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NEWSLETTER ON URBAN HEAT ISLAND COUNTERMEASURES

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Vol. 4

National Research Project on *Kaze-no-michi*

- Making the Best Use of the Cool Sea Breeze -

SUBCOMMITTEE ON HEAT ISLAND
COMMITTEE on the Global Environment, Architectural Institute of Japan
http://news-sv.aij.or.jp/tkankyo/s3/

Introduction

In this issue, a national research project on ventilation paths will be introduced as one of the efforts to mitigate the urban heat island effect.

Global warming has become a great concern of our time, and the heat island effect has become increasingly severe every year. While the annual average temperature in Japan has increased by 1 ˚C over the past 100 years, the annual average temperature in Tokyo has increased by 3 ˚C over the same period. This suggests that the heat island effect has contributed to the temperature increase in Tokyo by 2 ˚C in contrast to the 1 ˚C contributed by global warming. The rate of increase in air temperature due to the heat island effect is faster than that due to global warming. Therefore, the heat island effect has become an environmental issue which requires urgent measures at the national level.

In light of this circumstance, a research team centered around the Ministry of Land, Infrastructure, Transport, and Tourism (the National Institute for Land and Infrastructure Management, the Building Research Institute, and the Geographical Survey Institute) conducted a 3-year research project starting in 2004 to promote effective measures against the heat island effect. In this project, we focused on a measure that had not yet been sufficiently and scientifically investigated. This measure is called *Kaze-no-michi* (ventilation path), which is an attempt to lower the summer temperature in the center of a large coastal city by securing a path for cool wind to flow in from the ocean.

What is *Kaze-no-michi*?

