TRANSBOUNDARY FLOOD FORECASTING THROUGH DOWNSCALING OF GLOBAL WEATHER FORECASTING AND RRI MODEL SIMULATION

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ABSTRACT

The study comprise of a transboundary basin at which there is no access to hydrological or Meteorological data across the border. The use of NWP is quite important for flood early warning in this river basin. The study area has steep topographic features, due to which the flood water peak arrival time is the shortest as compared to other main river catchment areas in the country. Global Satellite and Mapping (GSMaP) near real time data has been used in this study for calibration. Rain forecast data from European Center for Medium range Weather Forecast (ECMWF) and National Center for Environmental Prediction (NCEP) Global Forecast System (GFS) were utilized for the early prediction of flood in this study.

Original data from ECMWF and GFS was not a good representative of the rainfall while downscaling of those forecasts to a higher resolution, gave better rainfall scenario. Better rainfall forecast were selected in comparison with GSMaP corrected rainfall and used in Rainfall Runoff Inundation (RRI) hydrological Model. Downscaling of NCEP-GFS rain forecasts showed more reliability as compared to those of ECMWF rainfall in the current study. Although temporal distribution of the rain forecast data did not agree well with observed GSMaP corrected rainfall, but forecasts were able to predict high flood discharge with a lead time of 4 days.

Keywords: Downscaling, GFS, GSMaP, ECMWF.

1. INTRODUCTION

In order to predict flood situation in any river basin rainfall is the parameter which acts as a base to run all the hydrological models. Most of the catchment areas (especially mountains) have less rain gauging

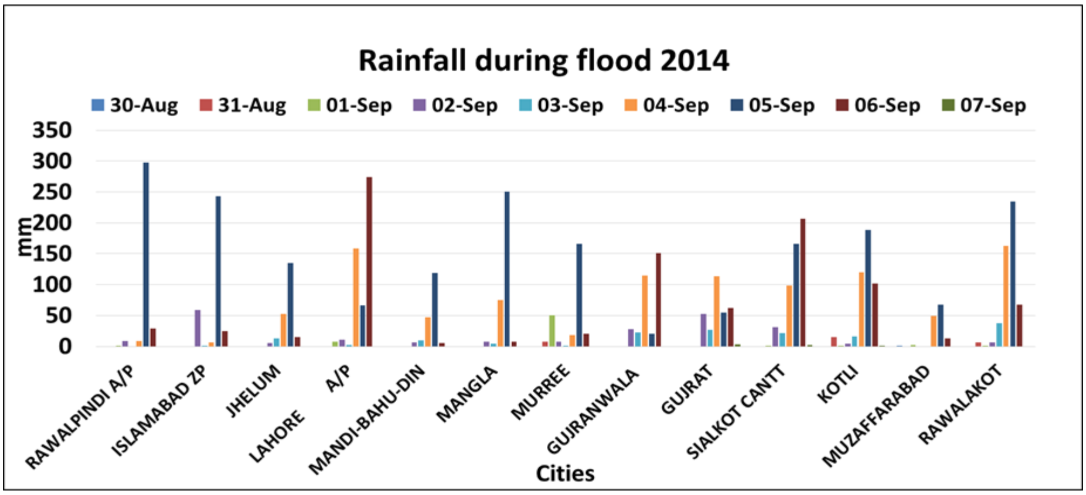

Figure 1: Observed rainfall during September 2014 flood event.

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stations, so less rain information is available. Even if the rain information is available for the flash flood prone areas, the lead time of currently available hydrological models does not provide enough time to issue flood warning and complete evacuation process. For this kind of situation Quantitative Precipitation Forecasts (QPF) by numerical weather prediction system can provide us some information about rain with longer lead time. This information will then be useful to issue flood warnings and to complete evacuation process in flash flood prone river catchment areas.

In the first week of September 2014, heavy rainfall occurred in the upstream catchment areas of eastern rivers of Punjab province and adjoining areas of Kashmir. The rainfall started on the evening of second September, with maximum rainfall occurring between 4th and 6th September. This heavy rainfall caused the water level to rise in all the eastern rivers (Jhelum, Chenab, Ravi and Sutlej) but the maximum rainfall occurred in the upstream area of Chenab River. This rainfall overtopped the banks of Chenab River at Head Khanki barrage and caused inundation damages.

THEORY AND METHODOLOGY

In the study, rainfall forecast data of European Center for Medium range Weather Forecasts (ECMWF) and NCEP GFS forecasts were used. The original data available at the data points is of lower grid resolution, so in order to get better rain forecast data of surface level, the rainfall data was downscaled by using a Regional Model (WRF) Weather Research and Forecasting Model.

