Exploring the **tropical solar radiation profile** using **X-data-linked DTR and RS41** in Kota Kinabalu, Malaysia

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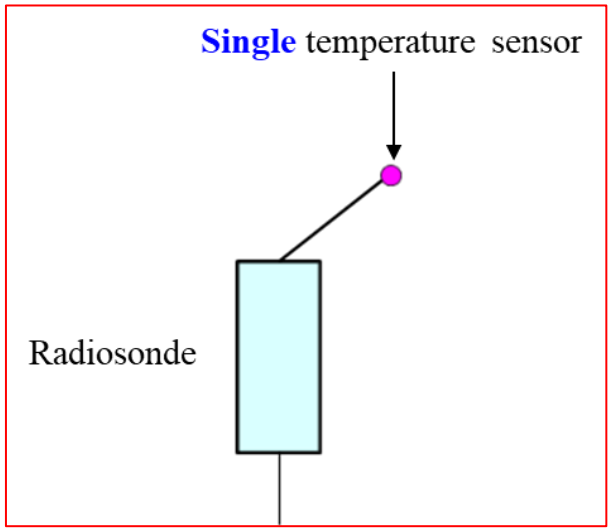
I. Introduction

Radiosonde under day/night sounding

- Temperature reading is biased to higher on daytime, and to lower on nighttime
- Radiation correction should be done to get an accurate air temperature.



$$t_{air} = t_{raw} + \Delta t_{cal} + \Delta t_{rad}$$

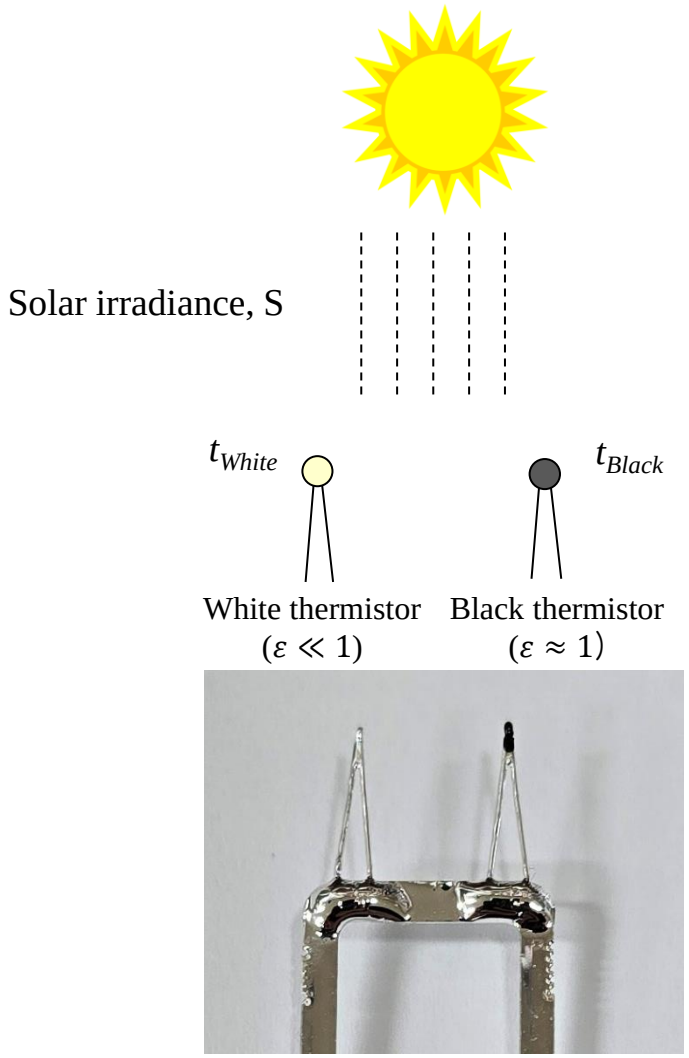
t_{raw} : raw A/D signal
Δt_{cal} : calibration correction
Δt_{rad} : radiation correction

