Potential Application of Gauge merged Satellite Derived Precipitation data in Nile Basin for Local Scale Climate Change Impact Assessment and Hydrological Modeling

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ABSTRACT

The most outstanding challenge in the Nile Basin countries remains the lack of suitable hydro-meteorological data for water resources planning as well as evaluating risks and impacts of emerging challenges such as climate and land use change. Some of these challenges require a distributed modeling approach with adequate spatial and temporal coverage of hydro-meteorological data, which usually are considered data intensive. As a means of tackling the limitation in data scarce basins like in the case of Nile Basin, researchers have tended to use either satellite derived precipitation or gridded re-analysis precipitation data sets from limited observational data. Some studies have also shown successful integration of gauge merged remotely sensed data in large scale hydrological forecasting model for the Nile basin (*see*, Elshamy, 2006). Particularly the Nile Forecast System (NFS) uses the real time gauge merged satellite (Meteosat) derived rainfall merging with limited observational data from the basin to effectively forecast the inflow to Aswan Lake. In this paper, the accuracy and adequacy of gauge merged satellite (Meteosat) rainfall data is evaluated in two important catchments of the Basin in view of applicability of the data for local water resources planning and assessment of climate change impacts in the wake of absence or limited data availability. Generally, evaluation of the data in two selected catchments of the Upper Blue Nile basin (Gilgel Abbay) and Lake Victoria sub basin (Kagera Catchment) showed encouraging results. The performance of the gauge merged satellite rainfall particularly appears to be promising after 1988 where we have the chance of comparing data for both catchments using common period.

The data was used to demonstrate the potential application of the gauge merged satellite data for hydrological application (runoff simulation) and climate change impact assessment for Gilgel Abbay. The runoff simulated using historical rainfall data and gauge merged satellite rainfall data was found adequately fit in terms of the shape and the volume of the hydrograph, further illustration of the adequacy of the data for use in hydrological studies. An attempt to us the data for climate change is also promising.

Given the temporal (daily) and spatial resolution (20 by 20 km), the gauge merged satellite rainfall data (meteosat derived) could be used to the Nile basin catchments as well as the whole Nile basin after rigorous evaluation the product in different parts of the basin. The data is one of the promising data products for future use in the basin.

Key words: *satellite derived precipitation, hydrological modeling, and climate change impact*

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BACKGROUND AND INTRODUCTION

The Nile is the world's longest river, stretching 6,700 km in length and covering an area of about 3 million km3. The river originates from two distinct geographical zones, the basins of the White and Blue Niles. The source of the White Nile is in the Equatorial Lakes Region, and is also fed by the Bahr-el-Jebel water system to the north and east of the Nile-Congo Rivers divide from Sudan (Bedient and Huber, 1992). Its catchment area includes the riparian states of Tanzania, Rwanda, Burundi, Uganda, DRC, Kenya and Sudan. The Blue Nile originates in the highlands of North western part of Ethiopia. Other major tributaries of the Nile, originating from Ethiopian highlands include the Atbara in the North and Baro-Akobo-Sobat sub-basins in the west of the country.

In this regard, this study makes selection of two catchments located in different hydro-meteorological regimes of Nile and has varying spatial scale. The Gilegel Abbay Catchment in Ethiopia and Kagera, in the Equatorial Nile basin (Lake Victoria sub-basin catchment)

Gilgel Abbay is one of the main contributors of Lake Tana from the south. The flow measuring station is located near Merawi at 110 22'N latitude and 370 02'E longitude. Gilgel Abbay River, which literally means in Amharic "The little Abbay," has its source in the mountainous Sekela area and flows northward receiving other tributaries on its way to Lake Tana. It is the largest contributor to the Lake. According to the Ministry of Water Resources, the catchments area is 1664 km^2.

The Kagera basin is among the 23 sub catchments of the Victoria Lake. Geographically, it lies in the Southern West of the Victoria Basin. It is located at the following coordinates 0°45' and 3°55' south latitudes, and 19°15' and 31°51'east longitudes. The basin area differs from literatures and the remote sensing technique in combination with SRTM data used in this study revealed that the basin has an approximately total area of 58349 sq kilometers (roughly 22.64% of the Victoria basin), with 345 kilometers long, north to south, and has a maximum width of about 275 kilometers – east to west. The Kagera River is known as the most remote headstream of the Nile River and the largest tributary of the Victoria Lake. The surface area of the basin includes 6% occupied by the lake and swampy arms (Georgia Water Resources Institute et al., 2006).

