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Climate of the Past
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Combined analysis of early pressure observation data and historical daily weather documents for winter climate reconstruction in Japan

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Abstract

The East Asian winter monsoon is characterized by a strong east–west surface pressure gradient and the outbreak of cold air around Japan. It causes heavy snowfall in the Sea of Japan side of the Japanese Islands. Meanwhile, fine weather prevails over the Pacific Ocean side owing to topographical effects. Documents pertaining to daily weather in Japan often provide useful weather information regarding the appearance of typical "winter-monsoon-type weather patterns" in the historical period. In addition to historical daily weather documents, we recovered several early pressure observation series in Japan and China from the 19th century. A combined analysis of historical daily weather documents and early surface pressure observation may result in an effective detection of outbreaks arising from the East Asian winter monsoon in the historical period. Knowledge regarding atmospheric circulation fields associated with "winter-monsoon-type weather patterns" is essential for this combined analysis. We first investigate temporal evolutions of circulation fields associated with "winter-monsoon-type weather patterns" for the present day (1968–1980). The result indicates that the southward expansion of the Siberian High and eastward movement of extratropical cyclones around Japan result in a significant east–west surface pressure gradient in East Asia. This pressure gradient causes "winter-monsoon-type weather patterns" in Japan. Subsequently, we attempted to reconstruct the outbreak of the winter monsoon around Japan for the winter of 1851/52 using both historical weather documents and newly recovered early instrumental pressure data of Japan and China. The reconstructed results show that the outbreak of the East Asian winter monsoon can be reasonably detected by focusing on the sequence of reconstructed daily weather patterns and the east–west pressure gradient calculated using early instrumental pressure data.

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1 Introduction

Knowledge regarding climate conditions prior to the 19th century is important for evaluating natural background climate variability because anthropogenic effects on climate are negligible. However, meteorological data prior to 1850 are scarce, except for several areas, such as Europe and North America (Lamb, 1977). Historical climatologists have used documentary data as climate proxies to reconstruct climate variations prior to the 19th century. Various types of documentary data, such as the times of grain and wine harvest, plant phenology, freezing of water bodies, and daily weather documents, have been used to reconstruct past climate conditions, primarily in Europe (Brázdil et al., 2005), China (Ge et al., 2016), and Japan (Mikami, 2008). These documentary data are particularly important because they address short-term climatic fluctuations in the most recent past (Bradley, 2014).

In Japan, daily weather documents exist that provide important climate information from the 18th to the 19th centuries. Many weather diaries are preserved in local libraries and museums (Mikami, 2008). Yoshimura (1993, 2007, 2013) compiled the Historical Weather Data Base based on information regarding various places obtained from these documents. Official meteorological data from the Japan Meteorological Agency (JMA) were not available before the construction of the Hakodate Meteorological Observatory in 1873. Therefore, historical daily weather documents were used to reconstruct climate variables prior to 1872.

Daily weather documents were documented simultaneously at various locations in Japan. Therefore, they are useful for reconstructing daily synoptic weather patterns. The reconstruction of daily synoptic weather patterns is particularly effective for understanding winter climate variations. Typical daily weather patterns caused by the north-westerly winter monsoon can be identified from daily weather maps. Typically, the "winter type" pressure pattern is accompanied by a high pressure over the Eurasian continent and a low pressure over the North Pacific. This pressure pattern causes the north-westerly winter monsoon.

The north-westerly winter monsoon results in orographic precipitation (snowfall) in the Sea of Japan side. Fine weather prevails over the Pacific Ocean side because the backbone mountain range obstructs snow clouds from the Sea of Japan side. Hence, we can identify typical "winter-monsoon-type weather pattern days (WMDs)" for the historical period based on this weather contrast. Researchers have previously attempted to detect WMDs in historical periods based on daily weather patterns reconstructed from daily weather documents (Mizukoshi, 1993; Fukaishi and Tagami, 1992; Hirano and Mikami, 2008). In these previous studies, it was difficult to investigate the relationship between reconstructed WMDs and circulation fields around Japan because of insufficient reliable meteorological data prior to the mid-19th century in Japan. Therefore, whether the outbreak of the East Asian winter monsoon can be accurately detected based on reconstructed synoptic weather patterns is yet to be elucidated. Meanwhile, we recovered several early instrumental surface pressure series during the 19th century in Japan (Können et al., 2003; Zaiki et al., 2006, 2018).

Recently, we newly recovered surface air pressure observations in Beijing for the period 1841–1855, reported in "*Annuaire magnétique et métérologique du Corps des ingénieurs des mines de Russie*" and "*Annales de l'observatorie physique central*

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de Russie" (Zaiki et al., 2008). These early instrumental pressure series are expected to provide useful information pertaining to the east–west surface pressure gradient around Japan, which is associated significantly with the East Asian winter monsoon. Therefore, we considered a combined analysis using both historical daily weather documents and early surface pressure observations to achieve an accurate reconstruction of wintertime climate in and around Japan.

To conduct a combined analysis, knowledge regarding the temporal evolution of large-scale circulation fields associated with synoptic weather patterns is essential. The lifetime of an outbreak from the East Asian winter monsoon is longer than one day (Shoji et al., 2014). Therefore, we must clarify the sequence of circulation fields and synoptic weather patterns. Although it is empirically known that the north-westerly winter monsoon causes a clear weather contrast between the Sea of Japan and Pacific Ocean sides, few studies have focused on the sequence of large-scale circulation fields associated with WMDs in Japan.

The purpose of this study is to determine if an analysis combining historical daily weather documents and early instrumental surface pressure series is effective for wintertime climate reconstruction around Japan in the historical period. First, we investigated the temporal evolution of circulation fields and synoptic weather patterns for the present day (1968–1980). Subsequently, we investigated the East Asian winter monsoon activity for the winter of 1851/52 based on reconstructed daily weather patterns and early surface pressure observations. We selected this year as a case study because both freezing records of Lake Suwa in Central Japan (Mikami and Ishiguro, 1998) and snowfall ratio computed from the Hirosaki Clan Agency Diaries in northern Japan (Fukuma, 2010; 2014) implied a typically cold winter for the abovementioned year.

