Intercomparison of meteorological variables measurement, between the National Institute of Industrial Technology (INTI) and the National Meteorological Service (SMN)

Javier García Skabar[1], Rocío Napán[1], Mario García[2], Marcelo Solari[2], Paola Sayago[2]

[1] National Institute of Industrial Technology, Buenos Aires, Argentina.
[2] National Meteorological Service, Buenos Aires, Argentina.
jskabar@inti.gob.ar, maldonado@inti.gob.ar, garcia@smn.gov.ar, msolari@smn.gov.ar

In November 2015, it was held in Buenos Aires, Argentina, the CIMO Training Workshop on Metrology for RA-III and RA-IV Spanish-speaking countries of the World Meteorological Organization (WMO), and a survey among Members to know the status of calibration of meteorological instruments in the region. As a result of both activities, the recommendations of the participating experts were received and proposed the reactivation of the Regional Instrument Centre “Dr. Benjamin Gould Davies" (CRI Buenos Aires) of National Meteorological Service (SMN).

The SMN requested assistance from the National Institute of Industrial Technology (INTI) for which progress was made in an agreement and , among the actions proposed to carry forward to the reactivation of the CRI , we can mention the following: Develop a plan of upgrade and standardization CRI Buenos Aires , renewal of equipment and ensuring the traceability of measurements to the International System of Units, implementation of international standards ISO/IEC 17025 applicable to calibration laboratories, and active participation in inter laboratory comparisons.

This will allow us to maintain updated the laboratory personnel and improve the quality of work. Also it predisposes positively to the staff involved and motivated to keep improving.

For this reason, in June of this year, a comparison inter laboratories will be organized in the quantities of temperature (-10 °C to +40 °C) and humidity (10% rh to 90% rh) at temperatures between -10 °C to +40 °C.

The results of this inter comparison will be evaluated and analyzed in order to verify the consistency of measurements realized between the SMN and the INTI, additionally serve to determine the actual status of CRI, essential to define the action plan that allows us to reactivation.

Introduction

The Regional Instrument Centre (CRI Bs. As.) laboratory has spent years conducting control and adjustment of instruments for measuring quantities such as pressure, temperature, relative humidity and wind speed among others. The staff of the laboratory has extensive experience in measuring these meteorological variables and is also formed in conducting inspections of weather stations. The laboratory has enough equipment to cover needs of basic calibration in the field of meteorological measurements, pressure, temperature and relative humidity.

However, the CRI Bs. As. has become out of date from the point of view of equipment, instruments, and the training of human resources to meet the current demands of calibration services in the area of meteorology and climatology in accordance with international standards and to ensure traceability to SI. In the CIMO Training Workshop on Metrology for RA-III and RA-IV Spanish-speaking countries of the World Meteorological Organization (WMO) held in November 2015 in Buenos Aires the regional nature of this issue and the urgent need for reactivation and transformation of CRI Bs. As. became apparent.

With the collaboration of INTI, as National Metrology Institute of Argentina, we began to work in this direction taking action for the formulation of a recovery and transformation plan. The recovery plan involves that CRI Bs. As. strengthen and develop the capabilities of the laboratory for calibration services needed in the field of meteorology and implement the standard ISO / IEC 17025 (IRAM 301).

We present a diagnosis of the current state of the laboratory, we analyze the results of an inter-laboratory exercise, we describe the most relevant findings and state the actions that we consider most important as a draft recovery plan for CRI Bs. As.. Initially, we focus on the most important technical aspects and in two basic meteorological magnitudes, temperature and humidity.

Figure 1: SMN Argentino – CRI Bs As - CIMO Training Workshop on Metrology 2015

Analysis of the current state

In order to analyze the CRI Bs. As. lab we begin by evaluating the production of the laboratory reports and certificates, and review its resources, that is to say, the training and experience of its staff and its equipment and facilities.

Production

Currently laboratory services in relation to measurement are aimed at ensuring compliance with tolerance requirements (see table 3), or informing the corrections to instrument indication. Hygrometers and thermometers under test or calibration are compared against laboratory standards and its correction or compliance with a tolerance is reported in a document issued by the lab.

