Application and verification of ECMWF products 2012

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1. Summary of major highlights

At Croatian national meteorological service, ECMWF products are regarded as the most important source of information in the operational weather forecast, especially for medium- and long-range forecasts. For several years our service provides long range forecasts as end products: a monthly (4 week) forecast, based on direct model output by ECMWF, as well as a 3-month forecast, based on ECMWF seasonal forecast. In the recent years the emphasis of this paper is on long term forecasts verification.

Regular verification is traditionally done by the point-to-point method, with synop data verified against nearest grid point of the model. Parameters mostly verified are 2m-temperature and precipitation.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

Introduction of Kalman filter of 2m-temperature is in development phase.

2.1.2 Physical adaptation

Including limited-area models, hydrological models, dispersion models etc. using ECMWF model data as input

2.1.3 Derived fields

Including post-processing of EPS output e.g. clustering, probabilities

2.2 Use of products

In the operational duties, ECMWF products are widely used, particularly for medium and long range forecasts. For short range forecasts, the emphasis is put to the high resolution model (ALADIN). This is especially pronounced for severe weather and warnings

For medium range, significance of ensemble approach is constantly increasing.

For long range, ECMWF forecasts are practically the only source. Furthermore, monthly and seasonal forecasts, issued regularly at our service, are based on ECMWF direct model output, with the description and comment of the forecaster

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

No relevant verification is carried out for medium range ensemble forecasts.

Deterministic medium range forecasts are verified regularly, particularly for temperature and precipitation. Since the results for this verification are similar to those from past years, they will be presented briefly in this paper.

Figure 1 presents some verification scores (Wilks, 2011) for maximum 2m-temperature forecast. Bias (forecast-observed), mean absolute error, skill (against climatology forecast) and skill for different seasons are compared to years 2010 and 2009. A pronounced negative bias (underforecasting) is usually found. For mean absolute error, results exhibit somewhat less accuracy for last year, compared to 2009 and 2010. Still, if skill is defined with respect to climatology forecast, skill for 2011 can be regarded as comparable to previous years. If divided by seasons, results for summer and winter show betters skill than those for spring and autumn.

Same calculations are carried out for 00 UTC run, and for minimum 2m-temperature forecast as well.

