

Climate Change and Cherry Tree Blossom Festivals in Japan

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Climate change is already having an influence on plants throughout the world, with warming trends creating conditions that cause many plant species to extend to cooler zones on mountain slopes or farther north of their original ranges. Plants are leafing out earlier in the spring and holding leaves longer in the autumn, creating an extended growing season. Of all of the characteristics of

plants that relate to global warming, the timing of flowering is the one for which there are the greatest number of observations. These data demonstrate that plants are now flowering earlier than they did a few decades ago, and that changes are mainly a product of temperature increase, rather than a result of other aspects of the weather. Although observations of flowering time tell a convincing story of the impacts

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People enjoying the cherry blossom festival in Ueno Park, a popular spot in the center of Tokyo.



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A well-organized cherry blossom party being celebrated by a group of business people at Yasukuni, a park in the center of Tokyo.

of global warming, the record extends back a mere 150 years, at most. The studies are predominantly from Europe, with a scattering of more recent studies from the United States, and many of these studies of climate change are from cities where additional warming is associated with urbanization. Scientists working on long-term climate change need additional studies from elsewhere in the world and conducted over a longer period of time. Such studies could provide evidence that the earlier flowering time—observed in Europe and the United States—is caused by a warming trend, a truly global phenomenon extending beyond the historical weather record of the 19th and 20th centuries.

Kyoto Cherries as Indicators of Climate Change

A unique data set that can potentially supply these insights is the record of annual cherry blossom festivals in Japan. Cherry blossom fes-

tivals, or *Hanami*, are a special feature of Japanese life that really has no equivalent in other countries. During modern festivals, all ages spend time outdoors, enjoying the beauty of the cherry blossoms by day and by night, with their family, friends, and workmates. Festival activities include eating seasonal foods, such as bamboo shoots, rice cakes with red beans, and wild vegetables, playing games, listening to musical instruments, and singing. More enthusiastic pursuits include dancing and drinking sake—Japan's special rice wine—and beer. The festivals have been the subject of numerous poems and songs and have been depicted in paintings, pottery, and textiles for hundreds of years. Because of their great popularity and cultural significance, local governments, meteorologists, botanists, and newspapers have recorded the flowering times of cherry blossom times for an extraordinarily long time. In Kyoto, a beautiful ancient city on the main island of Honshu, the cherry blossom



People boating in the moat surrounding the Imperial Palace in Tokyo, when the cherry trees are in full flower.

festivals have been part of court life for over one thousand years. The diaries of court officers often include mention of the festival dates, a peculiarity of the region's history that allows modern scientists to track the influence of a changing climate on flowering times.

Kyoto became the capital city of Japan in 784 A.D., and was the focus of a rich court life for several hundred years, a time known as the Heian Period. Cherry trees were prominently planted in the gardens of aristocratic residences, and cherries were an important imperial symbol. During the flowering period, people made special trips to visit particular sites around Kyoto to view cherry trees planted in attractive settings, such as temple gardens, and imperial parties went on excursions of up to several days into the surrounding Arashiyama hills to enjoy the cherry blossoms at their peak.

While double-flowered cherries and unusual cultivars were sought for the gardens of the

nobility, ancient cherry blossom festivals focused on the blossoming of wild cherry trees, known in English as the Japanese mountain cherry and in Japanese as the *yama-zakura*. Scientifically this species is known as *Prunus serrulata* var. *spontanea*, or less commonly as *Prunus jama-sakura*. It is typically found in the foothills of central Japan, often in secondary forests. In contrast with many other species of cherries, the mountain cherry is long-lived and easily raised from seed. Its white five-petaled flowers, about 1 to 1½ inches (5 to 8 cm) across, help with identification, and the species is more readily recognized because the young leaves are brownish-red to red in color, presenting a striking contrast with the green leaves of most other cherries.

