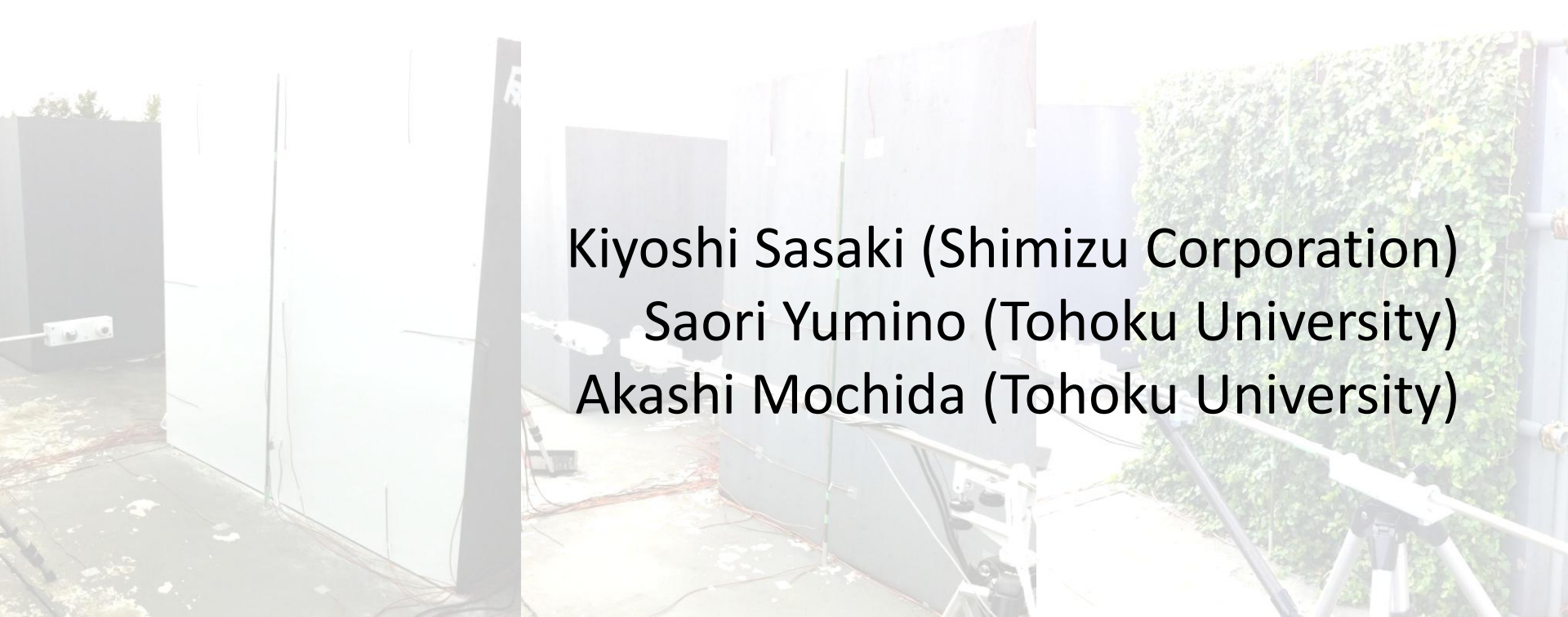
INFLUENCE OF PHYSICAL PROPERTIES OF VERTICAL WALL SURFACES ON HUMAN THERMAL SENSATION BASED ON FIELD MEASUREMENTS AND MICROCLIMATE SIMULATION



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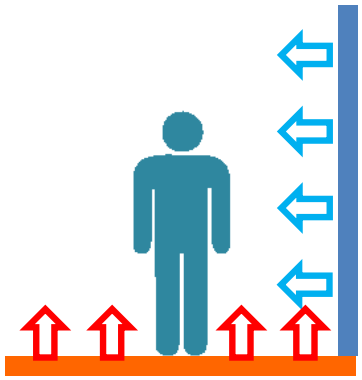
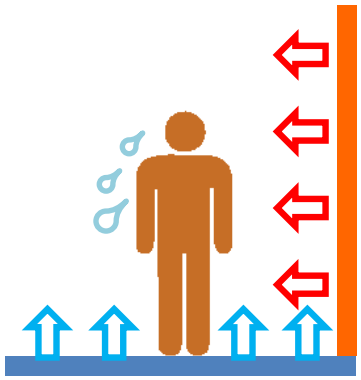
Introduction

- Previous studies have shown that radiation has a great influence on outdoor thermal sensation in summer.
- considering the shape of the human body, the physical properties of vertical wall surfaces have more influence on thermal sensation in pedestrian spaces than those of horizontal wall surfaces.

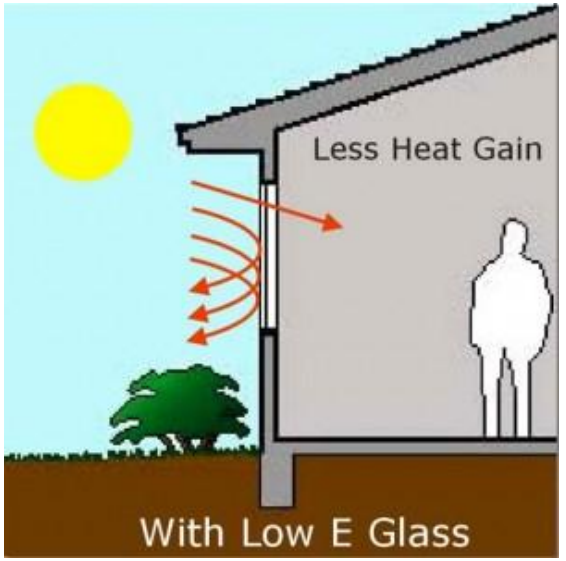


Which is it better,
cooling vertical or horizontal wall?



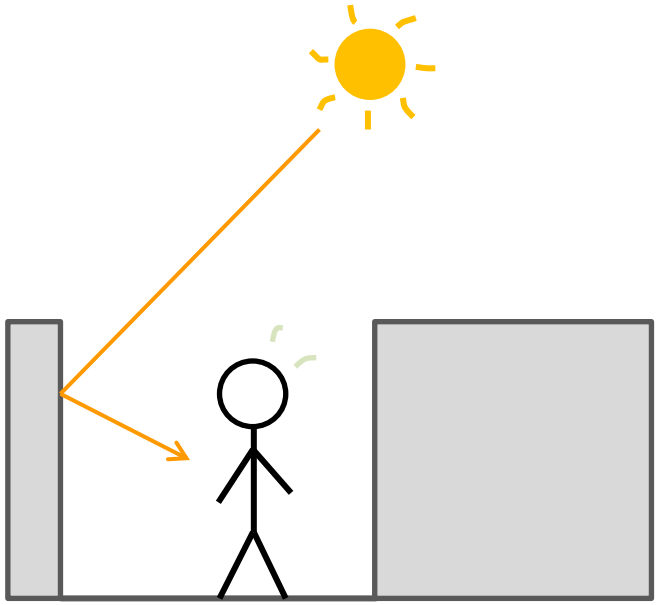
Introduction

- The properties of building cladding materials for vertical walls have been mainly studied for reducing the heating and cooling loads of indoor spaces.



Porpose

- In order to
  clarify the influence of the modification of physical properties of vertical walls on outdoor thermal sensation,
  field measurements and the radiation and conduction simulations were carried out.

