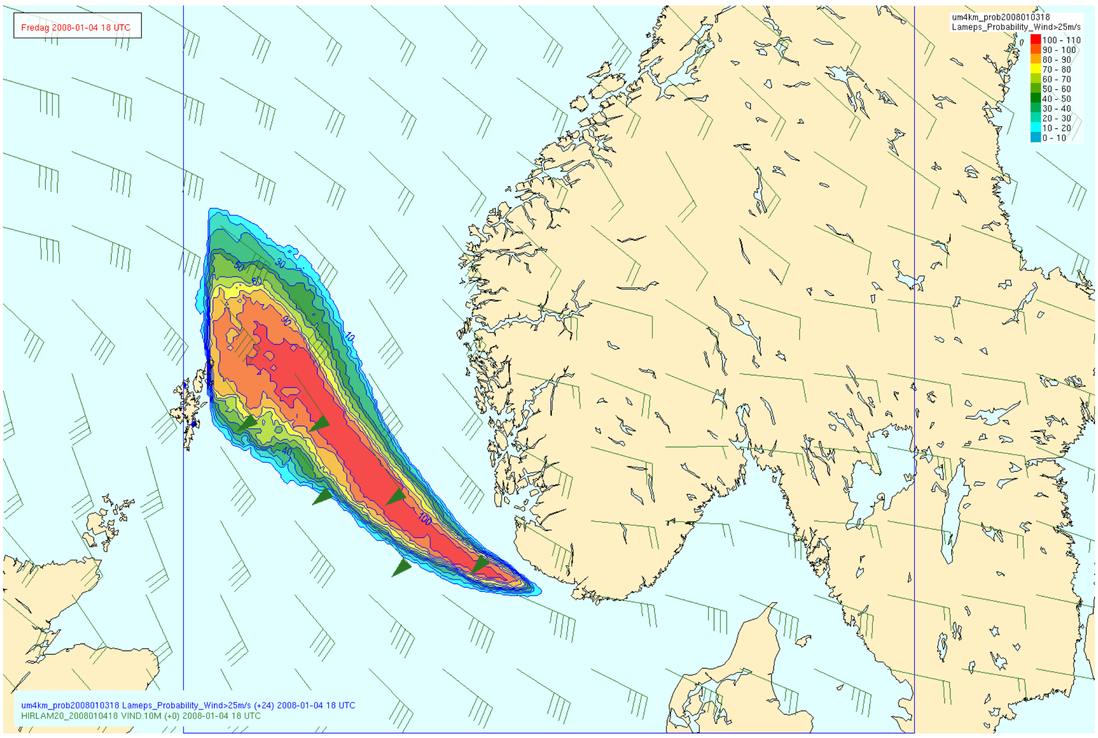
Norwegian Meteorological Institute met.no

met.no report

no. 8/2008
Meteorology

Down-scaling of LAMEPS

Marit Helene Jensen, Dag Bjørge and Inger-Lise Frogner



Norwegian Meteorological Institute met.no

report

Title Down-scaling of LAMEPS	Date 8/5-2008
Section Meteorology	Report no. No 8
Author(s) Marit Helene Jensen, Dag Bjørge and Inger-Lise Frogner	Classification ☉ Free ○ Restricted ISSN 1503-8025 e-ISSN 1503-8025
Client(s)	Client's referenc

Abstract

This report describes four cases of down-scaling met.no's limited ensemble model system (LAMEPS) with the Met Office Unified Model TM. We have down-scaled 4 different cases where the main activity takes place over the southern part of Norway. The four situations deal with winter storms passing over southern Scandinavia, all giving strong winds and heavy precipitation. In three of the four cases a new, higher resolution version of LAMEPS is used as well, to see if better resolution in LAMEPS itself can give some of the benefits seen with the non-hydrostatic model, with much lower computer costs.

Keywords

Down-scaling, ensemble prediction, TEPS, LAMEPS, Unified Model

Disiplinary signature	Responsible signature
Knut Helge Midtbø	Øystein Hov

Postal address
P.O.Box 43, Blindern
NO-0313 OSLO
Norway

Office
Niels Henrik Abelsvei 40

Telephone
+47 22 96 30 00

Telefax
+47 22 96 30 50

e-mail: met@met.no
Internet: met.no

Bank account
7694 05 00628

Swift code
DNBANOKK

Introduction

At the Norwegian Meteorological Institute (met.no) several different limited area numerical weather prediction models are implemented. The horizontal resolution is ranging from 22 km down to 1 km. For the regional scale we use a hydrostatic limited area model (HIRLAM) and for the local scale we use a non-hydrostatic model (Met Office Unified Model TM (UK) – UM), all giving deterministic weather forecasts up to 60 or 66 hours.

met.no also runs a limited area model ensemble prediction system (LAMEPS) utilizing the HIRLAM model. This report describes experiments where the UM is used to down-scale LAMEPS forecasts for selected cases. In ensemble prediction one typically evaluates forecast probabilities for a weather parameter to exceed different thresholds instead of the weather parameters. The aim of this study has been to see how much extra information the non-hydrostatic model with high resolution adds to forecast probabilities of strong wind and heavy precipitation.

Due to the high computer costs involved by running an operational high resolution ensemble system, we have chosen to down-scale four different weather cases, all winter storms hitting the southern part of Norway. In addition to the operational met.no LAMEPS at 22 km resolution, we have also tested a new version of LAMEPS (LAMH12) with 12 km resolution. The aim is to see if higher resolution in HIRLAM/LAMEPS will give some of the benefits seen with the non-hydrostatic model, with much lower computer costs.

Model setup

LAMEPS is a limited area ensemble system set up with 20 perturbed members and one control run. It is driven by a targeted version of the ECMWF EPS (TEPS). TEPS is similar to EPS except that the singular vectors are targeted over Northern Europe and the adjacent sea areas, and TEPS has 20+1 members compared to the 50+1 members of EPS.

The HIRLAM analysis is used as initial field for the control run, and perturbations from TEPS are added to the HIRLAM analysis to get initial fields for each ensemble member. TEPS runs are performed ECMWF, the computations starts at 12UTC and forecasts and boundary fields are produced for 72 hours. With a 6 hour delay, LAMEPS is started at met.no at 18UTC and forecasts are made for 66 hours ahead.

Up to mid February 2008 the operational LAMEPS was run with a horizontal resolution of 0.2 degrees (~22 km, 126*200 grid points) and 40 vertical levels, but from 13 February it has been run with 12 km horizontal resolution (232*371 grid points) and 60 levels. The new version is called LAMH12. The integration domain was approximately kept the same. At the same time the model version of HIRLAM changed from version 6.2 to 7.1.3. LAMEPS is now also run twice a day (06UTC and 18UTC), both forecasts are driven by the same TEPS forecast. The TEPS initial fields are now perturbations of the HIRLAM 12km analysis.

In this study we have used LAMH12 in addition to LAMEPS to see if and how the new higher resolution version influences the forecasted probabilities.