The idea of *Kaze-no-michi* (ventilation path), which

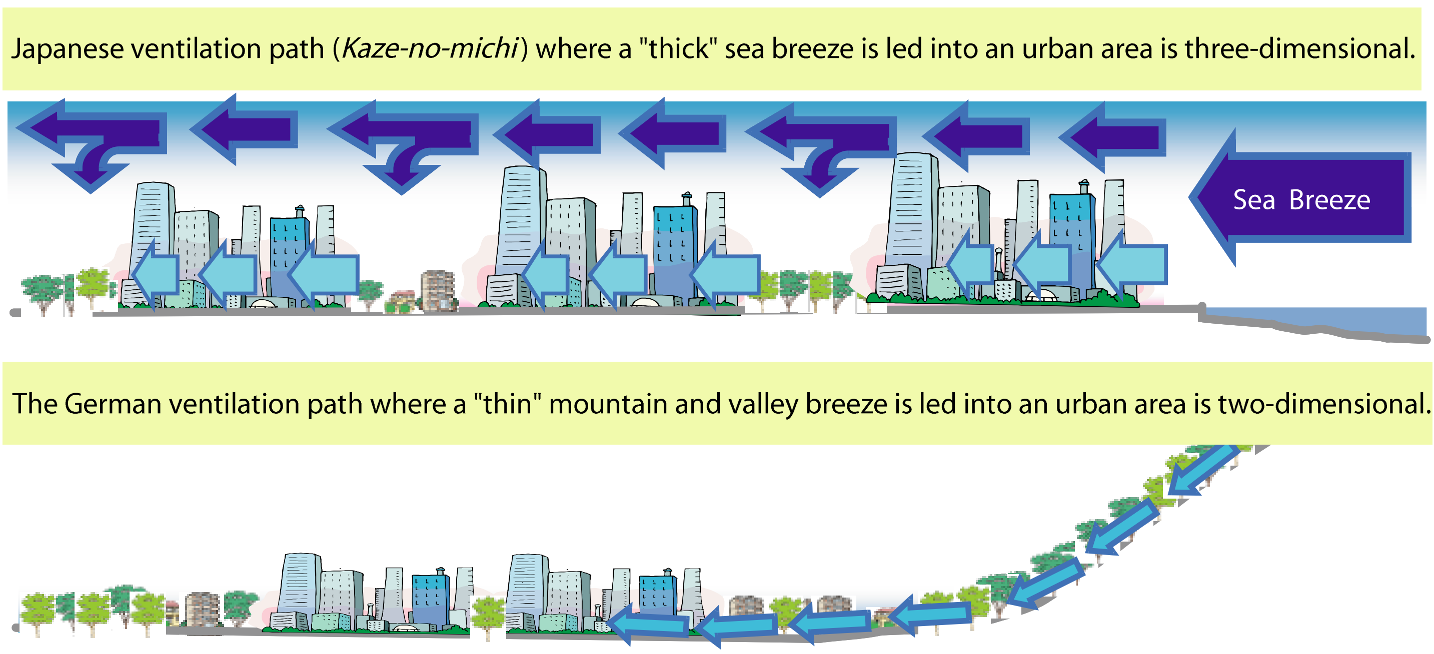

Figure 1. Comparison of ventilation paths between Japan and Germany.

has received attention as one countermeasure against the heat island effect, is based on the German ecological city planning approach. With this method, mountain and valley breeze are used to mitigate pollution and the heat island effect in inland cities such as Stuttgart. The breeze that flows into a city from its peripheral mountains is believed to be as deep as a few meters to tens of meters and is located near the ground surface.

Most large cities in Japan are situated near coastal areas. Therefore, in contrast to the mountain and valley wind used in the ventilation paths in the inland cities of Germany, sea breeze with a depth of more than a few hundred meters flows into large cities in Japan. The ventilation paths in Germany utilize relatively shallow mountain and valley wind, which can be considered planar at most a few ten meters in thickness. On the other hand, sea breeze with a depth of more than a few hundred meters can be used for large coastal cities in Japan. Therefore, *Kaze-no-michi* is three-dimensional with a depth larger than the height of a skyscraper (Fig. 1).

Accordingly, we call the ventilation paths in Japan *Kaze-no-michi* to distinguish them from the German ventilation paths. "*Kaze-no*" and "*michi* " stand for "wind's" and "path(s)" in Japanese, respectively.

Effects of *Kaze-no-michi*

In the summer of 2005, a large-scale field experiment was conducted in the center of Tokyo and the Tokyo Bay Area to quantify the effects of the sea breeze on the urban climate.

For this experiment, thermometers and hygrometers were deployed at 190 locations, which included locations on streets, on high-rise buildings, and along rivers. At these locations, observations were made at 5- to 10-minute intervals over approximately 2 weeks throughout the day and night. In addition, midair airflow measurements were made for a few days by pilot and captive balloons (Fig. 2).

The observational data showed that the sea breeze in the Tokyo Bay Area reduces air temperature in locations within approximately 2km of the sea coast or more. The reduction of the air temperature was large particularly along rivers and wide streets, where sea breeze flows in easily. This result suggested the importance of *Kaze-no-michi* . Accordingly, we have focused our attention on the rivers and wide streets which constitute continuous vacant space within an urban area, and have examined the effects of the rivers and wide streets as *Kaze-no-michi* (Fig. 3).

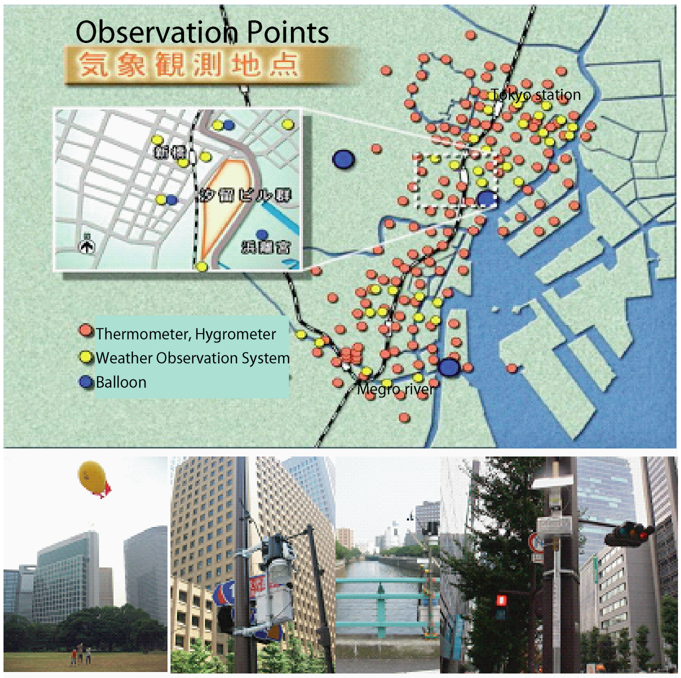

Figure 2. Meteorological observation points (190 points) in the center of Tokyo and in the Tokyo Bay area.

