Assessment of flood risk by using satellite based rainfall data in watershed scale

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ABSTRACT: Flood is the major disaster in Asia. For some big rivers such as Mekong, Chaophraya and Ganges, the flood in the lower basin is caused by the intensive rainfall for long period on some parts in the catchment a few months before the event, whereas, the flash floods are caused by the heavy rainfall for about a few or several days before the event on the site. In this study, the risk of flood was assessed by using satellite based rainfall data such as GsMAP from the previous flood events reported to Sentinel Asia which works as the emergency response for disasters in Asia and Pacific by the space agencies in the region since 2006. The daily rainfall data from April 2000 to March 2017 of GsMAP was used for the analysis. A watershed model was applied to understand the accumulated rainfall in catchment areas for the study area. The assessment was conducted through statistical approach in order to detect the anomaly in accumulated rainfall based on areas and periods in various scale, and a flood risk index was proposed. The index has a potential to support early warning for some cases of previous flood events. To improve the reliability of the index, issues about the accuracy of rainfall data and feasibility of watershed model are discussed.

1. INTRODUCTION

Flood damage is occurring every year in various parts of Asia, and many of them cause serious damage.Flood damage is of course caused by abnormal rainfall, but in tropical Asia, high intensity rainfall occurs relatively frequently. Thus, heavy rain does not immediately lead to a flood, but it is falling Spatial distribution of period and rainfall is important information.Therefore, in order to evaluate the possibility of a flood at a certain point, it is necessary to know not only the rainfall that has been falling at that point, the precipitation that fell in the past few hours, several days, but also in the upstream area including that point, It is necessary to consider how much it fell. However, in many developing countries, the information observed on the ground is limited on the temporal and spatial distribution of rainfall, and many such areas are difficult to predict. In this research, by using the rainfall data observed from the satellite, considering its temporal and spatial distribution, and from the hydrological point of view, by estimating the amount of water accumulated at a certain point, flood Consider whether it is possible to judge the risk of occurrence.

2. DATA

In this study, two datasets were used to develop the model. One is the rainfall data in regional/global scale with daily base, and the other is hydrological distribution model which is applicable to a hydrological model to estimate the runoff from the watersheds in the region.

2.1 RAINFALL

Fig.1: GsMAP

GSMaP(Global Satelite Mapping of Precipitation) was used in this study. It provides a highly accurate global rainfall map with a high resolution. Values are estimated using multi microwave radiometer data and a rain rate retrieval algorithm based on a reliable rainfall physical model. Data are also comprehensively provided using precipitation radar and infrared radiometers on geostationary satellites. The spatial resolution is 0.1 degree (latitude and longitude) and the original temporal resolution is one hour however, various types of GSMaP products are distributed in several data formats. More detail ca be see at: http://sharaku.eorc.jaxa.jp/GSMaP/index_e.htm. Fig.1 shows an example of daily base GsMAP

2.2 WATERSHED

HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales) was used in this study to define the watersheds in the region and to model. It provides hydrographic information in a consistent and comprehensive format for regional and global-scale applications. HydroSHEDS offers a suite of geo-referenced data sets in raster and vector format, including stream networks, watershed boundaries, drainage directions, and ancillary data layers such as flow accumulations, distances, and river topology information. Available resolutions range from 3 arc-second (approx. 90 meters at the equator) to 5 minute (approx. 10 km at the equator) with seamless near-global extent. HydroSHEDS data are free for non-commercial and commercial use. See License Agreement for specific restrictions and use requirements. The details of the dataset can be seen at: http://www.hydrosheds.org

3. ANALYSIS

There are many hydrological models to simulate the river discharge and to assess the risk of flood(Chen et al., 2005; Sugiura et al., 2008). However, these models require many parameters to simulate the output fitting to the observation. In this study, we used a simple tank model as a model in which precipitation flows out by a hydrological process(Fig.2). However, the purpose of this study is not to simulate the river discharge, but to assess or provide early warning to a flood occurred in a large watersheds in macro scale. From the view point of the aim, a tank model, which was originally developed to reproduce the river discharge using complex structure, is simplified and installed based on generality and easiness for handling, especially focusing on flood for big rivers and their basins. Even though the land use, topography and water use are different in different watersheds, a simplified tank model was used.

