

Urban Heat Island Countermeasures Summary & White Paper

Patrick Curran SWA Fellowship

Alexander Robinson

Sunday, July 11, 2010

Table of Contents

1. What is Urban Heat Island (UHI)
2. UHI Impacts
3. UHI Countermeasures & Global Warming
4. Microclimatic Design Principles (from Moleskin Notes)
5. *Case Study // Stuttgart, Urban Climatology in Practice*
6. *Parametric Studies // Selection of Contemporary Research*
7. *UHI Infrastructure // New Goals & Purpose*
8. APPENDIX A: Resources & Bibliography
9. APPENDIX B: Proposal

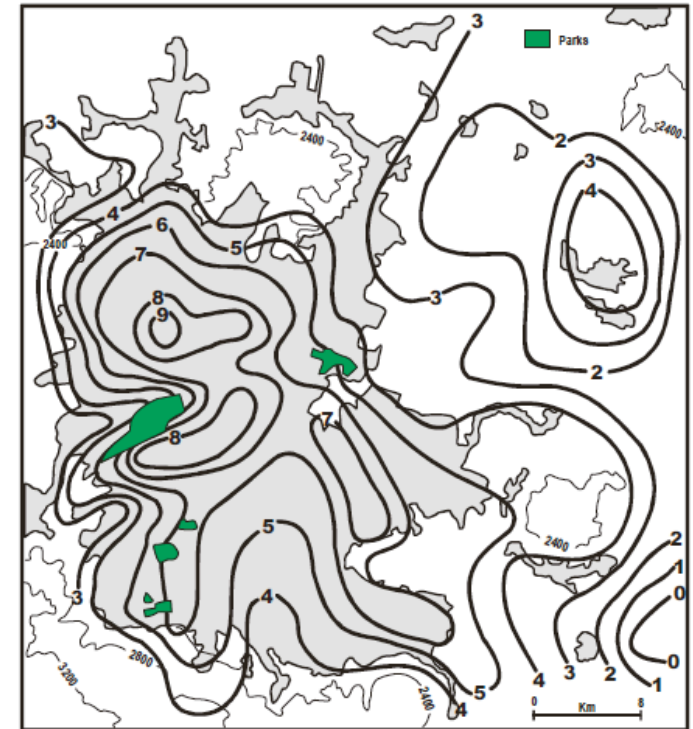


Figure 2: Mean minimum temperature for November 1981 in Mexico City. Redrawn from [4].

1. WHAT IS URBAN HEAT ISLAND (UHI)?

UHI refers to the generally warm urban temperatures compared to those over surrounding, non-urban, areas.

UHI is generally presented as a temperature difference between the air within the Urban Canopy Layer and that measured in rural areas, outside the settlement.

The greatest magnitude of UHI is observed in the evening and night, peaking about 4 hours after sunset. Urban sites cool slower than rural.

Energy Balance

The formation of the UHI can be understood from the viewpoint of the energy balance of urban area. They are numerous factors that are thought to contribute to the effect.

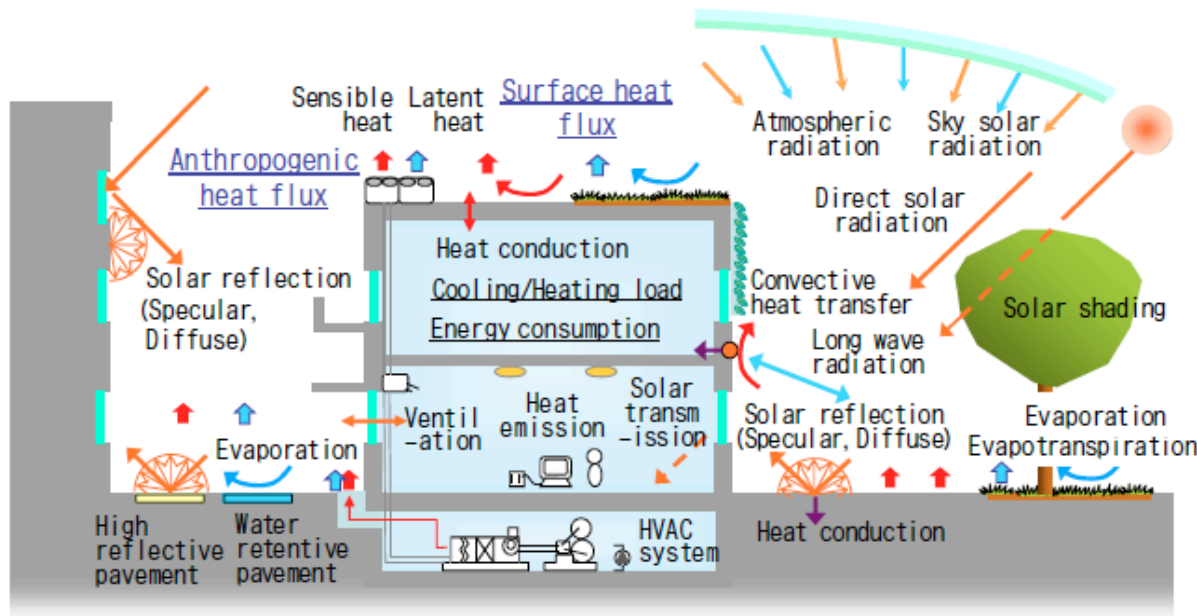


Fig. 1 Heat and energy balance in an urban canopy and the calculation items in the simulation system

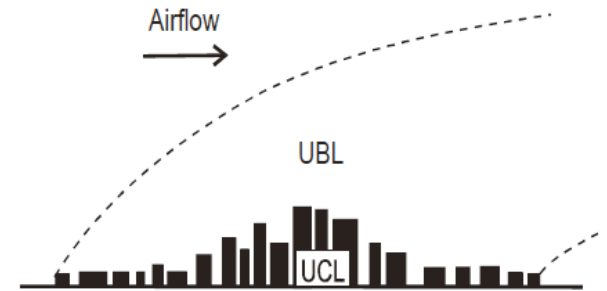


Figure 1: A vertically exaggerated cross-section of the urban atmosphere and its two main layers. The slope of the UBL is between 1:100 and 1:200 in reality.

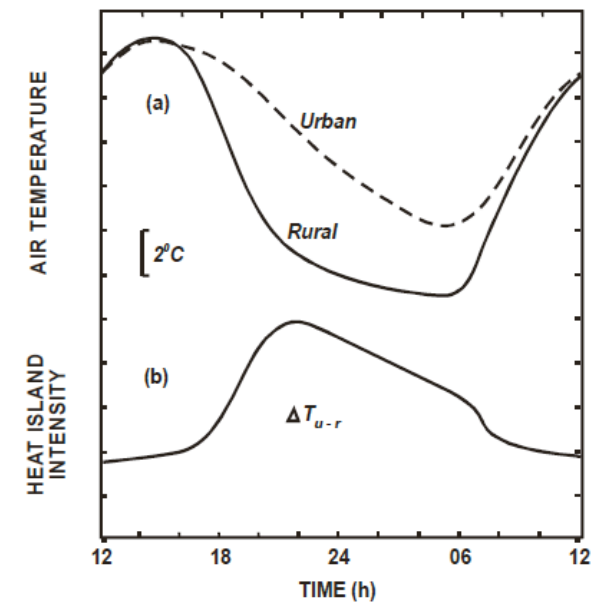


Figure 4: Typical temporal variation of urban and rural air temperature under clear skies and weak airflow. The UHI is produced by the difference between the cooling rates. Redrawn from [13].

1. What Is Urban Heat Island (UHI)?

LESSON: Waste Heat is not the a major contributor

Contrary to some anecdotal observations anthropomorphic generated heat, directly emitted by machinery or by other means, is not a significant contributor to UHI.

LESSON: The material and spatial composition of the urban surface is the greatest contributor.

Energy Balance term	Urban features	Urban effect
Increased K^*	Canyon geometry	Increased surface area and multiple reflection
Increased $L_{\downarrow sky}$	Air pollution	Greater absorption and re-emission
Decreased L^*	Canyon geometry	Reduced sky view factor
Q_F	Buildings & traffic	Direct addition of heat
Increased ΔQ_S	Construction materials	Increased thermal admittance
Decreased Q_E	Construction materials	Increased water-proofing
Decreased (Q_H+Q_E)	Canyon geometry	Reduced wind speed

Urban Surface Factors

A. Urban Albedo

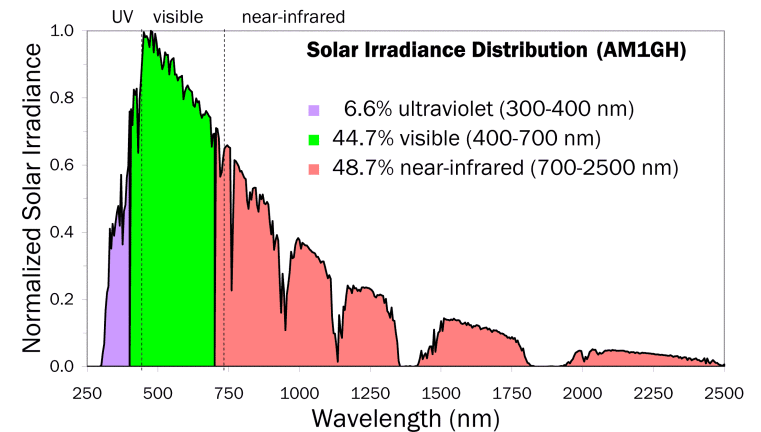
Albedo, or solar reflectance, is an number describing the percentage of total solar radiance (ultra-violet, visible, and near-infrared) that a surface reflects. Surfaces, both natural and urban have a wide range of albedos that are usually indexed to various common urban materials (asphalt, brick, turf grass).

In general, the lower albedo of urban materials results in greater absorption of solar radiation during the daytime, contributing to UHI.

Judging only by the popularity of countermeasures, improving the albedo values of a city is the easiest and most effective way to reduce UHI and, in general, seems to be the first step in terms of government policy.

However, while the prevalent wisdom is that high albedo surfaces are good and low albedo surfaces are bad, there are some other factors that should be considered in terms of albedo:

1. Most albedo measurements do not specify the range of radiance that the surface reflects. Darker materials don't necessarily have low albedos. Terra cotta tiles, for example, absorb a lot of visible light, but reflect most near-infrared, making them a good counter-UHI materials material, even though they are not light-colored. Many materials are being developed or are available with this property.



$$\text{Solar reflectance } R_{sol} = 6.6\% \times \text{ultraviolet reflectance } R_{uv} + 44.7\% \times \text{visible reflectance } R_{vis} + 48.7\% \times \text{near-infrared reflectance } R_{nir}$$

© 2009 Ronnen Levinson (RMLLevinson@LBL.gov)

1. What Is Urban Heat Island (UHI)?

- High albedo materials may not always contribute to the micro climate and ultimate comfort of an urban landscape. Glare, reflected heat, and cool surfaces can run counter to promoting comfort and use. A high albedo landscape can direct heat to users instead of capturing and storing it. See section on micro-climatic design.
- The albedo of materials can change over time. For example, the albedo measurements of asphalt and concrete converge over relatively little time (5 years).

Table 1. Solar reflectance (albedo), Emittance, and Solar Reflective Index (SRI) of select material surfaces (9,10,11,12)

Material surface	Solar Reflectance * / Albedo	Emittance	SRI*
New asphalt	0.05	0.9	0
Aged asphalt	0.1	0.9	6
"White" asphalt shingle	0.21	0.91	21
Aged concrete	0.2 to 0.3	0.9	19 to 32
New concrete (ordinary)	0.35 to 0.45	0.9	38 to 52
New white portland cement concrete	0.7 to 0.8	0.9	86 to 100

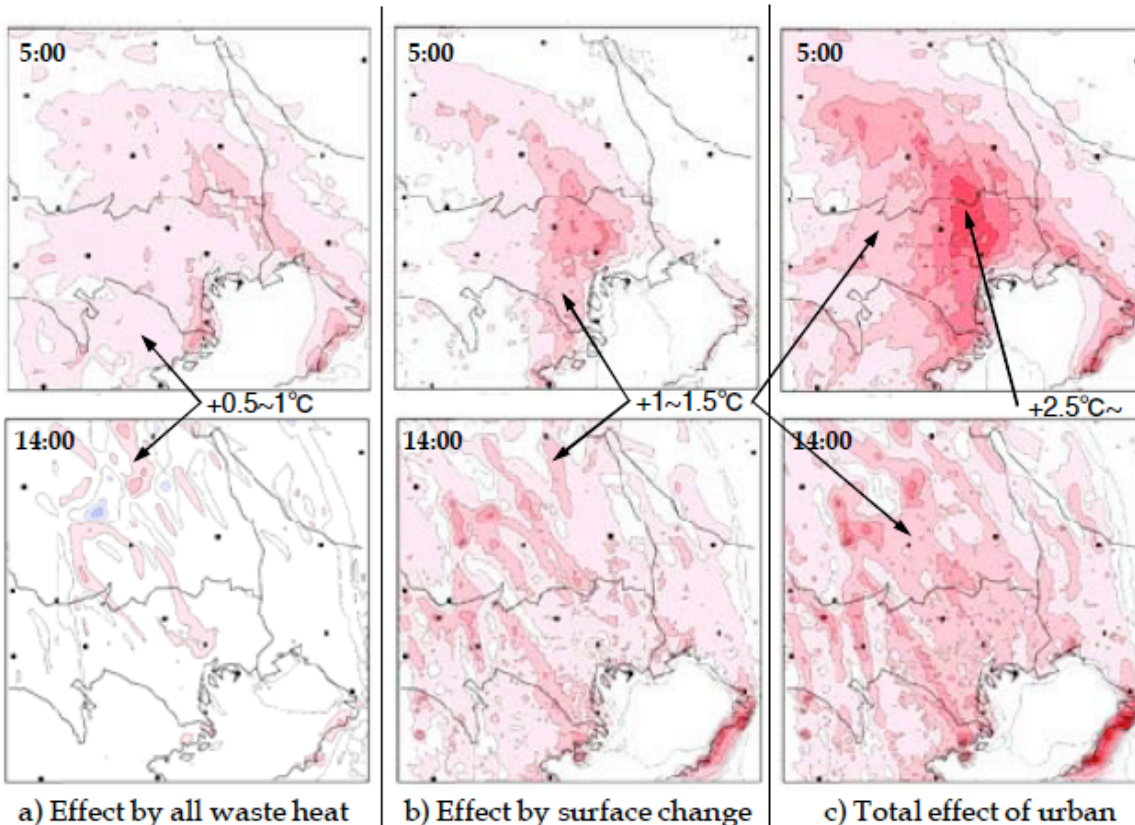


Figure 2 Influence of man-made courses on urban heat island. The upper panels are the near-ground air temperatures at 5:00 local time, while the lower panels are at 14:00 local time. The left panels are the subtraction of CASE2 from CASE1, the middle panels are the subtractions of CASE0 from CASE2, and the right panels shows the subtraction of CASE0 from CASE1. The case studies suggested that the near-ground air temperature difference may reach more than 2.5 °C in the case of Tokyo metropolitan area, and surface change contributes to heat island rather than anthropogenic heat.

1. What Is Urban Heat Island (UHI)?

B. Urban Geometry And Solar Factors

The reflectance properties of urban materials and the composition of the urban 'surface' is not a sufficient explanation of UHI. Multiple reflections within the urban canopy lowers the albedo of the urban 'surface'. Urban geometry is considered a major contributor to UHI. For instance, correlations between Sky View Factor (a measurement of the visibility of the sky) and UHI are correlated.

Predicting and measuring the impacts of urban geometry is difficult and often highly contingent on the local environment and relative solar position. Note, in the field of UHI streets with housing are often referred to as urban canyons.

Also, in some cases urban geometries result in too little light reaching the ground and creating an uncomfortable situation. In Teardrop park, by MVV Associates, this was improved by heliostats that reflect light from the rooftops of the adjacent buildings into the darker recesses of the park.

Some of the major factors of Urban Geometry and UHI are:

1. The material composition of vertical surfaces can alternatively reflect and trap light.
2. Amount of sky that is visible from any one point (Sky View Factor). Width of space or street effects this. Generally, a smaller sky view factor results in a cooler space.
3. Solar orientation of street or space (East/West, North/South).

C. Urban Geometry and Air Movement

The geometry of urban environments can also have a large impact on the movement of air at both macro and micro scales. Lower average wind speed within urban environment suppresses turbulent exchanges and reduce the distribution of heat. Also buildings and other built elements can obstruct major cooling air flows. This is particularly common in coastal cities where high-density development is concentrated on the coast.

In addition to reducing the exchange of heat, restricted urban air flows can also severely exacerbate pollution.

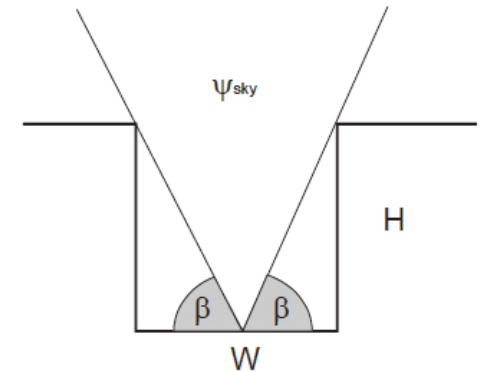


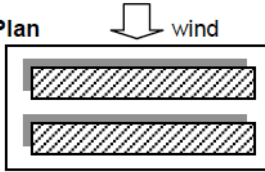
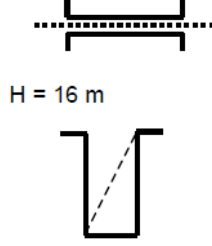
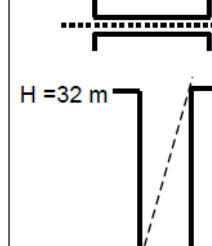
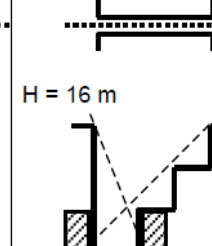
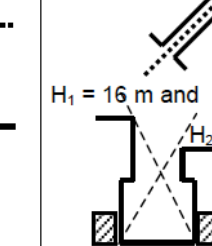
Figure 4. A depiction of the sky view factor in a symmetrical street canyon, described by its width (W) and its height (H), $\psi_{\text{sky}} = \cos \beta$. [12]



1. What Is Urban Heat Island (UHI)?

Modeling and predicting air flow of any given site is very complicated and requires expert consultants and very large and complex computations. Also, at a macro-scale every city has a different set of air-flow conditions. However, due the significant impact that large-scale air flows can have on urban comfort and health, large-scale studies are often funded to evaluate alternative development scenarios and identify critical air flow pathways.

Table 1: Schemes of the simulated streets canyons

street width: 8 m bldg height H: variable building length: 6 H wind speed: 5 m/s at 10m Asphalt road: albedo: 0.1 Brick walls: albedo: 0.3 roof: albedo: 0.15 Plan 	(a) reference street: E-W oriented street with an aspect ratio of H/W = 2  H = 16 m	(b) E-West oriented street with an aspect ratio of H/W = 4  H = 32 m	(c) E-W oriented street with an asymmetrical profile H/W = 2 and 1, including galleries  H = 16 m	(d) NE-SW oriented street with horizontal overhangs and galleries  H ₁ = 16 m and H ₂ = 12 m
---	---	--	--	--

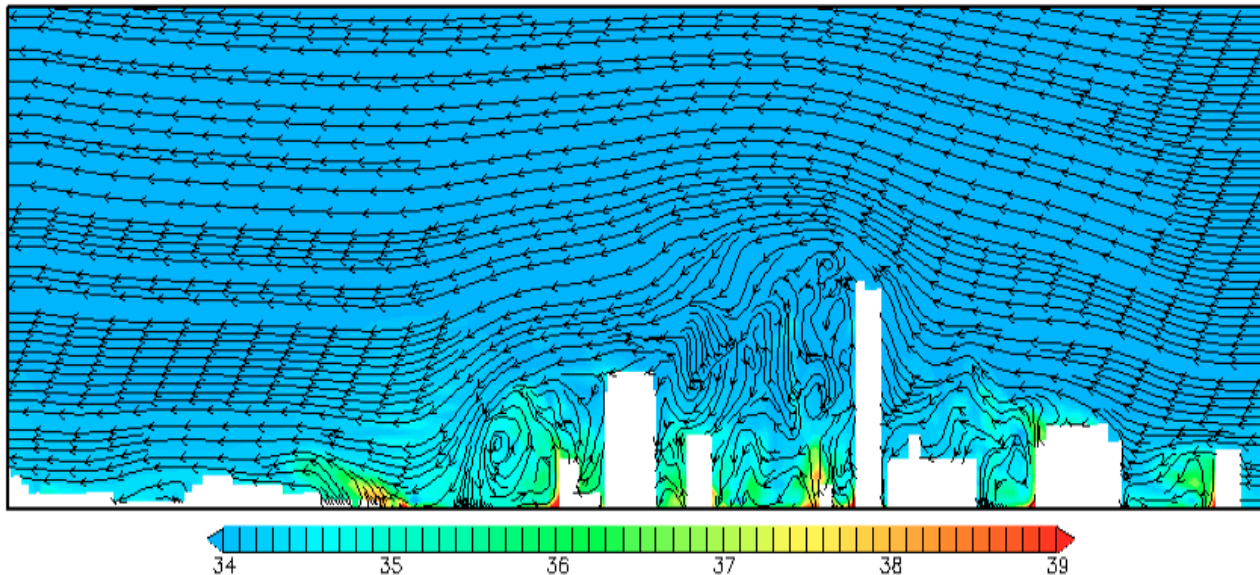


Fig.5. Wind stream function and temperature distribution in for the vertical.

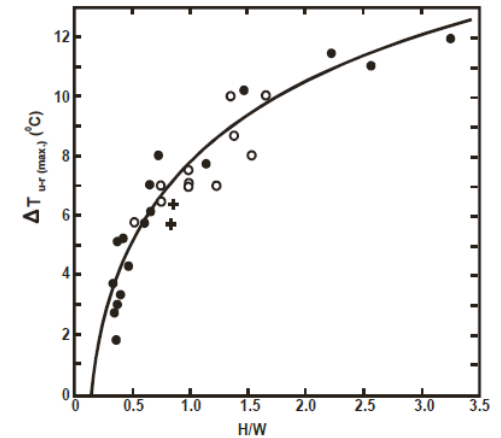


Figure 5. Relation between the maximum heat island intensity ($\Delta T_{u-r(max)}$) and the height to width ratio (H/W) of the street canyons in the centres of the settlement (Based on observations for 31 cities in N. America (•), Europe (◦) and Australasia (+)). Redrawn from [11]. The relationship can be expressed as

$$\Delta T_{u-r(max)} = 7.45 + 3.97 \ln(H/W)$$

or

$$\Delta T_{u-r(max)} = 15.27 - 13.88 \psi_{sky}$$

1. What Is Urban Heat Island (UHI)?

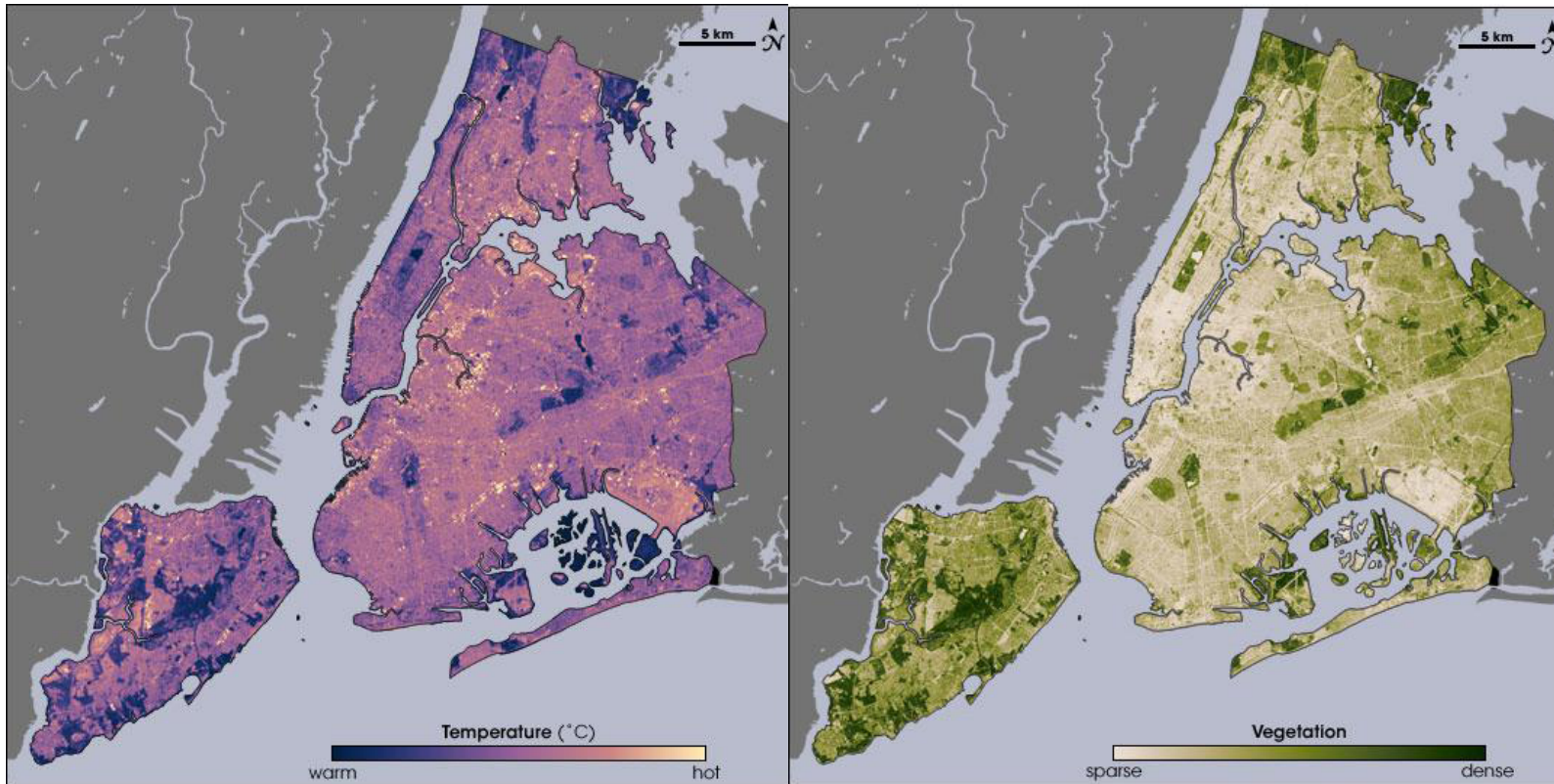
Some urban geometry factors have been generalized for certain urban fabrics. Examples are given in the case of Stuttgart and Hong Kong. In the absence of specific recommendations for a certain condition or area, these results can be generalized to other conditions.

1. What Is Urban Heat Island (UHI)?

D. Evapo-transpiration

Impervious, un-vegetated surfaces hinder evaporative cooling. Dr. Reuter, the head of the Stuttgart Department of Urban Climatology and Noise Protection, asserted that whether a surface is porous and can evapo-transpirate is a more significant indicator of UHI than the albedo of the surface materials. Porous pavements, for instance, have been demonstrated to be cooler, even though they may have a low albedo. Also, in regions where excessive rainfall coincides with warm temperatures there are multiple proposals for evapo-transpiration pavers as a cooling measure. On the other hand, water logged soils and mud can absorb massive amounts of heat and contribute to heat island. At a certain point water-logged material is able to conduct and store excess heat.

Landsat thermal image & Vegetation Density // NYC August, 2002



1. What Is Urban Heat Island (UHI)?

Evapo-transpiration Pavers and their performance.

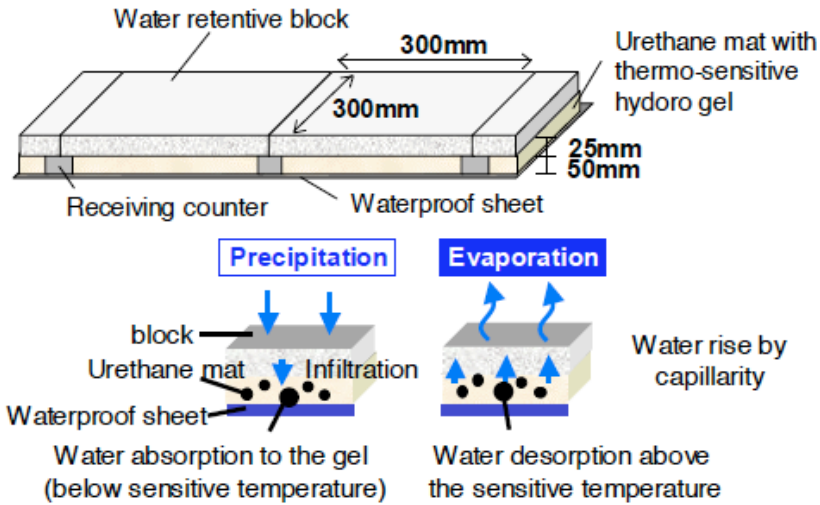


Fig. 8 Composition and expected function of the pavement system

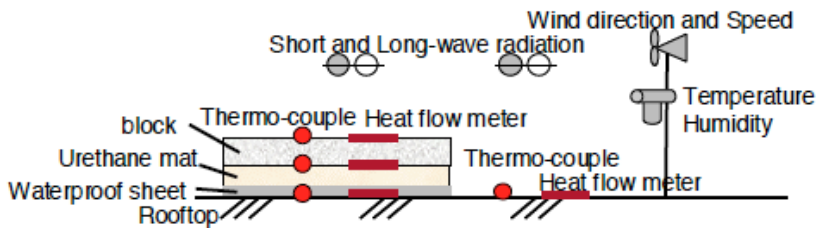


Fig.9 Mesurement apparatus for water retentive pavement

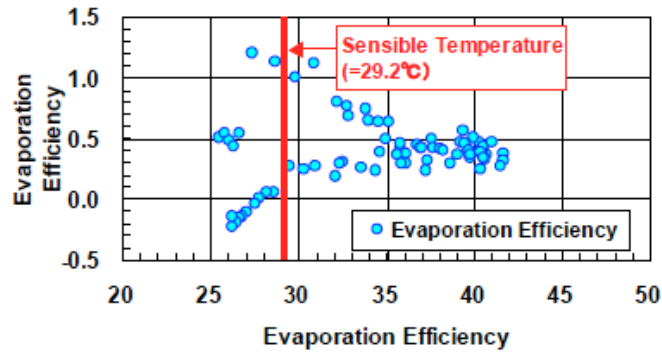
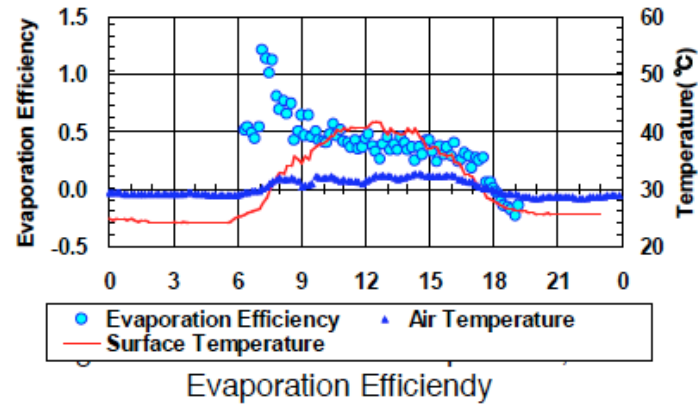


Fig.11 Relative of evaporation efficiency and surface temperature

2. UHI IMPACTS

Summary

The impacts of UHI in the urban environment are far reaching and complex. The following provides a summary of those impacts. Perhaps one of the most important impacts of UHI, as far as landscape architects are concerned, is that high-density cities may be our best sustainable model and making them comfortable can have some of the largest ecological / sustainable impacts.

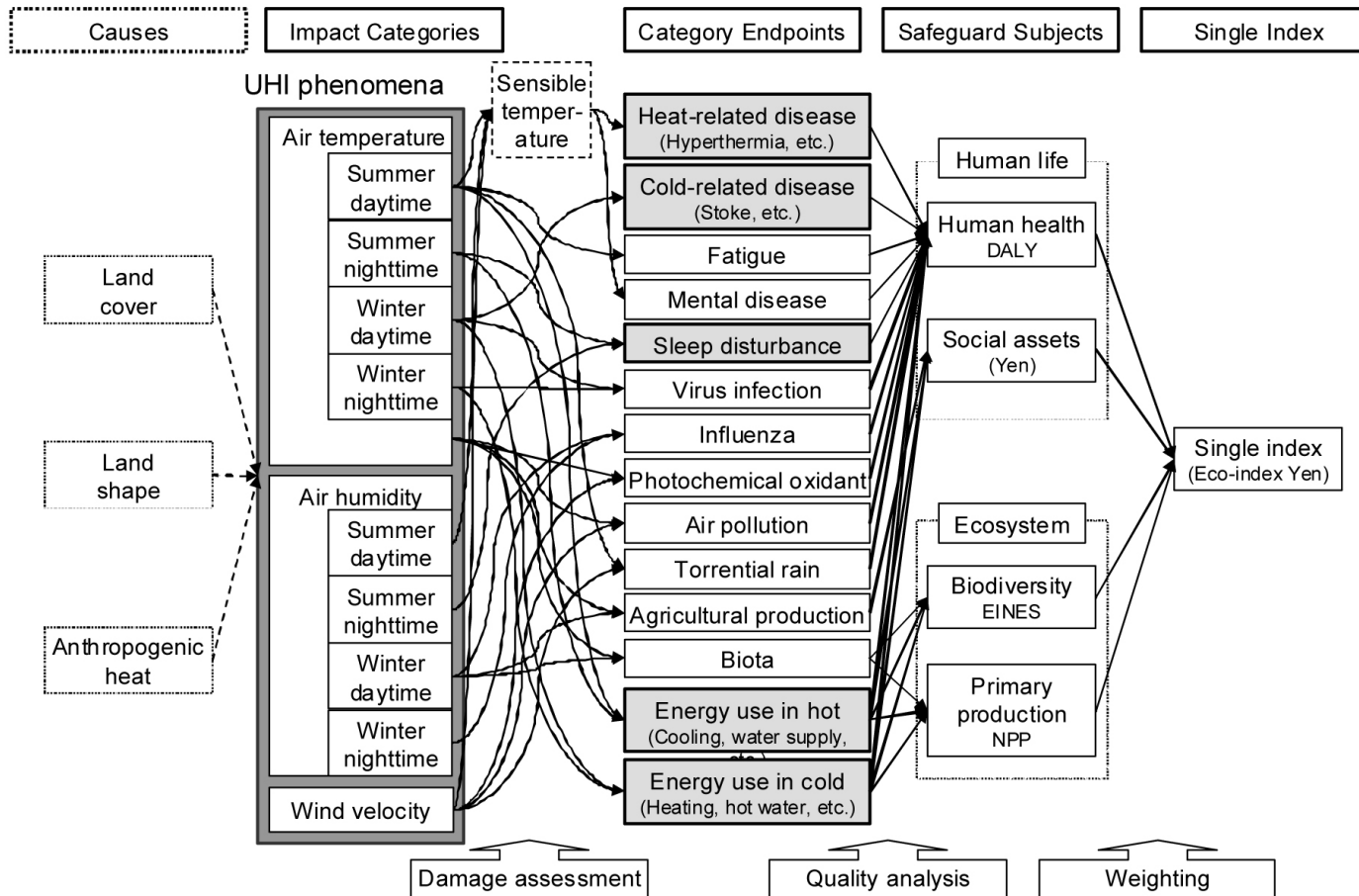


Fig. 1 Framework for evaluating environmental impact of UHI

2. UHI Impacts

Health

The most dramatic health impact that UHI contributes to are heat wave mortalities. During extreme heat wave conditions UHI areas show measurably much greater mortalities than areas outside of the UHI impacted area. UHI contributes directly to a host of other health issues, including fatigue, sleep disturbance, and disease. It is important to determine whether the region you are practicing is susceptible to such an impact. In general, excess heat will increase mortalities.

- The 2003 heat wave in Europe was responsible for 37,451 deaths.
- The 1995 Chicago heat wave was responsible for approximately 600 heat related deaths.

As related to air movement:

UHI impacts are often associated with reduced air flow and subsequent transfer of heat out of the urban environment. This excess heat and stagnant air are often associated with increased disease in an urban environment. The SARS scare in Asia was an impetus for many cities to tackle UHI and, in particular, counter SARS by increasing air circulation and reducing UHI.

UHI has a host of other indirect impacts on health. See diagram “Framework for evaluating environmental impact of UHI”.

Materials

Materials exposed to UHI conditions will degrade faster and release more polluting chemicals, especially petrochemical products. Thus UHI countermeasures should create a longer lasting landscape.

Sustainable Cities

Cities and their residents are particularly susceptible to impacts of UHI and therefore an increase in UHI in cities can have both a large impacts on environment in terms of direct energy use, but also have larger impacts on the environment by making dense living situations uncomfortable.

What is interesting to Landscape Architects, is that if you consider the importance of cities the impact of UHI and climate change on the comfort urban individuals begins to have a large impact on sustainable living:

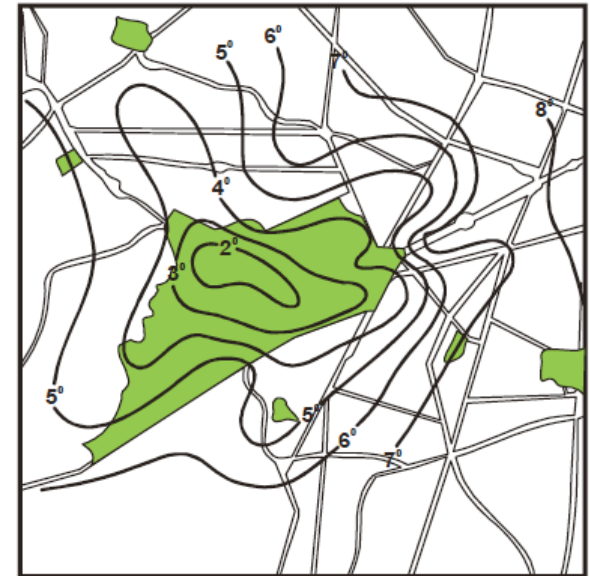


Figure 3: Isotherms in Chapultepec Park on December 3, 1970 (5:28 to 6:48), with clear sky and calm air. Redrawn from [5].

Cities are Critical to the Environment and People of Earth

- 0.5% to 2% of Earth's area (estimates vary)
- >50% of global population.
- > 400 cities with 1,000,000+ people
- 20 “mega-cities” with 10,000,000+ people
- 80% of global CO2 emissions
- 75% of global energy consumption

Cities are our Best Model of Sustainable Living

- New York City inhabitants generates 7.1 metric tons of greenhouses gases annually, less than 30% of the U.S. average of 24.5 metric tons.
- New York residents use less water, burn less fossil fuel, and produce less solid waste. The households use much less electricity: 4,696 kWhrs / year, compared to 16,1116 kilowatt hours in Dallas. 82% of employed Manhattanites use alternative transportation. 10 times the rate of Americans in general; 8 times the rate of workers in LA County.
- This is a by-product of a high-density living situation. The density of NYC is 67,000 people per square mile, or more than 800 times that of the U.S. and roughly 30 times that of Los Angeles
- (New York City benefits from a number of factors that support dense living, including extensive access to cleaning and cooling sea breezes and large parks.)

Reduced Access to Comfortable Outdoor Environment in Cities Leads to:

- A. *Reduced Use of Alternative Transportation*
 1. Increases energy consumption via cars, exacerbating global warming.
 2. Increases pollution and directly increases UHI.
 3. Reduces ridership & public support for Public Transit.
- B. *Reduced Access to Outdoor Exercise*
 1. Reduced health, increased health care costs.

2. UHI Impacts

2. Sedentary activities increases agricultural production & land consumption.

C. *Reduces General Interaction of City & Critical Mass of Neighborhood*

1. Jane Jacobs, etc.

D. *Reduces use and value of outdoor spaces.*

Sum of effects reduces Urban Quality of Life and leads people to live less sustainably or exit from city and generally expand their energy and ecological footprint.

