A Study on the Solar Correction for the RS41 using the Upper Air Simulator at KRISS

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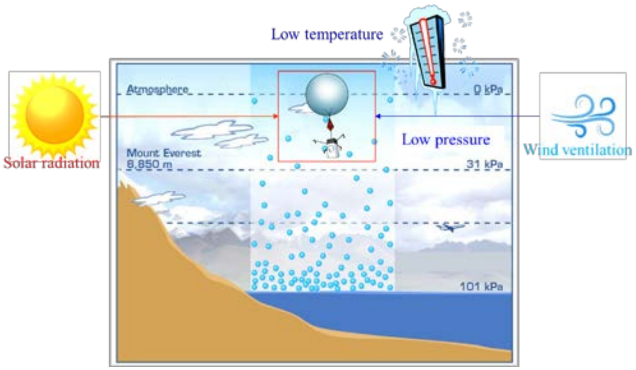
Calibration of radiosonde

- In common, calibration has been done at ground laboratory.
  - Calibration of Temperature, Humidity and Pressure **at static conditions**
    - It cannot reflect the upper air conditions.
  - In case of **temperature measurement**,
    - Ventilation, low pressure and solar radiation effects should be counted for the precise calibration.
    - Ventilation can decrease the air thermometer reading.
    - Solar radiation (radiation cooling) can increase (decrease) the sensor temperature.
    - Low pressure, so-called low air density, can enhance the solar radiation effects.
  - **It is necessary to make more realistic test systems and procedures for calibration of radiosonde.**
- Recently **KRISS developed the Upper Air Simulator for calibration of radiosonde** in 2018.



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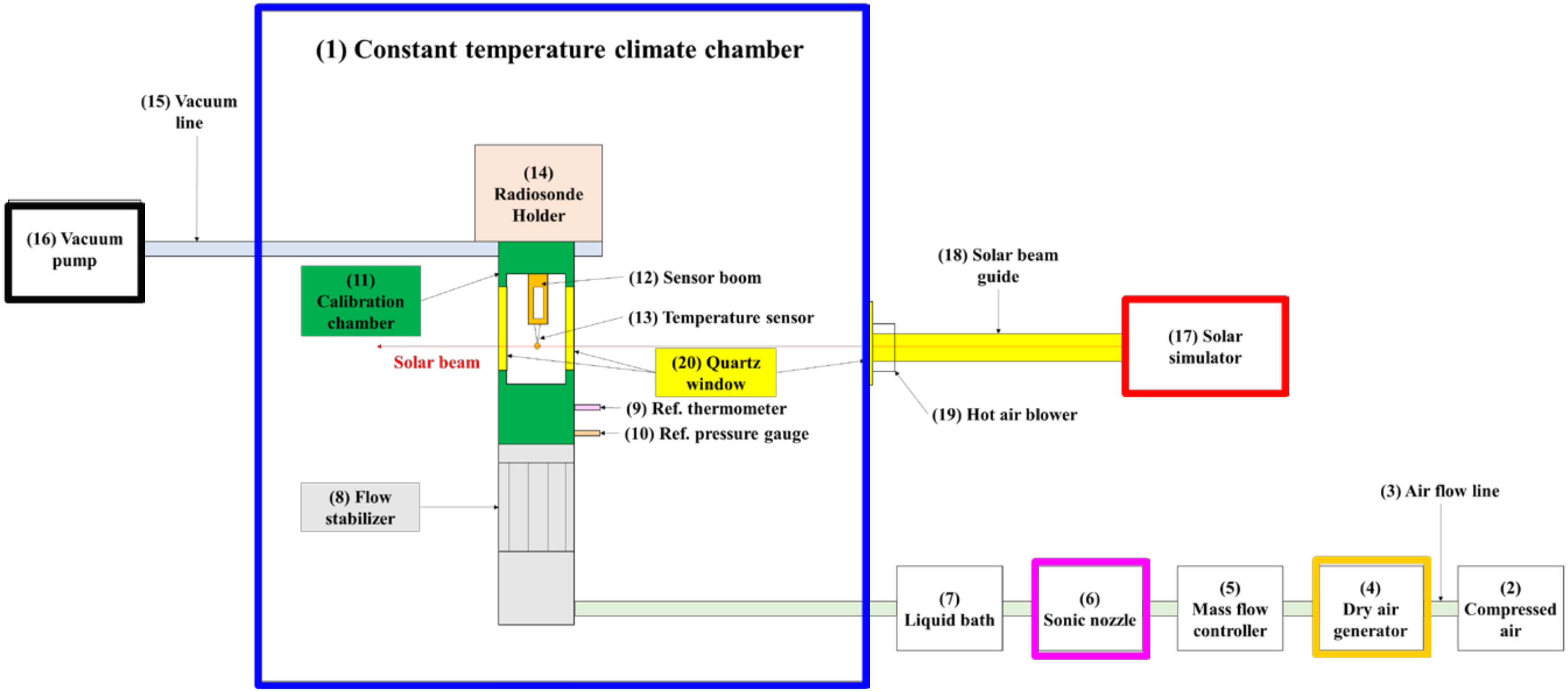
In this presentation

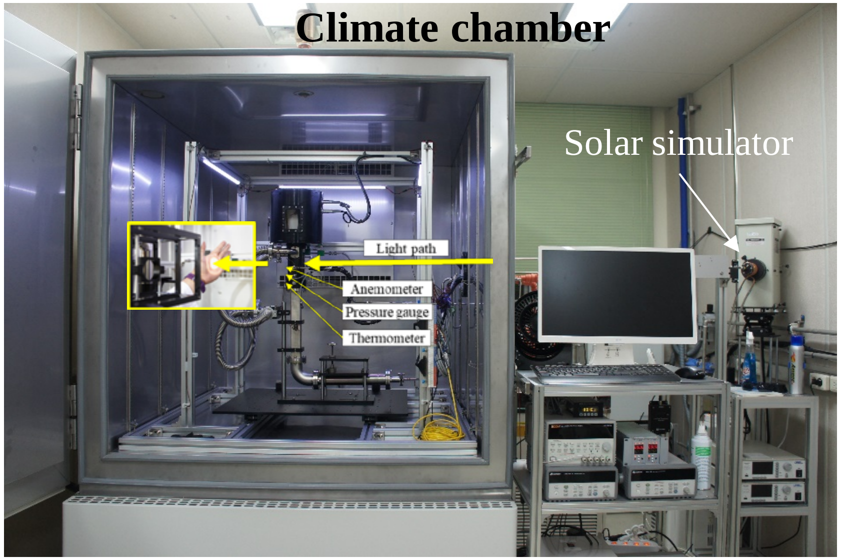
- Introduction of **UAS** and its operating features using a **RS41** tested at conditions of:
  - Temperature from -70 ^{o}C to 20 ^{o}C
  - Pressure range from 7 hPa to 100 hPa
  - Solar radiation at 900 W/m^2
  - Wind ventilation from 4 to 6.5 m/s
- Estimation of solar correction formula and comparison with the measured sounding data of CoreTemp2017 at Lindenberg

