https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

Revisiting the daily weather information in the *Guan Tingfen Diary* (Haining, China, 1815-1865)

Siyu Chen[1,2], Stefan Brönnimann[1,2]

[1]Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
[2]Institute of Geography, University of Bern, Bern, Switzerland

Correspondence to: Siyu Chen (siyu.chen@unibe.ch)

Abstract. Historical weather diaries provide valuable high-resolution information for investigating past weather and climate variability before instrumental observations. Here, we digitize and systematically categorize weather- and climate-related information from the *Guan Tingfen Diary*, a nearly continuous daily record from Haining, eastern China, spanning 1815–1865. The diary documents precipitation and sky conditions, together with wind, perceptions on cold/warm, hydrological conditions, unusual phenomena, and societal responses to weather and climate. Descriptive records were converted into standardized categories while retaining their original information as much as possible. Comparisons with other climate datasets show that the diary captures meaningful climatic variability. The high temporal resolution of the diary provides detailed insights into the intra-seasonal evolution of extreme climate events that cannot be resolved by conventional seasonal reconstructions. The diary also contains unusual weather and atmospheric phenomena that may provide additional evidence for investigating the climatic impacts of major volcanic eruptions. These results highlight the value of the *Guan Tingfen Diary* as a high-resolution documentary climate record and its potential for investigating historical climate variability and extremes and reconstructing daily weather in the early nineteenth century.

1 Introduction

The reconstruction of long-term climate records provides the foundation for understanding past climate change. Although paleoclimatologists worldwide have made substantial progress in climate reconstruction using proxy records and rescued early instrumental observations, most of these datasets have monthly or seasonal resolution (Dobrovolný et al., 2010; Ge et al., 2016; Hao et al., 2012; Lundstad et al., 2023). Private diaries are among the few sources capable of providing daily or even sub-daily weather information. Although such records are primarily descriptive, they are particularly valuable given the increasing attention to extreme events, especially for regions and periods where early instrumental observations were unavailable. Moreover, their largely independent and personal nature suggests that the recorded weather information can generally be regarded as honest and contemporaneous accounts (Adamson, 2015; Ge and Zhang, 1990).

Over the past few decades, historians and climatologists have uncovered a large number of weather diaries. The information recorded in these diaries—such as sky conditions, weather types, wind directions, phenological observations, and subjective

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

perceptions on cold/warm—can be extracted, transformed, and utilized to reconstruct monthly- and seasonal-scale variations in temperature, precipitation, and solar radiation, as well as to analyse the evolution of extreme climate events (Brönnimann, 2023; Chen et al., 2020; Ichino et al., 2025). In China, most long-term and continuous weather records preserved in private diaries date from the second half of the nineteenth century (Huang et al., 2013). Among them are four of the most renowned diaries of the Late Qing Dynasty: the *Xiangqilou Diary*, *Weng Tonghe Diary*, *Yuematang Diary*, and *Yuandulu Diary*. The weather- and climate-related information contained in these diaries has been digitized and used to reconstruct seasonal temperature variations and changes in the Meiyu rain belt, as well as to investigate dust events (Xiao et al., 2008; Zhang et al., 2006; Zheng et al., 2021).

The *Guan Tingfen Diary* is one of the longest weather diaries available from the early nineteenth century. It provides an almost continuous record of daily and sub-daily weather in the Haining region from 1815 to 1865, offering exceptionally rich information. What makes this diary particularly valuable is that it was authored by a single individual, providing a high degree of consistency in the observations. While previous studies have used this diary to reconstruct monthly precipitation and seasonal temperatures, the present study systematically revisits the diary by digitizing and categorizing its records of precipitation, sky conditions, wind direction, and perceptions on cold/warm, with the aim of uncovering additional insights and demonstrating the diary's broader potential for climate research (Liu et al., 2018; Tang et al., 2016; Zheng et al., 2014, 2021). Since the first half of the nineteenth century was marked by multiple volcanic eruptions of varying magnitudes, information potentially related to volcanic eruptions is also of particular interest in this study.

Section 2 introduces Guan Tingfen's life and his diary. Section 3 describes the categorization and digitization of the weather- and climate-related information contained in the diary. Section 4 presents the digitized dataset and evaluates it through comparisons with other climate datasets. Finally, Section 5 discusses the broader potential of the diary for historical climate research.

2 Guan Tingfen and his diary

Guan Tingfen (1797–1880) was a private book collector and textual critic during the Qing dynasty. His diary, which spans around fifty years and provides valuable documentary evidence for understanding both Guan Tingfen and his contemporaries, has been well preserved and published (Li, 2016). Although he was neither a meteorologist nor a climatologist, he observed and recorded daily weather throughout most of his adult life, from the age of 18 to 68, leaving abundant weather- and climate-related information.

Guan Tingfen spent most of his life in his hometown, Haining County, Zhejiang Province (Fig. 1). He occasionally left Haining for brief trips to Hangzhou, the provincial capital at the time, either to take the imperial examination or to visit acquaintances. Given the close proximity of Haining to Hangzhou, Guan Tingfen was sometimes able to make a round trip

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

within a single day. In addition, he made brief visits to Jiaxing County twice, in 1823 and 1825, Xiaoshan County in 1829, and Ningbo County in 1849. Overall, his activities were largely confined to Zhejiang Province. His longest and farthest journey began in October 1830, when he travelled to Beijing, and he did not return home until February 1832 (Li, 2016).

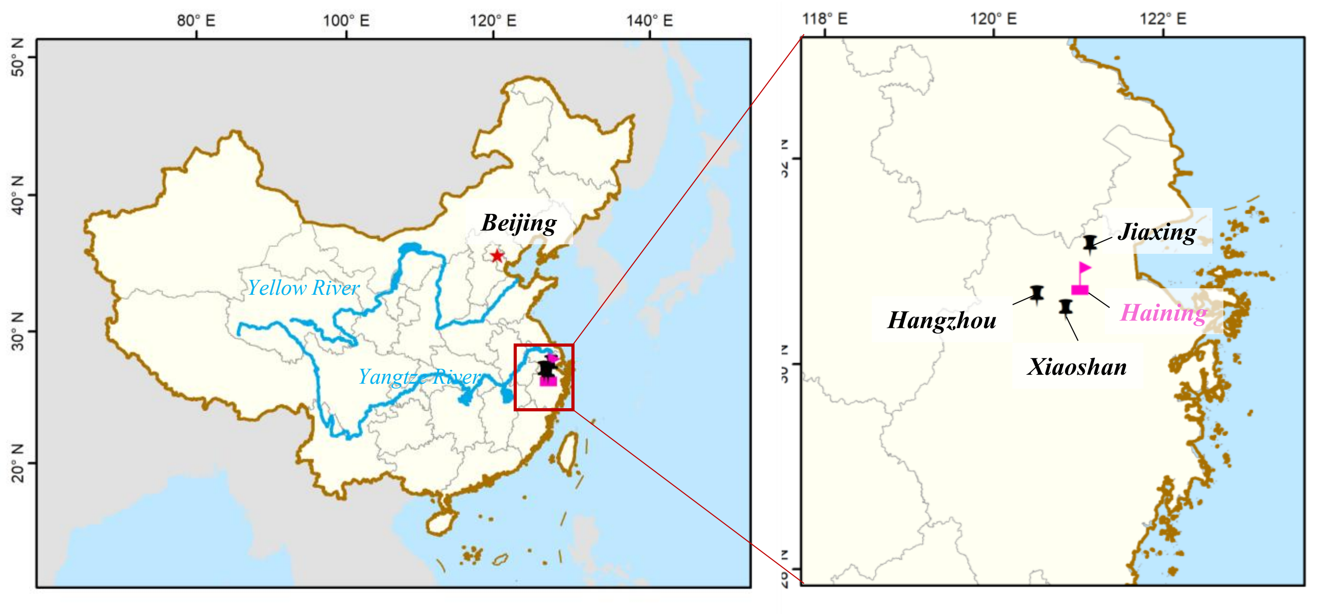

Figure 1 Location of *Guan Tingfen Diary*. The land basemap was made using Natural Earth vector map data, available at https://www.naturalearthdata.com. Province-level administrative boundaries and rivers were made using vector map data available from the Resource and Environmental Science Data Platform (https://www.resdc.cn).

Guan Tingfen's continuous observations began in the second month of the 20th year of the Jiaqing reign (March 11, 1815) and concluded in the twelfth month of the fourth year of the Tongzhi reign (February 14, 1866). Prior to 1815, only brief recollections containing limited climatic information are available for the period from 1797 to 1814. The diary is relatively complete and continuous from 1815 to 1865. Nevertheless, only approximate records are available for the period from 1817 to 1819. The diary entries recorded during his journey to Beijing and his return journey were also digitized and included in the dataset but were excluded from the subsequent analyses (Fig. 2).