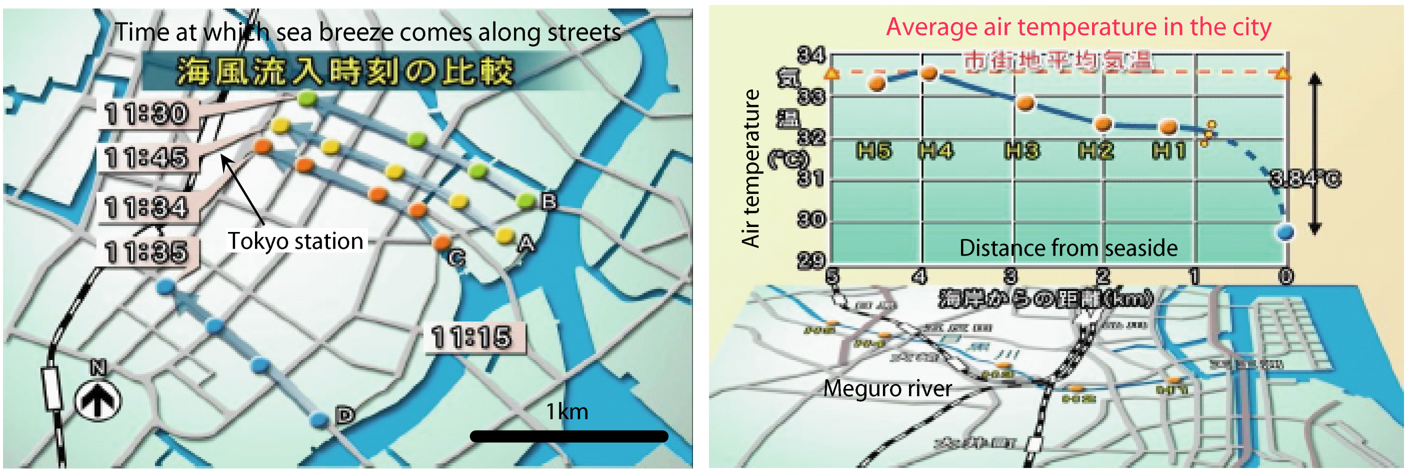

Figure 3. Examples of the meteorological observation results.

To study the effects of the present *Kaze-no-michi*, case studies were conducted using a wind tunnel. These case studies were for two areas in Tokyo: the Tokyo Station and its surroundings and the Nihonbashi River and its surroundings (Fig. 4). For these areas, extensive redevelopment is currently being examined and implemented.

In the Tokyo Station area, twin towers have recently been constructed. Between the towers, there exists a shopping center building which is connected to Tokyo Station. The shopping center building is currently in the process of removal as a part of the redevelopment. With this redevelopment, the shopping center, which appears like a castle wall from the sea side, will disappear. Then, a *Kaze-no-michi* is expected to form along a wide street extending from Tokyo Bay through the Tokyo Station area to the Imperial Palace in the center of Tokyo.

The Nihonbashi River is connected Tokyo Bay and has been flowing through Japan's center of commerce since the Edo Era. Thus, the surrounding area of the River is a valuable district in terms of history and landscape. Over the Nihonbashi River, an elevated expressway was constructed in the period of high economic growth in the 1960s, and the expressway has deteriorated in the meantime. Due to the timing of its renewal, the removal of the expressway has been proposed so that the river bank can be widened and the old riverside landscape can be restored.

If this proposal is brought to realization, a continuous open space will be formed along the Nihonbashi River from Tokyo Bay, and this space is expected to function as a *Kaze-no-michi.*

We examined the airflow change between pre- and post-development with wind tunnel experiments. For these experiments, the above-mentioned districts were reconstructed with detailed 1/750 models. According to the experiments, the proposed development will create a *Kaze-no-michi* and wind speeds will increase within a few hundred meters of the development site. This increase in wind speed is likely the result of enhanced ventilation, thus it is likely accompanied by effects that promise to reduce the air temperature.

