Application and verification of ECMWF products.

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1. Summary of major highlights.

Medium range weather forecasts issued by IMO are mainly based on 00 and 12 UTC ECMWF products. In the short range, these products are used together with other models. Local weather forecasts based on ECMWF deterministic products are automatically generated for a large number of locations and made available to the general public and as special services to customers. The EPS products are not received at IMO but regularly consulted on the ECMWF web page and used together with ECMWF deterministic products to issue text forecasts. The verification of local forecasts has continued as in previous years.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

The main statistical adaptation method used at IMO is Kalman filtering. It is applied to local two-metre temperature and ten-metre wind-speed forecasts from ECMWF 00 and 12 UTC runs up to T+168h, at more than 120 locations in Iceland and 30 foreign locations.

The probability of precipitation (PoP) in 24h is also predicted at 11 locations with a generalized linear model, from T+24h to T+120h, using input information from ECMWF 12 UTC run.

Quantitative precipitation forecast (QPF) maps are also derived by statistical downscaling of ECMWF 00 and 12 UTC precipitation forecasts, using high resolution climatic precipitation maps taking into account the terrain complexity. These QPF 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 used operationally at IMO, with horizontal resolutions of 9 and 3 km is using boundaries from ECMWF.

2.1.3 Derived fields

2. Use of products

During wintertime, the medium range forecasts are used to assess the risk of weather conditions that could lead to avalanches.

The QPF maps are used to assess the rainfall triggered landslide risk by comparison to a critical value that depends on the accumulation time and the mean annual precipitation.

3. Verification of products

3.1 Objective verification

A routine verification, updated daily, monitors the performances of two-metre temperature and ten-metre wind-speed forecasts valid from T+12 to T+48 over the last 7 days, at all stations where local forecasts are produced automatically. A more detailed verification procedure including also precipitation and surface pressure is run quarterly and annually for forecasts valid up to T+168. Around 40 stations are concerned for precipitation and 45 for surface pressure. Scatter plots and various statistical scores are plotted individually for each verified location, and the results can be consulted internally on a web page.

Local precipitation forecasts are difficult to verify quantitatively because of measurement errors affecting the rain-gauge data such as wind-loss, wetting and evaporation. These measurement errors are not corrected operationally, and the verification is made against uncorrected raingauge data, for precipitation accumulated in 24h or longer.

3.1.1 Direct ECMWF model output

Local two-metre temperature forecasts exhibit systematic errors at a large number of sites, resulting mainly from discrepancies between model and real orography. Underestimation of 10-metre wind-speed predominates inland, while along the coast, the forecasts tend to exhibit a positive bias.

A comparison of statistical scores (mean error and mean absolute error) averaged over all stations, was made between 2005 and 2006 for two-metre temperature and ten-metre wind-speed forecasts (Figures 1 and 2). Results indicate that no major difference exists between the 00 and 12 UTC model runs. The diurnal temperature variation is not always well predicted, and forecasts valid at noon often exhibit a colder bias than those valid at midnight. It also appears that two-metre temperature forecast has become more biased in averaged in 2006, towards colder values. The number of sites for which the bias has degraded reaches 60 to 70% of the verified locations beyond T+72. The scores for ten-metre wind-speed are quite similar between model runs and a slight improvement in quality is observed from 2005 to 2006, with 2006 being less biased at about 60% of locations.

Results from 3 stations located on Reykjanes peninsula, SW Iceland (see Figure 3) illustrate how different the quality of precipitation forecast can be, depending on the topographic environment of the station under consideration (Figures 4 to 6). The verified period is June to August 2006 and the forecast ranges are T+72 and T+96. Reykjavík (WMO=4030) is located on the northern (lee) side of a large mountain range and the forecast systematically overestimates precipitation (Figure 4). Hellisskard (WMO=4862) is located 26 km from Reykjavík, on the southern side of the same mountain range exposed to the dominating south and south-easterly winds, and is subject to orographic enhancement. The forecast mainly underestimates the largest precipitation amounts (Figure 5). Finally, the forecast for Keflavík airport (WMO=4018), located in an open area, 34 km from Reykjavík, is relatively unbiased (Figure 6). Similar features are observed at other sites, according to location.

The probability of detection (POD) for precipitation accumulated in 24h decreases with the forecast range but is usually above 80% at the verified sites, in average during the year 2006. The false alarm ratio (FAR) varies from 10% to 50% during the year 2006, depending on location and forecast range.

3.1.2 ECMWF model output compared to other NWP models

Local ECMWF and HIRLAM two-metre temperature and ten-metre wind speed forecasts are routinely compared at all sites for which an automatic forecast is issued, as part of our daily monitoring procedure. These comparisons apply to both DMO and Kalman filtered predictions. The comparisons include time series plots and error statistics. A set of maps showing the model giving the best prediction over the last five days, at each of the verified locations is also published daily. The criterion used to define the best prediction is simply the model whose prediction is more often closest to the observation.

