Application and verification of ECMWF products 2012

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1. Summary of major highlights

ECMWF products have extensively being used at SMHI for many years. Short range ECMWF forecasts are used together with products from the limited area models Hirlam and Harmonie. Harmonie is the ALADIN based limited area model linked to the IFS system. Harmonie is used with Arome physics at 2.5 km resolution and with 65 levels. Hirlam forecasts have two different resolutions, 11km and 5.5 km. 60 or 65 levels are used. ECMWF provides boundaries for all runs except one, where Hirlam11km is used instead. Arome is still are in a pre-operational mode and thus not directly used in production.

The overall result for ECMWF forecast is continuously good, and the best one for upper air parameters and 2m dew-point temperature. But some of the new models preform better for certain parameters. Fore instance, Arome is better for 10m wind over mountains and one of the new Hirlam versions with new physics has a better 2m temperature forecast. Cloud base is a new parameter being verified. Here, Arome shows good results for the lowest clouds compared with other models, including ECMWF.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

There are no new statistical adaptations during the recent years. A Kalman filter is used for adjusting 2 meter temperature and 10 meter wind speed forecasts.

ECMWF data, (e.g. CAPE) is still used for creating wind gust forecasts and thunderstorm probabilities.

2.1.2 Physical adaptation

The ECMWF model data is used to provide lateral boundary conditions and other input data for limited area modelling. This includes both atmospheric and oceanographic models. The ECMWF data is used in the same way as in 2011. There are plans use boundary conditions for every hours, instead of every third hour as today. Hourly boundary update seems to increase the quality of precipitation forecasts, and to some degree also other forecast variables.

2.1.3 Derived fields

There are a lot of such products, but no new ones have be implemented during the last year.

2.2 Use of products

Many ECMWF products are used for public warnings. ECMWF forecasts have a good reputation as a guideline for those warnings for many years, and the use of ECMWF has not changed during the last year, compared with previous years.

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

3.1.2 ECMWF model output compared to other NWP models

3.1.3 ECMWF model output compared to other NWP models

2 metre temperature

The quality of the ECMWF 2-metre temperature forecast is high, and for the short range essentially the same as for the Hirlam model. ('Hirlam' is the old coarser version with 11 km resolution verified here. A new version with updated surface physics and 5.5 km resolution called 'E05' will be mentioned later in this paper)

