Metrology for Meteorology

Andrea Merlone

METROLOGIA PER LE OSSERVAZIONI AMBIENTALI. VERSO NUOVI STANDARD E METODI

Andrea Merlone

BIPM – CCT WG Environment chair

EURAMET TG Environment chair

IMEKO TC 12 Scientific Secretary

MeteoMet coordinator

BIPM is located in Sevres

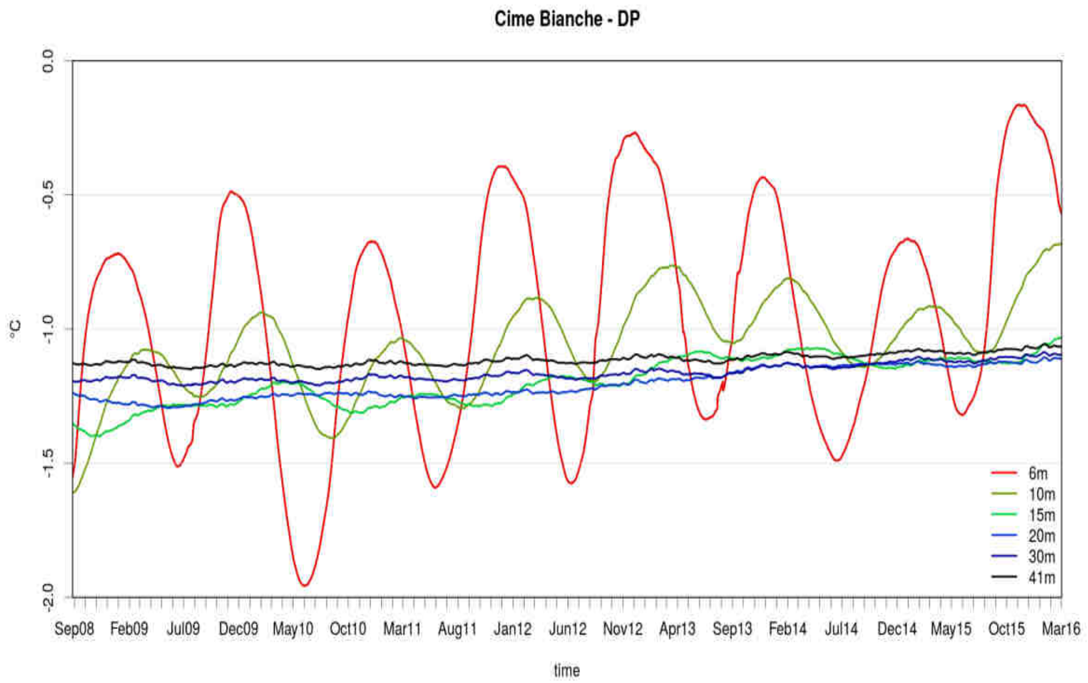
Andrea Merlone

BIPM

Accuracy

Accurate Measurements

Are needed to assess and reduce time necessary to capture trends

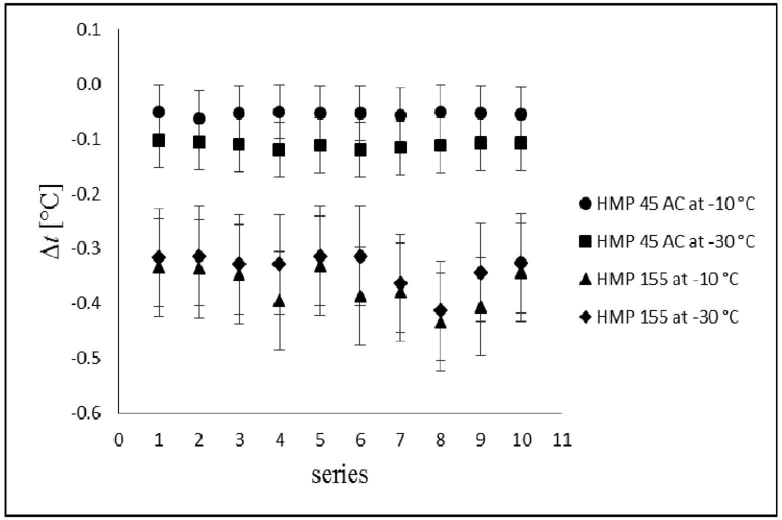


Closeness of the agreement between the result of a measurement and a true value of the measurand

Uncertainty

...dispersion of the values that could reasonably be attributed to the measurand

The uncertainty is evaluated by completing the uncertainty budget



Type A uncertainties: Statistical
Type B: all the rest

x_i		$u(x_i)$ [°C]	
		HMP 155	**HMP 45 AC**
Components derived from the reference thermometer		$5.12 \cdot 10^{-3}$	$5.02 \cdot 10^{-3}$
Components derived from measurement system		$1.27 \cdot 10^{-2}$	$1.27 \cdot 10^{-2}$
Components derived from meteorological thermometer	repeatibility	$3.47 \cdot 10^{-2}$	$2.06 \cdot 10^{-2}$
	resolution	$4.04 \cdot 10^{-3}$	$2.89 \cdot 10^{-3}$
	reproducibility	$1.40 \cdot 10^{-2}$	$5.00 \cdot 10^{-4}$
	hysteresis	$2.00 \cdot 10^{-2}$	$1.73 \cdot 10^{-3}$
	$u(x) = (\sqrt{\sum u^2(x_i)})^{1/2}$	$4.45 \cdot 10^{-2}$	$2.50 \cdot 10^{-2}$
	$U(x) = 2 \cdot u(x)$	**0.090 °C**	**0.050 °C**

