

RECONSTRUCTION OF TROPICAL CYCLONE AFFECTING EAST CHINA DURING 1450-1949 FROM HISTORICAL DOCUMENTS

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ABSTRACT

The natural disaster information in the historical documents in mainland East China are investigated and collected. A set of criteria is set up to discern the tropical cyclone (hereafter TC) influences from these records. The criteria construction is based on the knowledge of TC and TC disasters in instrumental era. Five TC features are considered in the criteria, they are occurring time, spatial scale, lasting time, disaster characteristics and associated weather phenomena. Altogether 1445 affecting TC events are found from historical documents during 1450-1949 in mainland East China. The contents of the reconstructed data include three parts—the yearly number, the occurring time and influential scope of every event. Some characteristics of the reconstructed data, temporal resolution, seasonal distribution and temporal evolution, are also discussed.

Keywords: Tropical cyclone Reconstruction, East China, Discerning Criteria

1. Introduction

The relationship between global warming and trends in tropical cyclone activity is an active research topic. Many studies from different authors argue this topic (Henderson-Sellers et al. 1998; IPCC 2001; Chan and Liu 2004; Emanuel 2005; Landsea 2005; Webster et al. 2005; Pielke 2005; Chan 2006; Landsea et al. 2006), but the consensus conclusion hasn't been attained. One way to help settle the argument is to expand knowledge about tropical cyclone occurrence back in time beyond the limits of conventional instrumental records. A long-term record of hurricane activity on timescales of centuries to millennia is especially important in understanding the spatial and temporal variability of the rare but most intense landfalling tropical cyclones which may have return periods of longer than 150 years (WMO, 2006).

There are two kinds of methodology to reconstruct paleoclimatic tropical cyclone proxy data, geologically based method and historical document based method. Among the geologically based proxies, overwash sand layers deposited in coastal lakes and marshes have proven to be quite useful (Liu and Fearn, 1993, 2000; Liu 2004; Donnelly and Webb 2004; Donnelly, 2005). Historical documents can also be used to reconstruct some aspects of past tropical cyclone

activity. Investigators have used the sources such as newspapers, plantation diaries, various instrumental weather records, and annals in the Caribbean to reconstruct the past tropical cyclone activity in the U.S., Caribbean, Gulf of Mexico, and Atlantic basin for last several centuries (Fernandez-Partagas and Diaz, 1996; Mock 2004; Landsea et al. 2004; Garcia-Herrera et al., 2004; Garcia-Herrera et al., 2005; Chenoweth, 2006). Even longer documentary records of tropical cyclone activity, extending back for more than 1000 years, have been found and investigated in South China (Liu et al. 2001; Louie and Liu 2003; Louie and Liu 2004). Typhoons and intense storms occurring in the Philippine Islands and their vicinity (Garcia-Herrera et al., 2007) and those in the Western North Pacific (Ribera et al., 2005) were reconstructed from records in Manila Observatory.

Tropical cyclones are low pressure systems that have thunderstorm activity and rotate counterclockwise. The tropical cyclones in western North Pacific are called typhoons. Like South China and Philippine, East China is vulnerable to tropical cyclone attack, and the reconstruction of tropical cyclone data in this area will expand our knowledge of tropical cyclone behavior over the western North Pacific Ocean, but few attempts have been made in this area. The tropical cyclone reconstruction we have done are based on historical documents. In historical documents, all the clues are the descriptions on disasters, so what we try to reconstruct were the tropical cyclones causing disastrous effects in the history. The process of the reconstruction

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consists of three parts: historical document collection, time determination and the deduction of proxy data. The original documents we have investigated are listed in section 2. The reconstruction method is described in section 3. The reconstruction results are discussed in section 4, and the last section is conclusion.

2. Source of original records

China has a long civilized history, and tradition of history written is one important aspect of Chinese civilization. Severe disaster information is an integrated part in the various historical documents. East China has been one of its economical and culture centers in China since South Song dynasty (1127-1279), in which the historical documents are plentiful and with high quality. The rich historical documents are good resources for climate proxy reconstruction. East China, a geographic conception in this paper, usually consists of 8 provinces, including present Shandong, Jiangsu, Anhui, Shanghai, Zhejiang, Fujian, Jiangxi and Taiwan (Figure 1). Jiangxi and Anhui are two inland provinces, and Shandong is located at the north. Most of the tropical cyclones influencing these three provinces are usually reflected in the other provinces' documents, and the quantity is relatively rare. And the historical documents of Taiwan are hard to access. So the historical documents of the four coastal provinces in mainland, namely Jiangsu, Shanghai,

Zhejiang and Fujian, are investigated in this research.