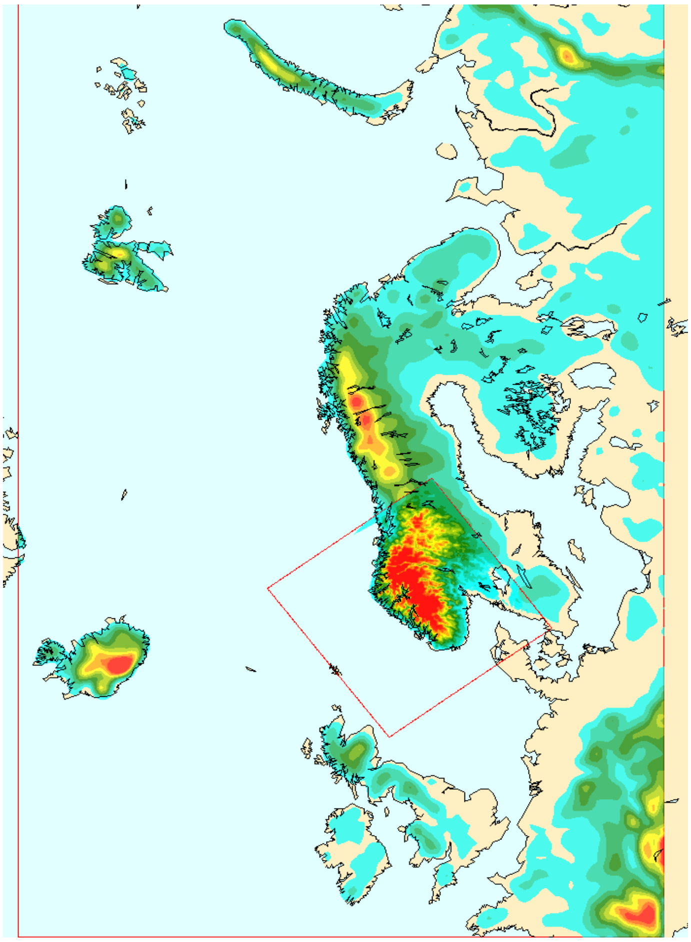


Figure 1: Integration domain of LAMEPS/LAMH12 (outermost area) and UMEPS (the innermost area).

Operationally at met.no the non-hydrostatic high resolution model, UM, is run twice a day at 4 km horizontal resolution on a 300*500*38 grid. Due to the relative high computer costs by running a non-hydrostatic model, the integration domain used in this study has been reduced to a 220*220*38 grid. Each LAMEPS ensemble member provides hourly boundary fields to an UM model run, giving an ensemble of UM runs (UMEPS). For three of the four cases LAMH12 has been used for boundary generation. In Figure 1 the integration domains and the orography of LAMEPS and UMEPS are shown.

The down-scaling experiments

In this study we have down-scaled 4 different cases where the main activity takes place over the southern part of Norway. The four situations deal with winter storms passing over southern Scandinavia (one in January 2007 and three in January 2008), all giving strong winds and heavy precipitation. In 3 of the 4 cases the forecasters on duty at met.no classified the forecasts as “extreme weather situations”, causing warnings to be issued. Both the public and local authorities receive special warnings of potential danger caused by the extreme weather conditions. Extreme weather forecasts in Norway are named; therefore these tree situations are given the name - Per, Sondre and Tuva.

One can not draw any final conclusions about verification of an ensemble system and the effect of down-scaling with only four cases, but one can say something about the result in each case.

For the first case, Per, we have only run the old version of LAMEPS and used that to force the down-scaling of UMEPS. For Per, forecast probabilities of 10m winds from LAMEPS and UMEPS are shown.

For the tree last cases we present forecast probabilities of 10m winds and 6 hour accumulated precipitation from LAMEPS, LAMH12 and UMEPS. As a “truth” for 10m winds (used to compare areas with strong wind against the forecast probability for strong wind), we have taken analysis or short forecasts from the operational HIRLAM with 22 km horizontal resolution. For the precipitation we only show the forecast probability. To give an overview of each weather situation we show short forecasts from HIRLAM.

a) Per – 14 January 2007

On 14 January 2007 a low pressure centre hit the western coast of Norway. This storm was classified as an extreme weather situation and given the name Per. The wind along the south-western cost (Slåtterøy lighthouse) of Norway came up to hurricane strength early in the morning before the storm moved across Skagerak and also hit Denmark and the southern part of Sweden causing large damages. In Figure 2 a 4 hour forecast of MSLP from HIRLAM is shown (valid at 04UTC, the time the strongest wind was observed at Slåtterøy). The figure shows tight isobars (5 hPa isolines) south of the low pressure centre, indicating strong wind directed towards the coastline.

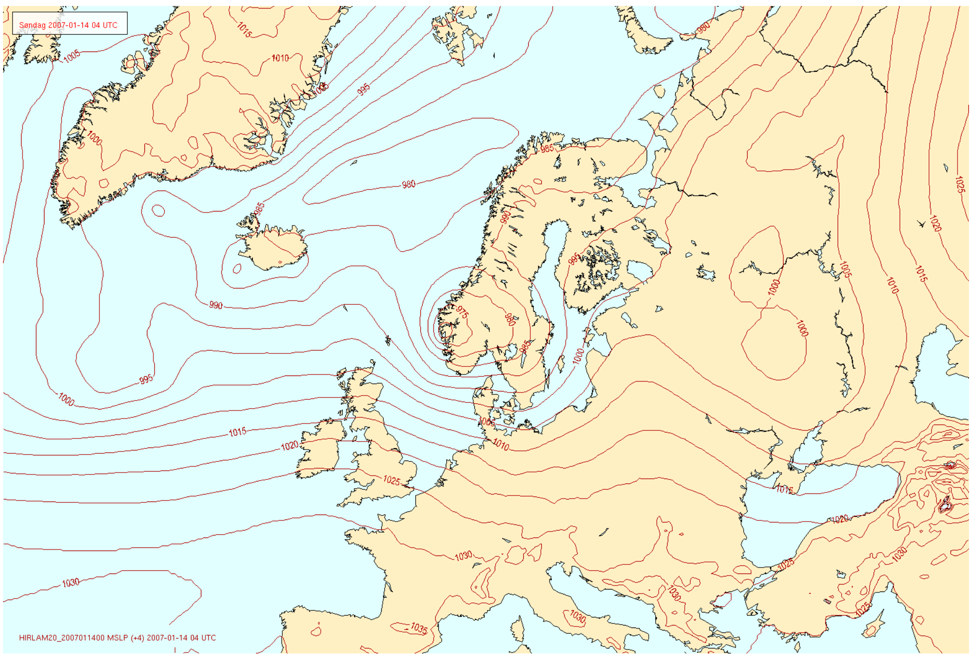
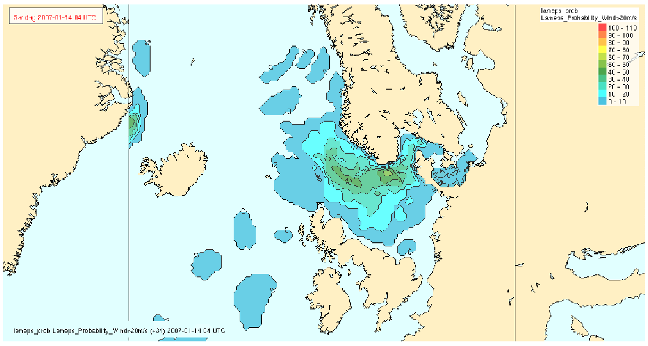


