Application and Verification of ECMWF Products 2021

1.

2. Verification of ECMWF products

2.1 Direct Use of ECMWF Products

2.2 Other uses of ECMWF output

THE STORM SURGE MODEL

The Météo-France storm surge model for the west European coasts is operated 15 times per day with a variety of atmospheric forcings including the deterministic forecasts from ECMWF. The storm surge model is developed by SHOM and Météo-France in the framework of the French HOMONIM project. It is based on a barotropic configuration of the HYCOM code (https://hycom.org/) with a resolution of around 600 m for the ATL domain (Bay of Biscay, Channel and North Sea) and 1000 m for the MED domain (Mediterranean Sea).

The operational storm surge suite includes 4 forecast runs driven by IFS/HRES forecasts (base time: 0/6/12/18 UTC, forecast range: 120/90/120/90 h) and 2 additional forecast runs driven by the AROME-IFS[1] forecasts (base time: 0/12 UTC, forecast range: 48h).

In 2017, two other configurations of the storm surge model have been added: one for the West Indies and the French Guyana (variable horizontal grid size, from 900 m to 2.3 km) and the other for the SW of the Indian Ocean (horizontal grid size of 3 km, with nested grids over La Réunion at 800 m resolution and over Mayotte at 200 m resolution). These models are run 4 times a day (forecasts up to 42h), driven by the AROME-OM models and completed by the HRES winds and the sea level atmospheric pressure on the area not covered by the AROME-OM domains.

The storm surge (and the total sea level) forecasts are mainly used for the marine flooding warning system, and are visualized as temporal series (every 10 minutes) on given points of the coast. Fig. 1 displays the forecasts at Dunkerque (North of France) starting the 27th December 2020 at 18 UTC. We can clearly see the good capturing of the storm surge peak (roughly 80 cm) of the event in comparison with observation from tide gauge.

THE WAVE MODELS

Météo-France operates 2 wave models, one for the high seas (MFWAM) and another for the coastal areas with a finer mesh size (WW3).
The Météo-France global wave model MFWAM (spatial resolution of 1/10°) uses surface winds and sea ice fraction from IFS-ECMWF system and its outputs are provided to the global Copernicus Marine Service (CMEMS). The model MFWAM is also driven by surface currents from CMEMS ocean system in order to describe accurately the sea state in strong wave/currents interactions ocean areas. The assimilation of the global wave system uses altimeters wave data and SAR wave spectra from Sentinel-1 and CFOSAT. Following the request of CMEMS users, the forecast period is increased to 10 days. Figure 2 shows the good performance of the model MFWAM with scatter index of significant wave height roughly less than 9 % in the high and mid latitudes. The wave system performs pretty well in the Southern Ocean dominated by strong winds. In the tropics the scatter index of significant wave height is even smaller than 8 %, which is remarkable regarding to these swell pool ocean regions.

