1st Workshop of the GCOS Surface Reference Network

# *Research on Uncertainty of Air Temperature Measurement of GSRN*


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# Contents

# 1. Background


GSRN network:

Provide sustained reference quality observations, with full traceability and defined and quantified uncertainties.

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GSRN pilot phase:

Understanding uncertainties, developing data products with considering all uncertainty components (using measurements of AQI).

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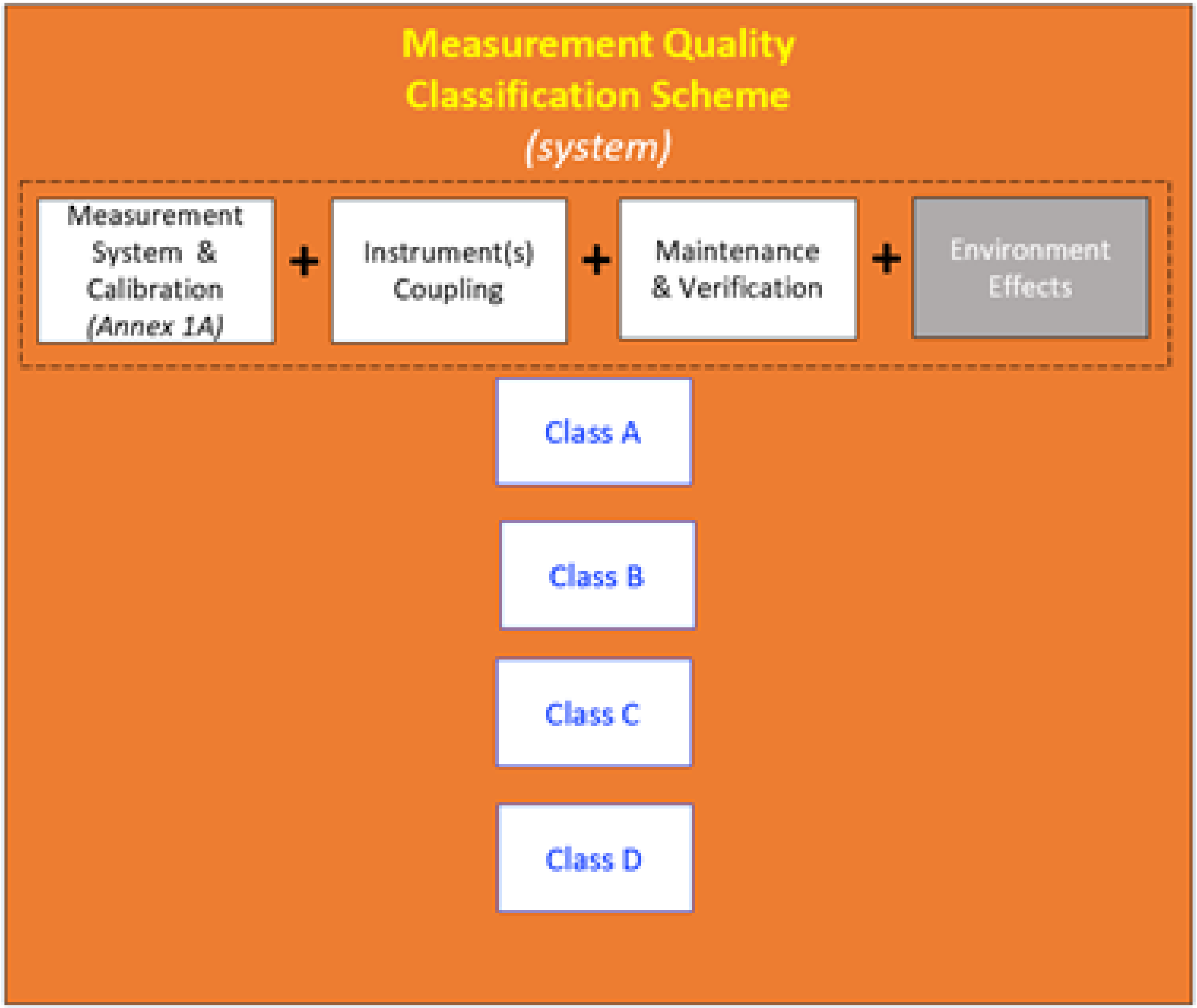
# 1. Background



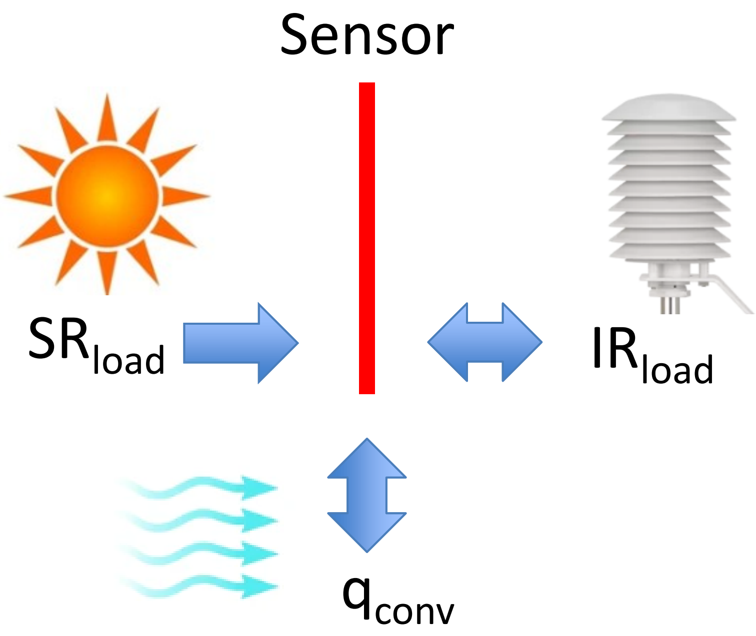

Environmental Effects - AQI

- Precipitation and precipitation temperature
- Relative humidity
- Global solar radiation (upward looking pyranometer)
- Reflected solar radiation (downward looking pyranometer)
- Wind speed and direction

# 1. Background

## ✓ Factors Contributing the Uncertainty

- **□** Absorbed Solar Radiation Loading ($SR_{load}$)
  - Solar radiation penetration into the radiation shield
- **□** Net infrared Radiation Loading($IR_{load}$)
  - Net infrared radiation exchange between the shield surface and sensor surface.
- **□** Convection Heat Exchanging ($q_{conv}$).
  - The heat transfer rate across the sensor surface due to convection
  - Related with wind speed, surface area and temperature difference




$$\alpha_s SR_{\mathrm{load}} + IR_{\mathrm{load}} = q_{\mathrm{conv}}$$

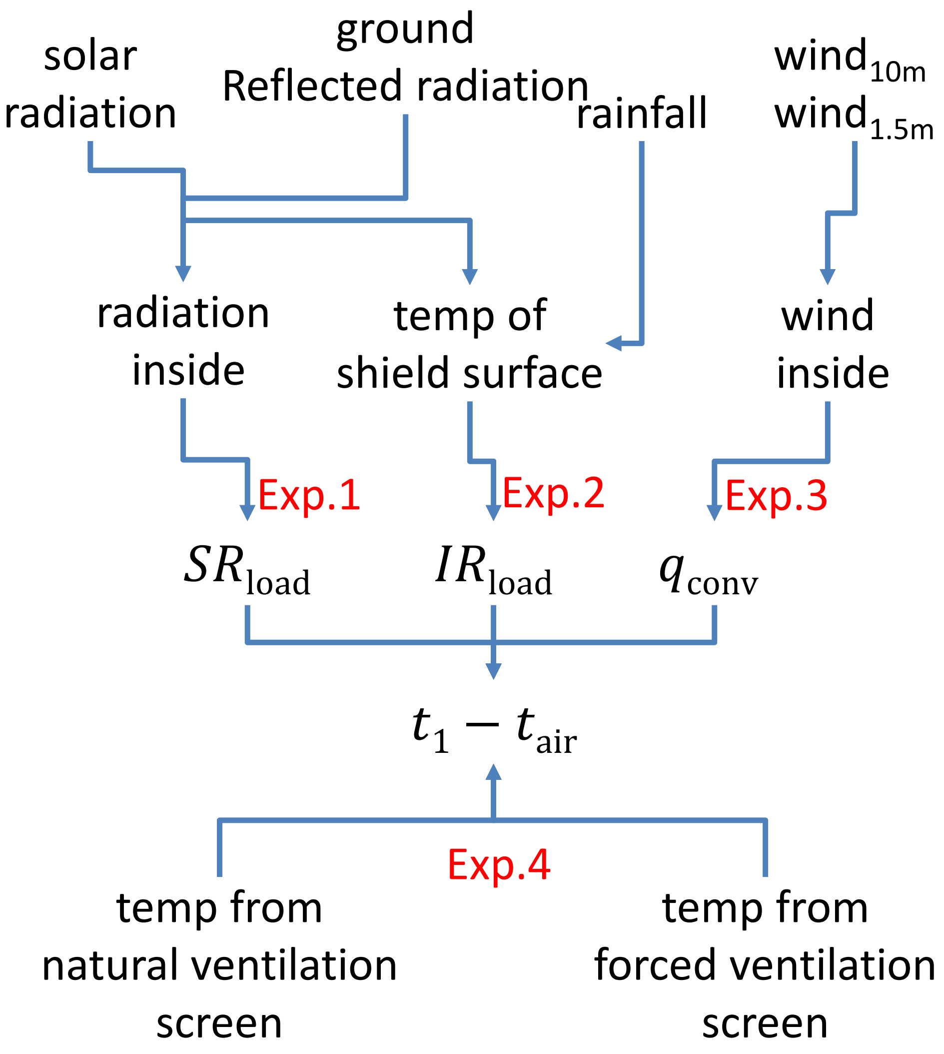

Lin X, Hubbard K G, Walter–Shea E A. RADIATION LOADING MODEL FOR EVALUATING AIR TEMPERATURE ERRORS WITH A NON–ASPIRATED RADIATION SHIELD[J]. Transactions of the ASAE, 2001, 44(5): 1299.

