CIPM

Consultative Committee for Thermometry

Working Group Environment
and
Task Group Air Temperature

Report 2022-2024

Andrea Merlone
Åge Andreas Falnes Olsen

Andrea Merlone

Åge Andreas Falnes Olsen

CCT WG ENV + TG AirT

Joint meeting

14 May 2024

10 participants in person
19 participants online

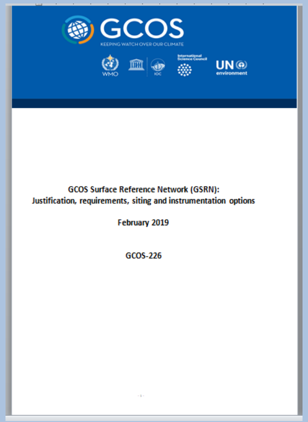
3 WMO representatives

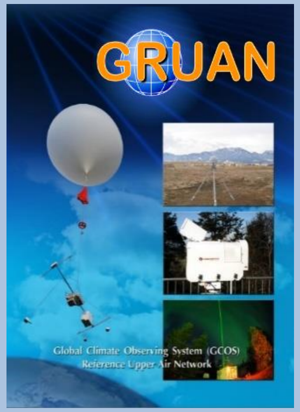
Andrea Merlone

Åge Andreas Falnes Olsen

CCT main subjects of interaction with the WMO

- Air Temperature (ground stations – upper air)
- Sea water temperature
- Permafrost temperature profile
- Cryosphere – Arctic Science
- Heat fluxes - Precipitation
- Reference stations for climate
- Uncertainties and best practices
- ILC and Istrument comparisons
- Training





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Growing involvement and personal participation

Gaber Beges + *Jovan* (LMK)
Member ET QTC
WMO ILC Coordinator

Stephanie Bell (NPL)
Member ET QTC

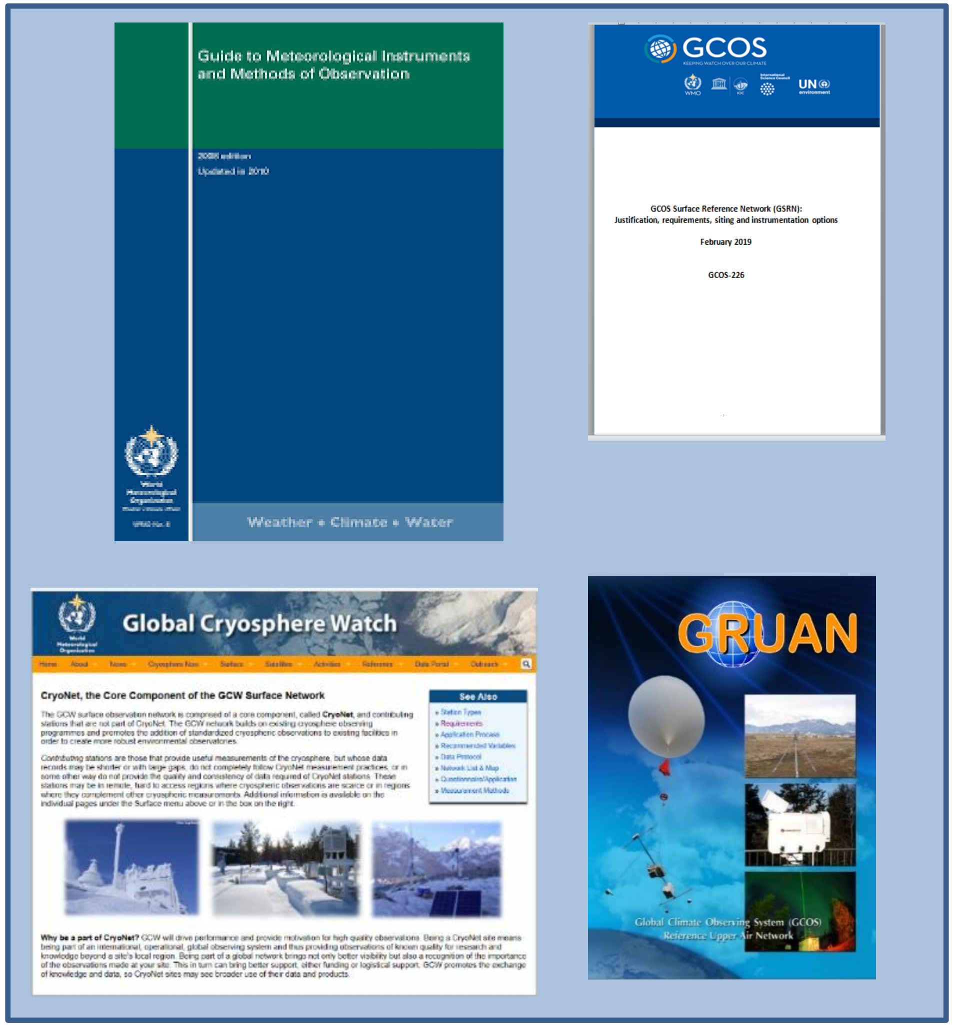
Carmen G. Izquierdo (CEM)
Member ET QTC
Member ET Surface & Sub Surface

Andrea Merlone + *Graziano* + *Chiara* (INRiM)
Chair ET MU
Chair GSRN SG5
Co-chair Permafrost best practice
National delegate at the WMO Commission and Congress
Member Standing Committee SC-MINT
Member ET QTC

Javier Garcia Skabar
Member ET QTC

Yon Gyoo-Kim
Member ET MU – ET Upper Air

DTI, JV, BEV, SMU, CNAM, LNE, INTiBS, CMI, SMD, VNIIM, NMIJ, NMIA …



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GCOS Surface Reference Network

CCT Members: Andrea Merlone, Dolores Del Campo

Provide sustained **reference quality observations, with full traceability and fully defined uncertainty**, on a global scale (on land) of at least the ECVs surface temperature and precipitation in order to quantify their variability, long-term change and inform on extremes

2023 Pilot Phase started

17 Stations preliminarily selected

Metadata format defined

Uncertainty and data product defined (A. Merlone)

GSRN Lead Center – CMA China

Andrea Merlone

Åge Andreas Falnes Olsen

INRiM

Andrea Merlone

Åge Andreas Falnes Olsen

COAT

Increasing the comparability of extreme air temperature measurements for meteorology and climate studies

2020-2023

ATM

Air Temperature Metrology

2017-2024

METEOMET

Metrology for Meteorology

2011 - 2017

CRS

Climate Reference Station

a MeteoMet initiative

2019-2023

INCIPIT

Metrology for non-catching rain instruments

2018-2022

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ATM
Air Temperature Metrology

Report from interlaboratory comparison of air thermometer calibration procedures

EURAMET project 1459

Åge Andreas Falnes Olsen, Dubhaltach MacLochlainn, Carmen García Izquierdo, Denis Smorgon, Regina Deschermeier, Carolyn Eckerleben, Florian Bubser, Michal Voldán, Magnus Holmsten, Peter Pavlasek, Milan Ioan Maniur, Seda Oğuz Aytekin, Paul Carroll, Stephanie Bell, Iska Kolaveri, Christina Hofstätter-Mohler, Jan Nielsen, Peter Rothmund, Reidun Anita Bergerud, Miruna Dobre, Debby Van Den Berghe, Jovan Bojkovski, Patrick Raab, Helmut Mitter, Tanja Vukićević, Alexandra Kowal, Justyna Dobosz, Semir Cohodarevic, Richard Högström, Emese Turzó-András, Eric Georgin, Rafał Jarosz, Slavica Simic, Evmorfia Kokkini, Javier de Lucas Veguillas, Jaime García Gallegos

19.09.2023

Justervesenet

ATM
Air Temperature Metrology

EURAMET Project 1459

Task 1.

Comparison of thermometers calibrations in air from -80 °C to +60 °C

Interlaboratory comparison protocol

Version 2.3 (Final), May 2019, amended September 2019

ATM
Air Temperature Metrology

EURAMET

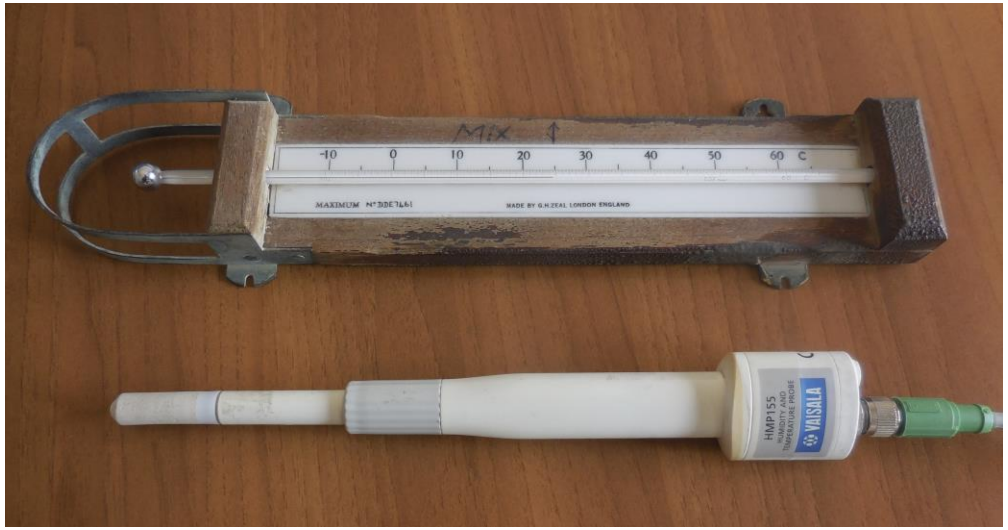
Andrea Merlone

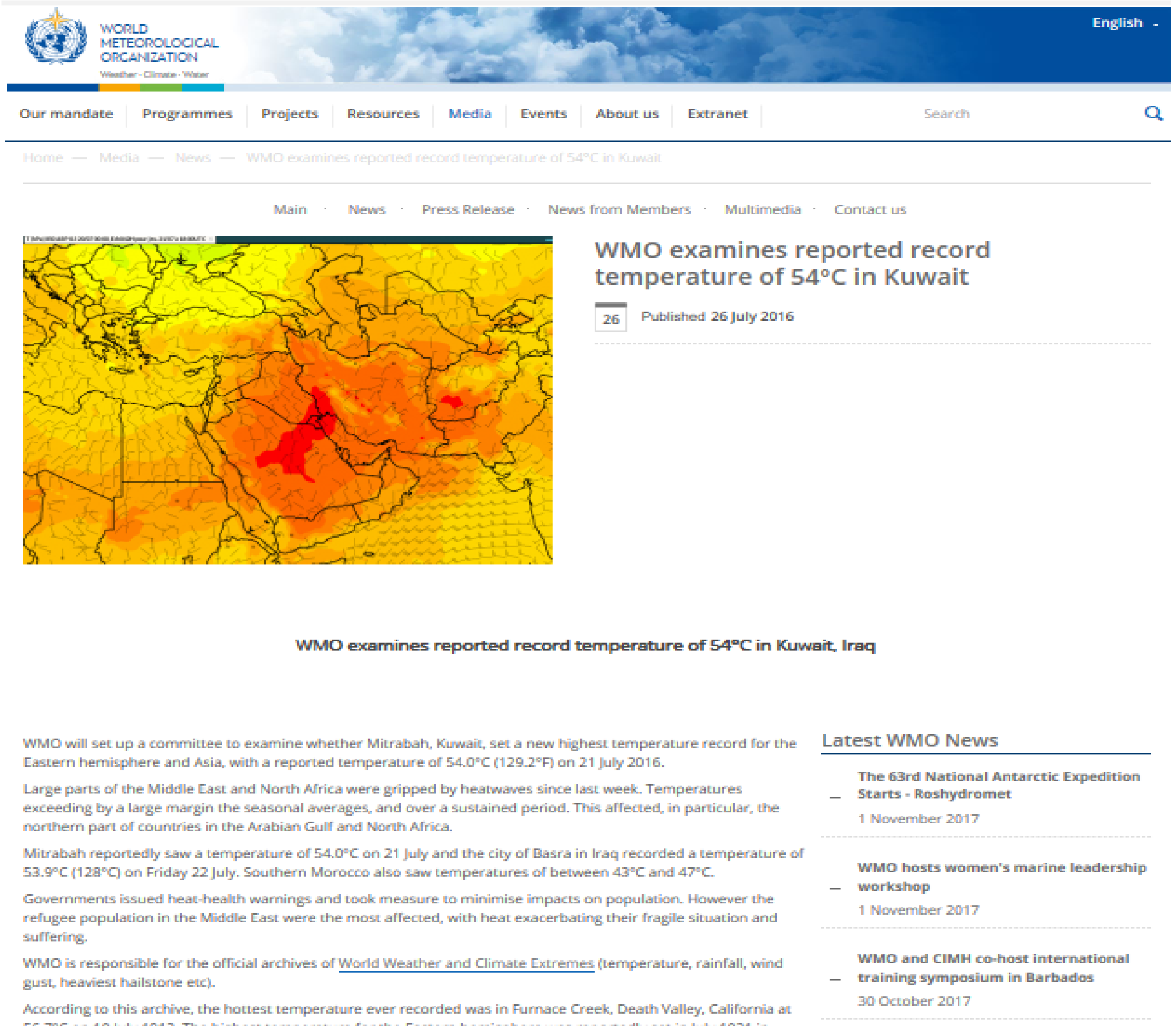
Åge Andreas Falnes Olsen

WMO Formally requests to validate two temperature records, being the third value ever recorded and the highest in Asia

2016 Mitribah - Kuwait 54 °C
2017 Turbat - Pakistan 54 °C

Study and research on conditions, heat wave, instruments, uncertainties





WORLD METEOROLOGICAL ORGANIZATION
Weather · Climate · Water

English

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Home — Media — News — WMO examines reported record temperature of 54°C in Kuwait

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WMO examines reported record temperature of 54°C in Kuwait

26 Published 26 July 2016

WMO examines reported record temperature of 54°C in Kuwait, Iraq

WMO will set up a committee to examine whether Mitrabah, Kuwait, set a new highest temperature record for the Eastern hemisphere and Asia, with a reported temperature of 54.0°C (129.2°F) on 21 July 2016.

Large parts of the Middle East and North Africa were gripped by heatwaves since last week. Temperatures exceeding by a large margin the seasonal averages, and over a sustained period. This affected, in particular, the northern part of countries in the Arabian Gulf and North Africa.

Mitrabah reportedly saw a temperature of 54.0°C on 21 July and the city of Basra in Iraq recorded a temperature of 53.9°C (128°C) on Friday 22 July. Southern Morocco also saw temperatures of between 43°C and 47°C.

Governments issued heat-health warnings and took measure to minimise impacts on population. However the refugee population in the Middle East were the most affected, with heat exacerbating their fragile situation and suffering.

WMO is responsible for the official archives of World Weather and Climate Extremes (temperature, rainfall, wind gust, heaviest hailstone etc).

According to this archive, the hottest temperature ever recorded was in Furnace Creek, Death Valley, California at

Latest WMO News

- The 63rd National Antarctic Expedition Starts - Roshydromet
  1 November 2017
- WMO hosts women's marine leadership workshop
  1 November 2017
- WMO and CIMH co-host international training symposium in Barbados
  30 October 2017

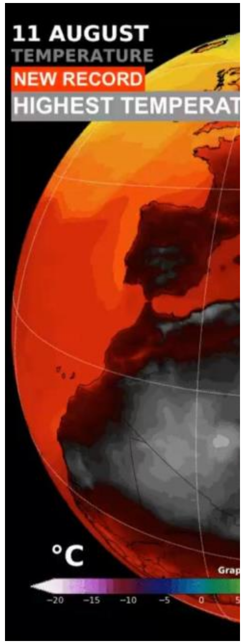
Andrea Merlone Åge Andreas Falnes Olsen

Temperatu ... y

WMO Con

Data and

Results pu



WORLD METEOROLOGICAL ORGANIZATION
Weather Climate Water

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Home / WMO confirms verification of new continental European temperature record

WMO confirms verification of new continental European temperature record

NEWS

30 January 2024

The World Meteorological Organization (WMO) has officially confirmed a new record temperature for continental Europe of 48.8°C (119.8°F) in Italy on 11 August 2021. The findings were published in the International Journal of Climatology.

