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A distributed model of runoff generation in the permafrost regions

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Abstract

A physically based distributed model of snowmelt and rainfall runoff generation in the permafrost regions has been developed. The model describes snow cover formation and snowmelt, thawing of the ground, evaporation, basin water storage dynamics, overland, subsurface and channel flow. An important feature of the model is taking into account influence of the depth of thawed ground on water input, water storage and redistribution of water input between surface and subsurface flow. The choice of the structure of the model is based on the analysis of the long-term observations of the runoff generation processes at the Kolyma water balance station and is orientated to the available standard hydrometeorological information in the cold regions. A case study of the proposed model has been performed for the Upper Kolyma River basin (the catchment area is 99,400 km^2).

Keywords: Distributed modelling; Runoff; Permafrost region, Model calibration/verification; River Kolyma

1. Introduction

The permafrost regions cover approximately one-quarter of the land surface of the world, more than 60% of Russia and one-half of Canada. Because of small density of population, expensive access, and limited human activity, these regions have a sparse and extremely unevenly distributed hydrometeorological network. The extensive collection of field measurement data during the last decades has considerably increased the available information on the hydrometeorological processes in the cold regions but most of these data are too fragmentary. As a result, the peculiarities of permafrost hydrology have been investigated weakly. At the same time, the growth of economical activity in the northern areas, the problem of protection of the northern environment, and also an increasing attention to studies associated with the global processes make investigation of permafrost hydrological processes and especially runoff generation highly important and urgent. For this reason, there is much interest in developing models of the hydrological processes in permafrost regions. However, in spite of significant progress in modelling separate hydrological processes (snow cover formation and snowmelt, freezing–thawing of the ground, infiltration into frozen soil), the attempts to construct a detailed physically based model of the hydrological cycle and runoff generation for these regions met with a little success. At the same time, the comprehensive physically based models of runoff generation developed for the temperate regions can not be applicable to the permafrost river basins because of essential differences in the main processes and the lack of adequate hydrometeorological data and basin characteristics.

In this work, we have tried to construct a distributed

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