Application and verification of ECMWF products at SMHI 2006-2007

1. Summary and major highlights

ECMWF products, especially in the medium range are extensively used. Also in the short range the ECMWF forecasts are used together with products from the HIRLAM model. The HIRLAM model is run at 22 km resolution using 40 vertical levels and also at 11 km and 60 levels. ECMWF data is used for boundaries.

Surface parameter verification shows good results for 2 meter temperature, 10 meter wind speed and precipitation, which are partly shown below. Statistical adoptions using a Kalman filter gives increased quality of 2 meter temperature and 10 meter wind speed.

River flow predictions based on EPS precipitation forecasts is an interesting application utilizing this type of data.

In the objective verification below, Kuipers Skill Score (KSS) has been chosen because of its relation to the potential economic value of a forecast. The results show that ECMWF and HIRLAM forecasts both have quality attributes, not identical but both providing substantial value to the society

2. Use and application of products

Monthly forecasts of precipitation and 2 metre temperature have been made since 1993 for up to 20 places within the Nordic countries. The costumers are mainly different newspapers. The first week of the forecast is based on direct model output from the ECMWF model, the second week on EPS mean values and the third and forth week a statistical relation between the two first weeks, an ECMWF monthly forecast and observed mean values. For precipitation a bias correction is first applied to the model data.

For the electric energy consumption market 10 days forecasts are produced using DMO and EPS mean values.

2.1 Post-processing of model output

2.1.1 Statistical adaptation

A Kalman filter is used for adjusting 2 meter temperature and 10 meter wind speed forecasts. The corrections increments are derived station wise and are then interpolated to a grid using optimal interpolation and utilizing the original forecast as a background field. It has been shown that adjustments derived in this way rather correct systematic errors than adds local features to the forecast.

2.1.2 Physical adaptation

The ECMWF model data is used to provide lateral boundary conditions for limited area modelling using HIRLAM for two different areas. The larger area with a horizontal resolution of 22 km is covering Europe and the north Atlantic and the smaller northern Europe with 11 km resolution. The purpose of the small area is to provide a somewhat more detailed forecast than that from ECMWF for the short range and thereafter a smooth transition to the Centre's forecast.

An oceanographic circulation model including ice, HIROMB, is forced by the HIRLAM and the ECMWF model data and is run up to 10 days.

Ensemble river flow predictions are made daily at the hydrological forecasting division at SMHI. It utilizes precipitation forecasts from all the EPS members in calculating the run offs by the SMHI HBV- model.

Recently, an off-line three-dimensional Chemistry Transport Model developed at SMHI (MATCH- Multiple-scale Atmospheric Transport and CHemistry model) was used extensively to study the meteorologically induced inter-annual variability and trends in deposition of sulphur and nitrogen as well as concentrations of surface ozone, nitrogen dioxide and particulate matter and its constituents over Europe during 1958-2001 (Andersson et al). The model was coupled to the meteorological reanalysis product ERA40. In this study 6 hourly meteorological data of the lowest 39 levels from the ERA40 meteorological data set were used. Most input variables were taken from analyses, except precipitation and albedo, which were taken from the 6 hr forecast. The ERA40 data was interpolated from the original 125 _ 125 km horizontal resolution to 0.4_ _ 0.4_ (ca. 44 km) used by MATCH to take advantage of the 50 km emission data resolution, and in time to 1 hr data. To illustrate the type of results which were obtained, figure 1 shows the deviation in annual total deposition of NHx-N, compared to the 44 yr average of annual total deposition.