3. UHI COUNTERMEASURES & GLOBAL WARMING

Global Warming

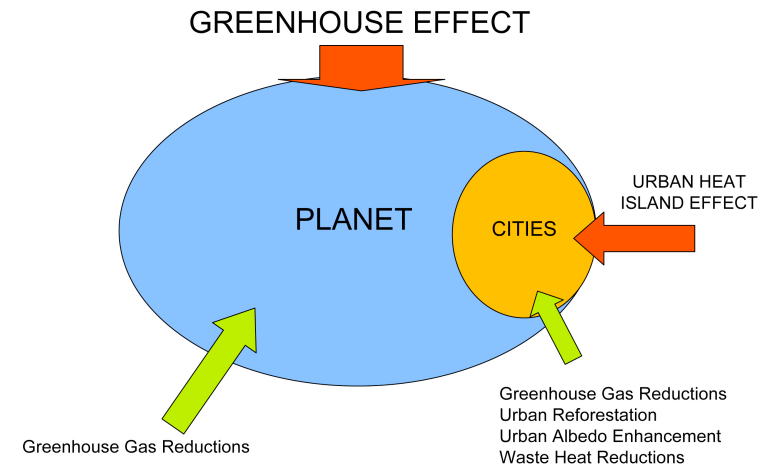
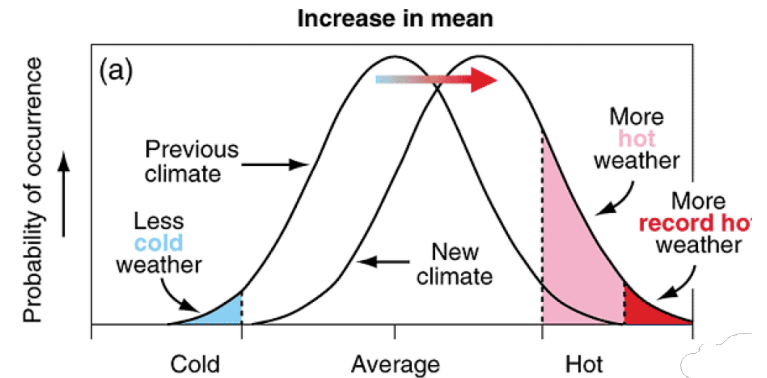
In general global warming will only exacerbate the impacts attributed to UHI and as such forms half of the double threat to cities.

Global Warming or UHI Trends?

One of the major questions concerning UHI is whether global warming or UHI related impacts are warming cities. If for example, the rural areas are warming as much as urban areas than UHI cannot be blamed for these conditions. This has been shown to the case in some conditions where an “oasis effect” has occurred with the increase of lawns and landscaping within the city. In general, research has shown that cities are warming faster than the rural surroundings, but that both are warming significantly, due to global warming. In this way cities face the dual threats of UHI and global warming.

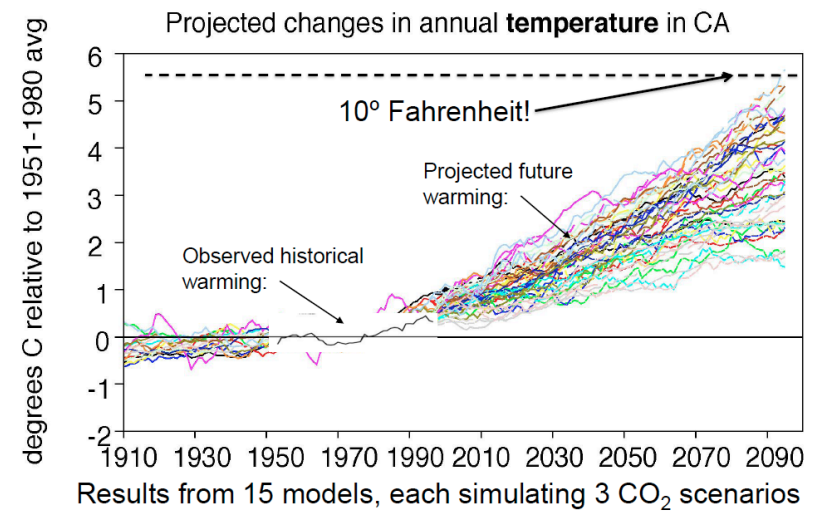
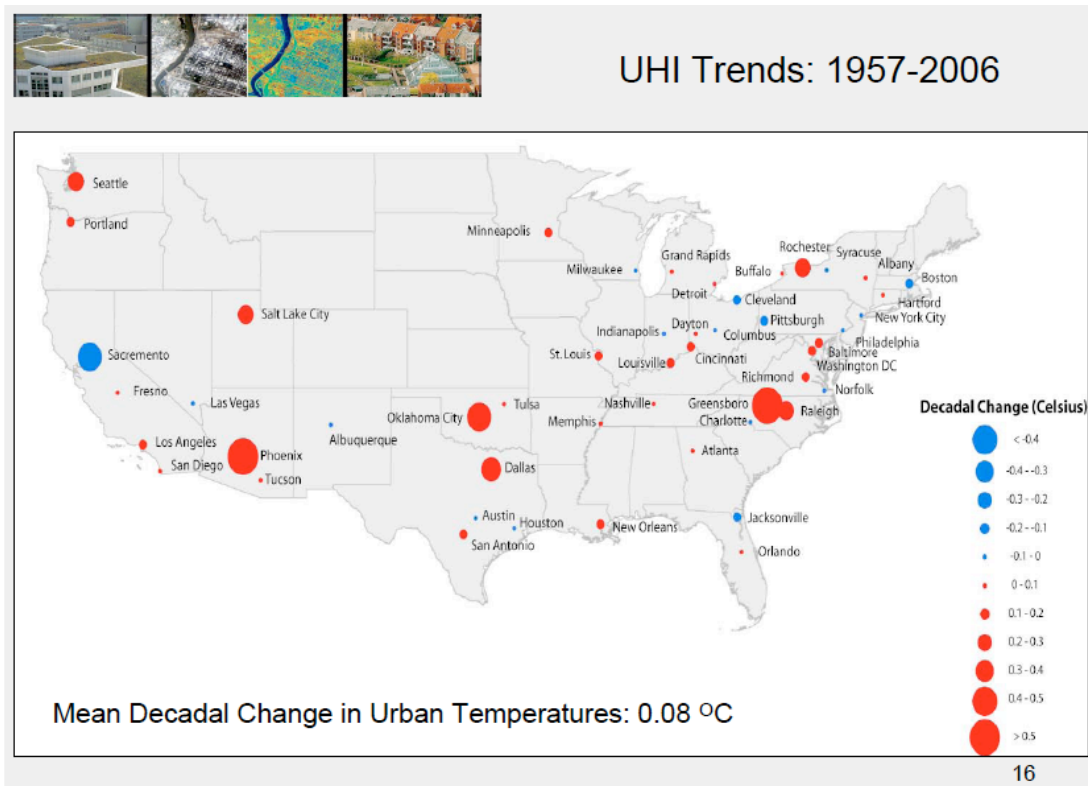
- On average, the decadal rate of warming in large U.S. cities was approximately 50% greater than that of proximate rural areas taken to represent “background” warming trends over the period of 1957- 2006.
- For cities in which the urban heat island effect intensified during this period (60%), the decadal rate of warming was approximately 160% greater than that of proximate rural areas.
- As warming scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) are based on background global rates of warming, these scenarios (1.4 to 5.8 OC by 2100) are likely to significantly underestimate the rate of warming in large cities over time.

UHI is calculated by comparing the difference in recorded urban and rural conditions. All areas showed urban warming, but in some cases, such as the cities in blue in the diagram “UHI Trends: 1957-2006”, rural warming outmatched urban warming. The data represented in this map likely includes various anomalies due to the weather stations. In most cases the urban weather station is located at the local airport and is not necessarily reflective of the UHI effects that may be present within high-density urban areas. Furthermore, the rural station(s), while standardized to some extent, may record a certain micro-



3. UHI Countermeasures & Global Warming

climate, in particular due to the high variability of the rural landscape. Also, in some cases rural land use trends has resulted in changes in mean temperature



that are not a product of global warming.

Global Warming/UHI Countermeasures

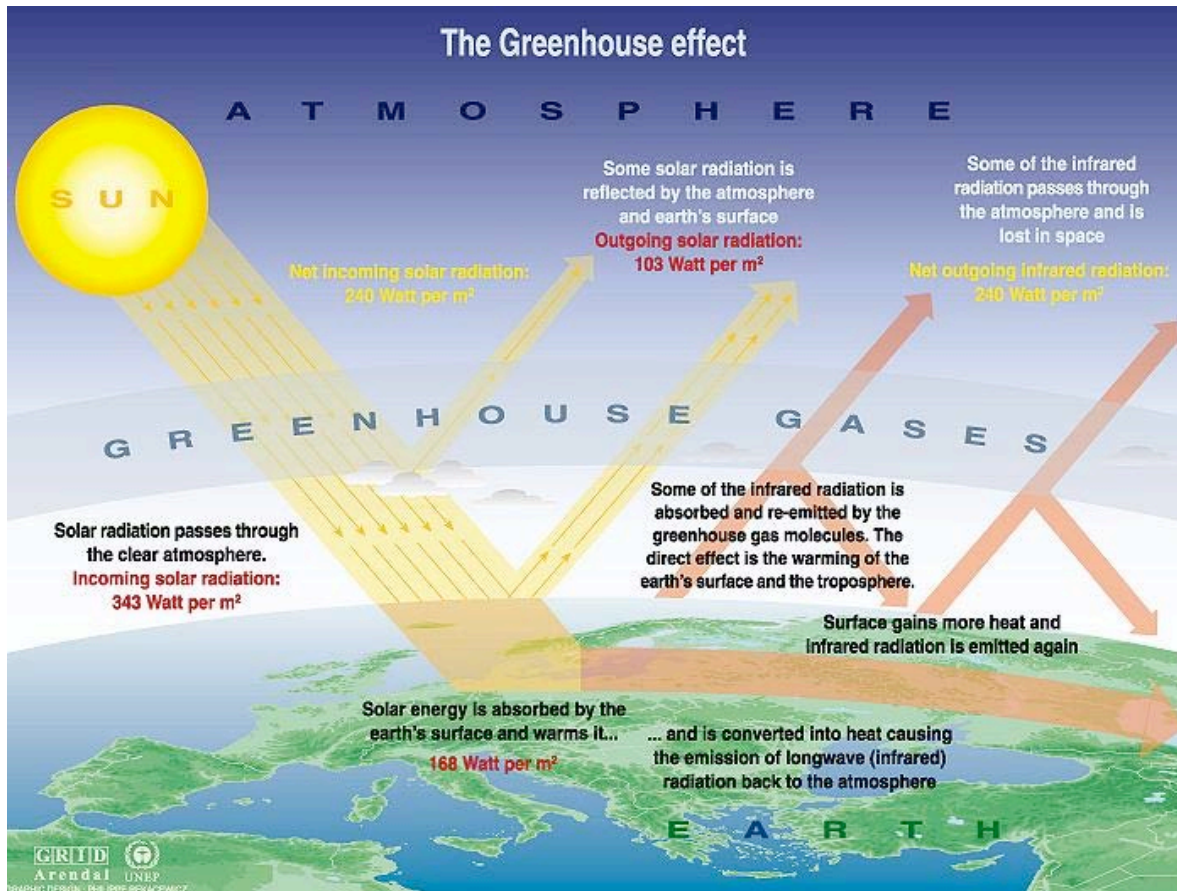
As discussed in the previous section about sustainable cities, rising temperatures in cities, whether due to global warming or UHI, can significantly contribute to further global warming by contributing to a self-perpetuating loop of net energy consumption per person. For this reason, reducing the temperature of cities has multiple immediate benefits, including a reduction in energy use -- the likely cause of global warming. While it is itself a countermeasure to global warming, reducing temperatures with global warming

3. UHI Countermeasures & Global Warming

countermeasures is very challenging and its ultimate effects may lag by many years or decades. On the other hand, the temperature effects of UHI countermeasures are immediate and could theoretically be used to counter both UHI and buffer us from the effects of global warming. Even areas that only suffer from global warming could benefit from UHI effects.

Macro vs. Micro Countermeasures

An important distinction that was rarely addressed was whether it was more important to manage the comfort of an individual city-dweller or reduce the net temperature of the entire city / environment. For instance, in some cases a low



3. UHI Countermeasures & Global Warmi

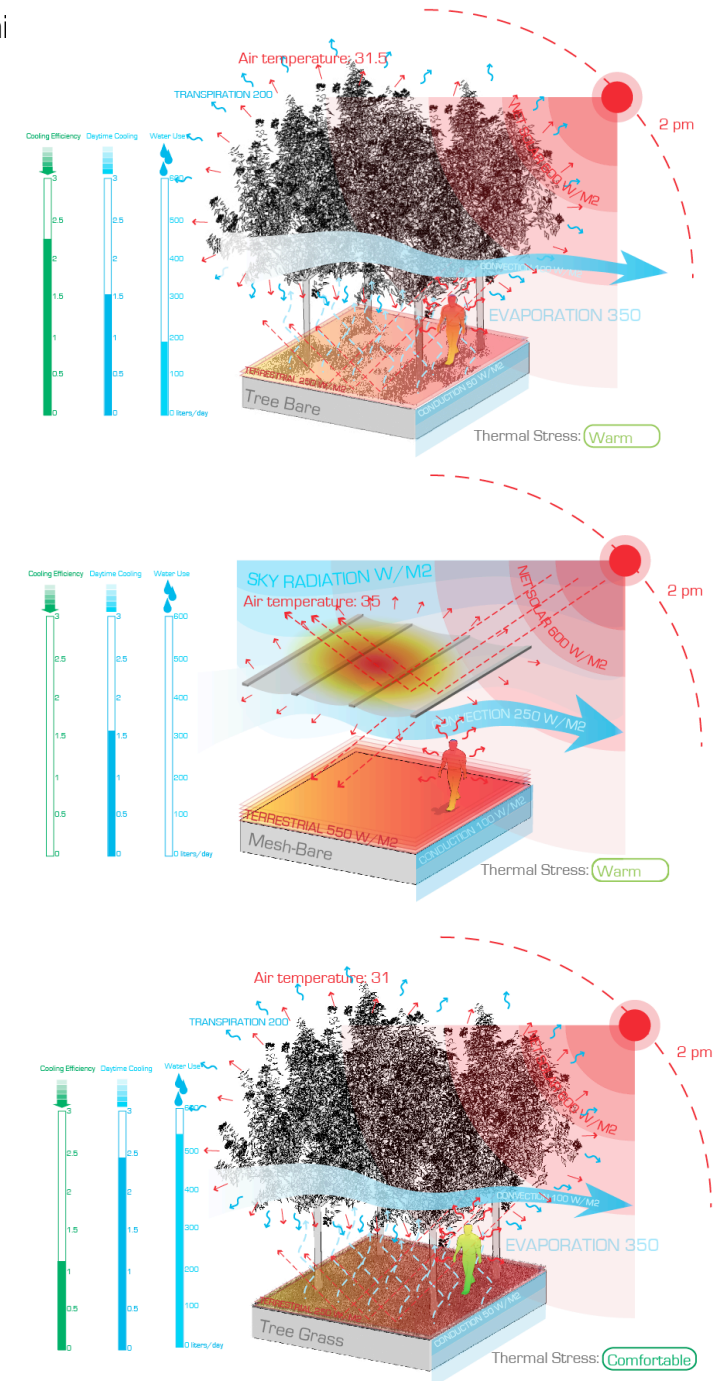
albedo paving surface, such as a dark paving stone, may be preferable for personal comfort in order to reduce reflected heat & glare or to create a warmer micro-climate in the evening.¹ However, such an approach may exacerbate overall discomfort within the city. Other macro / micro effects conflicts exist -- planting trees in urban corridors produce important benefits, but also can reduce air circulation (individual trees do little to directly filter pollution).

Water Efficient vs. Cool Landscapes

Furthermore, the prevalence of low-water use landscapes, a response to water shortages and calls for sustainability, could theoretically have the unintended consequence of exacerbating UHI in sensitive areas and creating a variety of ill effects and ultimately cost more in terms of other resources than the water saved. The water efficiency of various cooling countermeasures has been measured (see research summary) by researchers -- besides shade structures, trees offer the best cooling per unit of water. Advanced need maps could help clarify where the benefits of resource-demanding landscapes are efficient use of resources.

Primary UHI Countermeasures

This section will provide an overview of countermeasures that will be covered in more detail in the contemporary research section. There are a great spectrum of countermeasures, ranging from architecture and landscape architecture design to material technology and policy decisions. The focus of this document are countermeasures that lie within the scope of landscape architects and to the largest extent possible, countermeasures that relate to design and not just material use.



¹ Brown, Robert D., and Terry J. Gillespie. *Microclimatic landscape design: creating thermal comfort and energy efficiency*. New York: J. Wiley & Sons, 1995.

3. UHI Countermeasures & Global Warming

1. Surface Modifications

Surface modifications are the most common easily mandated improvements and will probably represent the first set of countermeasures taken. They generally consist of using higher albedo materials, but can also include vegetation, porous materials, or even water. California and many states have already implemented policies to require higher albedo roofs. Akhbari has calculated the potential impacts of using cool roofs and some of the parameters for cool paving:

a. CO₂ Equivalency of Cool Roofs World-wide (Tropics+Temperate)

- Cool Roofs alone could offset a total of 24 Billion Tons (Gt) CO₂
- Worth > €240 Billion (Pre-recession was €600B)
- To Convert 24 Gt CO₂ one time into a rate
- Assume 20 Year Program, thus 1.2 Gt CO₂/year
- Average World Car emits 4 tCO₂/year, equivalent to 300 Million Cars off the Road for 20 years. (600 million cars in the world)

b. Cool pavement technologies are diverse.

- Solar reflectance of freshly installed asphalt pavement is ~ 0.05
- Aged asphalt pavements have a solar reflectance of 0.10 - 0.18
- Light-color (low carbon content) concrete can have an initial solar reflectance of 0.35 - 0.40 that will age to about 0.25 - 0.30
- Recommend using cool pavement materials to increase the solar reflectance of paved surfaced by ~ 0.15
- Current pavement construction standards do not account for the solar reflectance of pavements. However, the maximum temperature of a pavement and the diurnal range of pavement temperature is an important consideration in design of a pavement.
- Laboratory tests have demonstrated that cooler pavements have a longer life time.
- LEED Green Building Rating System assigns one rating point for the use of cool pavements in its Sustainable Sites Credit.

Note that cool paving may not always be compatible ideal landscape micro-climate design.

3. UHI Countermeasures & Global Warming

2. Urban Geometries & Planning

This encompasses a large range of strategies and particular countermeasures, ranging from particular urban canyon geometries to urban design strategies that ensure access to a diverse range of climatic conditions. Urban geometry design can have impacts multiple UHI and non-UHI environmental impacts, such as air quality.

3. Microclimatic Design

Microclimate design distinguishes itself from the other countermeasures by focusing on the individual comfort of individuals rather than the entire urban condition. As mentioned above, in some cases the micro-climate design of a space may conflict with city-wide UHI countermeasures. Microclimatic design also includes a variety of technologies, such as street level misters or fractal geometry pergolas. Brown and Gillespies' *Microclimatic landscape design: creating thermal comfort and energy efficiency* provides a good overview for general principles of microclimatic landscape design.

EPA Urban Heat Island Countermeasure Suggestions

- Trees and Vegetation
- Green Roofs
- Cool Roofs
- Cool Pavements

5. CASE STUDY/ /STUTT GART, URBAN CLIMATOLOGY IN PRACTICE

Stuttgart Section of Urban Climatology

Stuttgart in Germany has the oldest known urban climatology city department, dating back from 1938. The department urban climatology was established early due to the fact the city is surrounded by hills and has poor ventilation, leading to air pollution and heat island problems. Of the many urban planning measures that the department has addressed are the facilitation of clean cool air sources from the forested sections of the hills, while diverting and cleaning hot and polluted air streams. Los Angeles and surrounding areas, as an example, have similar issues of pollution entrapment and consistent air currents, but little or no planning is done to account for these.

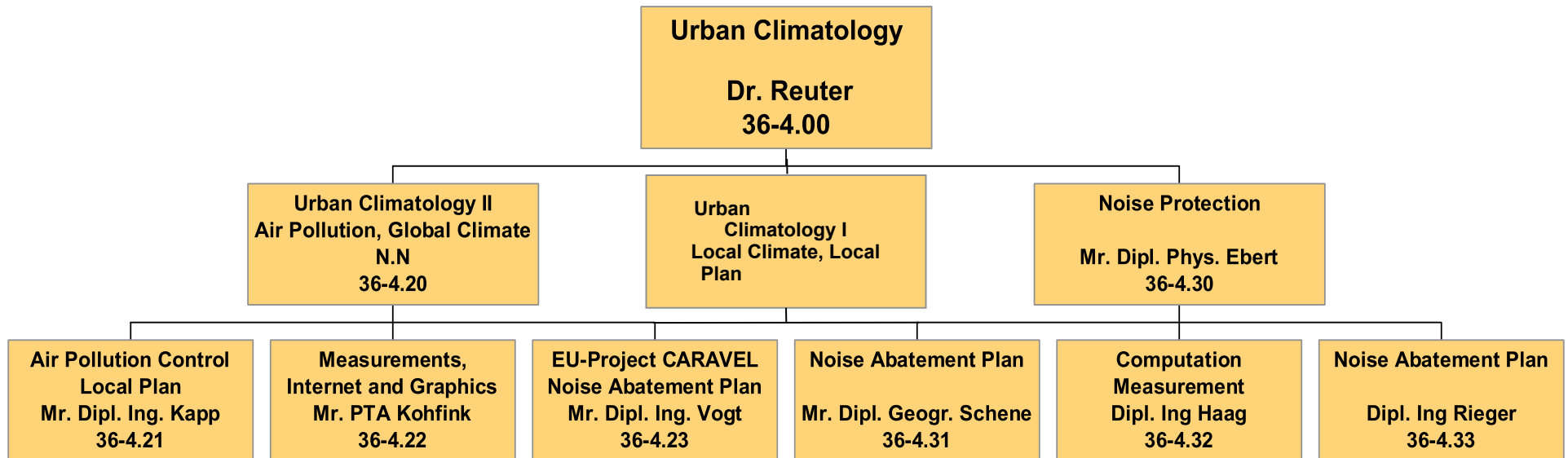


Stuttgart is nestled in a valley with a single outlet, creating a condition with restricted air flows and both UHI and air pollution implications.

Stuttgart Existing Conditions

UHI & Air Pollution Conditions

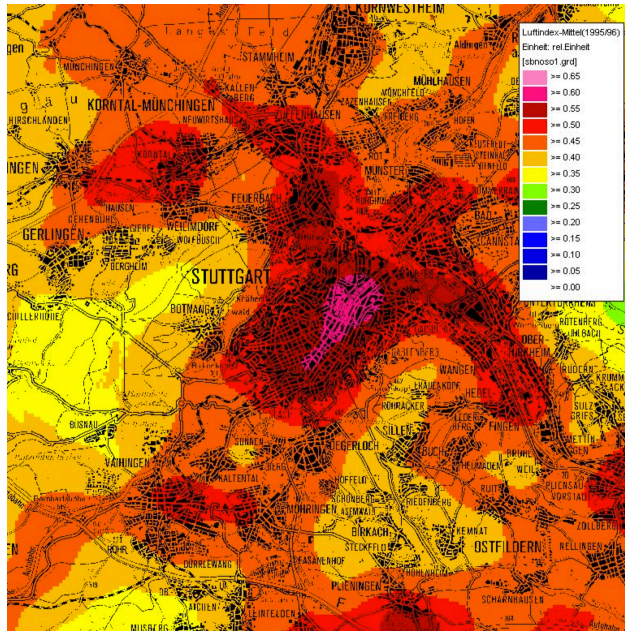
The topography of the city environs induces an “inversion” condition that creates an unfavorable UHI and air pollution condition.



5. Case Study // Stuttgart, Urban Climatology in Practice

Index of Air Pollution in Stuttgart

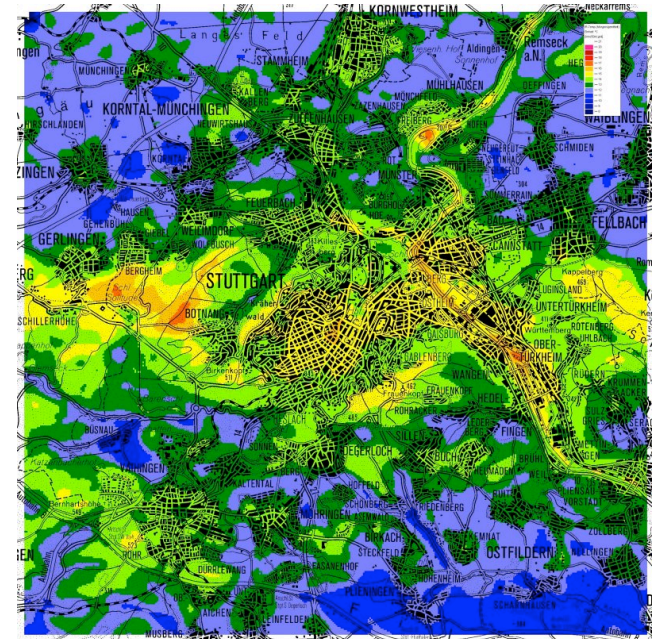
Calculated with:
CO, SO₂, NO₂ and dust.



Observed Urban Heat Island (UHI)

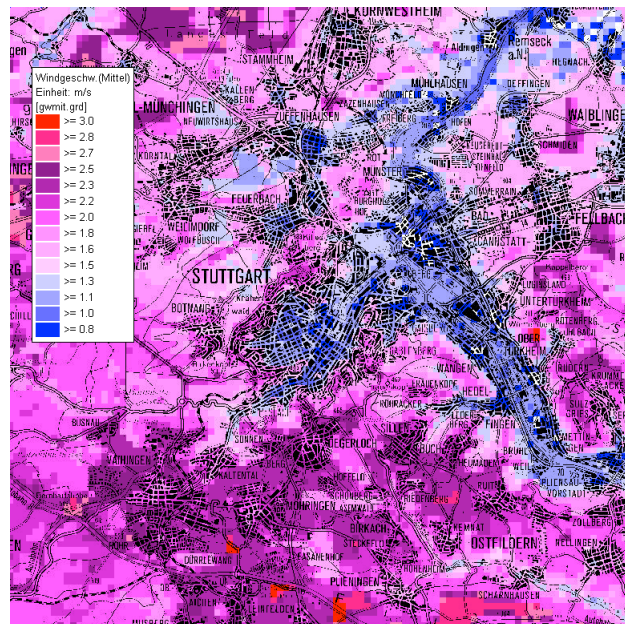
August 1988 before sunrise

red = 20 °C; blue = 10 °C



Wind Velocity

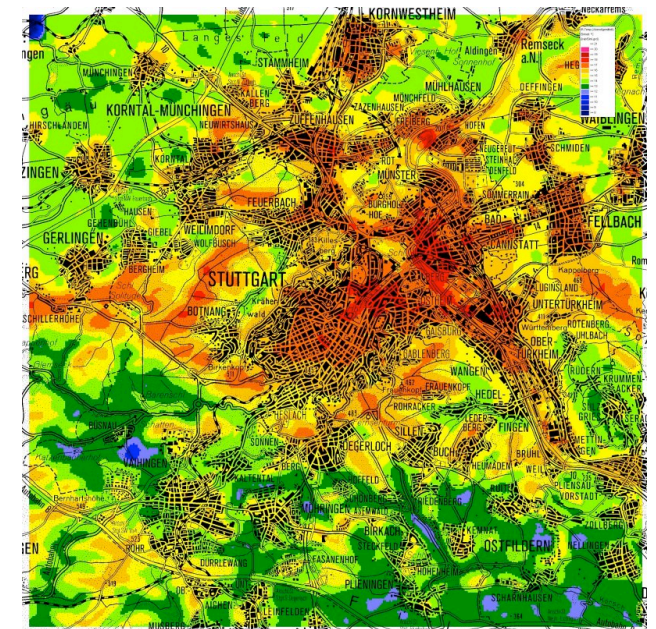
Stuttgart is well known for its differences in wind velocity between the city center (1.5 m/s) and surroundings (2.5 m/s).



Observed Urban Heat Island (UHI)

August 1988 after sunset

red = 20 °C; blue = 10 °C



Nocturnal Cold Air Flow

One of the natural effects of the topographic condition that helps alleviate UHI and air pollution are the nocturnal air flows. One of the primary efforts of the Stuttgart Section of Urban Climatology is preserving and enhancing these natural flows that originate in the cooler surrounding forest.

Stuttgart UHI & Air Pollution Countermeasures

Ventilation zones “STEP“

The “STEP” zones have been identified by the city as critical areas where the city should impede development and preserve and enhance the flow of nocturnal air.

Identifying Ventilation Zones

- Identify UHI & Pollution Zones
- Identify Critical Cold-Air Generators (e.g. Agricultural fields, forests), ideally with a local climate atlas.
- Identify critical (or potential) flow corridors.

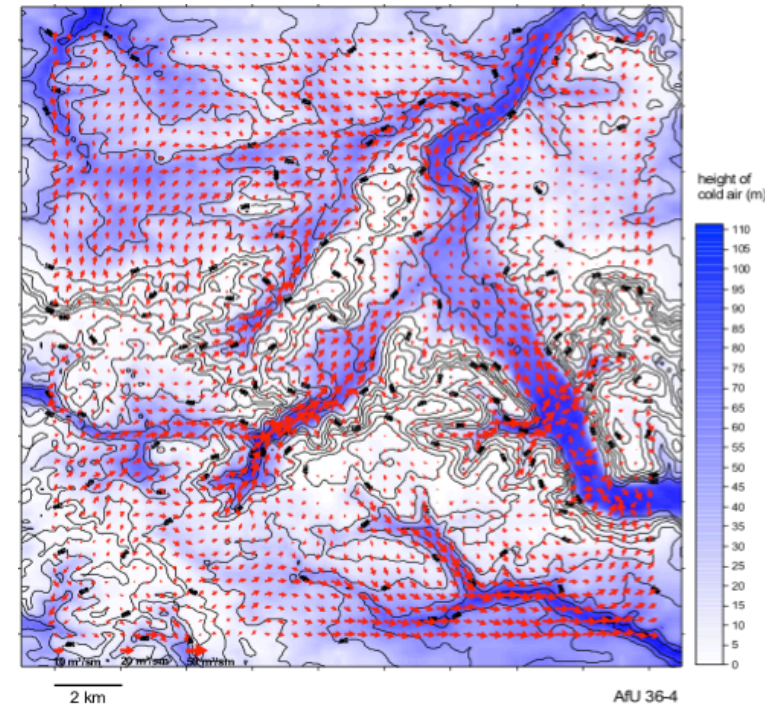
Corridor Design Parameters

- 100m wide min.
- Keep free of any wind obstructions (including trees!), pollution generators (at time of cold air flows)

“STEP” Zone Air Corridor



Nocturnal Cold Air Flows in Stuttgart



“STEP” Zone Air Corridor











- (The study of katabatic flows (cold air flows) in forest is currently being modeled in Hong Kong.)




Climate Atlas

The Stuttgart Section of Urban Climatology has prepared climatic maps that details the following elements that could influence future development and urban design:





Legend

Climatopes

-  **Railway climatope:** extreme daily temperature curves, dry, open to winds, ventilation lane.
-  **Industry climatope:** intense heat island effect, partly strong wind field disturbances, problematic air exchange, high air pollution (large-scale significance).
-  **Business climatope:** strong variations of all climatic elements, heat island effect, partly high air pollution.
-  **Town centre climatope:** intense heat island effect, low humidity, strong wind field disturbances, problematic air exchange, air pollution.
-  **Town climatope:** strong variations of all climatic elements in comparison with open land, formation of a heat island, air pollution.
-  **Suburban climatope:** significant influences on temperature, humidity and wind, disturbances of local wind systems.
-  **Garden town climatope:** slight influences on temperature, humidity and wind.
-  **Green space climatope:** pronounced daily temperature and humidity curves, climatic compensation area within the settlement.

-  **Forest climatope:** strongly attenuated daily temperature and humidity curves, production of fresh and cold air, filtering function.
-  **Open land climatope:** undisturbed strong daily temperature and humidity curves, open to winds, high production of fresh and cold air.
-  **Water body climatope:** thermally compensating, high humidity, open to winds.





Cold air areas

-  **Cold air production area:** production of cold and fresh air on open land during the night.
-  **Cold air catchment area:** catchment of cold air on relatively low levels, cold air channels.
-  **Stagnant cold air through drainage obstacles.**
-  **Areas with a high frequency of ground inversions.**








Wind rose: wind direction frequencies.

Air exchange

-  **Mountain/valley wind system:** intense cold-air flows.
-  **Downslope wind:** areal cold-air drainage.
-  **Ventilation lane, unpolluted:** valleys, cols.
-  **Ventilation lane, polluted:** emitters in valleys, cols.

Air pollution through emissions

-  **Road with extreme traffic loading:** extreme air and noise pollution.
-  **Road with very high traffic loading:** very high air and noise pollution.
-  **Road with high traffic loading:** high air and noise pollution.
-  **Business and industry:** relatively high pollutant emissions.
-  **Dwellings:** relatively high domestic fire emissions.

Comprehensive Urban Climatology Analysis for New Developments

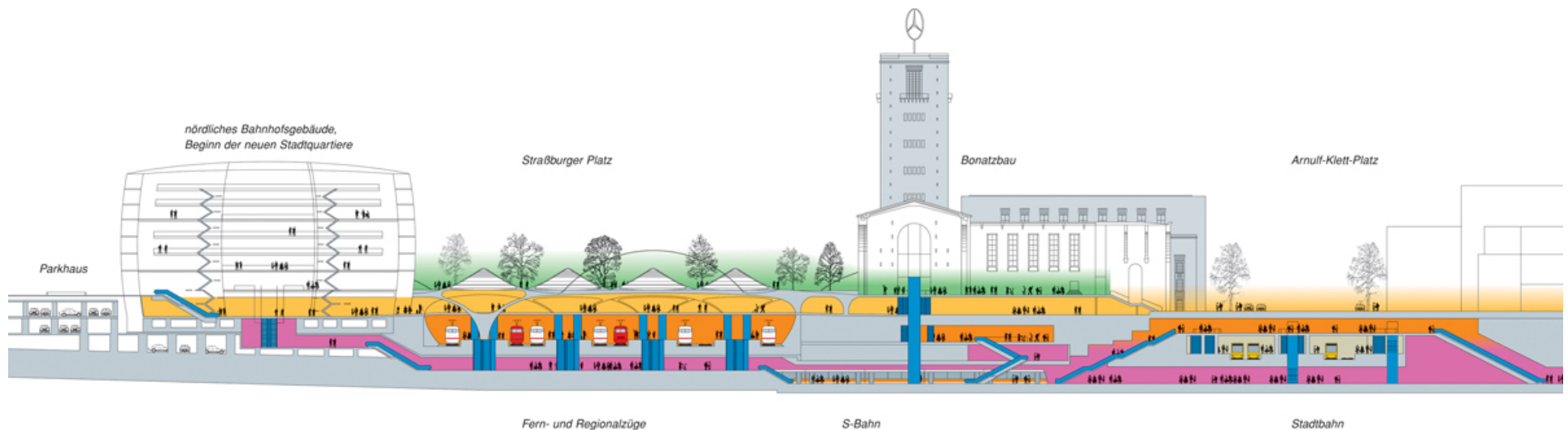
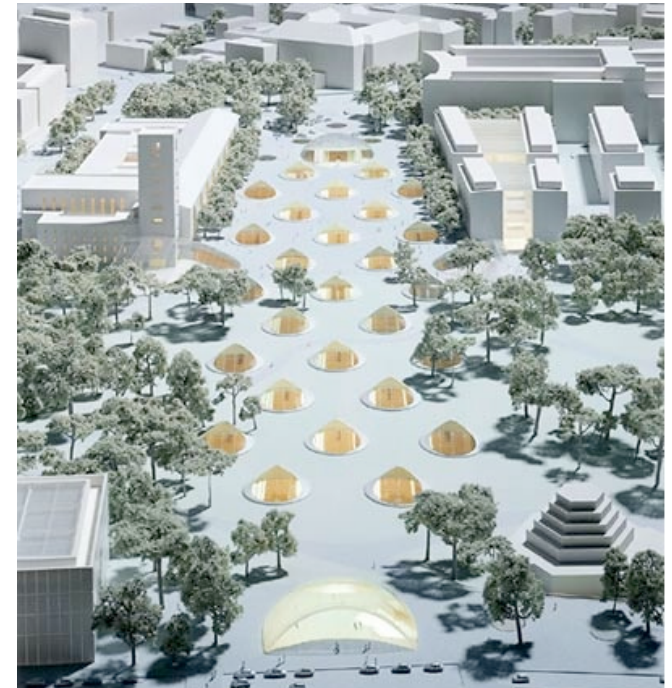
Stuttgart 21 Environmental Analysis

“Stuttgart 21 is a project that includes the redevelopment of Stuttgart's rail junction and central station as well as the urban development of a central area in the inner city. The project opens up a vision into the 21st century for the evolution of Stuttgart and its surrounding region.

Railway works and city planning within the Stuttgart 21 project require a detailed environmental study on the basis of various advisory questions. The used methods range from computer-based model calculations and simulations to experiments with a full-scale model in the wind tunnel and to measurements, drilling, mapping and nature observation in the plan area and its surroundings.

In order to ensure the intended transparency of the planning concepts for Stuttgart 21, the available original expert opinions within the analysis programme are published in the scripts of the Office for Environmental Protection.” -- Stuttgart 21 Environmental Analysis

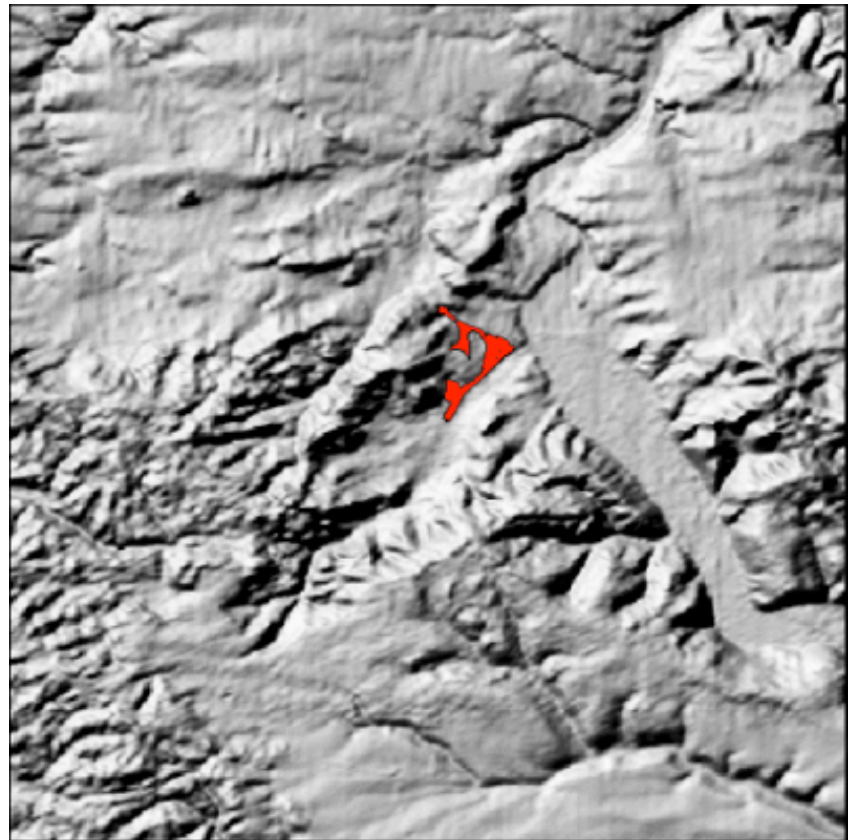
The following pages are excerpts from plan, showing the range of studies and some of the conclusions that influenced the final design.



2. Topographic conditions

2.1 Entire territory of Stuttgart

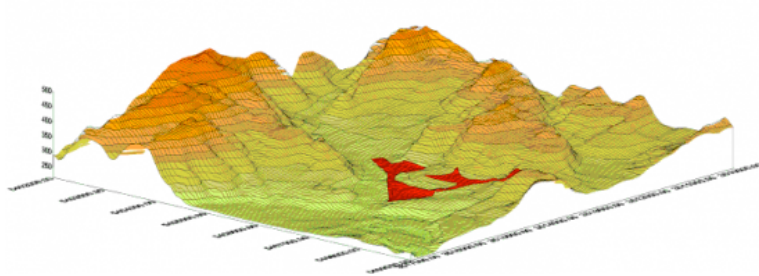
Stuttgart's climate, which is mild and has little wind, is predominantly influenced by its sheltered position in the Neckar basin (besides other climate-influencing components). The city is shielded by the Black Forest in the West, the Swabian Alb in the South, the Schurwald in the East and the Stromberg and Heuchelberg region in the Northwest. Stuttgart's variety of landscapes reflects the geological conditions: the arable land in the North, the rolling Keuperberg region in the South and the Filder plains further south. The Neckar valley divides the region from South to North and marks a clear cut in the landscape arrangement. Due to the variety in topographic structures, Stuttgart's territory has altitude differences of more than 300 m.



