Climate Limited-area Modelling Community

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Newsletter

No. 20

Content

See YOU at

ICCARUS 2023

06 – 10 March

Offenbach, Germany / hybrid meeting

Announcement:

CLM Assembly 2023

18 – 22 September 2023

Leuven, Belgium

Dear colleagues,

Welcome to the 20th CLM-Community Newsletter!
The Newsletter celebrates its 20th anniversary. Happy birthday!

The first CLM-Community Newsletter was published in August 2013 and since then, a new issue was created every six months. After the 10th anniversary in February 2018, we can now already celebrate the 20th anniversary of the community newsletter.
Over the years, the newsletter brought many interesting interviews with some background information on different community members, information about important community topics, updates on the activities in IPCC, CMIP and CORDEX and of course about 40 articles in our category "Research Notes", that always provided very interesting insights in the research and findings of many community members. Thank you very much to everybody who contributed to the newsletter in one or the other way in the last 10 years!
The current issue of the newsletter contains an interview with Klaus Keuler from BTU Cottbus, an update on the CORDEX activities, a review of the CLM Assembly 2022 and outlooks to ICCARUS 2023 and the ICON training course in March. Furthermore, there is a brief introduction of the new working group Model Development (MODEV) by Mariano Mertens from DLR, an update on the new wiki and chat functionality of the community portal from Philipp Sommer (Hereon) and, as always in the last 19 issues of the Newsletter, two research notes. The first research note was provided by Naveed Akhtar and Beate Geyer from Hereon and analyses the impact of wakes generated by the offshore wind farms on power generation and near-surface climate in the North Sea. The second research note is a contribution from Emmanuele Russo from ETH Zurich and discusses the long-standing dilemma of European summer temperatures at the Mid-Holocene.
Enjoy reading!

Yours sincerely,
Susanne Brienen, Anja Thomas and Christian Steger

Five questions to…. Klaus Keuler

Brandenburg University of Technology (BTU)

Klaus Keuler is senior scientist at the Brandenburg University of Technology (BTU) in Cottbus. He studied Physics, Mathematics and Meteorology at the University of Bonn and finished his first model developments with the Dr. degree in natural sciences at the Meteorological Institute in 1989. Afterwards he moved to the Fraunhofer-Institute for Atmospheric Environmental Research in Garmisch-Partenkirchen and started here with the development of regional climate models. In 1997 he moved to the BTU in Cottbus to establish a regional climate modelling group together with the former head of the institute, Prof. Eberhard Schaller. He is one of the initiators of the CLM-Community, enabled the initial coordination by a project funding from the BMBF and contributed to several climate projection programs for Germany like DEKLIM, ReKlies-De, RegIKlim and to the coordinated regional downscaling experiments for Europe, the Euro-CORDEX initiative. Besides his scientific activities, he also teaches students in the field of environmental sciences.

1. *Klaus, you work at the Brandenburg University of Technology Cottbus-Senftenberg in the group Atmospheric Processes. Can you please tell us something about the institute, the work of the group and your tasks there?*

The general focus of our institute is on interactions between the land surface and the atmosphere. The research has a substantial experimental component. Model simulations are used to improve the understanding of the underlaying exchange processes, but also to investigate regional climate characteristics and their spatial and temporal variation. The current focus of my working group is the generation of new, high resolution climate change scenarios for Germany from global CMIP6 simulations. We particularly analyse the bandwidth of the simulated changes and the impact on extreme precipitation.

2. *You are a member of the CLM-Community from the very first day. How do you see the development of the community over time and which occasions come to your mind when you think about the last two decades?*

The rapid growth of the community and its diversity is very impressive and was not expected by me in the early days. Despite this diversity and all the individual research projects of the community members, the central ideas of cooperation, mutual support, and further development of the jointly used regional climate models, should always play an important role in our community. Especially for central tasks like the evaluation of new versions and further model improvements, I would like to see a broader active support by more community members in the future than is currently the case.

3. *Actually, you participated in the COSMO-CLM development already before the CLM-Community was established. Can you please tell us something about the motivation for the development, the development process and which major problems in regional climate models remain until today in your opinion?*

I started with my first climate model developments in the early 1990s within the Bavarian climate research program BayForKlim. The idea of regional climate simulations was still very new at that time. But I quickly recognized that the development of such models is a big challenge and can only be successfully realized in a larger group of scientists with different expertise. Therefore, I decided to join the REMO group first. When the idea came up to use the brand-new Local Model (LM) of DWD also for regional long-term simulations, we joined forces at BTU with colleagues from PIK, HZG (now Hereon), and a little later also from KIT to extend the weather forecast model to a regional climate model and to compare its quality with that of REMO. This strategy was successful and led to the model(s) we use in our community today. The main problem, I see for our model, is that it is only an atmospheric model. The global ESMs are already much further in considering more components of the earth system. As their resolution continues to increase, it seems necessary to expand our regional climate model into a Regional Earth System Community-Model as soon as possible. The necessary capacities and components are available in our community. In my view, this would be the major challenge for the coming years in order to remain internationally competitive.

4. *You were also very active in the ICON-CLM development and led the project group ICON for many years. What were, in your opinion, the main problems and successes in the process and which parallels or differences do you see to the COSMO-CLM development twenty years ago?*

One of the main problems was again the technical extension of the NWP version into a climate model, such as the consideration of time-dependent greenhouse gas concentrations and SSTs or the calculation of additional diagnostic quantities. Much of what we had already incorporated into COSMO-CLM was unfortunately not transferred in the development of the regional ICON version. Therefore, a lot of work and testing had to be done again for ICON-CLM. Due to extensive experiences with COSMO-CLM, the big support by DWD colleagues, and because we had already expected many of the problems that occurred, it was a bit easier this time. The performance of the new model seems now comparable to that of COSMO-CLM, so that we dare now to downscale some climate scenarios of the CMIP6 ensemble even if not everything works to our full satisfaction yet. However, I am convinced that the simulation quality can be further improved by suitable adjustments of the model configuration, especially at higher resolutions in the km range. But we should never feel too safe from new surprises.

5. *You will (unfortunately) retire in a not too distant future. Do you already have plans for your retirement?*

First of all, I will take more care of my health and do more sports again. I also hope to have more time for my other hobbies, like attending more cultural and sporting events, expanding my wine cellar and wine knowledge, and reanimating my rudimentary keyboard skills. And I hope I have enough lifetime left to observe the ongoing climate change and compare it to our projections. And when the first results of ICON-ESM are available, I would like to attend another CLM-Community Assembly to see the results.

Thank you very much for the interview!

Brandenburgische
Technische Universität
Cottbus - Senftenberg

CORDEX activities

Update (EURO-)CORDEX and CMIP6 downscaling

Christian Steger (Deutscher Wetterdienst)

In The “EURO-CORDEX experiment design for dynamical downscaling of CMIP6” has been published at the end of September. The suggestions for the GCMs that should be used as boundary conditions and the variable list had already been published before. Thus, the most important information for the configuration of the regional models and the production of the simulations are now available. The only open issue is the archive specifications document, but this doesn’t affect the model configuration and framework for the simulations directly and is only necessary for the postprocessing and standardization of the data before the publication.

