Quantitative analysis of the anomaly in radiosonde air temperature measurement above the cloud layer

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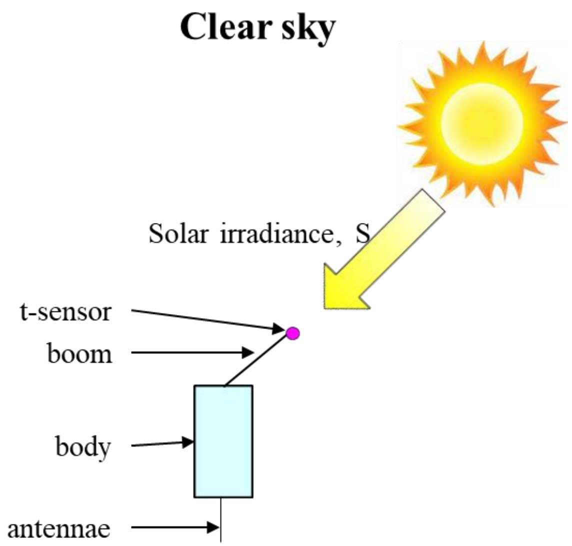
Comparison in case of clear and cloudy sky

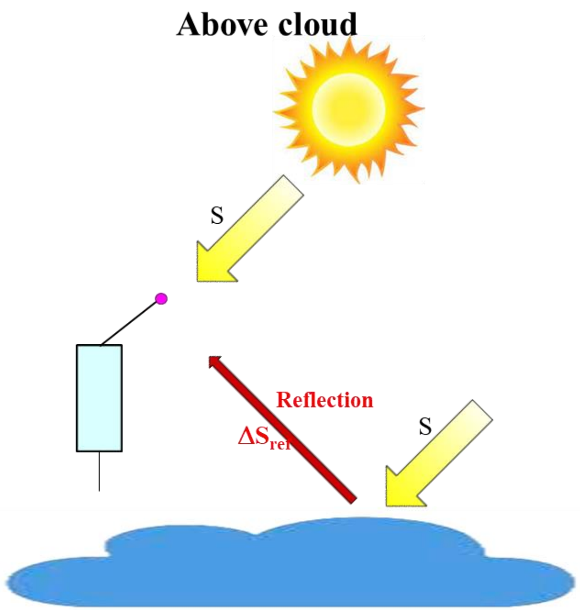


Clear sky		Above cloud
P_{clear}	$=$	P_{cloud}
T_{clear}	$=$	T_{cloud}
v_{clear}	$=$	v_{cloud}

$$\boldsymbol{S_{\text{clear}} < S_{\text{clear}} + \Delta S_{\text{ref}}}$$

$$\Downarrow$$

$$\boldsymbol{T_{\text{reading,clear}} < T_{\text{reading,cloud}}}$$



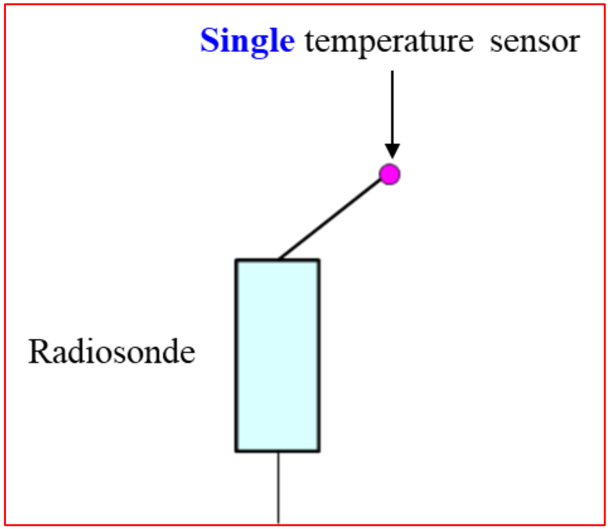
$$\boxed{t_{air} = t_{measured} + \Delta t_{rad}}$$

$$\Delta t_{rad} = f(S, P, T, v)$$

S: solar irradiance (W/m^2)
P: air pressure (hPa)
T: air temperature (^{o}C)
v: wind ventilation speed (m/s)

$$\boxed{\therefore \ \Delta t_{cor,clear} < \Delta t_{cor,cloud}}$$

Temperature measurement of typical radiosonde



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

- t_{raw} : raw A/D signal
- Δt_{cal} : calibration correction
- $\boldsymbol{\Delta t_{rad}}$ **: radiation correction**

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

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

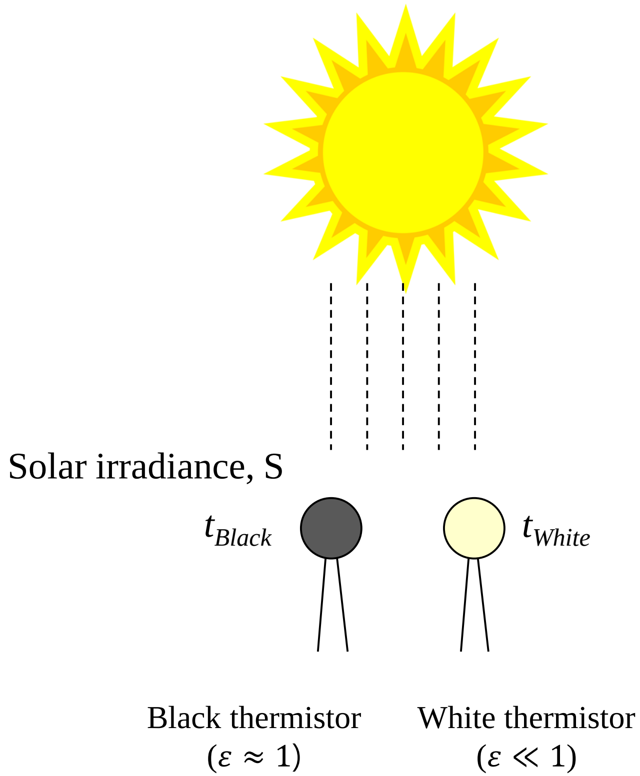
$\therefore\ \boldsymbol{\Delta t_{rad} = f\big(time, location\ (GPS\ position)\big)}$

- ✓ Single T-sensor radiosondes(STR) do not know the existence of clouds.
- ✓ It cannot reflect the local variation of environmental conditions.
- ✓ Therefore, the correction value is the same regardless of clouds.

