Application and verification of ECMWF products 2016

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1. Summary of major highlights

The major highlights are:

a) Development of several parameters used to identify favourable environments for the onset of severe convective storms;

b) A new application for computing the lightning probability;

c) A new formulation for the computation of the weather conditions that uses HRES and ENS forecasts.

2. Use and application of products

2.1 Post-processing of ECMWF model output

2.1.1 Statistical adaptation

Statistical adaptation of ECMWF forecasts is made to improve daily minimum and maximum temperatures forecasts in selected locations up to 10 days. The system comprises forecasts from ECMWF and AROME models, whenever available. The application computes linear regression model (MOS) and kalman filter (KALMAN) adjusted temperatures for each model and the final forecast is then computed as the average of all available forecasts. This framework is applied to the 2 m temperature and relative humidity, as well as the 10 m wind speed. Products are 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 a mobile app (Meteo@IPMA).

2.1.2 Physical adaptation

The spectral density of ECMWF limited area ocean-wave model (WAM) is used together with 10 m wind of ALADIN as the input to the Simulating WAves Nearshore third-generation model, with 0.05º of horizontal resolution, 36 directions and 36 frequencies. Processing of its fields is done with an hourly frequency and forecasts are produced until H+72h. Three-hour forecasts are also available on IPMA's portal (http://www.ipma.pt/pt/maritima/cartas/).

2.1.3 Derived fields

The HRES 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.

The Fog Stability Index (FSI) is derived operationaly from ECMWF forecasts. This index is based on 2 m air temperature, 2 m dew point temperature, 850 hPa temperature and 850 hPa wind speed. The performance of FSI based on hourly forecasts of ECMWF and AROME models for the Lisbon airport, assessed for two extended winters (November–March), is presented in Belo-Pereira and Santos (2016).

Since December 2015, several parameters commonly used to identify favourable environments for the development of severe convective storms are derived from operational ECMWF deterministic forecasts. These parameters include bulk wind shear in 0-1 km and 0-6 km layers, storm relative helicity in 0-1 km and 0-3 km layers and several instability indices. The application of these parameters to an F3 tornado event in Portugal is highlighted in Belo-Pereira et al. (2016).

A new application for lightning probability has been developed and validated. The method uses a logistic regression model, with four stability indices as predictors. The probabilities are computed up to 5 days, with a frequency of 6 hours, with an example being shown in Fig 1. This product provides useful guidance on the areas where convection and lightning will likely occur. The product is computed from the HRES forecasts for now.

