Report of CoreTemp2017:
Intercomparison of dual thermistor radiosonde (DTR) with RS41, RS92 and DFM09 radiosondes

Yong-Gyoo Kim*, Ph.D and GRUAN Lead center

*Upper-air measurement team

Center for Thermometry and Fluid Flow

KRISS, Daejeon, Korea

dragon@kriss.re.kr

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Ⅱ Comparison Details

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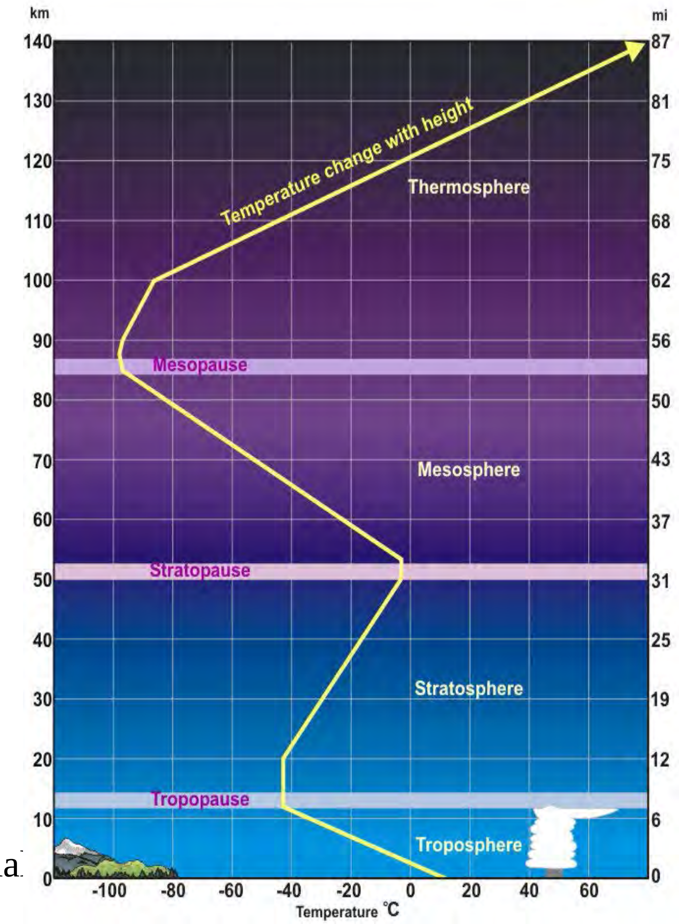
1 Introduction

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 measurement

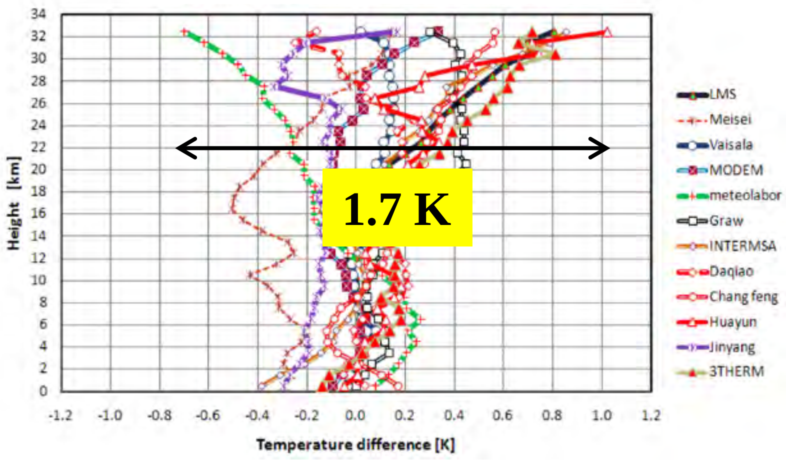
Radiosonde

- 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

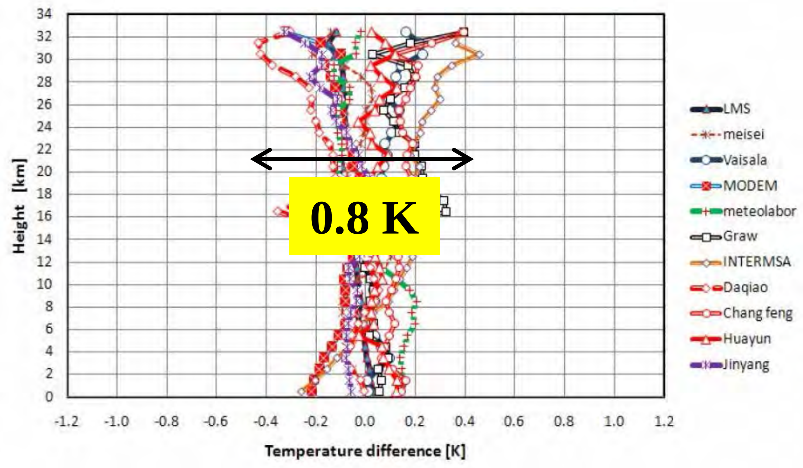
8th 2010 WMO Radiosonde intercomparison

Yangjiang, China

Day time measurement



Night time measurement



- Larger day time temperature differences than night time
  - Due to **the solar radiation effects (solar heating)**

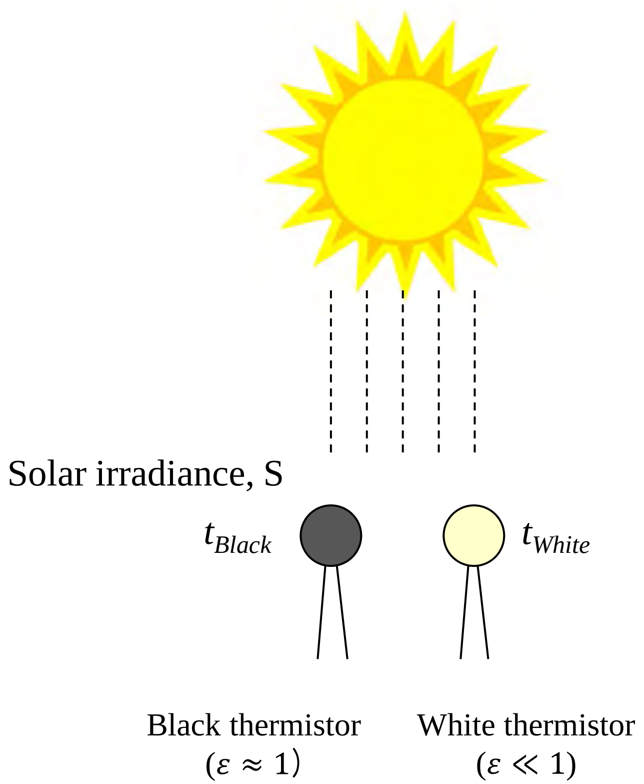
Software radiation correction of Yangjiang

Manufacturer	Correction at 10 hPa /ºC	Temperature sensor type
LMS	0.95	**Thermistor**
Modem	1.5	**Thermistor**
InterMet	1.1	**Thermistor**
Jinyang	2.1	**Thermistor**
Changfeng	0.6	**Thermistor**
Huayun	2.3	**Thermistor**
Graw	1.0	**Thermistor**
Meisei	1.8	Thermistor +W helix
Daqiao	0.9	**Thermistor**
Vaisala	0.7	Capacitive wire
Meteolabor	1.8	Thermocouple wire

