Study on the effect of morphologic features and material properties on microclimatic development and pedestrian comfort

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1. Introduction

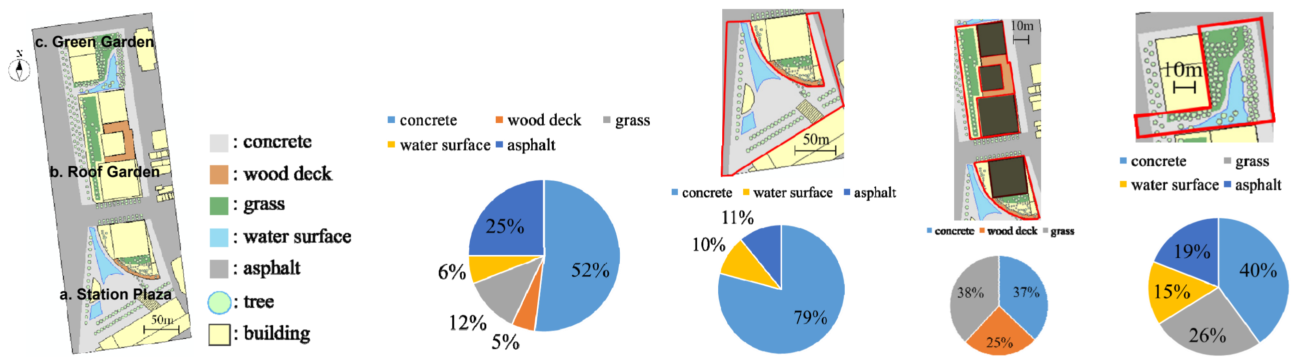
Several urban heat island measure technologies such as green cover and water surface are applied to the redevelopment buildings in front of central Osaka station, in Osaka, Japan. With regards to a previous study, Akagawa et al. (2011) analyzed the outdoor thermal environment of a rooftop garden on a large commercial building. In subsequent research, they also compared SET* at an area shielded by objects, trees, and semi-open spaces in a large, artificial green space. SET* was found to be lowest in semi-open spaces in the morning and evening, and in spaces shielded by trees in the daytime. The purpose of this study is to evaluate the effect of morphologic features and material properties on microclimatic development and pedestrian comfort, through the case study in the redevelopment buildings in front of Osaka station based on the observation and calculation.

2. Measurements

Measurement period is from 22 to 26 July 2013. Air temperature, relative humidity, surface temperature, wind direction and velocity, thermal image are measured by thermistor, capacitive humidity sensor, infrared thermometer, windsock, hot-wire anemometer, thermo-camera at 10:00, 13:00, 17:00, 20:00 at 5 or 6 measurement points in each area; a. Station Plaza, b. Roof Garden, c. Green Garden (Aoyama et al., 2014). Objective buildings, trees and covering materials arrangement and area ratio of each ground cover materials are shown in figure 1.

In Station Plaza, 6 measurement points are selected in consideration of the distance from water surface. In Roof Garden and Green Garden, 5 and 6 measurement points are selected in consideration of ground surface cover, ventilation and orientation, respectively.

In the daytime, air temperature is higher in the order of Station Plaza, Roof garden, Green Garden. In the night time, it is lowest in Roof garden. The difference of relative humidity is small. However, it is locally high at the measurement points near water surface in Station Plaza and Green Garden. Wind velocity is large in the daytime at several measurement points in Roof garden. In the daytime, the artificial ground surface temperature in Station Plaza and Roof garden is high due to solar radiation absorption.



Whole objective buildings and area ratio *a. Station Plaza* *b. Roof Garden* *c. Green Garden*

Fig.1 Objective buildings, trees and covering materials arrangement and area ratio of each ground cover materials

3. Solar radiation shield by buildings and trees

Evaluation results of hourly solar radiation shield by buildings and trees in Station Plaza and Green Garden are shown in figures 2 and 3.

