Application and verification of ECMWF products 2015

Instituto Português do Mar e da Atmosfera, I.P.

1. Summary of major highlights

At Instituto Português do Mar e da Atmosfera (IPMA) ECMWF products are used as the main source of data for operational weather forecasting. ECMWF short-range forecasts are used along with those provided by the limited area models of ALADIN numerical weather prediction system (ALADIN and AROME).Major highlights in 2014-15 were:

- Migration of part of the post-processing system,
- Improvements in the post-processing of NWP products.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

Statistical adaptation of ECMWF forecasts is applied to improve daily minimum and maximum temperatures forecasts in selected locations up to 240 hours. This system combines forecasts from ECMWF and AROME models, whenever available. The application computes MOS and KALMAN adjusted temperatures for each model and the final forecast is then computed as the average of all available forecasts. This framework has been extended to 2 m temperature and relative humidity, as well as 10 m wind speed, all available with an hourly frequency up to 3 days and 3/6h frequency up to 10 days, depending on availability. These products are available through IPMA's website (http://www.ipma.pt/pt/otempo/prev.localidade.hora/) and an app for mobile phones (Meteo@IPMA).

2.1.2 Physical adaptation

SWAN (Simulating WAves Nearshore) third-generation model, with 0.05º horizontal resolution, 36 directions and 36 frequencies, forced (i) by ECMWF LAM wind wave spectra at the lateral boundaries, and (ii) by ALADIN 10 m winds of ALADIN. SWAN operates with 0.05º of horizontal resolution, 36 directions and 36 frequencies. Hourly processing of its fields is performed with forecasts produced until H+72h. Tri-hourly forecasts are also available on IPMA's portal (http://www.ipma.pt/pt/maritima/cartas/).

2.1.3 Derived fields

The deterministic forecast from ECMWF is used on a daily basis to produce some derived-processed fields such as the 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.

Statistical adaptation of surface parameters has also been used to compute a forecast of Universal Thermal Climate Index (UTCI), mainly for civil protection purposes.

Since June 2013, an icing index, named SFIP, has been operational at the Portuguese Meteorological Watch Office. The index is based on hourly ECMWF forecasts of temperature, relative humidity, vertical velocity and cloud water content. A comparison was made with other icing algorithms for two winter periods from 5 December 2012 to 17 April 2013 and from 9 October to 11 December 2013. This comparison was performed over the eastern USA, where pilot reports of aircraft icing are issued regularly.

SFIP outperforms other indices, particularly in the detection of moderate to severe icing (Belo-Pereira, 2015). An example of the SFIP forecast for a severe icing episode on February 2014 over mainland Portugal is show in figure 1.

