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PREFACE

The Chinese National Committee of IAHS is glad to provide the national report from 2007 to 2010 on hydrological science to the members of IUGG. The main developments in hydrological science contributed by Chinese Scientists in the past four years are included in this report. It involves the following aspects: hydrological cycle and surface water, groundwater, land erosion, snow and ice, water quality, water resources system, application of RS in the management of hydrology and water resources, soil-vegetation-atmosphere system in hydrological process, and application of isotope technique in the management and assessment of hydrology and water resources etc.

This report can be considered as a contribution and authoritative record of the developments about the active fields in 2007-2010. It is available for reference to the scientists and professors engaged in these fields. I would like to express my appreciations to the Chinese National Committee for IUGG for the guidance and supports during my preparing the report, also to the authors, such as YANG Dawen, LIU Zhiyu (Chapter 1), WU Xiaofeng (Chapter 2), FU Xudong (Chapter 3), YE Baisheng, LIU Shiyin (Chapter 4), ZHOU Huaidong, LI cong (Chapter 5), JIA Yangwen (Chapter 6), LU Jingxuan, PAN Shibing (Chapter 7), YANG Dawen, CONG Zhentao (Chapter 8), SONG Xianfang (Chapter 9) particularly to Mr. LIU Zhiyu and YANG Dawen, for their hard editing job.

Prof. ZHANG Jianyun

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CONTENTS

CHAPTER 1 ADVANCES IN RESEARCH ON HYDROLOGICAL CYCLE AND SURFACE WATER

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1.1 INTRODUCTION

The researches on water science in China have continued to make new advances since 2003, promoted by the two major causes: (1) Participating in the international cooperative scientific research programmes, such as the International Geosphere and Biosphere Programme (IGBP), World Climate Research Program (WCRP), International Hydrological Program (IHP), Global Energy and Water Balance Experiment (GEWEX) etc. These scientific programmes face the common challenges of the human, such as climate warning, sea-level rising, aggravating hydrological and meteorological disasters and deteriorating ecological habitat etc., aiming at protection of living environment and sustainable development of the human. To develop international cooperation researches, China actively participates in those research activities organized by such international scientific organizations, as IHP, IAHS etc. Many aspects of current international scientific cooperation are involved in these research fields, to which China makes own contributions. (2) Conducting research activities to solve the important challenges encountered in sustainable development of the country, for instance, flood and drought, water resources scarcity and water environmental deterioration etc. This article will describe the progress made in these aspects respectively. The reference materials of the article are mainly from 30 open-publishing domestic and oversea scientific journals involved with the water field, e.g. “Journal of Geographical Sciences”, “Acta Meteorolgica Sinica”, “Journal of Hydraulic Engineering”, “Advances in Water Science”, “Journal of Glaciology and Geocryology”, “Journal of Lake Sciences”, “Journal of Natural Resources”, “Advance in Earth Science” etc. The papers published in these journals in the past four years are reviewed. Simultaneously, the important national projects and project research reports of the Natural Scientific Foundation of China in the recent four years, such as “Study on ecological environmental change in the west China”, one of national key scientific and technological projects during the Tenth National 5-plan, also are referred to. However, we are very regret that some excellent results cannot be introduced into this article due to limitation of the length as well as obtained materials.

1.2 STUDY ON HYDROLOGICAL CYCLE

1.2.1 Study on Elements of Hydrological Cycle

1.2.1.1 Study on Precipitation

Some remarkable progresses in the study on precipitation are made in following several aspects in the last four years:

(1) Strengthening the study on macroscopic background of precipitation, i.e., exploring the physical climatic causes of generation and evolution of precipitation. Our meteorologists used the MM5 to simulate or predict the precipitation in some catchments in China, and made some analysis or improvement on the application (Liu et al. 2003, Guo et al. 2003).

Wei et al. (2004) reviewed the importance of applying the radar rainfall measurement to hydrology, analyses the key influence on the results of hydrological prediction and puts forward some proposals to improve its application to hydrology.

Using the method of the nonlinear cross-prediction error and the TBB (the cloud top black body temperature) nonlinear time series of data (GMS-5), Chen et al. computed and analyzed the characteristic of stationarity and nonstationarity of the extraordinary rain-storm in Wuhan. It is consistent with the variation trend of the actual rainfall (Chen et al., 2006).

(2) The inhomogeneous spatial and temporal distribution of precipitation has great influence on basin runoff.

Some study was done on the effects of spatial scale to runoff simulation, showed that using the distributed hydrological model based on the DEM saturation-excess runoff was sensitivity for the rainfall time and spatial variance (Wei et al., 2006).

The space-time variability of precipitation should be fully taken into consideration when the process of basin water cycle is simulated. A spatial interpolation method of daily precipitation in large-scale basin is introduced, according to the method, the reference rain gauges are selected with correlativity (Zhou et al., 2006).

A comparison was made on several spatial rainfall interpolation methods commonly used, and a new Co2Kriging method was put forward, taking the elevation information as an influencing factor of the second class. It showed that the new Co2Kriging method was obviously superior to the Thiessen polygon method and the reverse distance weighting method (Shi et al. 2005).

The uncertainty in the spatial interpolation of rainfall data caused mainly by the number of stations, temporal scale, cell size of interpolation grid and different interpolation methods was analyzed, and the results indicated the basic way to reduce the uncertainty in rainfall data is to introduce other relative variations with high sample density and to integrate them in present interpolation methods (Zhu et al., 2004).

Considering it is hard to collect the complete long series short duration precipitation data, a model of temporal downscaling of daily rain is presented, and the approach of temporal downscaling of daily rain to acquire short-term rain data in lack-data watershed is studied (Zhou et al., 2005).

1.2.1.2 Study on Runoff

In the aspect of study on the runoff, the great attention was given to the study on the transit curves in the 1960s to 1970s (such as study on Nash's hydrograph etc.) and to the study on hydrological models in the 1980s to middle 1990s. Since the next half of 1990s, studying response of river runoff to climate change, the effect of human activities on runoff and further on water resources, the runoff-generating mechanism in the northwest China, and the application of modern technology to the runoff computation etc is the emphasis during the period. In terms of study on response of river runoff to climate change, the study on possible change of runoff amount under various climate scenarios is mainly developed so as to expatiate the possible effect of climate changes on water resources.

In the last four years, Wang et al. pointed out the natural-artificial two-term evolvement theory of the annal runoff in terms of studying the influence of human activities on runoff generation, and applied the theory in the Wuding River basin (Wang et al. 2004). The effect of different factors on runoff was also studied, for example, Jia et al. studied the water the water budgets and spatial-temporal variations of hydrological cycle components in the Heihe river basin by using the distributed hydrological mode, and pointed out that the forest for water conservation made the runoff outcome from mountains slightly decreased (Jia et al., 2006).

In terms of the relationship of runoff and environment, Wang et al. did some research on the evaluation method for river s' water requirements of the instream environmental flow: based on the analysis of the relationship among environmental flows of river requirements, the efficiency of water resource utilization and the consumption coefficient, and discharge concentration of waste water, the water quantity and water quality calculation method of environmental flows of river requirements in dualistic water cycle is developed, and the criteria for environmental flows of river requirements are established (Wang et al., 2006).

1.2.1.3 Study on Evaporation

Different methods for evapotranspiration estimation were applied and compared in some basins.

Surface evapotranspiration has obvious spatial variability, but traditional measurement methods are based on point measurements. Remote sensing and the surface energy balance algorithm for land (SEBAL) model were developed to show the spatial variability of surface evapotranspiration. The remote sensing provides extensive surface information. The SEBAL model used the Landsat TM/ETM images as the main data source to calculate regional evapotranspiration. Liu et al. applied RS and SEBAL model to estimate evapotranspiration in arid regions, and improved the model by incorporating parameters for the specific study region. The example showed that the model can be applied extensively, especially in areas where data is scarce (Liu et al., 2004). Zhang et al. summarized and evaluated widely used models that were applied for predicting regional ET using satellite remotely sensed data and routine meteorological data, such as SEBAL and VITT, and showed the great prospect of quantitative ET retrieval with remotely sensed data at large scale (Zhang et al., 2006).In the ungauged Hulun Lake Basin, water evaporation was estimated by Penman-Monteith equation by using daily meteorological records at Manzhouli Station (Li et al., 2006).

Some research was done on the relationship between evaporation and agriculture. For example, Chen et al. analyzed the effects of different rowspaces on the soil evaporation and in winter wheat field (Chen et al., 2005).

Liu et al. estimated the evaporation rate from soil surface using stable isotopic composition of through fall and stream water in a tropical seasonal rain forest in Xishuangbanna, China (Liu et al., 2006).

1.2.2 Studies on Hydrological Cycle and Water Balance

Some research was done on the hydrological cycle in northwest areas in China, and the study of the global hydrological cycle is paid more attention.

Gao et al. analyze the character of water cycle in Inland River in Hexi Region: formation of water resources in mountain areas, scatter and disappear of water resources in plain areas and duality composition in artificial area (Gao et al., 2004).

Gao et al. studied the coupling of enhanced land surface hydrology with atmospheric mesoscale model, and analyzed its implement in Heihe river basin (Gao et al., 2006).

A dynamic hierarchical assessment methodology of water resources is put forward in this paper ,that is, according to the effective , controllable and renewable principle of water resources , the resources structure of precipitation is classified in order to realize the hierarchical assessment of water resources including general water resources , special water resources , water resources with runoff form and available water resources. The dualistic water resources assessment model combining distributed hydrological model with physical mechanism and centralized water resources allocation model is used. Furthermore, dynamic assessment of water resources is realized with changed underlying surface condition and water use condition (Wang et al., 2006).

The methods of deviation and accumulated difference and the Kendall’s rank verification were used to analyze the observed data of temperature and river runoff in the Hotan oasis in the second half of last century. It showed that the annual average temperature had a clear and gradual trend of increasing, which means it fell into a warming period. The evaporation changed in accordance with temperature. The rainfall varied dramatically from year to year and it distributed concentrative within one year. Some unusual rainfall events happened. The atmosphere humidity changed little, because water vapor would diffuse rapidly to the desert around. The river runoff had a distinct trend of decreasing due to human activity, such as water diversion for irrigation (Shen et al., 2003).

1.3 STUDY ON SURFACE WATER

1.3.1 Study on Potamology

In the last four years, concerning aspects of studying potamology research results are as follows:

Zhou et al study the abnormal characteristics analysis of groundwater temperature field in canyon areas. The groundwater temperature field shows some abnormal phenomena due to special topographic and geomorphic conditions and geologic characteristics in canyon areas. Taking groundwater temperature field in canyon areas at Xiluodu hydroplant as an example, the groundwater temperature field is analyzed systematically through the numerical simulation, the analogy and the regression analysis method (Zhou et al., 2003).

Chen et al do experimental study on development of river pattern in the process of river reformation. The changing of flow condition caused by construction of hydro projects will result in river reformation and development of river pattern downstream of the reservoir. In this paper, the development of river pattern in the process of reformation is studied by means of flume experiment and the influences of river slope, angle between main flow and thalweg, discharge and grain size of river bed material are analyzed according to the experimental data and theory (Chen et al., 2003).

Wang et al study the water & sediment load variation and development at longitudinal & transversal profiles of the lower Yellow River. The study on the drainage system in the North Slope of the eastern Kunlun Mountains indicates that the E-W trending basin-mountain geomorphology was formed after the Kunlun-Yellow River tectonic movement. This tectonic movement established the early stage of drainage system in which the main river developed along the E2W direction valley. Another important tectonic event, Gonghe tectonic movement, occurred between the Middle Pleistocene and Late Pleistocene, caused the N-S Direction Rivers to erode quickly southward and capture the drainage system of early stage, when the framework of present drainage pattern was also formed. Then, there was a relatively stable stage during Late Pleistocene. A sequence of thick and large 2-scale sediments of T5 aged between 52. 4 ka and 18. 4 ka deposited along most of the rivers during this stage. Since 18. 4 ka , the tectonic events in the area have been frequent but with limited intensity. Besides, five terraces were developed after 18. 4 ka. The later terraces were upper-overlapping the fifth terrace and did not cut through the deposits of the fifth terrace (Wang et al., 2003).

In the past 30 years, the lower Yellow River has been watching obvious variation in water and sediment load, which has caused the readjustment of longitudinal & transversal river bed profiles. This article studies the characteristics of the water & sediment load from 1960 to 1997 and the longitudinal & transversal bed profile from 1977 to 2002 by employing statistic analysis (Wang et al., 2006).

1.3.2 Study on Limnology

1.3.2.1 Study on lakes

Study on lakes is mainly on water environment. Yu et al study the evaluation of Oxygen Stable isotope Fractionation among Different Carbonate Minerals in the sediments of Lake Qinghai. Mineralogical examination and stable isotope analyses for the Lake Qinghai sediments indicate that authigenic carbonate minerals are present either in the form of one type or several types in the sediments, and those large differences in $\delta^{18}O$ of up to 6.5‰are shown for selected sediment samples. These $\delta^{18}O$ values are highly and positively correlated with total carbonate contents (TCC) and are not affected by shifts in carbonate mineral composition. This indicates that oxygen stable isotope fractionation among co-existing carbonate minerals formed in natural environmental conditions are limited to 0-1‰ in $\delta^{18}O$. The $\delta^{18}O$ proved to be a useful environmental proxy for the study of the past changes in P-E budget of closed-basin lakes (Yu et al., 2004).

The water environment has been tending to deterioration since 1990s, which promotes the study on lake water environment. Thereinto, these studies in the aspects of Lake Eutrophication, lake water chemistry, lake water movement and diffusion of pollutants etc have obtained better scientific results (Xie et al., 2004; Song et al., 2005; Wei et al., 2006). The studies on lake pollution, prediction and prevention as well as improvement will be sequentially taken as one of important topics in the field of lakes in China.

1.3.2.2 Study on marsh

The highly effective studies have been made in the aspects of ecological diversity in marsh and protection of marshes in China in the last four years and a significant exploration is also conducted in the study aspects of palaeoclimate and disposal of contaminative water in marches, using these marshes.

Tian et al investigated the ecological environment degradation and degradation mechanism of Napahai Karst Wetland in Southwestern Yunnan Plateau. Based on in-situ technique of locating experiment site, a two-year study on the degradation of Napahai Karst wetland, northwestern Yunnan Plateau was carried out. The results show that there are significantly ecological environment deteriorations that are destroying the wetland. Those deteriorations include wetland shrinking, type of marsh alternation, aridity and sandification, retrogressive ecological succession, mesophytes and xerophytes instead of helophytes, biodiversity decline, soil subsidence, water quality decline and soil enzymes activities changes. The causes of natural water drainage from limestone geological structure and human interferences like over pasture, wetland reclamation and cultivation are discussed, among which the human interferences are te main driving factor that degrade the ecological environment of Napahai Karst wetland (Tian et al., 2004).

Liang et al study the seasonal variation of Macrophytes Root-zone microorganisms and Purification Effect in the constructed wetland system. Constructed wetland systems are increasingly used to treat domestic sewage, industrial wastewater and agricultural runoff in recent years. The wetland treatment process has been gaining international interests and applications due to its low maintenance and operational cost, and high removal capacity. Because environment has significant effects on the purification ability of constructed wetland systems, it is very necessary to study purification effects of constructed wetland systems in different seasons (Liang et al., 2004).

Xiong et al study the distribute on soil nutrients and correlation analysis in Lake Liangzi wetlands, Hubei Province. The wetlands in Lake Liangzi in the middle reaches of Yangtse River were investigated in autumn, after late rice harvest in 2003. Five typical paddy soils were identified, i.e. submersed, bleached, gleyed and swamp paddy soils. Soil profiles as well as samples from different horizons were collected for measuring organic matter, TN,TP, TK and available N, P,K etc (Xiong et al., 2005).

Liu et al study the primary study on the rule of removing Phosphorus in simulated wetland. The rule of removing phosphorus in small-scale simulated wetland system has been studied. Considering the influence of the environmental factors as dissolved oxygen, pH, etc, we chose not only the aquatic plants, but also rooted emergent macrophyte as the experimental macrophytes. By contrasted four kinds of macrophyte systems, we found out that the absorbency and functionary mode of removing phosphorus by macrophytes are different (Liu et al., 2005).

These studies provide scientific foundation for protecting and utilizing marshes.

1.3.3 Study on Glacial Snow Cover and Permafrost

China is one of the countries where the mountainous glaciers are developed very much. In the recent years, the study on glacial snow cover and permafrost has made new progresses, driven by the climatic change and the western development.

Concerning aspects of studying glacier and climatic change, the representative research results are as follows:

(1) Yang et al study the response of the Climate records in the Guliya Ice Core to ENSO events. The period of ENSO is 2～10 a. In the lower and middle latitudes of the world, ENSO event is one of the very important factors for climate variation. Many scientists studied the impact of ENSO events on the climate in China. The studies of ENSO and precipitation variations in semi-arid regions in northern China showed that El Nino events corresponded with the deficit of precipitation in northern China and Southern Oscillation Index (SOI) significantly correlated with precipitation variations (Yang et al., 2003).

(2) He et al study the modern changes of the climate and glaciers in China's monsoonal temperate-glacier region. Climatic data, ice core records, the tree ring index and recorded glacier variations have been used to reconstruct a history of climatic and glacial changes in the monsoonal temperate-glacier region of southwestern China during the last 400 years. All the results indicate that the temperature in the region increased in a fluctuating manner during the 20th century, after the two cold stages of the Little Ice Age during the 17th-19th centuries, with a corresponding retreat of most of the glaciers against a background of global warming. However, the amount, trend and amplitude of variation of precipitation have differed in different parts of the region (He et al., 2003).

(3) Wei et al study the changes of glaciers and glacial lakes in the Pumqu Basin on RS and GIS. The glaciers are retreating year after year because of the global warming. As a result, the glacial lake outburst floods (GLOF) become frequent. So that more attention should be paid on them. But the study of glacial lakes with static and isolated means has not satisfied the need to monitor the glacial lake change. The basic data in this paper includes relief maps in 1970s and aster images in 2001 and 2002. The GIS tools are used to digitizing the spatial distribution of the glaciers and glacial lakes during these two periods. The results show that the glacier area decrease 9% and the glacial lake area increase 13%. Then 24 potential risk lakes are identified in Pumqu Bain. The results are vary important to monitor the GLOF and constructing an effective pre-alarm system of the GLOF hazards (Wei et al., 2004).

Zhou et al review the study on land surface process in soil freezing and thawing. Freezing soil is a natural phenomenon in cold and mountain areas, which has great impact on the regional climate, water cycle, and water balance. The land surface process in the condition of soil freezing and thawing is one of the most important processes in the area. This paper firstly reviews the present study on land surface process in the condition of soil freezing and thawing, especially the development after the hydrological land surface model introduced into the study of General Circulation Model, then introduces the undergoing international research project, such as Project for Inter-comparison of Land-surface Parameterization Schemes and Cold Land Process Field Experiment by NASA, and finally analyses and puts forward the future research field and topics (Zhou et al., 2005).

Implementing the western development strategy will need to construct many works, such as roads, bridges and culverts etc., in the high cold permafrost region of the western China. Many permafrost problems have been raised in foundation treatment of these works and safety operations after completed. Accordingly, these studies on engineering problems of permafrost are promoted, e.g. the investigation and mechanism analysis of the major secondary harmful frozen-soil phenomena along Qinghai-Tibet railway (Yu et al. 2005) is a current representative result.

Reference

[1] Liu Dong (2003), Performance Verification of Mesoscale Model MM5V3to Regional Climate Simulation, *Plateau Meteorology*, Vol. 22 No. 1, p71-77 (in Chinese).

[2] Guo Jianxia (2003), Numerical Simulation Tests of the Meso-scale System for the North of Shaanxi Province, *Meteorological Monthly*, Vol. 29 No. 9, p13-17 (in Chinese).

[3] Wei Linhong (2004), Application of radar rainfall measurement to hydrology, *Water Resources and Hydropower Engineering*, Vol. 35 No. 5 (in Chinese).

[4] Chen Gangyi (2006), A Research of The Cross-Prediction Error Of Weather Satelltiete TBB Data in the Rainstorm Prediction. Scientia Meteorologica Sinica, Vol. 26 No. 5, p553-557 (in Chinese).

[5] Wei Linhong (2006), Study on effects of spatial scale of rainfall to runoff simulation, *Journal of W ater Resou rces &W ater Engineering*, Vol. 17 No. 6, p19-23 (in Chinese).

[6] Zhou Zuhao(2006), Interpolating Precipitation in Space and Time in Large-Scale Basin Based on Rain Gauges, *Hydrology*, Vol. 26 No. 1, p6-11 (in Chinese).

[7] Shi Peng(2005), Comparison and improvement of spatial rainfall interpolation methods, Journal of Hehai University (Natural Sciences), Vol. 33 No. 4, p361-365 (in Chinese).

[8] Zhu Huiyi(2004), Uncertainty in the Spatial Interpolation of Rainfall Data, Progress In

Geography, Vol. 23 No. 2, p34-42 (in Chinese).
[9] Zhou Zuhao(2005), Temporal Downscaling Daily Precipitation in Lack-Data Watershed — A Case Study in Yellow River.
[10]Wang Hao (2004), The Natural-Artificial Two-Term Envolvement Theory and its Application in the Wuding River basin, *Science in China,Ser.E*, p42-48(in Chinese).
[11] Jia Yangwen (2006), Distributed model of hydrological cycle system in Heihe River basin Ⅱ.Applications, Journal of Hydraulic Engineering, Vol. 37 No. 6, p655-661 (in Chinese).
[12]Zhang Xiaotao (2006), Comparative analysis of regional evapotranspiration estimation models using remotely sensed data, *Transactions of the Chinese Society of Agricultural Engineering*, Vol. 22 No. 7, p6-13 (in Chinese).
[13]Liu Zhiwu(2004), Remote sensing and the SEBAL modelfor estimating evapotranspirationin arid regions, J Tsinghua Univ (Sci & Tech), Vol.44, No.3, p421-424(in Chinese).
[14]Li Chong(2006), Estimation of Water Evaporation and Water Balance in Ungauged Hulun Lake, *Journal of China Hydrology*, Vol.26, No.5, p41-44(in Chinese).
[15]Chen Suying (2006), Effects of different rowspaces on the soil evaporation and water use in winter wheat f ield, *Chinese Journal of Eco-Agriculture*, Vol.14, No.3, p86-89 (in Chinese).
[16]Liu Wenjie (2006), Estimation of evaporation rate from soil surface using stable isotopic composition of throughfall and stream water in a tropical seasonal rain forest in Xishuangbanna, China, Acta Ecologica Sinica, Vol.26, No.5, p1303-1311(in Chinese).
[17]Gao Qianzhao (2004), Analysis of water cycle in inland river basins in Hexi Region, Advances In Water Science, Vol.21, No.12, p1283-1292(in Chinese).
[18]Gao Yanhong (2006), Coupling of Enhanced Land Surface Hydrology with Atmospheric Mesoscale Model and Its Implement in Heihe River Basin, Advances in Earth Science, Vol.21, No.12, p1284-1292 (in Chinese).
[19]Wang Hao (2006), Theory and methodology of water resources assessment based on dualistic water cycle model, Journal of Hydraulic Engineering, Vol.37, No.12, p1496-1502 (in Chinese).
[20]Shen Bing (2003), Study on the water cycling characteristics of Hotan oasis during the second half of last century, Journal of Hydraulic Engineering, p78-83, (in Chinese).
[21]Zhou Zhi et al. (2003), abnormal characteristics analysis of groundwater temperature field in canyon areas, *Advances In Water Science*, No.1 (in Chinese).
[22]Chen Li et al. (2003), Experimental study on development of river pattern in the process of river reformation, *Journal of Hydraulic Engineering*, No.7 (in Chinese).

[23]Wang An et al., (2003), Characteristics of River Terraces in North Slope of Eastern Kunlun Mountains and Their Relationship with Plateau Uplift, *Earth Science-Journal of China University of Geosciences*, No.6 (in Chinese).

[24]Wang Zhaoyin et al. (2006), Water & sediment load variation and development at longitudinal & transversal profiles of the lower Yellow River, *Journal of Hydroelectric Engineering*, No.5 (in Chinese).

[25]Yu Junqing et al., (2004), Evaluation of Oxygen Stable isotope Fractionation among Different Carbonate Minerals in the Sediments of Lake Qinghai, *Journal of Lake Science*, No.3 (in Chinese).

[26]Xie Ping et al., (2004), A Lake Eutrophication Stochastic Assessment Method by Using Empirical Frequency Curve and Its Verification, *Journal of Lake Science*, No.4 (in Chinese).

[27]Song Yuzhi et al., (2005), Primary Estimation of Atmospheric Wet Deposition of Nitrogen to Aquatic Ecosystem of Lake Taihu, *Journal of Lake Science*, No.3 (in Chinese).

[28]WEI Haiying & CHAI Lihe, (2006), Non-linear dynamic characteristics of phosphorus cycle and eutrophication, *Journal of Lake Science*, No.6 (in Chinese).

[29]Tian Kun et al., (2004), The Ecological Environment Degradation and Degradation Mechanism of Napahai Karst Wetland in Southwestern Yunnan Plateau, *Journal of Lake Science*, No.1 (in Chinese).

[30]Liang Wei et al., (2004), Seasonal Variation of Macrophytes Root-zone Microorganisms and Purification Effect in the Constructed Wetland System, *Journal of Lake Science*, No.4 (in Chinese).

[31]Xiong Hanfeng et al., (2005), Distributi on Soil Nutrients and Correlation Analysis in Lake Liangzi Wetlands,Hubei Province, *Journal of Lake Science*, No.2 (in Chinese).

[32]Liu Laisheng et al., (2005), Primary Study on the Rule of Removing Phosphorus in Simulated Wetland, *Journal of Lake Science*, No.4 (in Chinese).

[33]Yang et al., (2003), The Response of the Climate Records in the Guliya Ice Core to ENSO Events, *Journal of Glaciology and Geocryology*, No.4 (in Chinese).

[34]He et al., (2003), Modern Changes of the Climate and Glaciers in China's Monsoonal Temperate-Glacier Region, *Acta Geographica Sinica*, No.4 (in Chinese).

[35]Wei Hong et al., (2004), Study on changes of glaciers and glacial lakes in the Pumqu Basin based on RS and GIS, *Journal of Lanzhou University (Natural Science Edition*, No.4 (in Chinese).

[36]Zhou Yuhua et al., (2005), Review of the study on land surface process in soil freezing and

thawing, *Advances in Water Science*, No.4 (in Chinese).

[37] Yu et al. (2005), the Investigation and Mechanism Analysis of the Major Secondary Harmful Frozen-Soil Phenomena along Qinghai-Tibet Railway, *Chinese Journal of Rock Mechanics and Engineering*, No.6 (in Chinese).

CHAPTER 2 RESEARCH ON GROUNDWATER EXPLOITATION, UTILIZATION AND ANALYSIS

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2.1 GROUNDWATER EXPLOITATION, UTILIZATION AND PROBLEMS

The groundwater is not only an important component of water resourcess but also the major water supply source in many cities and northern country areas of China. It plays an important role in guarantying the people’s life, promoting the economy development and improving the environment.

The mean annual amount of groundwater resourcess in China is 923.5 billion m^3, in which 883.7 billion m^3 is freshwater, this is about 1/3 of the total amount of water resourcess in China. The mean annual amount of the fresh groundwater that could be exploitated is 352.7 billion m^3.[1]

According to the occurrence of groundwater in subsurface, the groundwater resources in China can be divided into four types: pore water in friable rock, fissured water in bedrock, karst water and suprapermafrost water. Among them, pore water in friable rock plays an important role in the exploitation and utilization of groundwater resources. This part of groundwater is mainly distributed in the plains and the basins; its amount is the largest and is exploded and used widely. Fissured water in bedrock is mainly distributed in the fracture zone and weathering zone of bedrock or the pore of clastic rock. It is very difficult to form a concentrated water supply zone except a few developed areas of the bank water structure. Karst water mainly distributes in Karst region, in most of the karst region it is rich of groundwater and generally it’s the source of water supply.

Precipitation and surface water are the main recharge sources of groundwater. The distribution of groundwater is very uneven in China. The area of the Yellow River, the Huai River, the Hai River, the Songliao River in north and the Inland occupy 61 percent of the total area of China, however, the annual groundwater resources amount distributed in these areas is only 255.1 billion m^3, which is about 31 percent of the total groundwater resources amount of China. On the other hand, the area of the Changjiang River, Zhujiang River in south and some rivers in southeast and southwest occupies 39 percent of the total area of China, their annual average groundwater resources amount is 573.7 billion m^3, which occupies 69 percent of the total annual groundwater resources amount of China.[2]

2.1.1 Exploitation and Utilization of Groundwater

Compare to the other water resources, the groundwater has many advantages. Firstly, it has good quality because it is filtrated and cleaned in the unsaturated zone in the process of forming groundwater. Secondly, the investment of groundwater supply engineering is very little but the efficiency is very high.

It has a long history to exploit and use groundwater in China. However, large amount of groundwater exploitation happened in recent years. Before the mid of 1960's, the exploitation of the groundwater is relative little. From the mid of 1960's to the end of 1970's, it is the period of developing and utilizing groundwater in large scale in China. To the end of 1979, the total exploitation amount of groundwater in whole country reached 40 billion m^3. Since 1980, with the rapid development of national economy and the sharp increasing of water consumption the exploitation amount of groundwater has been up to 102.6 billion m^3 in 2004. [3]

According to the statistics, in 2004, the total amount of water supply in whole country is 554.8 billion m^3, among which 445.5 billion m^3 is from surface water sources, accounting for 82.1 percent of the total amount; while 102.6 billion m^3 is from groundwater sources, accounting for 18.5 percent; and 1.7 billion m^3 is from other water supply sources, accounting for 0.3%. Groundwater is very important water supply source in north part of China. In seven provinces Hebei, Beijing, Shanxi, Henan, Shandong, Liaoning, Neimenggu, the amount of groundwater supply occupies more than 50% of the total water supply amount. [4]

Up to now, nearly 400 cities in China develop groundwater as their water supply source. Accounting to the incompletely statistics, more than 60 cities regarded groundwater as their mainly water supply source, such as Shijiazhuang City, Taiyuan City, Hohehot City, Shenyang City, Jinan City, Haikou City, Xi'an City, Xining City, Yichuan City, Urumchi City, Lhasa City and so on. Other cities which regarded the groundwater and surface water as their water supply are as follow: Beijing City, Tianjin City, Dalian City, Harbin City, Nanjing City, Hangzhou City, Nanchang City, Qindao City, Zhengzhou City, Wuhan City, Chengdu City, Guiyang City, Kunmin City, Lanzhou City, Changchun City, Shanghai City and so on.

2.1.2 Problems in the Process of Developing Groundwater

The exploitation and utilization of the groundwater contributes a lot to the national economy development and increasing people's life level. On the other hand, because it is not controlled well the serious over exploitation in many regions caused many geological problems such as the groundwater depression continually, seawater intrusion, downward of salt-water interface, subsidence of land surface and desertification, etc. According to the statistics, more than 160 regions have the problem of over exploitation of groundwater up to now in China and the total area of over exploitation regions is about 180,000km^2, among which the area of severely over exploitation is up to 80,000km^2 occupies more than 40% of the total over exploitation area.

According to the publication of the administration, there are 24 provinces in China are facing the problem of groundwater over-exploitation, among them Hebei Province is the most serious one, where over-exploitation area has achieved 67,000 km^2, occupies 90% of its total plain area.

A series environmental and geological problem appeared because of the groundwater over-exploitation, which can be summarized as follows:

(a) Regional groundwater depression continually.

Because of the over-exploitation of the groundwater continually and with high intensity in some regions, the groundwater resources can't be recharged in time and the depression cones have been enlarged, which even leads to the draining of the aquifers, the reduction of the water yield in a single well or discard of the wells and the depletion of the water resources. For instance, in Xi'an City of Shanxi province, because of the over exploitation of groundwater for a long time, the depression cone has been enlarged every year. [5]

(b) Subsidence of land surface

The over-exploitation of the groundwater not only cause the water level declined, but also lead to land surface subsidence in some areas mainly with the deep groundwater exploitation. Yangtze River Delta, North China Plane and Fenhe-Weihe Down-Faulted Basin Belt is three biggest areas of the subsidence of land surface in China. Subsidence of land surface has been a critical obstacle which slowed economic growth in these areas; the main inducement is over exploitation of ground water. [6]

(c) Seawater Intrusion

Seawater intrusion is mainly occurred in the coastal regions of China. The reason is that after the large scale exploitation of the groundwater, arisen the seawater circumfluence. The relatively severe areas are Dalian City in Liaoning Province, Qinghuangdao City in Hebei Province, Qingdao City in Shangdong Province and some other areas.

(d) Ground collapse

The over-exploitation of the groundwater in bed rock region (mainly in Karst area) will lead to some bad geological phenomena such as ground collapse, fissure and so on. Ground collapse is occurred widely in China, in the southern China, the occurring rate is higher than the north because of the distribution of karst water.

(e) Pollution of Groundwater

Over-exploitation of the groundwater not only quickened the infiltration of surface water but also the pollutant in the surface water, which enhanced the groundwater contamination. Once the groundwater is been contaminated, it is very difficult to recover. Now the groundwater resources is polluted very severely in many cities. According to the statistics, there are more than 130 big and middle cities whose groundwater has been polluted in different degree and the main pollution source is industry and living pollution. The groundwater in local agricultural region is also been polluted, which is mainly caused by the sewage irrigation Up to now, there are over 20 million mu farms irrigated by sewage water, and this leads to the pollution of groundwater directly. Also in agricultural area, the groundwater is been threatened by the pollutants like the pesticide, the fertilizer etc..

(f) Soil desertification

The continuous decline of groundwater level will lead to the degeneration of vegetation and destroy the eco-environment, which is one reason of soil desertification. This phenomenon has occurred in Inner Mongolia, northwest of China and some parts of Heibei Province.

2.2 MONITORING AND MANAGEMENT OF GROUNDWATER

2.2.1 Groundwater Monitoring

The groundwater dynamic monitoring began from the 1960's in the departments of Ministry of Water Resourcess. After several years' hard work, a groundwater monitoring network with a certain scale which provides the evidence for water resources management and reasonable development and utilization of groundwater had been set up. The Monitoring items include groundwater level, water amount, water quality and water temperature and so on, which could collect, transmit store and analysis data at one time. Because of the promptitude, veracity, and scientificity, the Monitoring items have been used in several aspects instead of manual observation.[7]

A kind of new-type groundwater monitoring system has been developed to carry out the demand of remote observation of groundwater. The technique is based on PLC&GSM short massage data transmission. [8]

But the work of groundwater monitor is still weak and it's difficult to meet the demand of water resourcess management and regulation. Many problems are still existed including the sparse density of observation wells, lack of monitoring wells in the funnel area and important water sources, the old monitoring equipments, the laggard observation and transmission method which can’t ensure the information will be transmitted in time and insufficient fund for groundwater monitor.

Because basins in China have special water resourcess characteristic, and based on scarcity and pollution actuality of water resourcess in many basins, researching and developing a real-time monitoring and management system is necessary. The system includes several aspects, such as rectification and improvement of current groundwater monitoring stations, modulation and examination of reservoir operational rules and technical parameters, regulation of flood resourcess and recharge of groundwater artificial, waste water treatment and eco-environmental water demand, unified operation of flood control and useful storage, monitoring and management of surface water and groundwater and the benefit, risk and standardization after the real-time monitoring and management project bring into effect. [9]

2.2.2 Management of Groundwater

One side, water resources is seriously short in China and the over exploitation of groundwater leads to many environmental and geological disasters. On the other side, wasting of the water resources is very severe. Irrigation is the main water consumer, which occupies 70% of the total water consumption in China. Because the irrigation technology is out of date, most of the channels are soil channels and the facilities are very old, the traditional irrigation technology is used in most of the agricultural areas. In some irrigation areas farmers even still use the flooding irrigation method, which waste water very seriously. The utilization rate of industrial water consumption is not high either. The water loss through the water transportation pipe and water facilities has reached over 20 percent.

In order to develop and utilize groundwater more reasonably, reduce the water waste, optimize the distribution of water resources and improve the water utilization rate, in recent years a lot of work has been done on the groundwater planning and strengthening the legalization of groundwater management, which is useful for restricting the groundwater over exploitation.

Tianjin city integrated applied ArcGIS technique, Database technique, Model of water quality evaluation technique to develop its Groundwater environment quality evaluation system. The system has several functions, such as management and analysis of groundwater quality data and GIS data, integrated evaluation of groundwater quality and so on. This system can easily grip situation of dynamic pollution, special distribution, evolution tendency of groundwater. [10]

GIS technology and its application is the main focus in the development of water resources subject. Most of the developed countries have use this technique to manage their groundwater, and have got a lot of experience.[11]A groundwater resources management information system base on GIS technology has been developed.[12] The tendency and direction of groundwater management model is founded multi-purpose dynamic planning model for groundwater management. While, it needs advanced intelligent optimization approach to solute the problem. [13]

Water Resources Demonstration & Management Rules of the Construction Project shows us for the new, rebuilding or expand construction projects that takes water from the rivers, lakes and underground directly, the owner of the construction projects must apply the water license, and should carry out the water resources demonstration and compile the report.

Besides the technical measures, administration management is also important to control the scarcity situation of groundwater. Reinforce the management and supervision of groundwater is imperative under the situation. [14]

2.3 RESEARCH ON GROUNDWATER ANALYSIS

Strengthen the research on groundwater analysis is the basis of the scientific management of groundwater. Resent years a lot of work has been conducted on groundwater analysis, some details are given as follows:

2.3.1 Assessment of Groundwater

The first national water resourcess assessment was carried out at the beginning of 1980’s. During this period first national groundwater assessment were carried out, thid report provided important evidences for groundwater planning and management. But in the past 20 years, both of surface water and groundwater varied greatly because of human activities. Thus it is necessary to conduct the national water resources assessment again.