TEMPERATURE	
Thermometers: +/- 0.4 °C	Data loggers: +/- 1°C
RELATIVE HUMIDITY	
Hygrometers: +/- 5 % rh	Data loggers: +/- 10 % rh
PRESSURE	
Barometers +/- 0.5 hPa	Data loggers: +/- 1 hPa
WIND SPEED	
+/- 0,5 m/s less of 5 m/s	+/- 10% more of de 5 m/s

Table 1 Tolerance by magnitude

The CRI Bs. As. lab does not assess the uncertainties of measurement procedures and does not report this in its issued documents. In any of the main activities of the laboratory it is necessary to make an assessment of the uncertainty of measurement processes. In the case of corrections, it is necessary to provide information on the quality of these data and in the case of tolerance it is necessary to determine if the quality of measurement is enough to ensure compliance of tolerance.

The CRI Bs. As. lab is not yet a calibration laboratory in the metrological sense. The lack of this information in their reports and standardization procedures jeopardizes the quality of measurements and traceability to SI.

Staff

The laboratory technicians have extensive experience in the field of meteorological instrumentation and specific training for the stations inspection. Their broad understanding of the requirements and measurement needs in the area of meteorological variables measurement. Table 2 is an important value.

Name	Skill	worked in lab since year
Solari, Marcelo	Weather Inspector - Weather Observer	2002
Sayago, Paola	Weather Inspector - Weather Observer	2010
Olmedo, Daniel	Weather Observer – Section Mercury	1990
Quintana, Julio	Electronic technician	2005

Table 2: Staff profile

The laboratory staff do not have metrological training. It is necessary, that they be trained to implement ISO/IEC 17025, to make basic uncertainty computations and that they strengthen concepts in specific base magnitudes.

To achieve an effective recovery and transformation of the laboratory the role of technical director of the laboratory must be created. A technician responsible of the implementation of the standard, of studying the methods and measurement models, of developing data analysis and uncertainty budgets, of maintaining calibration status of instruments and equipment, of reviewing documents and records and of preparing procedures and a laboratory quality manual. This role can be exercised by any member of the laboratory staff that must be trained in the necessary metrological aspects.

Equipment and instruments

The current equipment allows the Lab to meet a moderate volume demand of the basic instruments used in meteorological measurements magnitudes. While we must study in detail the needs and requirements of calibration for each quantity demanded, we can say, looking at the list of current instruments and equipment, that a renewal will be necessary and / or the increasing in the amount thereof (see Table 3 and Figure 1). It is important to mention that the laboratory has a large volume wind tunnel, the availability of an equipment like this is not common in Argentina and in the region

Brand – Serial Number	**Model**	**Instrument**	**Range**
Standard			
VAISALA N° G4110027	PTB 330	BAROMETER	500 to 1100 hPa
VAISALA N° B4710021	HMT333	THERMOHYIGROMETER	-40°C to 60°C - 5 to 100% rh
SIAP N° 1 Y N° 2	MERCURY	THERMOMETER	-20 °C to 50 °C
VAISALA N°F0830006	ULTRASONIC WD30	ANEMOMETER	2 to 30 m/s
Working standard			
VAISALA	PTB 300	DIGITAL BAROMETER (5 units)	500 to 1100 hPa
THIES CLIMA	HAND HELD	ANEMOMETER	0.5 to 30 m/s
VAISALA B4320001	HMP45	THERMOHYIGROMETER	-20 °C to 60 °C - 5 a 100 % hr

Table 3: References instruments

Figure 2: Calibration bath, climatic chamber, and pressure chamber.

To meet the demand resulting from a modernization and expansion of observation instruments, which will have more demanding calibration requirements. it will be necessary to renew the equipment and to increase its capacity and quantity. In some cases the old design and wearing of equipment provoke that these do not meet the required technical specifications for the quality measurement needed.

