GENERAL REQUIREMENTS FOR THE ACCURACY OF HYDROMETEOROLOGICAL MEASUREMENTS

Anna Yordanova, Stanislava Radeva
National Institute of Meteorology and Hydrology, BAS
Sofia-1784, Tzarigradsko shosse №66,
yordanova61@gmail.com; stanislava.radeva@meteo.bg

Abstract. The purpose of the measurements is to obtain hydrological and meteorological quantitative meanings, which reflect the atmosphere state at a particular location. For this purpose, it is necessary to provide reliable data from observations. The results of the instruments measurement are numeric values. In the process of measurement becomes the accumulation of error, due to the instrument and to the measurement conditions. Here the establishment of the real value for a measurement is shown.

***Keywords**: accuracy, measurement, meteorology, error*

INTRODUCTION

In the meteorological network of NIMH air temperature is measured with a standard instrument - a mercury thermometer, and experimental electronic sensor (though only in individual stations). The aim of the measurements is to obtain quantitative hydrological and meteorological values, which reflect the state of the atmosphere at a particular site. Data obtained from hydrological and meteorological observations is used in:

- Forecasts and warnings for extreme weather events;
- Preparation real-time weather analysis;
- For the purposes of economic sectors that depend on weather;
- And for conducting research in hydrology and meteorology.

For these purposes, reliable monitoring data through standardization have to be provided. This could be done by specifying:

- The location, type and condition of the equipment;
- The manner of its operation;
- Particular circumstances in which measurements are conducted.

The characteristics of the location of the hydrological and meteorological stations are time-varying as a rule. Therefore, metadata information about the geography of the place and the sources of impact must be regularly updated. Furthermore, the replacement of the instruments of the station should be avoided, because it can lead to a change in the statistical characteristics of meteorological variables.

If the replacement is imperative, then the old and new equipment should work simultaneously for a period of not less than 1 year and the data collected should be analyzed.

Observers are required to pass professional training and should be tested by an authorized service for finding their competence to conduct measurements in accordance with the standards. They must be able to interpret the instructions using the instrument insurance and manual work methods, applied to the relevant specific systems.

Instruments requirements

The main requirements for hydrological and meteorological devices are:

1. Accuracy in accordance with the statutory requirements for a specific value;
2. Reliability and stability;
3. Easiness of operation, calibration and maintenance;
4. Simplicity of design (in accordance with requirements);

5. Durability;
6. Reasonable price of the device, consumables and spare parts.

Especially important is the accuracy that ensures the instrument over its operation.
The initial calibration, as a rule, presents deviations from ideal performance, which requires the introduction of correction data when conducting transactions with them. The adjustment coefficient should be stored into the device documentation. Clear instruction for application of adjustment coefficients should be given to observers.
Each device requires maintenance, service and technical examination, even if it is not broken. Capabilities of instruments deteriorate with time and use the due to aging components or misuse. These changes cause a gradual reduction of the accuracy of the measurement results. Especially for complex electronic measuring instruments where individual measurement parameters can be interdependent.
This means that the expected accuracy of the measurement device is limited to a certain period of time. This is why almost all manufacturers of electronic measuring instruments determine the validity of certain limits for a period of one year and only exceptionally to two years. Although these changes can’t be avoided, they can be found in time to correct mathematical or adjusted by calibration. Proper calibration ensures comparability and compatibility of data in the time series as well as their comparability with data from different parts of the world.
Calibration is an operation, that under certain conditions:

- Gives the relationship between the values - of the measured value shown by the meter and the corresponding values - realized by the standards of measurement
- Use this dependence to obtain results for a particular indication of measurement.

Calibration should not be confused with the correction of the measurement system.
The term "standard" means a device, method and scale used to establish the measurement uncertainty. The nomenclature for the standards of measurement are described in the International vocabulary of basic and general terms in metrology, prepared by the International Organization for Standardization.

DATA AND METHODS:

For the study purpose manual measured data as well as automatically measured ones from Chepellare climatic station are analyzed.