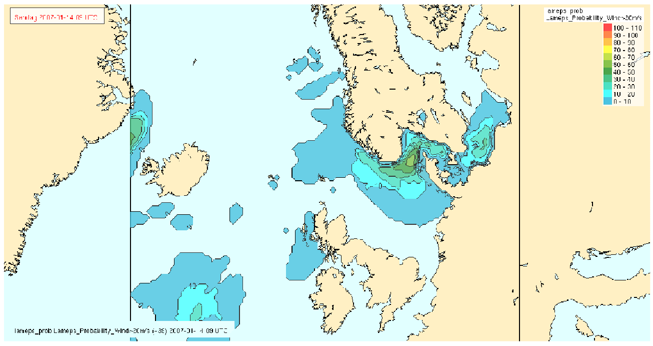
Figure 2: A 4 hour forecast of MSLP from HIRLAM showing the storm Per reaching the coast of Norway.

In Figure 3 forecast probabilities for more than 20 m/s from LAMEPS (a and b) and UMEPS (c and d) are shown. In panel a and c the forecast probabilities for the time with the most intense wind along the south-west coast of Norway are shown (34 hour forecast valid at 04UTC) and panel b and d are valid at the time for the strongest wind in Skagerak (39 hour forecast valid at 09UTC). For both forecast times one sees from these figures that there are more structures in the probability fields from UMEPS. For the first forecast time both ensemble systems have probabilities up to 50% south of Norway, but both systems have small probabilities for high wind speeds along the south-western coastline of Norway. For the second forecast time the UMEPS is able to maintain somewhat higher probabilities for strong wind along the south-western coast of Norway. Some of the members of UMEPS also have strong wind in the mountains for both forecast times. The UMEPS has also higher probabilities for more than 20m/s over Denmark, showing the advantage of higher resolution in the model when the storm moves in over land.

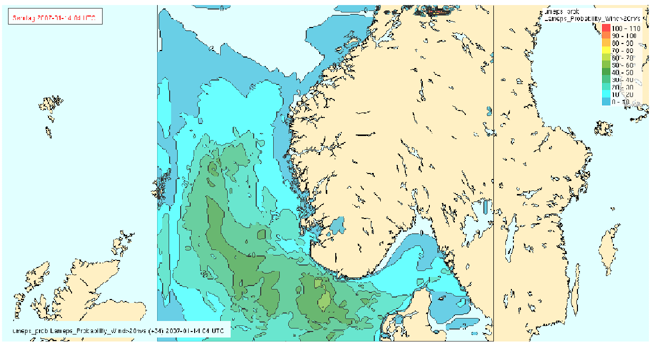
Both ensemble systems had forecast probabilities up to 20-30% for more than 25m/s along the coast of Denmark. The probabilities were somewhat higher in the UMEPS than in LAMEPS, but the structures were quite similar. The effect of down-scaling was in this case small, but visible. UMEPS had somewhat higher probabilities for strong wind, especially in the mountains.



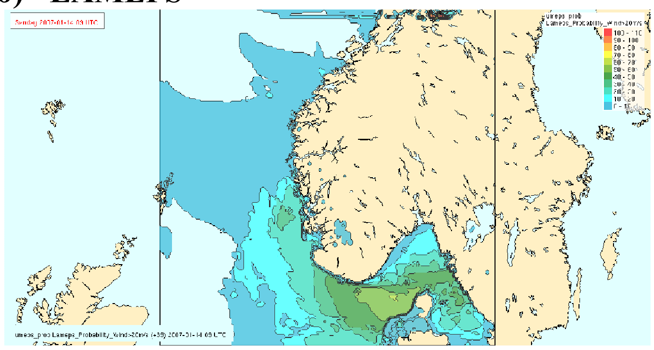
a) LAMEPS



b) LAMEPS



c) UMEPS



d) UMEPS

Figure 3: 34 hour forecasts of probabilities for more than 20 m/s (at 10 m) from LAMEPS (a) and UMEPS (b), and 39 hour forecasts of probabilities for more than 20 m/s from LAMEPS (c) and UMEPS (d).

b) 4-5 January 2008

In the start of January 2008 a low pressure system south of Iceland combined with a high pressure over Russia caused strong wind as well as large precipitation amounts (as snow) along the southern cost of Norway. This storm was not classified as an extreme weather event, but forecasts predicting much snow and difficult driving conditions were issued by met.no. Figure 4 shows a 6 hour forecast of MSLP and 6 hours accumulated precipitation from HIRLAM. The storm caused heavy snowfall (up to 1m snow in 24 hours) which in combination with the strong wind had large impact on the infrastructure along the coastline and in the mountains.

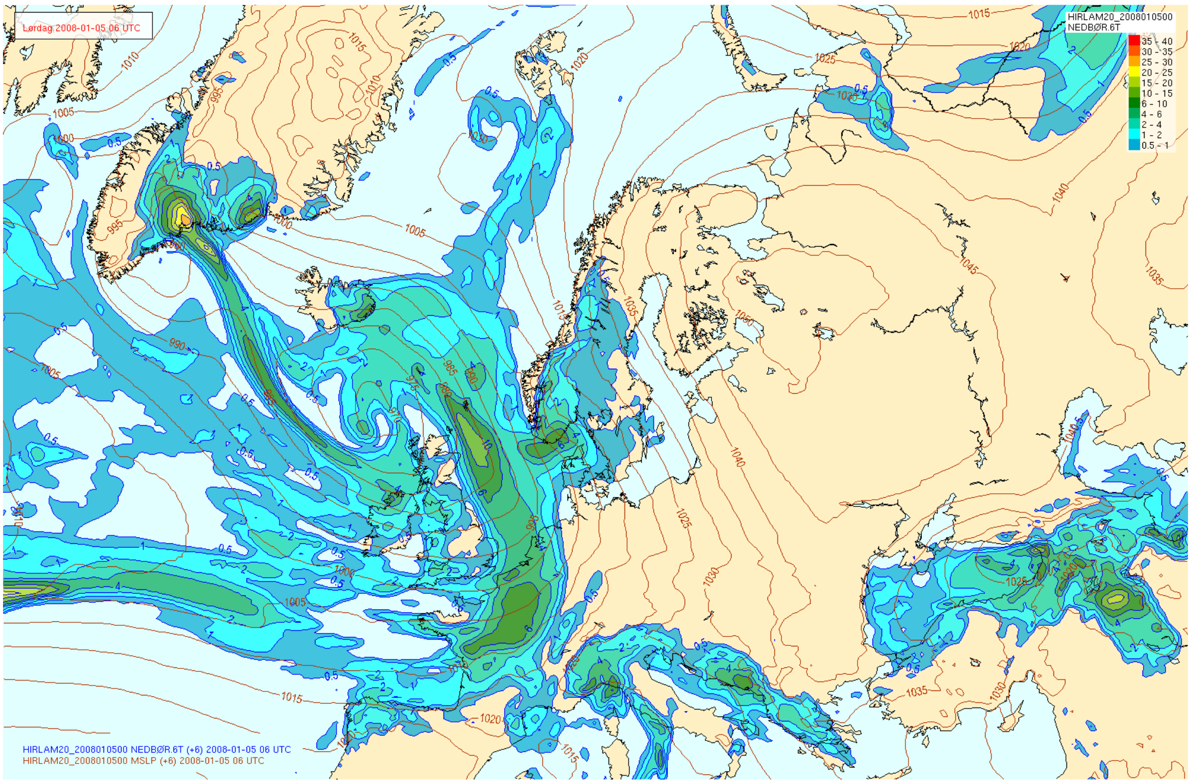
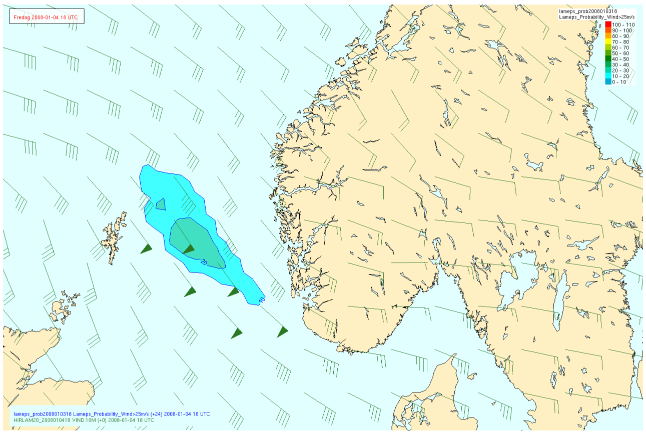


