Snow Albedo Effect on Air Temperature Measurements

Task 3.5 of the JRP ENV58 MeteoMet2 Project

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About MeteoMet

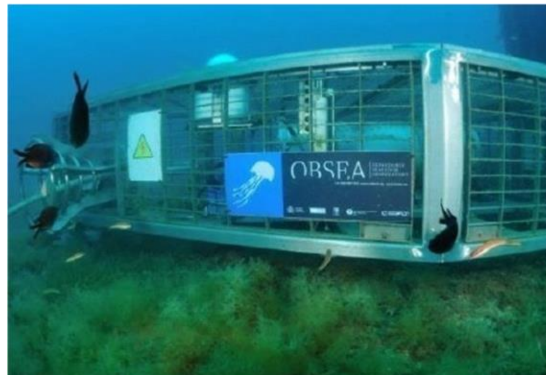
- MeteoMet 2011 – 2017 .... http/://www.meteomet.org
- JRP ENV07 MeteoMet
  - EMRP[1] is jointly funded by participating countries within EURAMET[2] and the European Union
  - metrology for pressure, temperature, humidity and airspeed in the atmosphere
  - need for the project → Metrology for Meteorology (WMO & CCT)
- Objectives
  - methodes to calibrate
  - calibration methods for automatic weather stations
  - understanding & minimising sources of MU[3] in historic temperature datasets

(1) European Metrology Research Programme
(2) European Association of National Metrology Institutes
(3) Measurement Uncertainty

Overview of the MeteoMet2 Project

- Metrology for Essential Climate Variables (ECV)
  - MeteoMet2 (EMRP Joint Research Project, No. ENV58)
  - participants: EURAMET NMIs & DIs; 2013 – 2017
- Aim
  - overall measurements uncertainties for ECVs
  - task: evaluation of uncertainty budget for quantities involved in the meteorological observations & climate evaluations
- Need as stated by GCOS
  - long-term, high-quality & uninterrupted observations based on a sustained traceability to the SI & with uncertainties associated to measured ECVs

- MeteoMet2 ist structured in 3 work packages (WPs)
  - air (WP 1)
  - sea (WP 2)
  - **land (WP 3)**



- ECVs consider
  - water vapour in upper-air and surface atmosphere, surface & deep sea temperature, salinity, air temperature, precipitation, albedo, permafrost temperature, soil moisture

- MeteoMet WP3
  - metrological procedures for evaluation
    - » air temperature
    - » humidity sensors
    - » radiation shield
  - analyization of effects of influence parameters
    - » sensor siting
    - » rain
    - » albedo
  - numerical & experimental characterizations of Automatic Weather Stations (AWS) to supply meteorological community the corrections and uncertainties

- Task 3.5 of WP 3 of the MeteoMet2 Project

tracability for the air & permafrost measurements in high mountain sites

snow coverage albedo effects on air temperature measurements of AWS

BEV
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with the support of

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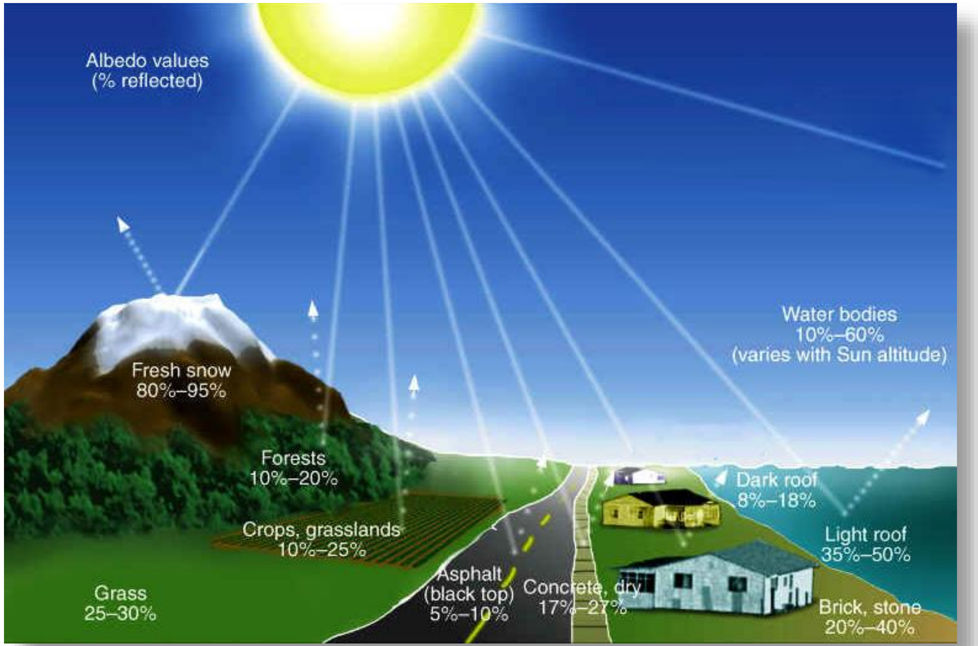
- Snow albedo effect on air temperature measurements under metrological approach

The albedo of a surface is the fraction of the incident sunlight that a surface reflects. Radiation is partly absorbed by surface. The absorbed energy raises the surface temperature, evaporates water, melts and sublimates snow and ice, and energizes the turbulant heat exchange between the surface and the lowest layer of the atmosphere.



