MS/CS "Green Book' Report 2024

Section 1: Background

* 1.1 Country

Spain

* 1.2 Author(s)

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* 1.3 Organisation

AEMET - Spanish Meteorological Agency

* Section 2: Summary of major highlights

ECMWF forecast products are fundamental for the Spanish Meteorological Agency (AEMET) not only in the short range but also in the medium, extended and long ranges. Besides, the increase of resolution of the EPS was very well received. Notwithstanding, there are some biases in some of the main forecast variables.

Section 3: Forecast Products

3.1. Direct use of ECMWF forecast products

*a) Medium Range (e.g. for high impact weather forecasting)

- Production of maps for forecasters for short and medium ranges, and for our website.
- EFI and SOT maps from IFS-ENS are used as an early warning for possible extreme events, especially in medium range forecasts. They are used in combination with clusters and probability maps for different thresholds and variables.
- As an input to AEMET Digital Forecast Database (BDDP), with other NWP models (see 3.3).
- The permalink access to products is widely used and extremely useful. Its availability in the new catalogue will be warmly welcomed.

*b) Extended Range (monthly)

Production of maps for forecasters and for our website.

*c) Long Range (seasonal)

Products used by the technicians who carry out the official AEMET seasonal forecasting.

*d) CAMS and Fire-related output (ecCharts mainly)

Production of maps for our website (https://dust.aemet.es) of Dust AOD and Dust Surface Concentration (72 hours forecast, regional domain: Northern Africa, Middle East and Europe).

Fire-related products used by ARISTOTLE Forest Fires experts/forecasters (through ecCharts).

3.2. Cycle 48r1

***a) <u>Positive</u> impacts of model cycle 48r1**

Positive impact in general terms. Particularly, the confidence in the EPS has been reinforced thanks to the resolution increase. It is also very positive to have the extended forecast produced daily as it allows to better assess its reliability.

*** b) <u>Negative</u> impacts of model cycle 48r1**

On the other hand, we have the feeling that the resolution increase might lead to uncovered scenarios. We would say (subjectively) that the dispersion has decreased and, sometimes, it is accompanied by a model failure (for instance, episode of snowfall and intense precipitation in the NE of Spain on the 10^{th} of January 2024 that disappeared suddenly in between runs).

c) Systematic changes in forecast output since model cycle 48r1 was implemented

Probabilistic products adapted to the new ENS resolution.

3.3: Derived Fields

- 2 m temperature: IFS HRES (both 12 and 00 UTC runs) 2T grids are statistically downscaled to generate 1 km grids for the next 10 days. The method uses a bias correction ('exponential decay correction' based on observed temperatures from the automated spanish network) and an altitude correction (from a 1 km altitude grid) and is applied to both the 'Peninsula/Baleares' and the 'Canary Islands' areas.
- Production of thermodynamic diagrams and hodographs from pseudo soundings with all the hybrid levels of IFS HRES up to 120 hours using a tool fully developed in AEMET.
- Direct irradiance: calibration of the direct irradiance provided by the IFS ENS using a quantile regression method to improve its spread for the short range (1-2 days ahead) for specific geographical locations.
- 5 km grid: We adapt the original resolution of IFS fields (HRES and ENS) to the 5 km “standard” resolution of our Digital Forecast Database (BDDP), used for producing automatic products. In this BDDP we use forecasts from several models; HRES is generally used from H+48 ahead and ENS is used from H+0.
- Every day for both 00 and 12 runs, we generate 6 or less objective clusters in two specific areas (Peninsula/Baleares and Canary Islands), for a 15-day period using the clustering method developed in the ECMWF (Ferranti et al, 2014).
- We produce probability maps for cloudiness, rainfall, snow, CAPE, wind, wind gusts, temperature and temperature variations.
- We also obtain other derived fields for several specific uses (turbulence indices, 0 ºC wet bulb temperature altitude, etc.)
- Automatic products (BDDP) in text and pictogram formats which include deterministic and probabilistic information are generated for AEMET´s website.
- Snowpack evolution analysis in order to assess snowfall (Spain and synoptic regions). The difference in the snowpack depth analysis between the lasts two HRES runs is generated in order to evaluate possible snowfall in the last 12 hours. This process is extended to 24, 48 and 72 hours.
- NivoGraM: A web app that shows the evolution of different postprocessed fields, related to snow and snow cover, for 72 hours.
- Use of variables related to forest fires up to D+7 for the prediction of AEMET's forest fire index.
- CAMS participates in the generation of our multimodel products. These products are built with the models available daily in our regional centre being the median of the multimodel and probability exceedance maps. Both with a 72 hour forecast of Dust AOD and Dust Surface Concentration for the regional domain of our centre (Northern Africa, Middle East and Europe).
- CAMS also participates in the generation of our Sand and Dust Storms Warning Advisory System (SDS-WAS) for Cabo Verde, Mauritania, Senegal, Mali, Burkina Faso, Niger and Chad (https://dust.aemet.es/products/daily-dust-products?tab=forecast&section=was). Thresholds are based on the percentiles of a multimodel median time series. The warning consists in coloured code maps for the first administrative division of each country.

