Chinese Science Bulletin 2005 Vol. 50 No. 2 137—144

Climate change, social unrest and dynastic transition in ancient China

ZHANG Dian[1], JIM Chiyung[1], LIN Chusheng[1], HE Yuanqing[2] & LEE Fung[1]

1. Department of Geography, University of Hong Kong, Hong Kong, China;
2. Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

Correspondence should be addressed to Zhang Dian (e-mail: zhangd@hkucc.hku.hk)

Abstract **The evident connection between human evolution and climatic changes has been concurred by scientists. Although many people are trying to forecast the impacts of climatic changes on our future society, there are not any studies to quantitatively scrutinize the interrelation between climatic changes and social developments by using historical data. In line with this knowledge gap, this study adopted a scientific approach to compare the paleoclimatic records with the historical data of wars, social unrests, and dynastic transitions in China spanned from the late Tang to Qing Dynasties. Results showed that war frequency in cold phases was much higher than that in mild phases. Besides, 70%—80% of war peaks and most of the dynastic transitions and nationwide social unrests in China took place in cold phases. This phenomenon could be attributed to the diminishing thermal energy input in cold phases resulting in the fall of land-productivity and hence, the deficiency of livelihood resources across society. Accompanied with certain social circumstances, this kind of ecological stress was transformed into wars and social unrests, followed by dynastic transitions in most of the cases. By closer examination, it was even found that war frequency was negatively correlated with temperature anomaly series. As land carrying capacities vary from one climatic zone to another, the magnitude of war-temperature association also differed among different geographic regions. It is suggested that climatic change was one of the most important factors in determining the dynastic cycle and alternation of war and peace in ancient China.**

Keywords: climatic change, war, social unrest, dynastic cycle, temperature anomaly.

DOI: 10.1360/03wd0641

The alternation of war and peace accompanied by dynastic transitions was shown to be the rhythm of social developments throughout Chinese history. Western scholars attempted to use the "Dynastic Cycle" theory to explicate why the socio-economic development in China was embedded in such a historical rhythm[1—4]. Dynastic cycle theory states that any dynastic rise-and-fall, social accord-and-discord, and economic upturn-and-downturn are closely related to the trend of societal development and the quality of emperor's governance. However, there are not any quantitative evidences to sustain the theory. Besides, it cannot explain why history always repeats itself. We considered that the theory itself simply relies on humanistic conception to interpret history, while the influence of physical environment upon human society is basically ignored. Nevertheless, many scientists have already accentuated the importance of climatic fluctuation upon the socio-economic development in human society. For instance, Cowie[5] showed that climatic fluctuation was significant in controlling the emergence and collapse of culture. Hsu[6] also considered that human civilization has once been rigorously clouted by climatic fluctuation. Recently, some scholars even used high-resolution paleoclimatic data to elucidate the fall of ancient cultures in some places before historical record started[7—11]. Yet, no one has tried to employ the notion of paleoclimatic fluctuation to scientifically construe the documented wars, social unrests, and dynastic changes for a long historical period. Indeed, dynastic cycle in ancient society was usually accomplished by wars and social unrests. War is not simply a socially organized armed-conflict but an important means in facilitating societal evolution[12−14]. However, most of the historians used to seek the explanations of war from political, economic, cultural, or even ethnic perspectives[15 − 18]. They concluded that social unrests should be the consequences of class struggle or mis-governance[19,20]. We regarded that physical environmental changes play a very important role in human civilization in that land productivity, which has its links to a number of socio-economic parameters, is mediated by one of the environmental factors, climate. These linkages are particularly noticeable in densely populated ecologically-sensitive areas of ancient agrarian society. When land productivity diminished, famines, migrations, or even nation's declines would follow. Wars and social unrests then became predestined consequences, which might even bring out dynastic transitions.

China has a vast territory that is separated by different climatic belts. Climatic characteristics are also revealed via the livelihood and residential distinctiveness across the nation. Therefore, climatic changes deemed to have profound effects in shaping Chinese history[21]. "Favourable climate", which means climatic condition in sense, was regarded as one of the most important factors in determining the destiny of emperor's governance in ancient China. In that way, China is believed to be an archetype for investigating the association between climatic changes and societal transitions.

In this study, we explored the interrelation between climatic changes and societal transitions from a new perspective. By the means of high-resolution data comparison, both the inceptions of historical events and the pertinent environmental conditions would be quantitatively scrutinized in order to seek out the ultimate cause in shaping human history. These events were defined in terms of wars, social unrests, and dynastic transitions. The events can be accurately verified by historical documentations and mirror the important changes occurring in ancient China. We believed that this kind of analytical approach could scientifically uncover the connection between the climatic and societal rhythms in China.