[1]AROME-IFS: downscaling of the IFS/HRES forecast with the AROME model

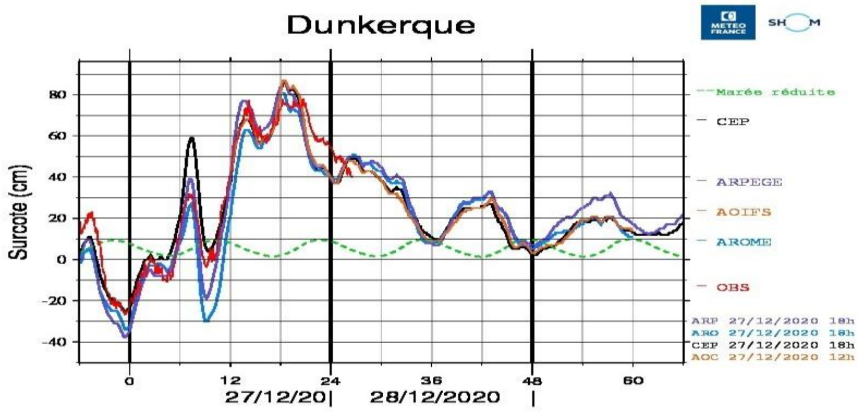

Figure 1: Time series (every 10 minutes) for the storm surge (and the total sea level) forecast at Dunkerque (North of France) starting 27/12/2020 at 0 UTC driven by the analyses and continuing with forecasts from 27/12/2020 at 18 UTC to 29/12/2020 at 18 UTC (forecasts are limited to 48h). The storm surges are computed by the Hycom2D model driven by the global model IFS (black), the French global model ARPEGE (purple) and the AROME (blue for Arome coupled with Arpege and light brown for Arome forced by IFS). The red line represents the observations (tide gauge), available until the 28th December 2020 at 0 UTC

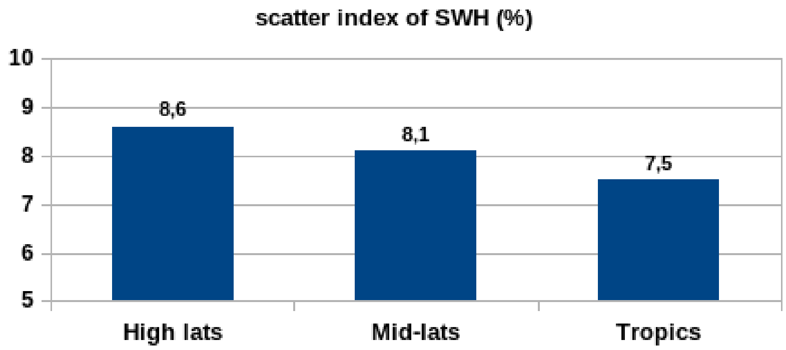

Figure 2: Normalized scatter index of significant wave height (in %) from the operational wave model MFWAM in various ocean basins during January and February 2021. High lats, Mid-lats and Tropics represent latitudes greater than 50°, between 20° and 50° and smaller than 20°, respectively. The validation is performed with altimeter significant wave height from HY-2B satellite data which are not assimilated in the system.

A coastal waves model WW3 is also used on specific areas, with IFS (HRES) or Arome-IFS wind forecasts as forcing : French Atlantic coasts, west indies and French Guyana coasts, La Réunion and Mayotte coasts (Indian Ocean). The mesh size goes down to 200 m near the French coasts (up to 100 m for Mayotte). All these configurations are nested in the global MFWAM model forced by IFS (HRES), and run 4 times per day (0, 6, 12 and 18 UTC). The relative mean scores on the significant waves height for the Atlantic configuration compared to observations from ten French coastal buoys during the 4 last years and only for wave heights greater than 50 cm, are 10.3 % for the bias and 14.4% for the RMS.

3.1 Objective verification

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

HRES, ARPEGE and AROME-FRANCE

The 3 models are compared (Fig. 3) by using a synthetic indicator averaging the Brier Skill score with a neighbourhood of 50 km against the persistence forecast for 4 parameters: gusts above 40 km/h, 6h-accumulated rain greater than 0.5, 2 and 5 mm. The reference is provided by the surface stations over France and the scores are averaged over a temporal window of 12 months. AROME-FRANCE performs always better than HRES in particular during the very thundery spring of 2018. This is explained by the higher resolution of AROME-FRANCE (1.3 km) which allows the explicit simulation of deep convection in comparison to the 2 global models HRES and ARPEGE, which use a convection parameterization.

