would include comprehensive control of logical relations among a number of variables (the internal consistency of data). For the further treatment of data it is necessary to keep the results of the E-QC data quality control together with the information on how suspect or wrong data had been treated. One possibility is to flag data passing through QC.

WMO Guide of the GDPS, WMO-No. 305 as the standard guidance on surface data quality monitoring methods also deals with limit checks and consistency checks for surface data from AWS. The algorithms applied in the guide are suitable for AWS data transmitted in SYNOP reports only. With respect to the planned migration strategy from alphanumerical to binary data representation the proposed algorithms should be redefined using related BUFR descriptors and code/flag tables.

The proposal of a new approach to E-QC checking algorithms is as followed:

QC of AWS Basic Parameters (AWS BUFR 10-minute data)
Internal consistency checks of data

The different parameters in AWS BUFR N-minute data[2] reports are checked against each other. In the description below, the suggested checking algorithms have been divided into areas where the physical parameters are closely connected. Symbolic names of parameters used in the listed algorithms are described (explained) in the Table bellow.

(a) Wind direction and wind speed

[2] N ≤ 10 minutes

The wind information is considered to be erroneous in the following cases:

wind_direction = 00 and wind_speed ≠ 00;

wind_direction ≠ 00 and wind_speed = 00;

wind_gust_speed ≤ wind_speed;

(b) Dry temperature and dew-point temperature

The temperature information is considered to be erroneous in the following case:

temperature_dew_point > temperature_dry;

temperature_dry - temperature_dew_point > 5°*C* and obscuration is from {1, 2, 3};

(c) Dry temperature and present weather

Both elements are considered suspect when:

temperature_dry > +5°*C* and precipitation_type is from {6, …, 12};

temperature_dry < -2°*C* and precipitation_type is from {2};

temperature_dry > +3°*C* and precipitation_type is from {3};

temperature_dry < -10°*C* and precipitation_type is from {3};

temperature_dry > +3°*C* and obscuration is from {2} or
(obscuration is from {1} and obscuration_character is from {4});

***(d)* Visibility and present weather**

The values for visibility and weather are considered suspect when:

obscuration is from {1, 2, 3} and visibility_horizontal > 1 000 m;

obscuration is from {7, 8, 9, 11, 12, 13} and visibility_horizontal > 10 000 m;

visibility_horizontal < 1 000 m and obscuration is not from {1, 2, 3, 8, 9, 10, 11, 12, 13} and precipitation_type is not from {1, … , 14};

obscuration = 7 and visibility_horizontal < 1 000 m;

visibility_horizontal > 10 000 m and precipitation_type is missing and obscuration is missing and weather_phenomenon is missing;

***(e)* Present weather and cloud information**

Clouds and weather are considered suspect when:

cloud_cover_total = 0 and precipitation_type is from {1, …, 11, 13, 14}
or weather_phenomenon is from {2, 5, … , 10};

(f) Present weather and duration of precipitation

Present weather and duration of precipitation are considered suspect when:

precipitation_type is from {1, … , 10, 13, 14} and precipitation_duration = 0;

precipitation_type is not from {1, … , 10, 13, 14} and precipitation_duration > 0;

(g) Cloud information and precipitation information

Clouds and precipitation are considered suspect when:

cloud_cover_total = 0 and total_precipitation > 0;

(h) Duration of precipitation and other precipitation information

Precipitation data are considered suspect when:

total_precipitation > 0 and precipitation_duration = 0;

(i) Cloud information and sunshine duration

Clouds and sunshine duration are considered suspect when:

cloud_cover_total = 100 and sunshine_duration > 0;

Table

Parameters/type of data, corresponding BUFR descriptors (as reference) and symbolic names of parameters used in QC algorithms (a) – (i)

