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D3.5.3 Report on RCM evaluation for the AMMA region

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Final

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Dissemination Level		
PU	Public	√
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

Introduction

In addition to the European regional climate model simulations, the ENSEMBLES RT3 regional climate models (RCMs) were also applied for Western Africa, in concert with the EU/AMMA project studies (see Figure 1). The effort contributed both to research on the RCMs themselves and to studies of the African region. Fruitful interaction was facilitated with the AMMA efforts.

By the end of ENSEMBLES, 11 RCM sets of two runs each had been accomplished (cf. D3.5.2), relying on the common simulation set-up design (cf. D3.5.1). All runs encompassed the AMMA region at a horizontal grid spacing of ~50 km. One of the two runs per set was driven by the ERA-Interim reanalysis for the period 1989-2007 while second was climate projection exercise for 1990-2050, driven by some of the same global models as in case of the European RCM runs in RT2B. The results were stored in the ENSEMBLES RCM databank at DMI using the same protocol as for the European runs.

This Deliverable concerns some basic evaluation of the runs (temperature, precipitation) with some additional focus on the West Africa Monsoon (WAM), which is one of the main climatic features affecting this region. Over West Africa most of the annual precipitation is accounted for by the West Africa Monsoon during the period of April through September.

The ERA-Interim driven simulations

Figure 1 shows observed 1990-2007 annual precipitation climatology from GPCC and nine[1] of the RCMs to it. Also a multi model ensemble (MME) mean is provided.

Figure 1 shows that many RCMs tend to overestimate precipitation over the Sahara, albeit there also are exceptions. The same is true for much of the subtropical and equatorial Africa, except for the coastal regions where precipitation is underestimated. The latter may be due to the relatively smooth model topography even at 50 km that does not capture the presence of coastal mountain systems in West Africa. Six of the models tend to follow this general pattern of systematic bias, although with varying bias magnitudes. The exceptions are the two HIRHAM versions, which have a prevailing negative bias over equatorial Africa and the REMO model, in which the areas of positive and negative bias are distributed somewhat differently from the MME. Comparison of the MME systematic biases with the biases from individual models indicates that the MME is generally superior (lower biases) to the individual RCMs. Excessive precipitation compared to GPCP is especially obvious over the Sahara in two of the models (PROMES and HadRM3P).

The WAM is characterized by three distinct phases (Le Barbé *et al.,* 2002; *Gallée et al.,* 2004). In March, rainfall begins along the Guinea Coast and extends progressively northward. After this primary phase, a distinct northward jump in the rainband occurs in late June/early July, which marks the onset of rains in the Sahelian zone. In September, the Sahelian rainy season ends with a southward retreat of the rainband, which brings a second rainfall peak along the Guinea Coast.

The RCM skill in reproducing the seasonal cycle of rainfall over this region is shown in Figure 2. The models generally capture the three distinct phases of the monsoon. The inter-model variability in the magnitude and timing of the seasonal phases is nevertheless quite large. The most notable biases include an overestimation of rainfall at latitudes of about ~5 °N in CCLM, REMO, HadRM3, and the two HIRHAM models. RCA3 (INM) shows a general underestimation of rainfall magnitude throughout the year, which, however, is not at all obvious in the other RCA (SMHI) run.

[1] Due to the late completion of few of the runs, the analyses provided here do not cover all the simulations. The complete sets will be available for continued analyses.

The distinct jump from the primary monsoon phase to the Sahelian onset is reasonably well replicated by all models. Further analysis of the onset and cessation dates for the three phases (not shown) indicates spread between the models. For the primary monsoon phase, the models show both early and late onset, spanning a range of 8 pentads. All models simulate an early end to this first phase. Furthermore, all the models show an early onset and late end to the Sahel rainy season and a late onset and late cessation of the second Guinea Coast season. It is evident that, although the RCMs simulate the basic precipitation patterns over West Africa, some systematic biases are at least qualitatively are common across the models. In this regard, it should be stressed that although the ERA-Interim represents the best quality reanalysis product available, it might still have problems in representing the hydrologic budget of the tropics, which would transfer to the nested RCMs.

