Development of a new dual thermistor radiosonde (DTR)

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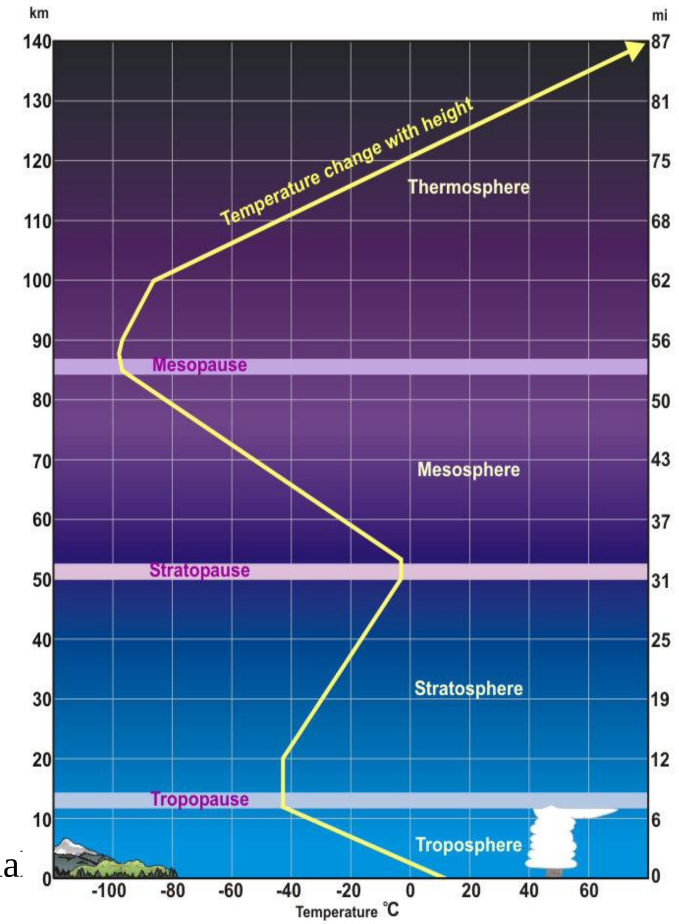
Air temperature

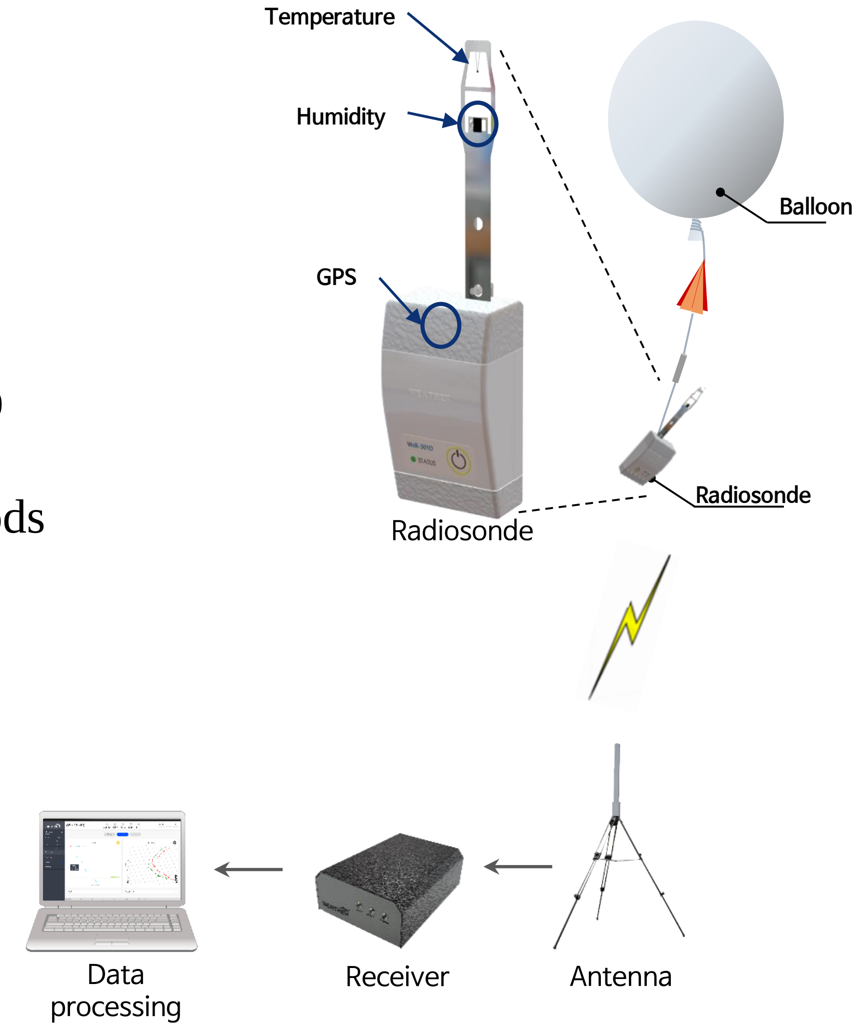
- **Direct index of global warming**
  - Very basic to the **energy budget** of the climate system
  - Essential for understanding and predicting the behavior of the atmosphere
- **Upper air temperature**
  - Key importance for detecting and attributing **climate change in troposphere and stratosphere**
  - Needed for the development and evaluation of **climate models** and for the initialization of **forecasts**
  - Temperature change
    - influencing the ***hydrological and constituent cycles***
    - changing in ***water vapor contents and cloud form***ation
    - Affecting the ***polar stratosphere clouds*** and consequential ***ozone loss***