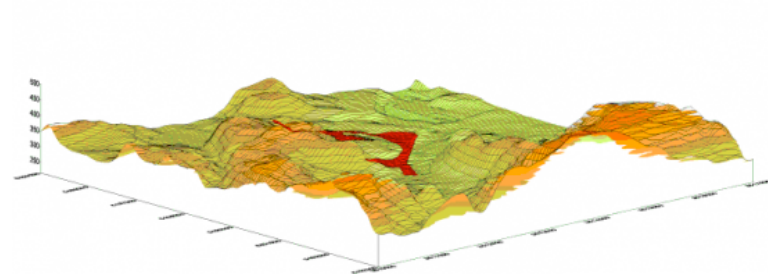
Relief picture of the city of Stuttgart and the surrounding region

2. Topographic conditions

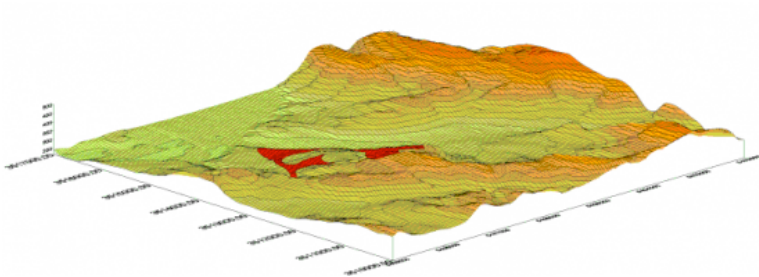
2.2 City centre with the plan area for Stuttgart 21



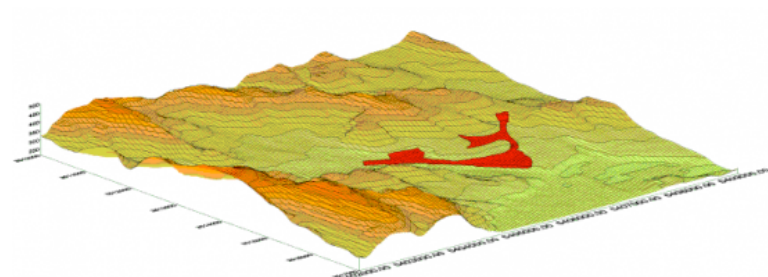
Northeastern perspective on the city basin and the plan area for Stuttgart 21 (in red)



Southwestern perspective on the city basin and the plan area for Stuttgart 21 (in red)



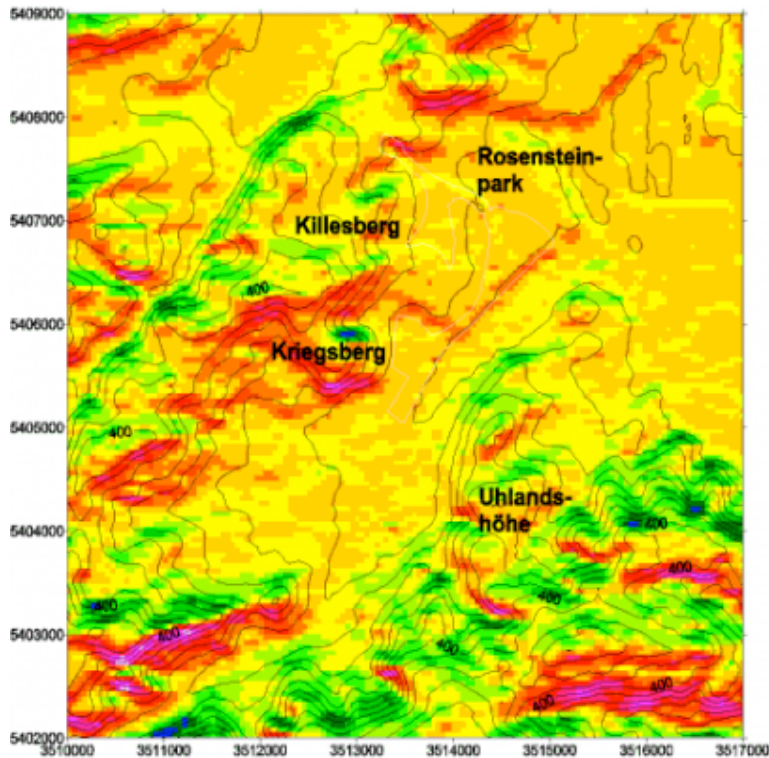
Northwestern perspective on the city basin and the plan area for Stuttgart 21 (in red)



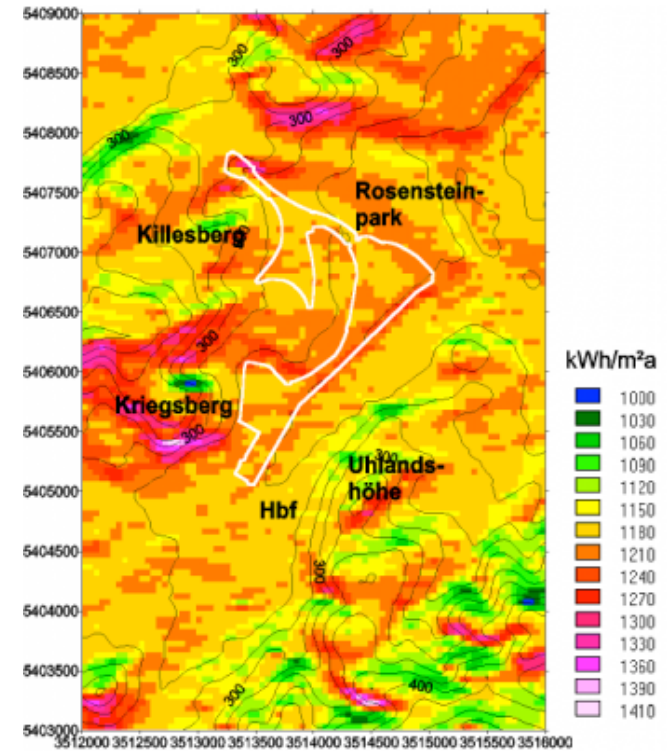
Southeastern perspective on the city basin and the plan area for Stuttgart 21 (in red)

3. Radiation

Solar radiation is an essential parameter for the urban climate. This is particularly true for cities like Stuttgart with a large variety of orographic structures. As a result, solar radiation may vary significantly from one place to another, especially at slopes with different inclinations and direction to the sun.



Sums of the average annual global radiation (kWh/m²) in Stuttgart

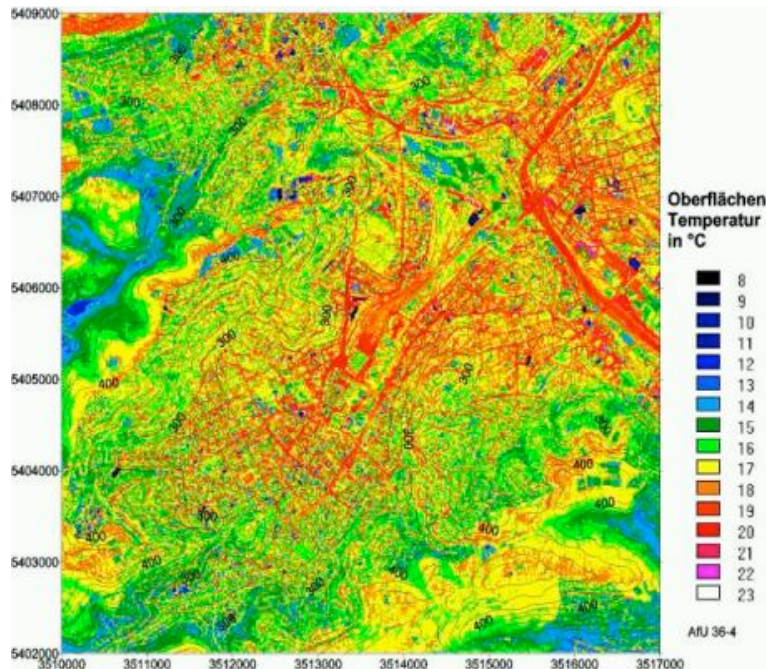


Sums of the average annual global radiation (kWh/m²) in the region around the plan

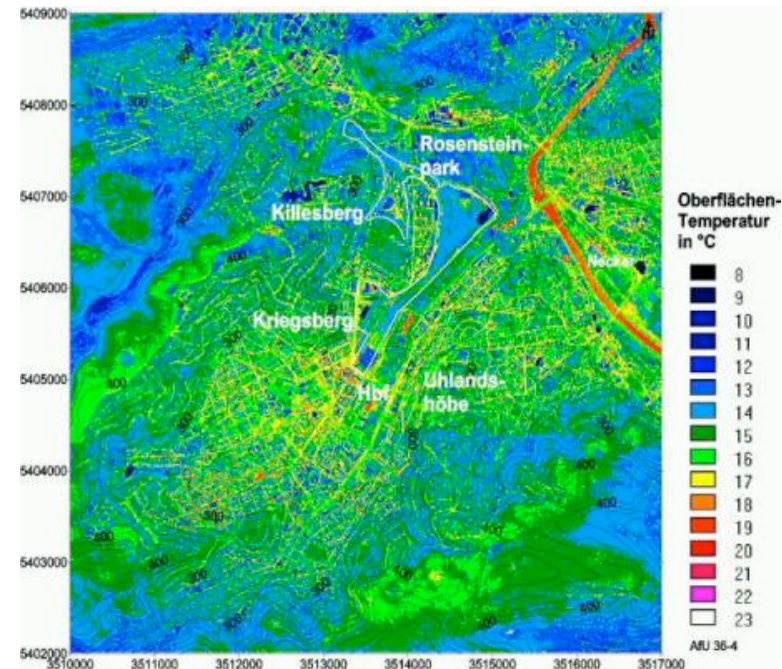
4. Thermal situation

4.1 Thermal pictures

Infrared thermography provides a picture of the current temperature distribution on the earth's surface. This method is based on the fact that the surface temperature of an object can be determined in a non-contact measurement from the distance by measuring its infrared thermal radiation. Aircrafts scan entire regions in order to detect thermal infrared and provide high-resolution thermal images.



Surface temperatures in Stuttgart after sunset (18 August 1988)

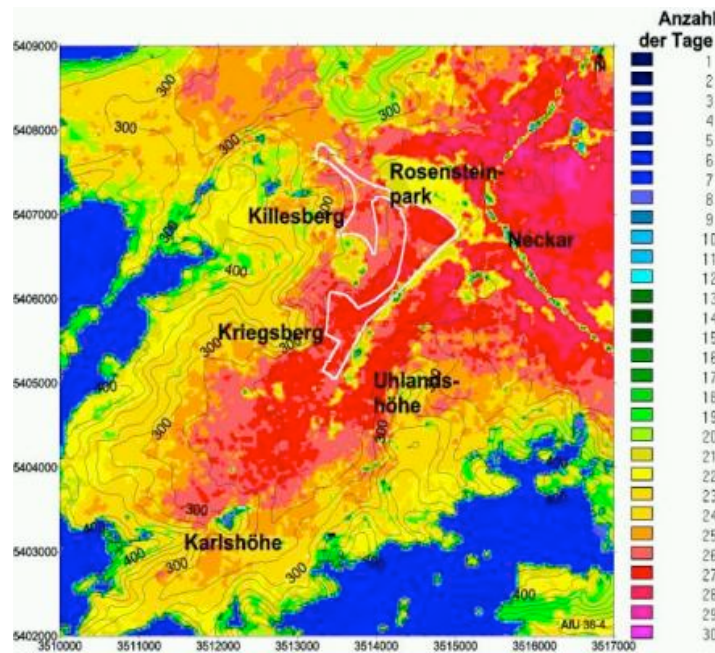


Surface temperatures in Stuttgart before sunrise (19 August 1988)

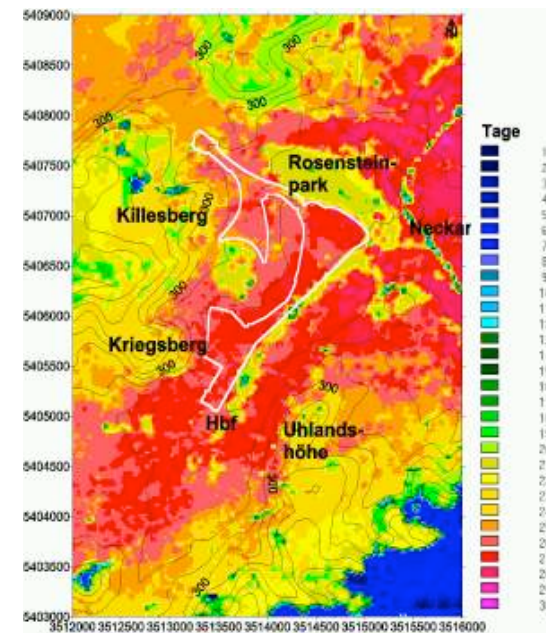
4.2 Bioclimate

4.2.1 Days with heat stress

A person's heat balance is their closest link to the atmospheric conditions. These conditions range from the meteorological elements air temperature, humidity and wind speed to short and long wave radiation with thermophysiological effects on people. Their significance for health is connected with the cross-linking of thermal and circulatory regulation.



Average annual amount of days with heat stress in Stuttgart

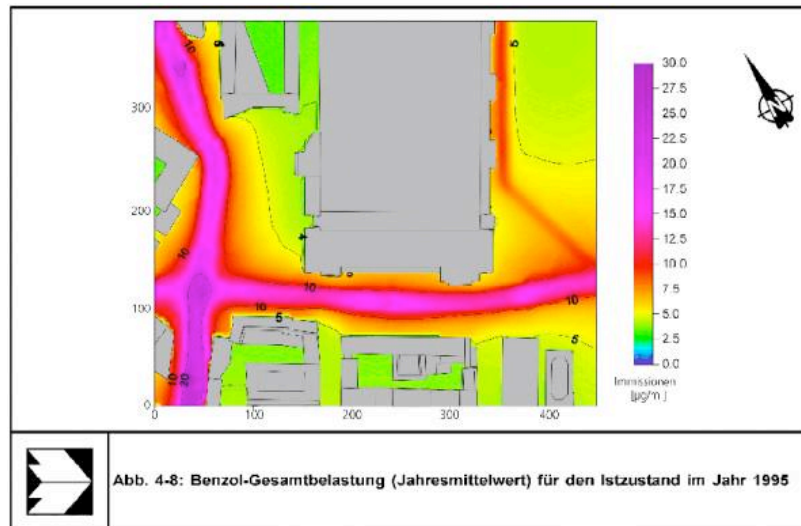


Average annual amount of days with heat stress in the plan area for Stuttgart 21

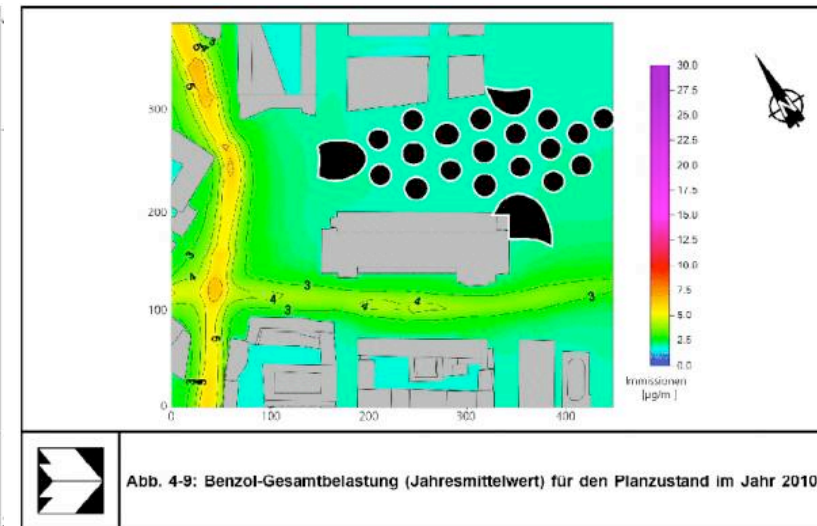
4. Thermal situation

4.2.2 Local models

The current picture shows a relatively high benzene concentration around the central station. The inspection value of the 23rd Federal Emission Control Ordinance ($10 \mu\text{g}$ benzene per m^3) is clearly exceeded at a building on the east side of Friedrichstraße. The predicted concentration for 2010 indicates a significantly lower level of emissions. The highest concentration of benzene at the built-up area near Heilbronner Straße is about $4.5 \mu\text{g}/\text{m}^3$. This is the result of less traffic and fewer exhaust fumes emitted by vehicles.



Total amount of benzene (annual average) for the current state of 1995

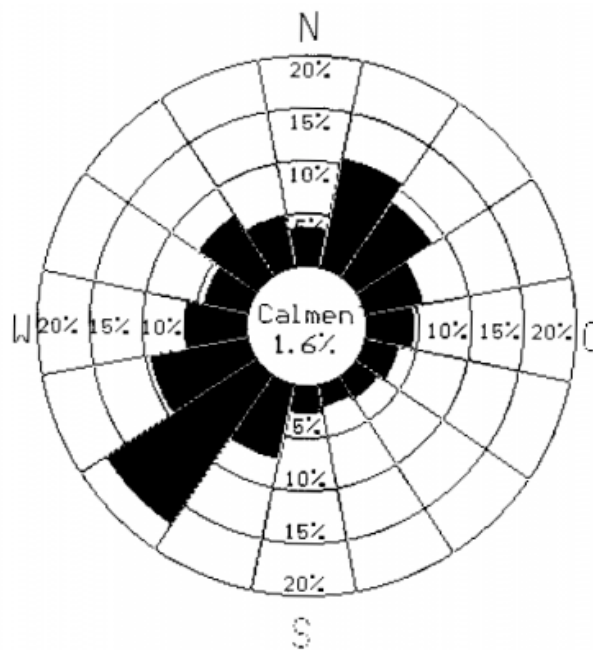


Total amount of benzene (annual average) for the predicted state of 2010

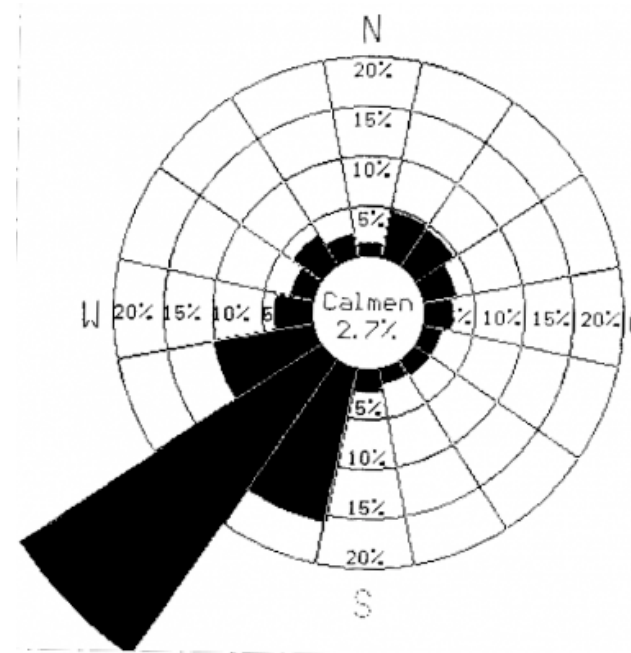
5. Wind conditions

5.1 Wind measurements

Wind is characterized by its speed and its direction. Its function is to exert push and pull forces, to transport particles, to create air exchange, aeration, drifts and heat transfer as a consequence of turbulences and to make noises. It regulates the spreading of air pollutants and therefore plays a major role for the air hygiene in cities.



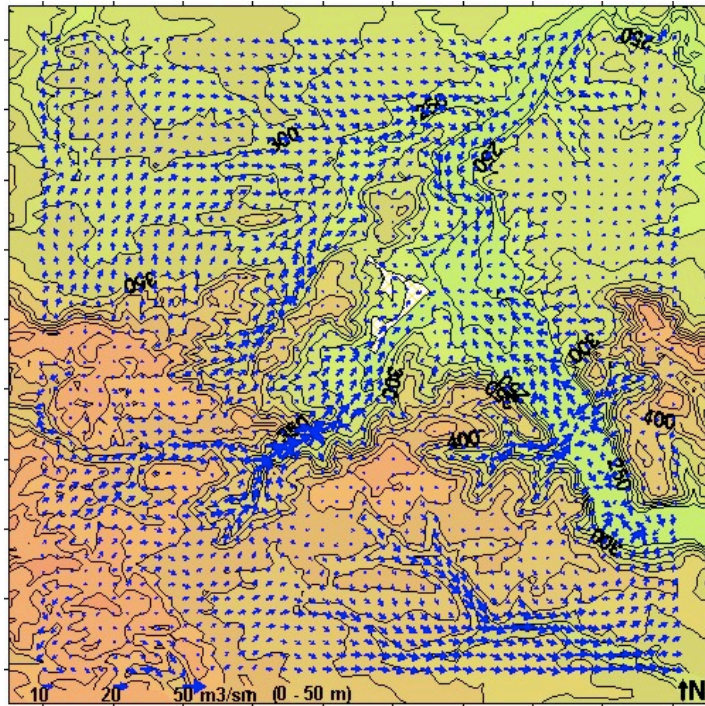
Frequency of occurrence of the wind direction during the day (Schwabenzentrum) in 1994



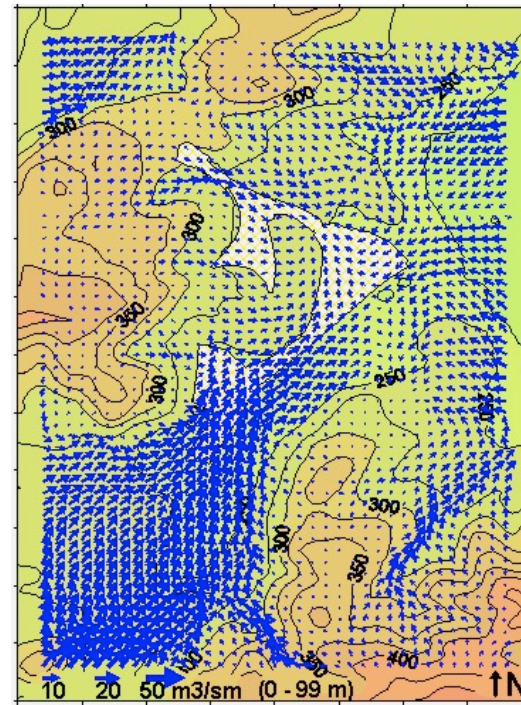
Frequency of occurrence of the wind direction during the night (Schwabenzentrum) in 1994

5.2 Cold air flow

As a consequence of the shielding effect of the surrounding mountain ranges, local wind systems, that are often formed at slopes and in valleys, are very much in evidence. Even if they have no high wind speeds, they play a significant role for the local aeration of Stuttgart's city districts.

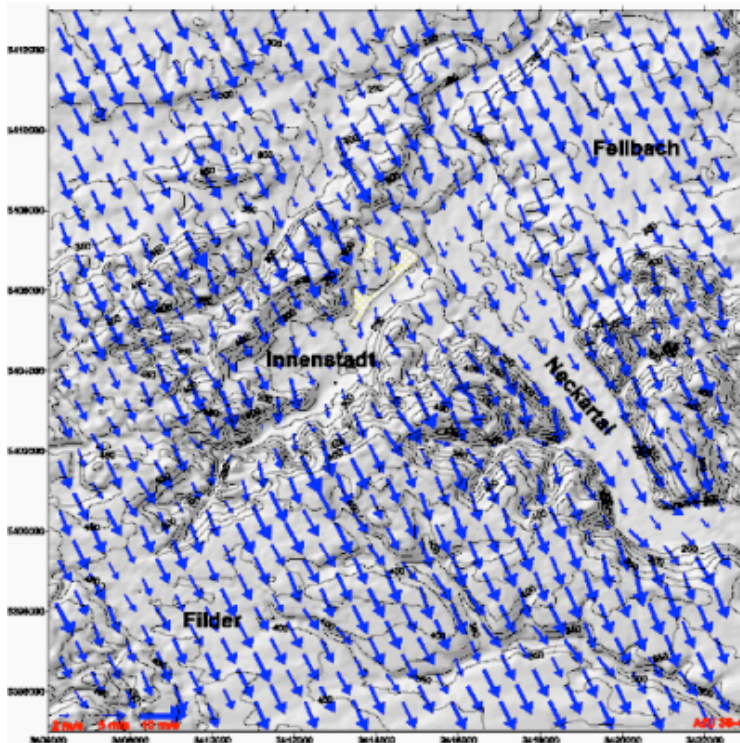


Cold-air flows in Stuttgart, current state as volume flow density (m^3/sm) (average layer height of 0-50 m)

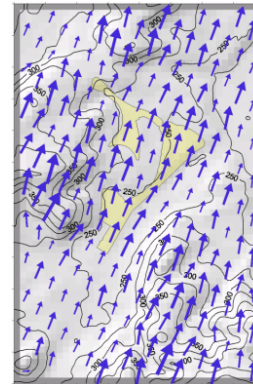


Cold-air flows in Stuttgart's inner city (including the plan area), current state as volume flow density (m^3/sm) (average layer height of 0-50 m)

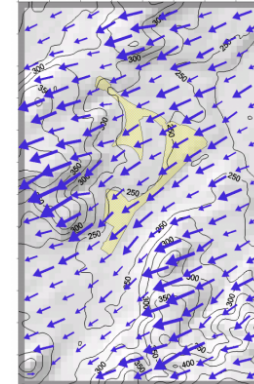
5.3 Wind field with simultaneous consideration of the topographic conditions



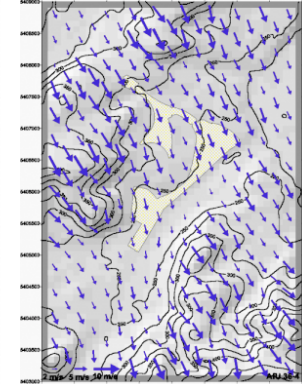
Wind field in Stuttgart with large-scale inflow from the Northwest (10 m/s at 700 m asl.)



Wind field in the proximity of the plan area for Stuttgart 21 with large-scale inflow from the Southwest (10 m/s at 700 m asl.)



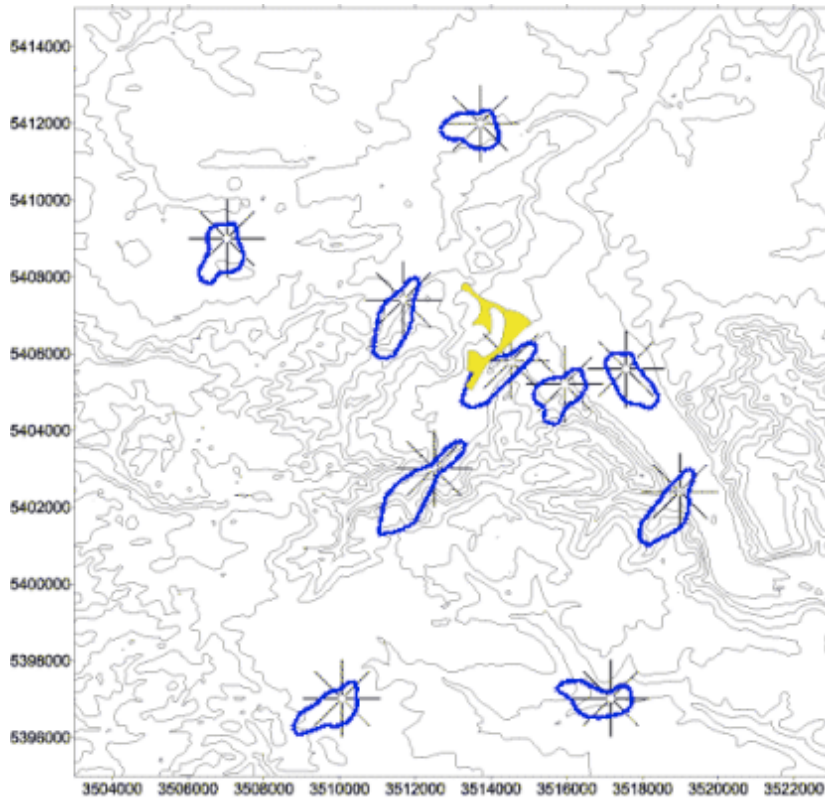
Wind field in the proximity of the plan area for Stuttgart 21 with large-scale inflow from the East (10 m/s at 700 m asl.)



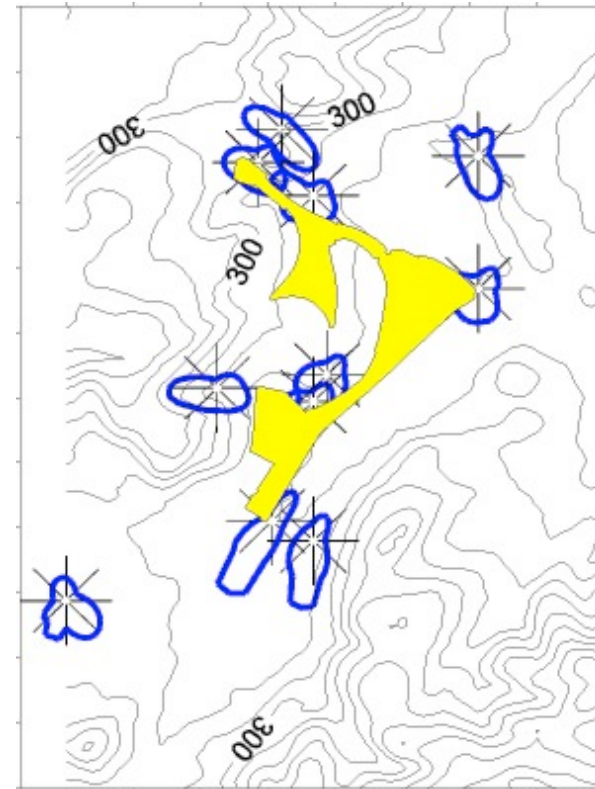
Wind field in the proximity of the plan area for Stuttgart 21 with large-scale inflow from the Northwest (10 m/s at 700 m asl.)

5.4 Calculated wind roses

The representation of the laminar distribution of the wind statistics provides an outline of the average wind conditions in the area under consideration.



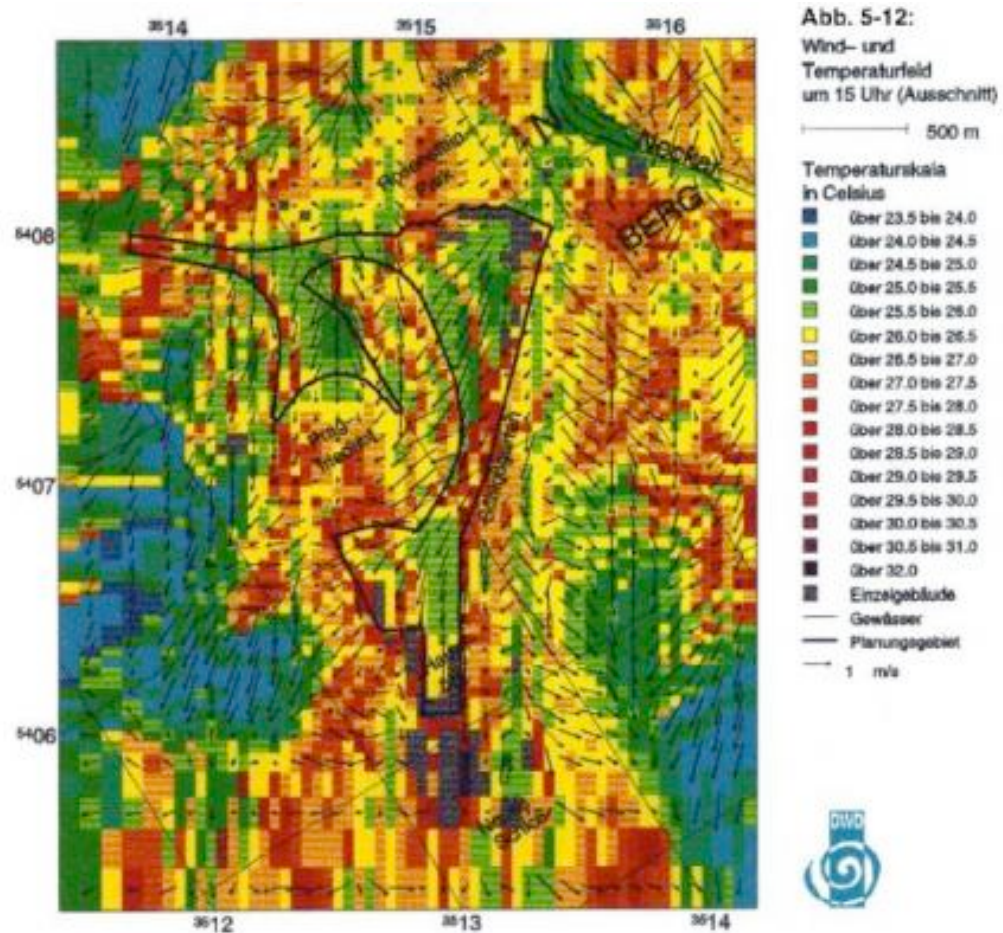
Synthetic wind roses in Stuttgart



Synthetic wind roses in Stuttgart

5.5 Wind field with simultaneous consideration of built-up areas

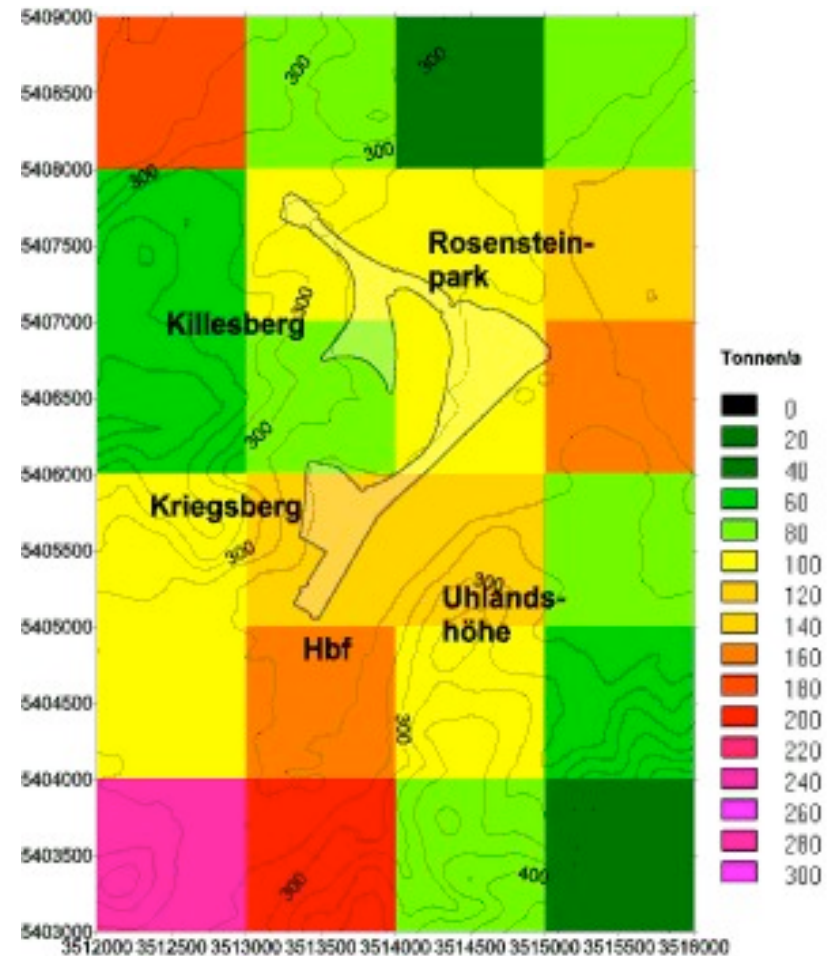
The German Meteorological Service uses the MULIMO-3 model to analyse the climatic situation on a summer day three times a day (3 pm, 9 pm, 3 am) and this for both the current state and the predicted state for 2010.



Wind and temperature field at 3 pm (excerpt)

6. Emissions

There is no current data on emissions in the plan area for Stuttgart 21 and its surroundings. The emission inventory, which is the basis for the clean air plan Stuttgart, dates from 1985. The updating of the inventory is in progress but not yet completed. First results are not to be expected before the spring of 1997.



*Nitrogen oxide emissions around the plan area in 1988/89
(Environment Ministry of Baden-Württemberg, 1990)*

7. Emissions

7.1 Extensive air pollution

In order to be able to provide information on the basic pollution of the plan area for Stuttgart 21, we resort to the measuring stations Stuttgart-Zentrum and Stuttgart-Bad Cannstatt (within the regional measuring network) and the Schwabenzentrum measuring station (run by the Office for Environmental Protection). Average air pollution values can be indicated approximately for the plan area for Stuttgart 21 by averaging the concentrations measured at these stations in 1995.

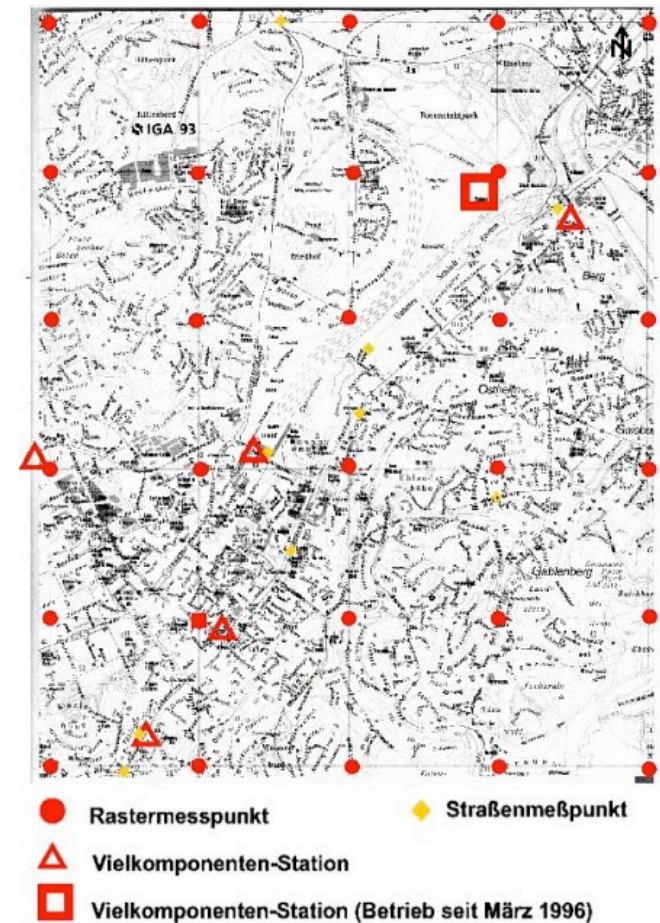


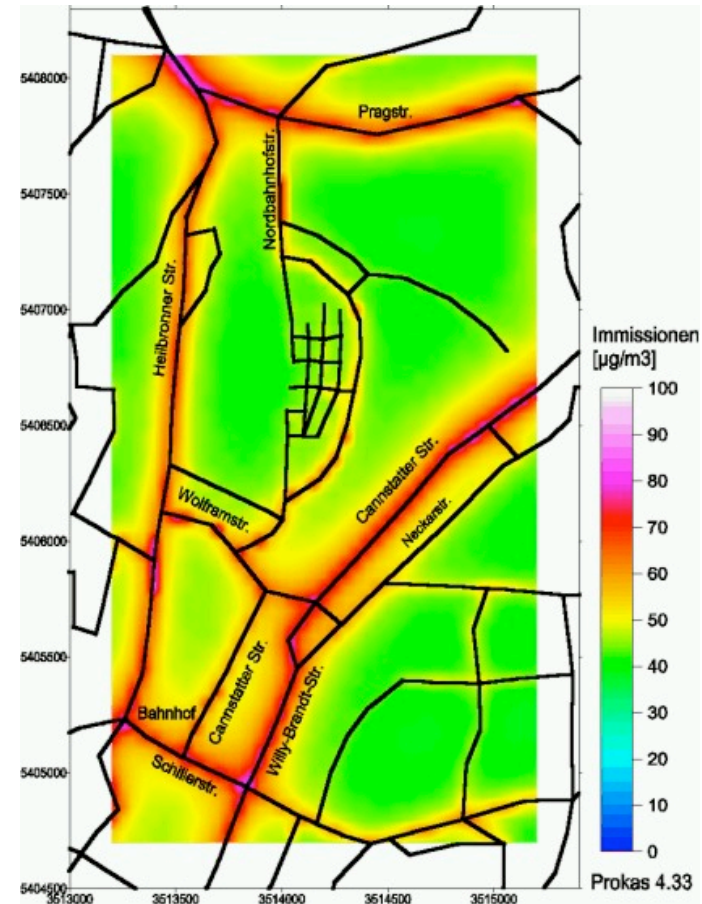
Abb.7-1: Meßstationen und Messpunkte in der Umgebung des Plangebietes "Stuttgart 21"

Basic concentration of pollutants in the plan area for Stuttgart 21 Values in $\mu\text{g}/\text{m}^3$

Measuring stations and measuring points around the plan area for Stuttgart 21

7.3 Air pollution along roads (calculations)

For the estimation of the pollutant concentration along roads, it is essential to simulate exactly the causal relationship between emission, transmission and immission. What comes out is a dispersion model. In our case, the calculations were conducted by the Dr. A. Lohmeyer Engineering Office in Karlsruhe on the basis of the PROKAS calculation model and in consideration of the road network tangent to the plan area.