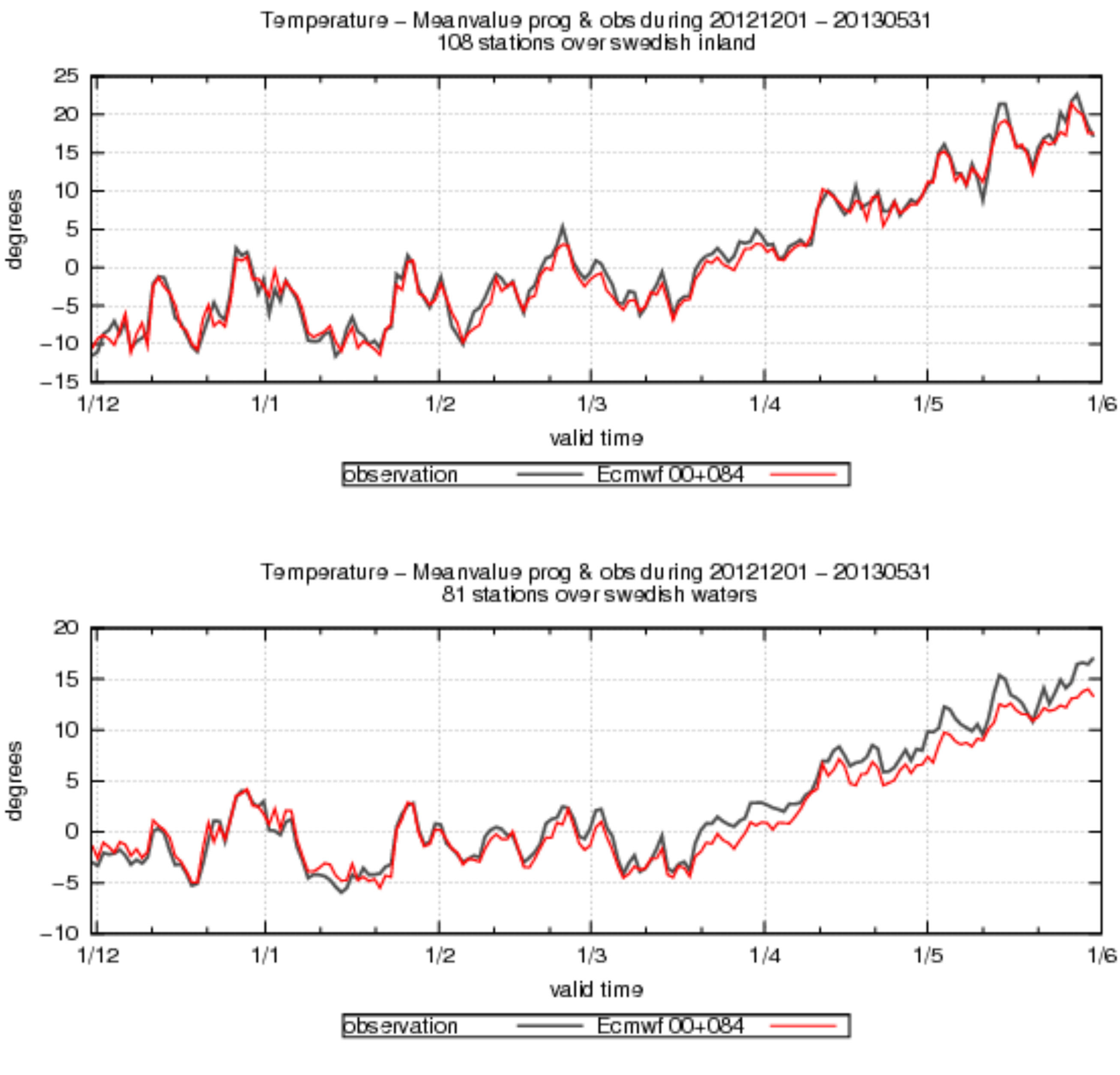

Figure 1 Time series of 2 metre temperature forecasts (red) and observations. Upper panel for inland stations and lower for coastal stations.

As shown in Figure 1, there is a difference in characteristics between temperature forecasts for inland stations and stations in coastal areas. During the spring and early summer the temperature does not rise enough in the forecast for coastal stations. This may be due to a too coarse model resolution making the lower temperature of the sea affecting the coastal belt too far inland.

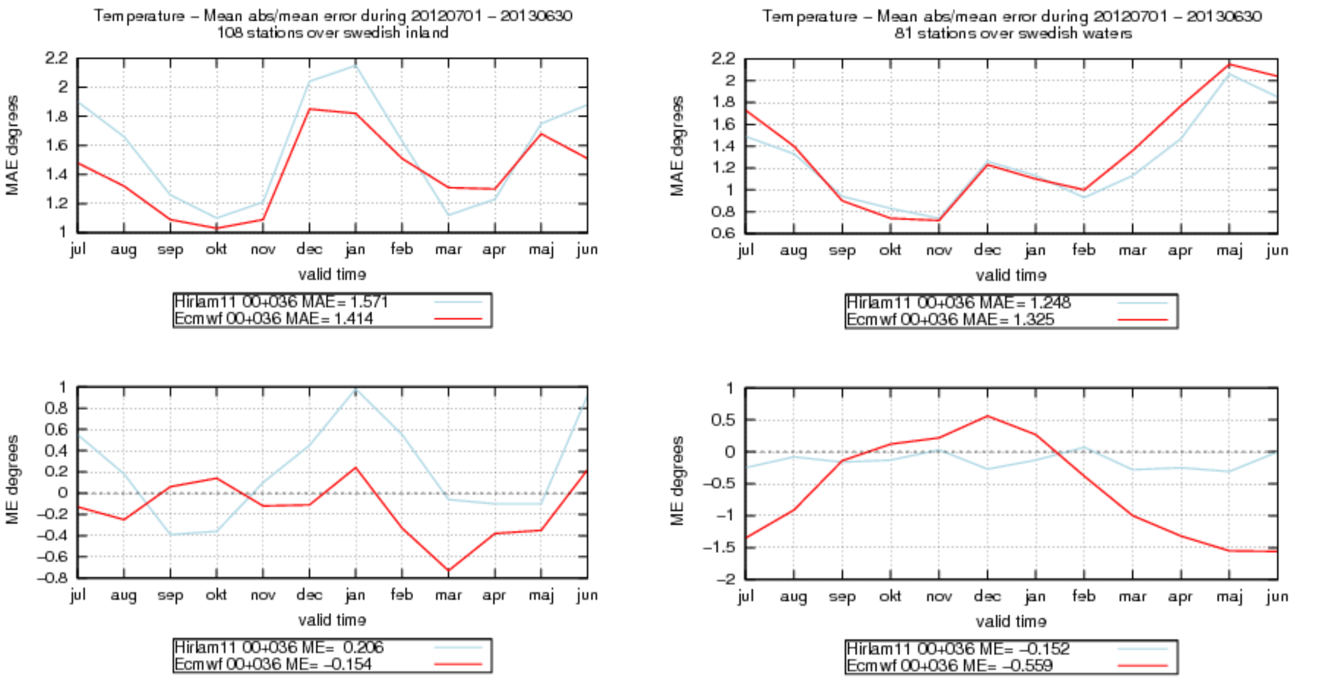

Figure 2 Forecast 2 metre temperature 00z+036 hour for coastal area. Left panels for inland stations and right for coastal stations. Above mean absolute error and below mean error. Red is ECMWF and blue is Hirlam.

