Application and verification of ECMWF products at Finnish Meteorological Institute

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1. Summary of major highlights

A new verification system will become operational by the end of 2008, and this new scheme will mostly replace the previous one. The technical structure is totally new providing better ways to enhance and further develop the system. It will allow for direct comparison of direct model output, post-processed model output and forecaster-edited end products.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

ECMWF EPS temperature and precipitation forecasts have been used as input variables in hydrological forecasting to provide probabilistic water level and discharge forecasts by the Finland's Environmental Administration. Also deterministic data are available for hydrological forecasting.

The error statistics indicate that EPS data have quite similar systematic error structures as deterministic data with additional error originating from the coarse horizontal resolution. The quality of temperature forecasts in general is good. All forecasts are typically better than climatology up to D+10. Most problems appear during night time in winter associated with stable stratification of the atmospheric boundary layer. The most important season for flood forecasting is spring when melting of snow cover together with precipitation often causes floods.

Optimal calibration increases the quality of EPS temperature forecasts and, consequently, water level and discharge forecasts. The hydrological model requires all individual EPS members as input and hence distribution-based input cannot be used, even if calibrated.

A study to find optimal ways to calibrate temperature forecasts based on ECMWF EPS output has been made. The methods tested were a simple recursive bias correction and different Kalman filtering (KF) versions. The best method was selected for operational use according to the verification statistics. Deterministic wintertime verification results indicate that Kalman filtered operational forecasts are best up to D+2, while Kalman filtered EPS mean is best after D+5 (Figure 1). Using Kalman filter to correct the EPS mean and then applied to correct the 51 individual EPS members provided the best choice in terms of probabilistic verifications scores (Figure 2 and Figure 3).

The error dressing method has been applied for several other deterministic ECMWF variables to provide probabilistic forecast guidance for e.g. Finnish Armed Forces. Among these experimental variables are the common ones like temperature, relative humidity and wind speed, and some derived variables like ceiling height. Some of the variables are treated as continuous and some as categorical ones.

2.1.2 Physical adaptation

ECMWF fields are used as lateral boundaries for the HIRLAM analysis and forecasting system. The present system has two nested versions of HILAM model (RCR and MBE) and AROME.

2.1.3 Derived fields

A wide range of derived fields are produced from ECMWF output for visualization and other use at the forecasting office as in earlier years.

2.2 Use of products

Both operational and EPS data are widely used in operations and in downstream applications. The EPS data is also transferred to Finnish Environmental Institute for input of hydrological model.

3. Verification of products

A new verification system is under development and the first stable version is expected to be released by the end of 2008. It will be used both for internal evaluation and to produce the annual official verification results for the government.

The system enables the verification of point forecasts of various surface parameters from basically any non-probabilistic models. Grid-based forecasts and analyses are interpolated to station locations prior to any statistical calculations, and the interpolated values are stored into the verification database for rapid access. The required observations and station metadata are fetched from several operational in-house databases. The system supports the definition of station groups for which the verification results are computed. Scheduled off-line batch jobs are configured to compute station and station-group specific results for the supported meteorological parameters.

The current system covers monthly, seasonal, and annual statistics from 2002 to present for the following models: ECMWF, HIRLAM_RCR, HIRLAM_MBE, MESAN, GFS, in-house road weather model and operational edited end forecasts produced by the forecasters.

The statistical analyses and the database loading are written mainly in C++, and the periodic tasks are performed by using the standard Linux crontab. The verification database (PostgreSQL) holding the interpolated values and calculated results occupies currently approximately one terabyte of disk space. The graphical user interface (GUI, "the presentation layer") is a web site implemented in PHP5 and running on an Apache web server. Figures 4-7 provide an outlook of the user interface and some examples of the graphics output of the system.

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

Weekly mean anomalies of temperature and precipitation originating from the EPS monthly forecasting system have been verified against observations in Southern Finland (Juga, 2008). Forecast data were collected from ECMWF web pages. Figure 8 shows a time series of forecast and analysed temperature anomalies during 2007 for the first week (days 5 thru 11) of the monthly system. The corresponding comparison for the third week (days 19 thru 25) is given in Figure 9. Figure 8 illustrates that the correspondence is generally good during the first forecast week. Even the cold period from late January to early March is rather well captured and after that some forecasts are almost perfect. The results for the third forecast week show rather poor correlation. The match for precipitation (Figures 10 and 11) is less good than for temperature.

The analysis was extended to evaluate the sign of the anomaly. The data were divided into three categories: (i) right signal, (ii) wrong signal, and (iii) no signal. The results are given in Figure 12 (temperature) and Figure 13 (precipitation). The temperature anomaly forecasts show some skill up to the third week, but for precipitation only the first forecast week shows any skill and beyond that the “no signal” category dominates.

3.1.2 ECMWF model output compared to other NWP models

The novel object-based verification measure SAL (Structure-Amplitude-Location) (Wernli et al., 2008) has been adapted for the verification of quantitative precipitation forecasts (QPF) in hydrological catchments in Finland as part of a cooperation project with the Finland’s Environmental Administration.

Thirty-hour forecasts of three NWP models, ECMWF, reference HIRLAM_RCR and meso-beta HIRLAM_MBE are covered in this model performance comparison. In addition, QPF fields as generated by human forecasters using the operational “SmartMet” grid editing tools, having model output as their guidance, are verified against radar-derived precipitation analyses. Figures 14-17 show results for a medium-size (c. 40000 sqkm) Kokemäenjoki river catchment in western Finland during the winter months of 2007-2008(Nurmi et al., 2008).

In an ideal situation S, A and L would all equal = 0. The S (structure) component is positive, on average, for all configurations indicating that the forecast precipitation objects were generally too large and/or too flat. The distribution looks worst for ECMWF (Fig. 14) and best for the high-resolution MBE version of HIRLAM (Fig. 16). This result nicely supports “eyeball verification”, i.e. being compatible with how the human eye would evaluate the precipitation pattern forecasts. The A (amplitude) component is close to zero, on average, for all three models, although the variations are quite large. However, there is a marked under-estimation of the amplitude of precipitation for the human-edited forecasts which calls for further investigations. The use of radar-derived precipitation as “truth” especially during wintertime has no doubt effects on the results. These have not been examined, though. The L (location) component is not considered here, but it behaved typically quite similarly for all configurations.

