The Thorpex polar low analysed with AROME-Arctic

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Research questions

1) How well does AROME-Arctic simulate the Thorpex polar low?
2) How does the Thorpex polar low develop?
3) How sensitive is this polar low to the sea-surface temperature?

1) The Thorpex polar low

In February and March 2008, in connection to the International Polar Year (IPY) - The Observing System Research and Predictability Experiment (THORPEX) - several flight missions were conducted in the European Arctic. Three flights were going through a polar low that developed 3-4 March 2008 in the Norwegian Sea - commonly refered to as the Thorpex polar low.

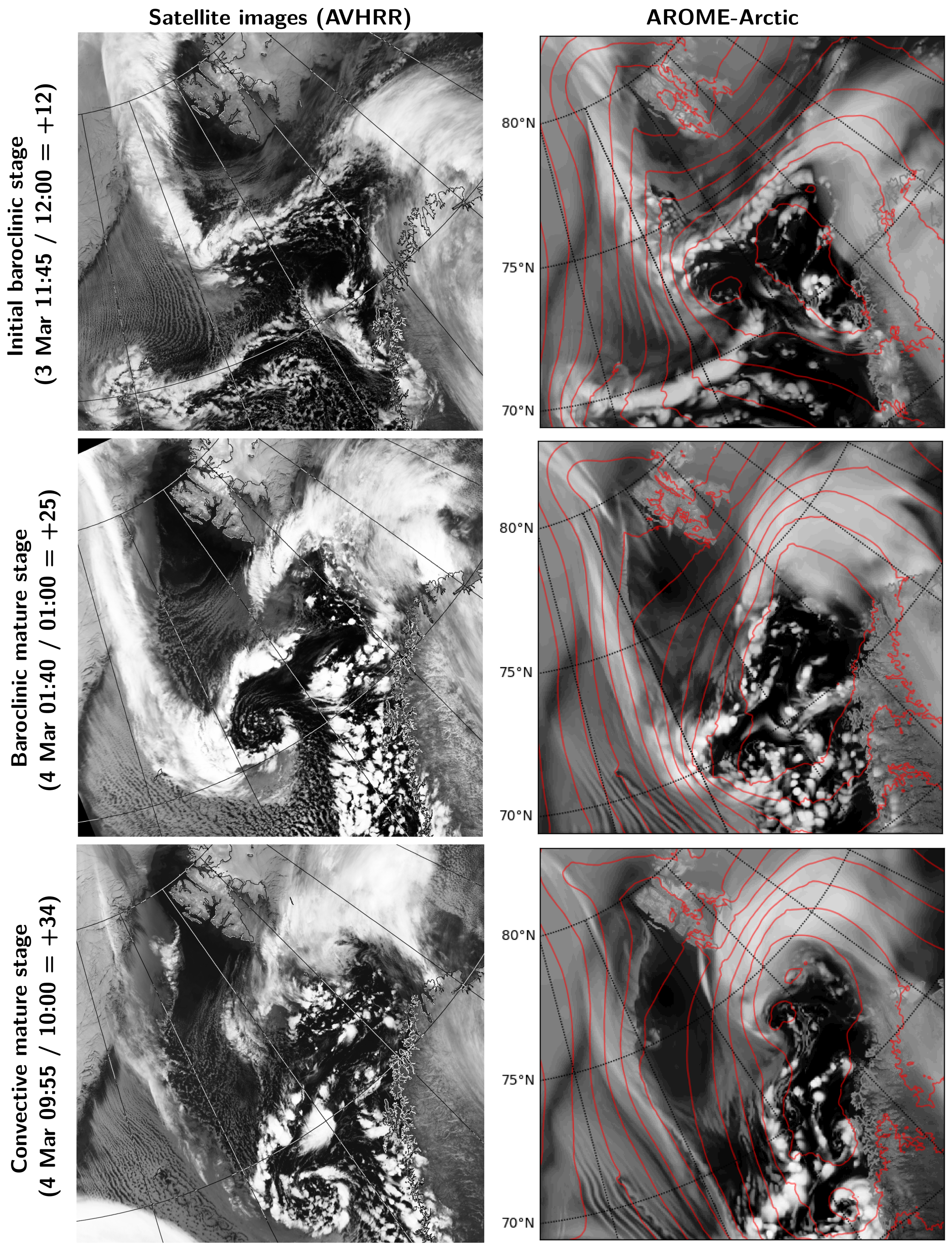

Figure 1 – The development of the Thorpex polar low at 3-4 March 2008. First column: Infra-red images from AVHRR (Advanced Very High Resolution Radiometer) channel 4, from the NERC satellite retrieving station. Second column: Pseudo satellite images displaying the cloud-top temperature (shading) and sea-level pressure (contours at 4 hPa interval) from a AROME-Arctic simulation starting at 3 March 2008 00 UTC. The time of the satellite images and model fields together with the model forecast length (+hh) are depicted on the left side of the figure.

- AROME-Arctic realistically captures the polar low at initial stages of the simulation.
- After a forecast length of more than 24 h AROME-Arctic deviates considerably from reality (more than the ECMWF HRES model for this case).
- Evaluation against dropsondes (not shown here) reveals that the model overestimates deep convection and underestimates the strength of the capping inversion over the shallow cold-air outbreak.

2a) Intensity evolution

The evolution of the polar-low intensity is compared between the control experiment (CTR, also presented in Fig. 1) and sensitivity experiments with suppressed surface sensible heat flux (noTH), latent heat flux (noQH), both surface flux components (noFLX) and condensational latent heat release (noCondens).

