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Empirical downscaling of rainfall in the upper Blue Nile Basin for use in hydrological modeling

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Introduction

Hydrological models need future projections of precipitation to simulate future flows. However, future projections from GCMs have coarse spatial resolution & cannot be used directly for hydrological modelling, which is usually performed at a catchment scale. Empirical downscaling, which involves developing quantitative relationships between large-scale atmospheric variables (i.e. predictors) & local surface variables, such as rainfall (i.e. predictands), is a widely used approach to overcome the scale mismatch. The objective was to establish statistical models for downscaling rainfall in the upper Blue Nile Basin (UBN) (Figure 1)

Fig 1. Location of upper Blue Nile basin (Background: ArcGIS data)

Climate stations

- Five stations which have reasonably good quality data for the period of 1961-1990 & located in the different parts of the basin were selected for the downscaling (Figure 2).
- Observed monthly rainfall data was obtained from the Ethiopian Meteorological Agency.

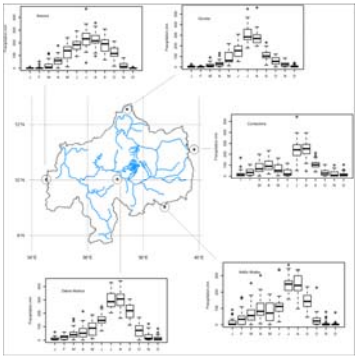

Fig 2 Map showing the locations of the climate stations. Linked box-plots show the interquartile range of monthly rainfall

Predictors

- Observed monthly data of the large scale predictor variables representing the current climatic conditions (1961-1990) were taken from the NCEP.
- These data are GCM-generated, through assimilation of observations & have a spatial resolution of 2.5° latitude by 2.5° longitude
- Data for future climate change scenarios for the seven predictor variables were extracted from the ECHAM5 from the Max-Plank Institute of Meteorology following the IPCC SRES A1B scenario (resolution of 1.9° latitude by 2.5° longitude)

Table 1. Description of predictors for downscaling

No.	Predictors	Unit	Abbr.	Levels (hP)
1	Geopotential height	M	Z	500, 850
2	Relative humidity	%	Rh	500, 850
3	Zonal wind speed	m/s	U	200, 500, 850
4	Meridional wind speed	m/s	V	500, 850
5	Mean sea level pressure	Mb	MSLP	Surface
6	Sea surface temperature	K	SST	Surface
7	Precipitable water	kg/m^2	Precw	Entire atmospheric column

Domains for downscaling

- The selection of domains was based on the climatology of the UBN through correlation analysis.
- First six candidate domains were tested: Arabian Peninsula (AP), Indian Ocean (IO), Southern Tropical Atlantic Ocean (STAO), North Atlantic Ocean (NAO), Mediterranean and North Africa region (MNA) & UBN (Figure 3).

Fig. 3 Location of domains

Correlation analysis

- Monthly correlation between the seven predictor variables from each domain & the observed station data was tested & showed mixed results.
- When monthly & seasonal correlations were considered no single domain was better than the others (Figure 4).
- Consequently, a new combined predictor was synthesized from the five by extracting the months with the highest correlation from each domain. The resultant improvement in the correlation coefficient (R) is shown in Figure 5.

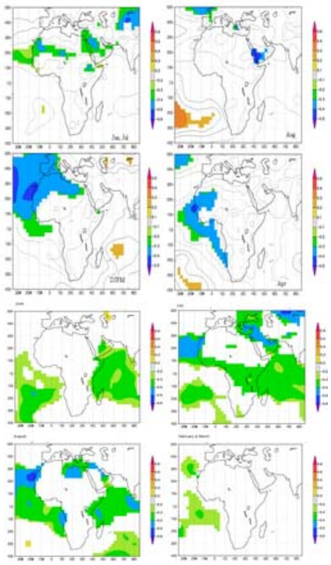

Fig. 4 Monthly correlation between mean sea level pressure & observed rainfall at Debre Markos (top) & Gondor (bottom) for a period of 1954-1990 at 10% significant level

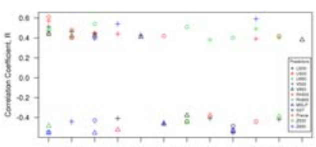

Fig. 5. Monthly correlation between observed data & large-scale predictors at Addis Ababa after combining domains and screening of candidate predictors on monthly basis

Calibration & validation

- Area averaged monthly combined predictors were used to establish a regression model between NCEP predictors & observed data from the five meteorological stations.
- The period, 1961-1990 was chosen as to represent the current climate. A split year approach was followed to calibrate the model from 1961-1980 & validate it from 1981-1990.
- The Mean Absolute Error varies from 10-25 mm. The established statistical models were used for downscaling of ECHAM A1B outputs in the UBN.

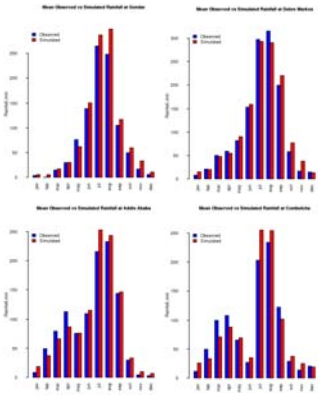

Fig 6. Validation results of the multiple regression models at four stations

Future climate scenarios

- The ECHAM5 run using the validated statistical downscaling models (SDMs) for the A1B scenario showed that in four of the five stations the average rain during the small rainy season decreased by 6-12% (Figure 7).
- Mixed results were obtained for the main rainy season. Compared to the current period an increase of 1-10% was observed at Assosa, Combolcha & Addis Ababa & a decrease of 1-7% at Debre Markos & Gondar during June, July & August.
- However during September the downscaled rainfall increased by 1-7% for four of the meteorological stations (Assosa, Debre Markos, Gondar & Addis Ababa).

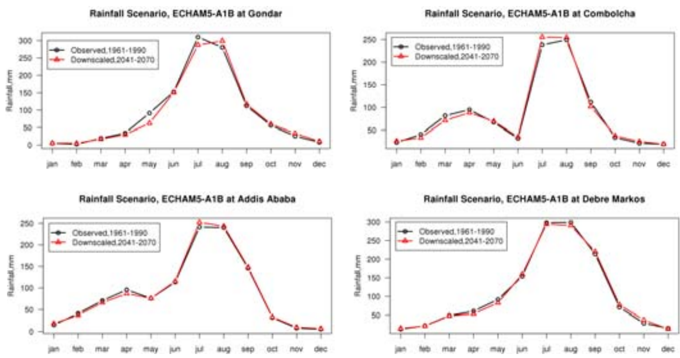

Fig 7. Trend in rainfall at five meteorological stations for future (2041-2070) climate change scenario (ECHAM5-A1B) in the upper Blue Nile basin.

Conclusions

Downscaling rainfall in the UBN is not straight forward. The use of more than one testing climate stations to determine the location of downscaling domains is essential. Due to significant variation in monthly correlation between predictors (atmospheric & ocean variables) & predictand (rainfall) within the annual cycle in different domains, rainfall downscaling in UBN should consider combining predictors from different domains rather than using a particular domain to obtain better SDMs.

The result of future climate change simulation using ECHAM5-A1B outputs as input to SDMs developed for the basin showed: i) a decrease in rainfall by 6-12% during the small rainy period & ii) mixed results for the main rainy season. Future research in downscaling rainfall in the UBN should consider different IPCC emission scenarios & use of multiple GCMs. In addition the effect of domain size on model performance, uncertainties in the statistical downscaling & the data used should be evaluated.

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