Parameter / Type of data	**BUFR Descriptor**	**Parameter Symbolic name**
Wind direction	0 11 001	Wind_direction
Wind speed	0 11 002	Wind_speed
Wind gust	0 11 041	Wind_gust_speed
Dry temperature	0 12 101	Temperature_dry
Dew-point temperature	0 12 103	Temperature_dew_point
Cloud cover total	0 20 010	Cloud_cover_total
Horizontal visibility	0 20 001	Visibility_horizontal
Type of precipitation	0 20 021	Precipitation_type
Character of precipitation	0 20 022	Precipitation_ character
Duration of precipitation	0 26 020	Precipitation_ duration
Other weather phenomena	0 20 023	Weather_phenomenon
Intensity of phenomena	0 20 024	Phenomena_ intensity
Obscuration	0 20 025	Obscuration
Character of obscuration	0 20 026	Obscuration_ character
Total precipitation	0 13 011	Total_precipitation
Total sunshine duration	0 14 031	Sunshine_duration

Quality Control Procedures on Higher Levels of Data from Automatic Weather Stations used in Central Institute for Meteorology and Geodynamics (ZAMG) in Vienna, Austria

This Annex contains Quality Control Procedures (QC) of Automatic Weather Station (AWS) data applied in Central Institute for Meteorology and Geodynamics (ZAMG). These Quality Control Procedures are an example of operational quality control applications at the monitoring centre of ZAMG, Technical Department. The dissemination of all data from Automatic Weather Stations is centralized and carried out by this monitoring centre. A sophisticated network is needed to run such Quality Control Procedures. This monitoring is automatically done as well as manually. Wrong data from Automatic Weather Stations can be avoided more or less before dissemination.

The concept of these Quality Control Procedures is extended to different levels. The goal is to identify questionable data. Many of the Quality Control Procedures are related to thresholds. The thresholds are empirical and can easily be changed. Seasonal thresholds are in discussion. The Quality Control Procedures concerns three levels. Beside the basic Quality Control Procedures are Quality Control Procedures from data of Automatic Weather Stations dependent on time and on areas. Additional levels according to climatological Quality Control Procedures are in use but not reported in this example.

First level: Basic Quality Control Procedures

Second level: Enhanced Quality Control Procedures according to time

Third level: Enhanced Quality Control Procedures according to areas

1. Basic Quality Control Procedures of Automatic Weather Station data applied in the monitoring centre

- Wind_direction
  range 0 –360
- Wind_speed
  range 0,33 – 50 m/sec,
  above 1500m: 0,33 – 75 m/sec (higher limit in moutain areas)
- Global and diffuse radiation
  range 0 –140 W/m2
- Pressure
  range 630 – 1060 hPa
- Relative Humidity
  range 0 – 100 %
- Temperature_dry
  range – 50 to +50 degrees

2. Enhanced Quality Control Procedures according to time of Automatic Weather Station data applied in the monitoring centre

The online monitoring faces a general timestep of 10 minutes and a maximum period of 36 hours. Reported values without any change during 2 hours are considered to be suspect.

Temperature_dry, temperature_ground/soil +5 cm, -10 cm, -20 cm, -50 cm:

- variance < 3,0 degrees (for continuous timesteps)
- 4 consecutive mean values of 5 continuous timesteps (50 min), variances of these mean values and comparison of the 3 variances

  2nd variance <= 1st variance + factor

  2nd variance <= 3rd variance + factor

  concerning temperature_dry: factor = 3,0 degrees

  concerning temperature_soil –10 cm: factor = 1,0 degree

  concerning temperature_soil –20 cm: factor = 0,7 degree

  concerning temperature_soil –50 cm: factor = 0,3 degree

- mean values of 5 continous time steps without considering the median, comparison of mean value and median

  concerning temperature_dry: threshold = 3 degrees
  concerning temperature_soil –10 cm: threshold = 0,4 degree
  concerning temperature_soil –20 cm: threshold = 0,2 degree
  concerning temperature_soil –50 cm: threshold = 0,1 degree