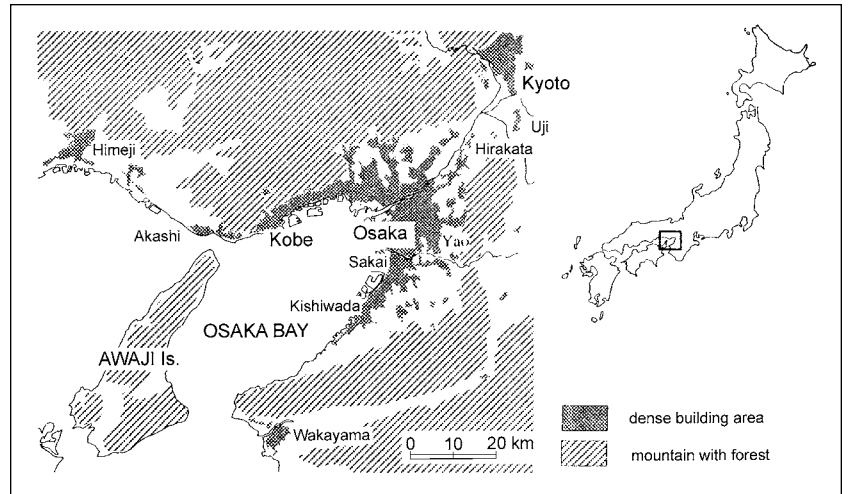
The mountain cherry trees are still found in abundance around Kyoto and have been planted extensively in gardens. The hills of Arashiyama are especially noted for them. Paintings from

Kyoto depict boatmen paddling small boats in the nearby Oigama River, with their passengers observing the flowering trees on the riverbanks nearby and the hills above. And the Arashiyama Hills have featured prominently in Japanese literature, most notably as the occasional 17th century residence of the great Haiku poet Matsuo Basho.

For over eighty years, Japanese scientists have been examining court records and diaries from Kyoto to extract information on when the cherry blossom festivals have been celebrated in Kyoto. The date of the celebrations are determined several days before peak flowering by observations of the flower buds, and may be adjusted some days earlier if the weather is unusually warm or later if the weather is unusually cold. The past dates of the festival thus indicate when the Japanese mountain cherries were in full flower and provide an estimate of the temperature in that year. The earliest of these studies, published in 1939 and 1969, were carried out by meteorologists primarily interested in using this data to reconstruct past climate and to predict the timing of the modern cherry blossom festivals based on climate variables. The researchers were able to find fairly abundant records for the 15th and 16th centuries, with less complete records extending back to the 11th century, and forward to the present.

Studies by Aono and Omoto

In the 1990s, the agricultural meteorologist Dr. Yasuyuki Aono of the Osaka Prefecture University, along with his colleague Yukio Omoto, began to search all available court records and diaries, with the goal of having a complete set of cherry blossom festival dates for Kyoto. These documents were stored in libraries, archives, and museums, primarily in Kyoto, Nara, and other historical centers of Japan. The documents were hand written in ancient Japanese script on paper and parchment. Over many years, Dr.



The location of Kyoto and Osaka in Japan. The urban area of Kyoto is densely shaded.

Aono taught himself to read these documents, and he gradually converted them to modern Japanese characters. In addition, the dates on the documents corresponded to the Japanese calendar and had to be converted to the Western calendar. His lifetime goal of analyzing ancient and modern climate data has filled his modest office with boxes of photocopies of court records, old books, and computers.

During fifteen years of dedicated searching, Dr. Aono was able to greatly increase the number of years for which there were dates of the Kyoto cherry blossom festivals, with many additional dates going back to the 11th century. From 1401 to the present time, a 605 year time span, there are now records of the festivals for most years. For the period 1476 to 1553, there is a record for every single year.

The cumulative flowering record shows a six week range in flowering dates from as early as late March to as late as early May. The extreme flowering dates are scattered throughout this time period. There are, however, periods of decades with earlier than average flowering and decades with later than average flowering. Many of the flowering records from the 12th and 13th centuries are noticeably earlier than average, along with the decades before and after 1600. In contrast, the period from the mid-1600s to the early 1800s is characterized by later than average flowering. After approximately 1830, the

flowering times become progressively earlier. By the 1980s and early 1990s, average flowering times had become earlier than at any time previously during the entire flowering record of over one thousand years.