In Station Plaza, the period obtained direct solar radiation is long, and direct solar radiation is shielded by the building behind the trees. At the measurement point 5 direct solar radiation is shielded by the west side low-rise building in the afternoon. It is also confirmed slightly at the measurement points 4 and 7.

In Green Garden direct solar radiation is shielded by the south side building especially at the measurement points 2, 4, 6 and 8. However, direct solar radiation shield is smaller at the measurement points 3, 5, 7 and 9 where are a little away from the south side building. It is limited to the neighborhood of the building. It is also shielded at the measurement points 16 to 18 and slightly shielded at the measurement points 26 to 28 by the west side building in the afternoon. Although in Green Garden, direct solar radiation is shielded by mainly buildings on the back of trees rather than trees at relatively large number of measurement points.

Daily integrated solar radiation shield and the distance from southern building are shown in figures 4 and 5. Relationship between the distance from south side buildings with the height of 45m and 154m and the daily integrated solar radiation shield is shown in figure 4. At the measurement points near the building corner, the daily integrated solar radiation shield is a little small. It is dominated only to the distance from the south side building on leaving more than 20m from the corner and it becomes zero in 6m from the south side 20m building, 12m from the south side 40m building, 45m from the south side 160m height building.

Since the daily integrated solar radiation shield is 2,000 W/m^2 or less (less than half of the daily integrated direct solar radiation no solar radiation shield) in the case that the distance from the south side building is larger than 10m, solar radiation shield by the trees is required in the range of more than 10m from the south side building.

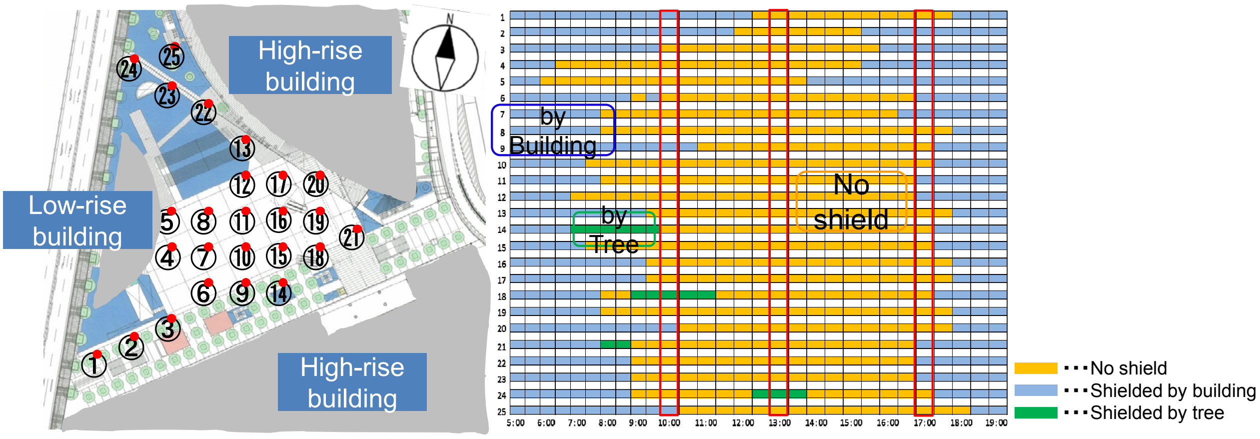


Fig. 2 Evaluation results of hourly solar radiation shield by buildings and trees in Station Plaza

