Application and Verification of ECMWF Products 2021

Instituto Português do Mar e da Atmosfera, I.P. (IPMA)

João Rio (joao.rio@ipma.pt), with contributions by Célia Gouveia, Isabel Trigo, Lourdes Bugalho, Nuno Moreira, Manuel Lopes, Rita Durão.

1. Summary of major highlights

Verification results for near-surface variables are shown, comparing IFS Cycles 47r1 and 47r2, in the period between January and May 2021. Additionally, some conditional validation results are shown for the 10m wind speed.

2.1 Direct Use of ECMWF Products

ECMWF products are the main source of data for operational weather forecasting. In the short-term, this is complemented with the operational AROME forecasts.

The Forest Fire Hazard Group of the ARISTOTLE-eENHSP project provides a service of Fire Danger Assessment based on ECMWF High Resolution forecasts of several meteorological parameters available on EC-Charts, together with the combination of fire danger indices, developed by Copernicus Forest Fire Indices, available through the EFFIS and GWIS platforms. Additionally, fire weather products specially developed for the project, available through the EC-Charts layers, are used to improve the fire danger assessment.

The Forest Fire Hazard ARISTOTLE-eENHSP service provides a daily fire danger monitoring and forecast 2-3 days in advance, for the Pan-European area, which is included in the Multi-Hazard Impact Oriented Brief Report (MHOB); and also emergency assessments of ongoing fires at a global scale.

An example of a fire danger assessment produced for the 26/08/2020 MHOB report, based on ECMWF specific products developed for the ARISTOTLE-eENHSP project.

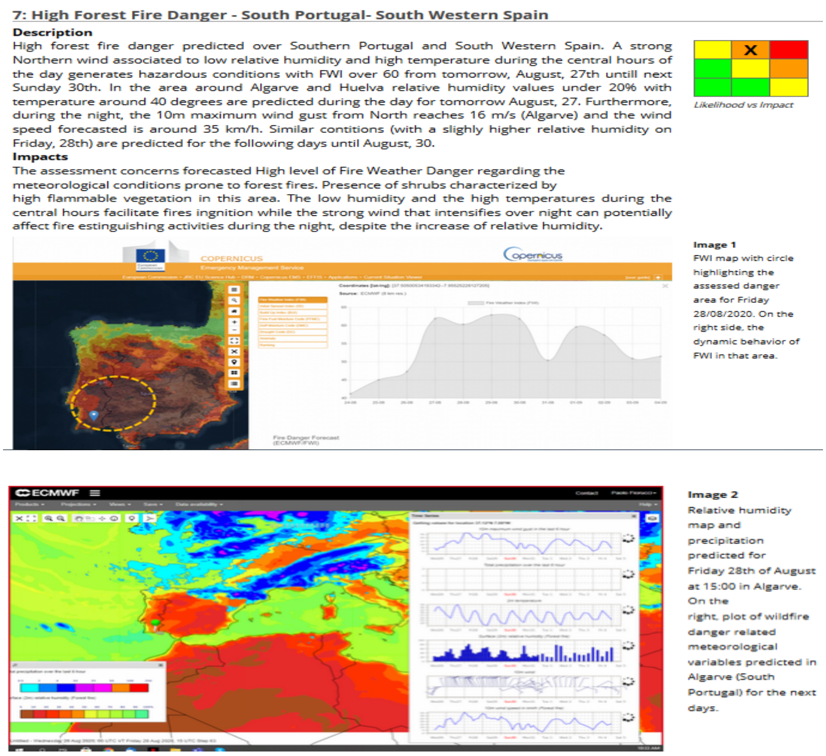


Figure 1- Fire danger assessment produced for the 26/08/2020 MHOB report, based on ECMWF specific products developed for the ARISTOTLE-ENHSP project.

The "Open Charts" products initiative is useful, as the webpage is fast and efficient. The availability of meteograms with the model climate and the ensemble vertical profile is particularly useful. One feature that is most convenient is the ability to check the forecast consistency, by showing the output valid at a given time from different model runs. Easy access to verification results is welcomed, namely in the extended and seasonal ranges, as this is crucial to the interpretation of the forecasts. Section 4 shows a product that could be a useful addition.

2.2 Other uses of ECMWF output

2.2.1 Post-processing

There has been an effort to increase the usage of ENS data, both in operational forecasting as well as in applications. An example of a recent application that was designed to use exclusively ENS data is the computation of the probability of dry thunderstorms, which uses the lightning flashes density and the total precipitation. Another one is the Automatic City Forecast, which relies on the combination of HRES and ENS, but from day 6 depends solely on ensemble data.

2.2.2 Derived fields

2.2.3 Modelling

ECMWF-HRES data is used for the initial/boundary conditions for the third-generation wave model SWAN (with resolution 0.05°x0.05°), which is run in four domains of interest.

3. Verification of ECMWF products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both HRES and ENS), and other NWP models

IFS Cycle 47r2 was implemented on May 11th, 2021 and ECMWF presented the overall validation results. Figures 1 to 6 show the verification results for Cycles 47r1 and 47r2, in the period between January 1st and May 5th, 2021, using around 150 weather stations in Mainland Portugal. The results are valid for the 2m air temperature and relative humidity, 10m wind speed and precipitation (3 and 24h). The scores shown are the RMSE and the BIAS; for precipitation, the Heidke Skill Score is used. Overall, the results show that Cycle 47r2 is neutral or improves the quality of the forecasts.

