Heat Island Research History, Countermeasures, Adaptation, and Implementation in Japan

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- Guideline for urban heat island measures by Japanese government
- Evaluation and certification program in Japan
- “Cool roof guidebook” published by Architectural Institute of Japan
- Reviews of contributions to this field by Japanese researchers
- Conclusions and acknowledgements

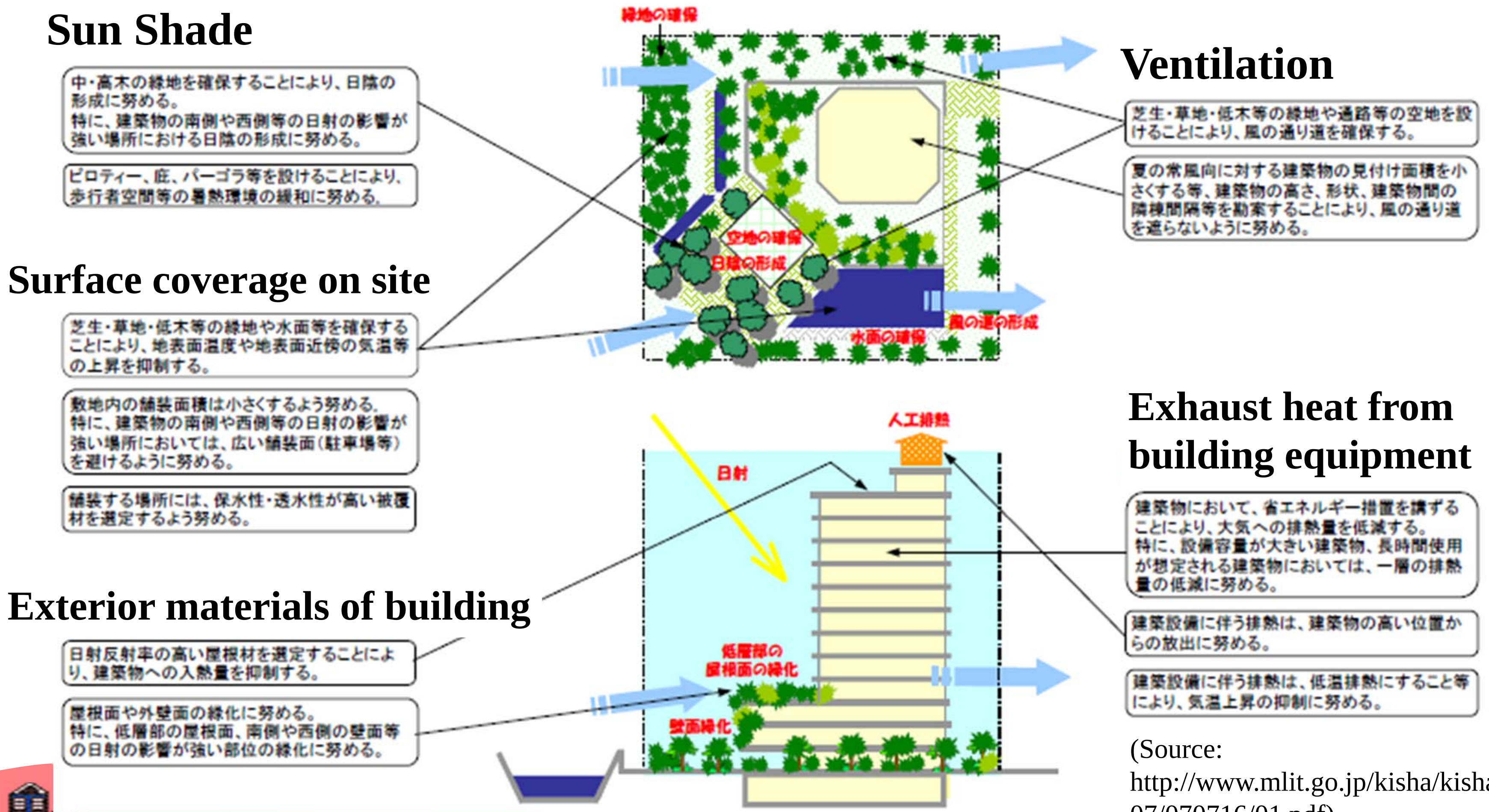
Guideline for urban heat island measures by Japanese government

Guideline for urban heat island measures by Japanese government

- **The building design guideline** for mitigating heat island phenomena by *Ministry of Land, Infrastructure, Transport and Tourism, Japan*
- Evaluation tool similar to LEED "**CASBEE-HI**" by *Ministry of Land, Infrastructure, Transport and Tourism, Japan*
- **The guideline for countermeasure against heat island** by *Ministry of the Environment, Japan*
- *The local government guidelines* for urban heat island measures; e.g. Tokyo, Osaka, …

The building design guideline by Ministry of Land, Infrastructure, Transport and Tourism

Consideration example of building design based on the building design guideline for urban heat island mitigation



(Source: http://www.mlit.go.jp/kisha/kisha04/07/070716/01.pdf)

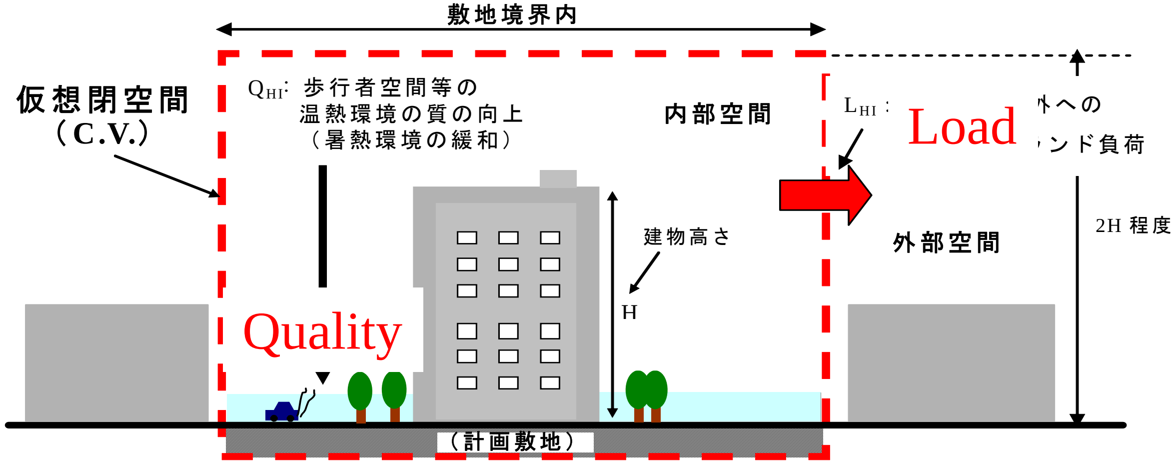
CASBEE-HI

- Mitigation effect is evaluated by heat island load Q (W/m^2)
- Adaptation effect is evaluated by SET* (^oC)

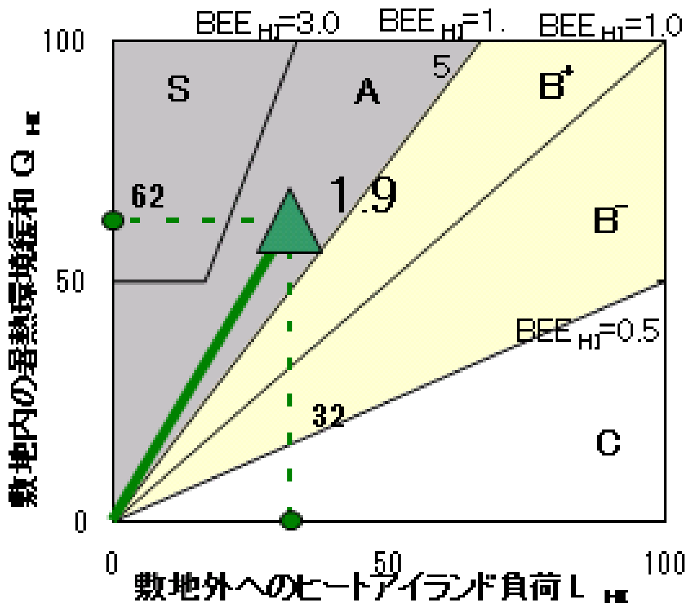
Quality

$$BEE_{HI} = \frac{SET^*(^oC)\text{: adaptation}}{Q(W/m^2)\text{: mitigation}}$$

Load



Quality (SET*(^oC))

