Annual Reports Projects 849, 859, 785, 776

Project: **849**

Project title: **MiKlip Module C - Regionalization of Decadal Predictions**

Project leader: **Hendrik Feldmann**

Report period: **1.1.2014 - 31.12.2015**

Overview

Within this project three major contributions to the MiKlip ("Mittelfristige Klimaprognose", decadal climate prediction) program and MiKlip Module C "Regionalization" in particular were performed:

1. A significant portion of the second generation regional decadal hindcast ensemble was generated within this project. About 200 decadal simulations, with a coarser resolution of 0.44°, were performed for Europe with the RCM COSMO-CLM (CCLM) driven by global simulations with MPI-ESM-LR. The focus during this phase was more on generation a large sample size (44 years) than on a maximum ensemble size (7 instead of 10, generated several MiKlip Module C projects at DKRZ).
2. A set of 7 uninitialized long-term simulations over the period 1958 – 2014 were performed - using otherwise the same configuration as the decadal hindcasts – as reference to quantify the added value of initialization to reproduce the regional climate variability.
3. A 10 member ensemble of regional decadal forecasts for the period 2015 – 2024 was generated.

Project publications

Khodayar S., A. Sehlinger, H. Feldmann and Ch. Kottmeier, 2015: Sensitivity of soil moisture initialization for decadal predictions under different regional climatic conditions in Europe, Int. J, Climatol. 35, 1899-1915

Mieruch, S., H. Feldmann, G. Schädler, C. J. Lenz, S. Kothe, and Ch. Kottmeier, 2014: The Regional MiKlip Decadal Forecast Ensemble for Europe: the Added Value of Downscaling., Geosci. Model Dev., 7(6), 2983-2999, doi:10.5194/gmd-7-2983-2014.

3 additional joined publications with the other MiKlip Module C will be submitted within the next months.

Selected Results

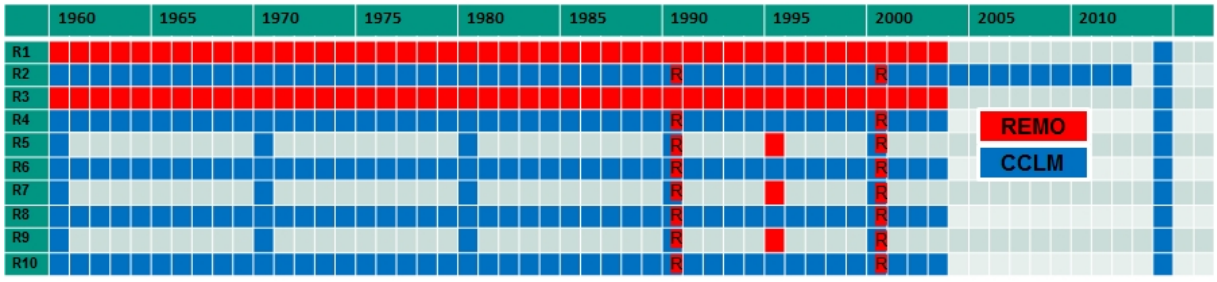


***Figure 1**: Simulation matrix of the MiKlip Module C regional ensemble (0.44° resolution). Each box denotes the starting year of a decadal hindcast simulation. Blue boxes indicate simulations with the RCM COSMO-CLM, red ones REMO simulations. In total more than 4000 years were simulated. The CCLM simulation for the realisations R4 – R10 and the forecast ensemble starting 2015 where generated within this project.*