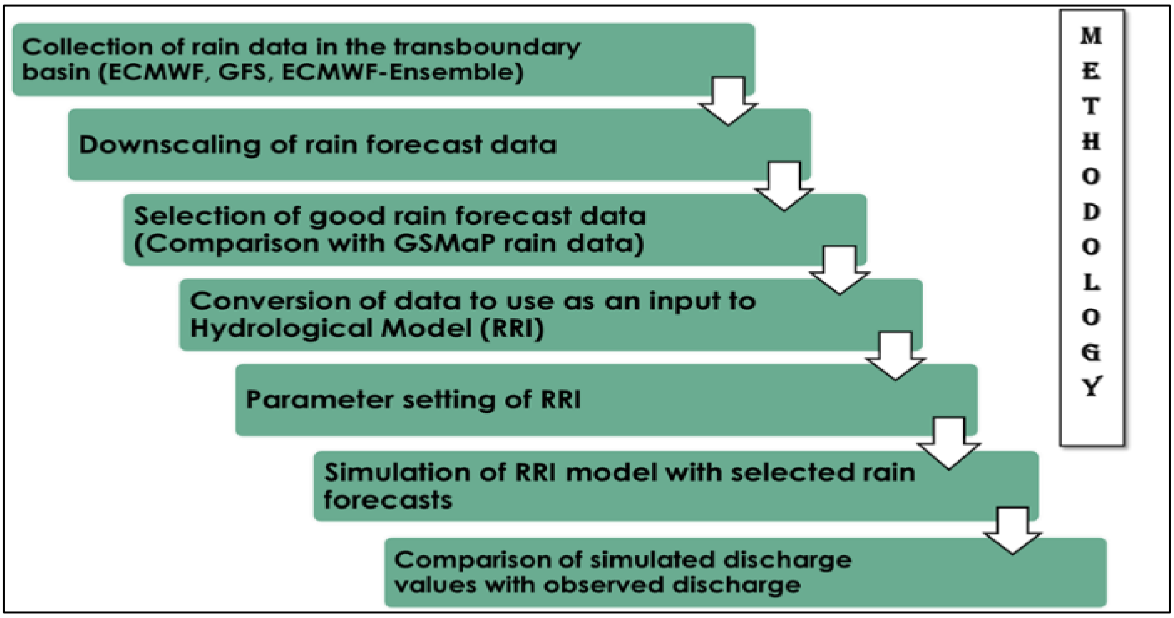

Figure 2: Methodology

The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting needs. It was used in the study 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.

Rainfall-Runoff-Inundation (RRI) model is a two-dimensional model capable of simulating rainfall-runoff and flood inundation simultaneously. The selected rain forecast data after downscaling was used in the RRI model to get the expected discharge in the river. The discharges were compared with the observed discharges. The expected discharge values were obtained with a lead time of 4 days, which is very useful in flood preparatory measures.

DATA

The rain 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. In the study, NCEP GFS data was also used after downscaling using WRF Model. The original data is available from the website (http://nomads.ncdc.noaa.gov/data/gfs4/). The forecast frequency is four times a day 00, 06, 12, 18 UTC. The forecast time period is up to 7.5 days, i.e. 180 hours with 3 hours interval. The data resolution is 0.5x 0.5x26 levels (originally 27 km resolution). The data format is Grib2 format which needs to be converted to Grid Analysis and Display System (GrADS) readable format before usage.
To validate the results of my study, I 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 starts observation of data and 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/).

RESULTS AND DISCUSSION

ECMWF daily forecasts were downloaded and then downscaled from 31st August, 2014 to 4th September, 2014 with an interval of 24 hours. The rain forecasts results were improved after it was downscaled. Similarly GFS rain forecasts were also downloaded and then downscaled from 31st August, 2014 to 4th September, 2014 with an interval of 6 hours.