1 Data and method

Recently, there are a number of studies aiming to provide high-resolution temperature reconstruction records for the past 1000—1150 a[22−28]. Despite their diversified sources of data and the associated methods of reconstructions, the strikingly high congruence among the reconstructed records warranted their validity and reliability. Briffa and Osborn exemplified climatic changes by contrasting seven of the most representative paleotemperature reconstruction records of Northern Hemisphere (NH) for the last millennium. In this research, five paleotemperature anomaly series spanned more than 1000 a used by Briffa and Osborn were employed to set the benchmark for examining climatic fluctuations[29]. Those series were reconstructed by using the proxy data derived from tree ring, coral, ice-core, borehole, and historical documentation, with China to be one of the sampled areas. Briefly, the proxy data were first recalibrated with the AD 1881—1960 mean annual temperature observations over the land area north of 20°N via linear regression, and then smoothed by a 50-a low-pass filter to give the reconstructed climatic records. Out of the five chosen series, two with the first data point started from AD 850, whilst the remaining three series started from AD 1000. In order to delineate the boundaries between cold and mild climatic phases, we averaged the five paleotemperature anomaly time-series at the very beginning. From AD 850 to 1000, the average was worked out from Esper's and Briffa's time-series[24,27]. From AD 1000 to 1980, all five times-series were used to calculate the averaged figures. Based on the figures' value and variability, a cycle of cold and mild phases would be confirmed if the averaged temperature anomaly had an amplitude exceeding 0.14℃. However, only if the averaged figures were below –0.35℃, could the period be categorized into cold phases. Based on this principle, the boundary between cold and mild phases would be the mid-point between the maximum and the minimum averaged temperature anomaly of each cold-mild cycle. From AD 850 to 1911, the aggregate duration of cold phases was 549 a and that of warm phases was 512 a respectively. Besides, 16 climatic phases were also identified (Fig. 1(a)).

In China, there is also a considerable progress in the field of paleoclimatic study. Yang et al.[30] recapitulated the recently published paleoclimatic reconstruction records to produce the 10-a resolution temperature anomaly time-series of China. Ge et al.[31] also used a vast amount of historical documentations to reconstruct the temperature anomaly time-series of eastern China (30-a resolution) (Fig. 1(d)). Both of the time-series show a good match with the air temperature in the area north of 20°N, except that there is a remarkable discrepancy regarding the temperature in the 13th century. Yang et al. and Ge et al. designated that the period was relatively warm, while the figures from the NH's temperature anomaly series were revealed to be the opposite. Furthermore, other studies regarding the temperature anomaly of eastern China also attested the coldness of the period[32,33]. Due to these disputes, together with the low-resolution of the reconstructed data, the temperature anomaly series of Yang et al. and Ge et al. were just included for comparison.

A multi-volume book entitled "Tabulation of Wars in Ancient China" is believed to be the most comprehensive existing documentation in listing the warfare in China[34]. However, in order to avoid any inconsistency and discrepancy that might result from the diversification of information sources, only the date, number, type of participant, and location of wars listed in the book were considered to be reliable for data analyzing. Based on such information, the frequency, participant-type, and geographic distribution of wars were converted into time-series. The classification of wars was based on the types of participant (particularly the leaders) of the two sides in any armed conflicts, with two categories formed: rebellions or other wars. In order to quantitatively illuminate the interrelation between temperature anomaly and war frequency, we conducted a series of Pearson's correlation analysis at different temporal scales. To the operational definition of social unrests, only those historically documented nationwide social unrests (with more than five provinces affected at a time) caused by the unanimous underlying factor were included in this study. The records of dynastic transitions were entirely based on "Zhongguo Tongshi" compiled by Fan[20]. One noteworthy point is that the included dynasties were not only the main dynasties (e.g. Ming, Qing, etc.), but also the subsidiary dynasties (e.g. Xixia) formed by minorities who had once governed five provinces or even larger areas[35].

Seeing the spatial disparity of climatic condition, China is physically divided into three macro regions in this study, namely: (i) Northern China with continental humid, semi-humid, semi-arid, and arid temperate influenced by both the monsoons and westerlies. Major agricultural activities are wheat farming and grazing. (ii) Central China with its climate dominated by the monsoons. The region serves as China's major rice production area. (iii) Southern China with subtropical and tropical climates. Cultivation enjoys a long growing season and with double or even triple cropping for paddy annually. All of wars and

