WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

OPEN PROGRAMME AREA GROUP ON INTEGRATED OBSERVING SYSTEMS

EXPERT TEAM ON REQUIREMENTS FOR DATA FROM AUTOMATIC WEATHER STATIONS

GENEVA

28 JUNE - 2 JULY 2004

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).
New and important priorities for the World Meteorological Organization (WMO) are emerging in the areas of climate change, freshwater and air supply, and transportation. All are related to public and economic sector user needs of our data. Data needs are related to national economies, the environment, and public safety. Data User’s are placing greater dependency on accurate and timely weather and water information, which has become increasingly critical to the WMO Membership.

The meteorological community is entering a future where a diverse collection of automatic observations will become readily available to users when and where needed. Included in our national networks will be many automatic in situ mesoscale networks, automatic road surface and near road environment networks, fixed and mobile automatic stations using land, sea and air transportation vehicles that continuously measure meteorological conditions.

The Automatic Weather Station (AWS) has become the primary platform for providing observational of data. To ensure data quality and consistency from AWSs, we must clearly define how to eliminate or at least minimize inconsistencies and reduce the amount of doubtful, wrong, or missing data. Identifying user needs and developing data requirements is the mission of the Commission on Basic Systems (CBS) through its many expert teams.

The expert team on Automatic Weather Stations was formed at the request of CBS to investigate the current state of knowledge regarding the automatic weather station approach in gathering weather data. The tasking of this ET is to enhance operational production of weather-related information. The recommendations will help the WMO capitalize on existing capabilities and take advantage of future technological opportunities.

This report has been drafted and reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the WMO. This report provides the Team’s consensus findings and recommendations.
1. ORGANIZATION OF THE SESSION

1.1. Opening of the meeting (Agenda item 1.1)

The session of the Expert Team on Requirements for Data from Automatic Weather Stations (ET-AWS) of the Commission for Basic Systems (CBS) Open Programme Area Group on Integrated Observing Systems was opened by its Chairman, Mr. Rainer Dombrowsky, at 10h00 on Monday 28 June 2004 at WMO Headquarters in Geneva, Switzerland. The list of participants is attached in Annex 1.

On behalf of the WMO Secretariat, Director of WWW Department, Mr. Dieter Schiessl welcomed the participants to WMO. He highlighted the most important topics the meeting was expected to address. He specifically recalled the issues related to (a) maintenance definition and house-keeping of metadata, (b) reporting both nominal and instrument parameters from automatic weather stations, (c) guidelines on quality control procedures for data from AWSs, and (d) the role of AWSs in the integrated surface observation system.

1.2. Adoption of the agenda (Agenda item 1.2)

The agenda adopted by the ET as 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. The meeting agreed to begin each day at 09h00 and to continue until 16h30 hours with a one-hour lunch break.

2. REPORT OF THE CHAIRMAN

The Chairman’s report provided a summary on ET-AWS membership. The report announced the loss of our Canadian member due to retirement. It was also announced that the secretariat has since received confirmation that the vacant Canadian membership will be filled in the near future. In addition to the status report regarding ET membership the chairman thanked the members for their attendance and reports. He also announced the receipt of new business items indicating which items would be added to the meeting agenda.

3. ISSUES RELATED TO DEFINITION, REPORTING AND MAINTENANCE OF AWS DATA

3.1. Review and refine definition of radiation

The representative of CIMO presented the opinion of the radiation experts of the need to refine the definition of radiation. The definition as stated in the Guide to Meteorological Instruments and Methods of Observation, WMO-No.8, (CIMO Guide) is correct. However, some confusion may arise if the table on accuracy requirements (Annex 1.B to Chapter 1) is not correctly interpreted. The confusion is related to the incorrect use of terminology, i.e., the variable radiation is used as a common term for both the amount and intensity of radiation. The term "irradiance" is the measure of intensity or power measured in Wm⁻², while "radiant exposure" an "energy" term or of "physical work" is measured in terms corresponding to time over the "irradiance". The unit of "radiant exposure" is therefore Jm⁻², not Jm⁻²d⁻¹.

To avoid such confusion, variables like irradiance and radiant exposure should be used to distinguish between the physical quantities of power and energy. In this regard, the meeting recommended updating the CIMO Guide, Part I, Chapter 1, Annex 1.B, relevant parts of Chapter 7 and table element names in Class 14 of BUFR Table B, to reflect these differences. The ET adopted Recommendation 3.1 for approval by CBS (Annex 11).
3.2. Issues related to the maintenance of metadata

Metadata (station and data history), as applied to measurement and observation, describe the location, instrument and method of observation, quality, and other characteristics of data. Metadata are important for data users in understanding the origins of meteorological values. Metadata are especially important for understanding elements particularly sensitive to exposure, such as precipitation, wind and temperature.

Metadata are an extension of the station administrative record, containing all possible information related to the station siting, instruments installations, instrument type, schedule of maintenance, and scheduled and unscheduled system changes that occurred during the history of an observing system. Expanded metadata information should also include digital images.

Metadata are dynamic. Station location, ground cover, instruments, observation measurement and reporting practices, algorithm processing; data formats etc. change over time. As computer data management systems gradually become an important component of the data delivery systems, it is desirable that metadata are available in near-real time as a computer database allows for computerized composition, updating, and delivery.

The information provided in the WMO Core Metadata Profile is suitable for use by decision makers and users based on the ISO DIS 19115. It is recommended as a starting point for development of more detailed metadata standards relating to all WMO Programme requirements. The ET was also informed on the current work on metadata in other technical commissions, such as the “Guidelines on Climate Metadata and Homogenization”, WMO-TD No. 53.

In this regard, the meeting, recognizing the need to define metadata elements for AWS, agreed in principle on the standard set of metadata elements for all AWS installations (See Annex 3). This proposal must still be refined. Members of the ET have been tasked to provide their comments by 15 August 2004 so that the final version could be submitted to CBS-XIII for approval and publication.

The expert team recommended that the proposed Standard set of metadata elements for all AWS installations be published in both the Manual on the Global Observing System (GOS), WMO-No. 544 and in the Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8, to ensure complete and correct information about data. The ET adopted Recommendation 3.2 for approval by CBS (Annex 11).

In the future, the ET will develop practical examples based on the proposal in Annex 3 and make them available to data producers. The meeting also agreed that it is important to develop details of the individual categories presented in Annex 3 in the form of tables as well as a glossary.

3.3. Review and refine reporting of water vapor measurements

In general it is a common practice to identify all water vapour related quantities as humidity. Typical variables used in meteorology to represent humidity are dew point temperature, relative humidity, vapour pressure, water content, mixing ratio, etc. Using accepted thermodynamic equations, (see International Meteorological Tables, WMO-No. 188) these variables, such as dew point temperature, vapour pressure and water content can be derived directly. Therefore, these variables are considered primary quantities. On the other hand, relative humidity, saturation (or wet bulb) temperature, mixing ratio, and other variables require air temperature or dry air pressure for the calculation of such primary quantities. Therefore, if an AWS measures a ratio such as relative humidity, it is required to measure air temperature as well in order to be able to determine the primary quantity related to humidity (water vapour). In practice, the measurement of relative humidity is widely used and accepted. In this regard the meeting recommended that AWS should report both relative humidity and the primary physical quantity, dew point temperature. The ET adopted Recommendation 3.3 for approval by CBS (Annex 11).
3.4. Possibility of reporting both nominal and instrument values in BUFR/CREX

The CBS-Ext.(02) acknowledged the efforts of the Expert Team on Data Representation and Codes for the finalized BUFR templates for AWS data and noted with appreciation the work carried out by the ET-AWS in developing accompanying BUFR/CREX descriptors. It was also agreed that BUFR templates were suitable for the exchange of AWS data. The CBS considered the recommendation of the ET that BUFR/CREX template for AWS should support reporting of both instrument and nominal values.

The WMO Manual on GDPS, WMO-No. 485 defines Level I data as primary data or instrument readings, Level II data as meteorological parameters or nominal values and provides appropriate guidelines requirements for data reporting:

**Level I data: Primary data.** In general these are instrument readings expressed in appropriate physical units and referenced in Earth coordinates. Level I data require conversion to the meteorological parameters specified in data requirements.

**Level II data: Meteorological parameters.** These are obtained directly from the meteorological instruments or derived from the Level I data.

Data exchanged internationally must be Level II data. If Level I data meet the requirement for data reporting as defined in WMO manuals and guides, then no adjustment is needed. In such a situation both Level I and Level II data will have identical values.

The meeting considered the proposal developed jointly by Mrs E. Červená (ET/DR&C) and Mr I. Zahumenský (ET-AWS) for reporting both Level I and Level II data and agreed to submit it to CBS-XIII for approval (see Annex 4). The ET adopted Recommendation 3.4 for approval by CBS (Annex 11).

The meeting also recommended that further work should concentrate on:

(a) Specifying the elements for which a nominal value is required;

(b) Defining the representative sensor height for all elements;

(c) Specifying the adjustment procedures for elements for which the nominal value is required;

(d) Refining the BUFR template for AWS data to allow for reporting both nominal and instrument values.

3.5. Issues related to documentation of AWS algorithms

The meeting recalled that different types of algorithms were being used to compute the same parameter, which might lead to different results. It is therefore important to link those parameters with the algorithm used in its computation. The meeting agreed that this would have to be addressed as a part of metadata issue in the Future WMO Information Systems (FWIS).

The meeting agreed that the CIMO WEB Portal would be the best site where the links to manufacturers and other producers of different algorithms could be established for the purpose of acquiring information on sensor algorithms. In this regard, the meeting requested the Executive Secretary of the HMEI to communicate this request to the members of the HMEI and possibly to other manufacturers.

4. DEVELOPMENT OF IMPROVED GUIDELINES ON EXTENDED QUALITY CONTROL PROCEDURES FOR DATA FROM AWS

The ET considered the proposal for the Guidelines on Quality Control (QC) Procedures for Data from Automatic Weather Station developed by Mr Zahumenský. It was noted that there are different quality control procedures for the various phases of the data collection process. Notably, there is an absence of comprehensive quality control at all levels. It is evident that data quality flagging is of utmost importance and should be implemented at all levels of data quality control.
The proposal addresses only QC of data from a single AWS platform, while spatial QC is beyond a scope of the proposal. The same is also true for checks against analyzed or predicted fields as well as for QC of formatting, transmission and decoding of errors.

Every AWS BUFR message must include outputs of Basic QC, using BUFR descriptor 0 33 005 (Quality Information AWS data) and 0 33 020 (Quality control indication of following value) or preferably a new flag table yet to be defined (for example 0 33 019 (Quality control indication of following value), such as the Flag Table below proposed by the ET.

Flag Table 0 33 019 “Quality control indication of the following value”, data width 8 bits

<table>
<thead>
<tr>
<th>Bit N°</th>
<th>Quality control indication</th>
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<tbody>
<tr>
<td>1</td>
<td>Good</td>
</tr>
<tr>
<td>2</td>
<td>Inconsistent</td>
</tr>
<tr>
<td>3</td>
<td>Doubtful</td>
</tr>
<tr>
<td>4</td>
<td>Wrong</td>
</tr>
<tr>
<td>5</td>
<td>Not checked</td>
</tr>
<tr>
<td>6</td>
<td>Has been changed</td>
</tr>
<tr>
<td>7</td>
<td>Reserved</td>
</tr>
<tr>
<td>All 8</td>
<td>Missing value</td>
</tr>
</tbody>
</table>

The code table 0 33 020 defines the quality control indication of the following value. It should be possible to indicate several quality control indications to a same value. It could be done if an equivalent flag table were developed.