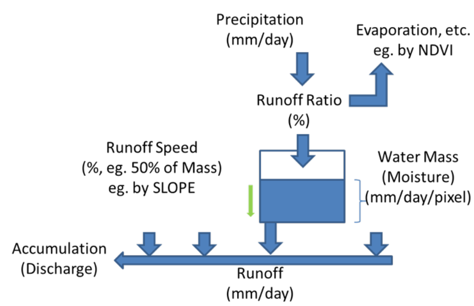

Fig.2: Tank Model Based River Discharge Model

4. RESULT and Discussion

In order to evaluate the effectiveness of GsMAP data and the adaptability of the applied tank model, the output of observation and model were compared at two points in the Ganges River basin where observations of daily flow rate can be ascertained(Fig.3).

Fig.4 (a) is a comparison of the hydrograph between the observation and the model output at point A. According to it, the rainy season seems to start at around the145 th day of the year, and the dry season lasts before that. The observation data for the dry season were continuously low level. On the other hand, some large outflow peaks have been seen three times in the model output. It seems that some rainfall occurred in the first and third times because the observation values are rising slightly, but clearly the precipitation by GsMAP seems to be overestimated.

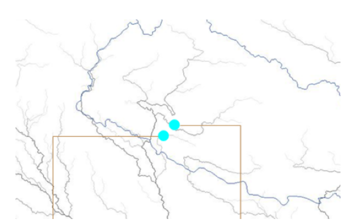

Fig.3: Points for Observation Data

For the second peak of the hydrograph, the value of GsMAP itself may be an error if the observation is correct, because the incread of the discharge had not been observed on the time. However, even if such errors and overestimated values are there in the dry season, the flow rate of the same level is observed frequently in the rainy season. This means that the output from the model using GsMAP has still potential to forecast flood even though it contains defects in measuring the actual rainfall on the ground.

On the other hand, the pattern of the hydrograph in the rainy season often corresponds to the observation data pattern. This illustrates that the model has a potential for early warning on floods occurring in the downstream of the large catchment area due to a long period of rainfall, but not flash flood by a heavy rainfall in short time. Because we need to know the duration and location of the intensive rainfall in a certain watershed, so the model can show a possibility that it can be detected at an early stage.

Fig.4 (b) is a comparison of the hydrograph between the observation data and the model output at point B. As with point A, although there are several outputs which seem to be errors or obvious overestimated values, it seems to be caused by short-term excessive precipitation recorded by GsMAP, and in detecting floods due to long-term rainfall , It is possible to reduce the influence of such errors.

Fig.5 shows the adjustment of the parameters of the tank model and is consistent with the observed hydrograph. It is possible to approach the actual hydrograph to some extent by adjusting the parameters for each basin in this manner. Given that the objective of this research is to detect the sign of flood early, rather than bringing the hydrograph closer to reality, it is necessary to first detect abnormal values of precipitation in the basin and to detect early detection of signs of flood I will give priority to evaluating the possibility.