# 2. Experiment scheme

$$\alpha_s SR_{\text{load}} + IR_{\text{load}} = q_{\text{conv}}$$

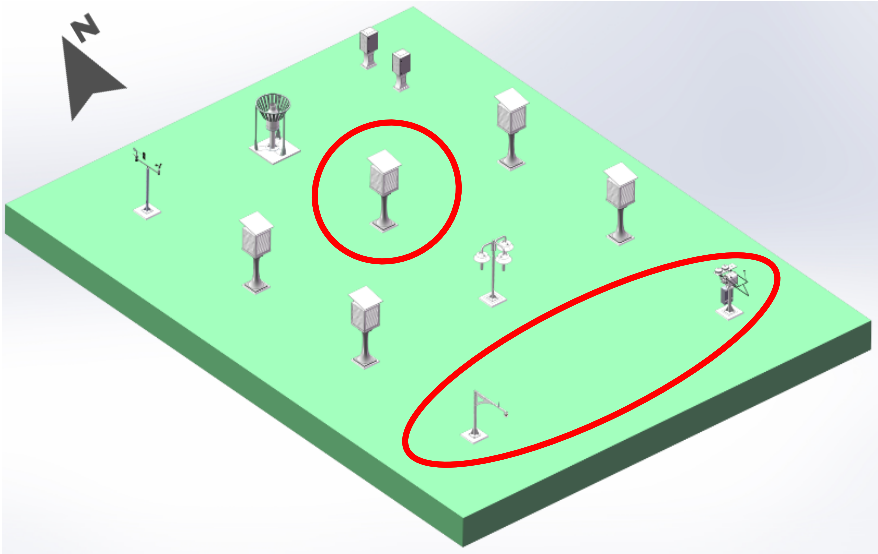
$$\alpha_s\, SR_{\text{load}} + \frac{J_1 - Eb_1}{A_1 R_1} = HA_1(t_1 - t_{\text{air}})$$

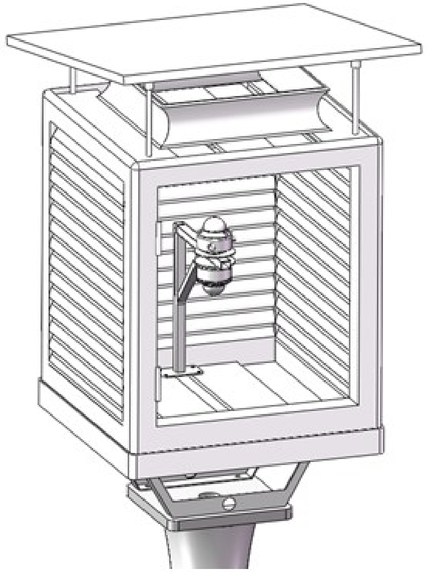
$$t_1 - t_{\text{air}} = \frac{\alpha_s\, SR_{\text{load}} + \frac{J_1 - Eb_1}{A_1 R_1}}{HA_1}$$



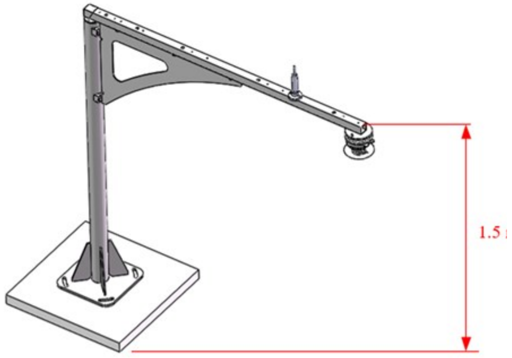
# 2. Experiment scheme

## ✓ Solar Radiation Loading –exp.1

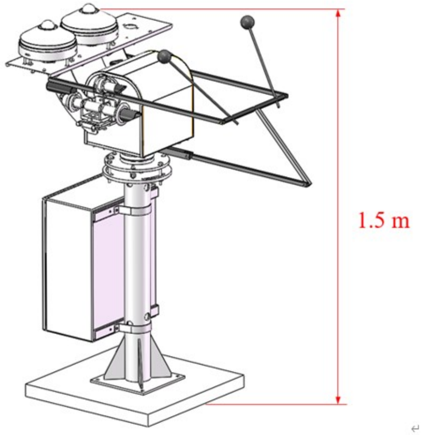


two global radiometer inside(one up and one down)




Reflected radiometer



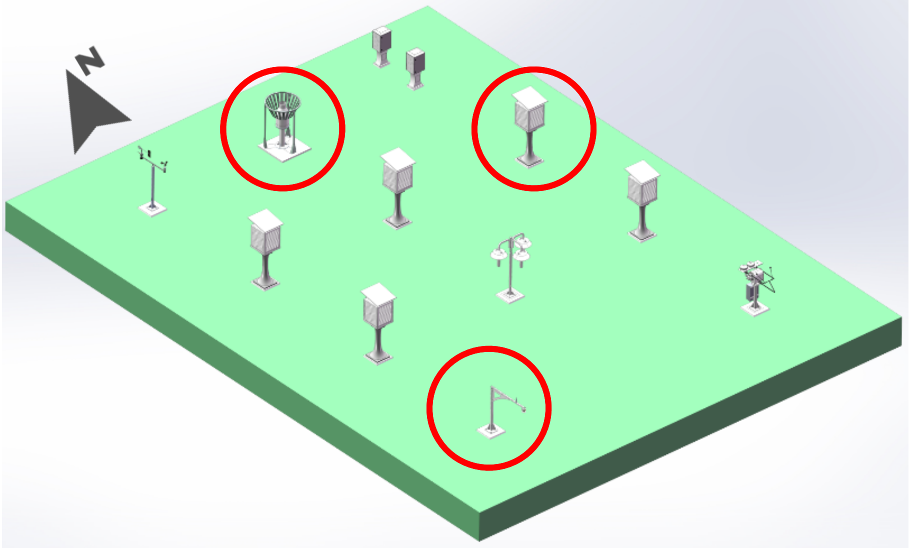

global、direct、scattered radiation

Radiation system

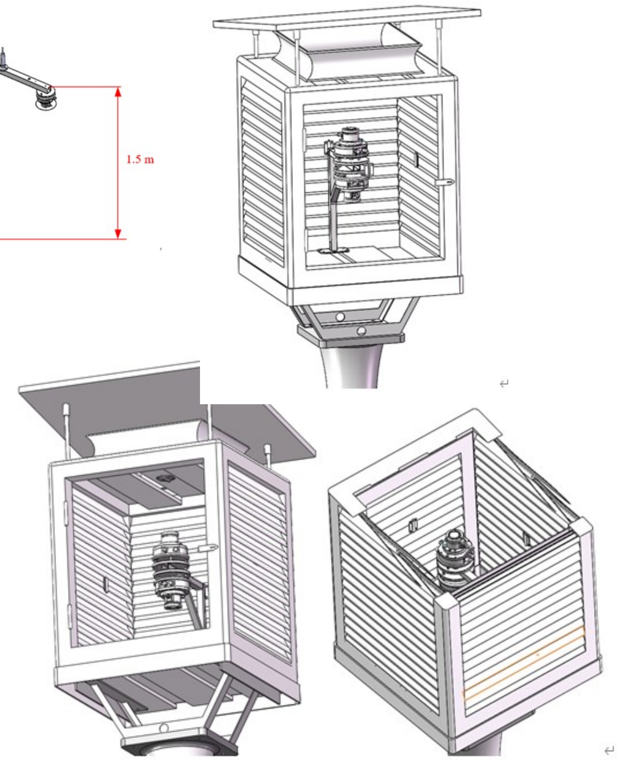
- To investigate the radiation into the shield.
- By comparing with the external radiation, the relationship between the internal and external radiation ratio and the sun altitude angle, the underlying surface, the sensor height and other factors.

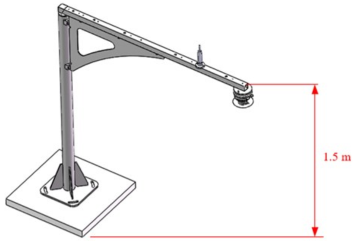
# 2. Experiment scheme

✓ **Infrared Radiation Loading –exp.2**

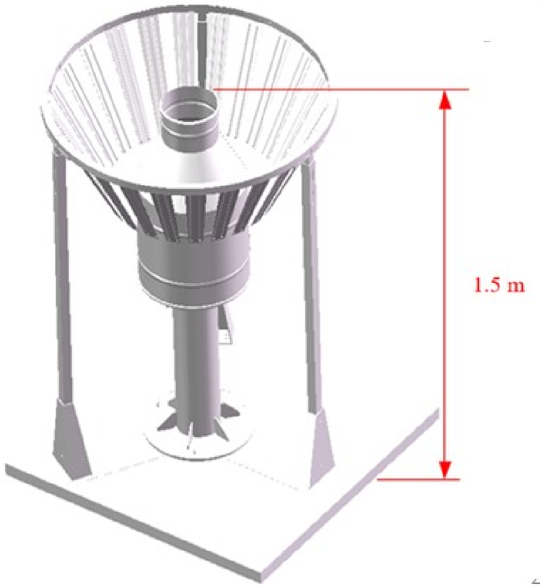


Rain temperature






rain gauge

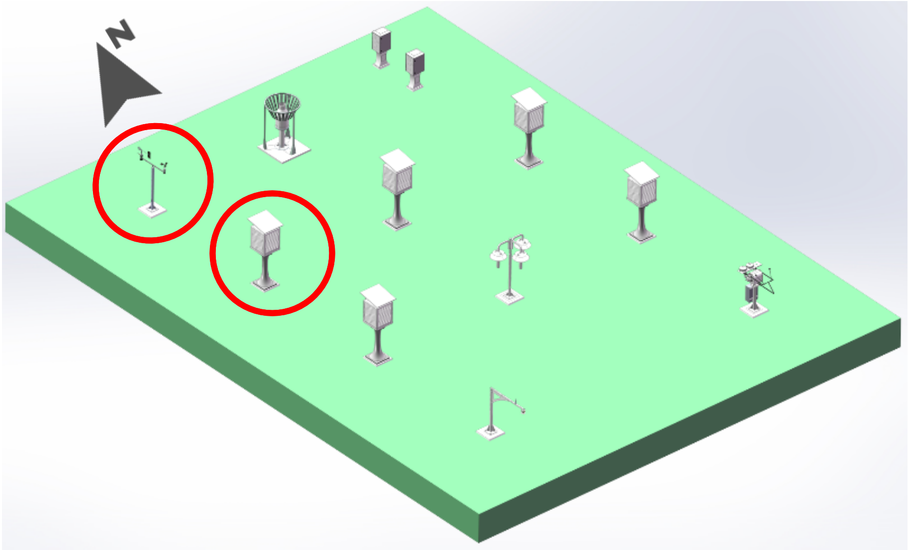


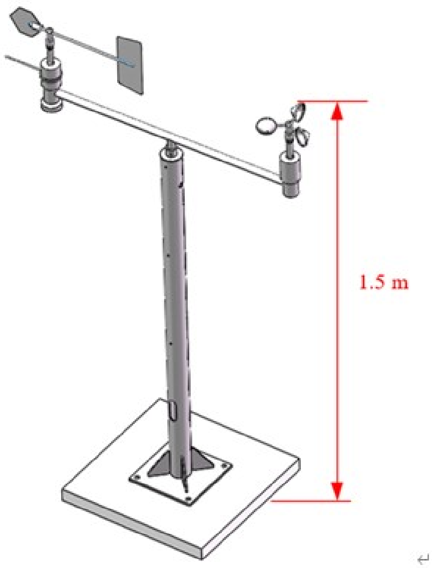

six surface temperature sensor and two Long-wave radiometers

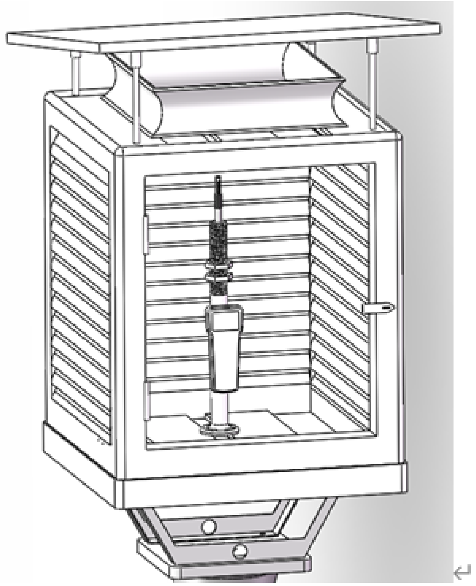
- To investigate the $IR_{load}$ of shield's surfaces influencing on the air temperature sensor.