Figure 4: A 6 hour forecast of MSLP and 6 hour accumulated precipitation from HIRLAM valid at 06UTC 5 January 2008.

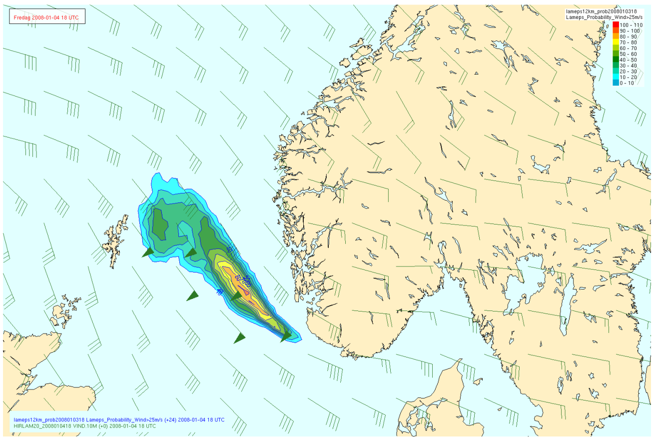
In this case UMEPS were down-scaled from LAMH12 and not LAMEPS.

Figure 5 shows a 24 hour forecast of forecast probability for wind stronger than 25 m/s from LAMEPS (a), LAMH12 (b) and UMEPS (c), all together with analysis of wind from HIRLAM (wind arrows in knots). The forecasts are valid at 18UTC 4 February (the time of the strongest observed winds). In this case we can clearly see the influence of higher resolution on the forecast probability, even over sea. In LAMEPS only a few ensemble members forecasted this strong wind, giving low forecasted probability (maximum 20-30% and not in the same place as the maximum wind from the HIRLAM analysis). In LAMH12, more ensemble members (up to 100%) predicted the strong wind and the forecast probabilities were also more in line with the analysed wind. In the UMEPS all ensemble members had at least 25 m/s for the whole area where the HIRLAM analysis showed more than 50 knots.

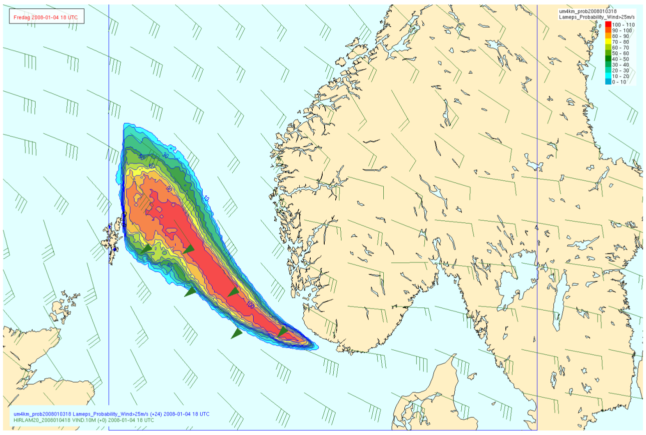
While the strongest wind hit the south-western part of Norway on the evening of 4 January, most of the snow came on the south-eastern side the next day.



