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Thermal and Humidity Variations over East Europe and Asia during the Last 2500 Years by Proxy Data

Andrei SELIVANOV

Geography Department, Lomonosov Moscow State University, 119899, Moscow, Russia

ABSTRACT. Basing on various kinds of historical (documentary) and other kinds of proxy data (glaciological, limnological, faunistic, palynological etc.), an analysis of climate changes during the last 2500–3000 years over the whole extratropical Asia and East Europe was conducted. Major phases of thermal changes during this period, Iron Age cooling, Medieval climate optimum, and Little Ice Age, can be traced over the whole Eurasia, but they are usually aged from earlier times in eastern sectors of the continent. The similar pattern of set in with the larger time lag (up to 3–6 centuries) characterizes periods of increased precipitation and river runoff.

Negative correlation of temperature and humidification anomalies appears to be the important feature in the arid sectors of Eurasia, whereas in most other regions correlation of these parameters is usually positive, but less intensive. As a first approximation, eight regions can be discerned in the extratropical Asia and East Europe by the differences in their humidity response to the large-scale changes in air temperature during the last millennia.

KEY WORDS: aridity, humidity, historical data, proxy data, Medieval climate optimum, Little Ice Age.

Introduction

Historical, or documentary, data serve as an important independent source of information on past climates, including humidity, precipitation, and river runoff. Together with the other kinds of proxy data covering time scales of several hundreds to several thousand millennia, they fill in the gap between data of direct, instrumental, observations and palaeodata. Extensive data bases of such proxies have been compiled from the Chinese, Russian, and other historical sources. However, a variety of human-induced factors (national mentality, wars, etc.) that affected registration of climatic and hydrological events often prevent scholars from application of such data to the quantification of past climate changes.

Methods and material used

China and Russia, the most severe and stable former totalitarian empires in the whole world, are notable for the duration, continuity, and reliability of their chronicles. They cover time periods from AD 1000–1100 in Russia and from the 3rd century BC in China. In Russia, chronicles were held in cloisters, whereas in China state officials were responsible for their entity and truthfulness. Occasional climatic data from AD 800–850 are contained in Japan chronicles. The present author analysed all available data (over 3000 registrations) on extreme climatic events in East Europe, Central Asia, China and Japan during the last millennia. The respective methodology for estimation of reliability, climatic interpretation and cross-verification of documentary and other kinds of proxy data (glaciological, limnological, faunistic, palynological, etc.) was elaborated (Selivanov, 1994). Fractions of climate extremes of certain kinds among all extremes registered during the time interval were used to evaluate summer, winter, and annual values of surface air temperature, precipitation, and river runoff. This technique was applied to different regions of European Russia for three decade-long time intervals beginning from 1120 (Selivanov and Voronov, 1988; Klige et al., 1993; Selivanov, 1994). Further investigations in this field for Central and East Asia will be published elsewhere (Selivanov, 2000).

Results and discussion

It is widely known the Holocene thermal history has a worldwide character. Three major climate phases can be distinguished during the last 2500 years roughly covered by the Late Holocene in a geologic periodization. They are Iron Age cooling (IAC), Medieval (Little) climatic optimum (MCO), and Little Ice Age (LIA). Our analysis demonstrates that the periods can be traced over the extratropical Eurasia. Nevertheless, air temperature changes did not coincide in details over the whole region. Thermal culminations usually occurred several decades or even centuries earlier in East Asia than in Europe. E.g. MCO in Japan culminated near AD 500, in East China in the 7–8th centuries, in Central Asia in the 8–10th centuries, and in the 12–13th centuries in East Europe, whereas in East Asia the last period was marked by a gradual cooling. Events of smaller temporal scale and intensity, e.g. warm periods in the middle 20th century also occurred in East Asia one or two decades earlier that in the central and western parts of the continent (e.g. Drozdov, 1985).

Is worth to be noted that the earlier set in of climate anomalies in the east of Eurasia and their westward migration were described by King (1974), Lamb (1977) and Wigley et al. (1991).

Climate humidity represented by any indicator shows larger spatial and temporal variations than air temperature. This phenomenon arises primarily from an integral character of humidification, i.e. from its dependence upon global and regional thermal conditions that determine a potential evaporation, as well as upon regional and local supplies of water vapour, determining real evaporation.