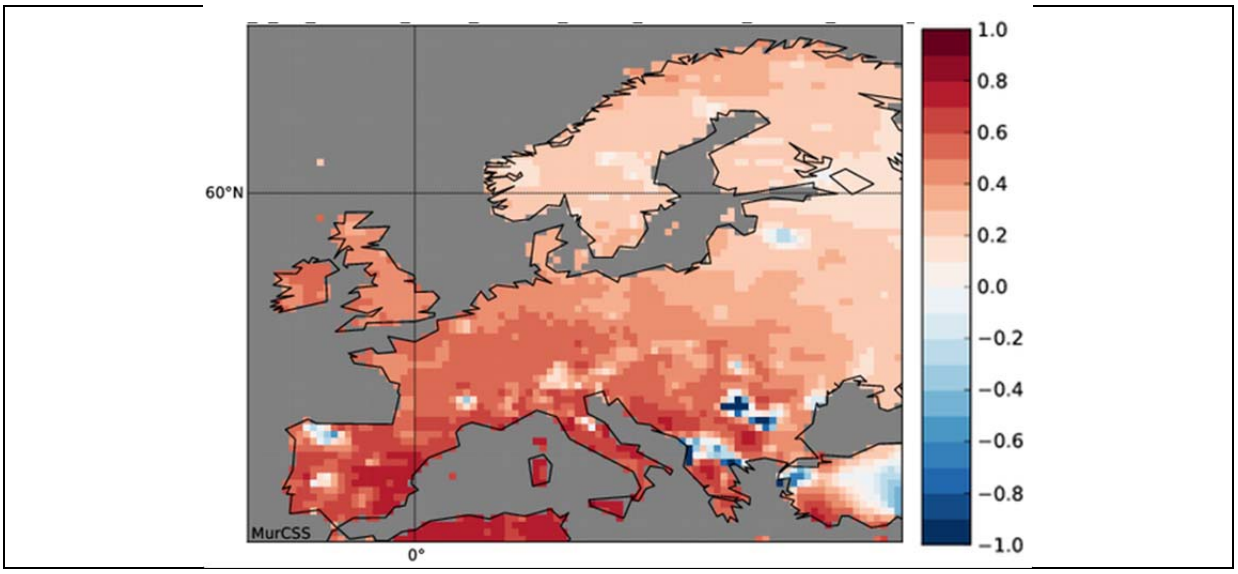


Figure 2: *Mean square error skill score (MSESS) of the regional hindcast ensemble for annual mean near surface temperature – forecast time year 2 – 5 – compared to E-Obs observations. Red colours indicate positive skill, blue colours no skill. The regional baseline1 ensemble shows skill due to the initialization up to 5 year ahead especially in Western and Southern Europe. Blue areas can partly be attributed to inhomogeneous observation data.*

