A contribution to the summertime heat improvement in a marathon course by application of radiate and airflow simulation

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Introduction / back Ground

■ UHI simulation models (so many)

✓ Meso-scale model
✓ Urban Canopy model
✓ CFD

} non steady state condition

→ mainly, steady state condition

■ Outdoor thermal sensation

✓ Air temperature, humidity
✓ Velocity
✓ Radiation (short & long wave)

⇔ non steady state / steady state

Outline of the system developed

Meso-scale model (JMA)

400km × 400km@2km

Boundary condition

Urban district model (NILIM)

Thermal airflow

Radiation

Indoor climate

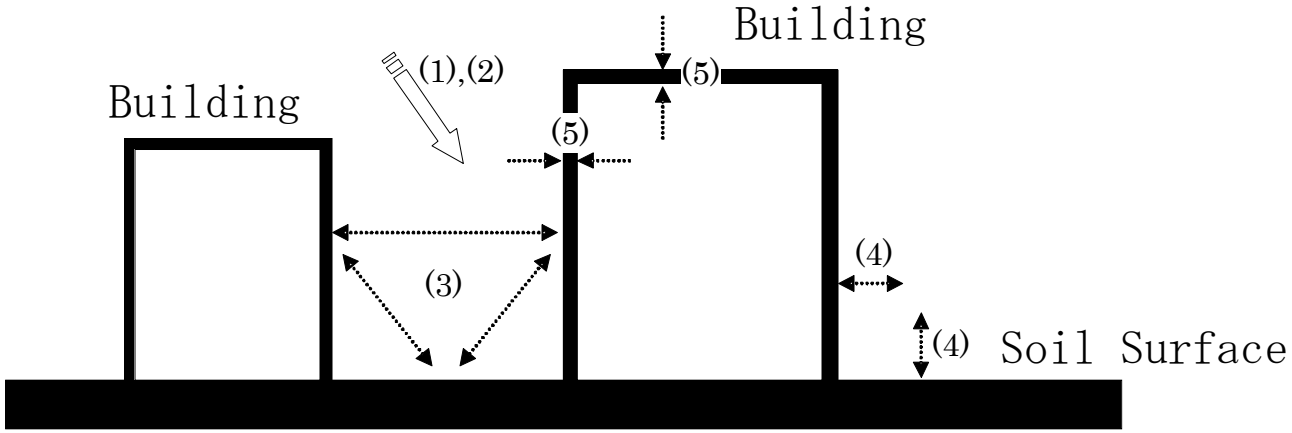
1000m × 1000m@5m

Outputs

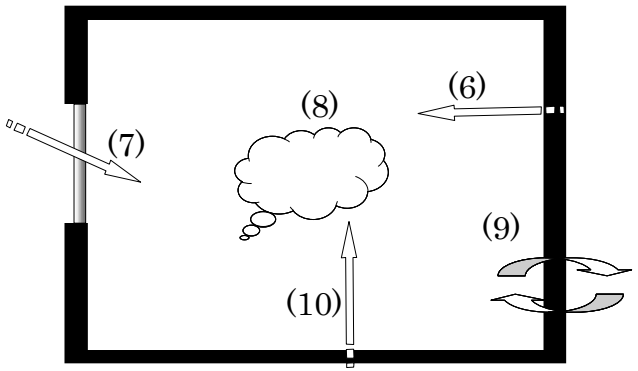
Thermal sensation model (several types)

- ✓SET*
- ✓WBGT etc.

Heat balance model of urban surfaces coupling Indoor climate



(a)Heat balance of urban surfaces.