How to make the best use of *Kaze-no-michi*

We have confirmed the presence of *Kaze-no-michi* and its cooling effects in Tokyo. To make the best use of this *Kaze-no-michi* concretely for effective and practical application in urban planning, the details of its path between the coast and the city center need to be clarified.

The key component that enabled this clarification was the use of simulations by super computers. The present project used "the Earth Simulator", which possesses one of the fastest computing speeds in the world and is known as Japan's super computer.

With the Earth Simulator, researchers centered around Dr. Yasunobu Ashie of the Building Research

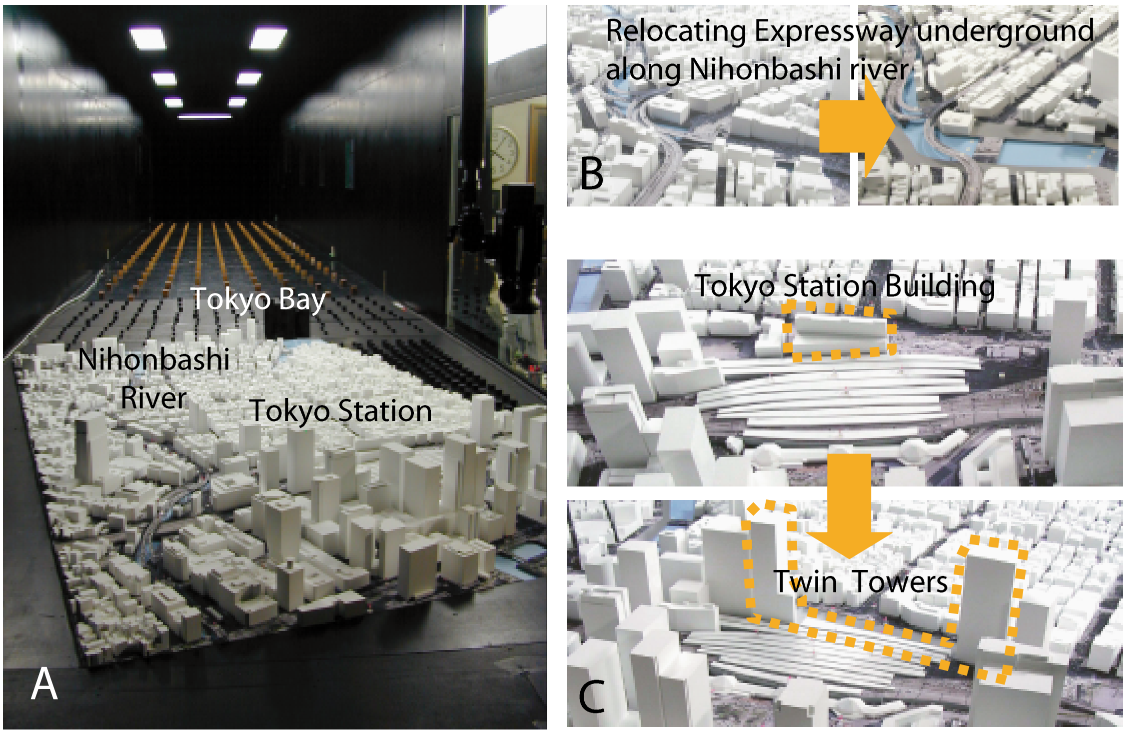

Figure 4. Wind tunnel experiment using an urban district model.
A: Urban district model installed in BRI's turbulent boundary layer wind tunnel
B: Proposed plan of relocating the expressway underground along the Nihonbashi River
C: Tokyo Station development plan.

Institute (BRI) and his group set out to reconstruct the heat island effect that has been observed over the entire city. In this reconstruction, very fine details of the heat island effect were computed using the vast amount of data of air temperature, wind speed, and wind direction from the above-mentioned field observations.

This effort has enabled simultaneous visualizations of the air temperature and wind conditions between the surface and the 500m height in the 23 wards of Tokyo (Fig. 5). This horizontal area corresponds to approximately 30km-square, and the simulation results show the details of the air temperature and wind conditions around the city's over 160 million buildings and along their surrounding squares, streets, and rivers. Moreover, the simulation result was found to be highly accurate with an RMS error of less than 1 ˚C with respect to the data from the large-scale field observations. Thus, we can now map the detailed wind flow of the sea breeze, up to a few hundred meters in thickness, from the ocean to the center of Tokyo and the resulting reduction of air temperature along the wind flow.

