INVESTIGATING THE SIMULATIONS OF HYDROLOGICAL and ENERGY CYCLES OF IPCC GCMS OVER THE CONGO AND UPPER BLUE NILE BASINS

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Introduction

The simulations of the hydrological cycle in general circulation models (GCMs) are characterized by a significant degree of uncertainty. This uncertainty is reflected in the wide range of IPCC (Intergovernmental Panel on Climate Change) GCMs predictions of future changes in the hydrological cycle, particularly over major African basins. Here, we explore the relations between the surface radiation and hydrological cycle within the IPCC GCMs over the Congo and Upper Blue Nile (UBN) basins. Most GCMs overestimate the hydrological cycle over the basins compared to observations. This overestimation is associated with excess net surface radiation, attributed to an underestimation of total cloud cover. However, we find some improvement in the seasonal cycle of the water hydrological cycle with horizontal resolution, which highlight that some high-resolution GCMs includes better models for climate change studies over the studied regions. Through this method, we aim:

(i) investigate GCMs ability in representing the hydrological and energy cycles under present-day climate conditions over major African basins.
(ii) identify the processes that determine their skill in representing the hydrological cycle.

Data

In this analysis we use the following data:

(i) CRU TS 3.1 precipitation dataset (Mitchell and Jones, 2005)

(ii) RivDISv1.1 observed stream flows at the outlets of the Congo and Upper Blue Nile basins (Vörösmarty et al. 1998)

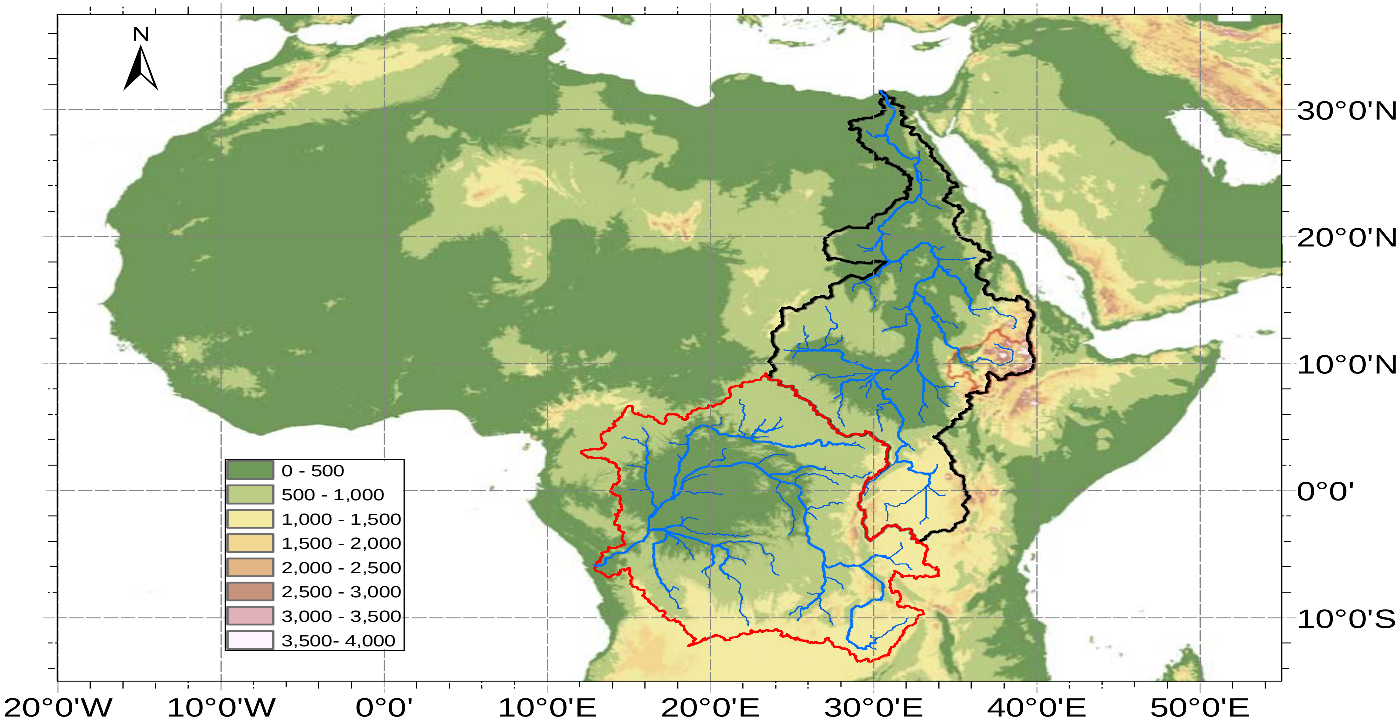
(iii) The NASA-Langley's Surface Radiation Budget (NASA-SRB) Release-3.0 is used to validate the simulated GCMs surface longwave and shortwave radiation (Gupta et al., 1999), (iv) The International Satellite Cloud Climatology Project (ISCCP) D2 data set is used to validate the total cloud cover (Rossow et al., 1996), and (v) Simulation outputs from 17 GCMs of the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (Meehl et al., 2007), as well as 11 GCMs of the CMIP5 multi-model dataset (Taylor et al., 2012).