Inter-laboratory comparison

After several interviews and visits of INTI experts to CRI Bs. As. lab, the realization of two inter-laboratory comparisons was planned, in temperature and in relative humidity. Knowing the state of development and capabilities of the laboratory, this exercise was thought not only as a tool for evaluation of laboratory performance but also as a training opportunity for lab staff. The lab technicians have had a first approach to the calculation of uncertainty and the process to make a comparison.

For the two magnitudes that were compared, two protocols were prepared. These protocols were previously agreed on between the two participants. The measuring range, transfer instruments, calibration methods and criteria to evaluation are described in these protocols.

The lab does not have an established procedure for the assessment of uncertainties. A simple measurement model, according to the measurement procedure carried out, was raised in order to assess this uncertainty. This was the first experience in uncertainties evaluation of CRI Bs. As. lab staff. It is necessary to review the methods of measurement and study in more detail the components considered to establish their contribution more accurately.

INTI applied their existing procedures for calibration of digital thermometers by comparison with standard platinum resistor thermometers (SPRT) in stabilized calibration baths. The hygrometer was calibrated in a two pressures generator with traceability to SI by the calibration of its pressure and temperature sensors.

The method of normalized error (En) was used to evaluate laboratory performance criteria, whose acceptance is satisfactory if $|En| \leq 1$.

Temperature comparison

Transfer instrument = Instrument Under calibration (IUC)				
Reader	**Sensor**	**Serial number**	**Resolution**	**Range**
Testo 735	Electrotherm PT100	01157025/512 - 2001-01	0,05	-40º C a 200º C

Temperature comparison final results					
Lab	RIC Bs As SMN				
Points	**IUC Temperature / °C**	**Correction / °C**	**Expanded Uncertainty / °C**	**Cover factor (k)**	**En**
0	0,12	0,03	0,52	2	0,2
10	10,33	0,03	0,42	2	0,2
20	20,30	0,10	0,35	2	0,5
30	30,14	0,08	0,30	2	0,5
40	40,13	-0,02	0,43	2	0,2
0	0,30	0,07	0,50	2	0,2
-5	-4,92	-0,10	0,38	2	-0,1
20	19,94	0,08	0,28	2	0,5
40	40,17	0,00	0,29	2	0,3

Table 4: Temperature comparison results

Temperature uncertainty budget example of CRI Bs. As. Lab.

Uncertainty component	Symbol	Value		Type	Interval		Cov. Fac	u_i		%
Temperature IR and repeatability	IR t	20,02	°C	AN				0,042	ºC	8,6%
Resolution IR	δ 1	0,00	°C	BR	0,050	°C	1,73	0,03	ºC	4,0%
Calibration IR	δ 2	0,00	°C	BN	0,200	°C	2,00	0,10	ºC	48,3%
Drift between calibrations IR	δ 3	0,00	°C	BR	0,010	°C	1,73	0,01	ºC	0,2%
Bath non-Uniformity	δ 4	0,00	°C	BR	0,02	°C	1,73	0,01	ºC	0,6%
Temperature IUC and repeatability	IBC t	19,94	°C	AN				0,021	ºC	2,1%
Reproducibility IUC	δ 5	0,00	°C	AN				0,03	ºC	4,4%
Resolution IUC	δ 6	0,00	°C	BR	0,025	°C	1,73	0,08	°C	31,7%
Correction IUC	Cx	0,03	°C	N	0,28	°C	2,0	0,14	ºC	100%

IR: Reference Instrument, IUC: Instrument Under Calibration

Measurement model: **Cx = IRt - IBCt +** δ 1 **+** δ 2 **+** δ 3**+** δ 4 **+** δ 5 **+** δ 6