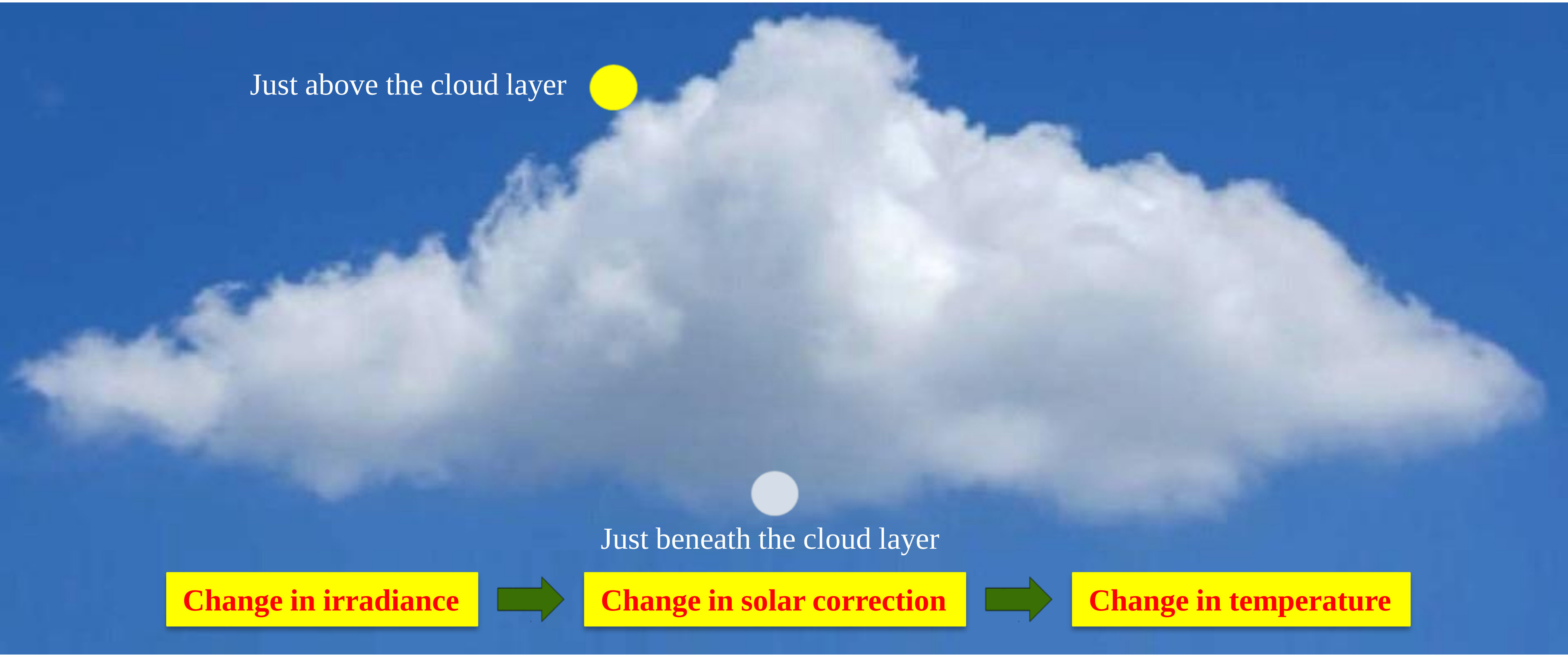
Requiring precise and traceable measurements

Radiosonde

- Crucially important instruments for upper-air measurements by WMO
  - Battery-powered **telemetry** instrument
  - Carried into atmosphere by a **weather balloon**
  - to measure **temperature**, humidity, pressure, altitude, geographical position, wind speed and direction, cosmic ray, etc
  - Operated at a **radio frequency** of 403 MHz ~ 1680 MHz
- It serves as a reference to other remote methods with fairly good accuracy.
- But it is affected by many environmental parameters such as solar irradiance, pressure, wind ventilation, etc.
- **Solar correction is the most important and influential parameter.**



Ambiguities in the solar correction



- **Common radiosondes with single T-sensor cannot detect the cloud effects!**
- **How to realize the *in-situ* solar correction during sounding?**

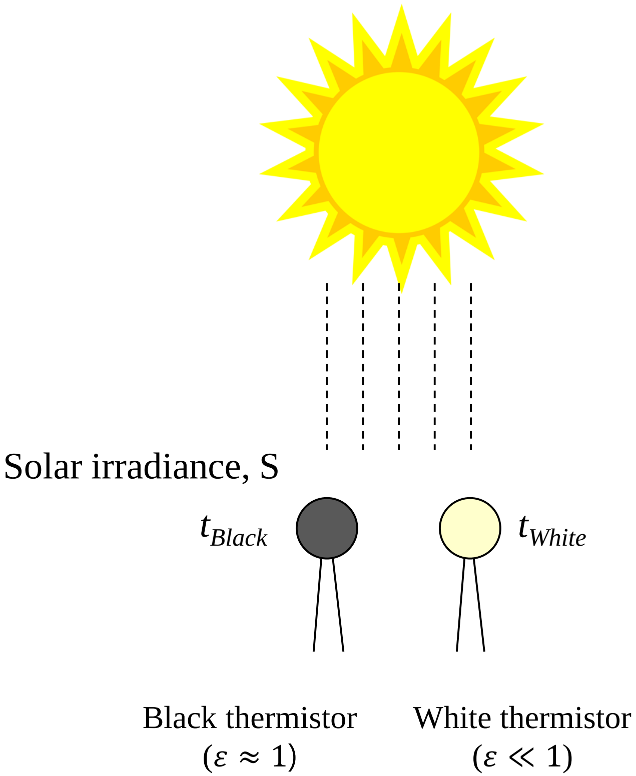
In this presentation,

- A new noble method to calculate the *in-situ* solar irradiance is presented,
- And a new radiosonde having dual thermistors and its measurement uncertainty is introduced.
- Finally, dual thermistor radiosonde (DTR) is compared with RS41 at day and nighttime.
- As a case study, sounding results at clear or cloudy day are shown to give direct evidences of irradiance change due to the cloud layer.