In Section 2, the data used in this study are presented. In Section 3, the methodology used in this study is described. In Section 4, the relationship between circulation fields and synoptic weather patterns for the present day (1968–1980) is analyzed. In Section 5, the relationship between synoptic weather patterns and variations in surface pressure data for the winter of 1851/52 is analyzed. The conclusions are presented in Section 6.

2 Data

2.1 Historical daily weather records

To reconstruct winter synoptic daily weather patterns, we used daily weather documents from nine locations in Japan (Fig. 1). Among the nine locations, we selected five locations (blue circles in Fig. 1) for the Sea of Japan side, where snowfall is typically observed during the winter monsoon (Suzuki, 1961). The other four locations (red circles in Fig. 1) were in the Pacific Ocean side, where dry weather prevailed. All diaries used in the present study were digitized and recorded in the historical weather database (Yoshimura, 1993; 2007; 2013).

2.2 Early instrumental pressure data in Japan and China

We used early surface pressure observation data from Tokyo, Nagasaki, and Beijing (red circles in Fig. 2) for the winter of 1851/52. The surface pressure data of Tokyo and Nagasaki have been reported in previous studies (Können et al., 2003; Zaiki

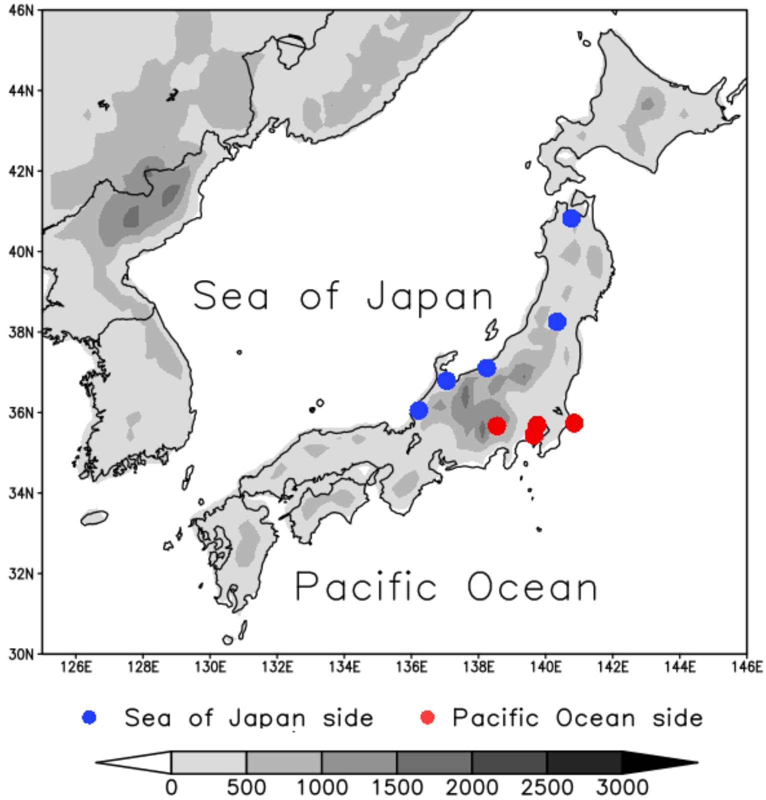

Figure 1: Locations of historical daily weather records used in this study. Red (blue) circles indicate locations of weather records in Pacific Ocean side (Sea of Japan side). Gray shading indicates elevation (unit: m)

et al., 2006). The pressure data of Nagasaki were observed at the Duch settlement of Dejima in Nagasaki (Können et al., 2003). Pressure observations in Tokyo were acquired by the Tokugawa Government Bureau of Astronomy for the calendar making of Edo ("*Reiken-koubo*" collection). The original handwritten lists of observations stored in the National Astronomical Observatory in Japan are not accessible; however, contemporary handwritten copies of these lists are available from the National Archives of Japan (Zaiki et al., 2006). The original source of the Beijing data is reported in "*Annuaire magnétique et météorologique du Corps des ingénieurs des mines de Russie*" and "*Annales de l'observatorie physique central de Russie,*" which report geomagnetic and meteorological observations from many locations in Russia (Kupffer, 1850,1851,1852,1853a,1853b,1855a, 1855b,1856 and 1857); furthermore, these observations have been imaged through the National Oceanic and Atmospheric Administration (NOAA) Central Library Climate Data Imaging Project. Because the original units of air pressure data was "demi-lignes" (20 English inches) at 13.33° Réaumur (16.66 °C). We converted the surface air pressure (demi-lignes) to the sea-level pressure (SLP) in units of hectopascal.

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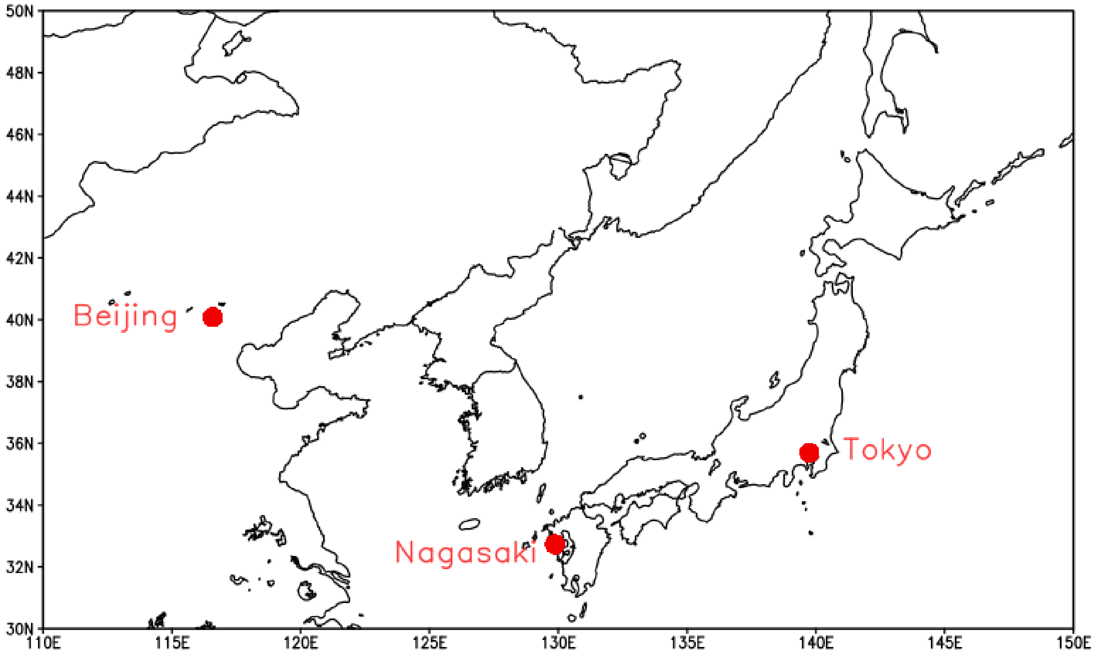

Figure 2: Locations of early instrumental surface pressure data used in this study.

