REQUEST FOR A SPECIAL PROJECT 2021–2023

MEMBER STATE: Sweden

Principal Investigator[1]**:** Dr. Danijel Belušić

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Sweden

Other researchers: Dr. Ralf Döscher

Project Title: A large ensemble of climate projections on convection-permitting scale

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.)	2021	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2021-2023: (To make changes to an existing project please submit an amended version of the original form.)		**2021**	**2022**	**2023**
High Performance Computing Facility	(SBU)	60 000 000	60 000 000	60 000 000
Accumulated data storage (total archive volume)[2]	(GB)	35 000	70 000	105 000

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.

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Extended abstract

The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

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.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF as well as the Scientific Advisory Committee. The evaluation of the requests is based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and 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 asking for 1,000,000 SBUs or more should be more detailed (3-5 pages). Large requests asking for 10,000,000 SBUs or more might receive a detailed review by members of the Scientific Advisory Committee.

Background

The assessment of natural climate variability, extreme conditions and uncertainty of climate projections at the regional and local scale is a major challenge due to the need of a massive ensemble of climate model simulations, and due to our inability to resolve convection processes at the km scale in large global ensembles (LENS) due to limited computational resources. In this project we address that challenge by downscaling an existing LENS with a convection permitting regional climate model (CPRCM).

Information from LENS experiments can now be downscaled to the km scale for the first time, to our knowledge. Resulting climate information allows regional assessment of climate change with unprecedented fidelity, especially with respect to the complete spectrum of precipitation (Belušić et al. 2020, Lind et al. 2020).

CPRCMs exhibit a conceptual change in the ability to reproduce extreme precipitation compared to the GCMs and RCMs that parameterize deep convection. As an illustration of this change, Figure 1 shows tremendous 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). We can identify a qualitative advancement with simulation statistics very much agreeing with comparable observations. Due to this, it is likely that the future changes of extreme precipitation cannot be properly reproduced by convection parameterizing models. The large practical importance of extreme precipitation and its future projections strongly motivates the use of CPRCMs for climate studies.