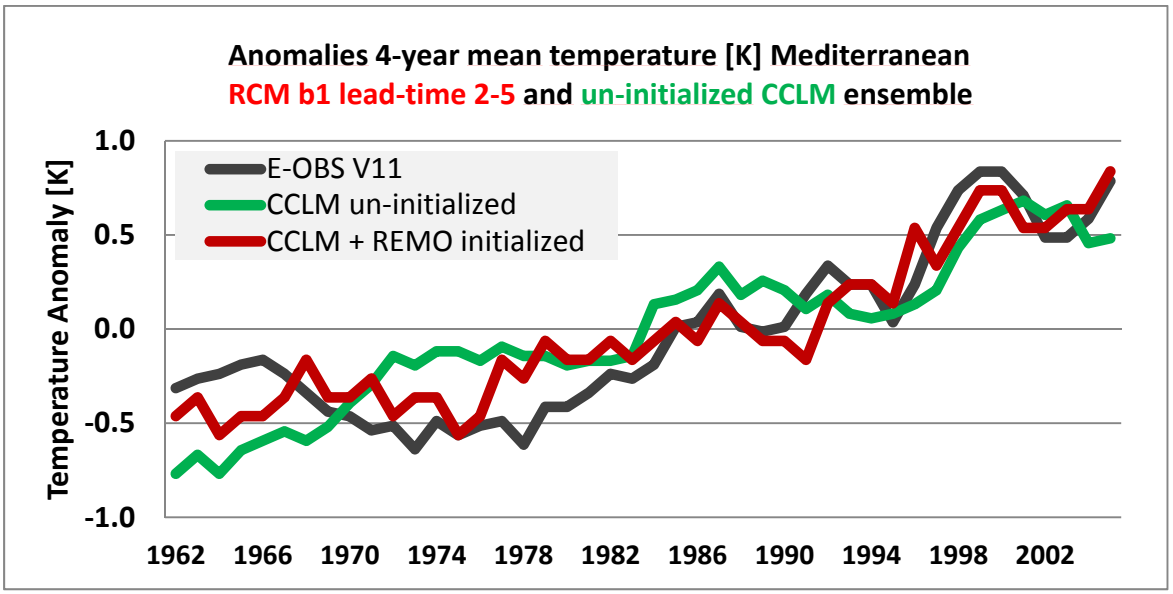


Figure 3: *Time series for 4-year mean temperature anomalies over the Mediterranean region starting years 1961 - 2003. Black: E-Obs observations; green: Ensemble mean un-initialized CLM ensemble (7 members); red: Initialized hindcast simulations (7 member ensemble, cf. Figure 1). Both ensembles reproduce the general warming trend, but the initialized simulations show an improved timing of the climate variability. The un-initialized ensemble completely misses the cooling trends from the 60s to the 70s. The skill of the initialized predictions is higher in the most recent decadal than in the first phase. The causes for this improved skill have yet to be determined: Stronger impact of the climate trend, changing teleconnection pattern related to the Atlantic Multi-decadal Oscillation (AMO) or better observation data – either for the initialization or verification – might contribute.*

Project: **859**

Project title: **Regional Decadal Predictability**

Project leader: **Sebastian Mieruch/Hendrik Feldmann**

Report period: **1.1.2014 - 31.12.2015**

Overview

Project 859 “Regional Decadal Predictability” (DecReg) contributes to the efforts of MiKlip (“Mittelfristige Klimaprognose”, decadal climate prediction) program and especially to MiKlip Module C “Regionalization”.

The specific tasks of DecReg are:

1. Contributing to the regional ensemble by downscaling decadal hindcasts generated with the MPI-ESM with the RCM COSMO-CLM (CCLM). A specific topic here is for instance the effect of the ensemble size on the predictive skill and reliability. During the reporting period about 30 simulations with a resolution of 0.22° were performed as part of the regional MiKlip ensemble (Figure 1).
2. Improve the regional prediction system by testing the impact of using more sophisticated soil-vegetation-atmosphere exchange models (SVAT) compared to the standard sub-model of CCLM.
3. To test the added value of very high resolution (7km and 2.8km) on the decadal predictability especially of extremes. 20 decadal simulations with 7km resolutions were performed (Figure 1.)

1. Overview of the Ensemble

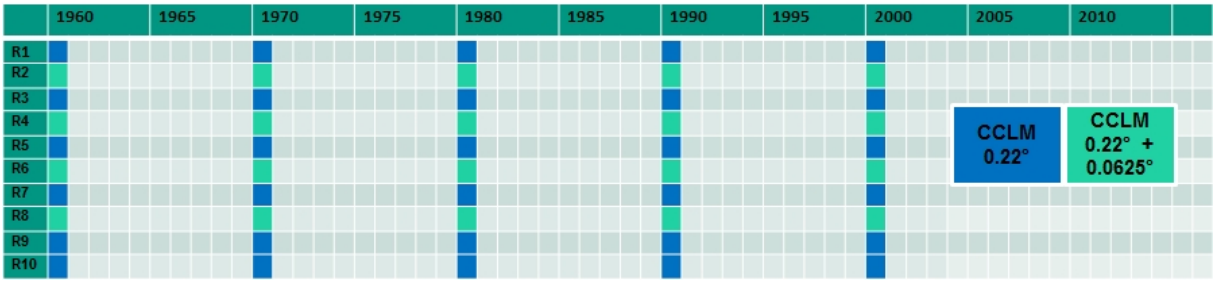


Figure 1: *Matrix of the Module C hindcast ensemble with CCLM with the resolution of 25km (0.22°) and 7km (0.0625°).*

2. Use of a different SVAT

The simulations with the coupled system of CCLM and VEG3D included the two resolutions 0.22° and 0.0625°. Their results are similar for Germany. In Fig. 1, the MSSS for the 2m temperature and the precipitation are shown. A known cold bias in the 2m temperature was reduced using VEG3D, especially for summer, by 0.3 K. The annual field averaged precipitation sum remained nearly unchanged, although spatial and temporal seasonal patterns are different.

