TRANS BOUNDARY FLOOD FORECASTING THROUGH DOWNSCALING OF GLOBAL WEATHER FORECAST AND HYDROLOGICAL MODEL SIMULATION

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ABSTRACT

Pakistan was effected by vulnerable floods in past. Very severe flooding was occurred in 2010, again in 2011 but that was not severe like 2010, and also in 2012, 2014, 2015 respectively. It is very well known that the main cause of flooding in Pakistan is heavy rainfall especially in the upper catchments of the rivers of Pakistan. As Pakistan have trans boundary rivers, specially the rivers coming from Indian side are very much disastrous for Pakistan because not any kind of meteorological and hydrological data sharing from the other side. The purpose of this study is to estimate flood peak magnitude and time by using Numerical Weather Prediction (NWP) and satellite data The NWP was achieved by downscaling global NWP of European Center for Medium range Weather Forecast (ECMWF) using Weather Research and Forecasting (WRF) model. For flood forecasting Rainfall Runoff Inundation (RRI) hydrological model is used. GSMap rainfall data is used for the calibration of RRI model

We applied the flood forecasting system on the severe flood event occurred on 5 Sep. 2014 in Jhelum River. It predicted flood peak and time fairly well at least 4 days before the flood occurrence. The system showed a potential for issuing flood alert in a trans boundary basin with long enough lead time for people's evacuation.

Keywords: GSMap rainfall, RRI Hydrological model, ECMWF, Downscaling.

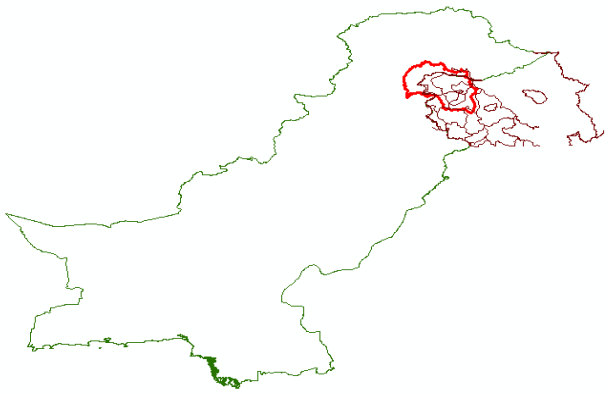

Figure 1. Study area map inside Pakistan

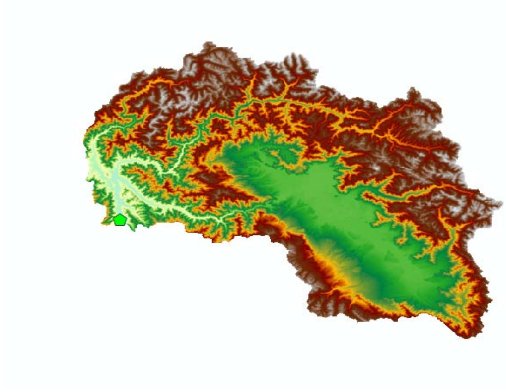

Figure 2. Topographic map of study basin

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INTRODUCTION

Flood prediction in trans boundary rivers is quite difficult due to non-availability of data on the trans boundary side. As the trans boundary rivers of Pakistan are also steep in upper catchment areas.

As severe flooding was happened in Sep, 2014 after heavy downpours in the upper catchments of the Jhelum, Chenab, Ravi and Sutlej rivers. Maximum intensity of rainfall occurred in between 4th to 6th September as per GSMaP rainfall data. This heavy downpours effected the area and in some plain of downstream water level crossed the limits and inundation happened.

Even in a trans boundary basin with limited ground observation data, rainfall observation by satellite are available. It is known that the rainfall observation by microwave sensors on satellite have serious bias. Therefore, the rainfall need to be corrected their bias by utilizing available ground rain gauges. Furthermore, numerical weather prediction is a powerful tool for flood forecasting even in a trans boundary basin. We applied it in this study and examine its usefulness for flood forecasting.