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2.3 JMA weather data

We used daily weather data observed at the JMA observatories to identify WMDs for the present day (1968–1980). We selected nine JMA observatories that were nearest to the location of the diaries. The JMA observes daily weather during the daytime (06:00–18:00) and at night (18:00–06:00). For the historical daily weather documents, it is assumed that weather phenomena at night are disregarded by the observers (Mikami, 1993). Therefore, we used only daytime weather observations to compare them with those in the historical period. JMA weather data from the late-1960s to the present are available. However, the format of weather description by the JMA changed in most observatories after the mid-1980s. Standardized JMA weather data after the mid-1980s are not appropriate for comparison with historical weather documents. Therefore, we used JMA weather data for the period from 1968 to 1980.

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2.4 Reanalysis data

To investigate the sequence of circulation fields associated with WMDs for the present day (1968–1980), we used NOAA-CIRES-DOE Twentieth Century Reanalysis, version 3 (20CRv3) (Slivinski et al., 2019), which includes the global atmosphere at a spatial resolution of T254, corresponding to approximately 0.5° × 0.5° latitude/longitude. As input data, only surface pressure observations were assimilated. Sea ice concentrations (HadISST2.3) and SST fields (SODAsi.3 and HadISST2.2) were used as boundary conditions. We defined the winter season as the period from December to February. Subsequently, we selected January 1, 1868 to December 31, 1980 as the analysis period.

2.5 Gridded precipitation data

We used historical high-resolution (0.05° × 0.05° latitude/longitude) daily precipitation gridded data over the Japanese islands (APHRO_JP V1207) from the Asian Precipitation-Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources project (Kamiguchi et al., 2010). We used APHRO_JP data to investigate the sequence of daily precipitation patterns associated with an outbreak from the East Asian winter monsoon.

2.6 Station pressure data

We used station pressure data observed in Nagasaki and Tokyo in Japan (red circles in Fig. 2) observed by the JMA for years 1968–1980. In addition, we used the surface pressure data observed at the Beijing International Airport. Surface pressure data from the Beijing International Airport were obtained from the website of the National Canters for Environmental Information of the NOAA.

3 Methods

3.1 Definition of WMD

We present the procedures for detecting WMDs. First, we categorized daily weather into three types: snowfall, rain, and fine or cloudy, according to the methodology of Yoshimura (2013). When several different weather descriptions appeared on the same day, we prioritized the weather categories as follows: 1) snowfall, 2) rain, and 3) fine or cloudy (no precipitation). For example, when snowfall, rainfall, and cloudy conditions were described for one day, snowfall was adopted as the weather for that day. Using these weather categories, we created daily weather maps during the study period. Subsequently, we detected WMDs by focusing on the weather contrast between the Sea of Japan side (blue circle in Fig. 1) and Pacific Ocean side (red circle in Fig. 1).

The WMD was defined as follows: 1) snowfall was recorded in more than three locations in the Sea of Japan side, and 2) precipitation was not recorded at any location in the Pacific Ocean side. We detected 413 WMDs in the present day (1968–

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1980) using weather data observed in the JMA observatories. With respect to the historical period, we detected the WMDs using historical daily weather documents.

3.2 Analysis of sequence of circulation fields and weather pattern for the present day

To clarify the temporal evolution of circulation fields associated with WMDs, we conducted a lag composite analysis of the circulation fields using 20CRv3. We calculated the lag composite of the daily mean SLP and 850 hPa-level temperature for the present day (1968–1980). We selected the WMDs and the preceding four days for the lag composite analysis. If WMDs appear continuously for several days, then we select the first WMD and the preceding four days. Subsequently, we selected 69 WMD days for the composite analysis. Furthermore, we conducted a composite analysis of the daily precipitation pattern for WMDs and the preceding four days in Japan using the APHRO_JP gridded precipitation data.

To determine whether a limited number of surface pressure observations and weather data can capture the East Asian winter monsoon activity in a specific year, we analyzed the relationship between the temporal variation of the SLP in three locations (Tokyo, Nagasaki, and Beijing) and the occurrence of WMDs for the winter of 1973/74 as a case study.

3.3 Analysis of sequence of circulation fields and weather pattern for the winter of 1851/52

We analyzed the temporal variations of the SLP in the morning observed in Tokyo (approximately 7:00 JST, 16:00 UTC), Nagasaki (6:20 JST, 15:20 UTC), and Beijing (7:00 Local Time, 15:00 UTC) and their association with synoptic weather patterns for the winter of 1851/52. We detected WMDs for the winter of 1851/52 using historical daily weather documents based on the same methodology used for the present day (1968–1980). In this analysis, we primarily focused on the east–west SLP gradient and the occurrence of WMDs in Japan. To analyze the east–west SLP gradient, we calculated the SLP difference between Nagasaki and Tokyo (SLP N-T) and that between Beijing and Tokyo (SLP B-T).

4 Sequence of circulation fields and synoptic weather pattern for the present day

4.1 Composite of circulation fields associated with synoptic weather pattern

First, we describe the temporal evolution of SLP fields associated with WMDs for the present day (1968–1980) (Fig. 3). The anticyclonic anomaly centre was located over central Siberia on day 4, which represented the Siberian High (Fig. 3(a)). The Siberian High gradually expanded southward from day 2 to day 1 (Figs. 3(c)–(d)). The southward expansion of the Siberian High was assumed to have contributed significantly to the southward intrusion of cold air outbreaks in East Asia (Song and Wu, 2017; Abdillah et al., 2021).