# 2. Experiment scheme

✓ **Convection Heat Exchanging –exp.3**



1.5m wind

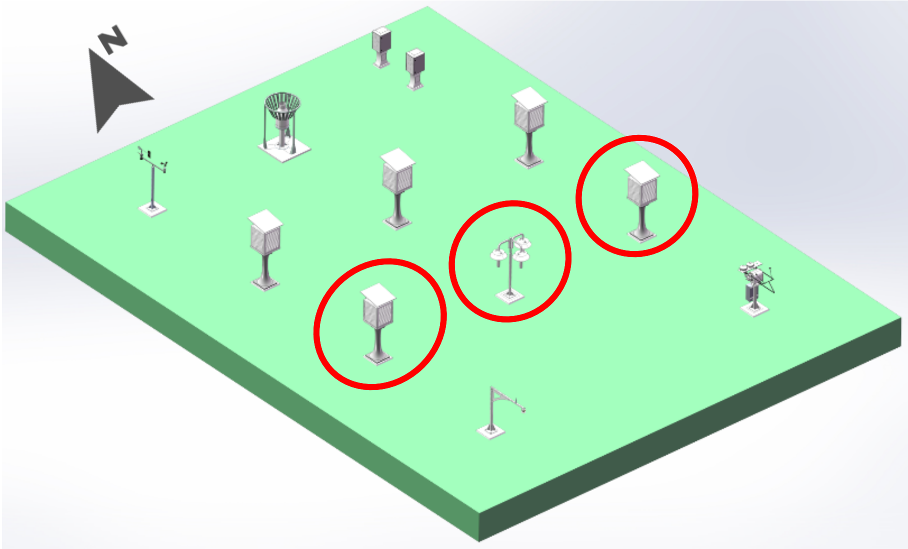
A hot-wire anemometer for measuring the inside wind speed

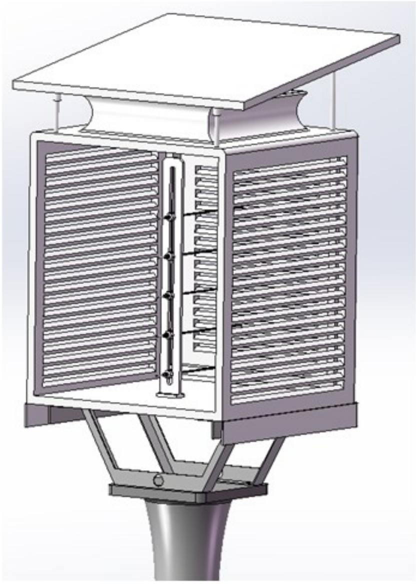
- Obtain the wind speed inside the shield
- Obtain relation between the internal and external wind speed.

10m wind in the operational site

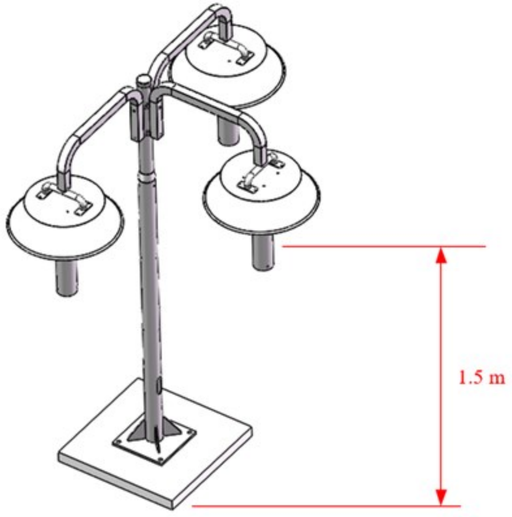
# 2. Experiment scheme

✓ **The difference measurement – exp.4**

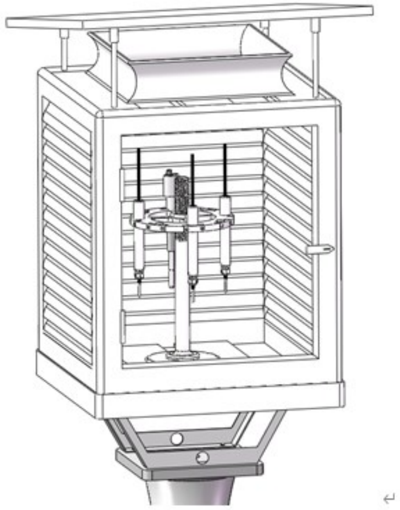




Five sensors for gradient temperature



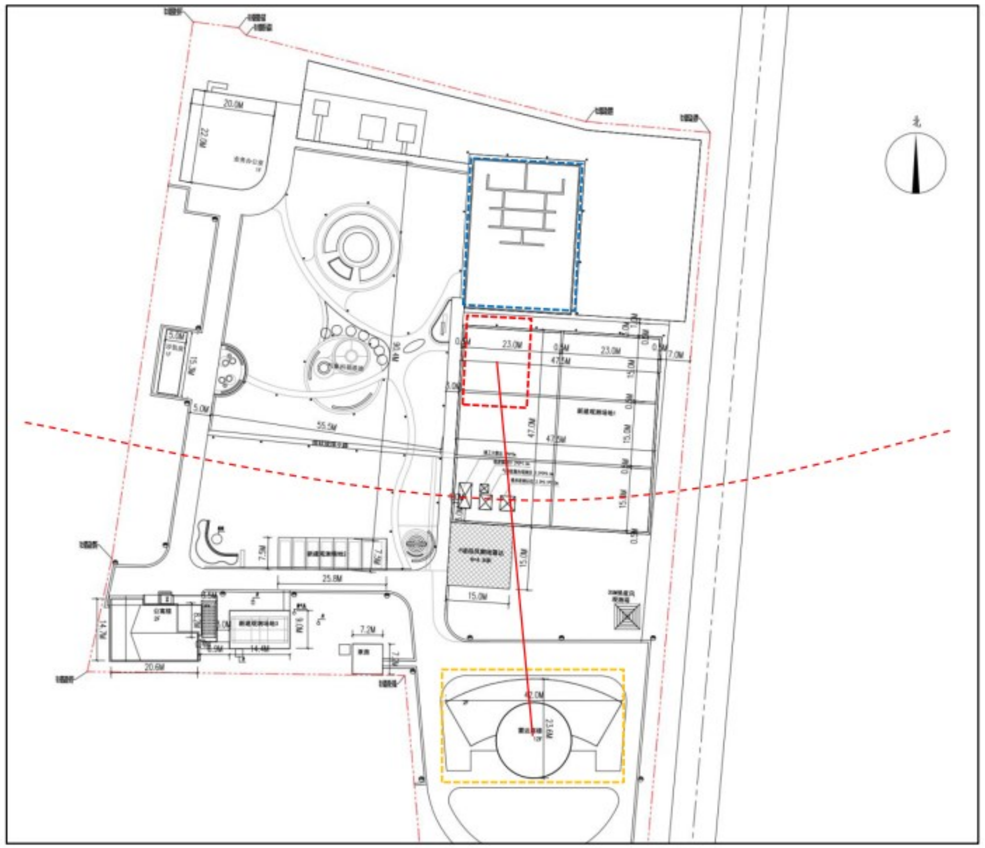

Forced ventilation system ( three temperature sensor in east, west, south)



Operational measurement (three temperature sensor and humidity sensor)

- To investigate the difference of temperature measurement between operational system and forced ventilation system.
- To obtain the microenvironment inside the shield.

# 3. Experiment field



*Lon: 108°58'20 "  lat: 34°26’44 "  Alt: 407.6m*

- experiment observation field (red area)
    - Jinghe observation site(blue area)
        - Radar station(yellow area)

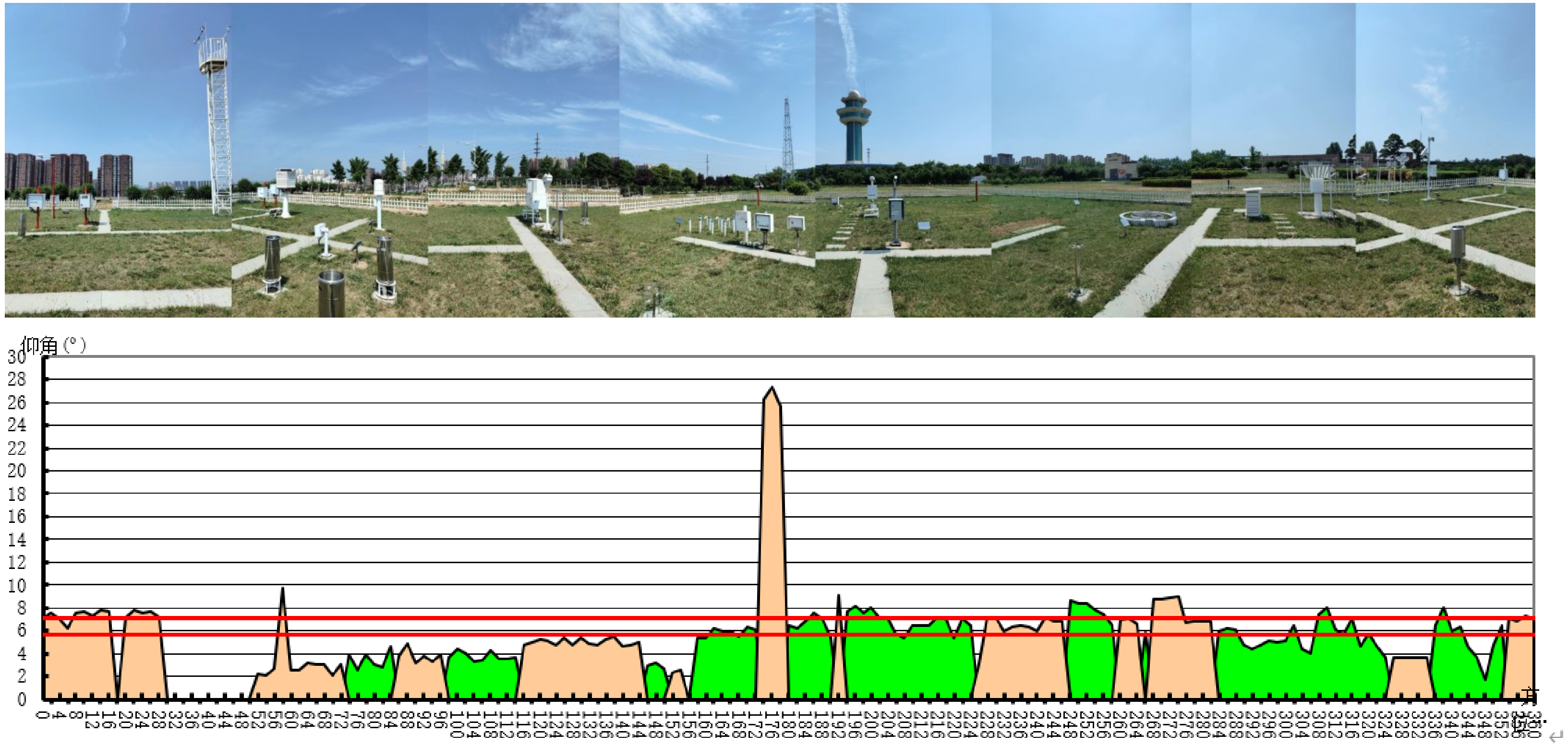
The red curved dotted line to the south is the area where the shadow of the radar tower

Top view of the observation layout at the observation site

25.June,2024

- ✓ Well calibrated before experiment.
- ✓ real time data monitor.
- ✓ weekly maintenance.