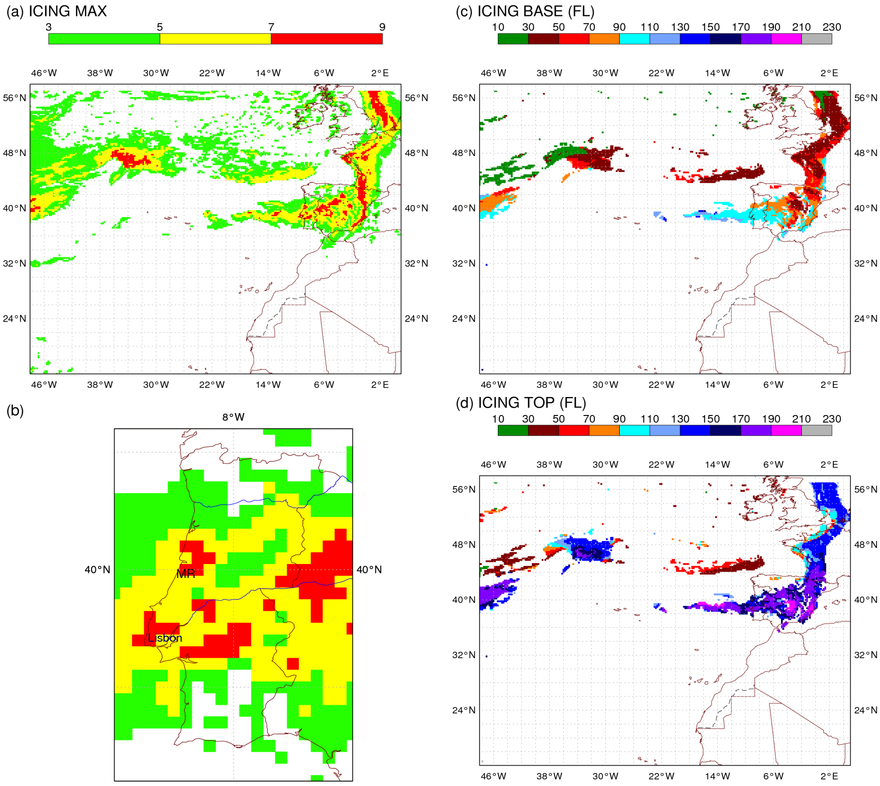

Figure 1 Icing severity derived from the SFIP index based on the ECMWF H+14 forecast valid at 1400UTC on 11 February 2014. Maximum severity in the layer between FL010 and FL230, for (a) the area covering the Portuguese Flight Information Regions and for (b) Continental Portugal. The location of a report of severe icing (voice report) is marked with a "MR". Green and yellow areas indicate respectively light and moderate icing. Red areas refer to severe icing. Flight level of (c) base and (d) top of the MOG icing layer. Flight level 10 (FL010) corresponds to 1000 ft.

New applications using ECMWF forecasts have been tested recently and include:

a) Precipitation forecasts (real time basis) to calculate spatial statistics for the Portuguese river basins, as input to a flood monitoring system (figure 2);

b) Use of daily precipitation forecasts (historical) on a hybrid spatial interpolation model with rain gauge precipitation observations, improving the prediction errors at unsampled locations (figure 3).

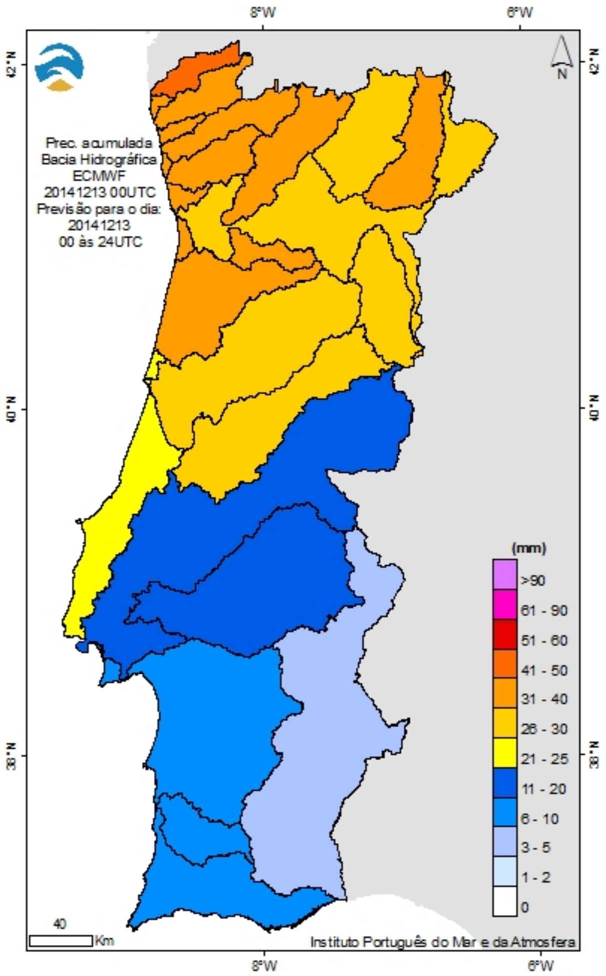

Figure 2 Spatial average of the rainfall by drainage basin, computed from ECMWF daily precipitation forecast (example for 13-12-2014).