Future applications of this verification methodology will most likely cover all of the major catchments in Finland as well as inclusion of the meso-scale AROME model in the model comparison.

4. References to relevant publications

Juga, I, 2008: ECMWF monthly forecasts in Finland 2006-2007, **http://www.ecmwf.int/newsevents/meetings/forecast_products_user/Presentations2008/Juga.pdf**

Nurmi, P., S. Näsman and **A. Niros**, 2008: QPF Verification in River Catchments with the SAL Measure. *Joint MAP D-PHASE Scientific Meeting - COST 731 Mid-term Seminar (Bologna, Italy, 19-22 May)*. **http://www.smr.arpa.emr.it/dphase-cost/presentazioni/21-may/afternoon/session_3_pm/3.12-nurmi/3.12_Nurmi_Bologna_FIN.pdf**.

Wernli, H., M. Paulat, M. Hagen, and **C. Frei**, 2008: SAL – a novel quality measure for the verification of quantitative precipitation forecasts *(Monthly Weather Review, submitted).*

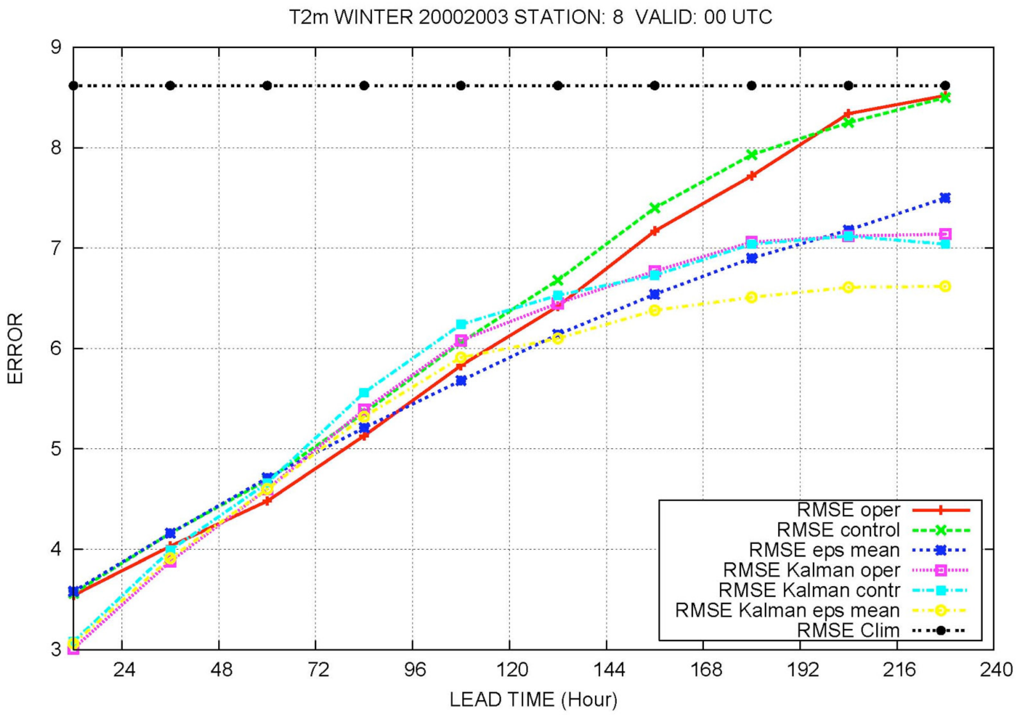

Fig. 1 Wintertime RMS Error of operational, control and EPS mean temperature forecasts and corresponding Kalman filtered forecasts, averaged over eight stations in Finland.

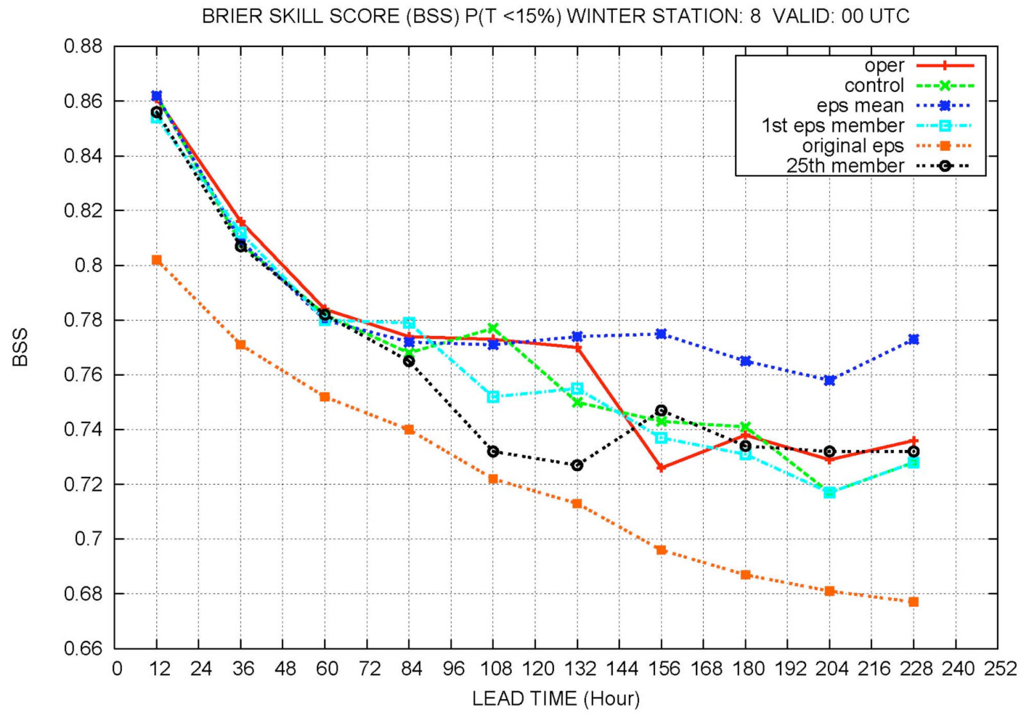

Fig. 2 Wintertime Brier Skill Score (BSS) of ECMWF EPS temperature forecasts corrected with Kalman filtered operational, control, EPS mean, 1^{st} individual EPS member, 25^{th} individual EPS member and original EPS, averaged over eight stations in Finland.