Data: GCMs used in this study

Project	Model	Outputs Resolution	Agency
CMIP3	1- HADGEM1	1.875°x1.25°	Hadley Center for Climate Prediction and Research, Met Office, UK
	2- MPI-ECHAM5	1.875°x1.87°	Max Planck Institute for Meteorology, Germany
	3 -CSIRO-MK3.5	1.875°x1.86°	CSIRO Atmospheric Research, Australia
	4- CSIRO-MK3	1.875°x1.86°	CSIRO Atmospheric Research, Australia
	5- GFDL-CM2	2.5°x2°	Geophysical Fluid Dynamics Laboratory, USA
	6- BCCR-CM2	2.8°x2.8°	Bjerknes Center for Climate Research, Norway
	7- MRI-CGCM2.3.2	2.8°x2.8°	Meteorological Research Institute, Japan
	8- NCAR-PCM1	2.8°x2.8°	National Center for Atmospheric Research (NCAR), NSF, DOE, NASA, and NOAA
	9- CNRM-CM3	2.8°x2.8°	National Center of Meteorological Research, France
	10- IAP-FGOALS	2.8°x2.8°	Institute of Atmospheric Physics, Chinese Academy of Sciences, China
	11- CCMA-GCM3.1(T63)	2.8°x2.7°	Canadian Center for Climate Modeling and Analysis, Canada
	12- HADCM3	3.75°x2.5°	Hadley Center for Climate Prediction and Research, Met Office, UK
	13- IPSL-CM4	3.75°x2.5°	Institute of Pierre Simon Laplace, France
	14- MIUB-ECHO	3.75°x2.7°	Meteorological Institute University of Bon, Germany
	15- CCMA-GCM3.1(T47)	3.75°x3.7°	Canadian Center for Climate Modeling and Analysis, Canada
	16- GISS-AOM3.1	4°x3°	Goddard Institute for Space Studies, USA
	17- INMCM3	5°x4°	Institute for Numerical Mathematics, Russia
CMIP5	1- MRI-CGCM3	1.12°x1.12°	Meteorological Research Institute
	2- CNRM-CM5	1.4°x1.4°	National Center of Meteorological Research, France
	3- INMCM4	2°x1.5°	Institute for Numerical Mathematics, Russia
	4- HadGEM2-CC	1.875°x1.25°	Hadley Center for Climate Prediction and Research, Met Office
	5- CSIRO	1.85°x1.85°	CSIRO Atmospheric Research, Australia
	6- IPSL-CM5-MR	2.5°x1.26°	Institute Pierre Simon Laplace, France
	7- NORM-ESM-ME	2.5°x1.9°	Norwegian Climate Centre, Norway
	8- GISS-E2-H	2.5°x2°	Goddard Institute for Space Studies, USA
	9- GFDL-CM3	2.5°x2°	Geophysical Fluid Dynamics Laboratory, USA
	10- BCC-CSM1	2.8°x2.8°	Beijing Climate Center, China
	11- CAN-ESM2	2.8°x2.8°	Canadian Center for Climate Modeling and Analysis, Canada

