The WASCAL regional climate simulations for West Africa: How to add value to existing climate projections?

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WASCAL — West African Science Service Center on Climate Change and Adapted Land Use

Climate projections for West Africa: highly needed but uncertain

With climate change being one of the most severe challenges to rural Africa in the 21st century, West Africa is facing an urgent need to develop effective adaptation and mitigation measures to protect its constantly growing population. WASCAL (West African Science Service Center on Climate Change and Adapted Land Use, http://www.wascal.org) is a large-scale research-focused program designed to enhance the resilience of human and environmental systems to climate change and increased variability. An integral part of its climate services is the provisioning of a new set of high resolution, ensemble-based regional climate change scenarios for continental West Africa.

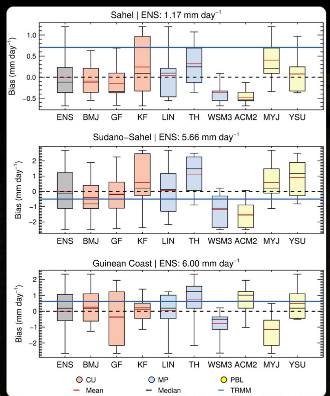
III. Towards a regional climate modeling system for West Africa

For each of the three regional climate models used here, an optimal model configuration is required to reduce biases and reproduce the observed annual cycle of the WA monsoon precipitation. Recently, Klein et al. (2015) investigated the performance of 29 WRF model configurations with respect to monsoon dynamics, precipitation patterns, temperature distribution and large-scale wind systems using re-analysis data for two monsoon seasons 1999 (Fig. 3) and 2002 (not shown). Based on their findings, we evaluated the most promising candidate configurations using MPI-ESM MR data (which is close to the CMIP5 multi-model mean for West Africa) to account for the different characteristics and model resolution (Table 1).

For the Cosmo-CLM runs, we adopt the CORDEX WA setup identified by Panitz et al. (2012), while for the RegCM runs, the Sylla et al. (2010) setup is used.

Table 1. WRF setup

Microphysics	WSM5
Radiation SW/LW	RRTMG
Cumulus	GD
Boundary layer	ACM2
Surface layer	MM5
Land surface	Noah



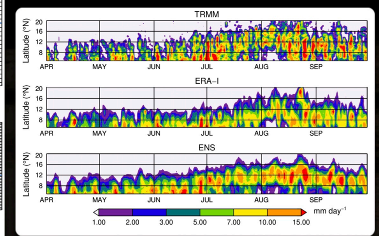


Fig 3. (left) Box plots of precipitation bias wrt. ensemble mean (interquartile ranges, max/min). CU schemes mostly affect single events on sub-daily scale, MP the amount of rainfall and PBL the position of the rain band. (top) Hovmöller diagrams of 1999 daily rain (Klein et al., 2015).

I. The WASCAL regional climate projections: experiment design

To determine the uncertainty in the regional climate simulations stemming from the driving global circulation model and the limited area model itself, we adopt an ensemble approach. This has proven useful in recent large-scale modeling projects such as ENSEMBLES or CORDEX, where the multi-model mean and the spread of the ensemble describe the most likely projection and the uncertainty of it. In WASCAL, we combine three global circulation models (GCM) and three regional climate models (RCM) for the future emission scenario RCP4.5. To validate the performance of our models, we conduct historical runs and control runs using re-analysis data (Fig. 1).

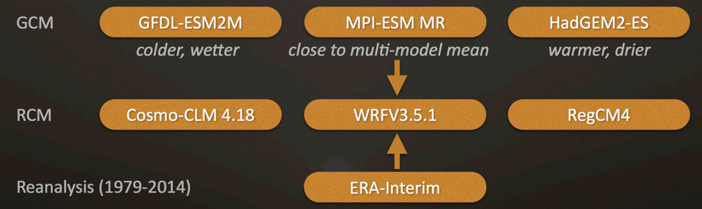
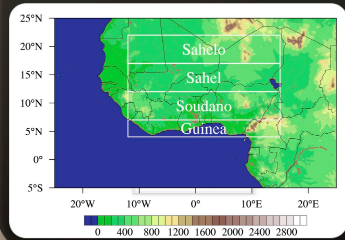


Fig 1. WASCAL experiments: historical (1979-2005) and RCP4.5 (2006-2100) runs

II. The WASCAL WRF simulations: model and domain setup

The governing meteorological feature over West Africa is the summer monsoon. This annual change in large-scale circulation and pressure systems plays a pivotal role in people's life as it provides the majority of the annual precipitation and the basis for agriculture in the region. As shown in a recent study by Brown and Sylla (2012), a large domain centered over West Africa is required to capture these processes and to generate the mesoscale convective cells. To provide added value over existing projections, we use a high spatial resolution of 12km in a 5:1 nesting setup. We use spectral nudging to keep the outer domain aligned with the driving model (Fig 2).

