O3_6

Field intercomparison of candidates for measuring the reference surface air temperature

Akira Yamamoto, Hiroshi Ishimoto
Meteorological Research Institute , Japan Meteorological Agency
Shinichi Miyatake
Meteorological Instrument Centre, Japan Meteorological Agency

山本哲・石元裕史／日本気象庁気象研究所
宮武真一／気象庁気象測器検定試験センター

Acknowledgments: This work was supported by JSPS KAKENHI Grant Number JP17K20051.

Summary

- We have begun a field intercomparison:
  - A shielded thermometer
  - Candidates for measuring the reference surface air temperature
    - A very thin handmade thermocouple
    - Two ultrasonic anemometer and thermometers
    - Two types of instruments using the brightness temperature of atmospheric radiation.
- Our preliminary analysis indicates:
  - Radiometer have great potential for measuring the reference surface air temperature.
  - Radiation effect on very fine sensor is larger than previous studies.
  - Unexplained dependency on wind speed is found.

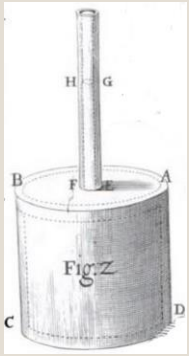
Air temperature has been measured by thermometers over 300 years, but a thermometer measures only “a temperature of a thermometer”

Heat budget of a thermometer (Kondo, 1982)

$$\frac{dT_s}{dt}=\frac{S}{c_0 M}\{R-\sigma T_s^4-c_p\rho(C_h U)(T_s-T)\}$$

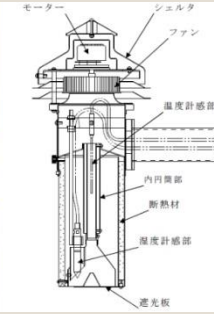
T_s: Temperature of a thermometer
T: Air Temperature

- energy from outside sources
- radiation emitted by a thermometer
- heat exchange between air and a thermometer



Hooke, 1665

- Solar radiation is majority of energy from outside sources.
- Numerous types of thermometer screens/shields has been developed to minimize the impact of radiation.



Japan Meteorological Agency

“Numerous types of thermometer screens/shields has been developed…”
















Lacombe et al. 2011

Many intercomparisons have been performed to evaluate their characteristics…

WMO field intercomparison of thermometer screens/shields and humidity measuring instruments: Ghardaia, Algeria, November 2008-October 2009