$$\Delta t_{rad} = f(S)$$

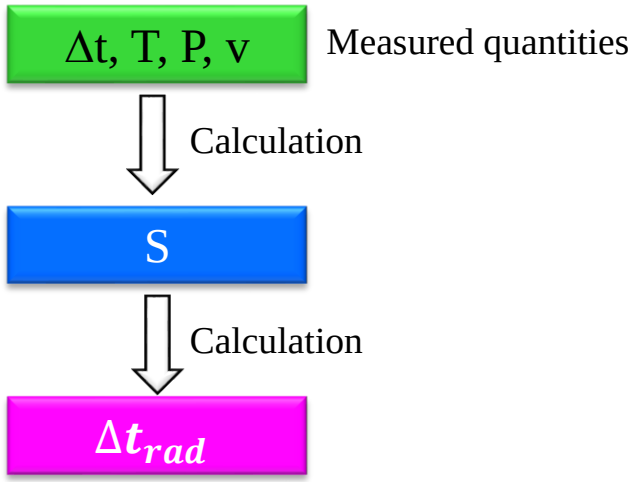
S : Pre-determined solar irradiance depending on time and location

$$\therefore \ \Delta t_{rad} = f(time, location\ (GPS\ position))$$

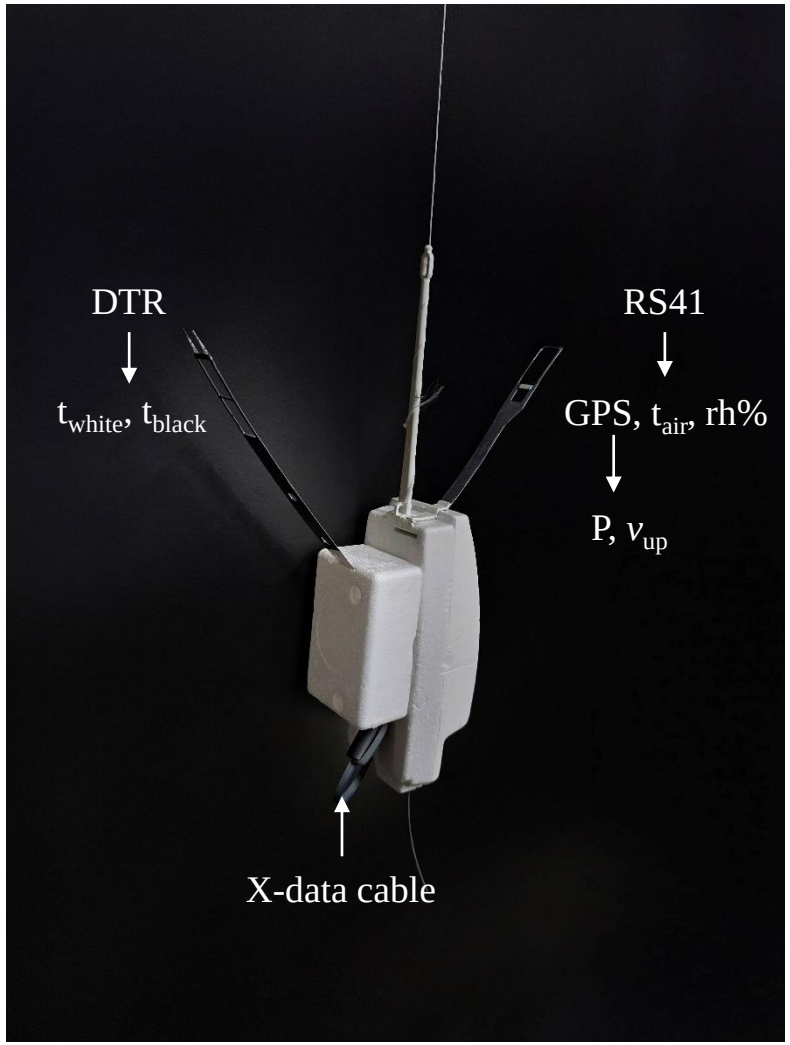
KRISS's DTR sensor



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



DTR vs RS41 via X-data connection



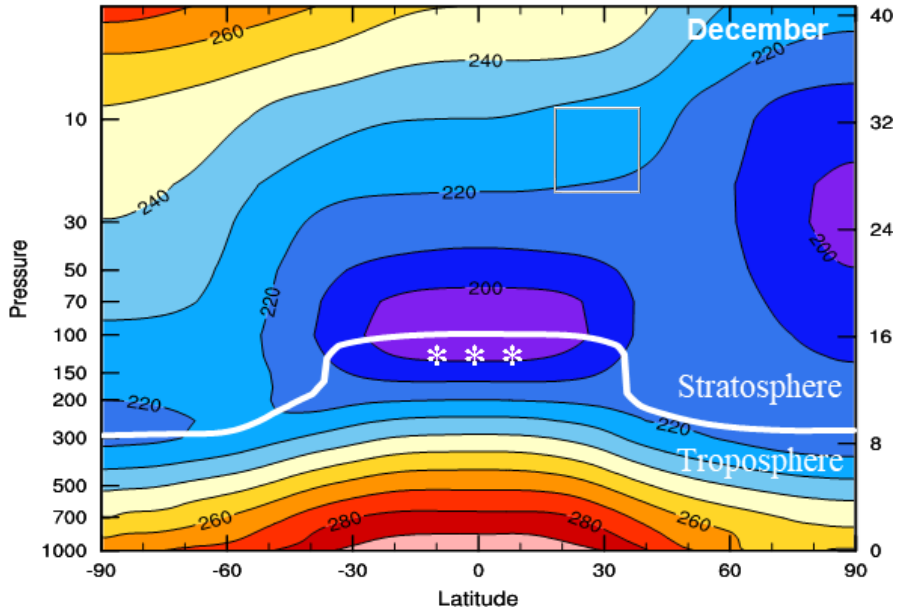
- From RS41
  - Get Key climate variables
    - **t_{air}, rh%, P, $v_{air\ up}$**
- From DTR
  - Get radiance variation
    - From **t_{white}** and **t_{black}**
- To give wide applicability, **X-data** format adopted
  - Mother(eg. RS41) and kids (DTR)
  - RS41+up to 2 DTRs
  - Applicable to all other manufacturers' radiosondes
- **X-DTR** is registered in **NOAA**

XDATA Instrument ID Allocation

name	bytes allocated	Contact Information	Date Started	Date Finished
KRISS DTR	0x4D	sangwook@kriss.re.kr	10/16/2024	ongoing
KRISS DQCM	0x4E	sangwook@kriss.re.kr	10/16/2024	ongoing

Purpose of this work

- **Sounding with DTR and RTS41** at the tropical zone (Kota Kinabalu in Malaysia)
  - Higher troposphere (up to 16 km) than middle latitude region (S. Korea)
  - Expected to be more sensitive to the solar radiation
  - Investigation of the radiation profile using DTR on daytime and nighttime
- **Experimental verification of X-data linked DTR with RS41**
  - Data compatibility and reliability

