

New Challenge of Global Change

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We briefly review the development of global change research program in the last decade, introduce the new structure of global change in the next decade, discusses the opportunities and challenges for China, and gives some suggestion on the supporting fields during the Tenth Five-Year Plan Period from 2001 to 2005.

Key words global change, human-living environment, social sustainable development

In the evolution of the earth, natural factors construct the primary environment where human being has been living. Nowadays, the environmental change has its unique and challenging characteristics, not only owing to its own procedure change in range and magnitude, but also for the human being's interference capacity by conscious or unconscious means. The use of fossil fuel has caused the increment of atmospheric greenhouse gases concentration, which can greatly change climate, agriculture, forestry, and other land-use activities. With the addition of industrial activities, rubbish disposal, and transposition activities, this has changed land ecosystem and coast ecosystem, and then affected bio-productivity, water resource, and global atmospheric chemistry. Some other fundamental environmental changes, e.g. the decrease of stratospheric ozone and the acid deposition, are beyond the traditional subject classification, and the caused potential damages are far exceeding the boundaries of one country. How to forecast and respond to this rapid change of global environmental mainly depends on our capacity of observing and understanding on the processes of the earth system. Aim to reply for this challenge, ICSU (the International Council of Scientific Union) organized the IGBP (International Geosphere-Biosphere Programme), i.e. the research of global change.

At present, the economics of China is progressing

in a high speed. Some big projects, such as the Three Gorge Project, The Qinghai-Tibetan Railway Project, the South-North Water Transfer Project, etc., have drawn the world's attention. China is going to enter WTO, and Beijing will hold the 2008 Olympic Games. All of these bring severe challenges and also good opportunities to our living environment. How to improve our living environment and keep sustainable development in socioeconomic have become the hot-topics concerned by government and society. Therefore, it is important to review the past achievements and accomplishments in global change research, and image the future development and scientifically formulate the strategic plan in global change research areas.

1 Brief Review of International Global Change Research

Since ICSU proposed IGBP Program in 1990, the terms of "Global Change" or "Global Environmental Change" gradually has some specific content, which was scientifically defined as the change of global environmental system, including interactive physical, chemical, and biological processes among atmosphere, hydrosphere, biosphere and geosphere as well as the interactive processes between human being and environment. Global change, being a new systematic science undergone establishment, development, and comprehensiveness courses in the past decade, has become an integrated system in the end of the twenty century, which was mainly related to four programmes^[1], viz., IGBP (International Geosphere-Biosphere Programme), WCRP (World Climate Research Programme), IHDP (International Human Dimensions Programme on Global Environmental Change), and DIVERSITAS (Ecological Diversity Program). Each of these four programmes comprises of several core projects or sub-programs. For example, IGBP has eight

core projects and three framework activities. Considering of all of the sub-programs in other three programs, global change has become a super international programme, which involves multidisciplinary and the fields from natural science to social science. Although many countries have made great efforts to conduct programs and have made great achievements^[2], it was gradually realized by international sciences community that the focus should be on some limited aims, rather than unlimited spread to a big area, with the agreement to adjust research directions, and strengthen the collaboration among each programs. The specific actions are as follows:

(1) The Earth should be considered as an integrated system, i.e. to take atmosphere, hydrosphere, geosphere and biosphere as a whole. This coupled system is composed of interactive processes among spheres in physical, chemical, and biologic processes, and the human being should be considered as a main driving force. More attention should be paid on the study of environmental impact on human activity and social economic adaptation to the global change.

(2) The depth and scope of multidisciplinary should be enhanced. The cooperation among IGBP, WCRP, and IHDP should be strengthened, and coupled model describing physical, chemical, and biologic processes should be developed. Joint-operation between core projects should be organized, such as Joint-operation in CO₂ between WOCE (World Ocean Circulation Experiment) and JGOFS (Joint Global Ocean Flux Study), Joint-operation in water between GEWEX (Global Energy and Water Cycle Experiment) and BAHC (Biospheric Aspects of Hydrological Cycle), and cross-operation between CLIVAR (Climate Variability and Predictability) and PAGES (Past Global Change), etc.

(3) The combination of global and regional research is more explicit. Global environmental change research should aim at regional study, and the regional study should embody global study. So, more attention should be drawn to the regional response to global change. Asia is going to become strategic keystone of global change studying, since Asian accounts for more than 60% of the world's population, more than 50% of the world's fertilizer, more than 60% of the world's dams, and 5 of the 10 biggest river carrying sand in the world. Asia will become focus of the global change studying, especially because of the sustained develop-

ment of Chinese economics.