- mean value of the variances (during 36 hours)

  concerning temperature_dry: threshold = 0,6 degrees
  concerning temperature_soil –10 cm: threshold = 0,35 degree
  concerning temperature_soil –20 cm: threshold = 0,35 degree
  concerning temperature_soil –50 cm: threshold = 0,3 degree

- temperature gradient during morning and afternoon shall be different

Temperature_dew_point:

- variance of temperature_dew_point

  threshold = 3 degrees (for continuous timesteps)

- calculation of relative humidity with temperature, dew point and temperature, dry and comparing with the measured relative humidity threshold

  0 – 49%: difference 20%
  50 – 69%: difference 20%
  70 – 100%: difference 20%

Wind_speed (ff) (calculation with vectors):

- wind_speed multiplied by a factor and compared with wind_gust_speed (ffx) algorithm:

  ff < 3 m/sec ---
  ff < 5 m/sec factor 8
  ff < 10 m/sec factor 6
  ff > 10 m/sec factor 3

- mean value of ffx of 2 following timesteps (M), absolute value between these ffx (D)

  M > 10 m/sec and D < M/2

- mean value (arithmetic) (ffa), (QC of ff and dd sensor)

  1 < ffa <= 5 m/sec and difference between ffa and ff < ff/2
  ffa > 5 m/sec and difference between ffa and ff < ff/10

Wind_direction (dd)

- Difference (D) of absolute value between dd and wind_gust_direction (ddx) during 36 hours (QC of the dd sensor) counter calculation

  D = 40 – 80 degrees and ff < 8 m/sec counter +1
  D = 40 – 80 degrees and ff > 8 m/sec counter +2
  D > 80 degrees and ff < 8 m/sec counter +3
  D > 80 degrees and ff > 8 m/sec counter +4

Pressure:

- 4 consecutive mean values of 5 continuous timesteps (50 min), variances of these mean values and comparison of the 3 variances

  2nd variance <= 1st variance + 2 hPa
  2nd variance <= 3rd variance + 2 hPa

Relative Humidity:

- variance < 10 % (for continuous timesteps)

Global radiation (gr), diffuse radiation (dr), sunshine (s)

- gr during night time = 0
- if s > 0 then gr > 0
- if gr - dr > 140 W/m2 then s > 0
- if gr > 315 W/m2 then s > 0
- if s 600 seconds and gr > 315 W/m2 then gr – dr > 175 W/m2

Precipitation (RR)

- permanent signal of RR detector over 3 hours, amount of RR > 0
- amount of RR > 1 mm, precipitation in the previous and following timestep (1 minute) > 0
- maximum amount of RR (RRx): ranking method, comparing RRx with the mean values of RRx of the following neighbouring amounts of RRx
- if amount of RR > 0 mm then signal of RR detector in the previous and following timestep (1 minute) > 0
- no RR when gr > 315 W/m2 and s > 300 seconds

3. Enhanced Quality Control Procedures according to areas of Automatic Weather Station data applied in the monitoring centre

Temperature_dry, temperature_ground/soil +5 cm, -10 cm, -20 cm, -50 cm:

- comparison of amplitudes of all AWSs (24 hours) ranking method, comparing amplitude with the mean values of amplitudes of the following neighbouring amplitudes
- calculation of the mean values of differences according standard atmosphere for each AWS, area comparison of neighbouring AWSs of the mean values of these differences threshold = 3 degrees
- area comparison, calculation of mean values, comparing mean values with value of a single AWS, the comparison is made with AWSs of more or less the same altitude weighted threshold = 5, 7, 9 degrees

Wind_gust_speed (ffx):

- area comparison: if more AWSs are reporting such a ffx, change of the factor algorithm:

ff < 3 m/sec	-
ff < 5 m/sec	factor 10
ff < 10 m/sec	factor 7
ff > 10 m/sec	factor 4

Wind_gust_direction (ddx):

- comparison of wind_gust_direction (ddx) with the neighbouring AWSs with the correspondent wind_gust_speed (ffx)

threshold dependent	if ffx	>12 m/sec	40 degrees
		> 8 m/sec	70 degrees
		> 5 m/sec	100 degrees
		> 2 m/sec	130 degrees