KRISS's new solar correction technique

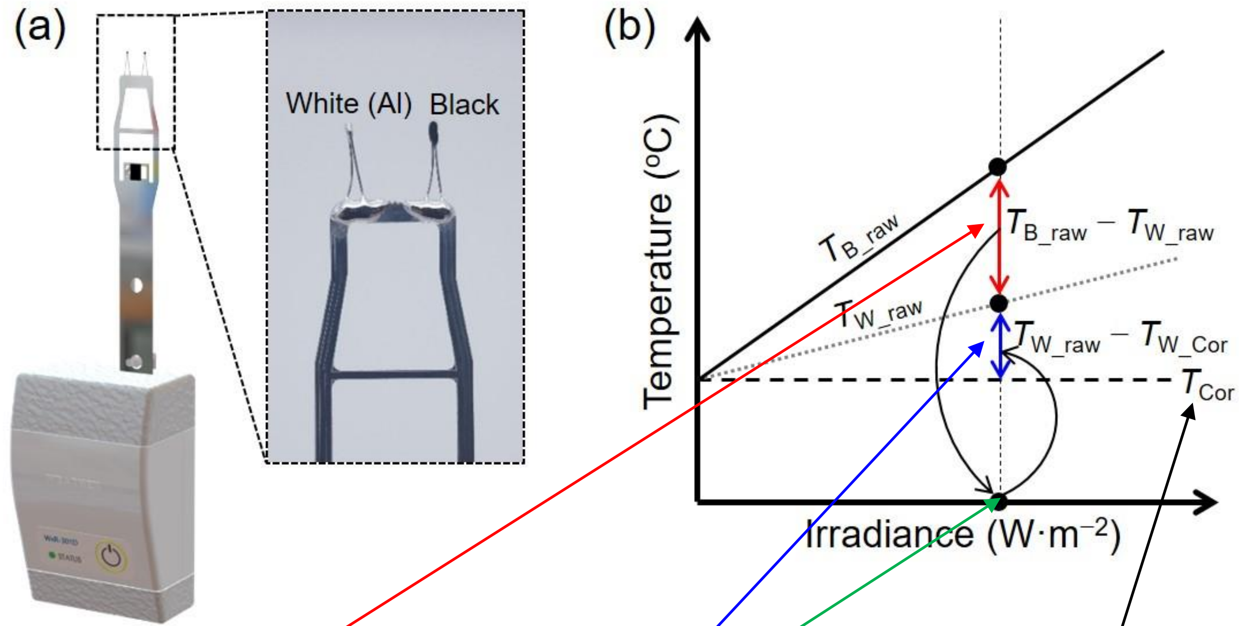
Dual Thermistor Technique

Temperature difference of two radiosonde sensors with **different emissivity** depends on the amounts of **solar irradiation**.



- $t_{Black} > t_{White}$
- $\Delta t(t_{Black} - t_{White}) = f(S, T, P, v)$
  - S: solar irradiance (W/m^2)
  - T: air temperature (^{o}C)
  - P: pressure (Pa)
  - v: wind speed(ventilation) (m/s)

DTR (Dual Thermistor Radiosonde)



$$\Delta t_s = S \times f(T,P,v) \rightarrow S$$

$$\Delta t_{cor} = S \times g(T,P,v) \rightarrow T_{cor}$$

Experiments at ground lab

Experimental *in-situ* radiation correction technique

Flow chart of this research

High reflectivity **Al-coating** on sensor boom with two thermistors

↓

High emissivity **black epoxy** coating on one thermistor bead

↓

Massive **temperature calibration** in the climate chamber

↓

Electric circuit board test on **A/D conversion** of resistance

↓

Individual radiation tests using a rotational radiation tester (RRT)

↓

UAS radiation tests for some selected representatives

↓

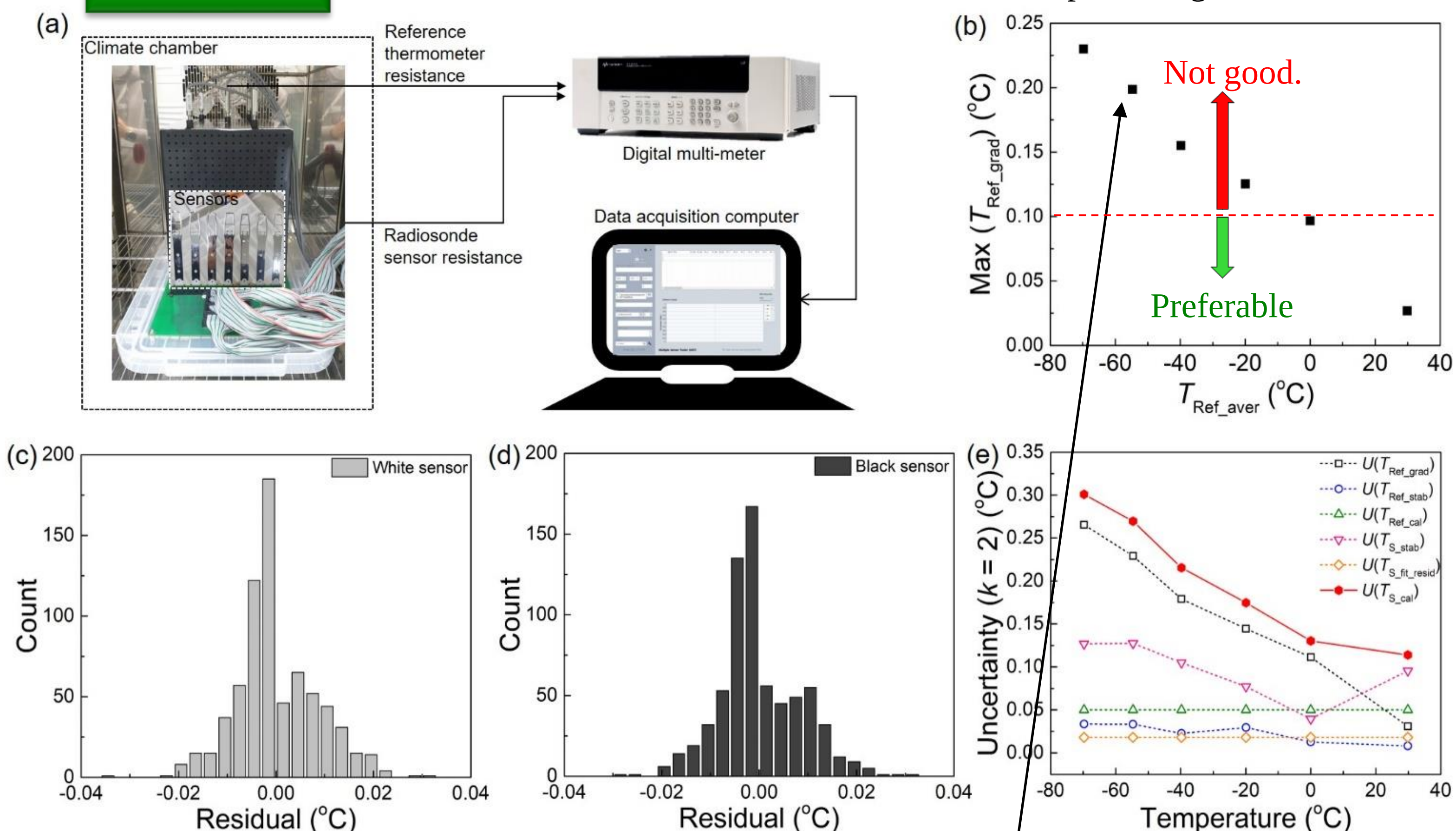
Comparison **sounding tests** with RS41 and **uncertainty** evaluation

*Most of data in this presentation were captured from the submitted paper (**AMT-2021-343**).