a) LAMEPS

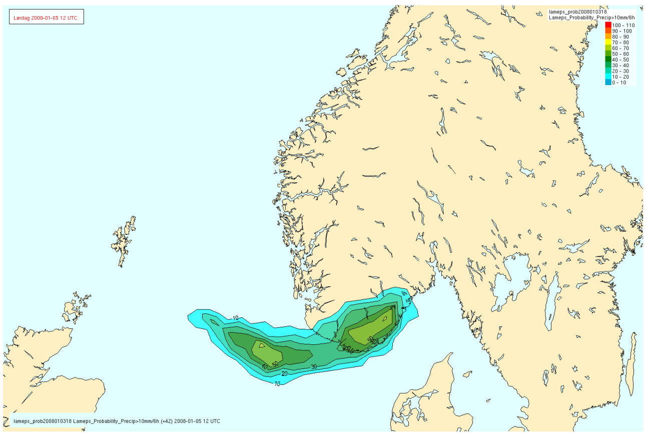


b) LAMH12

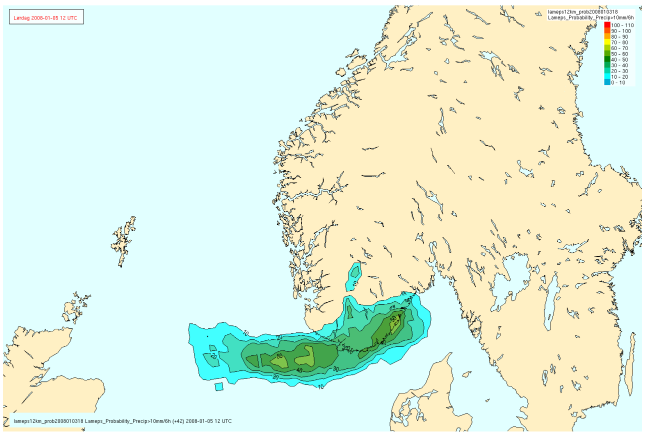


c) UMEPS

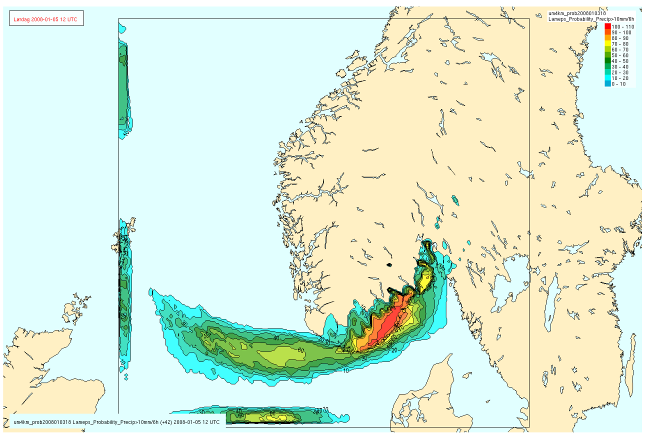
Figure 5: 24 hour forecasts of forecast probabilities for more than 25 m/s (at 10 m) from LAMEPS (a), LAMH12 (b) and UMEPS (c). Analysis of 10 m wind from HIRLAM (wind arrows are in knots) is shown together with the forecast probabilities. The forecasts are valid at 18 UTC on 4 January 2008.



a) LAMEPS



b) LAMH12



c) UMEPS

Figure 6: 42 hour forecasts of probabilities for more than 10mm/6hours from LAMEPS (a), LAMH12 (b) and UMEPS (c). The forecasts are valid at 12 UTC 5 January 2008.

Figure 6 shows a 42 hour forecast of forecast probability of more than 10mm/6hours for LAMEPS (a), LAMH12 (b) and UMEPS (c). The forecasts are valid at 12UTC 5 January. In these figures we see that the forecast probability is somewhat lower in the new LAMEPS version than in the old, but with some more structure. LAMH12 also has higher probabilities for snow in the mountains. In UMEPS the forecast probability is much higher and one also sees more of the terrain-structures in the precipitation pattern.

In this case one clearly sees the effect on down-scaling LAMEPS. Some of the positive effect is already seen in LAMH12, but the high-resolution UMEPS has a much better forecast of forecast probabilities of both wind and precipitation.

c) Sondre – 25 January 2008

A low pressure centre approached from south of Iceland and hit the north-western coast of Norway on 25 January 2008. An extreme weather forecast for storm surge along the coast was given by met.no, and the storm was name Sondre. In Figure 7 a 12 hour forecast of MSLP and 6 hour accumulated precipitation valid at 12 UTC on 25 January, from HIRLAM is shown. Also in this case LAMH12 is used for boundary conditions to UMEPS.

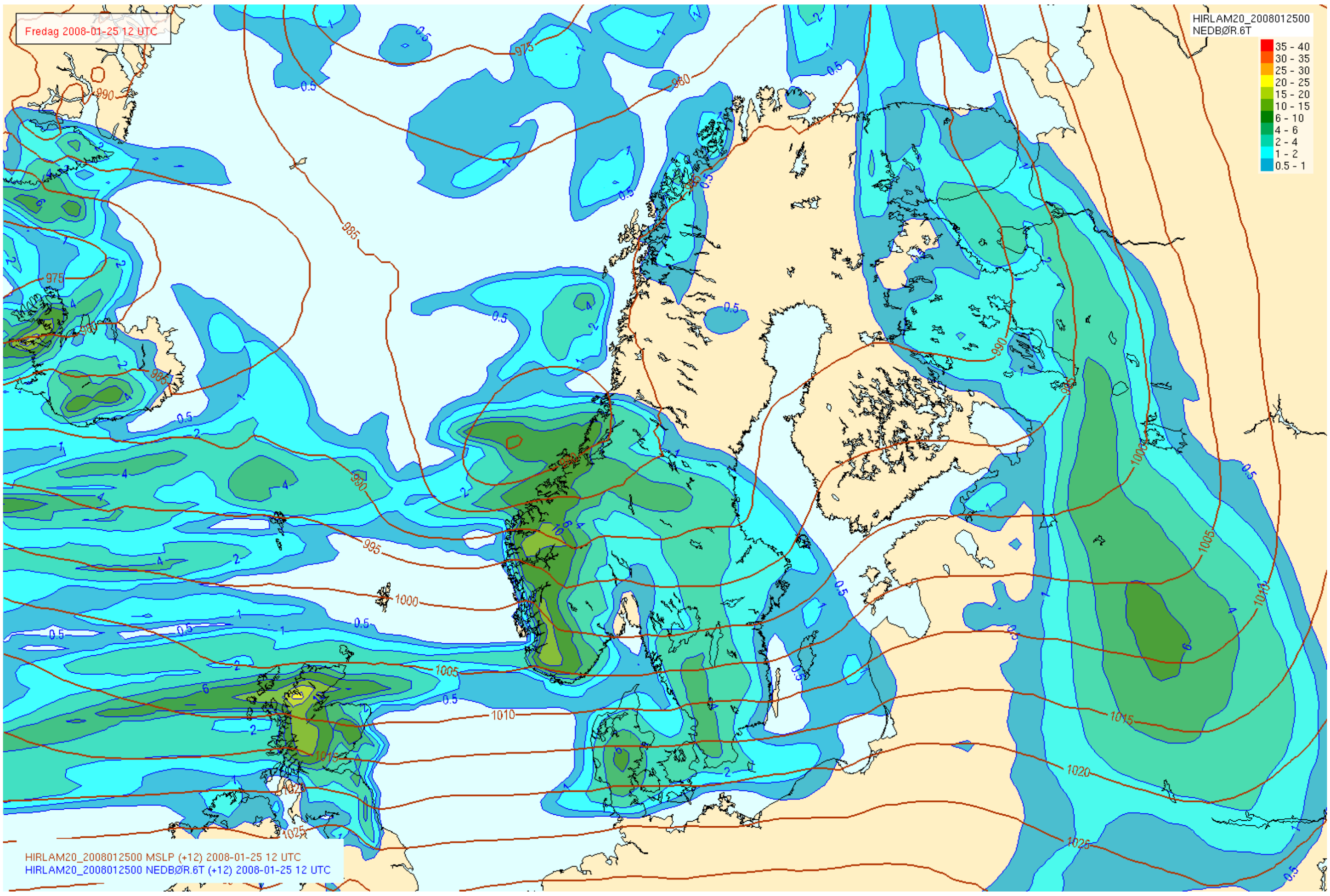
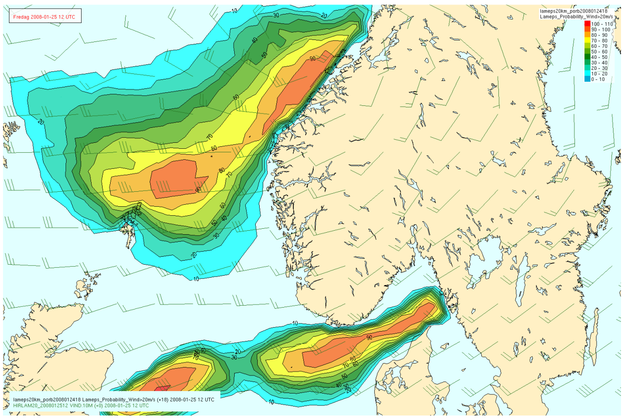
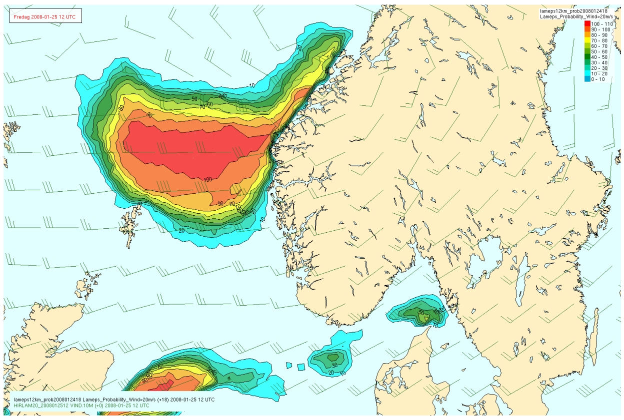