Schematic design of UAS

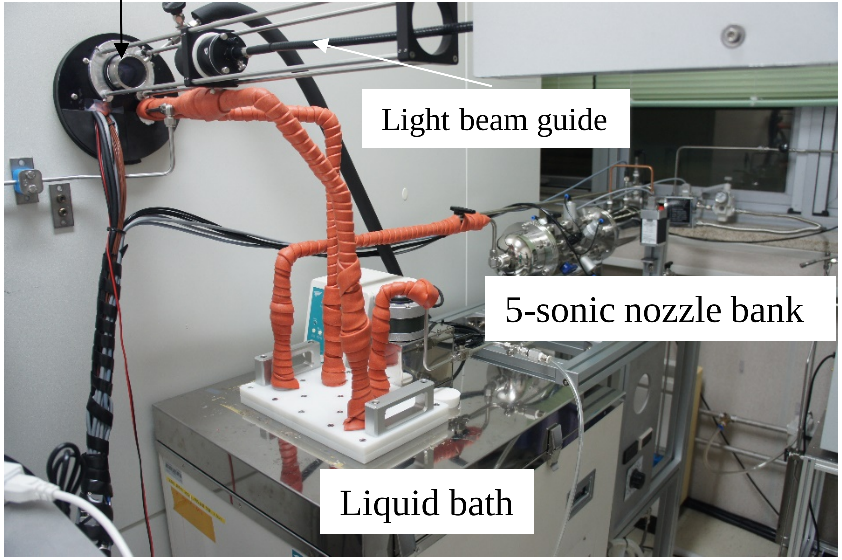


- 5 main components
  - **Climate chamber** to control temperature (Capacity: -70 ^{o}C ~ 90 ^{o}C)
  - High pressure **dry air generator** (Capacity: 6 atm, -80 ^{o}Cdp
  - **Solar simulator** to mimic radiation (Capacity: 0 ~ 1500 W/m^2)
  - **Sonic nozzle** to make air ventilation (Capacity: 3 m/s ~ 6.5 m/s)
  - **Vacuum pump** to control pressure (Capacity: 3 hPa ~ 1000 hPa)

