Simulation of polar lows over Norwegian and Barents seas using the COSMO-CLM and ICON models for the 2019–2020 cold season

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Motivations-Introduction

Prediction of polar lows by numerical modelling is a difficult but very crucial task. Polar lows (PLs) are small in size and have a relatively short lifetime, it makes their prediction problematic. Nevertheless PLs, which are rapidly developing, can lead to such extreme weather events as stormy waves, strong winds, the icing of ships, and snowfalls with low visibility, which can influence communication along the Arctic seas. Previous studies using the COSMO model focused on the various factors of polar lows formation, such as sea surface temperature, the presence and position of the ice edge, the strength and presence of a jet stream in one or two PL cases [2,3,4]. In our work, in contrast to previous works, we considered seven polar lows cases which appeared in the Norwegian and Barents Seas last winter. While we did not pay much attention to the factors of PL formation, which are considered in earlier works, we investigated the dependence of the forecast on the lead time and on the model grid steps.

We have identified seven well-developed PLs by the daily analysis of satellite images during the cold period of 2019–2020 (November–March) in the area from Greenland to the Norwegian and Barents seas. The area of investigation with the trajectories of the identified PLs is presented in Figure 1.

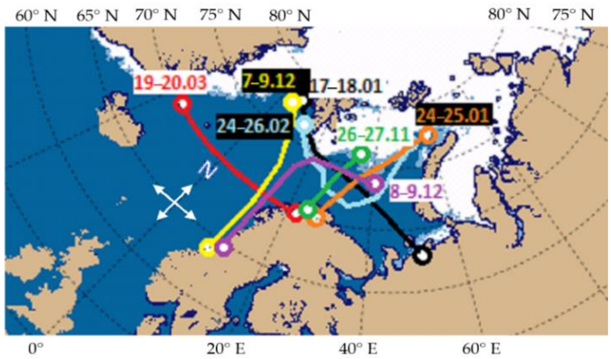


Figure 1. Trajectories of polar lows. Cold period: November 2019–March 2020. The date shows the start point of the trajectory.

2.Models

In this work, we used the COSMO-CLM and ICON Limited-Area models (LAM) [1, 5]. The output of the global ICON model was used for the initial and boundary conditions. The computational domains of all the used model configurations are shown in Figure 2.

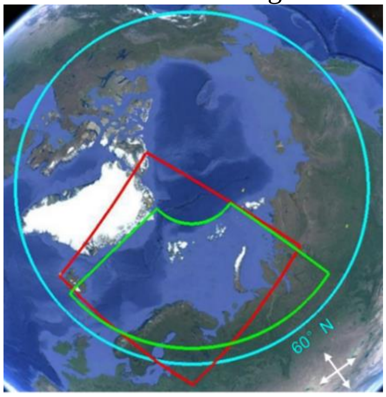


Figure 2. Computational domains. Blue—ICON-A6.5 (with grid spacing 6.5 km); green—ICON-A2 (with grid spacing 2 km); red—COSMO-CLM-A6.6 (with grid spacing 6.6 km).

3.Results

3.1. Comparisons of COSMO-CLM and ICON-A6.5. Case of PL of 20 March 2020

The polar low observed near the Norwegian coast on 20 March 2020, was formed during the day of 19 March in the west of the Norwegian Sea in the cold air flows from the sea ice near the eastern part of Greenland. Then, the vortex moved generally to the east with a steering flow along approximately 70° N, activating during the movement (Figure 3).

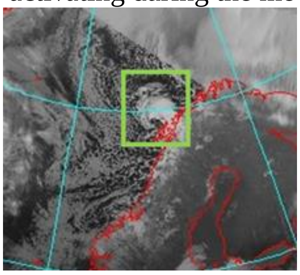


Figure 3. Satellite images of the polar low, 10:00 UTC 20.03. Images available from the Antarctic Meteorological Research Center (AMRC). Polar low shown by square.

The sensitivity of the modelling accuracy to the growth of the forecast lead-time in this case was studied on the basis of numerical experiments with different base times and lead times for the same valid time. With a lead time of 36 h, both models (started 1 day before) produced approximately the same wind gusts, but simulated different locations of the PL (Figure 4 c,d). In 12h forecasts, the PL destruction near the Scandinavian coast was more intense (and additionally quicker for COSMO- CLM) than in reality. With a lead time of 36 h, the PL according to COSMO-CLM was significantly displaced to the northwest (Figure 4c); in the case of ICON, the zone of strong winds was close to that obtained in the experiment with a short lead time (Figure 4a), however the cyclonic vortex itself was reproduced worse (Figure 4d).

3.2. Modelling of PLs with Increasing Model Resolution

The second stage of this work is devoted to an analysis of the forecast quality of the same cases with the ICON model with different resolutions, 2 and 6.5 km, and a study of the structure and peculiarities of the PLs produced by the model, as well as a point data verification using wind speed observations. A noticeable increase in the 10 m wind speed and gusts was observed at some coastal and island meteorological stations when the PL approached the coast of Norway.

