SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2025
Project Title:	NorCP 2nd Phase: A suite of 'convection-permitting' regional climate model simulations over the Nordic region
Computer Project Account:	spselind
Principal Investigator(s):	Petter Lind
Affiliation:	Swedish Meteorological and Hydrological Institute
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Fuxing Wang, Yi-Chi Wang, Aitor Aldama Campino
Start date of the project:	01/01/2025
Expected end date:	31/12/2027

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	n/a	n/a	150 000 000	19 262 851
Data storage capacity	(Gbytes)	n/a	n/a	75 000	~ 5 000

Summary of project objectives (10 lines max)

The project is a continuation and expansion of the first phase of the Nordic Convection-Permitting Climate Projections (NorCP) project (Lind et al., 2020). In this second phase, a new version (cycle 46) of the HARMONIE-Climate (HCLIM) convection-permitting regional climate model (CPRCM) will be applied in a suite of simulations at km-scale over the Nordic region. The objectives involve: i) run HCLIM46 forced by ERA5 reanalysis over a time period covering the last ~40 years; ii) perform a set of HCLIM46 simulations forced by several GCMs from the CMIP6 and forthcoming CMIP7 ensembles, covering both pre-industrial (for attribution studies), present and future time periods. The high-resolution climate data will be used in impact modeling, climate adaptation studies and also support the development of AI/ML methodologies and tools. In addition, benchmark simulations will be performed with a coupled atmosphere-ocean version of HCLIM.

Summary of problems encountered (10 lines max)

The development and evaluation of the new version of HCLIM, cycle 46, has taken longer time than anticipated, due to unforeseen technical problems running the model code, developments of model physics components and configurations not being ready and tested in time, and issues related to model performance. We estimate that the model will be ready for operational long-term applications by September or early October 2025.

Another issue is the delays experienced in finalizing the new versions of the GCMs planned to provide forcing conditions to HCLIM46. However, this is a minor issue since we will start with the ERA5 driven evaluation simulation in 2025, while GCM forced runs will start in 2026.

Summary of plans for the continuation of the project (10 lines max)

The main priority in the very near future is to complete the evaluation and finalize the operational configuration of HCLIM cycle 46. As soon as the model is ready, by late September/early October, the evaluation simulation, forced by ERA5, will be initialized. With this simulation we expect to use the SBUs and storage allocated for the current year. GCM driven simulations for a historical period are currently planned for the first quarter of 2026, with past/future scenario simulations following in the second or third quarter.

List of publications/reports from the project with complete references

Lind, P., Belušić, D., Christensen, O.B. et al. Benefits and added value of convection-permitting climate modeling over Fenno-Scandinavia. *Clim Dyn* 55, 1893–1912 (2020). https://doi.org/10.1007/s00382-020-05359-3

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

In the first half of 2025, the work in this project has been focused on developing and finding a suitable configuration of the most recent version of HCLIM, cycle 46 (HCLIM46). Compared to the previous operational HCLIM version, cycle 43 (HCLIM43), HCLIM46 includes several important new features, such as support for dual precision (single plus double precision), a new dry soil layer parameterization, and an increased number of patches in the SURFEX land surface model (from 2 to 3), among other updates. A series of tests were carried out to adapt HCLIM46 (using both ALADIN and AROME physics configurations) for deployment on ECMWF computing infrastructure over the Fenno-Scandinavia domain (e.g., Fig. 1). These tests include assessments of processor compatibility, testing of dual precision (which will enhance the computational efficiency during runtime), regular debugging procedures, and possible biases introduced by the model updates.

Several multi-year simulations using HCLIM46 have been conducted on ECMWF systems to evaluate systematic biases. These simulations included runs with the default configuration, as well as experiments incorporating new features such as a dry soil layer, multi-patch surface representation (3 patches), and an updated solar constant based on values used in the sixth phase of the Coupled Model Intercomparison Project (CMIP6). Additional sensitivity experiments have been carried out with shallow convection deactivated when the grid-point vertical velocity was considered sufficiently strong to support deep convection.

The performance of the simulations with AROME physics with 3 km horizontal resolution for the Scandinavian domain has been assessed through extensive analysis and comparison against various observational and reanalysis datasets. The evaluation indicates that HCLIM46 produces annual and seasonal averages of precipitation and temperature that are broadly similar to those from HCLIM43. For instance, Figures 1 and 2 illustrate the seasonal and regional differences between HCLIM46, HCLIM43, and observational datasets, highlighting notable biases in precipitation and temperature – particularly during summer and autumn in southern and coastal areas, as well as persistent cold biases in daily maximum temperature (tasmax) over Scandinavia.

Further experiments and analyses are ongoing to better document and understand these biases, aiming to fully assess HCLIM's capability in simulating regional climate. A more comprehensive summary of results can be found in the HCLIM community GitHub repository: https://github.com/Hirlam/HCLIM/wiki/Evaluation.