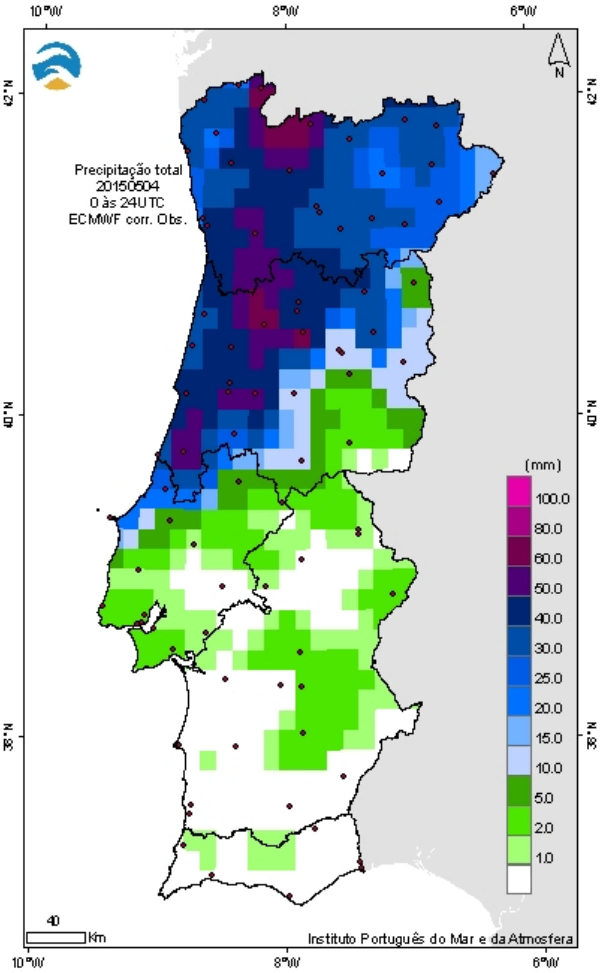

Figure 3 Daily precipitation (example for 04-05-2015), obtained using a hybrid interpolation model of observations at the stations and precipitation forecast of ECMWF.

2.2 Use of products

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

ECMWF monthly forecast is used to produce a bulletin twice a week with 2 meter air temperature and precipitation for mainland Portugal for the 4 forecast weeks. This bulletin is made available at IPMA's Web page and for external clients if requested, including civil protection authorities. Every week, a draft on the evolution of the anomaly signal of every specific week is performed internally.

The EUROSIP seasonal forecast is used to produce a monthly bulletin with forecasts of 2 meter air temperature and precipitation for Portuguese mainland for the 3 trimesters of forecast. This bulletin is also made available at IPMA's Web page and 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 ECMWF alone seasonal forecast is also evaluated.

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

3.1.2 ECMWF model output compared to other NWP models

ECMWF forecasts are compared with the operational limited area models (LAM) ALADIN and AROME forecasts, respectively, with 9 and 2.5 km horizontal resolution.

Figures 4 to 7 show, respectively, the monthly RMSE of the 2 m temperature, relative humidity, 10 m wind speed and mean sea level pressure, valid at step H+39. RMSE was computed with a sample of 21 weather stations in mainland Portugal. Figure 8 shows the monthly Heidke Skill Score of the 24h precipitation (H+06 to H+30), computed in a sample of 48 stations in mainland Portugal. All scores are shown for the period October 2007 to July 2015.

The RMSE of the 2 m temperature, relative humidity and 10 m wind speed shows a trend towards smaller errors. However, in the case of the 2 m temperature, the RMSE seems to have levelled out; this is seen in all models used at IPMA. In the case of the relative humidity and wind speed the trend is still apparent.

The RMSE of ECMWF relative humidity forecasts is similar to the one computed for ALADIN and AROME. In the case of 2 m temperature, ECMWF forecasts have the lowest RMSE in autumn and winter months when compared with LAM. This situation is reversed in the summer periods as AROME forecasts usually have the lowest RMSE.

In the case of the 10 m wind speed ECMWF has usually larger values of RMSE when compared to ALADIN and AROME. However, since the middle of 2013 there has been a noticeable improvement, resulting in an error of ECMWF similar to the ones computed for ALADIN and AROME.

In the mean sea level, there is no clear trend and the RMSE of ECMWF forecasts is usually the lowest. The Heidke Skill Score of 24h precipitation, computed at 48 stations using the single observation-single forecast approach, is similar in all three models. After a trend upwards, again since 2013 it seems to have levelled out.