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

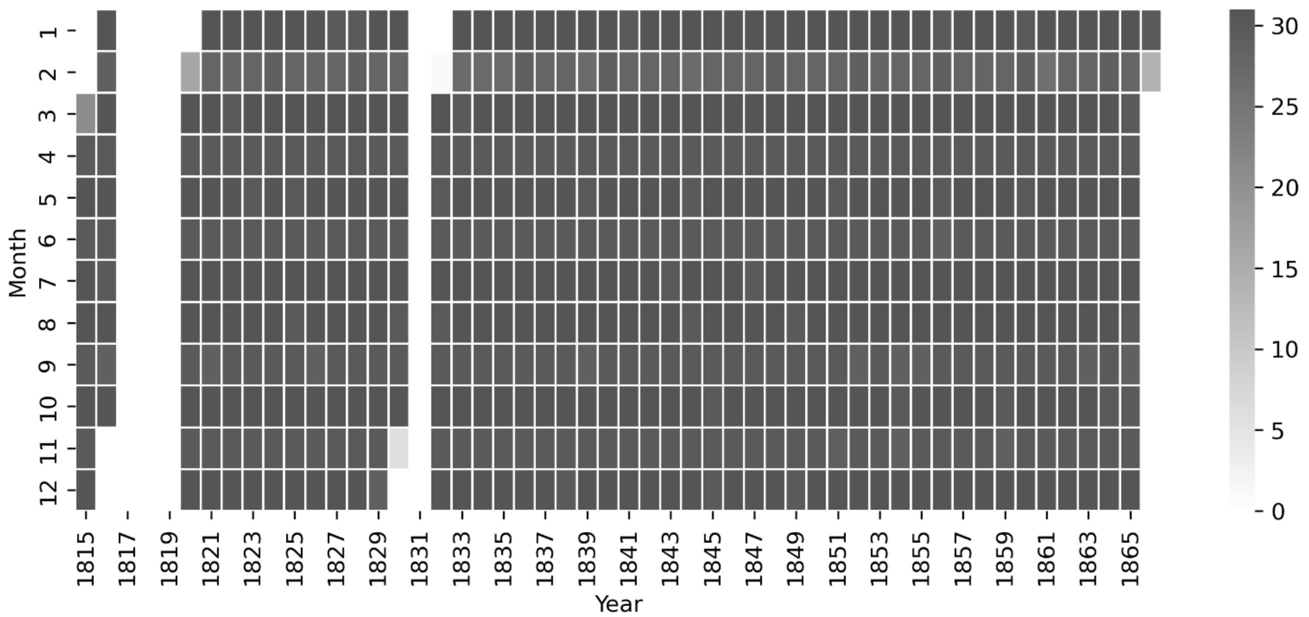

Figure 2 Number of daily entries per month (entries during journey to Beijing were not included)

3 Methods: Extraction, categorization, and digitization of weather information

In this diary, Guan Tingfen primarily recorded five types of weather- and climate-related information: precipitation (rainfall and snowfall), sky conditions, wind, perceptions on cold/warm, and hydrological conditions. Precipitation and sky conditions were documented on an almost daily or even sub-daily basis, whereas wind, perceptions on cold/warm, and hydrological conditions were generally noted in association with unusual weather conditions. In addition, certain notable phenomena—such as precipitation-related events (e.g., fog, frost, and hail) and unusual optical or astronomical phenomena (e.g., solar and lunar eclipses)—were also observed and recorded. Unlike instrumental observations, the diary also provides information on human responses to weather and environmental conditions.

In the diary, daily entries generally began in the morning. Accordingly, for the purpose of digitization, each diary day was defined as the period from 6:00 a.m. on a given day to 6:00 a.m. on the following day. Guan Tingfen employed three different systems to indicate time: the twelve-*Shichen* system (十二时辰), the five-*Geng/gu* night-watch system (更/鼓制), and a number of colloquial temporal expressions (Fig. S1). The twelve-*Shichen* system divides a full day (24 hours) into twelve *Shichen* (时辰), each lasting two hours. For example, *Wu* (午) roughly corresponds to the period from 11:00 a.m. to 1:00 p.m. The five-*Geng/gu* system divides the period from sunset to sunrise into five segments, with drum signals marking the transition from one *Geng/gu* to the next. In the twelve-*Shichen* system, *Mao* (卯) and *You* (酉) approximately correspond to sunrise and sunset, respectively. The five nighttime *Shichen* between *You* and *Mao*—*Xu* (戌), *Hai* (亥), *Zi* (子), *Chou* (丑),

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

and *Yin* (寅)—roughly correspond to the five *Geng/gu* of the night-watch system. In addition, common temporal references in the diary include "morning" (晨), "noon" (午), "late afternoon" (晚), "evening" (暮), "night" (夜), "midnight" (宵分), and "dawn" (晓), among others. These expressions do not correspond to fixed clock times but instead represent flexible, experience-based temporal categories, from which approximate time periods can generally be inferred.

The categorization of weather information was based on the semantic differential method. This method has been widely used to convert descriptions of different weather and climate conditions in historical documents, including weather diaries, into indices such as dry/wet indices, cold/warm indices, and precipitation indices (Chinese Academy of Meteorological Sciences, 1981; Zhang et al., 2007). In the *Guan Tingfen Diary*, rainfall information was separated into two components: rainfall intensity and rainfall duration. Rainfall intensity was categorized into four levels (Tab. 1). Level 1 represents light rainfall, such as drizzle or light rain explicitly recorded by Guan Tingfen. Level 2 represents moderate rainfall and includes instances in which Guan Tingfen merely noted the occurrence of rain without providing further details or qualifiers, as well as other descriptions of ordinary rainfall. Level 3 represents heavy rainfall, indicated by descriptions such as loud or intense rain sounds, heavy rain, thunderstorms, or other expressions indicating intensified rainfall. Level 4 represents extreme rainfall, characterized by expressions describing torrential or pouring rain.

Table 1 Categorization of rainfall intensity and corresponding descriptions

Rainfall intensity	Description
1-Drizzle	drizzle/light/dripping rain (微雨、小雨、丝雨、霡霂、滴沥)
2-Moderate	rain (雨); not very heavy rain (雨不甚大); continuous but not heavy rain (雨绵绵); dense rain (密雨); audible rain (有雨声); overcast and rainy conditions (阴雨); mixed rain and snow (雨雪交作)
3-Heavy	sudden and intense rain (急雨/骤雨); heavy rain (大雨); (heavy) thunderstorm ((大)雷雨); loud rain sounds (雨声大/壮/甚繁/甚厉/喧然/淅浪/淋漓); intense rain (雨势急/大/壮)
4-Extreme	torrential rain (暴雨); pouring rain (大雨如注/泼)

Rainfall duration was also categorized into four levels: brief, short-duration, half-day, and full-day (Tab. 2). Level 1 represents rainfall that lasted only briefly or was followed shortly by clearing conditions. Level 2 is a relatively broad category, including rainfall lasting from tens of minutes to several hours, intermittent rainfall during the day, and records for which the exact duration was not specified. Level 3 corresponds to rainfall lasting for approximately half a day, covering either the entire daytime or the entire night-time period. Level 4 represents rainfall persisting throughout both the daytime and nighttime periods, approximating a full diary day.

Table 2 Categorization of rainfall duration and corresponding descriptions

Rain duration	Descriptions

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

1-Brief	brief rain (雨，即止); rain followed immediately by clearing (雨，即晴)
2-Short-duration	rain for a while (一阵); lasting more than a quarter-hour/several quarter-hours (逾刻/数刻); morning/late-afternoon rain (晨雨/晚雨); alternating rain and clear conditions (晴雨无定); duration not specified (未提及)
3-Half-day	persistent rain (雨不止/不住/不停); lasting throughout the daytime (竟日); stopping in the late afternoon/at night/around midnight (晚/夜/中霄止); lasting throughout the night (彻夜/彻霄/连霄); lasting until dawn (达旦)
4-Full-day	continuous day and night (日夜不绝、晓夜不绝、日夕不止)

Based on the combination of rainfall intensity and duration, a daily rainfall index ranging from 1 to 4 was derived (Tab. 3). Higher index values represent greater overall rainfall, resulting from greater rainfall intensity, longer duration, or a combination of both. For example, moderate rainfall lasting for approximately half a day was classified as Level 3, whereas heavy rainfall of brief duration was classified as Level 2.

Table 3 Daily rainfall index based on rainfall intensity and duration

Rainfall duration / Intensity	Light	Moderate	Heavy	Extreme
Brief	1	1	2	3
Short-duration	1	2	3	4
Half-day	2	3	4	4
Full-day	3	4	4	4

Sky conditions were categorized into seven levels, ranging from cloudy to clear (Tab. S1). Snowfall was categorized into three levels, ranging from light to heavy snowfall (Tab. S2). Wind information was categorized into eight directions and four intensity levels (Tab. S3). Perceptions on cold/warm were categorized into six levels, ranging from very cold to very hot (Tab. S4). In addition, various unusual weather phenomena and hydrological conditions were extracted and categorized (Tab. S5 and Fig. S2, respectively).