Figure 2 shows that Hirlam do not suffer from the same problem of too low coastal temperatures in early spring and summer. For inland stations, the absolute error is lower for ECMWF compared to Hirlam, except in early spring, where ECMWF forecasts are too cold. In other seasons, the mean error is also generally closer to zero for the ECMWF 2 metre temperature inland forecasts than the Hirlam forecasts.

Precipitation

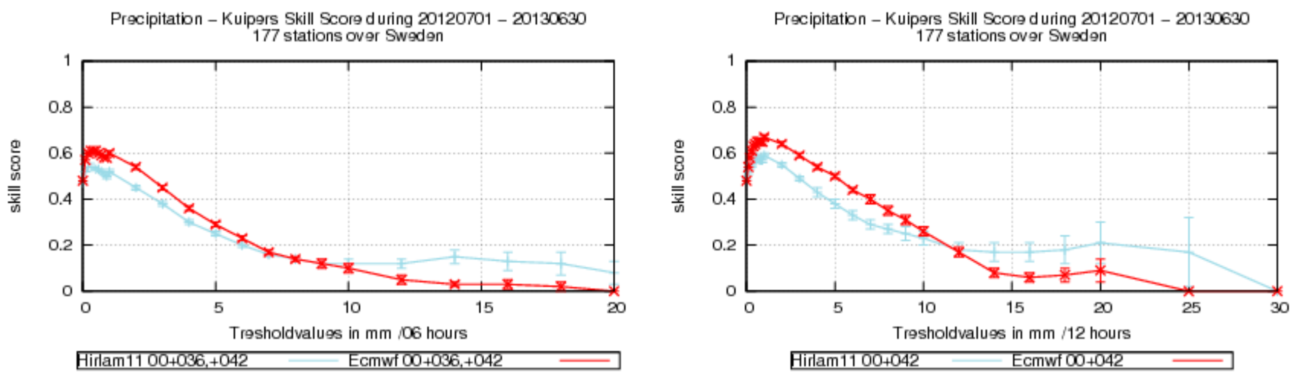

Figure 3 Left panel shows Kuipers Skill Score (KSS) for forecasts of precipitation valid two six hour periods until 00z + 36 hours and 00z + 42 hours. Right panel the same but for a twelve hour period. Red is ECMWF and blue is Hirlam.

The value of the precipitation forecasts as expressed by KSS is shown in Figure 3 and is slightly higher for ECMWF than for Hirlam. That is true for small and moderate amounts of precipitation. For larger amounts Hirlam seems to be somewhat better. For longer accumulation periods the KSS value is slightly higher than for shorter.

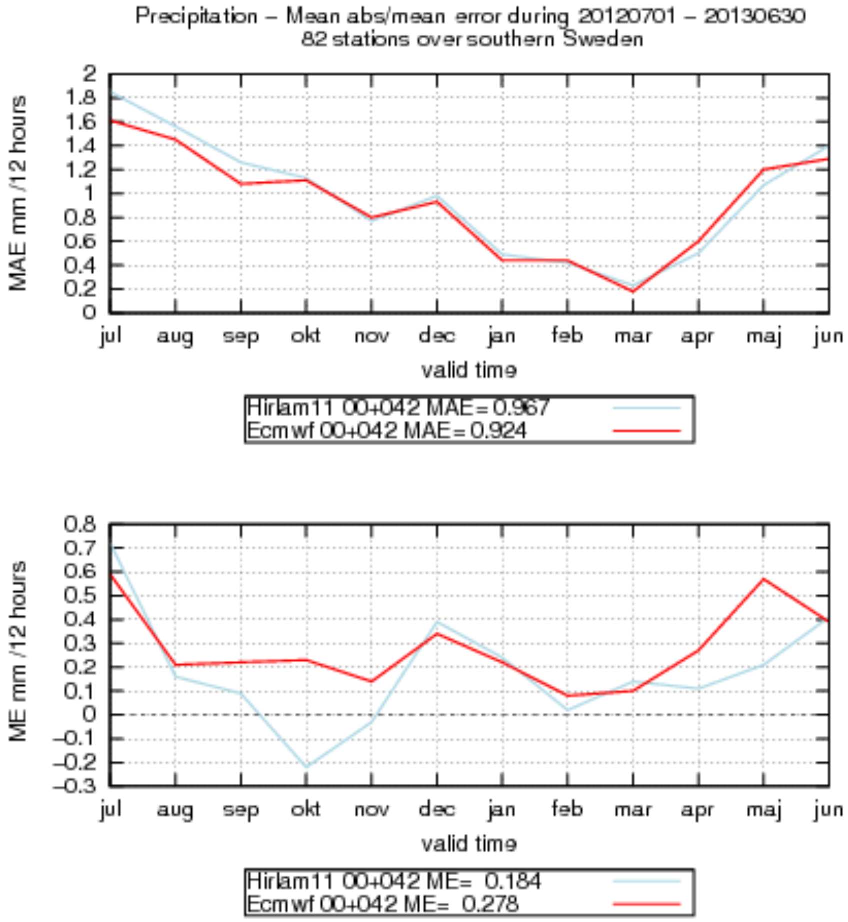

Figure 4 MAE above and ME below for a 12 hour precipitation forecast valid "next day". Red is ECMWF and blue is Hirlam.