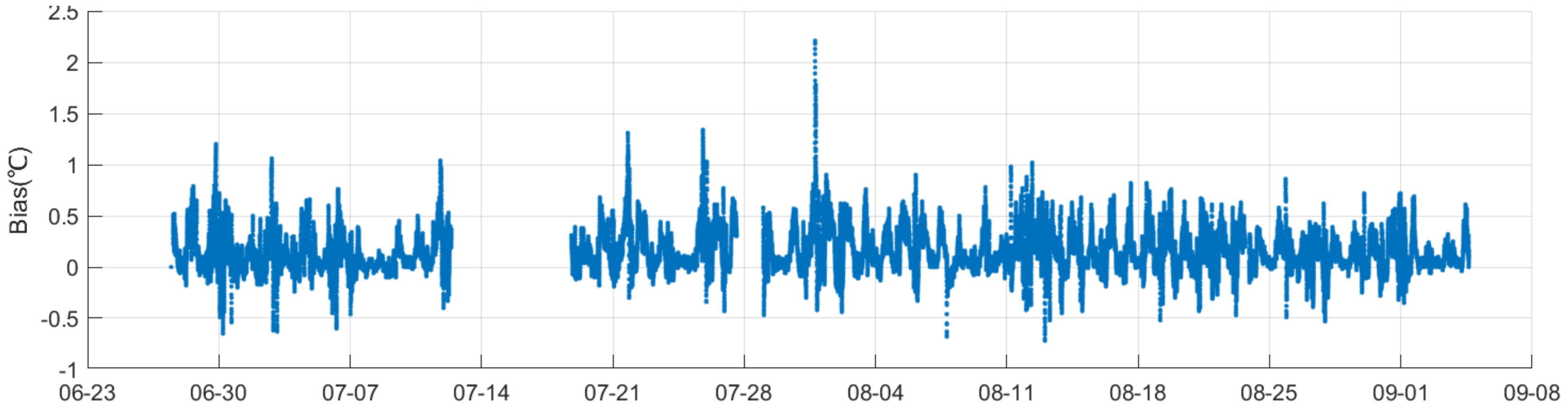
# 3. Experiment field



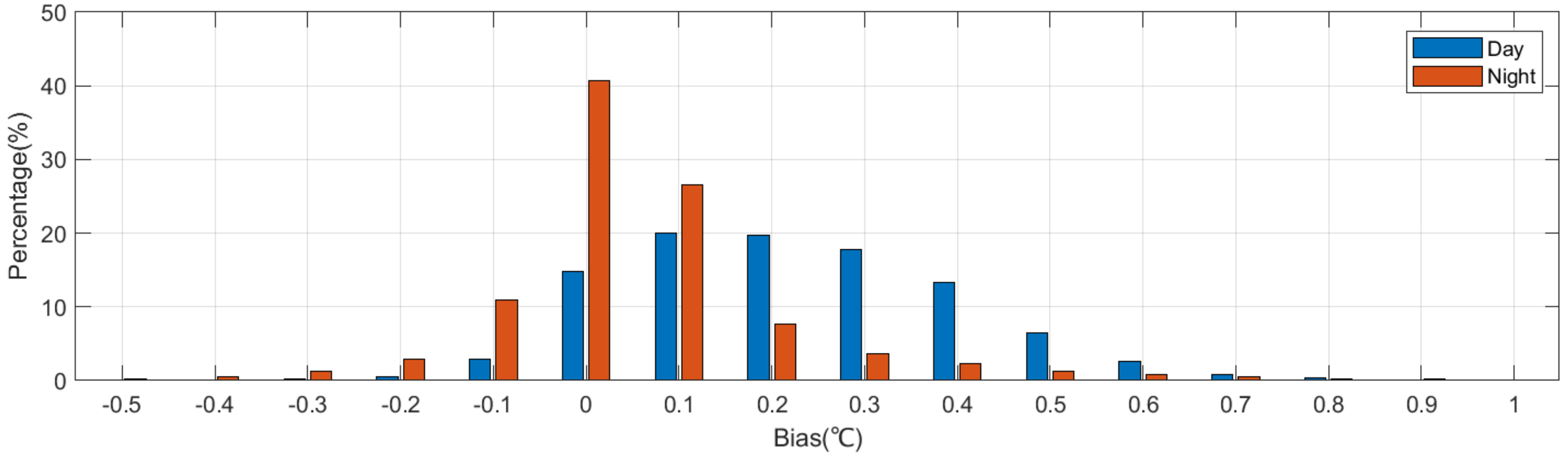

The obstacle, height-distance ratio and occlusion elevation diagram of 0~360° range around the observation field (center).

- The range of 164-168° (the southeast) is covered by the new generation of weather radar station in Xi ‘an, the elevation angle is between 25.7° and 27.3°, and the distance from the observation field is about 150m.

# 4. Preliminary results




Bias value = Natural ventilation - forced ventilation




The probability distribution of the deviations

- The air temperatures measured on natural ventilation were higher than those measured on forced ventilation, and more significant during the daytime.

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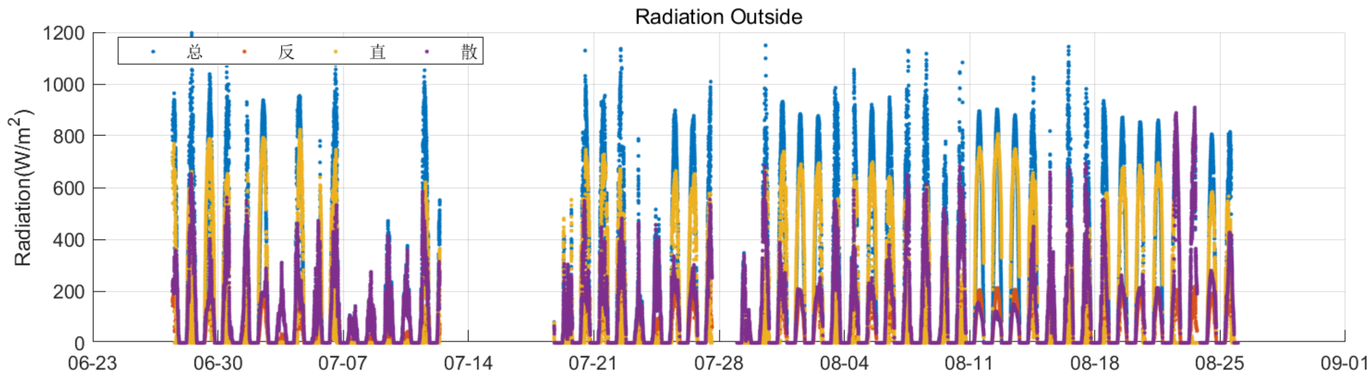
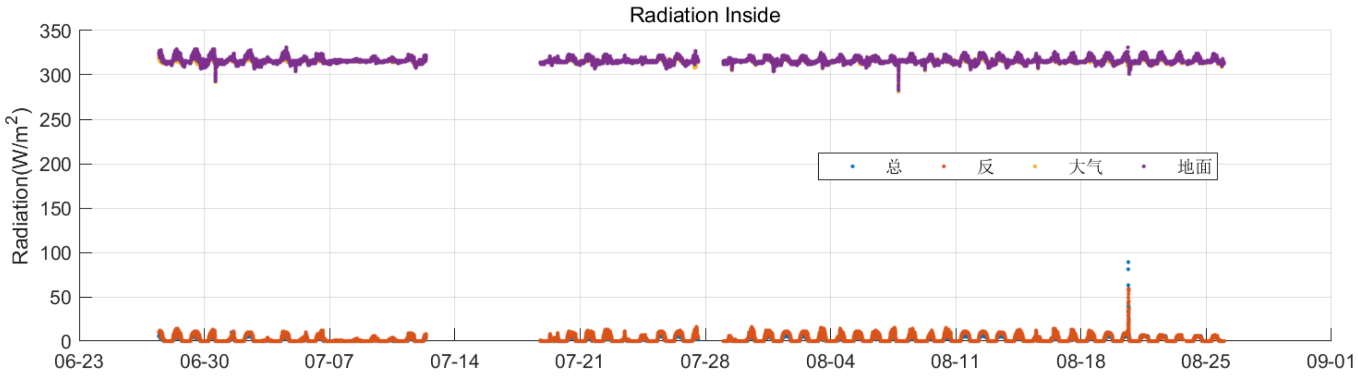
# 4. Preliminary results




**Outside:**

- GR(Total radiation)
- RR(Reflected radiation)
- DR(Direct radiation)
- SR(Scattered radiation)

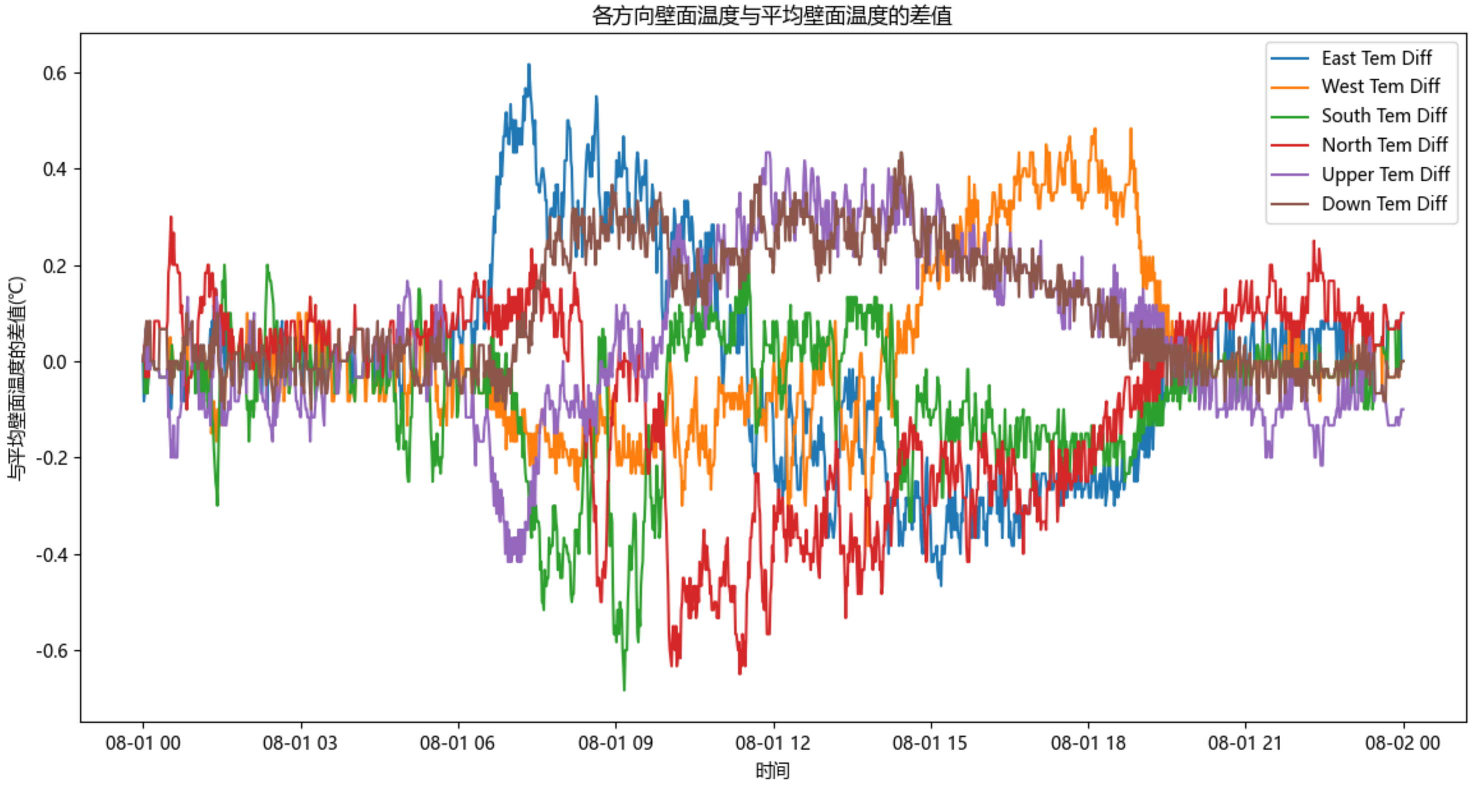
**Inside:**

- Atmospheric long-wave radiation
- Ground long-wave radiation
- Total radiation
- Reflected radiation

- The external radiation(GR,RR,DR,SR) shows obvious diurnal variation.
- The long-wave radiation(290-330W/$m^2$) inside the box is greater than the solar radiation (0-20W/$m^2$) inside the box.