Total nitrogen dioxide concentration (average annual values) for the plan area for Stuttgart 21 in the current state of 1995

Target values for Stuttgart's air quality along roads

8.2 Noise emission plan



Noise emission plan Road traffic, current state Plan area A1 during the night



Noise emission plan Railway traffic, current state Plan area A1 during the night

9. Consequences for the planning of Stuttgart 21

Example of Recommendations:

Hierarchy of Cleansing Airflows

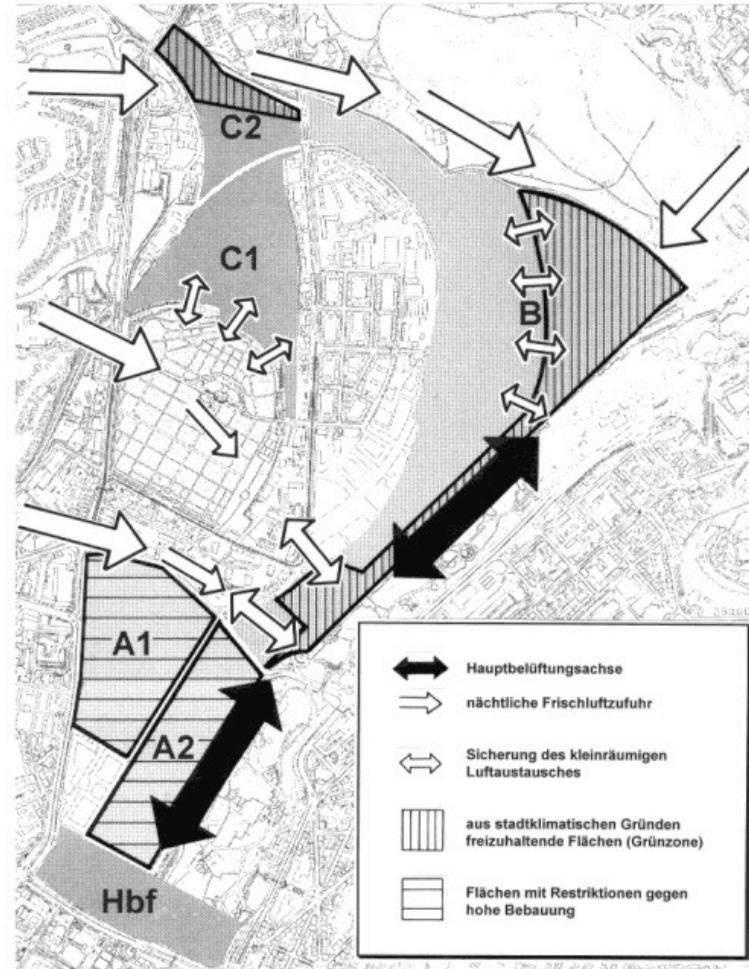
- Main Airflow Axis (to be expanded)
- Nightly Fresh Air (maintained)
- Cross Exchange Areas (capitalized on)

Zoning Areas

- Flat Development-Free Green Zones
- Height Restricted Development Areas

Specific Development Analysis (not shown)

- Orientation of buildings and distribution of program elements based on microclimatic comfort modeling (sunlight / wind and warm / cold)
- Program placement relative to air pollution streams and noise.
- Placement of pollution sources

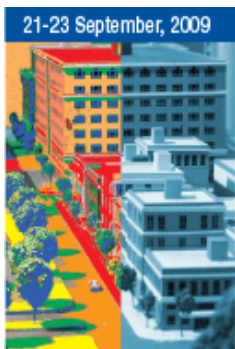


Preliminary notes of urban climatology for the planning of Stuttgart 21

6. PARAMETRIC STUDIES // SELECTION OF CONTEMPORARY RESEARCH

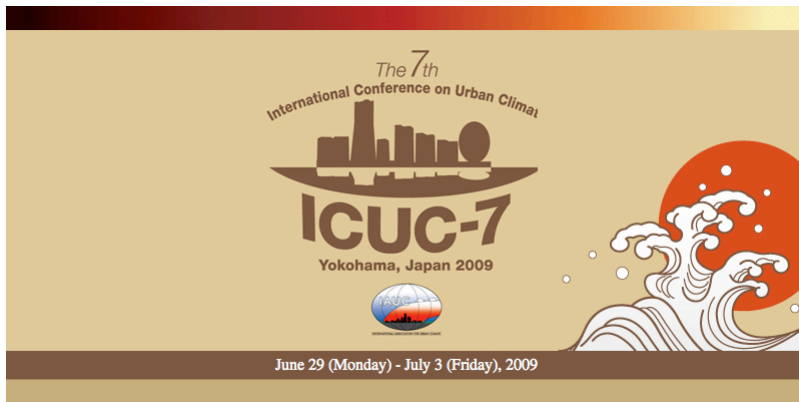
Contemporary Conferences

A large portion of the research focused on contemporary research to discover the latest innovations, practices, and technologies. Besides visiting Stuttgart's Urban Climatological Department I also attending the Second International Conference on Countermeasures to Urban Heat Islands and reviewed papers from the ICU-7 Conference.



Second International Conference on Countermeasures to Urban Heat Islands

September 21-23, 2009 in Berkeley, California
Environmental Energy Technologies Department
E.O. Lawrence Berkeley National Laboratory
46 Presentations / Papers



International Association for Urban Climate
~600 Presentations / Papers

Categorized Papers

Contemporary research collected from these conferences were categorized in the following categories. Original papers in these directories are available on the SWA server.

- a. Air Movement (88 / 17%)
 - i. General Features
 - ii. Katabatic / Cool Air Sinks / Generators
 - iii. Modeling Measurements
 - iv. Sea Breeze
 - v. Micro
 - vi. Sky Scrapers Design
 - vii. Urban Situation
- b. Air Pollution (50 / 10%)
- c. Carbon Sequestration (5 / 1%)
- d. Countermeasure Technologies (4 / 1%)
- e. Digital Modeling (14 / 3%)
- f. Energy Balance & Built Forms (11 / 2%)
- g. Forestry (4 / 1%)
- h. Green Roof (3 / 1%)
- i. Health Issues (16 / 3%)
- j. Urban Heat Island (93 / 18%)
 - i. Urban Measurements (29 / 6%)
 - ii. Modeling (34 / 7%)
 - iii. General (30 / 6%)
- k. Light Pollution (1 / 0%)
- l. Los Angeles (4 / 1%)

6. Parametric Studies // Selection of Contemporary Research

- m. Measurement Techniques (9 / 2%)
- n. Meteorological Effects (6 / 1%)
- o. Micro Climate (17 / 3%)
- p. Outreach / Community (1 / 0%)
- q. Rainfall (12 / 2%)
- r. Water Vapor / Evapo-Transpiration (10 / 2%)
- s. Urban Green Spaces (Parks) (19 / 4%)
- t. Urban Planning (23 / 5%)
- u. Urban Rivers (6 / 1%)
- v. UV Studies (1 / 0%)
- w. Vegetation (14 / 3%)

~500 Papers Total

Research Summary and Overview

The following pages are excerpts from some of the most compelling contemporary research papers, especially in relation to the practice of landscape architecture:

PARK // Parametric Analysis

Planning and evaluation of urban green space for thermally comfortable environment in the station square –Numerical analysis using 3D CAD –based thermal environment simulator.

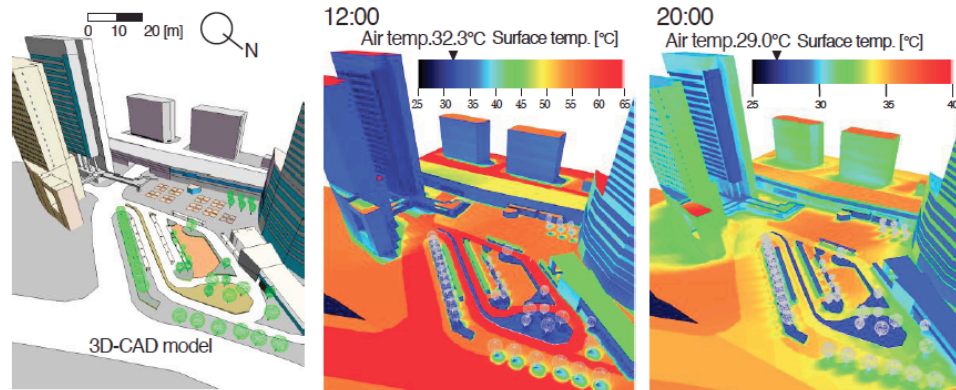


Figure.3 Simulation results of the surface temperature distribution of the present station square (clear sky day in summer)

Table.1 Difference in air temperature between inside and outside of urban park

Measured site	Size (ha)	temperature difference(°C)	References
Meiji Jingu	70.0	4.0	Kanda(1999)
Singuku Gyoen	58.0	3.0	Narita(2004)
Osaka Castle Park	50.0	2.5	Moriyama(2001)
Izumi Shizen Park	40.0	5.0	Fujisaki(1994)
Kōkyo	21.0	4.1	Mikami(2007)
Shakujii Park	18.8	2.1	Mruta(1995)
Setagaya Park	7.9	1.5	Mruta(1995)
UtuboPark	6.6	2.0	Moriyama(2001)
Sano Park	6.0	3.0	Maeda(1990)
Motofuchie Park	4.0	1.5	Maruta(1995)
Myoshoji Park	1.2	1.2	Maruta(1995)

Temperature difference between open space and urban area

Table.3 Outflow of Cold-air currents from large urban green space at day and night

	Measured site	spread of cold-air	References
Seeping-out phenomenon during the night	Nagoya city east area	100 ~ 150m	Yahiro(2003)
	Singuku Gyoen	80 ~ 100m	Narita(2004)
	Meiji Jingu Kōkyo	flow the forest wind ~ 250m	Kanda(1995) Mikami(2007)
Outflow cold or warm air in the daytime	Singuku Gyoen	200 ~ 250m	Narita(2004)
	Kōkyo	~ 350m	Mikami(2007)

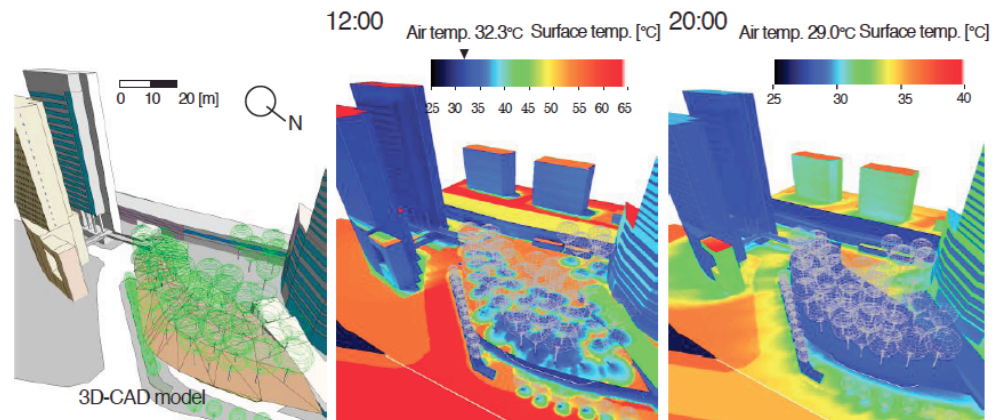


Figure.7 Simulation results of the surface temperature in the proposed urban park at the station square (clear sky day in summer)

URBAN GREENING // Parametric Analysis + Modeling

Study on Methodology about Environmentally Friendly Urban Development for Creating Cool Spots and Reducing CO2 Emissions in Urban Area

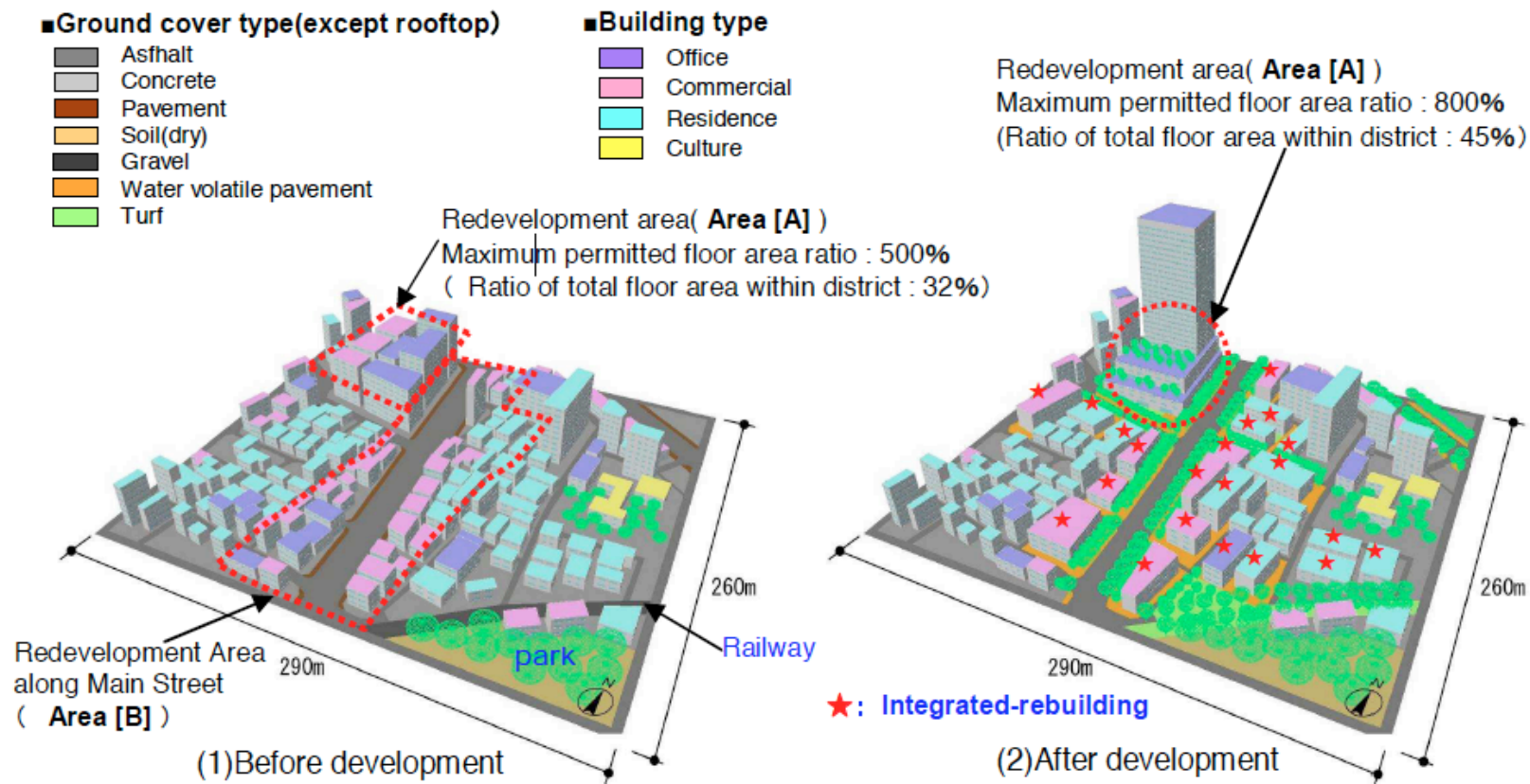


Fig. 1 Evaluation Case

URBAN GREENING // Parametric Analysis + Modeling

Study on Methodology about Environmentally Friendly Urban Development for Creating Cool Spots and Reducing CO₂ Emissions in Urban Area

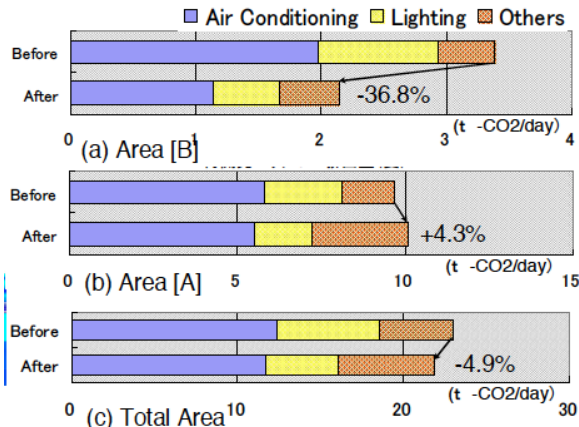


Fig. 5 CO₂ Emissions per day (August)

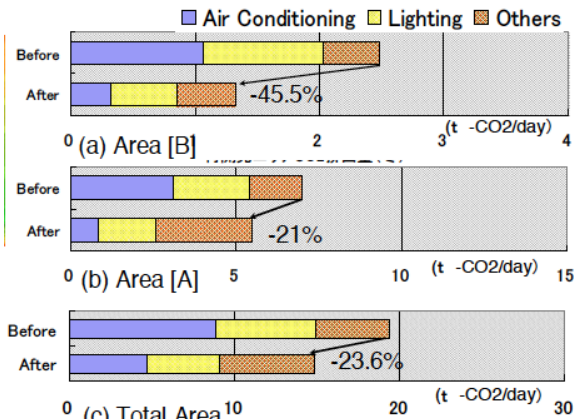


Fig. 6 CO₂ Emissions per day (February)

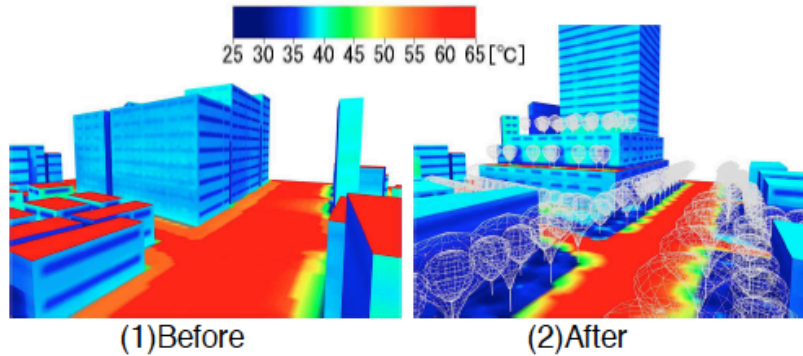


Fig. 2 Distribution of Surface Temperature (12:00)

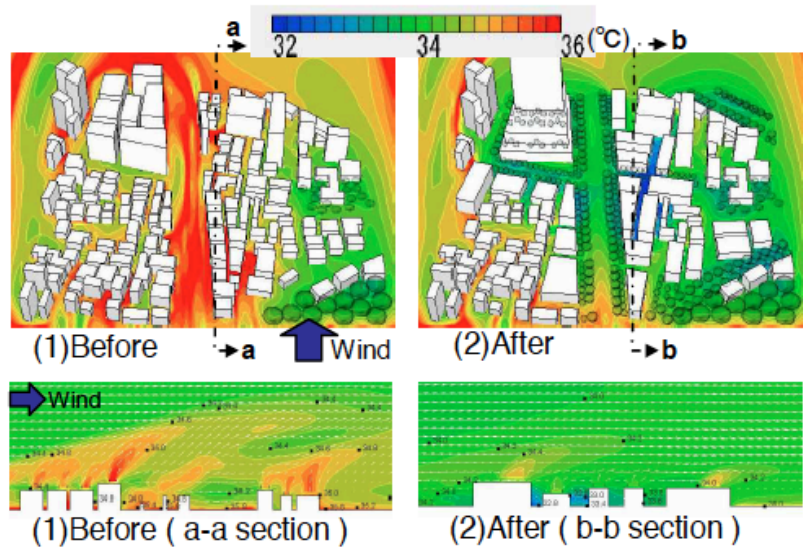


Fig. 3 Distribution of Air Temperature (12:00, GL+1.5m)

PARK // Breeze

Research on the park breeze from the Daisen park, Osaka pref.

We conducted a survey of the park breeze in Daisen Park in Sakai City, Osaka, between August 21-24, 2007, and the most remarkable park breeze was observed on August 24. On this day, the park breeze phenomenon was greatest at the intersection of land and sea breezes, and a slow air current intersected perpendicularly with the outer edge of the park towards an urban area within the whole park area. Although the park breeze phenomenon was observed even for sea and land breezes of only 1.0 m/s, wind direction disorder of the park breeze might arise in response to the influence of wind, resulting in the lack of park breeze on the windward side.

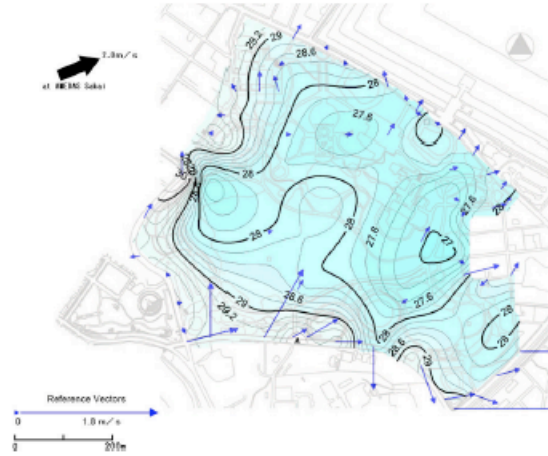


Fig-4 Wind direction, velocity and temperature at 20:00

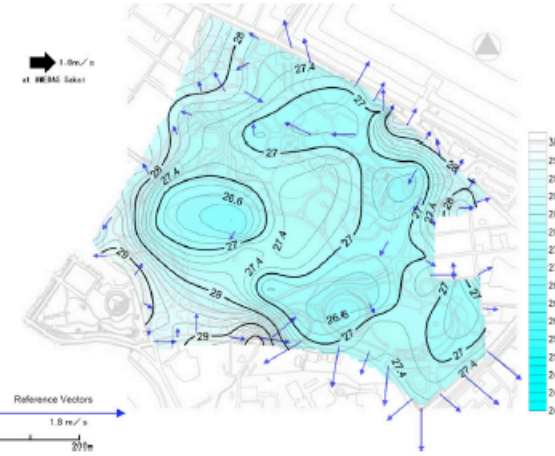


Fig-5 Wind direction, velocity and temperature at 21:30

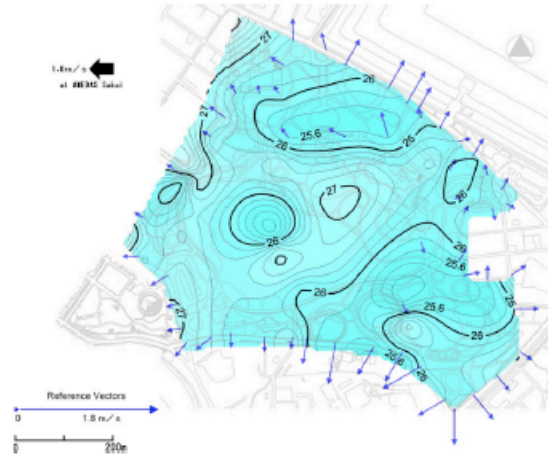


Fig-6 Wind direction, velocity and temperature at 23:00

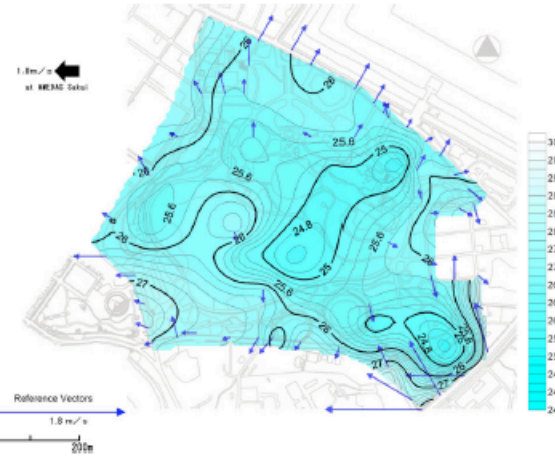


Fig-7 Wind direction, velocity and temperature at 00:30

PARK // Cold Air Seepage

COLD AIR SEEPING FROM AN URBAN GREEN SPACE, IMPERIAL PALACE, IN CENTRAL TOKYO

Ken-ichi Narita*1, Hirofumi Sugawara*2, Hitoshi Yokoyama*3, Ikusei Misaka*4 and Dai Matsushima*5

*1Nippon Institute Technology, Saitama, Japan;

*2National Defense Academy, Kanagawa, Japan

*3 Tokyo Metropolitan Research Institute for Environmental Protection, Tokyo, Japan

*4 R&D Institute, Takenaka Corporation, Chiba, Japan;

*5 Chiba Institute of Technology, Chiba, Japan

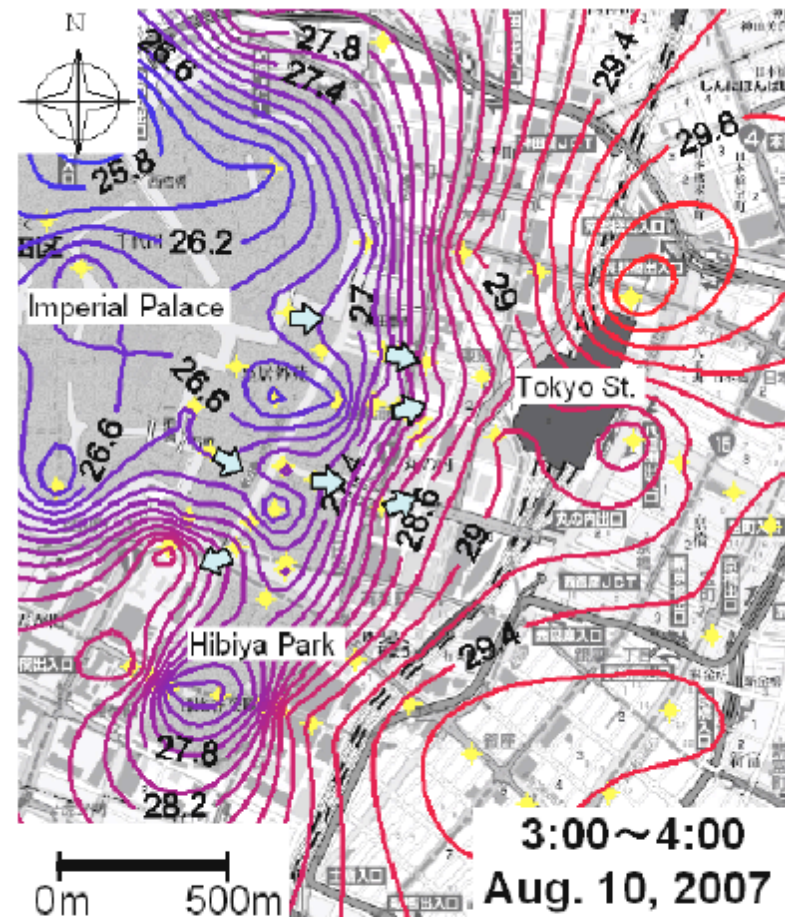


Fig.5 Temperature field and wind direction when seeping-out phenomena appeared.

URBAN RIVERS // Heating of Urban Streams

URBAN STREAM TEMPERATURE SIMULATION UNDER STRONG ANTHROPOGENIC INFLUENCES

Urban streams often have large inputs of warm waste water flows reducing their ecological viability. Study shows correlation between Sky View Factor and Urban Stream Temperature.

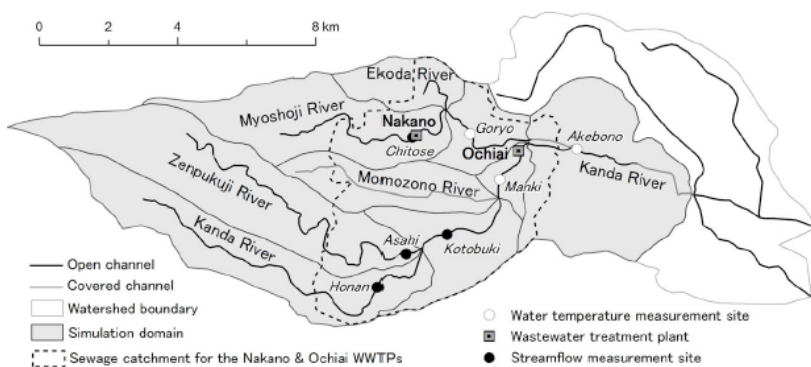


Figure 1. Outline of the Kanda Watershed

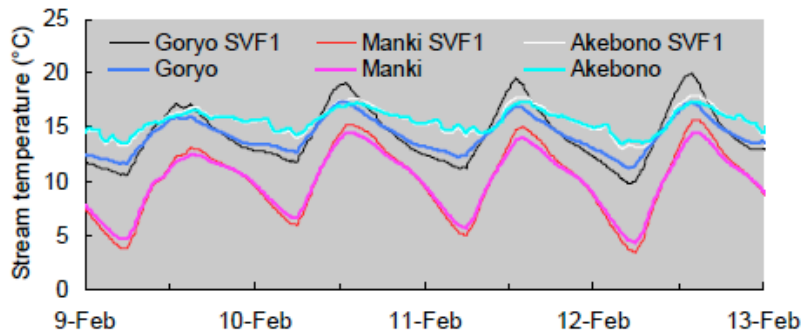
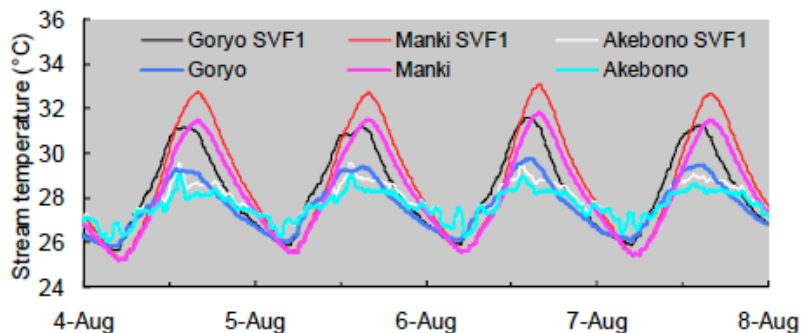


Figure 3. Effect of sky view factor on stream temperature

URBAN RIVERS // Urban Streams, Cooling, and Water Temperature

COOLING EFFECT BY URBAN RIVER, 2009

Water depth / exposure has impact on water temps.

Water temps can induce vertical mixing, flooding urban areas with cool breezes (seabreezes).

Figure 6 shows that the vertical ventilation has larger cooling effect than the cold water surface does. Also shown in Fig. 1 and 3, negative heat flux at water surface has small absolute value. In the sense of urban thermal mitigation, therefore, cooling by cold water surface should not rely on too much. **On the other hand, the cold river water has great effect for the human sensation at the river side through the lower infrared radiation from it.** In order to make the lower water temperature through the renovation, **we should consider the depth of water.** Net radiation flux into the water surface was largely used for the heat storage in the water body (Fig. 3).

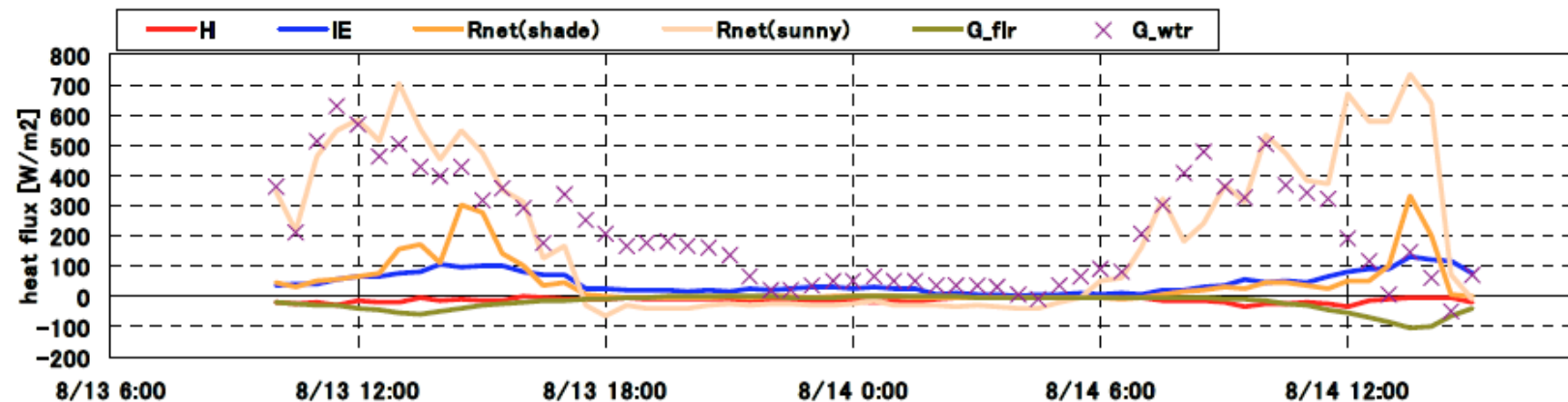


Figure 1. Heat flux measured at the river water. H, sensible heat; IE, latent heat; Rnet, net radiation; G_flr, heat flux into the river bottom; G_wtr, heat storage into the water body.

URBAN RIVERS // Cooling Effects

MECHANISM OF MITIGATION OF ATMOSPHERIC ENVIRONMENT BY A LARGE RESTORATION OF INNER-CITY RIVER (CHEONG-GYE STREAM IN SEOUL) (2009)

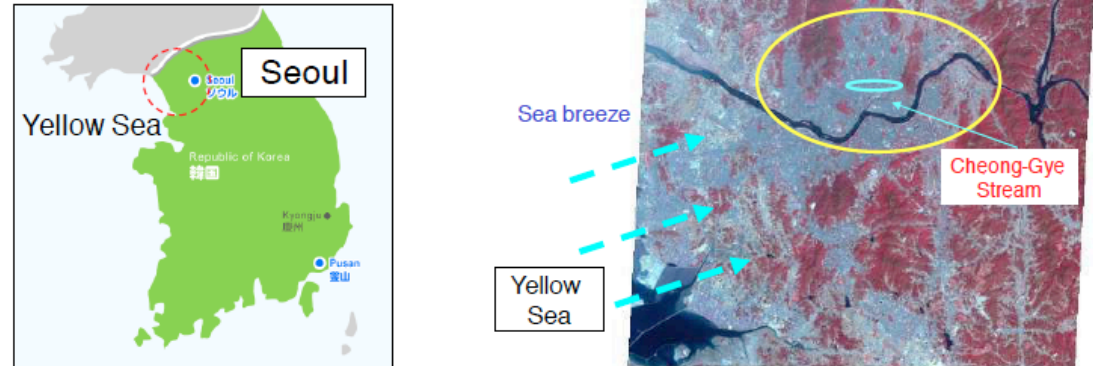


Fig. 2 Location of Seoul City and the Cheong-Gye Stream (Base map: ASTER)

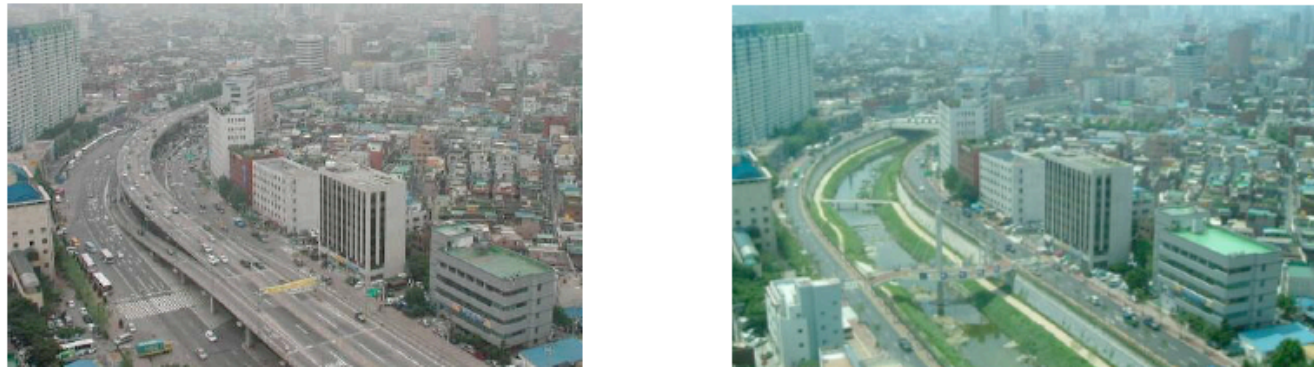


Fig. 1 The Cheong-Gye Stream before and after the restoration (left: June 2003, right: August 2005)

URBAN RIVERS // Cooling Effects

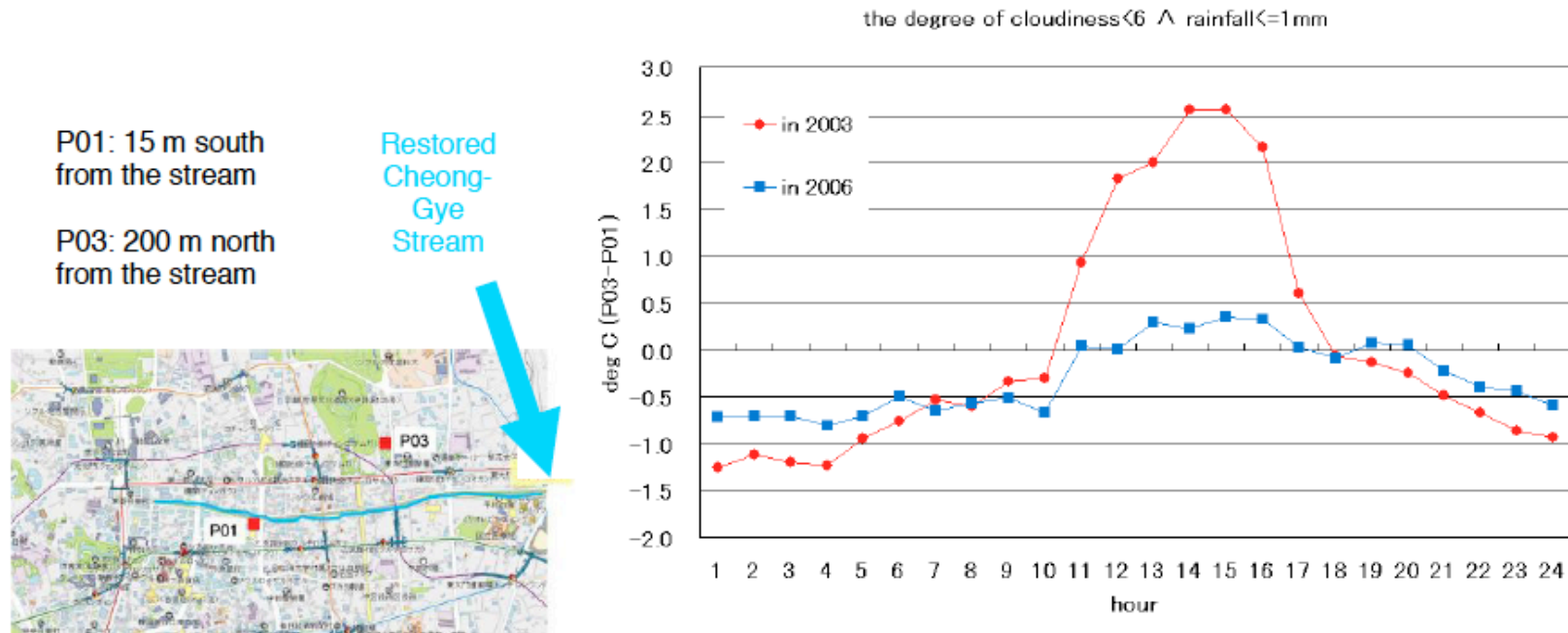
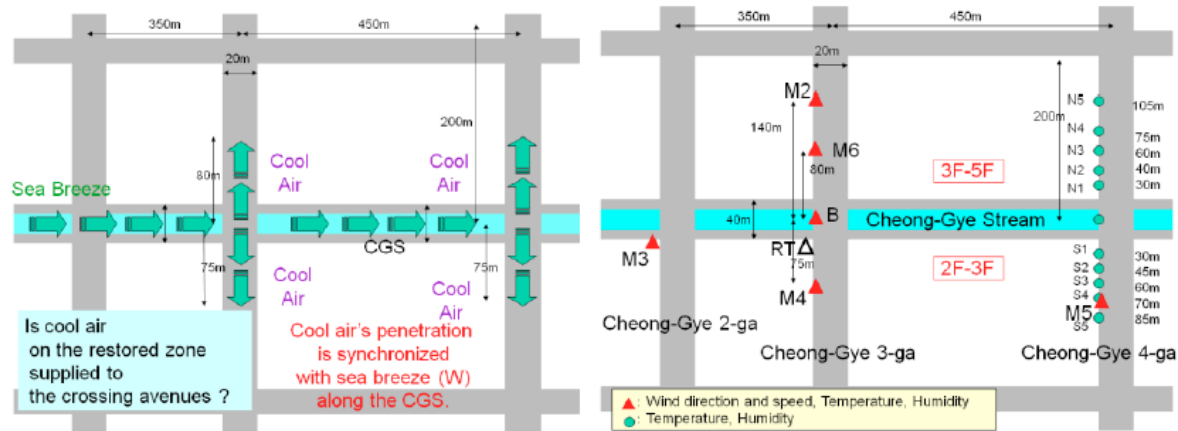


Fig. 3 The difference in temperature by hour on typical fine days in August in 2003 and 2006
Observation in 2003 was performed as collaboration with METRI/KMA etc.