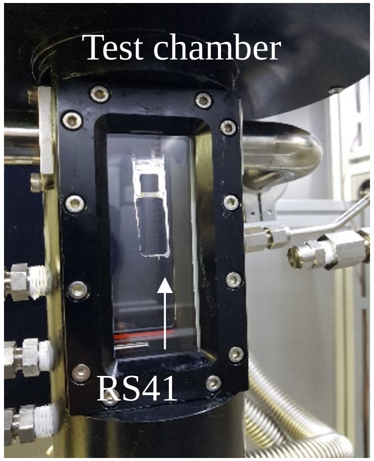
View of UAS components



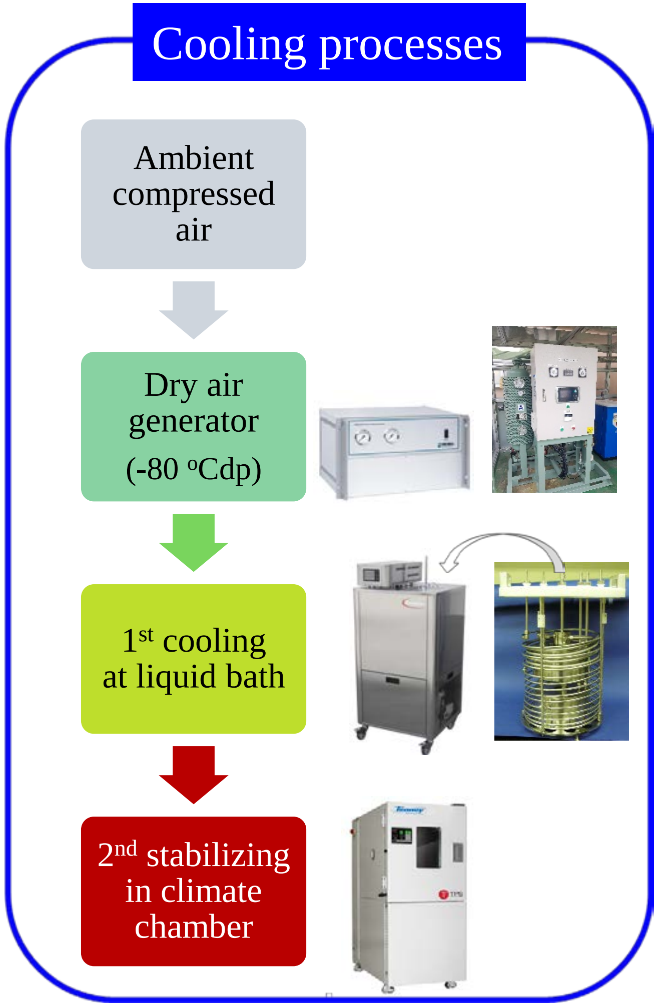
Hot air blower
to protect frost



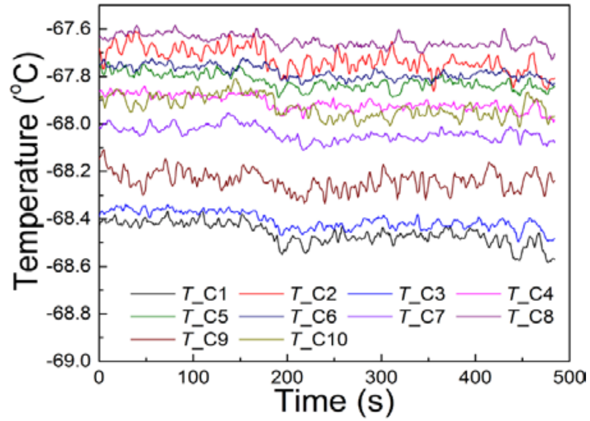
<Vacuum pump>



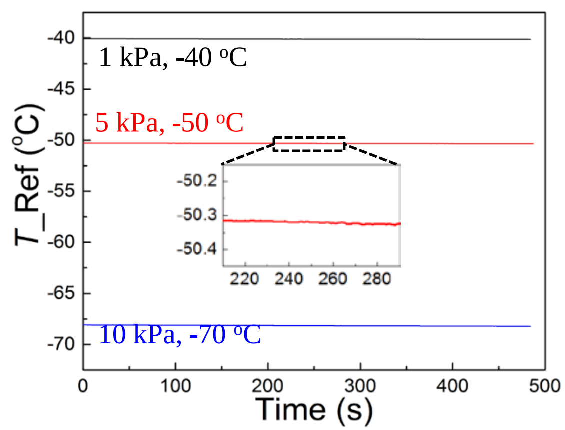
Air Temperature



Temperature stability inside chamber@-70 °C set

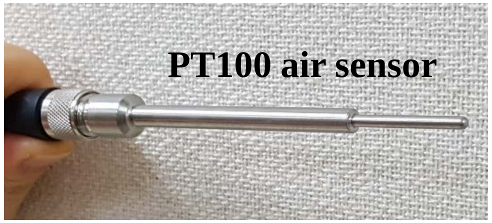


- Type E thermocouple
- Stability of ±0.1 °C
- Gradient of ±0.4 °C



Reference air temperature

- PT100 thermometer
- Uncertainty of 50 mK(k=2)
- **Stability of ±0.01 °C**



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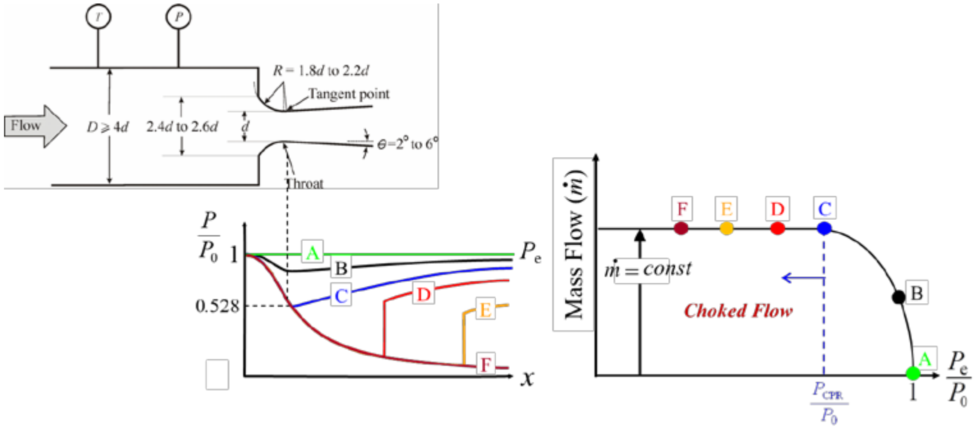
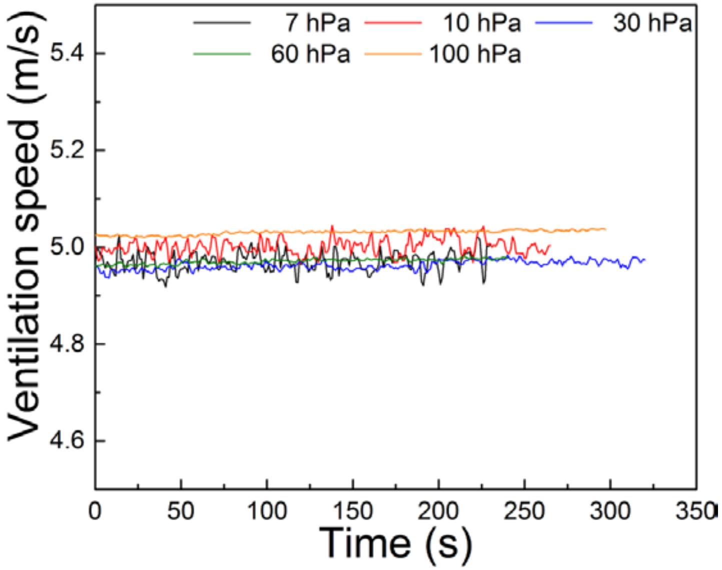
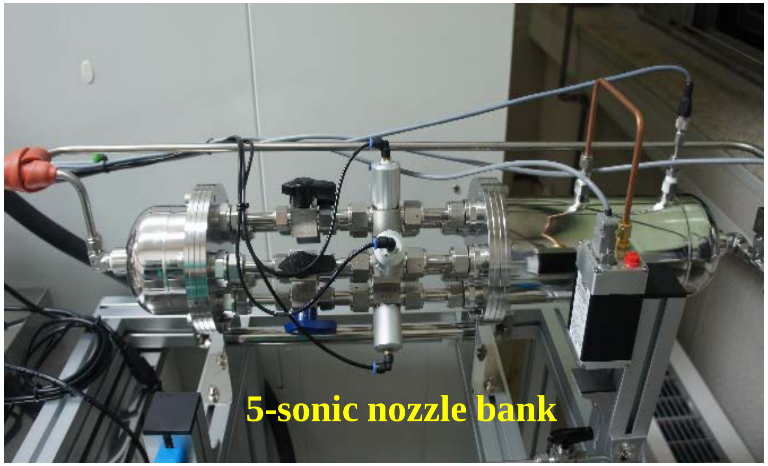
Wind ventilation

- Mass flow control using sonic nozzle
  - Five set of nozzle diameter (*d*)
    - (0.2, 0.28, 0.4, 0.8, 1.12, 3.2) mm
  - 3 m/s ~ 6.5 m/s @(3 ~ 500) hPa
    - Set accuracy of ±0.05 m/s
  - **Stability of ±0.02 m/s**







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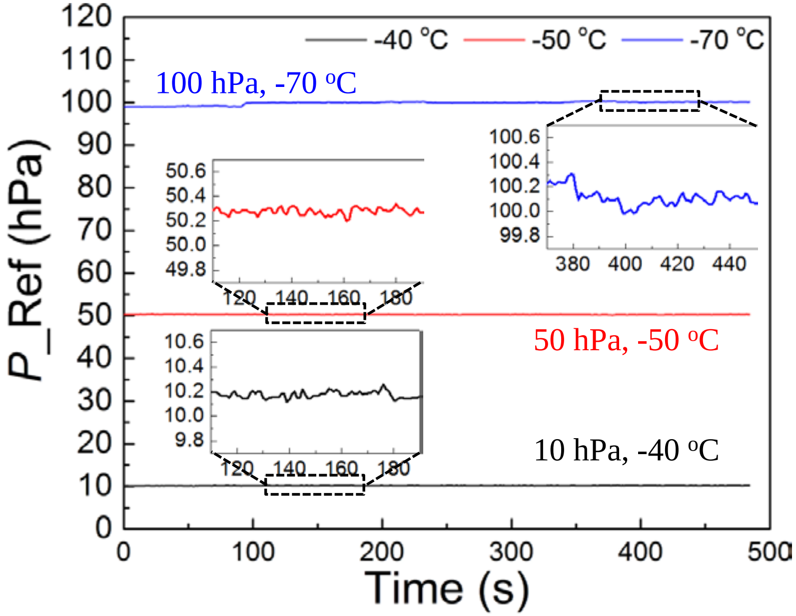
Pressure

