Application and verification of ECMWF products 2009

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1. Summary of major highlights

At the Instituto de Meteorologia, I.P. (IM), the ECMWF products are the most important source of data for operational weather forecast. In the short-range, the ECMWF data is used together with the ALADIN operational forecast.

Verification of ECMWF products is briefly shown for a group of selected weather stations, in the period from June 2008 to May 2009, as well as a comparison against the ALADIN model.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Physical adaptation

The ECMWF model forecasts are used as the initial conditions for the sea-wave model, named MAR3G, used to forecast the sea conditions. MAR3G - is a third generation wind-wave model that, solves the transport using a Mercator projection (propagation in lat-long grid) with a grid mesh 1º latitude per 1º longitude, and source and sink terms based on a physical approach to wave growth induced by wind, non-linear wave-wave interaction and dissipation by white capping. MAR3G also includes a parameterization for the effect of the wind variability on the Miles mechanism for wave generation that improves the model performance. The model is integrated 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. Ray model reproduces the effects of shelter by the shore, refraction, shoaling and dissipation by bottom friction. This model, constrained by the bathymetry, computes 25 ray fans (one for each of the frequencies of MAR3G) using 360 rays spaced by 1º at the origin.

MAR3G is also objectively verified. In particular, a validation of model's parameters is made, in order to evaluate the model's performance. Several statistical parameters, such as mean error (ME), mean absolute error (MAE) and root mean square error (RMSE), are calculated for significant wave height, peak period and mean wave direction.

A LAM-EPS has recently been developed, which is presently on a pre-operational mode. The results obtained so far, seemed to have some positive subjective implications in the forecasts, mainly in extreme weather events. A considerable amount of data is being stored and shortly it will be possible to objectively check the performance of the model during the first semester of 2008.

The mesoscale model is ALADIN Cy32T1 forced with LBC and IC given by the ECMWF T399 resolution and 50 members EPS. The outputs to the forecasters are:

- Ensemble mean and standard deviation maps
- EPSgrams for the main Portuguese cities
- Threshold maps

The model's area is centered in mainland Portugal with about 11 km grid resolution. The model runs once a day (12 UTC) in hpce ECMWF supercomputer, producing H+3, H+6, …,H+60 forecasts. The data is then downloaded to our local computers. The whole process takes about 3 hours.

2.1.2 Derived fields

The deterministic forecast from ECMWF is used daily to produce the following post-processed fields, which are used operationally at IM:

- Thermal frontal parameter and Q-vector convergence;
- Temperature advection at 850 hPa;
- Vorticity advection at 500 hPa;
- Differential temperature advection in the layers 800-500 hPa and 700-300 hPa;
- Differential vorticity advection in the layers 850-500 hPa and 700-300 hPa;
- Low-level moisture convergence;
- Total-Totals and Jefferson indices.

Additionally, the forecasts are also used in a 2D trajectory model, used operationally for weather forecast and to follow the trajectory of radioactive plumes in nuclear emergencies (in cooperation with the Environment Institute). Finally, the forecast data from ECMWF is also used in the computation of tephigrams for selected locations in Portugal.

2.2 Use of products

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 forecast is made based on Anomaly, Probability and tercile products for the 4 weeks and on multiparameter outlook for the first 2 weeks, which are considered the most skilful, mainly temperature. 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. The forecast is made based on ensemble mean, probability of exceeding median, probability of the lower/upper third of the distribution, probability for lowest/highest 20%. 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. Both ECMWF monthly and seasonal forecast were evaluated more extensively for the period January 2006- May 2007.

3. Verification of products

Verification of near surface variables from ECMWF forecasts is done for a sample of 48 mainland synoptic weather stations, shown in figure 1.