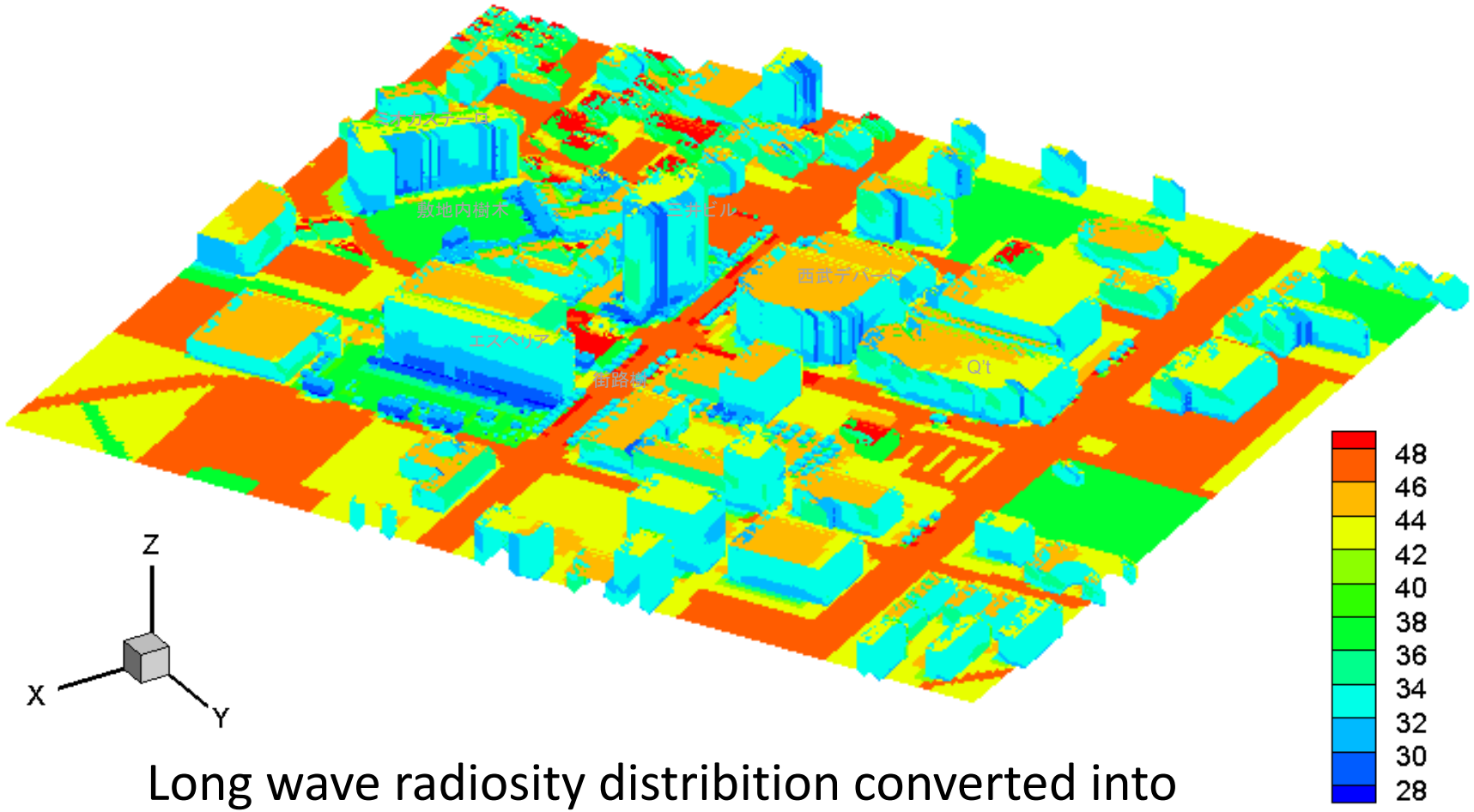
(b)Indoor climate

(1) Short wave radiation
(2) Long wave atmospheric radiation
(3) Mutual radiative exchange
(4) Sensible and latent heat
(5) Heat conduction
(6) Heat convection
(7) Sun inlet
(8) Heat generation
(9) Ventilation
(10) Heat released from floor

Characteristics of the simulation code

Item	Description
Flow field	Compressible compound flow under a low Mach number condition
Governing equations	•Continuity equation •Momentum equations (Effects of buoyancy, Coriolis force, and drag forces of plants are taken into account.) •Energy equation (Formulated using potential temperature. Release of sensible heat from artificial sources, walls, etc. is taken into account.) •Transport equation for water vapor (Formulated using specific humidity. Release of latent heat from artificial sources, wall, etc. is taken into account.) •Transport equation for turbulent kinetic energy, k (Production of turbulent energy by buoyancy, humidity, and plants is taken into account.) •Transport equation for dissipation rate of k, ε (Dissipation of turbulent kinetic energy by buoyancy, humidity, and plants is taken into account.) **All equations are formulated based on FAVOR method in order to take into account the effects of the sub-grid scale parts of the ground and buildings.
Turbulence model	Standard k- ε model
Coordinate system	3-dimensional Cartesian coordinate system
Computational grid	Staggered grid
Discretization method	Finite difference method
Spatial discretization	1st order upwind differencing scheme (For convection term.), 2nd order central differencing scheme (Except for convection term.)

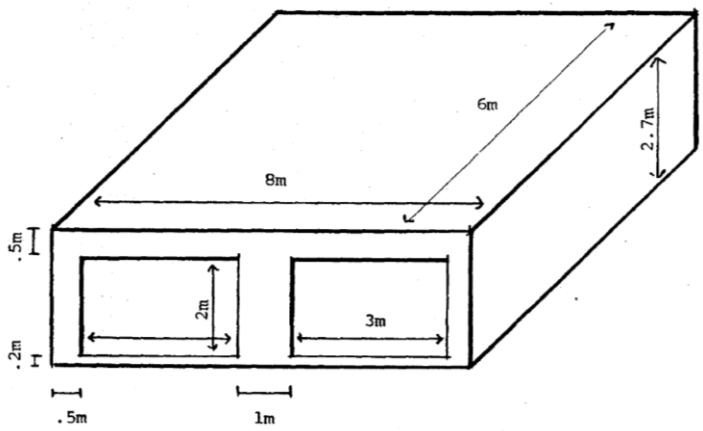
Example of surface temperature distribution