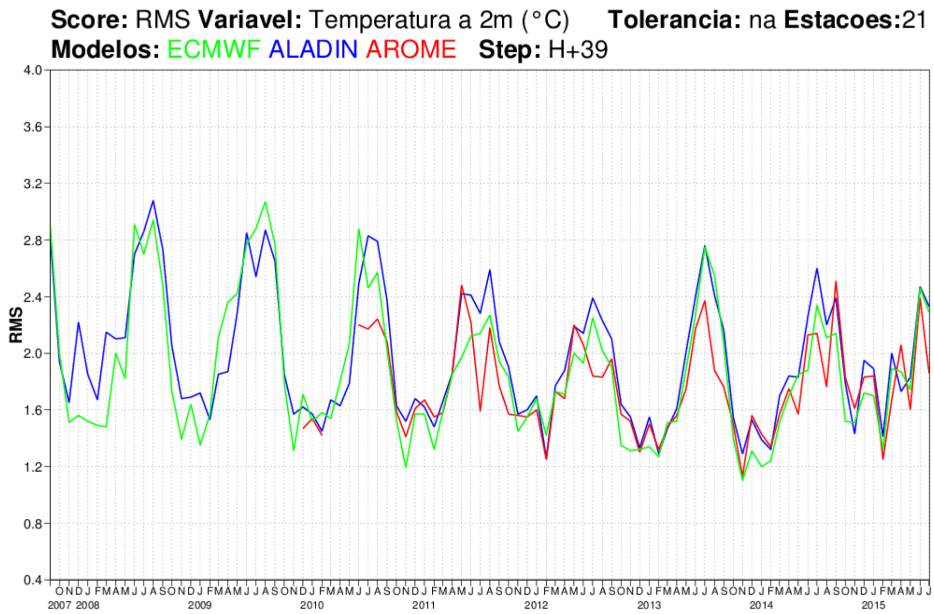

Figure 4 Monthly RMSE of the 2 m temperature, at step H+39.

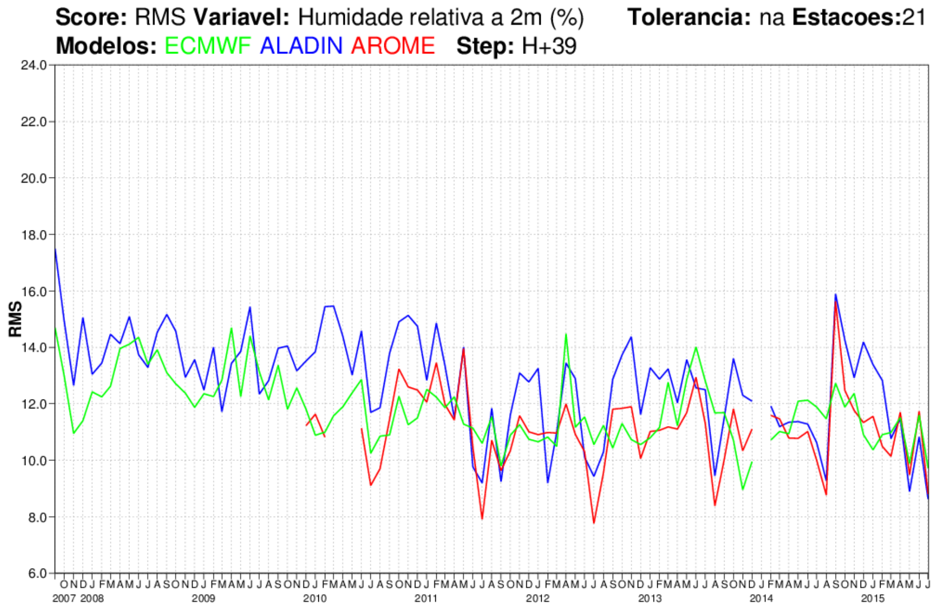

Figure 5 Monthly RMSE of the 2 m relative humidity, at step H+39.

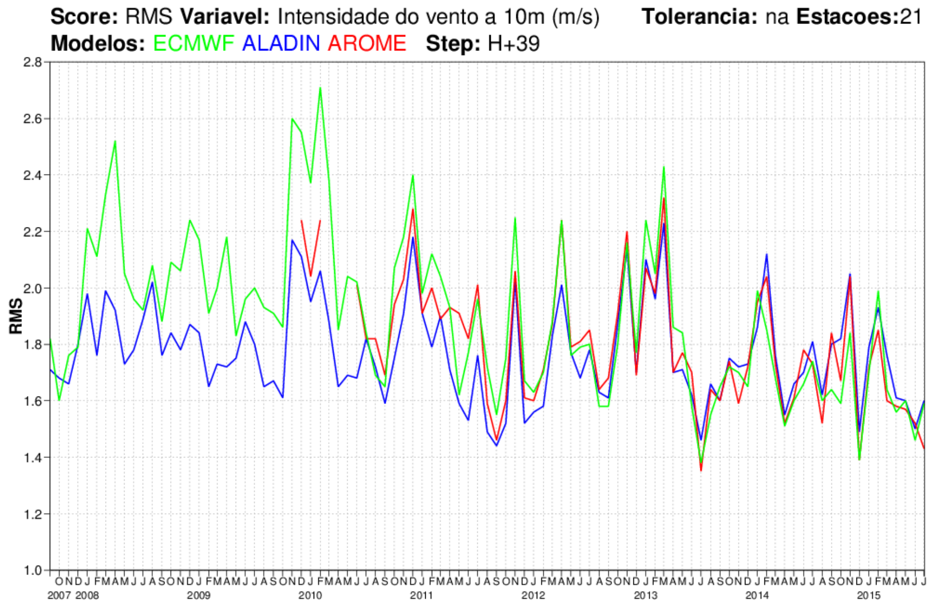

Figure 6 Monthly RMSE of the 10 m wind speed, at step H+39.