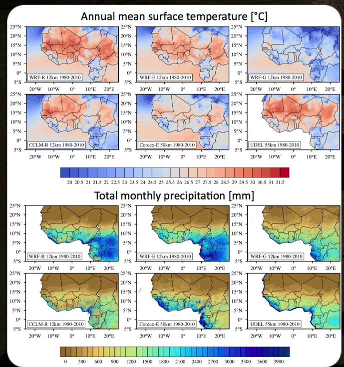


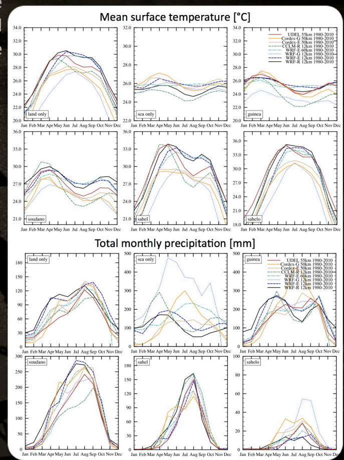
A large set of output variables on 24 pressure levels is provided every 3hr model time (see the WASCAL website for a complete list). Initial tests of two different methods to bias-correct the forcing GCM data led to mixed results (Heinzeller et al., 2014). Accordingly, no bias correction is applied to the forcing data in our simulations.

Fig. 2. Inner domain d02, 500x330x40 grid points, terrain height in m.

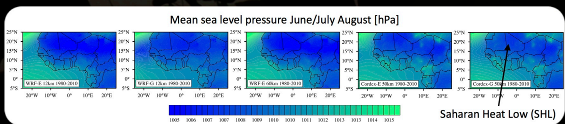
IV. Model validation: historical and control runs

WRF runs at 12km resolution, driven by ERA-Interim re-analysis (R), MPI-ESM MR (E) and GFDL-ESM2M (G) for the period 1980-2010. Additionally, CCLM runs at 12km, WRF runs at 60km (outer domain), observational data from UDEL and two CORDEX runs using RCA4 are displayed (Colins et al., 2012). Observed mean surface temperatures are matched best by the 12km WRF/CCLM-R control runs and the 12km WRF-E run. GFDL-driven models show a distinct cold bias. Monthly rainfall over WA is closest to UDEL for the 12km control runs, followed by GFDL-driven historical runs. The WRF-R/E runs over-predict rainfall in Central Africa. Offshore, GFDL-driven models produce extreme precipitation with effects on Guinea.



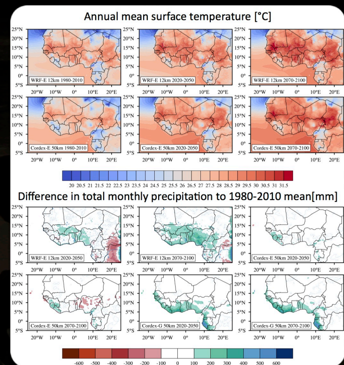


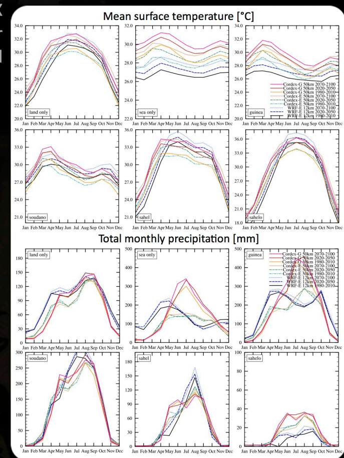
CORDEX models have higher psl. SHL deepest in WRF-E runs for 60km and 12km.



V. First projections: a warmer and wetter future?

First results for the 12km WRF-E runs show a warming signal of 2°C towards the end of the 21st century, in accordance with the CORDEX data. WRF-E indicates an increase in precip for WA, while CORDEX-G predicts a weaker trend and CORDEX-E a drier future for some areas.





So, where is my added value?

Our historical runs indicate that the 12km models reproduce the annual cycle in temperature and rainfall better than existing CORDEX runs, and provide more accurate results for the sub-saharan regions. This comparison is hampered by the fact that up to now, no CORDEX-WRF runs over WA are available. The large spread in projected rainfall for different forcing data and/or regional models suggests to increase the ensemble size with further combinations of GCMs and RCMs for a better estimation of the projected uncertainty. With a higher resolution in time and space, our data can serve as input for further downscaling experiments at convection-resolving resolution (wascal2wps code available).

References

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