The Domenico model is used in combination with ASTM E 1739 in a Tier 2 risk assessment of chlorinated organic solvents contaminated groundwater sites to predict potential contaminant concentration in groundwater down-gradient from the point of exposure (POE). Knowledge of the dispersivity parameters is necessary for carrying out this calculation. A constant longitudinal dispersivity of 10 m is often used in analytical and numerical calculation. However, because of the scale effect of dispersion, two other main approaches are currently often used. From the viewpoint of conservative principle in risk assessment, it is necessary to determine which dispersivity data will give a higher predicted concentration, corresponding to a more conservative risk calculation. Generally, it is considered that a smaller dispersivity leads to a higher predicted concentration. This assumption is correct when dispersion is the only natural attenuation factor. However, degradation of commonly encountered chlorinated organic solvents in environment under natural condition has been widely reported. Calculations given in this paper of several representative cases show that a general consideration of the influence of dispersivity on concentration prediction is not always correct when a degradation term is included in the calculation. To give a conservative risk calculation, the scale effect of dispersion is considered. Calculations also show that the dispersivity parameters need to be determined by considering the POE distance from the source, the groundwater velocity, and the degradation rate of the contaminant. [15]

2.3.2 Prediction of Groundwater Dynamic Analysis

Many institutes and experts did a lot of work on the prediction of groundwater analysis. The prediction of groundwater level is important for the utilization and management of groundwater resources. At present there are many ways to do the dynamic prediction of groundwater level. The main method is to set up a model of groundwater movement and simulate the process of groundwater movement and predict the state. One groundwater dynamic prediction model is based on inversion models and self-memory formulation. Examples show that, this model is effective, and it also has satisfactory accuracy rate. [16][17] Another model use principle factor time as main factor of prediction model, and river course’s replenishment and precipitation as modifying factors, which makes the physics model easy to understand, problem easy to solve. [18] A new model of groundwater table simulation is developed using the mass-lumped finite element method and is coupled with the land surface model of Variable Infiltration Capacity (VIC). The simulation results show that the new model not only can simulate the groundwater table dynamically, but also can evade the choice of water table depth scale in computation with a low computation cost. [19]

According to the research of prediction models, there are two way to increase the reliability and accuracy of prediction of groundwater dynamic analysis. One way is to found affirmatory stochastic coupled model, which could describe both inner characteristic and outer characteristic; the other is to found groundwater system’s FBSDE model, and make the inner factor of the system as random variables, while it’s outer circumstance factor is also be treat as random time series to solve fixed solution problems, and the solution is showed as probability distribution. [20]

2.3.3 Analysis and assessment of groundwater pollution

In China groundwater pollution is quickly increasing every year because of the surface water pollution, irrigation with sewage water, unreasonable utilization of groundwater, leakage of harzadous substances from industrial factories and so on. Groundwater pollution has the characteristics of point, line and side distribution. The point pollution indicates the local severe pollution around the city and town or the farm because of the concentrated population, developed industry and feedlot with middle or large scale in rural areas. The line pollution indicates the groundwater pollution around the river caused by river pollution. The side pollution means the irrigation with sewage water and the pollution of misusing fertilizer and pesticide in agriculture.

In recent years, we strengthened the work of water quality monitor and assessment in departments of water resources and achieved many analysis and assessment results. One of the difficulties frequently encountered in water quality assessment is that there are many factors and they cannot be assessed according to one factor, all the effect factors associated with water quality must be used. In order to overcome this issues the projection pursuit principle is introduced into water quality assessment, and projection pursuit cluster(PPC) model is developed in this study. The PPC model makes the transition from high dimension to one-dimension. In other words, based on the PPC model, multifactor problem can be converted to one factor problem. The application of PPC model can be divided into four parts: (1) to estimate projection index function ; (2) to find the right projection direction; (3) to calculate projection characteristic value of the sample , and (4) to draw comprehensive analysis on the basis of . On the other hand, the empirical formula of cutoff radius is developed, which is benefit for the model to be used in practice. Finally, a case study of water quality assessment is proposed in this paper. The results showed that the PPC model is reasonable, and it is more objective and less subjective in water quality assessment. It is a new method for multivariate problem comprehensive analysis. [21]

In 2005 according to analysis of groundwater quality done by Ministry of Land Resources in 158 cities and areas of China, it is concluded that totally groundwater quality in China is good, but in most of the cities the groundwater is suffering point and nonpoint pollution threaten, which results in exceeding standard of some elements in local regions. The main polluting elements are the degree of mineralization, the total degree of hardness, sulphate, nitrate, nitrite, ammonia, nitrogen, chlorid, fluorid, Ph value, iron and manganese, etc. Regarding on the pollution degree, generally, the pollution in northern cities is much higher than those southern cities.

Reference

[1] COMMUNIQUE ON LAND AND RESOURCESS OF CHINA 2003

[2] LIN Zuoding (2004), The Status and Analysis on the Groundwater Development and Utilization in China, Hydrology

[3][4] CHINA WATER RESOURCESS BULLETIN 2004

[5] LIU Cong and HU Gaoshe (2004), Analysis on the Environmental Geologic Effects of Ground Water Exploitation in Xi’an, Shanxi Architecture

[6] GAO Yanbin (2006), a Discussion on Subsidence of Land Surface, Inner Mongolia Science Technology and Economy

[7] (2006) The Management System of Monitoring Groundwater and Surface Water, China Water Resourcess

[8] WANG Pengfeng, QIN Jianmin, LU Huafang (2005), A Kind of New-Type Groundwater Water Level Monitoring System, CONTROL & AUTOMATION

[9] XIE Xinmin, JIANG Yunzhong, YAN Jijun, YANG Xiaoqing, BIAN Jingzhen (2003), Study on Real-Time Monitoring and Management System for Water Resourcess in River Basin, Advances in water science
[10] WANG Xudong, XU Suning, WU Qiang, ZHANG Wei (2003), The Development of Groundwater Environment Quality Evaluation System in Tianjin City, South-to-North Water Transfers and Water Schience&Techonology
[11] ZHAO Jun and JIA Yanhong (2005), Application and Inspiration on GIS in the Groundwater Management and Research in Abroad, Underground Water
[12] CONG Fangjie, WANG Guoli, XIAO Chuancheng, LIU Jinfeng (2006), Research and Development of the Groundwater Management Information System Based on GIS, Hydrology
[13] SHU Yan and WANG Hongqi (2005), The development of groundwater management models, Hydrogeology and Engineering Geology
[14] LI Lierong (2005), Reinforce the management and supervision of groundwater, Hydrogeology and Engineering Geology
[15] WU Xiaofeng and TANG Jie (2004), Selection of Dispersivity in Groundwater Risk Assessment, Journal of Tsinghua University (English Vision)
[16] LI Rongfeng (2005), Study for Self-memory Model and Tts Application in Predicting Groundwater Level, Shanxi Hydrotechnics
[17] LI Rongfeng, SHEN Bing, ZHANG Jinkai (2005), Groundwater Depth Dynamic Prediction with DAMSM Model, Journal of Xi'an University of Technology
[18] TENG Kai (2004), Further Studies on Groundwater Dynamic Prediction Model, China Rural Water and Hydropower
[19] Yang Hongwei and XIE Zhenghui (2003), a new method to dynamically simulate groundwater table in land surface model VIC, Advances in Earth Science (English Vision)
[20] PING Jianhua, LI Sheng, QIN Lijuan, JIANG Jiqi (2006), Review and prospect of dynamic prediction model for groundwater, Water Resourcess Protection
[21] WANG Shunjuu, YANG Zhifeng, DING Jing (2004), Projection pursuit cluster model and its application in water quality assessment, Journal of Environmental Sciences (English Vision)

CHAPTER 3 STUDY PROGRESS ON LAND EROSION

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In China, soil erosion is not only one of the most serious environmental problems, but also a natural process with complex mechanism. The soil erosion has multiple consequences: 1) Within the source area, soil resource and fertility will be washed away, which influences agricultural production and the ecosystem greatly; and 2) In the downstream river channel, the sediments produced by erosion will accumulate on the river bed, which increases the frequency of flood. As a result, the safety of cities and counties will be threatened. It was reported that the total soil erosion in China is estimated to be 50 billion tons per year. Classified by the climate zonation and erosion conformation, soil erosion can be divided into four categories: water erosion, wind erosion, freeze-thaw erosion, and gravitational erosion. All of these erosions are distributed widely in different regions of China. Under these circumstances, for many years scientists in China have been studying soil erosion intensively using different approaches. Lots of research works have achieved important and valuable results. A brief summary of the research works on land erosion is presented as follows to shed some light on the future research projects.

3.1 POLICY BACKGROUND ON EROSION RESEARCH

Both the Chinese central government and the government departments always put emphasis on water and soil conservation. As early as in 1991, China has promulgated the law for water and soil conservation. This document pledges the conservation activities and the legal obligation for prevention, recovery and supervision on soil erosion. Moreover, government departments have published several policies further supporting and strengthening the erosion research. In 2003, the minister of the Ministry of Water Resources of P.R.C, Mr. Wang Shu-cheng ranked the check dams (i.e., sediment trapping dams) as the “bright point” project in recent years, and as a good start, much more investments will be put into this field to promote systematic research on optimization and stability of dam systems. With some key problems resolved, the construction of check dam systems stepped into an advanced level. In 2004, the director of the Yellow River Conservancy Commission, Mr. Li Guo-ying revealed a theoretic framework named “1493” for the first time, i.e., one ultimate target, four main indications, nine approaches and “three yellow rivers”. The “three yellow rivers” consists of “prototype yellow river”, “model yellow river” and “digital yellow river”. These three yellow rivers indicate three different measurements, which are prototype measurement, scale model experiment, and digital simulation, respectively. The three yellow rivers cover nearly all aspects of the research works which may simulate and predict the activities of the Yellow River more fully and accurately. Two new concepts, “model Loess Plateau” and “digital Loess Plateau” which are originated from the framework, provided powerful means to support the reformation of land erosion in the Loess Plateau in particular and the water and soil conservation in general. In August, 2006, with the suggestion put forward by some academicians who are members of an inspection team of soil and water loss and environmental safety of China, the project named “Study on soil erosion process and erosion control in main water erosion regions in China” (2007CB407200) is officially added to the “973 Plan”. This will facilitate the critical projects of conservation and soil erosion researches greatly.

3.2 STUDY PROGRESS ON SOIL EROSION THEORIES

The objective of research on soil erosion theories is to discover the qualitative or semi-quantitative relationship between external phenomena and its internal influencing factors of the erosion processes. The basic approaches of theoretical research are field data analysis and laboratory simulation. The results of this kind of research are always diagrams, simplex formulas which just indicate the laws in a certain aspect. Although theoretical research itself cannot be applied directly to forecast the land erosion processes in river basins, the laws discovered can provide proper directivity and verification data for further model construction.

3.2.1 Study on earthquake-induced land erosion

The Wenchuan Earthquake on May 12, 2008 has triggered a large number of land erosions such as landslides, collapses, and debris flows in the mountainous regions, as a kind of secondary disasters. The local natural landscape has been tremendously changed. Huge landslides buried valleys and created many gentle slope lands. A lot of disaggregated solid materials exist on slopes on the unstable disturbed lands, and debris flow can easily occur. Stabilization and development of the new lands is a new challenge for land recovery and erosion control. The second challenge is due to the damming of rivers and then the quake lakes by landslides, which induces intensive fluvial process and may have long term effects on the river morphology. Many deposits from collapse consist of large stones without soil and fine sediment on the surface. Grain erosion problem (Wang et al., 2010) and vegetation restoration on such deposits is the third challenge. These problems are studied by Wang et al. (2009) based on field investigation and field experiments.

Slope debris flows (as opposed to channelized debris flows) are defined as phenomena in which high-concentration mixtures of debris and water flow down slopes for short distances to highways and river banks. Rainstorms triggered numerous slope debris flows with great damage to highways and rivers over the subsequent two years after the earthquake. Based on field investigations and measurements of 19 slope debris flows, their main characteristics and potential mitigation strategies were studied by Li et al. (2010b). High rainfall intensity is the main triggering factor. Critical rainfall intensities for single, several and numerous slope debris flow events were 20 mm/day, 30mm/day, and 90 mm/day, respectively. The debris flow consists mainly of gravel, cobbles and boulders, and the liquid phase plays the role of lubrication instead of transporting medium. They are two-phase debris flow rather than viscous debris flow although its specific weight is extremely high. The velocity of these debris flows is much smaller and their transport distances are much shorter (several tens of meters) than that of the viscous debris flows because the collision of boulders and cobbles consumes a lot of energy. It is found that the construction of drainage systems, reforestation, and artificial step-pool system can stabilize the landslide body and control or mitigate debris flows on the newly formed land.

Quake lakes posed high risk of catastrophic flash flood hazards to downstream human life and properties after the Wenchuan earthquake. Among them, the Tangjiashan Quake Lake is the largest one. A physics-based numerical simulation approach is proposed by Wang et al. (2008b) for real-time prediction of dam breach development of the Tangjiashan Quake Lake in the case of emergency treatment. Bed erosion and lateral development of the dam breach are represented through accounting for the underlying physics including selective sediment transport and gravitational collapse. Conceptualized breach erosion model that involves few parameters enables quick calibration based on the monitored hydrological data in emergency analysis where fully geotechnical information about the barrier dam is not available. The process of dam breach development is found to be nonlinear in cascades due to the combined effects of head cutting and bank collapse. The agreement between the simulation results and the observed data shows the applicability of the proposed approach for emergency analysis of quake lakes.

Grain erosion is defined as the phenomenon of breaking down bare rocks under the action of insolation and temperature change, detachment of grains from the rockwalls by wind, flow down of grains on the slope under the action of gravity, and accumulation of grains at the toe of the mountain, forming a deposit fan. The newly bared rocks created by the Wenchuan earthquake are undergoing continual intensive grain erosion. Grain erosion caused flying stones, injured humans and resulted in numerous slope debris flows. The process of grain erosion and strategies to limit the erosion were studied by field investigations and field experiments by Wang et al. (2010). According to these field investigations and field studies, the most serious grain erosion occurs in spring and early summer when it is very dry. Rocks are broken down to grains under the action of insolation and temperature change. Then, wind blows the grains from the bare rock down slope. Experimental results showed that the amount of grains blown down by wind per area of rock surface per unit time is proportional to the fourth power of the wind speed. However, the size of the grains blown down by wind increases linearly with the wind speed. An experiment proved that grain erosion can be controlled with two moss species. Moss spores were mixed with clay suspension and splashed on bare rocks. The moss species germinated on the rock surface in one month and greened the bare rocks in two months. The moss layer protected the rocks from insolation and mitigated the effects of temperature change, thus effectively mitigated grain erosion.

Zhang et al. (2009) estimated the soil erosion changes in the Wenchuan earthquake disaster area using the Revised Universal Soil Loss Equation (RUSLE) and geo-spatial information technology. Firstly, using thematic maps taken before the earthquake and airborne images taken after the earthquake, information about the destroyed landscape were extracted by utilizing remote sensing and geographical information system (GIS) techniques. Then, taking into account multi-year precipitation, vegetation cover, soil type, land use, and elevation data, the soil erosion intensity was evaluated using the RUSLE. Results indicate that the soil erosion in earthquake-hit areas was exacerbated, with the severe erosion area increasing by 279.2 km^2, or 1.9% of the total statistical area. Large amounts of soil and debris blocked streams and formed many barrier lakes over an area of more than 3.9 km^2. It was evident from the spatial distribution of soil erosion areas that the intensity of soil erosion accelerated in the stream valley areas, especially in the valleys of the Min River and the Jian River.

3.2.2 Study on macroscopical theories of soil erosion

3.2.1.1 Relationship between soil erosion and hyper-concentrated flow

Wang et al. (1982) have studied the mechanisms of soil erosion and hyper-concentrated sediment-laden flow as early as in 1980s. By analyzing the data from runoff plot on sloping land in Tuanshangou and Duanchuan stations, they found that hyper-concentrated sediment-laden flow can be observed in every erosion processes including splash erosion, flow erosion, gravitational erosion and channel erosion. At the same time, they also found the fact that the frequency of sediment concentration peak late than the flood peak goes from 13% on slope area to 41.7% on gully area, which denotes the gravitational erosion to be the most important sediment source for hyper-concentrated flow. Based on this research, Xu (2004) analyzed the relationships between measured sediment concentration and discharge covering nearly all recorded flood in 1966 in Dujiagou. He found out the frequency with which the sediment concentration peak late than the flood peak goes from 10% to 87% with the study area goes from sloping area to whole basin, and this fact shows clearly that with the dimension become larger, the influence by the gravitational erosion will became much more remarkable.

3.2.1.2 Scale effect and spatiotemporal variability of soil erosion

From some kind of significance, soil erosion is a problem of geonomy with multiple hierarchies and scales. Although in a certain circumstance soil erosion is produced by certain microcosmic mechanics, the general mechanism of erosion is produced by series of nonlinear actions in different hierarchies. As a result, the characteristic parameters for erosion in different hierarchies should be reconsidered.

Wang et al. (2003a) analyzed the suitable degree between the influencing factors (rainfall, vegetation, soil and topographic) and their spatio-temporal scales. They found that some certain factors are quite sensitive to scales. Degree of slope is a main factor when the research scale is hillslope, however, when the scale becomes larger, especially the whole basin, the effect of this factor has greatly been weaken, so, we have to find some new factors to characterize erosion action at basin scale. Liu et al. (2005) discussed the dynamic processes of runoff and erosion in different scales. The result shows that, with the scale increasing, the process of sediment concentration will be more skewed and last longer, at the same time, the discharge which causes the amplitude of sediment concentration lower increases with the scale. Zhang et al. (2006a) clarified the meaning of erosion modulus and its calculating method under different scales, and deduced six expressions of erosion modulus for different scales.

Numerical models have been also applied to reveal the inherent mechanism of the scale effect in soil erosion and sediment transport, especially in the highly erodible Loess Plateau. For example, Qiu et al. (2004) calculated the erosion distribution of Nanxiaogou basin for five different scales using LISEM model. The result shows that optimizing of the land use will increase the spatial variability of soil erosion, and the increasing variability will be help to disperse the risk of erosion. Li et al. (2009b) applied the Digital Yellow River Model (Wang et al., 2007) that integrates sub-models to simulate the sub-processes of rainfall—runoff—soil erosion—sediment transport response with high resolution to the Chabagou watershed, and the distributed results representing scale effects were obtained. Analysis on the simulation results was carried out to find that gravitational erosion and hyper-concentrated flow contribute most to the variation of hydrographs and sediment graphs in spatial scale. The superposition of different sub-processes and their different spatial scale distributions are the main causes of scale effects.

3.2.1.3 Influence on Erosion by Human Activities

Human activities in modern society impact the process of erosion greatly. The influences include the mode of land use and the damage on ground vegetation by human agricultural production, as well as water and soil conservation practices. Therefore, it becomes more important to study the relationship between human activities and soil erosion to establish sustainable development of river basins.

Wang et al. (2005c) collected the data of land use and soil erosion from interpretating Landsat TM Images acquired in 5 years, then a digital environmental model was built and the relationship between land use and soil erosion were analyzed for those years. The result shows that the soil erosion is affected by different land use types, and irrational land use will accelerate soil erosion. So rational land use and optimized land use structure are significantly important for regional sustainable development.

Wang et al. (2003b, 2005d) defined a new concept named vegetation dynamics which is a new interdisciplinary science, studying the law of evolution of watershed vegetation under the action of various kinds of ecological stresses, especially soil erosion. They found that the ecological stresses impacting the vegetation are: (1) Natural stresses, such as the erosion storm, eruption of volcano and the damages by animals as well pests and diseases; (2) Human stresses, such as air pollution, grazing, logging, reclamation, mining and road construction. According to this concept, they built a vegetation dynamics model and applied it to the Xiaojiang basin on

Yunnan Plateau of south China. The results demonstrate that the vegetation-erosion dynamics is a powerful tool for the prediction of vegetation and soil erosion evolution. In addition, Li et al. (2006), Yu et al. (2006), Chen et al. (2005a) respectively discussed the statistical relationship between vegetation and soil erosion using data from vegetation experiment and field collections.

Besides the recovery of vegetation, other human activities in the Loess Plateau, such as terracing, building sediment trapping dams, and etc., can also relief the intensive soil erosion. The policy returning farmland to forest and grassland that formally began in 1999, along with related plans, encouraged the building of a large number of sediment trapping dams. Those dams generally controls a relatively small area and do not have spillways, which lead to the complete interception of streamflow with sediment during mild and moderate floods. Therefore, stream runoffs and sediments generated in the contributing areas of sediment trapping dams basically cannot contribute to the annual runoff and sediment discharge at basin outlet. It can be concluded that in some tributaries of the middle Yellow River, the sharp decline of stream runoff and sediment discharge in the new century is mainly caused by human activities, including sediment trapping dams and other soil and water conservation practices.

3.2.3 Laboratory simulation on soil erosion

Because of the complex mechanism of soil erosion, much more experiments are needed to discover the regularity. Laboratory simulation generally has two functions. The one is to summarize some laws which are helpful for the determination of the structure, parameters and tendency for erosion model. The other is the simulation results can always serve as verification data for numerical models.

Chen et al. (2005b) designed a series of miniature rills to analyze the dynamic process of rill development. The result shows some tendency of the dynamic performance in the process, and there is also high randomness in it. Some empirical relations between the rill width or wet perimeter and discharge and slope are presented as follows:

$$B = 0.596 Q^{0.316} S_0^{-0.23} \quad (1)$$

$$p = 1.512 Q^{0.371} S_0^{-0.245} \quad (2)$$

where B is rill width (m), p is wet perimeter (m), Q is discharge (m^3/s), and S_0 is slope. Correlation coefficient for (1) is 0.674, for (2) is 0.901.

In order to conduct similarity experiment to efficiently utilize the results on small watersheds in the Loess Plateau of China, Gao et al. (2005) established a design means and experimentation technology based on similarity theory and hydrodynamic principles of rainfall, runoff and infiltration. The verification experiment results indicated that the movements of rainfall, flow, sediment yield and bed deformation agreed with the practical situation in the Kangjiagou small watershed in the Loess Plateau of China. It can be used to control soil erosion, schedule farm operations and utilize water and soil resource effectively.

Zheng et al. (2003) established an experiment with various combinations of rainfall intensities and slopes. They found that the flow pattern is always torrent turbulent on the steep slope. The relation between Reynolds number *Re* and resistance coefficient *f* is a power function and both of them go with slope following parabolic equation, at the same time, the relation between Froude number *Fr* and resistance coefficient *f* is a negative power function.

Sun et al. (2003) simulated soil erosion in laboratory with various combinations of rainfall intensities and slope lengths. The result indicated that the general regularity is that erosion increases along the slope, however, under different rainfall intensities, some exception appeared. For example, when rainfall intensity remains weak, erosion in the section 5~7 m from the top increase fast, but when rainfall intensity becomes higher, the particular section will move to the upper direction.

In addition, Wu et al. (2004) used a dual-box system to quantify effect of up-slope runoff and sediment on down-slope ephemeral gully erosion process under different sediment concentrations from up-slope runoff and rainfall intensities. Zhang et al. (2005) established an experimental method for dam system in gully area in the Loess Plateau based on the analysis of the characteristic of model experiment on erosion.

3.3 STUDY PROGRESS ON SOIL EROSION MODELING

Numerical model for soil erosion and sediment yield is an effective tool to simulate the dynamics of flow and sediment in watersheds. It employs the theories from hydraulics and fluvial dynamics and etc. to establish a systematic method for fully simulation and prediction.

From 1980s on, some statistical models constructed from measured data have emerged. These models make the best of information implied in measured data and are competent for general use. However, with the development of computer technology and the increasing demand for more accurate simulation, physically-based models with the ability to simulate the temporal and spatial distribution of erosion become the main direction of research.

Qi proposed a method that firstly divides a watershed into multiple continuous grids and saved the information of natural factor and human activity influence into the grids. The next step is to solve the finite difference equations on each grid. The simulation results agreed well with the measured, and the temporal and spatial distribution of erosion can be simulated quite well for each grid cell.

Wang et al. (2005a, 2007) developed an integrated model named the Digital Watershed Model (DWM) which is based on the digital elevation model (DEM) and the codification (Li et al., 2010a) of extracted drainage network. The model structure is shown as in Fig 1. The model layer is the kernel of the DWM. It has mainly two kinds of physically-based sub-models, which are hillslope models, and channel models, including water yield and soil erosion models for hillslope (Li et al., 2009a), gravitational erosion model for gully slope (Wang et al., 2005b), and flow routing and sediment transport model for channel (Wang et al., 2008a). By applying the DWM on watersheds in different scales such as the Chabagou watershed and the coarse sediment source region of the Yellow River, the results show that the model can give the temporal and spatial distribution and the nonlinear action of soil erosion and sediment transport.

Jia et al. (2005) established a distributed water erosion prediction model for small watershed in the Loess Plateau based on the DEM. The model is composed of hydrological component and erosion component. The erosion component simulates detachments caused by raindrop splash, interrill flow, rill flow, ephemeral gully flow and channel flow, and the calculation of sediment yield is realized according to the principle of dynamic balance of mass. The simulation result of single rainfall event with rainfall intensity higher than medium grade shows that the accuracy of the prediction is acceptable.

3.4 APPLICATION OF ADVANCED TECHNIQUE AND INTERDISCIPLINE ON EROSION RESEARCH

In recent years, advanced techniques and newest research productions from other field have been introduced into the study of soil erosion. New techniques and methodologies not only broaden the eyereach of erosion research, but also obtain more information which is too difficult to get by conventional methods.

Various radionuclides (i.e., ^{137}Cs, ^{210}Pbex and ^{7}Be) and magnetic tracing method have been tried in field of erosion measurement. Zhang et al. (1990, 1999) introduced ^{137}Cs measurement above all to document soil erosion in the Loess Plateau and established the ^{137}Cs models to

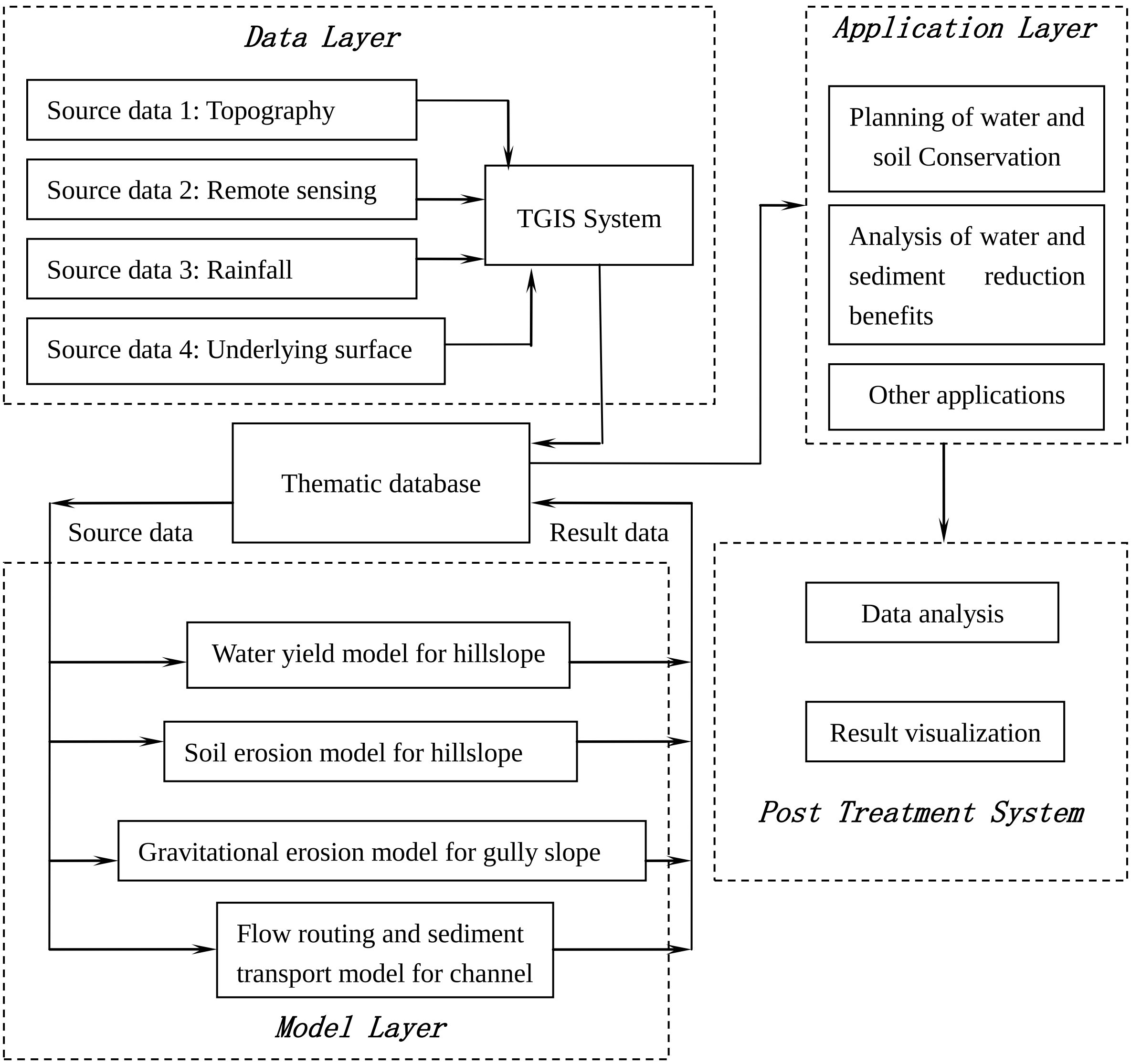

Figure 1. Framework of the Digital Watershed Model

estimate erosion rates for the agricultural field and undisturbed field.Wei presented the fundamentals of the technique of ^{137}Cs tracing and summarized its advantages and limitations. Two key problems of ^{137}Cs technique, namely acquiring the reference value of ^{137}Cs fallout in research area and selecting the quantitative model about the amount of ^{137}Cs lost from the erosion site and soil erosion rate, were discussed. Based on the data of 39 soil profiles in different areas of red soil, Pu et al. (2006) analyzed the relationship between ^{137}Cs content and the composition of soil particles using statistical methods. The result showed that ^{137}Cs had a positive correlation with sand and silt contents, and had a negative correlation with gravel and clay contents within

20 cm of the soil surface. They also found that in different layers, sand content was the main factor cont rebutting to ^{137}Cs. The quantitative model for the relationship between ^{137}Cs and the composition of soil particles was constructed. Yang et al. (2006) partitioned the contributions of sheet and rill erosion using ^{7}Be and ^{137}Cs. The sediment source of flood in small watershed was studied by Yang and Xu (2010) using “fingerprint” measurement. The results indicated that 33.7% of the suspended sediment was derived from the main gully, 60.0% from the surface of orchard area, 3.0% from the surface of cultivated area and 3.3% from the sub-gullies area. ^{137}Cs measurement was also used to date and interpret the sedimentation processes of check dams by Zhang et al. (2006b).

Due to the complexity and nonlinear characteristic of soil erosion, some scientists begin to study soil erosion by using the theory of nonlinear. Zhao built a three-layer feed-forward back-propagation network model for slope soil erosion under different tillage measures. The structure of the model has five input variables, including rainfall intensity, gradient, length of slope, percentage of prophase soil moisture content and soil volume weight, and one output variable for the sediment yield of secondary rainfall of slope soil erosion. The network model was trained and predicted by using the observed data of the field simulated rainfall experiment. The result shows that back-propagation network model is reasonable and can be referred as an effective method for studying slope soil erosion laws. Based on fractal theory and the general model of small watershed, Cui et al. (2006) studied the quantitative coupling relationship between topographic fractal feature and sediment yield by simulation rainfall experiment, high precise photogrammetry and GIS technology. The result shows that during different phases, the variation trend of fractal information dimension (D_i) of watershed model topographic feature was similar to that of relative sediment transport rate (S_r) of watershed model and their relationship presented positive correlation with power function. Therefore, the parameter D_i can be an integrated index of quantifying topographic feature for soil erosion and sediment yield prediction of watershed model.

The study on soil erosion is a systematic project, which consists of theoretical analysis, field survey, laboratory experiment, model construction. Furthermore, the support by policy and laws is also important for erosion research. The success China achieved on erosion research is obvious to all and the achievement will also lay stable foundation of soil erosion research.

References

Chen Hao, Liang Guanglin, Zhou Jinxing, Cai Qiangguo, Lu Zhongchen, Huang Jianguo (2005a). Influence of the recovery of vegetation on erosion and sediment yield in middle reaches of Yellow River and the prospect of improvement. *Science in China ser.D Earth Sciences*. 35(5): 452-463 (in Chinese).

Chen Lei (2002). Water and soil conservation in china. *Soil and Water Conservation in China*. 7: 4-6 (in Chinese).

Chen Li, Liu Qingquan, Li Jiachun (2005b). Scouring experimental study on rill erosion on the slope. *Journal of Hydrodynamics.* 20(6): 761-766 (in Chinese).

Cui Lingzhou, Li Zhanbin, Zhu Yongqing, Guo Yanbiao, Xiao Xuenian (2006). Experimental study on quantitative coupling relationship between topographic fractal feature and sediment yield in small watershed. *Journal of Soil and Water Conservation.* 20(2): 1-5 (in Chinese).

Gao Jianen, Wu Pute, Niu Wenquan, Feng Hao, Fan Henghui, Yang Shiwei (2005). Simulation experiment design and verification of controlling water erosion on small watershed of Loess Plateau. *Transactions of the CSAE.* 21(10): 41-45 (in Chinese).

Jia Yuanyuan, Zheng Fenli, Yang Qinke (2005). Distributed water erosion prediction model for small watershed in loess plateau. *Journal of Hydraulic Engineering*. 36(3): 328-332.

Li Peng, Cui Wenbin, Zheng Liangyong, Ru Huanan (2006). Effects of vegetative cover on runoff hydraulic characteristics and erosion. *Science of Soil and Water Conservation.* 4(1): 55-59 (in Chinese).

Li T., Wang G., Chen J. (2010a). A modified binary tree codification of drainage networks to support complex hydrological models. *Computers & Geosciences.* In press. doi:10.1016/j.cageo.2010.04.009

Li, T.J., Wang, G.Q., Huang, Y.F., Fu, X.D. (2009a) Modeling the process of hillslope soil erosion in the Loess Plateau. *Journal of Environmental Informatics*. 14(1): 1-10.

Li, T., Wang, G., Xue, H., Wang, K. (2009b) Soil erosion and sediment transport in the gullied Loess Plateau: Scale effects and their mechanisms. *Science in China Series E - Technological Sciences*. 2(5): 1283-1292.

Li Y., Wang Z., Shi W., Wang X. (2010b). Slope debris flows in the Wenchuan Earthquake area. Journal of Mountain Science. 7(3): 226-233. doi: 10.1007/s11629-010-2014-2

Liu Jigen, Cai Qiangguo, Liu Qianjin, Liu Yuyuan (2005). Study on the regularity of sediment yield processes in catchments under different scales *Journal of Sediment Research.* 8(4):

7-13 (in Chinese).

Pu Lijie, Han Shucheng, Jin Pinghua, Wang Jinlei, Pan Shaoming (2006). Relationship between ^{137}Cs content and composition of soil particles in red soil region. *Bulletin of Soil and Water Conservation* 26(4): 11-16 (in Chinese).

Qi Wei, Cao Wenhong, Guo Qingchao, Lu Qin (2004). Study on A Distributed Model for Soil Erosion and Sediment Yield in Small Watersheds. *Science of Soil and Water Conservation*. 2(1): 16-21 (in Chinese).

Qiu Yang, Fu Bojie, Wang Jun, Chen Liding (2004). Spatio-temporal variability of the soil erosion and its relation s to the influencing factors on the Loess Plateau, China. *Acta Eologica Sinica*. 24(9): 1871-1877 (in Chinese).

Sun Yaping, Zhang Keli (2003). The distribution of soil loss on the surface of loess slope. *Journal of Sediment Research.* 2(1): 33-38 (in Chinese).

Wang Fei, Li Rui, Yang Qinke (2003 a). Scaling in the Soil Erosion Research. *Research of Soil and Water Conservation*. 10(2): 167-169 (in Chinese).

Wang G., Li T., He L., Xue H. (2008a). Sediment transport simulation for the drainage network in the gullied rolling loess region. *Journal of Sediment Research*. (3): 19-25 (in Chinese).

Wang G., Liu F., Fu X., Li T. (2008b). Simulation of dam breach development for emergency treatment of the Tangjiashan Quake Lake in China. *Science in China Series E - Technological Sciences*. 51(Suppl. 2): 82-94.

Wang Guangqian, Liu Jiahong, Li Tiejian (2005a). Digital Watershed Model of the Yellow River. *Journal of Basic Science and Engineering*. 13 (1): 1-8 (in Chinese).

Wang G., Wu, B., Li T. (2007). Digital Yellow River Model. *Journal of Hydro-Environment Research*. 1(1): 1-11.

Wang Guangqian, Xue Hai, Li Tiejian (2005b). Mechanical Model for Gravitational Erosion in Gully Area. *Journal of Basic Science and Engineering*. 13(4): 335-344 (in Chinese).

Wang Siyuan, Wang Guangqian, Chen Zhixiang (2005c). Relationship between land use and soil erosion in Yellow River Basin. *Journal of Natural Disasters.* 14(1): 32-37 (in Chinese).

Wang Xingkui, Qian Ning, Hu Wei-de (1982). The formation and process of confluence of the flow with hyper-concentration in the gullied-hilly loess areas of the Yellow River basin. *Journal of Hydraulic Engineering.* 7: 26-35 (in Chinese).

Wang Zhaoyin, Guo Yanbiao, Li Changzhi, Wang Feixin (2005d). Vegetation-erosion chart and its application in typical watershed in China. *Advances in Earth Science.* 20(2): 149-157 (in Chinese).

Wang Z., Shi W., Liu D. (2010). Continual erosion of bare rocks after the Wenchuan earthquake and control strategies. *Journal of Asian Earth Sciences*. In Press. doi: 10.1016/j.jseaes.2010.07.004

Wang Z., Shi W., Yu G., Qi L. (2009). New challenges of river management induced by the Wenchuan Earthquake. *Hydro-science and Engineering*. (4): 22-32 (in Chinese).

Wang Zhaoyin, Wang Guangqian, Gao Jing (2003b). An ecological dynamics model of vegetation evolution in erosion area. *Acta Eologica Sinica*. 23(1): 98-105 (in Chinese).

Wei Yanchang, Ouyang Zhiyun, Miao Hong, Wang Xiaoke, Gao Jun (2006). Application of radioactive fallout cesium -137 for soil erosion measurement. *Agricultural Research in the Arid Areas*. 24(3) : 200-206 (in Chinese).

Wu Min, Zheng Fenli, Huang Bin (2004). Experimental study on upslope runoff effects on ephemeral gully erosion processes at loessial hillslope. *Research of Soil and Water Conservation.* 11(4): 74-76 (in Chinese).

Xu Jiongxin (2004) Sediment-heavily containing flows in slope-channel systems of gullied hilly area in the Loess Plateau (I): Influences of landforms and gravitational erosion. *Journal of Natural Disasters.* 13(1): 55-60 (in Chinese).

Yang M.-Y., Walling D. E., Tian J.-L., Liu P.-L. (2006). Partitioning the contributions of sheet and rill erosion using Beryllium-7 and Cesium-137. *Soil Science Society of America Journal*. 70: 1579-1590.

Yang Ming-yi, Xu Long-jiang (2010). Fingerprinting suspended sediment sources in a small catchment on the Loess Plateau. *Journal of Soil and Water Conservation*. 24(2):30-34.

Yu Xinxiao, Zhang Xiaoming, Wu Sihong, Wei Tianxing, Zhang Xuepei (2006). The effect of vegetation and precipitation upon runoff and sediment production in sloping lands of loess area. *Journal of Mountain Science*. 24(1): 19-26 (in Chinese).

