Annual Reports Projects bb0849

Project: **849**

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

Project leader: **Hendrik Feldmann**

Report period: **1.1.2016 - 31.12.2016**

Overview

MiKlip II Module C works on the downscaling of global climate predictions with the regional climate model COSMO-CLM (CCLM). The project aims are to improve the regional prediction system and to provide reliable information about regional decadal predictability for Europe.
The efforts of Module C are an essential contribution to the development of an operational decadal prediction system within in the BMBF funded program MiKlip II. All regionalization efforts of the research program are bundled within this DKRZ project bb0849.
MiKlip II Module C is organized in 8 work packages (WP), with 5 WPs requiring considerable computing time at DKRZ, where the other 3 use these data for analysis and post-processing. The project has currently 15 active members of whom 8 participants use the major part of the resources.
Participating Institutions are: KIT Karlsruhe, DWD, Goethe University Frankfurt (GUF), University of Cologne and University Würzburg

2016 is basically the first complete year of the MiKlip II project (start Nov. 2015). The concept for this phase consists of several steps, which build on each other, to produce the simulations needed for the analysis and assessment of the regional decadal predictions within MiKlip.

- The first step is to provide an optimized setup for the new recommended CCLM version (cf. Objective 1) which is the basis for all simulations within Module-C.
- Several WPs had to configure and test their coupled model version, which include alternative soil models (cd. Objective 2) and a regionally coupled ocean model (cf. Objective 3).
- The next step is to provide re-analysis driven reference simulations, which are used to initialize the decadal simulations.
- The final step is to produce regional decadal hindcast ensembles.

Step 1 was finished in Q1 2016, reference simulations became available in Q2 (Objective 1) until Q3 2016. The regional decadal hindcasts for Europe are currently performed (objective 1, 2 and 5) but will not be finished before 2017.

1. Objective: Ensemble Generation **(WP: C3-WP3)**

Hans-Jürgen Panitz (KIT), Sascha Brand (DWD)

Main WP Goals

Module C of MiKlip II will establish and improve the regional component for the operational use of MiKlip decadal prediction system. All efforts in MiKlip II regarding the regional component of the MiKlip-System will concentrate on the Regional Climate Model (RCM) COSMO-CLM (CCLM), which is the climate version of the

operational weather forecast model of the German weather service (DWD), with a regional focus on (Central) Europe. MiKlip II aims build upon the most promising results from MiKlip I. The regional model will be improved. Gaps, which have been identified, will be studied and the analysis of regional predictability on decadal time-scales will be strengthened to gain a better understanding of the mechanisms involved. The findings will be integrated into an operational regional component of the MiKlip system including suitable post-processing.
Module-C will perform a regional downscaling of hindcast ensembles (Figure 1.1).

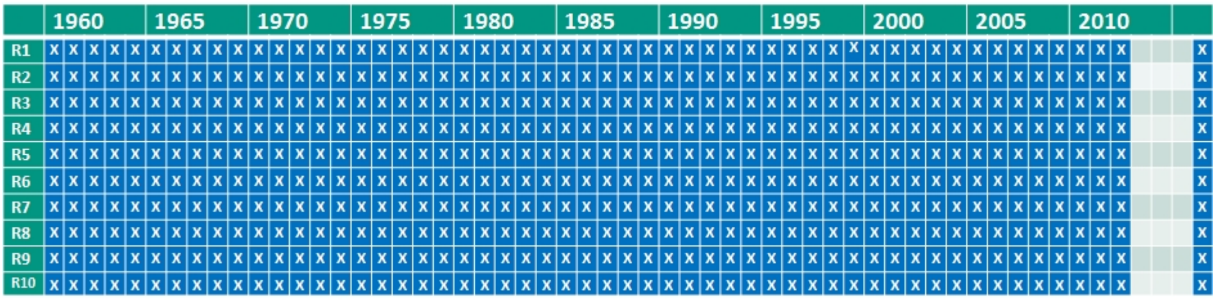


***Figure 1.1**: Simulation plan for the regional core ensemble. Each X denotes the starting year of a decadal hindcast or forecast simulation. 10 realizations are generated using 1-day shifted starting conditions.*

The tasks of Module C within MiKlip II were grouped into three main objectives. Each of these objectives is further divided into several work packages.
This report concentrates on objective C3 “Optimizing regional ensembles” and its work package (WP) C3-WP3 “Ensemble Generation”.
The goal of this work package is to produce a sufficient set of dynamically downscaled regional decadal hindcast simulations, from which recommendations for the ensemble composition, best suited for the operational system, can be derived. The full MiKlip hindcast period from 1960 onward will be considered in order to account for inter-decadal variability and to assess the robustness of the analyses. The final result will be a robust and reliable moderate size ensemble for the operational system fulfilling a balance between scientific (reliability, accuracy) and practical (computational costs) criteria and proven added value compared to the global predictions. Existing global hindcasts from MiKlip I as well as newly generated global hindcasts from MiKlip II will be used as driving data. The underlying global climate model (GCM) is MPI-ESM in its LR and HR versions.
The model domain for the regional decadal simulations of MiKlip II coincides with the domain chosen in MiKlip I, respectively in the frame of EURO-CORDEX (Figure 1.2). The horizontal grid-spacing has been fixed to 0.22° (≈25 km).

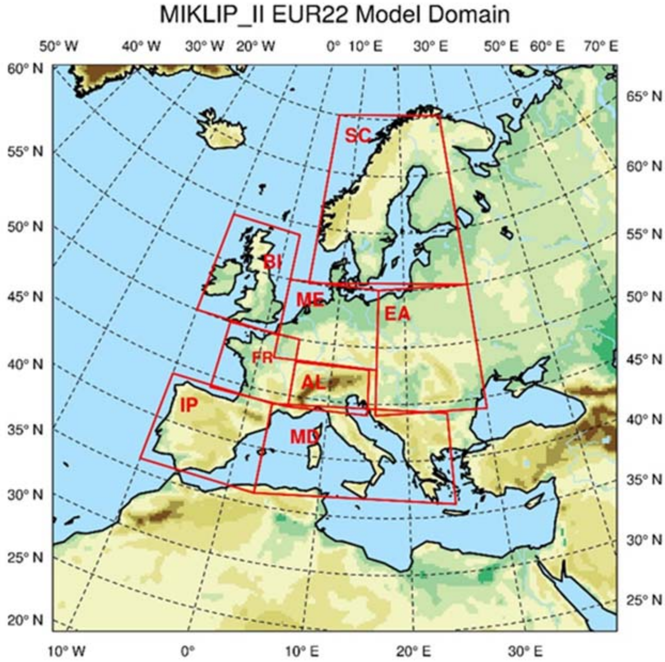


***Figure** 1.2: Model domain for the decadal simulations using CCLM within MiKlip. Shown are the orography and the location of eight sub-regions generally been used for detailed analyses. The domain includes a “sponge” zone of 13 grid-points at each lateral boundary that should be ignored when analysing the model results.*

