Application and verification of ECMWF products 2008

SMHI – Lars Häggmark

1. Summary of major highlights

ECMWF products, especially the medium range forecasts, are extensively used at SMHI. Also for the short range the ECMWF forecasts are used together with products from the HIRLAM model. The HIRLAM model is run at three different resolutions, 22, 11 and 5 km using 40 vertical levels for the coarse resolution and 60 for the others. ECMWF data is used for boundaries for the 22 and 11 km runs while HIRLAM 11 provides boundaries for HIRLAM 05.

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

Streamflow predictions based on EPS precipitation forecasts is a valuable and challenging application of ECMWF data and verification results are presented.

2. Use and application of products

SMHI is using the medium range ECMWF forecasts while making products to the media, energy market, etc. For a few local newspapers we sell monthly forecast, based on ECMWF products. These monthly forecast are integrated with statistics from climate statistics. The customer response to these monthly products is positive and forecasters are confident that the predictions on the monthly scale are gradually improving.

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 correction increments are derived station-wise and are then interpolated to a grid using optimal interpolation and utilizing the original forecast as a background field.

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- or stremflow 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.

There are two recent papers presenting the evaluation of ensemble streamflow predictions. In the first one, “Evaluation and calibration of operational hydrological ensemble forecasts in Sweden.” (Olsson, J. and Lindström, G. 2008) a system for ensemble streamflow prediction, ESP, which has been operational at SMHI since July 2004, based on 50 meteorological ensemble forecasts from ECMWF is discussed. Hydrological ensemble forecasts are produced daily for 51 basins in Sweden. All ensemble members, as well as statistics (minimum, 25% quartile, median, 75% quartile and maximum), are stored in a database. This paper presents an evaluation of the first 18 months of ESP median forecasts from this system, and in particular their performance in comparison with today's categorical forecast. The evaluation was made in terms of three statistical measures: bias B, root mean square error RMSE and absolute peak flow error PE. For ESP forecasts the bias ranged between -20% and 80% with a systematic overestimation for Sweden as a whole. A comparison between bias in input precipitation and ESP output, respectively, revealed only a weak relationship, but stream flow overestimation is likely related mainly to model properties. The results from the streamflow forecast comparison showed that the ESP median in deterministic terms overall performs as well as the presently used categorical forecast. Further, ESP has the advantage of providing at least a qualitative measure of the uncertainty in the forecasts, with probability forecasts being the ultimate goal.

In a second paper, “Deterministic evaluation of ensemble streamflow predictions in Sweden.” (Johnell et al 2007), the daily operational hydrological 9-day ensemble forecasts during 18 months in 45 catchments were evaluated in probabilistic terms. The forecasts were generated by using ECMWF meteorological ensemble forecasts as input to the HBV model, set up and calibrated for each catchment. Two kinds of reference discharges were used in the evaluation, "perfect forecasts" and actual discharge observations. A percentile-based evaluation indicated that the ensemble spread is underestimated, with a degree that decreases with increasing lead time. The share of this error related to hydrological model uncertainty was found to be similar in magnitude to the share related to underdispersivity in the ECMWF meteorological forecasts. A threshold-based evaluation indicated that the probability of exceeding a high discharge threshold is generally overestimated in the ensemble forecasts, with a degree that increases with probability level. In this case the contribution to the error from the meteorological forecasts is larger than the contribution from the hydrological model. A simple calibration method to adjust the ensemble spread by bias correction of ensemble percentiles was formulated and tested in five catchments. The method substantially improved the ensemble spread in all tested catchments, and the adjustment parameters were found to be reasonably well estimated as simple functions of the mean catchment discharge.

2.1.3 Derived fields

Probability fields for near gale warnings are prepared from deterministic forecasts. Special indices used forecasting of thunderstorms are also generated.

2.2 Use of products

Use of ECMWF products in operational duties, in particular use in severe weather situations

The Central Forecast Unit at SMHI makes use of a lot of ECMWF products, especially the deterministic runs from 00z and 12z. These are chosen as basic data in the quality controlled forecast database, normally from +36 hours but sometimes as early as from +6 hours. During the last year, DMO temperature from ECMWF has shown lower bias than those from HIRLAM 11. To obtain even better scores, a Kalman filter is used on both ECMWF and HIRLAM. In our forecast database we are still only able to make a choice between different deterministic forecasts. However, in an ongoing project we are working hard to use *Lagged* EPS as well as “*Normal*“ EPS in our database.