- Albedo
  - t_{air} increases under those conditions due to albedo effect
  - albedo of a snow covered surface ranges up to 90%

- Affects air temperature measurement and quantity to be measured
  - instruments are effected by radiative extra heating
  - temperature records can be different from t_{air} value

    $\Rightarrow$ warming sensors by conduction & convection inside the shield
  - different instruments show different magnitude of this effect

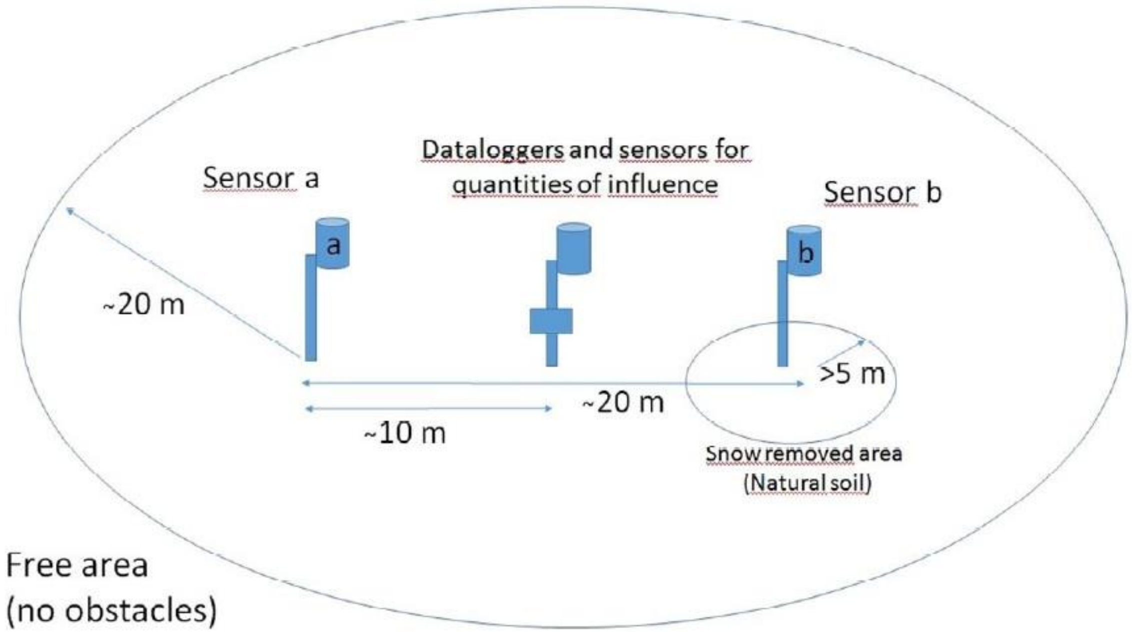
- Objectives
  - evaluation of this effect in terms of correction and uncertainty component of air temperature (t_{air}) measurements
  - report to users on how to include the albedo effect
  - recommendations to manufacturers on how to reduce the effect

- Metrological point of view

  ⇒ influence of snow albedo on t_{air} measurements in terms of uncertainty component

- Under external winter weather conditions exposure
  - uncertainty calculation model
  - experimental in-situ measurements
  - report and recommendations

- Method:
  - evaluation of Δt_{air} of couples of identical sensors exposed
    $\Rightarrow$ snow covered surface vs. natural soil



  - monitoring air temperature, wind speed, radiation & relative humiditiy

- Theoretical model for uncertainty component in t_{air} measurements

$$U_t = t_a(t_{air}) - t_b(t_{air})$$

  - U_t … difference in temperature readings t_a & t_b of 2 identical sensors
    i. considering affects due to presence of obstacles
    ii. zero relative difference between the two sensors
    iii. asymmetric distribution of U_t
    iv. variables/conditions & quantities influencing U_t
    v. uncertainty component on U_t evaluated

  - $U_t = U_t(h, s, w, Rad, Rh)$:
    - h … snowthickness
    - s … snow condition
    - w … wind condition
    - Rad … solar radiation
    - Rh … relative humiditiy

MeteoMet2 Task 3.5 – Work Plan

(1) Preparation of the experiment protocol & method for evaluation of uncertainty components

(2) Collection of instruments from manufacturers

(3) Laboratory characterisation of sensors & complete systems

(4) Identification of site experiment & logistics

(5) Installation & start-up

(6) Measurements campaign & site maintenance

(7) Data analysis

(8) Report & recommendations

(1) Preparation of the experiment protocol & method for evaluation of uncertainty components

- experimental setup
- site requirements
- measuring/evaluation quantities of influence
- measurements ⇐ influencing quantities
- preliminary characterization of sensor pairs (laboratory/field)
- theoretical assumption & practical applications


3a

METEOMET
Metrology for Meteorology

BEV

Uncertainty calculation model for the
MeteoMet2 project, Task 3.5
High mountains observations: permafrost and albedo
Snow coverage albedo effect on air temperature sensors.

July 2016

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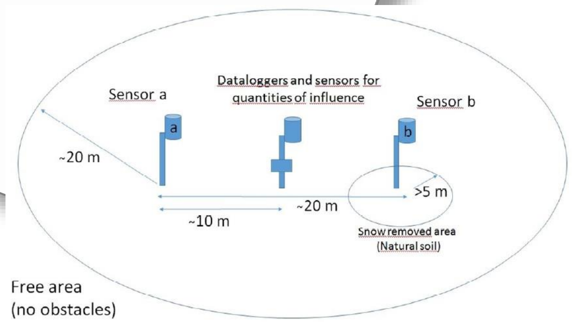