Comparison of the Areal Gauged Rainfall and the Gauge Merged Satellite Derived Rainfall

The most outstanding challenge in the Nile Basin countries remains the lack of suitable rainfall data for hydrological as well as climate change impact assessment. Most of the hydrological works including the recent Nile DST model suffers from such fate of scarcity of reliable rainfall data and reverts to either using partially generated stochastic data or relied on the remotely sensed data. As a result, more and more hydrological models are relying on alternative source of data for modeling purposes. This study evaluates the potential application of the gauge merged satellite rainfall data for catchments in the Nile Basin. The data was assimilated product derived from the limited observed data and meteosat derived cold cloud duration information. The data was obtained from the Egyptian Nile Forecasting Centre (NFS). It is available in 20km by 20 km grid scale for the whole Nile Basin as a daily rainfall time series. The data set was evaluated for two selected catchments of Gilgel Abay and Upper Blue Nile Basin (Ethiopia) and Kagera catchment from the Lake Victoria sub-basin (only the catchment located in Rwada).

For both catchments, the gauge merged satellite data was extracted for the duration historical data is available. In the cases of Gilgel Abbay, historical daily data was available from 1988 to 2000 while for Kagera data was available from 1979 to 1992. The areal average rainfall over the catchmets' was used to evaluate the performance of the data set.

As shown in Figure 2 and 3, the two rainfall sets appear to have excellent fit for Gilgel Abbay catchment while the fit for Kagera is improved after 1986. When the common durations between 1988 to 1992 is compared for both catchments, the performance in both cases is above 92% in terms of R^2 criteria indicating the potential improvements the gauge mereged satellite data to be used for further application.

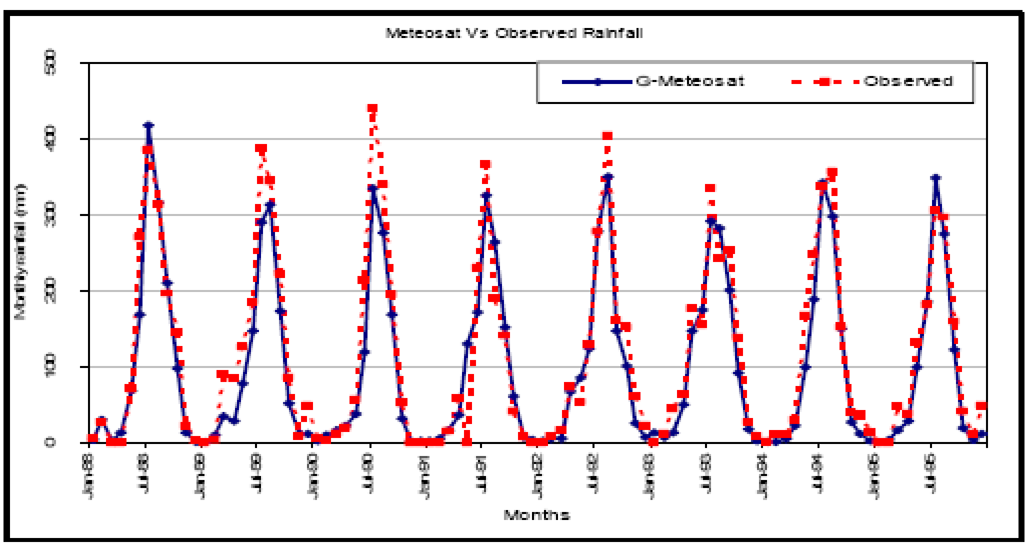

Figure 2: Monthly fit between the rainfall derived from gauge merged satellite (meteosat) and Observed data (Gilgel Abbay).