The cyclonic anomaly appeared over eastern China on day 4 (Fig. 3(a)). It propagated northeastward from day 3 to day 2 (Fig. 3(b)–(c)), implying the migration of extratropical cyclones along the south coast of Japan (south-coast cyclone) (Tasaka, 1980;

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Ueno, 1993; Ando and Ueno, 2015; Yamazaki et al., 2015). The cyclonic anomaly amplified when it reached the Northern Pacific. A strong east–west SLP gradient over Japan appeared from day 1 to day 0 (Figs. 3(d)–(e)). This significant SLP gradient represents the active phase of the East Asian winter monsoon. A significant SLP gradient is favourable for cold air advection in Japan.

The composite of the 850 hPa temperature field showed dipole-like warm and cold anomalies over eastern Eurasia on day 4 (Fig. 4(a)). The warm anomaly extended from the coastal areas of China to Japan. This warm anomaly appeared to imply a warm sector of the south-coast cyclone (see Figs. 3 (b)–(c)). Cold anomalies over Siberia gradually migrated southeastward and reached East Asia on day 1 (Fig. 4(d)). Subsequently, they intensified over East Asia and extended southward as far as Taiwan on day 0 (Fig. 4(e)). Song and Wu (2017) classified significant cold events over China into “north cold events” and “south cold events.” The southward expansion of the cold anomaly (day 0) was inconsistent with their “strong south cold events” (Fig. 16(a) of Song and Wu 2017).

Figure 5 represents a lag composite of daily precipitation patterns in Japan from day 4 to day 0. The precipitation area spread over both the Pacific Ocean side and Sea of Japan side from day 4 to day 1 (Figs. 5(a)–(d)). The precipitation over the Pacific Ocean side was caused by the passage of the south-coast cyclone (Tasaka, 1980, 1988; Ueno, 1993). Therefore, we can consider precipitation events in the Pacific Ocean side as an indicator of the passage of the south-coast cyclone. Meanwhile, the precipitation area on day 0 was limited to the Sea of Japan side (Fig. 5(d)) and was caused by the northwesterly winter monsoon.

The sequence of circulation fields and weather patterns is summarized as follows: First, the southward expansion of the Siberian High and the eastward movement of the south-coast cyclone occurred simultaneously in East Asia. When the south-coast cyclone reached the southern coast of Japan, precipitation occurred in the Pacific Ocean side. The warm sector of the south-coast cyclone caused warm advection along the southern coast of Japan. A strong east–west SLP gradient was formed when the south-coast cyclone reached off the coast of eastern Japan. This resulted in an outbreak of cold surges. Clear weather contrasts appeared between the Sea of Japan side and the Pacific Ocean side. It is reasonable to expect the SLP data of Japan and China to provide useful information regarding winter monsoon activity around Japan.

Next, we investigated the composite time series of SLP variations at three stations (Tokyo, Nagasaki, and Beijing) from day 4 to day 0 (Fig. 6). We selected these stations because early pressure observations in the 19th century were available. Figure 6 shows the decreasing trend of SLP in Tokyo from day 4 to day 1. In particular, the SLP in Tokyo decreased abruptly on day 1. Consequently, a significant east–west SLP gradient was formed. Hence, we can consider the abrupt decrease in SLP in Tokyo as an indicator of the appearance of a WMD in the following day. It is noteworthy that the decrease in SLP in Tokyo was caused by the eastward movement of the south-coast cyclone.

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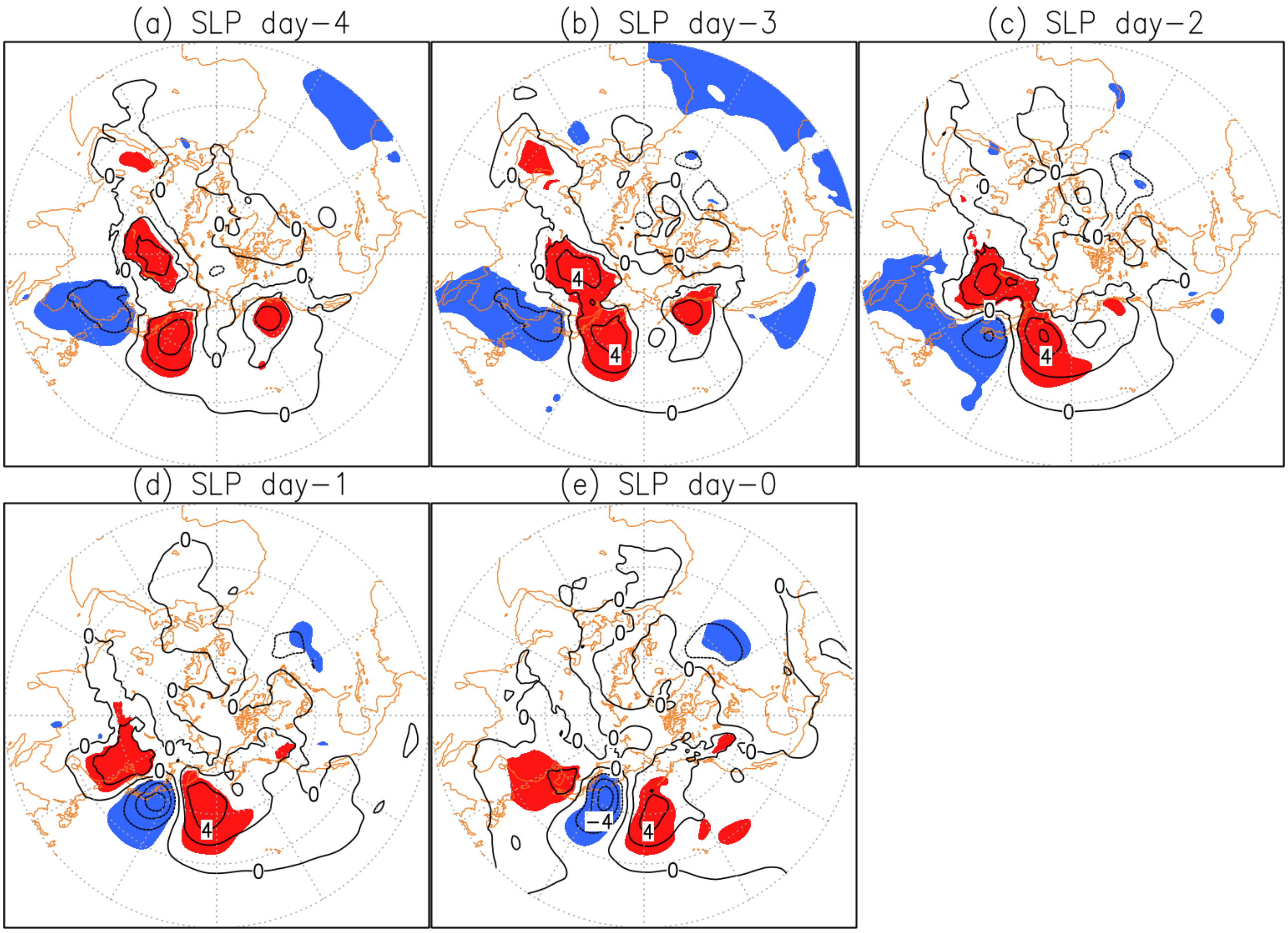