The CLM-Community internal naming convention for the standardized CORDEX data will be the same as in CORDEX-CMIP5. This means that the institution_id will consist of “CLMcom” and the shortcut of the institution that has produced the simulation, e.g. “CLMcom-KIT” or “CLMcom-BTU”. A document with detailed information about the naming conventions is in preparation and will be finalized as soon as the information about the archive specifications for EURO-CORDEX are available.

The community makes also very good progress in the preparation for the downscaling in the last months. We decided already on the contributions of the member institutions. The CLM-Community will use COSMO-CLM and ICON-CLM for the downscaling and will contribute to the EURO-CORDEX balanced matrix with simulations driven by MPI-ESM1-2-HR, EC-Earth3-Veg, MIROC6 and CMCC-CM2-SR5. The overview of the contributions from the community is available here:
https://docs.google.com/spreadsheets/d/1ucEdjdygFBJS_WLvbNis1rywmptSZcutqRkWaZI1SVY/edit#gid=634702028

The converter programs for the preparation of the boundary data for the four GCMs that have been chosen for the downscaling in the first phase are ready. Thank you very much to Patrick Ludwig and colleagues from KIT and Mario Raffa and colleagues from CMCC for the work. Some of the caf files for the different GCMs and scenarios that are used as input for COSMO-CLM and ICON-CLM have already been produced and are available in the /pool/data project at DKRZ.

→

The remaining scenarios will follow in the next months. All the data sets will be made available at DKRZ and can be used by all community members who want to run regional climate simulations with boundary conditions from CMIP6. It is important to mention, that the data have global coverage. It cannot only be used for the European domain, but also for other CORDEX domains or for simulations for any other region of the world. If you want to use another GCM for the downscaling or if you have already produced a converter program or caf files for another GCM, please get in contact with the coordination office. It would be very helpful if the software and/or the data could be shared with the community.

The COPAT2 initiative also made good progress and the tests for the configuration of COSMO 6.0 are completed. The information about the recommended configuration will be distributed soon. Thanks go to the COPAT2 team and especially to Ronny Petrik, Emmanuele Russo, Beate Geyer and Klaus Keuler for leading the initiative and/or running most of the test simulations and performing the analyses of the results. Great job!

The same exercise will now be repeated for ICON and we hope to be able to provide the first recommended version and configuration for ICON-CLM in the near future, that the groups can start with the planned simulations for CORDEX..

WCRP CORDEX

Coordinated Regional Climate Downscaling Experiment

Remember!

... part of your scientific success relies on the work of those people providing the reference model setup, maintain the codes, etc. Therefore, it would be more than a sign of courtesy to offer them co-authorships once in a while.

Please, do not forget to state that you used the “COSMO model in Climate Mode (COSMO-CLM)” and, please, also include the statement “COSMO-CLM is the community model of the German regional climate research community jointly further developed by the CLM-Community” in each publication.

Review CLM-Community Assembly 2022

Susanne Brienen (Deutscher Wetterdienst)

The CLM-Community Assembly 2022 took place from 19 – 23 September and was again organized as a virtual meeting. During the five days, 24 oral presentations have been given in seven plenary sessions. In addition, eight working groups (SUPTECH, SOILVEG, ICON, AIO, EVAL, CP, CRCS, CO) met for discussing specific topics, such as the ICON development, the coordinated community contributions to different CORDEX activities, the coordinated model evaluation, the community tools and different physical aspects of model performance. Also, the SAB members gathered for their annual discussion.

In the community meeting on Friday, the PG ICON was closed, because the main tasks of the project group have been completed. It is replaced by the new working group Model Development (MODEV), in which all colleagues who contribute to the model development are invited to meet and discuss related issues regularly. As usual, there have been also discussions and votes for some changes in the community documents, which were mainly necessary because of the new community management tool, the ICON license and the associated development agreement with the DWD. Furthermore, it was decided that the assembly 2023 will take place in Leuven, Belgium. Most of the participants were in favour that the community assembly should go back to a complete in-person meeting as before the COVID-19 pandemic from 2023 on. Working and project group meetings at ICCARUS (which will be in a hybrid format) and in-between can be conducted as video-conferences.

Finally, the CLM-Community says Good-bye and a big Thank-you to Burkhardt Rockel, who has contributed enormously since the beginning of the community to the COSMO-CLM development and numerous other community tasks and who leaves now for his well-earned retirement.

The program, abstracts, some of the presentations and further session material can still be accessed through the community management website:

https://hcdc.hereon.de/clm-community/events/clmcommunity-assembly-2022/

Outlook ICCARUS 2023

Christian Steger (Deutscher Wetterdienst)

ICCARUS (ICON/COSMO/CLM/ART USER SEMINAR) 2023 will be organized as hybrid conference with the aim to provide similar conditions for the participants online and on-site. To achieve this goal, the organization committee has decided on some adjustments compared to the traditional on-site format as well as to the pure online format of the last two years are necessary.

The plenary sessions will take place form Monday, 06 March to Wednesday 08 March 2023. The speakers can give their presentation in the conference area of the DWD headquarter in Offenbach or via the video conference system and both options are of course also available for the audience. The plenary session will again include four keynote presentations that cover different aspects of the ICON modelling framework. The invited talk will be given by Stephanie Johnson from ECMWF. She works on the scientific and technical development of ECMWF's seasonal forecast system and will give an overview of the system and the plans for the upcoming years.

The poster session is scheduled for Thursday afternoon (09 March). The poster session is the most difficult part in a hybrid conference and there is not really a good hybrid solution available. Based on the experiences of the last years, a virtual session seems to be the best option. All participants who attend the first three days of the conference in Offenbach can travel home on Wednesday evening or Thursday morning and should then be able to participate in the online poster session in the afternoon. Gather.town will be used again for the poster session as in 2022. This software worked very good for the meeting last year and allows for direct interaction with the presenters or discussions in small groups and provides an overall experience that is as close to an on-site poster session as one can get in a virtual meeting.

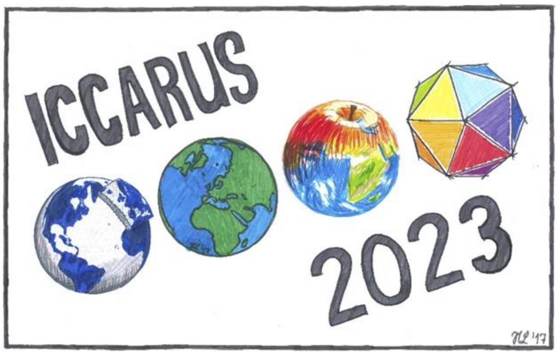
The working group meetings will also be organized as virtual meetings in the weeks before or after the plenary sessions with the aim to fully involve people that cannot travel to Offenbach for the meetings. To keep the personal contact to the colleagues from other institutions at least once per year, the concept foresees on-site meetings of the working groups at the COSMO General meeting and the CLM-Community Assembly, which both usually take place in September.