KRISS's solar correction technique

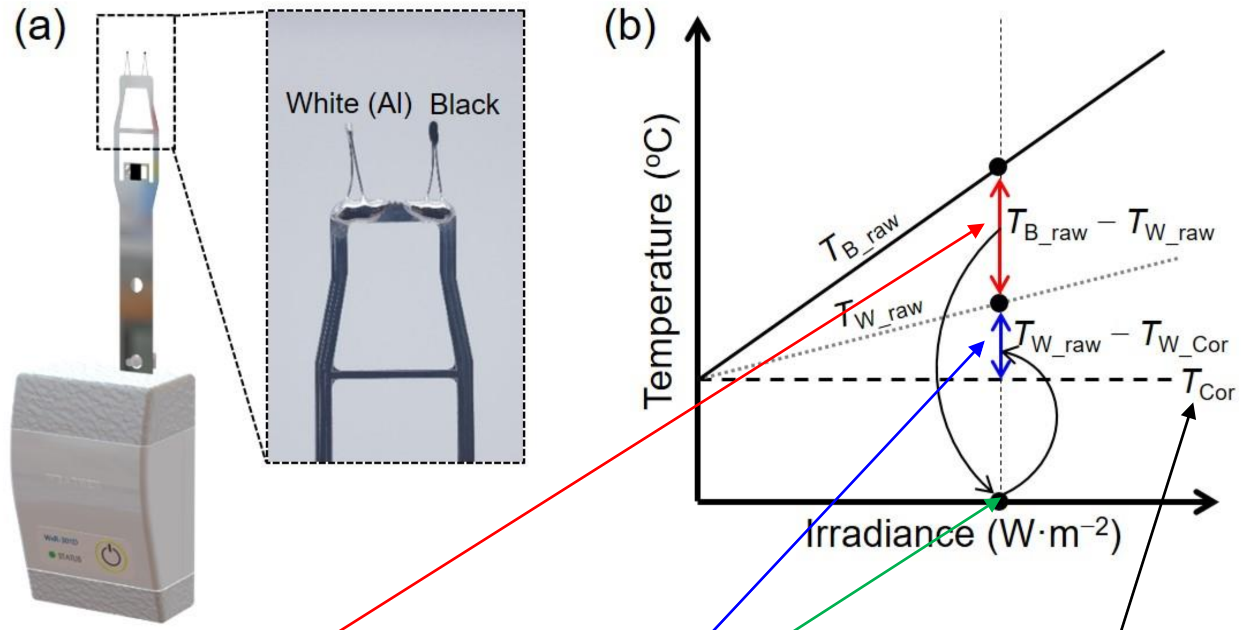
Dual Thermistor Technique

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)



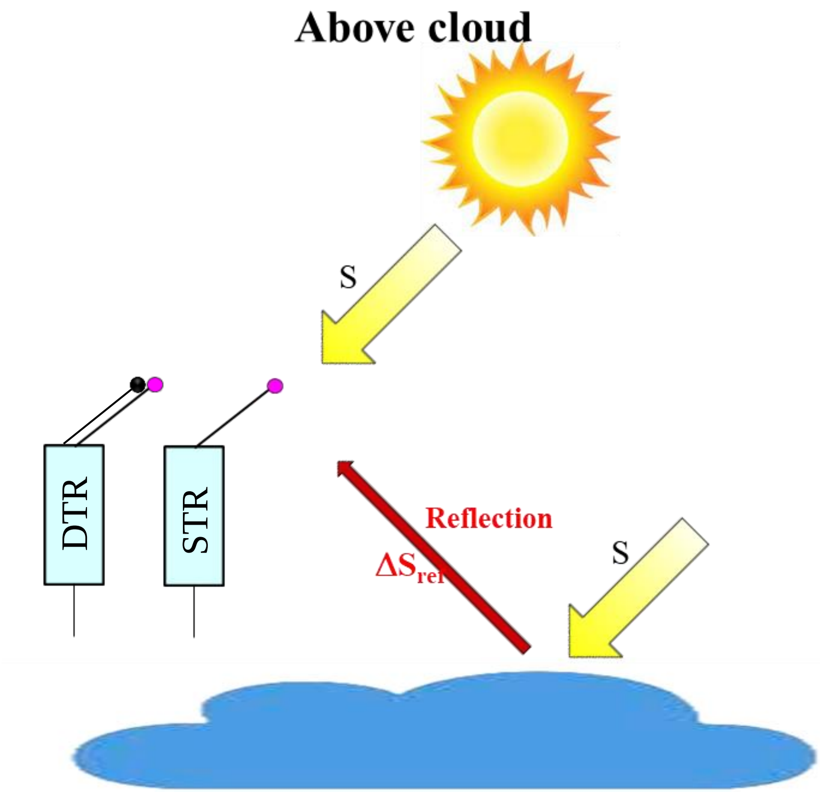
$$\Delta t_s = S \times f(T,P,v) \rightarrow S$$

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

Experiments at ground lab

Experimental *in-situ* radiation correction technique

DTR vs STR above the cloud



Extra radiation from the cloud

$$t_{STR,mea} > t_{DTR,mea}$$
$$\therefore \Delta t_{DTR-STR} < 0$$

- STR overheated by the extra radiation.
- DTR corrected by the relative compensation.

Purpose of this work

- **Comparison sounding with DTR and STR**(RS41 as the representative radiosonde) on various weather conditions
  - On Rainy, Cloudy, Sunny and Night
  - In the troposphere below 10 km
  - To investigate how the temperature profiles are different from each other.