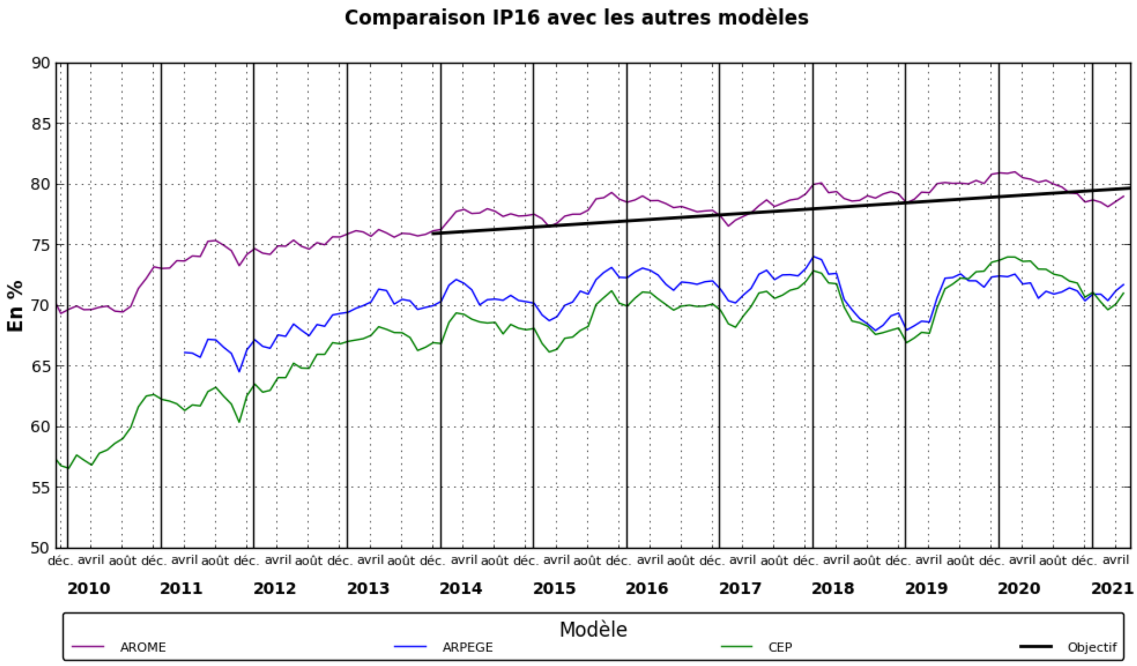

Figure 3: Synthetic quality indicator built from the Brier skill scores against the persistence forecast for 6 hours accumulated rain and maximum wind gusts. The thresholds are 0,5 2 and 5 mm/6h and 40 km/h. The black curve indicates the quantitative goal assigned to the operational model.

AROME-OM:

5 AROME-OM models perform dynamical adaptation of the HRES model over 5 overseas areas (Guyana, West Indies, Caledonia, Polynesia and Réunion). They use the non-hydrostatic dynamical core AROME and a 2.5 km horizontal resolution. It improves the HRES forecasts in several ways (only some surface parameters are verified):

- AROME-OM reduces the cold bias of HRES T2m, with better RMSE for all lead times and domains (Figure 4 left)
- AROME-OM is dryer than HRES (which tends to be too wet) (Figure 4 right). AROME-OM has better RMSE for Hu2m for all lead times and domains
- AROME-OM is better for wind speed at 10m than HRES for all lead times and domains (better RMSE).