The Central Forecast Unit, is also using EPS products available on the ECMWF website. Especially the probability charts for precipitation and wind gusts are used. The plume charts are just to obtain signals how the EPS members are forecasting temperature and pressure. These are very useful to clarify how confident the forecast is.

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

Precipitation

To study the capabilities of different models to predict the probability of precipitation over certain threshold values and for different areal sizes, the Fractional Brier Skill-Score (FBSS) has bean calculated. The observed and predicted 24 hour precipitations were taken for a 10 month period from November 2006 until August 2007. Observations were taken from the Swedish climate station network (770 stations). The studied models were ECMWF, HIRLAM, The Unified Model (UM, Met Office), and ALADIN.

To calculate the FBSS, Sweden was divided into areas of a certain size. The fraction of observations over a threshold value and corresponding forecast values were calculated. Areas with less then 3 observation stations were not used. The observed sample climate fraction was used as the reference value in the FBSS calculations. The computation was made for different threshold values and area sizes.

The results (figure 1) show a good ability for all models to predict the fraction of area covered with rain for larger areas (550x550 km) and for more or less all thresholds values. When area size is made smaller the skill is also demising but is still positive for almost all models and thresholds down to an area size of 110x110 km. For a size of 27x27 km there is no, or negative skill for most precipitation thresholds but ECMWF and UM both proves to have an ability to forecast the fraction of an area with 1 or 6 mm rain in 24 hours.