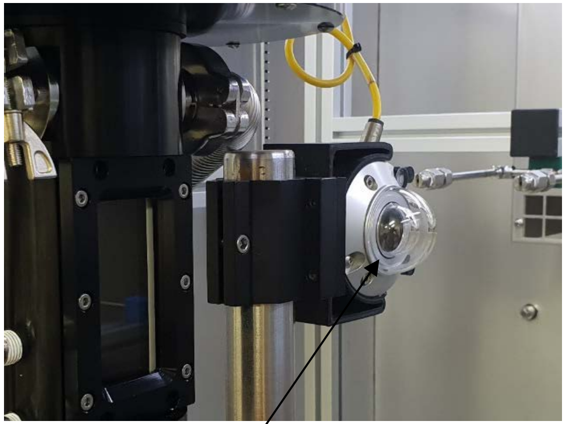
- Vacuum gauge
  - INFICON CDG 020D
  - (10 ~ 1000) torr
  - 1 % of reading accuracy

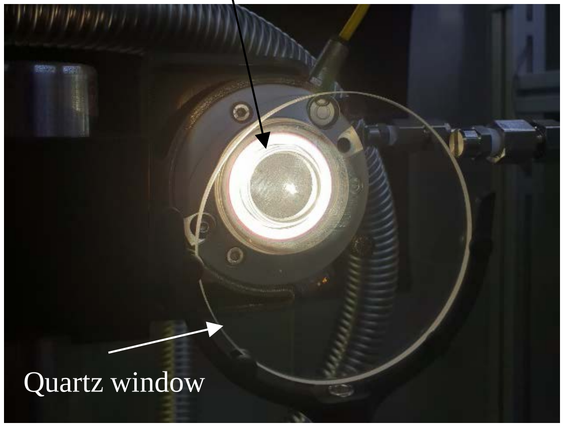


Stability of ± 0.1 hPa

Solar Irradiance

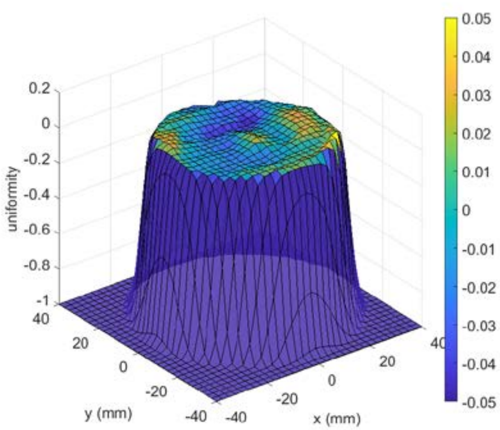
- Solar simulator
  - Newport Research Xe Arc Lamp
  - Max. 1000 W with ozone-free Xe
  - Tested at irradiance (~900 W/m^2)
  - Calibration with a reference pyranometer
  - **Stability of ± 1.5 W/m^2**

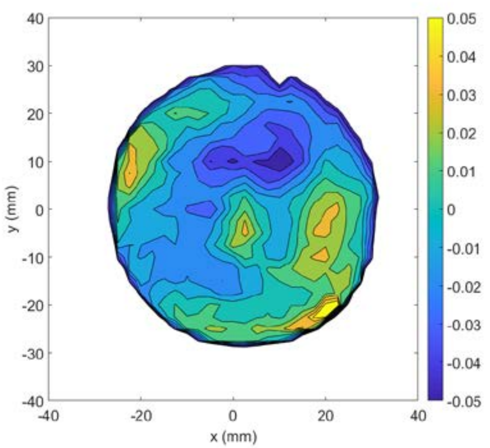




Reference pyranometer

<Uniformity check: within ± 5 %>





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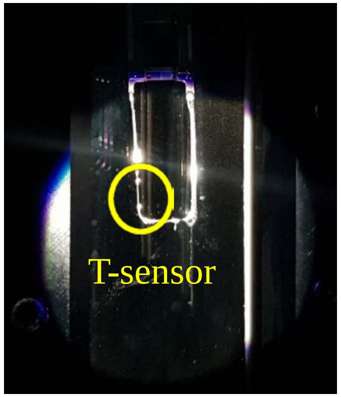
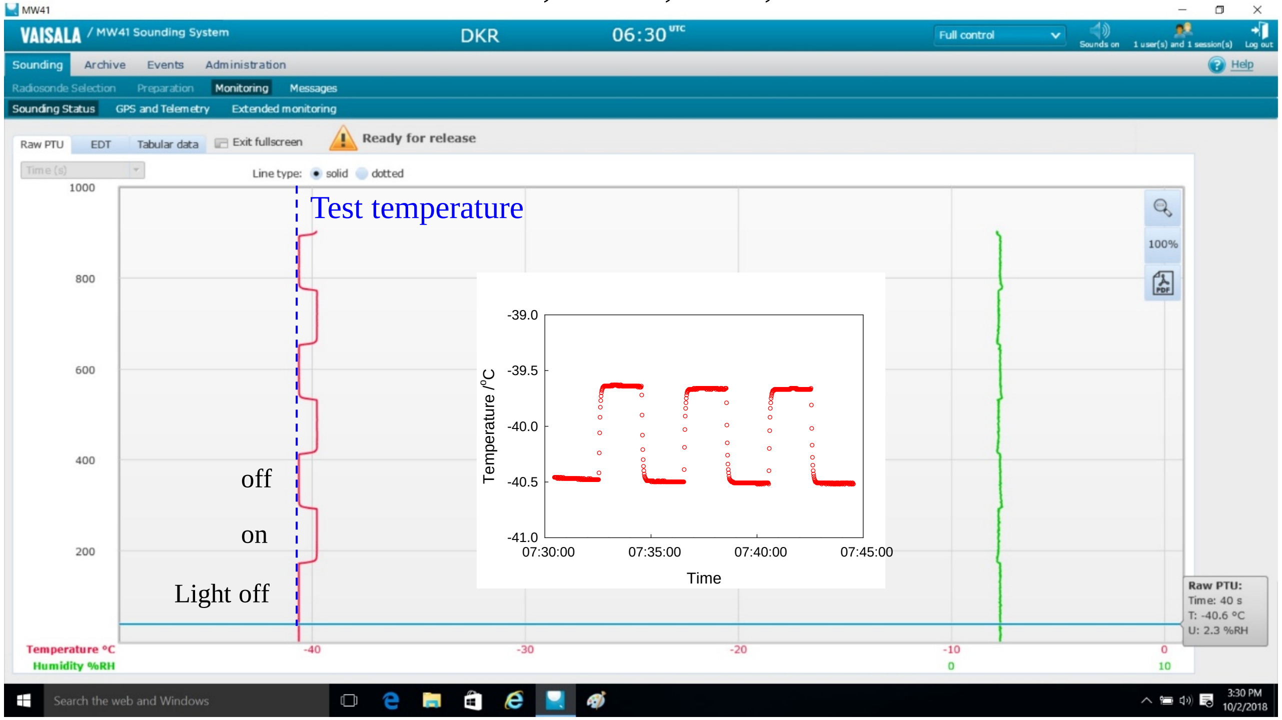
Setup of RS41