- With same type of sensor, correction values ranged from **0.6 ºC ~ 2.3 ºC, it is too spread!**
  - **They are all calibrated at the ground level, but NOT in the upper air conditions.**
- **More reliable, SI-traceable and economic correction technique required, regardless of sounding time and location**

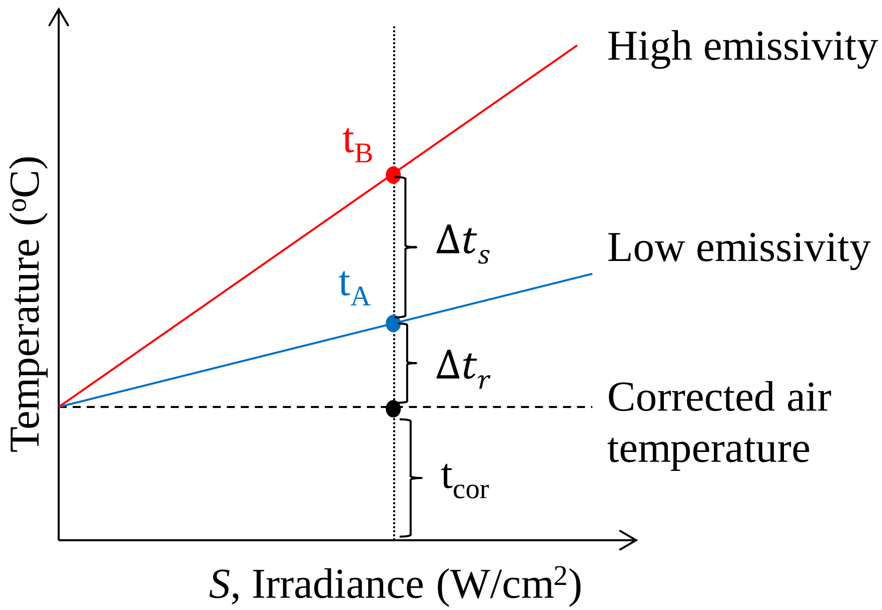
KRISS's new solar correction technique

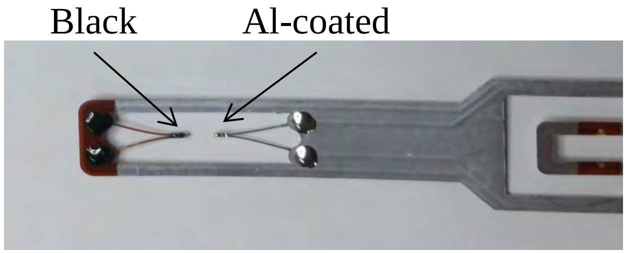
- **Temperature difference** of two radiosonde sensors with **different emissivity** depends on the amounts of **solar irradiation**.



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

DTR (Dual Thermistor Radiosonde)





- $t_B = \Delta t_s + \Delta t_r + t_{cor}$
- $t_{cor} = \boldsymbol{t_B} - \boldsymbol{\Delta t_r} - \boldsymbol{\Delta t_s}$
  - t_B, Δt_s : Can be measured during flight
  - Δt_r: obtained by calibration

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

Related Articles
Meteorol. Appl. **23**: 691–697 (2016)
Meteorol. Appl. **25**: 49–55 (2018)
Meteorol. Appl. **25**: 209–216 (2018)
Meteorol. Appl. **25**: 283–291 (2018)
Patent FI 127041 B
Patent KR 1742906
Patent KR 1787189
Patent US 15/306,697

Real time *in-situ* radiation correction technique

Motivation of Intercomparison

- To verify the DTR technique by comparison with other radiosondes
- Study on the solar correction technique for more accurate upper-air temperature measurements

KRISS
Thermometry Center

DWD
GRUAN Lead Center

CoreTemp2017

'Comparison of Radiation Effect on
Temperature Sensors of Radiosondes 2017'

