Impact of global warming on the sensible heat load in a detached house in Tokyo in the 2030s

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Background

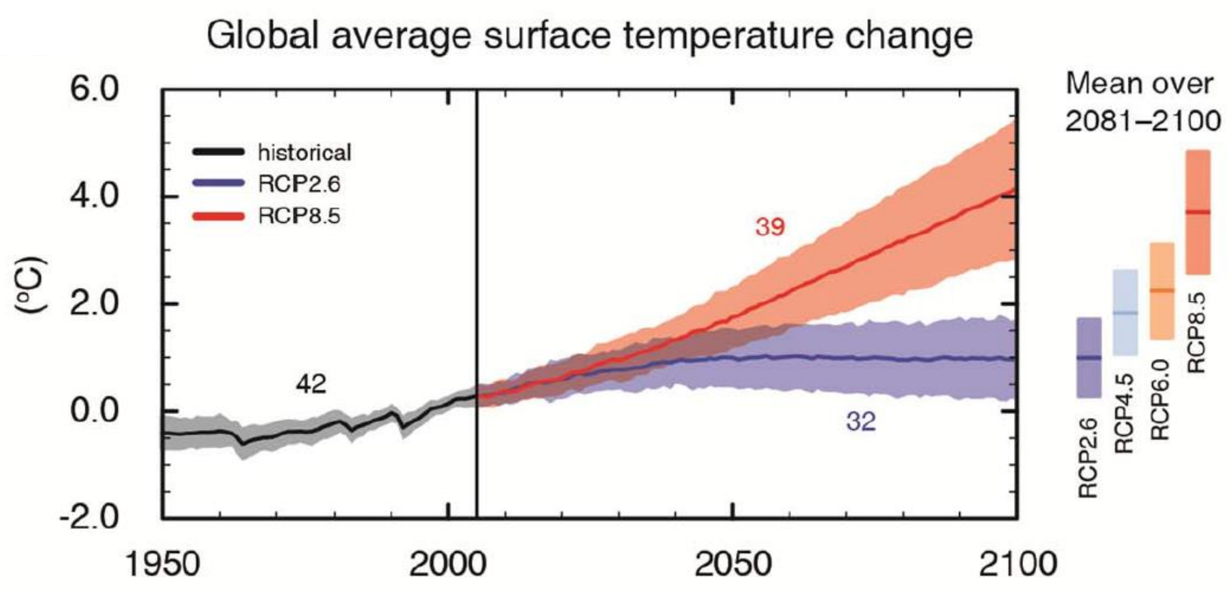
- Global warming and urban heat islands promote an increase in energy consumption for air-conditioning of buildings in summer periods.
- Building energy simulations (BESs) are used in design process of buildings to estimate their energy consumption.
- BESs require regional climate and weather data.
- Most buildings are used for several decades, over which the climate will gradually change.

Present design process of buildings

- Weather data based on observations
  > Design adopting to the **past** and present climate
- **Not** optimized to climate situation in which designed buildings will actually be used

Ideal design process of buildings

- Weather data based on future climate
  > Design adopting to the present and **future** climate



IPCC 5th Assessment Report (2013)

Purpose of this study

- Developing near-future weather data using the dynamic downscaling method of numerical climate models
- BES with weather data obtained from the downscaling simulation
- Assessing the impact of climate change on the sensible heat loads in a detached house in Tokyo in summer in the 2030s

Dynamical downscaling for near-future weather data

Global Climate Model (GCM)

- Analysis of climate of whole the earth
- **Good:** Prediction of macroscale climate change (e.g. the global warming)
- **Bad:** Coarse grid resolution (~ 100 km)

Regional Climate Model (RCM)

- Analysis of climate of mesoscale
- **Good:** Sufficiently fine grid resolution (~ 1 km)
- **Bad:** Unable to contain macroscale climate change

Dynamical Downscaling from GCM to RCM

- GCM data provides initial and boundary conditions for RCM
- RCM downscales macroscale climate data based on physical processes
- Results contain both of the global and local climate phenomena