Another innovation for the working group meetings in 2023 will be the joined session that are structured by topics rather than by community. Historically, several user groups have grown and successfully established their own working group structures around ICON and the COSMO model. These established structures should be opened up with the aim to bring together developers and users from different communities working on the same topic. More specifically, this allows for COSMO and CLM members to get in exchange with other ICON developers. The topics that are suggested should cover all aspects that require exchange between the different communities. For community-internal topics, further internal meetings are of course also possible at any time. The following working group meetings will be organized at ICCARUS 2023:

- Data Assimilation & Ensemble
- Verification & Interpretation (NWP)
- Evaluation (Climate)
- Model Dynamics
- Soil, Vegetation & Land surface
- Chemistry & Aerosol
- Ocean & Coupling
- Atmospheric Boundary Layer
- Radiation & Clouds
- ICON Support Framework
- Runtime environment for experiments
- ICON on GPUs

The registration for ICCARUS 2023 is still open (online participation). For registration and further information, please visit: www.dwd.de/iccarus.

We hope that many of you will come to Offenbach or participate online in the conference, the poster session and the working group meetings and we are looking forward to an interesting conference in a new format.



Training Course 2023

Christian Steger (Deutscher Wetterdienst)

The Numerical Model Training Course 2023 will take place from 27 – 31 March 2023. The upcoming training course will bring several innovations and changes compared to the courses that have been provided in the past.

The last in person training course took place in 2019 in the DWD training centre in Langen. For the CLM part, the course was still based on the COSMO model at the time. In the years 2020-2022 the course could not take place because of the COVID-19 pandemic. The colleagues from the research department at DWD provided an online training with reduced content for NWP in 2021, but only for people who were already registered for the cancelled course in 2020.

The first innovation of the course in 2023 is that lectures and practical exercises will only deal with the ICON modelling framework. The course will be organized in three parallel groups and provide user tailored exercises for ICON NWP for academia, NWP for meteorological services and an ICON-CLM part for regional climate simulations. This is the second innovation, because it is the first time that the course provided by the CLM-Community will introduce the participants to the ICON model instead of the COSMO model.

The third innovation will be that the course will not take place in the DWD training centre in Langen anymore. The training centre hosted the course for many years, but due to access restrictions to the area of the German air traffic control, where the training centre is located, and some other organisational changes and difficulties, it was decided to organize the course in the DWD Headquarter in Offenbach this time. Many of you might know the facilities from ICCARUS. A consequence of the shift to the new location is that there are no computer rooms available anymore and all participants have to bring their own devices and will conduct the practical exercises on their own laptops.

The overall concept of the course, however, does not change. The participants of all three parts (NWP – academia, NWP – meteorological services and CLM) will have lectures about the theoretical background of the ICON modelling framework in the mornings and practical exercises that are tailored for the specific user groups in the afternoons. A social event and maybe also a guided tour through the DWD headquarter will complete the program.

In the CLM part, the participants will learn the basic handling of the model and the runtime environment SPICE. This will include amongst other topics the installation of SPICE, the preparation of grid and external parameter files and setting up the model for a new domain, running the model with boundary conditions from CMIP6 global climate models and the evaluation of the results by usage of the EvaSuite.

More information about the training can be found at www.dwd.de/training. The training team is looking forward to the first ICON-CLM course and hopes that it will be interesting, instructive and helpful for the participants and simplify the use of and the work with the model.

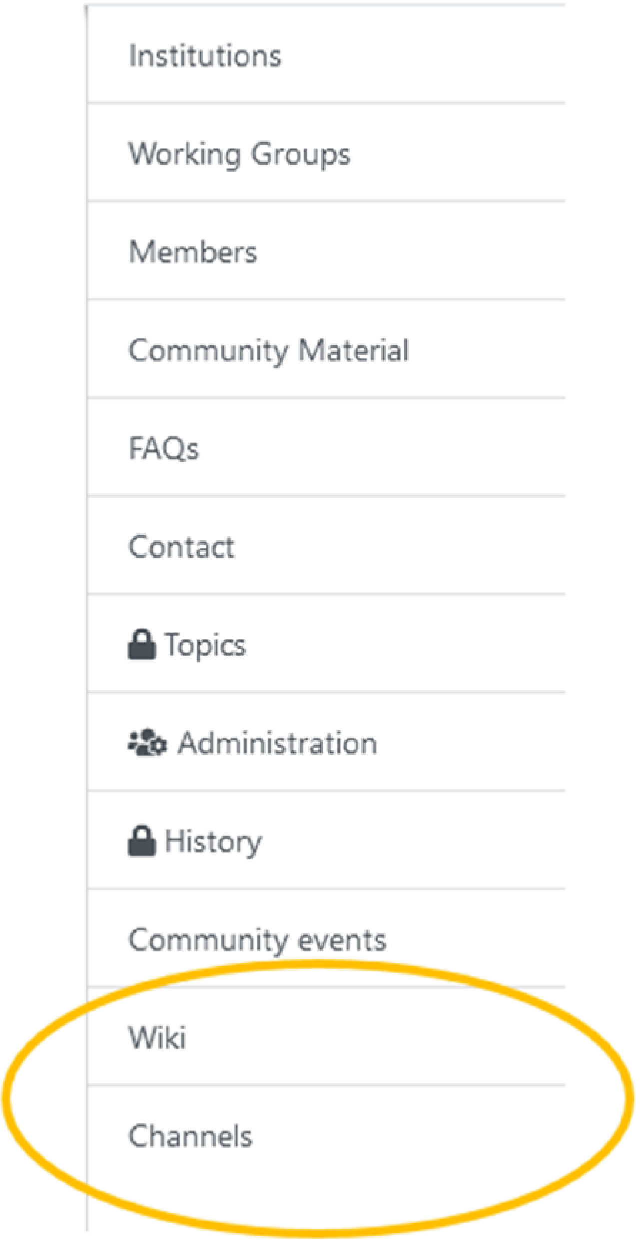
Migration of RedC to the Community Portal

Philipp S. Sommer and Beate Geyer (Hereon)

Last autumn, all content of the old Redmine-Instance at https://redc.clm-community.eu has been migrated to our new community portal at https://hcdc.hereon.de/clm-community. RedC has been taken offline.

The wikis have been migrated manually. You can access them from the Wiki section in the main menu (burger menu in the upper right corner of the community portal). After login, you can see here the wikis of your working/project groups. Each working group leader has the right to edit the wiki. If a regular working group member wants to edit one of the pages, he or she needs to ask the respective working group leader for permissions. To see if you can edit a page, look for a blue button with a pen in the upper right corner, or append a ?edit to the URL of the page. The wiki is created with the content management system django-cms. Please contact Philipp Sommer if you have any questions.

The material that has been uploaded to RedC is now accessible from different points: from the Community Material section in the main menu, from the pages of the corresponding working group, or from the pages in the new Wiki.
All issues, forums and discussions have been migrated to the new channel system in the community portal. They can be accessed from the Channels section in the main menu or from the pages of the corresponding working group.
We also implemented redirects for old issues and uploads on RedC. For any further information to the migration, please have a look at the RedC section in the FAQs.