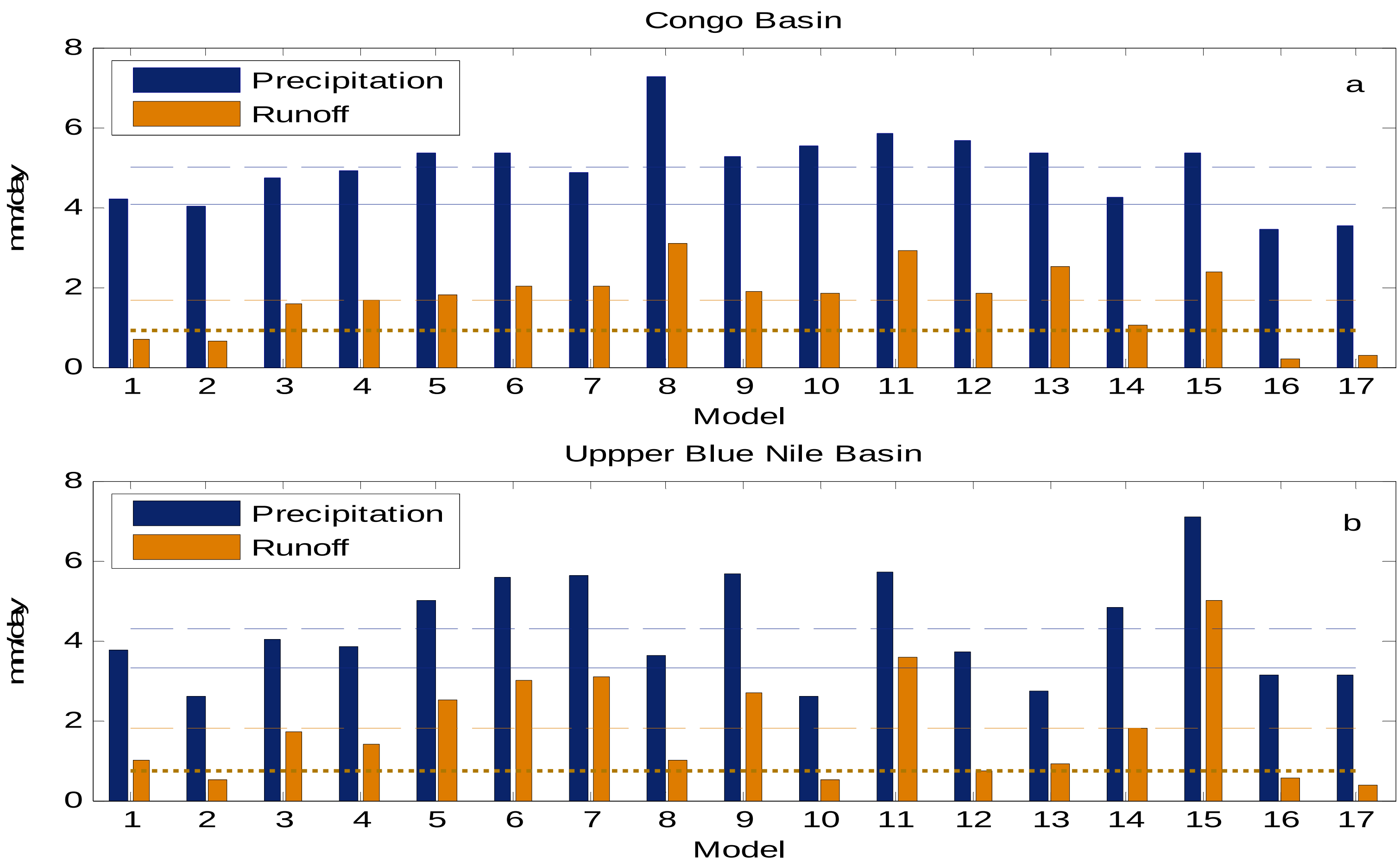
Study Areas

Two different study areas with diverse climatic conditions and different complexity of topographical conditions are considered, the Congo and the Upper Blue Nile basins.