Zhang B., Jiao Q., Wu Y., Zhang W. (2009). Estimating soil erosion changes in the Wenchuan earthquake disaster area using geo-spatial information technology. *Journal of Applied Remote Sensing*. 3: 031675.

Zhang Hongwu, Xu Xiangzhou, Zhang Ouyang, Wu Teng (2005). Experimental method for dam system in gully area of Loess Plateau. *Yellow River*. 27(12): 1-3 (in Chinese).

Zhang Xinbao, He Xiubin, Wen Anbang, Qi Yongqing (2006a). Soil erosion rates under different land scale conditions. *Bulletin of Soil and Water Conservation.* 26(2): 69-71 (in Chinese).

Zhang X., Higgitt D. L., Walling D. E. (1990). A preliminary assessment of the potential for using cesium-137 to estimate rate of soil erosion in the Loess of China. *Hydrological*

Sciences Journal. 35: 267-276.

Zhang X. B., Walling D. E., He Q. (1999). Simplified mass balance models for assessing soil erosion rates on cultivated land using caesium-137 measurements. *Hydrological Sciences Journal*. 44(1): 33-45.

Zhang X., Walling D. E., Yang Q., He X., Wen Z., Qi Y., Feng M. (2006b). ^{137}Cs budget during the period of 1960s in a small drainage basin on the Loess Plateau of China. *Journal of Environmental Radioactivity*. 88(1): 78-91.

Zhao Xining, Wu Pute, Feng Hao, Wang Wanzhong, Wu Faqi (2004). Research on Slope Soil Erosion Based on Manpower Neural Network. *Science of Soil and Water Conservation*. 2(3): 32-35 (in Chinese).

Zheng Liangyong, Li Zhanbin, Li Peng (2003). Experimental study on soil erosion characteristics of steep slope on Loess Plateau. *Research of Soil and Water Conservation*. 10(2): 46-51 (in Chinese).

CHAPTER 4 PROGRESS IN STUDIES OF SNOW AND ICE

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4.1 GLACIERS CHANGE AND ITS EFFECTS ON WATER RESOURCES

After first 12-volume (22 issues) Chinese Glacier Inventory, the second Chinese glacier inventory has been conducted by States Key Laboratory of Cryospheric Sciences, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, from 2007 and the data will be expected to release within next 2 years. The glacier change has been reported in recent 50a based on the two times glacier inventory data in some regions.

4.1.1 Glacier Change DuringRecent 50a

Using remote-sensing and Geographic Information System methods, the glacier change has been monitored in more than 5000 glaciers in main mountains in West China over the past 50 years *(Liu et al., 2004; 2005*; *Shangguan et al.,* 2004a,b;2006; 2007). The glacier changes have been summered recently (*Ding et al.,* 2006, *Liu et al.,* 2006a, b). The results indicate that more than 80% of monitored glaciers in western China have retreated in past about 50a, losing 4.5% of their combined area coverage, although some glaciers have advanced. In addition, regional differences characterize glacier changes over the past few decades. For example, glaciers in the central and northwestern Tibet Plateau (TP) were relatively stable, while glaciers in the mountains surrounding the TP experienced extensive wastage. Mass-balance variations for some glaciers show accelerated ice shrinkage in the last two decades.

A comparison of glacier termini from Landsat Thematic Mapper (TM) images acquired in 2000 and 2001 and aerial photographs taken in 1956, 1966 and 1972 indicated that the 33 glaciers monitored on the northeastern slope of the eastern end of the mountains were all receding, with a mean length reduction of 11.5ma–1. Six glaciers completely disappeared during 1972 and 2001. In the western section of the mountains, 95% of the monitored glaciers retreated at a mean rate of 4.9ma–1, but we determined that ten glaciers advanced between 1956 and 2000/01. Our analysis indicated that about 170 glaciers monitored on the northwestern slope of the western section lost 4.8% of their total area during 1956–90, with a much more intensive area reduction (23%) for small glaciers (<1km^2) (*Liu et al.,* 2003).

There are more than 9000 glaciers, with a total area of 9225km^2, in the Chinese Tianshan. Repeat aerial photogrammetric mapping from two acquisitions of aerial photographs has been carried out for measurement of glacier variations in the Urumqi river basin (1962 and 1992) and source tributaries of the Yili river basin (1962 and 1989) on the north slope of the Tianshan. All of the 251 glaciers studied retreated during the periods indicated above, but the overall area reduction differed significantly between the two basins: 13.8% in the Urumqi river basin, but only 3.1% in the Yili river basin. However, the estimated ice-volume change indicates that the average thickness of glaciers after thinning is similar for the two basins: 5.8m for the Urumqi and 6.1m for the Yili (*Liu et al.,* 2002). As for glacier changes on the south slope of the Chinese Tianshan during1960s-1999 or 2000 shows that 69.4% of the monitored glaciers have receded and 30.4% have advanced during the past 40 years. Subtracting the area increase from the advance of some monitored glaciers with a total area of 2093.8km^2 in the early 1960s, glaciers in the southern Tianshan still lost 4.6% of their area.

The north slope of Karakoram is one of the most highly glacierized areas in China, and the second highest mountain peak in the world, K2, is located there. Early research from in situ observations in 1937, topographic maps in 1968 and a Landsat Multispectral Scanner (MSS) image in 1973 show that K2 (Qoger) Glacier retreated by 1.7km between 1937 and 1968 but the retreat slowed between 1968 and 1973. Similar changes occurred in two nearby glaciers, but two advancing glaciers were found in the region during the same period (Zhang, 1980). A careful analysis based on maps and Landsat Enhanced Thematic Mapper Plus (ETM+) imagery indicates that glacier changes in this region are complicated; some of the large glaciers were in a steady state (equilibrium) or have advanced or even surged during recent decades (Shangguan et al., 2004b).

Glaciers on the TP account for 84% and 81.6%, respectively, of the total area and volume of glaciers (including those in Karakoram and the Qilian Shan) in China. Due to the complex meteorological factors of the westerlies and south Asian monsoons, glaciers on the TP are of monsoonal maritime (temperate, southeast part and Hengduan Shan), subcontinental (Himalaya, central northeast part) and extremely continental (central and northwest part) types. Glacier changes in the TP reflect differing patterns of climate in different parts of this large region. Glaciers in the Kunlun Shan, a mountain range along the northern margin of the TP, which extends from west to east, have generally retreated during the past four decades, but the reduction in glacier area is larger (17%) than that in 1966 (*Liu et al.*, 2002) at the eastern end and smaller (0.3%) than that in 1970 (*Shangguan et al.*, 2004a) at the western end of the mountains, with intermediate changes in the central section *(Liu et al.,* 2004). In the central part of the TP, glaciers have been in relative equilibrium but with a trend toward a general retreat state during the past three decades (e.g. a decrease of 1.7% in glacier area in the basin that serves as the source of the Yangtze River) (*Lu et al.,* 2002). However, glaciers on the north slope of the Himalaya have experienced extensive wastage (*Jin et al.* 2004); many small glaciers may have actually disappeared during the last 20 years.

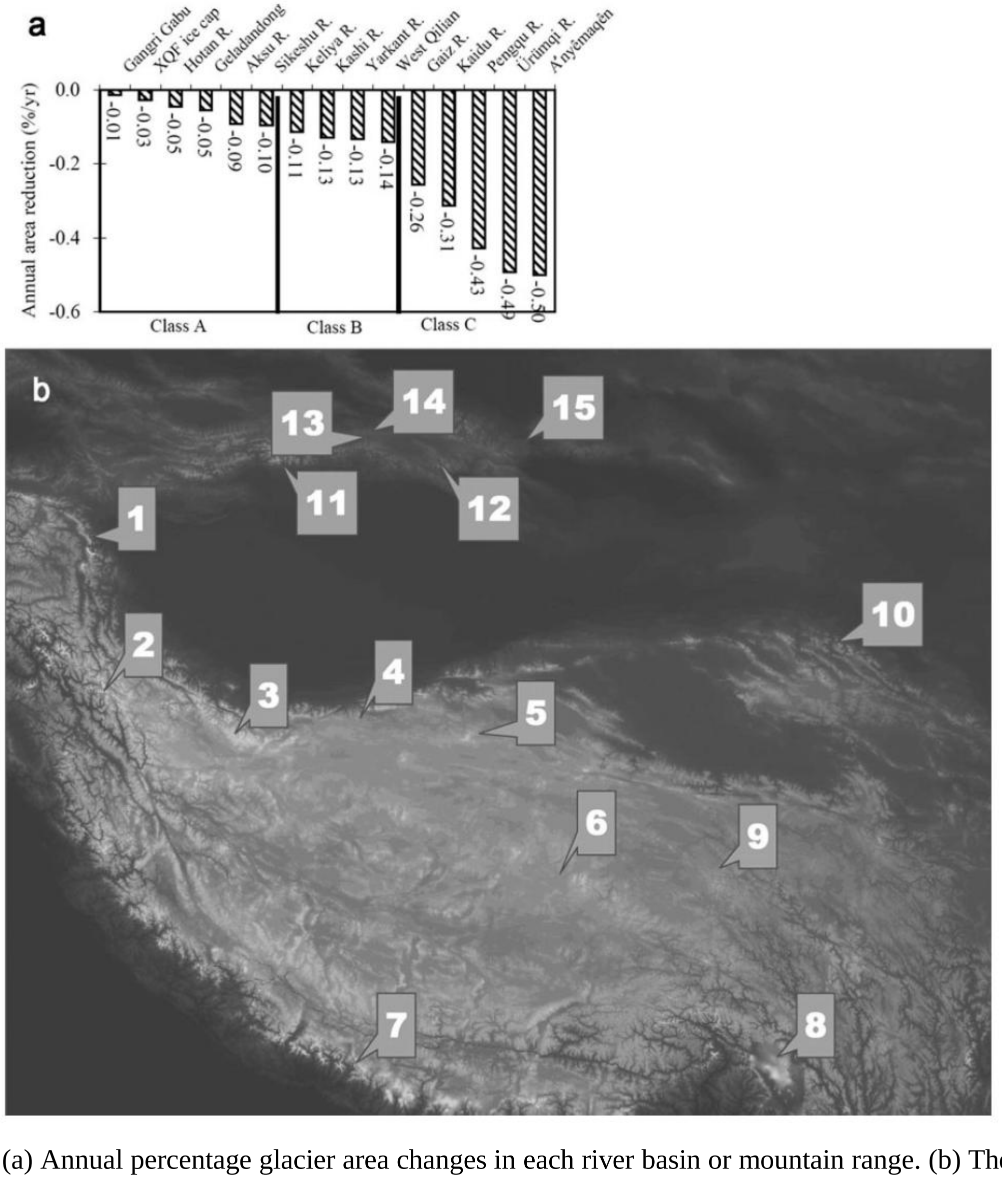

Fig 1. (a) Annual percentage glacier area changes in each river basin or mountain range. (b) The

monitored regions: 1. Gaiz river; 2. Yarkant river; 3. Hotan river; 4. Keliya river; 5. Xinqingfeng (XQF) ice cap; 6. Geladandong mountain; 7. Pengqu river; 8. Gangri Gabu range; 9. A'nyeˆmaqen mountains; 10. west Qilian Shan; 11. Aksu river; 12. Kaidu river; 13. Kashi river; 14. Sikeshu river; 15. Urumqi river (from Ding et al., 2006).

Yao et al. (2004) estimated that the glacier volume in west China may reduce about 452.77-486.94km^3 in past 50a. The analysis of discharge in Tailan River, a branch of Aksu river in Xinjiang show that glacier runoff in 1980's and 1990's has increased by 4.5% and 6.9%. The increase of glacier runoff contributed to 1/3 of river runoff increase (*Liu et al.,* 2006c). The measured glacier area and estimation of glacier ice volume change indicates that the glacier area and volume decreased by 1307.2 km^{2}and 87.1 km^3 (about 3.8m glacier depth thinning), respectively, about 6.6% and 3.8% of corresponding volume in 1963, respectively. The measured glacier mass balance in No.1 glacier in Urumqi river source in Tianshan during last 45a indicate the glacier mass loss can reach 480mm induced by 1℃ summer air temperature increase (*Ye et al.,* 2005).

4.1.2. Glacier runoff

All observed and modeling result show that the glacier runoff has been increased obvious in west China in past decades due to glacier shrinking caused by climate warming. The glacier increased enhanced river discharge increase or weaken the discharge decrease.

(1) Observed results

a. The Urumqi River source Glacier No. 1 in Tianshan

The long-term observed results over the past 45 years (1959-2004) in Urumqi River source region, the Tianshan Mountains of China show that summer temperature and annual precipitation near the glacier increased by 0.8℃ and 87 mm (19%), respectively. The glacier continuously retreated from 1962 to 2003, with the cumulated mass balance being -10,032 mm, or 20% of the glacier volume. Annual basin runoff has significantly increased by 413 mm or 62% during 1980–2003 due to precipitation increase and enhanced glacier melt caused by summer climate warming. Both summer precipitation and temperate are negatively correlated with mass balance and positively associated with runoff. Relative to precipitation mass balance relation, the regression between temperature and mass balance is much stronger, indicating that summer temperature controls glacier mass balance and runoff changes. A 1℃ increase in summer temperature leads to an increase of 486 mm glacier mass loss (Figure 1) (Ye et al., 2005). The annual glacial runoff calculated at the Urumqi glacier No. 1 hydrometeorological station has increased by 145.5×104 m3 a-1, a factor of 2, over the 48-year span from 1959 to 2006. A significant increase in runoff occurred after 1985, particularly after 1995 due to an increase in both temperature and precipitation in the area (Li et al., 2010).

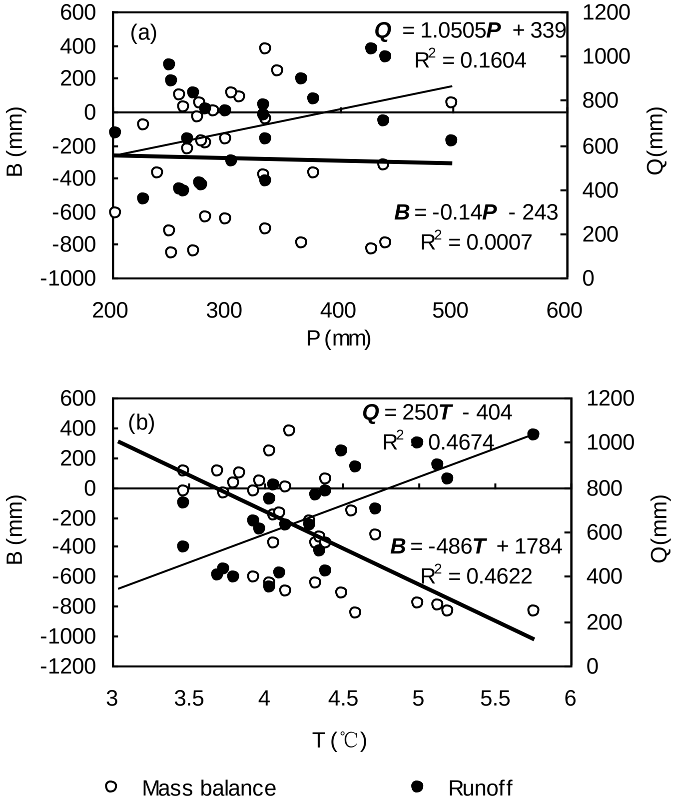

Figure 1. Regression relationships of summer temperature (T) and precipitation (P) vs. mass balance (B) and runoff (Q) during 1959–1966 and 1980–2003 (Ye et al., 2005)

b. The Glaciers in on Mt. Hengduan and Baishui glacier No.1 on Yulong

Ablation is heavy in the glacier tongue areas, and the mean ablation water equivalent in Hailuogou glacier in Sichuan during 1990/91–1997/98 was 876 mm more than that in 1982/83. Ablation depth on the exposed ice area increased by 1.4 m/a over the period 1983/84–1990/91. Mass balance records also show that glaciers suffered a constant mass loss of snow and ice, and the accumulated mass balance in Hailuogou basin and Baishui glacier No.1 was -10.83 mwater equivalent in the past 45 years, and -11.38 m in the past 52 years. Local hydrological and climatic data demonstrated that, in Yanggong basin during 1979–2003 and Hailuogou basin during 1988–2004, runoff from the glacier areas has been increasing both seasonally and annually. Overall, it is clear that China's monsoonal temperate glaciers are losing mass and are retreating under the background of climate warming (Li et al., 2010). The Hailuogou glacier area subject to melting has increased and the ablation season has become longer due to the warming, the ablation of glacier enhanced, leading to increasing contribution of meltwater to annual river discharge (Pang et al., 2010).

c. Rongbuk Glacier in Mt. Qomolangma Region

The discharge of the Rongbuk Glacier catchment from 8 April to 11 October in 2005 shows a time lag ranging from 8 to 14 hours between daily discharge peaks and maximum melting (maximum temperature). Compared with the discharge data in 1959, the runoff in 2005 was much more, and the runoff in June, July and August increased by 69%, 35% and 14%, respectively. The rising of temperature is a major factor causing the increase in runoff. The discharge induced by precipitation accounts for about 20% of the total runoff, while snow and ice melting for about 80% (Liu, et al., 2010).

d. Keqikaer glacier, south slope of Tuomuer mountain

There is large lag time in the lag time in Keqikaer glacier, south slope of Tuomuer mountain. The lag time is exceeds 1 day in May and September but falls short of 1 day in other months, and it decreases from May to August, but increases in September (Xie et al., 2006). The degree-day model results show that under the warming and wetting scenario, the primary supply for the runoff in Keqikaer basin is glacier meltwater, with precipitation being the dominant secondary source; 84% and 8% of total runoff, respectively (Zhang et al., 20061). Also, the artificial neural networks has been used to simulate meltwater runoff of Keqikaer Glacier (Chen and Ding 2009). The effect of change in temperature is much more noticeable than that for change in precipitation (Zhang et al., 2007a).

e. Zhadang Glacier in Nyainqêntanglha Rang

2007/2008 observation in the Zhadang Glacier located on the northern slope of e, Tibet, indicates precipitation increased by 17.9% in summer months of 2008 compared with the same period in 2007, drainage basin runoff decreased by 33.3%, and glacial meltwater decreased by 53.8%. Change in positive accumulated air temperature explained approximately half of the inter-annual difference in glacial meltwater using a degree-day model. This suggests that the glacier is extremely sensitive to changes in air temperature. Energy balance analysis showed that change in glacier surface albedo, considered to be caused by difference in precipitation form, resulted in the large inter-annual difference in glacial meltwater. It was shown statistically that precipitation form in the summer months of 2007 was mainly rainfall which comprised 71.5% of total precipitation, while during the same period in 2008 rainfall accounted for 30.7%, with the majority of precipitation falling as snow. Precipitation form should be considered an independent factor when analyzing glacier sensitivity to climate change or forecasting the runoff from certain glaciers.

(2) Glacier runoff change in typical basins

The degree-day model is widely used for glacier ablation. The degree-day factor (DDF) is an important parameter for the degree-day model, which is a widely used method for ice- and snowmelt computation. The spatial variations of the DDF varied among 2.6 and 13.8 mm/d/℃ with mean of 7.113.8 mm/d/℃ for ice and between 3.1-5.9 mm/d/℃ with 4.1 mm/d/℃ for snow over China. the DDF for a single glacier is subject to significant small-scale variations, and the factor for maritime glaciers is higher than that for subcontinental and extremely continental glaciers (Zhang et al. 2006b). The model has been used to calculate the glacier runoff for basin scale in China.

.

a. the Yangtze River source

Most of the glaciers in the Tuotuo River basin, western China has retreated in the period from 1968/1971 to 2001/2002, and their shrinkage area is 3.2% of the total area in the late 1960s. As a result, glacier runoff has increased in the last 44 years, especially in the 1990s when a twothirds increase in river runoff was derived from the increase in glacier runoff caused by loss of ice mass in the entire Tuotuo River basin. (Zhang et al., 2007b). Glacier runoff from the Yangtze River source region ()at Zhimenda gauge station (YRSR), China, is estimated for the period 1961–2000 using a degree-day approach. In the investigation area, glacier runoff accounts for 11.0% of the total river runoff during the period 1961–2000. In the 1990s its contribution to river runoff rises to 17.0%. Due to the current rate of glacier decline, the impact of glacier runoff on river runoff has recently increased in the source region (Figure 2). The glacier runoff also has been projected using the GCM scenario output (Liu, et al., 2009).

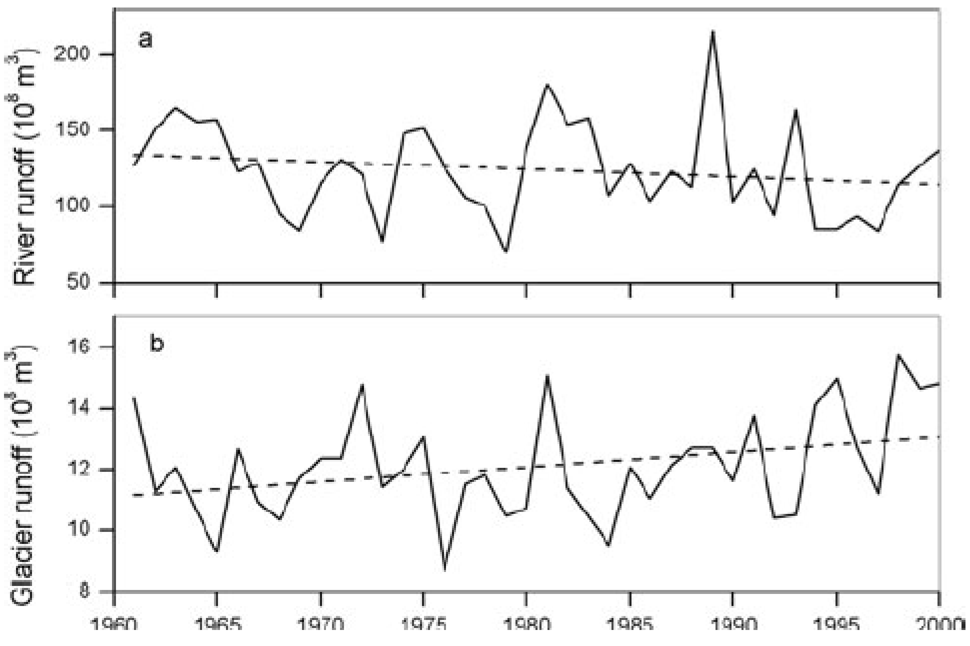

Figure 2. Variation in annual river runoff (a) and glacier runoff (b) of the YRSR for the climatic normal period 1961–2000. Dashed lines are regression lines indicating trend(Liu et al., 2009).

b. the Tarim River Basin (TRB)

The degree-day model simulated the glacier ablation and runoff over Tarim River basin. The result shows mean annual glacier mass balance during 1961–2006 was −139.2 mm per year and the cumulative mass balance over the 46 year period was −6.4 m in the TRB. The average annual glacier runoff in the TRB was 144.16×108 m3 for 1961–2006. The results also show that glacier runoff has increased in the last 46 years, especially since the 1990s with 85.7% of the increased river flow being derived from the increased glacier runoff caused by loss of ice mass. Over the entire TRB, glacier runoff accounts for 41.5% of the total river flow during 1961–2006. The impact of glacier runoff on river flow has increased in the TRB as a result of glacier shrinkage (Figure 3) (Gao et al., 2010).

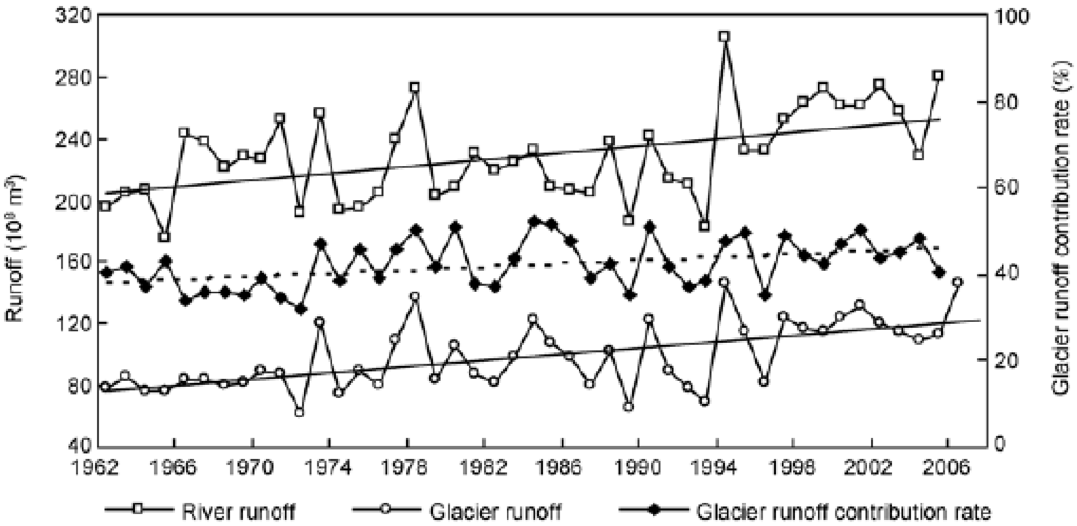

Figure 3 Variations in annual river flow, glacier runoff and the contribution of glacier runoff to river flow at four source rivers in the TRB during 1961–2006. The solid lines are the linear trend in river flow and glacier runoff, and the dotted line is the linear trend in the contribution of glacier runoff to river flow (Gao et al., 2010).

5. Glacier lake

5.1 Lake with glacier supply

The all lake area in Nam Co catchments has been extended in Nam Co Catchment from 1070s-2000s, meanwhile the glacier are in retreating (Figure 5). This indicate the lakes supplied by glacier have been extended during last 40a due to glacier retreat/mass losses caused by the climate warming(Yao et al., 2010).

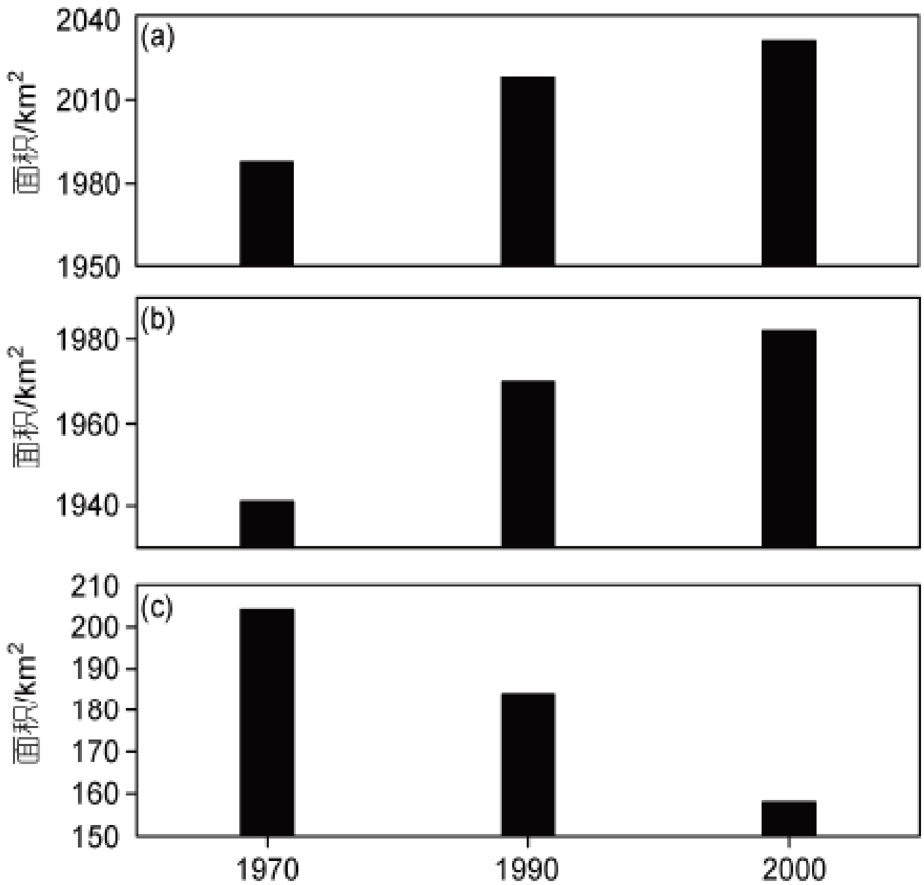

Fig. 5 The areas of (a) all lakes, (b) Nam Co Catchment and (c) Glacier area in different decades in Nam Co Catchment from 1070s-2000s (Yao et al., 2010)

4.1.3 Outburst floods of glacier lake

The thermo-mechanical modelling has been successfully used to interpret a 40-year flood record from Merzbacher Lake in the Tian Shan. We show that the mean air temperature during each flood modulates its peak discharge, by influencing both the rate of meltwater input to the lake as it drains, and the lake-water temperature. The flood devastation potential thus depends sensitively on weather, and this dependence explains how regional climatic warming drives the rising trend of peak discharges in our dataset. For other subaerial ice-dammed lakes worldwide, regional warming will also promote higher-impact of subglacial outburst floods by raising the likelihood of warm weather during their occurrence, unless other factors reduce lake volumes at flood initiation to outweigh this effect (Figure 6) (Ng et al., 2007).

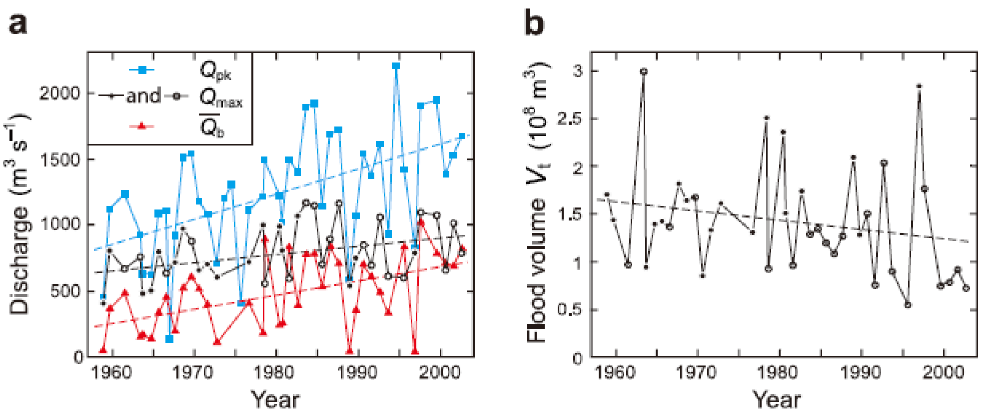

Figure 6. Merzbacher flood characteristics from 1958 to 2002. (a) Xiehela peak discharge Qpk, mean Xiehela base flow Qb, and flood peak discharge Qmax. Linear trends for Qpk, Qb, Qmax are +19.0, +10.5, +6.2 m3/s/yr, respectively. (b) Flood volume Vt; linear trend -1.0×106 m3/yr (Ng et al., 2007).

4.2 SNOW COVER VAIRATATION IN RECENT 50A OVER CHINA

The snow cover variation has been studied using the observation data in meteorological stations over during 1951-1997 China (*Qin et al.*, 2006; *Ren et al.*, 2005).

4.2.1 The Distribution of Snow Covers over China

The snow cover occurred in about $9\times10^6 km^2$ over China (more than 90% area), extending south to 24°-25°N. However, the snow duration is short in most regions. The temporal or unstable snow cover (annual mean snow cover duration is less than 60 days) is dominated in most regions, about $4.8\times10^6 km^2$. The stable snow cover are existed in $4.2\times10^6 km^2$ which are distributed in three regions: (1) Qinghai-Tibetan Plateau with $2.3\times10^6 km^2$ including Pamir, Kalakunlun, Kunlun, Qilian Mountains and south Gansu province, west Sichuan and northeast Yunnan, but excluding valley in south Tibet, North Tibet Plateau and Chidamu Base; (2) Tianshan in Xinjiang with $1.04\times10^6 km^2$, (3) Northeast China and inner Mongolia with $1.4\times10^6 km^2$.

The thin and various distributions of snow covers are characterized. The snow covers are very thin in most regions. There is only 3.5cm daily snow average depth and 50% region has less than 3cm daily snow average depth. The most snow covers are concentrated in mountains in north China and northwest China. More than 50% snow is distributed only in mountains with less than 10% area. Usually, there is thin snow cover over the plain in north China. The snow depth is about 2-3cm in west region of northeast China and north China, and less than 1cm in the arid northwest China with 16% area. There is center rich in snow in Xinjiang. The snow depth is about 50-60cm in Altai, 40-50cm in Tianshan, Pamir and Kalakunlun mountains and 20-30cm in Kunlun mountains. However, there is no snow in most years, except for rich snow year in Tarim Basin. The rich snow cover also exist with 30-50cm depth in the mountains surrounding to Qinhai-Tibet Plateau, especially in Nyainqintanglha and Tanglha mountains in East region of Plateau and Karakunlun and west region of Himalaya in west region of Plateau. There is discontinuous and short-duration snow cover with less than 10cm in central Qinhai-Tibet Plateau. There is nearly no snow cover in the valley in south Tibet and Qaidam Basin. The maximum snow cover depth is about 15cm averaged in whole Plateau. The deep snow covers with 20-30cm depth exist in mountains and thin snow cover occurred in plain in northwest China. The snow cover distribution is controlled main by air temperature, elevation and climatic system, also affected by surface conditions.

4.2.2 Seasonal Variation in Ssnow Covers

The snow cover duration is about half year over China. The snow cover formed in middle September, reach the maximum in early January and disappeared in June in Qinghai-Tibet Plateau. The snow storages are 45.2%, 28.0% and 21.2% in winter (December to February), spring (March to May) and fall (September to November). The annual maximums of snow storage has largely variation, the difference of annual snow storage can be $30X10^9$ m^3 between years with rich and poor snow. The snow cover exists in middle November, then slowly extends to maximum in later February to early March, starts to melt in Spring and disappeared in middle April in Xinjiang. The annual maximum snow storages is about $7X10^9m^3$ water equivalent, have low variation, but its duration has large difference in the regions. The maximum snow storage duration is about 72 days in rich snow year and only about 30 days in poor snow year. The snow cover duration has long period, 5-7 months in Inner Mongolian and Northeast China. The snow cover duration exist from middle October to later April in most north regions (north of 50 °N), and from middle November to end of March in most south regions. The average snow depth is about 11cm over the region. The minimum average snow depth is only 4cm. the difference of snow storage between maximum and minimum is up to 24 $X10^9m^3$ water equivalent, very close to Qinghai-Tibet Plateau variation. The large variation can cause drought and waterlog in spring, and affect on local agriculture activities.

4.2.3 The Fluctuation of Snow Covers during Recent 50a

The geographical distribution and spatial and temporal variabilities of snow cover has been studied in the western China during the past 47 yr between 1951 and 1997 (Qin et al., 2006). The data used consist of Scanning Multichannel Microwave Radiometer (SMMR) 6-day snow-depth charts, NOAA weekly snow extent charts, and the daily snow depth and number of snow cover days from 106 selected meteorological stations across western China. Empirical orthogonal function was performed on the SMMR dataset to better understand the spatial pattern and variability of the Qinghai–Xizang (Tibet) snow cover. A multiple linear regression analysis was conducted to show the association of interannual variations between snow cover and snow season temperature as well as precipitation. Further, the autoregressive moving average model was fitted to the snow and climate time series to test for their long-term trends. Results show that western China did not experience a continual decrease in snow cover during the great warming period of the 1980s and 1990s. It is of interest to note that no correlation was identified between temperature and precipitation in the snow cover season. However, year-to-year fluctuation of snow cover is caused by both snowfall and snow season air temperature. About one-half to two-thirds of the total variance in snow cover is explained by the linear variations of snowfall and snow season temperature. The long-term variability of western China snow cover is characterized by a large interannual variation superimposed on a small increase trend (Fig.2). The positive trend of the western China snow cover is consistent with increasing snowfall, but is in contradiction to regional warming.

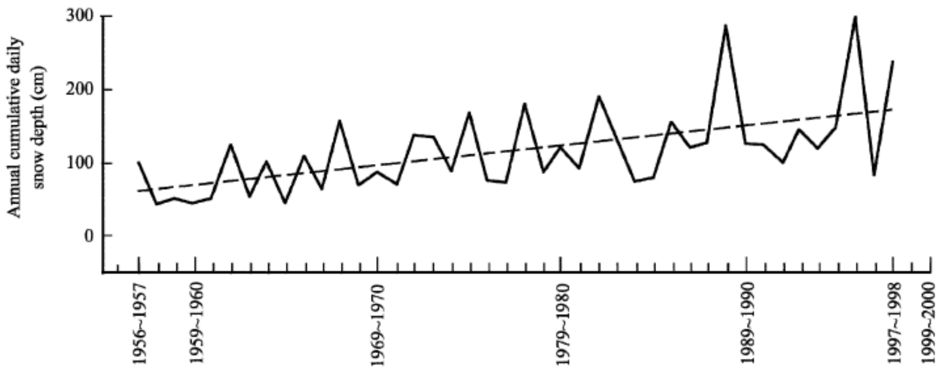

Fig.2 Variation of annual cumulative daily snow depth over the Qinghai–Xizang (Tibet) Plateau, 1957–98 (*Qin et al.*, 2006)

The trend of snow cover is insignificant positive in Xinjiang during last 50a. There is positive relationship between snow cover and winter precipitation in Xinjiang, however, negative relationship exist between snow cover and winter air temperature. The snow cover show slight decreased trend (1%/10a) in inner Mongolian and northeast China. The deceased snow cover is consistent with decrease of winter precipitation and increase of winter air temperature. These relationships imply that the change of snow cover mainly depend on winter precipitation change over China. The reason may be the lower winter air temperature in China than in Europe and North America.

The snow covers in three main regions has inconsistent fluctuations in past 50a. The difference occurred not only in long-term trend, but also in period with maximum and minimum snow covers. For example, there is large snow cover in Xinjiang in 1959/1960 and 1958/1959, but there is low snow cover in inner Mongolian and northeast China. There is normal or low snow cover in inner Mongolian and northeast China when the heavy snow disaster occurred in 1985/1986 and 1995 /1996 in Qinghai-Tibet Plateau.

4.2.4 Estimation of the Snow Covers Change in Future

The analysis on the relationship between snow cover, winter air temperature and precipitation indicates the snow cover may increase in future in Qinghai-Tibet Plateau, North Xinjiang and some region in Inner Mongolian. Both the area and duration of unstable/temporal snow cover may decrease over China. This implies that snow change will enhance snow disaster in snow increased region and drought in decreased region in spring, and negatively affect on ecology and environments.