2 Comparison details

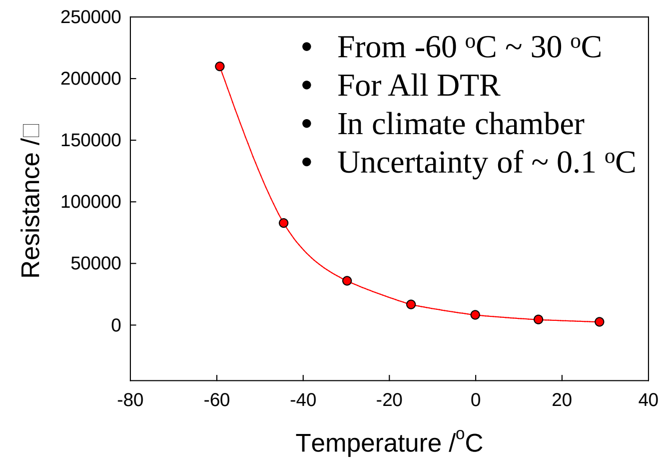
Preparation of DTR

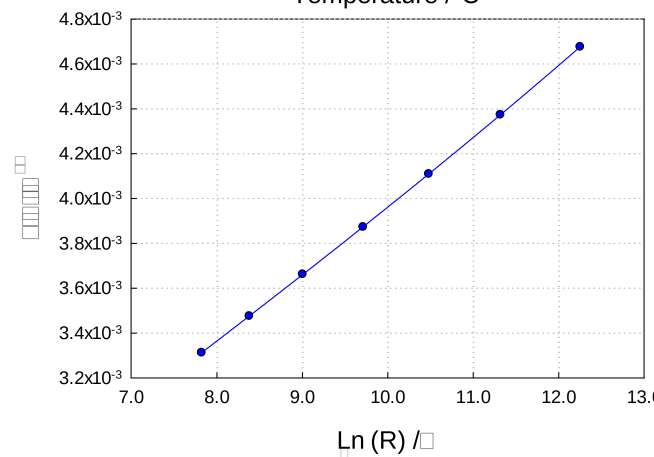
Two thermistors
<Black and Al-coated>

RF module with
styrofoam case
and antennae

<Calibration of thermistor>

$$\frac{1}{T} = A_0 + A_1 \ln R + A_2 (\ln R)^2 + A_3 (lnR)^3$$

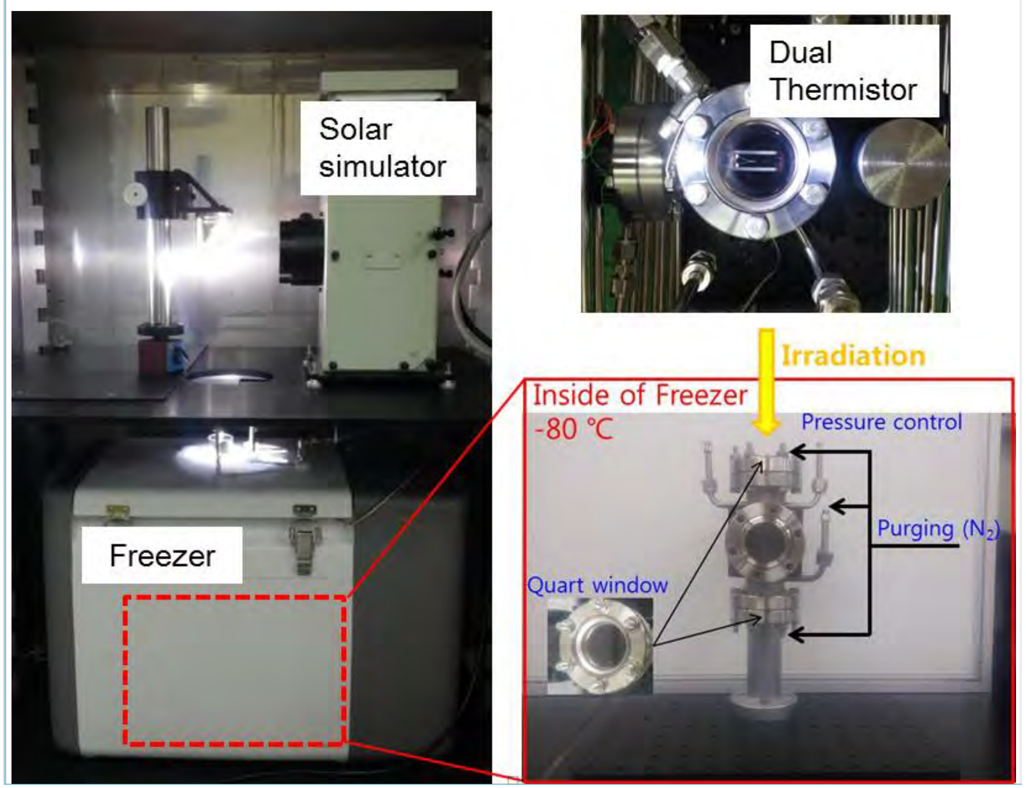




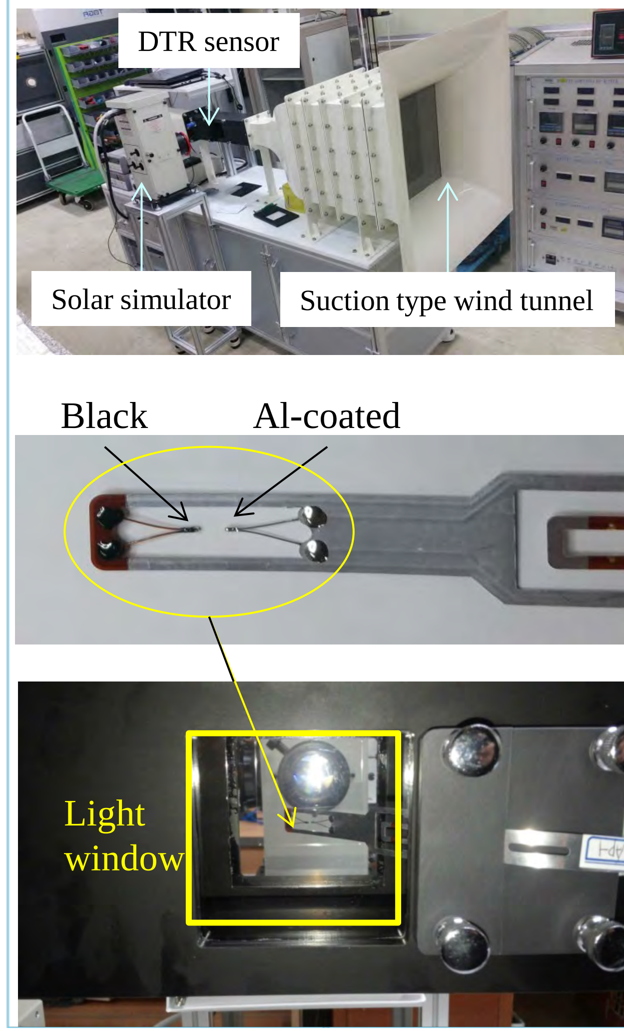
Calibration under solar irradiation

- Solar irradiation: 0 ~ 1500 W/m^2
- Wind speed: 0 ~ 10 m/s
- Temperature: -80 ^{o}C ~ 25 ^{o}C
- Pressure: 10 hPa ~ 1000 hPa