The meeting proposed that the current BUFR templates for AWS (one-minute, n-minute and one-hour period) include descriptors for “Quality Control Indication”.

The proposal was reviewed and updated during the session, including a number of relevant inputs from the representative of EUOMETNET. The meeting agreed on the final proposal to CBS-XIII for approval and recommended the Guidelines on Quality Control Procedures for Data from Automatic Weather Stations (see Annex 5) be published in both the WMO Guide on Global Data Processing System (WMO-No. 305) and in the Guide to Meteorological Instruments and Methods of Observation, WMO-No.8. The ET also proposed that the ET/DR&C address the issue of developing a Flag Table and refine the current BUFR templates for AWS. The ET adopted Recommendations 4.1 and 4.2 for approval by CBS (Annex 11).

5. OTHER BUSINESS

5.1. Status of the Earth Observing System initiative

The ET-AWS membership was briefed by Dr. Donald Hinsman as to the status of the Earth Observing System Initiative. The presentation gave a detailed summary as to its status and future plans. Dr. Hinsman also provided details relating to WMO status within the framework of GEOS and WMO decision to establish an integrated work team to formulate the WMO’s strategy for how WMO-coordinated systems should operate within the framework of the GEOSS Plan. A summary highlighting the key points of his presentation is contained in Annex 10 of the ET-AWS Final Report.

5.2. Role of AWS in the integrated observation concept

The chairman presented the latest vision of the United States meteorological services plan for transition to an integrated surface observation structure. In line with the Global Environmental Observing System, the United States is establishing a system of systems framework. The planning for the initial phase of this transition will take place in July, 20-22, 2004. The initial phase will begin with the integration of the National Oceanic and Atmospheric Administration’s (NOAA) Climate Reference Network, Cooperative Observer Network and its Automated Surface Observing Systems. Following successful integration, other important weather and climate-related observation networks will be integrated. The end result of this activity will be
the full integration from within NOAA and extending out to include other public and private sector meso-networks. The Integrated Surface Observation System (ISOS) will assimilate environmental network data, apply real-time quality control, distribute data through various mediums including Internet to public and private sector data users, monitor network performance in near-real time and retrospective quality control for use in deriving information for decision makers across many disciplines. Future plans include the establishment of an Integrated Tropospheric Observation System (ITOS). The ITOS will follow a similar approach through the integration of radiosonde, wind profiler, AMDAR, and other tropospheric monitoring networks.

5.3. Standardization of AWS platforms

To meet society’s diverse and expanding needs for weather-related information, there is a need to increase the number, breadth, accuracy, and availability of AWS observations. In conjunction with these enhancements, standards for platform configuration are needed to ensure continuity and consistency across integrated AWS networks.

The expected outcome is a comprehensive observation system should support all meteorological, climatological and hydrological applications. Such a system will provide uniform, high quality data sets resulting in increased user satisfaction. User satisfaction will be associated with the benefits derived from better information provided to decision makers.

The expert team discussed the need for establishing a basic set of variables to be reported by all AWS (see Annex 6). It was agreed that this issue needs further careful consideration.

5.4. Issues related to AWS documentation

The meeting was informed of inconsistencies in the definition of an AWS between the Manual on GOS, WMO-No.544, the Guide to Meteorological Instruments and Methods of Observation, WMO-No.8, the Manual on Codes, WMO-No.306, and the International Meteorological Vocabulary, WMO-No.182. The meeting and proposed an updated definition of AWS in the Manual for the GOS, the CIMO Guide and the Manual on Codes:

“Automatic Weather Station”: A Meteorological station at which observations are made and transmitted automatically."

The ET adopted Recommendation 5.4 for approval by CBS (Annex 11).

The ET also proposed changes in paragraphs within the CIMO Guide addressing Data reduction, Data Quality Control and Data Centres (See Annex 7).

5.5. Developing guidance on QA/QC of surface meteorological data

The chairman presented a document requesting participants to review and provide comments to the chair by no later than August 15, 2004. The document review has to be made at the request of the Chair CCI OPAG 1 – Climate Data and Data Management. The request is a collaborative effort between CBS and CCI in the development of a guideline document on "Data Quality Assurance and Quality Control" for NHMSs. This would essentially be an update to: Abbott, P.F., “Guidelines on Quality Control of Surface Climatological Data" - WMO/TD-No.111.

5.6. Functional Specifications for Automatic Weather Stations

The meeting reviewed the Functional Specifications for AWSs as agreed at the second session of the ET on AWS and determined the need for further refinements. The Functional Specifications present user requirements and these may be used by manufacturers in designing instruments. The proposal as presented in Annex 8 provides changes related to BUFR/CREX code tables.
The meeting agreed that this proposal should be submitted to CBS-XIII for approval and be published in the Guide on the GOS, WMO-No.488. The ET adopted Recommendation 5.6 for approval by CBS (Annex 11).

5.7. Operational Accuracy Requirements and Instrument Performance

The meeting reviewed the Operational Accuracy Requirements and Instrument Performance as agreed at the second session of ET on AWS. The meeting identified the need for further refinements (See Annex 9). The table contains new suggested values together with the current ones for reader to see the changes and is proposed for publication in this form.

The expert team agreed to submit the Operational Accuracy Requirements and Instrument Performance to CBS-XIII for approval. It was also proposed that the president of CBS requests the president of CIMO to consider publishing Operational Accuracy Requirements and Instrument Performance in the CIMO Guide. The ET adopted Recommendation 5.7 for approval by CBS (Annex 11).

5.8. Position of a Automatic Weather Station

The representative of CIMO informed the ET that WMO Manuals or Guides do not clearly state the requirement for accuracy in determining the position of a station. Moreover he indicated that with modern numerical applications, the position of a station should be presented in degrees only and in a decimal format. Taking into account that the determination of the position with an uncertainty of about 100 m will be accurately enough for most applications, it was noted however, that for other applications the accuracy of the position of a station should be at least to one thousandth of a degree in both latitude and longitude. It was also noted that such accuracy can be met by most GPS receivers used today. The ET adopted Recommendation 5.8.1 for approval by CBS (Annex 11).

The representative of CIMO informed the ET that no standard reference system has been endorsed by the WMO to be used as reference for both the horizontal position of a station (given as longitude and latitude) and the vertical position of a station (for mean sea level, MSL). He explained that the WMO definition of MSL requires such a reference. Furthermore, he informed the meeting that ICAO had endorsed a standard referencing system, the World Global System 84, (WGS 84). It was proposed that WMO should consider endorsing the World Global System 84 (WGS 84) as its reference for horizontal positioning and the GEOID-99 as reference for vertical positioning. The ET adopted Recommendation 5.8.2 for approval by CBS (Annex 11).

5.9. Averaging of observational data

The representative of CIMO informed that it is common practice to report observational data averaged over time, but that clear definitions for averaging are not given in WMO Manuals or Guides. Moreover, the mathematical techniques for averaging are not defined. He presented two reasons for averaging:

(a) To remove fluctuations and noisy measurements (natural or artificial);

(b) To compute a new value with a higher degree of spatial representativeness.

For both issues, different mathematics may be chosen. The typical RC filter method will reduce noise, not an arithmetic mean based on a time window. An arithmetical mean based on a time window might be more favorable, although the use of a constant weighting factor is questionable. Moreover the use of the median value, for observations with defined period, is favorable because it is in the middle of the data.

It was noted that in special cases using averages might introduce some error. For instance, the Meteorological Optical Range (MOR) derived after averaging the measured extinction coefficient gives a different value compared to when the MOR is averaged directly. Such differences will not occur if median values are chosen.
The meeting agreed that averaging of each observed value for further reporting should be based on a well-defined and documented method. The mathematics chosen should be well described. Therefore, the meeting recommended that the CBS address this issue through the appropriate expert team. **The ET adopted Recommendation 5.9 for approval by CBS (Annex 11).**

5.10. Optical extinction profile

Based on the ET-AWS-2 recommendations, WMO has adopted the optical extinction profile as a new variable. The height of cloud base and cloud extent can be derived directly from the optical extinction profile without further measurements, using one-minute time series. However, a clear definition of such a profile is needed for publication in the CIMO Guide. The most practical approach would be to use a similar approach as with the extinction coefficient used for determining of MOR values. **The ET adopted Recommendation 5.10 for approval by CBS (Annex 11).**

5.11. Definitions of BUFR descriptor Element Names

The meeting noted that the BUFR Code contains descriptor Element Names, the meaning of which are not always clearly defined. For example, the Element Name “Height of altitude” (0 07 002) is used in a number of cases, but it is not clear whether it refers to the geometric altitude or the geopotential altitude. It was noted that AMDAR observations use such “altitude” as “pressure altitude”, which, however, are two completely different quantities. Such difference may introduce confusion and create inconsistent climatological datasets.

The meeting agreed that BUFR Code descriptor Element Names should be linked to appropriate references to the International Meteorological Vocabulary or WMO Manuals and Guides. **The ET adopted Recommendation 5.11 for approval by CBS (Annex 11).**

5.12. Definition of a common BUFR template for both AWS

The representative of EUMETNET pointed out that problems may arise in data representation from AWS in BUFR code as templates have not yet been developed for standard synoptic hours. The expert team recommended that that CBS ET on DR&C address this problem. **The ET adopted Recommendation 5.12 for approval by CBS (Annex 11).**

6. RECOMMENDATIONS TO BE SUBMITTED TO CBS-XIII

During the course of this meeting, the ET-AWS formulated fifteen recommendations for consideration by CBS-XIII. These recommendations are presented in Annex 11.

7. FUTURE WORK PLAN

The ET concluded by identifying priority activities for the next intersessional period. It was agreed that periodic review of the BUFR coding requirements for AWS must be accomplished. It was acknowledged that observational platforms change for many reasons and existing data management and reporting techniques would also require change. This requires a more frequent exchange of information between the ET-AWS and the ET-DR&C. As ET members identify or are informed of problems with the encoding and reporting of AWS data the teams will need to reconcile the problem. Due to the diverse nature of AWS, regular coordination, throughout the intersessional period, is necessary between CBS, CCI, JCOMM, GCOS, and CIMO. Based on the proposal from members, the meeting agreed on the future plan as described below.

(1) The ET, jointly with the ET-DR&C, to develop a procedure for reporting both Level I and Level II data for submission to CBS XIII.

(2) The ET, jointly with CCI, JCOMM, GCOS, and CIMO, to develop the guidelines for AWS quality control procedures for future publication in WMO Guide on Global Data Processing System (WMO-No. 305), the CIMO Guide, and WMO/TD-No.111.
(3) The ET, jointly with the CCI, JCOMM, GCOS, and CIMO, to develop standards for a basic set of variables to be reported by AWS.

(4) The ET will develop practical examples based on the proposal for a standard set of metadata for AWS.

(5) The ET, jointly with HMEI and CIMO, to develop procedure whereby users can access information on how various parameters are computed. This development will be addressed as part of the metadata needs and the Future WMO Information Systems (FWIS).