Using these old records and more modern temperature data, Dr. Aono's goal was to develop a model that could predict the modern flowering time of cherry trees from temperature data, then use this model to predict past spring temperatures from past flowering dates. The modern values used for calibrating the model come from the Arashiyama Hills, the same site

where ancient court officials went for their parties. He and Omoto published the results of their work in the *Journal of Agricultural Meteorology* in 1994, a journal appropriate to his background in agricultural meteorology, and his appointment in a College of Agriculture within his university. Using a complicated equation, he was able to show that estimates of flowering time of the Japanese mountain cherry could be made using just the temperature in the months before the cherry trees flowered. These estimates using temperatures corresponded closely with the actual flowering times of



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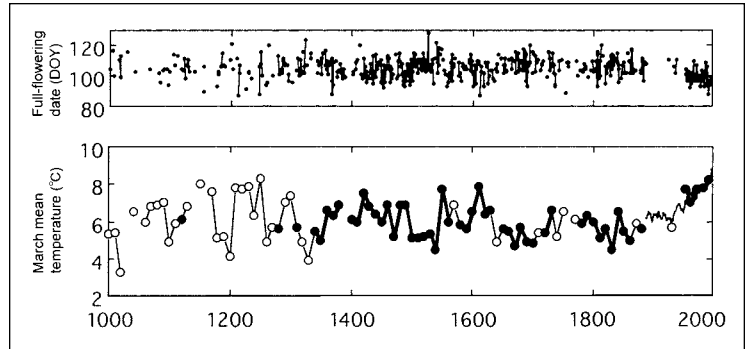
Old court diaries and records let us know the past dates of the cherry blossom festivals in Kyoto. This diary of Tokitune Hiramatsu, a well-known court figure of the Edo era, provides the following entry on April 14, 1644: “In Seiryoden Palace, Kyoto, we enjoyed watching cherry blossoms and took sake provided by the emperor.” The translation of the highlighted sentence is shown in red. The black entry is the date, according to the Japanese calendar.

cherry trees in Kyoto during the last few decades.

With this equation and past dates of cherry blossom festivals, Dr. Aono was then able to estimate March temperatures in Kyoto going back to the 11th century. Obviously the accuracy of the estimates depends on the number of years for which data exist, with the greatest certainty available for the middle and later periods of this one thousand year span. The calculations show that during the 11th through the 13th centuries, average temperatures were at their warmest averages, often as high as 8° C, as indicated by early dates of the cherry blossom festival. There were occasionally very cold years, as indicated by late flowering years, but on the whole this was the warmest average period. From 1400 to the mid 1500s, temperatures were variable, but they appear to have declined slightly on average. Certain decades, both before and after 1600, were noticeably warmer. In the following centuries, temperatures generally declined to 6° C, with particularly low temperatures in the periods from 1690 to the 1710s, and from 1810 to the 1830s.

And by using estimates made from the cherry blossom records, over the past 170 years, Dr. Aono saw a general rise in temperature in the Kyoto area of 3.4° C. The estimated temperature increase during this period corresponds well to the increase in temperature recorded from regular meteorological records, and is attributed, primarily to the warming associated with the urbanization of the Kyoto area, and secondarily with the general global climate warming of Japan. If we assume that Kyoto has experienced the average global increase of 0.6° C, then the remaining 2.8° C is due to urbanization.

Dr. Aono has been active in tracking down ever more obscure historical records to fill in the remaining gaps in the records of Kyoto's cherry blossom festival times. He has located records going back even further in time, back



COURTESY OF DR. YASUYUKI AONO AND YUKIO OMOTO, 1994

*Upper figure. Known dates of the cherry blossom festival (full flowering of *P. jamasakura*) in Kyoto from the 11th century to the present time. April 1 is the 91st day of the year (in years without a Leap Year); May 1 is the 122nd day of the year. In recent decades, flowering times have become earlier than in the past.*

Lower figure. Estimated March mean temperature in each decade, as calculated from flowering dates. Means calculated from 5 or more years are shown as solid dots. Decades with less than 5 years of data are shown as open circles. While temperatures have varied over this period, recent decades have been warmer on average than any time during the past 1000 years.

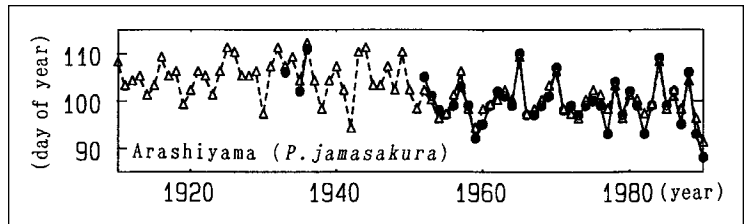
to the early 9th century, and many scientists around the world are awaiting the published results of his new work.