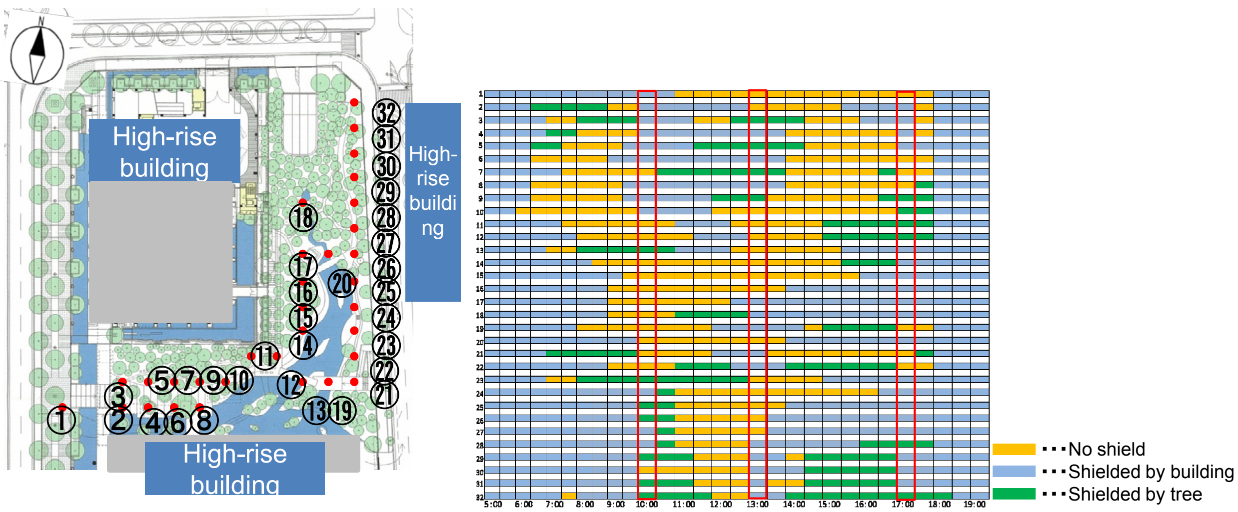


Fig. 3 Evaluation results of hourly solar radiation shield by buildings and trees in Green Garden

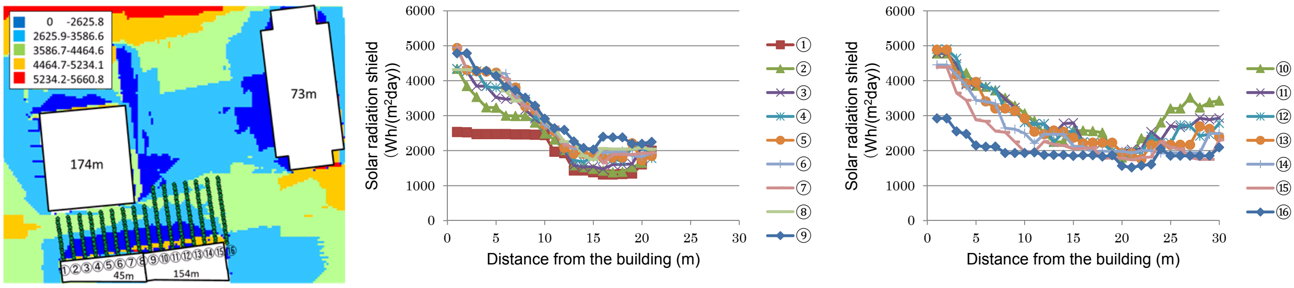


Fig. 4 Daily integrated solar radiation shield and the distance from southern building

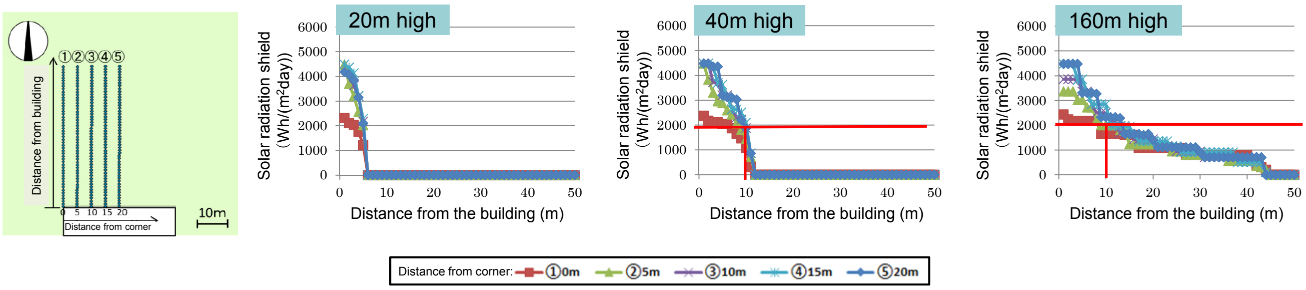


Fig. 5 Daily integrated solar radiation shield and the distance from southern building with several heights