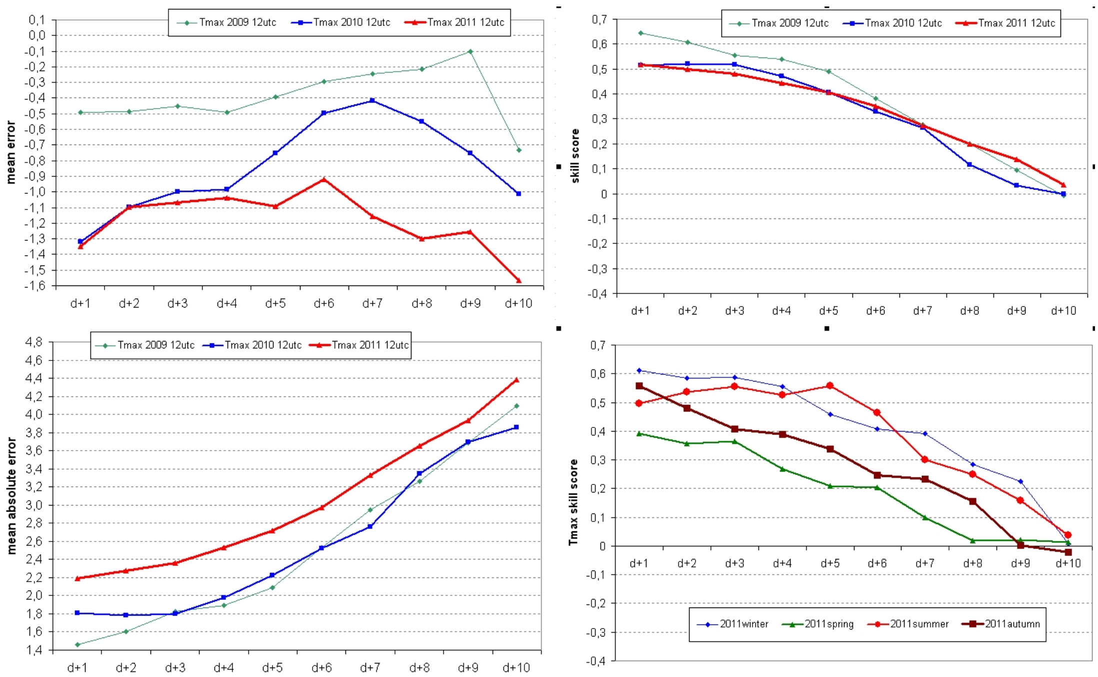

Figure 1 Verification scores for maximum 2m-temperature ECMWF forecast, 12 UTC run, for station Zagreb Maksimir (12240): mean error (upper left), mean absolute error (lower left), skill against 1961-1990 climatology forecast (upper right) and skill according to seasons (lower right)

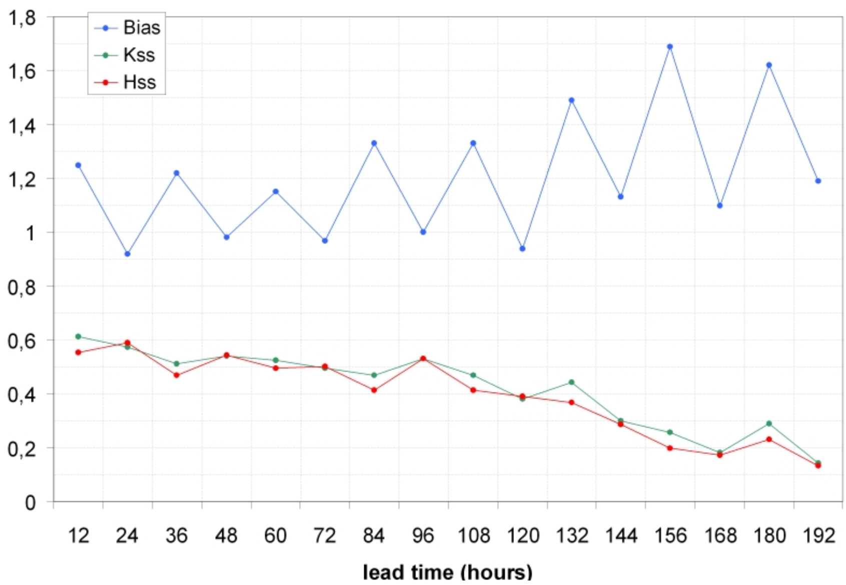

Figure 2 Verification scores for ECMWF 12-hour precipitation for station Zagreb Maksimir (14240). Bias, Hansen-Kuipers skill score and Heidke skill score are displayed.

Figure 2 gives an example of precipitation verification results. Bias of 12-hour precipitation forecast is calculated throughout the forecasting period. In the last decade a significant overestimation of precipitation has been regularly noticed (overforecasting). However, compared to previous years, bias for year 2011 is significantly reduced, and approaches much closer to ideal value 1. A significant daily variation of bias (forenoon and afternoon) is also pronounced, and this is a well known feature of the ECMWF model forecast.

For the same forecast, skill is also calculated, employing Hansen Kuipers skill score for different lead times. Degradation of the skill can be perceived, typically approaching zero values for range between day 7 and day 10.

An extensive verification is carried out also for long range forecasts;

For monthly (4 weeks) forecast, comparison of forecasted and observed mean weekly temperatures is displayed in pictures bellow. Mean error (ME) and mean absolute error (MAE) are calculated. According to ME, a general underestimation of temperature can be observed on Figure 3 (blue lines). Furthermore, mean error is the largest for week 1, and for weeks 2,3 and 4 oscillates around around -0.5 °C. However, according to mean absolute error, the accuracy of the forecasts is decreasing with respect to lead time.