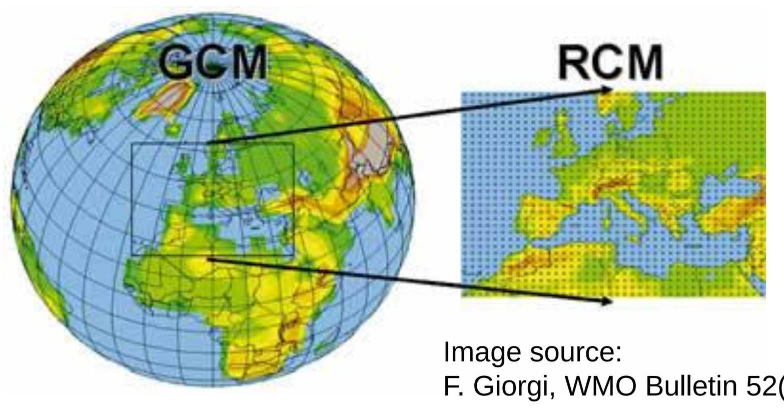


Image source:
F. Giorgi, WMO Bulletin 52(2), April 2008.

Dynamical downscaling

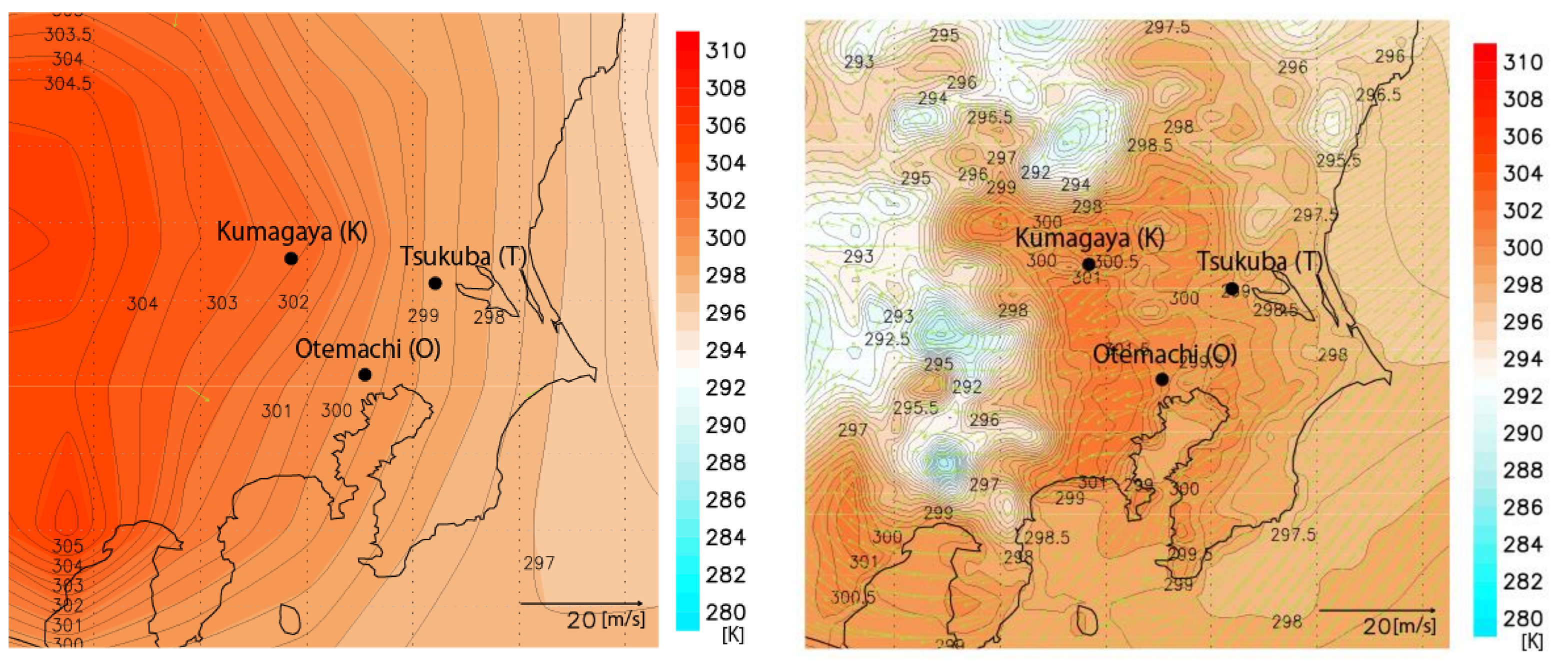
Method: Dynamical downscaling

GCM: MIROC4h data

- Model for Interdisciplinary Research On Climate (CCSR et al.) [1]
- Results of
  - Present case: 2006–2010 predicted from 1981
  - 2030s case: 2031–2035 predicted from 2006
- Grid resolution: 60 km
- Green house gas concentration scenario: RCP4.5 (Medium-low)