Several external datasets were used to compare with the weather information extracted from the diary and to assess its utility. The Reconstructed Asian Summer Precipitation (RAP) dataset provides a gridded reconstruction of summer precipitation spanning 544 years (1470–2013), based on tree-ring and historical documentary records (Shi et al., 2018). It was used for comparison with the rainfall information derived from the diary. The Twentieth Century Reanalysis version 3 (20CRv3) is an atmospheric reanalysis dataset spanning 1806–2019 (Slivinski et al., 2019). We extracted ensemble-mean temperature and precipitation from 20CRv3 for comparison with the rainfall and perceptions on cold/warm derived from the diary. In addition, hourly wind data from the ERA5 reanalysis covering 1940–2019 (https://cds.climate.copernicus.eu/) were used to compare with the wind directions recorded in the diary. Hourly zonal and meridional wind components were first averaged to daily values, from which daily wind directions were calculated and subsequently classified into eight 45° sectors to match the wind direction categories used in the diary.

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

4 Results: The weather and climate information in the diary and comparison to other data sources

To characterize the categories, contents, and homogeneity of the weather information recorded in *Guan Tingfen Diary*, we focus on four main types of information: rainfall, sky conditions, wind, and perceptions on cold/warm, and compare them with other climate datasets.

4.1 Rainfall

Based on the categorization of daily rainfall intensity, duration, and the daily rainfall index, we calculated the proportion of days in each category (Fig. 3a–c). The distributions of rainfall intensity and duration are broadly similar, with moderate-intensity and short-duration rainfall accounting for the largest fractions, at approximately 22%. This is partly because a considerable proportion of the diary records merely noted the occurrence of rainfall without providing further details on its intensity or duration. The intensity and duration of such records were therefore classified as Level 2. In contrast, extreme-intensity rainfall and full-day rainfall account for only very small proportions. The distribution of the daily rainfall index, which integrates both intensity and duration, shows a somewhat different pattern. The proportion of medium rainfall decreases to approximately 16%, whereas the proportion of very high rainfall is greater than the proportions of either extreme-intensity or full-day rainfall. This suggests that combining multiple descriptive dimensions allows different types of rainy days in the diary records to be more effectively distinguished.

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

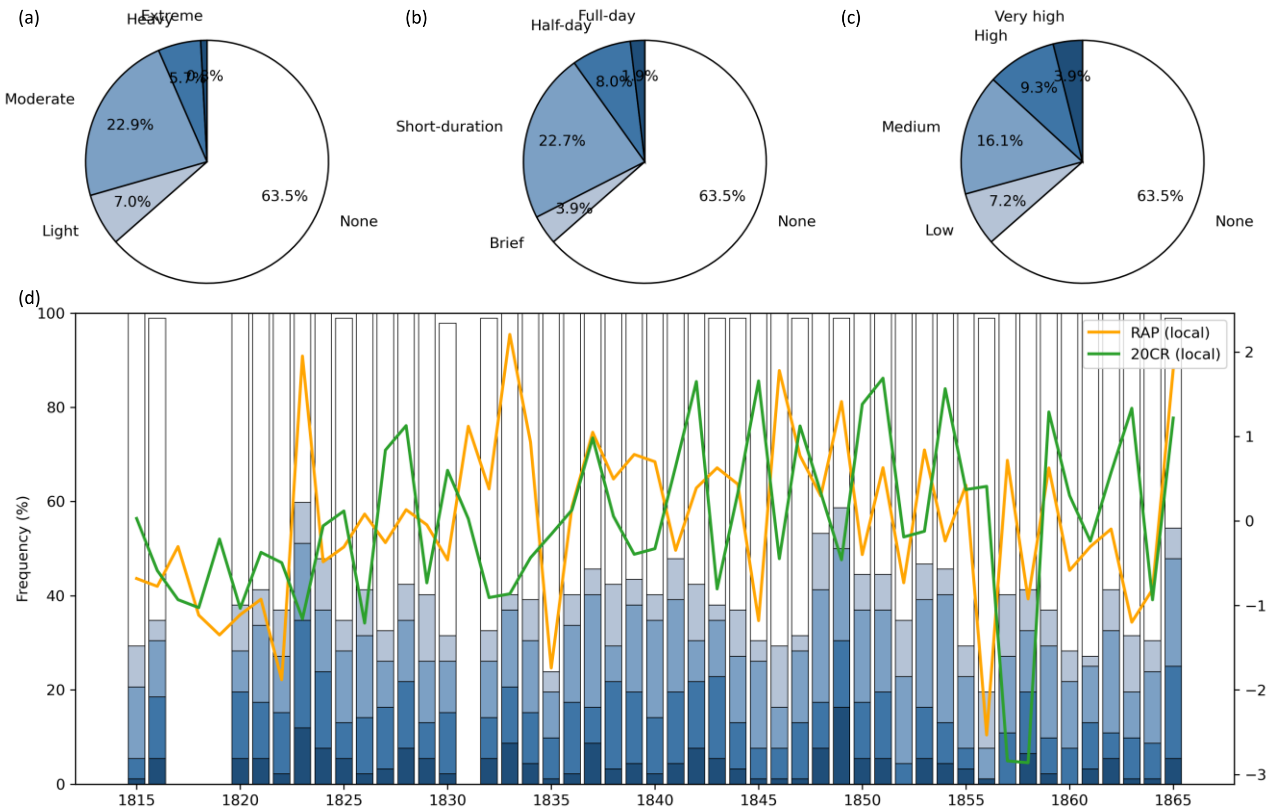

Figure 3 Rainfall information in the diary. (a–c) Proportions of different categories of rainfall intensity, rainfall duration, and the daily rainfall index, respectively. (d) Comparison of the proportions of different daily rainfall index during June–August with precipitation from the RAP and 20CRv3 datasets.

We compared the June–August rainfall information derived from the diary with precipitation from the grid cells nearest to Haining in the RAP and 20CRv3 datasets (Fig. 3d). The number of rainy days recorded in the diary shows good agreement with the RAP reconstruction, capturing relatively wet summers with more rainy days, such as 1823, 1849, and 1865, as well as relatively dry summers, such as 1835 and 1856. In contrast, the agreement with precipitation from 20CRv3 is relatively weak. This discrepancy may partly reflect differences in the information and observations underlying the two datasets.

4.2 From cloudy to sunny

Descriptions of sky conditions in the diary are generally less detailed than those of rainfall, making their categorization particularly challenging. Most entries simply indicate whether the sky was cloudy or clear, or describe a combination of cloudy/rainy and clear conditions within the same day. Only a small number of entries provide more detailed descriptions, such as weak sunshine or brief cloudiness followed by clearing conditions. Consequently, the two broad categories representing cloudy and clear conditions dominate the overall distribution, highlighting the limited ability of the diary records to distinguish subtle variations in sky conditions (Fig. 4).

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

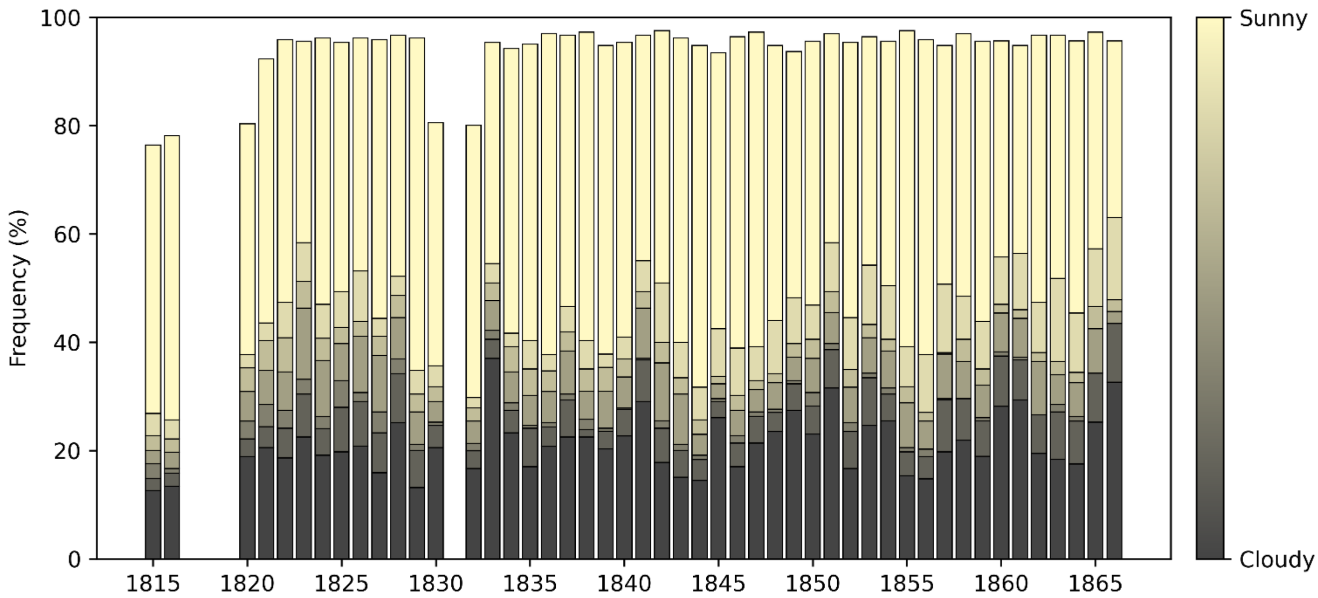

Figure 4 Sky conditions recorded in the diary

4.3 Wind

Unlike precipitation and sky conditions, wind direction was typically recorded in the diary only under particular weather conditions, such as when winds were strong or accompanied by rainfall. We therefore focus on the proportions of recorded wind directions (Fig. 5a–c). Northwesterly winds dominate the annual records, followed by northeasterly and easterly winds. The diary records also show a clear seasonal difference. During the summer half-year, easterly winds are most frequently recorded, followed by northeasterly and southeasterly winds. In contrast, the winter half-year is dominated by northwesterly winds, with northeasterly winds ranking second. This seasonal difference is consistent with the expected seasonal variation in monsoon circulation at the diary location, indicating that, although the wind direction records are intermittent and event-based, they still capture a meaningful seasonal signal.