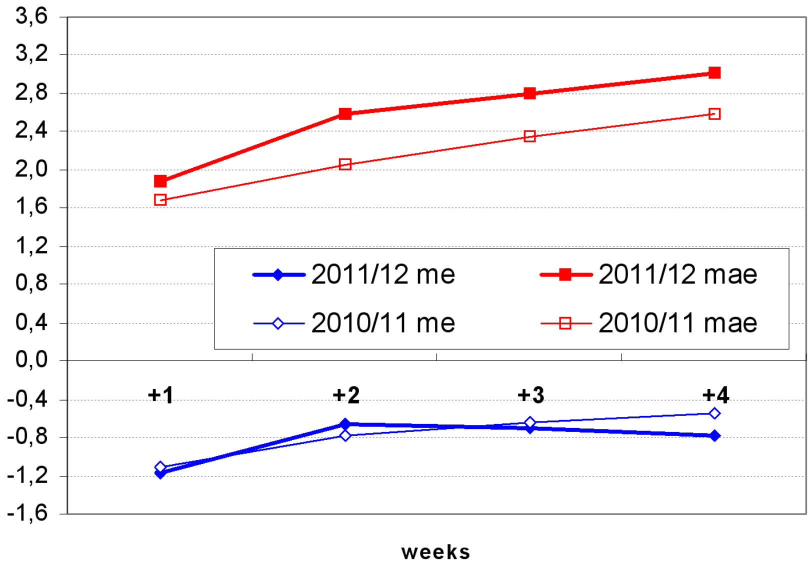

Figure 3 Mean error (ME) and mean absolute error (MAE) of mean weekly 2m-temperature forecast (ECMWF monthly forecast system) for period from 1st July 2010 to 30th June 2011, and for period from 1st July 2011 to 30th June 2012 (station Zagreb Maksimir)

Still, the skill of the forecasts (verified against climatology as reference) is constantly decreasing, with positive skill for week 1 and 2, some skill for week 3, and low or negative skill for week 4 (Figure 4). It is interesting to point that the results are better when the reference climatology period is 1961-1990 rather than 1981-2010. This is probably due to very warm last two decades.

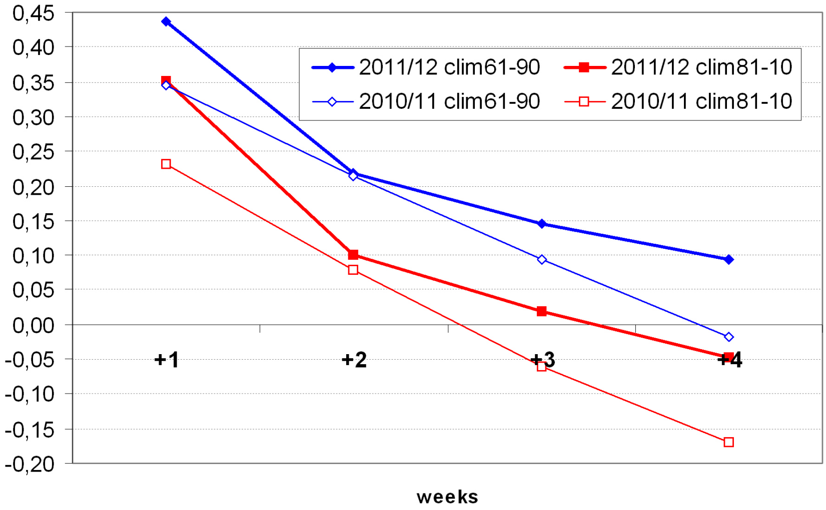

Figure 4 Skill of ECMWF monthly forecast for mean weekly 2m-temperature forecast for period from 1st July 2010 to 30th June 2011, and for period from 1st July 2011 to 30th June 2012 (station Zagreb Maksimir)

Seasonal forecast is also a very important product, and it is based on direct model output of ECMWF seasonal forecasting system. General features of verification (mostly done for temperature) such as relatively low variation of forecasts, compared to observed data ("low signal"), and general underestimation of temperature ("too cold") were described in previous reports. Figure 5 presents mean absolute error of forecasted monthly temperature anomalies (based on two different climatological periods), depending on forecast range (from month+1 to month+6). Unlike last year, when there was no significant change of error through the whole forecasting period, a continuous degradation of the score can be observed. Scores based on climatological period 1961-1990 seem to be more valuable than for 1981-2005 period.

