Future Water Supply Projections in Ethiopia Under Climate Change Using NASA NEX-GDDP and LDAS Simulations

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November 21, 2022

Abstract

Ethiopia's socioeconomic development is strongly dependent on both its natural resources and hydroclimatic dynamics. Current and projected effects of climate change and variability in the Horn of Africa pose an enormous challenge to the country's water resources management. We modeled multi-basin runoff scenarios in the country by calibrating statistical models first followed by extrapolation of the regressed functions into a future data domain under assumptions of stationarity. Precipitation and average near-surface air temperature predictors were used to calibrate Generalized Linear Models (GLM) to project 2011-2070 monthly runoff in a high-emission scenario (RCP 8.5) for selected General Circulation Models (GCM). Gridded fields of downscaled and bias-corrected precipitation, T_{max} and T_{min} for 10 CMIP5 GCMs were obtained from the NASA NEX-GDDP database. Hydrologic simulations from the NASA Land Data Assimilation System (LDAS) were used as proxies of observational basin response. Noah-MP's climate forcings (CHIRPS precipitation and MERRA temperatures) were used to perform additional bias-correction over basin-averaged predictors extracted from the NEX-GDDP ensemble models. Monthly mean estimates for precipitation/temperature projections showed wetter/warmer conditions than the baseline for almost all regions. 2011-2040 July temperature climatology in most GCMs exhibited the strongest warming (> 1.5C ^{o}) in Central Ethiopia and it gradually decreased northwards and southwards. Correlation analysis showed that precipitation variations explain most of runoff variability during the rainy seasons. Future GLM runoff estimates suggest a generalized national increase of mean annual water supply when compared with historical LDAS, although spatio-temporal differences were observed across the country. The mentioned hydrological gains are driven by spatially distributed changes in precipitation with the biggest positive trends in the southeastern region followed by moderate precipitation increases in the Central Highlands and neutral changes in the Northwest. Few GCMs (e.g., GFDL-CM3) project drier conditions in the rainy seasons and a slight decrease in the mean annual runoff for most basins. The wettest model in the Abay basin, IPSL-CM5A-LR, predicts 15% increase in annual runoff when compared to historical averages.

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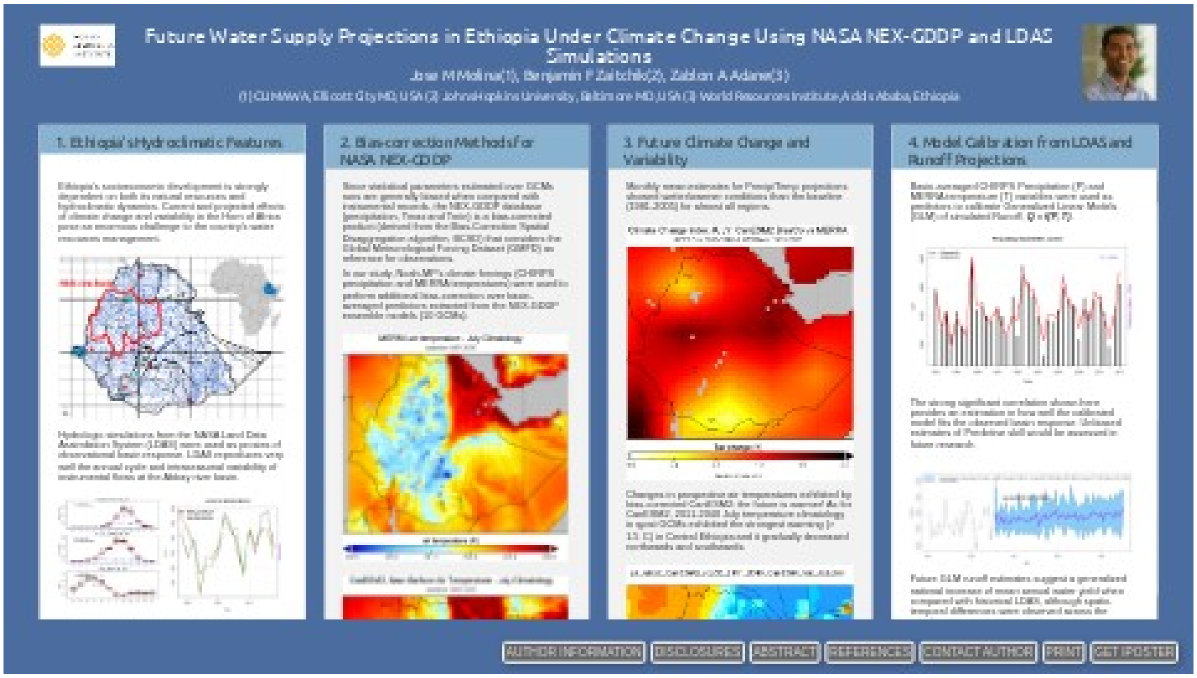

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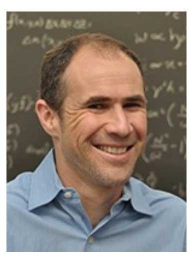