The difference in quality between the various models are, as seen in figure 4, strikingly small. Note that the overall positive bias of precipitation may at least partly an effect of that the observed precipitation is underestimated.

10 metre wind speed

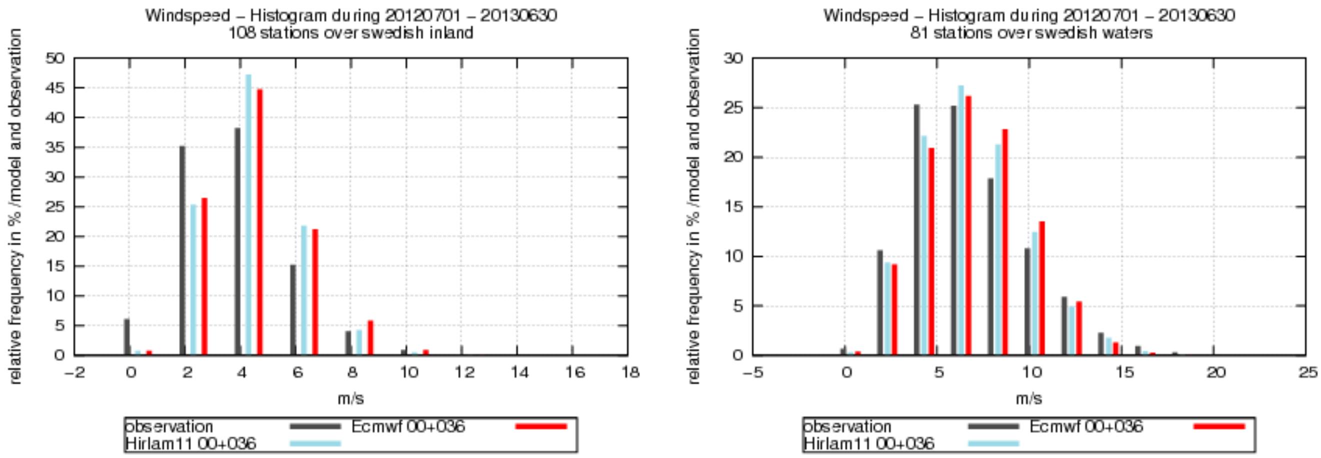

Figure 5 Frequency of different wind speeds, partly for inland stations (left) and partly for station close to the coast.

Both ECMWF and Hirlam have roughly the same distribution of different wind speeds and the similarity between the different models is greater than between any of the models and the observations (figure 5). The frequency of low wind speeds are underestimated by between 5 and 10 percentages for inland stations while moderate wind speeds are forecast too often in model data. One reason for those differences between observations and forecasts may be that local effects give a higher spread of the observed frequency distribution.

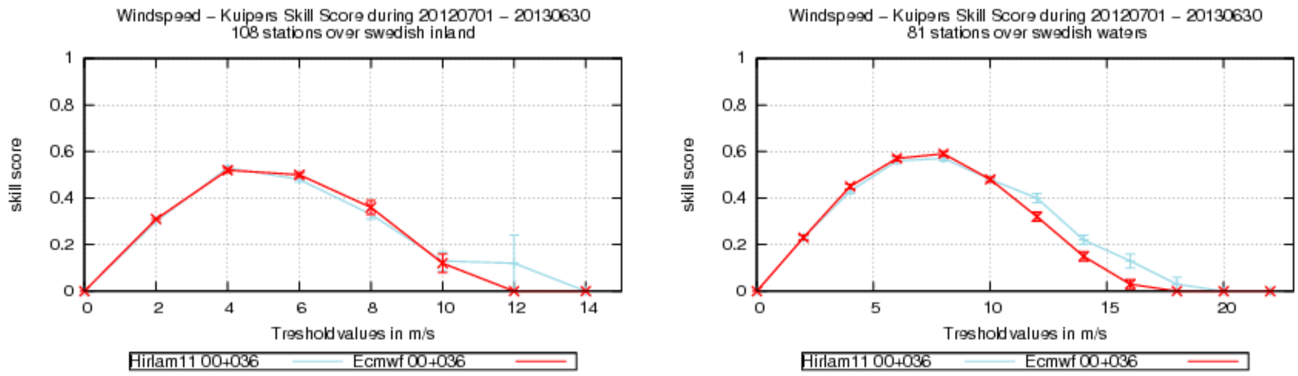

Figure 6 KSS for inland (left) and coastal stations for 10 metre wind speed. Red is ECMWF and blue is Hirlam.

The difference in KSS between the models is very small (figure 6). This applies to both inland and coastal areas. For the latter type of area however Hirlam has a slightly better results for high wind speeds.