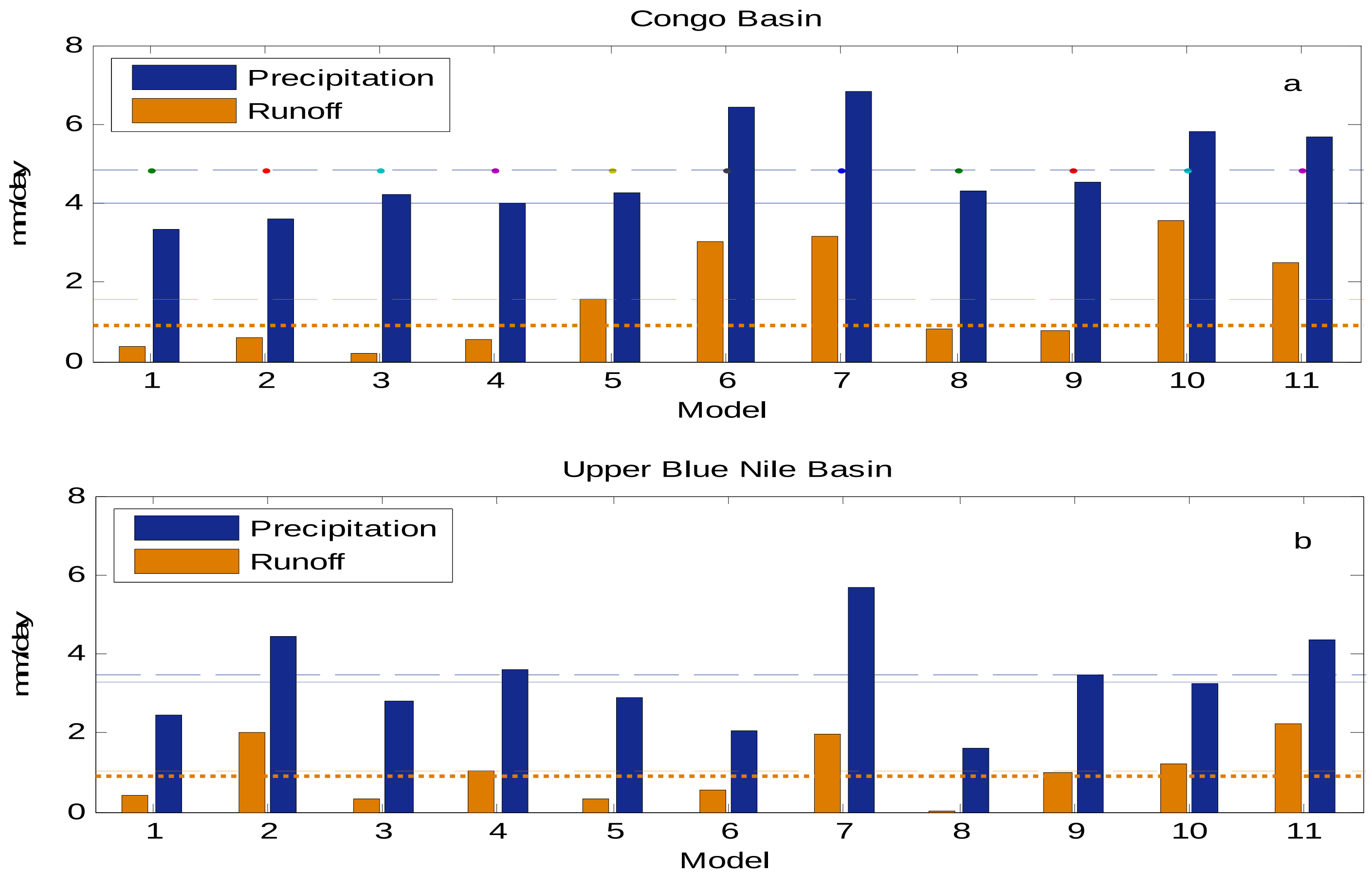
Topographic map of North Africa and the Middle East

The Hydrological Cycle of GCMs



Analysis of precipitation and runoff for 22 years (1979-2000) for 17 GCMs of the CMIP3 project for; a) the Congo basin, b) the Upper Blue Nile basin. The long-term average of the CRU TS 3.1 precipitation (Blue Solid line) and the observed streamflow (Brown dotted line). The dashed lines are for the multi-model ensemble average. The model number is as listed in slide 4.