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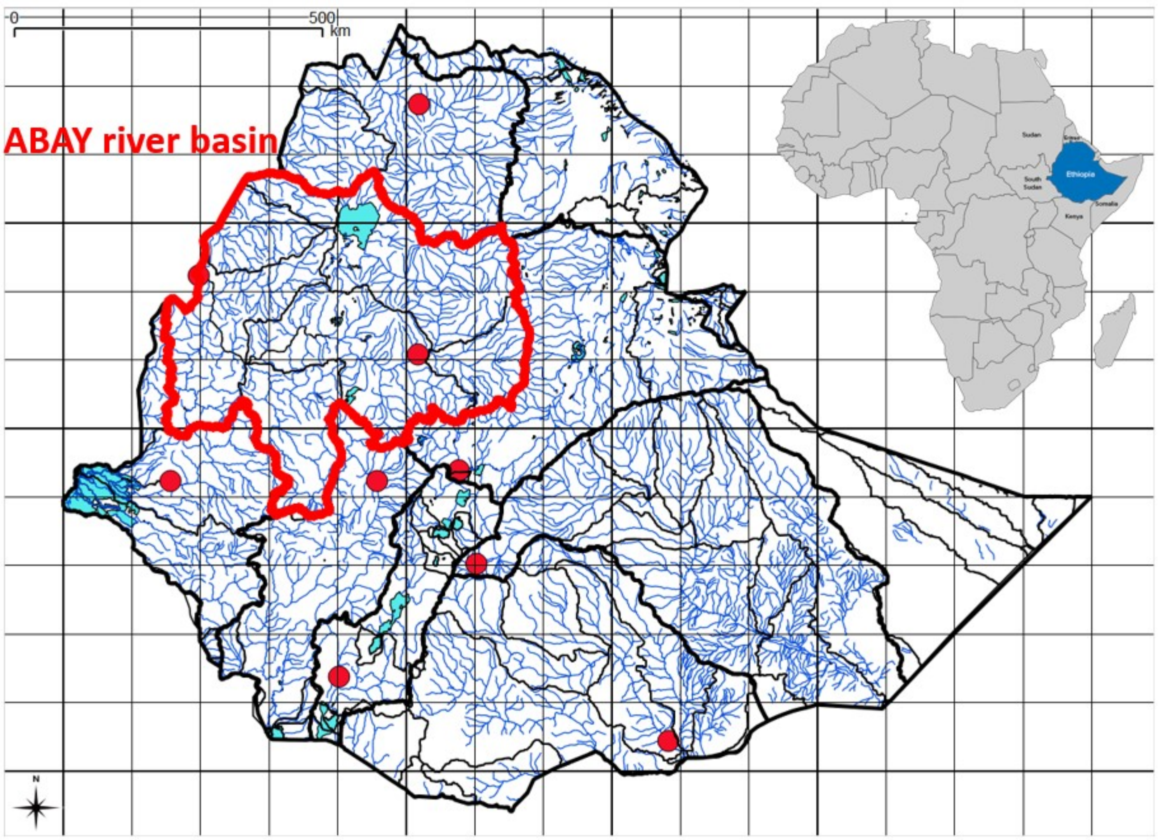
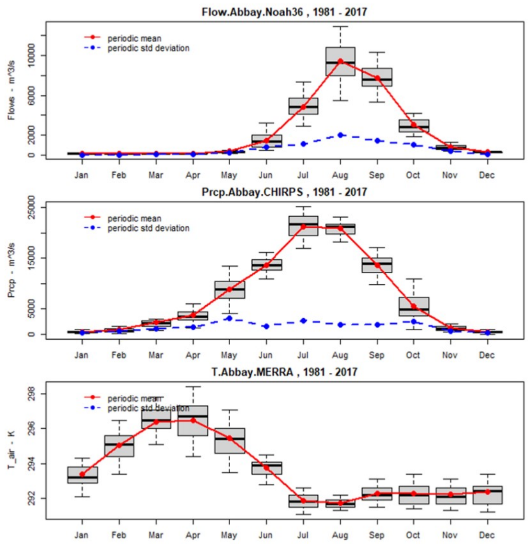
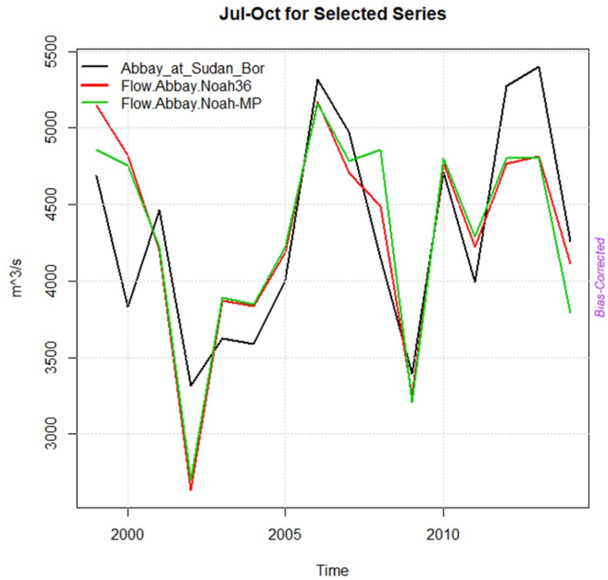
1. ETHIOPIA’S HYDROCLIMATIC FEATURES

Ethiopia’s socioeconomic development is strongly dependent on both its natural resources and hydroclimatic dynamics. Current and projected effects of climate change and variability in the Horn of Africa pose an enormous challenge to the country’s water resources management.