RCM: WRF analysis

- Weather Research and Forecasting model ver. 3.4 (NCAR) [2]
- 4 levels nesting (Grid resolutions: 54, 18, 6, 2 km)
- Initial & Boundary conditions from MIROC4h data
- Analysis period:
  - Present case: August in 2006–2010
  - 2030s case: August in 2031–2035

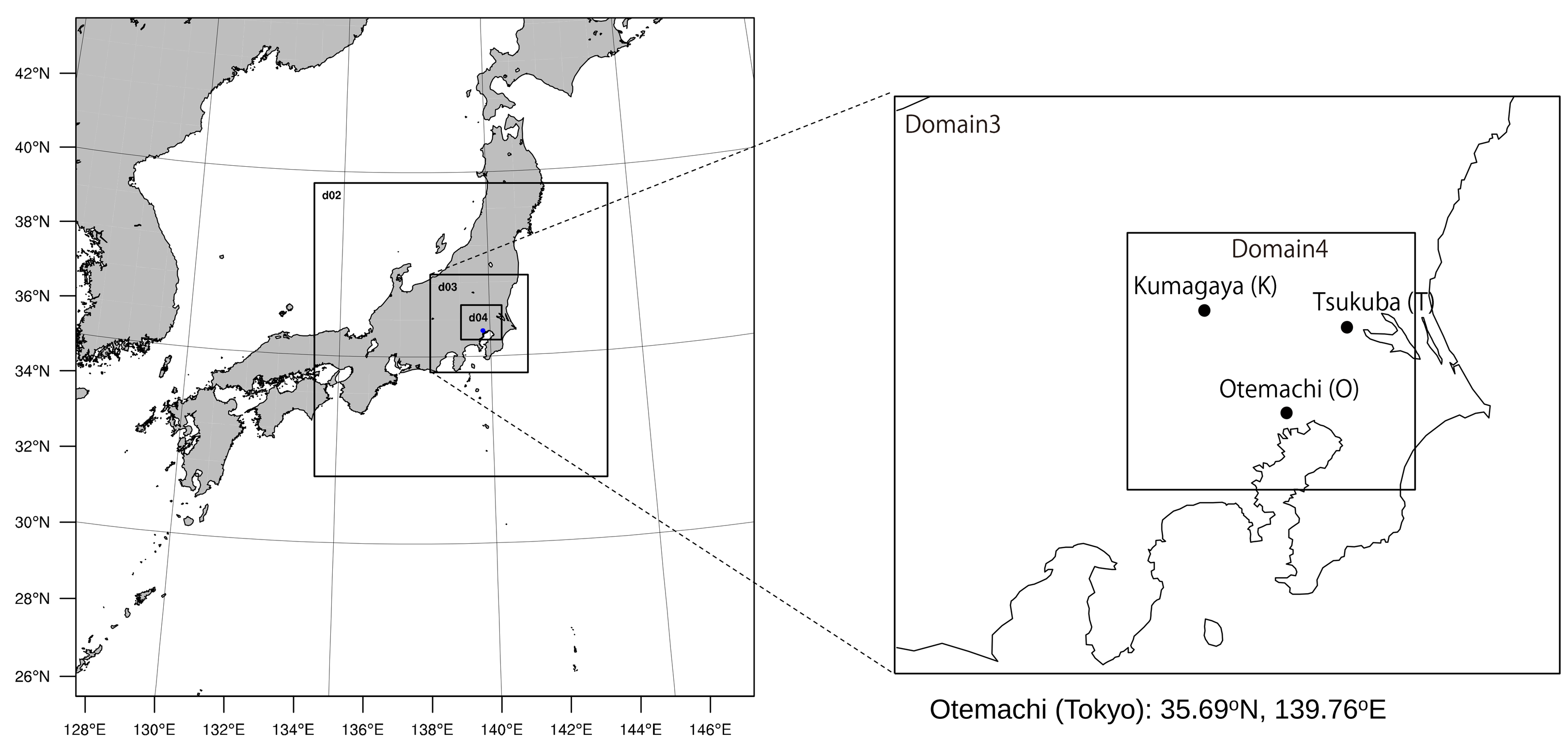


GCM (MIROC) **RCM (WRF)**

Snapshot of air temperature at 2m height (Kanto region, Japan)

