Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 24 (2011) 643 – 648

Procedia Engineering

www.elsevier.com/locate/procedia

2011 International Conference on Advances in Engineering

Impact analysis of climate change on water resources

Yang Nan,Men Bao-hui*,Lin Chun-kun

(National Engineering Laboratory for Biomass Power Generation Equipment, Renewable Energy Institute, North China Electric Power University, Beijing, 102206, China)

Abstract

It has theoretical and realistic meanings to study the climate change's impacts on hydrology and water resources, so as to understand and solve some problems in hydrology and water resources, such as plan management, operation management, environmental protection, ecological balance and so on. And hydrology and water resource system has close relationship with industry, agriculture, city development and economic fields. This paper reviews the relationship between climate change and water resources, water circulating response of climate change. And then summarizes some study methods of analyzing the impacts of climate change on hydrology and water resources, such as generation technology for climate change scenario and hydrologic simulation. At last, it raises problems in study and puts forward the development trend, including perfecting the distributed hydrological model, improving the precision of climate models and hydrologic models and developing the two-way coupling techniques of climate models and hydrological models.

© 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and/or peer-review under responsibility of ICAE2011.

Key words: Climate Change, Water Resources, Climate Change Scene, Hydrologic Cycle, Hydrological Simulation

1. Introduction

Climate change refers to a period piece, ten years or longer in climate average state and deviation in which both one or two occur significant change together in the sense of the statistics[1]. It main show is a time state variable and happened vary significantly compared with starting time. The effects of climate change is multi-scale, all-round, multi-level, both positive and negative effects. Climate change not only affects the hydrological, biological and ecological system, but also affects the economy, life, so the future climate change effect the sustainable development of regional, national, and even the world are the most important [2]. This paper on the basis of the predecessors comprehensive research in the relationship

* Corresponding author. Tel.: 010-61772077;
E-mail address:menbh@126.com

1877-7058 © 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
doi:10.1016/j.proeng.2011.11.2710

between water resources and climate change, exploring water resources, climate change and its related mechanism, in order to provide many response for further research to climate change.

2. The relationship between climate change and water resources

The water resources and the hydrologic cycle is a very important link of climate change. The effect of climate change on water resources is because of the water and water quality changes that caused by climate factors (mainly includes rainfall and temperature changes).And it is achieved by the changes of the various water cycle links. Climate change will change the world of the present situation of the hydrologic cycle, and cause the redistribution of water resources in time and space. It also will have a direct effect on the evaporation, runoff, the soil humidity and so on. The redistribution and changes of water resources in space will cause the human society and ecology change a lot. At the same time, the water resources system changes will affect the local climate, and will exacerbate climate change in a certain extent.

This relationship as shown in fig 1

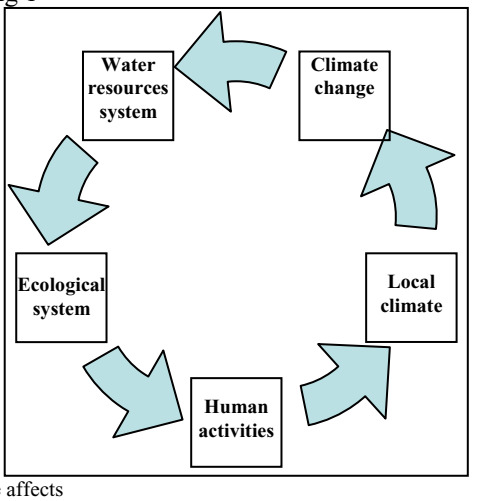

Fig 1 Cycle diagram of climate change affects

The impact of climate change on water resources have developed many research on internal and external. On external, people started to research the impact of climate change on water resources from the 1980s. In 1985, the World Meteorological Organization (WMO) published the review about the impact of climate change on water resources. After that, the WMO put forward some test and evaluation method and published the sensitivity analysis report that impact of climate change on hydrology and water resources [4]. In 1987, the WMO summarized the sensitivity problems in the water resources system for the future and modern climate change [5].In order to speed up the research, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) jointly set up the Intergovernmental Panel on Climate Change (IPCC) in 1988.The IPCC is specialized in evaluation of climate change, and it have completed four assessment report in 1990, 1995, 2001 and 2007. The report has become the main scientific basis which international society to know and understand the problem of climate change.