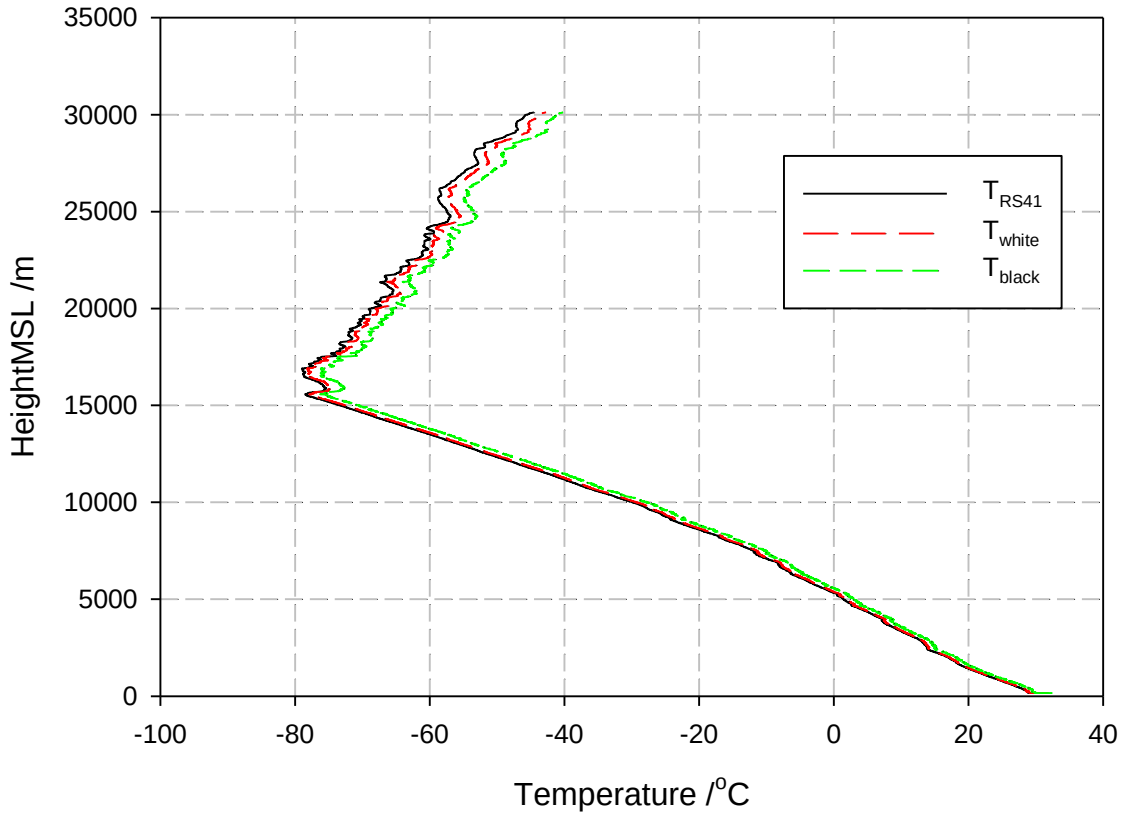


II. Sounding procedures

- July 14 ~ 18, 2025
- 1 RS41+1 DTR+other test sensors (O_3, NO_2, QCM)
- 10 times sounding on day and night
  - 3 times failed due to DTR sensor break and blackout

III. Experimental results

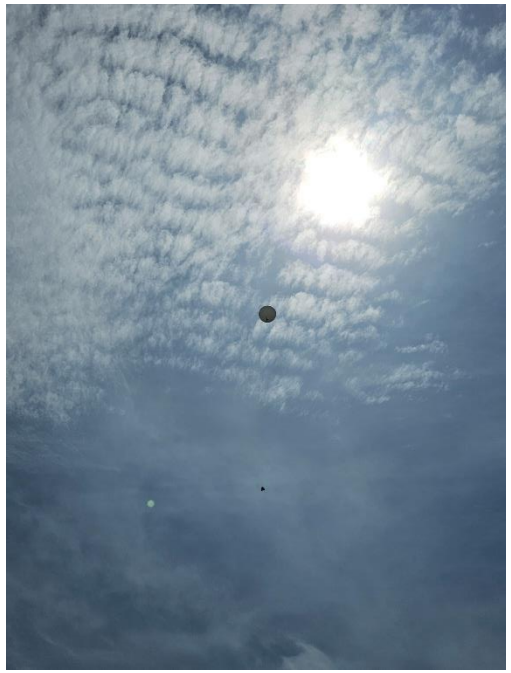
<Example of RS41/DTR temperature profile>



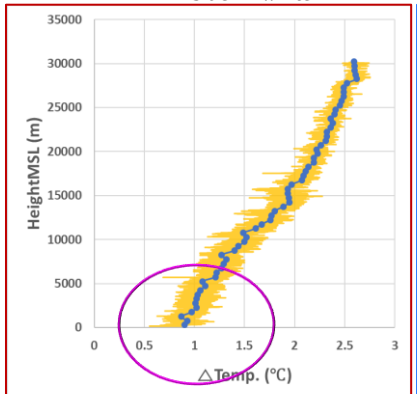
DTR/X-data/RS41 was functioning well.