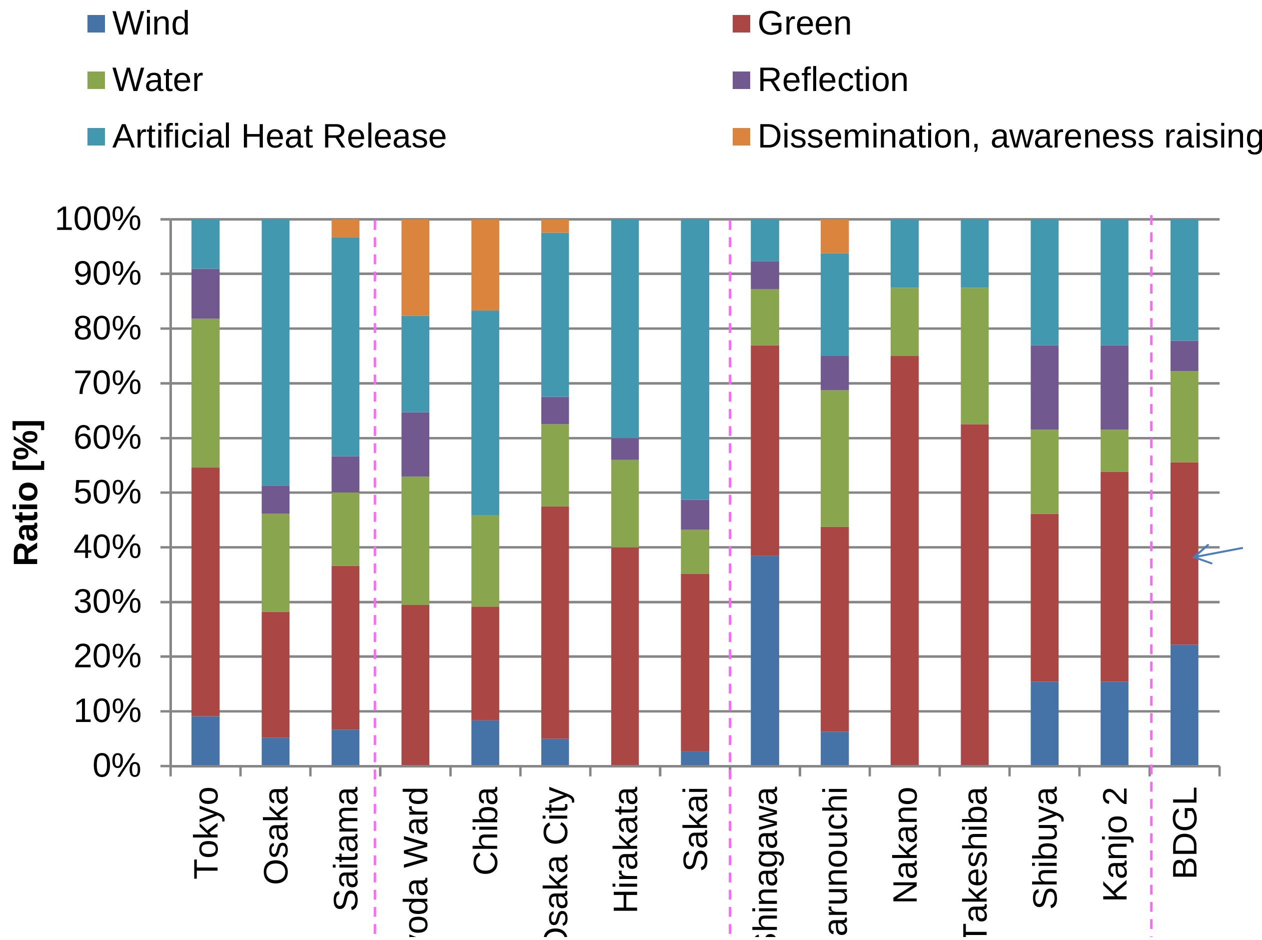


Load Q(W/m^2)

Countermeasure techniques in guideline by Ministry of the Environment for urban heat island measures

Countermeasure techniques		Mitigation		Adaptation		Energy Conservation
		Daytime	Nighttime	Daytime	Nighttime	
Use of Wind	Sea breeze and mountain-valley winds	○	○	○	○	
	Wind from rever	○		○		
Use of Planting	A park and a green area	○	○	○	○	
	Roadside trees	○	○	○	○	
	Making green space on a parking	○	○	○		
	Making green space on a site	○	○	○	○	
	Roof greening	○	○			○
	Wall greening	○	○	○		○
Use of Water	Fountain	○		○		
	Pavement with permeable materials	○	○	○	○	
	Use of permeable materials to walls	○	○			○
	Water sprinkling			○	○	
	Mist			○		
Use of Reflection	Pavement with heat barrier materials	○	○	○	○	
	High albedo roof	○	○			○
Artifical heat release	District heating and cooling system	○	○	○	○	○
	Reduction of exhaust heat from a building	○	○	○	○	○
	Reduction of exhaust heat from a car	○	○	○	○	○
Dissemination, awareness raising	Prevention of heat stroke by providing information			○		

Local government guideline menus for urban heat island measures in Japan



Menus including energy-saving effect are desirable

Japanese prefer Green technology?

Source: S. Yoshida, T. Sato, H. Takebayashi, T. Tanaka, A. Mochida, R. Ooka, R. Yoshie, Investigation on differences among the guideline in Japan, Study on the proposal of a countermeasure guideline against urban ... Part 1), Hokuriku Branch of Architectural Institute of Japan, 2013 (in Japanese)

Japanese consumers have various information about the countermeasures technology.

Evaluation and certification program in Japan

Evaluation and certification program in Japan

- **High reflectance paint, sheet, tile and water retaining material** are evaluated by *the Environmental Technology Verification (ETV-Japan) Program in Ministry of the Environment*. However, they are **just evaluated and not certified.** Consumers will select one based on the evaluated performance which is listed on the web.
- **High reflectance paint, sheet, tile, pavement** are **certified and labeled** by *Osaka HITEC* if its solar reflectance is larger than 0.4. Currently, water retaining materials, exterior insulation, green roof, reflectivity reduction by aging are considering for the certification.

Environmental Technology Verification (ETV-Japan) Program in Ministry of the Environment

The ETV Program solves the marketing problem of advanced environmental technologies, that are ready for commercial application and are believed to be useful, but nevertheless are not yet being widely used since as end-users such as local governments, private enterprises and consumers, refrain from introducing them simply because of the absence of an objective assessment of their environmental conservation effects, etc.

(Source: http://www.env.go.jp/policy/etv/en/index.html)

Verification criteria related to urban heat island:

Sunshade adhesive films for glazing, sunshade coating materials for glazing, **high reflectance paint for roofs** and **water retentive materials for roofs**

Certification program by Osaka HITEC (Heat Island Measures Technology Consortium)

Certification criteria

- More than *40% of solar reflectance* in initial value for high solar reflectance **paint** on the building rooftop; Authenticate 3 products
- More than *40% of solar reflectance* in initial value for high solar reflectance **pavement** except for roadway; Authenticate 5 products
- More than *40% of solar reflectance* in initial value for high solar reflectance **sheet (membrane)**
- More than *40% of solar reflectance* in initial value for high solar reflectance on the **residential rooftop (tile, slate)**; Authenticate 2 products

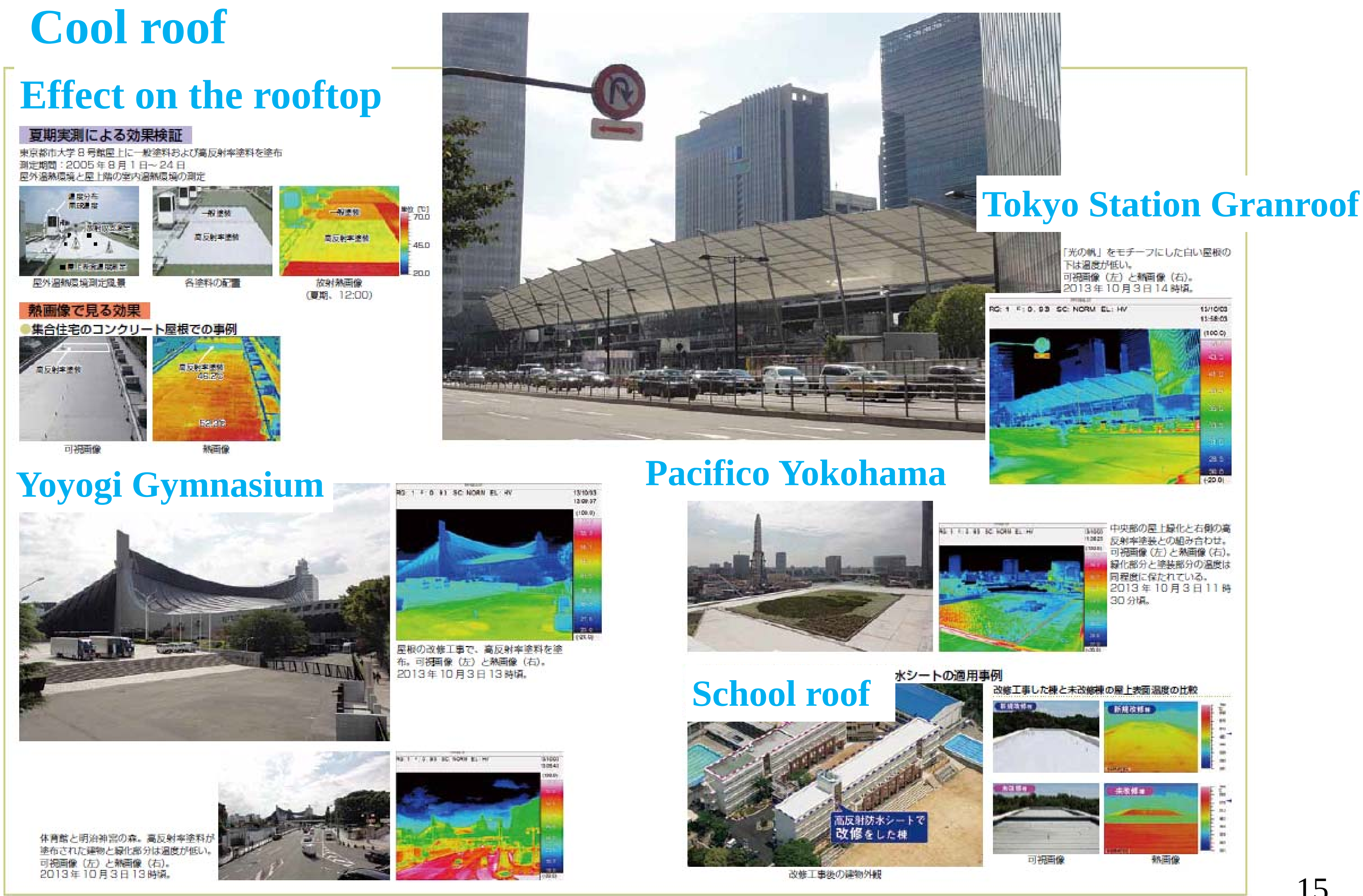
大阪 HITEC
ヒートアイランド
対策技術認証
認証(●●●●●)-2012-0001
大阪ヒートアイランド対策技術コンソーシアム