8. CLOSURE OF THE SESSION

The meeting was closed at 12h15 noon on 2 July 2004.
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<td></td>
</tr>
<tr>
<td>WMO SECRETARIAT</td>
<td>WWW website</td>
</tr>
<tr>
<td>7 bis, avenue de la Paix</td>
<td><a href="http://www.wmo.int/web/www/www.html">www.wmo.int/web/www/www.html</a></td>
</tr>
<tr>
<td>CH-1211 Geneva 2</td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td></td>
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<tr>
<td>Dr Alexander KARPOV</td>
<td>Observing System Division, Chief, World Weather Watch Department</td>
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<tr>
<td>Dr Miroslav ONDRAŠ</td>
<td>Senior Scientific Officer, Observing System Division, World Weather Watch Department</td>
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</tbody>
</table>
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 ISSUES RELATED TO DEFINITION, REPORTING AND MAINTENANCE OF AWS DATA
   3.1 Review and refine definition of radiation
   3.2 Issues related to the maintenance of meta-data
   3.3 Review and refine reporting of water vapor measurements
   3.4 Possibility of reporting both nominal and instrument values in BUFR/CREX
   3.5 Issues related to documentation of AWS algorithms

4 DEVELOPMENT OF IMPROVED GUIDELINES ON EXTENDED QUALITY CONTROL PROCEDURES FOR DATA FROM AWS

5 OTHER BUSINESS
   5.1 Status of the Earth Observing System initiative
   5.2 Role of AWS in the integrated observation concept
   5.3 Standardization of AWS platforms
   5.4 Issues related to AWS documentation (CIMO Guide)
   5.5 Developing guidance on QA/QC of surface meteorological data
   5.6 Functional Specifications for Automatic Weather Stations
   5.7 Operational Accuracy Requirements and Instrument Performance
   5.8 Position of a Automatic Weather Station
   5.9 Averaging of observational data
   5.10 Optical extinction profile
   5.11 Definitions of BUFR descriptor Element Names
   5.12 Definition of a common BUFR template for both AWS

6 RECOMMENDATIONS TO BE SUBMITTED TO CBS-XIII

7 FUTURE WORK PLAN

8 CLOSURE OF THE SESSION
Proposal for the standard set of metadata elements for AWS installations

A metadata database should provide detailed information necessary for users to gain adequate background knowledge about the station and observational data, together with updates due to changes that occur.

Major database elements include the following:

- Network information (beyond a scope of this document);
- Station information;
- Individual instrument information;
- Data processing information;
- Data handling information;
- Data transmission information.

1 Station information

There is a great deal of information related to a station’s location, local topography and others. Basic station metadata include:

- Station name and station index number(s);
- Geographical co-ordinates;
- Elevation above mean sea level;
- Types of soil, physical constants and profile of soil;
- Types of vegetation and condition;
- Local topography description;
- Type of AWS, manufacturer, model, serial number;
- Observing programme of the station: parameters measured, reference time, times at which observations/measurements are made and reported;
- The datum level to which atmospheric pressure data of the station refer.

2 Individual instrument information

(Information related to sensors installed at the station, including recommended, scheduled and performed maintenance and calibration)

Relevant metadata should be:

- Sensor type, manufacturer, model, serial number;
- Principle of operation; method of measurement/observation; type of detection system;
- Performance characteristics;
- Unit of measurement, measuring range;
- Resolution, accuracy (uncertainty), time constant, time resolution, output averaging time;
- Siting and exposure: location, shielding, height above ground (or level of depth);
- Data acquisition: sampling interval, averaging interval and type;
- Correction procedures;
- Calibration data and time of calibration;
- Preventive and corrective maintenance: recommended/scheduled maintenance and calibration procedures, including frequency, procedure description;
Results of comparison with travelling standard.

3 Data processing information
For each individual meteorological element, metadata related to processing procedures include:
- Measuring/observing programme: time of observations, reporting frequency, data output;
- Data-processing method/procedure/algorithm;
- Formula to calculate the element;
- Mode of observation/measurement;
- Processing interval;
- Reported resolution;
- Input source (instrument, element, etc.);
- Constants and parameter values.

4 Data handling information
Metadata elements of interest include:
- Quality control procedures/algorithms;
- QC flags definition;
- Constants and parameter values;
- Processing and storage procedures;

5 Data transmission information
The transmission-related metadata of interest are:
- Method of transmission;
- Data format;
- Transmission time;
- Transmission frequency.
Proposal for reporting both nominal and instrument values in BUFR/CREX

1 Nominal value indicator

A new descriptor in the Class 8 is proposed as a nominal value indicator (Level II data indicator):

0 08 083 Nominal value indicator, Flag table, 0, 0, 15

<table>
<thead>
<tr>
<th>Bit No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Adjusted with respect to representative height of sensor above local ground (or deck of marine platform)</td>
</tr>
<tr>
<td>2</td>
<td>Adjusted with respect to representative height of sensor above water surface</td>
</tr>
<tr>
<td>3</td>
<td>Adjusted with respect to standard surface roughness</td>
</tr>
<tr>
<td>4</td>
<td>Adjusted with respect to wind speed</td>
</tr>
<tr>
<td>5</td>
<td>Adjusted with respect to temperature</td>
</tr>
<tr>
<td>6</td>
<td>Adjusted with respect to pressure</td>
</tr>
<tr>
<td>7</td>
<td>Adjusted with respect to humidity</td>
</tr>
<tr>
<td>8</td>
<td>Adjusted with respect to evaporation</td>
</tr>
<tr>
<td>9</td>
<td>Adjusted with respect to wetting losses</td>
</tr>
<tr>
<td>10-14</td>
<td>Reserved</td>
</tr>
<tr>
<td>All 15</td>
<td>Missing value</td>
</tr>
</tbody>
</table>

Note: The term correction is not suitable to use as all measured values are corrected first (e.g. calibration correction, etc.).

The above-proposed descriptor will allow reporting of Level II data (meteorological parameters, i.e. nominal values) in addition to Level I data (instrument values) in BUFR templates for surface observation data, especially for data from automatic weather stations.

In some cases, the WMO recommendations require adjustment of Level I data with respect to more than one aspect. The descriptor 0 08 083 will allow to indicate whether the instrument value has been adjusted with respect to all required aspects or only with respect to some of them or not at all.

Exhaustive validation of this descriptor, as well as a way of unambiguous reporting of Level II data, would be desirable. It is also to be considered that insertion of nominal values will increase volume of the data substantially.

Representation of nominal values using the nominal value indicator 0 08 083 in BUFR templates can be realized in several ways. One of the possibilities requires introducing two new descriptors: one for a representative height of a sensor above local ground (or deck of marine platform) and one for a representative height of a sensor above water surface, as described below.

2 Representative height of a sensor above local ground (or deck of marine platform)

In BUFR templates, some meteorological elements are preceded by the descriptor 0 07 032 to indicate the actual height above local ground (or deck of marine platform) at which the element is measured. Nominal values of these elements are proposed to be preceded by a descriptor from Class 7 which would indicate the standard (representative) height of the sensor above local ground (or deck of marine platform) required by WMO documentation. If bit No.1 of 0 08 083 (nominal value indicator) is set to 1, the following value of the meteorological element is adjusted (recalculated) to this standard (representative) height of the sensor above local ground (or deck of marine platform).

The standard (representative) height of a sensor above local ground is (or will be) defined in the WMO documentation, e.g. the standard height for wind sensor is 10 m.

Therefore, a new descriptor in Class 7 is proposed:

<table>
<thead>
<tr>
<th>F X Y</th>
<th>Element name</th>
<th>BUFR</th>
<th>CREX</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 07 065</td>
<td>Representative height of a sensor above local ground (or deck of marine platform)</td>
<td>m</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>m</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
with a note:
The representative height of a sensor above local ground (or deck of marine platform) is the standard height of the sensor required by WMO documentation. A value of the following meteorological element should be adjusted using a formula (or a recommended procedure for obtaining nominal values). For example, a standard height recommended in WMO documentation for a surface wind sensor is 10 m. If the sensor is placed at the different height, the wind speed should be adjusted using a formula (or a recommended procedure for obtaining nominal values).

3 Representative height of a sensor above water surface

In BUFR templates, some meteorological elements are preceded by the descriptor 0 07 033 to indicate the actual height above water surface at which the element is measured. Nominal values of these elements are proposed to be preceded by a descriptor from Class 7, which would indicate the standard height of the sensor above water surface required by WMO documentation. If bit No. 2 of 0 08 083 (nominal value indicator) is set to 1, the following value of the meteorological element shall be recalculated (adjusted) to this standard height of the sensor above water surface. Therefore, a new descriptor in Class 7 is proposed:

<table>
<thead>
<tr>
<th>F</th>
<th>X</th>
<th>Y</th>
<th>Element name</th>
<th>BUFR</th>
<th>CREX</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>07</td>
<td>066</td>
<td>Representative height of a sensor above water surface</td>
<td>m</td>
<td>1 0 12</td>
</tr>
</tbody>
</table>

with a note:
The representative height of a sensor above water surface is the standard height of the sensor required by WMO documentation. A value of the following meteorological element should be adjusted using a formula (or a recommended procedure for obtaining nominal values).
Proposal for Guidelines on Quality Control Procedures for Data from Automatic Weather Stations

INTRODUCTION

There are two levels of the real-time quality control of AWS data:

- **QC of raw data (signal measurements)**: It is basic QC, performed at an AWS site. This QC level is relevant during acquisition of Level I data and should eliminate errors of technical devices, including sensors, measurement errors (systematic or random), errors inherent in measurement procedures and methods. QC at this stage includes a gross error check, basic time checks, and internal consistency checks.

- **QC of processed data**: It is extended QC, partly performed at an AWS site, but mainly at a Data Processing Centre. This QC level is relevant during the reduction and conversion of Level I data into Level II data and Level II data themselves. It deals with comprehensive checking of temporal and internal consistency, evaluation of biases and long-term drifts of sensors and modules, malfunction of sensors, etc.

Comprehensive documentation on QC procedures applied, including the specification of basic data processing procedures for a calculation of instantaneous (i.e. one minute) data and sums should be a part of AWS’ standard documentation.

A set of guidelines deals only with QC of data from a single AWS, therefore spatial QC is beyond the scope of the document. The same is also true in case of checks against analyzed or predicted fields. Furthermore, QC of formatting, transmission and decoding errors is beyond the scope of the document due to a specific character of these processes, as they are dependent on the type of a message used and a way of its transmission.

**Notes:**

Recommendations provided in guidelines have to be used in conjunction with the relevant WMO documentation dealing with data QC:

1. Basic characteristics of the quality control and general principles to be followed within the framework of the GOS are very briefly described in the Manual of GOS, WMO-No. 544. QC levels, aspects, stages and methods are described in the Guide on GOS, WMO-No. 488.

2. Basic steps of QC of AWS data are given in the Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8, especially in Part II, Chapter 1.

3. Details of QC procedures and methods that have to be applied to meteorological data intended for international exchange are described in Guide on GDPS, WMO-No. 305, Chapter 6.


CHAPTER I DEFINITIONS AND ABBREVIATIONS

**Quality control, quality assurance**

**Quality control**: The operational techniques and activities that are used to fulfill requirements for quality.

The primary purpose of quality control of observational data is missing data detection, error detection and possible error corrections in order to ensure the highest possible reasonable standard of accuracy for the optimum use of these data by all possible users.

To ensure this purpose (the quality of AWS data), a well-designed quality control system is vital. Effort shall be made to correct all erroneous data and validate suspicious data detected by QC procedures. The quality of AWS data shall be known.
**Quality assurance:** All the planned and systematic activities implemented within the quality system, and demonstrated as needed, to provide adequate confidence that an entity will fulfill requirements for quality.

The primary objective of the quality assurance system is to ensure that data are consistent, meet the data quality objectives and are supported by comprehensive description of methodology.

Note: Quality assurance and quality control are two terms that have many interpretations because of the multiple definitions for the words "assurance" and "control."

(For a detailed discussion on the multiple definitions, see ANSI/ISO/ASQ A3534-2, Statistics-Vocabulary and Symbols - Statistical Quality Control, www.asq.org)

**Types of errors**

**Random errors** are distributed more or less symmetrically around zero and do not depend on the measured value. Random errors sometimes result in overestimation and sometimes in underestimation of the actual value. On average, the errors cancel each other out.