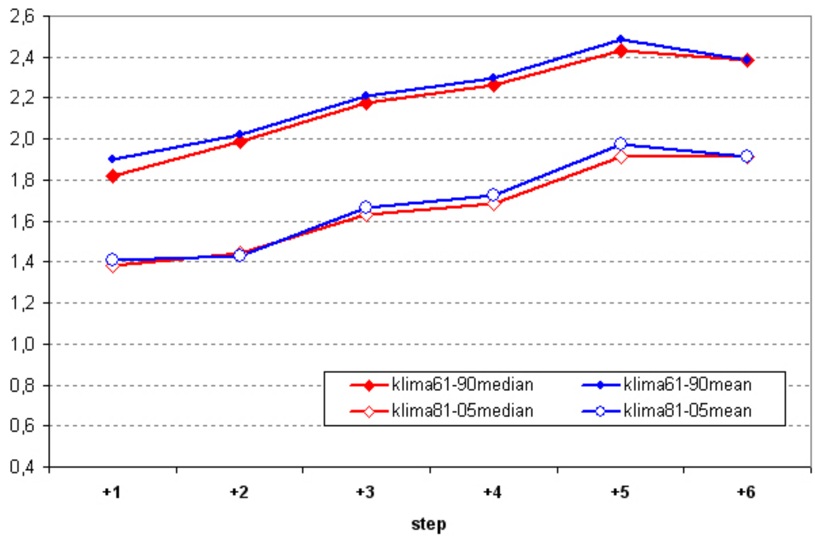

Figure 5 Mean absolute error of monthly temperature anomaly (ECMWF monthly forecast system) for year 2011 (station Zagreb Maksimir), with respect to different forecast range (month+1 to month+6)

Scores can be also presented in terms of the skill (Figure 6) and exhibit significantly better results than for year 2010. Compared to climatology reference, forecast for month+2 seems to have the best skill. It then degrades up to month+5, and for month+6 it slightly improves. Furthermore, results with respect to 1981-2005 climatological period give somewhat better results than for 1961-1990 climatological period.

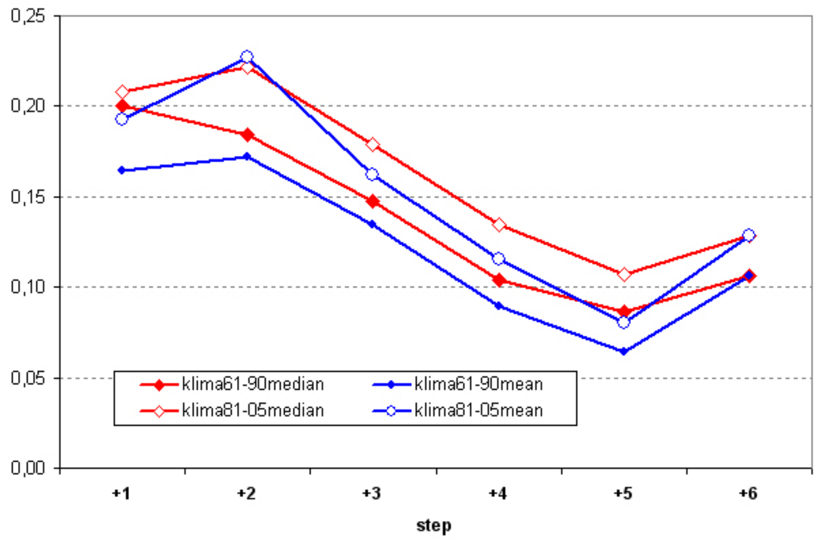

Figure 6 Skill of monthly temperature anomaly forecast (ECMWF monthly forecast system)) for year 2011 (station Zagreb Maksimir), with respect to different forecast range (month+1 to month+6).

