The performance of WRF model setup, physics- and parameterization schemes to reproduce observed precipitation characteristics in West Africa

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Motivation

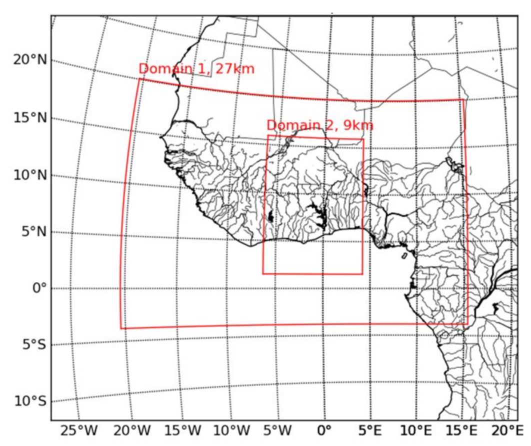
The investigation of climate change impacts requires spatiotemporal high resolution surface flux information for the region of interest. A common way is to use a regional atmospheric circulation model (RCM) to refine the coarse information from a general circulation model. Before starting a RCM simulation an appropriate model setting must be selected for the region of interest. In the framework of this study we investigate the effect of changing specific model settings of the Weather Research and Forecasting model (WRF, Skamarock et al., 2005) to reproduce monthly and daily precipitation characteristics in West Africa. We would like to highlight the following issues in this presentation:

- The need of performing this kind of optimization for WRF for the region of interest.
- The effect of changing the resolution of WRF on reproducing precipitation characteristics. A low and a high resolution simulation is performed using same set of parameterization schemes and boundary conditions.
- The effect of changing WRF parameterization schemes on reproducing precipitation characteristics. Two simulations with a different set of schemes (a standard and an optimum set) are performed using the same domain and boundary conditions.
- The need of evaluating precipitation characteristics of RCM simulations on a high temporal resolution such as daily time scale.

Experimental design of WRF simulations

A. Coarse versus high resolution simulation

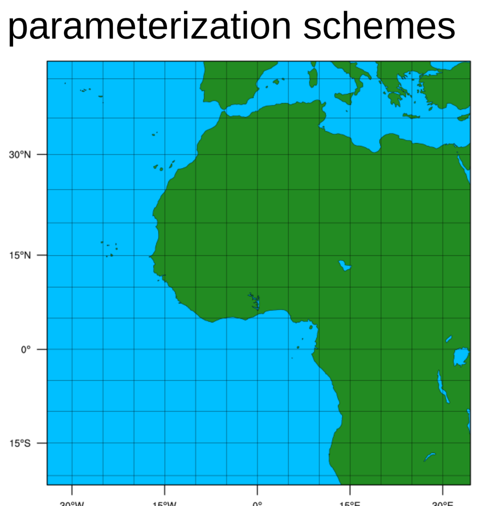
The first and second run uses the same parameterization set but a different nesting approach (Table 2). The coarse resolution simulation is done with a single domain based on a horizontal resolution of approximately 27 km. The high resolution run uses additionally a subdomain with a finer resolution (9 km x 9 m). The size of both domains is illustrated in the right map. A similar domain configuration has been proposed by Jung and Kunstmann (2007) who used this configuration for performing long-term climate simulations and regional climate projections with MM5. The parameterization schemes selected for both simulations are given in the right table. The simulations are done for 1982.



	Run 1	Run 2
year	1982	1982
duration	12 months	5 months
region	WA	VB
RCM	WRF 3.3	WRF 3.3
ndom [-]	1	2
Δx,Δy [km]	27 x 27	27 x 27, 9 x 9
MP	WSM5	WSM5
CU	KF	KF
RS	RRTM/Dudhia	RRTM/Dudhia
PBL	YSU	YSU
LSM	Noah	Noah

B. Standard set versus quasi-optimum set of parameterization schemes

The third and fourth run of the simulation experiment uses the same domain but two different sets of parameterization schemes: a standard set of schemes of WRF 3.3 (run 3) and a set which has been proposed by Flaounas et al. (2011) for the West African region (run 4). They performed six WRF simulations with the same boundary conditions and the same domain but different parameterization schemes for the rainy season in 1998. The domain for both simulation runs is illustrated in the right figure. The simulations is done for 1984 in a horizontal resolution of approximately 50 km.