URBAN RIVERS // Cooling Effects



The air temperature corresponds to wind speed.

The temperature was lower when the sea breeze was strong.

The temperature was higher when the sea breeze was weak.

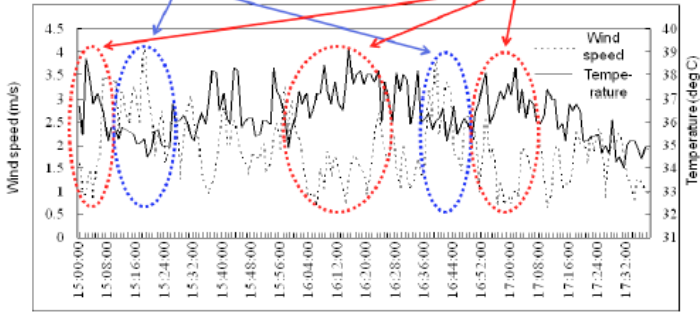
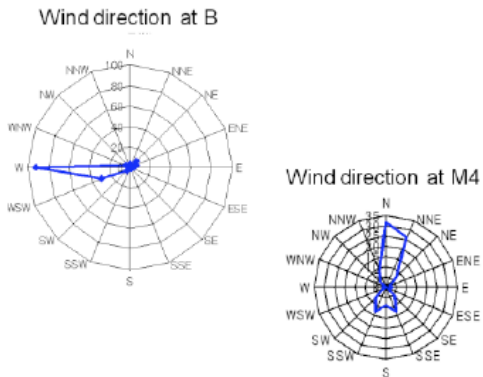


Fig. 4 Relationship between the wind speed at B and air temperature at M4 (13th of August, 2006)

URBAN RIVERS // Pollution Effects

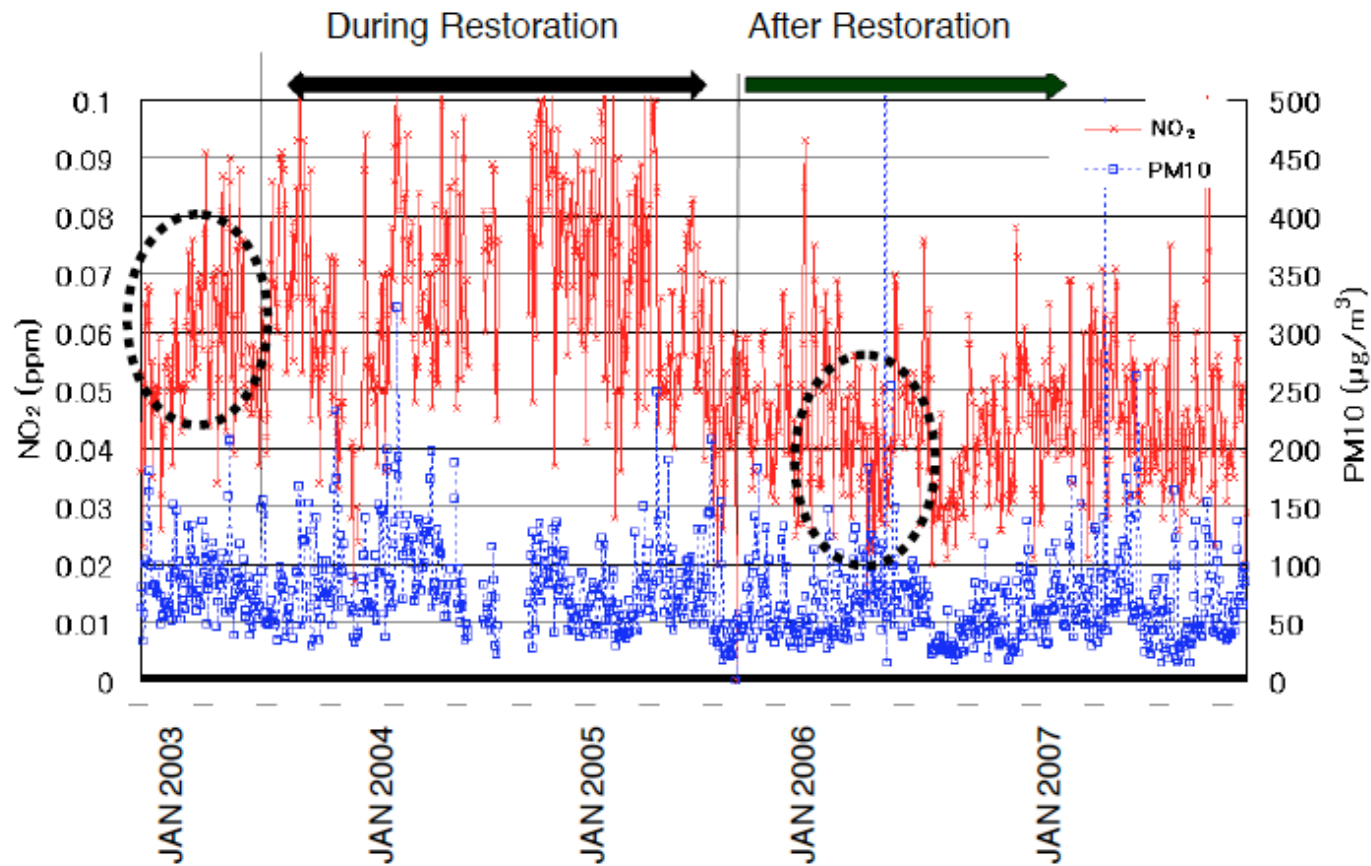


Fig. 6 The interannual change in NO₂ (red line) and PM₁₀ (blue line) concentrations beside the stream (in “Cheong-Gye 4-ga” monitored by Seoul Metropolitan Government)

URBAN TOPOGRAPHY // Basic Concepts + Influences

UPDATING THE URBAN TOPO-CLIMATOLOGY - A REVIEW

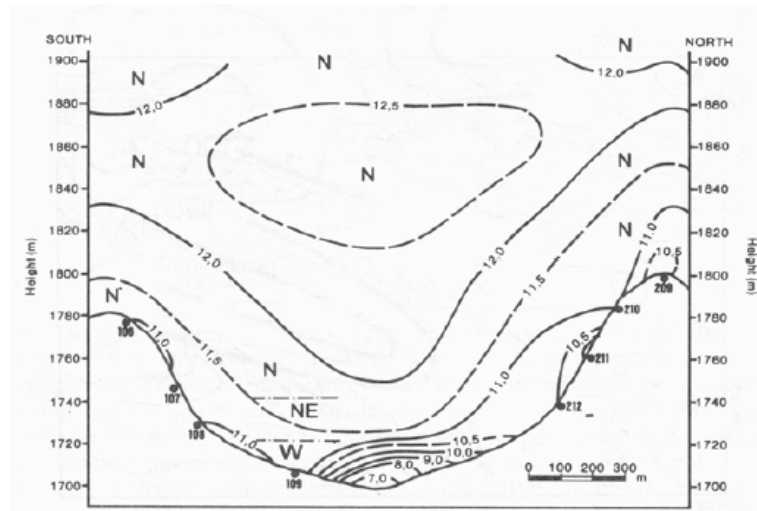


Figure 3: Bezuidenhout Valley temperature (°C) cross-section at 23h20 (22.07.86). Letters indicate wind directions.

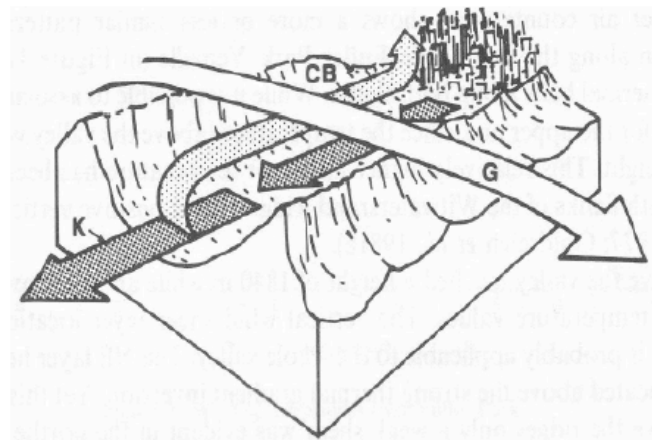


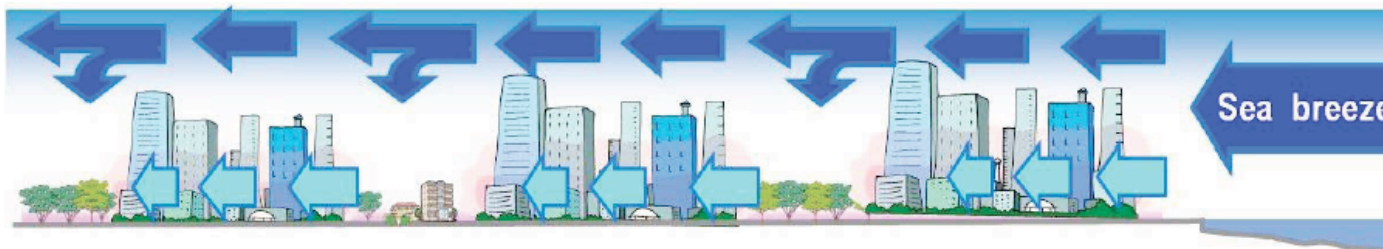
Figure 4: Schematic 3D model of the generalized wind at three levels. K, katabatic flow; CB, country breeze and G, the synoptic gradient wind.

COASTAL HIGH DENSITY CITY // Tokyo Redesign & UHI Countermeasures

National Research Project on Kaze-no-michi for City Planning: Creation of Ventilation Paths of Cool Sea Breeze in Tokyo

Comparison of ventilation paths between Japan and Germany

The Japanese ventilation path (*Kaze-no-michi*) where a “thick” sea breeze is led into an urban area is three-dimensional.



The German ventilation path where a “thin” mountain and valley breeze is led into an urban area is two-dimensional.



COASTAL HIGH DENSITY CITY // Tokyo Redesign & UHI Countermeasures




COASTAL HIGH DENSITY CITY // Tokyo Redesign & UHI Countermeasures

追跡
ディープランド


湾岸 東京を「熱地獄」にする！

高層ビルが 将来は最悪4°C上昇も



巨大なビル群が海風を遮断して、沿岸シオサイトのビル群が本社へ入り込む。

海風ビル通せんぼ



海風がビル群の間をすり抜けていく。弱風域が形成されている。

1〜2度暑く 汐留再開発で

東京湾沿いの海沿いに、ある再開発地区「汐留シオサイト」の計画が進行中。南北に広がる約31万㎡、南北が、海からの強い風を遮り、内側の都市部が蒸気化するヒートアイランド現象を助長している。可視性が高いことが、2大弊害の一つ。汐留再開発で、汐留シオサイトをR1新橋駅と有明駅間の東側に広がる約31万㎡、南北が、海からの強い風を遮り、内側の都市部が蒸気化するヒートアイランド現象を助長している。可視性が高いことが、2大弊害の一つ。

汐留再開発で

汐留シオサイトのビル群が本社へ入り込む。巨大なビル群が海風を遮断して、沿岸シオサイトのビル群が本社へ入り込む。

汐留シオサイトのビル群が本社へ入り込む。巨大なビル群が海風を遮断して、沿岸シオサイトのビル群が本社へ入り込む。

汐留再開発で

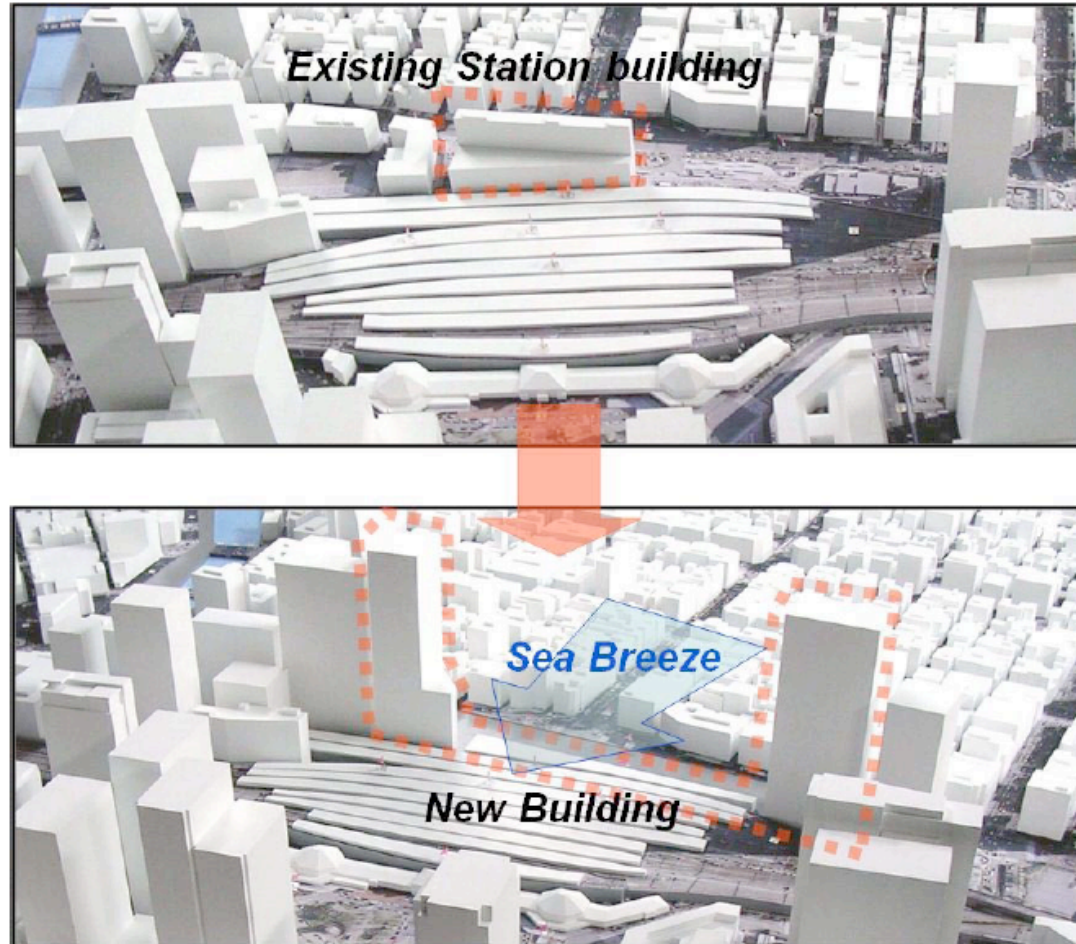
汐留シオサイトのビル群が本社へ入り込む。巨大なビル群が海風を遮断して、沿岸シオサイトのビル群が本社へ入り込む。

COASTAL HIGH DENSITY CITY // Tokyo Redesign & UHI Countermeasures



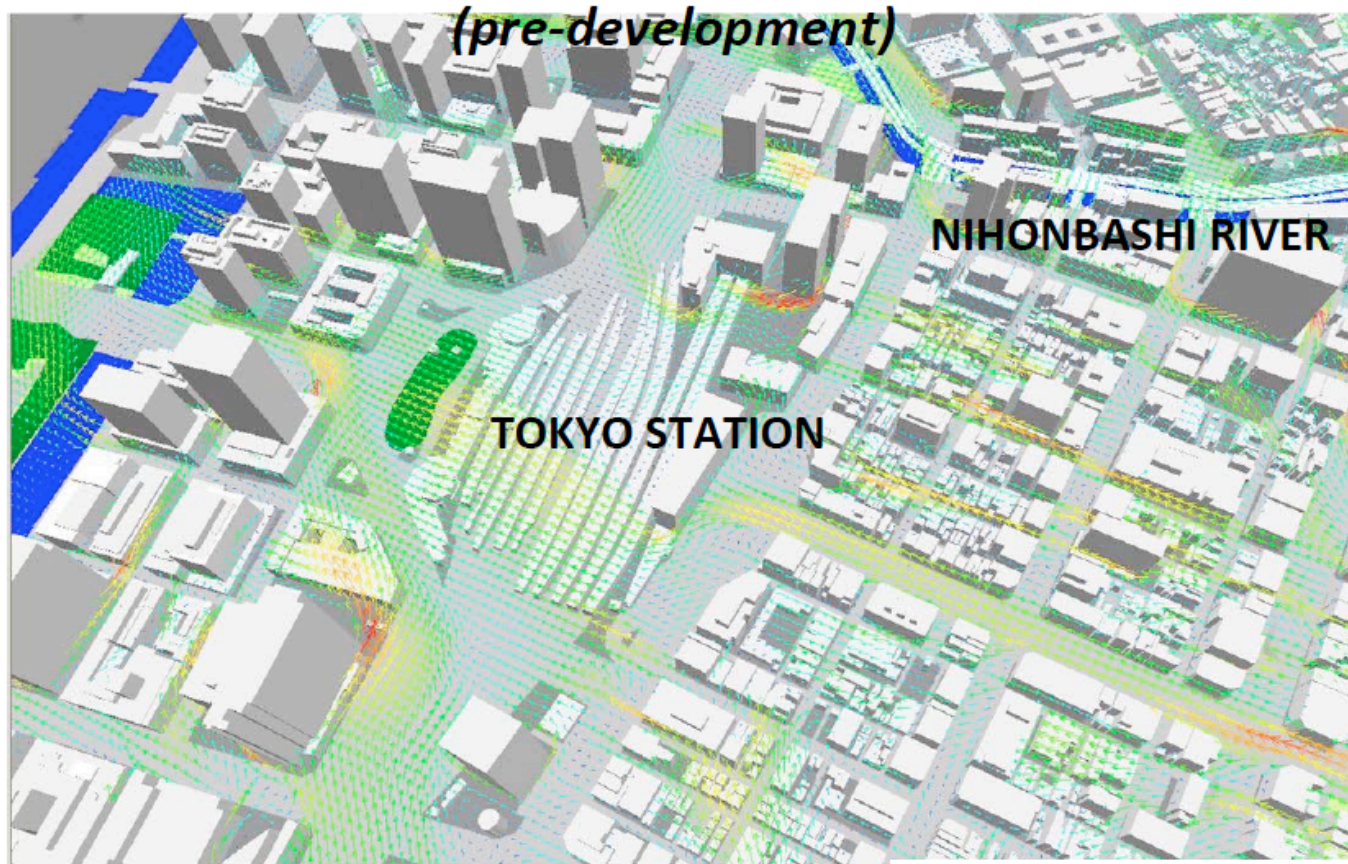
COASTAL HIGH DENSITY CITY // Tokyo Redesign & UHI Countermeasures

Redevelopment of Tokyo Station



COASTAL HIGH DENSITY CITY // Tokyo Redesign & UHI Countermeasures

CFD simulation result using E.S.

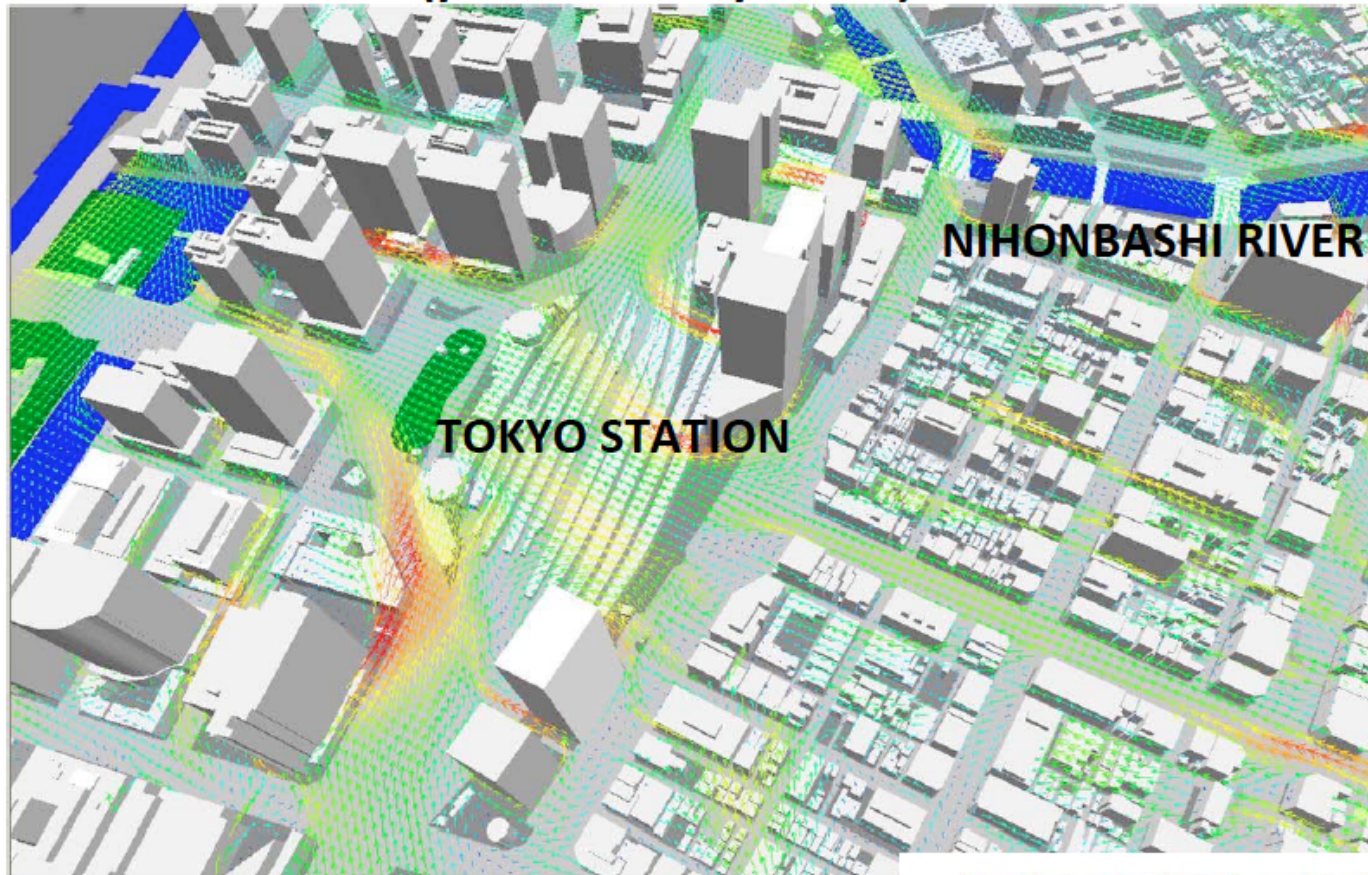


Simulated in 1m resolution, Drawn in 10m resolution

Wind speed 30m above ground level



COASTAL HIGH DENSITY CITY // Tokyo Redesign & UHI Countermeasures
CFD simulation result using E.S.
(post-development)



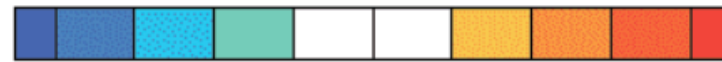
Simulated in 1m resolution, Drawn in 10m resolution

Wind speed 30m above ground level



COASTAL HIGH DENSITY CITY // Tokyo Redesign & UHI Countermeasures

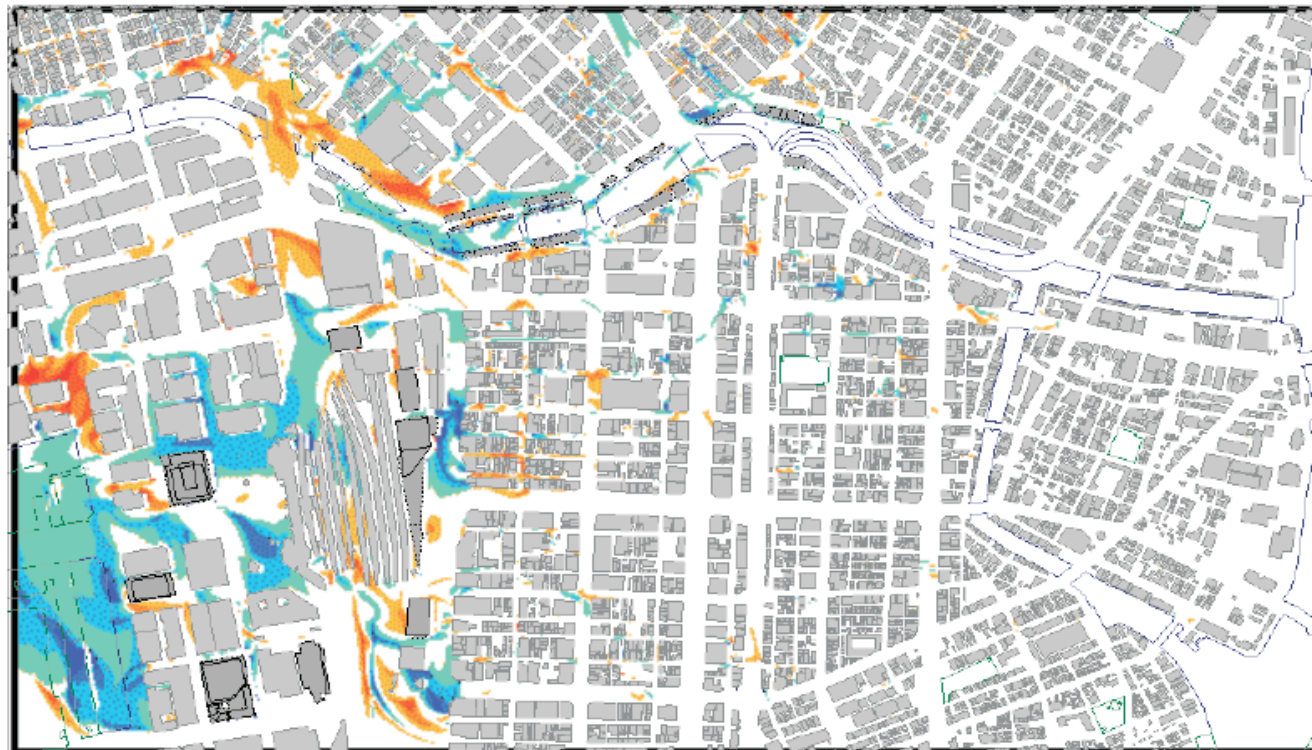
Air Temperature Difference (between pre- and post development)



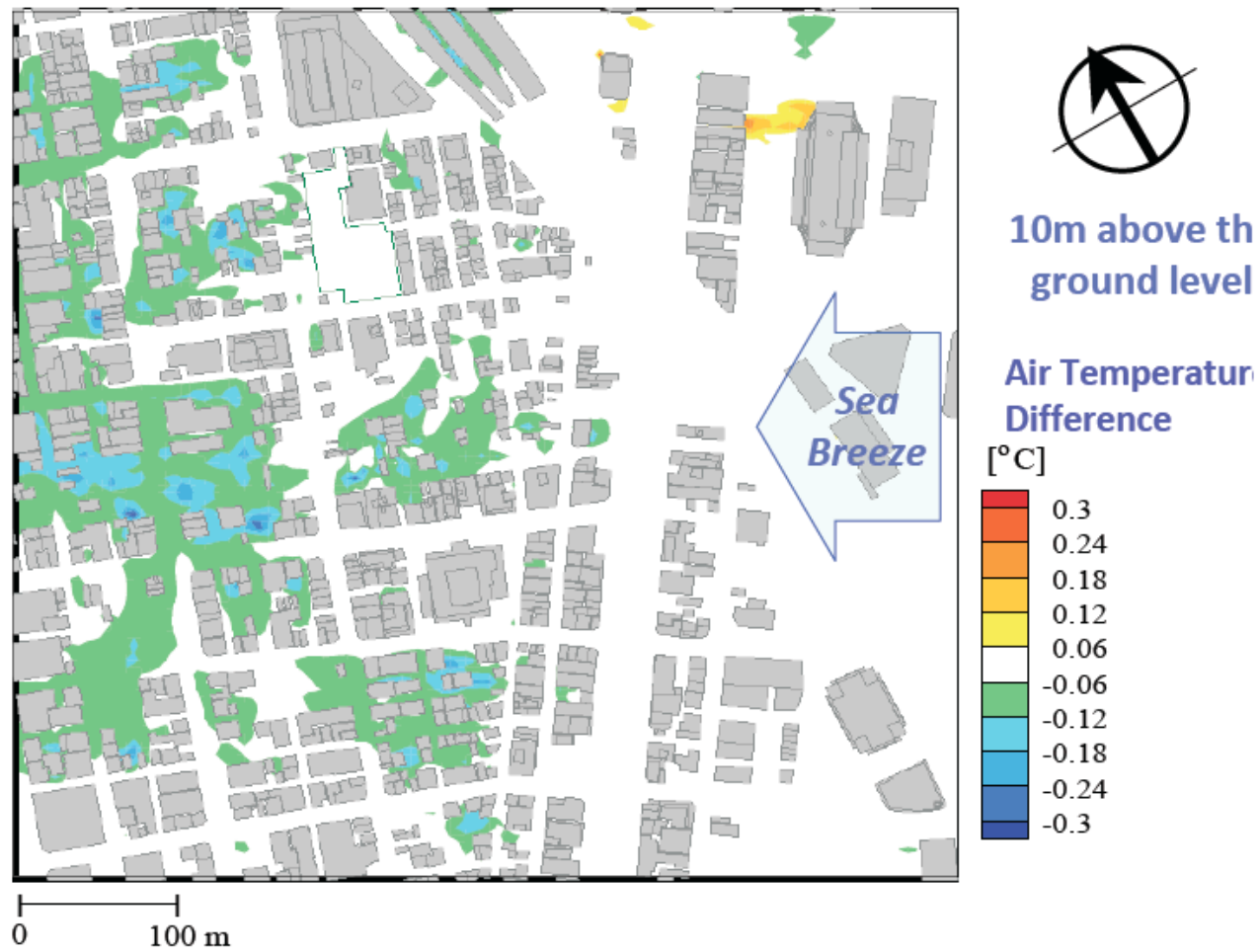
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2
Air Temperature Difference (Degrees Celsius)

2m above the ground level

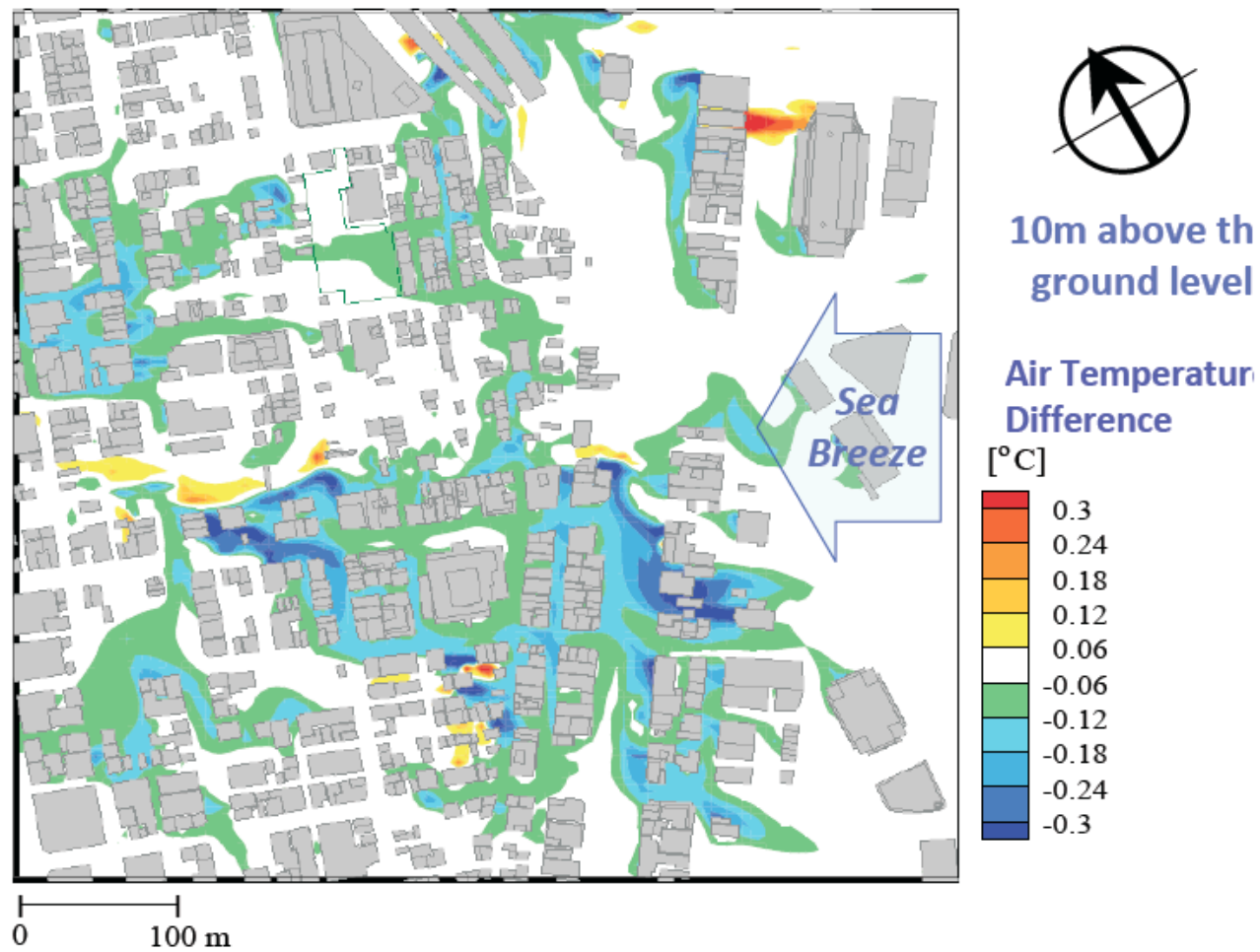
500m



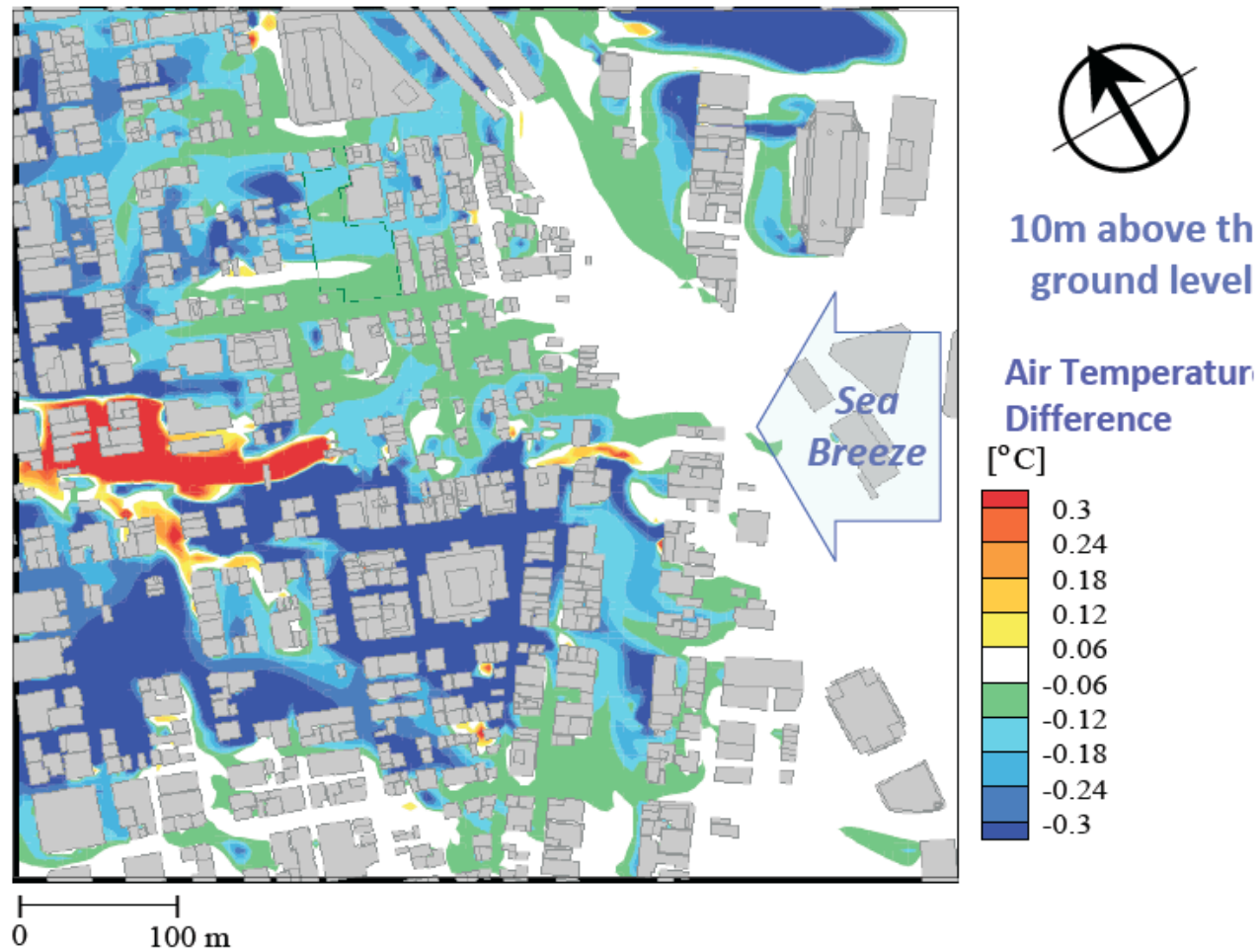
Effect of Roof-top greening



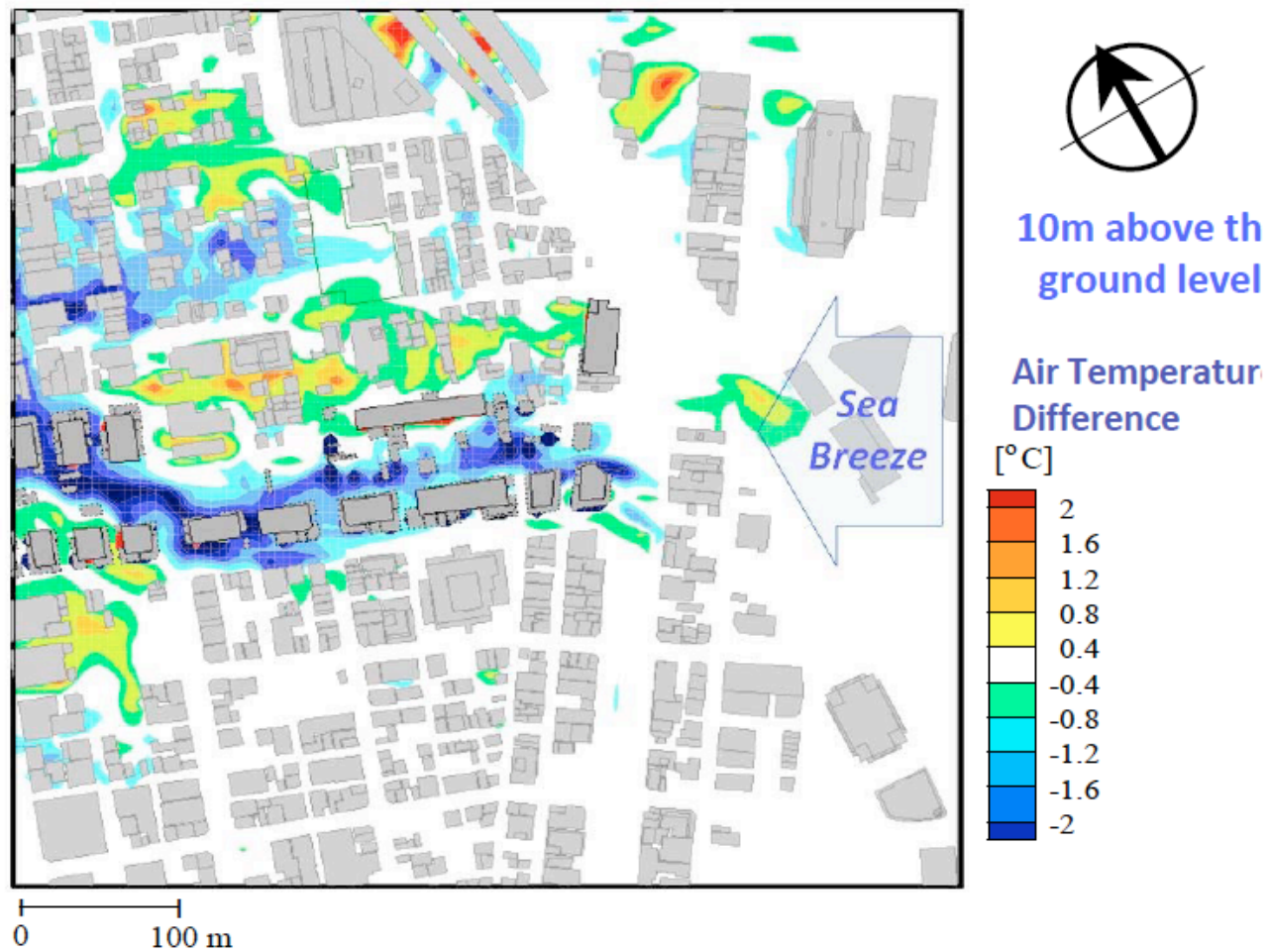
Effect of greening and cool pavement



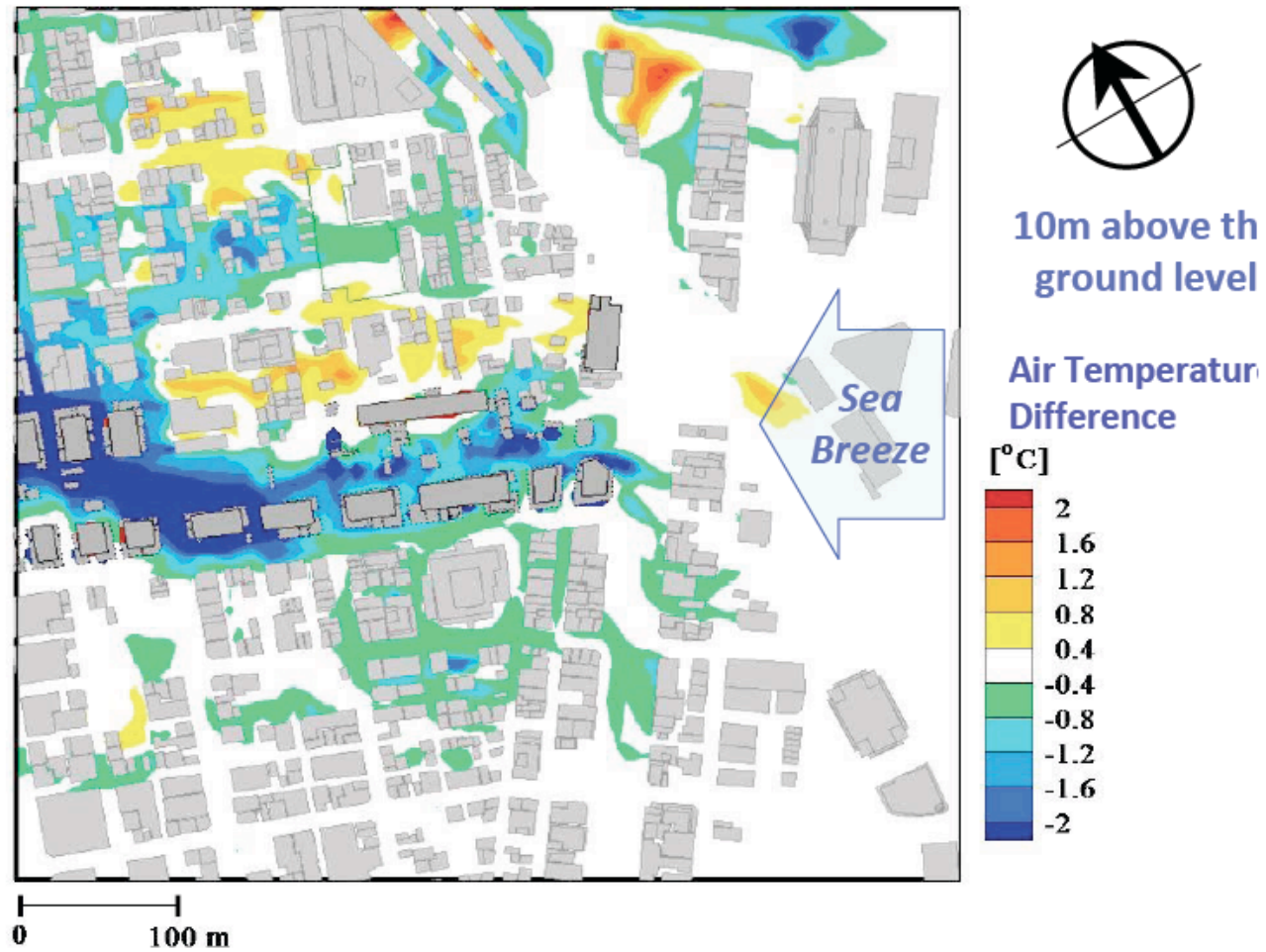
Effect of energy omission (e.g.. Improving the performance of air conditioner)