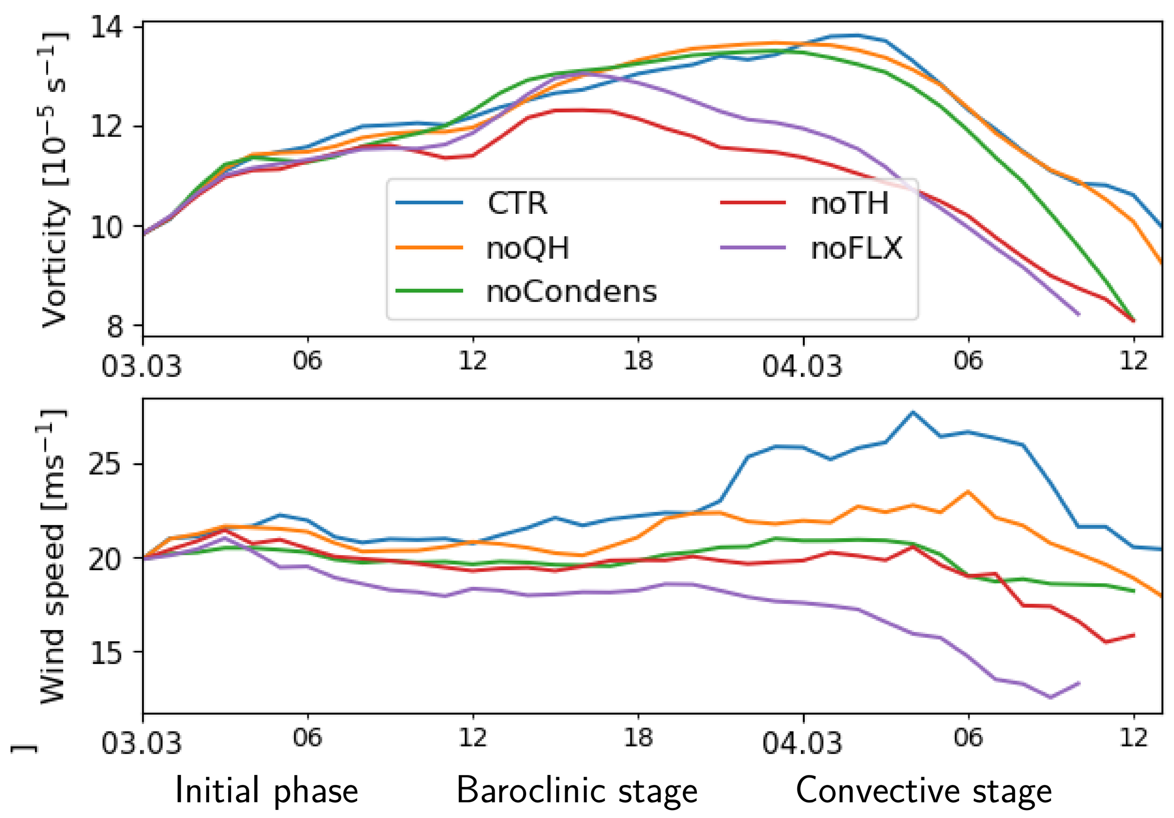

Figure 2 – The evolution of the intensity of the polar low centre (shown e.g. in Figure 5b) in different experiments. The intensity is here given by the filtered 850 hPa relative vorticity of the centre (Gaussian filter with 100 km radius) and the maximum near-surface wind speed in the vicinity of the vorticity centre (within 400 km radius).

- Sensible heat flux and latent heat release have a comparable influence on intensification of the near-surface wind speed.
- Condensational heat release has only a small effect on the vortex intensification.

2b) Baroclinicity

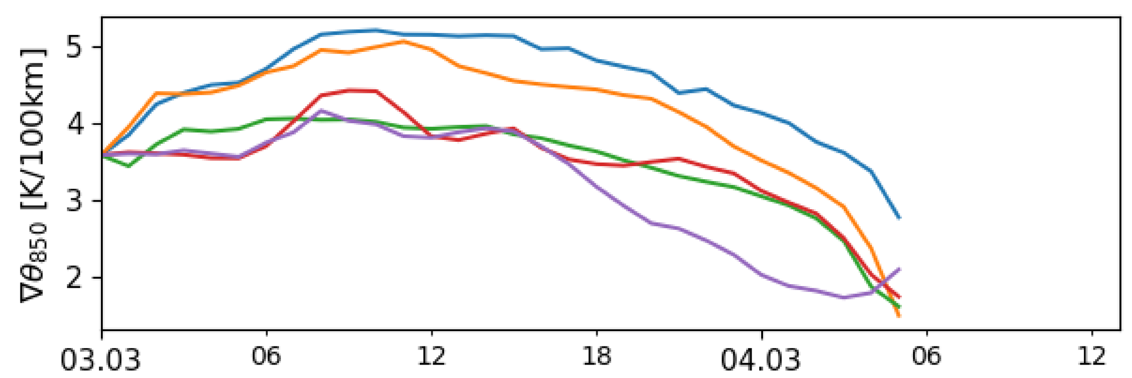