WRF physics schemes

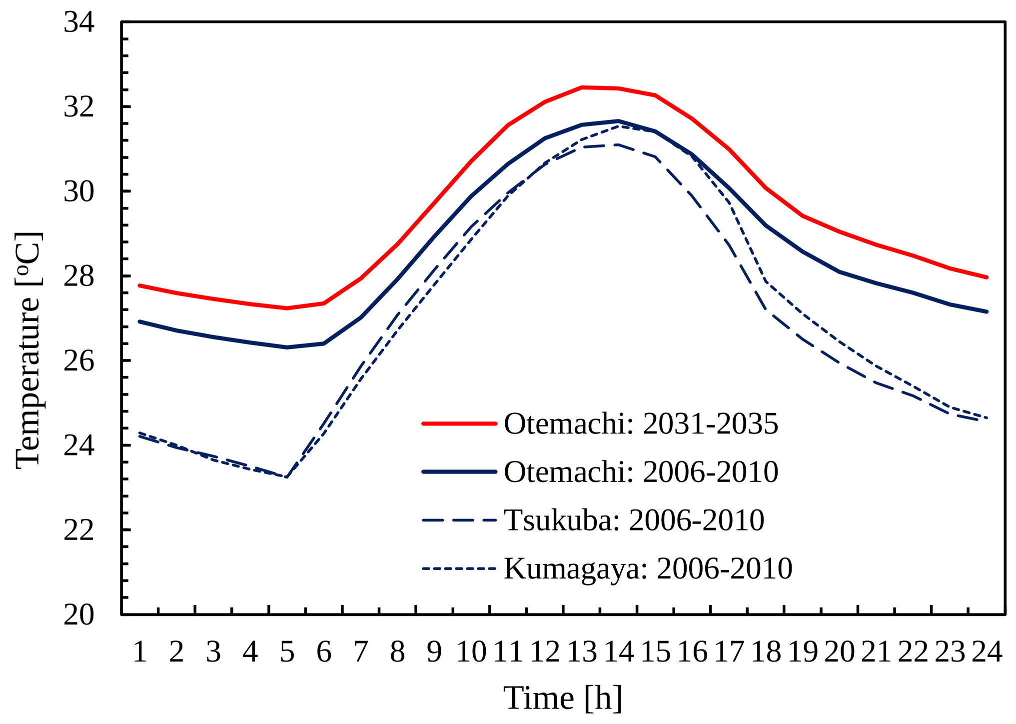
Cumulus parameterization	Domains 1&2: Grell 3D scheme; Domains 3&4: none
Microphysics	WRF single-moment 6-class scheme
Planetary boundary layer	Yonsei University scheme
Long-wave radiation	RRTM scheme
Shortwave radiation	Dudhia scheme
Land surface	Noah land surface model (Noah LSM)