**Systematic errors** on the other hand, are distributed asymmetrically around zero. On average these errors tend to bias the measured value either above or below the actual value. One reason of random errors is a long-term drift of sensors.

**Large (rough) errors** are caused by malfunctioning of measurement devices or by mistakes made during data processing; errors are easily detected by checks.

**Micrometeorological (representativeness) errors** are the result of small-scale perturbations or weather systems affecting a weather observation. These systems are not completely observable by the observing system due to the temporal or spatial resolution of the observing system. Nevertheless when such a phenomenon occurs during a routine observation, the results may look strange compared to surrounding observations taking place at the same time.

**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWS</td>
<td>Automatic Weather Station</td>
</tr>
<tr>
<td>B-QC</td>
<td>Basic Quality Control</td>
</tr>
<tr>
<td>BUFR</td>
<td>Binary Universal Form of the Representation</td>
</tr>
<tr>
<td>DPC</td>
<td>Data Processing Centre</td>
</tr>
<tr>
<td>E-QC</td>
<td>Extended Quality Control</td>
</tr>
<tr>
<td>GDPS</td>
<td>Global Data-Processing System</td>
</tr>
<tr>
<td>QA</td>
<td>Quality assurance</td>
</tr>
<tr>
<td>QC</td>
<td>Quality control</td>
</tr>
</tbody>
</table>

**CHAPTER II  BASIC QUALITY CONTROL PROCEDURES**

Automatic data validity checking (basic quality control procedures) shall be applied at an AWS to monitor the quality of sensors' data prior to their use in computation of weather parameter values. This basic QC is designed to remove erroneous sensor information while retaining valid sensor data. In modern automatic data acquisition systems, the high sampling rate of measurements and the possible generation of noise necessitate checking of data at the level of samples as well as at the level of instantaneous data (generally one-minute data). B-QC procedures shall be applied (performed) at each stage of the conversion of raw sensor outputs into meteorological parameters. The range of B-QC strongly depends on the capacity of AWS' processing unit. The outputs of B-QC would be included inside every AWS BUFR message.

The types of B-QC procedures are as follows:

- **Automatic QC of raw data (sensor samples)** intended primarily to indicate any sensor malfunction, instability, interference in order to reduce potential corruption of processed data; the values that fail this QC level are not used in further data processing.
• **Automatic QC of processed data** intended to identify erroneous or anomalous data. The range of this control depends on the sensors used.

All AWS data should be flagged using appropriate QC flags. At B-QC five data QC categories are enough:

- good (accurate; data with errors less than or equal to a specified value);
- inconsistent (one or more parameters are inconsistent);
- doubtful (suspect);
- erroneous (wrong; data with errors exceeding a specified value);
- missing data.

It is essential that data quality is known and demonstrable; data must pass all checks in the framework of B-QC. In case of inconsistent, doubtful and erroneous data, additional information should be transmitted; in case of missing data the reason of missing should be transmitted. In case of BUFR messages, BUFR descriptor 0 33 005 (Quality Information AWS data) and 0 33 020 (Quality control indication of following value) can be used.

### I. Automatic QC of raw data

#### a) Plausible value check (the gross error check on measured values)

The aim of the check is to verify if the values are within the acceptable range limits. Each sample shall be examined if its value lies within the measurement range of a pertinent sensor. If the value fails the check it is rejected and not used in further computation of a relevant parameter.

#### b) Check on a plausible rate of change (the time consistency check on measured values)

The aim of the check is to verify the rate of change (unrealistic jumps in values). The check is best applicable to data of high temporal resolution (a high sampling rate) as the correlation between the adjacent samples increases with the sampling rate.

After each signal measurement the current sample shall be compared to the preceding one. If the difference of these two samples is more than the specified limit then the current sample is identified as suspect and not used for the computation of an average. However, it is still used for checking the temporal consistency of samples. It means that the new sample is still checked with the suspect one. The result of this procedure is that in case of large noise, one or two successive samples are not used for the computation of the average. In case of sampling frequency six samples per minute (a sampling interval 10 seconds), the limits of time variance of the samples implemented at AWS can be as follows:

- Air temperature: 2 °C;
- Dew point temperature: 2 °C;
- Ground and soil temperature: 2 °C;
- Relative humidity: 5 %;
- Atmospheric pressure: 0.3 hPa;
- Wind speed: 20 ms⁻¹;
- Solar radiation (irradiance) : 800 Wm⁻².

There should be at least 66% (2/3) of the samples available to compute an instantaneous (one-minute) value; in case of the wind direction and speed at least 75 % of the samples to compute a 2- or 10-minute average. If less than 66% of the samples are available in one minute, the current value fails the QC criterion and is not used in further computation of a relevant parameter; the value should be flagged as missing.

### II. Automatic QC of processed data

#### a) Plausible value check

The aim of the check is to verify if the values of instantaneous data (one-minute average or sum; in case of wind 2- and 10-minute averages) are within acceptable range limits. Limits of different
meteorological parameters depend on the climatological conditions of AWS' site and on a season. At this stage of QC they can be independent of them and they can be set as broad and general. Possible fixed-limit values implemented at an AWS can be as follows:

- Air temperature: -80 °C – +60 °C;
- Dew point temperature: -80 °C – 35 °C;
- Ground temperature: -80 °C – +80 °C;
- Soil temperature: -50 °C – +50 °C;
- Relative humidity: 0 – 100 %;
- Atmospheric pressure at the station level: 500 – 1100 hPa;
- Wind direction: 0 – 360 degrees;
- Wind speed: 0 – 75 ms⁻¹ (2-minute, 10-minute average);
- Solar radiation (irradiance): 0 – 1600 Wm⁻²;
- Precipitation amount (1 minute interval): 0 – 40 mm.

If the value is outside the acceptable range limit it should be flagged as erroneous.

b) Time consistency check

The aim of the check is to verify the rate of change of instantaneous data (detection of unrealistic jumps in values or ‘dead band’ caused by blocked sensors).

- **Check on a maximum allowed variability of an instantaneous value (a step test):** if the current instantaneous value differs from the prior one by more than a specific limit (step), then the current instantaneous value fails the check and it should be flagged as doubtful (suspect). Possible limits of a maximum variability can be as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit for suspect</th>
<th>Limit for erroneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature:</td>
<td>3 °C</td>
<td></td>
</tr>
<tr>
<td>Dew point temperature:</td>
<td>2 °C or 3°C²</td>
<td>4°C</td>
</tr>
<tr>
<td>Ground temperature:</td>
<td>5 °C</td>
<td>10°C</td>
</tr>
<tr>
<td>Soil temperature 5 cm:</td>
<td>0.5°C</td>
<td>1°C</td>
</tr>
<tr>
<td>Soil temperature 10 cm:</td>
<td>0.5°C</td>
<td>1°C</td>
</tr>
<tr>
<td>Soil temperature 20 cm:</td>
<td>0.5°C</td>
<td>1°C</td>
</tr>
<tr>
<td>Soil temperature 50 cm:</td>
<td>0.3°C</td>
<td>0.5°C</td>
</tr>
<tr>
<td>Soil temperature 100 cm:</td>
<td>0.1°C</td>
<td>0.2°C</td>
</tr>
<tr>
<td>Relative humidity:</td>
<td>10 %</td>
<td>15%</td>
</tr>
<tr>
<td>Atmospheric pressure:</td>
<td>0.5 hPa</td>
<td>2 hPa</td>
</tr>
<tr>
<td>Wind speed (2-minute average)</td>
<td>10 ms⁻¹</td>
<td>20 ms⁻¹</td>
</tr>
<tr>
<td>Solar radiation (irradiance):</td>
<td>800 Wm⁻²</td>
<td>1000 Wm⁻²</td>
</tr>
</tbody>
</table>

¹ In extreme meteorological circumstances, unusual variability may occur. In such circumstances, data may be flagged as suspect, though being correct.

² If dew point temperature is directly measured by a sensor, a 2°C limit is to be used. If dew point is calculated from measurements of air temperature and relative humidity, a larger limit of 4°C is recommended, to take into account the influence of the screen protecting the thermometer and hygrometer. A screen usually has different 'system response time' for air temperature and water vapour, and the combination of these two parameters may generate fast variations of dew point temperature, which are not representative of a sensor default, but are representative of the influence of the screen during fast variations of air temperature and relative humidity.
Another possibility is to compare the difference between the current instantaneous value with the previous and the following (next) ones. If the following condition is not fulfilled then the current instantaneous value fails the check.

The algorithm used is as follows: \[ |V_i - V_{i-1}| + |V_i - V_{i+1}| \leq 4 \cdot \sigma_V \],

where:

- \( V_i \) is the current value of the parameter,
- \( V_{i-1} \) is the previous value of the parameter,
- \( V_{i+1} \) is the next value of the parameter,
- \( \sigma_V \) is the standard deviation of the parameter calculated at least from the last 10-minute period.

If the previous value or the next one is missing, the corresponding part of the formula is omitted and the comparison term is \( 2 \cdot \sigma_V \).

- **Check on a minimum required variability of instantaneous values** during a certain period (a persistence test), once the measurement of the parameter has been done for at least 60 minutes. If the one-minute values do not vary over the past 60/120/240 minutes by more than the specified limit (a threshold value) then the current one-minute value fails the check. Possible limits of minimum required variability can be as follows:
  - Air temperature: 0.1°C over the past 60 minutes;
  - Dew point temperature: 0.1°C over the past 60 minutes;
  - Ground temperature: 0.1°C over the past 60 minutes\(^3\);
  - Soil temperature may be very stable, so there is no minimum required variability.
  - Relative humidity: 1% over the past 60 minutes\(^4\);
  - Atmospheric pressure: 0.1 hPa over the past 60 minutes;
  - Wind speed: 0.5 m.s\(^{-1}\) over the past 60 minutes\(^5\).

If the value fails the time consistency checks it should be flagged as doubtful (suspect).

A calculation of a **standard deviation** of basic variables such as temperature, pressure, humidity, wind at least for the last one-hour period is highly recommended. If the standard deviation of the parameter is below an acceptable minimum, all data from the period should be flagged as suspect. In combination with the persistence test, the standard deviation is a very good tool for detection of a blocked sensor as well as a long-term sensor drift.

c) **Internal consistency check**

The basic algorithms used for checking internal consistency of data are based on the relation between two parameters (the following conditions shall be true):

- dew point temperature \( \leq \) air temperature;
- wind speed = 00 and wind direction = 00;
- wind speed \( \neq \) 00 and wind direction \( \neq \) 00;
- wind gust (speed) \( \geq \) wind speed;

\(^3\) Only if ground temperature is not in the interval \([-0.1°C, +0.1°C]\) (This interval rather than 0°C, to take into account the measurement uncertainty). Melting snow can generate isothermy, during which the limit should be 0°C.

\(^4\) Only if the measurement relative humidity is less than 95%, to take into account the measurement uncertainty.

\(^5\) Only if 10-minute average wind speed during the period is larger than 0.1 m.s\(^{-1}\).

\(^6\) Only if 10-minute average wind speed during the period is larger than 0.1 m.s\(^{-1}\).
• both elements are suspect\(^1\) if total cloud cover = 0 and amount of precipitation > 0\(^7\);
• both elements are suspect\(^1\) if total cloud cover = 0 and precipitation duration > 0\(^8\);
• both elements are suspect\(^1\) if total cloud cover = 8 and sunshine duration > 0;
• both elements are suspect\(^1\) if sunshine duration > 0 and solar radiation = 0;
• both elements are suspect\(^1\) if solar radiation > 500 Wm\(^{-2}\) and sunshine duration = 0;
• both elements are suspect\(^1\) if amount of precipitation > 0 and precipitation duration = 0;
• both elements are suspect\(^1\) if precipitation duration > 0 and weather phenomenon is different from precipitation type;

\(^1\): possible used only for data from a period not longer than 10 minutes.