To further assess the reliability of the wind records, we compared the diary-derived wind direction distributions with local wind direction derived from the ERA5 reanalysis. The diary-derived wind direction distribution shows good agreement with ERA5 during the summer half-year. During the winter half-year, however, northerly winds are notably underrepresented in the diary records. This discrepancy may partly reflect a sampling bias arising from the diary's tendency to record wind direction primarily during stronger wind events.

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

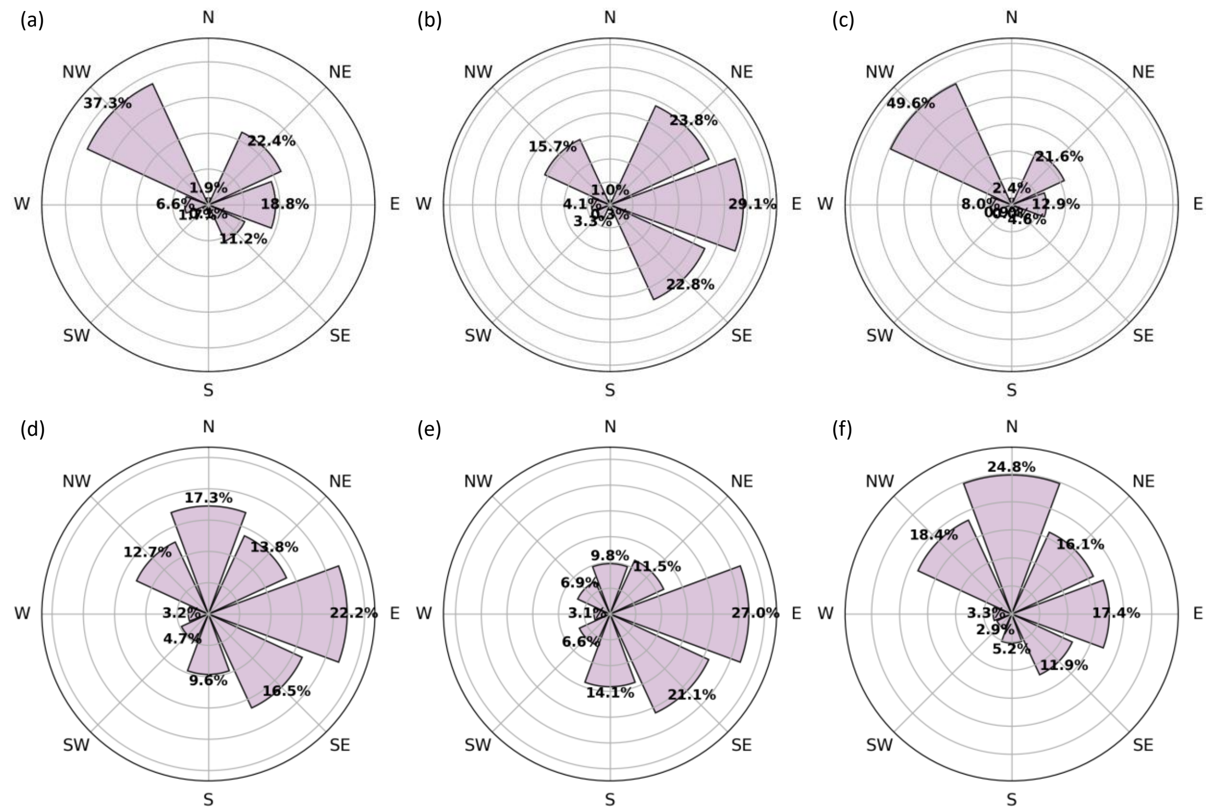

Figure 5 Proportions of recorded wind directions. (a–c) Wind direction proportions derived from the diary records for the whole year, summer half-year (April–September), and winter half-year (October–March), respectively. (d–f) Corresponding wind direction proportions derived from the ERA5 dataset.

4.4 Human perception

Beyond the weather observations described above, the diary also contains extensive records of Guan Tingfen's perceptions on cold/warm. Although an individual's perception of cold/warm may change with age, a continuous record spanning approximately fifty years from the same observer remains highly valuable. Notably, within the six categories distinguished in this study, Guan Tingfen used different terms to distinguish hot weather ("燠") from muggy or humid-hot conditions ("蒸燠", "湿燠", and "闷燠"). This distinction suggests that he perceived these two types of weather differently, with the latter potentially reflecting an enhanced perception of heat under high-humidity conditions. We compared the numbers of perceived cold and hot days during summer and winter with seasonal temperatures from the 20CRv3 dataset (Fig. 6).

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

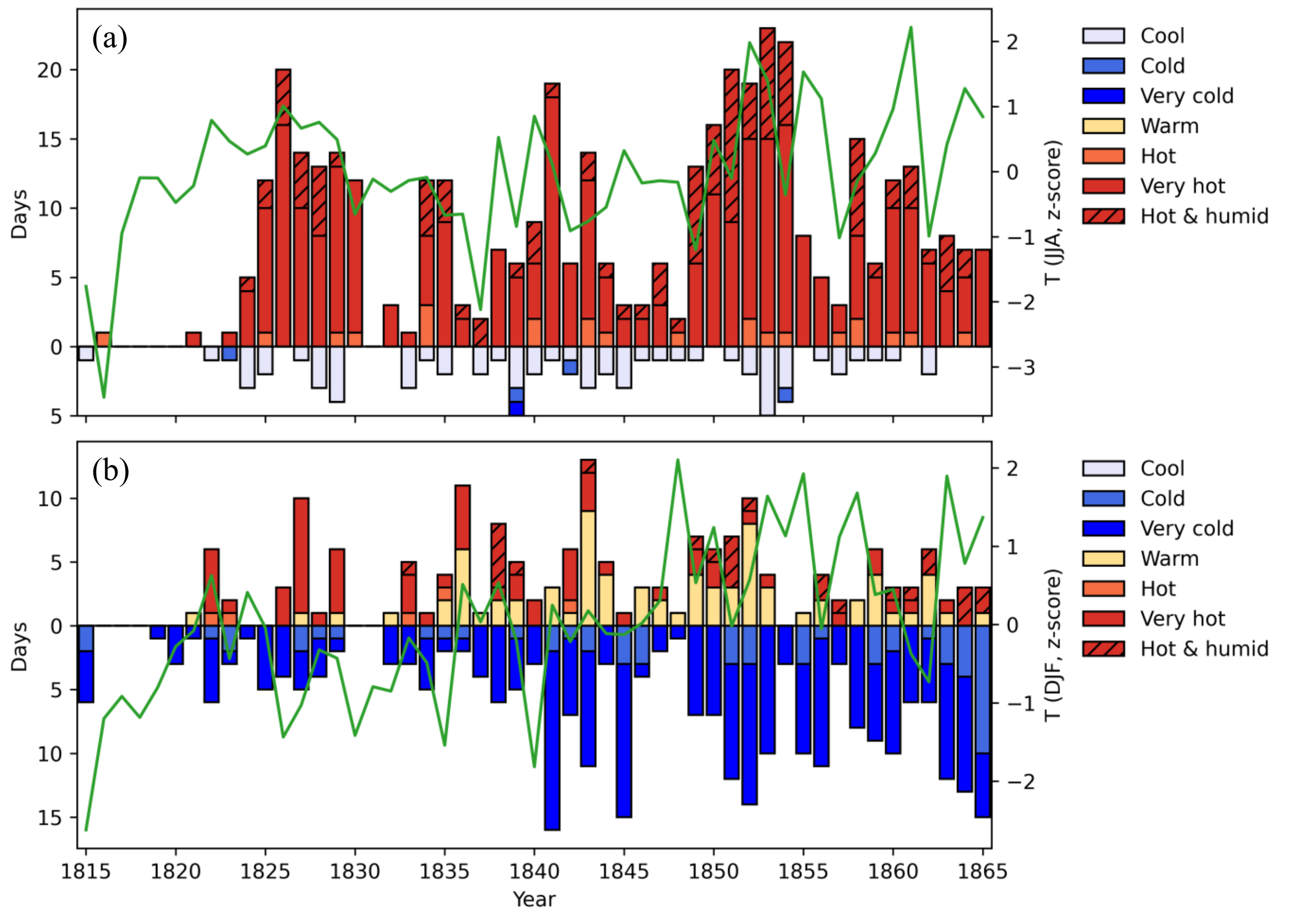

Figure 6 Variation of number of days with perceptions on cold/warm. (a) summer and (b) winter. The green line is seasonal temperature derived from 20CRv3.

