


Editorial

Regional Climate Modelling with COSMO-CLM: History and Perspectives

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The history of the COSMO (COnsortium for Small-scale Modelling) model goes back to the early 1990s, when the Deutscher Wetterdienst (German Meteorological Service, DWD) decided to develop a non-hydrostatic model, the Lokalmmodell (LM) [1], to be able to produce weather forecasts at convection resolving resolution. Convection resolving simulations require a mesh size of less than ten kilometers and this was not possible with the hydrostatic Deutschlandmodell (DM), the operational model at DWD at the time. DWD started the development and in 1999, the new model LM (LM 1.1) replaced the Deutschlandmodell as operational weather forecast model.

A non-hydrostatic kernel that allows for mesh sizes (much) lower than ten kilometers, a modern, clear and modular programming, (including the efficient MPI parallelization) seemed to also be reasonable criteria for the development of a regional climate model. Therefore, it was not surprising that the Potsdam Institute for Climate Impact Research (PIK, Germany) took the LM into account when they looked for Regional Climate Model for the WAVES project at the end of the 1990s [2].

In the next years, scientists from BTU Cottbus (Germany) and GKSS Research Centre (Germany) joined the developer group and together it was possible to develop the first climate version of the Lokalmmodell, which was completed in summer of 2002. Two years later, in 2004, the second version CLM (LM 2.19 = LM 3.1 = CLM 2) was released.

In fall 2004 PIK, GKSS and BTU Cottbus presented the new regional climate model and invited all interested scientists to join the developer group and establish a network for the coordinated and systematic development of the CLM. This was the hour of birth of the CLM-Community.

The first multi-year evaluation runs, i.e., simulations of fifteen years driven by ERA15 reanalysis were also conducted in 2004. Based on these evaluation runs, the community carried out an intensive validation of the CLM with a focus on the ability of the model to serve as a regional climate model. The study also included a comparison to other state-of-the-art RCMs. BTU Cottbus did the major part of this validation, finding that the accuracy of CLM was in the same range as that of other RCMs that resolve similar scales. CLM also showed competitive results in time slice experiments, which were conducted for the PRUDENCE project [3].

In summer 2005, Andreas Will (BTU Cottbus) became the first coordinator of the CLM-Community and in the same year, CLM was officially nominated as the community model of the German climate research community by the steering committee of the German Climate Research Centre (DKRZ). On 30 September of the same year, the decision that COSMO (former LM) and CLM should be unified regularly was taken.

In 2006, the 1st CLM-Community Assembly took place at the training center of DWD in Langen, Germany. Since then, the annual meeting of the CLM-Community took place every year at alternating locations and was organized and hosted by many different member institutions of the CLM-Community. In addition, in 2006, the 3rd version of CLM was released and the CLM-Community members performed

transient climate change simulations for the period 1960–2100 under the SRES scenarios A1B and B1 with boundary conditions from the global climate model (GCM) ECHAM5.

The first unified version of the model, which included developments from the weather and climate communities, was released in 2007 (COSMO 4.0 = CCLM 4). In January 2008 the decision about the official naming conventions for the model and the community were taken. For the model, the name COSMO-CLM (or CCLM), which stands for COSMO model in CLimate Mode, was established. For the community, the name CLM-Community was chosen as abbreviation of Climate Limited-area Modelling Community.

The CLM-Community had 70 members from 21 institutions in summer 2008. In August 2008 the first Special Issue for COSMO-CLM with the title “Regional climate modelling with COSMO-CLM (CCLM)” was published in *Meteorologische Zeitschrift* [4].

In 2009, the CLM-Community started to participate in the Coordinated Regional Climate Downscaling Experiment (CORDEX, <https://cordex.org>). Since then, many member institutions of the CLM-Community have performed simulations for different CORDEX domains and contributed to the various CORDEX activities (see below). The community grew rapidly and had 125 members from 36 institutions at the end of 2009.

