# REQUEST FOR A SPECIAL PROJECT 2025–2027

**MEMBER STATE:** Sweden

**Principal Investigator[1]:** Petter Lind

**Affiliation:** Swedish Meteorological and Hydrological Institute (SMHI)

**Address:** Folkborgsvägen 17, 601 76 Norrköping, Sweden

**Other researchers:** Fuxing Wang, Aitor Aldama Campino, Grigory Nikulin, Nathan Grivault

**Project Title:** NorCP 2nd Phase: A suite of "convection-permitting" regional climate model simulations over the Nordic region

To make changes to an existing project please submit an amended version of the original form.)

| | | |
|---|---|---|
| If this is a continuation of an existing project, please state the computer project account assigned previously. | **SP** …………. | |
| Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.) | 2025 | |
| Would you accept support for 1 year only, if necessary? | YES ☒ | NO ☐ |

| **Computer resources required for project year:** | | **2025** | **2026** | **2027** |
|---|---|---|---|---|
| High Performance Computing Facility | [SBU] | 150 000 000 | 150 000 000 | 150 000 000 |
| Accumulated data storage (total archive volume)[2] | [GB] | 75 000 | 100 000 | 150 000 |

| **EWC resources required for project year:** | | **2025** | **2026** | **2027** |
|---|---|---|---|---|
| Number of vCPUs | [#] | | | |
| Total memory | [GB] | | | |
| Storage | [GB] | | | |
| Number of vGPUs[3] | [#] | | | |

*Continue overleaf.*

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3] The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

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# Extended abstract

*All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.*

*Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.*

*Requests exceeding 10,000,000 SBU should be more detailed (3-5 pages).*

## Background

With continual widespread climate change unfolding, there is an increased need for more detailed, "actionable" climate information from impact researchers, stakeholders and policy makers for regional-to-local climate change assessments. In the recent decade, so-called "convection-permitting" regional climate models (CPRCMs) have emerged as a highly promising tool to improve regional and local-scale climate change information (Lucas-Picher et al. 2021). Even though performing decadal-long CPRCM climate change projections is computationally very demanding and also requires huge data storage capabilities, the greater realism and representation of local scale meteorological and climate processes constitutes a strong incentive to perform such high-resolution climate projections.

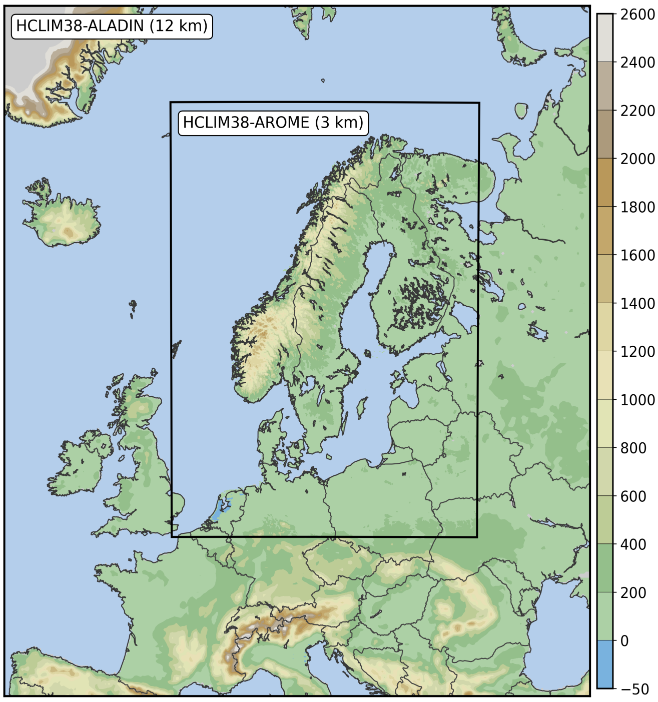


*Figure 1: NorCP domain setup showing HCLIM-ALADIN (12 km) and HCLIM-AROME (3 km) domains.*

Recently, a Nordic collaboration termed the Nordic Convection-Permitting Climate Projections (NorCP; Lind et al. 2020; Lind et al. 2022) has been established, with the aim to perform and explore the benefits of the HARMONIE-Climate (HCLIM) CPRCM applied at around 3 km grid resolution over a northern European domain (Fig. 1). HCLIM cycle 38 (HCLIM38) was here forced by two global climate models (GCMs) from the Coupled Model Intercomparison Project phase 5 (CMIP5). The results from these experiments showed a good performance of the HCLIM CPRCM in representing the regional and local climate over the Nordic region when compared to observations. In particular, the CPRCM showed larger skill and added value in the simulation of precipitation characteristics, especially extremes, compared to the coarser HCLIM RCM (Médus et al. 2022; Lind et al. 2020). As an illustration of this, Figure 2 shows the clear improvements in the diurnal cycle timing and intensity of extreme precipitation in the CPRCM HCLIM38-AROME compared to the driving regional model EURO-CORDEX RCM RACMO (ca 12 km resolution).

