

## **BACKGROUND AND SUMMARY**

### **Regional hydrological impacts of climate change— hydroclimatic variability**

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## **INTRODUCTION**

Climate variability and change represent key threats to water resources systems. The provision of adequate water supply is of fundamental importance to social and economic security worldwide. As greater demands are placed upon limited resources, it becomes increasingly important to safeguard water resources systems from pollution, over-exploitation and the vagaries of climate variability and change. The challenges of water security are most acutely felt in the less developed countries. In this light, the hydrological sciences have a key role to play in providing deeper insights into the sustainability and suitable management of water resources systems. In this volume, 30 papers are presented where the main emphasis is on the quantification of climate variability and apparent change. These papers document hydroclimatic variability from a diverse range of regional areas, presenting a fair sample of climatic zones and climate threats, as well as the inherent variability of hydrological systems themselves.

## **SOUTH AMERICA**

Marengo and Ronchail *et al.* provide insights into South American hydroclimate variability. The use of coupled ocean–atmosphere models is receiving increased attention as viable predictors of seasonal climate. Marengo presents an objective comparison of observed and modelled variability. The results indicate reasonable reproduction of seasonal and El Niño–Southern Oscillation (ENSO) variability, identifies decadal signals and points to further areas of development for GCM type approaches. Ronchail *et al.* evaluate 80 discharge station data against sea-surface temperatures (SST) in the Pacific and Atlantic oceans. They also evaluate decadal variability and show that significant links between Amazonian variability and SST exist with potential for prediction.

## OCEANIA

James Terry provides an interesting evaluation of the role of ENSO on Fijian hydrological variability. In particular it is shown that low-flow periods are highly correlated to ENSO offering the prospect of enhanced predictability of such drought periods. Verdon *et al.* also provide an assessment of the role of ENSO in determining eastern Australian climate. The authors subsequently evaluate the role of the Interdecadal Pacific Oscillation (IPO) in modulating the ENSO impacts. In particular, it is demonstrated that La Niña events increase streamflow which are then further enhanced during the IPO negative epoch. Finally, Chiew provides an analysis whereby long-term modes of variability are extracted from hydrological time series—empirical model decomposition is used to identify long periodic variability. This technique is applied within a bootstrapping methodology to provide some quantification of the statistical significance of identified modes, and hence represents a useful statistical tool in identifying long-term persistence.

## NORTH AMERICA AND EUROPE

The papers received with study areas located in North American and Europe follow the theme of quantifying hydrological variability and its associated impacts and implications. Blazejczyk *et al.* evaluate rainfall variability, with a particular focus on the ecological impact of drought periods. Kundzewicz assesses hydrological flood extremes and apparent changes in flood frequency from 70 basins across Europe. In particular the results indicate a systematic shift in flood frequency pre- and post-1980s.

Lizama Rivas & Koleva-Lizama evaluate the impact of climate variability on water resources in the South Black Sea Basin, Bulgaria. In particular, they demonstrate recent decreases in rainfall and consequent runoff. Kerkhoven & Gan present a modified land surface scheme which is then utilized to evaluate the hydrological impacts of future climate change. The climate scenarios represent a range of different GCM models, but interestingly most models predict further decreases in flows over the next 100 years.

Snorrason & Jónsdóttir present a new Nordic research initiative to evaluate future climate impacts on hydrological flow and extremes. Initial results indicate the potential for increasing design floods in future years. Yatheendradas *et al.* present a methodology for providing flash-flood forecasts in semiarid areas. The methodology is particularly welcome given the extreme nature of flooding in semiarid areas. Rosolem *et al.* calibrate a land surface model to a field site pre- and post-logging in an evaluation of the impacts of logging on land surface response. They demonstrate that changes in vegetation canopy do not significantly impact the response, and that calibrated models always outperform the model simulation using default parameterizations for the site.

## AFRICA

A large number of papers were received which addressed different aspects of climate variability and hydrological vulnerability in Africa. Both Afouda *et al.* and Kane

quantify hydrological variability as a function of rainfall variability. Friesen *et al.* also quantify climatic variability and attempt to distinguish an anthropogenic signal for changing hydrological function. Similarly, Liénou *et al.* show large interannual variability in southern Cameroon.

Mahé *et al.* demonstrate marked nonlinearity between rainfall and runoff in the Sahel and demonstrate that marked changes over the recent decades may be due to changes in groundwater levels. Ndiritu investigates long-term changes in southern Africa. Approximately 40% of time series show significant increases in the annual maximum rainfall. Amraoui *et al.* demonstrate the impact of prolonged drought on a water supply aquifer in Morocco.

Ardoin-Bardin *et al.* investigate the hydrological consequences of climate variability and change utilizing GCM driven scenarios. They demonstrate the potential reduction in water resources in Senegal and Gambia whilst suggesting possible increases in the basins of Sassandra and Chari. Le Lay & Galle utilize the GRJ4 rainfall–runoff model with a variety of rainfall scenarios to evaluate the impact of climate variability and change on the hydrological response of the Upper Ouémé River, Benin. Onibon *et al.* introduce the use of a Gibbs sampler to disaggregate spatial rainfall fields in an application to Sahelian rainfall with promising results.

## ASIA

In an evaluation of the predictability of Central Asian river flows, Barlow & Tippett utilize canonical correlation analysis and NCEP reanalysis data. They demonstrate that some predictability is available and future extension may include the use of Pacific data to provide longer lead times. Ye Baisheng *et al.* investigate historic variability in 678 precipitation stations as well as the four largest rivers in China. Their results demonstrate regional increases and decreases with mixed implications. Guobin Fu & Shulin Chen evaluate historic variability in the Yellow River. In particular, they quantify the nonlinearity of hydrological processes, demonstrating the sensitivity of river flow to changes in climate.

Kawamura *et al.* investigate the role of the El Niño/Southern Oscillation (ENSO) with respect to climate variability in Korea and Japan. They show significant correlations with lead times up to 4–5 months. Similarly, Kiem *et al.* investigate the role of ENSO in determining the snow-covered area of the Mekong basin. They demonstrate useful correlations that may become more important as increased demands are placed upon river flow. Sharma & Sharma investigate natural and anthropogenic factors in northeastern India and provide regression equations relating flooding to rainfall. Similarly, N. Singh *et al.* investigate climatic variability across India using 316 stations and document many extreme events over the 20th century.

Zhan *et al.* investigate the use of a joint hydrological–meteorological approach to estimating evapotranspiration across China. They then proceed to evaluate historic variability with this approach. Of particular interest, they demonstrate an increasing trend in evapotranspiration since 1990, which is apparent in most regions but most pronounced in arid and semiarid regions. Finally, A. Singh *et al.* provide a methodology for downscaling GCM-derived circulation patterns into rainfall fields

that are more appropriate for hydrological analysis. Their methodology has the potential to provide realistic input to many hydrological applications.

## **SUMMARY**

In summary, the collected papers in this volume represent diverse investigations in many different climate zones and regions of the globe. Many of the presented papers investigate historic variability, primarily as a function of climate variability, but also as a function of land-use changes. It is clear that many areas of the world face major challenges in providing adequate water supply in the face of both natural and unnatural hydrological variability. It is hoped that the insights developed through this eclectic mix of hydrological studies may lead to a wider appreciation of these challenges and robust methodologies to deal with these and future challenges.