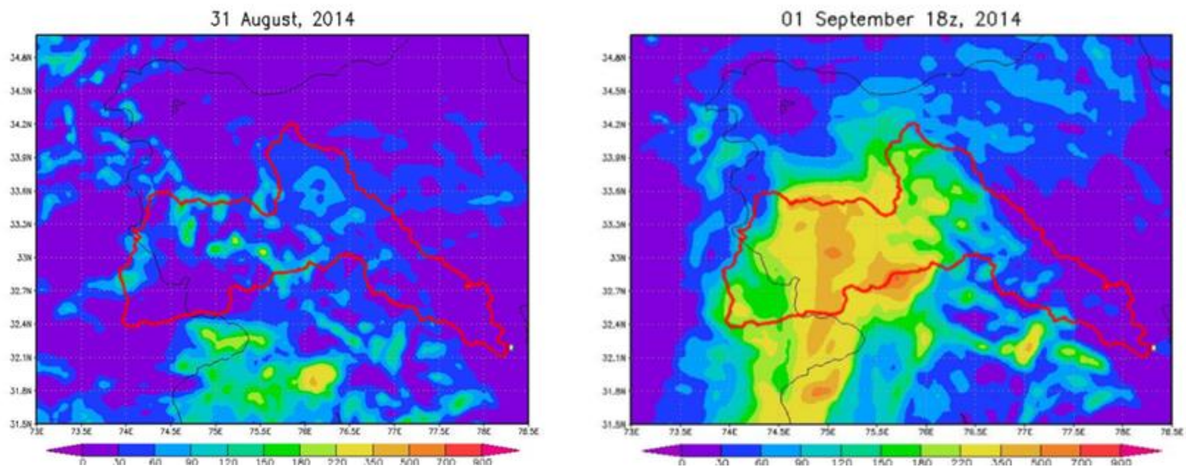

Figure 3: Downscaled rainfall forecasts predicted heavy rain

As shown in the figures, the forecast of 31st August was not able to show the coming heavy rainfall event between 4th and 7th September, 2014. The forecast of 1st September and onwards showed the arrival of the heavy precipitation event in the basin. The GFS forecasts also started to show the sign of heavy precipitation in the study area, with some variations. However, it provided forecasts at an interval of 6 hours.
After downscaling all the rain forecast, the good forecasts were selected based on comparison with GSMaP corrected rainfall to use into the hydrological model (RRI). Red circles in Figure 4 selected rain forecasts with spatial correlation greater than 0.60, while stars in Figure 5 show selected rain forecasts from Figure 4 with RMSE less than 130. Most of the selected good forecasts were GFS rain forecasts.

Recommendations can be done for future, whether which forecasts should be given importance for consideration.

		31st Aug	01st Sep	2nd Sep	3rd Sep	4th Sep
ECMWF		0.42	0.39	0.42	0.49	0.60
GFS	00z	0.42	0.67	0.46	0.77	0.62
	06z	0.06	0.46	0.71	0.06	--
	12z	0.53	0.50	0.56	0.67	--
	18z	0.44	0.76	0.65	0.52	--
Ensemble		0.45	0.54	0.46	0.64	0.42

Figure 4: Spatial correlation of forecasts with GSMaP corrected rainfall

		31st Aug	01st Sep	2nd Sep	3rd Sep	4th Sep
ECMWF		39	146	121	146	162
GFS	00z	54	152	66	125	121
	06z	70	102	115	70	--
	12z	96	127	107	124	--
	18z	98	98	81	102	--
Ensemble		46	70	138	125	163

Figure 5: RMSE of forecasts with GSMaP corrected rainfall.

The selected rainforecasts basin average rainfall was compared with GSMaP corrected basin average rainfall. All the rain forecasts predicted the presence of heavy rainfall event between 4th and 7th September, 2014 with a little temporal variation.

