Application and verification of ECMWF products 2011

INSTITUTO DE METEOROLOGIA, I.P. – edited by João Rio

1. Summary of major highlights

ECMWF products are used as the main source of data for operational weather forecasting. In the short-range these forecasts are used along with the ones provided by the ALADIN forecasting system (ALADIN, ALARO and AROME).

A significant update to MOS and KALMAN forecasts was done to improve minimum and maximum temperatures. Results show that a simple combination of MOS and KALMAN forecasts from different models improves the quality of the forecasts.

Validation of forecasts from ECMWF against Limited Area Models (LAM) forecasts is done operationally. Some results for the period between 2007 and 2011 are shown.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

A new application for MOS and KALMAN forecasts was developed and applied to minimum and maximum temperatures. The verification of this forecasts show a clear improvement of the statistical approach over direct model output. The new system computes, for each location and forecast day (up to 72 hours, whenever available), MOS and KALMAN forecasts for three models: ECMWF, ALADIN and AROME. The final forecast is then computed as the average value of all the 6 forecasts (3 MOS and 3 KALMAN) and provides the best results as shown in chapter 3.

2.1.2 Physical adaptation

An ALADIN LAM-EPS system is run using LBC and IC provided by the ECMWF's ensemble members. The system runs daily at the ECMWF's c1a machine and results are sent to IM-Portugal headquarters. The forecasts have a resolution of 11 km and are run for 60 hours.

A calibration of the LAM-EPS runs operationally every Thursday with the last 18 years and a moving time window of 5 weeks. This allows to access the LAM-EPS climatology and to perform a bias correction of several parameters, namely the 2 meter temperature and precipitation on a daily basis which is available to the forecasters.

ECMWF model forecasts are used as the input for the sea-wave model MAR3G. The model is run once a day up to H+120h, with a 6h time step. A ray model is then used to transform waves from the open seas to near-shore. ECMWF forecasts are also used in a trajectory model, in cooperation with the Environment Institute.

2.1.3 Derived fields

The deterministic forecast from ECMWF is used daily to produce the post-processed fields (*e.g.* thermal frontal parameter and Q-vector convergence, temperature advection at 850 hPa, vorticity advection at 500 hPa, Total-Totals and Jefferson indices). Several other indices (*e.g.* Lifted Index) are computed and tephigrams are plotted for selected locations in Portugal.

2.2 Use of products

Apart from the deterministic forecasts, in the short and medium range, many of the products derived from the ensemble forecasting are used daily and considered to be very beneficial.

The ECMWF monthly forecast is used to produce a weekly bulletin with forecasts on the 2 meter air temperature and precipitation for Continental Portugal for the 4 weeks of forecast. The bulletin is made available for external clients on a regular basis, including civil protection authorities. Every week, a draft on the evolution of the anomaly signal of every specific week is performed internally.

The ECMWF seasonal forecast is used to produce a monthly bulletin with forecasts on the 2 meter air temperature and precipitation for Continental Portugal for the 4 trimesters of forecast. This bulletin is made available for external clients if requested, including civil protection authorities. Every month, a draft on the evolution of the anomaly signal of every specific trimester is performed internally. The anomaly signal for the EUROSIP seasonal forecast is also evaluated.

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

Figures 1 and 2 show the RMSE of the 10m wind speed in Summer 2010 and in Winter 2010/11 for ECMWF's forecasts, with a post-processing resolution of 16 (ATP_160) and 25 km (IBER_25). The scores were computed for the 00UTC run and the number of weather stations used was 80.