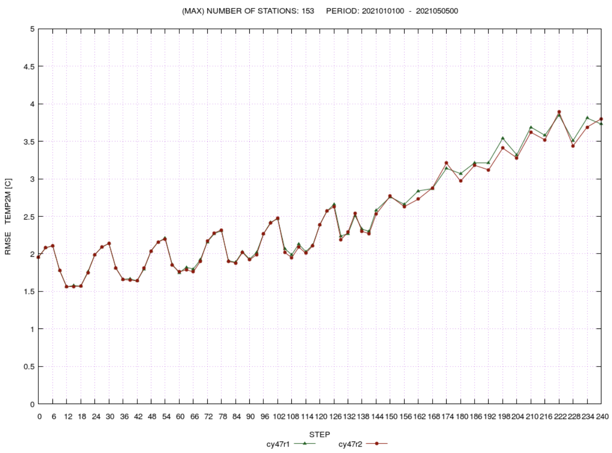
Figures 7 and 8 show a limited set of results of conditional verification for the 10m wind speed. A set 80 weather stations with high wind exposure have been selected and these have been split in 3 groups, depending on location: coastal (20), mountainous (19) and plains (41), the latter including the ones in plateau areas.

Two periods were chosen. The first comprises January 15th to February 25th, 2021, in which Iberia was affected by a westerly flow, with frequent Atlantic weather systems. The second comprises April 5th to May 10th, 2021 and represents a period of low average wind speeds, with large scale stability or cut-off lows west of Iberia. For conciseness, only results for the bias are shown. All the results are for the short-term (up to 48h range) and were computed with direct model output from HRES.

The results show that when all weather stations are accounted for, the bias is quite negligible in both periods. In the plains and coastal regions, the bias increases slightly, to around +0.5 m/s, except in the latter domain with lower wind speeds.

There is no evidence of a daily cycle. In the sample of weather stations in the mountains the results show a negative bias (around -1 m/s), stronger in the first period. There is a sharper daily cycle, with lower bias in the daytime (12/15UTC). As the data is direct model output, these results are partly caused by the model resolution, as the difference between the model's and real altitudes reach 400/500 m in some stations (in smaller and/or steeper mountains).

Scatterplots (not shown) of the 10m wind speed clearly signal that the model overestimate lower wind speeds (typically below 4 m/s) and underestimates high wind speeds. This remark applies to all types of locations.



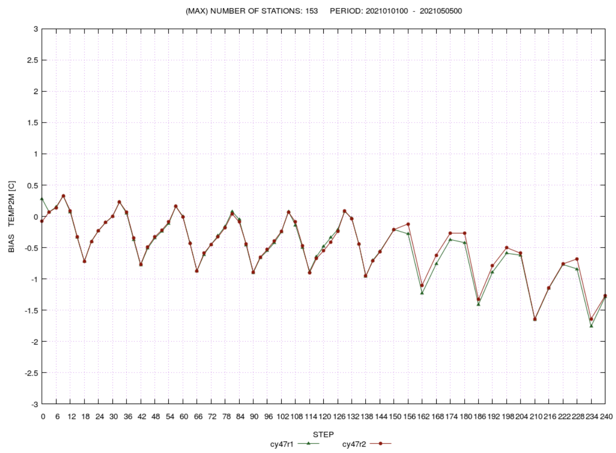


Fig 1 – RMSE (left) and bias (right) of the 2 m temperature, for cy47r1 and cy47r2, in the period January to May 2021.

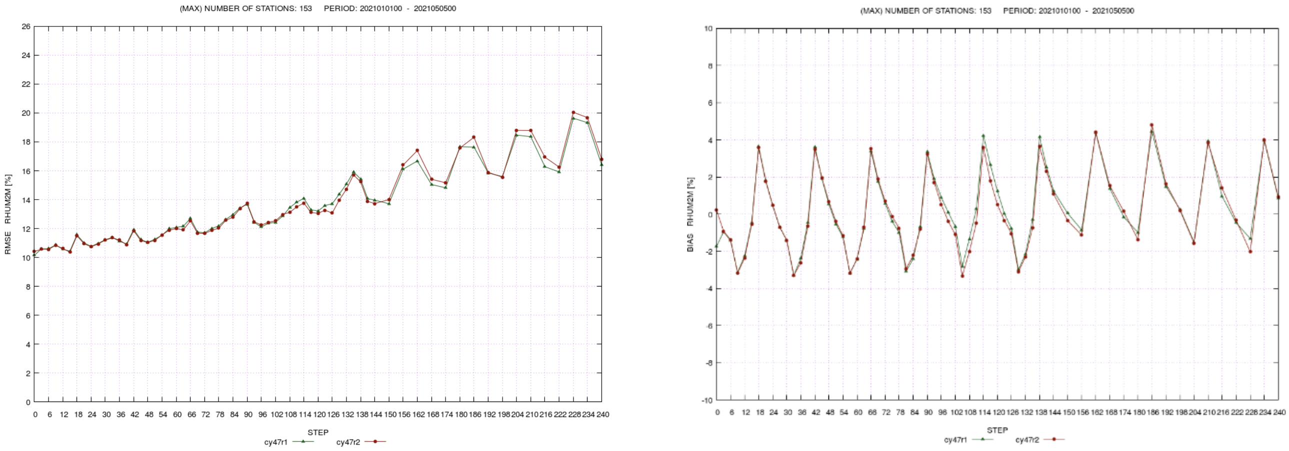


Fig 2 – RMSE (left) and bias (right) of the 2 m relative humidity, for cy47r1 and cy47r2, in the period January to May 2021.