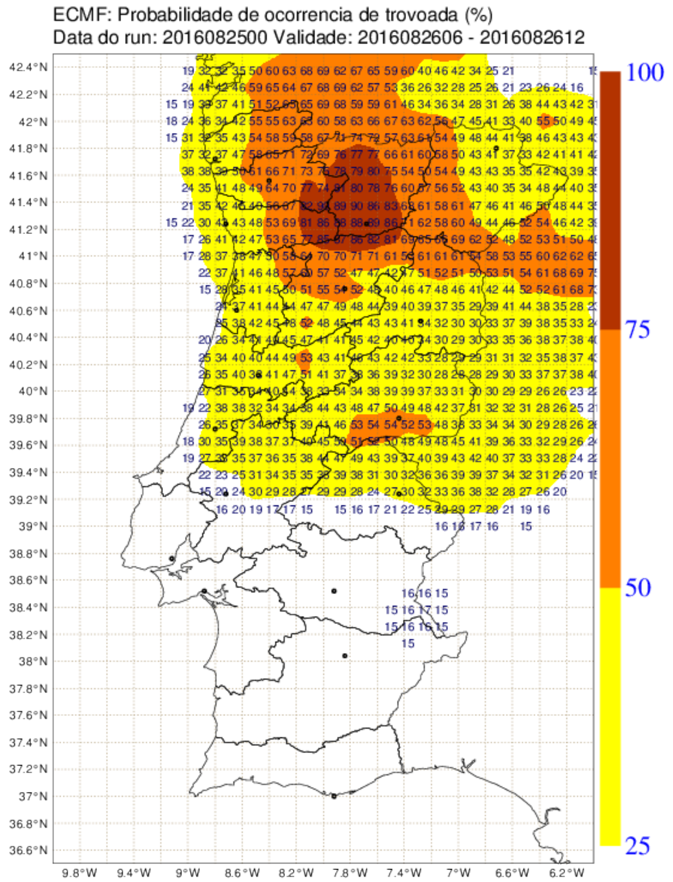
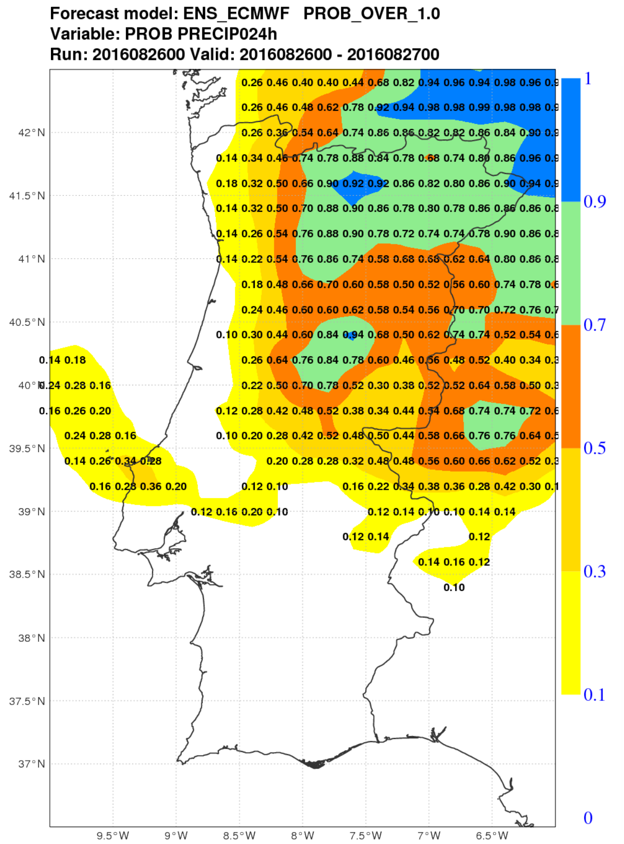


Fig. 1 Lightning probability (of at least 2 lightnings within a maximum distance of 0.4º) from the 00 UTC run of August 25th 2016, valid for the 6 hour period between 6 and 12 UTC, August 26th 2016.

A new version of the application that computes automatically the weather is being validated and will be become operational in the near future. Unlike the previous algorithm which relied only on the HRES forecast, the new one also uses the ensemble forecast data and therefore smoother fields can be obtained, which are more adequate for public purposes. Fig 2 shows the probability of precipitation over 1 mm/24h (left) and the weather symbol for the same day (right) - August 26th, which is computed based on the hourly weather. In the 24h weather, the blue and green colors mean precipitation (rain or showers), and the yellow to grey mean clear to cloudy skies.

The showery 24h weather in the north and centre of Portugal, computed with the hourly weather (using lower thresholds for precipitation), matches quite well the areas where the probability of precipitation above 1 mm/24h exceed the 30 %. Another feature of the map is the fact that there is not an excessive variability of the 24h weather, which is common to see in automatic forecasts.