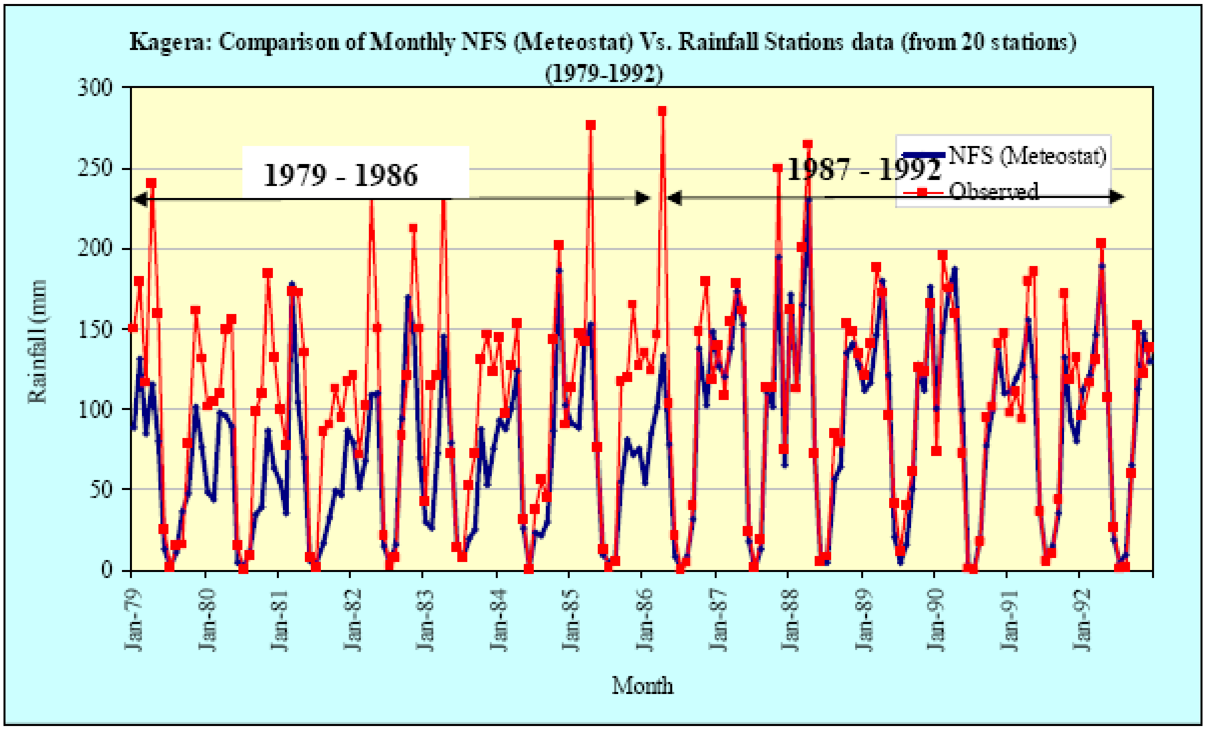

Figure 3: Monthly fit between the rainfall derived from gauge merged satellite (meteosat) and Observed data (Kagera catchment).

Application of the gauge merged satellite rainfall data for Runoff Simulation

The HBV conceptual model was used to evaluate the performance of the data with regard to application in runoff simulation. First, the model was calibrated using the historical data from 1988 to 1996 and verified using the data from 1997 to 2000. The performance of the model, as measured using (R2), during calibration and verification periods was 79.2 and 82.0 % respectively for the daily data sets. Almost 80% of the initial variance of the data is accounted for by the model. This implies the model has represented well the observed variations in the response behavior of the runoff. In terms of the long term volumetric fit, the index of volumetric fit (IVF) for calibration and verification is 1.07 and 0.88 respectively. The model exhibits slight over estimation in the calibration and underestimation in the verification period. While the model reproduced better hydrograph fit in terms of shape, there appears to be consistent slight underestimation of the peak discharges both in the calibration as well as verification periods.

