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Mt. Tambora, Climatic Changes, and China’s Decline in the Nineteenth Century*

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Mt. Tambora, an active volcano located on the island of Sumbawa, Indonesia, symbolizes the remarkable global impact of nature on human society. Regarded as extinct and inactive for about five thousand years before the second decade of the nineteenth century, Mt. Tambora stood as a known landmark for sailors out at sea, with a height of more than 4,200 meters above sea level. Its awakening began some time in 1812. Earthquakes and small eruptions of steam and ash continued for three years until the evening of 5 April 1815, when the first significant eruption occurred.1 The eruption pro-

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duced a column of ash and smoke probably as high as 25 kilometers, and the explosion was heard more than 1,000 kilometers away.² Small eruptions followed for days. On the evening of 10 April, a deafening eruption created a column of smoke, ash, and pumice more than 40 kilometers high, and the roar was heard in western Sumatra, more than 2,500 kilometers to the west,³ and in Ternate in the Moluccas, 1,400 kilometers to the east.⁴ After that, Mt. Tambora remained active for several weeks. When silence returned, Mt. Tambora was reduced from 4,200 meters high to its present height of 2,863 meters.

The eruption of Mt. Tambora in 1815 is the largest ever in recorded history, with a volcanic explosivity index (VEI) of 7.⁵ Astonishingly, it also boasts the largest magma (and thus ash fallout) eruption, with a bulk volume about 150 cubic kilometers of pumice and ash.⁶ With such a scale, it made history for itself in local, regional, and global contexts. The explosions and subsequent whirlwinds destroyed villages, killed people, and altered the ecology of the island, as well as damaging others

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² De Boer and Sanders, *Volcanoes in Human History*, p. 143.
³ Ibid.
⁴ Stothers, “Great Tambora Eruption in 1815,” p. 1192.
⁵ K. R. Briffa, P. D. Jones, F. H. Schweingruber, and T. J. Osborn, “Influence of Volcanic Eruptions on Northern Hemisphere Summer Temperatures over the Past 600 Years,” *Nature* 394 (June 1998): 452. VEI indicates the eruption power by measuring how much volcanic material is thrown out, how high the eruption goes, and how long it lasts. Its scale goes from 0 to 8. An increase of one point indicates an eruption ten times more powerful. The Yellowstone eruption in 640,000 B.P. is assigned with a VEI of 8. Some other indexes include the dust veil index (DVI) and the ice-core volcanic Index (IVI). DVI estimates the amount of material dispersed into the atmosphere and the time span it stays in the stratosphere. DVI also indicates that the 1815 Mt. Tambora eruption was the most influential in recorded history. See Stothers, “Great Tambora Eruption in 1815,” p. 1197. IVI measures volcanic aerosol loading, and has been widely adopted in research studies. While these indexes highlight different aspects of eruption, they all have their own disadvantages and problems. See Briffa et al., “Influence of Volcanic Eruptions,” p. 451; and William S. Atwell, “Volcanism and Short-Term Climatic Change in East Asian and World History, c. 1200–1699,” *Journal of World History* 12, no. 1 (2001): 30–36.
⁶ The estimates of erupted magma vary, but recent studies have narrowed the gap. Stothers concludes a volume of about the equivalent of 150 cubic kilometers of pumice and ash (equivalent to 30–75 cubic kilometers of dense rock), while many others estimate 50 cubic kilometers of dense rock. Stothers, “Great Tambora Eruption in 1815,” p. 1194; Haradur Sigurðsson and Steven Carey, “The Eruption of Tambora in 1815: Environmental Effects and Eruption Dynamics,” in Harrington, *Year without a Summer?* pp. 16, 27; De Boer and Sanders, “Eruption of Tambora in 1815,” p. 144.
in the vicinity. A tsunami with 4 or 5 meter high waves followed, buffeting many of Indonesia’s islands, and ash fallout continued for days, reaching islands more than 1,000 kilometers away.

While many people perished directly in the eruption, its indirect effects were just as deadly and much wider in scale. Ashes from the eruption fell on land and destroyed vegetation, including the staple plantations needed for survival. Famines followed, with endemics on the island and its neighbors, including Bali. The estimate of the numbers killed varies; one study concludes with a figure of at least 117,000.7 Furthermore, the eruption caused worldwide climatological changes, one of which is commonly known as “the year without a summer” (1816).8 Weather extremes wreaked havoc in the following two to three years. These climatic changes created and complicated prevailing socioeconomic problems around the world.

Recently some climatic extremes have been brought forward by a few historians to caution against conventional political and socioeconomic narrative, especially of some monumental historical shifts. Mike Davis, for example, has examined the three global droughts in 1876–1879, 1889–1891, and 1896–1900 resulting from the mega El Niño.9 His study has demonstrated that imperialism not only weakened traditional methods of disaster relief but also increased the vulnerability of peasants around the world. Richard H. Grove moves on to examine the global impact of the El Niño of 1789–1793, thus establishing another case of climatic extremes in world history.10 William S. Atwell, focusing on another significant climatic event in human history, has reviewed the progress of scientific studies on volcanism and short-term