The Hydrological Cycle of GCMs

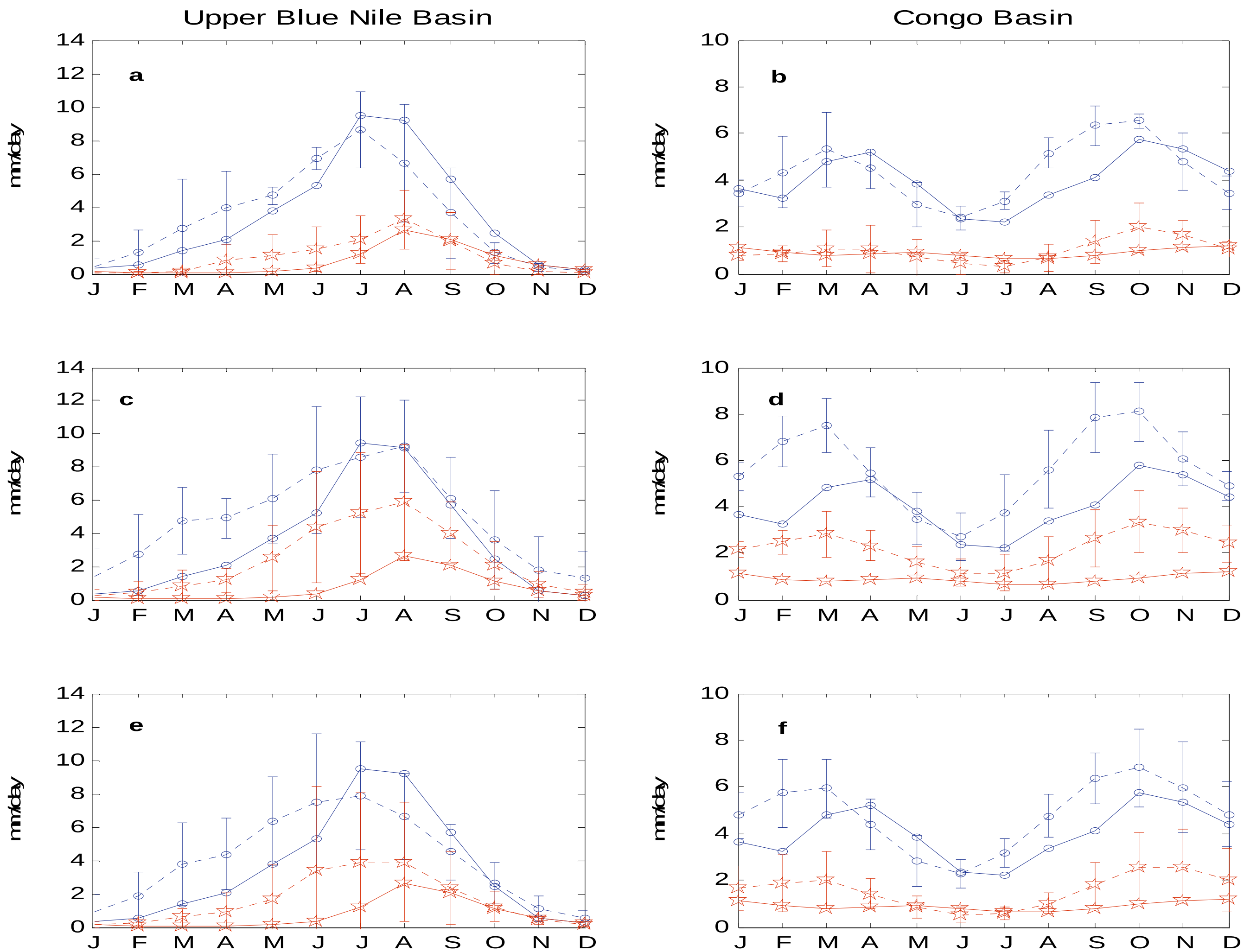


Analysis of precipitation and runoff for 22 years (1979-2000) for 11 GCMs of the CMIP5 project for; a) the Congo basin, b) the Upper Blue Nile basin. The long-term average of the CRU TS 3.1 precipitation (Blue Solid line) and the observed streamflow (Brown dotted line). The dashed lines are for the multi-model ensemble average. The model number is as listed in slide 4.