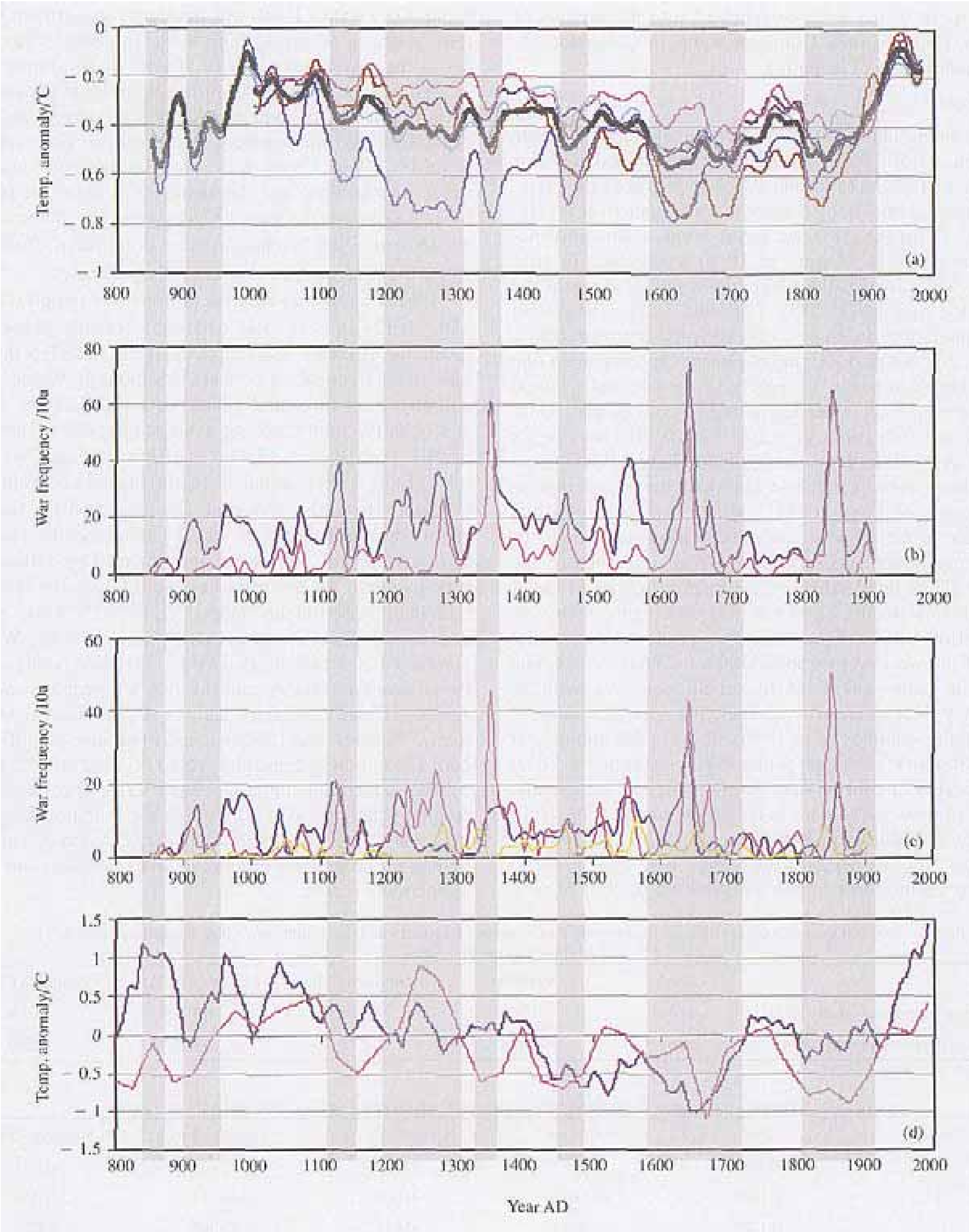

Fig. 1. Climatic changes and the incidence of wars in China. (a) Normalized temperature anomaly records for the land areas north of 20°N from AD 850 to 1980: Mann (pink), Briffa (turquoise), Jones (dark blue), Cowley and Lowery (dark red), Esper (blue), and the average of these five series (black). (b) Frequency of wars (dark blue) and rebellions (pink) in the whole China. (c) Frequency of wars in northern China (dark blue), central China (pink), and southern China (yellow). (d) Temperature anomaly series of China of Yang et al. (dark blue) and Ge et al. (pink). Cold phases are shaded as gray strips.

rebellions in China were categorized into the regions of northern China, central China, or southern China according to their places of inception.

