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Research Project Entitled "The Dynamics and Physical Processes in The Weather and Climate System" —Part I: A Brief Introduction

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ABSTRACT

In the beginning of the 21st century, the Tenth Five-Year Priority Research Projects of the Earth Sciences of the National Natural Science Foundation of China (NSFC) were initiated. After nearly a two-year long process to prepare, the first version of six Priority Research Projects of Earth Sciences was published in October 2001 by NSFC, viz., Local Response to Global Changes, Life Process and Environment, Dynamics and Physical Processes in the Weather and Climate System, Continental Dynamics, Regional Sustainable Development, Solar-Terrestrial Environment and Space Weather. The process involved more than 200 renowned Chinese scientists and many departments and agencies in China. The six Priority Research Projects guide the research effort of the earth sciences for the NSFC from year 2001 to 2005. This paper provides a brief introduction to the Third Priority Research Project of the Department of Earth Sciences of NSFC—-Dynamics and Physical Processes in the Weather and Climate System (DPWCS).

Key words: introduction, priority research project, weather and climate

1. Introduction

Human activities including social and economic developments, are closely related to the change of the weather and climate system. Since the beginning of time, weather and climate, which are the general terms for the entire range of phenomena and processes taking place in the atmosphere, are the most basic environmental elements of survival human beings have faced. Thus, the main body of atmospheric science research is always related to weather and climate.

Although the weather and climate phenomena mainly occur in the lower and middle layers of the atmosphere, there are many other elements that can change the weather and climate. These elements include the different spheres of the whole earth system and the main process of the terrestrial-solar system, i.e., Atmosphere, Ocean, cryosphere, Biosphere (such as soil and vegetation), as well as solar activity, etc.

Atmospheric science research involves thermodynamics, dynamics, physical and chemical processes, and even biological processes in the atmosphere. With the continuous development of our society, human activities have an increasing effect on all the above processes and are becoming an important element in these processes related to weather and climate change.

Each year, China experiences economic losses as high as 200 Billion RMB, which are directly caused by severe weather and climate events. These losses account for 2.5% of China's total GNP (Gross National Product). It is considered that the global climate change with the warming tendency could bring about even more serious regional severe weather and climate disasters in China. However, the weather and climate forecasts in China are not as accurate as expected and cannot satisfy the demands of the public or our societal development.

There are many fundamental scientific problems that need to be deeply investigated and researched. Weather and climate dynamic and physical processes have caught the particular attention of scientists all over the world. The need to engage in such research has also been listed as one of the priorities mandated by the Department of Earth Sciences of the NSFC dur-

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ing the Tenth Five-Year Period, named, Dynamics and Physical Processes in the Weather and Climate System (DPWCS). The execution of this project is particularly imperative to advance sustainable development of the national economy and also the development of the western region of China.

The main objective of DPWCS is to study the different kinds of weather and climatic systems in the atmosphere, their changes and interactions, including the physical mechanisms in terms of the dimensions of time and space. It not only includes the weather and climate systems in the troposphere, but also the processes taking place on the top of the troposphere and on the surface of the Earth as the lower boundary of the atmosphere. Due to the complexity of the weather and climate processes, which involve interactions of different kinds of spheres, the project calls for both disciplinary and interdisciplinary proposals on the basis of open solicitations by the Department of Earth Sciences of NSFC in each year during the Tenth Five-Year Period.

2. Scientific goals of DPWCS

The goals of DPWCS are to realize and investigate the spatial-temporal characteristics, interactions, behaviors, and mechanisms of all scales of weather and climate processes (dynamic, physical, chemical, and biological processes) that occur in the middle and high atmosphere and on the land surface, that influence the weather and climate change, as well as the development of Atmosphere-Ocean-Land coupled climate system models.

The project mainly focuses on four aspects:

(1) Climate change and predictability;

(2) Severe weather dynamics and processes;

(3) Energy and mass transportation in the atmospheric boundary layer; and

(4) Interaction between the troposphere and stratosphere and their climatic and environmental effects.

2.1 *Climate change and predictability*

The scientific goal of this aspect is to realize the variety of the physical processes, the characteristics, and the mechanisms of the atmosphere-ocean-land coupled climate system, to reveal the mechanics of seasonal, annual, and inter-decadal scale climate anomalies, and to research the seasonal and annual climate prediction.

Considering the regional characteristics of China, the goal includes the following:

(1) Interactions of atmospheric circulations in different latitudinal regions and the complexity of ENSO-Monsoon relationships;

(2) The effects of snow cover, sea ice, and soil moisture and temperature on the East Asian regional climate change;

(3) The physical and chemical processes of atmospheric compositionaerosol cloud and their radiative and climatic effects; and

(4) Global atmosphere-ocean-land coupled climate system models and climate predictability.

