Combining the ISBA land surface scheme with a Distributed Hydrological model

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INTRODUCTION

Land surface schemes provide an excellent description of surface process. Using these schemes one can obtain with a reasonable accuracy the rates of energy and moisture transfer at the soil vegetation surface. Several schemes with varying degrees of complexity have been developed and tested including Dickinson[1)], SIB[2)] and ISBA[3)] etc.

The ISBA scheme considered in this study like all others was primarily developed for application in Global circulation models. The scheme calculates five variables: surface temperature, soil temperature, surface soil moisture and deep soil moisture in addition to energy balance terms at the surface and moisture balance of the canopy layer. One important feature of this scheme is that energy and moisture balance depends on soil and vegetation parameters. Therefore once distributed soil and vegetation data is available the scheme provides ideal means for characterizing the spatial variability of energy and moisture balance over the land surface.

Distributed hydrological models on the other hand require well estimated distributed inputs. The single most important input of such models is the net rainfall the net rainfall. This is the remainder of the liquid moisture reaching the ground during rainfall, after subtracting the amount evaporated back to atmosphere and that which is infiltrated into the ground.

Land surface schemes can provide not only the net rainfall but also with also the antecedent conditions (moisture) required for hydrological simulations. The fact that these schemes use parameters which depend on soil and vegetation makes them ideal for application in physically based distributed hydrological models (PDHM). In the ideal case the use of such schemes enables the modeler to simulate deterministically river flow, groundwater recharge or any other component of the hydrological cycle. This approach has the advantage of avoiding adopting models whose parameters have to be calibrated prior to simulations. It may be seen immediately that the use these schemes gives the PDHM more capability and flexibility to be used in a range of application including: prediction of the effects of landuse changes, flood forecasting, flood warning etc. It is well known that such tasks can not easily be performed by lumped model or models whose parameters must be established by calibration.

However to apply a land surface scheme at a scale of hydrological model some modification may be required. This may concern the scale issues in terms of inputs and processes.

In this paper the ISBA land surface scheme is adopted for use in a distributed hydrological model. The limitations of applying this model to generate spatially distributed net rainfall are highlighted. The shortcomings of the scheme in this case mainly included the difficulty of meeting the conditions for surface runoff generation. In the ISBA scheme run off is assumed to occur when the top or bottom soil layer reaches saturation level[3)]. Due to slow rate at which soil moisture changes this condition is only fulfilled if the soil moisture is initiated very close to saturation value. This tendency is considered unrealistic and can not assure satisfactory results if initial soil moisture condition is to be provided from independent source like remotely sensed soil moisture. To simulate more accurately the catchment response to rainfall the scheme was modified by incorporating the infiltration model of Green and Ampt as modified by Chu[4)]. The Green and Ampt model is invoked during rainfall storms to define the soil moisture recharge and excess rainfall (see Fig. 1). A modified model was applied in Yasu river basin where it is shown that the modifications were necessary to obtain realistic estimation of river flow. (See Figs 2 and 3)

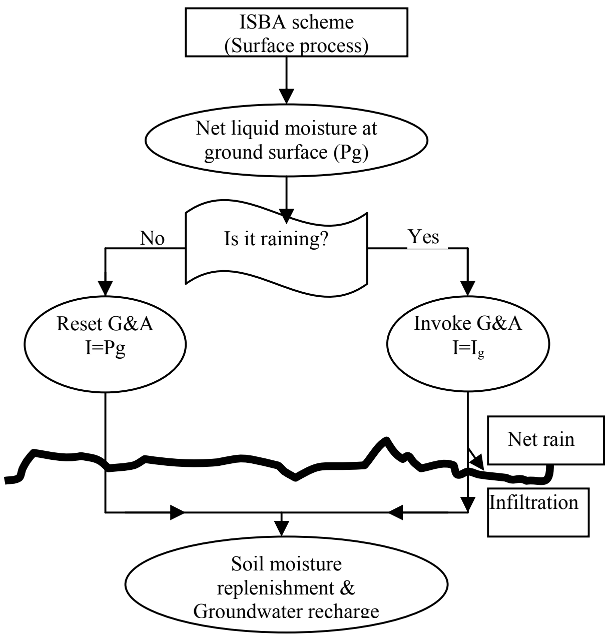

Fig. 1 schematic layout of Modified ISBA Model for PDHM

THE ISBA LAND SURFACE SCHEME

The scheme developed by Noilhan and Planton 1989 is an improved version of Deardorff[5,6)]. It includes single layer canopy with physiological resistance for transfer of water vapor into the atmosphere. The scheme predicts the evolution of five variables: surface temperature (T_s), soil temperature (T_2), surface volumetric water content (W_g) and soil volumetric

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water content (W_2) and canopy moisture (W_r). The force-restore method is used in calculating the soil moisture transfer rates between atmosphere and soil as well as heat transfer between atmosphere and soil. The scheme has been formulated to keep the number of parameters describing the physical process at the land surface at minimum. This has been possible by introducing calibrated parameters in soil and heat transfer equations to account for unknown behaviors. These parameters given according to textural soil types and vegetation[3)] together with other properties derived from soil and vegetation data sets form the physical basis for applying this model in a variety of soil and vegetation combinations.

