Application and verification of ECMWF products in Portugal, 2007

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1. Summary of major highlights

The present document reports briefly the applications and the use of ECMWF forecasts products at IM, ranging from the short-range to the long-range seasonal forecasts. An objective verification of the deterministic weather forecasts for surface parameters is made and a brief comparison with the limited-area model ALADIN, which runs operationally at Instituto de Meteorologia (IM), is also shown.

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 has as 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.

For each point of the model, a spectral grid of 24 directions and 25 frequencies is calculated; and consequently, are calculated wave parameters, such as significant wave height, mean wave direction and mean period. The model is integrated once a day up to H+120h, with a 6h time step.

To transform waves from the open seas to near-shore is used a Ray model, that 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. The parameters obtained by Ray model are: significant wave height, wind sea height, swell height, maximum height most probably in 6 hours, power density, mean period, peak period, peak period unidirectional, power equivalent period, spectral width, peak direction, mean direction, wind sea direction, swell direction and power direction.

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 mositure 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 mainland Portugal.

2.2 Use of Products

2.2.1 Short-Range Forecasts

In the time frame up to 48/72 hours, several sources of information are used for providing the official weather forecasts at IM. The main source of data comes from the ECMWF forecasts, with some limited additional information from the UKMO model.

IM runs operationally the limited-area model ALADIN twice a day, producing forecasts up to 48 hours. The products from ALADIN are used as a confirmation of the guidance provided by the ECMWF model for producing the official weather forecasts. For specific areas such as aviation and products like the fire hazard, the ALADIN model is used as the basic source.

2.2.2 Medium-Range Forecasts

In the time frame between 3 and 10 days, the ECMWF products are used as the main guidance for producing the weather forecasts. Even though these products are not provided to the media, the information is provided to anyone who accesses a paid service. Detailed forecasts are made for the first 4-5 days and then some guidance to the most likely weather conditions is provided for the rest of the period.

2.2.3 Long-range Forecasts

The IM has started evaluating the ECMWF monthly and seasonal forecasts on a regular basis on January, 2006. This evaluation focus mainly precipitation and 2m temperature and is based on anomaly and probability maps. The forecast information is compiled on a internal bulletin updated weekly, for monthly forecasts, and monthly, for seasonal forecasts.

Recently the bulletin was made available for external clients along with basic information regarding the forecast methodology and on how to interpret the forecast.

3. Verification of products

The objective verification of the ECMWF was done using 68 weather stations located in mainland Portugal, in the following four trimester periods: July-September 2006, October-December 2006, January-March 2007 and April-June 2007. Even though they differ from the regular definition, hereafter the winter will be taken as the period between January and March. The same comment applies to the remaining seasons.

The validation presented here was done for the 12 UTC run and the variables used are the 2 meter temperature and relative humidity and the 10 m wind speed. The forecast verification was done up to four days and the scores used were the Heidke skill score (HSS), the Root Mean Square Error (RMSE) and the bias, depending on the parameter.

3.1 Objective verification of ECMWF Model Output

Tables 1 to 3 show the RMSE and bias for the 10 meter wind speed and the 2 meter temperature and relative humidity, in the four selected periods, for the 68 weather stations admitted in this study.

Table 1 ECMWF two meter temperature RMSE and Bias, for 68 weather stations, in the four periods under analysis.

Step (H+)	July-September 2006		October-December 2006		January-March 2007		April-June 2007	
	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)
00	2.56	-1.04	1.89	0.07	1.81	-0.02	2.15	-0.38
24	2.79	-0.95	2.05	-0.21	2.07	-0.13	2.39	-0.62
48	2.83	-0.66	2.06	-0.30	2.06	-0.12	2.49	-0.60
72	3.20	-0.10	2.35	-0.37	2.49	-0.03	3.28	-0.64
96	4.31	-	2.63	-0.72	2.89	-0.03	4.33	-0.62

Table 2 ECMWF two meter relative humidity RMSE and Bias, for 68 weather stations, in the four periods under analysis.

