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Quality Control procedures of data from Automatic Weather Stations

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Summary and purpose of document

This document contains proposal of the new concept of Quality Control Procedures of Automatic Weather Station data.

Action proposed

The meeting is invited to examine the concept of proposed Quality Control procedures for Automatic Weather Station data and to consider the possibility of the validation of checking algorithms.

References:
1. CBS-XII/PINK 6.2(3), Geneva, 29 November to 8 December 2000
2. Final Report, ET/AWS, Geneva, 3 to 7 July 2000
3. Final Report, ET/DR&C, Toulouse, 23 to 27 April 2001
4. Manual on Codes, WMO-No. 306, Volume I.2.
5. Guide on GDPS, WMO-No. 305

Background

The standardization and the Quality Control (QC) of Automatic Weather Station (AWS) data are becoming more important with the introduction of new more sophisticated sensors and processing algorithms. There is a strong need to develop and implement the basic guidelines for a quality management. The real-time quality control of data from AWS should be performed at both AWS site and at the Data Processing (Data Management) Centres. The Basic quality control procedures should be applied within the AWS while the extended quality control procedures should be applied at the Data Processing (Data Management) Centres. The information of the quality control outputs should be also disseminated to users. A BUFR code provides an excellent environment for doing it.

Basic Quality Control (B-QC)

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

A comprehensive documentation on B-QC, including the specification of basic data processing procedures for the calculation of instantaneous (i.e. one minute) data and sums should be a part of AWS' standard documentation. The range of B-QC strongly depends on the type of AWS and a level of its sophistication. The outputs of B-QC would be included inside every AWS BUFR message (BUFR descriptor 0 33 005 - Quality Information (AWS data) as suggested at the ET/DR&C meeting, Toulouse, April 2001 (Annex 1)).

Five types of B-QC procedures are suggested:

1) **The technical monitoring** of all crucial parts of AWS including all sensors. Most of the manufactures already provide technical monitoring for intelligent sensors, however result of the monitoring is not distributed to users. The technical monitoring provides an information on quality of data through the technical status of instrument and an information on the internal measurement status. Those would be represented in BUFR descriptor 033 006 - Internal measurement status information (AWS) as suggested at the ET/DR&C meeting, Toulouse, April 2001 (Annex 1) with additional information represented in BUFR descriptor 0 33 005 mentioned above.

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

3) **The time variance of the signal** (temporal consistency of measured values). The samples are checked every 3 seconds in case of wind speed and direction and every 10 seconds in case of temperature, humidity, pressure and global radiation. After each signal measurement the

current (actual) sample is compared to the previous one. If the difference of these two samples is more then specified limit then the current sample is identified as a suspected and not used for computation of an average. However, it is still used for checking of the temporal consistency of samples. It means that new sample is still checked with the suspected one. The result of this procedure is that in case of a large noise one or two successive samples are not used for the computation of an average. The limits of time variance of the samples implemented in SHMI are listed in Annex 2.

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

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

   (a) dew-point temperature ≤ dry bulb temperature;

   (b) wind speed = 00 and wind direction = 00;
   wind speed ≠ 00 and wind direction ≠ 00;
   wind gust speed ≥ wind speed;

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

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

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

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

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

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

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

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

where:
N means a number of signal measurements (sampling) over period of the last XY minute;
X means average value;
X_i means values of individual samples.

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

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

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

Extended Quality Control (E-QC)

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

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

The proposal of a new approach to E-QC checking algorithms is given in Annex 3.

Quality Information and Internal measurement status information for AWS data

0 33 005
Quality Information (AWS data)

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

0 33 006
Internal measurement status information (AWS)

Code figure	Internal measurement status information (AWS)
0	Self-check OK
1	At least one Warning active, no Alarms
2	At least one Alarm active
3	Sensor failure
4-6	Reserved
7	Missing value

Measurement ranges implemented at AWS in SHMI

- dry-bulb temperature: -45 °C ... +45 °C;
- ground temperature: -50 °C ... +65 °C;
- relative humidity: 1 ... 100 %;
- pressure:
  870 - 1040 hPa (AWS between 0 – 1000 m above MSL),
  750 - 1000 hPa (AWS between 1000 – 2000 m above MSL),
  650 - 950 hPa (AWS between 2000 – 3000 m above MSL);
- wind speed:
  0 - 30 $m.s^{-1}$ (10-minute average) (AWS between 0 – 1000 m above MSL),
  0 - 50 $m.s^{-1}$ (2-minute average) (AWS between 0 – 1000 m above MSL),
  0 - 50 $m.s^{-1}$ (10-minute average) (AWS between 1000 – 3000 m above MSL),
  0 - 75 $m.s^{-1}$ (2-minute average) (AWS between 1000 – 3000 m above MSL);
- soil temperature: -20 °C ... +45 °C;
- global radiation: 0 ... 1600 Wm^{-2};
- precipitation intensity 3 mm/minute.

