Components of uncertainty in measurements by means of AWS

sacchio, A. Merlone
Ricerca Metrologica

Outline

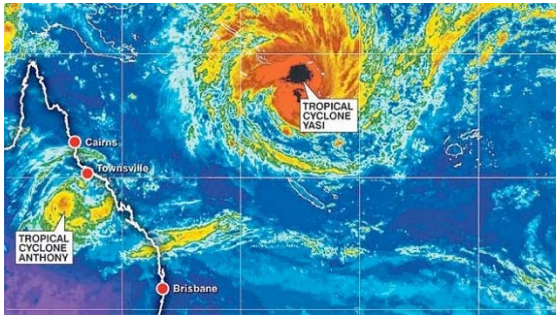
- Metrology and Meteorology
- Uncertainty in temperature measurements
- Test case experiments:
  1. Road siting influence (Coppa et al, subm, Met Apps)
  2. Albedo influence (Musacchio, Coppa et al, in prep)
  3. Wind gust influence (Coppa, Vukicevic, Merlone, in prep)
- Conclusions

INRiM
ISTITUTO NAZIONALE
DI RICERCA METROLOGICA

METEOMET
Metrology for Meteorology

Meteorology

Meteorology is the interdisciplinary scientific study of the atmosphere.



Metrology

Metrology is the science of measurements

Metrology for Meteorology. Why?

Contribution in evaluating measurement uncertainties (Full documented traceability)

Dedicated calibration procedures (Definition of reference grade data)

Metrology terminology

All definitions taken from *Vocabulaire International de Métrologie*

Uncertainty. Parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

Accuracy. closeness of agreement between a measured quantity value and a true quantity value of a measurand. **It is not a quantitative value.**

Error. Measured quantity value minus a reference quantity value.

Precision. Closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions. Measurement precision is used to define measurement repeatability, intermediate measurement precision, and measurement reproducibility.

Types of uncertainty

Type A evaluation (of uncertainty): method of evaluation of uncertainty by the statistical analysis of series of observations

Type B evaluation (of uncertainty): method of evaluation of uncertainty by means other than the statistical analysis of series of observations:

- Stability of comparison medium
- Uniformity of comparison medium
- Logger/reader resolution
- Dynamic behavior of sensor (hysteresis, time lag, …)
- …

Total uncertainty: combination of both

Calibration uncertainty vs **measurement** uncertainty

- Calibration performed in a controlled environment
- Measurements are not -> much harder to evaluate!

Meteorology

World Meteorological Organization
Weather • Climate • Water

The **mission** of WMO is to:

Facilitate worldwide cooperation in the establishment of networks of stations for the making of meteorological observations as well as hydrological and other geophysical observations related to meteorology, and to promote the establishment and maintenance of centres charged with the provision of meteorological and related services;

Promote the establishment and maintenance of systems for the rapid exchange of meteorological and related information;

Promote standardization of meteorological and related observations and to ensure the uniform publication of observations and statistics;

Further the application of meteorology to aviation, shipping, water problems, agriculture and other human activities;

Promote activities in operational hydrology and to further close cooperation between Meteorological and Hydrological Services;

Encourage research and training in meteorology and, as appropriate, in related fields, and to assist in coordinating the international aspects of such research and training.

INRiM ISTITUTO NAZIONALE DI RICERCA

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)

October 1st, 2011

MeteoMet Joint Research Project official start date!

2011 -> 2017

METEOMET
Metrology for Meteorology

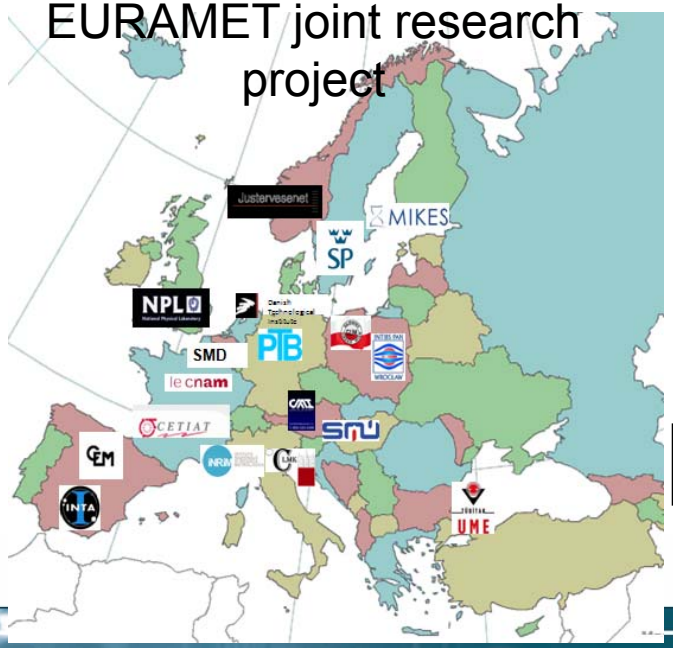
11 M€ Budget

300 Deliverables

960 Man months

(80 years!)

Meteomet is a EURAMET joint research project



MeteoMet is the larger EURAMET consortium

- 21 National Institutes of Metrology
- 12 Universities
- 13 Research centers
- 9 Instrument Companies
- 10 Meteo agencies

Collaborators – Meteo and Research Institutions

CIMO & CCl

Collaborators – Private companies

INRiM
ISTITUTO NAZIONALE
DI RICERCA METROLOGICA

Collaborators – Universities

METEOMET
Metrology for Meteorology

METEOMET
Metrology for Meteorology

University of Reading

UPC
UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH

UNIVERSITÀ DEGLI STUDI
DI GENOVA

PRINCETON
UNIVERSITY

Uniwersytet
Wrocławski

AARHUS UNIVERSITY

Achievements – WP3 LAND

•**Land**

• **Air temperature sensors dynamics:** instruments collection from several manufactures completed. Recommendation on uncertainty evaluation being prepared for ISO17714:2007 and to CIPM/CCT. Tests on self heating and dynamics ongoing.

•**Influence of the siting on air temperature measurements uncertainty:** Protocol prepared and sent to the WMO Expert Team on Observation in situ technologies: positive feedback. Three large scale experiments started in three partner nations. Data ready by July 2017 for the WMO Sustained Performance Classification for Surface Observing Stations on Land

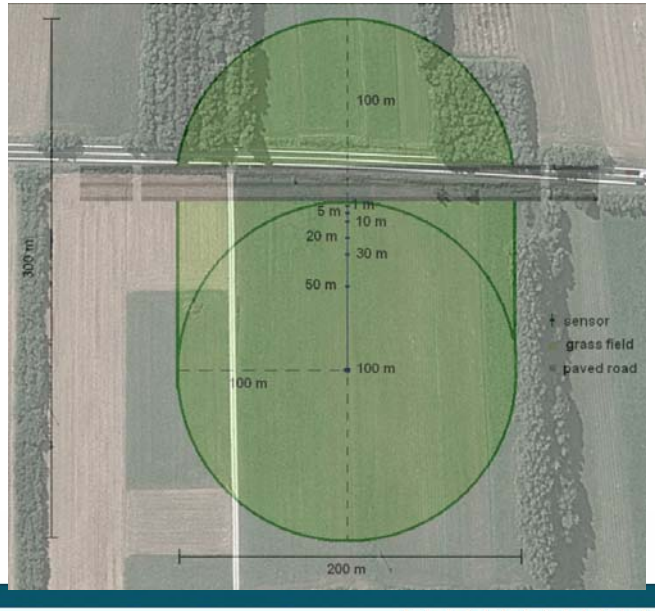
Influence of rain on air temperature measurements. To be started by DTI

Influence of snow albedo on air temperature measurements. Ongoing

Comparison of National Meteorological and Hydrological laboratories: protocol ready; ILC finished. WMO evaluating the possibility to perform a comparison in agreement with such protocol also in Asia regions.

