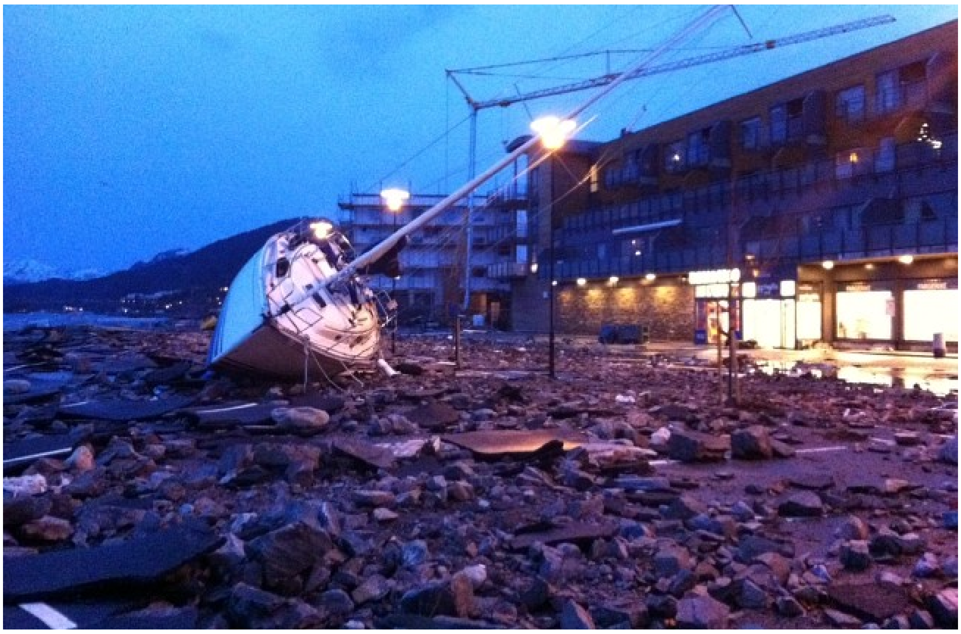
METCOOP MEMO No. 01/2014

An operational view on HARMONIE AROME for MetCoOp

A case based verification study of “Dagmar” 25-27.12.2011

Bjart Eriksen, Anne-Mette Olsen, Eirik Samuelsen, Solfrid Agersten, Ole Vignes, Karl-Ivar Ivarsson



Front: “Dagmar” near by “Stockholm”, by Lars Häglund.

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and
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Summary

This report describes three experiments with the weather model HARMONIE AROME, the purpose being to evaluate and optimize the setup of the model for Scandinavian climatology. In the first part of the report a comparison of the physiography datasets Ecoclimap 1 and Ecoclimap 2 is done. No notable differences were found between them. In the second part of the report 1-hourly and 3-hourly updated data on the lateral boundaries were compared. Improvements in the forecast using 1-hourly updated data on the lateral boundaries were found, especially with regard to MSLP and 10m winds. In the last part HARMONIE AROME version cycle 37 was compared to the newer cycle 38. Only minor differences were found between them, but cycle 38 had a somewhat better wind field but too much slowed down over land, and slightly better precipitation for this Dagmar case.

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1 Background

The purpose of this report is to study some of the qualities of HARMONIE AROME. This study is a supplement to previous verification studies (METCOOP MEMO's see http://metcoop.org/memo). Normally, verification scores consist of mean values in time and space, so that it is not easy to see how well the model describes the weather situation in, for example, an extreme event. It is very important that a numerical weather model has the ability to predict such events due to their effect on society both socially and economically.

In this study we will look at the extra-tropical storm, called "Dagmar", which affected Norway during the period 25-27 of December 2011 (for more information about the period, see Køltzow et.al [1]). The storm caused huge damage, as seen from the front picture, and there were frequent weather reports about the storm in the news, for example: http://www.yr.no/nyheter/1.7929835 .

In the first chapter of the results we will examine how the forecast is affected by using different types of physiographic description; ECOCLIMAP 1 and ECOCLIMAP 2.

In the second chapter we will look into the effect of the boundary update frequency; hourly updated boundaries and three hourly updated boundaries.

In the third chapter of the results we give a brief overview of the differences between the HARMONIE AROME model versions cy37 and cy38.

Thanks to Rebecca Rudsar and others in the MetCoOp group for contribution and feedback regarding this report.

2 Methodology

There is no exact scientific method to describe a subjective verification. Some of the key elements are visual recognition and the subjective experience within weather forecasting. A meteorologist studies a forecast-parameter at a high time resolution, for instance every hour, and then compares the parameter as a field for a region or a sub region with observations, using satellite images (looking at the weather from above), and surface observations (looking at the weather situation from below). An absolute overview of the weather situation for a given domain does not exist, therefore the meteorologist's experience of interpreting the weather situation in different situations is valuable. If the form and orientation of the field is similar to the observation, with similar placement of the extremes within the field, we find a model to have a high quality simulation of the respective parameter. Even if the parameter value is wrong or placed elsewhere compared to observations, the model may produce a more correct dynamical picture (simulation) of the weather situation. Subjective quality is an assessment of form, placement and quantity for the important parameters that describe the atmospheric condition at a given time. The method is quite complex and time-consuming due to all the information that needs to be processed to get an overview of the overall quality.

A subjective description and verification, in contrast to a point- and summarized verification, will give more information about the dynamical fields produced by the model, instead of the quality of a field at a certain point or place.

For an extreme weather situation such as the period studied in this report, it is difficult to get a good picture of how well the model performs with a statistical summation, because this type of situation does not occur very often. In such occasions subjective verification is a valuable (and necessary) addition to obtain knowledge about the behaviour of the weather model and how well it fits the observations. This type of extreme weather event has a huge impact for people who use and need weather data and it is therefore necessary to ensure that the quality of the weather prediction is good.

2.1 Experiments

The reference experiment that is used in this study is based on the non-hydrostatic model HARMONIE AROME run with cycle 37h1.1. The boundaries used are ECMWF forecasts on 16 km resolution. The domain remains unchanged, with 2.5 km horizontal resolution, see Figure 1 in Ivarsson et.al [2]. AROME runs with 3DVAR assimilation (6 hourly cycling) with only conventional observations. The model is set up with surface assimilation (CANARI OI-Main), and with roughness parameterization option CROUGH = Z01D.

3 Results

3.1 ECOCLIMAP 1 versus ECOCLIMAP 2

A good representation of land surface characteristics is necessary for numerical models to reproduce realistically certain meteorological events and climatological patterns. Soil/vegetation–atmosphere transfer schemes (SVATS) require only a few primary parameters as inputs (leaf area index, vegetation fraction and albedo). ECOCLIMAP is a model method to calculate these primary parameters. ECO-CLIMAP1 is a global database of land surface parameters at 1 km resolution. In ECOCLIMAP2 there are some new features:

- New land cover maps (GLC2000 and Corine) to determine ecosystems.
- Inter-annual database with the spot/vegetation data.
- Improvement of the albedo fields.
- The resolution has been improved to 250 m for Europe.
- For Norway the representation of permanent ice is improved in ECOCLIMAP 2.

In this chapter we will give a short evaluation of the situation during the extreme weather Dagmar when using the reference experiment with ECOCLIMAP 1 (EC1) compared to an experiment using ECOCLIMAP 2 (EC2).

3.1.1 Mean Sea Level Pressure (MSLP)

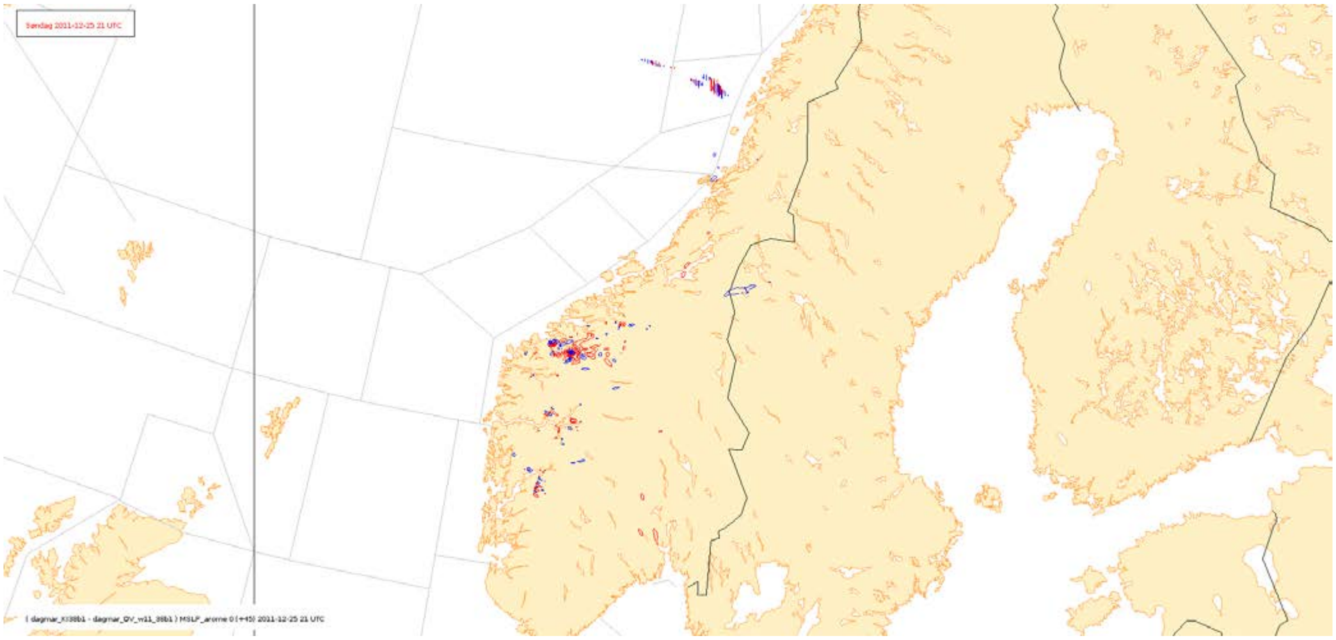

Figure 1.Forecast +45h. Differences in MSLP between EC2 and EC1. Equdistance is 1 hPa. Blue indicates higher pressure in ECOCLIMAP1, and red indicates higher pressure in ECOCLIMAP2.

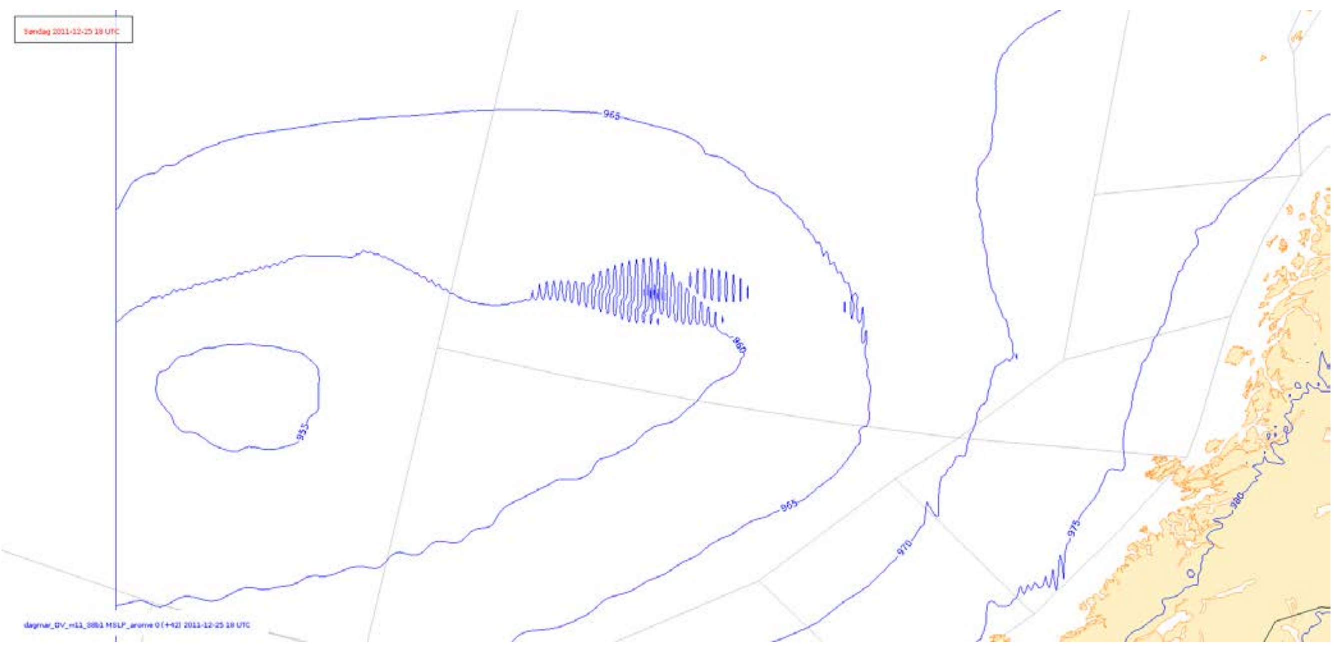

Figure 2. MSLP EC1. Forecast +4h2. Equdistance 5 hPa

From Figure 1 it can be seen that the change of ECOCLIMAP doesn't affect the synoptic low pressure system responsible for the extreme winds. There are only small differences, mostly over land areas, between the MSLP from the two experiments. Both experiments seem to have some numerical noise with spurious gravity waves northeast of the low pressure system see Figure 2 .

