

Climate Change in Japanese History and Prehistory:
A Comparative Overview

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I. Introduction

It is difficult to think of a contemporary issue as important or widely discussed as global warming. Scarcely a day goes by without another story about melting glaciers, shrinking icecaps, torrential storms, or devastating droughts. Debate has shifted from whether or not global warming is real, or whether or not we are to blame; most observers now agree that it is, and we are. The question is no longer what is happening or why; it is what we can expect if present trends continue and what, if anything, we can do to slow or halt them.

Although popular accounts sometimes give the impression that climate was relatively stable before people began burning fossil fuels, that is far from the case: it changed frequently, and for largely natural reasons. Global temperatures fluctuate on scales of 20,000-100,000 years as the result of changes in the earth's orbit (the so-called Milankovich cycles). Climate is also affected by natural changes in the atmospheric concentration of greenhouse gases and aerosols, in solar radiation, in volcanic activity, and

in oceanic and atmospheric circulation.¹ Some of these variations, such as those in atmospheric composition, operate at truly geological scales²; others, such as those caused by volcanic eruptions, are measured at most in years.

During the lifetime of our species, perhaps the most striking example of climate change was the long, bumpy transition from the Last Glacial Maximum or LGM (23,000-18,000 BP³) to the warm, stable conditions of the Holocene or recent period (roughly the last 10,000 years).⁴ This early instance of global warming was what made agriculture – and civilization as we know it – possible.⁵ As this example suggests, in

¹ Committee on Surface Temperature Reconstructions for the Last 2,000 Years, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, National Research Council of the National Academies, ed., *Surface Temperature Reconstructions for the Last 2,000 Years* (Washington, D.C.: The National Academies Press, 2006), 25-26, 99-105; Robert B. Dunbar, “Climate Variability During the Holocene: An Update,” in *The Way the Wind Blows: Climate, History, and Human Action*, ed. Roderick J. McIntosh, Joseph A. Tainter and Susan Keech McIntosh (New York: Columbia University Press, 2000).

² Regarding extremely long-term changes in atmospheric composition and their effect on the evolution of life on earth, see Peter Douglas Ward, *Out of Thin Air: Dinosaurs, Birds, and Earth’s Ancient Atmosphere* (Washington, D.C.: J. Henry Press, 2006), and *Under a Green Sky: Global Warming, the Mass Extinctions of the Past, and What They Mean for Our Future* (New York: Smithsonian Books / Collins, 2007).

³ Before Present; “present” customarily refers to 1950 CE.

⁴ On yet earlier climatic shifts of equal magnitude and the role they played in the human exodus from Africa, see Stephen Oppenheimer, *The Real Eve: Modern Man’s Journey out of Africa*, revised paperback ed. (New York: Carroll & Graf Publishers, 2004).

⁵ According to William James Burroughs, *Climate Change in Prehistory: The End of the Reign of Chaos* (Cambridge: Cambridge University Press, 2005), reduced climatic variability, rather than increased temperature per se, was the key factor.

premodern times climatic change could have an important, if not determining, influence on society – unlike today, when the influence tends to run the other way. (Another conclusion to be drawn is that climatic change, even global warming, is not necessarily a bad thing: it all depends.)

During the past few decades, historians and archaeologists in Europe and North America have paid increasing attention to the role of climate change in human history.⁶ Ultimately, this trend reflects scholars' concern about contemporary environmental and climatic issues, but it has also been facilitated by spectacular new scientific data from ocean sediments, ice cores, and other sources. (Needless to say, most of the research responsible for the new data has also been spurred by current concerns over climate change.)

Detailed climatic reconstructions for Japan are also available, but so far have failed to attract widespread attention from historians. True, Japanese archaeologists are quick to

⁶ See, for example, McIntosh, Tainter and McIntosh, eds., *The Way the Wind Blows*; Burroughs, *Climate Change*; Brian Fagan, *The Little Ice Age: How Climate Made History 1300-1850* (New York: Basic Books, 2000); Fagan, *The Long Summer: How Climate Changed Civilization* (New York: Basic Books, 2004); and Fagan, *The Great Warming: Climate Change and the Rise and Fall of Civilizations* (New York: Bloomsbury Press, 2008).

acknowledge the importance of climate for prehistoric cultures in the archipelago. And for the historic period, the crop failures and famines of the seventeenth through nineteenth centuries are routinely blamed on Little Ice Age conditions. But there have been few systematic attempts to examine the larger patterns in Japanese history from a climatic perspective.⁷ This is unfortunate, not just because of the contemporary relevance of the topic, but because (as we shall see) the Japanese case offers some interesting comparisons and contrasts with what is known from other regions of the world.

The purpose of the present study is to summarize what is known about Japan's climatic history during the period of human occupation, and to offer some tentative speculations about the role of climate in Japanese history and prehistory from an explicitly comparative perspective. I begin with an overview of the various methodologies that have

⁷ Important exceptions include Yutaka Sakaguchi, "Warm and Cold Stages in the Past 7600 Years in Japan and Their Global Correlation — Especially on Climatic Impacts to the Global Sea Level Changes and the Ancient Japanese History —," *Bulletin of the Department of Geography, University of Tokyo* 15 (1983): 1-31; Sakaguchi, "Kako 8000 nen no kikō henka to ningen no rekishi" (Climate Change and Human History during the Past 8000 Years), *Senshū jinbun ronshū* (Senshū University Essays in the Humanities) 51 (1993): 79-113; William S. Atwell, "Volcanism and Short-Term Climatic Change in East Asian and World History, ca. 1200-1699," *Journal of World History* 12, no. 1 (2001): 29-98; and William Wayne Farris, "Famine, Climate, and Farming in Japan, 670-1100," in *Heian Japan, Centers and Peripheries*, ed. Mikael S. Adolphson, Edward Kamens, and Stacie Matsumoto (Honolulu: University of Hawai'i Press, 2007), 275-304.

been used to reconstruct past climates in Japan. This is followed by a new, eight-stage periodization of the Japanese past based on climatic criteria. For each era, I provide a brief description of major climatic trends and discuss some of the important historical questions they suggest when viewed from a comparative, global perspective.

II. Methodologies

How can we reconstruct past climates? The most reliable information, of course, comes from instrumental data, but this is generally unavailable for premodern times. In the absence of instrumental data, past temperatures or climatic trends can be reconstructed using proxies. These fall into two major types: information gleaned from historical sources (historical proxies), and that based on measurements of various physical quantities (natural proxies).

1. Instrumental Data

Until recently, it was believed that instrument-based meteorological observations in Japan began as part of the Meiji government's modernization program, specifically with the establishment of a meteorological station in Hakodate, Hokkaido, in 1872. (Observations in Tokyo began three years later, in 1875.) However as Demarée and others have recently shown, Dutch observers in Nagasaki were making instrument-based observations as early as 1819, over half a century before the Hakodate station was established.⁸ That said, it

⁸ Gastone Demarée, "Some XVII-th and XVIII-th Centuries Dutch Meteorological Observations at Deshima, Nagasaki (Japan), Seen as a Complement to Japanese Climatological Historical Documents," in *Proceedings of the International Conference on Climate Change and Variability – Past, Present and Future –*, ed. Takehiko Mikami (Hachioji-shi, Tokyo: International Geographical Union Commission on Climatology / Department of Geography, Tokyo Metropolitan University, 2000), 107-13; T. Mikami, M. Zaiki, G.P. Können, and P.D. Jones, "Winter Temperature Reconstruction at Dejima, Nagasaki Based on Historical Meteorological Documents During the Last 300 Years," in *Proceedings of the International Conference on Climate Change and Variability*, 103-6; G.P. Können, M. Zaiki, A.P.M. Baede, T. Mikami, P.D. Jones, and T. Tsukahara, "Pre-1872 Extension of the Japanese Instrumental Meteorological Observations Series Back to 1819," *Journal of Climate* 16 (2003): 118-31; Tsukahara Tōgo, Zaiki Masumi, Matsumoto Keiko, and Mikami Takehiko, "Nihon no kiki kansoku no hajimari: Dare ga, dono yō na jōkyō de hajimeta no ka / Beginning of Instrumental Meteorological Observation in Japan: By Whom, in What Context, and Its Transitional Nature," *Gekkan chikyū* (Earth Monthly) 27, no. 9 (2005): 713-20; Zaiki Masumi, Tsukahara Tōgo, Mikami Takehiko, and Matsumoto Keiko, "Nihon ni okeru 19 seiki ikō no kokishō kiroku to sono kikōgaku teki igi / Old Instrumental Records in Japan since 19th Century and Its Climatological Significance," *Gekkan chikyū* 27, no. 9 (2005): 706-12; and M. Zaiki, G.P. Können, T. Tsukahara, P.D. Jones, T. Mikami, and K. Matsumoto, "Recovery of Nineteenth-Century Tokyo/Osaka Meteorological Data in Japan," *International Journal of Climatology* 26 (2006): 399-423.

remains true that prior to the nineteenth century we are entirely without instrumental data on Japanese weather and must rely on proxies such as those discussed below.

2. Historical Proxies

Japan has a voluminous historical record going back to about 700 CE (and containing references, not always reliable, to still earlier times). Descriptions of weather conditions are found in sources ranging from poetry collections (e.g., *Man'yōshū*; Collection of Ten Thousand Leaves) to official chronicles (e.g., *Nihon shoki*; Chronicles of Japan). However, by far the best information comes from diaries. For the old capital of Kyoto, we have aristocratic diaries going back to the ninth century. For the rest of the country, diary coverage is relatively limited until the Edo period (1600-1867), when literacy became widespread and warriors, clerics, and even commoners throughout the country began to take note of their daily activities.⁹ Japanese diary entries, whether written by Heian

⁹ For a more or less comprehensive index of fifteenth-century and later diaries and travel accounts useful for purposes of climatic reconstruction, see Yamamoto Takeo, Fukaishi Kazuo, Maejima Ikuo, Mizukoshi Mitsuharu, Yoshimura Minoru, Shitara Hiroshi, Urushibara Kazuko, Hayashi Yōsei, and Kurosaka Hiroyuki, “Kokikō fukugen ni riyō

aristocrats or nineteenth-century schoolchildren, routinely begin with a laconic comment about the weather, so taken in sum, these sources constitute a very precious resource for the climate historian.

Since about 1970, Japanese researchers have used a variety of techniques to reconstruct past climate from historical proxies, particularly for the well-documented Edo period. The following discussion, which is by no means exhaustive, introduces some of the principal methodologies employed.

a. Phenological data from dates of cherry-viewing

Anyone who has lived in Japan will be familiar with the custom of “cherry-blossom viewing.” This custom is an ancient one and many old diaries, particularly from Kyoto, note the dates of the flower viewing parties held each spring on the day or days when the

dekiru nikki, ryokōki nado no chiiki betsu mokuroku (I)” (Regionally-Organized Catalogue of Diaries, Travelogues, Etc., That Can Be Used to Reconstruct Past Climates, Part 1), *Kikōgaku, kishōgaku kenkyū hōkoku* (Climatological and Meteorological Research Reports) 5 (1982): 60-82; and Yamamoto, Fukaishi, Maejima, Mizukoshi, Yoshimura, Shitara, Urushibara, Hayashi, and Kurosaka, “Kokikō fukugen ni riyō dekiru nikki, ryokōki nado no chiiki betsu mokuroku (II)” (Regionally-Organized Catalogue of Diaries, Travelogues, Etc., That Can Be Used to Reconstruct Past Climates, Part 2), *Kikōgaku, kishōgaku kenkyū hōkoku* 8 (1983): 54-59.

cherries were in full bloom. As we all know from experience, warm weather in early spring causes flowers to bloom early, while cool weather tends to delay their appearance. Annual variations in the date of blossom viewing parties at a given location, then, presumably reflect differences in mean spring temperatures. Arakawa, Yamamoto, and most recently Aono and Omoto have used this approach to reconstruct climatic trends in Kyoto.¹⁰ Aono's work, in particular, is noteworthy for its use of comparative modern data to calculate mean

¹⁰ H. Arakawa, "Climatic Changes as Revealed by the Blooming Dates of the Cherry Blossoms at Kyoto," *Journal of Meteorology* 13 (1956): 599-600; Yamamoto Takeo, "Rekishī no nagare ni sou Nihon to sono shūhen no kishō no henshen" (Meteorological Change in Japan and Vicinity over the Course of History), *Chigaku zasshi / Journal of Geography* 76 (1967): 115-41; Yamamoto, "On the Climate Change in XV and XVI Centuries in Japan," *Geophysical Magazine* 35, no. 2 (1971): 187-206; Yamamoto, "On the Nature of the Climatic Change in Japan since the 'Little Ice Age' Around 1800 A.D.," *Journal of the Meteorological Society of Japan* 49 (1971): 789-812; Yamamoto, "On the Nature of the Japanese Climate in So-Called 'Little Ice Age' Between 1750 and 1850," *Geophysical Magazine* 35, no. 2 (1971): 165-85; Yamamoto, *Kikō no kataru Nihon no rekishi* (Japanese History as Told by Climate), Soshiete bunko (Society Library), (Tokyo: Soshiete, 1976); Y. Aono and Y. Omoto, "Variation in the March Mean Temperature Deduced from Cherry Blossoms in Kyoto since the 14th Century," *Journal of Agricultural Meteorology* 48, no. 5 (1993): 635-38; Aono and Omoto, "Sakura no kaika shiryō ni yoru 11 seiki ikō no Kyōto no kion no suitei" (Temperature Trends in Kyoto since the Eleventh Century Based on Records of Cherry Blooms), *Nōgyō kishō* (Agricultural Meteorology) 49, no. 4 (1994): 263-72; Aono, "Sakura no kaika no kisetu suii" (Seasonal Trends of Cherry Blossoms), *Kikō eikyō, riyō kenkyūkai kaihō* (Bulletin of Research Group on Climate Influence and Use) 19 (2001): 15-20; and Aono, "Kyōto no kokiroku o mochiita sakura no kaikabi no fukugen to kion e no yomikae" (Reconstruction of Cherry Bloom Dates Using Old Records from Kyoto and Their Conversion into Temperatures), in *Kikōgaku to rekishigaku no sōgū* (*Higashi Ajia kankyōshi, kikō hendō kokusai shinpojiumu hōkokusho*) (The Encounter of Climatology and History [Proceedings of the International Symposium on East Asian Environmental History and Climate Change]), ed. Tsukahara Tōgo, Mikami Takehiko, and Naitō Tomoko (Kobe: Tsukahara Tōgo, 2003), 27-41.

March temperatures for Kyoto going back more than 1200 years to 801 CE. Climatic reconstruction based on the dates of cherry blooms has also been attempted for Kanazawa (by Kawamura) and Tokyo (by Aono) but only since the early nineteenth century, presumably for lack of suitable earlier data.¹¹

b. Snow ratio and snow cover

Diaries also contain useful information on precipitation, including snowfall. Yamamoto, Maejima, and others have computed the “snow days ratio” (the ratio of snowy days to total days with precipitation during the winter months) for various sequences of years (again, mainly for Kyoto).¹² The basic idea is that higher snow ratios reflect colder winter

¹¹ Aono, “Climatic Change in March Temperature Deduced from Phenological Record for Flowering of Cherry Tree in Tokyo since the Late 18th Century,” *Bulletin of Osaka Prefectural University, Series B* 50 (1998): 11-19; Takeshi Kawamura, “Estimation of Climate in the Little Ice Age Using Phenological Data in Japan,” in *Proceedings of the International Symposium on the Little Ice Age Climate*, ed. T. Mikami (Tokyo: Editorial Committee of LIAC Proceedings, Department of Geography, Tokyo Metropolitan University, 1992), 52-57.

¹² Yamamoto, “Rekishi no nagare ni sou Nihon to sono shūhen no kishō no henshen”; Yamamoto, “On the Climate Change”; Yamamoto, “On the Nature of the Climatic Change”; Yamamoto, “On the Nature of the Japanese Climate”; Yamamoto, *Kikō no kataru*; Yamamoto, “Kikō to rekishi” (Climate and History), in *Kikō to bunmei, kikō to rekishi* (Climate and Civilization, Climate and History), ed. Suzuki Hideo and Yamamoto Takeo (Tokyo: Asakura shoten, 1978), 71-144; Yamamoto, “A.D. 1-1600 nen no Nihon

temperatures. Another rough guide to mean winter temperatures is the date of first or last appearance of snow cover on selected hills or mountains. This approach was used by Yamamoto for Mt. Kurakake in Yamanashi, northern Honshu, and by Yaji and Misawa for Mt. Iwaki in Aomori, also northern Honshu.¹³

c. Freezing of lakes and rivers

Also indicative of winter temperatures are the dates of freezing or thawing of rivers or lakes. Yamamoto used records of freezing of the Yodo and Saho Rivers in the Kansai area to argue for the existence of cold winters in the early eighth century.¹⁴ However, by far the best source of information on winter freezes comes from Lake Suwa in Nagano, for which a

(seinan Nihon Kyōto-shi) no kikō henka” (Climate Change in Japan [Kyoto City, Southwest Japan], A.D. 1-1600), *Kishō kenkyū nōto* (Meteorological Research Notes) 147 (1983): 627-39; Ikuo Maejima, “Some Remarks on the Climatic Conditions of Kyoto During the Period from 1474 to 1533 A.D.,” *Geographical Reports of Tokyo Metropolitan University* 1 (1966): 103-11; and Ikuo Maejima and Yoshio Tagami, “Climatic Change During Historical Time in Japan — Reconstruction from Climatic Hazard Records,” *Geographical Reports of Tokyo Metropolitan University* 21 (1986): 157-71.