Further simulations were performed on the Earth Simulator to evaluate the effects of the redevelopment in the Tokyo Station and Nihonbashi River areas, for which case studies were conducted with wind tunnel experiments. Fig. 6 shows a comparison of wind speed and direction among the results of the field observations, wind tunnel test and numerical simulation. These results are in good agreement with each other. And the simulations predicted that the formation of *Kaze-no-michi* would reduce the air temperature as much as 2 ˚C in these areas (Fig. 7).

Having learned with certainty that continuous wind flow over streets and rivers are present in urban spaces, we would like to utilize this wind flow effectively for urban planning.

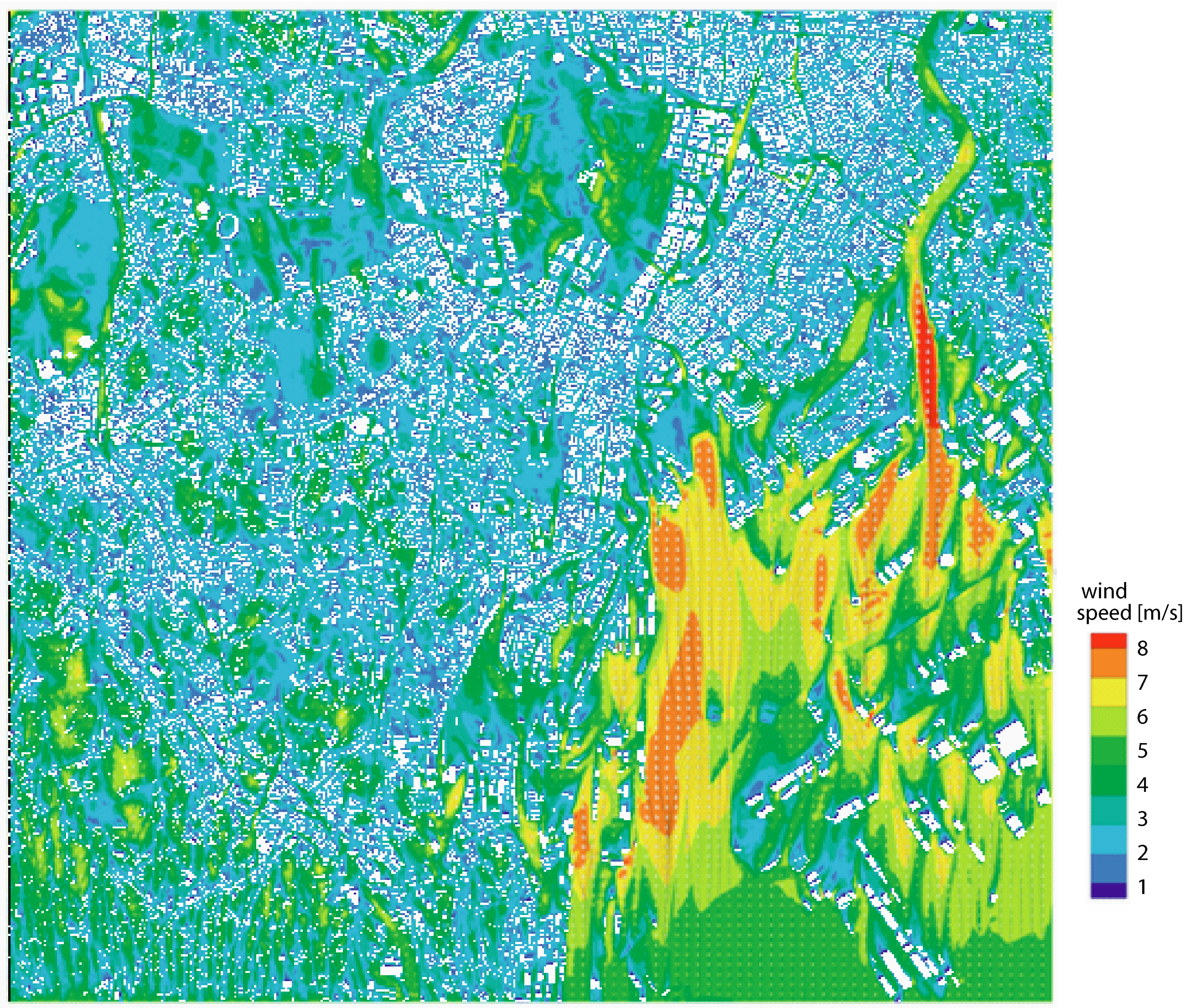

Figure 5. Result of a numerical simulation by the Earth Simulator.
Wind speed and wind direction at 10m above ground level at 14:00 on July 31.
Courtesy of Y. Ashie, BRI.