THEORY AND METHODOLOGY

The purpose of this study is to alert this inundation which was happed due to heavy downpours on Sep 4th to 6th, 2014 by issuing timely forecast for flood peak with good lead time for evacuation before the disaster happened. For this purpose downscaled ECMWF forecasted rainfall is used. ECMWF forecasted rainfall without downscaled can't show the results good for the flood prediction. To downscale the ECMWF forecasted rainfall to get better results of flow discharge, Weather Research and Forecasting Model (WRF) is used. The WRF model is used to simulate rainstorm over Kashmir and Upper Punjab region for the case of September flood 2014. Two domains were selected to downscale the precipitation forecast. The outer grid resolution was selected as 20km and inner was selected at 5km grid resolution. All runs utilize the same physical functions on a Lambert conformal projection. The vertical structure of the model includes 28 layers covering the whole troposphere. The WRF single-moment 3-class microphysics parameterization and Kain-Fritsch cumulus parameterization which are related to precipitation simulation, have been used on both domains for all runs. Other options were set to default mode. Simulations were conducted for the period from 0000 UTC 30th August 2014 to 0000 UTC 2nd September 2014 with 24 hour interval for ECMWF forecasts. The rainfall in upper catchment area for the flood event 2014 for the Jhelum River was observed by GSMaP rainfall.

As the ground raingauge data is not available in the Indian side of the basin, it is not possible to compute accurate discharge. Therefore, we utilized GSMaP satellite rainfall data to compute flood peak. The original GSMaP rainfall significantly underestimated the real rainfall. So, we corrected its bias by using point to point rainfall data comparison on the bases of available four ground raingauge data and applied the correction ratio on the original GSMaP rainfall. There is another correction method of GSMap rainfall made by the JAXA. But this method did not work properly, since the ground raingauge was only a side of the basin. So the first method was used to correct the bias of the GSMaP satellite rainfall and used for the calibration of RRI model. As the method we employed can estimate rainfall in ungauged basin, it is useful to compute flood discharge from transboundary basin with limited ground raingauge.

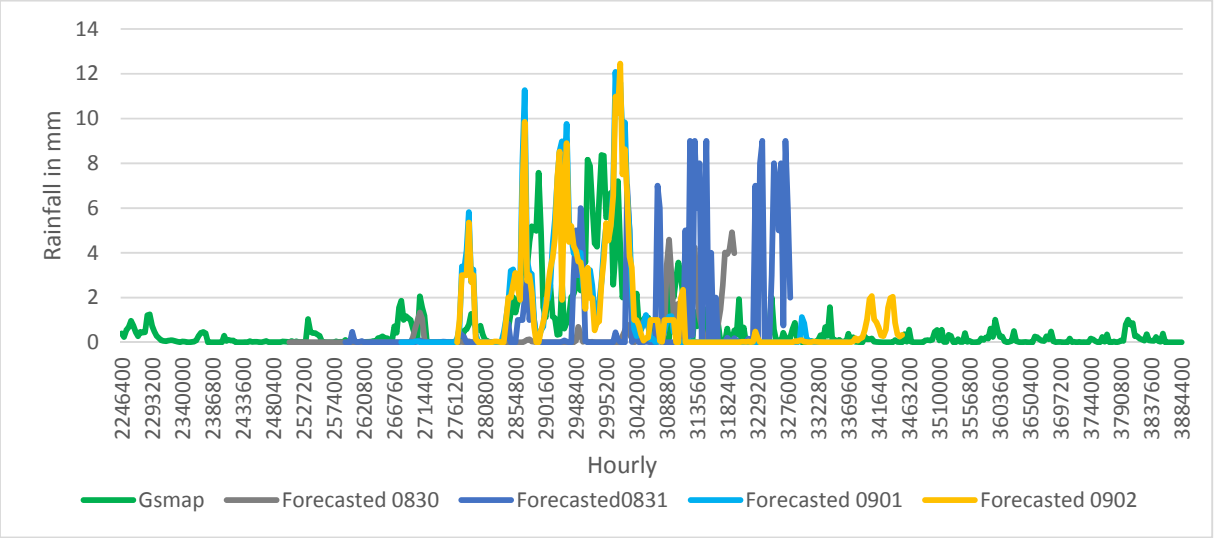

Figure 3. GSMap rainfall for Sep, 2014.