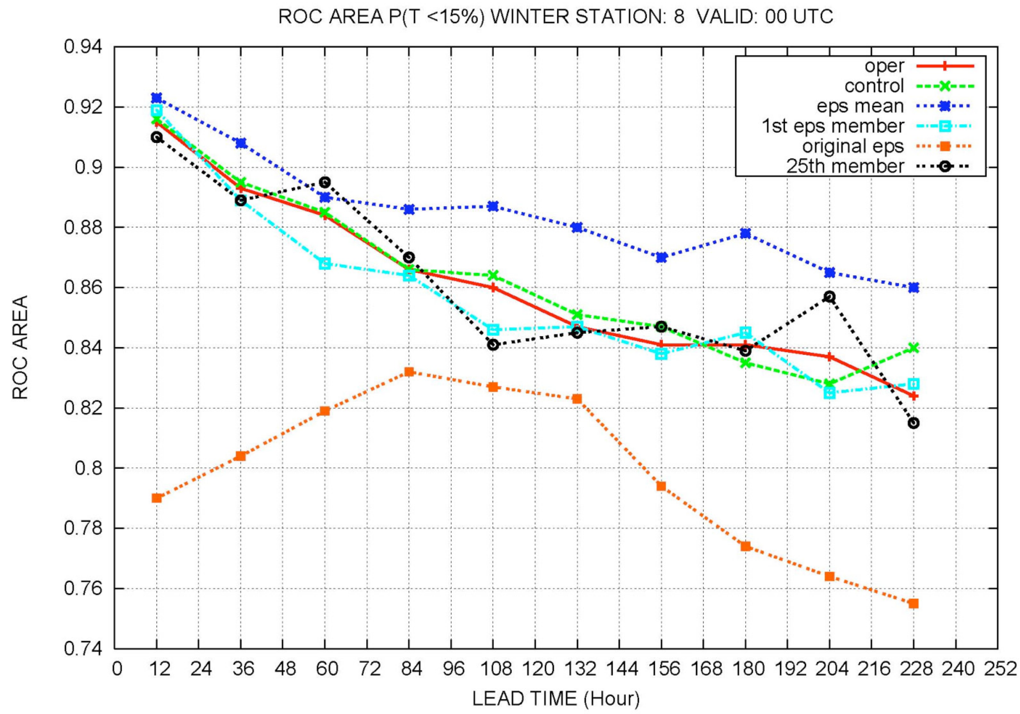

Fig. 3 As in Fig.2 but for the area under the ROC curve.

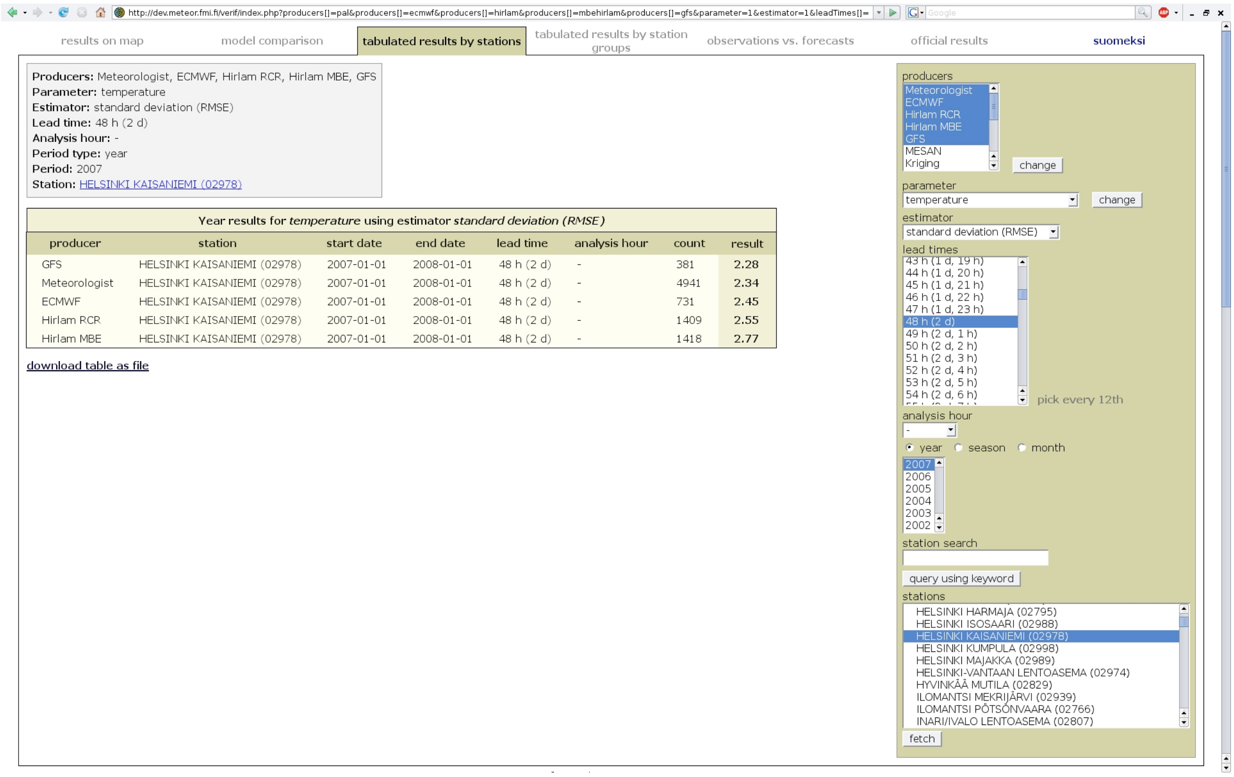

Fig. 4 Example of user interface of the new verification system.

