Some Preliminary Results on Pilot Study of Global Change in China

Chen Panqin (陈泮勤)
Bureau of Resources and Environmental Sciences, Chinese Academy of Sciences
and *Yan Zhongwei* (严中伟)
Institute of Atmospheric Physics, Chinese Academy of Sciences
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ABSTRACT

On the basis of existing data and research results the changes of life supporting environment in China in the history are briefly described. The differences between regional climate variations and climate jump are the very important features and phenomena in estimating the trend of environmental evolution in the future. Finally, it is pointed out that sensitive zone is an ideal place to study global change. Many evidences show that the response of environmental elements in the sensitive zones to global change events is very obvious, so that much attention should be paid to the study of sensitive zone.

I. INTRODUCTION

In recent years, humanity is being faced with large number of urgent environmental problems, such as greenhouse effect, ozone depletion, biological extinction, deforestation, desertification, etc. In 1986, the International Council of Scientific Union (ICSU) launched a programme called "International Geosphere–Biosphere Programme— A Study of Global Change" (IGBP) in order to meet the challenge of global environmental problems. Following this, the Chinese Academy of Sciences launched a project—a pilot study on assessment of current state of life supporting environment in China in order to understand and to better organize a study of global change in China. Here, life supporting environment is defined as that it consists of four basic components: atmosphere, water, vegetation and soil.

The objectives of this project are:

1) To see what changes that have already occurred in China in the past years;

2) To try to locate where our present environment in China is now standing and will go to;

3) Is it possible for us to distinguish human–induced global change from nature induced global change at present?

This project consists of the following scientific components:

* Changes of atmospheric composition and climate (precipitation, temperature, trace gases, such as CO_2, CH_4, NO_x, etc.).

* Changes of vegetation cover (forests, grassland, crops) and their relationships to human activities (e.g. overgrazing, deforestation, etc.).

* Changes of soils (loess, salty soil, desertification, soil erosion, soil acidification, pollution and degradation) and their relationships to human activities.

* Changes of environment related to water body (area of water body in China, run off of rivers, lake level, swamps, sea level, snow cover in winter, retraction and advance of glacier,

etc.), the causes of water body variations (if can be found), their impacts on climate, as well as their relationships to human activities.

* *Comprehensive and integrated analysis on life supporting environmental changes in China.*

In order to understand what changes that have really occurred in the past three time periods, the high temperature period in Holocene (Climate Optimum 8000–5000 yr.BP), the Qin dynasty (Little Ice Age), as well as the last 100 yrs. (present) are chosen because of data limitation. The existing data including those measured in the instrumental period, and proxy data deduced from literature and geological records obtained by various modern scientific technology and results spread individually are analysed and integrated from point of view of global change, and some useful results have been obtained.In this paper only some main points and suggestions will be given.

II. RESULTS

1. *Changes of Life Supporting Environment in China in the History*

As one knows that variation of driving force inside or outside the Earth system can cause changes of the Earth environment. However, we should first know what environmental change has really occurred in the past. Many evidences we have found from the existing data have shown that global environmental change has really occurred in the history.

Given in Fig.1a is the Luochuan loess sediment series compared with the deep ocean oxygen isotope series (An et al., 1990; Prell et al., 1986; Prell et al., 1987). It is clear that with regard to the last interglacial–glacial cycle, the environmental evolution in China in the past 100,000 yrs is approximately in–phase with the global change.

Fig.1b reveals the tremendous transition from the last glacial extremes to the modern Holocene(An et al., 1990). It seems that the present environmental variations are not beyond the natural range of variation in the Holocene.

2. *Location of Our Present Environment*

(1) *Position of present environment*

When we talk about the position of the present climate we have to look at its historical evolution.

Figs.2a and 2b show the variations of temperature in the period of 3000 BC–1970 AD. and period of 1380′s–1980′s(Zhu, 1973).