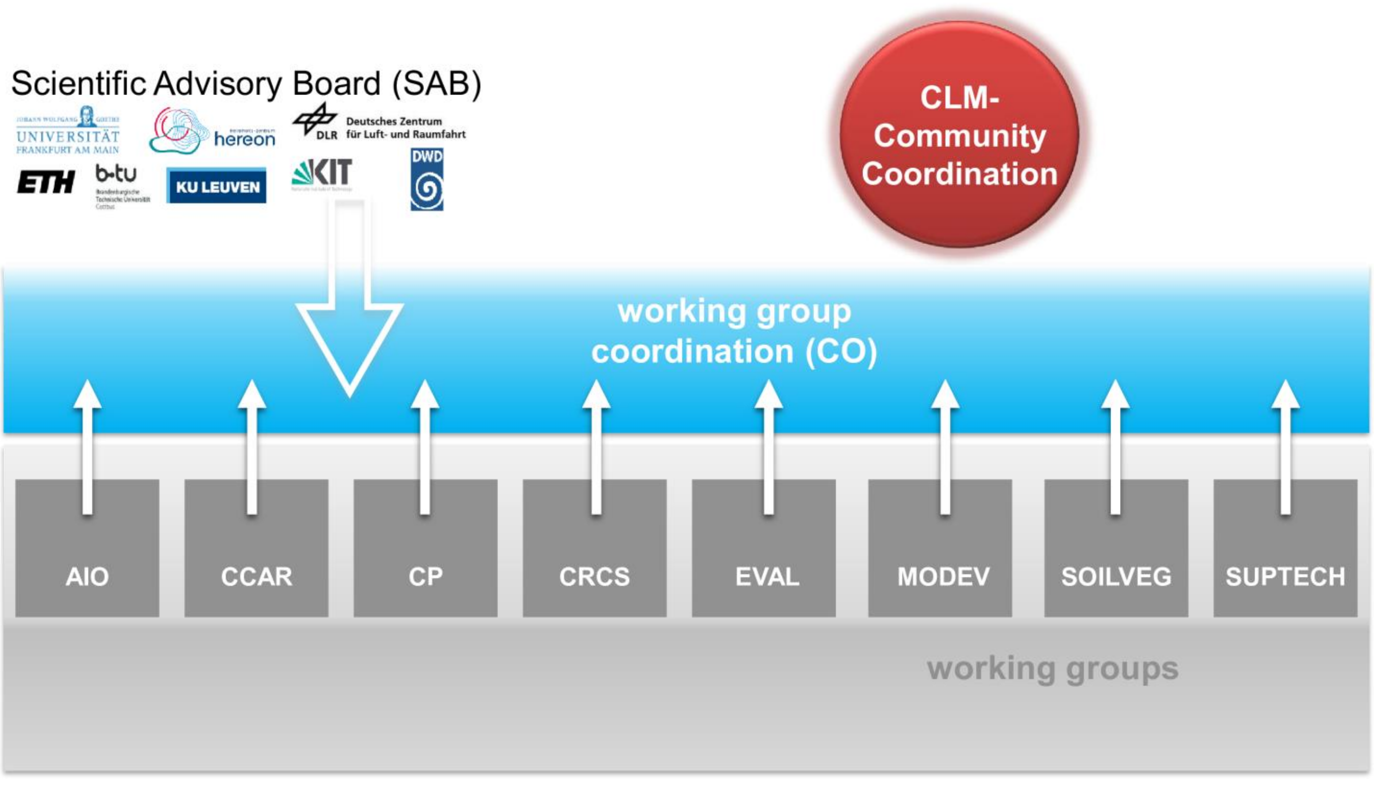


New Working Group Model Development established

Mariano Mertens (DLR)

During the last CLM Assembly the proposal of the new Working Group Model Development (short MODEV) has been accepted by the CLM-Community members. The interim lead of the WG is Mariano Mertens (DLR-PA). The WG MODEV deals with continuous model developments that are ongoing in the CLM-Community. The goal of the WG is to pool the knowledge about ICON(-CLM) within the CLM-Community in one WG. This will enable faster progress of model developments.

The new WG will not be a body that solves model related issues for community members on request, but it will be a platform in which members of the CLM-Community dealing with model developments can exchange their knowledge and support each other. Therefore, the WG MODEV will only be open for members of the community who participate actively in the development of ICON-CLM and/or the CLM tools. A first kick-off meeting of the WG will take place in February during which the terms and conditions of the WG will be further refined. In case you would like to join the WG please contact the coordinator of the working group or the coordination office (clm.coordination@dwd.de).



Impact of wakes generated by the offshore wind farms on power generation and near-surface climate in the North Sea

Naveed Akhtar[1] and Beate Geyer[1]

[1] Institute of Coastal Systems - Analysis and Modeling, Helmholtz-Zentrum Hereon, Geesthacht, Germany

More details can be found in:

1. *Akhtar, N., Geyer, B., Rockel, B. et al. Accelerating deployment of offshore wind energy alter wind climate and reduce future power generation potentials. Sci Rep 11, 11826 (2021). https://doi.org/10.1038/s41598-021-91283-3*
2. *Akhtar, N., Geyer, B. & Schrum, C. Impacts of accelerating deployment of offshore windfarms on near-surface climate. Sci Rep 12, 18307 (2022). https://doi.org/10.1038/s41598-022-22868-9*

Introduction

To fight climate change by reducing carbon emissions wind has become a major source of renewable energy production in recent years. The European Commission aims to install about 450 GW of total offshore wind energy by 2050. Due to strong and reliable wind resources at shallow water depths, a major part of these installations (47 %; 212 GW) will be located in the North Sea1. This has stimulated the rapid deployment of offshore wind farms (OWFs) in the North Sea with an annual consenting rate of 8.8 GW during the 2020s[2]. These massive developments in the North Sea have formed one of the world's hotspots of OWFs. In order to exploit wind resources and to minimize the deployment and operation costs, OWFs are usually clustered around transmission lines. Wind turbines convert a part of the kinetic energy (KE) extracted from the atmosphere into electric power and the rest into turbulent kinetic energy (TKE) that drives wakes (a downwind wind speed deficit and enhanced turbulence)[3–5]. The wake length depends on the atmospheric conditions: in stable atmospheric conditions, a wind farm can generate a wake that reaches up to 50-70 km downwind at a hub height[6,7]. Wakes generated by the upwind wind farms can decrease the power production of the downwind wind farms by obstructing the wind speed and increasing the atmospheric turbulence, which also increases the load on wind turbines and affects their efficiency. An increase in temperature and a decrease in humidity are observed in the wake area[8]. This also reduces the efficacy of the downwind of the wind farms as colder and denser air would deliver more energy compared to warmer and lighter air at a given wind speed. Therefore, wakes generated by the upwind wind farm can undermine the potential of cost-efficient power production of the downwind wind farm. Wakes can also affect the near-surface wind speed and TKE, which can change the turbulent fluxes. Furthermore, enhanced vertical mixing in the rotor area transports cold and moist air aloft leaving dry and warm air in near-surface layers[9,10]. Changes in turbulent and radiative fluxes can modify the energy budget of the atmosphere[11,12].

In the mentioned studies for the first time, we assess the impact of wakes on power production and near-surface climate for the North Sea using both, existing and planned scenario OWFs over a period of 10 years. These 10 years of simulation period allow us to consider the natural variability in the wind climate of the North Sea. We performed two high-resolution simulations, one undisturbed control simulation without wind farms, and one with existing and planned OWFs in the North Sea (Fig. 1). In order to validate the wind farm parameterization, the simulated wake effect has been compared with high-resolution airborne measurements[6] (please read the original publication no. 13). In addition to that, simulated wind speed and wind direction data have been compared with the FINO1 and FINO3 mast measurements[13].