The calibration uncertinty

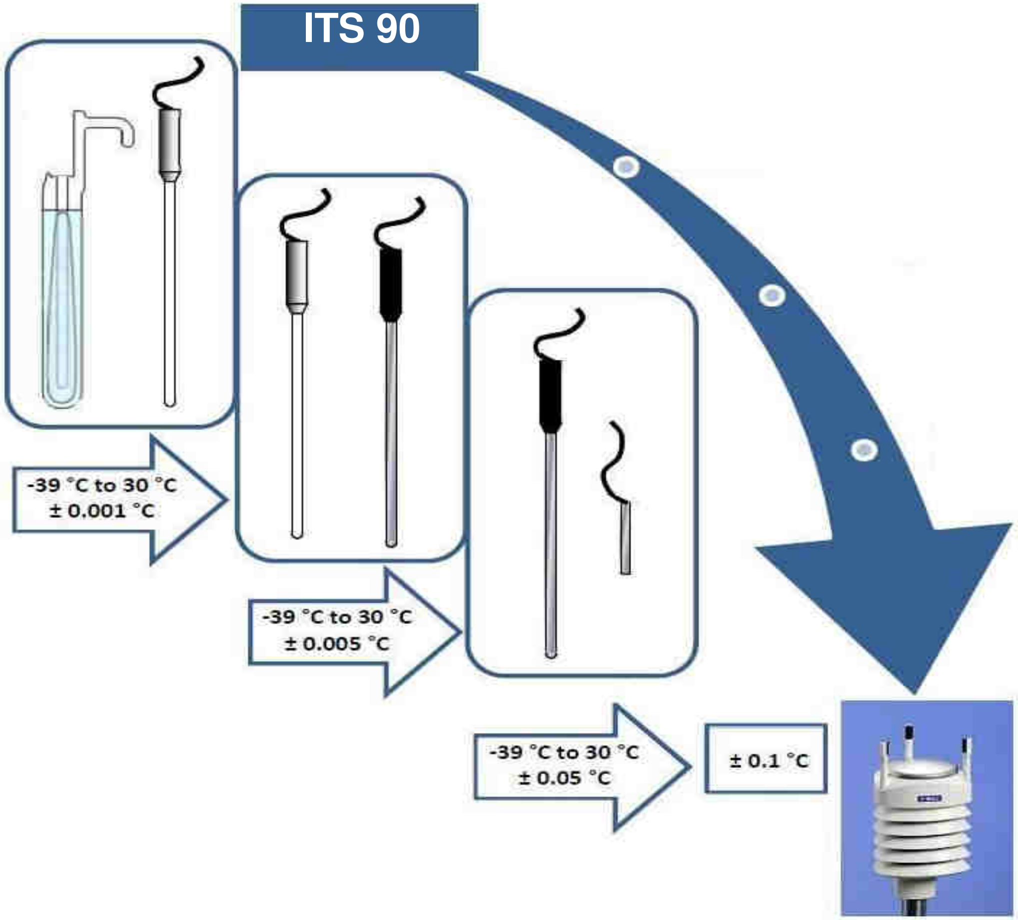
is NOT

the measurement uncertainty.

Traceability (Riferibilità metrologica)

"property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty".

*property of a measurement result whereby the result is related to a reference through a documented unbroken chain of calibrations, and the measurement uncertainty is composed of each of the calibration uncertainties **and contributions due to the measurement conditions.***


ITS 90
-39 °C to 30 °C
± 0.001 °C
-39 °C to 30 °C
± 0.005 °C
-39 °C to 30 °C
± 0.05 °C
± 0.1 °C

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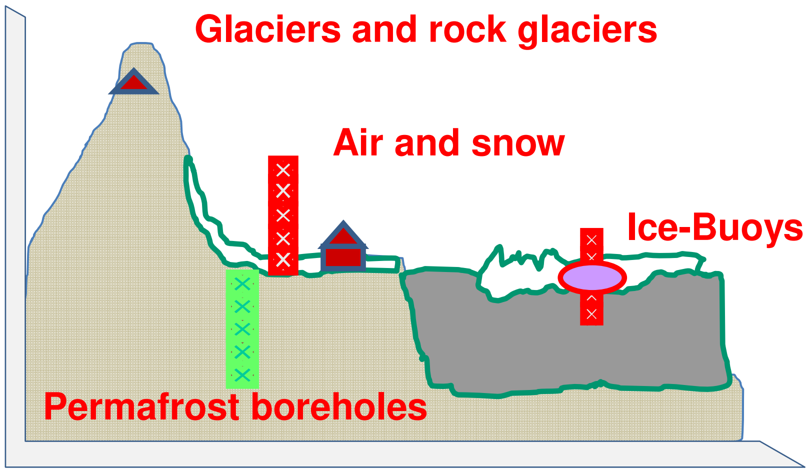
ITS 90

TRACEBILITY

Traceability is required to reach full comparability

- Comparability on climate-change scales
- Comparability to fundamental physical models
- Comparability across generations
- Comparability across borders & organizations
- Comparability across metodologies



Did you know?...