# 4. Preliminary results

The diurnal variation of east, south, west, north, upper,down surface temperature




*1.Aug 2024 :*

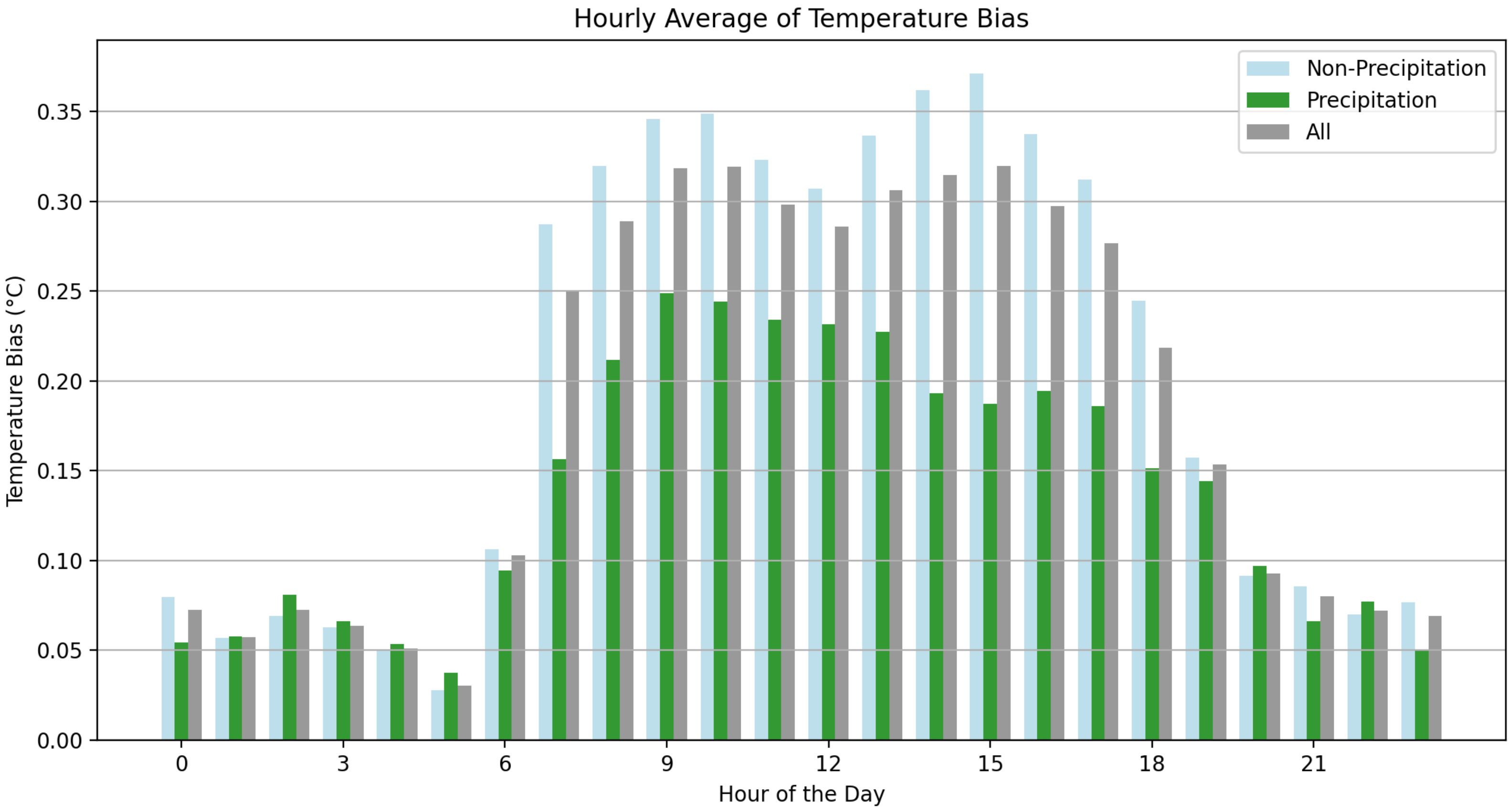
The solar altitude angle reaches maximum at 12:40

The heating order of the surface mainly depends on the solar azimuth angle

The east and west receive radiation mainly in the morning and afternoon respectively, the south receives radiation all day, and the north receives radiation only before 8:30 and after 17:00

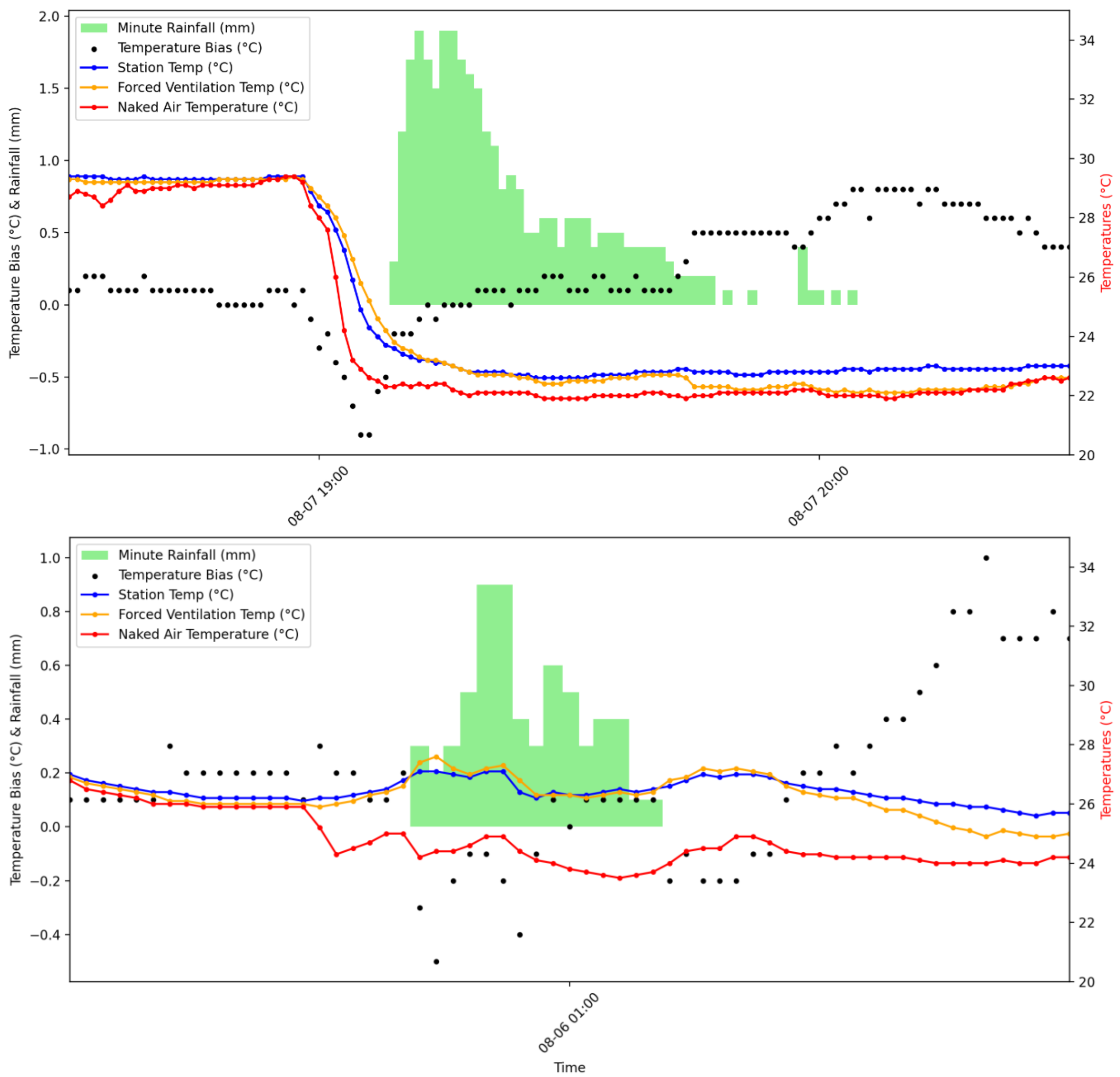
The total radiation received in descending order : east = west > south > north

# 4. Preliminary results



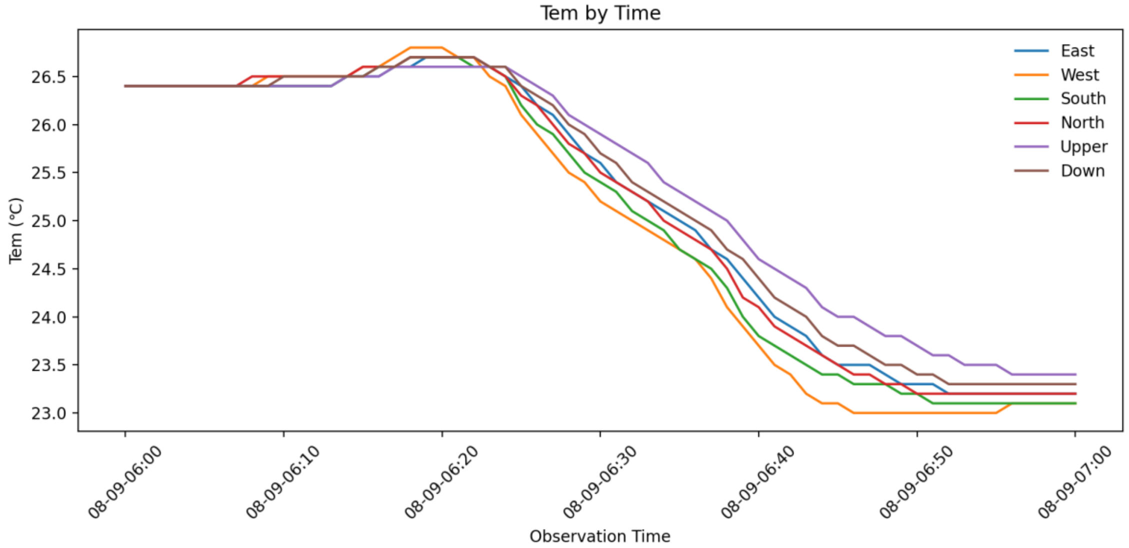

- The bias in the daytime is larger than the nighttime.
- The bias of temperature decreases during the rainfall.