¹³ Yamamoto, “On the Nature of the Climatic Change” and “On the Nature of the Japanese Climate”; Yaji Masataka and Misawa Meiko, “Tenpō kikin zengo no kikō ni kansuru ichikōsatsu / Some Notes on the Japanese Climates before and after the Tempo Lean Years, 1828-1844,” *Science Reports of the Yokohama National University: Section II, Biological and Geological Sciences* 28 (1981): 91-108.

¹⁴ Yamamoto, “On the Climate Change,” “On the Nature of the Climatic Change,” “On the Nature of the Japanese Climate,” and “A.D. 1-1600 nen no Nihon.”

near-continuous historical record (kept by officials at the lakeside Suwa Shrine) exists from the fifteenth century. Dates of freezing and “*omiwatari*” (literally, “divine crossing”), an unusual buckling of surface ice caused by geothermal circulation in the lake, have been used by Yamamoto and others to estimate mean winter temperatures for the region.¹⁵ Most recently, Mikami and coworkers used statistical comparisons with modern data to produce an absolute curve of mean winter temperatures going back to 1444 (Figure 1).¹⁶

¹⁵ Arakawa Hidetoshi, “5 seiki ni wataru Suwako omiwatari no kenkyū / On Five Centuries of Freezing Dates of Lake Suwa (36° N, 138° E) in the Central Japan,” *Chigaku zasshi / Journal of Geography* 63, no. 4 (1954): 1-8; Arakawa, “Fujiwara Sakuhei hakase ikō ‘Suwako keppyō kijitsu narabi ni omiwatari kijitsu nippyō’ ni tsuite / Fujiwhara on Five Centuries of Freezing Dates of Lake Suwa (36° N, 138° E) in the Central Japan,” *Chūō kishōdai kenkyū jihō / Journal of Meteorological Research* 6, no. 5 (1954): 138-46; Yamamoto, “On the Climate Change” and “A.D. 1-1600 nen no Nihon”; Minoru Tanaka and Masatoshi M. Yoshino, “Re-Examination of the Climatic Change in Central Japan Based on Freezing Dates of Lake Suwa,” *Weather* 37 (1982): 252-59.

¹⁶ T. Mikami and Y. Tsukamura, “The Climate of Japan in 1816 as Compared with an Extremely Cool Summer Climate in 1783,” in *The Year without a Summer? World Climate in 1816*, ed. C.R. Harrington (Ottawa: Canadian Museum of Nature, 1992), 462-75; Mikami Takehiko and Ishiguro Naoko, “Suwako ketsuei kiroku kara mita kako 550 nenkan no kikō hendō” (Climate Change during the Past 550 Years as Seen from Records of Freezing of Lake Suwa), *Kishō kenkyū nōto* (Meteorological Research Notes) 191 (1998): 73-83; Mikami, “Quantitative Climatic Reconstruction in Japan Based on Historical Documents,” *Kokuritsu rekishi minzoku hakubutsukan kenkyū hōkoku / Bulletin of the National Museum of Japanese History* 81 (1999): 41-50; Mikami, “Summer and Winter Temperature Reconstructions in Japan,” *PAGES News* 10, no. 3 (2002): 17-18; Mikami, “Kako 1000 nenkan no kikō hendō to 21 seiki no kikō yosoku / Global Climatic Variations for the Last 1000 Years and Their Prospects in Future,” *Chiri zasshi / Journal of Geography* 114, no. 1 (2005): 91-96.

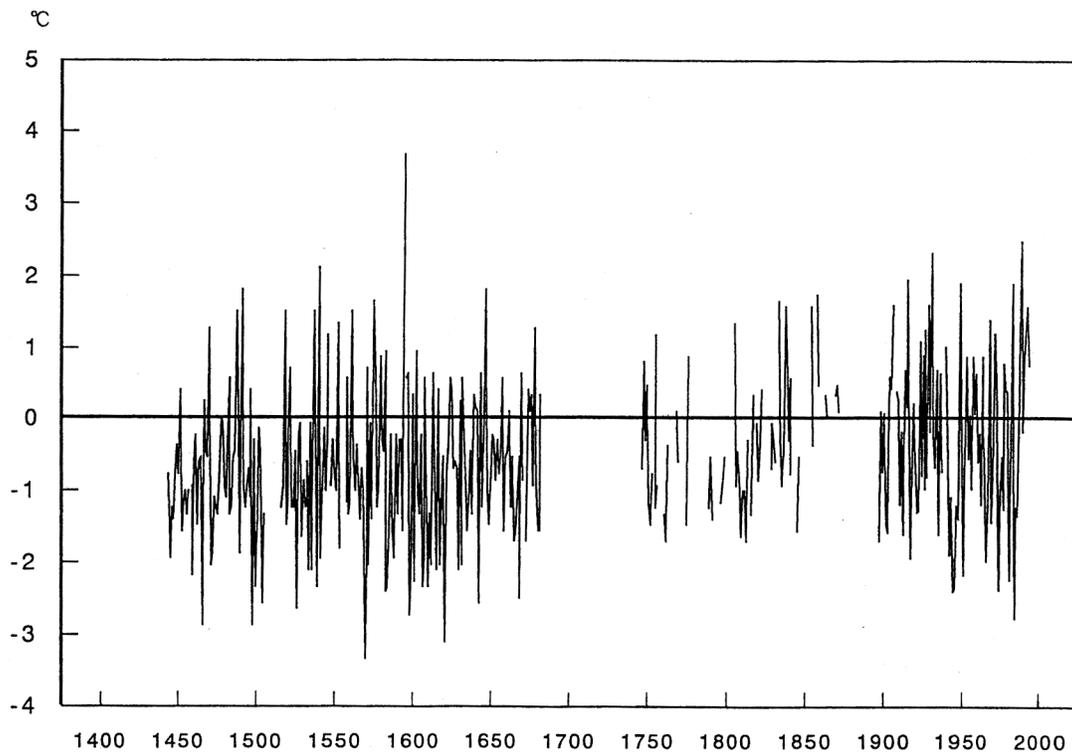


Figure 1. December-January Temperatures at Lake Suwa,
1444-1870 (Reconstructed) and 1891-1995 (Observed)

Source: Takehiko Mikami, “Quantitative Climatic Reconstruction in Japan Based on Historical Documents,”
*Kokuritsu rekishi minzoku hakubutsukan kenkyū hōkoku / Bulletin of the National Museum of Japanese
History* 81 (1999): 47. Used with permission.

d. Precipitation frequency

Summer temperatures have also been estimated on the basis of comparisons with modern data. The earliest work in this area was, again, by Yamamoto¹⁷, but the best recent research

¹⁷ Yamamoto, “On the Climate Change,” “On the Nature of the Climatic Change,” and “On the Nature of the Japanese Climate.”

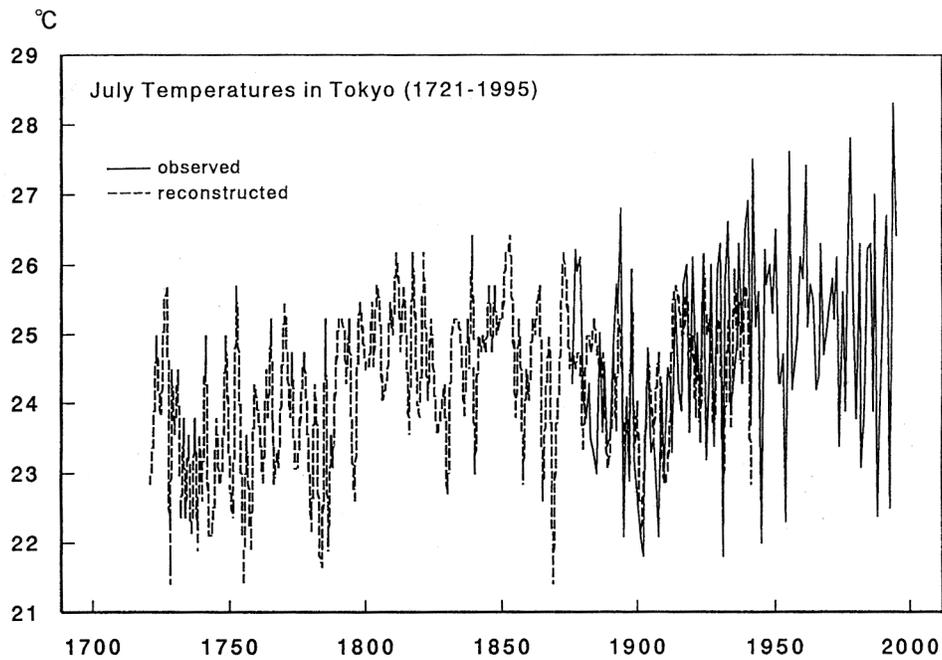


Figure 2. July Temperatures in Tokyo, 1721-1995

Source: Takehiko Mikami, “Quantitative Climatic Reconstruction in Japan Based on Historical Documents,” *Kokuritsu rekishi minzoku hakubutsukan kenkyū hōkoku / Bulletin of the National Museum of Japanese History* 81 (1999): 45. Used with permission.

is by Mikami. Modern instrumental data show a negative correlation between frequency of summer precipitation and mean summer temperature in Tokyo; Mikami combined this data with information on rainfall from Edo-period sources to produce an absolute curve of summer temperatures going back to 1721 (Figure 2).¹⁸

¹⁸ Mikami, “Climate Variations in Japan During the Little Ice Age – Summer Temperature Reconstructions since 1771 –,” In *Proceedings of the International Symposium on the Little Ice Age Climate*, ed. Mikami, 176-81; Mikami, “Nikki tenkō kiroku kara suitei shita

3. Natural Proxies

As interesting as these techniques may be, they retain the limitations of the sources on which they are based. Historical data are subjective and increasingly fragmentary the farther we go back in time, disappearing for all practical purposes around 700 CE. For more objective, complete data on historical periods, and for any data at all on earlier periods, we must turn to physical evidence, that is, to natural proxies. Some of the more important natural proxies that have been used by to reconstruct Japanese climate are described below.

a. Pollen

As in many other countries, the first scientific studies of past climates in Japan made use of fossil pollen. Although various researchers have contributed, by far the most important body of work is by Sakaguchi, who (like Mikami) worked at Tokyo Metropolitan

shōhyōki kōhan no kaki onhendō / Summer Temperature Variabilities in Japan Reconstructed from Diary Weather Records During the Little Ice Age,” *Chiri zasshi / Journal of Geography* 102, no. 2 (1993): 144-51; Mikami, “Long Term Variations of Summer Temperatures in Tokyo since 1721,” *Geographical Reports of Tokyo Metropolitan University* 31 (1996): 157-65; Mikami, “Quantitative Climatic Reconstruction”; Mikami, “Summer and Winter”; and Mikami, “Kako 1000 nenkan.”

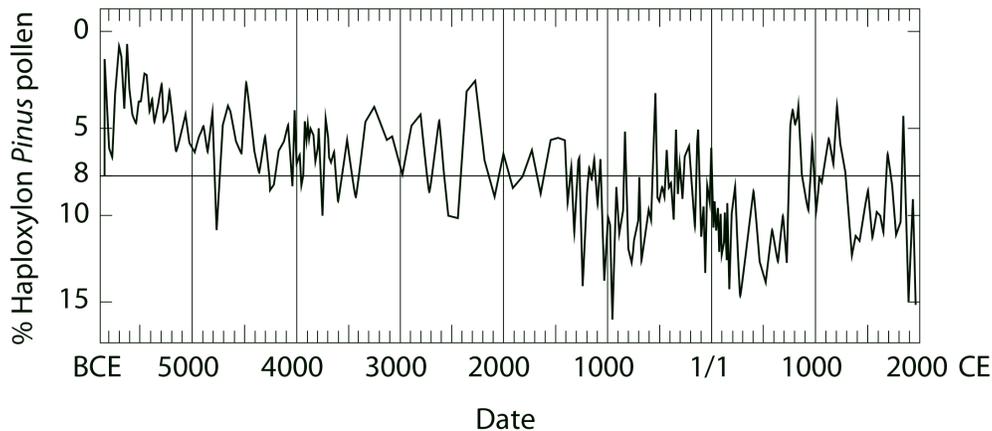


Figure 3. Temperature Reconstruction
Based on Pine Pollen from Ozegahara (Full Sequence)

Source: Redrawn from Sakaguchi Yutaka, “Kako 8000 nen no kikō henka to ningen no rekishi” (Climate Change and Human History during the Past 8000 Years), *Senshū jinbun ronshū* (Senshū University Essays in the Humanities) 51 (1993): 86.

University for most of his career. In an important series of papers, Sakaguchi analyzed

pollen from a 450 cm peat column collected from a pit dug at Ozegahara Moor in 1973.¹⁹

¹⁹ Except as otherwise noted, information in this and the following paragraph come from Yutaka Sakaguchi, “Warm and Cold Stages in the Past 7600 Years in Japan and Their Global Correlation — Especially on Climatic Impacts to the Global Sea Level Changes and the Ancient Japanese History —,” *Bulletin of the Department of Geography, University of Tokyo* 15 (1983): 1-31. Other important works by the same author are: “Climatic Variability During the Holocene Epoch in Japan and Its Causes,” *Bulletin of the Department of Geography, University of Tokyo* 14 (1982): 1-27; “Nihon no senshi, rekishi jidai no kikō: Ozegahara ni kako 7600 nen no kikō henka no rekishi o saguru” (Climate in Japanese Prehistory and History: Searching at Ozegahara for the History of Climate Change during the Past 7,600 Years), *Shizen* (Nature) 39, no. 5 (1984): 18-36; *Ozegahara no shizenshi* (Natural History of Ozegahara), Chūkō shinsho (New Books from Chūō Kōron), No. 928 (Tokyo: Chūō kōronsha, 1989); and “Kako 8000 nen no kikō henka to ningen no rekishi” (Climate Change and Human History during the Past 8000 Years), *Senshū jinbun*

(Ozegahara, the largest raised bog in Japan, is located approximately 150 km north of Tokyo in the mountains of Gunma.)

For his analysis, Sakaguchi sliced the column in sections of 2 cm in thickness before extracting and identifying the enclosed pollen grains. He obtained ^{14}C dates at intervals of 50 cm and calibrated them using the known dates of four intercalated layers of tephra (volcanic ash). The total record extended back about 8000 years. Sakaguchi based his analysis on pine pollen, which fell into two types, spherical (Diploxylon) and hemispherical (Haploxylon). The Haploxylon pollen were ascribed to *Pinus pumila* and *P. parviflora*, two cold-adapted species currently found on the slopes of nearby Mt. Shibutsu.

The average proportion of Haploxylon pollen among total pine pollen across the entire interval was 8%. Samples containing more than 8% were interpreted by Sakaguchi as representing cooler intervals, and those with less as representing warmer ones (Figures 3, 4).

The general validity of this approach was confirmed by the tendency of Haploxylon pollen frequencies to fluctuate in parallel with those of pollen from cold-loving conifer genera

ronshū (Senshū University Essays in the Humanities) 51 (1993): 79-113.

such as *Abies* (fir), *Picea* (spruce), and *Tsuga* (hemlock). According to Sakaguchi, average annual temperatures at Ozegahara varied on the order of ± 3 °C over the period in question.²⁰ To this day, Sakaguchi’s work on the Ozegahara peat column remains unique in Japan for its chronological depth and completeness.

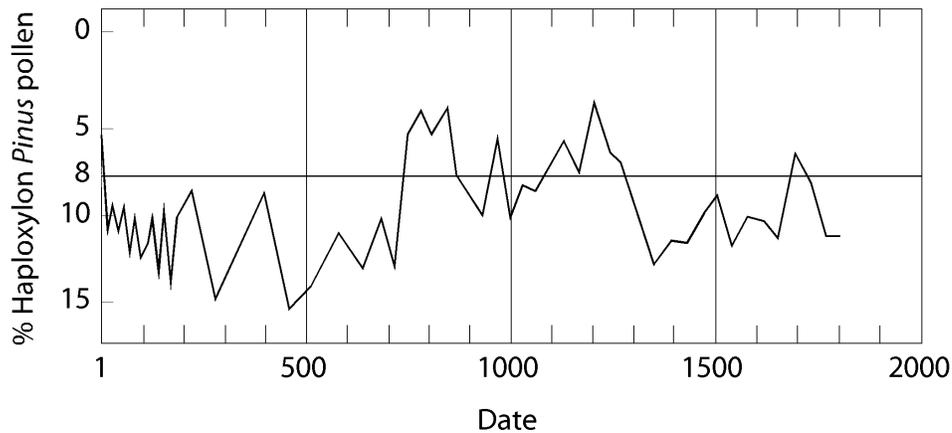


Figure 4. Temperature Reconstruction

Based on Pine Pollen from Ozegahara (Last Two Millennia)

Source: Redrawn from Sakaguchi Yutaka, “Kako 8000 nen no kikō henka to ningen no rekishi” (Climate Change and Human History during the Past 8000 Years), *Senshū jinbun ronshū* (Senshū University Essays in the Humanities) 51 (1993): 86.

²⁰ Sakaguchi, “Kako 8000 nen,” 80.

b. Tree rings

Important information about past climates can also be obtained from tree rings.