***New* SI in 2018**. Based on fundamental constants.

Last values submission to CODATA: **01 July 2017**

Adoption of new SI: CGPM **2018**

Practical change in the defined standards: **20 May 2020**

The (new) SI will be the system of units in which:

- the ground state hyperfine splitting frequency of the caesium 133 atom $(^{133}Cs)_{hfs}$ is exactly 9 192 631 770 hertz,
- the speed of light in vacuum c is exactly 299 792 458 metre per second,
- the Planck constant h is exactly 6.626 06X x 10^{-34} joule second,
- the elementary charge e is exactly 1.602 17X x 10^{-19} coulomb,
- the Boltzmann constant k_B is exactly 1.380 6X x 10^{-23} joule per kelvin,
- the Avogadro constant N_A is exactly 6.022 14X x 10^{23} reciprocal mole,
- the luminous efficacy K_{cd} of monochromatic radiation of frequency 540 x 10^{12} Hz is exactly 683 lumen per watt,

New definition of the kelvin.

The kelvin, symbol* K*, is the SI unit of thermodynamic temperature; its magnitude is set by fixing the numerical value of the Boltzmann constant to be equal to exactly* 1.380 65X × 10^{-23} *when it is expressed in the SI base unit* s^{-2} m^{2} kg K^{-1}*, which is equal to* J K^{-1}*.

Thus one has the exact relation k = 1.380 65X × 10^{-23} J/K. The effect of this definition is that the kelvin is equal to the change of thermodynamic temperature T that results in a change of thermal energy kT by 1.380 65X × 10^{-23} J.

But no worries…

ITS-90 will remain for years (decades…).

And temperature will still be measured and expressed in kelvin (K) or degrees Celsius (°C).

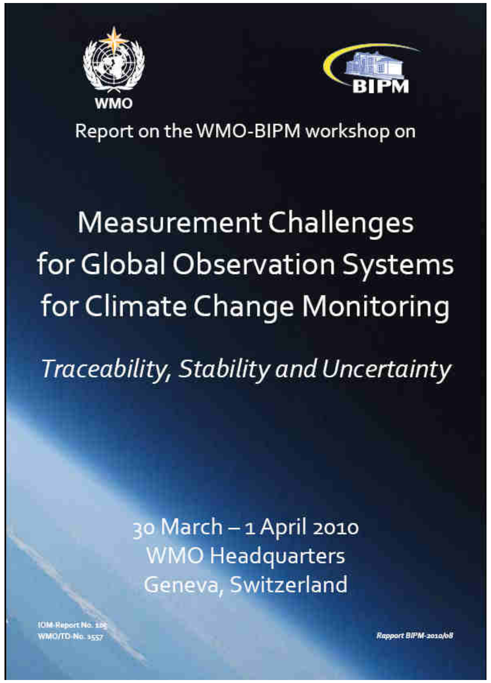
And the conversion from kelvin to dgrees Celsius does not introduce any uncertainty.

World Meteorological Organization
Working together in weather, climate and water

MRA

BIPM

Michel Jarraud, Secretary General of the WMO, signed the Arrangement on behalf of the WMO. The signing ceremony took place on *1 April 2010*



Left to right: Len Barrie (WMO), Andrew Wallard (Director BIPM), Michel Jarraud (Secretary General WMO), Ernst Göbel (President CIPM), Wenjie Zhang (WMO)

2010 May 4-7.
XXV Comité Consultatif de Thermométrie (CCT) meets and prepares a significant reccomendations for the CIPM.

2014 CCT launches WG ENV - A. Merlone Chair

25th Meeting of the
CCT • 51

RECOMMENDATION T 3 (2010)
On climate and meteorological observations measurements

The Consultative Committee for Thermometry (CCT),

considering that

- global average temperature records are essential in understanding how the climate is changing;
- the consequences of these changes have deep impacts on different aspects of social, political and economic life;
- the need exists to improve the quality of data collection by assuring worldwide traceability in measurements involved in climate studies and meteorological observations, as expressed by climate-data users and during the recent WMO-BIPM joint workshop on "Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty" (Geneva March 2010);
- the signing of the MRA by WMO will lead to closer liaison and cooperation with the thermal metrology community;

recommends

- to encourage NMIs and the scientific community, especially temperature metrologists, to be prepared to face new perspectives, needs, projects and activities related to the traceability, quality assurance, calibration procedures and definitions for those quantities involved in the climate studies and meteorological observations;

quality assurance needs of the climate change and monitoring communities.

- to support a strong cooperation between NMIs and Meteorological Institutions at local, national and international levels;
- to encourage NMIs to work with the relevant meteorological networks to support a monitoring framework for traceable climate data over long temporal terms and wide spatial scales based on best practice metrology;

EURAMET is the European Association of National Institutes of Metrology.

Manages the European research programs in metrology, under the article 185.

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EURAMET

EURAMET Task Group Environment. Established 2014 to contribute to the **Strategic Research Agenda**

Convener:
Andrea Merlone

2011 October 1.

MeteoMet Joint Research Project official start date!

METEOMET

2011 -> 2017

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METEOMET

Metrology for Meteorology

11 M€ Budget

300 Deliverables

960 Man months

(80 years!)