- **Vaisala RS41** and **MW41** sounding system
  - **Direct exposure** to the radiation (Perpendicular to the beam direction)
    - Expose for 3 min
- Measurement in remote mode using the MW41.



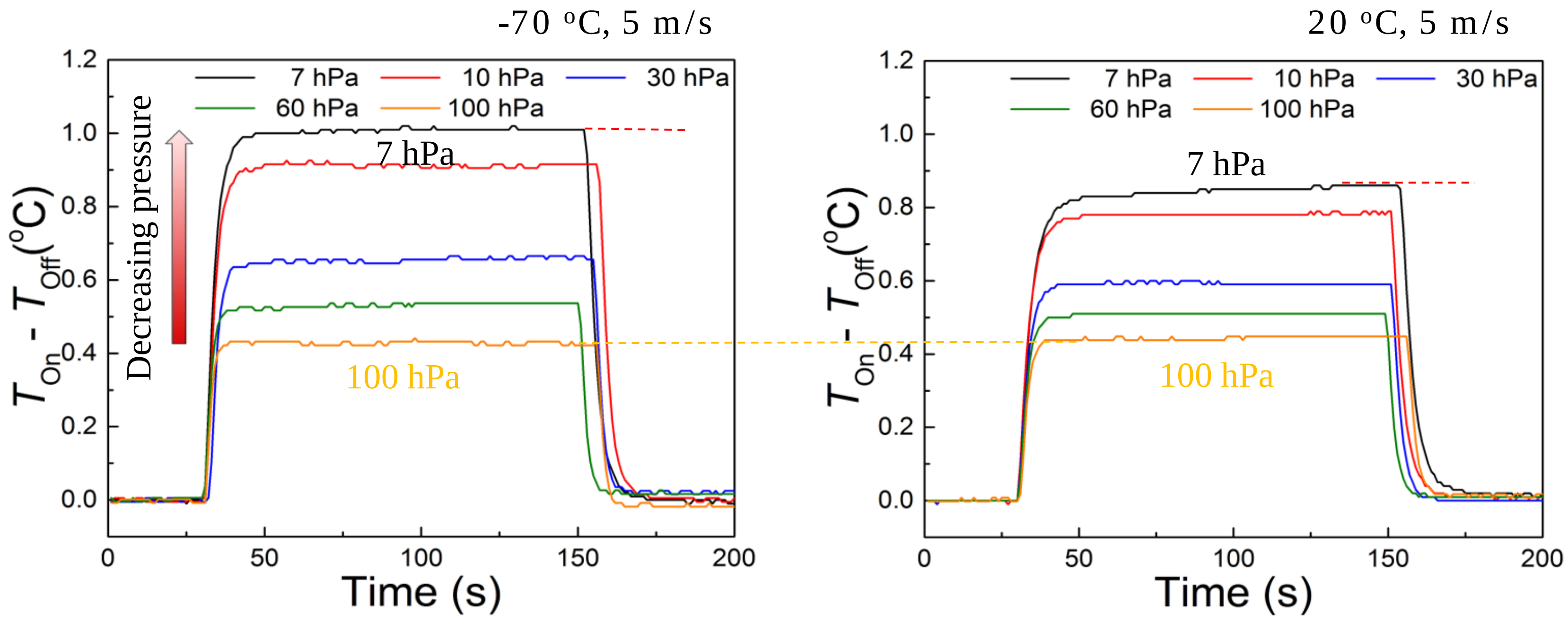
-40 °C set, 10 hPa, 5 m/s, 900 W/m²



P-T matrix

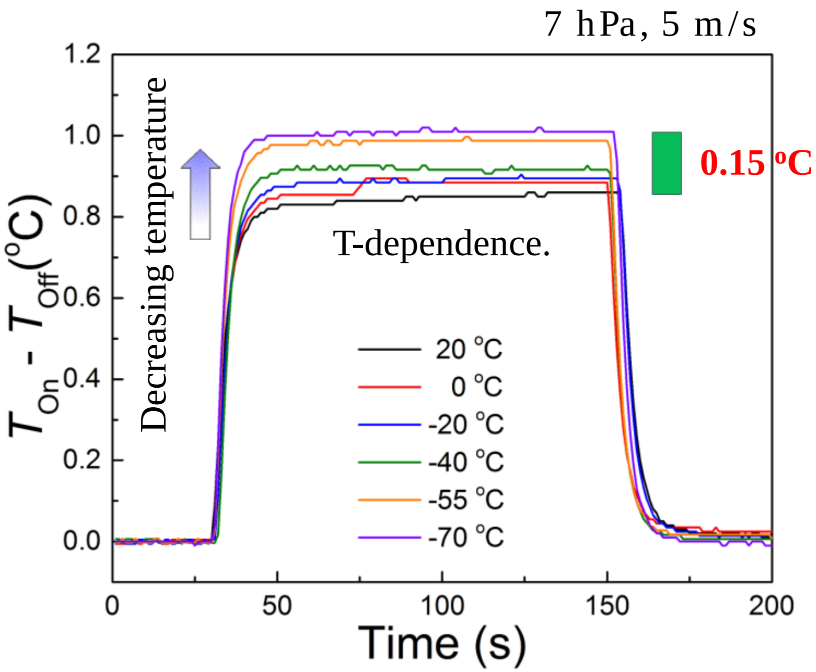
T \ P	**7 hPa**	**10 hPa**	**30 hPa**	**60 hPa**	**100 hPa**
-70 ^{o}C	v=5 m/s	v=5 m/s	v=5 m/s	v=5 m/s	v=5 m/s
-55 ^{o}C	v=5 m/s	v=5 m/s	v = 0 4 5 6.5	v=5 m/s	v=5 m/s
-40 ^{o}C	v=5 m/s	v=5 m/s	v=5 m/s	v=5 m/s	v=5 m/s
-20 ^{o}C	v=5 m/s	v=5 m/s	v=5 m/s	v=5 m/s	v=5 m/s
0 ^{o}C	v=5 m/s	v=5 m/s	v = 0 4 5 6.5	v=5 m/s	v=5 m/s
20 ^{o}C	v=5 m/s	v=5 m/s	v=5 m/s	v=5 m/s	v=5 m/s