2 Result

(i) Interrelation between war frequency and climatic variation. Both NH's climatic variations and the war frequency of China (a turbulent period followed by a relatively tranquil one) demonstrated a cyclic pattern (Fig. 1(a) and (b)). From Fig. 1(b), we can see that all three distinctive war peaks (>50 wars in 10 a) took place in cold phases, while two of the related cold phases were in the "Little Ice Age" (AD 1583—1717 and 1806—1912, with the temperature anomaly consecutively dropped below –0.5℃). Six out of the eight cold phases encompassed one or two high war peaks. Generally, those war peaks started within 5—30 a after the beginning of cold phases. Only two (in the 16th century) out of the 10 high war peaks (>25 wars in 10 a) were outside cold phases. When comparing the war frequency of China with the paleotemperature records of Yang et al.[30], it can also be found that seven out of the 10 war peaks occurred in the troughs of their temperature anomaly series. With reference to the eastern China temperature reconstruction record of Ge et al.[31], there were also eight war peaks during the relatively cold period (<0℃). Therefore, it is prudent to state that most of the wars erupted in cold phases. Warfare in China was principally dominated by rebellion (46%), with its frequency fluctuating in accordance with the oscillation of temperature anomaly (Fig. 1(b)). It was also found that four distinctive rebellion peaks (>20 rebellions in 10 a) were located in cold phases. Additionally, the geographic pattern of wars was shown to be very apparent (Fig. 1(c)). In the humid southern China, the correlation between war frequency and temperature fluctuation was very weak. In northern China, most of the wars started in cold phases. From AD 1300 to 1600, war frequency in northern China remained at a relatively high level. In central China, six out of the seven war peaks (>20 wars in 10 a) took place in cold phases. Viewing from the geographic perspective, in northern China, when cold phases approached, war peaks followed immediately, except in the 14th and 19th centuries when China was ruled by northern nomadic tribes (the Mongol and the Manchu) at the time. In contrast, war peaks in central China generally came with a 5—15-a time lag behind the ones in northern China or a 10—50-a time gap after the start of cold phases.

When dichotomizing the entire study period (i.e. AD 850—1912) into 16 cold and mild climatic phases, the results of Person's correlation analysis revealed that the maximum frequencies of wars/rebellions in whole China and also wars in central China were significantly associated with the minimum and average temperature anomaly of NH, with the correlation coefficients being –0.56 or over (Table 1). At annual scale, the lagged correlation coefficients (from 0—30-a time lags) between the frequencies of wars/rebellions in whole China and the temperature anomaly of NH were significant. This relationship was also held for the wars in central China. In short, the correlation coefficients ranged from –0.109 to –0.190, with their highest numbers in 10—15-a time lag. We also conducted a series of Person's correlation analyses between war frequencies and the two temperature anomaly series of China created by Yang et al. and Ge at al. respectively. Various war frequencies were also significantly correlated to the temperature record of Yang et al.[30] (Table 3). But to the temperature anomaly series of eastern China reconstructed by Ge et al.[31], only the rebellion frequency in whole China was significantly correlated to it. This may be due to the regional limitation and low-resolution of the temperature record.

Table 1 Pearson's correlation coefficients between the maximum war frequency and the minimum/average temperature anomaly (℃) in the 16 climatic phases

	Total	Rebellion	Northern China	Central China	Southern China
Minimum temperature anomaly/℃	–0.612 a)	–0.564 a)	–0.440	–0.591 a)	–0.438
Average temperature anomaly/℃	–0.664 a)	–0.628 a)	–0.441	–0.635 a)	0.490

a) $P < 0.05$ (two tailed).

Table 2 Pearson's correlation coefficients between temperature anomaly and war frequency at annual scale

Time lag/a	Total	Rebellion	Northern China	Central China	Southern China
0	–0.109 a)	–0.158 a)	0.013	–0.144 a)	–0.051
5	–0.134 a)	–0.169 a)	–0.001	–0.171 a)	–0.043
10	–0.148 a)	–0.185 a)	–0.011	–0.186 a)	–0.036
15	–0.146 a)	–0.190 a)	–0.009	–0.185 a)	–0.037
20	–0.134 a)	–0.182 a)	0.003	–0.172 a)	–0.049
25	–0.118 a)	–0.164 a)	0.018	–0.157 a)	–0.059
30	–0.102 a)	–0.145 a)	0.030	–0.143 a)	–0.062 b)

a) $P < 0.01$ (two tailed); b) $P < 0.05$ (two tailed).

Table 3 Pearson's correlation coefficients between temperature anomaly and war frequency at 10- and 30-a scales

Temperature anomaly time-series	Total	Rebellion	Northern China	Central China	Southern China
Yang et al.[30]	–0.302 a)	–0.262 b)	–0.207 b)	–0.223 b)	–0.295 a)
Ge et al.[31]	–0.228	–0.522 a)	–0.009	–0.244	–0.259

a) $P < 0.01$ (two tailed), b) $P < 0.05$ (two tailed).

(ii) Interrelation between societal changes and climatic phases. Since AD 850, all of the seven nationwide social unrests were found in cold phases (Table 4). Besides, 24 dynastic changes during the study period also occurred in cold phases, except the collapse of the Yuan Dynasty and the establishments of Ming and Xixia Dynasties. Actually, the replacement of Yuan by Ming was the direct consequence of peasant uprisings starting in the late Yuan Dynasty (in the AD 1334—1359 cold phase) and the incident happened just 8 a after the ending of the cold phase (AD 1368). In the eight cold phases, seven of them led to nationwide social unrests and the subsequent dynastic transitions. Regarding the temperature anomaly series of China, 86% nationwide social turbulences and 59% dynastic transitions were in the troughs of the temperature series of Yang et al.[30], while 100% nationwide social turbulences and 54% dynastic transitions were also positioned in the relatively cold periods as indicated by the temperature series of Ge et al.[31] (<0℃).