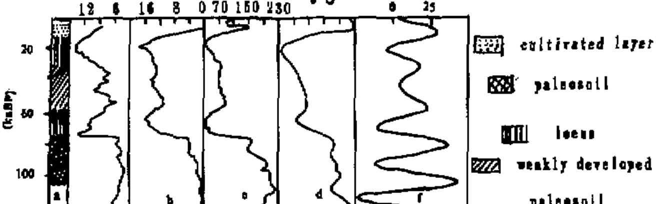

Fig.1a. The series of the past 130,000 years of a. Luochuan loess sediment and b. its medium diameter, c. the $CaCO_3$ content, d. the magnetic succeptivity, e. deep ocean oxygen isotope and f. deviation of the N. H. Summer solar radiation (from An et al., 1990; Prell et al., 1986; Prell et al., 1987).

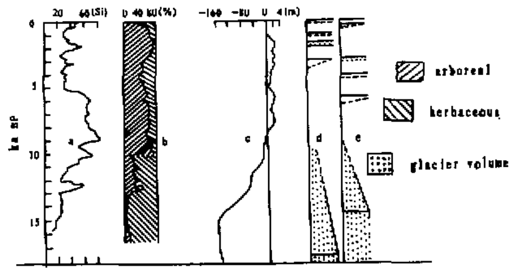

Fig.1b. The series of the past 18000 years of a. Baxie (36°42′N, 103°24′E) loess magnetic susceptivity, b. Weinan (34°28′N, 109°29′E) pollen sediment, c. Chinese coastal sea level, d. Southwest China mountain glacier and e. Northwest China mountain glacier (from An et al., 1990).

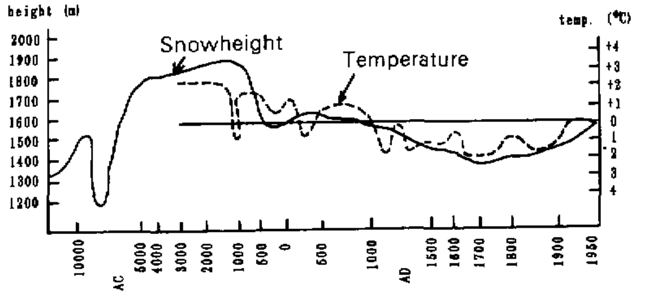

Fig.2a. Temperature change in China during the last 5,000 years (from Zhu, 1973).

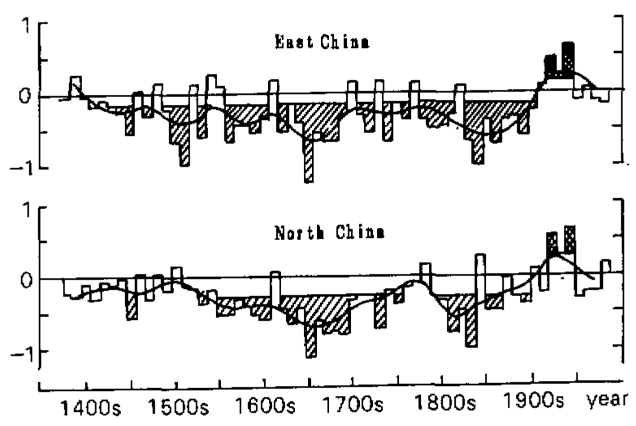

Fig.2b. 10–year mean annual temperature departure from the normal (1880–1979) for East China and North China during 1380′s–1980′s.

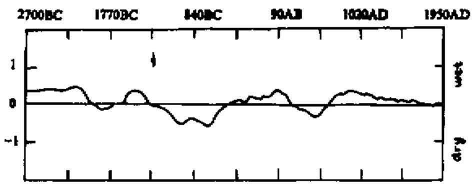

Fig.3a. 50-year mean F / D-grade series of Henan (34°N, 113°E) during 2700 BC-1950 AD (redrawn from Yan, Ye and Wang, 1991). The sharp transition around 1300 BC is indicated.

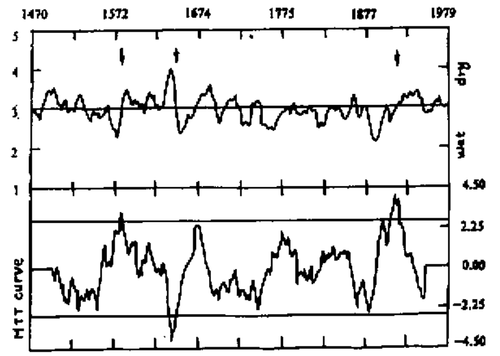

Fig.3b. F / D-grade series of Haihe region of North China during 1470-1979. The arrows denote the jump events detected by moving T-test at 0.01 significance-level.