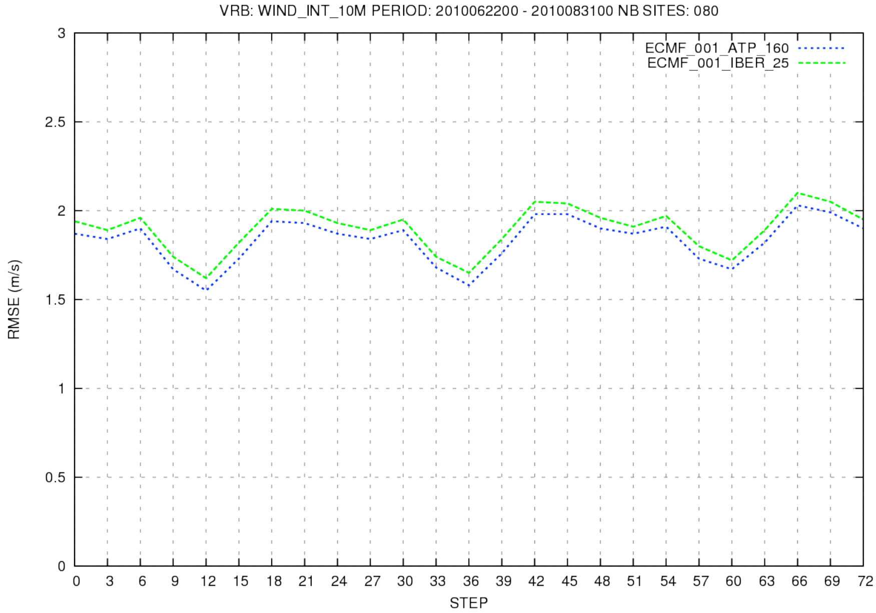

Figure 1 RMSE of the 10m wind speed in Summer 2010, with a post-processing resolution of 16 (ATP_160) and 25 km (IBER_25).

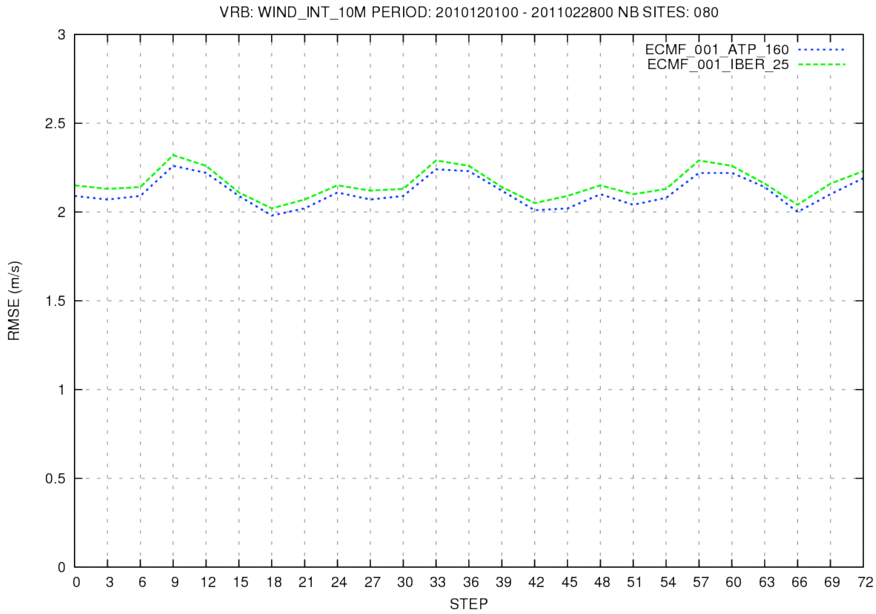

Figure 2 RMSE of the 10m wind speed in Winter 2010/11, with a post-processing resolution of 16 (ATP_160) and 25 km (IBER_25).

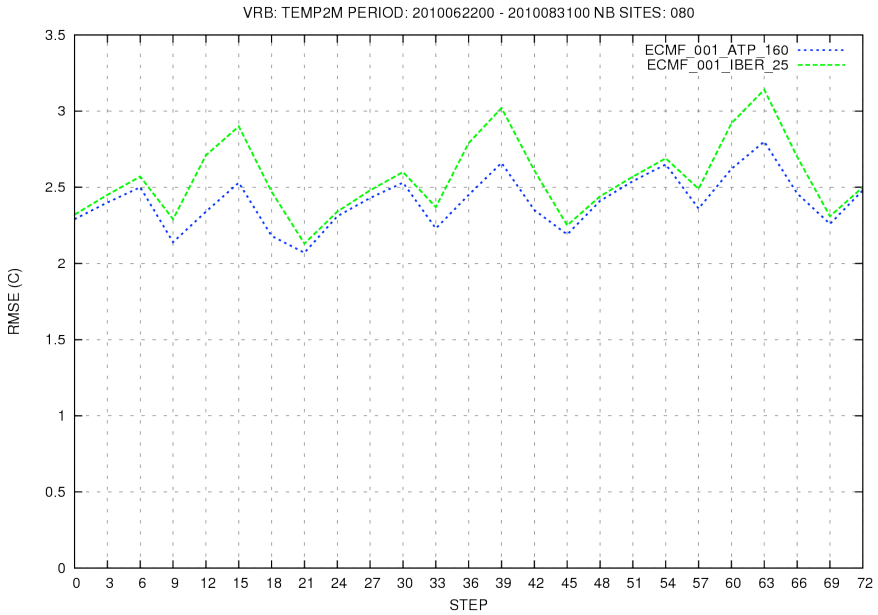

Figure 3 RMSE of the 2m temperature in Summer 2010, with a post-processing resolution of 16 (ATP_160) and 25 km (IBER_25).