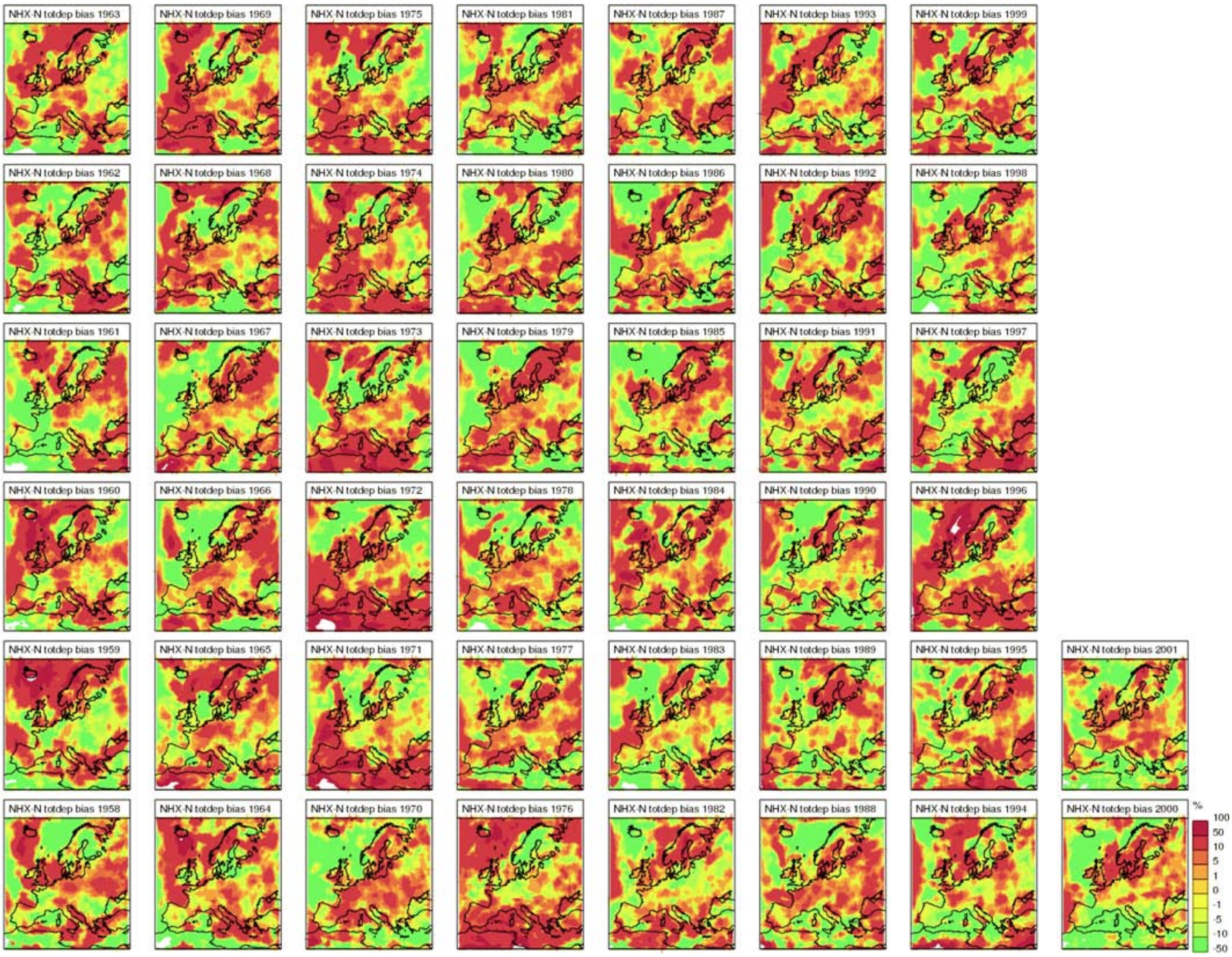

Fig. 1 Deviation in annual total deposition of NHx-N, compared to the 44 year average of annual total deposition. Upper left corner shows the bias from 1963 and lower right from 2000.

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2.1.3 Derived fields

In order to present EPS information in an easy-to-grasp manner SMHI has tried many ways and in figure 2 one of those is presented.