3 Discussion

(i) War frequency and temperature variation. By comparing war frequency with temperature anomaly series, it can be found that the considerable match-up between cold phases and war peaks is by no means accidental. We consider that the reduction of thermal energy in cold phases was the root cause to induce the upsurge of wars and the debilitation of social stability. During the "Little Ice Age", there were famines in many places of the world[36,37], which even caused large-scale migration[6]. Ancient China was a traditional agrarian society. This kind of social structure implies that the whole nation was entirely sustained by agricultural production that was contingent upon climatic conditions. The reduction of thermal energy input would definitely lead to the shrinkage of agricultural production. Compared with AD 1730—1770 (mild phase), the agricultural production in AD 1840—1890 (cold phase) was dropped by 10%—25%[38] because the reduction of thermal energy input led to a series of chain effects, including the lengthening of frost periods, increase of cold strikes, and shortening of growing seasons. Both of these effects hampered agricultural production. This phenomenon was also apparently shown in the planting history of double-cropping paddy in the

Table 4 Interrelations between climatic variations, wars, dynastic transitions, and nationwide social unrests from the late Tang to Qing Dynasties

Year (AD)	Average temperature anomaly/℃	Climatic phase	Duration/a	No. of wars	No. of wars/a	Dynastic transition and nationwide social unrest
850—875	–0.518	cold	26	10	0.38	Huang Chao Rebellion
876—901	–0.335	mild	26	7	0.27	
902—965	–0.423	cold	64	93	1.39	Collapse of Tang, chaos of Five Dynasties & Ten Kingdoms, establishments of Song, Liao, and Dali
966—1109	–0.233	mild	143	169	1.20	Establishment of Xixia
1110—1152	–0.368	cold	43	93	2.16	Establishment of Jin, Fang Na Rebellion, collapses of North Song and Liao
1153—1193	–0.315	mild	41	41	1.00	
1194—1302	–0.419	cold	109	252	2.31	Establishment of Great Mongol, collapses of Xixia, Jin, South Song, establishment of Yuan, collapses of Dali and Tufan
1303—1333	–0.362	mild	31	33	1.07	
1334—1359	–0.454	cold	26	90	3.46	Late Yuan peasant uprising
1360—1447	–0.345	mild	88	189	2.15	Collapse of Yuan and establishment of Ming
1448—1487	–0.461	cold	40	89	2.23	
1488—1582	–0.392	mild	95	208	2.19	
1583—1717	–0.534	cold	135	266	1.97	Late Ming peasant uprising, collapse of Ming, establishment of Qing, revolt of the three local governors
1718—1805	–0.413	mild	88	72	0.82	
1806—1912	–0.456	cold	106	204	1.93	Taiping Rebellion, Xinhai Revolution, collapse of Qing, establishment of the Republic of China

Changjiang region. Double-cropping paddy was first planted in China since the Tang Dynasty (AD 618—906), and became prevalent in the Ming Dynasty (AD 1368—1643). During the period from AD 1620 to 1720, the paddy could not be planted in Changjiang region due to cool temperature. But, in the period from AD 1720 to 1800, double-cropping paddy became widespread again in the middle and low reaches of Changjiang River. In the 19th century, despite the Qing government's effort in advancing the planting techniques of double-cropping paddy, the end result was poor as the climate at that time was not warm enough[39].

The possible consequences of diminishing agricultural production would be famines, the diminution of tax revenue, or even the weakening of nation's power. The population growth facilitated by the previous mild phase might further exacerbate the shortage of livelihood resources. In Webster's view, war is an adaptive ecological choice under the synthesis of population growth and shortage of resources[40]. Therefore, the outbreaks of wars and rebellions were highly concentrated in cold phases. The rebellions in China were largely composed of peasant uprisings in cold phases. The rebellion fluctuation in Fig. 1(b) shows that three distinctive war peaks corresponded to the three renowned peasant uprising periods in history (i.e. late Yuan, late Ming, and Taiping Rebellion). Some historians also admitted that one of the underlying causes of these uprisings was natural hazards and famines[20].

The lagged correlation results between war frequency and climatic variation have implications upon the societal bearing capacity. As the agricultural surplus stored in mild phase could be used to relieve famines and sustain nation's power for a period of time, the shrinkage of agricultural production in cold phases therefore would not immediately debilitate social instability in a sense.

