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Global climate change and water resources decision-making

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Abstract. The multiple design of water resource systems and their management decision-making, under the influence of global climate change, is analyzed on a wider context. I mean to say the chain reaction that interconnects the phases among climate, hydrology, water resource systems and society. Each interface requires the contribution of hydrologists, atmospheric scientists, ecologists and socio-economists without the traditional boundaries of their separate disciplines. Various aspects regarding data requirements, methodologies and space-time scale problems are presented in each phase.

INTRODUCTION

While climate changes over periods of years are well documented, hydrologists have been rather reluctant to agree for as long as a decade (1960 to 1970) as to whether changes within typical water resource systems design periods (100 years or less) can indeed be distinguished from random variations in a physical hydrological time series (US National Academy of Sciences 1983). The advent of General Circulation Models (GCMs) over the last decade and consensus about the direction of future global climate change threw light on the controversial theme, thus making acceptable the aspect that climate change does exist.

Thus, in February 1979 the World Meteorological Organization (WMO 1979) with the support of UNEP, FAO, UNESCO and WHO convened the first World Climate Conference regarding

a) the improvement of climate processes understanding,

b) attendance of climate change and variations, and

c) the implementation of existing and forecast climate information for the mankind benefit.

Just recently, the International Association of Meteorology and Atmosperic Physics and International Association of Hydrological Sciences in the Assembly held at Yokohama, Japan (IAMAP-IAHS 1993) analyzed the update findings of the executive programs (e.g. IGBP, BAHC, EFEDA, FIFE, HAPEX, etc) about climate and climate change stydies and mapped out also the future research strategy on:

1) macroscaling modelling of the hydrosphere,

2) exchange processes at the land-surface-atmosphere interface for a range of space and time scales, and

3) extreme hydrological events: precipitation, floods and droughts.

However, our ability to predict climate changes is still very limited and any predictions that are made are debatable. The fact that the man himself may be the cause of such changes has given the whole question far greater importance and urgency. While the reasons of current climate change may be studied by those interested in the history and philosophy of science, society has every right to expect scientists, engineers and decision-makers to face the subject with the utmost seriousness.

The mankind survival requires adequate water supplies for food and clothing, as well as safety measures from floods, droughts and other acts of God. Therefore the most important impacts of climate change on society are introduced through a multi-faceted scheme of the water cycle. Accordingly, hydrologists and water resource engineers must undertake the study and planning of the aforesaid impacts in a coordinated fashion at national and international levels.

EVOLUTION OF REQUIREMENTS FOR CLIMATE CHANGE INFORMATION

Climate change is the difference among long-term mean values of a climatological variable (or its statistical parameter) (WMO 1985). A related condition to climate change is climate variability including extreme events and differences of monthly, seasonal and annual values in relation to the climatically expected values (WMO 1985).

The distinction between climate change and climate variability is clear in principle but it is not by no means easy to apply in practice. In order to study the impacts of climate change separately from those of climate variability, a series of problems related to space-time scales (e.g. global, regional, catchment - long-term, annual, daily), variables (precipitation, temperature, wind speed and direction, runoff, soil moisture, etc) and statistics (mean, variance, persistence, etc) must be solved.

At present climate predictions concetrate on changes in the mean values of a few selected variables over periods of ten to thirty years on a global or continental basis. It is not at all clear at first sight what characteristics of which elements are likely to be of great significance with regard to the impacts on water resources. Precipitation is a prime candidate, but we know very little about the predictions regarding this variable. Similarly, while abrupt changes or trends in mean values are important, increased or decreased dispersion and/or probabilities of extreme values are likely to be far more critical.

The last three years climate information has focused on the importance of hydrological land-surface processes in global change models. Climate model simulations are sensitive to changes in land surface albedo, soil moisture, evaporation and surface roughness, all of which are influenced by vegetation and snow cover. Nevertheless, the role of the biosphere is not sufficiently described in these models and the representation of hydrological processes is one of the weakest and most challenging aspects of the present GCMs. A profound knowledge of the bio-hydrological processes at the land-surfaces is needed to assess the impact which climate change exerts on the biosphere and, through the latter, on the availability and management of water resources.

CLIMATE CHANGE AND HYDROLOGICAL PROCESSES

Interactions between the physical climate system and the hydrological cycle involve a large number of processes that operate over a continuous range of spatial and temporal scales. So the impact of global climate change follows a chain reaction with the first link of the chain being the impact on hydrological processes. Until very recently, the hydrological model was the mostly basic approach to analyze the responses of climate change. The various parameters and inputs of the model were adjusted for global climate change which was simulated by hypothetical or GCM-modelled climate change scenarios in order to study the model responses to these disturbances. Even if a specific prediction scenario was given, it was difficult to decide what adjustments were to made to which parameters; it was even more difficult to interpret the results of speculative scenarios.