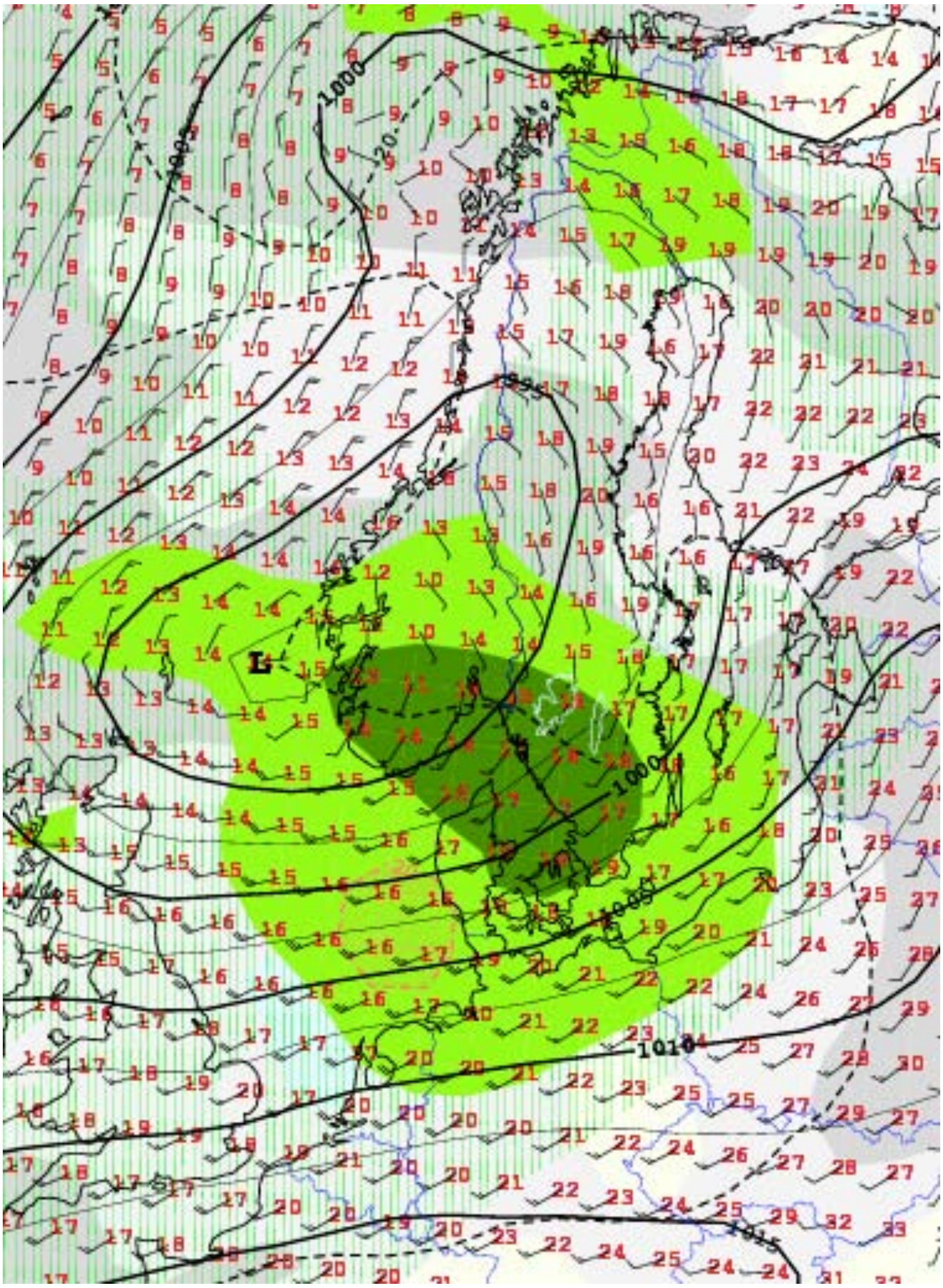

Fig. 2 Overview of EPS information presented to the forecasters. Precipitation in different shades of green are based on threshold values for 66% of the EPS members giving 0.1, 1, 5, 12 or 20 mm/12 hours. Broken lines for wind speed in 20% of the cases giving 8, 14 or 25 m/s. Mean values for 2 metre temperature (red figures), total cloud cover (shaded grey) and surface pressure.

2.2 Use of products

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output

3.1.2 ECMWF model output compared to other NWP models

Temperature

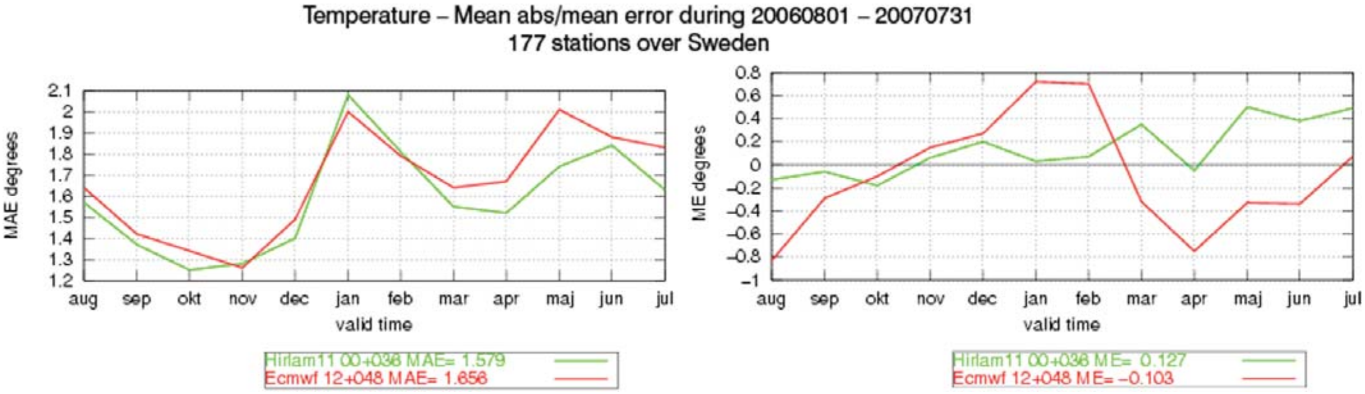

Fig. 3 Mean absolute error (left), and mean error (right). Red is ECMWF and green HIRLAM.

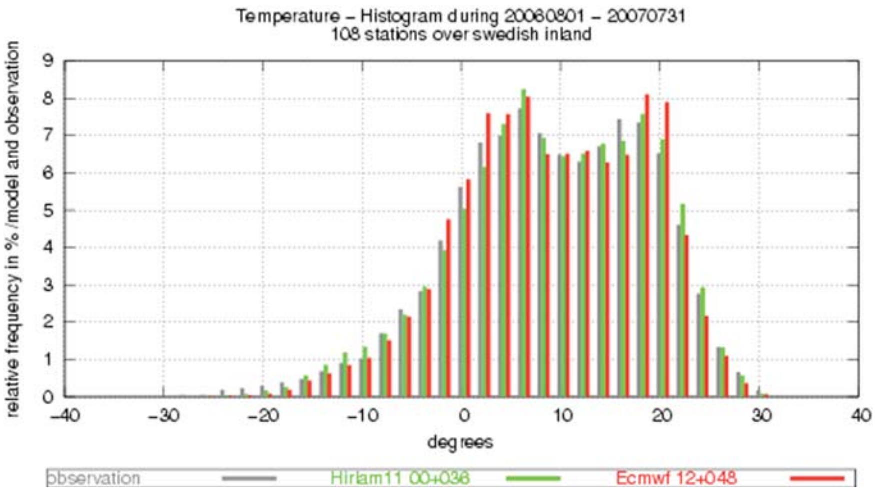

Fig. 4 Observed and forecast frequencies. Colours as in 3.