(ii) Geographic pattern of wars. The analysis stated in the previous section can be further substantiated by the geographic pattern of wars. Reduction of temperature in cold phases would have little effect on the subtropical coastal regions and tropic regions where the heat energy and moisture supply are abundant. Even though temperature reduction could adversely affect harvest, more alternative crops could be adapted within the agricultural system in southern China and thereby, temperature reduction would not have tremendous impacts upon local society. By contrast, the climate of central China is controlled by cold and arid Siberian air mass in winter, while in summer it is controlled by warm oceanic air mass. Thus, temperature fluctuation could have an enormous impact on agricultural production. Nevertheless, as the agricultural surplus stored in mild phases could be consumed for a period, it would take some time to reach the threshold of war outbreak after the commencement of cold phases. This conclusion can explain why the short cold phase in the 15th century did not lead to a higher ratio of war outbreak. In Fig. 1(b), we can see that war frequency was the highest in the mid of or shortly after the long cold phases (14th, 16th, and 19th centuries). There were also some studies to explicate the association between aridity and war outbreak using individual cases[11]. We also observed that China was in arid period during the 12th and 13th centuries[32], and the frequent dynastic transitions and soaring war frequency in nothern China during this period might be more related to aridity in a sense. However, there are also many paleoclimatic studies to indicate that in China, cold and arid winter monsoon was more influential in cold phases, while in mild phases the country was dominated by warm and humid summer monsoon[41,42]. Consequently, cold phases often coincided with arid period in China. Indeed, the regional variability of precipitation is much more various and complex than that of temperature. Up to now, there are not any published high-resolution paleo-precipitation records. In that way, the quantitative relationship between war frequency and paleo-precipitation awaits to resolution.

In northern China, people livelihoods were primarily supported by pastoral activities. Yet, pastoral production is highly sensitive to temperature reduction. Besides, the reduction will lead to not only the drop of animal produces, but also desertification and land degradation resulting in the collapse of regional ecological system. In addition, pastoral products could not be stored for a long period and hence, war peaks would follow right away when cold phases commenced (except in the 14th and 19th centuries). Numerous wars in northern China were related to the invasion of nomadic tribes in capturing the fertile land resources in China. Superficially, there should be a high association between war frequency and cold phases in northern China. However, by closer examination, the statistical associations between the war data and paleoclimatic record were not significant. One possible explanation is that from the late Tang to Qing Dynasties, northern nomadic tribes had ruled China for more than 400 a. In addition, during the South Song, nomadic tribes occupied nearly half of central China. To sum up, in nearly half of the study period, China was directly under the rule of nomadic tribes. In the cold phases during these periods, the ruling northern nomadic tribes could migrate southward or in reverse, the livelihood resources could be transported northward from southern China. Consequently, the chance of war outbreak in northern China was largely diminished during the periods, which also leads to the insignificant correlation between wars and climate.

Population growth is another factor to induce ecological stress. It was not until AD 1741 when the Baojia system was adopted the reliable population data of China became available[43]. Based on this data, we noticed that in the later half of the 18th century (mild phase), the annual population growth rate was up to 2%. In the first half of the 19th century (cold phase), though the rate was dropped but there was still a 0.64% increase per year. In AD 1850, total population in China had reached the high of 0.43 billion. Eventually, this led to the Taiping Rebellion, which cut the total population back to 0.26 billion in AD 1862[44]. Migration can be taken as a means to liberate ecological stress. From AD 1000 to the 19th century, northern hemispheric temperature had been gradually reducing as shown in Fig. 1(a). This helped to make clear why the major trend of internal migration in China was a southward one[21]. Compared with the paddy-farming regions, the wheat-farming and pastoral regions could only support fewer populations. Since the Tang Dynasty, the economic and cultural centers in China were also gradually moved to the south of China, especially the fertile middle and lower reaches of Changjiang River since the Song Dynasty, 60% of the China population had been residing in central and southern China. It was not until AD 1984, the population in central and southern China was reduced to 57% of the country's total. This was stemmed from the northeastward internal migration from the densely populated Shandong, Henan, and other provinces during the early 20th century. Actually, this migration trend also mirrored the upward trend of temperature starting from the early 20th century. Fang[45] also regarded that climatic cooling drove the internal migration within China in the past two millennia.

(iii) Dynastic cycle and climate. Climatic cooling reduced the harvests of agricultural produces. When such a reduction lasted for a period, the resultant ecological stress would be transformed into famines, the diminution of tax revenues, and the dwindling of nation's power. In turn, these incidents further intensified societal conflicts, which could only be resolved by dynastic transitions with wars and social unrests to be the means. Thereby, the establishments and collapses of dynasties were often achieved via social unrests and invasions by northern nomadic tributes in ancient China. In the boundary regions of China, some dynasties were also established by tribal expansions. Many scholars also recognized that this kind of primary level dynastic establishments resulted from ecological stress[13,14]. This viewpoint can be further evidenced by the fact that the establishment of six out of the seven subsidiary dynasties and all nationwide social unrests in ancient China were found in cold phases (Table 4). When Yang et al.'s and Ge et al.'s temperature anomaly series were compared with the data of dynastic changes, the dynastic transition ratio in cold phases was not very impressive. But, when the regional disparity between the temperature records of eastern and western China was taken into account[46], the dynastic transition ratio in cold phases could reach 75% because most of the dynastic changes occurred in western China. The "Dynastic Cycle" theory simply attributes dynastic transitions to the matters of military strength, the quality of governance, incoming tax revenue, and the changes of national stability. But, from the fundamental perspective, apart from the quality of governance, all the other factors are related to the base of economy, agricultural production. Skinner has pointed out the possibility of how climatic cycle determined the economic cycle in ancient China. He said that if this supposition can be proven by the future research, then the notion of long-term climatic cycle can be used to elucidate why there was a cyclic pattern of economic development throughout Chinese history[1].

