REQUEST FOR A SPECIAL PROJECT 2020–2022

MEMBER STATE: Denmark

Principal Investigator[1]**:** Ole B. Christensen, Senior Scientist, PhD

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Other researchers: Emma D. Thomassen, PhD student, Danish Meteorological Institute and Technical University of Denmark

Rasmus A. Pedersen, Scientist, PhD, Danish Meteorological Institute

Project Title: Simulations of extreme precipitation over Denmark and its dependence on resolution

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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.)	2020	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2020-2022: (To make changes to an existing project please submit an amended version of the original form.)		**2020**	**2021**	**2022**
High Performance Computing Facility	(SBU)	9 million	9 million	-
Accumulated data storage (total archive volume)[2]	(TB)	7,5	15	-

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.

This proposed special project will aim at improving the understanding and future projections of extreme precipitation over Denmark. The work will be a part of the PhD project by Emma D. Thomassen, and will further contribute to the future projections in DMI's Climate Atlas, which will be published gradually from 2019-21. It builds on the work done in the special project "The Danish Climate Atlas: HCLIM experiments" (SPDKPEDE, 2019-21), and will provide additional insight into the spatio-temporal characteristics of extreme (convective) precipitation events, specifically the resolution dependence of simulated extreme precipitation.

Recent research has shown that kilometer-scale regional climate models, so-called convection permitting models (CPRCM), improves the simulation of precipitation on sub-daily scales (Ban et al., 2014; Coppola et al., 2018; Prein et al., 2015). As these events and their future manifestation have a large societal impact (IPCC, 2012), improved future projections are in high demand – justifying the computationally expensive simulations with CPRCMs. Here, we employ HARMONIE-Climate (HCLIM, Belusic et al., 2019), the regional climate model based on the HARMONIE numerical weather prediction model system (Bengtsson et al., 2017), using the AROME physics setup which allows for very high resolution, non-hydrostatic simulations.

Within the HCLIM consortium, the Nordic countries (Denmark/DMI, Finland/FMI, Norway/MET Norway, and Sweden/SMHI) have made a large joint effort to create a CPRCM ensemble with HCLIM covering a domain over Northern Europe (Fenno-Scandia) in 3-km horizontal resolution (cf. special projects "*HCLIM-NorCP: Nordic Convection Permitting Climate Projections with the HCLIM model*" and "*The Danish Climate Atlas: HCLIM experiments*"). These simulations will be analyzed and further downscaled to a set of even higher resolution experiments over Denmark. This yields a set simulations with a wide range of resolutions: ERA-Interim (driving data, ~80 km), regional climate model intermediate downscaling (RCM, ~12 km), CPRCM (~3 km), and very high resolution CPRCM (< 1 km). Together, these experiments can clarify the differences between model simulations with varying spatial resolution, and identify any added value of running simulations with resolutions down to sub-kilometer scale.

Simulations with sub-kilometer resolution can help to fill the gap between current RCM projections future precipitation (~10 km) and the scale needed for application in e.g. urban hydrology. Climate information in high resolution is needed to make cities resilient to pluvial flooding. Schilling (1991), Einfalt et al. (2004) and Thorndal et al. (2016) have proposed resolution requirements of 1-5 minute temporal resolution and 1 × 1 kilometer spatial resolution for applications in urban hydrology, due to the quick response time in these systems. Extreme events at a very local scale can cause pluvial flooding (Schilling 1991, Thorndal et al. 2016) and simulations on sub-kilometer resolution can help improving our understanding of how these events will change (intensity, duration, occurrence) in a future, warmer climate.

HARMONIE-NWP is currently being tested in a domain over Denmark in 750 m resolution (Figure 1). We plan to use this domain as a starting point for testing sub-kilometer scale performance. This domain contains approximately the same number of grid points as the 3 km Scandinavian domain – meaning that storage requirements per model year are similar. The time step is shorter, meaning that the estimated SBU cost per model year will be increased. As our focus is on local extreme events on a sub-hourly time scale, we have estimated a relatively high storage requirement per model year to allow us to save selected variables with a high frequency (e.g. sub-hourly precipitation and other relevant fields).

Figure 1 The Scandinavian domain used in the simulations with 3 km horizontal resolution (orange) and a suggested domain for 750 m resolution experiments focusing on Denmark (red).

We plan to test the capability of sub-kilometer simulations with HCLIM to reproduce the spatio-temporal statistics of extreme convective precipitation by the means of several variables. Comparisons will be performed against gridded observational data and model simulations with varying resolutions (sub-kilometer, 3 km, and 12 km). Due to the computational cost of the very high resolution experiments, we may focus on the representation of specific events or individual seasons and years. We plan to assess the added value of the sub-kilometer scale runs and quantify the actual spatial extent of extreme events and how this depends on model resolution – e.g. using spatial correlation as suggested by Gregersen et al. (2013) and Mayer et al. (2015).

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