(2) Collection of instruments from manufacturers

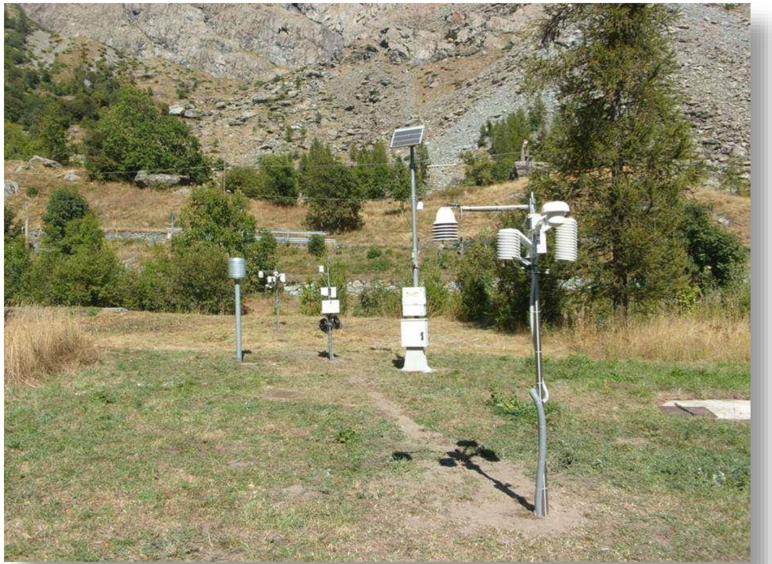
– 4 manufacturers (6 different models)
– different solutions to cover most commonly used devices
– additional sensors (wind, thermo hygrometer, albedometers, …)

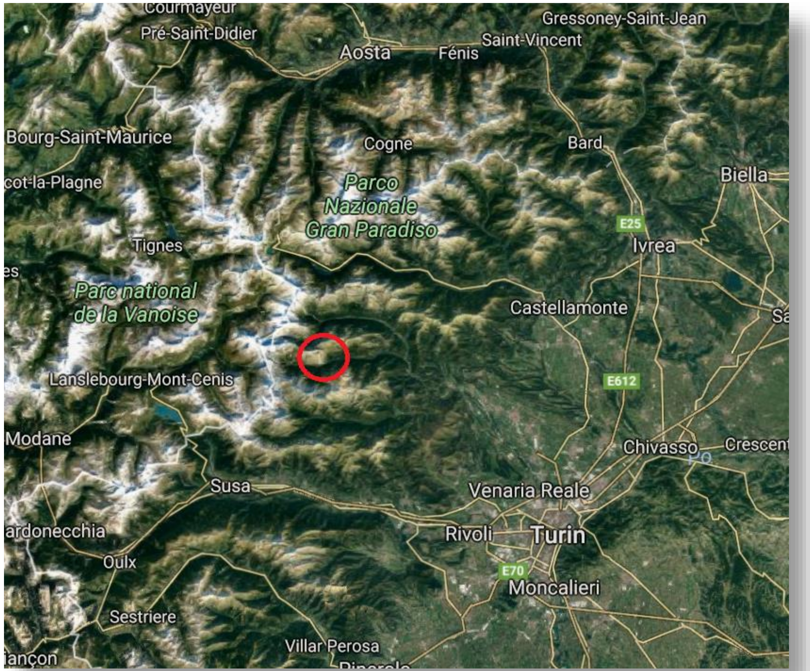
(3) Laboratory characterisation of sensors & complete systems

– different datalogger ⇒ mounting solutions
– different couples of sensors including shields ⇒ controlled environment

(4) Identification of site experiment & logistics

- considering all requirements (snow cover duration, flat surfce, less obstacles, electric current, easy access for maintaince, …)
- Balme *(1415 m elevation, 45° 8‘ 09“ N, 7° 13‘ 19“ E)*





(5) Installation & start-up

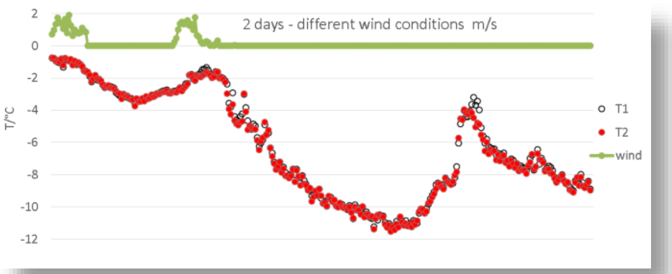
(6) Measurements campaign & site maintenance

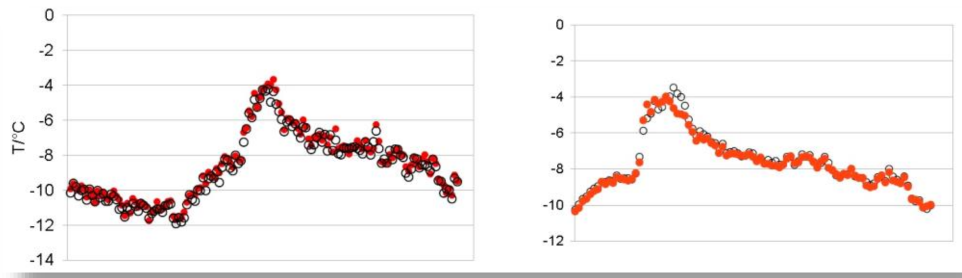
- snow period:
  Nov 2016 – Mar 2017
- constant supervision

Measurements site:

- original configuration
- snow removed at position B

(7) Data analysis ⇒ results

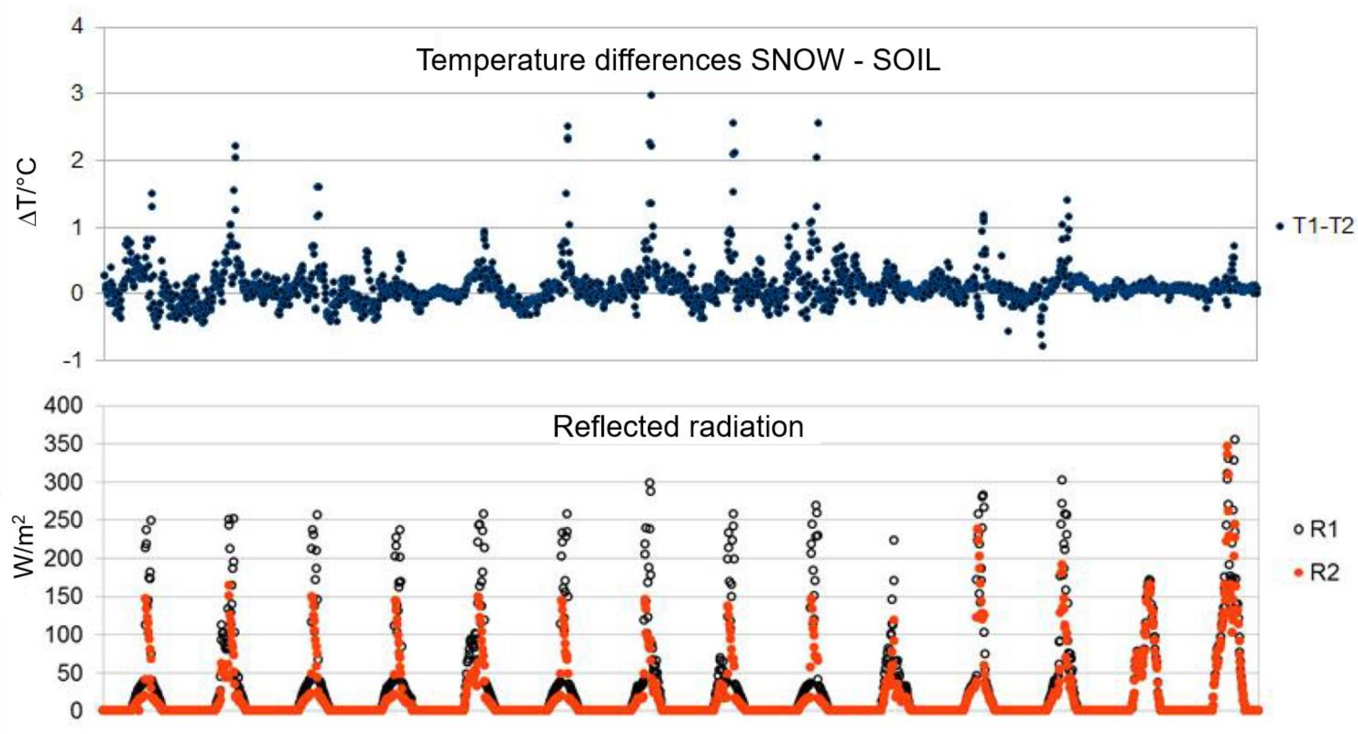




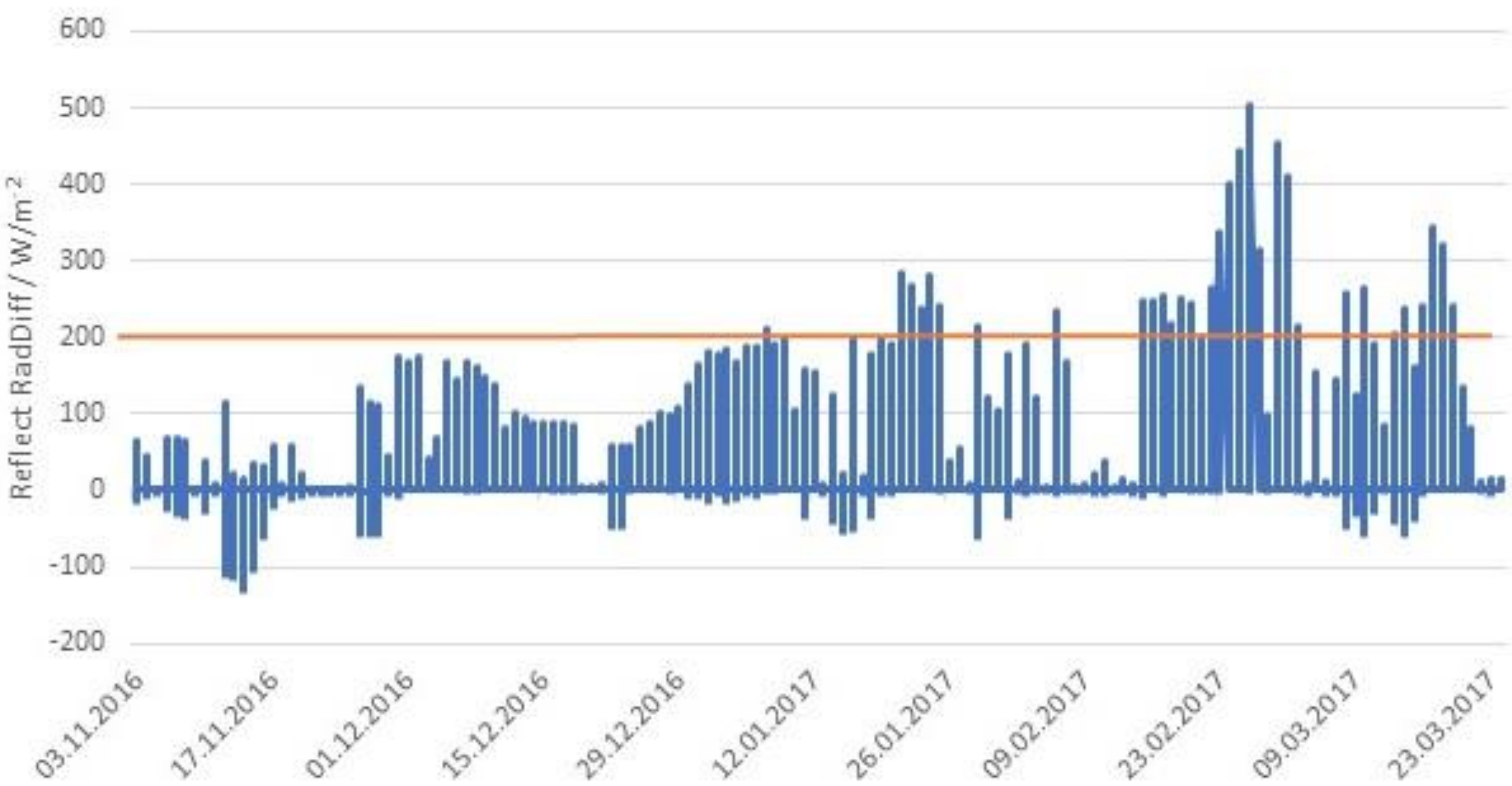
(8) Report & recommendations

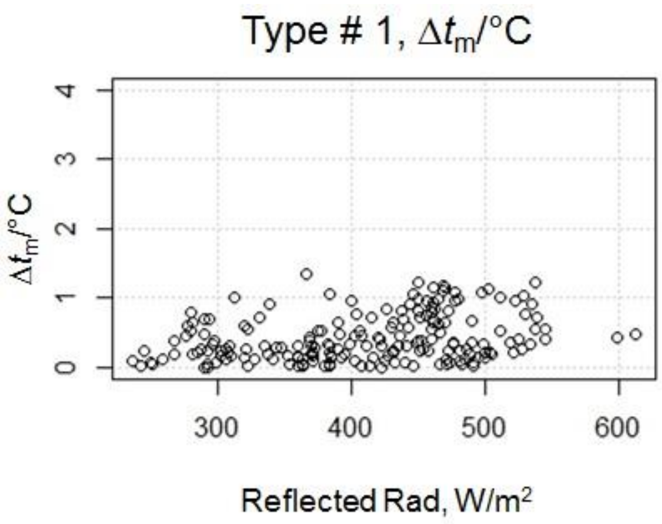
- Data analysis
  - focused on associating t_{air} differences between each pair of identical sensors to radiation differences at position **a** and **b**
  - scope on maximum on t_{air} records due to presence of snow
    - concentrated on daytime periods