24-hour precipitation

24-hour precipitation has been verified against a dense network of climate-stations in Sweden in order to examine the quality new high resolution models AROME (2.5 km grid) and HIRLAM with new physics (5.5 km grid). The verification is from August 2012 to March 2013. Fractions Brier Skill-Score (FBSS) has been used. The result is seen in figure 7.

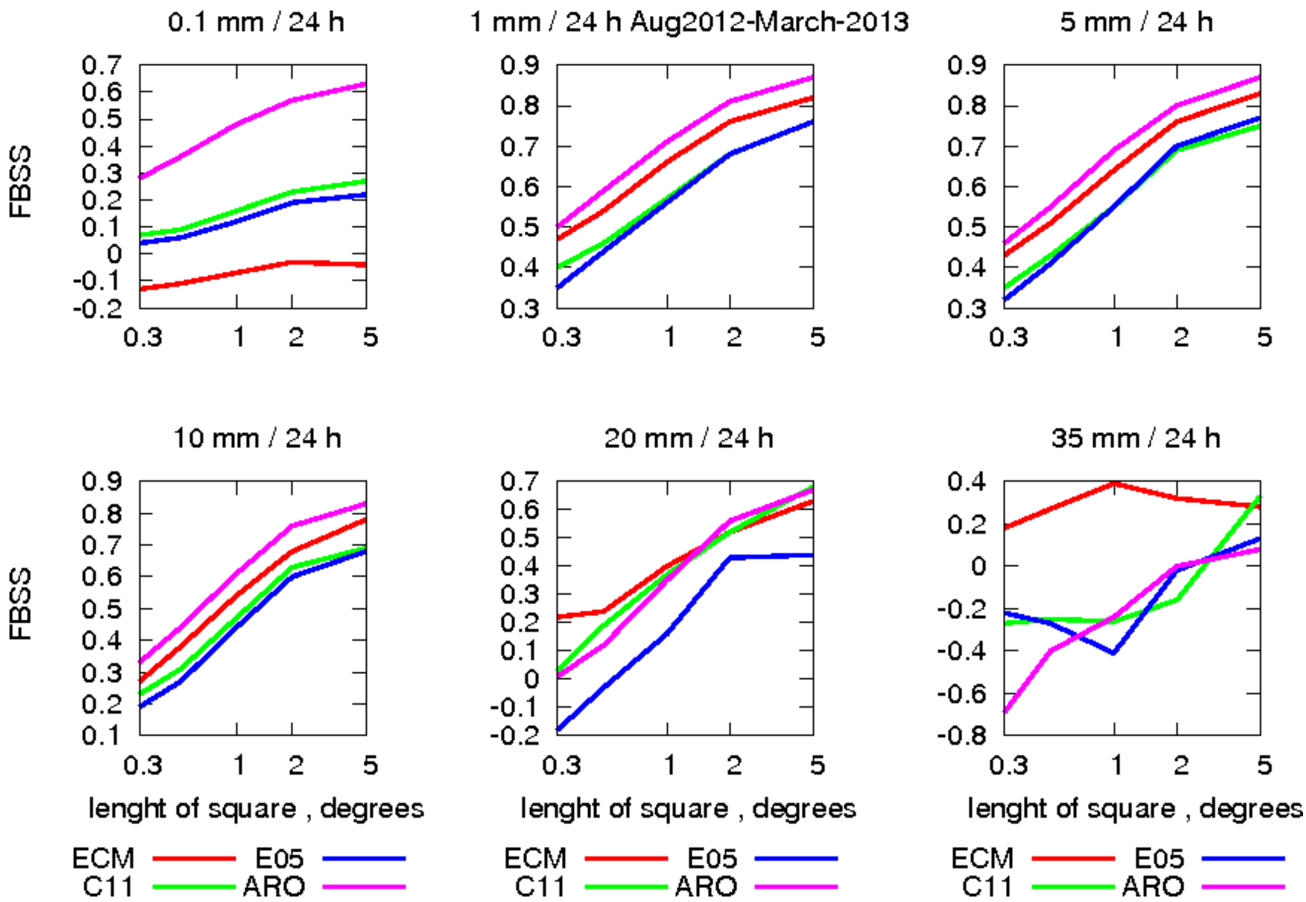

Figure 7 FBSS for different thresholds of precipitation FBSS values at the vertical axis and the size of different squares in degrees. One degree is about 111 km. ECM (red) is ECMWF forecasts, C11 (green) is Hirlam with 11km grid, E05 (blue) is a new Hirlam version with 5.5km grid and ARO (purple) is AROME with 2.5 km grid. The reference forecast is sample climatology.

The new Hirlam version does not perform better than the older one with a more coarse resolution, but AROME has the best FBSS score for all thresholds up to 10 mm/24 hours. ECMWF is the only model which has a positive skill for the smallest squares of about 33 km for 20mm- and 35 mm thresholds. ECMWF is the only model with positive skill for all sizes of squares for the 35mm threshold. But one the other hand, ECMWF is the only model with negative skill for 0.1 mm/24 hours for all sizes of squares.