The documents we have investigated can be classified into four groups. The first group is special records like *Flood and drought records in last 500 years*. The second is special historical books as e.g. *Meteorological historical books*, *Geographical historical books* and *Hydrological historical books*. The third is local historical records, the main document resource of the research. The local historical records have three district levels, which are county level, prefecture level and province level. The fourth group is dynasty history documents, such as royal records in Ming dynasty and royal records in Qing dynasty. The most of the documents we have investigated are those openly published after 1949, and preserved in the public library and local history archives. Most of the records we used are from Shanghai local history archives. For the books we referenced are written in modern time, most of the disaster recordings in our research are secondary sources.

The records related to disasters related to rain, wind, tides and flooding are investigated and collected. The earliest disaster record we found in our research is in West Han Dynasty (48 B.C. - 220 A.D.), the date coverage of the disaster record in most books is from Song dynasty (960 -1279) to P.R.China time (1949-). East China around Shanghai area developed most quickly after Ming dynasty in Chinese history, so in our work, time coverage of the

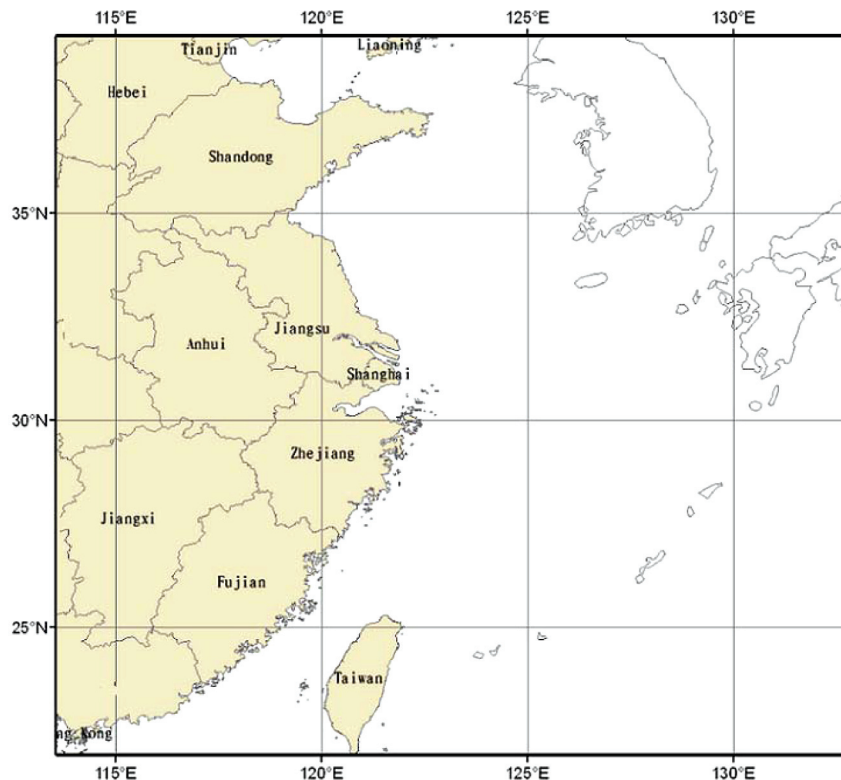


FIG. 1. Map of East China

record investigation is from 1400 to 1949, which covers three periods in Chinese history---Ming dynasty (1368-1644), Qing dynasty (1644-1911) and Republic of China (1912-1949).

More than 300,000 items of related records were collected, and the reconstruction work is to discern the typhoon from these records on the basis of the relationship of tropical cyclone attacks and their influential phenomena.