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7 De Jong Boers, “Mount Tambora in 1815,” pp. 50, 58. Richard B. Stothers concludes that more than eighty-eight thousand people died directly and indirectly from the eruption. Stothers, “Great Tambora Eruption in 1815,” p. 1191.
8 While its climate impact was global in scale, G. Thompson Lonnie and Ellen Mosley-Thompson point out that the specific regional response was quite complicated. G. Thompson Lonnie and Ellen Mosley-Thompson, “Evidence for Changes in Climate and Environment in 1816 as Recorded in Ice Cores from the Quelccaya Ice Cap, Peru, the Dunde Ice Cap, China, and Siple Station, Antarctic,” in Harrington, Year Without a Summer? pp. 479–492. The Dunde ice cap at the Dunde site, Qinghai Province, reveals “a cooling trend underway before the eruption,” while the eruption “might have strengthened the cooling trend” in the second decade of the nineteenth century. Lonnie and Mosley-Thompson, “Evidence for Changes in Climate and Environment in 1816,” p. 479.
climatic anomalies and discussed some historical events in East Asia and beyond during the period 1200–1699.11 This present research synthesis follows his pioneering work and brings the Mt. Tambora eruption in 1815 and climatic changes into history, particularly Chinese history.12 It first introduces scientific studies that have established the correlations between volcanism and global climatic abnormalities (commonly simplified as global cooling), particularly by focusing on the case of Mt. Tambora. Attempts follow to synthesize some recent research in China concerning the Mt. Tambora impact and the cold period in the nineteenth century and hence to substantialize and revise some general statements made previously in the case of China. These case studies not only cover various regions in Qing China such as the Yangzi Delta, Yunnan in Southwest China, the Jiaodong Peninsula in coastal North China, and the North China Sea region but also touch upon a wide range of topics such as flooding, famines, economic recessions, changes in crop patterns (including those of New World crops), and Pacific herring catches. Finally, some reflections attempt to bring climate into the specific temporal span of the Qing Empire. We propose further studies of Mt. Tambora’s impact in China, share some suggestions, and discuss a few issues and problems. We then raise the question of the role of climate in the decline of Qing China. The early nineteenth century saw the beginning of a cold period and the depression and crisis in Qing China before the arrival of Western gunboats. Was it simply a coincidence? Whatever the cause, the questions addressed here are how the cold period affected Qing China’s sharp wane and accelerated the rise of Western imperialism, and in what different ways the various regions and societies responded to the natural disasters.

**Volcanic Climatic Changes: The Case of Mt. Tambora**

As early as 1784, Benjamin Franklin suspected that the volcanic dust veil played a role in reflecting the sun’s rays and thus reducing the


temperature of the earth, but it was not strictly until the twentieth century that the mechanism between volcanism and short-term climatic changes was revealed. As this article discusses the impact of Mt. Tambora’s eruption in 1815, the authors would like to divide the meteorological role of volcanic eruption into two questions. First, theoretically, how does a major volcanic eruption cause a global cooling trend? And second, what was the role of the 1815 Mt. Tambora eruption in the global extremes in 1816 and thereafter?

The correlation between volcanism and short-term climatic anomalies has been scientifically established. Volcanic eruptions of substantial size and their meteorological and optical phenomena not only were observed and sometimes recorded by contemporary people but also left their immediate and long-lasting marks on the earth’s surface. While some marks have been erased with the passage of time, many others are available, especially with the help of modern technology. Scientists today have adopted many effective ways to reveal the influence of eruptions in both regional and global contexts. Ash layers in the deep sea (if available), tree rings, acid precipitation on ice cores, and even coral growth during the discussed years have been collected and analyzed to illustrate climatic changes (i.e., temperature and precipitation). One prominent impact of the eruption was a cooling trend with high precipitation, although some details are still under debate on this extremely complex issue.

Volcanic eruptions throw out enormous amounts of magma and thus ash fallout. The ash fallout and fine particles form dust veils and enter the stratosphere. The dust veil can stay there for a year or two and reflect the sun’s rays, thus, less solar light energy penetrates to warm the planet. Using scientific language, after a volcanic eruption, high in the stratosphere,

\[ \text{sulfur dioxide [SO}_2\text{] molecules combined with water vapor to yield sulfuric acid aerosols.} \]

Prevailing winds carried the aerosols around the world. They formed veils that reflected a significant amount of sun-

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light, preventing its warmth from reaching the earth’s surface. And because the veils remained above the clouds and were not washed out of the atmosphere by rain, they remained in place for years and created a long-term cooling trend.

Once the acidic aerosol droplets began to sink lower in the atmosphere, moreover, they provided nuclei for condensation and hence increased cloud formation. Acidic droplets are smaller than the droplets in normal clouds, and many small droplets are much more reflective than fewer large droplets. Thus the clouds themselves became more reflective, which added to the cooling trend.\(^\text{15}\)

Clearly, in theory, volcanic eruptions do contribute to temperature cooling. Nevertheless, many other factors simultaneously play their roles. William S. Atwell has presented general readers with an excellent introduction to the three major factors on short-term climate changes: volcanic eruption, the El Niño–Southern Oscillation phenomenon, and solar radiations. Primary attention hereinafter is paid to discussing how these factors contributed to the 1816 abnormalities.

The year 1816 is well known as “the year without a summer.”\(^\text{16}\) It is generally accepted by scientists that the surface temperature in the northern hemisphere landmass may drop by a few tenths of a degree Celsius following major volcanic eruptions and that this impact may last for two to three years.\(^\text{17}\) Scientists conclude that global tempera-

\(^{15}\) De Boer and Sanders, *Volcanoes in Human History*, p. 149. Many factors affect the ability of dust veils to reflect the sun’s rays, such as the latitude location of the volcano, the time of year, the magma composition, the size of the dust particles, and their height in the atmosphere. Dust concentration in the lower stratosphere (20–27 kilometers) is a key reason, as the decrease in surface temperature primarily results from the residue of sulfate aerosols that nucleate in the stratosphere. See Michael R. Rampino and Stephen Self, “Historic Eruptions of Tambora (1815), Krakatau (1883), and Agung (1963): Their Stratospheric Aerosols, and Climatic Impact,” *Quaternary Research* 18 (1982): 127–143.