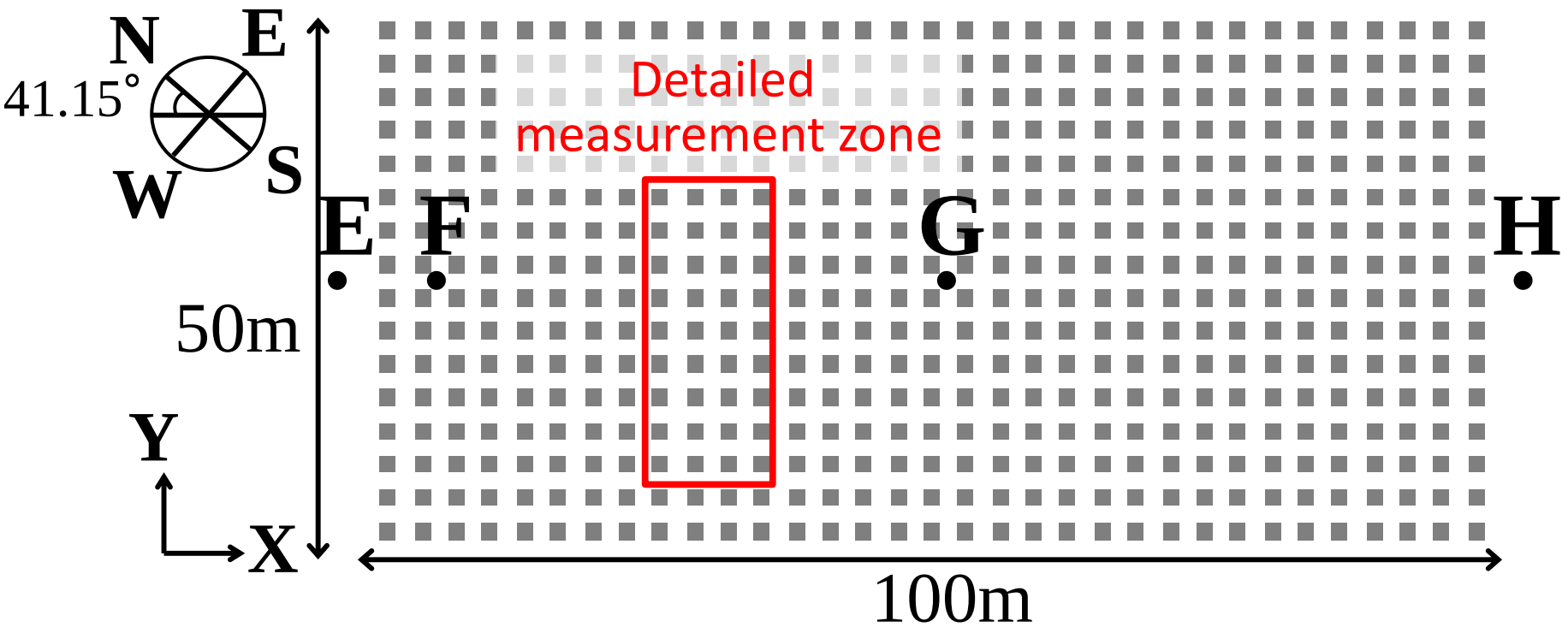


Field measurements

Measurement site and period

- Measurement site
  COSMO(Comprehensive Outdoor Scale Model) site
  (the premises of the Nippon Institute of Technology)
- Measurement period
  August 28th – September 8th, 2011

Measurement site



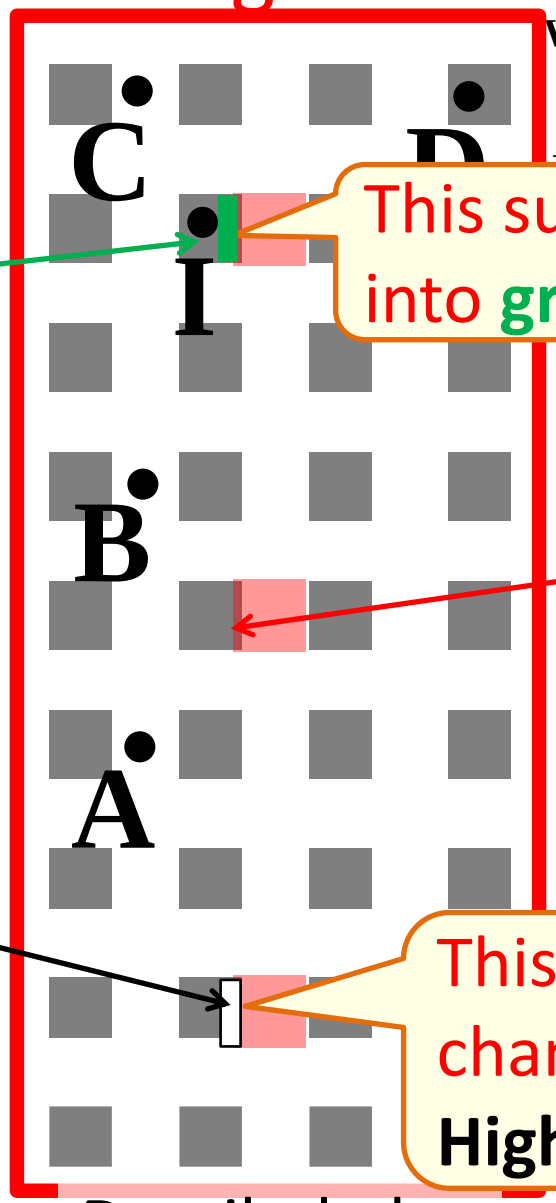
Layout of building models in COSMO site

- All cubes are made of concrete and cubes and ground surfaces were coated with grey diffusive paint.
- 1.5 meter-high concrete cubes are arranged.

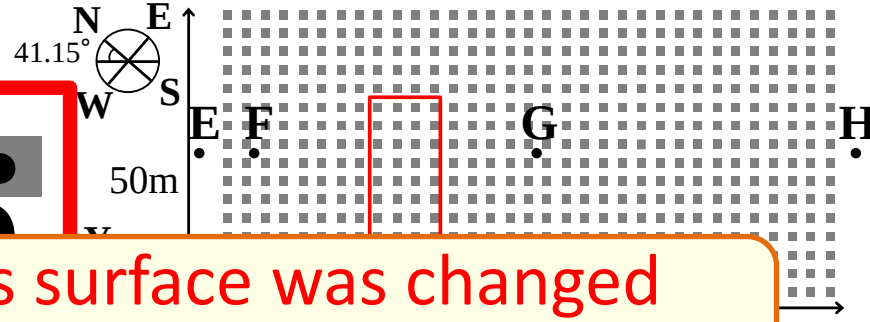
Measurement setting

Greening (GR)

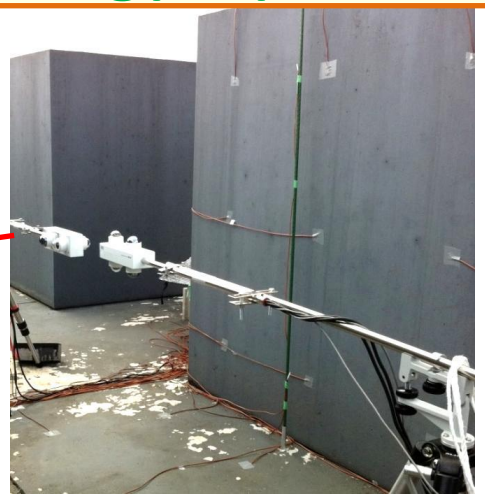
High Reflective material (HR)



Detailed plan of the zone



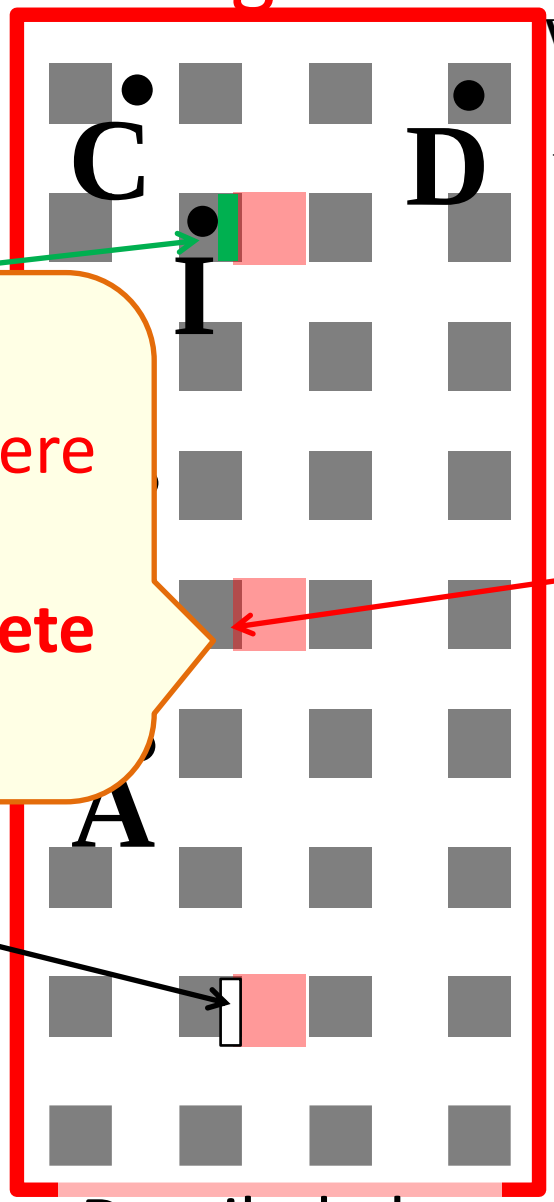
This surface was changed into greening(GR)

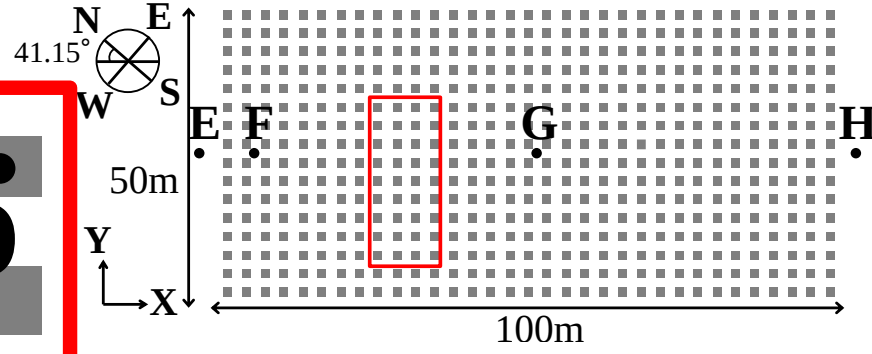


Concrete (CO)