1) Calibration of temperature sensor in chamber

-70 °C ~ 25 °C

Temperature gradient in chamber

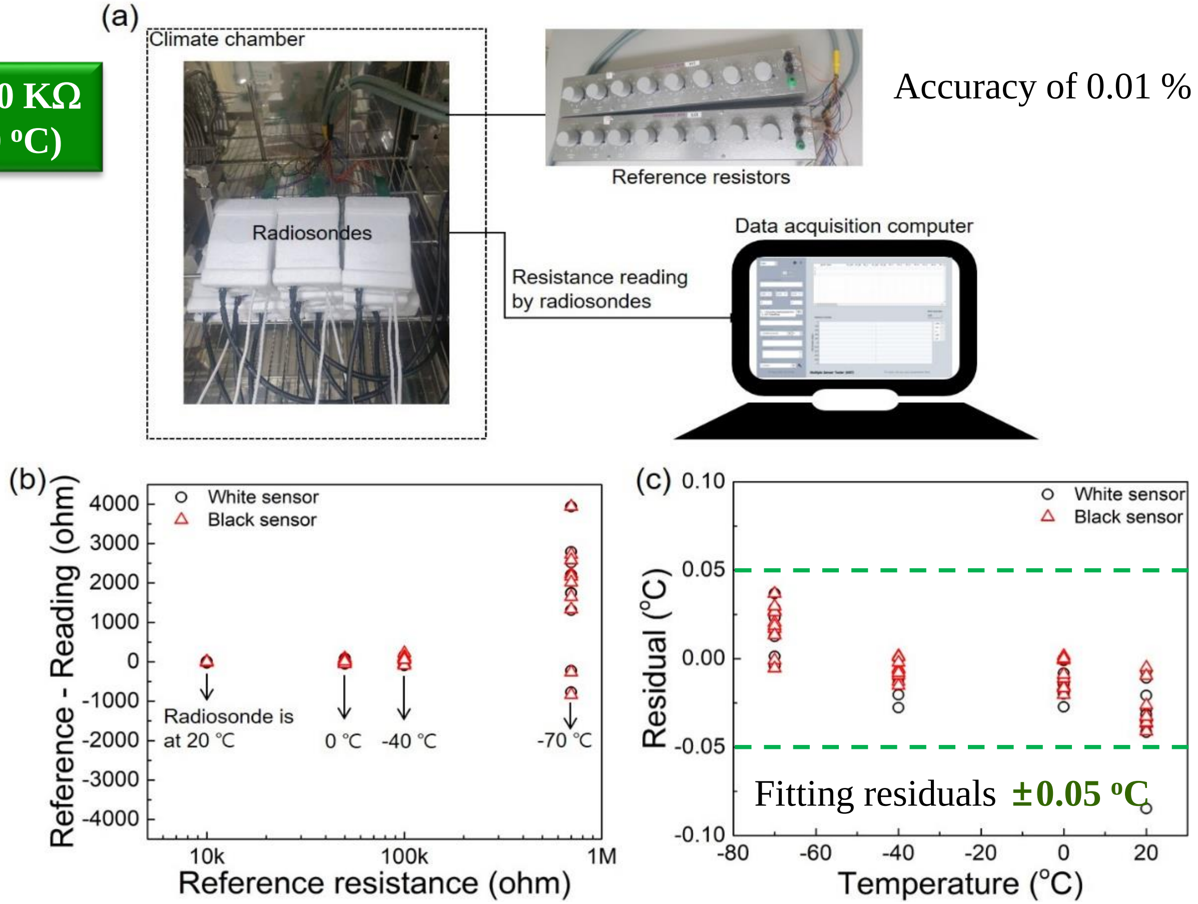


Calibration residuals: ± 0.02 °C

- Main uncertainty component
  →Chamber temperature gradient
  →Could be improved.

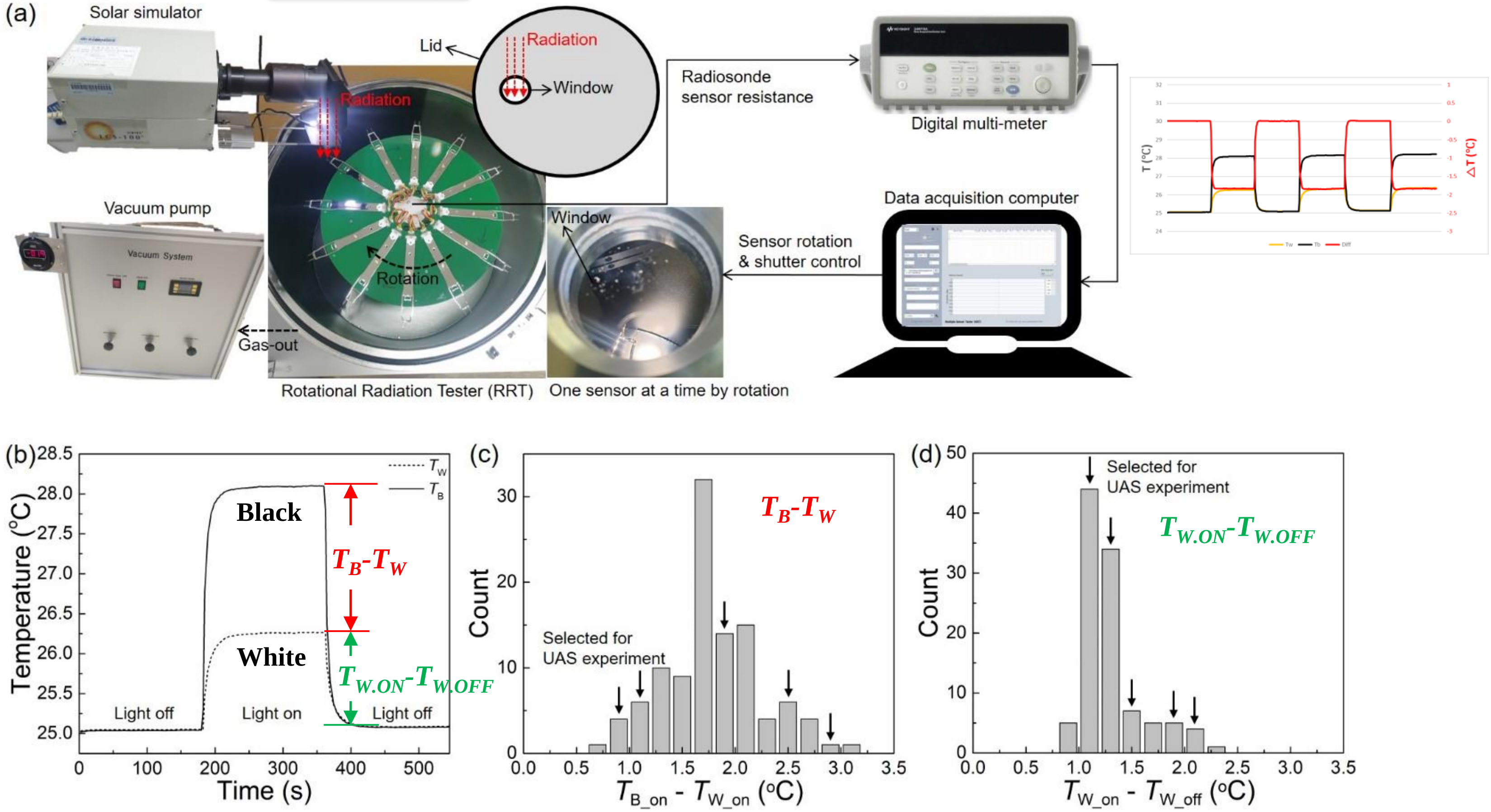
2) Test for input resistance into A/D board