\(^{16}\) For abnormal weather in 1816, C. Wilson provides a good summary of major world regions. C. Wilson, “Workshop on World Climate 1816: A Summary and Discussion of Results,” in Harrington, *Year without a Summer*, pp. 523–555; For the hot and dry summer, see C. Wilson, “Workshop on World Climate in 1816: A Summary and Discussion of Results,” in Harrington, *Year without a Summer*, p. 532; T. Mikami and Y. Tsukamura, “The Climate of Japan in 1816 as Compared with an Extremely Cool Summer Climate in 1783,” in Harrington, *Year without a Summer*, pp. 462–475. As mentioned, regional climate response varied. While the summer was cool in 1816 on the Eurasian land mass (generally speaking) and northwestern North America, in the central United States, Eastern Europe, and Japan, it was fairly hot and dry.

tures in 1816 decreased by about 0.4–0.7°C (0.7–1.3°F). This change is primarily accredited to Mt. Tambora, but what other factors might there have been?

As early as 1924, Willis I. Milham, based on his study of weather records in Williamstown, Massachusetts, from 1816 to 1838, illustrated an extremely cold summer in 1816 and insightfully pointed out that Mt. Tambora was the possible prime factor alongside certain other elements, such as changes in solar activity, the sea surface temperature (SST), atmospheric composition (particularly carbon dioxide changes), and accidental causes.19

With the help of progressive scientific methods many scholars are now able to provide scientific mechanisms to explain Milham’s list. While acknowledging that Mt. Tambora constituted a cause and most probably the major cause, both Edward Skeen and William S. Atwell, for example, also highlight the role of the sun and the SST.20 The sunspot minimum in conjunction with volcanic activity can drop the Earth’s temperature by 1°F, and the SST can increase or decrease significantly, particularly under the influence of the El Niño–Southern Oscillation phenomenon.21 The El Niño–Southern Oscillation refers to the cycle of waxing and waning in the strength of the pressure gradient across the Pacific that can lead to an increase in the SST by up to 4°C, while La Niña, the reverse of El Niño, can cause below-normal sea surface temperatures in the eastern Pacific.

Willie Soon and Steven H. Yaskell have further refined the sun-earth connection in this discussion. They argue that the abnormal summer of 1816 in the northern hemisphere was caused by a combination of natural factors, including the catastrophic eruption of Mt. Tambora in 1815, the Dalton Minimum (ca. 1795–1820), and probably the wobbling of the sun.22 The Maunder Minimum (ca. 1645–1715) and the Dalton Minimum refer to the “extended period of very weak solar activities, spanning about 70 and 25 years, respectively.”23 During these

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18 Stothers, “Great Tambora Eruption in 1815,” p. 1197. Bernice de Jong Boers states that the summer of 1816 was an average of 1 to 2.5 degrees cooler than normal but fails to cite a source. See de Jong Boers, “Mount Tambora in 1815,” p. 51.
19 Milham, “The Year 1816.”
22 Soon and Yaskell, “Year without a Summer,” pp. 13–22.
23 Ibid., p. 16.
periods, far fewer sunspots were recorded than normal, which means very weak solar magnetic activity. As a result, the earth receives less solar light energy. The year 1816 was around the maximum of the sun’s eleven-year sunspot cycle, but the number of sunspots only amounted to thirty-five, far fewer than the one hundred or so for a normal sunspot maximum year. The question still remains as to what degree the low solar activity affected global cooling; the sun, compared with the Mt. Tambora eruption, played just a minor role in cooling the earth, at least for that year.

The wobbling sun may have had its role in another way. Every 178–180 years, the sun moves around the solar system’s center of mass (bary-center) in cycles, due to the gravity tug of the planets (mainly Jupiter and Saturn). The sun’s motion around the barycenter coincides with some years of weak solar activity (such as 1632 and 1811) and natural catastrophes on earth, such as earthquakes, volcanic eruptions, torrential rainfall, and changes in surface air temperature. The exact nature of this relationship, however, is still under speculation.

In conclusion, among the many factors causing the global cooling in 1816, the Mt. Tambora eruption played a major role, and ash fallout, particularly aerosols, was the prime cause of the year without a summer. Surprisingly though, the year 1816 was not the coldest statistically. The average deviation of mean temperature (−0.7°C) in the northern hemisphere in 1816 hardly seems significant compared with the year 1814 (−0.7°C too), or the year 1812 (−1.0°C). In fact, the standard deviation in the period from 1800 to 1840 was +0.5°C to −0.5°C. So why has the year 1816 been remembered as the “year without a summer” and “eighteen hundred and frozen to death”?