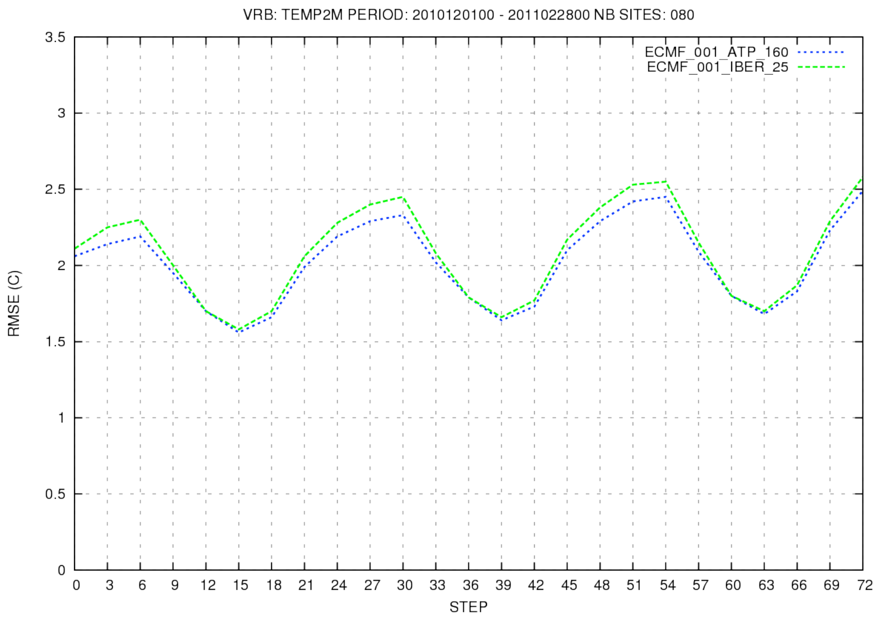

Figure 4 RMSE of the 2m temperature in Winter 2010/11, with a post-processing resolution of 16 (ATP_160) and 25 km (IBER_25).

Even though the model is run at the resolution of 16 km, figures 1 to 4 show that verification scores can vary due to the resolution of the post-processing. The differences are slightly larger in Summer than in Winter, this being a feature also seen is other variables such as precipitation and relative humidity (not shown).

3.1.2 ECMWF model output compared to other NWP models

Figures 5 and 6 show the RMSE of minimum and maximum temperatures, in the period between October 2007 and June 2011, for availbale LAM and ECMWF's forecasts. The scores were computed for the 00UTC run, are valid for day 2 (between H+24 and H+48) and the number of weather stations used was 21.