Analysis of the GCM driven scenario simulations

Some basic regional climate projection results are depicted in Figure 3 (one of the first RCMs to make it to the database was looked at earlier by Rummukainen *et al.* 2009), for temperature and precipitation changes by 2031-2050, compared to 1991-2010. (Twenty-year periods are used rather that 30-year means as the common projection period runs only from 1991 to 2050.) The contrast between generally significant temperature trends and generally non-significant[2] precipitation trends is obvious. There are, however, also some sub-regional discrepancies even when the same GCM provides the boundary conditions.

Figure 4 shows linear fit trends of the annual precipitation time series between 2001 and 2005 [mm/50 years] for many of the RCM runs, as well as the MME mean. All runs follow the A1B emission scenario. See D3.5.2 for the forcing GCMs. Trends that are statistically significant at the 5% level are marked by black dots. Two experiments that include projected land cover change are also shown from the AMMA project.

It is evident that the response is quite varying in the overall projected precipitation change, and this is true also across the RCMs that have the same GCM forcing. In many instances the trends are not significant at the chosen level and also of opposite sign, so that the MME signal is generally small. This suggests that although similarities are found between models using the same GCM forcing (e.g. the positive trend over equatorial Africa in RegCM, RACMO and one of the two HIRHAM cases, the lateral boundary forcing does not necessarily exert a dominant influence on the projected changes in monsoon precipitation. Rather, effects associated to the internal model physics appear to be at least as important. This is further emphasized by the fact that when land cover change (REMO+LCC) are included, the trends are very different from those of the same RCM using stable land cover. Thus, local processes would seem to play a key role in determining precipitation changes and also are potentially very important to address in climate change and variability studies for the region in question.

Summary

The RCM simulations performed for Western Africa using the ENSEMBLES models and common experiment design approach represent an unprecedented set of that allows improved assessments for

[2] The statistical significance for the climate change signal for different periods is based on nonparametric bootstrap method i.e. the original seasonal mean fields are randomly resampled with replacement. 500 synthetic samples of the same size (20 years) as the original time series were generated for each individual simulation and means for three periods (1991-2010, 2011-2030 and 2031-2050) are computed for each generated sample. From these 500 surrogate means we derive the critical statistics for the two-sided difference of mean test and find the differences among the periods that are significantly different at the 5% significance level.

regional climate and projected climate changes over Africa. The preliminary analyses lead to three basic conclusions:

1) Although the RCMs employed in general provide a realistic simulation of the WAM development, some systematic biases are still present;
2) Local processes are important in determining the simulated monsoon precipitation change, such as land cover change, which emphasizes the need for coupled RCM-land cover change simulations;
3) The simulated precipitation changes are for the most part small compared to natural variability for the early 21st Century. Projected temperature changes are significant already in 2011-2030 (not shown), and increase further to the 2031-2050 period.

These findings imply that more model testing and development is needed to improve the current European RCMs for general application to non-European regions. The use of multiple RCMs represents an important source of insight and emphasizes the value in multi-model approaches. Local processes, e.g. those associated with land-atmosphere interactions or aerosol radiative forcing, seem to be important constraints for the modelled evolution of the WAM under global warming.

These simulations were completed and became available towards the end of the ENSEMBLES project. The present analysis is preliminary. Further analysis of these AMMA-related simulations will continue beyond the ENSEMBLES project, and will be documented in the peer-reviewed literature.