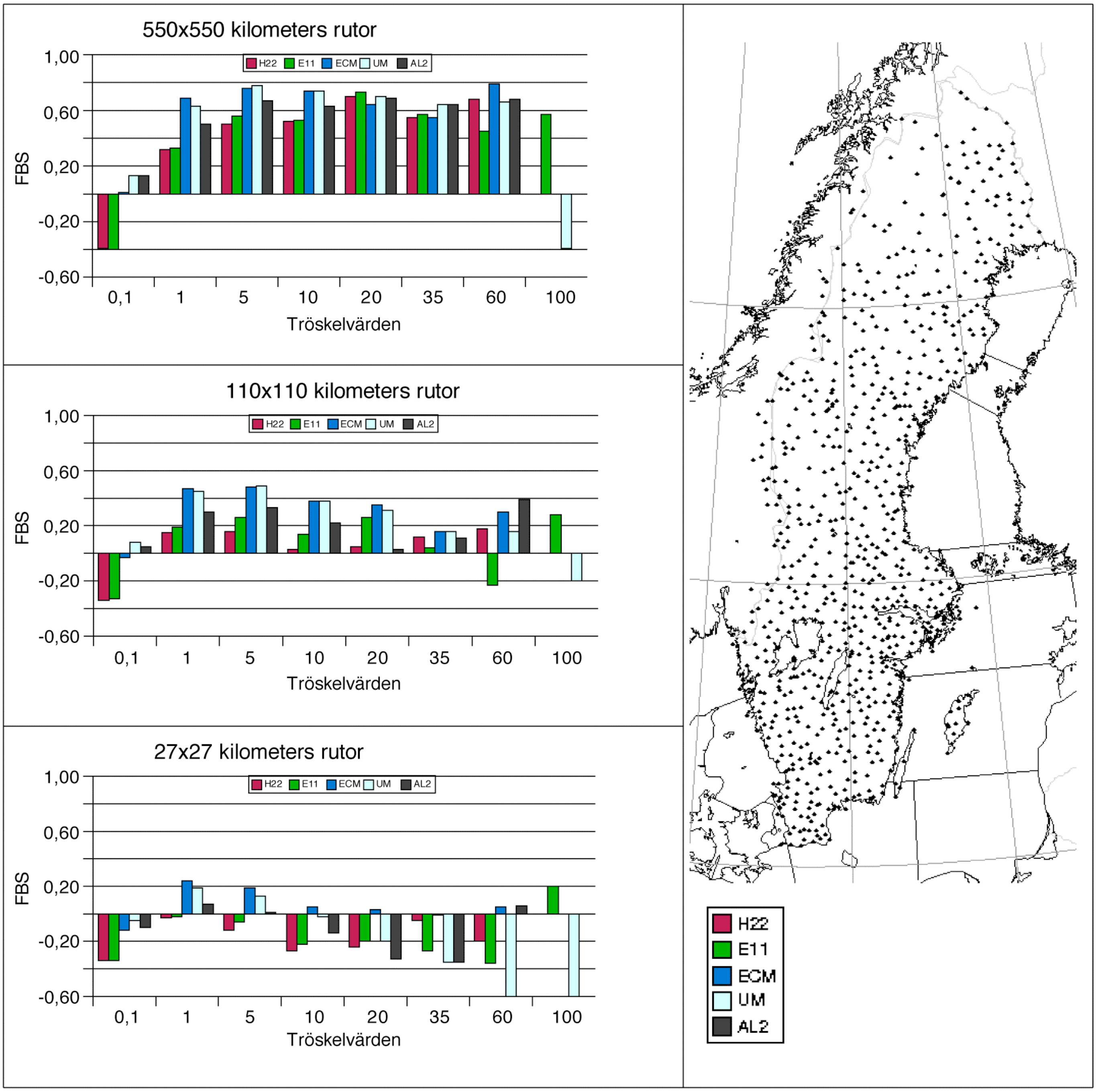

Fig.1 Fractional Brier Skill Score (FBSS) for different large areas, forecast and observed 24 hour precipitation. In the diagrams the x-axes shows threshold values for precipitation and the y-axes corresponding FBSS-values. Observations are taken from 770 climate stations over Sweden (right panel). The forecast models used are HIRLAM with 22km horizontal resolution (H22) and 11 km (H11), ECMWF (ECM), The Unified Model calculated at met.no with 4 km resolution and ALADIN (AL2) with a grid size of 11 km.

2 meter temperature

The overall quality of the ECMWF 2-metre forecasts are very good and for the short range essentially of the same quality as the HIRLAM forecast. During spring time a difference in performance between inland and coastal stations was noted. As the temperature increased day by day there was systematically larger negative bias for coastal stations for each new forecast. For inland stations no such error could be seen. (N.b. HIRLAM has a tiled surface scheme and the land tiles are used for the verification; ECMWF fields undergo a rotation and interpolation to the forecasting data base grid (= = HIRLAM grid). See also Anders Persson’s presentation about problems with interpolation and coastal stations at the User meeting 2008).

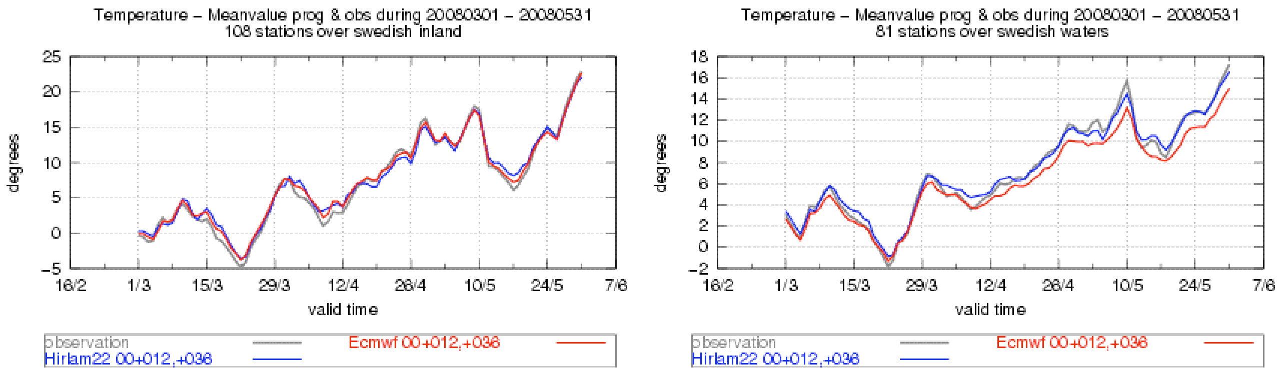

Fig.2 Temperature forecasts during springtime. Left for inland stations and right for coastal stations. Red is ECWMF, blue HIRLAM and grey observed mean daytime temperatures.

10 metre wind

For inland stations ECMWF forecasts overestimates the 10 metre wind speed with a bit less than 1 m/s. The error is observed to be larger during winter than summer. The same is true for coastal stations but the systematic error is less while the mean absolute error is larger.