Certificate, logo, thermal load simulation result are issued to the applicant company

"Cool roof guidebook" published by Architectural Institute of Japan

"Cool roof guidebook" published by Architectural Institute of Japan

Cool roof guidebook



Cool roof guidebook

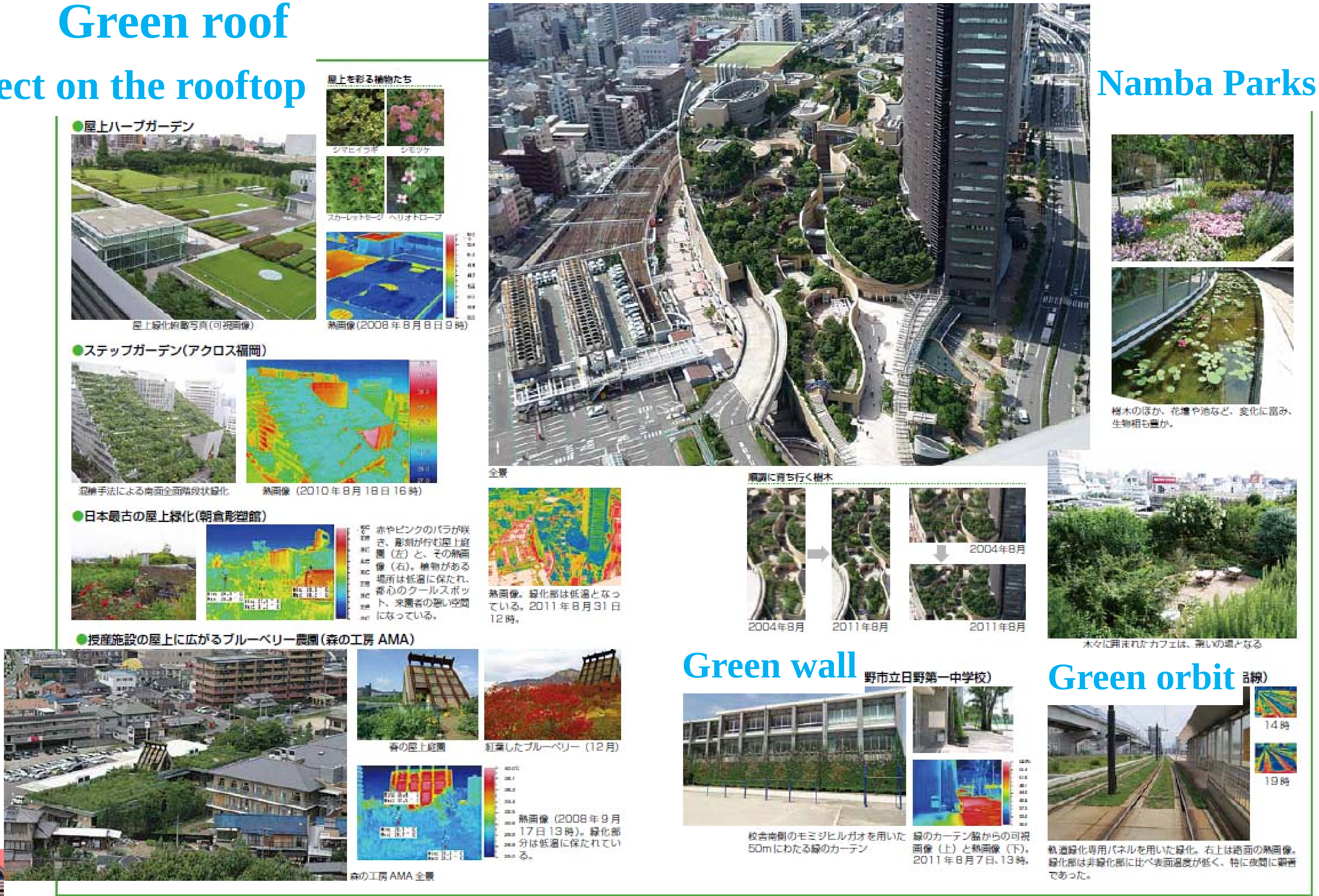
Green roof

Effect on the rooftop

Namba Parks

Green wall

Green orbit


●屋上ハーブガーデン

屋上緑化俯瞰写真(可視画像)

屋上を彩る植物たち

シマヒイラギ　シモツケ

スカーレットセージ　ヘリオトロープ

熱画像(2008年8月8日9時)

●ステップガーデン(アクロス福岡)

混植手法による南面全面階段状緑化

熱画像（2010年8月18日16時)

●日本最古の屋上緑化(朝倉彫塑館)

赤やピンクのバラが咲き、彫刻が佇む屋上庭園（左）と、その熱画像（右）。植物がある場所は低温に保たれ、都心のクールスポット、来園者の憩い空間になっている。

●授産施設の屋上に広がるブルーベリー農園(森の工房 AMA)

森の屋上庭園

紅葉したブルーベリー（12月)

熱画像（2008年9月17日13時)。緑化部分は低温に保たれている。

森の工房 AMA 全景

全景

熱画像。緑化部は低温となっている。2011年8月31日12時。

順調に育ち行く樹木

2004年8月　2011年8月　2004年8月　2011年8月

樹木のほか、花壇や池など、変化に富み、生物相も豊か。

木々に囲まれたカフェは、憩いの場となる

野市立日野第一中学校)

校舎南側のモミジヒルガオを用いた50mにわたる緑のカーテン

緑のカーテン脇からの可視画像（上）と熱画像（下)。2011年8月7日、13時。

線)

14時

19時

軌道緑化専用パネルを用いた緑化。右上は路面の熱画像。緑化部は非緑化部に比べ表面温度が低く、特に夜間に顕著であった。

Water retaining materials

Cool roof guidebook

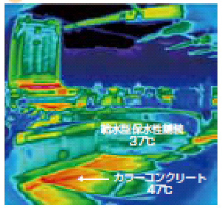
Cool pavements

Effect on the rooftop

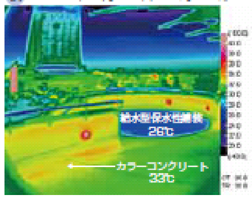
●保水性ブロック舗装の屋上への適用

施工写真

昼 2003年8月22日12時



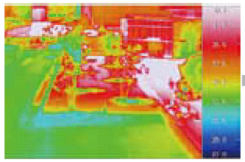
夜 2003年8月22日19時30分

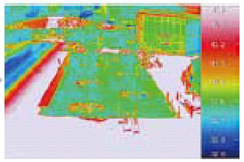


熱画像の比較。蒸発冷却の効果が明らか。

●流水型水盤による散水システム

水盤の外観



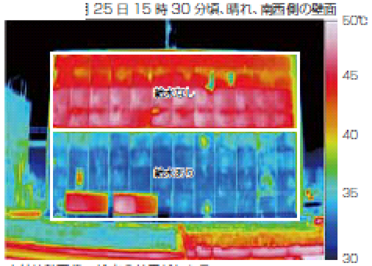


熱画像。水盤上の温度は、給水前（左）より給水後（右）のほうが低い。

water-retentive wall

保水性壁体の外観

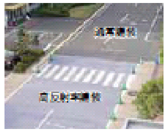
25日15時30分頃、晴れ、南西側の壁面



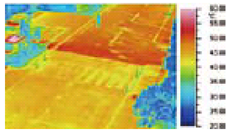
赤外線熱画像。給水の効果がわかる。

Effect on the pavement

●東京都内の構内道路への適用



可視画像

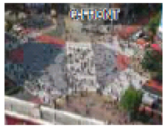


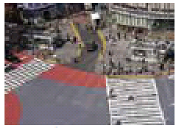
熱画像

実測日：2006年8月31日6時～9月1日6時
（天候：晴れ）
24時間熱画像から、高反射率塗装と通常舗装の温度差が明らか。

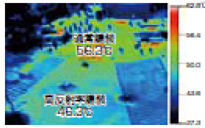
●渋谷駅前交差点

交差点内：高反射率舗装は灰色、通常舗装は黒色あるいは赤褐色



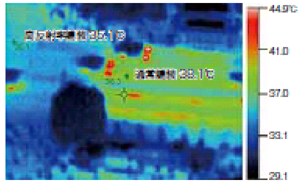


可視画像（日中）



熱画像（日中）

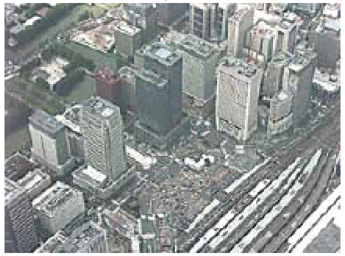
可視画像（夜間）

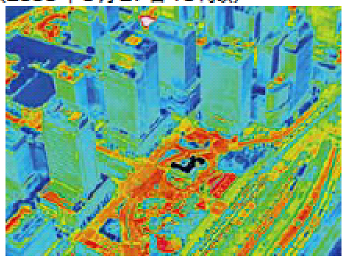


熱画像（夜間）

Various urban surface

●ヘリコプターから撮影した東京駅丸の内付近(2009年8月27日13時頃)





熱画像（右）から、屋上緑化や保水性舗装の部分は、温度が低く保たれている。

Cool roof guidebook

Contents

- Cool roof and urban heat island
- High reflectance technology
- Green technology
- Evaporative technology
- Performance evaluation method
- Physical properties, parameters for performance evaluation

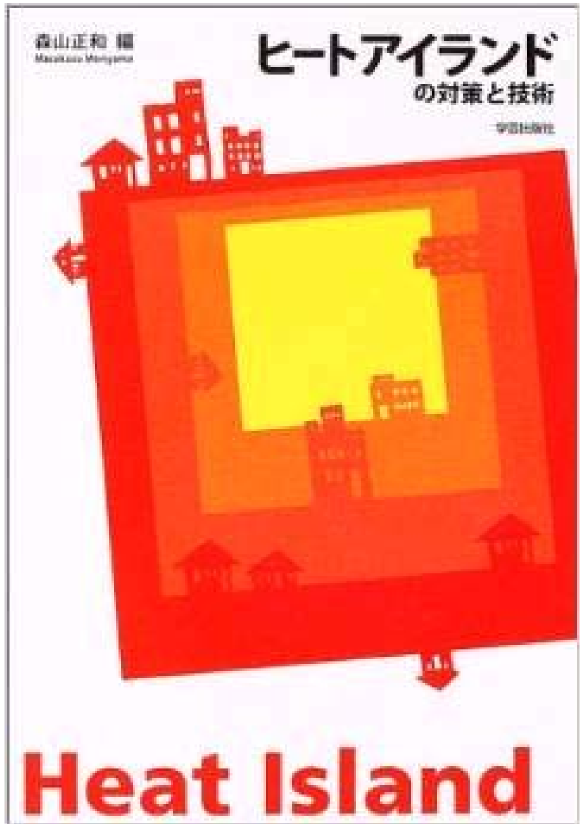
High reflectance paint, high reflectance pavement, high reflectance membrane, high reflectance sheet, green roof, green wall, green parking, green schoolyard, green orbit, water-retentive pavement, water sprinkling, water-retentive wall all over Japan are explained.