Table 5: Temperature uncertainty budget

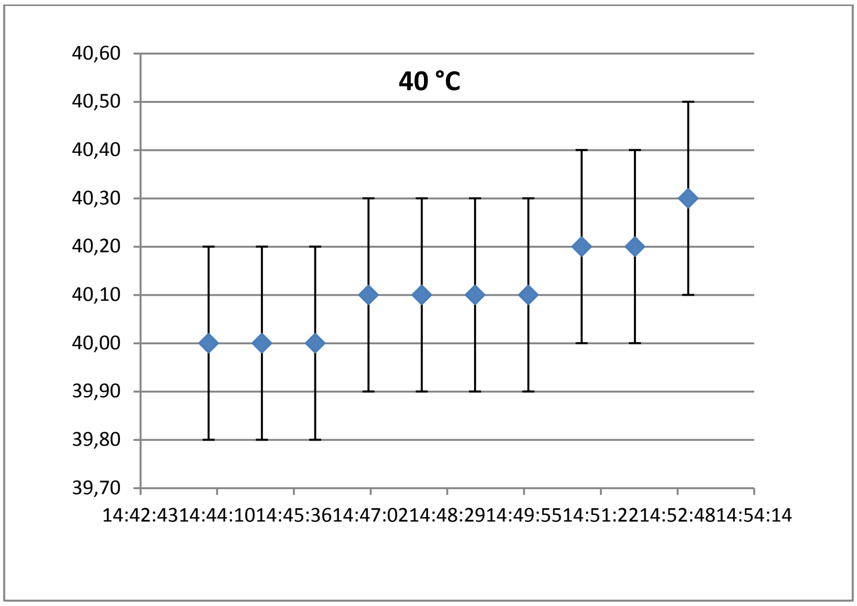

Figure 3: CRI Bs. As. Lab measurements at 40 °C

The uncertainty evaluation for the comparison has shown that the two components of greater impact on uncertainty were the bath stability and the reference instrument calibration uncertainty.

When a good bath stability was achieved, the calibration uncertainty of reference thermometer made the largest contribution to the total uncertainty. When this did not happen, the dispersion of the thermometer readings, product of bath instability, was the greatest impact component.

The normalized errors calculated were satisfactory in all measured points, $|En| \leq 1$, but it is important to note that calculated uncertainties were close to 0.5 °C and the differences between corrections measured by the INTI laboratory and CRI Bs. As. Lab in several cases were close to 0.1 °C.

We must remember that the laboratory determines compliance with tolerances. There are different views on the relationship that uncertainty and correction for compliance with a tolerance should keep. Whatever the approach adopted for this, the uncertainty of the measuring system cannot exceed the tolerance that is needed to ensure. If the results of uncertainty calculations performed for this comparison are confirmed, the laboratory would be in this situation.

Humidity comparison

Transfer instrument = Instrument Under calibration (IUC)				
Reader	Sensor	Serial number	Resolution	Range
Vaisala MI70	Capacitive HMP75	1950042 - H3120013	0,01	0 a 100 %rh

RESULTADOS FINALES DE LA COMPARACIÓN HUMEDAD RELATIVA					
INSTITUTO:	SMN				
Relative humidity at 20 °C					
Points	**Relative humidity IUC / %rh**	**Correction / %rh**	**Expanded Uncertainty / %rh**	**Cover factor (k)**	**En**
20 %rh	20,32	-0,3	1,9	2,00	0,15
40 %rh	36,23	3,6	9,5	2,30	0,38
60 %rh	52,18	3,8	17,5	2,60	0,22
90 %rh	90,39	2,1	2,8	2,00	0,76
20 %rh	19,53	-0,2	1,8	2,00	0,12

Table 6: Humidity comparison results

Relative humidity uncertainty budget example of CRI Bs. As. Lab.

Uncertainty component	Symbol	Value		Type	Interval		Cov.Fac	u_i		%
rh IR and repeatability	IRhr	19,51	%	AN				0,137	%rh	2,2%
Resolution IR	δ 1	0,00	%	BR	0,005	%	1,73	0,00	%rh	0,0%
Calibration IR	δ 2	0,00	%	BN	1,300	%	2,00	0,65	%rh	50,2%
Temperature effect on IR	δ 3	0,00	%	BR	0,300	ºC	1,73	0,17	ºC	0,0%
Drift between calibrations IR	δ 4	0,00	%	BR	1,000	%	1,73	0,58	%rh	39,6%
Chamber non-Uniformity	δ 5	0,00	%	BR	0,30	ºC	1,73	0,17	%rh	3,6%
rh IUC and repeatability	IBChr	19,53	%	AN				0,186	%rh	4,1%
Reproducibility IUC	δ 6	0,00	%	A1				0,040	%rh	0,2%
Resolution IUC	δ 7	0,00	%	BR	0,005	%	1,73	0,00	%rh	0,0%
Temperature effect on IUC	δ 8	0,00	%	BR	0,300	ºC	1,73	0,17	ºC	0,0%
Correction IUC	Cx	-0,02	%		1,82	%	1,98	0,92	ºC	100%