In fact, the global climatic impact caused by Mt. Tambora was far more complex than the phrase “a year without a summer” suggests. First of all, the Mt. Tambora eruption occurred during the Little Ice Age around the nineteenth century transition. It had exacerbated the global cooling trend. Nevertheless, a cold summer in 1816, to be accurate, was a regional phenomenon, and an accurate term for the

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24 Ibid., pp. 14, 20. Contemporary records of large sunspots in 1816 and 1817 say they were even seen with the naked eye because of the thick volcanic haze. Other optical phenomena such as beautiful sunsets and twilights were also recorded. For their mechanism, see Stothers, “Great Tambora Eruption in 1815,” pp. 1194–1195.
25 Soon and Yaskell, “Year without a Summer,” p. 17.
28 Ibid.
29 De Boer and Sanders, Volcanoes in Human History, p. 149.
1816 weather is “abnormities,” correctly phrased by Milham in 1924. Harrington summarizes the findings of an international meeting titled “The Year without a Summer? Climate in 1816” in 1988 as follows:

Evidently, the massive injection of Tambora aerosols into the atmosphere in 1815 resulted in crossing a threshold to highly anomalous weather (probably involving blocking highs and break monsoons) in many parts of the globe. Certainly “the year without a summer” in 1816 was a regional phenomenon. In the northern hemisphere parts of western North America, eastern Europe and Japan seem to have had average or above-average temperatures, as opposed to the remarkable cold that characterized much of eastern North America, western Europe, and China.

Thus, the usage of the annual average deviation of mean temperature serves to reveal the macro-level meteorological conditions and consequently the power of the eruption over a period of a year or two or even longer, but it fails to map regional climate responses and their subsequent immediate catastrophes. For example, a drop of 0.5°C of the average deviation seems fairly normal in some years or over a period of time, but a drastic drop of temperature caused by frost and cold winds over a short period (i.e., a few days or a week) proves to be fatal to crops during their growing seasons, as happened in New England in the summer of 1816. In fact, the average temperature for the year 1816 in northeastern North America was only slightly cooler than normal, due to a warm February, October, November, and December. The commonly cold summer was made notorious by three very cold spells, in June, July, and August, respectively, which proved to be fatal to crops. Milham’s empirical study illustrated that 1816 was a phenomenal year not because the year as a whole averaged so low, not because each month of the year was uniformly cold, but

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30 Atwell has explained how climatic anomalies were created due to various factors. Atwell, “Volcanism and Short-Term Climatic Change in East Asian and World History,” p. 34.
32 Skeen, “Year without a Summer,” p. 52. While acknowledging that Mt. Tambora “was a cause and possibly even the major factor” for the weather of 1816, he reminds us of some other factors, such as sunspots and the decrease of the surface temperature of the ocean. See Skeen, “Year without a Summer,” pp. 62–63. John A. Eddy points out that the 1815 Mt. Tambora eruption took place during a span of several decades of colder temperatures, and that this colder spell was possibly related to a coincident depression in solar activity between about 1790 and 1830, the so-called Dalton Minimum or the Little Maunder Minimum. John. A. Eddy, “Before Tambora: The Sun and Climate, 1790–1830,” in Harrington, Year without a Summer, p. 11.
because the three summer months and the two adjacent ones were all cold, and chiefly because the lowest temperatures were extremely low in a locality where the difference of a very few degrees in the lowest temperature during the summer months makes all the difference between a severe frost and the absence of frost.  

Mt. Tambora, Climatic Changes, and Their Aftermath in China

Since the end of the last century, some revisionist historians have evaluated the place of East Asia (China represented by the Yangzi Delta) and Europe (represented by Britain) in the world economy. Some interesting yet still hotly debated findings have fascinated scholars. These new revolutionary findings point out that “East Asian economies maintained strength and vitality up to the end of the eighteenth century, [that] they participated in an interconnected world economy throughout the early modern era, and [that] only sometime after 1800 did they fall behind rapidly growing European economies.” Put simply, China was as economically sound as Britain until the end of the eighteenth century, if not better, and the turning point suddenly took place only in the early nineteenth century.

No matter whether such a world historical hypothesis is true or false, the first few decades of the nineteenth century seem to have been crucial for the Qing Empire. Whereas many challenges could have found their earlier origins, this period witnessed a rapid recession in