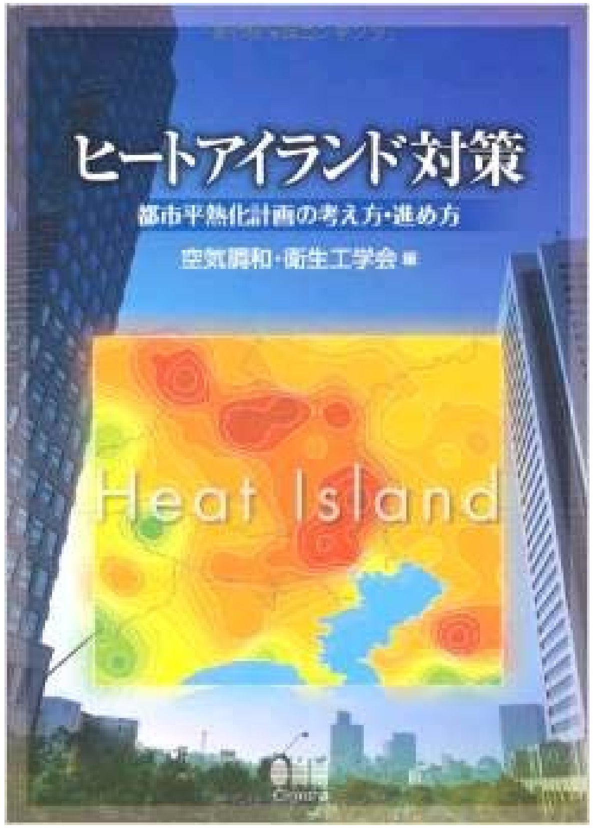
Other books on heat island measures in Japan

"Technology and measures of urban heat island" edited by Prof. Moriyama (2004)

"Architecture, urban and heat island, Vision and challenge of measures" edited by AIJ (2007)

"Heat island measures, Concept and method to cool the city" edited by SHASEJ (2009)





Reviews of contributions to this field by Japanese researchers

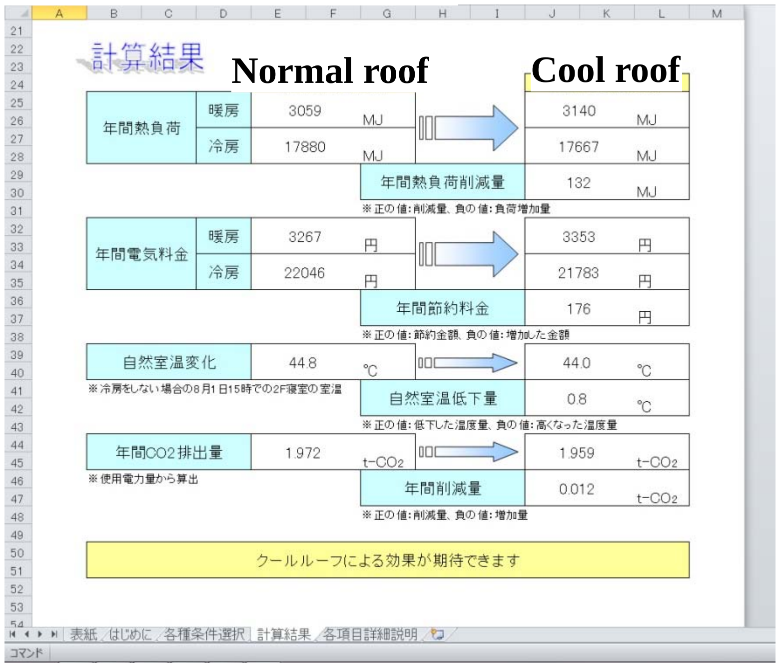
Countermeasures by cool roof

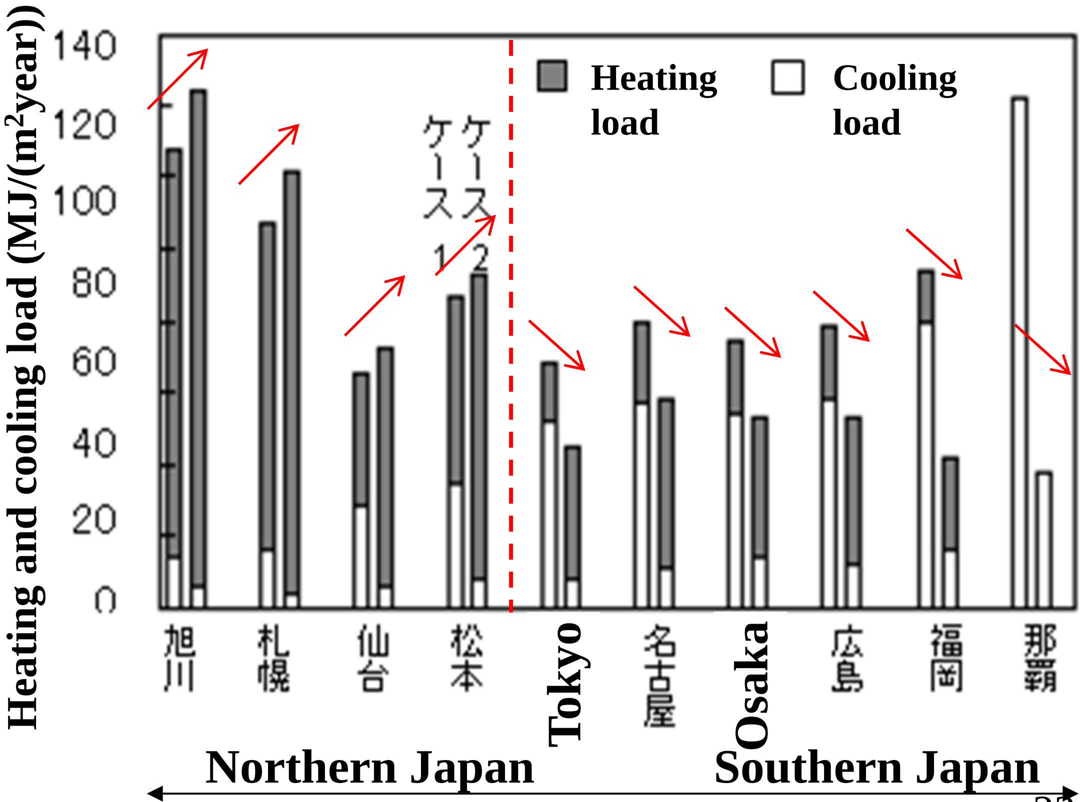
Outstanding contributions by Japanese researchers

Prof. Yasushi KONDO, et al. have developed **the cool roof calculator and calculated the cooling and heating load in each city in Japan.** Cool roof is effective in the region south of Tokyo.

Kunihiro Udoh, Yasushi Kondo, Hitoshi Takeda, Simple evaluation system of cool roof for proper promotion, AIJ J. Technol. Des. 31, 849-854, 2009 (in Japanese with English abstract)

Cool roof calculator





Outstanding contributions by Japanese researchers

Prof. Masayuki ICHINOSE, et al. have **assessed paint performance over time with respect to surface contamination and degradation of reflectivity through environmental exposure tests.** They also confirmed the effects of washing on solar reflectivity.

Masayuki Ichinose, Takashi Inoue, Yoshihito Sakamoto, Long-term performance of high-reflectivity exterior panels, Building and Environment 44 (2009) 1601–1608

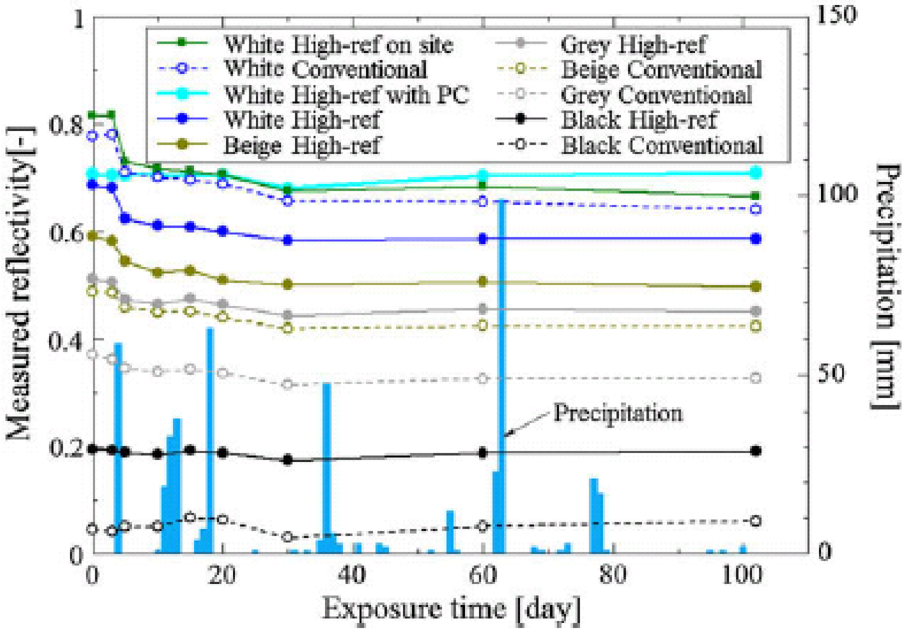


Fig. 14. Fluctuation of solar reflectivity compared with precipitation measured by spectroradiometry.