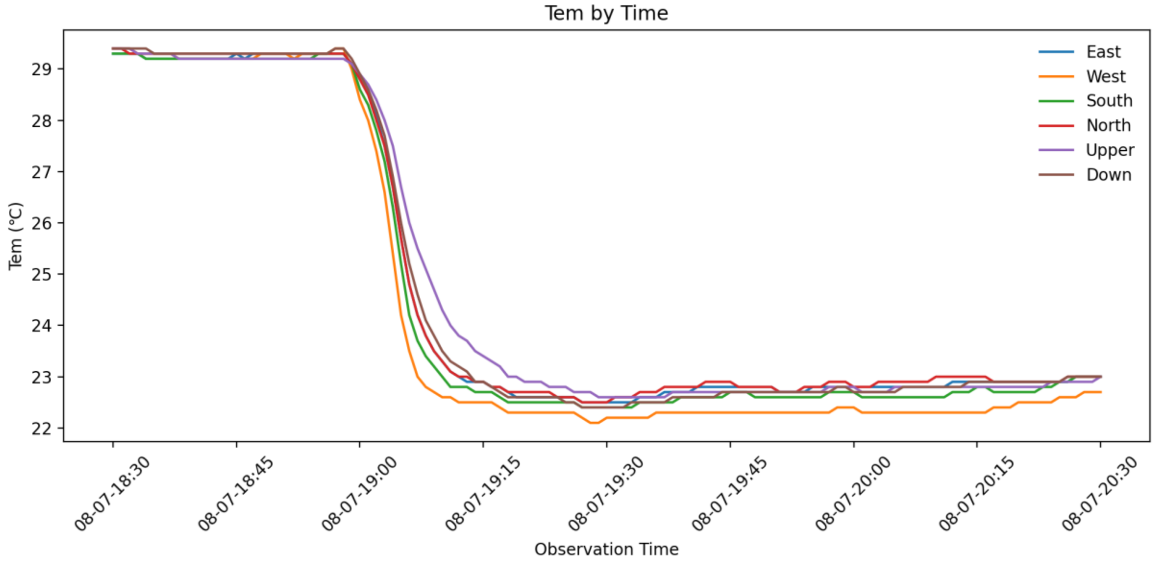
# 4. Preliminary results

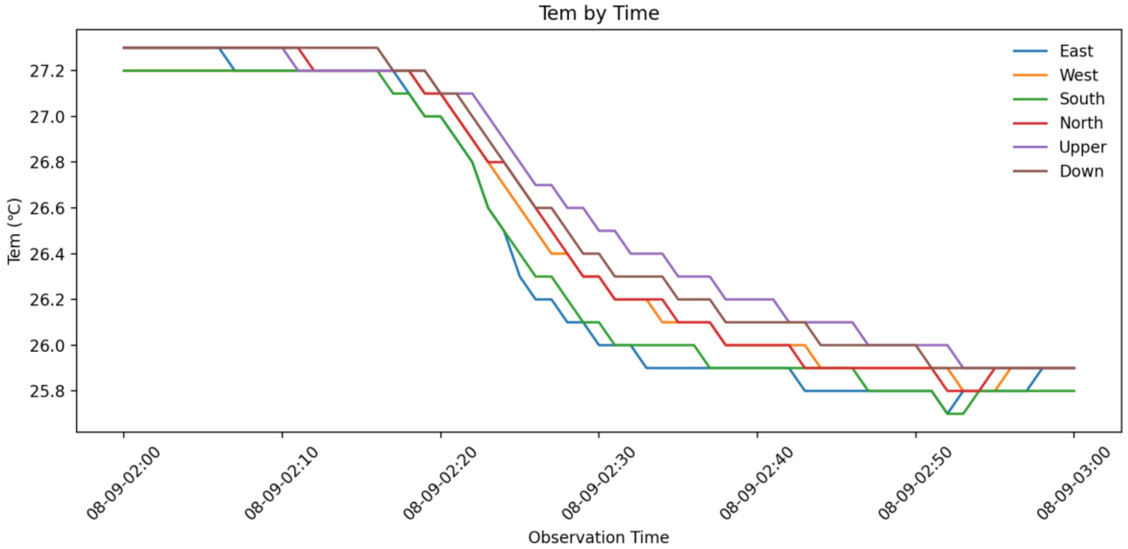



- The $T_{air}$ drops firstly and then $T_1$
- The temperature bias at the beginning of precipitation increased significantly and was negative, then tend to positive.
- The greater the rainfall per minute, the greater the bias.

# 4. Preliminary results



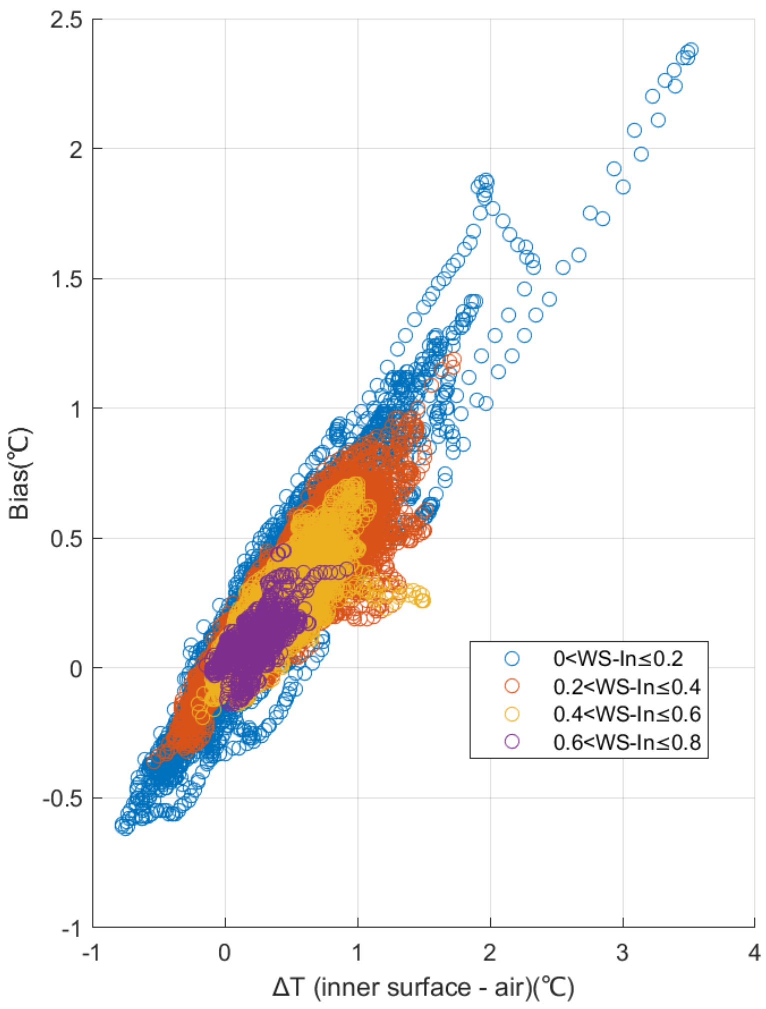



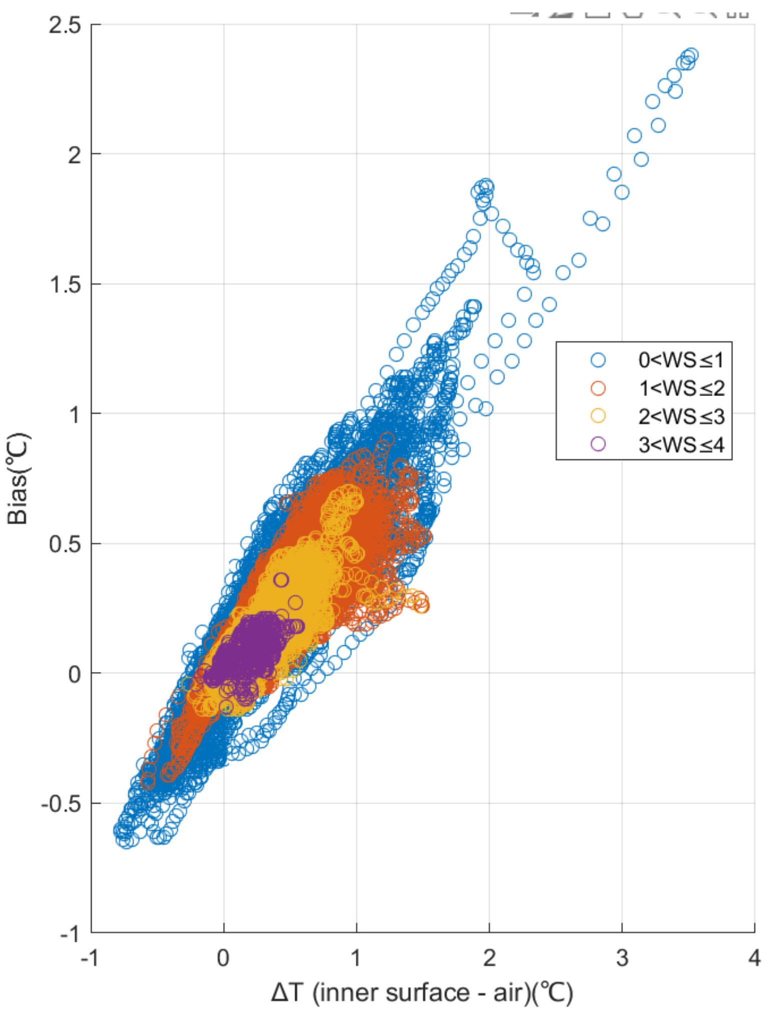




- $T_{suface}$ of six direction in precipitation process

- Short-term heavy precipitation has a more significant cooling effect on the inner surfaces of the shield during the day
- The direction in which the surface temperature drops first is usually consistent with the external dominant wind direction during this period

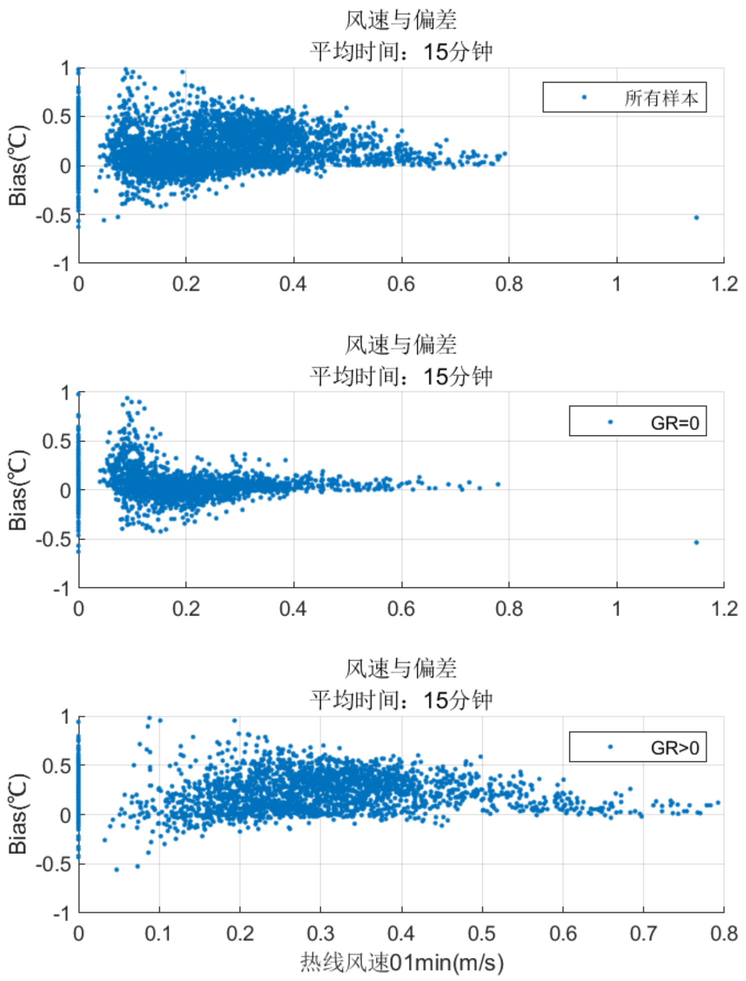
# 4. Preliminary results



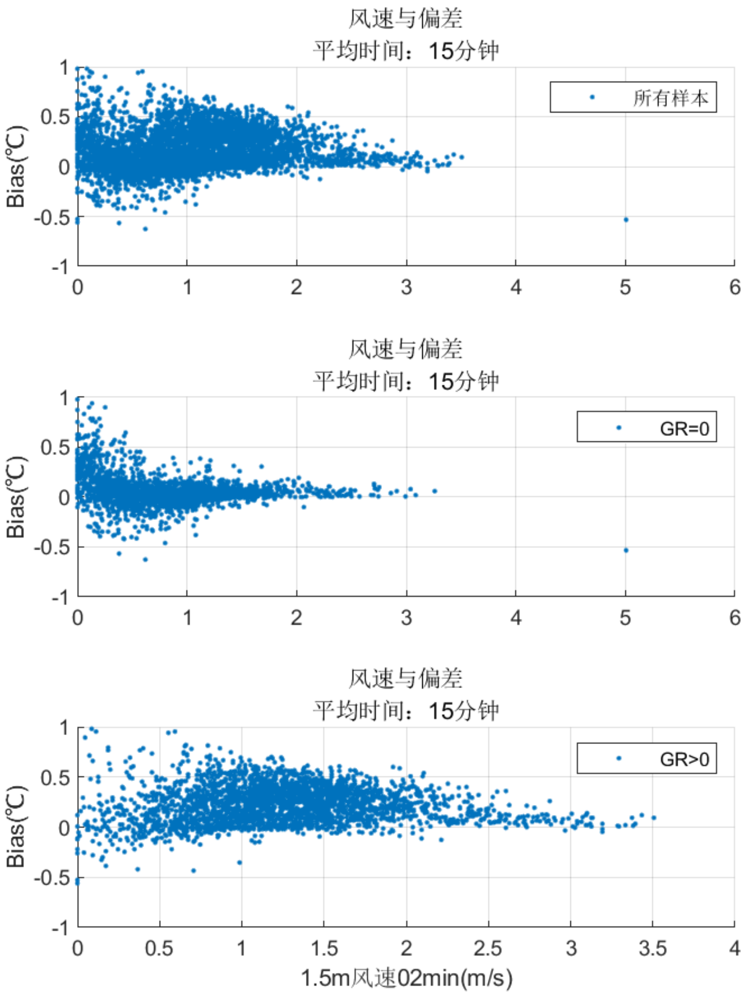




*The relationship between $T_1$-$T_{air}$ and the $T_{suface}$ -$T_{air}$ under different wind speed*