Guan Tingfen's perceptions on hot weather, including both hot and very hot conditions, show considerable agreement with summer temperatures from 20CRv3. This agreement is particularly evident during three relatively warm periods: 1825–1830, approximately 1835–1845, and 1850–1855. The total number of days classified as Level 5 (hot) or Level 6 (very hot) is significantly correlated with JJA mean temperature from 20CRv3 (r = 0.39, $p < 0.01$). When humid-hot conditions are excluded, the correlation increases slightly to r = 0.42 ($p < 0.01$). Given that perceptions on cold/warm are neither instrumental measurements nor natural proxies, these significant correlations suggest that the diary records nevertheless contain meaningful information about summer temperature variability. Cool or cold conditions were also occasionally recorded during summer. However, the descriptions suggest that most of these episodes were associated with wind or rainfall and may therefore reflect short-term or sub-daily temperature variations rather than sustained low-temperature conditions.

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

Compared with summer, perceptions in winter show weaker agreement with temperature variability in 20CRv3. The climatic value of perceptions on cold/warm recorded in private diaries has also been demonstrated in a previous study of the *Weng Tonghe Diary* in Beijing (Zhang et al., 2007). In the *Weng Tonghe Diary*, the frequency of extremely cold weather showed relatively strong correlations with monthly mean temperatures in winter and autumn, whereas extremely hot weather provided less indication of summer temperature variability. This differs from the pattern found in the *Guan Tingfen Diary*. Whether this difference reflects regional climatic differences or systematic differences between the two diaries remains unclear.

4.5 Other information

Beyond the daily weather observations described above, Guan Tingfen also recorded a wide range of discontinuous information on meteorological phenomena, hydrological conditions, and societal responses, providing considerable potential for further investigation. Here, we briefly examine thunder and freezing-related phenomena as two examples (Fig. 7). As a convective weather phenomenon, thunder shows a pronounced seasonal difference (Fig. 7a), occurring predominantly in July and August. On longer timescales, its frequency does not appear to be directly related to overall rainfall (Fig. 7b). Interestingly, several records of "thunder without rain" occurred during dry summers, such as 1835.

Guan Tingfen recorded freezing phenomena during 37 winter half-years, including 42 occurrences of general water freezing, 14 occurrences of ground or object freezing (e.g., ground freezing after snowfall and ice causing bamboo to break), four occurrences of river or lake freezing, and one occurrence of coastal ice formation. Among these winters, the winter of 1845/1846 stands out as particularly cold. On 15 December 1845, Guan Tingfen observed that the river had frozen over, and on 8 January 1846, he recorded thin ice along the coast together with accumulated frost and snow, describing the conditions as "such extraordinary cold as had rarely occurred in several decades." Records of widespread freezing of rivers and lakes, snowfall events, and cold damage to vegetation across southern China further support the exceptional cold of this winter (Hao et al., 2011).

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

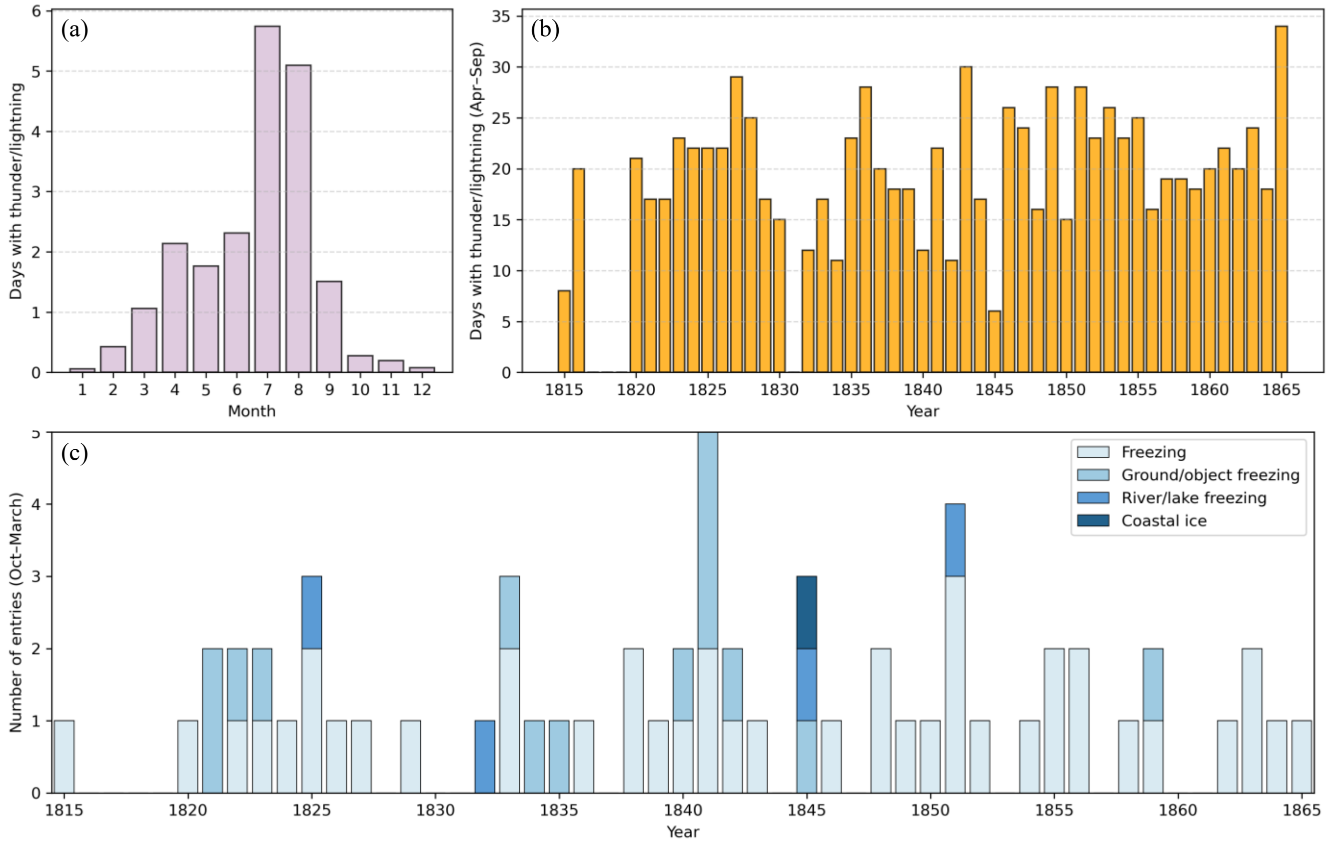

Figure 7 Information on other phenomena. (a) Multi-year average number of days with thunder for each month, (b) Long-term variation of the total number of thunder days during April–September, (c) Number of entries with freezing-related phenomena.

230 ## 5 Discussion: The potential of the *Guan Tingfen diary*

5.1 Potential signals of volcanic eruptions in the diary

The diary may also preserve records of unusual atmospheric and climatic phenomena potentially associated with major volcanic eruptions. We therefore compared the timing of major eruptions identified in the recently developed volcanic stratospheric sulfur injection dataset, eVolv2k-plus-D4i, with unusual phenomena recorded in the diary (Sigl et al., 2023).
235 Five entries describe unusually red lunar coloration, using expressions such as "月色甚红/月色皆红/月色皆赤" (the Moon appeared extremely red/entirely red/reddish). Interestingly, four of these observations occurred following three major nineteenth-century volcanic eruptions. Two were recorded in April and June 1816, following the Tambora eruption in 1815; another occurred in August 1831 following the Zavaritskii eruption (Hutchison et al., 2025) ; and another was recorded in July 1862 following the Makian eruption. The diary also contains an unusual description of the Sun in April 1865: "早晚日

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

轮如血而绝大，可异焉” (in the morning and evening, the Sun appeared blood-red and exceptionally large, which was regarded as highly unusual). This observation followed the sequence of eruptions associated with the Icelandic “Tröllahraun fires”. Similar anomalous reddening and apparent enlargement of the Sun around sunrise and sunset have been associated with atmospheric optical effects following major volcanic eruptions (Oppenheimer et al., 2018; Thordarson and Self, 2003). The diary also documents rare summer snowfall and exceptionally cold conditions. For example, in July 1840, Guan Tingfen reported hearing that snowfall with accumulation had occurred in the mountains of Huizhou. In August 1848, he described the weather as “extremely cool, unprecedented in several years” and reported that snowfall had occurred over the sea a few days earlier. Records from local gazetteers in nearby areas also document anomalous summer snowfall and cold conditions during these two summers (Zhang, 2013). Such phenomena do not establish a volcanic origin, as unusual atmospheric optical phenomena and warm-season snowfall can arise from multiple causes. Nevertheless, these observations illustrate that the diary may preserve qualitative evidence of atmospheric optical and climatic anomalies that could potentially be investigated in relation to volcanic forcing.