•**Permafrost sensors traceability and measurement uncertainty.** Ongoing

Survey prepared and launched on soil moisture sensors. Numerous responses collected. Workshop held in Madrid 2016

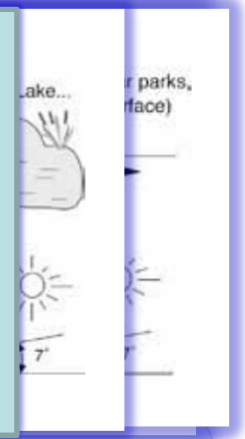


Siting related uncertainty

WMO current classification of meteorological observation sites is a qualitative one based on operative procedures by Météo-France.
It establishes a 5-class hierarchy based on the distance of the sensors from a range of obstacles (roads, trees, buildings,

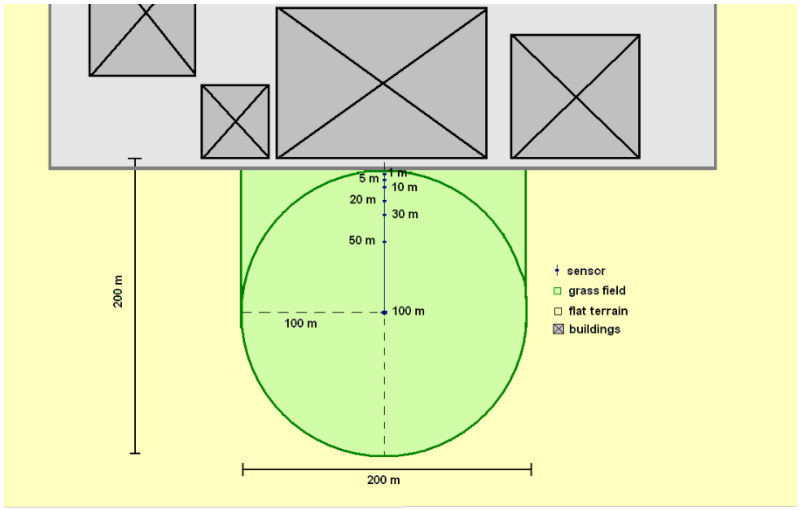
Class 5

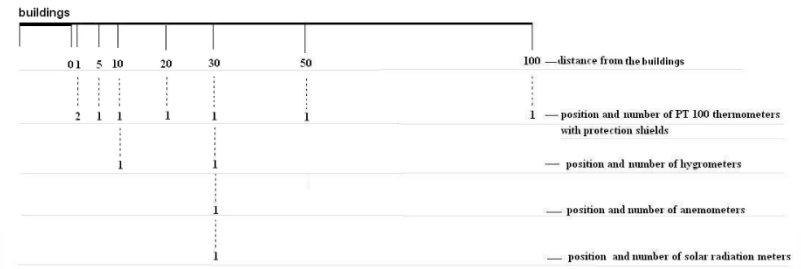
None of the previous!



Within project MeteoMet2 a task is dedicated to the evaluation of the influence of obstacles **(«siting»)** on the uncertainty in surface air temperature measurements.
INRiM, CEM, CMI and IMBIH prepared a threefold experiment, in three different countries, each one dedicated to the evaluation of different siting effects on temperature.

Experimental layout





- Three identical experiments in three nations (Italy, Spain, Czech R.)
- Only variable is the nature of the obstacle:
  - Road…
  - Trees…
  - Buildings…

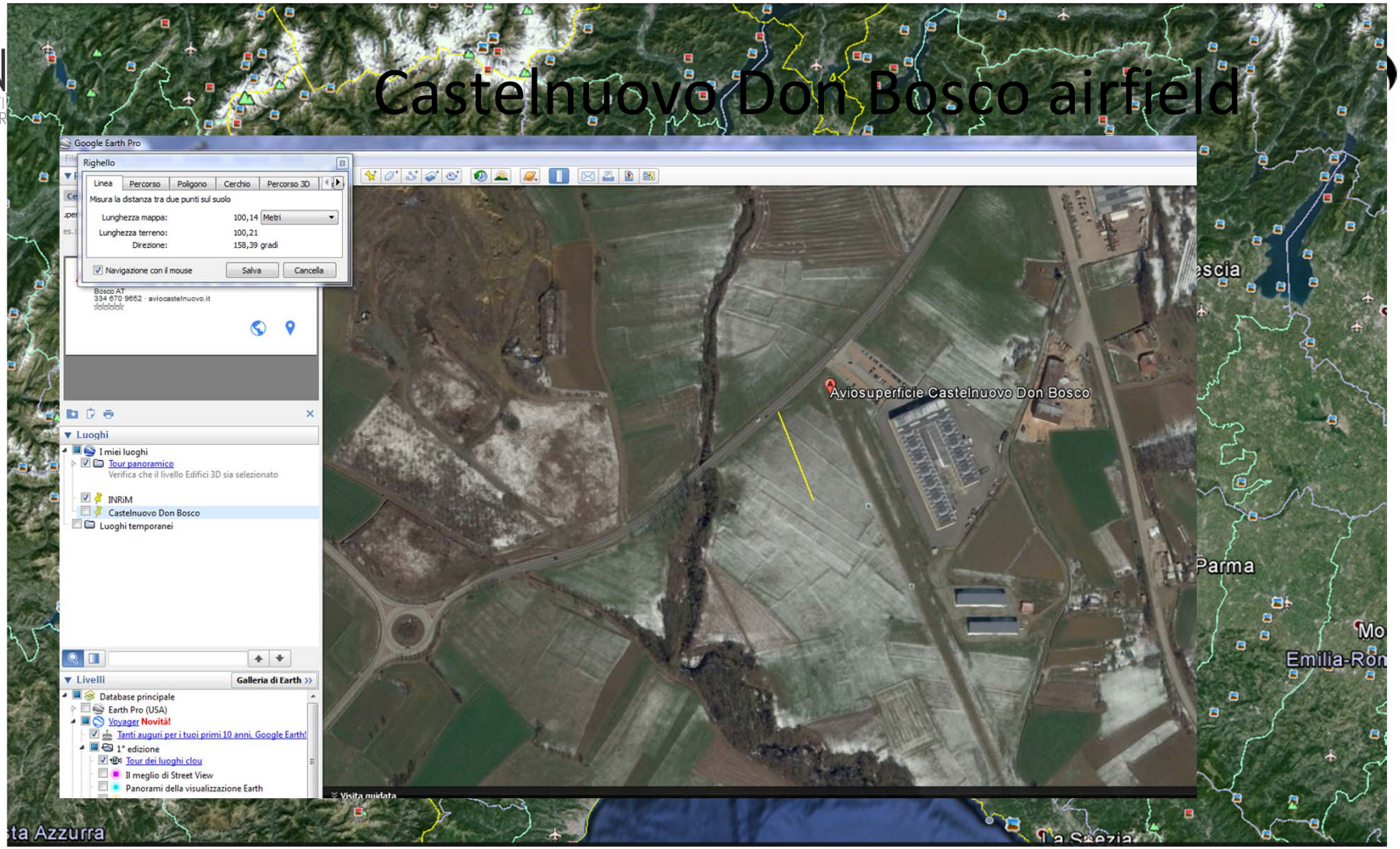
- 7 stations
- Increasing distances from the obstacle
- 7 Pt100 thermometers + 1 redundancy
- 2 hygrometers (#3 - #5)
- 1 anemometer (#5)
- 1 radiometer (#5)