Andrea Merlone

Åge Andreas Falnes Olsen

Contribution to the WMO Guidelines for the evaluation of weather and climate extremes

The following are thanked for their outstanding contributions to this publication:

- Thomas C. Peterson, President of the former WMO Commission for Climatology, retired from the National Oceanic and Atmospheric Administration (NOAA), United States of America
- Derek Arndt, NOAA/National Centers for Environmental Information (NCEI), USA
- Randall S. Cerveny, Arizona State University, USA
- Fatima Driouech, Direction de la météorologie nationale du Maroc, Morocco
- Philip Jones, University of East Anglia (UEA)/Climatic Research Unit (CRU), United Kingdom of Great Britain and Northern Ireland
- Bianca Le, Monash University, Australia
- Andrea Merlone, Istituto Nazionale di Ricerca Metrologica (INRiM), Italy
- Blair Trewin, Bureau of Meteorology, Australia
- Xuebin Zhang, Environment and Climate Change Canada, Canada

WMO Secretariat:

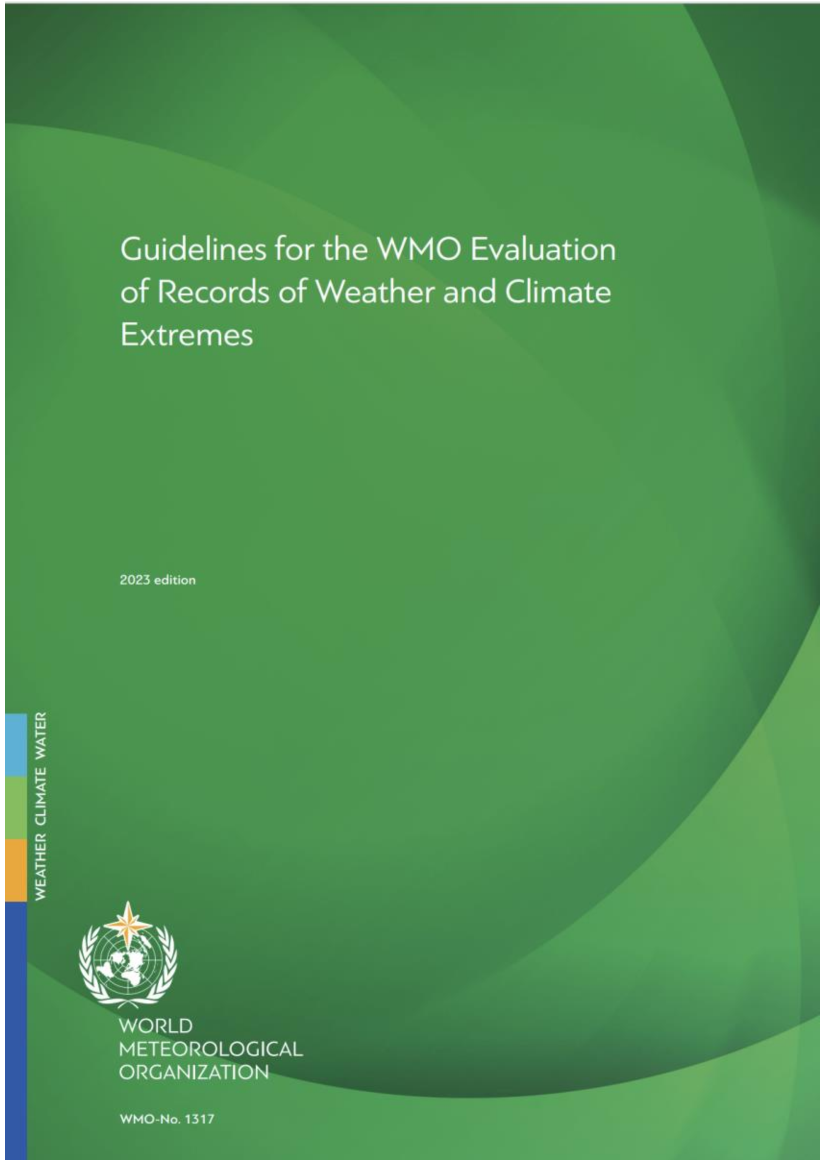
- José Álvaro Pimpão Silva
- Clare Nullis
- Krunoslav Premec

The review of these guidelines by experts from the following expert teams is highly appreciated:

- Expert Team on Climate Monitoring and Assessment (ET-CMA)
- Expert Team on Quality, Traceability and Calibration (ET-QTC)
- Expert Team on Measurement Uncertainty (ET-MU)

The following WMO Secretariat staff also contributed to the development of these guidelines or helped to review this publication:

- Omar Baddour
- Maxx Dilley
- Peer Hechler
- Nirina Ravalitera
- Isabelle Ruedi
- Igor Zahumensky



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Corrections on temperature profiles

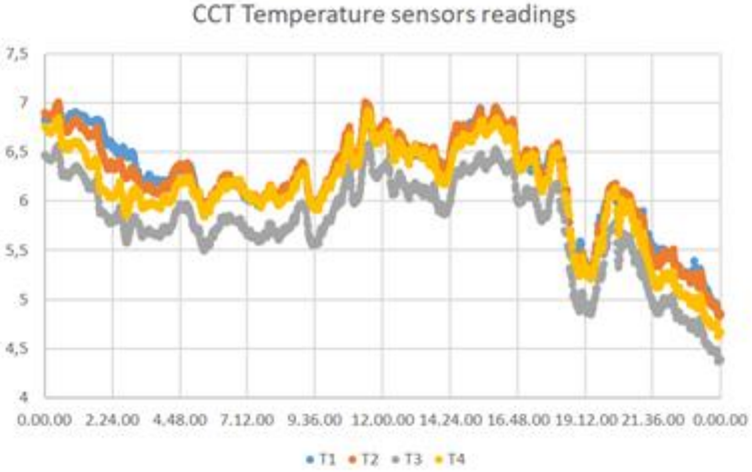
13/07/2017

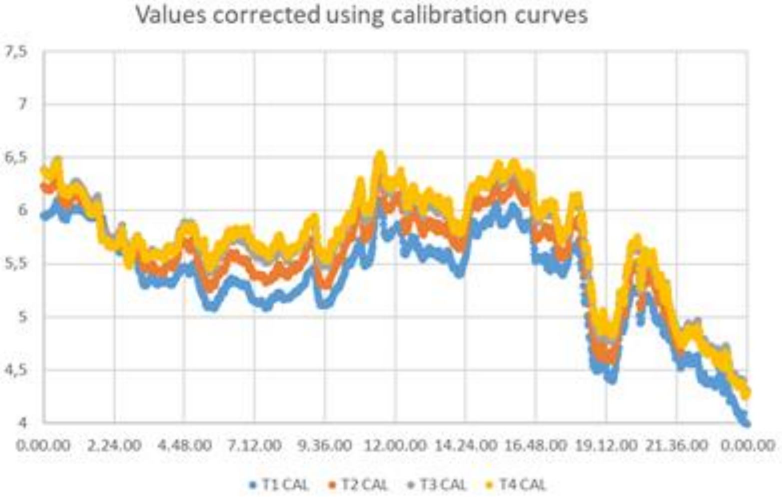
T1 34 m

T2 10 m

T3 5 m

T4 2 m





Paper under second run of revision

Andrea Merlone | Åge Andreas Falnes Olsen

COAT Intercomparison of thermometers and solar shields in Arctic Environment – Svalbard 2022-2023

Andrea Merlone

Åge Andreas Falnes Olsen

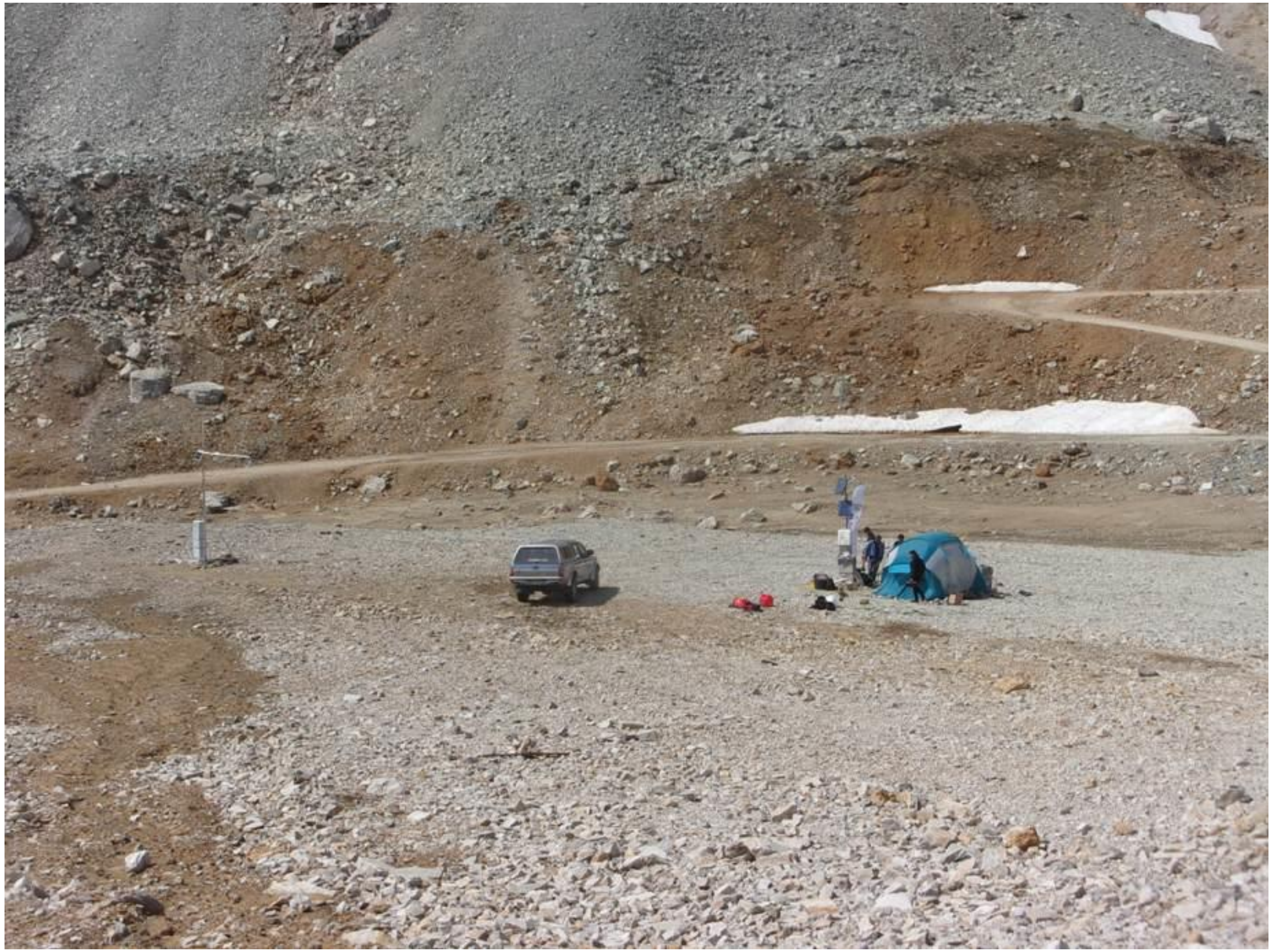
"Permafrost best practice"

3 yars of work involving the WMO, the GCW, the GTNP, the IPA, research Institutes and accademia.

Permafrost temperature measurements, to detect permafrost melting, depth and profiles.

It contains paragraphs on

4.2.3.6 Calibration
4.2.3.5 Uncertainty



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The **decision** presented **“without debate”**

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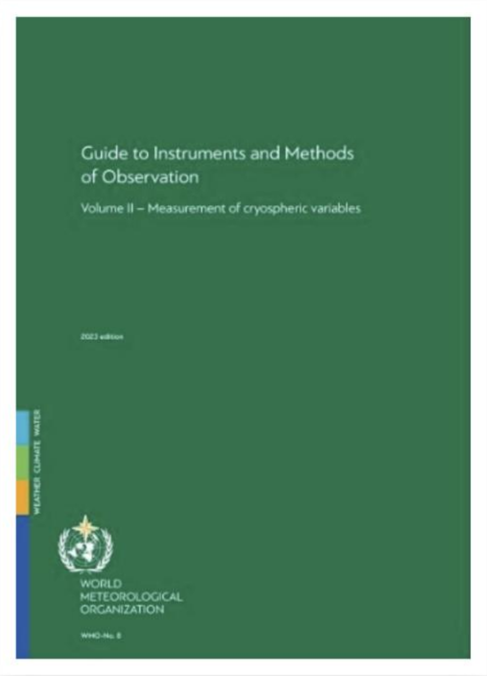


Guide to Instruments and Methods of Observation

Volume II – Measurement of Cryospheric Variables

WMO-No. 8

Collection(s)	Technical Guides and other guidance
Authors	World Meteorological Organization (WMO)
Published by	WMO
Published in	Geneva

Approved in April 2024

GCW Permafrost - Guide on Best Practices

(Work in Progress by the Permafrost Task Team of the GCW Advisory Group)

Under the guidance of the GCW Advisory Group and in coordination with the GCW Best Practices Coordinator, the Permafrost Task Team developed the Permafrost Best Practices Guide. It will be included in the WMO Guide for Instruments and Methods of Observation (WMO No.-8), Volume II, Measurement of Cryosphere Variables Chapter 4.

The guidelines cover measured variables, the ... observa... m... used instrumentation, the required co... a... the ...vant ... reporting aspects.

DRAFT

Andrea Merlone

Åge Andreas Falnes Olsen

SoMMet

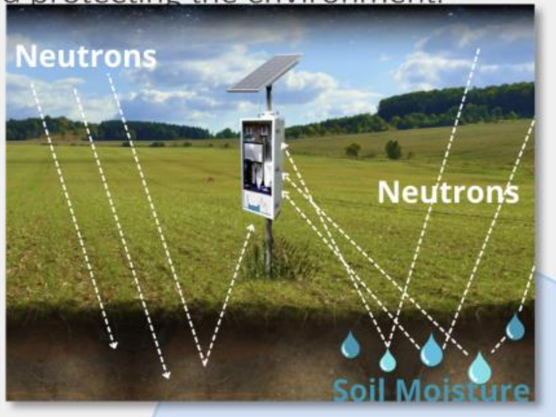
Soil Moisture Metrology

An EMP Project

Coordinator: Miroslav Zboril - PTB

Farming and Environment: Farmers use soil moisture information to decide when to irrigate crops. It's also important for managing water resources and protecting the environment.

Cosmic rays are high-energy particles (protons or atomic nuclei) that move through space at nearly the speed of light. They originate from the Sun, from outside of the Solar System in our own galaxy, and from distant galaxies. Upon impact with Earth's atmosphere, cosmic rays produce other particles, including **neutrons**.



Neutrons reaching the **soil** interact with the hydrogen present in the water: by measuring the neutrons reflected from the soil, we can monitor the **amount of water present**.

SoMMet: Soil Moisture Metrology.
A European project to improve measurements of soil moisture

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CRS

Climate Reference Station

a MeteoMet initiative

«Climate Reference Station»

Coordinator: A. Merlone

Primary supporter: WMO

Andrea Merlone

Åge Andreas Falnes Olsen

WEATHER CLIMATE WATER

World Meteorological Organization

COMMISSION FOR WEATHER, CLIMATE, WATER AND RELATED ENVIRONMENTAL SERVICES AND APPLICATIONS

First Session (Second Part)
22 to 26 February 2021, Virtual Session

SERCOM-1(II)/
Doc. 5.1.3(4)

Submitted by:
Chair

25.II.2021

APPROVED

AGENDA ITEM 5: **TECHNICAL REGULATIONS AND OTHER TECHNICAL DECISIONS**

AGENDA ITEM 5.1: **Decisions requiring approval by the Services Commission at this Virtual Session**

AGENDA ITEM 5.1.3: ***Standing Committee on Climate Services (SC-CLI)***

CLIMATE SERVICES REQUIREMENTS FOR CLIMATE REFERENCE STATIONS

2.1 Definition of climate reference data

Climate reference data is a series of traceable measurement results able to quantify the variability and change of climate-relevant variables.

Notes:

The result of the measurement is a single record of the observed parameter, while the overall measurand is the variability and change of the variable.

To be traceable, a measurement result requires that each instrument involved in the measurement process is related to a reference standard of the System of Units (SI) or other standards through a documented unbroken chain of calibrations.

The absolute requirement of a measurement is that it be made in such a way that after accounting for all sources of uncertainty it can be concluded that the true value of the measurand lies within the reported uncertainty interval with specified confidence. The result of a reference-grade measurement is such that it can be used to improve the quality of other (lower-tier) measurements.