3. Reconstruction method

For there was no instrumental observation in ancient China, all the related records in historical documents are disaster information and special natural phenomena. These records cannot be directly treated as tropical cyclone affecting results. The key of reconstruction is to discern tropical cyclone events among diverse disaster information. The proxy reconstruction is a kind of solving inversion-problem, and the constraint conditions should be constructed for solving inversion-problem. The constraint conditions should be based on the knowledge of tropical cyclone and tropical cyclone disaster. Under the assumption that the basic climatology of tropical cyclone has remained stable for the last 550 years including both of non-instrumental period and instrumental period, we can apply the instrumental observation data to set up the linkage between tropical cyclone and its influential phenomena, which provides the clues to reconstruct tropical cyclone in historical documents. In this paper five discerning criteria are pointed out to help the tropical cyclone reconstruction in mainland East China.

The data we used in the relationship analysis are observation data from 82 meteorological stations in mainland East China during 1951-2000, by which 634 tropical cyclone-affecting cases are analyzed. Of the 634 cases, 334, 278, 130 and 117 tropical cyclones affected Fujian, Zhejiang, Shanghai, and Jiangsu respectively. The 82 meteorological stations include 25 stations in Fujian, 30 stations in Zhejiang, 8 stations in Shanghai and 19 stations in Jiangsu. When at least one station satisfies one of the following conditions as tropical cyclone landfalls or passes nearby, we define it as one tropical cyclone influence event: 1) Process precipitation $\geq 50\text{mm}$; 2) Mean wind speed $\geq 13.9\text{ m/s}$ or gust wind speed $\geq 17.2\text{ m/s}$; 3) Process precipitation $\geq 30\text{mm}$ and mean wind speed $\geq 10.8\text{ m/s}$ or gust wind speed $\geq 13.9\text{ m/s}$. Similarly, one serious affecting tropical cyclone event is defined when one of the following conditions in no-less-than one station are satisfied: 1) Process precipitation $\geq 200\text{mm}$; 2) Mean wind speed $\geq 24.5\text{ m/s}$ or gust wind speed $\geq 28.5\text{ m/s}$; 3) Process precipitation $\geq 100\text{mm}$ and mean wind speed $\geq 20.8\text{ m/s}$ or gust wind speed $\geq 24.5\text{ m/s}$. These conditions are from the climate operation standards in East China.

a. Calendar comparison

The date of the event is an important part in historical

record, so the time of proxy in the document based reconstruction is usually definite. But dating the related events is a problem in our work, for the dates in the historical records all used in Chinese calendar, a different calendar system from the western Gregorian calendar. Namely, Chinese calendar is a combination system based on both solar and lunar calendar. The Chinese calendar year is determined by the cycling time of the earth round the sun, and the Chinese calendar month is determined by the cycling time of the moon round the earth. The length of a year in the Chinese calendar (usually 354 days) is different with that in western calendar (365 days). Though one year includes nominally twelve months in the two systems, an additional month (called *run yue* in Chinese) will be usually added to one year every several years to settle the contradiction of the two astronomical cycles, and the rule is seven *run yues* in every 19 years. There are 12 months, corresponding first to twelfth month of a year in Chinese calendar, they are denoted as January (Chinese Calendar), February (Chinese Calendar), etc. in this paper. And we can also find some *run yues* in dating records, they are denoted as second January (Chinese calendar), second February (Chinese calendar), etc. in this paper. Approximately, the beginning of New Year often appears 20-50 days later in Chinese calendar than in western calendar. Actually, the years show a linear correspondence for both dating systems, thus the yearly number of tropical cyclones coincides for both systems in our work. In ancient Chinese historical records, the year was recorded in Emperor year-sign, and the date was recorded in a set of Chinese character sign called *tiangan dizhi* instead of digits. Occurring time is important information for tropical cyclone discerning, so as to solve date recording problem, a set of comparison form of Chinese calendar and western calendar is set up as the basis of reconstruction.

b. Discerning criteria

Most of the records in the historical documents are on disaster description. It is necessary to construct the linkage between tropical cyclone attack and its impacts. The knowledge of tropical cyclone and tropical cyclone disaster is used for constructing the criterion to identify tropical cyclone.