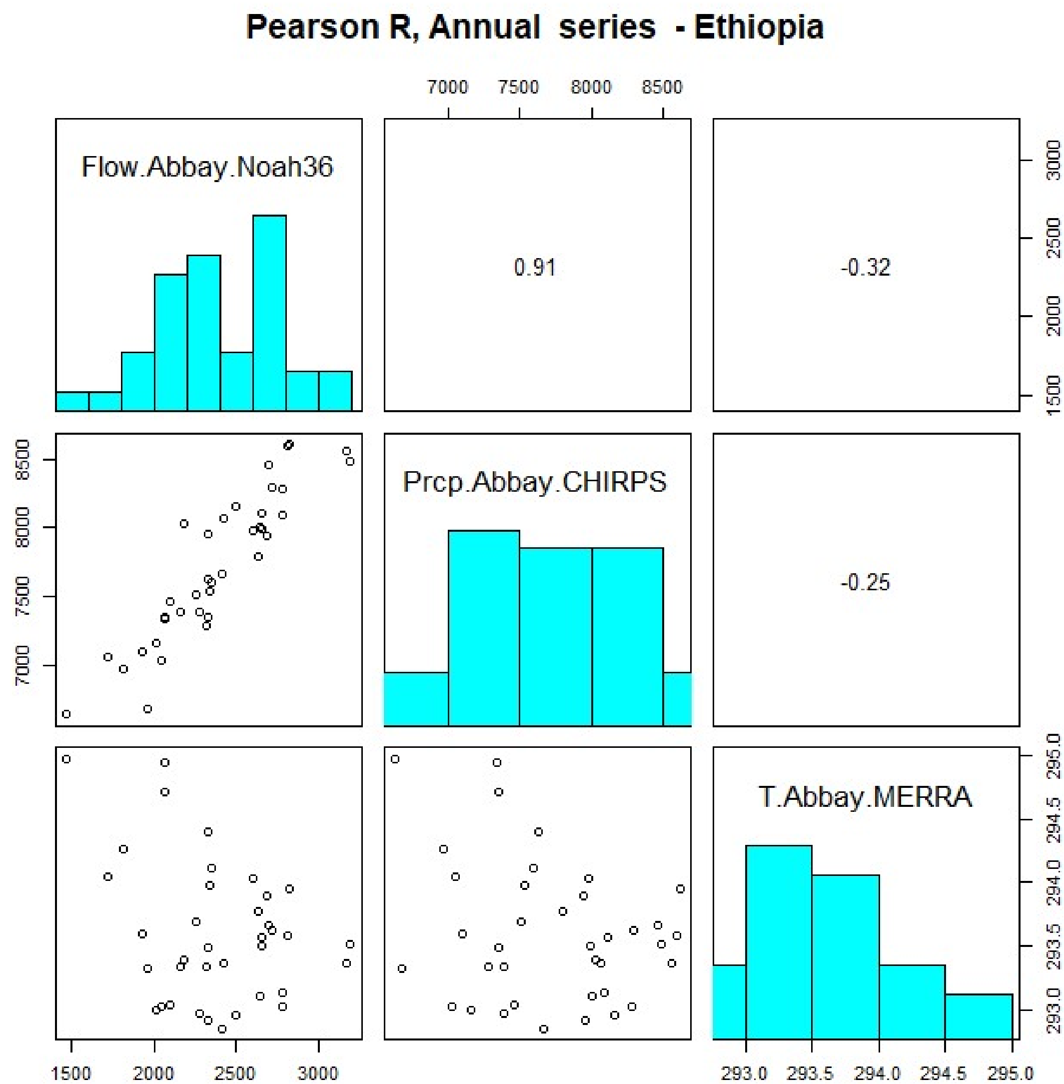


Hydrologic simulations from the NASA Land Data Assimilation System (LDAS) were used as proxies of observational basin response. LDAS reproduces very well the annual cycle and intraseasonal variability of instrumental flows at the Abbay river basin.





The rainy season in Abay (July-October) has a significant effect in the hydrologic response, and precipitation is considered the main driver of basin response variability in this region (e.g., annual basin-averaged precipitation in Abay explains more than 90% of annual variability of basin water yields).