- Quantitative and experimental analysis on the degree of temperature difference between DTR and STR above the clouds

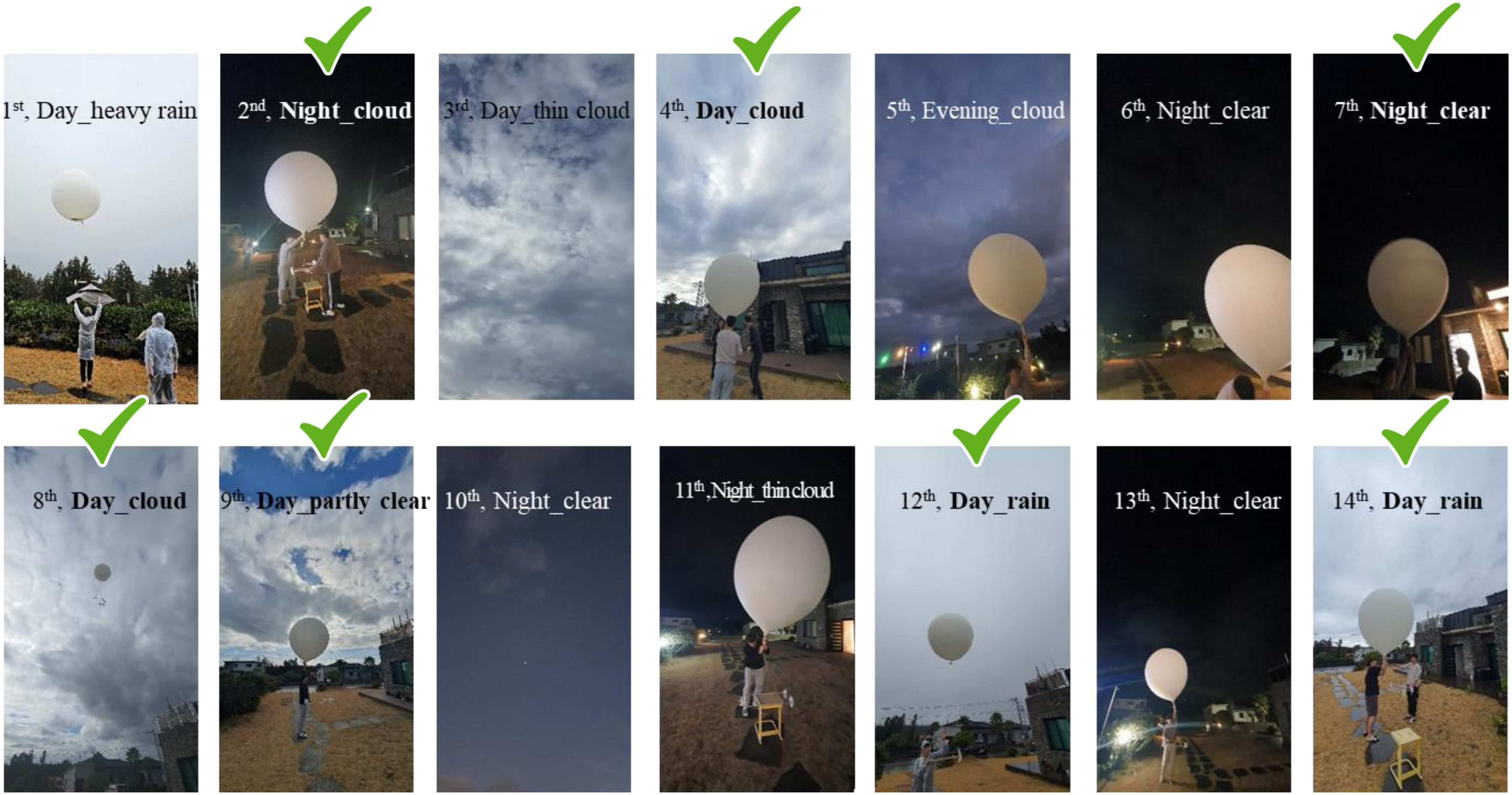
Experimental procedures

- December 11 ~ 15, 2023, in Jeju Islands
- **2 DTR + 1 RS41** in H tray
- **14 times** sounding on day and night
- **DTR_raw data vs RS41_edited data**

Summary of sounding

Sounding No.	Date	Launch Time(LOC)	Weather
1	Dec. 11, 2023	14:20	Day, heavy rain
2	Dec. 11, 2023	19:35	Night, cloud
3	Dec. 12, 2023	10:30	Day, thin cloud
4	Dec. 12, 2023	14:45	Day, thin cloud
5	Dec. 12, 2023	17:52	Evening, cloud
6	Dec. 12, 2023	20:50	Night, clear with small cloud islands
7	Dec. 12, 2023	23:30	Night, clear
8	Dec. 13, 2023	11:27	Day, cloud with small blue hole
9	Dec. 13, 2023	14:07	Day, cloud with partly blue sky
10	Dec. 13, 2023	18:12	Night, clear
11	Dec. 13, 2023	20:53	Night, thin cloud
12	Dec. 14, 2023	12:26	Day, light rain
13	Dec. 14, 2023	20:49	Night, clear with small cloud islands
14	Dec. 15, 2023	12:05	Day, rain