Meteomet is a EURAMET joint research project

MeteoMet is the

larger EURAMET consortium

24 National Institutes of Metrology

12 Universities

13 Research centers

9 Instrument Companies

12 Meteo agencies

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Technology position

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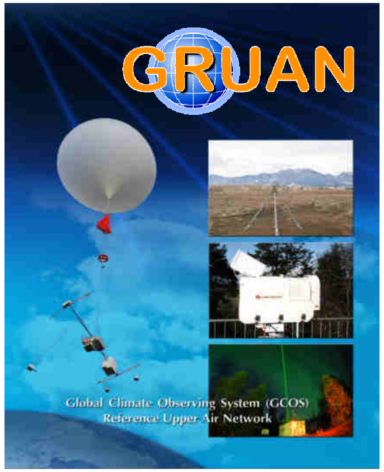
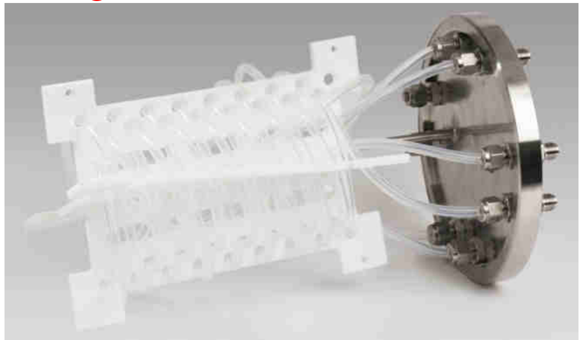
MeteoMet is the only project addressing metrology to

Radiosondes Measurements and GRUAN

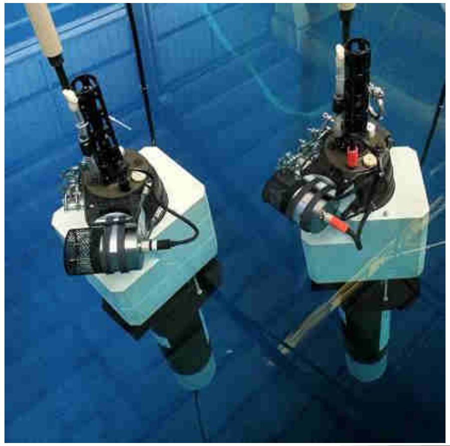


Airborne humidity sensors

Water vapour enhancement factor And portable generators



Temperature and pressure effects on new generations of salinometers



Thermodynamic calibrations for environment

Technology position

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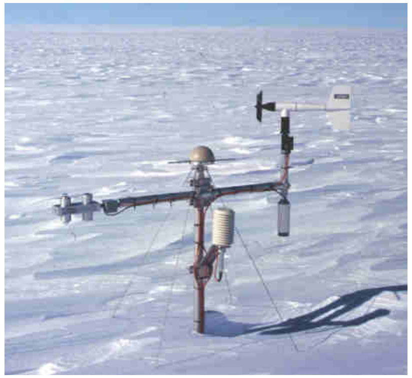
Deep sea thermometers:
•temperature-resistance linearisation model
•Pressure dependence

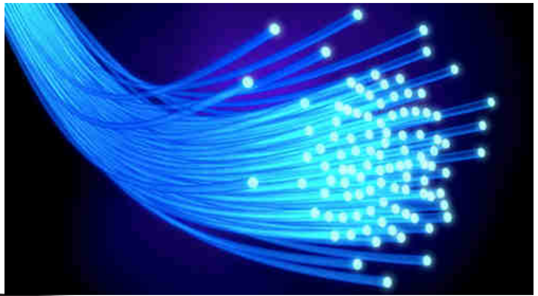
Field siting Classification and uncertainty

Permafrost measurements and snow albedo effect



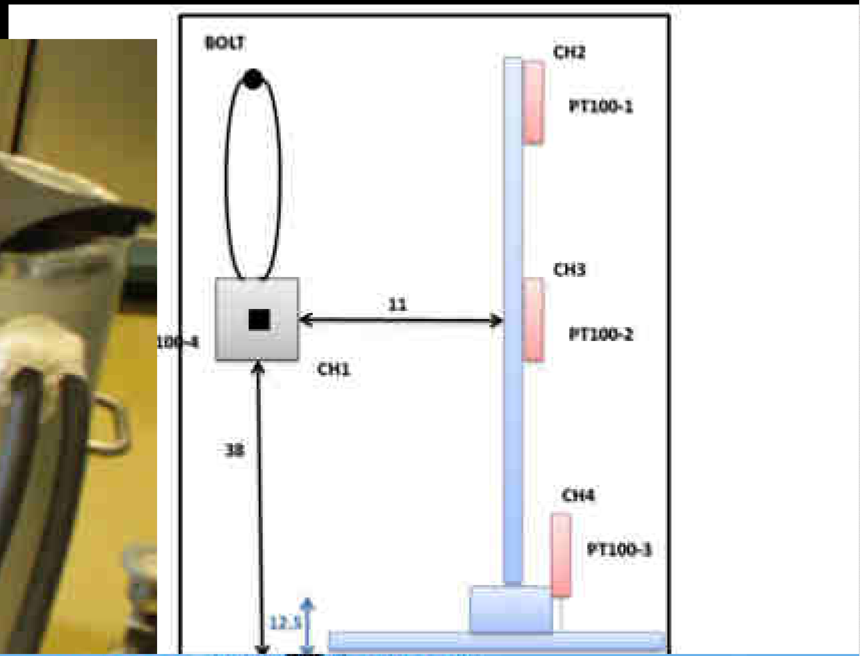
Temperature sensors dynamics and non contact thermometry

Sea temperature measurements by means of fiber optics



Metrology for the Cryosphere

July 2013 characterisation tests and training of Pyramid operators



❖ August 2013 EDIE2 goes to Kathmandu first…

EDIE-2

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Assembling the calibration chamber
and auxiliary equipment in the Everest Pyramid.