3.4: Artificial Intelligence (AI) / Machine Learning (ML) techniques

- We are developing an objective synoptical classifier to asses in the future the atmosphere uncertainty contained in the ENS-IFS members. This classifier is based on a Convolutional Neural Network trained using predictor fields from the ERA-5 reanalysis, and a subjective classification well known in AEMET, called the Font's classification, which has a strong link to weather regimes in the Iberian Peninsula and Balearic Islands. We are in an advanced phase of its development.

- We are working on a new statistical temperature postprocessing based on Neural Networks which are being training with HRES-IFS. Currently, we are in a first step of its development.

- We are going to participate in the ML Pilot Project, coordinated by ECMWF. Our goals for that project are:
  - To prepare datasets suitable for training over the Iberian Peninsula. In particular we plan to use ERA5 (and ERA6 in the future) extensively, among other reanalyses.
  - To learn how to train and use advanced ML data-driven models, and other related infrastructure useful to run them, drawing on ECMWF experience (AIFS, and Anemoi).
  - To try to design a LAM data-driven model which might be used by AEMET in conjunction with ECMWF AI models.

3.5: Dynamical Adaptation

- Deterministic integrations using HARMONIE-AROME model:
  - IFS HRES early delivery forecast cycles at 00, 06, 12 and 18 are used as boundary conditions for the HARMONIE-AROME limited-area model. We run HARMONIE-AROME at 2.5 km with 3 hr analysis cycles and 72 hours forecast length at 00, 06, 12 and 18 UTC. For the initial condition, the first guess is constructed using the large scale from IFS HRES and the small scale from HARMONIE-AROME (blending method). Except for SST, surface fields do not use IFS data (pure HARMONIE-AROME cycle).
  - We maintain a HARMONIE-AROME 2.5 km deterministic run as a Time Critical facility at ECMWF computers which is used as backup for the local integrations.
- In research mode we use CAMS aerosols forecasts as input to HARMONIE-AROME model both in radiation and microphysics.
- IFS HRES is also used in dynamical adaptation in the operational multi-model multi-boundary EPS LAM system.
- We use IFS HRES forecast fields as forcing of the CTM MOCAGE and its dispersion model version MOCAGE-ACCIDENT. MOCAGE is a multi-scale chemical transport and aerosol model that can be configured with up to three nested domains and it is used by AEMET to provide air quality forecast over Spain through a license agreement of use with Météo-France. The configuration used comprises a global domain at 2º resolution, a continental domain (40ºW-26ºE and 24ºN-60ºN at 0.5º resolution) and a regional domain (15ºW-10ºE and 33ºN-45ºN at 0.1º resolution). In the operational execution we use IFS HRES forcing (surface and up fields at model levels) for the global and continental domains and Harmonie-Arome forcing for the domain of higher resolution. The system runs with a 48-hour scope twice a day (at 00 and 12 UTC). We also run MOCAGE-ACCIDENT for giving response to civil protection authorities in environmental emergencies over different areas and at different resolutions. We use IFS HRES forecast fields (the three components of wind, temperature, specific humidity at model levels and precipitation and pressure at surface) as forcing for global domain at 1º resolution and for continental domain at 0.2º resolution.
- The AEMET wave prediction system is based on a local area configuration of the ECMWF CY47R1 (ECWAM) global wave model. It consists of a single nesting that receives forcings and hourly boundary conditions from the model that is operationally executed in the ECMWF. The spatial resolution has been increased to 4 km to capture in greater detail the evolution of wave energy as it interacts with obstacles and shorelines. The system runs with a 72-hour scope twice a day (at 00 and 12 UTC).