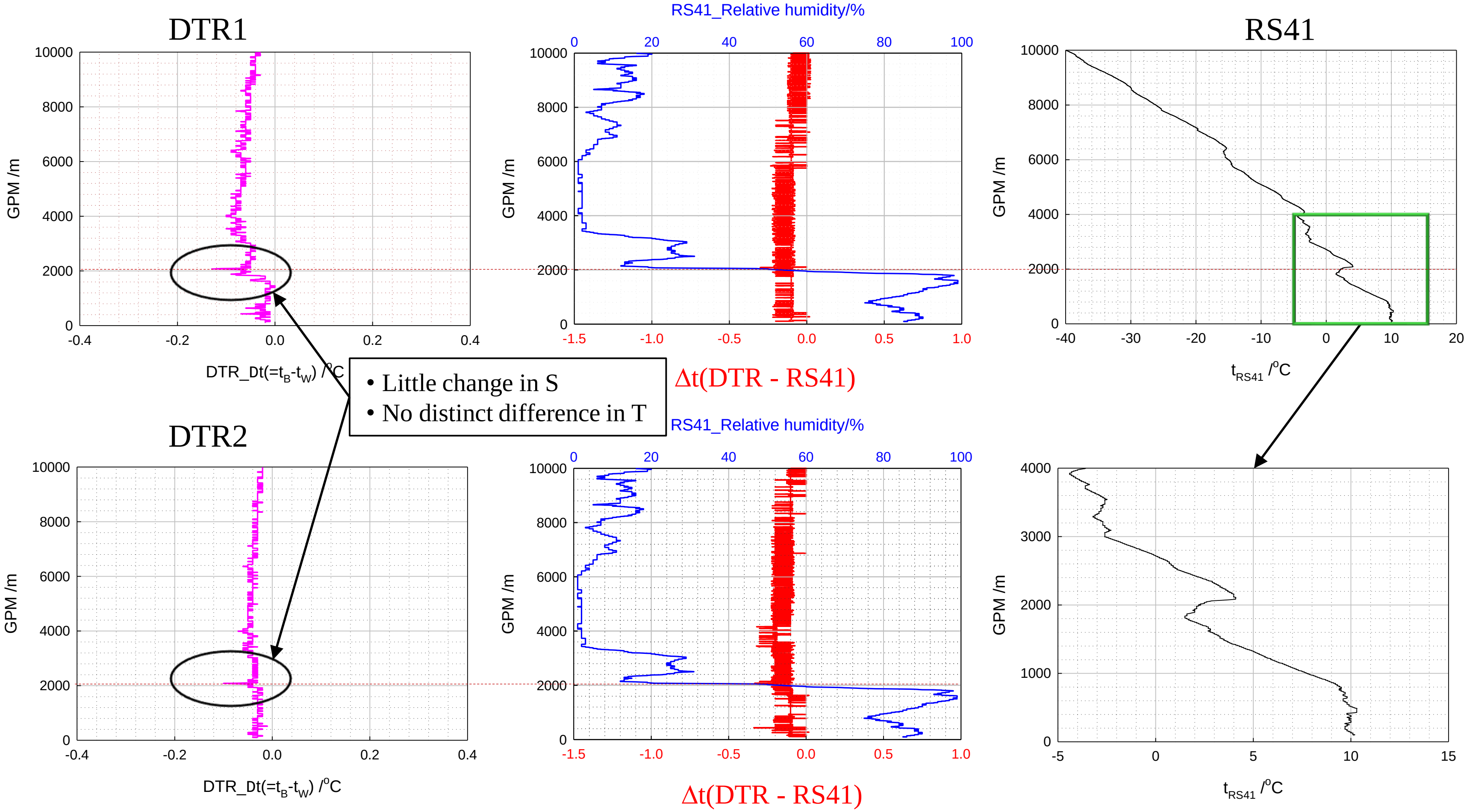
Sky view photos



Case studies
- Two Night: Clear and Cloud
- Five Day: 2 Rain/2 Cloud/1 partly Clear