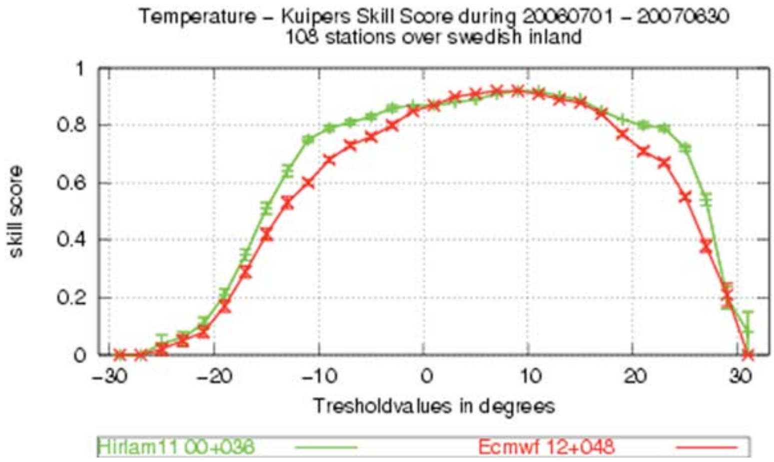

Fig. 5 Kuipers Skill Score for different threshold values.

The temperature forecasts from both ECMWF and HIRLAM have the smallest absolute error in the autumn and the largest during winter (figure 3). The ECMWF forecasts suffer from a positive bias in winter and a negative in spring and early summer. The frequencies of higher values are somewhat underestimated for temperatures above 15 degrees Celsius and for temperatures blow minus 5 (figure 4). This is probably the reason for a lower forecast value in terms of KSS for high and low temperatures (figure 5).

Precipitation

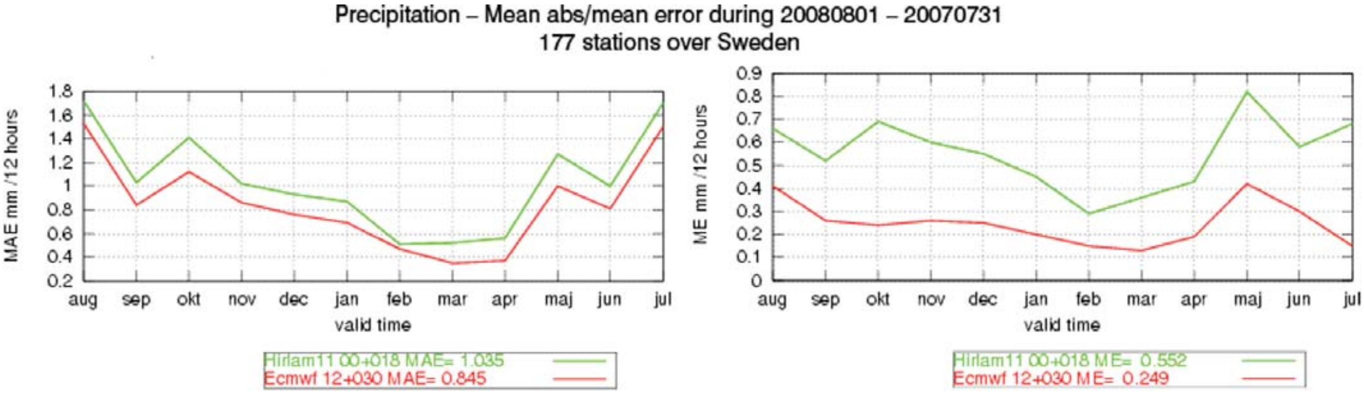

Fig. 6 Mean absolute error (left) and mean error (right) for forecast 12 hour precipitation valid 06-18z the first day of the forecast. Colours as in figure 3.

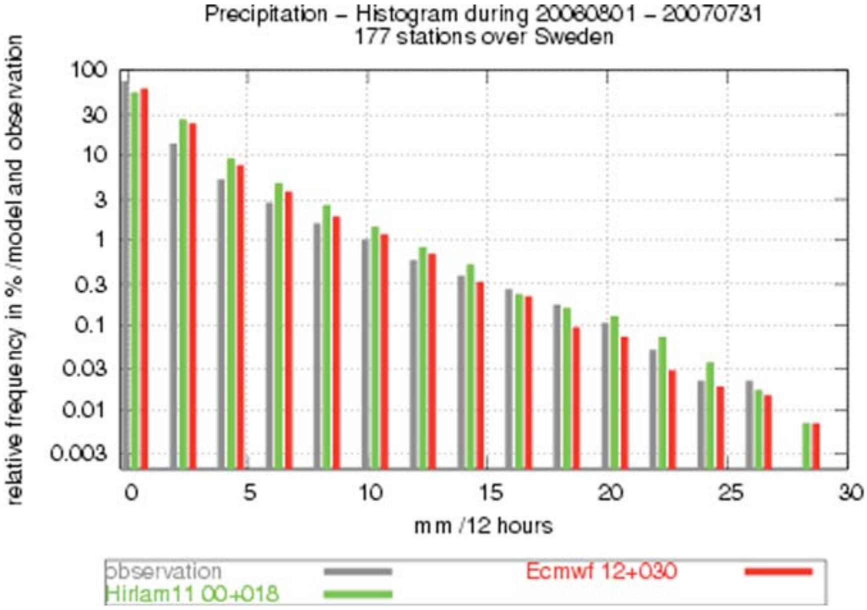

Fig. 7 Observed and forecast frequencies of 12 hour precipitation.

