SPECIAL PROJECT FINAL REPORT

Project Title:	Convection-permitting ensemble simulations for West Africa, based on different soil moisture fields
Computer Project Account:	SPDELM
Start Year - End Year :	2012 - 2014
Principal Investigator(s)	Leonhard Gantner, Norbert Kalthoff
Affiliation/Address:	Karlsruhe Institute of Technology (KIT) Institut für Meteorologie und Klimaforschung 76128 Karlsruhe GERMANY
Other Researchers (Name/Affiliation):	Vera Maurer

Summary of project objectives

- Investigation of predictability of convective systems within the West African monsoon system and especially in the Sahel region by convection-permitting ensemble simulations

- Assessment of the influence of the land surface on the predictability by including realistic soil perturbations in the ensemble

- use of a clustering method to choose members of the EPS from ECMWF that can be taken as initial and boundary conditions for convection-permitting ensemble simulations

Summary of problems encountered

Not applicable

Experience with the Special Project framework

We are content with the Special Project framework.

Summary of results

For this project, convection-permitting ensemble simulations were performed for West Africa to investigate the predictability of precipitation generated by mesoscale convective systems (MCSs) during the West African monsoon. Especially in the Sahel region, where MCSs only occur during the northernmost position of the monsoon rain band in July and August, the land-surface atmosphere feedback is strong. Mesoscale soil-moisture patterns left by antecedent MCSs, for example, can influence the subsequent development of deep convection, as vegetation is often sparse.

The investigations mainly can be divided into two main parts: 1) The setup of soil perturbations that were optimized to account for uncertainties regarding the initialization of soil moisture in short-range weather prediction as well as the realization of ensemble simulations using the soil perturbations and the assessment of their effectiveness; 2) the verification of different setups of convection-permitting ensemble simulations as well as the analysis of the gain of these compared to global ensemble simulations.

1) By analysing soil moisture fields derived from satellite observations as well as from model simulations (Klüpfel et al., 2011), it was shown that model soil moisture can differ strongly from observed values. For modelling, soil moisture is used as a quantity to control evaporation and its patterns as well as its absolute values depend strongly on parameters of the soil model. Therefore, four soil perturbations comprising soil moisture fields from different sources were generated such that they were adapted to the model. Details can be found in Maurer et al. (2015). These soil perturbations were then combined with atmospheric initial and lateral boundary conditions (IBCs) for the limited-area model (COSMO) taken from three different model analyses to generate 12 ensemble members. The ensemble simulations were performed for a 10-day period (23 July to 01 August 2006), with daily initialization and a lead time of 36 hours. Comparing ensemble spread generated by soil perturbations with spread generated by IBCs, it could be shown that both IBCs

and soil perturbations had an equally large influence on the predictability of convective precipitation in the West African monsoon (Maurer et al., 2015).

2) The ensemble setup as described in 1) can be regarded as a multi-analysis ensemble. As shown by Marsigli et al. (2014), using a larger number of IBCs by choosing members from the ECMWF EPS can increase the spread as well as the skill of a limited-area ensemble. For this reason, a second ensemble setup (single-model setup) was tested, using IBCs from 12 different members of an experimental IFS ensemble forecast. The EDA was not yet available for 2006 so that the 10 EDA perturbations for the experimental IFS simulations for 2006 were used from a different year. The soil perturbations were added randomly on the 10 ensemble members of the convection-permitting forecast. Additionally, the operational forecast was used twice with different soil perturbations to create 12 ensemble members. For the 10-day forecast period of 2006, three ensemble forecasts could thus be compared: The convection-permitting multi-analysis and the single-model version, and the experimental global IFS forecasts.
Additionally, a second forecast period was selected for 2011, when the EDA was already operational. For this period, another convection-permitting ensemble forecast was performed according to the single-model setup for 2006, but this time with 16 members from the operational ECMWF EPS forecasts that were selected by a clustering method after Molteni et al. (2011), which is operationally used for the Limited Area Ensemble Prediciton System (LEPS) developed within the COSMO consortium (Montani et al., 2011). It was adapted to the particular synoptical conditions in West Africa: Four variables (both horizontal wind components, specific humidity, and geopotential) are used on three pressure levels (925 hPa, 700 hPa, and 500 hPa) and the forecast hours 12, 36, and 48. Another difference of the single-model version of 2011 compared to the one of 2006 was the version of the COSMO model (4.26 instead of 4.18). The model change with the largest physical consequences was a modification in the parameterization of the high cloud cover used by the radiative transfer. Moreover, a climatological, satellite-derived albedo was used in the new version only as it had not been available before. Especially in the Sahel zone as well as in the Sahara, i.e. in regions with sparse vegetation, the climatological albedo shows much higher values than the original parameter-derived one used in the earlier model version. As for 2006, the precipitation forecasts of this single-model version were compared to the operational forecasts from the ECMWF EPS.