We further explored whether the diary preserves potential traces of the climatic impacts of volcanic eruptions. As shown in Section 4.4, Guan Tingfen’s perceptions on hot weather in summer show good agreement with summer temperatures from 20CRv3, supporting the value of these qualitative observations for investigating temperature variability. We therefore used the number of days perceived as hot or very hot during June–August to examine whether potential climatic influences of volcanic eruptions can be detected in the diary. Eight major volcanic eruptions between 1815 and 1865 were selected from the eVolv2k-plus-D4i dataset, defined here as events with volcanic stratospheric sulfur injection (VSSI) of at least 1 Tg. We then performed a superposed epoch analysis (SEA) of the number of perceived hot days during the summers before and after each eruption (Fig. 8).

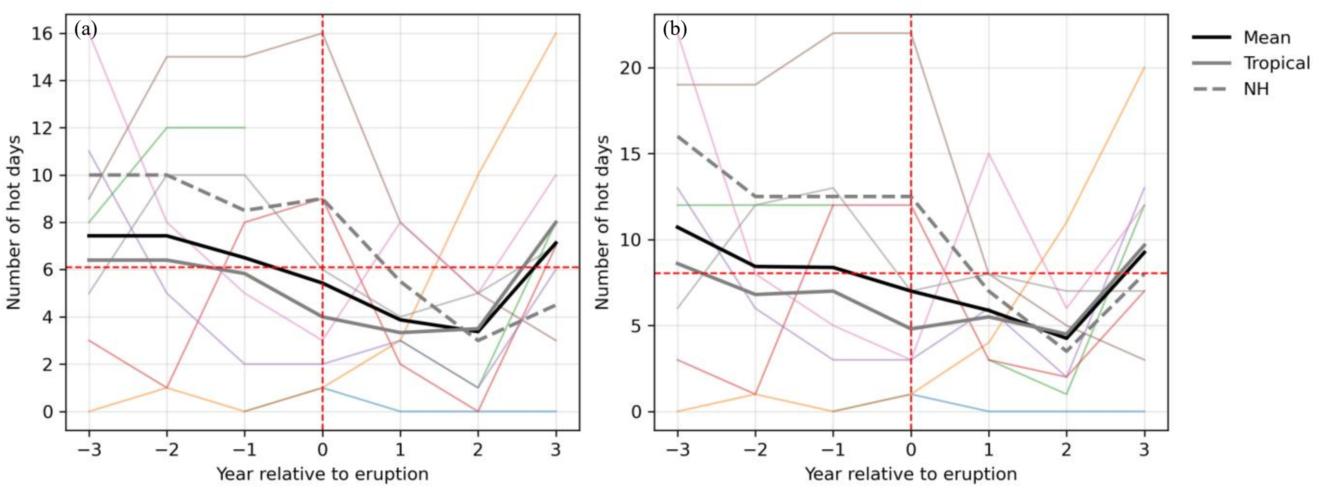

Figure 8 Perceived hot days in summer before and after volcanic eruptions. (a) Hot-humid days excluded; (b) Hot-humid days included.

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

The results show a decrease in the number of perceived hot days during the first three summers following the eruptions compared with the pre-eruption period, with values also below the long-term mean. Although the diary unfortunately contains gaps around two major eruptions, in 1815 and 1831, the available records remain broadly consistent with the overall pattern. No daily records are available for 1817–1819. Nevertheless, during the period of frequent volcanic eruptions between 1813 and 1822, only one or no days were described as hot in each summer during 1815–1816 and 1820–1823, an exceptionally low frequency not observed elsewhere in the diary. Similarly, although Guan Tingfen was in Beijing, far from Haining, during the summer of 1831, he had returned to Haining by 1832. Only three and one hot days were recorded in the summers of 1832 and 1833, respectively.

5.2 Intra-seasonal evolution of extreme events

Weather diaries have been widely used to reconstruct the evolution of various extreme climate events, including severe droughts, floods, and cold winters. Here, we use two examples of cold winters (1841/1842 and 1862/1863) and one example of drought (1835) to demonstrate the potential of the dataset.

The winter of 1841/1842 has been identified as an extremely cold winter based on historical documentary evidence (Hao et al., 2011). However, winter temperature reconstructions for the middle and lower reaches of the Yangtze River indicate near-normal mean temperatures for this winter (Hao et al., 2012). In contrast, the winter of 1862/1863 was not identified as extremely cold based on documentary evidence of anomalous phenomena, yet winter temperature reconstructions identify it as one of the coldest winters of the half-century. By reconstructing the daily evolution of weather conditions from the diary (Fig. 9), we find that the winter of 1841/1842 was characterized by several distinct cold episodes. Continuous ice formation was recorded on 3–4 December, followed by nearly nine consecutive days of snowfall between 13 and 21 December. However, neither the first nor the last snowfall date was particularly unusual, and no clear cold episodes were recorded in November or March. In contrast, the winter of 1862/1863 exhibited a markedly different pattern. The first snowfall occurred on 20 November, nearly one month earlier than in 1841/1842, while the last snowfall and final occurrence of freezing were recorded on 27 March, almost one month later than in 1841/1842. This extended cold season contributed to a colder winter overall, despite the absence of intense, consecutive cold episodes comparable to those observed in 1841/1842.

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

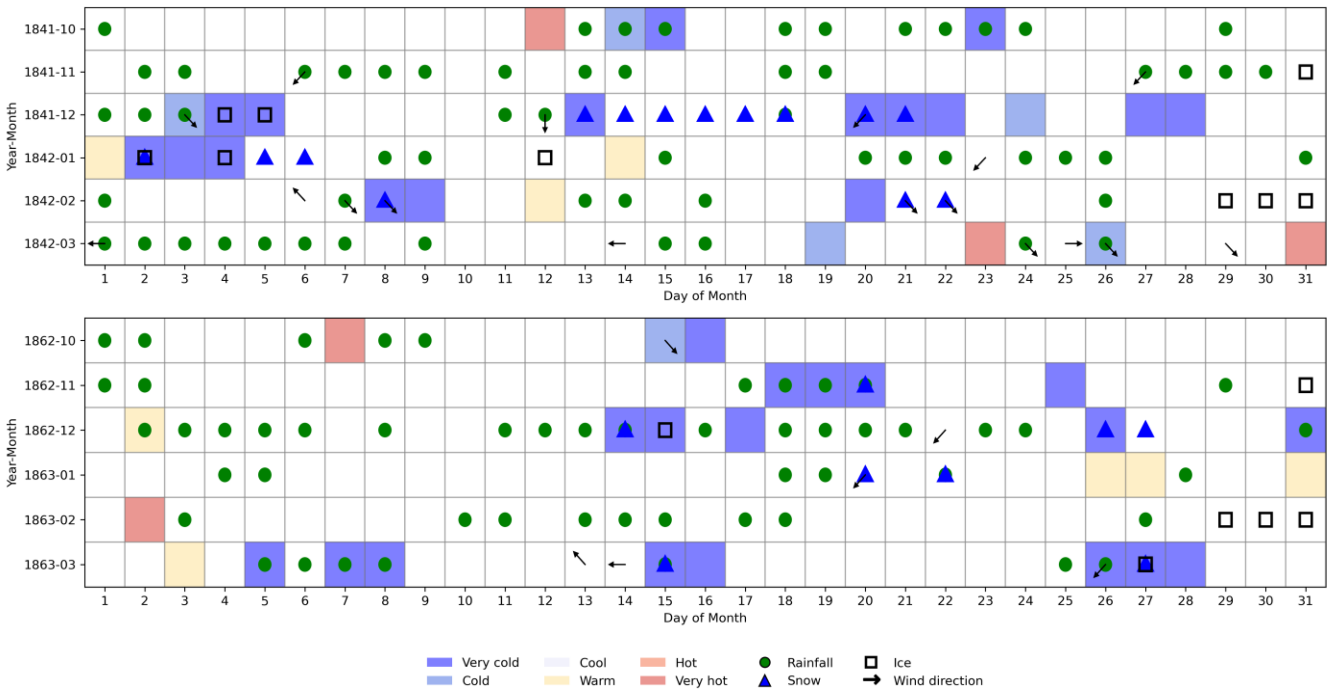

Figure 9 Weather map of winter 1841/1842 (upper) and 1862/1863 (lower)

Another example is the intraseasonal variation in rainfall and hydrological conditions during 1835 (Fig. 10). The documentary-based Dry/Wet Index reconstruction indicates widespread drought across the middle and lower reaches of the Yangtze River in 1835, and this severe drought has also been identified in tree-ring records (Chinese Academy of Meteorological Sciences, 1981; Yue et al., 2024). Beyond these seasonal-scale reconstructions, the diary provides intraseasonal information that allows the day-to-day evolution of rainfall and hydrological conditions during this drought to be investigated in greater detail. Most days in June 1835 were characterized by no or only light rainfall. On 2 July, the first record of extremely low river levels appeared, with Guan Tingfen noting that "the river had already largely dried up." This was followed by a month-long dry spell from 19 July to 18 August, during which only one day with medium rainfall was recorded. Prayers for rain were held from 9 to 11 August, while the river gradually dried up again. Several days with medium to high rainfall between 19 and 26 August then resulted in a rapid rise in river levels. Importantly, the diary further reveals a local flood in autumn despite the severe summer drought. Several days with high and very high rainfall occurred between 29 September and 11 October. On 7 October, Guan Tingfen observed that the streets were inundated by more than one *chi* (approximately 33 cm) of water, making them impassable on foot, while the water level in the lower river had risen to the riverbank.

