A proposed high-resolution EPS for forecasting polar lows

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There is now considerable understanding of polar lows, and numerical weather prediction (NWP) models, data assimilation methods and remote sensing observations have reached far with respect to resolution and sophistication. However, forecast uncertainty can never be completely eliminated. The often large uncertainty in the polar low development and intensification stages makes the current practice of single-value (deterministic) forecasts inaccurate beyond several hours and the prediction of polar lows frequently fails (Noer and Ovhed, 2003; McInnes et al., 2011). The often large differences between subsequent model runs (jumpiness) is a challenge for operational forecasting and creates uncertainty among the forecast users. Also, the coarser mesoscale NWP models have fully parameterized convection and the severe weather associated with the smaller scale features (e.g. organized convection) cannot be reliably forecast beyond a day (Kristiansen et al., 2011; McInnes et al., 2011).

Convection-permitting ensemble prediction systems (EPSs) are therefore needed for better forecast resolution and reliability. High-resolution local data assimilation is challenging. Direct dynamical downscaling of a coarser resolution EPS is therefore a sensible first approach. Kristiansen et al. (2011) documented for the 3-4 March 2008 polar low the ability to predict the severe weather up to 2 days in advance and before the polar low started to develop. The non-hydrostatic Met Office Unified Model® (UK; Davies et al., 2005) at 4-km resolution was employed to dynamical downscale the 21 ensemble members of the HIRLAM-based LAMEPS which is run twice daily with 12-km resolution at the Norwegian Meteorological Institute since February 2008 (Frogner and Iversen, 2002). LAMEPS includes a 3DVar-based control forecast valid at 0600 or 1800 UTC, and initial and boundary perturbations are taken from ECMWF-EPS. The forecast range is 60 h. The high-resolution EPS add value to the coarser LAMEPS, which is in support for the basic assumptions behind dynamical downscaling. Sensitivity to model formulation was also documented as the forecasts were sensitive to model version and choice of stable boundary layer vertical mixing scheme.

As such, an operational high-resolution, limited area EPS to enable early warnings of polar lows (EPS-PL) is suggested. Due to its computational cost, EPS-PL must necessarily employ a smaller domain size than LAMEPS (or its like) does. But a single EPS-PL domain cannot alone cover the Nordic and Barents Seas. The forecast quality depends crucially on the size and location of the model domain. A domain size of about 400 x 500 grid points (1600 x 2000 km) may if, favorably placed, be sufficiently large for short-range forecasts of polar lows whereas a smaller sized domain will be too small and the forecasts strongly controlled by the lateral boundary data (Kristiansen et al., 2011). For EPS-PL we have therefore selected 4 partly overlapping domains as seen in Fig. 1. In the operational environment one of these domains is selected a priori by the forecasters to be run ‘on-demand’. EPS-PL will be run every day during the polar lows season but automated instead of ‘on-demand’ on days without favorable conditions for the development of polar lows. It is important to recognize that a high-resolution forecast system cannot be expected to improve complete failures in the coarser resolution forecasts.

As a novelty in polar low forecasting we employ the forecast tracks to estimate polar low strike probabilities, Fig. 1. These strike probabilities effectively summarize the vast amount of information in the EPS. A method has been implemented to track the movement of a polar low by following vorticity maxima. The tracking is performed on the 925 hPa vorticity field of the different ensemble members.

Scales smaller than 200 km and larger than 600 km are first removed with a spectral spatial filter, and the maximum vorticity is traced. The tracking algorithm then filters the numerous spurious small-scale vortices: The tracks are constrained to fulfill criteria and thresholds based on characteristics of polar lows, such as wind speed, duration and static stability, by utilizing known forecasting methodologies (e.g. as reported in Noer and Ovhed, 2003) and long-time forecast experience.