Road – INRiM/IMBiH

Trees - CMI

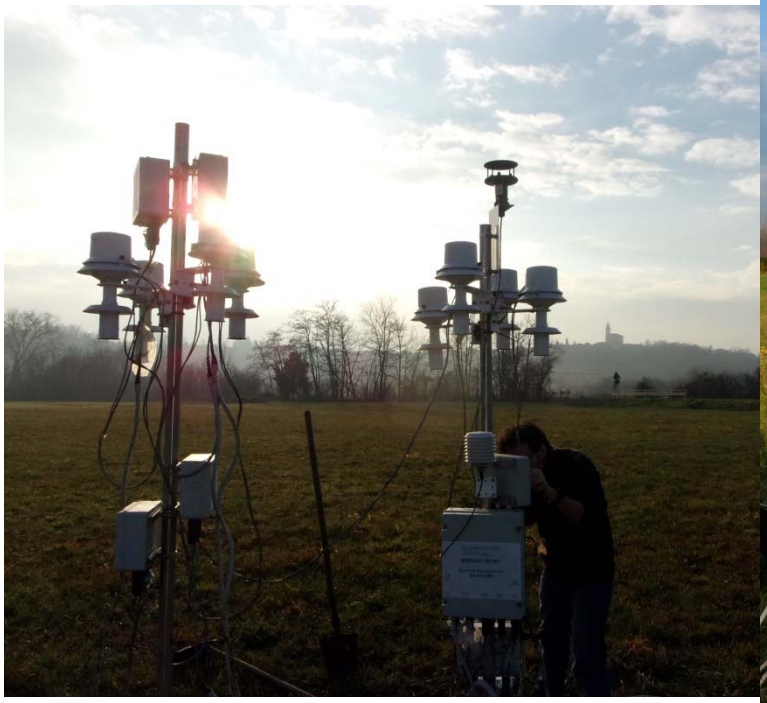
Building - CEM

Castelnuovo Don Bosco airfield

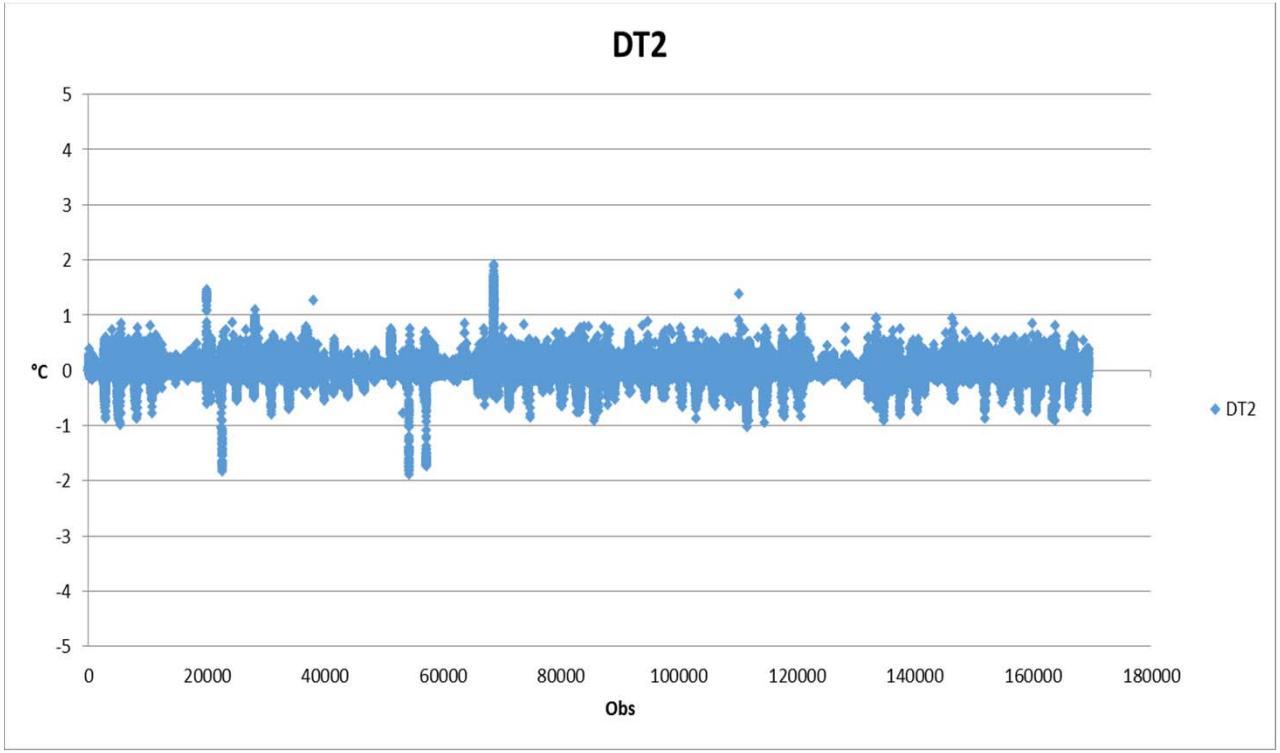


Measurement uncertainty - Italy

Evaluation of in-field behaviour of thermometers in the same conditions



Measurement uncertainty



Evaluation of in-field behaviour of thermometers in the same conditions

MAX(DT) = 2 °C (spikes)

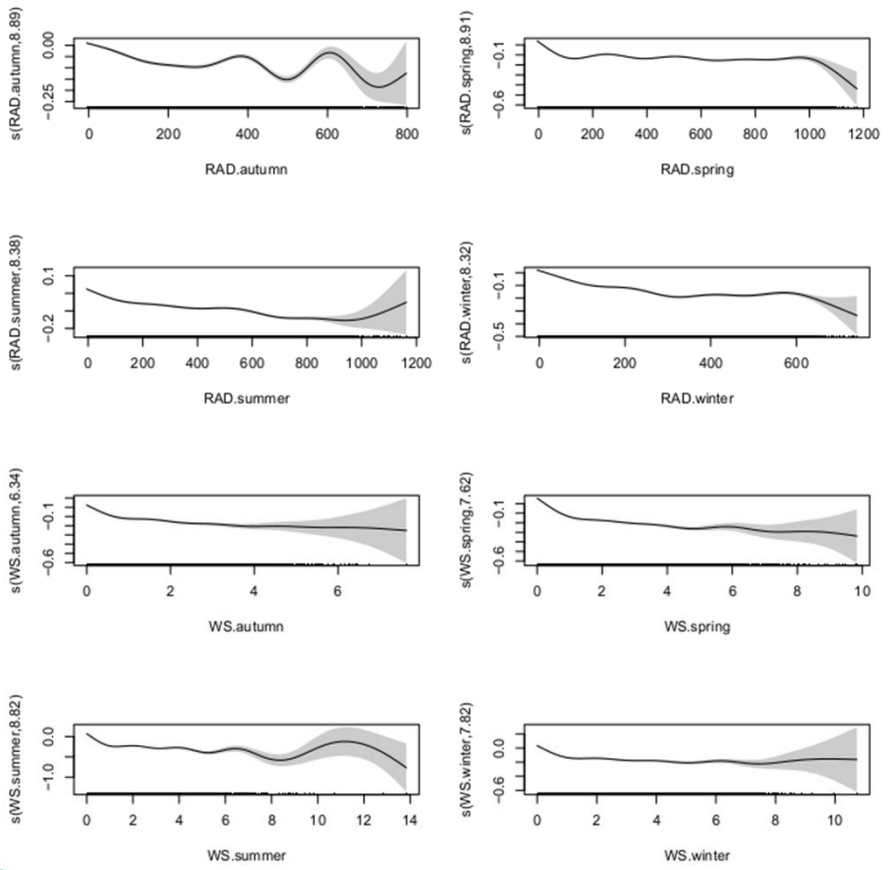
ST.DEV(DT) = 0.1 °C

This is what we assume as measurement uncertainty

Also useful to assess systematics (#1)