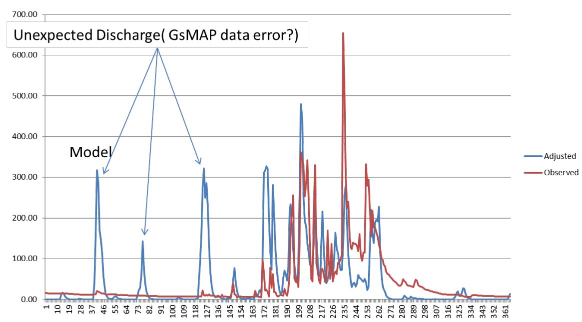

Fig.4(a): Comparison the model result with the observation

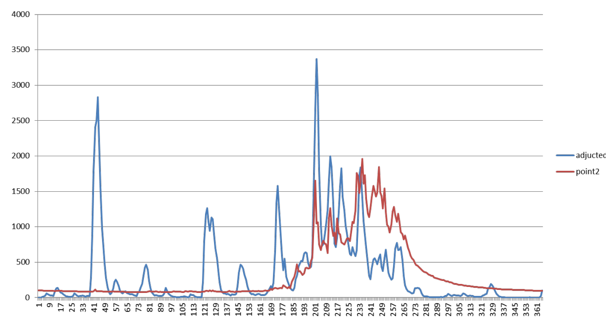

Fig.4(b) : Comparison the model result with the observation

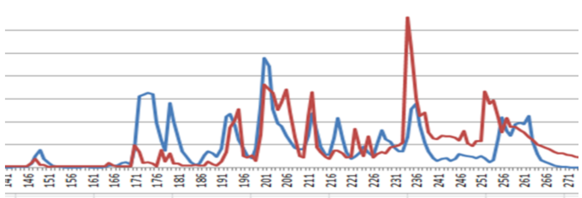

Fig.5:Comparison the model adjusted with the observation

Fig.6 shows the comparison of hydrographs in between 2010 and 2011, at the lower point on Chao Phraya River, Thailand. The downstream area of the river was severely damages by the flood occurred in 2011. The characteristics of the rainfall in 2011 is that there are precipitation greatly exceeding the previous year from May to June, there is a very strong rainfall due to the typhoon in July. Also, a heavy precipitation can be seen in September. Considering that the floods in the downstream area of the river began in September, the a part of rainfall accumulated from May to September stayed in the watershed without draining and seems to have caused damage in September.

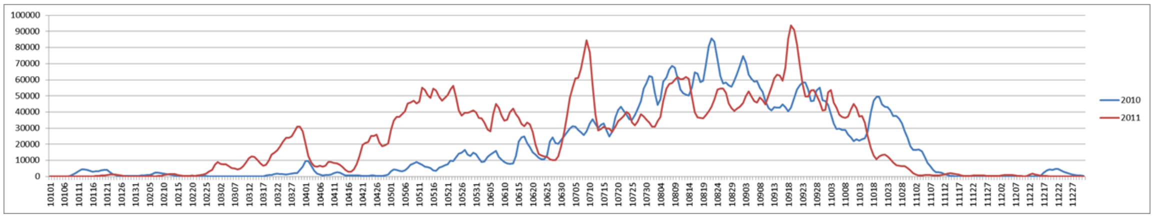

Fig.6: Model based Hydrograph comparison between 2010 and 2011 for Chao Phraya River basin.

In case that rainfall throughout the basin over a long period causes flooding downstream, the model has a possibility to provide early warning of floods from the historical data. And it is applicable to other rivers in Asia which have big cities with highly concentrated population in the flood plains.

6. CONCLUSION

In this research, a method was proposed to predict the occurrence of floods mainly for large watersheds, by using open-access rainfall data (GsMAP) and watershed model (HydroSHED). The model is applicable and the data are available in global scale. Because the flood damage depends not only on the intensity of the rainfall but also on the drainage capacity of the basin and the resistance to flooding in the area, it is more important to evaluate the risk based on the past experiences than to simulate the river discharge precisely. In this respect, this research could provide an important knowledge to future early warning sysytems.

REFERENCES

Sugiura T., Fukami K. and Inomata H., 2008, Development of Integrated Flood Analysis System(IFAS) and its Applications, World Environment and Water Resources Congress 2008, Ahupua'a.

Chen J.M., Chen X., Ju W. and Geng X, 2005, Distributed hydrological model for mapping evapotranspiration using remote sensing inputs, 15-39, 305(2005).