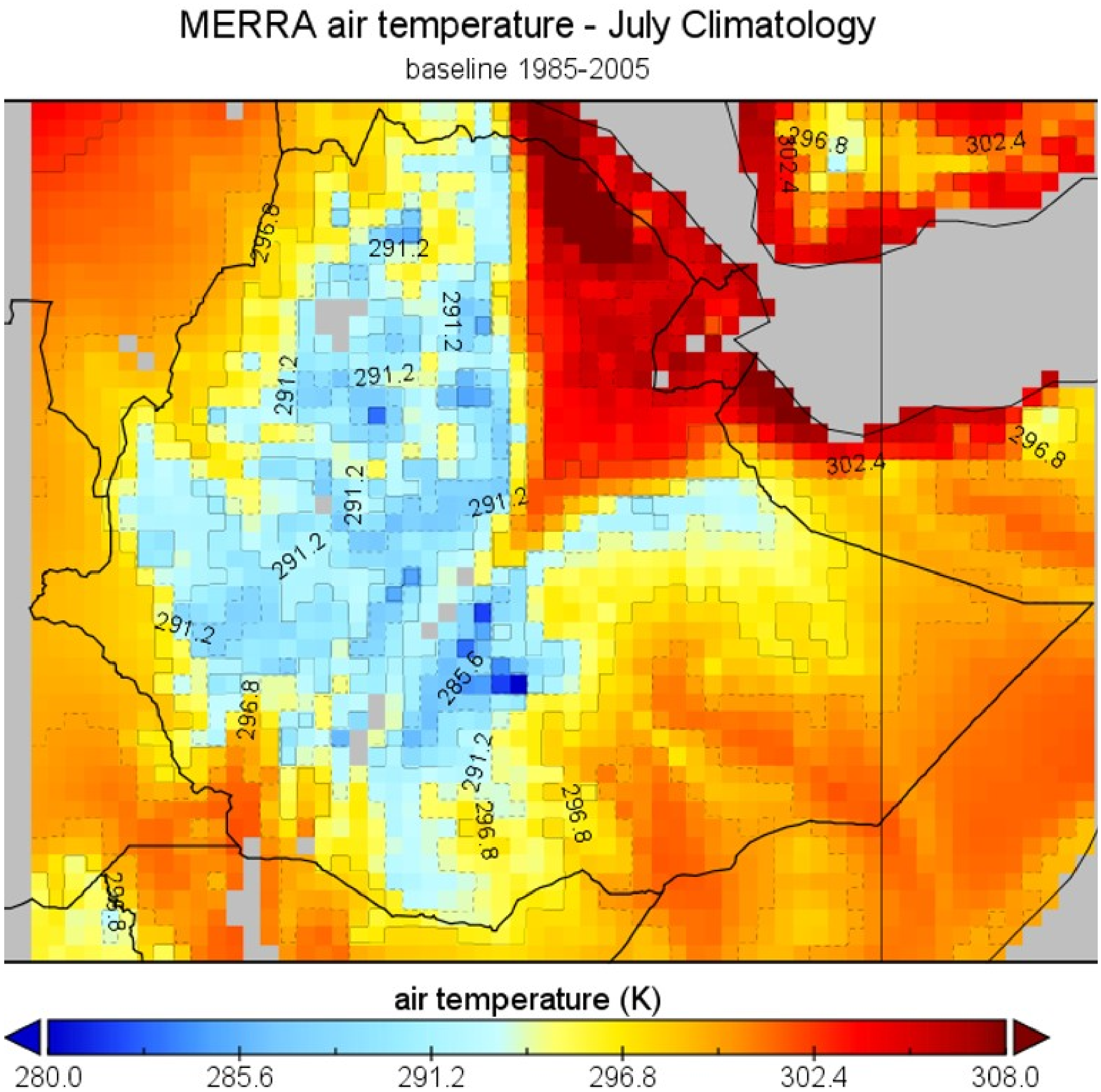


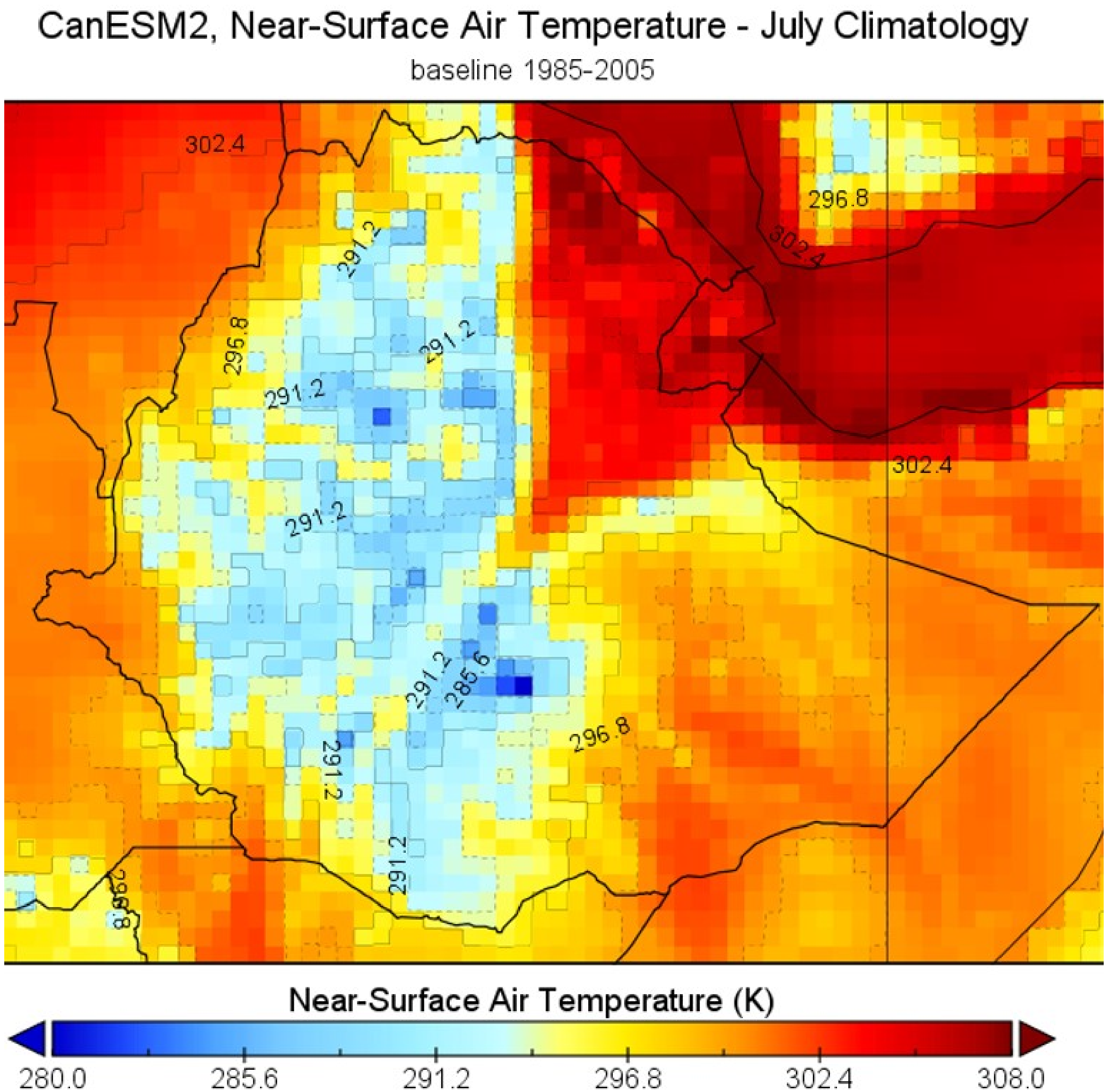
Other basins in the country exhibit a very different hidrology to Abay, with high-intermittency in the river flows, and very dry climatologies and arid environments in the North, South, and Southeast. Noah-MP realizations were considered for runoff analysis in this study.

