Application and verification of ECMWF products 2011

Icelandic Meteorological Office (www.vedur.is) – Guðrún Nína Petersen

1. Summary of major highlights

Medium range weather forecasts issued at IMO are mainly based on ECMWF deterministic products, at 0.5^{o} horizontal resolution. In the short range ECMWF products are used along with products from other models such as MM5, HIRLAM and the UK Unified Model. Local weather forecasts are automatically generated for more than 120 locations in Iceland. Forecasts are made available to the general public and as special services to customers, e.g. the hydro-power energy sector. The EPS products are not received at IMO but regularly consulted on the ECMWF web page. Monthly and seasonal forecasts are also consulted and used to provide guidance to the energy sector. Short and medium range local weather forecasts are verified as in previous years. The verification is performed individually at each station where local forecasts are automatically generated. A daily verification is run and used to appreciate the quality of 2-metre temperature and 10-metre wind-speed forecasts valid from T+12h to T+48h over a 10-day window. An annual verification procedure for each calendar year, including precipitation and surface pressure, is run for forecasts valid up to T+168h. Most of the results can be consulted on the internal web pages.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

Kalman filtering is used to post-process local 2-metre temperature and 10-metre wind-speed forecasts from ECMWF 00 and 12 UTC deterministic runs, up to T+168h (Crochet, 2004).

The probability of precipitation (PoP) in 24h is predicted at 11 locations with a generalized liner model, from D+1d to D+5d, using input from ECMWF 12 UTC deterministic run (Crochet, 2003).

ECWMF 00 and 12 UTC deterministic precipitation forecasts are downscaled using high resolution climatic precipitation maps and taking into account the terrain complexity. The resulting maps are derived for precipitation accumulated in 6h, 12h, 24h and 48h up to T+96h.

2.1.2 Physical adaptation

The MM5 NWP model, which forecast is received operationally at IMO with horizontal resolution of 9 and 3 km, is run with boundaries from ECMWF. The MM5 is run at 9 km resolution 4 times a day with the forecast range being 72 hours but extending to 168 hours at 00 and 12 UTC. The lateral boundaries for the 3 km resolution simulation are provided by the 9 km resolution simulation. The MM5 is run at 3 km resolution 4 times a day and the forecast range is 54 hours.

The climatic precipitation maps used to downscale precipitation forecasts have been derived from a 1-km gridded precipitation dataset made with an orographic precipitation model forced by ERA-40 fields for the period 1958-2001 and ECMWF analysis for the period 2002-2006 (Crochet et al., 2007; Jóhannesson et al., 2007). This gridded dataset has been placed in the public domain: http://www.vedur.is/vedur/vedurfar/kort .

2.1.3 Derived fields

A vessel icing forecast chart based on the Overland algorithm (Overland et al., 1986; Overland, 1990) for vessel icing is derived from ECMWF model wind ground speed, 2-metre temperature and sea surface temperature. These forecasts are used internally by forecasters to evaluate and forecast the risk of vessel icing as a part of the textual shipping forecast.

2.2 Use of products

The ECMWF products are vital for operational weather forecasting. For general weather forecasting the ECMWF short range forecasts are used along with other available short range forecasts and the medium range forecasts updated daily, day 3-7, are mainly based on the ECMWF medium range forecast. The medium range forecasts, week 1-3, that are produced for the hydro power energy sector are mainly based on the ECMWF deterministic forecast and the EPS products.

During wintertime, ECMWF forecasts are used together with other NWP forecasts to assess the risk of weather conditions that could lead to snow avalanches.

The downscaled precipitation maps are used to assess the rainfall-triggered landslide risk by comparison to critical values that depend on the accumulation time and the mean annual precipitation. Due to volcanic ash on glaciers in southern Iceland after recent volcanic eruptions additional emphasis has been on this feature since summer/autumn 2010.

The ECMWF SST analysis and forecast are used by the forecasters. Charts of the analysed SST and the 5-day and 10-day forecasts are produced and published on the external web along with other marine weather forecasts. There are plans to increase the range of marine forecast products in the near future.

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

Local direct model output (DMO) 2-metre temperature forecasts exhibit systematic errors at a large number of sites resulting mainly from discrepancies between the model orography and the actual orography, as well as the horizontal resolution the output is retrieved at. In general the temperature is too low but at mountainous sites the temperature is often too high. To illustrate this Figure 1 and figure 2 show that there is about -2^{o}C bias for Reykjavík (WMO 4030, station height 52 m a.s.l.) while for Bláfjöll (WMO 4138, station height 530 m.a.s.l.), located on a nearby mountain ridge, the bias is about +1.3^{o}C.