Figure 3: Composite of daily mean SLP (hPa) from day 4 to day 0 for present day (1968–1980). Contour interval was 2 hPa. Red (blue) shading denotes positive (negative) anomalies significant at 95% confidence level based on two-tailed Student's t-test.

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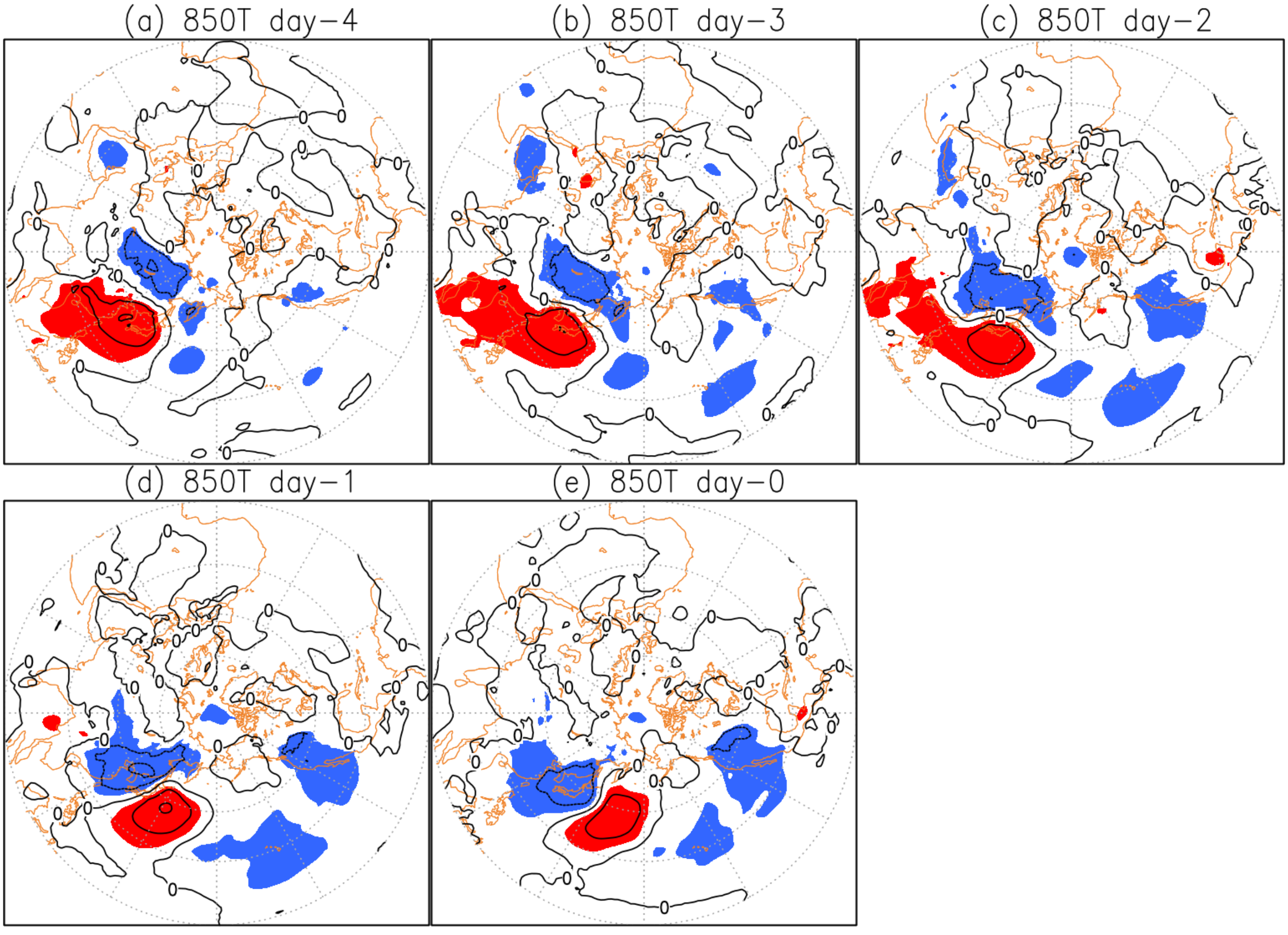

Figure 4: Composite of daily mean 850 hPa temperature (°C) from day 4 to day 0 for present day (1968–1980). Contour interval was 2 °C. Red (blue) shading denotes positive (negative) anomalies significant at 95% confidence level based on two-tailed Student's t-test.