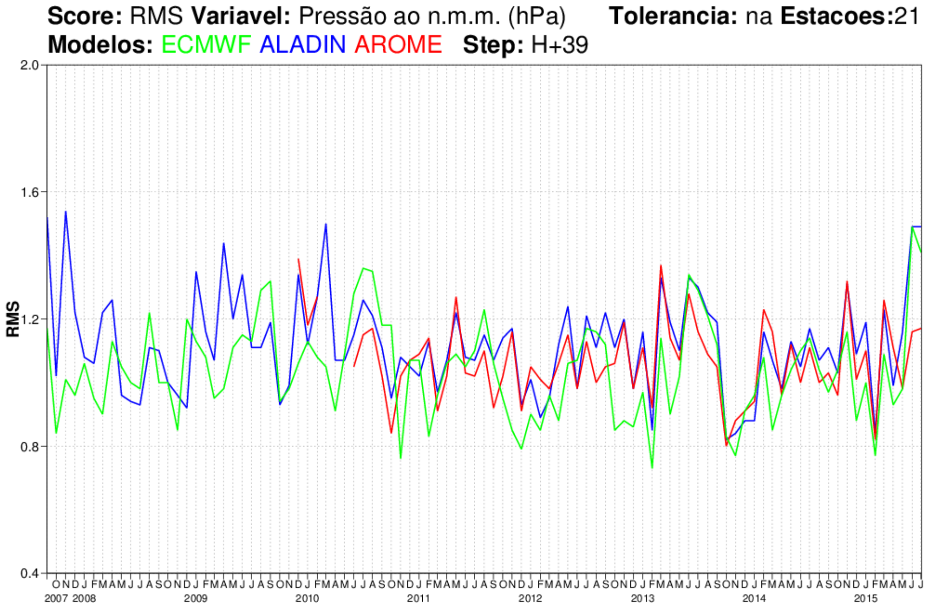

Figure 7 Monthly RMSE of the mean sea level pressure, at step H+39.

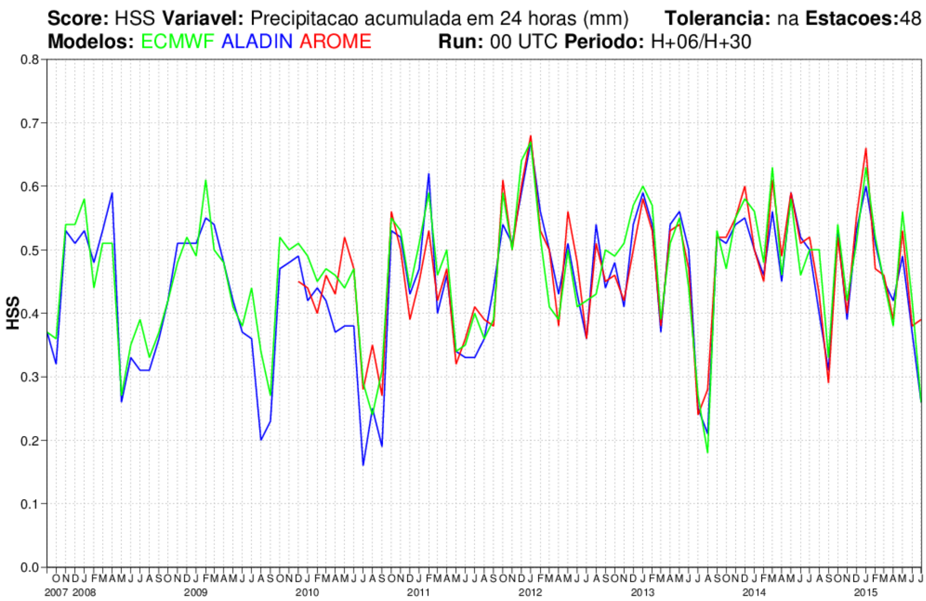

Figure 8 Monthly Heidke Skill Score of the 24h precipitation (H+06 to H+30).

3.1.3 Post-processed product

Figures 9 and 10 show the RMSE of the minimum and maximum temperatures, for the summer of 2015 (23th of June until 20th of August). Scores are valid for the 00 UTC run and computed at a maximum of 105 weather stations. The plots allow the comparison of the statistical post-processing (STA) and the direct model output (DMO) of ECMWF and AROME forecasts.

