<u>LATE</u> REQUEST FOR A SPECIAL PROJECT 2016–2018

MEMBER STATE: Norway

Principal Investigator[1]: Prof. Rune Grand Graversen

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Project Title:

Investigations of polar lows using AROME Arctic

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

Computer resources required for 2016-2018: (The project duration is limited to a maximum of 3 years, agreed at the beginning of the project.)		**2016**	**2017**	**2018**
High Performance Computing Facility	(units)	400,000	4,000,000	4,000,000
Data storage capacity (total archive volume)	(gigabytes)	3000	3000	3000

An electronic copy of this form ***must be sent*** *via e-mail to:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):
24.10.2016

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 an annual progress report of the project's activities, etc.

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Extended abstract

Introduction

Polar lows are intense, fast developing meso-scale cyclones occurring in the cold season at high latitudes (Rasmussen, 2003). They often develop when cold air from sea-ice or continental areas is advected over warm ocean water. The temperature difference between the warm ocean and cold air above causes vertical instability of the atmosphere. A synergy between vertical instatbility, baroclinicity, and upper level forcing may lead to vorticity intensification and to polar-low formation.

Polar lows are often having gale-force surface winds reaching 25 m/s. They therefore cause severe problems for ship traffic and other maritime activities. Although polar lows are fast weakening when reaching land, they are associated with intense winds and snowfall in high-latitude coastal regions such as along the coast of Norway. Also it has been argued that polar lows contribute to vertical mixing in the Nordic Seas, and hereby to the meridional overturning circulation and inflow of warm water to this area (Condron and Renfrew, 2012).

Polar lows have been investigated using observations (*e.g.* Wilhelmsen, 1985; Bracegirdle and Gray, 2008; Noer *et al.*, 2011), idealised model simulations (Terpstra *et al.*, 2015), and dynamical downscaling of climate model data (Zahn and von Storch, 2010; Chen *et al.*, 2014) and reanalysis data (Zahn and von Storch, 2010) based on high-resolution regional climate models. Although these studies show that polar lows are a cold season phenomenon, the studies do not agree on the average yearly frequency of occurrence of these storms. Also the relative importance of the processes that are believed to play a role for the development of the storms is understood only to a limited extent.

Because of their small horizontal scale (100-600 km) and their short life time (<2 days), polar lows have been only crudely represented in global climate models and reanalysis such as the European Centre for Medium-Range Weather Forecasts (ECMWF) Re-analysis ERA-interim. However the state-of-the-art high-resolution regional weather-prediction models such as the AROME-Arctic (Seity *et al.*, 2011) resolve polar lows reasonably well (Randriamampiania *et al.*, 2011).

The main objective of the proposed project is to investigate polar lows based on the AROME-Arctic model (Seity *et al.*, 2011). The AROME-Arctic is build on a non-hydrostatic dynamical core, which is an important aspect of the model regarding its ability to resolve meso-scale convective phenomena such as polar lows. In addition the model has a horizontal resolution of 2.5 km and a vertical resolution based on 65 vertical layers of which 32 are below 3 km. Also the high resolution, especially when it comes to the lower part of the troposphere, is important for the model's ability to resolve polar lows. The model has recently been set up by the Norwegian Meteorological Institute (met.no) for the Norwegian Sea, Barents Sea and the Svalbard and Fram strait area. This area extents from the ice-covered regions in the north over ocean areas further to the south where polar lows tend to develop. With this model set-up, and being state-of-the-art regarding model dynamics and physics, AROME-Arctic provides a significantly improved platform for studying the physical processes important for the polar low development. The model is already installed on the ECMWF supercomputer system.

Scientific plan

We plan the following two work packages:

WP1: Downscaling of Polar Low cases. Downscaling of reanalysis data (e.g. ERA-interim) with AROME-Arctic will be performed in order to obtain highly resolved climatological data before and during observed Polar lows. Downscaling of polar lows using AROME-Arctic will provide an improved climatology of the meteorological settings associated with polar lows, for instance of surface turbulent fluxes, atmospheric baroclinicity and vertical instability. The study will also be used for categorising polar lows based on the governing processes.

Met.no hosts a unique polar low observation data set (Noer, 2010) which includes data from radiometer, scatterometer and synoptic observations from 2002 until present day. These data will be used to evaluate the model results.

WP2: Physical mechanisms important for polar low development. AROME-Arctic will be used to study processes important for polar low development. The processes we have in mind include latent and sensible heat release from the surface, the strength and direction of the background flow, the internal energy of the background flow, upper tropospheric circulation disturbances, and background baroclinicity. Other processes may be discovered an tested during the study. Sensitivity studies will be performed with AROME-Arctic where perturbations of the processes are implemented one-by-one and in combinations. Hereby the importance of a given process for polar low development will be revealed. The background settings will be controlled by boundary fields and by "nudging" to a given background state. For nudging, either the embedded facilities in the model of data assimilation can be utilized or the nudging approach by Denis et al., 2002, can be implemented. In this approach, important fields determining the circulation, such as geopotential height and temperature are changed above the boundary layer so that they approach a given background state.

These investigations will lead to a better understanding of polar low development. They may also lead to suggestions for improvement of parametrizations of the physic schemes of the model. For instance the schemes of the boundary layer are in many cases developed for mid or low-latitude conditions and may not be fully applicable for high-latitude conditions.

Time plan and resources

The first package will be performed during 2016-2017, and WP2 during 2017-2018. We expect that WP1 will lead to at least 1 publication, and WP2 to 2 publications.

We see a large advantages in running AROME-Arctic at the ECMWF supercomputer facilities since the model experiments will be highly dependent on input data obtained from the ECMWF MARS archive, such as the ERA-Interim data. In addition the project is performed in corporation with scientists at met.no, who also work with AROME-Arctic on the ECMWF supercomputer facilities. By working on the same machine we can more easily share experiences, data, and code.

Justification of computer resources

We ask for 4,000,000 SBU per year. From colleagues using AROME-Arctic at the ECMWF supercomputer facilities, we have learned that one experiment with AROME-Arctic of the dimension that we plan for costs ~17,000 SBU. We expect to run ~24 such experiments per month, and work on the project 10 months per years. That is:

Units = 17,000 SBU/experiment * 24 experiments/month * 10 months ~ 4,000,000 SBU

Technical characteristics of the code (AROME-Arctic)

The base language of the AROME-Arctic is Fortran. As mentioned above, the model is already installed at the ECMWF supercomputer facilities. Here the model often run on 8 nodes, but the parallelisation can be adjusted by the user.

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