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The importance of initial snow cover and snow depth in HIRLAM forecasts

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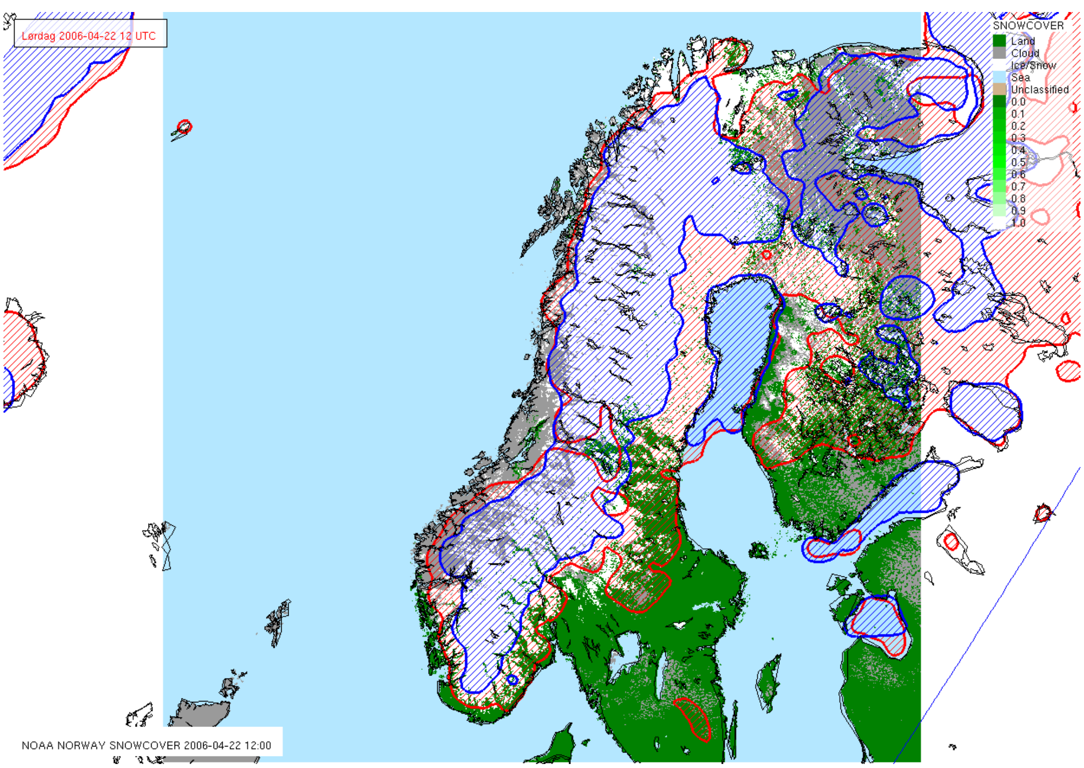

Snow cover from AVHRR, and two different HIRLAM10 forecasts for 22.April 2006.

Norwegian Meteorological Institute met.no **report**

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Abstract

For April 2006 two parallel runs have been performed with HIRLAM giving daily 06UTC +60h forecasts. The first run use initial snow based on snow from the Sea Ice Service at met.no, while the other run use snow from the snow analysis in the HIRLAM model. Forecast results are compared against observational station data, HIRLAM analysis and satellite picture over Scandinavian. The two sources for initial snow depth and snow cover are quite similar regarding snow cover, however they differ in snow depth. As the forecast time increases the differences in snow cover increases due to melting. The forecasts from the HIRLAM snow analysis are in best agreement with satellite pictures and station data for snow cover and depth, respectively. The forecasts using the HIRLAM snow analysis are also clearly in best agreement with HIRLAM analysis for T2m as the forecast length increases.

Keywords

Snow on ground, HIRLAM forecasts

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1. Introduction

Snow on the ground influence the earth-atmosphere system in several aspects. The snow act as an insulator, change the surface albedo and during melting the presence of snow keep the surface temperature at 0°C. Through these processes snow act as an important regulator of the energy available at the surface. This is especially important during spring when solar radiation increases while snow still is present.

To simulate the effects of snow properly it is important to have the initial snow depth and snow cover correct in the forecast model, and that the snow evolves properly during the forecast. Efforts should therefore be given both the initial snow and the snow scheme in a forecast model. At The Norwegian Meteorological Institute (met.no) the weather forecast model HIRLAM is employed for forecasts up to +60h. In HIRLAM, snow depth (measured in water equivalents) is a prognostic variable, while snow cover is diagnosed from the snow depth. In HIRLAM the surface is 100% covered with snow if the water equivalent exceeds 0.015m (equal to approximately 15cm of fresh snow), and totally snow free if the water equivalent equals 0m. Between these limits a linear approach is used to decide the snow cover.

Until December 2005 the initial snow in the met.no version of HIRLAM was taken from the Sea Ice Service at met.no which is updated once a week (see section 2.1 for description). On 13 December 2005 version 6.4.2 of HIRLAM was taken into operational use at met.no and the initial snow depth was then found by the snow analysis scheme in HIRLAM. The importance of initial snow depth and snow cover in HIRLAM forecasts has earlier been studied by Jensen (2003). It was then concluded that the use of snow from the Sea ice Service at met.no improved the forecast over Norway compared with using climatological snow. However, they did not find further improvement using the snow analysis in HIRLAM. In Jensen (2003) version 6.2 of HIRLAM was applied. In that version the snow analysis was done by successive corrections. In version 6.4.2 the successive corrections has been replaced by a method based on Optimal Interpolation.

In this report we study the effect of changing the initial snow taken from the Sea Ice Service at met.no with the HIRLAM snow analysis implemented in version 6.4.2 of HIRLAM. First a description of the two methods of finding the snow depth is given in section 2, while the experimental setup is given in section 3. In section 4 the results are compared with station based observations, HIRLAM analyses and AVHRR detected snow cover. The study is summarized and concluded in section 5.

2. Description of initial snow in HIRLAM

2.1 Snow from the Sea Ice Service at met.no

The Sea Ice Service at met.no makes maps of snow cover and snow depth. Snow maps are made based on satellite measurements and surface observations, and new fields are available once a week. These fields are digitalized and were used as initial snow in HIRLAM until December 2005.

2.2 Snow analysis in HIRLAM

The HIRLAM snow analysis is described by Cansado et al. (2004). Only a brief summary is given in this report. The snow analysis is done on the fractional average over the ice fraction and the three land tiles whitin each grid box. The first guess field is taken from the previous forecast. The prognostic variable snow water equivalent [m] in the model is converted to snow depth [cm] by assuming a monthly varying snow density and the analysis are performed on snow depth.

Only observations of snow depth from surface reports are used. The analysis method is optimal interpolation. With this method the fundamental hypothesis is that only a few observations are important in determing the analysis increment. The observation weights are scaled to account for the difference between model orography and observational height. Finally the analyzed field is converted back to equivalent water snow mass in the different tiles.

3. Experimental setup of one spring month

Version 6.4.2 of HIRLAM is applied on an area shown in figure 1 (operational HIRLAM10 area). The model use 0.1° horizontal resolution and 248 x 400 grid points and 40 vertical levels. Except for the initial snow, all initial and boundary conditions are taken from the operational HIRLAM20 (0.2° horizontal resolution, 40 vertical levels with an integration domain shown in figure 1). For April 2006 two parallel runs have been performed giving daily 06UTC +60h forecasts. The first simulation use snow from the Sea Ice Service at met.no, while the other use snow from the snow analysis in the operational HIRLAM20.

4. Evaluation of HIRLAM forecasts

In this section HIRLAM forecasts for one spring month (April 2006) with two different ways to set initial snow depth are evaluated against available observations, satellite measurements and HIRLAM analysis. For atmospheric variables we focus on temperature in 2 meters height. This is a diagnostic variable in the model but it is close connected to the surface temperature and the temperature from the lowest model layer which both is prognostic variables. Only minor impacts on other variables are found so we limit the analysis to temperature and snow depth.

4.1 Comparison of HIRLAM forecasts and observations

Temperatures in 2m height from both forecast runs are compared with observations from 50 inland stations in Norway. At some locations forecasts with snow from the HIRLAM analysis performed slightly better regarding mean error and standard deviation. However, on other locations the forecasts with snow from Sea Ice service at met.no was in slightly better agreement with the observed temperature. On several locations it was no differences between them. This lack of pattern in the errors was present for all forecast lengths and gives no significant differences in the summarized results.

Snow water equivalent from the initial snow depth in HIRLAM was transformed to snow depth in centimeter and compared with observed values at 22 locations in Norway. This transformation uses the same assumptions on snow density as done in the snow analysis. For 16 locations the forecasts with snow from the HIRLAM analysis was better than the forecasts with snow from The Sea Ice Service at met.no. A common feature among the 6 remaining stations is that they are all situated close to steep topography which may not be captured well in the model. However it is expected that the HIRLAM snow analysis would be in quite good agreement with the observations as it are the same observations that are used in the snow analysis. It is also in this discussion important to recognize that while the HIRLAM variables represent a 0.1° x 0.1° square, one observation represent one point.

4.2 Comparison of HIRLAM forecasts and analysis

In this section 10-days average of 2m air temperature and snow depth for +6hour and +30hour forecasts are compared with the same averaged variables from the HIRLAM20 analysis. The HIRLAM20 analysis represents our best estimate of the truth. The 10-days average is done to remove noise, and be able to detect differences originating from different initial snow depth.

<u>1.April – 10.April</u>

This period is illustrated with Figure 2a-d (+6h) and Figure 3a-d (+30h). After +6h forecast the snow covered areas are in general similar with both initial snow fields. However, with the HIRLAM snow analysis more snow is present in parts of southern Sweden and the snow layer is in general thicker. The difference in southern Sweden snow is reflected in the difference in T2m temperature, where the snow analysis forecast is in better agreement with HIRLAM20 analysis. The same is seen for +30h forecast, but the signal is more pronounced.

<u>11.April – 20. April</u>

This period is illustrated with Figure 4a-d (+6h) and Figure 5a-d (+30h). The same pattern that was present in the first 10 days of April is also present in this period. The differences are clearer and extended to larger areas than for the previous ten-day period. Looking at the evolution of snow depth in the forecasts it seems like the model melt snow rapidly. As the initial snow from the HIRLAM analysis is the thickest, clear differences is seen as melting happens. Less snow depth initially from the Sea Ice Service at met.no creates snow-free surfaces rapidly and large differences in 2m air temperature as the prognosis length increases.

