SNOW MELT RUNOFF MODELLING USING DIFFERENT HYDROLOGICAL MODEL

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ABSTRACT

Major source of freshwater for the downstream present at the reservoir is the runoff initiated by the snow melt, snow melt runoff is an important form of precipitation. Precipitation occurred during the winter season at the Himalayan region is the main cause of this snow cover but due to the increasing runoff rate the snow melt runoff has also shown sudden rise in it, which could result in significant flood risk as well, many researchers are already working on the studies related to snow melt runoff, as different models are being used for the snow-melt runoff modelling, two of these GIS based models used in large-scale are VIC and SWAT which are chosen for studies related to various snowmelt routines, ranging from energy balance to simple degree-day approaches respectively. Both the models require remote sensing data so the present study has been done as a review for these models, how they work and their advantages and disadvantages on the basis of literature work.

Keywords: Runoff, Snowmelt Runoff, VIC, SWAT

I. INTRODUCTION

Snowmelt runoff is the valuable and one of major source of freshwater for many regions throughout the world. It is being accumulated in the mountainous region during the winter season and is then is participated in the process of runoff. These melted snow packs fulfills 33% demand of irrigation water in the world (Brooks et al., 1997).

Runoff from the snow cover can be an important source for groundwater recharge and few of the seasonally formed surface waterbody as well which can be thereafter used for various commercial and domestic purposes as well (Singh and Singh, 2001). But since last few decades due to rapid change in land use land cover (LULC) pattern mainly due to urbanization and industrialization rate of melting snow has increased a lot resulting in excessive runoff from the snow which is a major cause of concern as it may increase the risk of flood in nearby place which ultimately result in socio-economic factor of the place. Snowmelt run-off (SMR) and glacier mass balance are the two aspects which are directly affected by changes in climatic conditions of the region (Adam, et al., 2009).

II. HYDROLOGICAL MODELS

A model is a simplified representation of the real world scenario as per the description given by Sorooshian et. al, 2008. Literature and other related studies suggest that the best model is one which has an easier graphical or programming interface is relatively simple rather than that of the complex one, those with lesser input values to be entered and whose generated output is also quite accurate and can be understood clearly. A Hydrological model uses combination of various equations and algorithm to predict the behavior of hydrological process, for any model uses three different parameters which area:

- **Topography**
  Along with watershed characteristics, vegetation cover, water, snow area, forest, river channel, soil moisture, soil porosity, soil conductivity, ground water aquifer and digital terrain model.

- **Climate Data**
  Two data are mandatory for hydrological modelling these are precipitation data and Temperature data, optional data used are Wind speed, Solar radiation and dew factor.

- **Discharge Data**
  Discharge data is important for validation of model and for predicting the behavior of run-off analysis.
III. TYPES OF HYDROLOGICAL MODELS

Basically hydrological models are classified in three types based on their parameters and principle components which are: Lum-sump model, Distributed /Semi-distributed and Grid model. Many of the researchers were used to grid or semi-distributed model where is model based on the parameters as a function of time and space. In this type of model lot of data is available freely from various satellites and other sources like drone and man-made instruments which are being installed in river channel and barrage for data capturing and storage. It uses single set of input and gives accurate results in output.

As Moradkhani and Sorooshian (2008) said in their papers about the lump model that the entire river is taken as a whole and then using the discharge value as input derives the desired result.

Whereas, in distributed and grid model can make prediction in hydrological model which are distributed in some small unit of catchment of total watershed that can be different for each portion of catchment which also changes its input parameters.

Some researchers used the classification based model that are static and dynamic both, static model is used for fixed time interval or we can exclude time interval but dynamic model is used for précising behavior of hydrological time interval. Sorooshian (2008) has also classified the model based on event and in continuity.

Table 1. Characteristics of Hydrological model (Devia et al., 2015)

<table>
<thead>
<tr>
<th>Empirical model</th>
<th>Conceptual model</th>
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<td>Data Based</td>
<td>Parametric</td>
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<td>Black Box Model</td>
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<td>Mathematical Equation</td>
<td>Physical basin and semi empirical equation</td>
<td>Spatial Distribution and physical characteristics</td>
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<td>Few input requirement</td>
<td>Calibration through field data</td>
<td>Required physical and morphology of catchment</td>
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<td>Lower input and high productive</td>
<td>Computer code is easy to perform</td>
<td>More complex and lot of human expertise</td>
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<td>One process for one study</td>
<td>No of variable required as input</td>
<td>Problem with scale factor</td>
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<td>Unit hydrograph and Artificial Neural network</td>
<td>Top Model</td>
<td>SWAT</td>
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<tr>
<td>Valid with one catchment boundary</td>
<td>Calibration involve curve fitting</td>
<td>Valid for wide range</td>
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IV. DESCRIPTION OF FEW MODELS IN BRIEF

There are few hydrological models which are most commonly used by the researchers for deriving various output, these are discussed below:

SWAT

Soil and water Assessment Tool (SWAT) was developed by Texas & Agriculture management university, Texas. It is an ongoing process of development for removal of bugs of enhancement of ongoing capability and behavior. SWAT model is a grid based semi-distributed model designed to predict and forecast the agricultural production, to do runoff analysis, for sediment transportation and snow melt runoff within an ungauged and gauged basin.