	Run 3	Run 4
year	1984	1984
duration	12 months	12 months
region	WA/CA	WA/CA
RCM	WRF 3.3	WRF 3.3
ndom [-]	1	1
Δx,Δy [km]	50 x 50	50 x 50
MP	WSM5	WSM5
CU	KF	BMJ
RS	RRTMG	RRTMG
PBL	YSU	MYJ
LSM	Noah	Noah

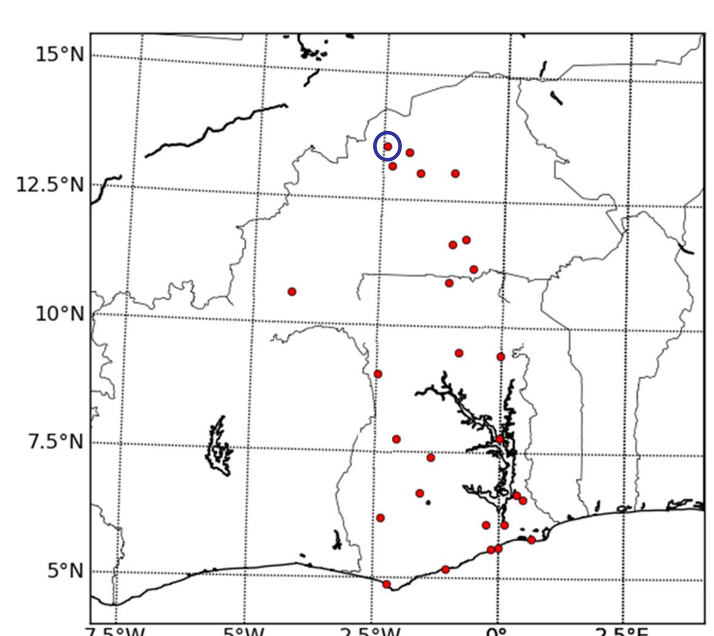
So far, there are only a few investigations which performed similar experiments with an RCM for West Africa. The first study was performed by Jenkins in 1997 who tested two cumulus parameterization schemes of RegCM2 for a rainy season. Some basic simulation settings used in various studies are given in the lower table.

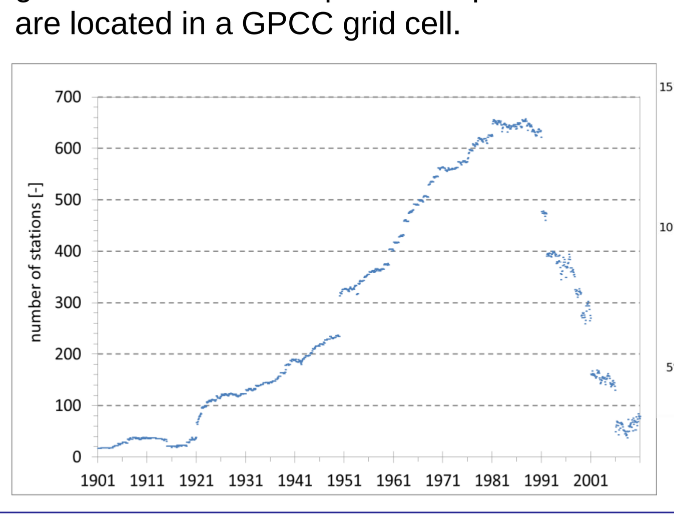
							Number of parameterisation schemes [-]				
Author	RCM	region	year	period	duration [month]	nsim [-]	RS	LSM	PBL	MP	CP
Jenkins et al. (1997)	RegCM2	WA	1988, 1990	JJAS	4	3	1	1	1	n.n.	2
Kunstmann and Jung (2003)	MM5	Vb	1998	JA	1	16	3	1	1	5	4
Tchotchou and Kamga (2010)	RegCM3	WA	1993, 1999	(M)JJAS	(5) 4	8	1	1	1	1	4
Fernandez et al. (2010)	WRF 3.1	A	1998	year	12	8	2	3	3	2	3
Flaounas et al. (2011)	WRF 3.1	WA	2006	AMJJAS	6	6	1	1	2	1	3