Effect of redevelopment with a main road



Effect of overall measures



COASTAL HIGH DENSITY CITY // Tokyo Re-design Simulations

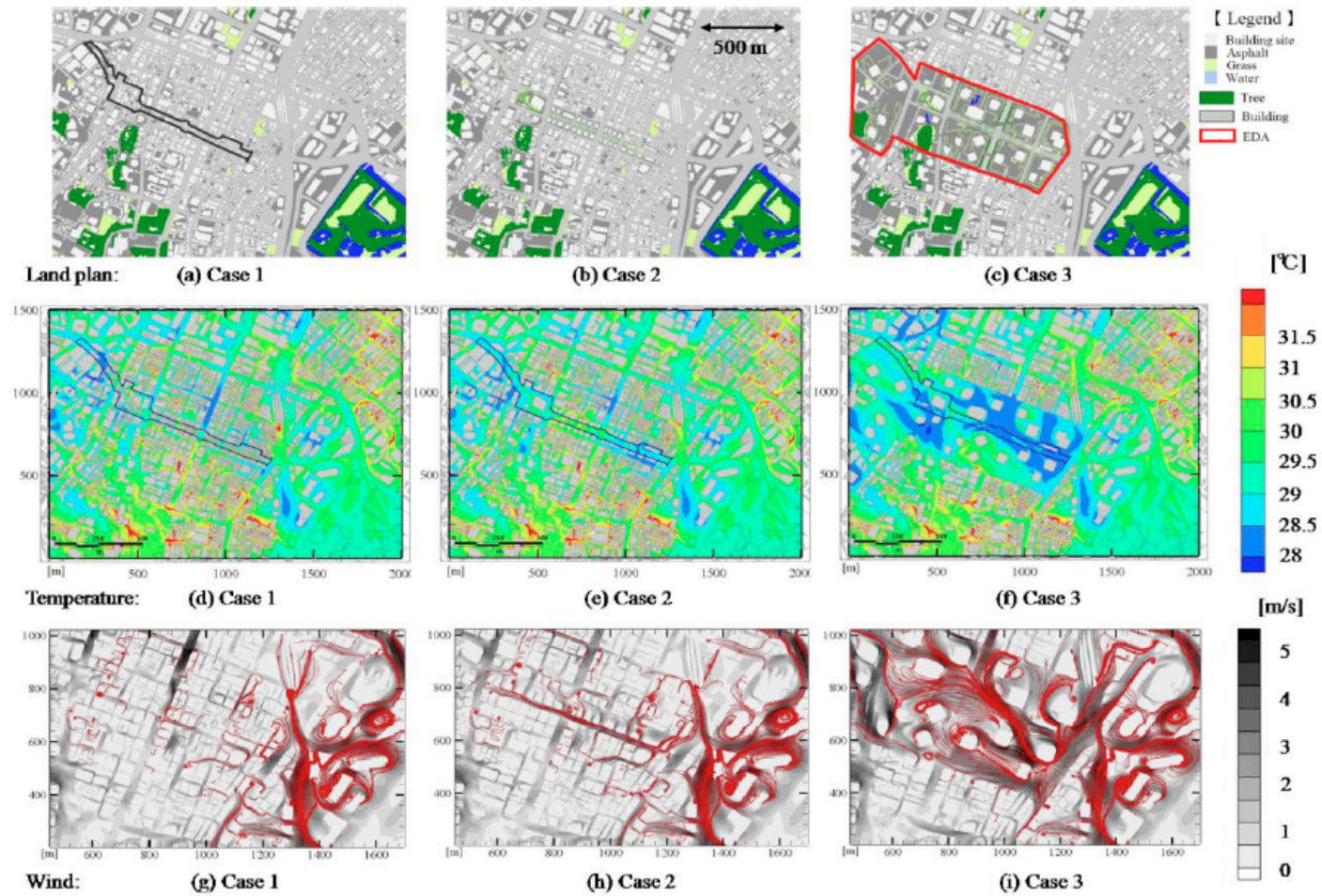


Figure 6. Land use (upper) and air temperature* (middle), velocity *(bottom)
 * Numerical simulation result of 5m above soil surface (12 o'clock, 31 July, 2005)

COASTAL HIGH DENSITY CITY // Tokyo Bay Sea Breeze Cooling

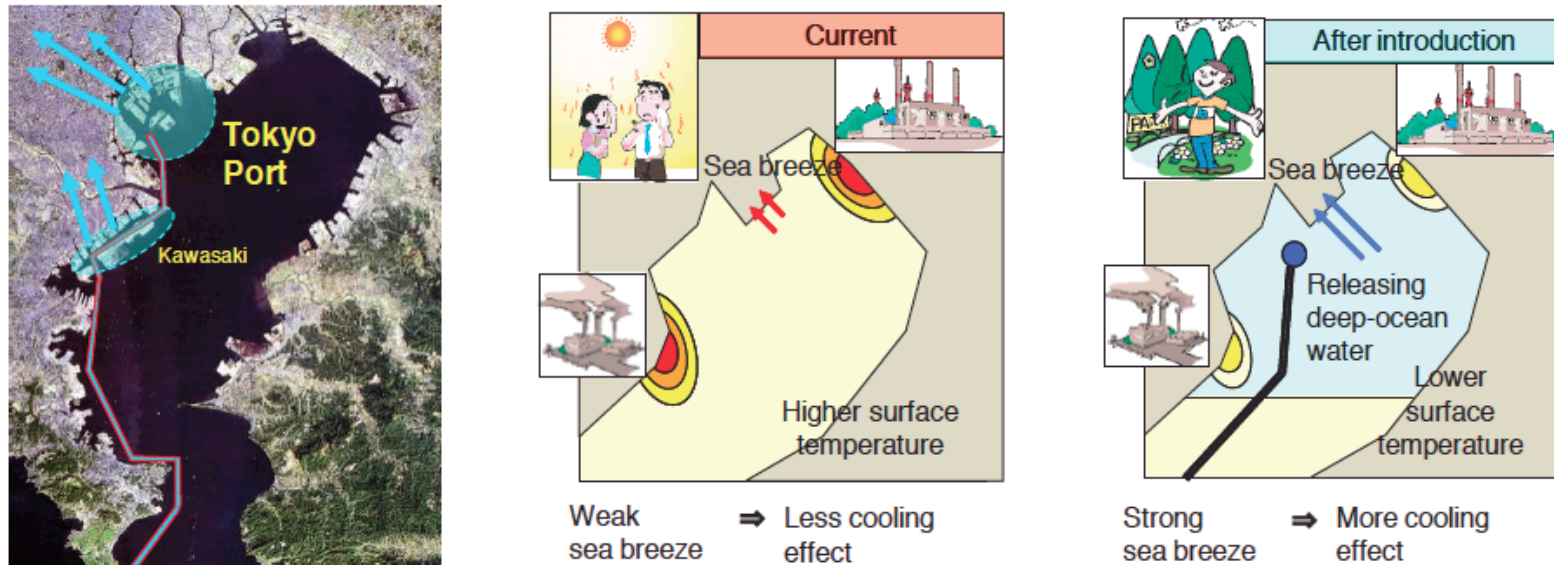
A numerical simulation with CSU-MM (e.g. Ichinose, 2003) showed that 2 deg. C decrease in bay's sea surface temperature on fine days of late July would lead to 1 deg. C drop in air temperature in central part of Tokyo and to 1 m/s enhancement of the bay breeze.

Cost of Heat Island Mitigation for 23 Wards:

Water retentive pavement: 70 million (m²) x 18,000 (JPY/m²) = 1.30 trillion (JPY)

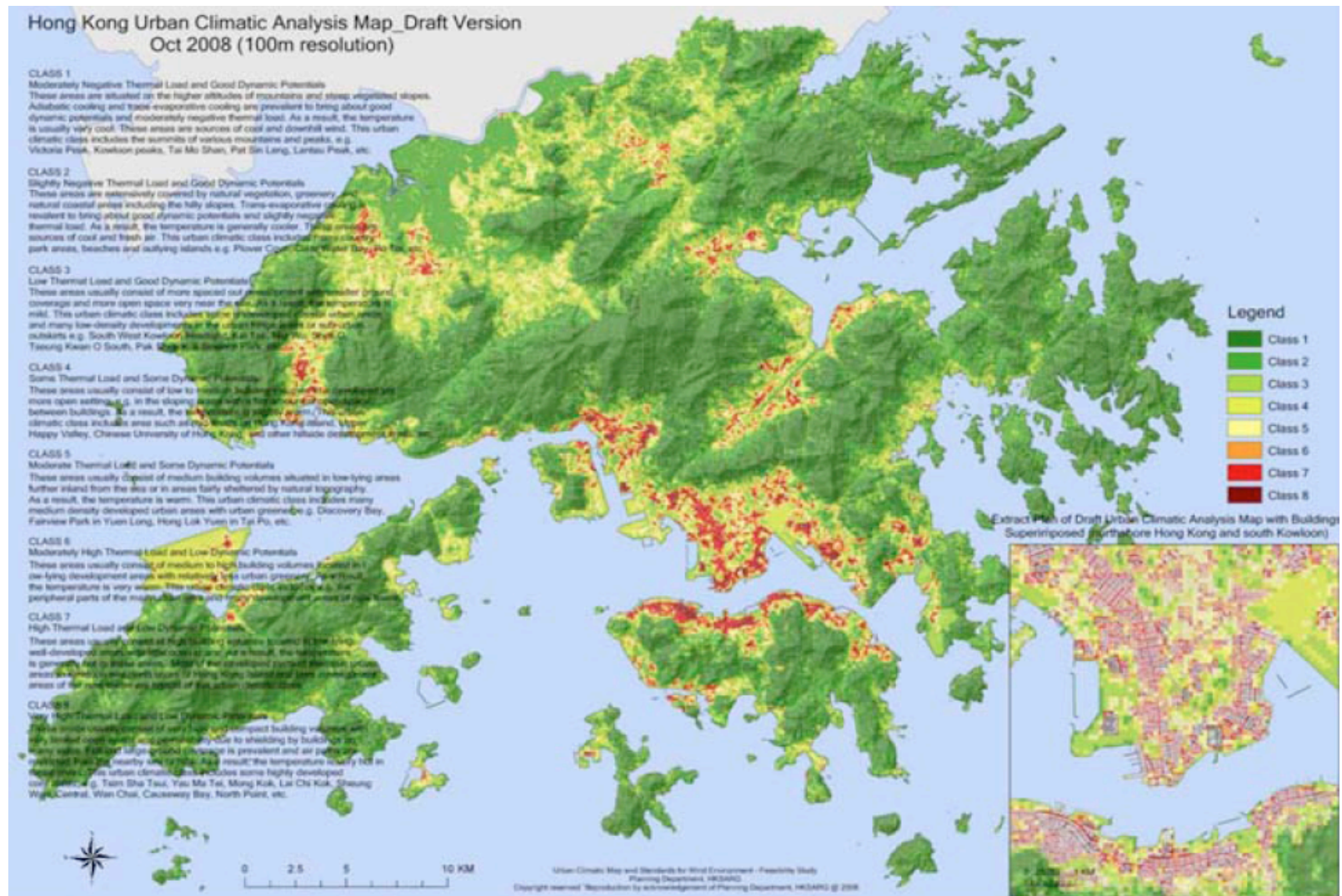
Rooftop vegetation: 140 million (m²) x 20,000 (JPY/m²) = 2.80 trillion (JPY)

Deep Water Pipeline: 50 (km) x 2.5 billion (JPY/km) = 125 billion (JPY)

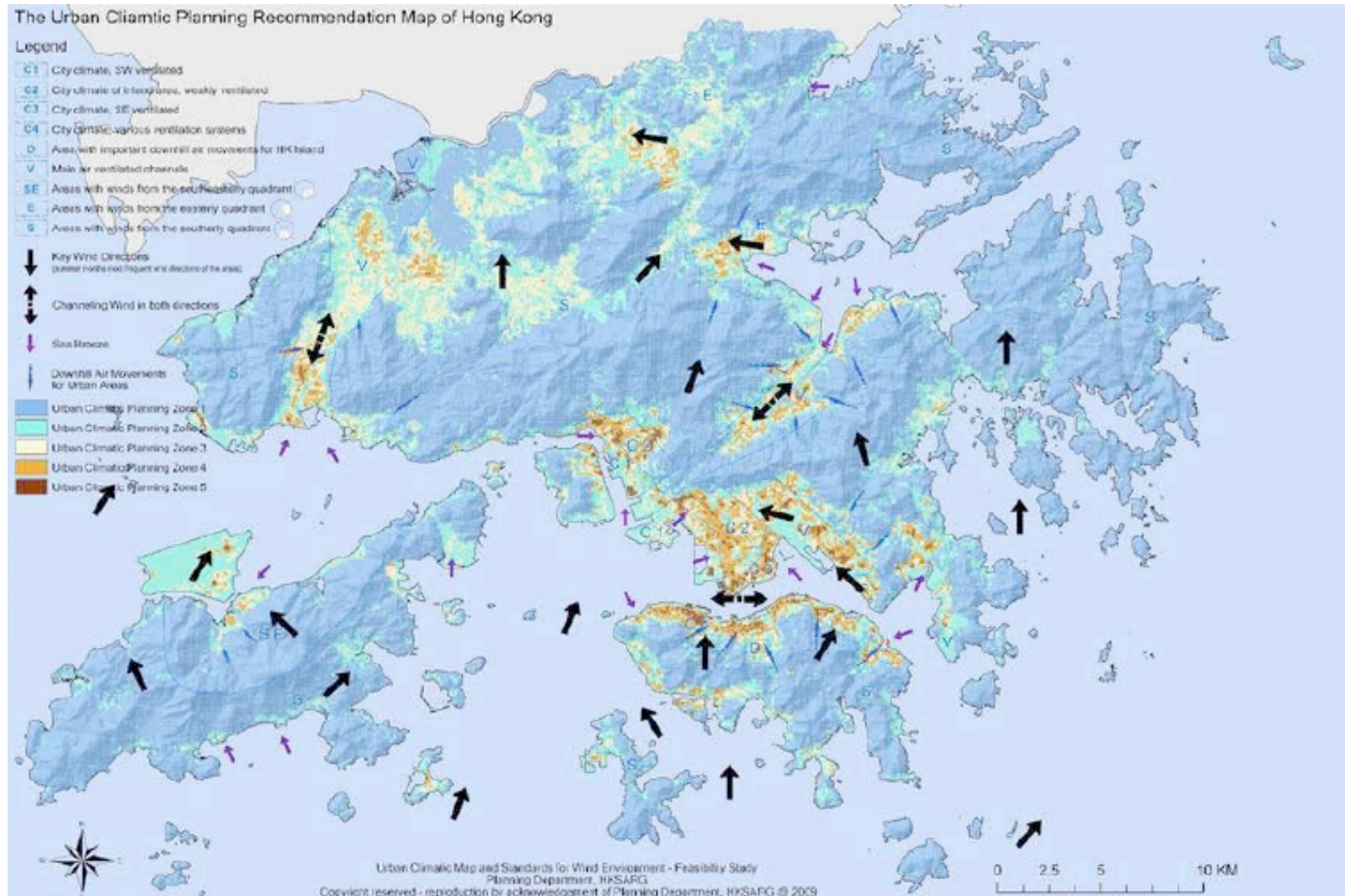


(left one) Fig. 1 Tokyo Bay and expected directions of sea breeze from the Pacific Ocean
(right two) Fig. 2 Concept of mitigation on urban thermal pollution by introducing deep-ocean water from the Pacific Ocean to Tokyo Bay

COASTAL HIGH DENSITY CITY // Hong Kong Sea Breeze + Air Ventilation Guidelines



COASTAL HIGH DENSITY CITY // Hong Kong Sea Breeze + Air Ventilation Guidelines



COASTAL HIGH DENSITY CITY // Hong Kong Sea Breeze + Air Ventilation Guidelines

1. Breezeway / air path

As a general rule, the more air ventilation to the streets, the better it will be for these dense urban areas. The overall permeability of the district has to be increased at the ground level. This is to ensure that the prevailing wind travelling along breezeways and major roads can penetrate deep into the district. This can be achieved by proper linking of open spaces, creation of open plazas at road junctions, maintaining low-rise structures along prevailing wind direction routes, and widening of the minor roads connecting to major roads. Also avoid obstruction of the sea breeze. Any localised wind problem along the waterfront should be dealt with locally and not affect the overall air ventilation of the city.

2. Podium / Site Coverage

The effect of building layout (especially in terms of building site coverage) has a greater impact than that of building height on pedestrian wind environment. (Figure 5) Stepping building heights in rows would create better wind at higher levels if differences in building heights between rows are significant. The “podium” structures commonly found in Hong Kong are not desirable from the viewpoint of maximizing wind available to pedestrians. The podia with large site coverage not only block most of the wind to pedestrians (affecting comfort and air quality), but also minimize the “air volume” near the pedestrian level (affecting air quality).

3. Building Heights

Vary the heights of the blocks with decreasing heights towards the direction where the prevailing wind comes from. If not, it is better to have varying heights rather than similar / uniform height. Given the extremely high density of the urban fabric and narrow streets, a probable strategy for improving the air ventilation is by varying building heights for diverting winds to the lower levels. Nonetheless, assessment will be required to further quantify the

actual performance of such potential in view of the common deep urban canyon situations in Hong Kong.

4. Building permeability

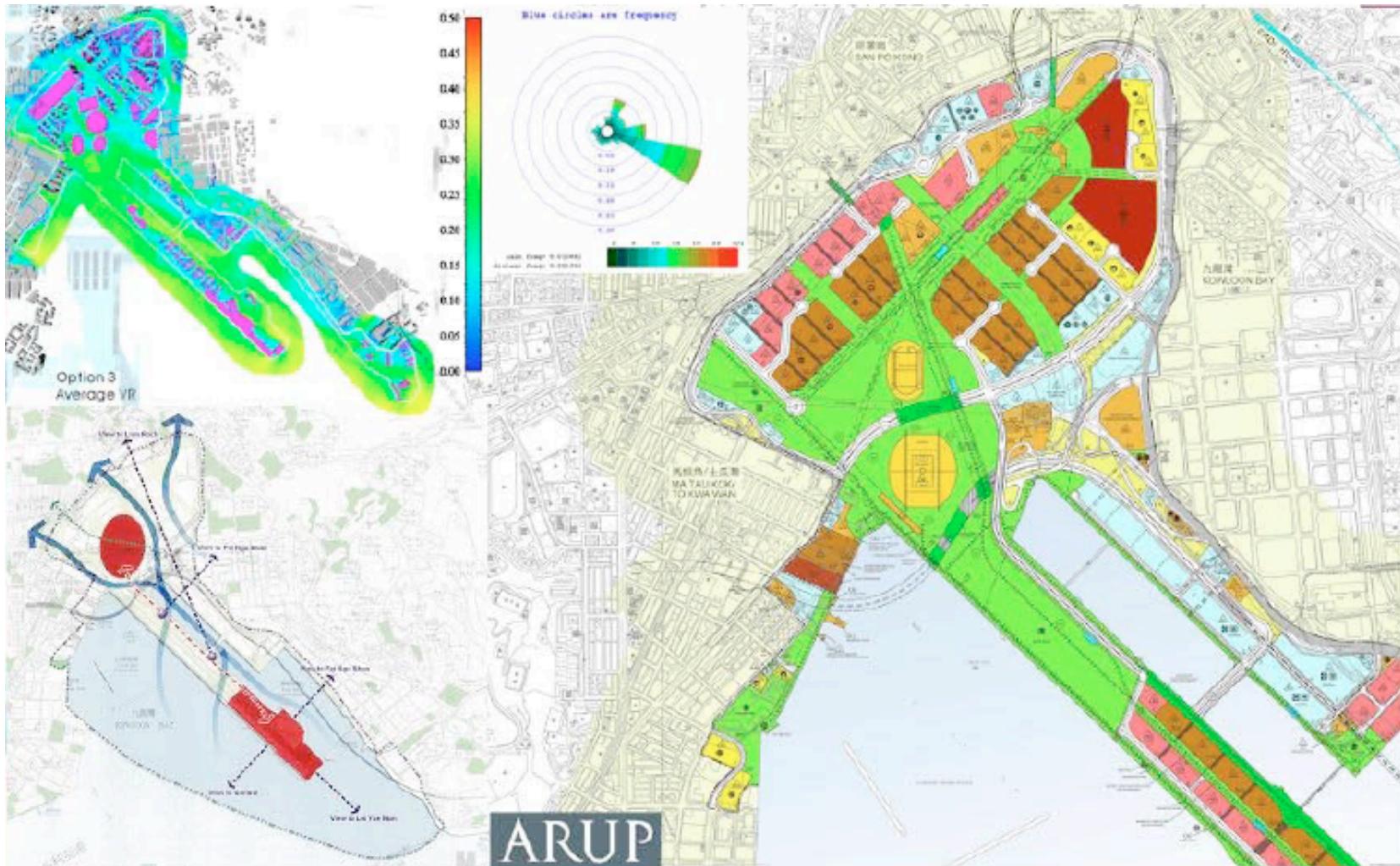
The provision of permeability / gap nearer to the pedestrian level is far more important than that at high levels. Create permeability in the housing blocks. Try to create voids at ground level to improve ventilation for pedestrians. This will improve not only the air movement at the ground level (thus improving the pedestrian comfort), but also help to remove the pollutants and heat generated at ground level. The channelling effect created by the void also helps to improve the ventilation performance for those residential units at the lower floors. Creation of openings in the building blocks to increase their permeability may be combined with appropriate wing walls that will contribute to pressure differences across the building facades and thus will permit the air to flow through the openings of the buildings. The wing walls have to be designed according to the known standards. For very deep canyons or very tall building blocks, mid-level permeability may be required to improve the ventilation performance for those occupants situated at mid-floors.

5. More the Better

It was in general opined that unlike most cities in the world, wind gust may not be a problem in most areas in Hong Kong. On the contrary, wind stagnation and blockage is a main problem. For the tropical climatic conditions of Hong Kong where wind in the summer is a welcoming quantity, it was opined unanimously that “more the better” should be the guiding spirit. That is to say, designs and developments should focus on not blocking the incoming wind, as well as to minimise the stagnant zones at the pedestrian levels.

COASTAL HIGH DENSITY CITY // Hong Kong Sea Breeze + Air Ventilation Guidelines

Air Ventilation Assessment for High Density City - An Experience from Hong Kong



COASTAL HIGH DENSITY CITY // Hong Kong Sea Breeze + Air Ventilation Guidelines

Air Ventilation Assessment for High Density City - An Experience from Hong Kong

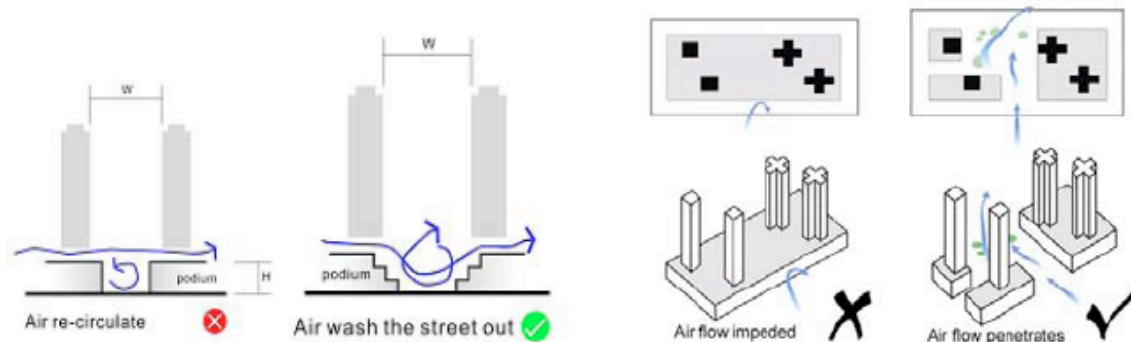


Figure 2: Two examples of the guidelines dealing with the shape of the podium.



Figure 3: (left) The 328 hectares old Kai Tak airport site designed to benefit from the south-east prevailing wind. (right) The Tamar Government Headquarters building.

INLAND CITY // Cold Air Generation

ANALYSIS AND EVALUATION OF COLD AND FRESH AIR GENERATION AREAS FOR MITIGATING URBAN HEAT ISLAND IN CHANGWON, SOUTH KOREA

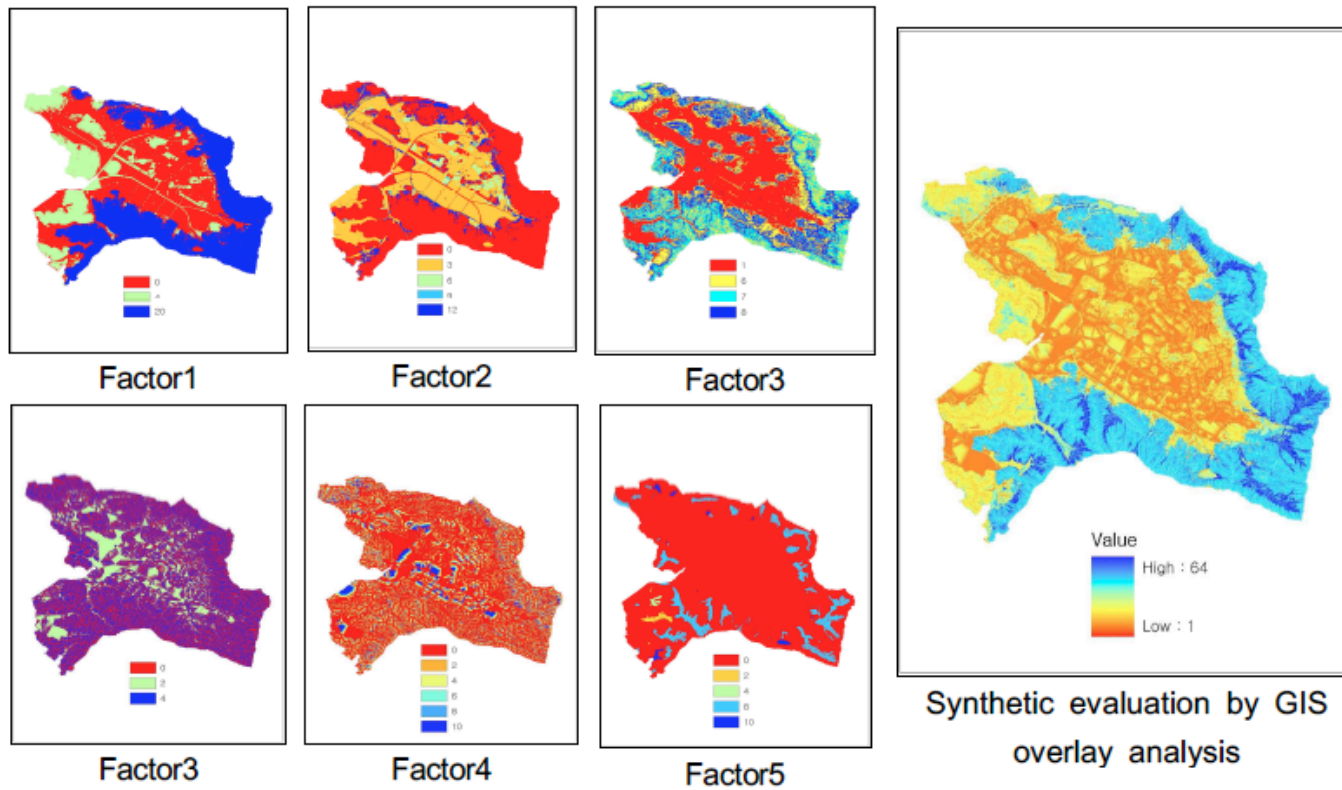


Figure 4. Evaluation maps of cold air generation function

STREET CANYONS // Air Pollution Design

Field Measurement and CFD Analysis on Thermal Environment and Ventilation Efficiency in Street Canyons to Investigate the Influence of Roadside Trees and Moving Automobiles

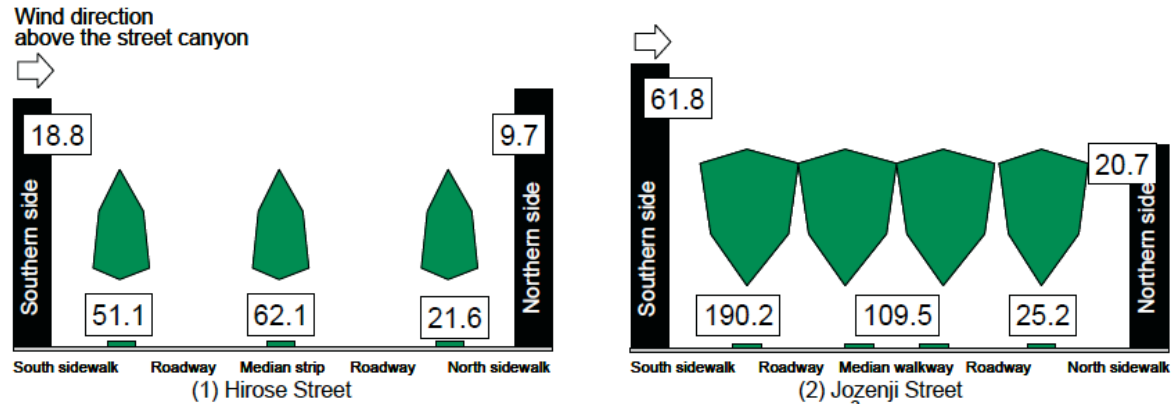
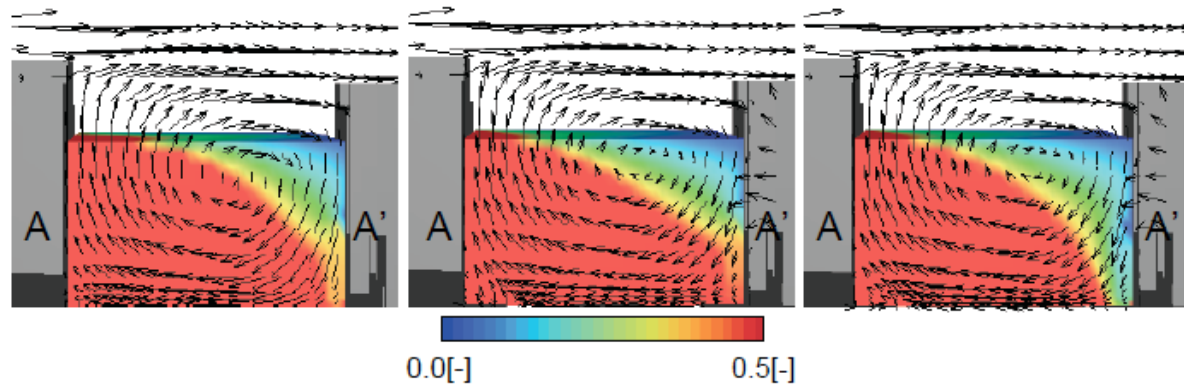


Fig. 5: Normalized NO_x concentration (9:00 on August 11th) [m³/ automobile]

Table 2. Incoming and outgoing flow rates at the upside of the evaluation domain [m³/s]

	Case1	Case2	Case3
Incoming Flow rate	258	209	218
Outgoing Flow rate	1122	841	868



(1) Case 1 (without trees) (2) Case 2 (actual condition) (3) Case 3 (Trees are pruned)
Fig. 8. Vertical distributions of wind velocity vectors and SVE3 (12:00 on August 11th)

STREET CANYONS // Air Pollution Design



(1) Hirose Street (cf. Fig. 1, Area A)



(2) Jozenji Street (cf. Fig. 1, Area B)

Photo 1: View of measurement areas

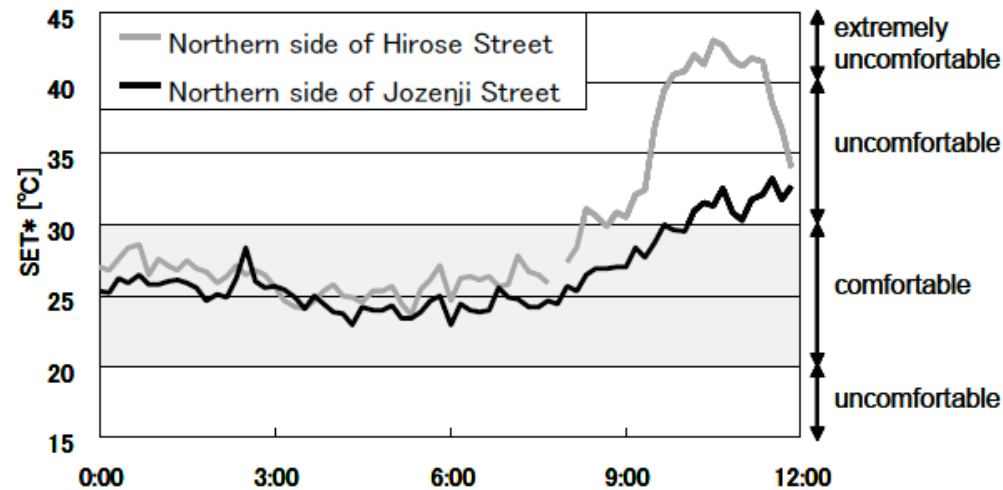
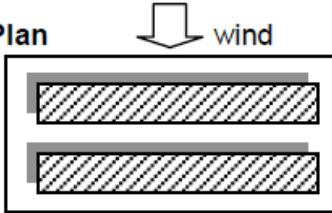
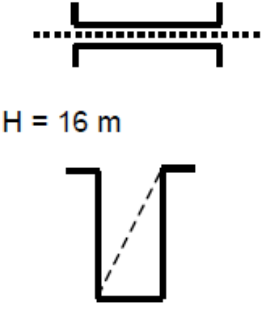
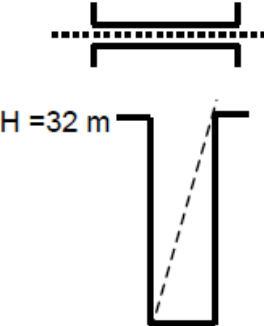
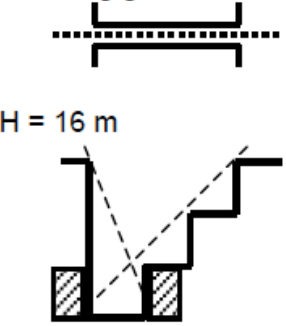
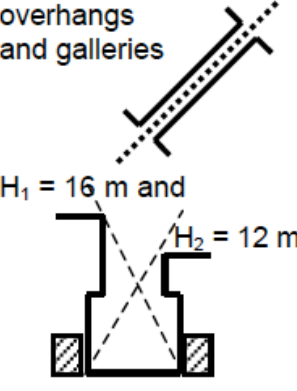


Fig. 2: SET* (h=1.2m, August 11)

STREET CANYONS // Street Orientation

Table 1: Schemes of the simulated streets canyons

<p>street width: 8 m bldg height H: variable building length: 6 H wind speed: 5 m/s at 10m Asphalt road: albedo: 0.1 Brick walls: albedo: 0.3 roof: albedo: 0.15</p> <p>Plan </p>	<p>(a) reference street: E-W oriented street with an aspect ratio of $H/W = 2$</p>  <p>H = 16 m</p>	<p>(b) E-West oriented street with an aspect ratio of $H/W = 4$</p>  <p>H = 32 m</p>	<p>(c) E-W oriented street with an asymmetrical profile $H/W = 2$ and 1, including galleries</p>  <p>H = 16 m</p>	<p>(d) NE-SW oriented street with horizontal overhangs and galleries</p>  <p>$H_1 = 16$ m and $H_2 = 12$ m</p>
--	---	--	---	--

STREET CANYONS // Street Orientation

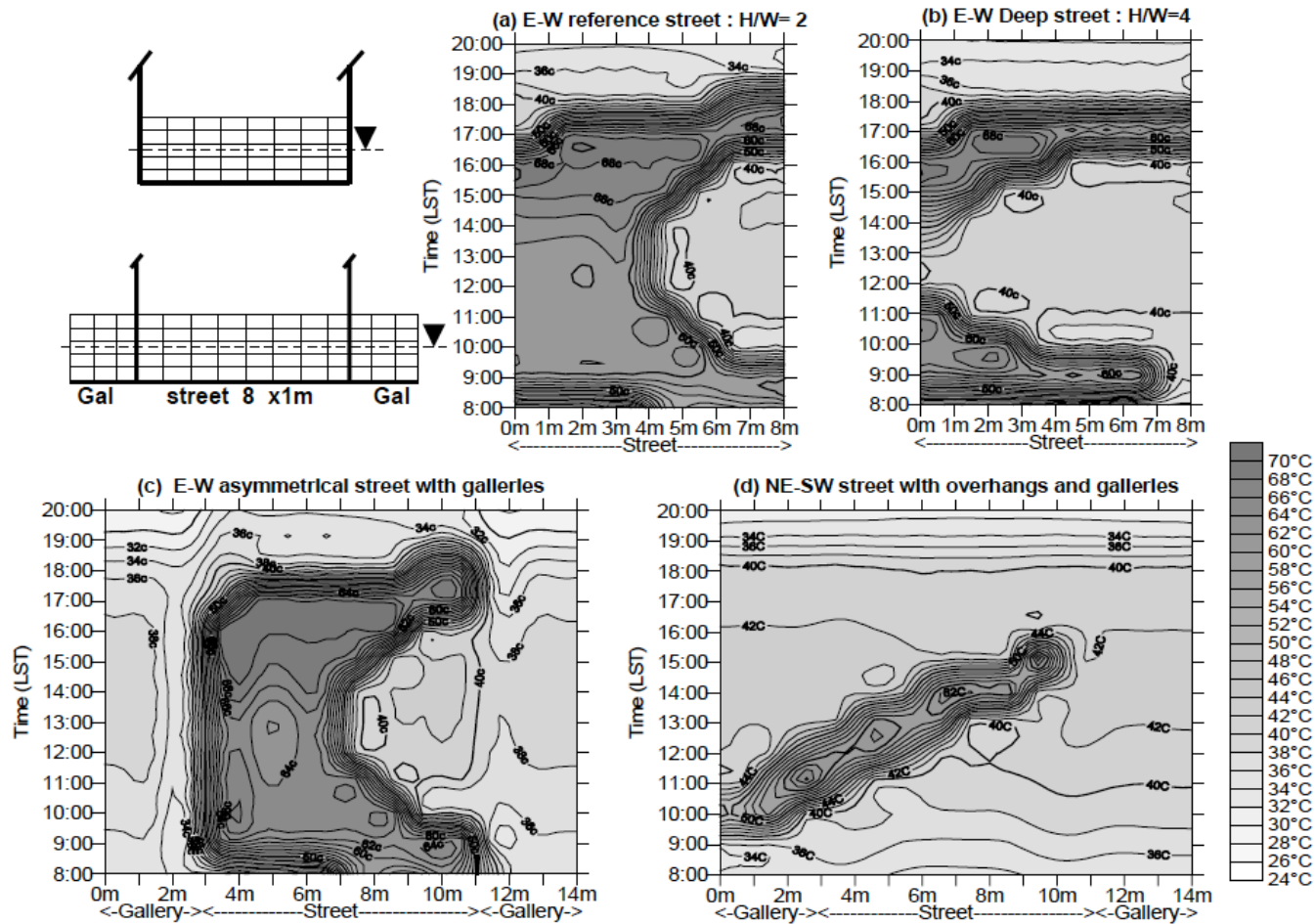


Figure 1: Spatial and temporal distribution of the Physiologically Equivalent Temperature PET at the height of 1.2 m above the ground (dotted line) for different streets. The schemes left show the XY resolution at street level for street with and without galleries (Grid equal to 1m horizontally and 0.4 m vertically).