Test on the temperature and pressure effects



Test on the ventilation effects

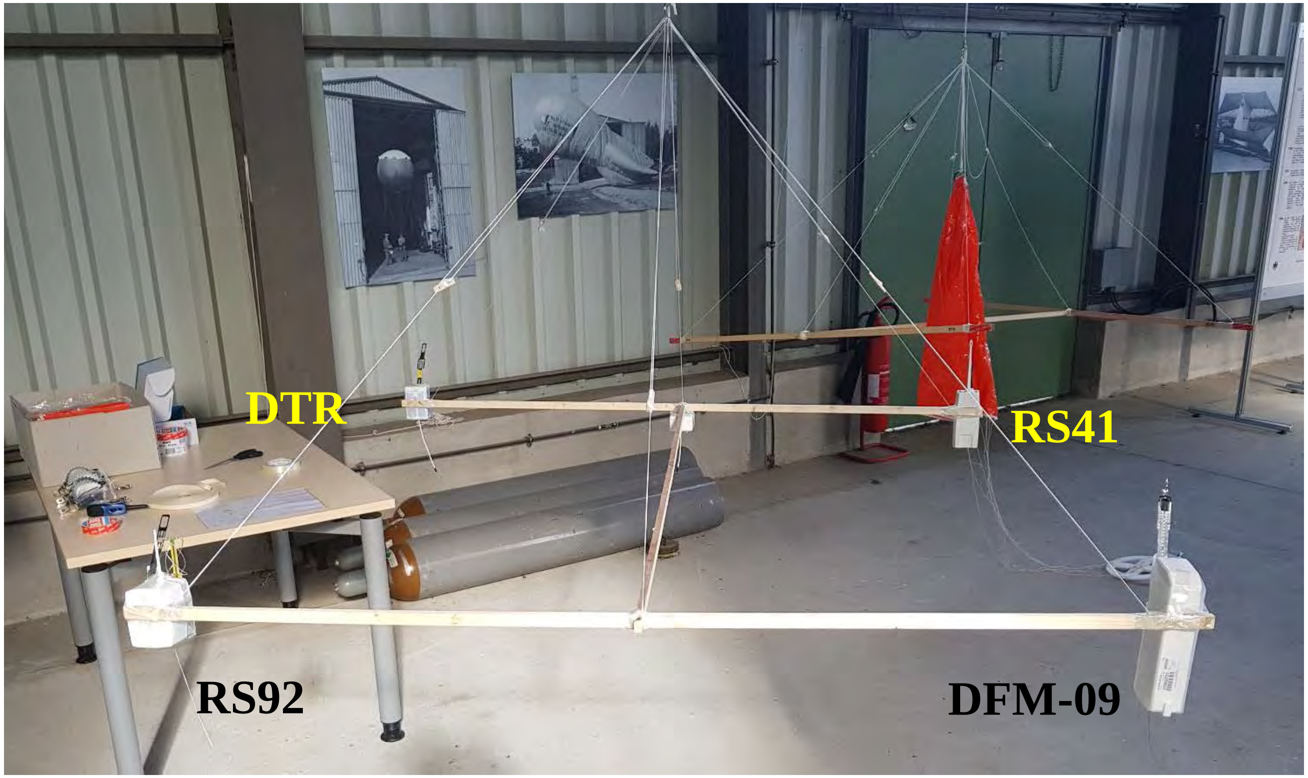


Intercomparison sites and date

From 11 ~ 15, September 2017

At Lindenberg observatory, DWD

Flying rig and comparing radiosondes



H-shaped rigs

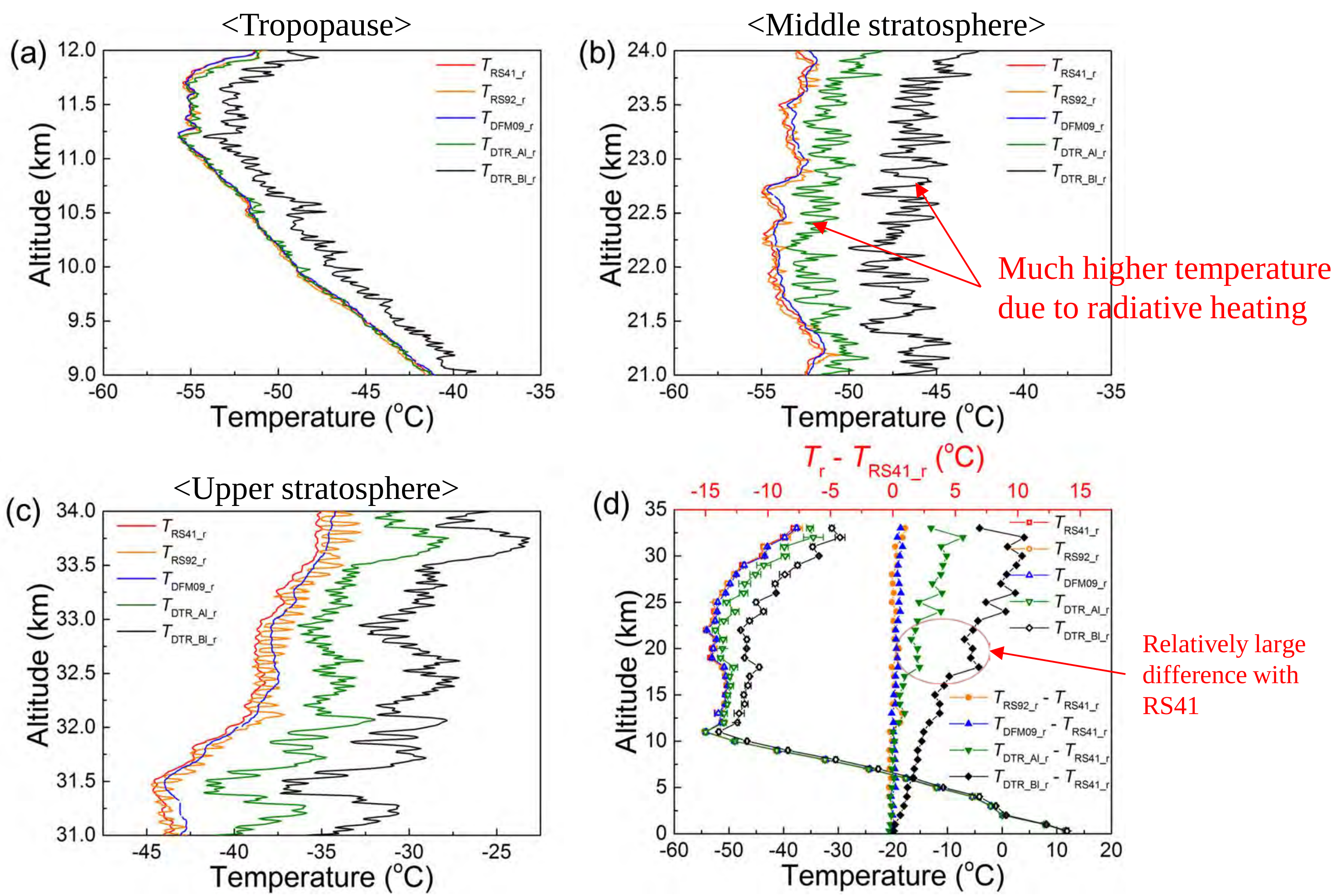
Flight schedule

8 daytime, 2 nighttime flights

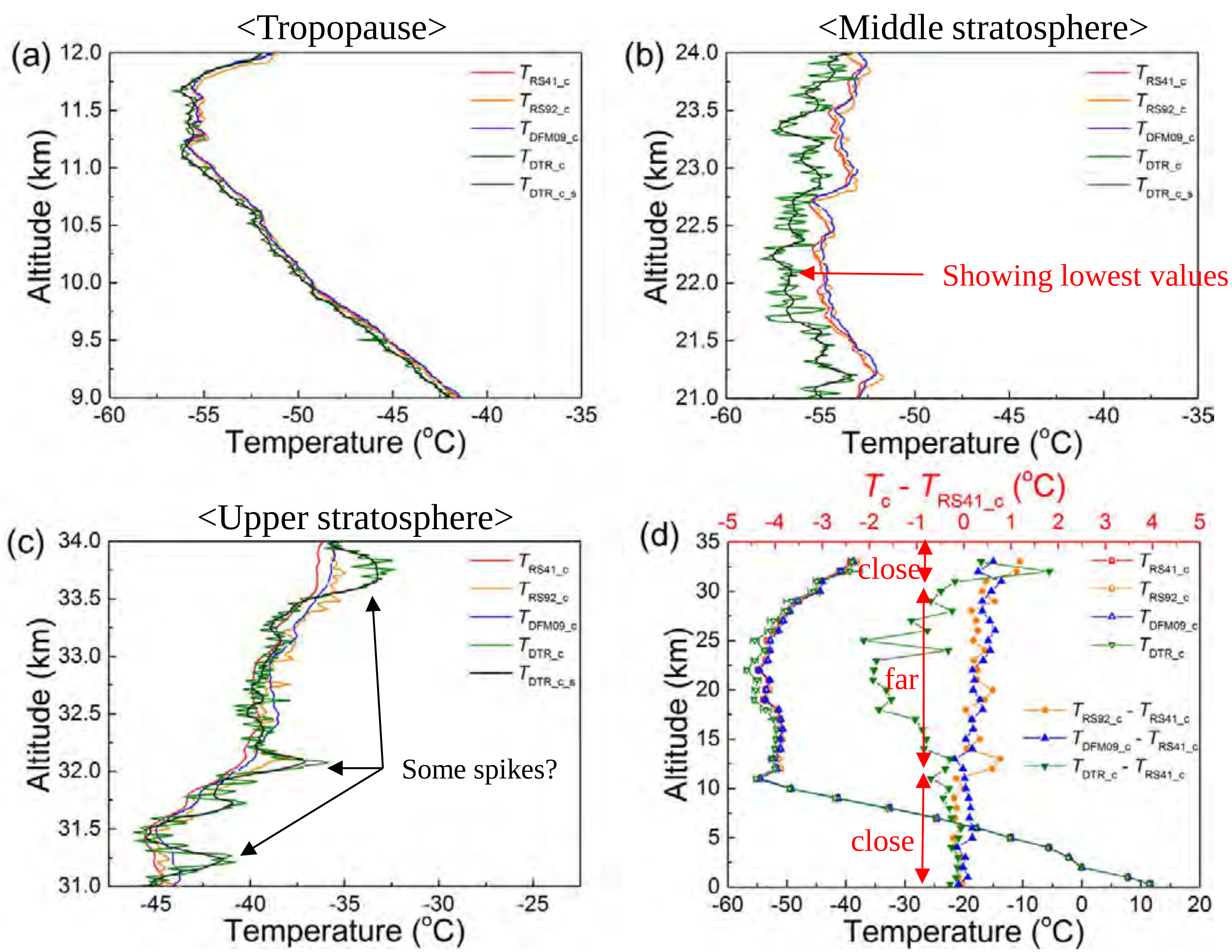
Flight number	Date (Month Day)	UTC (Hour:Min)	Day/ Night	Balloon Burst (km)	Remarks
1	September 12th	07:54	Day	33.8	
2	September 12th	10:57	Day	34.4	
3	September 12th	13:56	Day	31.6	
4	September 12th	19:34	Night	35.1	
5	September 13th	07:50	Day	34.0	
6	September 13th	14:08	Day	34.5	DTR failed
7	September 13th	20:10	Night	33.2	DTR partially failed
8	September 14th	07:58	Day	33.7	DTR Horizontal
9	September 15th	07:50	Day	32.6	Two more RS41s
10	September 15th	07:50	Day	33.2	Radiometers only