Cherry Tree Flowering Affected by Urbanization

As mentioned above, cherry tree flowering times have been strongly influenced by the urban heat island effect, the warming that comes from the added heating caused by removing trees and replacing them with roads, parking lots, buildings and other aspects of a human-dominated landscape. In studies of the impact of global warming, it is important to separate the effects of localized warming caused by urbanization from the more general aspects of warming caused by global climate change. Cherry trees can be used to separate these effects because they are planted at many locations—in cities, suburban areas, and more remote rural locations. It is again Drs. Aono and Omoto who lead the way in this research.

The most widely planted cherry species since the late 19th century, and therefore the most useful for climate change research covering the past one hundred years, is Somei-yoshino (*Prunus x yedoensis*), also known in the nursery trade as the Yoshino cherry. This cherry is

almost certainly a hybrid between the Edo-higan cherry (*P. pendula* f. *ascendens*) and the Oshima cherry (*P. serrulata* var. *speciosa*). The somei-yoshino is the most striking of the cultivated cherries with a profusion of white to pink, five-petaled flowers that appear on the branches before the leaves are produced. The 1½ inch (4 cm) wide flowers are produced in umbels of three to four flowers. This hybrid began to be widely planted in the late 19th century, and is now commonly cultivated in Japan. In the view of many Japanese, the Somei-yoshino is the most beautiful cherry tree, and it has replaced the yama-zakura as the focus of the cherry blossom festival. This is the same cherry tree that is planted in Washington, DC, and



*The flowering dates of mountain cherry trees (*P. jamasakura*) on the Arashiyama Hills outside of Kyoto have been getting earlier over the past 90 years; the different symbols represent different types of observations of flowering dates. Courtesy of Dr. Yasuyuki Aono and Yukio Omoto, 1994.*

enjoyed by Americans during the flowering season. Its flowering behavior is similar to the Japanese mountain cherry, so the results from the two species are comparable.

Due to the abundant records of cherry blossom festival records at numerous locations in Japan, it is possible to use the flowering dates

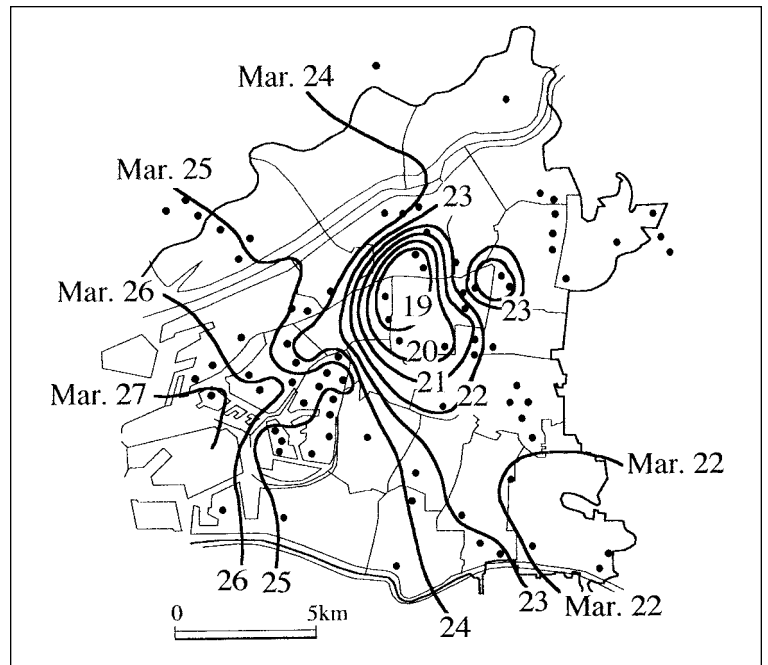
PHOTO COURTESY OF HIROYOSHI HIGUCHI



A cherry tree in flower in the built-up center of Osaka, the second largest city in Japan.

of the Somei-yoshino to measure how many days earlier plants flower as a result of the urban heat island effect. At locations near Kyoto, Osaka and Tokyo, urban, suburban, and rural locations had similar times of cherry blossom festivals in the 1950s. This indicates that urban, suburban, and rural areas still had essentially the same temperatures in the spring. Over the next 50 years, however, urban, suburban, and rural sites at each of these cities gradually began to diverge in flowering times, with urban areas flowering earlier than nearby rural and suburban areas. By the 1980s, the warmer temperatures in the city had shifted the flowering of cherry trees by eight days earlier in central Tokyo in comparison with nearby rural areas, and four to five days earlier in central Kyoto and Osaka than in their nearby rural areas.

