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Introduction: Global Climate Observing System (GCOS) stated that ‘Long-term, high-quality and uninterrupted observations of the atmosphere, land and ocean are vital for all countries, as their economies and societies become increasingly affected by climate variability and change’. High-quality observations of the Essential Climate Variables (ECVs) are only possible if they are based on SI traceability and on reliable uncertainty evaluation. Measurement uncertainties evaluation in field conditions is an issue still to be solved. Aware of this present limitation, WMO-INFCOM encourages the organization of global and regional field intercomparisons to achieve data quality consistent with users' requirements and global data compatibility, then, **WMO recognizes the field-based instrument intercomparisons as a fundamental tool for increasing the measurement comparability**. This fact in combination with the importance of air temperature measurements in the evaluation of climate change and the strong influence of external factors on air temperature measurements are the main reasons for **WMO-INFCOM recommending the organization of comparisons of thermometer radiation shields in extreme climates**. Comparisons of radiation shields have been performed in different climate conditions, but an intercomparison of radiation shields in the polar climate was still required. This, in conjunction with the fact that the Arctic is extremely sensitive to climate change, where the rigorous monitoring of ECVs provides early indications of global climate change trends, means the organization of an in-field instrument metrological intercomparison in the Arctic as an essential activity.

Metrology challenge, background:

1. Air temperature measurements are performed by different combinations of thermometers (Pt-100) and radiation shields.

- No defined ‘reference system’ yet
- Each radiation shield creates a specific microclimate inside.
- This limits the worldwide comparability of air temperature measurements.



2. **18SIP06 COAT Project:** Comparison of thermometer radiation shields in the Arctic.

- The Arctic research area of Ny-Ålesund – Svalbard.



-October 2020 –April 2024.

- Consortium composed by an international multidisciplinary team, with meteorologists, Earth science researchers and metrologists: INRiM (Italy), CNR-ISP (Italy), EDI (Switzerland) and CEM (Spain).

- Goals:

- a. Define a validated comparison **protocol**
- b. Perform the **field intercomparison**.
- c. Provide a **robust analysis** and conclusions.

Experiment: Comparison Campaigns

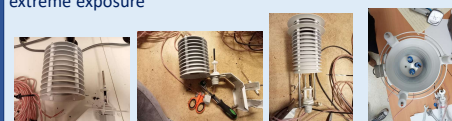
Equipment:

- 42 Pt-100
- 3 dataloggers fluke 1596a
- 11 different models of radiation shield and ancillary instrumentation from different providers:



Laboratory campaign:

Calibration of the thermometers (before and after) the field campaign: drift 10 mK, after 14 months of external extreme exposure

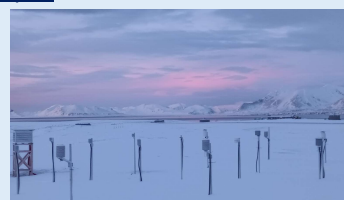


Field campaign (14 months external exposure):

- Correct siting exposure of the comparison field was considered.
- Redundant configurations of the shields
- One radiation shield per pole
- Big shields: with 3 Pt-100 (one of them with high emissivity)
- Small shield: with one Pt-100. Duplicated systems in the comparison field
- Sampling interval 2 minutes



Analysis:



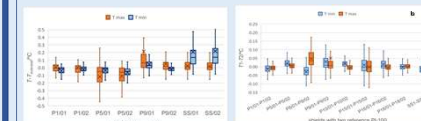
Quality control applied to all the data:

- Null data. $R = 0$ or $R = \text{void}$
- Erroneous data. $R(t) = R(t-2 \text{ minutes})$.
- Inconsistency data: $R \notin (-40, 40) ^\circ\text{C}$
- High variability of the data: Data: variation higher than $5 ^\circ\text{C}$ regarding the previous value
- **~95% of data passed the data quality control**

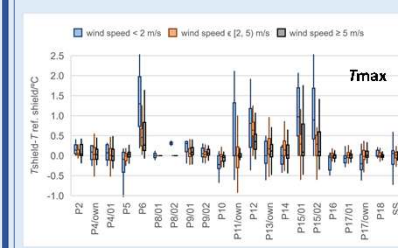
Reference shield

ISO 17714:2007 says that “screens that are cooler during the day and warmer during the night are likely to be giving measurements that are closest to the truth”.