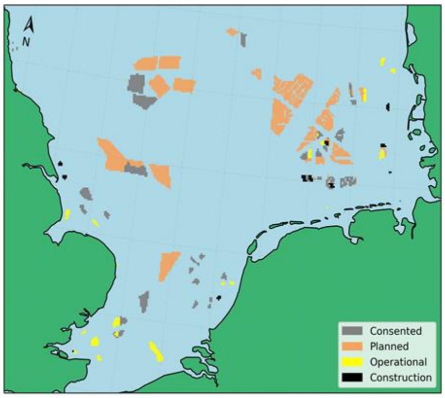


***Figure 1**. Model domain over the North Sea. Shapes of the included wind farms are shown in different colors according to their status, orange polygons indicate the planning status of the OWFs by 2015.*

Data and methods

In this study, we used the non-hydrostatic regional climate model COSMO-CLM5.0[14] to simulate the regional climate of the North Sea. To simulate the wind farm effects, the wind farm parameterization[15] formerly already used by Chatterjee has been reimplemented and further developed in the COSMO-CLM code. The wind farm parameterization represents the wind turbines as a sink of KE and a source of TKE. The wind turbines convert a part of the KE into electric power from each layer intersecting the rotor area, whereas the remaining part is converted into TKE. The amount of the extracted KE depends on the wind speed, thrust, power coefficients, rotor diameter, air density, and wind turbine density in a grid cell. The thrust and power coefficients of a wind turbine depend on wind speed. Here, we used the thrust and power coefficients from a theoretical REPower 5 MW offshore wind turbine[16]. It has cut-in wind speeds of 3 ms-1 and cut-out wind speeds of 25 ms-1, whereas the rated power wind speed is 11.4 ms^{-1}. The wind turbine has a hub height of 90 m and a rotor diameter of 126 m. We used a turbine density of approximately $1.8x10^{-6}$ m^{-2}. As it is not possible to resolve the effects of a single turbine in regional climate models, the effect of the wind turbine within a grid box is estimated using the average grid box velocity.

Here we used COSMO-CLM with a horizontal resolution of 0.02˚ (~2km; 396x436 grid cells) and 62 vertical levels. A third-order Runge-Kutta numerical scheme with a time step of 12 s has been used. The roughness length over the sea has been computed using the Charnock formula[17]. The physics options contained a 1-D prognostic TKE advection scheme for the vertical turbulent diffusion parameterization, cloud microphysics, and a delta-two-stream scheme for long and shortwave radiations. Both the simulations used initial and lateral boundary conditions from coastDat3 atmospheric simulation, 0.11° resolution and ERAint driven. We used a OWF-scenario according to the 2015 planning status[18]. These simulations were performed for a multiyear period from 2008–2017 to cover a range of different weather conditions in assessing the impact of large-scale OWF development on power generation and on near-surface climate. The loss in efficiency of OWFs due to the wake effect is estimated in terms of capacity factor (CF) at 90 m hub height, whereas the impact of wakes on near-surface climate is estimated in terms of sea surface fluxes of heat and momentum. Hereafter, “CCLM” refers to the COSMO-CLM control simulations and “CCLM_WF” refers to the COSMO-CLM simulation with wind farm parameterization.

Results

Wake impact of wind speed and CF

Our discussion here is focused on the dominating southwesterly winds (i.e., 200–280°) in the North Sea. The results show that the reduction in annual mean wind speed reaches up to 2-2.5 ms^{-1} for the prevailing wind direction (Fig. 2). These wind speed deficits can reach up to 3 ms^{-1} on a seasonal timescale.

In the North Sea, the wind speed at hub height varies seasonally, with a basin average maximum of 10-11 ms^{-1} in winter and a minimum of 7-8.5 ms-1 in summer.

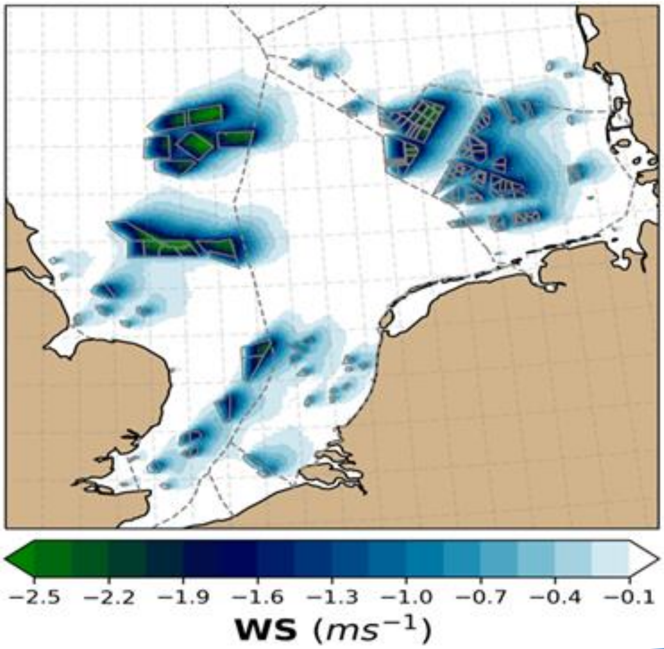


***Figure 2**. Reduction of wind speed at hub height (90 m) for prevailing winds (200–280°)*

The results show that wind speed deficits due to wind farms are higher during spring and summer compared to other seasons. This is due to more stable atmospheric conditions in spring and summer[19,20]. Horizontally, the wakes generated by the wind farms on average reach up to 40-45 km downwind of the wind farms. During stable atmospheric conditions wakes can extend up to 70 km downwind[6,21]. Vertically, the wind speed deficit reaches up to 600 m.

The capacity factor (CF) is defined as ratio of actual output over a given time period to the theoretical possible output of the wind farm. Wakes generated by the wind farms can reduce the CF by up to 22 % in annual mean during prevailing southwesterly winds (Fig. 3). On seasonal time scale this deficit in CF can reach up to 26 %. At a distance of about 35-40 km downwind of the wind farms a decrease of about 1 % is found for southwesterly winds. The seasonal mean values of CF in the North Sea vary spatially from 50-62 %, with a maximum of 65-70 % in winter and a minimum of 37-50 % in summer.

These results show that large clusters of wind farms and large wind farms can substantially undermine the power generation of downwind farms and turbines.

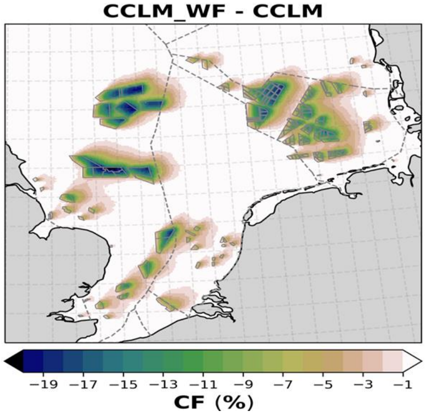


***Figure 3**. Change of the capacity factor as period mean with prevailing winds (200–280°).*

Large OWFs modify the horizontal as well as the vertical structure of the atmosphere within wind farms and wake areas by reducing wind speed and increasing TKE. Wind turbines increase vertical mixing that changes the vertical profile not only within the rotor area but also below the rotor area and approximately 450 m above the rotor area.