3 Comparison results

Example of raw data in daytime (Flight 5)

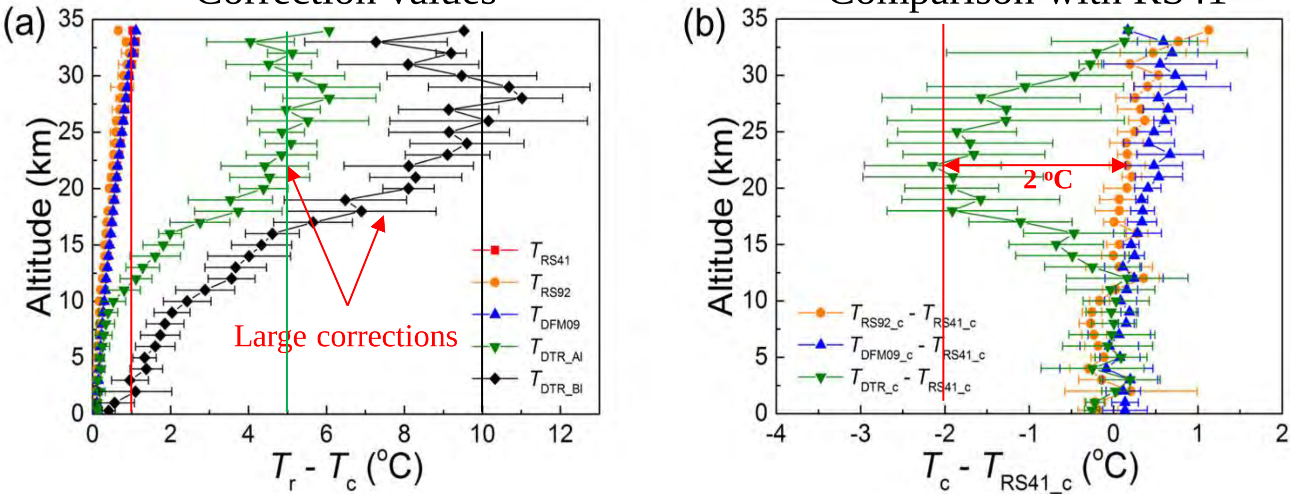


Corrected temperature in daytime (Flight 5)



Averaged solar correction values in daytime

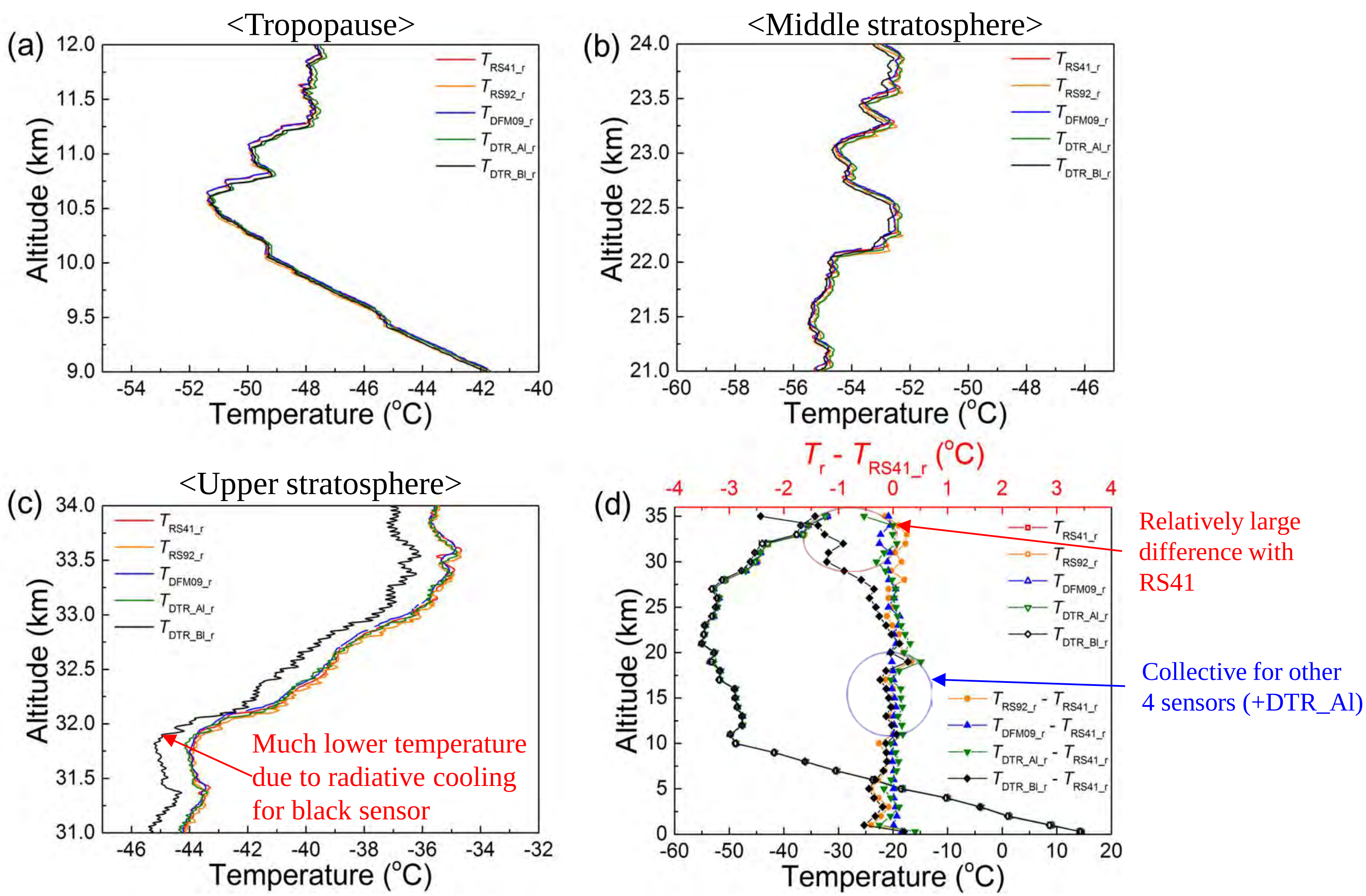
<Correction values> <Comparison with RS41>