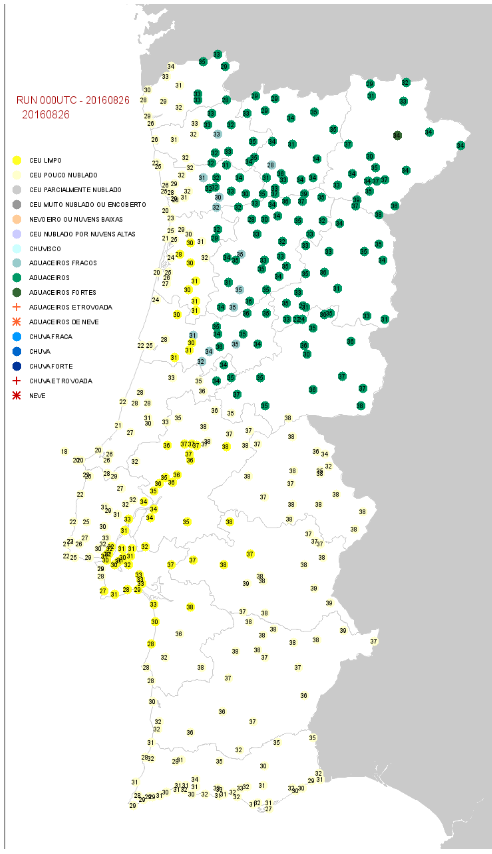


Fig. 2 Probability of precipitation over 1 mm/24h, on August 26th 2016 (left) and daily weather for August 26th 2016 (right), based on hourly weather types (clear or sunny skies are yellow and showers are green and blue).

2.2 Use of ECMWF products

Apart from the HRES forecasts, in the short and medium range, many of the products derived from the ensemble forecasting are used operationally and considered to be very useful.

The ECMWF monthly forecast is used to produce a bulletin twice a week with forecasts on the 2 meter air temperature and precipitation for mainland Portugal for the 4 weeks of forecast. 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 guidance on the 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.

In the context of scatterometers at IPMA, ECMWF/IFS model has two main applications. First, model fields are used to derive ASCAT high resolution products. Secondly, to perform product comparison in the framework of triple collocation techniques. High resolution scatterometer products, such as ASCAT-6.25, are considered to be of critical importance at IPMA coastal studies. However these products are not distributed operationally as other scatterometer products. IPMA uses ASCAT-6.25 products extensively in process studies and therefore runs AWDP-2.4 in house. In the AWDP-2.4 ASCAT-6.25 wind processing ECMWF’s land mask, sea surface temperature and first-guess winds are used. ECMWF/IFS forecasts are also used to assess measurement errors of NWP, scatterometer and buoys on the context of triple collocation method (this work is still in a preliminary phase).

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both HRES and ENS)

IPMA has some applications that compare, in real time, the wave model forecast with observations. IPMA compares the model with data that gets from buoys that are near the coast and also with satellite information, namely from the Jason 2 Altimeter. Our forecasters have access in real time to the comparison of the parameter of significant wave height between remote observation of Jason2 altimeter and ECMWF wave model HRES-SAW. Every time the orbit passes in Portuguese waters, a plot is made with the satellite data, as shown in Fig 3.

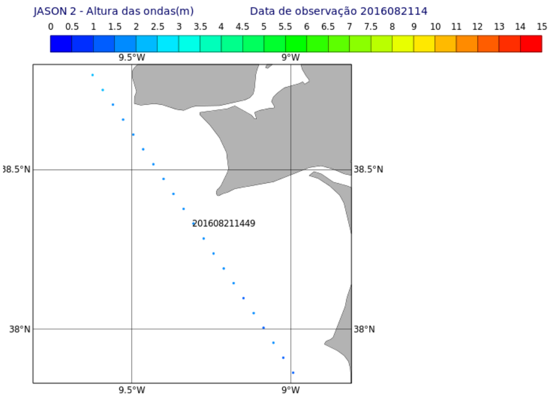


Fig. 3 Path of the Jason-2 Satellite off the west coast of Portugal.

A plot of the height versus longitude is also made and shown in Fig 4. They have access to the information for a large area of the ocean, but also for zones with more details, closer to the coast.

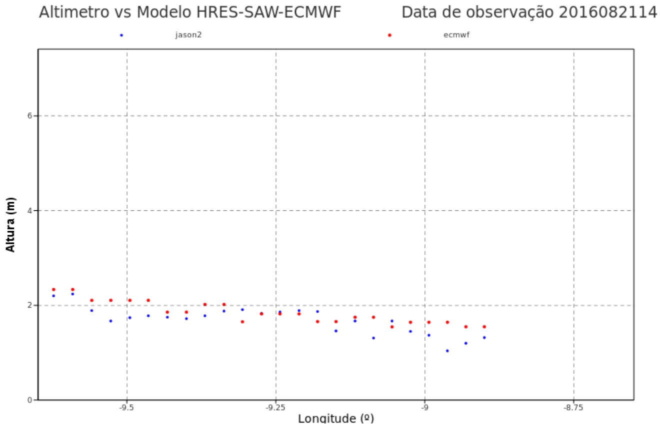


Fig. 4 Comparison between Jason2 and HRES-SAW model, height (*altura*) versus longitude.