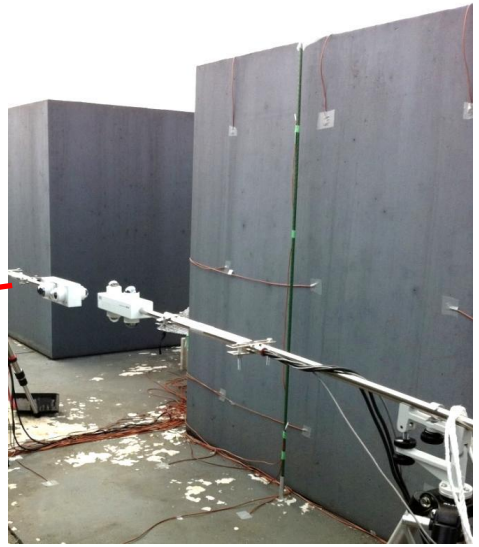
This surface was changed into **High reflective material(HR)**

Measurement setting

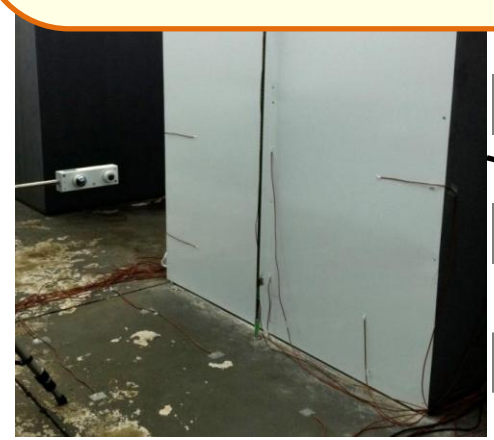




For comparison, measurements were also carried out around the **concrete (CO)** surface



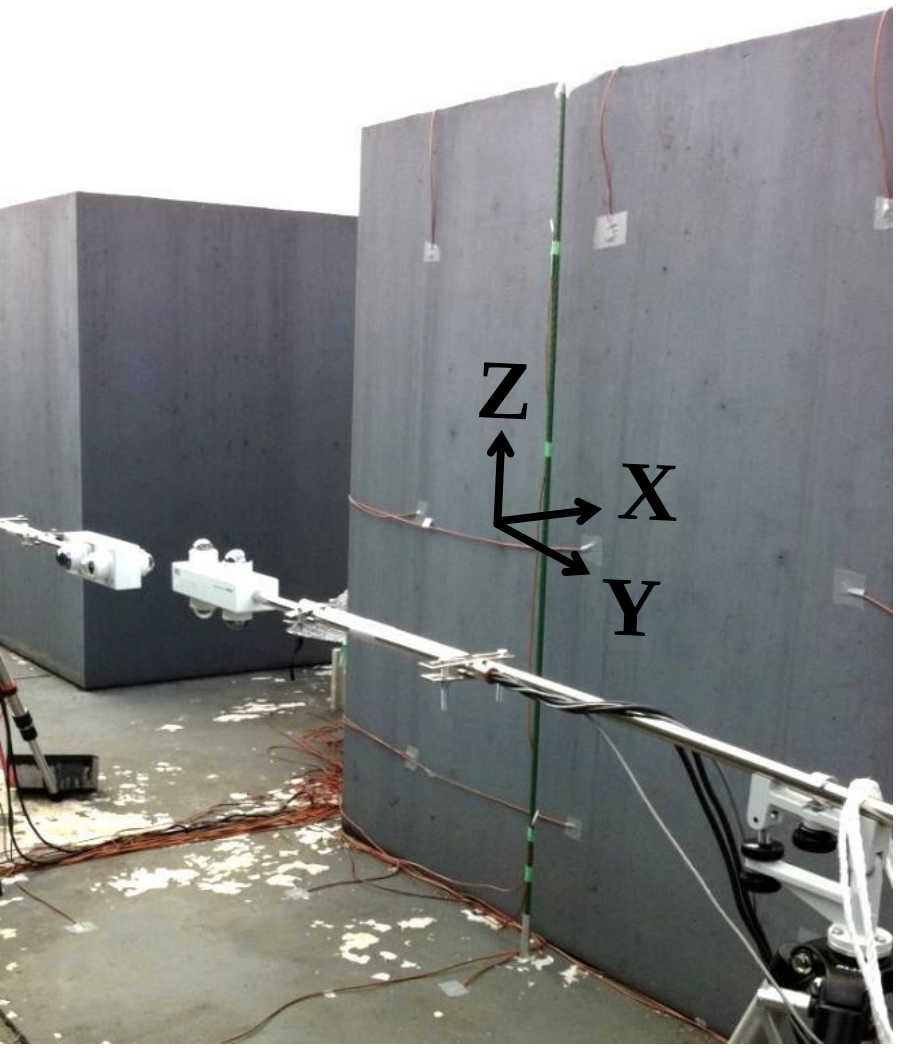
Concrete (CO)



High Reflective material (HR)

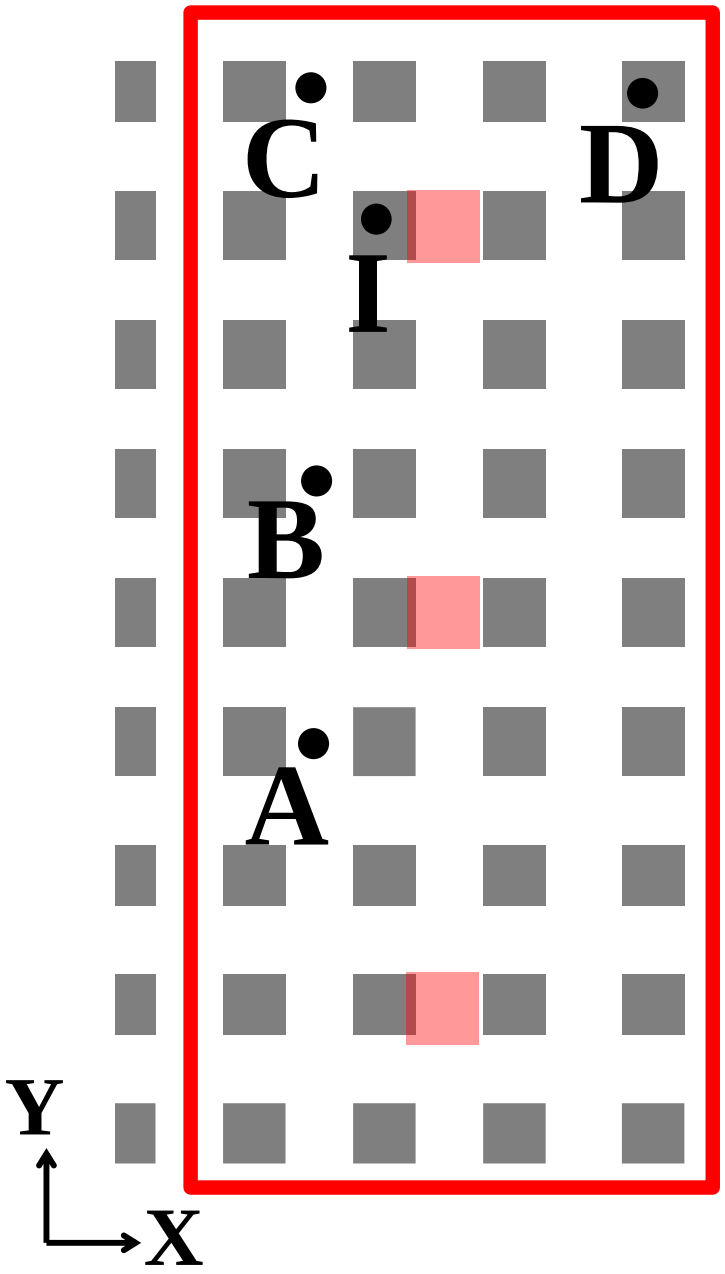
Detailed plan of the zone

3D radiant heat transport



- 3D radiant heat transports were measured at the center of each area.
- Since the sizes of the instruments were large compared to the measurement area, short- and long-wave radiations along the X, Y, and Z axes could not be measured at the same time.