4 Conclusion

The period from the late Tang Dynasty to the fall of Qing Dynasty spanned 1061 a. In this period, it was found that war frequencies, war peaks, nationwide social unrests, and dynastic transitions all highly corresponded to the cold phases in NH and the paleo-temperature reconstruction records of China. Such a concurrence demonstrates that the historical changes in ancient China were closely related to paleo-temperature fluctuation. The key explanation is that ancient China was a traditional agrarian society with the agricultural output largely controlled by climate. Any climatic fluctuations would be directly translated into ecological stress in debilitating societal stability. Despite the fact that we can identify the immediate causes of every war and social unrest from political, economic, cultural, or even ethnical reasoning, the ecological stress engendered by the deficiency of livelihood resources in cold phases that expedited the outbreak of wars, nationwide social unrests, or even dynastic transitions should not be overlooked. From a macro point of view, climatic change was one of the most important factors to determine the occurrence of war outbreaks, nationwide social unrests, and dynastic transitions. As climatic changes can be expressed in terms of the cyclic alternations of temperature (cold vs. warm) and precipitation (dry vs. humid), this partly elucidates why there was also a cyclic pattern of societal transitions in ancient China. We are neither the zealots of Darwinism nor the endeavourers of Environmental Determinism. Nonetheless, through the quantitative comparison and systematic scrutiny between paleoclimatic data and several social parameters, we realized that climatic change has played a more important role in human civilization than what has so far been suggested.

Acknowledgements The authors would like to thank Prof. K. R. Briffa for providing paleo-temperature reconstruction data and Miss K. Y. Ng for identifying war locations. This work was supported by the CRCG grant (HKU7123/029) from HKRGC, CRCG for the project entitled "The processes of desertification and its control in North China" from HKU, and the Hundred-Talents Project from the Chinese Academy of Sciences (CAS2002-2004).

References

1. Skinner, G. W., Presidential address: the structure of Chinese history, Journal of Asian Studies, 1983, 44: 271—292.
2. Elvin, M., The Pattern of the Chinese Past, Stanford: Stanford University Press, 1973.