4.2.5 Snowmelting runoff

2.1 variation of snow depth and runoff

Spatio-temporal variation of snow depth in the Tarim River basin has been studied by the empirical orthogonal function (EOF) based on the data collected by special sensor microwave/imager (SSM/I) and scanning multichannel microwave radiometer (SMMR) during the period from 1979 to 2005. The long-term trend of snow depth was significant in the northwestern, western and southern parts of the basin, whereas the long-term trend of runoff was significant in the northwestern and northeastern parts. The regression analysis revealed that the runoff of the rivers replenished by snow melt water and rainfall was related primarily to the summer precipitation, followed by the summer temperature or the maximum snow depth in the cold season. Our results suggest that snow is not the principal factor that contributes to the runoff increase in headstreams, although there was a slow increase in snow depth. It is the climatic factors that are responsible for the steady and continuous water increase in the headstreams (2009).

2.1 Snowmetling forecast

The Weather Research and Forecasting (WRF) modelling system and the Distributed Hydrology Soil Vegetation Model (DHSVM) to forecast snowmelt runoff has been coupled and used to forecast the

snowmelt runoff. In this study, a limited-region 24-h Numeric Weather Forecasting System was formulated using the new generation atmospheric model system WRF with the initial fields and lateral boundaries forced by Chinese T213L31 model. Using the WRF forecasts, the DHSVM hydrological model was used to predict 24 h snowmelt runoff at the outlet of the Juntanghu watershed. Forecasted results showed a good similarity to the observed data, and the average relative error of maximum runoff simulation was less than 15%. The results demonstrate the potential of using a meso-microscale snowmelt runoff forecasting model for forecasting floods. The model provides a longer forecast period compared with traditional models such as those based on rain gauges or statistical forecasting (Zhao et al., 2009).

4.3 . HYDROLOGY IN PERMAFROST REGIONS

4.3.1 hydrological regime and permafrost coverage in basin

The ratios of monthly maximum/minimum flows directly reflect discharge regimes. There is a significant positive relationship between the ratio and basin permafrost coverage. This relationship indicates that permafrost condition does not significantly affect streamflow regime over the low permafrost (less than 40%) regions, and it strongly affects discharge regime for regions with high permafrost (Figure 4) (greater than 60%) (Ye et al., 2009).

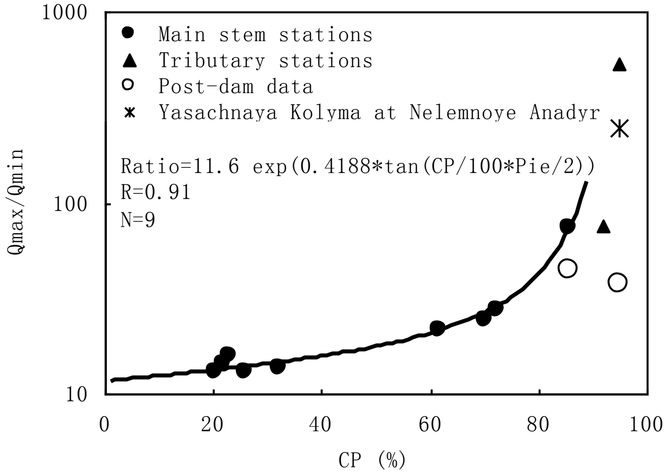

Figure 4. The ratios of Qmax/Qmin versus coverage of permafrost (CP) at the nine stations from the upper Lena to basin outlet without reservoir regulation. Two additional stations (the Aldan and Vilui subbasins in Lena basin) and one additional basin (the Yasachnaya Kolyma River) in East Siberian are also shown. The ratios of Qmax/Qmin are showed at the Vilui subbasin and Kusur at Lena basin outlet with reservoir regulation since 1967. Note: the Y axis is in logarithm scale.

4.3.2 Hydrological parameters change in basin with permafrost

The hydrological process in typical basins with various permafrost coverage (between 33%-73%) in northwestern China shows that the monthly recession coefficient (RC) in winter has increased obviously for the Shule and Heihe rivers to 73% and 58% permafrost coverage, respectively, but did not increase for the Shiyang River, and decreased insignificantly for the upper Yellow River, which had less permafrost coverage. There is a distinct positive relationship between RC and annual negative degree-day temperature (NDDT) at the meteorological stations in the basins with high permafrost coverage. These results imply that permafrost degradation due to climate warming affects hydrological processes in winter. The effect is obvious in the basins with high permafrost coverage but negligible in those with low permafrost coverage. Permafrost degradation increases infiltration, enlarges the groundwater reservoir, and leads to slow discharge recession. The result means that hydrological processes are affected strongly by permafrost degradation in river basins with high permafrost coverage, but less in river basins with less permafrost coverage (Niu, 2010). Also, The statistically significant trends in basin hydrological regime has been detected in northwest China for the period 1957–2004 included strong increases in winter air temperatures and winter monthly flows (December to March) (Liu et al., 2007). A monthly-scale spatial-distributed hydrological model with consideration of snow and permafrost has been developed. The simulated result in upper Yangtze River (Zhang et al., 2006).

4.4 BIAS-CORRECTED PRECIPITATION CLIMATOLOGY FOR CHINA

Long-term monthly climatic data during 1951–1998 at 627 meteorological stations over China have been analysed in this study to examine the impact of bias corrections on monthly and yearly precipitation trends. The impacts of bias corrections on trends depended on the gauge catch efficiency and changes of wind speed, temperature, snow percentage, and number of trace and measurable precipitation days. Trends of corrected and measured monthly and yearly precipitation have similar regional patterns over China, although the trends are different quantitatively over some regions. Precipitation trends in summer months are generally higher than winter season because of high precipitation in summer and low in winter. For instance, trends in January and July are -8 to +20 mm/10a and -37 to +55 mm/10a over China for the measured data during 1951–1998, respectively. Bias corrections enhance monthly precipitation trends in every month by about 7 to 18%, leading to an 8% overall enhancement of absolute yearly precipitation trends over China. For the individual stations, the difference in corrected and measured annual precipitation trends varies from -4.1 to +19.0 mm/10a (-5.0 to +1.7%/10a) across China. It is important to note that bias corrections can change precipitation trend. (Ding et al., 2007). The further results show there is only -1.9%/10a trend of measured precipitation, but -6.0%/10a trend of the bias corrected precipitation during 1955-2004 over China (Ye et al., 2008). Our analyses show that bias corrections have changed monthly and yearly precipitation trend direction from positive to negative over some regions in China. The trend changes reported here are large enough to affect regional climate and hydrology analyses, particularly over cold regions.

Referencecs

[1]. Braithwaite R J, Zhang Y. Sensitivity of mass balance of five Swiss glaciers to temperature changes assessed by tuning a degree-day model. J Glaciol, 2000, 46: 7–14

[2]. Ding Y, Yang D, Ye B, Wang N, 2007. Effects of bias correction on precipitation trend over China. J. Geophys. Res., 112: D13116. doi:10.1029/2006JD007938.

[3]. Ding, Y., D. Yang, B. Ye, and N. Wang (2007), Effects of bias correction on precipitation trend over China, J. Geophys. Res., 112, D13116, doi:10.1029/2006JD007938.

[4]. Ding Yongjian, Liu Shiyin, Li Jing et al.. 2006. The retreat of glaciers in response to recent climate warming in western China. Annals of Glaciology, 43: 97-105

[5]. Gao X, Ye B S, Zhang S Q, et al. Glacier runoff variation and its influence on river runoff during 1961–2006 in the Tarim River Basin, China. Sci China Earth Sci, 2010, 53: 880–891, doi: 10.1007/s11430-010-0073-4

[6]. He Yuanqing, Pu Tao, 138 Li Zongxing, Zhu Guofeng, Wang Shijin, Zhang Ningning, Wang Shuxin, Xin Huijuan, et al., 2010, Climate Change and Its Effect on Annual Runoff in Lijiang Basin-Mt. Yulong Region, China, Journal of Earth Science, 21(2):137–147, DOI: 10.1007/s12583-010-0012-5

[7]. Jansson P, Hock R, Schneider T. The concept of glacier storage: A review. J Hydrol, 2003, 282: 116–129

[8]. Jin, R., C. Tao, X. Li and L. Wu. 2004. Glacier variation in the Pumqu Basin derived from remote sensing data and GIS technique. J. Glaciol. Geocryol., 26(3), 261–266. [In Chinese]

[9]. Kane, D. L., and D. Yang (2004), Overview for Water Balance Determinations for High Latitude Watersheds. In Northern Research Basins Water Balance (Edited by Douglas L. Kane and Daqing Yang), Int. Assoc. of Hydrological Sciences Publication 290. 1-12.

[10]. Laumann T, Reeh N. Sensitivity to climate change of the mass balance of glaciers in southern Norway. J Glaciol, 1993, 39: 635–665

[11]. Li Z., W. Wang, M. Zhang, F. Wang and H. Li, 2010, Observed changes in streamflow at the headwaters of the Urumqi River, eastern Tianshan, central Asia, HYDROLOGICAL PROCESSES Hydrol. Process. 24, 217–224.

[12]. Li, Zongxing, He Yuanqing, Pu Tao, Jia Wenxiong, He Xianzhong, Pang Hongxi, Zhang Ningning, Liu Qiao, Wang Shijing, Zhu Guofeng, Wang Shuxin, Chang Li, Du Jiankuo, Xin Huijuan，2010，Changes of climate, glaciers and runoff in China’s monsoonal temperate glacier region during the last several decades，Quaternary International， 218 13－28

[13]. Liu Jingshi, Siyuan Wang, and Yuying Huang, 2007, Effect of Climate Change on Runoff in a Basin with Mountain Permafrost, Northwest China, Permafrost and Periglac. Process. 18: 369–377

[14]. Liu S Y, Ding Y J, Wang N L et al. Mass balance sensitivity to climate change of the Glacier No. 1 at the Urumqi River Head, Tianshan Mts. (in Chinese). J Glaciol Geocryol, 1998, 20: 9–13

[15]. Liu, SY; Zhang, Y; Zhang, YS, et al., 2009, Estimation of glacier runoff and future trends in the Yangtze River source region, China, Journal of Glaciology, 55(190): 353-362

[16]. LIU, Weigang, REN Jiawen, QIN Xiang, LIU Jingshi, LIU Qiang, CUI Xiaoqing and WANG Yetang，2010，Hydrological Characteristics of the Rongbuk Glacier Catchment in Mt. Qomolangma Region in the Central Himalayas, China，J. Mt. Sci. ，7: 146﹣156

[17]. Liu Shiyin, Lu Anxin, Ding Yongjian, Yao Tandong, Ding Liangfu, Li gang, H. Roger, 2002. Glacier Fluctuations and the Inferred Climate Changes in the A′Nyêmaqên Mountains in the Source Area of the Yellow River, 24(6):701-707. [In Chinese]

[18]. Liu Shiyin, Sun Wenxin, Shen Yongping and Li Gang. 2003. Glacier changes since the Little Ice Age Maximum in the western Qilian Mountains, northwest China. Journal of Glaciology, 49(164):117~124

[19]. Liu Shiyin, Shangguan Donghui, Ding Yongjian, Han Haidong, Zhang Yong, Wang Jian, Xie Changwei, Ding Liangfu, Li Gang, 2004. Variation of Glaciers Studied on the Basis of RS and GIS--A Reassessment of the Changes of the Xinqingfeng and Malan Ice Caps in the Northern Tibetan Plateau, Journal of Glaciology and Geocryology, 26(3):244-252. [In Chinese]

[20]. Liu Shiyin, Shangguan Donghui, Ding Yongjian, Han Haidong, Zhang Yong, Wang Jian, Xie Changwei, Ding Liangfu, Li Gang, 2005. Glacier Variations since the Early 20th Century in the Gangrigabu Range, Southeast Tibetan Plateau, Journal of Glaciology and Geocryology, 27(1)，55-63. [In Chinese]

[21]. Liu Shiyin, Shangguan Donghui, Ding Yongjian et al. 2006a. Glacier changes during the past century in the Gangrigabu Mountains, Southeast Qinghai-Xizang (Tibet) Plateau, China. Annals of Glaciology, 43:187-193

[22]. Liu Shiyin, Ding Yongjian, Shangguan Donghui et al., 2006b. Glacier retreat as a result of climate change due to warming and increased precipitation in the Tarim River Basin, Northwest China. Annals of Glaciology, 43: 91-96.

[23]. Liu Shiyin, Ding Yongjian, Zhang Yong, Shangguan Donghui, Li Jing, Han Haidong, Wang Jian, Xie Changwei, 2006c. Impact of the Glacial Change on Water Resources in the Tarim River Basin, Acta Geographica Sinica, 61(5):482-490. [In Chinese]

[24]. Lu Anxin, Yao Tandong, Liu Shiyin, et al. 2002. Glacier change in the Geladandong area of the Tibetan Plateau monitored by remote sensing. Journal of Glaciology and Geocryology, 24(5): 559-562. [In Chinese]

[25]. Ng, F., S. Liu, B. Mavlyudov, and Y. Wang (2007), Climatic control on the peak discharge of glacier outburst floods, Geophys. Res. Lett., 34, L21503, doi:10.1029/ 2007GL031426.

[26]. Niu L, Ye B S, Li J, et al. Effect of permafrost degradation on hydrological processes in typical basins with varying permafrost coverage in Western China. Sci China Earth Sci, 2010, 53: 1–10, doi: 10.1007/s11430-010-4073-1

[27]. Pang, Hongxi, He Yuanqing, Zhang Ningning, Li Zongxing, Wilfred H Theakstone, 2010, Observed Glaciohydrological Changes in China's Typical Monsoonal Temperate Glacier

Region since 1980s Journal of Earth Science, 21(2): 179–188

[28]. Qin Dahe, Liu Shiyin, Li Peiji, 2006. Snow Cover Distribution, Variability, and Response to Climate Change in Western China, Journal of Climate,19(9):1820-1833

[29]. Ren Guoyu, Guo Jun, Xu Mingzhi, Chu Ziying, Zhang Li, Zou Xukai, Li Qingxiang Liu Xiaoning, 2005, Climate change of China's mainland over the past half century, Acta meteorlogica Sinica, 63(6):942-956

[30]. Shangguan Dong-hui, Liu Shi-yin, Ding Yong-jian, Ding Lian-fu, Li Gang, 2004a. Glacier Changes at the Head of Yurungkax River in the West Kunlun Mountains in the Past 32 Years, Journal of Glaciology and Geocryology, 59(6)，855-862. [In Chinese]

[31]. Shangguan Dong-hui, Liu Shi-yin, Ding Yong-jian, Ding Lian-fu, 2004b. Monitoring Results of Glacier Changes in China Karakorum and Muztag Ata-Konggur Mountains by Remote Sensing, Journal of Glaciology and Geocryology, 26(3):374-375. [In Chinese]

[32]. Shangguan Donghui,Liu Shiyin, Ding Yongjian, et al. 2006, Monitoring the glacier changes in the Muztag Ata and Konggur Mountains on the east Pamirs Plateau with CGI and Landsat TM/ETM+ .Annals of Glaciology. 43:79 – 85

[33]. Shangguan Donghui, Liu Shiyin, Ding Yongjian,Li Jing, Zhang Yong et al. 2007. Glacier Changes in the West Kunlun Mountains, China from 1970 to 2001 derived from Landsat TM/ETM+ and Chinese Glacier Inventory data, Annals of Glaciology, 46 (in Press).

[34]. Xie Changwei, Yongjian Ding, Shiyin Liu, Response of meltwater runoff to air-temperature fluctuations on Keqikaer glacier, south slope of Tuomuer mountain, western China, Annals of Glaciogy, 2006, 43(1): 275-279.

[35]. Xu, CC; Chen, YN; Hamid, Y, et al., 2009, Long-term change of seasonal snow cover and its effects on river runoff in the Tarim River basin, northwestern China, Hydrol. Process. 23, 2045–2055

[36]. Yao T., Z. Li, W. Yang, X. Guo, L Zhu, S. Kang, H Wu., and W Wu, 2010, the glacier distribution, mass balance characteristics and their on the lakes in Yaluzangbu River Basin, Chinese Science Bulletin, (in Press)

[37]. Yao Tandong, Liu Shiyin, Pu Jiancheng, Shen Yongping, Lu Anxin, 2004. The retreat of glacier in high Asia and its effect on water resources in northwest China, Sciences in China (D), 34(6): 535-543.

[38]. Ye, B., D. Yang, K. Jiao, T. Han, Z. Jin, H. Yang, and Z. Li (2005), The Urumqi River source Glacier No. 1, Tianshan, China: Changes over the past 45 years, Geophys. Res. Lett., 32, L21504, doi:10.1029/2005GL024178.

[39]. Ye, B., D. Yang, Z. Zhang, and D. L. Kane (2009), Variation of hydrological regime with permafrost coverage over Lena Basin in Siberia, J. Geophys. Res., 114, D07102, doi:10.1029/2008JD010537.

[40]. Ye B, Yang D, Ding Y, Han TD, Toshio Koike, 2004. A bias-corrected precipitation climatology for China. J. of Hydrometeorology, 5(6): 1147–1160.

[41]. Ye, B., P. Chen, D. Yang, Y. Ding and T. Han, 2008, effects of bias-correction on changing tendency of precipitation over China, J. of Glaciology and Geocryology, 30(5):718-725
[42]. Zhang Yong, Liu Shiyin, Xie Changwei, Ding Yongjian, 2006a，Application of a degree-day model for the determination of contributions to glacier meltwater and runoff near Keqicar Baqi Glacier, southwest Tianshan Mountains. Annals of Glaciology, 43:280-284
[43]. Zhang Yong, Shiyin Liu, Yongjian Ding, 2006b, Observed degree-day factors and their spatial variation on glaciers in western China, Annals of Glaciology, 43: 301-306
[44]. Zhang Yong , Shiyin Liu, Junli Xu, Donghui Shangguan, 2007b, Glacier change and glacier runoff variation in the Tuotuo River basin, the source region of Yangtze River in western China, Environ Geol (2008) 56:59–68 DOI 10.1007/s00254-007-1139-2
[45]. ZHANG Yong, LIU Shiyin, DING Yongjian, 2007a,Glacier meltwater and runoff modelling, Keqicar Baqi glacier, southwestern Tien Shan, China, Journal of Glaciology, 53(180):91-98.
[46]. Zhang shiqiang, Ding yongjian, Ye Baisheng, 2006, The monthly discharge simulation/construction on upper Yangtze River with absent or poor data Coverage, Liu Zhiyu & Yang Dawen edit, Proceedings of the international symposium on flood forecasting and water resources assessment for IAHS-PUB,324-333Chen Caiping and Ding Yongjian, The application of artificial neural networks to simulate meltwater runoff of Keqikaer Glacier, south slope of Mt. Tuomuer, western China, Environ Geol (2009) 57:1839–1845, DOI 10.1007/s00254-008-1471-1
[47]. Zhao Q., Z. Liu, B. Ye, Y. Qin, Z.Wei and S. Fang, 2009, snowmelt runoff forecasting model coupling WRF and DHSVM, Hydrol. Earth Syst. Sci., 13, 1897–1906.
[48]. Zhou S Q, Kang S C, Gao T G, et al. 2010, Response of Zhadang Glacier runoff in Nam Co Basin, Tibet, to changes in air temperature and precipitation form. Chinese Sci Bull, 55: 2103−2110, doi: 10.1007/s11434-010-3290-5

CHAPTER 5 THE PROGRESSES OF WATER QUALITY RESEARCH IN CHINA

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5.1 OVERVIEW

The continuously rapid growth of China's economy since the reform and opening up is rarely seen in the history of world economy. However, the process of China's economic development is still basically characterized by extensiveness and a considerable part of the growth has been obtained at the cost of sacrificing ecological environment and great consumption of resources. The continuously rapid economic growth has brought about a huge pressure on China's urban and rural ecological environments and led to even more serious damage to water environment and ecology.

According to the environmental bulletins published by the State Environmental Protection Administration (State Environmental Protection Administration of China, China Environmental Bulletins in 2002-2005), in recent years, the major rivers of China are generally confronted with organic pollution; the situation of surface-source pollution is becoming increasingly serious; and the proportion of rivers with Grade IV water or under in the major rivers is up to 53.7%---64 % (see Table 1). Dianchi Lake, Taihu Lake and Chaohu Lake have seen a rising trend of eutrophication (see Table 2).

Table 1. Water Quality of China's Major Rivers

Year	Grade I-III	Grade IV- V	under Grade V
2002	46.3％(main stream)	26.1％(main stream)	27.6％(main stream)
2003	53.4％(main stream)	37.3％(main stream)	9.3％(main stream)
2004	36.3％(main stream)	33.9％(main stream)	29.8％(main stream)
2005	36％(main stream)	40％(main stream)	24％(main stream)

Table 2. Water Quality of Dianchi Lake, Taihu Lake and Chaohu Lake

Lake	Year	Water quality assessment
Taihu	2002	In 20 water quality monitoring points, the proportion of sections with grade V or under was 60%. Major pollutants were TN and TP, and the lake was in a state of moderate eutrophication.
	2003	Compared with the previous year, the lake was polluted seriously, in which the proportion of sections with grave V or under was up to 85.7%, and without grave Ⅰ～Ⅲ.
	2004	The contents of nitrogen and phosphorus in 21 water quality monitoring points were seriously excessive of the limits and the lake was in a state of moderate eutrophication.
	2005	Compared with the previous year, there was no significant change in Lake water. The permanganate indexes and the average of the TP reached the requirements of planning.
Dianchi	2002	The water quality was under grade V; nitrogen and phosphorus pollution was very striking; and eutrophication was serious. The permanganate indexes reached the requirements of planning.
	2003	The pollution was still serious. Compared with the previous year, the water quality declined slightly. The main polluted indexes were nitrogen and phosphorus. the lake was in a state of serious eutrophication.
	2004	Although the water quality of the lake had improved, the pollution was still serious. The permanganate indexes reached the requirements of the grave Ⅲ and eutrophication was serious.
	2005	The water quality in 10 monitoring points was under grade V; Chaohai lake pollution was striking; and the Waihai lake was better in a state of moderate eutrophication. Compared with the previous year, there was no significant change in Lake water.
	2002	The water quality of the 12 monitoring points was of grade V or under entirely; and the water body is in a state of eutrophication.
	2003	The water quality in 50% of 12 monitoring point was under grade V; the contents of total nitrogen and total phosphorus exceeded the limits; and the water body was in a state of moderate eutrophication.

Chaohu	2004	Compared with the previous year, there was no significant change in Lake water. The pollution of the western half of the lake was more serious than that of the eastern half; the western half was in a state of moderate eutrophication; the eastern half was in a state of moderate nutrition.
	2005	The water quality of all of the 12 monitoring points was under grade V; The pollution of the western half of the lake was more serious than that of the eastern half, and the lake was in a state of moderate eutrophication.

Though the sewage treatment rate in China is continuously increasing, the volume of sewage discharged every year is still rising rapidly. The total volume of sewage discharged in whole China in 2005 was 8.5 billion ton more than that in 2002; and the total volume of COD discharged increased by 472 thousand ton (see Table 3).

Table 3. The Situation of Sewage and COD Discharge in China

Year	Volume of sewage discharged（million ton）			Volume of COD discharged（thousand ton）		
	Total	Industrial	Domestic	Total	Industrial	Domestic
2002	43950	20720	23230	13670	5840	7830
2003	46000	21240	24760	13336	5119	8217
2004	48240	22110	26130	13392	5097	8295
2005	52450	24310	28140	14142	5548	8594

The quality of ground water also allows no optimism. According to the circular from the Ministry of Land and Resources about the situations of ground water in the major cities and area of China in 2005, the statistical analysis of the quality of ground water in 160 cities and areas in all parts of the country shows that the overall quality of ground water is in a relatively stable situation, but the ground water in most cities has suffered point-sources and non-point sources pollution to a certain extent and the contents of some elements in some places have exceeded the limits. The main pollution elements include total solids, total hardness, sulfate, nitrate, nitrite, ammonia nitrogen, chloride, fluoride, pH value, iron and manganese.

The ground water pollution elements in the major cities of northeast China mainly include total hardness, total solids, nitrate, nitrite, iron and manganese and then sulfate and chloride. The ground water pollution elements in the major cities and areas of north China mainly include total hardness and total solids and then sulfate, nitrate, chloride and fluoride. The total hardness and total solids of ground water in this region are seriously excessive of the limits. Especially in Handan City and Tangshan City of Hebei Province, the total hardness is seriously excessive of the limit and the water quality is very poor. The total numbers of bacteria and bacillus coli colonies are obviously excessive of the limits in Xuchang City of Henan Province. The ground water pollution elements in the major cities of Northwest China mainly include total solids, total hardness, nitrate and sulfate and then chloride, fluoride, nitrite and ammonia nitrogen. In addition, the pollution of chromium (VI) in Xi'an City and Hanzhong City of Shanxi Province is excessive of the limit. The ground water pollution elements in the major cities of south China mainly include nitrite, ammonia nitrogen, iron, manganese, total hardness and nitrate. In addition, the ground water of some cities is acidic and the pH value is seriously excessive of the limit. The excessive ground water pollution elements in the major cities and areas of central south mainly include nitrite, nitrate, ammonia nitrogen, iron and manganese and then total hardness, fluoride and pH value. The pollution of iron and manganese is mainly caused by the primitive environment and this pollution is very common. The ground water pollution elements in the major cities and areas of Southwest China mainly include total hardness, total solids, nitrite, ammonia nitrogen, iron and manganese and fluoride, sulfate, organic phenol, oxygen consumption and pH value. The pollution elements are mainly distributed in a point type and the limit-exceeding rate is low.

Generally speaking, the characteristics of ground water pollution in China are as follows: In terms of the degree of pollution, the pollution in the northern cities is generally more serious than that in the southern cities; the number of pollution elements is big and the limit-exceeding rate is high; and the pollution in North China is especially serious. In terms of pollution elements, the pollution of "three nitrogen components" is serious in all parts of China. The pollution of total solids and total hardness is mainly distributed in the northeast, north, northwest and southwest regions. The pollution of iron and manganese is mainly distributed in the south. In respect of the trend of change, the quality of ground water in most cities is becoming stable or rising slightly; the ground pollution in some cities and areas is aggravating, to which we should pay more attentions.

5.2 WATER PURIFICATION AND TREATMENT TECHNOLOGY

Super critical water oxidization (SCWO) is a new oxidization technology that can completely destroy the structure of organic pollutants and has unique advantages in wastewater treatment. However, China's research in this aspect has just broken the ice. In the treatment of wastewater containing aromatic compounds, Sun Yinghuang and some other experts have used this technology and studied the influence of temperature, pressure and retention period on the rate of phenol removal in intermittent and continuous reactors under sub-critical and critical conditions. They have found that the removal rate increases with the increase of temperature, pressure, and retention time. The removal rate of phenol can reach 96% or more during a short retention time, and the highest removal rate of acetic acid in wastewater is 99%. Yao Hua and other persons have also made preliminary studies on phenol or nitrobenzene in different wastewater with SCWO method. The result of their studies indicates that SCWO may produce a very good effect for removing the phenol and nitrobenzene; and the rate of the degradation of organic components can reach more than 96% in a very short retention period. Qi Xinhua has studied the aniline wastewater Scwo reaction with hydrogen peroxide as an oxidant. The research indicates that the Scwo technology to deal with the high percentage aniline wastewater is effective (SUN Yinghuang, 2005).

Membrane biological reactor (MBR) is an efficient wastewater treatment technology that has been developed in recent years. Although membrane technique is of virtues as high quality filtrate, low lump-sum investment, taking up not much land, low motion cost, there is a problem of the membrane fouling pollutions and some pathogens in the filtrate, sometimes with water color, odor and other fly in the ointment. The technology of ultrasonic and ozone oxidation is a new technique to clean the biomembrane (MBR) element using membrane technique, ozone oxidation technique and modern ultrasonic wave cleaning technique based on the traditional technology of disposing and recovering of class biochemistry waste water. It can clean up the pollutants which stuck inside and outside the surface of the membrane, and can avoid the harm to membrane from the pollution to environment from the detergent, using modern ultrasonic technique. With strong oxidation of ozone, it can completely remove the possible harm to persons who use the recovery waste water from bacterium, peculiar sell, colority, etc, by using ozone oxidation technique, and make disposed waste water really safe and daily life water. The cleaning process of membrane components with the ultrasonic is that the use of ultrasonic energy in this special form, washing the pollutants attached to the outside wall of membrane components, peeling the pollutants, thus restoring the membrane flux and filtration. The procession can prolonged the life of membranes and increased the membrane replacement cycle, thereby achieved the purposes of increasing MBR economic (Zhao Kunyu, 2006).

Membrane filtration technique is a liquid separation technology, with high efficiency, low energy consumption and easy operation. Compared to traditional methods of wastewater treatment, membrane technology has many advantages, such as the circulatory use of wastewater and recovery of useful substances. The application of membrane separation process in wastewater treatment mainly includes several membrane filtration techniques, such as micro-filtration, electro dialysis, reverse osmosis, ultra-filtration, nano-filtration and so on. Membrane filtration techniques have been researched deeply in the treatment of wastewater containing oil, dye, heavy metal and organic compounds with high concentration. The treated water is transparent; Tang Yanhui et al. has used ultra filtration membrane to treat the oily wastewater. Experiments showed that CODcr decreased from 728.64 mg / L to 87.8 mg / L, oil concentration from 5000 mg / L to 2.5 mg / L, the removal rates were respectively 87.95% and 99.95%. The treated sewage effluent has reached national emission standards. Yang gang et al. has used nano-filtration technology to treat the dye wastewater. When the pressure is 1.8 MPa, the concentration of NaCl from 1.05 mol / L dropped to 0 .049 mol / L and the NT concentration concentrated from0.14 mol / L to 0.25 mol / L above. The average retention rate of NT components has reached to 99.8%. The Membrane filtration technique also has obtained impactful effect in the treatment of organic compounds wastewater with high concentration.. Wang et al. have used the IMBR to treat the beer wastewater. When the retention period of hydraulic force is3.5—5 h and the COD load is 3.54 ~ 6.225 kg/(m3.d), the removal rates of COD, NH3-N, SS and turbidity in wastewater are respectively 96%,99%,90% and 100%(Xu Dezhi,2006).

According to the characteristic of heavy concentration municipal wastewater in cities in northern china, the treatment technique of sequencing batch reactor (SBR) is adopted to treat the wastewater. Xue Yingwen et al. have used the SBR method to treat the municipal waste water of ShiHeZi in XinJiang Province. Through this experiment, it proves that the SBR technique has a high effect on removing COD、TN、NH4+、-N and TP. When COD, TN, NH4+, -N, TP concentration are respectively 1231.2, 31.32, 20.67, 8.55mg/L in the raw sewage, the treated sewage effluent COD, TN, NH4 +, N, TP concentration dropped to 70.13, 12.81, 12.28, 0.85mg/L, respectively. The removal rates are respectively 94.3%, 59.09%, 40.6%, 90.02% and the wastewater reaches to the discharge standards of level 1(COD, NH4+, -N)and level 2 (P). Based on the experiments including the enrichment culture of EM, the formation of biofilm and the application of biofilm technology in wastewater treatment, Tian Na et al. (2005) have obtained the following conclusions: 1 When the filings and compound culture medium are cultivated together, EM can attach to the fillings and form biological films, and under the condition of 30℃ or more and sufficient aeration rate, biological films come into being in 10 days or so after cultivation using attapulgite clay and montmorillonite as fillings. 2 In sequence batch reactor (SBR), the removal rate of CODCr in domestic sewage can reach 80%-90% when attapulgite clay and montmorillonite a used as fillings (Xue Yingwen, 2005).

Luo et al. (2000) have combined magnetic treatment and artificial ecological system together for purifying organic wastewater. The result indicates that instantaneous magnetic treatment can directly remove about 20% of the COD in sewage; afterwards, the ecological effects caused by magnetization can promote the conversion of food chain and obviously improve the effects of purification. Xia Liqun et al. (2005) have used phyto-remediation technology to the treatment of wastewater in the coastal sea, such as Mariculture eutrophication, Oil and other organic pollution, red tide, heavy metal pollution of the coastal sea and so on. The advantages of the phyto-remediation technology in coastal pollution abatement includes: 1. it is acceptable to people because of its slight side effect for human and marine environment and its small ecological risk; 2. its post treatment is easy, and with little wastes, emissions, and problems left, it won’t cause secondary pollutions; 3. it contributes to ecological landscaping; 4. its output is large (Xia Liqun, 2005).

Qi jian et al. (2006) has studied the TiO2photo-catalytic oxidation technique for treatment of environmental pollutants. The mechanisms of TiO_2 photo-catalytic oxidation technique， preparation of catalyst and application of both suspended and immobilized TiO_2 to the treatment of organic pollutants were introduced. It is presented that suspended TiO_2 is mainly used in wastewater treatment， while immobilized TiO_2 can be used in the treatment of wastewater and leachate from landfill and the purification of environment. The development tendency of suspended $TiO_2$is to improve its activity and application to the surface deposition of heavy metals，surface coupling，surface sensitization，and intermingle of transition metal. The research tendency of immobilized TiO_2 is to improve its catalytic activity， to choose suitable carrier and make the best of it， to strengthen the combination between photo-catalytic oxidation and other techniques， and to use solar energy as light source. Qi Qiaoyan et al. (2006) have used TiO_2/AC in fluid bed reactor to degrade the Rhodamine B dye wastewater. The photocatalysis degradation reaction kinetics and degradation mechanisms of rhodamine B were studied. The results indicate that the degradation process conforms to the equation of first order kinetics. According to degradation mechanism, color group aniline and carbonyl of rhodamine B were destroyed, then the intermediary products were degraded gradually (Qi jian, 2006).

5.3 WATER QUALITY AND SAFETY

The quality of water environment is closely related to the people’s life and water produces influences on human beings directly or indirectly through plants and animals. Many accidents arising out of water environment pollution have happened every year and consequently led to huge economic losses. The water environment in rural areas is worsening with every passing day and the water hygiene conditions in such areas are very poor. The overall situation of water environment in Shandong is worsening. The shortage of water resources and conflict between water supply and water demand are both serious, and it is difficult to ensure the water supply for ecological use. Large amount of industrial, agricultural, and sanitary wastewater discharged into rivers leads to serious water pollution and deteriorates ecological environment. With the development of economy, water environment safety of Shandong Province is facing great challenges. Comprehensive measures, including water diversion and water-saving measures should be adopted. Clean production should be put into practice actively and pollutant emission should be controlled strictly (Ren Lijun, 2005).

Nowadays almost all the countries are concerned of the exploitation and land harnessing along big river watershed. Industry clusters of high density and high intensity under the great exploitation in Jiangsu Province along the Yangtze River will bring pressure onto the water quality in the river. On the basis of the social，economical and investigated environmental monitoring data, the results revealed that the pollutant load of Yangtze River in Jiangsu province contains 210 997.80 × 10^4t total waste water，380 817.20 t COD_{Cr} and 28 391.36t of NH_3-N in 2002，and will be 395 977.10 × 104 t, 598 197.80 t and 42 381.56 t respectively in 2010 as predict, with the increase ratio being 87.7 %，57.1 % and 49.3 % respectively. As for the polluted source treatment, more than 90% industrial waste water have met the discharge standard in China，but both domestic sewage disposal plant number and treatment depth can not meet the actual increase of domestic sewage treatment. On the purpose of the protection of ecological environment and the water source security，several principal countermeasures such as optimizing industrial structure, cutting down the pollutant load, strengthening the waste water treatment plant building and improving the main creeks treatment in the area are put forward(Yu Zhonghua, 2005).

At the same time, the pollution of non-point pollutant and sewage has been more serious with the expansion of towns in Jiangsu, China. The concentration of pollutant is high and its discharging is concentrated during urbanization, which was pushed by industrialization in Southern Jiangsu. River water quality has deteriorated rapidly that has been a new carrier of pollutant to decrease environmental capacity of water. The countermeasures to control water environment include implementing ecological engineering and environmental engineering, reinforcing environmental programming and management in the process of urbanization, and encouraging the population who are not peasantry to concentrate to the main towns nearby.(Li xin, 2005).

The major problems with drinking water in China's rural areas are caused by decentralized water supply and reflected in the aspects of seriously excessive microorganisms, poor states for sense organs (mainly including color, turbidity and excessive iron and manganese contents) and serious organic pollution. The microbial pollution of drinking water is still a very serious problem in rural areas at present. It's a long-term task for the public health and anti-epidemic workers to strengthen the sterilization and hygiene management of drinking water in rural areas and prevent the prevalence of hygrophilous epidemic diseases. Many places in the south use water from lakes and reservoirs as domestic drinking water, but most of these lakes and reservoirs are in a state of eutrophication. Therefore, studies on algal toxicants and antiphytes are an important link for improving the quality of municipal water supply. Furthermore, the halogenated hydrocarbon compounds resulted from the sterilization of city water with chlorine have become a new pollution source (Yin Jie, 2005).

Most of the water quality indexes of the drinking water sources in Anhui Province are problematic and the major problem is the seriously excessive content of bacteria caused by pollution. There is domestic pollution or industrial pollution around more than 70% of the water sources and hygiene protection facilities are very poor. Karst groundwater sources in Huaibei City, the coli was 3-18 个/L in general and the phenol content in some wells reached to 0.003mg/l. From 1968 to 2000, there were 66 people died of cancer because of drinking the groundwater including harmful substances 4.1-21.4 times more than the national standard of groundwater in Huaibei City District Shitai Duji Liu Village. Examination of the past five years, 13 were found suffering from liver cancer and stomach cancer. The water supply facilities in most areas are simple and short of complete technological processes; and the quality of most of the water supplied to consumers cannot reach the national standard on the sanitation of drinking water (Zhang Xin, 2004).

The pollution of domestic drinking water sources in cities is even more serious. According to Xi'an City Water Company's investigation of the water quality of its ground water source (the Yellow River) and the upper stream, because of the discharge of domestic sewage near the water source, bacillus coli colony is the principal pollutant in all stream segments (Liu, 2006). The pollution of drinking water leads to the appearance of large amounts of algae. Some algae can produce algal toxicant, which is very harmful to human health. It's discovered in research that mycrocystin toxicant in Dianshan Lake, Taihu Lake and Chaohu Lake is probably a non-genetic toxic carcinogen or supplementary carcinogen and its pollution of water is possibly one of the important factors of drinking water-incurred cancer; and the traditional drinking water sterilization method can not entirely eliminate algal toxicants in water (China Environmental Bulletins, 2005).

Gao Jijun et al. (2004) had studied the concentrations distribution of the Cu, Hg, Cd, As in drinking water in the 8 city districts and 10 counties in Beingjing based on a total of 120 random samples. Health risks associated with 4 metals in drinking water were assessed using USEPA health risk assessment model. The results showed that the concentrations of the heavy metals in drinking water in Beijing ranged from 0.81 to 6.96 μg /L for Cu, 0.34~0.82 μg /L for Cd, 0.10~0.74 μg /L for Hg and 0.19~3.02 μg /L for As. Among the health risks caused by the carcinogens in drinking water, the largest risk associated with As should be in Tongzhou county (2.0 × 10-5. a-1) and that with Cd should be in Changping County (2.3 × 10-6. a-1), while both were significantly lower than the maximum allowance levels recommended by ICRP (5 × 10-5. a-1). Among the non-carcinogenic risks levels ranged from 10-8 to 10-9, much lower than the maximum allowance levels recommended by ICRP (Gao Jijun, 2004). Yang Liujun (2006) had analyzed the water quality safety in source area of Honggang water plant in NanTong according to the influence of carrying capacity of environment, pollution sources, and spill accidents in the source area. It is concluded that the water environment capacity is large in the water function region. Pollution sources into the river have little impacts on water quality, while the oil spill accidents in the petrol products loading wharf are threatening the water quality safety. Emergency measures should be put forward and adopted to alleviate and avoid the harms caused by risk accidents.