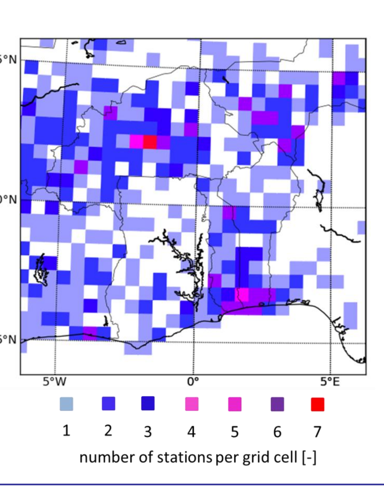
WA = West Africa, Vb = Volta basin, CA = Central Africa, A = Africa, nsim = number of simulations, RS = radiation scheme, LSM = land surface model, PBL = planetary boundary layer, MP = microphysics, CP = cumulus parameterization, ndom = number of domains, Δx, Δy horizontal resolution, KF = Kain-Fritsch, BMU = Betts-Miler-Janjic, YSU = Yonsei State University, RRTM = Rapid Radiative Transfer Model, MYJ = Mellor-Jamada-Yanjic

Study region and data

The focus region of the WRF simulations is a semi-arid region in Ghana and Burkina Faso. The daily precipitation characteristics are calculated from daily point observations measured at a land surface station (Ouahigouya) located in Burkina Faso. The station is highlighted in the left map with a blue circle. The locations of further precipitations stations are indicated as red dots. Additionally, a monthly gridded precipitation data set provided by the Global Precipitation Climatology Centre (GPCC) operated by the German weather service (DWD) is used (Adler et. al., 2003). This data set is globally available and it is often selected in regional climate modeling for model evaluation. Probably, the biggest advantage of this data set is in comparison to other global data set that the information comes from a huge archive of land surface stations. Even for the study region in 1982 and 1984 more than 600 stations are used for the interpolation of the monthly precipitation values (see lower left figures). The spatial distribution of these stations for August 1982 is given in the lower map. The map illustrates the number of stations that are located in a GPCC grid cell.