Measurement accuracy

In the process of measurements the error accumulation, due to device indicated error and error due to measurement conditions, takes place.

At all stages of measurement both systematic and random errors are monitored.

"Systematic error" is the average value of the infinite number of measurements of the same magnitude in recurring conditions rather than the actual value of the measured value.

"Random error" is the result of a measurement taken instead of the average value of the infinite number of measurements of the same magnitude in recurring conditions.

"Accuracy" is the degree of matching the measurement result with the actual value of the measured parameter:

<Real value> = <measured value> <total error>

Effective operating procedure for quality control is a comparison of the results of observations for a station with results of numerical analysis of the site obtained based on the use of data from neighboring stations in this area if there is enough reliable stations.

Differences when comparing, explain the effectiveness of the work of the observation station. For a specified averaging period however, the error analysis of neighboring stations may be considered 0. Then they can determine the mean value and standard deviation of the differences between the station and those of analysis. These two parameters characterize the error of measurement.

To determine the accuracy of any meter in the first place, statistical approach that will apply should be chosen. For this purpose are defined definitions:

a) Standard accuracy;
b) Standard deviation;
c) Statistical interval for a distribution.

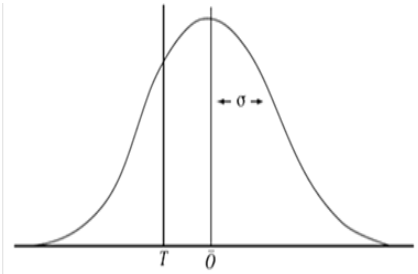


Fig.1 Data distribution of the variable **0** with **n** number of measurements

If **n** observations are made for a particular device, in which the measured value T and any other significant variables are not amended and if the best estimate of the actual value is established by model standard and the measured value is Gaussian distributed, than the measured data could be presented with the distribution in Fig. 1. Where T is the real value, **0** is the average value for **n** values of T, measured with the same device, and **σ** is the standard deviation of measured values.

Evaluation of real value in large n:

In demonstrating the presence of random or systematic effects that can not be eliminated or reduced, you need to evaluate the overall measurement uncertainty. which is the amount of the assessment due to accidental impacts and assessment due to systematic effects.

In a case of large **n**, the distribution of the average is normal. Then the limits within which the real value of the average lies are[2]:

- Upper Limit $L_U = \bar{X} + k.\frac{\sigma}{\sqrt{n}}$ (1)
- Lower limit:: $L_L = \bar{X} - k.\frac{\sigma}{\sqrt{n}}$, (2)

where:

$\bar{X}$ is the average value of the observations $\bar{O}$;

$\hat{\sigma}$ is the standard deviation of the population;

k is a ratio, corresponding to the selected degree of reliability, which is determined by the function of the standard normal distribution.

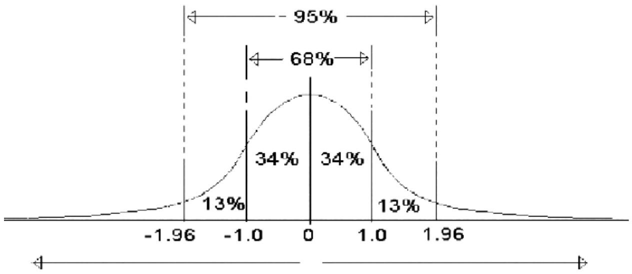


Fig.2 Confidence intervals of the average
for different reliability

Most commonly used k are given in the table::

Table 1

Confidence probability	90%	95%	99%
$\boldsymbol{k}$	1,645	1,960	2,575

By the standards, adopted in our country, it must be fulfilled:

$$\frac{\sigma_{\bar{x},\beta}}{\bar{x}}.100\% < 10\% \quad (3)$$

Evaluation of real value for small n

In this case, the average value of the measurements has the Student t-distribution, provided that the measurement error is with distribution close to normal.
Then the limits within which lies the real value of average are:

- Upper limit $L_U \approx \bar{X} + t.\frac{\sigma}{\sqrt{n}}$ (4)
- Lower limit:: $L_L \approx \bar{X} - t.\frac{\sigma}{\sqrt{n}}$, (5)