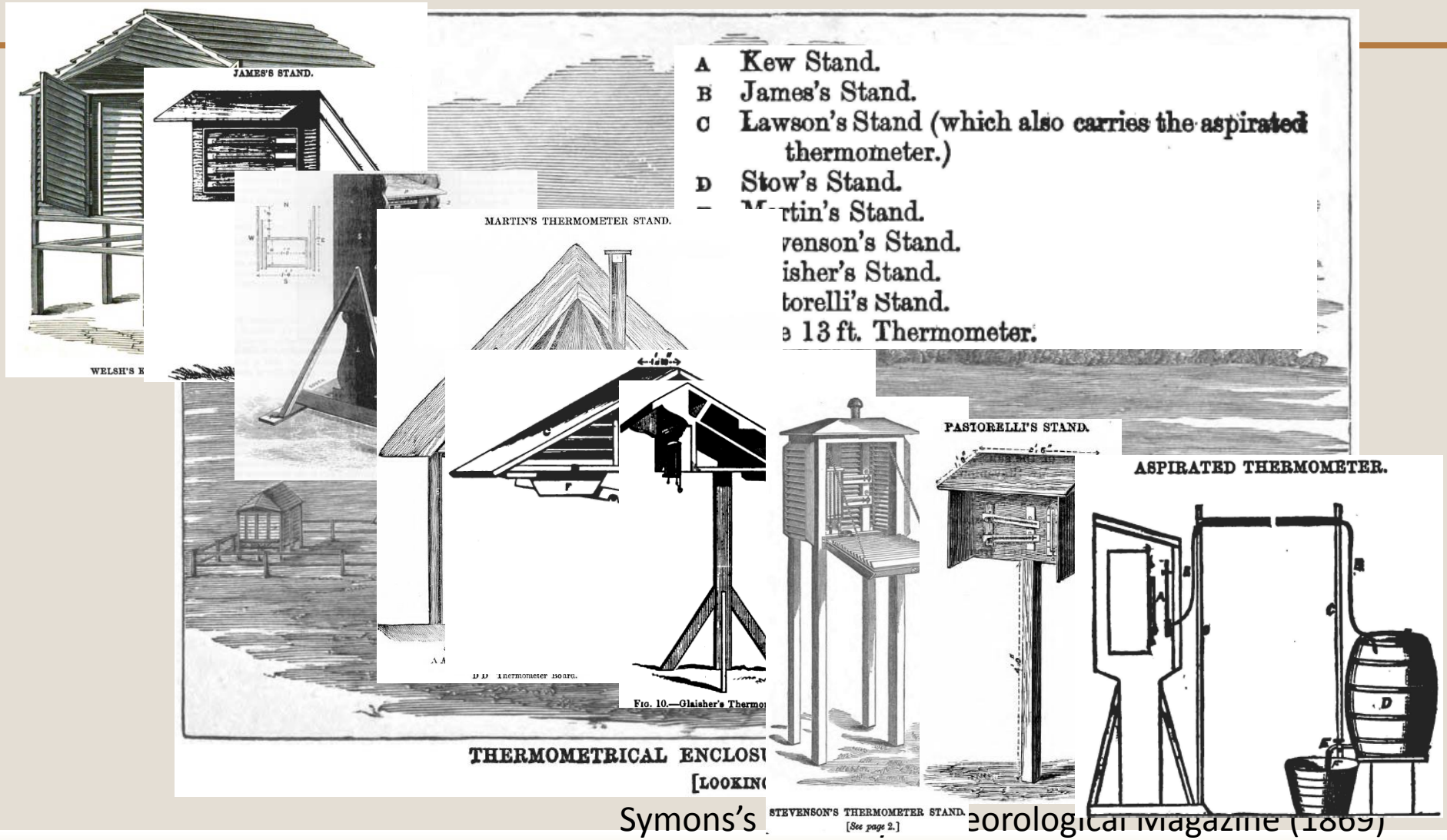
18 types of screens/shield (11 naturally ventilated,7 Artificially ventilated)

Meterorological Instrument Centre, Japan Meteorological Agency, Tsukuba, Japan, August, December 2009-September 2010

11 types of screens/shield (4 naturally ventilated, 7 Artificially ventilated)

…from 150 Years ago

Intercomparison of thermometer stands in England 1868-1870



Symons's … eorological Magazine (1869)

Which one is “true”?