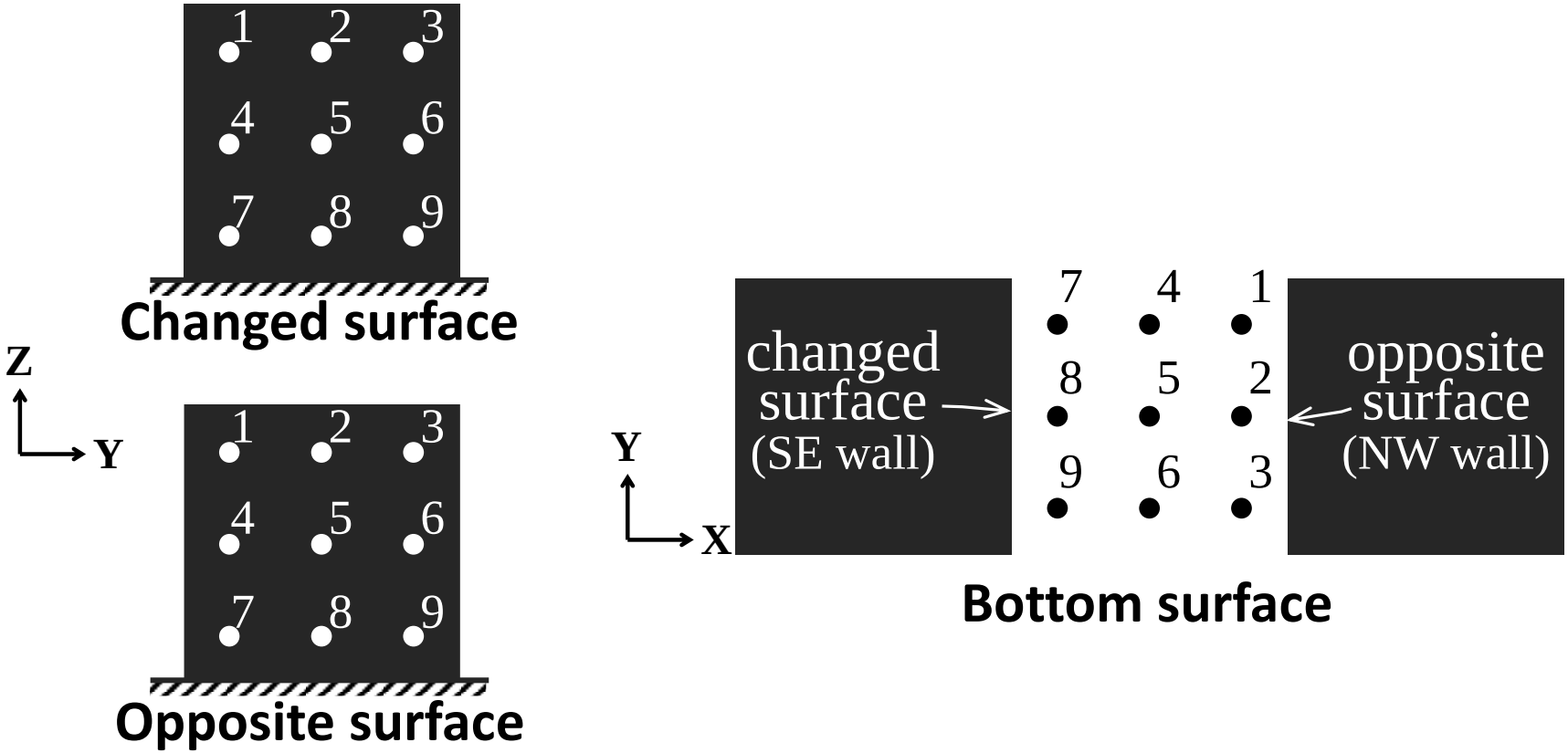
3D radiant heat transport



- Short- and long-wave radiations along the X and Z axes were measured at the same time in each area

- The Y axis was measured at point A, assuming the uniformity of radiant heat transport in the Y direction within the COSMO site.

Surface temperatures

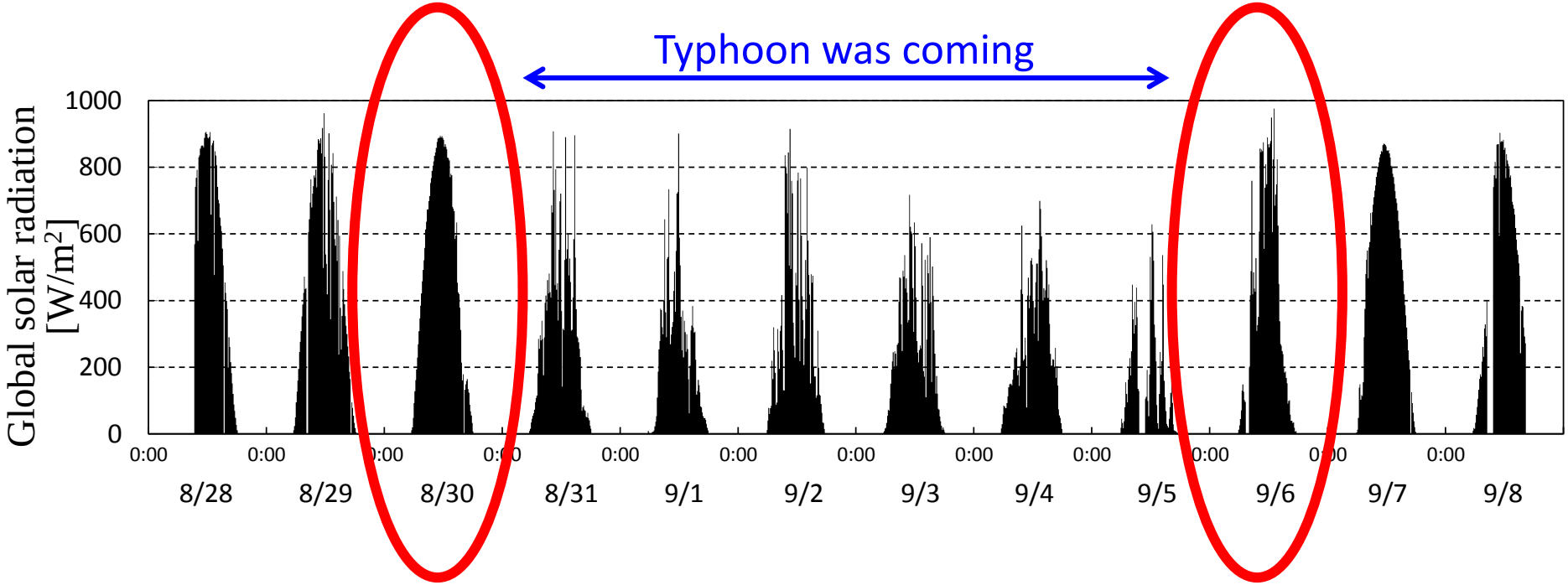


Measuring points at each surfaces

- Surface temperatures were measured at 9 points per surface.