It is capable of performing short and long term simulation along with calibration and validation, SWAT models divide the entire watershed to some part of catchment, which are divided into other characteristics like lulc, soil and hydrological response unit (HRU).

SWAT uses three types of data for grid based analysis:

Spatial Data- Model uses available spatial datasets which has to be formatted as per the model requirements before starting the simulation process.
Meteorological Data - Two main types of data used are precipitation data and Temperature data, rest of the metrological data like solar radiation, relative humidity, wind speed etc. can be used in order to increase the accuracy of obtained results.

Once the data is available, database has to be created as per the required input data format in order to run the model.

For the estimation of evapotranspiration Penman-Monteith and Priestley-Taylor Evaporation equation (Allen et al. 1998, Allen 2005) is being used which is:

\[
\Delta \cdot (Rn - G) + \rho_a \cdot c_p \cdot (e_s - e_a)\Delta + \gamma \cdot (1 + rsra) \cdot (1) \lambda_v ET_{pm,o} = \Delta \cdot (Rn - G) + \rho_a \cdot c_p \cdot (e_s - e_a)\Delta + \gamma \cdot (1 + rsra)
\]

Where:
\( ET_{pm,o} \): Penman-Monteith evapotranspiration in m day\(^{-1}\)
\( \lambda_v \): Volumetric latent heat of vaporization, 2453 MJ m\(^{-3}\)
\( \Delta \): Slope of the saturation vapor pressure-temperature curve (kPa C\(^{-1}\))
\( Rn \): Net radiation (MJ m\(^{-2}\) day\(^{-1}\))
\( G \): Soil heat flux density (MJ m\(^{-2}\) day\(^{-1}\))
\( \rho_a \): Air density for a given air pressure (kg m\(^{-3}\))
\( c_p \): Specific heat of air (MJ kg\(^{-1}\) C\(^{-1}\))
\( e_s \): Saturation vapor pressure (kPa)
\( e_a \): Actual vapor pressure (kPa)
\( r_a \): Air resistance (day m\(^{-1}\))
\( \gamma \): The psychrometric constant (kPa C\(^{-1}\))
\( r_s \): Surface resistance (day m\(^{-1}\))

Model uses water balance equation (Arnold et al. 2012; Gassman et al. 2007; Nasiri et al.) as well which is:

\[
SW_t = \frac{1}{4} SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw})
\]

Where,
\( SW_t \) is the final soil water content (mm)
\( SW_0 \) is the initial water content (mm)
\( t \) is the time (days)
\( R_{day} \) is the amount of precipitation on day \( i \) (mm)
\( Q_{surf} \) is the amount of surface runoff on day \( i \) (mm)
\( E_a \) is the amount of evapotranspiration on day \( i \) (mm)
\( W_{seep} \) is the amount of water entering the vadose zone from the soil profile on day \( i \) (mm)
\( Q_{gw} \) is the amount of return flow on day \( i \) (mm)

Fig. 1. Schematic representation of SWAT Hydrological Model (Amatya et al., 2013)
Mike SHE Model

It is an integrated hydrological modelling system which is used for simulating surface water flow and groundwater flow, it was developed by three European organization: The institute of hydrology (The United Kingdom), SOGREAH (France) and DHI (Denmark) (Abott, NB et al., (1986) (Young et. al,2000). The model requires many types of input like basin physical characteristics, stream flow and meteorological data. It is good for small basin for better output

![Fig 2. Schematic representation of mike SHE model (Keilholz et al., 2015)](image)

VIC Model

Variable Infiltration Capacity (VIC) model (Liang et al., 1994) is a grid-based land surface Model representation which simulates surface atmosphere fluxes of moisture and energy. The model was developed for coupled Land Surface Model (LSM) and Global Circulation Model (GCM) simulations. VIC is basically a conceptual models which is not based on physical parameters like CN method. Model is majorly used for flood forecasting and water supply.

![Fig 3. Structure of VIC model (Barrett et al., 2007)](image)
V. DISCUSSION

By the above review it can be demonstrated that SWAT is good for various application like Rainfall runoff analysis, Snowmelt runoff analysis, soil erosion, nutrient & sediment transport, Easton et al., 2010 found the natural resources using this application for two variables like determining the runoff and soil erosion. SWAT have two sub-component that can be performed separately and the output from the model can be used as input in SWAT-CUP and SWAT-EDITOR.

Young et al., 2000 suggested that mike SHE is a complex model as it takes many variables as the input data for its simulation like basin characteristics and physical characteristics so this model is best fitted for small watershed. Hence, according to the studies done, it can be said that it give more accurate results when combined with different models.

Earlier VIC model was based on python programming language, few years ago it has been upgraded with the help of some researchers and organization into GUI window based model.

Nijssen et al (1997) VIC model is basically grid model and perform the many applications based on river network and perform well in moist area.

According to him each grid have unique identity and used used unique variables Par and Markes (2014) VIC is used for snowmelt and also drive the flood peak in different time interval.

VI. CONCLUSION

By the above study it can be concluded that all the three models are good in some aspect while it has some disadvantages as well but it can be said that SWAT model is relatively good for work, as it is relatively an easier model, and uses data in simpler form as a input values. Generally hydrological model is used for estimating the hydrological activity in real world. Many organization develop the different type of model for different type of application. Some researcher develop and contribute the owe idea for developing the some interface of model or transformed the model for better visualization. Some application will used in any region.

VII. REFERENCES


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