The Hydrological Cycle of GCMs

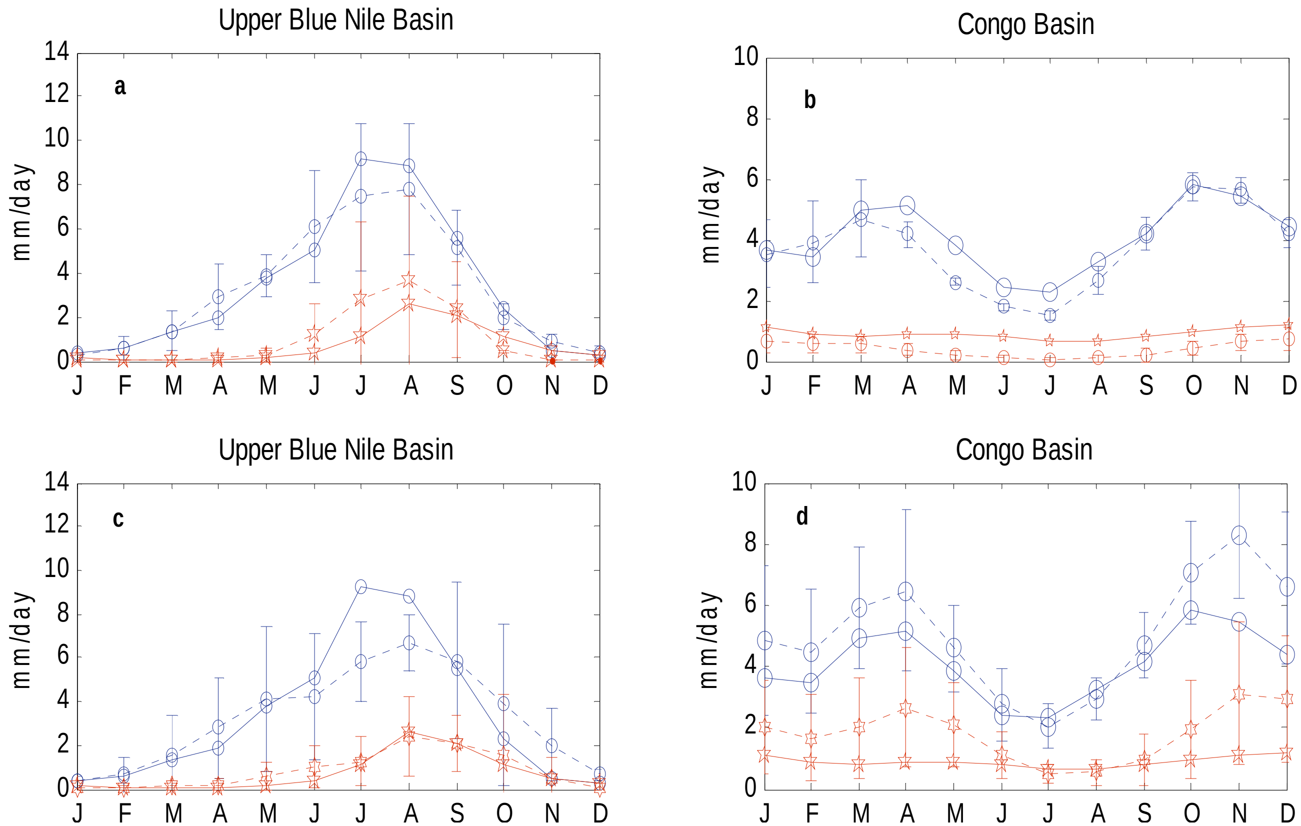
The previous two silides illustrate the biases present in the analyzed GCMs for simulating the precipitation and runoff for the UBN and Congo basins. A general pattern seen in these models is that most of the models, particularly among the CMIP3 models, show a wetter climate by overestimating precipitation and runoff, as reflected by their high multi-model ensemble averages compared to observations..