Figure 3 – The evolution of the maximum baroclinicity ($\nabla\theta_{850}$ - Gaussian filtered with 100 km radius) in the vicinity of the polar-low centre (within 400 km radius) of the experiments presented in Fig. 2.

- In the initial phase the polar low builds up baroclinicity, which is first maintained and then consumed in the baroclinic phase.
- Sensible heat flux and latent heat release contribute equally to the baroclinicity production.

2c) Heat fluxes

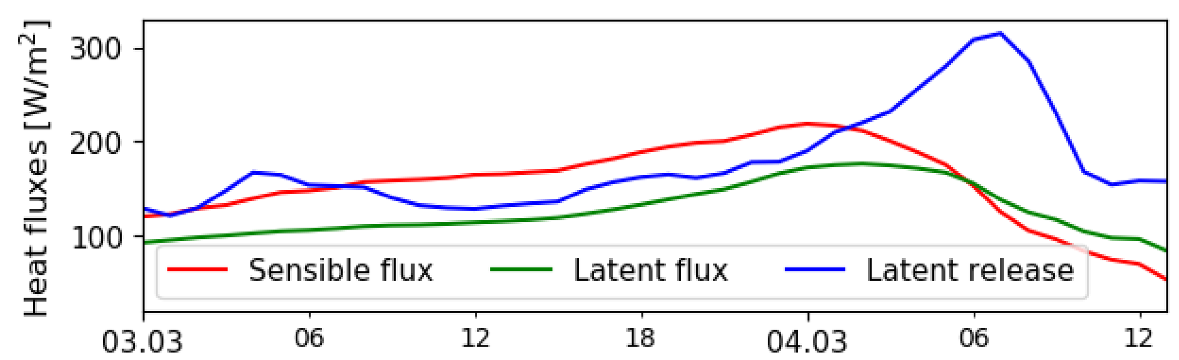

Figure 4 – The surface sensible and latent heat fluxes and condensational latent heat release around the polar-low centre (mean within a radius of 300 km). Note that the western eye wall, the area of strongest surface heat fluxes, is just outside the domain after 04 March 6 UTC.