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the whole of the eighteenth century saw territorial expansion, frontier incorporation, economic growth, population boom, urbanization, cultural sophistication, and intensified global trade. Commonly called the Prosperous Age of the Kangxi-Qianlong, this period suddenly ended during the transition into the nineteenth century. As soon as he had ascended the throne, the Jiaqing emperor (r. 1796–1820) faced many internal problems, including ethnic riots, economic downturn, and natural disasters, alongside bureaucratic corruption, of course. This trend in decline was so evident in the Daoguang reign (r. 1821–1850) that scholars now call it the Daoguang Depression (Daoguang xiaotiao). It was during this period that Sino-Western interactions turned into the violent Opium Wars and that the Taiping Rebellion (1851–1864) broke out, which almost ended the Manchu dynasty. In short, the first six decades of the nineteenth century (roughly the Jiaqing and Daoguang reigns, plus the Xianfeng reign, 1851–1861) saw China’s economic shift from prosperity to recession and finally crisis, and constituted a very crucial part in the change of Qing China from a world economy to a lag-behind. In this section, some case studies from Jiangnan (the Yangzi Delta), Yunnan in southwest China, the Jiaodong Peninsula in Shandong Province, and the North China Sea region are summarized to reveal the far-reaching impacts of climatic change on Qing China, in which Mt. Tambora made its voice heard a few thousand miles away.\footnote{Li Bozhong, “The Daoguang Depression and the 1823 Flood Economic Decline, Climatic Cataclysm and the Nineteenth-Century Crisis in Songjiang,” Shehui Kexue [Journal of Social Sciences] no. 6 (2002): 173–178; Yang Yuda, Man Zhimin, and Zheng Jingyun, “Jiaqing Yunnan Dajihuang (1815–1817) u Tanbola Huoshan Penfa” [A Serious Famine in Yunnan (1815–1817) and the Eruption of Tambola Volcano], Fudan Daxue Xuebao no. 1 (2005): 79–85; Cao Shuji, “Tanbola Huoshan Baofa yu Zhongguo Shehui Lishi” [The Tambora Eruption and Chinese Society and History], Xueshujie [Academics in China] no. 5 (September 2009): 37–41; Li Yushang, “Huanhaifei de Fengqian yu 1815 Nian Zhihoub de Qihou Tubian” [The Fluctuations of Clupea Pallasi and the Climatic Change since 1815], Xueshujie [Academics in China] no. 5 (September 2009): 42–55; Wang Baoning, “Jiaodong Bandao Nongzuowu Jiegou Biandong yu 1816 Nian de Qihou Tubian” [The Change of Crop Structure in the Jiaodong Peninsula and the Climatic Change since 1816], Xueshujie [Academics in China] no. 5 (September 2009): 56–70. The rest of the section goes on to summarize the studies mentioned earlier, unless otherwise specified. The three essays by Cao, Li, and Wang are a forum in the journal on the impact of Mt. Tambora’s eruption in China.}
Many socioeconomic problems plagued the Daoguang reign, such as monetary problems (the high price of silver), agricultural stagnation, market recession, floods, famine, social unrest, and other setbacks. Such a recession was deeply felt in Jiangnan, the economic, commercial, and cultural center of late imperial China. But what factors caused the decline of Jiangnan’s once prosperous society? Taking Songjiang in Jiangnan (one of the most wealthy prefectures in Qing China for its rice and cotton industry) as an example, Li Bozhong cites contemporary sources and pinpoints the economic depression during the Daoguang reign, as revealed by the great drop in land prices, the decrease in agricultural yields (and thus peasants’ incomes), and the stagnation and eventual bankruptcy of the cotton textile industry. The case of Songjiang indeed epitomized Jiangnan, where the long-term recession began in the 1820s. The economic change caused considerable social unrest and consequently accounted for the fact that Jiangnan, the economic core, became a major base for the Taiping Rebellion, which originated from a mountainous ethnic area in Guangxi, a southern periphery of the empire.

Acknowledging that the reasons behind the decline were complex, Li Bozhong dismisses the conventional wisdom that regards Western industrialization as the main cause of economic recession in Jiangnan. Instead, Li argues that the global climatic cataclysms in the early nineteenth century constituted one of the most important conditions. In 1823, rain fell from the second month to the ninth month (lunar calendar), with short intervals only in the sixth and eighth months. As a result, Songjiang witnessed unprecedented flooding, which in turn caused a total failure of the rice crop (and presumably a serious decrease in cotton). Flooding also caused a severe reduction in soil fertility, which had a far-reaching impact on agriculture. No sooner had Songjiang recovered from this disaster than another flood in 1833 inundated the region. With hardly a break, a third big flood occurred in 1850, leaving Songjiang no time to recover. The mechanism of flooding is complex, but the three in Songjiang were indeed directly related to earth temperatures in the northern hemi-

In his work, Li Bozhong insightfully detailed the effects of climate on rice production in Ming-Qing Jiangnan. Li Bozhong, “‘Tian’ ‘Di’ ‘Ren’ de bianhua yu Ming Qing Jiangnan shuidao shengchan” [Changes of Climate, Land, and Human Effort, and Rice Production in Ming-Qing Jiangnan], Zhongguo Jingjishi Yanjiu [Studies in Chinese Economic History] no. 4 (1994): 103–121; Li Bozhong, “Changes in Climate, Land, and Human Efforts: The Production of Wet-Field Rice in Jiangnan during the Ming and Qing Dynasties,” in Elvin and Liu, Sediments of Time, pp. 447–486.
sphere from 1815, with a cold phase in China, as in the rest of the northern hemisphere.³⁸

While Li and some other scholars have examined the relationship between agricultural or economic problems with climatic change in a short period, they have not categorically confirmed that Mt. Tambora had anything to do with climatic acidity. Certain other scholars during the last decade have explicitly correlated agricultural production, socioeconomic disasters, and climatic changes with the 1815 Mt. Tambora eruption. The period from 1812 to 1817 was cold all over the world, primarily due to several major eruptions (Mt. Soufrière on St. Vincent Island in the West Indies erupted on 30 April 1812, Mt. Mayon on Luzon Island in the Philippines in 1814, and Mt. Tambora in April 1815).³⁹ Based on local gazettes, official histories, governmental documents, and personal diaries, some scholars have noted “anomalously cold and stormy weather from the winter 1815–1816 to summer 1817 in 14 provinces.”⁴⁰ Immediately after the eruption of Mt. Tambora, the most severe famine in pre-twentieth-century Yunnan swept this frontier area in southwest China for three successive years (1815–1817). This famine incurred a massive death toll, displaced refugees, and fomented social unrest. Just as happened in New England in 1816, low temperatures and cold spells came to Yunnan during the crop growth season. Unfortunately, unlike in Williamstown, Massachusetts, China did not have any modern meteorological records at that time. However, local gazetteers did provide a similar profile. The low temperatures first appeared in western and central Yunnan in 1815, and then affected almost the entire province in 1816. Heavy precipitation followed, making the weather unusually wet. Frost and even snow took place during the summer in some areas. The mean temperature deviation in August 1816 at Kunming, capital of Yunnan, might have been 2.5–3°C lower and even more extreme in some other areas. As a result, local staple crops such as rice and buckwheat failed massively. The general situation improved in 1817 and returned to normal in 1818. Yang Yuda and his colleagues unanimously conclude that the great famine in Yunnan was primarily caused by Mt. Tambora’s eruption and low solar activity.