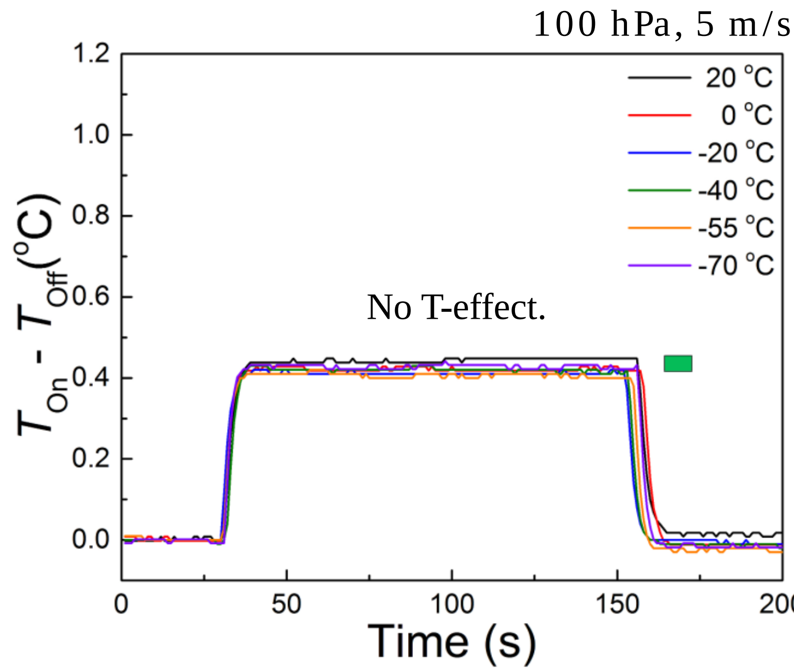
Solar heating behavior with pressure



- As pressure decreases, degree of solar heating become larger.
  - At 7 hPa and -70 ºC, temperature rising of about 1.0 ºC was observed.
  - At higher pressure of 100 hPa, degree of temperature rising decreased to about 0.4 ºC.
- Stronger air convection at higher pressure may reduce the temperature rising.

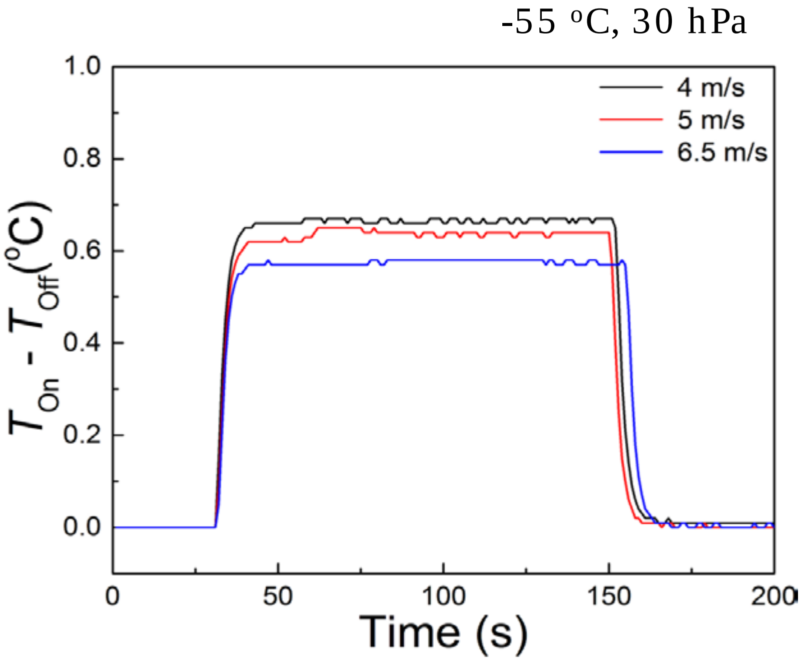
Solar heating behavior with temperature

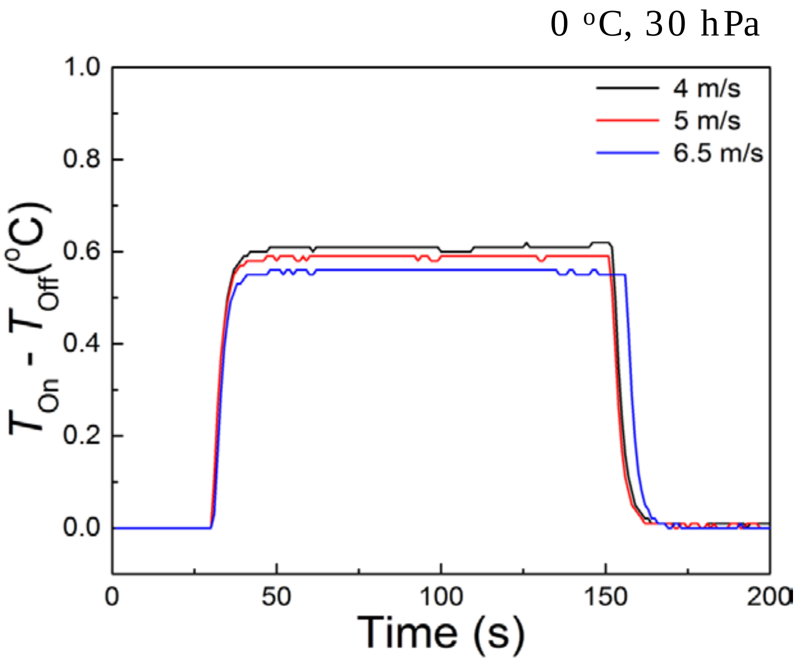




- At low pressure, solar heating increases as temperature decreases.
  - At 7 hPa, about 0.15 °C temperature difference was observed with temperature.
  - At 100 hPa, there was no clear temperature effects.
- This may be related to the change of long wave radiation from the sensor with temperature ($E_{rad} = \sigma\varepsilon T^4$) under low influence of convection.