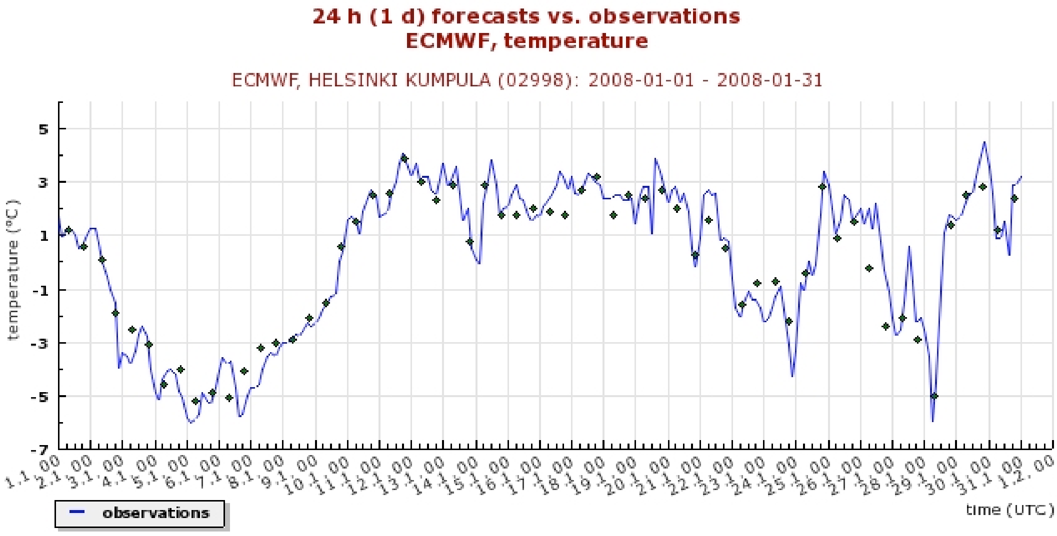

Fig. 5 Example of forecast vs. observation time-series plot of the new verification system.

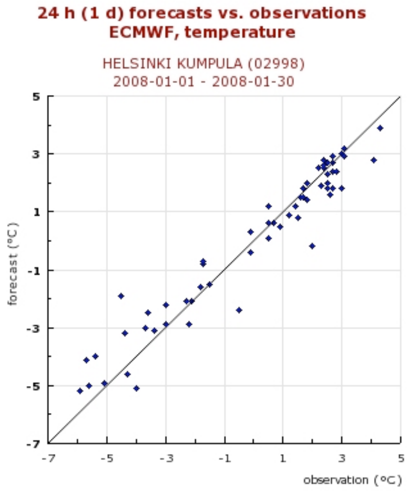

Fig. 6 Example of scatter plot of forecasts vs. observations of the new verification system.

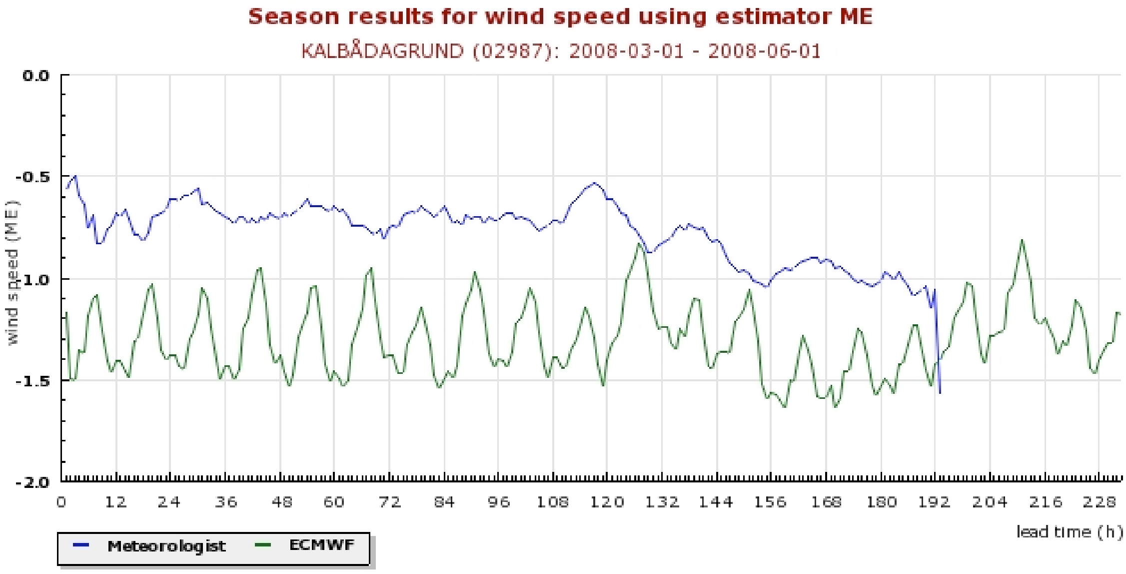

Fig. 7 Example of plot of mean error (bias) of ECMWF wind speed vs. forecaster's output at a selected station of the new verification system.