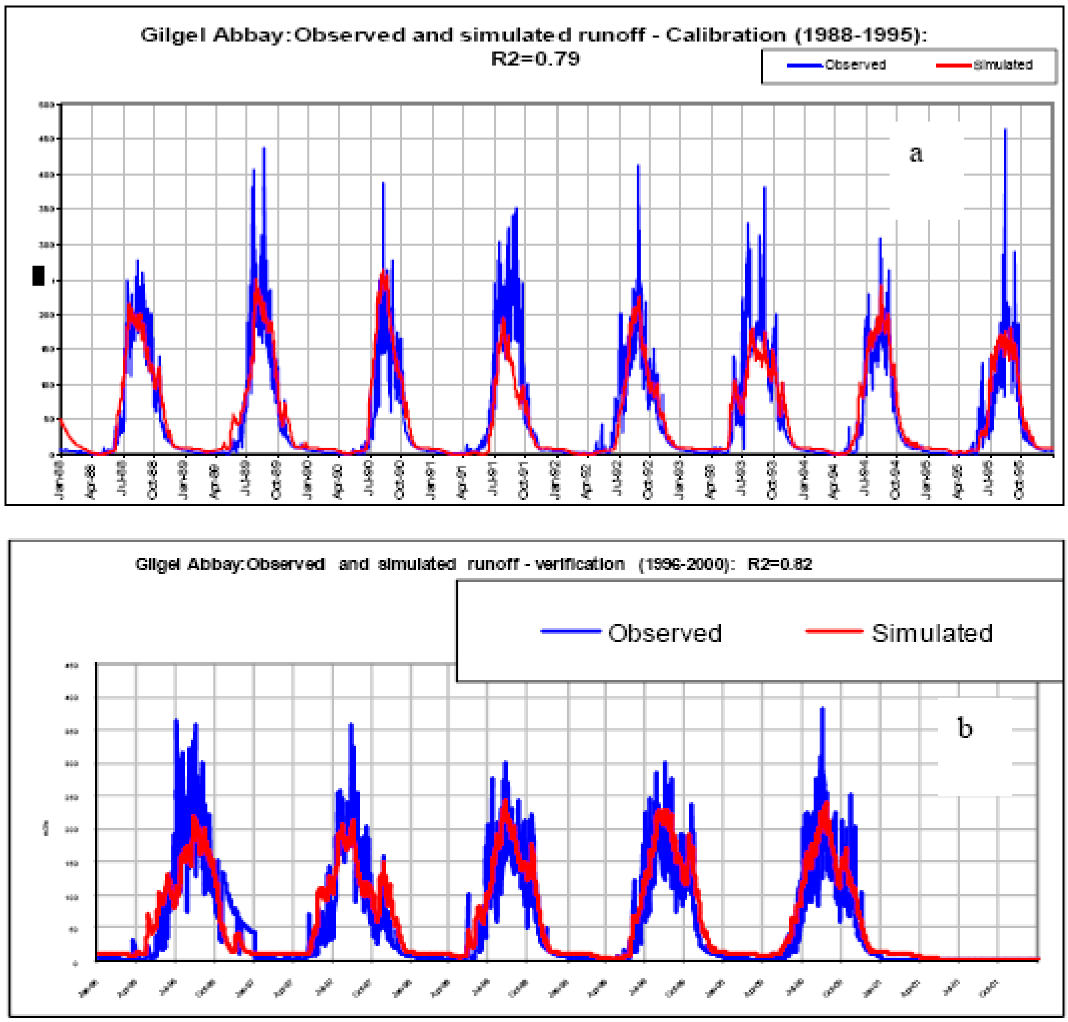

Figure 4: Results of a) calibration and b) verification HBV model

The gauge merged meteosat data set was then used to simulate the runoff from the catchment of Gilgel Abbay without changing the parameters of the HBV model.

The model fit between the runoff simulated using observed data and gauge merged meteosat data was (Figure 5) was found to be exceedingly good with R^2 of 85%. The gauge merged satellite data set has shown improvement in terms of generating the rainfall data as well as simulating the runoff as shown for Gilgel Abbay. This indicates the potential application of the data set for hydrological simulation in the Nile basin. But the data set should be tested independently for each catchment of the Nile as well as the time period used as the earlier time period may be less reliable as compared to the present data sets as seen from Kagera catchment.