Where:

- **t** is the Student coefficient, which depends on the chosen k and n;
- $\hat{\boldsymbol{\sigma}}$ is an evaluation of the standard deviation for the n-these measurements, i.e.:

$$\hat{\sigma}^2 = \frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1} = \frac{\sum_{i=1}^{n} O_i{}^2}{n-1} = \frac{n}{n-1}.\sigma_O^2 \quad (6)$$

For $df = n - 1$ degree of freedom for **t** , the following values are applicable:

Table 2

Confidence probability / df	90%	95%	99%
1	6,314	12,706	63,657
4	2,132	2,776	4,604
8	1,860	2,306	3,355
60	1,671	2,000	2,660

For increasing **n, t** –coefficient tends to ***k***- value.
In common practice in hydrology and meteorology the 95% degree of confidence is used, i.e. .:
:

$$<Total\ error> = 1,960\ .\ \sigma$$

Therefore, the actual significance of the measured value is:

<Actual value> = <Measured value> ∓ <Total error> =

= <Measured value> ∓ *1,960 . σ*

The comparison of the results for observations at a station with results, from numerical analysis for the same station, obtained on the use of neighboring station data, is an effective operating procedure for quality control, if there are enough reliable stations in this area. The differences in the comparison can be explained by interpolation error and of the monitoring station efficiency. For a specified averaging period, however, the error analysis of neighboring stations may be considered 0.

RESULTS AND DISSCUSION

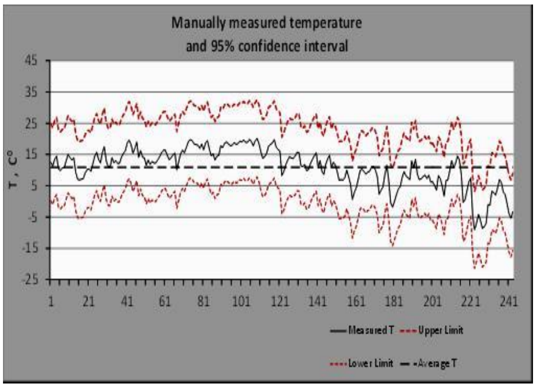
In this example, n = 243 measurements of the temperature of the automatic station in Chepellare are given. For the same place and time period manually measured temperature data are available also. It is assumed, that the distribution is close to normal distribution, because of the large number of measurements. The greater number of measurements is, the closer to normal scale the distribution becomes. If however, the data distribution is different from the normal, i.e. asymmetrical, then it is more correctly to use the confidence intervals of the respective distribution.

The determined average value and standard deviation of the differences between the T_D data (manual and automatic - T_M , T_A) are in table 1. These two parameters characterize the error of measurement.

Table 3

Statistical parameters	Measurement type T[C^o]		
	Manual T_M	Automated T_A	Difference T_D=(T_M-T_A)
Mean value $\overline{\mathbf{T}}$	10,96	11,19	-0,23
Standard deviation σ	6,29	6,55	1,56

For the researched number of observations, the following confidence intervals are valid:



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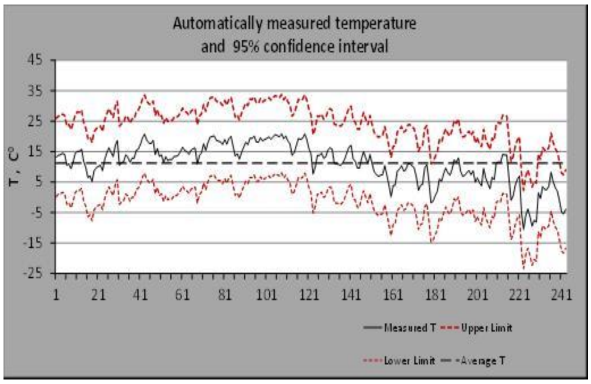

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According to equations (1) and (2) the value of the average for the automatically measured temperature data is located in the following of 95% confidence interval - [10.36; 12:01] and the manually measured data - [10.17; 11.75].