2.2 *Severe weather dynamics and processes*

The scientific goal of this aspect is to understand the process, structure, formation, and evolution of the severe weather that occurs in China, and to conduct research on forecasting theory and technology through enhancing the analysis of severe weather physical processes and numerical simulation. Furthermore, the aspect also aims to promote the research and forecasting levels of severe weather disasters in China.

The goal includes the following:

(1) The dynamic processes of the structure, formation, and evolution of severe weather systems and forecasting theory;

(2) The physical processes, parameterization, and model development for weather systems; and

(3) The scientific principles and methods for weather modification.

2.3 *Energy and mass transportation in the atmospheric boundary layer*

The goal of this aspect is to reveal the characteristics of energy and mass transportation in the interacting soil-vegetation-atmosphere interfaces, and to realize the mechanism of the interaction between the atmospheric boundary layer and free atmosphere in some representative climatic regions and atmospheric conditions in China by means of field observation, theory, and numerical simulation. In addition, this goal entails the launching of research into the parameterization and upscaling and downscaling methods of energy and mass transportation in different surface types, and finally to supply reliable parameters and the solid scientific basis for parameterization of different weather and climate system models.

The goal includes the following:

(1) Exchange process of energy and mass between the ground surface and the atmosphere for some typical surface conditions and climatic regions in China; and

(2) Parameterization of the different kinds of landscape sub-grid scale heterogeneities and scale transferring technology, including upscaling and downscaling.

2.4 *Interaction between the troposphere and stratosphere and their climatic and environmental effects*

By mean of field and radar observation, remote sensing, data analysis, and dynamic physical chemical model simulation as well as theory, the scientific goal of this aspect is to understand the principle of

the dynamic physical chemical process of Stratosphere Troposphere and Exchange (STE). The goal is also to deeply understand the physical and chemical processes of the tropopause in East Asian middle latitude regions, and the mechanism of different scales and processes of STE affecting or controlling the global or semi-sphere STE. Furthermore, such research will assist scientists to better understand the stratospheric process, its long term change, and its impacts on the weather and climate change in the troposphere, especially to understand the affect of the stratospheric process and ozonosphere environmental change as the indicators of important weather and climate events. Finally, such research will assist scientists to understand the physical climate characteristics and the top boundary layer radiation and microphysical chemical process of the tropopause, to understand the processes of the tropopause, stratopause, and mesopause, and to establish the physical foundation for the development of whole atmospheric circulation models.

The goal includes the following:

(1) Multi-scale processes of STE and their effect on weather and climate; and

(2) The variation and interaction of tropopause, stratosphere, and mesosphere and the development of whole atmospheric circulation models.

In order to assure the successful accomplishment of the goals, it is necessary to strengthen the research into new theories, methods, and technology to probe the atmosphere, which includes researching new sensors, platforms, satellite and radar retrieving technologies, as well as their application in the coming several years.

3. Core scientific contents

3.1 *Climate change and predictability*

3.1.1 *Interactions of atmospheric circulations in different latitudinal regions and the complexity of ENSO-Monsoon relationships*

Chinese scholars have found that the winter cold waves in the Northern Hemisphere can cross the Equator and affect the climate in the Southern Hemisphere and vice versa. How do the atmospheric circulations from the hemispheres actually interact? And how do the summer and winter circulations convert into one another? What kind of role do the monsoon systems play in the interaction between the two hemispheres′ circulations? As to the relationship between ENSO and monsoon, there has been evidence showing that the relationship between the East Asia Monsoon and ENSO changes from year to year. This presents meteorologists with new challenges in understanding East Asian climate changes. The answers are the fundamental basis in understanding the predictability of the East Asian climate system.

Research focuses in the Tenth Five-Year Period:

(1) The multi-temporal scale physical processes and mechanisms of the Asian monsoon systems and numerical simulation;

(2) The implication of the ENSO-Monsoon relationship;

(3) The interaction between the ocean surface and the lower atmospheric layer and the effect of the two on the monsoon anomaly; and

(4) The physical processes of the summer and winter circulation conversion in both hemispheres.

3.1.2 *The effects of the snow cover, sea ice, and soil moisture and temperature on the East Asia regional climate change*

Research has shown the possibility that the snow cover on the Tibetan Plateau, sea ice in the northern polar region, and the soil temperature and moisture and their anomalies have significant effects on the regional climate change in East Asia. Nonetheless, nothing conclusive has been determined by this research. Thus, it is especially crucial to determine how to take these effects into consideration in short term climate forecast models under the fact of the shortage of up-to-date datasets of snow cover, soil temperature, and moisture.