# 4. Preliminary Results



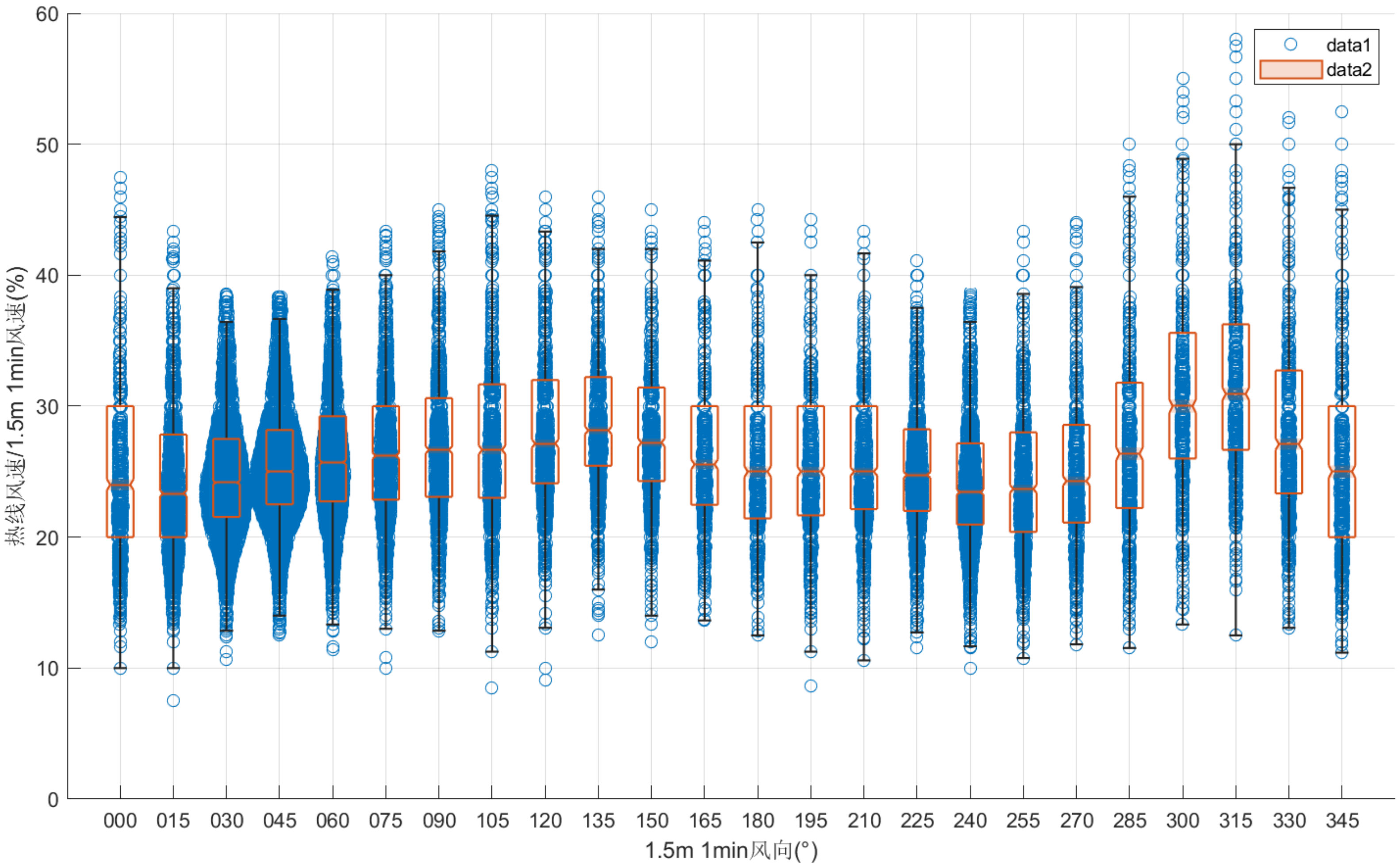

Inside wind speed with Bias (all,night,day)




Outside 1.5m wind speed vs Bias(all,night,day)

- In general, with the increase of the wind speed inside and outside the box, the bias decreases.
- It's half positive and half negative bias at night, positive bias dominate during the day.

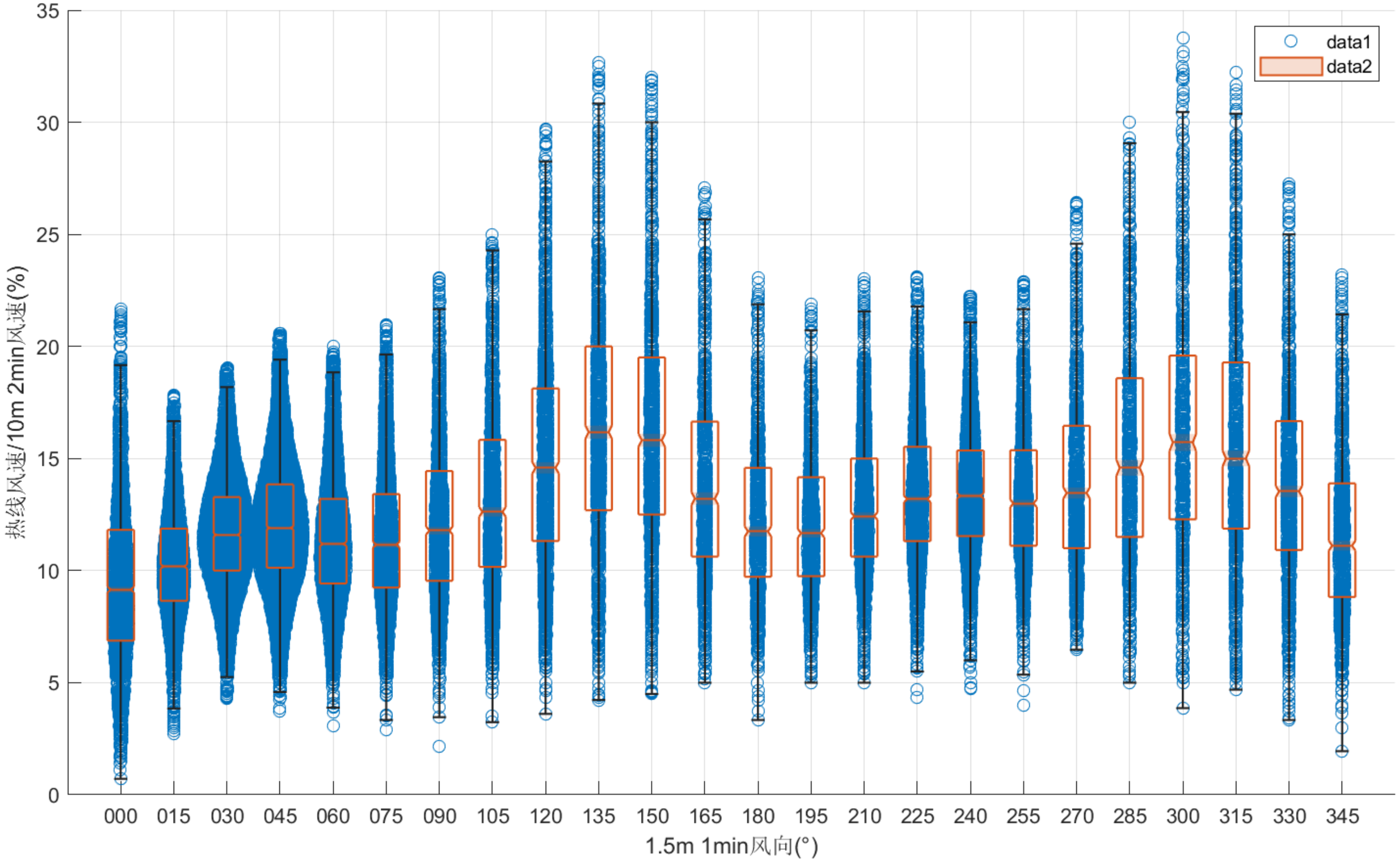
# 4. Preliminary Results




- Inside /1.5m wind speed with 1.5m wind direction

- The distribution of internal and external 1.5m wind speed ratios in different wind directions shows that the wind is mainly from the northeast and high ratio is mainly from northwest.