The comparison of the intervals of the real value for the average T is shown in the figure:

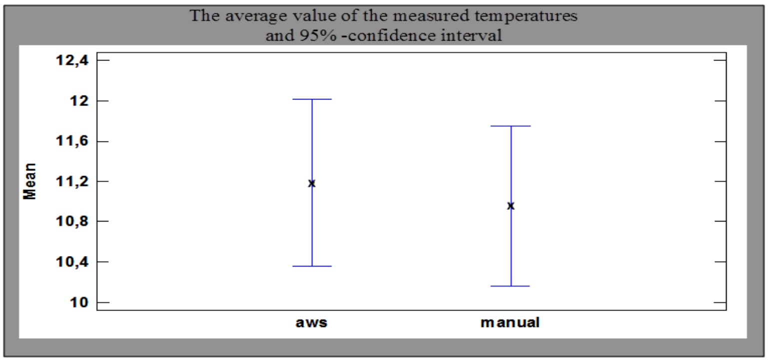


Fig.5

In comparing the two data sequences, the research of normality should be made for the distribution of differences between them, namely $T_D=(T_M - T_A)$.

Assuming that the distribution is close to normal, then:

$$< \textit{mean value of } T_A > \; = \; < \textit{mean value of } T_M > \pm \mathbf{1{,}960} \; . \; \boldsymbol{\sigma_D}$$

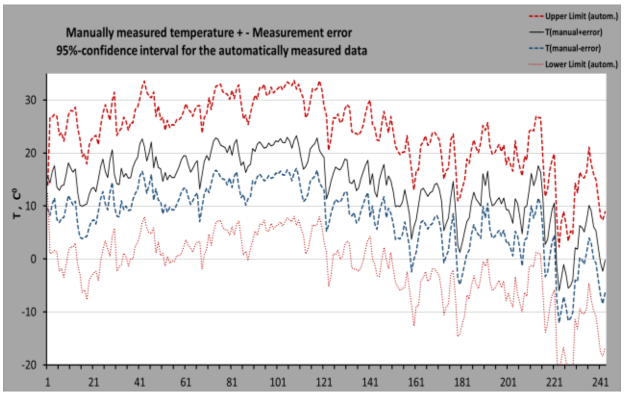
$$\overline{T_A} \in \left[\overline{T_M} - 1{,}96.\sigma_D ; \; \overline{T_M} + 1{,}96.\sigma_D\right]$$

I.e., the average value of the automatic measurement T_A is within the interval, obtained by manual measurement of the temperature, namely:

$$\overline{T_A} \in [7.90 \; ; \; 14.02]$$

If we consider the automatically measured data close to reality, then with a base of manually measured parameters, confidence interval in which the first found with 95% probability is applied to this equation:

$$< \textit{стойността на } T_A > \; = \; < \textit{стойността на } T_P > \pm \mathbf{1{,}960} \; . \overline{\boldsymbol{\sigma_D}}$$



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The standard accuracy is:

$$er = \frac{\overline{T}}{\sqrt{n}} \qquad (7)$$

It is a measure of the deviation of the average value of sample of volume **n** compare to general population average. The larger the sample size is, the smaller is the standard error of the mean value.

SEM matter sample

Standard error of mean value of the sample:

$$er = \frac{10{,}96}{243} = 4{,}51\%$$ -for manual measurement;

$$er = \frac{11{,}19}{243} = 4{,}60\%$$ - for automatic measurement.

The relative error of the mean value, due to that the measurement is manually instead of automatically is:

$$er = \frac{\overline{T_A} - \overline{T_M}}{\overline{T_M}} \qquad (8)$$

$$er = \frac{11{,}19 - 10{,}96}{10{,}96} = 2{,}1\%$$

i.e. the automatic measurement can be replaced with the manual measurement as a representative.

Literature

1. Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8, 2008 edition Updated in 2010, 2012.
2. David S. Jones, Pharmaceutical Statistics, 2002