Andrea Merlone

Åge Andreas Falnes Olsen

WMO Measurement Lead Center
Traceability and Field Metrology

METEOMET
Metrology for Meteorology

World Meteorological Organization

INRiM
ISTITUTO NAZIONALE DI RICERCA METROLOGICA

The research infrastructure
In Metrology for Meteorolgy

Andrea Merlone

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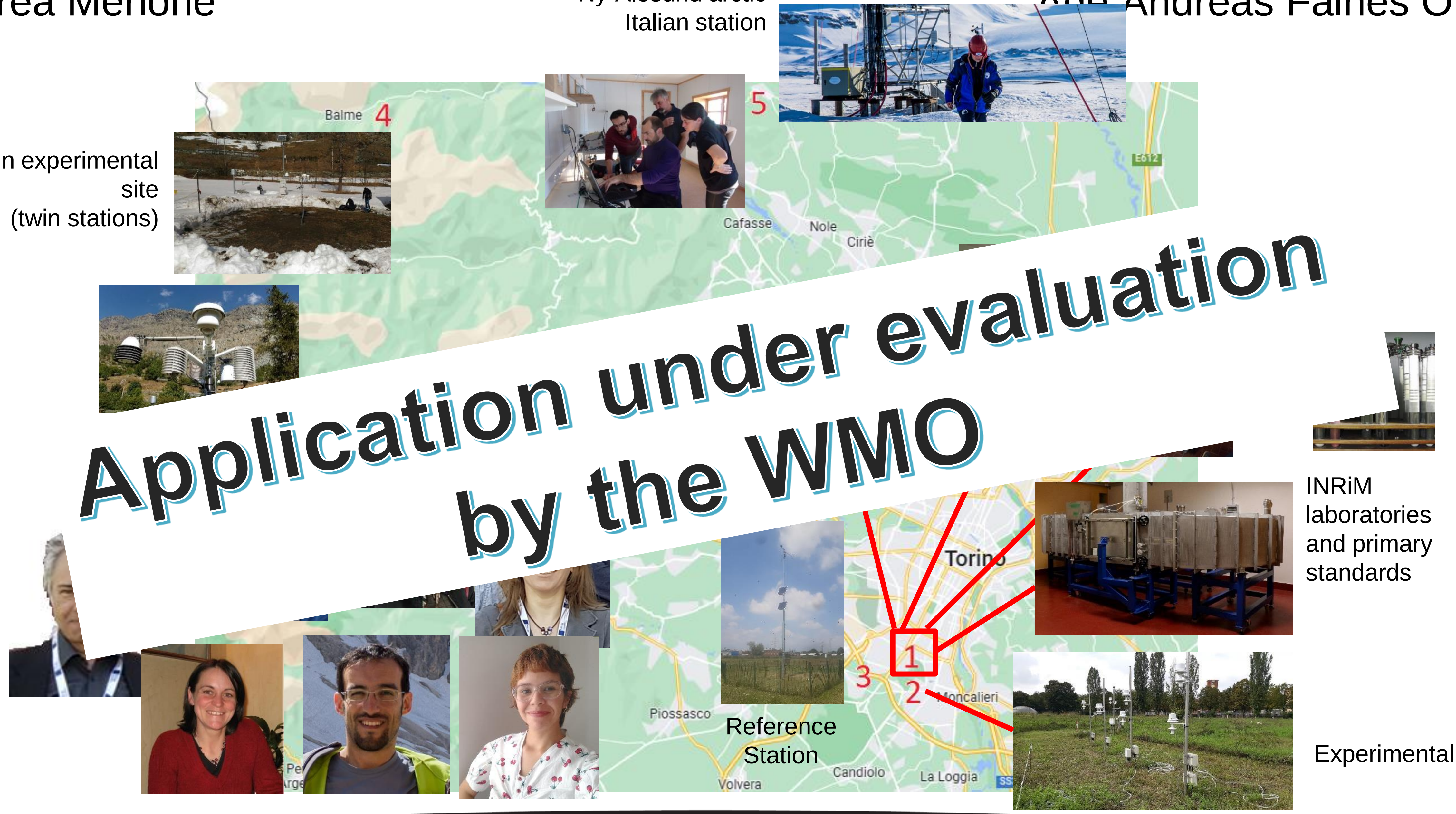

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MMC Torino 2023

METROLOGY FOR METEOROLOGY AND CLIMATE

Venues

MMC Torino 2023
METROLOGY FOR METEOROLOGY AND CLIMATE

Palazzina di Caccia di Stupinigi

INRiM

Venues

MMC Torino 2023
METROLOGY FOR METEOROLOGY AND CLIMATE

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MMC Torino 2023

METROLOGY FOR METEOROLOGY AND CLIMATE

150 participants

- Scientific sessions
- Meetings of WMO Ets
- Meeting og GCOS-GSRN
- Training of Marine scientists
- MINKE project meeting
- Cultural and scientific visits

GCOS

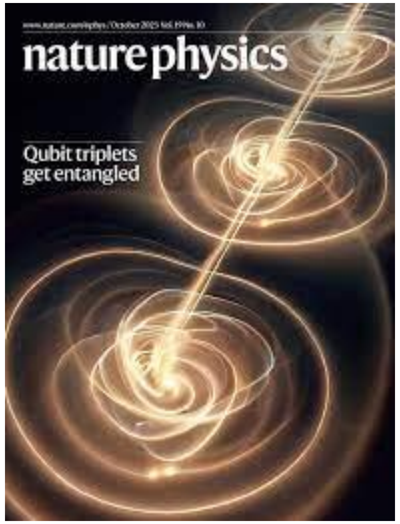
Global Climate Observing System

WMO

SC-MINT (Standing Committee on Measurements, Instrumentation and Traceability)

INRiM Scientific production

Nature physics – V. 19 – October 2023



A difference of consequence

Check for updates

Metrology and meteorology: just two letters separating two similar and frequently confused words. Andrea Merlone, Chiara Musacchio and Walter Bich tell us about these different disciplines and ways in which they collaborate.

The World Meteorological Organization and the International Committee for Weights and Measures were created in the same period when humanity began to understand the importance and value of a common and global view on natural phenomena together

measurement methods, understand uncertainties and establish traceability. MeteoMet inspired research projects ranging from deep-sea measurements to Mount Everest research, from South America to the Arctic.

and it was used recently to confirm the highest European temperature ever recorded of 48.8 °C on 11 August 2021 in Sicily.

Also at low temperatures, metrology is here to stay in climatology. In 2014 a laboratory took up its work calibrating instruments and improving analysis of uncertainties to support environmental observations in Ny-Ålesund, the northernmost inhabited village, which hosts arctic research stations of eleven nations[4].

Another effort is related to a calibration tent in the Alps, equipped with high-quality thermal baths, resistance bridges and temperature standards. It can operate up to altitudes of 3,000 m for the onsite calibration of permafrost temperature sensors at the level

Andrea Merlone

Åge Andreas Falnes Olsen

Measure for measure

https://doi.org/10.1038/s41567-024-02428-w

The air temperature conundrum

Check for updates

Measuring air temperature is far from a trivial task, as Andrea Merlone, Graziano Coppa and Chiara Musacchio explain.

If you happen to have a thermometer within reach, try measuring the air temperature. As you will discover, this is much more difficult than it seems.

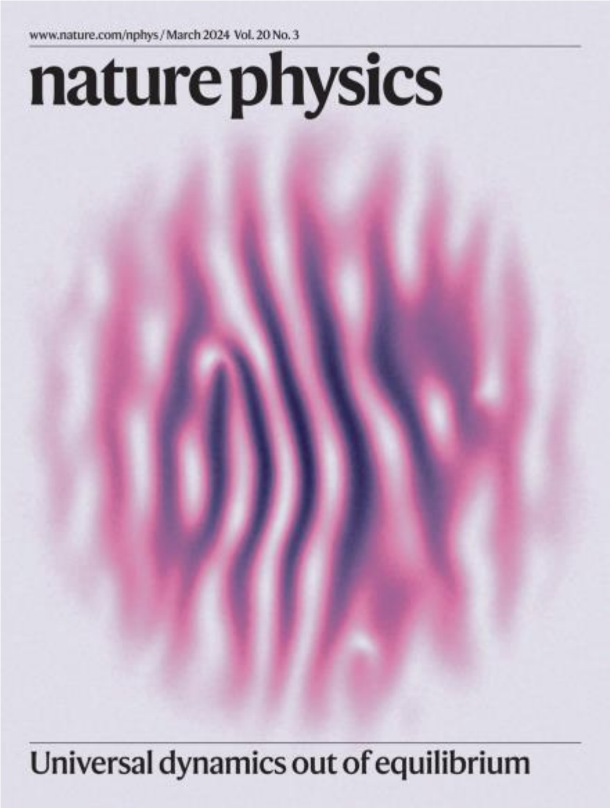
The results will be affected by radiative heat, so the thermometer needs to be protected from sunlight. If you are indoors, you will have to consider how to define room temperature and where to measure it. Or if you are outdoors, you will need to ask how representative the measurement will be. Pictured is a setup used to study the effect of meteorological thermometers' distances from the ground.

Indoors, you will experience temperature gradients – from the floor to the ceiling – or

establish comparability among different

Temperature is a key quantity in climatology and the main observable we have for assessing whether climate change mitigation efforts will be efficient. The Intergovernmental Panel on Climate Change requires a careful consideration of the impacts associated with a global temperature increase of over 1.5 °C above pre-industrial levels. Thus air temperature needs to be measured and compared with historical records in locations where the effects of climate change are amplified, such as in the Arctic.

With both those needs and challenges in mind, the metrology and meteorology communities have started to work in close and intense cooperation, for example in a Task Group focusing on air temperature with three main goals: providing a definition of air temperature, assessing the corresponding measurement uncertainty, and publishing an international guideline for the calibration of thermometers in air.



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REVIEW ARTICLE | Free to Read

Evaluation of the highest temperature WMO region VI Europe (continental): 48.8°C, Siracusa Sicilia, Italy on August 11, 2021

Andrea Merlone, Luigi Pasotti, Chiara Musacchio, Pierre Bessemoulin, Manola Brunet, Khalid El Faldi, Philip Jones, Gerard van der Schrier, Adriano Raspanti, Blair Trewin, Dan Krahenbuhl, Randall Cerveny

First published: 30 January 2024 | https://doi.org/10.1002/joc.8361

Read the full text >

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Abstract

A maximum temperature of 48.8°C (119.8°F) was purportedly recorded for the automated station in Siracusa (Syracuse) Contrada Monasteri, on the island of Sicilia (Sicily) Italy on August 11, 2021. A World Meteorological Organization (WMO) ad hoc evaluation committee was assembled to assess the possibility that the Sicilia temperature was the highest recorded temperature in WMO Region VI (continental only). After a detailed review of the site considerations and of the regional synoptic weather conditions, combined with detailed sensor testing and calibration by the Istituto Nazionale di Ricerca Metrologica (INRiM), the WMO evaluation committee concluded (and the Rapporteur accepted) that (1) on August 11, 2021 the high temperature recorded for the automated station in Siracusa C. da Monasteri, did reach a maximum value of 48.8°C (119.8°F), (2) that temperature is recommended to be listed as the WMO official "highest recorded temperature in WMO Region VI (continental only)" and (3) although, as the INRiM testing established, the recorded value of 48.8°C is actually an underestimate of the temperature, the committee recommend that the recorded (likely conservative) value of 48.8°C be the value listed in the Archive. An arbitrated archive of current weather and climate extremes is one means of ensuring that we have the best possible data for climate change analysis and public dissemination.

International Journal of Climatology — RMetS

RESEARCH ARTICLE | Open Access

Climatological reference stations: Definitions and requirements

Andrea Merlone, Gaber Beges, Alberto Bottacin, Manola Brunet, Alba Gilabert, Drago Groselj, Andrew Harper, Peer Hechler, Mirjana Ivanov ... See all authors

First published: 05 March 2024 | https://doi.org/10.1002/joc.8406

SECTIONS PDF TOOLS SHARE

Abstract

Ground-based stations are one of many observing systems contributing to the generation of data to evaluate climate trends and variations locally and globally. Networks of stations are made of various numbers of observing sites, equipped with different typologies and varieties of instruments, differently managed and maintained. Among such networks a limited number of stations are required as a reference, to provide top quality traceable measurements and as the top level of a tiered approach; it is these stations which are here designated as Climatological Reference Stations (CRS). At present, there is no

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INTiBS

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Cooperation

University of Wroclaw, Institute of Geography & Regional Development

- Department of Climatology & Atmosphere Protection

Institute of Meteorology and Water Management – National Research Institute

- Central Control Instruments Laboratory

Wroclaw University of Environmental and Life Science

University of Gdansk, Faculty of Oceanography and Geography

Institute of Oceanology Polish Academy of Sciences

Institute of Geophysics, Department of Polar and Marine Research PAS

- The Institute has a polar station on Hornsund

- Training in measurement, traceability and uncertainty estimation
- Performing measurements, checks and / or calibrations
- In-situ measurements
- New cooperation in the field of polar research
- A new national project in 2023 and new application for 2024-2026

30

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NMIA

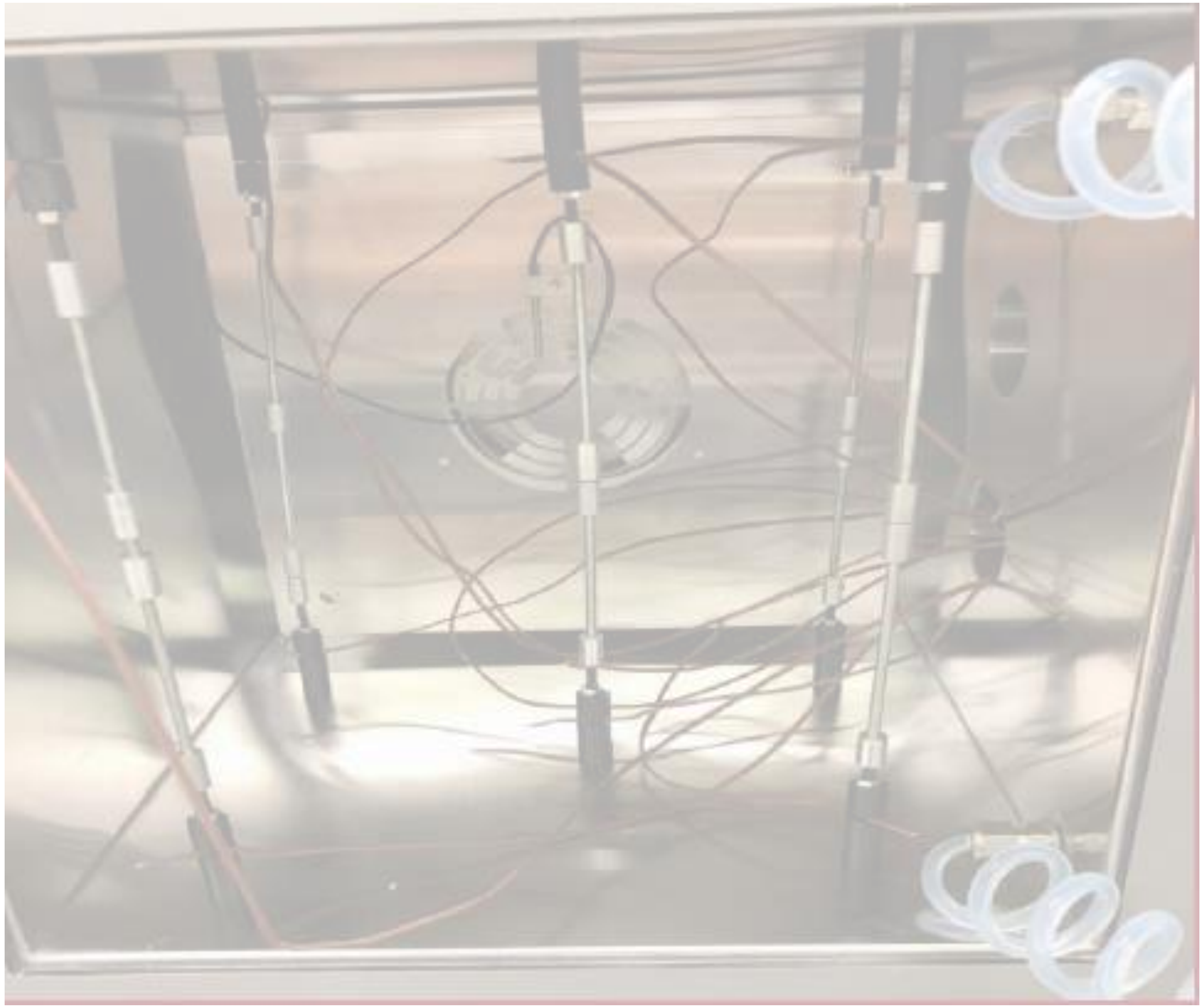
Andrea Merlone

Åge Andreas Falnes Olsen

Estimation of uncertainty in air temperature measurement using conventional calibrated PRTs

- NMIA recently purchased an ISOTECH microK-50 bridge with 10 channel scanner to map the temperature uniformity in the Thunder chamber volume and wall.
- This profile will be measured *in-situ* for every DUT calibration and used dynamically for the uncertainty budget.
- **NMIA already includes the radiation effect and self-heat when measuring in air**. However, more work has to be done when implementing dynamic profiles, *i.e.*, improve to radiation and self-heat corrections.