(4) Develop new method for synthesis^[3]. According to IGBP, synthesis is to integrate the different or opposite idea, mass or individual action, diverse element and force into a unified or balanced action, so as to reach an explicit goal (especially to get a theory system from diverse or opposite idea and view). One aim of this is to develop new hypotheses and theories for the fundamental issues of earth system based on current scientific research achievements, and another is to provide decision-maker available knowledge by multi-subject synthesis studying on a series of practical problems concerning human social sustainable development.

(5) Global change study should combine with sustainable development of environment, and supply scientific support and evidence for sustainable development^[4]. In the future, social sustainable development must combine organically with environmental change. The sustainable development is a rule which guide human to adapt global change, and this adaptation must consistent with sustainable development. Therefore, the adaptable study of global change would become one of the emphasis studies in international global change in the near future.

2 Simulating Role of NSFC to the Global Change Research

Global change research has been supported and promoted by NSFC since its founding in 1986. The course can be briefly divided into three stages^[5], viz., the Seventh Five-Year Plan during 1986—1990, the Eighth Five-Year Plan during 1991—1995 and the Ninth five-Year Plan during 1996—2000. Early in 1989, global change had already been chosen as an encouraged research area by several divisions in the Department of Earth Sciences of NSFC. Since 1989 this area was appointed as a special field and persistently supported through the three layers of Programs, i.e., the major program, the key program and the general program. In accordance with statistics^[6], from 1986 to 1995, NSFC had funded the following research projects related to the global change: 233 projects of general programs with a grant of over 17 million yuan RAM; 7 major programs with a grant of almost 13.7 million yuan in the Seventh Five-Year Plan period; and 13 key programs with about 9.37 million yuan and 6 major programs with 15.3 million yuan in the period of the Eighth

Five-Year Plan. The total sum of the above mentioned grant amounted to more than 55 million yuan, which accounted for 4% of the total financial aid of NSFC in the said period of time.

With the encouragement for multidisciplinary research in the Ninth-Five Year period, Global Change research was appointed as priority areas^[7], and related policies were established to assure it by NSFC, accompanying with added financial support. There are 170 general programs with 25.3 millions yuan, 48 key programs with 51.6 millions yuan and 9 major programs with 43.9 millions yuan in the Ninth-Five Year; the portion for this areas was twice of the total 10 years before with total 120 millions yuan. The supported research areas spread from climate system and sea level change of 1986 to paleoenvironment, land ecological system, biospheric aspect to the hydrological cycle, global atmospheric chemistry, global ocean flux, global water and energy cycle experiment, global climate variability and predictability, and the ocean ecological system dynamics etc. This big programs finally got many world-known scientific results, e.g. the NECT (Northeast China Transect) and NSTEC (North-South Transect of Eastern China) plan seem to be the hot topic and frontier in IGBP terrestrial ecosystem research, and then become a part of ecosystem transect plan of international global change. In the paleo-environment research area, relying on loess, ice core, Karst, lake and deep-ocean sediments tree rings and historical literature and so on, Chinese scientists have tried to find and reconstruct the paleoclimate series with the time scale from century, ten century until hundred century, and gradually initiate this area to be the PEP II (Pole-Equator-Pole) Program and ODP (Ocean Drilling Program) conducting ODP Leg 184 in South China and play the most important role in this research areas. Speak to the Chinese and global climate change in 20 century, Chinese scientists set up the 120-year historical temperature and precipitation data series in China and sea level pressure patterns as well as the patterns of 500-hp height anomaly in northern hemisphere. This is of great theoretical and practical importance for climate diagnosis and prediction research. The Chinese scientists as the pioneers conduct the research on ocean flux at continental margin in the world, and supply the important scientific evidence for the role of continental shelf in global carbon circulation. Also the Chinese scientist firstly find the ozone lower-value area over the Qinghai-Tibet Plateau, which provides new evi-

dence for global ozone dissipation. The major project Bohai Sea Ecosystem Dynamics and Biological Resources Sustainable Utilization initiated in 1996 actually was the first GLOBEC (Global Ocean Ecosystem Dynamics) in the national level, which then was spread to National Key Basic Research Development Planning in 1999 titled East and Huanghai Sea Ecosystem Dynamics and Biological Resources Sustainable Utilization, promoting this important research area in China be a advanced section in the world. The Chinese scientists have changed the situation from actively joint the international cooperation to as a leader to organize the international programs, and have given much contribution to the international Global Change research.