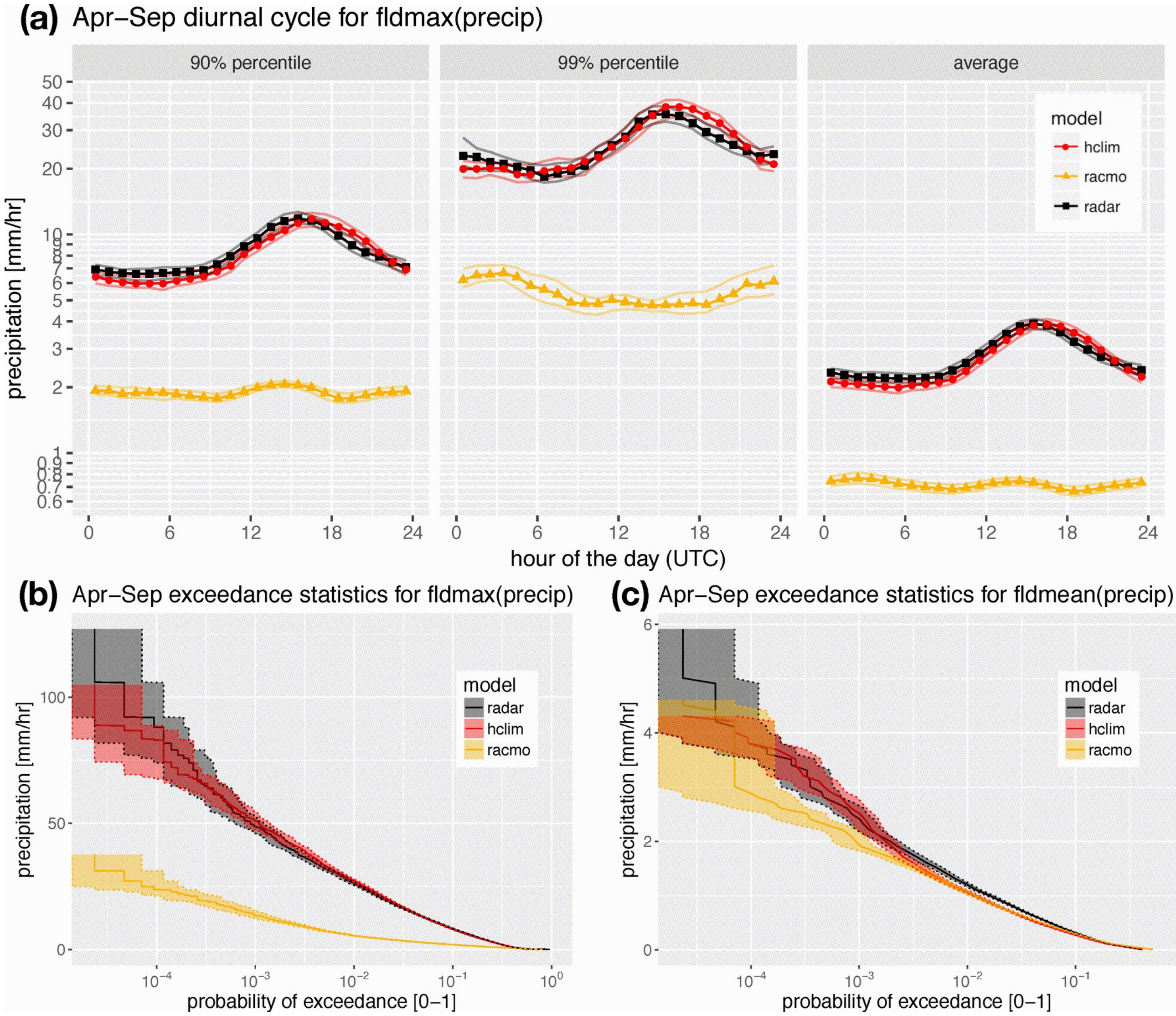

Figure 1. (a) Diurnal cycle of two high percentiles and the average of the FLDMAX hourly precipitation distribution (Apr–Sep), for radar, CPRCM and driving RCM. Probability of exceedance (Apr–Sep) for (b) the FLDMAX precipitation and (c) the FLDMEAN precipitation (note the difference in the vertical scale). [Reproduced from Belušić et al., 2020].

Scientific plan

The global Earth System Model EC-Earth has been used at SMHI to generate a massive ensemble of climate change projections (SMHI-LENS) following selected climate scenarios of the Coupled Model Intercomparison project 6 (CMIP6). The simulations are covering the time frame 1970 - 2100; i.e. starting in the historical phase and smoothly turning into a climate projection. The underlying scenarios are spanning a range of possible climate emission scenarios from SSP1-1.9 (the Paris scenario) via SSP4-3.4 (a moderate scenario) to SSP5-8.5 (the most extreme scenario). Also the SSP3-4.5OS overshoot scenario is included. With 50 ensemble simulations per scenario, this results in the very large ensemble with the total of 200 members.

High-impact weather events from a choice of these scenarios will be selected for downscaling with the CPRCM HCLIM at 3 km resolution for a Nordic domain (“NorCP” domain, Fig. 2), for historical and future periods. We will focus on types of extreme events for which CPRCMs show considerable added value in the present climate and differences in changes in the future climate compared to conventional models, such as extreme precipitating convective systems and extreme local to regional wind events. We will use an automated algorithm for detecting designated extreme events from the GCM output. The typical CMIP6 set of variables is stored for all SMHI-LENS ensemble members, but the model levels could not be stored due to large disk space requirements. Instead, yearly restart files were saved which allow re-running the GCM and saving model levels for the specific year where one or more extreme events are detected. In the automated procedure developed at the Rossby Centre, the whole chain is addressed: detection of events in the GCM fields, re-running GCM for the specific year and saving model levels, running an intermediate 12 km resolution domain with HCLIM-ALADIN for the specific event, and finally running HCLIM-AROME at 3 km resolution for the same event using HCLIM-ALADIN as forcing.

Given the large computational demands we aim at the total number of events that will sum to 90 simulated years. During the first year of the project, after initial testing, we expect to downscale about 300 extreme events using about 1 month long simulation per event. In the following two years we plan to downscale additional 700 events, for the total ensemble of 1000 extreme events. This is an unprecedented undertaking with a CPRCM and will provide a unique database for statistical and dynamical analyses of extreme events and their dependence on climate change, for studying their impacts using other models (e.g. urban flooding, windthrow, coastal upwelling), and for quantifying the benefits of CPRCMs for different types of extremes.