Australian Government
Department of Industry, Science and Resources
National Measurement Institute



Andrea Merlone

Åge Andreas Falnes Olsen

CEM

Research Activities:

1. Coordinator of **COAT** project: Comparison of thermometers and shields in the Arctic

   (October 2020- April 2024)

   Calibrations and field measurements finished

   Analysis ongoing

2. Coordinator of the Euramet Unfunded Project **CryoMet:** Metrology for Cryosphere

   Developing a **roadmap** for specific technical metrological needs on cryosphere

Membership:

1. WMO/SC-MINT-Expert team Quality, Traceability and Calibration
2. WMO/SC-MINT. Expert team on Surface and Sub-surface measurements
3. GCOS-AOPC:

Conferences and workshops:

1. Rapporteur in the cryosphere section of the **WMO-BIPM workshop: Metrology for Climate Action**
2. TECO
3. MMC

Andrea Merlone | Åge Andreas Falnes Olsen

KRISS

2. Involvement in international organization

- WMO expert activities (2022 ~ 2024)
  - WMO SC-MINT/ET-UAM (Upper Air Measurement)
  - WMO SC-MINT/ET-MU (Measurement Uncertainty)
- GRUAN activities (2022 ~ at present)
  - Participation in the GRUAN ICM-14 (2022) ICM-15 (2024) meeting
    - Presentation of three research results
- ISO activities (2022 ~ at present)
  - TC 146/SC 5/WG 11, Radiosonde
  - Three documents under development
    - ISO CD-8932-1: Laboratory Test method for calibration error of temperature sensor in radiosonde
    - ISO WD-8932-2: Laboratory test method for errors in radiosonde humidity sensor calibration
    - ISO WD-8932-3: Laboratory test method for solar radiation error of temperature sensor in radiosonde

Andrea Merlone Åge Andreas Falnes Olsen

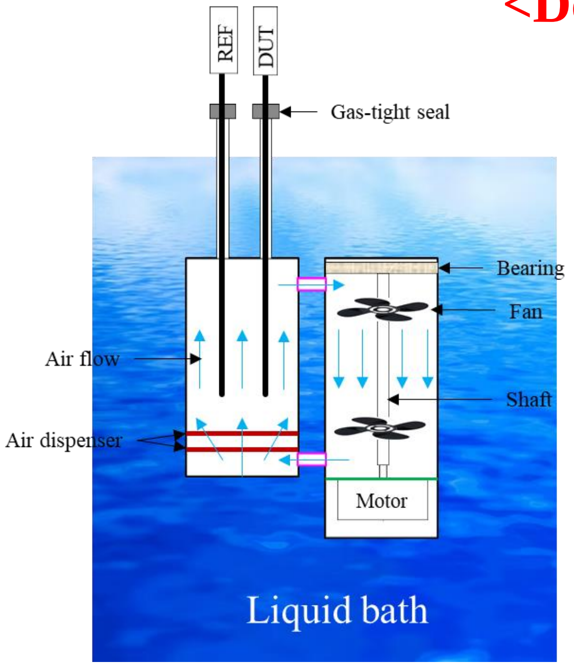
1. Activities in WG-ENV/TG-AT/Subgroup3

Conceptual design of CCT-WMO ILC

Setup of the design concept of the transfer cell for CCT-WMO ILC of air thermometer

- Two (Air Chamber + Liquid Bath) in One
- Design of circulation scheme

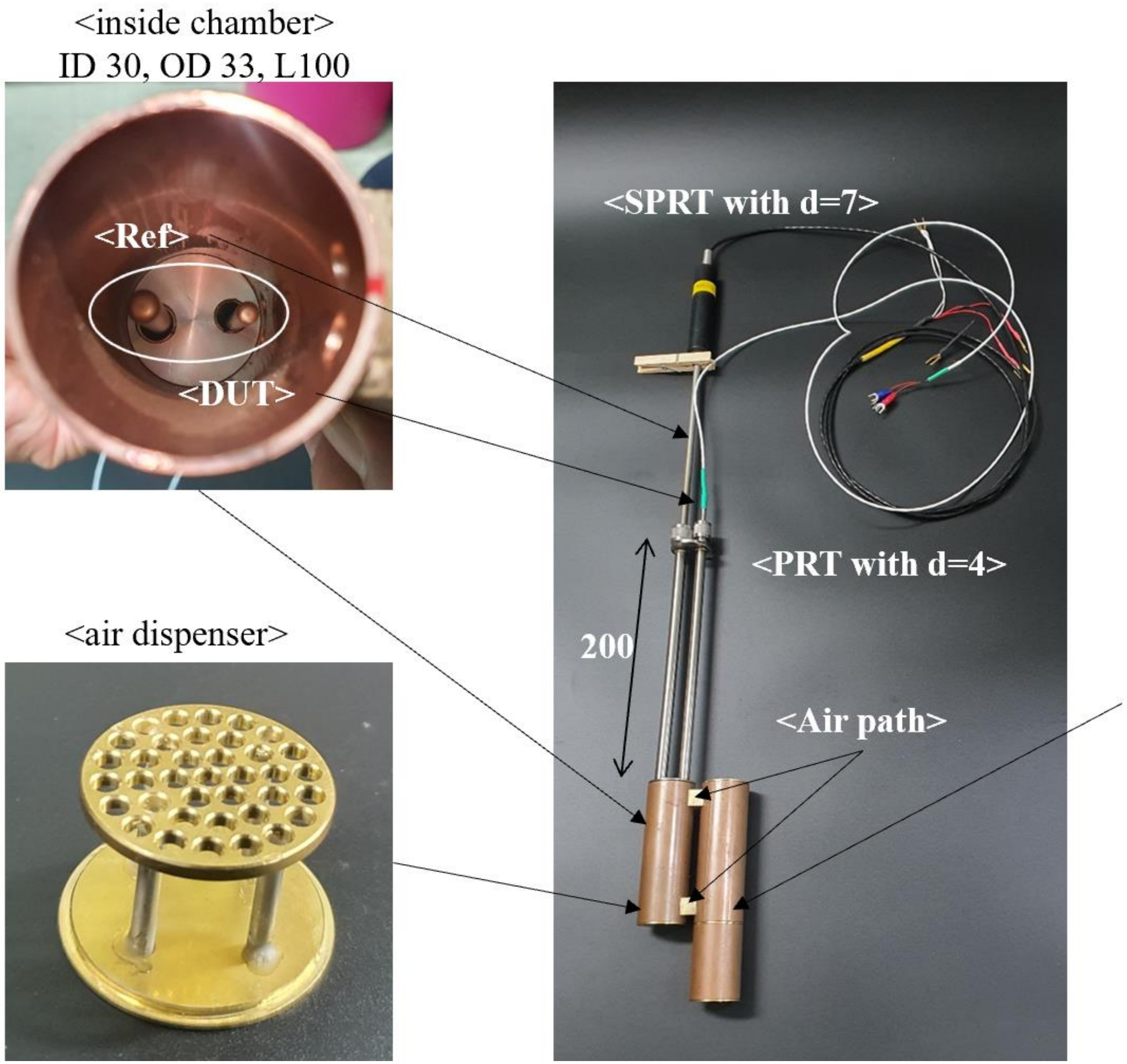
<Design of Two-in-One cell>

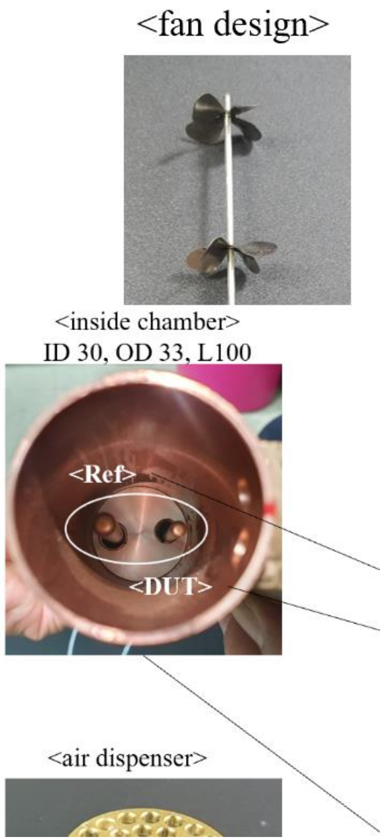


- All parts are immersed.
- Two connected cells
  - Comparison cell
    - Ref/DUT thermometers
      - With gas-tight sealing caps
  - Motor cell
    - DC-Motor + fan
  - Ventilation speed
    - **Desired speed: (0.3±0.05) m/s**

Andrea Merlone

Åge Andreas Falnes Olsen





NMIJ

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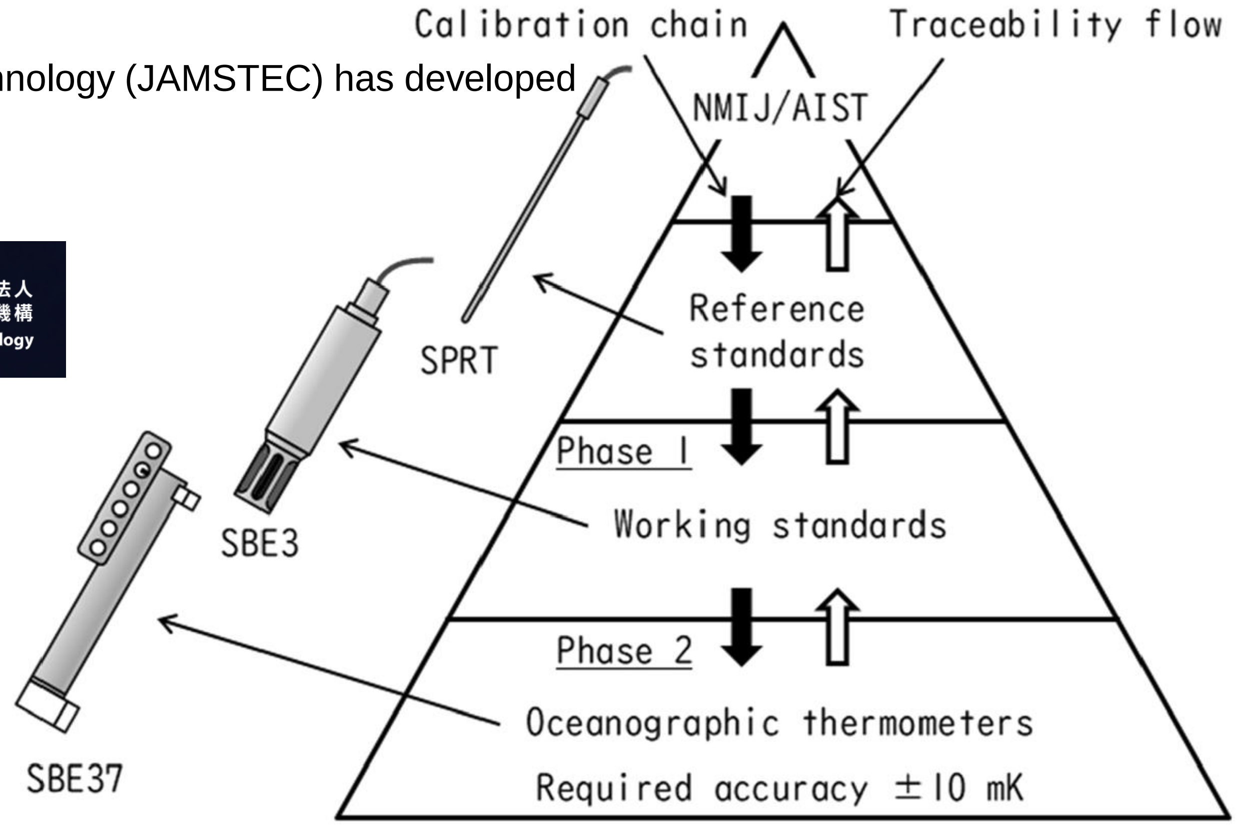
NMIJ/AIST and Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has developed a calibration system for oceanographic thermometers.

Expanded uncertainty for both calibration phases are in 1.5 mK and 3.5 mK for the first and the second phases, respectively, which **satisfy the requirements of the oceanographic community** for the accurate monitoring of ocean temperature.

Fig. 1

From: A Calibration Scheme for ITS-90-traceable Oceanographic Thermometers



A calibration systems were established in Phases 1 and 2, respectively.

S. Baba, I. Saito, K. Yamazawa and T. Nakano, Int. J. Thermophys. 44, 154 (2023) https://link.springer.com/article/10.1007/s10765-023-03257-4

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CMI

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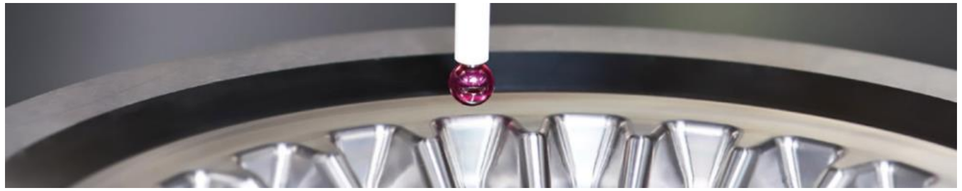
Åge Andreas Falnes Olsen



21GRD02 DURATION 2022-2025 Short Name: BIOSPHERE,

Metrology for Earth Biosphere: Cosmic rays, ultraviolet radiation and fragility of ozone shield

CZECH METROLOGY INSTITUTE

21GRD08 DURATION 2022-2025 Short Name: SoMMet

Metrology for multi-scale monitoring of soil moisture

MetEOC-4 DURATION 2020-2023 Short Name: MetEOC-4,

Metrology to establish an SI traceable climate observing system

Andrea Merlone Åge Andreas Falnes Olsen

SMU

Andrea Merlone

Åge Andreas Falnes Olsen

Slovenský metrologický ústav

Characterization of climate reference station thermometers

Air Temperature Calibration System (ATCS)

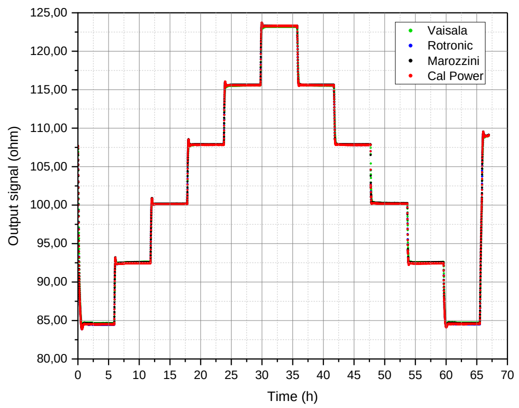
SOMMET and other projects

Andrea Merlone   Åge Andreas Falnes Olsen

Characterization of climate reference station thermometers

- ❑ Measured data of sensor self-heating
- ❑ Measured data of sensor stability
- ❑ Measured data of sensor hysteresis

	Vaisala	Rotronic	Marozzini	Cal Power
t nominal	PRT1	PRT2	PRT3	PRT4
°C	°C	°C	°C	°C
-40,00	0,04	0,04	0,03	-0,02
-20,00	-0,01	0,00	-0,01	0,00
0,00	-0,05	-0,01	-0,01	0,02
20,00	-0,02	0,00	0,00	0,00
40,00	0,00	0,00	0,00	-0,01



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Åge Andreas Falnes Olsen

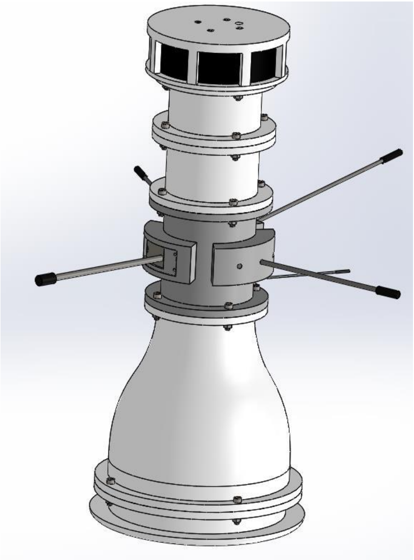
Air Temperature Calibration System (ATCS)

Slovenský metrologický ústav

Bundesamt für Eich- und Vermessungswesen

- Development of an ATC-sub chamber for air temperature measurements in climate and environmental chambers.

- Development of a unified calibration procedure for industrial temperature sensors with corresponding standard specifications for calculating the U budget



Andrea Merlone Åge Andreas Falnes Olsen

VNIIM

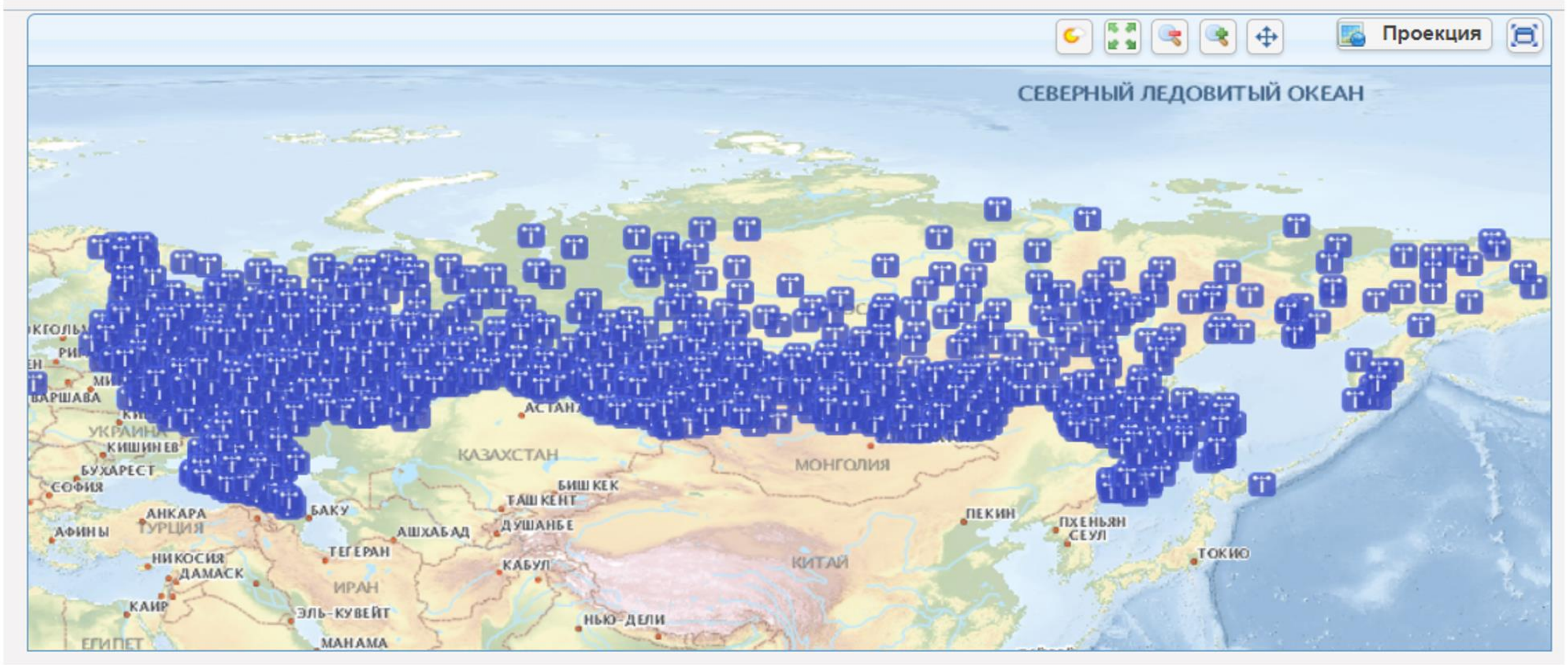
ВНИИМ

ФГУП "Всероссийский научно-исследовательский институт метрологии им. Д.И.Менделеева"

1. Assuring traceability of meteorological observations
2. Development of innovative travelling standards
3. Scientific research on

1 Providing state system of calibration laboratories for meteorology

There are 21 accredited laboratories - Departments of Hydrometeorology and Environmental Monitoring, which provides 1230 active meteorological stations



Online map of meteorological stations in Russia

Andrea Merlone

Åge Andreas Falnes Olsen

2

Desing new portable and laboratory standards for calibration of meteorological thermometers and hygrometers

Humidity (portable)

Temperature (portable)

Temperature (lab)

Nominal values: 11 % (LiCl), 33 % ($MgCl_2$) 75 % (NaCl) 97 % (K_2SO_4) Uncertainty (k=2) (with hygrometer): 1 %	Range: from -60 °C to 60 °C Uncertainty of calibration (k=2): 0,01 °C For sensor up to 16 mm diameter	Range: from -60 °C to 60 °C Uncertainty of calibration (k=2): 0,02 °C – in liquid, 0,2 °C – in air. Any shape of sensors

3

New scientific activity

Investigation new effect of photomolecular evaporation for hygrometry

Effect can lead to
- decreasing results on hygrometers due active evaporation from hygrometer’s sensor
- Increasing value of relative humidity above the surface saturated salt solution

Researching new thermometers for air temperature

Begining research thermometers using properties of air:
- Density;
- Viscosity (methods of rolling globe and the air screw);
- Speed of sound;
- Light reflectance.