Step (H+)	July-September 2006		October-December 2006		January-March 2007		April-June 2007	
	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)
00	11.65	5.57	9.78	-0.94	10.29	-0.20	11.23	1.47
24	12.59	3.51	11.63	-2.37	12.29	-2.48	12.56	0.10
48	12.74	2.79	12.15	-2.44	12.73	-2.41	13.12	0.07
72	14.82	0.92	13.53	-3.73	16.15	-2.89	17.95	0.86
96	16.32	1.35	16.15	-4.18	17.48	-1.31	19.26	1.42

Table 3 ECMWF ten meter wind speed RMSE and Bias, for 68 weather stations, in the four periods under analysis.

Step (H+)	July-September 2006		October-December 2006		January-March 2007		April-June 2007	
	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)
00	1.70	0.08	2.48	1.36	2.11	0.93	1.76	0.65
24	1.71	0.23	2.67	1.56	2.18	0.98	1.95	0.91
48	1.72	0.16	2.60	1.49	2.21	0.92	1.98	0.86
72	1.91	-0.08	3.46	1.36	3.03	1.03	2.50	0.85
96	2.18	0.06	3.33	1.04	3.35	1.32	2.63	0.90

3.2 Comparison between ECMWF and ALADIN model outputs

The comparison between the direct output of the ECMWF and ALADIN models is presented for the periods, variables and scores mentioned above. Tables 4 to 6 show the RMSE and bias for the ten meter wind speed and the two meter temperature and relative humidity, in the four selected periods, for the 68 weather stations admitted in this study.

Table 4 ALADIN two meter temperature RMSE and Bias, for 68 weather stations, in the four periods under analysis.

Step (H+)	July-September 2006		October-December 2006		January-March 2007		April-June 2007	
	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)
00	2.47	0.21	1.56	-0.22	1.68	0.26	2.08	-0.03
24	2.79	-0.02	1.96	-0.56	1.80	-0.25	2.34	-0.09
48	3.01	0.03	2.04	-0.57	1.91	-0.25	2.51	0.11

Table 5 ALADIN two meter relative humidity RMSE and Bias, for 68 weather stations, in the four periods under analysis.

Step (H+)	July-September 2006		October-December 2006		January-March 2007		April-June 2007	
	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)
00	13.51	2.51	13.44	7.43	13.06	4.59	15.60	6.63
24	14.49	1.24	12.69	5.50	12.81	3.87	15.54	5.21
48	15.29	1.47	13.42	5.24	13.02	3.61	15.93	4.62

Table 6 ALADIN ten meter wind speed RMSE and Bias, for 68 weather stations, in the four periods under analysis.

Step (H+)	July-September 2006		October-December 2006		January-March 2007		April-June 2007	
	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)	RMSE (ºC)	Bias (ºC)
00	1.44	-0.20	1.69	0.24	1.58	0.01	1.43	-0.31
24	1.76	0.57	2.02	0.75	1.77	0.51	1.56	0.36
48	1.81	0.60	2.06	0.67	1.79	0.40	1.69	0.37

The analysis of the tables from ECMWF and ALADIN suggests that:

- ECMWF presented a 2 m temperature cold bias, which was much clearer in the warmest periods in study. The RMSE is identical in both models, even though ALADIN presents slightly lower values in fall/winter;
- ECWMF showed some tendency to be somewhat drier than observed in winter and wetter in the summer. ECMWF had better 2 m relative humidity scores than ALADIN;
- ECMWF presented a positive bias for the 10 m wind speed in all periods but summer; ALADIN provided better forecasts for the wind speed variable, regardless of the period considered.

Figures 1 to 4 present the 2 meter temperature RMSE, up to 48 hours, for four selected weather stations in Portugal. Two locations are representative of the coastal north (Porto) and centre (Lisboa) and the other two are inland sites: Bragança, which is located in the mountainous northeast and Beja is in the flat low-level areas of the south. The RMSE values are shown for both ECMWF and ALADIN direct model output in the four selected periods.