Dendroclimatological studies in Japan have been based on physical characteristics such as width and density of tree rings, as well as chemical characteristics such as the ratio of stable carbon isotopes. All of these are affected in complex ways by climate and other variables.

Let us begin with isotope ratios.

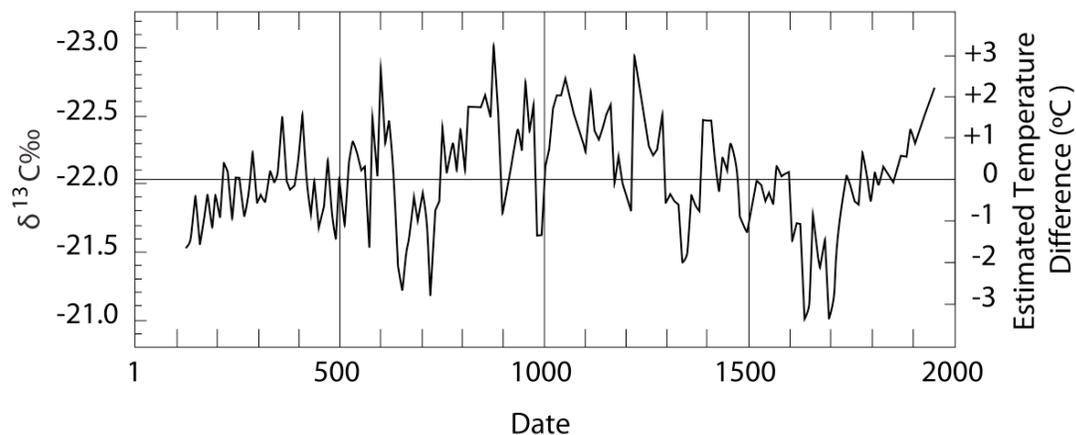


Figure 5. Temperature Reconstruction
Based on $\delta^{13}\text{C}$ from Yaku Island Cedar

Source: Redrawn from Kitagawa Hiroyuki, “Yakusugi ni kizamareta rekishi jidai no kikō hendō” (Climate Change during the Historical Period as Inscribed in Yaku Cedars), in *Rekishi to kikō* (History and Climate), ed.

Yoshino Masatoshi and Yasuda Yoshinori, vol. 6 of *Kōza: Bunmei to kankyō* (Lectures on Civilization and Environment) (Tokyo: Asakura shoten, 1995), 50.

Probably the best-known dendroclimatological study in Japan is that by Kitagawa and Matsumoto, who examined carbon isotopes in giant Japanese cedars (*sugi*; *Cryptomeria japonica*) on Yaku Island to the south of Kyushu. These authors measured $\delta^{13}\text{C}$, that is, the ratio of ^{13}C to ^{14}C expressed in parts per thousand (‰), from tree cellulose in modern cedars on the island. They found that $\delta^{13}\text{C}$ was highly dependent on elevation, and hence average annual temperature. (Specifically, $\delta^{13}\text{C}$ increased as temperatures went down and decreased as they went up.) Although other factors, including precipitation, physiology, and light intensity, also affect $\delta^{13}\text{C}$ values, these were fairly uniform across the area of study and could safely be ignored. Kitagawa and Matsumoto then applied the observed relationship between $\delta^{13}\text{C}$ and temperature to a core taken from a giant ancient cedar growing on the same island, measuring $\delta^{13}\text{C}$ for every tenth successive tree-ring to create a reconstruction of temperatures fluctuations in Yaku over the past two millennia (Figure 5).²¹ Although the time depth in this study is significantly less than in Sakaguchi's

²¹ Kitagawa Hiroyuki, "Yakusugi ni kizamareta rekishi jidai no kikō hendō" (Climate Change during the Historical Period as Inscribed in Yaku Cedars), in *Rekishi to kikō*, ed. Yoshino and Yasuda, vol. 6 of *Kōza: Bunmei to kankyō* (Lectures on Civilization and Environment) (Tokyo: Asakura shoten, 1995), 47-55; H. Kitagawa and E. Matsumoto,

palynological work, the resolution is much better because tree rings are annual and can be counted with minimal risk of error.

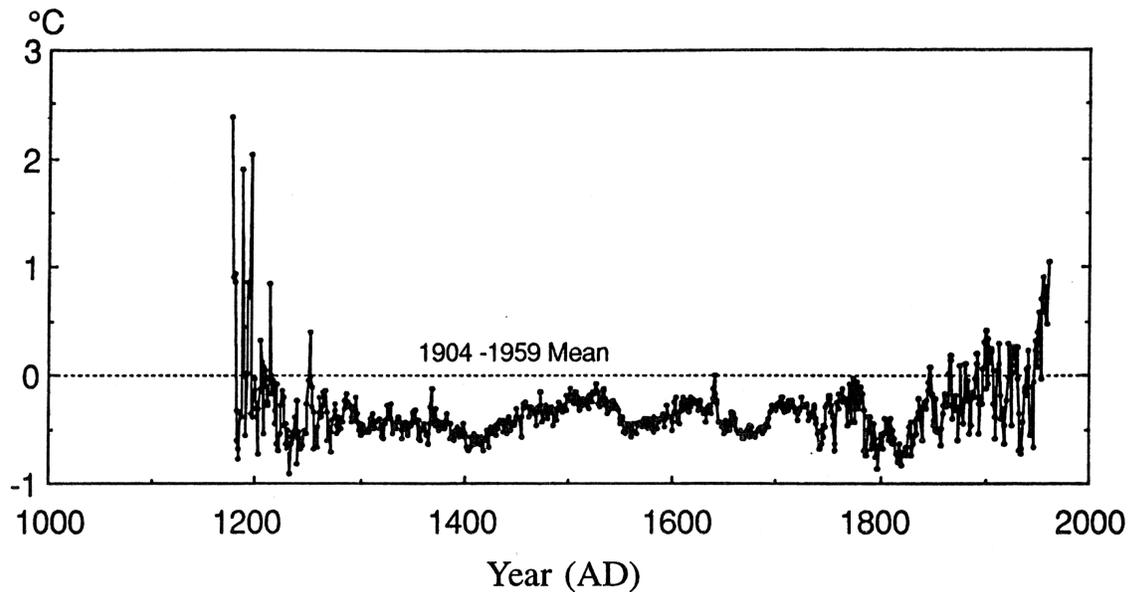


Figure 6. Temperature Reconstruction
Based on Kiso Cypress Tree-Ring Widths

Source: Tatsuo Sweda, "Dendroclimatological Reconstruction for the Last Sub-Millennium in Central Japan," *Terrestrial, Atmospheric and Oceanic Sciences* 5, no. 3 (1994): 440. Use authorized by publisher.

"Carbon-Isotope Variation within Trunks of Japanese Cedars from Yakushima Islands, Southern Japan," *Geochemical Journal* 29, no. 2 (1995): 149-53; Kitagawa and Matsumoto, "Climatic Implications of $\delta^{13}\text{C}$ Variations in a Japanese Cedar (*Cryptomeria japonica*) during the Last Two Millennia," *Geophysical Research Letters* 22, no. 16 (1995): 2155-58; and Kitagawa and Matsumoto, "Yakusugi nenrin no tanso dōitaihi hendō kara suitei sareru kako 2000 nenkan no kikō hendō" (Climate Change during the Past 2000 Years as Inferred from Carbon Isotope Variations in Tree Rings of Yaku Cedars), *Kishō kenkyū nōto* (Meteorological Research Notes) 191 (1998): 1-13.

There is also some Japanese research based on physical characteristics of tree rings such as width and density. Of particular note are several papers by Sweda, who studied Japanese cypress (*hinoki*; *Chamaecyparis obtusa*) trees from Kiso in the mountains of central Honshu. Sweda first established an empirical correlation between winter temperature and width of tree-rings in modern cypress. Then he went on to apply these results to disks and cores from about 200 medieval and early modern logs lying in the same forest. The result was a detailed temperature curve going back to 1177 CE (Figure 6).²² Similar studies, with somewhat less impressive results, have been published by Kobayashi and coworkers for fir (*Abies*) and by D'Arrigo and coworkers for oak (*Quercus*).²³ Another

²² Sweda, Tatsuo. "Dendroclimatological Reconstruction for the Last Sub-Millennium in Central Japan," *Terrestrial, Atmospheric and Oceanic Sciences* 5, no. 3 (1994): 431-42. Also see Sweda, "Little Ice Age Climate of Central Japan as Revealed by Dendroclimatological Reconstruction," in *Proceedings of the International Symposium on the Little Ice Age Climate*, ed. Mikami, 34-39; and Tatsuo Sweda and Shinichi Takeda, "Construction of an 800-Year-Long *Chamaecyparis* Dendrochronology for Central Japan," *Dendrochronologia* 11 (1994): 79-86. Sweda refers to the trees in his sample as "Japanese cedar," but here I use the more standard English translation to avoid confusion with *sugi* or *Cryptomeria*.

²³ O. Kobayashi, Y. Abe, and T. Sweda, "Construction of a Tree-Ring-Width Chronology for the Ishizuchi Range, Japan," in *Proceedings of the International Conference on Climate Change and Variability*, ed. Mikami, 127-32; R.D. D'Arrigo, D.K. Yamaguchi, G.C. Wiles, G.C. Jacoby, A. Osawa, and D.M. Lawrence, "A Kashiwa Oak (*Quercus dentata*) Tree-Ring Width Chronology from Northern Coastal Hokkaido, Japan," *Canadian Journal of Forestry Research* 27 (1997): 613-17.

approach is represented by the research of Yasue and coworkers, who found that the density of spruce (*Picea*) tree-rings correlated positively with summer temperatures and used this result to calculate temperatures in northern Japan going back to 1750.²⁴

c. Borehole temperatures

To the layman, possibly the most bizarre scientific approach to climatic reconstruction involves the measurement of actual temperatures at different depths in boreholes.²⁵ The basic idea is that temperature at a given depth is a function of surface temperature, thermal conductivity distribution, and heat flow from below. If measured temperatures differ from what would be predicted based on these factors, it is argued, the deviation reflects variations in past surface temperatures, whose effects have propagated downward in proportion to elapsed time. As even its practitioners admit, borehole temperature analysis

²⁴ Koh Yasue, Ryo Funada, and Yoshihiro Nobori, “Tree-Ring Data Obtained by Densitometric Analysis as Indicators for Past Climate Reconstruction in Northern Japan,” in *Proceedings of the International Conference on Climate Change and Variability*, ed. Mikami, 121-26.

²⁵ Note that this technique differs from the others discussed here in that “temperature itself is being measured, not a proxy for temperature”: Committee on Surface Temperature Reconstructions for the Last 2,000 Years, *Surface Temperature Reconstructions for the Last 2,000 Years*, 78.

has rather poor resolution – centuries, as opposed to decades or years. Nonetheless, it can be useful in confirming long-scale climatic trends.

In Japan, borehole temperatures have been the subject of several studies. Perhaps the most ambitious was by Gotō and coworkers, who recorded temperatures within a 920 m borehole at Karasuma on the southeastern coast of Lake Biwa, central Honshu, and then used the data to reconstruct surface temperature trends for the past 3000 years (Figure 7). Although the analysis produced credible results (showing, among other things, effects due to the Medieval Warm Period and the Little Ice Age), the researchers found somewhat greater temperature disparities than they expected. They attributed this to tectonic movement, specifically earthquakes that had alternately drowned and exposed the location of the borehole relative to the surface of the lake.²⁶ In addition to the work by Gotō and coworkers, a number of rather crude reconstructions going back to 1500 have been

²⁶ Shusaku Goto, Hideki Hamamoto, and Makoto Yamano, “Climatic and Environmental Changes at Southeastern Coast of Lake Biwa over Past 3000 Years, Inferred from Borehole Temperature Data,” *Physics of the Earth and Planetary Interiors* 152, no. 4 (2005): 314-25. The invocation of tectonic movement seems somewhat strained to me.

published online by Taniguchi.²⁷

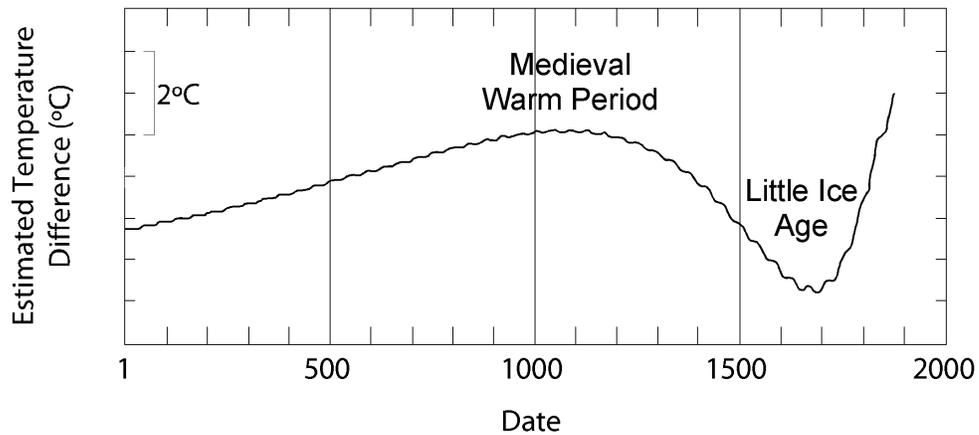


Figure 7. Temperature Reconstruction Based on Borehole Temperatures at Lake Biwa (Last Two Millennia)

Source: Redrawn and modified from Shusaku Goto, Hideki Hamamoto, and Makoto Yamano, “Climatic and Environmental Changes at Southeastern Coast of Lake Biwa over Past 3000 Years, Inferred from Borehole Temperature Data,” *Physics of the Earth and Planetary Interiors* 152, no. 4 (2005): 321.

d. Lake sediments

Other data related to paleoclimates comes from sediment cores from lakes, which can be dated by counting annual varves or, more typically, by AMS (accelerator mass

²⁷ Available in the Borehole Temperatures and Climate Reconstruction Database maintained by Shaopeng Huang at the University of Michigan: <http://www.geo.lsa.umich.edu/climate/ASI.html>

spectrometry) radiocarbon. Researchers record geochemical or sedimentological features of the sample at various depths, and then attempt to relate observed variations to climatic fluctuations, such as temperature, in the past. In Japan, some of the more illuminating studies using lake cores were by Fukusawa for Lake Suigetsu (Fukui) and Lake Mikurigaike (Toyama), both on the Sea of Japan coast of Honshu, and by Adhikari and Kumon for Lake Nakatsuna (Nagano) in the mountains of central Honshu.²⁸

e. Other

Other proxies abound, for example variations in annual bands in coral, which were used by

²⁸ Fukusawa Hitoshi and Yasuda Yoshinori, “Suigetsuko no sairyū taisekibutsu de kenshutsu sareta kako 2000 nenkan no kikō hendō” (Climate Change during the Past 2000 Years as Recovered from Fine-Grained Sediments from Lake Suigetsu), *Rekishī to kikō*, ed. Yoshino and Yasuda, 26-46; Fukusawa, “Koshō nenkō taisekibutsu ni yoru chūsei ondanki no kikō hendō to tozan katsudō no kaishi / Onset of Mountain Climbing Caused by Climate Warming since the Medieval Warm Period: Investigation from Varved Lacustrine Sediments,” *Gekkan chikyū* 27, no. 9 (2005): 665-72; and D.P. Adhikari and F. Kumon, “Climatic Changes During the Past 1300 Years as Deduced from the Sediments of Lake Nakatsuna, Central Japan,” *Limnology* 2, no. 3 (2001): 157-68. Also see Megumi Kato, Osamu Fujiwara, and Yoshinori Yasuda, “Non-Glacial Varved Sediments in Lake Tougou-Ike, Western Japan and High Resolution Relationships between Global Climate and Sea-Level Changes During the Holocene,” in *Proceedings of the International Conference on Climate Change and Variability*, ed. Mikami, 267-70; and Fujio Kumon, Rie Ohno, Toshikazu Sakai, Sanae Sakami, and Jun’ichi Sakai, “Climatic Records During the Last 40,000 Years in Lake Nojiri, Central Japan,” in *Proceedings of the International Conference on Climate Change and Variability*, ed. Mikami, 41-44.

Morimoto and coworkers to calculate ancient sea surface temperatures for the waters around Kikai Island, south of Kyushu.²⁹ But enough on methodology; it is now time to turn to the results of the various studies described above and what they imply for human history in Japan.

III. Climate in Japanese History and Prehistory

After such a lengthy buildup, it is perhaps anticlimactic to report that most studies conducted in Japan, whether using historical or natural proxies, simply confirm what is already known about global climatic trends.³⁰ Of course, there are many short-term

²⁹ Maki Morimoto, Hajime Kayanne, Nobuyuki Yonekura, Osamu Abe, Ching-Hsin Chiu, and Eiji Matsumoto, “Sea Surface Temperature around 6000 Years Ago: Reconstructed by Coral Annual Bands from Kikai Island in the Subtropical Northwestern Pacific,” in *Proceedings of the International Conference on Climate Change and Variability*, ed. Mikami, 29-33.