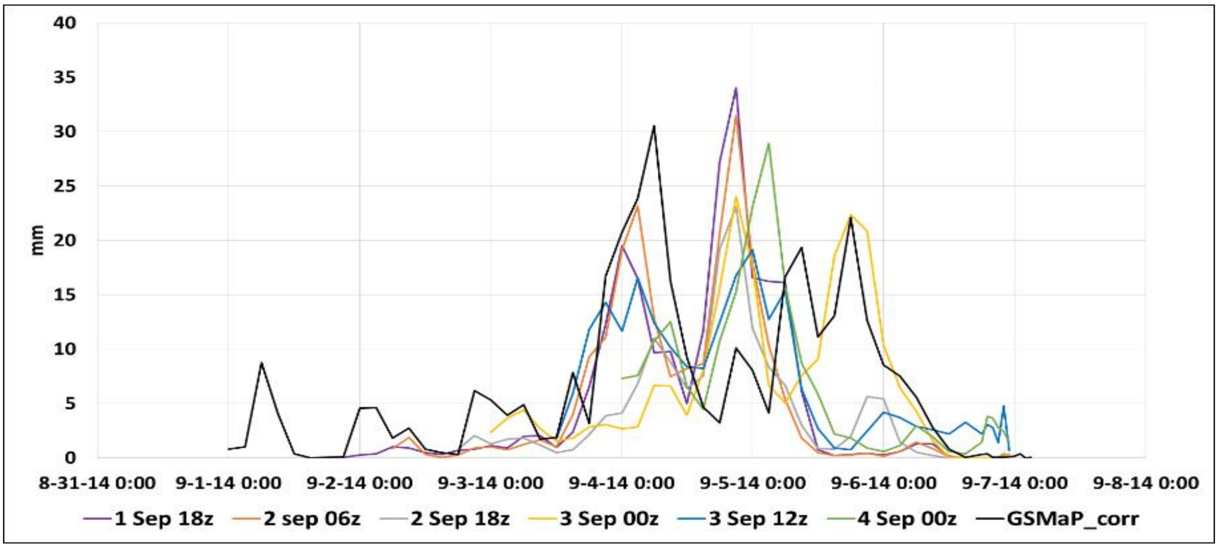

Figure 6: Basin average rainfall forecasts in comparison with GSMaP_corrected rainfall

The selected rain forecasts were then used as an input to RRI model. The rain forecasts predicted considerable discharge values at the river outlet. The information is thus very useful for flood preparatory measures. Almost all the forecasts predicted huge discharges but the forecast on 1st September predicted discharge of about 23,063 m³/s close to the observed discharge of 25,691 m³/s.

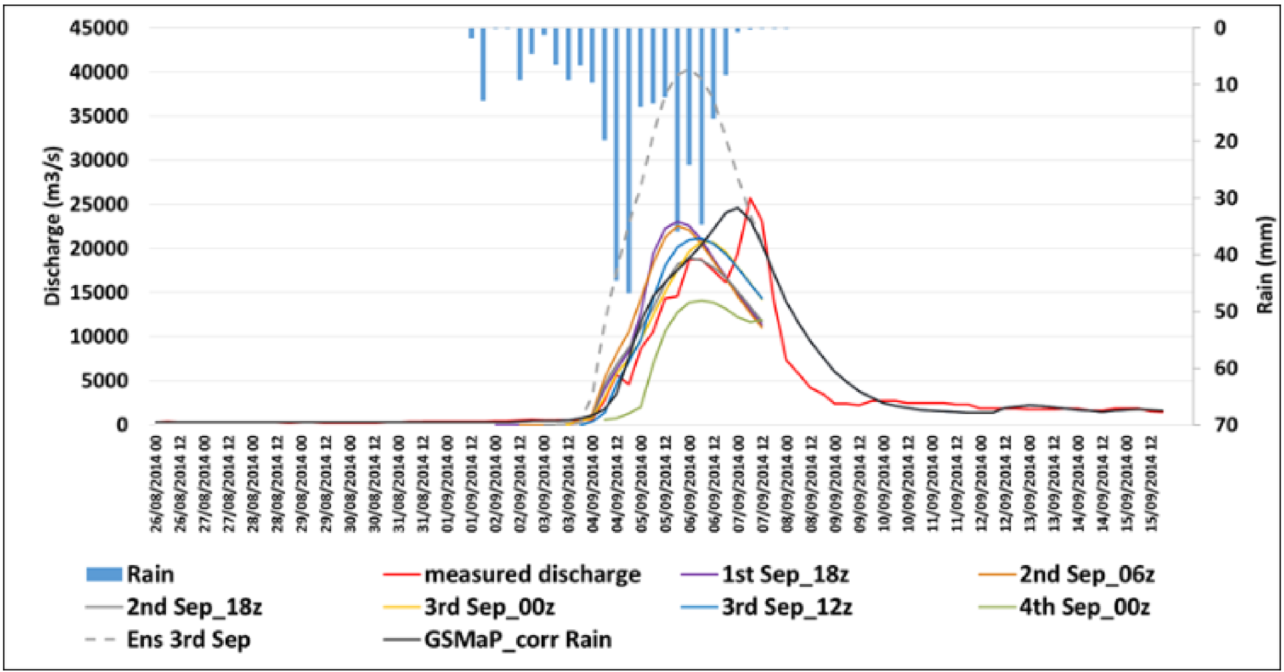

Figure 7: RRI simulation with selected good rainfall forecasts

RECOMMENDATION

The study revealed important aspects for studying any basin using Meteorological and Hydrological characteristics. The availability of ground based information plays an important role in this regard. If the ground observations are not available, the latest scientific products can be used to get the information about the ungauged basin. Although the temporal prediction of peak discharge was not well matched with observed, but the amount of predicted discharge was 23,063 m³/s close to the observed discharge of 25,691 m³/s.

It is therefore recommended to use the information for flood preparation and management purpose. The GFS rain forecast were information was well matching with the observed GSMaP rain with availability of forecast at every 6 hour interval. This information will be very helpful for the management authorities and flood fighting organizations. The water level in the mainstream can be controlled to a safe level. This is turn will be helpful in saving lives and property.

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