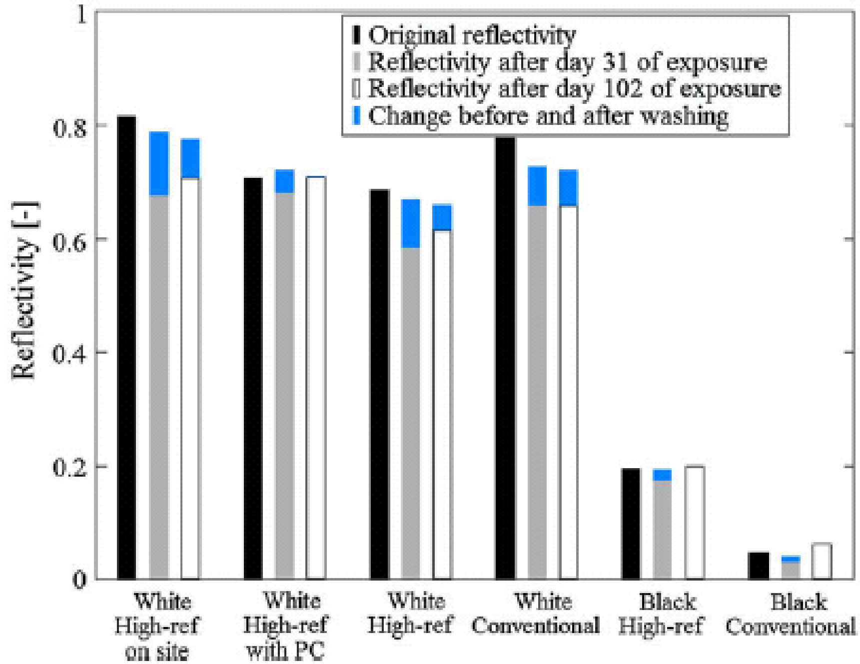


Fig. 16. Effects of washing on solar reflectivity.

Outstanding contributions by Japanese researchers

Prof. Ken-ichi NARITA et al. have **investigated the mitigation effects of green spaces in urban areas** by several microclimatic observations in Tokyo. A significant air temperature drop in an adjacent built-up area was observed within a range of 80–90 m from the boundary in the case of Shinjuku-Gyoen Park.

Ken-ichi Narita, Hirofumi Sugawara, Cold-air Seeping-out Phenomena in an Urban Green Space, Journal of Geography 120（2）411–425 2011

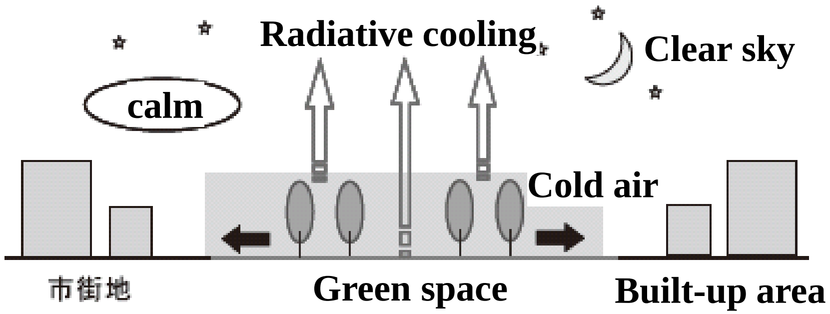


図 2 「にじみ出し現象」の概念図.

Fig. 2 Schematic image of seeping-out phenomena.

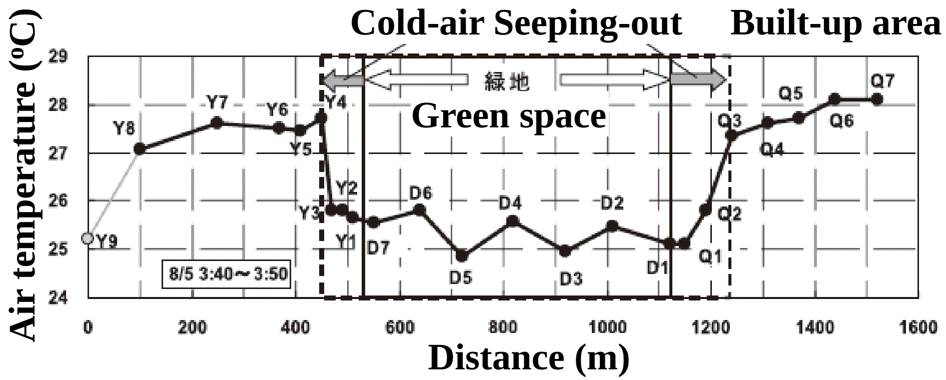


図 3 「にじみ出し現象」出現時の気温断面分布.

Fig. 3 Temperature distribution along cross-section line when seeping-out phenomena appeared.

Adaptation

Outstanding contributions by Japanese researchers

Prof. Atsumasa YOSHIDA, et al. have presented a method for quantification and evaluation of urban thermal environment in terms of feeling temperature or subjective thermal perception through the use of a human energy balance model. In a steady state, and **even in an unsteady state** with its variations in weather and human factors, **thermal comfort values can generally be obtained by using the overall human thermal load.**

Yasuhiro Shimazaki, Atsumasa Yoshida, Ryota Suzuki, Takeshi Kawabata, Daiki Imai, Shinichi Kinoshita, Application of human thermal load into unsteady condition for improvement of outdoor thermal comfort, Building and Environment 46 (2011) 1716-1724

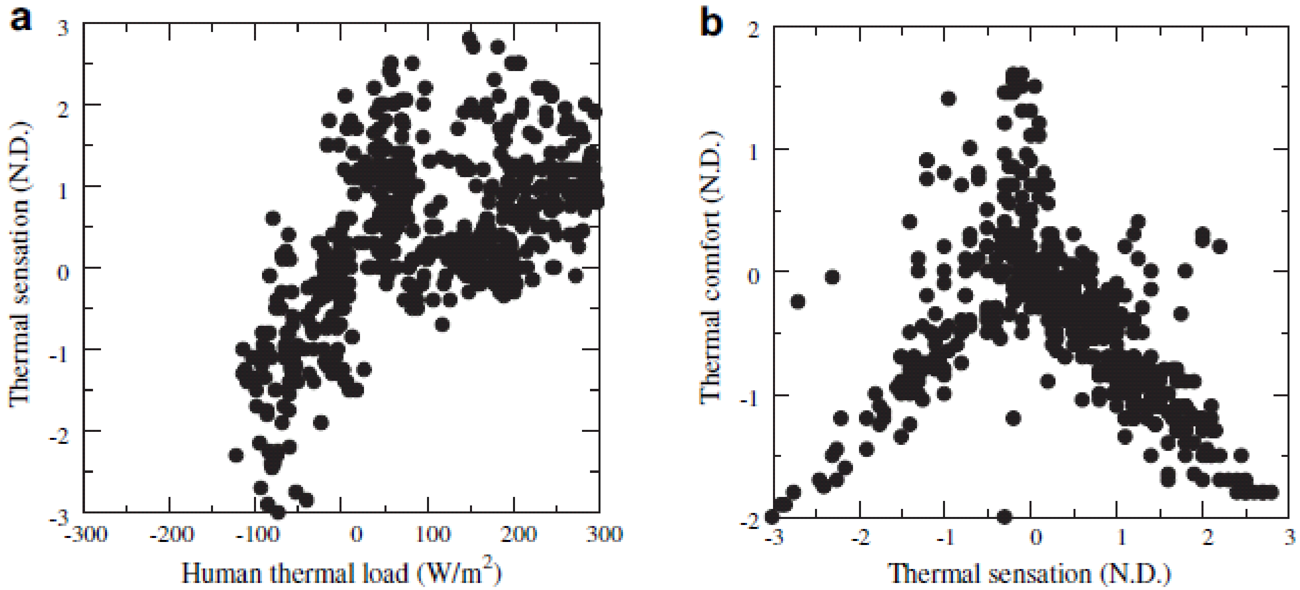


Fig. 9. Relationships among human thermal load, thermal sensation, and human thermal comfort in an unsteady state. (a) Relationship between human thermal load and thermal sensation. (b) Relationship between thermal sensation and human thermal comfort.

Implementation

Outstanding contributions by Japanese researchers

Prof. Hideki TAKEBAYASHI, Prof. Masakazu MORIYAMA et al. have **examined the priority for the implementation of urban heat island mitigation measures**. Top priority concerns the buildings with large roof areas. They also have **examined on the appropriate selection of urban heat island measure technologies** to urban block properties.