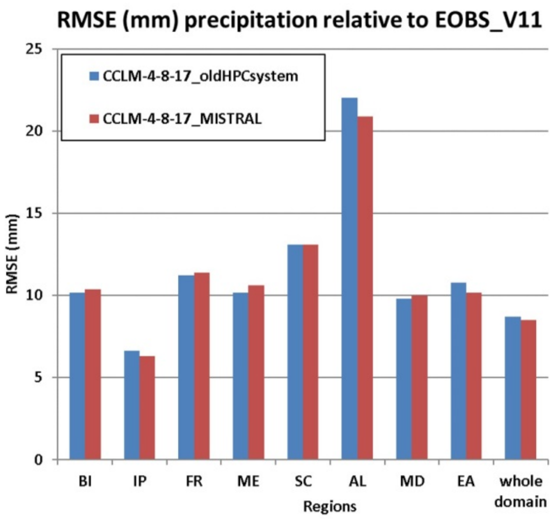
Activities and Results

At the beginning of reporting period we worked on the answer of the following questions:

i. What is the impact of DKRZ’s new HPC system “MISTRAL” on the results in comparison to the old system “BLIZZARD”
ii. What is the impact of the recently evaluated version of CCLM, COSMO_5.0_clm9 (CCLM-5-0-9), and its recommended configuration for simulations over Europe on the results? The older, but also evaluated version COSMO_4.8_clm19 (CCLM_4-8-19) had been applied within MiKlip I.
iii. What is the impact of the strong initial drift, observed in the hindcasts of MPI-ESM-LR after full field initialization, on the results of the regional model CCLM?

i.: **The impact of DKRZ’s new HPC system “MISTRAL”**

In the frame of MILIP I an evaluation of CCLM-4-8-19 had been performed on the domain shown in Fig. 1.2, using ERA40 (period 1961-1978) and ERA-Interim (from 1979 on) as driving data. The results are available from the MIKLIP-Server. The computing system was DKRZ’s old HPC system “BLIZZARD”. This evaluation has been repeated on the new system “MISTRAL” for the period 1979 to 1985, using ERA-Interim as driving model, the model version CCLM-4-8-19, and the identical model setup, as in MiKlip I. A comparison of the results showed that the new system had a negligible impact. This is demonstrated in Fig. 1.3 that shows, in terms of the root mean square errors (RMSE), a comparison of simulated temperature and precipitation with the corresponding data from EOBS, Version 11.



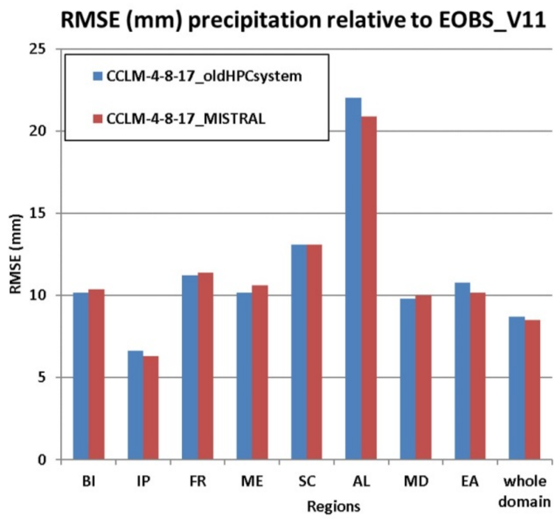
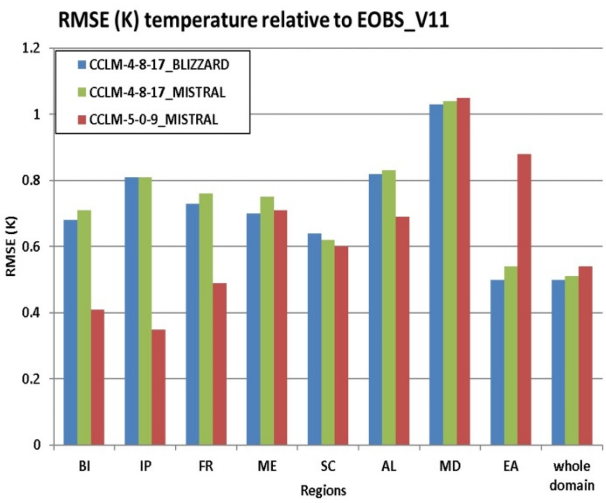


Figure 1.3: *Root mean square errors (RMSE) of simulated mean monthly values of temperature (left) and precipitation (right) relative to EOBS, version 11. Blue bars denote the CCLM-4-8-19 simulation using the old HPC system "BLIZZARD", red bars the simulations using the new system "MISTRAL.*

ii.: **Impact of new CCLM version and its recommended configuration**

After a comprehensive evaluation process performed by the evaluation working group of CLM-Community, CCLM-5-0-9 had been released as the new evaluated version, together with a recommended configuration for simulations over the European domain. This new version and the recommended configuration have been applied for the period 1979 to 1985, again using ERA-Interim as driving data, and the results have been compared with those from CCLM-4-8-19. For precipitation, the application of the new version led to an improvement of the results, except the two sub-regions British Isle (BI) and Scandinavia (SC). For temperature the agreements are also better except for the Mediterranean region (MD) and Eastern Europe (EA).



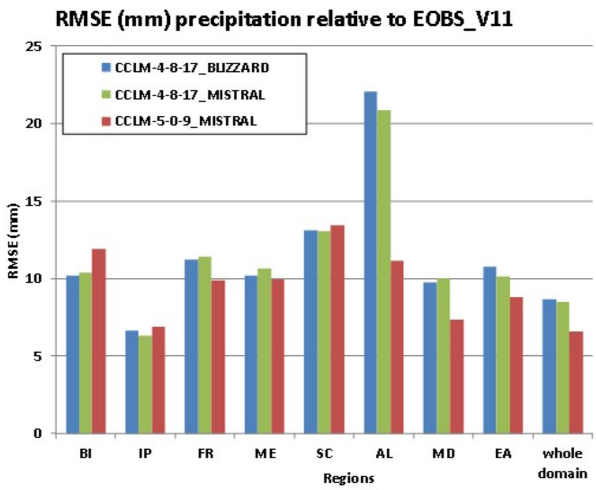


Figure 1.4: *Root mean square errors (RMSE) of simulated mean monthly values of temperature (left) and precipitation (right) relative to EOBS, version 11. Blue bars denote the CCLM-4-8-19 simulation using the old HPC system "BLIZZARD", green bars the simulation applying CCLM4-8-19 on the new system "MISTRAL. Red bars show the results of the new*

RCM version CCLM-5-0-9 using the new recommended model configuration.

iii.: **Impact of drift in GCM hindcasts**

Decadal hindcast simulations of the GCM MPI-ESM-LR during Development Stage 3 of MiKliP I, so called prototype simulations, were characterized by the full field (FF) initialization method. This FF initialization led to erroneous drifts away from climatological means, especially in oceanic parameters like AMOC or Ocean Heat Content, and also Sea Surface Temperature (SST). The left picture in Fig. 1.5 shows the trend pattern (left, in °C/10 years) of surface air temperature over land and of SST for the period 2001 to 2010 (Decade 2000), derived from MPI-ESM-LR prototype hindcast, realization 1. In the North Atlantic a region can be detected, showing a pronounced cooling trend of SST of more than 5 °C within the 10 years period.