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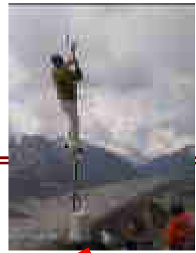
EvK2CNR

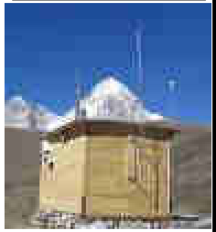
Changri Nup
(5,750 m)

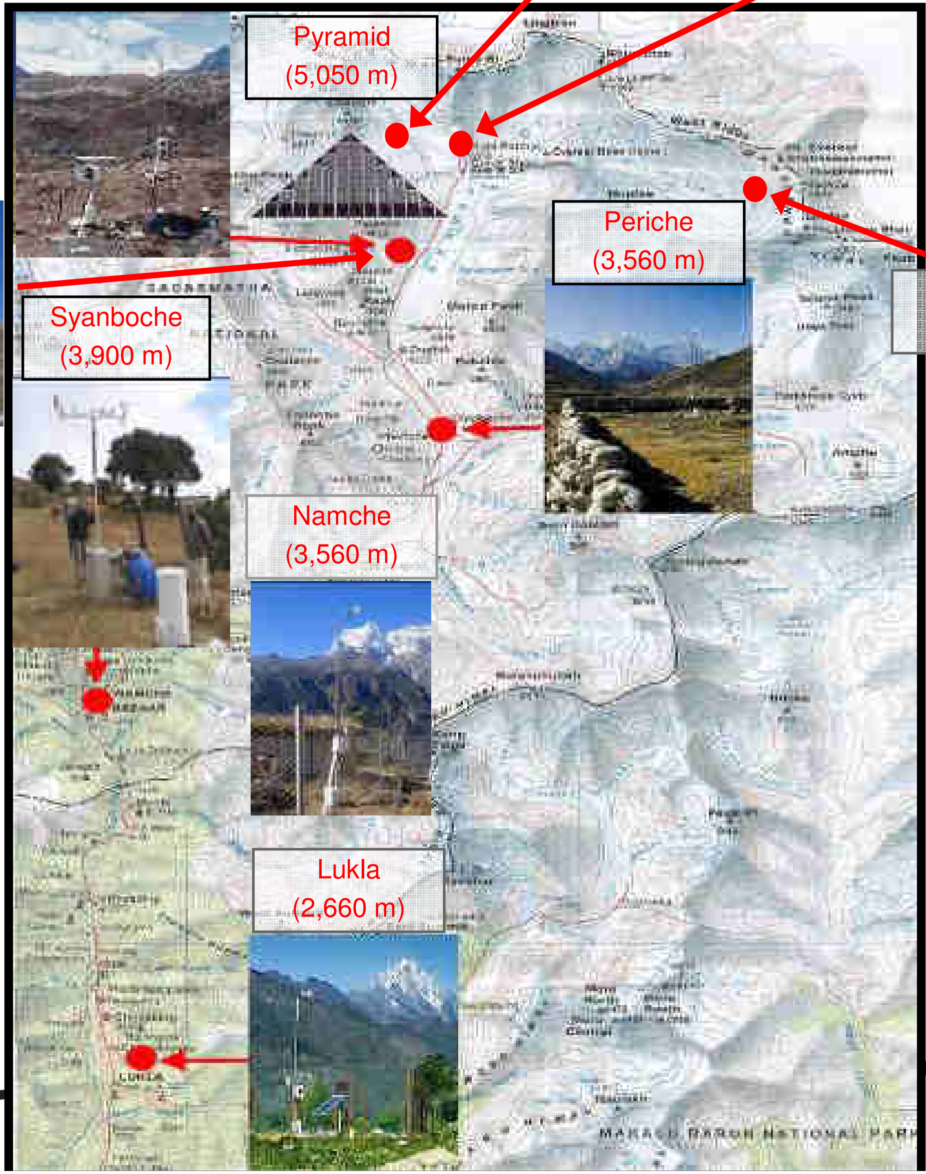


Kala Patthar
(5,550 m)

SHARE
Stations at High Altitude for Research on the Environment

NCOP-P
(5,079 m)