There are also reports about ground water pollution. By the end of 1999, due to severe exploiting of underground water, the North China Plain had been the world's largest underground water landing funnel, with a total area of the 5×104km2 above, and there had been linked together into one mass. Excessive exploitation of underground water resulted in the shortage of urban water resources and deterioration of groundwater quality. Yu Kaining (2003) discussed the impact mechanisms and positive-negative effects of urbanization on groundwater quality based on a three-year study in Shijiazhuang by quantitative calculation and analysis of urbanization level and groundwater pollution. The results show that growth of urbanization is helpful to improve the groundwater quality, but may easily result in salt pollution.

The result of studies made by Zhu Zheng (2005) on the causes of the groundwater pollution of all big cities in Shanxi Province from the polluting paths of the groundwater indicates the polluting trend of the groundwater of Shanxi province, and points out that the groundwater pollution and its land-sourced pollution present the positive correlation. The major sources of groundwater pollution in Shanxi province are the following: 1. industrial sewage is a major one, especially the untreated industrial wastewater and the sewage under the discharge standards; 2. a large of sewage from life is one of the reasons for groundwater contamination. 3. An industrial solid wastes and life garbage pollute the groundwater certainly. 4. The sewage irrigation in agricultural production and an unreasonable application of fertilizers and pesticides result in pollution of groundwater by the water infiltration. 5. There are no measures to prevent the infiltration of the sewage drains. 6. The over-exploitation of groundwater makes the water level dropped sharply causes the hydraulic communication of the aquifer, so that pollution caused by the shallow water polluted the deep water. 7. The consecutive drought drier in recent years in Shanxi was resulted the increase of hardness in the shallow groundwater generally.

Liulin Well, as the biggest well in Luliang region, is one of the major protective wells, and the main water resources for the electric-coal zone and three counties (Lishi County, Zhongyang County, and Liuling County) of Luliang Region as well. Since 1990s, a lot of changes in the water source area have been taken place. A group of the pollution and harmful elements constantly increased, in which the harmful elements were various, such as coliform bacteria, sulfate, ammonia, fluoride, phenol, mercury, hexavalent Cadmium. From 1996 to 2003, the detection rate of these harmful elements and pollutants was 100% and in a gradual increasing trend, and some water overstepped the three GB groundwater quality standards. Water quality will be worsening further with the decrease of water and environmental changes (Kang Yinchang, 2003). Wang Yan’en (2005) has summed up the groundwater environment problems in Zaozhuang city and pointed out the countermeasures for its regulation. Shiliquan and Dingzhuang-Dongwangzhuang headwaters, the important water sources, have been over-exploited over a long period. The groundwater level had been continuously descending, which brought about hydrodynamic changes in groundwater. The groundwater undercuts the soil above, breaking the natural balance of rock and causing karst collapse. With the descending of groundwater level, the expansive clay formed in the Quaternary period in the rock formation of the Yicheng basin becomes desiccated and shrunk, forming fissures in the soil. The extraction of water from aquifer results in radially tensile zone of father wells, accelerating the desiccation fissure. The seepage of sanitary sewage and industrial wastewater into the aquifer causes serious groundwater pollution in Shiliquan.

5.4 WATER QUALITY STANDARD AND WATER QUALITY MONITORING METHOD

Water environment standard system is a complete management system for comprehensively planning the work of water environment standardization, coordinating the mutual relations and clarifying the functions and applicable scopes of the relevant standards. China's water environment standard system can be summed up in "five categories and three levels". The five categories include the standard of water environment quality, the standard of water pollutant discharge, the basic standard of water environment, the standard of water monitoring and analysis method and the standard of standard water environment samples; and the three levels including national level, industrial level and local level. However, the hygienic standard of water environment also contains a lot of information about water quality. By the end of July 2002, the State Environmental Protection Administration totally promulgated 370 national standards concerning water environment (exclusive of the hygienic standard of water environment), which account for 64.8% of the total national standards on environmental protection (Li Guibao, 2003).

China's water quality standard has been continuously improved since 1999. In 1999, the State Environmental Protection Administration approved the Standard of Environment Quality Standards for Surface Water (GHZB 1~1999), which was implemented as of Jan. 1, 2001. Because of the improperness of some selected indexes and values of indexes and for more effective coordination of interdepartmental relationship, in 2002, the State Environmental Protection Administration promulgated the amended Environment Quality Standards for Surface Water (GB 3838-2002), which has being implemented since June 1, 2002. One thing worth attention is that the index of oxygen consumption is added in the routine test items. The water conservancy system has built up 251 Water Environment Monitoring Center, 3228 types of surface water quality monitoring stations, and 11,620 groundwater monitoring stations. The national water quality monitoring network coverage all of the river and lake was established. The laboratory of 51 Water Environment Monitoring Center has achieved the national measurement certification, which accounted for 61.49% of the Water Quality Control Center System and included the Department of the provincial, regional and basin water environment monitoring center (Li and Zhou, 2003).

The Standard of Water Quality for Industrial Boilers (GB 1576-2001) was promulgated in 2001. The water quality-related standards promulgated by the other industries and departments include: Standard of Water Quality for Miscellaneous Domestic Water Consumptions (CJ/T 48-1999), Quality Standard for Reclaimed Wastewater Reused as Scenic Water (CJ/T 95-2000), Water Quality Standard for Fine Drinking Water (CJ 94-1999), Standard of Water Quality for Domestic Drinking Water Sources (CJ 3020-1999), Discharge Standard for Municipal

Wastewater (CJ 3082-1999), Foods without Public Nuisance--Quality of Drinking Water for Domestic Animals and Fowls (NY 5027-2001), Foods without Public Nuisance--Quality of Water for Livestock Product Processing (NY 5028-2001) and Standard of Water Quality for Petrochemical Water Supply and Drainage (SH 3099-2000) (Sun and Li, 2006).

The standards on water quality monitoring methods mainly include two categories, i.e. the standards of water sampling, sample keeping and management technology and the standards of experiment analysis and determination method. By the end of Sep. 2001, the State Environmental Protection Administration totally promulgated 134 national standards about water quality monitoring methods, which accounted for 58.5% of the total national standards on environmental protection. In the promulgated standards, there are 6 standards about water sampling (including the design of sampling, technical guidance, sample keeping, sampling of water in lakes and reservoirs, the general principles for rainfall sampling and the collection and keeping of samples), 3 standards about the determination of the physical properties of water (temperature, color and turbidity), 2 standards about industrial wastewater test method (test of total nitro-compounds), 4 standards about aquatic organisms and their toxicity (determination of microorganisms, determination of acute toxicity, determination of various substances’ acute toxicity to algae and determination of various substances ¡¯ acute toxicity to freshwater fish), 11 standards about rainfall test method, 13 standards about the method for determining radioactive substances in water (mainly including strontium, uranium, radium-226, thorium, kalium-40, plutonium, polonium and iodine-131); 25 standards about organic pollutant determination method and 70 standards about the determination of inorganic pollutants in water. However, all these standards were promulgated before 1998.

In the industrial standards promulgated by the State Environmental Protection Administration, there are 14 standards about water quality analysis and determination methods, all of which have been promulgated in recent years. These standards specify the methods for determining boron, trichloro-aldehyde, total salt, beryllium, sulfide, chemical oxygen demand of perchloric wastewater, total organic carbon, repeftal, dibutyl phthalate, vinyl cyanide, chlorobenzene, polychlorinated benzodioxole, polychlorinated benzofuran, absorbable organic halogen (AOX), inorganic negative ion and etc. The quality of water environmental monitoring stations is a problem at present. From 1998 to 2001, the Ministry of Water Resources made a measurement accreditation and changed the working permit. Based no the Statistical examination pass rate from the spot checks, checks 1st examination failure rate is 33% in 1999, 36% in 2000, and 42% in 2000. The quality of monitoring has seen a decline phenomenon. The quality of the staff also needs to be further improved (Gao Juan and Li Guibao, 2006).

5.5 WATER QUALITY PLANNING AND ASSESSMENT

Because of water deficiency, many cities and areas have made water resources planning in recent years. Water quality (water environment) is an important part of the planning. Hu Jinmin (2005) has studied the content of the overall water environment plan of Shijinghe city and the planning method. Yang Jie et al (2004) has comprehensively evaluated the water quality of the Wuhan reach in Hanjiang River with the artificial neural network (ANN) method. In the comprehensive evaluation of water quality, the results obtained by using those traditional methods for determining the weighting factors are normally quite subjective. ANN method now can effectively exclude the interference of some subjective factors in determining the weighting factors. A three-layer back-propagation (BP) ANN model is constructed for the comprehensive evaluation of the multi-factor water quality. Taking BOD5, NH3-N and TP as the evaluation factors, the application of this ANN method indeed are more objective than those obtained by the traditional methods and are very consistent with the observation.

The water bodies with different environmental functions in the areas crisscrossed by waterways have different requirements on water quality. Xu and Chen (2005) have assessed the water quality of one reach of the Cache River with the synthetic index method and grey clustering method. The monitoring sites of water quality were arranged according to the water quality characteristics of wastewater, and the pollution sources and hydrogeology were investigated comprehensively. Based on the water quality assessment on main factors selected, it is concluded that the results of the two methods are almost the same, but the result from synthetic index method is more suitable and correct. In view of the uncertainty of indexes for evaluating water quality, Zhang and Liang (2005) applied the entropy value theory to combine with fuzzy matter-element method to establish an entropy fuzzy matter-element model. The coefficients of weight in this model are derived from the avail value of data reflecting the information entropy， by this method the problem of weight allocation can be avoided . The calculation result for an example is compared with those by integrated evaluating method and attribute recognition model. It indicates that the proposed method is reasonable and practical.

Many articles have published in respect of water environment quality appraisal, but few substantial breakthroughs have been made. Li and Zhao (2004) have discussed the model of the appraisement and the forecast for the Chaniang River’s water quality, carried through qualitative and quantitative analysis on the recapitulative situation and inter local distributing of the Changjiang river's water quality for near two years. Based on the mainly statistic datum for near ten years (hydrology years), some compounding models in consisting of several kinds of excessive functions, and trendlines of relatively statistic datum have given, in which developing trend of the percentage of every kind of water quality I -V, in ferior V and the trend of the quantity of pollution water (wastewater) have shown, At the same time the state of water pollution of the Changjiang river's water for future 7 years have been forecasted. In the end some suggestion to solve the problem of water pollution of Changjiang River has been listed. Combined with the project of Comprehensive Assessment for River Water Quality and Quantity, Xu Yeping (2005) reviewed sampling interval, water quality simulation and prediction, water quality evaluation for different quantities，dynamic water environment capacity evaluation. Methods, technique line，and available conclusions of the research were introduced，and suggestions for further study were also made.

Based on water resources survey and evaluation in China, Tang et al. (2006) analyzed the groundwater quality systematically. The assessment of the hydrochemical of groundwater shows that most groundwater is of bicarbonate type with high hardness and TDS (Total Suspended Solids). The PH of groundwater is mostly neutral and alkalescent. As the groundwater quality is poor naturally, the recognition of hydrogeochemical characteristics of natural groundwater is important for the groundwater quality protection. Through analyzing the comparison of the consistency of over-standard parameters with the evaluation results and statistical analyses of the distribution features in the groundwater samples, Zhang and Yan (2005) adopted the fuzzy evaluation method as a suitable method to evaluate the groundwater quality in Tianjin. The evaluation results show that phreatic water in Tianjin is of bad quality, and the area of water in Class Ⅴ of national surface water quality standard accounts for 70 percent of the total plain area, and the quality of deep confined groundwater is also bad, with the Ⅴ class water accounting for40 to 50 percent of the total area.

In accordance with the characteristics of the organic pollution on the groundwater, Yin and He (2006) established a graded comprehensive index model, with clarified levels and explicit physical significance, is established herein based on both the limit of detection and the single contaminated factor standardized in the secondary standard given in the relevant EPA water quality standard; with which the problems from the range produced from the primary evaluation standard concerned are avoided. The case study demonstrates that better applicability to evaluate the organic pollution on the quality of the groundwater can be obtained from the model.

Recently, as economy is rapidly thriving in Urumqi-Chanji region and a new economic development area in the east of Miquan is quickly extending, more and more water supply is urgently needed. On the other hand, because of the especially geographic position of the city, surface water in the region has been polluted, resulting in contamination of groundwater at some degree. Zeng (2006) have collected and analyzed several groundwater samples in the rural region in the city. Based on investigation, the quality of groundwater in country area of Miquan was evaluated and some suggestions on protecting and managing the water environment in the region were introduced.

5.6 WATER QUALITY SIMULATION AND CALCULATION

The establishment of water quality simulation model and calculation is indispensable for water quality planning and appraisal. The field of water quality simulation and calculation is very active. Chen Shouyu et al. (2005) have put forward a new model in comprehensive evaluation of water quality. Under systematic view, a comprehensive evaluation model for water quality was established based on variable fuzzy sets method, and the water quality evaluation was converted from the qualitative assessment to a quantitative one. The method can scientifically and reasonably determine membership degrees and relative membership functions of water quality indexes at level interval. Weights of indexes can be obtained binary comparison and quantification based on the importance of indexes. By calculating the characteristic value of each level, water quality of the Yongding River in Beijing was evaluated using the variable fuzzy sets method, which showed that the proposed method was feasible. The result of calculation indicates that this plan is effective and universal and applicable to various comprehensive environmental quality appraisals (Chen Shouyu, 2005).

Fan Li-ping and Yu Haibin et al. (2005) introduced the river water quality model No.1 (RWQM1) developed by the International Water Association (IWA). It is an effective approach to improve river water quality and to protect ecological environment by integrated management of urban wastewater with the view of better water quality. This model was described like the standard Activated Sludge Model (ASM) and the organic matter and nutrients were characterized by COD. Water quality constituents and model state variables characterizing circling of carbon， hydrogen， oxygen, nitrogen, and phosphorous were selected in the model to describe the cycling process under aerobic and anaerobic conditions. Connected directly with Activated Sludge Model (ASM), the model can be used in the decision，planning, monitoring of the integrated urban wastewater system(Fan and Yu, 2005).

WASP6 is an enhanced Windows version of the USEPA Water Quality Analysis Simulation Program (WASP).WASP 6 includes 4 dynamic equilibrium calculation processes, such as dissolved oxygen, eutrophication, toxic and organic compounds. The main features of WASP 6 are as follows:① the development of user-friendly Windows-based interface; ② include the WASP identifiable conversion data format; ③ eutrophication and organic contaminants with the efficient processing module; ④ the results of WASP with the measured one can be directly compared in curve. Yang and Xiao et al (2005) have used WASP6 to simulate the present water quality for Xiangfan Reach of the Hanjiang River. Water quality indices, including BOD5， NH3-N，and DO，were studied. The simulation results were verified using the field data in 2001. It is showed that the averaged relative error of BOD5，NH3-N，and DO are 10.7%，11.0%，and 5.6% respectively. Results indicated that the application of WASP6 to the water quality simulation in Hanjiang River is satisfactory.

Zhang Xingnan and Geng Qingzhai et al (2004) have developed a software system for simulating water quality based on the platform of GIS. It possesses the functions of input data processing, real-time modeling calculation and visualized output of calculation result. The interface of this system is friendly and the display of the output is directly perceivable. Water quality model coupled with the GIS have the advantages in some aspects : 1、the use of digital devices and GIS to sum and mesh the study area, will significantly reduce the preparatory work for the model, reduce human error and improve the accuracy; 2、the grid vector function of GIS can be used to produce high-quality color filled concentration distribution graph; 3、the spatial data processing functions of GIS calculated the real-time concentrations, the average concentration of the time and space and showed that output. Query Module can visit the results of inquiries. This can provide an effective and scientific instruments for the decision makers to monitor and manage the regional pollution; 4、 the model results are more directly and explicitly with the visual language system; 5、in combination with computer technology to achieve a centralized data management and information sharing. The system is applied to the information management system of aquatic environment capacity of Jiangsu Province, China.

Gong ChunSheng and Yaoqi et al (2006) have developed 2-D plane flow-water quality-bed sediment pollutant coupled model. The control equation of water quality considering the bed sediment pollutant is deduced according to the characteristics of turbulent disturbance. The equation is coupled with shallow flow equation to establish the depth averaged 2-D plane flow-water quality-sediment pollutant transport model. Under the framework of finite volume method, the Riemann approximate solver is applied to obtain the numerical solution of the equation. The model is used to simulate the total phosphorus transport in the Xuanwu Lake，Nanjing. The result is in good agreement with observation data.

References

[1] Chen Shou-yu, Guo Yu (2005). Application of variable fuzzy sets method in comprehensive evaluation of water quality [J]. Water Resource Protection, 21(6): 19-22 (in Chinese).

[2] Fan Li-ping，Yu Hai-bin，Yuan De-cheng (2005). Introduction and case studies ofriverwater quality model No.1 (RWQM 1) [J]. Water Resource Protection, 21(4): 4-8 (in Chinese).

[3] Gao Juan, Li Gui-bao，Hua Luo (2006). Development and problems of surface water environment monitoring [J]. Water Resource Protection, 22(1): 5-9 (in Chinese).

[4] Gao Ji-jun, Zhang Li-ping, Huang Sheng-biao et al. (2004). Preliminary health risk assessment of heavy metals in drinking waters in Beijing [J]. Environmental Science, 25(2): 47-50 (in Chinese).

[5] Gong Chun-sheng，Yao Qi，Fan Cheng-xinz et al.(2006). 2-D plane flow-water quality-bed sediment pollutant coupled model [J]. Hydraulic Engineering, 37(2): 205-210 (in Chinese).

[6] Guo Fei, Zhu Xue-yu, Liu Jian-li et al. (2004). Numerical modeling of contaminant transport in fracture-karst aquifer and measures for pollution remediation [J]. Hydraulic Engineering, 7:

57-63 (in Chinese).
[7] Han Long-xi, Lu Dong (2004). Prospects of water quality numerical simulation for plain river network [J]. Journal of Hohai University(Natural Sciences), 32(2): 127-130 (in Chinese).
[8] Kang Ying-chang, Zhao Gao-ze, Li Xin-hua (2003). Measures against groundwater pollution of Karsts of Liuling Well [J]. Ground Water, 25(1): 21-23 (in Chinese).
[9] Li Gui-bao (2003). Water quality monitoring for trans-boundary rivers [J]. Environmental Monitoring in China, 19(4): 60-63 (in Chinese).
[10] Li Gui-bao (2003). Water quality monitoring for trans-boundary rivers [J]. Environmental Monitoring in China, 19(5): 59-66 (in Chinese).
[11] Li Gui-bao, Hao Hong, Zhang Yan (2003). The development ot the water environmental quality criterion in China[J]. Hydrotechnics Monitoring, 3: 5-7 (in Chinese).
[12]Li Gui-bao, Zhou Huai-dong(2003). The development of the water environmental standardization in China[J]. Hydrotechnics Monitoring, 4: 1-3 (in Chinese).
[13] Li Xin, Jiao Feng (2005). Menace to Water Quality During the Process of Urbanization in Southern Jiangsu of China [J]. Environmental Protection Science, 31: 4-7 (in Chinese).
[14] Liu Xiu-hua (2006). Analysis of water environment contamination in X i'an city [J]. Journal of Northwest University (Natural Science Edition), 36(1): 157-160 (in Chinese).
[15] Liu Xue-fei, Hang Da-chao, Lv Lin et al. (2006). Discussion of the model for appraisement and forecast of the Changjiang River water quality [J]. Journal of Chongqing Three Gorges University, 22: 58-61 (in Chinese).
[16] Li Yu-lan, Zhao Wan-xing (2004). Simulation study of water quality for the Three Gorges Reservoir in Chongqing [J]. Journal of Chongqing University(Natural Science Edition), 27(11): 34-38 (in Chinese).
[17] Qi Jian，Chen Liang，Zhou Xuan (2006). Advances in research of TiO2photo-catalytic oxidation technique for treatment of environmental pollutants [J]. Water Resource Protection, 22(1): 15-19 (in Chinese).
[18] Qi Qiao-yan, Sun Jian-hui (2006). Kinetics and mechanisms of photocatalysis degradation of rhodamine B by supported nanometer TiO2 [J]. Water Resource Protection, 22(2): 56-59 (in Chinese).
[19] Ren Li-jun, An Qiang, Han Mei (2005). Problem and countermeasures of water environment

safety in Shandong Province [J]. Water Resource Protection, 21(3): 39-41 (in Chinese).
[20] SunTian-hua, Li Guibao, Fu Hua et al. (2006). Water environment standard and sustainable development of water resources [J]. Water Resource Protection, 22(1): 53-57 (in Chinese).
[21] Sun Ying-huang, Li Yan-xu, Chen Pei-yi, Wang Guo-sheng(2005). Supercritical water oiddation method and its application in organic wastewater treatment [J]. Water Resource Protection, 25(6): 75-78(in Chinese).
[22] Tang Ke-wang, Hou Jie, Tang Yun (2006). Assessment of groundwater quality in China: Hydrochemical characteristic of groundwater in plain area [J]. Water Resource Protection, 22(2): 1-5 (in Chinese).
[23] Tian Na, Zhu Liang (2005). Study on biodegradation using biofihn technology of EM [J]. Water Resource Protection, 21(6): 72-74(in Chinese).
[24] Tu Xiang-yang, Gao Xue-ping(2003). Application of fuzzy mathematical method in evaluation of seawater intrusion [J]. Hydraulic Engineering, 8: 64-69 (in Chinese).
[25] Wang Shao-ping, Cheng Sheng-tong, Jia Hai-feng et al. (2004). GIS and scenario analysis aid to water pollution control planning of river basin [J]. Environmental Science, 25(4): 32-37 (in Chinese).
[26] Wang Yan-en, Han Ru-zhao, Li Nian-guo (2005). Groundwater environment problem and countermeasures for regulation in Zaozhuang City [J]. Water Resource Protection, 21(1): 62-64 (in Chinese).
[27] Wang You-chuan, Xie Hong-yu, Wu Zheng-bing et al. (2003). Application of artificial neural network and GIS to water quality evaluaton[J]. Engineering Journak of Wuhan University, 36(3): 7-12 (in Chinese).
[28] Xu Dezhi, Xiang Bo, Shao Jianying, Li Yijiu(2006). Application of membrane technology to the industrial wastewater treatment [J]. Industrial Water Treatment, 26(4): 1-4 (in Chinese).
[29] Xu Ye-ping (2005).Compehensive assessment of water quality and quantity of rivers [J]. Water Resource Protection, 21(4): 34-37 (in Chinese).
[30] Xue Ying-wen, Cheng Xiao-ru, Zeng Yong et al. (2005). Experiment on high consistency municipal wastewater treatment using sequencing reactor [J]. Engineering Journal of WuHan University, 38(3): 92-95 (in Chinese).
[31] Xia Li-qun, Zhang Hong-lian, Jian Ji-chang et al. (2005). Sthudy on the application of

phytoremediation technology to the treatment of wastewater in the coastal sea [J]. Water Resource Protection, 21(1): 32-35(in Chinese).

[32] Yang Jie, Wu Yi-ming, Wan Biao(2004).ANN method for comprehensive evaluation of water quality in Hangjiang River [J]. Engineering Journak of Wuhan University, 37(1): 51-54 (in Chinese).

[33] Yang Liu-jun (2006). Water quality safety analysis of water source area of Honggang water plant [J]. Water Resource Protection, 22(2): 45-48 (in Chinese).

[34] Yang Jia-kuan, Xiao Bo，Liu Nian-feng et al. (2005). Simulation on the water quality for Xiangfan Reach of Hanjiang River using WASP6[J]. Water Resource Protection, 21(4): 8-10 (in Chinese).

[35] Yin Jie (2005). The major problems with drinking water in China's rural areas and the countermeasures [J]. Environmental Science in Chongqing, 27(5): 35-36 (in Chinese).

[36] Yin Shu-hua, He Jiang –tao, Zhong Zuo-shen (2006). Graded comprehensive index model for evaluation of organic pollution on groundwater [J]. Water Resources and Hydropower Engineering，37：56-58 (in Chinese).

[37] Yu Kai-ning, Wang Li, Du Qin-jun (2003). Positive and negative effects of urbanization on groundwater quality [J]. Earth Science—Journal of China University of Geosciences, 28(3): 333-336 (in Chinese).

[38] Yu Zhong-hua, Huang Wen-yu, Shu Jin-hua (2005). Water environment pollution load along the YangZe River in Jiangsu Province in the condition [J]. Resources and Environment in the Yangtze Basin, 14(3): 348-352 (in Chinese).

[39] Zhang Wei, Yan Xue-jun (2005). Evaluation of groundwater quality in Tianjin Ciy [J]. Water Resource Protection, 21(2): 31-35 (in Chinese).

[40] Zhang Wen-ge, Guan Xin-jian, Xu Qing-shan (2006). Water environment quality evaluation based on fuzzy nearness method [J]. Water Resource Protection, 22(2): 19-22 (in Chinese).

[41] Zhang Xian-qi，Liang Chuan (2005). Application of fuzzy matter-element model based on coefficients of entropy in comprehensive evaluation of water quality [J]. Hydraulic Engineering, 36(9): 1057-1061 (in Chinese).

[42] Zhang Xin, Zhou Tao-fa, Chen Fu-rong et al. (2004). Research on resources and environment in the process of sustainable development in Anhui Province [J]. Journal of

Hefei University of Technology (Social Sciences), 18(3): 109-115 (in Chinese).

[43] Zhang Xing-nan, Geng Qing-zhai, Pang Yong (2004). Integration research of water quality model with GIS [J]. Hydraulic Engineering, 1: 90-94 (in Chinese).

[44] Zhang Yun, Liu Chang-li, Liu Ping-gui et al. (2006). Pollution and prevention of heap garbage to the area of groundwater sources in Shijiazhuang [J]. Hydrological and Engineering Geology, 1: 115-119 (in Chinese).

[45]. Zhao Kun-yu,WuXiao-long, Piao Shang-xian(2006).The application of cleaning the biomernbrane with ultrasonics technique and ozone oxidation technique in the recovery of neutral waste water [J]. Environmental Science And Management, 31(1): 118-221(in Chinese).

[46] Zeng Rong (2006). Monitoring an evaluation on groundwater quality of a rural region in Miquan [J]. Journal of Agri-Environment Science, 25:306-309 (in Chinese).

[47] Zhu Zheng (2005). Analysis on an changing trend of the groundwater pollution of Shanxi Province [J]. SCI/TECH Information Development & Economy, 15(4): 102-103 (in Chinese).

CHAPTER 6 WATER RESOURCESS SYSTEM

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6.1 RESEARCH OF HYDROLOGY AND HYDROLOGICAL CYCLE

6.1.1 Research of Water Resources Evaluation

The evaluation on water Resources in China has developed during 2002~2004, since the first time performed in 1980. According to the uniform technologic demand, and adopted the working means as three classes linkage of country-River Basin-province and cooperation of industries, departments, and subjects, the results of the evaluation was summed up after several harmonizing, testing and auditing step by step. The results, including quantity evaluation of water Resources, quality evaluation of water Resources, investigation and analysis of water Resources exploitation, and survey and analysis of water entironment, which reflected external condition of the water Resources in our country and problems in the process of exploitation in the round and by the numbers.

6.1.2 Research of Hydrological cycle under Nature-Manpower-Dualistic-Driver

The more people interfere in water Resources during hydrological cycle progress, the more critical social property of water Resources has, meanwhile, the exploitation, utilization and management of water Resources is faced with more crisis and challenge. Academician Wang Hao, professor in Institute of Water Resources and Hydropower Research, founded Nature-Manpower dualistic water circulated theory, and established Nature-Manpower dualistic water circulated model based on the theory, coupled with WEP-L distributed hydrological model worked out by Jia Yangwen and River Basin water Resources ration model. The model, not only reappeared the exchange process among atmosphere, vegetation, surface, soil and subbase under the interfere of people in Huanghe River Basin genuine, also revealed water Resources evolving mechanism and rule under changing environment in Huanghe River Basin quantificational, at one time, it evaluated the effect to water Resources by decades' changing climate and several kinds of human influences dynamically and separately.

6.1.3 New Techniques Used in Water Resources Evaluation

Water Resources evaluating technology is the core technology in hydrology and hydrological cycle technical system. Conventional evaluating technology is guided by influx water Resources circulated theory, and the primary object is runoff cycle. Conventional evaluating technology and rules cannot suit the demand in order to exert the integrated benefit under new condition any longer as a result of embedment in exploitation of water Resources. Under this situation, Wang Hao pointed out a dynamic full aperture layering evaluating method, and reformed water resources evaluating technical system. This method analyzes the resources' structure of precipitation based on validity, controllability, and renews ability, and actualizes layering evaluation of broad sense water resources, narrow sense water resources, runoff kind of water resources, and available national economy mobilization. This method can be achieved by dualistic water resources evaluating model, which is coupled with distributed simulated model and adjustment model. Variable underlying surfaces and manual water intake is the variable of model in order to achieve water resources dynamic evaluation.

6.2 CONTINUABLE UTILIZATION OF WATER RESOURSE

6.2.1 Scheme of Water Resources

As the economy is developing day by day, water resources optimal allocation is developing in the area of water resources basic research. The main achievements are as follows:

In order to satisfied the demand of water resources' unified management and allocation in river basins, the research of *Index system and method for assessing water resources renewability of the Yellow River Basin* has started up, which is an example of north semi-arid river basin in the research of water resources unified management and allocation. This project has two significant harvests in the basic theory and research in water resources, enumerated as follow: 1. it is the first time to figure out and practice four-layer-controlled-structure in river basin's water resources allocation which based on simulation-allocation-evaluation-scheduling, and provide an intact system in the research of river basin's water resources allocation. 2. it is the first time to couple and nest water resources macroscopically allocated scheme and real-time scheduling scheme, which provide a effective measure to unified manage river basin water resources.

The project of *Studies on Rationally Water Resources Allocation under Economic and Ecological System of Ningxia* figured out a new theory and its research method of broad sense water resources rational allocation. This project starts from the rational allocation of broad sense water resources, and its aim is to satisfy the demand of water supply in society and eco-environment, which prodigiously maintains the sustainable development of regional society-economy-ecosystem. In the content of allocation, this project can not only allocate controllable surface water and ground water, but also can allocate semi-controllable groundwater and even un-controllable precipitation, which vary the contents of allocation.

6.2.2 Construction of Water-Saving Society

Since the 16th National Party Congress to propose ways to implement the scientific concept of development and building a resource-saving and environment-friendly society, the strategic approach, by the idea of building a water-saving society in China to develop pilot projects to be deeper and broader. Our country established Zhangye City in Gansu Province, Mianyang City in Sichuan Province. Dalian City in Liaoning Province, etc. 12 national pilot project for a water-saving society and achieved initial success. Zhangye success as a pilot representative, a series of basic experience in building a water-saving society in China has formed, and that preliminary answer the question of what is a water-saving society, should it be able to build a water-saving society, and how to build a water-saving society; This experimental plot laid the foundation in building a water-saving society under Chinese characteristics. In March, 2005, the replication of *plan of structure of water-saving society in Ningxia* made Ningxia the first provincial pilot project.

In resent years, a large number of cities and regions have drafted plans for the construction of a water-saving society and measures followed these pilot cities, which has great significant in perfecting our aim, mode, measure and content of the construction in building a water-saving society. On this basis, in 2005, Hydraulic Ministry launched the "National" 11th Five-Year "plan for construction of a water-saving society" in the preparation. The plans clarify the strategic plan of building a water-saving society; clear the goal in building a water-saving society during "11th Five-year Plan" period; figure out countermeasures and emphases of development, and develop social systems and the construction of major water-saving plans for the implementation of the project. This plan is a program of action in this period for the construction of water-saving society. As one of the special plans, Hydraulic Ministry launched project in constructing a water-saving society in Yellow River Basin.

Considering the Chinese characteristic of water scarce condition, an advanced theory, construction of water-saving society, which is advanced in international water-saving area, has been figured out. However, construction of a water-saving society is a complex, comprehensive and long-term systems engineering, which involves water conservation projects, technology, and many other aspects of economic management. The complexity and chronicity in building a water-saving society decides that the project should be done steady by continuously review and exploration.

6.2.3 Efficiency of Water Reuse

Agriculture is the principle part in economy water supply. In our country, efficient use of irrigation, precipitation, crop moisture is the focus in improving agriculture water resources efficient. On the aspect of basic theories on the efficient use of water resources in agriculture, some scholars figured out some concepts, such as Limited irrigation, No-full irrigation, Regulated deficit irrigation, etc. The emphases of water-saving is changing from saving in supplying and irrigating to bio-water-saving, precise control, and scientific management, and the real amount saving water is calculating the decreasing amount of evapotranspiration. In the past 20 years, China's basic research in the efficient use of water resources in agriculture has achieved important progress, and not only introduce the concept and calculation of the actual saving, but also make a number of independent innovation, such as Natural Science Foundation of major projects, "the North China Plain water-saving agriculture in basic research". The study made a breakthrough in many aspects, such as regulation of water recycling and water saving farmland law, SPAC water and farmland into a typical operation and regulation, and Regulating the biology and water-saving agriculture. NSFC fund nearly 50 studies on the basis of efficient use of water resources in agriculture in the past five years, and made great progress in the law of moisture transferring, simulation of water nutrient transport, crop water requirement and the calculate model in mechanism of drought. Judging the trend of development, irrigation is transformed form traditional abundant irrigation to water-saving high-yield absent irrigation, and the experiment is changing from normal state test to inferior state test accordingly, and water supply is changing from simple distribution by time to special allocation.

In China, industry water is developing toward water-saving techniques integration and water system optimization. Besides, the circulated economy has gradually introduced into water-saving areas in cities, and renewable water technique and policy has gained much attention. In 2005, five ministries in the State Development and Reform Commission jointly issued *China Policy Commitment Saving Technologies*, and this covered relative water-saving technology and the current domestic economic policies comprehensively. Generally speaking, urban water micro-efficient water supply's technology has been developed by leaps and bounds, while urban water circulation, water efficiency evaluation, theoretical conversion and safety standards and mechanisms of efficient use of water and other basic research is rather weak.

6.2.4 Reproducibility of Water Resources

As the problem of water resources scarcity is more and more grievously, the research of water resources renewable capacity in China has received much attention in recent years. In Yellow River 973 research project, we solve the evaluation problem of renew ability in natural resources and urban cities' resources. The main characteristic of water resources renews ability is it needs considering natural renew ability, social renew ability, and artificial composite renew ability in water resources.

6.3 THE RESEARCH OF ZOOLOGY EVOLVEMENT UNDER THE CONTROL OF THE EVOLVEMENT OF HYDROLOGICAL CYCLE

By the influence of human activities, kinds of ecosystems are degrading in an unprecedented speed. The research on the protection and restoration of ecological system is attached many Chinese scholars. Studies on eco-hydrology progress can seek academic support in constructing rational eco-hydrology pattern and sustainable use of water resources. As some international projects, such as BAHC in water circulation and International auspices of UNESCO's international hydrological program (UNES CO/IHP2.3~2.4), etc. are carried out, research on eco-hydrology progress has developed rapidly and gained extensive attention.

Ecological protection, restoration and water accounting relies on the mechanism of eco-hydrology interaction. Domestically, water driven ecological succession theory, Layered Structure Theory was constructed by the comparison with water succession and ecological succession in the program of the research in north-west; mean while, a correspondence between groundwater and vegetation was also established in the rolling project. In the special study in Heihe River Basin, in addition to the use of ecosystem model to forecast downstream oasis' change, model of the relationship between vegetation coverage and water-salt was also established.

6.4 RESEARCHES ON OTHER ASPECT

6.4.1 Research of Edaphic Water

The water cycle is the process of transforming the dynamic expression. With the changing of the water cycle research, the existence and evolution of forms of water change,resulting in the further expansion of the concept of water resources. As for the water cycle,the maintenance of the ecological environment and the vegetation growth, holard plays an important role in them.People gradually pay attention to the evaluation of it. Falkenmark and other scholars in 1995 published the concept of green and blue water. Precipitation stored in the river,lakes or aquifers is called the "blue water", precipitation stored in unsaturated soils, which back into the atmosphere by the evaporation of forests, grasslands and farmland is called the "green water." With the publishing of the concept of "green water", the evaluation of the "green water" resource caused widespread concern in the world. Stockholm International Water Research Center consider that the green water is an important resources of human well-being, and draw the outline of a new management strategies of water cycle with a concise water sysle chart; International Fund for Agricultural Development (IFAD) and the Global Water System Project (GWSP) also committed themselves to the research of “green water”. Nevertheless, the relevant research is still in its infancy stage with no systemic theory. In China, academician Chen Guodong and academician Liu Changming have "green water" explained a connotation of resources; Academician Wang Hao brings up the concept of generalized water against the validity of the geometrical shape in the water cycle process[23],included the "green water" resources and "blue water" resources, and apply them in the Yellow River Basin. Not only evaluates the "Blue Water" ,a narrow assessment of water resources, but also completely evaluates different forms of the evapotranspiration of holard. To some extent, he achieves a coupling and comprehensive evaluation about "blue water" and "green water". Meanwhile, the "green water" essentially consumes quantity of holard of the vegetation evapotranspiration. He further evaluates the efficient and inefficient, the ineffective and effective of evapotranspiration in the Yellow River valley. This lays the groundwork of making a transit of an ET overall control of the region, rational use of "green water" resources, coordination of the "blue water" and "green water" to the rational allocation and effective utilization of resource.

6.4.2 Initiatory Distribute Theory of Water Resources Usufruct

In China, due to the water resources belong to the state, and not be allocate the initial water rights adopted some general principles through legislation, while contradiction between the supply of and demand for water have increased, making the initial allocation of water rights research developed gradually since the end of last century. Not only many scholars devote into the research and debate on the meaning of the water rights and the principle of water distribution, initial water rights distribution is attempted in some valley. In 1987, a water divide indicator in the provincial Administrative Regions at the Yellow River Basin is approved and promulgated by the State Council. This is the earliest byelaw of initial allocation of water use rights. The allocation and scheduling in the work of exploitation and utilization the water resources in the Yellow River valley is still based on *Yellow River for water distribution program*; Zhangye in Heihe River Vally established two indicators management systems on total control and Quota Management. The volume of water was strictly controlled, the cities total water rights gradually allocated to counties, townships, villages, even to households. This makes the efficiency of water use increase greatly. Dalinghe introduced "water rights allocation of the initial work program in Dalinghe Vally", called for the establishment of initial water rights distribution system, and worked out the initial water rights allocation program.