3.1.3 Post-processed products

Kalman filtering

The Kalman filtering (KF) procedure removes efficiently systematic errors, but these predictions are not better than the DMO at locations where there are no systematic errors. The prediction intervals derived from the KF procedure are usually reliable at all ranges and most locations, making the use of this information useful to assess the prediction uncertainty, even at sites where there are no systematic errors. Figure 7 presents the annual statistical scores obtained in 2006 for two-metre temperature forecast in Egilsstadir (WMO=4191), an inland station located in eastern Iceland and surrounded by mountains. The scores are the mean error (forecast - observation), mean absolute error, root mean squared error, standard-deviation of error, and a score giving the percentage of cases where the Kalman filtered forecast is closest to the observation than the DMO. The systematic underestimation is well corrected at all forecast ranges. Figure 8 presents similar scores obtained for ten-metre wind-speed forecast in Hveravellir (WMO=4156). Similarly, the systematic underestimation is well corrected at all forecast ranges.

Probability of Precipitation (PoP) in 24h.

The verification indicates that the PoP is usually reliable at most forecast ranges and sites where it is estimated. The area under the ROC curve is usually greater than 0.7. Figure 9 presents an example of verification statistics obtained in 2006 for Stykkishólmur (WMO=4013), a coastal station located in western Iceland.

3.1.4 End products delivered to users

See 3.1.1 for precipitation and 3.1.3 for two-metre temperature and 10-metre wind-speed.

3.2 Subjective verification

3.2.1 Subjective scores

3.2.2 Synoptic studies

4. References

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

Crochet, P., 2004: Adaptive Kalman Filtering of two-metre temperature and ten-metre wind-speed forecasts in Iceland. *Meteorol. Appl.* **11**, 173-187.

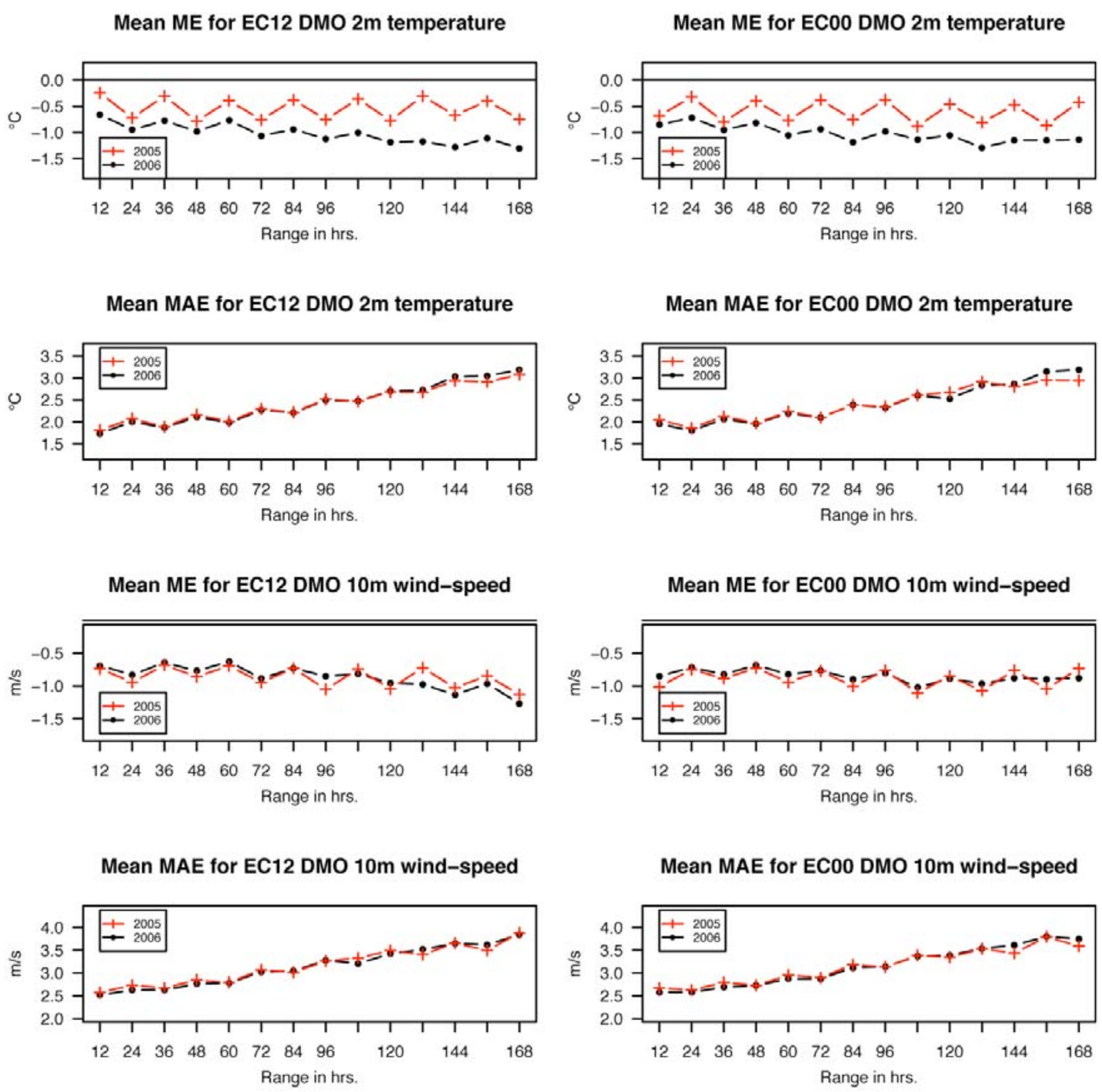

Fig. 1 ECMWF 00 12 UTC 2m temperature and 10m wind-speed DMO: Mean error (forecast –observation) and mean absolute error averaged over all stations in 2005 and 2006.