The analysis…

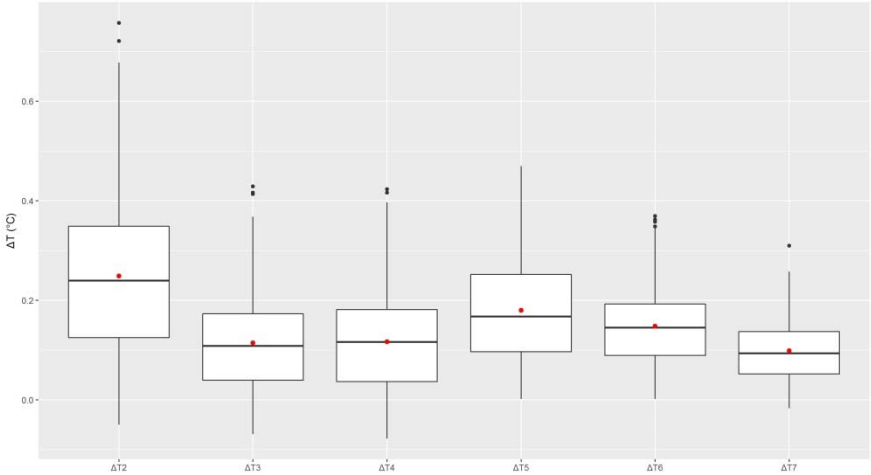
Statistical analysis of the data carried out in cooperation with Università di Torino

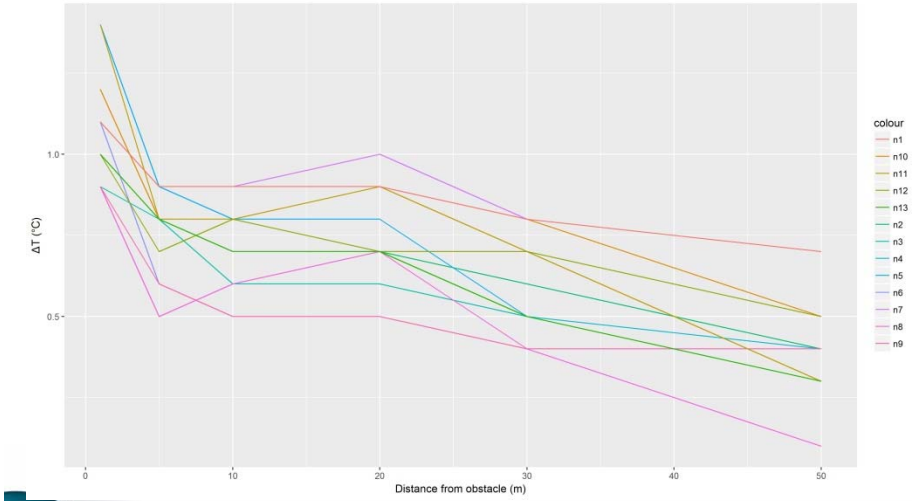


The analysis…

Distributions of ΔTi

- Basically flat after few m
- Within measurement uncertainty
- Station #5 possibly polluted by electronics, low numbers on #4





«Best moments» evaluation

- Sudden drop after only 5 m
- Basically no difference between 10 and 30 m
- Values up to 1.5 °C at 1 m.

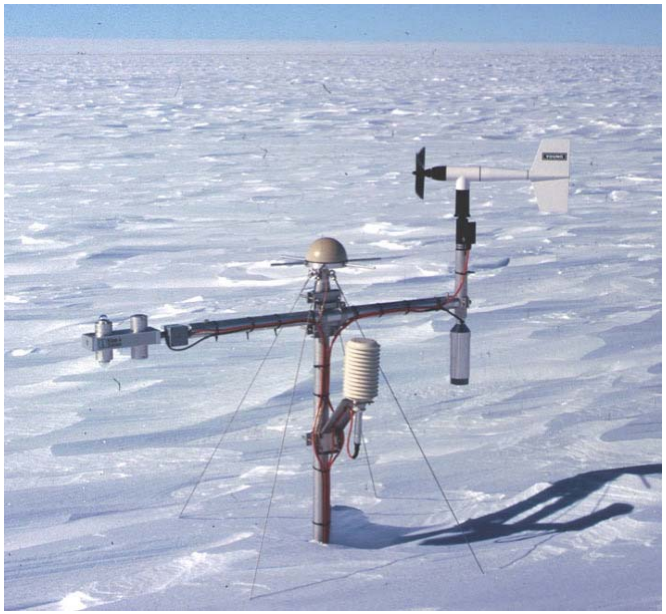
Albedo effect on temperature data

Up to now, the influence of the albedo on air temperature measurements using AWSs in high mountain sites has not been measured following metrology considerations, thus evaluation correction curves and/or uncertainty components to the air temperature data.

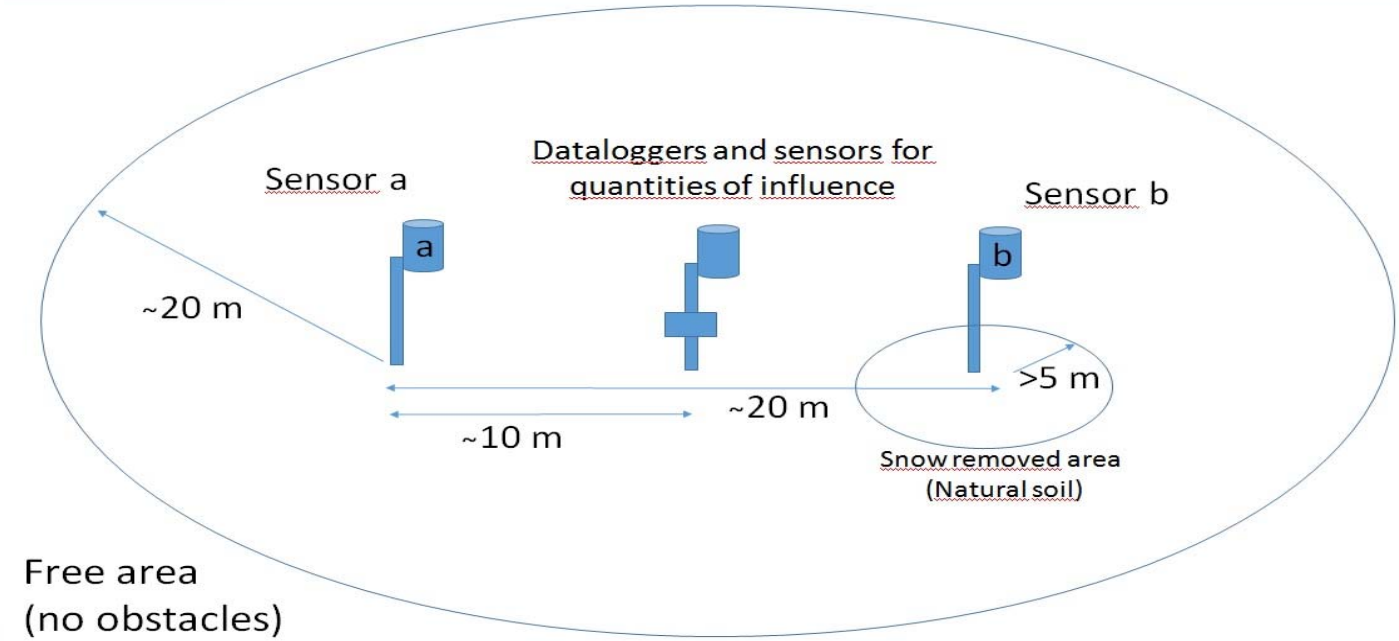
Uncertainty model developed (June 2016)

Experimental installation (Sept 2016).