<u>21.April – 30.April</u>

This period is illustrated with Figure 6a-d (+6h) and Figure 7a-d (+30). As for the previous periods the differences in both snow and air temperature is pronounced between the two forecasts. It is also clear that the effect reaches larger areas and both forecasts have a warm bias over parts of Sweden. That the temperature differences increases with forecast length suggest that both the initial snow and the treatment of snow during the forecast are important for the forecast skill.

4.3 Comparison of HIRLAM snow and snow from AVHRR

At met.no snow cover is daily extracted from AVHRR measurements. With this instrument snow on ground is not detected under cloudy conditions, it is therefore difficult to do a systematic validation of model snow with AVHRR. However, in Figure 8a and 8b we compare HIRLAM snow and AVHRR retrieved snow on two days (11.April and 22.April) when large parts of Scandinavia was cloud free. The AVHRR data is valid for 12UTC so the HIRLAM snow is +6hour forecasts. On these two occasions snow from the snow analysis in HIRLAM is in best agreement with the satellite measured snow. The difference is most clearly seen over Sweden, and is consistent with the results presented in section 4.2.

5. Summary

One month of HIRLAM forecasts during spring with different initial snow depth is compared. Only minor differences are found for other variables than 2m air temperature and snow depth. Comparison between the two sets of forecasts at Norwegian synop stations reveal only small differences for T2m, and it is not possible to conclude that one is superior to the other. However, for snow depth, the snow analysis done in HIRLAM is the best. Comparing 2m air temperature forecasts with HIRLAM20 analysis shows distinct differences during daytime and the difference increases with forecast length. The forecasts started with analyzed snow are in best agreement with the HIRLAM analyzed temperature. A possible explanation for this is that even if the initial snow cover is quite similar, the initial snow depth differs. In addition the HIRLAM model melt snow rapidly, which means that the difference in snow covered areas in the two forecasts may increase with forecast length. Satellite pictures from two days with small amounts of clouds in Scandinavia support that snow from the HIRLAM snow analysis is better than using snow input from the Sea Ice Service at met.no. Comparison with HIRLAM analysis and AVHRR measurements shows that the differences are much clearer seen over Sweden than in Norway. This explains why no significant impact was found when comparing with observational station data in Norway. Even though the HIRLAM snow analysis perform well it should be possible with further improvements. For example are only station based observations included. These observations show a coarse spatial resolution. Using satellite measured snow products and observations of precipitation may give further skill of the HIRLAM snow analysis.

References

Alberto Cansado, Carmen Martin and Beatriz Navascués, Optimum interpolation new snow depth analysis in HIRLAM, HIRLAM Newsletter 45, May 2004.

Jensen, M. H, HIRLAMs følsomhet for snødekkeanalyse, Research Report no. 144, Norwegian Meteorological Institute, 2003.

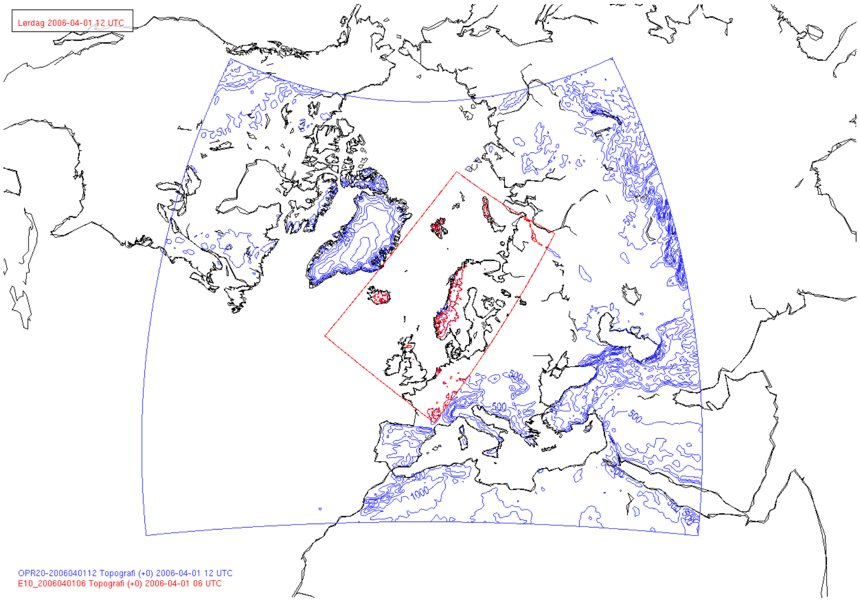


Figure 1. Integration domain for operational HIRLAM20 (blue) and HIRLAM10 (red). The model topography is in blue and red, respectively.

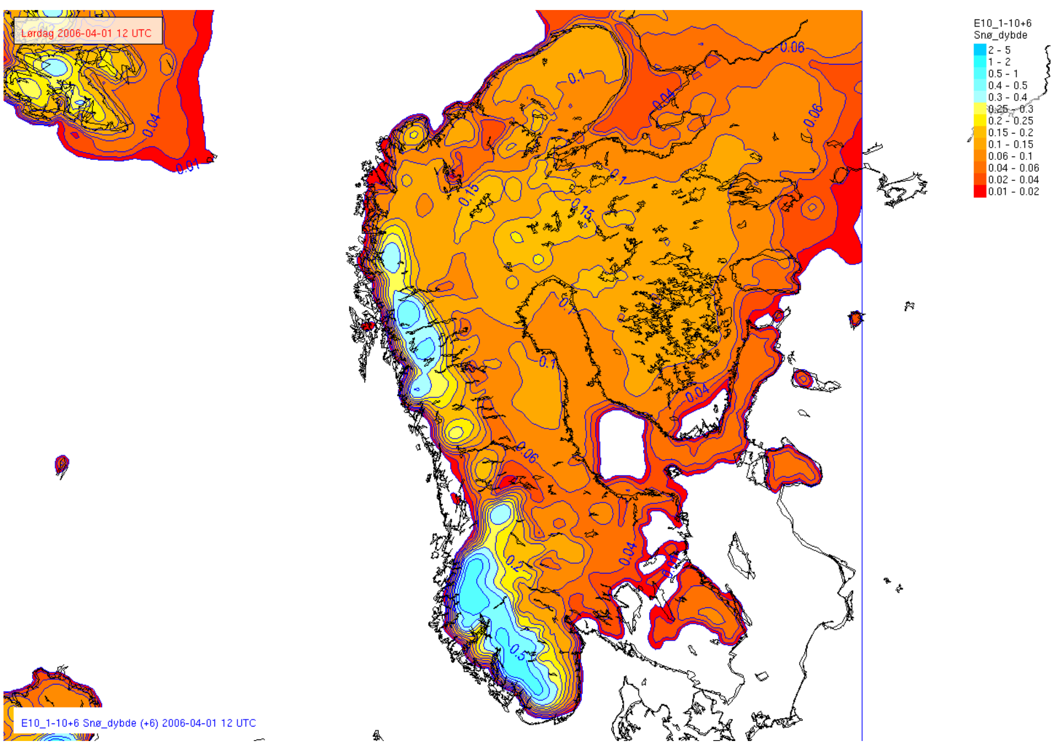


Figure 2a) Snow depth valid for +6h forecasts started with snow from the HIRLAM snow-analysis averaged over 1.April to 10.April

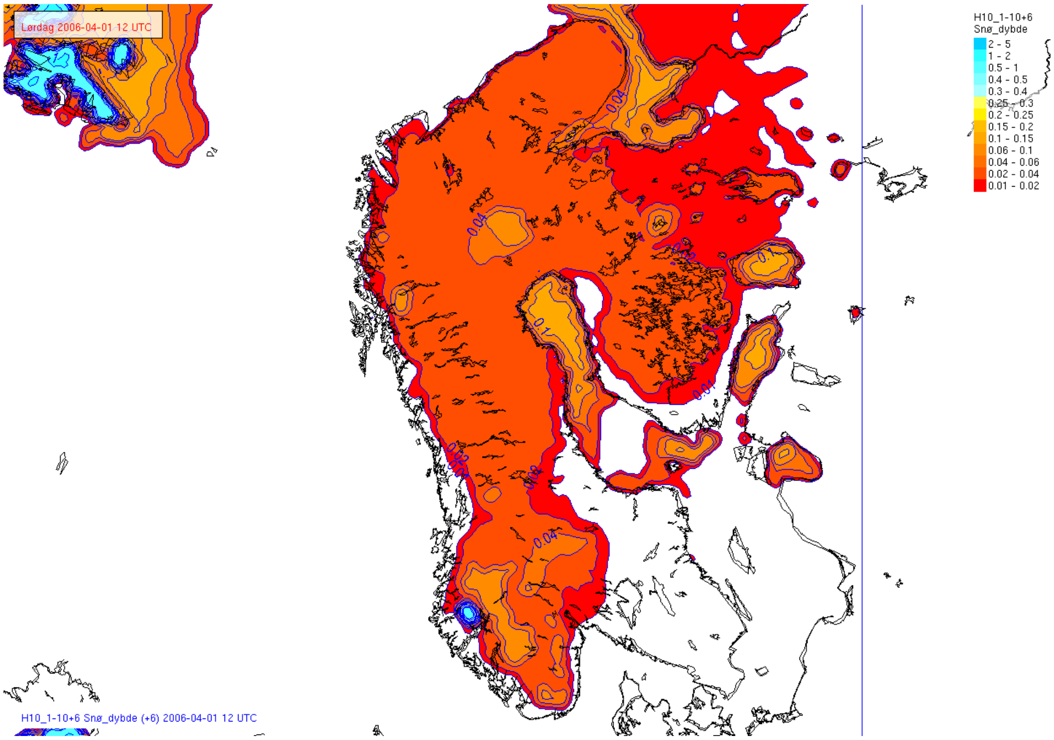


Figure 2b) Same as Figure 2a, but initial snow from Istjenesten at met.no.