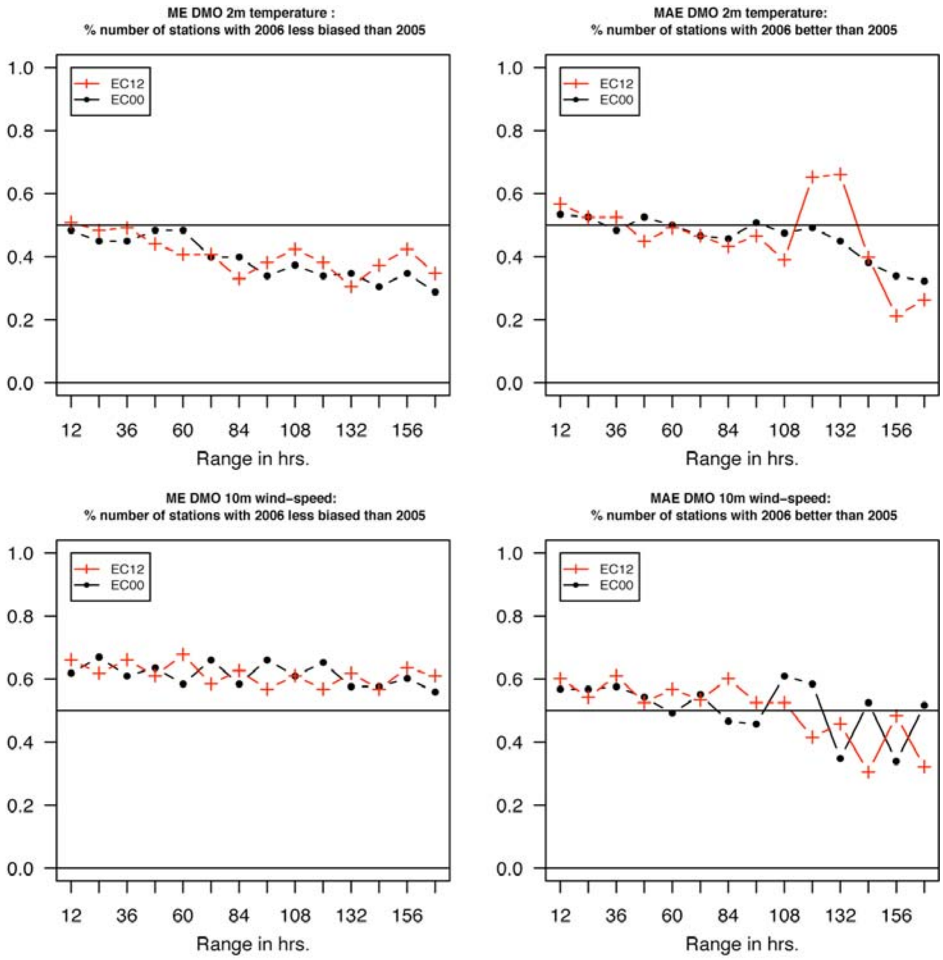

Fig. 2 ECMWF 00 and 12 UTC 2m temperature and 10m wind-speed DMO: Percentage number of stations with 2006 better than 2005, for mean error and mean absolute error.