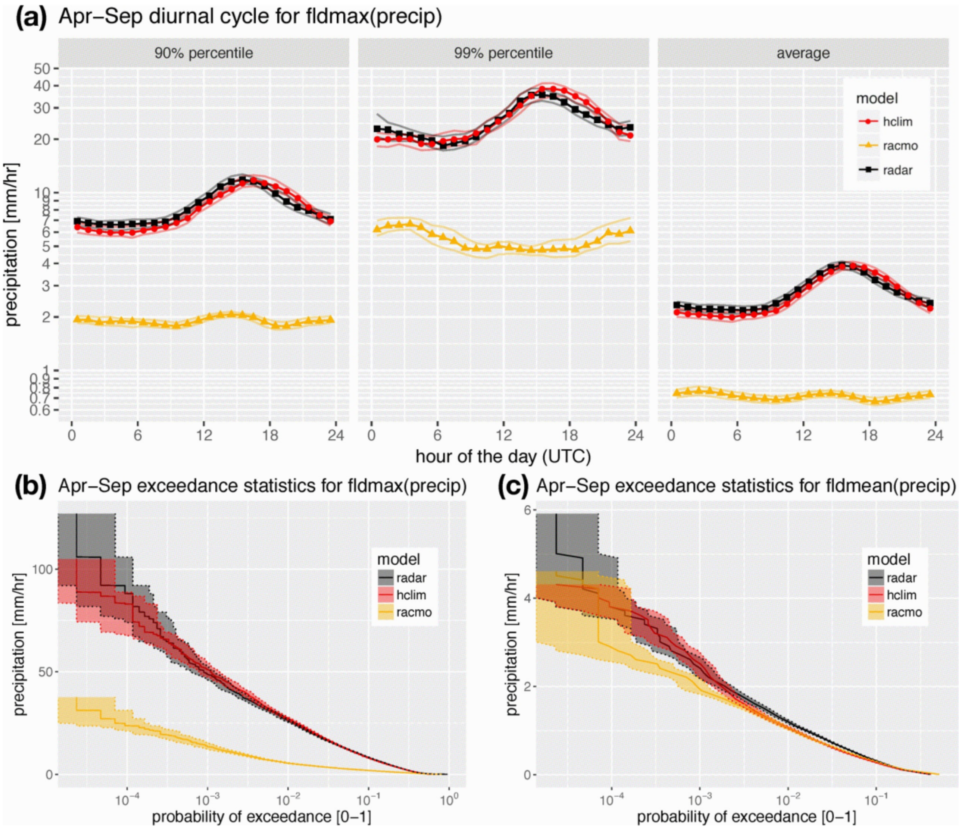


*Figure 2: (a) Diurnal cycle of two high percentiles and the average of the FLDMAX hourly precipitation distribution (Apr-Sep), for radar, CPRCM and driving RCM. Probability of exceedance (Apr-Sep) for (b) the FLDMAX precipitation and (c) the FLDMEAN precipitation (note the difference in the vertical scale). [Reproduced from Belušić et al., 2020].*

However, due to the large computational demand, only a limited number of simulations with the CPRCM could be produced in the first phase of NorCP, limiting a comprehensive assessment of uncertainties in future changes. Also, we could identify biases in HCLIM, to some extent likely due to missing or incomplete representation of certain processes, for example transient temporal changes in aerosols and dynamic vegetation. In this project the main aim is to expand and improve based on previous experiences in the NorCP project through additional simulations with HCLIM CPRCM, using the new updated version of HCLIM (cycle 43) that includes new and/or improved configurations and components of the model. In addition, HCLIM will be forced by the latest generation of GCMs from the CMIP6, which have shown increased skill in for example representing the large-scale circulation over the Euro-Atlantic region.

## Scientific plan

A set of GCMs from CMIP6 have been or are currently being dynamically downscaled with the HCLIM-ALADIN regional climate model (RCM) on national HPC systems by SMHI and other partners in HCLIM community as part of its contribution to the EURO-CORDEX framework. The integrations are performed over Europe at 12 km horizontal grid resolution for the recent past (1950-2014) and over the 21st century (2015-2100) forced by Shared Socio-economic Pathway (SSP) emissions scenarios. For this project, the second phase of NorCP, these RCM simulations, initially a subset of them, will provide lateral boundary conditions to HCLIM-AROME (CPRCM) nested over a domain covering the Nordic region with approximately 3 km grid spacing. Simulations will be performed both for historical and future time periods, as well as a hindcast forced by ERA5 reanalysis data. A subset of these HCLIM-AROME downscalings are the subject of our computer application.