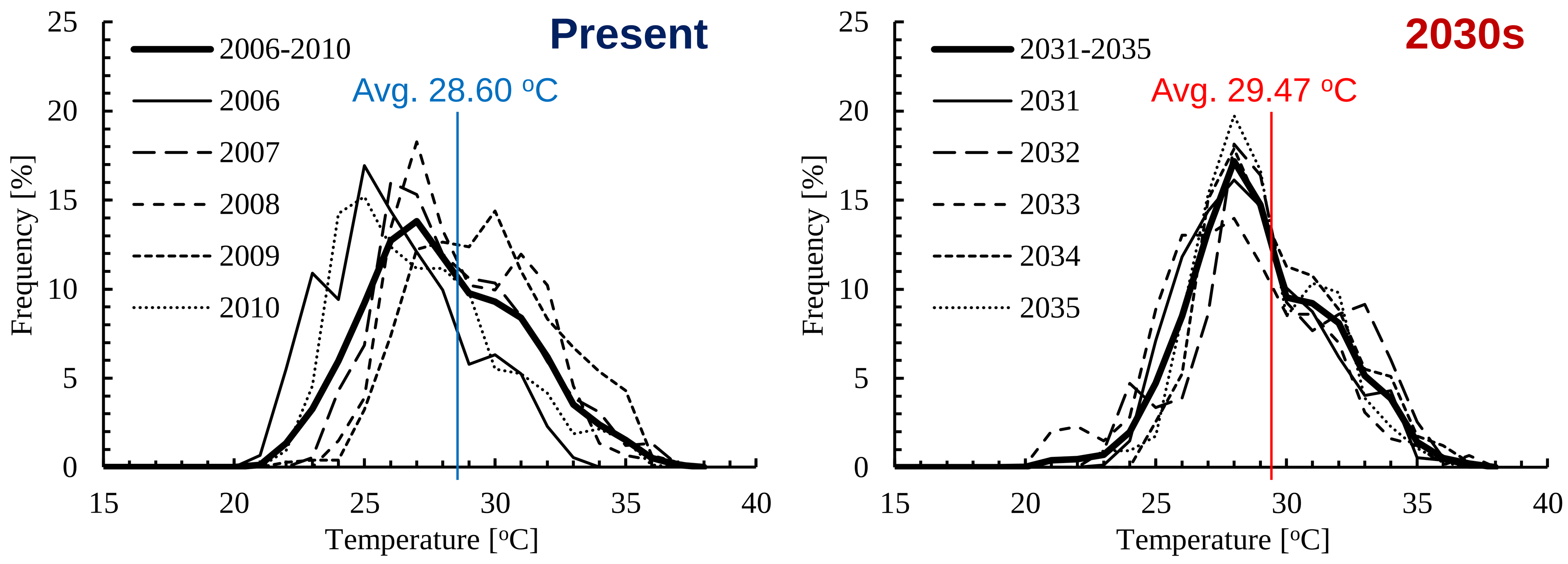
Analysis region and nested domains in WRF simulation

Results: Climate data in 2030s

- The mean outdoor temperature in August at Tokyo (Otemachi) was predicted to increase by **0.87 °C** from the present to the 2030s.



Averaged daily changes of outdoor air temperature at 2m height in August at three locations



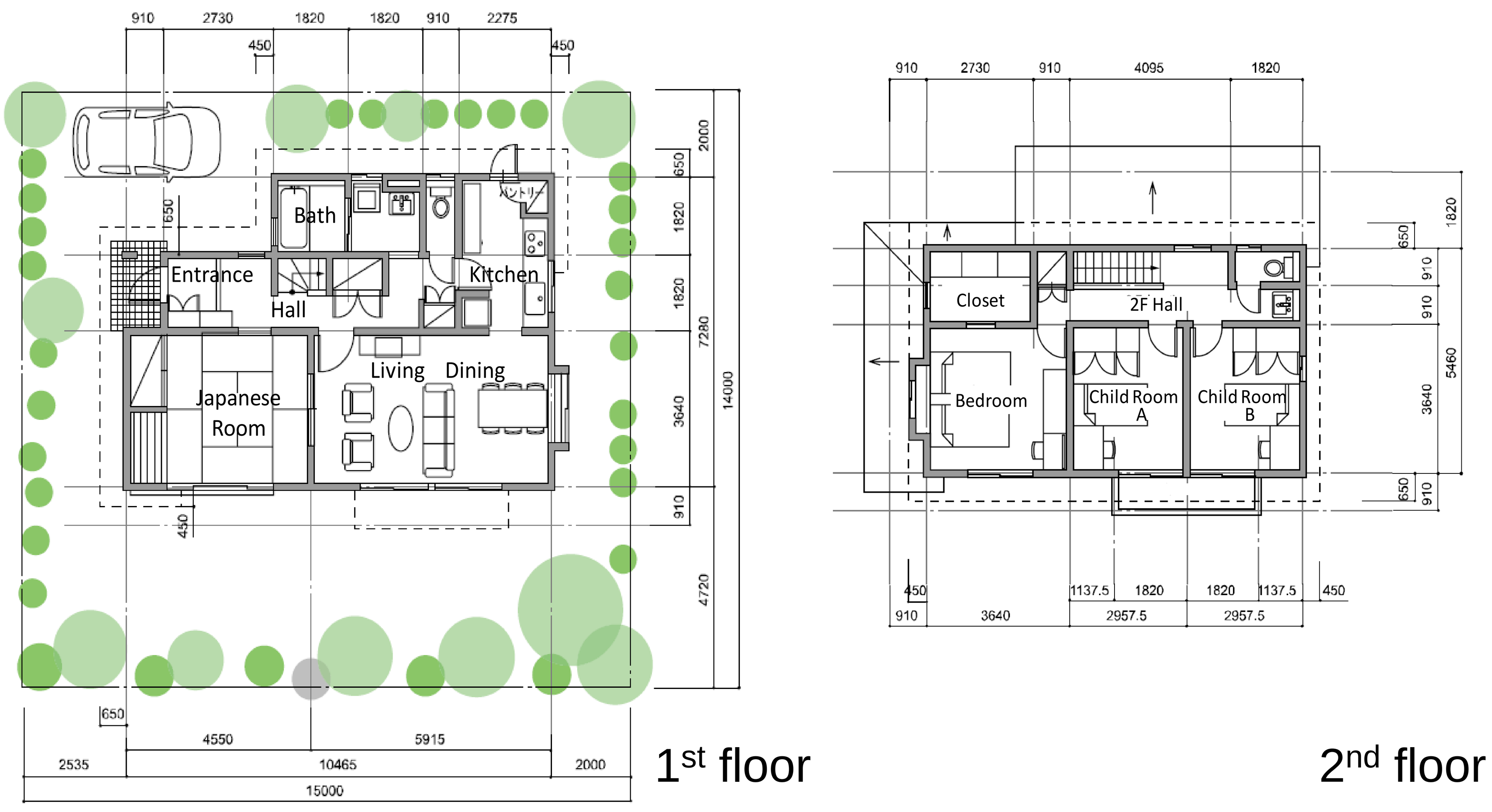
Frequency distributions of outdoor air temperature in August at Tokyo in the present and the 2030s (annual and 5-yr mean)