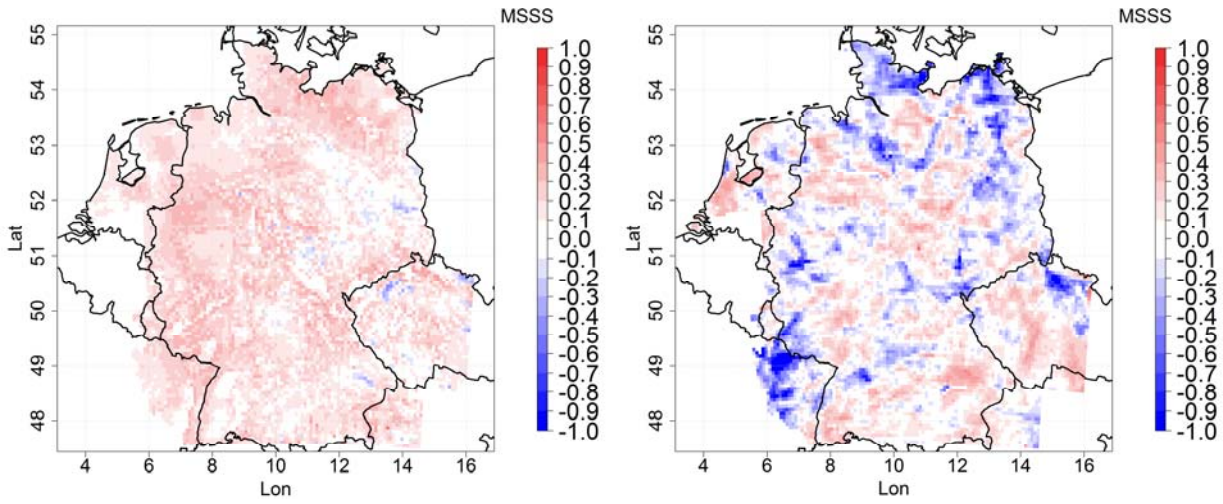
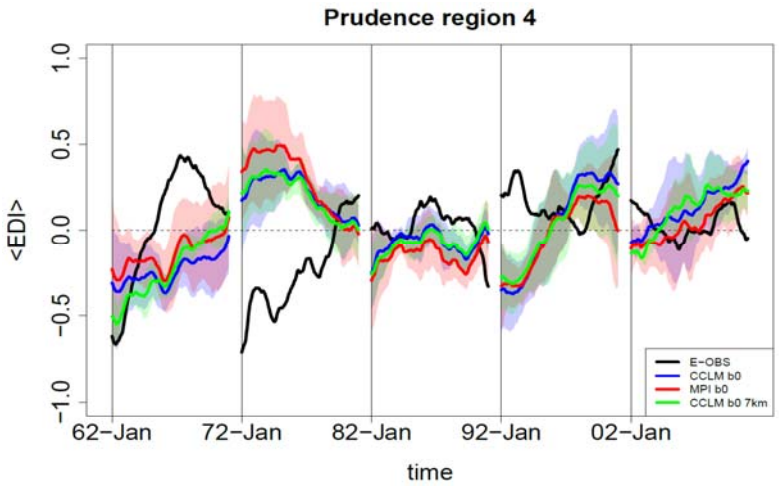


Figure 2: *MSSS of the summer mean 2m temperature (left) and monthly precipitation sums of the summer months (right) for CCLM_VEG3D to CCLM_TERRA-ML with HYRAS observations over Germany 7km for the years 2002 – 2005; red indicates areas where CCLM_VEG3D is in better agreement with the observations; blue vice versa for CCLM_TERRA-ML.*

3. Added value of the 7km resolution



The EDI precipitation index was calculated to evaluate the potential added value due to the higher resolution. In Fig. 2, the EDI for the five decades is shown. The global model MPI and the CCLM with the different resolution have a similar trend for all decades, all deviating largely from the observations.
The higher resolution shows for most decades no distinct added value.

Figure 3: *EDI for the five simulated decades Prudence 4 (Germany) comparing the CCLM and MPI results to the E-OBS data.*

Project publication

Mieruch, S., H. Feldmann, G. Schädler, C. J. Lenz, S. Kothe, and Ch. Kottmeier, 2014: The Regional MiKlip Decadal Forecast Ensemble for Europe: the Added Value of Downscaling., Geosci. Model Dev., 7(6), 2983-2999, doi:10.5194/gmd-7-2983-2014.