3.1.2 Wind

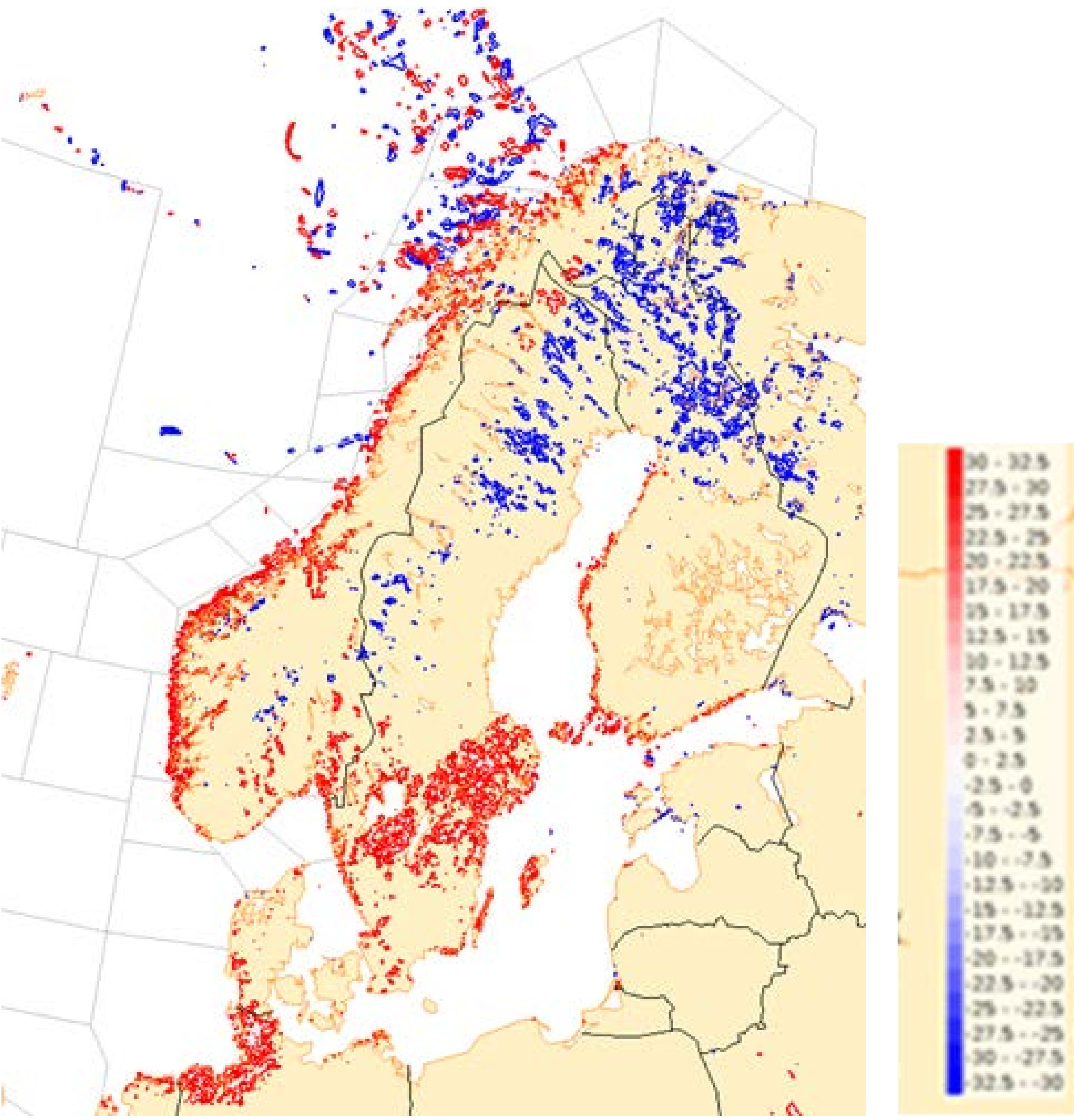

Figure 3. Forecast +42h. Wind speed from EC1 minus wind from EC2. Red is positive values and blue is negative values. Equidistance 2.5 m/s.

Using EC1 seems to give some areas with more wind than EC2, in particular on the coast of Norway and in southern part of Sweden and in Denmark. Using EC2, on the other hand, seems to give more wind inland in the northern part of Sweden and Finland and also in eastern part of Finnmark in Northern Norway (Figure 3 and Figure 4).

Over *land* areas in the southern part of Norway both model experiments have too little wind, see Figure 4.

In Figure 8, the station 01322 is observing 50KT, while the model forecast for +42h had around 20KT.

It is difficult to determine which of the two experiments that is best.

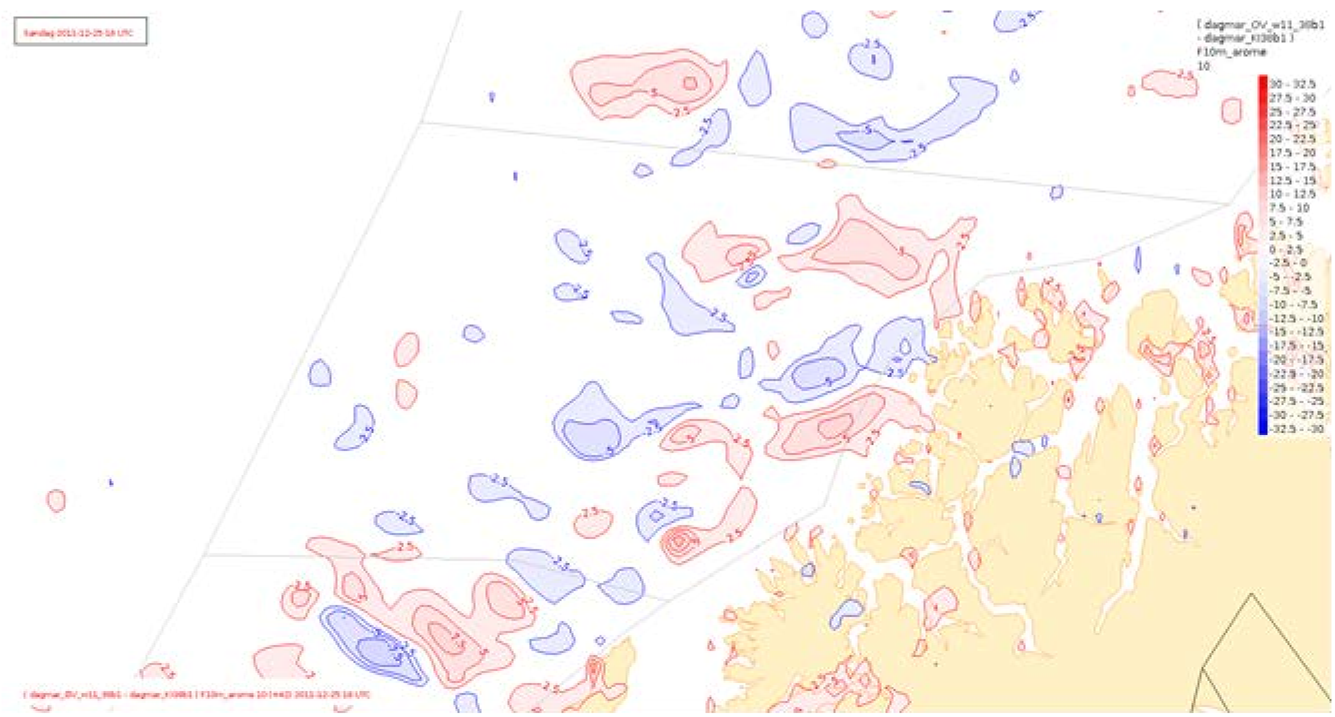

Figure 4. Same as Figure 3, but zoomed in on the convective area northwest of Troms. Equidistance is 2,5 m/s. Red shows more wind in EC2 and blue shows more wind in EC1.

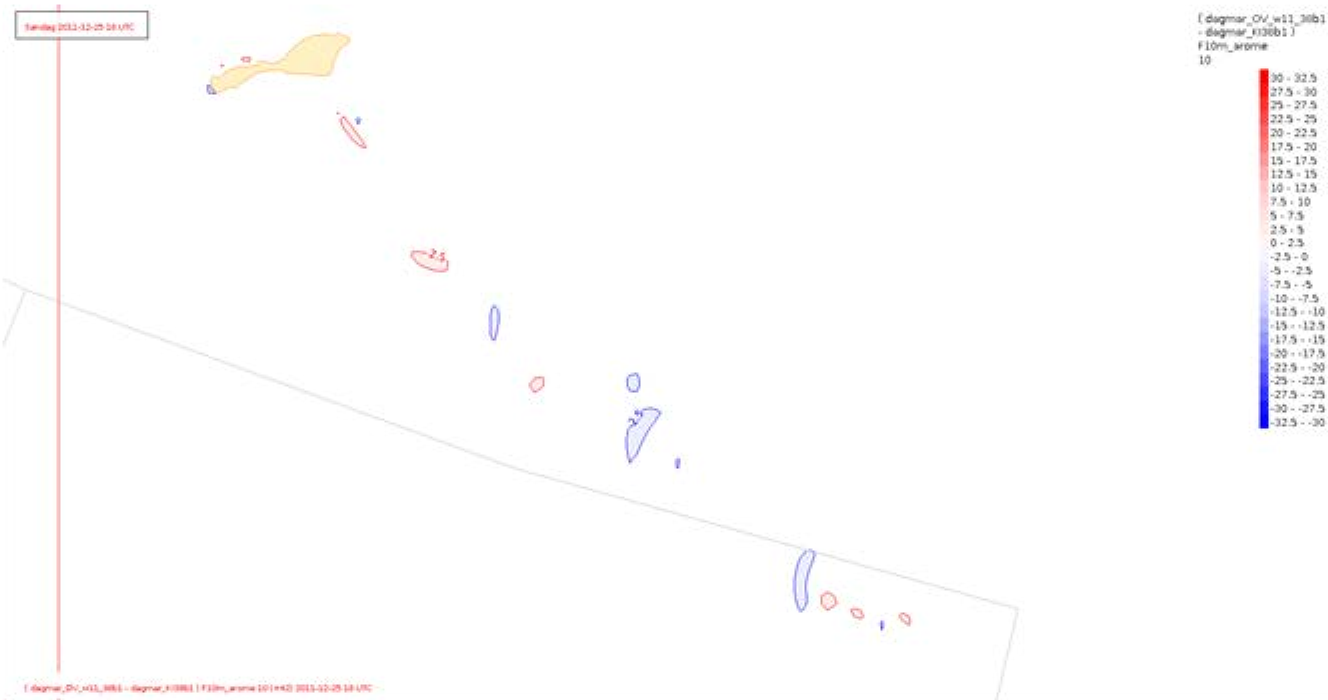

Figure 5.Same as Figure 3,, but zoomed in on the area containing Von Karman Vortex downstream of Jan Mayen. Equidistance is 2,5 m/s. Red shows more wind in EC2 and blue shows more wind in EC1.

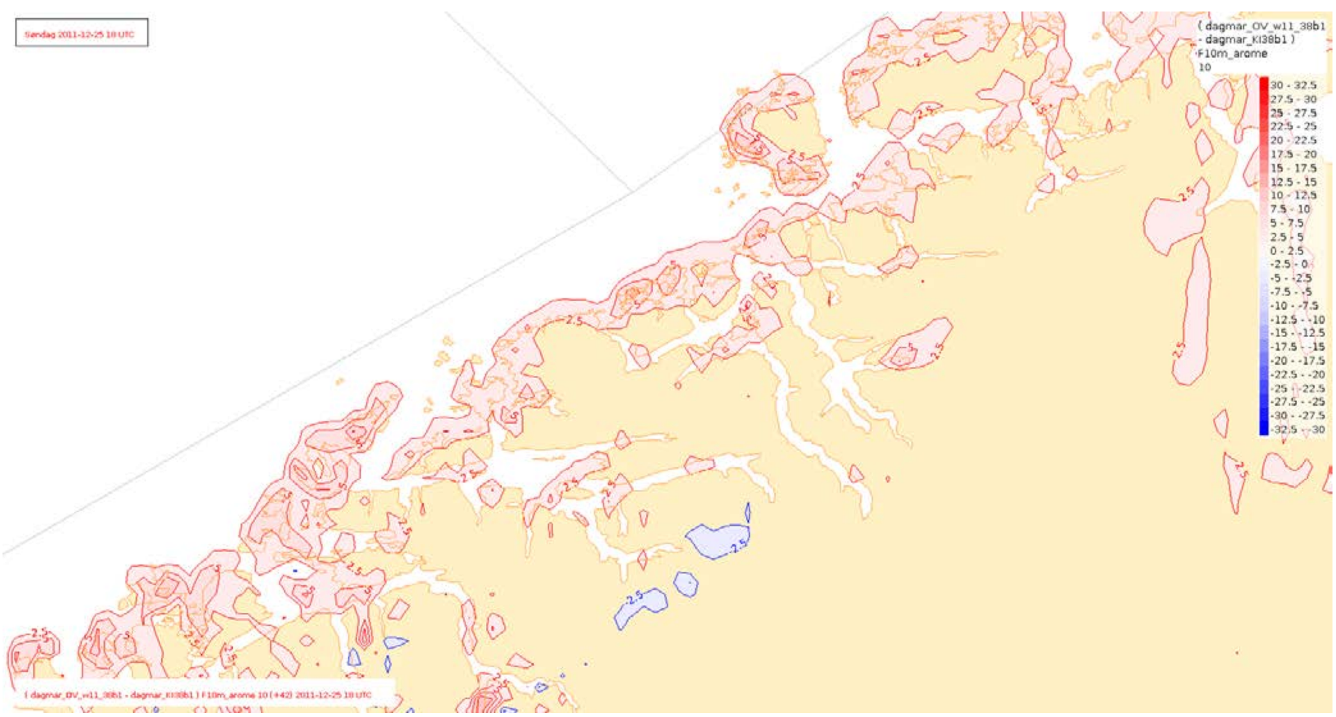

Figure 6. Same as Figure 3, but zoomed in on northwestern parts of Southern Norway.

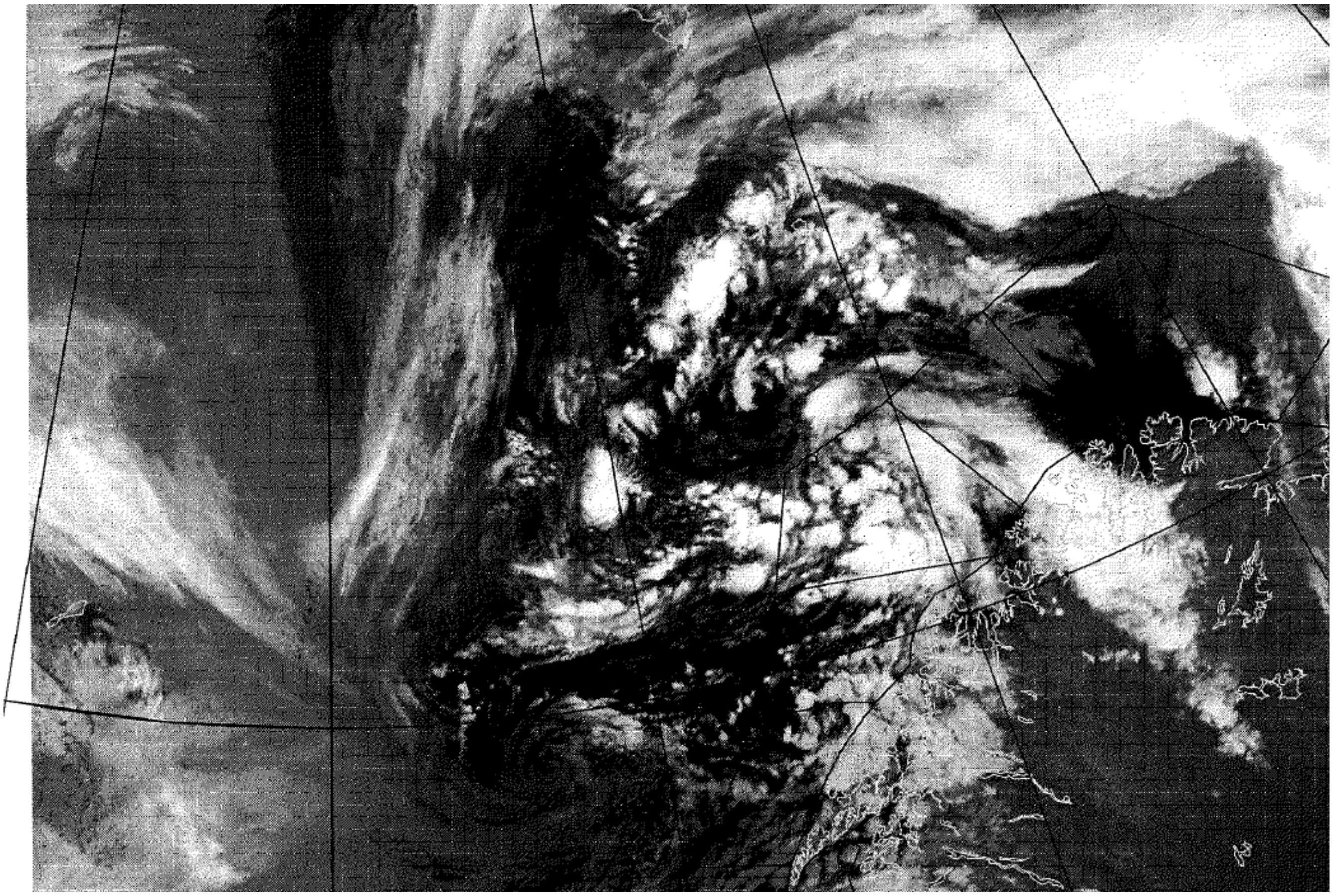

Figure 7. Satellite image from NOAA at 1755Z 25th December 2011 over Northern part of Norway and Jan Mayen.