At the beginning of 2010, the community established a new body: The Scientific Advisory Board (SAB). Each core institution of the CLM-Community is represented in the SAB and the group should discuss and guide the overall development of the model and the community. Later in the same year, the first discussion started between BTU Cottbus and DWD about the inclusion of DWD in the organizational and administrative tasks of the CLM-Community.

Beside the administrative improvements, the model development also continued. At the end of August 2010, the first meeting of the working group “Atmosphere–Ice–Ocean” (AIO) took place. The aim of this working group was the extension of COSMO-CLM by a coupling with a regional ocean model. In 2011, the Community Land Model was also coupled to COSMO-CLM.

In February 2012, the chair of the SAB and the CLM-Community Coordinator continued to discuss the opportunities of an institutionalization of the CLM-Community coordination at DWD with the leader of the climate and environment division at DWD. This resulted in the adoption of the coordination by Barbara Früh (DWD) in August 2013. Earlier in that year, in April 2013, COSMO4.8_clm17 became the official model version of the CLM-Community, together with a recommended configuration for Europe. The first CLM-Community newsletter was published in August 2013 and a new issue of the newsletter has been published every six months ever since.

The first version of the coupled atmosphere-ocean-ice system of COSMO-CLM and NEMO was released in 2014. In the same year, the next unification of the weather forecast and climate versions of the COSMO model took place, and resulted in the unified model version COSMO 5.0 (=CCLM 5). Furthermore, the project group ICON was established in September 2014, to coordinate the development of an ICON-based regional climate model within the CLM-Community. ICON is a new modelling framework based on an icosahedral grid that has been developed by DWD and Max-Planck-Institute for Meteorology (MPI-M) [5].

The 10th CLM-Community Assembly took place in September 2015 in Belvaux, Luxembourg. During this Assembly, the members of the CLM-Community voted on a new recommended version of COSMO-CLM and COSMO5.0_clm6 became the new recommended model version of the CLM-Community. At that time, the community had 250 members from 70 institutions.

In May 2016 the second special issue for COSMO-CLM “Recent developments in Regional Climate Modelling with COSMO-CLM” was published in *Meteorologische Zeitschrift* [6].

The 14th CLM-Community Assembly took place in September 2019 in Paestum, Italy. During the Assembly, Barbara Früh stepped back as coordinator of the CLM-Community and Christian Steger (DWD) was elected as new coordinator.

COSMO-CLM has been the main workhorse in the CLM-Community for more than 15 years now. It enabled the member institutions to perform regional climate simulations, to participate in projects,

to address a variety of scientific questions and to contribute to coordinated international initiatives such as CORDEX (incl. CORDEX-CORE and CORDEX flagship pilot studies (<https://cordex.org/experiment-guidelines/flagship-pilot-studies>) and PRINCIPLES, a project of the Copernicus Climate Change Service C3S (<https://climate.copernicus.eu>). In total, the CLM-Community has contributed with 80 simulations from five different domains to the CORDEX activities. An overview paper that summarizes the results of these simulations and compares the different versions and setups of COSMO-CLM that have been used is currently prepared by Silje Soerland (ETH) and co-authors.

At the time of writing, the last steps towards the release of the unified version COSMO 6.0 are completed. COSMO 6.0 is expected for the end of 2020 and will be the last official release of the COSMO model, because the main developers, DWD and the partners in the consortium for small scale modelling, will move to an ICON-based forecasting system for numerical weather prediction in the future.

COSMO-CLM 6.0 will certainly be used in several groups of the CLM-Community for the next few years. However, since the COSMO model will not be developed any further, and the support of COSMO and DWD for the model will be stopped, members of the CLM-Community already started to develop a regional climate mode of ICON several years ago. A first version of ICON-CLM (ICON Climate Limited-area Mode) was prepared in 2019 and a reference simulation showed that ICON-CLM already performs as well as COSMO in many aspects and is computationally more efficient [7]. However, there are still many technical developments necessary until the new modelling system will have the same functionality as COSMO-CLM today.

Beside the transition to an ICON-based modelling system in the next years, the CLM-Community also plans to participate in the downscaling of CMIP6 simulations in the CORDEX framework.

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