Effect of Models Resolution



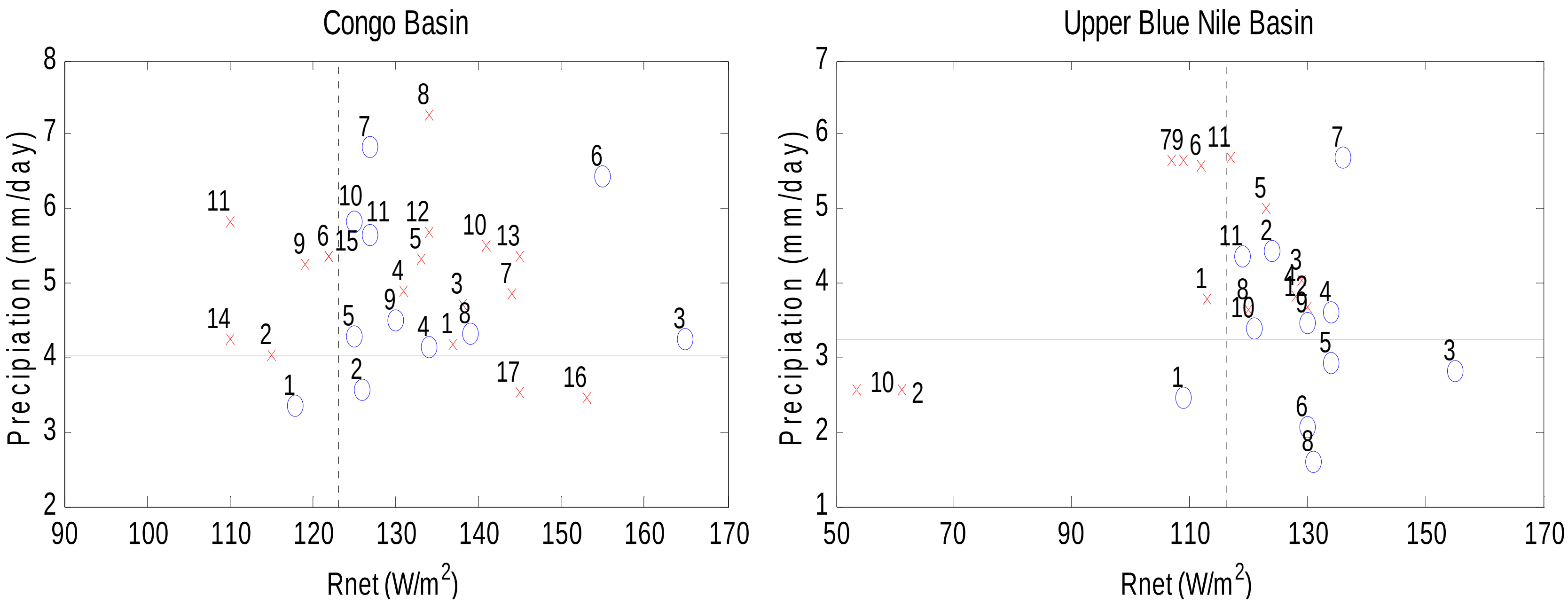
Seasonal cycle of precipitation and runoff of 22 years (1979-2000) for 17 GCMs of the CMPI3 project .The figures are sorted according to the spatial resolution of the GCMs; (a and b) are for the highest resolution GCMs, (c and d) are for medium resolution models and (e and f) for low resolution models . The error bars indicates model variation around the ensemble mean of the models of equivalent resolution by one standard deviation. The solid lines with circles and stars are for the long-term averages of observations of precipitation using CRU TS 3.1 and the observed streamflow respectively, while the dotted lines are for corresponding values from the GCMs.