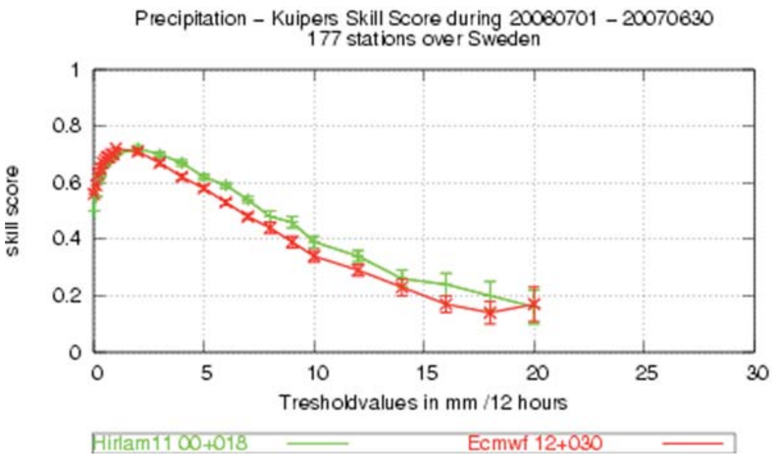

Fig. 8 KSS for different threshold values.

The ECMWF precipitation forecasts seams to be more reliable than those from HIRLAM. It is true both in terms of a smaller overestimation of precipitation, a halved mean error compared to HIRLAM, and also in a lower mean absolute error (figure 6). This is valid for all seasons. In spite of this, KSS values for HIRLAM is somewhat higher than for the ECMWF forecasts (figure 8). This means that users with a low cost/loss relation and threshold values above 2 mm/12 hours benefits from using the HIRLAM forecast.

Forecast and observed frequencies are in god agreement with observed for ECMWF although values above 15 mm/12 hours are somewhat under-predicted (figure 7). This might, however, well be what could be expected when comparing observed point measured values with forecast grid area mean values.