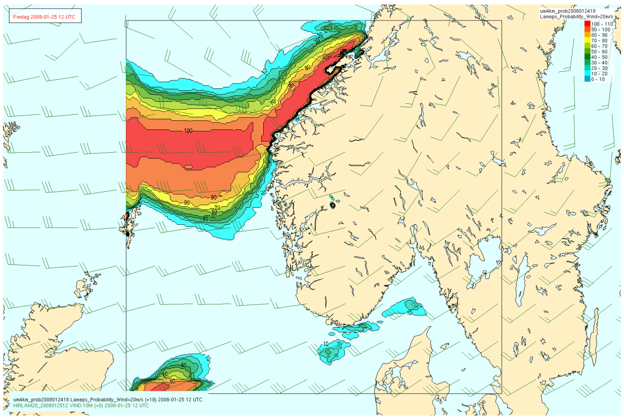
Figure 7: A 6 hour forecast of MSLP and 6 hour accumulated precipitation from HIRLAM valid at 12 UTC 25 Januarv 2008.



a) LAMEPS

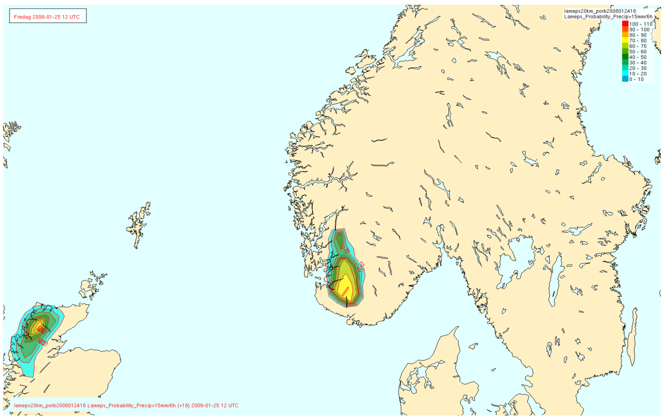


b) LAMH12

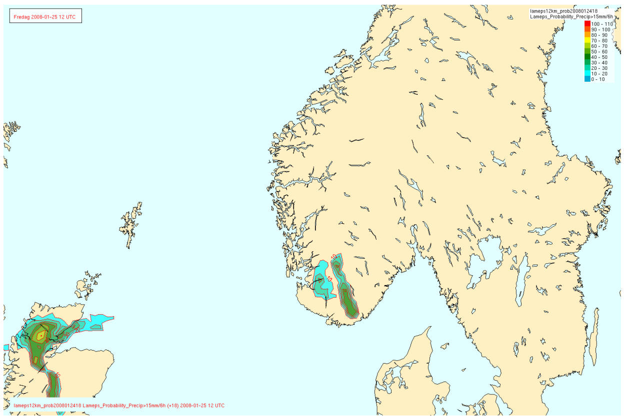


c) UMEPS

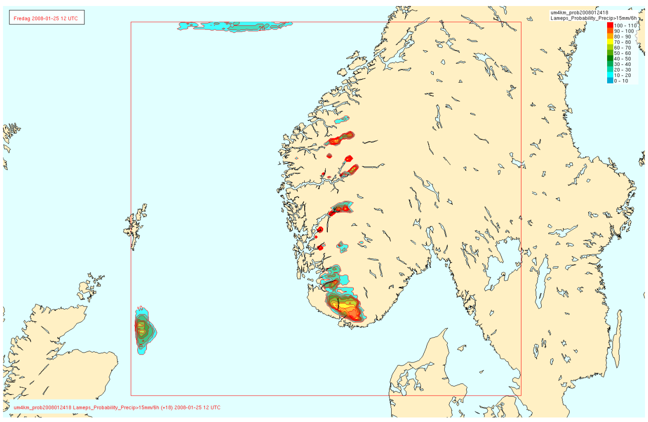
Figure 8: 42 hour forecasts of forecast probabilities for more than 20m/s (at 10 m) from LAMEPS (a), LAMH12 (b) and UMEPS 4km (c). Analysis of 10 m wind from HIRLAM (wind arrows are in knots) is shown together with the forecast probabilities. The forecasts are valid at 12 UTC on 25 January 2008.



a) LAMEPS



b) LAMH12



c) UMEPS

Figure 9: 42 hour forecasts of forecast probabilities for more than 15mm/6h from LAMEPS (a), LAMH12 (b) and UMEPS 4km (c). The forecasts are valid at 12UTC on 25 January 2008.

LAMEPS (a), LAMH12 (b) and UMEPS (c), all together with analysis of 10 m winds (the wind arrows are in knots) from HIRLAM. The forecasts are valid at 12UTC, the same time as the forecast in Figure 7. In Figure 8 one can see a quite large shift in the probability-fields going from one version of LAMEPS to another. LAMH12 has less spread in the ensemble, giving a narrower probability field along the west coast. But more members of LAMH12 have strong winds, giving higher probabilities. South of Norway, LAMEPS has higher probability for strong wind, but taking the wind analysis from HIRLAM as the "truth", this corresponds better with the analysed wind field. The probability fields from UMEPS are quite similar to the ones from LAMH12, but along the coast in the northern part the probabilities are higher. UMEPS also has some members with strong wind in the mountains giving small areas with probability for more than 20 m/s.

Figure 9 shows a 42 hours forecast of forecast probabilities for more than 10mm/6hours from LAMEPS (a), LAMH12 (b) and UMEPS (c). The forecasts are valid at 12UTC 25 January. Here we see that the probability patterns in the two versions of LAMEPS are quite different, with smaller probabilities for heavy precipitation in LAMH12. The forecast probability in UMEPS is higher over more areas, showing the effect of better resolved terrain in the high resolution model.