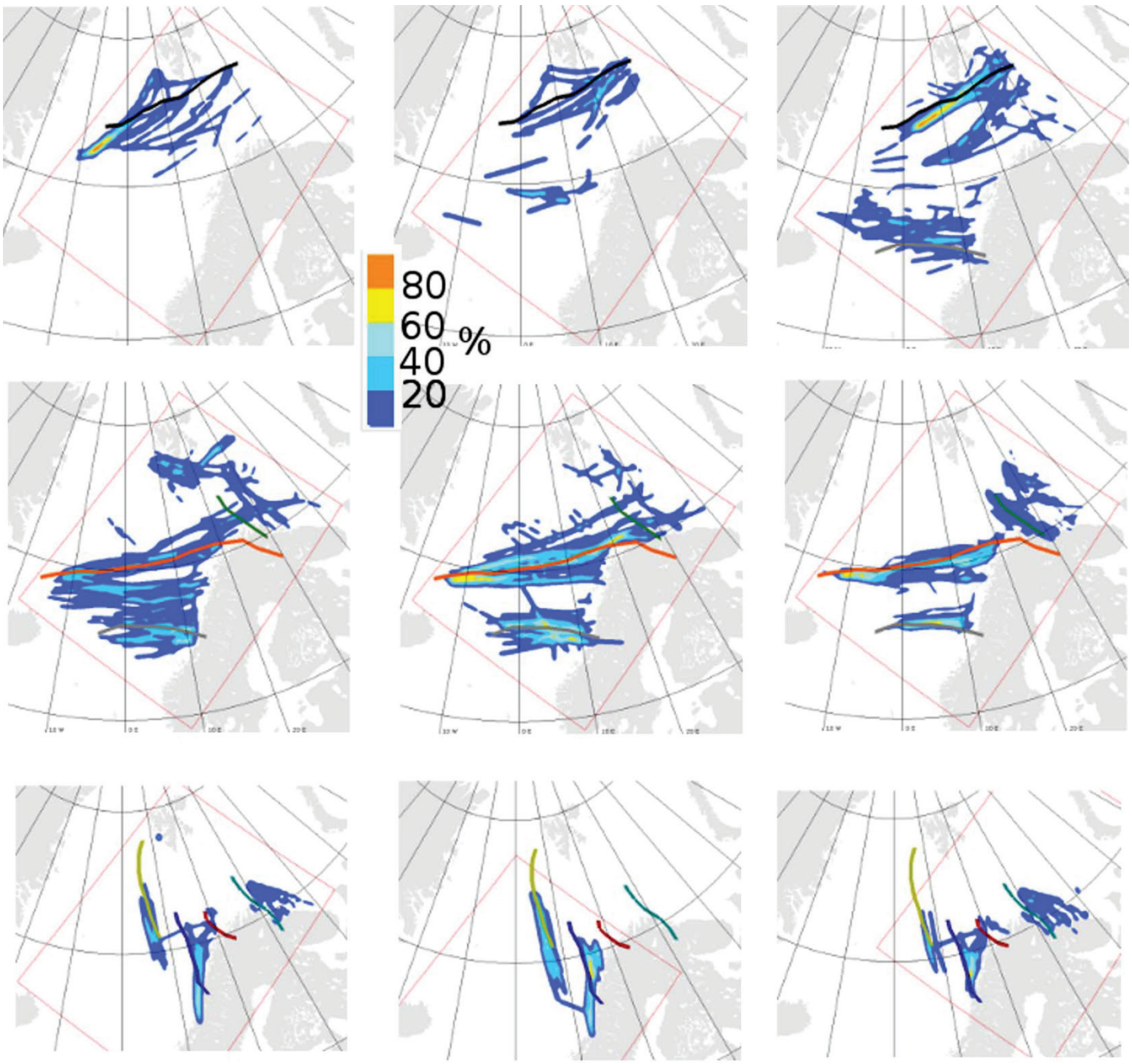

Figure 1: Strike probability maps for three polar low evens. The observed polar low track paths are displayed as thick solid lines. The red boundaries represent different EPS-PL model integration domains to be selected 'on-demand'. All domains are 400 x 500 grid points. See text for details.

EPS-PL has been run in hindcast mode for March 2011. During this period there were several polar low events. Figure 1 shows the forecast strike probability maps for some of these events. At about 1000 UTC 20 March 2011 a weak polar low developed east in the Greenland Sea (top row). It followed a northeasterly track until it dissipated 26 hours later (thick black line). The forecast started at 0600 UTC the previous day (top left corner) give nonzero probabilities in the same region but suggest a more northerly path. The next forecast 12 hours later places the highest probabilities south of Svalbard, and on the morning of the 20 March the EPS-PL forecast high probabilities close to the observed track. The probabilities are usually largest at the start of the polar low path track which makes the middle forecast more challenging to interpret. As illustrated by these events, there are challenges associated both with early detection of the fast developing and short-lived polar lows and with filtering of small scale phenomena such as the weaker trough seen east of the observed polar low track path. On the 22 March three different lows was observed in the Nordic and Barents Seas. The most intense of the three developed at about 0300 UTC northeast of Iceland, tracked eastward and lasted 36 h (orange). The second low (grey) started at the same time but made landfall at 2000 UTC in the middle of Norway. A third, short-lived (5 h) low developed at noon in the Barents Sea (green). Again, the strike probabilities are presented for three consecutive forecasts, from left to right, initiated at 0600, 1800 UTC 21 March and 0600 UTC 22 March. The forecast probabilities become gradually sharper with the more recent updates. The Barents Sea polar low is only captured in its right position by the latest forecast. The bottom row displays three different forecast for the same initial time but for different model domains. On the 24-25 March four polar lows occurred in the Norwegian and Barents Seas. This chase illustrates that there may not always be an optimal choice of domain size and location, and the selection of model domain may therefore introduce uncertainty in the forecasts (Kristiansen et al. 2011). It also highlights the challenging task of selecting a model domain a priori.

The EPS-PL forecasts is a tool for weather forecasters but could also produce useful products for the general public, for instance on www.BarentsWatch.no. A prevailing challenge with forecast probabilities is how we best present such products to the end user. Even a “perfect” forecast has little value to the users if they are uncertain about how to interpret and understand it or contain information of little relevance for their specific needs. Polar low strike probabilities is one such product and others will be developed as we interact with the users and gain experience.

Uncertainty is an integral and essential component of all meteorological forecasts and the use such information helps to protect among other lives, property and marine transportation efficiency (Hirschberg et al., 2011). EPS-PL will contribute to develop understanding and to apply experience from already ongoing exercises in the convection-permitting range and in the field of polar lows. A high-resolution EPS will also provide a valuable contribution for research into the dynamical structure and the growth mechanisms of polar lows. With the operationalization lies also an interesting challenge to design a system that take into account the practical consequences of computer limitations but also exploit the possibilities that comes with the developments within the field of supercomputing.

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