It seems from these figures that the present air temperature is right in the mid of temperature curve on time scale of thousand years. But it should be noticed that the temperature is now getting rise from the Little Ice Age centered around 17th century although there are many fluctuations during the last 200 years.

The rainfall changes are more uneven. Figs 3a and 3b show the variations of dryness / wetness in North China from 2700 BC to 1950 AD and from 1470 to 1979 AD, respectively (Yan et al., 1991). It can be found from both figures that in North China, the present rainfall condition is neither dry nor wet on time scale of 100-1,000 years. But in the last 100 yrs., significant drying trend around the beginning of this century is occurred (Fig.3).

In summary, we may say that the current climate in China or exactly in northern China is now at a position of gradually getting warm and dry on time scale of decade-to-century, there are still lower than the values of both temperature and rainfall reached in the Holocene extremes although the climate in China is in the normal condition on time scale of 1,000 yrs..

(2) *Where will we be brought to by the environment*

Where will we be brought to by the contemporary global warming? What relationships exist between the short time scale and long time scale climate changes? To answer these questions there are two important problems that need to be solved although they are the objectives of the study of global change in China in the future.

A. Differences between the regional climatic variations

It is well-known in China that there was a Sui-Tang warm period culminated around the 7th–8th century and ended around the 10th century, when the Medieval warm period in Europe, however, was going to its extremes. Some evidences also indicate the out-of-phase relationships between the Chinese and European cold extremes of the Little Ice Age.

The regional differences of such time scale climate variations bring great difficulties to us in developing the future scenario of environmental change. It may be beneficial for us to pay attention to the study of mechanisms of the Little Ice Age and the Sui-Tang warm period, which may be regarded as a natural background of the contemporary global warming.

B. Climate jump

The complexity of the environmental change is also reflected in the phenomenon of the so-called climatic jump. The climatic jump is a kind of strong signals of the environmental evolution. We have to pay attention to this phenomenon because our Earth system is now holding up at a weakly stable state, so that some small fluctuations may cause catastrophic change, as some theoretical analyses suggested.

In China, a notable jump was detected statistically around 3200 yr. BP, when central China became dry (Fig.3). Many other regions in the world also experienced drying at that time period as pointed out by many authors.

On the shorter time scale, many jumps could be detected statistically (Fig.3), though their mechanisms remained unknown. The change in the annual rainfall induced by these jumps is on the average, about 100 mm / yr or more. This is a considerable value for the semi-arid regions such as North China.

In the instrumental period, a well-known warming jump happened around the 1920's (Goossens and Berger, 1987). Some researchers have analyzed the relationships between the warming jump and the Indian monsoon activities in 1920's, and the possible impacts of global warming on the atmospheric circulations have been found.

Many other climatic jump events have been found so far. To avoid lengthy description it is no needs to list out all of them here.

3. *Global Change Events and Response of Environmental Subsystems to Global Change*

(1) *Global change events*

There are various time scale global change events. Only two types of global change events are concerned here because of data availability in the history, i.e. the global change events on time scales of 1000 yr and 10-100 yr (Zhu, 1973).

Zhu Kezheng (1973) investigated climate evolution in China in the past 5000 years and compared climatic change with that in other places of the world. From his results it is found that for climatic change on time scale of 1000 yr. (Fig. 2a) there exist a warm period from about 6000–5000 BC to 1000 BC which is called Climate Optimum and a cold period from 1000 AD to 1850-1900 AD (Little Ice Age). The coldest temperature appeared in 17–18 centuries. After the end of 19 century, the temperature began to rise.

For climatic change on time scale of 10–100 yr, it is also found from Zhu's results that the tendencies of temperature fluctuation in China and Greenland in the past 1700 years are very similar, showing that the change is of global scale. But there are some differences that the variation amplitude of temperature in China is greater than that in Greenland and in the period of 12 to 17 centuries the temperature fluctuation in China occurred several decades earlier than that in Greenland, which is significant in predicting regional climatic change.

(2) *Response of other environmental subsystems to climatic change*

Perhaps, one has already noticed in Fig.1b that there exist some differences between the series, which represent different responses of subsystems to the environment. Why are there so many large-amplitude fluctuations in the soil condition evolution while the sea level and the vegetation subsystems show more stable behavior especially during the Holocene?

