Hydrological modelling and flood inundation mapping in the Bago basin, Myanmar

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Abstract: Myanmar is susceptible to floods and these catastrophic floods cause significant socio-economic losses. Hydrological models can be used to estimate river discharges with high accuracy. In this paper, we used the Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM) which was developed by fully coupling biosphere scheme - SiB2 (takes into account the energy, water and carbon fluxes) with a geomorphology-based hydrological model – GBHM (redistributes water moisture through both surface and subsurface runoffs). WEB-DHM uses biophysical data such as DEM, Soil, Hillslope, Land use, LAI-FPAR data; and Meteorological data such as wind, pressure, humidity, short wave radiation, long wave radiation, air temperature and precipitation. The study area is the Bago river basin of Myanmar. Given the situation that observed data in Myanmar is scarce, the model was able to produce a reasonable hydrograph (both peak and base flows). The model was then validated with observed discharge data. Then, a simple 1-D model was used to generate the flood inundation map for the 2006 and 2011. The results show similarity with the observed ALOS data. Such well calibrated models can be used to predict the discharge of rivers in near real-time, which can be used for flood forecasting, early warning system, estimation of flood vulnerability etc.

Keywords: Flood inundation, Discharge, Hydrological model, WEB-DHM, Myanmar

1. Introduction

Occurrence of floods is a natural phenomenon all over the world and with the increase in population and human activity in the flood plains, flood damages represent an increasing hazard in many countries (Refsgaard et al., 1988).

Flood protection has always been among the most pressing hydraulic engineering tasks and therefore hydrological models for obtaining design floods have a long tradition. Although floods happen almost annually in monsoon-affected countries, many countries still lack flood modelling and subsequent hazard maps to prevent or mitigate such damages.

Hydrological models helps us understand such complex natural systems by providing detailed information about the region. They also help us to forecast the effects of different water resource management scenarios (eg. Cartwright et al., 2006, and Li et al., 2010).

Myanmar became a civilian democracy in 2011. Since then, large scale economic growth has been seen, which leads to growing disaster risk due to poor existing infrastructures. This paper presents a distributed hydrological model applied to the Bago river basin of Myanmar.

2. Study Area

The Bago river basin is a flood prone area of Myanmar. The Bago River (335 km) originates from the Bago Yoma mountainous region and it flows into the Yangon River finally draining to the Gulf of Mottama. With a catchment area of 4,893 km², it is one of the most populous regions of the country (Ye Htut et al., 2014). The average annual total rainfall at the Bago station is around 3,000 mm. Only two meteorological stations (Bago and Zaung Tu) are located in the basin. As of 2010, there were 5 meteorological stations (Bago, Kabaraye, Shwegyin, Tharawady and Zaung Tu) in and around the Bago river basin. The Bago basin with all the meteorological stations are shown in fig.1. As seen from the fig. 1, the lower basin is relatively flat compared to the mid and upper basin.
3. Water and Energy Budget based Distributed Hydrological Model (WEB-DHM)

The Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM) (Wang et al., 2009a,b), was developed by coupling a simple biosphere scheme (SiB2) (Sellers et al., 1986) with a geomorphology-based hydrological model (Yang, 1998) to describe water, energy and CO₂ fluxes at a basin scale. It calculates evapotranspiration based on both water and energy balances in each model grid and therefore has a more solid physical foundation relative to the traditional hydrological models. The overall structure of WEB-DHM is shown in fig. 2. The fig. 2 (a) shows the sub-basin; (b) shows the sub-division from sub-basin to flow intervals; (c) shows the discretization from a model grid to a number of geometrically symmetrical hillslopes; and (d) shows the detailed process descriptions of the water moisture transfer from atmosphere to river, including downward solar radiation, downward long wave radiation, sensible heat flux and the latent heat of vaporization. A better description of this model can be found in Wang et al. (2009b).

Fig. 1: The Bago river basin with the Meteorological stations.

Fig. 2: Overall structure of WEB-DHM model

4 Data sets used

4.1 Meteorological data

WEB-DHM uses the following as input data: precipitation, humidity, wind speed, air pressure, air temperature and downward solar radiation (short wave radiation, long wave radiation). Precipitation data were obtained from the Department of Meteorology and Hydrology (DMH), Myanmar. The remaining meteorological data were obtained from the Japanese 55-year Reanalysis (JRA-55) (http://jra.kishou.go.jp/JRA-55/index_en.html). The JRA-55 data is available globally.

4.2 DEM and remote sensing data

For digital elevation data, the 3-sec Conditioned DEM data product of HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales) were used. HydroSHEDS is a mapping product that provides
hydrographic information for regional and global-scale applications in a consistent format. It is based on high-resolution elevation data obtained during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM) ([http://hydrosheds.cr.usgs.gov/index.php](http://hydrosheds.cr.usgs.gov/index.php)).

Land-use data were obtained from the USGS ([http://edc2.usgs.gov/glcc/glcc.php](http://edc2.usgs.gov/glcc/glcc.php)). The land use types are reclassified as per the SiB2 land-use types (Sellers et al., 1996). For soil data, the global data product (2003) of Food and Agriculture Association (FAO) were used.

4.3 Observed discharge data

The observed discharge data of Bago and Zaung Tu stations were available. 2010 year’s data were used to calibrate the WEB-DHM model parameters.

5. Results and discussions

The WEB-DHM model was run for the year 2010. Figure 3 shows the model output. The horizontal axis shows the time period. The vertical axis shows the Discharge at the Zaung Tu station; the observed discharge in blue and model discharge in orange. The inverted vertical axis shows the gridded rainfall of the basin, upstream if the Zaung Tu station.

From the figure it can be seen that the model mirrors the observed discharge well. However, there are a five peaks where the model output doesn’t match with the observed discharge. The first peak can be explained by the fact there was little to no rainfall before May. Hence the soil condition was too dry and resulted in higher soil infiltration.

The remaining four peaks might be explained by the reservoir operation. The dam operation data for the year 2010 was not available. Hence it couldn’t be included in the current model analysis. However, such dam operation data can be easily incorporated into the model. The dam operation data is available from 2012 onwards.

5.1 Further improvement of the model

As input, WEB-DHM uses hourly data. All of the meteorological data except for rainfall data (and discharge data for validation) are hourly data. However, only daily rainfall (and discharge) data were available. Hence, these data were converted into hourly data by dividing into 24 entries and then the model was run. In 2013, new meteorological stations have been set up and from 2014 onwards, hourly rainfall and discharge data are available.

Fig. 3: Rainfall, model discharge and observed discharge for the year 2010.
As the next step of this research, the new input data will be used and the model will be calibrated accordingly. It is expected that the model will provide better results.

Also, reservoir operation data are available from 2012 onwards. These data will be included in the model development, so that better simulation results can be obtained which can mirror the reservoir operation accurately.

In 2015, DMH updated the rating curve for discharge measurement. It is expected to improve the observed discharge measurement.

For extreme cases such as flood disaster, using this improved model discharge as input to the inundation model, flood inundation maps will also be generated.

6. Conclusion

A distributed hydrological model (WEB-DHM) has been developed for the Bago river basin in Myanmar. The model results for the year 2010 were shown in this paper. The model was able to show good resemblance with the observed discharge. For better accuracy of the model’s result, daily rainfall data is required. Better observed discharge data will lead to a better calibration of the model.

References