References

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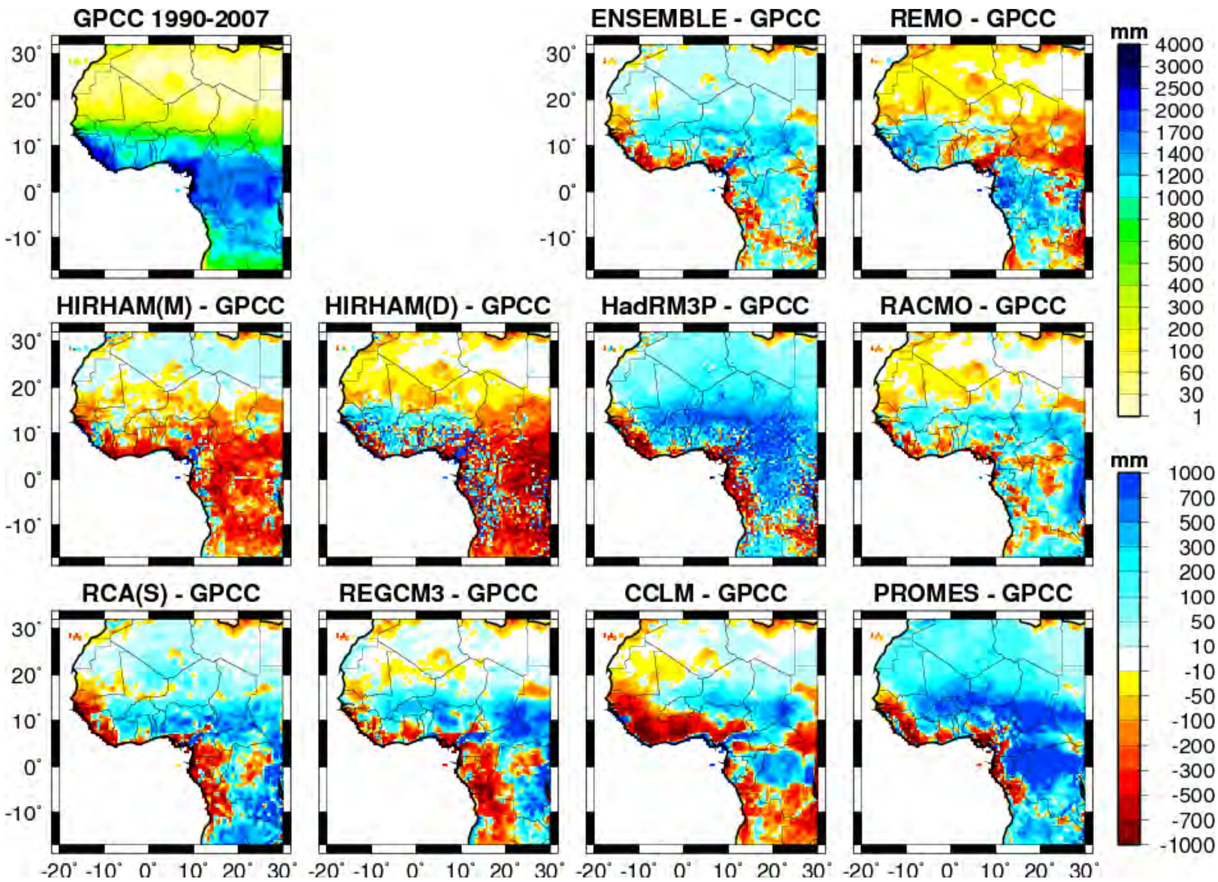

Figure 1. Observed 1990-2007 annual precipitation climatology from GPCC (Rudolph 1995 + updates; top left) and differences to GPCC in RCM simulations and in their MME mean. All runs are driven by the ERA-Interim reanalyses. (Paeth *et al.* in preparation).