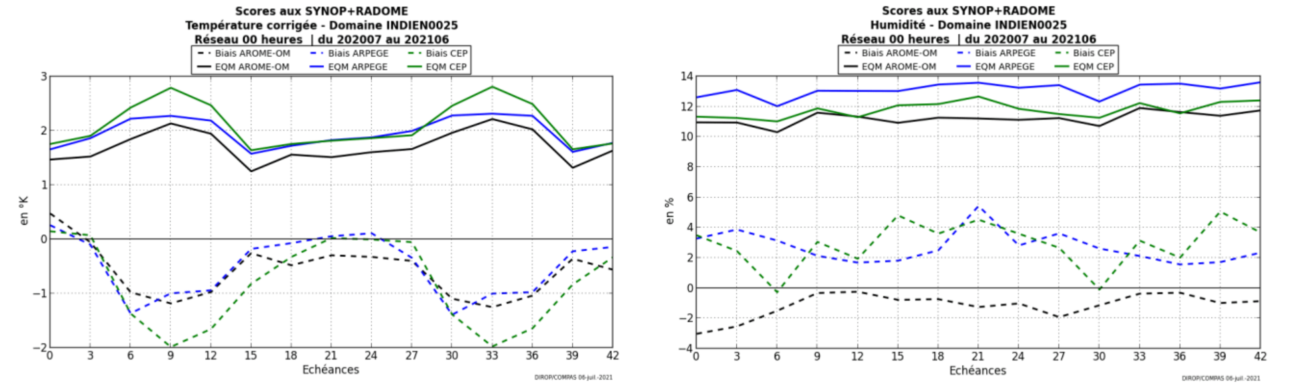

Figure 4 : Bias (dashed lines) and RMSE (full lines) for temperature at 2 m (left) and humidity at 2m (right) for the Western Indian Ocean domain (30S-7S and 33E-68E) between July 2020 and June 2021 as a function of the validity time for AROME-OM (black), ARPEGE (blue) and HRES (green). The reference is provided by the observations of the surface stations.

<u>AROME-IFS :</u>

AROME-IFS performs also a dynamical adaptation of the HRES model over western Europe. Its errors are greater at very short ranges for most surface parameters than the errors performed by AROME-France, which uses ARPEGE forecasts as boundary conditions because AROME-France forecast runs start from analyses issued from its own assimilation cycle. Their differences become smaller as the lead time increases: for most of surface parameters, AROME-France and AROME-IFS RMSE are close or AROME-IFS is sometimes even sligthly better for longer time ranges.

AROME-IFS improves forecasts of HRES in several ways (only some surface parameters are verified):

- AROME-IFS is colder than HRES, except at the sunset (figure 5 left); this reduces the warm bias during the night but increases the cold bias of HRES during daytime.
- AROME-IFS is wetter than HRES. This increases the sunset wet bias of HRES but reduces the night-time dry bias (not shown).
- AROME-IFS slightly reduces the over-estimation during the night of the wind speed (10m AGL) of HRES and the underestimation during the daytime (figure 5 right).

For all these parameters, RMSE of AROME-IFS are smaller than RMSE of HRES. It should be noted that the diurnal cycles of AROME-IFS bias are shifted by 3 hours in comparison to those of HRES.

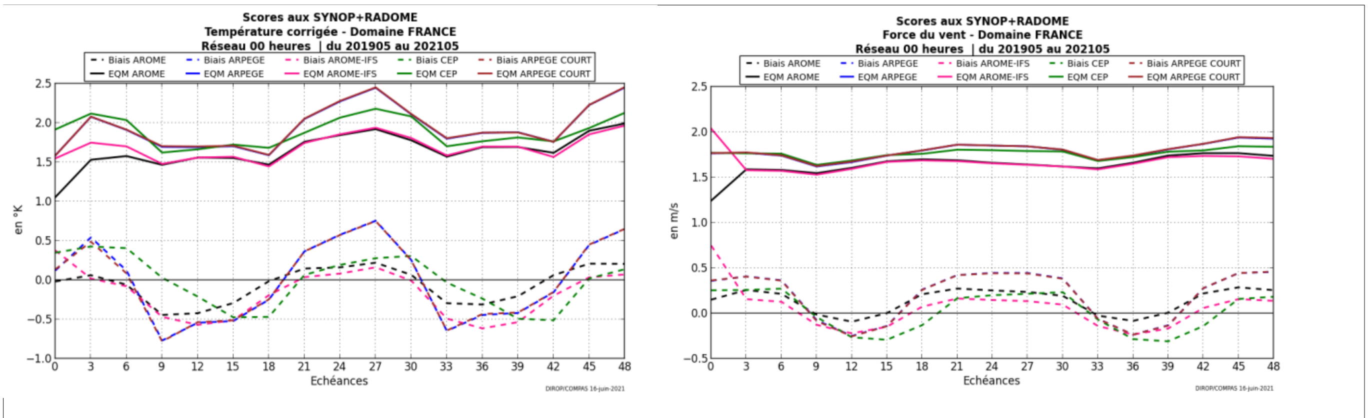

Figure 5: Bias (dashed lines) and RMSE (full lines) for temperature at 2 m (left) and wind speed at 10m (right) between June 2020 and May 2021 as a function of the lead time for AROME-France (black), AROME-IFS (pink), ARPEGE (blue, brown for its reduced cut-off version) and HRES (green).The reference is provided by the observations of the surface stations in France.