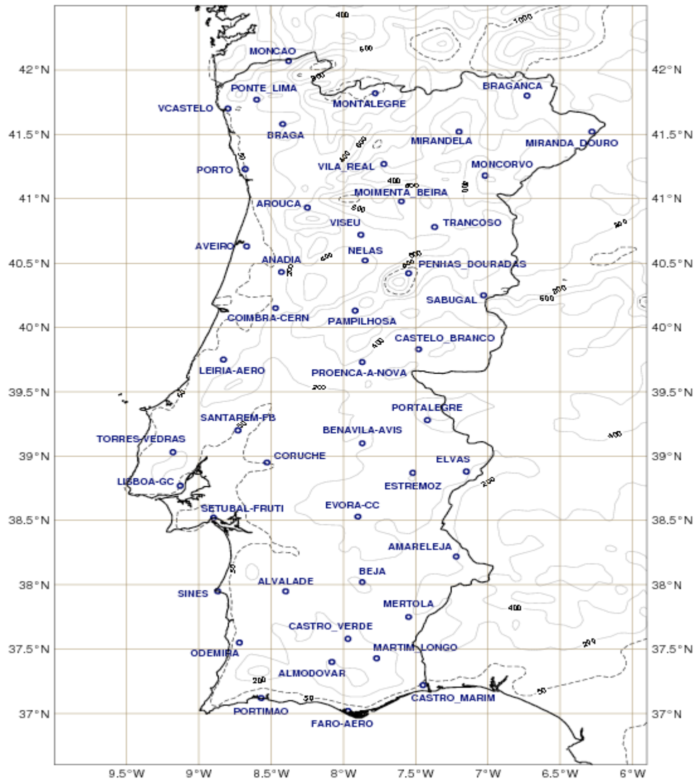

Fig. 1 - Location of the 48 selected weather stations in mainland Portugal.

The variables under analysis are the 2m temperature, mean sea level pressure, 10m wind speed and the 24h precipitation. For continuous variables the computed statistics are the bias (BIAS) and the root mean squared error (RMSE). In the case of precipitation, the forecasts' skill is assessed using the Bias, the Equitable Threat Score (ETS) and the Heidke Skill Score (HSS). All scores shown are valid for the 00 UTC run. The same variables and scores are then computed for the LAM model ALADIN, so that the scores can be compared.

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

The monthly RMSE for the 2m temperature, mean sea level pressure and 10m wind speed are shown for the period between December 2007 and May 2009. Results are shown for forecasts valid at 6 UTC and 15 UTC, within the first 48 hours. Notice that the computed score for each month use all forecasts started in that month.

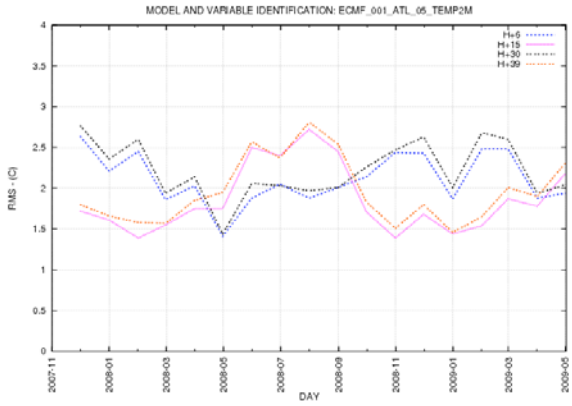

Fig. 2 - Monthly RMSE of the 2m temperature, for the selected 48 weather stations.

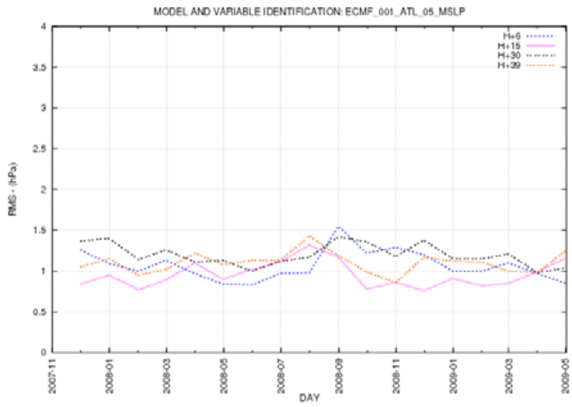

Fig. 3 - Monthly RMSE of the mean sea level pressure, for the selected 48 weather stations.