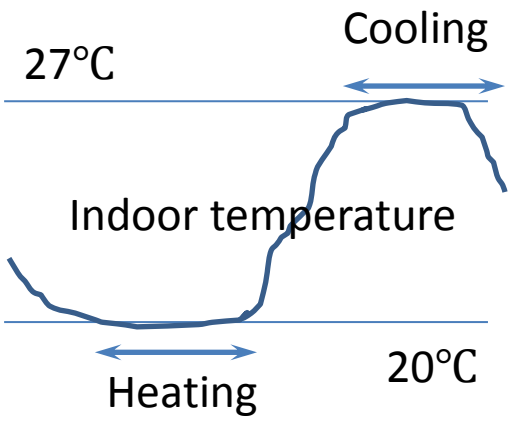


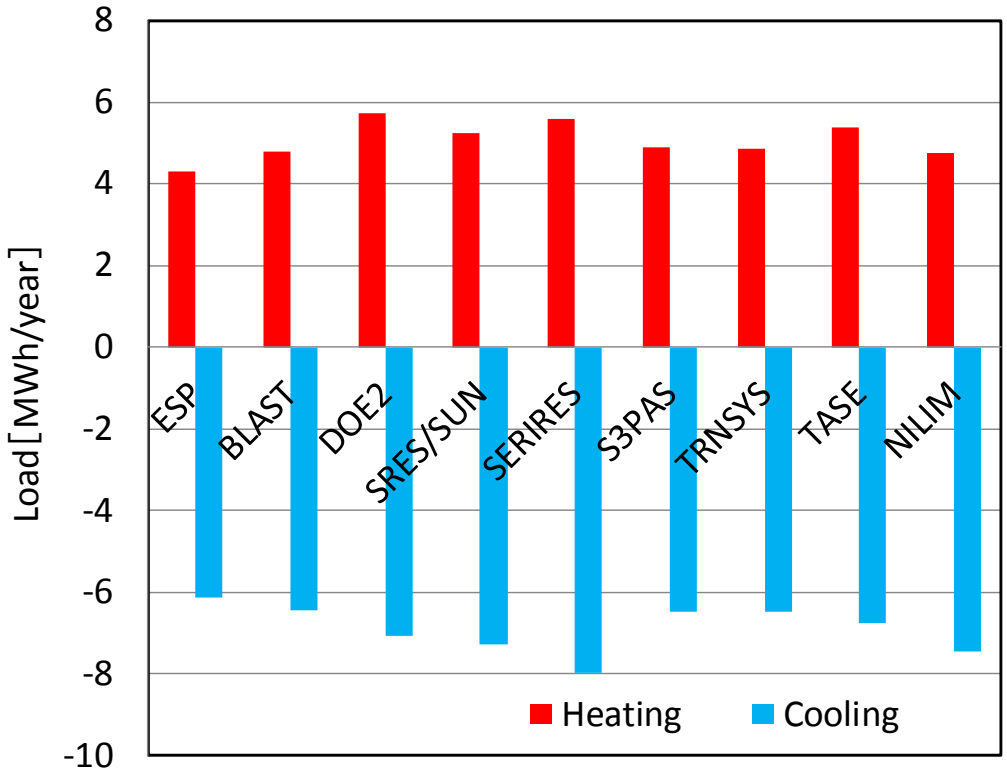
Long wave radiosity distribition converted into surface temperature distribution