If the value fails the internal consistency checks it should be flagged as inconsistent.

A technical monitoring of all crucial parts of AWS including all sensors is an inseparable part of the QA system. It provides information on quality of data through the technical status of the instrument and information on the internal measurement status. Corresponding information should be exchanged together with measured data; in case of BUFR messages it can be done by using BUFR descriptor 0 33 006 – Internal measurement status (AWS).

CHAPTER III EXTENDED QUALITY CONTROL PROCEDURES

Extended Quality Control procedures should be applied at the national Data Processing Centre. The checks that had already been performed at the AWS site should be repeated at DPC but in more elaborate form. This should include comprehensive checks against physical and climatological limits, time consistency checks for a longer measurement period, checks on logical relations among a number of variables (internal consistency of data), statistical methods to analyze data, etc.

Suggested limit values (gross-error limit checks) for surface wind speed, air temperature, dew point temperature, and station pressure are presented in the Guide on GDPS, WMO-No. 305. The limits can be adjusted on the basis of improved climatological statistics and experience. Besides that, the Guide on GDPS also presents internal consistency checks for surface data, where different parameters in a SYNOP report are checked against each other. In case of BUFR reports for AWS data the relevant checking algorithms have to be redefined using corresponding BUFR descriptors and code/flag tables.

Internal consistency checks of data

The different parameters in the AWS BUFR N-minute data report (N ≤ 10 minutes) 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. The symbolic names of parameters with the corresponding BUFR descriptors used in the algorithms are explained in the table below.

(a) Wind direction and wind speed

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) Air temperature and dew point temperature

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

---

\(^7\) Or greater than the minimum resolution of the rain gauge, to take into account the deposition of water by dew, etc.

\(^8\) But snow pellets can occur with cloud cover = 0
- dew point temperature > air temperature;
- air temperature - dew point temperature > 5°C and obscuration is from \{1, 2, 3\};

(c) **Air temperature and present weather**

Both elements are considered suspect when:
- air temperature > +5°C and precipitation type is from \{6, …, 12\};
- air temperature < -2°C and precipitation type is from \{2\};
- air temperature > +3°C and precipitation type is from \{3\};
- air temperature < -10°C and precipitation type is from \{3\};
- air temperature > +3°C and obscuration is from \{2\} or
  (obscuration is from \{1\} and character of obscuration 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 > 1 000 m;
- obscuration is from \{7, 8, 9, 11, 12, 13\} and visibility > 10 000 m;
- visibility < 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 < 1 000 m;
- visibility > 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:
- total cloud cover = 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:
- total cloud cover = 0 and amount of precipitation > 0\(^9\);

(h) **Cloud information and duration of precipitation**

Clouds and duration of precipitation are considered suspect when:
- total cloud cover = 0 and precipitation duration > 0;

(i) **Duration of precipitation and other precipitation information**

Precipitation data are considered suspect when:
- amount of precipitation > 0 and precipitation duration = 0;

\(^9\) Or greater than the minimum resolution of the rain gauge, to take into account the deposition of water by dew, etc.
(j) **Cloud information and sunshine duration**

Clouds and sunshine duration are considered suspect when:

- total cloud cover = 100% and sunshine duration > 0;

For each check, if the checked values fail the internal consistency checks, they should be flagged as suspect or erroneous (depending on the check) and inconsistent.

The symbolic name and the corresponding BUFR descriptor (as reference) used in QC algorithms:

(a) – (i):

<table>
<thead>
<tr>
<th>Symbolic name</th>
<th>BUFR Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind direction</td>
<td>0 11 001</td>
</tr>
<tr>
<td>Wind speed</td>
<td>0 11 002</td>
</tr>
<tr>
<td>Wind gust (speed)</td>
<td>0 11 041</td>
</tr>
<tr>
<td>Air temperature</td>
<td>0 12 101</td>
</tr>
<tr>
<td>Dew point temperature</td>
<td>0 12 103</td>
</tr>
<tr>
<td>Total cloud cover</td>
<td>0 20 010</td>
</tr>
<tr>
<td>Visibility</td>
<td>0 20 001</td>
</tr>
<tr>
<td>Precipitation type</td>
<td>0 20 021</td>
</tr>
<tr>
<td>Precipitation character</td>
<td>0 20 022</td>
</tr>
<tr>
<td>Precipitation duration</td>
<td>0 26 020</td>
</tr>
<tr>
<td>Weather phenomenon</td>
<td>0 20 023</td>
</tr>
<tr>
<td>Obscuration</td>
<td>0 20 025</td>
</tr>
<tr>
<td>Character of obscuration</td>
<td>0 20 026</td>
</tr>
<tr>
<td>Amount of precipitation</td>
<td>0 13 011</td>
</tr>
<tr>
<td>Sunshine duration</td>
<td>0 14 031</td>
</tr>
</tbody>
</table>

For 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. Therefore data, passing through QC, should be flagged. The output of the quality control system should include QC flags that indicate whether the measurement passed or failed, as well as a set of summary statements about the sensors.

Every effort has to be made to fill data gaps, correct all erroneous values and validate doubtful data detected by QC procedures at the Data Processing Centre choosing appropriate procedures.

**References**

8 Automated Surface Observing System (ASOS) User’s Guide
   www.nws.noaa.gov/asos/aum-toc.pdf
9 The Impact of Unique Meteorological Phenomena Detected by the Oklahoma Mesonet and
ARS Micronet on Automated Quality Control, Fiebrich, C.A., Crawford, K.C., 2001, Bulletin of
the American Meteorological Society, Vol. 82, No. 10.
   http://hprcc.unl.edu/aws/publications.htm
10 Quality Control of Meteorological Observations, Automatic Methods Used in the Nordic
Moe, Lars Andresen, Eino Hellsten, Pauli Rissanen, Þóranna Pálsdóttir, Þordur Arason
   http://www.smhi.se/hfa_coord/nordklim/
### Basic set of variables to be reported by the standard AWS for multiple users

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Pressure</td>
<td>M A</td>
<td>M A</td>
<td>X¹)</td>
<td>X</td>
<td>A</td>
</tr>
<tr>
<td>Pressure tendency &amp; characteristics</td>
<td>[M]</td>
<td>M</td>
<td></td>
<td>[A]</td>
<td></td>
</tr>
<tr>
<td>Air temperature</td>
<td>M²) A</td>
<td>M A</td>
<td>X</td>
<td>X³)</td>
<td>A</td>
</tr>
<tr>
<td>Humidity</td>
<td>M A</td>
<td>M</td>
<td>X⁴)</td>
<td>X</td>
<td>A</td>
</tr>
<tr>
<td>Surface wind</td>
<td>M A</td>
<td>M A</td>
<td>X</td>
<td>X</td>
<td>A</td>
</tr>
<tr>
<td>Cloud Amount and Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud-base</td>
<td>M [A]</td>
<td>M</td>
<td>X</td>
<td>X</td>
<td>A</td>
</tr>
<tr>
<td>Direction of Cloud movement</td>
<td>[M]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather, Present &amp; Past</td>
<td>M</td>
<td>M</td>
<td>X</td>
<td>X</td>
<td>A</td>
</tr>
<tr>
<td>State of de Ground</td>
<td>[M]</td>
<td>n/a</td>
<td>X⁷)</td>
<td></td>
<td>[A]</td>
</tr>
<tr>
<td>Special Phenomena</td>
<td>[M] [A]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visibility</td>
<td>M [A]</td>
<td>M</td>
<td>X</td>
<td>X</td>
<td>A</td>
</tr>
<tr>
<td>Amount of Precipitation</td>
<td>[M] [A]</td>
<td>[A]</td>
<td>X</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Precipitation Yes/No</td>
<td>A</td>
<td>[A]</td>
<td>X</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Intensity of precipitation</td>
<td>[A]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil temperature</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Sunshine and/or Solar radiation</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Waves</td>
<td>M [A]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea temperature</td>
<td></td>
<td></td>
<td></td>
<td>M A</td>
<td></td>
</tr>
</tbody>
</table>

**Explanation**
- **M** = Required for manned stations
- **[M]** = Based on a regional resolution
- **A** = Required for automatic stations
- **[A]** = Optional for automatic stations
- **X** = Required

**Notes:**
- 1) Also QNH & QFE
- 2) Optional: extreme temperatures
- 3) Inclusive extreme temperatures
- 4) Dewpoint temperature
- 5) Dewpoint temperature and/or RH and air temperature
- 6) wind speed and direction
- 7) snow cover
Proposal for amendments of
the Guide to Meteorological Instruments and Methods of Observation
(WMO-No.8)

PART II, Chapter 1
1.1.4 Types of automatic weather stations
Both types of stations can optionally be set up with means both for manual entry and for editing of visual or objective subjective observations which cannot yet be made fully automatically. This includes present and past weather or observations which involve high costs, such as cloud height and visibility. Such a station could be described as partially or semi-automated.

1.3.2.6 Data reduction
Although these variables or quantities could also be computed at a central network processing system where more processing power is normally available, AWS operational real-time constraints, limited data storage capacity, and local display requirements often require these variables to be calculated in the AWS. These variables or quantities can be computed at an AWS or at a central network processing system where more processing power is normally available.

1.3.2.8 Quality control
Quality control already starts with a careful design, selection, and test of the prototype AWS before acquiring, installing, and operating an AWS network. Considerable errors can be avoided by proper siting and exposure of the AWS. To ensure good quality data, the establishment and use of good maintenance, repair, and calibration procedures and facilities are absolutely necessary. There is as yet no general agreement upon what quality control routines should be used for measurements of specific variables. Indeed, since the quality control requirements are to some extent a function of the sensor performance and environmental conditions, it may not be possible to reach such general agreements. However any specification for an AWS should state explicitly a minimum set of quality control procedures to be used. Quality Control achieves assured quality and consistency of data output. It is achieved through a carefully designed set of procedures focused on good maintenance practices, repair, calibration, and data quality checks. Currently, there is no agreed upon set of procedures or standards for the various AWS platforms. Such a set of procedures should be developed and documented.