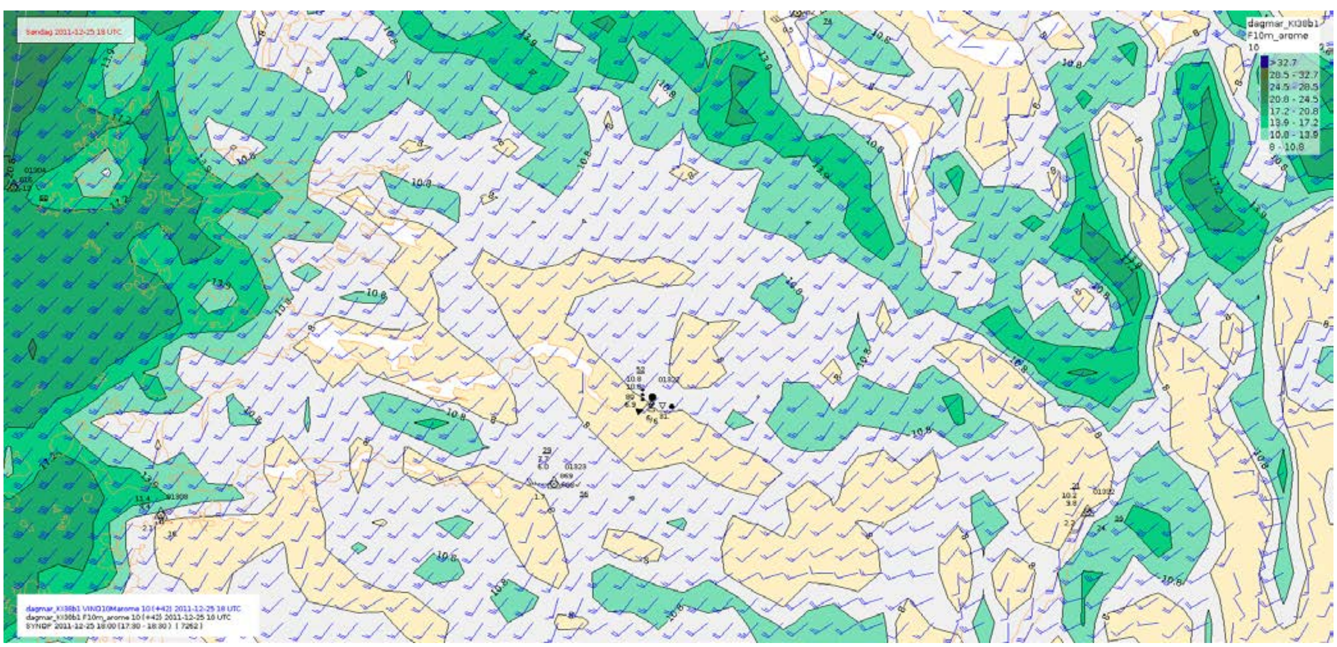

Figure 8. Forecast +42. The station 01322 is observing 50KT, while the model has around 20KT. The colors shows wind from 8 m/s, and the equidistance is 1 Beaufort.

Over *sea* there are more random differences between the two experiments. There are in particular two areas where differences are generated (Figure 3 and Figure 4):

1. northwest of Troms in Northern Norway in an area with strong convective cells (Figure 4)

2. south-southeast of Jan Mayen which seems to have the von Karman Vortex phenomenon (Figure 5) From the satellite picture (Figure 7) the convective cells northwest of Troms and the von Karman Vortices southeast of Jan Mayen are clearly seen.

It is difficult to determine which of the two experiments is most suitable for wind; in some areas use of EC1 seems to be best, and in other areas use of EC2 seems to be best. In areas with differences there were few observations.

3.1.3 Precipitation

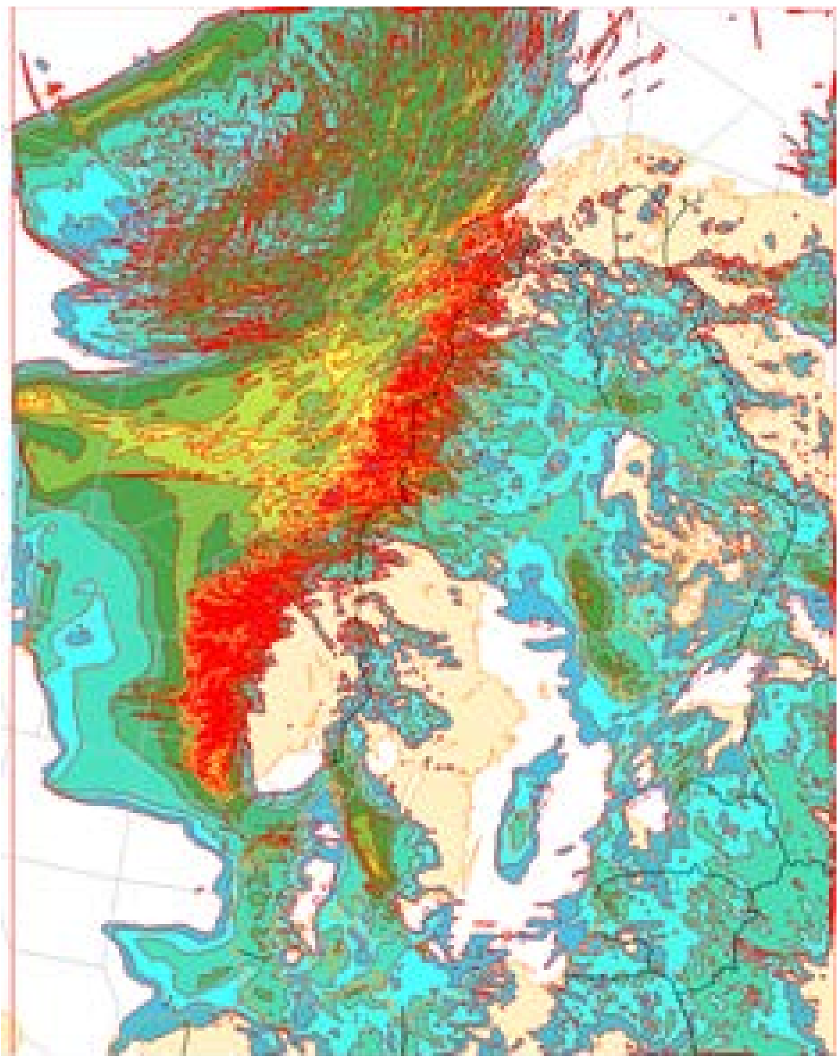

Figure 9. 24h accumulated precipitation at prognosis +48h for EC2 (26th December 2011 at 00Z).Warm colour (yellow and red) shows higher precipitation than cold colors (blue and green) Red color shows 30mm

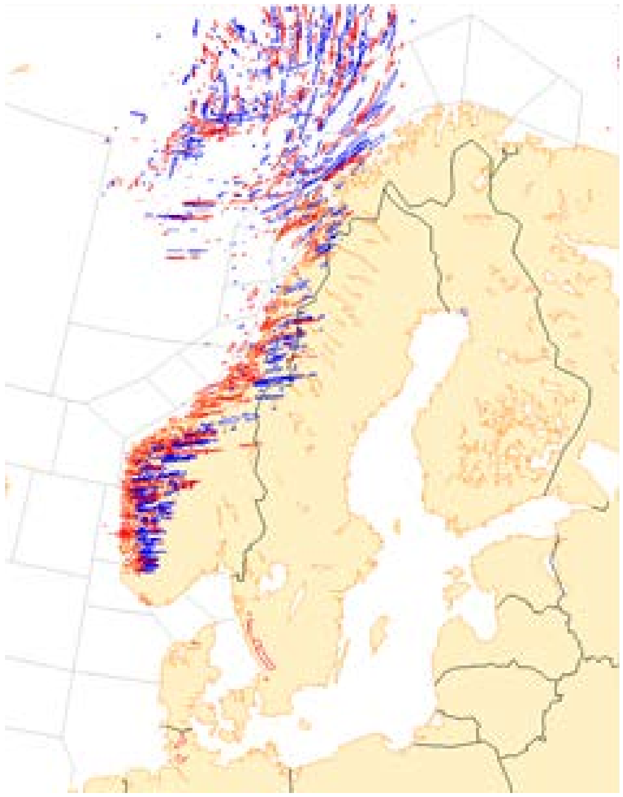

Figure 10. 24h accumulated precipitation. from EC2 minus EC1 at prognosis +48h (26th December 2011 at 00Z). Red positiv values, blue negative value.

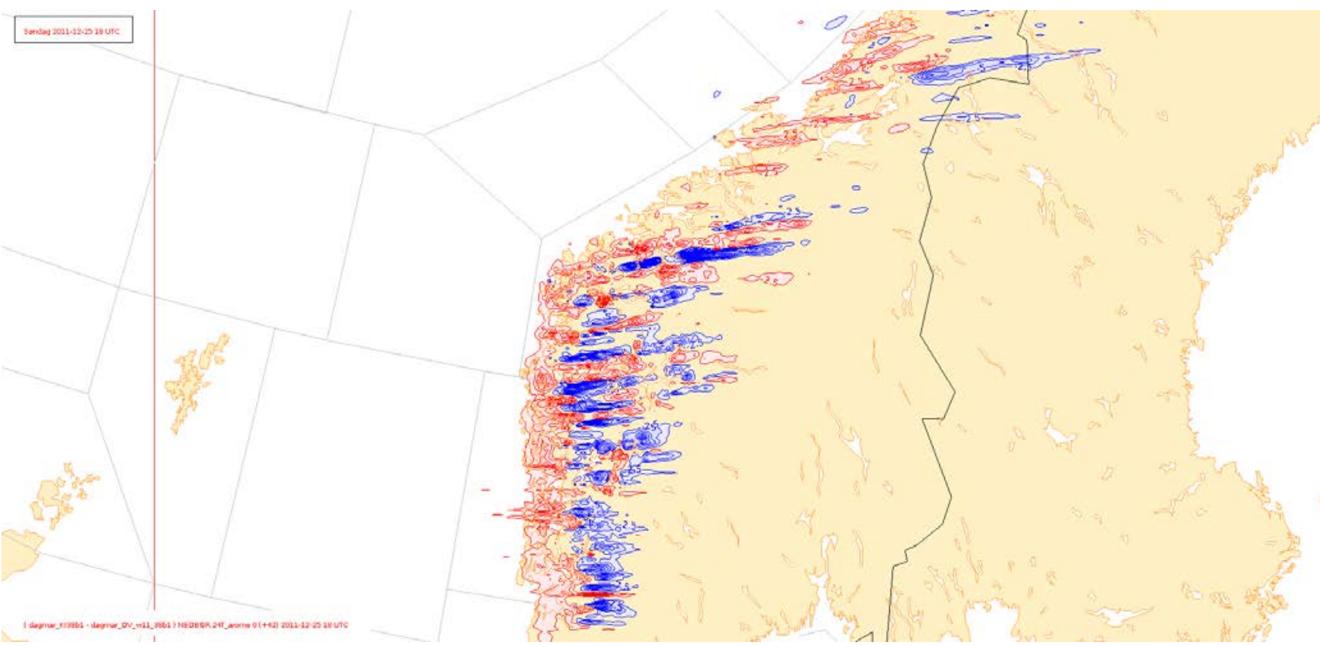

Figure 11. Same as Figure 10, but zoomed in on southern part of Norway.

From Figure 9 it can be seen that the model has most precipitation in the mountainous regions of Norway and also in the convective cells northwest of Troms. The difference in the accumulated 24h precipitation is also shown for the same areas, see Figure 10.

In the southern part of Norway where the wind has a clear westerly component perpendicular to the mountains, it is seen that using EC2 gives more precipitation near the coast, see Figure 11. This is almost the same area where the use of EC2 has less wind than EC1.

Over the more mountainous areas inland, using EC1 seems to give more precipitation, but there are also areas with the opposite effect. One possible explanation for this could be that the stronger wind in the EC1 run leads to slightly less precipitation at the coast and enhanced precipitation over the mountains (increased orographic precipitation).

It is difficult to establish which of the two experiments is correct for precipitation as there are too few observations.

3.1.4 Summary

In this experiment there were differences in MSLP, 10 m winds and precipitation. However, due to lack of observations both offshore and onshore it was difficult to establish which of the ECOCLIMAP sets verified best. These differences should be monitored over time to find out when and where this setting has effect.

3.2 Hourly boundaries versus three-hourly boundaries

Another experiment has been run with HARMONIE AROME cycle37h1.1 using hourly boundaries (called 1hB) that will be compared to the reference experiment with three-hourly boundaries (called 3hB). Naturally it is expected that a limited area model such as HARMONIE AROME over MetCoOp area will be influenced by the boundaries. That means that if the boundaries are updated more often, assuming that the boundary values are correct, the AROME model results will be more correct and update the weather situation. Here we want to measure the benefits/positive effect of using 1hB instead of 3hB.