Effect of Models Resolution



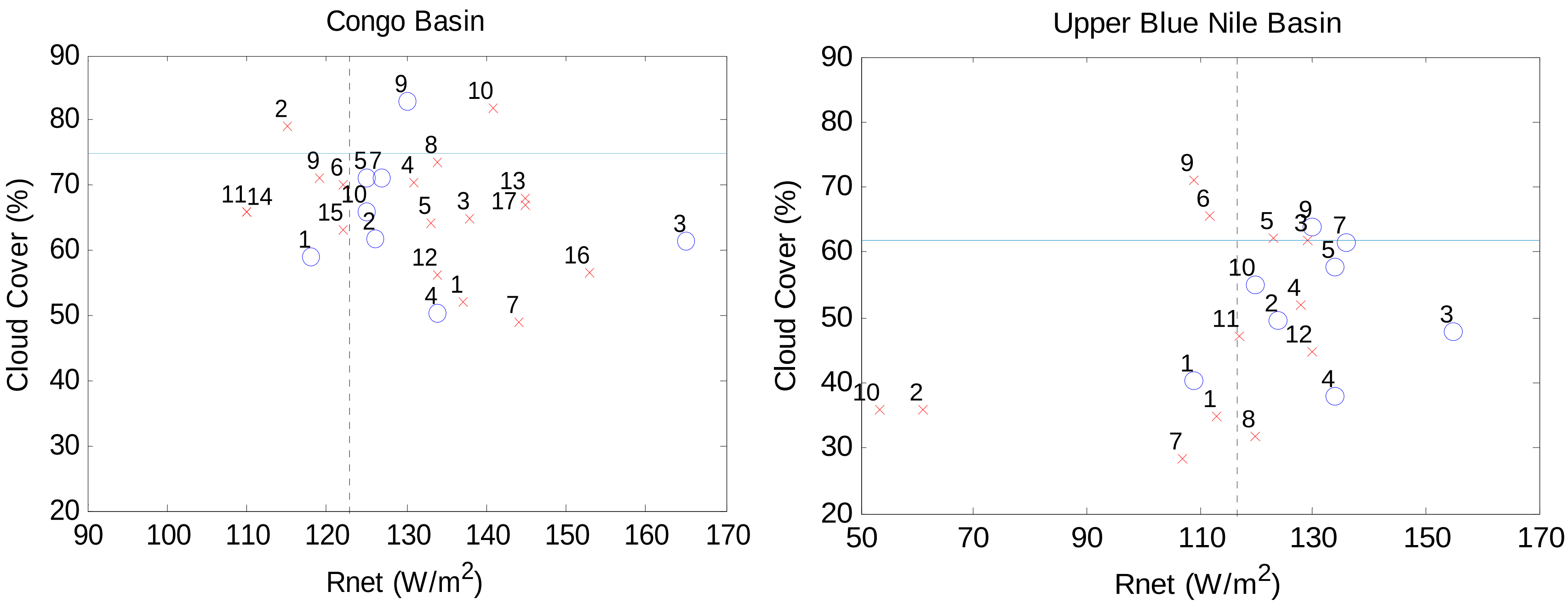
Seasonal cycle of precipitation and runoff of 22 years (1979-2000) for 11 GCMs of the CMPI5 project .The figures are sorted according to the spatial resolution of the GCMs; (a and b) are for the highest resolution GCMs, (c and d) are for medium resolution models and (e and f) for low resolution models . The error bars indicates model variation around the ensemble mean of the models of equivalent resolution by one standard deviation. The solid lines with circles and stars are for the long-term averages of observations of precipitation using CRU TS 3.1 and the observed streamflow respectively, while the dotted lines are for corresponding values from the GCMs.

Hydrological Cycle and Net Surface Radiation



Average net surface radiation and precipitation for 17 GCMs of the CMIP3 project (crosses) and 11 models of the CMIP5 project (circles), for the period (1979-2000). The horizontal straight lines represent the annual average of precipitation from the CRU TS3.1 observations and vertical straight lines are annual average net radiation from NASA-SRB observations for the period (1983-2000).

Hydrological Cycle and Net Surface Radiation



Average net surface radiation and total cloud cover for 17 GCMs of the CMIP3 project (crosses) and 11 models of the CMIP5 project (circles), for the period (1979-2000). The horizontal straight lines represent the annual average of the total cloud cover from the ISCPP observations for the period (1983-2000) and vertical straight lines are annual average net radiation from NASA-SRB observations for the period (1983-2000).

Conclusions

1. Most of the 28 GCMs of the CMIP3 and CMIP5 projects selected for this study simulate a strong-bias in the hydrological cycle over the Congo and UBN basins by overestimating precipitation and runoff compared to observations. These biases are associated with an overestimation of net surface radiation, attributed to an underestimation of cloud cover compared to observations.

2. The relationship between GCM horizontal resolution and their ability to simulate the hydrological cycle over the UBN and Congo basins showed that most of the models with the highest resolution (approximately 200 km) are able to simulate more accurately the seasonal cycle the hydrological variables compared to the medium (300 km) and low-resolution (400 km) models over both basins.

References

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