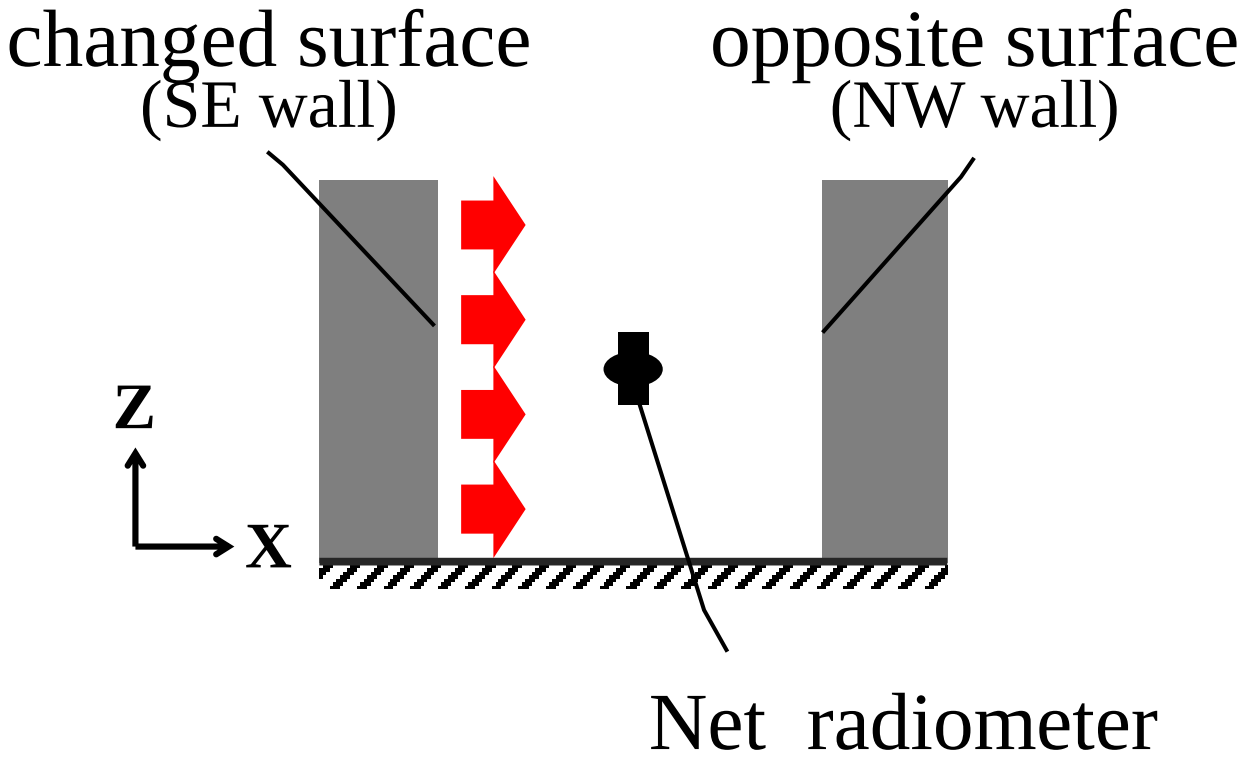
Results of field measurement

Meteorological condition

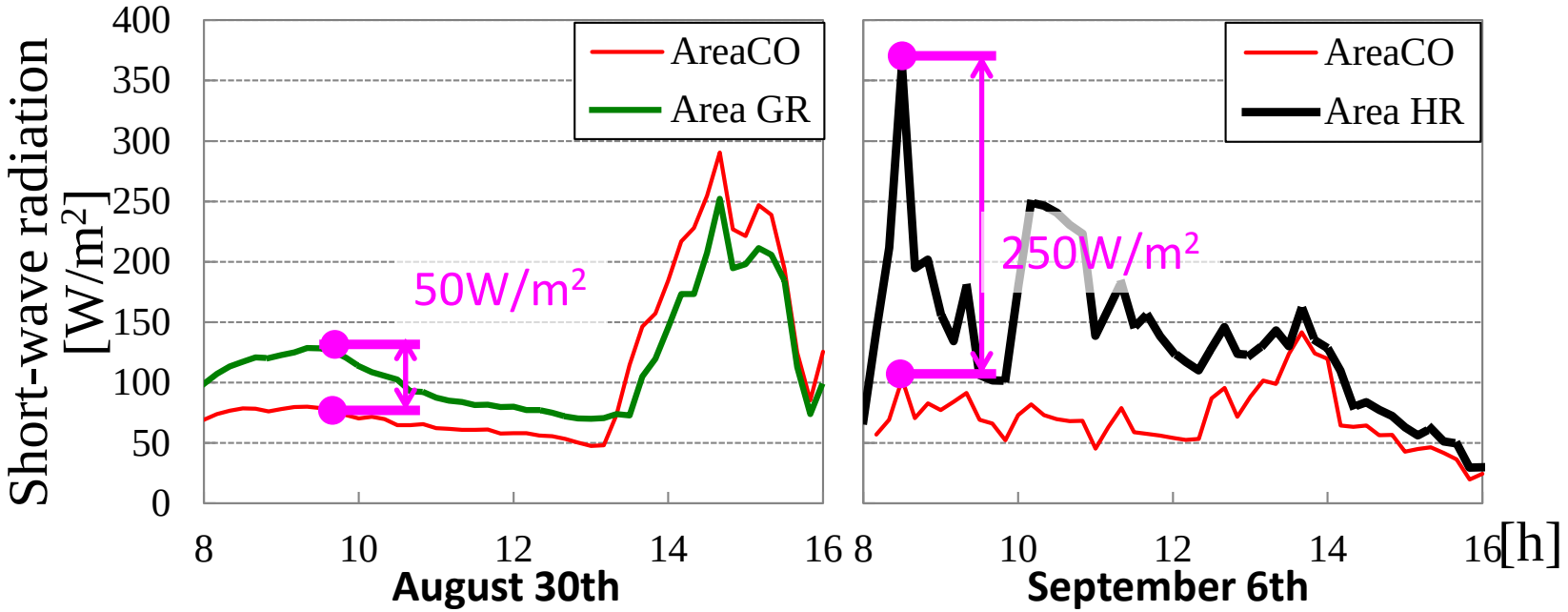


- Within the measurement period, August 28th, 29th, 30th, September 6th, 7th and 8th were sunny days.
- In this presentation, results on August 30th and September 6th are shown as typical cases.

Short-wave radiation coming from changed surfaces

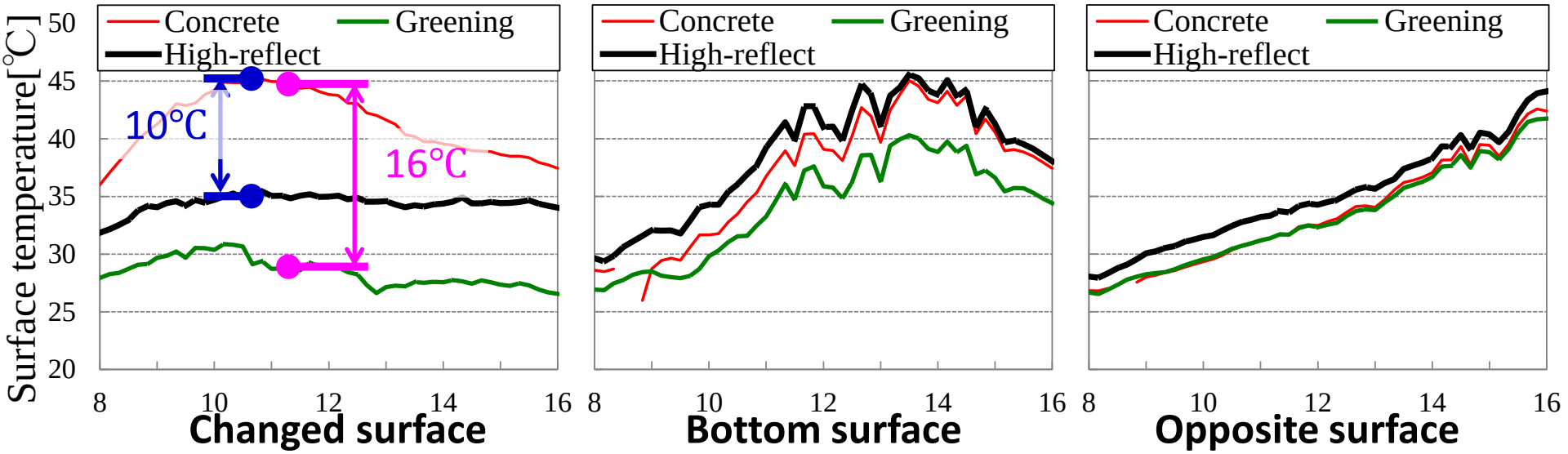


Short-wave radiation coming from changed surfaces



- Short-wave radiation from the **greening(GR)** surface was **greater** than that from **concrete(CO)** by up to about **50 W/m²**
- Short-wave radiation from the **high reflective material(HR)** surface was **greater** than that from **concrete(CO)** by up to about **250 W/m²**

Surface temperatures(average of 9 points of each surface, 8/30)



- The surfaces of **greening** and **high reflective material** were almost always **cooler** than the **concrete** surfaces, and the difference in surface temperature between **greening** and **concrete** was up to **16℃**, while that between **the high reflective material** and **concrete** was up to **10℃**.
- However, the **high reflective material** surface **heated up** the bottom and opposite surfaces more since it reflected more short-wave radiation than the **concrete** surface.

Calculation condition of MRT

- In this presentation, MRT values were calculated from the results of 3D radiant heat transport so that the different shapes and absorptivities of the human body in the cases of both long-wave and short-wave radiations were considered.

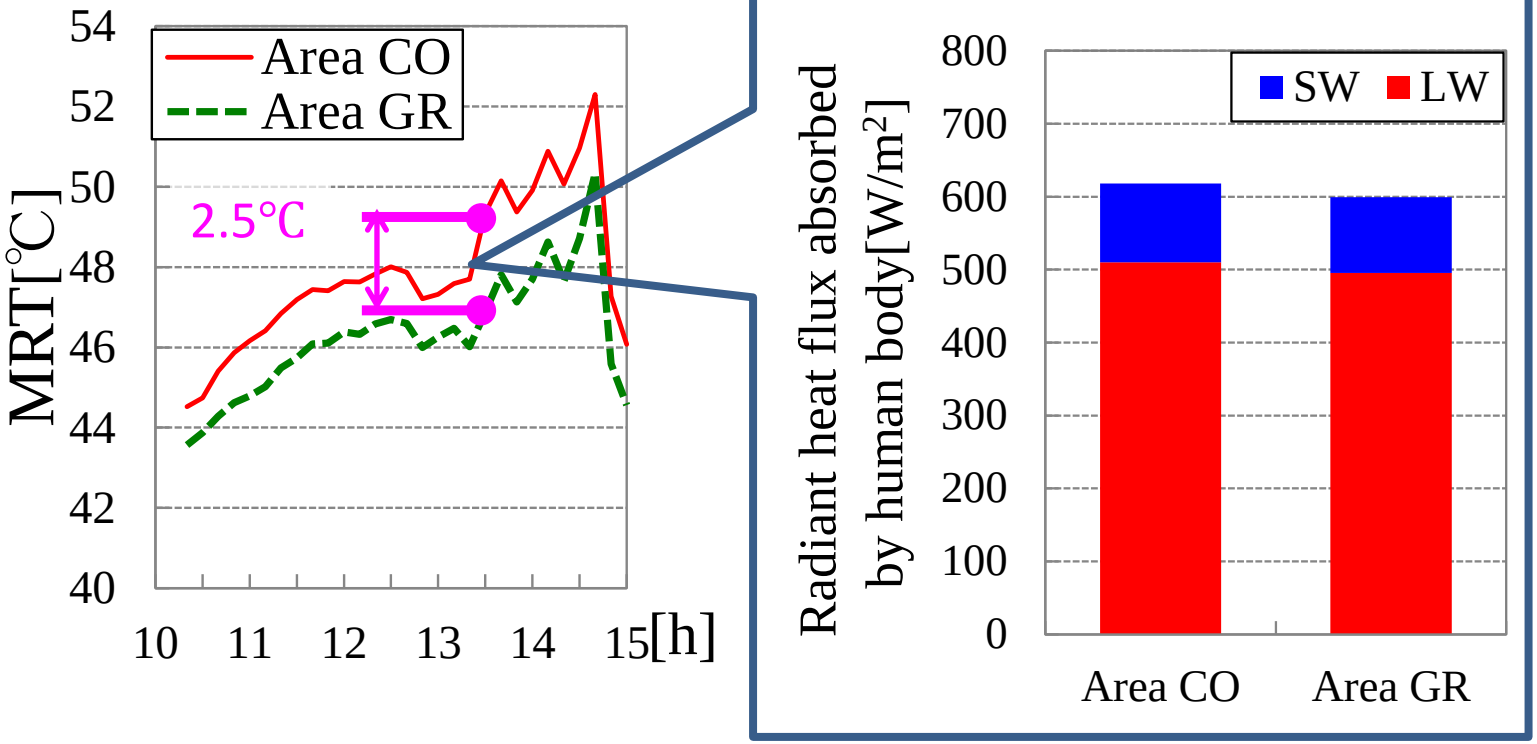
$$MRT = \left[\sum_{l=-3}^{3} \left(R_{LW}\varepsilon + R_{SW}\alpha \right) c_l \Big/ \sigma \right]^{1/4} - 273 \quad [\mathrm{^\circ C}]$$

where l = the index of direction of surface on cylinder ($\pm 1, 2, 3$),
R_{LW} and R_{SW} = amounts of long-wave and short-wave radiations, W/m^2,
e = long-wave absorptivity of object (in this paper, $e = 0.98$),
a = short-wave absorptivity of object (in this paper, $a = 0.5$), and
c_l = weight coefficient of each object surface
(in this paper, $c_{\pm 1, \pm 2} = 0.238$, $c_{\pm 3} = 0.024$).