    - reflected radiation exponation > 400 W/m^2
  - out of scope: recorded night differences
    - snow covered soil results colder than soil without snow under specific conditions (absence of wind, day temperature above 0°C) due to absorbed energy in snow $\Rightarrow$ 0,6 °C vs daytime

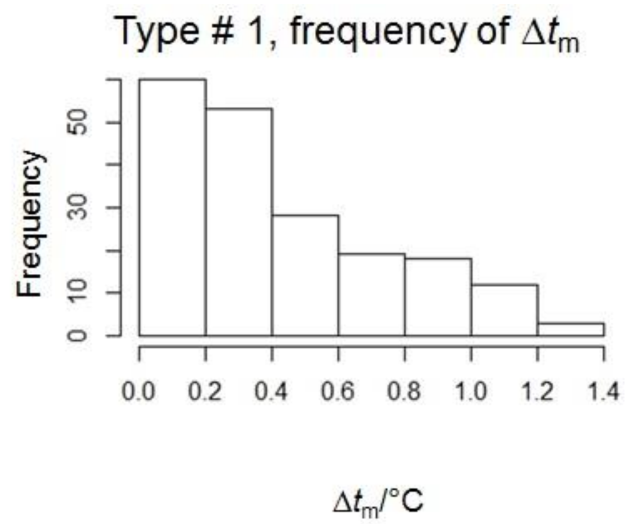
- Example: Δt_m linked to reflected radiation resumed within 2 weeks
  – upper graph: differences between one of the sensor pairs
  – lower graph: radiation measured at R1 (snow covered) & R2 (soil)