The limits of time variance of the samples implemented by SHMI

- dry-bulb temperature: 2 °C;
- ground and soil temperature: 2 °C;
- relative humidity: 5 %;
- pressure: 0.3 hPa;
- wind speed: 20 ms^{-1};
- global radiation: 800 Wm^{-2}.

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

The different parameters in AWS BUFR N-minute data[1] reports are checked against each other. In the description below, the suggested checking algorithms have been divided into areas where the physical parameters are closely connected. Symbolic names of parameters used in the listed algorithms are described (explained) in the Table bellow.

(a) Wind direction and wind speed

The wind information is considered to be erroneous in the following cases:
wind_direction = 00 and wind_speed ≠ 00;
wind_direction ≠ 00 and wind_speed = 00;
wind_gust_speed ≤ wind_speed;

(b) Dry temperature and dew-point temperature

The temperature information is considered to be erroneous in the following case:
temperature_dew_point > temperature_dry;
temperature_dry - temperature_dew_point > 5°*C* and obscuration is from {1, 2, 3};

(c) Dry temperature and present weather

Both elements are considered suspect when:
temperature_dry > +5°*C* and precipitation_type is from {6, …, 12};
temperature_dry < -2°*C* and precipitation_type is from {2};
temperature_dry > +3°*C* and precipitation_type is from {3};
temperature_dry < -10°*C* and precipitation_type is from {3};
temperature_dry > +3°*C* and obscuration is from {2} or
(obscuration is from {1} and obscuration_character is from {4});

(d) Visibility and present weather

The values for visibility and weather are considered suspect when:
obscuration is from {1, 2, 3} and visibility_horizontal > 1 000 m;
obscuration is from {7, 8, 9, 11, 12, 13} and visibility_horizontal > 10 000 m;
visibility_horizontal < 1 000 m and obscuration is not from {1, 2, 3, 8, 9, 10, 11, 12, 13} and precipitation_type is not from {1, … , 14};
obscuration = 7 and visibility_horizontal < 1 000 m;
visibility_horizontal > 10 000 m and precipitation_type is missing and obscuration is missing and weather_phenomenon is missing;

(e) Present weather and cloud information

Clouds and weather are considered suspect when:
cloud_cover_total = 0 and precipitation_type is from {1, …, 11, 13, 14}
or weather_phenomenon is from {2, 5, … , 10};

(f) Present weather and duration of precipitation

Present weather and duration of precipitation are considered suspect when:
precipitation_type is from {1, … , 10, 13, 14} and precipitation_duration = 0;
precipitation_type is not from {1, … , 10, 13, 14} and precipitation_duration > 0;

(g) Cloud information and precipitation information

Clouds and precipitation are considered suspect when:
cloud_cover_total = 0 and total_precipitation > 0;

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[1] N ≤ 10 minutes

(h) Duration of precipitation and other precipitation information

Precipitation data are considered suspect when:
total_precipitation > 0 and precipitation_duration = 0;

(i) Cloud information and sunshine duration

Clouds and sunshine duration are considered suspect when:
cloud_cover_total = 100 and sunshine_duration > 0;

... and definitely some other algorithms.

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

Parameter / Type of data	**BUFR Descriptor**	**Parameter symbolic name**
Wind direction	0 11 001	wind_direction
Wind speed	0 11 002	wind_speed
Wind gust	0 11 041	wind_gust_speed
Dry temperature	0 12 101	temperature_dry
Dew-point temperature	0 12 103	temperature_dew_point
Cloud cover total	0 20 010	cloud_cover_total
Horizontal visibility	0 20 001	visibility_horizontal
Type of precipitation	0 20 021	precipitation_type
Character of precipitation	0 20 022	precipitation_ character
Duration of precipitation	0 26 020	precipitation_ duration
Other weather phenomena	0 20 023	weather_phenomenon
Intensity of phenomena	0 20 024	phenomena_ intensity
Obscuration	0 20 025	obscuration
Character of obscuration	0 20 026	obscuration_ character
Total precipitation	0 13 011	total_precipitation
Total sunshine duration	0 14 031	sunshine_duration

BUFR Code and Flag Tables associated with BUFR descriptors 0 20 21 – 0 20 026

0 20 021
Type of precipitation

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

Note: Mixed precipitation is indicated by setting to one the bits of all the observed single types of precipitation

0 20 022
Character of precipitation

Code figure	
0	No precipitation
1	Continuous
2	Intermittent
3	Shower
4	Not reaching ground
5	Deposition
6-14	Reserved
15	Missing value

0 20 023
Other weather phenomena

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

0 20 024
Intensity of phenomena

Code figure	
0	No phenomena
1	Light
2	Moderate
3	Heavy
4	Violent
5-6	Reserved
7	Missing value

0 20 025
Obscuration

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

0 20 026
Character of obscuration

Code figure	
0	No change
1	Shallow
2	Patches
3	Partial
4	Freezing
5	Low drifting
6	Blowing
7	Increasing
8	Decreasing
9	In suspension in the air
10	Wall
11	Dense
12	Whiteout
13-14	Reserved
15	Missing value

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