URBAN DESIGN // Thermal Comfort + Density

STUDY ON OUTDOOR THERMAL ENVIRONMENT AROUND THE RESIDENTIAL BUILDINGS IN GUANGZHOU, CHINA WITH COUPLED SIMULATION OF CONVECTION, RADIATION AND CONDUCTION (2009)

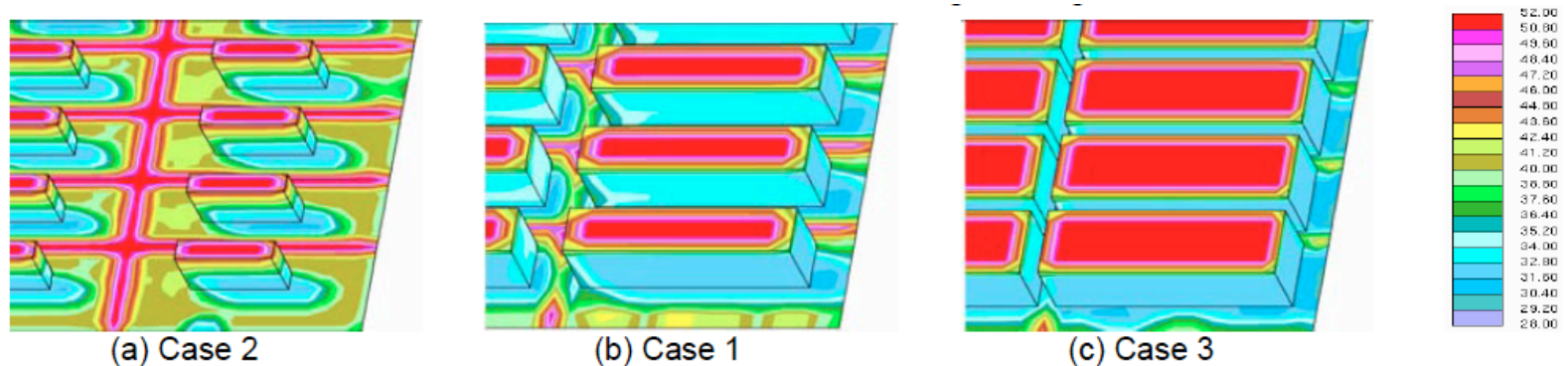


Fig.3 Surface temperature of part of ground and buildings for cases with different building coverage ratio (°C)

Table 2 Pedestrian-level calculation results of cases with different building coverage ratio

Case	Building coverage ratio (%)	Average velocity (m/s)	Average temperature (°C)	Average relative humidity (%)	Average SET* (°C)
2	10	1.385	33.15	82.05	44.3
1	40	1.3	33.98	78.32	45.02
3	70	1.209	33.82	78.47	45.3

URBAN DESIGN // Thermal Comfort + Density

STUDY ON OUTDOOR THERMAL ENVIRONMENT AROUND THE RESIDENTIAL BUILDINGS IN GUANGZHOU, CHINA WITH COUPLED SIMULATION OF CONVECTION, RADIATION AND CONDUCTION (2009)

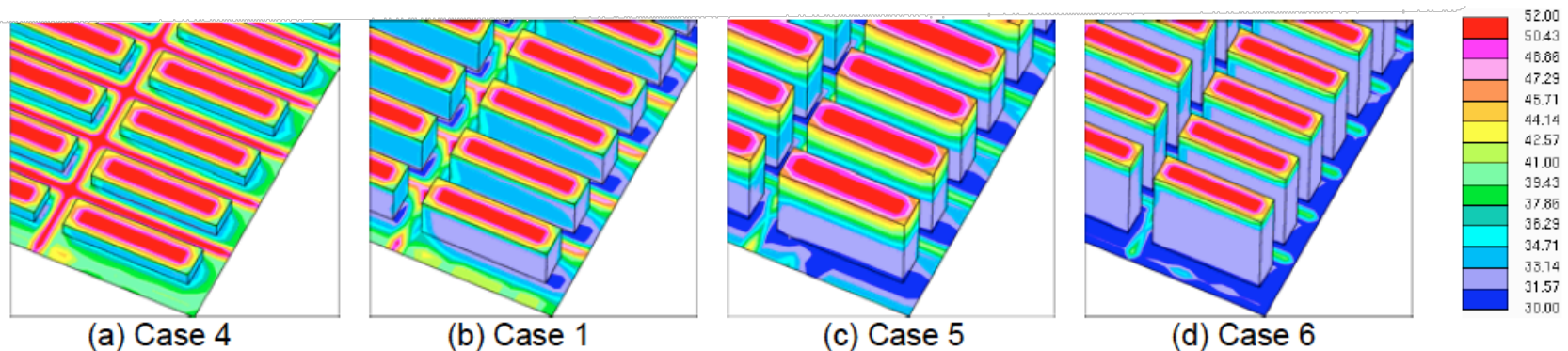


Fig.4 Surface temperature of part of ground and buildings for cases with different floor area ratio (°C)

Table 3 Pedestrian-level calculation results of cases with different floor area ratio

Case	Floor area ratio	Average building height (m)	Average velocity (m/s)	Average temperature (°C)	Average relative humidity (%)	Average SET* (°C)
4	0.8	7.5	1.188	33.99	78.42	45.48
1	2.8	22.5	1.3	33.98	78.32	45.02
5	5.6	45	1.39	33.28	80.44	44.41
6	7.6	60	1.294	32.85	82.16	44.74

MODELING // Energy Balance Modeling

PREDICTION OF SENSIBLE HEAT FLUX FROM BUILDINGS AND URBAN SPACES USING A DETAILED GEOMETRY MODEL OF A SUBSTANTIAL URBAN AREA - INTRODUCTION OF A PREDICTION MODEL OF ANTHROPOGENIC HEAT INTO AN URBAN HEAT BALANCE SIMULATION MODEL (2009).

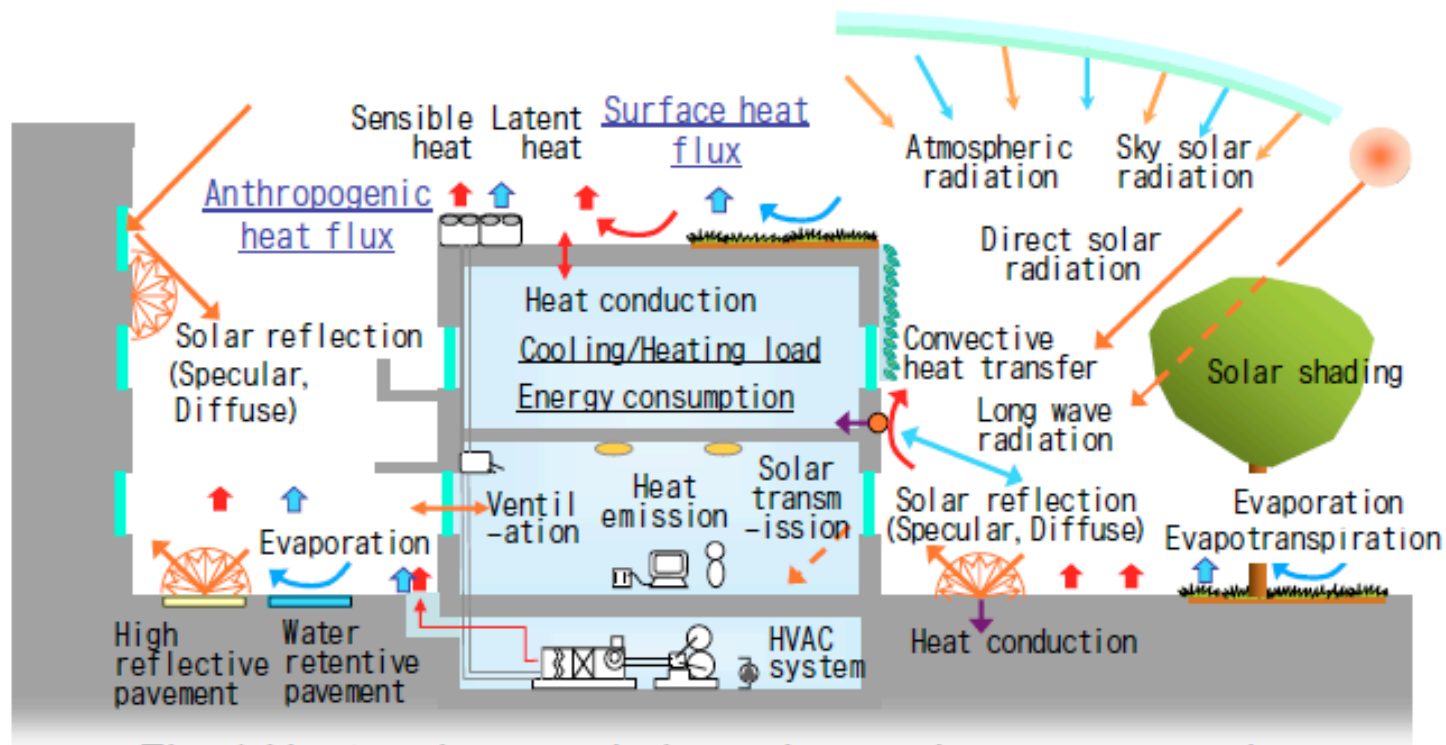


Fig. 1 Heat and energy balance in an urban canopy and the calculation items in the simulation system

MODELING TOOLS // Energy Balance Modeling

STUDY ON ENERGY SYSTEM SIMULATION TOOL FOR URBAN DESIGN

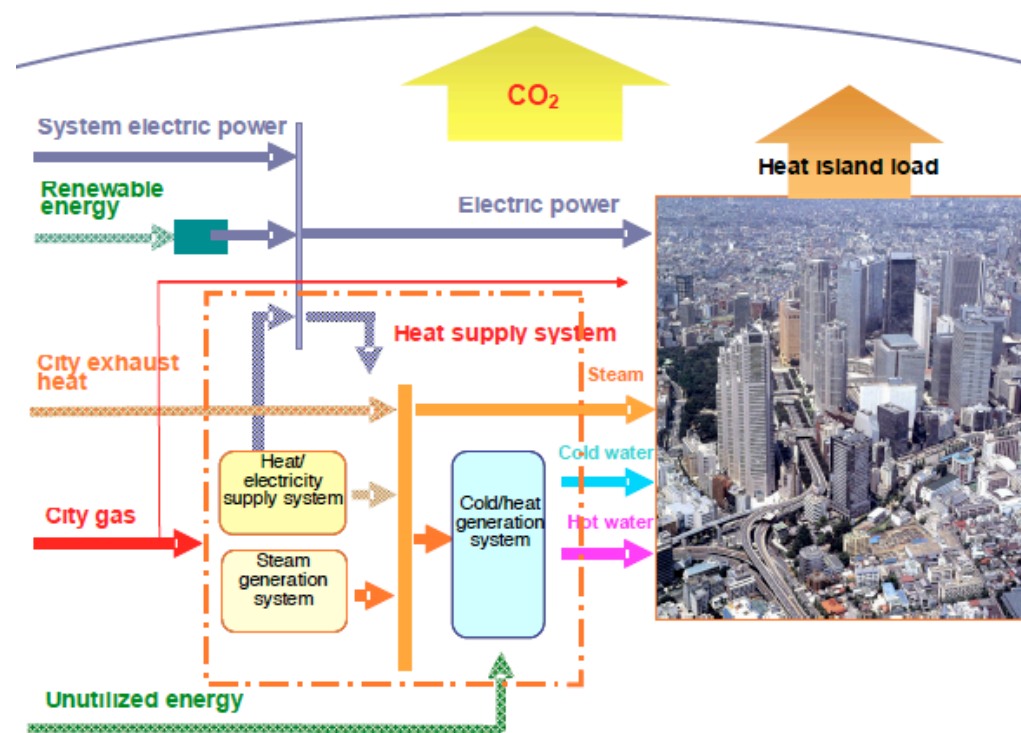


Figure 2: Modeling of urban energy system

TECHNOLOGIES // Green Roof Performance

EVALUATION OF EVAPORATION ABILITY OF THE SYSTEM FOR MITIGATING URBAN HEAT ISLAND

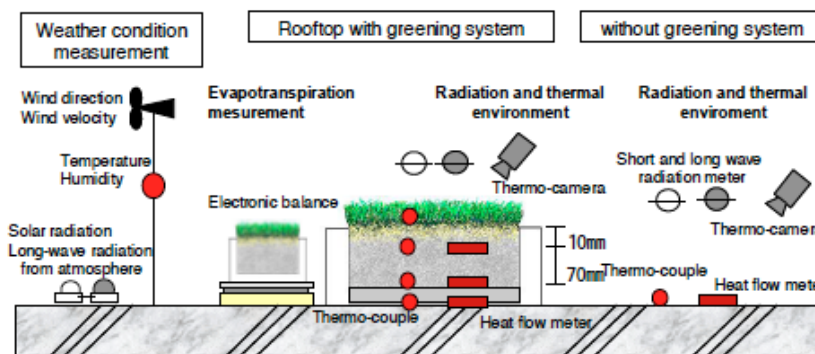
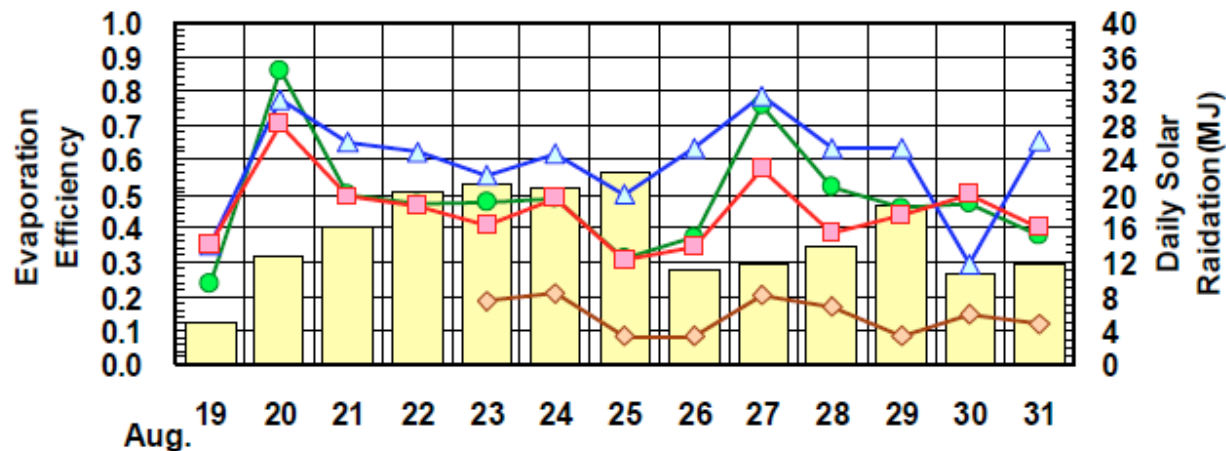


Fig. 2 Measurement apparatus of rooftop greening



1) Watering 5L/m² for a day



TECHNOLOGIES // Green Wall Performance

EVALUATION OF EVAPORATION ABILITY OF THE SYSTEM FOR MITIGATING URBAN HEAT ISLAND

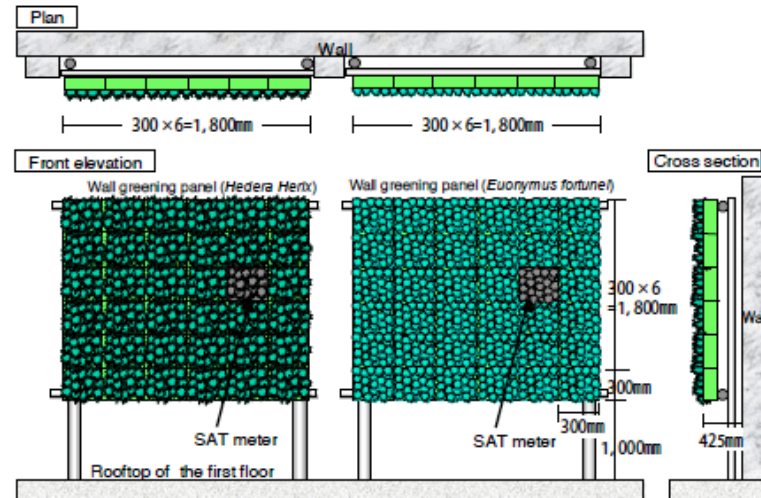


Fig. 5 The examination wall greening system

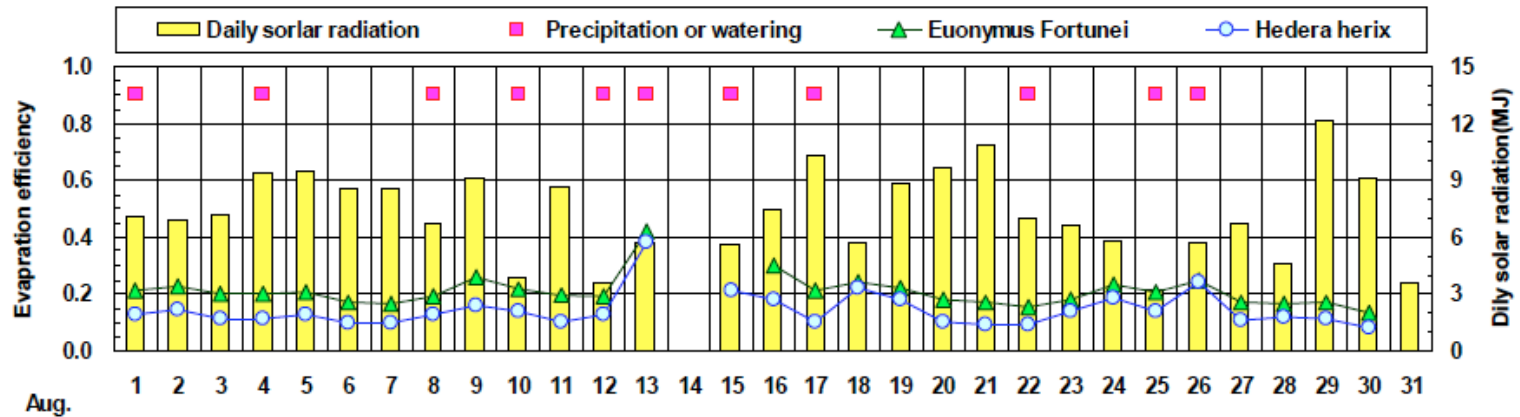


Fig. 7 Relation between evaporation efficiency of wall greening system and daily solar radiation

TECHNOLOGIES // Water Retentive Block Performance

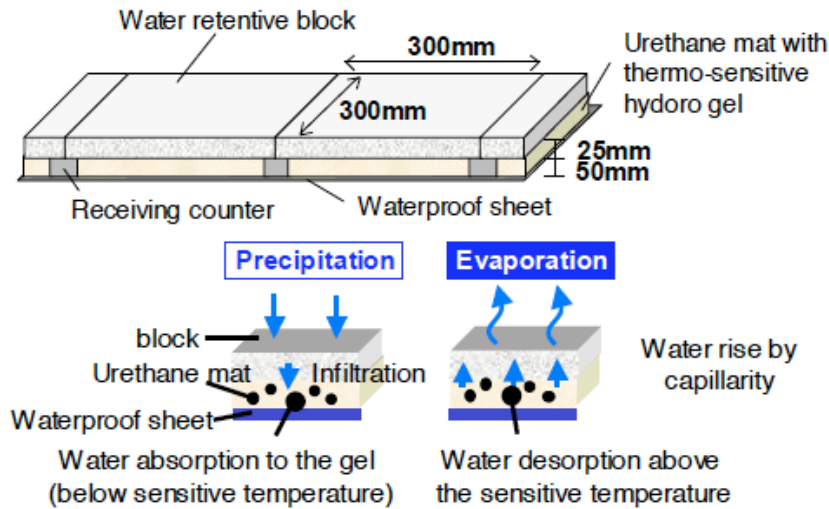


Fig. 8 Composition and expected function of the pavement system

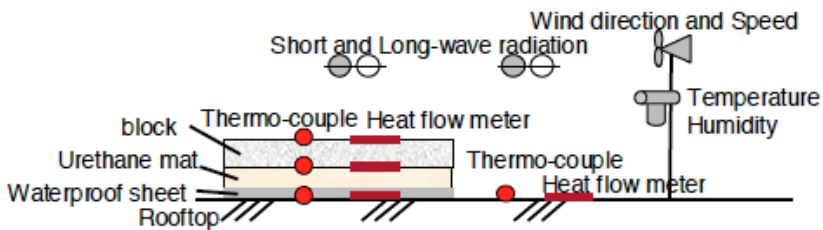


Fig.9 Mesurement apparatus for water retentive pavement

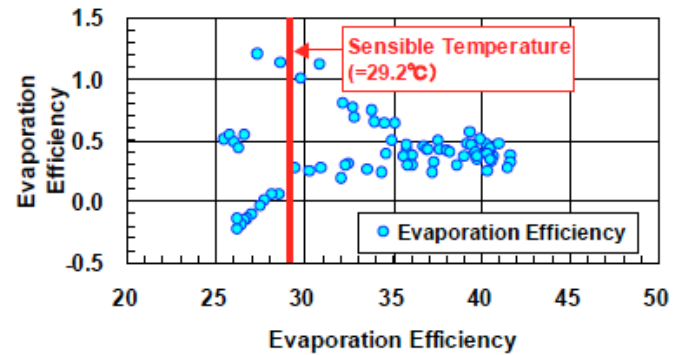
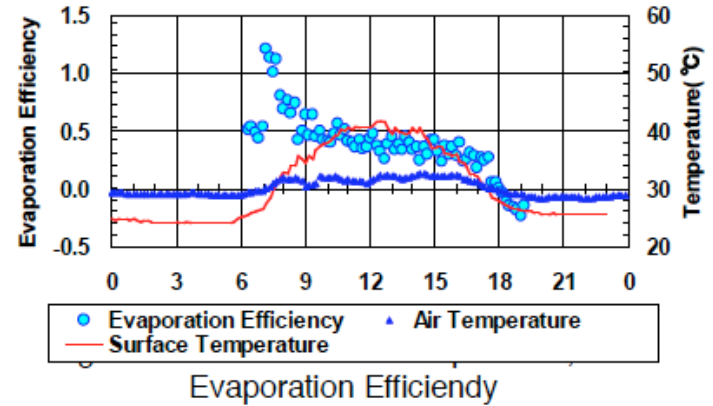


Fig.11 Relative of evaporation efficiency and surface temperature

TECHNOLOGIES // Sierpinski Tetrahedron

FRACTAL GEOMETRY OF THE GROUND SURFACE AND URBAN HEAT ISLAND

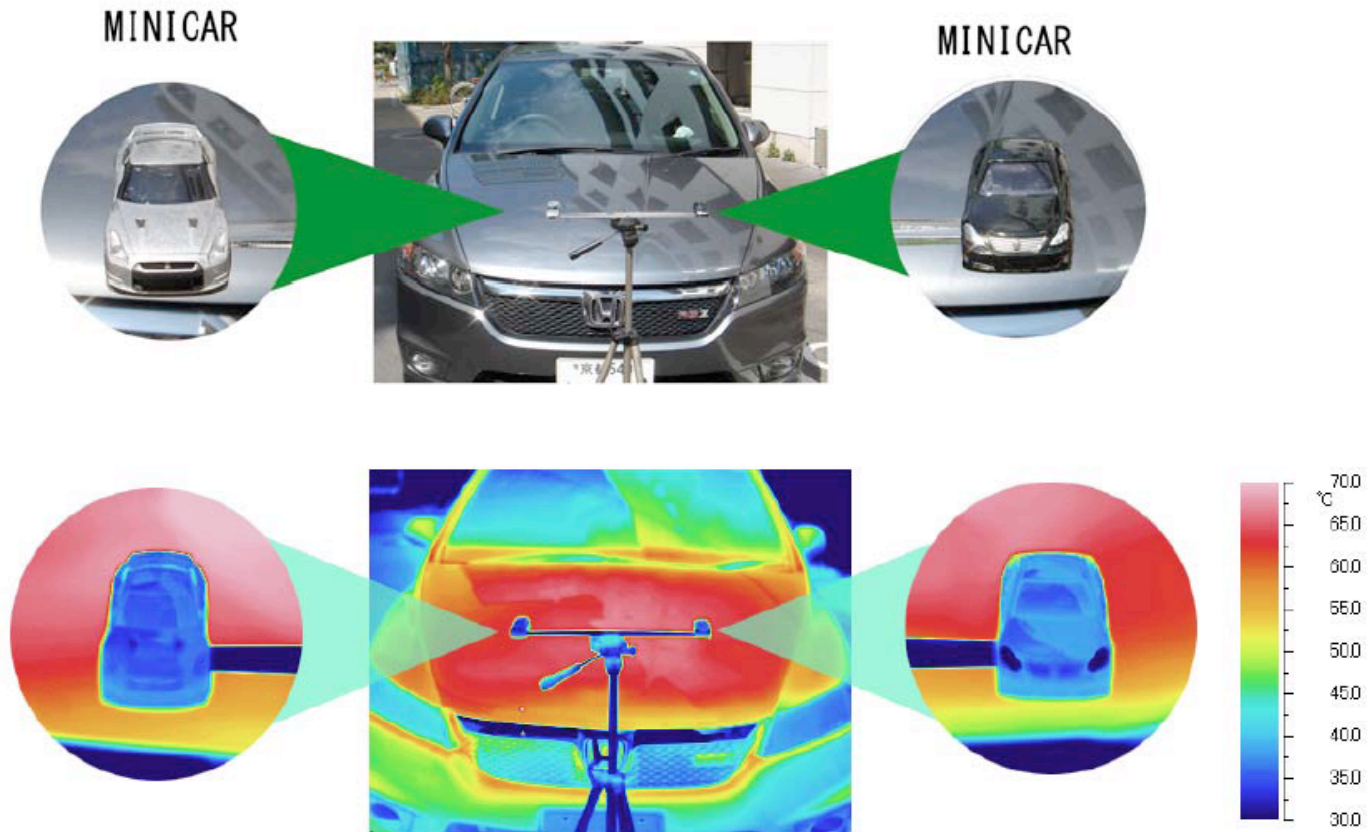


Figure 1 : Real car and miniture model cars under sun shine.

TECHNOLOGIES // Sierpinski Tetrahedron

Canphora

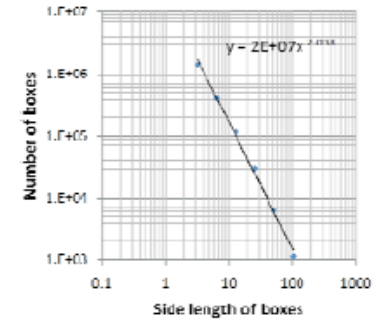
Over view



Cross section



Box dimension



Zelkova

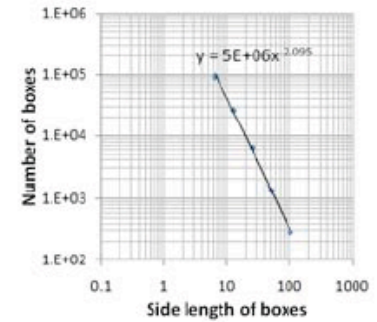


Figure 2 Fractal dimension (Box dimension) of natural trees.

TECHNOLOGIES // Sierpinski Tetrahedron

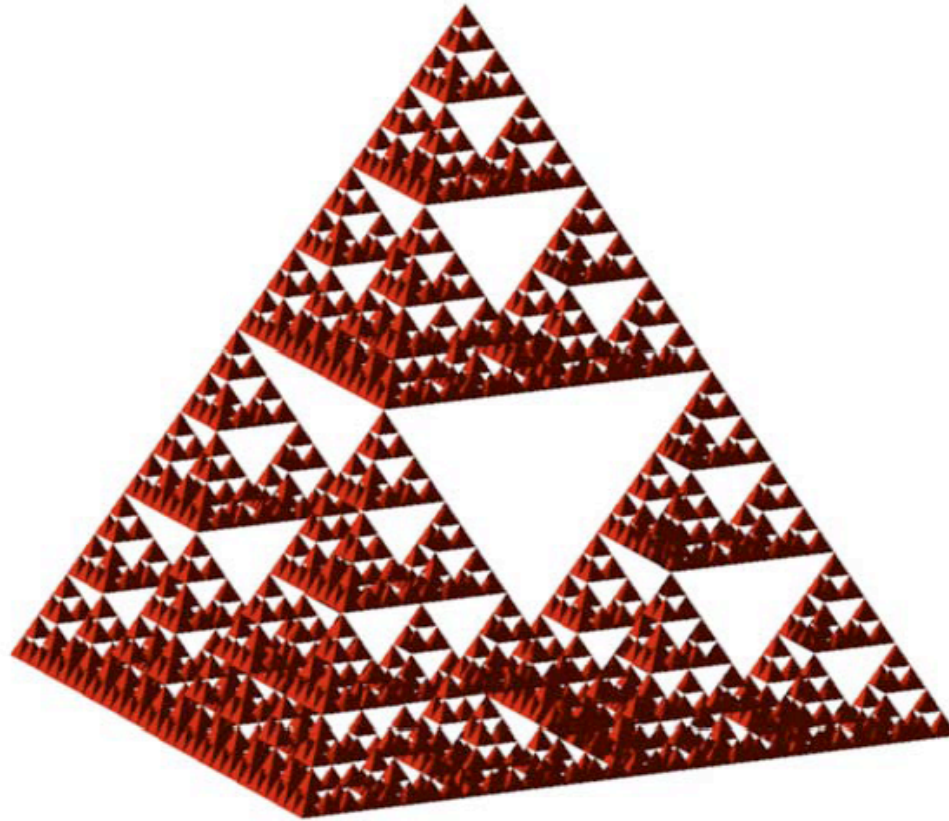


Figure 3: Sierpinski Tetrahedron

TECHNOLOGIES // Sierpinski Tetrahedron



TECHNOLOGIES // Sierpinski Tetrahedron

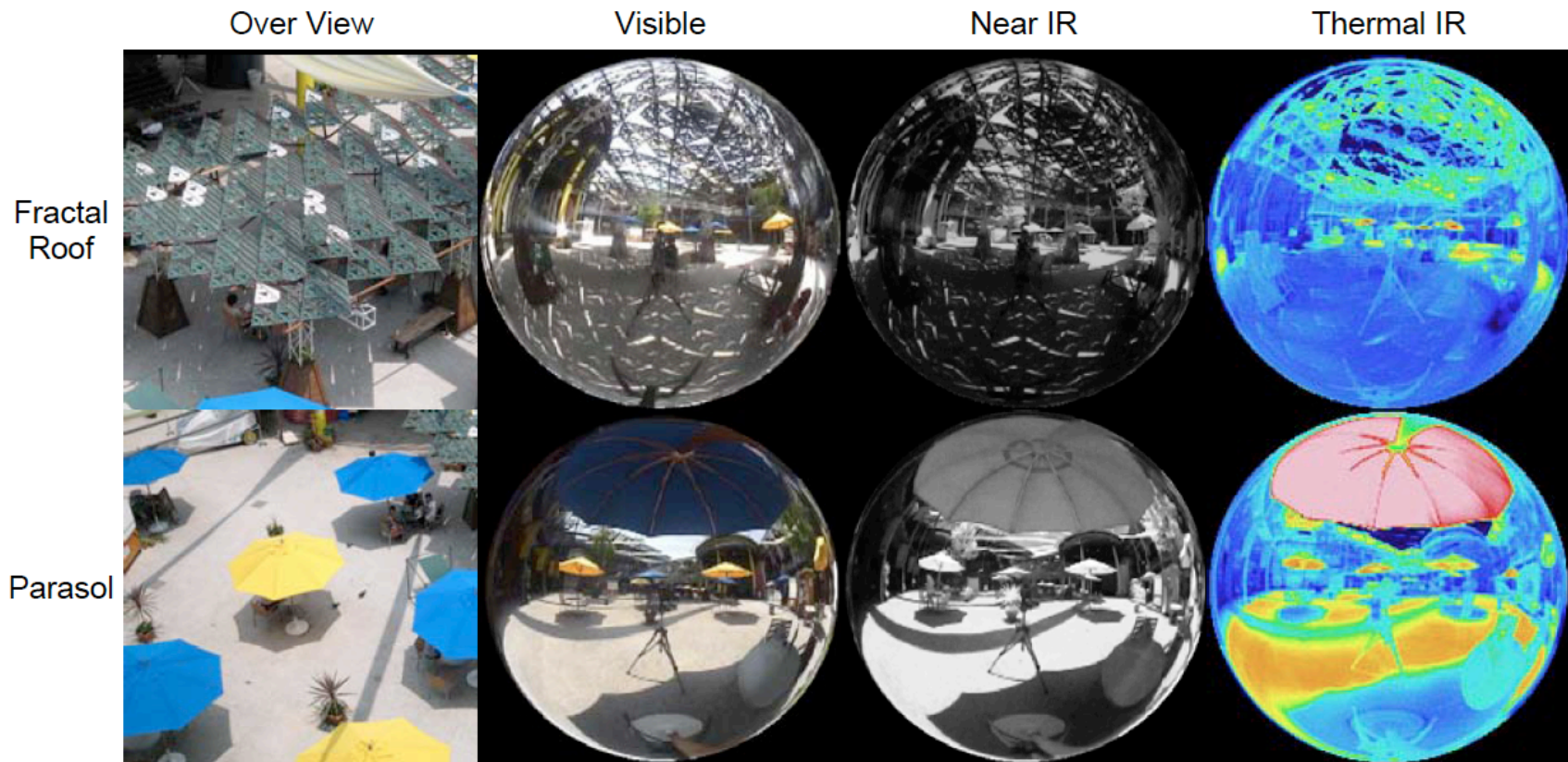


Figure 5 Fish-eye views under the fractal roof and a parasol in visible, near infra-red, thermal infra-red rays.

TECHNOLOGIES // Cooling Mists

Quantification of the Effect of Cooling Mists on Individual Thermal Comfort (2009)

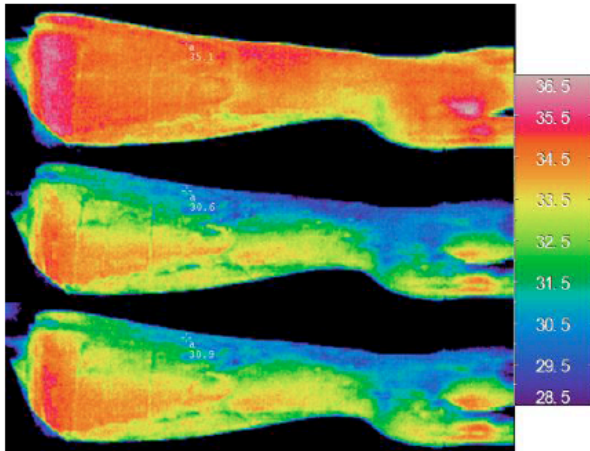


Fig. 1. Trial 2 thermal images. Top : before misting. Middle : during 30 sec. misting period. Bottom : 10 sec. after misting stopped.

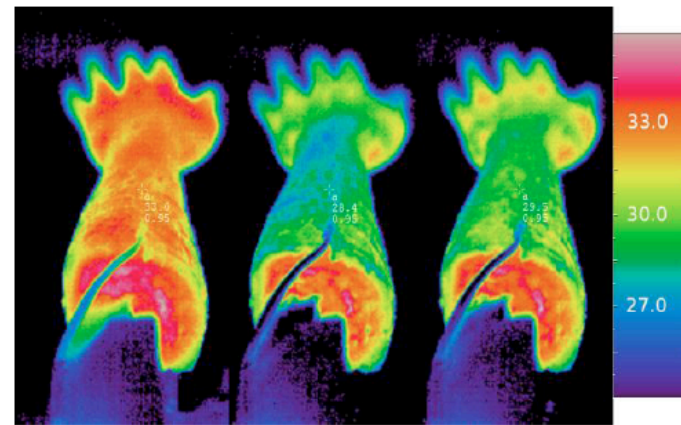


Fig. 2. Trial 3 thermal images. Left : before misting. Middle : during 30 sec. misting period. Right : 10 sec. after misting stopped.