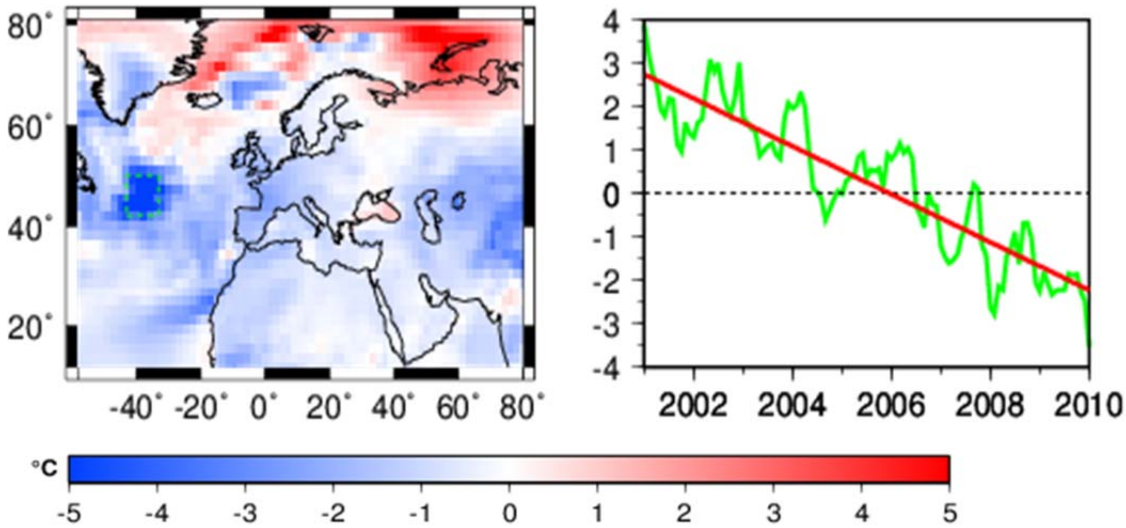


Figure 1.5: *Trend pattern (left, in °C/10 years) of surface air temperature over land and of SST for the period 2001 to 2010 (Decade 2000), derived from MPI-ESM-LR hindcast, realization 1. The right picture shows the time series of sea surface temperature (SST) anomaly with respect to the 2001-2010 mean, averaged over the region marked by the green box in the left picture. (Figure by H. Paeth, University of Würzburg).*

The SST is the only oceanic parameter from the GCM that is used in the RCM as a forcing parameter. It is prescribed by the GCM in 6 hourly intervals and will not be altered by the RCM. Therefore, we started to investigate whether the drift has an impact on the results of the RCM. For this purpose, decadal hindcast have been carried out with CCLM for five decades: 1961-1970 (Decade 1960), 1971-1980 (Decade 1970), 1981-1990 (Decade 1980), 1991-2000 (Decade 1990), and 2001-2010 (Decade 2000) using global prototype decadal hindcasts as forcing data. The analyses of this investigation are still ongoing in cooperation with the MiKlip II work package C3-WP2 “Optimized Ensemble Characterstics”.

At the end of August 2016, about four weeks later than expected, global decadal hindcasts with yearly start years from 1960 until 2012 of MPI-ESM-HR, realization 1, became available, and we began to downscale them using CCLM-5-0-9. In parallel, a set of four script packages had been developed with the aims to flexibilize the whole downscaling process in terms of GCM realization and user who performs the downscaling, and to carry out tasks in the four packages automatically and, as far as possible, simultaneously. Each of the four packages is steered by as script that configures the respective tasks and then submits batch jobs that perform the tasks.

i. ***Preselection script package***: it selects all required variables from the MPI-ESM-HR output files and converts them into the format needed by the pre-processor INTLM of CCLM. This conversion is done on a yearly base and it takes a Wall Clock Time (WCT) of about 2.2 h, which is nearly equivalent to the costs in node-hours (nh), since the corresponding batch job runs on one compute/compute2 node. Since all 10 years within a decade are more or less converted simultaneously, there is a certain time lag between two years, because the selection of the required variables for the second years also needs some time, the conversion process of a whole decade is completed in about 4-5 hours. The total costs per decade are about 22 nh. The amount of disk storage capacity for on decade is about 4.7 Tbyte. It is possible to consider more than one decade in one pre-selection and conversion step.
ii. ***Script Package Pre-Processor INT2LM:*** the pre-processor INT2LM reads the converted MPI-ESM-HR data and calculates the actual forcing data for CCLM on the final grid. The forcing data for a whole decade are created in one batch job, that needs about 6 hours on one node (usage of larger number of nodes does not accelerate the job considerably). The costs are about 6 nh. The storage needs are about 0.9 Tbyte per Decade. Again, several decades can be treated simultaneously.
iii. ***Script Package CCLM:*** CCLM performs the actual downscaling process using the forcing data created by INT2LM. The whole decadal CCLM simulation runs as a job-chain of 10 yearly jobs. The WCT needed for one yearly job varies between 2.5 h and about 3 h. Since 25 nodes are used the costs vary between about 63 nh and 75 nh. Thus, the total WCT for a whole decade is about 1 day, and the costs are in the order of 750 nh. After the successful end of a yearly job, post-processing and archiving jobs are submitted automatically. When CCLM finished a whole decade, then, after a short time lag, all CCLM output data are archived, and 10 years time-series exist for selected variables. The additional amount of costs for the archiving is about 12 nh per decade, and 3.5 nh per decade for the post-processing. The amount of disk storage needed per decade is about 2 Tbyte for the CCLM output and 0.75 Tbyte for the post-processed time-series. Again, several decades can be treated simultaneously.
iv. ***CMORisation script package:*** the last of the four script package performs some kind of CMORisation of those variables, which are available as time-series from package iii, that required for further analyses within MiKlip II. The CMORisation process consists of two step, the first for the de-rotation of wind components u and v at the 10 m level and on several pressure levels from a rotated coordinate system to a regular geographical system, the second for the actual CMORisation process. Both steps are performed as batch jobs, and together they cast about 5.1 nh.

Due to the application of the four script packages and due to their ability to perform tasks simultaneously we were able to finalize the regionalization of 53 global decadal MPI-ESM-HR, realization 1, hindcasts within about 3 weeks.

At the end of September 2016, 27 global hindcasts of MPI-ESM-HR, realization 2, became available. Their downscaling from the pre-selection to the provision of the CMORized data needed a time of about one week.

Computational aspects

The computational requirements on MISTRAL for the whole regionalization process of a global decadal hindcast using CCLM_5-0-9 are summarized in Table 1. The numbers given there are valid for one whole decade. In total, the costs are about 800 node-hours. The storage needs distribute as follows: about 5 Tbyte on MiKlip-Server, about 3.7 Tbyte on Lustre (work), and about 3.8 Tbyte in HPSS archive. Thus, the costs for a whole realization of the GCM (56 decades, yearly starts) are about 40000 node-hours, and the storage needs on Lustre (work) are about 200 Tbyte. It should be noted that these values are valid for the regionalization process using the standard version of CCLM_5-0-9. This means, that no alternative or additional Earth-System model component, like an alternative Soil-Vegetation-Atmosphere-Transfer (SVAT) model or an ocean model had been coupled to CCLM.

***Table 1**: computational requirements on MISTRAL for the whole regionalization process of a global decadal hindcast using CCLM_5-0-9. The numbers given there are valid for one whole decade*

Script Package	Nodes used	Costs (Node-h/year)	Disk storage (Tbyte)
Preselection	11	22	5.0
Pre-Processor INT2LM	1	6	1.0
CCLM	25	750	2.2
Post-Processing	1	3.5	0.8
Archiving of CCLM output	1	12	2.0 in HPSS
Archiving of Post-Processed CCLM data	1	2	0.8 in HPSS
CMORisation	1	5.1	0.3 on MiKlip server

It should also be noted that the consumption of requested compute time strongly depends on the availability of the output data of the global GCM hindcasts. Therefore, it is hard to foresee how much computation time will be consumed per 3 months, and a “uniform distribution” of the granted compute time over the 4 quarters of a year is nearly impossible.