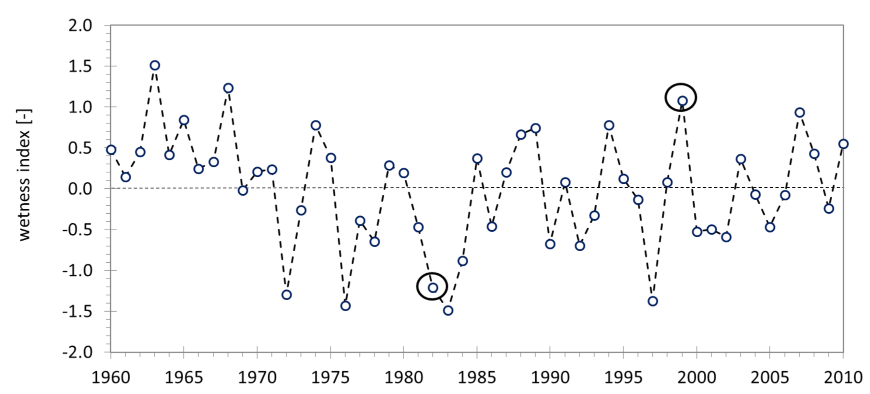


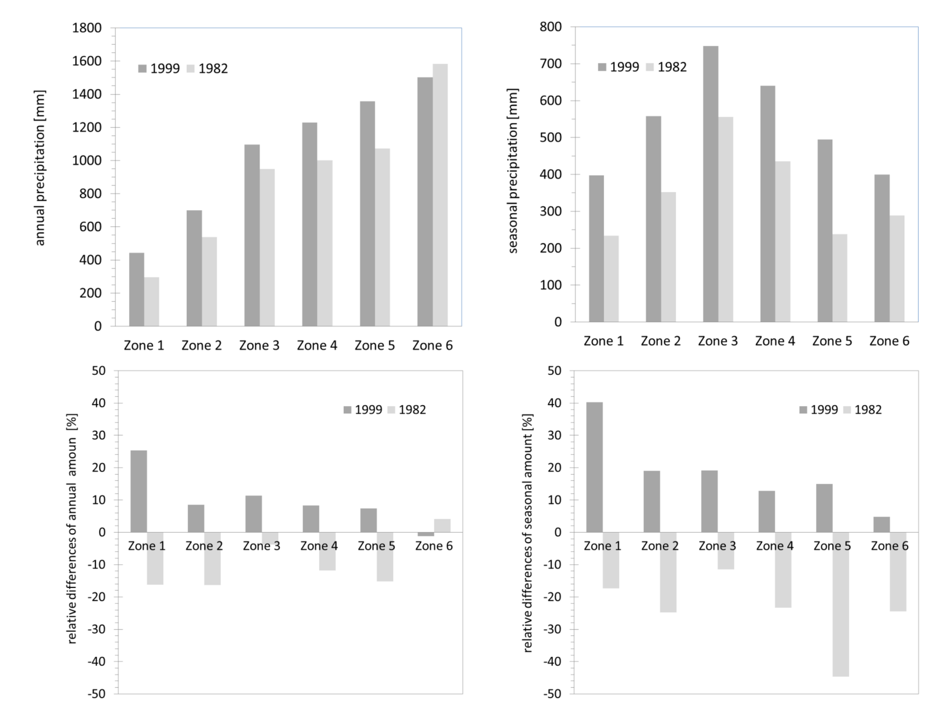




The ERA-Interim data (Dee et al., 2011) provided by the European Centre for Medium-Range Weather Forecasts is used as boundary conditions for the WRF simulation. The global data set is regularly updated and it is available since 1979. It contains 37 vertical levels with a spatial resolution of around 81 km at the equator. The WRF simulations are performed with time-varying SST information selected from the ERA-Interim data.