3.6: Data-driven (AI) models

***a) ECMWF's real-time AI model initiative**
The initiative is known.

***b) Use of AI forecasts for operational purposes**
None.

Section 4: Verification

4.1 Raw model output from ECMWF, and other operational models/ensembles

a) Short Range and Medium Range

Objective verification of HRES in the Short Range (0-72):

- Positive Bias in 10 m Wind Speeds. The Cy48r1 model tends to overestimate 10 m wind speeds by about 0.4 m/s in spring and summer, and 0.6 m/s in autumn and winter. This positive bias is most pronounced near the coast, where it can reach around 1 m/s. On the other hand, stations at elevations above 1000 m generally show a negative bias of around -0.4 m/s.
- Bias in 1-Hour Wind Gusts. The 1-hour wind gust measurements also have a positive bias of around 1.5 m/s. This is mainly because the model overestimates the frequency of gusts below 25 m/s. But above 25 m/s, the opposite happens - the model underestimates the frequency of the stronger gusts.
- Overestimation of light precipitation (less than 2 mm/h) and underestimation of moderate and heavy precipitation.
- For the CAMS evaluation we use AERONET AOD data and Dust AOD MODIS satellite product. Statistics are calculated near-real-time (only AERONET), monthly, seasonally and annually. (https://dust.aemet.es/products/daily-dust-products?tab=evaluation&section=statistics)

b) Extended Range (Monthly) and Long Range (Seasonal)

4.2 Post-processed products and/or tailored products delivered to users

- Temperature is post-processed by a methodology explained briefly in 3.3. Objective Verification of the extreme daily temperatures derived from this post-processing is carried out in more than 700 observation points, especially for 24 h lead time forecasts. Observation points are mainly located over the Spanish peninsular territory and over the Balearic and Canary islands.
  Results obtained over all 2023 year show a significant improvement of the outputs from postprocessing comparing to the ones from HRES-IFS. On average, maximum/minimum temperatures are underestimated/overestimated, respectively. In addition, squared root mean errors are also important in HRES-IFS outputs, being higher than 2.5 ºC/2 ºC for maximum/minimum temperatures, respectively.
- Verification is also analysed spatially, seasonally and under different atmospheric patterns. Under this point of view, the most important results are:
  - Higher dependence of T_{min} errors to the atmospheric patterns than T_{max} errors. Especially we have observed higher overestimations under anticyclonic patterns.
  - Important errors of T_{max} in mountain areas of the North and Central of the Iberian Peninsula. In addition, errors are also important along the southern Mediterranean coast and in the Balearic Islands. This behaviour is very frequently in all seasons, having little dependence on the atmospheric pattern.

4.3 Subjective verification

- In general, overestimation of **minimum temperatures** in anticyclonic situations (clear skies, calm winds; more marked with snow on the ground). On the other hand, we appreciate underestimation of minimum temperatures with clear skies and moderate winds. Examples are presented as cases of study 1 and 2.
- Good performance in synoptic episodes of **precipitation** and mainly in wind gusts (for example crossing fronts; see case of study 4).
- Commonly, in convective situations the IFS underestimates and generalizes the wind gusts as well as the precipitation.
- An overestimation of low intensity **wind gusts**, while underestimation of high intensity wind gusts have been observed.
- Overestimation of the **snow level**, mainly when cold air remains in the valleys or with heavy and persistent rainfall (see case of study 3).
- Underestimation of **precipitation** is seen, especially to the windward of the large mountain ranges (important for the issuance of precipitation warnings). On the contrary, overestimation leeward (e.g. in some areas of northern Spain, near the Cantabrian coast, with southerly winds).