Cooperation with other organizations

- State Hydrometeorologcal Observatory
- Institute of the North and Permafrost of Russian Academy of Sciences

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LMK with ARSO and WMO ET QTC

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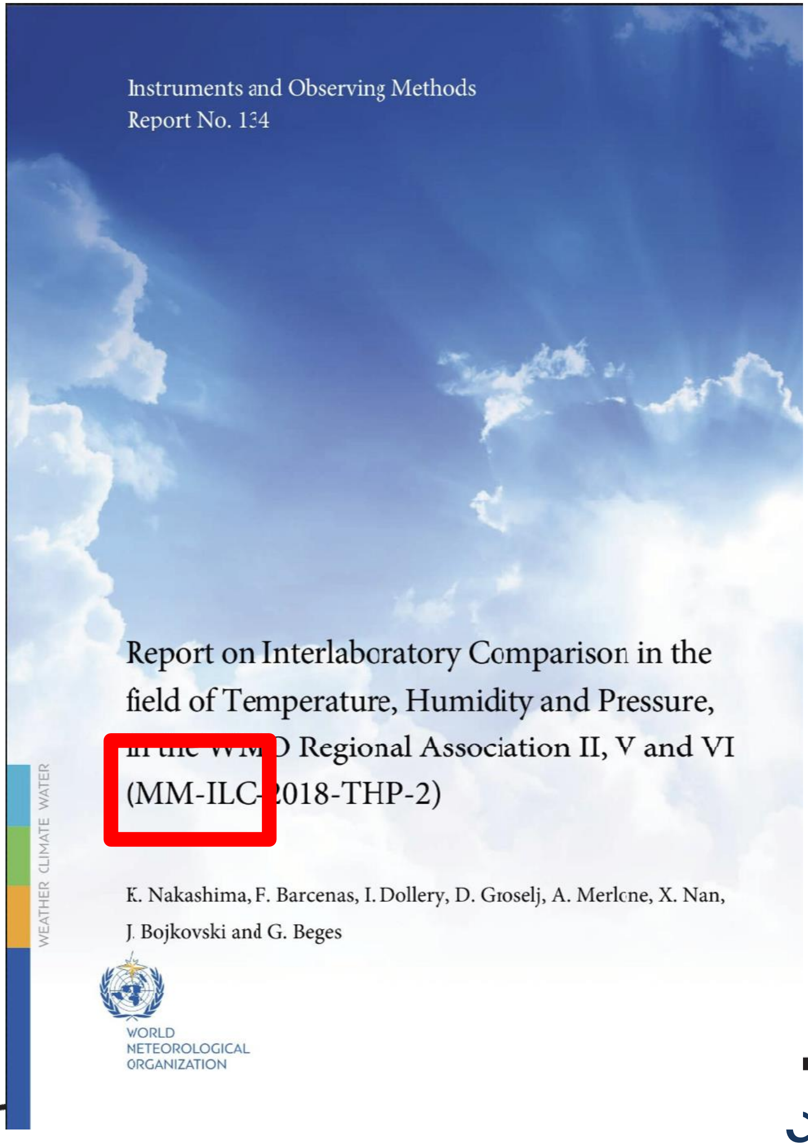
METEOMET

Metrology for Meteorology

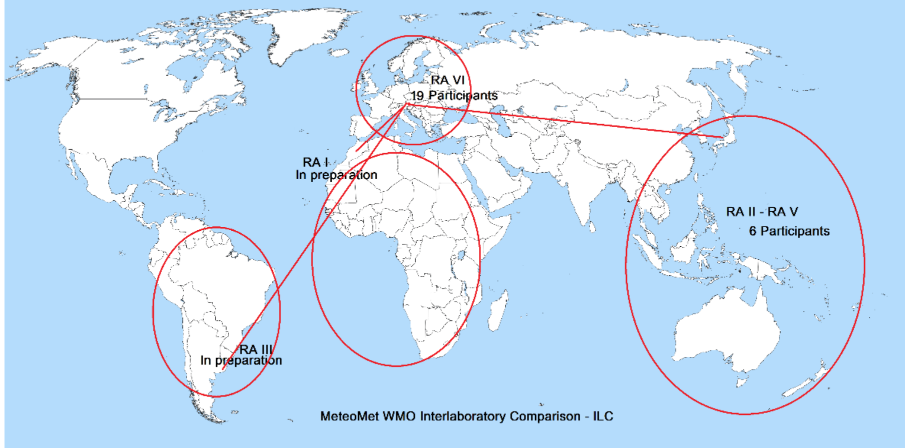

Instruments and Observing Methods
Report No. 134

Report on Interlaboratory Comparison in the field of Temperature, Humidity and Pressure, in the WMO Regional Association II, V and VI (MM-ILC-2018-THP-2)

K. Nakashima, F. Barcenas, I. Dollery, D. Groselj, A. Merlone, X. Nan, J. Bojkovski and G. Beges

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION



WMO-MM-ILC-2015-THP in WMO region VI published as IOM Report No. 128

University of Ljubljana Faculty of electrical engineering

WMO-MM-ILC-2018-THP-2 in WMO region II and V is in a final draft stage

気象庁 Japan Meteorological Agency

To spread the same idea is planned WMO-MM-ILC-2020-THP in WMO region I, III and IV

Instituto Nacional de Tecnología Industrial INTI

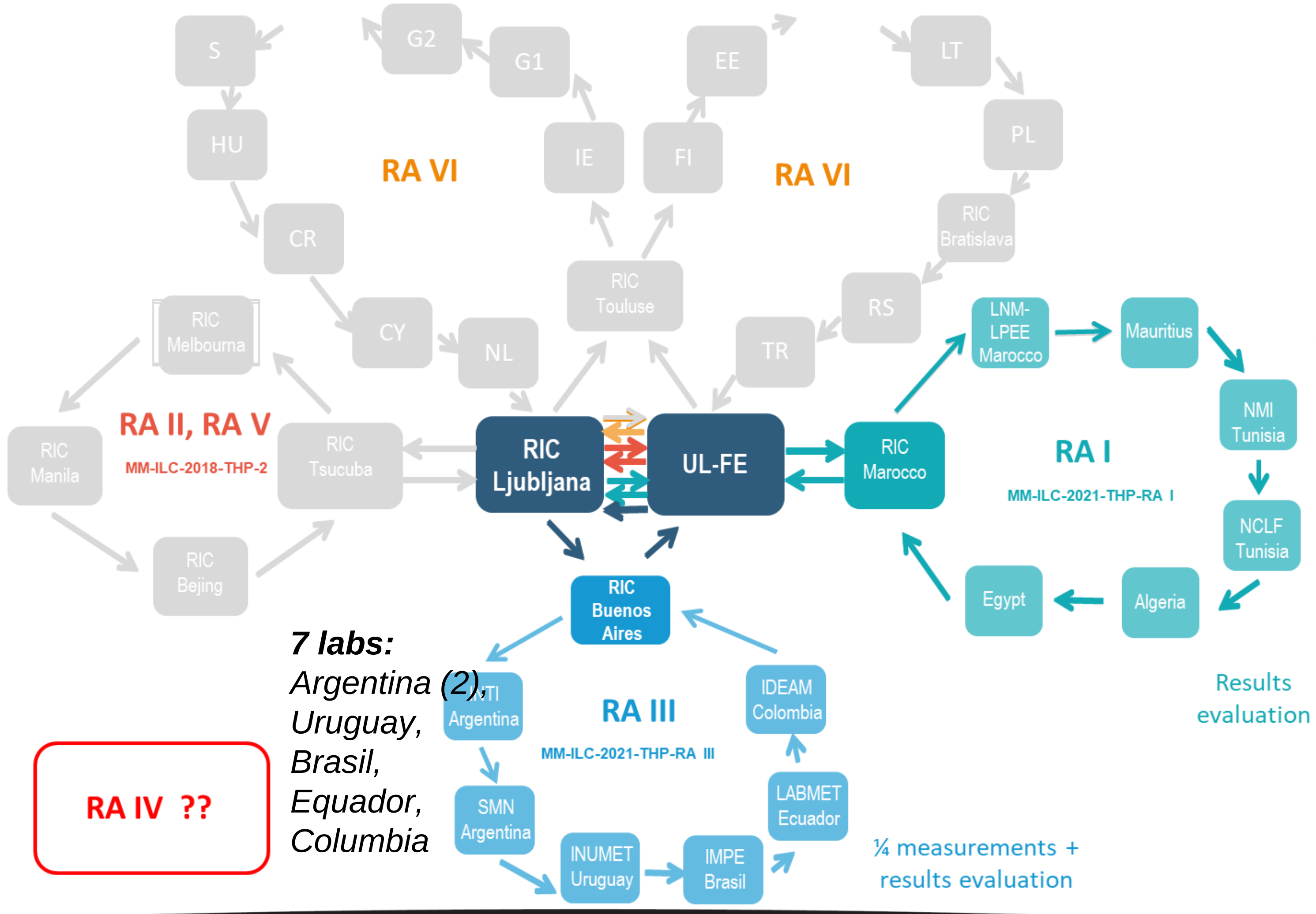
Andrea Merlone

Åge Andreas Falnes Olsen

- Same transfer standards
- Similar ILC protocol
- Same data evaluation
- Same linkage laboratories

TWO ILCs ARE ON-GOING:

ILC in RA I (Africa) *and* **ILC in Region III (South America)**



7 labs:
Morocco (2), Mauritious, Tunisia (2), Algeria, Egypt

7 labs:
Argentina (2), Uruguay, Brasil, Equador, Columbia

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

News from the WMO

Jane Warne
WMO SC-MINT Chairperson

Drago Groselj
WMO SC-MINT Chairperson

Andrea Merlone
WMO ET Measurement Uncertainty Chair
WMO GCW Permafrost Co-chair
GCOS-GSRN SG5 Chair

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

GCOS

GCW
Global Cryosphere Watch

Andrea Merlone

Åge Andreas Falnes Olsen

WMO INFCOM-2 2022

WMO INFCOM-3 2024

SC-MINT meetings (every 3-4 months)

ETs Meetings (every two months)

Decisions, ET worplans progress, documents preparations, WMO Guides revision, training, ILC…

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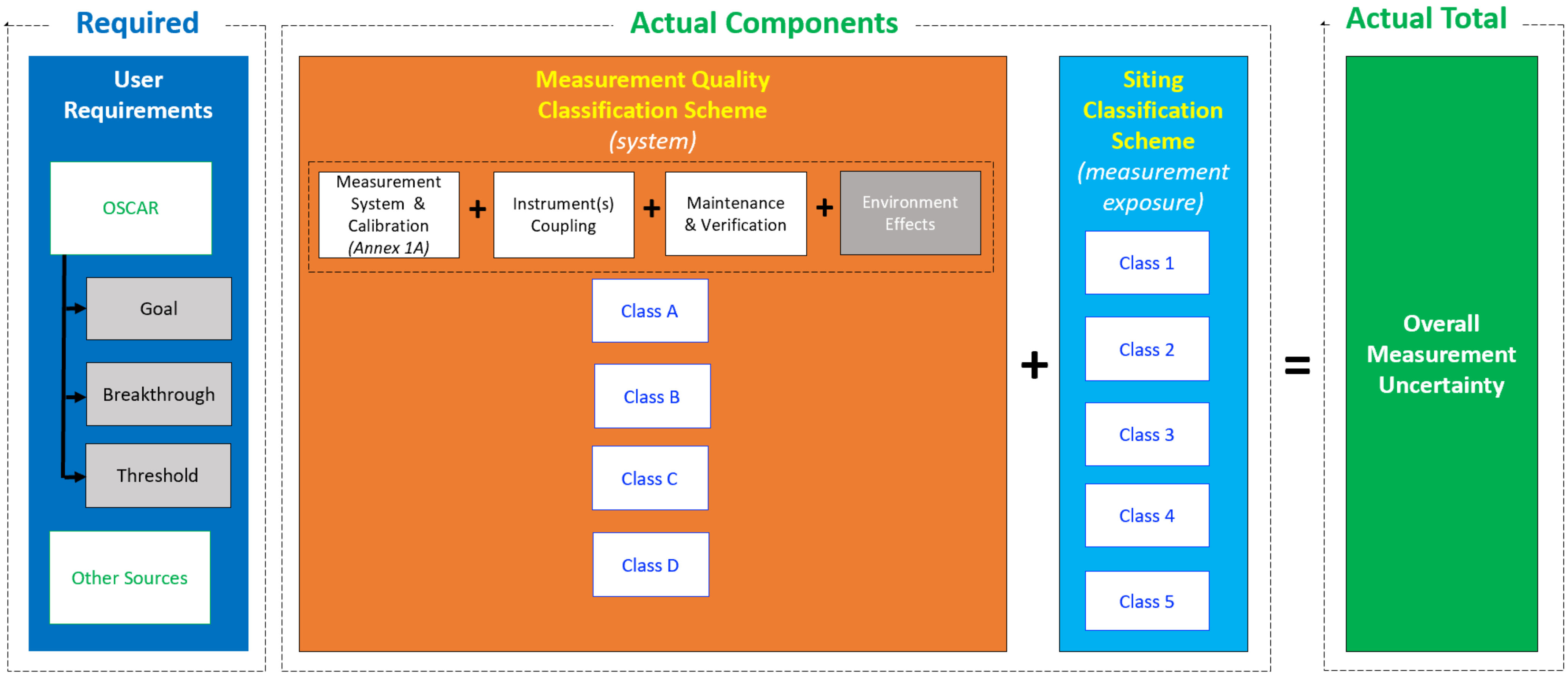
Measurement Quality Classification Scheme