In general, the responses of every components of the Earth system to driving force are different. For a gradual change of the Earth system, response order of components of the Earth system may be in turn the atmosphere, hydrosphere, vegetation and soil owing to the inertia. But for a great abrupt perturbation, responses of the components of the Earth system may occur simultaneously.

The following evidences that have been found show the response of other environmental subsystems to climatic change.

Given in Fig.4 is the lake level variation of Beiyangdian in the past 10000 yrs (Wang, 1983). The black shadow shows the present lake water area of Beiyangdian, and deshed line represents the lake water area in the middle and late Holocene. From this figure we can see that in the Climate Optimum Period the water body area was much larger than that at present.

An Zhisheng et al (1990) investigated paleo-environment in china in the past 20000 years and reproduced a diagram of vegetation distribution in Holocene in comparison with the present vegetation distribution in China. We found that the current vegetation zones had shifted 1–2 degrees latitude compared with that in the Holocene.

4. *Response of Sensitive Zones to Global Change*

(1). *Sensitive zone*

Sensitive zone is a place most sensitive to the global change and can be viewed as a window to investigate global change. However, what is the sensitive zone? The sensitive zone here is difined as:

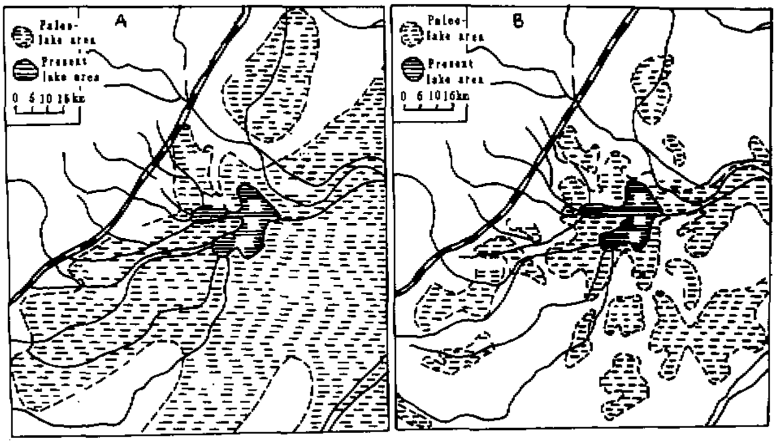

Fig.4. Lake area variations of Beiyangdian in the last 10,000 yrs. A: The mid-Holocene. B: The late Holocene (from Wang, 1983).

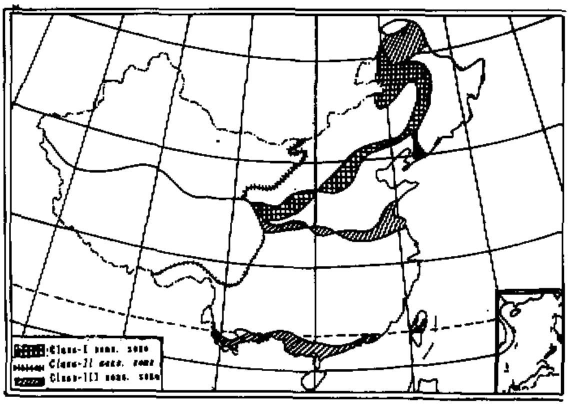

Fig.5. The sensitive zones in China.

(a) An area which is most sensitive to the perturbation or changes inside or outside the Earth system.

(b) Vegetation is the results of interaction among the subsystems of climate, water body, soil, etc., so that it can be thought as a comprehensive measure of certain environmental state.

(c) Ecotone or transitional zone of any two kinds of vegetations represents transitional area of any two kinds of environmental states. So when the condition outside the Earth system changes it varies inevitably and is represented as shift of its location.

According to the above defination, there are three kinds of sensitive zones in China (Fig.5)(Chen, 1991). Class-I sensitive zone, representing the boundary between forest and glassland; Class-II sensitive zone, representing the boundary between glassland and desert; and Class-III sensitive zone, representing the boundaries among the different forest vegetations.