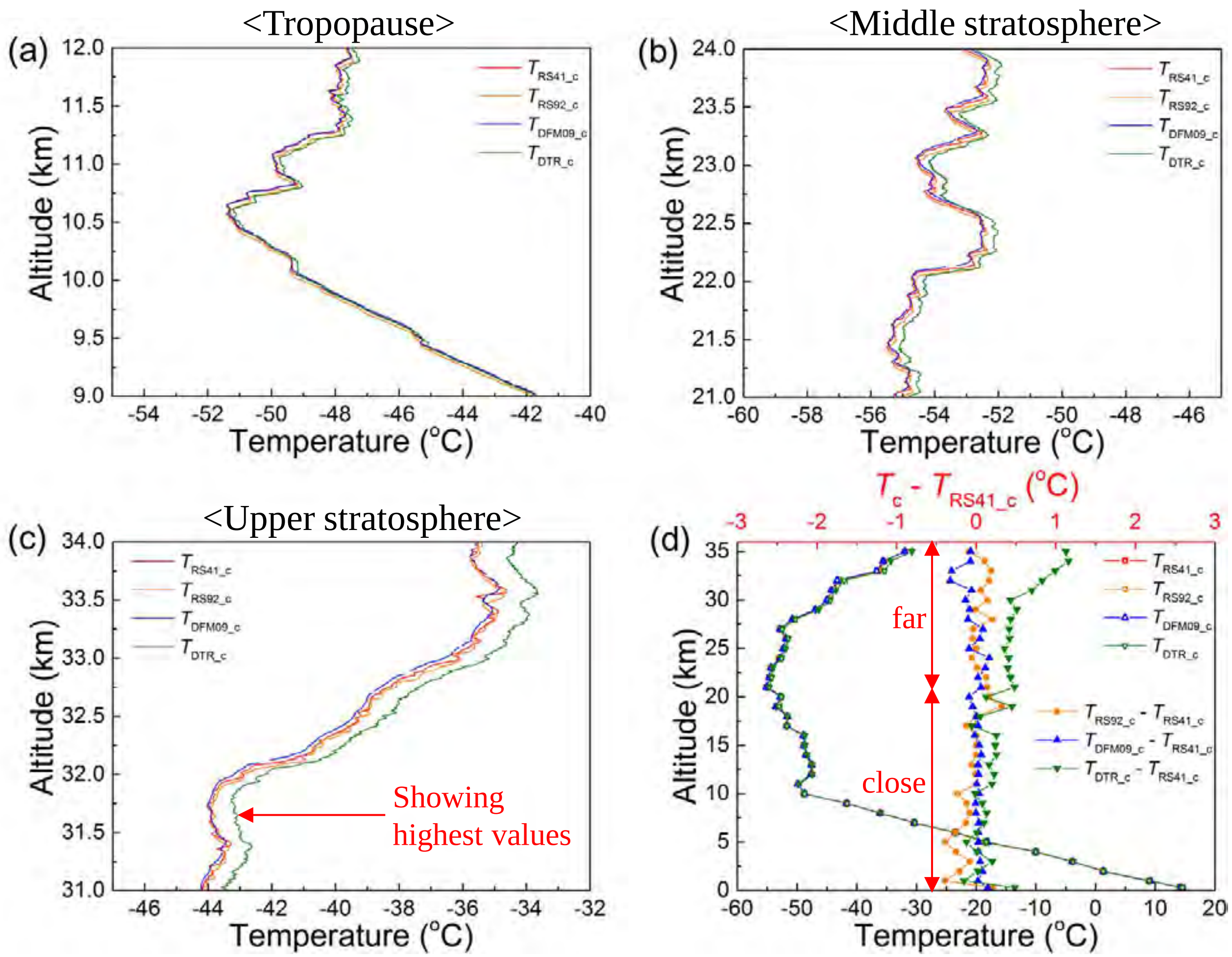
<Average of 5 flights in daytime>

- Collective behaviors of correction values for RS41, RS92 and DFM-09
  - Linear increase with altitude for all and Maximum of about 1 °C at 30 km
- Pretty large corrections for T_{DTR_Al} and T_{DTR_Bl}
  - 5 °C for Al, 10 °C for black
- Difference of about -2 °C in maximum with RS41 at altitude of about 25 km
  - In troposphere, fairly in good agreement with others
  - At middle stratosphere, big differences with other radiosondes
  - At upper stratosphere, become closer to others
- **DTR shows lowest corrected temperature at daytime.**

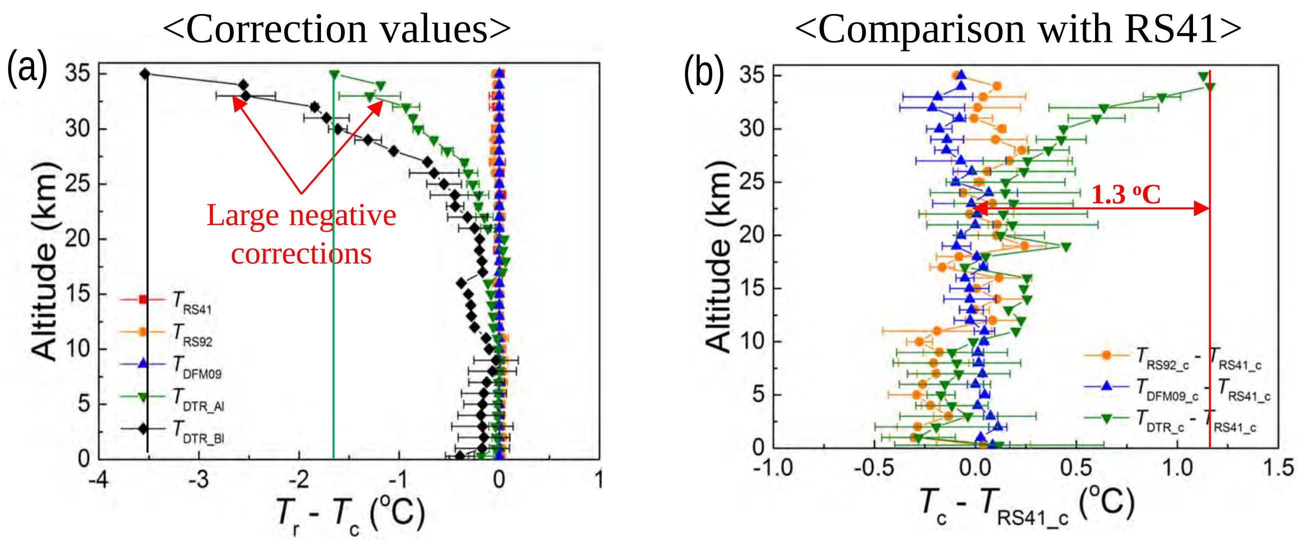
Example of raw data in nighttime (Flight 4)



Corrected temperature in nighttime (Flight 4)