³⁰ On which, see: Richard Alley, *The Two-Mile Time Machine: Ice Cores, Abrupt Climate Change, and Our Future* (Princeton, N.J.: Princeton University Press, 2003); Burroughs, *Climate Change in Prehistory*; Dunbar, “Climate Variability”; Committee on Surface Temperature Reconstructions for the Last 2,000 Years, *Surface Temperature Reconstructions for the Last 2,000 Years*; William F. Ruddiman, *Plows, Plagues & Petroleum: How Humans Took Control of Climate* (Princeton: Princeton University Press, 2005); and Ruddiman, *Earth's Climate: Past and Future*, 2^d ed. (New York, NY: W.H. Freeman and Co., 2008).

discrepancies. But what concern us here are the long-term trends, and for these, the Japanese results are similar to those from other temperate regions of the northern hemisphere. This is reassuring, because otherwise one would either have to doubt the validity of the Japanese studies, or look for an explanation of why Japan should be climatically unique.

What, then, are these broad, long-term features? At the crudest level, the northern hemisphere experienced rapid warming after about 14,500 BP, followed by a brief return to near-glacial conditions between roughly 12,900 and 11,600 BP (the so-called Younger Dryas), followed in turn by a long period of relative climatic stability (the Holocene) lasting until the present. The term “relative” is important, because the Holocene has also been punctuated by several climatic fluctuations, minor in absolute terms, but important to the people living through them. Among the more recent events were periods of marked cooling during the first millennium BCE and the first millennium CE; the so-called Medieval Warm Period; the Little Ice Age; and the recent period of anthropogenic warming.

Sakaguchi, based on his observations of these and other trends in the pollen samples

from Ozegahara, proposed a climatic periodization of Japanese prehistory and history.³¹

Although his scheme has much to recommend it, some modifications are called for in order to highlight the complex interaction between climate and human society.

For purposes of the following discussion, I have divided the period of human habitation in Japan into eight stages. These stages are based primarily on climatological trends, which are not unique to Japan. However since the purpose of the discussion is to highlight the interplay between climate and society in the Japanese islands, I have taken Japanese archeological and historical developments into account when that seemed appropriate. For each stage, I give a brief description of climatic conditions and then offer some speculations on how these may or may not relate to important social or historical trends. In the end, as shall be seen, we are left with many questions and few definite answers.

³¹ See works cited in note 19, above.

1. 35,000–14,500 BCE

The first human occupation of the Japanese islands took place during the last Ice Age.

Local temperatures were considerably lower than today, as attested by pollen and other fossil evidence. (Another potential, although largely unexploited, source of information is the 40,000-year sequence of varves from Lake Suigetsu on the Sea of Japan coast.³²)

Although popular works often convey the impression that the Japanese islands were connected to the Asian continent by “land bridges” during the Ice Age, this idea appears to be false except for the case of Hokkaido.³³ An important corollary is that the first people to arrive in the other Japanese islands must have done so by boat, as was the case in Australia, which was settled as early as 60,000 BP.

The date of initial human occupation of Japan has been the object of much scholarly

³² H. Kitagawa J. van der Plicht, “A 40,000 Year Varve Chronology from Lake Suigetsu, Japan: Extension of the Radiocarbon Calibration Curve,” *Radiocarbon* 40 (1998): 505-16.

³³ S.-C. Park, D.-G. Yoo, C.-W. Lee, and E.-I. Lee, “Last Glacial Sea-Level Changes and Paleogeography of the Korea (Tsushima) Strait,” *Geo-Marine Letters* 20, no. 2 (2000): 64-71; Kawada Shin’ichirō, “Nihon rettō no ho’nyūri” (Mammals of the Japanese Archipelago), in *Nihon rettō no shizenshi* (Natural History of the Japanese Archipelago), ed. Kokuritsu hakubutsukan (National Museum) (Tokyo: Tōkai daigaku shuppankai [Tōkai University Press], 2006), 94-97.

confusion, thanks to a series of spectacular frauds perpetrated in the late twentieth century by Fujimura Shin'ichi, a rogue amateur archaeologist. At present, the oldest actual human remains are the femur and humerus of a child of 6 or 7 that were discovered at Yamashita-chō Cave in Okinawa in 1986.³⁴ These have been radiometrically dated to 32,000 BP, which in terms of actual calendar years probably works out to a few thousand years earlier. (Currently, calibration for ¹⁴C dates extends back only to 26,000 BP.) A date in this general range makes very good sense in the context of what is known about the spread of anatomically modern humans in other parts of Asia and Oceania.³⁵ Note that this was considerably before the LGM, meaning that humans first came to the islands before sea levels reached their minimum.

³⁴ Baba, "Nihon rettō no kyūsekki jin," in *Nihon rettō no shizenshi*, ed. Kokuritsu hakubutsukan, 263-75; Mark J. Hudson, "Japanese Beginnings," in *A Companion to Japanese History*, ed. William M. Tsutsui (Malden, MA: Blackwell Publishing, 2007), 15-17.

³⁵ Research on this topic continues to expand exponentially; for a good recent overview (based largely on genetic research) see Oppenheimer, *The Real Eve*.

2. 14,500-1000 BCE

As noted above, the LGM came to an end around 18,000 BP. Temperatures oscillated and then warmed very dramatically around 14,500 BP (the “Bølling warming”). Then, between 12,900 and 11,600 BP, there was a return to near-glacial conditions (the “Younger Dryas”) when a massive burst of freshwater from Lake Agassiz temporarily shut down the Gulf Stream. (Lake Agassiz, in what is now eastern Canada, had formed from the melting of the Laurentide Ice Sheet.) Following the resumption of thermohaline circulation in the Atlantic, temperatures rose again until around a second pulse of meltwater from Lake Agassiz caused them to plummet between 8200 and 8000 BP. This so-called “8.2 ka event” was followed by the Holocene “climatic optimum” or “hypsithermal” of around 6000 BP, when average temperatures in the Northern hemisphere were several degrees above contemporary levels.³⁶ In Japan, according to Sakaguchi’s pollen data, the hottest period was between

³⁶ On these changes, see Fagan, *The Long Summer*; and Burroughs, *Climate Change in Prehistory*. Quite recently, a team of scientists has argued that the onset of the Younger Dryas resulted from extraterrestrial impacts in North America. This does not necessarily negate the “meltwater” hypothesis, as the impacts are said to have destabilized the Laurentide Glacier. See R.D. Firestone, A. West, J.P. Kennett, L. Becker, T.E. Bunch, Z. S. Revay, P. H. Schultz, T. Belgia, D.J. Kennett, J.M. Erlandson, O.J. Dickenson, A.C. Goodyear, R.S. Harris, G.A. Howard, J.B. Kloosterman, P. Lechler, P.A. Mayewski, J.

5871 and 4360 BCE.³⁷ (Sea levels also rose as the result of global warming and isostatic effects, culminating in the so-called “Jōmon Transgression” of c. 6500-5000 BCE.³⁸) In general, the climate remained warm until about 1000 BCE, although the pollen data for Japan show another brief cold spell between 2587 and 2409 BCE.³⁹

This period under discussion corresponds archaeologically to the Jōmon culture, distinguished from the Paleolithic culture that preceded it by the appearance of fixed settlements and what is apparently the world’s oldest pottery. The origins of the pottery are a mystery, but that aside, most studies of the Jōmon culture link its emergence to climatic changes, specifically to early Holocene warming. Many older works give the impression that the Jōmon culture appeared around 10,000 BCE, but that is not correct; the first pottery

Montgomery, R. Poreda, T. Darrah, S.S. Que Hee, A.R. Smith, A. Stich, W. Topping, J.H. Wittke, and W. S. Wolbach, “Evidence for an Extraterrestrial Impact 12,900 Years Ago That Contributed to the Megafaunal Extinctions and the Younger Dryas Cooling,” *Proceedings of the National Academy of Sciences* 104, no. 41 (2008): 16016-21; and D.J. Kennett, J.P. Kennett, A. West, C. Mercer, S.S. Que Hee, L. Bement, T.E. Bunch, M. Sellers, and W.S. Wolbach, “Nanodiamonds in the Younger Dryas Boundary Sediment Layer,” *Science* 323, no. 5910 (2009): 94.

³⁷ Sakaguchi, “Warm and Cold Stages,” 11-16; Sakaguchi, “Kako 8000 nen,” 87-89. Note that these dates give an impression of greater accuracy than exists: Sakaguchi’s data by no means have an annual resolution.

³⁸ Junko Habu, *Ancient Jomon of Japan*, Case Studies in Early Societies (Cambridge: Cambridge University Press, 2004), 45-46.

³⁹ Sakaguchi, “Warm and Cold Stages,” 11-16; Sakaguchi, “Kako 8000 nen,” 87-89.

actually dates from around 14,500 BCE. Habu, in her discussion of this problem, notes that this date places the emergence of the Jōmon culture before the end of the last Ice Age, nullifying any explanation based on climatic warming per se. Habu herself thinks that climatic oscillation was the deciding factor.⁴⁰ Presumably, rapid oscillations in climate would have placed unusual demands on human society.

For comparative purposes, it is perhaps worthwhile to note that the transition from the Ice Age to the Holocene is associated with the “Neolithic Revolution” in the core areas of Eurasia. In the Near East, which is best known, the initial warming after the LGM was followed by the emergence of fixed settlements and early experiments with the domestication of animals and plants. Then, during the Younger Dryas, arid conditions forced a subsistence crisis that could only be solved by a full-scale conversion to agriculture.⁴¹

The Jōmon people in Japan must also have faced difficult times during the Younger

⁴⁰ Habu, *Ancient Jomon*, 26-42.

⁴¹ See Fagan, *The Long Summer*; Burroughs, *Climate Change in Prehistory*; and Peter Bellwood, *First Farmers: The Origins of Agricultural Societies* (Malden, MA: Blackwell Pub., 2005).

Dryas, but they did not turn to agriculture, possibly because the natural environment was so rich, or possibly for lack of suitable cultigens. Rice and other cereals (with the possible exception of barnyard millet) are not native to Japan, and while remains of these and other cultigens have been found at various Jōmon sites⁴², it is not clear (at least to me) whether any of these finds go back as far as the Younger Dryas. Their presence later in the period shows that the Jōmon people had at least some contacts with the Asian mainland and were familiar with the idea of agriculture. That they never went further than limited horticulture is perhaps further evidence for the basic richness of their environment, making the Jōmon the ultimate “affluent foragers.”⁴³

3. 1000 BCE-250 CE

Like the previous stage, this one too contains some dramatic fluctuations. On the whole,

⁴² Gary W. Crawford, “East Asian Plant Domestication,” in *Archaeology of Asia*, ed. Miriam T. Stark (Malden, MA: Blackwell Publishing, 2006), 77-95. Also see Habu, *Ancient Jomon*, 70-72; and Keiji Imamura, *Prehistoric Japan: New Perspectives on Insular East Asia* (Honolulu: University of Hawai‘i Press, 1996), 106-9. Imamura believes that buckwheat may be indigenous, although the consensus would seem to favor an origin in southern China.

⁴³ Shuzo Koyama and David H. Thomas, *Affluent Foragers*, Senri Ethnological Studies, No. 9 (Osaka: National Museum of Ethnology, 1981).

though, it represents a transition between the warm conditions of the post-glacial Jōmon era and the extremely cold conditions of the succeeding stage. According to Fagan, a reduction in solar activity led to widespread cooling in the first millennium BCE.⁴⁴ For Japan, the story is best told by the pollen record at Ozegahara.⁴⁵ First, there was a sudden, dramatic cooling around 1000 BCE, described by Sakaguchi as “the most important climatic turning point of the past 8000 years.”⁴⁶ Next, there was a return to warm, wet conditions from around 580 to 100 BCE. Finally, between 100 BCE and 250 CE there was a gradual deterioration of climate forming a prelude to the very cold conditions that prevailed after 250 CE.

In terms of human society, this stage corresponds to the Yayoi period, which was initiated by the arrival of agricultural colonists from the Asian continent.⁴⁷ Food production fueled rapid population growth among the immigrants, who replaced or

⁴⁴ Fagan, *The Long Summer*, 197-98.

⁴⁵ Sakaguchi, “Warm and Cold Stages,” 16-17; Sakaguchi, “Kako 8000 nen,” 87-89.

⁴⁶ Sakaguchi, “Kako 8000 nen,” 88.

⁴⁷ The literature on this topic is, of course, immense, but one essential reading in English is Mark J. Hudson, *Ruins of Identity: Ethnogenesis in the Japanese Islands* (Honolulu: University of Hawai‘i Press, 1999).

absorbed the indigenous Jōmon foragers throughout much of the archipelago. Agriculture also facilitated surplus accumulation, social stratification, and the concentration of political power in regional chiefdoms.

The beginning of the Yayoi period is traditionally dated to 300 or 400 BCE, which appears to make sense climatologically – after all, would not the warm, wet conditions prevailing at that time be conducive to the adoption of agriculture? However, AMS dating now shows that the Yayoi period began much earlier than previously believed, specifically, around 900 or 1000 BCE.⁴⁸ This is just after the beginning of a very cold phase, suggesting a possible causal relationship between climatic deterioration and the appearance of the new culture. Were the Yayoi immigrants fleeing from harsher conditions in the continent? We may never know. In any case, it seems likely that colder conditions in Japan were inimical to the Jōmon way of life, making food production an attractive and indeed necessary alternative for immigrants and perhaps indigenes alike. Although the situation in Japan is

⁴⁸ Harunari Hideji and Imamura Mineo, eds., *Yayoi jidai no jitsunendai: tanso 14 nendai o megutte* (Absolute Age of the Yayoi Period: Regarding Carbon 14 Dates) (Tokyo: Gakuseisha, 2004).

complicated by the factor of immigration, the notion of human populations being forced into agriculture by climatic deterioration is congruent with what is known about conditions in the Middle East during the Younger Dryas. Once agricultural society was firmly established, the later temporary warming of the climate may have had little effect, except to facilitate the spread of wet-rice farming into the colder regions of northern Honshu.

4. 250-700 CE

The next stage, referred to by Sakaguchi as the “Kofun Cold Stage,” was one of profound and sustained cooling.⁴⁹ According to the same author, this was the longest cold stage of the past 7600 years, and its intensity exceeded that of the more famous Little Ice Age.⁵⁰ The period was not only cold but also wet, at least judging from the flood deposits seen at various archaeological sites.⁵¹

Like the other stages discussed in this paper, the “Kofun Cold Stage” was not

⁴⁹ Sakaguchi, “Warm and Cold Stages,” 17-22; Sakaguchi, “Kako 8000 nen,” 89-91.

⁵⁰ Sakaguchi, “Warm and Cold Stages,” 19.

⁵¹ Sakaguchi, “Kako 8000 nen,” 90-91.

localized to Japan; temperate zones everywhere experienced dramatic cooling. The initial cooling may have resulted from volcanism, which was rampant during the third century.⁵²

Another factor seems to have been lower concentrations of atmospheric CO₂, which are reported from ice cores between around 200 and 600. Ruddiman, an eminent climatologist, ascribes the reduction in atmospheric CO₂ to heavy mortality in Eurasia from plague and other epidemic diseases. Specifically, he claims that large-scale population loss was accompanied by the reversion of cropland to forests, resulting in lower atmospheric concentrations of CO₂ and CH₄ (methane).⁵³ It remains to be seen whether this argument will stand the scrutiny of other climatologists and historians.

Whatever the initial cause of cooling, conditions were considerably worsened in 536 CE by a mysterious “dry fog” recorded in historical sources from the Mediterranean to China. Tree ring studies confirm that solar irradiation was reduced for an incredible fifteen

⁵² Joel D. Gunn, “A.D. 536 and Its 300-Year Aftermath,” in *The Years without Summer: Tracing A.D. 536 and Its Aftermath*, ed. Joel D. Gunn (Oxford: Archaeopress, 2000), 11-12. Note, however, that Committee on Surface Temperature Reconstructions for the Last 2,000 Years, *Surface Temperature Reconstructions for the Last 2,000 Years*, 104, Figure 10-3, does not seem to support this claim.

⁵³ Ruddiman, *Plows, Plagues & Petroleum*.

years. There is no scientific consensus on the nature of the 536 event, although the leading contenders are comet debris and the eruption of a supervolcano. In any case, the disaster led to widespread crop failures and social disruption in Eurasia, Africa, and the Americas.⁵⁴

Although clearly important, the 536 event has been the subject of exaggerated claims by some authors. A book-length study by Keys, for example, argues that “in a matter of decades, the old order died and a new world – essentially the modern world as we know it today – began to emerge.”⁵⁵ Regarding Japan, Keys states that the event of 536 caused famines that paved the way for the introduction of Buddhism, the Sinicization of Japan, and “ultimately the emergence of the Japanese nation.”⁵⁶ Needless to say, this claim is so broad as to be virtually devoid of meaning. That said, there is some indirect evidence of famine, specifically a reference in *Nihon shoki* to the establishment of public granaries in 536 as

⁵⁴ Joel D. Gunn, ed., *The Years without Summer: Tracing A.D. 536 and Its Aftermath*, Bar International Series, No. 872 (Oxford: Archaeopress, 2000). Also see Antti Arjava, “The Mystery Cloud of 536 CE in the Mediterranean Sources,” *Dumbarton Oaks Papers* 59 (2005): 73-94; M.G.L. Baillie, “Dendrochronology Raises Questions About the Nature of the A.D. 536 Dust-Veil Event,” *Holocene* 3 (1994): 212-17; Emma Rigby, Melissa Symonds, and Derek Ward-Thompson, “A Comet Impact in AD 536?,” *Astronomy & Geophysics* 45, no. 1 (2004): 23-26; and R.B. Stothers, “Mystery Cloud of A.D. 536,” *Nature* 307 (1984): 344-45.