3-hour precipitation in summer

The precipitation in summer and its diurnal variation is of particular interest for agriculture and for people having their vacation. The diurnal variation of precipitation is seen in figure 8.

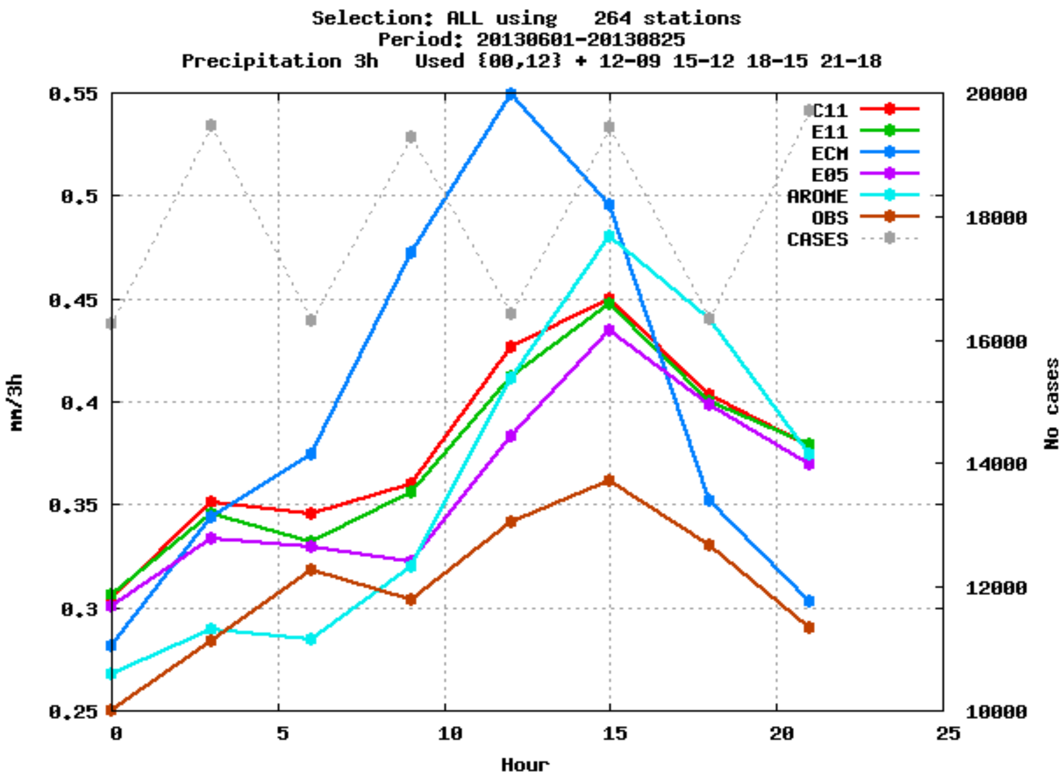

Figure 8 Time of the day in UTC on the horizontal axis and average precipitation during 3 hours on the vertical axis. The time is the end of the 3-hour period. The observed precipitation is in brown, ECMWF forecasts in blue, two different Hirlam forecast with 11 km horizontal grid in red and green respectively. Hirlam with 5.5 km grid in purple and Arome (2.5km grid) in light blue. The verification area is mainly the Nordic countries.

The minimum of precipitation during 21- and 00 UTC is well captured by all models in this verification. Also maximum between 12 and 15 UTC is in the right position, except for ECMWF. The maximum for ECMWF is about 3 hours too early, and is also over-amplified.

The equitable treat score (ETS) for the 3-hours precipitation is seen in figure 9.