Daily maximum temperature of artificially ventilated screen

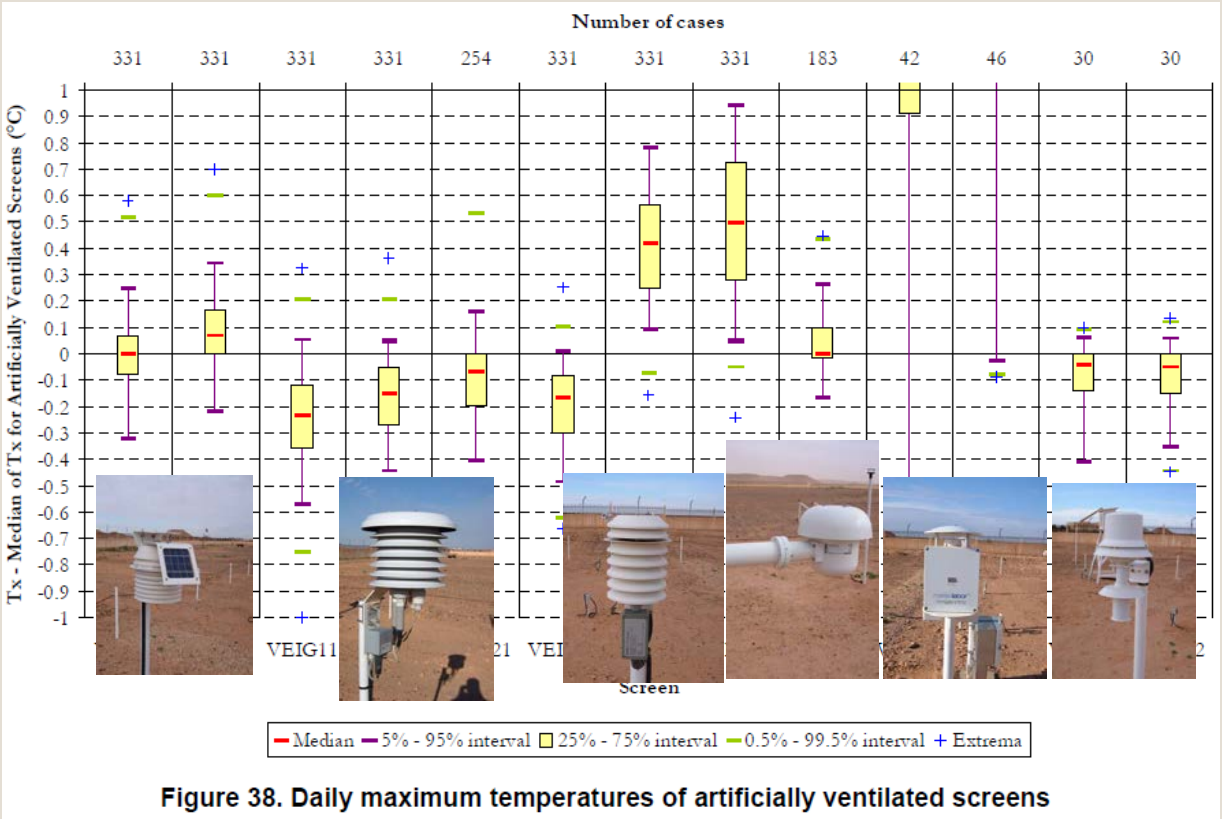


Figure 38. Daily maximum temperatures of artificially ventilated screens

Lacombe et al. 2011)

Intercomparison is only a relative evaluation.

“There is no recognised reference system for measuring the true air temperature.” (ISO 17714:2007)

Reference surface air temperature measurement is effective to evaluate characteristics of screens/shields

- “There is no recognized reference system for measuring the true air temperature” (ISO 17714:2007).
- Some potential candidates for measuring the reference surface air temperature have been suggested.
- Candidates:
  - Very thin resistive wire（ISO 2007)
  - Ultrasonic anemometer（Lacombe et al. 2011）
  - Radiometer (Yamamoto 2016)

Very thin wire

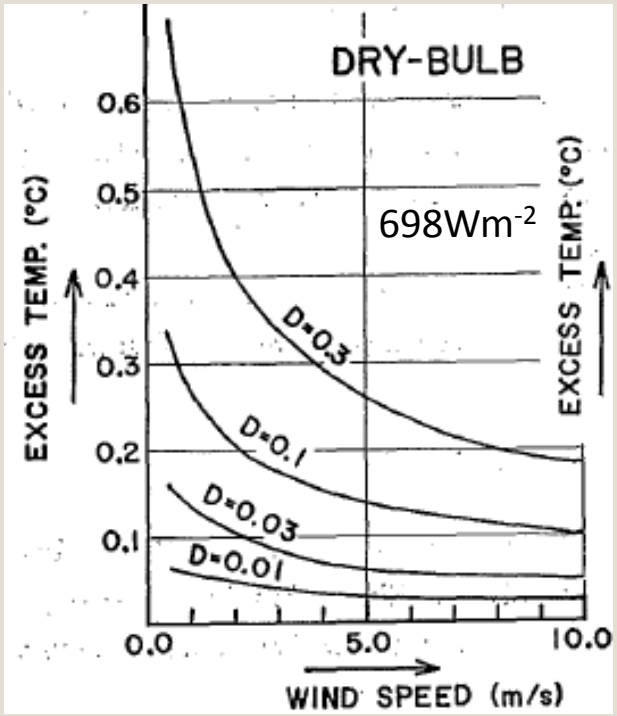
- The very thin wire (diameter < around 10μm) exposed to the air with no radiation screen may has little radiation effect less than 0.1K.
- We introduced very thin "handmade" thermocouples after Moriwaki et al. (2003) that are a less expensive and readily available.

Heat Budget of thermometer (Kondo 1982)