3.2.1 Mean Sea Level Pressure (MSLP)

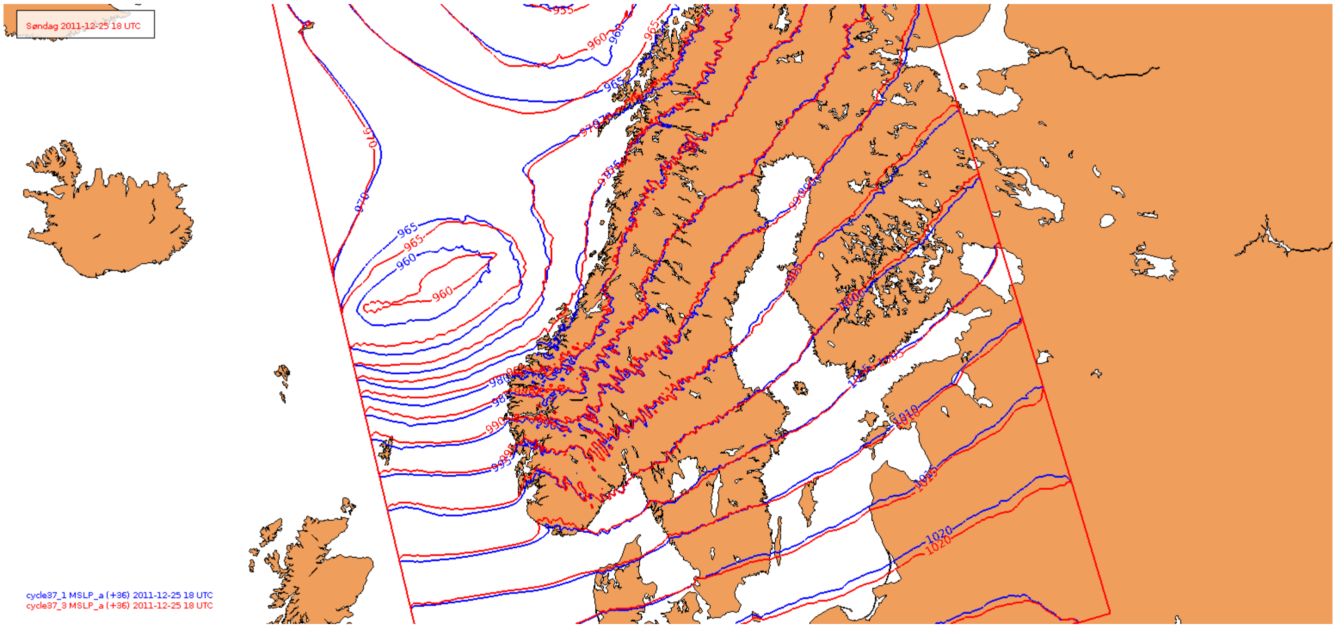

Figure 12. MSLP with equidistant 5 hPa at +36h, 2013-12-25T18Z. Blue contours model run with 1hB, red contours model set with 3hB.

Figure 12 and Figure 13 show a stronger pressure gradient in the region west of Stad and at Halten-banken in the model run with 1hB.These are also the regions with strongest winds at the time shown in the figures. Elsewhere the results are almost identical.

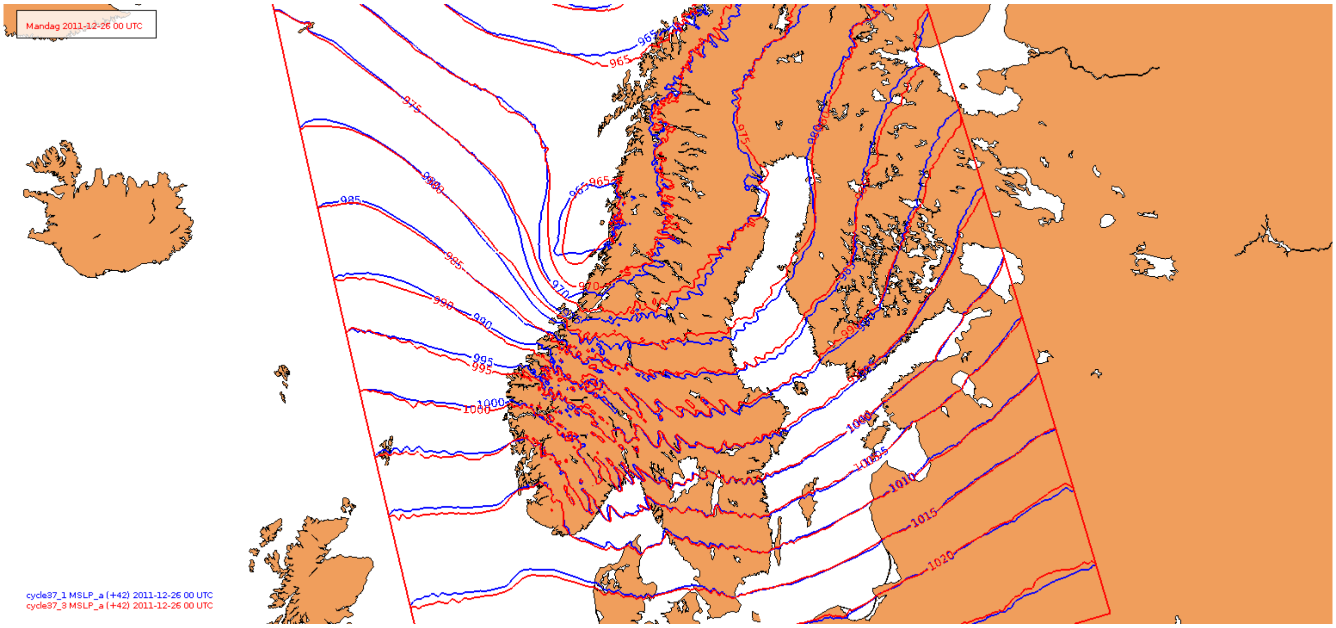

Figure 13. MSLP with equidistant 5 hPa at +42h, 2013-12-26T00Z. Blue contours model run with 1hB, red contours model set with 3hB.

3.2.2 Wind

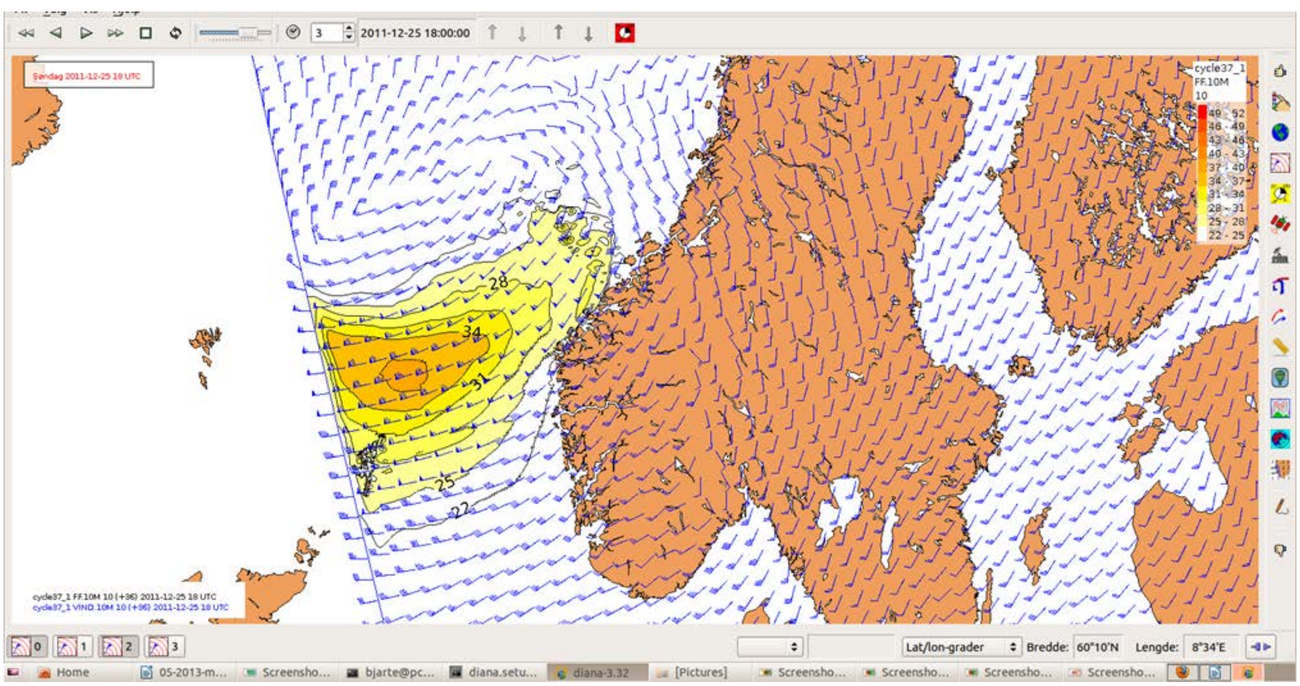

Figure 14. 10m wind vectors in blue for 1hB, the shaded area starts with winds stronger than 22 m/s, and the equidistance is 3 m/s, on 25.december 18 UTC. The inner isoline shows 37 m/s.

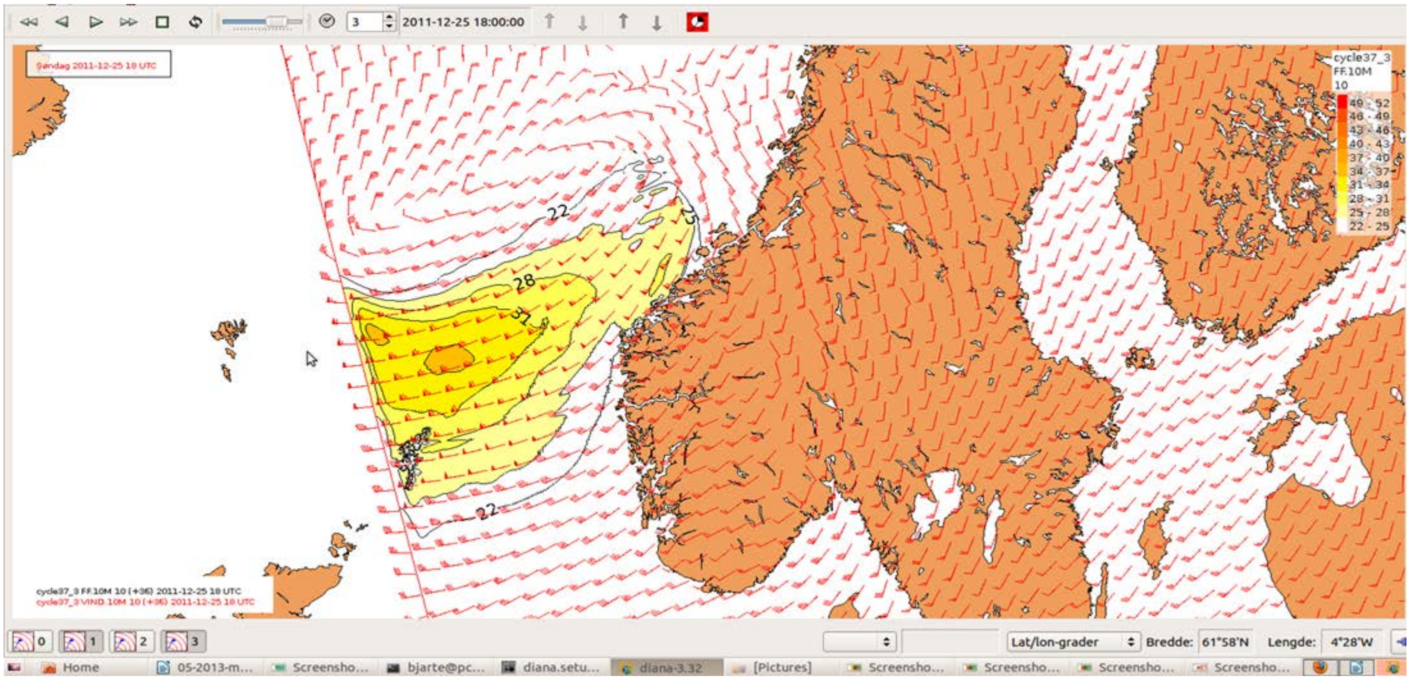

Figure 15. 10m wind vectors in red for 3hB, the shaded area starts with winds stronger than 22 m/s, and the equidistance is 3 m/s, on 25.december 18 UTC. The inner isoline shows 34 m/s.

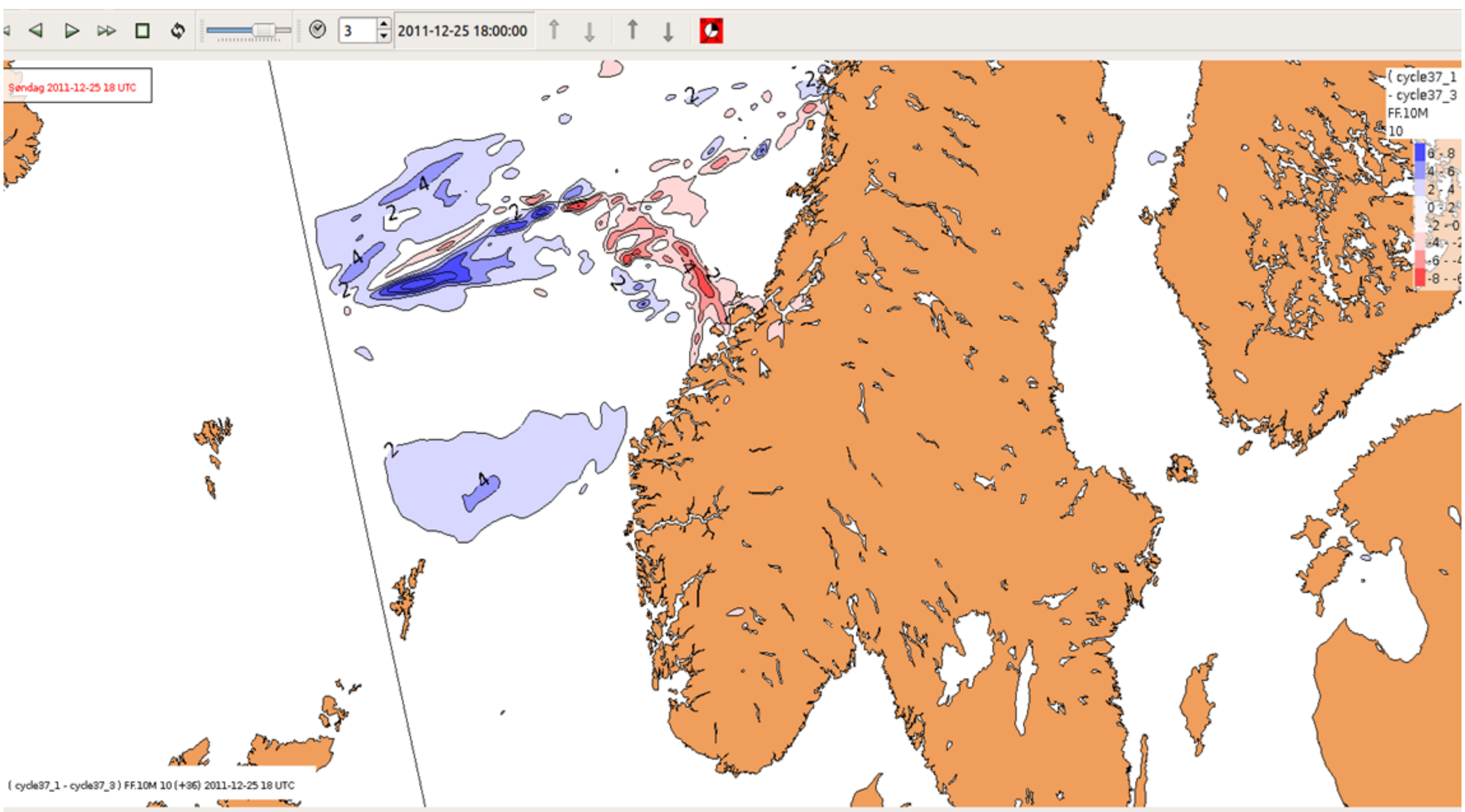

Figure 16. The differences in winds speeds [m/s] on 25 December 18 UTC between 1h- and 3h-boundaries, respectively. Figure 14 minus Figure 15. Blue colour indicates stronger winds with 1 h- boundaries. The equidistance is 2 m/s.