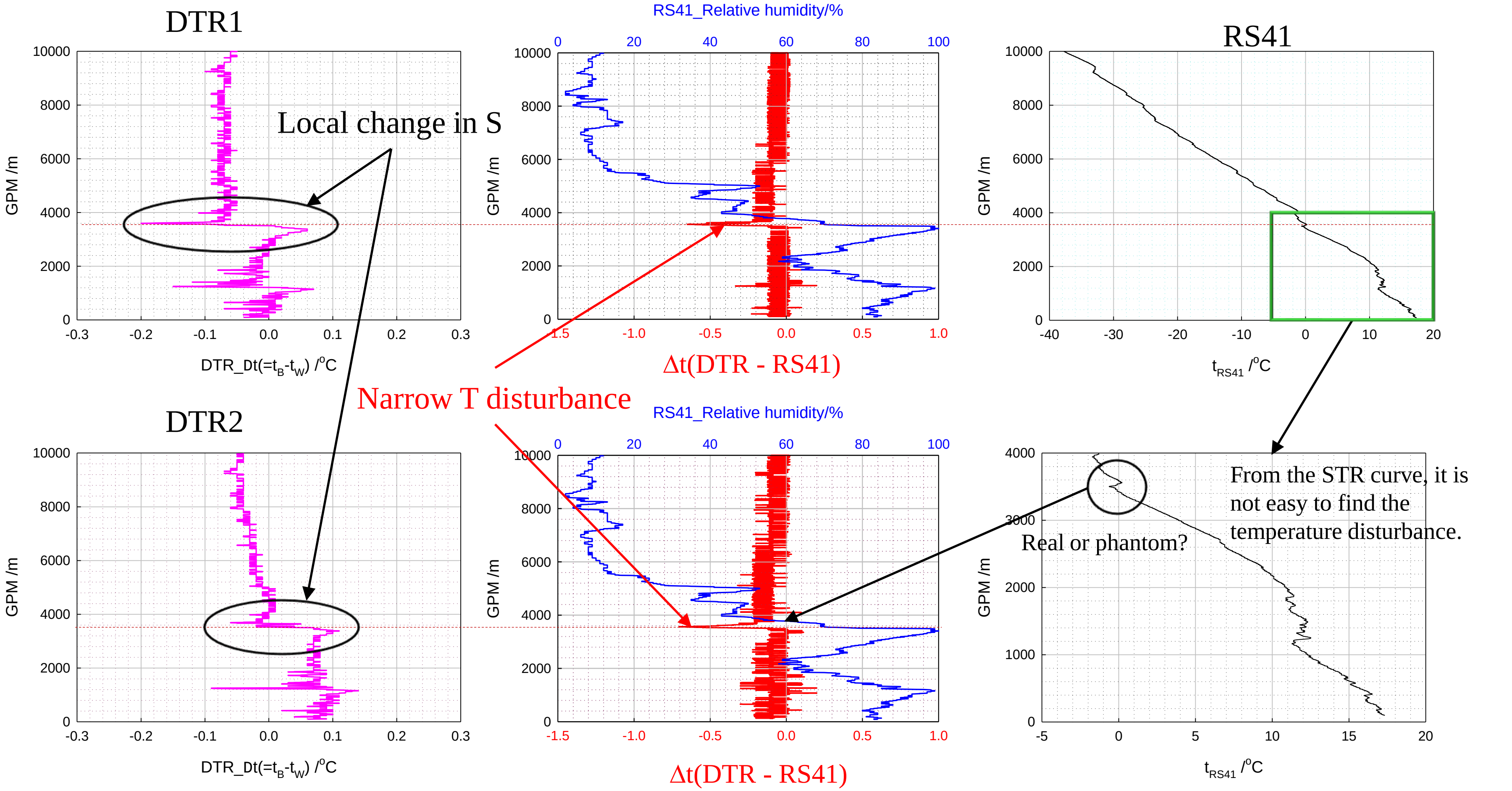
Case study 1 – Night, clear

- 7th sounding on pm 11:30, Dec. 12, 2023



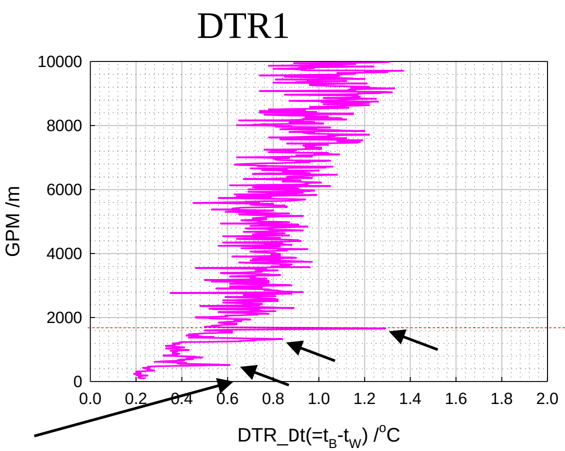
Case study 2 – Night, cloud

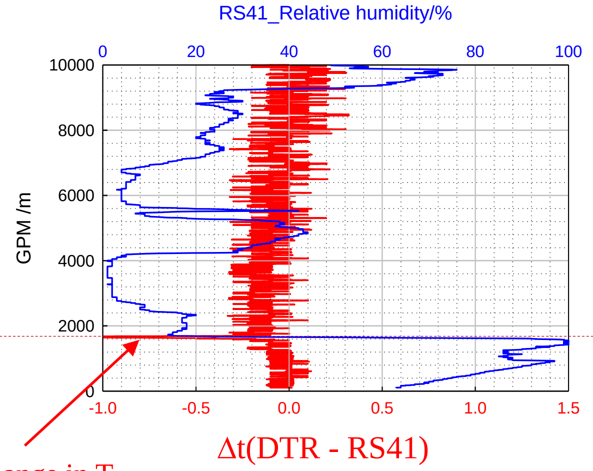
- 2nd sounding on pm 7:35, Dec. 11, 2023

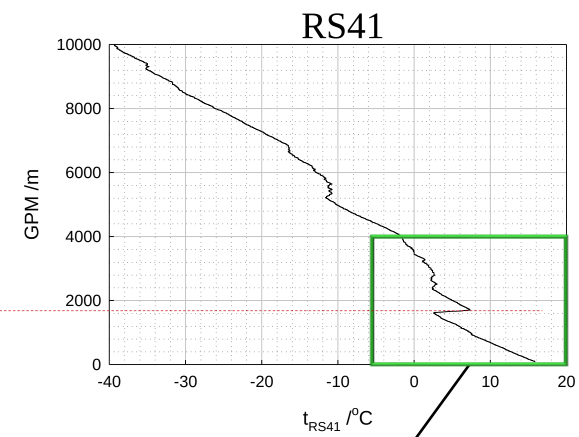


Case study 3 – Day, partly clear

- 9th sounding on pm 2:07, Dec. 12 2023

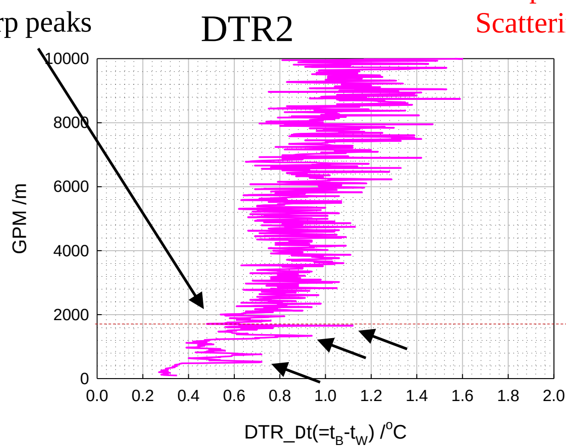


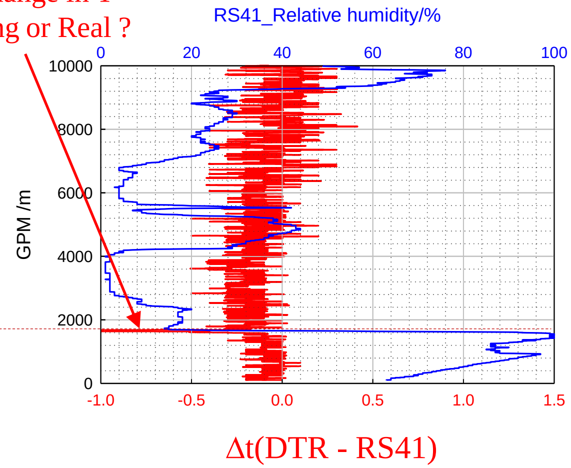


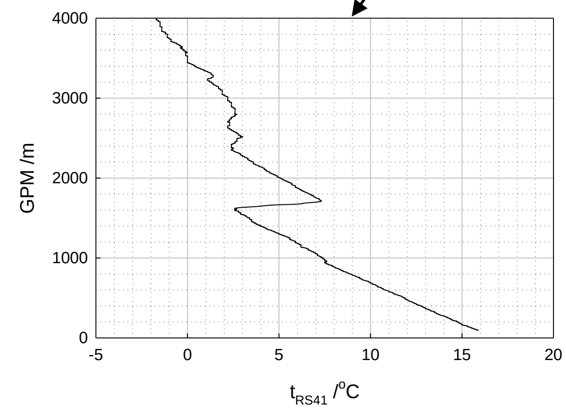


Reproducible sharp peaks

Sharp change in T
Scattering or Real ?