Figure 6. Comparison of wind speed and direction between field observations, wind tunnel test, and numerical simulation by the Earth Simulator (5m above ground level).

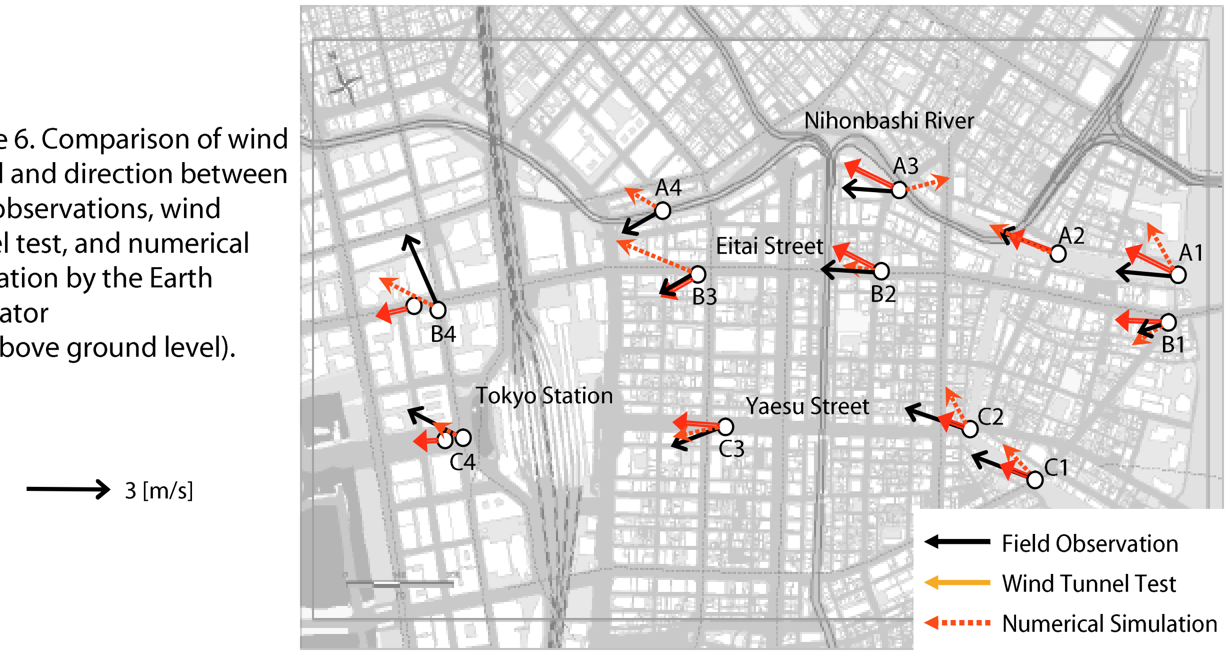

Figure 7. Numerical simulation of air temperature change due to reconstruction of Tokyo Station and relocation of Nihonbashi River expressway (12:00, July 31, 5m above ground level).
Courtesy of Y. Ashie, BRI.

To apply *Kaze-no-michi* in urban planning, we have classified it into 3 types (Fig. 8). This classification is based on past research achievements on Kaze-no-michi. Type 1: *Kaze-no-michi* created by the sea breeze that flows from the coast into the city along the earth's surface and along routes such as streets and rivers. Type 2: *Kaze-no-michi* that originates from sea breeze aloft. The sea breeze is directed to the earth's surface in the city by building complexes along streets and rivers. Type 3: *Kaze-no-michi* generated by sea breeze blocked by skyscrapers. When sea breeze is blocked by skyscrapers, warm air stagnates leeward of the buildings and cold air from above the skyscrapers is brought close to the surface. This cold air generates an area of low temperature a small distance away from the skyscrapers (Fig. 8).