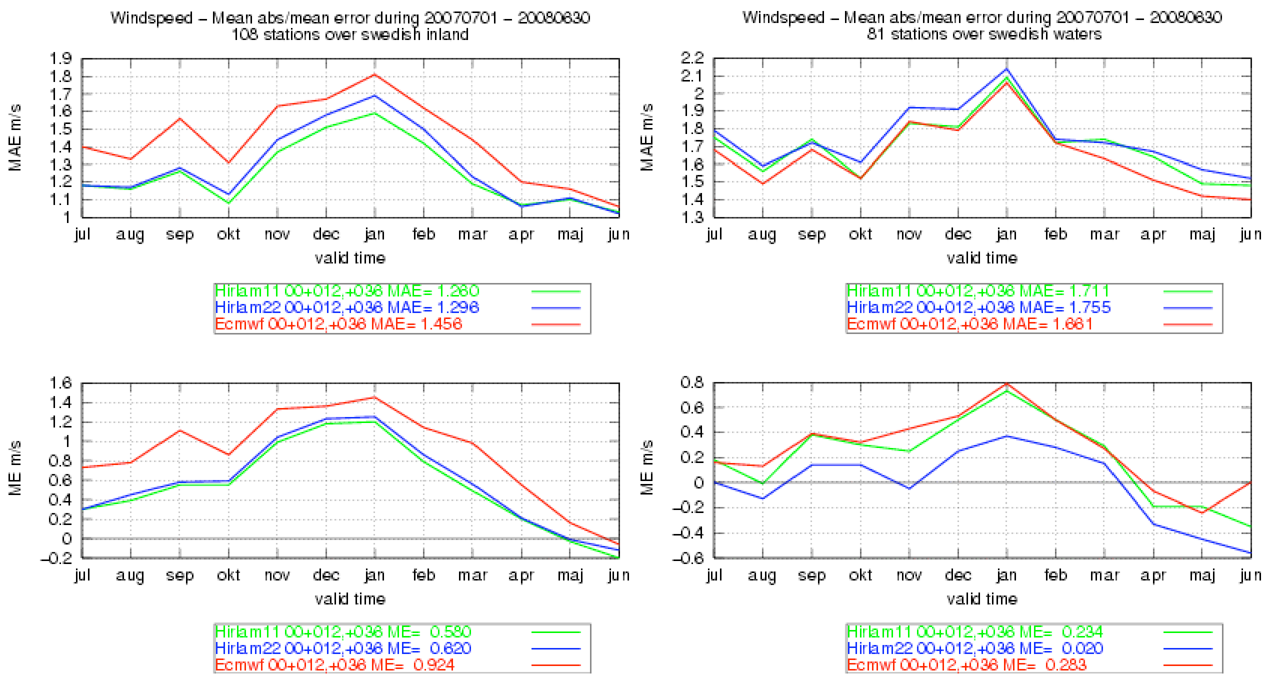

Fig.3 10-metre wind speed for inland stations left and coastal right. Above monthly mean absolute errors and below mean errors. Red is ECMWF, green HIRLAM with 11 km horizontal resolution and blue with 22 km.

3.1.3 Post-processed products

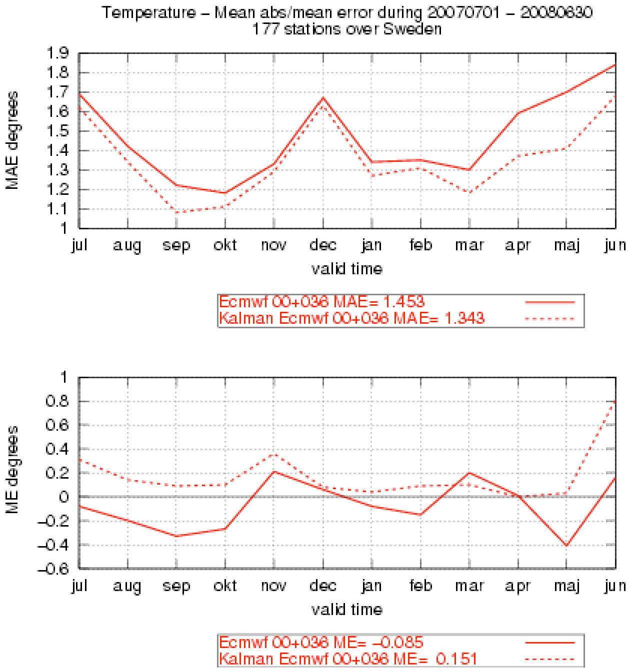

Fig.4 Kalman filtered temperature forecast (dotted line valid daytime for “tomorrow” and corresponding direct model output (solid line).