10 KΩ ~ 800 KΩ
(20 ºC ~ -70 ºC)



3) Radiation tests for individual sensor boom

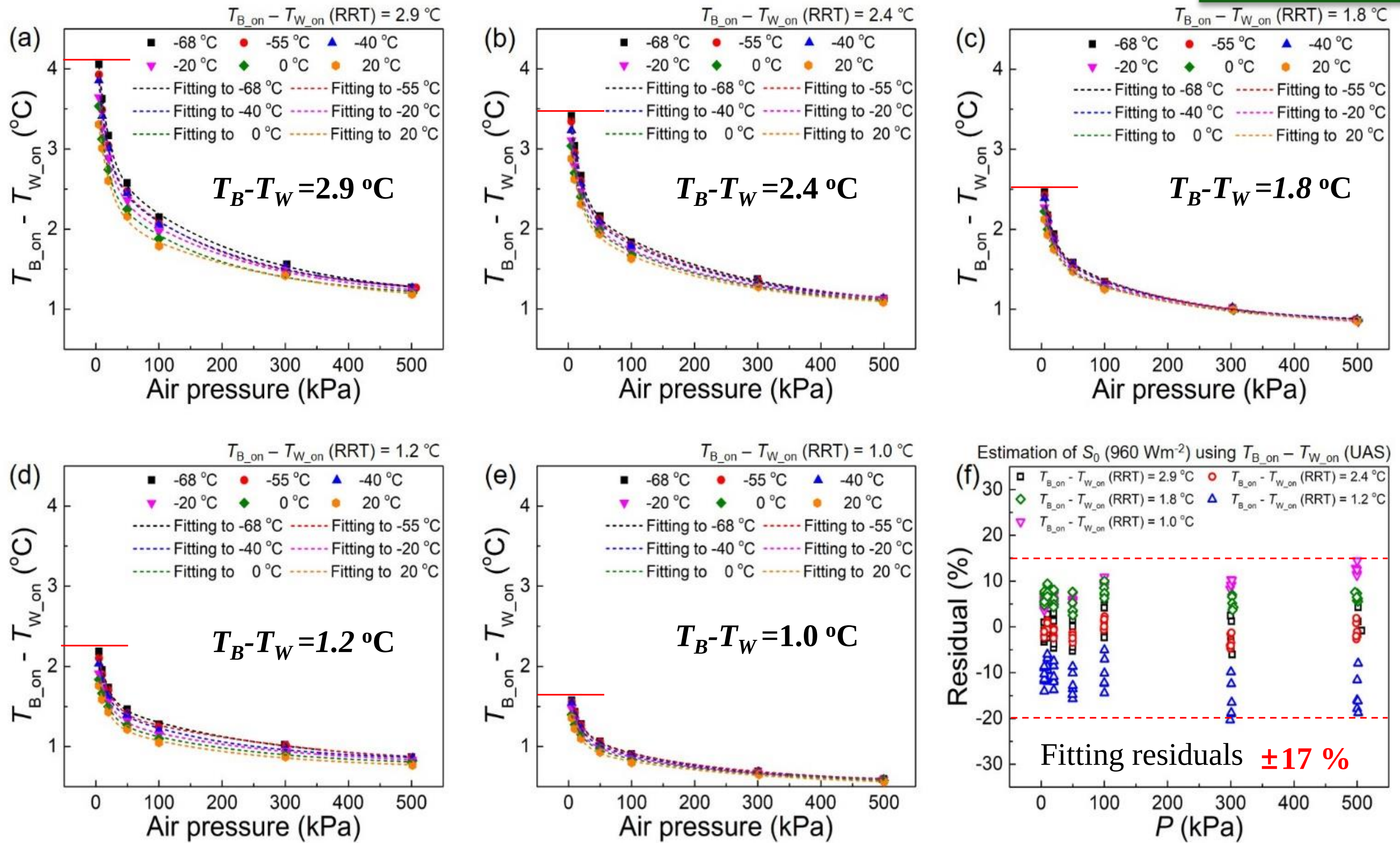
1000 W/m^2



❖ **The amount of the temperature rise due to the radiation varies from sample to sample.**