Pressure:

- comparison of amplitudes of all AWSs (24 hours); ranking method, comparing amplitude with the mean values of amplitudes of the following neighbouring amplitudes

- calculation of the mean values of differences according standard atmosphere for each AWS, area comparison of neighbouring AWSs of the mean values of these differences threshold = 4,0 hPa

Precipitation (RR):

- RR area comparison of neighbouring stations, if neighbouring AWSs have a signal of RR detector during 100 minutes, RR > 0
- area comparison of amount of RR during 1 hour (M), mean value of neighbouring AWSs (Mg)

  Mg – M <= 5mm

- overlapping amount of RR (RRs) during 6 hours compared with amount of RR of neighbouring AWSs (RRsg)

  RRsg/10 <= RRs if RRsg > 40 mm and RRs > 0 mm

Operational Accuracy Requirements and (Typical)[3] Instrument Performance,

{Proposed by the Expert Team on Requirements of Data From Automatic Weather Stations (ET-AWS), GENEVA, 2-6 SEPTEMBER 2002.
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 accuracy*[4,5]	*(6)* *Sensor time constant*[6]	*(7)* *Output averaging time*	*(8)* *Achievable operational 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 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] To be removed
[4] ± sign should be removed to be in accordance with ISO standards on *uncertainty of measurements*
[5] The term *accuracy* should be replaced by *uncertainty* to be in accordance with ISO standards on *uncertainty of measurements*
[6] n/a: not applicable.
[7] Suggestions.

2. Humidity[8]								*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			
					20 s	1 min	±0.2 K	Large errors are possible due to aspiration and cleanliness problems. If measured directly. Tending to ±1% when relative humidity[9] nears saturation.
2.2 Relative humidity	0 – 100 %	1 %	I	±1 % (old: ±3%)	***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								***(Range to sea-level)***[12]**.**
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 (±0.3 hPa)	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 (±0.2 hPa)	Differences between instantaneous values.
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]							

[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)

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.
6. Precipitation								
6.1 Amount	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				
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		Accuracy seriously affected by wind. Sensors may show significant non linear behavior
7. Radiation								
7.1 Sunshine duration	0 – 24 h	60 s (old: 0.1 h)	T	±0.1 h	20 s	n/a	±2 %	
7.2 Net radiation[18]	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 %	

[13] to be determined.
[14] To be determined for instrument measurements
[15] Distant constant; for anemometers: *response length*
[16] Specified for rainfall intensity by the expert team on rainfall intensity measurements (Bratislava, Slovakia, 23 to 25 April 2001)
[17] Totals reading

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:
   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.

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[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.

[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

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 2ó-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.

RECOMMENDATIONS

(Recommendation numbers refer to the item in the agenda under which this recommendation was formulated.)

Recommendation 2-1

CLARIFICATION OF THE UNIT OF RADIATION MEASUREMENT

Considering that:

1. 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;
2. In Annex 7.A of this Guide, the unit for *H* is J m^{-2} and not W m^{-2}; and
3. 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.

Therefore, it is recommended that:

A better definition of *radiation* be adopted to replace these divergent uses.

Recommendation 3-1

FUNCTIONAL SPECIFICATIONS FOR AWS

Considering that the proposed scheme would:

1. Increase the amount of climatological information and at the same time maintain the homogeneity of climate data sets,
2. Guarantee the homogenous recording of the basic set of climated parameters such as temperature, precipitation, pressure, sunshine duration, and wind because of the resolution and reporting intervals,
3. Ensure that extreme values are accurately and consistently recorded in a way that can be precisely related to older, manually observed data, and

Therefore it is recommended that:

1. Maintenance of accurate metadata for AWS installations must be accomplished, and
2. Automated and standardised water vapour measurements should be included in AWS parameters.