$$\frac{dT_s}{dt}=\frac{S}{c_s M}\{R-\sigma T_s^4-c_p\rho(C_h U)(T_s-T)\}$$

$$C_h U = aN/L$$

Smaller diameter (L) brings larger Heat transfer coefficient

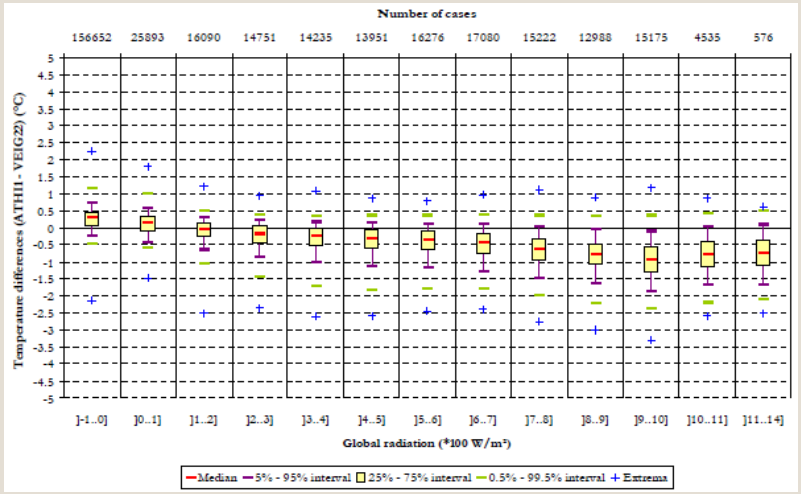


Sahashi (1973)

Ultrasonic Anemometer and Thermometer (UAT)

- Sonic anemometers measure the acoustic virtual temperature (no influence from solar radiation).
- Air temperature can be calculated using additional relative humidity and pressure information.

Ultrasonic anemometer
2D THIES CLIMA



Larger solar radiation, THIES Ultrasonic measured lower temperature the LAM630 screen.
Ultrasonic has calibration problem.

Working reference:
LAM 630
EIGENBRODT

Lacombe et al. 2011

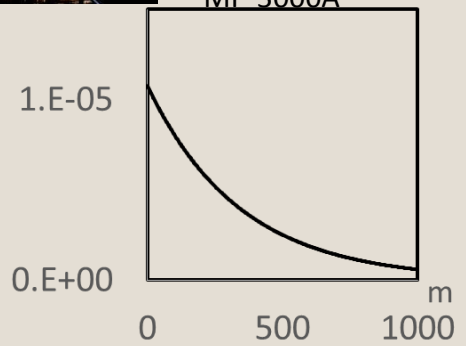
Radiometer

- Electromagnetic waves were absorbed and emitted at some absorption bands of atmosphere, and brightness (power of electromagnetic waves) is proportional to the temperature of atmosphere.
- Practical use in microwave radiometer (MWR) for measuring temperature profile.
- It is difficult to measure horizontal brightness by a radiometer directly, because of aperture angles and antenna siderobes.

$$B = \frac{2kT_B}{\lambda^2}\Delta f$$

B: Brightness
T_B: Brightness temperature
k: Boltzmann constant
λ: wavelength
Δf: band width

Radiometrics MP-3000A

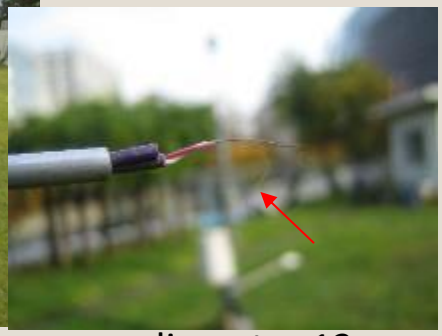


An example of weighting function.

Intercomparison has been started..

at Meteorological Instrument Centre, Japan Meteorological Agency, Tsukuba, JAPAN

Very thin thermocouples



diameter 13μm

Thermometer with artificial ventilated screen (identical to the system at the JMA)

Sonic SAT600

Radiometers

Ground-based MWR Radiometrics MP-3000A

Far Infrared camera

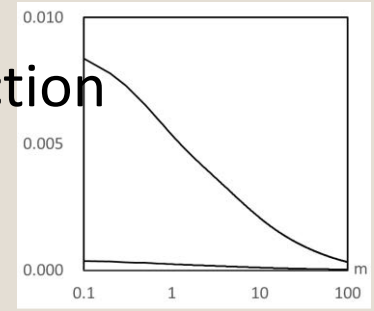
UATs

Vaisala WMT701

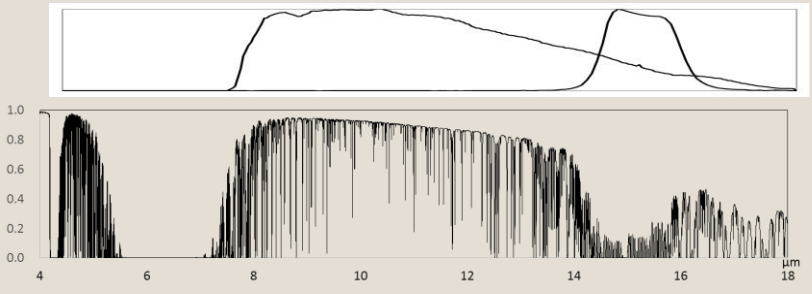
Far Infrared camera with a 14-16 μm bandpass filter has been newly developed for this intercomparison

- Strong absorption band of carbon dioxide exists in 14-16 μm wavelength.