4.4 Case Studies

a) Case Study 1: Overestimation T_{min}

We appreciate overestimation of minimum temperatures under clear skies and calm winds.

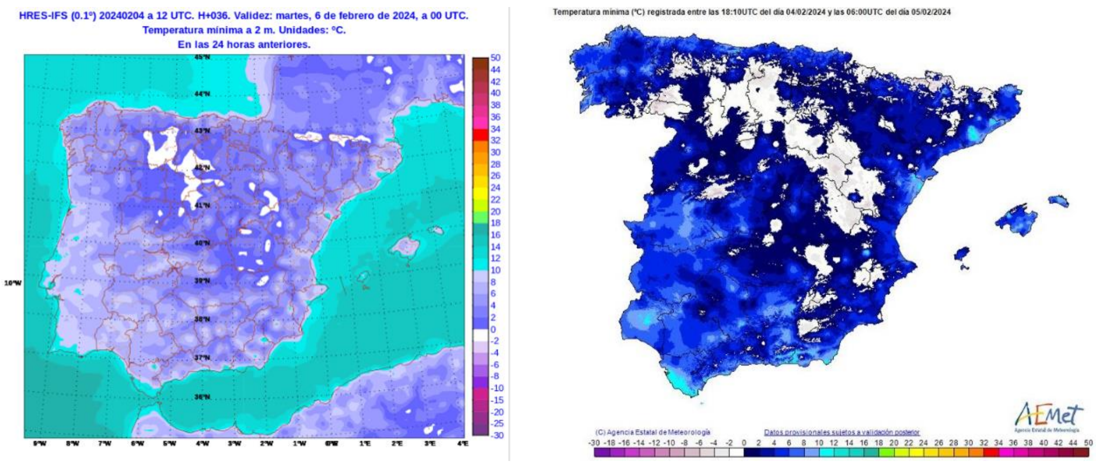

Figure 1: HRES-IFS minimum temperature forecast in 24h for the 5th of February 2024 (left) and T_{min} registered (right).

b) Case Study 2: Underestimation T_{min}

Frost forecasted, positive temperatures observed, wind gusts of 20-40 km/h.

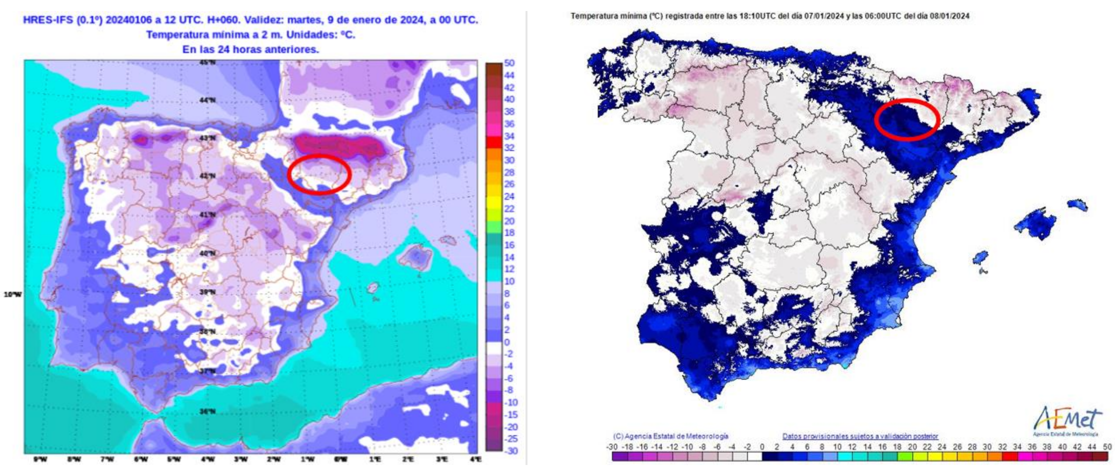

Figure 2: HRES-IFS minimum temperature forecast in 24h for the 8th of January 2024 (left) and T_{min} observed (right).