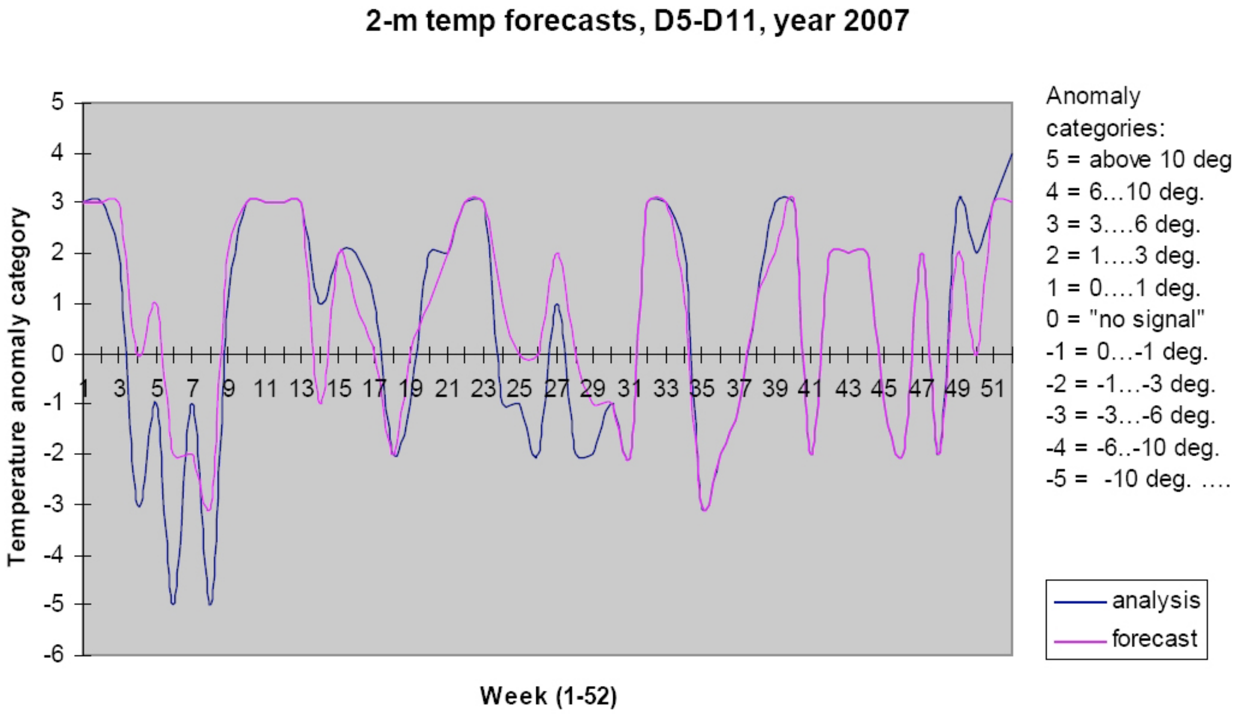

Fig. 8 Temperature anomaly forecast vs. analysis (in categories) for southern Finland during 2007 for the 1st week (D5-D11) of the monthly forecast system.

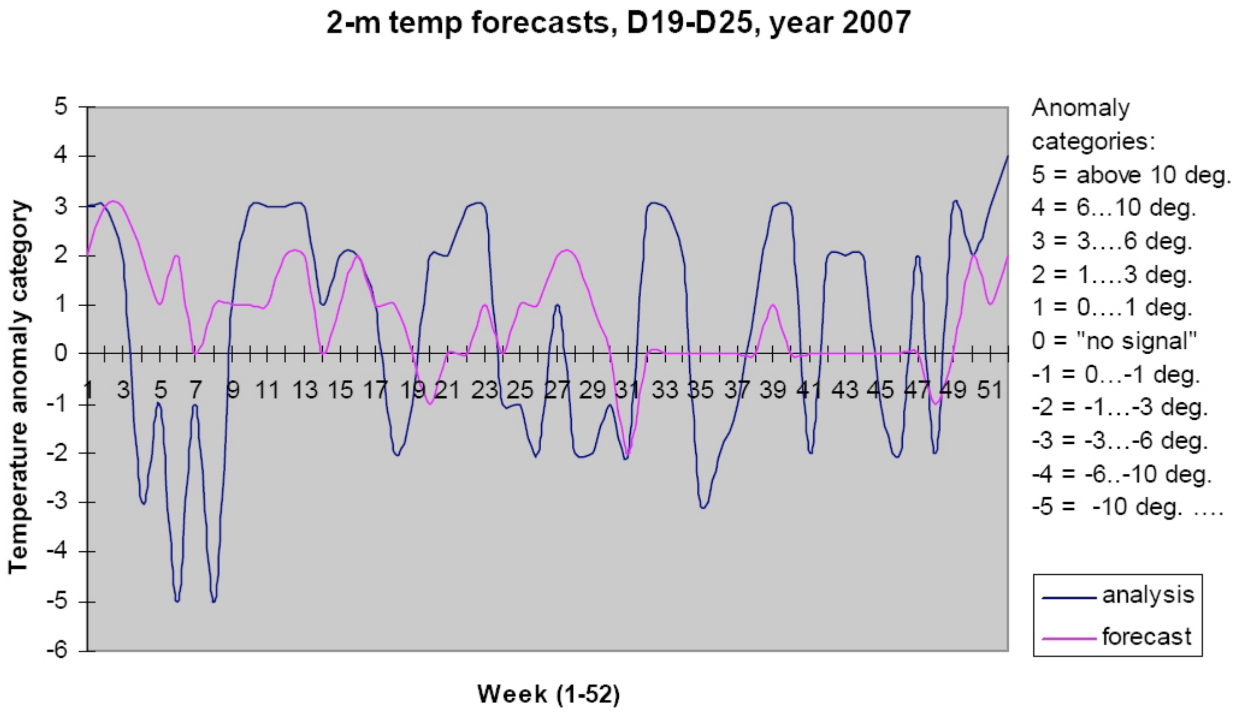

Fig. 9 As in Fig. 8 but for the 3rd week (D19-D25).