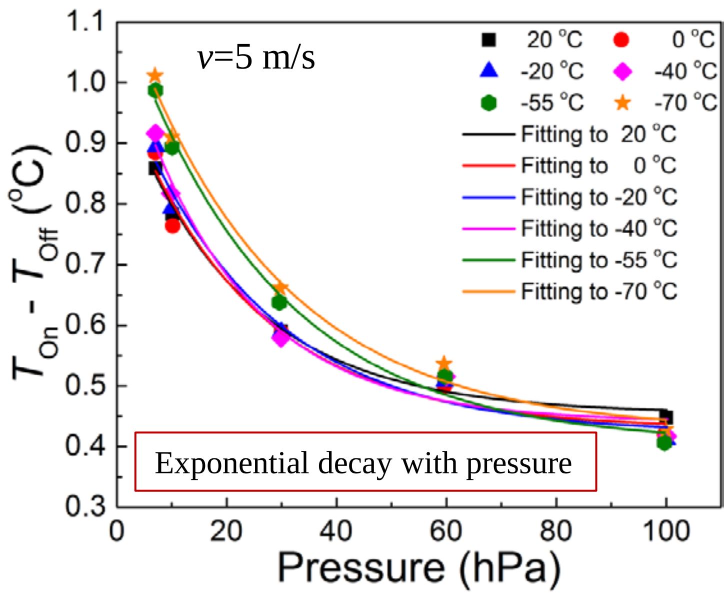
Solar heating behavior with ventilation speed

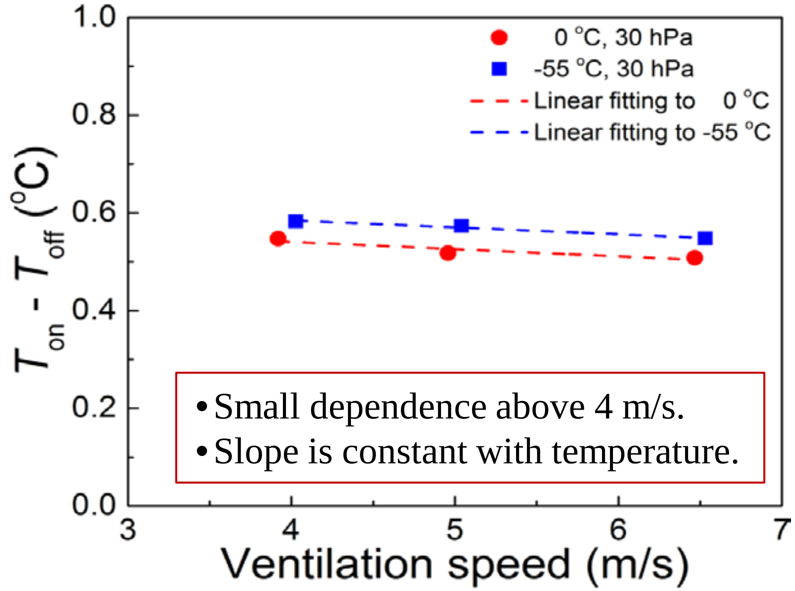




- For RS41, ventilation effects are not so big.
  - As speed increases, solar heating slightly decreases.
  - With pressure change at same temperature, similar behavior was observed.
  - The temperature dependence of ventilation speed is nearly same with the temperature.