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

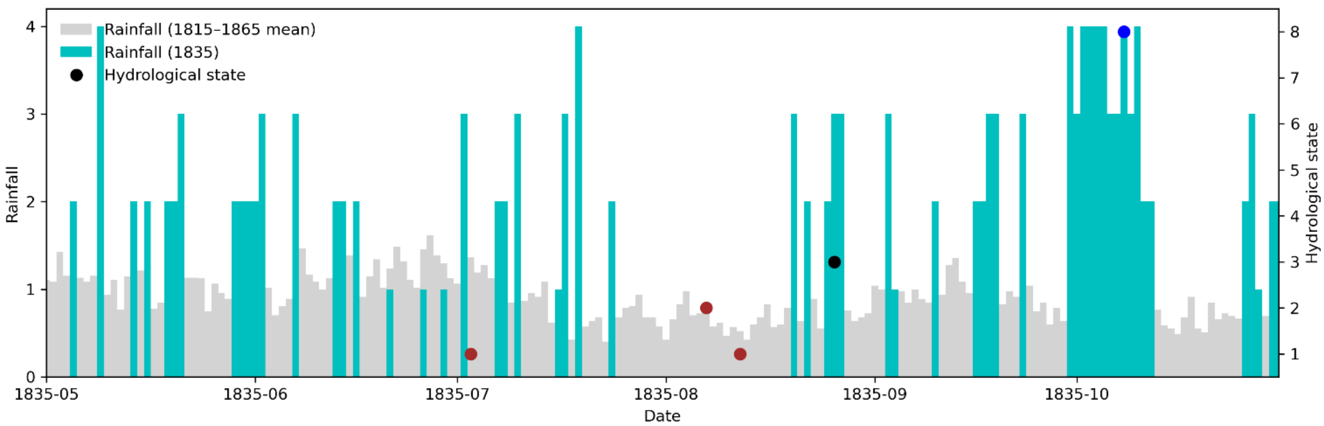

Figure 10 Rainfall and Hydrological condition in 1835

5.3 Potential for weather reconstruction

Historical weather diaries provide a unique source of continuous and relatively homogeneous daily observations, with precipitation and sky conditions being among the most consistently recorded variables and the easiest to quantify. Among these, daily precipitation has been the most widely used variable for reconstructing past climates. Previous studies have successfully utilized Guan Tingfen's daily precipitation records to reconstruct monthly precipitation totals, and similar reconstructions have been conducted using other daily-scale historical documents (Tang, 2022; Zhang et al., 2005). However, directly converting descriptive daily precipitation entries into precise precipitation amounts or ranges remains a significant challenge due to the qualitative nature of the original records.

The development of various data assimilation techniques and machine learning approaches offers new opportunities to leverage such daily historical records for weather reconstruction (Kinya et al., 2017; Pfister et al., 2025). For instance, the "best-member" approach is relatively straightforward to implement (Stucki et al., 2026). By calculating the Euclidean distance between standardized anomalies, the ensemble member that best matches the historical observations can be selected from a large ensemble, such as the 20CRv3 ensemble. This approach has demonstrated good performance in reconstructing atmospheric circulation compared with several other approaches. Alternatively, analogue resampling combined with ensemble Kalman fitting (EnKF) data assimilation can also be used to reconstruct historical weather fields (Imfeld et al., 2023). However, these approaches generally require a relatively dense network of historical observations, highlighting the need for further efforts in data rescue and digitization. In addition, Bayesian approaches provide a framework for maximizing the use of information contained in historical documentary sources (Camenisch et al., 2022). Although these records are often qualitative or semi-quantitative, they encode multisystem information spanning atmospheric, hydrological, agricultural, and social systems. Bayesian approaches can explicitly incorporate such multisystem information into the reconstruction process.

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

6 Conclusion

This paper describes the digitization of weather- and climate-related information from the *Guan Tingfen Diary*. The diary documents sky conditions, precipitation, perceived temperature, and occasional wind directions in Haining, Zhejiang Province, from 1815 to 1865, together with various unusual meteorological and hydrological phenomena. In addition, it contains valuable information on societal responses to weather and climate. Despite gaps in the records for certain years, the diary remains a highly valuable source of daily weather information. Its reliability and utility are supported by comparisons with other climate datasets, and Guan Tingfen's weather observations have also been successfully used in previous climate reconstruction studies. During the multiple volcanic eruptions of varying magnitudes that occurred in the first half of the 19th century, the *Guan Tingfen Diary* not only recorded optical phenomena potentially associated with volcanic activity, but Guan Tingfen's perceptions on hot weather in summer also show variations consistent with a possible volcanic cooling signal. Furthermore, the diary has considerable potential for investigating the evolution of extreme climate events and reconstructing daily weather during the first half of the 19th century.

Data availability statement: The Reconstructed Asian Summer Precipitation (RAP) dataset is available online from the NOAA World Data Service for Paleoclimatology archive (https://www.ncdc.noaa.gov/paleo/study/24391). The Twentieth Century Reanalysis version 3 (20CRv3) dataset is available online from the NOAA Physical Sciences Laboratory (https://psl.noaa.gov/data/gridded/data.20thC_ReanV3.html). The ERA5 dataset is available online from the Copernicus Climate Data Store (https://cds.climate.copernicus.eu/datasets). The daily weather dataset based on the Guan Tingfen Diary produced in this study is available online at https://doi.org/10.5281/zenodo.22163191

Code availability statement: All calculation and analyses were done in Python using standard code.

Author contributions: SC performed the data categorization, digitization and analysis, SB supervised the work and provided overall guidance. All authors contributed to writing the paper.

Funding Information: The work was funded by the China Scholarship Council, grant No. 202206040033; Swiss National Science Foundation, grant No. 219746.

Competing interests. The contact author has declared that none of the authors has any competing interests.

References

Adamson, G. C. D.: Private diaries as information sources in climate research, WIREs Climate Change, 6, 599–611, https://doi.org/10.1002/wcc.365, 2015.

Brönnimann, S.: The weather diary of Georg Christoph Eimmart for Nuremberg, 1695–1704, Climate of the Past, 19, 1345–1357, https://doi.org/10.5194/cp-19-1345-2023, 2023.

Camenisch, C., Jaume-Santero, F., White, S., Pei, Q., Hand, R., Rohr, C., and Brönnimann, S.: A Bayesian approach to historical climatology for the Burgundian Low Countries in the 15th century, Climate of the Past, 18, 2449–2462, https://doi.org/10.5194/cp-18-2449-2022, 2022.

Chen, S., Su, Y., Fang, X., and He, J.: Climate records in ancient Chinese diaries and their application in historical climate reconstruction – a case study of *Yunshan Diary*, Climate of the Past, 16, 1873–1887, https://doi.org/10.5194/cp-16-1873-2020, 2020.

Chinese Academy of Meteorological Sciences: Yearly charts of dryness/wetness in China for the last 500-year period, SinoMaps Press, Beijing, 1981.

Dobrovolný, P., Moberg, A., Brázdil, R., Pfister, C., Glaser, R., Wilson, R., van Engelen, A., Limanówka, D., Kiss, A., Halíčková, M., Macková, J., Riemann, D., Luterbacher, J., and Böhm, R.: Monthly, seasonal and annual temperature reconstructions for Central Europe derived from documentary evidence and instrumental records since AD 1500, Climatic Change, 101, 69–107, https://doi.org/10.1007/s10584-009-9724-x, 2010.

Ge Q. and Zhang, Piyuan: The Evaluation of Climatic Information in the Historical Literatures, ACTA GEOGRAPHICA SINICA, 45, 22–30, https://doi.org/10.11821/xb199001003, 1990.

Ge, Q., Zheng, J., Hao, Z., Liu, Y., and Li, M.: Recent advances on reconstruction of climate and extreme events in China for the past 2000 years, J. Geogr. Sci., 26, 827–854, https://doi.org/10.1007/s11442-016-1301-4, 2016.