We made a special research about the impact of climate change on hydrology and water resources since the 1980s in China. In 1988, the national natural science foundation of China approved the "trend and influence of china's climate and sea-level changes" as a major project in the Seventh Five Year Plan. It include that the impact of climate change on water resources research in the north and northwest of china [6]. In the “Tenth Five-Year Plan”, it launched a special subject that is “The impact and comprehensive evaluation of climatic anomaly on China's freshwater resources”. It is used to predict the threshold for climate change on the basis of the simulation of future water resources and water demand [7]. In recent years, our country has carried out the research on the evolution of our living environment and

the prediction of the drying trend in northern. According to the problem of global warming，it mainly studies arid areas in the north of China future climate situation, the mutual relationship and adaptive countermeasures between water resources and human activities[8].

3. Water cycle response mechanism of climate change

Water cycle is theoretical basis of the study of the impact of climate change on water resources. As an important part of the climate system, The hydrologic cycle is restricted by the climate and feedback it too. Climate change will cause water cycle changes, for watershed water cycle, in a great degree, its characteristics are decided by local climate conditions. The effect of Climate factors on the hydrologic cycle is complex, multi-layered. The climate system, directly or indirectly affect the process of water circulation by precipitation, temperature, sunlight, wind, humidity and other factors. The output of the climate system，the effect of precipitation on water cycle is the most direct. Analysis of climate change of water cycle evolution characteristics is influence foundation of assessing the future climate change to the valley hydrology and water resources. There are two kinds of driving factors effects on water cycle, natural and artificial, water cycle system is divided into natural water cycle system, "binary" water cycle system.

(1) Natural water cycle system

Affected by the sun radiation and the gravity of the earth, the water on the earth moves and forms natural water cycle. The water on the earth absorb solar heat energy, evaporation form, steam rose water vapor to high altitude, along with the atmospheric motion and spread to everywhere in the appropriate conditions and environment, condenses into precipitation, and falling to the ground. Water reaches the surface of the earth, except some intercepted by plants and evaporation, part of the flow moves along the ground becoming runoff, and part infiltrate underground aquifer becoming underground runoff, finally flow into the sea. Then evaporating again, continue to condense into rainfall evaporation, operation flow, reciprocating constantly.

(2) “Binary water” cycle system.

Climate change directly led to precipitation and evaporation and runoff process relates to water cycle. Climate change is the most main driver factor of water cycle. The constant change of the human society, human economic activities harder and harder, human activities this disturbance factors gradually strengthened the influence of water cycle in water resources own evolution process. The interference of human on water cycle, broke original natural water cycle system rules and balance, make the original water cycle system singly led by nature to a new system led by natural and manpower. The water cycle system called natural-artificial "binary" water cycle system [9].The influence of human activities on the hydrologic cycle mainly includes two kinds of situations: human's direct intervention caused the change of the hydrologic cycle, and the other is caused by part change because of human activity.

4. The research methods of the impact of climate change on water resources

The research of the impact of climate change on hydrology and water resources system is mainly through the basin temperature, precipitation and evaporation change caused by climate change such as to predict the trend may increase or decrease the runoff and its watershed water supply influence. Using the “what-if-then” pattern [10], which assume that a change climate scenarios as the hydrologic model input to find out each component in the water cycle in the change of scene. The pattern often include the following 4 steps:(1) Define climate change scenarios;(2) Establish, verification of hydrologic model;(3) Make the climate change) hydrologic model of the scene as input and simulate the change process of internal water circulation; (4) Using the simulation results of the hydrologic model to evaluate the climate change on the influence of hydrology and water resources.

Using the what-if-then model to find climate change on the influence of hydrology and water resources in river basin, climate change scene generation technology and hydrological model is the key to impact assessment.

4.1 The generation technology of climate change scene

Because of the complexity and uncertainty regional climate change, the climatologist can hardly accurately predict the future regional climate change. So in climate change research, scholars uses the word "scenario" to describe the future climate change state. The "scenario" refers to predict or expectations the outline or pattern of a series of events, which describe the choose scene that what would the future like and is a kind of suitable tools that analysis of various factors driving how to affect future emissions and assessment of the related results of the uncertainty. At present the main application of the scene generation methods are any scene setting method, time series analysis method and GCM climate scene output method based on the global climate model [11].