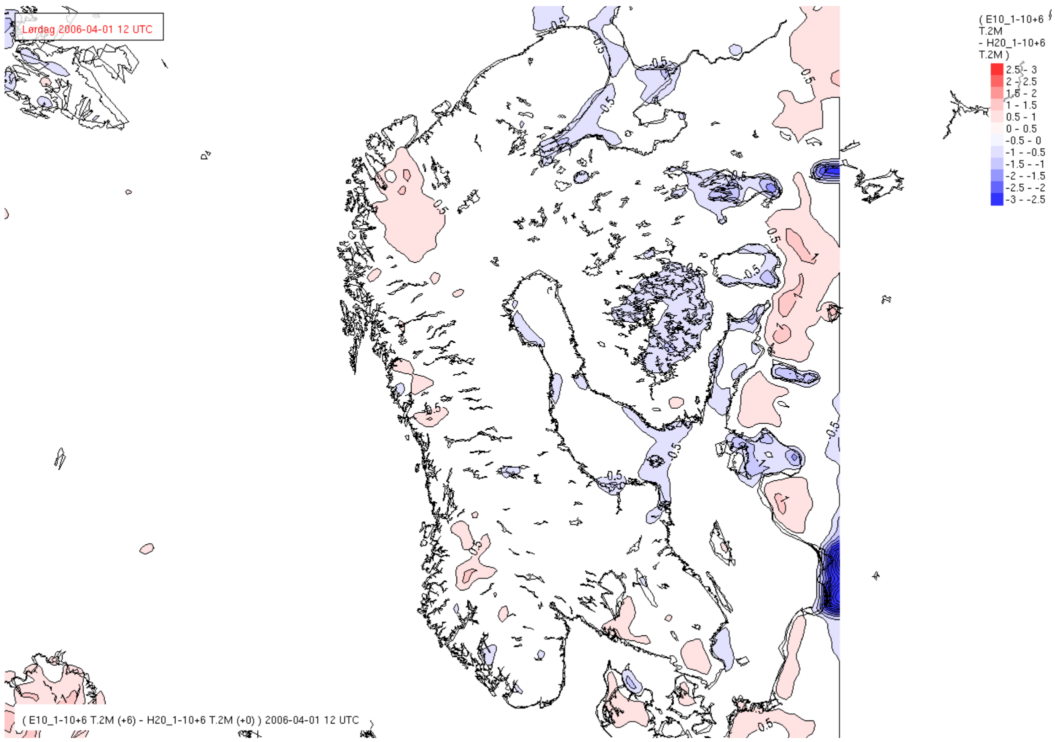
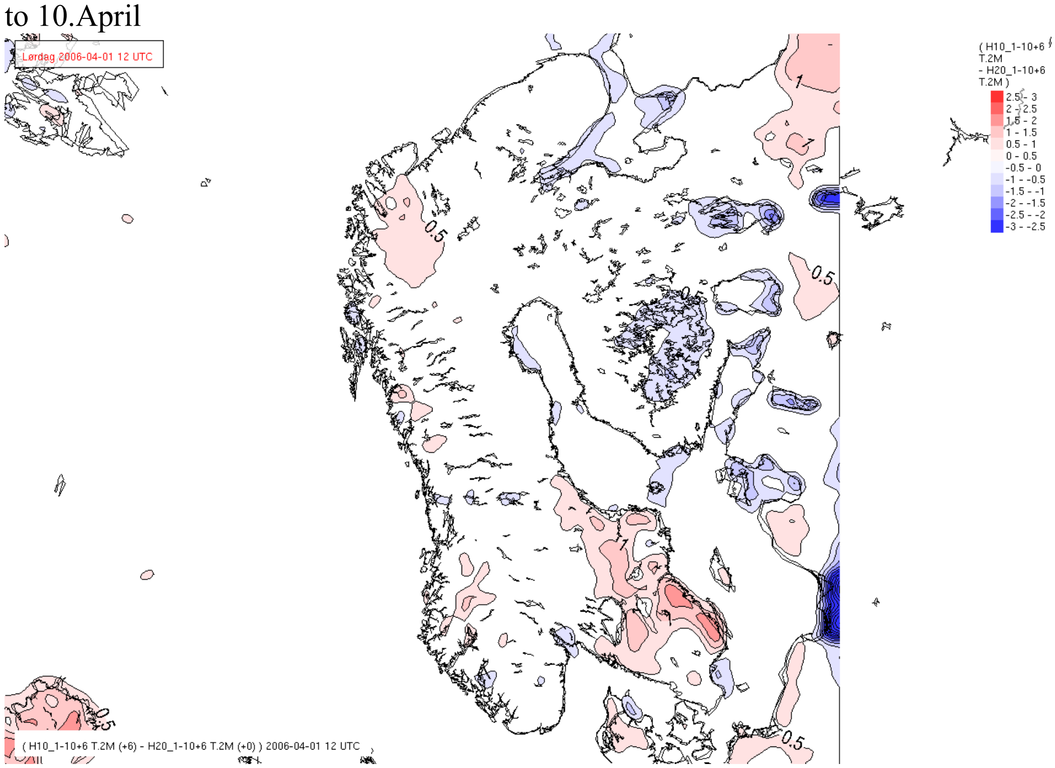


Figure 2c) T2m from +6h forecasts started with initial snow from the HIRLAM analysis minus T2m from HIRLAM20 operational analysis valid at 1200. Averaged over 1.April to 10.April



2d) As Figure 2c, but with forecasts with initial snow from Istjenesten at met.no.

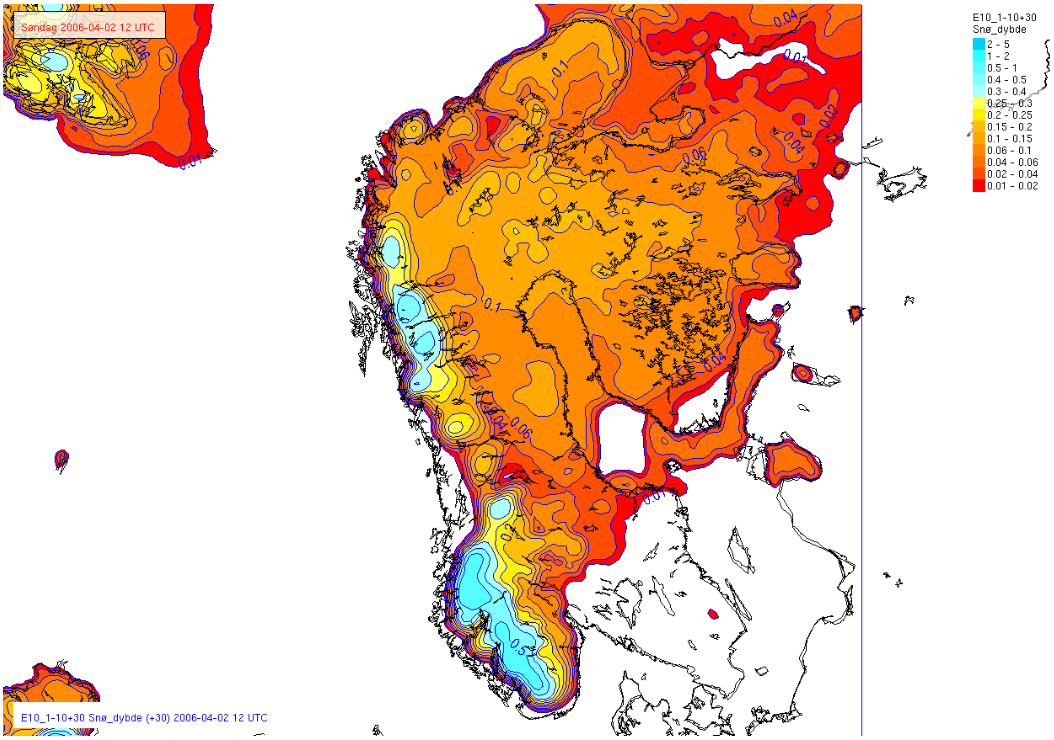
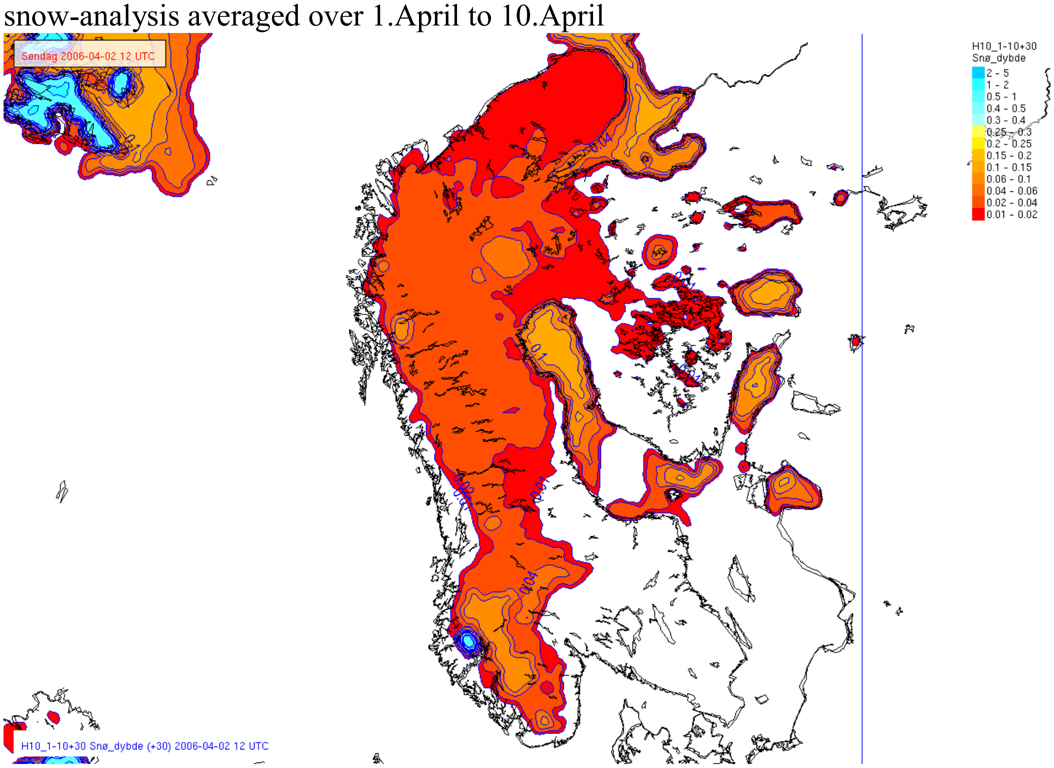


Figure 3a) Snow depth valid for +30h forecasts started with snow from the HIRLAM snow-analysis averaged over 1.April to 10.April



3b) Same as Figure 3a, but initial snow from Istjenesten at met.no.