In the case of the buoys, since the observation is always in the same place, we compare series of 24 hours forecast with the observations. Every time a new forecast is available, a graph is made showing the next 24 hours forecast. The previous run is also shown for comparison (Fig 5) and the plot is updated hourly, as soon as the observation is available. By now, the process is operational for 3 buoys in the Atlantic, close to mainland.

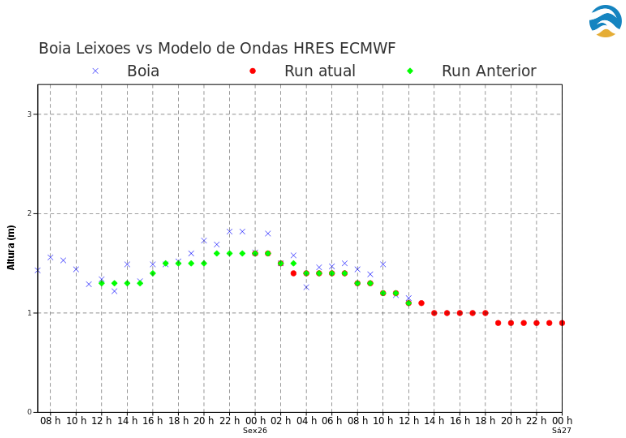


Fig 5 Observation of SWH versus hours for Leixoes coastal buoy and two consecutive forecasts of HRES-SAW model
[Blue is observation, Red is the last Run, Green is the RUN before].

3.1.2 *ECMWF model output compared to other NWP models*

Some scores from the direct model output, using only the 00 UTC run, are shown for the following two periods: (1) Spring 2016 [taken as March 18th to May 31st] and (2) Summer 2016 [taken as June 30th to August 26th]. In the first one the weather was rather unstable, with frequent precipitation and thunderstorms while in the second one it was very warm and dry, with extreme maximum observed temperatures around 43 ºC.

The models shown are the ECMWF and AROME, the latter running with an horizontal resolution of 2.5 km. Fig 6, 7 and 8 show the RMSE and the bias for the summer period, using 110 weather stations in Portugal, respectively, for the 2 m temperature, relative humidity and the 10 m wind speed. Fig 9, 10 and 11 are similar for the Spring period.

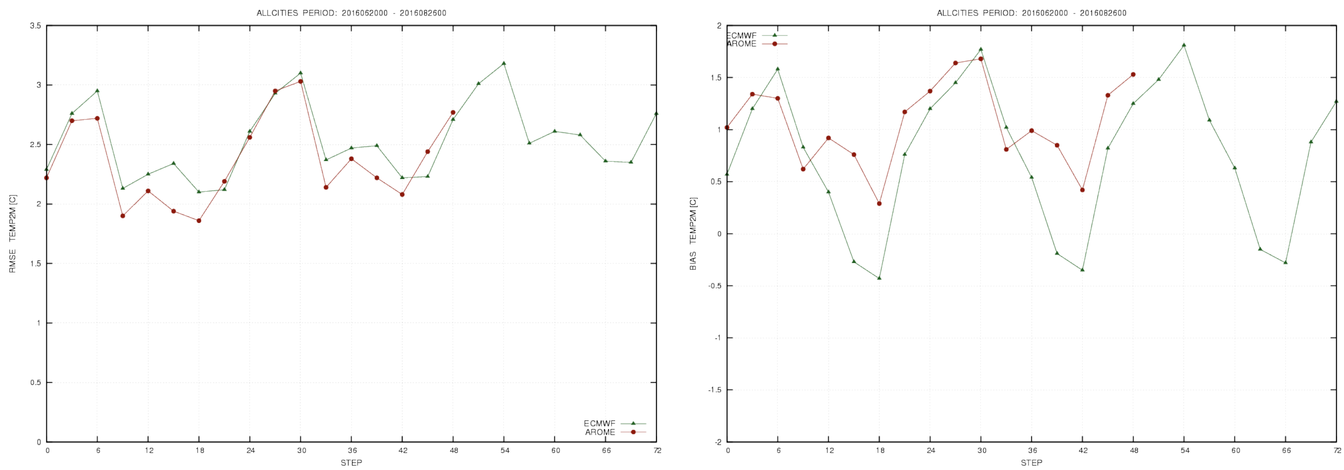


Fig. 6 RMSE (left) and bias (right) of the 2 m temperature from ECMWF and AROME forecasts.
The results were computed for the 00 UTC run, using 100 weather stations in Portugal, in the Summer of 2016.