Wind speed

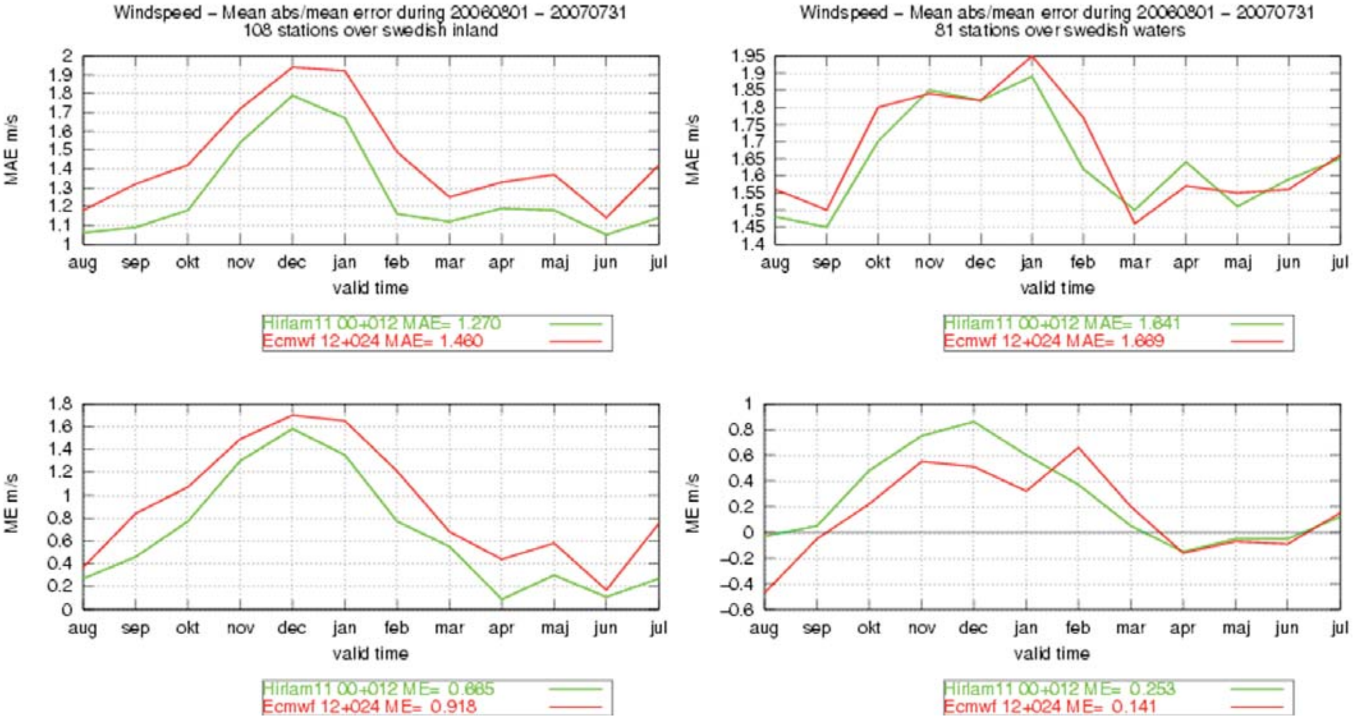

Fig. 9 10 metre wind speed. Above mean absolute error and below mean error. Left panel inland stations and right coastal. Colours as in figure 3.

The ECMWF model somewhat overestimates wind speed over land and especially during winter (figure 9).

3.1.3 Post -processed products

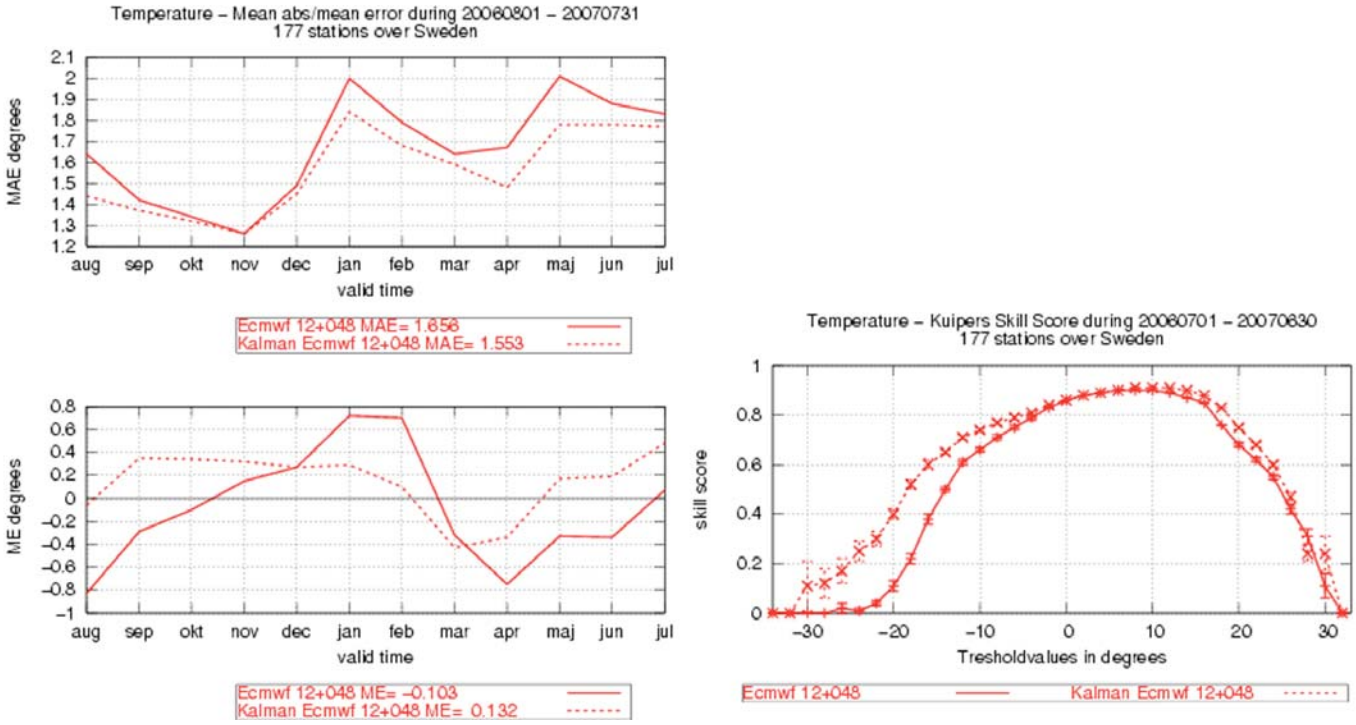

Fig. 10 DMO (solid line) and Kalman filtered (dotted line) temperature data from ECMWF. Upper left: mean absolute errors. Lover left: mean errors. Right: KSS for different threshold values.

Kalman filters decreases the errors in the 2 metre temperature forecast for all seasons and increases the value of the forecast (figure 10).

3.1.4 End products delivered to users

3.2 Subjective verification

The duty forecasters are mostly very happy with the forecasts. They are normally very reliable also for forecasts valid several days ahead. There are also some less good characteristic however, that may be worth noticing.