3. Hartwell, R. M., A cycle of economic change in imperial China: coal and iron in Northeast China, 750—1350, Journal of the Economic and Social History of the Orient, 1967, 10: 102—159.
4. RWGCRST (Research Working Group on Cyclic Rhythms and Secular Trends), Cyclical rhythms and secular trends of capitalist world-economy: some premises, hypothesis, and questions, Review, 1979, 2: 483—500.
5. Cowie, J., Climate and Human Change, Disaster or Opportunity? New York: Parthenon Publishing, 1998.
6. Hsu, K. J., Solar, climate, famine and great migrations, Science in China, Ser. D (in Chinese), 1998, 28: 366—384.
7. Weiss, H., Bradley, R. S., Archaeology-what drives societal collapse? Science, 2001, 291: 609—610.
8. Polyad, V. J., Asmerom, Y., Late Holocene climate and cultural changes in the southwestern United States, Science, 2001, 294: 148—151.
9. deMenocal, P. B., Cultural responses to climate change during the Late Holocene, Science, 2001, 292: 667—673.
10. Wu, W., Liu, T., 4000 a B.P. event and its implications for the origin of ancient Chinese civilization, Quaternary Sciences (in Chinese), 2001, 21: 443—451.
11. Wang, S., Zhou, T., Cai, J. et al., Abrupt climate change around 4 ka BP: role of the thermohaline circulation as indicated by a GCM experiment, Advances in Atmospheric Sciences, 2004, 21: 291—295.
12. Services, E., Primitive Social Organization, New York: Random House, 1962.
13. Fried, M., The Evolution of Society, New York: Random House, 1967.
14. Carneiro, R. L., A theory of origin of state, Science, 1970, 169: 733—739.
15. Evera, S. V., Causes of War: Power and Roots of Conflict, Ithaca and London: Cornell University Press, 1999.
16. Westing, A. H., Cultural Norms, War and the Environment, Oxford: Oxford University Press, 1988.
17. Seabury, P., Codevilla, A., War: Ends and Means, New York: Basic Books, 1989.
18. Pruitt, D. G., Richard, C. S., Theory & Research on the Causes of War, New York: Prentice Hall, 1969.
19. Zhou, G., General History of China (in Chinese), Hong Kong: Tai Ping Shuju, 1963.
20. Fan, W., General History of China (in Chinese), Hong Kong: Joint Publishing Co., 1995.
21. Chang, C., Climate and man in China, Annals of the Association of American Geographers, 1946, 36: 44—74.
22. Mann, M. E., Rutherford, S., Bradley, R. S. et al., Optimal surface temperature reconstructions using terrestrial borehole data, Journal of Geophysical Research-Atmospheres, 2003, 108: Art. No. 4203.
23. Cowley, T. J., Lowery, T. S., How Warm was the Medieval Warm Period? Ambio, 2000, 29: 51—54.
24. Esper, J., Cook, E. R., Schweingruber, F. H., Low-frequency signals in long tree-ring chronologies for reconstructing past temperature variability, Science, 2002, 295: 2250—2253.
25. Jones, P. D., Briffa, K. R., Barnett, T. P. et al., High-resolution palaeoclimatic records for the last millennium: interpretation, integration and comparison with General Circulation Model control-run temperatures, Holocene, 1998, 8: 455—471.
26. Mann, M. E., Bradley, R. S., Northern hemisphere temperatures during the past millennium: inferences, uncertainties, and limitations, Geophysical Research Letters, 1999, 26: 759—762.
27. Briffa, K. R., Annual climate variability in the Holocene: interpreting the message of ancient trees, Quaternary Science Reviews, 2000, 19: 87—105.
28. Villalba, R., Climatic fluctuations in Northern Patagonia during the last 1000 years as inferred from tree-ring records, Quaternary Research, 1990, 34: 346—360.
29. Briffa, K. R., Osborn, T. J., Paleoclimate-blowing hot and cold, Science, 2002, 295: 2227—2228.
30. Yang, B., Braeuning, A., Johnson, K. R. et al., General characteristics of temperature variation in China during the last two millennia, Geophysical Research Letters, 2002, 29: Art. No. 1324.
31. Ge, Q., Zheng, J., Fang, X. et al., Winter half-year temperature reconstruction for the middle and lower reaches of the Yellow River and Yangtze River, China, during the past 2000 years, Holocene, 2003, 13: 933—940.
32. Shi, Y., Yao, T., Yang, B., Decadal climatic variations recorded in Guliya ice core and comparison with the historical documentary data from East China during the last 2000 years, Science in China, Ser. D, 1999, 42(Suppl.): 91—100.
33. Tan, M., Liu, T. S., Hou, J. et al., Cyclic rapid warming on centennial-scale revealed by a 2650-year stalagmite record of warm season temperature, Geophysical Research Letters, 2003, 30: Art. No. 1617.
34. Editing Committee of China's Military History, Tabulation of Wars in Ancient China (2) (in Chinese), Beijing: People's Liberation Army Press, 1985.
35. Tan, Q., Concise Historical Atlas of China (in Chinese), Beijing: Sinomaps Press, 1991.
36. Ponte, L., The Cooling, Englewood: Prentice Hall, 1976.
37. Bryson, R. A., Murray, T. J., Climates of Hunger, Madison: Univ. Wisconsin Press, 1977.
38. Gong, G., Ge, Q., Xu, K., Influence of climate changes on agriculture, Historical Climate Changes in China (ed. Zhang, P.) (in Chinese), Jinan: Shandong Science and Technology Press, 1996, 406.
39. Yin, Y., Miao, Q., Tien, G., Climate Change and Regional Sustainable Development: A Case Study in the Changjing Delta Region of China, Beijing and New York: Science Press, 2003.
40. Webster, D., Warfare and evolution of state-reconsideration, American Antiquity, 1975, 40: 464—470.
41. An, Z., The history and variability of the East Asian palaeomonsoon climate, Quaternary Science Reviews, 2000, 19: 171—187.
42. Li, B., Zhang, D. D., Jin, H. et al., Paleo-monsoon activities of Mu Us Desert, China since 150 ka BP——A study of the stratigraphic sequences of the Milanggouwan Section, Salawusu River area, Palaeogeography Palaeoclimatology Palaeoecology, 2000, 162: 1—16.
43. Durand, J. D., The population statistics of China, A.D. 2—1953, Population Studies, 1960, 13: 209—256.
44. Liang, F., Statistics of Hukou, Cultivated Land Area and Land Tax in Different Dynasties of Ancient China (in Chinese), Shanghai: Shanghai People's Press, 1980.
45. Fang, J., Impact of climatic change on Chinese migration in historical times), Scientia Geographica Sinica (in Chinese), 1992, 12: 230—236.
46. Wang, S., Gong, D., Zhu, J., Twentieth-century climatic warming in China in the context of the Holocene, Holocene, 2001, 11: 313—321.

(Received December 16, 2003; accepted August 5, 2004)