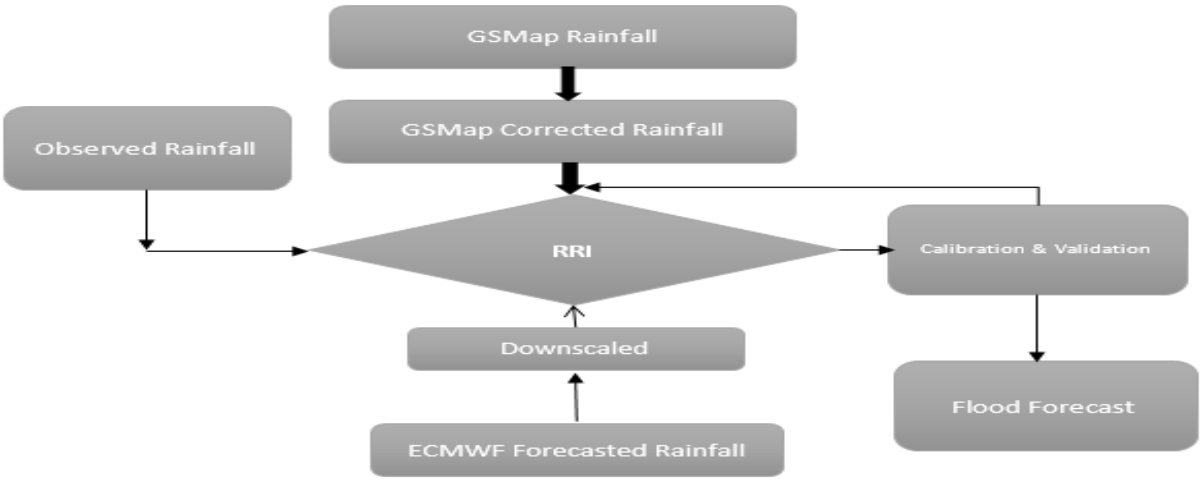

Figure 4. Methodology

The model used for this study is Rainfall Runoff Inundation (RRI) hydrological model, can simulate flow discharge and flooding in the catchment area. The use of forecasted rainfall for the purpose to predict flow discharge with good led time firstly the model was calibrated by using GSMaP corrected data and after the calibration the downscaled ECMWF forecasted data is used in the RRI model.

DATA

The study is about a basin which has less rain gauge information. To validate the results of my study, we used Global Satellite Mapping of Precipitation Near Real Time (GSMaP-NRT) data. The resolution of the data is 0.1 degree and it is available on hourly basis. The satellite provides the information after 4 hours via internet [Sayama *et al.*, 2012]. The data can be downloaded from the website (http://sharaku.eorc.jaxa.jp/GSMaP/).

The global forecast data of ECMWF were downloaded from TIGGE-ECMWF website (http://tigge-portal.ecmwf.int/). It provides Control Forecast for Surface and Pressure levels, which is at a lower spatial

resolution (0.5 x 0.5) for the whole globe twice a day 00 UTC and 12 UTC. The data provides forecast for the duration of two weeks (up to 360 hours) in interval of 6 hours. The data which is downloaded from ECMWF is originally in Grib2 format which can be read by GrADS after processing g2ctl.pl script.

RESULTS AND DISCUSSION

Dynamic downscaling is the best way to get higher resolution quantitative precipitation forecasts [Li, 2015]. The global forecast of the ECMWF is of lower resolution and its accuracy of rainfall amounts is not good at surface level. The data was unable to include important sub-grid scale features of clouds and complex topography. In order to obtain local scale weather and climate particularly at surface level, the data was downscaled to smaller grid scale and resolution.