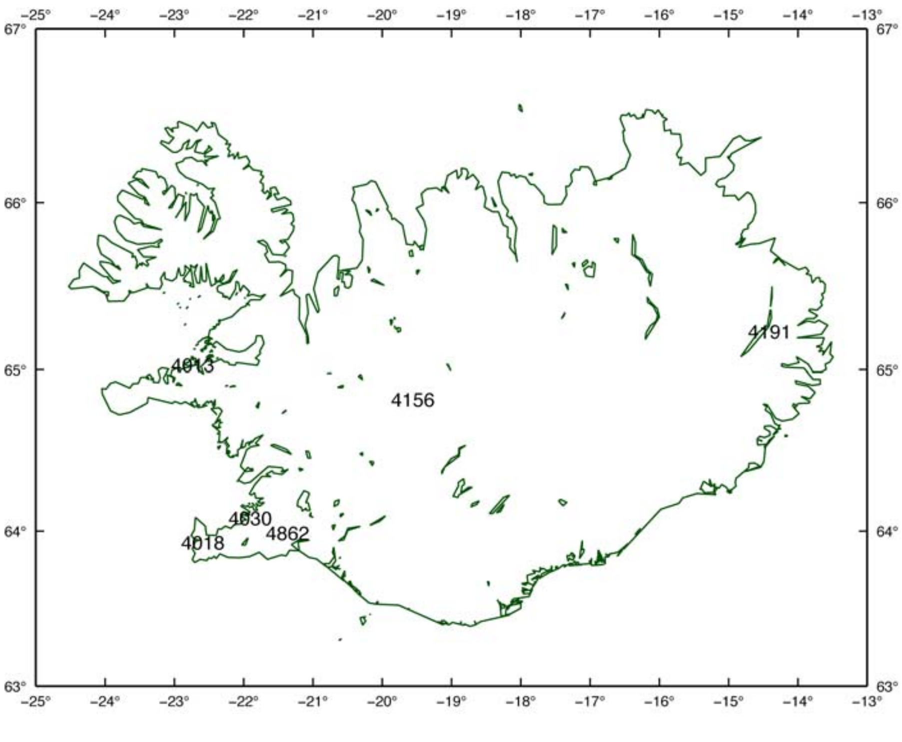

Fig. 3 Stations

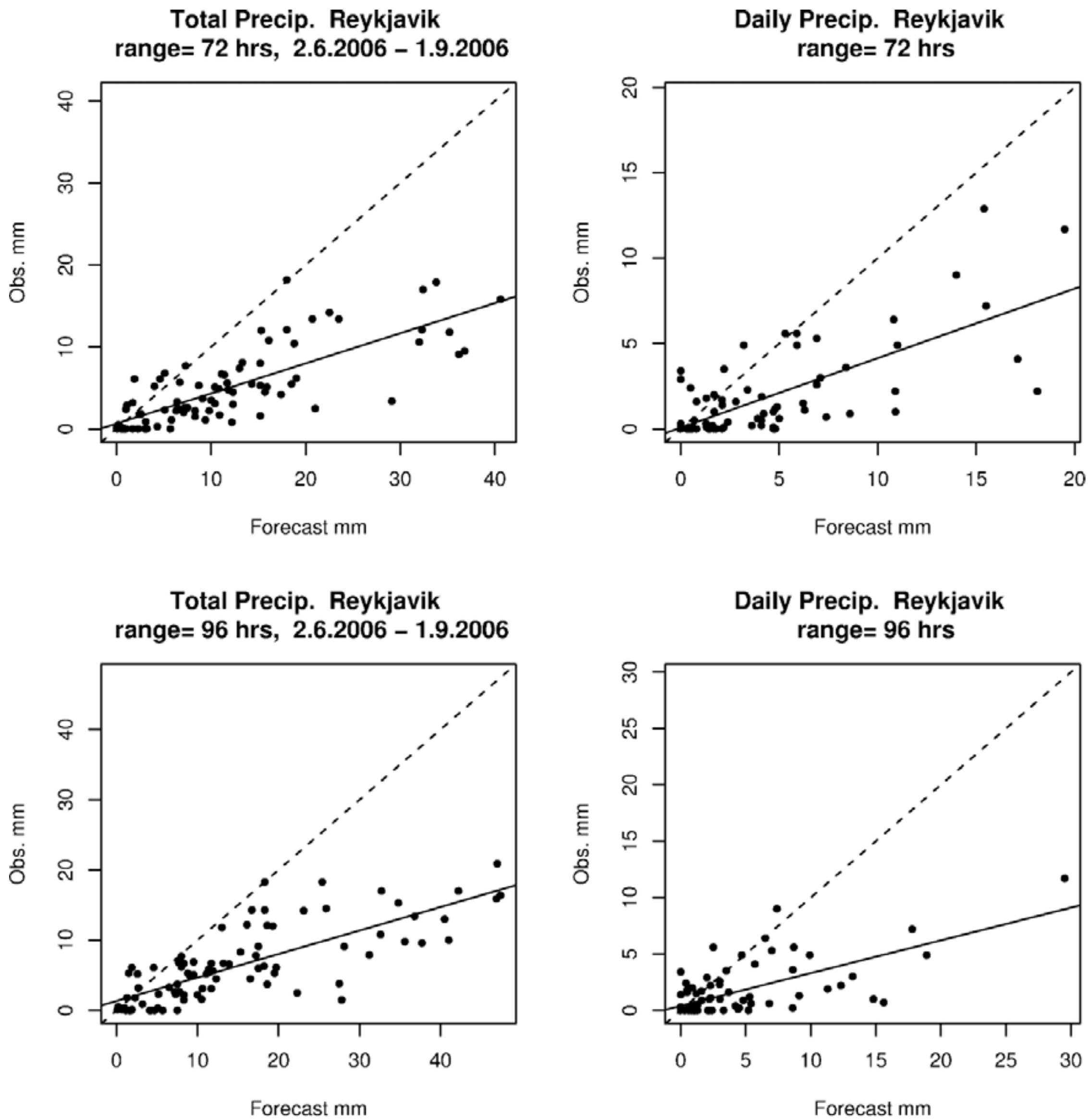

Fig. 4 ECMWF 12 UTC T+72 and T+96 precipitation forecasts in June-August 2006 for Reykjavík: D1-3, D1-4 and daily accumulated precipitation.