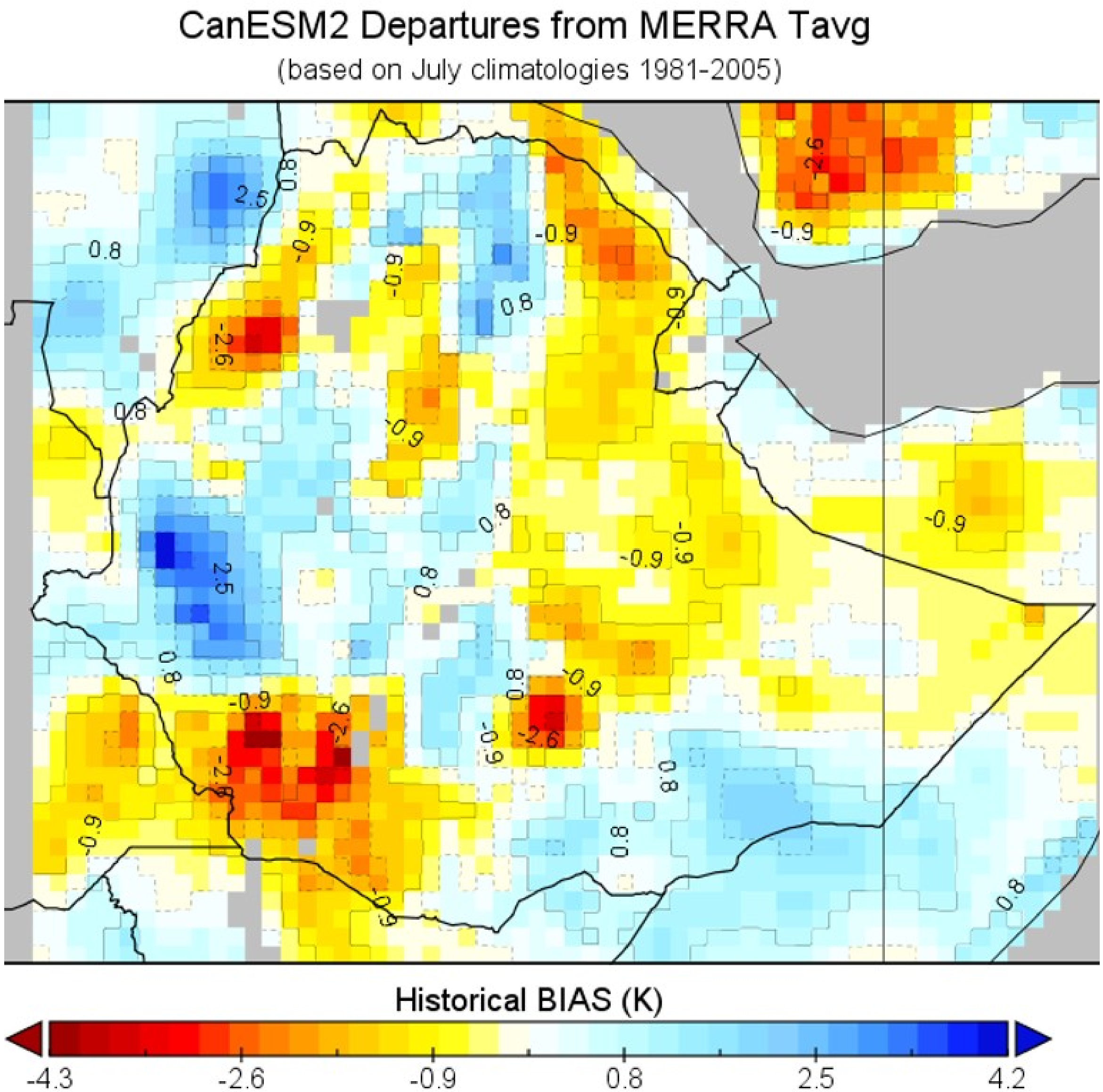
2. BIAS-CORRECTION METHODS FOR NASA NEX-GDDP

Since statistical parameters estimated over GCMs runs are generally biased when compared with instrumental records, the NEX-GDDP database (precipitation, Tmax and Tmin) is a bias-corrected product (derived from the Bias-Correction Spatial Disaggregation algorithm, BCSD) that considers the Global Meteorological Forcing Dataset (GMFD) as reference for observations.

In our study, Noah-MP's climate forcings (CHIRPS precipitation and MERRA temperatures) were used to perform additional bias-correction over basin-averaged predictors extracted from the NEX-GDDP ensemble models (10 GCMs).