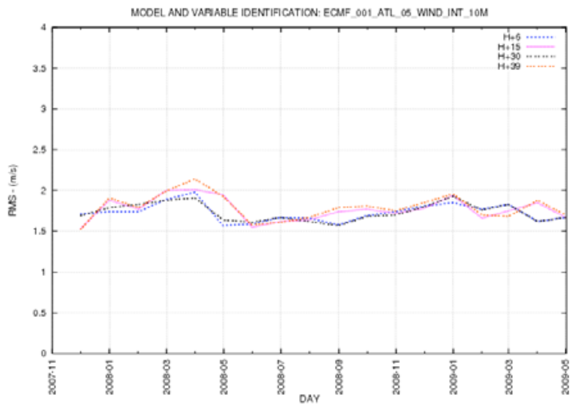

Fig. 4 Monthly RMSE of the 10m wind speed, for the selected 48 weather stations.

Figures 1 to 3 show similar skill within the period addressed in this study, with the scores being better during the afternoon or the morning period depending the time of the year. This is clearly seen in the 2m temperature, as the error is much bigger in the afternoon in summer and at 6 UTC in winter, which clearly reflects the lower model variability when compared to observations.

3.1.2 ECMWF model output compared to other NWP models

Figures 5 to 8 show the seasonal RMSE and the BIAS of the 2m temperature as a function of lead time. Please note that the operational ALADIN forecasts were upgraded in early December 2008, hence the skill for the summer and autumn are from the previous operational cycle. The scores were computed also with the same 48 weather stations used in the previous figures.

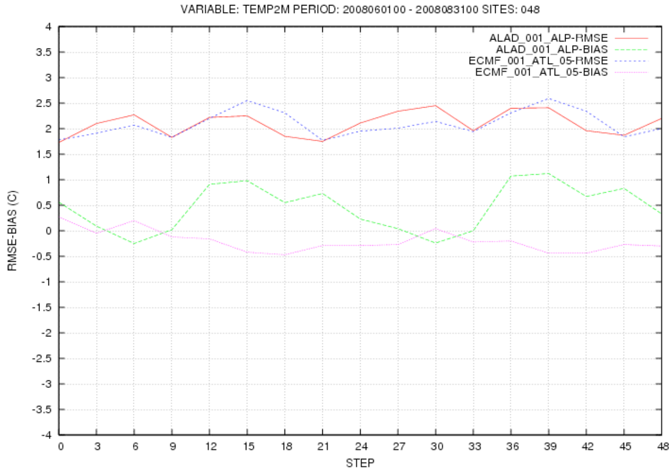

Fig. 5 - RMSE and BIAS of the 2m temperature for ECMWF and ALADIN, in summer 2008.

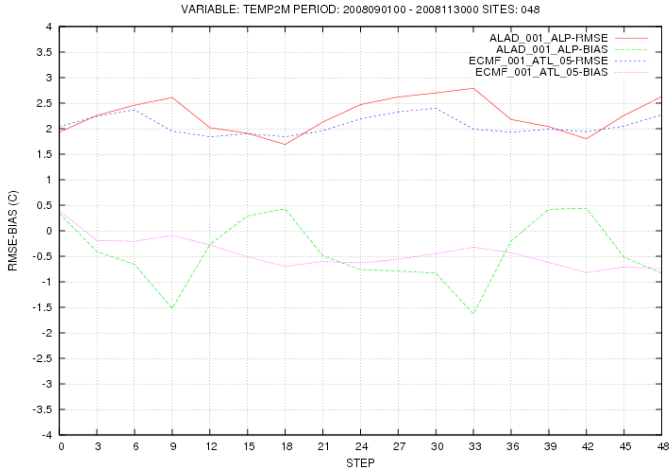

Fig. 6 - RMSE and BIAS of the 2m temperature for ECMWF and ALADIN, in autumn 2008.