Benchmark Test for heating and cooling loads

~ Building Energy Simulation Test ~

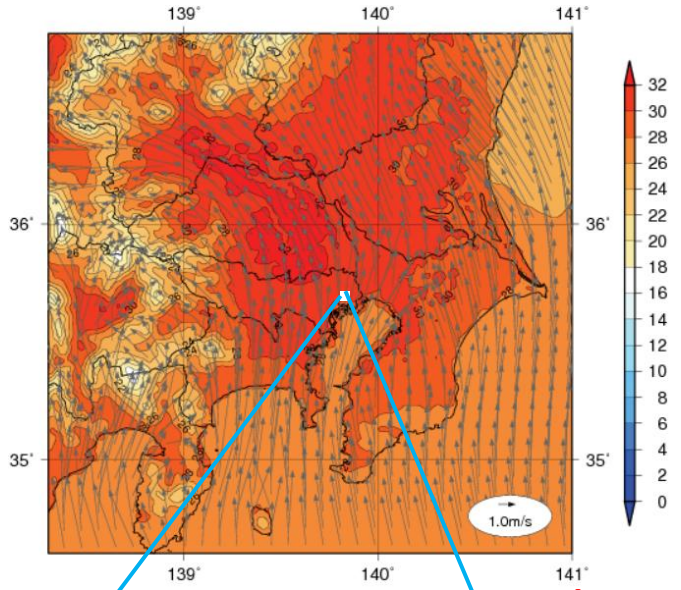




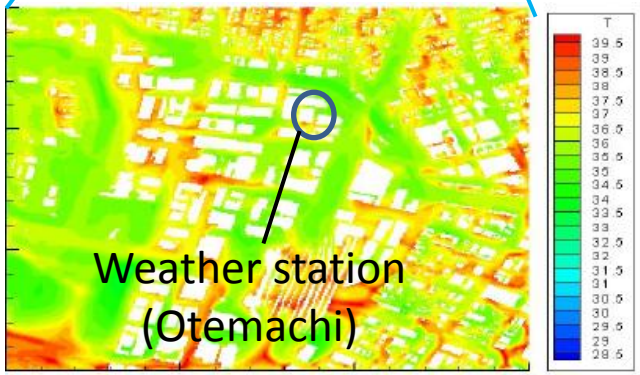


Simulated Heating and cooling loads

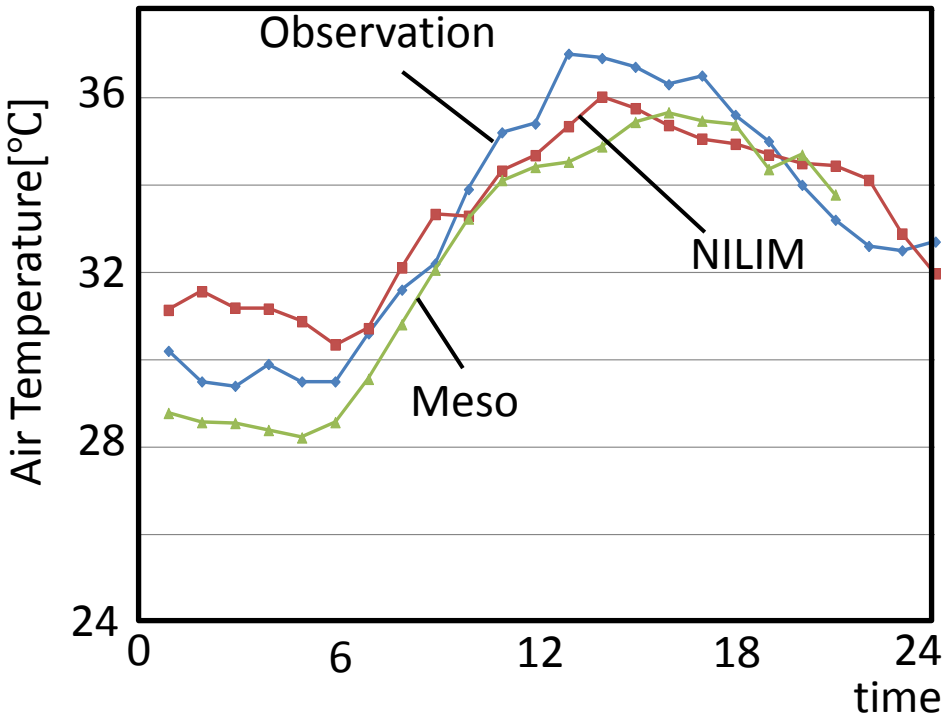
Validation of CFD simulation in urban areas



Meso-scale model (JMA)



Urban district model (NILIM)