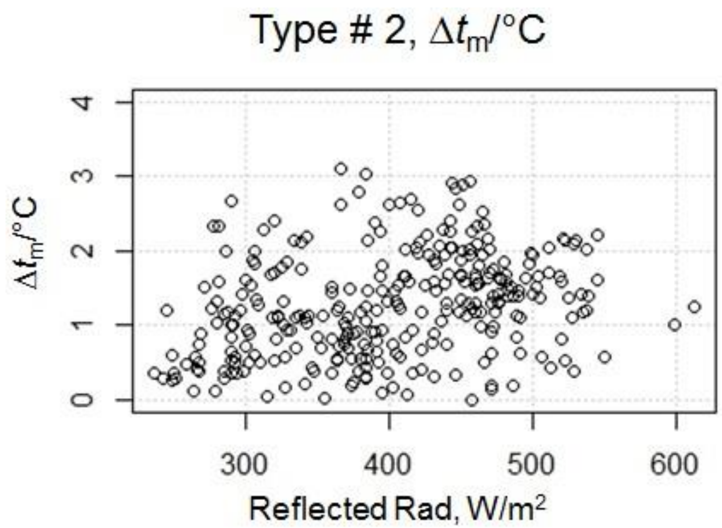


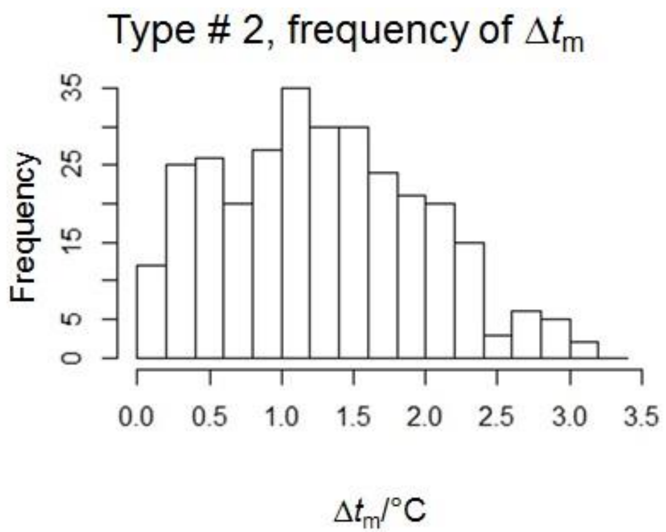
- Reflected raditation difference

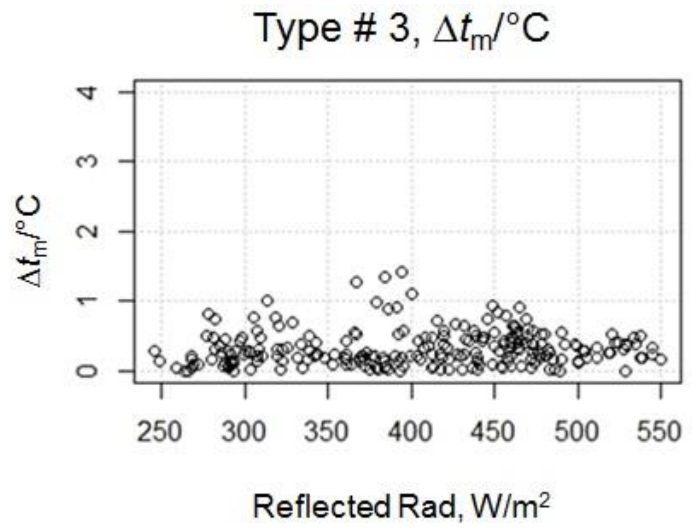


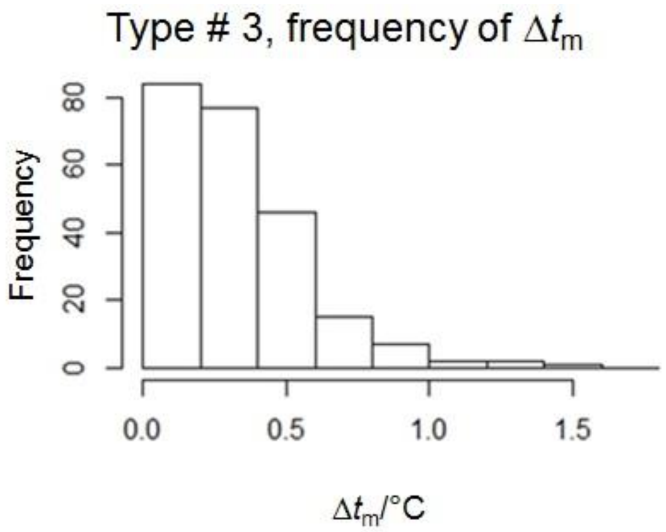

Type # 1, Δt_m/°C
Δt_m/°C
0
1
2
3
4
300
400
500
600
Reflected Rad, W/m²

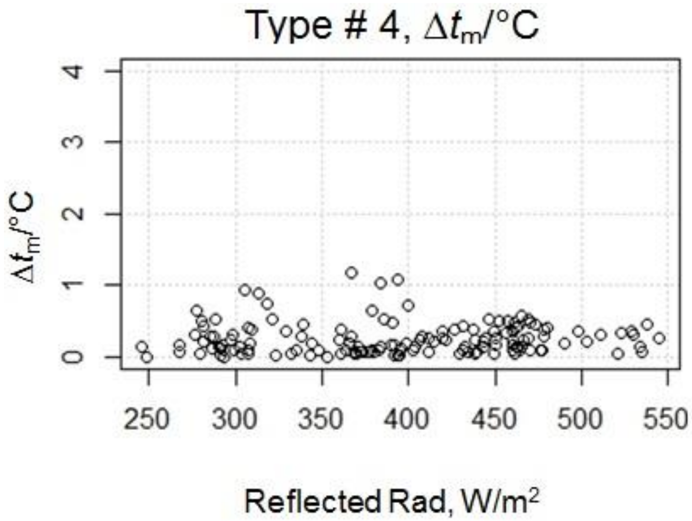

Type # 1, frequency of Δt_m
Frequency
0
10
30
50
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Δt_m/°C

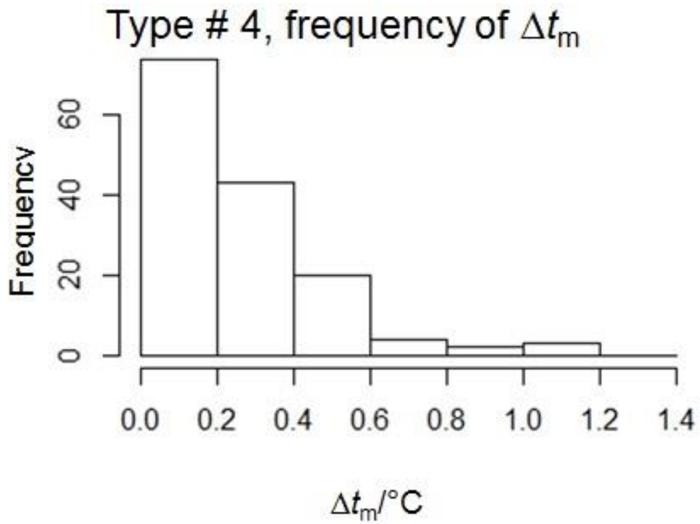

Type # 2, Δt_m/°C
Δt_m/°C
0
1
2
3
4
300
400
500
600
Reflected Rad, W/m²


Type # 2, frequency of Δt_m
Frequency
0
5
15
25
35
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Δt_m/°C

