Japan's Increasingly Subtropical Climate:

The Future of Civil Engineering Technology

Feature 3: Response of Japan's civil engineers

How civil engineering can deal with Japan's increasingly subtropical climate

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Climate change begins to receive attention

Many people have commented that the weather recently has been strange. Cherry blossoms bloom much earlier than normal. Last summer was unbearably hot, but then we had the heaviest snowfalls in a long time. Last year, the pollen from Japanese cedars was especially troubling for people with allergies, but this year has caused fewer problems. After a period of drought, several typhoons hit Japan, causing heavy rainfall and frequent mudslides.

In the past, climate change and climatic aberrations were generally considered the domains of academicians. However, frequent wind and water damage and a surge in unusual and record-breaking weather conditions have now made these concepts a part of everyday life.

The concept of "climate" was developed in ancient Greece. The word is derived from the Greek word *klima*, which means "slope" or "gradient." Long before it was learned that the earth is shaped like a ball, the ancients had noticed that temperature and humidity correlated with distance from the equator. Environmental variation was clearly related to differences in latitude, and this was perceived as a form of stability.

While exhibiting this spatial stability, climate also has shown variability over time on different scales. For the past several million years, ice ages and interglacial periods have alternated every 40,000 to 100,000 years, with variations of 7 to 8ºC or more in annual average temperatures. On a smaller scale, Europe experienced a temperate period from the tenth to fourteenth centuries, then a cold period that lasted until the nineteenth century. These are termed the "medieval temperate period" and the "little ice age," respectively. Meanwhile, El Niño, which is an oscillatory phenomenon that occurs two or three times every decade and is caused by the interaction of the air and sea in Pacific tropics, has been responsible for various climatic aberrations in the world's weather. In 2002, major flooding occurred in Europe when a high pressure system called a "blocking high" lingered for nearly 10 days, an aberration from the normal pattern in which high and low pressure systems alternate every three or four days.

For most of humankind's seven million year history, people worked together to build infrastructure in which they could live in safety and obtain enough to eat despite the hazards posed by natural climatic variations. Planning theory based on experience was developed in recent years as a way to build infrastructure that can withstand major climatic variations within a certain period. For example, in the case of river planning for many of Japan's Class A rivers, flood control plans are prepared with the goal of withstanding the kind of short, heavy rainfall that occurs once every one or two centuries. Planning for long-term droughts is based on the kind of drought

that occurs about once a decade.

However, it is now understood that human activity can cause climatic variations. The heat island effect on the urban climate is one such effect. Another is global warming. The combination of these factors is raising average temperatures in Japan, and Japan's increasingly subtropical climate has become problematic. These human activity induced climatic variations must be handled differently from the naturally occurring variations of the past.

What can cities experiencing the heat island effect do?

Climatic changes due to urbanization were recognized even during the Roman Empire, but were especially notable in London during the industrial revolution, when smoke and soot caused smog and decreased sunlight. Later, the problem was air pollution caused by chemical substances. Today, issues such as drying, structural changes, and the heat island effect due to an increase in exhaust energy have become important environmental problems in cities.

The air temperature in Tokyo has risen by 3ºC over the past 100 years. Around the turn of the twentieth century, summers in Tokyo had an average of only one tropical night (24-hour periods when the temperature never falls below 25ºC). However, this figure has soared, approaching 40 tropical nights each summer (see page 39, Column 1). In the Kanto region, inland regions such as Kumagaya and Maebashi often experience severe heat with daytime highs in excess of 38ºC. This is said to be the result of two interacting factors. 1) The hot air formed by Tokyo's heat island effect is moved inland by sea breezes from Tokyo Bay. 2) Southwesterly winds blowing from the Ogasawara high-pressure system pass through the Southern Japanese Alps and the Kanto Mountains, generating warm mountain (foehn) winds.[1]

When greenery and bodies of water decrease due to changes in land use and the soil is covered with asphalt and buildings, the earth's surface in urban areas becomes dry. The lack of soil and bodies of water means that radiant energy from the sun no longer evaporates water, and the lack of plants means no transpiration from photosynthesis. Instead, the radiant energy mercilessly heats the dried-out, paved-over surface, raising the temperature of the surface. Part of this heat is transferred into the air by the disordering effects of wind, causing a rise in daytime air temperatures. The remainder is stored in the earth through heat conduction. This heat then radiates from the earth's surface, heating the air, so that high temperatures are maintained even at nighttime. This is the heat island effect.