3.1.2 ECMWF model output compared to other NWP models

ECMWF forecasts are occasionally verified against other models, usually against Aladin Croatia limited area model (ALARO). Skill of the ECMWF model over Croatia is generally found to be comparable to that of the Aladin model (see previous reports).

Additionally, an operational real time daily and monthly verification is established for maximum and minimum 2m-temperature forecast. Aladin, ECMWF and final forecaster's prediction are compared to observed value, and basic scores are calculated. Figure 7 demonstrates an interesting example for maximum temperature forecast in November 2011. A relatively poor skill of ECMWF forecast (overforecasting) can be observed in the second half of the month, characterized by stable synoptic situations with extended fog. This is not a unknown feature of the model. It is interesting to analyze also the behaviour of the forecasters: after massive error at the beginning of the episode (17th), they started to predict lower temperatures, closer to Aladin forecasts, but still with a significant positive bias. However, in the second episode (28th), fog actually broke, so maximum temperature rose high above the prediction.

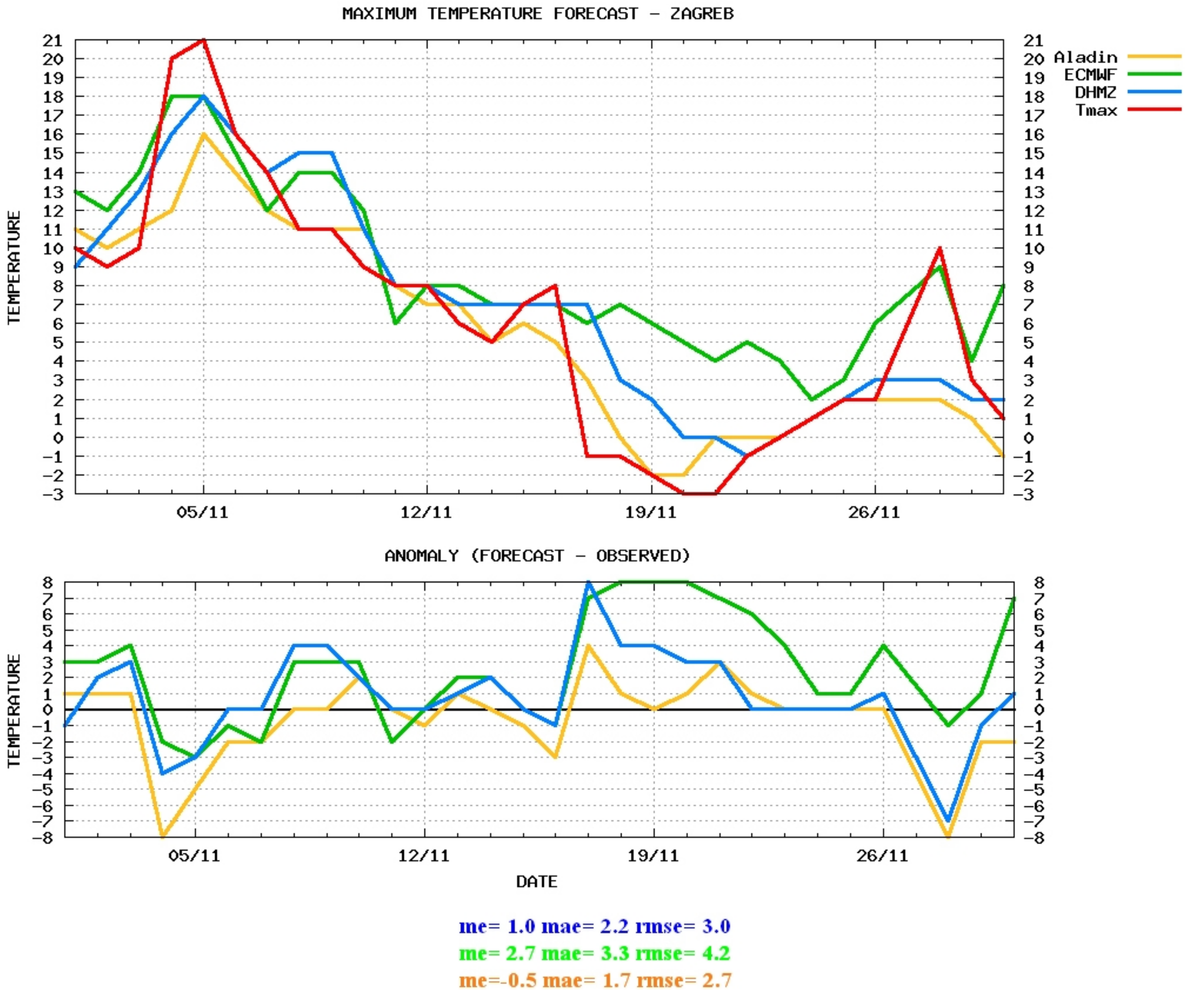

Figure 7 Maximum 2m-temperature forecast (for the following day) for station Zagreb Maksimir (14240) in November 2011. Aladin (yellow line), ECMWF (green line), forecasters prediction (blue line) and observed temperature (red line) are displayed. Mean error (me), mean absolute error (mae) and root mean square error (rmse) are calculated.

3.1.3 Post-processed products

No direct post-processed products have been delivered so far (Kalman filter, MOS etc.).

However, an attempt to use ECMWF precipitation forecast have been made recently for drought prediction. For the purpose of drought monitoring and in-time warning various indices are used to quantify and compare drought information. In this study the possibility of drought forecast in Croatia is tested employing the Standardized Precipitation Index SPI (McKee et al, 2005). SPI forecast is calculated at time scale from 1 day to 6 months, for several stations in Croatia, representing different climate regions. Preliminary results exhibit good correlation between forecasted and observed SPI indices (Cindrić and Kalin, 2011). Two examples are shown bellow (Figure 8): left panel presents SPI forecast for 1 month, based on combination of 21 past days and 9 days in the future, employing ECMWF medium-range precipitation forecast. Basic verification scores (ME, MAE, RMSE) confirm good performance of such forecast.

Right panel of Figure 8 presents SPI forecast on the 3-monthly scale. SPI prediction is calculated as combination of 2 past months and 1 month in the future, employing ECMWF seasonal forecast. The performance of such forecast can also be regarded as valuable, although some extreme events have been missed.