4. Discussion of SET* distribution

Surface temperature, MRT, wind velocity and SET* distribution at 13:00 on typical summer day (July 25, 2013) is shown in figure 6. We set a metabolic rate of 2.0 Mets, with the assumption of a certain walking place, and we set the amount of clothing at 0.6 clo, assuming the use of summer clothes. Both surface temperature and MRT are especially higher on the wood deck and asphalt surface. SET* is higher where surface temperature and MRT are higher. Effect on SET* by wind velocity is not clearly confirmed.

Aoyama et al. (2014) have carried out a sensitivity analysis by wind velocity and MRT to SET* at 10:00, 13:00, 17:00, 20:00, by using the measurement data. Effects of MRT and wind velocity on SET* at 13:00 on typical summer day are shown in figure 7. Left figure shows the analysis results by observation data and right figure shows that by calculation data. Indications from comfortable to discomfort are based on the study results of Ishii et al. (1988) In Station Plaza, MRT is high and the variation in wind velocity is large. In Roof Garden, MRT is also high, while the wind velocity is generally high. In Green Garden, the variation in MRT is large as well, but the wind velocity is low.

Diurnal variations of surface temperature and MRT on August 11, 2013 are shown in figure 8. The improvement of the surface cover material to such as grass or water is effective for the heat island mitigation, ie surface temperature reduction. Because the solar radiation shield by trees is limited in specific time. Solar radiation shield by trees or buildings is effective for the thermal environment improvement, ie MRT reduction. However, it is severe even in the shaded points on typical summer day. Not only the improvement of the surface cover material and the solar radiation shield, the control of air temperature by such as the mist is also necessary.