When assessing DMO forecasts, ECMWF and AROME have similar values of RMSE for the 2 m minimum temperature. In the case of the 2 m maximum temperature, the RMSE of ECMWF forecasts is higher when compared with AROME. The statistical post-processing has the lowest values of RMSE, regardless of the variable and forecast length.

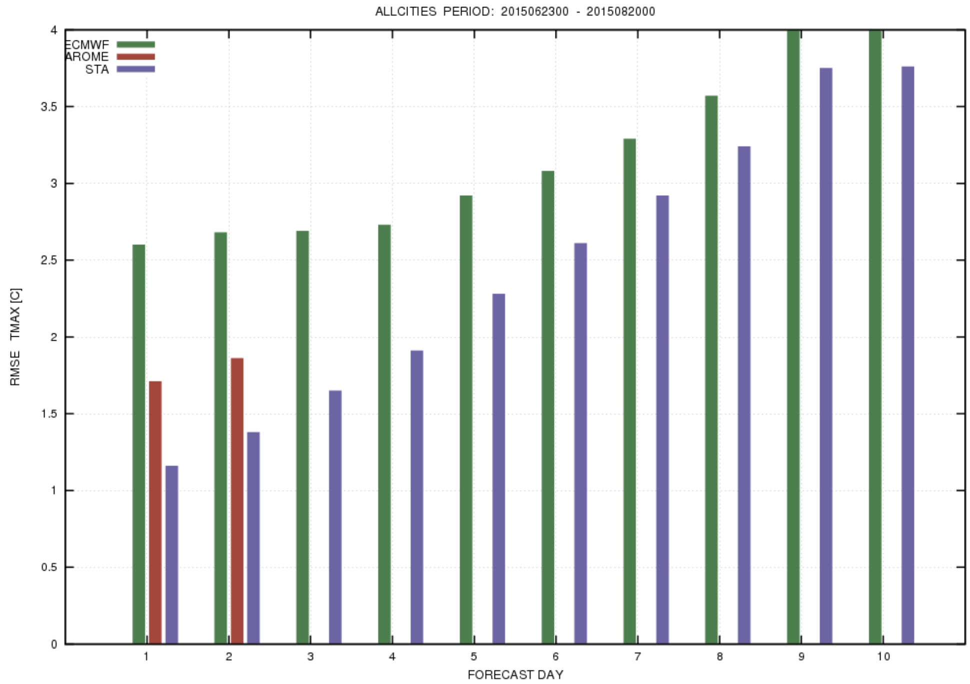

Figure 9 RMSE (ºC) of the 2 m minimum temperature, summer 2015. Scores were computed for DMO and statistical post-processing of ECMWF and AROME forecasts.