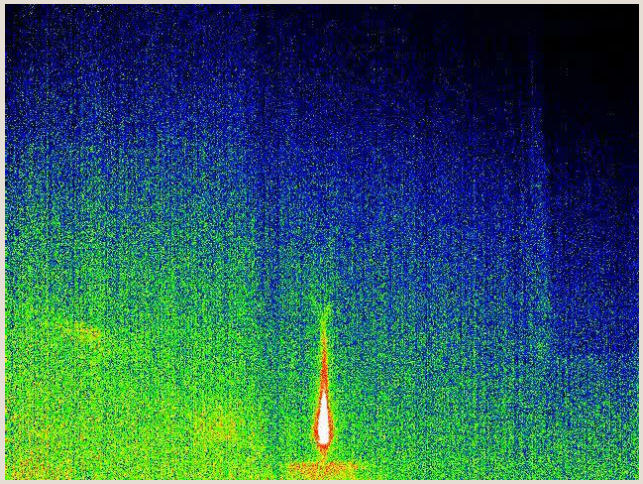
Weighting function



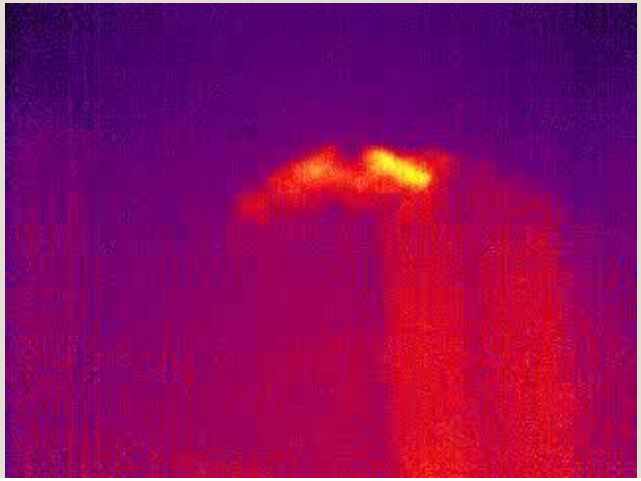
horizontal 1000m transmittance



candle



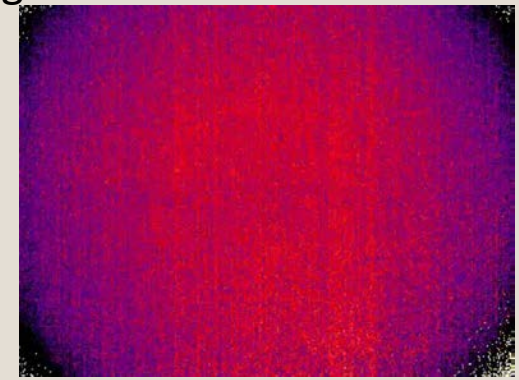
chimney

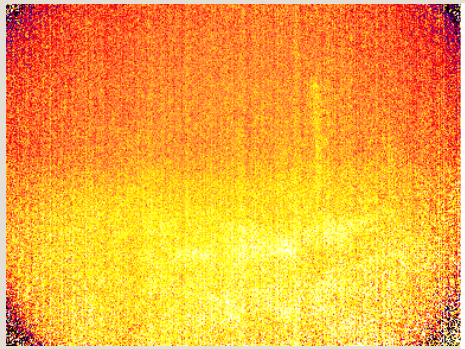


Far Infrared camera with a 14-16 μm bandpass filter detect the emitted radiation from carbon dioxide in the air

Power of the radiation should be proportional to the temperature of air, but we have many challenges to solve to get reasonable temperature data.