Preliminary data (May 2017).



1) Preparation of the experiment protocol and method for the evaluation of all uncertainty components.



INRiM
ISTITUTO NAZIONALE
DI RICERCA METROLOGICA

METEOMET
Metrology for Meteorology

BARANI

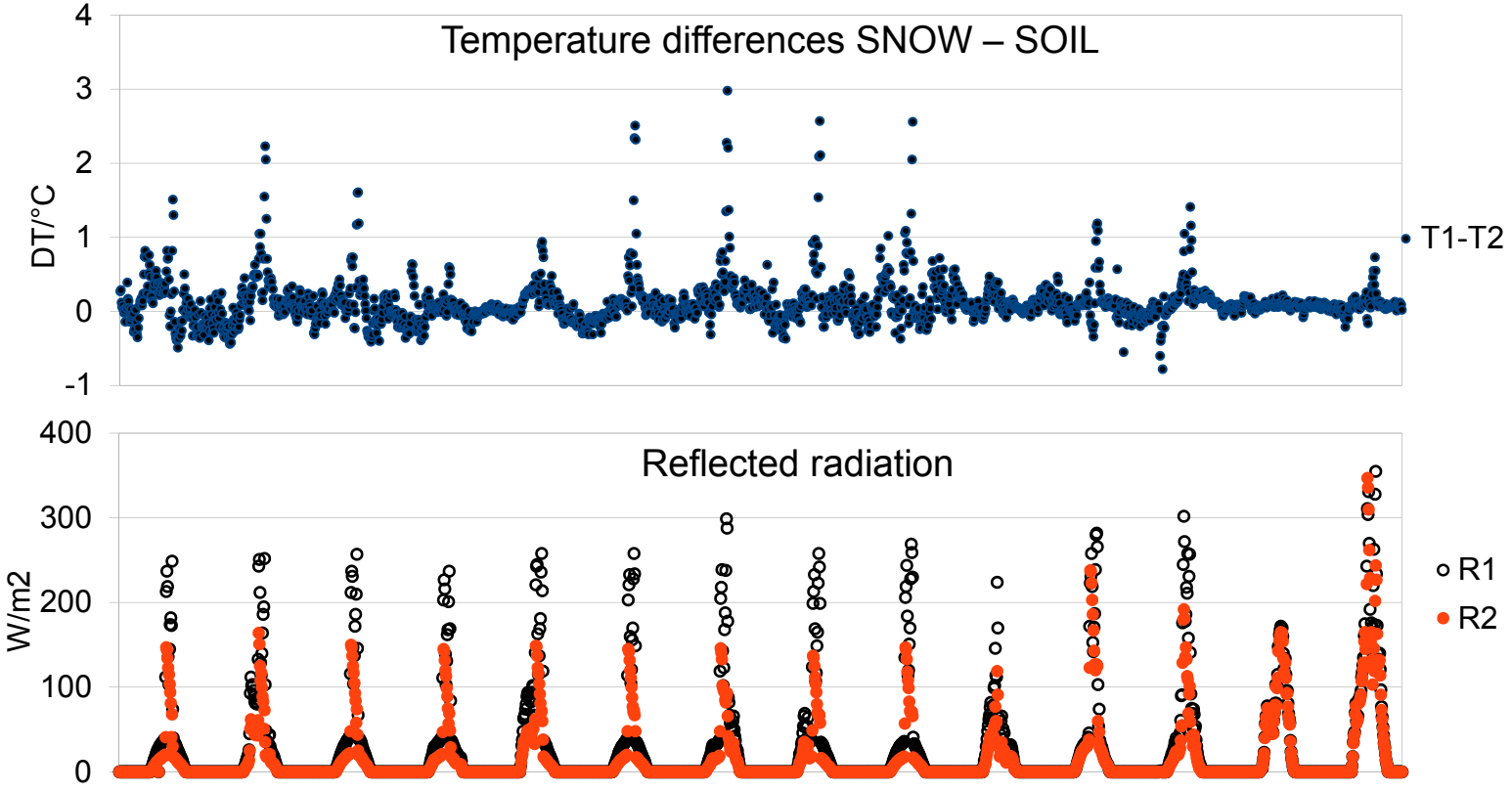
CAE
monitoring your world.