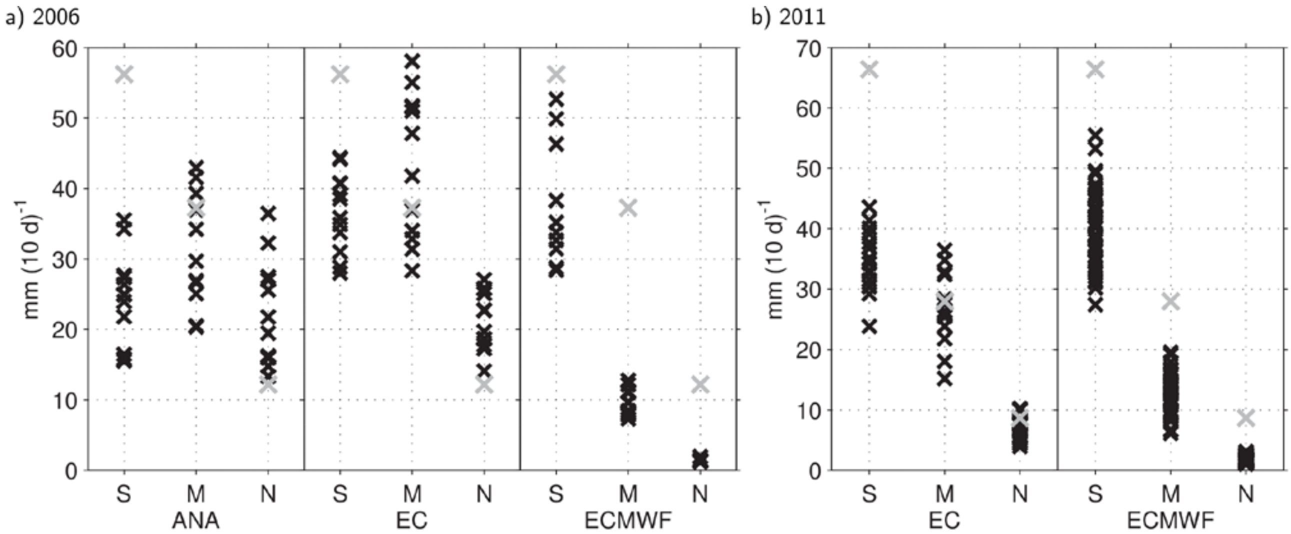

Fig. 1: Area-averaged precipitation sums in the three subdomains for all ensemble versions (multi-analysis version – ANA, single-model version – EC, and ECMWF forecasts) and all members as well as observed precipitation (gray cross)

For ensemble verification, a gridded, satellite-derived precipitation product was used (TRMM multi-satellite precipitation analysis 3B42_V7). The convection-permitting forecasts were regridded by averaging to the same horizontal resolution as the observational data. For the calculation of probabilities, a neighbourhood approach was also applied. As for the first part, the evaluation domain was divided from south to north into three subdomains, situated roughly within the three climate zones of the Guinean coast (S), the Sahel (M), and the Sahara (N).

Area-averaged precipitation sums show that both the multi-analysis and the single-model ensemble for 2006 have a large negative bias in the southern subdomain and a positive one in the northern subdomain (Fig. 1a). The biases are stronger in the multi-analysis ensemble. In the middle subdomain, ensemble members are well spread around the observation for both versions. In contrast, the ECMWF forecasts display a negative precipitation bias in all of the subdomains, which is weakest in the southern subdomain. For 2011 (Fig. 1b), the single-model ensemble displays a negative bias in the southern subdomain and area-averages that agree well with the observation in the middle and the northern subdomain, in contrast to the ECMWF ensemble with a negative precipitation bias in all three subdomains as for 2006.

For the computation of rank histograms, all daily precipitation sums that were smaller than 1 mm per day were set to zero, because larger areas with small sums existed in the ECMWF forecasts that otherwise would have contributed to a very high frequency of the lower ranks. For the multi-analysis version (Fig. 2a), the frequency of the highest rank is extremely high for the southern subdomain, according to the negative precipitation bias. For the single-model version (Fig. 2b), it is slightly smaller. The frequencies of the lower ranks are also larger than the average in the northern subdomain, confirming the positive precipitation bias for both versions, but it is less pronounced than in the southern subdomain. No large difference between the two versions can be discerned. In the middle subdomain, the frequencies of both lowest and highest ranks are above the average, indicating underdispersion for both ensemble versions. For the multi-analysis version, it is slightly higher than for the single-model version. For the ECMWF version, the rank histogram (Fig. 2c) indicates strong underdispersion in the southern subdomain and a negative bias in the middle and northern subdomain. Thus, both convection-permitting ensemble versions as well as the ECMWF ensemble suffer from large biases as well as underdispersion in areas where the bias is smaller.