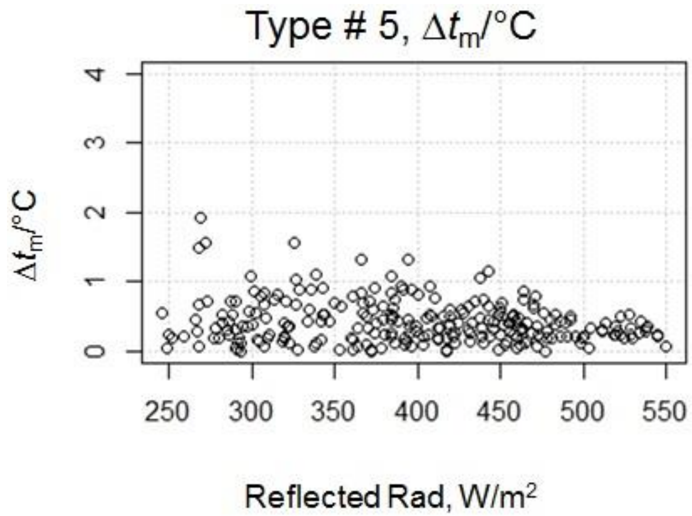

Type # 3, Δt_m/°C
Δt_m/°C
Reflected Rad, W/m²

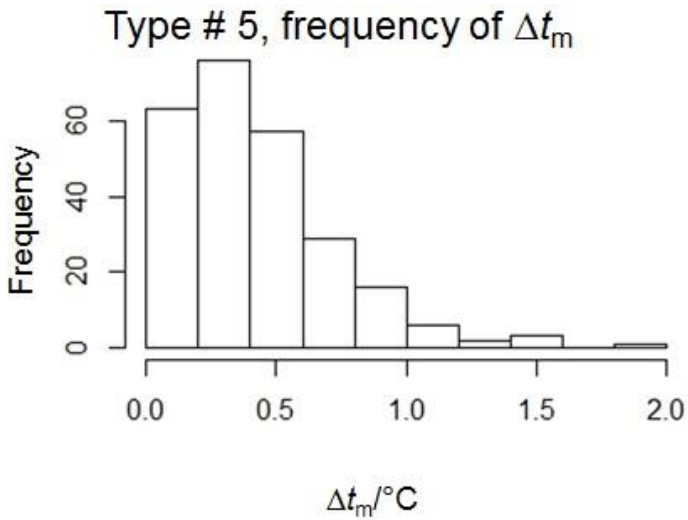

Type # 3, frequency of Δt_m
Frequency
Δt_m/°C

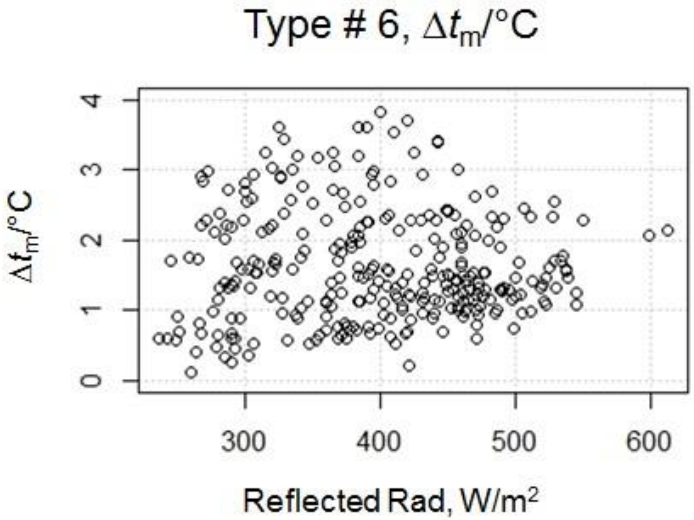

Type # 4, Δt_m/°C
Δt_m/°C
Reflected Rad, W/m²

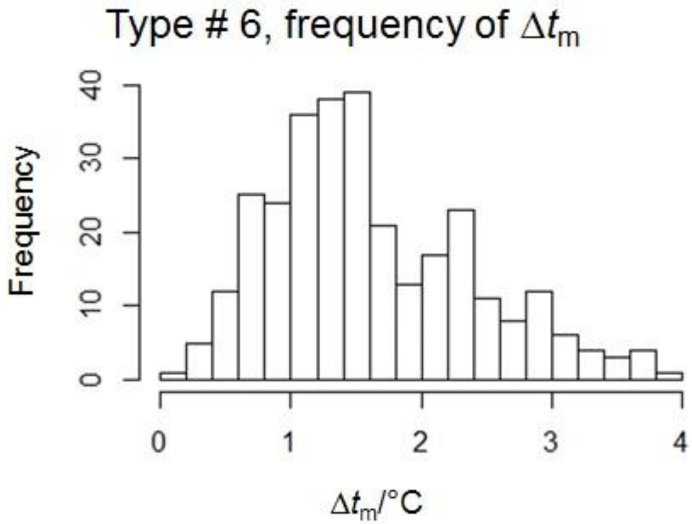

Type # 4, frequency of Δt_m
Frequency
Δt_m/°C

Results

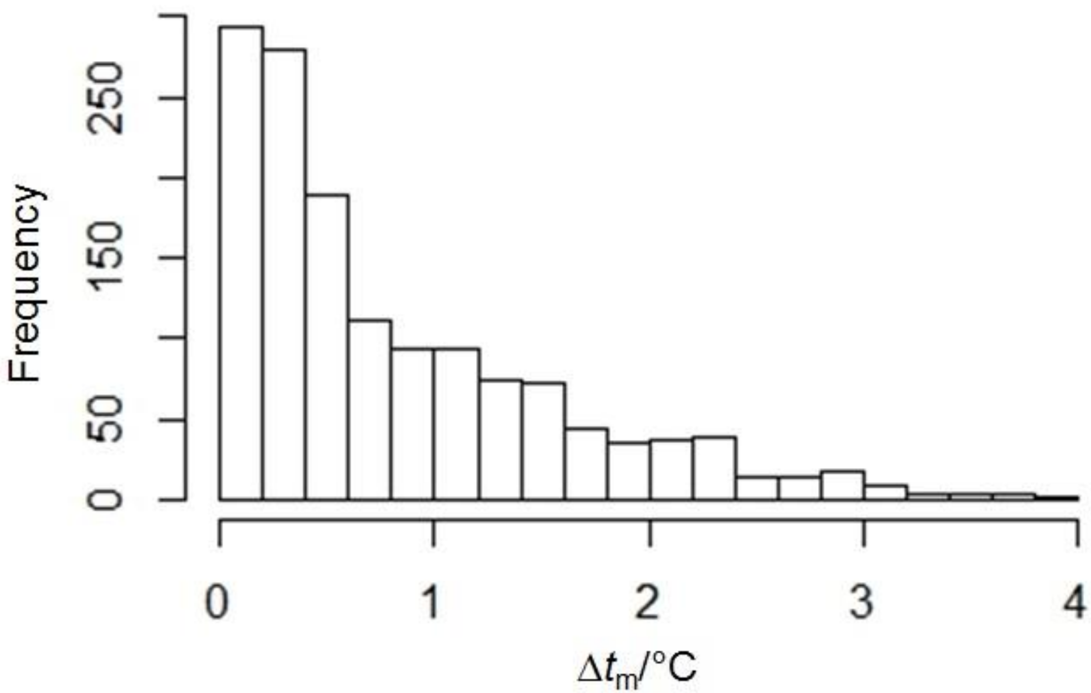

Type # 5, Δt_m/°C
Δt_m/°C
0
1
2
3
4
250
300
350
400
450
500
550
Reflected Rad, W/m²


Type # 5, frequency of Δt_m
Frequency
0
20
40
60
0.0
0.5
1.0
1.5
2.0
Δt_m/°C

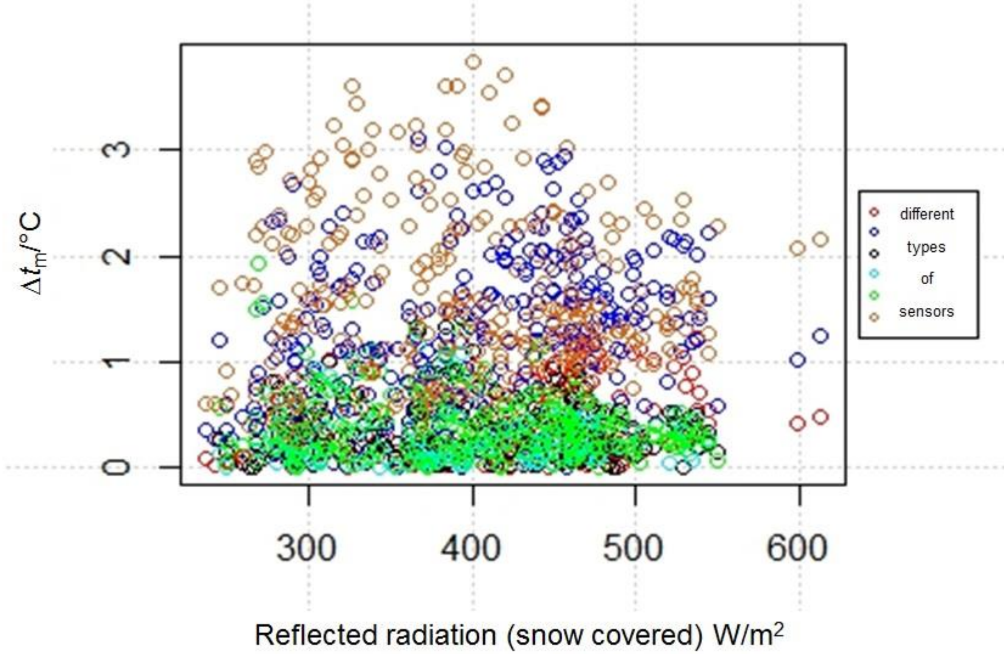

Type # 6, Δt_m/°C
Δt_m/°C
0
1
2
3
4
300
400
500
600
Reflected Rad, W/m²


Type # 6, frequency of Δt_m
Frequency
0
10
20
30
40
0
1
2
3
4
Δt_m/°C

- Frequency of temperature differences Δt_m
  - most frequent values: 0 °C – 0,4 °C
  - a lot of records: 0,4 °C – 1,6 °C
  - less populated: 2 °C – 4 °C



- Comparison of all sensors: Δt_m depending on reflected radiation (snow covered area)
  - most records: 0 °C – 2 °C
  - 2 types of sensors have a higher Δt_m
  - discussion: correlation between Δt_m & reflected radiation (< 400 W/m^2)



- Results: ΔT_{max} for each pair of sensors

Manufacturer	ΔT_{max} /°C	U_{diff} /°C (k=2)
Sensors type # 1 (Manufacturer I)	1,4	0,43
Sensors type # 2 (Manufacturer II)	3,1	0,45
Sensors type # 3 (Manufacturer III)	1,4	0,28
Sensors type # 4 (Manufacturer III)	1,2	0,28
Sensors type # 5 (Manufacturer IV)	1,9	0,34
Sensors type # 6 (Manufacturer IV)	3,8	0,34

Conclusions