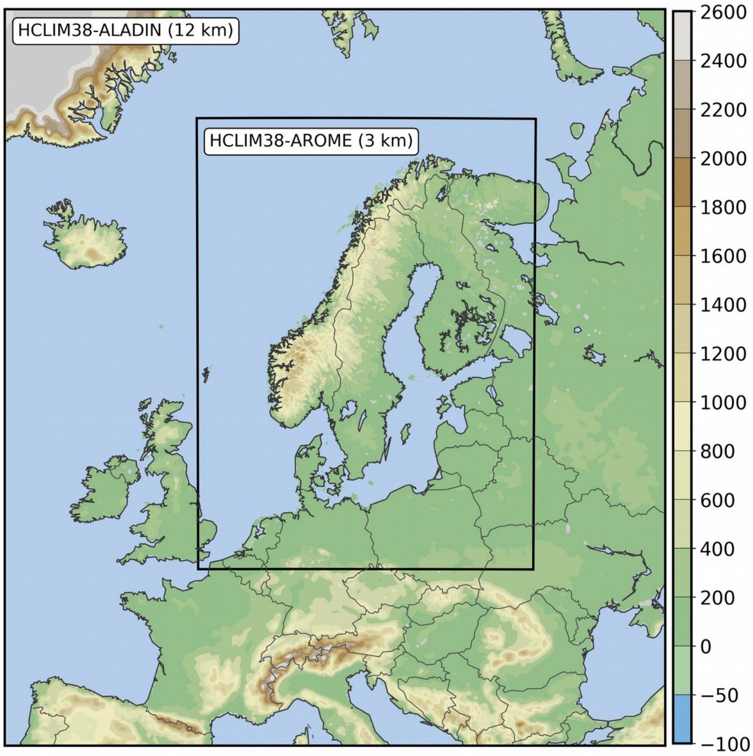

Figure 2. NorCP domain setup showing HCLIM-ALADIN (12 km) and HCLIM-AROME (3 km) domains.

Technical characteristics of the HCLIM code.

HCLIM is a regional climate model based on the NWP model configuration and scripting system called HARMONIE–AROME, which is a part of the ALADIN–HIRLAM NWP modelling 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).

HCLIM38-AROME in cycle 38 is being used in a number of national and international projects over different domains and climates ranging from equatorial to polar regions. An initial evaluation (Belušić et al. 2020, Lind et al. 2020) indicates that HCLIM38-AROME is applicable in different conditions and provides satisfactory results without additional region-specific tuning. That version is used for this special project.

To bridge the resolution gap between GCM simulations and convection permitting simulations, a double nesting approach with the HCLIM38-ALADIN configuration is used. HCLIM38-ALADIN is a hydrostatic model with a convection parameterization, typically run at a resolution of 12 km and coarser.

HCLIM is developed by a consortium of national meteorological institutes in close collaboration with the ALADIN–HIRLAM NWP model development.

Justification of the computer resources requested

HCLIM38 simulations have been tested and performed on the ECMWF computer system, in the configurations HCLIM-AROME (3 km) and HCLIM-ALADIN (12 km) for the NorCP domain that covers most of the Nordic area (Fig. 2). The computing costs are about 2 million SBU for HCLIM-AROME and 46,000 SBU for HCLIM-ALADIN per simulated year.

We expect to perform simulations for the total of 90 years over the 3 project years, which results in about 60 million SBU per project year for HCLIM-AROME in combination with HCLIM-ALADIN.

The estimated model output (NetCDF files) will require about 1.2 TB per simulated model year without taking into account the temporary files for downscaling. With the annual total of 30 simulated years, consisting of ca 330 sequences of 1 month length after initial testing experiments, we expect a standard annual output volume of ca 35 TB.

Once the new HPC system at ECMWF is available for testing, we will port the HCLIM code. HCLIM has been shown to run on different computer systems throughout the HIRLAM weather forecast consortium and is regularly used on ECMWF HPC by many member institutes.

References:

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