Photograph 1. A garden on the roof of a Dai Nippon Printing Co., factory in Shinjuku Ward serves as a rest area for employees. (Photo provided by Dai Nippon Printing Co., Ltd.)

Restoring greenery to the cities can effectively ameliorate the heat island effect. The “green roof” concept is a promising approach that has additional benefits under many cities' municipal ordinances and floor-area ratio regulations (Photograph 1). A civic movement wants to spray water for its cooling effect. Although the effects of water spraying are very short-lived, the movement is worthy in that it helps to interest the public in the problem. Meanwhile, the waterfront boom of recent

years is lining the coastal waterfronts with clusters of buildings. This is likely to significantly reduce the land-sea wind circulation that reduces the heat island effect in coastal cities. The arrangement of these buildings must be carefully considered (Fig. 1).

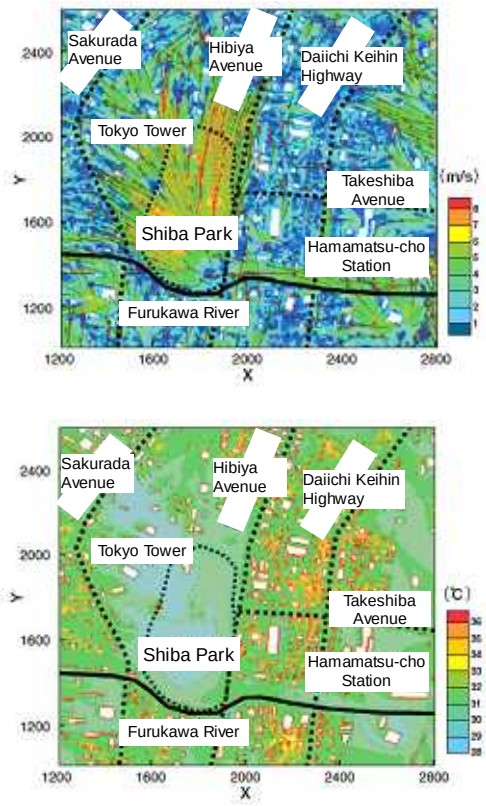


Fig. 1. Wind and air temperature along the coast of central Tokyo, simulated using a global simulator. Cool sea breezes flow into the city along the Furukawa River (left). From nearby Shiba Park, cool air flows to surrounding districts via roads, etc. (right). (Based on materials from the second study meeting on "Evaluating the heat environments of urban spaces and developing technological solutions," a general technology development project of the Ministry of Land, Infrastructure and Transport, on June 3, 2005.)

The "Kanpachi Street Cloud," a cloud band that appears along Tokyo's No. 8 Ring Road, became a subject of urban climatic studies in the 1990s. Kenji Kai and other scientists reported that the mechanism involves southerly sea breezes from Sagami Bay and southeasterly sea breezes from Tokyo Bay, which merge near the No. 8 Ring Road and form a rising air current. This phenomenon has provided a clear visualization of the ameliorating effect of sea breezes on the urban climate, and brought about renewed awareness of the wide-ranging nature of this effect. It is necessary to understand the overall picture of environmental mechanisms and take well-coordinated steps, including scientific research, technological solutions, efforts by private citizens, and policy guidance.

Global warming and water management

The public is familiar with the concept of global warming, in which heat radiation rises from the earth's surface and is absorbed by greenhouse gases, thereby heating the lower atmosphere. However, there is a surprising lack of general understanding of the subsequent processes. When the lower atmosphere is warmed, downward heat radiation increases, resulting in greater heating of the earth's surface. This increases atmospheric instability, leading to a rise in convection activity. The warmed air in the lower atmosphere spreads throughout the entire region of the convection currents. This is the phenomenon of global warming.