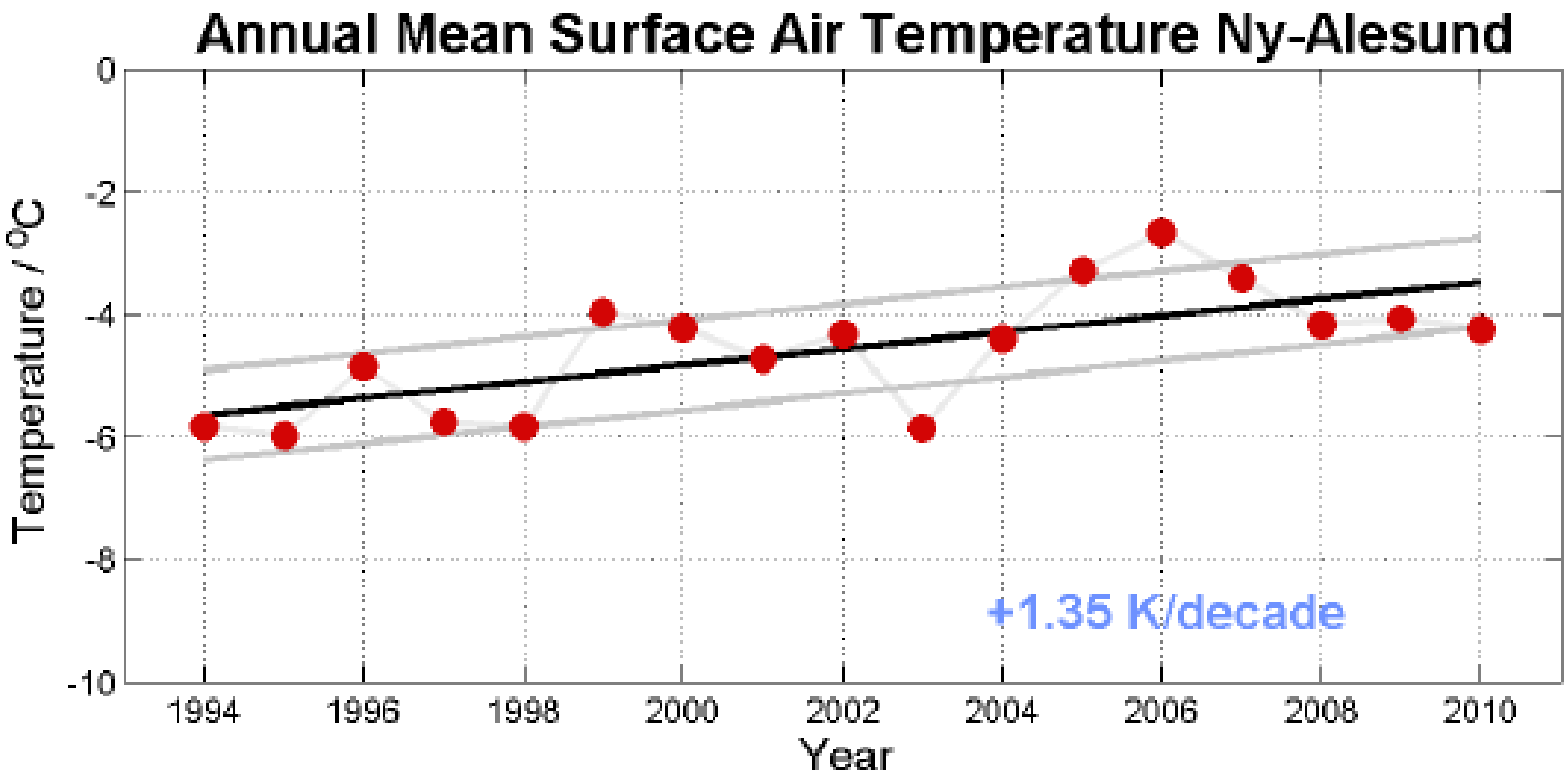
South Col
(7,986 m)

MeteoMet and SHARE project for the data traceability on the Kumbu valley and Everest Nepal side