3.1.2 Post-processed products and end products delivered to users

3.1.3 Monthly and Seasonal forecasts

3.2 Subjective verification

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

3.2.2 Case studies

A "Mediterranean" event hit the south of France on 19th September 2020; extreme values of QPE are reached with locally more than 500mm in 24h (figure Erreur : source de la référence non trouvée).

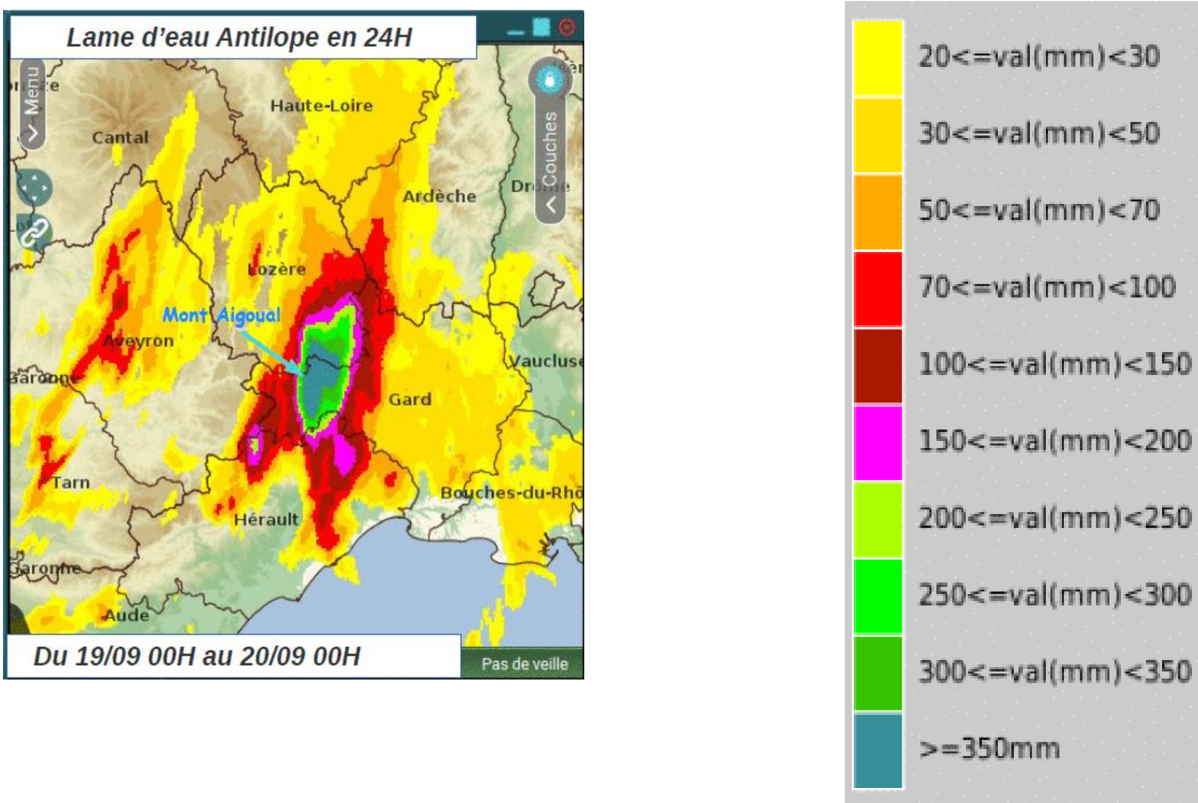

Figure 6: QPE from radar and raingauge observations in 24h over south-east of France between 19th September 2020 0UTC and 20th September 2020 0UTC.