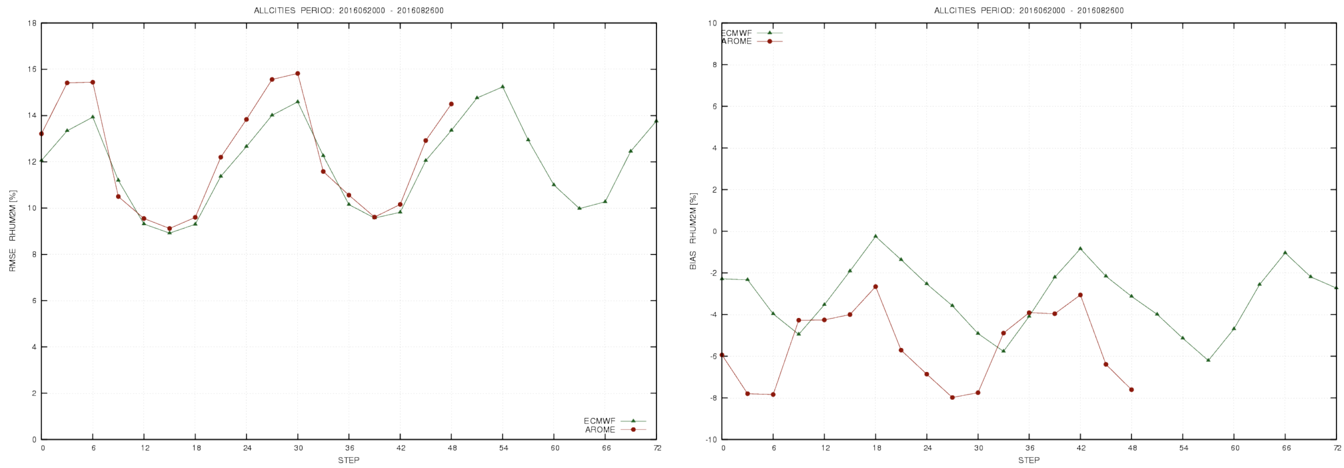


Fig. 7 RMSE (left) and bias (right) of the 2 m relative humidity from ECMWF and AROME forecasts.
The results were computed for the 00 UTC run, using 110 weather stations in Portugal, in the Summer of 2016.