In this case the differences between the two LAMEPS versions are bigger than the difference between LAMH12 and UMEPS for the wind probabilities. For the forecast probability for precipitation one sees more effect of the down-scaling with the non-hydrostatic model.

d) Tuva – 31 January 2008

In the end of January 2008 a deep low pressure centre developed in the North Sea. The storm was classified as extreme weather by met.no and given the name Tuva. Figure 10 show a 12 hour forecast of MSLP and 6 hour accumulated precipitation from HIRLAM. The figure

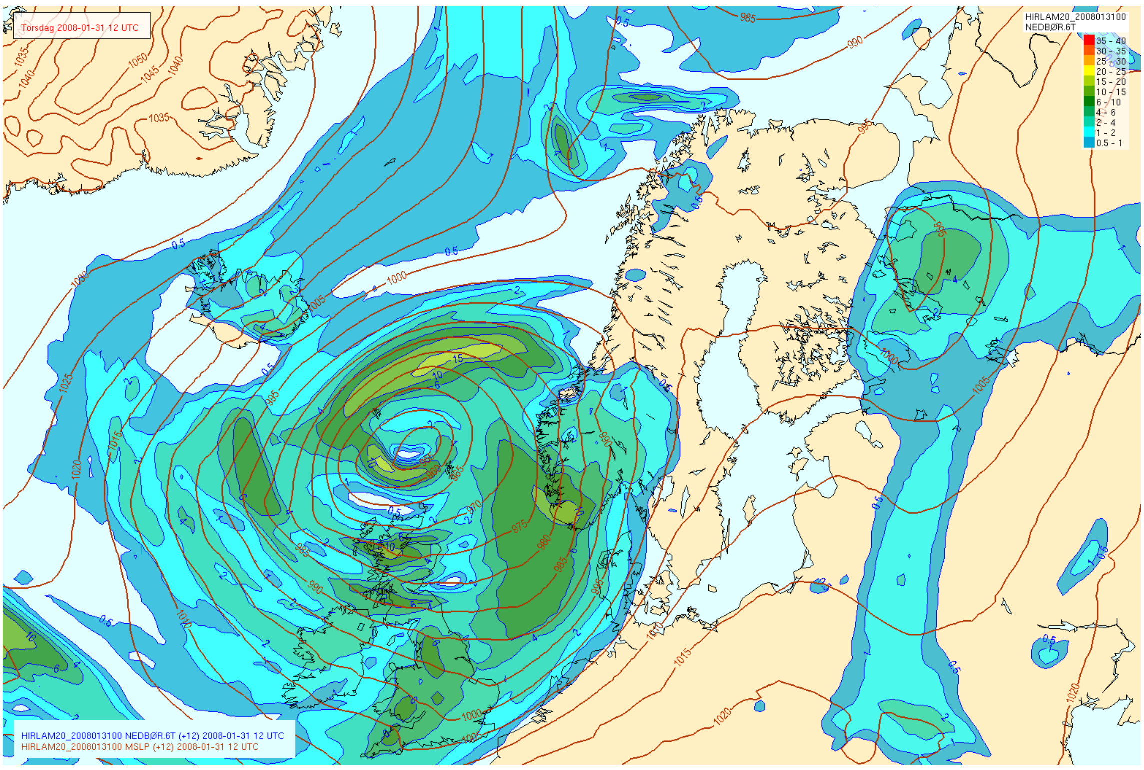
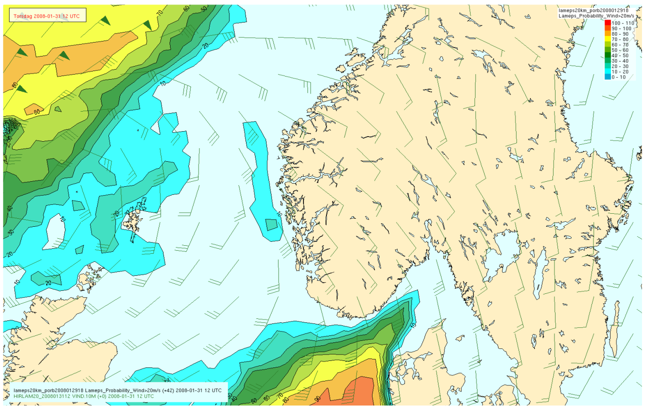


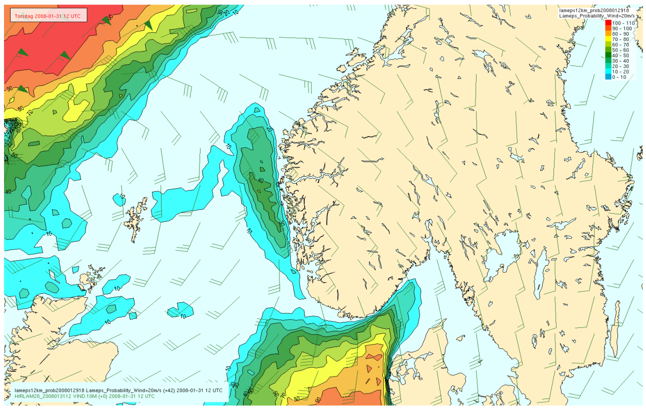
Figure 10: A 12 hour forecast of MSLP and 6 hour accumulated precipitation from HIRLAM. The forecast is valid at 12 UTC on 31 January 2008.

shows a minimum pressure in the forecast of less than 955hPa and large precipitation amounts in the south-western part of Norway. The strongest wind hit the west coast before noon and the east coast around 12UTC. The strongest wind measured was at Torungen lighthouse (outside Arendal at the south east coast) with 26.6 m/s in middle wind and 33.7 m/s gust. Boundaries from LAMH12 are used to drive UMEPS.

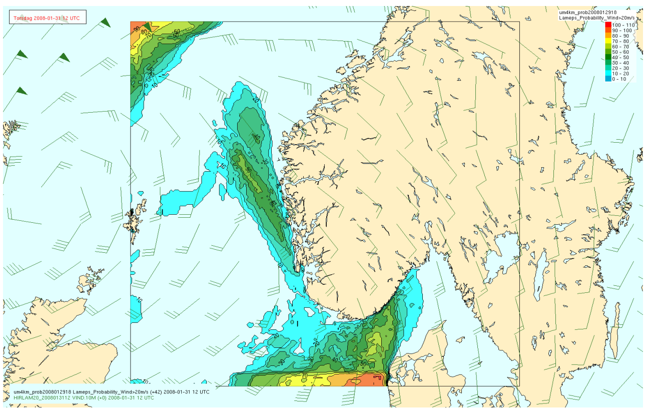
In Figure 11 an analysis of 10 m wind form HIRLAM is shown together with forecast probabilities from LAMEPS (a), LAMH12 (b) and UMEPS (c) (42 hour forecasts). The forecasts are valid at 12UTC 31 January, approximately at the time when the strongest wind hit the south-eastern coast of Norway. In the upper left corner of each panel one can see the strong wind on the north-western side of the pressure centre. Comparing the forecast probabilities from the two LAMEPS-versions (the integration domain of UMEPS is not adequate for this discussion) one can clearly see that the forecast probabilities for more than 20m/s are much higher from LAMH12, showing that more members of this ensemble had strong wind around the pressure centre. From the figure one can also see that none of the models had very high probabilities for over 20m/s along the east coast, but in LAMH12 and UMEPS the wind came closer to the coastline and the probabilities were somewhat higher than in LAMEPS. In UMEPS the forecast probabilities were up to 50-60% around Torungen lighthouse, in LAMH12 up to 10-20% and in LAMEPS below 10%.