PART III, Chapter 3
3.3.3 Data centres
AWSs in particular require careful attention at data centres because the on-station quality control systems lack the flexibility and perhaps the reliability of manual operations.
## Functional Specifications for Automatic Weather Stations

<table>
<thead>
<tr>
<th>VARIABLE 1)</th>
<th>Maximum Effective Range 2)</th>
<th>Minimum Reported Resolution 3)</th>
<th>Mode of Observation 4)</th>
<th>BUFR / CREX 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ATMOSPHERIC PRESSURE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td>500 – 1080 hPa</td>
<td>10 Pa</td>
<td>I, V</td>
<td>0 10 004</td>
</tr>
<tr>
<td><strong>TEMPERATURE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient air temperature (over specified surface)</td>
<td>-80 °C – +60 °C</td>
<td>0.1 K</td>
<td>I, V</td>
<td>0 12 101</td>
</tr>
<tr>
<td>Dew-point temperature</td>
<td>-80 °C – +60 °C</td>
<td>0.1 K</td>
<td>I, V</td>
<td>0 12 103</td>
</tr>
<tr>
<td>Ground (surface) temperature (over specified surface)</td>
<td>-80 °C – +80 °C</td>
<td>0.1 K</td>
<td>I, V</td>
<td>0 12 113</td>
</tr>
<tr>
<td>Soil temperature</td>
<td>-50 °C – +50 °C</td>
<td>0.1 K</td>
<td>I, V</td>
<td>0 12 130</td>
</tr>
<tr>
<td>Snow temperature</td>
<td>-80 °C – 0 °C</td>
<td>0.1 K</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Water temperature - river, lake, sea, well</td>
<td>-2 °C – +100 °C</td>
<td>0.1 K</td>
<td>I, V</td>
<td>0 13 082</td>
</tr>
<tr>
<td><strong>HUMIDITY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative humidity</td>
<td>0 – 100%</td>
<td>1%</td>
<td>I, V</td>
<td>0 13 003</td>
</tr>
<tr>
<td>Mass mixing ratio</td>
<td>0 – 100%</td>
<td>1%</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Soil moisture, volumetric or water potential</td>
<td>0 – 10^3 g kg(^{-1})</td>
<td>1 g kg(^{-1})</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Water vapour pressure</td>
<td>0 – 1000 hPa</td>
<td>10 Pa</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Evaporation / evapotranspiration</td>
<td>0 – 0.1 m</td>
<td>0.1 kg m(^{-2}); 0.0001 m</td>
<td>T</td>
<td>0 13 033</td>
</tr>
<tr>
<td>Object wetness duration</td>
<td>0 – 86 400 s</td>
<td>1 s</td>
<td>T</td>
<td>N</td>
</tr>
<tr>
<td><strong>WIND</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direction</td>
<td>0 – 360 degrees</td>
<td>1 degree</td>
<td>I, V</td>
<td>0 11 001</td>
</tr>
<tr>
<td>Speed</td>
<td>0 – 75 m s(^{-1})</td>
<td>0.1 m s(^{-1})</td>
<td>I, V</td>
<td>0 11 002</td>
</tr>
<tr>
<td>Gust Speed</td>
<td>0 – 150 m s(^{-1})</td>
<td>0.1 m s(^{-1})</td>
<td>I, V</td>
<td>0 11 041</td>
</tr>
<tr>
<td>X,Y,Z component of wind vector (horizontal and vertical profile)</td>
<td>0 – 150 m s(^{-1})</td>
<td>0.1 m s(^{-1})</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Turbulence type (Low levels and wake vortex)</td>
<td>up to 15 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Turbulence intensity</td>
<td>up to 15 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td><strong>RADIATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunshine duration</td>
<td>0 – 86 400 s</td>
<td>60 s</td>
<td>T</td>
<td>0 14 031</td>
</tr>
<tr>
<td>Background luminance</td>
<td>1·10(^{-6}) – 2·10(^{4}) Cd m(^{-2})</td>
<td>1·10(^{-6}) Cd m(^{-2})</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Global downward solar radiation</td>
<td>0 – 6·10(^{6}) J m(^{-2})</td>
<td>1 J m(^{-2})</td>
<td>I, T, V</td>
<td>N</td>
</tr>
<tr>
<td>Global upward solar radiation</td>
<td>0 – 4·10(^{6}) J m(^{-2})</td>
<td>1 J m(^{-2})</td>
<td>I, T, V</td>
<td>N</td>
</tr>
<tr>
<td>Diffuse solar radiation</td>
<td>0 – 4·10(^{6}) J m(^{-2})</td>
<td>1 J m(^{-2})</td>
<td>I, T, V</td>
<td>0 14 023</td>
</tr>
<tr>
<td>Direct solar radiation</td>
<td>0 – 5·10(^{6}) J m(^{-2})</td>
<td>1 J m(^{-2})</td>
<td>I, T, V</td>
<td>0 14 025</td>
</tr>
<tr>
<td>Downward long-wave radiation</td>
<td>0 – 3·10(^{6}) J m(^{-2})</td>
<td>1 J m(^{-2})</td>
<td>I, T, V</td>
<td>0 14 002</td>
</tr>
<tr>
<td>Upward long-wave radiation</td>
<td>0 – 3·10(^{6}) J m(^{-2})</td>
<td>1 J m(^{-2})</td>
<td>I, T, V</td>
<td>0 14 002</td>
</tr>
<tr>
<td>Net radiation</td>
<td>0 – 6·10(^{6}) J m(^{-2})</td>
<td>1 J m(^{-2})</td>
<td>I, T, V</td>
<td>0 14 016</td>
</tr>
<tr>
<td>UV-B radiation</td>
<td>0 – 1·2·10(^{3}) J m(^{-2})</td>
<td>1 J m(^{-2})</td>
<td>I, T, V</td>
<td>N</td>
</tr>
<tr>
<td>Photosynthetically active radiation</td>
<td>0 – 3·10(^{6}) J m(^{-2})</td>
<td>1 J m(^{-2})</td>
<td>I, T, V</td>
<td>N</td>
</tr>
<tr>
<td>Surface albedo</td>
<td>1 – 100%</td>
<td>1%</td>
<td>I, V</td>
<td>0 14 019</td>
</tr>
<tr>
<td>VARIABLE ⚡</td>
<td>Maximum Effective Range</td>
<td>Minimum Reported Resolution</td>
<td>Mode of Observation</td>
<td>BUFR / CREX ⚡</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------</td>
<td>-----------------------------</td>
<td>---------------------</td>
<td>----------------</td>
</tr>
<tr>
<td><strong>CLOUDS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud base height</td>
<td>0 – 30 km</td>
<td>10 m</td>
<td>I, V</td>
<td>0 20 013</td>
</tr>
<tr>
<td>Cloud top height</td>
<td>0 – 30 km</td>
<td>10 m</td>
<td>I, V</td>
<td>0 20 014</td>
</tr>
<tr>
<td>Cloud type, convective vs. other types</td>
<td>up to 30 classes</td>
<td>BUFR Table</td>
<td>I</td>
<td>0 20 012</td>
</tr>
<tr>
<td>Cloud hydrometeor concentration</td>
<td>1 – 700 hydrometeors dm⁻³</td>
<td>1 hydrometeor dm⁻³</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Effective radius of cloud hydrometeors</td>
<td>2·10⁻⁵ – 32·10⁻⁵ m</td>
<td>2·10⁻⁵ m</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Cloud liquid water content</td>
<td>1·10⁻⁵–1.4·10⁻² kg m⁻³</td>
<td>1·10⁻⁵ kg m⁻³</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Optical depth within each layer</td>
<td>Not specified yet</td>
<td>Not specified yet</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Optical depth of fog</td>
<td>Not specified yet</td>
<td>Not specified yet</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Height of inversion</td>
<td>0 – 1 000 m</td>
<td>10 m</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td><strong>CLOUD COVER</strong></td>
<td>0 – 100%</td>
<td>1%</td>
<td>I, V</td>
<td>0 20 010</td>
</tr>
<tr>
<td>Cloud amount</td>
<td>0 – 8/8</td>
<td>1/8</td>
<td>I, V</td>
<td>0 20 011</td>
</tr>
<tr>
<td><strong>PRECIPITATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accumulation</td>
<td>0 – 500 mm</td>
<td>0.1 kg m⁻², 0.0001 m</td>
<td>T</td>
<td>0 13 011</td>
</tr>
<tr>
<td>Duration</td>
<td>up to 86 400 s</td>
<td>60 s</td>
<td>T</td>
<td>0 26 020</td>
</tr>
<tr>
<td>Size of precipitating element</td>
<td>1·10⁻³ – 0.5 m</td>
<td>1·10⁻³ m</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Intensity - quantitative</td>
<td>0 – 2000 mm h⁻¹</td>
<td>0.1 kg m² s⁻¹, 0.1 mm h⁻¹</td>
<td>I, V</td>
<td>0 13 055</td>
</tr>
<tr>
<td>Type</td>
<td>up to 30 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>0 20 021</td>
</tr>
<tr>
<td>Rate of ice accretion</td>
<td>0 – 1 kg dm⁻² h⁻¹</td>
<td>1·10⁻³ kg dm⁻² h⁻¹</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td><strong>OBSCURATIONS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obscuration type</td>
<td>up to 30 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>0 20 025</td>
</tr>
<tr>
<td>Hydrometeor type</td>
<td>up to 30 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>0 20 025</td>
</tr>
<tr>
<td>Lithometeor type</td>
<td>up to 30 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>0 20 025</td>
</tr>
<tr>
<td>Hydrometeor radius</td>
<td>2·10⁻⁵ – 32·10⁻⁵ m</td>
<td>2·10⁻⁵ m</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Horizontal - extinction coefficient</td>
<td>0 – 1 m⁻¹</td>
<td>0.001 m⁻¹</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Slant - extinction coefficient</td>
<td>0 – 1 m⁻³</td>
<td>0.001 m⁻¹</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Meteorological Optical Range</td>
<td>1 – 100 000 m</td>
<td>1 m</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td><strong>RUNWAY VISUAL RANGE</strong></td>
<td>1 – 4 000 m</td>
<td>1 m</td>
<td>I, V</td>
<td>0 20 061</td>
</tr>
<tr>
<td>Other weather type</td>
<td>up to 18 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>0 20 023</td>
</tr>
<tr>
<td><strong>LIGHTNING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightning rates of discharge</td>
<td>0 – 100 000</td>
<td>Number h⁻¹</td>
<td>I, V</td>
<td>0 13 059</td>
</tr>
<tr>
<td>Lightning discharge type (cloud to cloud, cloud to surface)</td>
<td>up to 10 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Lightning discharge polarity</td>
<td>2 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Lightning discharge energy</td>
<td>Not specified yet</td>
<td>Not specified yet</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Lightning - distance from station</td>
<td>0 – 3·10⁴ m</td>
<td>10⁵ m</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Lightning - direction from station</td>
<td>1 – 360 degrees</td>
<td>1 degree</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>VARIABLE 1)</td>
<td>Maximum Effective Range 2)</td>
<td>Minimum Reported Resolution 3)</td>
<td>Mode of Observation 4)</td>
<td>BUFR / CREX 5)</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------</td>
<td>-------------------------------</td>
<td>------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>HYDROLOGIC OBSERVATIONS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow discharge - river</td>
<td>$0 - 2.5 \times 10^5 \text{ m}^3 \text{ s}^{-1}$</td>
<td>$0.1 \text{ m}^3 \text{ s}^{-1}$</td>
<td>I, V</td>
<td>0 23 017</td>
</tr>
<tr>
<td>Flow discharge - well</td>
<td>$0 - 50 \text{ m}^3 \text{ s}^{-1}$</td>
<td>$0.001 \text{ m}^3 \text{ s}^{-1}$</td>
<td>I, V</td>
<td>0 23 017</td>
</tr>
<tr>
<td>Ground water level</td>
<td>$0 - 1,800 \text{ m}$</td>
<td>$0.01 \text{ m}$</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Ice surface temperature</td>
<td>$-80 \degree C - +0 \degree C$</td>
<td>$0.5 \text{ K}$</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Ice thickness - river, lake</td>
<td>$0 - 50 \text{ m}$</td>
<td>$0.01 \text{ m}$</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Ice thickness - glacier, sea</td>
<td>$0 - 4,270 \text{ m}$</td>
<td>$1 \text{ m}$</td>
<td>I, V</td>
<td>0 20 031</td>
</tr>
<tr>
<td>Water level</td>
<td>$0 - 100 \text{ m}$</td>
<td>$0.01 \text{ m}$</td>
<td>I, V</td>
<td>0 13 071</td>
</tr>
<tr>
<td>Wave height</td>
<td>$0 - 50 \text{ m}$</td>
<td>$0.1 \text{ m}$</td>
<td>I, V</td>
<td>0 22 021</td>
</tr>
<tr>
<td>Wave period</td>
<td>$0 - 100 \text{ s}$</td>
<td>$1 \text{ s}$</td>
<td>I, V</td>
<td>0 22 011</td>
</tr>
<tr>
<td>Wave direction</td>
<td>$0 - 360 \text{ degrees}$</td>
<td>$1 \text{ degrees}$</td>
<td>I, V</td>
<td>0 22 001</td>
</tr>
<tr>
<td>Sea salinity</td>
<td>$0 - 50 \times 10^{-3} %$</td>
<td>$10^{-3} %$</td>
<td>I, V</td>
<td>0 22 062</td>
</tr>
<tr>
<td>Ice thickness</td>
<td>$0 - 3 \text{ m}$</td>
<td>$0.015 \text{ m}$</td>
<td>T</td>
<td>0 20 031</td>
</tr>
<tr>
<td>Ice mass</td>
<td>$0 - 50 \text{ kg m}^{-1}$</td>
<td>$0.5 \text{ kg m}^{-1}$</td>
<td>T</td>
<td>N</td>
</tr>
<tr>
<td>Snow density (liquid water content)</td>
<td>$100 - 700 \text{ kg m}^{-3}$</td>
<td>$1 \text{ kg m}^{-3}$</td>
<td>T</td>
<td>N</td>
</tr>
<tr>
<td>OTHER SURFACE VARIABLES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Runway conditions</td>
<td>up to 10 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>Braking action/friction coefficient</td>
<td>up to 7 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>N</td>
</tr>
<tr>
<td>State of ground</td>
<td>up to 30 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>0 20 062</td>
</tr>
<tr>
<td>Type of surface specified</td>
<td>up to 15 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>0 08 010</td>
</tr>
<tr>
<td>Snow depth</td>
<td>$0 - 25 \text{ m}$</td>
<td>$0.01 \text{ m}$</td>
<td>T</td>
<td>0 13 013</td>
</tr>
<tr>
<td>OTHER</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma radiation dose</td>
<td>$1 - 10 \text{ nSv h}^{-1}$</td>
<td>$1 \text{ nSv h}^{-1}$</td>
<td>I, T</td>
<td>N</td>
</tr>
<tr>
<td>Categories of stability</td>
<td>9 types</td>
<td>BUFR Table</td>
<td>I, V</td>
<td>0 13 041</td>
</tr>
</tbody>
</table>