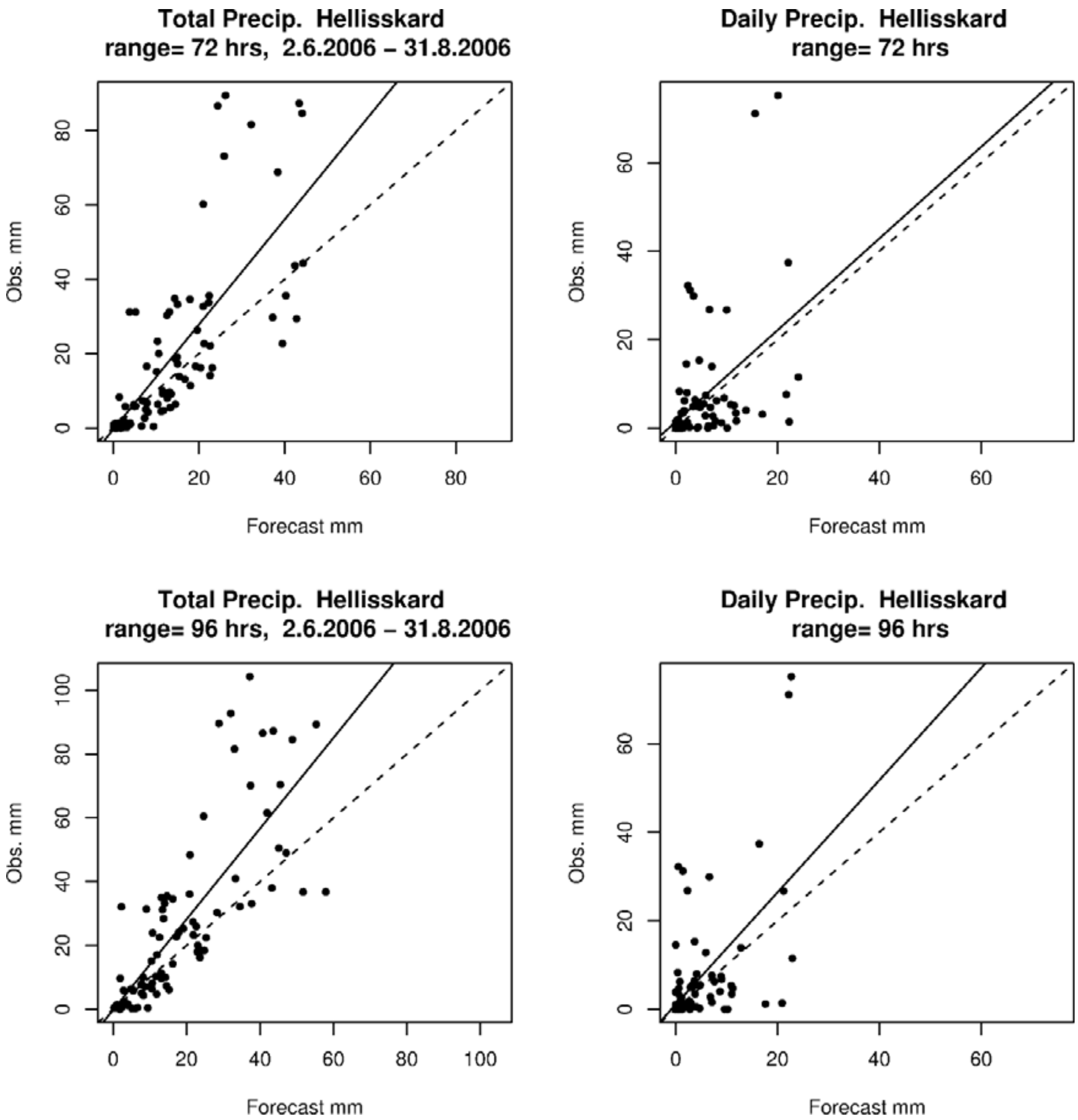

Fig. 5 Same as figure 4 for Hellisskard.