c) Case Study 3: Storm Juliette

During the storm Juliette, in February 2023, there was no snow forecasted by HRES-IFS in Mallorca (Balearic Islands). Finally, it snowed at sea level, more than 80 cm were registered over 800 m above sea level and more than 2 m were measured over 1200 m above sea level.

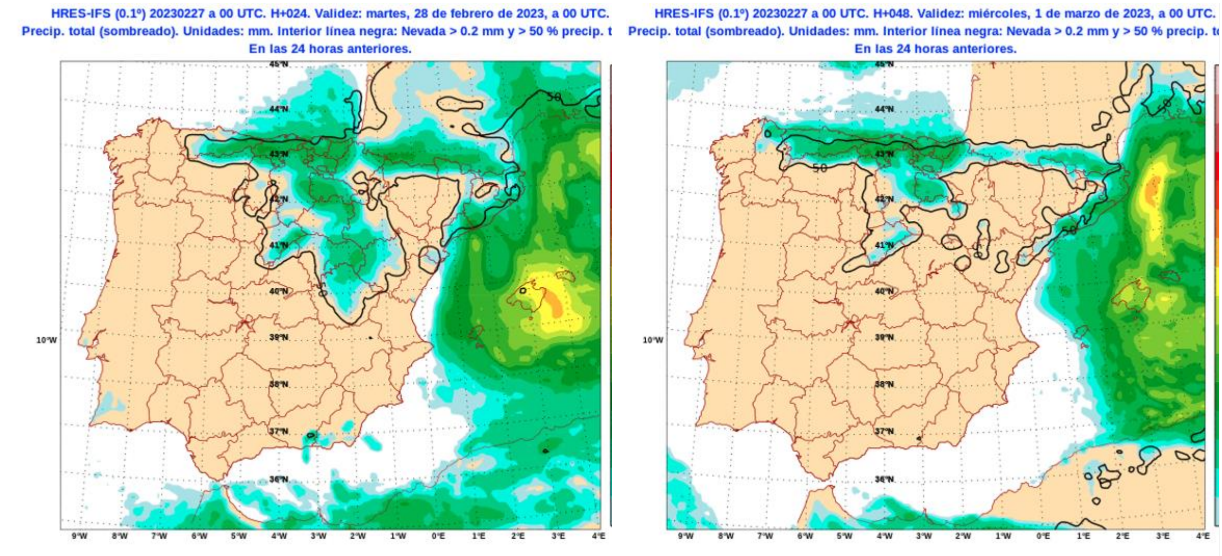

Figure 3: HRES-IFS total precipitation in 24h for the 27th (left) and the 28^{h} (right) of February 2023. The inside zone of the black line represents the forecasted snow above 0,2 mm and 50% of the total precipitation.

d) Case Study 4: Storm Nelson

In synoptic situations of high impact storms, a good behaviour in the wind gusts forecast is found.