Hao, Z., Zheng, J., Ge, Quansheng, and Ding, Lingling: Variations of Extreme Cold Winter Events in Southern China in the Past 400 Years, ACTA GEOGRAPHICA SINICA, 66, 1479–1485, https://doi.org/10.11821/xb201111004, 2011.

Hao, Z., Zheng, J., Ge, Q., and Wang, W.-C.: Winter temperature variations over the middle and lower reaches of the Yangtze River since 1736 AD, Climate of the Past, 8, 1023–1030, https://doi.org/10.5194/cp-8-1023-2012, 2012.

Huang, Y., Li, B., and Li, Z.: Review of climate reconstruction based on ancient diary, Progress in Geography, 32, 1545–1554, 2013.

Hutchison, W., Sugden, P., Burke, A., Abbott, P., Ponomareva, V. V., Dirksen, O., Portnyagin, M. V., MacInnes, B., Bourgeois, J., Fitzhugh, B., Verkerk, M., Aubry, T. J., Engwell, S. L., Svensson, A., Chellman, N. J., McConnell, J. R., Davies, S., Sigl, M., and Plunkett, G.: The 1831 CE mystery eruption identified as Zavaritskii caldera, Simushir Island (Kurils), Proceedings of the National Academy of Sciences, 122, e2416699122, https://doi.org/10.1073/pnas.2416699122, 2025.

Ichino, M., Masuda, K., and Mikami, T.: Reconstruction of solar radiation for Tokyo since 1720 using weather descriptions from historical diaries, Climatic Change, 178, 221, https://doi.org/10.1007/s10584-025-04036-w, 2025.

Imfeld, N., Pfister, L., Brugnara, Y., and Brönnimann, S.: A 258-year-long data set of temperature and precipitation fields for Switzerland since 1763, Climate of the Past, 19, 703–729, https://doi.org/10.5194/cp-19-703-2023, 2023.

Kinya, T., Panduka, N., Hyungjun, K., and Kei, Y.: Feasibility Study of the Reconstruction of Historical Weather with Data Assimilation, Monthly Weather Review, 145, 3563–3580, https://doi.org/10.1175/mwr-d-16-0288.1, 2017.

Li, X.: The lifeworld of rural gentry on the margins of “modernity”: An interpretation of Guan Tingfen’s diaries from the Jiaqing, Daoguang, Xianfeng, and Tongzhi periods, Social Science Research, 121–139, 2016.

Liu, B., Zhang, J., and Man, Z.: Reconstruction of winter mean temperature in Shanghai area during 1724 to 2016 AD, Journal of Chinese Historical Geography, 33, 70–77, 2018.

Lundstad, E., Brugnara, Y., Pappert, D., Kopp, J., Samakinwa, E., Hürzeler, A., Andersson, A., Chimani, B., Cornes, R., Demarée, G., Filipiak, J., Gates, L., Ives, G. L., Jones, J. M., Jourdain, S., Kiss, A., Nicholson, S. E., Przybylak, R., Jones, P., Rousseau, D., Tinz, B., Rodrigo, F. S., Grab, S., Domínguez-Castro, F., Slonosky, V., Cooper, J., Brunet, M., and Brönnimann, S.: The global historical climate database HCLIM, Sci Data, 10, 44, https://doi.org/10.1038/s41597-022-01919-w, 2023.

Oppenheimer, C., Orchard, A., Stoffel, M., Newfield, T. P., Guillet, S., Corona, C., Sigl, M., Di Cosmo, N., and Büntgen, U.: The Eldgjá eruption: timing, long-range impacts and influence on the Christianisation of Iceland, Climatic Change, 147, 369–381, https://doi.org/10.1007/s10584-018-2171-9, 2018.

Pfister, L., Wilhelm, L., Brugnara, Y., Imfeld, N., and Brönnimann, S.: Weather type reconstruction using machine learning approaches, Weather and Climate Dynamics, 6, 571–594, https://doi.org/10.5194/wcd-6-571-2025, 2025.

Shi, H., Wang, B., Cook, E. R., Liu, J., and Liu, F.: Asian Summer Precipitation over the Past 544 Years Reconstructed by Merging Tree Rings and Historical Documentary Records, Journal of Climate, 31, 7845–7861, https://doi.org/10.1175/JCLI-D-18-0003.1, 2018.

Sigl, M., McConnell, J. R., and Toohey, M.: Volcanic stratospheric sulfur injection between 1733 and 1895 CE based on the eVolv2k-plus-D4i ice-core eruption catalogue, https://doi.org/10.1594/PANGAEA.960975, 2023.

Slivinski, L. C., Compo, G. P., Whitaker, J. S., Sardeshmukh, P. D., Giese, B. S., McColl, C., Allan, R., Yin, X., Vose, R., Titchner, H., Kennedy, J., Spencer, L. J., Ashcroft, L., Brönnimann, S., Brunet, M., Camuffo, D., Cornes, R., Cram, T. A., Crouthamel, R., Domínguez-Castro, F., Freeman, J. E., Gergis, J., Hawkins, E., Jones, P. D., Jourdain, S., Kaplan, A., Kubota, H., Blancq, F. L., Lee, T.-C., Lorrey, A., Luterbacher, J., Maugeri, M., Mock, C. J., Moore, G. W. K., Przybylak, R., Pudmenzky, C., Reason, C., Slonosky, V. C., Smith, C. A., Tinz, B., Trewin, B., Valente, M. A., Wang, X. L., Wilkinson, C., Wood, K., and Wyszyński, P.: Towards a more reliable historical reanalysis: Improvements for version 3 of the Twentieth Century Reanalysis system, https://doi.org/10.1002/qj.3598, 2019.

Stucki, P., Brönnimann, S., Imfeld, N., Pfister, L., Ruth, C. E., Schmutz, Y. V., Brugnara, Y., Wegmann, M., Przybylak, R., and Filipiak, J.: Evaluation of nine gridded daily weather reconstructions for the European heatwave summer of 1807, Climate of the Past, 22, 517–540, https://doi.org/10.5194/cp-22-517-2026, 2026.

Tang, J.: Research on climate change in the Shanghai region since the 19th century based on diary records, Research Press, Beijing, 2022.

Tang, J., Zheng, W., Man, Z., and Yang, Y.: Reconstruction and characteristic analysis of the extreme flooding event in the Taihu lake basin in 1823, Quaternary Science, 36, 278–293, 2016.

Thordarson, T. and Self, S.: Atmospheric and environmental effects of the 1783–1784 Laki eruption: A review and reassessment, Journal of Geophysical Research: Atmospheres, 108, AAC 7-29, https://doi.org/10.1029/2001JD002042, 2003.

Xiao, L., Fang, X., and Zhang, X.: Location of rainbelt of Meiyu during second half of 19th century to early 20th century, Scientia Geographica Sinica, 28, 385–389, 2008.

Yue, W., Chen, F., Torbenson, M. C. A., Zhao, X., Zheng, Y., Xu, Y., Hu, M., Wang, S., Hou, T., Zhang, H., and Chen, Y.: Late Ming Dynasty weak monsoon induced a harmonized megadrought across north-to-south China, Commun Earth Environ, 5, 439, https://doi.org/10.1038/s43247-024-01602-5, 2024.

Zhang, D.: A compendium of Chinese meteorological records of the last 3,000 years, 2nd ed., Jiangsu Education Publishing House, Nanjing, 2013.

https://doi.org/10.5194/egusphere-2026-5219
Preprint. Discussion started: 21 September 2026

Zhang, D., Liu, Y., Liang, Y., and Li, J.: Reconstruction of annual and seasonal precipitation series of Nanjing, Suzhou and Hangzhou during the 18th century, Quaternary Sciences, 25, 121–128, 2005.

Zhang, X., Fang, X., Tian, Q., and Wang, L.: Sand dust weather of Beijing in the late half of 19th century recorded in the book Weng Tonghe Diary, Journal of palaeogeography, 8, 117–124, https://doi.org/10.7605/gdlxb.2006.01.012, 2006.

Zhang, X., Fang, X., and Qi, X.: Perception records on cold/warm in Weng Tonghe Diary and its significance to cold/warm variation, Journal of Palaeogeography, 9, 439–446, 2007.

Zheng, J., Hao, Z., and Ge, Q.: Variation of precipitation for the last 300 years over the middle and lower reaches of the Yellow River, Sci. China Ser. D-Earth Sci., 48, 2182–2193, https://doi.org/10.1360/03yd0392, 2005.

Zheng, W., Tang, J., and Yang, Y.: Reconstruction of historical typhoon frequency and analysis of typhoon paths influencing northern Zhejiang from 1815 to 1869 AD, Journal of Earth Enviroment, 5, 370–384, 2014.

Zheng, W., Yang, Y., and Man, Z.: Multiple movement characteristics of the Meiyu rain belt in East Asia: reconstructing historical data on the southern margin from 1861 to 2017, Climatic Change, 165, 20, https://doi.org/10.1007/s10584-021-03007-1, 2021.