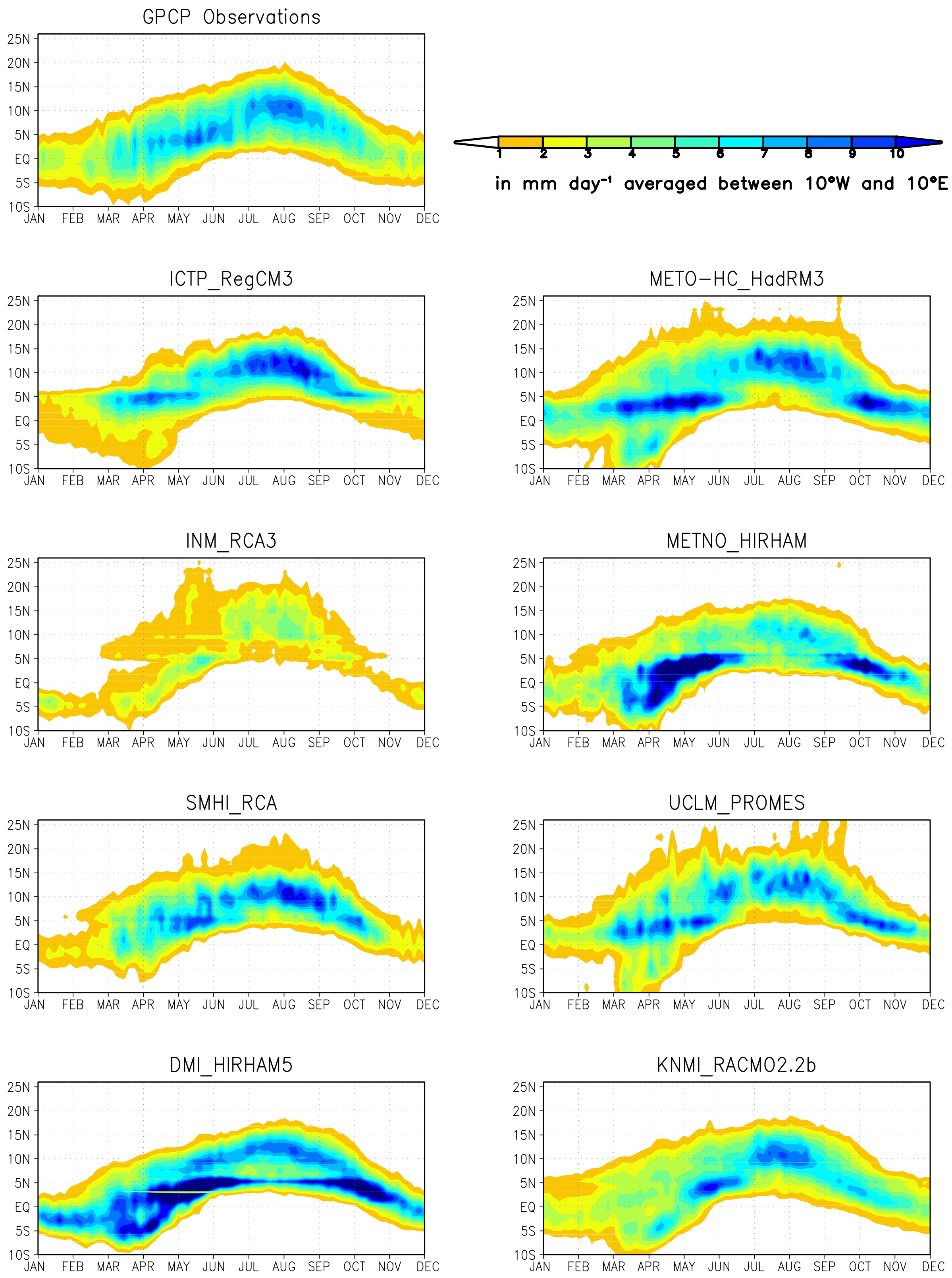

Figure 2. Time-latitude plots showing mean annual cycle of rainfall over the Guinea Coast and Sahel regions for each model and for GPCP observations (Xie *et al.*, 2003; top left panel). Data are binned into pentad means and zonally averaged between 10 °W and 10 °E.