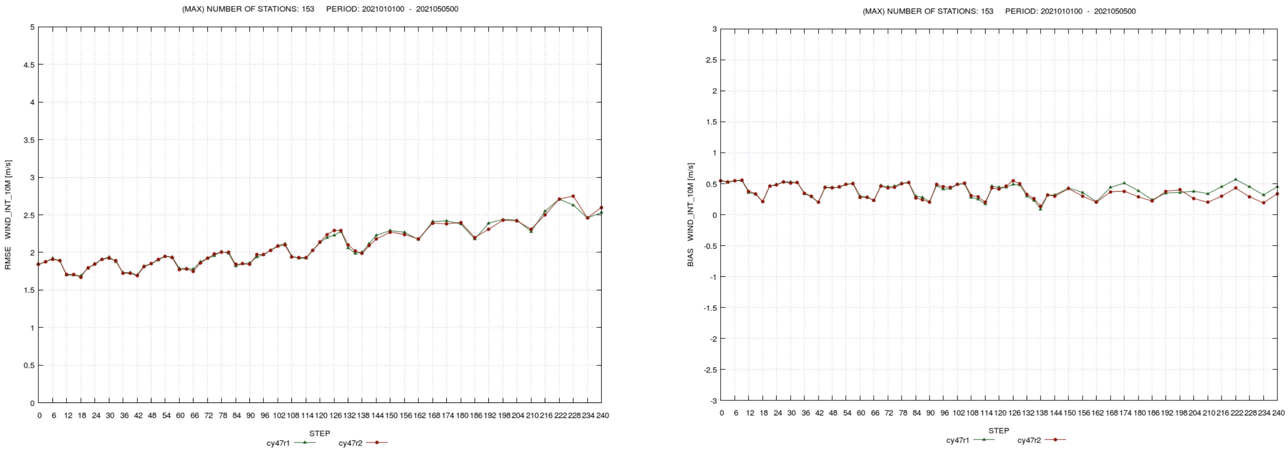


Fig 3 – RMSE (left) and bias (right) of the 10m wind speed, for cy47r1 and cy47r2, in the period January to May 2021.

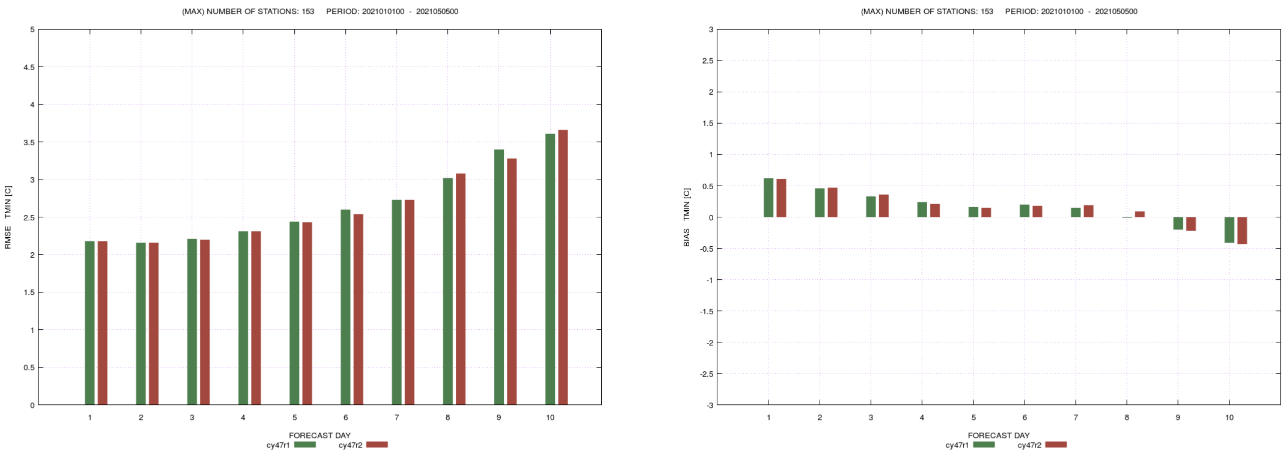


Fig 4 – RMSE (left) and bias (right) of the daily minimum 2m temperature, for cy47r1 and cy47r2, in the period January to May 2021.

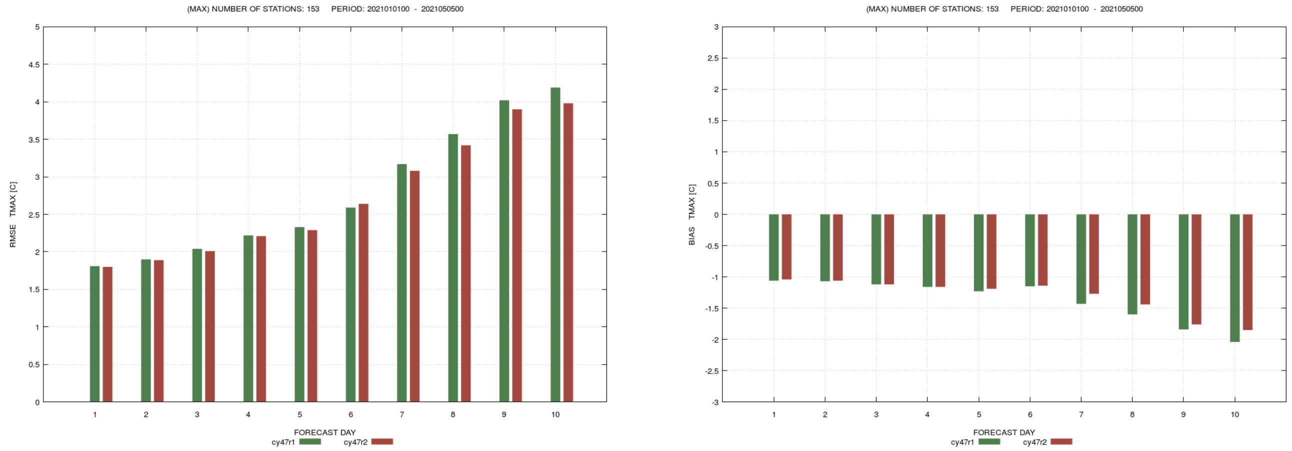


Fig 5 – RMSE (left) and bias (right) of the daily maximum 2m temperature, for cy47r1 and cy47r2, in the period January to May 2021.