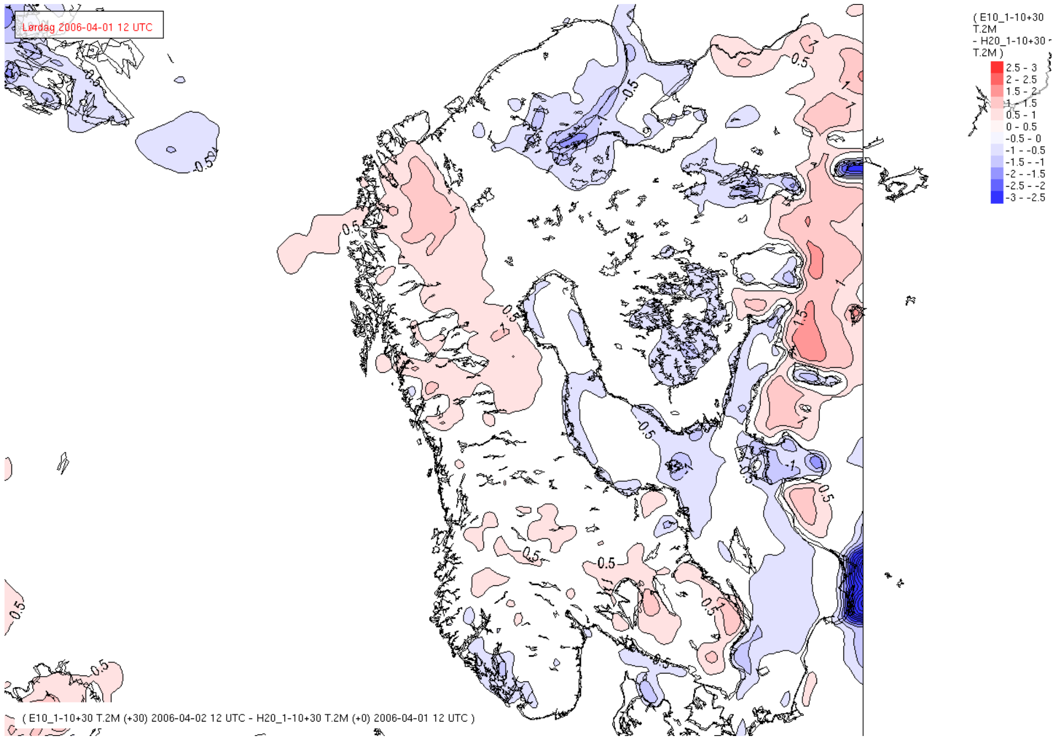


Figure 3c) T2m from +30h forecasts started with initial snow from the HIRLAM analysis minus T2m from HIRLAM20 operational analysis valid at 1200. Averaged over 1.April to 10.April

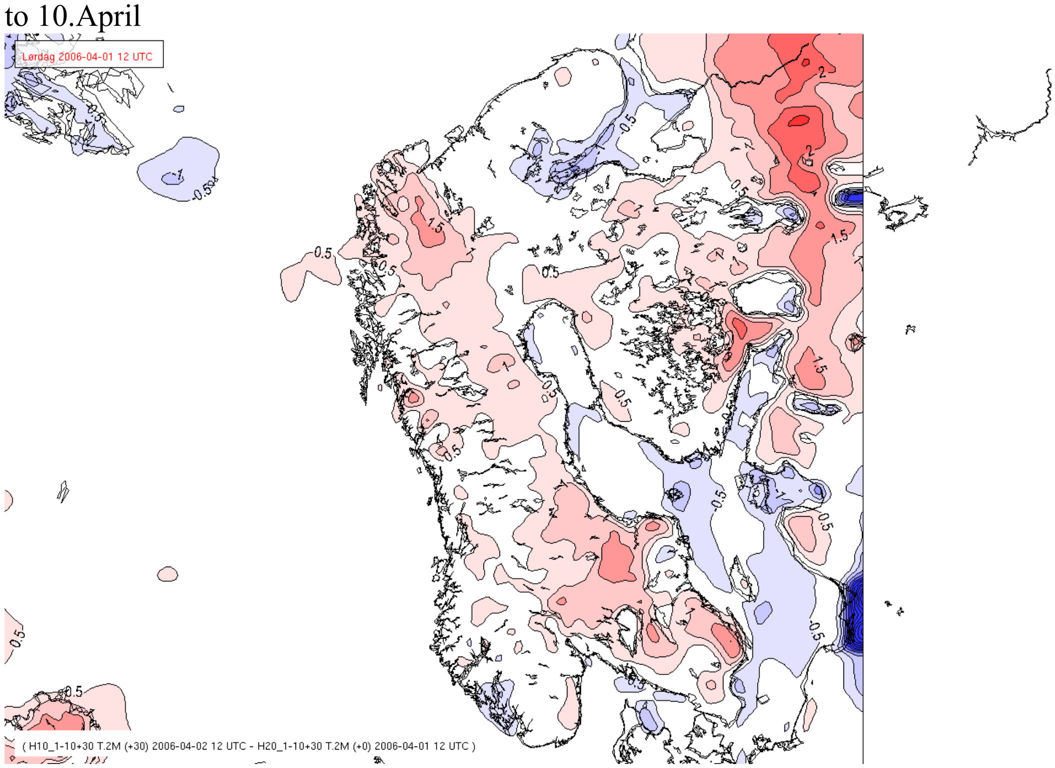


Figure 3d) As Figure 3c, but with forecasts with initial snow from Istjenesten at met.no.

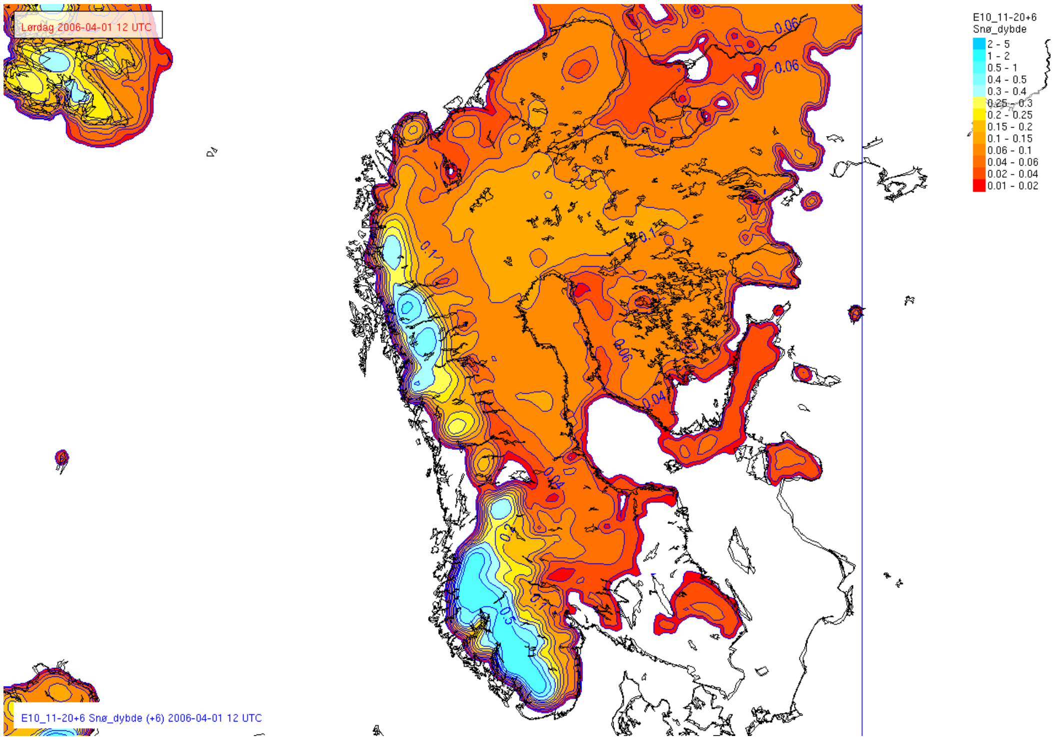


Figure 4a) Snow depth valid for +6h forecasts started with snow from the HIRLAM snow-analysis averaged over 11.April to 20.April

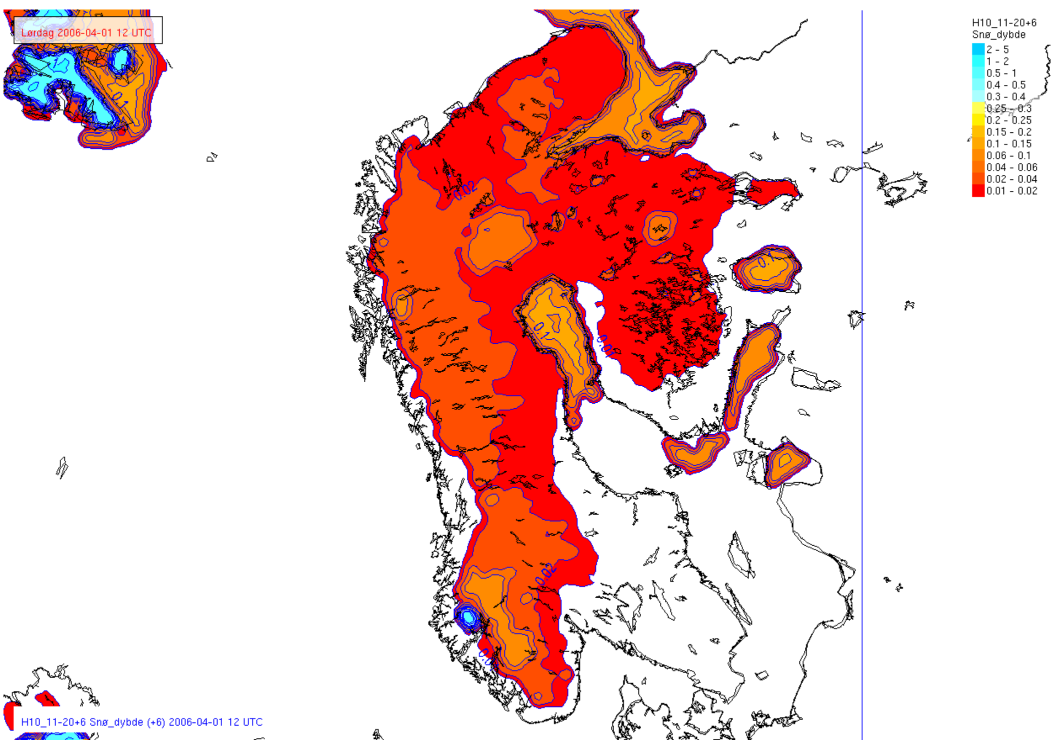


Figure 4b) Same as Figure 4a, but initial snow from Istjenesten at met.no.