Annex 1A as integral part of MQCS

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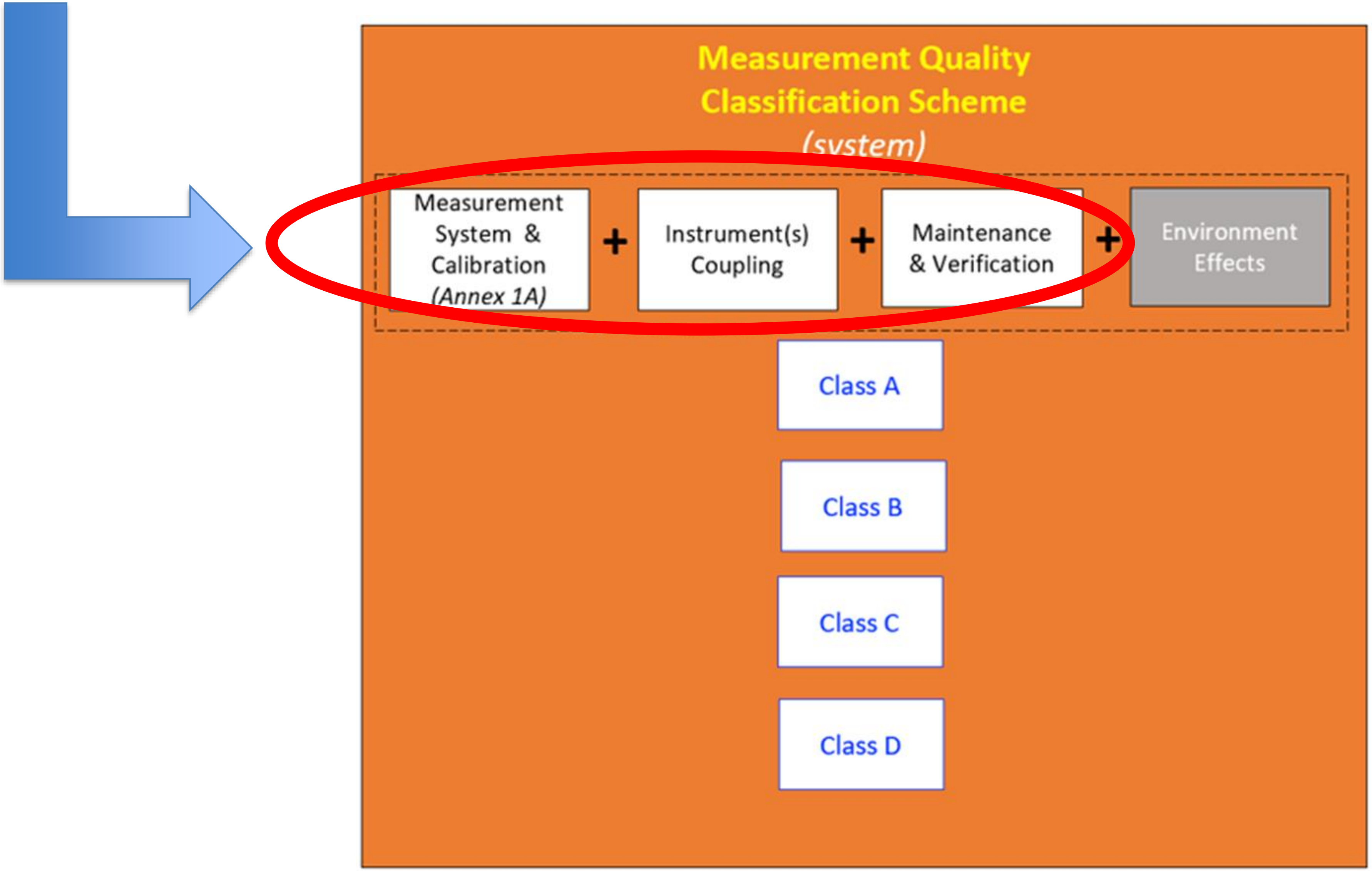
Åge Andreas Falnes Olsen



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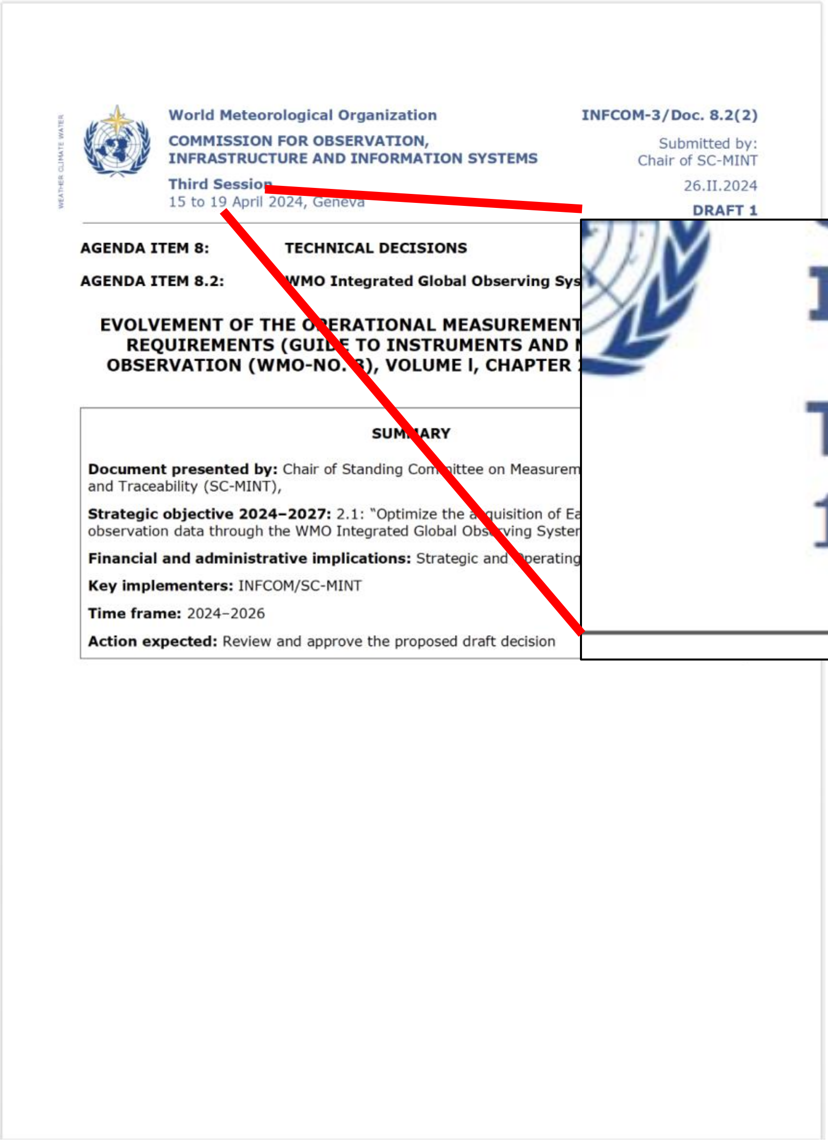


World Meteorological Organization

COMMISSION FOR OBSERVATION, INFRASTRUCTURE AND INFORMATION SYSTEMS

Third Session

15 to 19 April 2024, Geneva

INFCOM-3/Doc. 8.2(2)

Submitted by: Chair of SC-MINT

26.II.2024

DRAFT 1

AGENDA ITEM 8: TECHNICAL DECISIONS

AGENDA ITEM 8.2: WMO Integrated Global Observing Sys

EVOLVEMENT OF THE OPERATIONAL MEASUREMENT REQUIREMENTS (GUIDE TO INSTRUMENTS AND M OBSERVATION (WMO-NO. 8), VOLUME I, CHAPTER 1

SUMMARY

Document presented by: Chair of Standing Committee on Measurem and Traceability (SC-MINT),

Strategic objective 2024–2027: 2.1: "Optimize the acquisition of Ea observation data through the WMO Integrated Global Observing Syster

Financial and administrative implications: Strategic and operating

Key implementers: INFCOM/SC-MINT

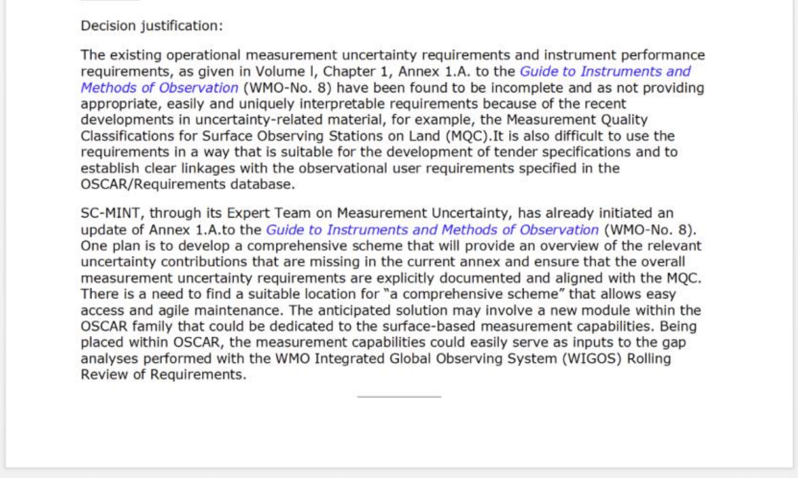
Time frame: 2024–2026

Action expected: Review and approve the proposed draft decision

INFRASTRUCTURE AND INFORMAT

Third Session

15 to 19 April 2024, Geneva



INFCOM-3/Doc. 8.2(2), DRAFT 1, p. 3

DRAFT DECISION

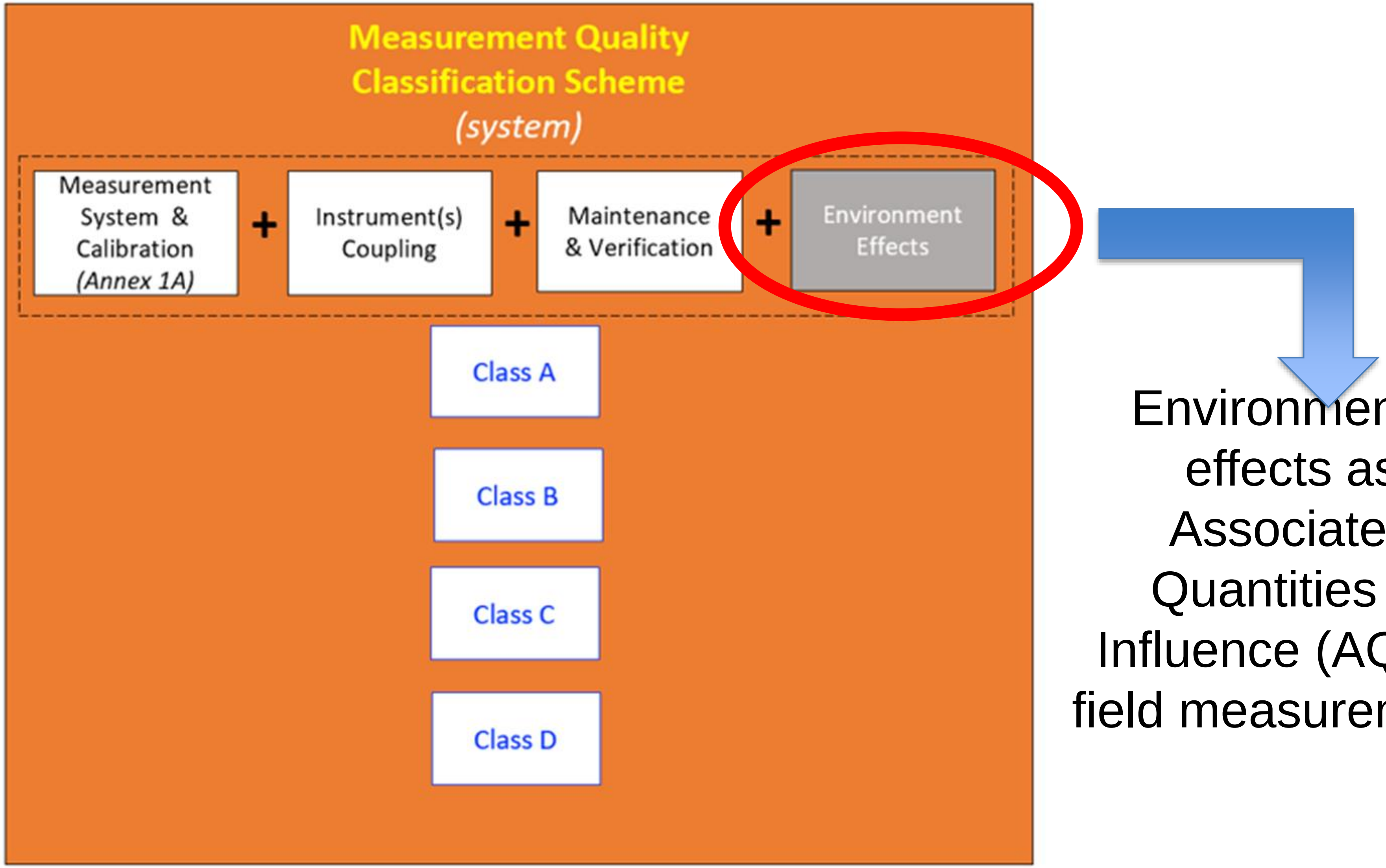
Draft Decision 8.2(2)/1 (INFCOM-3)

Decision justification:

The existing operational measurement uncertainty requirements and instrument performance requirements, as given in Volume I, Chapter 1, Annex 1.A. to the *Guide to Instruments and Methods of Observation* (WMO-No. 8) have been found to be incomplete and as not providing appropriate, easily and uniquely interpretable requirements because of the recent developments in uncertainty-related material, for example, the Measurement Quality Classifications for Surface Observing Stations on Land (MQC).It is also difficult to use the requirements in a way that is suitable for the development of tender specifications and to establish clear linkages with the observational user requirements specified in the OSCAR/Requirements database.

SC-MINT, through its Expert Team on Measurement Uncertainty, has already initiated an update of Annex 1.A.to the *Guide to Instruments and Methods of Observation* (WMO-No. 8). One plan is to develop a comprehensive scheme that will provide an overview of the relevant uncertainty contributions that are missing in the current annex and ensure that the overall measurement uncertainty requirements are explicitly documented and aligned with the MQC. There is a need to find a suitable location for "a comprehensive scheme" that allows easy access and agile maintenance. The anticipated solution may involve a new module within the OSCAR family that could be dedicated to the surface-based measurement capabilities. Being placed within OSCAR, the measurement capabilities could easily serve as inputs to the gap analyses performed with the WMO Integrated Global Observing System (WIGOS) Rolling Review of Requirements.

Total measurement uncertainty.

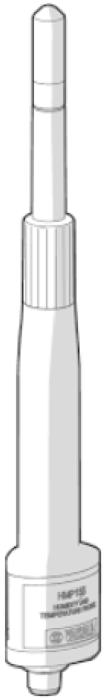


Environmental effects as Associated Quantities of Influence (AQI) in field measurements

Andrea Merlone

Åge Andreas Falnes Olsen

Calibration
Resolution
Drift
Logger
Sensitivity
Hysteresis
Repeatability



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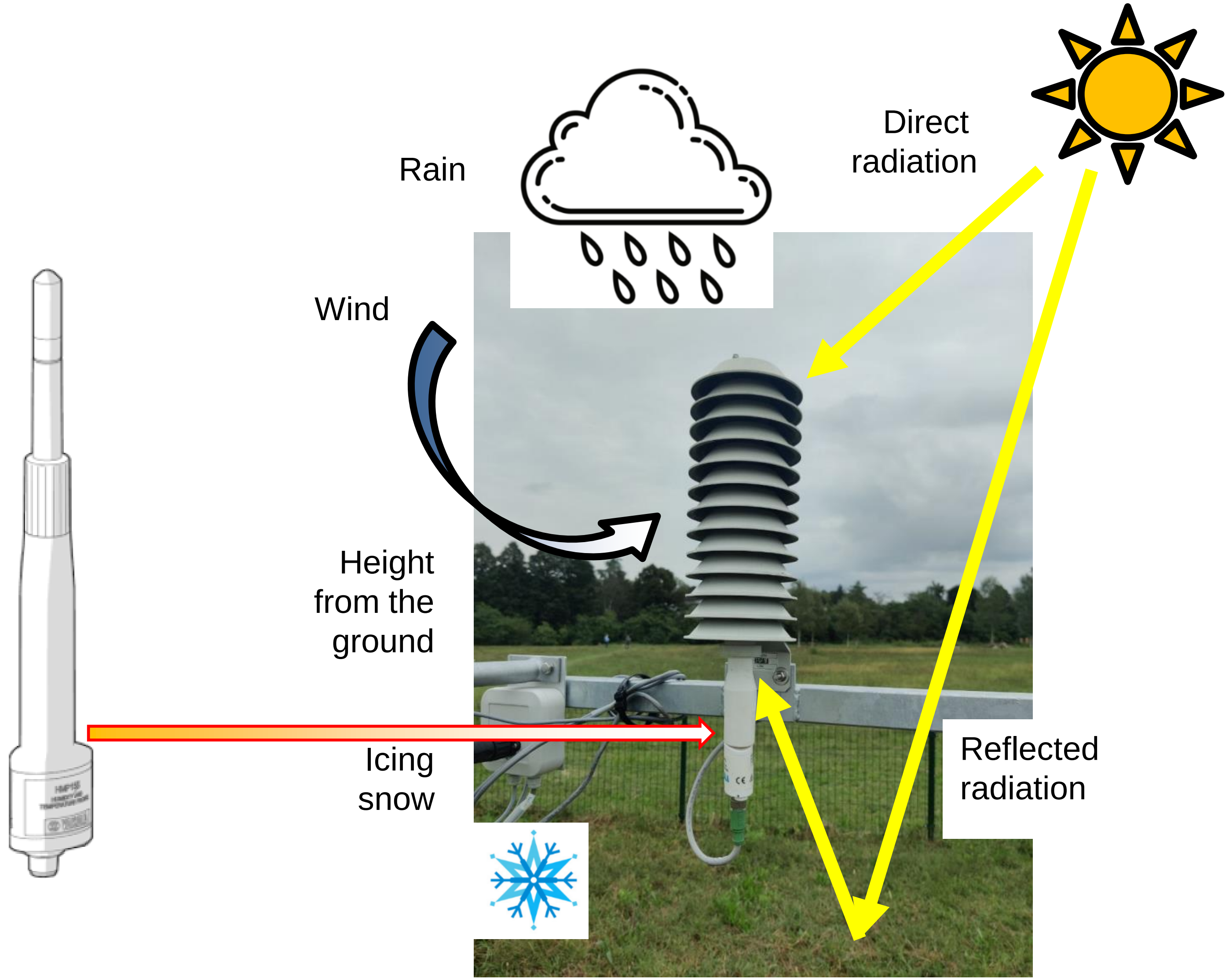
Calibration

- Resolution
- Drift
- Logger
- Sensitivity
- Hysteresis
- Repeatability



Andrea Merlone Åge Andreas Falnes Olsen

Example: near surface air temperature measurements

At present, **it is not possible to complete the total combined uncertainty budget** due to missing knowledge in quantifying effects of associated quantities of influence such as:

- Radiation: errors-corrections and associated uncertainty due to direct and reflected solar radiation
- Precipitation: over-cooling of sensors and their recovery time (including the relationship with the rain temperature) in case of precipitation events
- Optimized solar shields: relative analysis of the best characteristics of the variety of screens adopted
- Wind: the predominant convective effect in presence of wind, reducing errors and uncertainties with respect to radiative and condensation effects.
- And more such as height from the ground, effect of soil moisture and temperature on data representativeness, humidity, sensor dimensions and constant time….