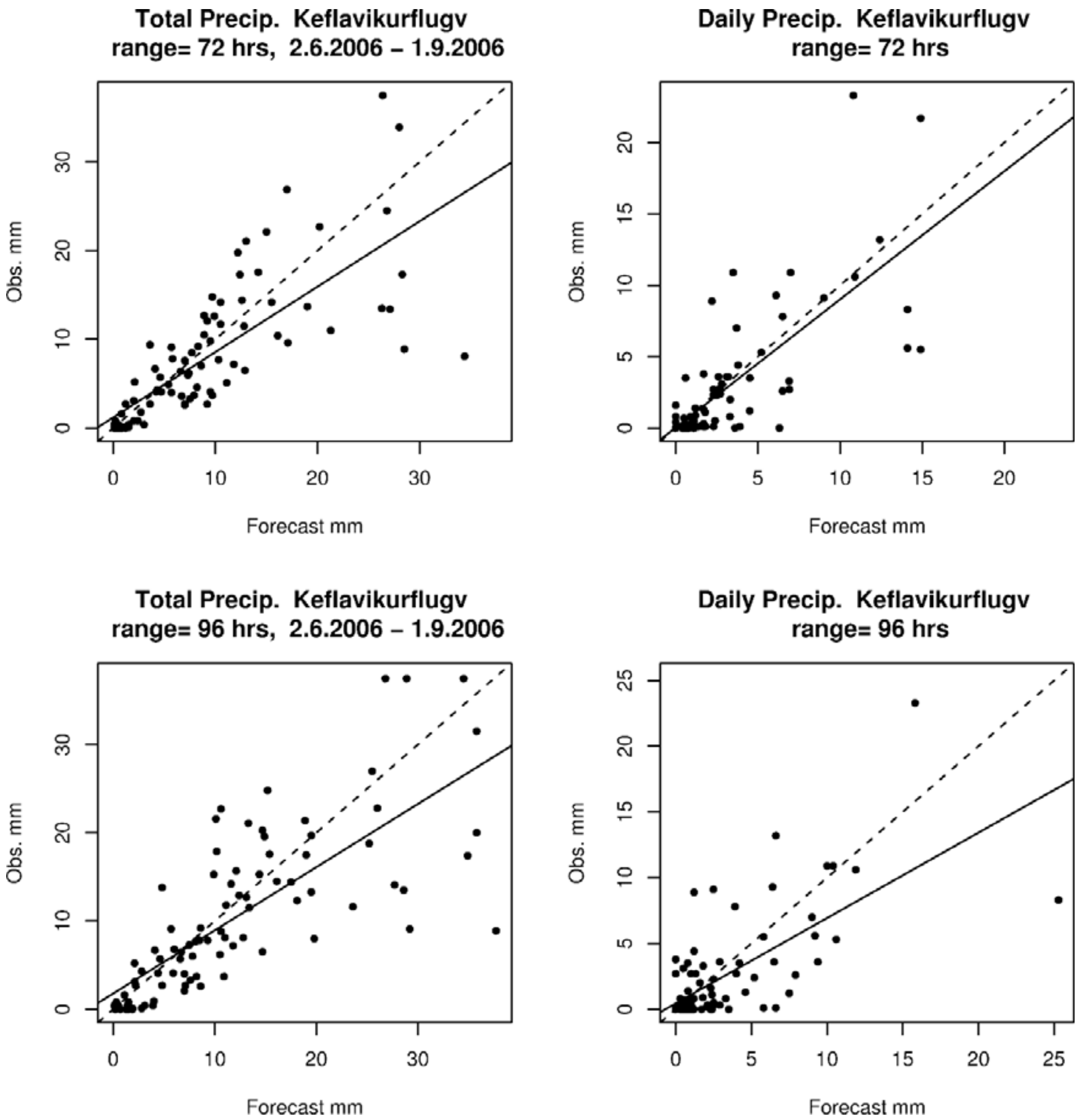

Fig. 6 Same as figure 4 for Keflavík airport.