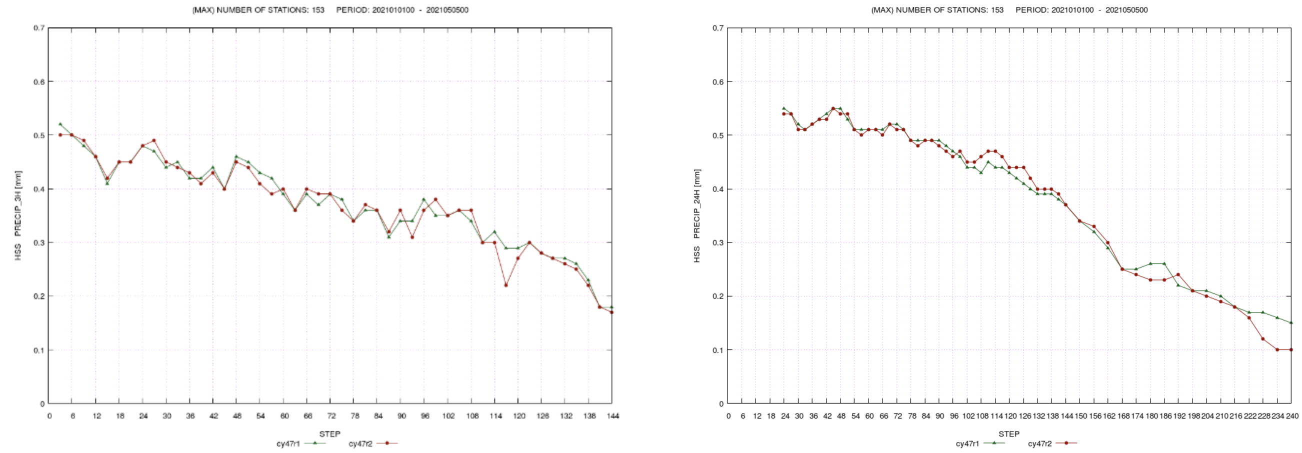


Fig 6 – Heidke Skill Score of 3h (left) and 24h (right) cumulated precipitation, for cy47r1 and cy47r2, in the period January to May 2021.