CanESM2, Near-Surface Air Temperature - July Climatology
baseline 1985-2005
302.4
296.8
302.4
291.2
296.8
291.2
291.2
302.4
291.2
291.2
285.6
296.8
291.2
291.2
Near-Surface Air Temperature (K)
280.0
285.6
291.2
296.8
302.4
308.0



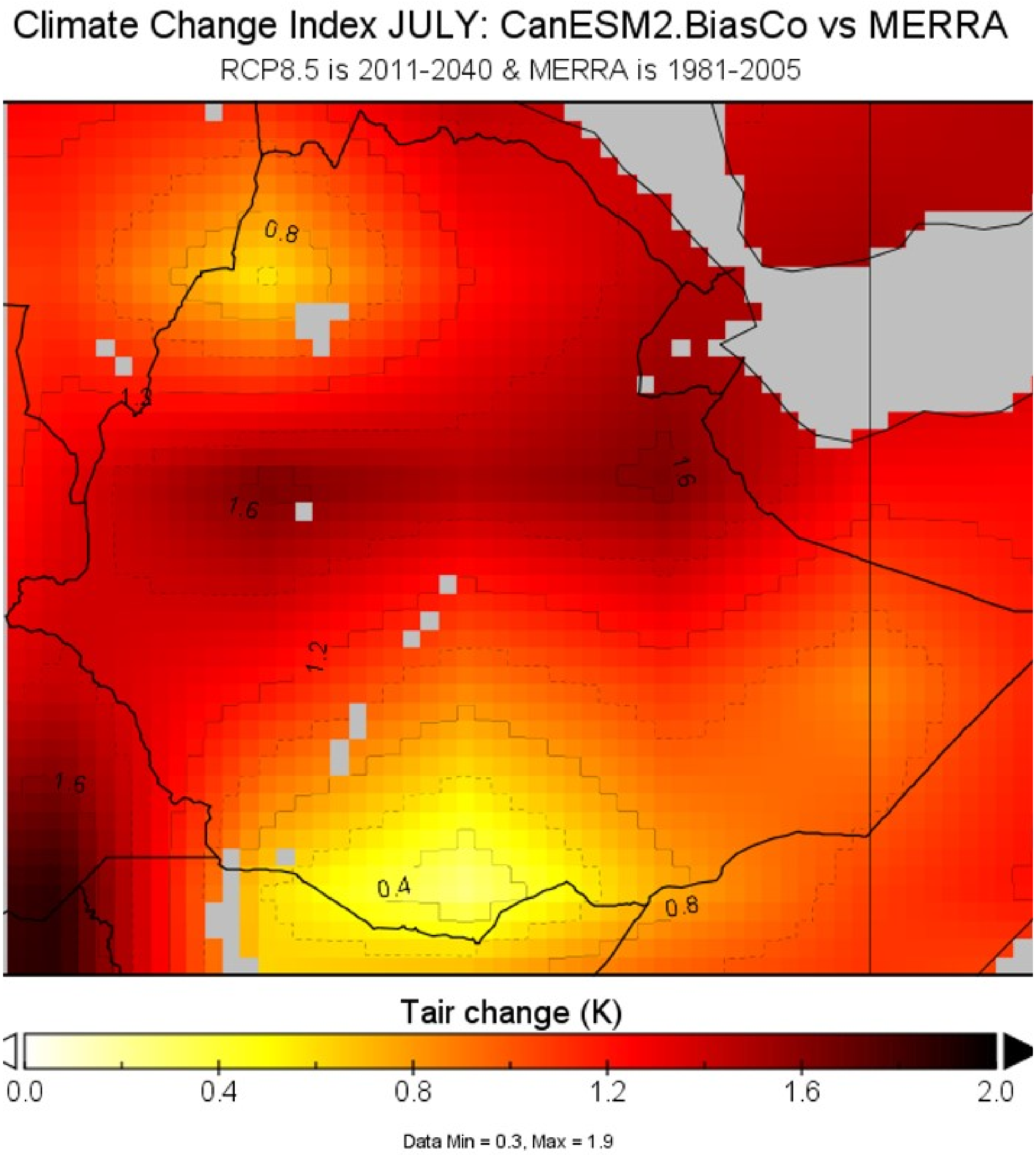
Bias-correction of future NEX-GDDP projections:

Calibration of prospective NEX-GDDP temperature is performed by removing historical bias from future GCM realizations:

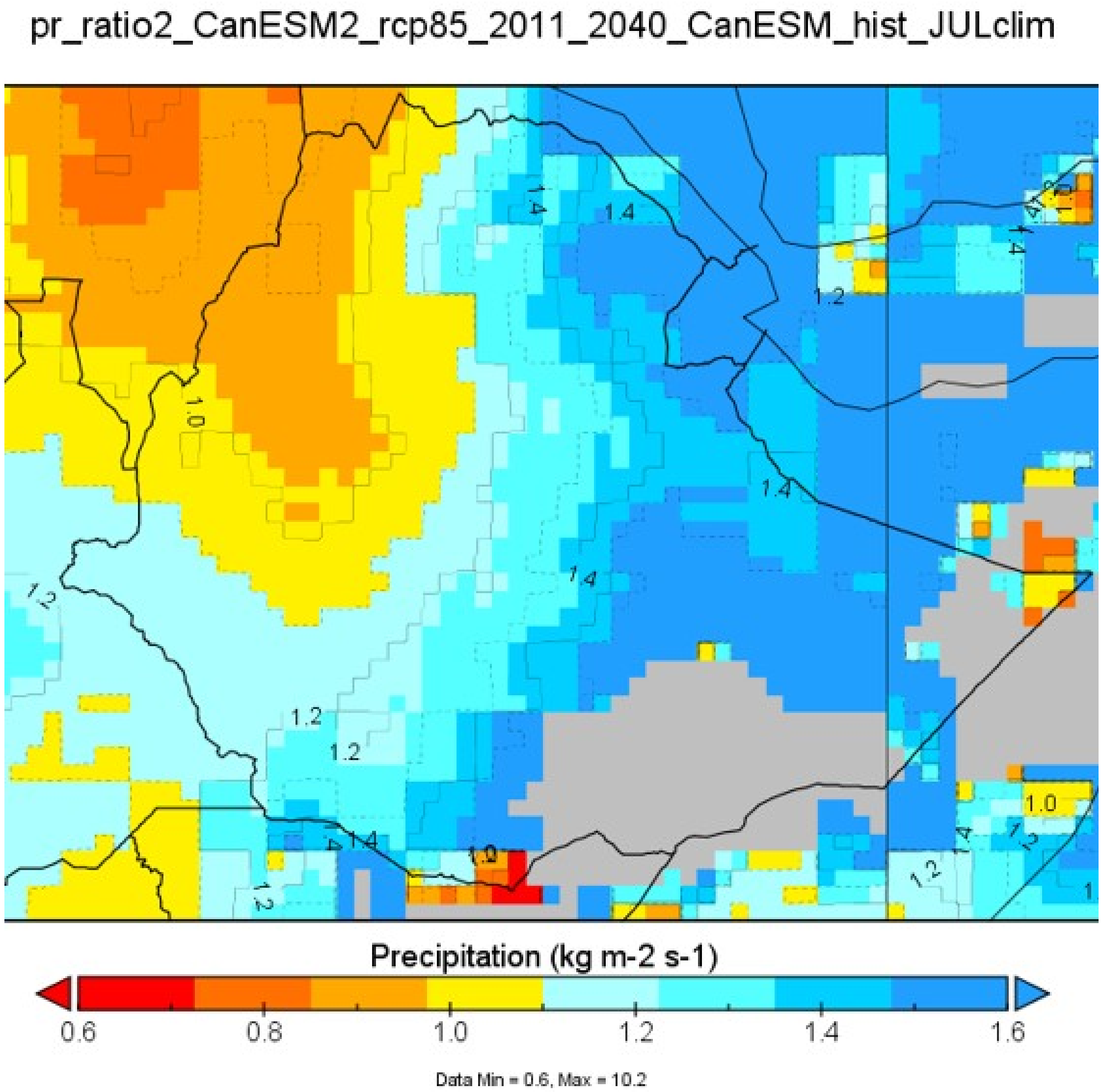
$GCM_{(fut)}.BC = GCM_{(fut)} - BIAS_{(hist)}$

3. FUTURE CLIMATE CHANGE AND VARIABILITY

Monthly mean estimates for Precip/Temp projections showed wetter/warmer conditions than the baseline (1981-2005) for almost all regions.



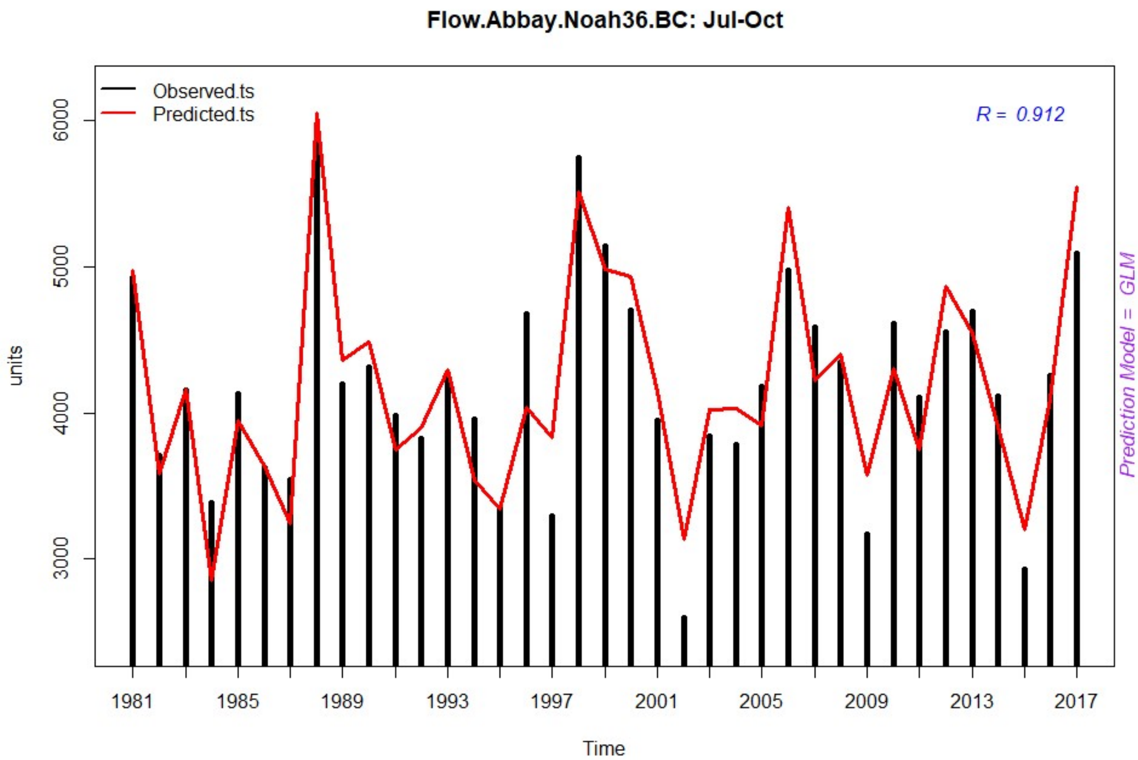
Changes in prospective air temperatures exhibited by bias-corrected CanESM2: the future is warmer! As for CanESM2, 2011-2040 July temperature climatology in most GCMs exhibited the strongest warming (> 1.5°C) in Central Ethiopia and it gradually decreased northwards and southwards.