- Too small amount of cloudiness is case of convection, especially convective precipitation in the summertime
- Too large amount of low clouds in case of very cold weather in winter (2 metre temperature below -20 Celsius)
- Too much fog over cold sea, especially in spring. When there is fog is such cases, the 2 metre temperature is often too low.
- Too little low clouds in spring over central and northern Sweden in case of westerly wind (too high mountain shadow effect)

3.2.1 Subjective scores

3.2.2 Synoptic studies: The "Per" storm January 14, 2007

On January 14, a severe storm caused a lot of damage over southern Sweden. The storm was slightly less severe than the "Gudrun" storm in January 2005. The deterministic forecasts were good or very good about 3 days ahead but less accurate for longer forecast lengths. The limited area model, HIRLAM with 11km resolution was also very good for shorter forecast lengths, 36 hours and less. Since the domain is quite small the result is partly due to the high quality ECMWF lateral boundary conditions. The 48 hour forecast from ECMWF at January 14, 12 UTC is compared with the analysis with HIRLAM with 5.5 km resolution and some 10 metre wind observations. (Figure 11)

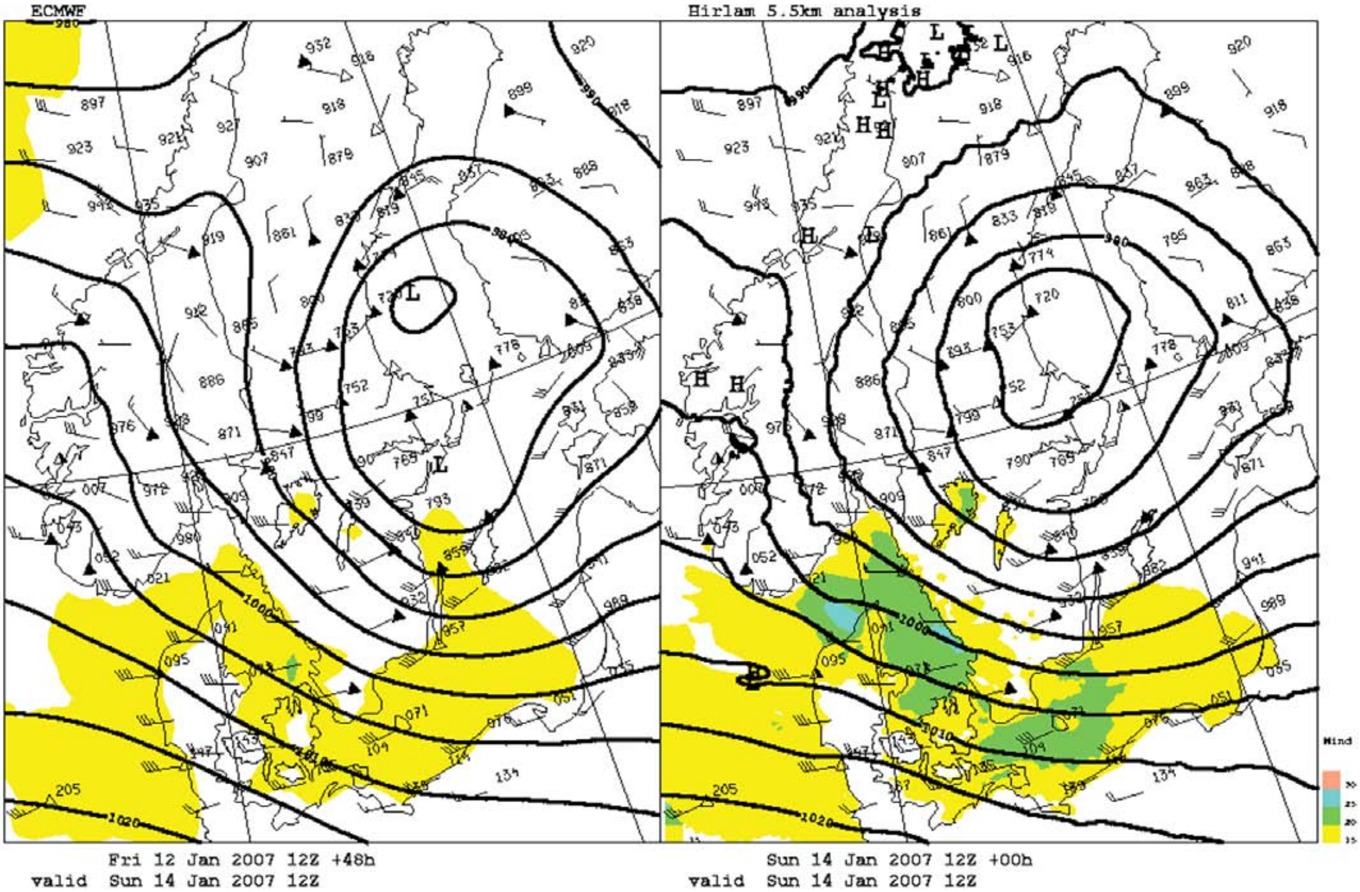

Fig. 11 Left: ECMWF forecast 2007-01-12, 12UTC valid at 2007-01-14 12 UTC, when the storm had its maximum intensity. Mean sea level pressure and forecast 10-metre windspeed (in colours) are plotted against observations. Right: The same, but for HIRLAM analysis with 5.5 km resolution.

The pressure field is rather accurate, but the 10 metre winds are somewhat too low, partly due too that the low is not deep enough in the forecast. The 36 hours forecasts of ECMWF and HIRLAM are seen in figure 12.