Analysis of a general character in humidity changes during the last 2500 years in different regions of temperate and subtropical Eurasia confirms its comprehensive nature (Fig. 1). Generally, periods of higher humidification correspond to both warm and cool periods, IAC, MCO, and LIA. However, the more continental is the climate, the more distinctive is the negative correlation of thermal and humidity conditions in temperate latitudes. During the Medieval climatic optimum increase of humidification, most significant in East China and Central Europe, was not registered at all in the arid Central Asia (Qinghai-Tibet Plateau and, to some extent, Tian Shan mountains), whereas increase of precipitation and river runoff during IAC and LIA was very intensive in the last region.

Just as thermal anomalies, humid periods set in earlier in the east sector of the continent. Time lag can be even more than for the thermal anomalies. E.g. a Medieval humidification culminated in the 5–8th centuries in East China and in the 13–14th centuries in East Europe. As is the case for thermal changes, the time lag is roughly proportional to an amplitude and time scale of the respective climate change. Nevertheless, time difference in the completion of a humid period is usually smaller, if exists. Periods of high humidification usually come earlier and resume for a longer time in the east sector of the continent than in its central parts. During the MCO area of high humidity broadened from the 7–8th to the 13th century covering almost the whole extratropical Eurasia excluding its Far-Eastern sector where aridification resumed (Fig. 2).

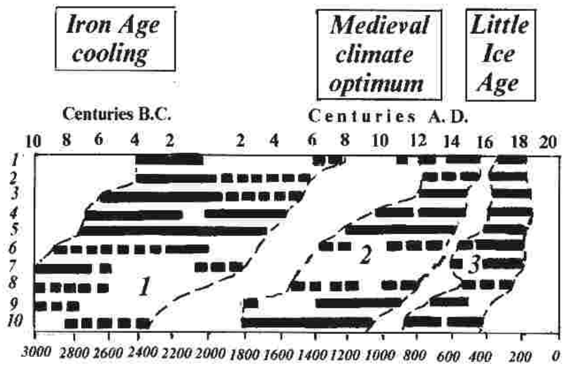

Fig. 1. Periods of high humidity in different sectors of extratropical Eurasia: 1 - England, 2 - East European Plain, central region, 3 - the Caucasus, 4 - the Caspian Sea, 5 - Aralo-Caspian watershed, 6 - West Tian Shan mountains, 7 - Qinghai-Tibet plateau, 8 - Central Mongolia, 9 - plains of East China, 10 - Japan, Honsu Island. Less reliable periods of humidification are shown by dotted bars. Mark that humid periods generally correspond to the Iron Age cooling (1) and the Little Ice Age (3), in most non-arid regions - also to the Medieval climate optimum (2). In western sectors of the continent humid periods set in several centuries later than in eastern ones.

Having been based on this information, one can try to discern regions most similar in their humidity response to the global air temperature changes. Simple four-rank scale (dry, semi-dry, semi-wet, and wet conditions) and a procedure of weighted pair nearest neighbour, or cluster, analysis (Davis, 1986) were used in such a regionalization. Eight regions discerned cover: (1) plains of East and North-East China, (2) middle and upper reaches of the Yangtze and Yellow River basins, Central and Inner Mongolia, (3) Qinghai-Tibet Plateau, (4) Kyrgyzstan and East Kazakhstan, presumably basins of the Issyk-Kul and Balkhash Lakes, (5) Central Asia, from Fergana valley in the east to the Aralo-Caspian watershed in the west, (6) the Caspian Sea and areas surrounding it from the north and west, including Caucasus, (7) central and southern sectors of East European Plain, (8) western sector of East European Plain (roughly corresponding to the present Baltic states and, partly, Belarus).

The above analysis can result in a sort of preliminary conclusions on future changes in humidity over Eurasia under the anticipated greenhouse-induced global warming. Milder climates and higher river runoff and lake water levels are expected in the monsoon East Asia, whereas arid Central Asia would preserve their aridity, at least for several decades, and most arid regions will suffer from further aridification. Precipitation and river runoff layer in the south of East Europe will possibly decrease by 10–20 percent. In the Baltic states significant changes are of low probability.