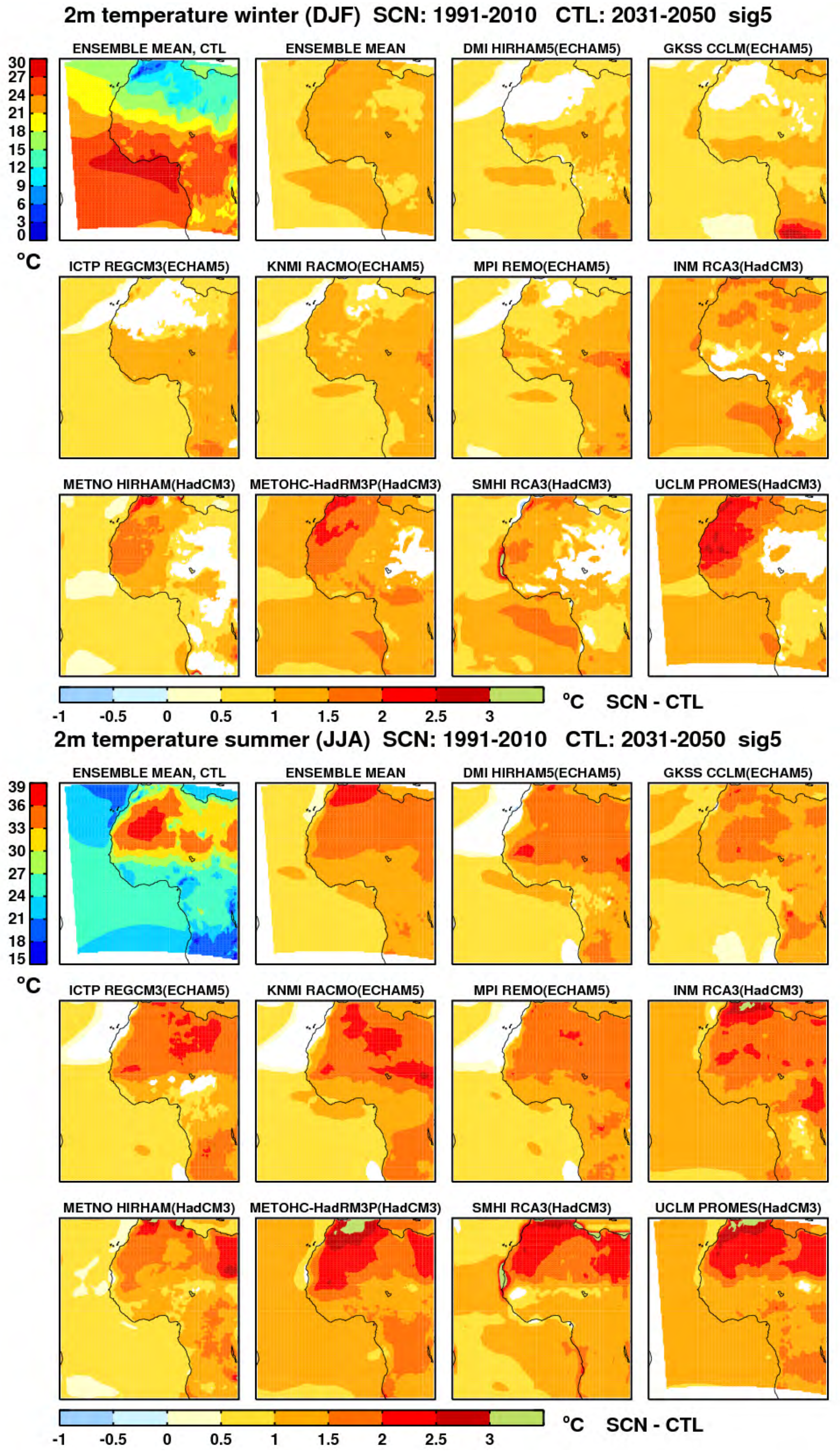

Figure 3a, b. Projected NH winter (DJF) and summer (JJA) two-meter temperature changes in 10 ENSEMBLES/RT3 runs for the 2031-2050 period compared to the 1991-2010 (see D3.5.2 for information on the forcing GCM; A1B emissions apply in all cases). The MME "present-day" period is shown on the top left as well as is the MME climate projection. Projected changes are shown only when they are significant at the 5% level.