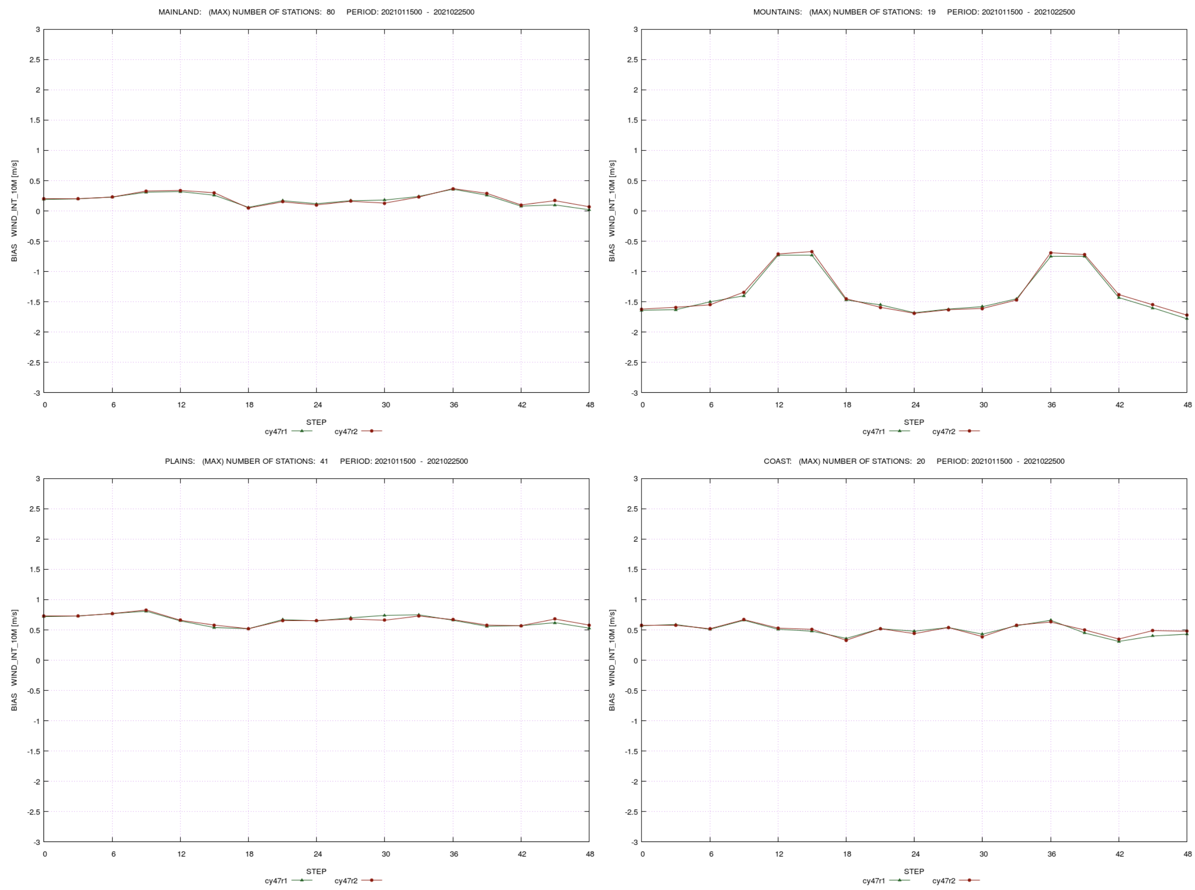


Fig 7 – Bias of the 10m wind speed, for cy47r1 and cy47r2, in the period January 15th to February 25th, 2021. Results valid for different kinds of locations (coastal, mountains, plains, all [Mainland]).

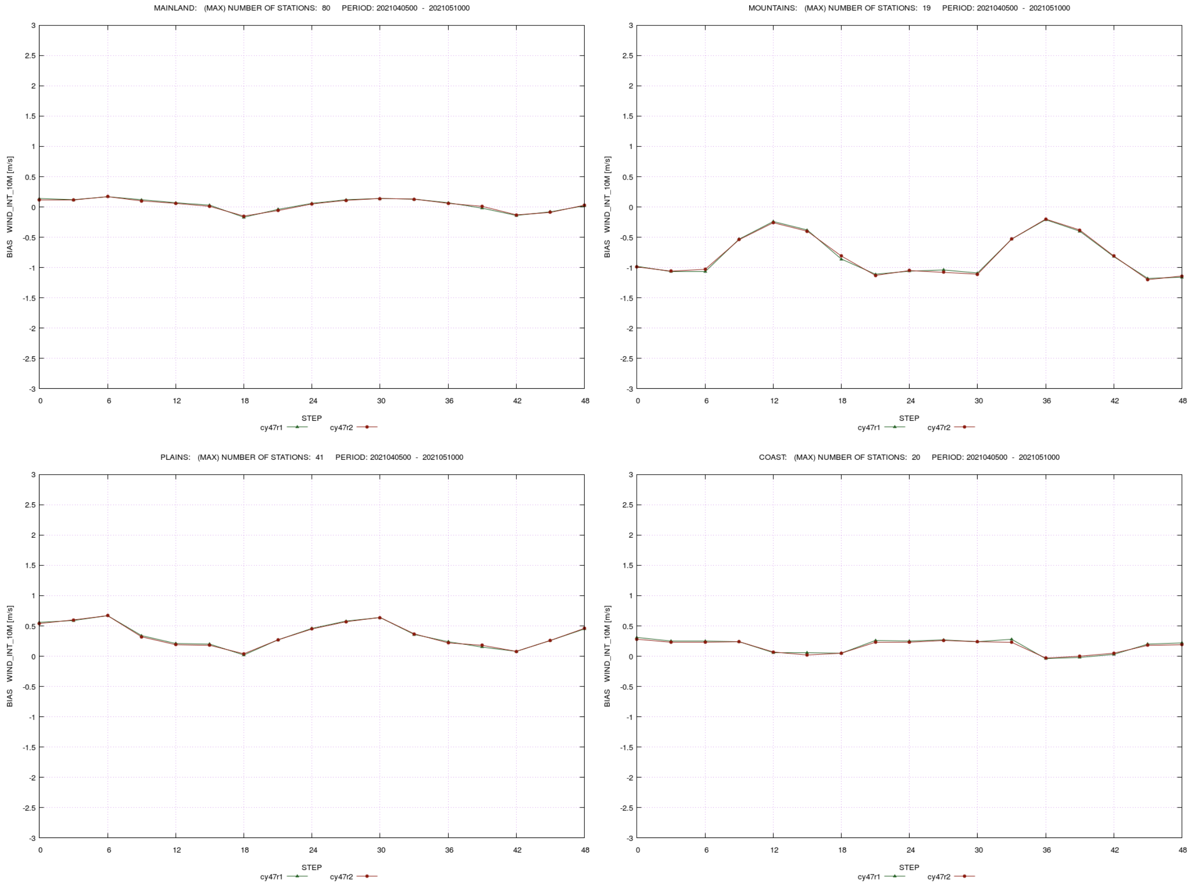


Fig 8 – Bias of the 10m wind speed, for cy47r1 and cy47r2, in the period April 5th to May 10th, 2021. Results valid for different kinds of locations (coastal, mountains, plains, all [Mainland]).

Figure 9 shows the observations of total column ozone in Lisbon, obtained with the Dobson D13 spectrophotometer, from November 2017 to December 2020, were compared with the 12UTC analyses of the ECMWF/CAMS operational model.

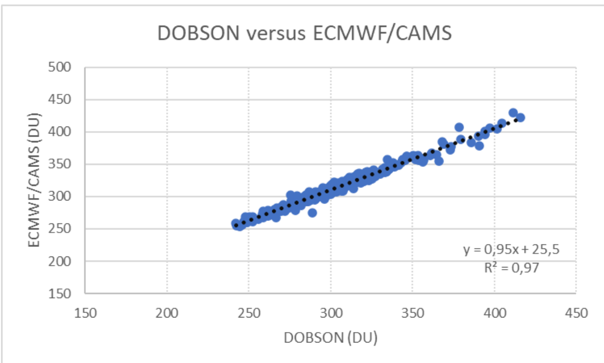


Fig 9 - Relationship between daily average values of total ozone observed in Lisbon with D13 and those estimated in the 12 UTC analyses of the ECMWF/CAMS operational model.