Example 1: Daytime 1 (July 15, 2025)

<Launch at LOC(UTC+8) 10:32>

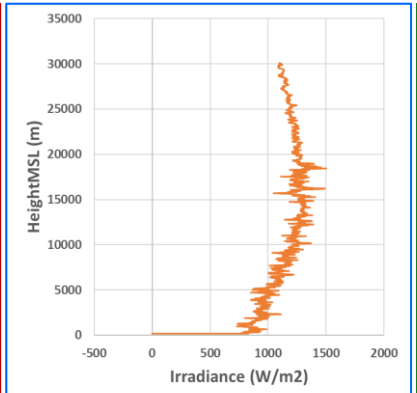


$\Delta t(t_{black}-t_{white})$



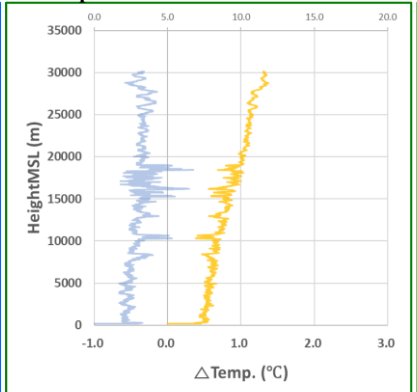
- $\Delta t(t_{black}-t_{white})$ of DTR with height up to **30 km**
- About (0.8 ~ 2.6) °C in full range
- Even at low altitude, Δt is significant by about 1 °C.
  - High solar irradiance
- Continuous change with height
  - Same behavior with the mid-latitude region

Solar irradiance



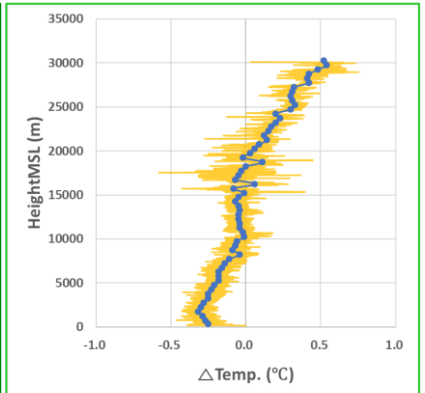
- Calculated S (irradiance) with height
- Max value at troposphere region

v_{up} and solar correction



- Solar correction value of DTR and ascending rate with height
- Correction of (0.5 ~ 1.3 °C) in full range
- Near surface, solar correction of 0.5 °C

t_{DTR}- t_{RS41}

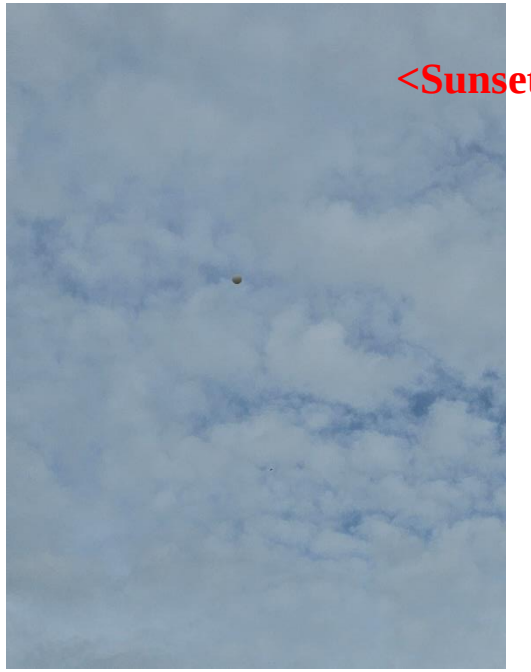


- Δt (t_{DTR}-t_{RS41}) with height
- Below troposphere, negative Δt
  - Smaller correction of RS41 than DTR