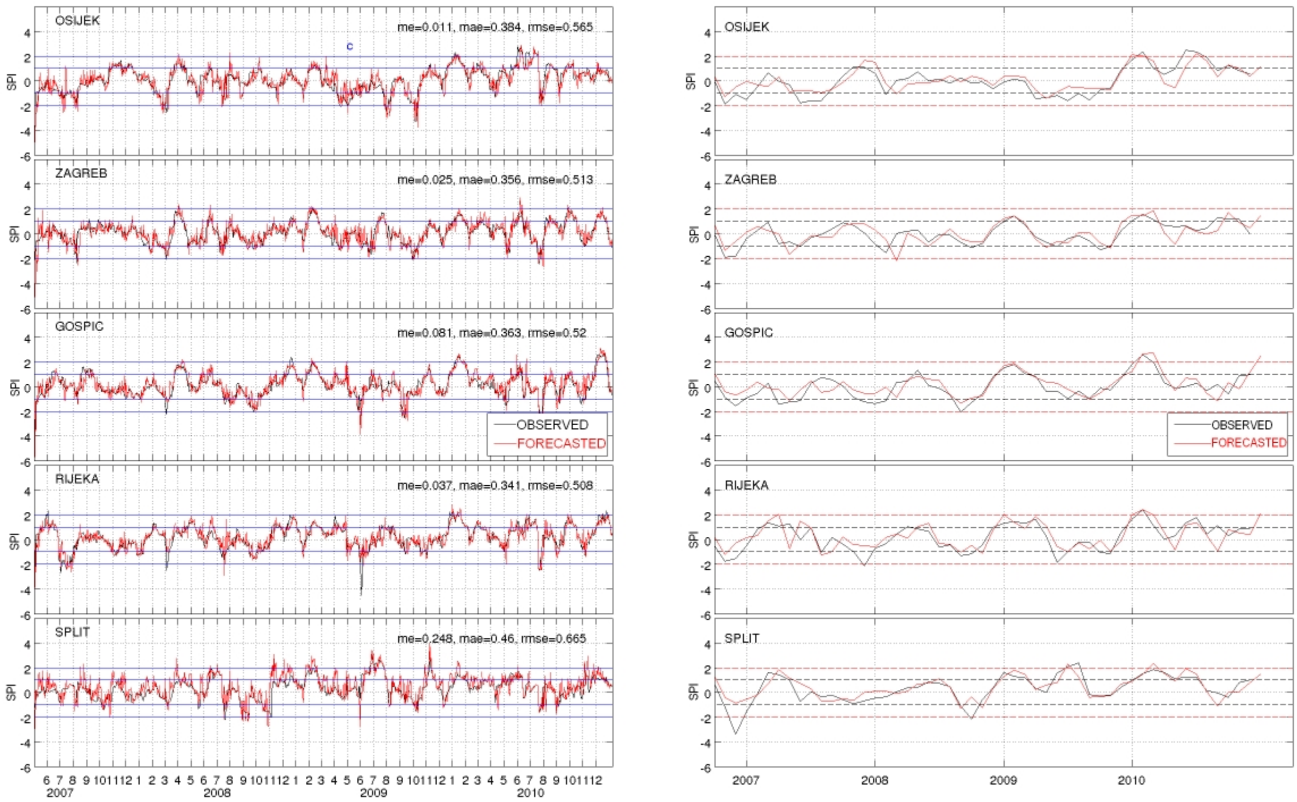

Figure 8 Prediction of Standardized Precipitation Index compared to observed results, for 5 representative stations (Osijek, Zagreb, Gospić, Rijeka, Split), for period 2007-2010. In the left panel, 1-month SPI is calculated as combination of 21 past days and 9 days with ECMWF medium range precipitation forecast. In the right panel 3-month SPI is calculated as combination of 2 past months and 1 future month using ECMWF seasonal forecast. Negative SPI exhibits dry, and positive exhibits wet conditions.

Monthly and multi-monthly SPI prediction calculated on exclusively ECMWF long range precipitation forecast exhibit significantly worse results, not being able to predict any extreme events. This is probably partly due to the use of ensemble mean/median, so for the future operational drought forecast a probabilistic approach should be considered, using all ensemble members.

3.1.4 End products delivered to users

Seasonal and monthly forecasts delivered to users are derived from ECMWF direct model output. See section 3.1.1.

3.2 Subjective verification

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

3.2.2 Synoptic studies

Subjective verification of ECMWF forecasts is done only occasionally, usually through individual studies, but no systematic verification has been carried out. For some general subjective remarks see previous reports.

4. References to relevant publications

(Copies of relevant internal papers may be attached)

Cindrić, K., Kalin, L., 2011: Drought forecasting in Croatia using Standardised Precipitation Index. *EMS Annual Meeting Abstracts / EMS (ed)*, Berlin

McKee, T.B., Doeksen, N.J and **C. Jones**, 2005: The relationship of drought frequency and duration on time scales, *Proceedings of the 8th conference of applied climatology (ed. C.A. Anaheim)*, 179-184, American Meteorology Society, Boston MA.

Wilks, D.S., 2011: Statistical methods in the atmospheric sciences. Third edition. Academic Press, London