Lombard&Marozzini
strumentazione e sistemi per l'industria e la ricerca

rotronic


26.02.2017

Preliminary results

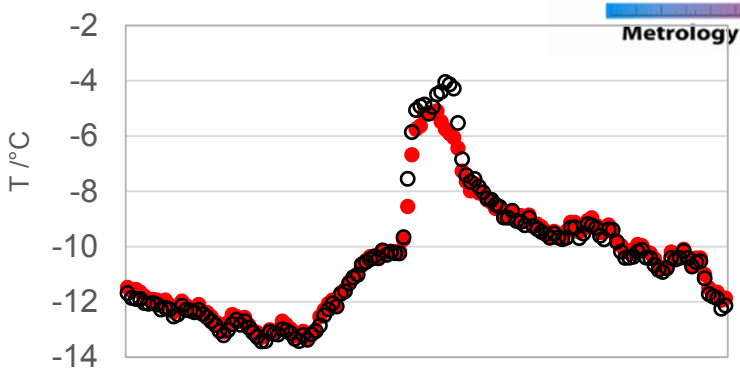


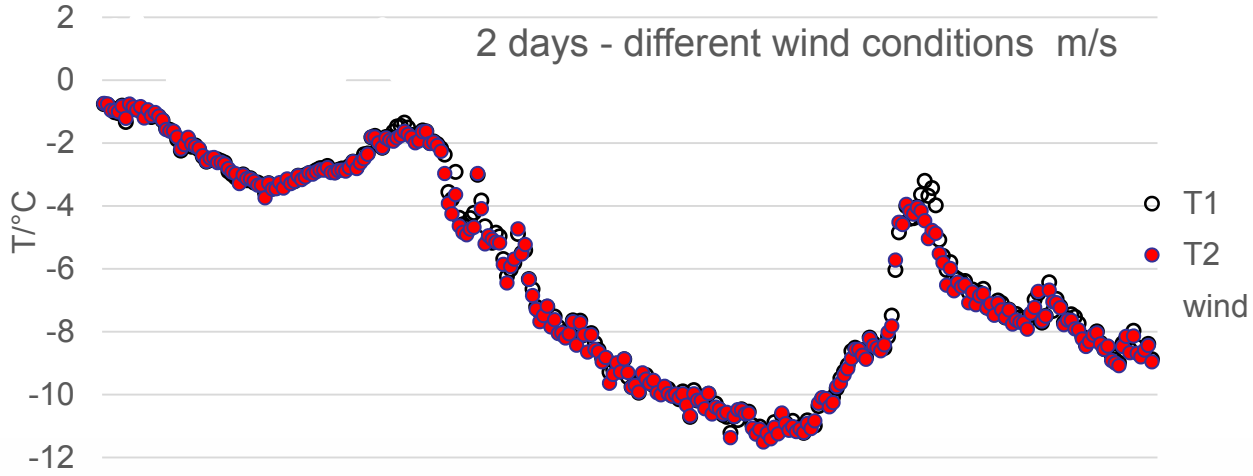
INRiM
ISTITUTO NAZIONALE
DI RICERCA METROLOGICA

METEOMET
Metrology for Meteorology

Preliminary results

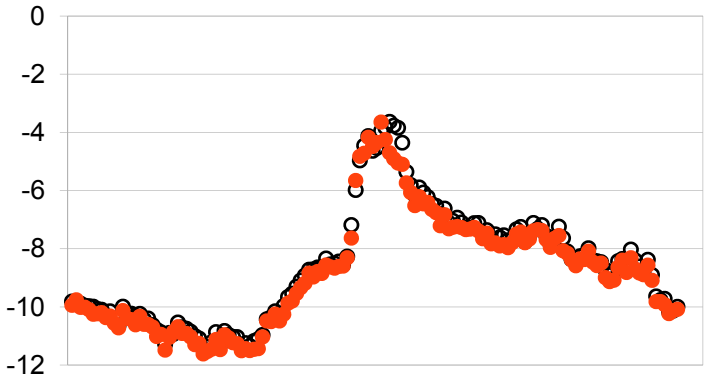
o SNOW
• NO SNOW



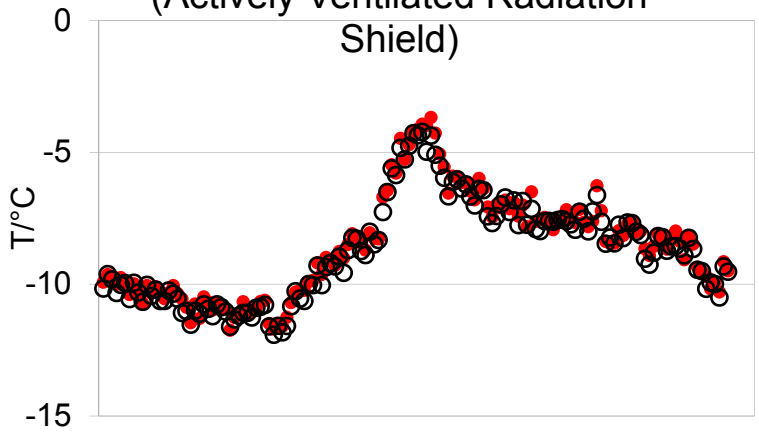


Preliminary results

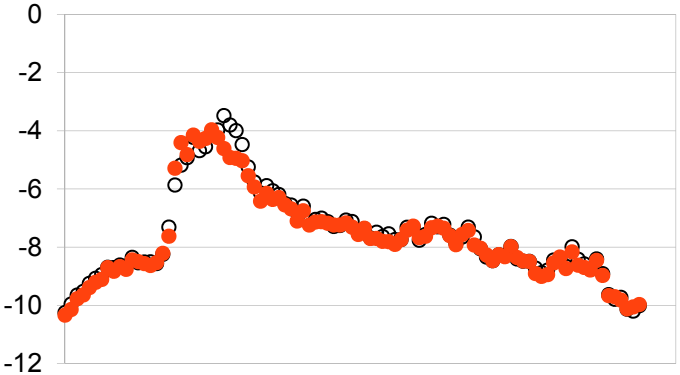
- SNOW
- NO SNOW



Manufacturer «A - r»
(Actively Ventilated Radiation Shield)

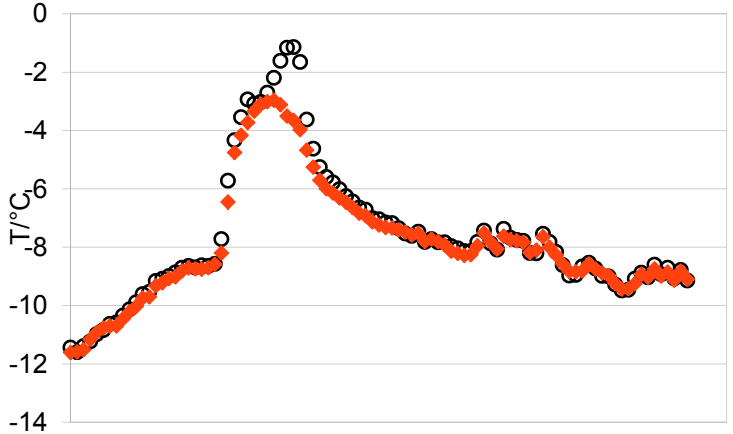


Manufacturer «B - b»
(Same sensor – different shield)

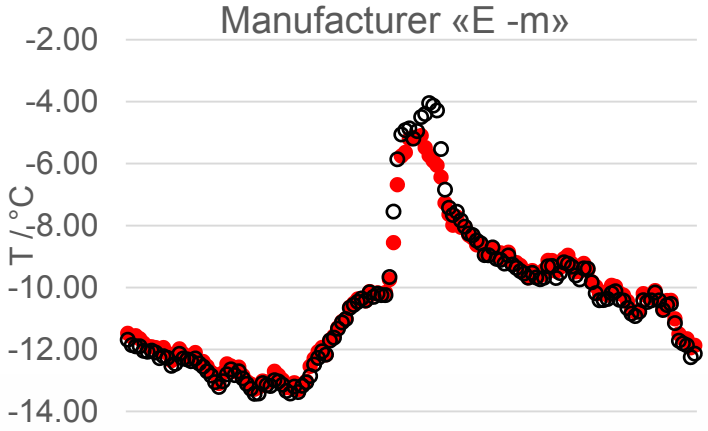


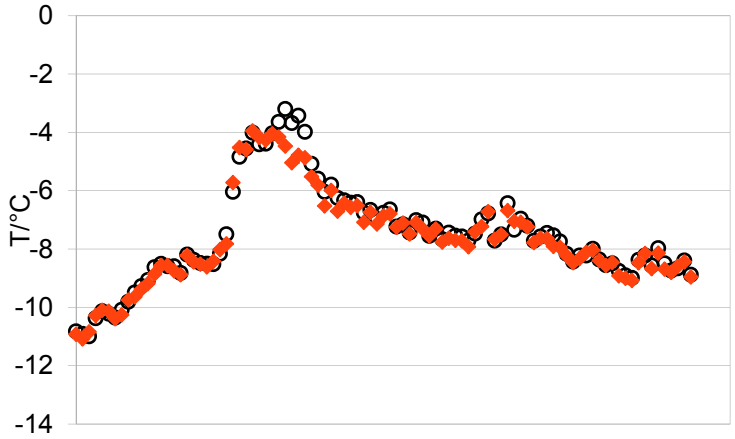
Preliminary results

- SNOW
- NO SNOW



Manufacturer «C - c»
(Same sensor – different shield)