The values obtained for the RMSE, BIAS, MAE and MAPE between the daily values of the total column ozone observed with the DOBSON D013 from November 2017 to December 2020 and the 12 UTC analyzes of the ECMWF/CAMS model were 11.4 DU, -9.9 DU, 10.3 DU and 0.034, respectively. Considering the absolute minimum value of the total column ozone for our latitudes of 220 DU (or considering the reference value of 300DU), the RMSE value of 11.4 DU (ECMWF/CAMS) represents an average error magnitude of at most 5.2% (or 3.8%).

3.1.2 Post-processed products and end products delivered to users

The automatic weather forecasts compute the daily minimum and maximum 2m temperatures for around 700 locations in Portugal. The post-processing is applied directly to ECMWF-HRES (and AROME, when available), using Kalman Filter and Multiple Linear Regression. The average of all the post-processed values is the final forecast (POST_PROC).

However, in the medium term this is clearly inadequate, as the HRES exhibits large variability. Hence the solution applied is to use the unbiased ensemble mean (ENS_BC), with the correction factor computed with the information coming from the POST_PROC in the short-term. The public forecast (STA) is then a combination between POST_PROC in the short-term and unbiased ensemble mean in the medium term, with a smooth transition in the forecast days 4/5.

Figure 10 shows the RMSE of the daily minimum and maximum 2m temperatures for the January-May 2021 period, for a set of 153 weather stations in Mainland Portugal. "MEAN" in the plots stands for the ensemble mean (direct model output). The results show that the calibration of the ensemble mean is simple and quite effective. Note that the STA forecast is equal to POST_PROC in the short-term and to ENS_BC from day 6. Overall, the percentage of correct forecasts (forecast within a 2ºC range of the observation) is around 85 to 90% in the short-term (not shown).

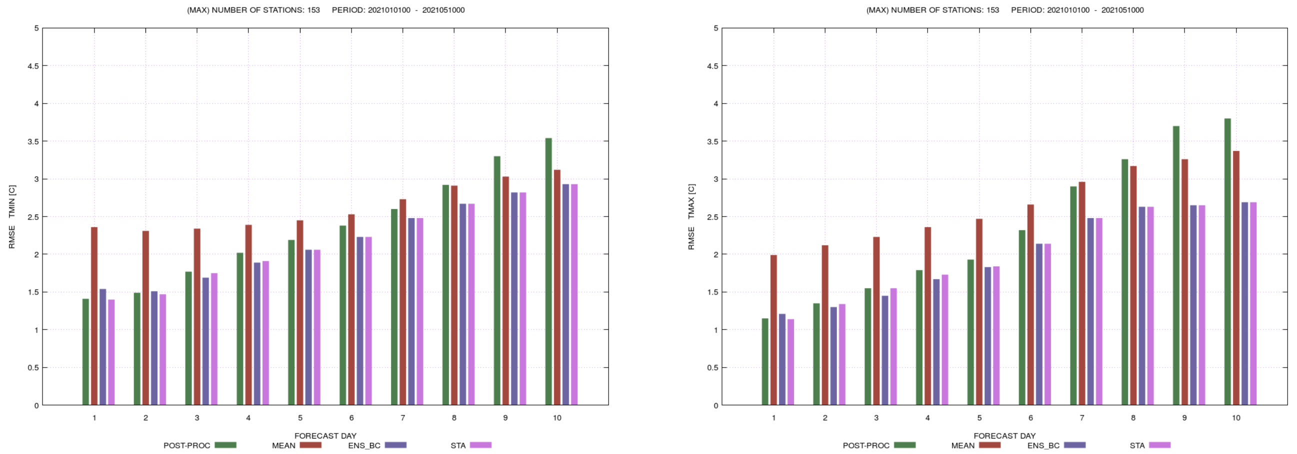


Fig 10 – RMSE of the daily minimum (left) and maximum (right) 2m temperature, in the period January to May 2021.

Verification results for a selected number of cities in Portugal is provided to the public on the website. The score used is the difference between the forecast and the observation, for forecasts made 1, 4 and 7 days in advance. The shaded area in the plots shows a correct forecast, with the definition given above (https://www.ipma.pt/pt/otempo/prev.localidade.hora/prev.verificacao/forecast-verification.jsp).

3.1.3 Monthly and Seasonal forecasts

3.2 Subjective verification

3.2.1 Subjective scores

Subjective evaluation of the model's performance suggests:

a) HRES forecasts usually underestimate the low clouds in the west coast (in summer) and inland in winter (northeast/Meseta Norte). Using ENS data helps to minimize this issue;
b) Dynamically driven convection (with a cut-off low to the west/southwest Iberia) is, frequently, very challenging;
c) The 3h maximum wind gusts at 10m have a slight positive bias. After some data handling, this can be quantified to be around 1 to 3 m/s. Please note that this result did not consider weather stations without high wind exposure or where local effects are obvious;
d) The density of lightning flashes is very useful, even though it estimates only the total number (roughly, only 20% of the lightning is cloud-ground – data from our lightning-detector network);
e) The model provides useful guidance (physically coherent) on the likelihood of dry thunderstorms;
f) In warm, moist south-westerly flow in western Iberia, the model overestimates light precipitation by the coast. This comment nevertheless considers the issue of grid-box mean value versus point observation;
g) Inherent to the forecasting system, forecast jumpiness is always an issue that operational forecasters must address. Even though ensemble forecasts are less jumpy, spring 2021 has provided an example of unusually low predictability. One of these events happened in late May, with the medium-range (4/6 days) daily maximum 2m temperature ensemble average (direct model output) changing up to 4ºC (when comparing consecutive 00 UTC runs).