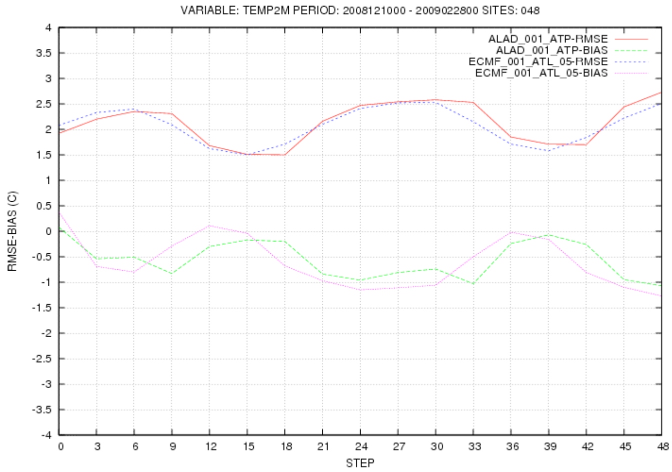

Fig. 7 - RMSE and BIAS of the 2m temperature for ECMWF and ALADIN, in winter 2008/9.

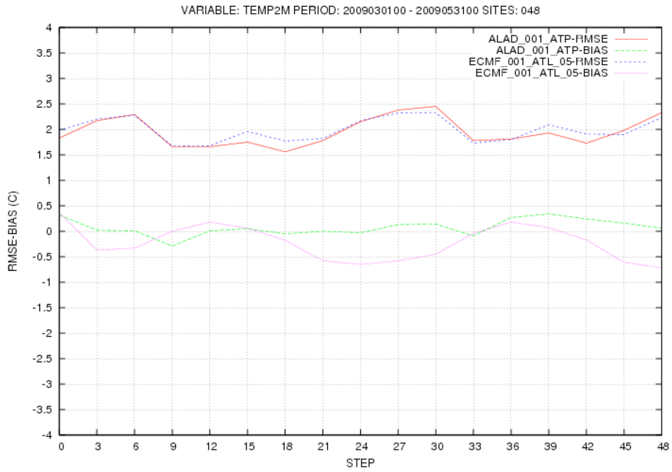

Fig. 8 - RMSE and BIAS of the 2m temperature for ECMWF and ALADIN, in spring 2009.

It is clearly shown the bias of the previous operational cycle of the ALADIN model, with overestimating in the afternoon and underestimating the night-time temperatures (fig 6). This situation was corrected with the new cycle as both models have now similar bias and additionally very close RMSE. Figures 9 to 12 are similar but for the 10m wind speed.

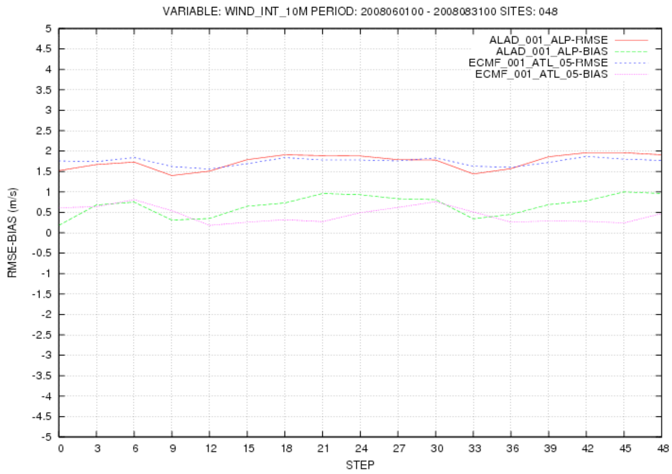

Fig. 9 - RMSE and BIAS of the 10m wind speed for ECMWF and ALADIN, in summer 2008.