2018/02/07

Arctic Metrology

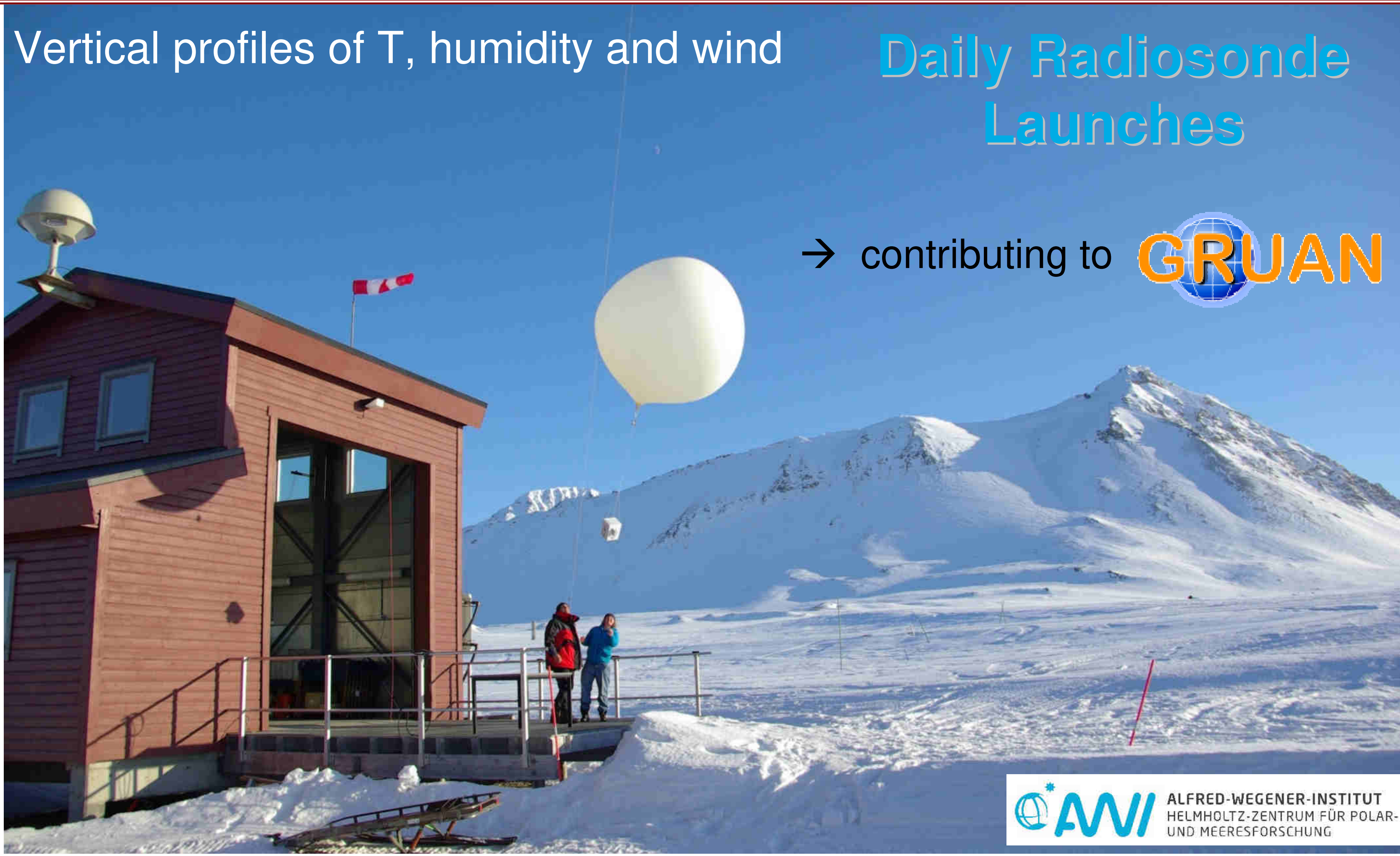
Mission “Arctic Metrology” 2014


Annual Mean Surface Air Temperature Ny-Alesund
Temperature / °C
0
-2
-4
-6
-8
-10
1994
1996
1998
2000
2002
2004
2006
2008
2010
Year
+1.35 K/decade

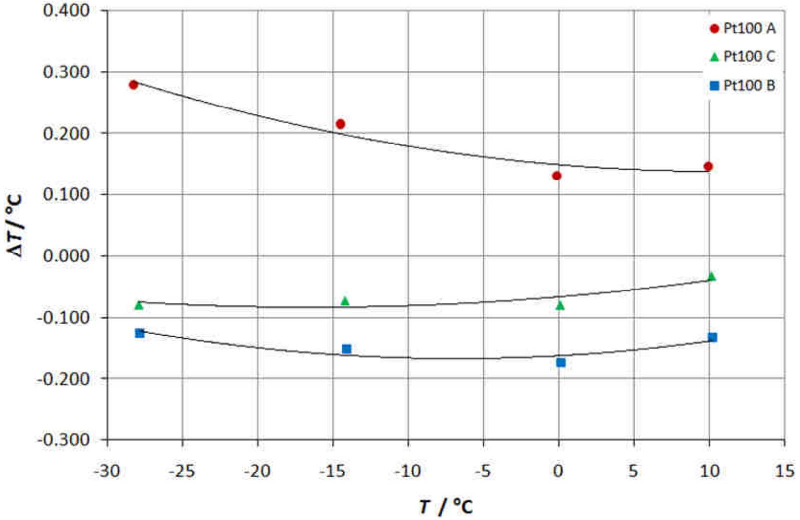
Vertical profiles of T, humidity and wind

Daily Radiosonde Launches

→ contributing to GRUAN



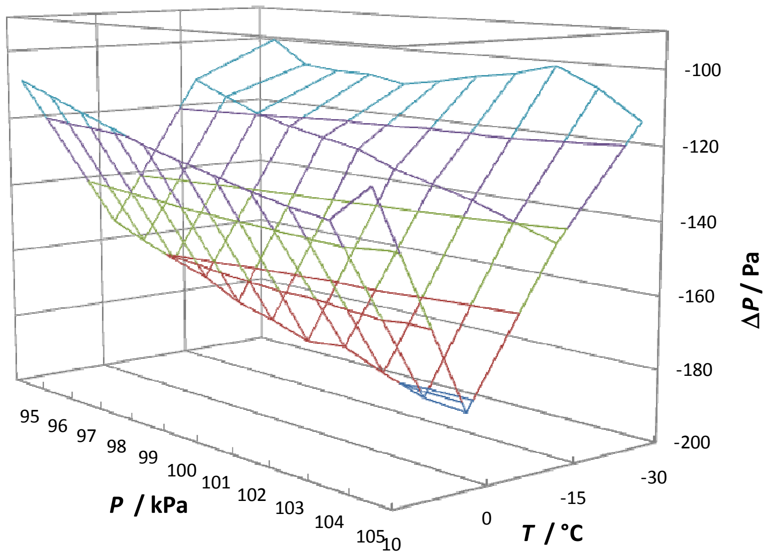
INRiM & AWI People



Calibration curves

$$T_c(T) = T - \Delta T(T) = T + a + bT + cT^2$$

Uncertainty contribution	PT100 A	PT100 B	PT100 C
Temperature reference	0.011 °C	0.011 °C	0.011 °C
Chamber uniformity	0.006 °C	0.009 °C	0.019 °C
Sensor under calibration	0.007 °C	0.008 °C	0.014 °C
Calibration curve	0.026 °C	0.017 °C	0.018 °C
Standard Uncertainty	**0.029 °C**	**0.022 °C**	**0.026 °C**
Expanded Uncertainty (*k*=2)	**0.058 °C**	**0.044 °C**	**0.052 °C**