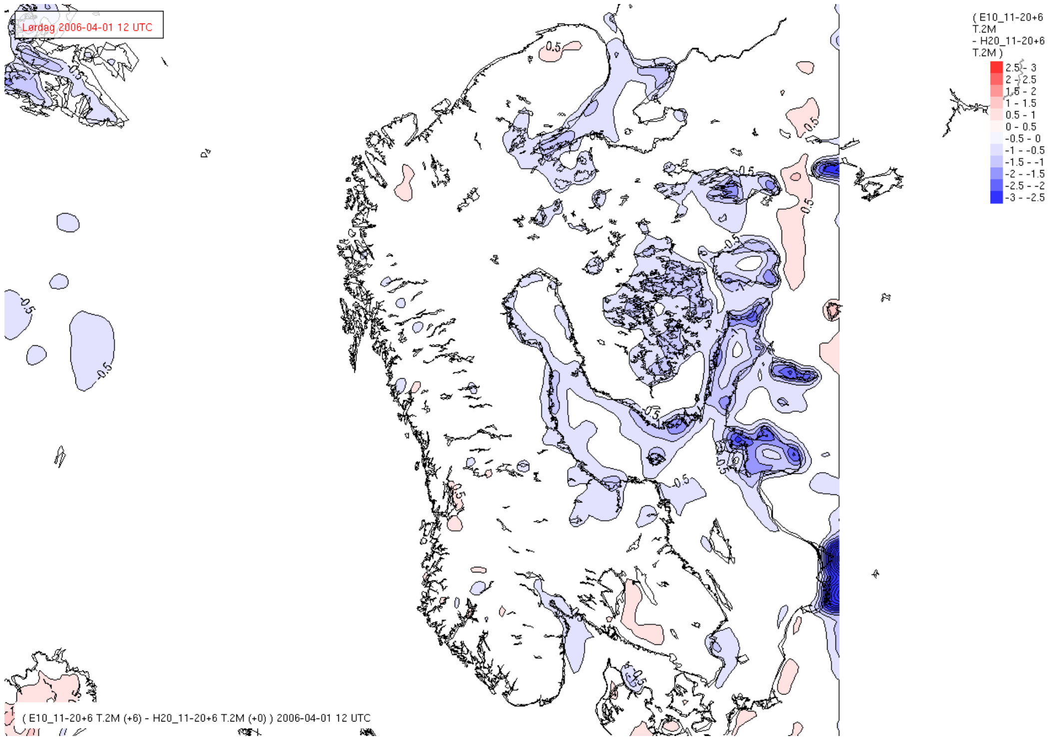
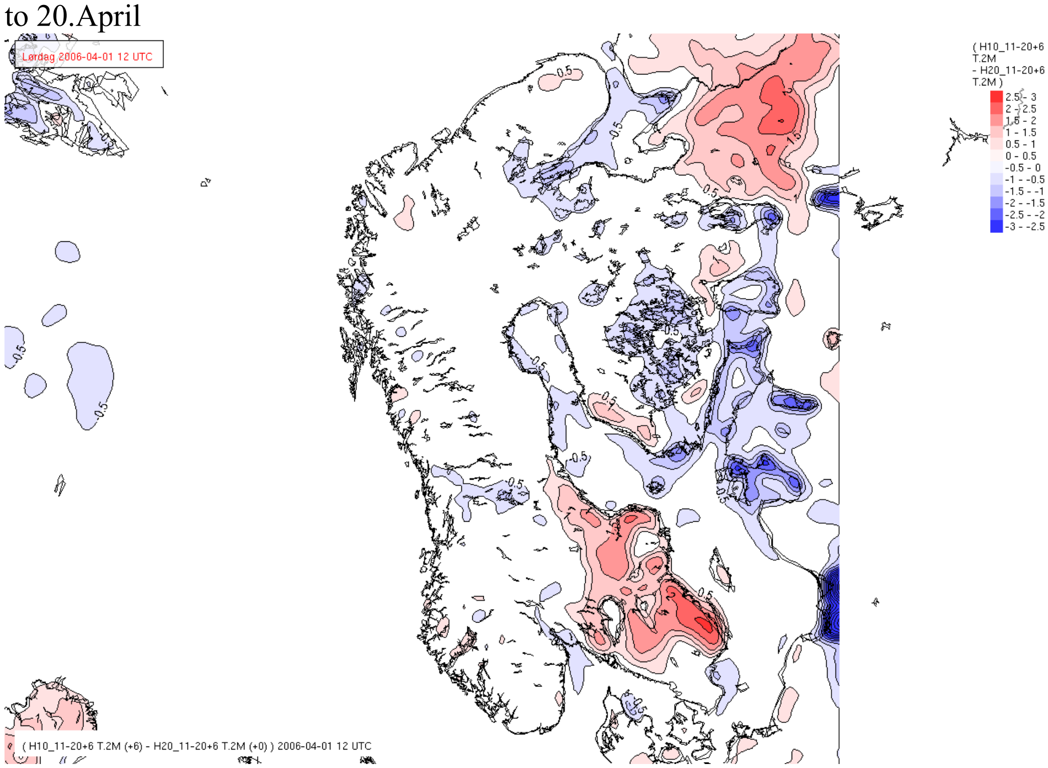


Figure 4c) T2m from +6h forecasts started with initial snow from the HIRLAM analysis minus T2m from HIRLAM20 operational analysis valid at 1200. Averaged over 11.April to 20.April



4d) As Figure 4c, but with forecasts with initial snow from Istjenesten at met.no.

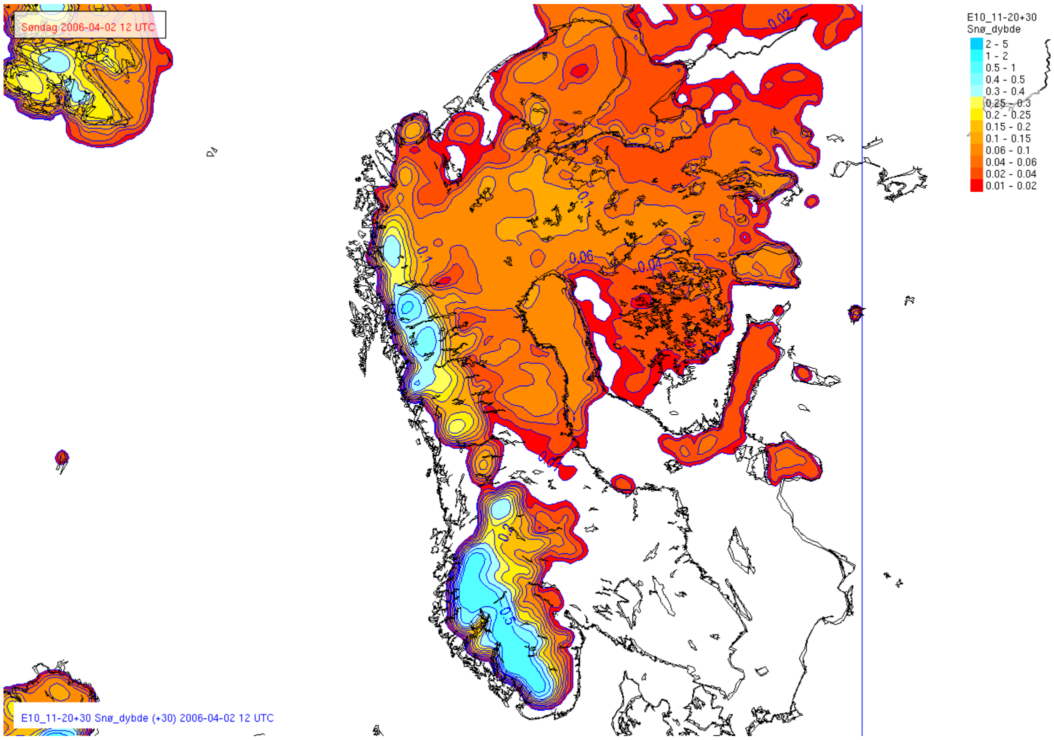
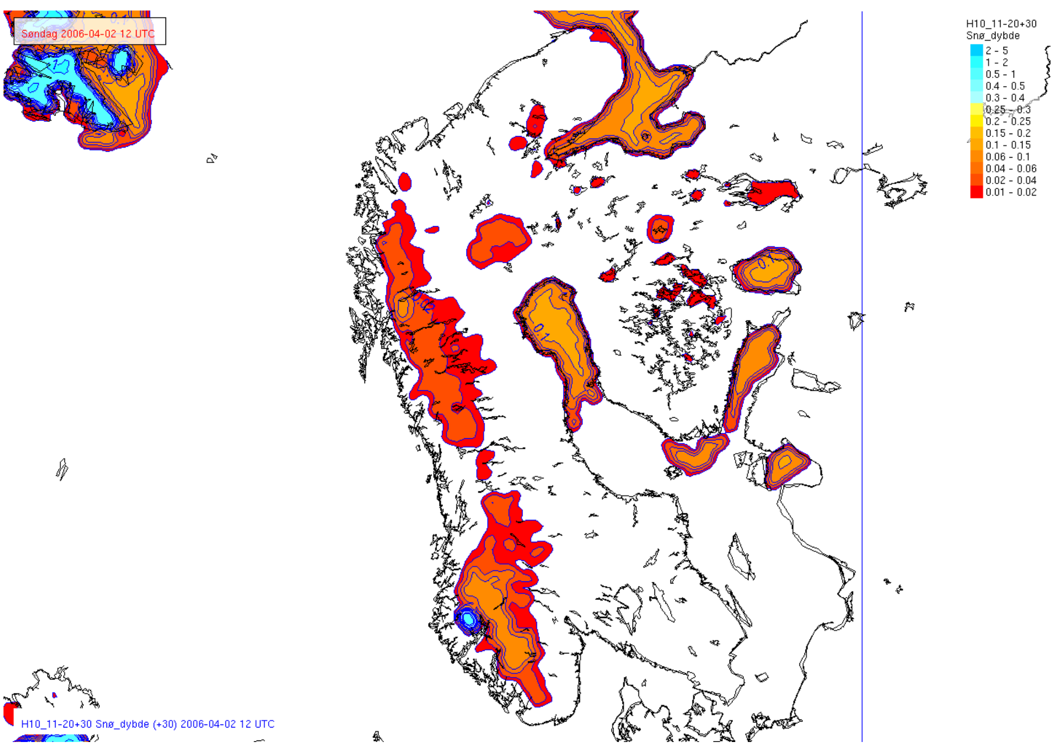


Figure 5a) Snow depth valid for +30h forecasts started with snow from the HIRLAM snow-analysis averaged over 11.April to 20.April



5b) Same as Figure 5a, but initial snow from Istjenesten at met.no.

