

Snowmelt-Runoff Simulation for Snowbound Ungauged Catchments

by

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to the



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dedicated

to

the memory of my father

CERTIFICATE

This is to certify that the thesis, entitled "*SNOWMELT-RUNOFF SIMULATION FOR SNOWBOUND UNGAUGED CATCHMENTS*", being submitted by **Mr. SAEID MORID** to the **Indian Institute of Technology, Delhi** for the award of the degree of *Doctor of Philosophy*, is a record of bonafide research work carried out by him under our guidance and supervision. The thesis work, in our opinion, has reached the standard, fulfilling the requirements for the said degree. The research report and the results presented in the thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.



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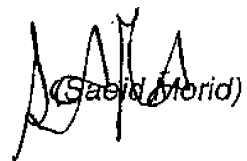
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(Saeid Morid)

Abstract

Snowmelt is the main source of water in high and mid-latitudes catchments. Many small and big water projects are established in such catchments, so prediction of snowmelt-runoff assume great importance in such areas. Unfortunately, in spite of importance of snowmelt runoff process, many of snowy catchments are ungauged, so it is necessary to develop and apply proper algorithms in hydrological models to cope up with data problem. Also implementation and evaluation of new techniques in hydrological simulation should be borne in mind. Out of the many categories of hydrological models, conceptual models are more suited for ungauged catchments. The SWAT (Soil and Water assessment Tools) model is one of the latest of these series of hydrological models, which has a special concern on ungauged catchments. In addition to the conceptual models, artificial neural networks (ANNs) is another model structure that requires comparatively less data and has shown considerable potential for hydrological simulation.

The present research work is mainly aimed to develop an algorithm for snowmelt-runoff simulation for ungauged catchments, wherein the required data has been generated. To fulfill this objective, response of some of the snow methods and models to synthesized data has been assessed. After reviewing a wide spectrum of the hydrological models, Degree-Day, SRM, ARNO, SN0W17, SHE, USAGE, and Kuzmin, which are combination of temperature, temperature-radiation and energy budget methods in snowmelt modeling have been selected. The snow module of these models has been programmed and put in the proposed snow module. It has been postulated that precipitation, air temperature and relative humidity are the data that can be supplied for snowy catchments and other should be estimated. Solar radiation lies in the second categories, of the data set that should be synthesized. In this regard a number of approaches including, temperature-based and stochastic methods along with ANNs have been used to estimate solar radiation. Results show better compatibility of temperature-base approach for estimation of solar radiation for snowmelt modelling in ungauged

catchments. This new snow module has been linked with the SWAT to evaluate the selected snow modules at same level of the prevailing condition.

ANNs, has also been formulated for snowmelt-runoff simulation as alternative model structure and its results at daily simulation have been compared with the SWAT model linked with the new snow module. Results show less dependency of this technique on data, expertise and requirement of calibration. It also reveals that the performance of ANNs during low flows is quite good, but in high flow the SWAT has performed better. In spite of some positive points with ANNs, after successful calibration of the SWAT model, there are many facilities that can accrue from this model, because of its physical basis, such as management scenario generation (e.g. evaluating change in hydrological regime due to change in crop type, landuse, etc) and climatic scenario generation (e.g. simulating changes which can occur in the hydrological regime due to change in the meteorological variables due to climatic change), estimation of sediment erosion and water qualities

In addition to snowmelt-runoff simulation, monitoring of snow water equivalent (SWA) and snow cover area (SCA) are other issues that have been embedded in the developed algorithm in conjunction with geographical information system (GIS), The applied methodology has been developed in such a manner that it is less dependent on rare data and also be applicable in ungauged catchments.

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