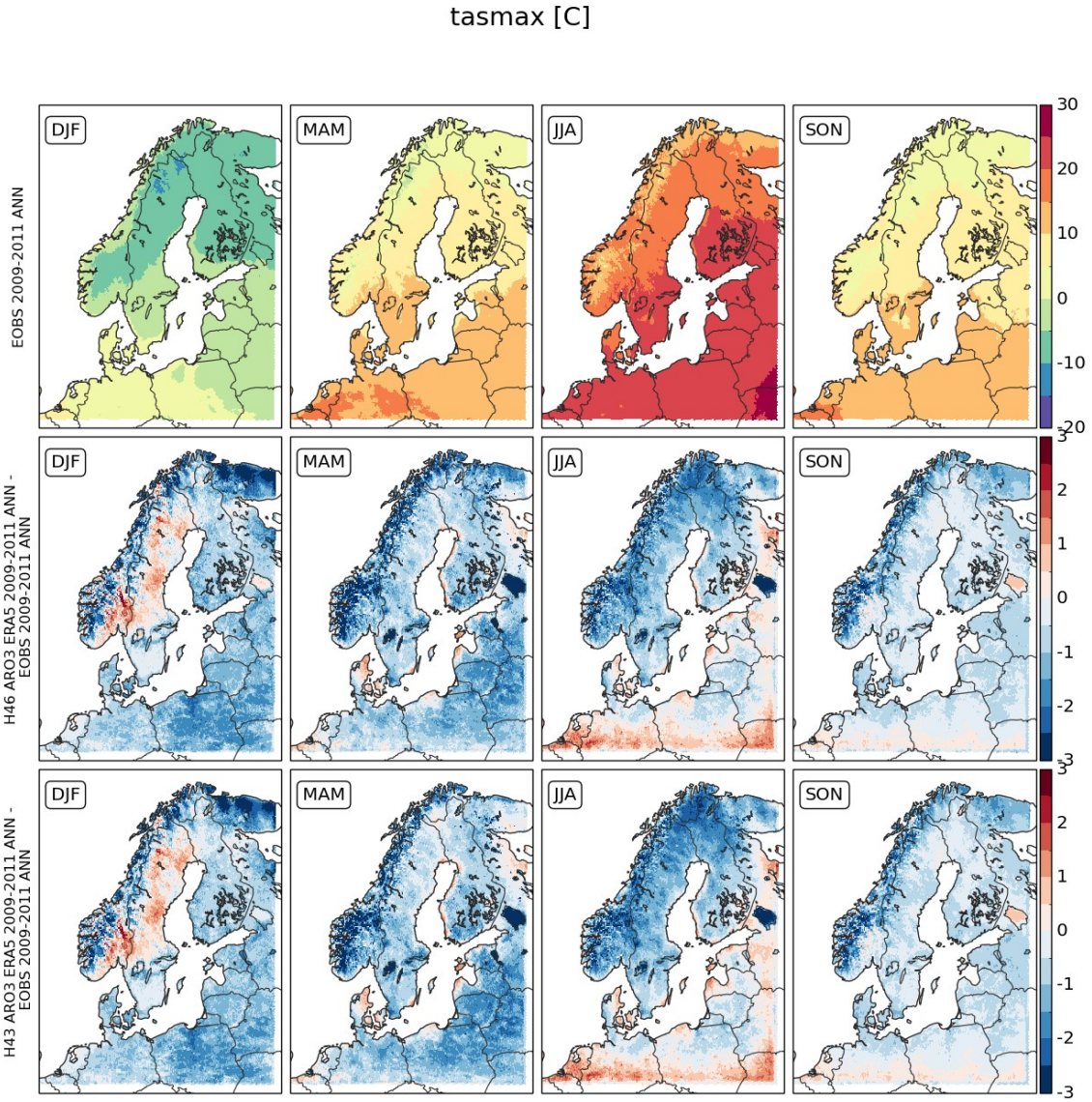

Figure 1: *Seasonal mean daily maximum temperature (tasmax, °C) averaged over 2009–2011 (2008 for spin-up) in HCLIM and observations. The top row shows E-OBS seasonal climatology for DJF (winter), MAM (spring), JJA (summer), and SON (autumn). The middle and bottom rows show differences in tasmax from HCLIM46 AROME3 and HCLIM43 AROME3 (both driven by ERA5), respectively, relative to E-OBS. Blue indicates a cold bias (model colder than E-OBS), and red indicates a warm bias.*