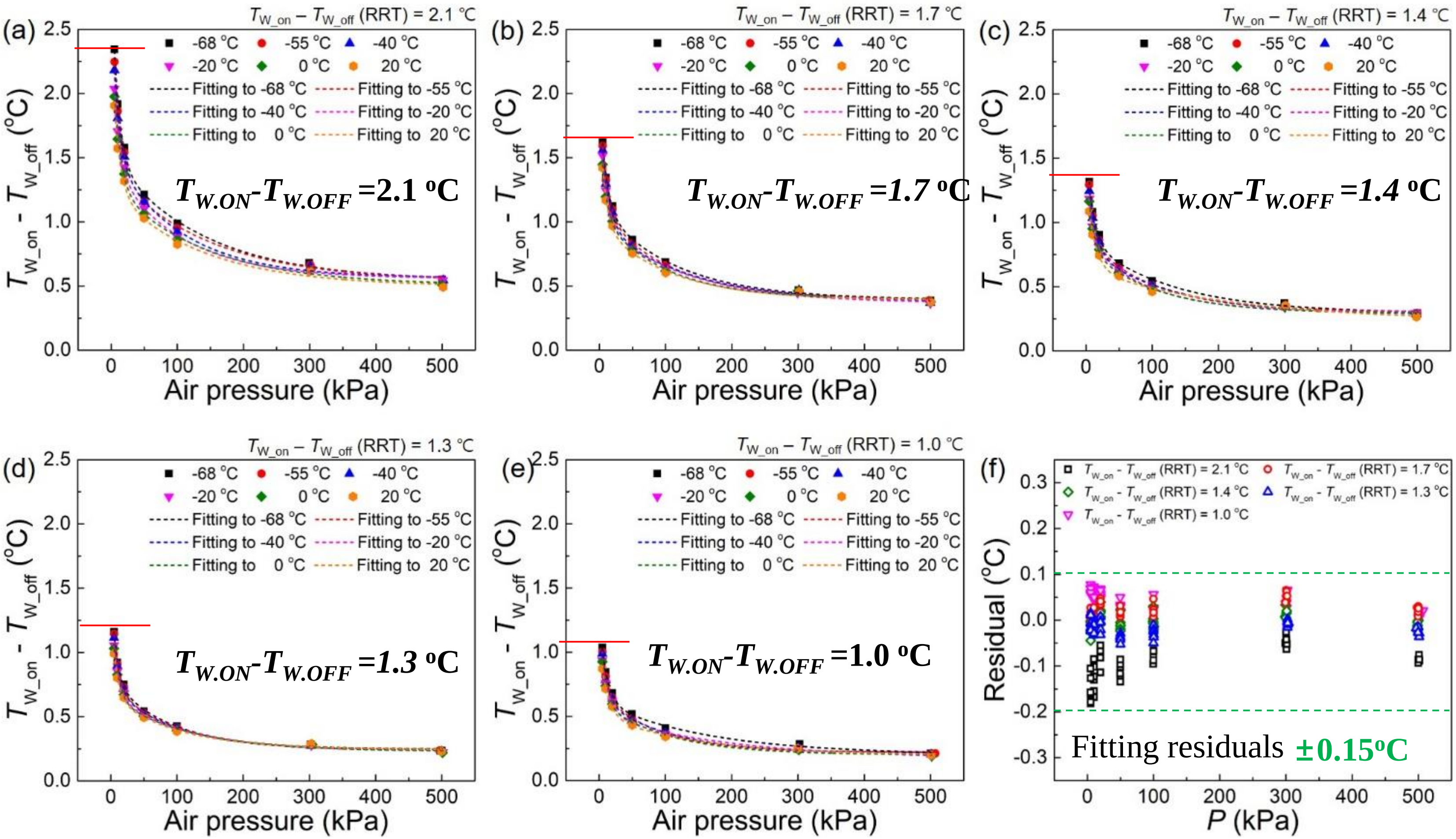
4) UAS test for selected samples, T_B-T_W

T: -68 °C ~ 20 °C
P: 5 hPa ~ 500 hPa
S: 1000 W/m²
v: 5.0 m/s



Step 1: Equation for estimation of solar irradiance

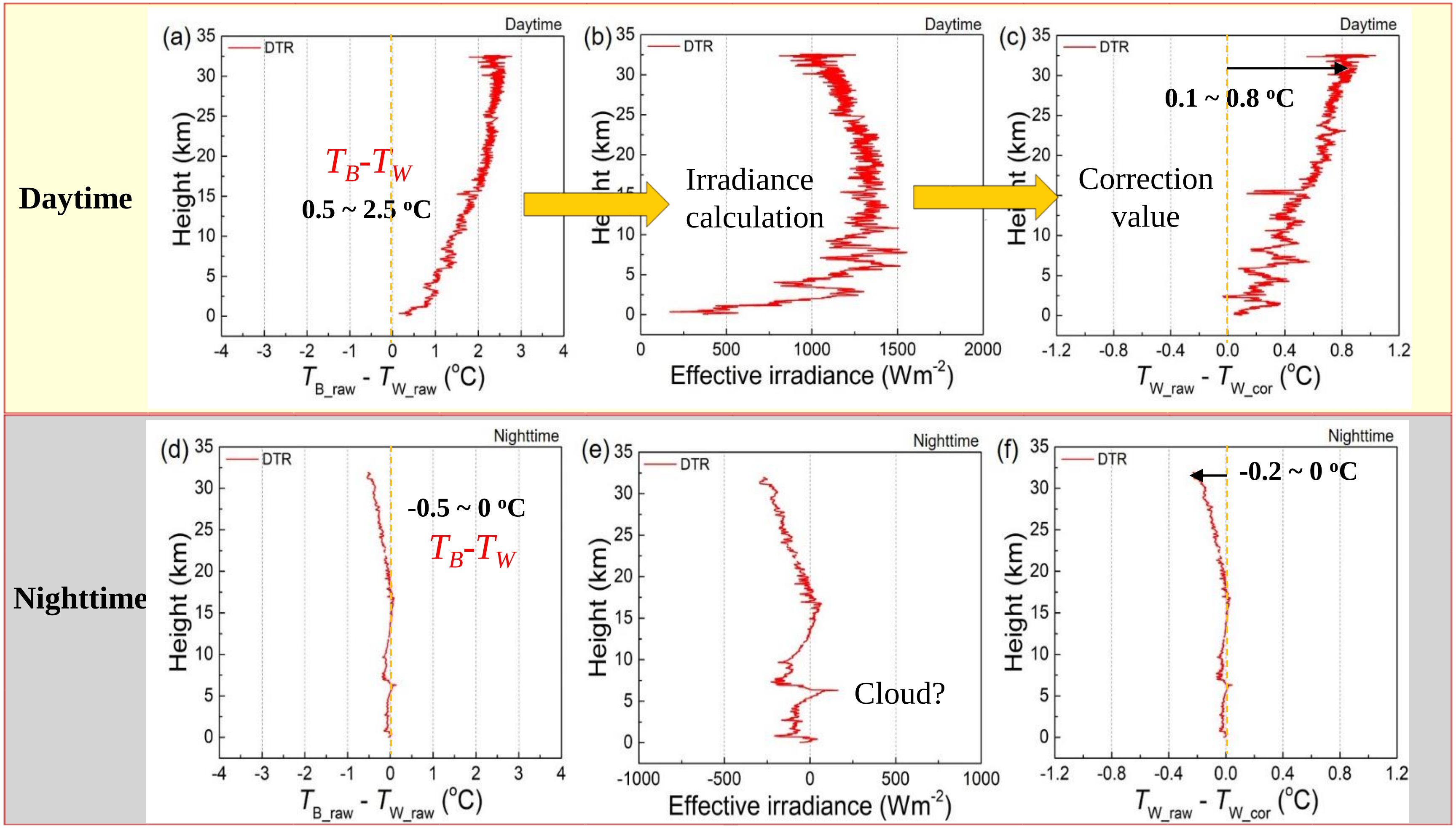
4) UAS test for selected samples, $T_{W.ON}$-$T_{W.OFF}$