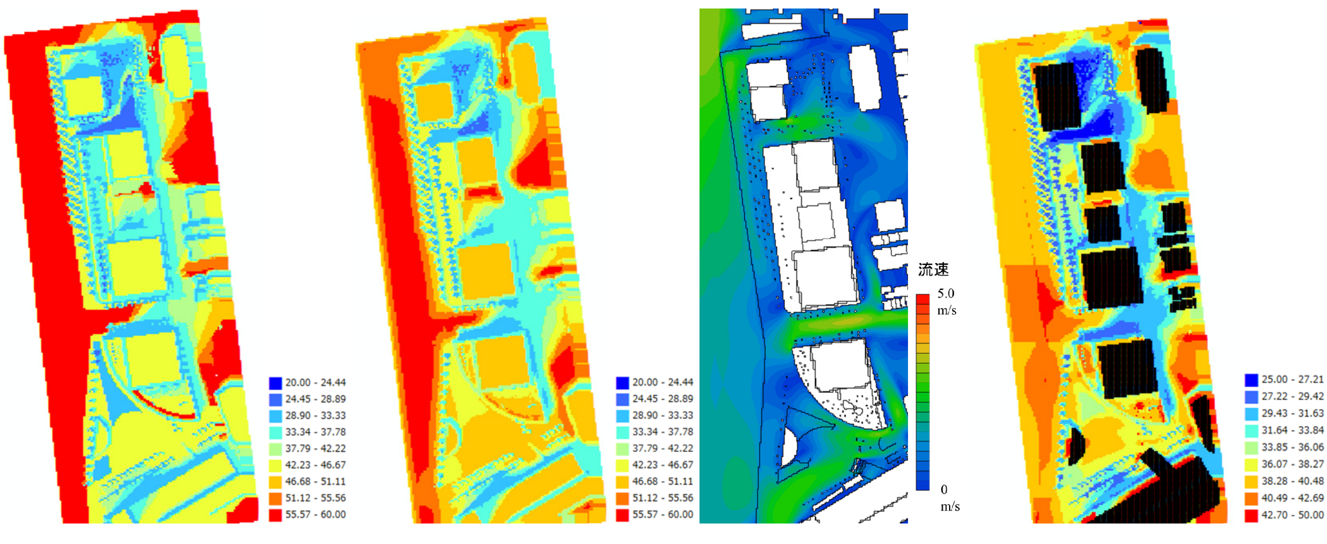


Fig.6 Surface temperature, MRT, wind velocity and SET distribution at 13:00 on typical summer day*

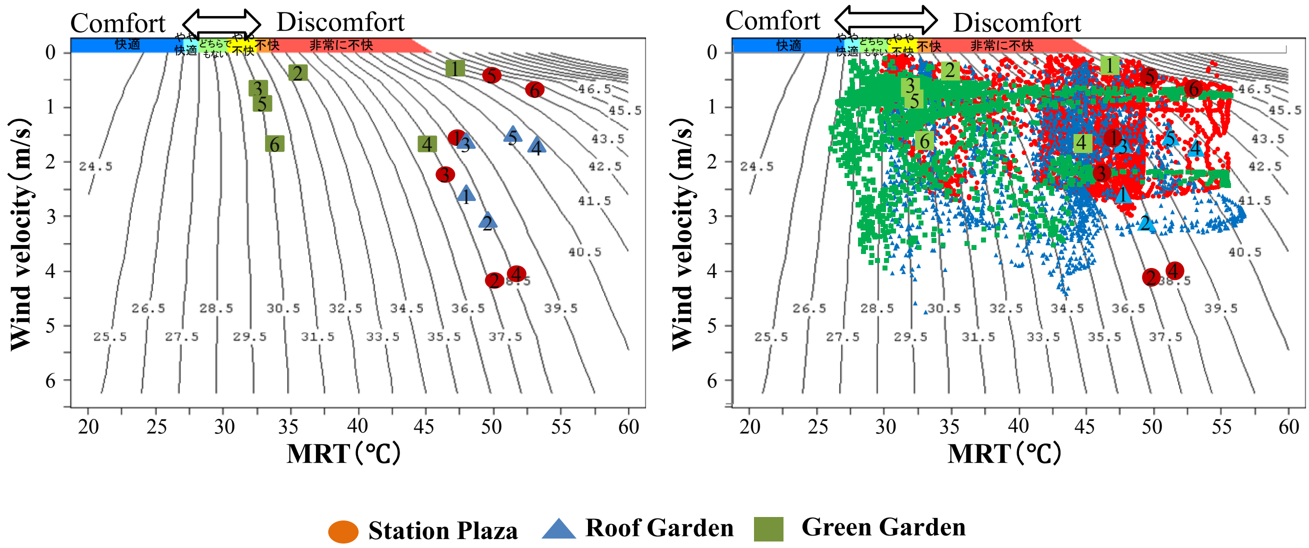


Fig.7 Effects of MRT and wind velocity on SET at 13:00 on typical summer day (left: observation, right: calculation)*