2. Objective: Predictive potential of land surfaces (WP: C1-WP2)

Marcus Breil (KIT), Gerd Schädler (KIT)

Workpackage C1-WP2 contributes to MiKlip II Module-C by investigating the predictive potential of land surface processes on the European Climate. For this, simulations with COSMO-CLM (CCLM) coupled to different soil-vegetation-atmosphere transfer schemes (SVATs) are performed and analyzed. By coupling the alternative SVAT VEG3D with CCLM via the OASIS3-MCT coupling software during MiKlip I, it could be shown that the used SVAT and the soil initialization affect the predictability of quantities like near surface temperature and precipitation in Europe and in Africa. Within MiKlip II, this potential for improvement of regional decadal predictions is further explored.

In the report period a transient stand-alone simulation with VEG3D, driven by ERA-20C reanalysis for the period 1955-2010, was performed, to provide soil water and temperature fields for the initialization of CCLM hindcasts for Europe. Additionally, the VEG3D source code and the model settings were further optimized to improve the robustness of the simulation results.

Furthermore, the impact of soil and vegetation processes on the uncertainties in regional climate predictions was investigated, by using stochastic soil and vegetation parameterizations in coupled CCLM-VEG3D simulations, driven by ERA-Interim for the period 2001-2010. For this, soil and vegetation parameters are randomly varied, within a sensible range, to create a stochastic ensemble representing the influence of these parameters on the simulation results.

The analysis revealed that the large scale circulation over North Africa and Southern Europe is strongly affected by the local soil water conditions. Fig. 2.1 shows how differences in the soil water content can lead to deviating near surface temperatures and precipitation sums between an unperturbed reference run and the stochastic ensemble. Due to lower soil water contents in North Africa in the reference run (Fig. 2.1a), the evapotranspiration rate decreases (Fig. 2.1b) and the near surface temperatures are increased (Fig. 2.1c). The resulting warm and dry air mass over North Africa is subsequently transported to the Iberian Peninsula by an anticyclonal flow, reducing the precipitation sums in Southern Europe (Fig. 2.1d).

In addition, it could be demonstrated that stochastic soil and vegetation parameterizations in coupled CCLM-VEG3D runs improve the simulation of monthly rainfall sums all over Europe, in particular the simulation of summer precipitation inside the continent (Fig. 2.2). This can be explained by a better representation of the large variability of land-atmosphere interactions within the stochastic ensemble compared to the unperturbed CCLM-VEG3D reference run.

The results of this study are summarized in a research article and have been submitted to the Journal of Hydrometeorology (Breil and Schädler 2016). The article is currently under revision.

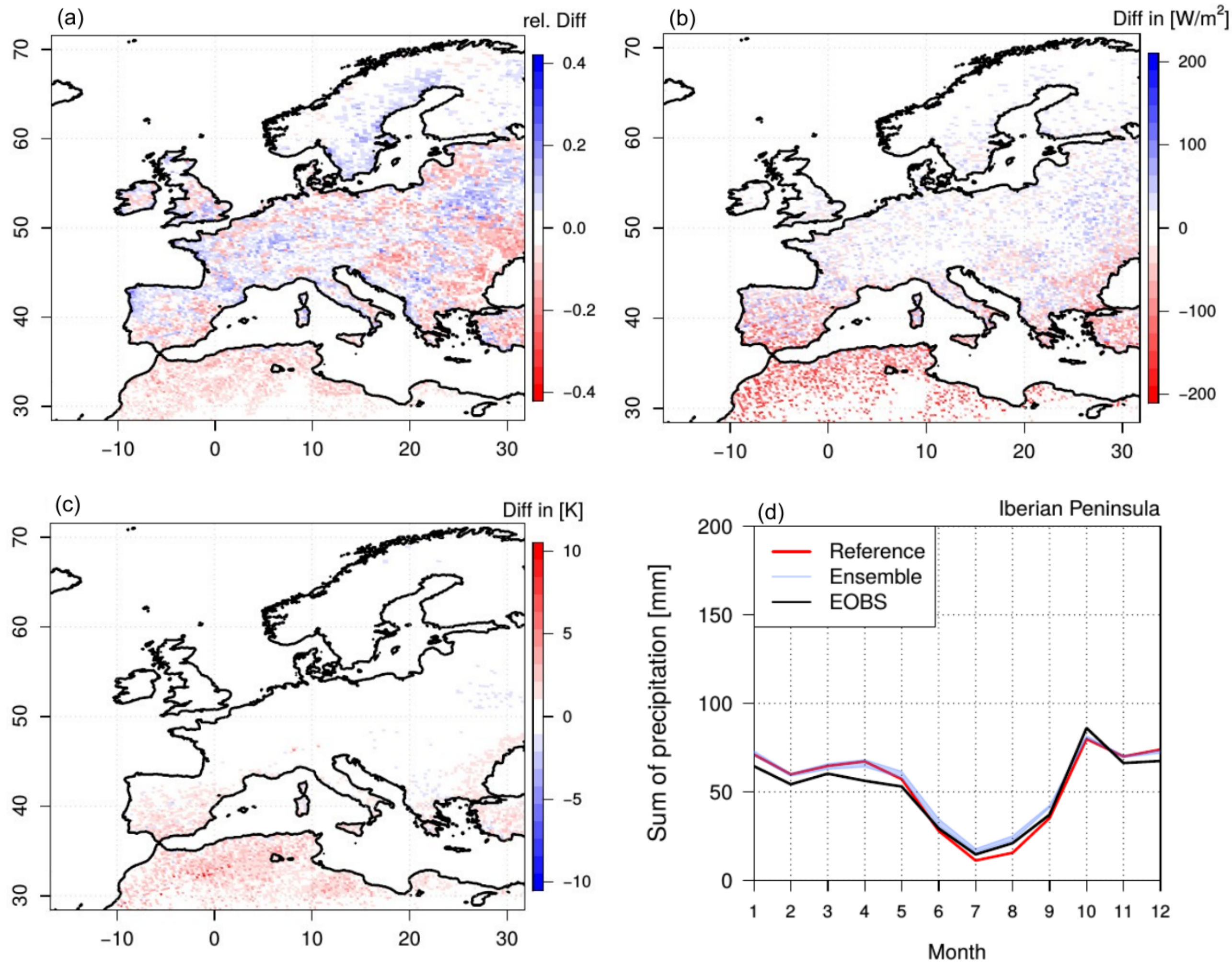


Figure 2.1: *Differences between CCLM-VEG3D reference run and the stochastic VEG3D ensemble in July for the period 2001-2010 for (a) mean soil water content in a depth of 1m, (b) mean latent heat fluxes and (c) mean 2m temperatures. (d) shows the monthly mean precipitation sums in the reference run (red), in the ensemble (blue) and for the E-OBS observations (black) for the Iberian Peninsula.*