Hideki Takebayashi, Masakazu Moriyama, Relationships between the properties of an urban street canyon and its radiant environment: Introduction of appropriate urban heat island mitigation technologies, Solar Energy 86 (2012) 2255–2262

Hideki Takebayashi, Yutaro Kimura, Sae Kyogoku, Study on the appropriate selection of urban heat island measure technologies to urban block properties, Sustainable Cities and Society 13 (2014) 217–222

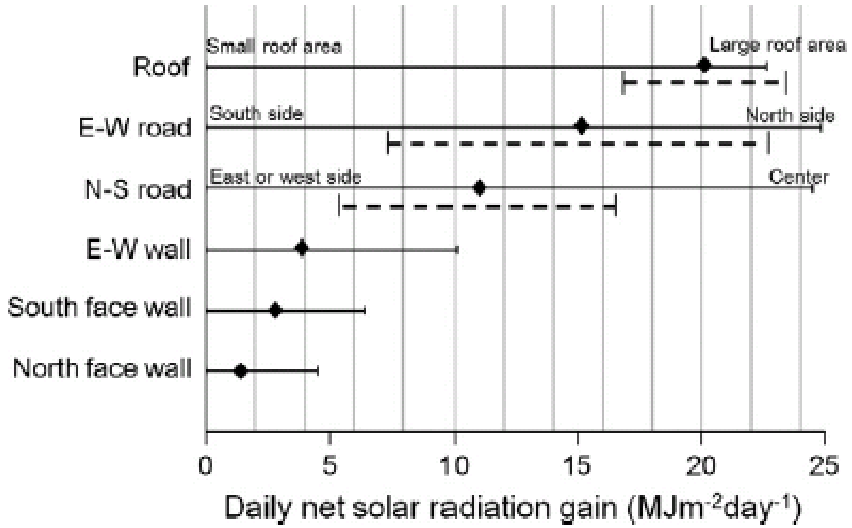


Fig. 15. Components of an urban street canyon and their daily net solar radiation gain levels and variations. Minimum, Mean, Maximum, Standard deviation.

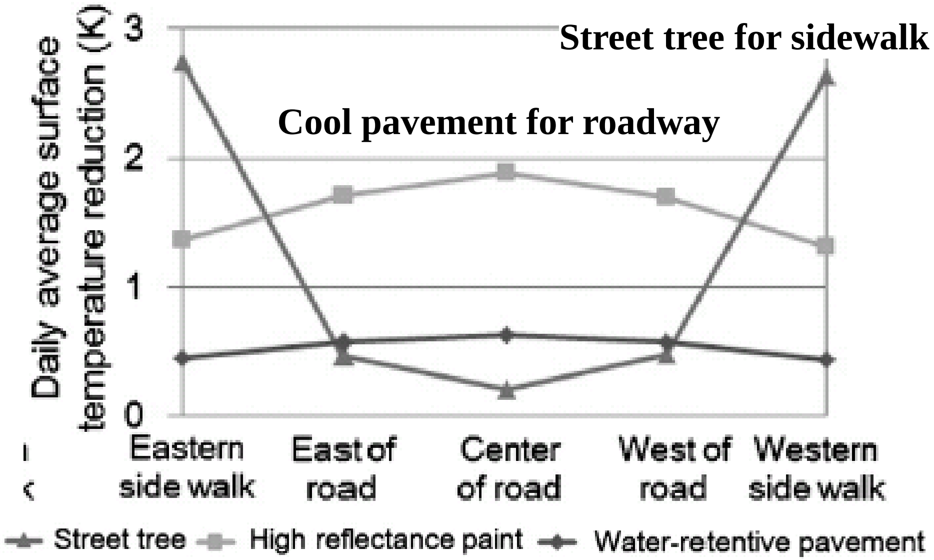


Fig. 6. Daily average surface temperature reduction due to a street tree, high reflectance paint, and water-retentive pavement

Outstanding contributions by Japanese researchers

Prof. Takashi ASAWA, Prof. Akira HOYANO, et al. have developed **a thermal design tool** for use in planning outdoor spaces by combining a heat balance simulation for urban surfaces, including buildings, the ground and greenery, **with a 3D-CAD system**.

Takashi Asawa,, Akira Hoyano, Kazuaki Nakaohkubo, Thermal design tool for outdoor spaces based on heat balance simulation using a 3D-CAD system, Building and Environment 43 (2008) 2112–2123

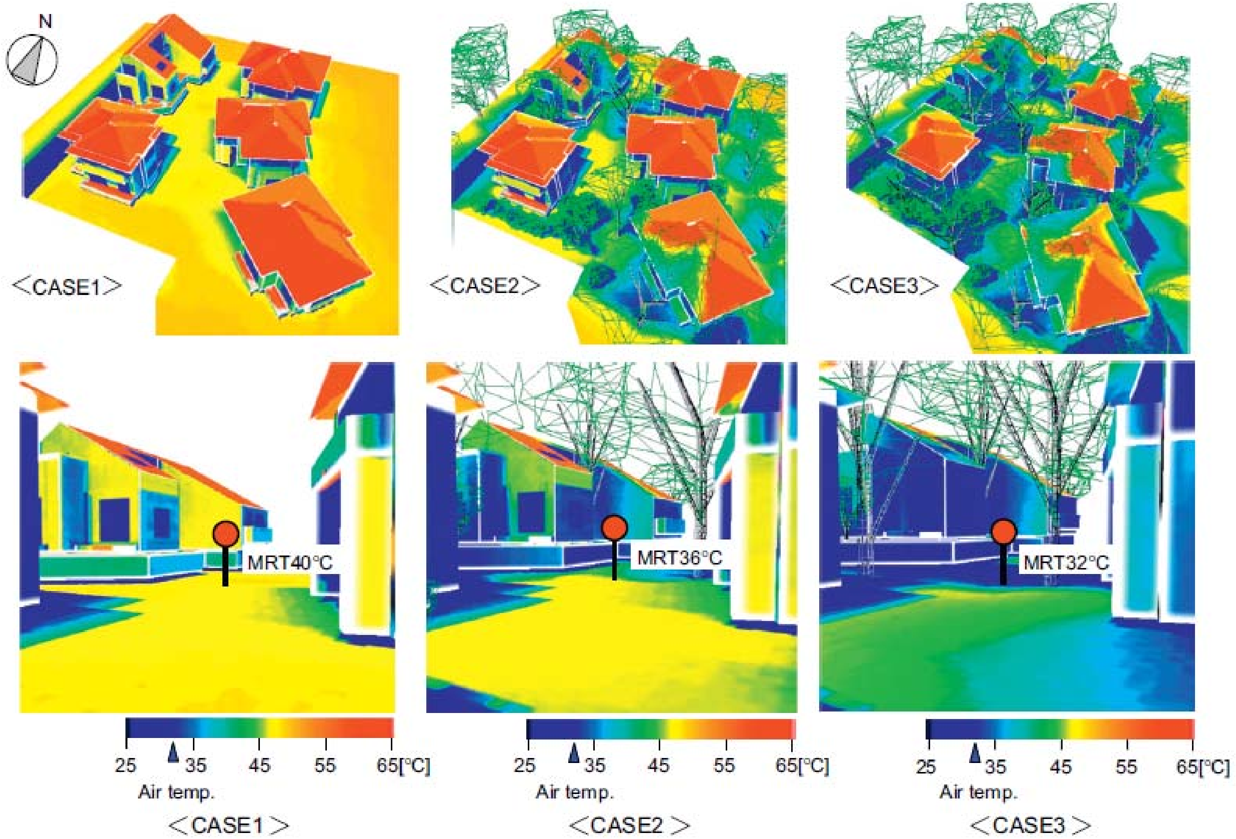


Fig. 14. Simulation results of the surface temperature of the residential area (clear sky day in summer, 12:00).

Countermeasures, Adaptation by wind

Outstanding contributions by Japanese researchers

Prof. Akashi MOCHIDA, et al. have developed **the guideline for prediction and assessment of the pedestrian wind environment around buildings** in the design stage. It covers Computational domain and representation of surroundings, Grid discretization, Boundary conditions, Solution algorithm, spatial discretization, Convergence of solution, Turbulence models, Validation of user's CFD model.

Yoshihide Tominaga, Akashi Mochida, Ryuichiro Yoshie, Hiroto Kataoka, Tsuyoshi Nozue, Masaru Yoshikawa, Taichi Shirasawa, AIJ guidelines for practical applications of CFD to pedestrian wind environment around buildings, Journal of Wind Engineering and Industrial Aerodynamics 96 (2008) 1749–1761

