**Project:** 726
**Project title:** WASCAL – Regionale Klimasimulationen Westafrika
**Project lead:** Ilse Hamann
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The regional climate modelling experiment in WASCAL is a continuous project over several years and consists of several tasks. The progress on these is briefly summarised in the following sections.

## 1. WRF sensitivity studies

The focus of this task is to identify an optimal configuration of the regional climate model (RCM) WRF for our region of interest. We conducted a detailed parameter study with 29 different WRF configurations for ERA-Interim re-analysis data and 21 configurations for MPI-ESM global circulation model (GCM) data, differing in their physical parameterisations of convection (cumulus physics), turbulence (planetary boundary layer physics) and microphysics. A thorough investigation of the modelled monsoon dynamics, in particular of the ERA-Interim-driven runs, brought important insights into the feedback of local processes on the large-scale monsoon circulation and helped us to identify an ideal setup of WRF for continental West Africa for our long-term climate simulations (see below). Our results were published in *Climate Dynamics* (Klein et al., 2015).

## 2. Coupled meteorological-hydrological studies

In this task, we investigate the impact of terrestrial hydrology on atmospheric processes using the fully coupled atmospheric-hydrological WRF-Hydro modelling system. The study region is the Sissili catchment, a WASCAL core-research site between Burkina Faso and Ghana. WRF-Hydro results for a one-year period were validated with gridded observation products of precipitation, temperature, evapotranspiration and soil moisture. Daily discharge data, measured at the outlet of the Sissili catchment, was used in addition to the classical prognostic variables. A comparison with an uncoupled WRF simulation revealed that the resolved overland flow in WRF-Hydro directly modifies runoff-infiltration partitioning, especially at the beginning of the wet season when the soil has run dry. This modifies the distribution of soil moisture, evapotranspiration and temperature throughout the entire simulation. We could show that the feedback on the modelled precipitation in the Sissili catchment is significant (Arnault et al., 2015a). Further, quantitative methods for investigating the role of local evapotranspiration on local precipitation in WRF and WRF-Hydro, implemented in form of evapotranspiration tagging and atmospheric water budgets, have been developed (Arnault et al., 2015b).

## 3. Long-term climate simulations

This task focusses on the long-term high-resolution regional climate simulations for West Africa with the goal to produce simulations of unprecedented resolution and accuracy for a large fraction of the 21st century and an area covering the whole of West Africa. The past has shown that in order to address the uncertainties in regional climate projections, caused by the diverging climate change signals in the driving global model data and the different regional models, an ensemble approach is best suited. Our ensemble consists of a combination of three GCMs with three RCMs for the green house gas scenario RCP4.5. The choice of RCP4.5 is based on the fact that the differences between RCP4.5 and RCP8.5 become apparent only after 2040 and that the RCP4.5 scenario – to current knowledge – is most realistic. The selected GCMs cover the extremes in temperature and precipitation of the GCM ensemble used in CORDEX. Control runs using re-analysis data are included for model verification and bias correction.

The required computational resources until now were supplied by splitting the experiment across several HPC facilities in Germany: DKRZ Blizzard, FZJ Juropa and SCC ForHLR1. With DKRZ Blizzard being the first supercomputer to which we had access, it served both the design and the testing of the long-term simulation experiments in 2013–2014 as well as the generation of the ERA-Interim-driven control-runs with two of the RCMs, CCLM and WRF, in 2014–2015. FZJ Juropa and SCC ForHLR1 were added in 2014 to conduct the historical and projection runs using WRF (FZJ) and CCLM (SCC). The runs with the remaining RCM, RegCM4, have not yet started. We are planning to conduct these on the new HPC facilities at the WASCAL Competence Center in Ouagadougou, Burkina Faso, which will be installed in early 2016. This will facilitate access to the HPC environment for the scientists at the Competence Center. The progress of the ensemble experiment is summarised in Table 1 in Appendix A. Figure 1 displays projected changes in rainfall from our WRF simulations as one exemplary output. A comprehensive set of results will be published in spring 2016.

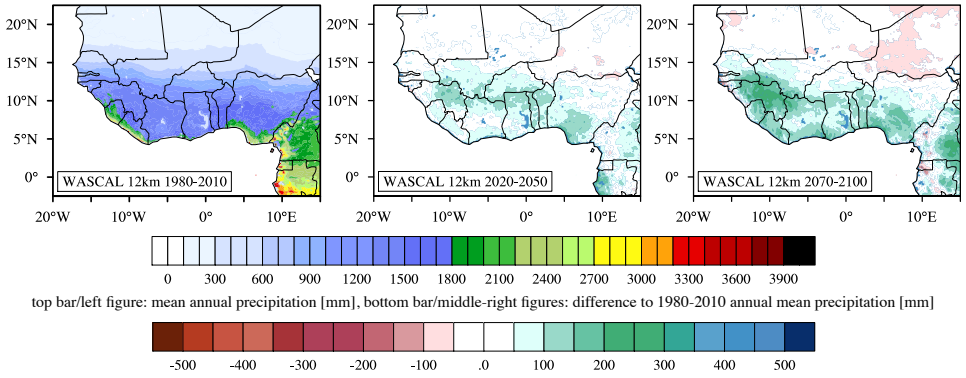


Figure 1: Mean annual rainfall 1980–2010 (left) and projected changes for 2020–2050 (middle) and 2070–2010 (right) obtained from the current WASCAL ensemble data.