Method: Building Energy Simulation

- BES software: TRNSYS (University of Wisconsin) [3]
- Target: A standard detached house in Tokyo
- A combined living/dining room and kitchen (LDK; 29.8 m^2), a bedroom (13.3 m^2), and a child's room A (10.8 m^2) are controlled by cooling systems.
- Cooling systems is activated when room air temperature exceeds 26 °C during scheduled air-conditioning periods.

Time settings of air-conditioning setting

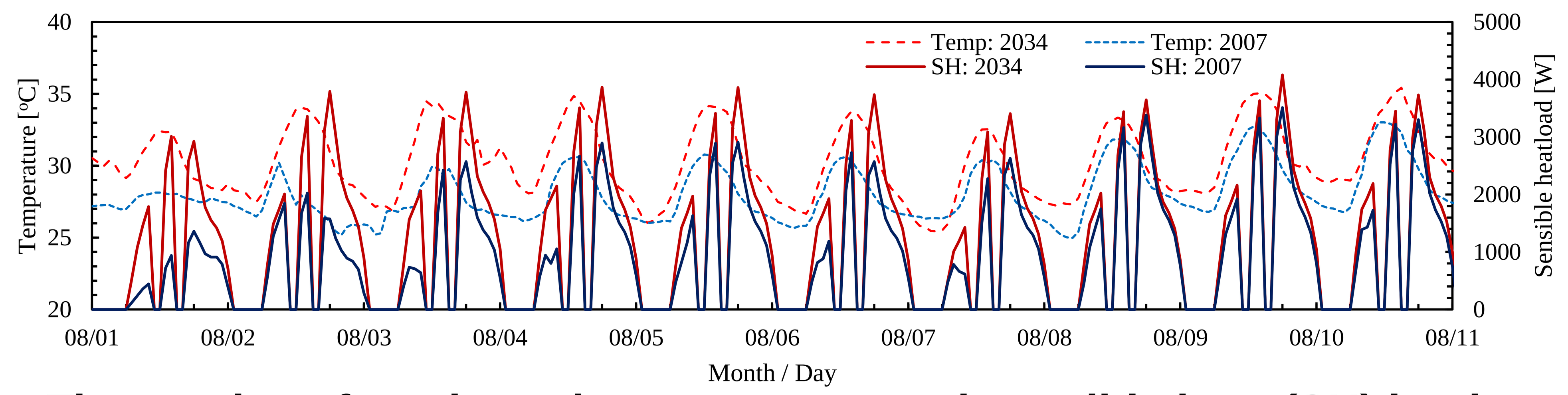
Room	Schedule of air-conditioning
LDK	6:00–10:00, 12:00–14:00, 16:00–24:00
Bedroom	21:00–23:00
Child room A	20:00–21:00, 22:00–24:00