For most stations there is a diurnal variation in the error statistics. For Reykjavík the bias, MAE and RMSE all have larger values during night than day, i.e. the 2-metre temperature is systematically underestimated more during the night than during the day, the difference being about 0.5^{o}C.However, most stations show larger absolute bias during day than night. This may be related to the coastal boundary layer in Reykjavík but this is currently not entirely understood as not all stations at the coast have larger error statistics during night.

A comparison of statistical score for 2008-2009 and 2010 shows that in general the ECMWF direct model output performance is better than in 2009 but slightly poorer than in 2008.

An underestimation of 10-metre wind speed dominates, especially inland. However, along the coast, especially where orography is complex, there is a tendency towards a positive bias.

The verification of precipitation is difficult due to well-known problems associated with rain-gauge measurements such as wind-loss that is a common problem in Iceland. Thus, as reported in previous reports most sites in Iceland show a model overestimation of precipitation.

It is likely that forecast error statistics, of especially 2-metre temperature and 10-metre wind speed, will improve when IMO upgrades the horizontal resolution of the ECMWF model output retrieved.

3.1.2 ECMWF model output compared to other NWP models

Comparisons of the ECMWF model output and HIRLAM model output are made routinely at all verified locations for 2-metre temperature and 10-metre wind-speed. These comparisons apply to both DMO and post-processed predictions. The comparisons are presented as time series plots and error statistics, as well as maps showing the model giving the best prediction over a 5-day window according to some criteria.

3.1.3 Post-processed products

The Kalman filter procedure reduces systematic errors, especially in the case of 2-metre temperature forecasts. Figure 1 and 2 show cases of the performance of the Kalman filtered forecasts exceeding the DMO in about 80% reduced to 60% of cases for Reykjavík as forecasting range increases but decreasing down to 50% of cases for longer forecast range for the mountain station Bláfjöll. Although in general the Kalman filter procedure removes systematic bias and slope errors there are cases where the procedure adds to the error. Figure 3 shows a good example of how the procedure decreases errors for the island stations Stórhöfði (WMO 4048, 118 m a.s.l.), when the DMO systematically overestimates low temperatures and underestimates high temperatures, while figure 4 shows a possible tendency for too cold post-processed temperatures at the lower end of the range for a highland stations Hveravellir (WMO 4156, 641 m a.s.l.).

In the case of 10-metre wind speed the results are more complicated. In general the Kalman filter procedure reduces wind speed forecast errors and improves forecast error statistics. For Stórhöfði, an island station from which weather information is important for fishing vessels, the Kalman filter procedure decreases number of cases with underestimated high wind speeds, see figure 5. However, it also increases cases of forecasted wind exceeding observed wind for low wind speed cases. This may have implications for the smallest fishing vessels that only sail in very light winds. This difference is seen clearer in figure 6 which shows cases of Kalman filter forecast improvement/deterioration as a function of observed wind speed and wind direction. While in the case of Reykjavík the Kalman filter process improves most forecasts when wind speed is about 6 m/s or less the effect is opposite for Stórhöfði. Clearly more effort is needed to understand the error statistics of both DMO and post-processed forecasts.

3.1.4 End products delivered to users

None.

3.2 Subjective verification

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

None.

3.2.2 Synoptic studies

None.

4. References to relevant publications

Crochet, P., 2003: A statistical model for predicting the probability of precipitation in Iceland. IMO report, 03028. http://www.vedur.is/um-vi/utgafa/greinargerdir/nr/03028.pdf

Crochet, P., 2004: Adaptive Kalman filtering of 2-metre temperature and 10-metre wind-speed forecasts in Iceland. *Meteorol. Appl.* **11**, 173-187. DOI: 10.1017/S1350482704001252

Crochet, P., T. Jóhannesson, O. Sigurðsson, H. Björnsson, F. Pálsson and **I. Barstad**, 2007: Estimating the Spatial Distribution of Precipitation in Iceland Using a Linear Model of Orographic Precipitation. *Journal of Hydrometeorol.* **8**, 1285-1306. DOI: 10.1175/2007JHM795.1

Jóhannesson, T., G. Aðalsteinsdóttir, H. Björnsson, P. Crochet, E.B. Elíasson, S. Guðmundsson, J.F. Jónsdóttir, H. Ólafsson, F. Pálsson, Ó. Rögnvaldsson, O. Sigurðsson, Á. Snorrason, O.G. Blöndal Sveinsson and **T. Thorssteinsson**, 2007: Effect of climate change on hydrology and hydro-resources in Iceland. Reykjavík, National Energy Authority, Rep. OS-2007/011. http://www.os.is/ces

Overland, J.E., C.H. Pease, R.W. Preisendorfer and **A.L. Comiskey**, 1986: Prediction of vessel icing. *Journal of Climate and Applied Meteorology*, **25**, 1793-1806.