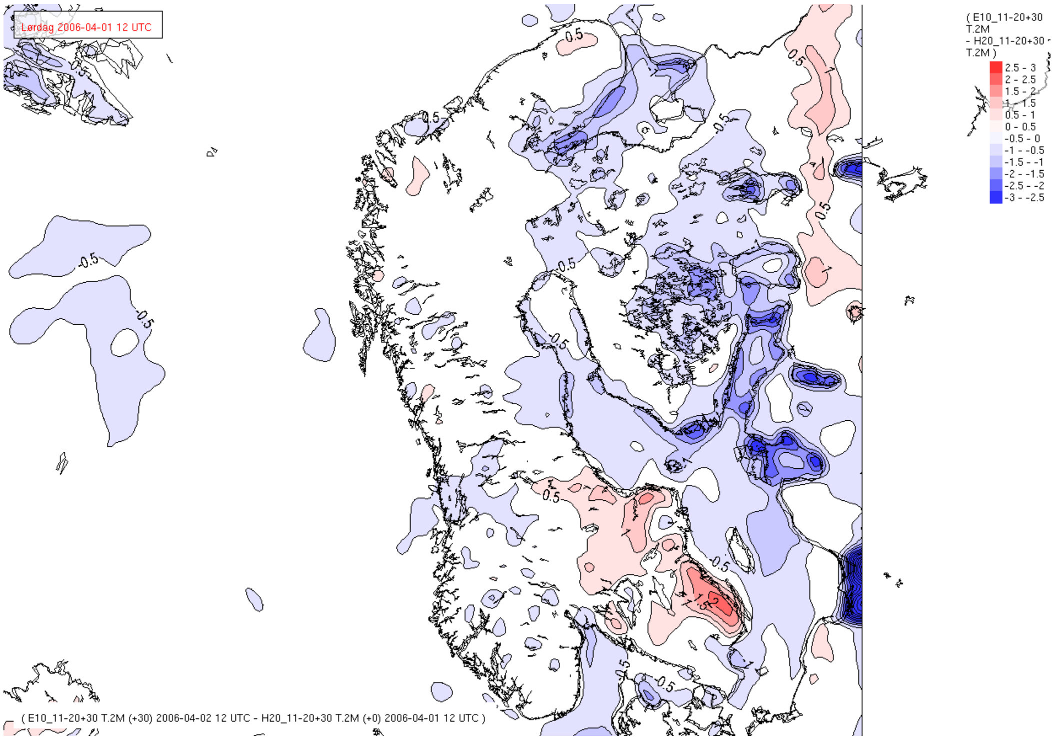
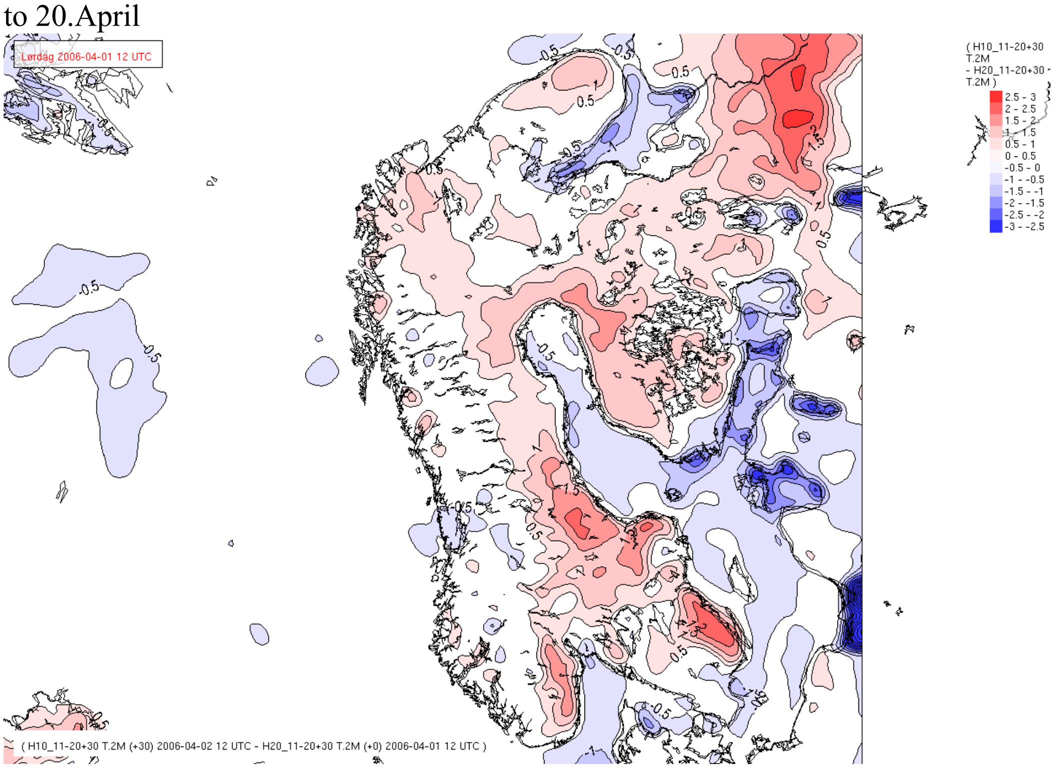


Figure 5c) T2m from +30h forecasts started with initial snow from the HIRLAM analysis minus T2m from HIRLAM20 operational analysis valid at 1200. Averaged over 11.April to 20.April



5d) As Figure 5c, but with forecasts with initial snow from Istjenesten at met.no.

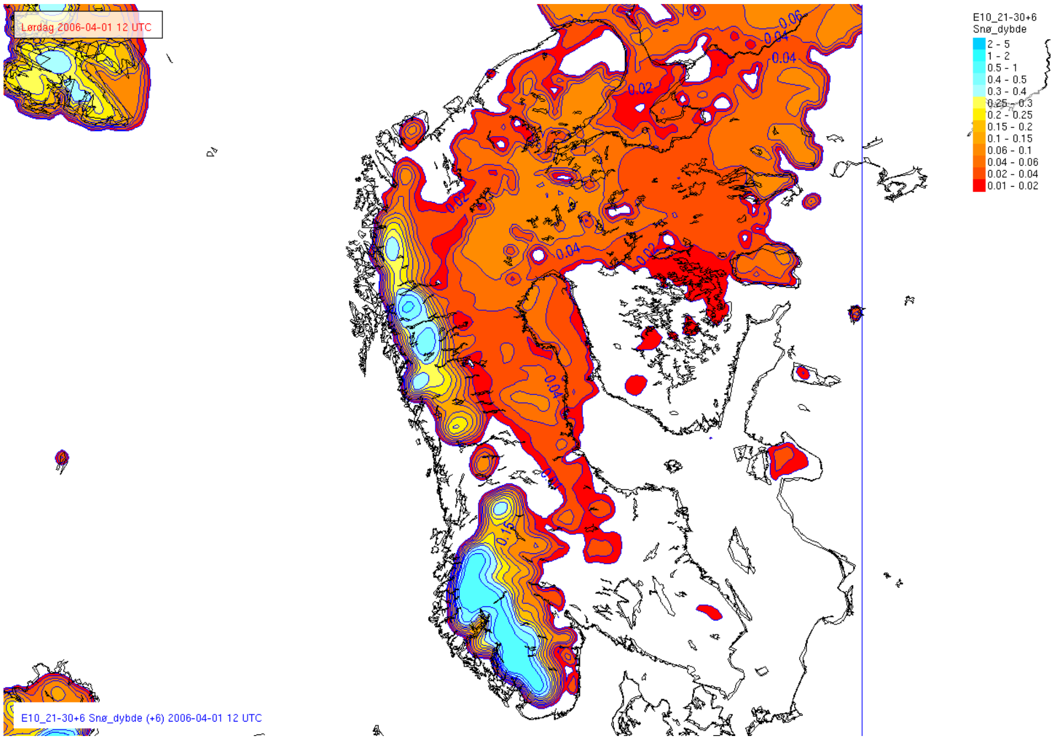


Figure 6a) Snow depth valid for +6h forecasts started with snow from the HIRLAM snow-analysis averaged over 21.April to 30.April

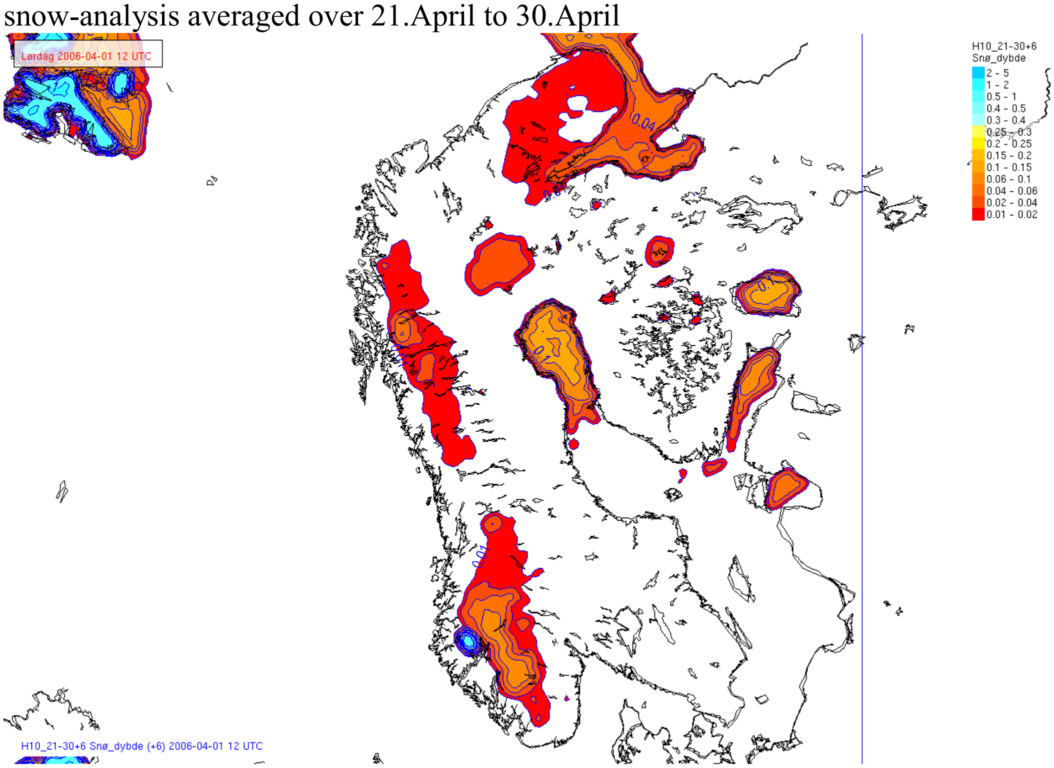


Figure 6b) Same as Figure 6a, but initial snow from Istjenesten at met.no.