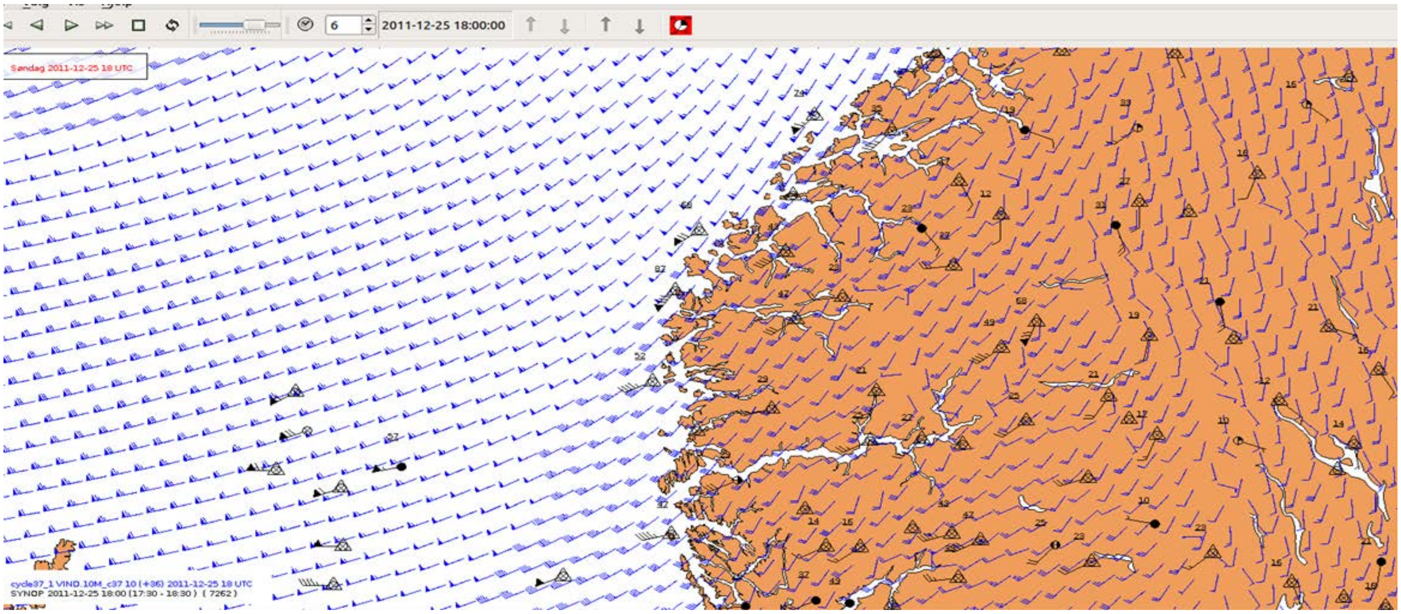

Figure 17. Wind observations at 25.December 18 UTC and 10M winds from the model run with 1h –boundaries

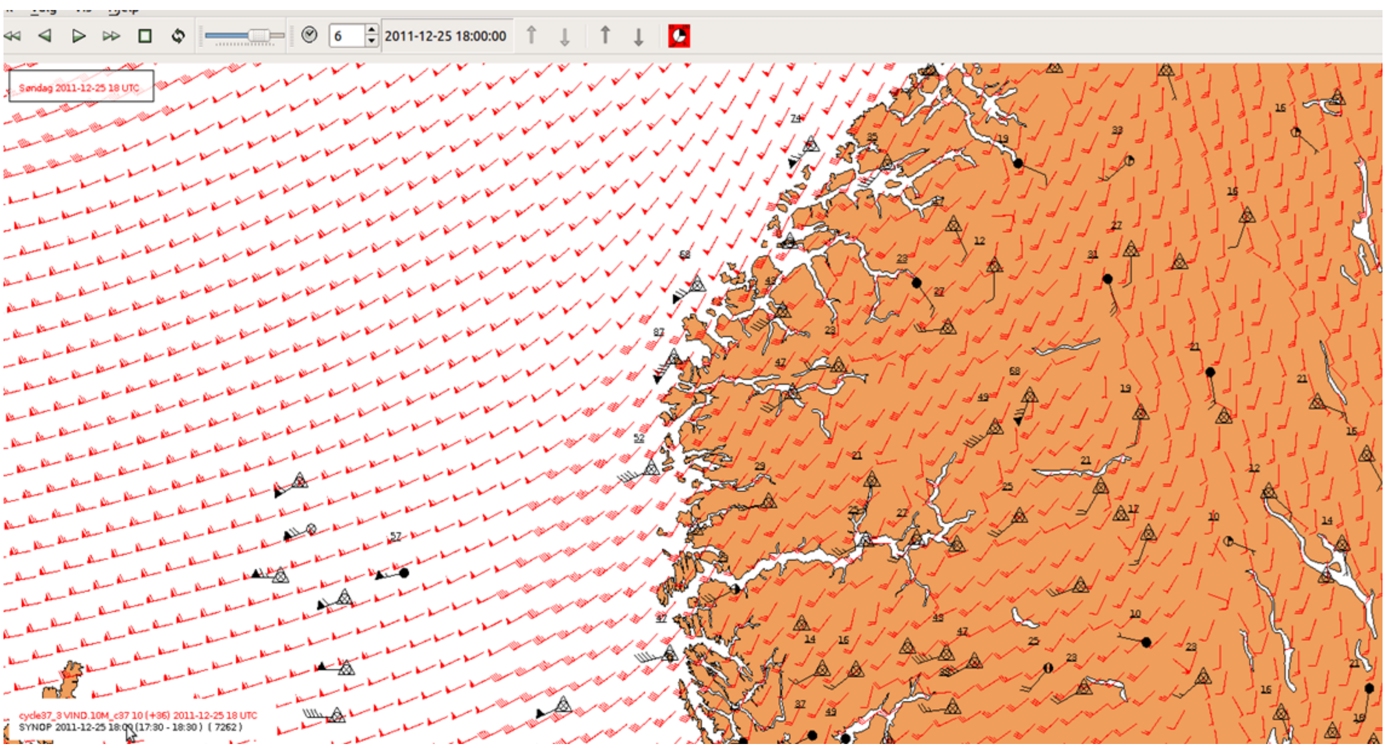

Figure 18. Wind observations at 25.December 18 UTC and 10M winds from the model run with 3h-boundaries,

Offshore winds are somewhat stronger in the 1hB-run (Figure 17) compared to winds in the 3hB-run (Figure 18), especially in the region west of Norway, close to the western (left) boundaries where winds exceed 30 m/s,. Onshore winds, however, vary in strength in both runs.

Overall, in the time range 18 Z- 00 Z there are indications that the 1hB-run simulates slightly stronger winds close to shore, and these winds are more comparable to the observations.

3.2.3 Precipitation (12-hours accumulated)

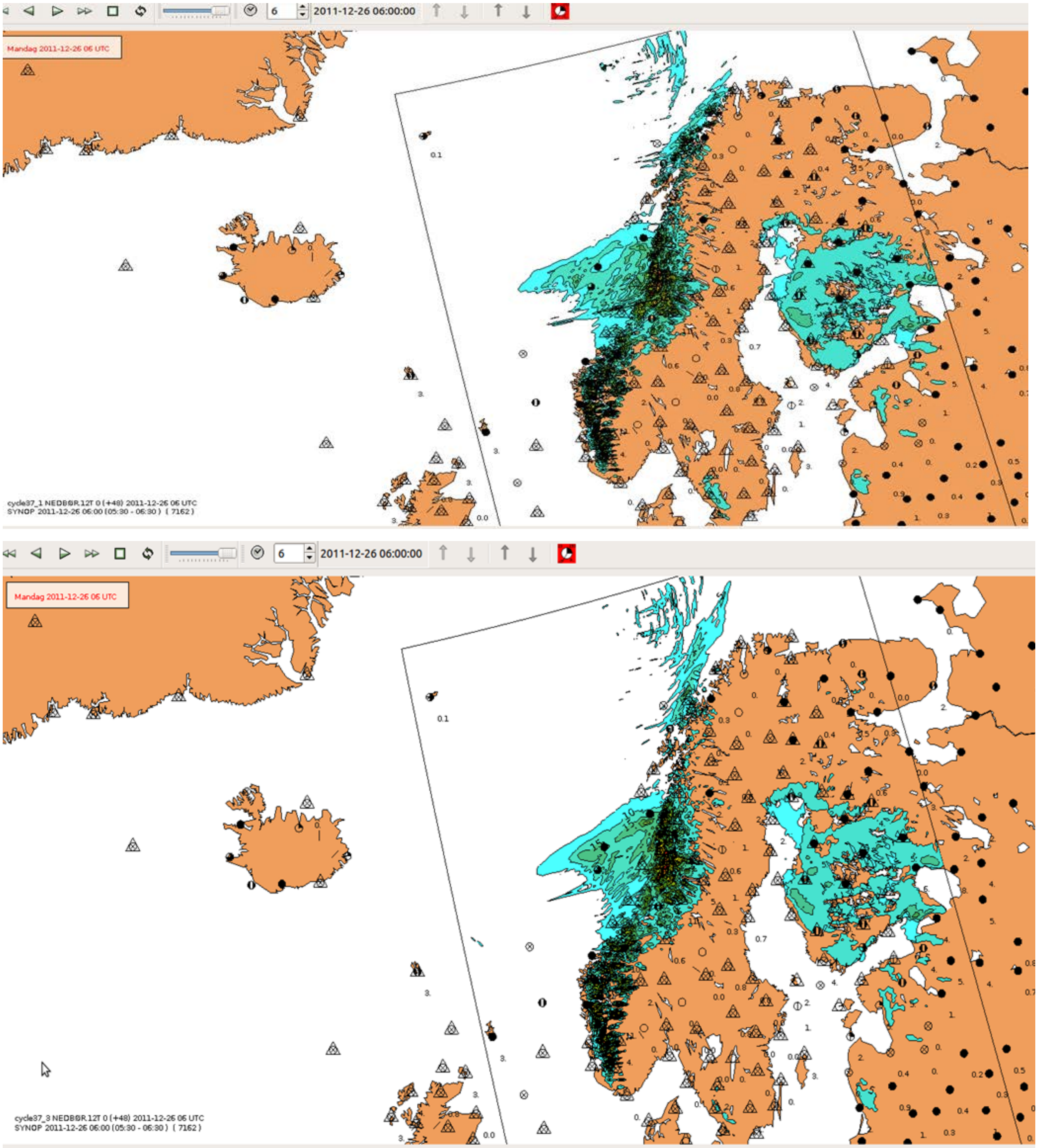

Figure 19.12h accumulated precipitation [mm] with overlaying shading at +48h, 26. December 06 UTC. Warm colour (yellow and red) indicates more precipitation than cold colour. (blue and green). Upper panel 1hB, and lower panel 3hB. Green color in the sea west of Norway indicates ~15 mm.

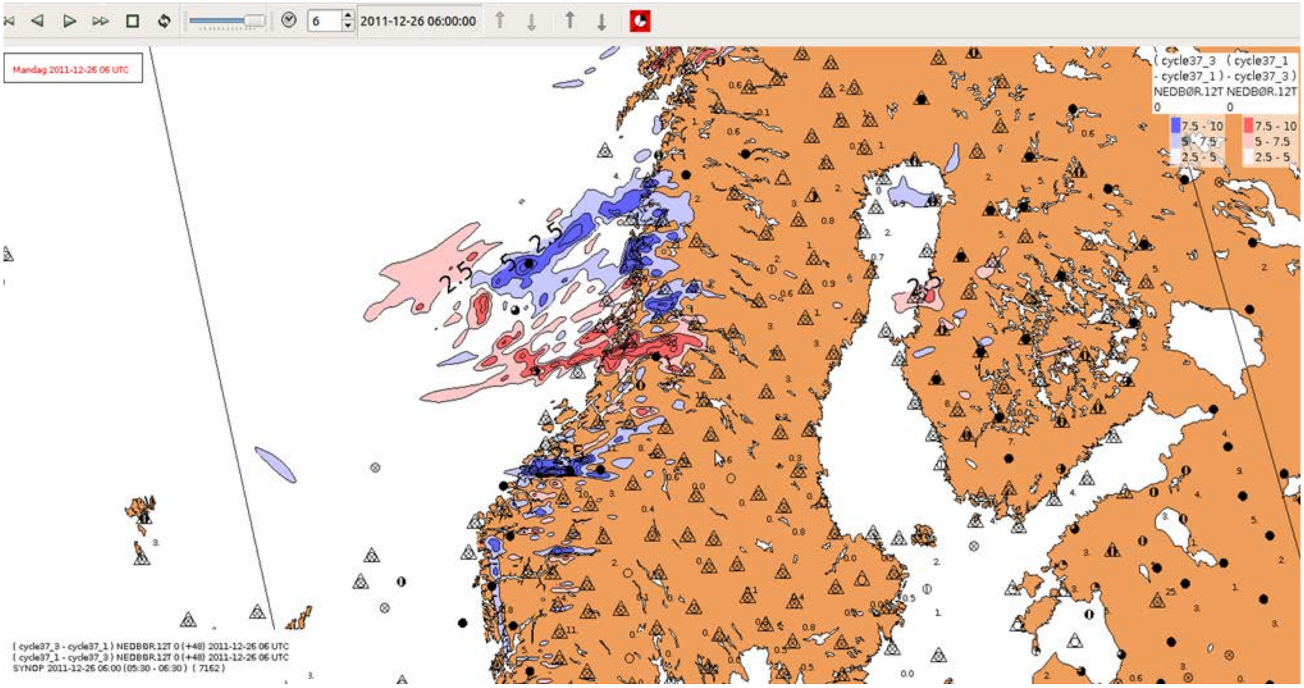

Figure 20. Differences in precipitation amounts, subtracting the 3h-run from the 1h- run. Blue (red) color indicates more precipitation amounts in the 1 h-run (3 h run). Equidistance is 2,5 mm.