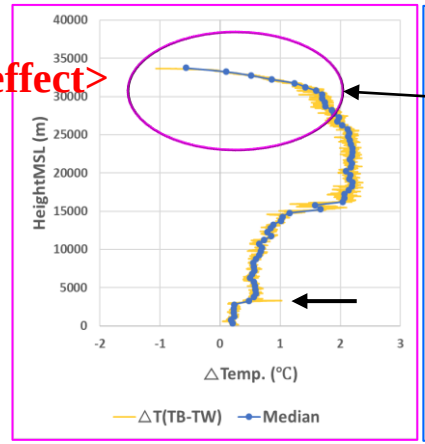
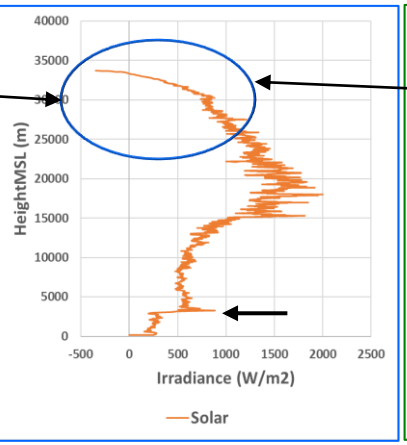
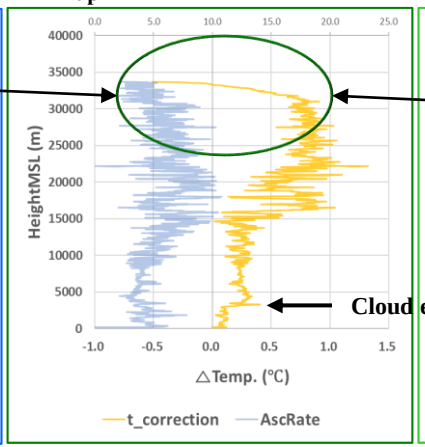
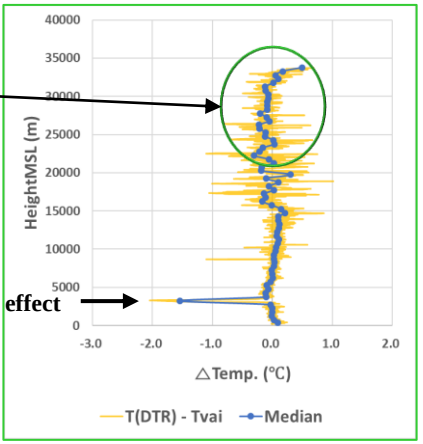
Clear solar effects on T_{air}

Example 2: Daytime 2 (July 15, 2025)

<Launch at LOC(UTC+8) 16:31>



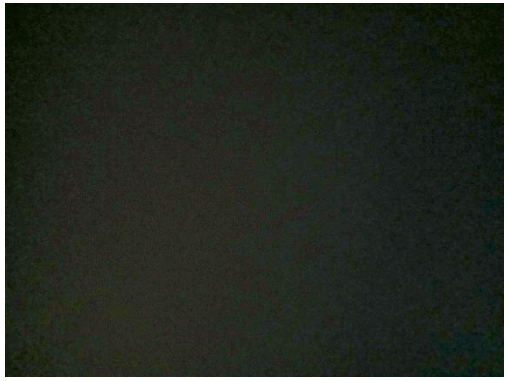
<Sunset effect>

$\Delta t(t_{black}-t_{white})$	Solar irradiance	v_{up} and solar correction	$t_{DTR}- t_{RS41}$
			
• $\Delta t(t_{black}-t_{white})$ of DTR with height up to **34 km** • About (0.1 ~ 2.2) ºC in full range • Drastic decrease at high altitude above 30 km ➢ Due to the sunset	• Calculated S (irradiance) with height • Max value at tropopause region	• Solar correction value of DTR and ascending rate with height • Correction of (0.1 ~ 0.9) ºC in full range • Near surface, solar correction of 0.1 ºC	• Δt ($t_{DTR}-t_{RS41}$) with height • Nearly zero difference ($\pm$0.1 ºC) up to 30 km • Above 30 km, positive difference ➢ Due to the sunset