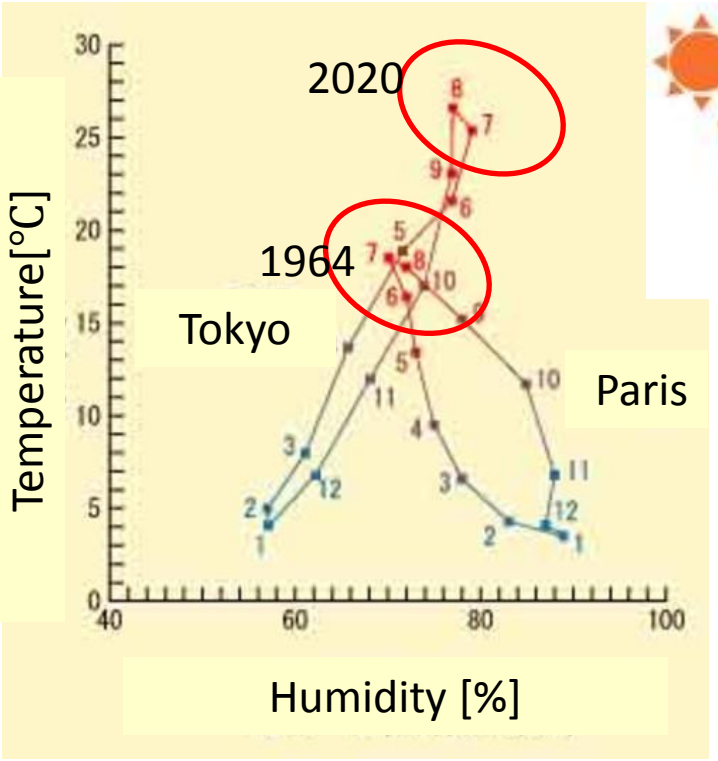


Daily change of air temperature on 10 Aug, 2013

Tokyo Olympic game 2020

Tokyo(1964) 10 Oct - 24 Oct

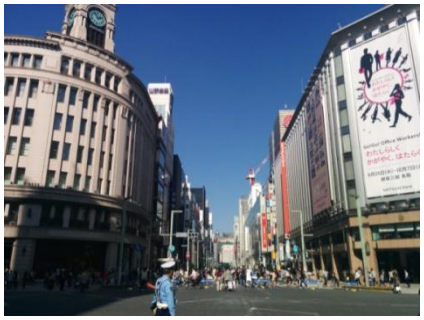
Tokyo(2020) 24 July – 9 Aug



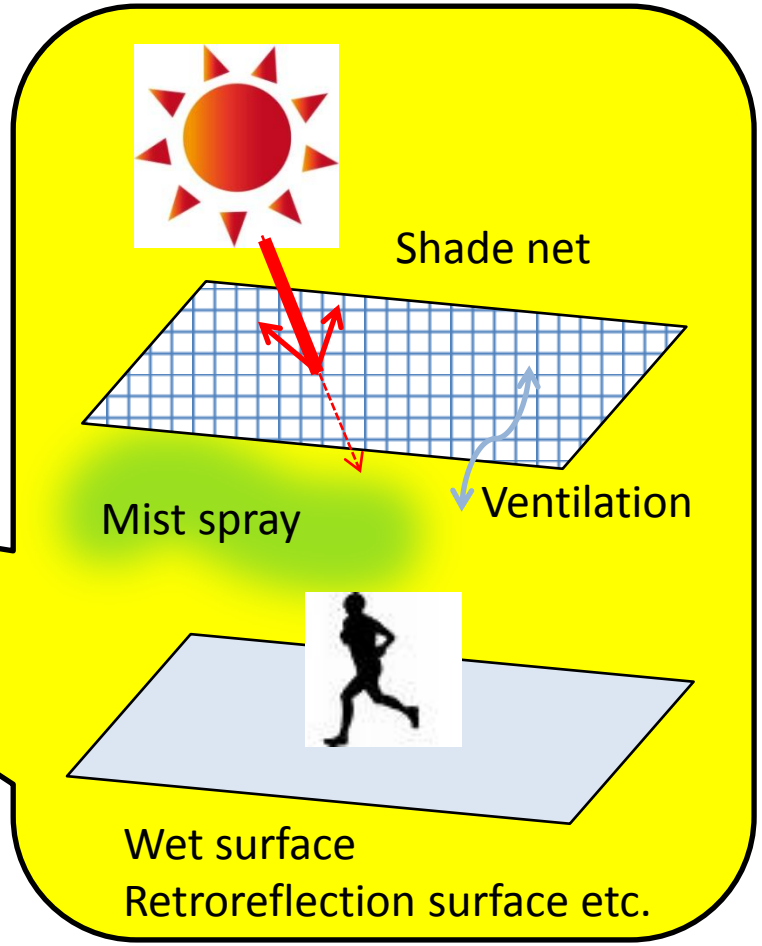
Heat countermeasures at the marathon course

Start & goal

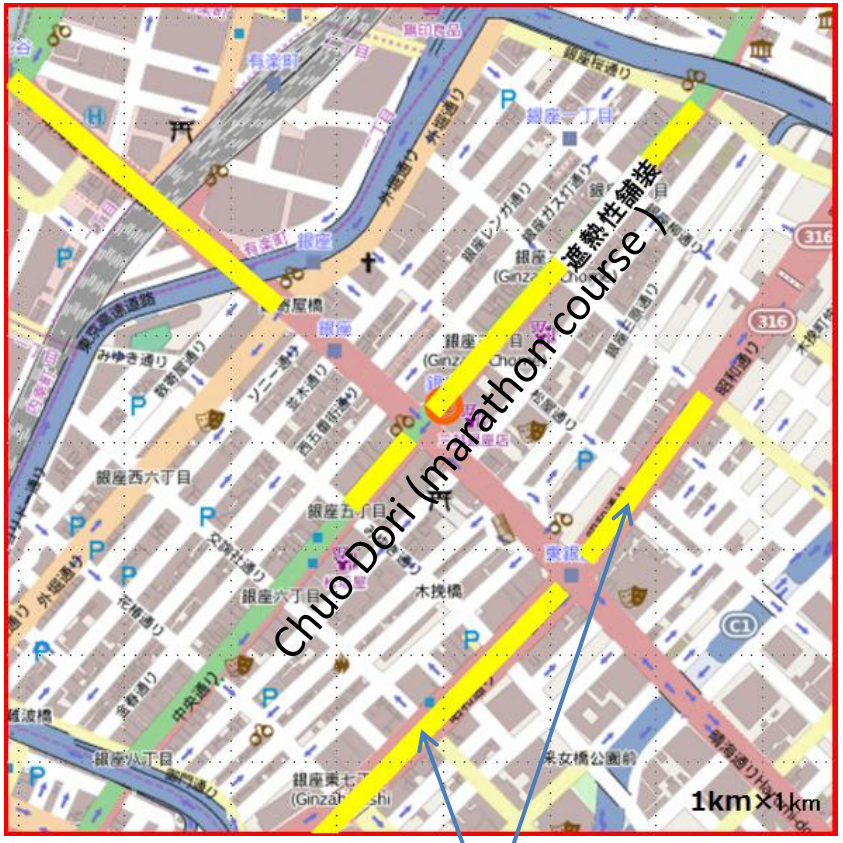
Turn



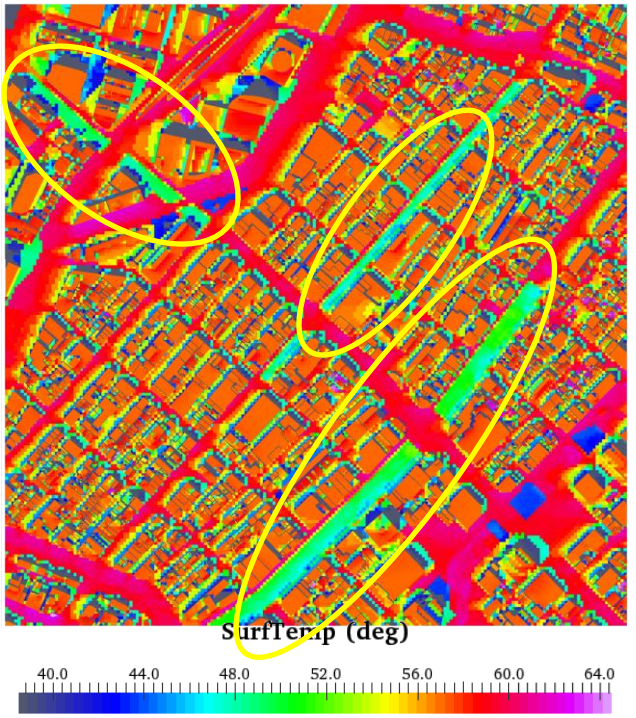
Sample area
(1000m × 1000m)