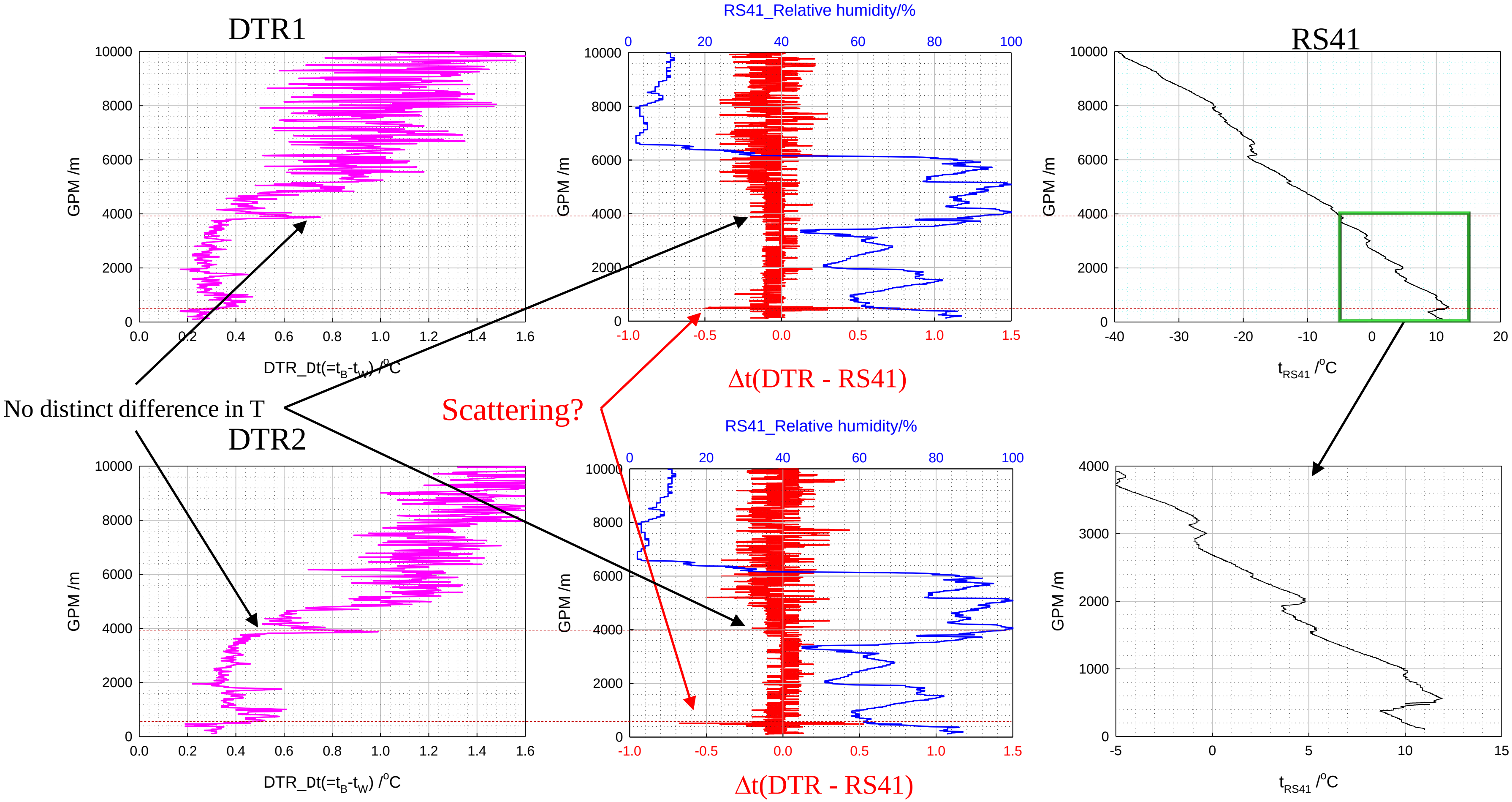






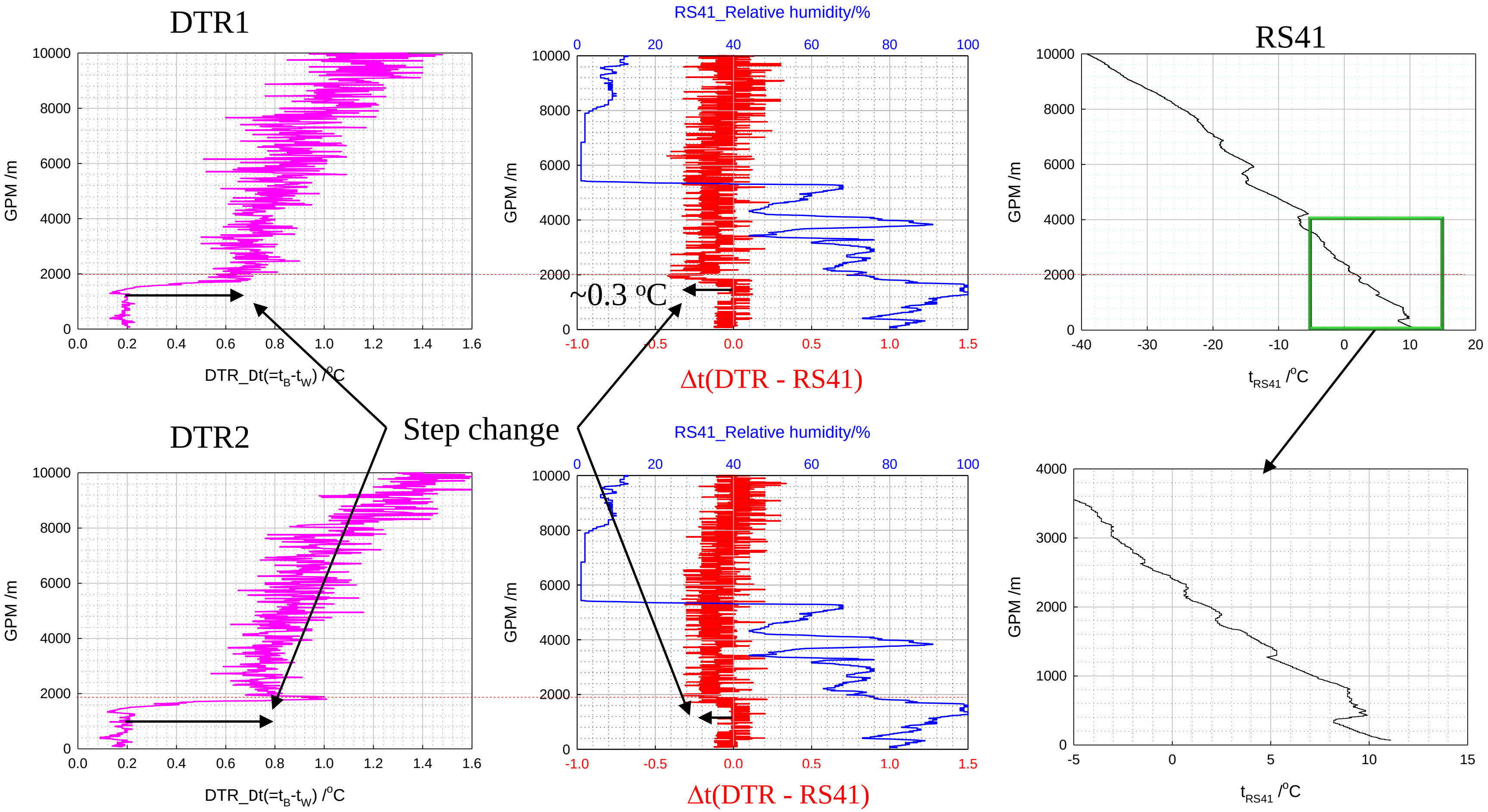
Case study 4 – Day, thin cloud 1

- 3rd sounding on am: 10:30, Dec. 12 2023



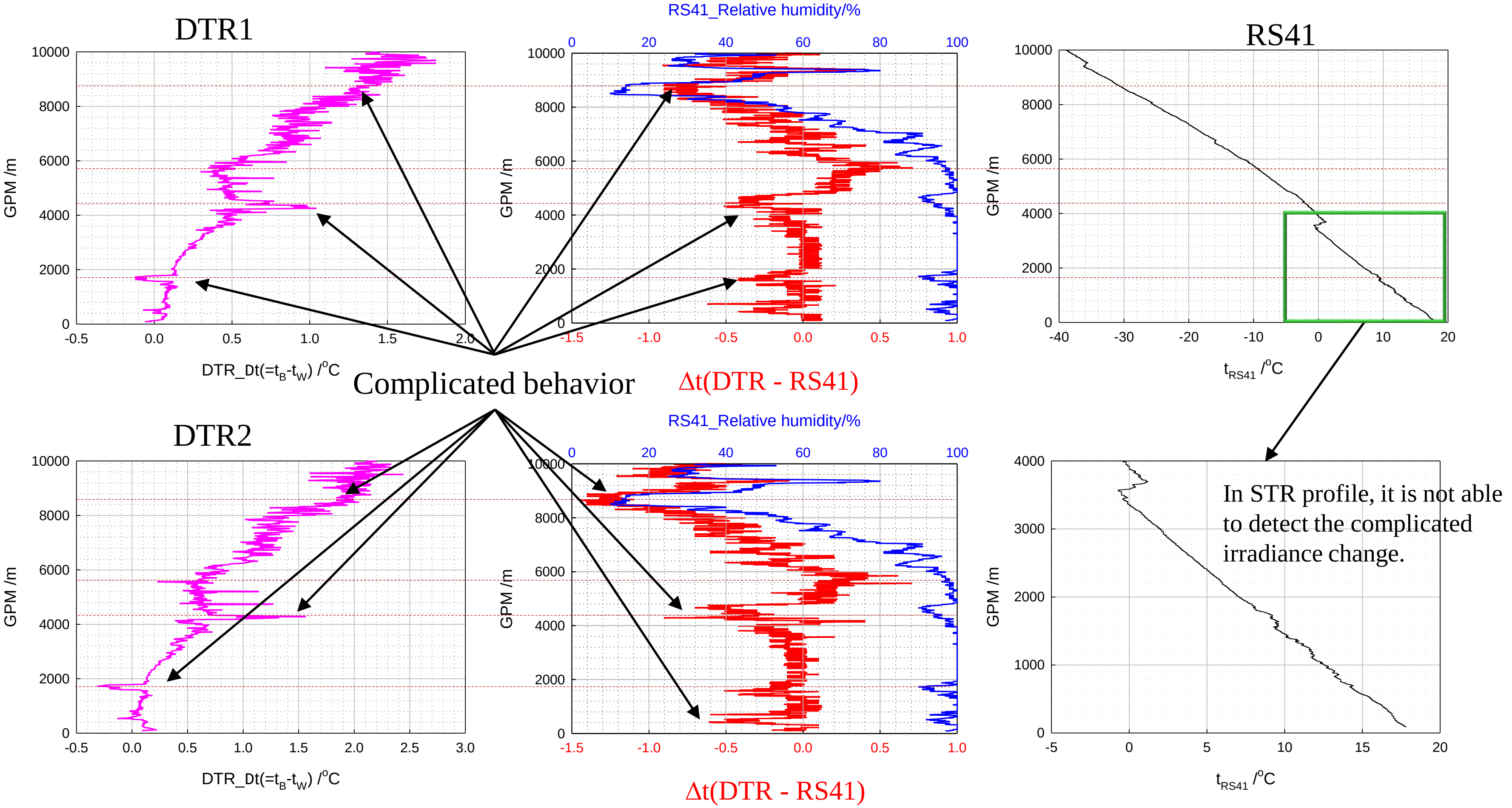
Case study 5 – Day, thin cloud 2

- 4th sounding on pm: 2:45, Dec. 12 2023



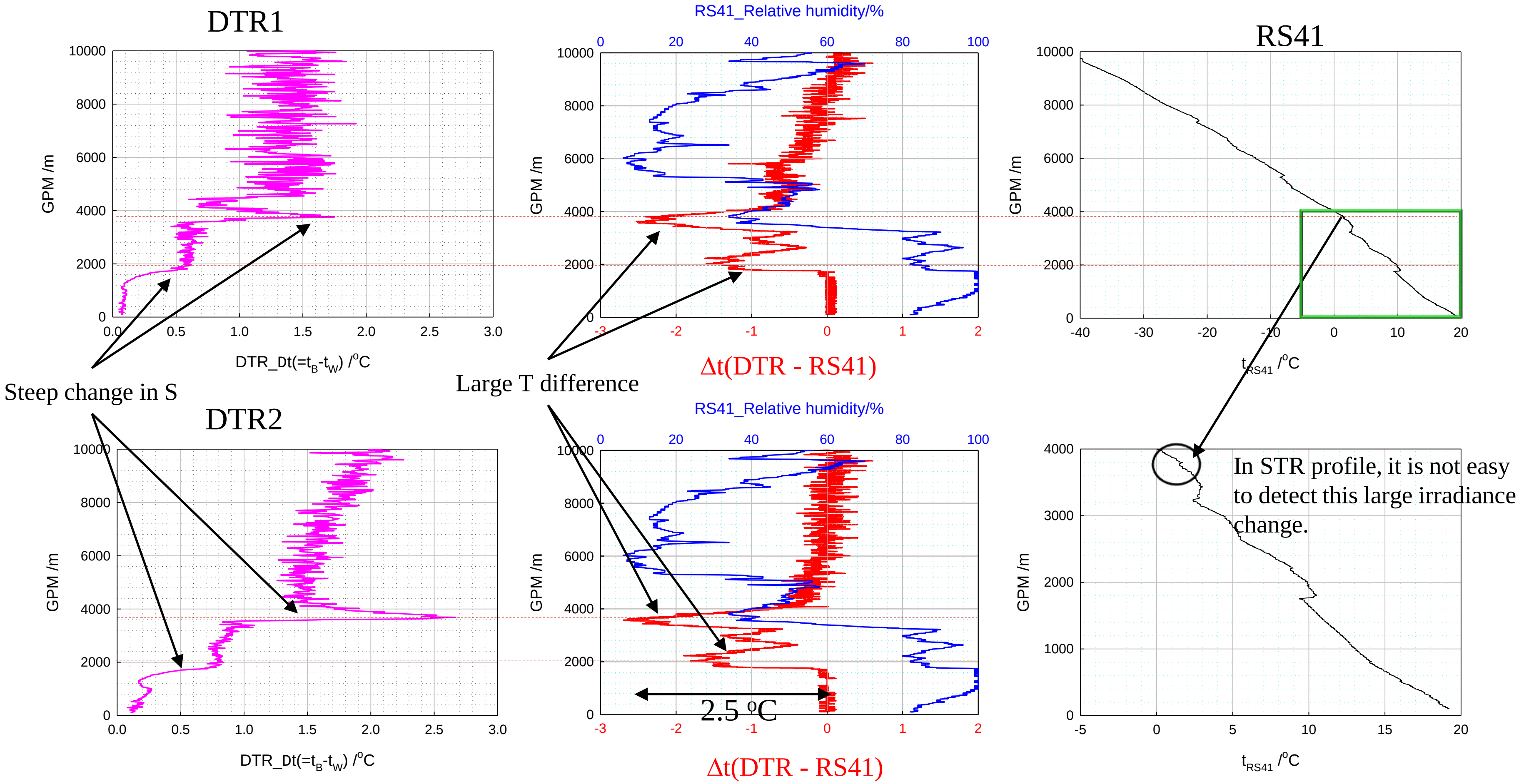
Case study 6- Day, rain 1