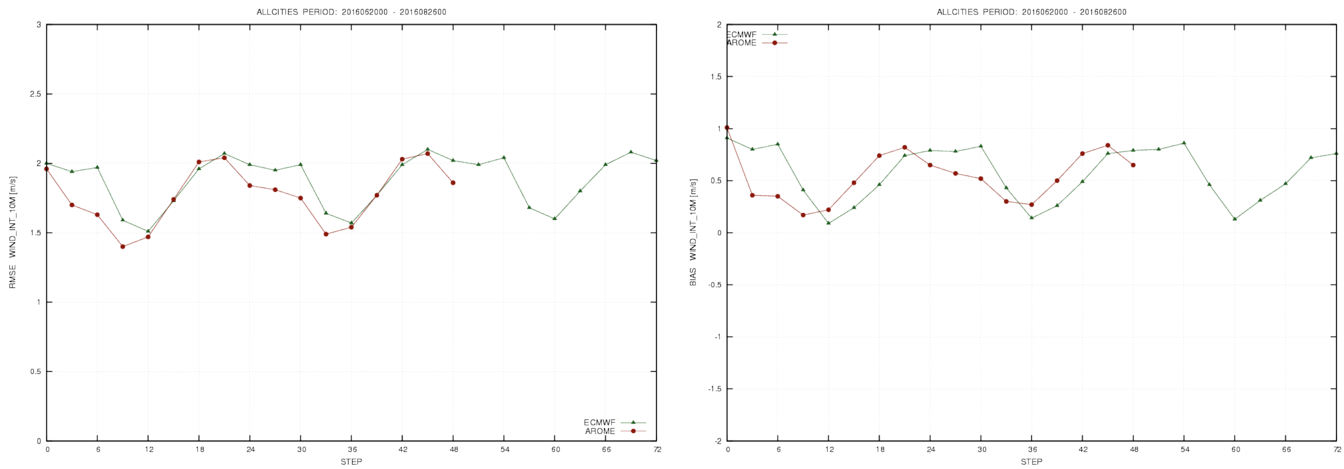


Fig. 8 RMSE (left) and bias (right) of the 10 m wind speed from ECMWF and AROME forecasts.
The results were computed for the 00 UTC run, using 110 weather stations in Portugal, in the Summer of 2016.

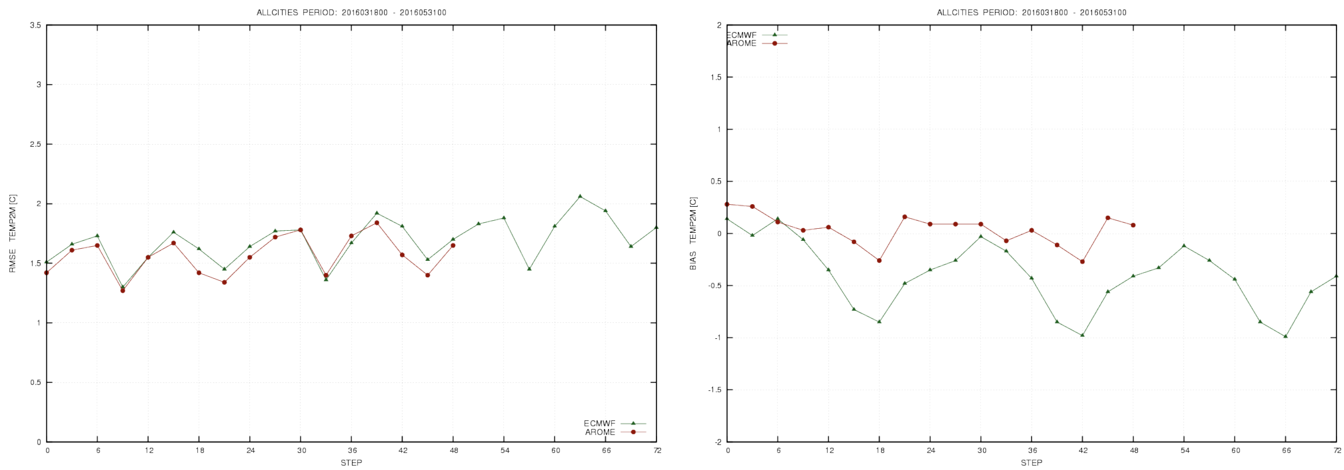


Fig. 9 RMSE (left) and bias (right) of the 2 m temperature speed from ECMWF and AROME forecasts.
The results were computed for the 00 UTC run, using 110 weather stations in Portugal, in the Spring of 2016.