⁵⁵ David Keys, *Catastrophe: An Investigation into the Origins of the Modern World* (New York: Ballantine Books, 1999), blurb on front cover flap.

⁵⁶ Keys, *Catastrophe*, 172-180; quotation from flow chart, 178.

(among other uses) a “preparation for evil years.”⁵⁷

Although it is difficult to make a case for the long-term effects of the 536 event per se on Japanese society, the “Kofun Cold Stage” as a whole is another matter. In terms of social development, the single most important feature of the four and a half centuries beginning in 250 CE was state formation, manifested archaeologically by the appearance of the huge tumuli or *kofun* for which the period is named.⁵⁸ I suggest, following earlier speculation by Sakaguchi⁵⁹, that state formation in the Japanese islands was at least in part a response to the cold, wet conditions prevailing at the time. The emergence of the Yamato polity is generally understood as the natural result of the growth in population and social complexity that accompanied the spread of agriculture in the preceding Yayoi period. There may be an element of truth to that, but just as the adoption of agriculture was probably “forced” by cold climate after 1000 BCE, so the emergence of a new level of social

⁵⁷ W.G. Aston, tr., *Nihongi: Chronicles of Japan from the Earliest Times to A.D. 697*, two volumes in one (Rutland, Vermont: Tuttle, 1972), vol. II, 34.

⁵⁸ On state formation in Japan see Hiroshi Tsude, “The Kofun Period and State Formation,” *Acta Asiatica* 63 (1992): 64-86; Joan R. Piggott, *The Emergence of Japanese Kingship* (Stanford: Stanford University Press, 1997); and Gina L. Barnes, *State Formation in Japan: Emergence of a 4th-Century Ruling Elite*, Durham East Asian Series (London: Routledge, 2007).

⁵⁹ Sakaguchi, “Warm and Cold Stages,” 20-21; Sakaguchi, “Kako 8000 nen,” 105-108.

organization – the state – may have occurred as a response to the challenges posed by increasingly cold, wet conditions. Among other things, I would argue, crop failures and floods required countermeasures such as public granaries and hydraulic works, which in turn required better organization and central direction. Japan’s first state may have been the result.⁶⁰

5. 700-1300 CE

The notion of a Medieval Warm Period originates with Hubert Lamb, the pioneer of historical climatology. Working from such evidence as was available in the 1950s and 1960s, Lamb argued that there had been four centuries of relatively warm weather beginning around 800. As he also showed, the onset and end of warming varied

⁶⁰ This hypothesis differs somewhat from the one offered by Sakaguchi, who places emphasis on competition between regional powers over increasingly scarce agricultural resources and on the role of rulers in introducing and improving agricultural techniques. On state formation in general, see the parsimonious discussion in David Christian, *Maps of Time: An Introduction to Big History*, The California World History Library, No. 2 (Berkeley and Los Angeles: University of California Press, 2004), 245-52. Christian distinguishes between “top-down” and “bottom-up” theories of state formation, concluding reasonably that most states probably resulted from a combination of top-down direction and bottom-up needs.

significantly by region. Today's scholars have access to much better data than did Lamb. Some have used the accumulating evidence of regional variation to discredit the idea of a Medieval Warm Period, but as a general rule Lamb's notion has held up surprisingly well.⁶¹

The causes of the Medieval Warm Period are not entirely clear, although one factor may have been reduced levels of volcanic activity.⁶² Also at work, according to Ruddiman, were increased levels of atmospheric CO₂ and methane, which he ascribes to population recovery (and thus renewed conversion of forests into agricultural land) after the "Dark Ages."⁶³

The Medieval Warm Period is generally defined as beginning around 800 or 900, but here I am using a chronology that seems to better fit the Japanese case. Although for earlier periods proxy evidence is mostly limited to pollen, tree rings, and borehole

⁶¹ See Fagan, *The Great Warming*, 12-18, for background. For a contrary view see Tim F. Flannery, *The Weather Makers: How Man Is Changing the Climate and What It Means for Life on Earth* (New York: Atlantic Monthly Press, 2005), 44, which states that "the idea of a global Medieval Warm Period is bunk." Flannery's point is that the period was not universally warmer than the present day, which may be true, but he ignores the important fact that in most regions it was considerably warmer than the immediately preceding or succeeding periods. (This lapse aside, Flannery's book has much to recommend it.)

⁶² Committee on Surface Temperature Reconstructions for the Last 2,000 Years, *Surface Temperature Reconstructions for the Last 2,000 Years*, 21.

⁶³ Ruddiman, *Plows, Plagues & Petroleum*.

temperatures, after 700 we also have historical records, making it possible to paint a rather detailed portrait of climate in Japan. Sakaguchi, based on his study of pollen at Ozegahara, argued that temperatures became warm after 732 and stayed that way through the thirteenth century.⁶⁴ Maejima, Tagami, and others have refined this picture using historical records. To summarize, summers between 700 and 1300 were generally hot, with frequent droughts, except for a temporary cool spell in the ninth century. Winter temperatures, however, did not warm up until about 900. Winters from 900 to 1300 were generally mild, with the exception of a cold spell in the late twelfth century.⁶⁵ (Note that here we are speaking here of average conditions; there was considerable variation from year to year.)

From a world historical standpoint, not just the timing, but also the effects of the Medieval Warm Period varied considerably by region. Some areas, for example Europe and China, experienced significant agricultural and demographic growth, although drought was

⁶⁴ Sakaguchi, “Warm and Cold Stages,” 22-23; Sakaguchi, “Kako 8000 nen,” 91-92.

⁶⁵ Ikuo Maejima and Yoshio Tagami, “Climatic Change During Historical Time,” 164-67. Also see Adhikari and Kumon, “Climatic Changes During the Past 1300 Years”; Aono and Omoto, “Sakura no kaika shiryō”; Aono, “Sakura no kaika no kisetsu sui”; and Aono, “Kyōto no kokiroku.” On droughts in particular, see Farris, “Famine, Climate, and Farming”; and Farris, *Japan’s Medieval Population: Famine, Fertility, and Warfare in a Transformative Age* (Honolulu: University of Hawai‘i Press, 2006).

sometimes a problem. Good weather is said to have allowed the Norse to colonize Iceland and Greenland, while conversely a drying out of the steppes is often cited as a factor in the eruption of the Mongols from their traditional homeland. In the Americas, recurrent, severe droughts associated with the Medieval Warm Period have been implicated in the collapse of the Classic Maya in Mesoamerica and of the Chaco Canyon culture and other societies in the American Southwest.⁶⁶

What about Japan? In terms of traditional historiography, the period from 700 to 1300 encompasses the Nara and Heian eras, as well as most of the Kamakura epoch. This half millennium witnessed the consolidation of imperial authority and the flourishing of aristocratic culture in the capital, followed by a slow drift toward decentralization and the militarization of local society. It is difficult to see what, if any, relationship such trends

⁶⁶ On the effects of the Medieval Warm Period, the best overview is Fagan, *The Great Warming*. On the Maya, see Richardson B. Gill, *The Great Maya Droughts: Water, Life, and Death* (Albuquerque: University of New Mexico Press, 2000); and Jared Diamond, *Collapse: How Societies Choose to Fail or Succeed* (New York: Viking, 2005), 157-77. On Chaco Canyon, see Diamond, *Collapse*, 136-56. Diamond presents a well-organized argument to the effect that social collapse typically results from some combination of five contributing factors: (1) damage that people inadvertently inflict on their environment; (2) climate change; (3) hostile neighbors; (4) decreased support by friendly neighbors; and (5) society's responses to its problems: Diamond, *Collapse*, 10-15.

might bear to climate.⁶⁷ More relevant for our purposes is the fact, recently established by Farris, that Japanese society experienced little or no demographic or economic growth during these five centuries.⁶⁸ At first glance this seems odd, especially given the apparently robust nature of the Nara and early Heian states. Farris places the blame on recurrent epidemics of smallpox, measles, and influenza, coupled with recurrent drought. Although the epidemics had nothing to do with climate, the droughts most certainly did. So it seems fair to say that the Medieval Warm Period was not particularly kind to Japan, although the consequences were far less severe than in the case of, say, the Classic Maya.

6. 1300-1600 CE

This brings us to the next period, here defined as lasting from about 1300 to 1600. Some researchers consider these centuries to be part of the Little Ice Age, while others prefer to reserve that term for the period after the late sixteenth or even late seventeenth century.

⁶⁷ Although it has been argued that rise of warrior society in eastern Honshu was made possible by warmer temperatures, which made the Kanto Plain more attractive for agriculture than in earlier centuries: Toyama Shūichi, *Shizen to ningen no kankeishi* (History of the Nature-Human Relationship) (Tokyo: Kokon shoin, 2008), 140.

⁶⁸ Farris, *Japan's Medieval Population*, and "Famine, Climate, and Farming."

This is mainly a matter of definition or taste, since all authors seem to agree that the climate began to deteriorate around 1300 but that the most severe conditions came later.

Accordingly, I have chosen to split the period in two, which makes sense not only climatologically but also in terms of historical developments in Japan. For reasons of convenience, the causes of the Little Ice Age will be discussed in the following section. In the present section we will stick to the climatic facts and their effects on human society in Japan.

First, regarding Japanese climate, we are on increasingly solid ground thanks to the many available natural and historical proxies. To make a long story short, summer in Japan remained generally warm throughout this period. The real difference from the preceding Medieval Warm Period came in winter, which was generally cold. The very coldest periods were in the 1340s through 1360s; around the beginning of the fifteenth century; around 1490; and then from the 1500s through the 1540s. Mild winters, by contrast, were the norm for a time after 1470 and during the second half of the sixteenth century.⁶⁹

⁶⁹ This is based mainly on Maejima and Tagami, “Climatic Change During Historical Time,” 164-67, with additional information from Adhikari and Kumon, “Climatic Changes

Next, regarding the historical implications of these trends, the record defies easy interpretation. Outside of Japan, famines in early fourteenth century Europe can be confidently ascribed to the deteriorating climate (specifically to cold and rain).⁷⁰ But from a world historical viewpoint, the most important events of the fourteenth through sixteenth centuries were the spread of the Black Death; the European “discovery” of the New World; and the resulting “Columbian Exchange,” in which (among other things) the native American population was decimated by exposure to Eurasian disease pools.⁷¹ It seems safe to say that none of these developments had much to do with climate.⁷²

What about Japan? As is well known, these centuries, roughly corresponding to the

During the Past 1300 Years”; Arakawa, “Climatic Changes as Revealed by the Blooming Dates”; Aono and Omoto, “Sakura no kaika shiryō”; Aono, “Sakura no kaika no kisetsu sui”; Ikuo Maejima, “Some Remarks”; Mikami and Ishiguro, “Suwako ketsuei kiroku”; Sakaguchi, “Warm and Cool Stages,” 23-24; Sakaguchi, “Kako 8000 nen,” 92-95; Yamamoto, “On the Climate Change”; Yamamoto, *Kikō no kataru*; and Yamamoto, “A.D. 1-1600 nen no Nihon.” See Atwell, “Volcanism and Short-Term Climatic Change,” for detailed discussion of some of the colder episodes and their causes.

⁷⁰ Fagan, *The Little Ice Age*.

⁷¹ The term “Columbian Exchange” originates with Alfred W. Crosby, *The Columbian Exchange: Biological and Cultural Consequences of 1492* (Westport, CT: Greenwood Press, 1972).

⁷² Unless for some reason cold weather brought humans into closer contact with rats, increasing the likelihood of plague transmission. For a fascinating ecological study of rats and plague in an earlier period, see Michael McCormick, “Rats, Communications, and Plague: Toward an Ecological History,” *Journal of Interdisciplinary History* 34, no. 1 (2003): 1-25.

Muromachi and Sengoku (Warring States) periods, were characterized by political and social turmoil. Many specific uprisings can be traced to crop failures resulting from bad weather.⁷³ One is therefore tempted to generalize and blame all of the sociopolitical problems of this period on the cooler climate. However that would be a mistake. Although temperatures were on average lower than during the Medieval Warm Period, overall that was probably a plus, as we shall see below. Further arguing against any simple link between climate and social conditions is the example of the subsequent stage, which saw a return to political stability despite profound climatic deterioration.

There is another aspect of this period that merits consideration, and that relates to agricultural production and demography. In stark contrast to the bleak political situation, Japan's economy and population grew by leaps and bounds during these three centuries. (In traditional agrarian societies, of course, economic and demographic growth are often more or less the same thing.) According to Farris, Japan's population "expanded on the order of 300 percent, from about 5.5-6.3 million in 1150 to 15-17 million in 1600, with almost all

⁷³ See the many cases discussed by Atwell, "Volcanism and Short-Term Climate Change."

the growth coming after 1280.”⁷⁴ Absent immigration (not a significant factor in medieval Japan), population growth can only result from increased life expectancy, or increased fertility, or both. Although Farris couches his argument in slightly different terms, both factors seem to have been present in this case. Longevity was promoted by decreased mortality from epidemic disease and famine, both of which had been rampant in the previous period. Longer life also resulted from a general increase in physical well-being, which Farris ascribes to agricultural improvements and a host of other indirect factors. Better health also presumably led to increased fecundity, although as Farris readily admits, the direct evidence for this is weak.

Looking at all of this from a climatological perspective, I would point out that the decreased number of famines probably relates to the return of temperatures to a more “normal” range following the extremes of the Medieval Warm Period. The obverse of this point is that climatic conditions in the Muromachi period were probably better suited to rice

⁷⁴ Farris, *Japan's Medieval Population*, 5. Note that Kitō, the leading Japanese authority, finds only a doubling, from 6.8 million to 12.3 million, over the same period: Kitō Hiroshi, *Jinkō kara yomu Nihon no rekishi* (Japanese History as Read from Population), Kōdansha gakujutsu bunko (Kōdansha Academic Library), No. 1430 (Tokyo: Kōdansha, 2000), 16-17.

agriculture than those in the preceding stage. It is usually a mistake to discount human agency, and I have no doubt that the technological and social improvements cited by Farris were important. But it would equally be a mistake to ignore the probable positive effects of climate change on agricultural productivity – and thus, indirectly on human longevity and fecundity – during the Muromachi and Sengoku periods.⁷⁵

7. 1600-1850 CE

This brings us to the (narrowly defined) Little Ice Age, which has been of particular interest to scholars because of its relatively dramatic consequences and its proximity to our own time.⁷⁶ Japanese climatologists, like their colleagues elsewhere, have actively pursued

⁷⁵ Farris, *Japan's Medieval Population*, 94-127, seems to recognize the role of climate when he describes the period from 1370 to 1450 as the “Muromachi Optimum,” but unfortunately there are problems with this concept. First, among climatologists the term “optimum” is reserved for periods that are hotter than normal (otherwise known as “hypsithermals”). So while the Medieval Warm Period was a climatic optimum (and is often referred to as such in the literature), the Muromachi period was not. It is possible, of course, that the years from 1370 to 1450, while not an *optimum* in the technical sense, were somehow *optimal* for agriculture in Japan. Perhaps this is Farris’s point. But if that is the case, there seems little need to single out this particular 80-year interval. Except for a few, relatively brief, periods of intense winter cold, similar climatic conditions prevailed throughout the fourteenth through sixteenth centuries in Japan.

⁷⁶ The classic study is Jean M. Grove, *Little Ice Ages: Ancient and Modern*, 2^d ed., Routledge Studies in Physical Geography and Environment (London: Routledge, 2004).

research on this period. Most significantly, in 1991 Tokyo Metropolitan University hosted an “International Symposium on the Little Ice Age Climate,” whose proceedings contain more than a dozen important papers on this topic as it relates to Japan.⁷⁷

In contrast to the Medieval Warm Period, which varied in timing and intensity according to region, the Little Ice Age was relatively uniform in its effects, at least in

For a more popular account, see Fagan, *The Little Ice Age*.