IR: Reference Instrument, IUC: Instrument Under Calibration

Measurement model: **Cx = IRhr - IBChr + δ 1 + δ 2 + δ 3+ δ 4 + δ 5 + δ 6+ δ 7 + δ 8**

Table 7: Humidity uncertainty budget

The humidity comparison had serious difficulties. First, the climatic chamber did not reach enough stability in humidity to make calibrations. Finally, the chamber broke and then it was only possible to make measurements at 20 °C.

There were few measurements available to analyze, the results of which are shown in table 6. While En is satisfactory, given the uncertainty levels obtained in many cases, this result is not representative of laboratory performance. The differences between corrections obtained by INTI laboratory and CRI Bs. As. Lab were in the order of 3% rh. Both differences in the correction values and high uncertainty values reported by the CRI Bs. As. Lab are due to the poor stability of the climate chamber in temperature and humidity.

The difficulties in making this comparison are exposing the need for renewal of equipment. The climatic chamber broke down due to wear and heavy use along the years. On the other hand, the characteristics of thermal stability and humidity stability are intrinsic to an old model chamber.

Actions proposed to recovery and transformation lab plan

This plan not only involves the purchase of some new equipment and instruments but also the training of human resources for the implementation and design of new procedures and for the daily operation of the laboratory.

A laboratory recovery plan requires action on several aspects simultaneously. We list here a series of actions and specific activities we consider necessary to begin the recovery.

Staff training:

- Introductory course to ISO / IEC 17025
- Introductory course to uncertainty evaluation

Under the cooperation agreement signed between the Argentine meteorological service and the INTI, the NMI of Argentina, INTI metrology experts can provide assistance to CRI Bs. As. Lab staff and give these courses also for other laboratories meteorological measurements in the region.

Procedures:

- Review the measurement procedures, determine measurement uncertainties required for each case, analyze the applied models and make calculation of uncertainties.
- Draw up procedures for testing and calibration services performed by the laboratory in order to implement the ISO IEC 17025.
- Designate a technical director of the laboratory to carry out these tasks and to monitor lab operation.

INTI, as NMI of Argentina supervises a network of calibration and testing laboratories (Argentine Calibration Service, SAC) working under the standard ISO / IEC 17025 or IRAM 301. The incorporation of Lab to SAC is proposed as medium-term objective and INTI will give advice for the implementation of the standard.

Equipment and instruments for temperature and humidity

It is necessary to

- Acquire a climatic chamber with appropriate uniformity and stability in temperature and humidity for instruments calibration.
- Move to platinum resistance thermometers (PRT) as temperature standards and increase its quantity for a better control of the measurement results.

- Improve stability load capacity and time response of calibration baths by improving the control system or acquiring new baths.

INTI experts are collaborating to determine the technical specifications of the equipment needed and to develop the specification to purchasing.

Conclusion

In recent years all meteorological measurements have advanced by the development of new instruments and measurement equipment, and the need to ensure the quality of measurements and to standardize the work procedures has been revealed. This has increased the links between metrology and meteorology and has promoted the development of metrology in all the areas of measurements of meteorological variables.

The growing technological advance offers instruments and equipment with better metrological characteristics, higher resolution, lower measurement uncertainties, more robust, and with high levels of automation. These advances have caused improvements in calibration capabilities, which are ultimately linked to equipment and instruments available in the calibration laboratory and the ability and skills of its staff.

The CRI Bs. As. lab needs to be reactivated to provide calibration service of modern instruments for meteorological measurements, ensuring the quality of measurements and traceability to SI.