In a typical application the model requires a full range of meteorological variables as input including: solar radiation, air temperature, air pressure, specific humidity, long wave radiation and rainfall. These data were obtained from a nearby meteorological station. The output of the model includes the five prognostic variables T_s, T_2, W_r, W_g, W_2 together with derived quantities such as Evaporation, Canopy moisture storage, Evapotranspiration, Components of surface energy balance etc.

THE HYDROLOGICAL MODEL

A distributed hydrological model for the study basin incorporating the ISBA scheme was developed. The study basin is divided into orthogonal grids (500 m) according to the aggregated DEM of the basin (original DEM is 50 m). A flow direction map at this grid size was derived and used to define the connection between grids treated as different objects of a watershed model constructed in object oriented programming. At each grid the modified ISBA scheme is used to calculate the net rainfall which is routed to the grid out let by a kinematic wave model. Landuse and soil data are used to define the parameters of ISBA scheme, Green and Ampt model and the Kinematic wave model. The distributed rainfall input was obtained by spatial interpolation from rain the gauges well scattered within the basin.

APLICATION RESULTS AND DISCUSSION

The developed hydrological model was applied to Yasu river basin. A typical example of simulation is given for a flood which occurred on 30th September, 1994. In the first case the estimation of river flow was performed by using the ISBA scheme alone. Different initial conditions were given to try to reproduce the observed flow. The condition for runoff generation in ISBA scheme is that either the top superficial layer or the deep soil layer must become saturated. It was found out during trial simulations that this condition can be met only if the initial moisture content is set very close to saturated moisture content. However this condition was not necessary when more physically based description of the infiltration process by Green and Ampt model was adopted. The results of this study support the proposition that ISBA scheme needs to be modified with a more realistic infiltration models during rainfall to generate runoff. The assumptions of runoff generation in the current scheme as put forth by Noilhan and Planton 1989 are inadequate to describe the runoff generation during rainfall. It is also observed that a suitable infiltration model will provide a link between hydrological model and the Scheme enabling the scheme to be verified with stream flow data in addition to short term radiation balance often used to validate land surface schemes.

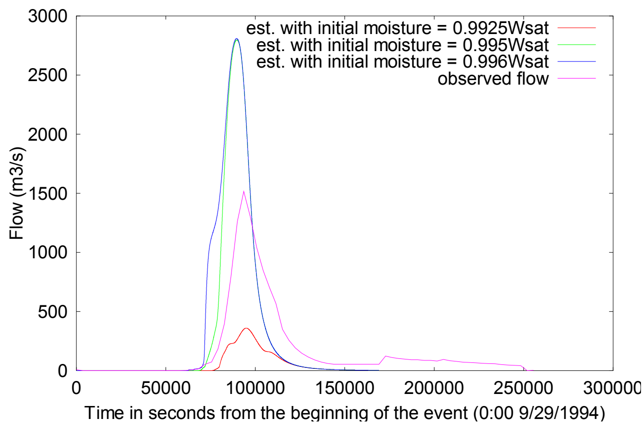

Fig.2 Observed and estimate flow at Yasu ISBA scheme with various initial moisture conditions as percentage of W_{sat}

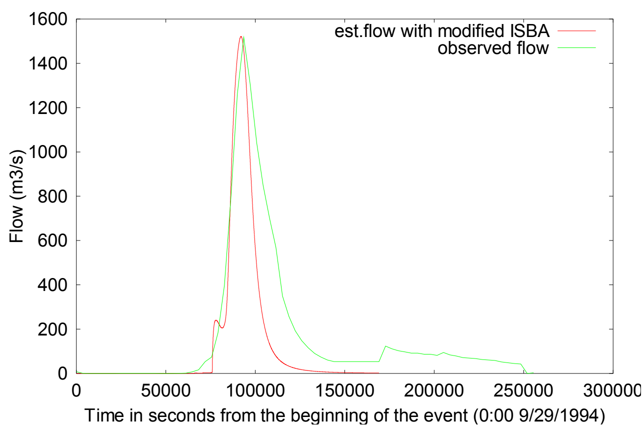

Fig. 3 Observed and estimate flow at Yasu using modified ISBA scheme including the Green and Ampt model.

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