Overland, J.E., 1990: Prediction of vessel icing for near-freezing sea temperatures, *Weather and Forecasting*, **5**, 62-77.

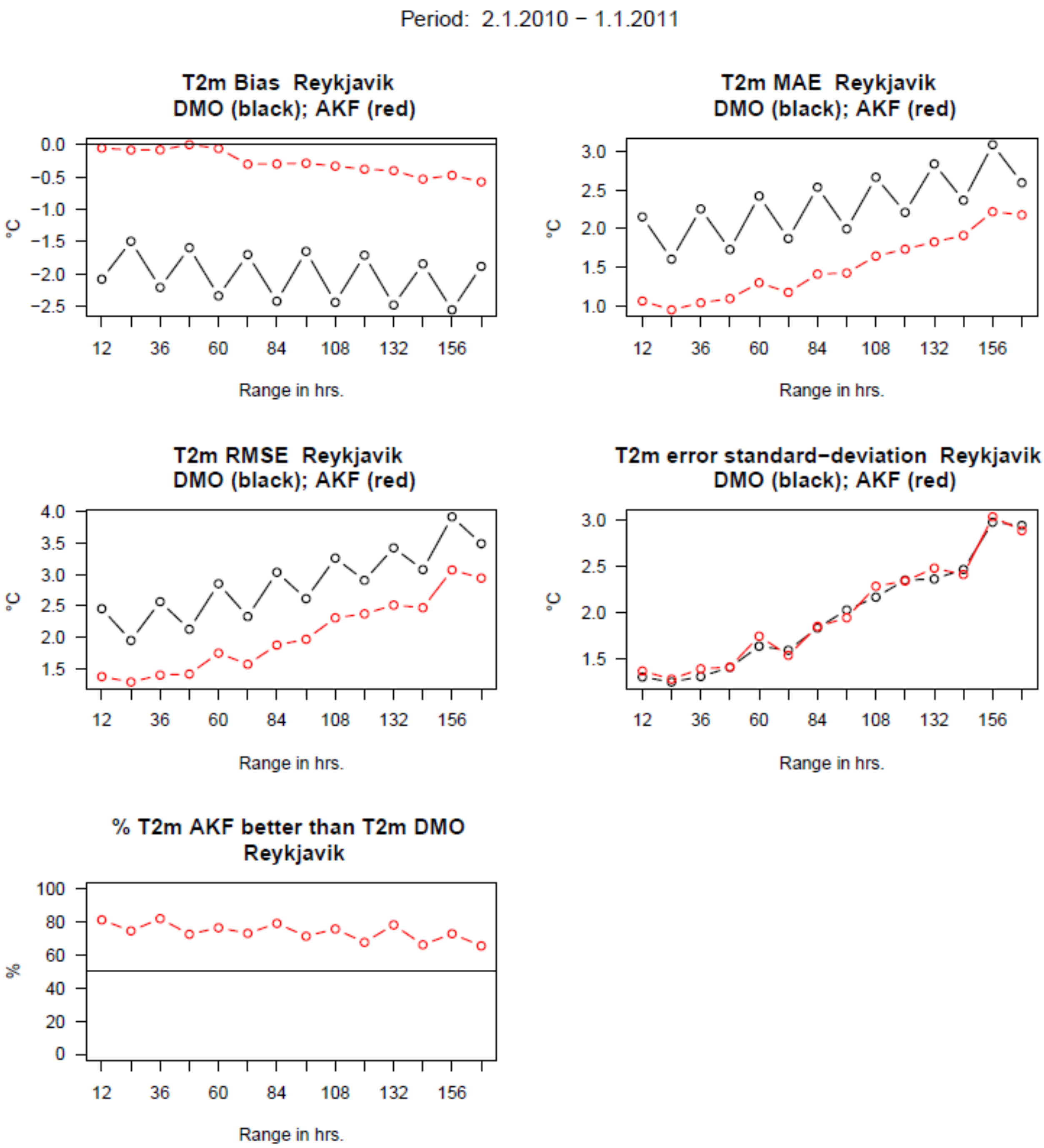

Figure 1 Verification of ECMWF (initiated at 12 UTC) DMO and Kalman filtered 2-metre temperature forecasts for Reykjavík (WMO 4030) for the year 2010. Statistical scores versus forecast range.