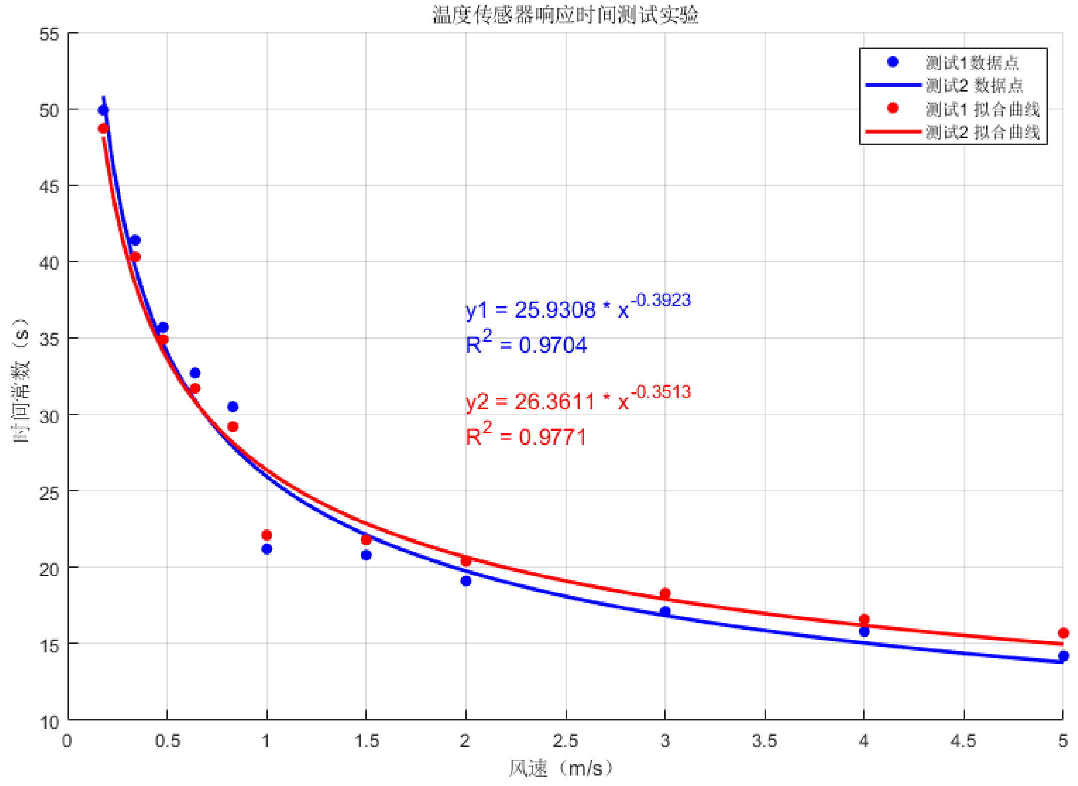
# 4. Preliminary Results

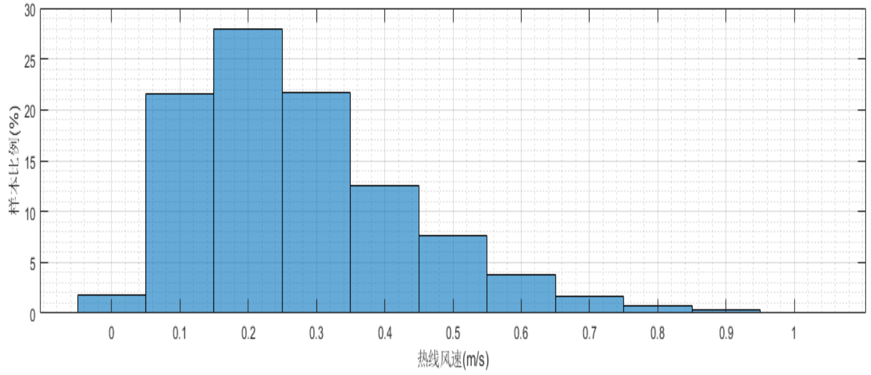


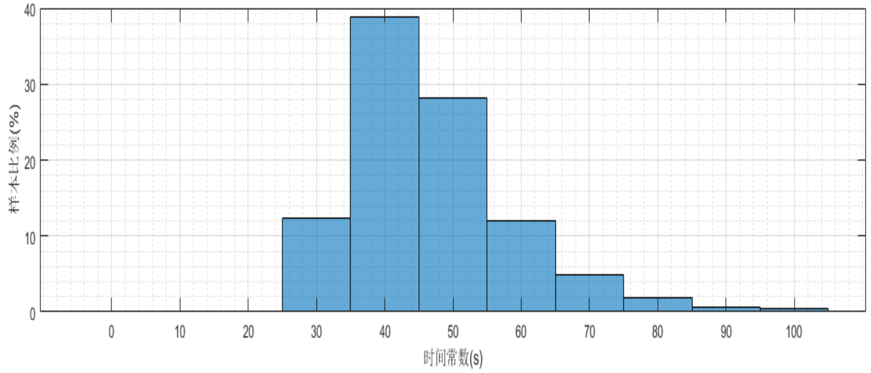

- The distribution of internal and external 10m wind speed ratios in different wind directions shows that the wind is also mainly from the northeast, but it shows bimodal distribution of high ratio, mainly from northwest and southwest.

- Inside /10m wind speed with 1.5m wind direction

# 4. Preliminary results



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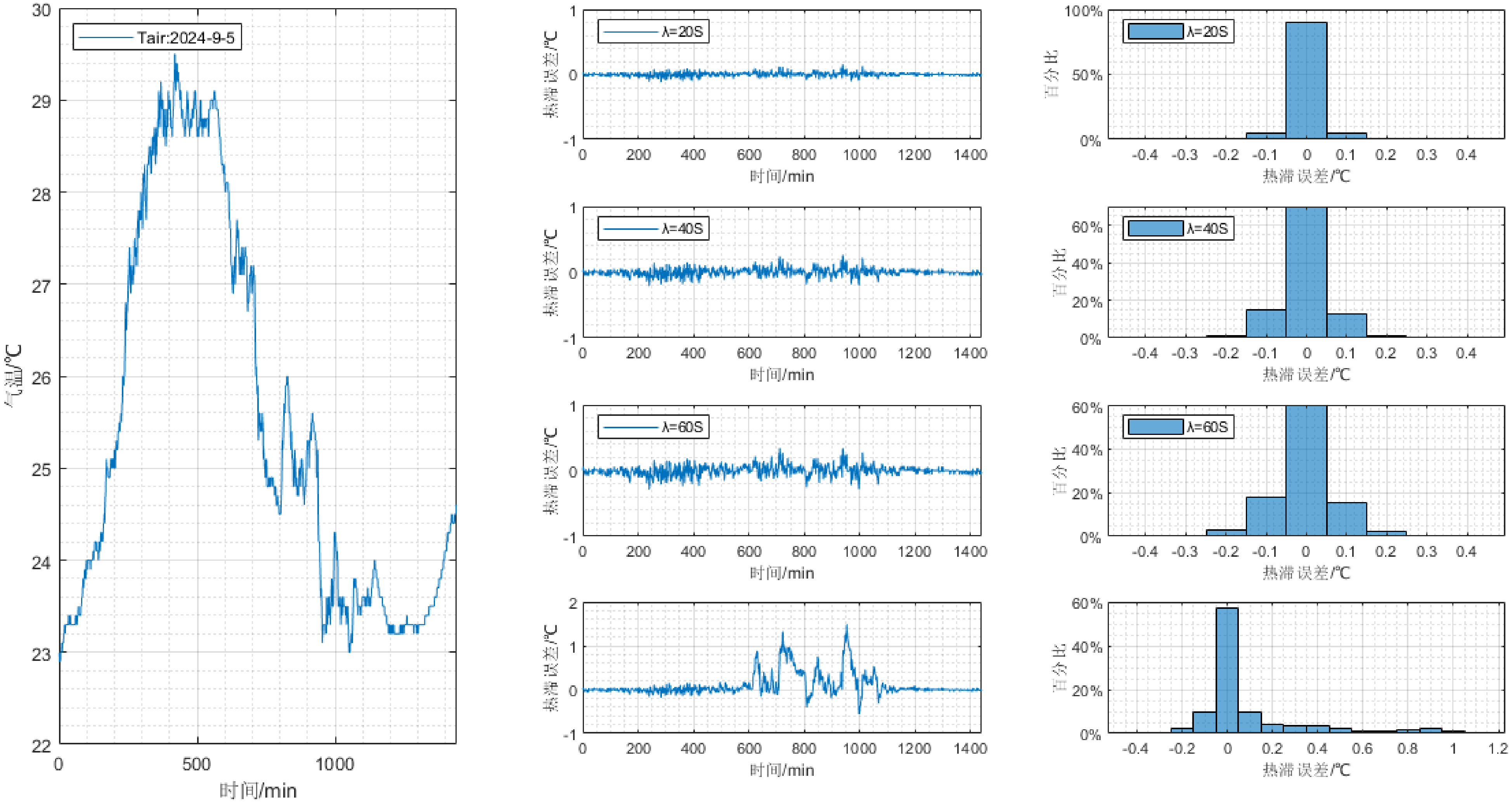

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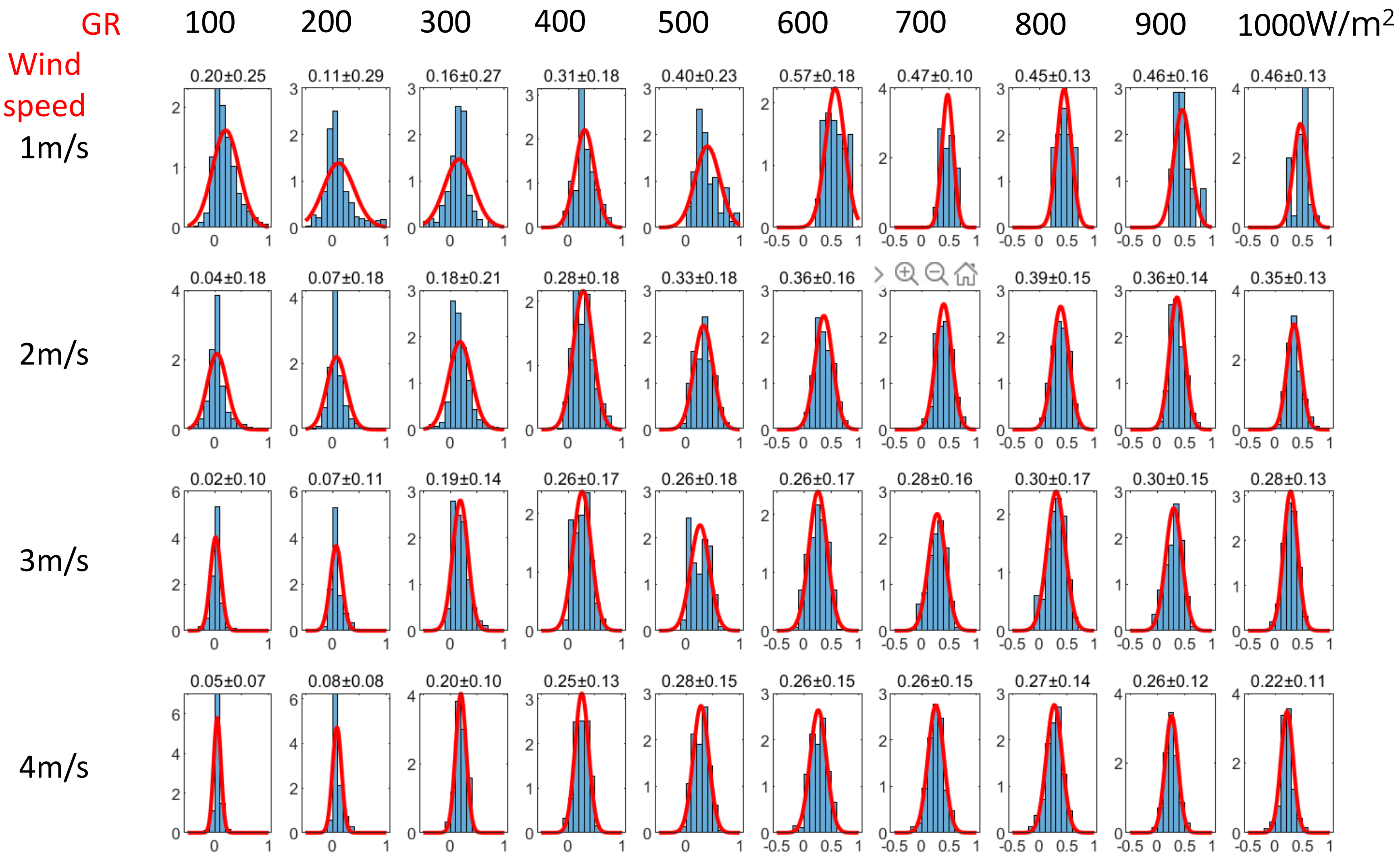


- $T_1$-$T_{air}$ probability distribution on different wind speed and radiation

# 5. Conclusion

- Solar radiation primarily affects the internal temperature by influencing the surface temperature of the shield. The relationship is non-linear.
- The impact of precipitation on the internal temperature occurs via cooling the shield, and the strength of this impact is associated with the rainfall intensity and the wind direction.
- The structure of the shelter is important to estimated the inside wind speed. The Convection Heat Exchanging increase with the wind speed.
- The time constant in low wind speed should be pay more attention.
- Precipitation may have a more obvious effect.

# Thank you

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