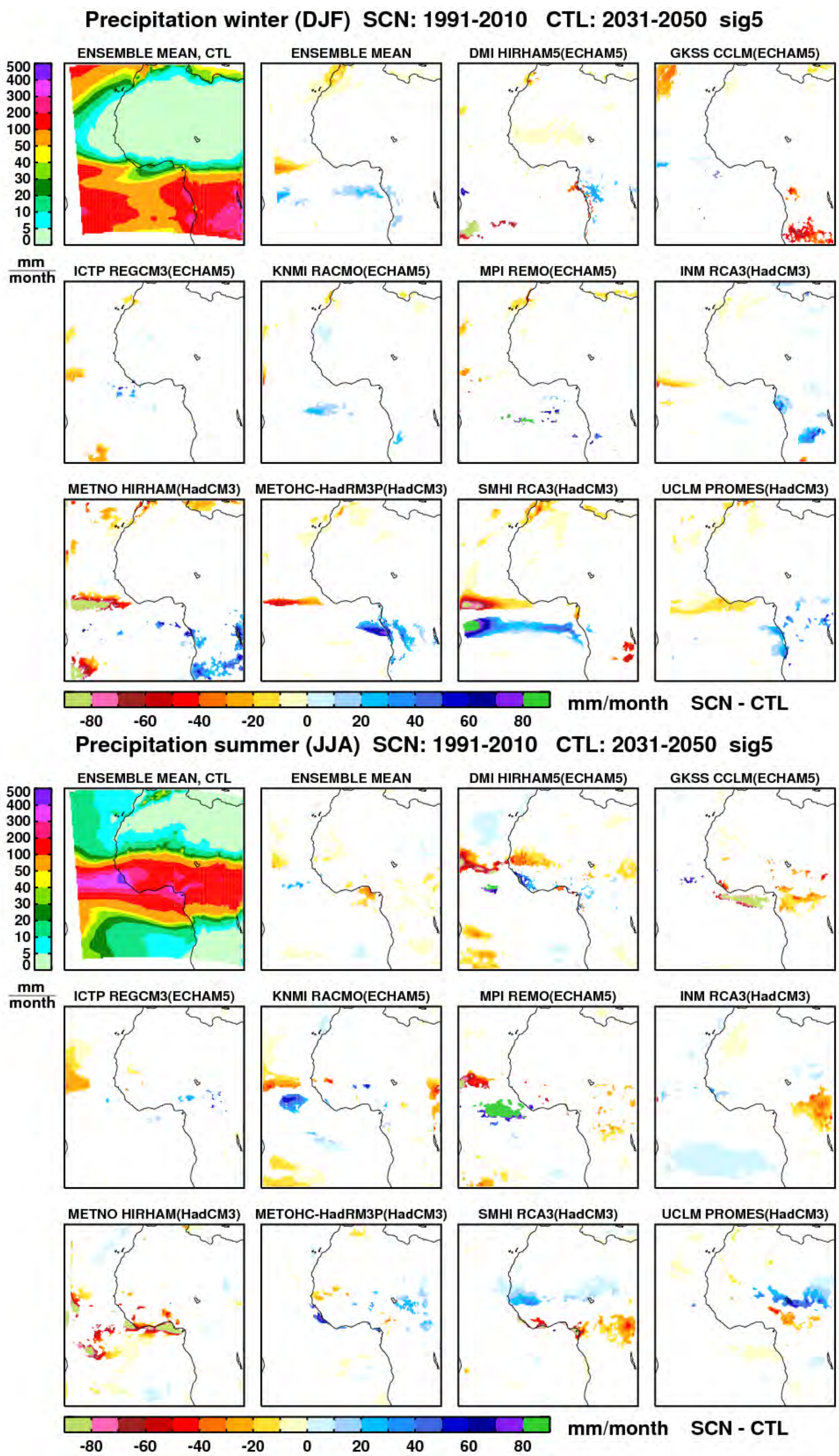

Figure 3c, d. Projected NH winter (DJF) and summer (JJA) precipitation changes in 10 ENSEMBLES/RT3 runs for the 2031-2050 period compared to the 1991-2010 (see D3.5.2 for information on the forcing GCM; A1B emissions apply in all cases). The MME "present-day" period is shown on the top left as well as is the MME climate projection. Projected changes are shown only when they are significant at the 5% level.