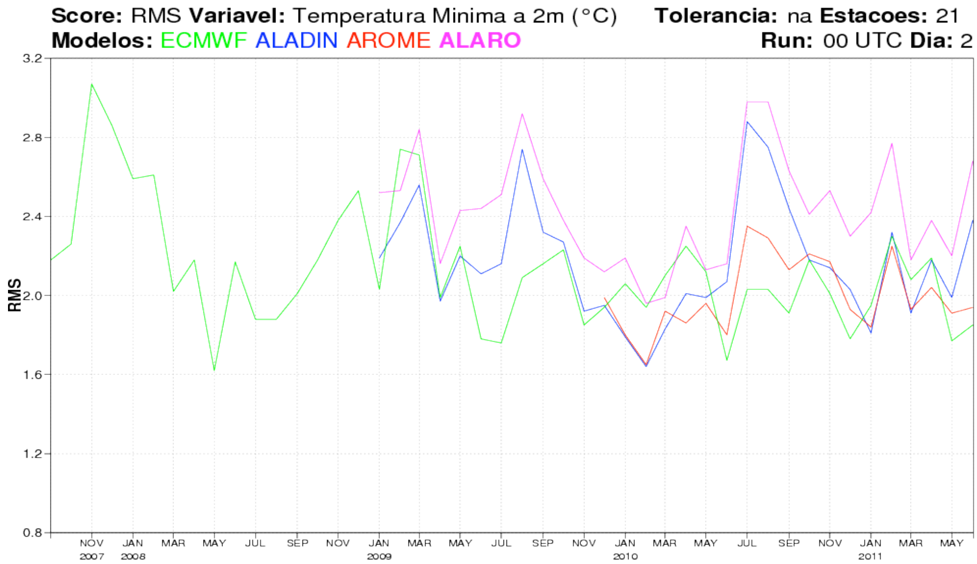

Figure 5 RMSE of the 2m minimum temperature, in the period between October 2007 and June 2011. The score is for day 2 of forecasts (H+24 and H+48).

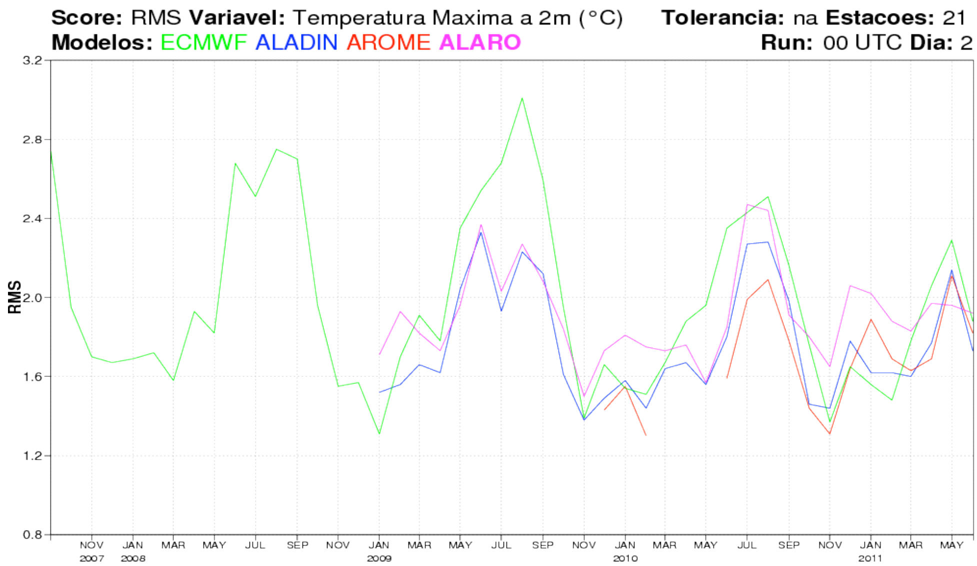

Figure 6 RMSE of the 2m maximum temperature, in the period between October 2007 and June 2011. The score is for day 2 of forecasts (H+24 and H+48).

The RMSE of the minimum temperature does not show any annual cycle. The RMSE of ECMWF's model is usually among the lowest of the available forecasts.

The RMSE of the maximum temperature shows a clear yearly cycle, with the highest values in Summer, when the model underestimates this variable. However, even though this feature is seen in 2010, it has become smaller, most likely due to the higher resolution of ECMWF forecasts. Apart from Summer, ECMWF's forecasts have similar values of RMSE to the ones computed for LAM models.

Figure 7 shows the Heidke Skill Score for 24h precipitation (H+06 – H+30), in the period between October 2007 and June 2011. The score is valid for the 00UTC run and 48 weather stations were considered.