Averaged solar correction values in nighttime

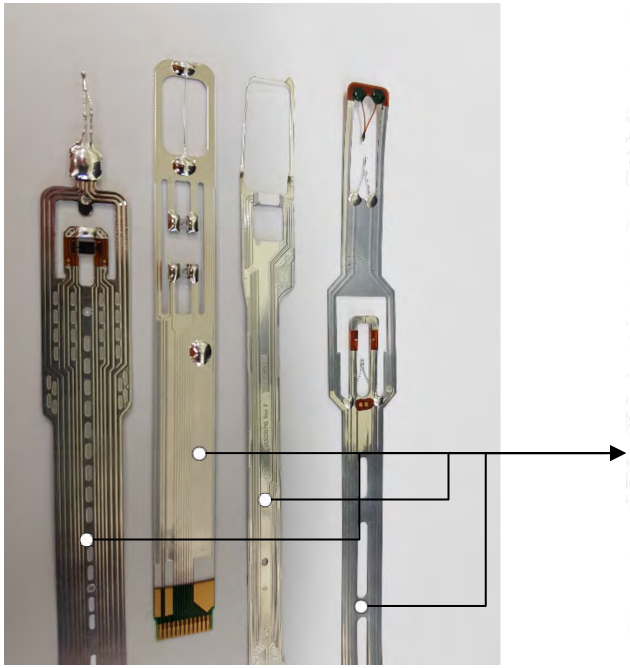


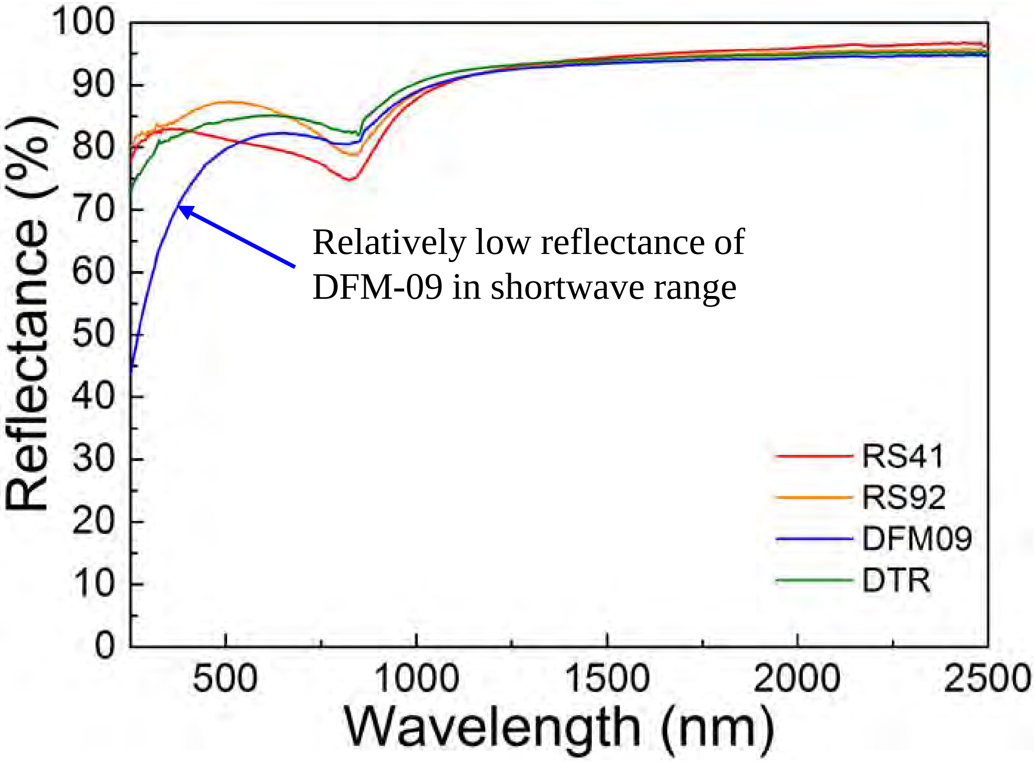
<Average of 2 flights in nighttime>

- Same behaviors of correction values for RS41, RS92 and DFM-09
  - Zero corrections regardless of altitude
- Pretty large corrections for T_{DTR_Al} and T_{DTR_Bl}
  - -1.7 °C for Al, -3.5 °C for black
  - Even raw data for T_{DTR_Al} is same to others, radiation correction done due to distinct Δt_s
- Difference of about 1.3 °C in maximum with RS41 at altitude of about 35 km
  - Up to middle stratosphere, not so much with other radiosondes
  - At upper stratosphere, difference becomes larger than others
- **DTR shows highest corrected temperature at nighttime.**

4 Discussions

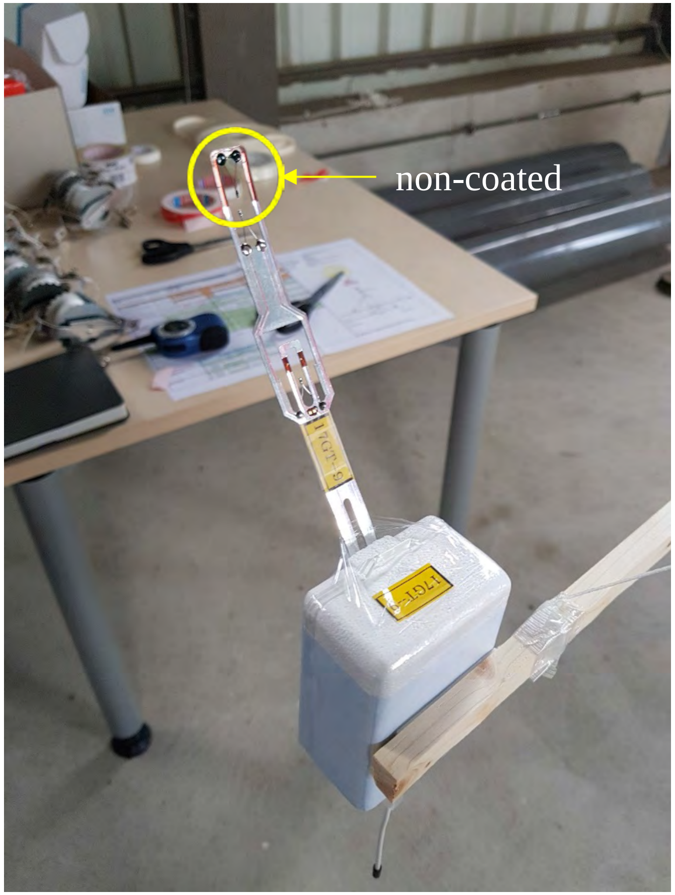
Reflectance tests on the sensor boom



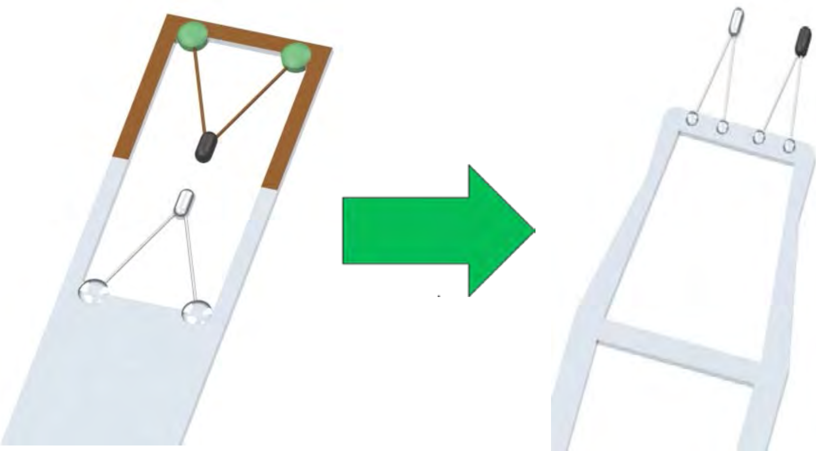


- Reflectance (quality of coating) may be not the main reason of large solar effects of DTR_{Al}.