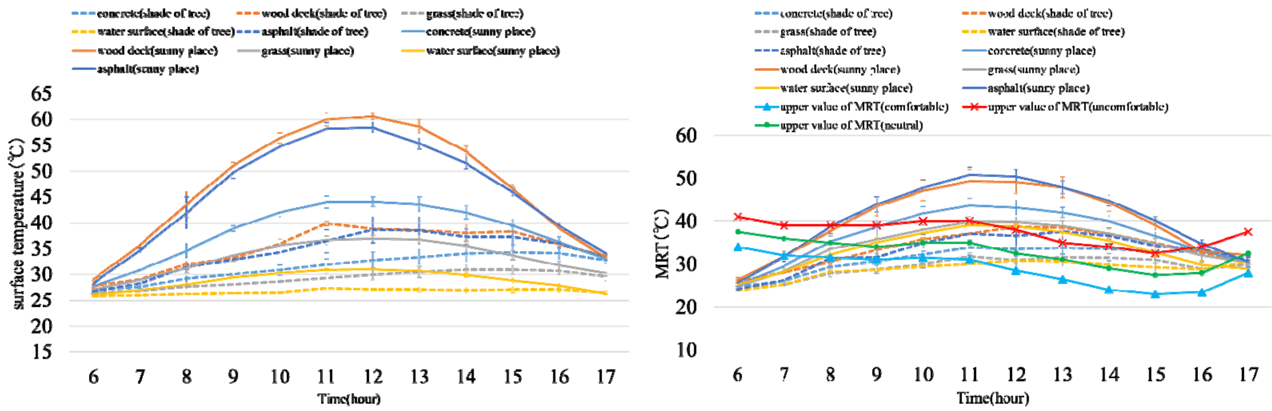


Fig.8 Diurnal variations of surface temperature and MRT on typical summer day

5. Summery

The effects of morphologic features and material properties on microclimatic development and pedestrian comfort are evaluated, through the case study in the redevelopment buildings in front of Osaka station based on the observation results and calculation. In both Station Plaza and Green Garden, direct solar radiation is shielded by mainly buildings on the back of trees rather than trees. Solar radiation shield by the trees is required in the range of more than 10m from the south side building, based on the relationship between the distance from south side buildings and the daily integrated solar radiation shield. In Station Plaza, MRT is high and the variation in wind velocity is large. In Roof Garden, MRT is also high, while the wind velocity is generally high. In Green Garden, the variation in MRT is large as well, but the wind velocity is low. The improvement of the surface cover material to such as grass or water is effective for the mitigation of urban heat island, ie surface temperature reduction. Solar radiation shield by trees or buildings is effective for the improvement of outdoor thermal environment, ie MRT reduction.

Acknowledgment

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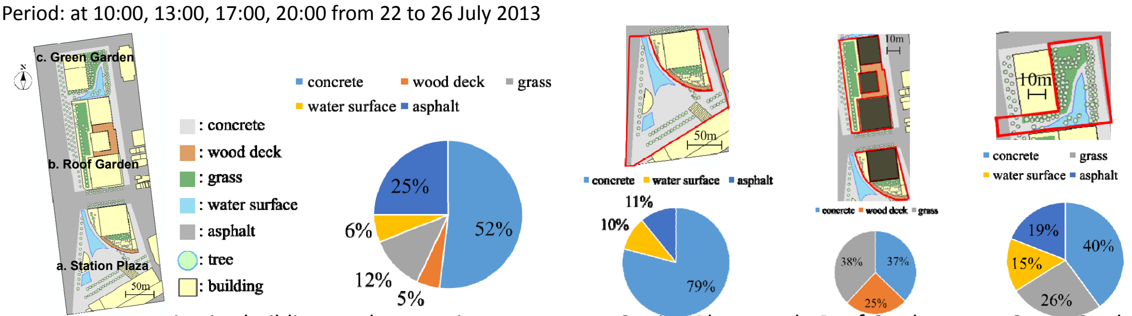
Measurements

Elements: Air temperature, relative humidity, surface temperature, wind direction and velocity, thermal image
Period: at 10:00, 13:00, 17:00, 20:00 from 22 to 26 July 2013



Whole objective buildings and area ratio a. Station Plaza b. Roof Garden c. Green Garden
Objective buildings, trees and covering materials arrangement and area ratio of each ground cover materials