Conclusions

Negative correlation of temperature and humidification anomalies appears to be the important feature in the arid regions of Eurasia, whereas in most other sectors correlation of these parameters is usually positive, but less intensive.

Major phases of thermal changes during the last 2500 years, Iron Age cooling, Medieval climatic optimum, and Little Glacial Age, can be traced over the whole Eurasia, but they are usually

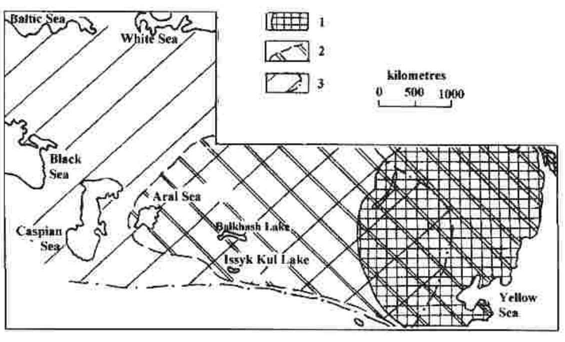

Fig. 2. Areas of increased humidity in extratropical Asia and East Europe during the Medieval climatic optimum (MCO). Note the westward "migration" of high humidity areas from the early phase of MCO, the 7th–8th centuries (1), to the 10th–11th centuries (2), and the late phase, the 13th–14th centuries (3).

aged from earlier times in eastern sectors of the continent. The similar time lag, often longer in duration (up to 3–6 centuries), characterizes periods of higher precipitation and river runoff. However, time difference in the completion of humid periods is shorter, if exists. Time lag exists also for climatic events of smaller temporal scale and intensity, but it is shorter in duration.

As a first approximation, eight regions can be discerned in the extratropical Asia and East Europe by the differences in their humidity response to the large-scale global changes in air temperature during the last millennia. The above approach can possibly be useful in long-term predictive studies.

Acknowledgements

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Abrupt Climatic Change in the Dry Steppe of the Northern Caucasus, Russia, in the Third Millennium BC

Alexander ALEXANDROVSKIY[1], Johannes van der PLICHT[2] and Olga KHOKHLOVA[3]

[1] *Institute of Geography, Russian Academy of Sciences, Staromonetny 29, 109017 Moscow, Russia*
[2] *Centre for Isotope Research, University of Groningen, Nijenborgh 4, 9747 AG Groningen, the Netherlands*
[3] *Institute of Physical, Chemical and Biological Problems of Soil Science, Pushchino, Moscow region, 142290, Russia*

ABSTRACT. The abrupt climatic and environmental changes in the dry steppe zone of the Northern Caucasus, Russia, in the Third millennium BC has been fixed on the basis of the paleosols study in the Big Ipatovsky kurgan. In paleosols separated the main mounds (layers) of the kurgan the small fragments of charcoal occurred. Their dating by AMS measurements showed that two upper paleosols with the most clear evidences of climatic aridization developed in the range of dates from 4000 ± 40 to 4080 ± 40 years BP or about 2450–2650 cal BC.

KEY WORDS: paleosols, Holocene, radiocarbon dating, climate change.

Introduction

The abrupt climatic and environmental changes in the Third millennium BC are evident from the different methods of investigation including the results of archaeological monuments studies (Weiss, 1993; Dalfes et al., 1997; Gerasimenko, 1997). The similar climatic changes have been revealed for the south of the European Russia from the study of paleosols buried under the kurgans (ramparts, burial mounds) of the Bronze Age (Fedoroff et al., 1997).

The big kurgans constructed with long interruptions during which soils have enough time to develop are of great interest to the climatic reconstructions. It can be many such soils in big kurgans; for example, in Big Ipatovsky kurgan it was five soils developed during interruptions of this kurgan construction.

The aim of this paper is to investigate a chronology of climatic changes in the Third millennium BC for the dry steppe zone of the Northern Caucasus, Russia based on AMS dating of soils and mounds in the Big Ipatovsky kurgan.

Methods and material studied

The Big Ipatovsky kurgan (BIK) was allocated at the northern periphery of the Stavropol' upland on the high terrace of