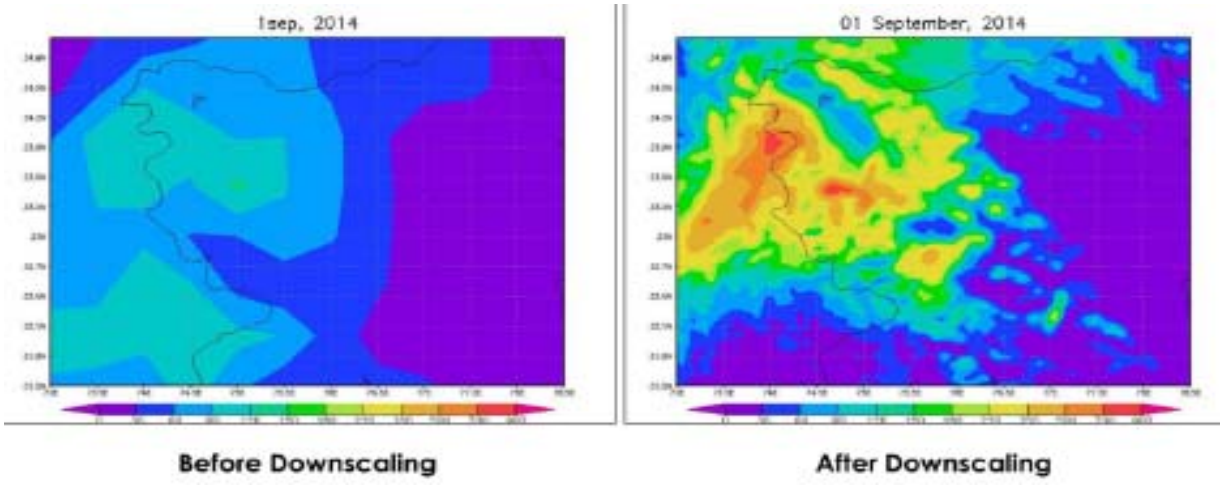

Figure 5. Improvement by Downscaling data

To select the domain for our study, we selected two domains. An outer domain of 20km resolution to observe the system coming from Bay of Bengal and Arabian Sea and to see the effect of westerly winds in the North West direction was also included. The inner domain of 5km was selected to include smaller grid features of the study area. After selection of these domains, the meteorological data was downscaled using WRF Model.

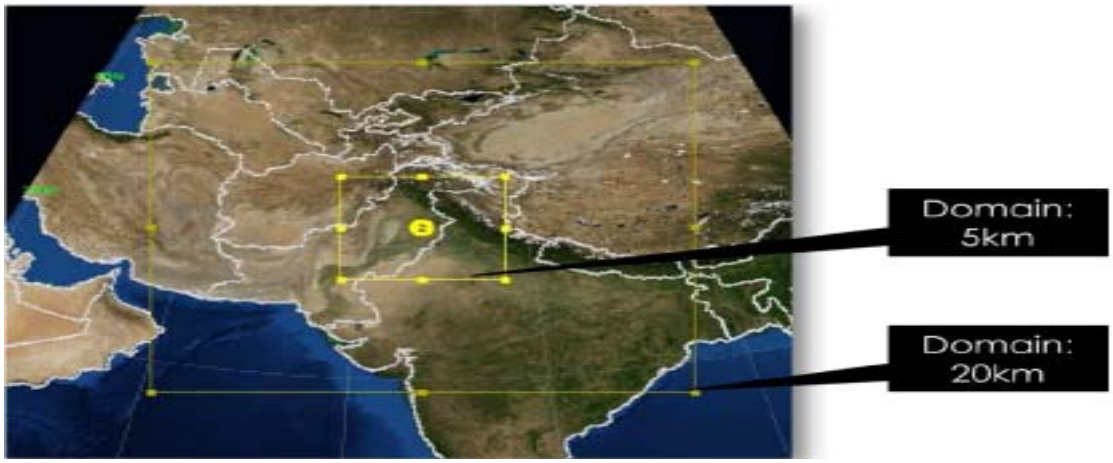

Figure 6. Selected Domains for the study

For the purpose to create rainfall observation data in the trans boundary basin, we following this procedure. We used GSMap-NRT real time data to simulate hydrological processes in our basin by RRI model. In RRI model when we used hourly original GSMap data the simulated discharge could not reach to the observed peaks on default parameters, then I used IF-2 JAXA method for the correction of GSMap rainfall. After correction results are still not acceptable. Then, another correction method, point to point rainfall comparison method, was applied for GSMaP rainfall enhancement.