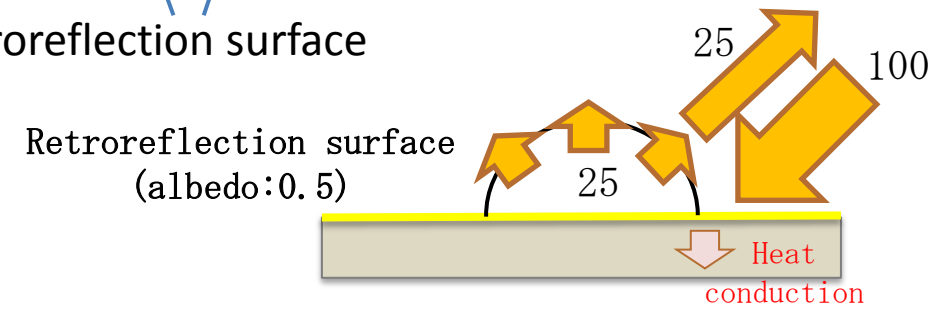
Present situation 1



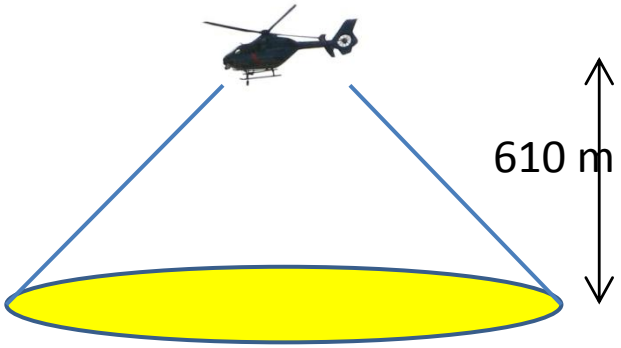
Retroreflection surface

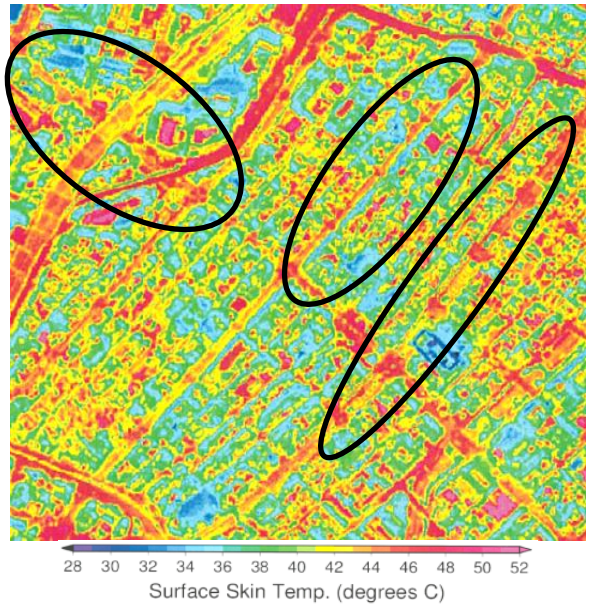


Simulated surface temperatures at 13:00 on 19 Aug, 2013

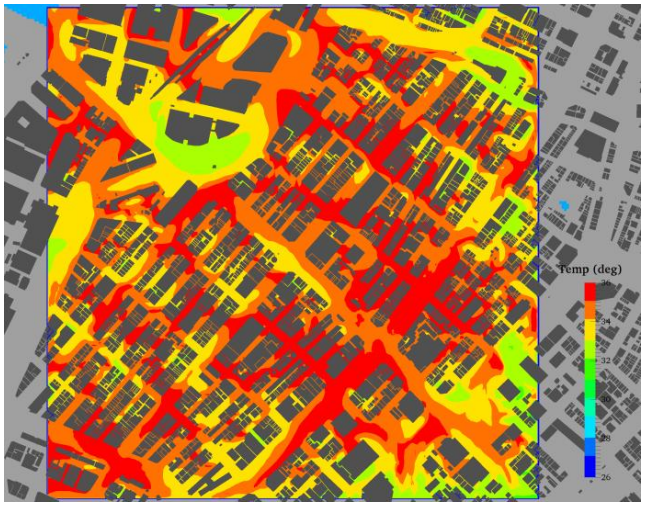


Present situation 2

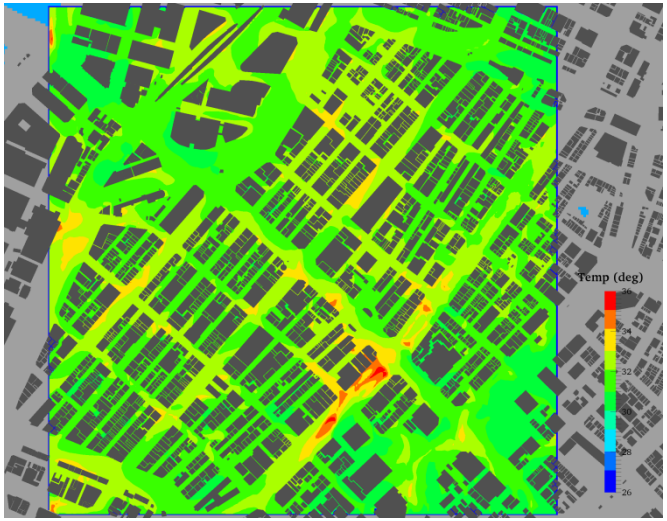




Measured Surface temperatures at 12:00-13:00 on 19 Aug, 2013



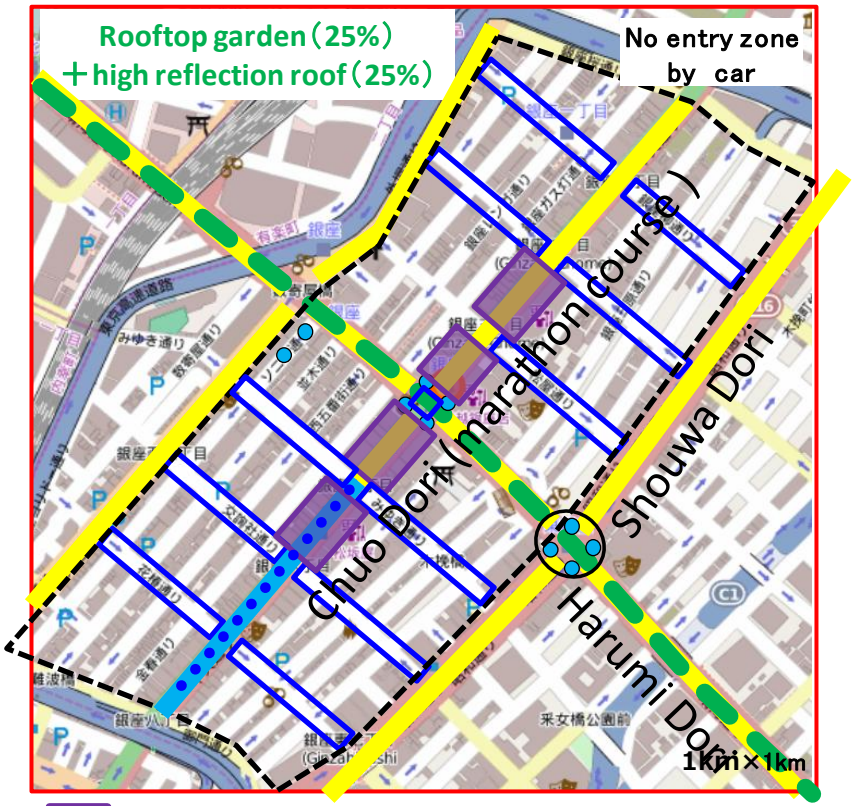
(a) 13:00