References

[1] Ministry of Water Resources, P.R.China, China Water Resources Bulletin, Beijing, China WaterPower Press，2005.

[2] Wang Hao, Chen Minjian, Qin Dayong el at. Water resources reasonable allocation and its carry capacity analysis in north-west China [M] . Huanghe WaterPower Press, 2003, 23~26.

[3] Wang Hao, Qin Dayong, Chen Xiaojun, Water Resources assessment standards and calculation specifications [J]. Water Resources and Hydropower Engineering 2004,(2):1~4.

[4] Wang Hao, Qin Dayong, Wang Jianhua, Advances on the research into the mechanism of hydrological cycle Based upon Multi-Tolerance Region and the Research of the Dual Mode of hydrological cycle [C]. Liu Changming, Chen Xiaoguo. Evolvement Law and Renewable Maintaining of Water Resources In the Yellow River Basin [A]. Huanghe WaterPower Press, 2001.

[5] Wang Hao, Wang Jianhua, Qin Dayong, et al, THE STUDY ON WATER

RESOURCESS ASSESSMENT AND SUBJECT SYSTEM OF WATER RESOURCESS STUDY ON MODERN TIMES [J]. ACTA Electronica Sinica, 2002, 17(1): 12~17.

[6] Jia Yangwen，Development and applications of WEP model [J]. Advances in Water Science, 2006，2003，14 (Supplement):50~56.

[7] Jia Yangwen, Wang Hao, Ni Guangheng, Yang Dawen, The Theory of distributed hydrological model and its Application [M]. China WaterPower Press. 2005. 196~236.

[8] Jia Yangwen, Wang Hao, Wang Jianhua, et al, Development and Verification of a Distributed Hydrologic Model for the Yellow River Basin [J]. Journal of Natural Resources , 2005，20(2):300~308.

[9] Jia Yangwen, Wang Hao. Development and Verification of a Distributed Hydrologic Model for the Yellow River Basin [J]. Advances in Water Science， 2003， 14(Supplement):118~123.

[10] Jia Yangwen, Tsuyoshi Kinouchi and Junichi Yoshitani，Distributed hydrologic modeling in a partially urbanized agricultural watershed using WEP model. Journal of Hydrologic Engineering, ASCE, 2005.10(4): 253~263.

[11] Jia Yangwen, Guangheng Ni, Junichi Yoshitani, Yoshihisa Kawahara and Tsuyoshi Kinouchi. Coupling Simulation of Water and Energy Budgets and Analysis of Urban Development Impact. Journal of Hydrologic Engineering, ASCE, 2002.7(4): 302~311.

[12] Jia Yangwen, Guangheng Ni, Yoshihisa Kawahara and Tadashi Suetsugi. Development of WEP Model and Its Application to an Urban Watershed [J]. Hydrological Processes, John Wiley & Sons, 2001, 15(11):2175~2194.

[13] Jia Yangwen, Tamai Nobuyuki. Integrated analysis of water and heat balances in Tokyo metropolis with distributed models. J. Japan Soc. Hydrol. & Water Resources, 1998, 11(2):150~163.

[14] Jia Yangwen, Tsuyoshi Kinouchi and Junichi Yoshitani，Distributed hydrological modeling in the Yata watershed using the WEP model and propagation of rainfall estimation error Weather Radar Information and Distributed Hydrological Modeling[C]. Proc. of 7th IAHS Congress, Sapporo, Japan, IAHS Redbook. 2003. (282):121~129.

[15] Wang Hao, Jia Yangwen, Wang Jianhua, et al, Evolutionary Laws of the Yellow River Basin's Water Resources under the Impact of Human Activities [J]. Journal of Natural Resources, 2005, 20(.2): 157~162.

[16] Qiu Yaqin, Zhou Zuhao, Jia Yangwen et al, Research on the Changing Tendency of Water Resources in Sanchuanhe River Basin [J]. Advances in Water Science, 2006, 17

(6):861～868.

[17] Qiu Yaqin, Jia Yangwen, Wang Hao, Preliminary Analysis of Hydrological and Water Resources Effects under the Impact of Water and Soil Conservation Engineering in Fenhe River Basin [J]. Journal of Natural Resources 2006，21 (1):24～30.

[18] Wang Hao, Wang Jianhua, Jia Yangwen, A Study on the Method of Water Resources Assessment in River Basin under the Present Environment [J]. Hydrology，Vol (25), 2006(3), 18~21.

[19] Wang Hao, Chang Bingyan, Qin Dayong, Research on Water Resources Allocation in the Heihe River Basin [J]. China Water Resources， 2004(9).

[20] Pei Yuansheng, Zhang Jinping, the Conceptual Framework for Rational Allocation of Water Resources [J] Resources Science 2006(4).

[21] Pei Yuansheng, Studies on rationally water resources allocation under economic and ecological system of Ningxia [J]，China Water Resources 2006（11）.

[22] Wang Hao, Practice of Establishing Water Conservation Society in Arid Area in Northern China--Experience in Zhangye, the first pilot city, China Water Resources 2002(10).

[23] Xia Jun, Wang Zhonggen, Liu Changming, the Renewability of Water Resources and Its Quantification of the Yellow River Basin in China [J]. Acta Geographica Sinica, Vol (58), 2003(4).534~541.

[24] Shen Zhenyao, Yang Zhifeng, Index system and method for assessing water resources renewability of the Yellow River Basin [J]. Journal of Natural Resources, Vol (17), 2002(2), 188-197.

[25] Chen Jianmin, Wang Hao, Wang Fang, Water-driven ecological evolution mechanism in inland arid region [J]. Acta Ecologica Sinica, 2004(10).

CHAPTER 7 APPLICATION OF REMOTE SENSING IN THE MANAGEMENT OF HYDROLOGY AND WATER RESOURCES

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7.1 INTRODUCTION

Remote sensing has been defined as the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by sensor that is not in direct contact with the target of investigation. During the period of year 2003 to 2006, the remote sensing technique and its application is rapidly developed in both the world and China. More and more sensors with higher spatial and temporal resolution were developed and put in optional use or research works in various fields. In China, Meteorology Satellite FY/1D and FY/2C were respectively lunched in May of 2002 and in October of 2004. The Earth Resources Satellite CBERS/02 was successfully lunched in October of 2003. The Ocean Satellite HY-1 was successfully lunched in May of 2002. Miniature Satellite BJ-1 was successfully lunched in October of 2005, and put in operation in June of 2006. These satellites have provided rich information for almost all of the departments allover the country. Also, the remotely sensed data pay very important roles in the field of water resources. Compared to conventional hydrological measurements, remote sensing has certain significant advantages, but also some disadvantages. In this chapter, remote sensing application to hydrologic monitoring and modeling, as well as water management in recent years are discussed with emphases on water cycle research, flood and drought hazard monitoring and evaluation, irrigation and drainage management, monitoring of ecologic environment related to water resources development and utilization.

7.2 REMOTE SENSING APPLICATION TO HYDROLOGIC MONITORING AND MODELING

7.2.1 Remote Sensing in Hydrologic Modeling

For hydrologic modeling, the time series of runoff and possibly precipitation, and a climatological estimate of monthly evapo-transpiration are very important, which may be obtained by the station-based observation system. The model development based on surface station for a large river basin is almost impossible due to the scarcity of land surface observations and difficulties in representing hydrological processes at large scales. Remote sensing may provide the required data, such as information on land surface/cover, soil texture, initial soil moisture and topography, for hydrological modeling at regional to global scales. For modeling land-atmospheric hydrologic interactions, remote sensing provides both model parameters and meteorological data, like surface air temperature, humidity, precipitation and radiation.

Liu S.C. and Zhang W.C. (2004) gave a review of application of remote sensing to retrieval of precipitation, land use/ cover classification, leaf area index, albedo, land surface heat flux and some indirect parameters in distributed hydrological model, and proposed a framework for developing a distributed hydrological model by integrating GIS and remote sensing. Wu J.F. and Liu C.M. (2002) considered that the data obtained from remote sensing is still hard to use in hydrological model directly, and the hydrological scale problem is the important aspect for hydrological modeling using remote sensing. Li D.F. et al. (2005) developed a physical-based distributed hydrological model to simulate the watershed runoff response process under climate and land-cover changes in the head area of Yellow River by using remote sensing and GIS. Liu C.M. et al. (2004) developed distributed hydrological model for Yellow River basin, which is a part of National Key Project "Yellow River Water Resources Evolution Law and Renewability Maintaining Mechanism". The area precipitation data obtained from meteorology satellite image was treated as an input for the model.

7.2.2 Remote Sensing in Water Cycle

Remote sensing pays important roles in water cycle research especially for regional scale or watershed scale, and the hydrological cycle components may involve precipitation, evapotranspiration, soil moisture, surface water as well as groundwater.

Precipitation is of primary importance in hydrology. It shows large and frequent spatial and rapid temporal variations. The scales over which precipitation occurs are so large that methods of measurement are wide ranging and usually complementary. Point measurements are insufficiently representative of catchment scales. So remote sensing becomes a very powerful tool for obtain the precipitation information for water cycle research. Currently, the emphases are put on the application of radar, ground-based or space-borne radar, as well as passive microwave data. The approaches based on visible and infrared satellite data were also developed. Two basic approaches namely the “life-history” and the “cloud-indexing” are widely used. Wang J.H. (2003) developed the area precipitation model according to the regression relationship between cloud and point precipitation by using GMS image and surface rain gage. The model prediction precision reached to 90% in Yellow River Basin. Huang Y. (2006) developed the Flood-Causing Torrential Rain Forecasting and Warning System for Huaihe River. Rainfall was estimated by using of satellite and CIN RAD-radar data. Furthermore, form GMS-5 multi-channel data, the empirical formula of rainfall measurement was developed by using statistic method in Huaihe River field. The model was tested verified by the application of flood season in year 2003.

Evapotranspiration plays an important role in earth-atmosphere interaction process, and has attracted a rather considerable amount of attention and research work. The researches are related to the use of thermal infrared observations and the land surface heat balance, as well as spectrum of multi-spectral measurements by space- and airborne instruments to estimate potential evaporation and crop water requirements for the purpose of water management especially in irrigation regions. Wang J.M. (2003), Guo X.Y. (2004) and Sun M.Z. (2005) et.al. gave a review of advances in the monitoring approaches of evapo-transpiration with remote sensing data and its application in water resources management. Sun M.Z. (2005) et al. developed SEBAL model by using spectral radiances recorded by satellite-based sensors，plus ordinary meteorological data, to solve the energy balance at the earth's surface, and to evaluate evapo-transpiration in the Haihe River Basin. Hu M.G. (2006) considered ET technique of remote sensing monitoring to realize the sustainable management of agricultural water supply in Beijing City. Pang Z.G. et. al. (2004) developed the evapo-transpiration estimation model based on energy balance by using remote sensing, and the approaches were demonstrated in Heilongjiang province.

Soil moisture is the interface between the solid earth surface and the atmosphere, and is very important to understand the hydrological cycle process in both smaller and larger scales. However, soil moisture is a very difficult variable to measure, not at a point in time, but at a consistent and spatially comprehensive basis. It has been shown the soil moisture can be measured to some extent by a variety of the electromagnetic spectrum. Successful measurement of soil moisture by remote sensing depends on the type of reflected or emitted electromagnetic radiation, and only the microwave region of the spectrum can provide a quantitative approach to estimate soil moisture under a variety of topographic and vegetation cover condition (E.T. Engman, 2000). Zhang H.M. and Sha J.M. (2005), Zhang C.L. (2006) summarized the theories and methods of soil moisture monitoring by remote sensing, including microwave remote sensing monitoring，thermal inertia, the composite index of crop vegetation and brightness index, as well as hot infrared monitoring. Bao Y.S. et al. (2005) discussed the estimation approaches of soil water content and wheat coverage with ASAR image. The authors concluded backscattering, which was greatly affected by land surface roughness and soil texture, is a key problem which must be considered in the retrieval of soil water content, and the vertical polarization backscattering coefficient is significantly correlated to soil water content while the horizontal polarization backscattering coefficient is significantly correlated to both soil water content and wheat cover.

Surface water may occur as lakes, reservoirs, rivers as well as snow and ice. Remote sensing can be used to estimate the area extent and water content of these surface water-bodies, as well as the changes in water regimes. One of the main obscuration to remote sensing application is the limitation of relatively cloud-free and daylight condition. Microwave satellites offer the potential all-weather application and the synergistic application of combined SAR and optical remote sensing for surface water estimates needs to be examined more closely (G. Kite and A. Pietroniro, 2000). Yang G.D. et al. (2003) presented a method for analyzing the surface water system in plain areas with the help of GIS, DEM and remote sensing. Hong Z.G. et al. (2006) utilized the various sources of remote sensing images combined with DEM and DOM data to analyze the characteristics of surface water system including springs, lakes, water resources of head regions in Tsinghai and Tibet plateau. Wang Y.J. and Zhang Y. (2005) developed a momentum BP neural network model to retrieve the water depth information for the South Channel of the Yangtze River Estuary using the relationship between reflectance derived from Landsat ETM+ satellite data and water depth.

Groundwater is essentially a subsurface phenomenon, so the common current remote sensing, mainly recording features on the surface, can only provide information to indirectly help qualitative or semi-quantitative analysis of groundwater system with simple geological condition and shallow groundwater table. The application of remote sensing involves two aspects, i.e. the conceptualization of the hydrogeology and water budget (Allard M.J. Meijerink, 2000). Abduwasit and Qin Q.M. (2004) presented a review of the development and progress of remote sensing application research on groundwater exploration, as well as the methods of regional groundwater monitoring, delineation and detection. Tashpolat Tiyip et al. (2005) developed a quantitative model for deriving groundwater level in oasis-desert ectone in arid area by using LandSat-7 ETM+ data.

7.2.3 Soil Erosion

Soil erosion, as a natural process caused by water, wind, and ice, has been accelerated by human activities. The consequence from soil erosion on loss of productivity, land degradation, and off-site, downstream damages from eroded soil particles on water quality become major concerns around the world. Soil erosion is characterized by spatially and temporally distribution on the landscape, it is difficult, time consuming, and expensive to use the classical soil erosion measurement techniques. The remote sensing techniques that measure the spectral properties of landscape are most commonly applied to soil erosion management and research. The data sources of remote sensing involve optical sensors like LandSat/TM, SPOT, IRS, AVHRR, ground-based and airborne laser system, as well as Synthetic Aperture Radar (SAR) for evaluating large-scale soil erosion patterns and rates. The application of remote sensing techniques to study and monitor soil erosion may include the following general approaches: photointerpretation /photogrammetry, model/GIS input, spectral properties, and topographic measurements. Xue L.H. and Yang L.Z. (2004) Zhou W.F. et al. (2005) gave a brief introduction to the theory, technique and methods of soil erosion with remote sensing, and discussed the future development trends and prospect of soil erosion with remote sensing. Bu Z.H. et al. (200) introduced the advance of quantitative remote sensing for monitoring annual soil erosion and its application in Taihu Lake basin. Tan B.X. et al. (2005) presented a method for extracting vegetation coverage and estimating soil erosion by remote sensing data combined with surface investigation information and DEM, and applied in Guishuihe river basin of Beijing City. Jiang H. et al. (2005) utilized remote sensing to establish the Universal Soil Loss Equation (USLE) for the dynamic monitoring of soil erosion in Changding County of Fujian province.

7.2.4 Water Quality

Monitoring and assessing the quality of waters in rivers, lakes, reservoirs, estuaries, and oceans are critical for managing and improving water resources and environment. Classical techniques for measuring indicators of water, in situ measures or laboratory analysis, are time consuming and expensive, although they can give accurate measurements. Remote sensing of indicators of water quality offers the potential of relatively inexpensive, frequent, and synoptic measurements. The indicators like suspended sediments (turbidity), chlorophylls, dissolved organic matter, thermal release and oils produce visible and/or thermal changes in surface waters that can change the energy spectra of reflected solar and/or emitted thermal radiation from surface waters. This fact is the basis for using remote sensing to estimate water quality of an individual water body or multiple water bodies across the landscape. Most chemicals do not directly affect or change the spectral or thermal properties of surface waters. Measuring water properties affected by chemicals can only be inferred indirectly from remotely sensed measurement of other water quality parameters affected by these chemicals (J.C.Ritchie and F.R.Schiebe 2000). With the coming availability of hyper spectral data, more parameters can be quantified using remote sensing technique. Yang Y. P. et al. (2004) Zhou Y. et al. (2004) Liu C.D.et al. (2005) presented a review of the current situation of application of remote sensing techniques to inland water quality monitoring and its development process, and explored the principles and methods of applying different kinds of remote sensed images. Lu H. et al. (2005) discussed three common methods of water quality inversion algorithm including empirical model, bio-optical model and artificial neural network model and their application limitation. The authors also discussed the main factors determining water quality retrieve accuracy, and pointed out the atmosphere correction models need to be developed for water quality remote sensing. Lei K. et al. (2004) proposed the models for the estimation of concentration of chlorophyll and total nitrogen in Taihu Lake based on the regression analysis between the CBERS-1 CCD data and semi-synchronous ground referenced data, with the consideration of the spectral characteristics of water components. He L.H. and Yang J.G. (2005) utilized NOAA/AVHRR images to measure hue, temperature, and transparency, in order to discern the different pollution level of water bodies in Yangtze River delta region by remote sensing. Yin Q. et.al.(2005) developed the optimal channel combination models for retrieving chlorophyll and suspended sediment concentration from remote sensing data of FY-01C multi-channel scanning radiometer, Landsat TM, SeaWiFS of Seasat and a supposed set of remote sensing channels. The models were used to estimate the eutrophic degree, its spatial distribution and its variation with time in Taihu Lake and Dianchi Lake. Wan Y. (2003) studied the possibility of using hyper spectral remote sensing to detect the degree of pollution. The water spectra can not only reflect the relative pollution degree but also determine the types and characteristics of water pollution.

7.2.5 Snow and Ice

Ice and snow, storing most of the Earth’s freshwater, are important components of the hydrological cycle. The ice and snow cover, also called as cryosphere, carry information on the other system components like climate system. Moreover, about one billion people depend on water resources originating from snowmelt runoff. Melt-water runoff is extensively used for hydropower generation, irrigation or freshwater supply. The positive aspects of ice and snow, particularly as freshwater, go in hand with a large number of natural hazards like floods (the outburst of subglacial lakes), slushflows, ice fall and so on. The investigation and monitoring of ice and snow cover is essentially important. However, the presence of ice and snow is confined to cold climates either at high altitudes or high latitude (or a combination of both). In many cases, ground-based observations of ice and snow properties are difficult to obtain in the respective regions due to lacking infrastructure and complex topography, harsh climates. Remote sensing has received increasing significance over last two decades, since it is the only feasible way for acquisition of ice and snow information. The EOS Science Plan (NASA, 1999) comprehensively describes the current sate of knowledge, the unsolved problems and new possibilities and strategies of ice and snow research by remote sensing system. The recent researches focus on radiative transfer models suitable to correct high-resolution VNIR and SWIR images for topographic adjancy and bi-directional reflectance distribution function (BRDF) effects, accurate retrieval of ice and snow properties from remote sensing data in particular snow water equivalent at high spatial and temporal resolution to develop the snowmelt runoff model, as well as the subpixel analysis algorithms such as the retrieval of snow properties in forested areas or detection of cloud contaminated pixels. Huang X.Y. (2004) presented a review of the application of microwave remote sensing in monitoring the snow and ice and its future directions. Che T. et al. (2004) used the SSM/I brightness temperature data to estimate the snow water equivalent (SWE) in Tibetan Plateau. The authors established an improved algorithm to retrieve the snow depth from the difference of 19 and 37 GHz brightness temperatures in horizontal polarization, and developed a statistical algorithm to estimate the snow water equivalent from the differences of 19 and 37 GHz in vertical polarization. Zhang Z.J. et.al.(2004) put forward an effective method of distinguishing snowpack, probability combined with threshold, by using NOAA-16/AVHRR3 and FY-1D/MVIRS, and established the operational system of snow cover monitoring. The features of winder snow cover distribution in China, from 1996 to 2003 were discussed. Liu Y.J. et al. (2003) calculated the percent of snow cover in west of China by the multi-spectral analysis of AVHRR data.

7.3 WATER MANAGEMENT WITH THE AID OF REMOTE SENSING TECHNOLOGY

7.3.1 Flood Hazard Monitoring and Assessment

Flood severely affects the life and environment at different places over the country each year. It causes considerable damage to buildings, roads, villages, towns and agriculture. Often floods cause also a high loss of human or animal life. Heavy rains, snow smelts or typhoons are reasons for the generation of floods. Rapid identification and response to flooded areas can help to safe life and to protect some important areas. Real-time flood monitoring with high resolution images in the optical wavelength range are desirable but usually not possible because of the cloudy and rainy weather conditions at this time. Because of their independency of weather and light conditions, Synthetic Aperture Radar data are used for these purposes. After the floods a precise assessment of the damaged areas can help local authorities in planning and organizing the reconstruction and future protection measures. Data from optical instruments in different spectral channels of satellites like SPOT or LandSat are very helpful in precise assessment of the situation and damages. Liu Y.L. et al. (2003) put forward the concept of normal water extent (NWE) to define the minimal values for the assessment of flood losses, referring to some special areas around the river, lake, reservoir and dyke and to the land use etc., which are easy to suffer the flood during the rain season. The basic data for NWE are TM or NOAA/AVHRR images. The authors set up the NWE database for seven large river basins of China, which were used to monitor and assess the floods in China since 1999. Yi Y.H. et al. (2005) put forward an algorithm to calculate the depth distribution within the inundated region extracted from the satellite imagery，which can be applied in the flood monitoring and loss evaluation. The algorithm combines the flood region with DEM and acquires a smooth elevation distribution in the flood borderlines after efficient error control due to inadequate precision in the satellite imagery processing. Li D.K. (2005) used MODIS data to identify the flood areas with high bedload content in Weihe river flood of 2003 and concluded that the method of vegetation and the false color composition of channel 2, 5 and 6 were effective to pick up the areas of a flood with high bedload content. Yu T.S. et al. (2003) discussed the monitoring and prediction approaches of drought and flood disasters using meteorological satellite, numerical prediction and field data in Changjiang and Huaihe river basins.

7.3.2 Drought Hazard Monitoring and Evaluation

Droughts, both natural or meteorological droughts and human-induced or agricultural droughts are frequent hazards which cause considerable economic loss in China. The monitoring and assessment of drought are essentially important for hazard alleviation and agriculture management. Remote sensing technique has superiority in drought monitoring compared with conventional means like ground-based measurement. The approaches by VIS/NIR/FIR bands of remote sensing include the methods based on soil thermal inertia, calculation of regional evapo-transpiration, vegetative cover index and temperature, and feature of soil water contents spectrum and so on. For regional drought monitoring and assessment, the polar orbit meteorology satellite like NOAA or FY, as well as Earth Observation System (EOS/MODIS) are the feasible sources because of the appropriate spatial and temporal resolution. Sun L. et al. (2004) Xia H. et.al. (2005) presented a review of the approaches of remote sensing based drought hazard monitoring and their applications. Zhang S.Y. et al. (2006) established the regional drought monitoring model, i.e. the thermal inertia model and vegetation supply water index（VSWI） model, using MODIS data and the work flow to process the remote sensing data, and the severe spring drought in Shaanxi province was successfully monitored in 2005. Mo W.H. et al. (2006) discussed the application of the vegetation supply water index（VSWI），the ratio of normalized difference vegetation index to land surface temperature，in the assessment of farmland drought with the NOAA satellite data from 1995 to 2000 and the digital information of land use in Guigang City of Guangxi Province. Qin Z.H. et al. (2005) described the methodology to retrieve land surface temperature from MODIS data for agricultural drought monitoring in China, and concluded that the band 31 and 32, of the 8 thermal bands, could be especially suitable for land surface temperature estimation. Zhang J.Y. et al. (2005) introduced the principles of the surface energy balance system (SEBS) and an arithmetic for quantitative survey of surface drought characters based on SEBS using NOAA satellite images and weather observations, discussed the application of the arithmetic, including the data processing, model parameter initialization, result evaluation and error analysis, on drought monitoring at large scale in China.

7.3.3 Irrigation and Drainage Management

The complexity of sustainable land and water management leads to a need for improved monitoring, understanding and modeling of spatial processes related to irrigation and drainage. The remote sensing technique pays a significant role for this purpose. The applications may include the high resolution mapping of irrigated lands, crop water requirement, crop water stress, detection of saline areas, catchment hydrology, and irrigation management. Liu X.L. et al. (2005) discussed the approach to assistant extraction of winter wheat cropping area using the time series of MODIS vegetation indicator. Bao Y.S. (2006) described the method for retrieving soil water content and winter wheat planted field from ENVISAT ASAR, by analyzing the relationship between winter wheat field's backscattering coefficient and soil water content or wheat coverage. Kang Q.et al. (2005) Fu Q.H. et al. (2005) presented a review of current major methods for soil salinazation monitoring by remote sensing and its prospective. Kang Q.et al. (2005) discussed the remote sensing application in studying soil salinization in arid areas based on ASTER images. A remote sensing dataset comprised of 9-band multi-spectral images of ASTER was used, and the accuracy of the method reached to 79.1%. Pan S.B.et al. (2004) discussed the impact of water resources development on the environment system in Shule River basin located in Hexi Corridor, Gansu province of China. The numerical groundwater simulation models for three irrigation commands was developed with the aid of remote sensing and GIS in order to analyze the ecological environment changes after the implementing of the agriculture development project.

7.3.4 Land Cover Changes and Water Resources Development

The production and use of information on land cover and land use has dramatically increased during the last 50 years in relation with the development of spatial planning policies on one hand and of remote sensing and GIS techniques on the other hand. Land cover i.e. the cover of the earth's surface with soil, water, vegetation, cities etc. depends on natural factors and human activities. The anthropogenic influence on land cover is related to land use and for agriculture, forestry and urbanization. Changes in land cover include changes in the hydrological cycle and in most of the mass and energy fluxes that sustain the biosphere and geosphere. As a result the amount of runoff, the soil moisture and groundwater recharge are strongly affected by land use changes. On the other hand, unreasonable water resources development, especially in arid or semi-arid regions, may also cause the land cover changes such as the degradation of vegetation and desertification. Chen H.L. et al. (2005) presented a review of remote sensing application in land use/cover change (LUCC) monitoring and assessment with emphasis on the composite application of multi-source data and numerical experiment. Yan Z.L. and Tang G.A. (2004) employed remote sensing to investigate the variation of vegetation after emergent water transferring in Tarim River basin in year 2000. Cui W.G. and Mu G.J. (2004) introduced the evaluation of Manas oasis, and the method using RS technology and the theory of physiognomy and geology to study oasis spatial and temporal change process. Wang Y.Y. and Li J. (2004) described new methods aiming at improving the conventional computer classifiers, such as statistic based classification, artificial neural network classification, knowledge based, support vector machine classification. Cao Yu, et al (2006) discussed the landscape ecological classification using vegetation indices based on remote sensing data, and demonstrated the method for natural oasis landscape analysis at Ejina of Inner Mongolia of China.

7.4 CONCLUSIONS AND FUTURE PERSPECTIVE

7.4.1 Conclusions

Remote sensing, particularly from various satellites in various spectral bands, can provide information on watershed characteristics for the spatial estimation of regional parameters for hydrological research and water resources management at various scales. Another important facet of remote sensing is the fact, that such data can be acquired in remote areas or under very difficult circumstances.

Many of the advances in the application of remote sensing technique in hydrology and water resources management have come from various fields including flood and drought hazard monitoring and evaluation, irrigation and drainage management, monitoring of ecologic environment, as well as water cycle research in catchment, watershed and global scale. The advantages of using remote sensing are as followings (E.T. Engman and G.A.Schultz 2000):

-- The ability to provide spatial data, rather than point data,

-- The potential to provide measurements of hydrological variables, such as soil moisture and snow water content, which are not available through traditional techniques.

-- The ability, through satellite sensors, to provide long-term, global-wide data, even for remote and generally inaccessible regions of the earth.

7.4.2 Future Perspective

The future development of remote sensing application in hydrology and water resources is likely to be great for several reasons such as:

-- The convergence of data acquisition and data visualization technologies,

-- The integration and fusion of data from all available sources and the development of models related to hydrology and water resources, as well as disaster and environment.

-- The possibility, to acquire data for large areas with a high resolution in space and time at one spot and in real-time, which may serve as basis for water management decisions in real-time.

In China, the Miniature Environmental Disaster Satellite Constellation, which is composed of four optical satellites and four radar satellites, is planned to be lunched in recent years. The CBERS -03/04, the succession of CBERS- 01/02, are also planned to be lunched before 2010. The spatial resolution and the quality of image of the satellites will be considerably improved.

FY-3 and FY-4, respectively the polar orbit and geostationary orbit of the second generation of meteorology satellites, are also put in planning. The applications of remote sensing in hydrology and water resources management could be expected to be greatly developed with more and more sources of satellites.

References

[1] Abduwasit Ghulam, Qin Qiming (2004), Overview of Methods and Theories af Remote Sensing Monitoring and Exploration of Groundwater, *Transactions of The CSAE*, Vol. 20 No. 1:184-188 (in Chinese).

[2] An Peijun, Liu Shulin, Xie Yaowen et al (2005), Quantitative Study on Vegetation Index Based on Remote Sensing Images: A Case Study of Minqin Oasis, *Remote Sensing Technology and Application*, Vol. 20 No.6: 574-580 (in Chinese).

[3] Bao Yansong, Liu Liangyun, Wang Jihua (2006), Estimation of Soil Water Content and Wheat Coverage with ASAR Image, *Journ. of Remote Sensing*, Vol.10, No.2: 253-271 (in Chinese).

[4] Bu Zhaohong, Tang Wanlong, Yang Linzhang et al (2003), The Progress of Quantitative Remote Sensing Method for Annual Soil Losses and its Application in Taihu-Lake Catchment, *Acta Pedologica Sinica*, Vol. 40, No.1: 1-9 (in Chinese).

[5] Cai Wei, Yu Junqing, Li Hongjuan (2005), Application and Prospect of Remote Sensing Techniques to Lake Environmental Monitoring, *Journal of Salt Lake Research,* Vol.13 No.4: 14-20 (in Chinese).

[6] Cao Yu, Chen Hui, Oyang Hua et al (2006), Landscape Ecological Classification Using Vegetation Indices Based on Remote Sensing Data: A Case Study of Ejina Natural Oasis Landscape, *Journal of Natural Resources*, Vol.21 No.3: 481-488 (in Chinese)

[7] Che Tao, Li Xin (2004), Retrieval of Snow Depth in China by Passive Microwave Remote Sensing Data and its Accuracy Assessment, *Remote Sensing Technology and Application*, Vol. 19, No. 5: 301-306 (in Chinese).

[8] Che Tao, Li Xin (2004), Development and Prospect of Estimating Snow Water Equivalent Using Passive Microwave Remote Sensing Data, *Advance in Earth Sciences*, Vol. 19 No. 2: 204-210 (in Chinese).

[9] Che Tao, LI Xin, Gao Feng (2004), Estimation of Snow Water Equivalent in the Tibetan Plateau Using Passive Microwave Remote Sensing Data (SSM/I), *Journal of Glaciology and Geocryology*, Vol. 26 No.3: 363-368 (in Chinese).

[10] Chen Huailiang, Xu Xiangde, Liu Yujie (2005), Review of Researches on Remote Sensing Monitoring and Impact on Environment of Land Use/Cover Change, *Meteorological Science and Technology*, Vol. 33, No. 4: 289-294 (in Chinese).

[11] Chen Jiwei, Li Junxiang (2004), Research on Metropolitan Surface Water GIS Using Remote

Sensing Technology, *Shanghai Geology*, No. 4,:7-10 (in Chinese).
[12] Chen Wanhui, Liu Liangyun, Zhang Chao et al (2005), Method of Soil Erosion Fast Investigation Based on Remote Sensing, *Research of Soil and Water Conservation*, Vol. 12 No. 6: 8-10 (in Chinese).
[13] Chen Xu (2004), The Soil Eroding Monitoring Using RS Technology, *North Environment*, Vol.29 No.2: 59-61 (in Chinese).
[14] Cui Weiguo, Mu Guijin (2004), Application of RS Technology in the Research of Oasis Dynamic Change, *Geo-Information Science*, Vol. 6, No.3 : 106-107, 125 (in Chinese).
[15] Deng Hui, Zhou Qingbo (2004), The Progress in Remote Sensing Method for Monitoring Soil Moisture, *Journal of China Agricultural Resources and Regional Planning*, Vol. 25, No.3: 46-49 (in Chinese).
[16] Deng Ruru, Tian Guoliang, Liu Qinhuo et al (2004), Research on Remote Sensing Model for Soil Water on Rough Surface, *Journal of Remote Sensing*, Vol. 8, No.1: 75-80 (in Chinese).
[17] Ding Jing, Tang Junwu, Lin Mingsen et al (2003), Acquisition of MODIS Ocean Color Satellite Data and its Data Processing, *Remote Sensing Technology and Application*, Vol. 18 No. 4: 263-268 (in Chinese).
[18] Ding Taisheng, Hu Wen, Ma Xiaoqun et al (2003), Research on Satellite Monitoring and Prediction of Drought and Flood Disasters in Jiang-Huai Valley, *Plateau Meteorology*, Vol. 22, No.2: 147-154 (in Chinese).
[19] Ding Xiaoying, Chen Xiaoxiang (2006), Study of Chlorophyll Detection in Coastal Waters Based on Environmental Factors, *J. of Remote Sensing*, Vol.9, No.4: 446-451 (in Chinese).
[20] Du Fenglan, Tian Qingjiu, Xia Xueqi (2004), Expectation and Evaluation of the Methods on Remote Sensing Image Classifications, *Remote Sensing Technology and Application*, Vol. 19 No.6: 521-525 (in Chinese).
[21] Duan Ping, Xu Yongwen, Zhao Xiaoming et al (2005), Remote Sensing Analysis of the Flood in Poyang Lake Area, *Geospatial Information*, Vol. 3, No.4: 30-32 (in Chinese).
[22] Engman E.T. Gurney R.J. (1991), Remote sensing in hydrology, Chapman and Hall
[23] Feng Qiang, Tian Guoliang, Liu Qinhuo (2003), Research on the Operational System of Drought Monitoring by Remote Sending in China, *Journal of Remote Sensing*, Vol.7, No.1: 14-18 (in Chinese).
[24] Feng Rui, Zhang Yushu (2004), Remote Sensing Evaluation System on Flood and Drought Disaster Based on GIS, *Meteorological in Liaoning Pronince*, No.2: 42-43 (in Chinese).
[25] Fu Qinghua, Ni Shaoxiang, Li Kaili (2005), Methods of Soil Salinization Monitoring by Remote Sensing, Study on Mechanization of Agriculture, No.1:110-113 (in Chinese).
[26] Gao Feng, Li Xin, R L Armstrong et al (2003), Preliminary Application of Passive Microwave Data to Operational Snow Monitoring in Tibetan Plateau, *Remote Sensing Technology and Application*, Vol. 18 No.6: 360-363 (in Chinese).
[27] Gert A.Schultz and Edwin T.Engman (2000), Remote Sensing in Hydrology and Water Management, NASA/Goddard Space Flight Center, Greenbelt,MD, USA.

[28] Gu Deyu, Xu Dewei (2003), Progress in Remote Sensing of Red Tide and Algorithm Study, *Remote Sensing Technology and Application*, Vol.18 No.6:434-444 (in Chinese).

[29] Gu Songyan, Gao Huilin, Zhu Yuanjing et al (2004), The Application of TMI Polarization Ratio PR in Flooded Area Detecting and Classification, *Journal of Remote Sensing*, Vol. 8, No. 3: 261-268 (in Chinese).

[30] Guo Guangmeng, Zhao Bingru, Monitoring Soil Moisture Content with MODIS Data, *Soils*. 36 (2): 219-221 (in Chinese).

[31] Guo Xiaoyin (2005), Study of Remote Sensing on ET Distribution in Heihe Basin, *Progress of Natural Science*, Vol. 15 No.10: 1266-1270 (in Chinese).

[32] Guo Xiaoyin, Cheng Guodong (2004), Advances in the Application of Remote Sensing To Evapotranspration Research, *Advance in Earth Sciences*, Vol. 19 No.1: 107-114 (in Chinese).

[33] Guo Yanjun, Zhai Panmao, Li Wei (2004), Snow Cover in China, Derived from NOAA Satellite Remote Sensing and Conventional Observation, *Journal of Glaciology and Geocryology*, Vol. 26 No. 6: 755-760 (in Chinese).

[34] He Longhua, Yang Jinpen (2005), Remote *S*ensing Study of Main Water Body Pollution in Changjiang Delta Region, *Journal of Fisheries of China*, Vol. 29, No.2: 173-177 (in Chinese).

[35] He Zhiyong, Zhang Xiaocan, Huang Zhicai (2004), Water Extraction Based on High-spatial Remote Sensing Images, *Journal of Zhejiang University*, 31 (6):701-707 (in Chinese).

[36] Hou Peng, Yang Fengjie, Cao Guangzhen (2003), Application of Remote Sensing on Water Quality Monitoring in Nansihu Lake of Shandong, *Journal of Shandong University of Science and Technology (Natural Science)*, Vol. 22 No.3: 22-25 (in Chinese).

[37] Hu Minggang, Pang Zhiguo, Li Qianxiang (2006), Realization of Sustainable Management of Agricultural Water Supply in Beijing with ET Technique of Remote Sensing Monitoring, *Technology of Water Conservancy and Hydro-Electric*, Vol.37 No.5: 103-106 (in Chinese).

[38] Hu Xingshu, Gong Jianya, Pan Jianping (2003), Current Situation of Remote Sensing Technology in the Contemporary Era and its Developing Tendency, *Engineering Journal of Wuhan University*, Vol. 36 No. 3A: 195-198 (in Chinese).

[39] Huang Xinyu, Feng Yun (2004), Development of Snow Ice Using Microwave Remote Sensing Data, *Remote Sensing Technology and Application*, Vol.19 No.6:533-536 (in Chinese).

[40] Huang Yong, Hu Wen, Zhang Aimin (2006), Flood-Causing Torrential Rain Forecasting and Warning System for Huaihe River, *Meteorological Monthly*,Vol.32 No.5:105-109 (in Chinese).

[41] Ji Juzhi, An Xiaocun, Wei Songlin (2005), Drought Monitoring by Use of Satellite Remote Sensing Technique, *Journal of Natural Disasters*, Vol. 14, No. 3: 61-65 (in Chinese).

[42] Jiang Hong et.al. Dynamic Monitoring of Water Loss and Soil Erosion Using Remote Sensing in Changding County of Fujian Province, *Proc.of Symposium on Remote Sensing Science and Technology 2005*, p205-212 (in Chinese)

[43] Jiang Hongmei, Ren Liliang, An Ru et al (2004), Application of Remote Sensing Information of Land Use and Land Cover to Flood Simulation, *Journal of Hohai University (Natural Sciences)*, Vol. 32, No. 2: 131-135 (in Chinese).