Andrea Merlone

Åge Andreas Falnes Olsen

World Meteorological Organization
COMMISSION FOR OBSERVATION, INFRASTRUCTURE AND INFORMATION SYSTEMS
Second Session
24 to 28 October 2022, Geneva

INFCOM-2/Doc. 7.4(2)
Submitted by: Chair
24.X.2022
APPROVED

AGENDA ITEM 7: **PROCEDURAL AND COORDINATION ASPECTS**

AGENDA ITEM 7.4: **Process for approval of publication of technical document series, uncertainty assessment and harmonization of uncertainty terminology**

UNCERTAINTY ASSESSMENTS AND HARMONIZATION OF UNCERTAINTY TERMINOLOGY

DRAFT DECISION

Draft Decision 7.4(2)/1 (INFCOM-2)

Towards improved uncertainty evaluations and harmonization of the uncertainty terminology across the key INFCOM-related WMO publications

The Commission for Observation, Infrastructure and Information Systems decides:

(1) To intensify activities on the assessment of uncertainty evaluations;

(2) To harmonize the definitions and terminology related to the term "uncertainty" across technical publications overseen by the Commission to ensure their use is correct, consistent and understood when used among WMO communities;

Requests SC-MINT to further promote, organize and coordinate field experiments and studies, necessary to refine and improve the uncertainty evaluation and traceability of measurements, including in collaboration with partners from the metrology community;

INFCOM-2/Doc. 7.4(2), APPROVED, p. 2

Decision justification:

Evaluation of uncertainties in measurements, their interpretation, and representativeness are critical for measurement data quality, comparability, and compatibility, in different observing networks, for example, Global Basic Observing Network (GBON) and Global Climate Observing System (GCOS) Surface Reference Network (GSRN). The uncertainties that are already presented throughout different WMO publications and tools, such as in the Measurement Quality Classifications for Surface Observing Stations on Land and in OSCAR/Requirements, require more in-depth technical justifications. This can be achieved, among others, through continued research supported by field experiments.

The term "uncertainty" is widely used throughout WMO publications, but often it is used with different definitions and without the necessary accompanying details for its proper interpretation and use. For example, uncertainty is sometimes used to designate the root mean square error of a single standard deviation, expressed at 67% (or k=1) confidence level, and in other cases, it relates to a quantity defining an interval about the result of a measurement, designated as expanded measurement uncertainty, and is expressed at 95% (k=2) confidence level. This leads to confusion in the use of WMO publications. Furthermore, in many instances, the term uncertainty is used interchangeably with terms such as error, accuracy, and precision, although all these terms represent different concepts and have different meanings.

Andrea Merlone

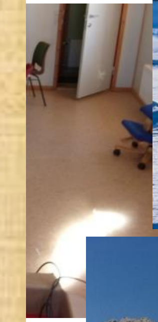
Åge Andreas Falnes Olsen

Main conclusions

- Pesent knowledge is not enough for completing the measurement and uncertainty contribution model,
- Field and laborato promote a bottom
- The multitude of c issues in identifyin evaluated contribu
- Technical solution constantly evolve and continuous investigation is needed (for example on non-contact systems for temperature and precipitation)

Need to jointly produce knowledge to evaluate measurement uncertainty and provide better quality data

Examples: Environmental influences
Precipitation
Wind speed
Solar radition
…



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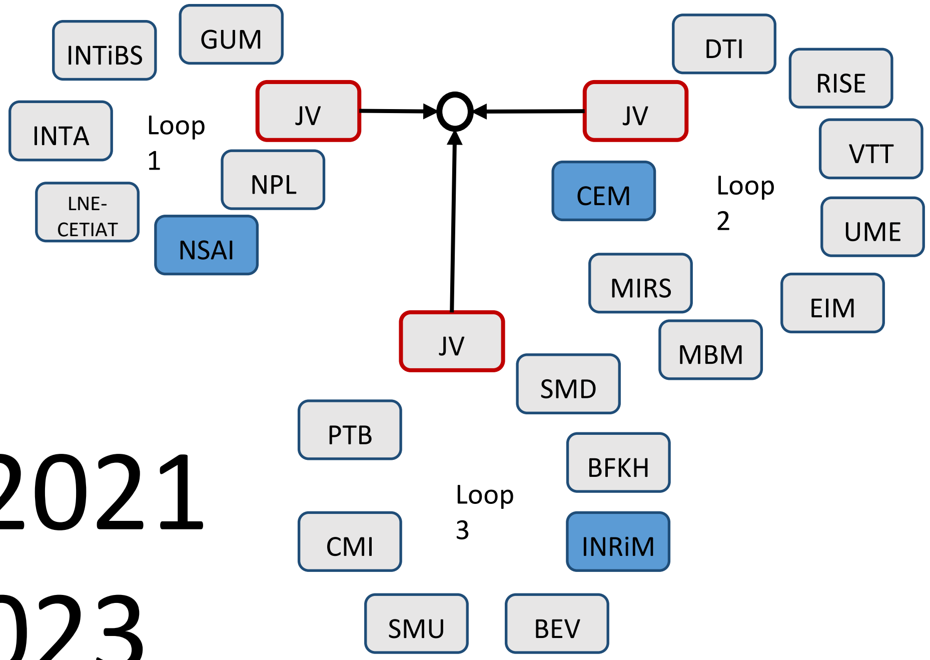
Åge Andreas Falnes Olsen

ATM project – EURAMET 1549

ATM
Air Temperature Metrology

EURAMET



ILC Concluded in end 2021

Final report in end 2023

Andrea Merlone

Åge Andreas Falnes Olsen

ATM project – EURAMET 1549

Learning points from the ILC in Europe

- Selfheating is hard to measure in air
- Drift requires more attention
- Setups need standardization
- How to manage consistency
- Transfer of calibration to the field

Andrea Merlone Åge Andreas Falnes Olsen

CCT Task Group on Air temperature «TG Air»

Åge Andreas Falnes Olsen – Chairperson

Andrea Merlone – Vice-Chair

Terms of Reference

* To work towards and propose a practical definition of air temperature	SG1 – Stephanie Bell
* To work towards and propose how to evaluate the uncertainty contributions in air temperature measurements	SG2 – Davor Zvizdic
* To develop guidelines for the calibration of thermometers in air	SG3 – Yong-Gyoo Kim

Andrea Merlone Åge Andreas Falnes Olsen

CCT TG Air T – SG1
Definition

Andrea Merlone

Åge Andreas Falnes Olsen

The air temperature measurand

What is air?

- Gas of atmospheric composition (N_2, O_2, Ar, H_2O, CO_2, other traces)
  - Water vapour the most variable constituent (from trace level to several percent)
- Treated as homogeneous – the concept of an “air molecule” for purposes of theory, modelling.
- “Synthetic air” used in some lab studies (N_2 and O_2 only)

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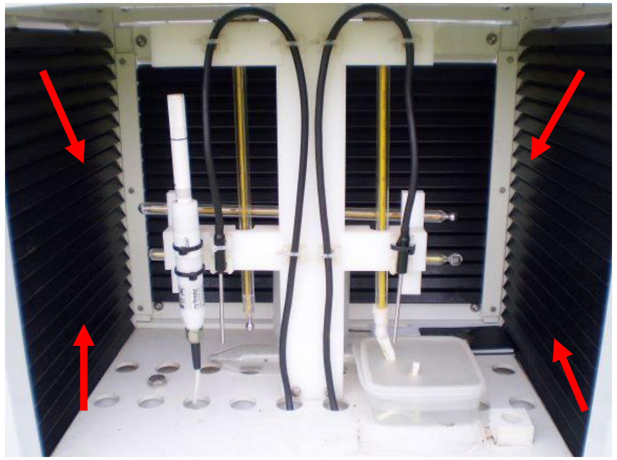
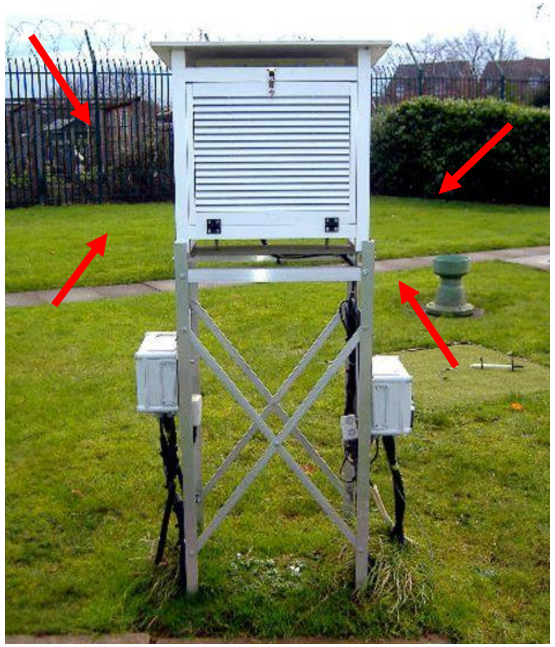
What is the measurand - ‘air temperature intended to be measured’?

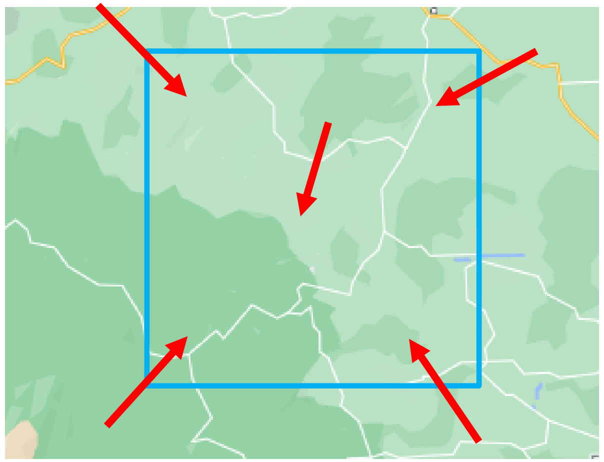
Temperature of thermometer?



Temperature of air inside weather-station screen, “sheltered from direct solar radiation”?



Temperature of air outside weather-station screen?



Temperature of air in wider local area?

- These can differ by a tenth or up to several tenths of a degree, due to radiative and other influences
- Choice of measurand depends on context: sensor calibration/verification; observation of weather (→ climate record); modelling; satellite ground-truthing …
- Relationship between the different measurands not well defined

Images: Met Office

Next actions:

Discuss some possible basis for definition of the measurand, air temperature

Start drafting a paper

Specific workshop/s

Andrea Merlone

Åge Andreas Falnes Olsen

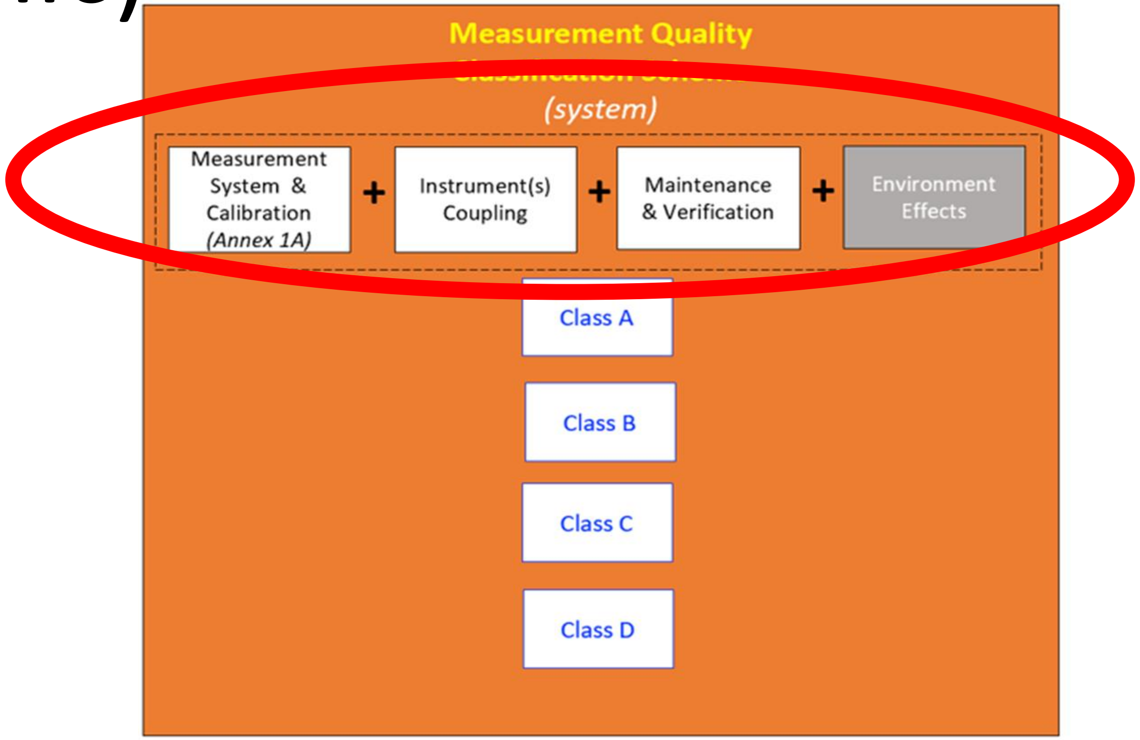
CCT TG Air T – SG2
Uncertainties

Measurement of air temperature is influenced by:

- **Uncertainties at probe calibration**
  - **Standard:** Calibration of standard; Type A; Measuring of resistance or voltage; Zone gradients; Zone stability; Radiation, Hysteresis; drift
  - **Probe:** Type A, Measuring of resistance or voltage, Hysteresis, Drift
  - **Interpolation**
- **Properties of air influences**
  - Altitude (pressure, density, humidity, diathermy, etc.)
- **Convection heat exchange influences**
  - Gas (wind) speed
  - Turbulent, laminar or mixed flow
  - Heat transfer coefficient
  - Convection surface area
  - Temperature gradients
  - Natural convection induced by stem or walls
- **Conduction heat exchange influences**
  - Coefficient of conductivity
  - Thickness of the conduction/insulation layers
  - Temperature gradients
- **Radiation heat exchange influence**
  - Emissivity coefficients
  - Reflectivity coefficients
  - Diathermy
  - Sub-surface conductivity (surface temperature)
  - Temperature difference
- **Phase change and heat sources**
  - Condensation/evaporation
  - Sublimation/melting
  - Heat sources in the thermometer body
  - Heat sources from dynamic temperature conversion (recovery)
- **Transient heat transfer**
  - Specific heat capacity of the thermometer
  - Mass of the thermometer
  - Initial temperature of the thermometer
  - Gas temperature dynamics (lag)
- **Measurement of air temperature in confined spaces**
  - Closed spaces
  - Partially closed spaces
  - Conduits and channelas

Clear distinction among measurements in

* laboratory-calibration (static-adiabatic)
* environment-field (dynamic)



Next actions:

start drafting guidelines for the evaluation of uncertainty budget

gap analysis on missing knowledge

weighted list of contributions (corrections and/or uncertainties)

priority list and study – experiments planning
according to WMO Decision INFCOM2- 7.4(2) 2022