Regarding precipitation there are some minor differences. The probable cause is related to MSLP and wind speed and the speed of the low pressure system which has a more accurate placement in the model run with 1h boundaries.

3.2.4 Temperature (T2M)

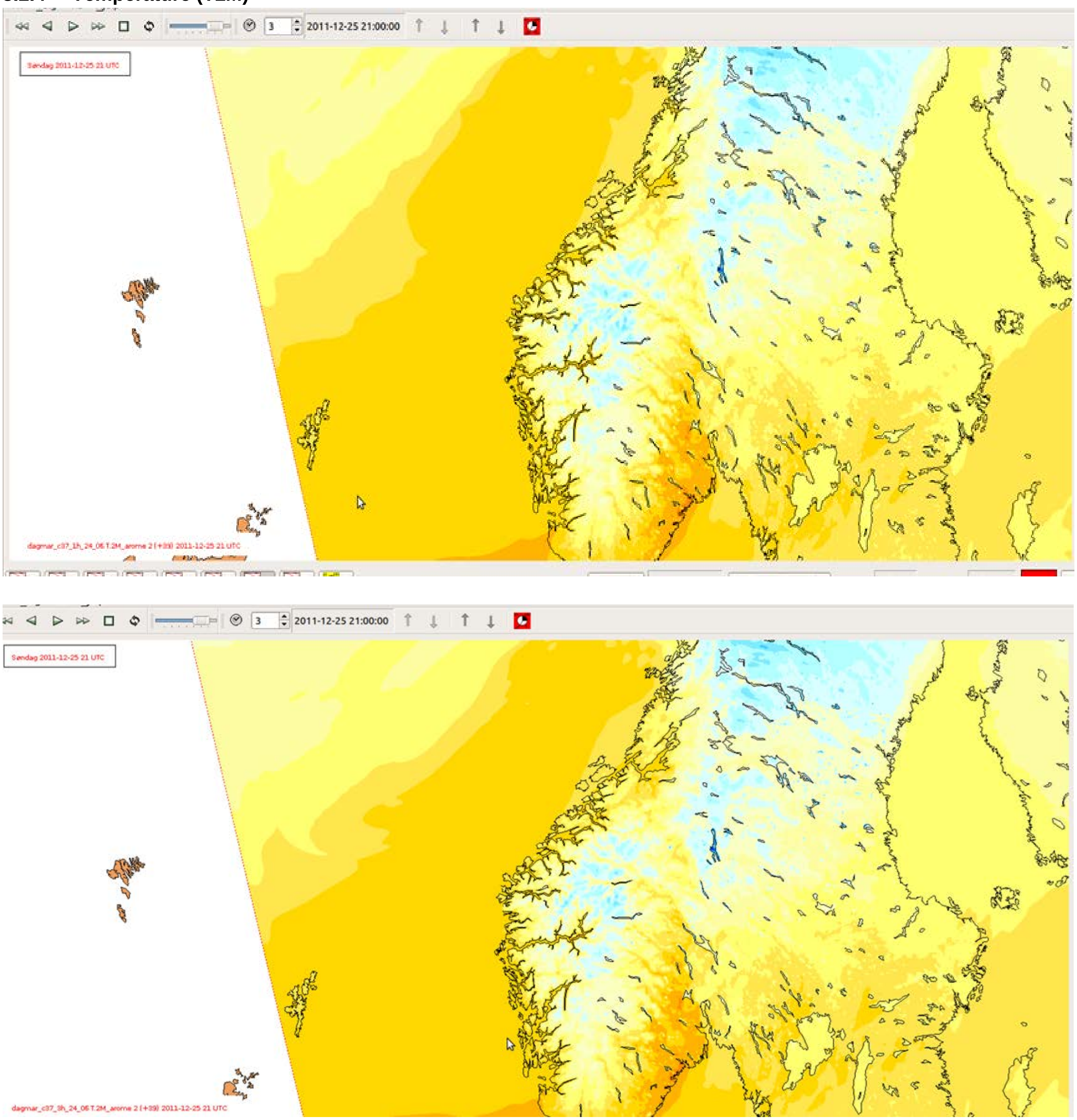

Figure 21. 2m temperature from the 1hB (upper panel) and the 3hB (lower panel). Warm color indicates temperature above 0 degrees celsius. Cold colour indicates below 0 degrees. Equidistance is 1 degree.

There are almost no notable differences for temperature over land, but offshore close to the boundaries in the westernmost parts there are some differences (see Figure 21). This is to be expected as the boundaries are updated more often in 1hB-run and the weather is moving eastwards. Looking over land there seems to be no particular differences.

3.2.5 Summary

This investigation reveals that there is some improvement using hourly boundary data instead of 3 hourly boundary data on the lateral boundaries, especially for mean sea level pressure (MSLP) and surface winds close to shore. There were very small improvements in precipitation and temperature (T2m).

3.3 Cycle 37 vs cycle 38

In this chapter we will give a short evaluation between using cycle 37 vs cycle 38 during the extreme weather Dagmar. A description of the changes in cy38 from cy37 can be found here: https://hirlam.org/trac/wiki/Harmonie_38h1 For cycle 37 the same experiment as used in the chapter above with 1 h Boundaries and 6 h cycling is used. For the cycle 38 experiment version h1.beta.1 with CANARI OI-Main and 3DVAR with conventional observations is used (plus an OpenMP bugfix). As standard implementation ECOCLIMAP 2 and 1 h boundary data were used and the assimilation cycle was every 3 hour. That means that it is more than one difference between these versions. The difference between 3 and 6 hourly cycling is already discussed in Ridal, Agersten, 2013 [3] in chapter 2 for August 2011. In general small differences between using 3 and 6 hours analysis cycling are seen for this summer 2011 experiment, for detail see: http://metcoop.met.no/verif/201108_37h11_3hcy_vs_6hcy_export/ (only visible SMHI and MET Norway). Summarization of the verification:

- Ground pressure: Slightly larger negative bias with 3-hour cycle and for the longest forecasts also slightly higher RMSE.
- 2m temperature: Slightly larger positive bias with 3-hour cycle, but despite this slightly lower RMSE
- Dewpoint and relative humidity: A little drier with 3-hour cycle and marginally larger RMSE.
- 10m wind, clouds and precipitation: No notable difference, except that Kuipers skill score is somewhat higher for cloud cover with 3-hour cycle.
- Verification against soundings: For temperature and specific humidity there are slightly smaller RMSE with 3-hour cycle, otherwise no notable differences.

For more verification results for cy37 and cy38 for the winter period that is evaluated in this chapter, can be found here: http://metcoop.met.no/verif/201112_37h11_38h1b1_b2_b3_export/

3.3.1 Mean Sea Level Pressure (MSLP)

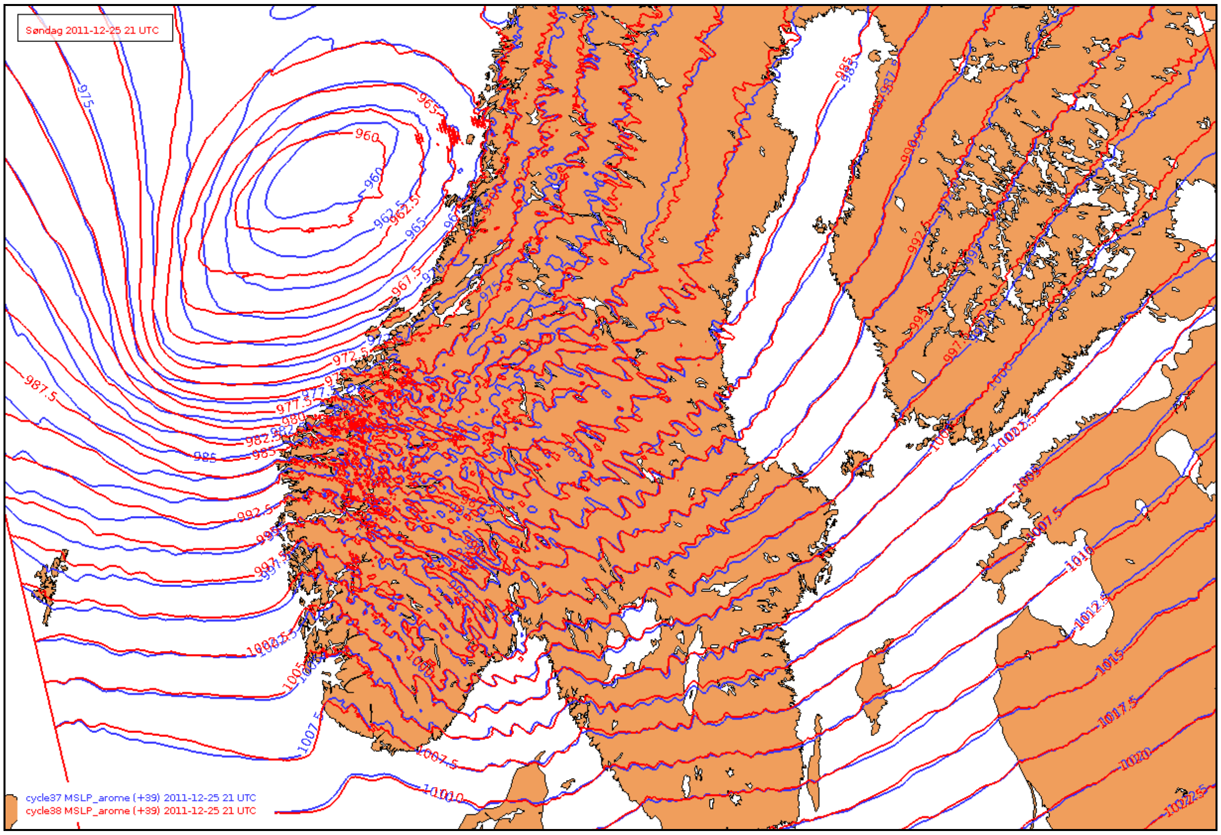

Figure 22.+39 hour forecast showing MSLP in cycle37 (blue) and cycle38 (red). Deepest low is 960 hPa . Equidistance is 2.5 hPa. (25th December 2011 at 21Z).

From Figure 22 it can be seen that the change from cycle 37 to cycle 38 doesn't affect the synoptic low pressure system responsible for the extreme winds. The low is almost at the same place and the pressure in the center of the low is similar. The only difference is the pressure gradient southwest of the center of the low, this gradient is stronger in cycle 38 than cycle 37.

3.3.2 Wind speed

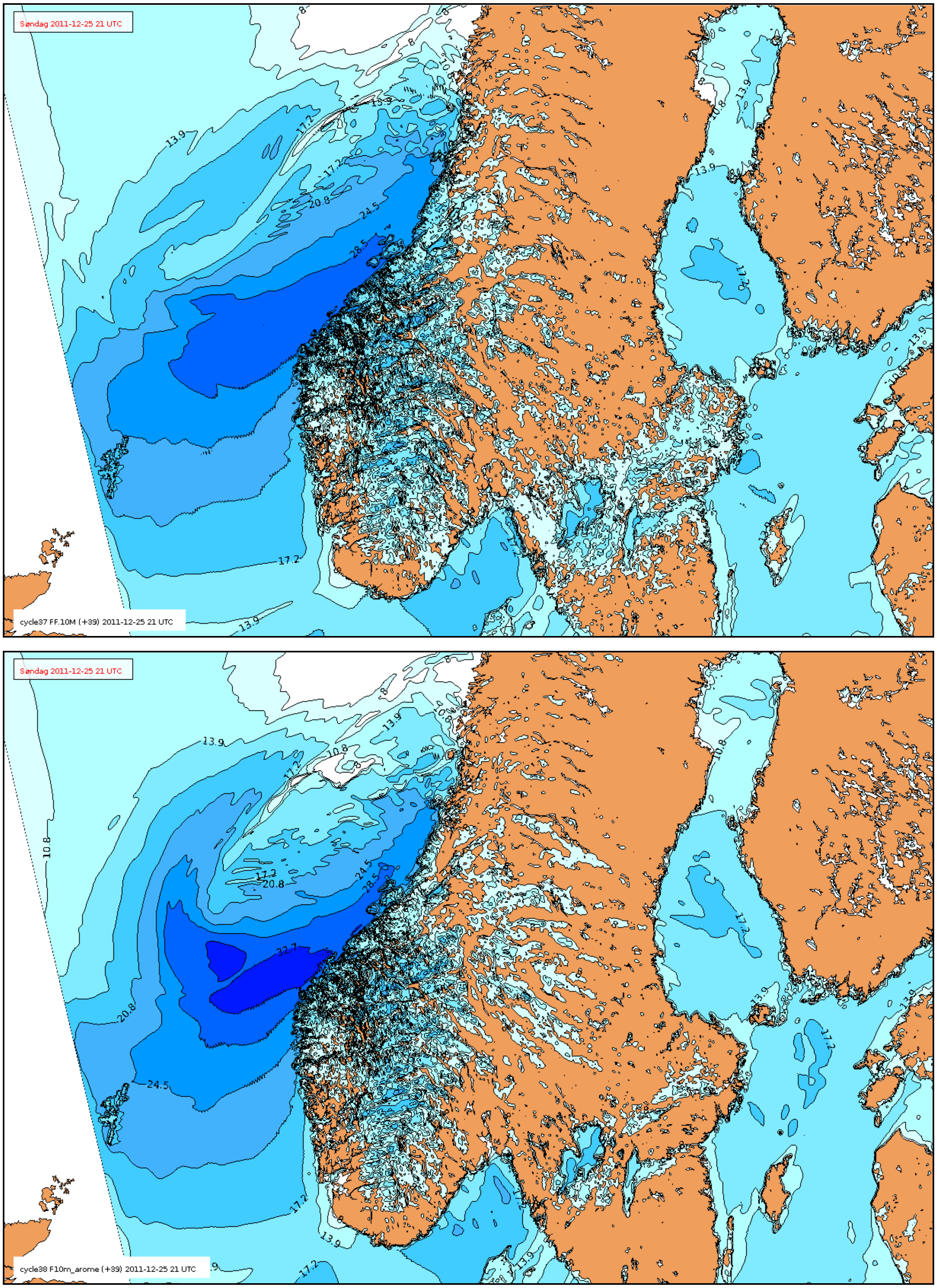

Figure 23.+39 hour forecast for 25th December 2011 at 21Z showing 10 m wind speed in cycle37 (top) and cycle38 (bottom). Darkest blue represents >32.7 m/s. Equidistance is 1 Beaufort.

From Figure 23 it can be seen that the wind speed is stronger in cycle 38 than cycle 37, as expected due to the stronger pressure gradient, southwest of the low pressure center. In cycle 37 the wind speed is violent storm force 11 just outside the coast of Møre og Romsdal, while cycle 38 has hurricane force 12. Cycle 38 gives stronger winds over the sea, and seems to fit better to the observations for the light-houses at the coast. Kråkenes, Svinøy and Ona lighthouses observed hurricane force 12 (see Figure 24) before 18 o'clock 25th December.