Precipitation characteristics of a dry and a wet year

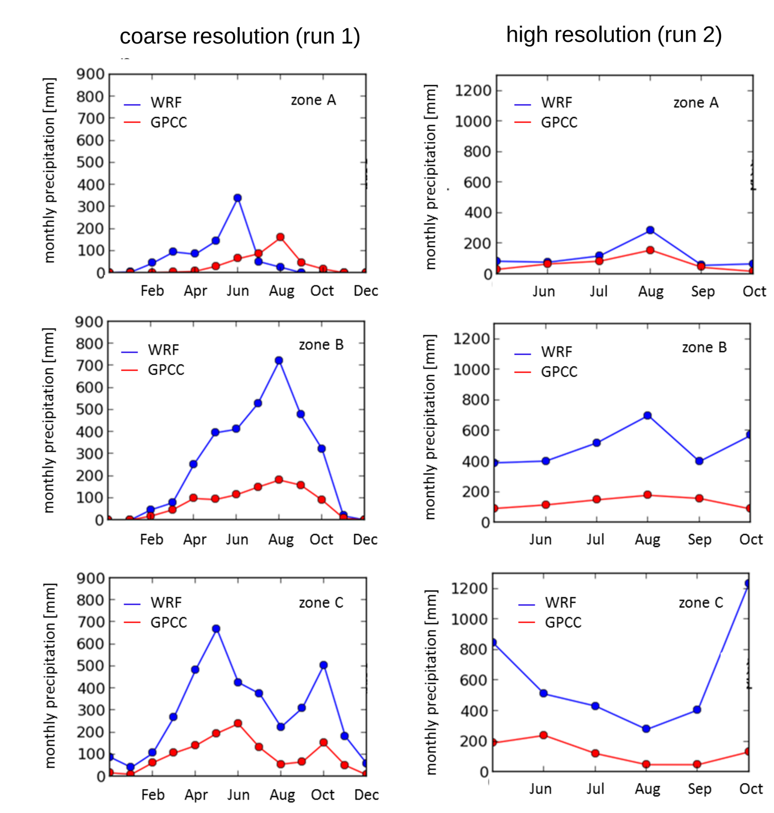


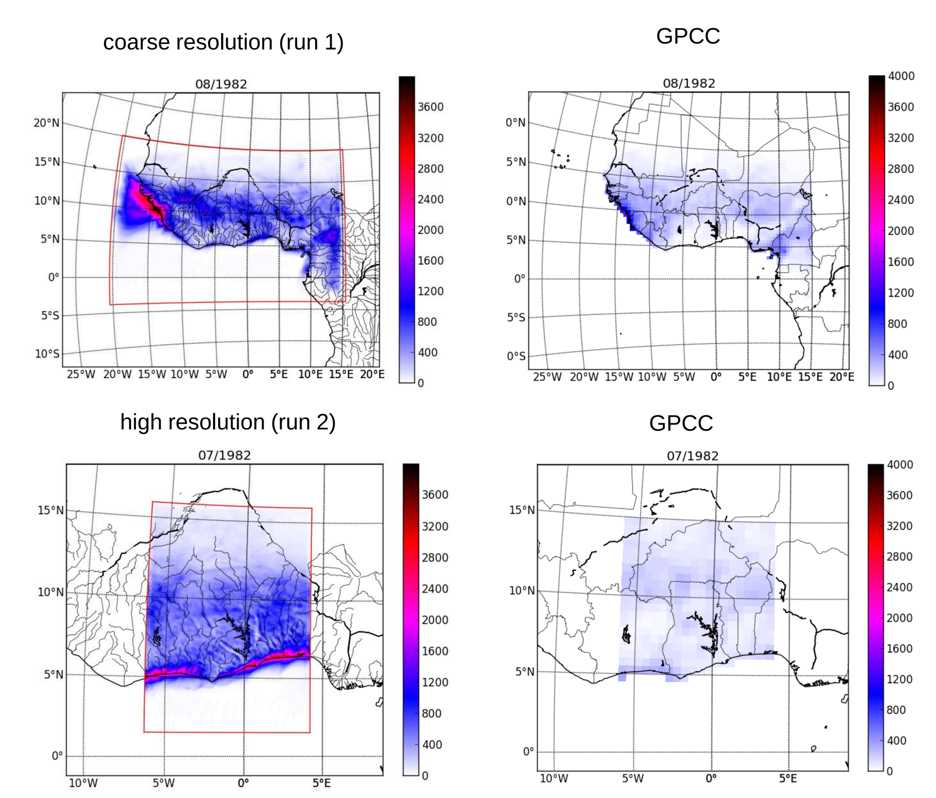


The annual and seasonal areal precipitation amount (June-July-August) for six latitudinal zones of the study region is illustrated for the dry year 1982 in comparison to a wet year in the upper right figures. The relative differences of both measures in comparison to the climatological mean (1960 – 2010) are given in the lower right figures showing the tremendous differences between the selected years although both years were not the driest and wettest year during the investigation period (see upper left figure). The wetness index is based on a z-score transformation to determine a kind of rainfall anomaly index. The transformation is done for each zone. Here, the average wetness index of the six zones is illustrated for the seasonal precipitation amount. The analysis is based on the GPCC data.

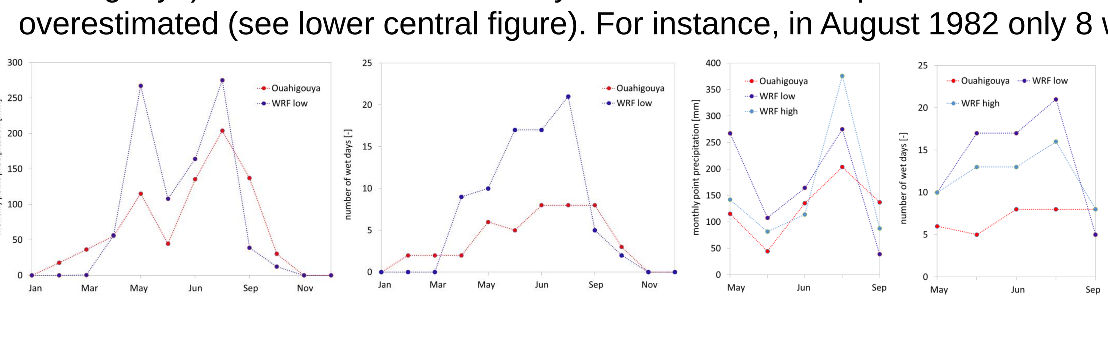
Simulations results in comparison with observations