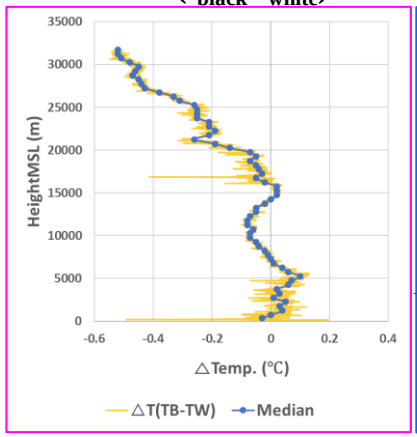
Apparent irradiance change during sunset

Example 3: Nighttime 1 (July 16, 2025)

<Launch at LOC(UTC+8) 21:56>

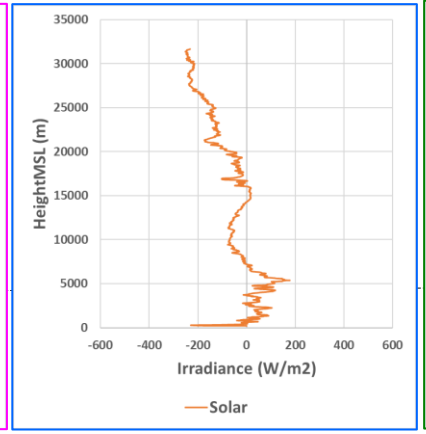


$\Delta t(t_{black}-t_{white})$



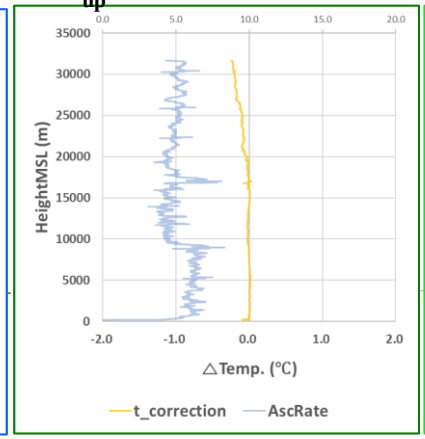
- $\Delta t(t_{black}-t_{white})$ of DTR with height up to **32 km**
- About (-0.5 ~ 0.1) ºC in full range
- Above 15 km, linear decrease to -0.5 ºC or lower

Solar irradiance



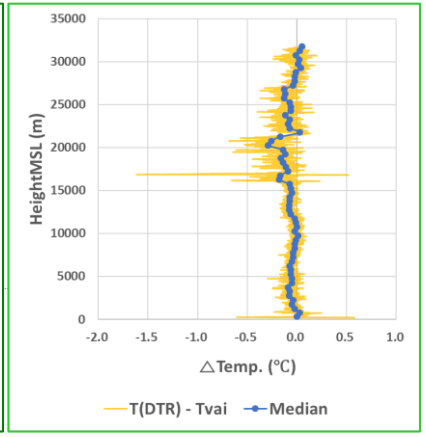
- Calculated S (irradiance) with height
- From zero to negative irradiance
- Long-wave cooling

v_{up} and solar correction



- Radiation correction value of DTR and ascending rate with height
- Correction of (-0.2~0.0ºC) in full range
- Fluctuation of ascending rate

t_{DTR}- t_{RS41}

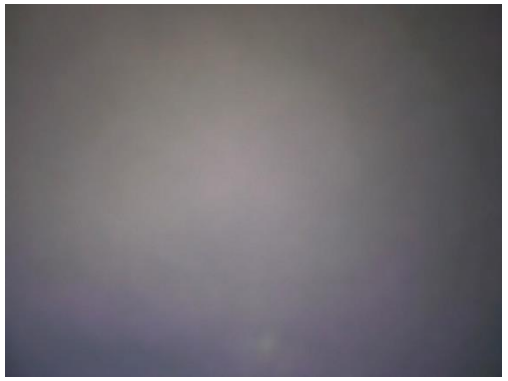


- Δt (t_{DTR}-t_{RS41}) with height
- Nearly zero difference ($\pm$0.1 ºC) up to 32 km (burst point)