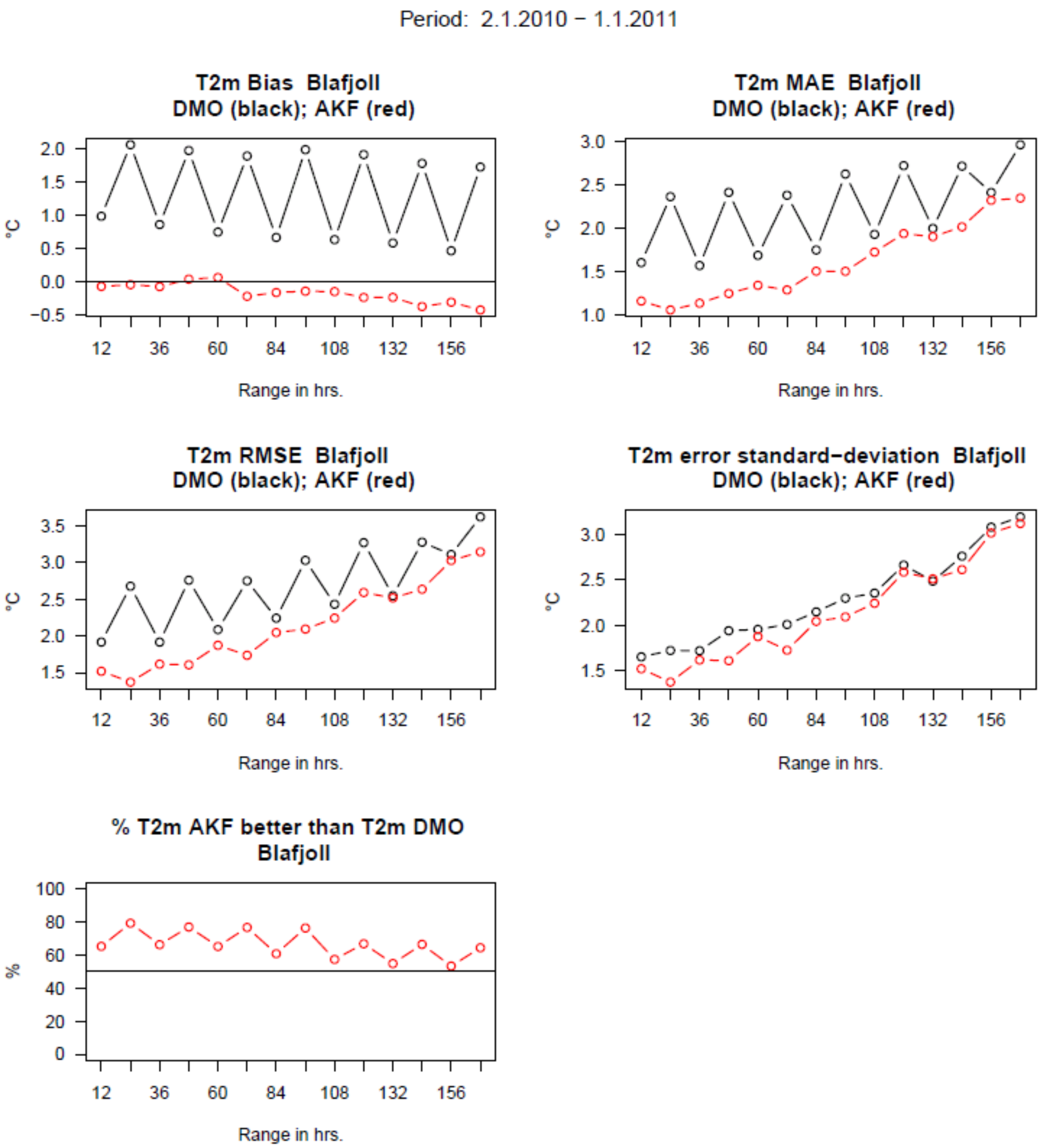

Figure 2 Verification of ECMWF (initiated at 12 UTC) DMO and Kalman filtered 2-metre temperature forecasts for Bláfjöll (WMO 4138) for the year 2010. Statistical scores versus forecast range.