Temperature rise of RS41 with *P* and *v*





$$(T_{on} - T_{off})_{P,T} = S/900 \times \{y_0(T) + A_0(T)\exp(-P/p_0(T))\}$$

Temperature and pressure effect

$$(T_{on} - T_{off})_{V} = S/900 \square \{-0.014(v-5)\}$$

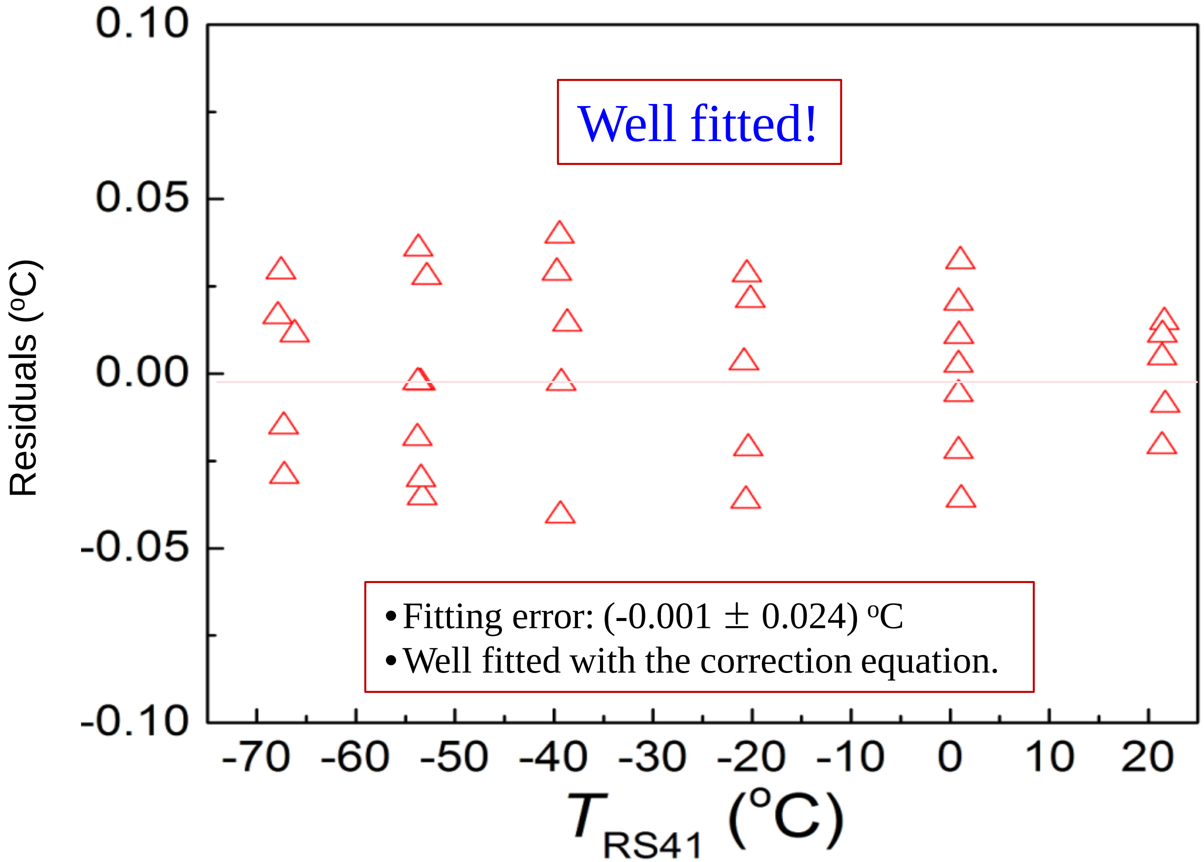
Ventilation effect

S: solar irradiance (W/m^2)
y_0, A_0, p_0: fitting coefficients

S: solar irradiance (W/m^2)
v: ventilation speed (m/s)

$$(T_{on} - T_{off})_{Total} = S/900 \square \{y_0(T) + A_0(T)\exp(-P/p_0(T)) - 0.014(v-5)\}$$

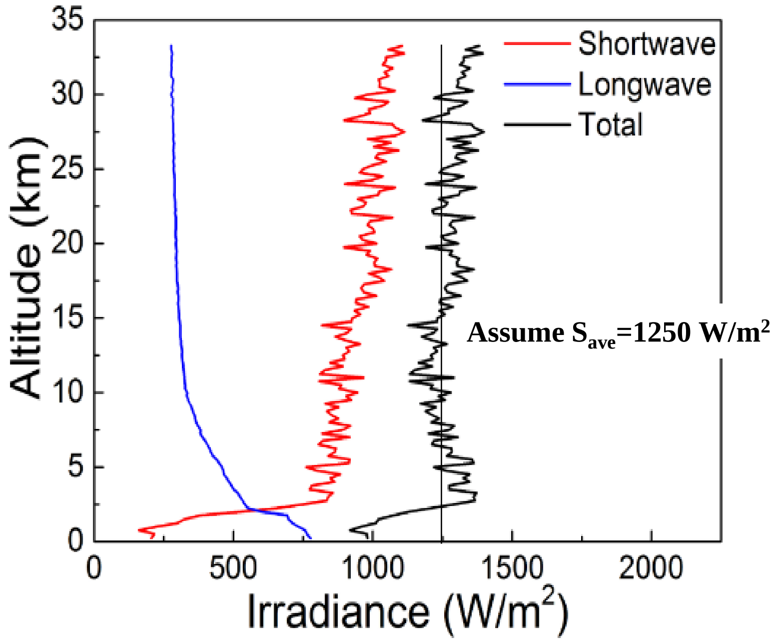
Estimation of fitting error

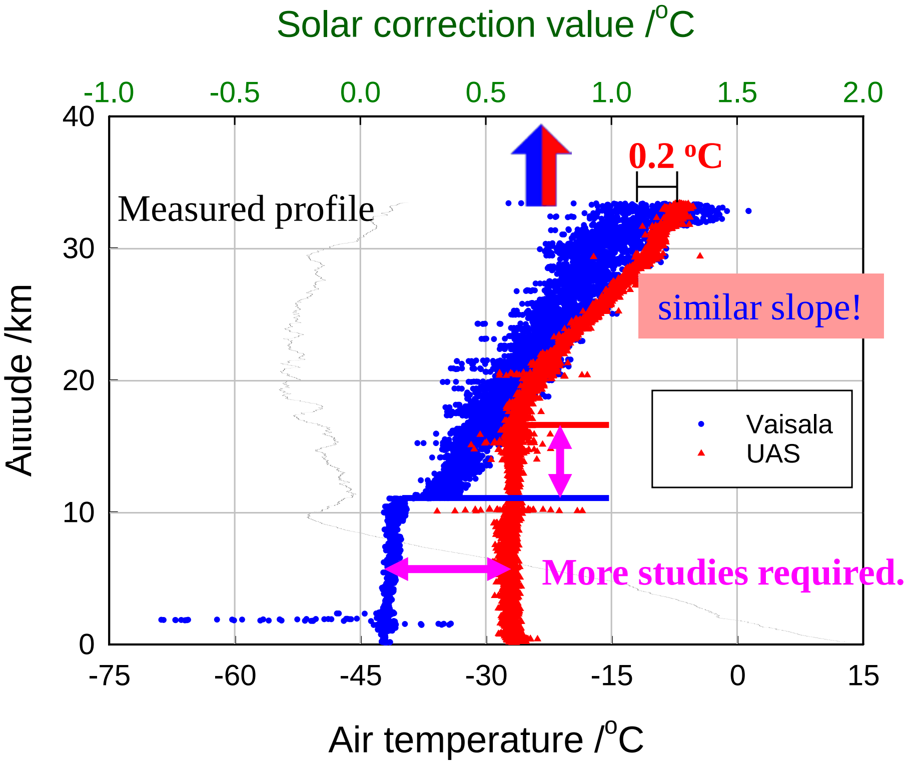


- Fitting error: (-0.001 ± 0.024) °C
- Well fitted with the correction equation.

Comparison with CoreTemp2017 data

<Measured at the Lindenberg, 2017>





- Measured spectrum with the altitude

- In stratosphere, good agreement.
- In troposphere, more studies required.

Much wider pressure dependence tests are required.

Summaries

- **Solar irradiance test for the Vaisala RS41** was conducted in the stratospheric region using the **KRISS Upper Air Simulator (UAS).**
  - Temperature of -70 °C to 20 °C and pressure of 7 hPa to 100 hPa under solar irradiance of 900 W/m^2 at various ventilation speed of (4 to 6.5) m/s
  - In addition to pressure and wind ventilation, it has been shown experimentally that temperature have to be taken into account.
  - It is possible to create a solar radiation correction formula from the measured data.
  - Solar correction data from UAS were in good agreement with CoreTemp 2017 data in the stratosphere region.
- In order to get more accurate results, UAS will be improved from the following point of view. (Now it is underway!)
  - Sensor boom tilt
  - Rotation of the sensor boom
  - Change of exposed area of sensor boom
- **With UAS, it will be able to calibrate all types of radiosondes with traceability to international measurement standards.**


Thank you for your attention
And
Thank my team!