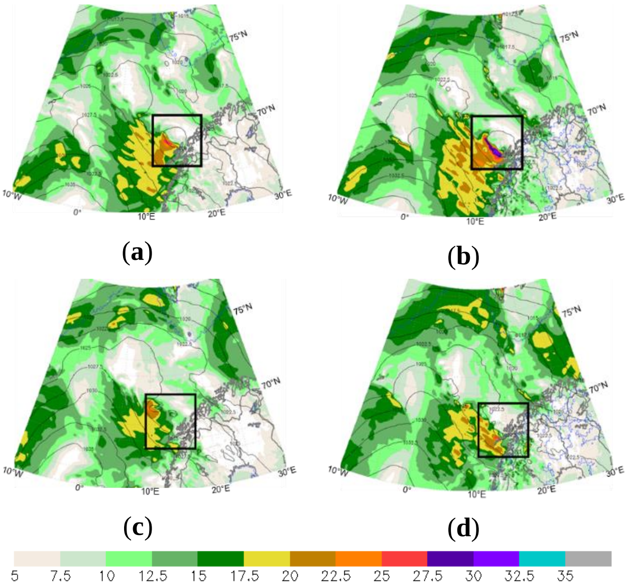


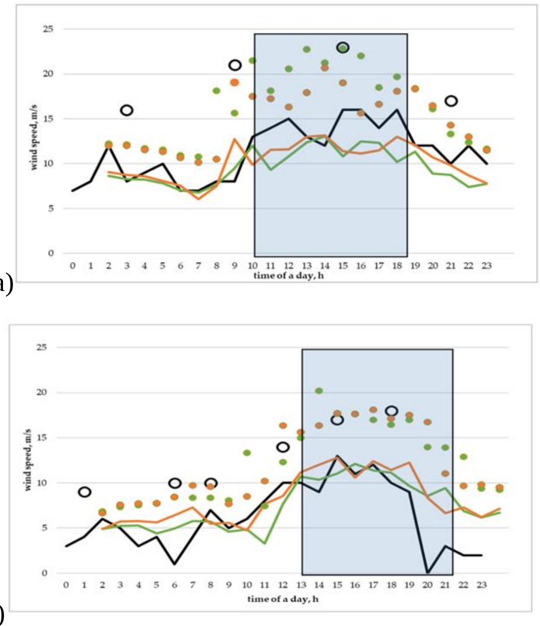
Figure 4. COSMO-CLM-A6.6 (left) and ICON-A6.5 (right) comparison for different lead times: wind gusts and sea-level pressure. Base times: 00:00 UTC 20 March 2020 with a lead time of 12 h (a,b) and 00:00 UTC 19 March 2020 with a lead time of 36 h (c,d). Valid time: 12:00 UTC 20 March 2020. Black square shows the position of the polar low (PL) according to the satellite image.

The simulation results are compared to the coastal observations in Figure 5 (the rectangle shows the time period in which the PLs influenced the coastal wind speed). It can be seen that ICON-A2 and ICON-A6.5 are close in their forecasts. The wind gusts were reproduced accurately; both model configurations also captured the maximum wind speed in the period from 14 to 17 UTC quite successfully. However, the wind weakening in the evening of 20 March was overestimated by the both ICON configurations for Skrova lighthouse.

Conclusions

A number of cases of PL formation in the cold period of 2019/2020 were identified over the Barents and Norwegian seas using satellite images. Numerical experiments using the COSMO-CLM and ICON models with a grid spacing of about 6.6 km and 6.5 km were carried out in the first part of this work. All the cases of detected PL were successfully simulated by all configurations. However, a rapid decrease in the accuracy of the modelling results was detected after the first 24 h of the forecast for all configurations. We can suppose that our simulations could benefit from taking into account temporal variations of the sea surface during the forecast as well as from data assimilation. Note also that the initial data in our experiments were taken from the global model with 13 km grid spacing. The difference between the ICON and COSMO simulations with the same resolution was bigger than that between simulations with two configurations of ICON. Some results showed that ICON-A2 was a little more accurate than ICON-A6.5, but the advantages of ICON-A2 are not always obvious. Simulations with ICON-A2 provide more detailed maps of wind speed, wind gust, and vorticity in comparison with ICON-A6.5 simulations.

(a)



(b)

Figure 5. ICON-A6.5 (orange); ICON-A2 (green); observations (black): 10 m wind speed (curves) and wind gusts (circles) on 20 March 2020. (a) Airport Röst (67°31’ N, 12°06’ E); (b) Skrova lighthouse (68°09’ N, 14°39’ E)

But point-to-point verification did not show significant advantages of ICON-A2. Orographic features of the surface can strongly influence the wind speed forecast in the polar low when it comes to the land. Detailed research of the polar lows over Norwegian and Barents Seas using the COSMO-CLM and ICON models for the 2019–2020 Cold Season can be found in [6]

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