A. Coarse versus high resolution simulation

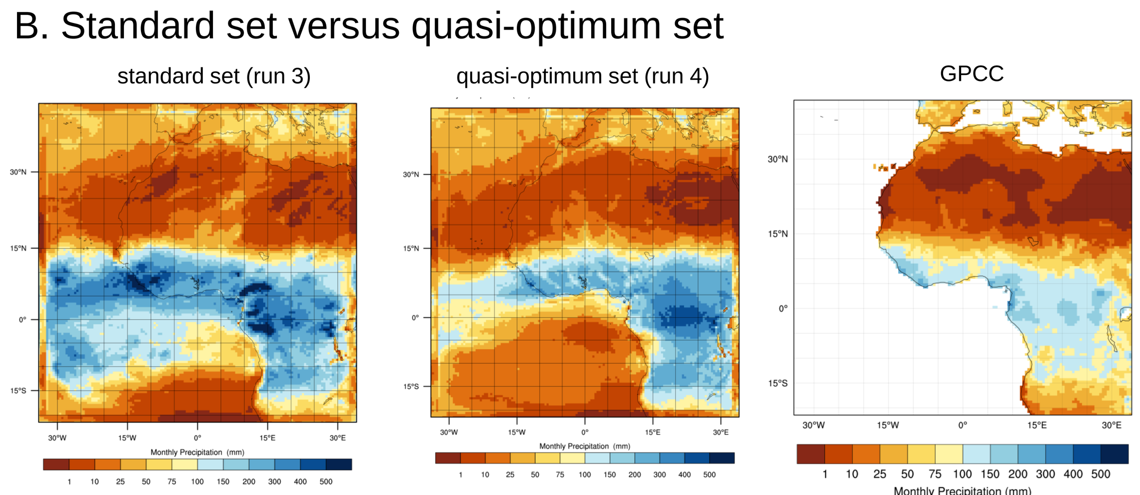




The annual cycle of the monthly areal precipitation for three latitudinal zones within the coarse and high resolution domain are given in the upper left figures illustrating a tremendous overestimation, in particular for zone B and zone C. The simulated monthly precipitation fields of coarse and high resolution domain are given for two months (June and August) in the upper left figures showing that e.g. precipitation in the coastal regions is highly overestimated. The WRF simulations are also compared with daily precipitation characteristics such as the number of wet days. Although the monthly precipitation regime is suitably simulated in zone A even in comparison with point observations (see lower left figure for station Ouahigouya), the simulation of daily characteristics is poor for this location. The number of wet days are clearly overestimated (see lower central figure). For instance, in August 1982 only 8 wet days are observed but 21 wet days are simulated by WRF although there is only a moderate difference between the observed and simulated monthly precipitation at this location. The clear overestimation can be slightly reduced for this station if an additional higher resolution domain is selected (see lower right figure).



B. Standard set versus quasi-optimum set



A large overestimation of WRF simulation is illustrated for 1984 if a standard set of parameterisation schemes are used. However, the change of the selected schemes to the quasi-optimum set can clearly reduce the overestimation for many tropical regions in West and Central Africa. The figures illustrate the spatial distribution of the mean monthly precipitation for the simulation year.

Conclusion and future research

The investigation illustrated that the observed precipitation characteristics in West Africa cannot be well reproduced using a standard set of parameterisation schemes of WRF. A clear overestimation of monthly precipitation can be reduced if a quasi-optimized set of schemes is used. This result indicates the importance of defining a suitable set of parameterisation schemes for WRF that can be used for regional climate simulations in this region. We also illustrated that the monthly precipitation regime at a certain location can be well simulated by WRF although daily precipitation characteristics are completely wrong which highlights the importance of evaluating precipitation simulations of RCMs not only on a monthly scale. The selection of a higher resolution domain indicated a slight improvement of the simulated precipitation characteristics. In future studies we will test further sets of parameterization schemes and a larger subdomain for high resolution simulations. The model validation will also focus on daily precipitation characteristics by incorporating additional stations.

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