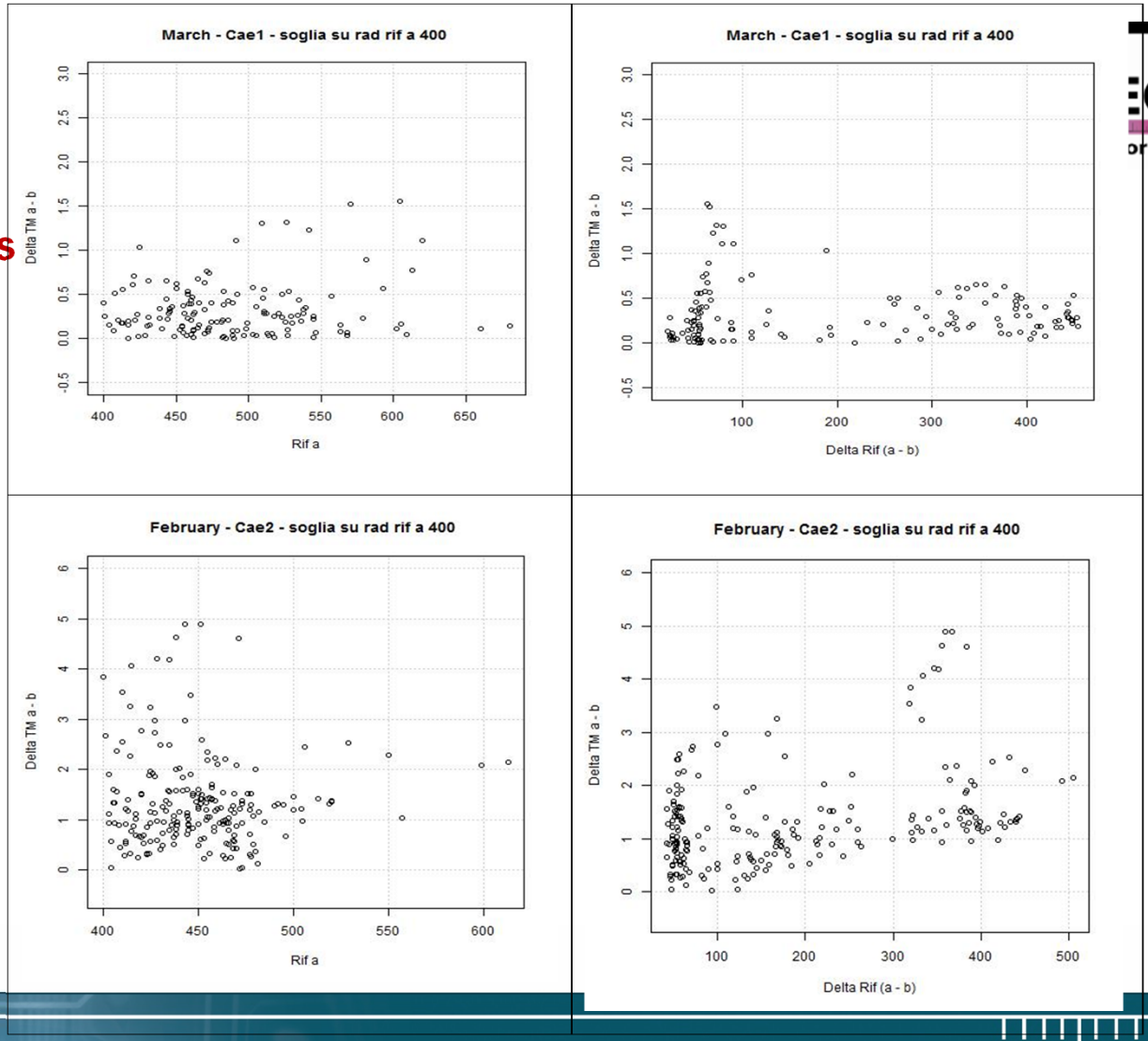


INRiM
ISTITUTO NAZIONALE
DI RICERCA METROLOGICA

EOMET
or Meteorology

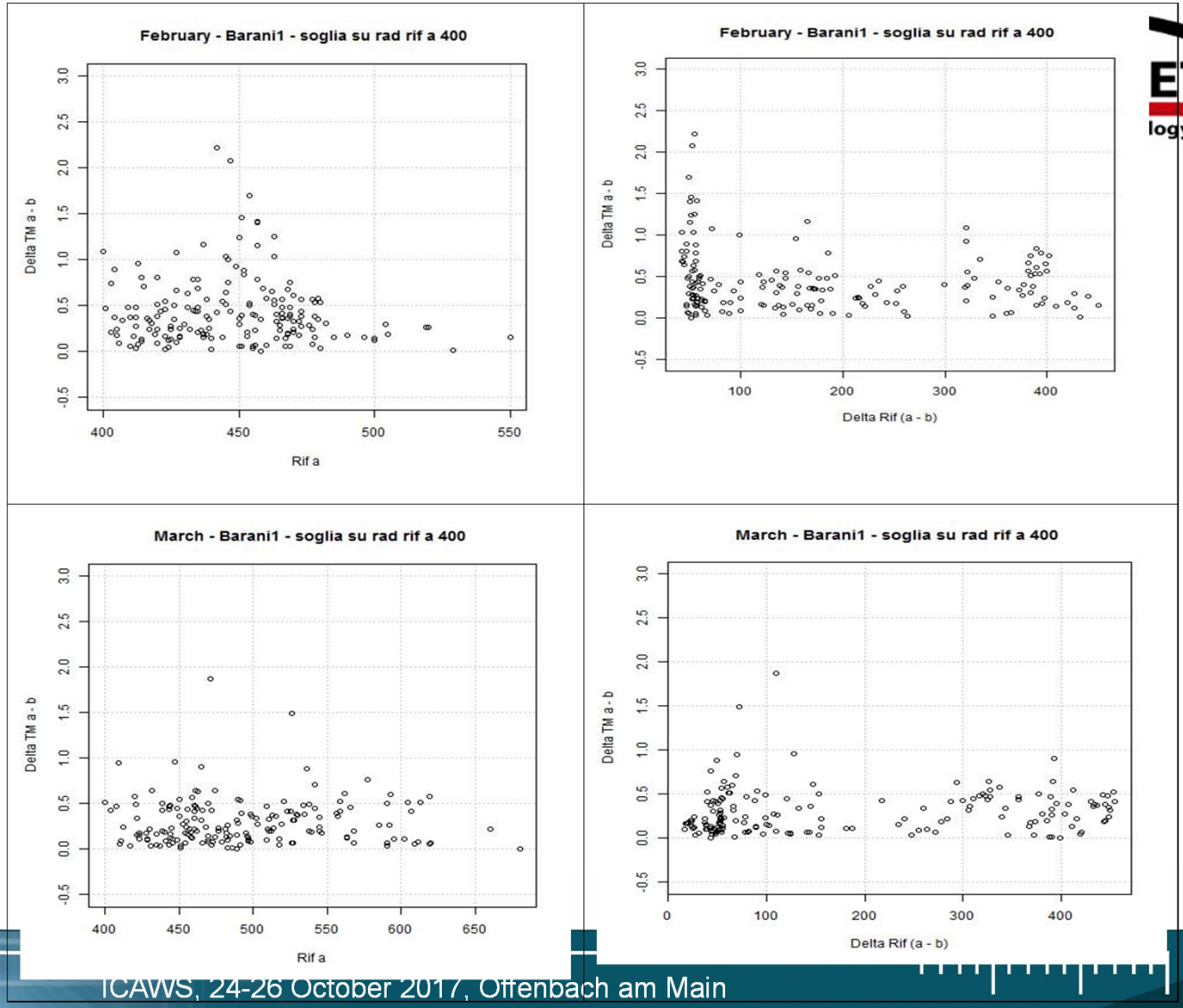
Preliminary results

Dependence of DT on radiation And Drad



Preliminary results

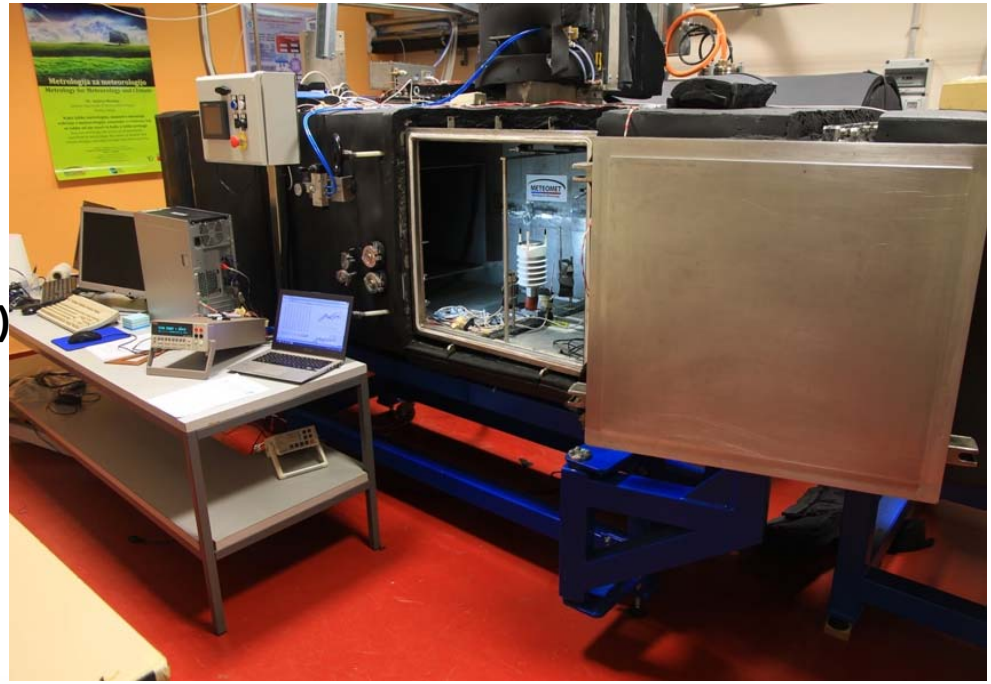
Dependence of DT on radiation And Drad



EDDIE (Earth Dynamics Direct Investigation Experiment) is a climatic chamber with wind generation.

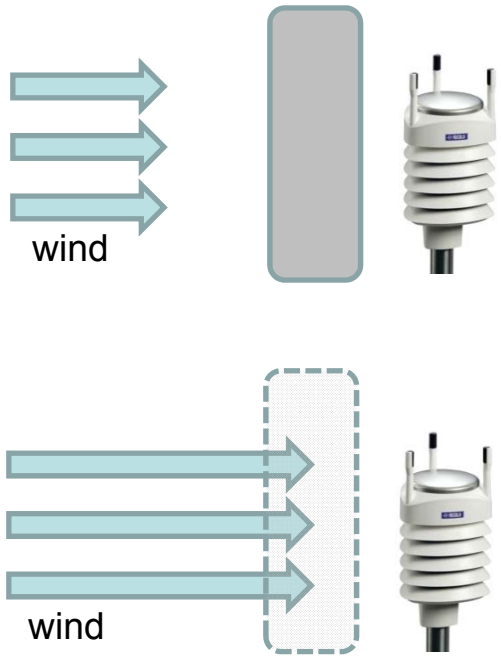
Temperature (- 40 °C -> +50 °C)
Humidity (0% - room)
Pressure (50 kPa -> 110 kPa)
Wind speed (0 -> 30 m/s)