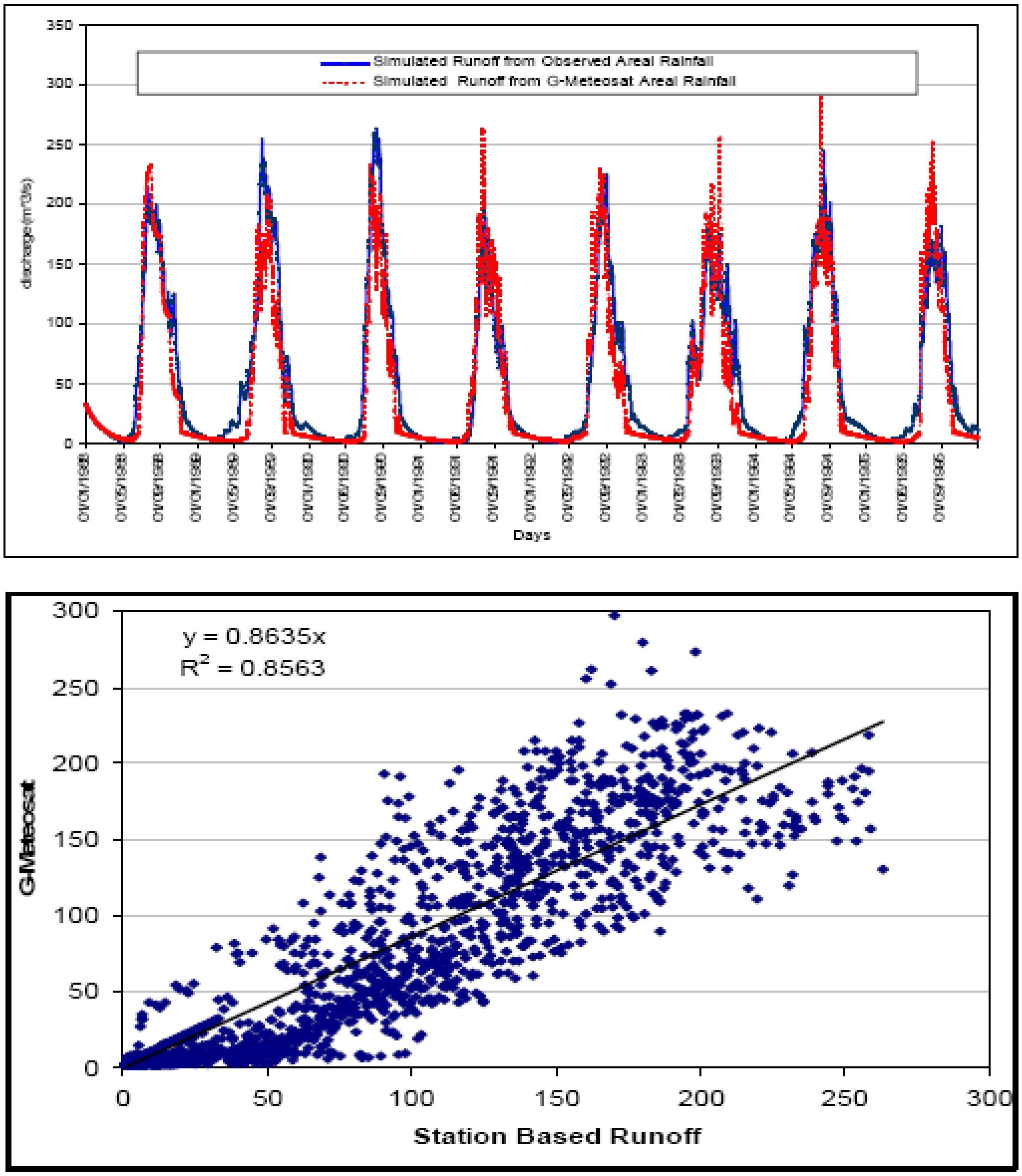

Figure 5: The runoff simulated using historical data and gauge merged satellite (meteostat) data sets.

Future Scenario and Climate Change Impact Assessment (based on Downscaled Precipitation)

On the basis of the gauge merged satellite data (Metosat) tested in section 2, the future daily precipitation scenario on the Nile basin was generated from one A1B emission scenario using Berknjes Climate Model (BCM). The BCM model output was downscaled applying bias correction techniques. Since the available daily data out from the BCM is only from 2081-2098, the downscaled precipitation data is limited to the same period. According to this GCM model (figure 6), there is a likely decrease of rainfall in the Gilgel Abbay catchment. Annual rainfall decrease is likely to be higher than 20 %. It has also been noticed the decrease is likely to be high and unreliable in during the transition periods from dry to wet season and wet to dry season. The model shows a trace of likely shift of the peak rainfall towards the end of August. However, this hasn't been clearly season in the monthly seasonal plot (figure 7). However, this has to be supplemented by other GCM model outputs and different downscaling methodologies.