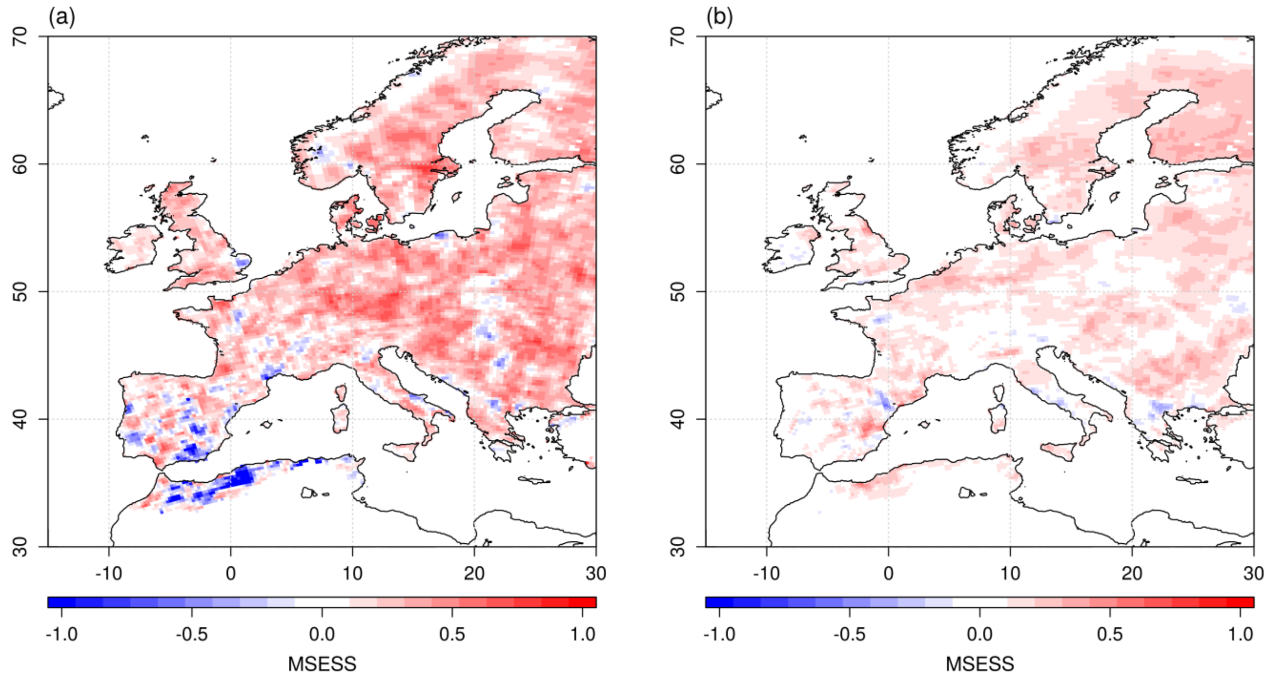


Figure 2.2: *Mean Square Error Skill Score (MSESS) of the stochastic ensemble mean compared to the unperturbed CCLM-VEG3D reference run for the monthly precipitation sums in summer (a) and in winter (b) between 2001-2010.*

3. Objective: Regionally coupled European marginal seas

(WPs: C1-WP1, C2-WP3)

Naveed Akhtar, Anika Obermann, Nora Leps, Bodo Ahrens (GUF)

Overview

1. Coupled models CCLM_CLM+NEMO-MED and CCLM_CLM+NEMO-Nordic and combined system CCLM_CLM+NEMO-MED-Nordic (domains in Fig. 3.1) are updated and tested to the latest versions of atmospheric model and ocean model.
2. A 30 year of ocean spin up for the Mediterranean Sea and simulations forced by the ERA-Interim data are performed from 1979-2015 with ocean spin up state. The other test simulations include the continues runs of coupled system from 1979-2014 initialized with MEDATLAS-II climatology and yearly instillation of ocean with MEDATLAS-II climatology to analysis the importance of Mediterranean Sea initialization on the regional climate. The results of sea surface temperature (SST) and sea surface salinity (SSS) are shown in the Figure 2. The ocean initialization has a small influence on interannual forecasts of SST but strong impact on SSS, which might become important in decadal forecasting.

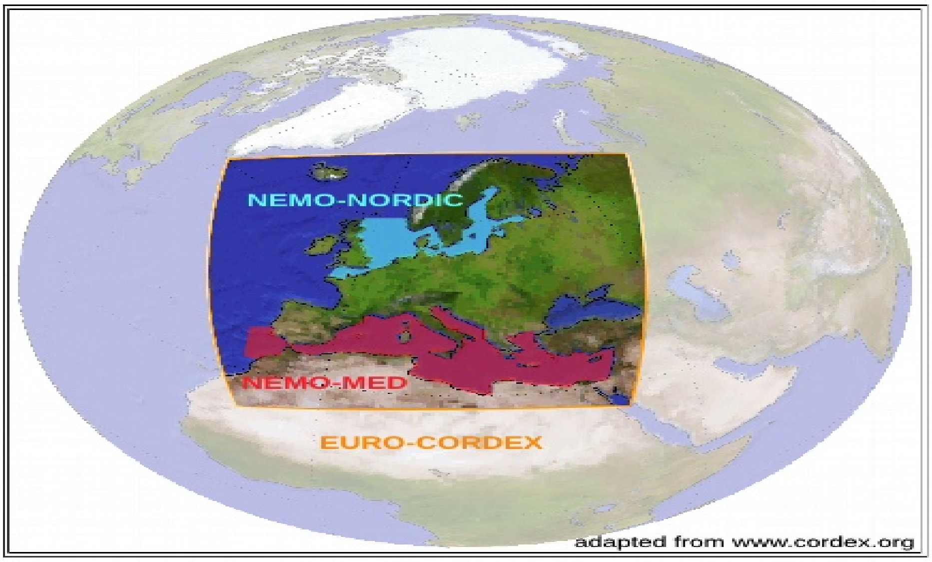


Figure 3.1: *Domain of atmospheric model (square box) and coupled Marginal Seas (red and light blue)*

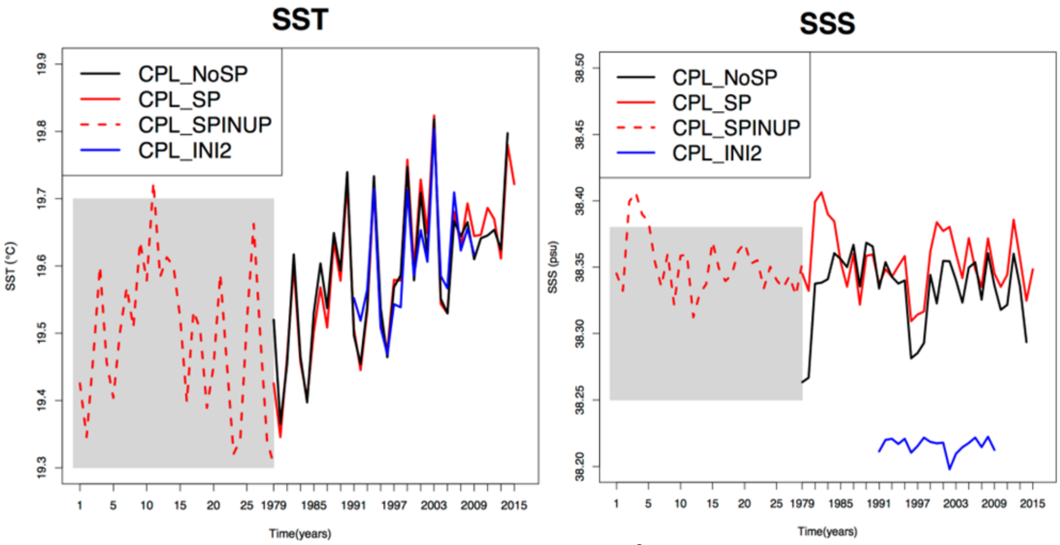


Figure 3.2: *(a) Sea surface temperature (^{o}C) and (b) sea surface salinity (psu) in CPL_SPINUP (random year coupled simulations for ocean spinup; 30 years), CPL_SP (coupled simulations with ocean spin-up state; 1979-2015), CPL_NoSP (coupled simulation initialized with MEDATLAS-II data; 1979-2014), CPL_INI2 (coupled simulation initialized with MEDATLAS-II every year in June; 1990-2009).*

Future plans

1. The combined coupled system (CCLM_CLM+NEM-MED-Nordic+TRIP) will be run over the ERA-Interim period for testing and validation
2. Finally, combined coupled system will be used for centennial simulations with MPI-ESM data

4. Objective: Decadal predictability of user-relevant variables
(WP: C2-WP1)

Joaquim G. Pinto, Mark Reyers, Julia Moemken, Benjamin Buldmann
(Institute for Geophysics and Meteorology, University of Cologne)

The aim of the sub-project C2-WP1 of MiKlip Module C is to quantify the decadal predictive skill of user-relevant variables and the added value of downscaling for their predictability. To reach these goals, the large MiKlip-Ensemble is consecutively analysed.