S. Mieruch et al., 2015: Decadal prediction of the Effective Drought Index (EDI) for the European continent from 1961 to 2010 -- sensitivity to simulation setup, Journal of Applied Meteorology and Climatology, submitted.

Project: **785**
Project title: **MiKlip-PRODEF**
Project leader: **Joaquim G. Pinto**
Report period **01.01.2014-31.12.2015**

Joaquim G. Pinto, Mark Reyers, Julia Moemken, Sven Ulbrich
Institut für Geophysik und Meteorologie, Universität zu Köln
E-Mail: jpinto@meteo.uni-koeln.de

In the report period the statistical-dynamical downscaling (SDD) methodology for wind energy, which was developed and evaluated in the 1st phase of MiKlip (Reyers et al., 2015), has been applied to the available global MPI-ESM hindcast generations (baseline0, baseline1, prototype) to quantify the decadal predictability of regional wind energy potentials over Central Europe. Due to the efficiency of the methodology with respect to the computing time the full ensembles of all hindcast generations with up to 30 yearly initialised hindcasts could be downscaled to a resolution of 0.22°. This enabled a direct comparison of the prediction skills of the different generations. The results revealed that the skill is lowest for baseline0, while similar skill scores are found for baseline1 and prototype. The highest potential for predictability of wind energy is found for the first 3 or 4 years after the initialisation of the hindcasts (see Fig.1). As large-scale sources of the prediction skill we could identify zonal westerly weather types with strong pressure gradients. The frequencies of these weather types determine the inter-annual and decadal variability of the wind energy potential over Central Europe. For these weather type frequencies the prediction skills are similar to the skills for wind energy in all hindcast generations, with highest skill scores for short forecast periods (Fig. 1). The results for wind energy achieved in the report period have been submitted as research article to the scientific journal Tellus A and are currently under revision (Moemken et al., 2015).

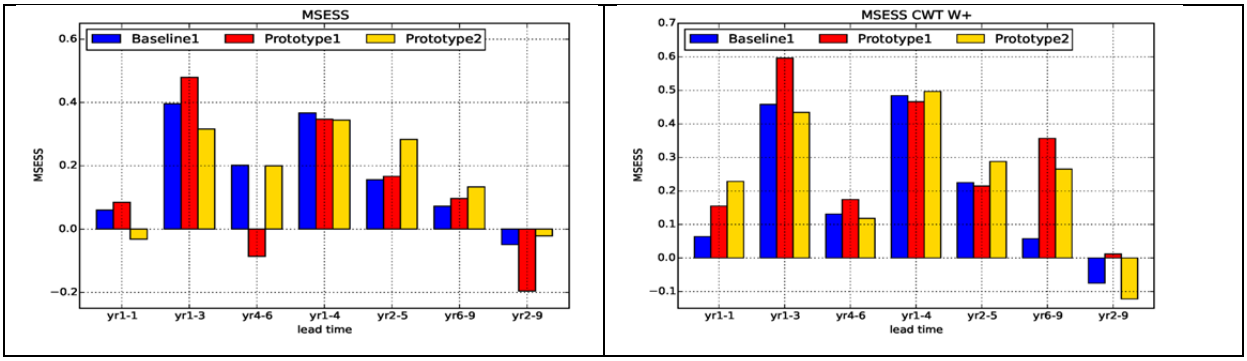


Figure 1: *Left: Mean square error skillscore (MSESS) for wind energy over Germany for different lead-time periods. Right: MSESS for the frequency of westerly weather types with a pressure gradient of more than 10 hPa/1000km for different lead time periods.*