1) Criterion of occurring time

The western North Pacific supports the development of tropical cyclones year round. The statistic results of the impacting time of tropical cyclone in East China can give us information of tropical cyclone active season in which related disaster records should be considered in the reconstruction. The results are shown in table 1. The tropical cyclone impacting time is from May to November with a peak from July to September. Most of the tropical cyclone events occur in this period. Considering this fact, the related phenomenon in the time from May to November may

TABLE 1. Tropical cyclone impacting time in East China (Time range of data: 1951–2000)

	Tropical cyclone impacting time	Severe tropical cyclone impacting time	Quantity of tropical cyclone event in July–September/ Quantity of yearly tropical cyclone event	Quantity of severe tropical cyclone event in July– September/ Quantity of yearly severe tropical cyclone event
Fujian	Beginning of May— end of November	Mid of May— mid of November	73.0%	78.4%
Zhejiang	Mid of May— end of November	Mid of May— mid of November	79.9%	77.7%
Shanghai	Mid of May— mid of October	Beginning of June— mid of November	88.5%	87.5%
Jiangsu	Beginning of June— mid of October	Beginning of June— mid of November	89.9%	91.3%

be tropical cyclone events. Converting the month in western calendar into Chinese calendar, the criterion is that the related phenomenon between *Si Yue* (the ordinary fourth month of a year in Chinese calendar, or April (Chinese Calendar)) to *Shi Yue* (the ordinary tenth month of a year in Chinese calendar, or October (Chinese Calendar)) in historical records are candidates of tropical cyclone events.

2) Criterion of disaster phenomena

The tropical cyclone disaster is associated with strong wind, heavy rain and high tides. So the criterion of disaster phenomena will focus on the wind, rain and tide. The records describing flooding, heavy rain, housing collapse, boats overturn, tree pulling down, severe tides, etc. in reasonable season in historical documents are considered as candidates of tropical cyclone events. It should be pointed out that the astronomical tides always occur at the 1st and 15th of every month in Chinese calendar, therefore tide disasters occurring at the time apart from two astronomical tides might be attributed to tropical cyclone.

3) Criterion of spatial scale

The spatial scale of tropical cyclone varies from several hundred kilometers to one thousand kilometers, and its influential scope is much larger. So the spatial correlation of the related phenomena must be considered in the reconstruction. Statistic results show 6% of the total cases only influence one station, 70.6 % of the total cases influence 2–25 stations, 20.4% of the total cases influence 26–60 stations, and 3% of the total cases have influential scope of over 60 stations. In those cases tropical cyclone only influences one station, all the influenced sites are stations on island or on coastline. Tropical cyclone often influences places in more than two provinces. Statistics tell us among the tropical cyclone cases impacting Fujian, 66.9% of them affects Zhejiang at the same time, 29.9% of them affect Shanghai, and 29.3% of them affect Jiangsu. Among the tropical cyclone cases impacting Zhejiang, 80.6% of them

affect Fujian, 45.2% of them affect Shanghai, and 42.8% of them affect Jiangsu. Among the tropical cyclone cases impacting Shanghai, 77.3% of them affect Fujian, 97% of them affect Zhejiang, and 75% of them affect Jiangsu. Among the tropical cyclone cases impacting Jiangsu, 80% of them affect Fujian, 96.8% of them affect Zhejiang, and 79.2% of them affect Shanghai.

So we obtain the criterion of spatial scale—except for those island sites at ocean or coastline, the disaster recorded over two places at the same time are candidates of tropical cyclone events.

4) Criterion of lasting time

Unlike convective weather, tropical cyclone influence at one certain place always last one to several days. Statistic results show that most of the tropical cyclone events lasted more than one day in east China, the average lasting time of all the sites is from 1.9 day to 3.4 day, 98.6 % of the sites have average lasting time more than two days. And the longest lasting time is 3 to 8 day, 98.6 % of the sites have the longest lasting time more than four days.

So the criterion is that the wind or rainfall events lasted more than one day are considered as candidates of tropical cyclone affecting.

5) Criterion of associated weather phenomena

There are many abnormal natural phenomena recorded in historical documents, in order to discern tropical cyclone hints from these records, additional criterion should be set up. Based on the tropical cyclone knowledge, small-scale convective weather and weather in cold season can be excluded. So the records associated with such weather such as tornado, soil rain, bean rain, ice rain and dust wind etc. are not the candidates of tropical cyclone event.