Recommendation 3-2

RECOMMENDATION ON THE IMPROVEMENT OF THE DEFINITIONS OF VARIABLES STATED IN THE MANUAL OF CODES

Considering that:

1. For principle weather stations, the meteorological variables to be determined by observations or measurements are stated in the Manual on the Global Observing System,
2. Both the nominal meteorological variables and the instrument readings should be implemented. in BUFR/CREX codes
3. No clear definition is given in the Manual on Codes to discriminate between nominal variables and instrument readings,
4. This lack of clear definition will introduce significant confusion at the user's site, and
5. It is required to disseminate through the networks both the nominal variables and the instrument readings in BUFR/CREX codes,

Therefore, it is recommended that:

BUFR/CREX shall support uniquely identified reporting of both nominal and instrument data values.

Recommendation 3-3

ALGORITHM IDENTIFICATION FROM BUFR/CREX TABLES

Considering that:

1. Some algorithms are mentioned in the new BUFR descriptors; and
2. Many applications, especially climate research, require knowledge of the parameters being reported to the highest achievable accuracy;

Therefore, it is recommended that:

1. Links should be provided in the documentation so that users may determine the specific algorithms used at the source.

Recommendation 5-1

RECOMMENDATION ON THE INTRODUCTION OF NEW VARIABLES AND THE IMPROVEMENT OF THE DEFINITIONS OF VARIABLES STATED IN THE MANUAL OF CODES

Considering that:

1. Observing sky condition and in particular the total amounts of clouds or overcast from the traditional observation position and with relatively large intervals of one hour or more, has significant limitations,
2. From the optical extinction profile of the atmosphere, using a one-minute interval time series, cloud bases and amount of cloudiness can be derived using simple calculations.
3. one minute interval (or less) time series of such profiles provide meteorologists and other users with much more appropriate information on the state of the atmosphere and the sky in particular,
4. current observing technology to determine such profiles is already in practice for more than 10 years and has demonstrated usefulness,

Therefore it is recommended that:

1. Introduce the *optical extinction profile of the atmosphere* as a basic parameter to be reported by principle automatic weather stations, to be included in the Manual on the GOS.
2. WMO regulations should indicate that these parameters may be derived directly from this profile without further measurement because from one minute based time series of this profile both *cloud base* and the *measure of cloudiness* can be determined.

Recommendation 6-1

CLOUD OBSERVATIONS

Considering that:

1. Cloud Observations derived from ceilometer data are generally used in conjunction with time integration algorithms to prepare estimates of sky cover;
2. Such reports are valuable to users – particularly in the aviation sector;
3. The need to employ numerous assumptions compromises their accuracy and reliability;
4. Forecasters, climatologists, and other such users require improved access to the actual measurement data.

Therefore, it is recommended that:

1. The following parameters be reported to supplement (but not necessarily to replace) whole sky estimates.
   - Time of observation,
   - Height of layer as detected at the time of observation directly over the sensor,
   - Top of layer as detected at the time of observation directly over the sensor,
   - Extinction profile at the time of observation, and
   - Total number of minutes for which layer was detected during the previous 60 minutes (persistence).

Recommendation 7-1

Considering that:

1. Basic Quality Control (B-QC) procedures (automatic data validity checking) should be applied at all Automatic Weather Stations (AWSs) to monitor the quality of sensors' data prior to their use in computation of weather parameter values;
2. A comprehensive documentation on B-QC, including the specification of basic data processing procedures for the calculation of instantaneous (i.e. one minute) data and sums should be a part of AWS' standard documentation;
3. The range of B-QC strongly depends on the type of AWS and a level of its sophistication; and
4. Every AWS BUFR message (BUFR descriptor 0 33 005 - Quality Information (AWS data)) should include outputs of B-QC.

Therefore it is recommended that:

1. The ET-AWS prepares improved guidelines on Extended Quality Control Procedures for Data from AWS as a standard for publication, and that
2. Members identify Contact Points as experts on Quality Control Procedures for Data from AWS for the exchange of operational applications and methods in cooperation with the ET-AWS.