Step 2: Equation for estimation of correction value

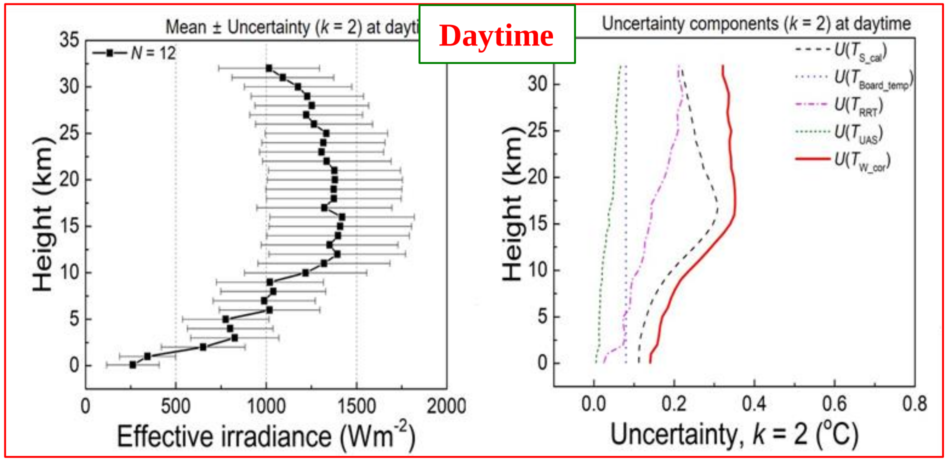
5) Examples of sounding tests (July, 2021 in Jeju Islands)

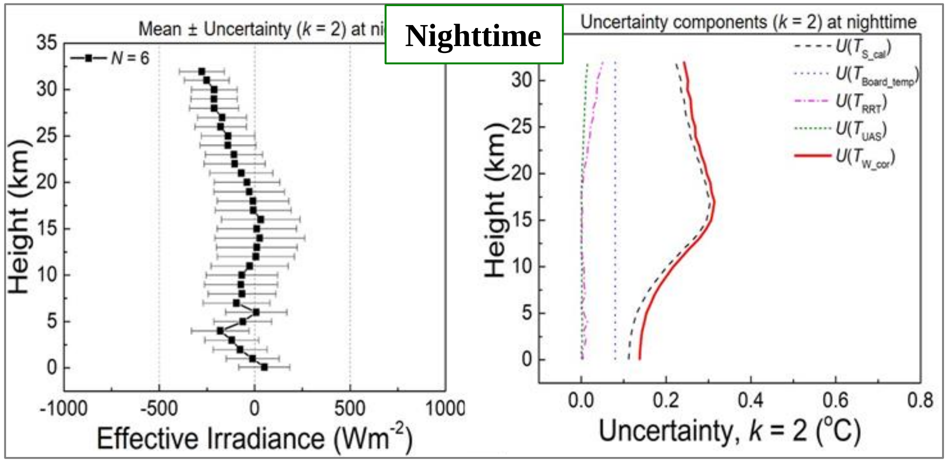
Weathex Radiosonde (WxR-301D) with ground receiver (WxRE-401)



Uncertainty evaluation of DTR

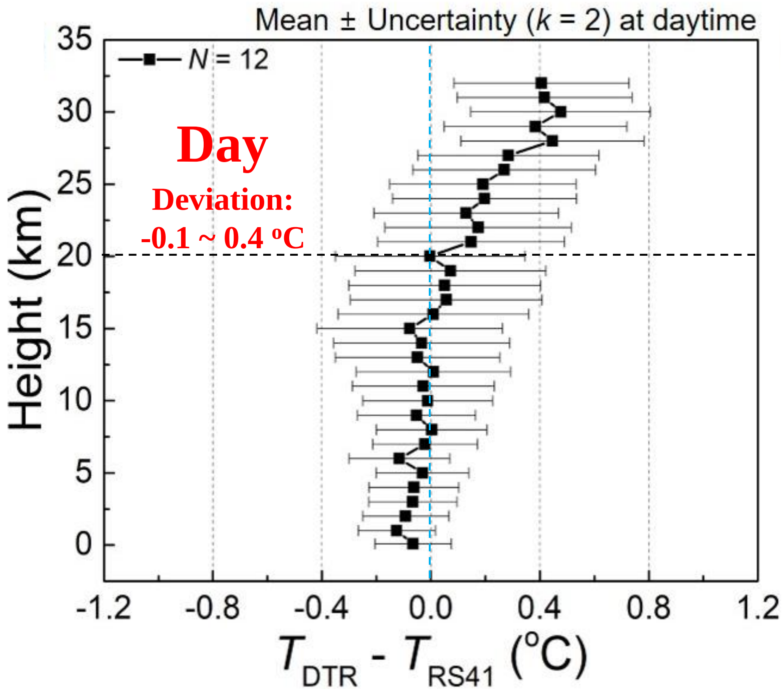
Altitude	$U(T_{W\_cor})$ @T_{W_cor}	$U(T_{W\_cor})$ @T_{W_cor}
	Daytime	Nighttime
0 km	0.14 °C @24.6 °C	0.14 °C @22.8 °C
5 km	0.17 °C @0.1 °C	0.15 °C @0.4 °C
10 km	0.24 °C @−29.3 °C	0.22 °C @−32.0 °C
15 km	0.34 °C @−68.0 °C	0.31 °C @−66.8 °C
20 km	0.35 °C @−63.2 °C	0.30 °C @−62.5 °C
25 km	0.34 °C @−50.8 °C	0.27 °C @−51.5 °C
30 km	0.33 °C @−42.5 °C	0.25 °C @−44.1 °C