³⁹ Skeen, “Year without a Summer,” p. 60.
Some scholars have not only noticed the immediate climatic changes caused by the Mt. Tambora eruption but also placed it into a relatively long-term time span. Wang Baoning, for example, has analyzed how the climatic changes shaped the crop structure in the Jiaodong Peninsula in Shandong Province throughout the nineteenth century. Based on the scrutiny of local gazetteers of various prefectures and counties in the Peninsula compiled in different reigns throughout the eighteenth and nineteenth centuries, Wang has shown that the changes in local crop structure corresponded closely to climatic changes. Local gazetteers in the late eighteenth century indicate that millet was the main crop in the area, while ragimillet existed only as a famine crop, usually placed at the end of supplementary crop lists. However, during the Daoguang reign, these roles were reversed. Ragimillet was widely planted while millet was dramatically reduced. In many counties and prefectures, ragimillet became the number one crop, and its output consisted of nearly half a year’s grain output. The key reason for this lies in the differing natures of millet and ragimillet. Millet is drought-resistant, requires an effective accumulated temperature (EAT) of 1,600–3,000°C, and prefers a dry and warm environment. Ragimillet requires an EAT of 1,800–2,000°C but is cold-resistant and hygrophilous. That is why ragimillet was widely planted when the peninsula experienced a cold climate with high precipitation during the Daoguang reign.

Wang Baoning also examined the spread of New World crops such as maize, sweet potato, and peanuts, and found that climatic changes also accounted for their varying roles in local society over time. In the last decades of the nineteenth century, the cold period was replaced by a warm one, and, as a result, ragimillet planting was reduced while millet made a comeback. However, millet never resumed its former importance, due to competition from maize, sweet potato, and peanuts, all of these being sensitive to cold spells and requiring an EAT of 2,700–3,500°C. The three New World crops reached China as early as the sixteenth century but were not reportedly planted in the peninsula until the Qianlong reign. After its introduction, sweet potato planting witnessed a hump pattern in the peninsula. It was soon widely planted and, by the end of the eighteenth century, became one of the main staples favored by the poor. In the mountainous coastal areas, it almost accounted for half a year’s grain. During the Daoguang reign, its planting scale was reduced, but from the 1870s onward, sweet potato quickly resumed and increased its significance. By the beginning of the twentieth century, sweet potato was a daily staple in Jiaodong.

Unlike the sweet potato, maize and peanuts underwent an explo-
sion pattern. As late as the Daoguang reign, the two crops were rarely recorded in local gazetteers and thus were unimportant in local society. From the Guangxu reign (r. 1875–1908) onward, both of these newcomers were planted on a large scale and soon became major crops. In the early twentieth century, some areas in the peninsula became a maize growth zone, while peanuts served as a key cash crop and contributed to the prosperous port economy of Qingdao. Many factors, such as population pressure, markets, and improved varieties, shaped the spread of New World crops in the peninsula, but obviously climatic change played a key role. Had there not been a cold period, sweet potatoes would have been a main crop as early as the 1820s, and maize and peanuts would have been popular four or five decades earlier. Wang Baoning’s work illustrates the complexity of New World crops in their colonization of China. Despite the fact that population pressure welcomed and facilitated their transplantation, especially on hilly frontiers, many other factors such as climate accounted for their regional trajectories.

Unlike these cases just mentioned that examine climatic impact on the landmass, Li Yushang chose to study Pacific herring (*Clupea pallasi*), a subarctic or north temperate cold-water species. Historically, Pacific herring were abundant in the North Pacific Ocean and were favored by American Indians, Europeans, Japanese, Koreans, and Chinese alike. Salinity and SST are the two decisive factors for their spawning and growth. More importantly, SST constitutes the most highly correlated factor for its recruitment fluctuations. Generally speaking, SST under 10°C is favorable. A close relationship between low to near-average SST and the appearance of very strong year-classes and between high SST and poor catches has been established in the case of the Japan Sea.

Along China’s coastal areas, fish are found only around the North China seas (specifically, the Bo Sea and the Yellow Sea along Shandong Peninsula). Pacific herring were once prolific along North China’s


coast during the Ming-Qing transition period, (the mid seventeenth century) when China experienced a cold period, but their numbers declined during the Qianlong reign. However, local gazetteers record that Pacific herring regained their population size during the second decade of the nineteenth century, and even attracted preying whales near the Liaodong Peninsula in the Bo Sea (an event still vividly retold by local people nowadays). Pacific herring continued to prosper throughout the Daoguang and Tongzhi (1861–1874) reigns but gradually disappeared roughly northward in the early 1880s, along the Luan River Bay (in the late 1870s). Interestingly, though, the disappearance of Pacific herring in Chinese seas drove Chinese fishermen to seek fish in the Korean seas in the closing years of the nineteenth century, as is revealed by both Chinese and Korean sources.