⁷⁷ Mikami, ed., *Proceedings of the International Symposium on the Little Ice Age Climate*. Other important studies of the Little Ice Age in Japan are Maejima Ikuo, “Shōhyōki nai no kikō hendō: Nihon to Yōroppa no kenkyū seika no hikaku no tame ni” (Climate Change within the Little Ice Age: For the Sake of a Comparison of Japanese and European Research), *Chiri shisō* (Geographic Journal) 35, no. 2 (1994): 1-71; Maejima and Tagami, “Climate of Little Ice Age in Japan,” *Geographical Reports of Tokyo Metropolitan University* 18 (1983): 91-111; Maejima and Tagami, “Nihon no shōhyōki no kikō ni tsuite: Toku ni 1661 nen - 1867 nen no Hirosaki no tenkō shiryō o chūshin ni” (Regarding Climate during Japan’s Little Ice Age: Based Chiefly on Weather Records from Hirosaki, 1661-1867), *Kishō kenkyū nōto* (Meteorological Research Notes) 147 (1983): 207-15; Mikami, “Shōhyōki: kikō no sūhyakunen hendō” (The Little Ice Age: Climate Change over Several Centuries), *Kagaku* (Science) 61, no. 10 (1991): 681-88; Mikami, “Shōhyōki no kikōzō” (Portrait of Climate in the Little Ice Age), *Chiri* (Geography) 37, no. 2 (1992): 25-30; Mikami, “Nikki tenkō kiroku”; Mizukoshi Mitsuharu, “Kinsei shōhyōki no kikō kankyō fukugen” (Reconstruction of the Climatic Environment of the Early Modern Little Ice Age), *Kōgakukan daigaku shakai fukushi gakubu kiyō* (Transactions of the School of Social Welfare, Kōgakukan University) 1 (1998): 137-42; Shuji Yamakawa, “Climate Variations and Natural Disasters in Little Ice Age,” *Kokuritsu rekishi minzoku hakubutsukan kenkyū hōkoku / Bulletin of the National Museum of Japanese History* 81 (1999): 51-56; Yamamoto, “On the Nature of the Climatic Change”; Yamamoto, “On the Nature of the Japanese Climate”; Minoru Yoshimura, “Climate in the Little Ice Age over Japan,” in *Nature and Humankind in the Age of Environmental Crisis*, ed. Ito Shuntaro and Yasuda Yoshinori (Kyoto: International Research Center for Japanese Studies, 1995), 153-59; Yoshimura, “Shōhyōki no kikō” (Climate of the Little Ice Age), in *Rekishi to kikō* (History and Climate), ed. Yoshino and Yasuda, 183-99; and Yoshimura, “Konikki kara Nihon no kikō o yomu: Shōhyōki to kikin no kankei” (Reading Japan’s Climate from Old Diaries: The Relationship between the Little Ice Age and Famine), *Kankyō kaigi* (Environmental Conference) 22 (2004): 86-89.

temperate regions of the northern hemisphere. The causes of the Little Ice Age seem to have been multifarious. Many scholars have blamed decreased solar activity, particularly during the so-called “Maunder Minimum” of c. 1645-1710. Volcanic eruptions also certainly played a role, especially in the late eighteenth and early nineteenth centuries. For example, the so-called “Year Without a Summer” in 1816 was caused by volcanic dust in the atmosphere from the 1815 eruption of Tambora, in what is now Indonesia. The Tambora eruption is said to have been the most violent of the entire Holocene.⁷⁸ Finally, as during the “Kofun Cold Stage,” ice cores show reduced levels of atmospheric CO₂, first between 1300 and 1400, and then again, more dramatically, from 1500 to 1750.⁷⁹ By now, readers will be unsurprised to learn that Ruddiman ascribes these drops in CO₂ levels to population loss following pandemics. Specifically, he attributes the fourteenth century drop to the effects of the Black Death in Eurasia, and that between 1500 and 1750 to the loss of native

⁷⁸ R.S. Bradley and P.D. Jones, “Records of Explosive Volcanic Eruptions over the Last 500 Years,” in *Climate since A.D. 1500*, ed. Raymond S. Bradley and Philip D. Jones (London: Routledge, 1992). Again, on volcanism as it pertains to East Asian history, the best source is Atwell, “Volcanism and Short-Term Climate Change.”

⁷⁹ Ruddiman, *Plows, Plagues & Petroleum*, 119.

populations in the Americas following the “Columbian Exchange.”⁸⁰

Moving on to Japan, climatic conditions during this period have been reconstructed in great detail using data from diaries and other historical records, tree-rings, and other proxies. The conclusions of various previous studies are summarized in Table 1, below. As was the case in Europe and elsewhere, temperatures were generally, but not uniformly, cold. The coldest conditions occurred from approximately 1611 to 1650, 1691 to 1740, and 1781 to 1880.⁸¹ During these three phases, winters were severe with much snowfall, particularly on the Sea of Japan side of Honshu. Summers were cool, particularly in the northern part of the country, and frequently rainy.⁸² Interestingly, the “Year Without a Summer” was wholly unexceptional in Japan, although an earlier “Year Without a Summer” occurred in 1783 following the eruptions of Mt. Asama in Japan and the Laki fissure in Iceland.⁸³

⁸⁰ Ruddiman, *Plows, Plagues & Petroleum*, 119.

⁸¹ Maejima and Tagami, “Climatic Change During Historical Time.” Also see Maejima and Tagami, “Climate of Little Ice Age in Japan.”

⁸² Yamamoto, “On the Nature of the Climatic Change,” and “On the Nature of the Japanese Climate.”

⁸³ Mikami and Tsukamura, “The Climate of Japan in 1816”; Demarée and Mikami, “1783 nen no Raki (Aisurando), Asama (Nihon) kasan funka ni yoru kikō e no eikyō / Climatic Impacts of Lakagígar (Iceland) and Asama (Japan) Volcanic Eruptions in the Year 1783,” *Gekkan chikyū* 27, no. 9 (2005): 687-92. Also see R.B. Stothers, “The Great Dry Fog of 1783,” *Climatic Change* 32 (1996): 79-89.

Table 1. Japanese Climate in 17th-19th c. as Reported by Previous Workers

Author(s)	Type of Data	Data Source	Region	17th c.			18th c.			19th c.		
				Winter	Summer	Winter	Winter	Summer	Winter	Summer	Winter	Summer
Yamamoto 1971 ^a , 1971 ^b	Records of snowfall & river freezing	Various	Various									
Maejima & Tagami 1983 ^c	Weather descriptions	Tsugaru domain records	Hirosaki (N. Honshu)	1611-50: very cold, heavy snow 1651-90: mild, light snow 1691-: very cold, heavy snow	1611-50: very cool, rainy? 1651-90: hot in first half 1691-: very cool, rainy	1700-20: very cold, heavy snow 1721-40: cold 1741-80: mild, light snow 1781-: cold	1700-20: very cool, rainy 1721-40: cool 1741-80: hot in second half 1781-: very cool, rainy	1800-20: cold 1821-50: very cold, heavy snow 1851-80: very cold, heavy snow	1800-20: very cool, rainy 1821-50: very cool, rainy 1851-80: warm			
Maejima & Tagami 1986 ^d	Climatic hazard records	Various	Countrywide	warm period centered on 1610 followed by rapid cooling	cold period centering on 1610; warm in mid-century; cold period centering on 1690	generally cold throughout	warm period centering on 1720 followed by cooling with low c. 1780	extremely cold in first half with low c. 1820; cold in second half	warm period centering on 1810 followed by cooling with low c. 1830			
Tagami & Fukaiishi 1992 ^e	Weather descriptions	Domain records	Countrywide (12 sites)	1670s: mild 1680-1700: cold	1660-80: cool 1690-: hot	1700s: mild 1720s: mild 1730s: cold 1740s: mild 1750s: cold 1780-: mild	1700-30: hot 1730-60: cool 1760-80: hot 1780s: cool 1790-: hot	1800-10: mild 1810s: cold 1840s: cold 1860s: mild 1870-90: cold	1800-30: hot 1830-50: cool 1850s: hot 1860s: cool 1880s: cool			
Fukaiishi & Tagami 1992 ^f	Weather descriptions	Domain records, etc.	Countrywide (26 sites)			1720-25: mild 1726-33: cold 1734-38: mild 1744-50, 1758-61: mild 1777-85: cold 1786-97, 1799-: mild		1800-07: mild 1808-19, 1826-36: cold 1847-51, 1853-61, 1865-69: mild				
Mikami 1993 ^g , 1996 ^h , 1999, 2002 ⁱ , 2005 ^k	Weather descriptions	Ishikawa family diary	Tokyo				variable but generally cool with lows in 1728, 1736, 1738, 1755, 1758, 1783, 1784 & 1786		generally warm with highs in 1810s and early 1850s; lows in 1830s, late 1860s, & late 1890s			
Mikami & Ishiguro 1998 ^l ; Mikami 1999 ^m , 2002 ⁿ , 2005 ^k	Records of lake freezing	Suwa Shrine records	Lake Suwa (Central Honshu)			cold with gradual warming after 1750		continued gradual warming				
Aono & Omoto 1993 ^o , 1994 ⁿ ; Aono 2001 ^c , 2003 ^p	Records of cherry blooms	Diary entries	Kyoto	1680s/1690s: very cold		1700-10s: very cold		1810s-30s: very cold				

Notes to Table 1

- ^aTakeo Yamamoto, "On the Nature of the Climatic Change in Japan since the 'Little Ice Age' Around 1800 A.D." *Journal of the Meteorological Society of Japan* 49 (1971): 789-812.
- ^bYamamoto, "On the Nature of the Japanese Climate in So-Called 'Little Ice Age' Between 1750 and 1850," *Geophysical Magazine* 35, no. 2 (1971): 165-85.
- ^cIkuo Maejima and Yoshio Tagami, "Climate of Little Ice Age in Japan," *Geographical Reports of Tokyo Metropolitan University* 18 (1983): 91-111.
- ^dMaejima and Tagami, "Climatic Change During Historical Time in Japan — Reconstruction from Climatic Hazard Records," *Geographical Reports of Tokyo Metropolitan University* 21 (1986): 157-71.
- ^eYoshio Tagami and Kazuo Fukaiishi, "Winter and Summer Climatic Variation in Japan from the 17th Century," in *Proceedings of the International Symposium on the Little Ice Age Climate*, ed. T. Mikami (Tokyo: Editorial Committee of LIAC Proceedings, Department of Geography, Tokyo Metropolitan University, 1992), 188-93.
- ^fFukaiishi and Tagami, "An Attempt of Reconstructing the Winter Weather Situations from 1720 to 1869 by the Use of Historical Documents," in *Proceedings of the International Symposium on the Little Ice Age Climate*, ed. Mikami, 194-201.
- ^gMikami Takehiko, "Nikki tenkō kiroku kara suitei shita shōhyōki kōhan no kaki onhendō / Summer Temperature Variabilities in Japan Reconstructed from Diary Weather Records During the Little Ice Age," *Chiri zasshi / Journal of Geography* 102, no. 2 (1993): 144-51.
- ^hMikami, "Long Term Variations of Summer Temperatures in Tokyo since 1721," *Geographical Reports of Tokyo Metropolitan University* 31 (1996): 157-65.
- ⁱMikami, "Quantitative Climatic Reconstruction in Japan Based on Historical Documents," *Kokuritsu rekishi minzoku hakubutsukan kenkyū hōkoku / Bulletin of the National Museum of Japanese History* 81 (1999): 41-50.
- ^jMikami, "Summer and Winter Temperature Reconstructions in Japan," *PAGES News* 10, no. 3 (2002): 17-18.
- ^kMikami, "Kako 1000 nenkan no kikō hendō to 21 seiki no kikō yosoku / Global Climatic Variations for the Last 1000 Years and Their Prospects in Future," *Chiri zasshi / Journal of Geography* 114, no. 1 (2005): 91-96.

^lMikami Takehiko and Ishiguro Naoko, “Suwako ketsuei kiroku kara mita kako 550 nenkan no kikō hendō” (Climate Change during the Past 550 Years as Seen from Records of Freezing of Lake Suwa), *Kishō kenkyū nōto* (Meteorological Research Notes) 191 (1998): 73-83.

^mY. Aono and Y. Omoto, “Variation in the March Mean Temperature Deduced from Cherry Blossoms in Kyoto since the 14th Century,” *Journal of Agricultural Meteorology* 48, no. 5 (1993): 635-38.

ⁿAono and Omoto, “Sakura no kaika shiryō ni yoru 11 seiki ikō no Kyōto no kion no suitei” (Temperature Trends in Kyoto since the Eleventh Century Based on Records of Cherry Blooms), *Nōgyō kishō* (Agricultural Meteorology) 49, no. 4 (1994): 263-72.

^oAono, “Sakura no kaika no kisetsu suii” (Seasonal Trends of Cherry Blooms), *Kikō eikyō, riyō kenkyūkai kaihō* (Bulletin of Research Group on Climate Influence and Use) 19 (2001): 15-20.

^pAono, “Kyōto no kokiroku o mochiita sakura no kaikabi no fukugen to kion e no yomikae” (Reconstruction of Cherry Bloom Dates Using Old Records from Kyoto and Their Conversion into Temperatures), in *Kikōgaku to rekishigaku no sōgū* (*Higashi Ajia kankyōshi, kikō hendō kokusai shinpojiumu hōkokusho*) (The Encounter of Climatology and History [Proceedings of the International Symposium on East Asian Environmental History and Climate Change]), ed. Tsukahara Tōgo, Mikami Takehiko, and Naitō Tomoko (Kobe: Tsukahara Tōgo, 2003), 27-41.

What effects did the Little Ice Age have on human society? Discussions of this topic by world historians typically center on crop failures and associated famines, particularly in Europe.⁸⁴ As noted earlier, there is also a substantial literature on the Little Ice Age in Japan, and much of this also focuses on famines. Many authors, for example, have noted that the Genroku Famine of 1695-1696, the Tenmei Famine of 1782-1787, and the Tenpō Famine of 1833-1839 all occurred during particularly cold periods, and that all had their

⁸⁴ See discussion in Fagan, *The Little Ice Age*.

most severe effects in northern latitudes, where temperatures were lowest.⁸⁵ Since the Tenpō Famine was part of the background to the domestic unrest that contributed to the fall of the Tokugawa Shogunate, the enthusiastic climate historian might be forgiven for claiming that the Little Ice Age put an end to Japan's ancien régime, paving the way for modernization.

While it is true that cool temperatures frequently led to famine, this is not all there was to the Little Ice Age, either in Japan or elsewhere. Another frequently-cited negative effect involves the failure of the Norse settlements in Greenland, which had been established during the preceding Medieval Warm Period.⁸⁶ But what climate historians

⁸⁵ Maejima and Tagami, "Climatic Change During Historical Time," 169. Also see Mikami, "Kikin no kōzō: Tenmei no kikin o rei to shite" (The Structure of Famine: The Case of the Tenmei Famine), *Chiri* (Geography) 27, no. 12 (1982): 51-57; Mikami and Tsukamura, "The Climate of Japan in 1816"; Yaji and Misawa, "Tenpō kikin zengo"; and Yamakawa, "Climate Variations and Natural Disasters." Another major famine, the Kyōhō Famine of 1732, was caused by a plague of locusts and was most severe in western Japan. There is some interesting evidence from upland regions in central Honshu that in times of poor harvests peasants began to cultivate horse chestnuts as an alternate source of food: J. Kitagawa, T. Nakagawa, T. Fujiki, K. Yamaguchi, and Y. Yasuda, "Human Activity and Climate Change During the Historical Period in Central Upland Japan with Reference to Forest Dynamics and the Cultivation of Japanese Horse Chestnut (*Aesculus turbinata*)," *Vegetation History and Archaeobotany* 13, no. 2 (2004): 105-13.

⁸⁶ Neil Roberts, *The Holocene: An Environmental History* (Oxford: Blackwell Publishers, 1998), 179-80; Diamond, *Collapse*, 248-76. Note that the Norse settlements met their end around 1500 and thus somewhat before the Little Ice Age as defined here.

have inexplicably failed to note is that the Little Ice Age was not universally bad. Viewed as a whole, the period saw dramatic demographic and economic growth, as well as state- and empire-building, throughout the core regions of Eurasia.⁸⁷ This suggests either that colder temperatures had some sort of positive influence on society (by stimulating people or states to greater efforts?), or alternatively, that the Little Ice Age was largely irrelevant to the important historical trends of the era. In either case, historians may need to take off their blinders and reexamine this topic from a broader perspective.

What can be said for world history can be said for Japanese history as well.

Although I concede that famines were important, and that many of them can be directly blamed on the weather conditions of the Little Ice Age, I must also note that this period saw some very positive developments, especially in the seventeenth century. As just one example, Japan's population continued to grow rapidly, doubling, according to Farris, from 15-17 million in 1600 to 31 million in 1721.⁸⁸ Most of this increase took place during very

⁸⁷ See John F. Richards, *The Unending Frontier: An Environmental History of the Early Modern World*, The California World History Library (Berkeley and Los Angeles: University of California Press, 2003).

⁸⁸ Farris, *Japan's Medieval Population*, 263. Kitō believes that Japan's population in 1600

cold conditions. While it is true that population growth ceased after 1721, this has nothing to do with climate; it was simply that Japanese society had reached the demographic “limits to growth” imposed by available resources and technologies. (Economic growth, however, did continue, albeit at a slower pace, throughout the period.) How are we to explain these facts if the Little Ice Age was such a terrible thing? Again, the question is begging to be reopened.

8. 1850-2000 CE

The last phase in Japan’s climatic history is the contemporary period of anthropogenic warming since around 1850. The facts are clear and well-known, and I see no need to reiterate them here. Moreover, unlike for all the earlier periods described above, there is little point in trying to tie specific developments in human society to climate. Climate was, and is, not irrelevant; but it was no longer the primary engine of change – if, indeed, it ever

was only 12 million, but agrees with the figure of 31 million for 1721. Kitō, *Jinkō*, 16-17. If this is correct, population growth during the early Edo period was even more rapid than Farris’s figures suggest.

had been. Society in the nineteenth and twentieth centuries developed largely according to its own logic.

IV. Conclusion

This survey of the role of climate in Japanese history and prehistory has been, at best, sketchy and tentative. Much work remains to be done before we have a comprehensive picture of how the weather and climatic change affected people and society in the Japanese archipelago. The big picture seems relatively clear, but many of the details are missing.

Worse (or perhaps better, for those who like puzzles), even when we know what happened, we do not usually know why.

Some of the results of this survey seem to fly in the face of common sense. For temperate regions like Japan, it would seem natural to expect that warm conditions were “good” for agriculture and society while cold conditions were “bad.” My working hypothesis when I began this study was that warm conditions would be associated with

periods of growth and consolidation, while cold conditions would be associated with periods of stagnation and disruption. That turns out not to be true; if anything, the reverse was the case.