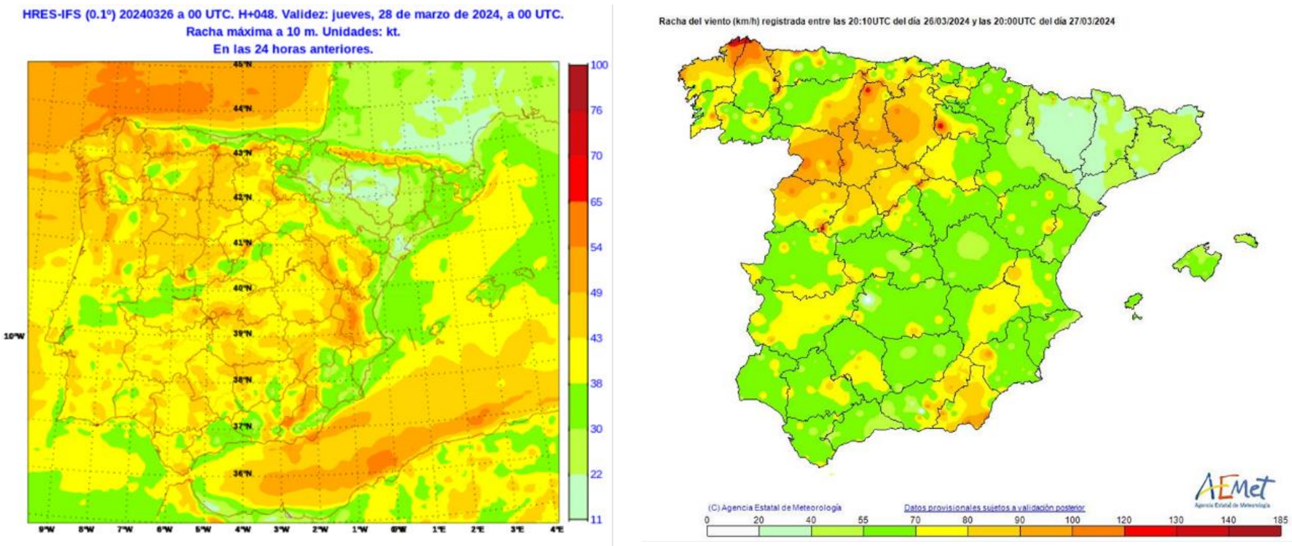

Figure 4: HRES-IFS maximum wind gust in 24 h on the 27th of March 2024 (left). Observed maximum wind gusts (right).

d) Case Study 5: overestimation of the snow level

It has been observed an overestimation in the Northern Plateau of the snow level (by 200 m approximately).