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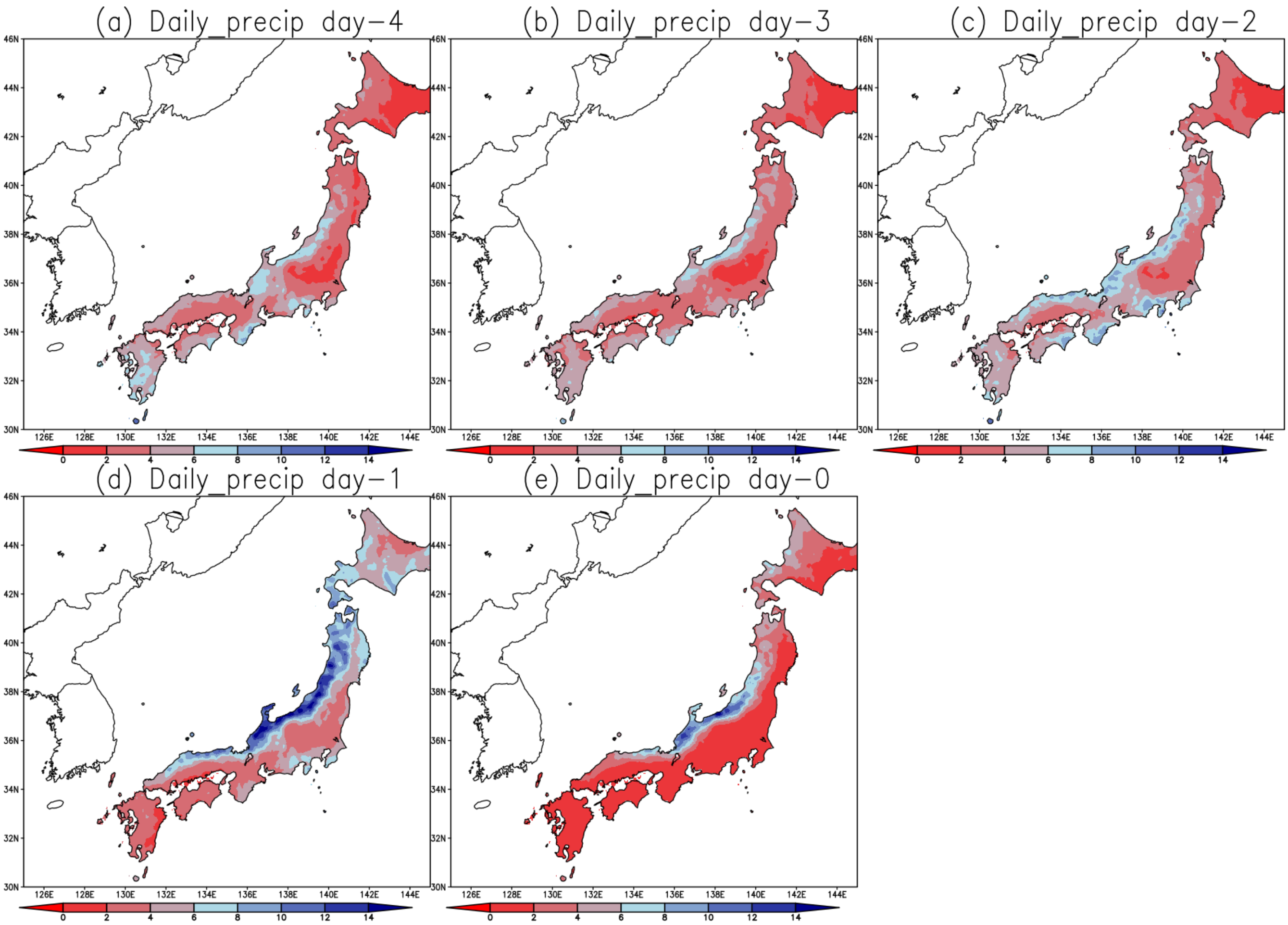

Figure 5: Composite of daily mean precipitation (mm/day) from day 4 to day 0.

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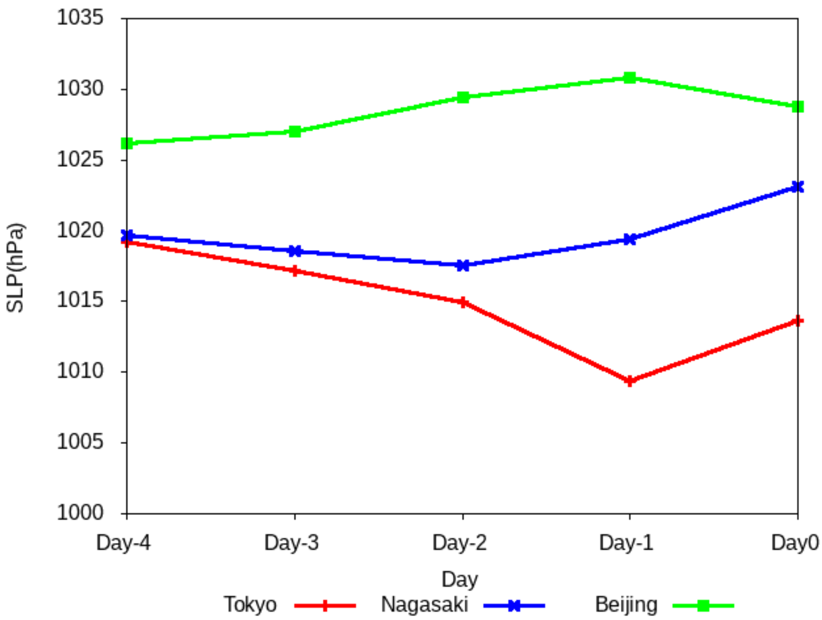

Figure 6: Composite time series of SLP in three stations (Tokyo, Nagasaki, and Beijing) from day 4 to day 0. SLP composite in Tokyo and Nagasaki were calculated using SLP data from 1968 to 1980. SLP composite in Beijing were calculated using SLP data from 1973 to 1980 because SLP data for Beijing prior to 1972 were unavailable.

4.2 SLP variation and synoptic weather pattern for 1973/74

We conducted a case study to investigate the relationship between SLP variations and synoptic weather patterns to confirm their relationship in a specific year. Figure 7(a) shows the temporal variation of SLP in three locations (Tokyo, Nagasaki, and Beijing) and occurrence of WMDs in the winter of 1973/74. We defined the "winter-monsoon weather pattern period (WMP)" as WMDs that occurred continuously for more than 3 days. We should emphasize that the onset of the WMP is characterized by an abrupt decrease in SLP in Tokyo and an increase in the east–west SLP gradient over East Asia.

Figure 7(b) shows the SLP difference between Nagasaki and Tokyo (SLP N-T). Interestingly, the peaks of SLP N-T were consistent with those of the WMP. Meanwhile, a decrease corresponded to the termination of the WMP. Furthermore, we present the SLP difference between Beijing and Tokyo (SLP B-T) (Fig. 7(c)). The peaks of SLP B-T agreed reasonably well with those of the WMP. SLP N-T and SLP B-T were positively correlated with each other (r = 0.62). Hence, a combined analysis of these SLP indices and weather patterns is effective for capturing the activity of the East Asian winter monsoon on an intra-seasonal timescale. It is reasonable to apply the same methodology to reconstruct the wintertime climate in the historical period.