The CPRCM simulations will constitute a comprehensive data set with high resolution climate information and higher quality (based on previous evaluations) compared to the coarser-scale models, especially concerning strong convective events and flash floods. It will not only serve to further our knowledge on future changes in regional and local weather and climate, but also provide high-quality input data to impact models that often require high spatial resolution (e.g. urban flooding, windthrow, coastal upwelling). Compared to previous model versions, we intend to investigate the impacts of several new developments and components of HCLIM cycle 43:

- First long-term tests coupling HCLIM with the ocean model NEMO (Pemberton et al., 2017) will be done to investigate the impacts on weather and climate of the ocean-atmosphere interactions over the North Sea and Baltic Sea areas.
- With the implemented and further developed Town Energy Balance model (TEB, Masson 2000) in HCLIM relevant physical processes and driving mechanisms for UHI will be further studied (Wang et al. 2024), including the impacts on climate and health of implementing various mitigation measures in an urban area, such as green areas or white roofs.
- Sensitivity tests in HCLIM have shown the importance of more accurate aerosol loadings in the model to reduce certain precipitation biases. Here, we will explore the recently implemented CAMS aerosol climatology and technical changes to allow transient changes in aerosol concentrations.
- We further plan to connect HCLIM CPRCM output with an dynamic vegetation model, LPJ-GUESS (Smith et al., 2001), both in offline and online configurations.

## Technical characteristics of the HCLIM code

The HCLIM regional climate model is developed by a consortium of national meteorological institutes in Europe. It is based on the NWP model configuration and scripting system called HARMONIE-AROME, which is a part of the ALADIN-HIRLAM NWP modeling system (Lindstedt et al., 2015; Bengtsson et al., 2017; Termonia et al., 2018). The HARMONIE-AROME model configuration is designed for convection-permitting scales and is used with nonhydrostatic dynamics, which is the primary focus of HCLIM development.

The HCLIM system uses a bi-spectral representation for most prognostic variables, with semi-implicit time integration and a semi-Lagrangian advection scheme. The details of the dynamics are described in Bengtsson et al. (2017) and Termonia et al. (2018).

HCLIM-AROME has been used in several national and international projects over different domains and climates ranging from equatorial to polar regions. To bridge the resolution gap between GCM simulations and convection permitting simulations, a double nesting approach with the HCLIM-ALADIN configuration is used. HCLIM-ALADIN is a hydrostatic model with a convection parameterization, typically run at a resolution of 12 km and coarser.

For this special project the most recent HCLIM version, cycle 43 (HCLIM43), will be used. Compared with the previous version, HCLIM38 (Belušić et al., 2020), several new features are implemented in HCLIM43. These include the replacement of the land cover data ECOCLIMAP V2.2 by the latest version Second Generation (SG), which is produced at 300-meter resolution and includes ten urban cover types.

Other significant additions are the implementation of the Multi-Energy Balance scheme (Boone et al., 2017) within SURFEX, and in the near-term the coupling to the NEMO ocean model (Pemberton et al., 2017). Within the project time we further intend to couple HCLIM to the dynamic vegetation model LPJ-GUESS (Smith et al., 2001).

## Justification of the computer resources requested

Multi-year simulations with HCLIM43 have been tested and performed on the ECMWF computer system, in the configurations HCLIM-AROME (3 km) and HCLIM-ALADIN (12 km) over various domains in Europe and Africa. In this project, the domain will cover the Nordic region similar to the NorCP domain (Fig. 1). The estimated computer cost of running HCLIM43-AROME (~3km) simulations on a Nordic domain is about 2 million SBUs per simulated year.

We plan to make 25-year time-slice experiments with HCLIM43-AROME for the historical, near and far future time periods, with lateral boundaries from HCLIM43-ALADIN forced by two GCMs. With an additional hindcast simulation forced by ERA5 this amounts to 175 simulated years. Some further test runs will be performed (targeting new model development), leading to a total of somewhat more than 200 simulated years, which results in about 150 million SBU per project year.

The analysis planned in NorCP will require information down to sub-hourly time-scales and cover a relatively large grid-space. However, most of the data needed will be restricted to 2D fields. The estimated model output will require about 1 TB of space per simulated model year and the data stored at ECMWF will be continuously reduced moving data to our own storing facilities.

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