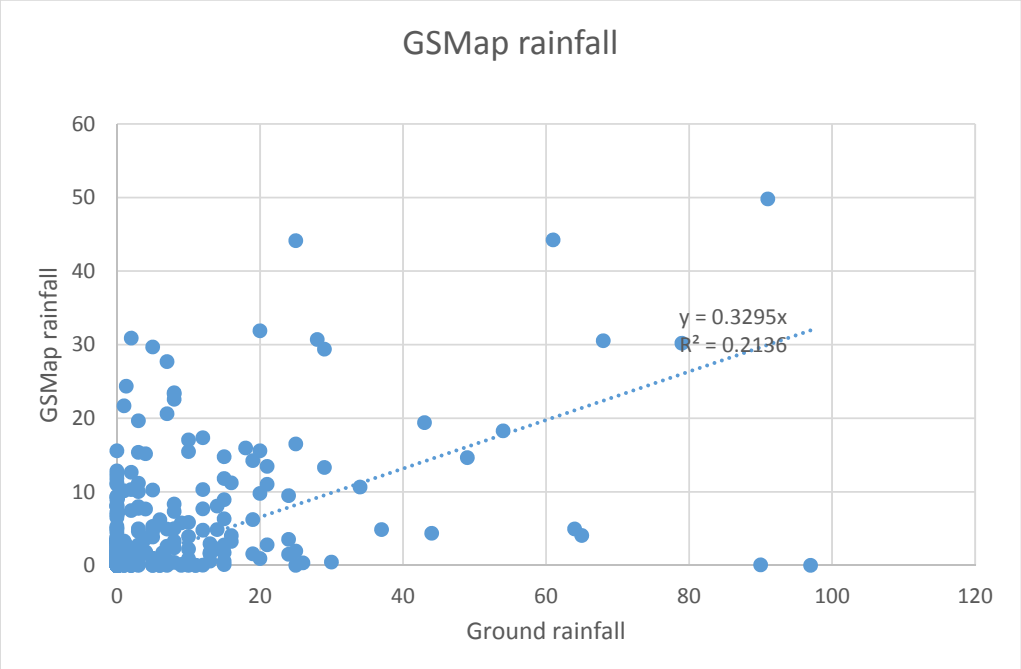

Figure 7. Point to point rainfall correction method

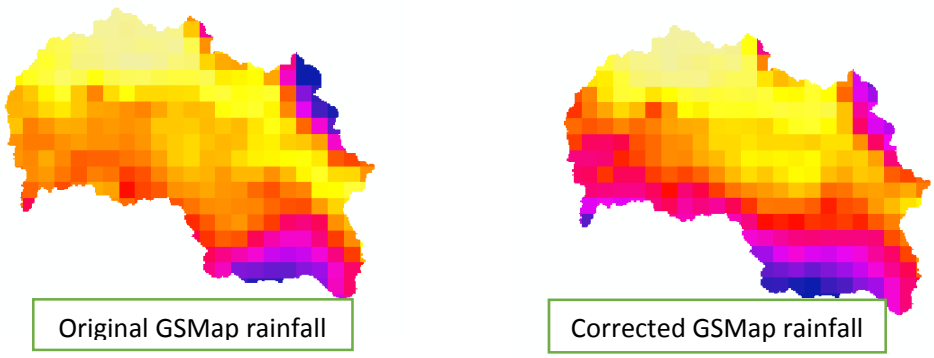

Figure 8. GSMap rainfall before and after correction

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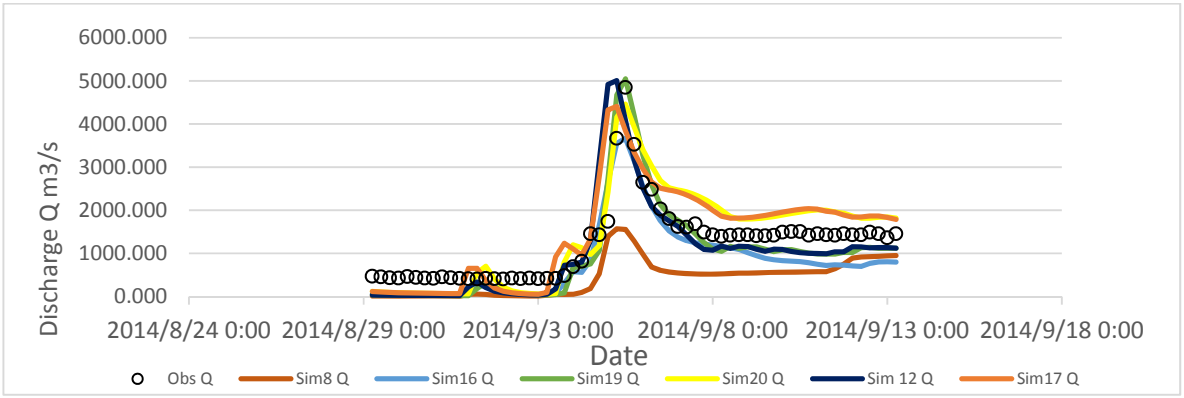

Figure 9. GSMap rainfall discharge results during calibration

Figure 10 introduces the flood forecasting, in which the rainfall by downscaling ECMWF global NWP started from 31st Aug to 2nd Sep, 2014 were used as input for the RRI model. In Fig. 10, two of the flood forecasts by NWP rainfall (from 0901 and 0902) were successful to predict flood discharge peak in 5 Sep. This result suggested the high potential