Change in 24 hours





Added function
To keep temperature of camera constant
October 2018~

Intercomparison has been started..

at Meteorological Instrument Centre, Japan Meteorological Agency, Tsukuba, JAPAN

April 2018~

April 2018~

June 2018~

April 2018~

April 2018~

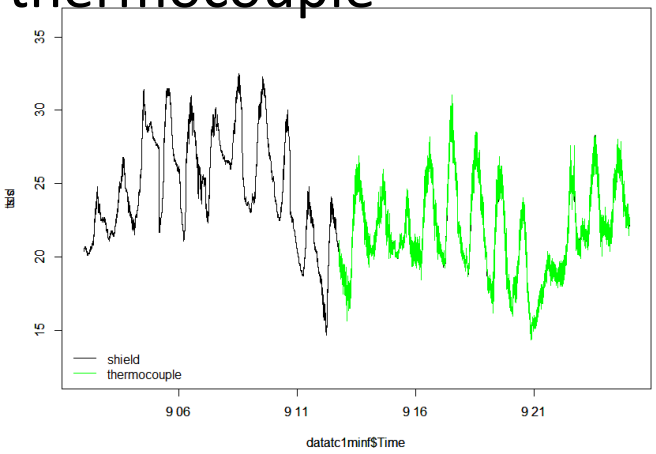
August 2018~

View from north to south view

Preliminary results from Sept 2-24 2018

reference: shielded thermometer (black curves) , and

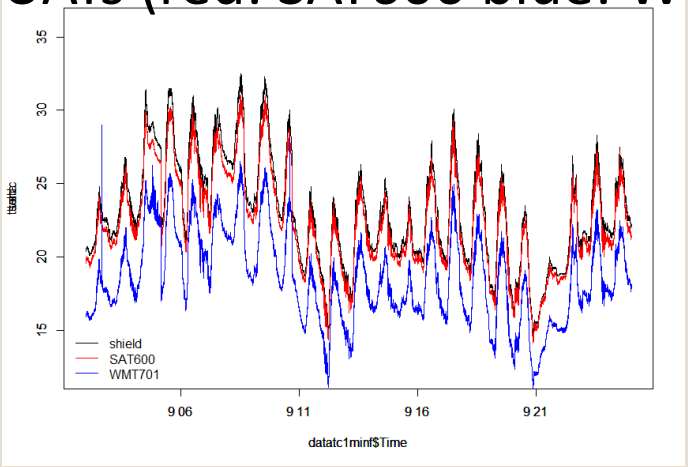
thermocouple



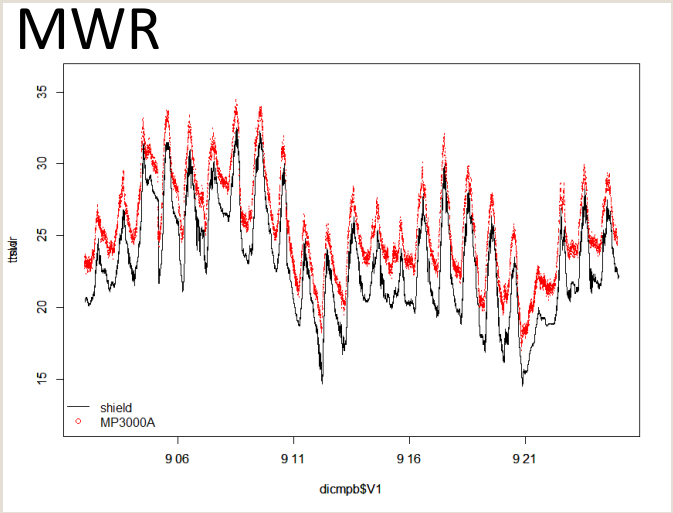
- UATs and a MWR have calibration problem

Thermocouples are installed after Sept. 12 because of logistical reason

UATs (red: SAT600 blue: WMT701)