(1) Any scene setting method

Any scene setting method is according to the future climate change's possible scope to give any climate elements variation value like temperature, precipitation, etc. The characteristics of this method is easy to design and application and can describe the effects of climate change corresponding curve determine the key factor of climatic effect.

(2) Time series analysis method

Time series analysis methods is through the analysis of hydrological elements of the long history of climate data like temperature and precipitation, runoff series in statistical, and project the future climate scenarios.

(3) GCM climate scene output method based on the global climate model

This method is using the simulation results of the GCM to generate future climate change scenarios. It is the most commonly used methods in exploring climate change influence on hydrology and water resources. The frequently-used GCMS including the United States Koda space research institute mode, the UK met office's mode, the United States Oregon state university mode, American geophysical fluid dynamics experimental mode, the Colorado State University mode, etc[12]. In future along with the deeper understanding of various process in climate system, the improvement of climate elements observation technology, the accumulation of observation data and the more rational process parameters of GCM, we can witness the GCM provide more accurate information about the future climate change.

4.2 Hydrological simulation technology

Climate change will cause global rainfall and temperature changes of time and space distribution, accordingly, the river basin runoff will also change. Hydrological simulation technology is the main tool to solve the hydrological variables information under climate scenarios basin. After more than half a century of development, there are many types of hydrologic models. At present, the hydrological model use for estimating regional hydrology and water resources of the response to climate change has three main categories as following:

4.2.1 Experience statistical model

This kind of model is according to the precipitation, runoff and temperature observation data of same period to establish the relationship among them to derive the precipitation and the temperature changes of runoff trend. This method applies only to having a long series of material in the region, and to the material short areas is more difficult. Since the future temperature and rainfall over the past history of climate is difficult to completely repeated, this kind of method which based on the past the temperature, precipitation, runoff relations appear to predict the future is with great limitations. The representative of this method is the work that have been done by Langbein，Stockton[13-15]. At present the method has been basic rarely used.

4.2.2 Conceptual hydrological model

Conceptual hydrological model use the foundation of physical concept hydrological phenomena to perform Simulation. It's not entirely true simulation physical entity but generalized the physical phenomena. Use conceptual hydrological model can study climate, the causal relationship between runoff,

and the river water resources to the response of the different climatic conditions. Base on the water balance model which was established by Thomthwaite[16], Glick[17] offers modified the water balance model and used for assessment of climate change to the influence of water resources system. David [18], Kenneth [19], Deng Hui-ping [20], etc. use the certainty of the month time scale water balance model to study the hydrological variables of the response to global climate change. Guo Jing etc. use statistical drop scale method and two on the water balance model parameters study of climate change on the influence of the Danjiangkou reservoir runoff process. [21].

4.2.3 Distributed hydrologic model

Distributed hydrologic model is through the water cycle and the dynamics of the mechanism to describe and simulation of hydrologic processes the mathematical model. This model determines the parameters for the model according to the physical properties of moving water medium to analysis of the change of the underlying surface runoff after change rule. According to the different of river terrain like soil, vegetation, land use and precipitation in everywhere, river basin is divided into several hydrological simulation units, and each unit with a set of parameters reflect the characteristics of the part of the basin. Compared with the conceptual model, Distributed hydrologic model with definite physical meaning of the parameters of the structure and the space of the opposite sex points reflect overall can more accurately a detailed description of the basin and reflect the real hydrological process.

5. Conclusions

Climate change scene generation technology changed from simple analysis and transplantation historical data to consider the development of greenhouse gas emissions GCM simulation. Also the hydrological simulation technology has changed from simple statistical model development to consider the atmosphere-vegetation-the exchange of soil distributed hydrological model. But because of the people do not have enough understanding to the atmosphere and the mechanism of the hydrologic cycle and the intrinsic link between them, the current study there are the following several insufficient:

(1) There is a large uncertainty of climate model prediction. This kind of uncertainty mainly comes from the uncertainty of emissions scene, GSM and scale degradation technique and the physical process parameter, etc.

(2) The present study mainly focused on the reflects of the climate change on runoff process average change, while the research of climate change to the extreme events of the hydrological response and to effect of water quality is rarely.

