SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2018
Project Title:	Investigations of polar lows using AROME-Arctic
Computer Project Account:	SPNOGRAV
Principal Investigator(s):	Rune G. Graversen, Patrick Stoll
Affiliation:	University of Tromsø
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………………… …………………………………………………………………
Start date of the project:	November 2016
Expected end date:	December 2018 *

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)	4 000 000	162 378	4 000 000	256 404 **
Data storage capacity	(Gbytes)	800	?	800	~ 32 ***

*We would like to extend the duration of the special project

** until June 2018. We do not expect to use more than 10% of our allocated time for this year

*** on ecgate at scratch for 30 June 2018. It varies a lot when simulations are performed. Often considerably more storage is used,

Summary of project objectives
(10 lines max)

Polar lows are intense, fast developing meso-scale cyclones occurring in the cold season at high latitudes. They are believed to develop by an interplay between vertical instability, baroclinicity, shear instability and upper-level forcing. Due to their small horizontal scale (100-500 km), the polar-low prediction was long a challenge for meteorlogical services. Today, weather-prediction models, such as AROME, seem to resolve polar lows reasonably well. Hence, the capability of high-resolution numerical models to simulate polar lows is used to investigate the physical mechanism leading to polar-low intensification.

The main objective of the proposed project is to investigate the development of polar lows with usage of the AROME model. From the start, this project was divided into two work packages (WPs):
1) Downscaling of polar-low cases to derive a polar low climatology.
2) Investigation of physical mechanisms important for polar-low development.

Summary of problems encountered (if any)
(20 lines max)

Several challenges were encountered, that lead to a modification of WP 1, and to the usage of considerably less ECMWF computing resources than allocated:

1) The set-up for downscaling of polar-low cases with AROME requires decisions on multiple options. This includes the choice of the starting time of the simulation, of boundary data and of the domain. Therefore thoughtful and time-consuming experiments were necessary to derive a good model set-up for the downscaling.

2) The quality of AROME simulations as compared to observations and to existing model products has not been investigated. Knowledge about the reliability of the model to correctly simulate polar lows is necessary to draw correct conclusions. In order to motivate the usage of AROME, it is necessary to examine to which degree it has a better ability to simulate polar lows than existing datasets, such as reanalyses.

3) The performance of numerous experiments with AROME is facing a larger challenge for data storage than for computational time. In order to study the dynamical process of polar-low developments, there is a need for the high-resolution data in horizontal, vertical and temporal dimension. This accumulates large amount of data. It was considered more important to investigate the high-resolution data thoroughly than to perform a downscaling of a long list of polar lows.

Summary of results of the current year (from July of previous year to June of current year)
This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

Due to different challenges, summarized in “problems encountered”, the WPs were slightly modified:
1a) Derivation of a global climatology of polar lows using reanalysis datasets.
1b) Validation of polar-low downscaling with AROME and comparison to other meteorological datasets, such as ERA-Interim.
2) Investigation of physical mechanisms important for polar low development.

WP 1a was successful finished and resulted in the publication of a scientific article (Stoll et al. 2018). Due to encountered problems mentioned in the last progress report, the approach to derive a climatology of polar lows was changed. Instead of downscaling numerous polar-low cases given from a subjective list with AROME, it was chosen to derive an objective climatology of polar lows from the reanalysis datasets ERA-Interim and the Arctic System Reanalysis (ASR). In order to obtain objective detection criteria, several parameters were compared for their efficacy to detect polar lows. This climatology gives the opportunity to apply statistical analyses in order to identify different types of polar lows. This is an ideal starting point to investigate the physical mechanisms leading to the development of polar lows in WP 2.

WP 1b is almost finished and is being documented in a scientific article. It was considered necessary in order to face the “problems encountered” 1) the downscaling with AROME leaves opportunity for different model settings, and 2) AROME has neither been evaluated for its ability to represent polar lows, nor been investigated for its benefits compared to other model products.

Hence, the performance of AROME to downscale polar lows is validated for the THOREX polar low. This polar low, occurring in March 2008, was investigates by dropsondes released from three flights missions, making it to one of the best observed polar-low cases. The obtained data of the vertical structure is considered valuable for the validation of model products.

In order to find a good model set-up, AROME is initialized at different times and with different boundary data. It is compared to the observations of the flight campaigns on one side, and other model products, such as ERA-Interim, ERA-5, ASR and ECMWF HRES on the other side.
The main conclusion is that the 3 to 24 hour forecast of AROME compares very well with the observations. Due to its convection-resolving physics, it captures the vertical structure of the temperature, moisture and winds reasonably well. It shows considerable advantages to the other model products. For longer forecasts the propagation speed of the polar low in AROME was predicted different from the observed one. The polar low in AROME was also developing a second core, whereas only one was observed.

Additionally, as start of WP2, several sensibility experiments have been performed for this polar low in order to investigate the importance of physical mechanism leading to the intensification. The effect of topography, a sea-ice scheme, turbulent heat fluxes and condensational heat release were studied. Both, topography and the sea-ice scheme have negligible influence on the development of this polar low. Turbulent heat fluxes have a large influence, and the polar low was quickly decaying if these fluxes are turned off. Another experiment showed that the heat flux is most important close to the center of the polar low. The amplification of turbulent heat fluxes by a factor of two, lead to intensification of one of the two developing cores of the polar low, however not by a factor of two. A separation of the turbulent heat flux into the sensible and the latent component reveals that the former is more important than the latter for the intensification of this polar low. The relevant aspect of the latent heating seems to be the condensational release of the energy, and to a smaller extent the flux of moisture at the surface.

The climatology of polar lows derived in WP 1a and the downscaling experiment performed with AROME in WP 1b gives the ideal opportunity to combine the advantages of the two approaches in WP 2. Firstly, composite analysis and statistics based on the climatology from reanalysis datasets can reveal different types of polar lows. Secondly, with the usage of the high-resolution AROME, representative cases of the different types can be investigated in detail. For WP 2 this combinational approach is planned. It is expected to lead to a better understanding for the development of polar lows.

List of publications/reports from the project with complete references

Stoll, P., Graversen, R. G., Noer, G., & Hodges, K. (2018). An objective global climatology of polar lows based on reanalysis data. *Quarterly Journal of the Royal Meteorological Society*.

Presentations at the EGU general assembly in Vienna and the European Polar Low Working group meeting in Trier both in April 2018 based on the scientific article.

Presentation at the “China-Norway workshop on polar observations and modelling” held in Tromsø in June 2018 on “Investigations on a polar low with the numerical weather-prediction model AROME”.

Summary of plans for the continuation of the project

(10 lines max)

A continuation of WP2 is planed with the combinational approach described in the end of “Summary of results”. It is planned to apply statistical analysis on the derived polar-low climatologies and to investigate representative cases in detail with the high-resolution AROME model. Differently from the beginning of the project it is no longer aimed to downscale a large amount of polar lows. Therefore we do not expect to use more than 10% of the allocated computational time for the year 2018.

Since the project of investigating polar lows is ongoing after the end of 2018, we would like to apply for the prolongation of this special project until the middle of 2020, but with only 10% of the recently allocated annual computation time. A continuation with WP 2 is considered to have the potential for 2 scientific publications. Please inform us about steps to be done to extend the duration of this project.