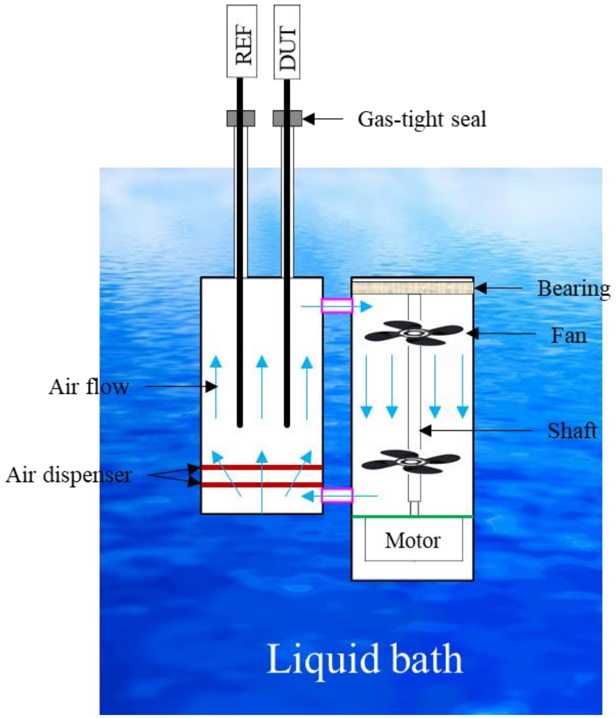
Andrea Merlone

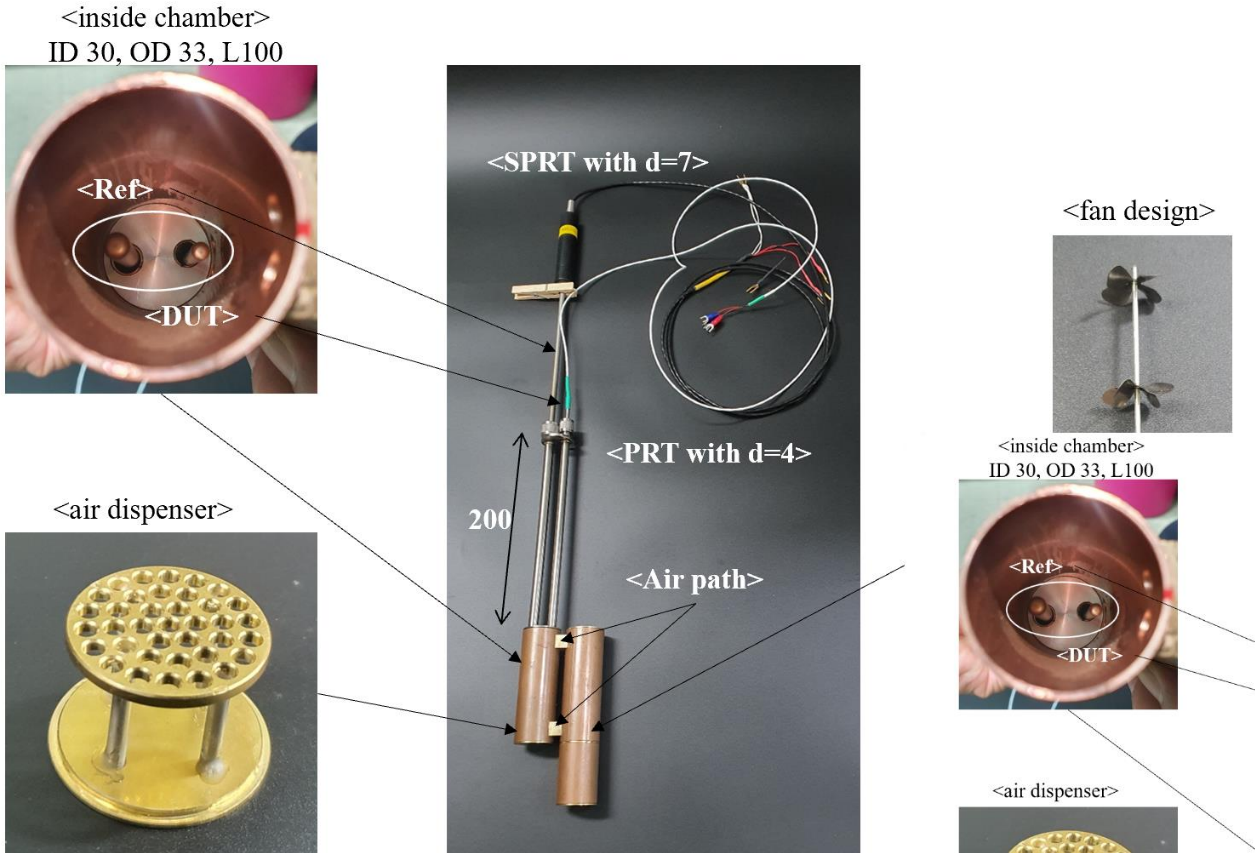
Åge Andreas Falnes Olsen

CCT TG Air T – SG3
ILC and guide

Andrea Merlone
Åge Andreas Falnes Olsen

Sub-chamber in liquid bath





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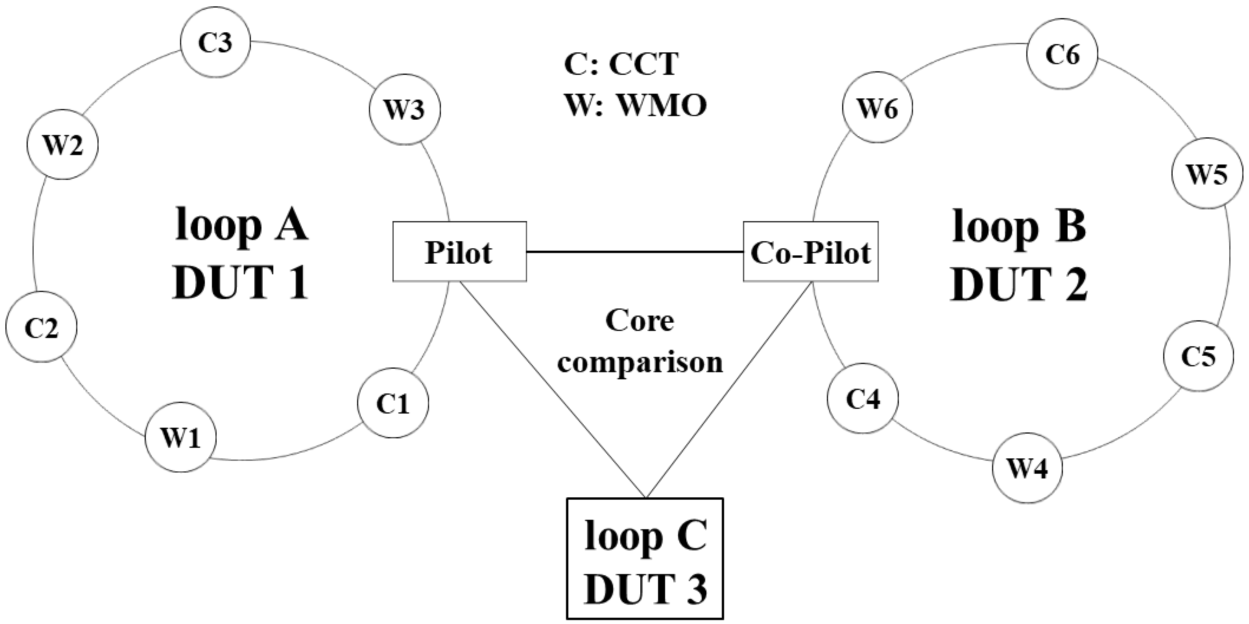
Design of the CCT-WMO ILC

Circulation scheme

- Two or three loops of round robin tests and 5 ~ 6 Labs per loop
- Core comparison tests between pilot and co-pilot(s)



Provisional time schedule

- by June 2024 (hopefully), test of the <2-in-1> transfer cell
  - Test range: -60 ºC ~ 60 ºC, 20 ºC interval
  - Reference thermometer: SPRT
  - Test DUT: four wire PT100
  - Comparison between Climate chamber vs Liquid bath vs <2-in-1> in liquid bath
- by August 2024, Comments from the members on the test results
- By October 2024, Call for the participants from CCT/WMO
- by December 2024, Preparation of the protocol
- by February 2025, Submission of the protocol to CCT

Andrea Merlone

Åge Andreas Falnes Olsen

EURAMET Green Deal Call 2024

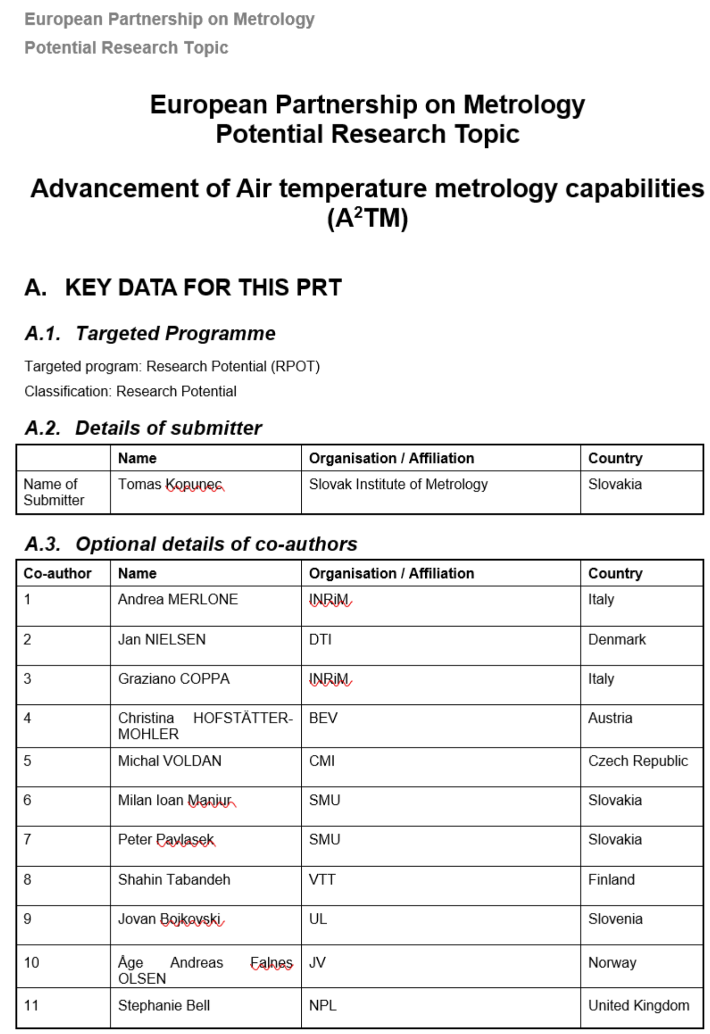
Andrea Merlone

Åge Andreas Falnes Olsen

A^2TM

To design and build research facilities that enable research studies under a range of conditions and influence factors. This objective will be realized by a mobile **sub-chamber system** that can be used with typical climatic chambers and laboratory setups used within the consortium.

…. to improve the calibration and measurement capabilities (CMCs) of NMIs in the field of air temperature measurements.



European Partnership on Metrology
Potential Research Topic

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Advancement of Air temperature metrology capabilities (A^2TM)

A. KEY DATA FOR THIS PRT

A.1. Targeted Programme

Targeted program: Research Potential (RPOT)
Classification: Research Potential

A.2. Details of submitter

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11	Stephanie Bell	NPL	United Kingdom

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Åge Andreas Falnes Olsen

Environmental Thermodynamics

Air temperature: to improve measurement and calibration techniques for reducing errors and evaluating uncertainties in meteo-climatological data, for reaching reference measurement uncertainty of 0.1 °C and decadal stability of 0.05 °C. These goals require the development and characterization of new calibration systems, evaluation and reduction of environmental influences on the sensors in field conditions, new data analysis methods.

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<*MeteoMet4* - Environmental Thermodynamics: “ET” >

A. KEY DATA FOR THIS PRT

A.1. Targeted Programme

Green Deal - EU's Climate ambition for 2030 and 2050 (CLIM)

A.2. Details of submitter

	Name	**Organisation / Affiliation**	**Country**
Name of Submitter	Andrea MERLONE	INRiM	Italy

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Full alignment with the

Strategic Planning CCT 2021-2030 DRAFT 2 *11 August 2021*

Strategy Document for Rolling Programme Development for 2021 to 2030

The Consultative Committee for Thermometry

Andrea Merlone

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Achievements 2017-2020	Future Scan 2021-2025	Future Scan 2025-2030+
Working Group for Environment		
CIPM RECOMMENDATION T3 (2010) "On climate and meteorological observations measurements" and the ToR of the CCT WG Environment are the basis for establishing long term collaboration with the scientific community involved in research on climate and environmental monitoring and motivates specific projects and actions from the NMIs.	Data comparability: Include as reliable as possible uncertainty analysis in historical data; study and assess traceability. Water content measurements (air and soil): Develop suitable measurement techniques and guides. Evolving technologies, such as non-contact instruments, for meteorological and climatological measurements will be constantly followed, with dedicated activities and studies.	CCT recommends NMIs to include in their vision documents all possible actions within the expertise of the thermal metrology community contributing to improve measurement quality and knowledge on observation and monitoring of the environment and climate.

Achievements 2017-2020	Future Scan 2021-2025	Future Scan 2025-2030+
The "Metrology for Meteorology and Climate" – MMC **Conference series** and associated workshops and satellite events • were fully participated in and endorsed by CCT WG ENV members • represent world top level events for increasing the collaboration between thermal metrologists and the stakeholder communities. Joint Research projects such as MeteoMet, INCIPIT, CRS, COAT progressed the scientific studies and technical research on improving calibration and measurement procedures and uncertainty evaluation. A metrology network on climate and ocean observation has been formed by EURAMET. The "ATM – Air Temperature Metrology" EURAMET project was launched in 2018, to execute an intercomparison of calibration procedures for thermometers in air and produce a guide. The project formed the basis to launch global initiatives on solving calibration and measurement issues for air temperature. APMP comparison on air temperature thermometers was also started in 2018. TG Air Temperature established.	Improved techniques, proposals of best practices (also for inclusion in the WMO guide no. 8) and on-site calibration devices will be addressed to cryosphere observations (high mountains and polar areas). Establishing reference test sites with the highest quality SI-traceable measurements of ECVs, including prototypes of climate reference stations and research infrastructures to support the implementation plan of the GSRN. Arctic Metrology: polar activities will continue with on site calibration campaigns, the implementation of the "Metrology Laboratory" at the arctic station in Ny-Ålesund, and a WMO intercomparison of thermometers and shields in polar environment. On-site thermometer shield with the minimum environmental effects will be designed and tested. Support in the validation of records associated to extreme events (such as temperature extremes and heat waves, precipitation events, pressure, wind speed etc.), through metrological analysis of the whole measuring process and instrumentation. Improved monitoring techniques for essential fresh water natural and artificial reservoirs and the creation of measurement recommendations.	The WG-ENV will continue to facilitate project proposals for funding and joint activities among the members on activities. WG-ENV members will continue studying and characterizing temperature, humidity and radiation sensors for ocean applications, ground based systems and radiosondes. Provide roadmap to address needs of data quality arising from possible new climate evolution scenarios. The CCT-WG-ENV will promote and contribute to interdisciplinary initiatives, worldwide and at regional level, to create forums and expert teams, to address the stakeholder's needs under coordinated efforts with other areas of metrology, also under future CIPM initiatives.

Achievements 2017-2020	Future Scan 2021-2025	Future Scan 2025-2030+
Collaboration and stakeholders	**Collaboration and stakeholders**	**Collaboration and stakeholders**
WG-ENV members are formally members of expert teams in the WMO INFCOM and SERCOM, in the Global Cryosphere Watch, the GCOS (GRUAN and GSRN Task Teams) and the BSRN. WG-ENV members are involved and supporting official WMO worldwide laboratory intercomparisons in Europe, Asia, Latin America and Africa. Formal collaborations with national meteorological and hydrological services, universities, research centres and manufacturers have been established.	The relationships with key world and international Institutions such as WMO, GCOS, and IAPWS will be sustained to provide channels for impact in the work of the WG-ENV. CCT-WG-ENV members will continue to contribute as experts in WMO, GCOS task teams. CCT-WG-ENV, together with operational meteorologists, climatologists and metrologists, to contribute with studies and activities to GCOS for the definition of the key aspects of GSRN in terms of station features, data characteristics and target uncertainties.	Impact: CCT members continue to organize events, meetings, workshops, conferences and training to discuss and plan common activities with the climate and environmental communities. The GCOS Surface Reference Network (GSRN) of observing stations on land implementation plan was approved by WMO in 2021 and will require a continuous support from the thermal metrology community, being temperature and humidity of air and soil key observables.
Task Group for Air Temperature		
In 2020 a new Task Group on "Air temperature" was formed, tasked: • To work towards and propose a practical definition of air temperature • To work towards and propose how to evaluate the uncertainty contributions in air temperature measurements To develop guidelines for the calibration of thermometers in air.	Practical definition of air temperature proposed Method proposed on how to evaluate the uncertainty contributions in air temperature measurements Draft guide for the calibration of thermometers in air	Practical definition of air temperature agreed by CCT and promulgated to key stakeholders Method for evaluating the uncertainty contributions in air temperature measurement agreed by CCT Guide for the calibration of thermometers in air published on CCT website

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Achievements 2017-2020	Future Scan 2021-2025	Future Scan 2025-2030+
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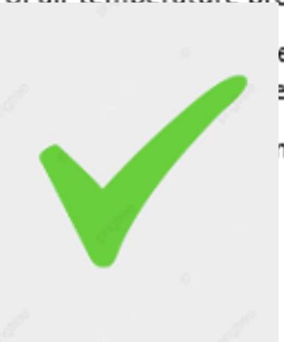
In 2020 a new Task Group on “Air temperature” was formed, tasked: • To work towards and propose a practical definition of air temperature • To work towards and propose how to evaluate the uncertainty contributions in air temperature measurements To develop guidelines for the calibration of thermometers in air.	Practical definition of air temperature proposed  Method proposed e uncertainty contributions in air ements Draft guide for the meters in air	Practical definition of air temperature agreed by CCT and promulgated to key stakeholders Method for evaluating the uncertainty contributions in air temperature measurement agreed by CCT Guide for the calibration of thermometers in air published on CCT website

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Metrology for climate and environment

Growing interest

Increased participation and memberships

Improved cooperation with the WMO and the GCOS

Increased activities, no more limited to funded projects

More staff in metrology for meteorology and climate

Extended scientific production

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- Thank you