Research focuses in the Tenth Five-Year Period:

(1) Collect and edit the snow cover and soil condition data of the Tibetan Plateau and estimate their effects on East Asian short-term climate change;

(2) Prepare quantitative estimates of summer precipitation anomalies caused by anomalies of snow cover, sea ice, and soil conditions in China; and

(3) Initialize the above-mentioned surface conditions by using limited land cover datasets and regular meteorological data.

3.1.3 *The physical and chemical processes of atmospheric composition-aerosol-cloud and their radiative and climatic effects*

Aerosols in the atmosphere affect the radiation budget of both the earth surface and atmosphere through absorbing and reflecting the radiation energy from the Sun, which is called aerosol direct radiative forcing. Currently, there are many uncertainties in the estimates of direct climate forcing of aerosols. In addition, aerosol particles cause indirect climate forcing by affecting the cloud condensation nuclei and can change the optical characteristics of cloud. However, the indirect effect of aerosols is far from clear. Due to the limitation of meteorologists′ understanding of cloud radiation, the physical processes of clouds and their radiative characteristics are one of the most uncertain elements in current climate system research. Therefore, research on atmospheric composition-aerosol-clouds,

and their effect on East Asian regional climate change, needs to be strengthened through a series of observations and experiments.

Research focuses in the Tenth Five-Year Period:

(1) Observation and theoretical study of the micro- and macro- physical characteristics of clouds in East Asia;

(2) The physical and chemical processes, radiative characteristics, and their variation patterns of atmospheric composition and aerosols in East Asia;

(3) The interaction between aerosols and clouds in East Asia;

(4) The observing platforms and retrieval methods of atmospheric composition, clouds, and aerosols in East Asia; and

(5) Numerical simulation of cloud and aerosol radiative forcing, parameterization, and climate effects in East Asia.

3.1.4 *The global atmosphere-ocean-land coupled climate system models and climate predictability*

The new generation of climate system models is the integrator of climate research. On the other hand, climate system models are also the key and basic tool for future advanced climate system research and prediction. Special attention should be paid to both the framework of the model designs and the different parameterizations of physical and chemical processes in the model development. By doing so, new generation models with advanced simulation ability and high resolution for the East Asia climate system, and even for the globe, can be developed and then used to do climate prediction research.

Research focuses in the Tenth five-year Period:

(1) Development of an advanced land surface model, which is suitable for China, and its coupling into the atmospheric circulation models;

(2) Development of ocean-atmosphere coupled models, which mainly focus on ocean-atmosphere interactions near the seashores of China;

(3) Development of a coupled climate system model;

(4) Effects of ocean-land-atmosphere interactions in high and middle latitudes on the predictability of monsoon climate systems in East Asia; and

(5) ENSO prediction and initialization theory and system for summer climate forecast models.

3.2 *Severe weather dynamics and processes*

3.2.1 *The dynamic processes of the structure, formation, and evolution of severe weather systems and forecasting theory*

The heavy rainfall system is the most important weather system in the summer, especially the mesoscale weather systems associated with heavy and persistent rainfall and flooding. However, there are still many uncertainties about its formation, development, and evolution, and these directly limit the improvement of weather forecasting in China.

Research focuses in the Tenth Five-Year Period:

(1) The characteristics of the three dimensional structure, development, and evolution of heavy rainfall weather systems in China;

(2) The effects of boundary layer, underlying surface, and terrain on heavy rainfall weather systems; and

(3) The predictability and forecasting theory of severe weather systems in China.

3.2.2 *The physical processes, parameterization, and model development for severe weather systems*

Large-scale weather systems and other important physical processes, such as microphysical processes, influence the structure and evolution of synoptic and sub-synoptic weather systems. In addition, there are complicated interactions among these processes, which in turn influence the structure and evolution of mesoscale weather systems. Thus, the dynamic analysis, parameterization, and development of advanced mesoscale weather forecasting models with high accuracy and assimilation systems in East Asian Monsoon regions are of great importance.

Research focuses in the Tenth Five-Year Period:

(1) Physical processes and parameterization of cloud and precipitation;

(2) Meso-scale and micro-scale turbulence dynamics;

(3) New methods of terrain treatment and computational skill for the Tibetan Plateau;

(4) Development of high resolution numerical models based on new observing methods and computational platforms; and

(5) New scientific bases for data assimilation technology and its feasible operational schemes.

3.2.3 *The scientific principles and methods for weather modification*

Weather modification is to effectively modify the local weather by man's intervention. Precipitation stimulation, hail suppression, and fog clearing are effective methods of relieving drought and other weather disasters. In order to carry out more effectively local weather modification, the scientific principles and methods need to be further researched.