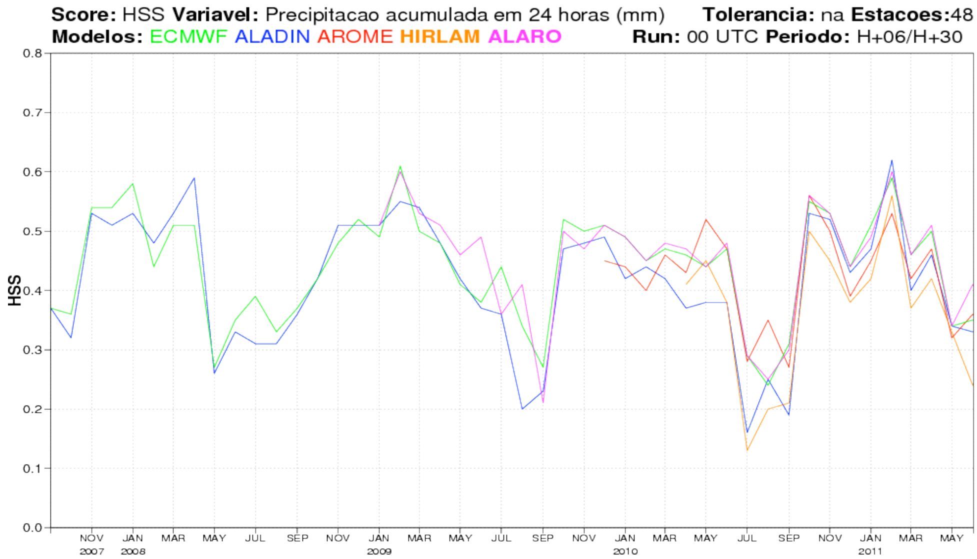

Figure 7 Heidke Skill Score of the 24h precipitation, in the period between October 2007 and June 2011.

An annual cycle is again clearly visible, with the highest scores in Autumn and Winter, because in this time of year precipitation is mostly due to synoptic weather systems. In Summer, when precipitation is mainly convective, scores are much lower.

ECMWF's model usually shows some of the highest skill of all the available forecasts. However, in Summer, higher resolution models such as AROME (2.5 km) and ALARO (5 km) are the ones that show the highest skill.

Figure 8 shows the RMSE of the 2m relative humidity, valid at step H+15, for the period between October 2007 and June 2011. The results are for the 00UTC run and 21 weather stations were used. Figure 9 is similar, but is for the 10m wind speed.

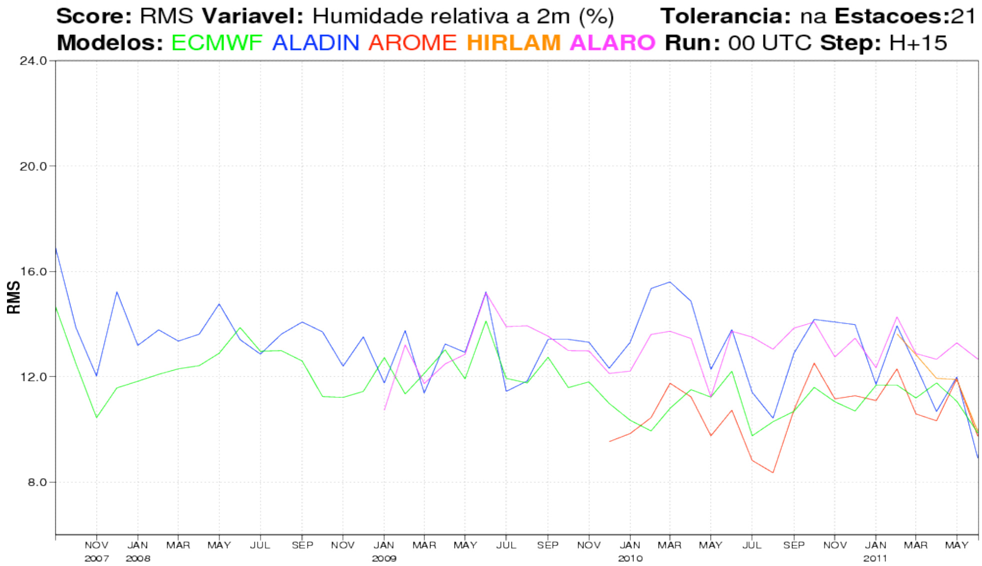

Figure 8 RMSE of the 2m relative humidity, in the period between October 2007 and June 2011, valid at step H+15.