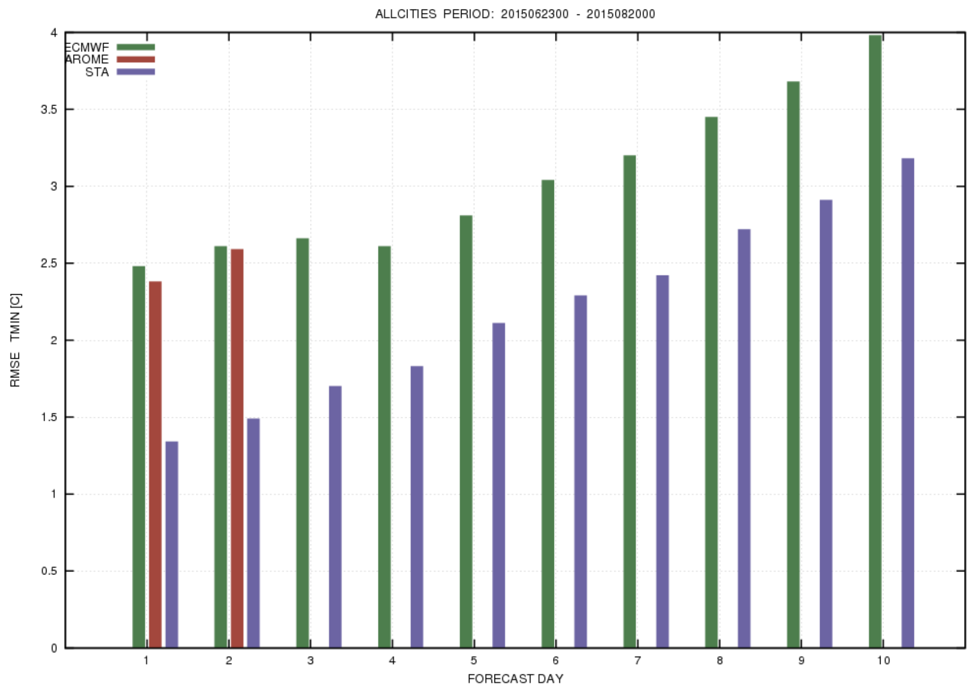

Figure 10 RMSE (ºC) of the 2 m maximum temperature, in the summer of 2015. Scores were computed for DMO and statistical post-processing of ECMWF and AROME forecasts.

3.1.4 End products delivered to users

3.2 Subjective verification

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

3.2.2 Synoptic studies

On Sept. 22, 2014, particularly over Lisbon (Portugal), between 12 and 14 UTC, there was a heavy rain event that caused flash floods in some parts of the city and in the district of Setúbal. From an estimate based on Coruche radar images, there may have occurred around 40 mm in two hours in some regions in Lisbon (Figure 11). Later that day, there was also heavy rainfall in the northern part of the district of Lisbon (in Lourinhã), in the districts of Leiia and Santarém, and also in the South, in the districts of Évora and Beja.

From an operational point of view, the synoptic pattern was derived from the ECMWF model fields, and on local scale, tephigrams over Lisbon were explored. The stationarity of the vertical vorticity associated with a zone of horizontal convergence, under a thermodynamically unstable environment, allowed the formation of transient disturbances, which were associated with convective cells that formed consecutively over Lisbon and Setúbal, and later in Lourinhã region and in Leiria/Santarém districts in the form of convective mesoscale systems (MCS). It was the interaction between planetary/synoptic scale and the mesoscale/local scale that favoured multi-cellular convection. During a short period over Lisbon, convection was characterized as "training", therefore being responsible for the flash floods over parts the city. The floods may also have been favoured by the high tide at the time.

The event was difficult to predict. Therefore, it was necessary to continuously evaluate the three-dimensional behaviour of the atmosphere through nowcasting and adapt the forecast, in order to move away from initial forecasts, as the ECMWF model precipitation field suggested (Figure 12). The whole process led to raise the level of warnings on the west coast of South and Central regions of Portugal as well as in the interior part of South region.