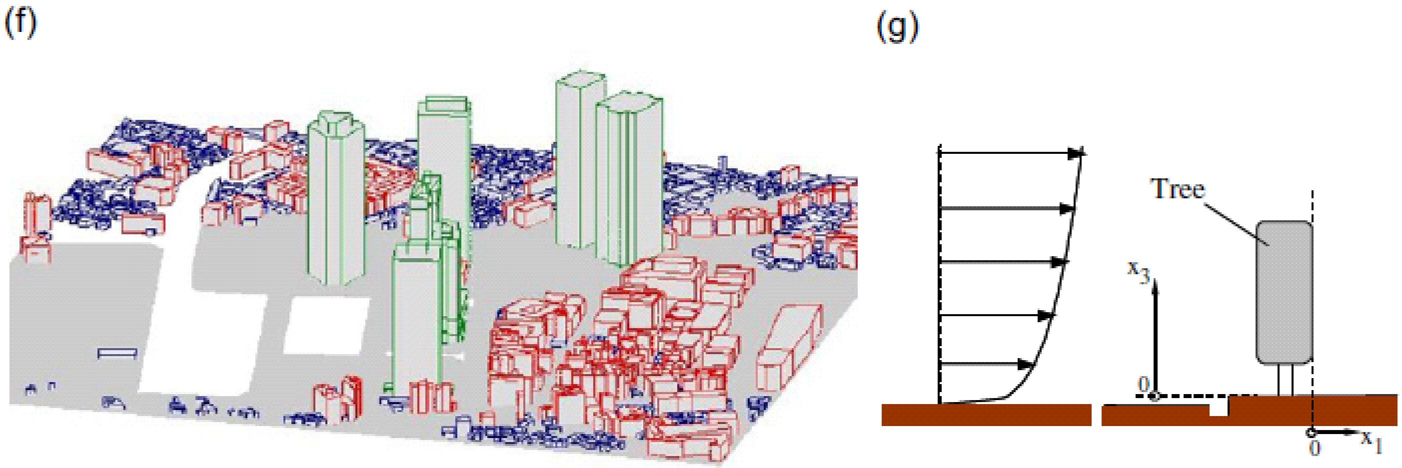
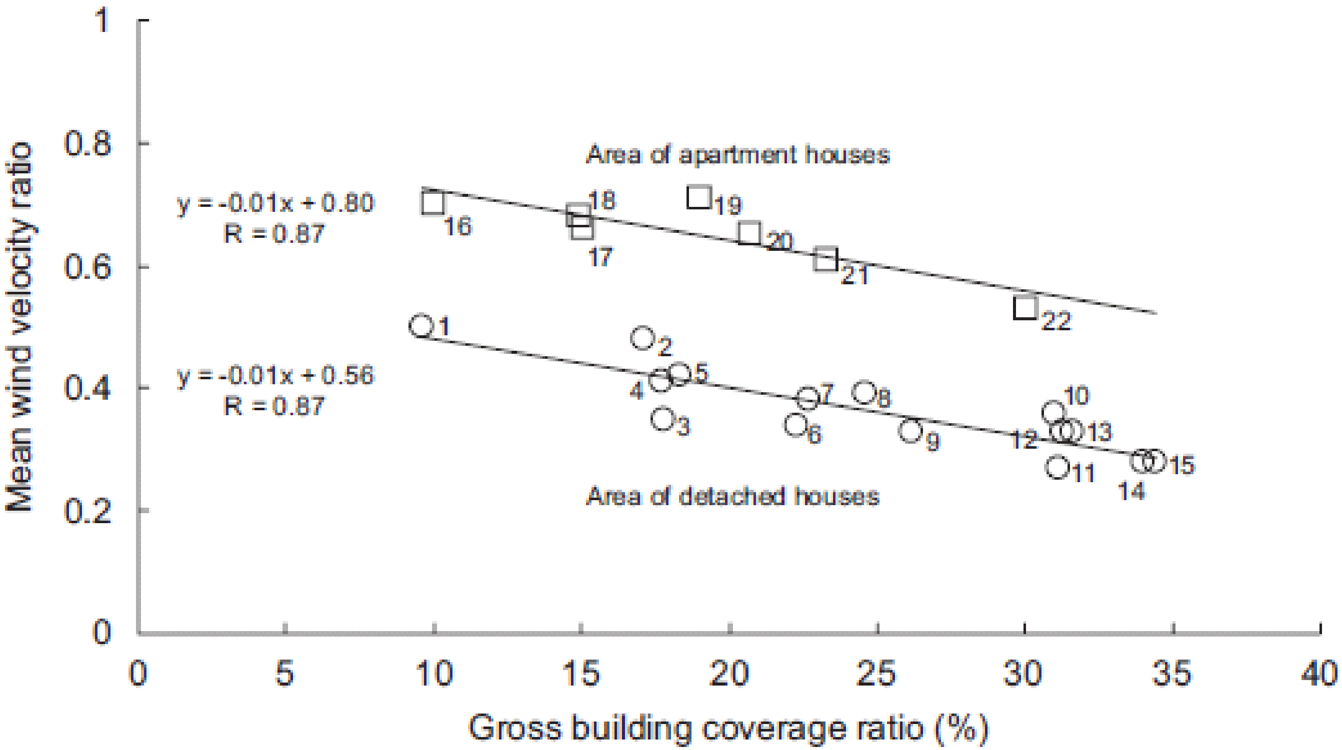


Fig. 1. Seven test cases for cross-comparison. (a) Test case A (2:1:1 square prism); (b) Test case B (4:4:1 square prism); (c) Test case C (Simple city blocks); (d) Test case D (High-rise building in city); (e) Test case E (Building complexes with simple building shapes in actual urban area); (f) Test case F (Building complexes with complicated building shapes in actual urban area); (g) Test case G (Two-dimensional pine tree).

Outstanding contributions by Japanese researchers

Prof. Akashi MOCHIDA, et al. have **revealed the relationship between the building density and the average wind velocity at pedestrian level** in residential neighborhoods. The development method of guidelines for realizing acceptable wind environment in residential neighborhoods using the gross building coverage ratio is proposed.

Tetsu Kubota,, Masao Miura, Yoshihide Tominaga, Akashi Mochida, Wind tunnel tests on the relationship between building density and pedestrian-level wind velocity: Development of guidelines for realizing acceptable wind environment in residential neighborhoods, Building and Environment 43 (2008) 1699–1708



Outstanding contributions by Japanese researchers

Prof. Yasunobu ASHIE, et al. have developed **a high-resolution computational fluid dynamics (CFD) model,** which takes into account complex urban morphology. Airflow and temperature fields over the 23 wards of **Tokyo were simulated** with a CFD technique using a total of approximately 5 billion computational grid cells **with a horizontal grid spacing of 5 m.**

Yasunobu Ashie, Takaaki Kono, Urban-scale CFD analysis in support of a climate-sensitive design for the Tokyo Bay area, Int. J. Climatol. 31: 174–188 (2011)

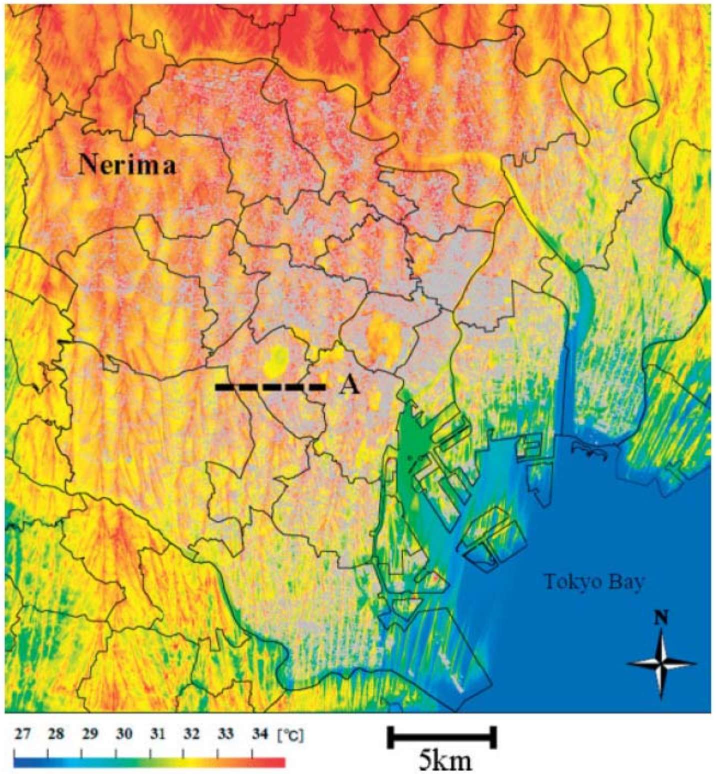


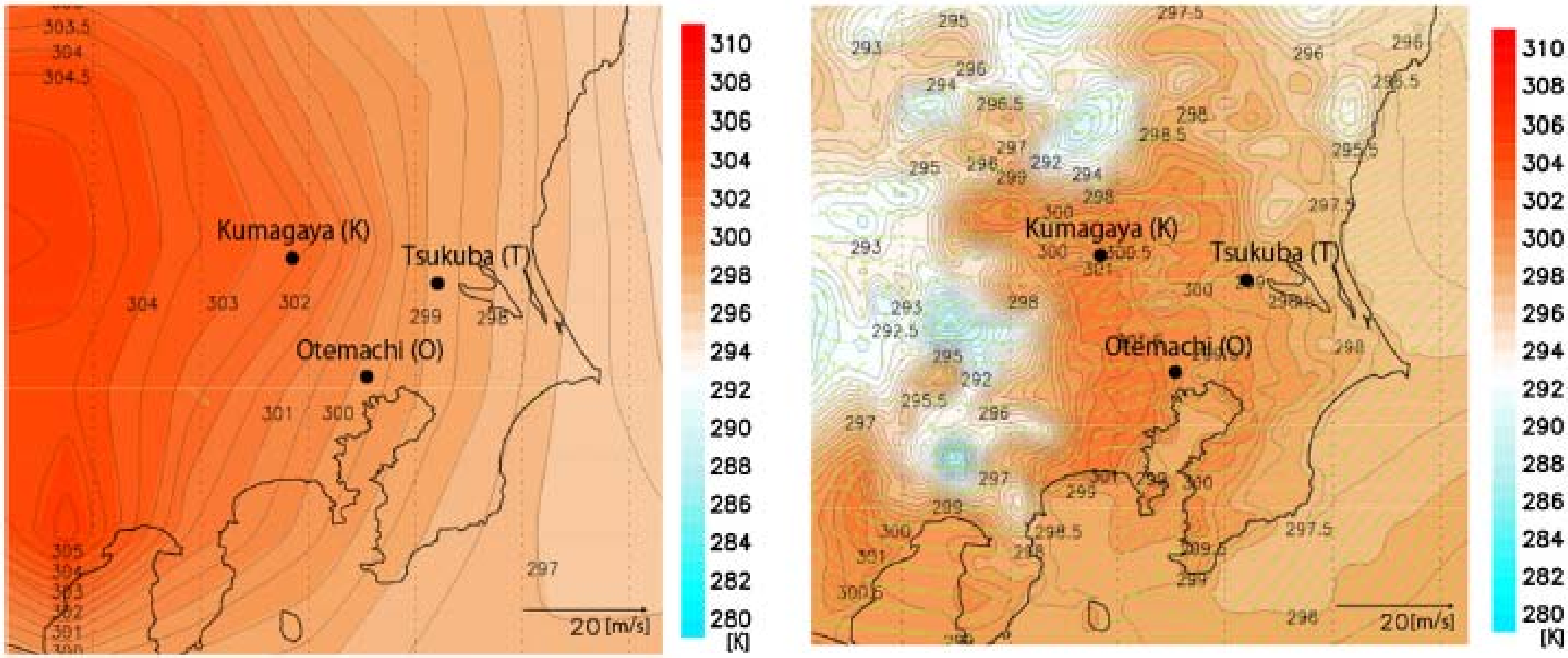
Figure 4. Simulated air temperature distribution at 10 m height above the ground surface. Line A shows the location of the cross-section in Figure 7.