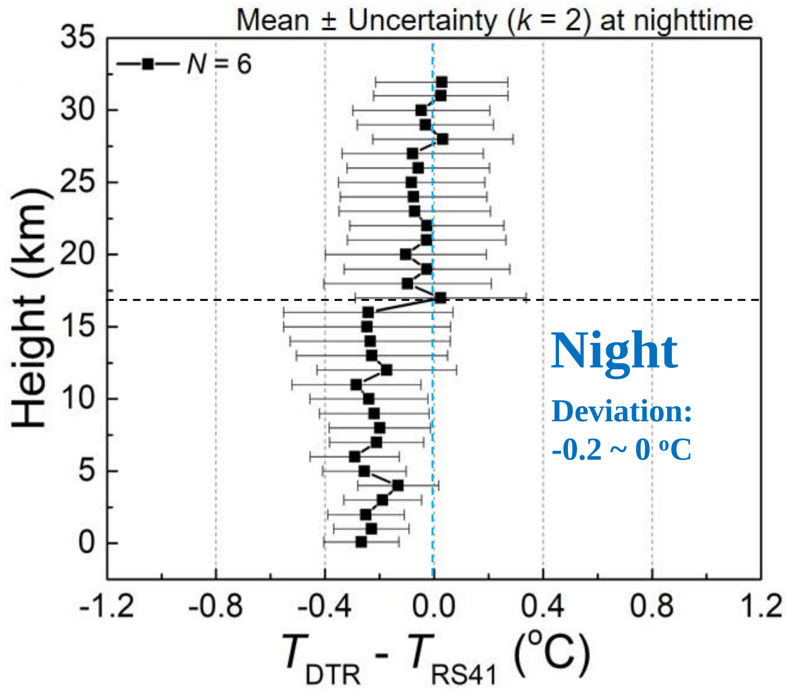


Uncertainty (k = 2): 0.14 °C ~ 0.35 °C

Comparison sounding with Vaisala RS41



Above 20 km, positive bias to about 0.4 °C



Below 17 km, negative bias to about -0.2 °C

Two radiosondes are consistent within 0.4 °C in maximum
(It is close to the uncertainty of DTR).

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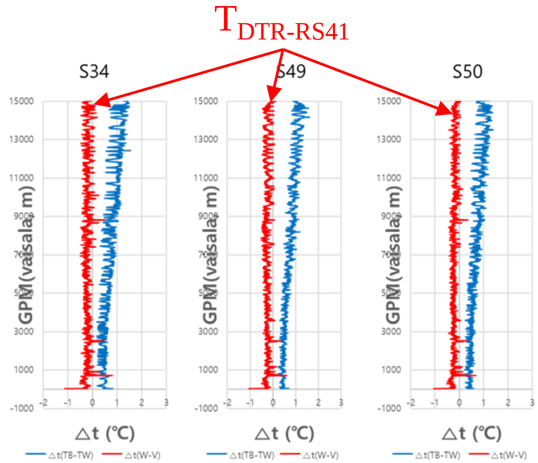
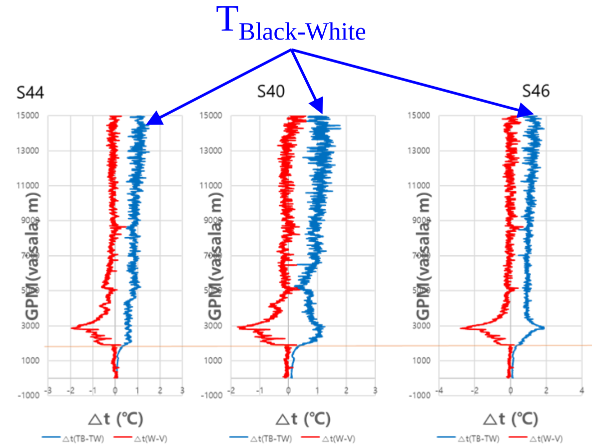
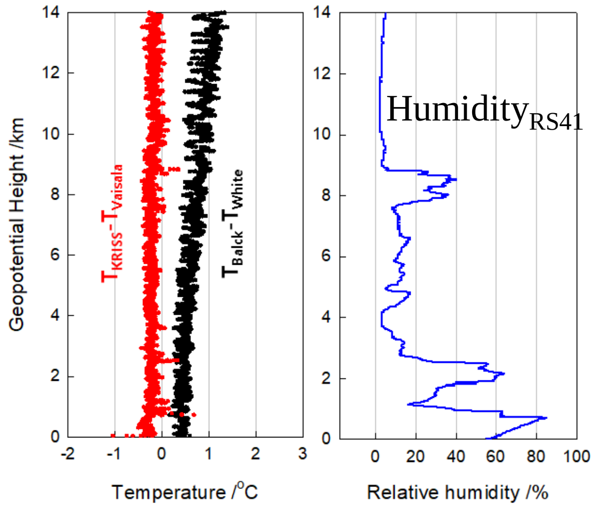
Case study – Detection of irradiance change due to cloud layer



- 3 DTR + 1 RS41
- Jeju islands, Dec. 2020

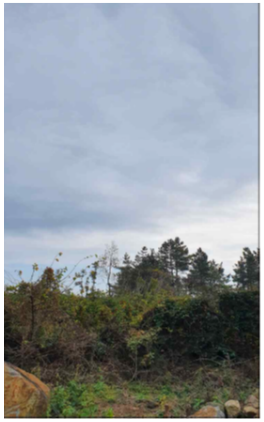


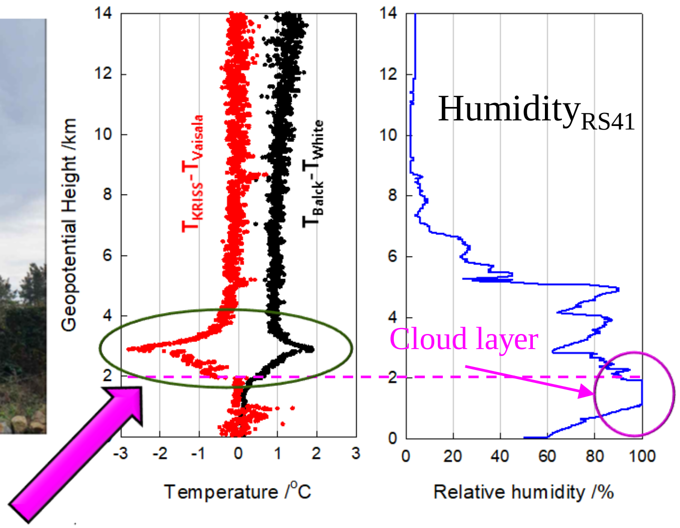
Clear sky



No noticeable change

Cloudy sky





- ❖ T_{DTR} is lower than T_{RS41} by about -2.5 °C.
- ❖ Higher irradiance →Larger correction → Lower temperature

Summaries

- KRISS has developed a new solar correction technique using white and black thermistors.

- DTR (Dual Thermistor Radiosonde) has been tested using UAS and succeeded in real sounding with the uncertainty of 0.14 °C ~ 0.35 °C depending on altitude.

- Through comparison tests with RS41, two radiosondes are consistent within 0.4 °C at daytime and 0.2 °C at nighttime.

- It is shown that DTR has the detection capability of the real time *in-situ* solar irradiance change.


Thank you for your attention