

The importance of metrological metadata in the environmental monitoring.

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Resumo: A propagação dos metadados metrológicos contribui de forma expressiva para a melhoria da análise dos dados dos sistemas de observação meteorológica. Uma síntese sobre os cenários do tratamento dos dados e metadados no monitoramento ambiental é apresentado neste artigo, assim como as formas da utilização dos resultados da calibração nos sistemas meteorológicos de medição e também a convergência nos métodos utilizados no tratamento das correções e estimativa de incerteza de medição das áreas metrológica e meteorológica.

Palavras-chave: metadados, metrologia, meteorologia, metrologia ambiental, rastreabilidade.

Abstract: The metrological metadata propagation contributes significantly to improve the data analysis of the meteorological observation systems. An overview of the scenarios data and metadata treatment in environmental monitoring is presented in this article. We also discussed the ways of use of the calibration results on the meteorological measurement systems as well as the convergence of the methods used in the corrections treatment and estimation of the measuring uncertainty in metrological and meteorological areas.

Keywords: metadata, metrology, meteorology, environmental metrology, traceability.

1. INTRODUCTION

The measurement results of the instruments used in observation systems reveal important features of the environment. The environmental data are often uncertain and require additional information that provides the context of who, what, where, how and why these measurements were performed [1; 2].

Metadata is additional information about the measurement that improves the results quality [2].

Beyond the geographic coordinates and meteorological measurements, users of meteorological observations require information about the type of instrumentation used. They need details about the installation, maintenance and historical calibration, to outline scientific conclusions and decision-making [3]. Efforts to collect, store and process the metadata should be implemented. They improve the reliability of measurement results by detecting problems, analyzing the data quality and verifying the compatibility between data sets.

In this article we denominate metrological metadata the additional information related to the science of measurements applied to meteorological instrumentation.

1.1. Monitoring and measurement

The climate change has become the greatest threat to humanity and the environment. Meteorology, and especially the climate community are support instruments in this scenario to minimize the impacts [4]. On the other hand, they require observation systems and reliable information.

The meteorological instrumentation used in observation systems follows the technological innovations. However, many manufacturers still do not show the traceability patterns used for calibration. Instead, they execute only one performance test, since they consider their sensors and meters a remarkable scientific equipment. Another important information that should compose the metadata database is the experimental site classification for each metrological variable. The classification takes into account topography, land cover, obstacles distance, artificial heat sources, reflective surfaces, distance from water sources, shading in relation to the solar elevation, distance relationship and obstacle height, protection devices (shield), latitude, etc. Depending on the classification, it is recommended the addition of significant uncertainties, such as $\pm 5^\circ \text{C}$ for the air temperature, $> \pm 25\%$ for rain and $> \pm 50\%$ for wind [3].

For example, if rainfall measurements are carried out for an extended period it is likely that local conditions have changed, such as vegetation cover (growth and appearance of trees), construction works and relocation of the meter. It can also occur meter replacement due to maintenance, recalibration or updates. These changes affect measurements. In the case of

climate studies, the changes must be analyzed and approved carefully, and the metadata must be updated [5].

Having in place observational networks that can take and record regular climate observations is a necessary, but not sufficient, condition for ensuring the climate record can adequately support climate monitoring and service provision. The data must also be properly quality-controlled, archived and easily accessible [4].

In many countries, great part of the environmental data is inadequately treated alone. As a consequence, the degree of reliability is unknown, [6]. A common protocol has not yet been established between Metrology, Instrumentation and Meteorology areas.

2. METROLOGY AND ENVIRONMENTAL MONITORING

The greatest challenge is making important decisions quickly from systems that contain huge variety of data decisions, especially in strategic sectors such as health, civil defense, energy and the environment. The consequences of inadequate decision-making can lead to economic problems, legal implications and negative environmental impacts, and have as the direct cause the data quality.