For 2011, the negative bias in the southern subdomain is also obvious in the rank histogram (Fig. 2c), while the ECMWF ensemble displays again a strong underdispersion (Fig. 2e). In the middle subdomain, the rank histogram for the convection-permitting ensemble is almost flat and a slight negative bias can be discerned in the north. For the ECMWF ensemble, the negative bias prevails in the middle and northern subdomain. With this, the single-model version for 2011 shows still a negative precipitation bias near the Guinean coast, but it is reduced and the positive bias in the northern subdomain is completely removed. The precipitation forecast for the Sahel region seems satisfying, while this is not the case for the ECMWF ensemble for this period. The use of a later model version of COSMO and selected members out of the whole ECMWF EPS was, thus, an important improvement.

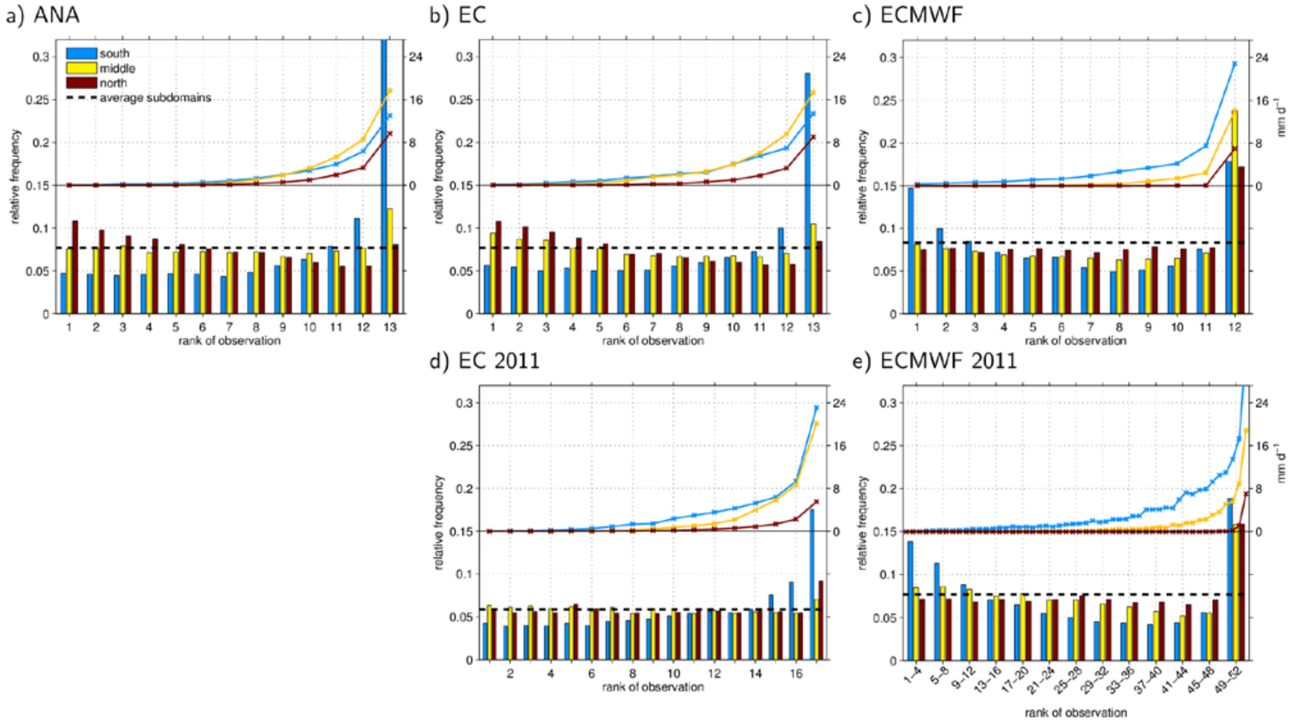

Fig. 2: Rank histograms of 24-h precipitation sums for all ensemble versions for the three subdomains, with average observed precipitation sum per rank (lines)

Altogether, the results show that the multi-analysis ensemble of convection-permitting forecasts for West Africa does not display smaller spread than the single-model ensemble, for which a larger number of atmospheric IBCs is used. This indicates on the one hand that analyses from different global models differ stronger than the members of the ECMWF ensemble and on the other hand, that the generated soil perturbations are appropriate to complement the IBCs in the multi-analysis ensemble.

The global IFS forecast generates too little precipitation especially in the Sahel region, which must to large part be attributed to the convection parameterization. However, the gain of the convection-permitting ensemble over the global IFS simulations is compromised by large precipitation biases. Nevertheless, a satisfying precipitation forecast was shown for the Sahel region.

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Future plans

At present there are no plans to continue with ensemble simulations for West Africa.