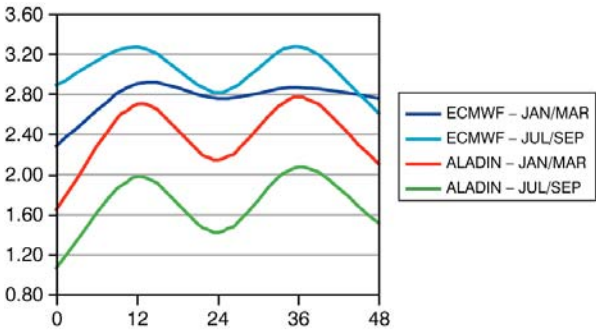

Fig. 1 Two meter temperature RMSE in the winter and summer for Bragança.

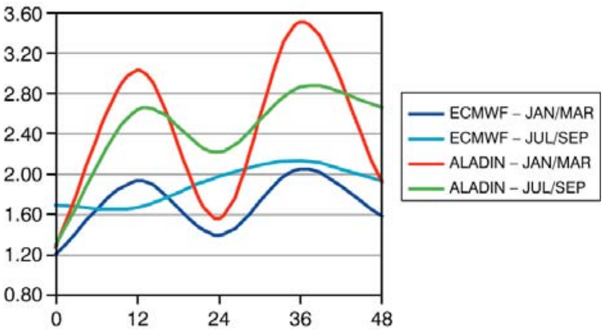

Fig. 2 Two meter temperature RMSE in the winter and summer months for Beja.

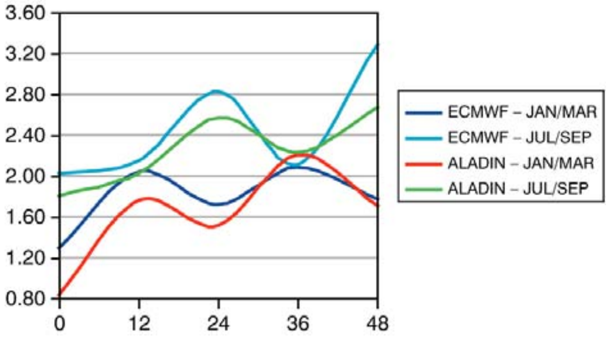

Fig. 3 Two meter temperature RMSE in the winter and summer months for Porto.

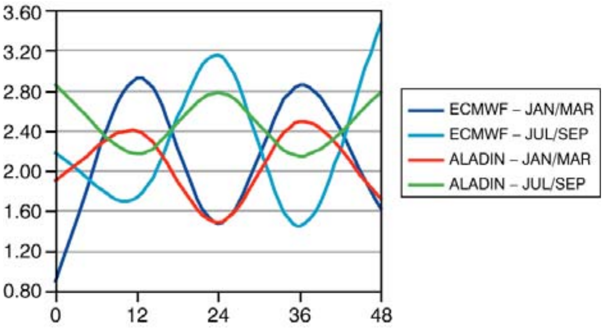

Fig. 4 Two meter temperature RMSE in the winter and summer months for Lisboa.

For the 12UTC (H+24) forecasts, ALADIN showed lower RMSE than ECMWF, except in Beja, where values were similar. This is most likely due to the fact that the coarser resolution of the ECMWF model has a lower impact on temperature in areas with flatter terrain. However, night-time temperatures are generally better in ECMWF than in ALADIN, except for Bragança.

3.3 Subjective verification of ECMWF forecasts

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 weather forecasters at the operational centre suggest that there has been a clear improvement in both quality and reliability. The forecasts are very good in the short term and provide useful guidance in the outlooks for days 5 to 7. Both the forecast 2 meter temperature and precipitation fields provide good forecasts, even though the latter is less useful when convection is the main feature.

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.

Regarding long-range forecasting, for now, our analysis on the skill of these forecasts is only subjective and concerns the consistency of successive forecasts.