6) Test of the criteria

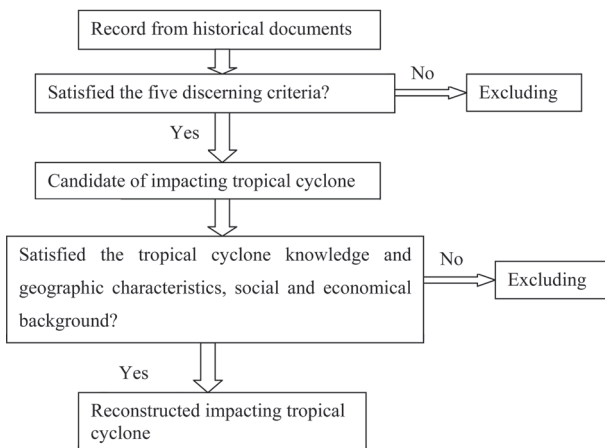
In order to validate the effects of the criteria, a test is carried out on it. We collected disastrous information during

1951-2000, and tried to reconstruct tropical cyclone by using the criteria. Altogether 185 “tropical cyclones” made disasters in mainland East China were found. All of them were truly tropical cyclones by comparing with meteorological records.

c. Process of reconstruction

On completion of the criteria construction, the reconstruction of tropical cyclone was started to carry out. For the criteria are necessary conditions instead of sufficient conditions, they are used to exclude unsuitable records. In order to guarantee the reliability of the reconstructed data, the records from different sources are referenced as much as possible in the process of reconstruction. The reconstruction proceeded in three steps. Firstly, every item of the records was checked based on the application of the discerning criteria, only those not conflicting with the criteria were discerned as candidates of impacting tropical cyclone. Secondly, the candidates remained were rearranged according to tropical cyclone knowledge and other knowledge such as geographic characteristics, social and economical background. And the data were checked and edited to form the ultimate reconstructed data at last. The quantity of the historical records before 1450 is rare, and it influences the reliability of the reconstructed data. So we ultimately treated the data during 1450-1949.

In order to validate the quality of the reconstructed data, we have compared our tropical cyclone events with those recorded by instruments from the book “Typhoon activity in western North Pacific for the last hundred years”(Wang, 1991). In Wang’s book, western North Pacific tropical cyclone data from 1884 to 1949 were compiled. The data from 1884 to 1949 from two sources have been compared. 72.8% of the tropical cyclones landfall East China in Wang’s book can be discovered by our reconstructed data. Considering the events we reconstructed were those made disasters, this ratio is quite high.



Flow-chart of reconstruction

4. Results

Altogether 1445 tropical cyclone events, of which 586 in Fujian, 950 in Zhejiang, 319 in Shanghai and 323 in Jiangsu, are found from historical documents during 1450-1949 in mainland East China. The contents of the reconstructed data include three parts: the yearly number, the occurring time and influential scope of every event. The reconstruction data have been publicized on the website www.typhoon.gov.cn since March 2006. For the English version of the website is still in construction, the notes of the data in English will be released in the same website in the future.

Many tropical cyclone tragedies in history are discovered, for example, the most destructive tropical cyclone disaster happened in 1696. The description of this disaster in the historical documents is tragic and startling: “Strong gust wind and heavy rain like pouring from sky came suddenly, and great tsunami happened at midnight, hurricane along with sea tide invaded into coastal inland several hundred *lis*. All the big trees were pulled down, and all the rice and cotton fields were drowned. Villages, cottages, woods, livestock and people were floated in the water in seconds. ... The number of people drowned to death was over 100 thousand. ... The rice and cotton this year got no harvest, and epidemic diseases prevailed to the next year. The agricultural fields all lay waste, and people was hardly seen.”

It is impossible to list all the cases in one paper, we present some statistical results here to further validate the quality of the data. Figure 2 shows the seasonal distribution of the reconstructed tropical cyclone data. The names on X-axis are the dates of reconstructed events, they are all written as month name in Chinese calendar. Most of the tropical cyclone events, 92.4% of the total, occurred in May of Chinese calendar to September of Chinese calendar, approximately June to November in western calendar. And 62.8% of the total cases influence one province, 23.9% of the total cases influence two provinces, 10.7% of the total cases influence three provinces, 2.6% of the total cases influence four provinces. All these features are consistent with the statistics in the instrumental era.

Figure 3 shows the temporal resolution of the data. Like those same kind works (Liu et al. 2001; Louie and Liu 2003; Louie and Liu 2004; Garcia-Herrera et al., 2007; Ribera et al., 2005), the temporal resolution of the data is quite high comparing with the geological method results, 60% of the data have temporal resolution of day, 27.9% of the data have temporal resolution of month, 7% of the data have temporal resolution of season.