In the report period the downscaling methodology for convective precipitation events has been further developed. For the development the pre-processing of the different used datasets (e.g. lightning data, radar data …) has been finished. The downscaling methodology

is based on a linear regression between large-scale stability indices and regional rainfall data. An outstanding feature of our downscaling methodology is the differentiation between events with and without the passing of a front. Since convective events exhibit different characteristics depending on the distance to a front, this differentiation enables a more realistic assessment of the rainfall statistics and thus a better calibration of the regression coefficients. The downscaling methodology is currently evaluated and will be applied to the full MiKlip-Ensemble to quantify the decadal predictability of convective events over Europe.
For a joint study of all sub-projects of Module C the dynamical simulated regional MiKlip-Ensemble has been analysed to assess the decadal predictability of temperature, precipitation and wind speed over Europe. The regional ensemble has been generated in the report period by dynamical downscaling the global MPI-ESM hindcast generations basline0 and baseline1 with COSMO-CLM (Euro-CORDEX region, 0.22° resolution). For both generations five starting years have been selected for the COSMO-CLM simulations (1961, 1971, 1981, 1991, 2001), and for each starting year 10 members have been downscaled. MiKlip-PRODEF has contributed to the generation of the regional ensemble by simulating the ten members of baseline1 starting at 1991. Each member covers a period of 10 years (1991-2000; thus altogether 100 years). The joint study analyses the differences between baseline0 and baseline1, the added value of downscaling and the skill dependency on the ensemble size. In general the results reveal an enhancement of the prediction skill when the number of hindcast members is increased. An added value of downscaling could particularly be identified for orographic structured regions in Europe. The results of the joint study are currently composed in a research article in charge of MiKlip-PRODEF, which is intended to be submitted in a scientific journal in 2016.

Literature:

Moemken J, Reyers M, Buldmann B, Pinto JG (2015): Decadal predictability of regional scale wind speed and wind energy potentials over Central Europe. Submitted to *Tellus A.*

Reyers M, Pinto JG, Moemken J (2015): Statistical-dynamical downscaling for wind energy potentials: evaluation and applications to decadal hindcasts and climate change projections. *International Journal of Climatology* **35**: 229-244. Doi:10.1002/joc.3975

Project: **776**
Project title: **Decadal Prediction of African Rainfall and Atlantic Hurricane Activity (DEPARTURE)**
Project lead: **Prof. Dr. Heiko Päth**
Report period: **1.1.2015 - 31.12.2015**

DEPARTURE was a joint project of six research institutions within the frame of phase I of the research program MiKlip: the universities of Würzburg (coordinating), Frankfurt/Main and Cologne as well as the MPI for Meteorology, the KIT-IMK Karlsruhe and the KIT-IMK Garmisch-Partenkirchen. DEPARTURE assessed the decadal climate predictability of the West African monsoon and the hurricane activity over the Atlantic Ocean. For different decadal hindcast periods (1966-1975, 1981-1990, 1991-2000, and 2001-2010) the results of the global earth system model MPI-ESM-LR have been downscaled to a horizontal resolution of 50 km applying three regional climate model (RCM): REMO; CCLM, and WRF. To take into account the prediction potential of ocean, atmosphere, and land surface, REMO has been coupled to a global ocean model, and CCLM has been driven by improved boundary and initial conditions (aerosols, sea surface temperature (SST), vegetation, land use, initial state of soil) for selected decades. The resulting multi-model ensemble comprises about 100 decadal simulations. During the report period, especially model runs using improved boundary and initial conditions, the coupled ocean, and the assessment of the hurricane activities have been carried out. Overall, results of DEPARTURE focusing on the bias and the decadal predictability of the West African monsoon precipitation as well as on the hurricane activity over the Atlantic can be summarized as follows.

Concerning the bias of the simulated West African monsoon precipitation, the RCMs show an added value in the central and western Sahel regions in comparison to the global MPI-ESM-LR model. But over a continental stripe along the coast of the Gulf of Guinea the positive bias found in the MPI-ESM-LR results is even increased. This overestimation of the monsoon rainfall in both GCMs and RCMs is caused by a positive SST bias in the south-eastern Atlantic. The coupling of the ocean to REMO reduces this SST bias and, consequently, the precipitation bias along the Guinea coast considerably (Fig. 1, left and middle). Furthermore, the precipitation bias can be reduced by the usage of improved boundary conditions (Guinea coast: improved SST and land cover; Central Sahel: vegetation; West Sahel: aerosols).