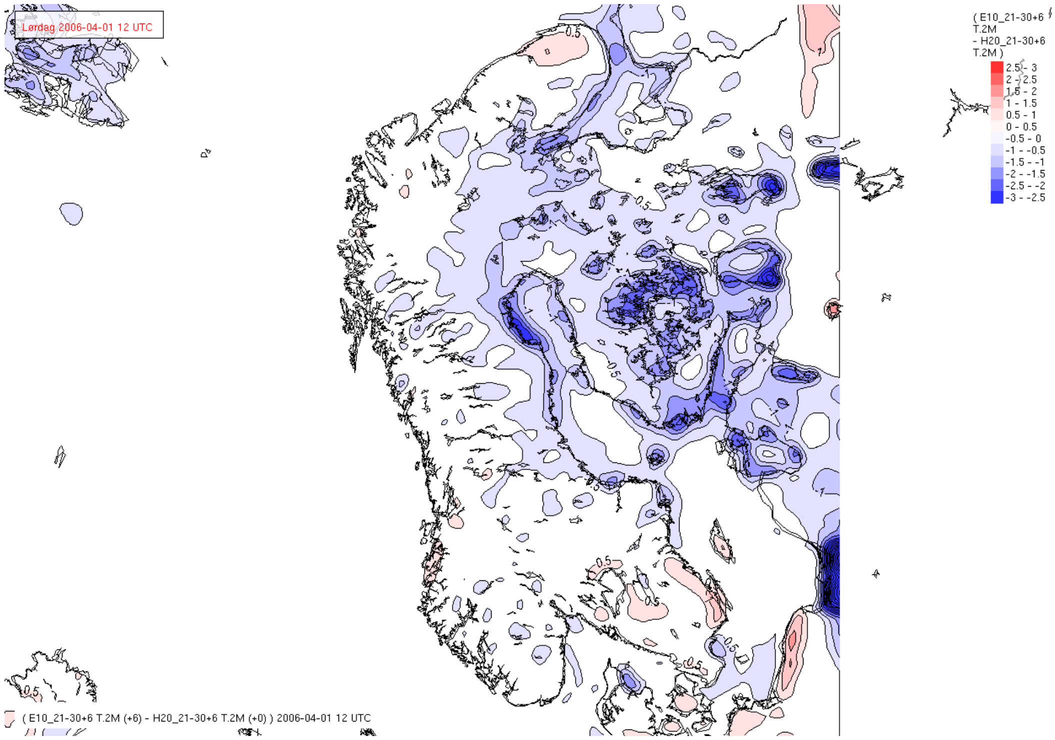


Figure 6c) T2m from +6h forecasts started with initial snow from the HIRLAM analysis minus T2m from HIRLAM20 operational analysis valid at 1200. Averaged over 21.April to 30.April

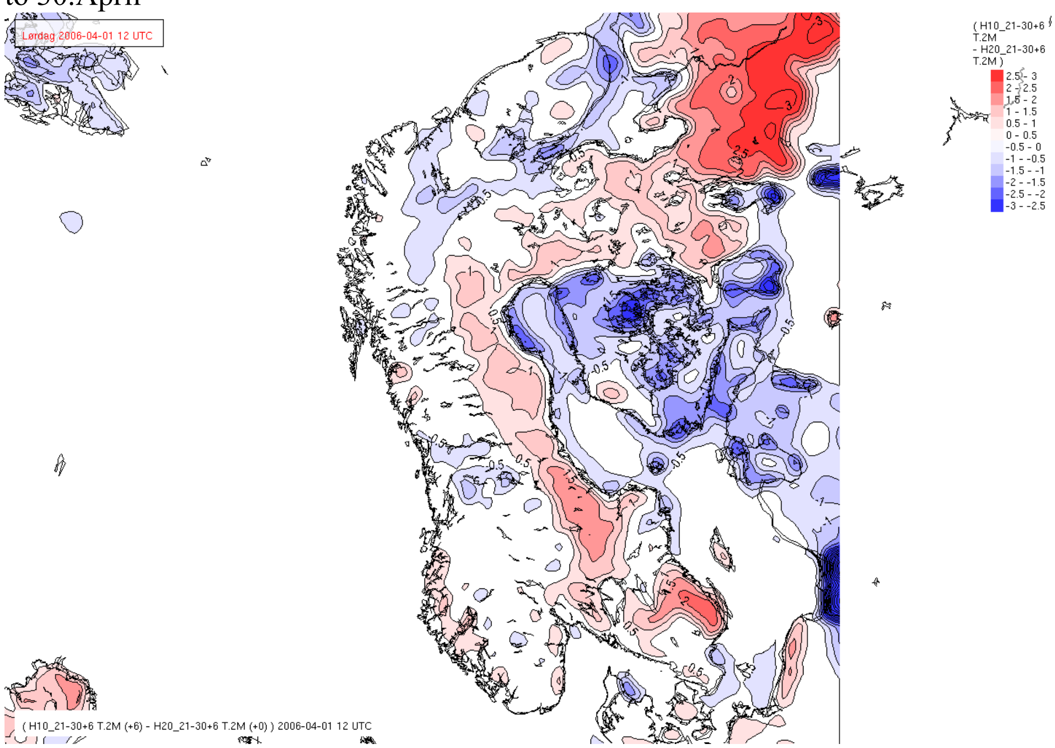


Figure 6d) As Figure 6c, but with forecasts with initial snow from Istjenesten at met.no.

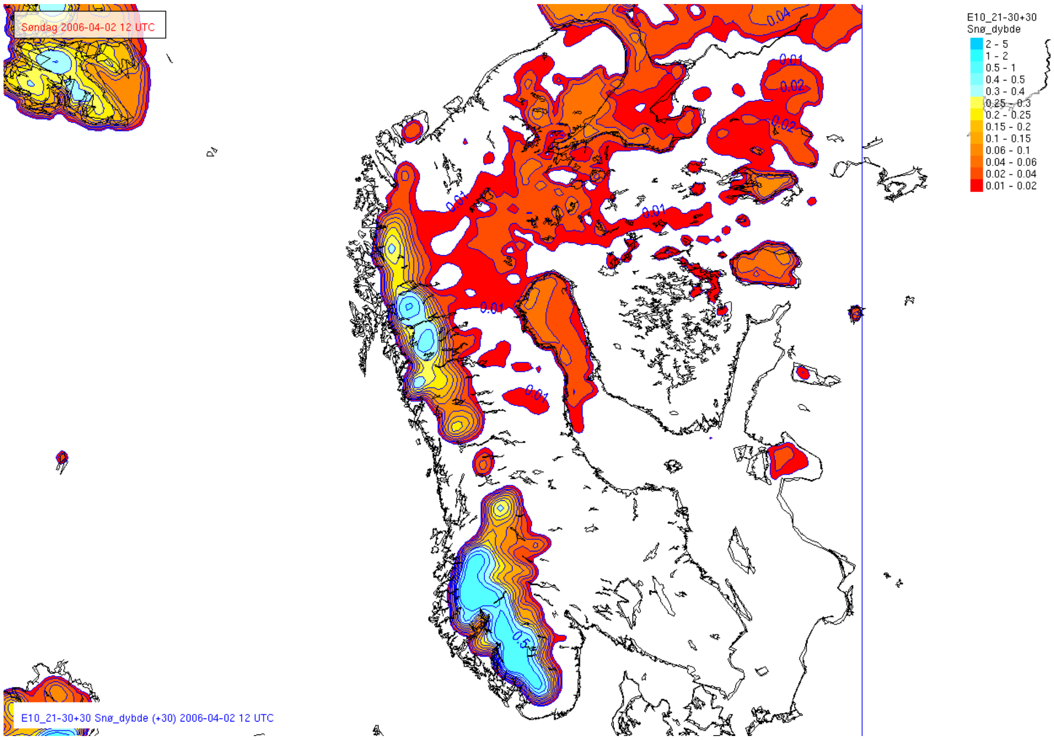
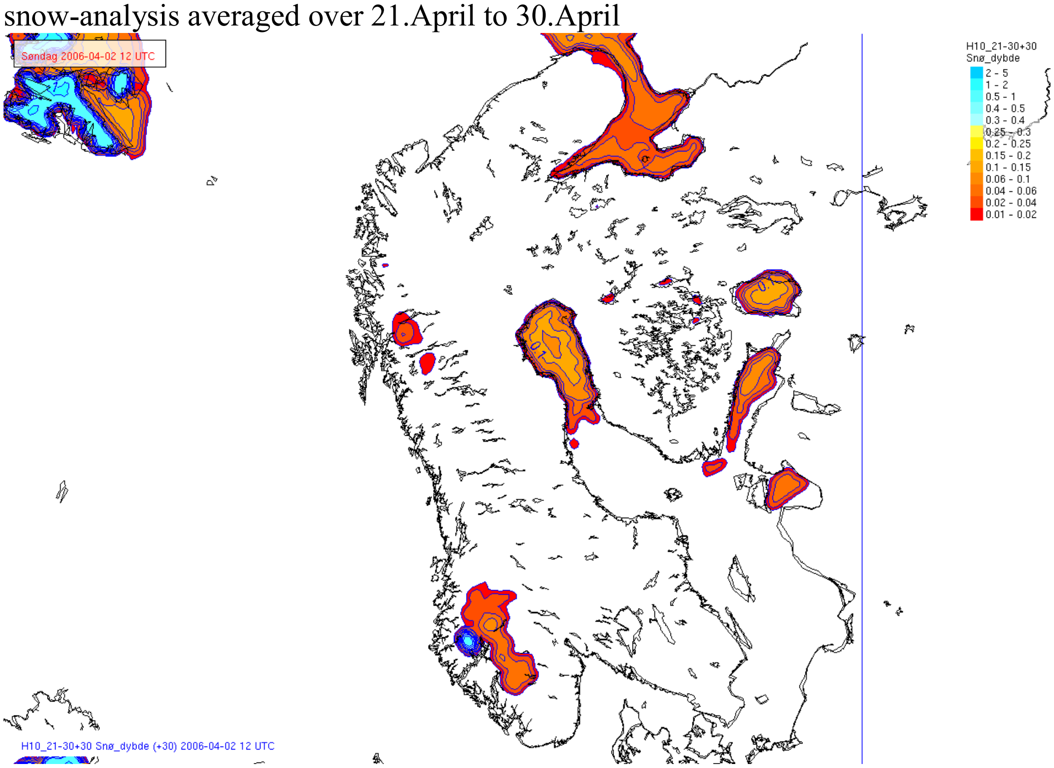


Figure 7a) Snow depth valid for +30h forecasts started with snow from the HIRLAM snow-analysis averaged over 21.April to 30.April



7b) Same as Figure 7a, but initial snow from Istjenesten at met.no.