Figure 4 shows the temporal evolution of the number of tropical cyclone events, the variation of the time series is obvious in the figure and oscillations at multiple scales can be found, and a small rising trend shows in the figure. More efforts are needed to determine the features of the decadal variability and change in this series.

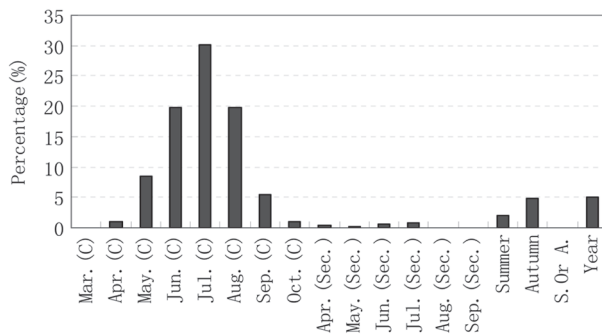


FIG. 2. Temporal Distribution of Reconstructed Tropical cyclone Data. The month names on the X-axis are all in Chinese calendar. Mar. (C) means March in Chinese calendar, approximately time around April in Gregorian calendar. Apr.(C) means April in Chinese calendar, approximately time around May in Gregorian calendar. May.(C) means May in Chinese calendar, approximately time around June in Gregorian calendar. Jun. (C) means June in Chinese calendar, approximately time around July in Gregorian calendar. Jul. (C) means July in Chinese calendar, approximately time around August in Gregorian calendar. Aug. (C) means August in Chinese calendar, approximately time around September in Gregorian calendar. Sep.(C) means September in Chinese calendar, approximately time around October in Gregorian calendar. Oct.(C) means October in Chinese calendar, approximately time around November in Gregorian calendar. Apr.(Sec.) means additional month after April in Chinese calendar. May.(Sec.) means additional month after May in Chinese calendar. Jun.(Sec.) means additional month after June in Chinese calendar. Jul.(Sec.) means additional month after July in Chinese calendar. Aug.(Sec.) means additional month after August in Chinese calendar. Sep.(Sec.) means additional month after September in Chinese calendar. S.or A. means summer or autumn.

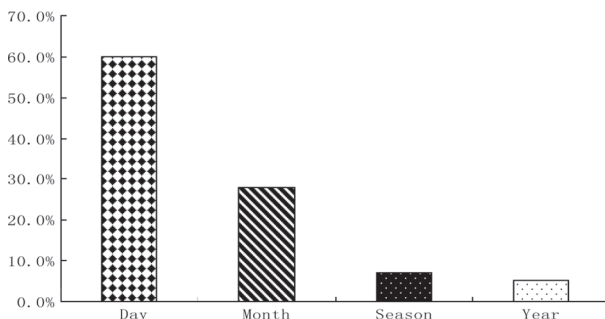


FIG. 3. Temporal Resolution of Reconstructed Tropical cyclone Data

5. Conclusion

Through three phases of work which including record collection, time determination and proxy data deduction, altogether 1445 tropical cyclone impact cases in mainland east China during 1450AD-1949AD are reconstructed. The preliminary analysis shows the results are promising. But the work still can be improved. For example, the intensity of tropical cyclone can be inferred on the basis of analysis

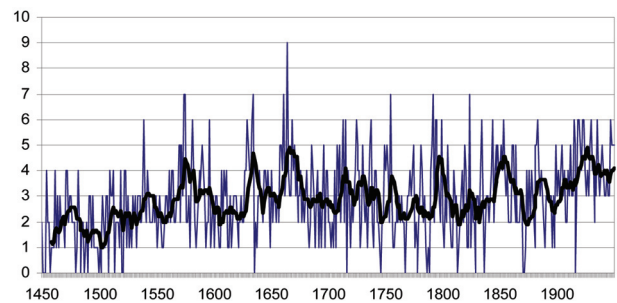


FIG. 4. Counts of Tropical cyclone Impacting East China. The thick line is 9 point moving average value.

on disaster intensity. And similar work can be further expanded to the other area surrounding western North Pacific. The development of the tropical cyclone reconstruction would possibly assist in understanding the potential for future climate changes to affect tropical cyclone activity, or vice versa.

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