Meso-scale model

Outstanding contributions by Japanese researchers

Prof. Hideki KIKUMOTO, Prof. Ryozo OOKA, et al. have **constructed a prototype of the future (2031–2035) standard weather data** based on the Model for Interdisciplinary Research on Climate (MIROC) and the Weather Research and Forecasting (WRF) model, then **estimated the impact of climate change on the energy performance of a detached house.**

Hideki Kikumoto, Ryozo Ooka, Yusuke Arima, Toru Yamanaka, Study on the future weather data considering the global and local climate change for building energy simulation, Sustainable Cities and Society, 2014, in press



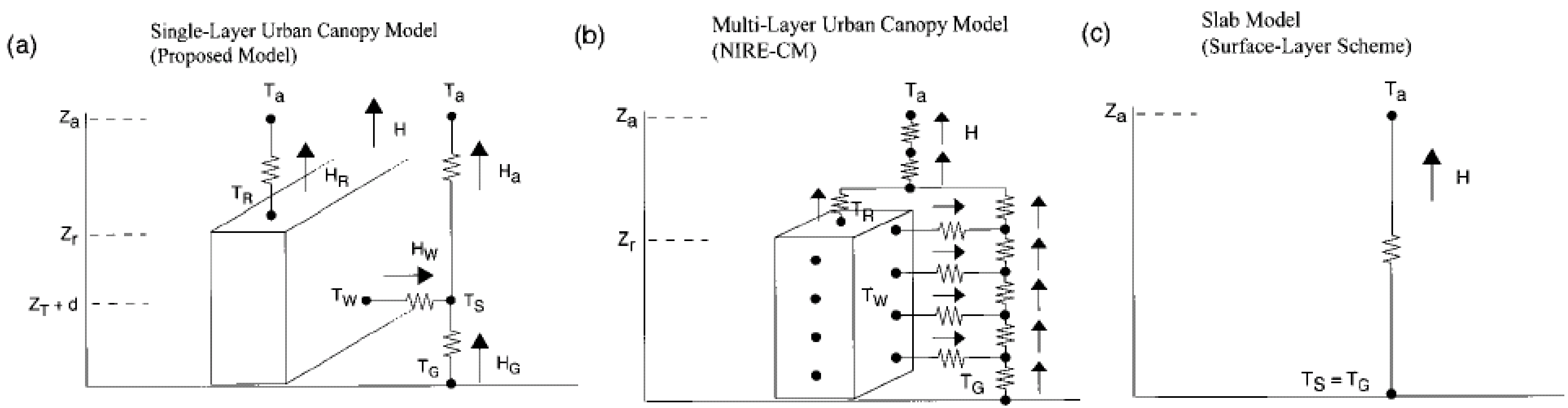
MIROC4h WRF

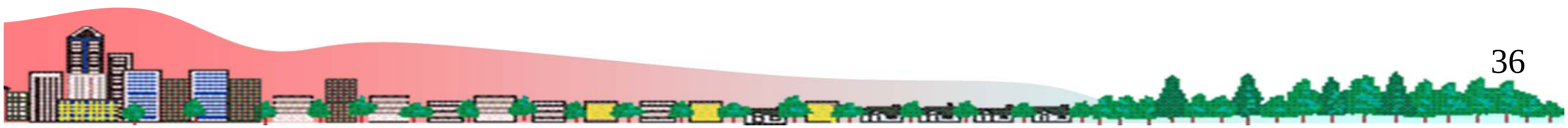
Fig. 4. Temperature at 2 m and wind field at 10 m predicted by MIROC and WRF at 21:00 August 16 2006. (a) MIROC4h and (b) WRF.

Outstanding contributions by Japanese researchers

Prof. Hiroyuki KUSAKA, et al. have **developed a simple, single-layer urban canopy model,** and compared it to both multi-layer and slab models. This model is **adopted in the WRF**, it is widely used worldwide.

Hiroyuki Kusaka, Hiroaki Kondo, Yokihiro Kikegawa, Fujio Kimura, A Simple Single-Layer Urban Canopy Model For Atmospheric Models: Comparison With Multi-Layer And Slab Models, Bound. -Layer Meteor., 101, 329-358. 2001





Implementation

Outstanding contributions by Japanese researchers

Prof. Masakazu MORIYAMA, et al. have **<u>proposed "Urban climate map" for planning support and held actual community planning workshop.</u>** And, participants of the workshop have made proposals.

Takahiro Tanaka, Takuhiro Yamashita, Masakazu Moriyama, Community planning workshop by using "urban climate map": Practice of workshop in the Komagabayashi neighborhood, Nagata, Kobe, J. Environ. Eng., AIJ, 511, 91-98, 2007 (in Japanese with English abstract)

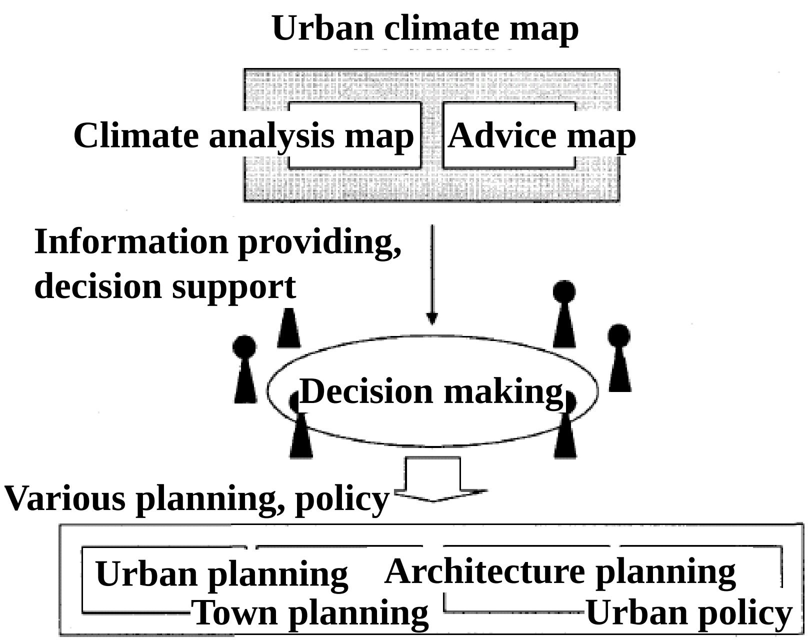
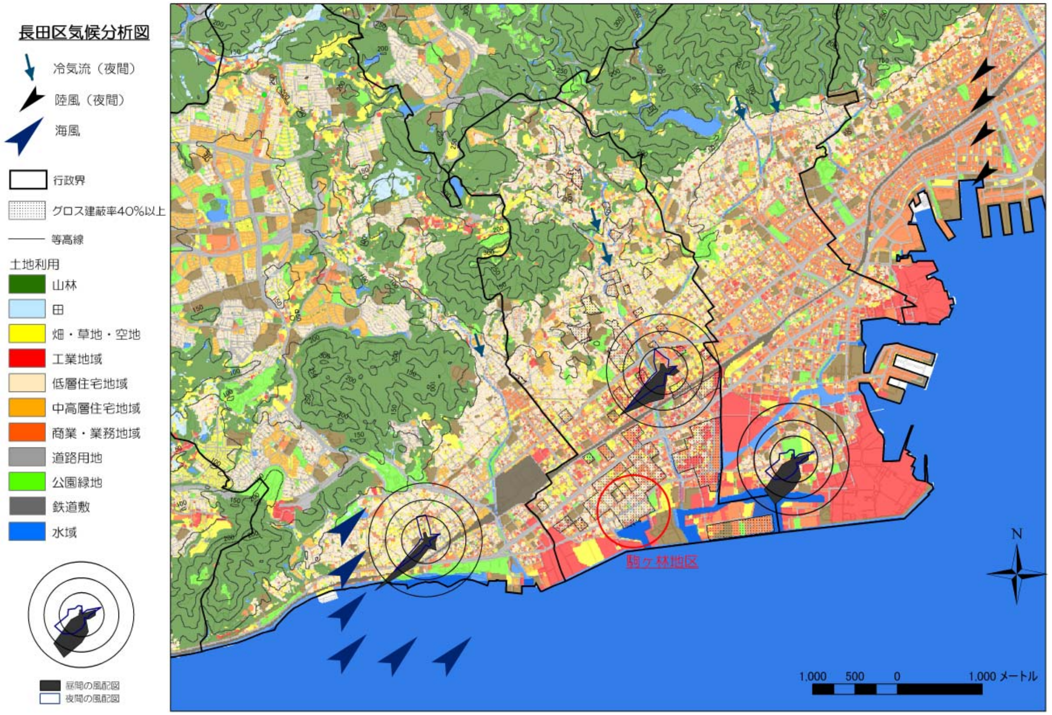


Image of "Urban climate map" use

Urban climate map



Conclusions and acknowledgements

- Guideline for urban heat island measures have been established by Japanese government and local governments
- Evaluation and certification program have been implemented by Ministry of the Environment and Osaka HITEC
- "Cool roof guidebook" was published by Architectural Institute of Japan recently. In this guidebook, recently history of heat island research in Japan have been aggregated.
- Some parts of contributions by Japanese researchers to this field have been introduced.

- I would like to thank everyone who provided information and sponsors from Japan (Miki Coating Design Office, Daikin Industries, Ltd., Nippon Paint Co., Ltd., which are organized by Heat Island Institute International).

Thank you for your attention.

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