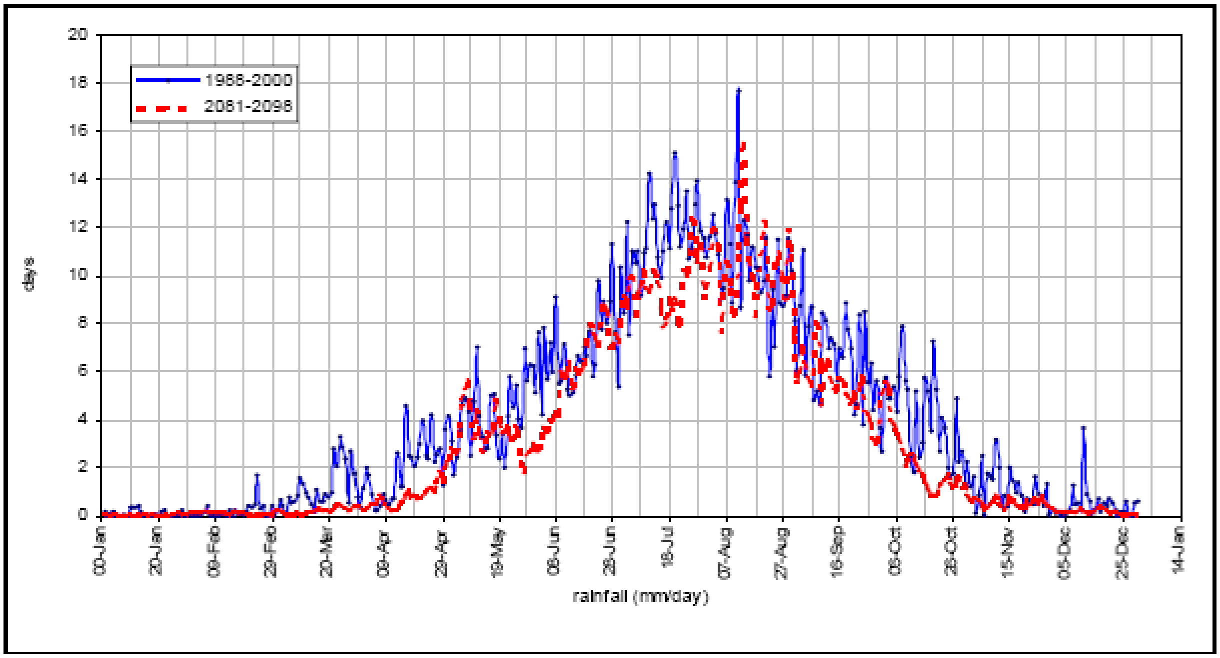

Figure 6: Comparison of seasonal daily gauge merged satellite rainfall with downscaled future rainfall scenario (2081-2098)

Consistent with the rainfall decrease, the runoff also shows overall decrease of 20% for Gilgel Abbay. The seasonal shift of the peak towards is late August is also clearly visible from the seasonal daily diagram. As the shift is from early August to late August it may not be clearly seen from monthly seasonal diagram (figure 8).