The temperature effects of urbanization on flowering times for Osaka City have been mapped in detail. In 1989, the first flowering times of somei-yoshino cherries were recorded at around eighty locations in Osaka City. First flowering was recorded starting on March 19 at locations in the city center. Flowering was recorded at successively later dates at distances farther from the city center. At around seven kilometers from the city center, plants were starting to flower as late as March 22 to March 27, as much as eight days later than in the city center. The latest dates were found along the bay to the west where the cooling influences of the water may have caused a further reduction in temperature, slowing flowering. Cherry trees in a city park just northeast of the city center also have a delayed flowering, indicating a local cooling effect. Based on models that relate temperature to flowering times, Drs. Aono and Omoto were able to show that these earlier flowering times in the center of Osaka City correspond to a temperature increase of 1 to 1.5° C.



Cherry trees were monitored for their flowering times in 1989 at numerous locations in Osaka, shown as black dots in this map. Isochrones are produced by a computer program to show the geographic pattern of flowering. Trees flower earliest on March 19 in the center of the city and progressively later at greater distances from the center. The latest flowering is along the coast to the west of the city, due to the moderating influence of the sea. A city park to the northeast of the city center also creates a small area of later flowering.

Conclusion

The dates of cherry tree festivals in Japan have emerged as one of the most important sources of information on the impacts of climate change on plants. The data set is exceptionally detailed, and extends back in time more than any other known data set on plant flowering times. Because cherry trees have such great cultural importance in Japan, the results of this climate change research have been widely appreciated and publicized, both in Japan and among the international scientific community. Even the cherry trees in Washington, DC, donated by the Japanese government, are responding to higher urban temperatures by flowering one week earlier than in the past, providing an example of the biological impacts of climate change right on the doorstep of the American government.

People and Cherries in Japan: The Shinagawa Family

The Japanese people often mark events in their lives by corresponding events in the natural world, and one of the most significant events on the Japanese calendar is the time of the cherry blossom festival. Mr. Fujiro Shinagawa, a well known psychologist and author of books on raising healthy children, often associates himself with the cherry blossom festival. He was born in Okayama Prefecture in western Honshu on April 15, 1916, a day on which the cherry blossom festival was being celebrated. As a child, the trees were always in flower on his birthday, and he considered himself a child of the cherry blossom. Living in Tokyo as an adult, however, the cherry blossom festival gradually moved forward in time and was celebrated before his birthday; in some years, the cherry trees had finished flowering by his birthday.

His twin daughters, Hiromi and Yoshimi, growing up in Tokyo from 1955 to 1965, associated cherry blossom festivals with their school opening ceremony—always held on April 8, an exciting day, when students, parents and teachers joined at the school for special activities. On that day, the cherry trees in the schoolyard were always covered in blossoms, creating a joyous start to the school year, and in some years, April 8 was even the day of the cherry blossom festival, creating a double holiday. But in the 1990s, when Hiromi sent her own son to school in Tokyo, the cherry blossom festivals were often held before April 8, and in some years the trees no longer had any flowers by that date. Hiromi felt that something joyous and beautiful was missing from her son's school ceremony without the profusion of cherry blossoms. But for her son, the earlier flowering time of cherry trees seemed normal.

At the retirement community in the western suburbs of Tokyo, where Mr. and Mrs. Shinagawa now live, the annual cherry blossom festival remains an important event. On this day, the staff put chairs and tables in the parking lot of their building, and serve a special meal under the gorgeous flowers of the cherry trees. Now, however, the date is typically at the end of March, two to three weeks earlier than in 1916, when Mr. Shinagawa, the cherry blossom child, was born.



PHOTO COURTESY OF HIROMI KOBORI

Mr. and Mrs. Shinagawa and their grandson enjoying a cherry blossom festival on April 5, 1992.

Further Reading

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