[44] Kang Qing, Yu Rong (2005), Advances in Remote Sensing Application of Soil Salinization, *Remote Sensing Technology and Application*, Vol.20 No.4:447-454 (in Chinese).

[45] Ke Changqing (2004), A Review of Monitoring Lake Environment Change by Means of Remote Sensing, *Transaction of Oceanology and Limnology*, No 4: 81-86 (in Chinese).

[46] Kuang Qing, Yu Rong, Zhang Zengxiang et al (2005), Remote Sensing Application in Studying Soil Salinization in Arid Areas Based on ASTER Images, *Arid Land Geography,* Vol. 28, No. 5:675-680 (in Chinese).

[47] Lei Kun, Zheng Binghui (2004), Monitoring the Surface Water Quality of Taihu Lake Based on the Data of CBERS-1, *ACTA Science Circumstance*, Vol. 24, No.3:376-380 (in Chinese).

[48] LI Daofeng, WU Yueying, LIU Changming (2005), Runoff Simulation with Physical-based Distributed, *Science Geographical Sinica*, Vol. 25 No. 3: 299-304 (in Chinese).

[49] Li Dengke (2005), Identifying Flood with High Bedload Content Using MODIS Data, *Journal of Catastrophology,* Vol. 20 No. 3: 29-35 (in Chinese).

[50] Li Hongling, Zhang Ying, Jiang Jie (2006), Study on the Inversion Model for the Suspended Sediment Concentration in Remote Sensing Technology, Vol. 17, No.2: 242-245 (in Chinese).

[51] Li Xingmin, Liu Anlin, Zhang Shuyu et al (2005), Use of Thermal Inertia Approach in the Monitoring of Drought by Remote Sensing, *Agricultural Research in the Arid Areas*, Vol. 23 No. 1: 54-59 (in Chinese).

[52] Li Yuhuan, Wang Jing, Cao Yingui (2006), Retrieved Deduction of Soil Moisture Spatial Distribution and Drought Discrimination Based on Remote Sensing, *Progress in Geography*, Vol. 25, No. 2: 123-130 (in Chinese).

[53] Li Yunju, Chang Qingrui, Yang Xiaomei et al (2005), Remote Sensing Detection of Suspended Sediment in the Yangtze River Estuary by MODIS Images, *Jou.r, of Northwest Sci-Tech Univ, of Agri, and Forst. (Nat. Sci. ED.)*, Vol.33 No. 4: 117-121 (in Chinese).

[54] Liang Li, Xu Min, Gao Lijin (2006), Schedule Arrangement Based on Genetic Algorithm, *Journal of Yunnan Normal University*, Vol. 26, No. 2 : 21-24 (in Chinese).

[55] Liu Cande, He Baoyin (2005), Progresses in Water Quality Monitoring Using Remote Sensing, *Study and Progress of Science of the World*, Vol. 27, No. 5 Oct, 2005:40-44 (in Chinese).

[56] Liu Changming, Xia Jun, Guo Shenglian (2004), Advances in Distributed Hydrological Modeling for Yellow River Basin, *Advances in Water Science*, Vol.15, No.4: 495-499 (in Chinese).

[57] Liu Di, Li Fanghua, Huang Yan (2005), The Application of Remote Sensing Technology in the Campaign of Anti-drought and Anti-flood in Heilongjiang Province, *Journal of*

Heilongjiang Hydraulic Engineering College, Vol.32, No.2: 110-111 (in Chinese).
[58] Liu Renzhao, Liao Wenfeng (2005), A Review of Research on the Application of Remote Sensing Image Classification, *Geospatial Information,* Vol. 3, No. 5: 11-13 (in Chinese).
[59] Liu Sanchao, Zhang Wanchang (2004), Distributed Hydrological Model and Integrated GIS and Remote Sensing Study, *Advances In Marine Science*, Vol.22 Sup.: 216-222 (in Chinese).
[60] Liu Tonghai, Wu Xinhong, Dong Yongping (2004), A Review of Study on the Remote Sensing Information of Land Desertifaication, *Remote Sensing Technology and Application*, Vol.19 No. 6 Dec, 2004: 526-532 (in Chinese).
[61] Liu Weidong, Frederic Baret, Zhang Bing (2004), Extraction of Soil Moisture Information by Hyperspectral Remote Sensing, *Acta Pedologica Sinica*, Vol.41, No.5: 700-706 (in Chinese).
[62] Liu Xulong et.al. (2005) Assistant Extraction of Winter Wheat Cropping Area Using the Time Series of MODIS Vegetation Indicator. *Proc.of Symposium on Remote Sensing Science and Technology 2005,* p149-153 (in Chinese)
[63] Liu Yalan, Wang Shixin, Wei Chengjie et al (2003), Development of Normal Water Extent Database for the Seven-river Basins of China Based on Remote Sensing, *Journal of Natural Disasters,* Vol. 12, No. 1 Feb, 2003: 36-41 (in Chinese).
[64] Liu Yani, Wu Jianjun, Xia Hong et al (2005), Summary of Tow-layer Models on Estimating Evapotranspiration Using Quantitative Parameters Derived from Remote Sensing, *Arid Land Geography,* Vol.28 No.1: 65-71 (in Chinese).
[65] Liu Yujie, Zheng Zhaojun, and Wang Libo (2003), Remote Sensing on Snow Cover and Variation Analyzing in West of China, *Climatic and Environmental Research*, Vol.8 No.1: 114-123 (in Chinese).
[66] Liu Yun, Yu Zhenrong, Sun Danfeng et al (2004), Canopy *T*emperature Monitoring *S*oil Water *C*ontent Based on Field *E*xperiment of *W*inter Wheat, , Vol. 15, No. 3: 352-356 (in Chinese).
[67] Liu Zhiming, Zhang Bai, Yan Ming et al (2003),Research Advances and Trends on Soil Moisture and Drought Monitoring by Remote Sensing, *Advance in Earth Sciences*, Vol. 18 No. 4: 576-583 (in Chinese).
[68] Liu Zhiwu, Lei Zhidong, Dang Anrong (2004), Remote Sensing and the SEBAL Model for Estimating Evapo-transpiration in Arid Regions, *J Tsinghua Univ (Sci&Tech)*, Vol. 44, No. 3: 421-424 (in Chinese).
[69] Lu Heng, Jiang Nan, Li Xinguo (2005), Water Quality of Inland Lake Monitoring by Remote Sensing, *Advances in Earth Science*, Vol.20 No.2: 185-192 (in Chinese).
[70] Mauser W., et.al. (1998), Modeling the Spatial Distribution of Evapo-transpiration on Different Scales Using Remote Sensing Data, Jour.of Hydrology, 212-213:250-267
[71] Mo Weihua, Wang Zhenhui, Sun Han et al (2006), Remote Sensing Monitoring of Farmland Drought Based on Vegetation Supply Water Index, *Journal of Nanjing Institute of*

Meteorology, Vol. 29 No. 3: 396-401 (in Chinese).

[72] Pan Shibing, Wang Zhongjing et.al. (2004) Impact of water resources development on the environment system in Shule River basin of China, 25th Asia Conference on Remote Sensing, Thailand, Vol.1:824-829

[73] Pang Zhiguo, Fu June, Li Jiren et al (2004), *R*emote *S*ensing Model for Estimating *E*vapotranspiration Based on Energy Balance, *Advances in Water Science*, Vol. 15, No.3: 364-368 (in Chinese).

[74] Qiao Pinglin, Zhang Jixian, Li Haitao et al (2003), Monitoring and Evaluating the Water Pollution in the River by Remote Sensing, *Journal of Image and Graphics*, Vol. 8 (A): 880-890 (in Chinese).

[75] Qiao Pinglin, Zhang Jixian, Wang Cuihua et al (2006), Study on Regional ET Quantity Using Remote Sensing Model, *Science of Surveying and Mapping*, Vol. 31 No.3: 45-47 (in Chinese).

[76] Qiao Pinglin, Zhang Jixian, Yan Qin (2003), Research on Quantity Calculation of Water Resources by Remote Sensing in the Valley of Shiyang River, *Remote Sensing Technology and Application*, Vol.18 No.4: 217-220 (in Chinese).

[77] Qiao Yanxiao (2005), Evaluation of the Groundwater Potentials in the North China Plain Using Remote Sensing, *The Technology Application, No.* 5: 49-51 (in Chinese).

[78] Qiao Yuliang (2003), Discussion on Related Technical Issues of Fast Soil Erosion Remote Sensing Investigation, *Geo-Information Science*, No. 4: 97-100 (in Chinese).

[79] Qin Zhihao, Gao Maofang, Qin Xiaomin et al (2005), Methodology to Retrieve Land Surface Temperature from MODIS Data for Agricultural Drought Monitoring in China, *Journal of Natural Disasters*, Vol.14, No. 4: 64-71 (in Chinese).

[80] Rango A. (1994), Application of remote sensing method to hydrology and water resources， Hydro. Scien. Jour， Vol.39, No.4.

[81] Sha Yiran, Wang Maoxin (2003), Monitoring of Snow Cover with Remote Sensing Data from Meteorological Satellites, *Meteorological*, Vol. 30, No. 4: 33-35 (in Chinese).

[82] She Wanming, Ye Caihua (2006), Progress on Remote Sensing Soil Moisture and Drought Monitoring Using MODIS Data, *Meteorological Application*, No.1,: 44-46 (in Chinese).

[83] She Wanming, Ye Caihua (2006), Review on Soil Mosisture and Drought Remote Sensing Monitoring Based MODIS Satellite Data, *Henan Meteorological*, No.1: 44-46 (in Chinese).

[84] Shen Fang**,** Kuang Dingbo (2003), Remote Sensing Investigation and Analysis for Water Resources Utilization and its Dynamic Change of Representing Mid-or Small Lake Groups in Taihu Drainage Area, *Journal of Remote Sensing*, Vol. 7, No.3: 221-226 (in Chinese).

[85] Jiang Dong, Wang Jianhua, Yang Xiaohuan et al (2003), Key Hydrological Parameters Retrieved by Using Remote Sensing Technique in Yellow River Basin, Vol. 14, No. 6: 736-739 (in Chinese).

[86] Shi Aiye, Xu Lizhong, Yang Xianyi et al (2003), Remote Sensed Images Fusion and Lake Water Quality Identification Based on Neural Networks and Evidence Theory, *Journal of*

Image and Graphics, Vol.10, No. 3 Mar, 2003: 372-377 (in Chinese).

[87] Shi Aiye, Xu Lizhong, Yang Xianyi et al (2006), A Neural Network Model for Water Quality Retrievals Using Knowledge and Remote Sensing Image, *Journal of Image and Graphics*, Vol. 11, No. 4: 521-528 (in Chinese).

[88] Shi Jiangqiang, Xu Lizhong, Huang Fengchen (2005), Method and Implementation of Water Quality Monitoring Using Remote Sensing and Geographical Information System Integration, *The Computer Program and Application*, Jul, 2005：160-163 (in Chinese).

[89] Song Zhirui, Ma Yilin, Tang Chunhua (2005), Remote Sensing Explanation of the Yangtze River Channel in Jiangxi Province, *Remote Sensing Technology and Application*, Vol. 20, No. 4: 415-419 (in Chinese).

[90] Sun Li, Chen Huanwei, Zhao Lijun (2004), The Advances of Drought Monitoring by Remote Sensing, *Journal of Agro-Environment Science*, 23 (1): 202-206 (in Chinese).

[91] Sun Minzhang, Liu Zuoxin, Lu Mouchao (2005), The Study of Monitoring ET by SEBEL and its Application in Water Resource Management of Hai River Basin, *Journal of Irrigation and Drainage*, Vol. 24, No. 3: 74-76 (in Chinese).

[92] Sun Minzhang, Liu Zuoxin, Wu Bingfang et al (2005), Monitoring *M*ethod of *E*vapo-transpiration by *R*emote Sensing and its Application in Water Resource Management, Vol. 16, No. 3: 468-474 (in Chinese).

[93] Tan Bingxiang, Du Jishan (2006), Analysis of Vegetation and Soil Erosion for Forest Areas Using Remote Sensing Data, *Scientia Silvae Sinicae*, Vol. 42, No.4: 7-11 (in Chinese).

[94] Tan Bingxiang, Li Zengyuan, Wang Yanhui et al (2005), Estimation of Vegetation Coverage and Analysis of Soil Erosion Using Remote Sensing Data for Guishuihe Drainage Basin, *Remote Sensing Technology Snd Application*, Vol. 20 No. 2: 215-220 (in Chinese).

[95] Tang Qiuhua, Ding Jisheng, Yang Dehai (2004), Remote Sensing Information Models of 3-D Seawater Temperature, *Advances in Marine Science*, Vol. 22 Sup.: 53-156 (in Chinese).

[96] Tashpolat Tiyip, Cui Jianyong, Ding Jianli (2005), Study on the Means of Groundwater Distribution beneath the Oasis-Desert Ecotone in an Arid Area by Using Thermal Infrared Data, *Arid Land Geography*, Vol. 28 No. 2: 252-257 (in Chinese).

[97] Tian Guoliang (2003), The Present Condition, Problem and Proposal of Remote Sensing Application in China, *Forum of the RS Information*, 2003. 3: 3-7 (in Chinese).

[98] Tian Jing, Yan Yu, Chen Shengbo (2004), The Advances In The Application of The Remote Sensing Technique To The Estimation of Vegetation Fractional Cover, *Remote Sensing For Land & Resources*, No.1: 1-5 (in Chinese).

[99] Wan Yuqing, Zhang Fengli, Yan Yongzhong (2003), The Application of The Hyperspectral Remote Sensing Technology To Water Environment Monitoring, *Remote Sensing For Land & Resources*, No.3: 10-14 (in Chinese).

[100] Wang Jianhua, Jiang Dong, Wang Hao et al (2003), Retrieval of Annual Precipitation in Yellow River by RS, *Resources Science*, Vol. 25, No.6: 8-13 (in Chinese).

[101] Wang Jiemin, Gao Feng, Liu Shaomin et al (2003), Remote Sensing Retrieval of

Evapo-transpiration over the Scale of Drainage Basin, *Remote Sensing Technology and Application*, Vol.18, No. 5: 332-338 (in Chinese).
[102] Wang Qimao, Ma Chaofei, Tang Junwu et al (2006), A Method for Detecting Red Tide Information Using EOS/MODIS Data, *Remote Sensing Technology and Application*, Vol.21 No. 1: 6-10 (in Chinese).
[103] Wang Shutong, Kang Ersi, Li Xin (2004), Progress and Perspective of Distributed Hydrological Models, *Journ. Of Glaclology and Geocryology*, Vol.26 No.1:61-65 (in Chinese).
[104] Wang Xiyuan, Shi Qingdong, Nurbay Abdusalih et al (2005), Review on Monitoring of Lake Water Quality with the Remote Sensing Technology in Arid Areas of the West China, *Journal of Agricultural Sciences*, Vol. 26 No. 1: 71-75 (in Chinese).
[105] Wang Yajuan, Sun Danfeng (2005), Review of the Regional Evapotranspiration Estimation Using Remote Sensing, *Transactions of the CSAE*, Vol. 21, No. 7: 162-167 (in Chinese).
[106] Wang Yanjiao, Zhang Ying (2005), Study on Remote Sensing of Water Depth based on BP Artificial Neural Networks, *The Ocean Engineering*, Vol. 23 No. 4: 33-38 (in Chinese).
[107] Wang Yuanyuan, Li Jing (2004), Classification Methods of Land Use/Cover Based on Remote Sensing Technology, *Review on Information of Remote Sensing*, 2004. 1: 53-59 (in Chinese).
[108] Weng Yongling, Tian Qingjiu, Hui Fengming (2003), Analysis and Evaluation of Remote Sensing Data Fusion, *Review on Information of Remote Sensing*, No.3: 49-54 (in Chinese). .
[109] Wu Chuangqing, Wang Qiao, Yang Zhifeng (2006), Cloud-moving of Water RS Image Based on Mixed Pixel Model, *Journal of Remote Sensing*, Vol. 10, No.2: 176-183 (in Chinese).
[110] Wu Min, Wang Xuejun (2005), Application of Satellite MODIS in Monitoring the Water Quality of Lake Chaohu, *J. Lake Sci.*, 17 (2): 110-113 (in Chinese).
[111] Wu Sai, Zhang Qiuwen (2005), Model of Water Body Extraction Based on Remote Sensing Data of MODIS, *Computer Science and Digital Program*, Vol.33 No.7:1-4 (in Chinese).
[112] Wu Xianfeng, Liu Changming (2002), Progress in Watershed Hydrological Models, *Progress in Geography*, Vol. 21, No. 4:341-348 (in Chinese).
[113] Xia Hong, Wu Jianjun, Liu Yani et al (2005), Progress on Drought Monitoring by Remote Sensing in China, *Review on Information of Remote Sensing*, 2005.1: 55-31 (in Chinese).
[114] Xiao Guojie, Li Guochun (2006), The Status and Progress on Soil Moisture Monitoring by Remote Sensing, *Acta Agriculture Boreali-Occidentalis Sinica*, 15 (1): 121-126 (in Chinese).
[115] Xin Xiaozhou, Tian Guoliang, Liu Qinhua (2003), Review of Researches on Remote Sensing of Evapotranspiration, *Journ .of Remote Sensing*, Vol.7, No.3:233-240 (in Chinese）.
[116] Xue Lihong, Yang Lizhang (2004), Research Progress on Remote Sensing of Soil Erosion in China, *Journal of Soil and Water Conservation*, Vol. 18 No.3: 186-189 (in Chinese).
[117] Yan Fenghua, Jin YaQiu (2004), Statistics of the Average Distance of Polarization Index Derived from Data of Space-borne Microwave Remote Sensing and Soil Moisture Mapping,

Chinese Journal of Radio Science, Vol.19, No.4: 386-392 (in Chinese).

[118] Yang Guodong, Hu Zhuowei, Liu Zhansheng (2003), Analysis of Surface Water System in Plain with the DEM and RS, *Geotechnical Investigation&Surveying*, No.6:47-49 (in Chinese).

[119] Yang Yipeng, Wang Qiao, Wang Wenjie et al (2004), Application and Advances of Remote Sensing Techniques in Determining Water Quality, *Geography and Geo-Information Science*, Vol. 20 No. 6: 7-12 (in Chinese).

[120] Yang Zhenglong, Tang Guoan (2005), Remote Sensing Based Monitor of Vegetation Recovery in Lower Reaches of Tarim River Following Implementation of Emergent Water Transfer Project, *Bulletin of Soil and Water Conservation*, Vol.25, No.3: 58-60 (in Chinese).

[121] Yao Chunsheng, Zhang Zengxiang, Wang Xiao (2004), Evaluating Soil Moisture Status in Xinjiang Using the Temperature Vegetation Dryness Index (TVDI), *Remote Sensing Technology and Application*, Vol. 19 No. 6: 473-478 (in Chinese).

[122] Yi Yonghong, Chen Xinwan, Wu Huan (2005), An Algorithm for Inundated Depth Calculation of Flood Based on Remotely Sensed Data, *Geography and Geo-Information Science*, Vol. 21 No. 3: 26-29 (in Chinese).

[123] Yin Qiu, Gong Cailan (2005), Method of Satellite Remote Sensing of Lake Water Quality and its Application, *J. Infrared Millim. Waves*, Vol.24, No.3:198-202 (in Chinese).

[124] Yuan Wei, Li Zongqian, Liu Ning et al (2004), Passive Microwave Remote Sensing for Soil Moisture Retrieval based on Bi-spectrum Scattering Model, *Chinese Journal of Radio Science*, Vol. 19, No. 1: 1-6 (in Chinese).

[125] Yuan Wei, Li Zongqian, Liu Ning (2004), Analysis of Data Sets with Different Microwave Remote Sensing Modes in Soil Moisture Retrieval, *Engineering Science*, Vol.6 No.6: 50-56 (in Chinese).

[126] Zeng Yongnian, Feng Zhaodong (2005), Advances in Sandy Desertification Detecting and its Environmental Impacts, *Journal of Mountain Science*, Vol.24, No. 2: 218-227 (in Chinese).

[127] Zhang Canlong, Ni Shaoxiang, Liu Zhenbo (2006), Review of Monitoring Soil Moisture Based on Remote Sensing, *The Study of Mechanism Agriculture*, No.6: 58-61 (in Chinese).

[128] Zhang Changchun, Wei Jiahua, (2004), Survey and Headway of Study on Remote Regional Evaporation, *Journal of Soil and Water Conservation*, Vol. 18 No.2: 174-182 (in Chinese).

[129] Zhang Chengcai, Wu Zening, Yu Hongjing (2004), The Compare Studied to the Methods of Estimating Soil Moisture by Remote Sensing, *Journal of Irrigation and Drainage,* Vol. 23 No. 2: 69-72 (in Chinese).

[130] Zhang Hongmei, Sha Jinming (2005), Study of the Method of Remote Sensing Monitoring the Soil Moisture, *Journal of Chinese Agriculture,* Vol.21 No.2: 301-311 (in Chinese).

[131] Zhang Hua, et al (2005), Multi-temporal Remote Sensing Model for Pollution Monitoring of Inland Water, *Environmental Monitoring in China*, Vol.21 No.5:63-68 (in Chinese).

[132] Zhang Jianyun, Yang Yang, Lu Guihua et al (2005), Study and Application on Quantitative Survey of Surface Drought Characters Based on Remote Sensing Technique, *Advances in*

Water Science, Vol. 16, No. 4: 541-545 (in Chinese).
[133] Zhang Jielin, Liu Dechang, Cao Daiyong (2004), Quantitatively Analytical Approach for Water System Based on Data Fusion Technology and Its Application, *Remote Sensing Technology and Application*, Vol, 19 No.1: 1-4 (in Chinese).
[134] Zhang Ka, Sheng Yehua, (2004), Progresses and Applications of New Technologies in Remote Sensing, *Review on Information of Remote Sensing*, No.2: 58-62 (in Chinese).
[135] Zhang Ruolin, Wan Li, Zhang Fawang (2006), Development of Research on Remote Sensing Classification Technology for Land Use and Cover, *South-To-North Water Transfers and Water Science e& Technology*, Vol. 4 No. 2: 39-42 (in Chinese).
[136] Zhang Shiqiang, Ding Yongjian, Lu Jian et al (2004), Simulative Study of Water-Heat Process in the Tibetan Plateau (I): Soil Moisture, *Journal of Glaciology and Geocryology*, Vol. 26 No. 4: 384-388 (in Chinese).
[137] Zhang Shuyu, Du Jiwen, Jing Yigang (2006), A Study on Routine Operation Remote Sensing Drought Monitoring Model Using MODIS Data, *Agricultural Research in the Arid Areas*, Vol. 24 No. 3: 1-6 (in Chinese).
[138] Zhang Sui, Chen Huijuan, Chen Pengxiao (2005), Analysis on Suspended Sediment of Changjiang Estuary by Remote Sensing, *Journal of Yangtze River Scientific Research Institute*, Vol. 22 No. 5: 23-25 (in Chinese).
[139] Zhao Xuelian, Chen Huali (2003), The GIS-Based RS Monitoring and Risk Evaluating System for Flood Hazard, *Geology and Resources*, Vol.12 No.1: 54-60 (in Chinese).
[140] Zheng Zhaojun, Liu Yujie, Zhang Bingchuan (2004), Improved Remote Sense Monitoring on Snow Cover Of China in Water, *Journal of Applied Meteorological Science*, Vol. 15, Suppl.: 75-84 (in Chinese).
[141] Zhiu Yi, Zhou Weiqi, Wang Shixin (2004), Application of Remote Sensing to Inland Water Quality Monitoring, *Advances in Water Science*, Vol.15, No.33: 312-317 (in Chinese).
[142] Zhong Ruofei, Guo Huadong, Wang Weimin (2005), Overview of Soil Moisture Retrieval from Passive Microwave Remote Sensing, *Remote Sensing Technology and Application*, Vol. 20 No. 1: 49-57 (in Chinese).
[143] Zhou Weifeng, Wu Bingfang (2005), Overview of Remote Sensing Approaches to Soil Erosion Monitoring, *Remote Sensing Technology and Application*, Vol.20 No.5:537-542 (in Chinese).

CHAPTER 8 RESEARCH PROGRESS ON WTER CYCLE OF SOIL-VEGETATION-ATMOSPHERE SYSTEM

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Water transfer through Soil-Vegetation-Atmosphere system is one of the most important multi-interface processes of land surface. A good understand those interface processes and their mechanism is helpful to determine and regulate the water requirements of an ecosystem.

Toward these ends, more attentions have been paid by the Chinese scientists. From the mid 1970s to the mid 1980s, researches were mainly focused on soil moisture holding capacity, dynamics and numerical simulation of moisture movement. In the mid 1980s, the conception of Soil-Plant-Atmosphere Continuum (SPAC) was introduced into China, a series of research, with focus on farmland's ecosystem, on reciprocity among soil, plants and atmosphere, laws of moisture movement inside SPAC and fluxes' evaluation model have been conducted. Coming into 21 century, the above researches were deepened while much more attentions were paid to researches on laws of crop water consumption and water-saving agricultural technology. In the recent years, the relations between hydrology and ecosystem have been paid more attentions in order to value and predict the influences of climate changes and human activities. The water cycle in Soil-Vegetation-Atmosphere system is the key to understand these relations. The researchers have focused on the frail ecosystem, such as the Tibetan Plateau and the Loess Plateau. At the same time, the carbon transfer has been coupled into water/hear transfer since they have similar mechanism.

During the past 3 to 5 years, the main activities of research on water transfer in Soil-Vegetation-Atmosphere in China can be outlined as the following aspects: (1) water transfer in farmland for water saving; (2) water/heat transfer in the Tibetan Plateau; (3) water/heat transfer in the Loess Plateau; (4) water/heat transfer in arid area in northwest; (5) coupling carbon and water/heat transfer. More details as follows:

8.1 WATER TRANSFER IN FARMLAND FOR WATER SAVING

The conception of Soil-Plant-Atmosphere Continuum (SPAC) was introduced into China in the mid 1980s. By the end of the 20th century, this theory had made great progress and was come into use in many areas. While, in resent years, researches are continued and many new evolvements have been made to make the theory more perfect.

Neoteric research of moisture circling is inclined to regard soil-vegetation-atmosphere as continuity in physics, which is called SPAC system. Meng and Xia (2005) founded crop growth period's water&heat transport model of SPAC system, and designed numerical analysis program to simulate water&heat state. The result shows that, the model factually reflect water&heat state of soil and dynamic progress of evapotranspiration in the progress of crop growth. This model could use to forecast soil moisture and frame appropriate water norms. [1]

Cong et al. (2005a, 2005b) coupled winter wheat growth and the water/heat transfer in Soil-Plant-Atmosphere Continuum (SPAC) to dynamically simulate the growth of wheat and the process of heat transfer simultaneously. The model is consisted of a soil model, a canopy model and a model for wheat growth. In the soil model, the finite element method is applied to simulate the movement of the soil water and heat. By introducing the improved Feddes mode and the root density distribution model in negative form the coupling of canopy model with SPAC model is realized. Based on the simulation of the leaf area index, crop height and root distribution the SPAC model is coupled with the winter wheat growth model, namely WheatSPAC model. The comparison between calculation result and observation data for winter wheat shows that the model can be satisfactorily used to simulate the leave area index, weight of dry material, soil temperature and soil moisture. It is found that the evapotranspiration consumption will be more than half of the net radiation gained by the plant after its turning green. [2] [3]

Ji et al. (2006) founded transportation of soil water's sub model of irrigated farmland in inland oasis SPAC system based on soil water dynamic theory. They did simulating research on soil section moisture content, evaporation, and foliage transpiration, and confirmed by measured value. After forecasting field moisture, soil evaporation, foliage transpiration of spring wheat growing season under the same plant and manage condition, we gained satisfactory result. Sensitivity analysis to the main factors of the model shows that these factors have great effect to soil water transport. [4]

Lei et al. (2007) carried out a field experiment in the Weishan Irrigation District along the downstream reaches of the Yellow River to study the energy-water transfer in the soil-plant-atmosphere-continuum (SPAC) to improve water use efficiency. The observations included the micrometeorology, radiation, eddy covariance observation systems and soil water content profiles. The observed data was used to verify an analysis of the variations of the energy and water fluxes during the growth stages of the winter wheat and summer maize in 2005. The accuracy of the eddy covariance system is consistent with other observations worldwide. The results show that most of the available energy is consumed by the latent heat flux when the leaf area index is relatively high. The water consumption is lower than the water supply in both crop seasons, which implies that the irrigation is sufficient. [5]

Liu et al. (2009) dealt with the connotation of "Five Water Types" (air, soil, plant, surface water and groundwater) interactions in farmlands. Based on this connotation, authors discussed water interactions in soil, plant and atmosphere, as coupling system of soil-plant-atmosphere continuum (SPAC). Considering field water saving, authors presented an approach to control water fluxes through SPAC interface. Based on system integration, models for water saving were suggested for application. Data show that decreasing water consumption while increasing yield can be achieved. [6]

8.2 WATER/HEAT TRANSFER IN THE TIBETAN PLATEAU

The Tibetan Plateau is a key region of land-atmosphere interactions, as it provides an elevated heat source to the middle-troposphere. The Plateau surfaces are typically characterized by alpine meadows and grasslands in the central and eastern part while by alpine deserts in the western part.

Yang et al. (2009) evaluated performance of three state-of-the-art land surface models (LSMs), SiB2 (the Simple Biosphere), CoLM (Common Land Model), and Noah, for the Plateau typical land surfaces. The identified key processes and modeling issues are as follows. First, soil stratification is a typical phenomenon beneath the alpine meadows, with dense roots and soil organic matters within the topsoil, and it controls the profile of soil moisture in the central and eastern Plateau; all models, when using default parameters, significantly under-estimate the soil moisture within the topsoil. Second, a soil surface resistance controls the surface evaporation from the alpine deserts but it has not been reasonably modeled in LSMs; an advanced scheme for soil water flow is implemented in a LSM, based on which the soil resistance is determined from soil water content and meteorological conditions. Third, an excess resistance controls sensible heat fluxes from dry bare-soil or sparsely vegetated surfaces, and all LSMs significantly under-predict the ground-air temperature gradient, which would result in higher net radiation, lower soil heat fluxes and thus higher sensible heat fluxes in the models. A parameterization scheme for this resistance has been shown to be effective to remove these biases. [7]

Genxu et al. (2009) assessed the impact of changes in vegetation cover on the coupling of soil water and heat in a permafrost region. Soil moisture, soil temperature, soil heat content, and differences in water-heat coupling were monitored on a seasonal and daily basis under three different vegetation covers (30, 65, and 93%) on both thawed and frozen soils. The soil property varied greatly under different vegetation covers, causing the variation of heat conductivity and water-heat hold capacity in topsoil layer in different vegetation cover. In addition to providing insulation against soil warming, vegetation in alpine meadows within the permafrost region also would slow down the response of permafrost to climatic warming via the greater water-holding capacity of its root zone. Such vegetation may therefore play an important role in conserving water in alpine meadows and maintaining the stability of engineering works constructed within frozen soil of the Qinghai-Tibet Plateau. [8]

Ma et al. (2009) proposed and tested a parameterization method based on ASTER (Advanced

Space-borne Thermal Emission and Reflection radiometer) data and field observations for deriving surface albedo, surface temperature, NDVI, MSAVI, vegetation coverage, LAI, net radiation flux, soil heat flux, sensible heat flux and latent heat flux over heterogeneous land surface. As a case study, the methodology was applied to the experimental area of the Coordinated Enhanced Observing Period (CEOP) Asia-Australia Monsoon Project (CAMP) on the Tibetan Plateau (CAMP/Tibet), located at the north Tibetan Plateau. [9]

Zhang et al. (2010) examined the radiation partitioning over a Kobresia meadow, the most widely distributed vegetation on the plateau, for the period from 2002 to 2005. An increase in soil water or leaf area index was correlated with a decrease of albedo over the meadow. The annual solar radiation lost 34% as longwave radiation, which was higher than values reported for lowland grasslands. The annual radiation efficiency over the meadow, at an average of 0.44, was, however, much lower than that for lowland grasslands. The net longwave radiation (L-n) and the normalized effective radiation (L-n/R-s) over the meadow were much higher than that for the global surface or for lowland grasslands, indicating that the longwave exchange between alpine meadow and atmosphere is the most important component of energy losses. A path analysis suggests that the water vapor pressure, air temperature, and cloud cover are the major factors governing the variations of both the net radiation and the net longwave radiation in the alpine meadow ecosystem. [10]

8.3 WATER/HEAT TRANSFER IN THE LOESS PLATEAU

The Chinese Loess Plateau is located in the north of China and has a significant impact on the climate and ecosystem evolvement over the East Asian continent.

The Loess Plateau land-atmosphere interaction pilot experiment (LOPEX) series were successful in collecting measurements data of the land surface energy fluxes, soil temperature and moisture, and near surface layer meteorological variables, vegetation leaf area index, vegetation water content, height and boundary-layer meteorology sounding datasets at temporal and spatial scale (Wen and Wei, 2009). Wen et al. (2007) summarized the data of LOPEX 2004. The autumn daily characteristics of heat and water exchange evidently differed between the mesa cornfield and fallow, and the imbalance term of the surface energy was large. This is discussed in terms of sampling errors in the flux observations-footprint; energy storage terms of soil and vegetation layers; contribution from air advections; and low and high frequency loss of turbulent fluxes and instruments bias. Comparison of energy components between the mesa cornfield and the lowland cornfield did not reveal any obvious difference. Liu et al. (2010) estimated the evapotranspiration based on the data of LOPEX 2005. With the combined data of the Medium Resolution Imaging Spectrometer (MERIS), the Advanced Along-Track Scanning Radiometer (AATSR) and some other variables such as air temperature, crop height and wind speed, the instantaneous net radiation, sensible heat flux and soil heat flux were calculated; the instantaneous latent heat flux was derived as the residual term of energy balance, and then converted to daily ET value by sunshine duration. The calculated daily ET from the model showed a good match with the measurements. [11] [12] [13]

Ao et al. (2007) simulated profiles of soil water content and temperature at root active zone in a cropped field on Loess Plateau area, taking the root water uptake, soil evaporation, and canopy transpiration into account. The water and heat transfer equations are solved by an iterative Newton-Raphson technique and a finite difference method is used to solve the governing equations. While the sum of the water and heat regimes yielded a much better match with the soil water content and soil temperature obtained from the field observations. The results obtained show that the model coupled water and heat transfer is able to capture the dynamics of soil water content. [14]

Mo et al. (2009) developed a distributed eco-hydrological model based on soil-vegetation-atmosphere transfer processes to estimate actual evapotranspiration (ET) and gross primary production (GPP) over the Wuding River basin, Loess Plateau, based on digital elevation model, vegetation and soil information between 2000 and 2003 over three grid sizes: 250 m, 1 km and 8 km. The grid size is shown to affect the spatial patterns of annual ET and GPP, the effect on GPP being more significant than that on ET. Although the annual GPP is more sensitive to the grid size than annual ET, both daily ET and daily GPP averaged over the whole basin seem to be insensitive to the grid size, illustrating that the coarse grid size can be used to simulate spatially-averaged variables without losing much accuracy. [15]

Yang et al. (2009) analyzed the impact of vegetation coverage on regional water balance under the framework of the Budyko hypothesis by using data from 99 catchments in the nonhumid regions of China, including the Inland River basin, the Hai River basin, and the Yellow River basin. The distribution of vegetation coverage on the Budyko curve was analyzed, and it was found that a wetter environment (higher P/E-0) had higher vegetation coverage (M) and was associated with higher evapotranspiration efficiency (E/E-0). Moreover, vegetation coverage was related not only to climate conditions (measured by the dryness index DI = E-0/P) but also to landscape conditions (measured by the parameter n in the coupled water-energy balance equation). A positive correlation was found between water balance component (E/P) and vegetation coverage (M) for most of the Yellow River basin and for the Inland River basin. [16]

8.4 WATER/HEAT TRANSFER IN THE INLAND RIVER BASIN

Heihe river basin, the second largest inland river basin in China, has attracted more attention in China due to the ever increasing water resources and eco-environmental problems. Gao et al. (2008) assessed the improvement in land surface information data sets and its impact on atmospheric modeling in the Heihe River Basin (HRB) in northwestern China. Fine-scale, remotely sensed, and in situ land surface data in HRB are derived and compared with the global data sets used in most mesoscale models, here MM5. Jia et al. (2009) developed a distributed model for simulating the land surface hydrological processes in the Heihe river basin. Water budgets and spatial and temporal variations of hydrological cycle components as well as energy cycle components in the upper and middle reach Heihe basin were studied by using the distributed hydrological model. In addition, the model was further used to predict the water budgets under the future land surface change scenarios in the basin. Li et al. (2009) applied SWAT model to upper reaches of the basin for better understanding of the hydrological process over the watershed. Parameter uncertainty and its contribution on model simulation are the main foci. In model calibration, the aggregate parameters instead of the original parameters in SWAT model were used to reduce the computing effort. The Bayesian approach was employed for parameter estimation and uncertainty analysis because its posterior distribution provides not only parameter estimation but also uncertainty analysis without normality assumption. [17] [18] [19]

For the inner Mongulia Plateau, Hao et al. (2007) conducted eddy covariance measurements of water vapor exchange over a typical steppe. The results of this research suggest that energy exchange and evapotranspiration were controlled by the phenology of the vegetation and soil water content. In addition, the amount and frequency of rainfall significantly affect energy exchange and evapotranspiration upon the Inner Mongolia plateau. Miao et al. (2009) conducted two years continuous measurements to examine the effects of cultivation and grazing on evapotranspiration (ET), using the eddy-covariance technique in two paired ecosystems. During the growing season, cultivation and grazing reduced the ecosystem ET. Liu et al. (2010) explored the seasonal and interannual variation in water vapor exchange and surface water balance over a grazed steppe. There was a high correlation between the mean normalized difference vegetation index (NDVI) and total precipitation, which reflects the important contribution of precipitation input and stored soil water during the previous year to ET. [20] [21] [22]

8.5 COUPLING CABON TRANSFER WITH WATER/HEAT TRANSFER

Using data from eddy covariance measurements in a subtropical coniferous forest, Gu et al. (2006) developed the model of Carbon Exchange in the Vegetation-Soil-Atmosphere (CEVSA) that simulates energy transfers and water, carbon and nitrogen cycles based on ecophysiological processes. The simulated seasonal variations in carbon and water vapor flux were consistent with the measurements. The results suggested that the improved model underestimated ecosystem photosynthesis and respiration in extremely condition. The present study shows that CEVSA can simulate the seasonal pattern and magnitude of CO2 and water vapor fluxes, but further improvement in simulating photosynthesis and respiration at extreme temperatures and water deficit is required. [23]

Mass and energy fluxes between the atmosphere and vegetation are driven by meteorological variables, and controlled by plant water status, which may change more markedly diurnally than soil water. Yu et al. (2007) tested the hypothesis that integration of dynamic changes in leaf water potential may improve the simulation of CO2 and water fluxes over a wheat canopy. Simulation of leaf water potential was integrated into a comprehensive model (the ChinaAgrosys) of heat, water and CO2 fluxes and crop growth. Photosynthesis from individual leaves was integrated to the canopy by taking into consideration the attenuation of radiation when penetrating the canopy. Transpiration was calculated with the Shuttleworth-Wallace model in which canopy resistance was taken as a link between energy balance and physiological regulation. A revised version of the Ball-Woodrow-Berry stomatal model was applied to produce a new canopy resistance model, which was validated against measured CO2 and water vapour fluxes over winter wheat fields in Yucheng (36 degrees 57', 116 degrees 36'E, 28 m above sea level) in the North China Plain during 1997, 2001 and 2004. Leaf water potential played an important role in causing stomatal conductance to fall at midday, which caused diurnal changes in photosynthesis and transpiration. Changes in soil water potential were less important. Inclusion of the dynamics of leaf water potential can improve the precision of the simulation of CO2 and water vapour fluxes, especially in the afternoon under water stress conditions. [24]

Reference

[1]. MENG Chunhong & XIA Jun (2005), Research on water and heat transfer in soil-plant-atmosphere system, Journal of Hydrodynamics (in Chinese)

[2]. CONG Zhentao, LEI Zhidong, HU Heping, YANG Shixiu (2005), Study on the coupling between the winter wheat growth and the water-heat transfer in Soil-Plant-Atmosphere Continuum I: Model. Journal of Hydraulic Engineering, 36(5): 575-580. (in Chinese)

[3]. CONG Zhentao, LEI Zhidong, HU Heping, YANG Shixiu (2005), Study on the coupling between the winter wheat growth and the water-heat transfer in Soil-Plant-Atmosphere Continuum II: Model Verification and Application. Journal of Hydraulic Engineering, 36(6): 741-745. (in Chinese)

[4]. JI Xibin, KANG Ersi, ZHAO Wenzhi, CHENG Rensheng, ZHANG Xiaoyou, ZHANG Zhihui (2006), Simulation of Soil Moisture Content Dynamics in SPAC System of Irrigated Farmland in Inland Oasis, Northwest China, Journal of Desert Research (in Chinese)

[5]. LEI Huimin, YANG Dawen, et al.(2007), Energy and water fluxes in the Yellow River irrigation region. Journal of Tsinghua University(Science and Technology), 47(6): 801-804 (in Chinese)

[6]. LIU Changming, ZHANG Xiying, HU Chunsheng (2009). Spac Interface water flux control and its application to water saving in agriculture. Journal of Beijing Normal University (Natural Science). 45(5/6), 446-451 (in Chinese)

[7]. Yang, K., Y. Y. Chen, and J. Qin (2009), Some practical notes on the land surface modeling in the Tibetan Plateau, Hydrol Earth Syst Sc, 13(5), 687-701.