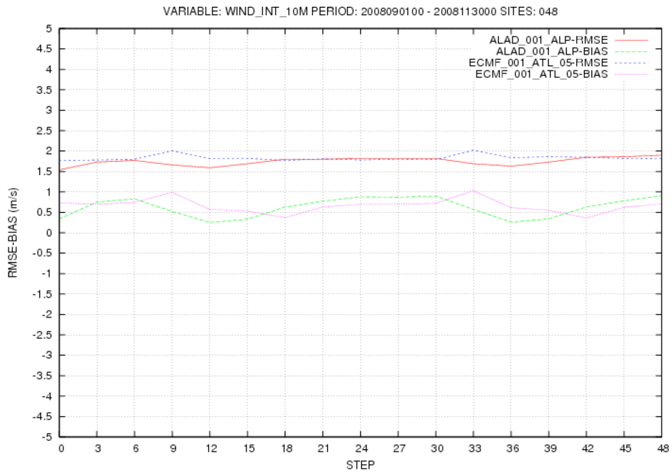

Fig. 10 - RMSE and BIAS of the 10m wind speed for ECMWF and ALADIN, in autumn 2008.

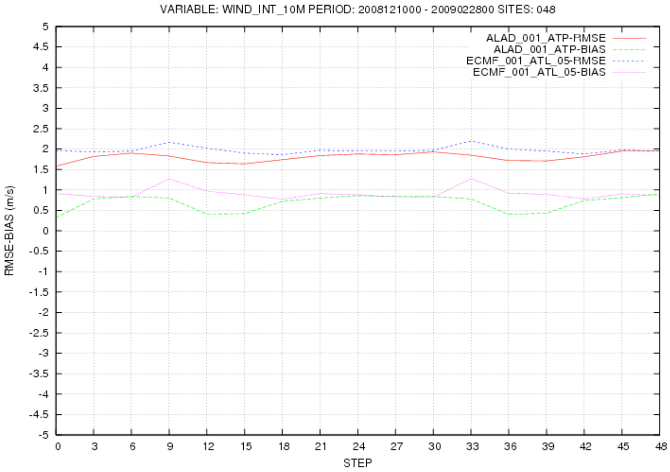

Fig. 11 - RMSE and BIAS of the 10m wind wind speed for ECMWF and ALADIN, in winter 2008/9.

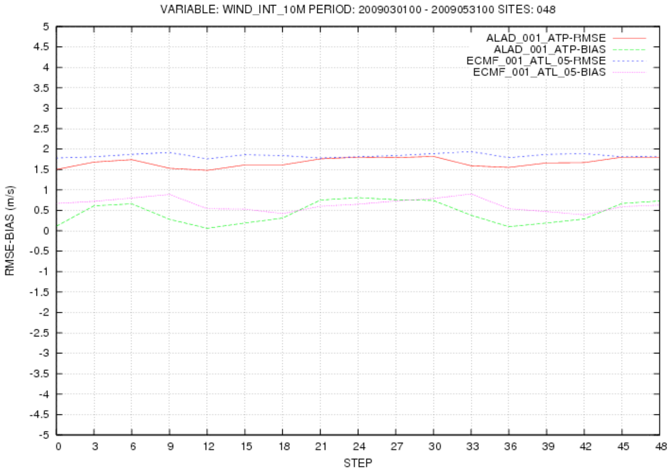

Fig.12 - RMSE and BIAS of the 10m wind wind speed for ECMWF and ALADIN, in spring 2009.

The scores for the 10m wind speed show that both models present similar skill, but ALADIN performs slightly better, regardless of the time of the year. This result is more evident with the new operational ALADIN forecasts (figs 11 and 12), where one notices the slight over-forecast of wind speed at ECMWF.

Figures 13 to 18 show the BIAS, ETS and HSS for the 24 hour total precipitation, accumulated between H+6 and H+30, in winter and spring 2009.

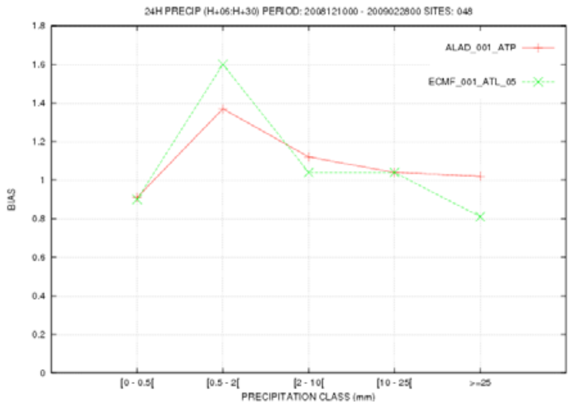

Fig. 13 - BIAS of the 24h total precipitation for ECMWF and ALADIN in winter 2009.