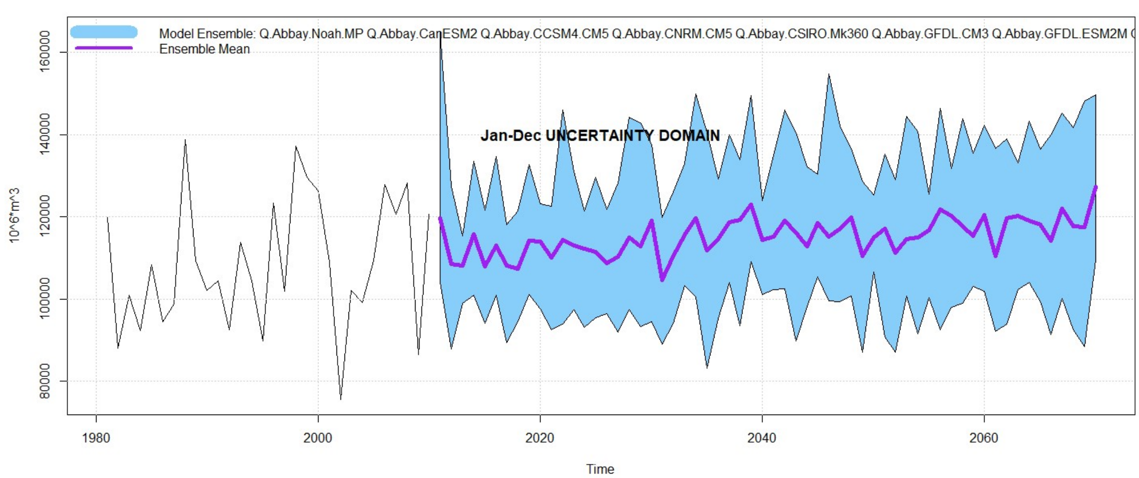
Although specific differences (and increasing variability and uncertainty) are expected for precipitation across basins and among climate models, GCMs show agreements for a wetter country in the future. Changes in prospective July precipitation exhibited by CanESM2 here: the biggest positive trends are in the southeastern region (>40%) followed by moderate precipitation increases in the Central Highlands (~10-20%) and neutral changes in the Northwest.

4. MODEL CALIBRATION FROM LDAS AND RUNOFF PROJECTIONS

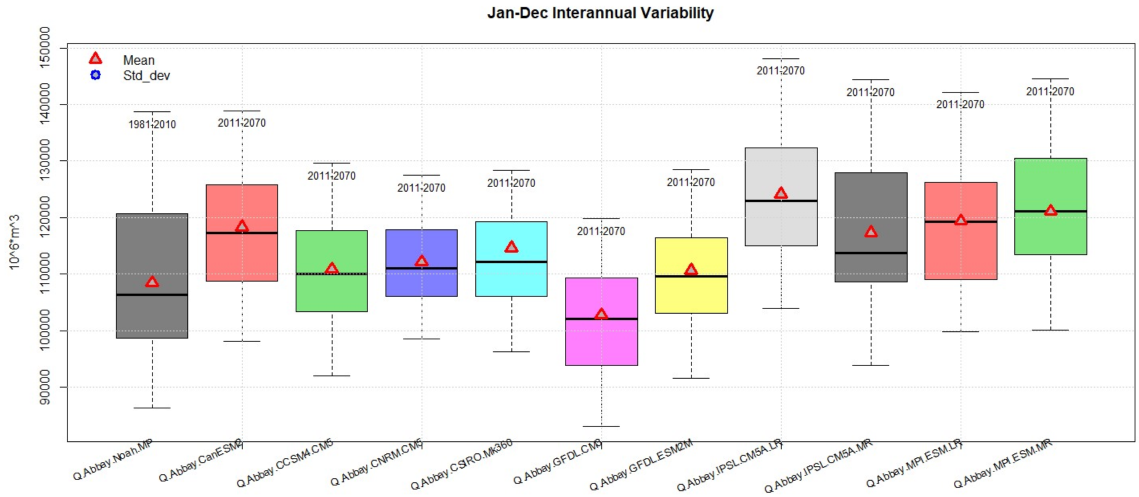
Basin-averaged CHIRPS Precipitation (P) and MERRA temperature (T) variables were used as predictors to calibrate Generalized Linear Models (GLM) of simulated Runoff, $\boldsymbol{Q = f(P, T)}$.



The strong significant correlation shown here provides an estimation in how well the calibrated model fits the observed basin response. Unbiased estimates of Predictive skill would be assessed in future research.



Future GLM runoff estimates suggest a generalized national increase of mean annual water yield when compared with historical LDAS, although spatio-temporal differences were observed across the country.



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Acknowledgements:

Climate scenarios used were from the NEX-GDDP dataset, prepared by the Climate Analytics Group and NASA Ames Research Center using the NASA Earth Exchange, and distributed by the NASA Center for Climate Simulation (NCCS).

This study was partially funded by the World Resources Institute, WRI, under the *Ethiopia Water Risk Analysis and Mapping Project*.

DISCLOSURES

The preliminary findings, interpretations, and conclusions expressed in this presentation are entirely our own and should not be attributed in any way to the organizations or the countries they represent

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