First, a list of variables which are potentially relevant for users has been pre-defined. Further variables will be defined in cooperation with users from different economic and governmental fields. Currently, the list of variables comprises heat extremes, heavy precipitation potentially leading to river floods, climate conditions for winegrowing, and ruinous wind gusts (in cooperation with the Provinzial Münster). For all variables focus is given to Central Europe.

In the report period, downscaling methodologies for daily maximum temperature (Tmax) and for precipitation have been developed. An analogue-methodology (AM) is used for precipitation. In this methodology several analogue days in the past will represent a specific 'problem day'. The analogues or most similar days are chosen based on a pseudo-euclidian distance. To overcome the tendency of this method to flatten the results, several statistical constellations were used. Basically analogues are not related day by day, but rearranged inside of a cluster of several days. As predictors the geostrophic wind at 1000hPa and 500hPa, based on ERA-Interim geopotential heights, are used. The target variable is daily precipitation, based on E-OBS. Different sensitivity studies are currently performed to find the optimal settings for the application in MiKlip. First results suggest that less cluster days, but more analogues per day improve the daily time-correlation, whereas no further significant improvement is found for a number of analogues of more than 30-40 (Fig. 4.1).

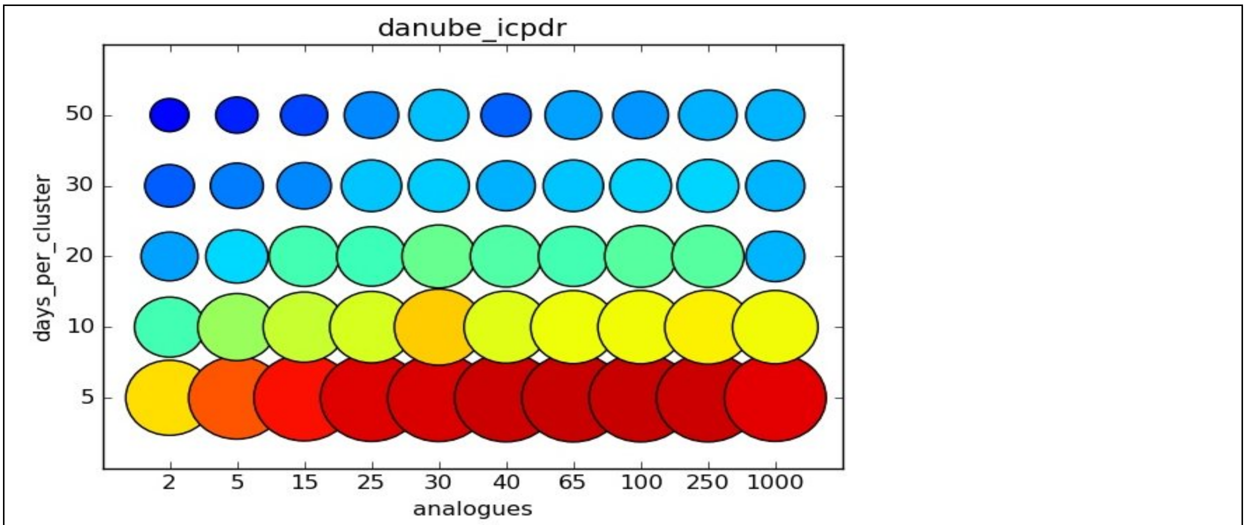


Figure 4 1: *Daily time correlation for the Danube catchment with different settings of days per cluster and analogues per day. Correlation values range from 0 (dark blue) to 0.6 (dark red).*

The downscaling procedure for Tmax is based on a multiple linear regression (MLR) using large-scale 2m-temperature at 12 and 18 UTC and temperature in 850hPa at

12 UTC as predictors and Tmax of E-OBS on 0.25° resolution as predictant. The MLR for Tmax has been trained for the odd years of the ERA40 and ERA-Interim period 1961-2014. For the even years MLR simulated Tmax has been validated against Tmax from E-OBS. For this validation the hit-rate and false alarm rate for summer days (here defined as Tmax ≥ 90th percentile) have been determined (Fig. 4.2). The hit-rate is generally high, and best performance is found for the Northern part of Germany and for the Netherlands. The false alarm rate with values mostly below 1% is very low across the complete investigation area. Altogether, the MLR simulates realistic local Tmax values across mid Europe. To analyse the decadal predictive skill for heat extremes in the MiKlip system, the MLR has been first applied to the baseline1 ensemble. The resulting Tmax values have been bias corrected to ensure that the mean values as well as the high percentiles are similar to the observed statistics from E-OBS. As prediction skill metrics we have used the mean square error skill-score MSESS (for mean Tmax) and the correlation coefficient (for summer days and for heat waves, here defined as of at least five consecutive days with ≥ 90th percentile). For mean Tmax highest skill-scores are found for the Northern and Eastern part of Mid-Europe, and for short lead times (Fig. 4.3). A high ACC is found for the number of summer days and the number of heat waves, but this is mainly related to the long-term trend. For the de-trended time-series a positive correlation is restricted to the western part of Germany and to short lead times (Fig. 4.3). These results suggest that the general trend of heat extremes is captured by the baseline1 ensemble, while the decadal predictive skill for peaks due to natural variability is lower. The MLR is currently applied to the prototype ensemble to analyse the effect of different initialisation methods on the prediction skill and to enhance the ensemble size.

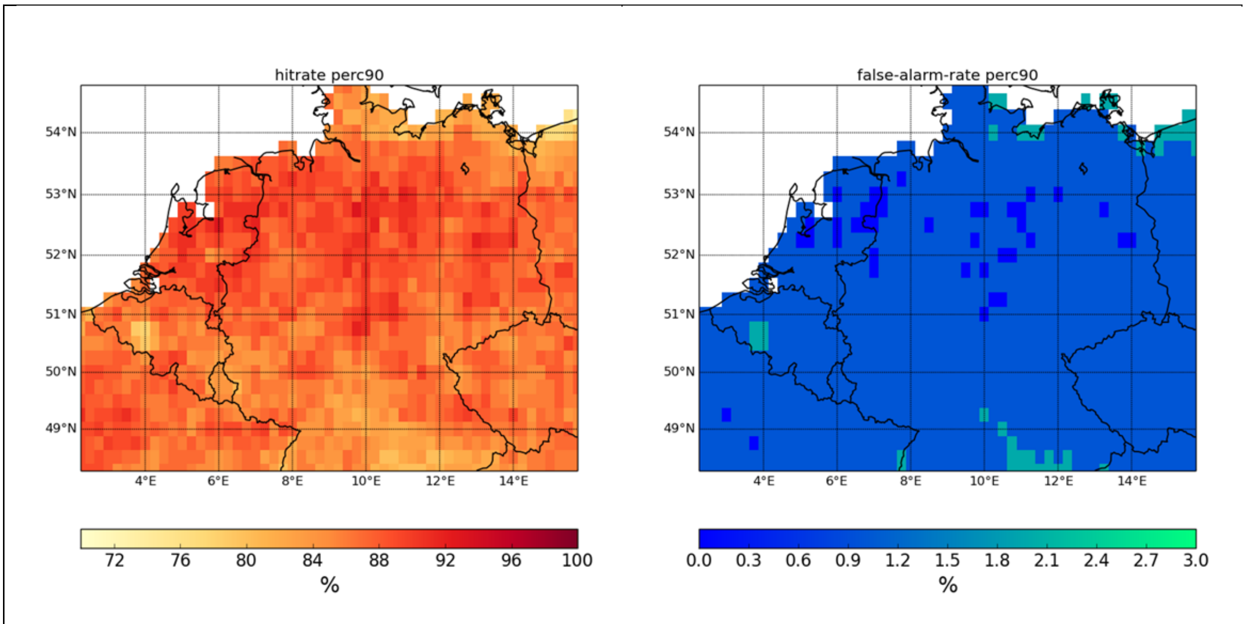


Figure 4.2: *Hit-rate (left) and false alarm rate (right) for the validation years of ERA40 and ERA-Interim for MLR simulated summer days (Tmax ≥ 90th percentile) versus E-OBS.*