Table 3 Mist amounts and temperature readings

Trial	Distance (m)	Remaining mist flow (of 36ml/min)	Surface Temp (°C) (camera / thermocouple)			Surf. Temp. drop (K) (cam / tcpl)	Core Temp. drop (K)
			Before mist	During mist	10 sec after		
1	1.0	54%	32.8 / 33.2	25.3 / 28.9	26.9 / 27.5	6.3 / 5.3	0.2
2	1.5	46%	35.1 / 34.6	30.6 / 33.0	30.9 / 31.3	4.2 / 3.3	0.0
3	2.0	38%	33.0 / 32.8	28.4 / 30.2	29.5 / 29.4	3.5 / 3.4	0.1

PERSONAL COMFORT // Brazil Outdoor Shade Test Case

The Impact of Vegetation on Outdoor Thermal Comfort in Urban Spaces

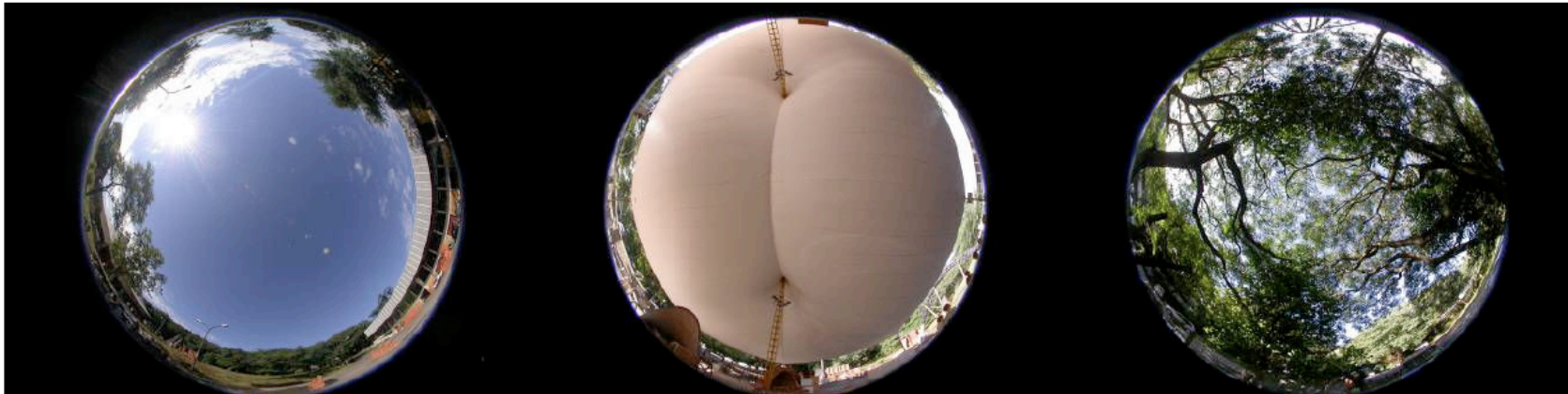


Figure 1: Sky view conditions of the three considered configurations

PERSONAL COMFORT // Brazil Outdoor Shade Test Case

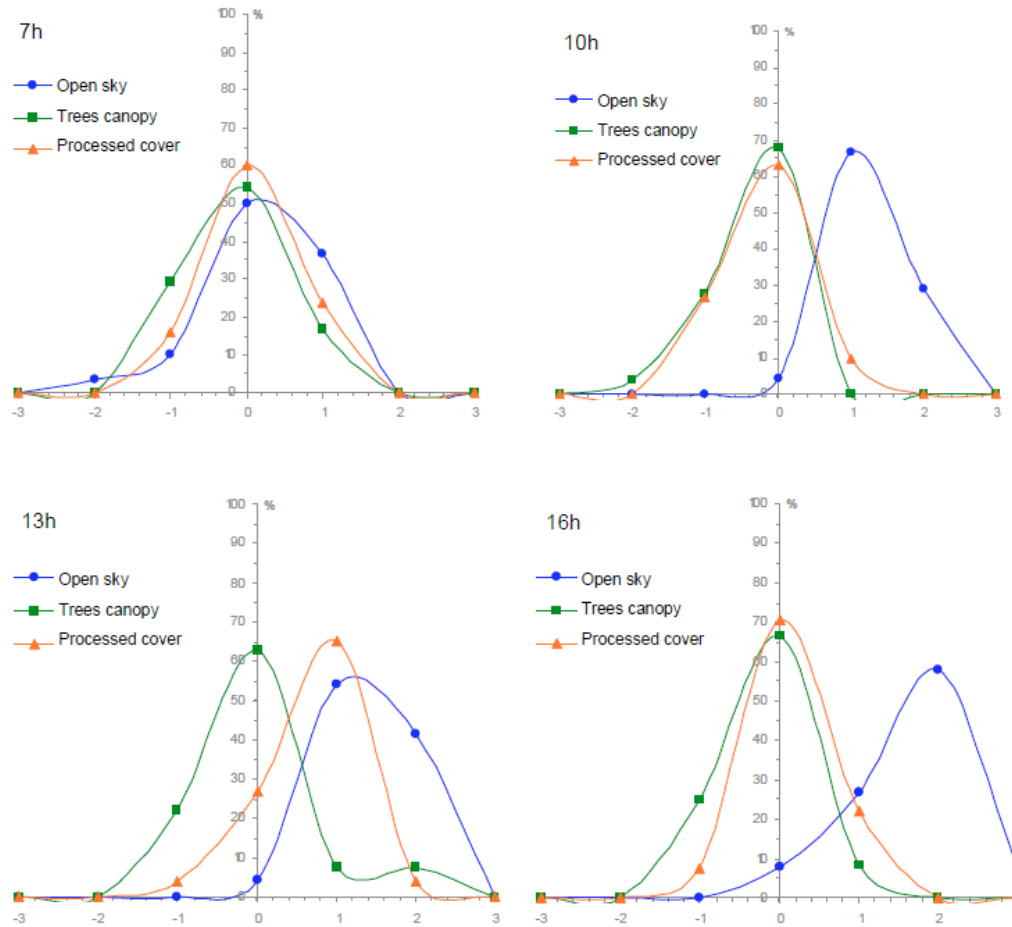


Figure 4: Results in terms of thermal sensation perception for the summer period

PERSONAL COMFORT // Arid Comfort Design and Water Efficiency

MICROSCALE VEGETATION EFFECTS ON OUTDOOR THERMAL COMFORT IN A HOT-ARID ENVIRONMENT

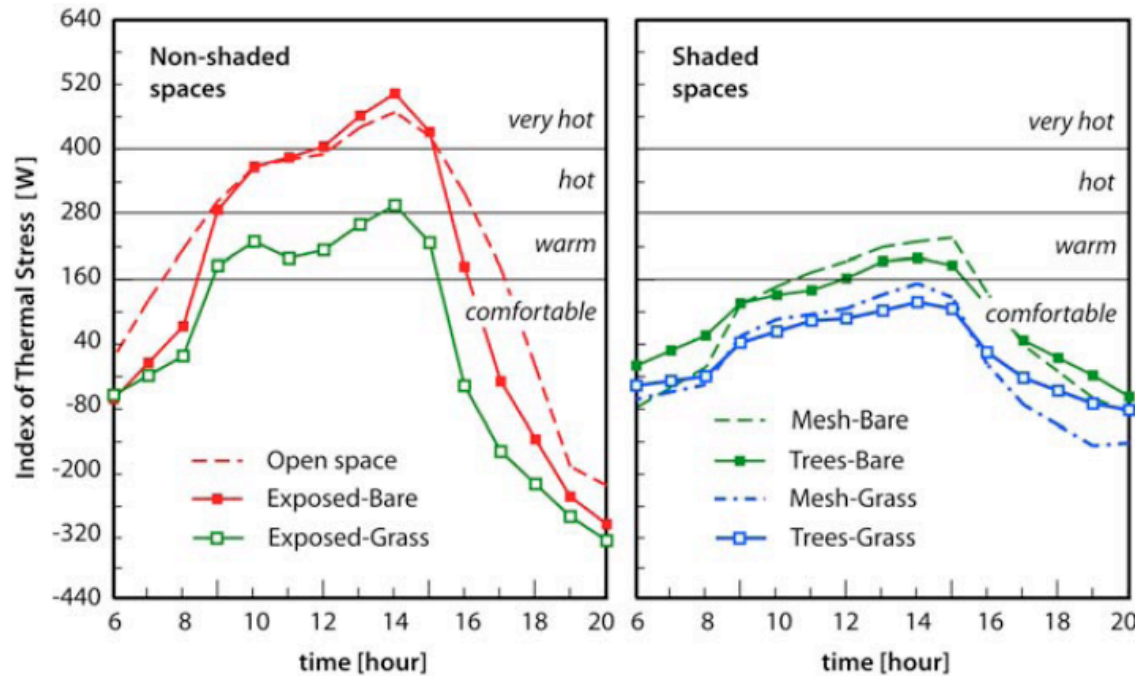


Figure 2. Normalized ITS values during summer daytime hours for non-shaded spaces (left) and for courtyard configurations with overhead shading by either trees or mesh (right), with corresponding levels of thermal sensation.

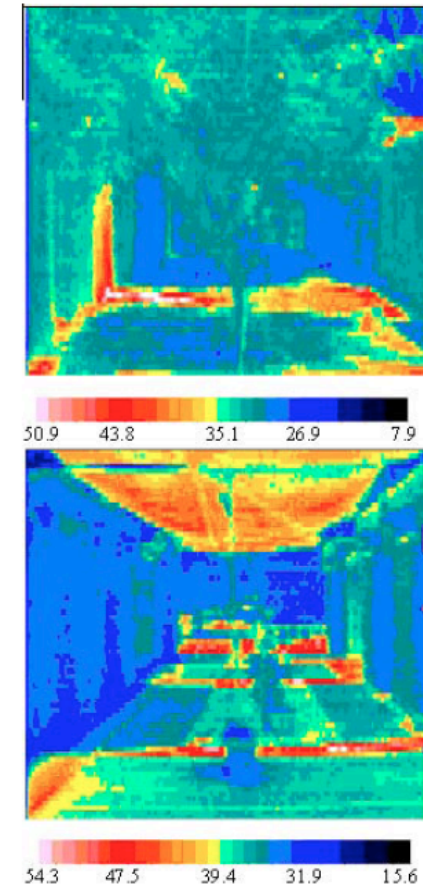
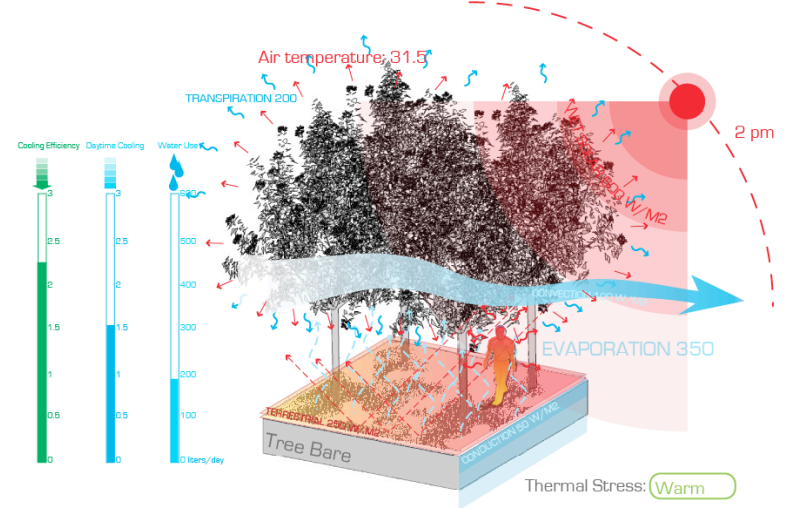
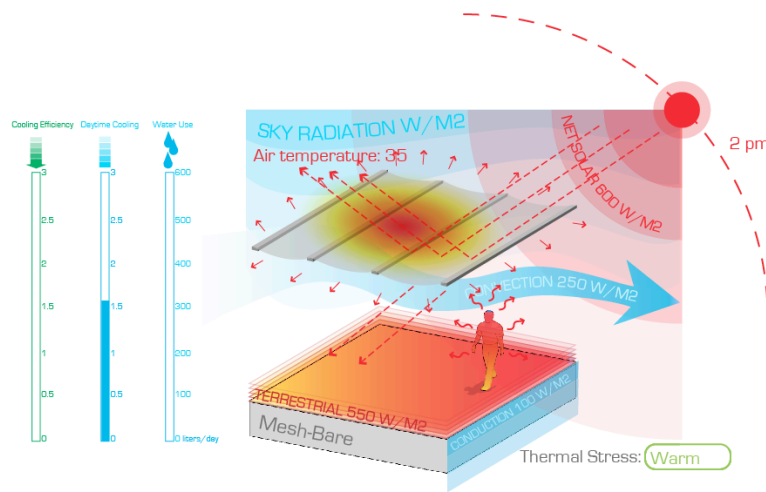
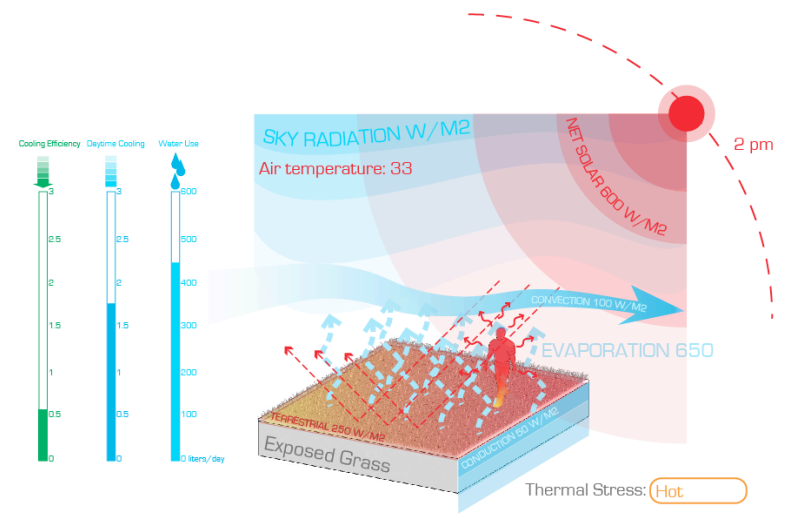
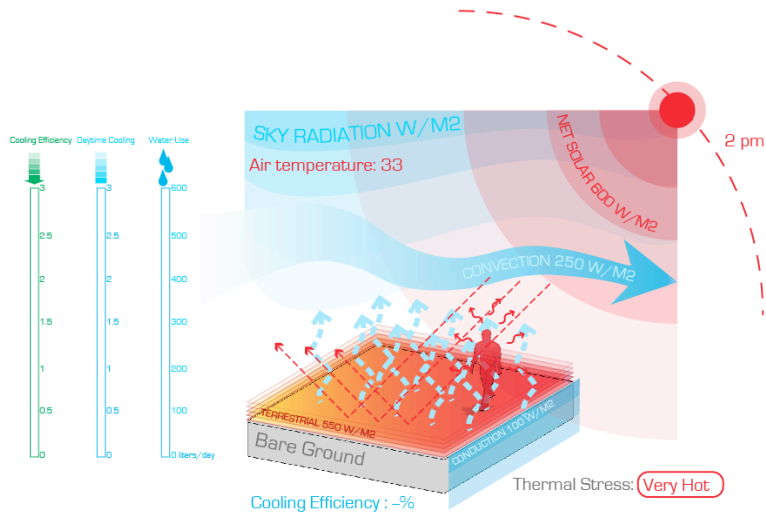


Figure 1. Thermal images of courtyards with trees and grass (top) and with paving and mesh (bottom).

PERSONAL COMFORT // Arid Comfort Design and Water Efficiency



PERSONAL COMFORT // Arid Comfort Design and Water Efficiency

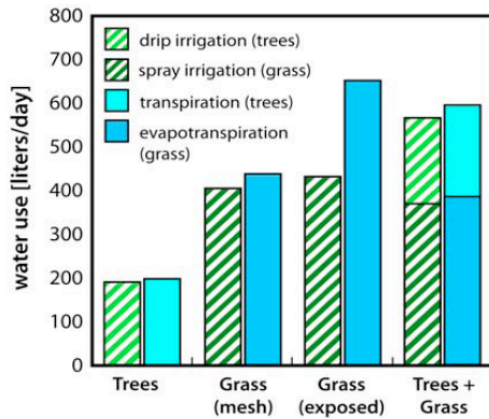
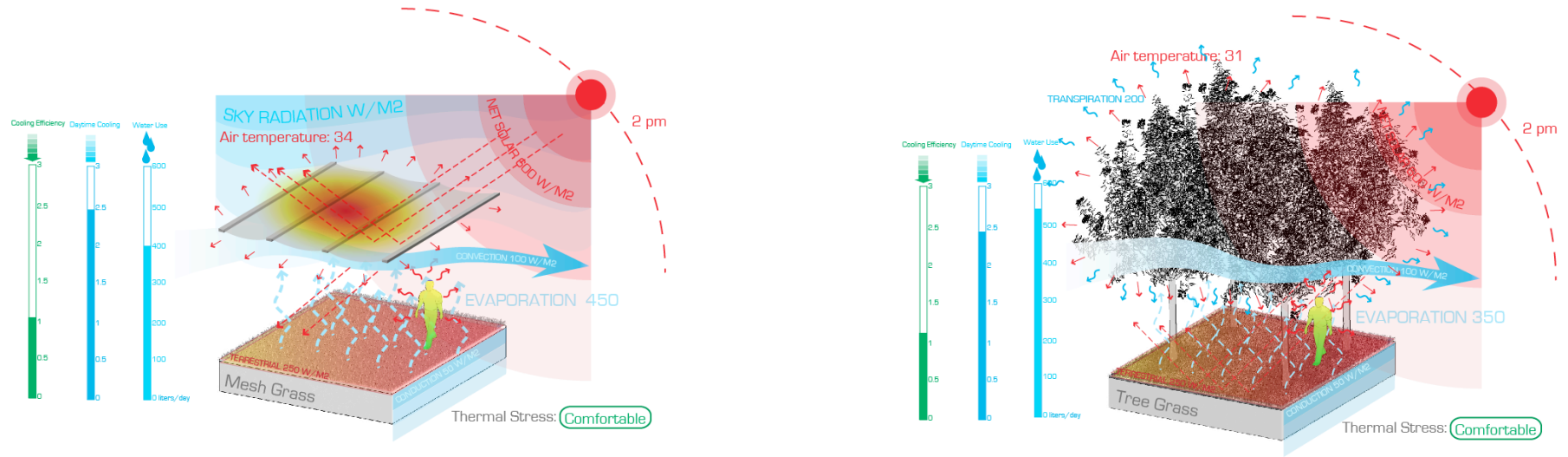


Figure 3. Daily water use for each of the vegetative treatments, in terms of irrigation provided and actual water loss through evapotranspiration (values not normalized).

Table 1. Summary of daytime reduction in thermal stress, latent heat of daily water loss and cooling efficiency for each of the landscape treatments.

Landscape treatment	Daytime cooling ΔITS [kWh]	Daily water use Q_E [kWh]	Cooling efficiency [%]
Mesh Bare	1.53	0.0	- NA -
Exposed Grass	1.75	331.7	0.53
Mesh Grass	2.47	241.6	1.02
Trees Grass	2.42	217.7	1.11
Trees Bare	1.50	55.2	2.72

PERSONAL COMFORT // Usage Modeling

ANALYSING HUMAN OUTDOOR THERMAL COMFORT AND OPEN SPACE USAGE WITH THE MULTI-AGENT SYSTEM BOTWORLD (2008)

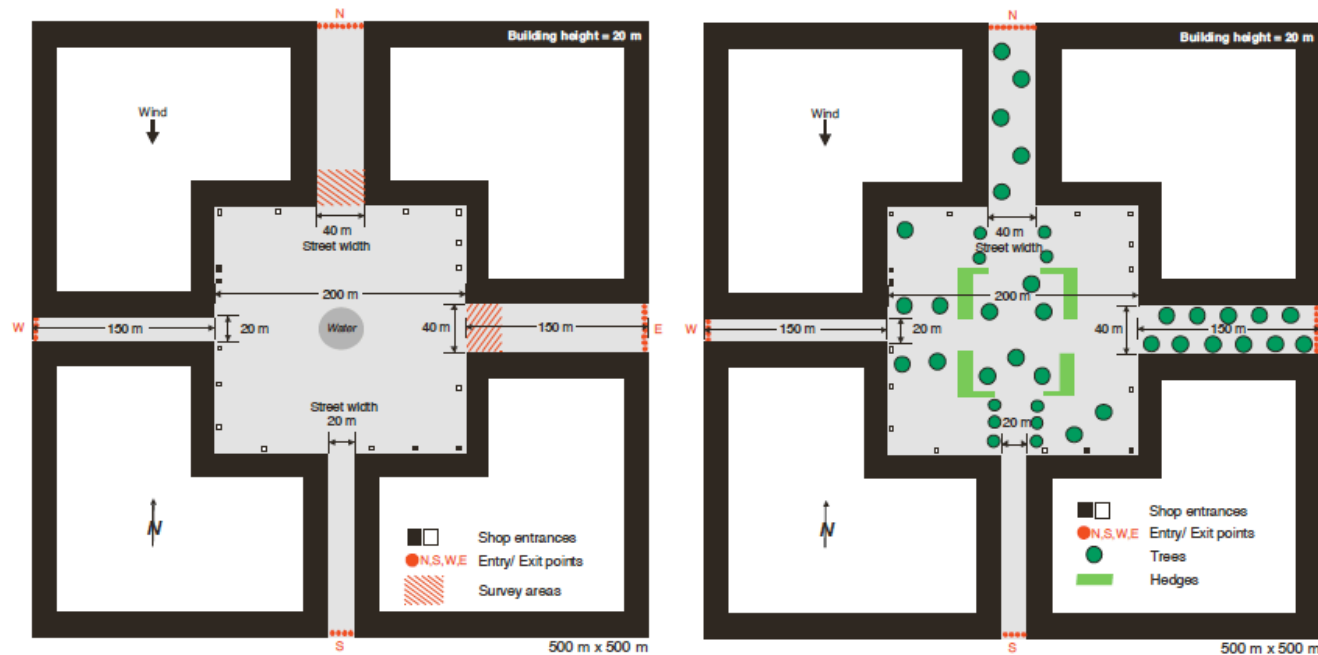


Figure 2: Layout of the case study seen from the top. Left: Old design without greening (“bare” scenario), Right: New design with additional trees and hedges (“green” scenario)

PERSONAL COMFORT // Usage Modeling

ANALYSING HUMAN OUTDOOR THERMAL COMFORT AND OPEN SPACE USAGE WITH THE MULTI-AGENT SYSTEM BOTWORLD (2008)

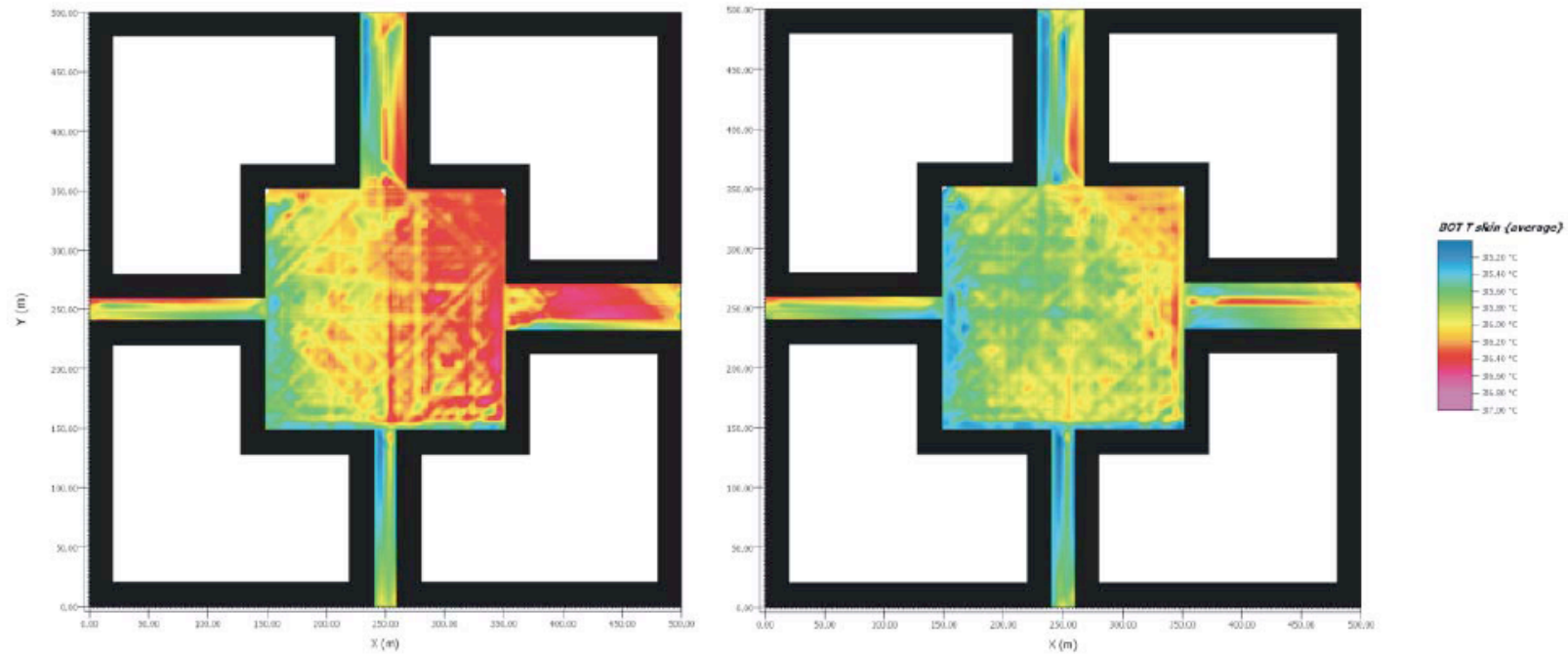


Figure 3: Distribution of average skin temperature calculated over 2300 (“bare” scenario, left) and 2000 (“green” scenario, right) different agents

PERSONAL COMFORT // Usage Modeling

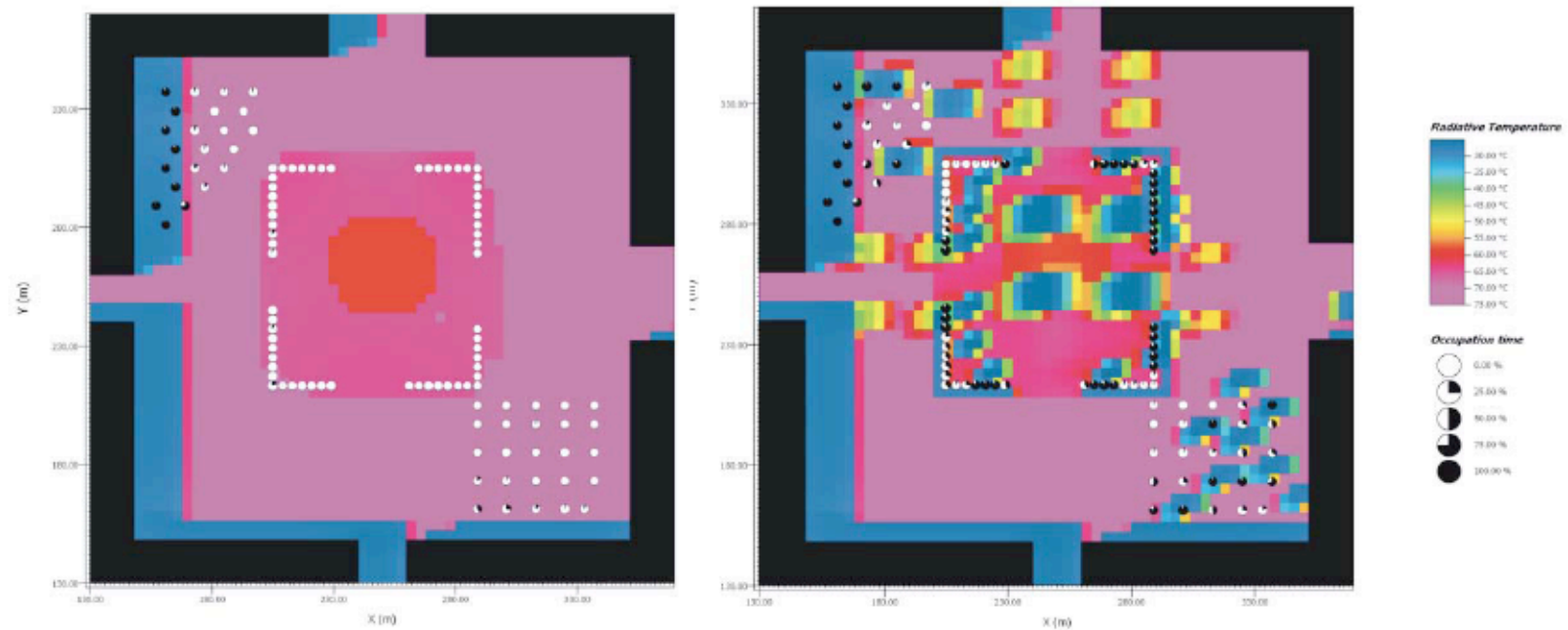


Figure 4: Distribution of Mean Radiant Temperature and relative occupation time of optional targets for the main center place (left: “bare” scenario, right: “green” scenario), Simulation for 14:00 local solar time

7. UHI INFRASTRUCTURE // NEW GOALS & PURPOSE

What is UHI Infrastructure?

- Could be Entire Urban Fabric
- Cold Air Generators (Parks, Forest, etc.)
- Ventilation Corridors (Parks, Roads, Rivers, etc.)
- Strategic Comfort Infrastructure (Cool streets, walkable microclimatic diversity, TBD)

Designing for Quantifiable Performances & Mitigation:

- UHI & Global Warming Health Impacts
- Reducing Global Warming
 - Resource Efficient Cities (Energy / Material Degradation)
 - *Making High-Density, Low-Consumption Living Comfortable & Healthy*
- Pollution Dispersal
- UHI Adapted Landscapes & Ecologies
- Comfortable, Successful Landscapes
- Mitigating Other Impacts...

Examples of UHI Mitigations Practices:

- Urban Design for Generating & Dispersing Cool Air Flows (Cold Air Generators & inland Katabatic flows)
- Urban Design for Seabreeze Penetration and Mitigation of UHI & Air Pollution
- Microclimatic Design: Creating Cool Outdoor Spaces (Strategic design for Comfort & Thermal Stress)
- Road & Development Configurations to Minimize UHI & Impacts
- Smart Materials & Technology Use for Reducing UHI

7. UHI Infrastructure // New Goals & Purpose

- Advanced Modeling for Smart Development
- Application Climate Atlas & Design Parameters

UHI INFRASTRUCTURE // SWA Group Continuing Research + Involvement

- Promoting Urban Heat Island Infrastructure
- Promoting Urban Climate Maps / Mapping
- Advanced Modeling Tools (Software + Consultants)
- Developing & Testing Anecdotal Prototypes / Advanced Guidelines
(Collaboratively with Freiburg Institute)
- Involvement in 100 Cool Cities Initiatives
- Attending further Urban Climate Conferences
- Joining Urban Climate Research Groups & Related Technology Groups
(Berkeley)

8. APPENDIX A: BIBLIOGRAPHY & RESOURCES

Research Institutions

Research Projects and Groups

- Aristotle University of Thessaloniki, [Laboratory of Heat Transfer and Environmental Engineering](#)
- [Baltimore Long-Term Ecological Research Site](#)
- [BUBBLE](#) , Basel Urban Boundary Layer Experiment
- COST 715 Working Group 1 ([Urban Wind Field](#))
- [EPiCC Environmental Prediction in Canadian Cities](#)
- ESCOMPTE home page
 - [English](#)
 - [Français](#)
- [FUMAPEX](#) : Integrated Systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure
- [Göteborg University Urban Climate Group](#)
- [Hungarian Urban Climate Home Page](#)
- [Meteorology Applied to Air Pollution](#) - COST 715
- [Phoenix Long-Term Ecological Research Site](#)
- [Salt Lake Valley Airshed Project](#)
- [Szeged Hungary: Urban - Rural Meteorological Data](#)
- [TRAPOS](#) home page
- SATURN ([Studying Atmospheric Pollution in Urban Areas](#))
- [USDA Western Center for Urban Forest Research and Education](#)
- [UWERN Urban Meteorology Programme](#)

Building-Scale Climate

- [US DOE Building Energy Software Tools Directory](#)

- [BLDG-SIM](#) - a mailing list for users of building energy simulation programs
- [Building Energy Simulation User News](#)

Urban Design and Planning

- [Green Roofs for Healthy Cities](#)
- [Heat Island Group](#) (Lawrence Berkeley Lab, USA)
- [RUROS](#) , Rediscovering the Urban Realm and Open Spaces
- [SMART \(Sustainable Materials and Renewable Technologies\) Program](#) (Arizona State University)
- [Sustainable Urban Design and Climate](#) (Australian Bureau of Meteorology)
- [US Department of Energy Center for Sustainable Development](#)
- [US Environmental Protection Agency \(EPA\) Heat Island Information](#)

Urban Areas and Climate Change

- [Climate Change and Urban Design; Third International Council for European Urbanism Congress.](#)

Remote Sensing Applications

- Ecole des Mines de Paris, Center for Energy Studies, [Urban Studies](#)
- Urban Heat Island Pilot Project (UHIPP), [Sacramento, CA](#)
- Urban Heat Island Pilot Project (UHIPP), [Salt Lake City, UT](#)

Websites

Stuttgart Section of Urban Climatology

Section of Urban Climatology in English

http://www.stadtklima-stuttgart.de/index.php?service_contact_about_us

Climate Booklet for Urban Development (online)

http://www.staedtebauliche-klimafibel.de/Climate_Booklet/index-1.htm

Heat Island Group

<http://eetd.lbl.gov/heatisland/graphic.html>

EPA Heat Island Website

<http://eetd.lbl.gov/heatisland/graphic.html>

International Associate for Urban Climate

<http://www.urban-climate.org/>

Books & Publications

Microclimatic Landscape Design: Creating Thermal Comfort and Energy Efficiency by Robert Brown & Terry J. Gillespie

Good overview of design from the perspective of individual comfort in the landscape.

Heat Islands: Understanding and Mitigating Heat in Urban Areas by Lisa Gartland

Decent overview of Urban Heat Islands and countermeasures.

9. APPENDIX B: FELLOWSHIP PROPOSAL TEXT

Applying Contemporary Urban Climatology Research & Countermeasures to Landscape Design Practices

Alexander Robinson, SWA Los Angeles, Summer 2009

*The world and our cities are getting hotter and more polluted.
How do we keep urban landscapes comfortable and save the planet too?*

Los Angeles has one of the worst heat island warming trends and the worst air quality in the country (ALA). Global warming is only going to make this worse, possibly much worse, for all cities. Given a growing body of urban climatology expertise, how can Landscape Architects best combat and anticipate Heat Island and its many deleterious side effects? Additionally, how can we better design spaces that are climatically comfortable?

Urban Heat Island

An urban heat island (UHI) is a metropolitan area that is significantly warmer than its surrounding rural areas.

Causes are many, including POOR DESIGN

Development, design practices, air quality, energy use and now Global Warming contribute to Urban Heat Island and the general warming of cities.

Effects are far reaching and NEED to be addressed

ENERGY Increased Energy Use (Estimated \$100M annual added electrical cost in Los Angeles) due to multiple factors, primarily temperature control, all contribute to the problem of global warming.

TRANSPORTATION Residents are more likely to use cars and not alternative forms of transportation.

Health Residents suffer from heat mortality (2003 European Heat Wave, ~35,000 people died) and are less likely to exercise, promoting obesity and associated energy costs for increased agricultural output.

AirQuality Increased temperature create ozone, release CO2 and worsen air quality conditions.

OPEN SPACE Open space that is not designed for warm temperatures suffers and is unused.

Materials Fabric of city and buildings degrade at faster rate, requiring greater investment.

WATER USE Increased temperature lead result in increased evapotranspiration, both in water bodies and in vegetation.

// Urban Head Island & Global Warming

Scope of problem is HUGE

While cities only cover 0.5% to 2% of the Earth's area, • they house ~50% (and growing) of its human population.

There are >400 cities with over a million people and 20 • mega-cities with over 10 million people.

These cities are responsibly for 80% of global CO2 emis• sions and 75% of global energy consumption.

Improving the climates of cities, or at least maintaining their comfort levels can have huge impacts on the world's environment and most people's health, and quality of life.

Landscape Architects **MUST** get involved

As the caretakers of comfort and ecology in the urban landscape (and as citizens of earth) Landscape Architects have a duty to make cities livable and sustainable. This is a problem that is applicable at many scales, from the comfort of an outdoor seating area to improving regional air quality and temperature. Many of the countermeasures to the problem are within the realm of our profession, yet few practitioners have enough expertise to combat them strategically.

The **KNOWLEDGE** we need is out there

Climate and comfort are a key component of landscape design, but are generally poorly understood by landscape architects. In part this was due to a limited amount of research on the subject and the complexity of meteorology. However, with Global Warming the field of Urban Climatology and its body of knowledge is growing rapidly. Even so, landscape architects are using little of this knowledge. The ultimate goal of this research is to apply this new

knowledge to designing landscapes that are comfortable and address the growing problems of Urban Heat Island.

// Urban Heat Island Research Plan Summary

Goal

Research the current state of Urban Climatology and Heat Island Countermeasures in order to develop design principles that can be practiced by Landscape Architects. Produce a resource to share this knowledge.

Research Plan

Research Trip 1

Part A: Visit oldest practicing city urban climatology department, *The Stuttgart Section of Urban Climatology*, to witness a city scale, comprehensive, and applied approach.

Part B: Visit leading international academic institution in urban climatology, *The Albert Ludwigs University in Freiburg, Meteorological Institute* and learn about state of the art research and research techniques.

Research Trip 2

Attend *International Conference on Countermeasures to Urban Heat Islands* to obtain maximum exposure to the state of the applied field.

In-House Research

Review contemporary journals and books for urban climatology research that is applicable to landscape architecture.

Product

1. Presentation
2. Urban climatology as applied to landscape architecture research brief/resource to be available to the offices, including a list of available resources and summary of research.

Benefit to Firm and Profession

SWA will benefit from having advanced expertise in urban climatology as applied to landscape design. This can benefit all scales of design and help

define SWA as visionary in sustainable and comfortable landscape design. Increasingly, when designing rooftops or in other extreme conditions this expertise is becoming necessary to our practice. In New York City, both the design of the New York Times rooftop garden and Teardrop Park employed advanced urban climatology analysis and technologies.

Each of these landscapes address urban heat island issues. Which is the most effective and why? Urban Climatology has answers.

// Research Plan Details

Research Trip 1A, Stuttgart, Germany

Stuttgart Section of Urban Climatology

Stuttgart in Germany has the oldest known urban climatology city department, dating back from 1938. The department urban climatology was established early due to the fact the city is surrounded by hills and has poor ventilation, leading to air pollution and heat island problems. Of the many urban planning measures that the department has addressed are the facilitation of clean cool air sources from the forested sections of the hills, while diverting and cleaning hot and polluted air streams. Los Angeles and surrounding areas, as an example, have similar issues of pollution entrapment and consistent air currents, but little or no planning is done to account for these.

With a current staff of seven the Stuttgart Section of Urban Climatology (Stadtklima) has played an active role in both framing the primary climate issues as well as finding solutions. As such I believe it would be a great value to meet and interview the staff. I am in contact with Ulrich Reuter, the head of the department, and he has assured that we could arrange a meeting and tour. While there, I would made some basic measurements of temperature and photo document the measures taken by the city.

Key questions

What and why are the key health and performance concerns that the department focuses on?

What are measures that they take to address these issues? Which are the most effective?

What measures could be practiced by landscape architects and urban designers?

Research Trip 1B, Freiburg, Germany

Albert Ludwigs University in Freiburg, Meteorological Institute

The Albert Ludwigs University in Freiburg, Meteorological Institute is one of foremost international research institutions in Urban Climatology. Last year the 5th German-Japanese Meeting on Urban Climatology was held there. While I am nearby, in Stuttgart, I think it would be beneficial to visit this academic institution and meet with the head, Professor Helmut Mayer. He has published many papers on urban climatology, such as Influence of street design on the heat perception by citizens during hot summer days. 2009, and in addition to providing a wealth of knowledge and practice, could become valuable resource for staying abreast current developments, or even for future collaborations.

The Stuttgart Section of Urban Climatology has mapped the quality, temperature, and direction of natural and manmade air currents. How have they applied this knowledge to landscape and urban design for the last 70 years?

The design of the rooftop landscape garden at the New York Times Building employed state of the art urban climatology modeling to determine an appropriate planting scheme.

Research Trip 2, Berkeley, CA

Second International Conference on Countermeasures to Urban Heat Islands

September 21-23rd

“The SICCUHI will be devoted to the science, engineering and public policies to help relieve the excess heat and air pollution of Summers in hot cities. It has long been recognized that the excessive heat and smog in many cities in the Summer, the “Urban Heat Island”, is partly due to the choices of building materials, vegetation and urban design.” -- Conference web site.

This conference is an incredible opportunity to immerse myself in current state of the field. From my initial research it appears that with increased energy demands and rapid global warming the field and its body of knowledge is rapidly growing. What is particularly interesting and relevant to the ultimate value

of my research to the firm is that the conference focuses on countermeasures; both policies and physical urban design strategies.

Key questions

How is the issue currently framed/understood by current experts?

What are the primary countermeasures that are being taken to combat urban heat islands?

What countermeasure strategies could be applicable to landscape architecture and urban design?

In House Research

Literature Review

There is a growing body of knowledge on Heat Islands and Urban Climatology. Some of it is summarized in books, but there has a great deal of recent research that is not otherwise available except in journals. As a adjunct faculty at USC I have convenient access to the extensive library and on-line journals. As part of my research project I would conduct a review of contemporary Urban Climatology literature that may be useful in SWA's practice of sustainable landscape practices. I would also review existing books. My expectation is that some articles would be useful for understanding the scope and potential effects of manipulating urban climatology, while others may provide concrete design principles.

Examples of potentially relevant articles:

Climatic behavior of various urban parks during hot and humid summer in the Mediterranean city of Tel Aviv, Israel, 2006

The role of evaporation in the energy balance of an open-air scaled urban surface, 2009

A numerical investigation of the impact of low boundary walls on pedestrian exposure to air pollutants in urban street canyons, 2008

The effect of urban evaporation on building energy demand in an arid environment, 2008

Restoration of an Inner-City Stream and Its Impact on Air Temperature and Humidity Based on Long-Term Monitoring Data, 2008

Large-eddy simulation for flow and dispersion in urban streets, 2009