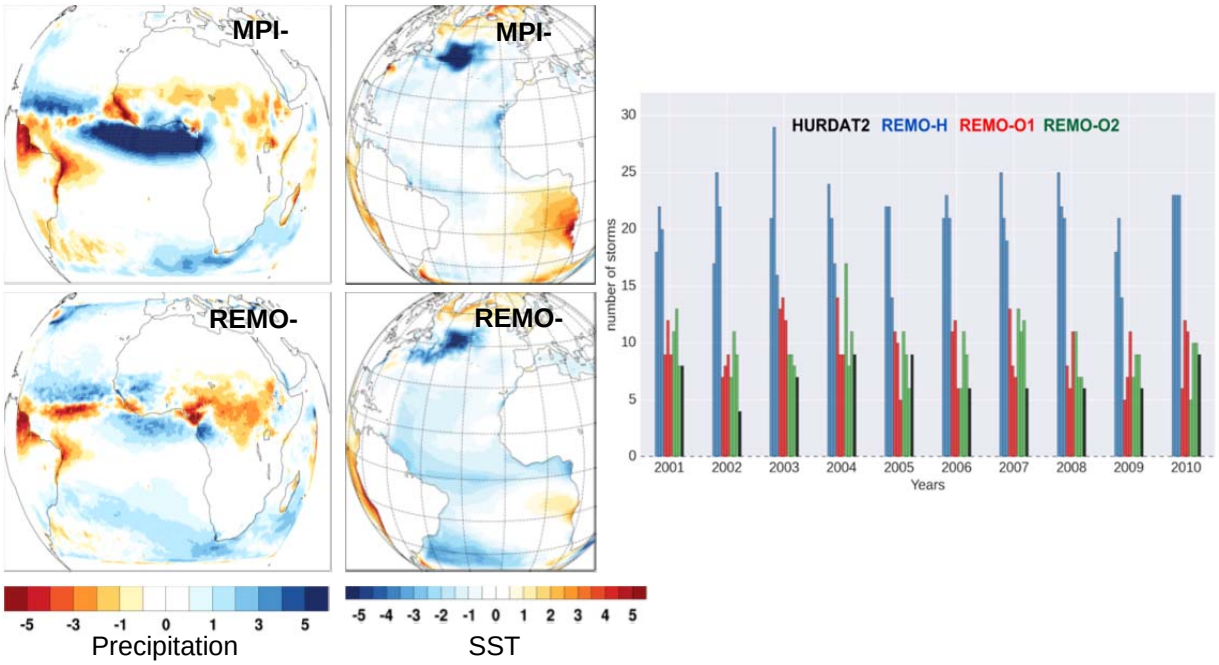


Fig. 1: Biases, relative to observations, of West African monsoon rainfall (left) and SSTs (middle) of the global MPI-ESM-LR (upper row) and the RCM REMO-O2 coupled to an ocean model (lower row). The right part shows the annual number of tropical cyclones and hurricanes over the Atlantic derived from observations (HURDAT2), the results of the uncoupled REMO version REMO-H, and the results of two coupled versions REMO-O1 and REMO-O2.

The decadal predictability of the West African monsoon precipitation over a whole decade often shows added values of single RCMs, but the positive correlations are hardly significant and vary between different decades. The intradecadal predictability within the four decades under consideration and the

interdecadal predictability between these decades reveal statistically more robust results and clear added values of at least one RCM in every region. The improved initial and boundary conditions show as well variable results of the decadal predictability but reach some significant added values (Guinea Coast: ocean coupling, SSTs and aerosols, Central Sahel: land cover, West Sahel: land cover and soil) which should be verified in further decades. Fig. 2 shows some exemplary improvements of the intradecadal predictability due to RCMs and improved initial and boundary conditions in selected regions and decades.