[8]. Genxu, W., H. Hongchang, L. Guangsheng, and L. Na (2009), Impacts of changes in vegetation cover on soil water heat coupling in an alpine meadow of the Qinghai-Tibet

Plateau, China, Hydrol Earth Syst Sc, 13(3), 327-341.
[9]. Ma, W. Q., Y. M. Ma, M. S. Li, Z. Y. Hu, L. Zhong, Z. B. Su, H. Ishikawa, and J. M. Wang (2009), Estimating surface fluxes over the north Tibetan Plateau area with ASTER imagery, Hydrol Earth Syst Sc, 13(1), 57-67.
[10]. Zhang, X. C., et al. (2010), Radiation partitioning and its relation to environmental factors above a meadow ecosystem on the Qinghai-Tibetan Plateau, J Geophys Res-Atmos, 115, -.
[11]. Wen, J., L. Wang, and Z. G. Wei (2009), An overview of the LOess Plateau mesa region land surface process field EXperiment series (LOPEXs), Hydrol Earth Syst Sc, 13(6), 945-951.
[12]. Wen, J., Z. G. Wei, S. H. Lu, S. Q. Chen, Y. H. Ao, and L. Liang (2007), Autumn daily characteristics of land surface heat and water exchange over the Loess Plateau mesa in China, Adv Atmos Sci, 24(2), 301-310.
[13]. Liu, R., J. Wen, X. Wang, L. Wang, H. Tian, T. T. Zhang, X. K. Shi, J. H. Zhang, and S. N. Lv (2010), Actual daily evapotranspiration estimated from MERIS and AATSR data over the Chinese Loess Plateau, Hydrol Earth Syst Sc, 14(1), 47-58.
[14]. Ao, Y. H., J. Wen, and S. H. Lu (2007), A study of the water and energy transfer at the soil surface in cropped field on the Loess Plateau of northwestern China, Environ Geol, 52(3), 595-603.
[15]. Mo, X. G., S. X. Liu, D. Chen, Z. H. Lin, R. P. Guo, and K. Wang (2009), Grid-size effects on estimation of evapotranspiration and gross primary production over a large Loess Plateau basin, China, Hydrolog Sci J, 54(1), 160-173.
[16]. Yang, D. W., W. W. Shao, P. J. F. Yeh, H. B. Yang, S. Kanae, and T. Oki (2009), Impact of vegetation coverage on regional water balance in the nonhumid regions of China, Water Resources Research, 45, -.
[17]. Gao, Y. H., et al. (2008), Enhancement of land surface information and its impact on atmospheric modeling in the Heihe River Basin, northwest China, J Geophys Res-Atmos, 113(D20), -.
[18]. Jia, Y., X. Ding, C. Qin, and H. Wang (2009), Distributed modeling of landsurface water and energy budgets in the inland Heihe river basin of China, Hydrol Earth Syst Sc, 13(10), 1849-1866.
[19]. Li, Z. L., Z. G. Xu, Q. X. Shao, and J. Yang (2009), Parameter estimation and uncertainty analysis of SWAT model in upper reaches of the Heihe river basin, Hydrological Processes, 23(19), 2744-2753.
[20]. Hao, Y. B., Y. F. Wang, X. Z. Huang, X. Y. Cui, X. Q. Zhou, S. P. Wang, H. S. Niu, and G. M. Jiang (2007), Seasonal and interannual variation in water vapor and energy exchange over a typical steppe in Inner Mongolia, China, Agr Forest Meteorol, 146(1-2), 57-69.
[21]. Miao, H. X., S. P. Chen, J. Q. Chen, W. L. Zhang, P. Zhang, L. Wei, X. G. Han, and G. H. Lin (2009), Cultivation and grazing altered evapotranspiration and dynamics in Inner Mongolia steppes, Agr Forest Meteorol, 149(11), 1810-1819.

[22]. Liu, S., S. G. Li, G. R. Yu, J. Asanuma, M. Sugita, L. M. Zhang, Z. M. Hu, and Y. F. Wei (2010), Seasonal and interannual variations in water vapor exchange and surface water balance over a grazed steppe in central Mongolia, Agr Water Manage, 97(6), 857-864.

[23]. Gu, F. X., M. K. Cao, X. F. Wen, Y. F. Liu, and B. Tao (2006), A comparison between simulated and measured CO2 and water flux in a subtropical coniferous forest, Sci China Ser D, 49, 241-251.

[24]. Yu, Q., S. H. Xu, J. Wang, and X. H. Lee (2007), Influence of leaf water potential on diurnal changes in CO2 and water vapour fluxes, Bound-Lay Meteorol, 124(2), 161-181.

CHAPTER 9 RESEARCH ON THE APPLICATION OF ISOTOPE TECHNIQUE IN THE MANAGEMENT AND ASSESSMENT OF HYDROLOGY AND WATER RESOURCES

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Environmental isotopes refer to isotopes that generate in natural conditions or by nuclear explosion and can transfer in water cycle. They can be divided into stable and radioactive isotopes by their radioactivity. Among them, oxygen and hydrogen isotopes are widely used in water cycle related study. In nature, there are two different stable isotopes for hydrogen and three for oxygen, ^{1}H, ^{2}H and ^{16}O, ^{17}O, ^{18}O, respectively, and there exists totally nine different molecular forms of H_2O, with only three of them, i.e. $H_2{}^{16}O$, $H_2{}^{18}O$, $^{1}H^{2}H^{16}O$ can be easily detected. Meanwhile, about 97% of water in the world is seawater, and the isotopic ratios of $^{2}H/^{1}H$ and $^{18}O/^{16}O$ are very small (in magnitude of 10^{-4} and 10^{-3}) and variable. In order for the ratios to be easily calculated and expressed, relative deviation of heavy isotopes relative to some standard was introduced and δ values are usually given in ‰ (per mil). At present, the most widely used standard is the Vienna Standard Mean Ocean Water, whose δ values (δD, $\delta^{18}O$) are both defined as 0（‰). And isotopic ratios of water are calculated using equation:

$$\delta = \frac{R_{Sample} - R_{VSMOW}}{R_{VSMOW}} \times 1000\,‰$$

Here, R_{Sample} and R_{VSMOW} stand for ratios $^{2}H/^{1}H$ and $^{18}O/^{16}O$ in water samples, respectively. Different waters in water cycle are characterized by different isotopic composition with different temporal and spatial variation. For precipitations worldwide, isotopic compositions are mainly controlled by the temperature when they experience evaporation, from which a series of isotopic effects are derived. They are such:

Latitude Effect: Isotopic composition of precipitation decreases with a higher latitude, and some call this to be annual temperature effect by some experts.

Altitude Effect: As heavy isotopes in water vapor masses may sink prior to light isotopes and so δ values of precipitations are usually depleted with altitude increases.

Continental Effect: Similar to the altitude effect, when water vapor evaporated from seawater surface or other origins moves across a continent, heavy isotopes tends to penetrate more easily.

So coastal precipitations have heavier isotopic compositions and the inner ones are lighter.

Seasonal Effect: Isotopic composition varies with local temperature, especially for the monthly mean temperature. Generally, rains have heavier isotopic composition in high temperature months.

Amount Effect: Isotopic compositions usually correlate with the amount of each rain event, and it often takes on a lighter isotopic composition for heavy rains and heavier for rains with long duration and small intensity.

Based on the effects above and other characteristics, isotopic composition can help to study the origin and movement of water vapor. Since 1950s, a series of isotopic studies have been carried out worldwide, and by far, a series of accomplishments have been achieved in distinguished aspects of water cycle based on environmental isotopes worldwide.

9.1. APPLICATION OF ENVIRONMENTAL ISTOPES IN METEORIC WATER STYDY

As the most important input for water cycle, isotopic analysis of precipitation is the foundation for systematic study of other outputs and median hydrological processes in integrated water cycle research in a watershed.

Due to parallel isotopic fractionation, isotopic compositions for δD and $\delta^{18}O$ vary in similar modes, and so there is a good relationship between them. In 1961, Harmon Craig found the linear relationship between δD and $\delta^{18}O$, which was called Global Meteoric Water Line (GMWL). The GMWL defines the relationship of δD-$\delta^{18}O$ in worldwide fresh surface waters:

$$\delta D=8\delta^{18}O+10 \text{ SMOW}$$

Here all the results used SMOW as reference. Through subsequent monitoring of isotopic compositions for precipitations by Global Network for Isotopes in Precipitation (Rozanski et al., 1993), the relationship was refined to be:

$$\delta D=8.13\delta^{18}O+10.8 \text{ VSMOW}$$

And here, the analysis results have been changed to VSMOW standard.

As δ value is integrated reflection of geographic and meteoric information, relationships between δD and $\delta^{18}O$ in different regions may vary in some degree, and in this sense they are usually called Local Meteoric Water Line. For example, for rainwater samples in 27 stations of China, the meteoric water line is $\delta D=7.82\delta^{18}O+8.48$, $R^2=0.97$. The relationship can be expressed to be $\delta D=A*\delta^{18}O+D_{excess}$, here A means slope of the water line, relating to the evaporation process water experienced, and D_{excess} is the intercept, indicating the moisture when water experiencing evaporation.

There have been many studies referring to isotopic composition for precipitation, and from these, a series of new domains are developed, such as water origin, vapor transport, paleoclimate reconstruction and so on. Since 1961, IAEA and WMO has been observing isotopic composition of rain water in more than 500 meteoric stations worldwide and studying their spatial and temporal distribution in global or regional scale (Araguas-Araguas et al., 2000). Craig et al firstly analyzed the isotopic composition of vapor above the sea surface. Schoch-Fischer et al (1984), Jocob et al (1991) and White et al (1984) systematically studied the isotopic ratios of water vapor near the surface, and found there is good relationship between δD and relative humidity of vapor when water evaporates.

In China, many isotopic studies for meteoric water have been performed, and problems such as local water origin have been discussed based on several years' observation, especially in the Tibetan Plateau (Zhang Xinping et al., 1996; Tian Lide et al., 1998; Yao Tandong et al., 2000). In international scientific cooperation aspects, there are still some advances for studies performed in Tibetan Plateau and North China (Tsutomu et al., 2004).

In glacier research, environmental isotopes of snow in different depth are usually used to perform climate reconstruction. Hou Shugui et al (1999) compared $\delta^{18}O$ of the NO.1 glacier in the headwaters of Urumchi with the meteoric information observed in Daxigou station, discussed the significance of $\delta^{18}O$ in climate study and spread the applicability for using $\delta^{18}O$ as a temperature index. Zhang Xinping et al (2002) also analyzed $\delta^{18}O$ values for the surface and superficial firn in the east branch of NO.1 glacier, and discussed its relationship with local temperature, as well as effect of melting and evaporation on isotopic evolution. Also many other studies have been performed in paleoclimate reconstruction, paleo-hydrogeology reconstruction and so on.

In water origin study, some latest significant results have been obtained. Liu Xiangchao et al (2005) identified the movement of summer vapor in Dongtaigou catchment using the changing mode for $\delta^{18}O$ and relationships between $\delta^{18}O$ and rainfall, elevation, air humidity in the catchment. So far, the Chinese Network of Isotopes in Precipitation is observing precipitation in 31 stations of the Chinese Ecosystem Research Network to study the vapor origin in China, and provide information for ecosystem related study. And precipitation sampling are still continued in many meteoric stations or experimental catchments, such as Niujiazhuang watershed in Taihang mountain area, Chongling watershed in Hebei province, and Chabaogu catchment in Loess Plateau Breck Revine region, North of Shaanxi Province.

9.2. APPLICATION OF ENVIONMENTAL ISTOPES IN SURFACE WATER STUDY

Using environmental isotopes such as D, ^{18}O can help perform hydrological separation (Dincer et al., 1970; Martinec et al., 1974), evaluate isotopic composition of local precipitation, on the basis of which paleoclimate reconstruction can be discussed. Surface water study can also provide useful information for problems such as precipitation infiltration, groundwater drainage. Many studies have been performed for different rivers in the world, and surface water related issues such as evaporation when surface water flows downstream, relationships between surface water and groundwater were discussed (Simpson et al., 1991; Mckenna et al., 1992; Vrbka et al., 1993; Gremillion et al., 2000).

Since 1990s, studies of surface water isotopic composition have been performed gradually. Gu Weizu et al (1995) studied surface and subsurface responses to rainfall events based on tritium and oxygen-18 isotopes in three specially designed catchments. From the daily variation of stable isotopes for surface water and in combination with that of local precipitation in Naqu River basin, Tibet Plateau, Tian Lide et al (2002) analyzed the characteristic of runoff, and found the isotopic evidence for lake water's role in regulating runoff of mainstream. In other regions, some studies about surface water are more likely to be related to groundwater for a integrated study for both surface water and groundwater.

On the whole, China is still lack of systematic study for surface water, while some special projects for water in several main rivers have been performed in the recent years. In the Yangtze River basin, in order to study carbon cycle and hydrochemistry, surface water samples are collected every 10 days in 8 sections (Pingshan, Beibei, Cuntan, Wanxian, Wuxiangmiao, Yichang, Hankou, and Datong) for carbon, hydrogen and oxygen isotopic analysis, with suspended matter collected in situ. In the Yellow River basin, three sections, i.e. Qingtongxia, Tongguan, Luokou station, were chosen to collect surface water samples every 10 days for stable isotopes and hydrochemical analysis, also with hydrological processes observed and suspended matters filtrated to analyze carbon cycle related items.

9.3. APPLICATION OF ENVIONMENTAL ISOTOPES IN SOIL WATER STYDY

As a media process in water cycle, the movement of soil water is very important to the water content distribution in soil interface and significant to evaporation. Through isotopic study of soil water in different depths, we can get the vertical profile of isotopes (Barnes et al., 1984), reveal the process of soil water recharging shallow groundwater, evaluate drainage of groundwater through upward diffusion from water table (Fontes et al., 1986), describe the evaporation process of soil water (Sonntag et al., 1985), and identify evapotranspiration effect (Allision et al., 1982, 1983a, 1983b) of vegetation.

Until recent years, isotopic studies for soil water have begun to be widely developed in China. Former studies mainly focus on arid and semi-arid regions and use T (Tritium) isotope in vertical profile as an indicator, e.g. Liu Ruifen et al (2001) found that the vertical infiltration of precipitation only accounts to about 12~13% of the total annual rainfall, and put forward that precipitation infiltration may not be the main mechanism for groundwater recharge. The changing mode both in different depths under different vegetation may provide some useful information for groundwater study and evapotranspiration process. At present, there are systematical observations for soil water in several experimental fields constructed by Key Laboratory of Water Cycle and Related Land Surface Processes, CAS. In the Taihang mountain area, Li Fadong (2005) systematically analyzed isotopic composition of soil water in three different vegetations, i.e. vitex, robinia and wild grass, and studied the different processes precipitation experiencing after infiltration from a series of linear relationships between δD and $\delta^{18}O$. Yang Cong (2006) analyzed the isotopic composition of soil water in several depths for different parts of the watershed, and studied the evaporating process in combination with soil water and corresponding meteorological observation in Dongtaitou experimental watershed, Beijing. Soil water under typical vegetations in Chongling experimental watershed, Hebei province, and soil water under different land coverage in Chabagou catchment, Loess Plateau are also collected for environmental isotopes studies. In combination with soil water content observation and normal meteoric observation, advanced long-term study of isotopic composition for soil water can help identify the process of soil water infiltration, evaporation and vegetation transpiration in these regions, on the basis of which an integrated study of water cycle can be obtained.

9.4. APPLICATION OF ENVIRONMENTAL ISTOPES IN GROUDWATER STUDY

In groundwater related study, environmental tracers, such as T, D, ^{18}O, ^{14}C, SF_6, CFCs and etc., have been widely used successfully in many fields since 1950s. Many problems including dating, renewability and recharging origin of groundwater, as well as other related processes can be solved using these techniques, among which D and ^{18}O played an important role. Integrated isotopic studies for precipitation, surface water and groundwater have been performed, with many valuable conclusions obtained internationally (Song Xianfang et al., 1999a, 1999b; Tang Changyuan et al., 2001; Rademacher et al., 2003; Chen Zongyu et al., 2005), and also a Geological Survey Ground-Water Resources Program was carried by USGS in 2001. These successful applications of environmental isotopes for groundwater have provided varieties of examples for domestic studies, and many conclusions gained from these are providing useful information for water resources exploitation and management.

So far, most isotopic studies in China focus on Tibetan Plateau and North China, mainly including the Heihe River, North China Plain, and Northeast of China. Until today, lots of studies have been performed in the Heihe River basin, northwest of China. Through environmental isotopes, hydrograph separation method and correlation analysis, Zhang Guanghui et al (2005) found that the rain , groundwater and snowmelt from the Qilian mountain area are the main sources to recharge groundwater in the middle reach of Heihe River basin in the Northwest internal region, and the recharge varies dynamically both during seasons and years. They also concluded that variation of rainfall in Qilian mountain area is the main factor to variation of groundwater recharge in the middle reaches, and human activities have been related to the decrease of groundwater recharge in the middle reaches since 1980. Zhang Yinghua et al (2005) found that irrigation water greatly influenced the relationship between surface water and groundwater in the oases of the middle Heihe River, and identified the transfer amount of the two features. Qian Yunping et al (2005, 2006) studied the recharge sources of deep groundwater in Ejina basin in lower reaches of Heihe River basin by 3 years hydrochemistry and isotopic information, and concluded that deep groundwater has multi-recharge sources and most formed before nuclear bombing period, and should be used with caution. Wu Xuanmin et al (2002a, 2002b) divided the groundwater system of the Ejina basin by field investigation, hydrochemistry, environmental analysis of T, ^{18}O and ^{14}C. Chen Jiansheng et al (2004) also discussed the hydrogeological conditions of deep confined aquifer in Ejina basin using environmental isotopes, artificial methods and hydrochemical information, and put forward a possible recharging source for lower reaches of the Heihe River. And this conclusion is still in discussion (Research group of Heihe Project, 2005).

In the aspect of relationships between precipitation and groundwater, relatively more studies were carried out in Southwest of China. Yin Guan et al (2000) studied the water cycle in Jiuzhaigou scenic spot, Sichuan province, and found that precipitation is the main water source, and different waters have different δ values due to many factors, such as time lag for rainwater recharging waters, elevation of recharging area, recharging mode, volume of groundwater water bank, residence time and etc. The author (Yin Guan et al., 2001) also discussed the variability of deuterium excess (D_{excess}) both in precipitation and groundwater of Jiuzhaigou and Yele, identified their isotopic meaning and controlling factors, and then compared the D_{excess} both in karst and local normal waters. Li Hongye et al (2005) and Wu Gang et al (2006) studied the hydrochemical characteristic and recharge-drainage conditions of groundwater in Jinshajiang Valley in Mounigou and Leijiawan, Sichuan province, respectively, and discussed the effect of precipitation recharging groundwater.

As an important water-scarce region in China, North China Plain still has many isotopic related researches for groundwater. Liu Cunfu et al (1997) discussed the isotopic meaning of D, ^{3}H, ^{18}O, ^{14}C and ^{36}CI, ^{37}CI in groundwater of Hebei Plain and compared their effect in identifying groundwater recharge and paleoclimate reconstruction. Chen Zongyu et al (1998, 2005) analyzed the paleo-environmental meaning of local groundwater by isotopic (D, ^{18}O, ^{14}C) and hydrochemical data, on the basis of which the effect of paleoclimate change on formation and evolution of groundwater were discussed, and deemed that ground water in the central and littoral part of the North China Plain is being mined under non-steady state conditions.

Still some researches were performed in other regions. Zhang Guangxin et al (2005) studied the mechanism of water salinization in western part of the Songnen Plain of Northeast China based on the isotopic and hydrochemical information, and found that the process of groundwater salinization is mainly attribute to water soil interaction, not only to the evaporative process. Gui

Herong et al (2005) observed the drift features of oxygen and hydrogen isotopes in deep groundwater in mining area of northern Anhui province, and discussed different water-rock interactions in distinguished aquifer systems. Still there are already some researches discussing groundwater isotopic stratification and their implications in groundwater related problems such as paleoclimate change and paleo-water recharge. Wang Yuan et al (2005) discussed the possibility to use environmental isotopes and hydrochemical information to study the distribution and forming factors of fractile confined water along west route of South-to-North water transfer Project.

In engineering domain, environmental isotopes can be used to identify the leakage of water through dams or other water-blocking facilities (Chen Jiansheng et al., 2004; Li Feng et al., 2005). By analyzing the environmental isotopes and artificial tracers in Beijiang Dyke Shijiao section, Chen Jiansheng et al (2003) approved the piping water origin in the dyke according to isotopic analysis of D and ^{18}O from water samples during flood season, and determined the leakage passage in the bedrock fault combining with the artificial tracer NaCI. Fan Zhechao et al (2006) analyzed the leakage of Gaoshuihe embarkment using D, ^{18}O and fuzzy clustering method, and found that the conclusion is identical with that from environmental isotopic and hydrochemical analysis.

Wholly speaking, isotopic studies in groundwater related domains are the most extensive, and nowadays, the current studies tend to identify the integrated processes between precipitation, surface water, soil water and groundwater from water cycle view. The main program being processed about isotopic composition for groundwater in China will be referred in the next part (water cycle related studies).

9.5. APPLICATION OF ENVIRONMENTAL ISOTOPES IN WATER SYCLE RESEARCH

The technique of environmental isotopes has become an important tool to study the water cycle problems. This is a more complicated process and should be based on detailed study of isotopic characteristic of different waters. Many experts have attempted to interpret D_{excess} for precipitation, surface water and groundwater from isotopic view. Chao Nianying et al (2004) interpreted the characteristic of D_{excess} in Hebei Plain and concluded that results will be better if D_{excess} parameter be used together with ^{3}H, ^{14}C, ^{36}CI, and etc. By far, water cycle studies based on environmental isotopes are on the increase.

In Chabagou watershed of Loess Plateau Breck Revine Region, isotopic compositions of precipitation, surface water, soil water and groundwater in different seasons were observed both in the whole catchment and in a small watershed, to study relationships between the four waters. Also, water vapor origin, origin and renewability of groundwater can be discussed in detail. In the Dongtaitou experimental basin, Beijing city, rain water, soil water, surface water and groundwater were collected for isotopic composition, which can provide some information for water cycle study in the catchment. While in the Chongling experimental basin, Yixian county of Hebei province, a whole observation and isotopic sampling system of four waters is working to study water cycle problems both in 10 km^2 and watershed scales. Through studying variation of isotopic composition for soil water in different depths (10cm, 20cm, 30cm, 50cm) comparing with that of precipitation, process of precipitation infiltration and recharging groundwater can be identified. Li Fadong et al (2005) performed water cycle study based on environmental isotopes and hydrological observations in the Taihang mountain area both for precipitation, surface water, soil water under different vegetation and groundwater, and got the water consuming mechanism for vegetation, and mechanism of hydrological and lateral recharge.

From the whole point, hydrogen and oxygen isotopes are being widely used in water cycle studies, which are playing a more and more important role in national water related studies. It tends to study complicated relationships between different waters in water cycle view, including precipitation, surface water, soil water, groundwater, and also vegetation water, vapor water near the land surface. And on such basis, more detailed hydrological features will be studied.

References

[1]Allison, G.B., 1982. The relationship between $\delta^{18}O$ and deuterium in water and sand columns undergoing evaporation[J]. Journal of Hydrology, 55: 163-169.

[2]Allison G.B., Barnes J.B., Hughes M.W. et al., 1983a. The distribution of deuterium and $\delta^{18}O$ in dry soils, 2. Experimental[J]. Journal of Hydrology, 64: 377-397.

[3]Allison G.B., Barnes J.B., Hughes M.W., et al., 1983b. The effect of climate and vegetation on oxygen-18 and deuterium profiles in soils. In: Isotope Hydrology 1983, IAEA Vienna: 105-123.

[4]Araguas-Araguas L, Froehlich K, Rozanski K., 2000. Deuterium and oxygen-18 isotope composition of precipitation and atmospheric moisture[J]. Hydrological Processes, 14:1341-1355.

[5]Barnes C.J. and Allison G.B., 1984. Distribution of deuterium and oxygen-18 in dry soils: 3. Theory for non-isothermal water movement. Journal of Hydrology, 100:143-176.

[6]Chao Nianying，Wang Peiyi，Liu Cunfu et al., 2004. Characteristic of deuterium excess parameter of groundwater in Hebei Plain[J]. Casologica Sonica, 23(4):335-338.

[7]CHEN Jiansheng , Dong Haizhou , Chen Liang, 2003. Application of the environment isotope method to study on the leakage passage in foundation of Beijiang Dyke Shijiao section. Advances in Water Science, 14(1):57-61.

[8]Chen Jiansheng, Wang Jiyang, Zhao Xia et al., 2004. Study of Groundwater Supply of the Confined Aquifers in the Ejin Basin Based on Isotopic Methods[J]. Geology Review, 50(6):649-658.

[9]Chen Zongyu, Zhang Guanghui, Xu Jiaming, 1998. Paleoclimate record deduced from groundwater and climate change implications of groundwater resources in North China[J]. Acta Geoscientica Sinica, 19(4): 338-345.

[10]Chen Zongyu, Nie Zhenlong, Zhang Zhaoji et al., 2005. Isotopes and Sustainability of Ground Water Resources, North China Plain[J]. Groundwater, 43 (4): 485-493.

[11]Dincer T., Payne B.R., Florkowski T., Martinec J., et al., 1970. Snowmelt runoff from measurement of tritrium and oxygen-18[J]. Water resources Research, 6:110-124.

[12]Fan Zhechao, Chen Jiansheng, Li Shixing, 2006. Application of environmental isotope and fuzzy clustering method to study leakage from embankment[J]. Advances in Water Science, 17(1):37-42

[13]Fontes J. CH., Yousfi M., Allison G. B., 1986. Estimation of long-term diffuse groundwater discharge in the northern Sahara using stable isotope profiles in soil water[J]. Journal of Hydrology, 86:315-327.

[14]Gremillion P., Martin Wanielista1., 2000. Effects of evaporative enrichment on the stable isotope hydrology of a central Florida (USA) river[J]. Hydrological Processes, 14:1465-1484.

[15]Gui Herong, Chen Luwang, Lu Xiaomei, 2005. Drift features of oxygen and hydrogen stable isotopes in groundwater in mining area of northern Anhui[J]. Journal of Harbin Institute of Technology, 37(1): 111-114.

[16]Gu weizu, 1995. Various patterns of basin runoff generation identified by hydrological experiment and water tracing using environmental isotopes[J]. Shuili Xuebao, 5:9-17.

[17]Hou Shugui, Qin Dahe, Ren Jiawen, 1999. Re-examination on the climatological significance of the ice core $\delta^{18}O$ records from the No.1 Glacier at the head of Urümqi River[J]. Geocihmica, 28(5): 438-442.

[18]Jacob H, Sonntag C. 1991. An 8 year record of the seasonal variation of ^{2}H and ^{18}O in atmospheric water vapor and precipitation at Heidelberg, Germany[J]. Tellus 43B:291-300.

[19]Li Fadong, 2005. Hydrological cycle research based on environmental isotopes and integrated hydrological experiments—Case study in a representative catchment, Taihang Mountain. Doctoral dissertation in graduate school of Chinese Academy of Sciences.

[20]Li Feng, Chen Zhoufeng, 2005. Analysis of karst leakage for Qilinguan Reservoir[J].

Advances in Science and Technology of Water Resources, 25(6):72-74.

[21]Li Hongye, Yin Guan, Yang Junyi et al., 2005. Isotopic hydrogeochemical characteristics of water bodies in Munigou, Sichuan[J]. Acta Geoscientica Sinica, 26(3): 255-258.

[22]Liu Cunfu, Wang Peiyi, Zhou Lian, 1997. The environment significance of H, O, C and CI isotopic composition in groundwater of Hebei Plain[J]. Earth Science Frontiers, 4(1~2):267-274.

[23]Liu Ruifen, Wei Keqin, 2001. Environmental isotope profiles of the soil water in loess unsaturated zone in semi-arid areas of China. Isotope based assessment of groundwater renewal in water scarce regions. Proceedings of a final Research Co-ordination meeting held in Vienna, 18-21.

[24]Liu Xiangchao, Song Xianfang, Xia Jun, et al., 2005. A study on oxygen isotope in precipitation of Dongtaigou basin in Chao and Bai River basin[J]. Geographical Research. 24(2): 196-205.

[25]Martinec J., Siegenthaler U., Oeschger H., et al., 1974. Event insights into the runoff mechanism by environmental isotopes. In: Isotope Techniques in Groundwater Hydrology. IAEA. Vienna, Austria. Pp:129-143.

[26]McKenna S.A., Ingraham N.L., Jacobson R.L., et al., 1992. A stable isotopic study of bank storage mechanisms in the Truckee River Basin[J]. Journal of Hydrology. 134: 203-219.

[27]Qian Yunping, Lin Xueyu, Qin Dajun et al., 2005.study on groundwater of Ejin basin at the lower reaches of the Heihe River using isotopes[J]. Arid land Geography, 28(5): 574-580.

[28]Qian Yunping, Qin Dajun, Pang Zhonghe et al., 2006. A discussion of recharge sources of deep groundwater in the Ejin Basin in the lower reaches of Heihe River[J]. Hydrogeology and engineering geology, 3: 25-29.

[29]Rademacher L.K., Clark J.F., Boles J.R., 2003. Groundwater residence times and flow paths in fractured rock determined using environmental tracers in the Mission Tunnel; Santa Barbara County, California, USA. Environmental Geology, 43:557–567.

[30]Research group for relations between surface water and groundwater in the Heihe River basin. Experts oppugning the opinion of finding groundwater sources in Badain Jaran Desert. Science Times, 2005-1-14.

[31]Rozanski K., Araguas-Araguas L., and Gonfiantini R., 1993. Isotopic patterns in modern global precipitation. In: Continental isotopes indicators of climate, American Geographical Union Monograph.

[32]Schoch-Fischer H, Rozanski K, Jacob H, et al., 1984. Hydrometeorological factors controlling the time variation of δD, $\delta^{18}O$ and ^{3}H in atmospheric water vapour and

precipitation in the northern westwind belt. Isotope Hydrology 1983[M]. International Atomic Energy Agency, Vienna, 3-31.

[33]Simpson, H.J. and Herczeg, A.L., 1991. Stable isotopes as an indicator of evaporation in the River Murray, Australia[J]. Water Resources Research, 27:1925-1935.

[34]Song Xianfang, Kayane Isamu, Tanaka Tadashi, et al., 1999a. A study of the groundwater cycle in Sri Lanka using stable isotopes[J]. Hydrological Processes, 1999a, 13:1479-1496.

[35]Song Xianfang, Kayane I., Tanaka T., et al., 1999b. Conceptual model of the evolution of groundwater quality at the wet zone in Sri Lanka[J]. Environmental Geology, 1999b, 39(2):149-164.

[36]Sonntag C., Christmann D., and Munnich K.O., 1985. Laboratory and field experiments on infiltration and evaporation of soil water by means of deuterium and oxygen-l 8. In: Stable and Radioactive Isotopes in the Study of the Unsaturated Zone[M], IAEA-TECDOC-357, IAEA Vienna: 145-160.

[37]Tang Changyuan, Machida Isao, Shindo Shizuo, et al., 2001. Chemical and isotopic methods for confirming the roles of wadis in regional groundwater recharge in a regional arid environment: A case study in Al Ain, UAE[J]. Hydrological Processes. 15, 2195–2202.

[38]Tian Lide, Yao Tandong, Yang Zhihong et al., 1998. A 4-year study on oxygen isotope in precipitation at Tuotuohe meteorological station, Tibetan Plateau[J]. Journal of Glaciology and Geocryology, 20(4): 438-443.

[39]Tian Lide, Yao Tandong, Shen Yongping et al., 2002. Study on stable isotope in river water and precipitation in Naqu River basin , Tibetan Plateau[J]. Advances in water science, 13(2): 206-210.

[40]Tsutomu Yamanaka, Jun Shimada, Yohhei Hamada, et al., 2004. Hydrogen and oxygen isotopes in precipitation in the northern part of the North China Plain: climatology and inter-storm variability[J]. Hydrological Processes, 18:2211-2222.

[41]Vrbka P., Jacob., H., Froehlich K., and Salih., M., 1993. Identification of groundwater recharge sources in northern Sudan by environmental isotopes[J]. Journal of Environmental Hydrology, 1 (4):98-125.

[42]Wang Yuan，Wang Xuechao，Wang Jianping，2005. Evaluations for hydrogeological conditions along west route of South-to-North water transfer project[J]. Chinese Journal of Rock Mechanics and Engineering, 24(20):3614-3619.

[43]White JWC, Gedzelman SD. 1984. The isotopic composition of atmospheric water vapor and the concurrent meteorological conditions[J]. Journal of Geophysical Research 89:4937-4939.

[44]Wu Gang ,Li Xiao ,Zhang Heng, 2006. Hydrochemical characteristics of Jinshajiang Valley in Leijiawan , Huidong County , Sichuan Province[J]. Research of Soil and Water Conservation. 13(42): 15-17.

[45]Wu Xuanmin, Shi Shengsheng, Li Zhiheng et al., 2002a. Groundwater system study in Ejin basin at lower reaches of the Heihe River in the Northwest[J]. Hydrogeology and Engineering Geology, 1:16-20.

[46]Wu Xuanmin, Shi Shengsheng, Li Zhiheng et al., 2002b. Groundwater system study in Ejin basin at lower reaches of the Heihe River in the Northwest[J]. Hydrogeology and Engineering Geology, 2:30-33.

[47]Yang Cong, 2006. Experiments of water cycle process in typical catchment, mountainous area, North China—Case study in Dongtaigou Catchment. Doctoral dissertation in graduate school of Chinese Academy of Sciences.

[48]Yao Tan-dong, Sun Weizhen, Pu Jianchen et al., 2000. Characteristics of stable isotope in precipitation in the inland area——a case study of the relation between$\delta^{18}O$ in precipitation and temperature in Urumqi, China[J]. Journal of Glaciology and Geocryology, 22(1): 15-22.

[49]Yin Guan, Fan Xiao, Guo Jianqiang et al., 2000. Isotope tracer on water cycle system in Jiuzhaigou, Sichuan[J]. Acta Geographica Sinica, 55(4):487-494.

[50]Yin Guan, Ni Shijun, Zhang Qichun, 2001. Deuterium excess parameter and geohydrology significance—Taking the geohydrology researches in Jiuzhaigou and Yele, Sichuan for example[J]. Journal of Chengdu University of Technology, 28(3): 251-254.

[51]Zhang Guanghui, Nie Zhenlong, Liu Shaoyu et al., 2005. Characteristic and variation of groundwater recharge resources in the middle reaches of Heihe River basin[J]. Advances in Water Science, 16(5): 673-678.

[52]Zhang Guangxin, Deng Wei, He Yan, 2005. Isotopic evidence of the mechanisms of water salinization in the western part of Songnen Plain of Northeast China[J]. Hydrogeology and Engineering Geology, 3:55-58.

[53]Zhang Xinping and Yao Tandong, 1996. Relations between δD and $\delta^{18}O$ in precipitation at present in the Northeast Tibetan Plateau[J]. Journal of Glaciology and Geocryology, 18(4):360-365.

[54]Zhang Xinping, Yao Tandong, Jiao Keqin et al., 2002. The Temporal and Spatial Variations of the$\delta^{18}O$ in Firn of the Glacier No. 1 at the Headwaters of the Urümqi River during Summer[J]. Journal of Glaciology and Geocryology, 24(1): 57-62.

[55]Zhang yinghua, Wu yanqing, Ding Jianqiang, et al., 2005. Exchange of groundwater and

river water in a basin of the middle Heihe River by using $\delta^{18}O$[J]. Journal of Glaciology and Geocryology, 27(1): 106-110.

[56]Zimmermann U., Ehhalt D., Munnich K.-O.Proc. Symp. 1967. Isotopes in Hydrology, Vienna, 567-584. International Atomic Energy Agency. 1967. Tritium and other environmental isotopes in the hydrological cycle [M]. Technical Reports Series No. 73, IAEA，Vienna, 83.