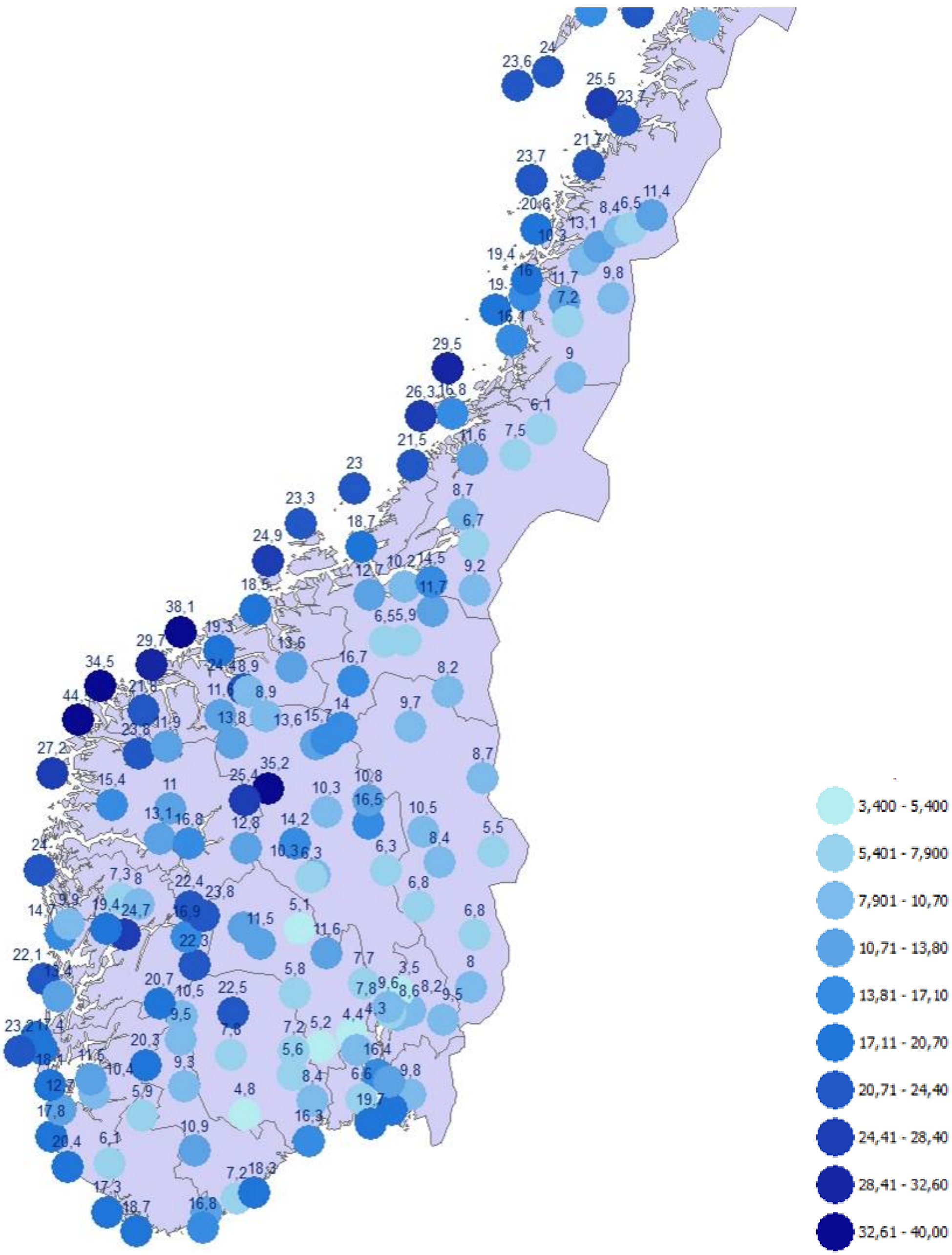

Figure 24, Highest observed 10 minutes average wind speed in m/s (10 meters above ground) from 18:00, 24th to 18:00 25th of December 2011. Equidistance is 1 Beaufort, color scale in m/s to the right. Maximum observed wind speed last hour was 44.5 m/s at KRÅKENES (wmo number 01203) 18 the 25'th.

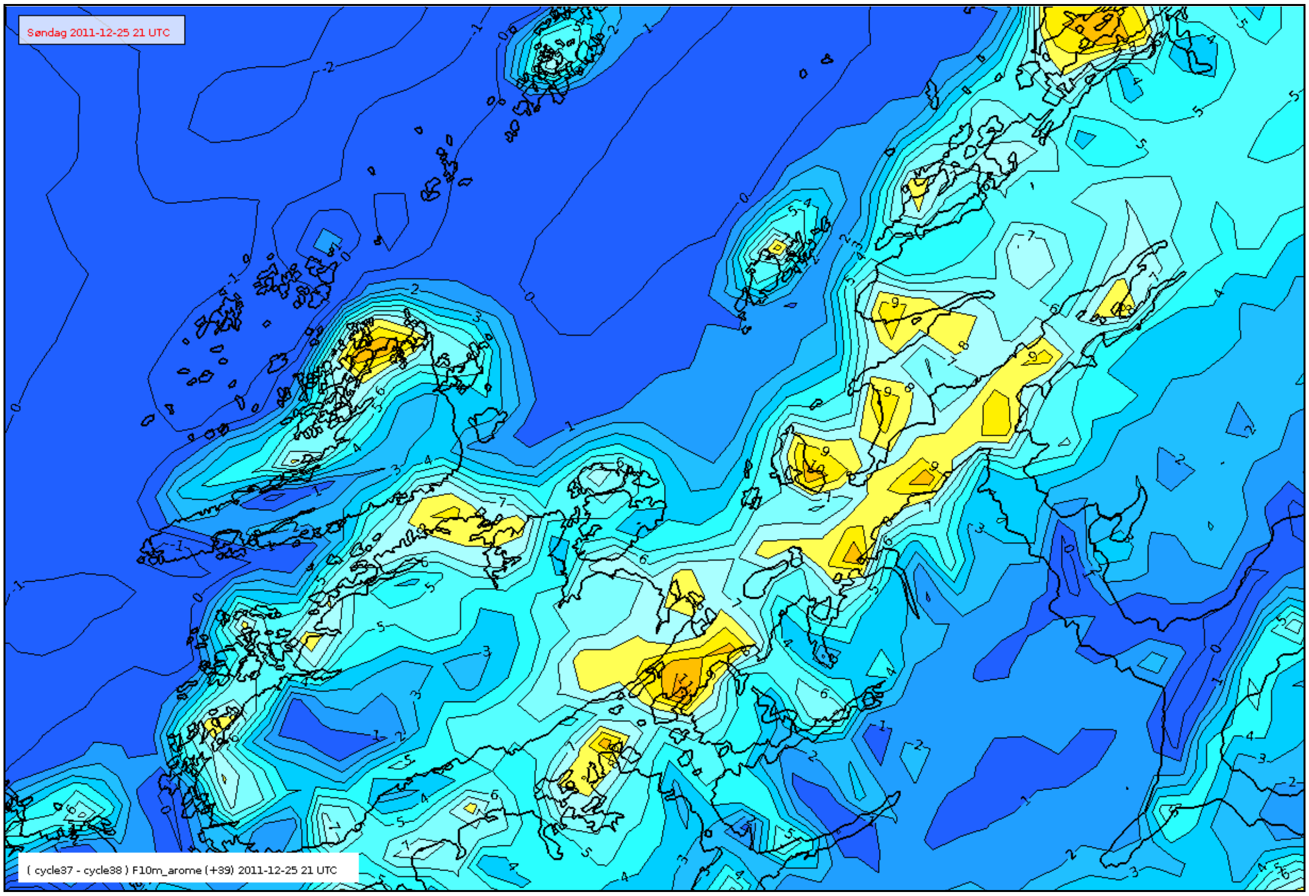

Figure 25. Forecast +39 that means 25th December 2011 at 21Z. 10 m wind speed in cycle 37 minus 10 m wind speed in cycle 38. Equidistance is 1 m/s, orange is largest with 10 m/s.

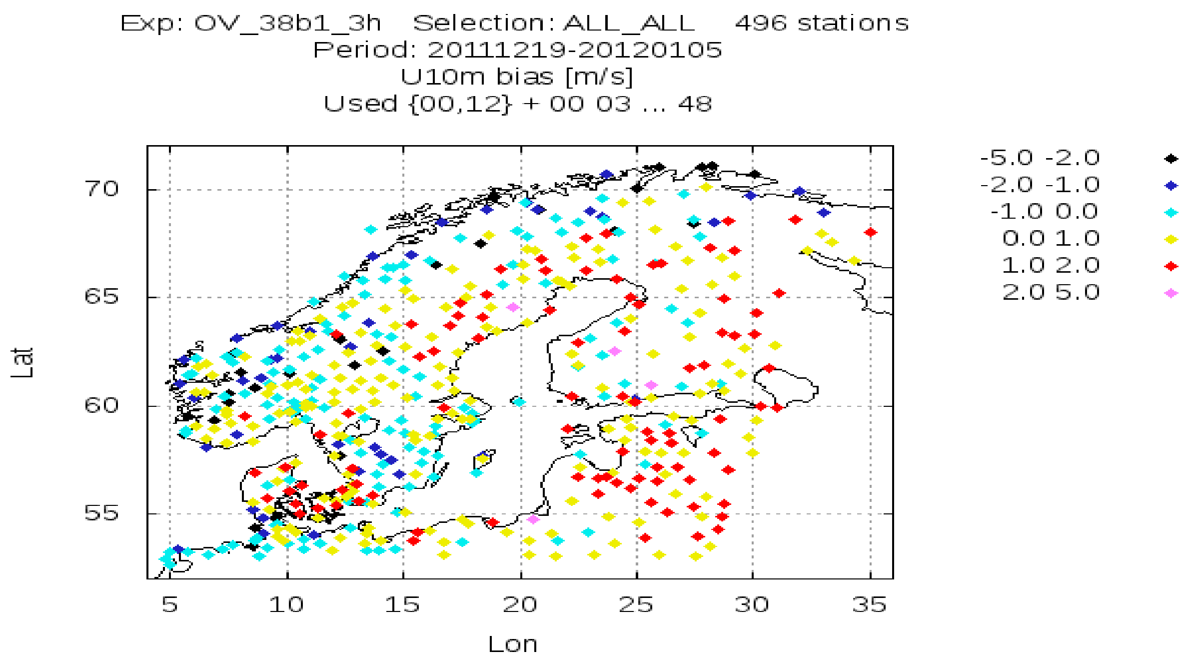

Figure 26. Wind speed. Mean differences between forecasts and observations for cycle38, 3h boundaries, using ECOCLIMAP 2

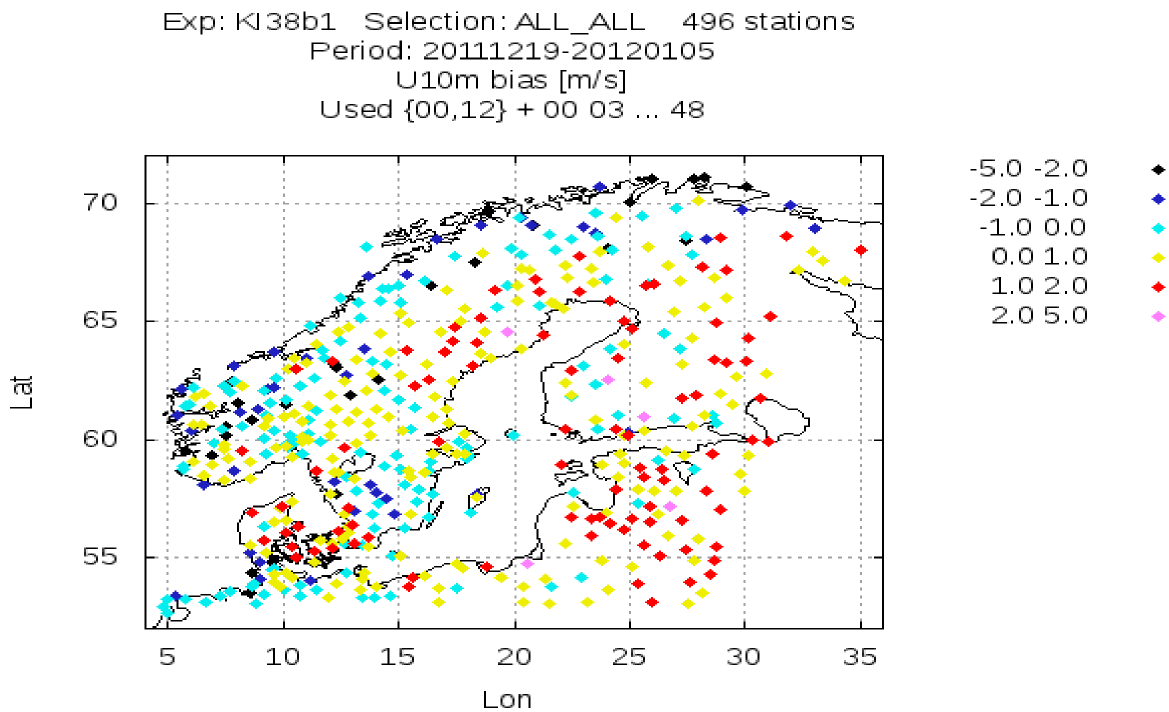

Figure 27. Wind speed. Mean differences between forecasts and observations for cycle38, 6h boundaries, using ECOCLIMAP 2