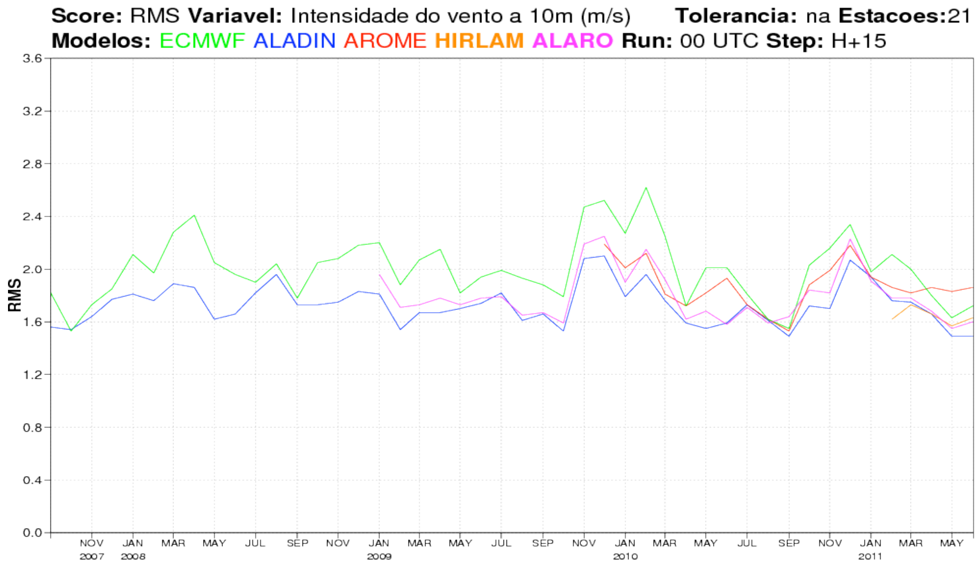

Figure 9 RMSE of the 10m wind speed, in the period between October 2007 and June 2011, valid at step H+15.

In the case of the relative humidity, ECMWF forecasts are again among the ones that show the lowest RMSE. The 10m wind speed is the only variable in which all LAM perform better.

3.1.3 Post-processed products

Figures 10 and 11 show the RMSE of the minimum and maximum temperatures, in the period between the 2nd of March and June 5th 2011. The scores are valid for the 00UTC and computed for 21 weather stations. The score compares direct model output (DMO), MOS and KALMAN forecasts for the three models: ECMWF, ALADIN and AROME. A final statistical forecast, called "ENS_001_ALL", is computed as the average of all the available MOS and KALMAN.

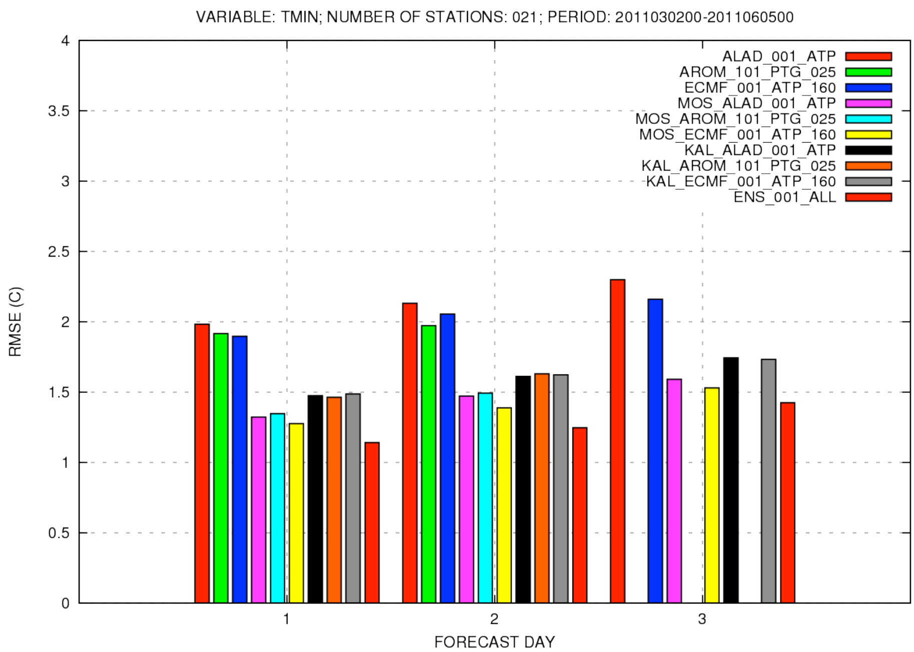

Figure 10 RMSE of the 2m minimum temperature, in the period between March and June 2011. Scores were computed for DMO and statistical post-processing of ECMWF, ALADIN and AROME forecasts.