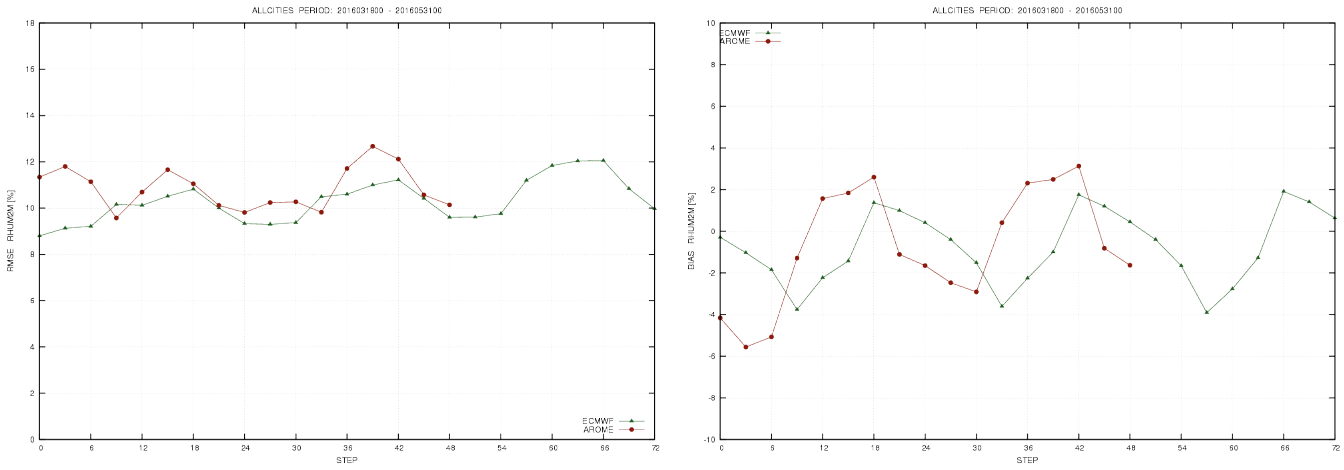


Fig. 10 RMSE (left) and bias (right) of the 2 m relative humidity from ECMWF and AROME forecasts.
The results were computed for the 00 UTC run, using 110 weather stations in Portugal, in the Spring of 2016.

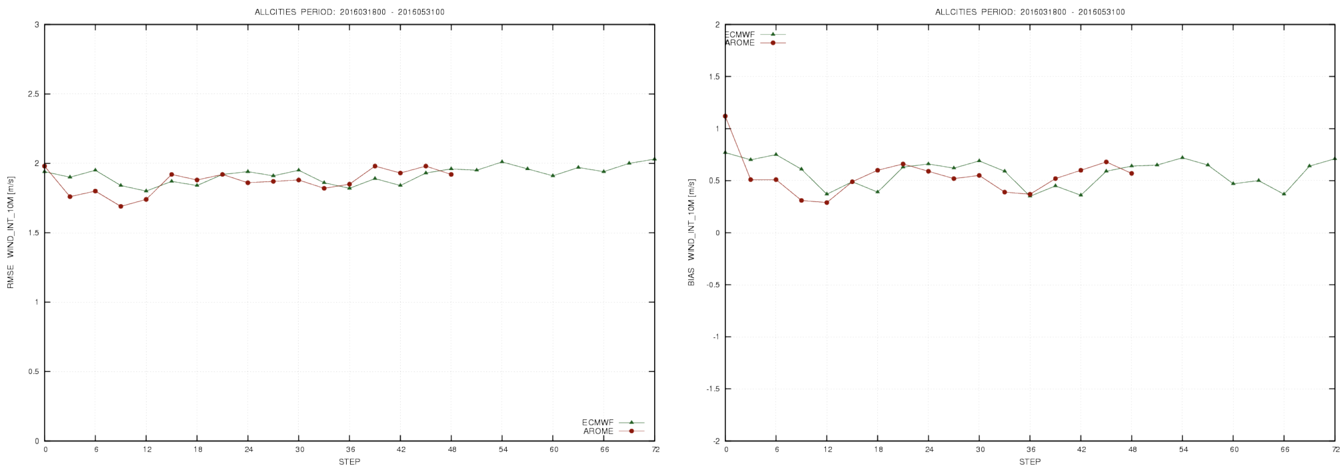


Fig. 11 RMSE (left) and bias (right) of the 10 m wind speed from ECMWF and AROME forecasts.
The results were computed for the 00 UTC run, using 110 weather stations in Portugal, in the Summer of 2016.

In the two periods under assessment, there are clear differences in the performance of the models, with larger errors in the Summer when compared to Spring. Both models have similar values of RMSE and bias, despite showing some differences in daily cycle, particularly in temperature and relative humidity.

Taking a single forecast single observation approach, the Heidke Skill Score of the ECMWF and AROME forecasts is similar for 24h periods, around 0.5 (not shown). When using a 3h period, ECMWF shows slightly higher values when compared to AROME, which is expected due to the latter’s higher resolution. Overall, ECMWF shows a positive bias for light precipitation.