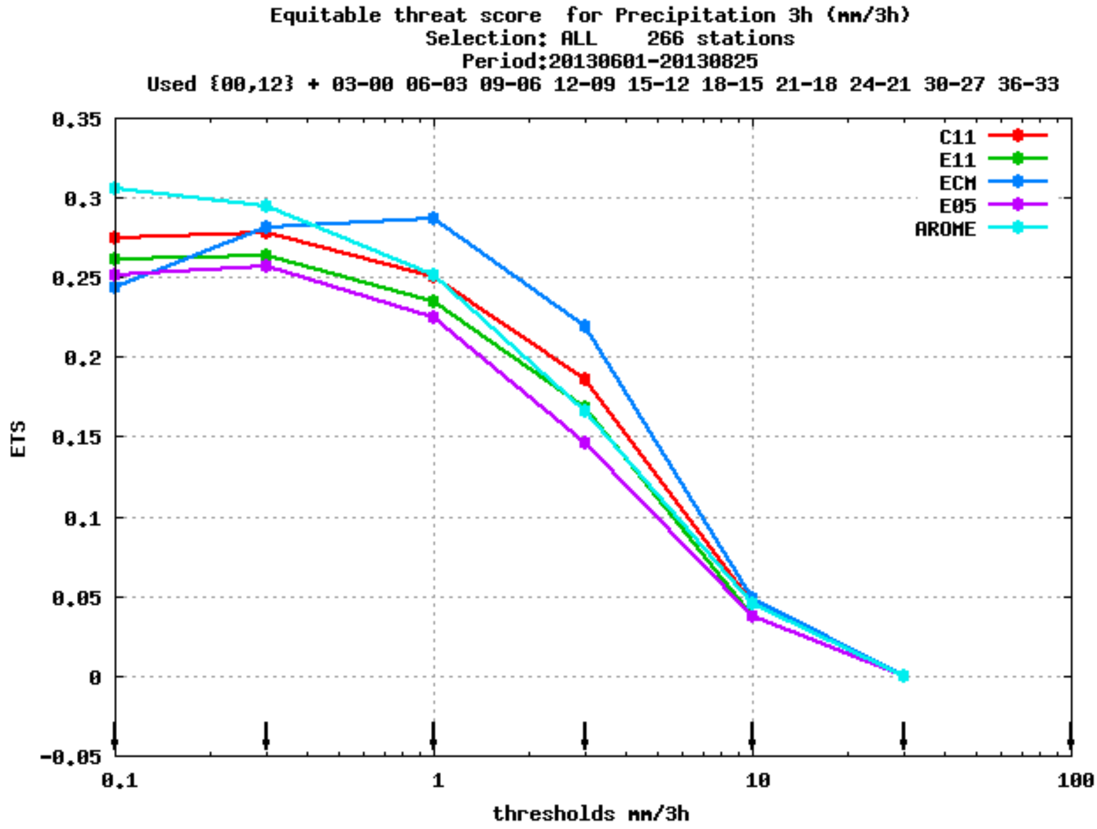

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Figure 9 Different thresholds of precipitation on the horizontal axis, and ETS value on the vertical axis. ECMWF forecasts in blue, two different Hirlam forecast with 11 km horizontal grid in red and green respectively. Hirlam with 5.5 km grid in purple and Arome (2.5km grid) in light blue. The verification area is mainly the Nordic countries.

The highest (=best) value is seen for the ECMWF forecasts, except for the lowest thresholds, where Arome and one of the Hirlam forecasts are better.

Low clouds

Low clouds have been verified against Swedish automatic stations. Those stations may give lower amount of cloud cover than manually observations due to different perspective effects and perhaps also because thin clouds are not always detected.

The diurnal cycle of low clouds in summer is seen in figure 10.

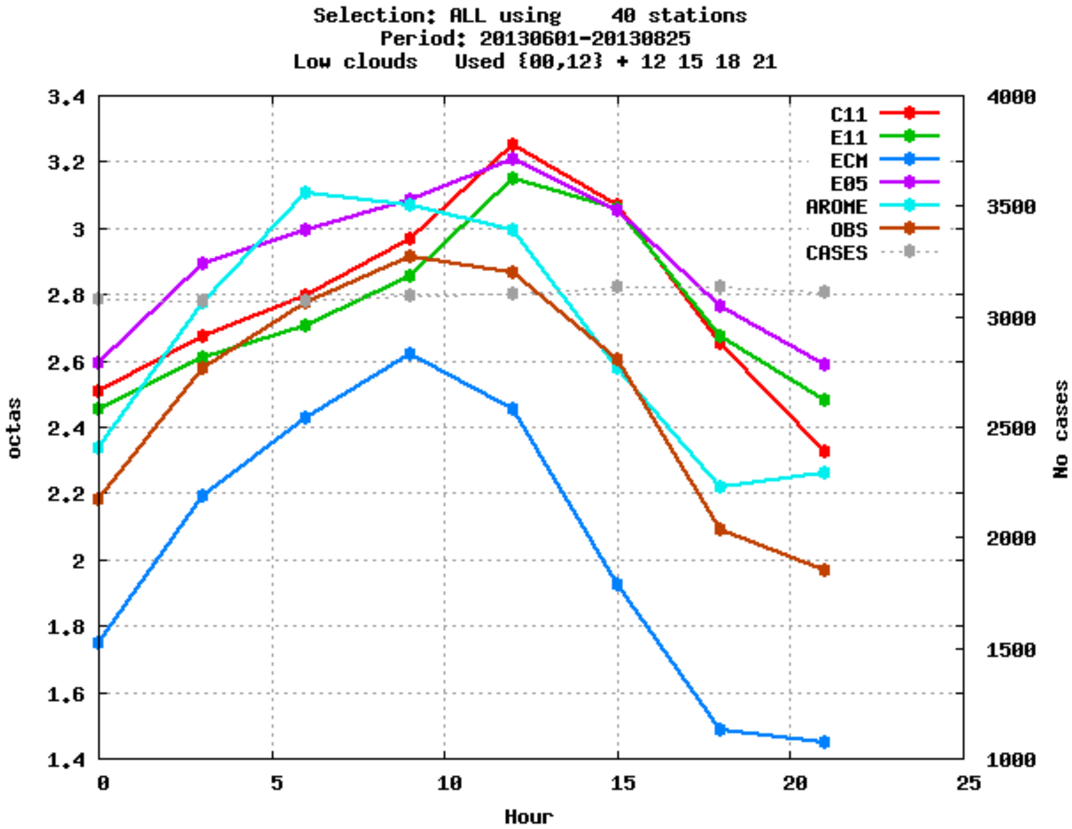

Figure 10 Time of the day in UTC on the horizontal axis and the average amount of low clouds in octas on the vertical axis. The observed cloud amount is in brown, ECMWF forecasts in blue, two different Hirlam forecast with 11 km horizontal grid in red and green respectively. Hirlam with 5.5 km grid in purple and Arome (2.5km grid) in light blue. The verification area is Sweden.