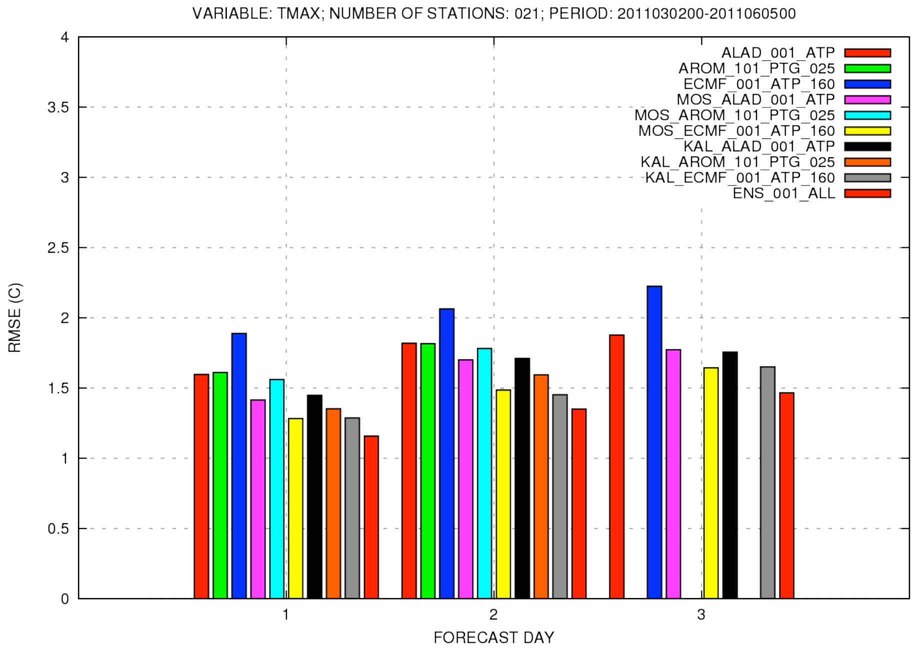

Figure 11 RMSE of the 2m maximum temperature, in the period between March and June 2011. Scores were computed for DMO and statistical post-processing of ECMWF, ALADIN and AROME forecasts.

Figures 10 and 11 show the clear benefit of the statistical post-processing of DMO forecasts. If all the statistical forecasts are combined, the RMSE becomes even lower, as shown in the scores obtained by the “ENS_001_ALL” forecast.

3.2 Subjective verification

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

Subjective verification of ECMWF forecasts products from the operational forecasters suggests that the forecasts provided are very good in the short term and provide useful guidance in the outlooks for days 5 to 7. Occasionally, reasonable guidance can extend up to ten days. Whenever convection is the main feature, the model's performance is more limited, as seen in the frequent forecasts of widespread low precipitation, during several events in Spring 2011.

Products derived from the ensemble forecasting system such as the EFI and probability maps for variables like the gust, mean wind speed, precipitation and temperature are found to be very useful in the operational forecasting, particularly for weather warnings.

3.2.2 Synoptic studies

In the period under analysis, four main severe weather events struck Portugal. Full reports (in portuguese) are ongoing so only a brief reference is given here.

In winter 2010, snowfall was far more frequent than usual. For example, in January 10th 2010, ahead of a warm front, widespread snowfall hit the north and centre of Portugal. The snow fell in locations as low as 250/300m in the centre and briefly touched coastal cities in the north (*e.g.* Porto). Overall, the model’s guidance was useful.

In February 20th 2010, severe flash floods hit the Madeira Island, mainly in the south coast. In the city of Funchal 123mm were recorded between 9-18UTC and in the mountains (around 1800m) the amounts reached 340mm in the same time frame. This event caused widespread damage, lost of lives and was widely reported in the news. In this event the ECMWF forecast provided some guidance, but as the precipitation was reinforced by orographic effects, the totals amounts were much smaller that those observed.

In general, ECMWF analysis were used to evaluate 7 events of heavy precipitation in Madeira during 2010 (February 2nd, 18th and 20th, April 20th, October 21st, November 25th and December 20th), which were characterized by a strong negative signal of the NAO index. Additionally, ECMWF forecasts of vertical profiles were used.

In February 27th 2010, a storm system swept by the west coast of Portugal, with a south-southwest to north-northeast trajectory. In this case, both the trajectory and development of the low were rather well forecasted. However, in this event the model overestimated the 10m wind speed and gusts. The superposition of ECMWF analysis of mean sea level pressure and wind speed with scatterometer wind data over the ocean for this event was initiated and the superposition with forecasts will follow.

The period October 29th – 31st 2010 in mainland was characterized by heavy precipitation events due to frontal activity, with a study being carried on using ECMWF analysis. Namely, on 29th a severe flooding event occurred in Lisbon, with maxima hourly precipitation amounts of 33 and 22 mm in two weather stations representing heavy urbanized areas of the city.

4. References