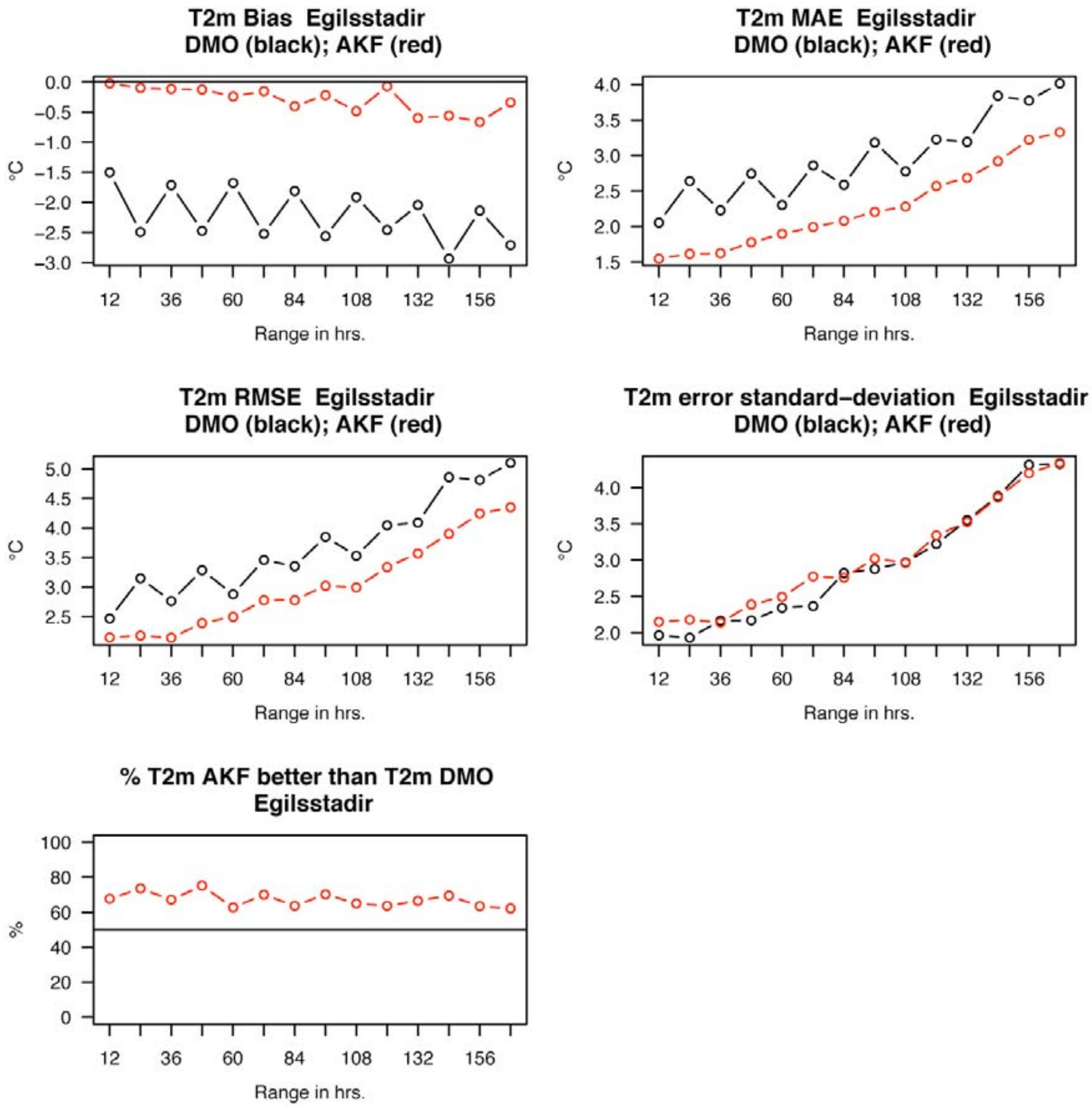

Fig. 7 Statistical scores obtained in 2006 for ECMWF 12 UTC DMO and KF 2m temperature forecasts in Egilsstadir.