Despite the possible underestimation of low clouds compared to manual observations, ECMWF has less amount of low clouds than the observations. It may partly be an effect of that the postprocessing of low clouds at ECMWF does not exactly correspond to the definition of low clouds according to the WMO standard, which is clouds up to 2.5 km. But at least for the evening and early night, the difference seems so large that this difference is not likely to be the only reason. But the daily maxima and minima is correct captured by the ECMWF forecast, although the diurnal cycle is too large. The other models have their maxima either too early (Arome) or too late (Hirlam).

The root mean square error for low clouds verified this way is lowest for the ECMWF forecasts, but it may partly be an effect a too low variability of the ECMWF forecasts. (Not shown.) The ETS values for different octas are seen in figure 11.

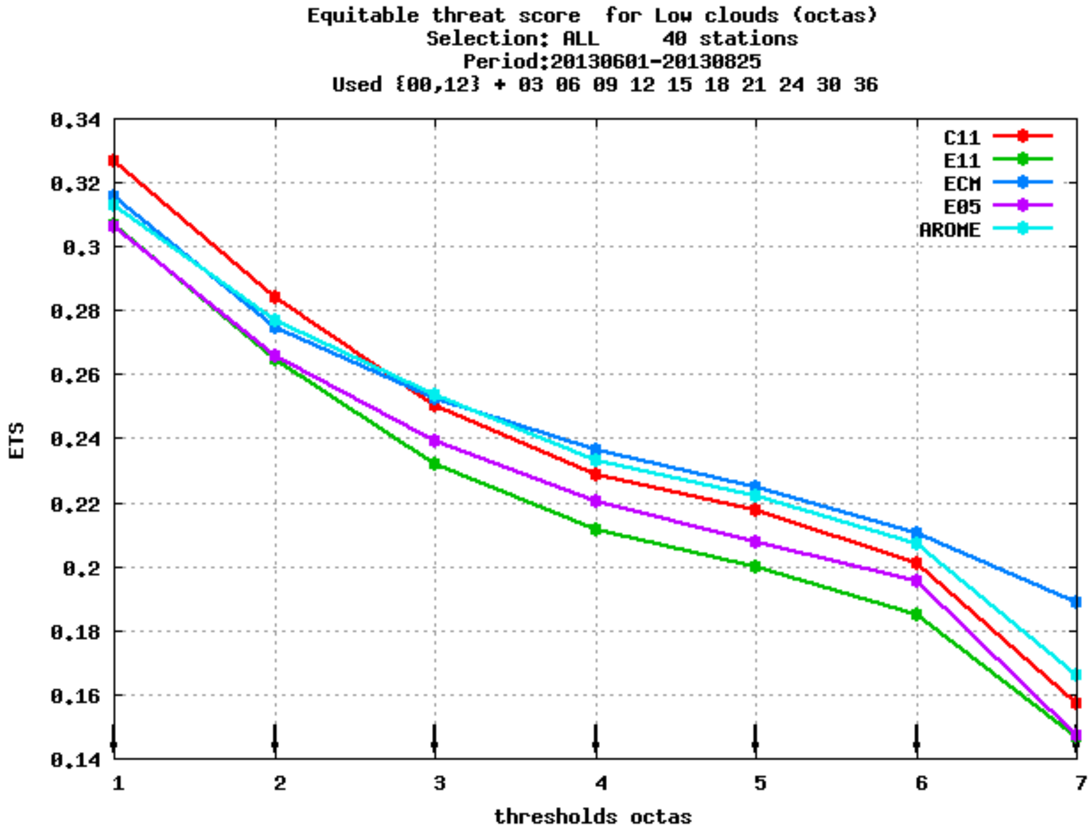

Figure 11 Different thresholds of cloudiness in octas on the horizontal axis and ETS value on the vertical axis. ECMWF forecasts in blue, two different Hirlam forecast with 11 km horizontal grid in red and green respectively, Hirlam with 5.5 km grid in purple and Arome (2.5km grid) in light blue. The verification area is Sweden.

ECMWF is mainly equally good as Arome and one of the Hirlam runs.

3.1.3 Post-processed products

3.1.4 End products delivered to users

3.2 Subjective verification

3.2.1 Subjective scores (including evaluation of confidence indices when available)

Duty forecasters are generally satisfied with the forecasts. But small amounts of precipitation are too frequent, and the diurnal cycle of low clouds are too strong in summertime.

3.2.2 Synoptic studies

4. References to relevant publications