Japan's average air temperature has risen about 1.0ºC during the past 100 years, a trend that has become significantly faster since the latter half of the 1980s. In the past century, eight of the ten years with the highest average temperature occurred during the 1990s. Someiyoshino cherry trees now bloom five days earlier than they did 50 years ago (see Column 4). Alpine plants are disappearing in Hokkaido, and tropical fish have appeared in Osaka Bay. These are just a few examples of the ecological aberrations that have been reported.[2] For these reasons, more attention is now being devoted to Japan's increasingly subtropical climate.

Since there is a non-linear relationship between air temperature and saturation vapor pressure, the volume of rain in heavy downpours rises as the climate warms. The total average rainfall increases little, however, since it is determined by the overall

global energy budget. As a result, heavy downpours are likely to occur more frequently as the climate warms. At the same time, an increasing number of locations and time periods will receive little or no rainfall.[3] According to calculations based on a scenario prepared by IPCC (720 ppm carbon dioxide concentration by 2100), the number of summertime days in Japan with torrential rains producing daily precipitation of at least 100 mm will increase sharply (Fig. 2).

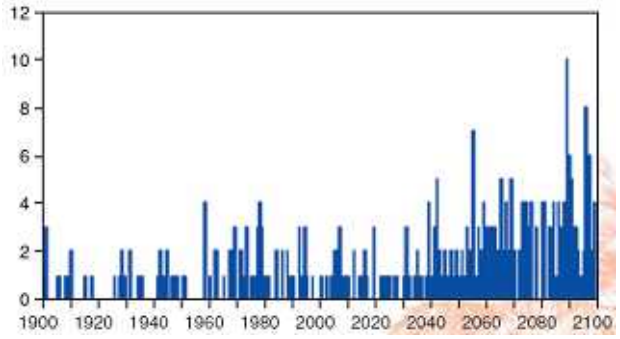


Fig. 2. Changes in the number of summer days of torrential rain in Japan (unit: days)

One day of torrential rain is defined under the A1B scenario of the IPCC as any day with precipitation of over 100 mm in one unit (about 100 kilometers square) of a lattice covering the Japanese archipelago. (Source: Report issued on September 16, 2004 by a collaborative research group consisting of the Center for Climate System Research, University of Tokyo; the National Institute for Environmental Studies; and the Frontier Research Center for Global Change.)

Records for the past 100 years or so indicate that short, heavy downpours are also occurring with increasing frequency in the U.S. and Europe. In Japan, there has been a statistically significant increase in the number of days in which torrential rains produced daily precipitation of at least 100 mm and at least 200 mm (Fig. 2). Meanwhile, there has been a consistently increasing trend since 1950 in the number of months with unusually low monthly precipitation (Fig. 3).[4] Flood control and water resource management are expected to become increasingly difficult because of these trends.

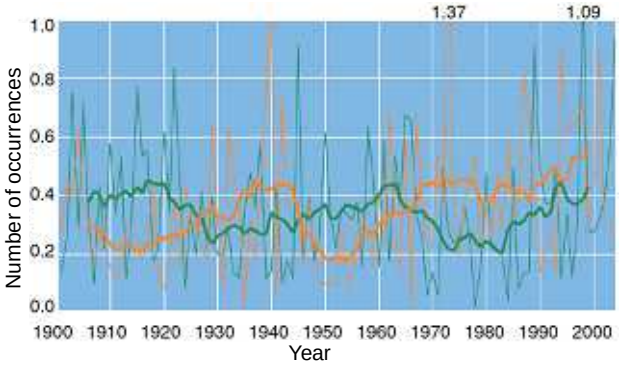


Fig. 3. Changes over time in the number of periods of unusually heavy rainfall and unusually dry spells. Unusually heavy rainfall: green. Unusually dry spells: orange. The fine line indicates each year's value. The thick line has been smoothened by eliminating year-to-year fluctuations. (Source: The Japan Meteorological Agency's 2005 report on climatic aberrations.)