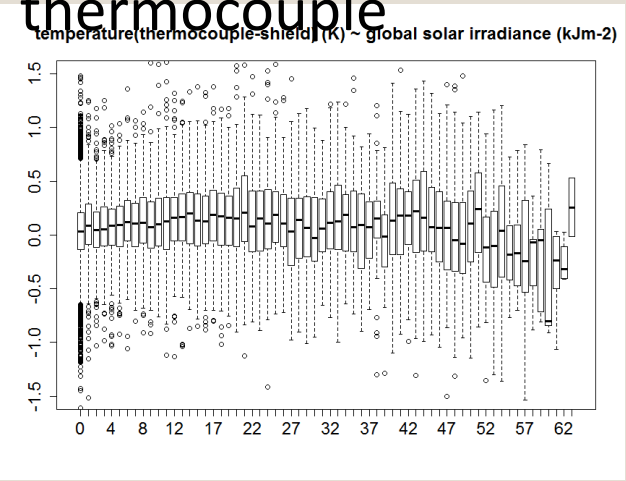
MWR



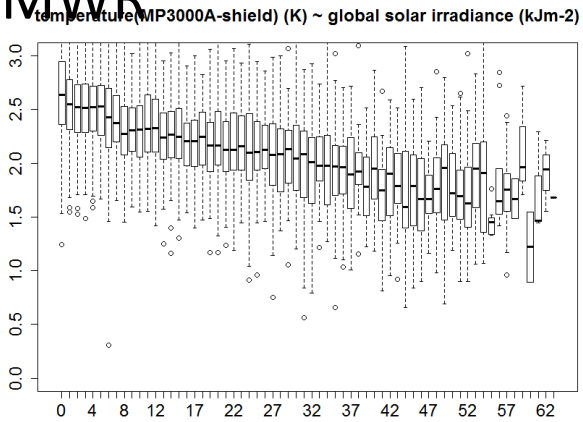
Preliminary results from Sept 2-24 2018

reference: shielded thermometer
global solar radiation (kW·min/m^{-2})

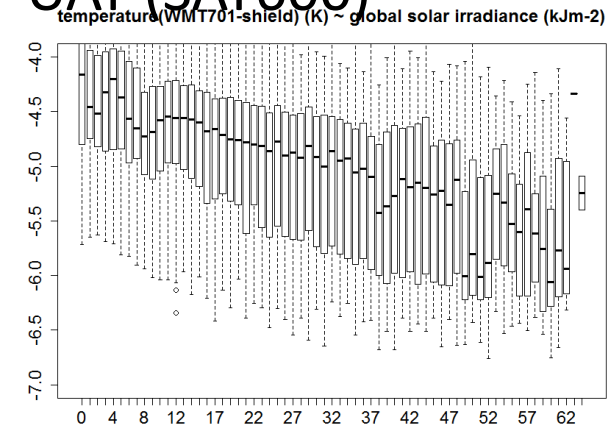
thermocouple



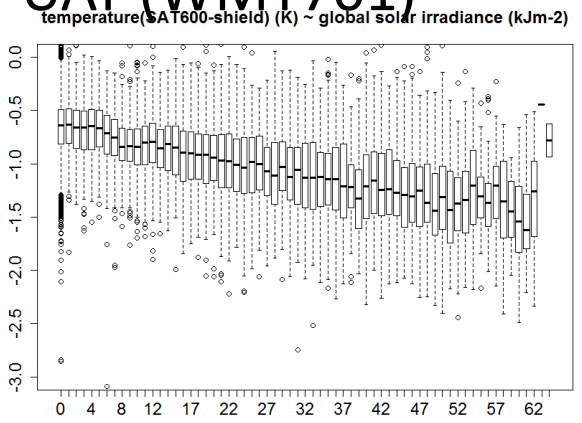
MWR



UAT (SAT600)



UAT (WMT701)



For UATs and MWR, the difference from the shielded thermometer is larger when solar radiation is larger.

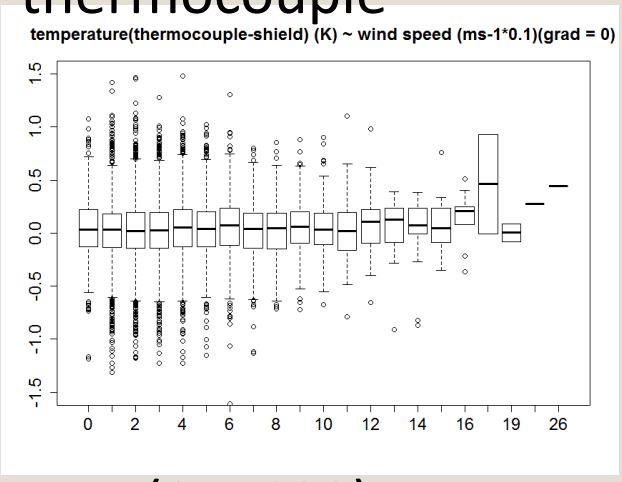
Major cause of these dependency is radiation effect on shield.

Some of them is pseudo dependence because of correlation between wind speed and solar radiation.