$$P_c(P,T) = P + a + bP + cT + dPT + eT^2$$

Uncertainty contribution	
Pressure reference	0.3 Pa
Chamber uniformity	2.5 Pa
Sensor under calibration	0.3 Pa
Calibration curve	26 Pa
Standard Uncertainty	**26 Pa**
Expanded Uncertainty (*k*=2)	**52 Pa**

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The climate Change Tower in Ny Alesund

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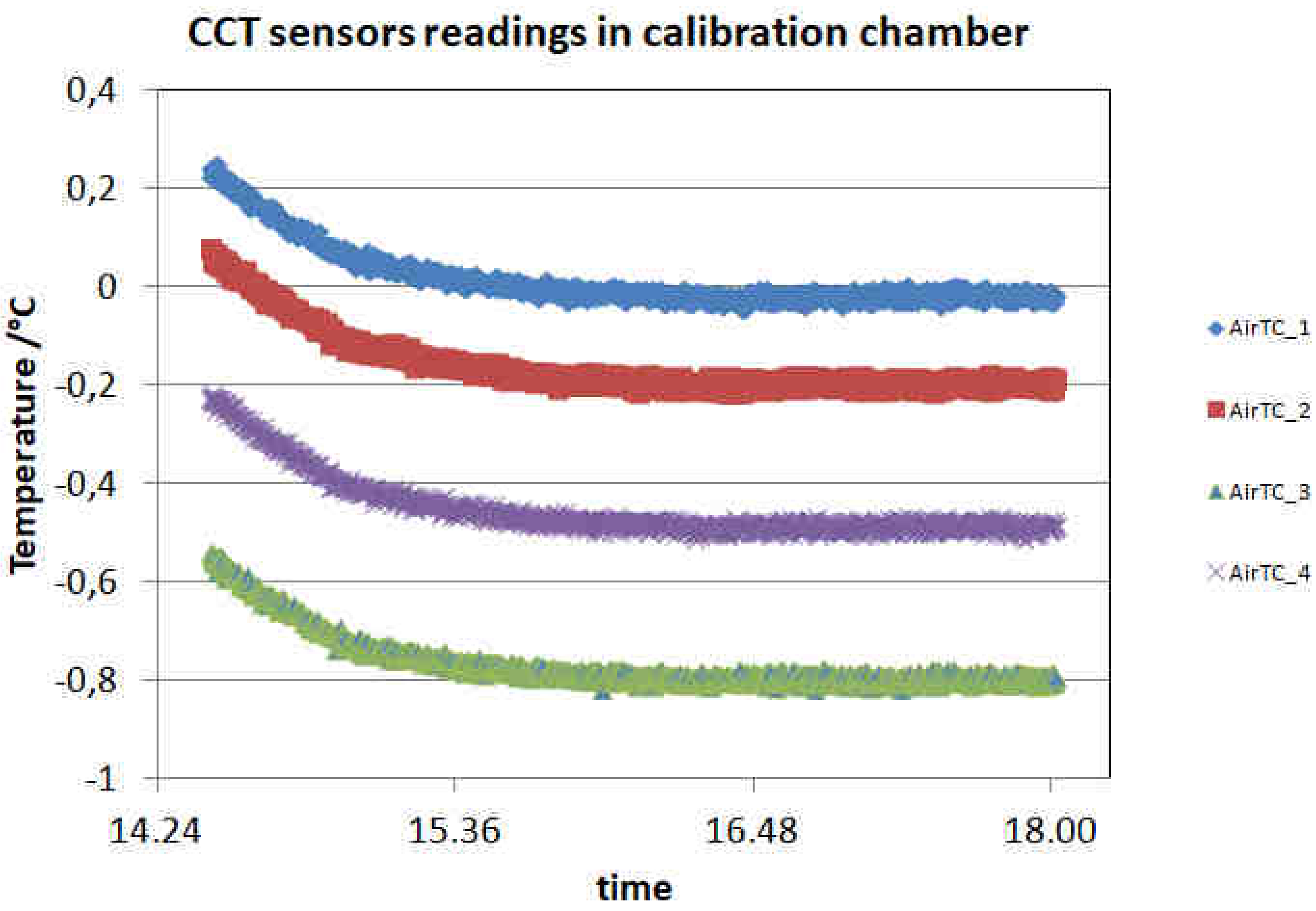
May – October 2017 metrology campaigns

4 temperature sensors and one barometer of the CCT were dismantled together with the logger.

The instruments were calibrated between -25 °C and + 15 °C and from 90 kPa to 110 kPa.

Permafrost sensors calibrated in October


CCT sensors readings in calibration chamber
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
Temperature /°C
14.24
15.36
16.48
18.00
time
AirTC_1
AirTC_2
AirTC_3
AirTC_4