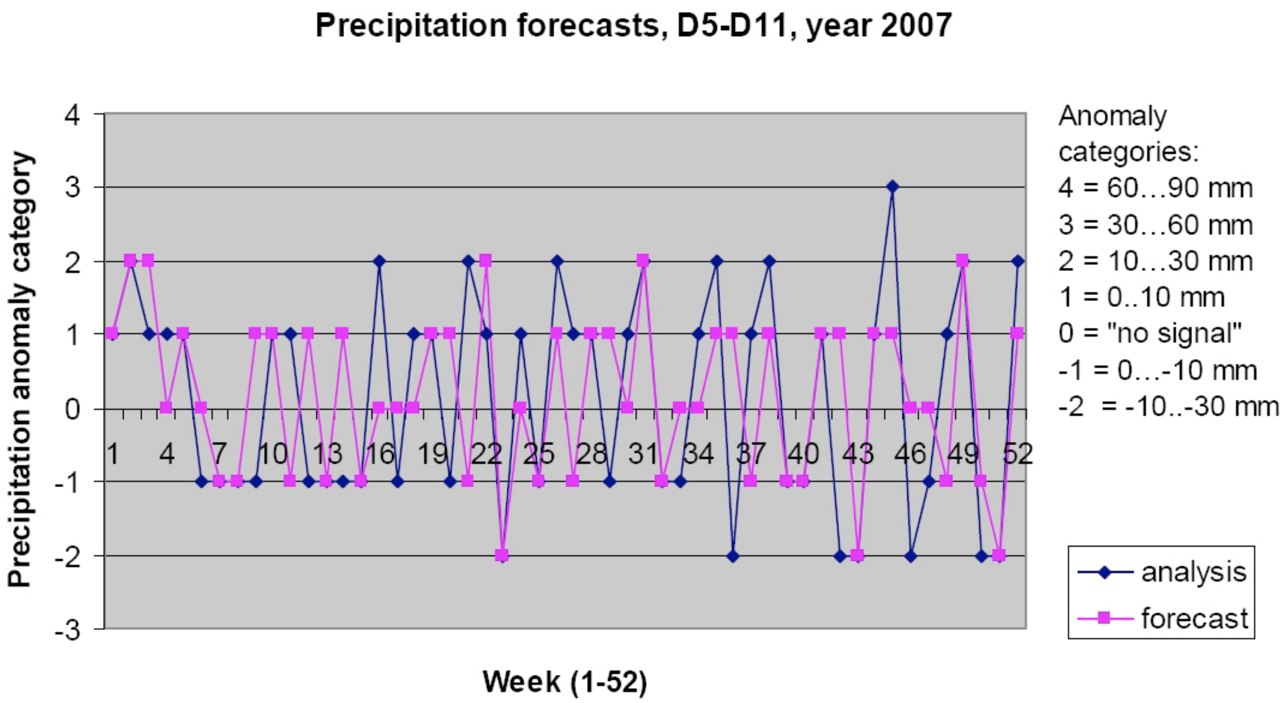

Fig. 10 Precipitation anomaly forecast vs. analysis (in categories) for southern Finland during 2007 for the 1st week (D5-D11) of the monthly forecast system.

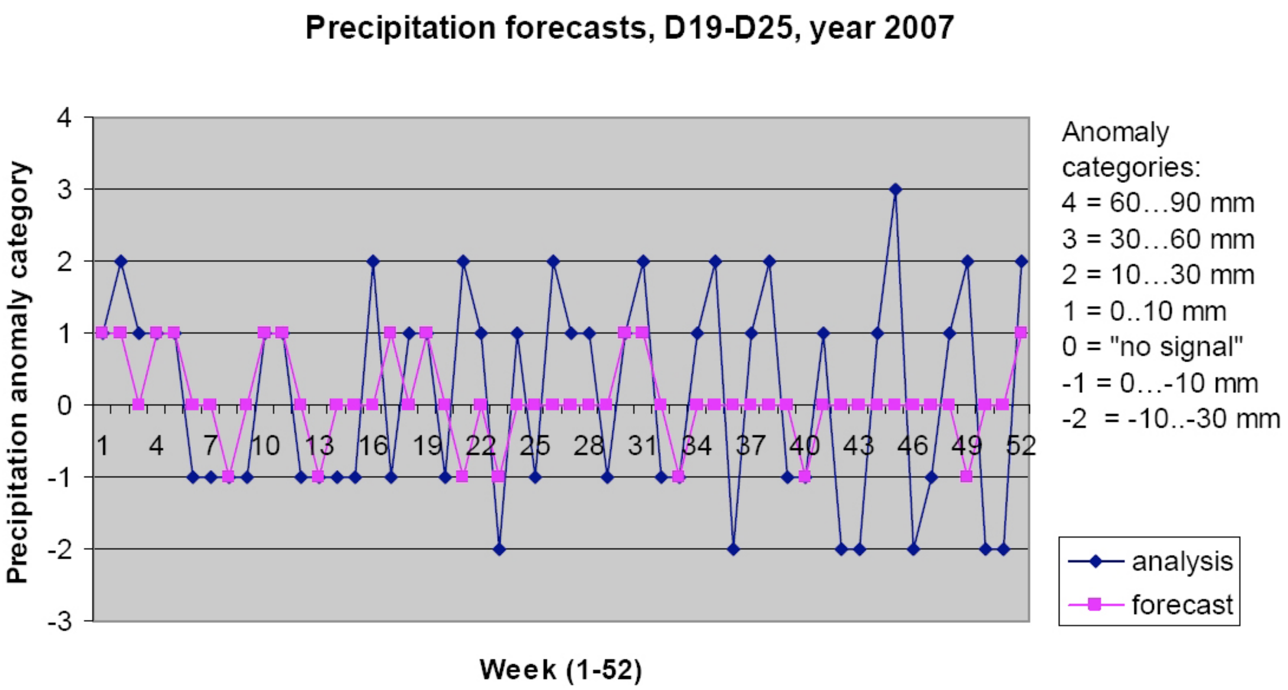

Fig. 11 As in Fig. 10 but for the 3rd week (D19-D25).

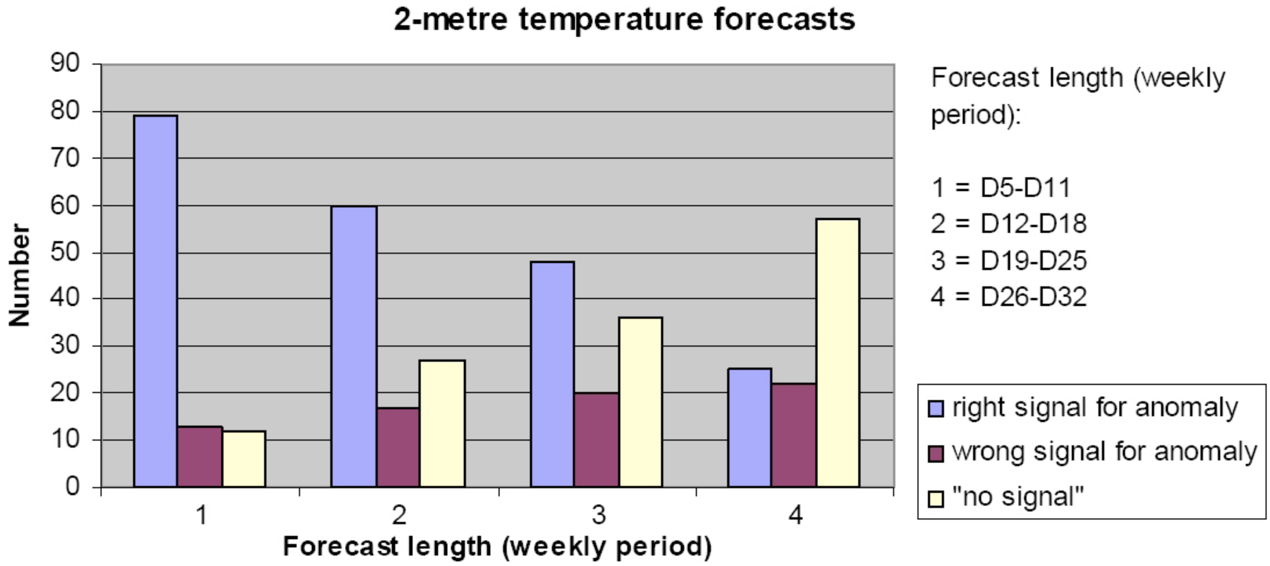

Fig. 12 Distribution of the temperature anomaly forecast in categories “right”, “wrong” or “no signal” for the four consecutive weekly forecast periods of the monthly forecast system in 2007.