# Appendix

## A. Status of the ensemble long-term simulation experiment

Table 1: Design and progress of the WASCAL high-resolution regional climate ensemble (CoC = Competence Center).

| GCM/ESM | RCM | Exp. | HPC | Oct. 2014 | Oct. 2015 |
|---|---|---|---|---|---|
| ERA-Interim | WRFV3.5.1 | control | DKRZ Blizzard | completed | completed |
| | CCLM 4.18 | control | DKRZ Blizzard | not yet started | completed |
| | RegCM4 | control | WASCAL CoC | not yet started | not yet started |
| MPI-ESM | WRFV3.5.1 | hist. | FZJ Juropa | completed | completed |
| | CCLM 4.18 | hist. | SCC ForHLR1 | not yet started | completed |
| | RegCM4 | hist. | WASCAL CoC | not yet started | not yet started |
| | WRFV3.5.1 | RCP4.5 | FZJ Juropa | just started | completed |
| | CCLM 4.18 | RCP4.5 | SCC ForHLR1 | not yet started | in progress |
| | RegCM4 | RCP4.5 | WASCAL CoC | not yet started | not yet started |
| GFDL-ESM2M | WRFV3.5.1 | hist. | FZJ Juropa | pre-processing | completed |
| | CCLM 4.18 | hist. | SCC ForHLR1 | not yet started | not yet started |
| | RegCM4 | hist. | WASCAL CoC | not yet started | not yet started |
| | WRFV3.5.1 | RCP4.5 | FZJ Juropa | not yet started | completed |
| | CCLM 4.18 | RCP4.5 | SCC ForHLR1 | not yet started | not yet started |
| | RegCM4 | RCP4.5 | WASCAL CoC | not yet started | not yet started |
| HadGEM2-ES | WRFV3.5.1 | hist. | FZJ Jureca | not yet started | just started |
| | CCLM 4.18 | hist. | SCC ForHLR1 | not yet started | not yet started |
| | RegCM4 | hist. | WASCAL CoC | not yet started | not yet started |
| | WRFV3.5.1 | RCP4.5 | FZJ Jureca | not yet started | pre-processing |
| | CCLM 4.18 | RCP4.5 | SCC ForHLR1 | not yet started | not yet started |
| | RegCM4 | RCP4.5 | WASCAL CoC | not yet started | not yet started |

**Notes.** The control runs are conducted for the period 1979-2014. The historical runs are generated for the period 1979-2005 and extended by the RCP4.5 runs until 2010. This approach allows us to derive statistics for the climatological reference period 1980–2010, as redefined by the WMO in 2015. Future projections are calculated at least for the periods 2019–2050 and 2069–2100 to provide similar 30-year windows for mid and end of the 21st century.

## B. Publications from project WASCAL

A comprehensive publication of our results of the ensemble long-term climate simulation experiment is expected for early 2016. The following list summarises publications that are related to our project on the DKRZ's Blizzard/Mistral through, for example, model optimisation and development and the usage of our data:

- Arnault, J., Wagner, S., Rummler, T., Fersch, B., Bliefernicht, J., Andresen, S., Kunstmann, H. (2015a): Role of runoff-infiltration partitioning and re-

solved overland flow on land-atmosphere feedbacks: A case-study with the WRF-Hydro coupled modeling system for West Africa. Submitted to J. Hydrometeor

- Arnault, J., Knoche, R.., Hui, J., Kunstmann, H. (2015b): Evapotranspiration tagging and atmospheric water budget analysis with WRF: A precipitation recycling study for West Africa. Submitted to Water Resour. Res.

- Bliefernicht, J., Kunstmann, H., Hingerl, L., Rummler, T., Andersen, S., Mauder, M., Steinbrecher, R., Frie, R., Gochis, D., Gessner, U., Quansah, E., Awotuse, A., Neidl, F., Jahn, C., Boubacar, B. (2013): Field and simulation experiments for investigating regional land-atmosphere interactions in West Africa: Experimental set-up and first results. IAHS-AISH, 359, 226–232

- Heinzeller, D., Duda, M.G., Kunstmann, H. (2015): Towards convection-resolving, global atmospheric simulations with the Model for Prediction Across Scales (MPAS): an extreme scaling experiment. Geoscientific Model Development Discussions, 8, 1–75

- Klein, C., Heinzeller, D., Bliefernicht, J., Kunstmann, H. (2015): Variability of West African monsoon patterns generated by a WRF multi-physics ensemble, Climate Dynamics, 10.1007/s00382-015-2505-5

- Siegmund, S., Bliefernicht, J., Laux, P., Kunstmann, H. (2015): Towards a Seasonal Precipitation Prediction System for West Africa: Performance of CFSv2 and High Resolution Dynamical Downscaling. Journal of Geophysical Research - Atmospheres, 10.1002/2014JD022692

## C. Ph.D. theses completed within project WASCAL

The following theses were completed in 2015 with contributions from our project through, for example, usage of our data or our model optimisations:

- Thompson Annor, Federal University of Technology Akure (FUTA): Potential Impacts of Climate Variability and Change on Hydrology and Water Resource over the Volta Basin

- Ayoola Olamitomi Awotuse, FUTA: Evaluation of the Seasonal Variability of Evapotranspiration using Micro-Meteorological Observation and Remote Sensing Techniques in Ghana and Burkina-Faso

- Emmanuel Quansah, FUTA: Estimation of Land Surface-Atmosphere Carbon Dioxide (CO2) Exchanges over Tropical Savannah Ecosystems

- Moussa Waongo, University of Augsburg: Optimising Planting Dates for Agricultural Decision-Making under Climate Change over Burkina Faso