☐ 12th sounding on pm 12:26, Dec. 14 2023



Case study 7- Day, rain 2

- 14th sounding on pm 12:05, Dec. 15 2023



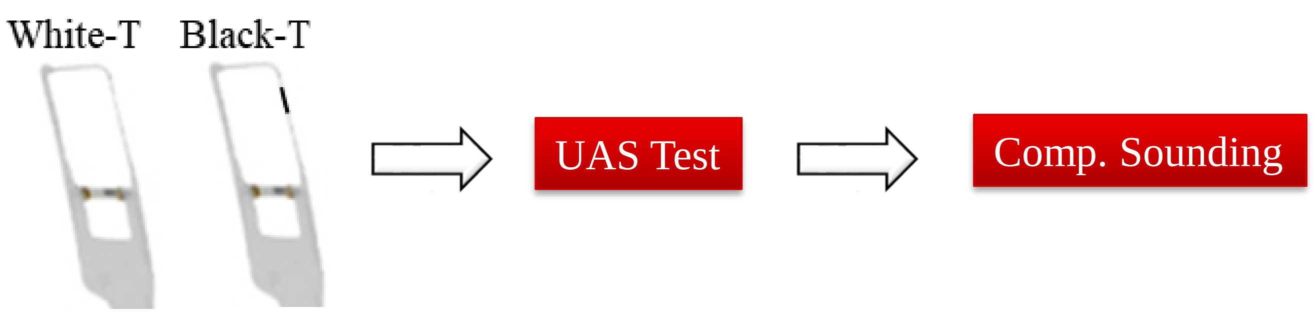
Summary

- **At night** without shortwave radiation from the sun, DTR and STR showed similar behavior because of lack of the distinct irradiance change up to 10 km.

- Above the cloud layer (estimated from the humidity profile), irradiance change could be detected using DTR technique **for daytime**.

- Between and/or above the cloud layers, DTR can observe the complicated atmospheric behavior.

- **White-RS41/Black-RS41** pair may prove the effectiveness of DTR technique and it will be tested future.




Thank you for your attention
Welcome the co-work!