**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.
Operational Uncertainty Accuracy\(^1\) Requirements and Typical\(^2\) Instrument Performance

Present values [from the Guide to Meteorological Instruments and Methods of Observations, 6\(^{th}\) 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.

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

\(^1\) The term accuracy is replaced by uncertainty to be in accordance with ISO standards on uncertainty of measurements

\(^2\) To be removed

\(^3\) ± sign should be removed to be in accordance with ISO standards on uncertainty of measurements

\(^4\) n/a = not applicable

\(^5\) Suggestions
<table>
<thead>
<tr>
<th>2. Humidity(^6)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Dew point temperature</td>
<td>-80 – +35 °C (old: -60 – +35 °C)(^7)</td>
<td>0.1 K</td>
<td>I</td>
<td>±0.1 K (old: ±0.5 K)</td>
<td>20 s</td>
<td>1 min</td>
</tr>
<tr>
<td>2.2 Relative humidity</td>
<td>0 – 100 %</td>
<td>1 %</td>
<td>I</td>
<td>±1 % (old: ±3%)</td>
<td>40 s</td>
<td>1 min</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Atmospheric pressure</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Pressure(^9)</td>
<td>500 – 1080 hPa (old: 920 -1080 hPa)</td>
<td>0.1 hPa</td>
<td>I</td>
<td>±0.1 hPa</td>
<td>20 s</td>
<td>1 min</td>
</tr>
<tr>
<td>3.2 Tendency</td>
<td>Not specified</td>
<td>0.1 hPa</td>
<td>I</td>
<td>±0.2 hPa</td>
<td>±0.1 hPa (old:±0.2 hPa)</td>
<td></td>
</tr>
</tbody>
</table>

\(\text{If measured directly. Tending to } \pm0.1 \text{ K when relative humidity}\(^8\) \text{nears saturation.}\)

### 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\(^8\) nears saturation.

### Solid state and others

- 40 s | 1 min | ±1 % (old:± 2– 5 %) | Solid-state sensors may show significant temperature and humidity dependence.

### Range to sea-level\(^{10}\)

- Uncertainty Accuracy seriously affected by dynamic pressure due to wind and temperature coefficient of transducer. Differences between instantaneous values.

---

\(^6\) Note that dewpoint temperature, relative humidity and air-temperature are linked, and thus their uncertainties are linked

\(^7\) Primary standards for dewpoint available for t-dew > -60°C

\(^8\) The string "relative humidity" can be removed

\(^9\) Both station pressure and MSL pressure

\(^{10}\) To be removed (also station pressure involved)
### 4. Clouds

<table>
<thead>
<tr>
<th>4.1 Cloud amount</th>
<th>0 – 8/8</th>
<th>1/8</th>
<th>±1/8</th>
<th>n/a</th>
<th>±1/8 to 2/8 (old: ±1/8)</th>
<th><strong>Note:</strong> Period (30s) clustering algorithms may be used to estimate low cloud amount automatically. *Uncertainty Accuracy difficult to determine since no definitions exists for instrumentally measured cloud base height.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2 Height of cloud base</td>
<td>0 m – 30 km (old: 30 m - 30 km)</td>
<td>10 m</td>
<td>±10 m for ≤ 100 m</td>
<td>±10 m for ≤ 100 m</td>
<td>n/a</td>
<td>±10 % for &gt; 100 m</td>
</tr>
<tr>
<td>4.3 Height of cloud top</td>
<td>not available (old: 30 m)</td>
<td>10 m</td>
<td>(old: 30 m)</td>
<td>n/a</td>
<td>±10 % for &gt; 100 m</td>
<td>approx. 10 m repeatability*</td>
</tr>
</tbody>
</table>

### 5. Wind

<table>
<thead>
<tr>
<th>5.1 Speed</th>
<th>0 – 75 m s⁻¹</th>
<th>0.1 m s⁻¹</th>
<th>A</th>
<th>±0.5 m s⁻¹ for ≤ 5 m s⁻¹</th>
<th>Dist. cont. 14 2–5 m</th>
<th>2 and/or 10 min</th>
<th>±0.5 m s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2 Direction</td>
<td>0 – 360º</td>
<td>1º</td>
<td>A</td>
<td>±5 %</td>
<td>2 and/or 10 min</td>
<td>±5 º</td>
<td></td>
</tr>
<tr>
<td>5.3 Gust</td>
<td>0.1 – 150 m s⁻¹ (old: 5 - 75 m/s)</td>
<td>0.1 m s⁻¹ (old: 0.5 m/s)</td>
<td>A</td>
<td>±10 %</td>
<td>3 s</td>
<td>±0.5 m s⁻¹</td>
<td></td>
</tr>
</tbody>
</table>

### 6. Precipitation

<table>
<thead>
<tr>
<th>6.1 Amount (daily)</th>
<th>0 – 500 mm (old: 0 -&gt; 400 mm)</th>
<th>0.1 mm</th>
<th>T</th>
<th>±0.1 mm for ≤ 5 mm</th>
<th>n/a</th>
<th>±5 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.2 Depth of snow</td>
<td>0 – 25 m (old: 0 - 10 m)</td>
<td>1 cm</td>
<td>A</td>
<td>±1 cm for ≤ 20 cm</td>
<td>±5 % for &gt; 20 cm</td>
<td></td>
</tr>
<tr>
<td>6.3 Thickness of ice accretion</td>
<td>Not specified</td>
<td>1 cm</td>
<td>I</td>
<td>±1 cm for ≤ 10 cm</td>
<td>±10 % for &gt; 10 cm</td>
<td></td>
</tr>
<tr>
<td>6.4 Precipitation intensity</td>
<td>0.02 mm/h - 2000 mm/h to be implemented</td>
<td>0.1 mm/h to be implemented</td>
<td>I</td>
<td>0.02 - 0.2 mm/h</td>
<td>0.2 - 2 mm/h: 0.1 mm/h &gt; 2 mm/h: 5% to be implemented</td>
<td>1 min to be implemented</td>
</tr>
</tbody>
</table>

---

11 New variable
12 To be determined
13 To be determined for instrument measurements
14 Distant constant; for anemometers: *response length*
15 Refined
16 New variable, specified for rainfall intensity by the expert team on rainfall intensity measurements (Bratislava, Slovakia, 23 to 25 April 2001)
### 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 – radiant exposure**
- Not specified
- 1 J m⁻² (old: 1 MJ m⁻² d⁻¹)
- 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)
- 20 s
- n/a
- ±5 %

### 8. Visibility

**8.1 MOR**
- 10 m – 100 km (old: <50 m-70 km)
- 1 m (old: 50 m)
- I, A
- ±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 %

**8.2 RVR**
- 10 m – 1500 m (old: 50 m-1500 m)
- 1 m (old: 50 m)
- A
- ±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
- ±21 %

### 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 %

**9.2 Wave period**
- 0 – 100 s
- 1 s
- A
- ±0.5 s
- 0.5 s
- 20 min
- 0.5 s

**9.3 Wave direction**
- 0 – 360º
- 1º (old: 10º)
- A
- ±10º
- 0.5 s
- 20 min
- 20º

---

17 Not applicable for reading of totals
18 Refined
19 Refined. 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.
20 A: For 10 min intervals, averaging over logarithmic values is advised.
21 In accordance with WMO Technical Regulations (WMO No. 49) - Vol. II, Attachment B
### 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.
5. Column 5 gives the recommended uncertainty **accuracy** requirement for general operational use. Individual applications may have less stringent requirements. The stated value of required uncertainty **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 uncertainty **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.
The session was informed that at the invitation of the United States of America, on 31 July 2003 in Washington DC, thirty-three nations, and the European Commission, joined together at the first Earth Observation Summit (EOS-I) to adopt a Declaration that called for action in strengthening global cooperation on Earth observations. The purpose of the Summit was to:

“Promote the development of a comprehensive, coordinated, and sustained Earth observation system or systems among governments and the international community to understand and address global environmental and economic challenges; and begin a process to develop a conceptual framework and implementation plan for building this comprehensive, coordinated, and sustained Earth observation system or systems.”

To this end, the Summit participants launched an ad hoc Group on Earth Observations (GEO), with the goal of furthering the creation of a comprehensive, coordinated, and sustained Earth observing system or systems. The group, co-chaired by the United States, the European Commission, Japan, and South Africa, and joined by more than 21 international and intergovernmental organizations, began its work by organizing five Sub-Groups, as well as a secretariat to support its activities. In order to promote the development of the now named Global Earth Observing System of Systems (GEOSS), GEO decided that a document describing the GEOSS framework and an associated 10-Year Implementation Plan would be developed.

The session noted that the document describing the GEOSS framework (referred to as the Framework Document) for the 10-Year Implementation Plan was presented for adoption at the second Earth Observation Summit (EOS-II) attended at the ministerial-level, in Tokyo, Japan on 25 April 2004, and the 10-Year Implementation Plan itself would be presented for adoption at the third Earth Observation Summit (EOS-III) hosted by the European Commission to be held February 2005 in Brussels.

Building on those efforts, the Association noted that the GEO process would:

- Cover the full spectrum of *in situ* and remotely sensed (space-based and aircraft) observations;
- Provide an opportunity for all nations and international organizations to work together for a common cause, under a commonly agreed approach, framework, and methodology;
- Actively involve developing countries in making improved observations within their national territories, and access and use observations made by others;
- Provide a means to build on the efforts of these international efforts to assess user requirements, identify gaps in global observations, improve communication among nations and organizations with common interests in similar observation capabilities;
- Provide high-level (ministerial) recognition of the universal need for improved Earth observation;
- Promote consensus-building among participants about the highest priority observation needs, which are unmet or require significant increase in resources to provide comprehensive solutions.

