Journal of Hydrology 388 (2010) 85–99

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Extreme snowmelt floods: Frequency assessment and analysis of genesis on the basis of the dynamic-stochastic approach

Alexander Gelfan *

Water Problems Institute of Russian Academy of Sciences, 119333, 3 Gubkin Str., Moscow, Russia

ARTICLE INFO

Article history:
Received 1 May 2009
Received in revised form 9 March 2010
Accepted 21 April 2010

This manuscript was handled by K. Georagakakos, Editor-in-Chief, with the assistance of Günter Blöschl, Associate Editor

Keywords:
Extreme flood
Snowmelt
Dynamic-stochastic approach

SUMMARY

A dynamic-stochastic approach, which combines a deterministic model of snowmelt runoff formation with a stochastic weather generator, has been proposed. The model describes snow accumulation and melt, vertical heat and moisture transfer in a soil, detention of melt water by the depressions at the catchment surface, overland and channel flow. The weather generator includes stochastic models that produce daily values of precipitation, air temperature, and air humidity during a whole year. Daily weather variables have been simulated by Monte Carlo procedure and transposed to snowmelt flood hydrographs on the basis of continuous simulation by the model of runoff generation. A specific censoring procedure has been developed to select among the generated weather scenarios the ones that can lead to generation of the extremely high floods. The developed procedure makes simulations more efficient and computationally fast. The proposed approach has been used to generate extreme snowmelt floods exceeding the maximum observed flood in the Seim River basin of central European Russia (catchment area, 7460 km^2), to estimate their frequencies and, importantly, to assess characteristic conditions of the genesis of such extreme floods.

1. Introduction

Snowmelt flood generation is among the classic problems of the watershed hydrology. A large number of hydrometeorological observations and measurements has been accumulated for decades and allowed hydrologists to develop a general understanding of the main processes that control generation of snowmelt floods under different physiographic conditions. However, due to the complexity and extreme spatial–temporal variability of these processes, it is not possible to investigate flood generation and create methods of flood prediction based only on available observations. Parallel with accumulating experimental data, the prospects are in developing models of snowmelt runoff generation which reflect the existing general understanding of the main hydrological processes and use, in full measure, the available observations.

Typically, capabilities for improvement of the models are associated by their developers with accounting, as far as possible, more detailed deterministic information (this information may include, for example, improved description of the main hydrological processes, accounting for peculiarities of the specific basin, assimilating new experimental data, etc.). As a result, a substantial advance has been made in the development of the watershed models, including snowmelt runoff models of different sophistication, e.g. IHDM (Morris, 1983), SHE (Abbott et al., 1986; Bathurst and Cooley, 1996), Hydrological Cycle Lab. Model (Kuchment et al., 1986), MIKE-SHE (Refsgaard and Storm, 1995), VIC-3L (Wood et al., 1997), ECOMAG (Motovilov et al., 1999), WASIM-ETH (Verbunt et al., 2003), HL-RMS (Koren et al., 2004), CRHM (Pomeroy et al., 2007) and many others. But whatever detailed deterministic model supplied with all needed data would be developed, the uncertainty still remains over some spatial–temporal scales indescribable by this model. To account for different sources of such an uncertainty, the appropriate stochastic information should be included in the model. Development of such a model which is based on the deterministic description of the hydrological processes and takes into account available stochastic information (on input variables, basin characteristics, model parameters, etc.) is the subject of the dynamic-stochastic approach to hydrological modeling.

Development of the hydrological model with random forcing is the dynamic-stochastic approach which allows one to account for the stochastic nature of the meteorological processes driving runoff generation. The resulting model integrates two components: deterministic model of runoff generation and stochastic models of the meteorological variables providing the inputs into deterministic model. Such integration opens up fresh opportunities for developing new approaches to flood frequency assessment and understanding processes of extreme flood generation.

* Tel.: +7 499 1355 403; fax: +7 499 1355 415.
E-mail address: hydrowpi@aqua.laser.ru

0022-1694/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.jhydrol.2010.04.031