Finally, just to mention we are looking forward to ECMWF's foreseen upgrades, namely in the moist physics processes and the increase of the horizontal resolution in the ENS.

3.2.2 Case studies

On December 25th, 2020, a severe weather event, with persistent convection in the eastern/northern half of the Madeira Island, caused frequent lightning and extreme precipitation, with over 250 mm/24h observed in the north coast. Despite the small size of the island and the coarse resolution of ECMWF (both HRES and ENS) for this kind of weather event, the model nevertheless provided useful information regarding how unusual this event could be, with 24h precipitation EFI around 0.8/0.9 (not shown).

On July 11th, 2020, there was convection in the afternoon in Mainland Portugal. Figure 11 shows the cloud-ground lightning flashes, in the period 18-19UTC. Figure 12 shows the location of location of ignitions caused by dry thunderstorms, according to official data from Law Enforcement authorities and figure 13 shows the probability of dry thunderstorms. This study is one example from several events that suggest that this product provides useful guidance. This application will be further assessed using official data on the cause of the forest fires and is likely to be upgraded, so that it can provide guidance in 3h periods.

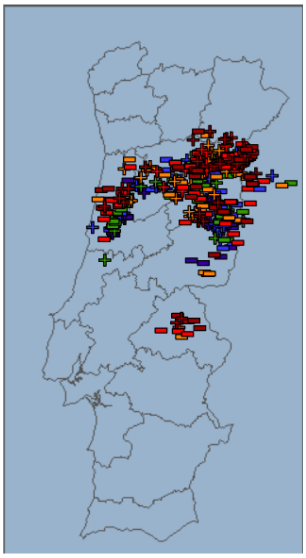


Fig 11 – Lightning flashes (cloud-ground) detected on July 11th, 2020, in the period 18-19 UTC.

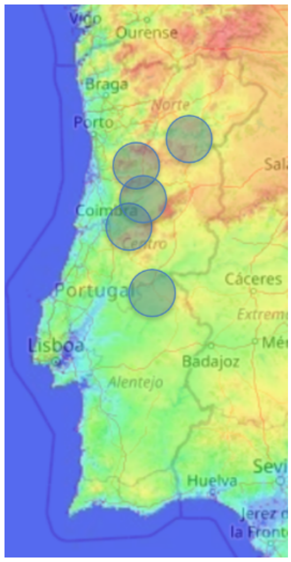


Fig 12 – Location of ignitions (blue circles) caused by dry thunderstorms, on July 11th, 2020, in the period 18-19 UTC. Fire data provided by Law Enforcement Authorities.

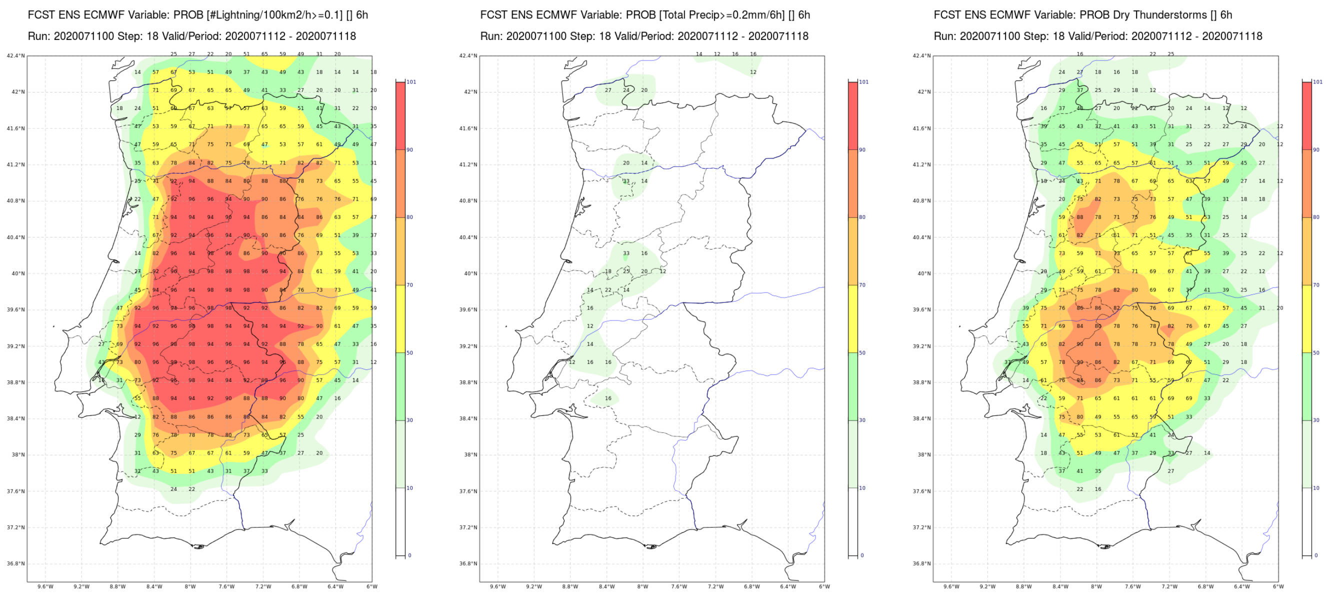


Fig 13 – Probability of lightning flashes above or equal 0.1/100km^2/h (left), probability of precipitation equal or above 0.2 mm/6h and probability of dry thunderstorms. All plots for 6h periods, valid on July 11th, 2020, 18UTC.