In the long-term, implementation of the 10-Year plan should result in:

- Commitment of nations to make more complete long-term collection of high-priority Earth observations;
- Filling of the gaps in observing capabilities;
• Attention to capacity-building in both developing and developed countries;

• Greater interoperability and connectivity among individual component observing systems for improved exchange and appropriate sharing of data and information to commonly agreed standards.

The session noted that four sessions of GEO had been held followed by the second Earth Observation Summit (EOS-II). The session noted that GEO-2, which met in Baveno, Italy, 28-29 November 2003, had agreed with the following recommendation concerning its architecture:

“GEOSS should be a system of systems supplemented by new observing components as and where required. This architecture would allow existing individual observing systems, e.g., WMO’s WWW GOS, to remain within their mandates as well as providing for new observing components. The architecture would require a new interface between individual observing components as well as a new component to exchange and disseminate observational data between those components. GEO members and participating organizations would need to agree upon a global interoperability specification to which all individual observing components would adhere. GEOSS would contain the necessary network structure to make available all required observations to satisfy the Data Utilization Model.”

EOS-II

The session noted that a Communiqué stating approval of the Framework Document, pointing the way forward in the GEO effort, and encouraging broad participation in and support for the GEO effort, was approved at EOS-II on 25 April 2004. Also agreed at EOS-II was a Framework Document consisting of: a high-level synopsis of the GEO effort for senior policymakers; a description of the GEOSS purpose and expected benefits; and a broad framework for developing the 10-year Implementation Plan.

Future Development of GEOSS

The session noted that the EC-LVI had adopted Resolution 13.4/1 on the Global Earth Observation System of Systems (GEOSS) in affirming its full support for the GEO process and resulting GEOSS. In reviewing the GEOSS Resolution approved by EC-LVI, the session noted that it specifically requested the technical commissions, as well as the Consultative Meetings on High-level Policy on Satellite Matters, to rapidly evaluate the draft Implementation Plan, to provide advice as necessary to ensure that the existing World Weather Watch Global Observing System, Global Atmosphere Watch, World Hydrological Cycle Observing System, Global Climate Observing System, Global Ocean Observing System, Global Terrestrial Observing System and other related observing systems are developed in a mode that is compatible with the Ten-year Implementation Plan; and, when the Plan is finalized, to provide advice as to how the WMO-coordinated systems should operate within the framework of the Plan. Thus, the session agreed that it should take into consideration the task created by the resolution in developing its near activities and long-term work programme to be discussed under agenda item 9.

The session agreed that its primary focus to seek ways and means to improve the utilization of satellite data, product and services should remain and that in doing so it would also meet the goals to be established in the GEO 10-year Implementation Plan.
RECOMMENDATION 3.1 “Definition of radiation”
Considering that:
1. There is a need for clear and unequivocal definitions of radiation and related variables, and
2. The definition exists in the International Meteorological Vocabulary,
The expert team recommended that:
1. Variables such as irradiance and radiant exposure should be used to distinguish between the physical quantities such as power and energy, and
2. The Guide to Meteorological Instruments and Methods of Observation, WMO-No.8, Part I, Chapter 1, Annex 1.B, relevant parts of Chapter 7 and relevant Table Element names in Class 14 of BUFR Code Table B, are updated accordingly.

RECOMMENDATION 3.2 “Issues related to the maintenance of metadata”
Considering that:
1. Metadata is crucial to the understanding of data characteristics,
2. Metadata is dynamic, and
3. Metadata is an extended version of the AWS history,
The expert team recommended that:
1. The proposed standard set of metadata elements for all AWS installations, as stated in the Annex 3, be submitted to CBS-XIII for approval and publishing in both the Manual on the Global Observing System, WMO-No. 544 and in the Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8, to ensure complete and correct information.

RECOMMENDATION 3.3 “Reporting Humidity”
Considering that:
1. Relative humidity is the derived value mostly used by the general population,
2. There is the need to report an absolute physical quantity,
It is recommended that:
1. Both relative humidity and dew point temperature be reported.

RECOMMENDATION 3.4 “Reporting of both nominal and instrument values of AWS in BUFR/CREX”
Considering that:
1. The Manual on the Global Observing System, WMO-No.544, recommends to exchange internationally Level II data (nominal values), and
2. The specific task was identified by CBS to investigate the possibility of reporting both nominal and instrument values in BUFR/CREX,
The expert team recommended that:
1. A proposal for reporting both Level I and Level II data by AWS, as presented in the Annex 4, is submitted to CBS-XIII for approval, and
2. The BUFR templates for AWS data should be refined accordingly.

RECOMMENDATION 4.1 “Guidelines on extended quality control (QC) procedures for data from Automatic Weather Station (AWS)”
Considering:
1. The efficacy of data validity check of raw data (sensor samples) at the AWS level,
2. The possibility of quality control at AWS level by making use of the availability of frequent data,
3. The general principles and basic steps of QC of AWS described in various Manuals and Guides of WMO, and
4. The Guidelines on Quality Control Procedures for data from AWS proposed by the ET/AWS,
The expert team recommended that:
RECOMMENDATION 4.2 “Quality Control (QC) information in the BUFR templates for Automatic Weather Station (AWS)”

Considering that:
1. The result of QC will lead to detection of good, doubtful, inconsistent, wrong, and missing data,
2. There is a need for the quality control indication of nominal and/or instrument values in BUFR, and
3. The ET on AWS proposed development of a new Flag Table for “Quality control indication of following value”,

The expert team recommended that:
1. CBS Expert Team on DR&C address the issue of the proposed Flag Table (see page 4 of this final report) and refine the current BUFR templates for AWS.

RECOMMENDATION 5.4 “Definition of Automatic Weather Station (AWS)”

Considering that:
1. There is a need for clear and unequivocal definition of AWS,
2. There is a need for consistency between WMO Manuals and Guides, and
3. There is a relevant definition in the International Meteorological Vocabulary, WMO-No.182,

The expert team recommended that:
1. WMO Manuals and Guides refer to International Meteorological Vocabulary, WMO-No.182, and

RECOMMENDATION 5.6 “Functional Specifications for Automatic Weather Stations (AWS)”

Considering that:
1. That the Functional Specifications for AWS change with time, and
2. That the Functional Specifications for AWS reflect the requirements for observational data,

The expert team recommended that:
1. The Functional Specifications for AWS, as presented in the Annex 8, are submitted to CBS-XIII for approval and publication in the Guide on the Global Observing System, WMO-No.488, Part II.

RECOMMENDATION 5.7 “Operational Accuracy Requirements and Instrument Performance”

Considering that:
1. The Operational Accuracy Requirements and Instrument Performance change with time,
2. The statement given here was the most authoritative at the time of writing, and

The expert team recommended that:
1. The Operational Accuracy Requirements and Instrument Performance, as presented in the Annex 9, are approved by CBS-XIII for publication, and
2. The Operational Accuracy Requirements and Instrument Performance replace the old Requirements in the Guide to Meteorological Instruments and Methods of Observation, WMO-No.8, Part I, Chapter 1, Annex.1B.

RECOMMENDATION 5.8.1 “Position of a station”

Considering that:
1. Observations from Automatic Weather Stations should refer to a specific, well defined location,
2. Such references should be of an appropriate accuracy,
3. The area of a station is of the order of magnitude of about 100 m x 100 m or less,
4. Computerized applications require the position of a location given in latitude and longitude represented by numerical, real values in decimal notation,
5. Confusion can arise between the use of degrees in decimal notation and the use in degrees, minutes and seconds, and
6. The recommended binary formats (BUFR) will use latitude and longitude in real, decimal values of a degree only,

The expert team recommended that:
1. The position of a weather station is presented by a longitude and a latitude in degrees in decimal notation and with an accuracy of at least 1/1000 of a degree.
RECOMMENDATION 5.8.2 “Adoption of a World Geodetic System and a global Geoid as references for positioning”

Considering that:
1. The position of a weather station is given by a longitude, a latitude and an altitude with respect to Mean sea level (MSL),
2. Presented longitude and latitude both require one universal standard positioning system as reference,
3. Mean sea level requires one universal global standard datum,
4. The standard reference system the World Geodetic System 1984 – Earth Geoid Model 96 [WGS 84–EGM 96] is applicable for the world wide use by all applications used in meteorology,
5. Most regional and national systems refer to WGS84,
6. WGS84 is endorsed by international bodies, such as ICAO,
7. MSL is defined as the average sea surface level for all stages of the tide over a 19-year period, usually determined from hourly heights observed above a fixed reference level,
8. The fixed reference level for MSL is to be appointed or defined, and
9. A well defined global geoid GEOID99 is applicable for all applications in meteorology,

The expert team recommended that:
1. CBS-XIII endorse adoption by WMO of the World Geodetic System 1984 [WGS 84] as primary reference for horizontal positioning,
2. CBS-XIII endorse adoption by WMO of the GEOID99 as the fixed reference level for MSL determination, and
3. The Technical Regulations and the appropriate Manuals and Guides are updated accordingly.

RECOMMENDATION 5.9 “Averaging observational data”
Considering that:
1. Averaging observational data to obtain Level II data is required in many circumstances,
2. The mathematics of averaging or the statistical methods are not described in detail in WMO Manuals or Guides, and
3. Calculating the arithmetic mean should not be a recommended method in all cases,

It is recommended that:
1. CBS take an action so that in case of prescribed averaging of data, reference is made to detailed mathematical calculus to be used.

RECOMMENDATION 5.10 “Optical extinction profile”
Considering that:
1. WMO has adopted the optical extinction profile as a new variable published in the Manual on the Global Observing System, WMO-No. 544, and
2. There is no corresponding definition in the Guide to Meteorological Instruments and Methods of Observation, WMO-No.8,

The expert team recommended that:
1. CBS asks CIMO to develop a suitable definition for inclusion in the Guide to Meteorological Instruments and Methods of Observation, WMO-No.8.

RECOMMENDATION 5.11 “Definitions of BUFR descriptor Element Names”
Considering that:
1. BUFR descriptor Element Names are not always uniquely defined in the basic WMO Manuals,
2. There is a need for clear and unequivocal definition of Element Names, and
3. A number of these descriptor element names given in the BUFR code cannot be found in other WMO documents,

The expert team recommended that:
1. CBS requests its ET on DR&C to update BUFR Code so that descriptor Element Names be referenced to International Meteorological Vocabulary or to WMO Manuals and Guides, and
2. The BUFR Code is updated accordingly.
RECOMMENDATION 5.12 “Definition of a common BUFR template for Automatic Weather Station (AWS)”

Considering that:
1. Several BUFR templates exist for:
   a. AWS data (one-hour period),
   b. SYNOP and SYNOP MOBIL data,
   c. SHIP data,
2. The AWS data template may also be used by manned (AWS) stations,
3. The AWSs are often also surface synoptic stations, which should therefore report SYNOP data,
4. The current BUFR template for AWS data (one-hour period) contains parameters representative of period of times of maximum one hour,
5. The SYNOP template contains some parameters representative of period of times of 3, 6, 12 or 24 hours,
6. Synoptic stations data have to be transmitted at synoptic hours and not necessarily every hour,
7. If the current BUFR template for AWS is used for transmission only at synoptic hours, some parameters over synoptic periods will be missing (for example amount of precipitation), and
8. In such conditions a synoptic AWS should transmit data both with the AWS data template and the SYNOP template,

The expert team recommended that:
1. CBS requests its Expert Team on DR&C to address the issue of mixing the current AWS template (for one-hour period) and the SYNOP template to a single template covering both AWS data to be transmitted at any intervals and SYNOP data to be transmitted at standard times.