(2). *Response of sensitive zones to global change events*

(a) Response of the first class sensitive zone

Fuluhe River valley near the Tianshui County (35°N,160°E), Gansu Province is situated in the western part of Class-I. Lifei et al.①found that Fuluhe River valley was covered by forest / glass in Saoyang and Qijia culture periods (6800-3900 yr BP), and its northern boundary reached 36.5 °N. However, in Chunqou Zhanquo period (2720-2156 yr BP) the vegetation there changed and was mainly covered by glass. Its northern boundary was at 35°N, moving by about 1.5° latitude southward .

In comparison with the climatic change shown in Fig. 2a, we find that before 3000-4000 BP, the climate both in China and globe was in the Hypsothermal period, and thereafter the climate turned to cold. It indicates that the shift of location of Class-I sensitive zone was coincident with climatic change at that time.

①Li F., Li S.-C., and Shui T., 1990: Ancient culture and paleo-environment in the Fuluhe River valley (draft).

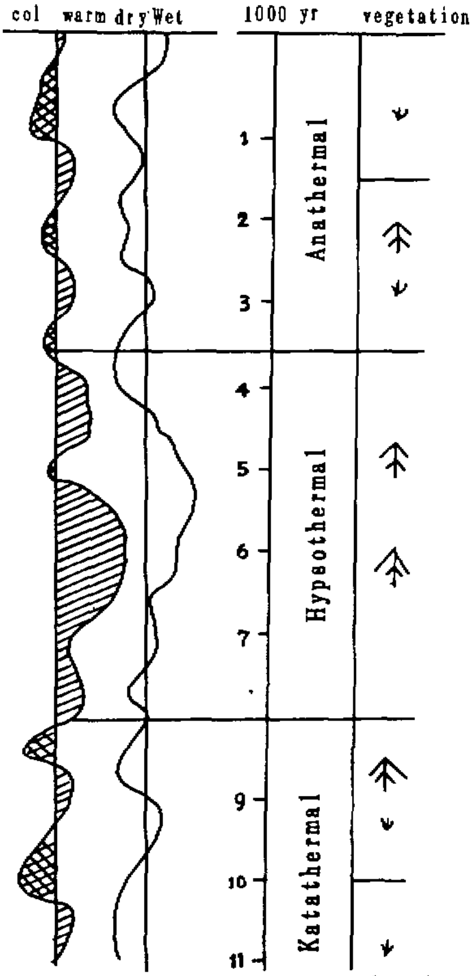

Fig.6. Variation of climate and vegetation change in Qinghai Lake area–the response of Class–II sensitive zone to climatic change.

(b) Response of the second class sensitive zone

The response of Class–II sensitive zone to climatic change may be demonstrated by the results of Kong Zhaohuan et al. (1990) on the variation of climate and vegetation in Qinghai Lake area.

Qinghai Lake (37°N, 100°E) is situated in the desert / glass transitional zone, belongs to Class–II sensitive zone mentioned above. Kong et al (1990) analysed climate and vegetation changes there by using pollen data. Their result is given in Fig.6. It shows that there has experienced at least 7 times cold–warm fluctuations and 6 times wet–dry variations in the past 10,000 yrs. But from point of view of the tendency of climatic change, there were three big fluctuations in climate: 1) Anathermal / drought period from 11000 to 8000 yr BP; 2) Hypsothermal / wet period from 8000 to 3500 yr BP; 3) Katathermal / drought period from 3500 BP till now. These changes were coincident with fluctuations of global climate change. Corresponding to these changes, the vegetations changed gradually from glass to forest when climate went from anathermal to hypsothermal and thereafter from forest to glass when climate went from Hypsothermal to Katathermal, which roughly reflected the response of vegetation to climatic change.

(c) Response of the third class sensitive zones

As we know that Elaphas maximums and rhinoceros are animals that live in the tropical and sub–tropical regions. Changes of rest place of these animals can indirectly reflect shifts of the northern boundary of subtropical zone–one of the Class–III sensitive zones.