Research focuses in the Tenth Five-Year Period:

(1) Field observation and numerical simulation for the macro-structure of the cloud, fog, and precipitation, and their evolution;

(2) Technology of observation and recognition of clouds which are suitable for precipitation stimulation and hail suppression;

(3) Mechanisms and theory of weather modification;

(4) Mechanisms and high technology for warm cloud seeding;

(5) Application of cloud models in precipitation stimulation and hail suppression activities; and

(6) Scientific methods of weather modification validation.

3.3 *Energy and mass transportation in the atmospheric boundary layer*

3.3.1 *Exchange process of energy and mass between the ground surface and atmosphere for some typical surface conditions and climatic regions in China*

Weather and climate system change are closely related to the exchange processes of energy, mass, and water. The sea and land surface are the important interfaces for the exchange and re-distribution of these three elements. The atmospheric boundary layer is the channel between the ground surface and the free atmosphere. Due to the complexity of the interaction between the ground surface and the atmospheric boundary layer, field experiments and observational data analysis are still in the pioneering stages to promote our level of understanding.

Research focuses in the Tenth Five-Year Period:

(1) Field experimental research on the exchange process between the ground surface and atmosphere in some typical regions in China;

(2) The effect of atmospheric turbulence, convection, waves, and advection in the process of energy and mass exchange between the atmospheric boundary layer and free atmosphere; and

(3) Energy and mass exchange processes between the cloud-covered atmospheric boundary layer and the free atmosphere, and modeling.

3.3.2 *Parameterization of the different kinds of landscape sub-grid scale heterogeneities and scale transferring technology, including upscaling and downscaling*

There are still important unsolved questions regarding upscaling and downscaling due to the strong effect and adjustment of landscape heterogeneities, including terrain, surface condition, vegetation, and even the sea surface, on the exchange between the atmospheric boundary layer and free atmosphere.

Research focuses in the Tenth five-Year Period:

(1) Fundamental parameters and parameterization for soil-vegetation-atmosphere exchange processes in representative land surfaces in China;

(2) New theory and methods of upscaling and downscaling in land-atmosphere exchange parameterization; and

(3) New theory and methods for meso-scale flux measurement and calculation.

3.4 *Interaction between the troposphere and stratosphere and their climatic and environmental effects*

3.4.1 *Multi-scale processes of stratosphere and troposphere exchange and their effect on weather and climate*

Stratosphere and troposphere exchange (STE) is the crux of the interaction between the high and low atmosphere. The hemispheric Brewer-Dobson circulation was considered to be mainly driven by heat with the source from deep convection current in tropical areas. Researchers also found that the contribution from the different scales and patterns and seasonal distribution of the STE in middle latitudes outside of the tropical region cannot be ignored. Research already shows that the stratosphere has controlling and especially predictive effects on the troposphere's weather and climate. Thus, it is necessary to investigate the physical and dynamic processes of stratosphere and troposphere exchange.

Research focuses in the Tenth Five-Year Period:

(1) Comprehensive observation and numerical simulation of the STE effect in summer strong convection over extra-tropical zone, large terrain, and Tibetan Plateau;

(2) The effect of severe synoptic and climatic events of East Asia on the local and global STE; and

(3) The physical processes and dynamics of the stratosphere and the effects of stratospheric circulation on troposphere weather and climate change as the indicators; and

(4) Ozonosphere and ground surface UV-B climatology.

3.4.2 *The variation and interaction of tropopause, stratosphere, and mesosphere and the development of whole atmospheric circulation models*

Weather and climate occurring in the troposphere are affected by the atmosphere in the stratosphere and above, and vice versa. Further research of the sun and atmosphere, including interactions of troposphere, stratosphere, mesosphere, and the thermosphere, will be important to understand the weather and climate system not only in the lower atmosphere but also in the higher levels. However, there are many unknown aspects in this field.

Research focuses in the Tenth Five-Year Period:

(1) The fundamental physical problems of the formation and variation of the tropopause and its climatology;

(2) Parameterization of troposphere gravity waves and their propagation to the upper layers;

(3) Climatology of the middle layer atmosphere, including tropospause, stratosphere, mesosphere, and the coupling physical and dynamic processes of the lower and higher atmosphere; and

(4) The fundamental physical problems in establishing whole atmospheric circulation models.

4. Implementation and outreach

From 2002 to 2003, a total of 21 programs enclosed in DPWCS were supported with total funds of 25 900 000 RMB. The implementation and outreach of the DPWCS project will be introduced in Part II.

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