Cold conditions often produced good results for society in Japan. For example, the origins of pottery (the Jōmon culture), of rice agriculture, and of the state all seem to be causally linked to unusually cold temperatures. The same is true of the explosive demographic and economic growth of the seventeenth and early eighteenth centuries. The full explanation for these apparent paradoxes must await the results of future research. Here let me simply repeat my “hunch” that adverse climatic conditions brought out the best in the residents of the Japanese islands, who collectively rose to the challenges presented them by nature.

Conversely, warm periods could produce bad results for society in Japan. True, the generally warm Jōmon period was one of exceptional prosperity for the hunter-gatherer residents of the archipelago. But following the advent of full-blown agriculture, warm conditions appear, if anything, to have been a liability. A case in point is the Medieval

Warm Period. Although the degree of political integration during the Nara and early Heian periods was generally high, from a demographic or economic perspective these centuries were characterized above all by stagnation. If this premodern example of global warming had such dire consequences for Japanese society, one can only wonder where current trends will lead. Yes, over time, the Japanese, like people elsewhere, have demonstrated increasing control over their environment. But will technology save the day this time around? Only time can tell.

References Cited

- Adhikari, D.P., and F. Kumon. "Climatic Changes During the Past 1300 Years as Deduced from the Sediments of Lake Nakatsuna, Central Japan." *Limnology* 2, no. 3 (2001): 157-68.
- Alley, Richard. *The Two-Mile Time Machine: Ice Cores, Abrupt Climate Change, and Our Future*. Princeton, N.J.: Princeton University Press, 2003.
- Aono, Y. "Climatic Change in March Temperature Deduced from Phenological Record for Flowering of Cherry Tree in Tokyo since the Late 18th Century." *Bulletin of Osaka Prefectural University, Series B* 50 (1998): 11-19.
- Aono Yasuyuki. "Kyōto no kokiroku o mochiita sakura no kaikabi no fukugen to kion e no yomikae" (Reconstruction of Cherry Bloom Dates Using Old Records from Kyoto and Their Conversion into Temperatures). In *Kikōgaku to rekishigaku no sōgū (Higashi Ajia kankyōshi, kikō hendō kokusai shinpojiumu hōkokusho)* (The Encounter of Climatology and History [Proceedings of the International Symposium on East Asian Environmental History and Climate Change]), edited by Tsukahara Tōgo, Mikami Takehiko, and Naitō Tomoko. Kobe: Tsukahara Tōgo, 2003.
- Aono Yasuyuki. "Sakura no kaika no kisetsu suii" (Seasonal Trends of Cherry Blooms). *Kikō eikyō, riyō kenkyūkai kaihō* (Bulletin of Research Group on Climate Influence and Use) 19 (2001): 15-20.
- Aono Yasuyuki and Omoto Yoshio. "Sakura no kaika shiryō ni yoru 11 seiki ikō no Kyōto no kion no suitei" (Temperature Trends in Kyoto since the Eleventh Century Based on Records of Cherry Blooms). *Nōgyō kishō* (Agricultural Meteorology) 49, no. 4 (1994): 263-72.
- Aono, Y., and Y. Omoto. "Variation in the March Mean Temperature Deduced from Cherry Blossoms in Kyoto since the 14th Century." *Journal of Agricultural Meteorology* 48, no. 5 (1993): 635-38.
- Arakawa, H. "Climatic Changes as Revealed by the Blooming Dates of the Cherry Blossoms at Kyoto." *Journal of Meteorology* 13 (1956): 599-600.

- Arakawa Hidetoshi. "Fujiwara Sakuhei hakase ikō 'Suwako keppyō kijitsu narabi ni omiwatari kijitsu nippyō' ni tsuite / Fujiwhara on Five Centuries of Freezing Dates of Lake Suwa (36° N, 138°e) in the Central Japan." *Chūō kishōdai kenkyū jihō / Journal of Meteorological Research* 6, no. 5 (1954): 138-46.
- Arakawa Hidetoshi. "5 seiki ni wataru Suwako omiwatari no kenkyū / On Five Centuries of Freezing Dates of Lake Suwa (36° N, 138° E) in the Central Japan." *Chigaku zasshi / Journal of Geography* 63, no. 4 (1954): 1-8.
- Arjava, Antti. "The Mystery Cloud of 536 CE in the Mediterranean Sources." *Dumbarton Oaks Papers* 59 (2005): 73-94.
- Aston, W.G., tr. *Nihongi: Chronicles of Japan from the Earliest Times to A.D. 697*. Two volumes in one. Rutland, Vermont: Tuttle, 1972.
- Atwell, William S. "Volcanism and Short-Term Climatic Change in East Asian and World History, ca. 1200-1699." *Journal of World History* 12, no. 1 (2001): 29-98.
- Baba Hisao. "Nihon rettō no kyūsekki jin" (Paleolithic People of the Japanese Archipelago). In *Nihon rettō no shizenshi* (Natural History of the Japanese Archipelago), edited by Kokuritsu hakubutsukan (National Museum). Tokyo: Tōkai daigaku shuppankai (Tōkai University Press), 2006.
- Baillie, M.G.L. "Dendrochronology Raises Questions About the Nature of the A.D. 536 Dust-Veil Event." *Holocene* 3 (1994): 212-17.
- Barnes, Gina L. *State Formation in Japan: Emergence of a 4th-Century Ruling Elite*. Durham East Asian Series. London: Routledge, 2007.
- Bellwood, Peter. *First Farmers: The Origins of Agricultural Societies*. Malden, MA: Blackwell Pub., 2005.
- Bradley, R.S., and P.D. Jones. "Records of Explosive Volcanic Eruptions over the Last 500 Years." In *Climate since A.D. 1500*, edited by Raymond S. Bradley and Philip D. Jones. London: Routledge, 1992.
- Burroughs, William James. *Climate Change in Prehistory: The End of the Reign of Chaos*. Cambridge: Cambridge University Press, 2005.

- Christian, David. *Maps of Time: An Introduction to Big History*. The California World History Library, No. 2. Berkeley and Los Angeles: University of California Press, 2004.
- Committee on Surface Temperature Reconstructions for the Last 2,000 Years, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, National Research Council of the National Academies, ed. *Surface Temperature Reconstructions for the Last 2,000 Years*. Washington, D.C.: The National Academies Press, 2006.
- Crawford, Gary W. "East Asian Plant Domestication." In *Archaeology of Asia*, edited by Miriam T. Stark. Malden, MA: Blackwell Publishing, 2006.
- Crosby, Alfred W. *The Columbian Exchange: Biological and Cultural Consequences of 1492*. Westport, CT: Greenwood Press, 1972.
- Demarée, Gaston. "Some XVII-th and XVIII-th Centuries Dutch Meteorological Observations at Deshima, Nagasaki (Japan), Seen as a Complement to Japanese Climatological Historical Documents." In *Proceedings of the International Conference on Climate Change and Variability – Past, Present and Future –*, edited by Takehiko Mikami. Hachioji-shi, Tokyo: International Geographical Union Commission on Climatology / Department of Geography, Tokyo Metropolitan University, 2000.
- Demarée, Gaston, and T. Mikami. "1783 nen no Raki (Aisurando), Asama (Nihon) kasan funka ni yoru kikō e no eikyō / Climatic Impacts of Lakagígar (Iceland) and Asama (Japan) Volcanic Eruptions in the Year 1783." *Gekkan chikyū* (Earth Monthly) 27, no. 9 (2005): 687-92.
- Diamond, Jared. *Collapse: How Societies Choose to Fail or Succeed*. New York: Viking, 2005.
- D'Arrigo, R.D., D.K. Yamaguchi, G.C. Wiles, G.C. Jacoby, A. Osawa, and D.M. Lawrence. "A Kashiwa Oak (*Quercus dentata*) Tree-Ring Width Chronology from Northern Coastal Hokkaido, Japan." *Canadian Journal of Forestry Research* 27 (1997): 613-17.

- Dunbar, Robert B. "Climate Variability During the Holocene: An Update." In *The Way the Wind Blows: Climate, History, and Human Action*, edited by Roderick J. McIntosh, Joseph A. Tainter and Susan Keech McIntosh. New York: Columbia University Press, 2000.
- Fagan, Brian. *The Great Warming: Climate Change and the Rise and Fall of Civilizations*. New York: Bloomsbury Press, 2008.
- Fagan, Brian. *The Little Ice Age: How Climate Made History 1300-1850*. New York: Basic Books, 2000.
- Fagan, Brian. *The Long Summer: How Climate Changed Civilization*. New York: Basic Books, 2004.
- Farris, William Wayne. "Famine, Climate, and Farming in Japan, 670-1100." In *Heian Japan, Centers and Peripheries*, edited by Mikael S. Adolphson, Edward Kamens, and Stacie Matsumoto, 275-304. Honolulu: University of Hawai'i Press, 2007.
- Farris, William Wayne. *Japan's Medieval Population: Famine, Fertility, and Warfare in a Transformative Age*. Honolulu: University of Hawai'i Press, 2006.
- Firestone, R.D., A. West, J.P. Kennett, L. Becker, T.E. Bunch, Z. S. Revay, P. H. Schultz, T. Belgya, D.J. Kennett, J.M. Erlandson, O.J. Dickenson, A.C. Goodyear, R.S. Harris, G.A. Howard, J.B. Kloosterman, P. Lechler, P.A. Mayewski, J. Montgomery, R. Poreda, T. Darrah, S.S. Que Hee, A.R. Smith, A. Stich, W. Topping, J.H. Wittke, and W. S. Wolbach. "Evidence for an Extraterrestrial Impact 12,900 Years Ago That Contributed to the Megafaunal Extinctions and the Younger Dryas Cooling." *Proceedings of the National Academy of Sciences* 104, no. 41 (2008): 16016-21
- Flannery, Tim F. *The Weather Makers: How Man Is Changing the Climate and What It Means for Life on Earth*. New York: Atlantic Monthly Press, 2005.
- Fukaishi, Kazuo, and Yoshio Tagami. "An Attempt of Reconstructing the Winter Weather Situations from 1720 to 1869 by the Use of Historical Documents." In *Proceedings of the International Symposium on the Little Ice Age Climate*, edited by T. Mikami. Tokyo: Editorial Committee of LIAC Proceedings, Department of Geography, Tokyo Metropolitan University, 1992.

- Fukusawa Hitoshi. “Koshō nenkō taisekibutsu ni yoru chūsei ondanki no kikō hendō to tozan katsudō no kaishi / Onset of Mountain Climbing Caused by Climate Warming since the Medieval Warm Period: Investigation from Varved Lacustrine Sediments.” *Gekkan chikyū* (Earth Monthly) 27, no. 9 (2005): 665-72.
- Fukusawa Hitoshi and Yasuda Yoshinori. “Suigetsuko no sairyū taisekibutsu de kenshutsu sareta kako 2000 nenkan no kikō hendō” (Climate Change during the Past 2000 Years as Recovered from Fine-Grained Sediments from Lake Suigetsu). In *Rekishi to kikō* (History and Climate), edited by Yoshino Masatoshi and Yasuda Yoshinori. Vol. 6 of *Kōza: Bunmei to kankyō* (Lectures on Civilization and Environment). Tokyo: Asakura shoten, 1995.
- Gill, Richardson B. *The Great Maya Droughts: Water, Life, and Death*. Albuquerque: University of New Mexico Press, 2000.
- Goto, Shusaku, Hideki Hamamoto, and Makoto Yamano. “Climatic and Environmental Changes at Southeastern Coast of Lake Biwa over Past 3000 Years, Inferred from Borehole Temperature Data.” *Physics of the Earth and Planetary Interiors* 152, no. 4 (2005): 314-25.
- Grove, Jean M. *Little Ice Ages: Ancient and Modern*. 2^d ed. Routledge Studies in Physical Geography and Environment. London: Routledge, 2004.
- Gunn, Joel D. “A.D. 536 and Its 300-Year Aftermath.” In *The Years without Summer: Tracing A.D. 536 and Its Aftermath*, edited by Joel D. Gunn. Oxford: Archaeopress, 2000.
- Gunn, Joel D., ed. *The Years without Summer: Tracing A.D. 536 and Its Aftermath*. Bar International Series, No. 872. Oxford: Archaeopress, 2000.
- Habu, Junko. *Ancient Jomon of Japan*. Case Studies in Early Societies. Cambridge: Cambridge University Press, 2004.
- Harunari Hideji and Imamura Mineo, eds. *Yayoi jidai no jitsunendai: tanso 14 nendai o megutte* (Absolute Age of the Yayoi Period: Regarding Carbon 14 Dates). Tokyo: Gakuseisha, 2004.
- Hudson, Mark J. “Japanese Beginnings.” In *A Companion to Japanese History*, edited by William M. Tsutsui. Malden, MA: Blackwell Publishing, 2007.

- Hudson, Mark J. *Ruins of Identity: Ethnogenesis in the Japanese Islands*. Honolulu: University of Hawai'i Press, 1999.
- Imamura, Keiji. *Prehistoric Japan: New Perspectives on Insular East Asia*. Honolulu: University of Hawai'i Press, 1996.
- Kato, Megumi, Osamu Fujiwara, and Yoshinori Yasuda. "Non-Glacial Varved Sediments in Lake Tougou-Ike, Western Japan and High Resolution Relationships between Global Climate and Sea-Level Changes During the Holocene." In *Proceedings of the International Conference on Climate Change and Variability—Past, Present and Future—*, edited by Takehiko Mikami. Hachioji-shi, Tokyo: International Geographical Union Commission on Climatology / Department of Geography, Tokyo Metropolitan University, 2000.
- Kawada Shin'ichirō. "Nihon rettō no ho'nyūru" (Mammals of the Japanese Archipelago). In *Nihon rettō no shizenshi* (Natural History of the Japanese Archipelago), edited by Kokuritsu hakubutsukan (National Museum). Kokuritsu kagaku hakubutsukan sōsho (National Science Museum Library), No. 4. Tokyo: Tōkai daigaku shuppankai (Tōkai University Press), 2006.
- Kawamura, Takeshi. "Estimation of Climate in the Little Ice Age Using Phenological Data in Japan." In *Proceedings of the International Symposium on the Little Ice Age Climate*, edited by T. Mikami, 52-57. Tokyo: Editorial Committee of LIAC Proceedings, Department of Geography, Tokyo Metropolitan University, 1992.
- Kennett, D.J., J.P. Kennett, A. West, C. Mercer, S.S. Que Hee, L. Bement, T.E. Bunch, M. Sellers, and W.S. Wolbach. "Nanodiamonds in the Younger Dryas Boundary Sediment Layer." *Science* 323, no. 5910 (2009): 94.
- Keys, David. *Catastrophe: An Investigation into the Origins of the Modern World*. New York: Ballantine Books, 1999.
- Kitagawa Hiroyuki. "Yakusugi ni kizamareta rekishi jidai no kikō hendō" (Climate Change during the Historical Period as Inscribed in Yaku Cedars). In *Rekishi to kikō* (History and Climate), edited by Yoshino Masatoshi and Yasuda Yoshinori. Vol. 6 of *Kōza: Bunmei to kankyō* (Lectures on Civilization and Environment). Tokyo: Asakura shoten, 1995.

- Kitagawa, H., and E. Matsumoto. "Carbon-Isotope Variation within Trunks of Japanese Cedars from Yakushima Islands, Southern Japan." *Geochemical Journal* 29, no. 2 (1995): 149-53.
- Kitagawa, Hiroyuki, and Eiji Matsumoto. "Climatic Implications of $\delta^{13}\text{C}$ Variations in a Japanese Cedar (*Cryptomeria japonica*) during the Last Two Millennia." *Geophysical Research Letters* 22, no. 16 (1995): 2155–58.
- Kitagawa Hiroyuki and Matsumoto Eiji. "Yakusugi nenrin no tanso dōitaihi hendō kara suitei sareru kako 2000 nenkan no kikō hendō" (Climate Change during the Past 2000 Years as Inferred from Carbon Isotope Variations in Tree Rings of Yaku Cedars). *Kishō kenkyū nōto* (Meteorological Research Notes) 191 (1998): 1-13.
- Kitagawa, H., and J. van der Plicht. "A 40,000 Year Varve Chronology from Lake Suigetsu, Japan: Extension of the Radiocarbon Calibration Curve." *Radiocarbon* 40 (1998): 505-16.
- Kitagawa, J., T. Nakagawa, T. Fujiki, K. Yamaguchi, and Y. Yasuda. "Human Activity and Climate Change During the Historical Period in Central Upland Japan with Reference to Forest Dynamics and the Cultivation of Japanese Horse Chestnut (*Aesculus turbinata*)." *Vegetation History and Archaeobotany* 13, no. 2 (2004): 105-13.
- Kitō Hiroshi. *Jinkō kara yomu Nihon no rekishi* (Japanese History as Read from Population). Kōdansha gakujutsu bunko (Kōdansha Academic Library), No. 1430. Tokyo: Kōdansha, 2000.
- Kobayashi, O., Y. Abe, and T. Sweda. "Construction of a Tree-Ring-Width Chronology for the Ishizuchi Range, Japan." In *Proceedings of the International Conference on Climate Change and Variability—Past, Present and Future—*, edited by Takehiko Mikami. Hachioji-shi, Tokyo: International Geographical Union Commission on Climatology / Department of Geography, Tokyo Metropolitan University, 2000.
- Können, G.P., M. Zaiki, A.P.M. Baede, T. Mikami, P.D. Jones, and T. Tsukahara. "Pre-1872 Extension of the Japanese Instrumental Meteorological Observations Series Back to 1819." *Journal of Climate* 16 (2003): 118-31.