- ΔT was found to vary among different types of shields
- aspirated shields falling in the lower mean values recorded
- naturally aspirated shields with special shapes scored lowest differences
- ΔT_{max} between couples of identical instruments linked to maximum reflected radiation differences
- effect of wind is reflected into a reduction of higher ΔT
- excluding outlayers & spikes $\Rightarrow \Delta T_{max}$: 2,7 °C
- overall uncertainty on complete setup: $\approx$ 0,3 °C in k=2
- distribution of differences in function of reflected radiation was found to be uniform
- resulting uncertainty in near ground t_{air} on a snow covered area:
  +1,73 °C in k=2
- night reserved differences are maximum 0,5 °C

... for atmospheric temperature sensors on snow covered surfaces

… to users	… to manufacturers
specific analysis; special procedures, reported protocol	
differences between snow covered area and natural soil are recorded for at least one full season	
ΔT_{max} recorded during stable hours (absence/minimum wind, higher reflected radiation); values recorded in series	
ΔT_{max} used as contribution to uncertainty budget in t_{air} on near surface observation station	solutions are adopted to minimize this effect; repeated measurements
contribution rounded to 2 °C added to uncertainty budget (in k=2) for $t_{air, near ground}$	ΔT_{max} is declared in data sheets as contribution to uncertainty budget (not as correction)

Acknowledgement

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Thank you for your attention!