Our results show that 10 m wind speed deficits reached up to 1 ms-1 at the wind farm areas in the CCLM_WF for southwesterly winds (Fig. 4). The spatial extent of wake effect at 10 m height is almost similar as found at 90 m hub height. However, an acceleration in 10 m speed (up to 0.5 ms^{-1}) is found at the upstream edge of the wind farms. This acceleration in the 10 m wind speed is more prominent in spring and summer during stable atmospheric conditions. Similar near-surface acceleration was also found in wind farm measurements[22] and model simulations with different models[23,24].

The wind turbines induce TKE, however, a slight reduction in near-surface TKE (up to 0.05 m^2s^{-2}) is found over the wind farm area in the mean values of CCLM_WF compared to those of CCLM. This is due to weak wind shear near the surface because of the wind speed deficit. However, an increase in TKE is also found at the upstream edge of the wind farms in the areas of near-surface acceleration. Our results show that due to increased vertical mixing atmospheric layers below the hub height become drier and warmer whereas moister and colder aloft[25]. Annual mean values show an increase in near-surface temperature of approximately 0.25 °C and decreases in specific humidity of approximately 0.09 g kg-1 (1.3%) in CCLM_WF compared to CCLM over the wind farms. These differences in temperature and specific humidity are more pronounced during spring and summer (see publication no. 2 for more details).

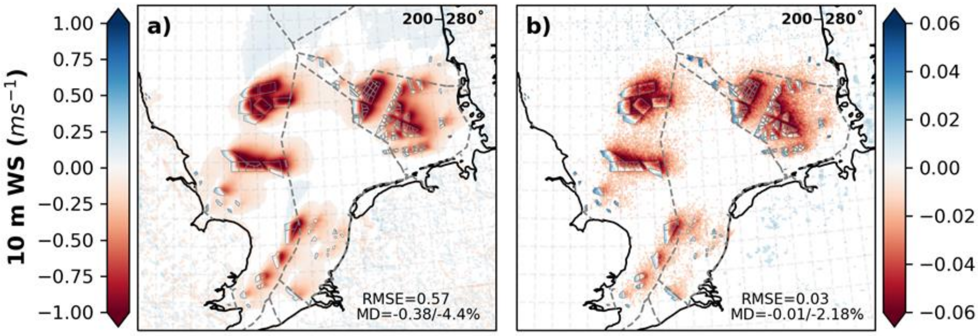


***Figure 4**. Changes in wind speed at a height of 10 m and near-surface TKE for prevailing winds.*

As already mentioned, results show a decrease in 10 m wind speed within and downwind of the wind farms in wake areas. However, due to the channeling effect, an increase in wind speed was found at the upstream edge of the wind farms. This change in near-surface wind speed and TKE alter the turbulent fluxes (Fig. 5). Annual mean values of latent heat flux LH show an increase by approximately 0.9% (total mean difference MD=0.4 Wm^{-2}) in CCLM_WF for the southwesterly winds for the wind farm areas. This increase in mean values of LH in CCLM_WF is due to an increase in LH values at the upstream edge of the wind farms for southwesterly wind. In the case of all wind directions (i.e., 0—360˚) mean values of LH are reduced in CCLM_WF. The annual mean differences of sensible heat flux SH show a reduction of up to 2.5 Wm-2 (MD=-1.9 Wm^{-2}/-28%) in the CCLM_WF compared to those of the CCLM (Fig. 5). Our results indicate that the change in LH is mainly dominated by the change in wind speed and TKE, whereas the change in sensible heat flux SH is mainly driven by wind speed and gradient in sea surface temperature and the lowest atmospheric layer. Wind farms also impact the radiative flux longwave and shortwave radiation by modifying low clouds due to enhanced vertical mixing. About 2 Wm^{-2} (MD=-1.2 Wm-2/-2.5%) reduction in the net surface upwelling longwave radiation LW is found in the CCLM_WF compared to the CCLM over the wind farm areas (Fig. 5). Similarly, net surface downwelling radiation SW decreased in the CCLM_WF compared to that in the CCLM by up to 2.0 Wm^{-2} (MD=-0.8 Wm^{-2}/-1.7%) over the wind farm areas. This reduction in turbulent and radiative fluxes leads to an overall reduction (MD=-1.68 Wm-2/-3.5%) in the surface upwelling net heat NH flux in the CCLM_WF compared to those in the CCLM for southwesterly winds. In the case of all wind directions (0-360˚), the reduction in mean annual values of NH reaches up to -2.0 Wm^{-2} (-63%).

The change in the radiative fluxes over the wind farm area is mainly influenced by the change in low clouds. The annual mean values of low clouds show an increase of up to 0.05 (MD=0.02/4.3%) in the CCLM_WF compared to the CCLM over the wind farm areas. This increase in low level clouds also increase the total precipitation by about 1 mm/month (7%) over the wind farm areas[25].

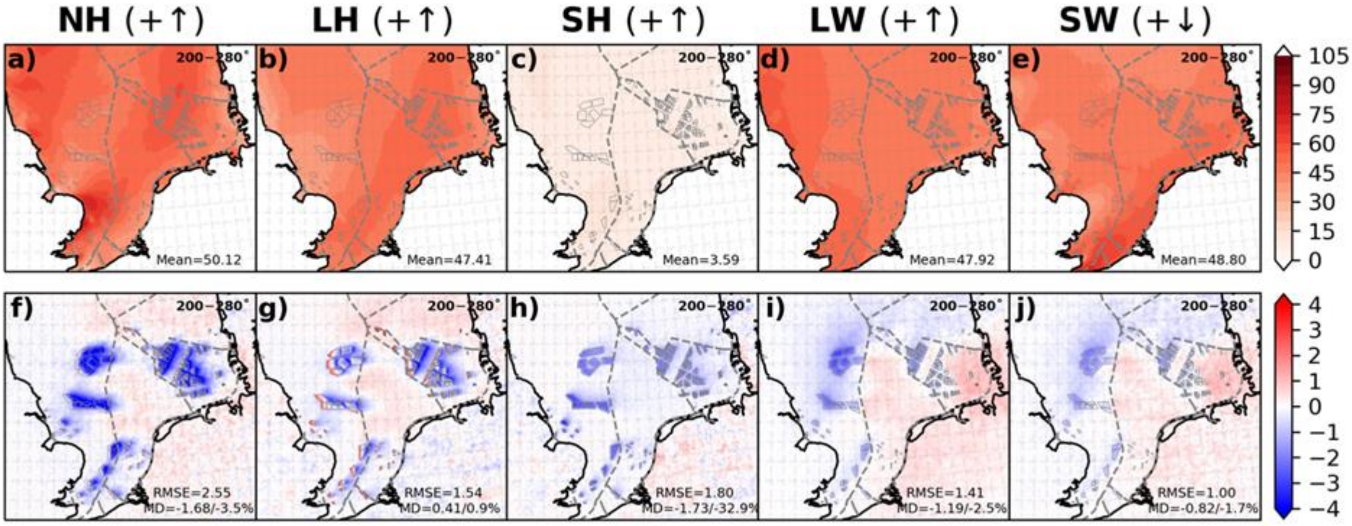


Figure 5*. Absolute mean values (upper row) and differences between WF and control simulation (second row) in net heat (NH) flux (a, f), latent heat (LH) flux (b, g), sensible heat (SH) flux (c, h), net upwelling longwave (LW) (d, i), and net shortwave downwelling (SW) (e, j).*