3 The New Structure of Global Change Research^[8]

Based on the achievements in the past decade, global change research would reach a new stage in the coming 10 years, with the goals to comprehensively and deeply understand the behaviors of the whole earth system. Therefore, IGBP has adjusted its former limited core programs, and initiated more systematic studies on the main components of earth system, including ocean, land, atmosphere and the interaction of them. Accordingly, strengthen the closely collaboration among IGBP, IHDP and WCRP by consideration both the frontier of earth system science and the sustainable development. As the first step, three joint projects have been organized, known as Global Carbon Cycle, Global Environment Change and Food System (GECAFS) and Water Resources. Therefore, the new structure of Global Change consists of nine core research elements (atmosphere, land and oceans, and the three interfaces between them with studies of the past, Earth System analysis and modelling) and the three IGBP-IHDP-WCRP joint projects. The emphasis and research content of each respective component are listed as following:

(1) **Atmosphere** The atmosphere transforms and transports a wide range of substances, and thus plays a key role in the biogeochemistry of the Earth System. Over the past decade, the International Global Atmospheric Chemistry (IGAC) Core Project has made significant advances in our understanding of the exchange of gases between the land and ocean surfaces and the atmosphere, the formation and fate of aerosols, and the production and reactivity of oxidizing gases. Further

challenges lie ahead. How does the atmospheric chemical system interact with the physical climate system to influence and change climate? What is the relationship between regional air quality and global atmospheric chemistry? What will be the effect on the global atmosphere of the rapidly growing mega-cities in the tropics?

(2)**Land** Nearly 50% of the land surface has been significantly transformed by human action, with major consequences for biodiversity, nutrient cycling, soil structure and climate. The Land Use and Land Cover Change (LUCC) Core Project, jointly sponsored by I-HDP and IGBP, focuses on the changing land surface, how we are transforming it and how it is impacted by global change. The Global Change and Terrestrial Ecosystems (GCTE) Core Project has built an impressive base of knowledge on the functioning of land systems in the face of a rapidly changing environment, and the implications of this for the Earth System. But more remains to be understood. Together, GCTE and LUCC must answer some fundamental questions. How does the changing structure of the land surface affect Earth's fundamental cycles? How is the capacity of ecosystems to provide goods and services affected by global change and human use? How do changes in Earth System functioning affect the vulnerability of human societies?

(3)**Ocean** The ocean constitutes the largest portion of the Earth's surface and it inextricably involved in the physical, chemical, and biological processes that regulate the Earth System. We now know much more about the role of marine life in controlling key Earth System fluxes from the results of the Joint Global Ocean Flux Study (JGOFS). The Global Ocean Ecosystem Dynamics (GLOBEC) Core Project studies how global change affect the structure and productivity of marine ecosystems. But what is the feedback from changes in the ocean to the global environment? What are the implications for fisheries? How are materials, especially carbon compounds, transported to and stored in the deep ocean? What are the key physical, chemical and biological processes that link the oceans to the continental margins?

(4)**Land -Atmosphere** The key considerations for research at the land-atmosphere interface in the new IGBP structure include: (i) Integration of water and energy exchange with biogeochemical processes - trace gas emission and uptake. (ii) Close integration of research with the terrestrial compartment in the new IGBP structure on fundamental processes, which control ex-

change of materials and energy between land and atmosphere. (iii) Broad-based approaches to the scaling issue-integrating processes at the appropriate scale, from patches to landscape to region, and up- and down-scaling these to the atmosphere. (iv) Close linkage with the human dimensions community to understand the role of human modification of land cover in modulating exchange processes between land and atmosphere.

(5)**Ocean-Atmosphere** An important feature of planetary functioning is the movement of materials and energy between the oceans and the atmosphere. However, these processes are still relatively poorly understood or quantified. The Surface Ocean-Lower Atmosphere Study (SOLAS) is a new core project sponsored by IGBP and the Scientific Committee on Oceanic Research (SCOR), to carry out research at the interface between the oceans and the atmosphere. It has as its goal: to achieve quantitative understanding of the key biogeochemical-physical interactions and feedback between the ocean and the atmosphere, and how this coupled system affects and is affected by climate and environmental change.

(6)**Land-Ocean** A rapidly growing proportion of the world's population lives in the coastal zone, with enormous impacts on this narrow but valuable strip. The LOICZ (Land-Ocean Interactions in the Coastal Zone) has developed scientific knowledge and tools that address global change in the coastal zone, focusing on material flux and human dimensions at regional and global scales. For LOICZ purposes, the coastal zone incorporates the domain extending from river catchments through the land-sea interface and coastal shelf, to the shelf margins. Globally LOICZ has established regional coastal projects addressing natural and socio-economic knowledge and tools development for material flux from river catchments to the coastal shelf.

(7)**Global Analysis, Integration and Modelling (GAIM)** GAIM approached its task by focusing initially on the global carbon cycle as a fundamental Earth System Cycle, and undertook a number of activities to build our understanding of carbon dynamics from components to the whole system. This decade-long effort has achieved impressive results, providing both the foundation for the carbon joint project and building the platform for the second-generation GAIM Task Force.