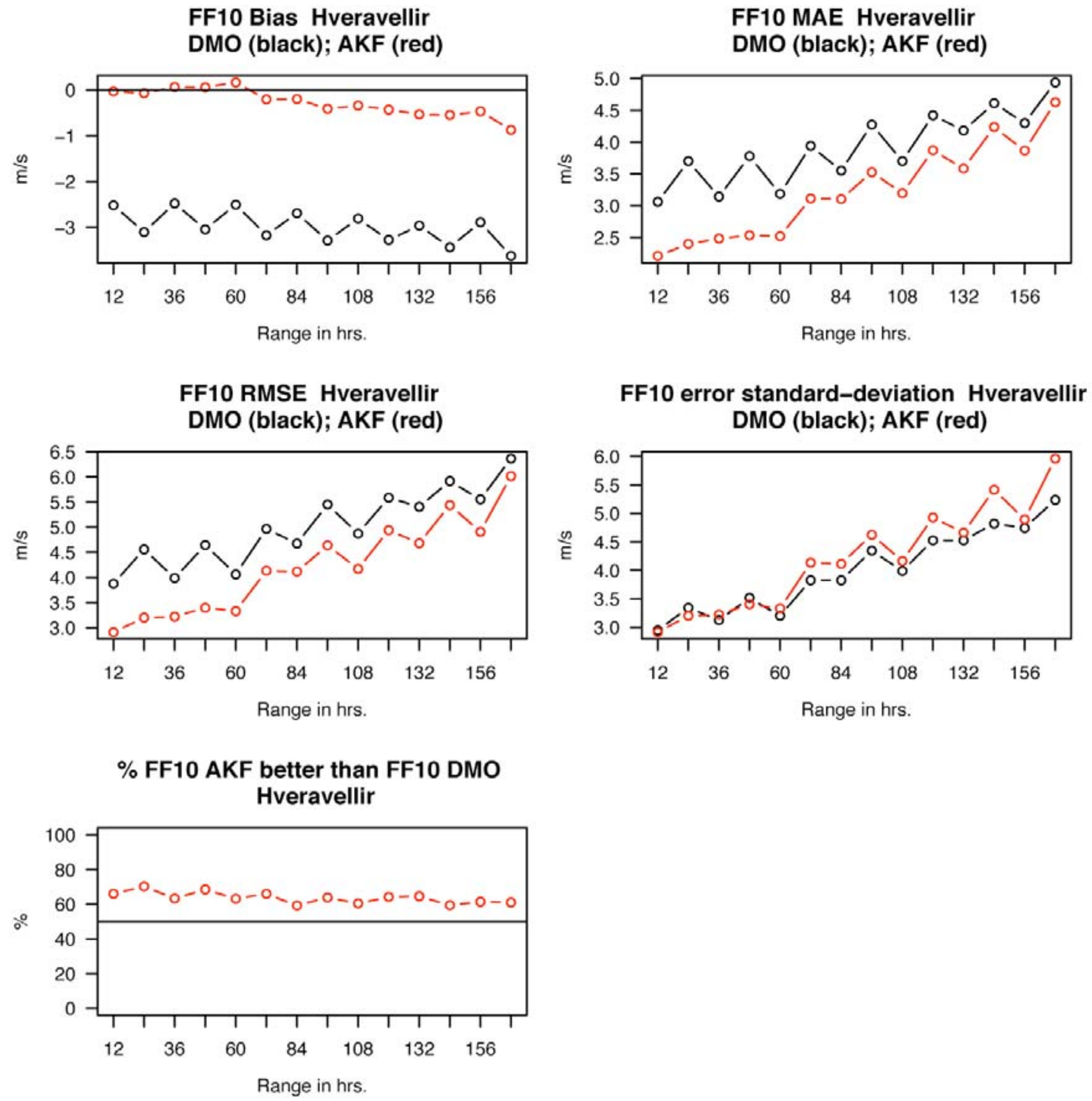

Fig. 8 Statistical scores obtained in 2006 for ECMWF 12 UTC DMO and KF 10m wind-speed forecasts in Hveravellir.

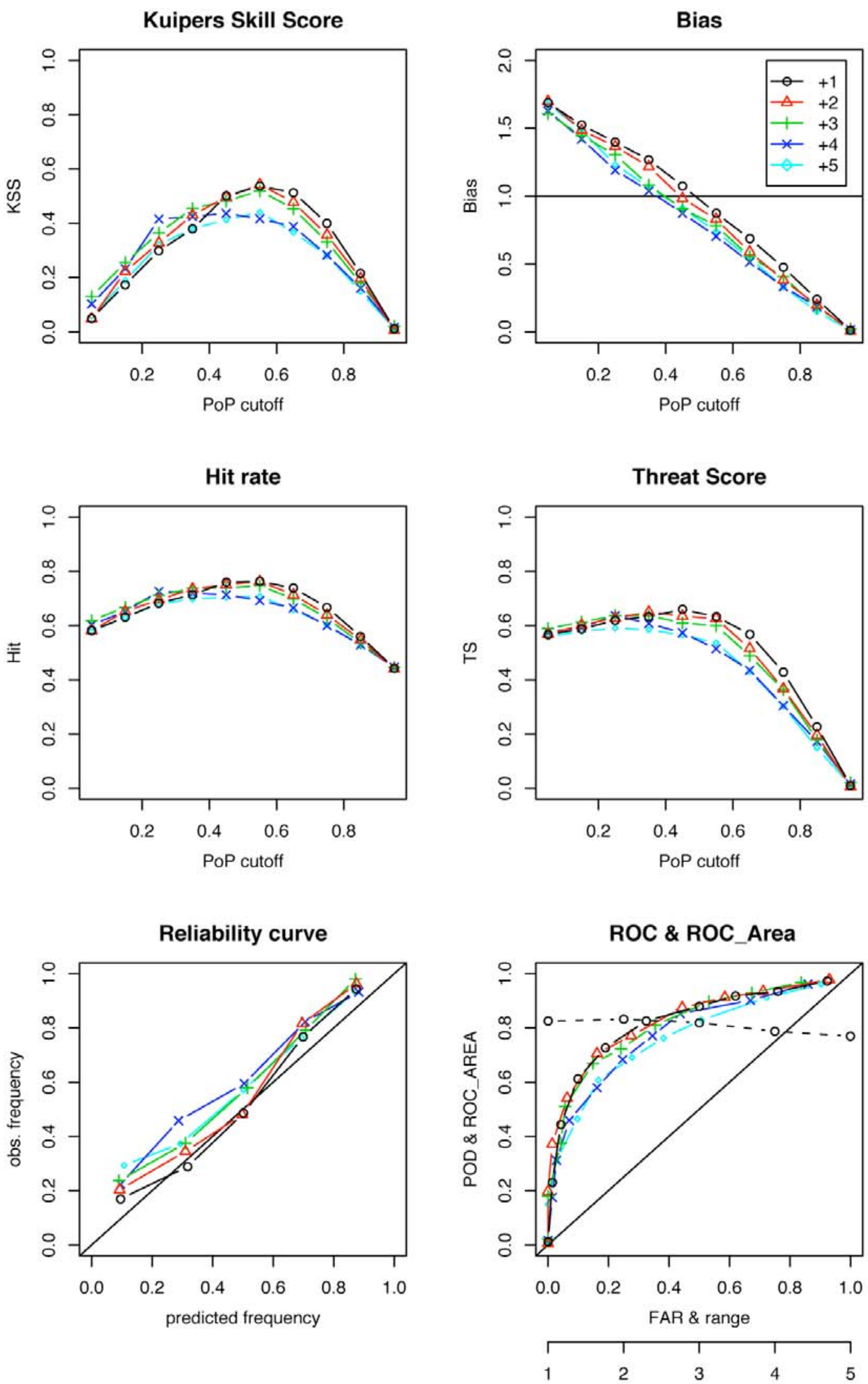

Fig. 9 Stykkishólmur: Statistical scores obtained for PoP in 2006, using input from ECMWF 12 UTC run.