of the flood forecasting system we developed. Another important point is, two forecasts could provide information of future flood peak 3 or 4 days prior to the actual flood occurrence. This is quite useful for flood alert and get time for evacuation. However, after the flood peak the predicted discharge quickly decreased rather than observed one, which suggests the rainfall prediction was underestimated. This figure shows quite useful information that we can utilize for flood alert system, as well as limitation of the flood forecasting system.

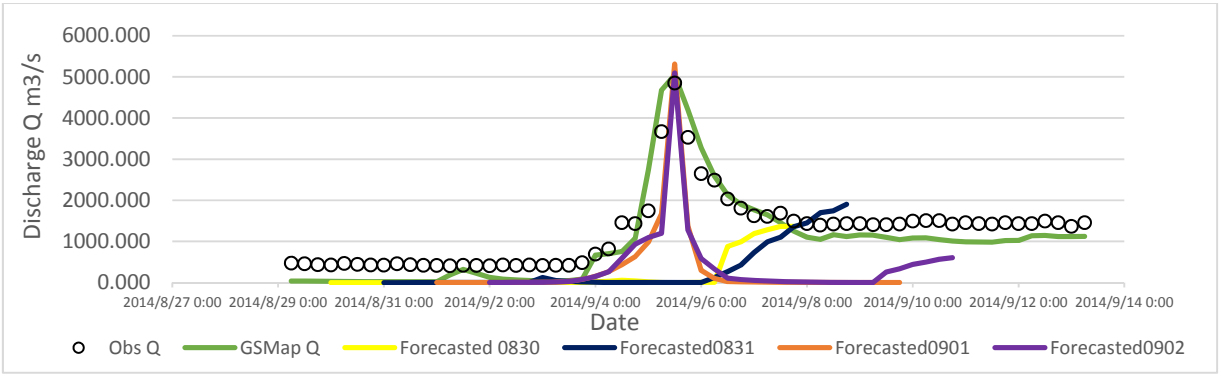

Figure 10. Adding forecasted rainfall

RECOMMENDATION

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