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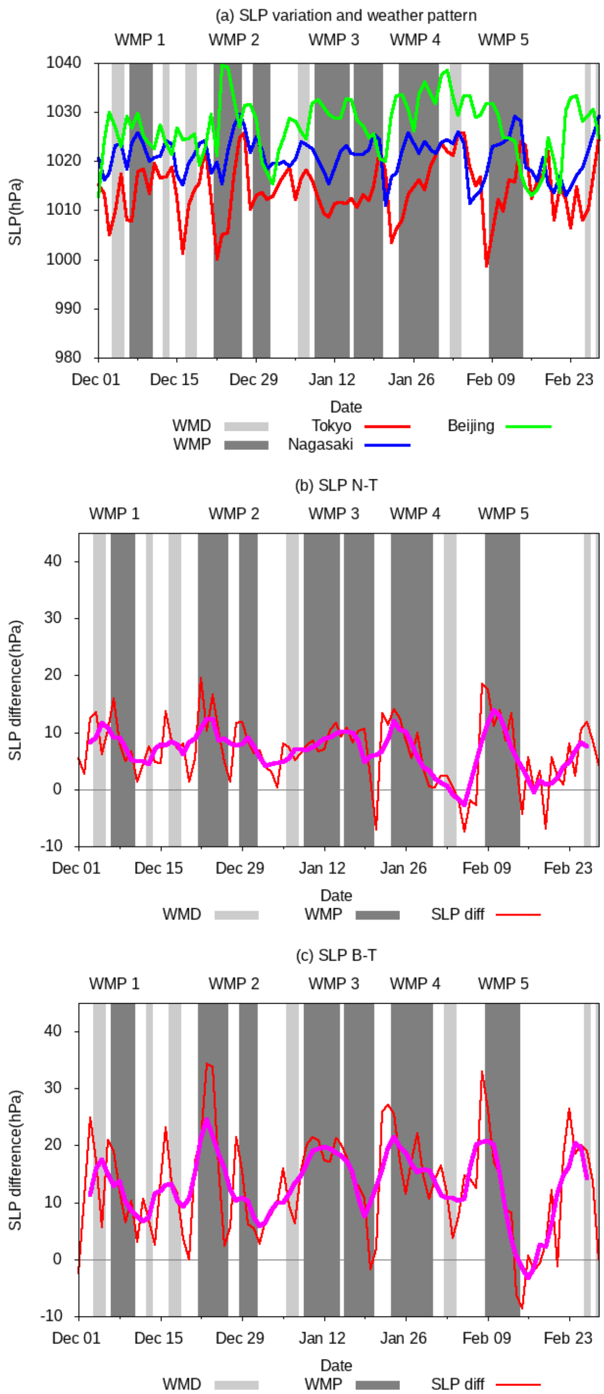

Figure 7: Temporal variation of SLP in three locations (Tokyo, Nagasaki, and Beijing) and weather pattern in winter of 1973/74. (a) SLP variations and weather pattern; (b) SLP N-T and weather pattern; (c) SLP B-T and weather pattern.

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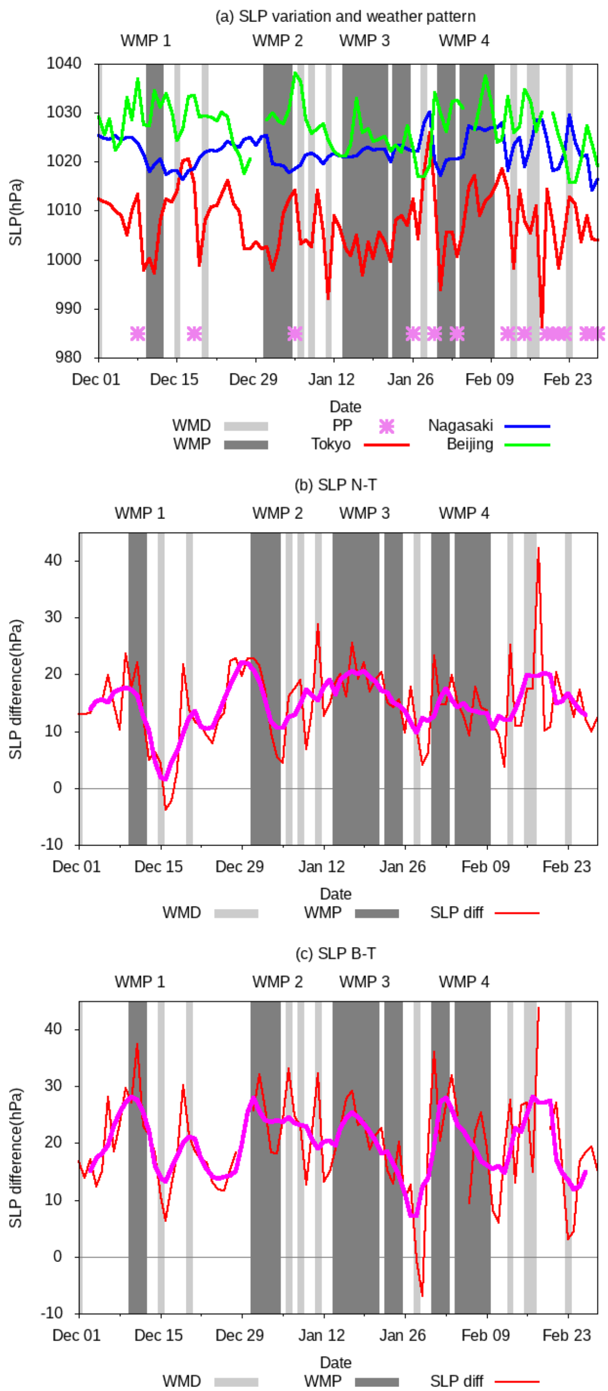

Figure 8: Temporal variation of SLP in three locations (Tokyo, Nagasaki, and Beijing) and weather pattern in winter of 1851/52. (a) SLP variations and weather pattern; (b) SLP N-T and weather pattern; (c) SLP B-T and weather pattern.