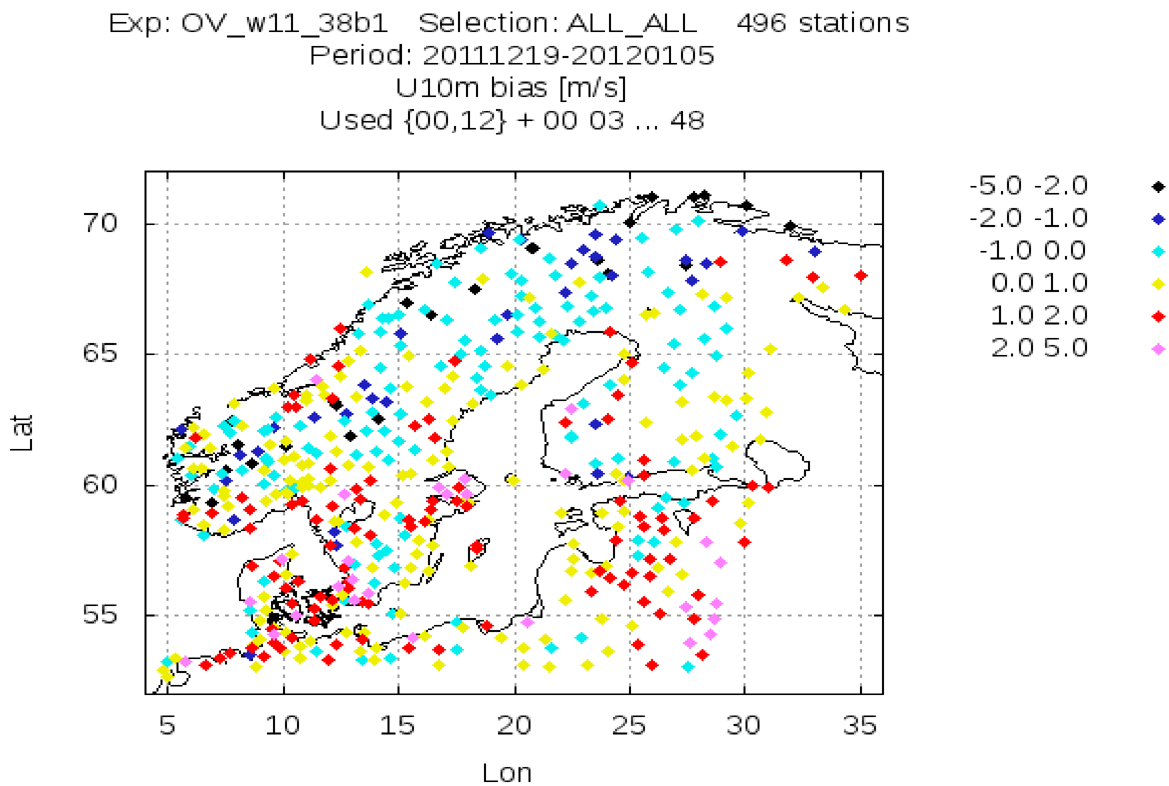

Figure 28. Wind speed. Mean differences between forecasts and observations for cycle38, 6h boundaries, using ECOCLIMAP 1

Both versions seem to underestimate the wind over land. From Figure 25 it can be seen that there are differences in wind speed over land areas and especially at the coast. Many places in the coastal areas the wind speed is about 5-10 m/s stronger in cycle 37 than cycle 38. The reduced windspeed over land in cycle 38 seems to be mainly because of the use of ECOCLIMAP 2, as seen from Figure 26 to Figure 28. Very small differences are seen between using 3 or 6 hours boundaries, but using ECOCLIMAP1 seems to give less reduced wind. This issue in cycle38beta1 version was addressed. In the tagged version cy38h1.1 the orographic drag setting (CROUGH) are set to NONE (instead of Z01D), since NONE gives better 10-meter wind speed over mountains and near the coast in winter. In summer the quality of 10 meter wind forecasts is also generally somewhat better with NONE. The only negative side-effect seen by choosing NONE is that in case of snow-covered forest, the 10-meter wind speed becomes generally somewhat too high.

3.3.3 Precipitation

In Figure 27 the 24 hour observed precipitation is shown for the same time as the forecasts shown in Figure 30, 24h accumulated precipitation at prognosis +48 h for cycle 37 (top) and cycle 38 (bottom) (26th December 2011 at 06Z). Maximum precipitation measured is 63.2 mm at Eikemo (south of Hardangerfjorden). This is also an area of maximum precipitation in the model. In cycle 37, the model gives above 80 mm at Eikemo, while cycle 38 gives 60-80 mm (see Figure 30).

Another maximum in 24 hour precipitation in the model is near the eastern border of Hordaland and Sogn og Fjordane. Here the model gives 60-100 mm in both cycle 37 and cycle 38, while the observations give about 40 mm. The largest observed precipitation amounts came the day after with maximum observed 24h value 146,1 mm at Ullensvang in Hordaland (WMO number 01342). From Figure 31 it can be seen that there are some differences in 24h accumulated precipitation between cycle 37 and cycle 38. Cycle 37 seems to have slightly more precipitation than cycle 38, and cycle 38 is closer to the observations.

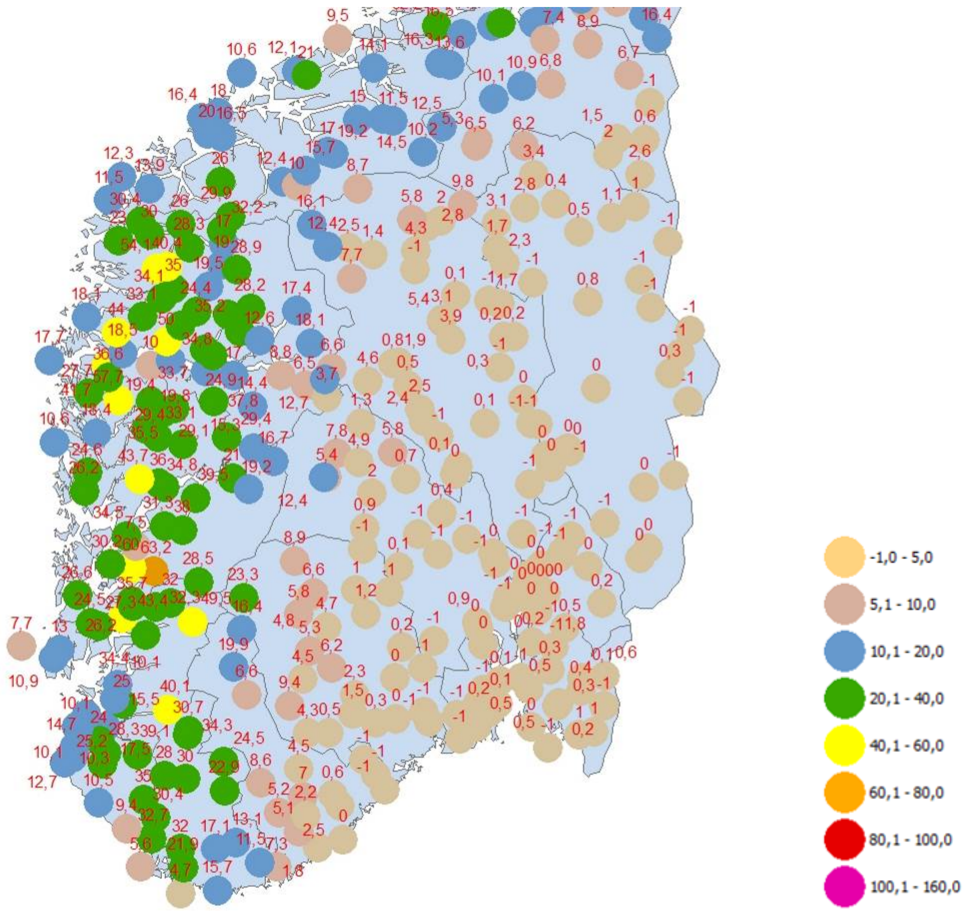

Figure 29, 24h observed precipitation at 27th December 2011 at 06Z, see color scale in mm to the right (amount written to the top of the bullet, -1 means no precipitation observed=0.0 mm).

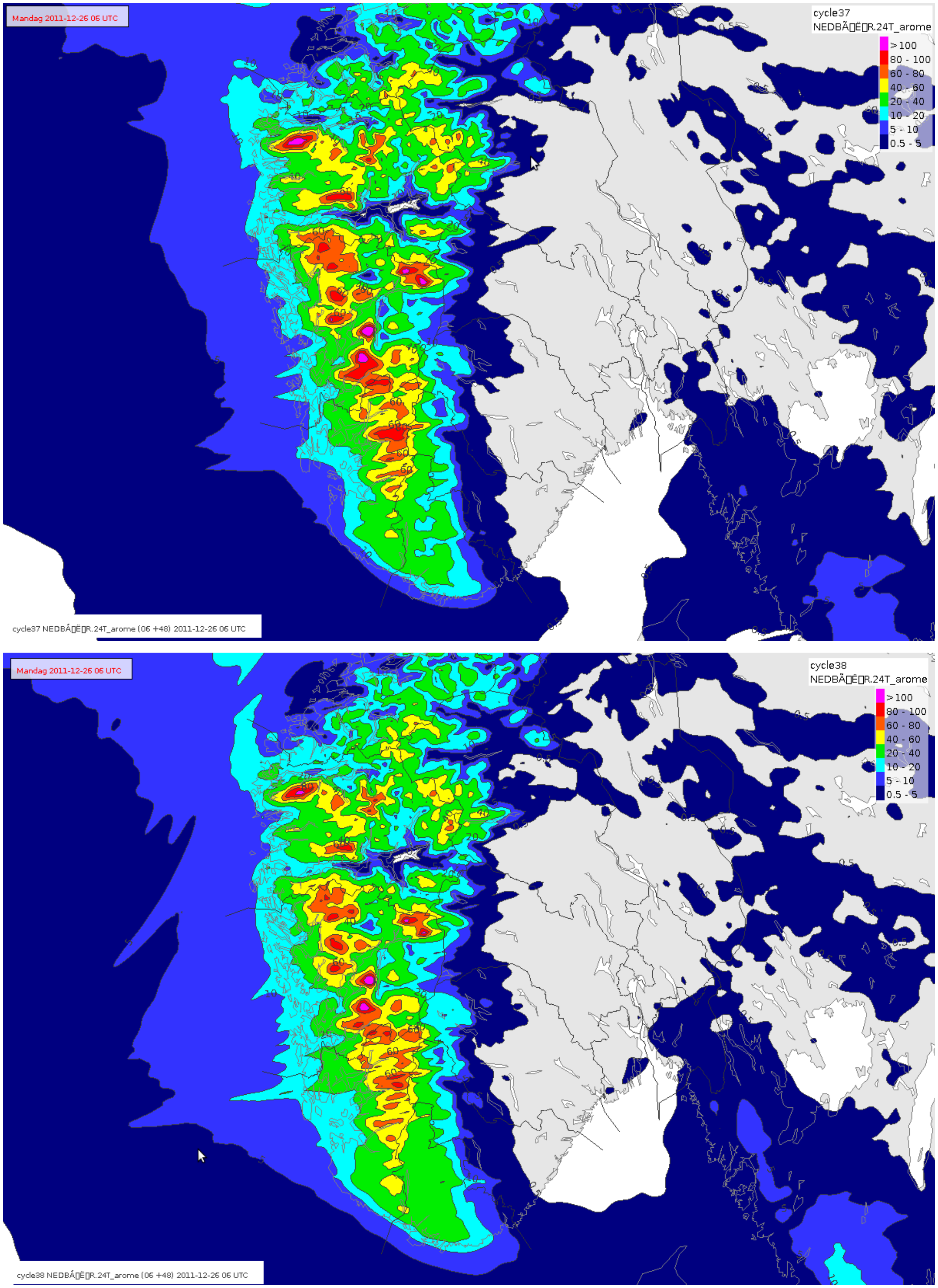

Figure 30, 24h accumulated precipitation at prognosis +48 h for cycle 37 (top) and cycle 38 (bottom) (26th December 2011 at 06Z).

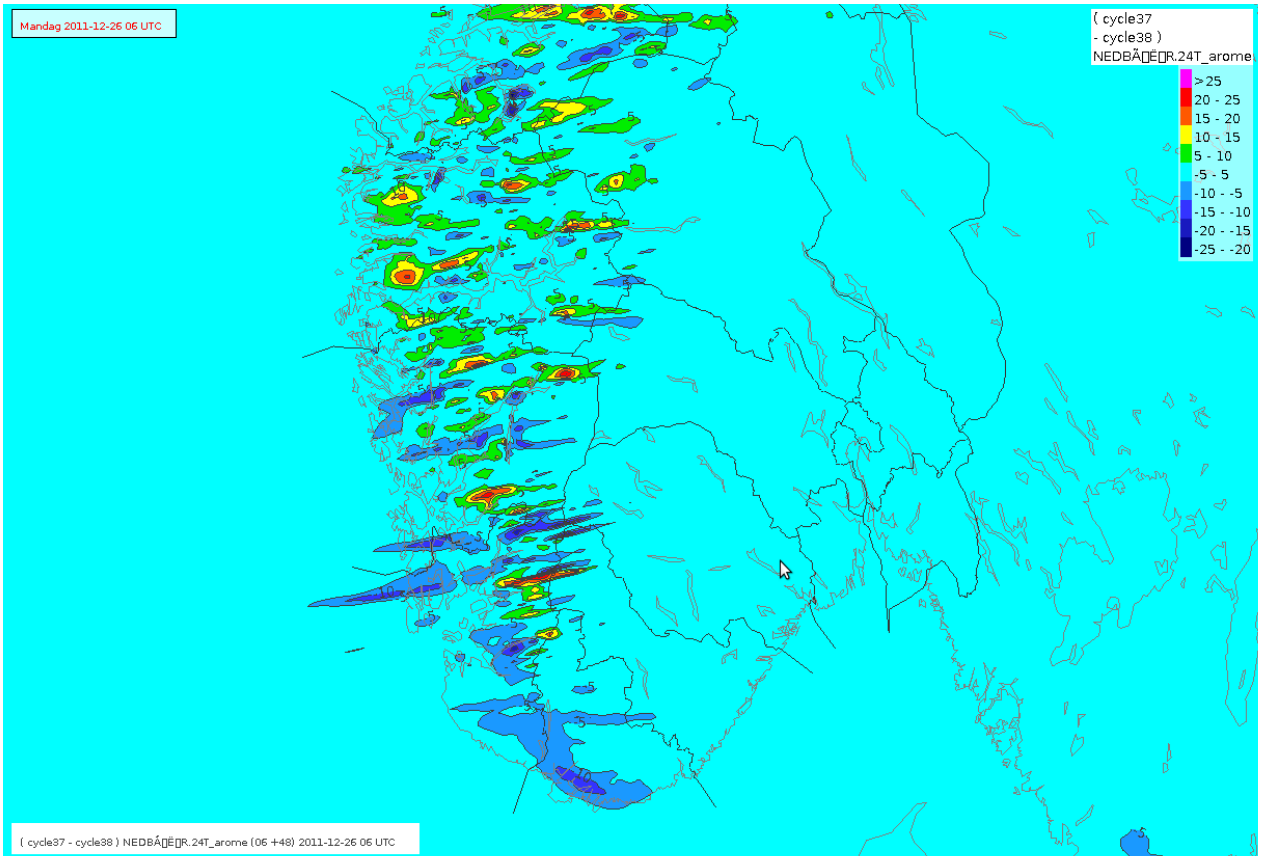

Figure 31, 24h accumulated precipitation at prognosis +48 h. Difference between cycle 37 and cycle 38. Equidistance is5 mm. (26th December 2011 at 06Z).

3.3.4 Summary

In this study of the Dagmar-case there were found only minor differences between cycle 37 and cycle 38. The main difference was the pressure gradient southwest of the low pressure. The pressure gradient southwest of the low, was stronger in cycle 38 which gave 1 Beaufort stronger winds at the coast of Møre og Romsdal.

There are some differences in 24h accumulated precipitation between cycle 37 and cycle 38. Cycle 37 had slightly more precipitation than cycle 38, and cycle 38 was closer to the observations.

4 References

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5 Figures and tables

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