a) LAMEPS



b) LAMH12

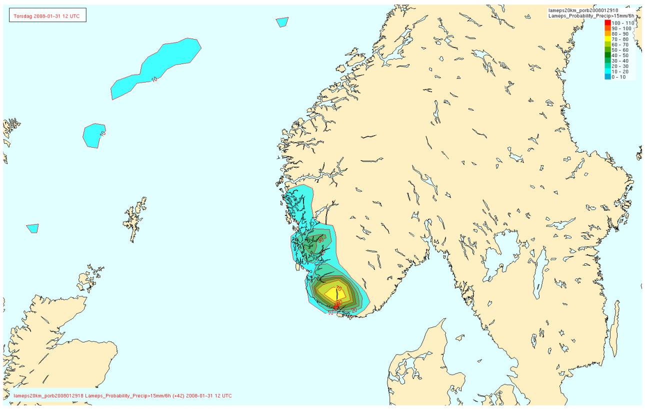


c) UMEPS

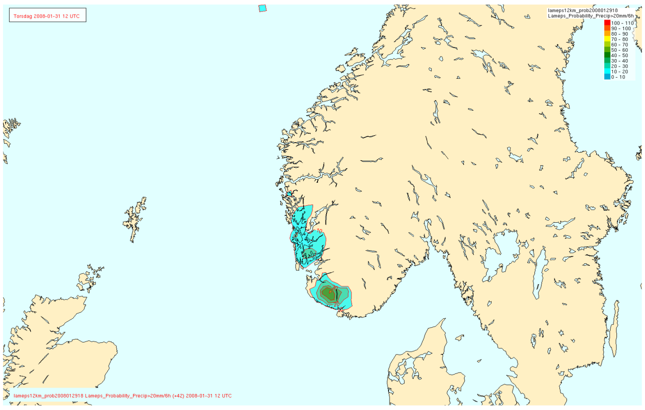
Figure 11: 42 hour forecasts of forecast probabilities for more than 20m/s (at 10m) from LAMEPS (a), LAMH12 (b) and UMEPS (c). Analysis of 10 m wind from HIRLAM (wind arrows in knots) is shown together with the forecast probabilities. The forecasts are valid at 12 UTC 31 January 2008.

Figure 12 shows 42 hour forecasts of forecast probabilities of at least 20mm/6 hour from the three ensemble systems (at 12UTC on 31 January). All three systems have high probabilities in the south of Norway, but they are highest in LAMEPS and UMEPS. UMEPS also has better structures showing the influence of better resolved orography on precipitation.

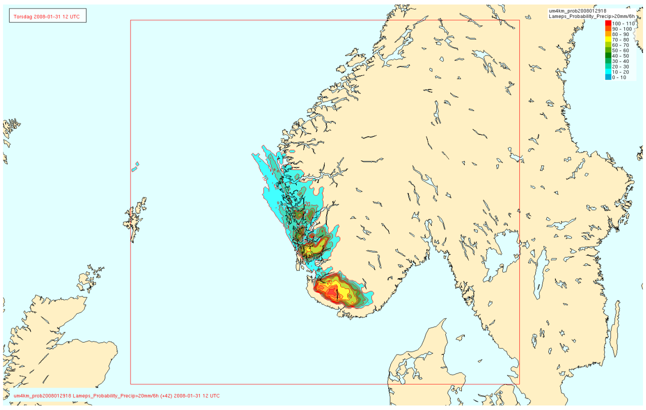
In this case moving from LAMEPS to LAMH12 gives larger differences in the forecast probability for wind than the differences between LAMH12 and UMEPS. For precipitation one can see more benefits from the UMEPS as this model has more realistic probability field structures.



a) LAMEPS



b) LAMH12



c) UMEPS

Figure 12: 42 hour forecasts of forecast probabilities of more than 20mm/6hours from LAMEPS (a), LAMH12 (b) and UMEPS (c). The forecasts are valid at 12 UTC 31 January 2008.

Conclusions

This report describes four cases where we have down-scaled met.no's limited area ensemble prediction system (LAMEPS) with the non-hydrostatic model (Met Office Unified Model TM (UK) – UM). Three of the four cases are also run with two different versions of LAMEPS (differences both in model version and resolution) to see if some of the benefits with down-scaling can be reached with a higher resolution hydrostatic model.

All four cases chosen are winter storms with both strong winds and heavy precipitation. Since one in ensemble prediction uses forecast probabilities of a weather parameter instead of the weather parameter itself, we have in this report concentrated on forecast probabilities of strong wind and heavy precipitation.

One can not draw any final conclusions about the effect of down-scaling with only four cases, but one may say something about the result in each case. For the first case – Per – we have only studied the wind and only one LAMEPS version. In this case there are some small effects on down-scaling, especially over land and near the coastline. With UMEPS the forecast probability gets somewhat higher for strong wind near and over land and the structures in the fields looks more realistic.

For the storm in the start of January 2008, we run both LAMEPS versions and used LAMH12 to drive UMEPS. In this case the down-scaling had large effect, even though the storm didn't move in over land. A large effect on moving to higher resolution was already shown in LAMH12 and with UMEPS the forecasted probability for strong wind seemed almost perfect compared to an analysis of wind from HIRLAM. The benefit of using a high resolution, non-hydrostatic model is much more noticeable when it comes to precipitation. The forecast probability for heavy precipitation is higher, covers larger areas and has more structure in UMEPS than in LAMEPS.

For Sondre the differences in the wind probabilities were larger between the two LAMEPS versions than between LAMH12 and UMEPS. Changing the resolution and HIRLAM version in LAMEPS gave a different structure of the wind probabilities. UMEPS had larger probabilities for strong wind near and over land than LAMH12. For precipitation the effect of high resolution in UMEPS was clearly shown in the westerly mountains.

Also in the last case – Tuva – the change from LAMEPS to LAMH12 gives larger differences in the forecast probability for strong wind than the differences between LAMH12 and UMEPS. But for the precipitation the effect of the UM model gives better forecast probability for UMEPS than for the two LAMEPS systems.

Running a non-hydrostatic high resolution ensemble system is relative expensive and the integration area has currently to be quite small. Upgrading LAMEPS to higher resolution gives promising results, especially looking at wind near the surface. It is takes much less computer time running a quite large model domain with 12 km resolution LAMEPS than a small 4 km resolution UMEPS. Today met.no does not have enough computer resources to run an ensemble system for a reasonable large area, with higher resolution than 12 km. Therefore in mid February 2008, met.no changed it's operationally LAMEPS system to a 12 km and 60 levels version. At the same time the HIRLAM version used for LAMEPS was changed. After a period of running the new LAMEPS results will be evaluated and the possibility of a new EPS system with higher resolution will be discussed.