The fluctuations in the Pacific herring catch indicate that the SST experienced a decreasing pattern similar to that on China’s landmass.\(^4^4\) This kind of pattern can be confirmed by the presence of jellyfish. Unlike Pacific herring, jellyfish are chill-sensitive, and thus the SST’s impact on jellyfish is directly opposite to that of Pacific herring. The jellyfish fishing season usually occurs in the autumn in North China. When Pacific herring gradually disappeared in the 1870s–1880s, the jellyfish season shifted to the spring, probably due to the increase in SST. Local sources on Pacific herring profiled the changes of SST. The period 1816–1853 was the coldest since the fourteenth century; from 1854, the SST began to rise and the warm trend increased rapidly in 1875, causing the disappearance of Pacific herring in North China seas from 1884 onward. The SST pattern in North China seas during this period, Li reveals, was identical to that in the subtropical South Pacific.\(^4^5\)

Reflections: Climate and Qing China in the Nineteenth Century

Historians in China have learned about the global impact of the eruption of Mt. Tambora, conjoined with many other factors, and they also are aware that the embedded effect of the Little Ice Age roughly cov-

\(^{44}\) The impact of Mt. Tambora’s eruption on SST is similar to that of the northern hemisphere landmass. However, we are not sure about the role of ocean currents in the relevant seas, especially over the period in question.

erected the first three quarters of the nineteenth century. Empirical studies have shown that a climatic mutation occurred in China around 1816, and it was not until around 1830 that the wet and cold climate became stable and lasted until the 1870s in China.\textsuperscript{46} It is agreed that Mt. Tambora’s eruption played a primary role in the 1816 climatic mutation and accelerated the cooling trend in the affected years,\textsuperscript{47} whereas the Little Ice Age played a role in long-term disturbances. Due to both its practical and symbolic roles, the Mt. Tambora eruption has been seen as the signal event in the studies mentioned here.

A distinguishing feature of the case studies cited above lies in their efforts to link climate (and environment) with historical changes. They could not help but notice the relationship between climate and socioeconomic changes in the nineteenth century, a period so crucial for the Qing dynasty and for Chinese civilization. The Daoguang Depression witnessed natural disasters, economic recessions, and social unrest, including the Taiping Rebellion, the deadliest civil war in history in which more than 20 million people perished. Qing China’s internal crisis accumulated and worsened more or less in line with this cold climate period. The empire, however, managed to deal with Western powers and suppress internal rebellions from the mid 1860s onward. Reforms to enrich the country and strengthen the army continued, known as the Tongzhi Restoration or the Self-Strengthening Movement (Yangwu Yundong), until the disastrous failure of the Sino-Japanese War (1894–1895). Social order resumed, Western technology and some institutions were introduced, political reform was placed on the agenda, and, interestingly, the reform period again closely coincided with the arrival of a warm period. Was this simply coincidence, though? Scholars doubt this explanation, partially because such a phenomenon had a few historical precedents.

The Ming-Qing transition in the early and mid seventeenth century is now seen as a world historical event and fits well into the so-called seventeenth-century crisis. This overlaps pretty much both with the Little Ice Age and the Maunder Minimum (ca. 1645–1715), and more interestingly, many volcanoes erupted around this time, thus contributing to a cold seventeenth century.\textsuperscript{48} Of the thirty coldest years in the

\textsuperscript{47} Ibid., 1:388–389.
\textsuperscript{48} Six or even eight major eruptions occurred in the seventeenth century, while there were another three in the last decades of the sixteenth century. Briffa et al., “Influence of Volcanic Eruptions,” p. 453.
last six centuries, eleven took place in the seventeenth century, and eight before 1675.49 As a result, a series of cool summers (1601, 1641–1643, 1659, 1666–1669, 1675, and 1698–1699 respectively) occurred in this century.50 How could this natural context help us understand the rise of the Manchus and their conquest of Ming China? Specifically, how did the climatic change function as a background and a role in the political centralization and militarization of the Manchu people? While a hypothesis connecting climate and southern invasions of nomadic people from Inner Asia has long been acknowledged, empirical and quantitative studies have long been overdue. In the case of the Ming-Qing transition, it might be more appropriate to consider how the climate contributed to the decline and collapse of Ming China before its loss to the Manchus. Drought and famine wracked the final decades of Ming China, and plague rendered the city of Beijing defenseless in the year 1644. Hence, the causes of the collapse of Ming China before the conquest by the Manchus must include the role of climate changes.

Equal to its formation, the decline of the Qing Empire constitutes another significant world history event. Qing China’s decline coincided with a cold climate. Conventional Marxist historiography in China accused Western imperialism of being the key source for national humiliation, while scholars since the 1980s have begun to reflect on Qing China’s internal crisis prior to the arrival of the Western gunboats. Overexpansion, population pressure, class struggle, and even Neo-Confucianism were blamed for the decline, and it was not until the 1990s that scholars in China came to accept the role of environment and climate. When Li Hongzhang (1823–1901), a key statesman in the Qing court, mourned in 1872 that Qing China was facing the most tumultuous situation in the past three thousand years, he was referring to foreign challenges from the sea, and his concern for the very survival of Chinese civilization. Representing the Chinese elite, Li was one of the few Chinese who best understood the turbulent international situation, but he might never have thought to include the role of climate in Qing China’s sharp decline. Ironically, climate left a deep mark in the minds of ordinary people; as a contemporary catchphrase captures it, “Jiaqing’s property, (was) washed away by Daoguang (Jiaqing jia, Daoguang chongguang).” This phrase serves to remind us to put flooding and thus climate together with both internal and external factors in this great historical change.