A Kalman filter decreases the mean absolute error for temperature forecasts valid at noon the day after the forecast were issued with approximately 0.1 degrees on yearly bases. The improvement was especially noticeable during the spring.

Also wind speed forecasts were improved substantially using the Kalman technique, and mean absolute errors for inland stations were about 30 percent lower on a yearly basis and during winter up to 50 percent lower.

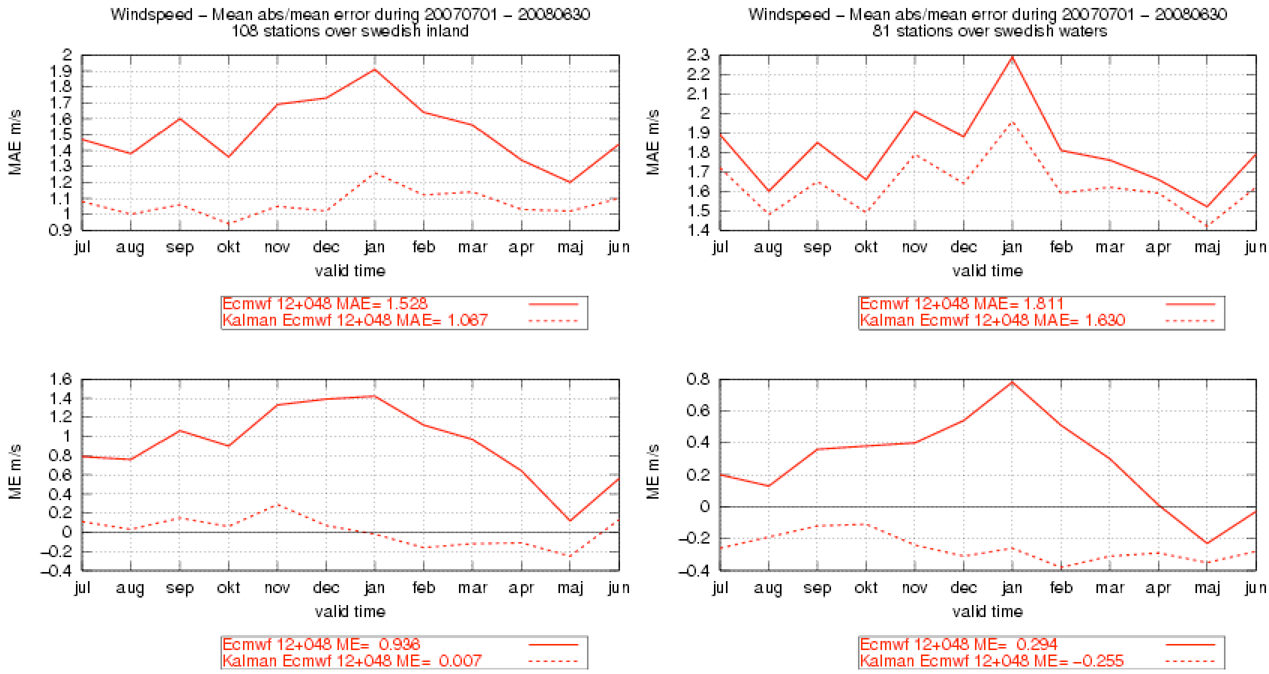

Fig. 5 Kalman filtered wind forecasts (dotted) and direct model output (solid) valid two days ahead. Left panels for inland stations and right coastal stations. Upper panels mean absolute error and below mean error.

3.1.4 End products delivered to users

3.2 Subjective verification

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

3.2.2 Synoptic studies

In January and February 2008, Scandinavia was hit by several deep low pressure systems with wind gusts exceeding 25 m/s. The meteorologists on duty reported that wind gusts coming from the ECMWF deterministic forecast were about 5 m/s higher than later observed. The model showed very small difference between wind gusts over open sea and land, as if there was no land-sea mask visible. During the worst storm the 22nd of February, the ECMWF deterministic runs showed much better pressure gradient compared to any other model. This also turned out to be correct afterwards when then verification had been made.