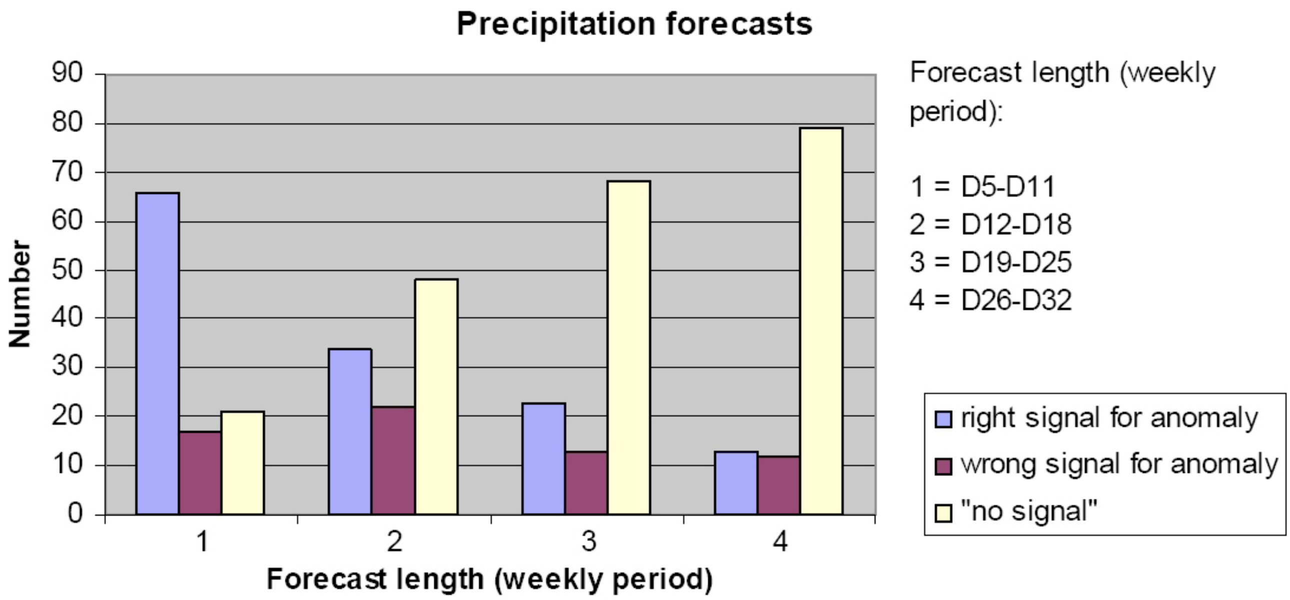

Fig. 13 As in Fig. 13 but for precipitation.

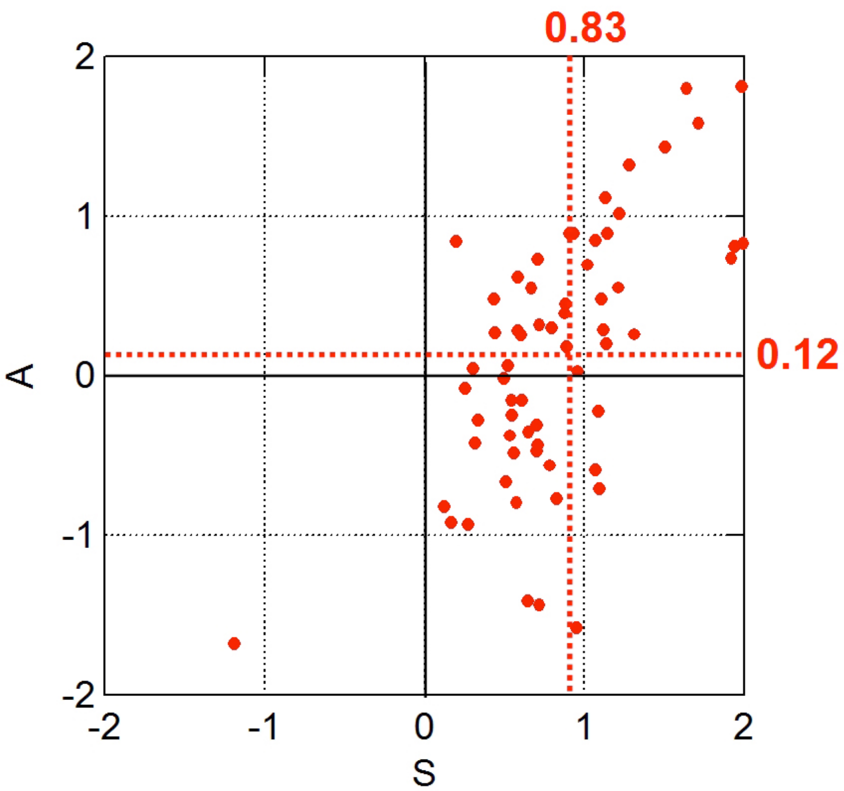

Fig. 14 Scatterplot of the S (structure) and A (amplitude) components of the SAL verification measure for ECMWF 30-hour deterministic QPFs for Kokemäenjoki river catchment during winter 2007-2008. There are 63 analysed cases and each S/A combination is represented by a solid blob. The dotted lines represent the mean values of S and A, averaged over the dataset.