The Boundary Layer Height (PBL), which has already been made available to users in the scope of forest fires management, was studied in more detail on a forest fire that also occurred on 11th July 2020, in Lousã (central Mainland Portugal), that lead to 1 fatality and 3 injured firemen. This forest fire was likely triggered by lightning, as that area was affected by a strong convective system.

In the evening, along with the dissipation phase of a large convective system close to the fire, there was widespread subsidence in the area, which is consistent with the decrease in the height of the boundary layer (Fig 14). This is likely to have contributed to the high concentrations of smoke at low levels.

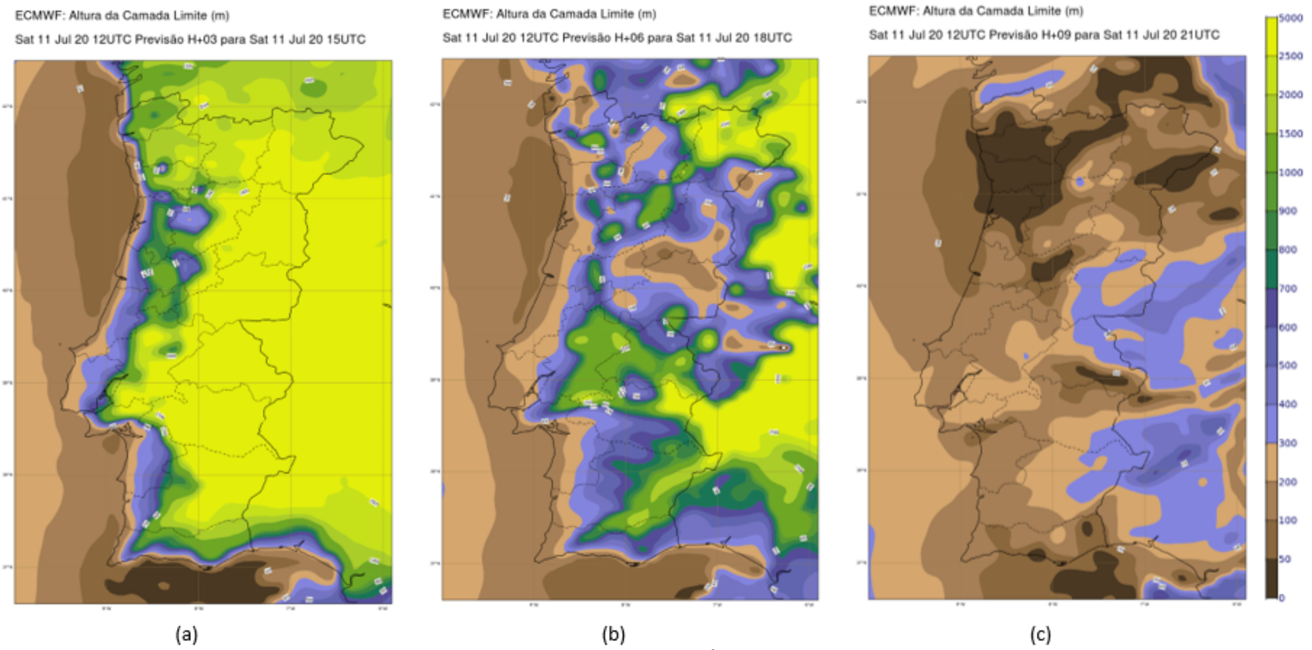


Fig 14 - HRES forecast of PBL height (m), from the 12UTC run on July, 11th 2020: (a) H+3 for 15UTC; (b) H+6 for 18UTC and (c) H+9 for 21UTC.

4. Requests for additional output

Figure 15 shows a plume like plot, for the 850 hPa temperature over Lisbon, considering the latest five HRES forecasts (00 and 12UTC runs only). Reference date for the plot is June 22nd, 2021. This is a clear example of low predictability in the medium-term, with high dispersion of the forecasts clearly seen from June 26th, 2021. There are already others way to check this (*e.g.* normalized standard deviation from the ENS), but this plot is quite simple, straightforward and does provides immediate insight. Adding data from the 06 and 18UTC runs would be beneficial.

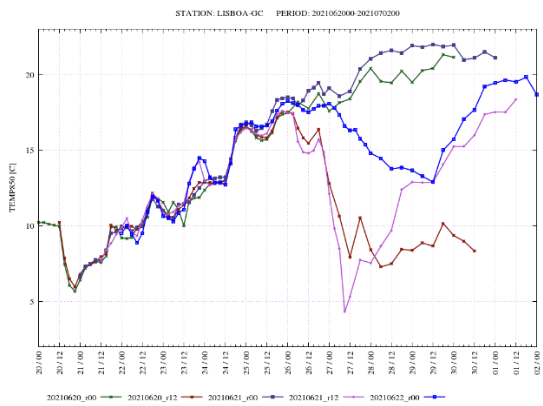


Fig 15 – HRES forecasts for 00/12UTC runs of the 850 hPa temperature over Lisbon. Reference date of the plot is June, 22nd, 2021.

5. References to relevant publications

L. Bugalho, D. Henriques, J. Marques, P. Drumont. Nota Técnica nº1/2021, IPMA, I.P (*in portuguese*).