Conclusions

In this study, we used the COSMO-CLM5.0 model to simulate the wakes generated by large existing and planned OWFs in the North Sea on power generation and near-surface climate. The result shows that on average wake effects can reach up to 35-40 km downwind of the wind farms at hub height. Depending on the wind farm geometry annual mean wind speed deficit within a wind farm can reach 2–2.5 ms^{-1}. This can strongly undermine the efficiency of the downwind of wind farms. The wakes and enhanced vertical mixing generated by the wind farms impact the near surface wind speed and TKE, which in turn effect the near surface climate by modifying the heat fluxes.

The 10 m wind speed is reduced by approximately 7% and the TKE by approximately 5% for all wind directions (0-360°), mainly within the wind farms and in wake area. The annual mean values of NH flux are reduced by approximately 63% over the wind farm areas in the CCLM_WF compared to that of the CCLM for all wind directions (0—360°). This means heating of the atmosphere from the sea surface over OWFs and wake areas is reduced in CCLM_WF compared to CCLM. These impacts of OWFs on sea surface fluxes are generally localized and smaller than the interannual variability of heat fluxes. However, it is comparable in magnitude to present-day climate change impacts.

Our results show a significant change of the surface climate in the vicinity of the OWFs and introduce noticeable spatial structures in the large uniform marine climate. Yet, the present study provides no evidence of considerable change the marine and coastal climate on a larger scale due to large OWFs deployments.

The results suggest that it is important to consider future large scale clustered OWFs when reconstructing and assessing marine climate and regional atmospheric and ocean dynamics. Sea surface winds are one of the main factors controlling the ecosystem productivity and structure. Thus, ecosystem management and fisheries assessment need to be considered. An optimization strategy based on both national and international considerations is mandatory to minimize economic losses and to assess the environmental impacts of large clustered OWFs in the North Sea.

The presented studies are based on atmosphere-only simulations that lacks important air-sea interactions and feedbacks. Future studies with high-resolution coupled regional ocean-wave-atmosphere climate models are required to include air-sea interactions and feedback processes in assessing the impacts of OWFs on the marine climate.

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The long-standing dilemma of European summer temperatures at the mid-Holocene and other considerations on learning from the past for the future using a regional climate model

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More details can be found in:
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Introduction

During the Mid-Holocene (MH, the period of time at 6000 years before present), a different Earth's orbit configuration around the Sun led to remarkable changes in the seasonal cycle of insolation, with higher summer solar radiation input over the Northern Hemisphere than today (Berger, 1978; Berger and Loutre, 1991). While climate models generally simulate a very homogeneous warming in summer across the whole of Europe for the MH (Mauri et al., 2015), evidence from continental-scale pollen-based reconstructions show a spatial dipole structure in European summer temperatures at the MH, with warmer temperatures over Northern Europe and a large extension of colder temperatures over the Mediterranean region (Huntley and Prentice, 1988; Davis et al., 2003; Mauri et al., 2015, Russo and Cubasch, 2016; Brierley et al., 2020). The discussion on which picture is to be considered more reliable has been long-standing and is still unsolved. In this study, with the main goal of uncovering possible processes that might help explaining the patterns of differences in European summer temperature between the MH and the pre-industrial (PI) periods as reconstructed from pollen data, a series of sensitivity experiments are conducted with COSMO-CLM, testing different model configurations. These experiments are additionally used to assess the reliability of the assumption of stationarity typical of calibration approaches used for RCMs, under different forcing.

Methods

The model version used in this study is COSMO-CLM 5.0_clm9. A new subroutine is implemented in the main radiation module of the model, following the same approach of other paleoclimate studies (Russo and Cubasch, 2016; Prömmel et al., 2013), for representing changes in the Earth's orbit on millennial timescales. Additional changes to the model's code are also required to account for different greenhouse gas concentrations at fixed MH and PI values. Below we describe in detail the set of all performed simulations.

Firstly, starting from a reference run (Sørland et al., 2021), two Physically Perturbed Ensembles (PPEs), each one composed of 31 different members covering 25 years each, are produced for a domain covering the whole of Europe at a spatial resolution of 0.44∘, for both the MH and PI periods. Then, eight additional sensitivity experiments are conducted by perturbing the initial soil moisture conditions of a reference state at the beginning of spring for the MH, over a shorter period of 6 months. These experiments consider different levels of soil moisture saturation at the beginning of spring, with respect to a reference with half-saturated soil.

Initial and boundary data used for all the presented simulations are obtained from global simulations with the Max Planck Institute Earth system model in paleoclimate mode (MPI-ESM-P, Jungclaus et al., 2013, 2012a, 2012b). The atmospheric component ECHAM6 (Stevens et al., 2013) is run at T63 spectral resolution (~1.875∘ on a Gaussian grid), while the ocean component MPIOM has a nominal resolution of 1.5°.

→

Results

PPE summer temperatures

Figure 1 shows the mean of the anomalies obtained by subtracting from the MH climatological mean of each realization of the PPE the corresponding PI value. The mean model behaviour presents warmer temperatures at the MH over the entire domain, in a range of 0 to +2.5° C, similarly to other studies (Brierley et al., 2020). Considering each realization of the PPE separately, none of the investigated changes in the model configuration leads to significantly different results that could be in better agreement with evidence from pollen-based reconstructions.

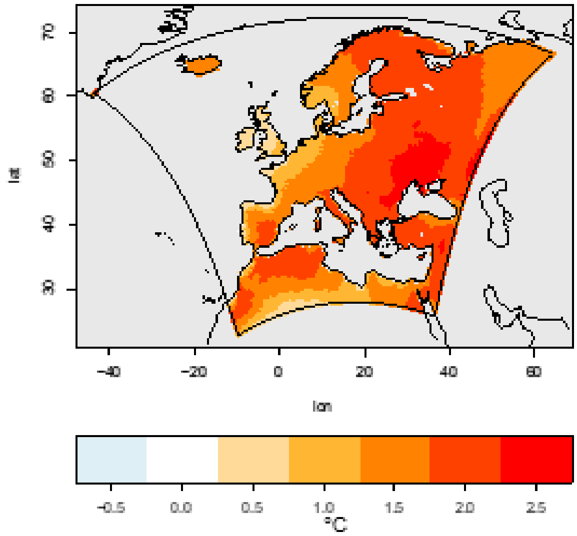

Figure 1: *Mean of anomalies of summer mean 2-meter temperature calculated between each of the ensemble realizations, subtracting to the climatological value of the mid-Holocene (MH) the one obtained for the pre-industrial period (PI).*

Perturbed soil moisture experiments

Changes in available spring soil moisture have an important effect on the simulated summer temperatures of the region (not shown). The temporal evolution of soil moisture at the different model levels over the entire 6 months of simulation for the experiments with wetter soil in spring (Fig. 2), shows that the depletion of moisture is considerably faster when more moisture is added to the initial conditions. This suggests that even if more soil moisture would be available in early spring in COSMO-CLM as a consequence of, for example, increased late-winter precipitation, often suggested as a plausible hypothesis for explaining the temperature pattern derived from pollen-based reconstructions, this would be depleted too quickly, leading to no appreciable changes in summer temperatures.