Another problem that the hydrologists faced was the appropriateness of the space and time-horizon models used in climate change studies. Erratic differences in the hydrological responses simulated for the same catchment size, the same climate change scenarios, yet with different approaches, have been noted (Panagoulia 1994). Klemes (1985) had set very exacting standards about the appropriateness of the used hydrological models in this context. Nevertheless the work that has already been done in this regard (e.g. Nemec and Schaake 1982, Lettenmaier and Gan 1990, Panagoulia 1991 1992 1993) is of great importance in that the hydrologists have been directed to focus their whole attempts dynamics on the land-surface-atmosphere interface processes and interactions.

The soil-vegetation-atmoshere interface belongs to the first link of the chain. The biosphere strongly interacts with the atmosphere by evaporation and transpiration. Therefore, changes in plant cover can have a significant impact on the hydrological cycle and consequently on the other components of the climatic system.

Remarkable progress is being made in Soil-Vegetation-Atmosphere Transfer (SVAT) modelling at the patch scale (10 km^2). The SVAT models (BAHC 1993) having different degrees of complexity represent approximations of reality and include numerous simplifications of the real processes. SVAT models also use more than 50 parameters to describe the local soil and vegetation conditions with data obtained from cuvette and tower measurements. A base of such patch data for a changing environment do not yet exist. The research activity to upscale the patch hydrological processes over larger areas belongs to the future in which also belong the regional-scale studies of land-surface properties and fluxes.

HYDROLOGICAL PROCESSES AND WATER RESOURCE SYSTEMS

The second link of the chain interconnects the hydrological processes and water resource systems. Water resource systems (reservoirs, dams, channels, etc) represent man's intervention in the use of hydrological cycle for his own benefit.

Even the simplest systems are subject to numerous external forces including global climate change influences. They interact in many ways and, on local scale, can modify the regional hydrological cycle. Therefore, while water resource systems may principally accept the climate impacts through the hydrological processes, they themselves can exert impacts on climate (Askew 1987).
In respect of this link, the anticipated changes in the hydrological processes can be introduced in the relevant parameters and time series inputs of mathematical models of the systems. The impact on their operation may then be analyzed through the system responses. Any error in the estimated hydrological processes and especially in the streamflow, which is the main input to operation system models, can essentially altered the system response due to the system complexity. In this case, the results interpretation of a such system simulated for global climate change is dangerous.
On the other hand, the interaction between hydrological processes and water resource systems may involve feed-back mechanisms, while significant changes in hydrological processes may cause the system to operate in a manner different from that experienced to-date, with the results obtained, if any, serving no real purpose (Askew 1987).
The interface between water resource systems and natural processes is very complex. Although the water resource systems are manmade works, their mode of operation is not well understood and may be subject to uncotrollable changes, and most easily at that. The decision-making is one of the main parameters of the systems management. For some systems it is possible to amend the management so as to face or take advantage of global climate change. For others the feasibility to change the management is very limited.
The actual way in which water resource systems are currently operated and managed is the result of a complex and stochastic balance of physical, socio-economic, political and human factors. Under this scheme, it is essetial that the management be included in water resource system studies.

WATER RESOURCE SYSTEMS AND SOCIETY

The third link in the chain, the one between water resource systems and society, is of great importance because it is dominated by feed-back mechanisms. Both the physical characteristics and the systems management have been used to face the needs of the society. This latter interface interconnects the environmental systems of climate and hydrology with the manmade socio-economic and management systems. Under these processes, the aforesaid interface is complex, dynamic, multi-faceted and difficult to predict its future characteristics and management.
A lot of valuable work has been done on the multi-objective design of water resource systems.Various techniques have been developed for rational estimation of the system demands in terms of finance and various measures of public safety and welfare. In theory, these techniques are easily developed, but in practice it is difficult to describe in concrete terms of desires and limitations the demands for future conditions. Therefore, we resort to future demand scenarios that could fit into all levels.
Not only the hydrological models, but also the socio-economic ones must be improved upon. Therefore, it is essential for the current modelling developments at land-surface interface to include management and decision- making of water resource systems in respect of global climate change.

CONCLUSIONS

The purpose of this paper is, primo, to place the whole field of the impact of global climate change on water resource decision-making into a wider context according to the last research developments, secundo, to raise further questions and data requirements, and, tercio, to propose what methodologies might be adopted in respect of space-time scales. The aspects noted earlier can be summarized as follows:
classification of the water resource issues especially in relation to episodic events (extended droughts, floods, etc) and greenhouse forcing
identification of climatological and hydrological parameters and their data requirements in the appropriate space-time scales that affect the water resources management and design
use of the recently developed SVAT models at land-surface-atmosphere interface to analyze the influence of future climate change on hydrological processes and water resources in various biome types and climates
use and testing of the watershed, biome and socio-economically interalated models to study the impact of global climate change on water resource decision-making
contribution to the studies of meteorologists of the Weather Generator following upscaling and downscaling procedures
The above tasks require the collaboration among hydrologists, atmospheric scientists, ecologists and socio-economists without the traditional boundaries of their separate disciplines.

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