Figure 1 illustrates the environmental monitoring scenarios: with and without the use of metadata. In the first scenario (in color), the information is based on reliable data guided by measurement results with traceability to the International System of Units (SI) and to quality control, leading to truly wise decision-making.

In the second scenario (without color), there is no metadata or they are insufficient or poor. It leads to decision-making that cause decline in quality of life and economic losses. On the other hand, the lack of measurements traceability leads to nowhere.

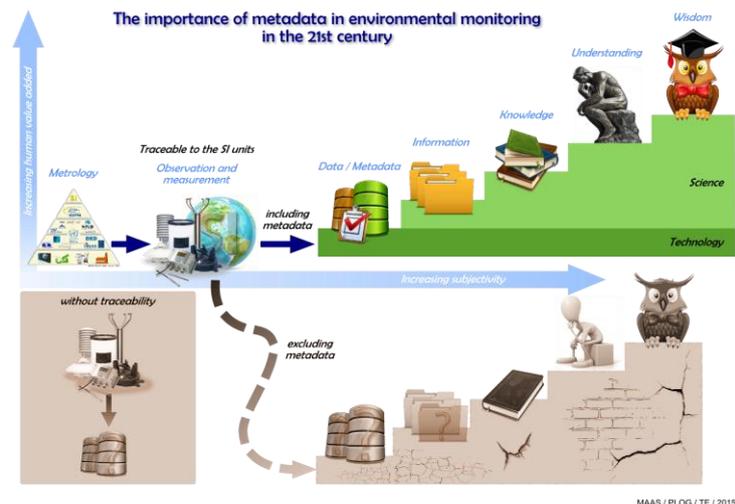


Figure 1. Ladder of knowledge - scenarios

Metrology is a horizontal scientific-technical field which underpins almost all subject fields in natural sciences and engineering [7]. The Environmental Metrology is considered an emerging multidisciplinary field and this interaction with other areas of human knowledge causes major impact on improving the quality of life. The propagation of information inherent to the metrological activities together with the meteorological instrumentation underpins the quality of the results of environmental monitoring. An adequate metrological infrastructure in the environmental area is essential to the development of the entire global economy [7]. In practice, calibration and periodic verification activities are the basis of quality. All data becomes questionable without metrological traceability.

3. METROLOGICAL TRACEABILITY

The modern society requires reliable measurements that give the same answer wherever they are made. This is achieved by ensuring traceability to the SI [7]. The meteorological traceability in the Ambiental Metrology can be represented by figure 2.

The smallest pyramid in the center represents the Regional Instrument Centres (RIC) from the 8^o Congresso Brasileiro de Metrologia, Bento Gonçalves/RS, 2015

World Meteorological Organization (WMO), a BIPM member since April 2010. They were established aiming to perform the meteorological instruments calibration to address the growing need for meteorological and hydrological data with high quality, the meteorological instruments standardization and international comparisons [3; 8; 9].

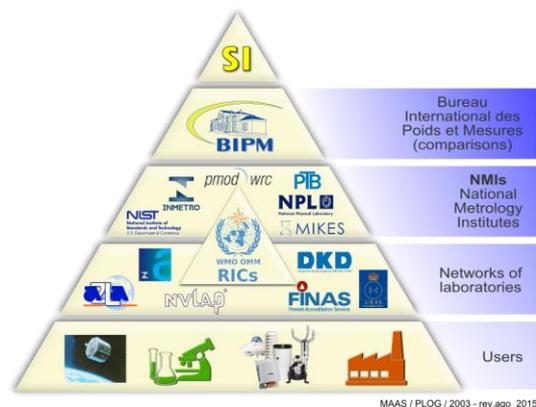


Figure 2. Traceability diagram applied to the Environmental Metrology area.

4. USE OF METROLOGICAL DATA AS METADATA IN METEOROLOGY

The final user believes that the data has corrected, the instrumentation technician believes that raw data is post processed and the metrologist believes that the information of calibration certificates are propagated during all of the

measurement process. Figure 3 shows the lack of integration between metrology, instrumentation and Meteorology areas.