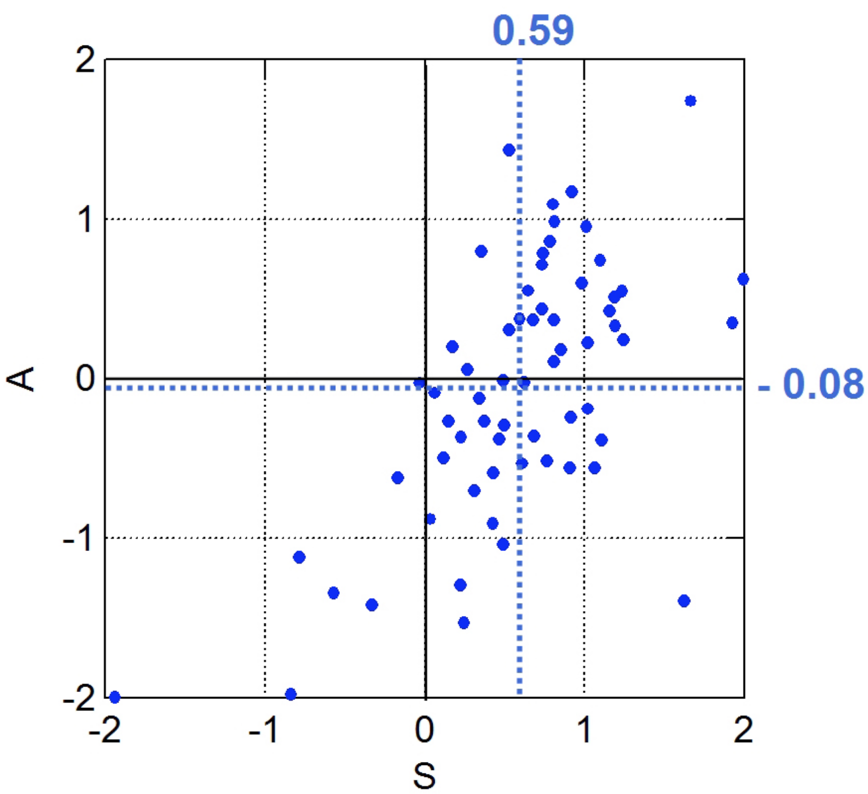

Fig. 15 As in Fig. 14 but for the reference HIRLAM_RCR.

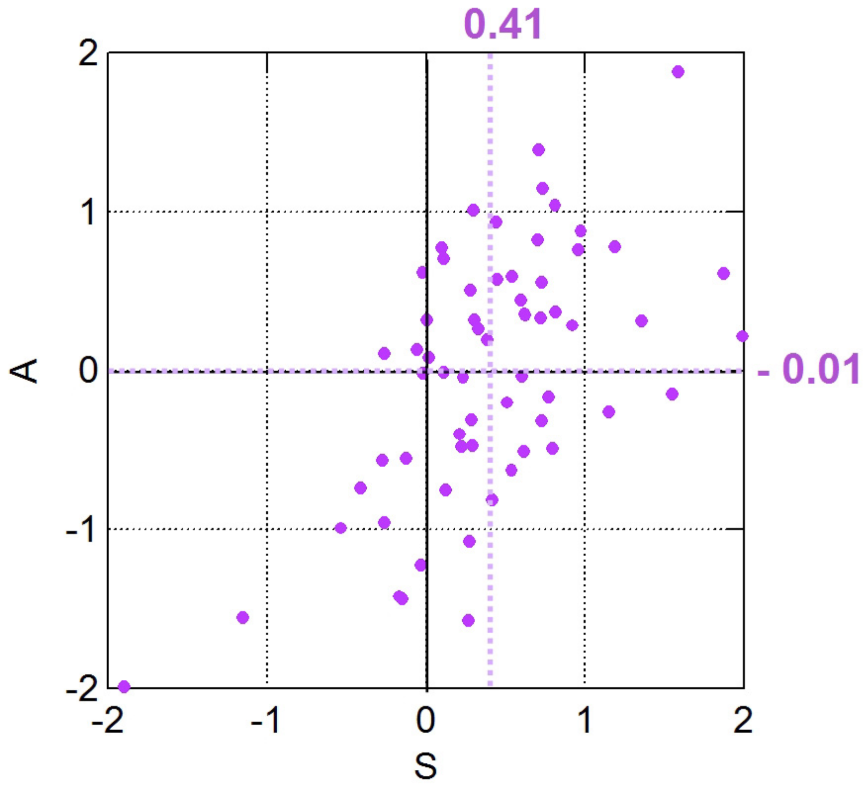

Fig. 16 As in Fig. 14 but for the meso-beta HIRLAM_MBE.

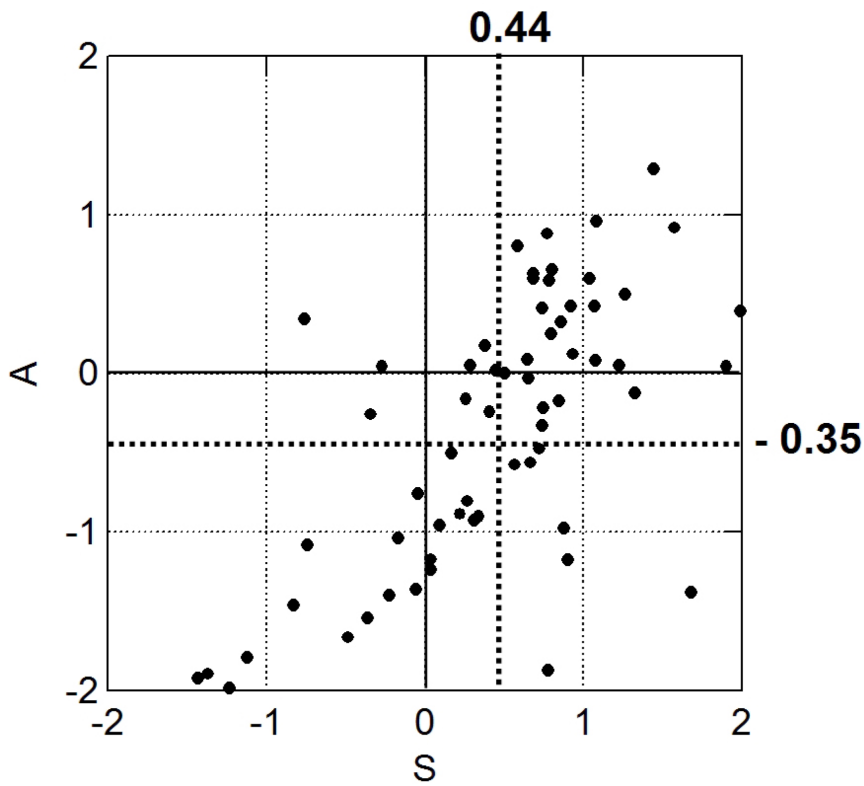

Fig. 17 As in Fig. 14 but for the human forecaster using the SmartMet grid editor.