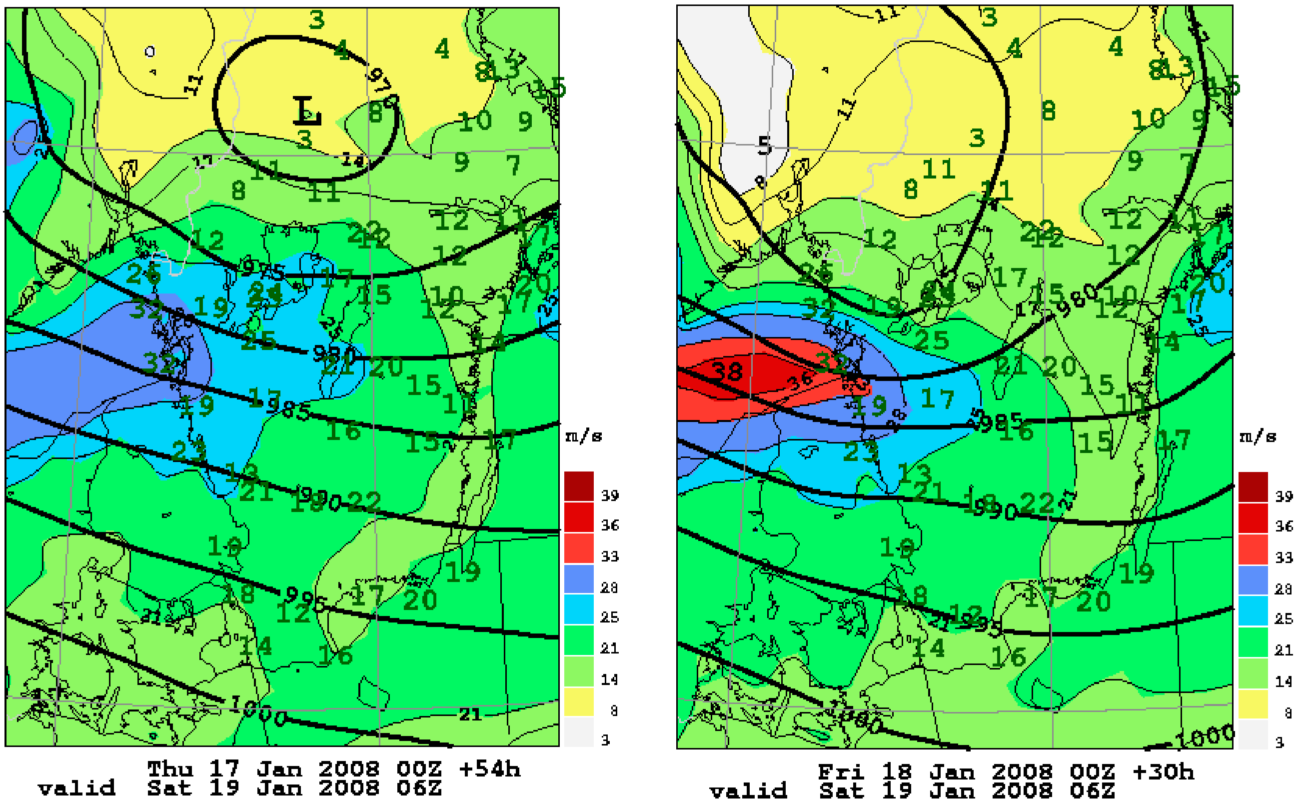

Fig. 6 Forecast gustiness from ECMWF valid the 19th of January 2008. The left panel is a 2 day forecast and the right one is a 1 day forecast. Observations are given as green numbers.

4. References to relevant publications

Olsson, J. and **Lindström**, G. (2008) Evaluation and calibration of operational hydrological ensemble forecasts in Sweden. *Journal of Hydrology*, **350**, 14-24.

Johnell, A., **Lindström, G.**, and **Olsson, J**. (2007) Deterministic evaluation of ensemble stream flow predictions in Sweden. *Nordic Hydrology*, Vol. **38** No 4-5 pp 441-450.