- Koyama, Shuzo, and David H. Thomas. *Affluent Foragers*. Senri Ethnological Studies, No. 9. Osaka: National Museum of Ethnology, 1981.
- Kumon, Fujio, Rie Ohno, Toshikazu Sakai, Sanae Sakami, and Jun'ichi Sakai. "Climatic Records During the Last 40,000 Years in Lake Nojiri, Central Japan." In *Proceedings of the International Conference on Climate Change and Variability—Past, Present and Future—*, edited by Takehiko Mikami. Hachioji-shi, Tokyo: International Geographical Union Commission on Climatology / Department of Geography, Tokyo Metropolitan University, 2000.
- Maejima Ikuo. "Shōhyōki nai no kikō hendō: Nihon to Yōroppa no kenkyū seika no hikaku no tame ni" (Climate Change within the Little Ice Age: For the Sake of a Comparison of Japanese and European Research). *Chiri shisō* (Geographic Journal) 35, no. 2 (1994): 1-7.
- Maejima, Ikuo. "Some Remarks on the Climatic Conditions of Kyoto During the Period from 1474 to 1533 A.D." *Geographical Reports of Tokyo Metropolitan University* 1 (1966): 103-11.
- Maejima, Ikuo, and Yoshio Tagami. "Climate of Little Ice Age in Japan." *Geographical Reports of Tokyo Metropolitan University* 18 (1983): 91-111.
- Maejima, Ikuo, and Yoshio Tagami. "Climatic Change During Historical Time in Japan — Reconstruction from Climatic Hazard Records." *Geographical Reports of Tokyo Metropolitan University* 21 (1986): 157-71.
- Maejima Ikuo and Tagami Yoshio. "Nihon no shōhyōki no kikō ni tsuite: Toku ni 1661 nen - 1867 nen no Hirosaki no tenkō shiryō o chūshin ni" (Regarding Climate during Japan's Little Ice Age: Based Chiefly on Weather Records from Hirosaki, 1661-1867). *Kishō kenkyū nōto* (Meteorological Research Notes) 147 (1983): 207-15.
- McCormick, Michael. "Rats, Communications, and Plague: Toward an Ecological History." *Journal of Interdisciplinary History* 34, no. 1 (2003): 1-25.
- McIntosh, Roderick J., Joseph A. Tainter, and Susan Keech McIntosh. *The Way the Wind Blows: Climate, History, and Human Action*. Historical Ecology Series. New York: Columbia University Press, 2000.

- Mikami, Takehiko. "Climate Variations in Japan During the Little Ice Age – Summer Temperature Reconstructions since 1771 –." In *Proceedings of the International Symposium on the Little Ice Age Climate*, edited by T. Mikami. Tokyo: Editorial Committee of LIAC Proceedings, Department of Geography, Tokyo Metropolitan University, 1992.
- Mikami Takehiko. "Kako 1000 nenkan no kikō hendō to 21 seiki no kikō yosoku / Global Climatic Variations for the Last 1000 Years and Their Prospects in Future." *Chiri zasshi / Journal of Geography* 114, no. 1 (2005): 91-96.
- Mikami Takehiko. "Kikin no kōzō: Tenmei no kikin o rei to shite" (The Structure of Famine: The Case of the Tenmei Famine). *Chiri (Geography)* 27, no. 12 (1982): 51-57.
- Mikami, Takehiko. "Long Term Variations of Summer Temperatures in Tokyo since 1721." *Geographical Reports of Tokyo Metropolitan University* 31 (1996): 157-65.
- Mikami Takehiko. "Nikki tenkō kiroku kara suitei shita shōhyōki kōhan no kaki onhendō / Summer Temperature Variabilities in Japan Reconstructed from Diary Weather Records During the Little Ice Age." *Chiri zasshi / Journal of Geography* 102, no. 2 (1993): 144-51.
- Mikami, Takehiko. "Quantitative Climatic Reconstruction in Japan Based on Historical Documents." *Kokuritsu rekishi minzoku hakubutsukan kenkyū hōkoku / Bulletin of the National Museum of Japanese History* 81 (1999): 41-50.
- Mikami Takehiko. "Shōhyōki: kikō no sūhyakunen hendō" (The Little Ice Age: Climate Change over Several Centuries). *Kagaku (Science)* 61, no. 10 (1991): 681-88.
- Mikami Takehiko. "Shōhyōki no kikōzō" (Portrait of Climate in the Little Ice Age). *Chiri (Geography)* 37, no. 2 (1992): 25-30.
- Mikami, Takehiko. "Summer and Winter Temperature Reconstructions in Japan." *PAGES News* 10, no. 3 (2002): 17-18.
- Mikami, T., ed. *Proceedings of the International Symposium on the Little Ice Age Climate*. Tokyo: Editorial Committee of LIAC Proceedings, Department of Geography, Tokyo Metropolitan University, 1992.

- Mikami Takehiko and Ishiguro Naoko. "Suwako ketsuei kiroku kara mita kako 550 nenkan no kikō hendō" (Climate Change during the Past 550 Years as Seen from Records of Freezing of Lake Suwa). *Kishō kenkyū nōto* (Meteorological Research Notes) 191 (1998): 73-83.
- Mikami, T., and Y. Tsukamura. "The Climate of Japan in 1816 as Compared with an Extremely Cool Summer Climate in 1783." In *The Year without a Summer? World Climate in 1816*, edited by C.R. Harrington. Ottawa: Canadian Museum of Nature, 1992.
- Mikami, T., M. Zaiki, G.P. Können, and P.D. Jones. "Winter Temperature Reconstruction at Dejima, Nagasaki Based on Historical Meteorological Documents During the Last 300 Years." In *Proceedings of the International Conference on Climate Change and Variability—Past, Present and Future—*, edited by Takehiko Mikami. Hachioji-shi, Tokyo: International Geographical Union Commission on Climatology / Department of Geography, Tokyo Metropolitan University, 2000.
- Mizukoshi Mitsuharu. "Kinsei shōhyōki no kikō kankyō fukugen" (Reconstruction of the Climatic Environment of the Early Modern Little Ice Age). *Kōgakukan daigaku shakai fukushi gakubu kiyō* (Transactions of the School of Social Welfare, Kōgakukan University) 1 (1998): 137-42.
- Morimoto, Maki, Hajime Kayanne, Nobuyuki Yonekura, Osamu Abe, Ching-Hsin Chiu, and Eiji Matsumoto. "Sea Surface Temperature around 6000 Years Ago: Reconstructed by Coral Annual Bands from Kikai Island in the Subtropical Northwestern Pacific." In *Proceedings of the International Conference on Climate Change and Variability—Past, Present and Future—*, edited by Takehiko Mikami. Hachioji-shi, Tokyo: International Geographical Union Commission on Climatology / Department of Geography, Tokyo Metropolitan University, 2000.
- Oppenheimer, Stephen. *The Real Eve: Modern Man's Journey out of Africa*. Revised paperback ed. New York: Carroll & Graf Publishers, 2004.
- Park, S.-C., D.-G. Yoo, C.-W. Lee, and E.-I. Lee. "Last Glacial Sea-Level Changes and Paleogeography of the Korea (Tsushima) Strait." *Geo-Marine Letters* 20, no. 2 (2000): 64-71.

- Piggott, Joan R. *The Emergence of Japanese Kingship*. Stanford: Stanford University Press, 1997.
- Richards, John F. *The Unending Frontier: An Environmental History of the Early Modern World*. The California World History Library. Berkeley and Los Angeles: University of California Press, 2003.
- Rigby, Emma, Melissa Symonds, and Derek Ward-Thompson. "A Comet Impact in AD 536?" *Astronomy & Geophysics* 45, no. 1 (2004): 23-26.
- Roberts, Neil. *The Holocene: An Environmental History*. Oxford: Blackwell Publishers, 1998.
- Ruddiman, William F. *Earth's Climate: Past and Future*. 2^d ed. New York, NY: W.H. Freeman and Co., 2008.
- Ruddiman, William F. *Plows, Plagues & Petroleum: How Humans Took Control of Climate*. Princeton: Princeton University Press, 2005.
- Sakaguchi, Yutaka. "Climatic Variability During the Holocene Epoch in Japan and Its Causes." *Bulletin of the Department of Geography, University of Tokyo* 14 (1982): 1-27.
- Sakaguchi Yutaka. "Kako 8000 nen no kikō henka to ningen no rekishi" (Climate Change and Human History during the Past 8000 Years). *Senshū jinbun ronshū* (Senshū University Essays in the Humanities) 51 (1993): 79-113.
- Sakaguchi Yutaka. "Nihon no senshi, rekishi jidai no kikō: Ozegahara ni kako 7600 nen no kikō henka no rekishi o saguru" (Climate in Japanese Prehistory and History: Searching at Ozegahara for the History of Climate Change during the Past 7,600 Years). *Shizen* (Nature) 39, no. 5 (1984): 18-36.
- Sakaguchi Yutaka. *Ozegahara no shizenshi* (Natural History of Ozegahara). Chūkō shinsho (New Books from Chūō Kōron), No. 928. Tokyo: Chūō kōronsha, 1989.
- Sakaguchi, Yutaka. "Warm and Cold Stages in the Past 7600 Years in Japan and Their Global Correlation — Especially on Climatic Impacts to the Global Sea Level Changes and the Ancient Japanese History —." *Bulletin of the Department of Geography, University of Tokyo* 15 (1983): 1-31.
- Stothers, R.B. "Mystery Cloud of A.D. 536." *Nature* 307 (1984): 344-45.

- Stothers, R.B. "The Great Dry Fog of 1783." *Climatic Change* 32 (1996): 79-89.
- Sweda, Tatsuo. "Dendroclimatological Reconstruction for the Last Sub-Millennium in Central Japan." *Terrestrial, Atmospheric and Oceanic Sciences* 5, no. 3 (1994): 431-42.
- Sweda, T. "Little Ice Age Climate of Central Japan as Revealed by Dendroclimatological Reconstruction." In *Proceedings of the International Symposium on the Little Ice Age Climate*, edited by T. Mikami. Tokyo: Editorial Committee of LIAC Proceedings, Department of Geography, Tokyo Metropolitan University, 1992.
- Sweda, Tatsuo, and Shinichi Takeda. "Construction of an 800-Year-Long *Chamaecyparis* Dendrochronology for Central Japan." *Dendrochronologia* 11 (1994): 79-86.
- Tagami, Yoshio, and Kazuo Fukaishi. "Winter and Summer Climatic Variation in Japan from the 17th Century." In *Proceedings of the International Symposium on the Little Ice Age Climate*, edited by T. Mikami. Tokyo: Editorial Committee of LIAC Proceedings, Department of Geography, Tokyo Metropolitan University, 1992.
- Tanaka, Minoru, and Masatoshi M. Yoshino. "Re-Examination of the Climatic Change in Central Japan Based on Freezing Dates of Lake Suwa." *Weather* 37 (1982): 252-59.
- Toyama Shūichi. *Shizen to ningen no kankeishi* (History of the Nature-Human Relationship). Tokyo: Kokon shoin, 2008.
- Tsude, Hiroshi. "The Kofun Period and State Formation." *Acta Asiatica* 63 (1992): 64-86.
- Tsukahara Tōgo, Zaiki Masumi, Matsumoto Keiko, and Mikami Takehiko. "Nihon no kiki kansoku no hajimari: Dare ga, dono yō na jōkyō de hajimeta no ka / Beginning of Instrumental Meteorological Observation in Japan: By Whom, in What Context, and Its Transitional Nature." *Gekkan chikyū* (Earth Monthly) 27, no. 9 (2005): 713-20.
- Ward, Peter Douglas. *Out of Thin Air: Dinosaurs, Birds, and Earth's Ancient Atmosphere*. Washington, D.C.: J. Henry Press, 2006.
- Ward, Peter Douglas. *Under a Green Sky: Global Warming, the Mass Extinctions of the Past, and What They Mean for Our Future*. New York: Smithsonian Books / Collins, 2007.

- Yaji Masataka and Misawa Meiko. “Tenpō kikin zengo no kikō ni kansuru ichikōsatsu / Some Notes on the Japanese Climates before and after the Tempo Lean Years, 1828-1844.” *Science Reports of the Yokohama National University: Section II, Biological and Geological Sciences* 28 (1981): 91-108.
- Yamakawa, Shuji. “Climate Variations and Natural Disasters in Little Ice Age.” *Kokuritsu rekishi minzoku hakubutsukan kenkyū hōkoku / Bulletin of the National Museum of Japanese History* 81 (1999): 51-56.
- Yamamoto Takeo. *Kikō no kataru Nihon no rekishi* (Japanese History as Told by Climate). Soshiete bunko (Society Library). Tokyo: Soshiete, 1976.
- Yamamoto Takeo. “Kikō to rekishi” (Climate and History). In *Kikō to bunmei, kikō to rekishi* (Climate and Civilization, Climate and History), edited by Suzuki Hideo and Yamamoto Takeo. Tokyo: Asakura shoten, 1978.
- Yamamoto, Takeo. “On the Climate Change in XV and XVI Centuries in Japan.” *Geophysical Magazine* 35, no. 2 (1971): 187-206.
- Yamamoto, Takeo. “On the Nature of the Climatic Change in Japan since the ‘Little Ice Age’ Around 1800 A.D.” *Journal of the Meteorological Society of Japan* 49 (1971): 789-812.
- Yamamoto, Takeo. “On the Nature of the Japanese Climate in So-Called ‘Little Ice Age’ Between 1750 and 1850.” *Geophysical Magazine* 35, no. 2 (1971): 165-85.
- Yamamoto Takeo. “Rekishi no nagare ni sou Nihon to sono shūhen no kishō no hensen” (Meteorological Change in Japan and Vicinity over the Course of History). *Chigaku zasshi / Journal of Geography* 76 (1967): 115-41.
- Yamamoto Takeo, Fukaishi Kazuo, Maejima Ikuo, Mizukoshi Mitsuharu, Yoshimura Minoru, Shitara Hiroshi, Urushibara Kazuko, Hayashi Yōsei, and Kurosaka Hiroyuki. “Kokikō fukugen ni riyō dekiru nikki, ryokōki nado no chiiki betsu mokuroku (I)” (Regionally-Organized Catalogue of Diaries, Travelogues, Etc., That Can Be Used to Reconstruct Past Climates, Part 1). *Kikōgaku, kishōgaku kenkyū hōkoku* (Climatological and Meteorological Research Reports) 5 (1982): 60-82.
- Yamamoto Takeo, Fukaishi Kazuo, Maejima Ikuo, Mizukoshi Mitsuharu, Yoshimura Minoru, Shitara Hiroshi, Urushibara Kazuko, Hayashi Yōsei, and Kurosaka

- Hiroyuki. “Kokikō fukugen ni riyō dekiru nikki, ryokōki nado no chiiki betsu mokuroku (II)” (Regionally-Organized Catalogue of Diaries, Travelogues, Etc., That Can Be Used to Reconstruct Past Climates, Part 2). *Kikōgaku, kishōgaku kenkyū hōkoku* (Climatological and Meteorological Research Reports) 8 (1983): 54-59.
- Yasue, Koh, Ryo Funada, and Yoshihiro Nobori. “Tree-Ring Data Obtained by Densitometric Analysis as Indicators for Past Climate Reconstruction in Northern Japan.” In *Proceedings of the International Conference on Climate Change and Variability—Past, Present and Future—*, edited by Takehiko Mikami. Hachioji-shi, Tokyo: International Geographical Union Commission on Climatology / Department of Geography, Tokyo Metropolitan University, 2000.
- Yoshimura, Minoru. “Climate in the Little Ice Age over Japan.” In *Nature and Humankind in the Age of Environmental Crisis*, edited by Ito Shuntaro and Yasuda Yoshinori. Kyoto: International Research Center for Japanese Studies, 1995.
- Yoshimura Minoru. “Konikki kara Nihon no kikō o yomu: Shōhyōki to kikin no kankei” (Reading Japan’s Climate from Old Diaries: The Relationship between the Little Ice Age and Famine). *Kankyō kaigi* (Environmental Conference) 22 (2004): 86-89.
- Yoshimura Minoru. “Shōhyōki no kikō” (Climate of the Little Ice Age). In *Rekishi to kikō* (History and Climate), edited by Yoshino Masatoshi and Yasuda Yoshinori. Vol. 6 of *Kōza: Bunmei to kankyō* (Lectures on Civilization and Environment). Tokyo: Asakura shoten, 1995.
- Zaiki, M., G.P. Können, T. Tsukahara, P.D. Jones, T. Mikami, and K. Matsumoto. “Recovery of Nineteenth-Century Tokyo/Osaka Meteorological Data in Japan.” *International Journal of Climatology* 26 (2006): 399-423.
- Zaiki Masumi, Tsukahara Tōgo, Mikami Takehiko, and Matsumoto Keiko. “Nihon ni okeru 19 seiki ikō no kokishō kiroku to sono kikōgaku teki igi / Old Instrumental Records in Japan since 19th Century and Its Climatological Significance.” *Gekkan chikyū* (Earth Monthly) 27, no. 9 (2005): 706-12.