(8)**Palaeosciences- PAGES** In the next ten years IGBP will work within a more systematic structure with major activities located in the three compartments-at-

mosphere, oceans and land - and in the three interfaces between them. PAGES research helps to integrate the programme by providing a longer time context for the dynamics of the Earth System as a whole, as well as for parts of it.

(9) **Water Resources** Increasing water scarcity and water quality degradation are phenomena affecting human livelihoods and environmental integrity in many regions of the world. It is increasingly recognized that these complex problems can only be tackled effectively by integrating biophysical and socioeconomic understanding.

(10) **Global Carbon Cycle** The specific objectives of the Global Carbon Cycle are: (i) to develop a comprehensive understanding of the anthropogenic processes and driving forces within the overall functioning of the carbon cycle at global and regional scales; (ii) to understand human responses to changes in the carbon cycle that will facilitate development of scenarios for the future evolution of the carbon cycle; (iii) to understand and predict the impacts of changes in the carbon cycle on individuals and societal groups.

(11) **Global Environmental Change and Food Systems (GECAFS)** The goal of GECAFS is to determine strategies to cope with the impacts of global environmental change on food provision systems, and to analyze the environmental and societal consequences of adaptation.

4 Supporting Direction of Global Change in the Tenth Five-Year Plan Period

It seems that the achievement of Global Change research has become one of the important symbols to show the nation's whole scientific levels. In this situation, the Tenth Five-Year Plan of NSFC should keep some important rule to guide the global change research. The strategy should insist on sustainable development policy and associate population growth, resource exploitation, ecological construction, environmental protection with economic growth, efficiently make use of our predominance in both scientific advantage and unique geophysical terrain. According to the strategy of global change in China of the Tenth Five-Year Plan, NSFC should choose some key scientific issues as the priority areas which may improve the whole regional environment, organize a series of programs, try to reveal the response and effect of China to

global change, analyze natural and human factors in environmental change, and provide scientific evidence for developing policy of the representative region in the background of global change.

4.1 The strategic objectives

In 1996, based on the strategy of NSFC, the Department of Earth Sciences coordinated with the Department of Life Sciences and Chemical Sciences, choose global change research as priority areas, meanwhile set up a expert group of global change and draw out the specific detailed plan. After one year and a half, the report of global change, The Opportunity and Challenge for China was completed^[1]. The strategic goal of global change study in China was clearly appointed in the report as following:

(1) Recognize and identify the impact of both natural factor and human activity on global change, study the interaction between natural factor and human being, and enhance understanding of effect of natural factor and human activity to Global Change.

(2) Analyze the influence of global change to our environment, society, economics, and human health, and give scientific evaluation about global environmental change.

(3) Predict future environmental change of China and its impact on the global change, and try to make involvement of natural environmental benefit to human beings.

(4) Provide credible scientific basis for solving environmental problems China faced.

The report seems still accordant with development of current global change research and goals emphasizing the human activity to affect on global environment and its adaptability. The aim was use to serve social and economic sustainable development of our country and people's health, and provide the scientific evidence for our environmental policy decision. Therefore, the report plays important role in providing scientific basis for drawing up global change research in the new century, and also helpful to guide the program support in the Tenth Five-Year Plan in NSFC.

4.2 Priority fields

Based on above strategy, NSFC takes The Regional Response for Global Change as the priority areas in the Tenth Five-Year Plan^[9], and then decide the specific research content enclosed in the plan. According to

achievements and accomplishments in the past 15 years around global change study in China, and the strategy of global change of the national Key Basic Research and Development Planning of the Ministry of Science and Technology in the Tenth Five-Year Plan^[10], the priority for supporting areas concerning with the global change plan in China were worked out as following:

The impact and adaptability research of global environmental change on China;

The impact of human activities on East Asia regional environment change;

Interaction between the spheres of East Asia climate system, and climate prediction;

The formation and evolution, environmental catastrophe and ecological processes of Qinghai-Tibet Plateau;

The Arctic and Antarctic response and impact on global change;

The impact of biosphere on water cycle and evaluating theory and method of water resource;

East Asia hydrological cycle and global change;

The carbon cycle of Chinese land and ocean system;

The response and adaptation mechanism of land ecosystem to global change;

The study of Chinese ecologic environment degeneration and recovery mechanisms;

Land-ocean interaction and coastal zone environment;

Ecosystem dynamics and biodiversity research in China coastal sea;

The rule of ocean environment evolution and sustainable utilization of resource in South China Sea;

The interaction between Pacific-Indian warm pool and the ocean circulation system;

Coastal ocean environmental variation and its re-

sponse to global change;

The relationship between China Sea level variation and global change;

The mechanisms of environmental quality change in inshore areas of southeast China and the environment adjusting strategy in this high-developed area;

The formation mechanism, effecting factors, and control strategy for regional complex atmosphere pollution around the cities.

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