Imperfect design of DTR



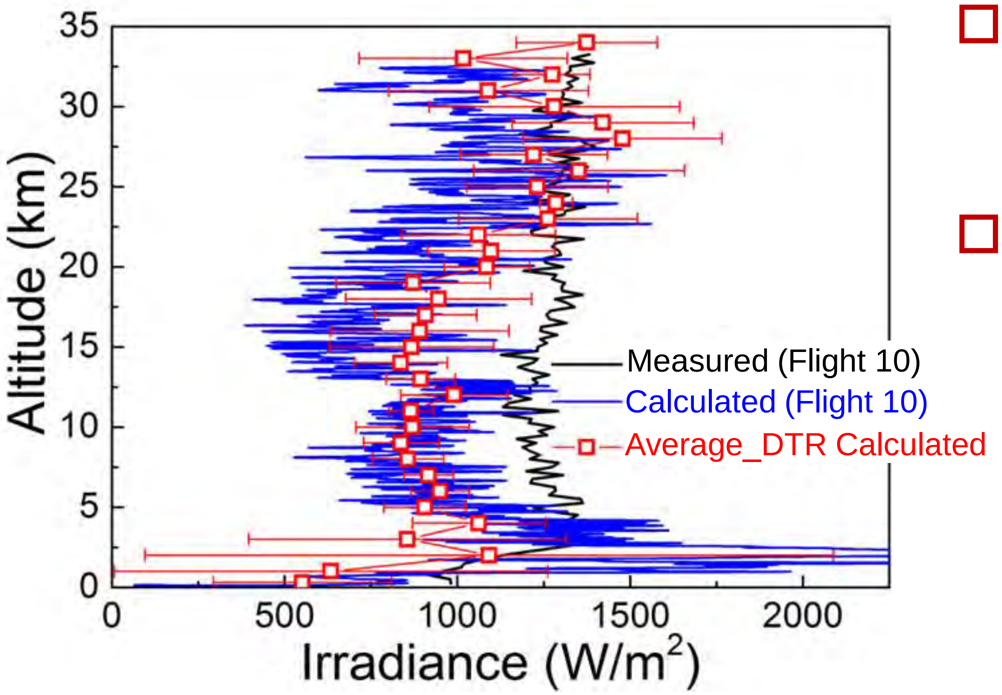
- Some part of sensor boom did not be Al-coated.
  - Not considered by just a mistake!
  - This part can take much more thermal energy giving rise to the much larger temperature change than others.
- Sensor boom design will be changed.



Before **After**

Correction at daytime

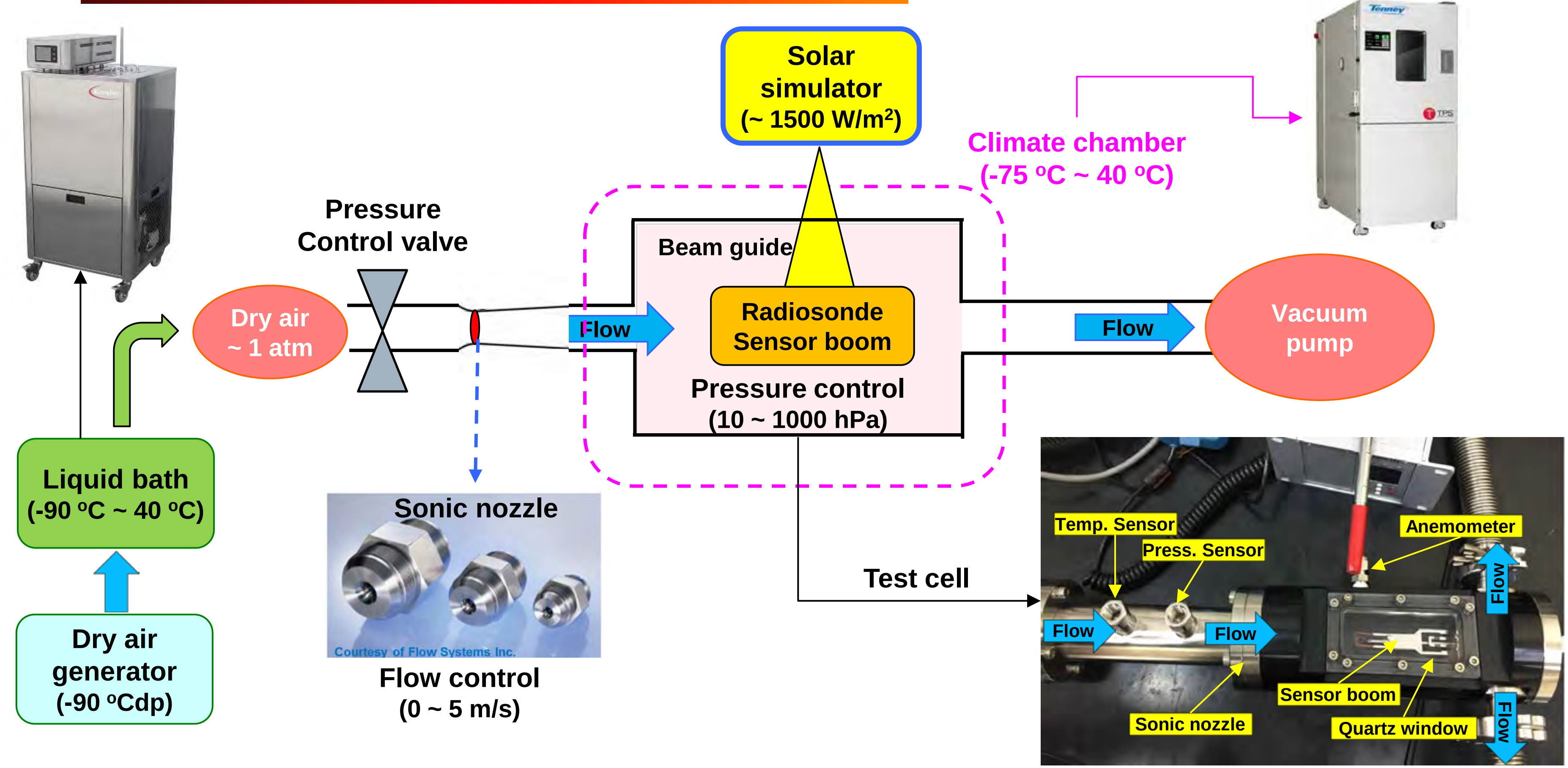
<Comparison of irradiation values>



- Comparison with measured and calculated irradiance
  - Some discrepancies between them
- Calculation of irradiance by DTR
  - Based on the two individual experiments
    - Wind effect and Temperature/Pressure effect
  - It is not enough to explain the daytime behaviors of DTR
  - It is still under studies.

New design of Upper-Air Simulator under Construction

Design concept of New **Upper-Air Simulator***



(Temperature, Pressure, Irradiance, Ventilation) Co-varying System

-75 ~ 40 °C | 10 ~ 1000 hPa | ~ 1500 W/m² | 0 ~ 5 m/s

*Submitted to TECO2018

5 Summaries

CoreTemp2017

- Comparison of DTR with RS41, RS92 and DFM-09 at Lindenberg observatory between KRISS and GRUAN Lead-Center
  - To test the solar radiation effects and to evaluate the DTR technology.
- Total 10 flights at day and nighttime.
  - At day time, DTR shows higher raw temperatures and larger correction values than others.
    - **DTR shows lowest corrected air temperature at daytime.**
  - At night, lower temperatures due to radiation cooling were observed.
    - **DTR shows highest corrected air temperature at nighttime.**
  - Solar heating and radiation cooling of DTR were **varied with the altitude, depending on temperature and pressure.**
- Imperfection of DTR design resulting from coating and shape
  - **Sensor boom design** will be changed to minimize the conduction error through a stem.
- Making an idea on the more realistic **upper-air simulator**
  - Temperature, pressure, irradiation and ventilation can be controlled separately.
- **More improved results are expected in next version of DTR, 2018.**


Thank you for your attention
CORETEMP
2017