We are continuing our research on how to include *Kaze-no-michi* in the urban planning system of Japan. For example, we are making efforts to incorporate *Kaze-no-michi* into urban planning guidelines that take the heat island effect into consideration.

Finally, in the present project, software has been developed to predict the effects of various countermeasures for the heat island effect. For this software development, the simulation models created for the Earth Simulator were used. In the near future, we aspire to release this software to the public so that national and local public agencies can use it for their decision making procedures. With input of data for an area of interest, the software is able to assess the effects of heat island measures such as urban greening, "cool roof" installation, water-retentive pavement installation, energy conservation, and *Kaze-no-michi* for the corresponding area. By combining this assessment with

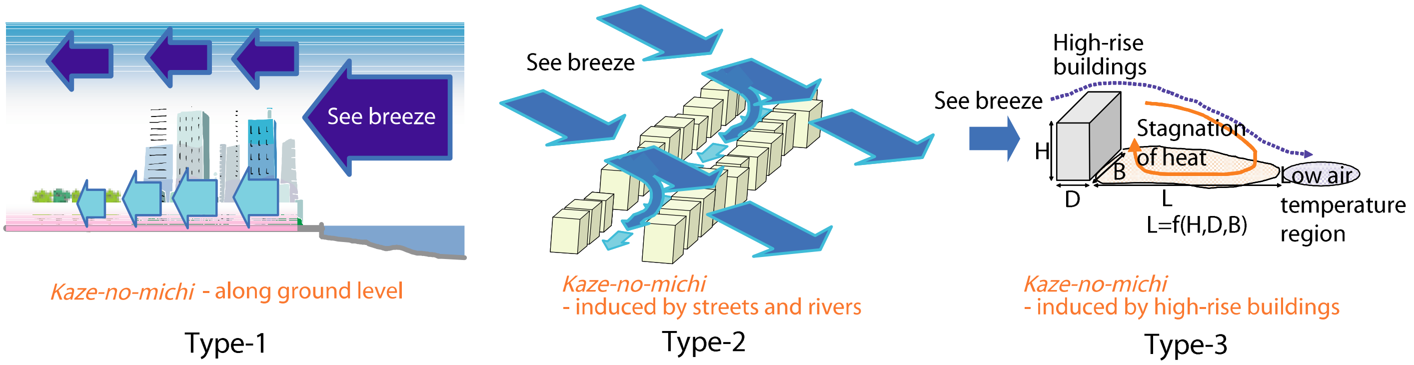

Figure 8. Classification of *Kaze-no-michi* (ventilation paths) which bring cool sea breezes into urban areas.

urban planning guidelines, the agencies will be able to discuss and choose the measures that are well-suited for the circumstances of the relevant area.

Information about this research project is available at the following website:

http://www.nilim.go.jp/lab/jeg/heat.htm (in Japanese only; English site will be available soon.)

Acknoledgements

The authors received considerable cooperation and advice from the following specialists during the committee meetings established to promote the present project: (affiliations and positions are those at the time of the meetings)

T. Ojima (Chairperson, Professor of Waseda University), K. Hanaki (Professor of the Graduate School of the University of Tokyo), A. Hoyano (Professor of the Graduate School of the Tokyo Institute of Technology), Y. Maruta (Professor Emeritus of Chiba University), T. Mikami (Professor of the Graduate School of Tokyo Metropolitan University), K. Narita (Professor of Nippon Institute of Technology)

The large-scale field observations in central Tokyo and the Tokyo Bay area were performed jointly by the National Institute for Land and Infrastructure Management (NILIM), Waseda University, Tokyo Metropolitan University, and the Nippon Institute of Technology.

Information

A planning meeting for the "International Conference on Countermeasures to Urban Heat Islands" was held on June 5-6, 2008, at the Lawrence Berkeley National Laboratory (LBNL) in the U.S. The meeting was attended by 20 participants from countries such as the U.S., Japan, China, Greece. In the meeting, the date of the conference was fixed and its management policy was defined.

Date: September 21-23, 2009

Location:Doubletree hotel, Berkeley, California, USA.

Website: http://www.heatislandconf.com

Planning meeting at LBNL.

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