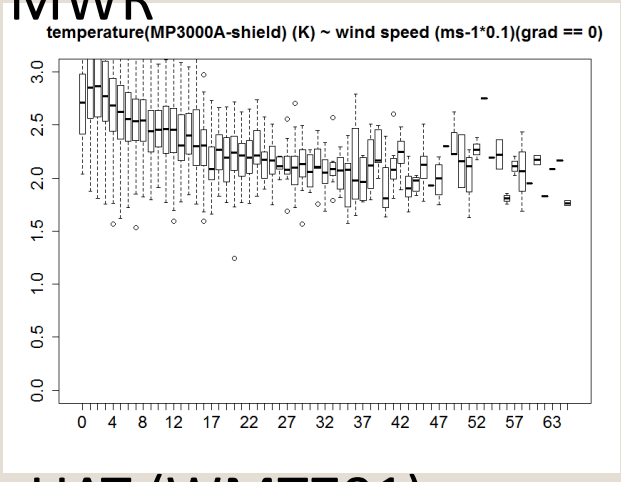
Preliminary results from Sept 2-24 2018

reference: shielded thermometer
wind speed (global solar radiation = 0)

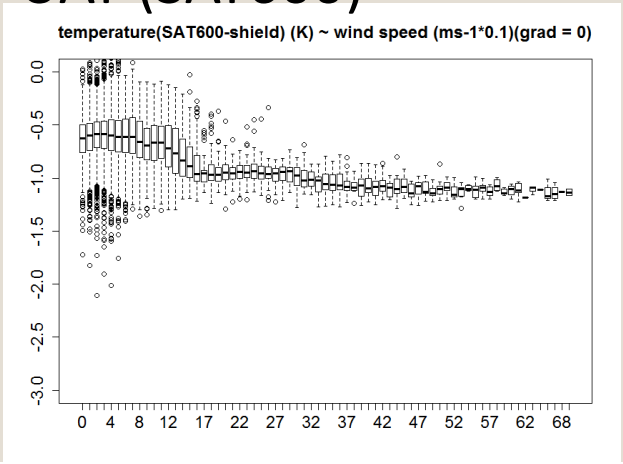
thermocouple



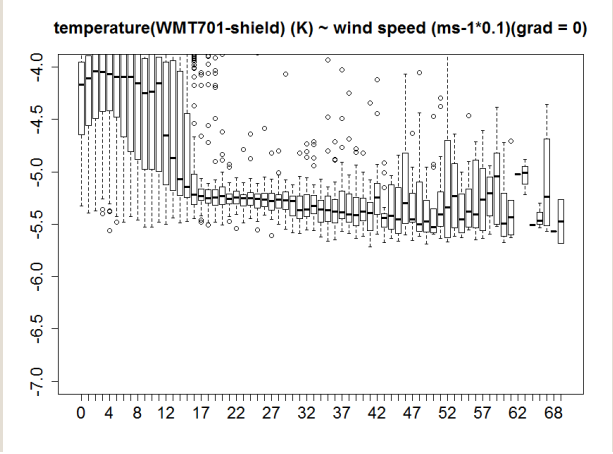
MWR



UAT (SAT600)



UAT (WMT701)



Thermocouple: No dependency on wind speed.

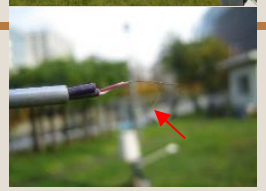
UATs and MWR have this dependency especially in weak wind.

Causes of this dependency are unexplained.

Summary of preliminary results

	☺	☹	Max. rad. effect
Very thin (D = 13μm) thermocouples	Cost effective	Weak, feasible Dependency on wind speed	~0.3K
UAT	Stable	Expensive Dependency on wind speed (?) Calibration Humidly data needed	~0.0K
MWR	Stable	Extrapolation method Not measured In rain Very expensive Several mimutes interval Calibration Dependency on wind speed (?)	~0.0K
Far infrared camera	Great potential	Not measured In rain Many challenges	--
Artificial ventilated screen	Stable All weather	Radiation effect	~0.5K

Conclusions

We have begun a field intercomparison between

- a shielded thermometer, and
- candidates for measuring the reference surface air temperature, including:
  - a very thin handmade thermocouple,
  - UATs and
  - MWR and Far infrared camera both using the brightness temperature of atmospheric radiation.




Our preliminary analysis indicates:

- Radiometer have great potential for measuring the reference surface air temperature.
- Radiation effect on very fine sensor is larger than previous studies.
- Unexplained dependency for UATs and MWR on wind speed is found.






Thank you for your kind attention!