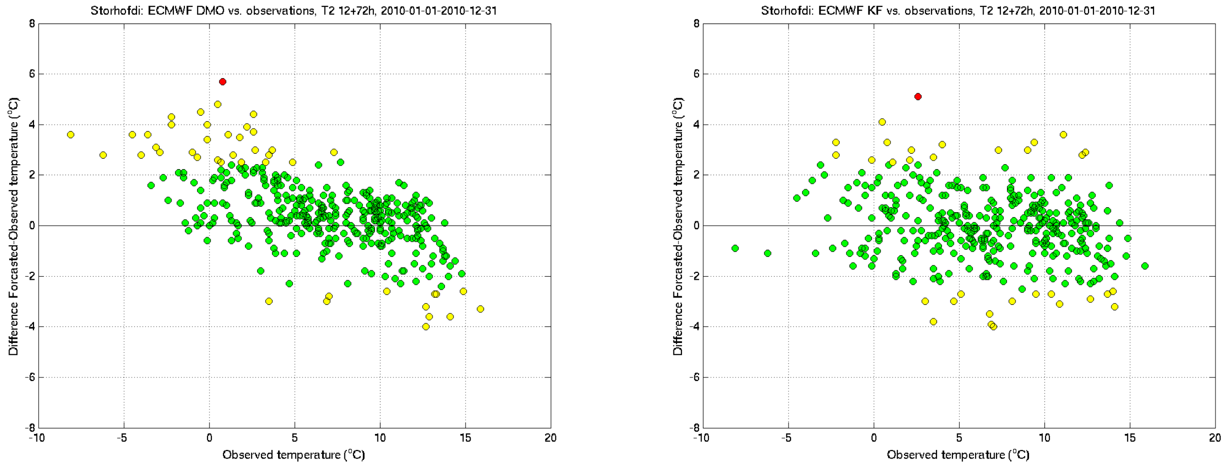

Figure 3 Scatter plots of (left) DMO and (right) Kalman filtered 2-metre temperature forecast errors versus observations at Stórhöfði (WMO 4048). Green dots: absolute forecast error less than 2.5°C, yellow dots: absolute forecast error in the range 2.5-5 °C and red: absolute forecast error exceeding 5 °C. Forecast range 72 hours and initial time 12 UTC.

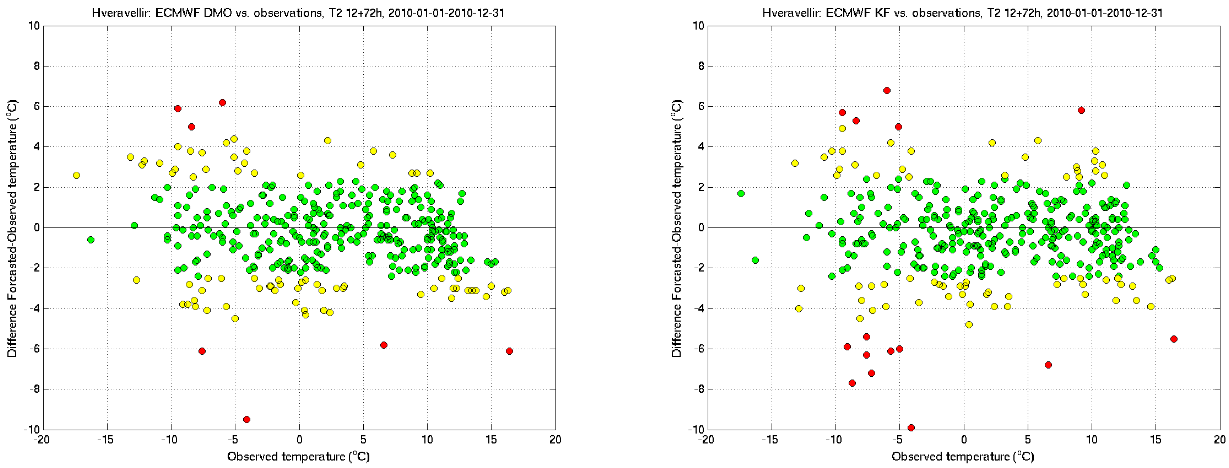

Figure 4 Scatter plots of (left) DMO and (right) Kalman filtered 2-metre temperature forecast errors versus observations at Hveravellir (WMO 4156). Green dots: absolute forecast error less than 2.5°C, yellow dots: absolute forecast error in the range 2.5-5 °C and red dots: absolute forecast error exceeding 5 °C. Forecasts for the year 2010, forecast range 72 hours and initial time 12 UTC.