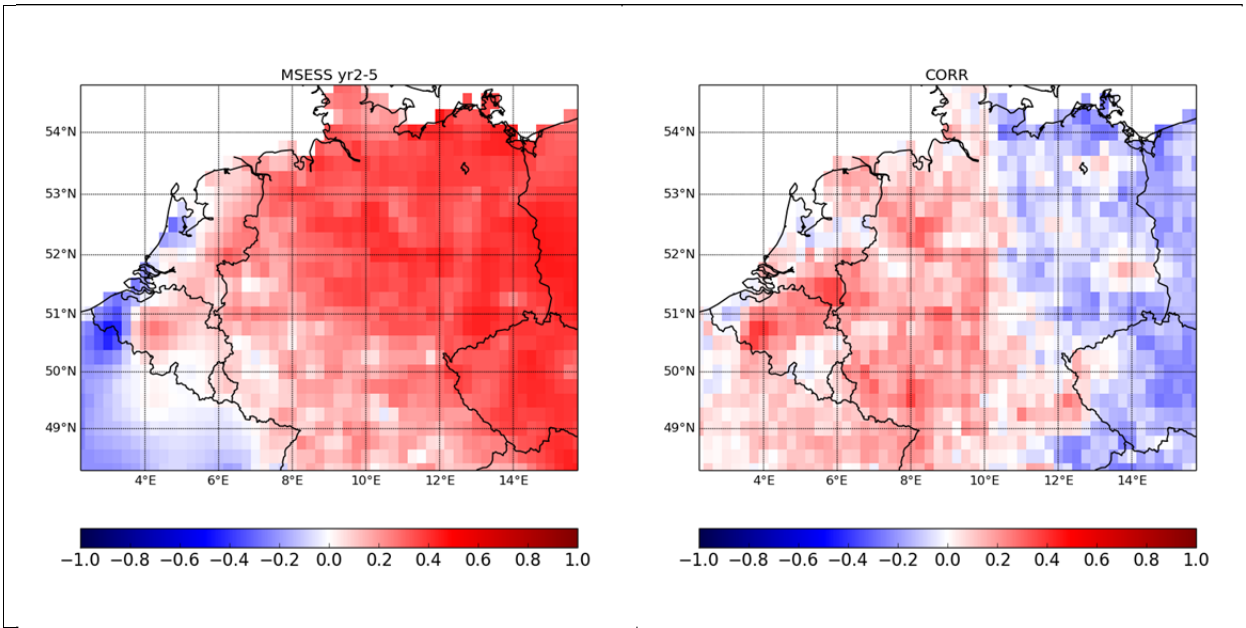


Figure 4.3: *MSESS for mean Tmax (left) and ACC for summer days (Tmax ≥ 90th percentile, right) for year2-5 of baseline1.*

For the assessment of the climate conditions for winegrowing a simple indices which is based on precipitation, temperature, humidity and parameterized soil water content will be used. The respective computation procedures are currently prepared.
For wind gusts, we will first apply a statistical downscaling tool, which has already been developed in the first phase of MiKlip. For further applications we will also use the newest regional MiKlip ensemble, which is simulated with COSMO-CLM on 0.25° resolution and is permanently updated in coincidence with the generation of the new global pre-op MPI-ESM-HR hindcasts. However, the exact course of action in this topic will be coordinated with the Provinzial Münster in regular meetings and audioconferences.

5. Objective: Centennial Hindcasting **(WP: C2-WP3)**

Hendrik Feldmann (KIT), Naveed Akhtar, Bodo Ahrens (GUF)

Often time-series of climate extreme indices exhibit (multi-)decadal variability or trends. To attribute these signals either to climate change or natural climate variability is uncertain. Since the natural variability within the climate system overlays the climate trends, it affects the climate change signals derived from model simulations even if they are generated over climatological (e.g. 30 year) periods. This attribution is crucial to the aim of MiKlip, because the confidence regarding the expected skill depends on how good the mechanisms behind the predictability are understood.
The historical period covered by reliable observations on the European scale or by CMIP/CORDEX type historical climate simulations usually just covers the second half of the 20th century, at best. But, this period is already affected by the climate trend. Furthermore, the periods are shorter than that of the leading multi-decadal variability indices, like the Atlantic Multi-decadal Oscillation (AMO), which is calculated from de-trended sea-surface temperatures of the North Atlantic. An extension of the examination period could provide valuable information on the attribution.
A regional downscaling for Europe has been performed with CCLM for the whole 20th century (simulation period 1901 – 2010) by downscaling MPI-ESM global

simulations which assimilate ensemble members from the NOAA-ESRL 20th century re-analysis (Compo et al., 2011; provided by the MiKlip project DROUGHTCLIP; Müller et al., 2014). These simulations improve the coverage of different phases of the AMO and other climate variability pattern and their impact on the European climate.
The long-term re-analysis products only use surface observations. Therefore, they do not provide as good estimates of the atmospheric state as recent-time re-analysis products, such as ERA-Interim. In addition, the evaluation of the results is more uncertain due to the lack of a dense observation network in the first half of the 20th century. This study uses several gridded observation and re-analysis products to evaluate the model results and to examine the consistency of different sources. The correlation between our ensemble and the reference data vary with respect to time, region and data source (Fig. 5.1). The general temporal evolution with a warming until the 1940s and a stagnation to slight cooling until the 1970s followed by a stronger warming afterwards is reproduced in all reference data sets as well as in the CCLM ensemble. The highest correlation was found for the ensemble mean of the HadCRUT4 observations with correlation coefficients above 0.8 in Western Europe to about 0.6 in Eastern Europe. This is roughly in line with the correlation between to reference data sets.