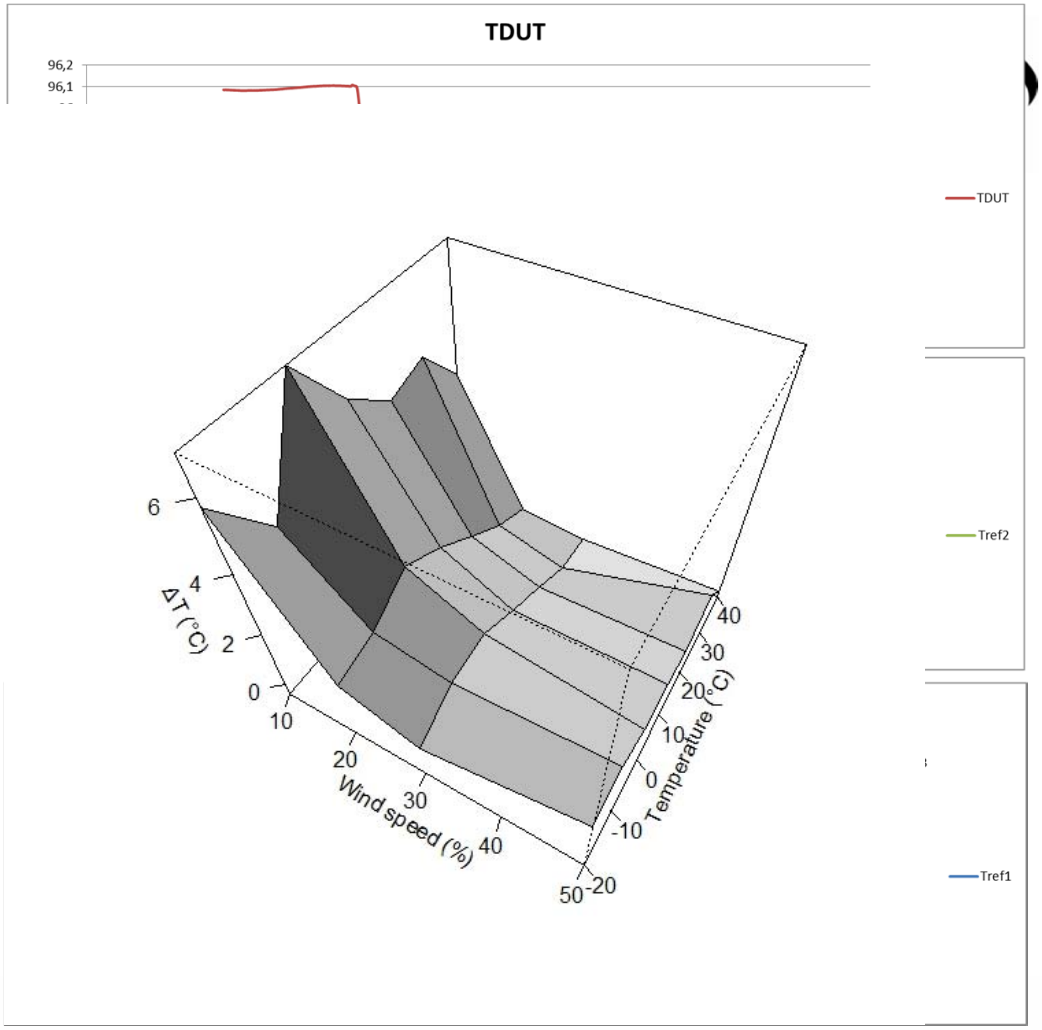
Available at INRiM
for calibration and testing.



Sensor dynamics

EDDIE chamber





In conclusion…

- Evaluation of calibration+measurement uncertainty and additional uncertainty due to quantities of influence of paramount importance
- EURAMET promoting a European Metrology Network to address these issues
- Reseach on the definitions of reference grade measurements in different environments and for different purposes (urban, mountain, agro-meteo, climate, etc..)

METEOMET
Metrology for Meteorology

Thanks for your attention