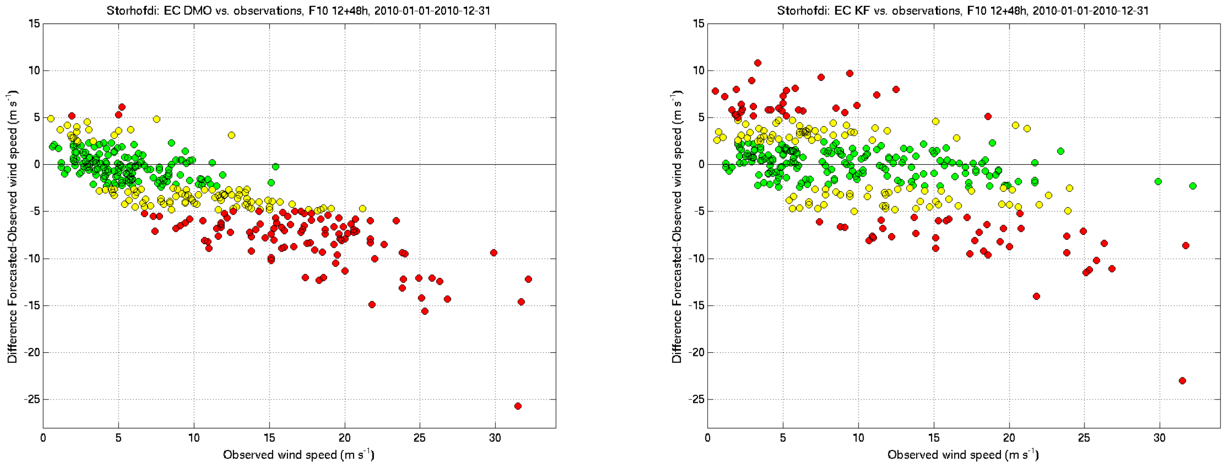

Figure 5 Scatter plots of (left) DMO and (right) Kalman filtered 2-metre temperature forecast errors versus observations at Stórhöfði (WMO 4048). Green dots: absolute forecast error less than 2.5 m/s, yellow dots: absolute forecast error in the range 2.5-5 m/s and red dots: absolute forecast error exceeding 5 m/s. Forecasts for the year 2010, forecast range 48 hours and initil time 12 UTC.

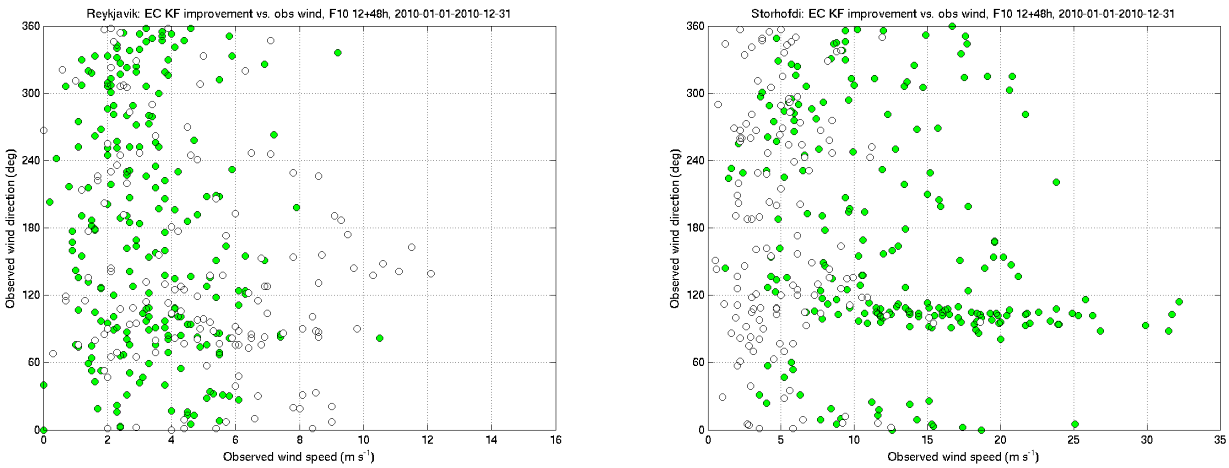

Figure 6 Scatter plots of showing distribution of cases when the Kalman filter process improved the forecast (green) and deteriorated it (white) Left: Reykjavík (WMO 4030) and right: Stórhöfði (WMO 4048). Forecasts for the year 2010, forecast range 48 hours and initial time 12 UTC.