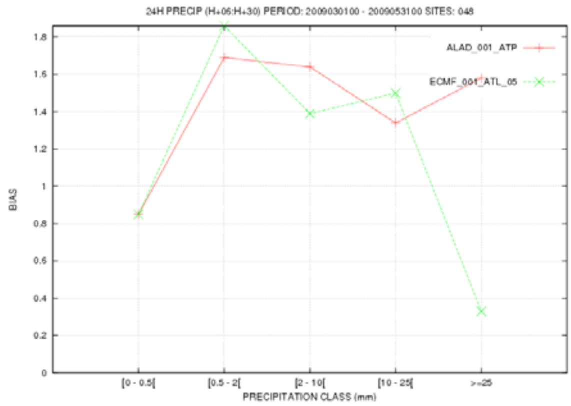

Fig.14 - BIAS of the 24h total precipitation for ECMWF and ALADIN in spring 2009.

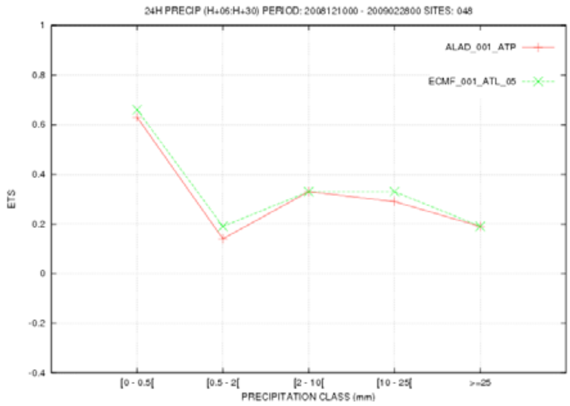

Fig. 15 - ETS of the 24h total precipitation for ECMWF and ALADIN in winter 2009.

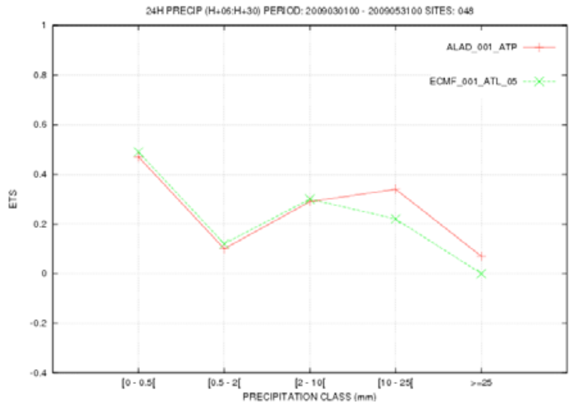

Fig.16 - ETS of the 24h total precipitation for ECMWF and ALADIN in spring 2009.

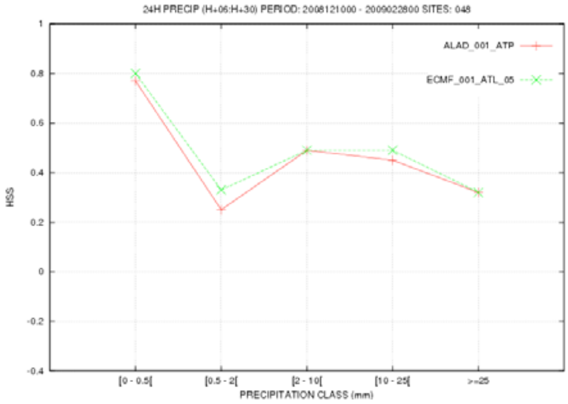

Fig. 17 - HSS of the 24h total precipitation for ECMWF and ALADIN in winter 2009.