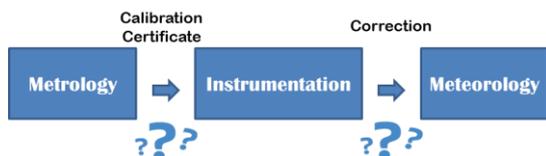


Figure 3. Areas of knowledge for environmental monitoring

Many times the environmental data are initially qualified but not systematically corrected. Because of a misinterpretation, many people understand that the calibrated instrument do not have or do not require a correction factor.

Normally, the qualification data consists of validation tests to verify if the georeferenced environmental data are within maximum and minimum range, and if there are temporal and spatial consistency. As a result, the absence of a metadata of the calibration results leads to the lack of knowledge of the reliability degree of measurements.

The use of metadata related to the instrumentation calibration can occur in three different situations: before, during or after the collection of the environmental data. The first case uses the Acceptance Criteria, which are the values that serve as limits to prove that the instrument is suitable for use. The Acceptance Criteria is defined before the calibration and results analyzed to verify if they fit within a desirable range. Normally, it uses a maximum error (E_{MAX}) where the sum of the error module or combined correction of a measurement system (C) with the module of the uncertainty associated (U) must be less than or equal to the maximum permissible value (Eq. 1):

$$E_{MAX} \geq |C| + |U| \quad (1)$$

In the second case (pre-processing), a correction equation or calibration factor is introduced in the data acquisition system of the weather station

(Figure 4). Then, the corrected data are inserted on the database server.



Figure 4. Offset adjustment and multiplier factor applied to a datalogger used in a weather station

Two situations occurs in this case: (1) data acquisition systems without features like an offset adjustment and/or a multiplier factor to correct the data, and (2) data acquisition systems with these features but requires technicians on the field to configure the systems individually the for each calibration. The uncertainty values U should be treated later. In the third case (post-processing), the Calibration Certificate information (Table 1) is treated as metadata, and the data can be corrected and qualified.

Table 1. Calibration certificate (partial data).

Nominal value	Conventional value, T_{ITS-90}	Measured value T_{IND}
25,0	25,1	25,2
Correction $T_{ITS-90} - T_{IND}, C$	Expanded measurement uncertainty, U	Coverage factor @ 95,45%, k
0,1	$\pm 0,2$	2

Suggestions of meteorological data correction procedures can be obtained from the Guide of Meteorological Instrumentation. An example is the case of precipitation measurements that are significantly affected by exposure conditions, wind and topography. In this case, the metadata are particularly important for users of the data, because the metadata describes the circumstances of the measures [3].

With the use of the metadata (C and U) which may correspond to systematic and random errors the measurement of the variable (M) obtained by an instrument or measurement system becomes a measurement range (RM), according with Eq. 2. In the case of meteorological observations, more

than one source of uncertainty has significant contribution in the measurement process.

$$RM = M + C + U \quad (2)$$

The combined correction (C) is the correction value to be applied to the measurement process and is the result of simultaneous action of systematic contributions from all sources of uncertainty [10]. The expanded measurement uncertainty (U) is estimated by combined standard uncertainty (U_C), which is the set of uncertainties type A with type B [11].

The methodologies used to estimate the measurement uncertainty on metrology area started in recent years in the meteorology area, in particular the *Guide to the expression of uncertainty in measurement* [11]

5. DISCUSSION AND CONCLUSION

We conclude that the results from the measurements by themselves rarely are sufficient to help answer questions about meteorological observations. Therefore the metadata becomes as important as the meteorological data.

Systems or environmental monitoring networks require investment, as well as current information processing systems. So, to achieve success in this investment, the quality and reliability must be guaranteed through the use of the metrological metadata in the area of meteorology.

Workshops, seminars and conferences that brings together meteorology, instrumentation and metrology professionals should be encouraged in order to accelerate the integration process between areas, to improve the computational models and to get improvement on the information reliability level.

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