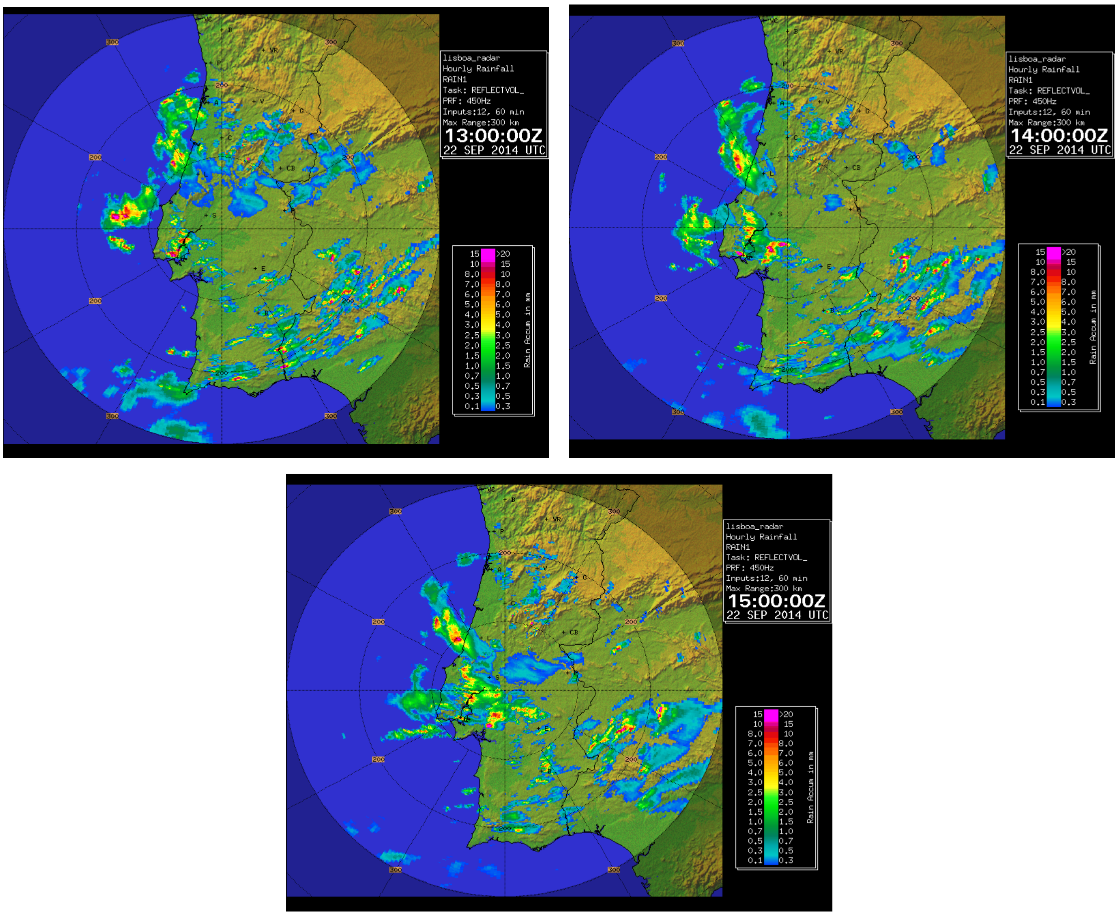

Figure 11 Hourly precipitation (mm) from Coruche /Cruz do Leão (C/CL) radar, at 13, 14 and 15UTC, on 22 September 2014.

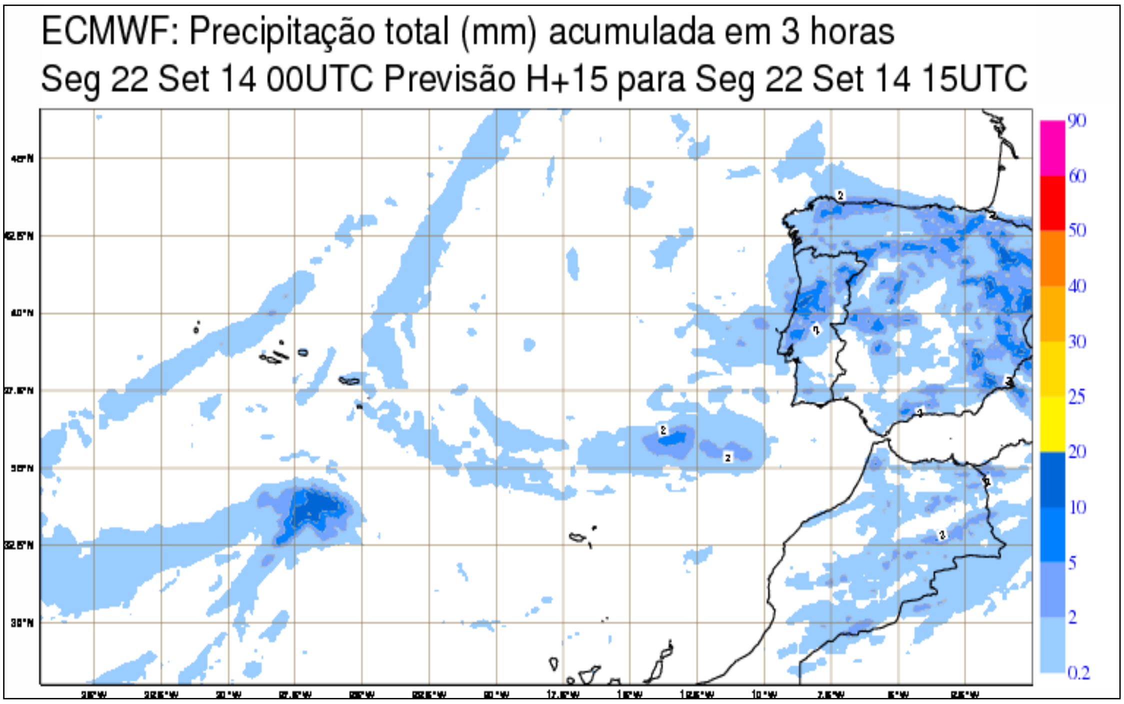

Figure 12 3-hourly precipitation from H+15 from ECMWF model, at 15 UTC, on 22 September 2014.

4. References to relevant publications

Belo-Pereira, M. 2015: Comparison of in-flight aircraft icing algorithms based on ECMWF forecasts. Met. Apps. doi:10.1002/met.1505.

Frada, M.J and **Narciso, P**., 2014: *Episódio de precipitação intensa na região de Lisboa em 22 de setembro de 2014*. IPMA internal Report DivMV 15/2014. In Portuguese.