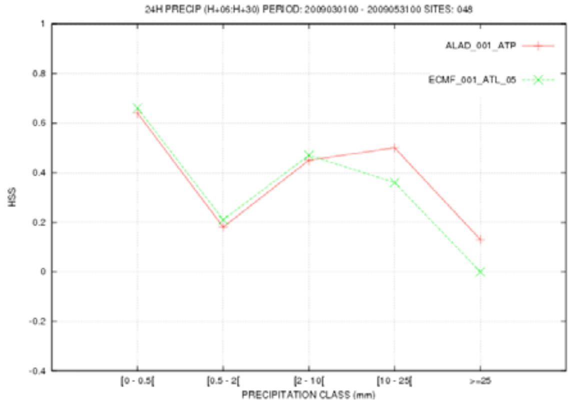

Fig.18 - HSS of the 24h total precipitation for ECMWF and ALADIN in spring 2009.

Both winter and spring 2009 had below average precipitation, especially in spring. The precipitation was mostly due to synoptic systems coming from the Atlantic. The analysis of figures 9 to 14 are as expected: both models can provide very useful forecasts for the yes/no precipitation, then they show a clear overestimate in light precipitation ([0.2-5[) and finally ECMWF clearly lacks forecasting in the over 25 mm class (mainly in spring). The ETS and HSS are very similar in both models, but in spring ALADIN has higher scores for precipitations over 10 mm.

3.2 Subjective verification

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

A subjective analysis of the mean sea level pressure field is done for the 12 UTC chart and is compared against the analysis of the model, in order to assess its behaviour.

Subjective verification of ECMWF forecasts products from the operational forecasters suggests that the forecasts provide 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. Nevertheless, whenever convection is the main feature the model's performance is much lower, as expected.

Products derived from the ensemble forecasting system such as probability maps for variables like the gust of at least 15 m/s, mean wind speed of at least 10 m/s, precipitation and temperature are found to be very useful in the operational forecasting, particularly for weather advisories.

3.2.2 Synoptic studies

An extensive study has been done on the floods that happened in Lisboa and Setúbal on 18th February 2008, which, generally, models failed to forecast in terms of precipitation amounts [1]. In summary, ECMWF performed well in locating relative precipitation maxima both spatially and temporally. For instance, Lisbon area has been well identified by the model between 18UTC on 17th and 00UTC on 18th, as well as between 00 and 06 UTC on 18th. Between 06 and 12 UTC on 18th (fig. 19) Lisbon area still has a local maxima, but the real precipitation pattern was not depicted. Between 12 and 18 UTC on 18th, ECMWF forecast a decrease of precipitation over Lisboa and an increase to the southeast, which fit what happened in reality. However, in a quantitative point view, ECMWF has largely underestimated precipitation amounts, as can been seen in Fig. 19. In EPS, the probability of TPP exceeding 20 mm is only larger than 80% on 16th, being around 40% on 12th and 15th, and below 30% on the other days (fig. 20). In fact, the Extreme Forecast Index (EFI) for precipitation was most likely the product that better reproduced this event as exceptional, with values between 0.9 and 1 in the area on the 16th.