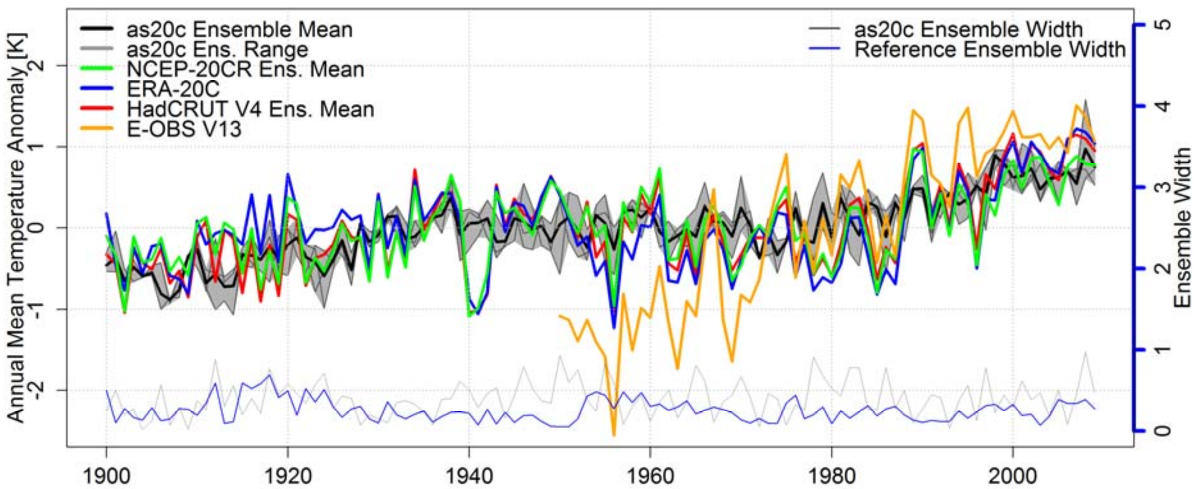


Figure 5.1: *Annual mean 2m-temperature anomalies 1900 – 2009 for Europe. CCLM as20c ensemble and reference data. Lower part and right axis: Width of the as20c ensemble (grey) and of the reference data (blue).*

Analysis of extreme value indices indicates different variability pattern in different parts of Europe. For some of the parameters recent trends exceed the variability detected for earlier periods. Often these indices correlate with the AMO index. Thus, there seems to be an impact of the natural climate variability on these extremes. For temperature derived climate indices – here the summer days (SU, days with T_{max} < 25°C; Fig 5.2) as an example - the climate trend is the dominant driver of the rising trend throughout most of the century. The effect of the natural variability represents itself mostly in phases with AMO switching into the positive mode (1920s-1930s and 1980s-1990s) with a growth of the number of summer days. During times with AMO in negative phase SU has no clear trend.
For precipitation based climate indices there is a stronger correlation with the AMO index (Fig 5.3). For example the number of days per year with more than 20mm/day show distinct maxima in phases of AMO+ (1930s/1940s and 1990s/2000s) and lower numbers in AMO- phases in between. There are some indications, that precipitation

intensities are higher in the recent AMO+ phase compared to the earlier phase in the first half of the 20th century. This might be an effect of the climate trend, but this has to be examined further.
The next step for this objective is to perform initialized regional hindcasts for the extended period to better determine the predictive skill in different AMO phases. This hindcasts have been started but are expected to be finished in 2017.

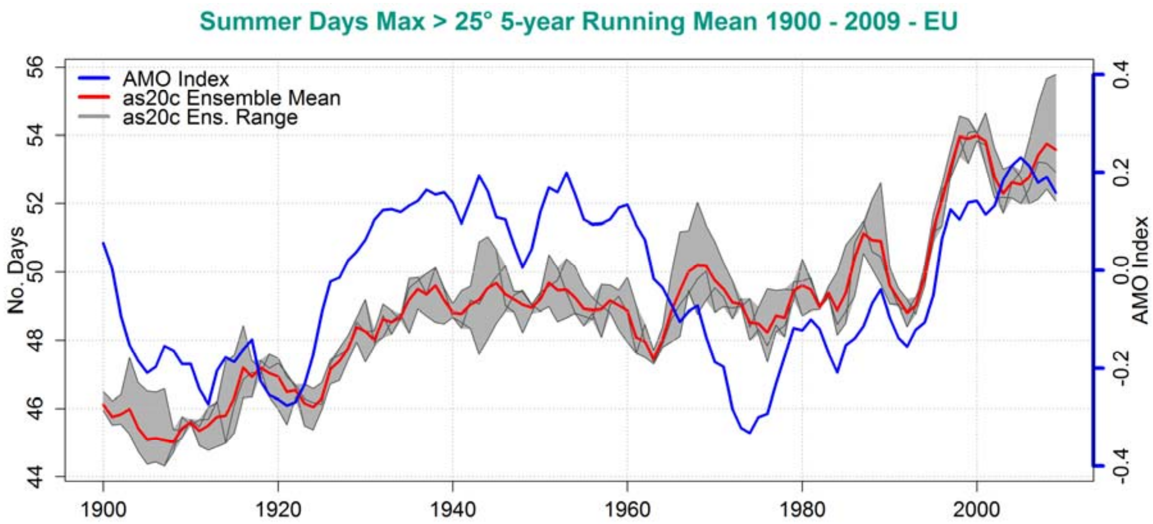


Figure 5.2: *Summer days in Europe (No. of days per year with T_{max} > 25°C) derived from the CCLM as20C ensemble compared to the AMO index (derived from observations).*

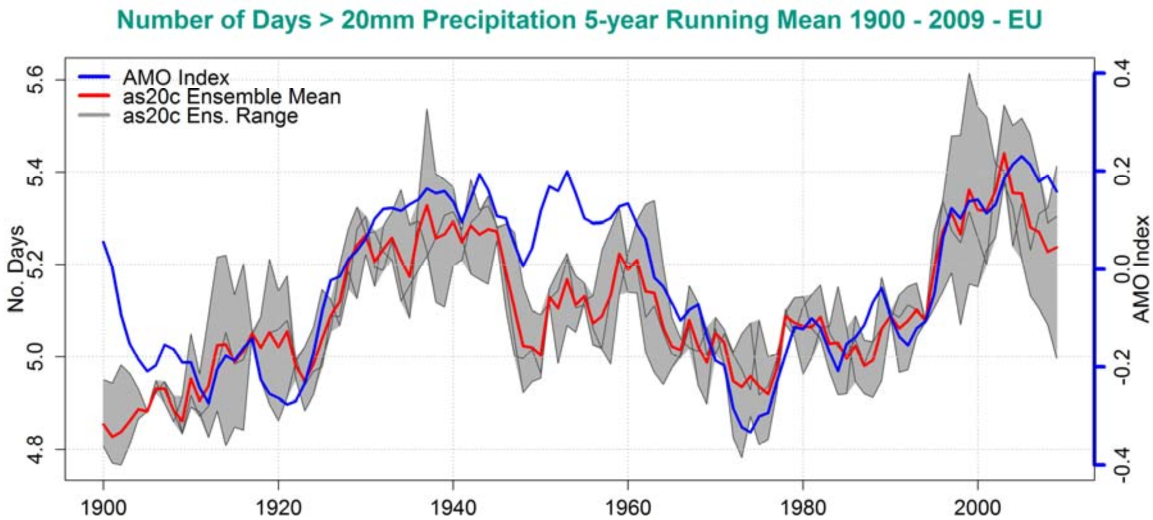


Figure 5.3: as Fig 5.2 but for No. of days with more than 20mm precipitation..

Project publication

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Feldmann, H., Uhlig, M., Kottmeier, Ch. (2016): Regional decadal predictions for Europe in MiKlip. Oral presentation COSMO/CLM/ART User Seminar 2016, Offenbach, 7.-9. March, 2016.

Feldmann, H., Uhlig, M. Kottmeier, Ch. (2016): 20th century downscaling simulation with CCLM – decadal variability of climate extremes. Poster 11th CLM Community Assembly, Lüneburg, 20 – 23 September 2016.

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Li, J.., Paeth, H., Pollinger, F., Panitz, H.-J. (2016): Bias Correction of CCLM simulated temperatures and precipitation in Europe using cross validated model output statistics. oral presentation, Berlin Workshop on Bias Correction in Climate Studies, Oct, 4th - 6th, 2016, Berlin

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