(3)In both precipitation and runoff process of land surface hydrology there are strong time uniformity grid, while most of GCM assume that model of mesh vegetation and soil in horizontal plane is uniform which makes the simulation accuracy is not high.

(4) GSM and hydrological model coupling mostly are one-way connection response. This kind of one-way connection coupling lacks of whole, physical unanimously description of the hydrologic cycle. Running alone of climate model and hydrological model can hardly feeds back the change of the land surface hydrologic cycle which was caused by human activities and climate change to climate model.

Therefore, the research of climate change on the influence of hydrology and water resources will tend to higher resolution of regional development space and time climate scenarios; perfect distributed hydrologic model and improve the accuracy of hydrological model in climate change conditions of land surface parameters; development models of the climate and surface hydrological model of land between two-way coupling techniques. Strengthen the research of extreme hydrological events, water quality and water environment and water resources system vulnerability under climate change.

Acknowledgements

It is a project supported by “the Fundamental Research Funds for the Central Universities(Grant No. 11MG15)”, and the National Natural Science Foundation of China (Grant No.50809027), and Open

Research Fund Program of State Key Laboratory of Water Resources and Hydropower Engineering Science (Grant No.2009B050).

References

[1] Qian Wei-hong. The global climate system[M]. Beijing: Peking University press,2009

[2] Ren Guo-yu, Jiang Tong, Li Wei-jing. Comprehensive analysis of impact of climate change on China water resources situation[J]. Water scientific progress. 2008，19(6):772

[3] IPCC. IPCC Fourth Assessment Report (AR4) [M]. Cambridge: Cambridge University Press.2007.

[4] HOUGHTON J T,MEIRA FILHO L G,CACCANDER BA,et al.IPCC Climate change 1995，the Science of Climate Change Cambridge. Cambridge University Press,1996.

[5] WMO .Water resources and climatic change: sensitivity of water resources systems to climate change and variability. Geneva: WMO,1987.

[6] Shi Ya-feng. The influence of Climate change on water resources in northwest north China[M]. Jinan,shandong science and technology publishing house,1995.

[7] Liu Chun-zhen. The impact of climate change on land water cycle[J]. Earth science progress, 2004，19(1):115~119.

[8] Wang Shun-jiu. Influence of global climate change on hydrology and water resources[J]. Climate change research progress, 2006，2(5):223~227.

[9] Chen Jia-qi, Wang Hao, Water introduction learn[M]. Beijing: China water conservancy and hydropower press,1996

[10] IPCC. Climate change 1995: A Report of the Intergovernmental Panel on Climate Change [M] 1995，IPCC，Geneva，SwitZerland.

[11] Sulzlnan E W，Polani K A，Kittel T G .Modeling Human—induced climate change: a summary for environmental managers[J]. Environmental Management，1995，19(2):197—224.

[12] Langbein W B. Annual run off in the United states，US Geological survey Circular 5，US DePt.of the Interior，Washington DC，1949

[13] Stockton C W，Boggess W R. Geohydrological implication of climate change on water resources，development .Fort Belvoir，Va: US Army coastal Engineering Research Center，1979

[14] Arinll N W. Factors controlling the effects of climate change : a river flow regimesin a humid temperature environment[J]. Journal of Hydrology，1992，132:321—342

[15] Leavesley G H. Modeling the effects of climate change on water resources[J]. A review Climate Change，1994，28:159—177

[16] Glick P H. The development and testing of a water balance model for climate impact assessment, modeling the Sacramento[J]. Basic Water Resources Research，1987,23(6):1049~1061.

[17] David C M，Kenneth D F. Water resources planning and climate change assessment methods[J]. Climatic Change,1997,37(1):25~40.

[18] Kenneth D F, David C M. Climate change and water resources[J]. Climatic Change,1997,37(1)：7~23.

[19]Deng Hui-ping, Tang Lai-hua. Response of Tuojiang watershed hydrology to climate change[J]. The geographical journal, 1998 (1) : 42 ploidy ~ 47.

[20]Liu Chun-zhen. The possible effect of climate change on hydrology and water resources in our country[J]. Water scientific progress, 1997，3:220~225.

[21] Guo Jing. Impact study of climate change on water cycle and water resources to impact[D]. Wuhan university.2010