MRT values

(Comparison between areas **GR**(greening) and **CO**(concrete))

August 30th



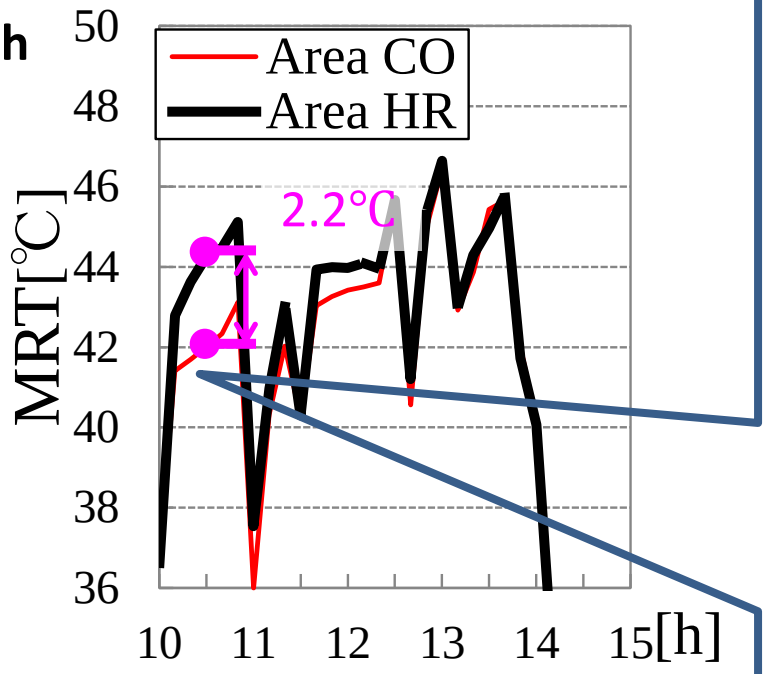
- The MRT at area **GR(Greening)** was **lower** by up to **2.5℃** than that at area **CO(Concrete)**

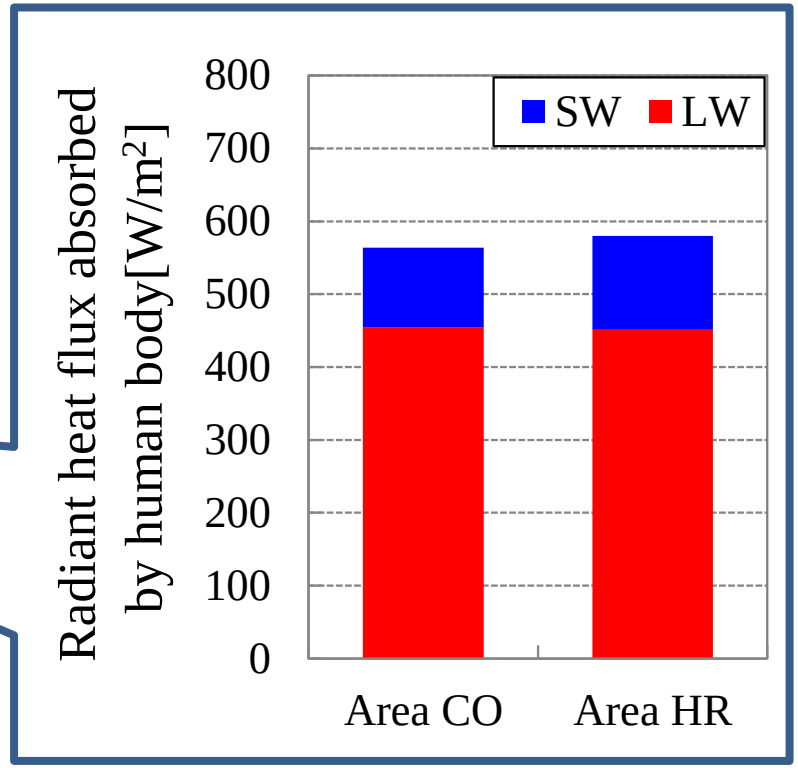
  ⇒the differences in the amount of long-wave radiation absorbed by the human body, caused by the differences in surface temperatures in each area.

MRT values

(Comparison between areas **HR**(high reflective material) and **CO**(concrete))

September 6th





- The MRT at area **HR(High reflective material)** was **higher** by up to **2.2℃** than that at area **CO(Concrete)**

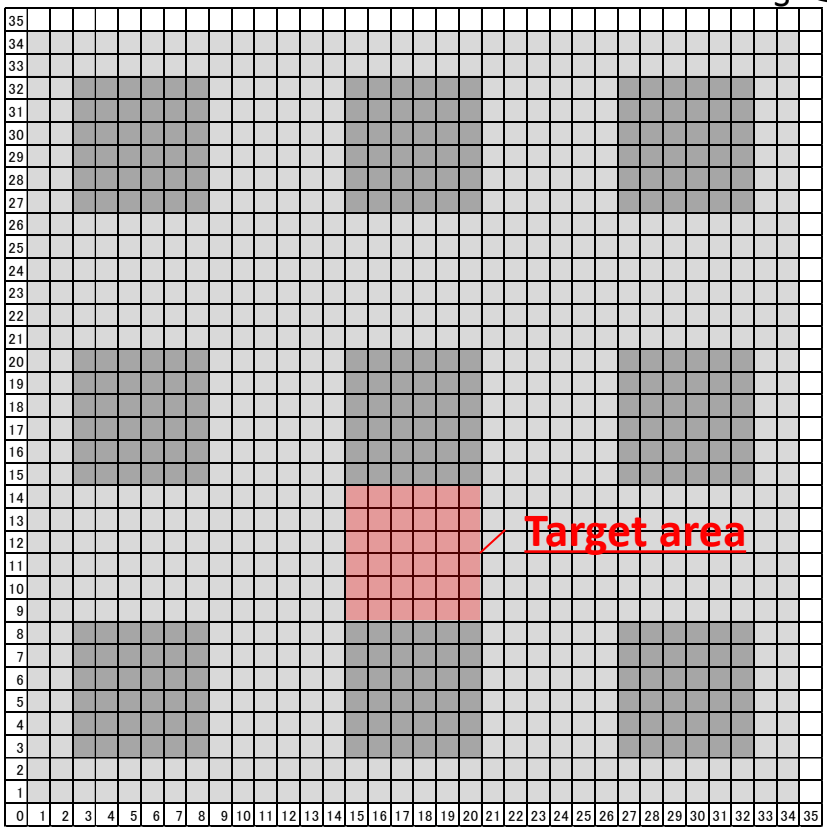
  ⇒the increase in the amount of short-wave radiation absorbed by the human body.

Radiation and conduction simulations

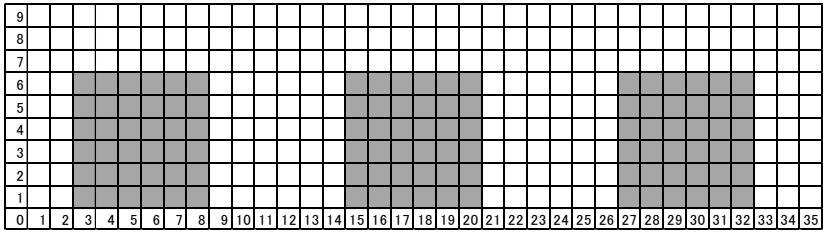
Simulation setup

3 × 3 buildings were modeled, and the target area was determined considering the uniformity of the radiant field in the COSMO site.