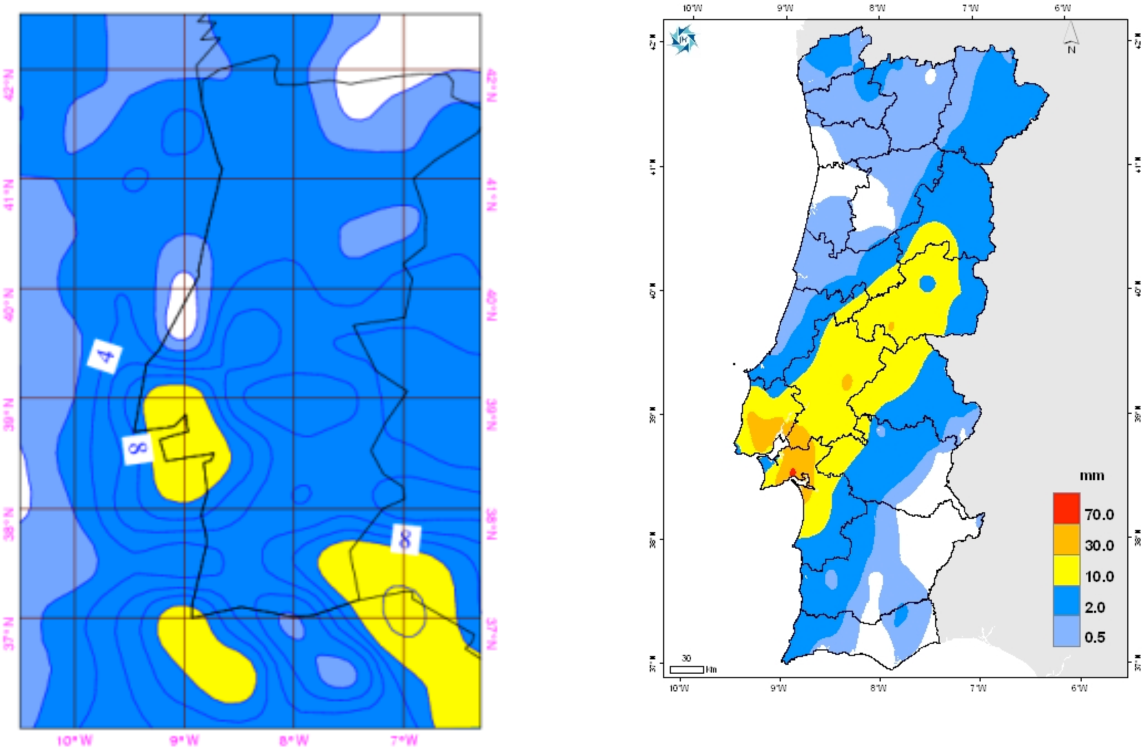

Fig. 19 – Precipitation forecast (mm) for ECMWF modelo (left) between 06 and 12UTC on 18th February 2008 from the analysis at 12 UTC on 17th February 2008. Right: Observed precipitation (mm) in the same period. Colour table on the right map.

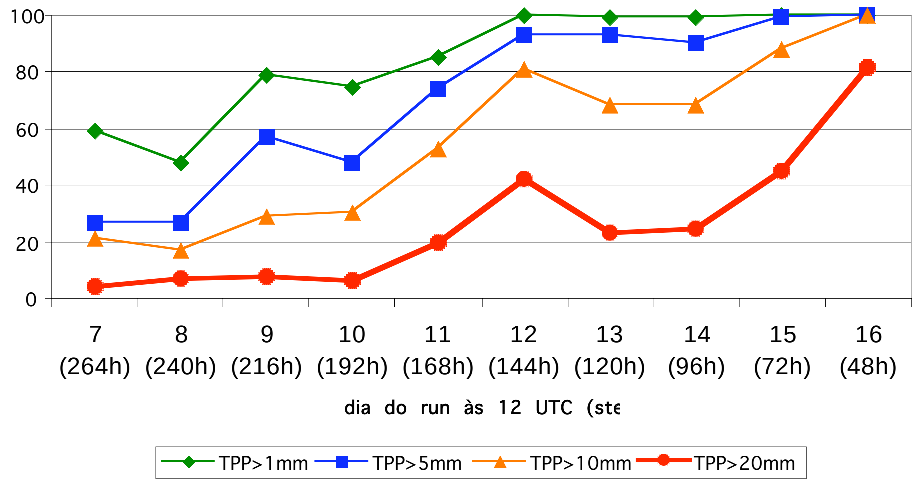

Fig. 20 – 24 hours Total Precipitation Probability (TPP) of ECMWF between 12 UTC on 17th and 12 UTC on 18th February 2008. PPT Thresholds of 1, 5, 10 and 20 mm.

4. References

[1] Moreira, N., Silva, A., Prates, F., Ferreira, J., Neto, J., Bugalho, L., Lopes, M.J., Mendes, M., Frada, M.J., Pinto, P., Cota, T., Cabrinha, V., 2008: “Cheias de 18 de Fevereiro de 2008”. Report DMC/CIME 01/2008. Instituto de Meteorologia, December (in portuguese).