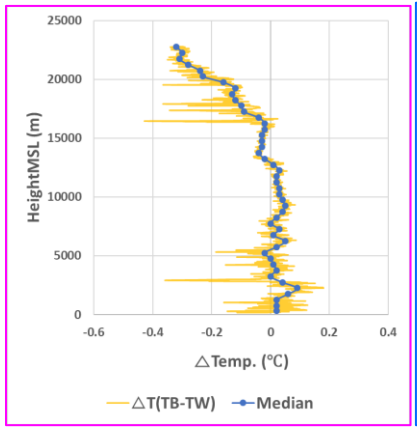
Apparent night cooling effects on T_{air}

Example 4: Nighttime 2 (July 17, 2025)

<Launch at LOC(UTC+8) 21:50>

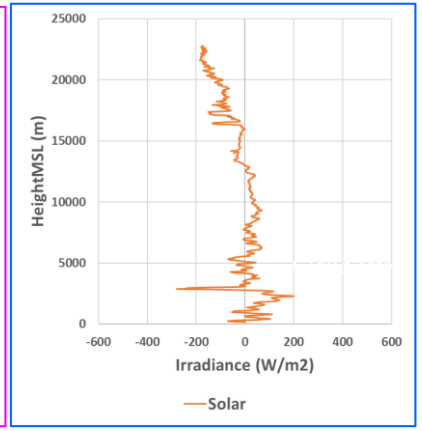


$\Delta t(t_{black}-t_{white})$



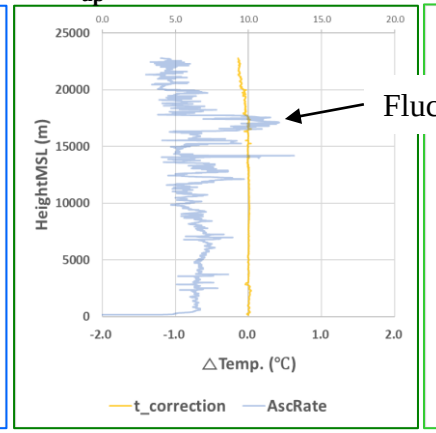
- $\Delta t(t_{black}-t_{white})$ of DTR with height up to **23 km**
- About (-0.3 ~ 0.05) °C in full range
- Below tropopause, nearly zero difference
- Above 15 km, go down to -0.3 °C or lower

Solar irradiance



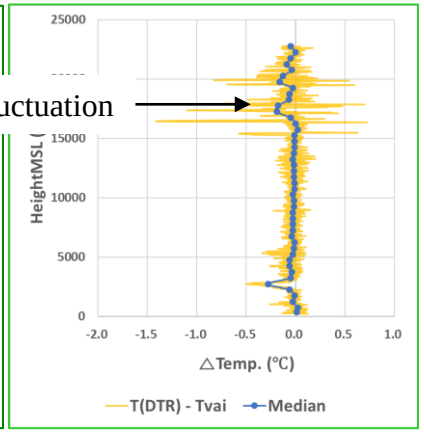
- Calculated S (irradiance) with height
- From zero to negative irradiance
- Long-wave cooling

v_{up} and solar correction



- Radiation correction value of DTR and ascending rate with height
- Correction of (-0.2~0.0°C) in full range
- Fluctuation of ascending rate

t_{DTR}- t_{RS41}



- Δt (t_{DTR}-t_{RS41}) with height
- Nearly zero difference (±0.1 °C) up to 23 km (burst point)

IV. Summary

- DTR with only temperature measurement module is developed and tested with RS41 by using X-data connection.
- Vertical radiation profiles during the day and night were revealed 10 times at Kota Kinabalu in the tropical area.
- It was confirmed that the X-data connection to RS41 was successfully operated and thus could get proper radio-sounding data.
- DTR showed apparent solar/sunset effects during the day, as well as radiation cooling effects at night.
- DTR can be applicable to any radiosonde having X-data connection, giving wide application to the vertical upper air researches.

Acknowledgement

This work was made possible through the comprehensive support of Jabatan Meteorologi Malaysia (Met Malaysia).

We are particularly grateful for the outstanding testing environment provided under the leadership of Dr. Mohd Hisham B Mohd Anip, Director General.


Thank you for your attention