Solar radiation shield by buildings and trees

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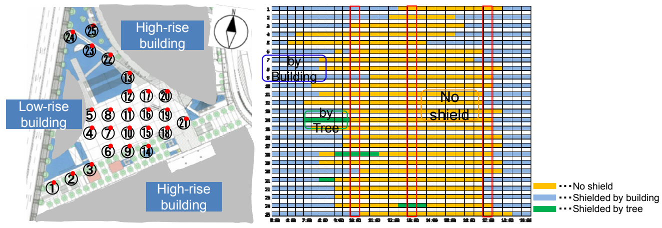
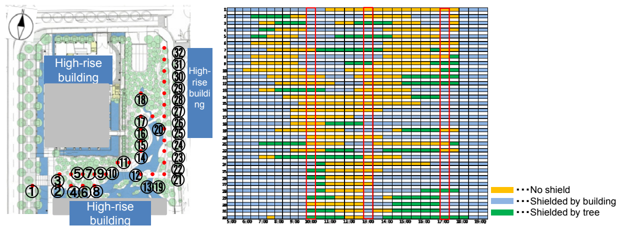
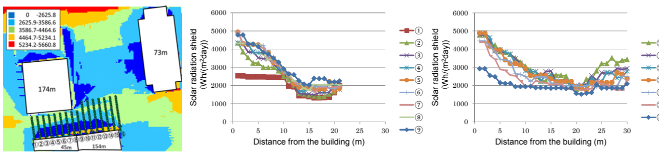


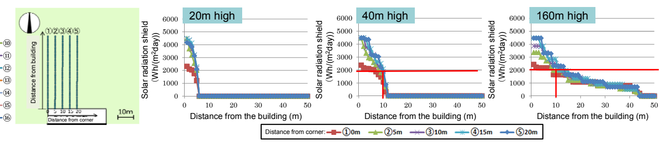
Evaluation results of hourly solar radiation shield by buildings and trees in Station Plaza



Evaluation results of hourly solar radiation shield by buildings and trees in Green Garden



Daily integrated solar radiation shield and the distance from southern building



Daily integrated solar radiation shield and the distance from southern building with several heights

Discussion of SET* distribution

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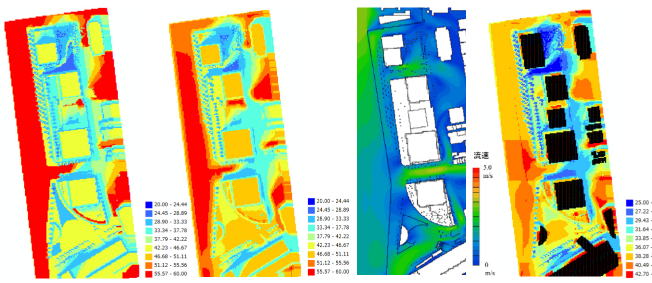
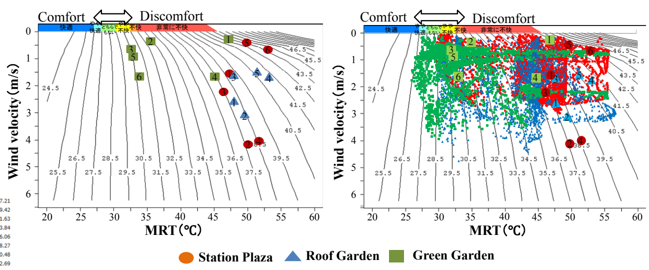
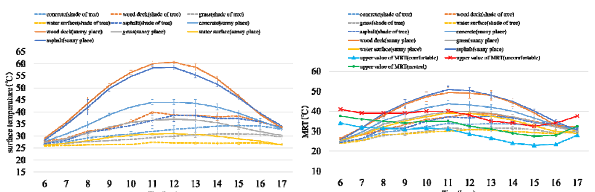


Surface temperature, MRT, wind velocity and SET* distribution at 13:00 on typical summer day



Effects of MRT and wind velocity on SET* at 13:00 on typical summer day (left: observation, right: calculation)



Diurnal variations of surface temperature and MRT on typical summer day

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