- In the convective mature phase condensational latent heat release maintains the polar low.
- In that stage less than half of the consumed latent heat is locally produced.

3) Sensitivity to sea-surface temperature

Sensitivity experiments with perturbed sea-surface temperatures (SST) are performed.

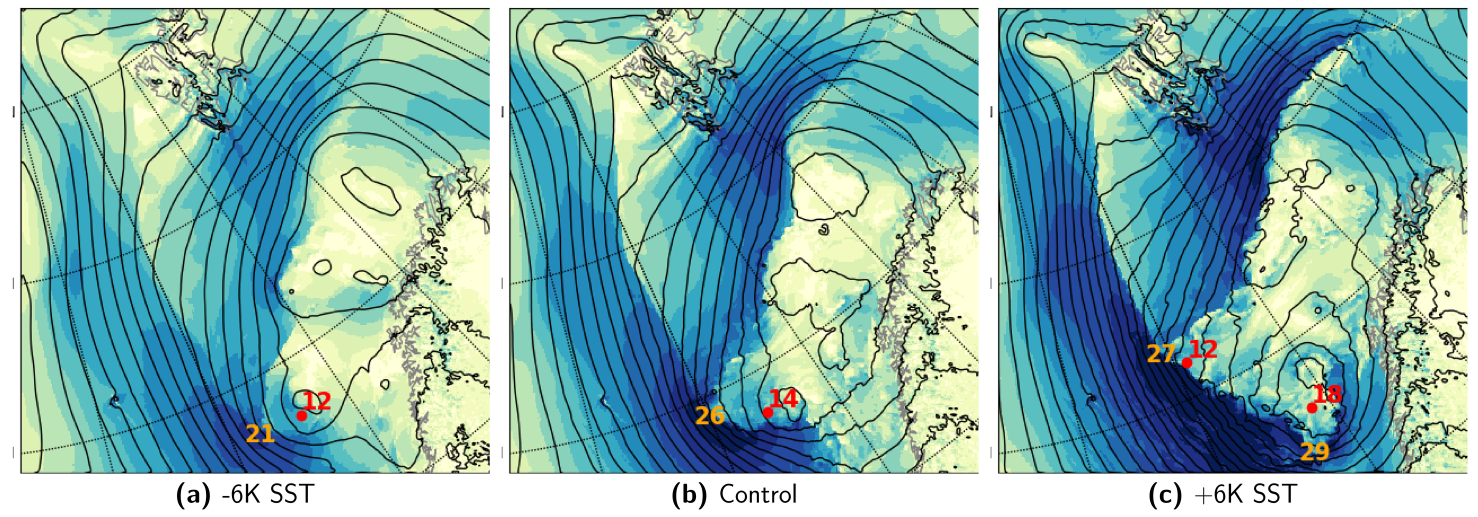

Figure 5 – The 10 m wind (in shading) and sea-level pressure (in contours, with 2 hPa spacing) after 27 hours of model integration for different simulations starting on 3 March 00 UTC. Red dots denote local maxima in the relative vorticity at 850 hPa (Gaussian filtered with radius 100 km) which defines the centre of the low, the red number indicates the strength in 10^{-5}s^{-1}. The orange number depicts the maximum wind speed within 400 km of the PL centre in ms^{-1}.