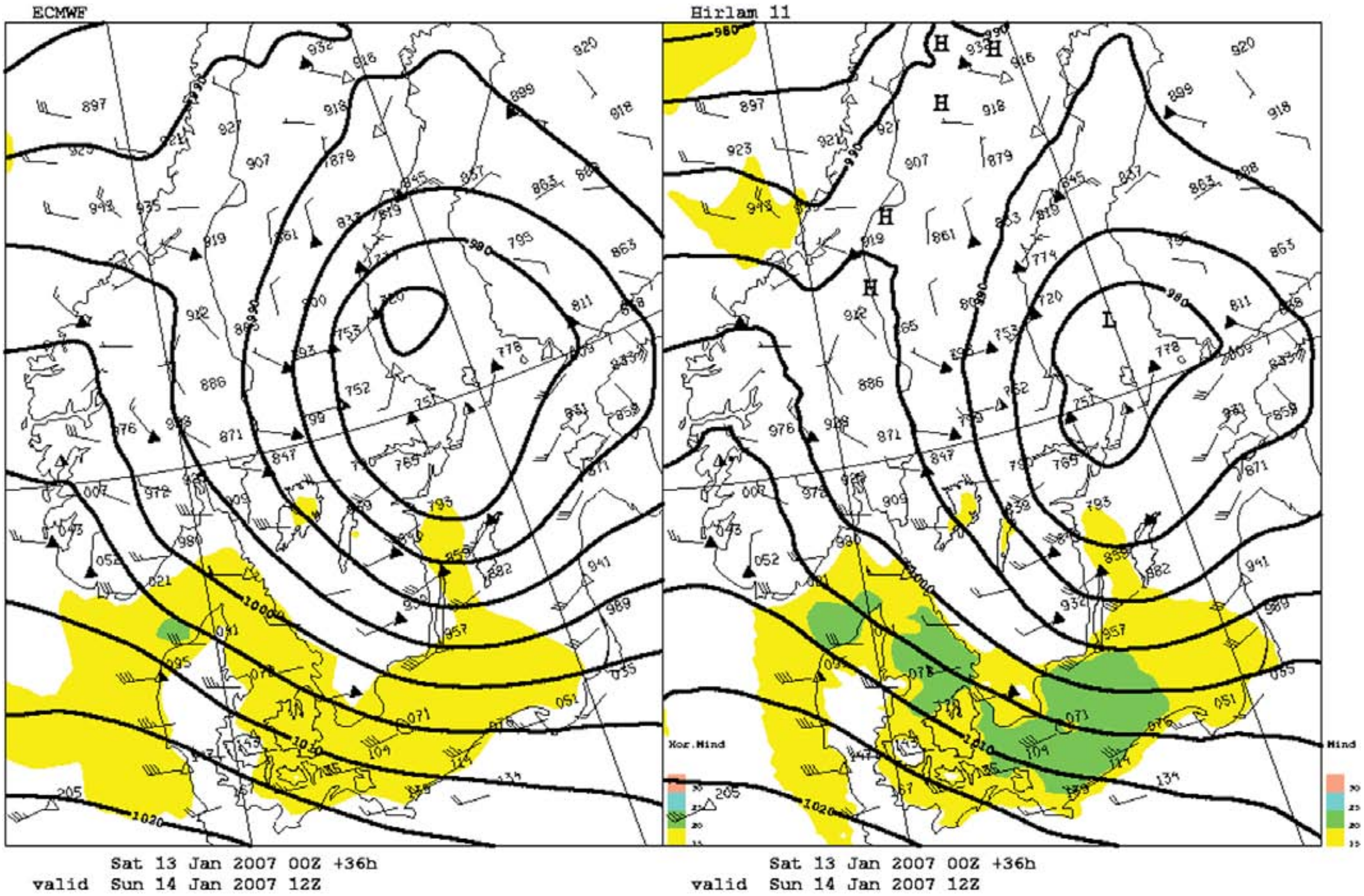

Fig. 12 Left: ECMWF forecast 2007-01-13, 00 UTC valid at 2007-01-14 12 UTC, when the storm had its maximum intensity. Mean sea level pressure and forecast 10-metre wind speed (in colours) are plotted against observations. Right: The same, but for the HIRLAM forecast with 11 km resolution.

The centre of the low is a little too far to south in both forecasts and the low is a little too shallow. Those errors are most pronounced in HIRLAM, but the 10-metre wind over the areas with the highest observed and analysed winds are better in HIRLAM.

The forecasts of wind gusts have also been studied. The ECMWF post processed (MOS) wind gusts from 2007-01-13 00 UTC, valid at 2007-01-14 12 UTC, was quite successful. The RMS error was 4.0 m/s and almost no bias. But that is if the forecast is compared to the maximum wind gust +/- 3 hours from 12 UTC. If a shorter time window is used, there is a significant positive bias. The wind gusts from HIRLAM was somewhat too low compared to observed maximum wind gust +/- 3 hours, except for near the coast where the forecasts were close to the observed values.

4. References

Andersson, Langner and **Bergström**, 2007: *Tellus* (2007), **59B**, 77-98