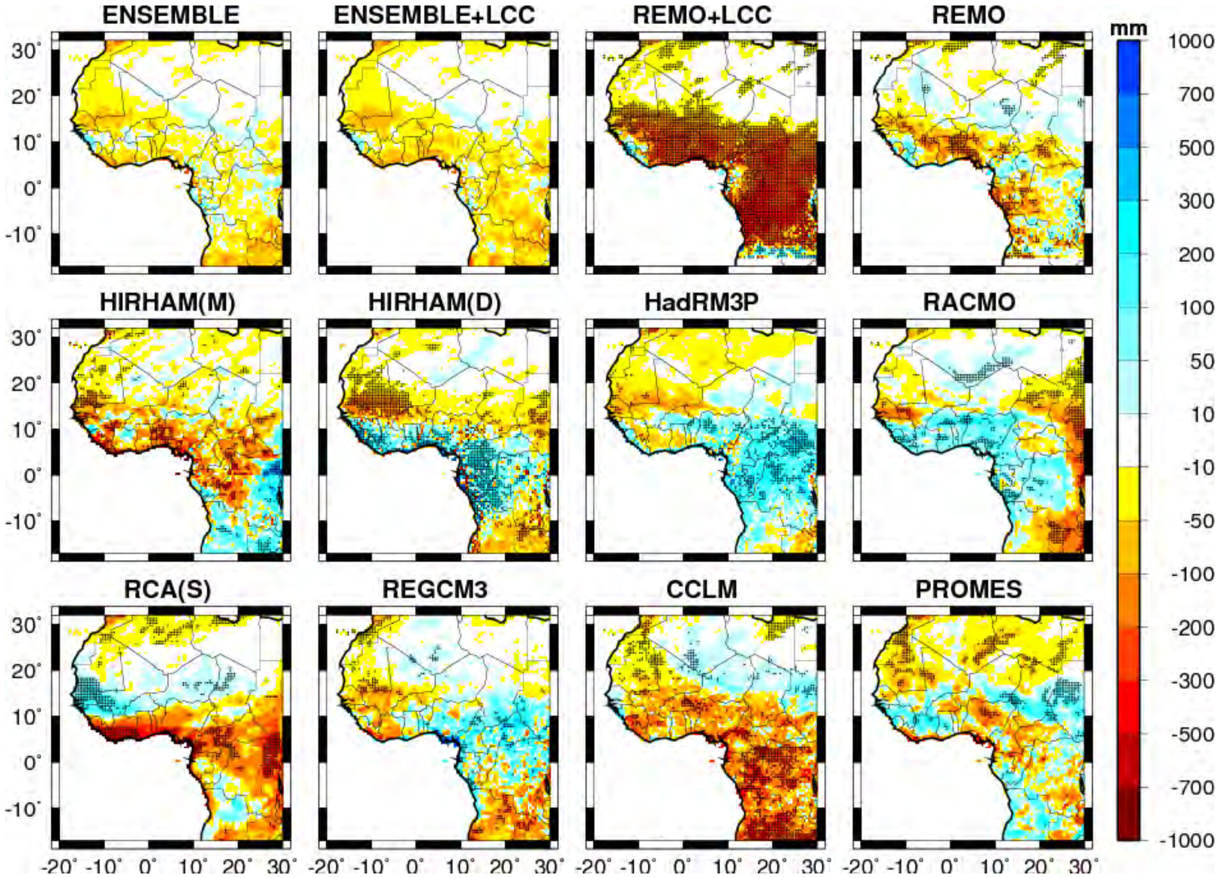

Figure 4. Linear fit trends of the precipitation time series between 2001 and 2005 [mm/50 years] from 10 RCM experiments and the MME mean under the A1B emission scenario. The top middle cases account also for some land cover changes. Trends statistically significant at the 5% level are marked by black dots. (Paeth *et al.* in preparation).