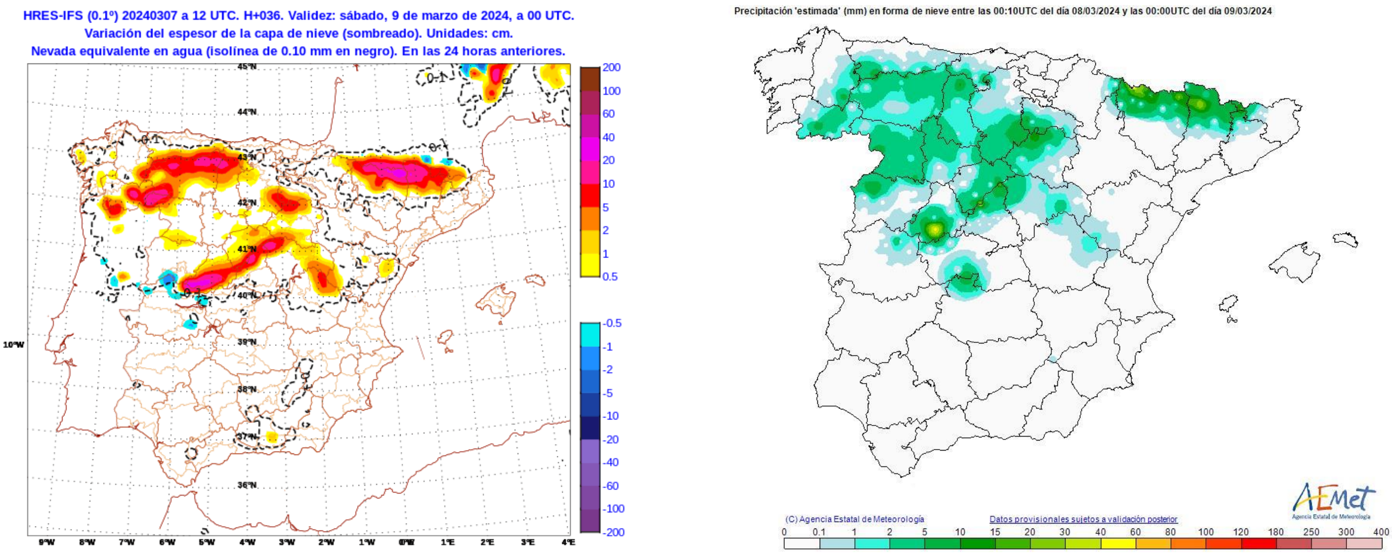

Figure 5: HRES-IFS variation in snow cover thickness forecasted for the 8th of March 2024 (left) and snow registered (right panel).

Section 5: Output Requests

a) Product request 1: Horizontal visibility

It would be helpful to have a product with the horizontal visibility.

b) Product request 2: Including some statistics in the dissemination of the ENS-IFS

It would be really useful for us to dispose of some fields related to the uncertainty of forecasts. Some percentiles, standard deviation, interquartile range or some other metrics related to these ones, would be interesting that they could arrive directly by dissemination.

c) Product request 3: Including the 800 hPa level in the dissemination

This level is really useful in places like the Canary Islands. It is used operationally for determining possible weather warnings.

d) Product request 4: Maximum/minimum 2-m temperature probability at 24-h intervals

Some time ago this output was available at 24-h intervals, in addition to the 6- and 12-h intervals. However, some months ago the interval was restricted to 6 h. From an operational perspective, this is not very useful, since we are usually interested in forecasting the maximum and minimum temperatures of the day. I would suggest returning to the 24-h interval, so that we can estimate the probability of exceeding certain temperature thresholds on a day (this is closely related to the issuance of warnings).

e) Product request 5: Vertical profiles every 3 hours

Vertical profiles are currently depicted only every 6 hours on ecCharts (0, 6, 12 and 18 UTC). It would be really helpful to have them every 3 hours, especially at 15 UTC when diurnal convection is usually at its peak of activity.

f) Product request 6: FWI sub-indices

It would be nice to be able to consult a product for each FWI subindex, as well as the anomalies of each one in ecCharts.

g) Product request 7: comparison of fields in ecCharts

It would be interesting to have the possibility to compare fields, to see more than one field at once, in the ecCharts Dashboard.

h) Product request 8: response time of ecCharts / openCharts

It would be very much appreciated if the response/refresh time of the ecCharts would be quicker.

i) Product request 9: Lightning forecast documentation

Commonly, the HARMONIE lightning post-processed forecast differs from the ECMWF one. A link to the ECMWF documentation regarding this product would be appreciated.

j) Product request 10: Fire layers documentation

We cannot find the documentation relating to the new fire layers. For example, it would be good for us to know the ranges and levels of the indices.

Section 6: References

- Sosa Cardo, José Antonio; Calvo Sánchez, Francisco Javier; Martín León, Francisco; "Pronóstico de rayos mediante el modelo no hidrostático HARMONIE"; XXXIII Jornadas Científicas de la Asociación Meteorológica Española (2014); (Arcimis: Pronóstico de rayos mediante el modelo no hidrostático HARMONIE (aemet.es)
- Fernández Matía, Alberto; Subías Díaz-Blanco, Álvaro; "La temperatura de fase en la transición de nieve a lluvia: definición y aplicación al cálculo de la cota de nieve"; Sexto Simposio Nacional de Predicción, Memorial Antonio Mestre. Agencia Estatal de Meteorología, 2019, p. 121-128 (Arcimis: La temperatura de fase en la transición de nieve a lluvia: definición y aplicación al cálculo de la cota de nieve (aemet.es)
- Casado-Rubio, José Luis; Revuelta, María Aránzazu; Postigo, María; Martínez-Marco, Isabel; Yagüe, Carlos; "A Postprocessing Methodology for Direct Normal Irradiance Forecasting Using Cloud Information and Aerosol Load Forecasts" ,Journal of Applied Meteorology and Climatology, 56, 6,1595-1608, 2017

Section 7: Additional comments and Feedback