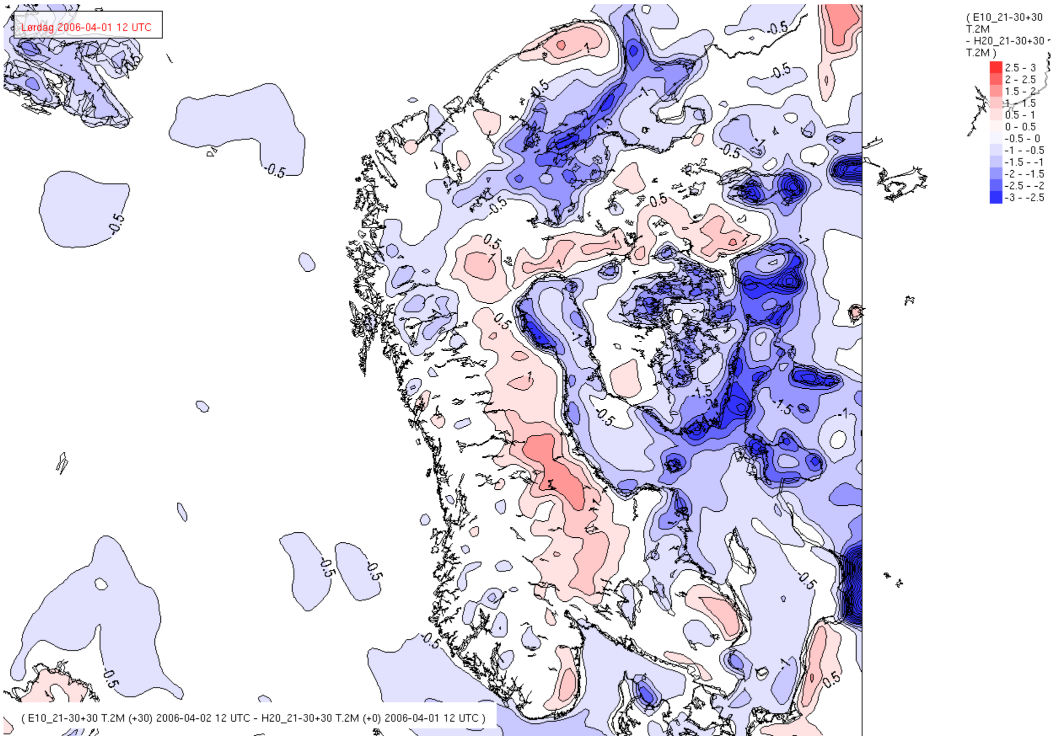


Figure 7c) T2m from +30h forecasts started with initial snow from the HIRLAM analysis minus T2m from HIRLAM20 operational analysis valid at 1200. Averaged over 21.April to 30.April

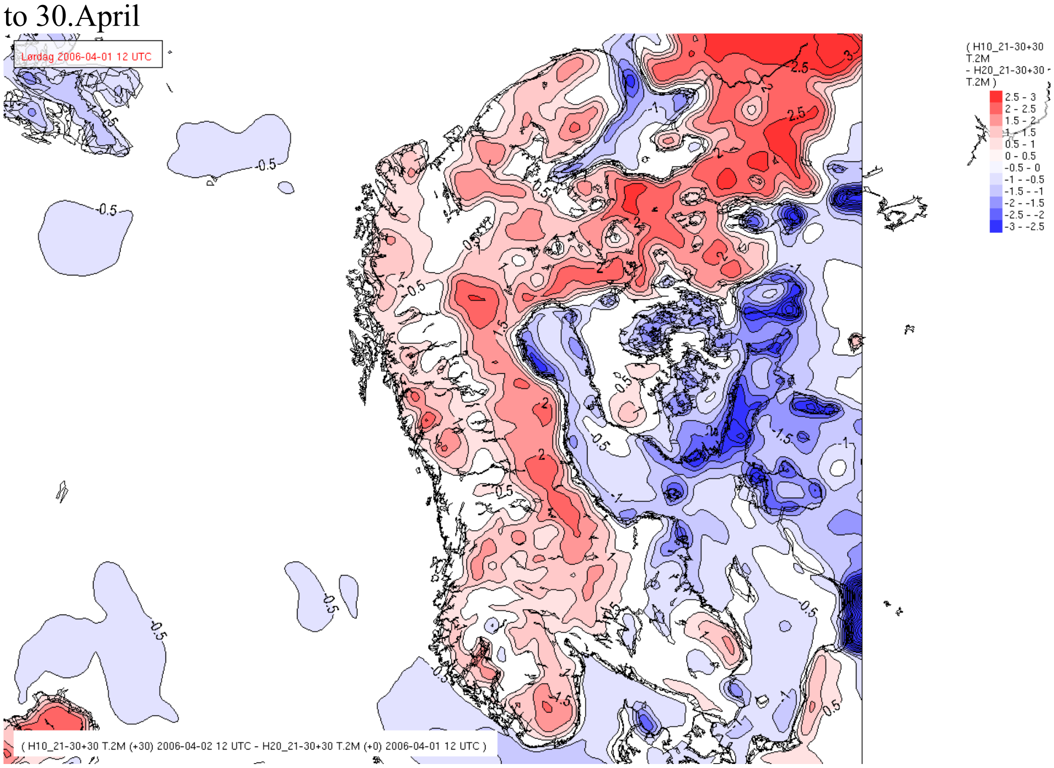


Figure 7d) As Figure 7c, but with forecasts with initial snow from Istjenesten at met.no.

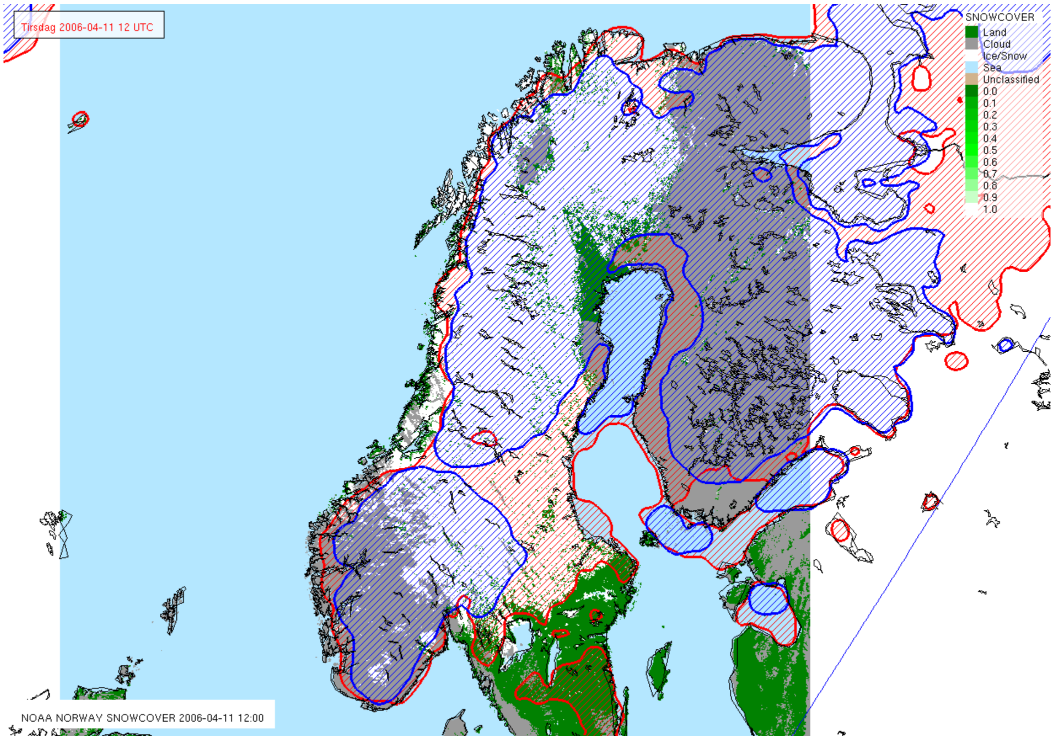


Figure 8a, Snow covered areas from satellite in white. Grey areas are cloud covered, while green are areas with no snow. Shaded areas enclosed by blue lines and red lines are areas covered with snow after +6h in the forecast with snow from Istjenesten at met.no and from the model analysis, respectively. The fields are valid for 11.04.2006.12UTC.

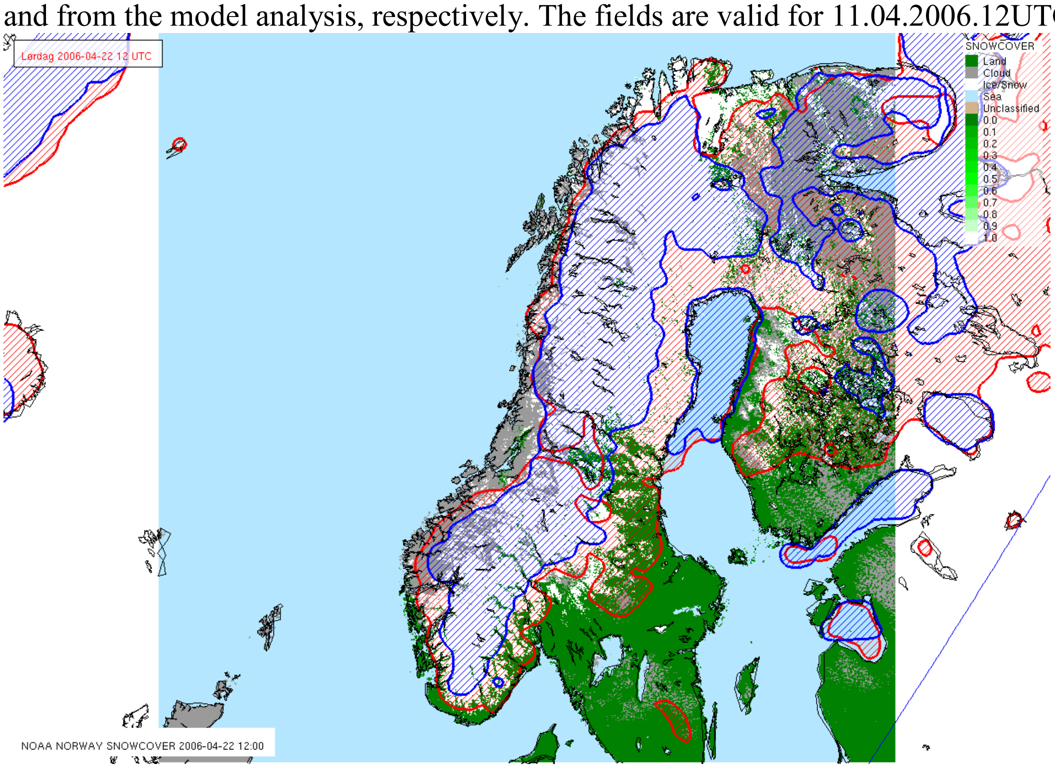


Figure 8b, the same as Figure 8a, but valid for 22.04.2006. 12UTC