49 Ibid., p. 450.
50 Ibid., p. 453.
The role of climate and environment is also pertinent when it comes to the debate on the great divergence between East Asia and Western Europe. A key question arises over how this cold period shaped China and Western Europe, respectively, especially considering the overwhelming pressure of the fragile environmental system in China. In other words, how did local societies respond to climatic changes and consequent calamities with their own traditions, institutions, mechanisms, and resources? Might these efforts have influenced the process of divergence, if not actually been a part of its origin? And how should the effects of climate be addressed in the comparison of macro-world history?

These wide-ranging questions cannot be discussed without being grounded in empirical studies at a local level. Further effort should be made to collect and analyze Chinese sources, to map empire-wide climatic changes, to reveal how the volcanic eruption and the cold period furthered and complicated ecological problems and socioeconomic unrest, and to discuss the local, Chinese, and possibly global implications. The first step is to explore Chinese local gazetteers, imperial archives, diaries, miscellaneous essays, and various correspondence, diaries in particular, in order to get a comprehensive profile of natural disasters related to the Mt. Tambora eruption. Preliminary studies indicate that in Beijing, the summer of 1816 was not cool and that during that winter snow was rare; quite the contrary was recorded, with the summer seeming relatively hot and the winter fairly warm.51 Given this, the generic statement that China in 1816 was relatively cold with heavy precipitation should be amended to note that there were regional variations. Regional variations, nevertheless, should be dealt with cautiously, since regional responses to climatic changes varied. Some areas were relatively sensitive, while others were not. This may have accounted for the uneven documentation of disasters even under similar or identical climatic or environmental changes.

Quantitative studies should examine the impact on both Chinese society as a whole and certain macroregions in particular, such as Jiangnan. Modern instruments and methods could be used to collect data from tree rings, ice cores, or pollen. Databases and models could be set up for scientific analyses. The far-reaching influence of climatic change on Chinese society, including agriculture, industry, and the economy, should be appropriately addressed. Specific attempts ought

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51 Personal email correspondence with Wang Tao. Wang’s study is based on the diary of Lin Zexu (1785–1851), governor-general of Guangdong and Guangxi when the First Opium War (1839–1842) broke out.
to be made to examine diseases and endemics. Scarcely documented before, schistosoma was ubiquitous during the Guangxu reign and became a deadly threat to many communities in Jiangnan. The authors suspect that the warm period facilitated the abundance of freshwater snails that in turn spread this disease. Social anxieties and responses including mobilization, relief, medication, and religious comfort (ash from the Mt. Tambora eruption, for example, was taken as a medicine in Borneo) should also be discussed.

In addition, climatic changes ought not to be confined within the boundaries of the empire, let alone the nation-state. Summer rainfalls in North China, for example, are brought by the combination of monsoons from both the Pacific and the Indian Oceans. The province of Yunnan in southwest China is particularly influenced by monsoons from the Bay of Bengal. Hence, climatic changes in Yunnan surely have some connection with the Bay of Bengal, especially considering the fact that local crops during their growth season rely primarily on rainfall brought by the Bengal monsoon. The authors find that the Jiaqing famine in Yunnan fits fairly well with the pattern of volcanic climate change in terms of its duration (two to three years). The first year saw the beginning and increasing impact of the eruption, the second year reached the apex of changes, and the third year returned to normal. However, the authors wonder how Yunnan responded so quickly to the eruption of Mt. Tambora in April 1815. Scientists have shown that the climate system responds to major eruptions much quicker than was earlier assumed. Northern hemisphere eruptions can decrease temperature as rapidly as within the same month of the eruption, and maximum cooling reached in the third month after the eruption, followed by a slow recovery over the next couple of years. But Mt. Tambora is located in the southern hemisphere, and the climate system responds to southern hemisphere eruptions a few months after those in the northern hemisphere. Cooling signals are first apparent in about the eighth month after an eruption, strongest in year 2, and disappear-

52 De Jong Boers, “Mount Tambora in 1815,” p. 42. Some scholars have made the link between the eruption and the first cholera epidemic from the Bay of Bengal to the world in the late 1810s and the 1820s. For this discussion, see de Jong Boers, “Mount Tambora in 1815,” pp. 53–55; Stommel and Stommel, “Year without a Summer,” pp. 184–186; Stommel and Stommel, Volcano Weather, pp. 109–115; De Boer and Sanders, Volcanoes in Human History, pp. 148–149.
54 Ibid., p. 751.
ing in year 3. Therefore, the cooling trend in 1815 Yunnan seems too quick to be a response to Mt. Tambora's eruption, while it may serve to confirm that a cold and rainy stage had started earlier.

Finally, there seems to be a classification of two kinds of disasters in human history, one as man-made or man-involved, the other as purely natural and in some cases unpredictable. The first one is usually related to or even caused by human activities. Landslides, floods, or droughts in modern times are directly or indirectly caused by human activities such as population booms, reclamation, deforestation, and so on. The other kind of disaster, such as earthquakes, volcanic eruptions, and arrivals of meteorites, are not related to human activities, and some are not predictable (such as earthquakes). These kinds of disasters have frequently shaped human society in general. Mt. Toba’s eruption in Sumatra more than seventy-one thousand years ago is said to have posed a deadly threat to human survival and stimulated rapid human genetic divergence. While human beings may be able to prevent, alleviate, and even avoid the first kind of calamity, they are at least currently helpless in preventing the outbreak of the second kind.

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55 Ibid., pp. 741–742.