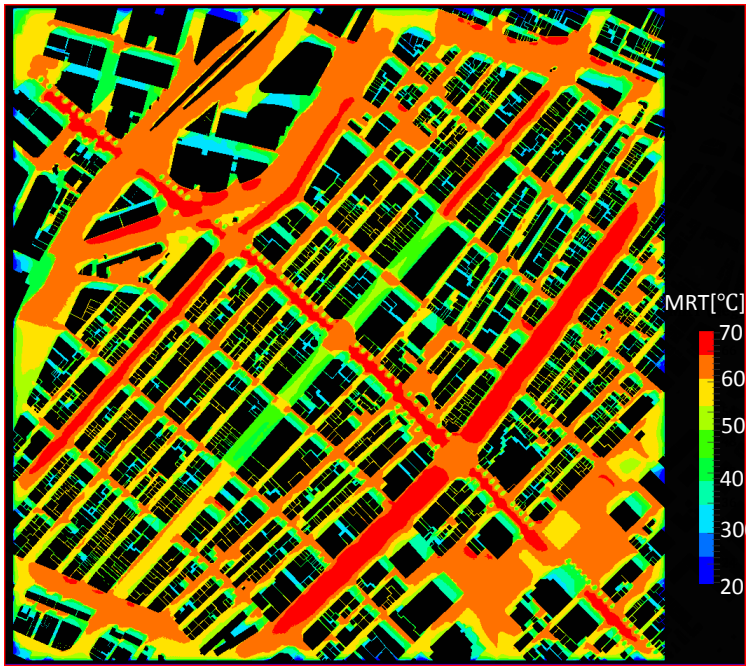


(b) 9:00

Simulated air temperatures on 19 Aug, 2013

After the Countermeasures 1





Simulated MRT at 13:00 on 19 Aug, 2013

Shade sheet

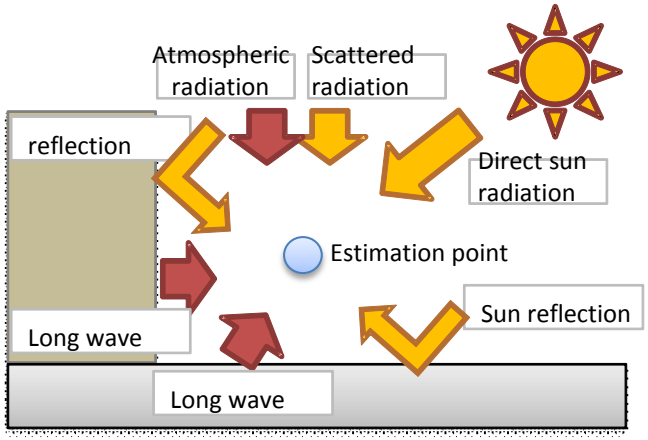
sprinkle water

Retroreflection surface

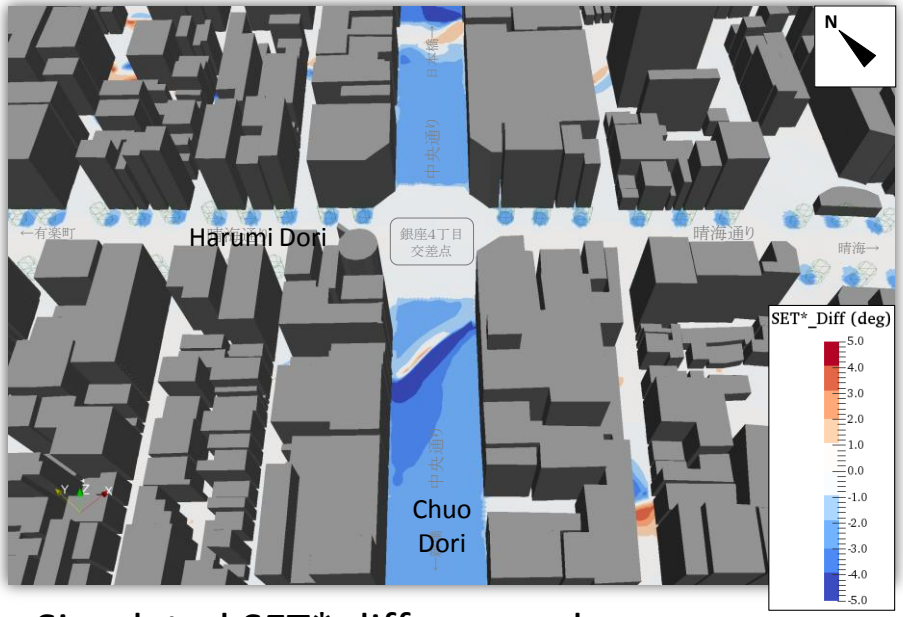
Water retentive pavement

Mist spray

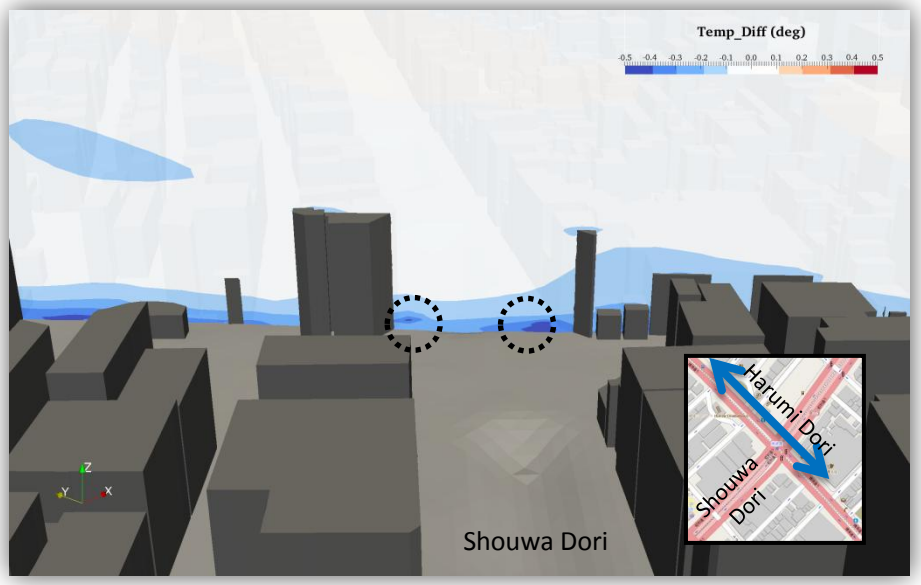
tree



After the Countermeasures 2

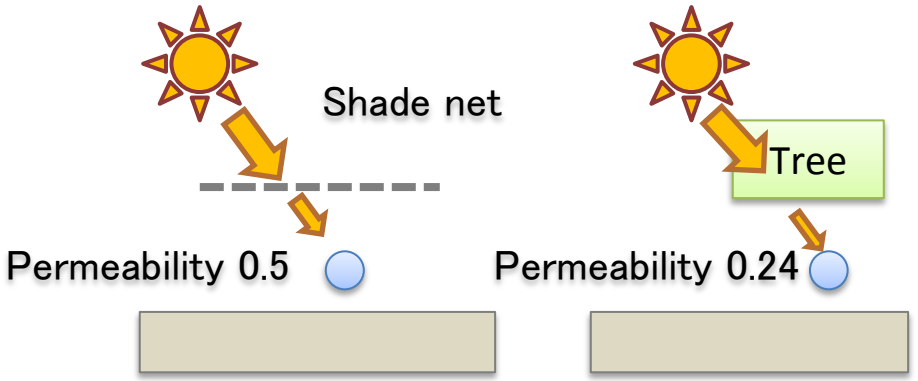


Simulated SET* differences by countermeasures at 13:00 on 19 Aug, 2013



Simulated air temperature differences by countermeasures at 13:00 on 19 Aug, 2013

Example using net to the streets (Malaga, Spain)



Conclusion

- Urban district model has been developed to estimate daily air temperatures and thermal sensation considering urban complex morphologies.

- Heat environment at the marathon course in Tokyo was simulated to clarify the thermal effects by UHI countermeasures.

Thank you