Fig.7 is the result given by Wen (1990) who investigated the evolution of Elaphas. From Fig. 7 we find that current location of the subtropics is at about 35°N, the same as that in the period of 900–200 yr. BC. But in the period of 4000–3000 yr. BP, the northern boundary of subtropical zone was located at 36°N, about one degree farther north than the present position. In the period of 7000–5000 yr. BP, the northern boundary of subtropical zone was even farther north, almost near 40°N. As we mentioned above that in the past 10,000 yrs there was a climatic event on time scale of 1,000 yr, i.e., before 3,000–4,000 yr BP the global climate was

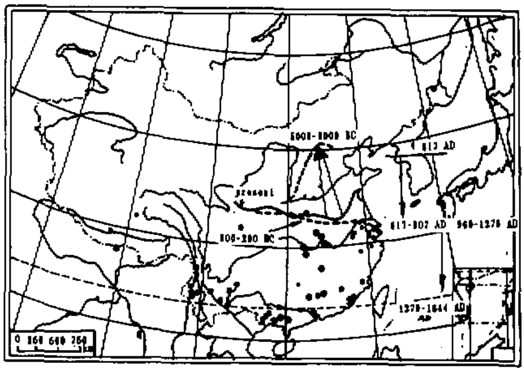

Fig .7. Historical evolution of Elaphas maximums: change of Class–III sensitive zone in China (from Wen, 1990).

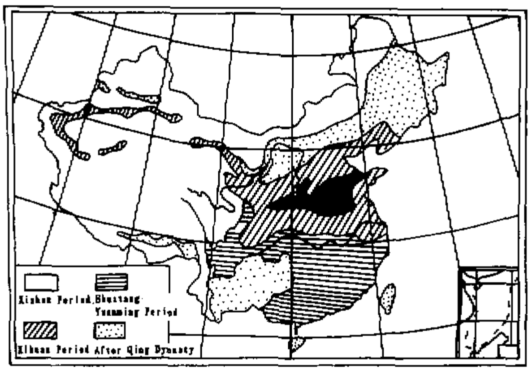

Fig.8. Farmland extension in the past 3000 yrs in China (from Institute of Geography, 1983).

much warmer than present which is called "Climate Optimum", but in the 16–18 centuries global temperature falled down to the lowest point and occurred "Little Ice Age". The shift of rest place of Elaphas maximums to some extent reflected the movement of northern boundary of subtropical zone which was coincident with global climatic change at that time. The same conclusion can be drawn from changes of rest place of Rhinoceros in the history in China.

(3). *Effects of human activities on the environment in the history in China*

Many evidences have indicated that human activity has strongly affected the Earth environment. Examples given here are the effects of human activities on the environment in the history in China.

Fig.8 shows the farmland extension in the past 3000 yrs in China (Institute of Geography, 1983), from where we can see that as human activities increase, such as population increase, agricultural development, etc., the natural forest vegetations were destroyed and turned to farmlands, showing the effect of human activities on natural vegetation distribution. At present time we could not know what effects have brought to the other environmental subsystems in quantity, which need to be further investigated.

Since the Iron Age agriculture development gradually broke away from natural restraint and brought strong influence to the environment, from results given by Ge et al. (1990) we found that the east part of agriculture–animal husbandry zone had almost no change in the past which was coincident with the location of Class-I sensitive zone. However, the west part of agriculture-animal husbandry moved by 2 degrees or so. It shonld be pointed out that great shifts occurred in the periods of 317-518 AD, 960-1644 AD other than in the period of 618-907 AD, although the climate in the periods of 317-518 AD, and 960-1644 AD was much colder than that in the period of 618-907 AD. These shifts may reflect strong influences of human activities on the natural environment in the history.

III. CLOSING WORDS AND REMARKS

We don't want to draw any conclusions from the pilot studies of global change in China. The only thing we attempt to do here is to address some questions and topics that need to be further investigated in the future.

1. How many global, regional and local change events (on time scale of 10yr., 100yr., 1000yr., etc) have occurred in the world in the past thousands years?
2. What are the relationships between global and regional change events?
3. Where is life supporting environment now standing?
4. How do we distinguish the impact of human activities on environment from natural variation and how strong are the human activities?
5. What are the earlier significant global change signals and how to monitor and detect them?
6. How do the water body, vegetation, and soil respond to climatic change?

And finally, we would like to point out that more attention should be paid to the study of theory of environmental change, such as predictability of global change, conceptual model, modelling of past global change, numerical description of key interactive processes, new theory of model development, etc.. In doing so we believe that great progress then could be made.

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