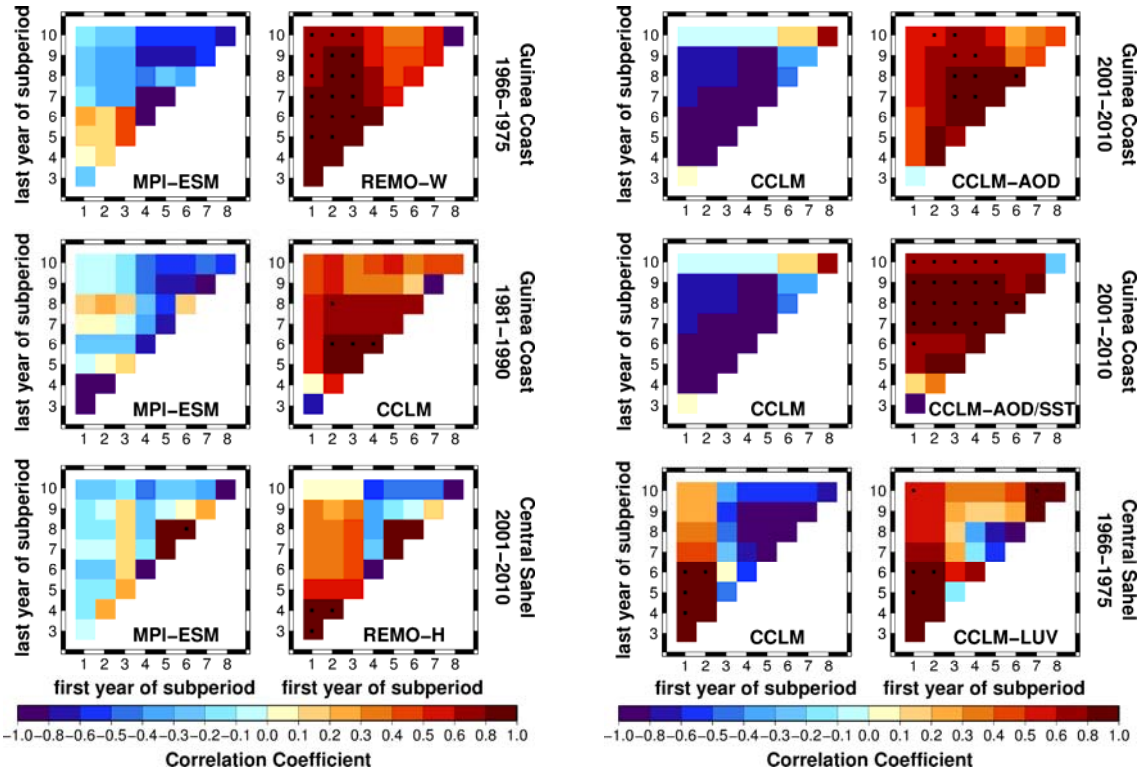


Fig. 2: Improvements of the intradecadal predictability of the West African monsoon precipitation due to different RCMs and improved initial and boundary conditions in selected regions and decades: REMO-W in Guinea Coast 1966-1975, CCLM in Guinea Coast 1981-1990, REMO-H in Central Sahel 2001-2010, CCLM-AOD with improved aerosols and CCLM-AOD/SST with improved aerosols and SSTs in Guinea Coast 2001-2010 and CCLM-LUV with improved land cover in Central Sahel 1966-1975. The correlation coefficients have been calculated over all possible subperiods of a decade with a length of at least three years. The black dots mark the statistical significance at the 5% level for a one-sided test

Concerning the Atlantic tropical storms and hurricanes, all uncoupled RCMs show positive biases of simulated numbers and intensities which can also be clearly reduced by the ocean coupling of REMO (Fig. 1, right). The decadal predictability of both variables reveals some improvements due to the ocean coupling but rarely reaches statistical significance and strongly varies between different decades.

Publications:

Paxian, A., Sein, D., Panitz, H.-J., Warscher, M., Breil, M., Engel, T., Toedter, J., Krause, A., Cabos Narvaez, W. D., Fink, A. H., Ahrens, B., Kunstmann, H., Jacob, D., Paeth, H. (2015): Bias reduction in decadal predictions of West African monsoon rainfall using regional climate models. J. Geophys. Res. Atmos., under Review.

Paeth, H., Paxian, A., Sein, D., Jacob, D., Panitz, H.-J., Warscher, M., Fink, A., Kunstmann, H., Breil, M., Engel, T., Krause, A., Toedter, J., Ahrens, B. (2015): Decadal and multi-year predictability of the West African monsoon and the role of dynamical downscaling. J. Clim., submitted.