The unsteady analysis was performed over a period of 48 h, <u>from 0:00 on August 29th to 24:00 on August 30th</u>



x - y



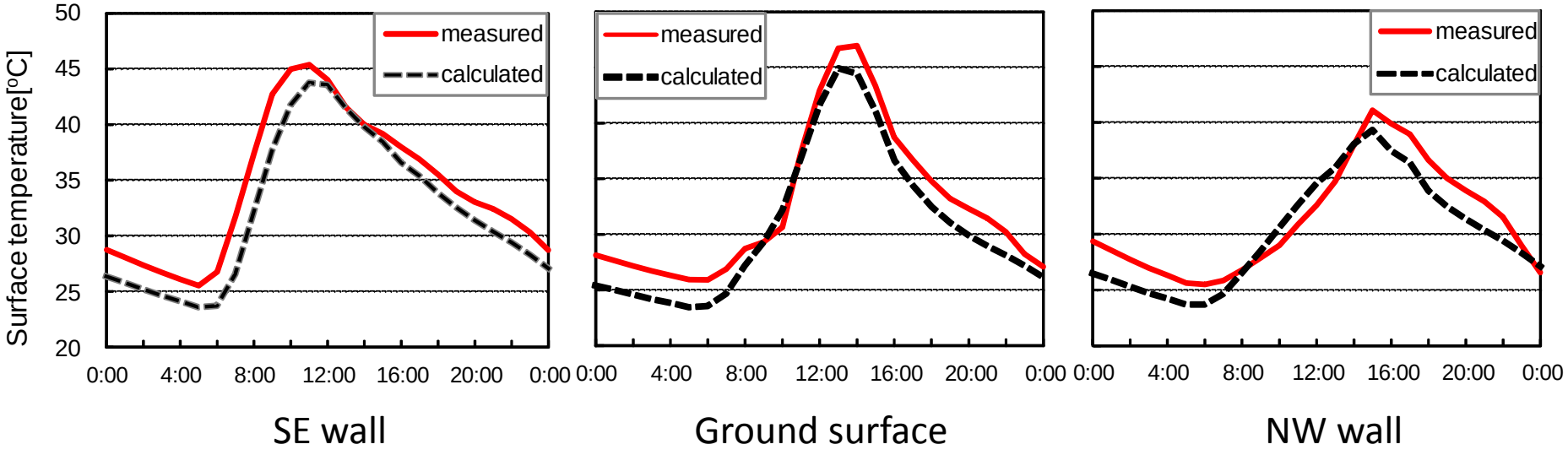
x - z

Thermal properties of the cubes and the ground

Materials	Ground		Concrete Cubes	Changed Surface	
	Concrete Slab	Soil		High Reflective	Greening
Thickness [mm]	150	1000	100	10	10
Albedo [-]	0.3	-	0.1	0.7	0.3
Emissivity [-]	0.9	-	0.9	0.9	0.9
Surface wetness [-]	0	-	0	0	0.7
Thermal conductivity [W/(m・K)]	1.6	2.0	1.6	1.6	1.6
Heat Capacity [kJ/(m^3・K)]	2300	3000	2300	2300	3000

These values were given from results of
the field measurement and the sensitivity analysis.

Comparisons of calculated surface temperature values with measured values in area CO

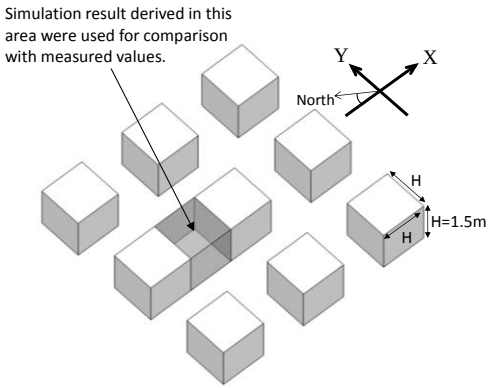


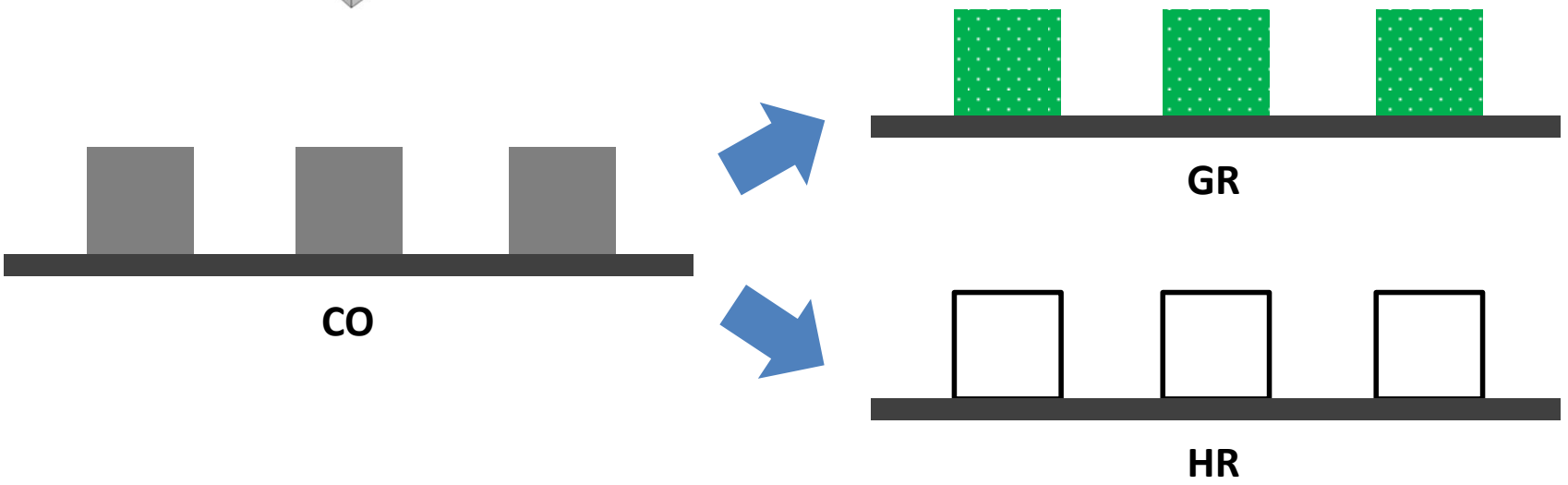
Calculated values from the three surfaces agreed fairly well with the measured value at each surface

However, predicted values were often slightly underestimated, although the magnitude of these differences was less than 3 °C

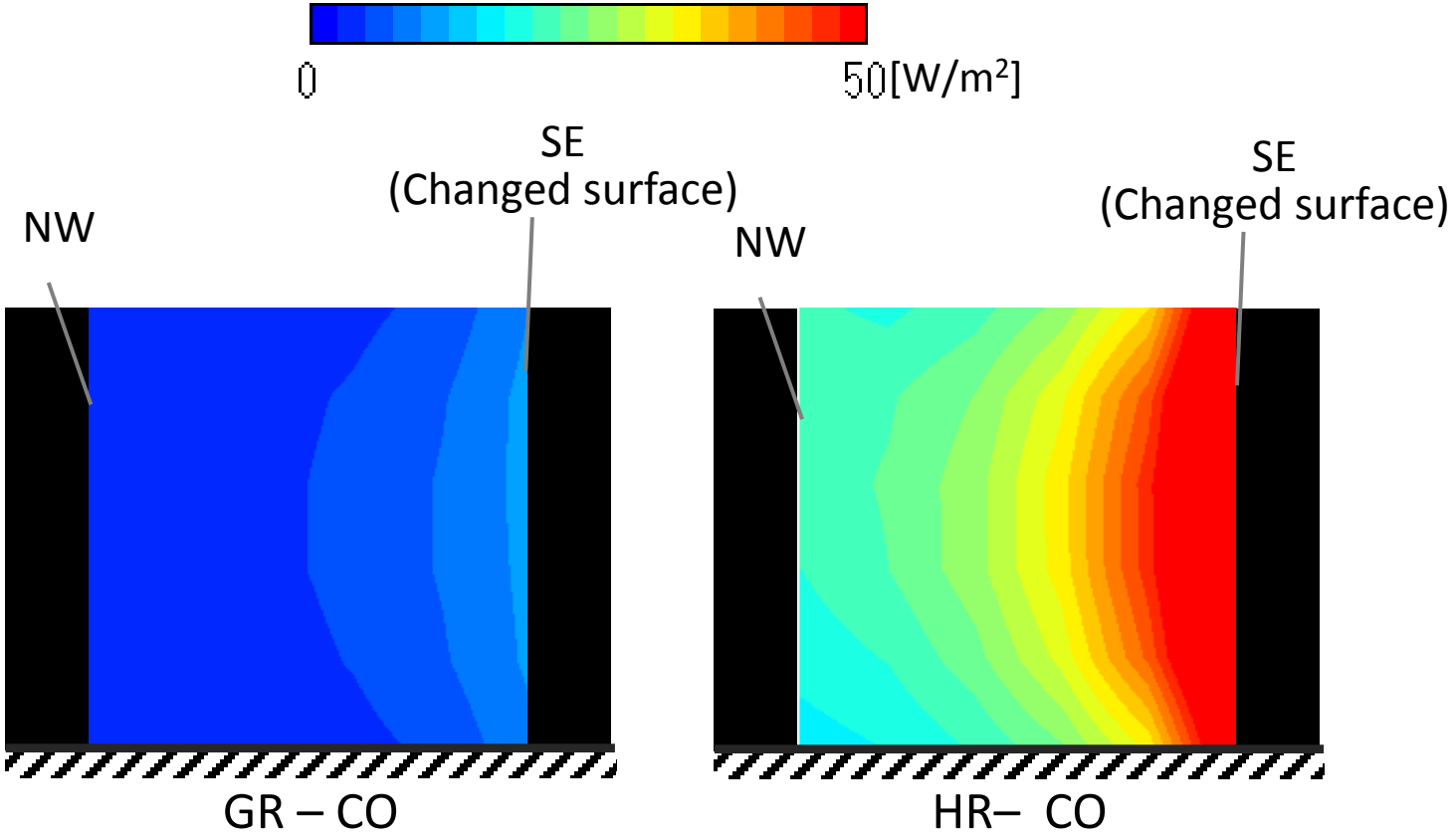
Thermal effects of greening and high reflective material