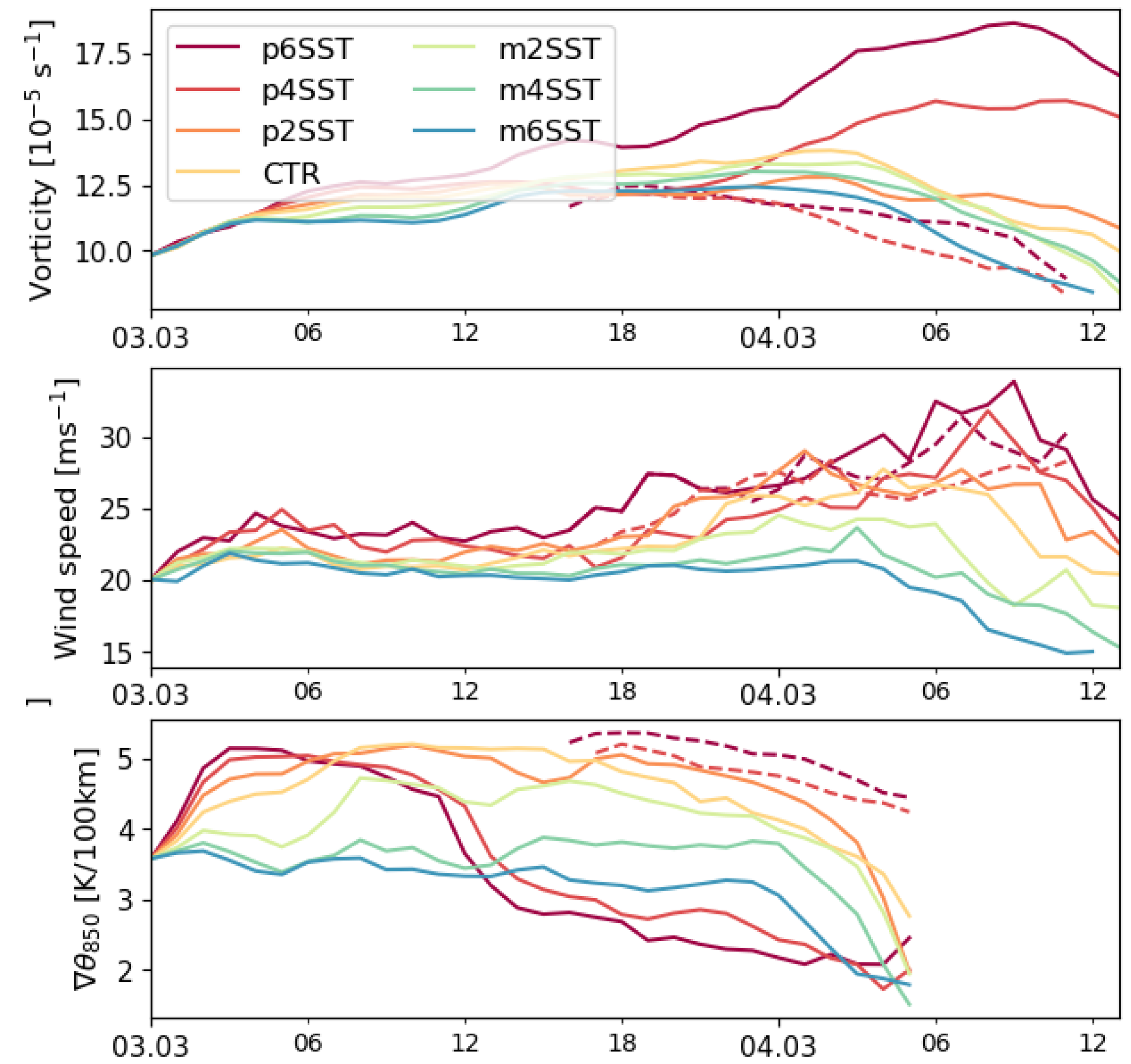

Figure 6 – As Fig. 2+3, but for sensitivity experiments with perturbed sea-surface temperatures. The solid line expresses the intensity of the leading centre and the dashed line of a secondary centre given that it develops.

- The intensity of the polar low increases non-linearly for incrementally increased SSTs.
- The maximum wind speed increases by 1-2 m/s per 1 K increase in SST.
- For highly increased SST a second polar low centre develops.

AROME-Arctic

AROME-Arctic (Applications of Research to Operations at MEsoscale for the European Arctic) is the operational weather-prediction model of the Norwegian Meteorological Institute since the end of 2015. The model has a horizontal model-grid resolution of 2.5 km and 65 vertical hybrid levels, from which 32 are below 3 km. Due to its fine resolution, it includes convection-permitting physics and non-hydrostatic dynamics. The model is operationally utilized for prediction of polar lows.

Acknowledgment

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