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5 SLP variation and synoptic weather pattern for 1851/52

In this section, we analyze the relationship between SLP variations and the sequence of synoptic weather patterns for the winter of 1851/52. Figure 8(a) shows the temporal variation of SLP in three locations (Tokyo, Nagasaki, and Beijing) and occurrence of WMDs. Similarly for 1973/74, we present the WMP in this figure. It is noteworthy that the decrease in the SLP in Tokyo occurred immediately prior to the onset of the WMP. This feature is similar to that observed in 1973/74. For example, an abrupt decrease in SLP in Tokyo occurred in early December, immediately prior to the onset of WMP1. An abrupt decrease in SLP at the end of January corresponded to the onset of WMP 4. As mentioned in Section 4.1, the eastward movement and amplification of south-coast cyclones caused the formation of a significant east–west SLP gradient around Japan. Therefore, we assumed that a decrease in SLP in Tokyo can reasonably represent the formation process of the SLP gradient around Japan. In Fig. 8(a), we present the precipitation events in the Pacific Ocean side area (PP). We defined PP as the day when precipitation was recorded in more than one location in the Pacific Ocean side (see red circles in Fig. 1).
PP tended to appear immediately before the abrupt decrease in SLP in Tokyo. As mentioned in Section 4.1, precipitation in the Pacific Ocean side was caused by a south-coast cyclone (Fig. 5). Therefore, it is reasonable that PP appeared prior to the decrease in SLP in Tokyo. An increase in SLP in Tokyo appeared to be associated with the termination of the WMP, which is similar to that for 1973/74. For example, a marked peak of SLP between WMP3 and WMP4 implies an inactive phase of the winter monsoon. The peaks of SLP in Beijing corresponded approximately to the WMP. This feature implies the amplification of the Siberian High over eastern China associated with the occurrence of WMDs (see Fig. 3).
Next, we calculated SLP N-T and SLP B-T using the same procedures as that for 1973/74. Figure 8(b) shows the results for SLP N-T. The peaks of SLP N-T corresponded to the WMP. A decrease in SLP N-T corresponded to the termination of the WMP. These results show that the combined analysis of SLP N-T and synoptic weather patterns can capture the active/inactive phase of the winter monsoon around Japan. Figure 8(c) shows the time series of the SLP B-T. An abrupt increase in SLP B-T corresponded to the onset of the WMP. SLP B-T was highly correlated with SLP N-T (r = 0.63). Therefore, we assumed that both time series can capture the behaviour of the east–west SLP gradient over East Asia.

6 Conclusions

In the present study, we investigated the relationship between circulation fields and winter synoptic weather patterns in Japan for the present day and historical periods. We aim to clarify whether a combined analysis of historical weather records and early instrumental surface pressure data is effective for wintertime climate reconstruction.
An analysis of the sequence of circulation fields and weather patterns shows that the southward expansion of the Siberian High over eastern China and the eastward movement of the south-coast cyclone contributed significantly to the formation of the

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east–west SLP gradient around Japan. The combined analysis of instrumental surface pressure data and weather data reasonably captured the activity of the East Asian winter monsoon around Japan on an intra-seasonal timescale. We discovered that the abrupt decrease in SLP in Tokyo was an indicator of the passage of the south-coast cyclone immediately prior to the onset of the WMP. The increase (decrease) in the two SLP indices (SLP N-T and SLP B-T) was consistent with the onset (termination) of the WMP.

We analyzed the SLP variations and weather patterns only for the winter of 1851/52 as a case study. We plan to digitize all of the surface pressure data reported in the Russian meteorological year book for the period from 1841 to 1855. In fact, we have recovered the early surface pressure observation series of Tokyo and Nagasaki in the 19th century. In addition, a large number of historical daily weather documents from the 18th to the 19th century are available in Japan. Further studies are required to clarify the inter-annual variation in the wintertime climate around Japan using both early instrumental data and daily weather documents.

Previous studies have suggested the existence of a temporal warm epoch around the 1850s in Japan based on early instrumental temperature data (Zaiki et al., 2006; 2018). However, features of the circulation patterns associated with this warm epoch have not been clarified. Therefore, further studies are required to clarify wintertime circulation patterns around Japan in the 1850s using historical daily weather documents and early instrumental pressure data.

The recovery of early surface pressure observations in East Asia is crucial for the quality assessment of long-term atmospheric reanalysis data from the 19th century. The NOAA-CIRES-DOE Twentieth Century Reanalysis (20CR) project has generated a four-dimensional global atmospheric dataset spanning from 1836 to 2015 by assimilating only surface pressure observations (20th Century Reanalysis ver3: 20CRv3) (Slivinski et al., 2019). However, few surface pressure observations in East Asia were assimilated during the 19th century. Therefore, it is unclear whether 20CRv3 is reliable in Japan. The recovered surface pressure observations in East Asia and 20Crv3 should be compared to investigate the reliability of the reanalysis data.

Data availability

All the data used to perform the analysis in this study are described and properly referenced in the paper. Historical daily weather documents in the Historical Weather Database and Surface air pressure observation in Tokyo and Nagasaki are available from the website of JAPAN-ASIA CLIMATE DATA PROGRAM (https://jcdp.jp/top-jp/). Surface air pressure observations in Beijing are reported in “Annuaire magnétique et métérologique du Corps des ingénieurs des mines de Russie” and “Annales de l’observatorie physique central de Russie”. These observations have been imaged through the National Oceanic and Atmospheric Administration (NOAA) Central Library Climate Data Imaging Project. Most of the modern meteorological data in Japan are available from the Japan Meteorological Agency. Historical high-resolution daily precipitation gridded data over the Japan (APHRO_JP V1207) are available from the website of Asian Precipitation Highly

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Resolved Observational Data Integration Towards Evaluation of Water Resources project (http://aphrodite.st.hirosaki-u.ac.jp/index.html).

Author contributions

JH collected data and performed most of the analysis with guidance of TM. TM designed the research method, supervised the study and assisted with interpreting the results. MZ collected and analyzed early surface pressure observation data in Japan and China. JH and TM made the figures and draft of the manuscript. All authors participated in the analysis and helped to improve the article.

Competing interests

The author declares that there is no conflict of interest.

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