In the Spring 2016 period, when instability was a common feature in Iberia, even though the HRES forecasts were able to provide good guidance on the areas where precipitation happened, the total amounts were excessively small, with values of over 10 mm/3h very uncommon. This issue is more severe in the ensemble forecasts due to their coarser resolution.

3.1.3 Post-processed products

Fig 12 shows the accuracy of the 2 m minimum and maximum daily temperatures for the Summer 2016, using a threshold of +/-2 ºC. These results show the improvement of the post-processed method (STA), which also includes AROME forecasts in order to compute the STA forecasts. In the first two days the accuracy is high, with values around 0.9. These values drop to around 0.7 at days 5/6 and eventually go below 0.5 at days 7/9. In Summer the drop in forecast accuracy is faster for the maximum temperature, while in Winter the minimum temperature shows worse scores.

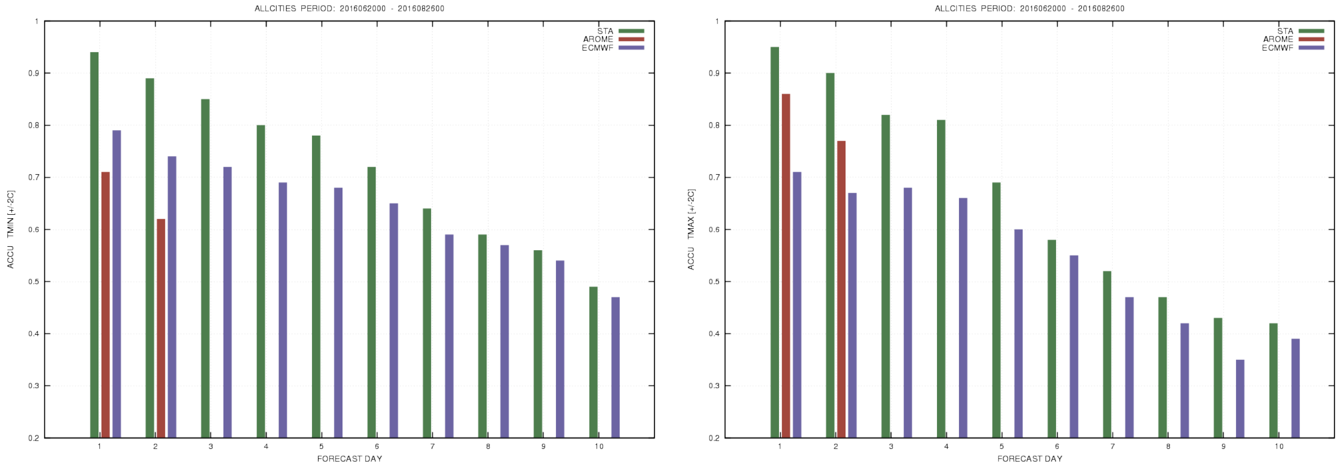


Fig 12 Accuracy [with a tolerance of +/- 2º C] of the minimum (left) and maximum (right) daily temperatures from the post-processed variables (STA), AROME and ECMWF forecasts. The results were computed with 110 weather stations in Portugal, in the Spring of 2016.

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 Case studies

4. Feedback on ECMWF "forecast user" initiatives

Both the mentioned initiatives are considered to be very useful at IPMA, particularly the one on the "known IFS forecast issues" page (https://software.ecmwf.int/wiki/display/FCST/Known+IFS+forecasting+issues), as it allow forecasters to access information on the model behavior. The severe event catalogue is also well regarded (https://software.ecmwf.int/wiki/display/FCST/Severe+Event+Catalogue) as a valuable database for model evaluation and development.

5. References to relevant publications

Belo-Pereira, M., C. Andrade e P. Pinto, 2016: A long-lived tornado on 7 December 2010 in mainland Portugal. *Atmospheric Research*, Under review.

Belo-Pereira, M. and J. A. Santos, 2016: A persistent wintertime fog episode at Lisbon airport (Portugal): performance of ECMWF and AROME models. *Meteorol. Appl*., 23, 353-370. *Doi*: 10.1002/met.1560.