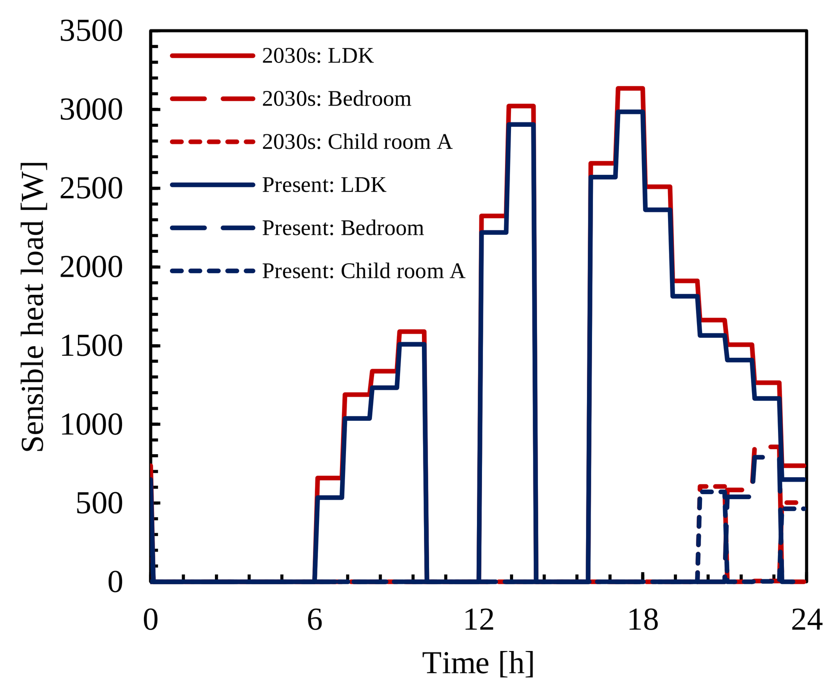
Plans for a model house used for BES (a standard detached house in Japan)

Results: Climate change and sensible heat loads

- The mean outdoor temperature and solar radiation for a given month varies each year, and the sensible heat loads in some years in the 2030s were lower than those in the present.
- However, based on the 5-yr mean, the sensible heat load in the 2030s was predicted to be **6.5%** higher than that for the present (3.13×10^3 to 2.94×10^3 MJ/mon).



Time series of outdoor air temperature and sensible heat (SH) load in the LDK in 2007 and 2034



Mean daily sensible heat load in August 2007 and 2034

Mean outdoor air temperature and total sensible heat load of the model house in August of each year and 5-yr mean

Year (present)	Mean temp. (°C)	Sensible heat load (MJ/mon)	Year (2030s)	Mean temp. (°C)	Sensible heat load (MJ/mon)
2006	26.73	2.19×10^3	2031	29.24	2.95×10^3
2007	29.01	3.12×10^3	2032	29.98	3.28×10^3
2008	29.35	3.32×10^3	2033	28.61	2.84×10^3
2009	30.19	3.46×10^3	2034	30.03	3.38×10^3
2010	27.69	2.60×10^3	2035	29.50	3.21×10^3
2006–2010	28.60	2.94×10^3	**2031–2035**	29.47	3.13×10^3

Conclusions

- We carried out climate simulations using the downscaling technique with GCM and RCM to derive weather data for August for 5 years in the present (2006–2010) and in the 2030s (2031–2035).
- Using the weather data, we conducted energy simulations of a detached house in Tokyo, Japan.
- Based on a 5-yr mean in August, the outdoor temperature was predicted to increase by 0.87 °C from the present to the 2030s.
- The sensible heat load for the house was predicted to increase by 6.5% under the study conditions.

Acknowledgement

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References

[1] Sakamoto, T., et al. (2012). MIROC4h—A new high-resolution atmosphere-ocean coupled general circulation model. Journal of the Meteorological Society of Japan, Vol. 90, No. 3, pp. 325-359.

[2] Skamarock, W. C., et al. (2008). A description of the advanced research WRF version 3. NCAR technical note, NCAR/TN-475+ STR.

[3] TRNSYS. Available from: http://sel.me.wisc.edu/trnsys/features/features.html