In order to assess the thermal effects of greening and high reflective material, the cases which changed all vertical surfaces of cubes in all computed domain to each material were calculated



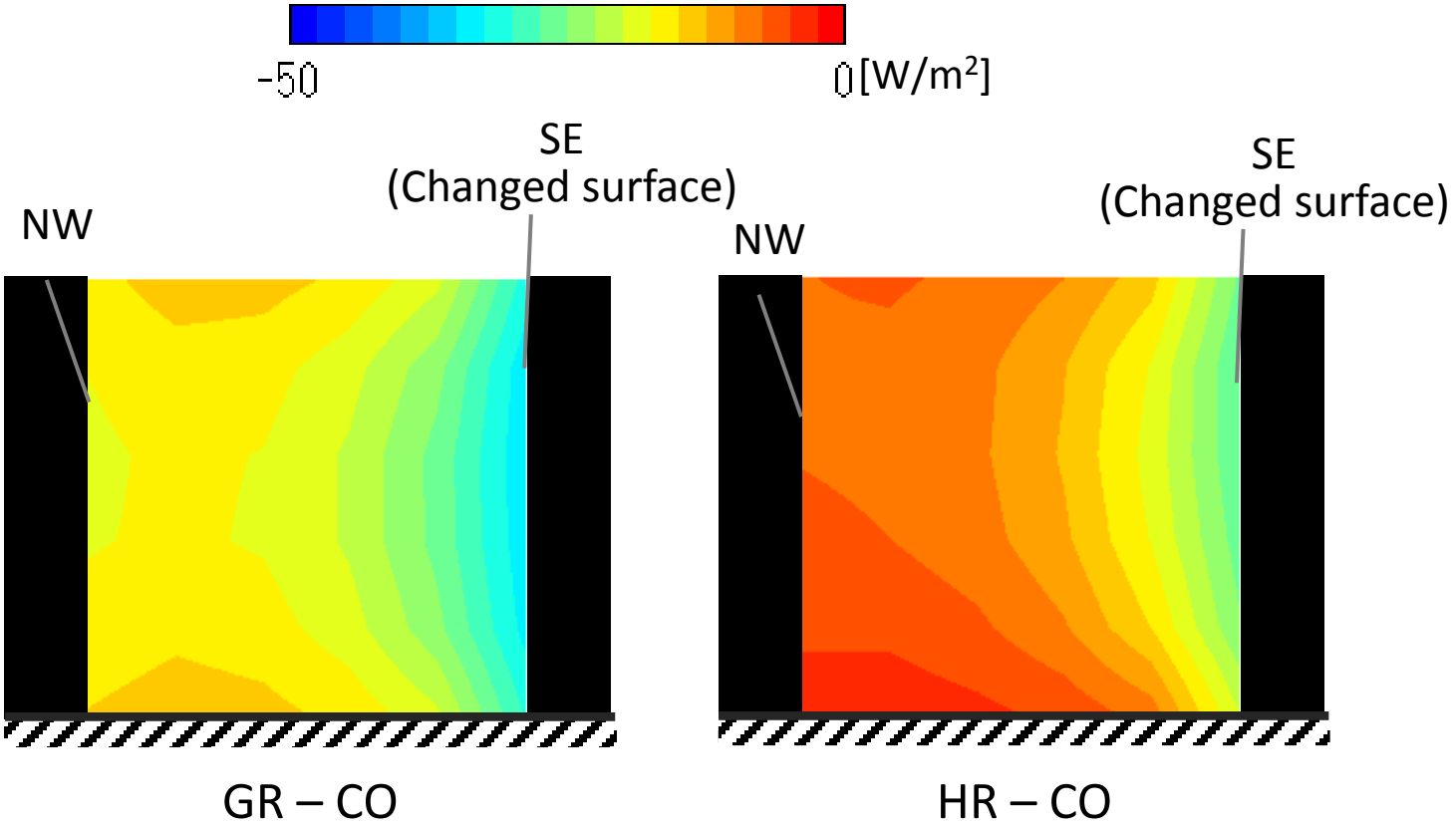


Comparison of short-wave radiation heat absorbed by a human body



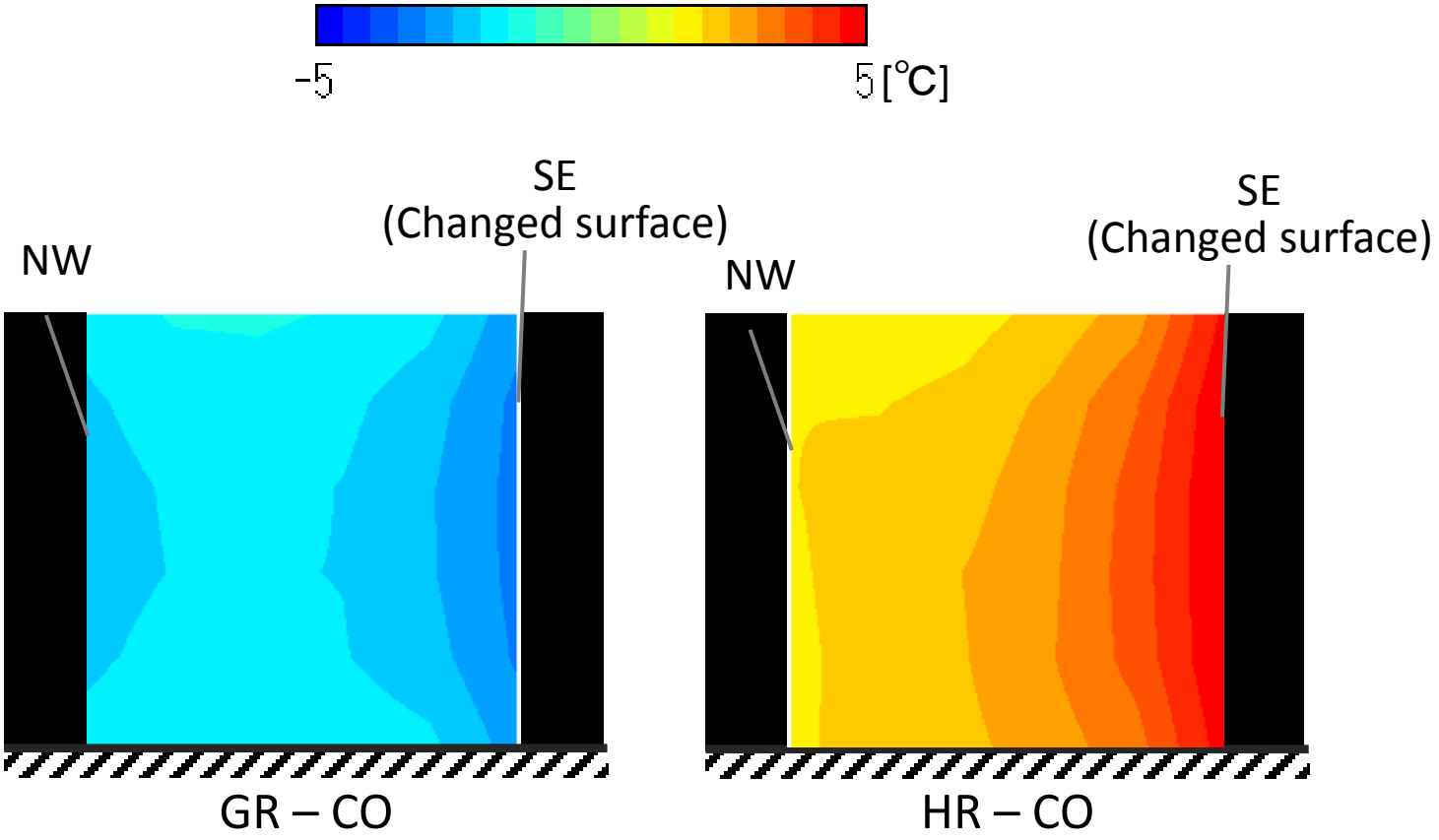
The amount of short-wave radiation absorbed by the human body of HR was much higher than CO.

Comparison of long-wave radiation heat absorbed by a human body



The much reduction in the amount of long-wave radiation absorbed by the human body of GR

Comparison of MRT



The MRT value of GR was lower on an average of 1.9 ^{o}C than CO.

The MRT value of HR was higher on an average of 2.7 ^{o}C than CO.

Conclusions

From the results of field measurement and radiation and conduction simulations,

- MRT values of greening wall were lower than grey painted concrete because much reduction of long-wave radiation.
- The high reflective surface increased MRT compared with grey painted concrete.
- Among the three cases compared, the radiant environment was evaluated to be the worst for the high reflective surface.

Thank you for your attention