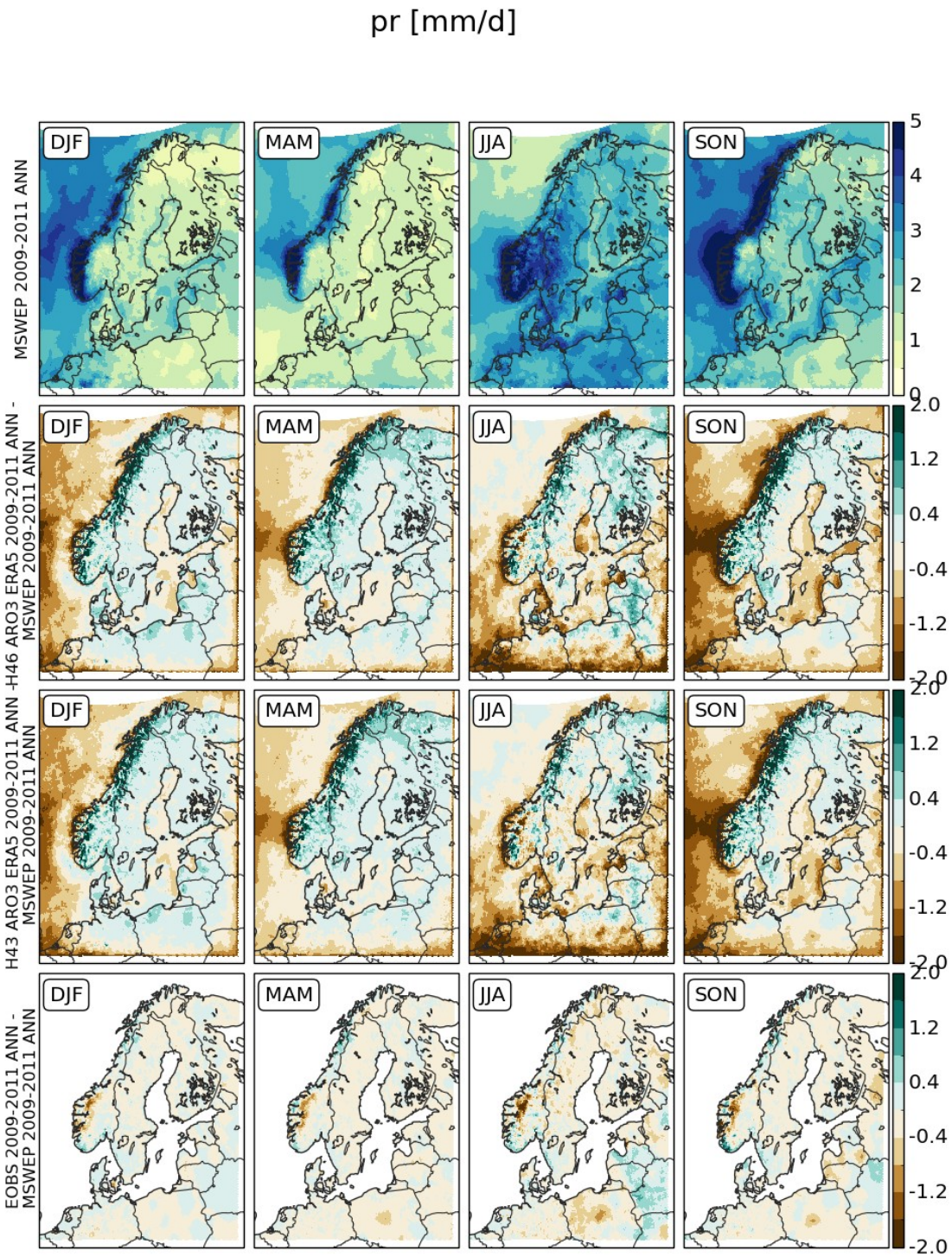

Figure 2: *Seasonal mean of precipitation (mm/day) averaged over 2009–2011 (2008 for spin-up) in HCLIM and observations. The top row shows MSWEP precipitation for each season: DJF (winter), MAM (spring), JJA (summer), and SON (autumn). The remaining rows show the difference relative to MSWEP for HCLIM46 AROME3 (2nd row), HCLIM43 AROME3 (3rd row), and E-OBS (4th row). Positive values (green) indicate higher precipitation than MSWEP, while negative values (brown) indicate lower precipitation.*

CORDEX FPS URB-RCC: testing HCLIM46 setup

An important step towards the new operational version of HCLIM46 is SMHI's participation in the CORDEX FPS URB-RCC project (https://ms.hereon.de/cordex_fps_urban/index.php.en), where we are contributing to stage 1 simulations using the HCLIM46 model. The overall plan of the project is to perform ERA5 driven simulations over Paris and several globally distributed satellite

cities for historical periods of around 10 years. SMHI is specifically involved in simulations over the cities of Paris and Johannesburg, both at 12.5 km and 3 km resolutions. In preparation for the long-term simulations, which are scheduled to begin around summer 2025, a number of test runs have been conducted. These preparatory tests explored different model configurations, adjustments to output variables required by the project, and optimization of the number of processors for the target simulation domains, etc. These steps help ensure readiness for efficient and reliable production simulations, but also for targeting future urban climate studies over Fenno-Scandinavia cities.