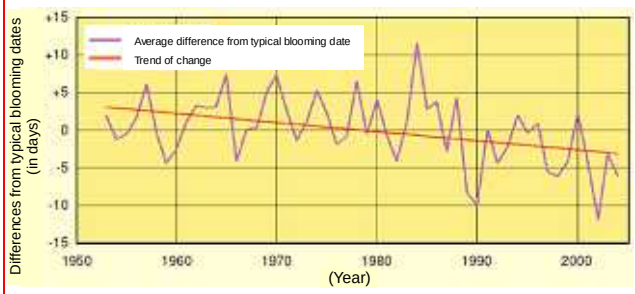
The implementation of the Kyoto Protocol and the commencement of specific international efforts to combat global warming should be celebrated as memorable steps for humankind, even though the system is still incomplete. Fundamental steps to control changes in climatic variation are urgently needed, as are efforts to reduce greenhouse gases. Major questions are being raised with regard to planning theory, which has supported the development of modern infrastructure. Up to the present, we have studied natural phenomena in terms of regular probability processes, based on the observational data collected over many years, and assigned levels of importance to each region in view of their population densities, asset integration densities, and economic activities. The foundations of this approach are being shaken. Since the early 1990s, when global warming began to be an issue, the need to revise this approach has been pointed out time after time. However, a great deal of hesitation remains about embarking on a fundamental restructuring of planning theory.

Column 4
Additional information about Japan's increasingly subtropical climate

■ Are cherry trees blooming abnormally early?

This year, cherry trees bloomed earlier than usual throughout the country. In Tokyo, the blossoms appeared on March 21, ten days earlier than last year and seven days earlier than in a typical year. In fact, many of the college entrance ceremonies in early April took place amid flurries of falling cherry blossoms. In statistical terms as well, cherry trees are blooming earlier nationwide, an average of 4.2 days earlier than 50 years ago. While the average in small and medium-sized cities is only 2.8 days earlier than 50 years ago, in large cities the average is 6.1 days earlier, reflecting the heat island effect.

Meanwhile, there have been frequent reports of plum trees blooming later than usual this year. If these types of trends continue, they will lead to ecological change. Eventually, even the traditional seasonal words used in haiku may have to be changed.



▲ Changes over time in cherry tree blooming date (average for large cities)

The graph above refers to large cities. The straight line shows the long-term trend of change. The typical blooming date is the average over a 30-year period from 1971 to 2000. (Source: The Japan Meteorological Agency's report on climatic aberrations, p. 165.)

Column 5
Additional information about Japan's increasingly subtropical climate

■ If you'd like to learn more...

Please visit these websites for additional information about meteorology [in Japanese].

- Information about the Japan Meteorological Agency, meteorology, and more:
  http://www.kishou.go.jp/menu/knowledge.html
- The Japan Meteorological Agency's 2005 report on climatic aberrations:
  http://www.data.kishou.go.jp/climate/cpdinfo/climate_change/index.html
- Meteorological information from forecaster Masamitsu Morita:
  http://www.weathermap.co.jp/kishojin/

The role of civil engineering

I see the role of civil engineering as creating the infrastructure that promotes harmonious relationships between nature and people, as well as between people and people. In order to deal with the urban heat island effect and global warming, which are making Japan's climate increasingly subtropical, it is necessary to build a social consensus based on a holistic scientific understanding of the interactions between nature and humankind. Infrastructure construction may seem to be a slow and gradual process, but it must adapt to changing times. Japan achieved remarkable economic development in the twentieth century. My hope is that, in the twenty-first century, Japan will use its scientific, technological, and cultural strengths to deal with the issue of climatic variations, and that it will share its knowledge with the global community.

References

1 Fumiaki Tobu: How have urban climates changed?, *Kagaku*, Vol. 75, No. 10, pp. 1177-1180, 2005.

2 Representatives of the Environment Committee of the Council for Science and Technology, eds.: The forefront of global warming research, pp. 83-94, 2003.

3 Akio Kitoh: Does global warming increase torrential rains?, *Kagaku*, Vol. 75, No. 10, pp. 1155-1158, 2005.

4 Japan Meteorological Agency: Report on climatic aberrations, p. 383, 2005.

[Note: All of the above references are in Japanese.]