The daily maximum and minimum temperature for each screen was examined in the summer, (June- September) when the diurnal solar radiation is most pronounced.



Shields difference to the reference one



Conclusions + Impact:

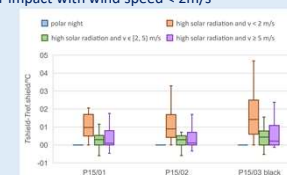
Shields difference to the reference one:

The **maximum difference between shields**: (1.29 $^\circ\text{C}$) for wind speeds lower than 2 m/s. This difference decreases with wind speed, reaching a value of 0.29 $^\circ\text{C}$ when the wind speed is higher than 5 m/s.

The associated **uncertainty** ranges from 0.27 $^\circ\text{C}$ to 1.2 $^\circ\text{C}$, and as a general rule, the uncertainty decreases with wind speed.

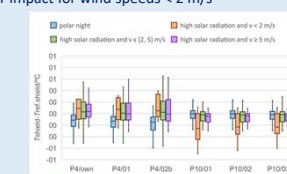
Impact of residual solar radiation inside the shields:

Higher impact with wind speed $< 2 \text{ m/s}$



Effect of ventilation in active ventilated shield:

Higher impact for wind speeds $< 2 \text{ m/s}$



Impact:

1. The **validated intercomparison protocol** was submitted to WMO/SC-MINT to be considered as reference document



2. Analysis published:

García Izquierdo, C. et al.; CoAT Project: Intercomparison of Thermometer Radiation Shields in the Arctic. *Atmosphere* **2024**, *15*, 841. <https://doi.org/10.3390/atmos15070841>

Derived and future activities:

European Metrology Project on Cryosphere Quantities

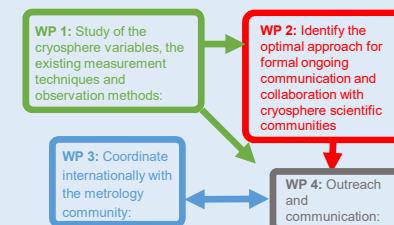
Overall project aim:

Addressing the recommendations raised during the BIPM WMO workshop ‘Metrology for climate action, 2022’ on Cryosphere section bearing in mind that, currently:

- The majority of Cryosphere essential climate variables require observations that are interdisciplinary, involving measurement methods from different CIPM-CCs.
- The degree of metrology implementation in each Cryosphere domain is very different.
- The knowledge of Metrology community about cryosphere quantities is, in general, very limited

It is a 3-year project with cross-disciplinary metrologists to:

1. Develop a roadmap for specific technical metrological needs on cryosphere.
2. Establish a basis for the promotion of more fluid, stable, and long-term communications between the two communities: **cryosphere and metrology**.
3. Support metrology institutes to increase their preparedness to respond to the specific metrological needs of the cryosphere scientific communities.



References:

- [1] Lacombe, M.; Bousri, D.; Leroy, M.; Mezred, M. Instruments and Observing Methods. Report n° 106; WMO Field Intercomparison of Thermometer Screens/Shields and Humidity Measuring Instruments: Geneva, Switzerland, 2011.
- [2] 4. Van der Meulen, J.P.; Brandsma, T. Thermometer screen intercomparison in De Bilt (The Netherlands), Part I: Understanding the weather-dependent temperature differences. *Int. J. Climatol.* **2008**, *28*, 371–387.
- [3] Brandsma, T.; Van der Meulen, J.P. Thermometer screen intercomparison in De Bilt (The Netherlands), Part II: Description and modelling of mean temperature differences and extremes. *Int. J. Climatol.* **2008**, *28*, 389–400.