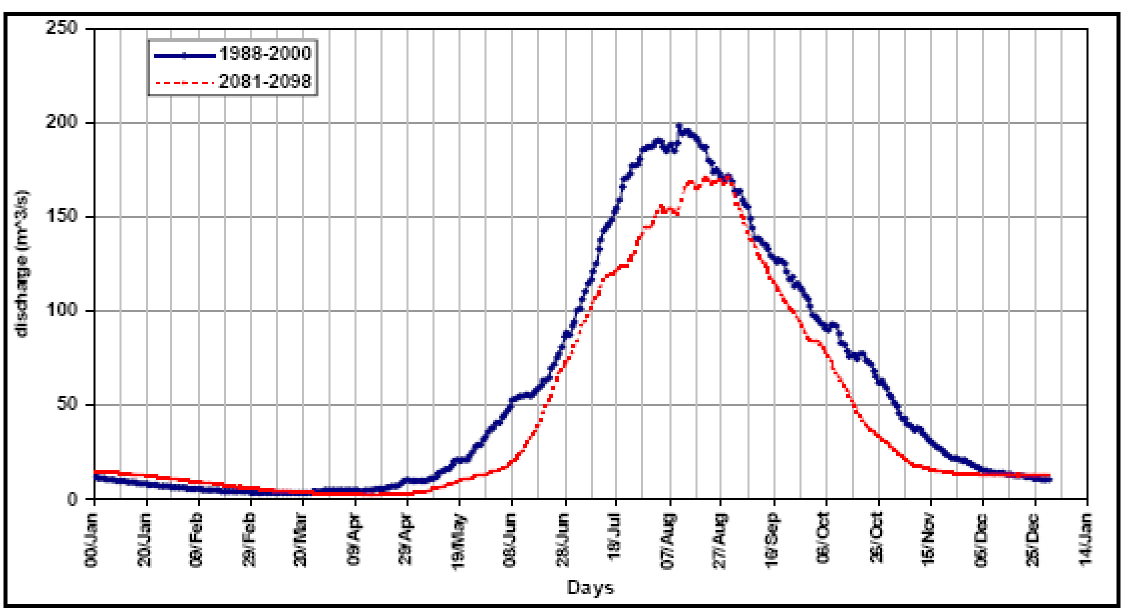

Figure 7: the seasonal daily mean runoff for present and future condition

However, In the seasonal monthly diagram, the simulated runoff exhibits consistent reduction in the runoff.

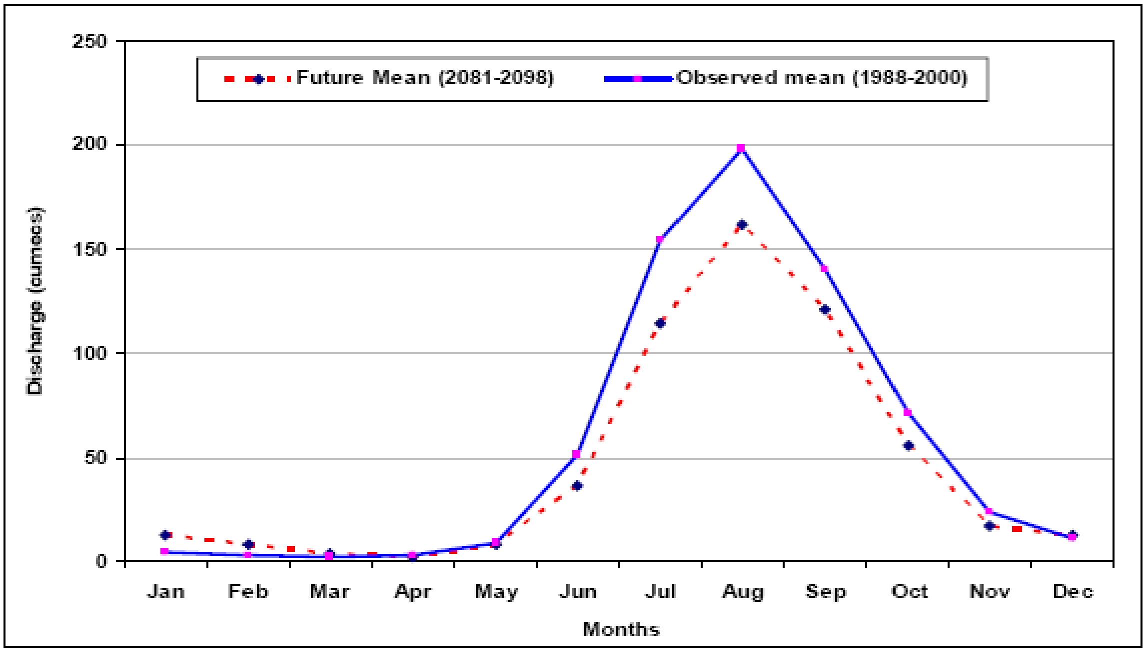

Figure 8: the monthly seasonal mean runoff for present and future condition

SUMMARY AND CONCLUSION

The purpose of this work was to evaluate the gauge merged satellite rainfall data for potential application in hydrological investigation and climate change impact assessment particularly at in the light of using the data set Nile River Basin catchments (local level use) where data is usually scant.

Genrally, evaluation of the data in two selected catchments of the Upper Blue Nile basin (Gilgel Abbay) and Lake Victoria sub basin (Kagera Catchment) showed encouraging results. The performance of the gauge merged satellite rainfall particularly appears to be promising after 1988 where we have the chance of comparing data for both catchments using common period.

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Given the temporal (daily) and spatial resolution (20 by 20 km), the gauge merged satellite rainfall data (meteosat derived) could be used to the Nile basin catchments as well as the whole Nile basin after rigorous evaluation the product in different parts of the basin. The data is one of the promising data products for future use in the basin.

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