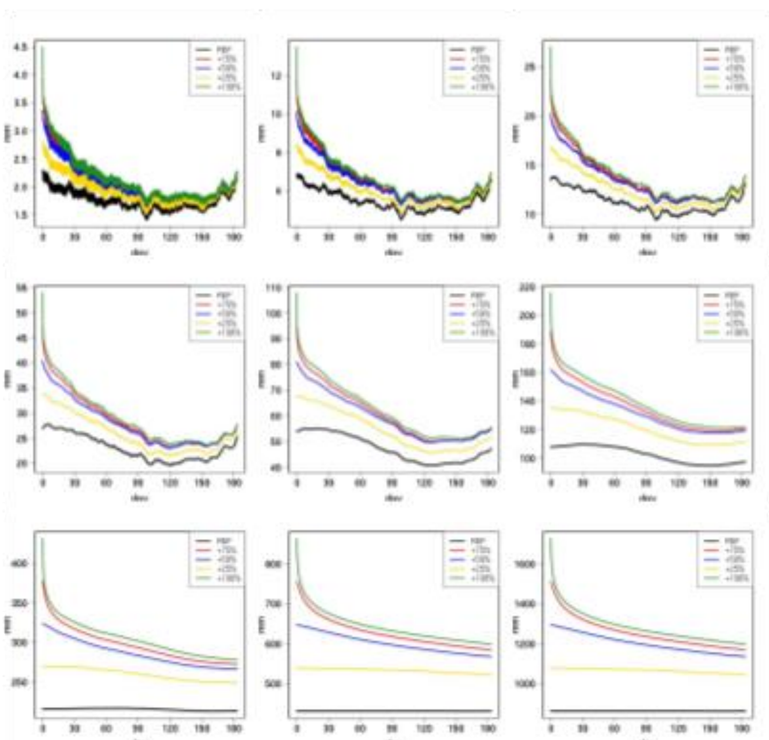

Figure 2: *Temporal evolution of soil moisture at the nine hydrological active layers (lev1 to lev9) for the experiments with increased initial soil moisture at the beginning of April.*

Assumption of stationarity of calibration approaches for RCMs

Finally, the PPEs produced for the PI and MH periods are also used for testing whether an optimal model configuration for one period can also be assumed to be the best under different forcings. Fig. 3 shows the probability distribution functions (PDFs) of total cloud cover daily mean anomalies derived for each member of the PPE, for a randomly selected point of the domain, in both periods. The realization closer to the target reference (reported in the top-left corner of each panel) changes in the two periods, with simulation 2 (with the exponent to get the effective surface area set to 0.1) being the best in one case, and experiment 26 (with the factor for turbulent heat dissipation set to 15) in the other. Considering the MAE calculated between the different PPE members and the reference run over daily mean anomalies for each land point of the domain, the "best" model configuration changes in the two periods for over 91 % of the points for 2-meter temperature, 92 % for precipitation and 89 % for total cloud cover.

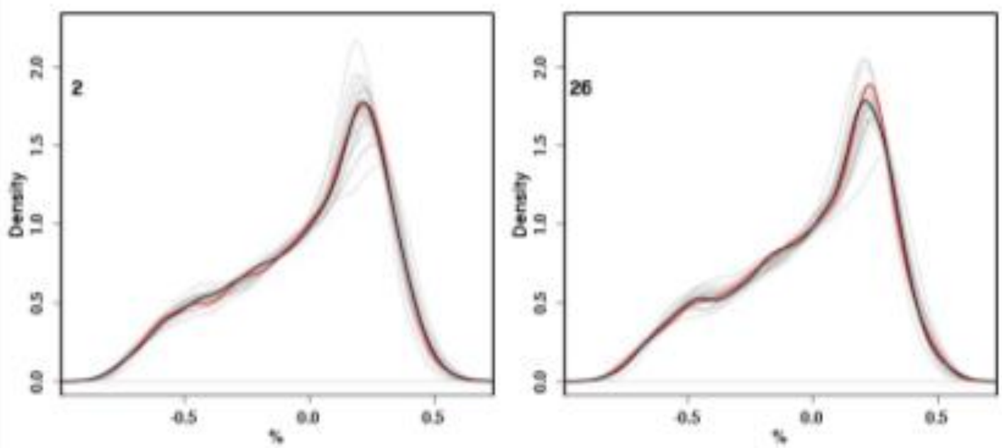

***Figure 3:** PDFs of daily mean anomalies of total cloud cover calculated for the different PPE members for the PI (left) and the MH (right) periods, for a randomly selected grid point. The reference simulation is highlighted in black in both periods and is considered as a theoretical "nature" state. The PDF of the member with the smallest Mean Absolute Error (MAE) with respect to the "nature" state in each of the two periods is represented by a red curve. All other realizations are plotted in light gray. The run closer to the reference in each period is reported on the top left corner.*

CONCLUSIONS

In this study, in a first step, two physically perturbed ensembles (PPEs) are produced to assess how COSMO-CLM reacts, for different parameter values and physical options, to changes in the radiative forcing over two distinct time spans (PI and MH). In general, each member of the PPE does not behave remarkably different with respect to the others for both the MH and PI periods and none of the investigated changes in the model configuration leads to remarkable variations in the MH European summer temperatures closer to the evidence from pollen-based reconstructions. Furthermore, additional sensitivity tests conducted for the MH by perturbing the model initial soil moisture conditions at the beginning of spring confirm a deficiency of the considered land scheme of COSMO-CLM in properly retaining spring soil moisture, already known from present-day studies. The presented results emphasize the role of soil–atmosphere interactions as one of the possible drivers of the differences in European pollen-based summer temperatures at the MH. At the same time, they suggest the importance of properly evaluating the skills of the soil component of a given climate model in retaining spring soil moisture when investigating MH European climate.

Finally, the analysis of the distribution of the PPEs for different variables (T2, PREC, TCLC) shows that, in almost all of the considered cases, an optimal model configuration in one period does not seem to be the best in another characterized by different radiative forcing. These results raise concerns about the usefulness of expensive calibration methods for RCMs. It might make sense to better channel computational resources to the production of small PPEs that target a set of model configurations, properly representing climate phenomena characteristic of the target region and that will be likely to contain the best model answer under different forcing.

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2022

Akhtar, N., Geyer, B., & Schrum, C. (2022): Impacts of accelerating deployment of offshore windfarms on near-surface climate. Sci Rep 12, 18307 (2022), doi:10.1038/s41598-022-22868-9

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March 27 – 31: ICON training course, Offenbach, Germany

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June 19-23: ICAM 2023, St. Gallen, Switzerland

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