Figure 7, 8 and 9 compare the forecasts of this event by IFS-HRES, Q90 of IFS-EPS and AROME-IFS. The event was early detected by IFS-HRES and IFS-EPS (more than 10 days before the event), with a rather good position of the event. Unfortunately, the two forecast systems suffers from a flip-flop effect (D-4): it's not surprising for the IFS-HRES due to the limited predictability of this kind of event but it's more problematic for an ensemble forecast. Both forecasts improve the positioning of the event for more recent simulations. However, the intensity of the event remains underestimated by both systems (particularly by the forecast of IFS-HRES starting at the date of the event).
AROME-IFS forecasts more realistic structures. However, AROME-IFS underestimates the intensity of the event but far less than its coupling model.

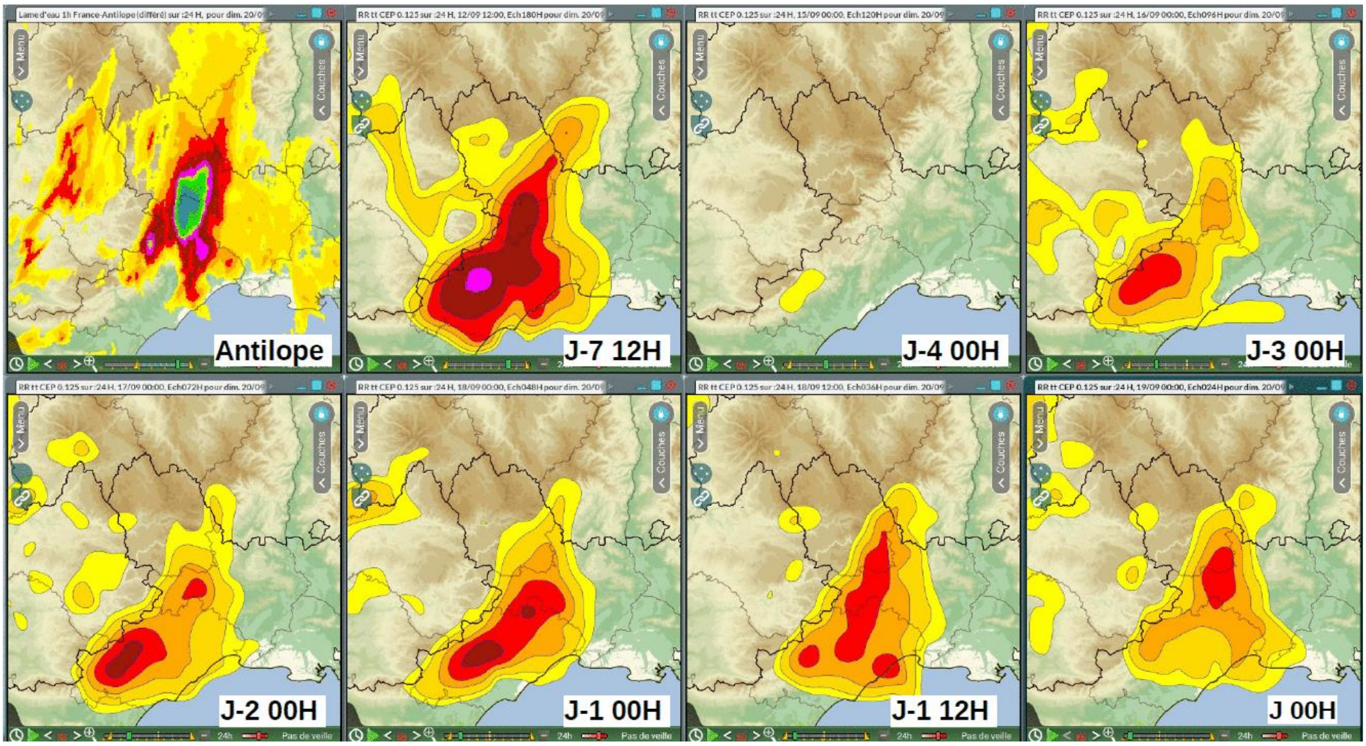

Figure 7: QPE analysis for the 19th September 2020 (top left). 24-h QPF for the 19th September forecast by IFS-HR from Day-7 (J-7) at 12UTC to D (J) at 0UTC (left to right, top to bottom)

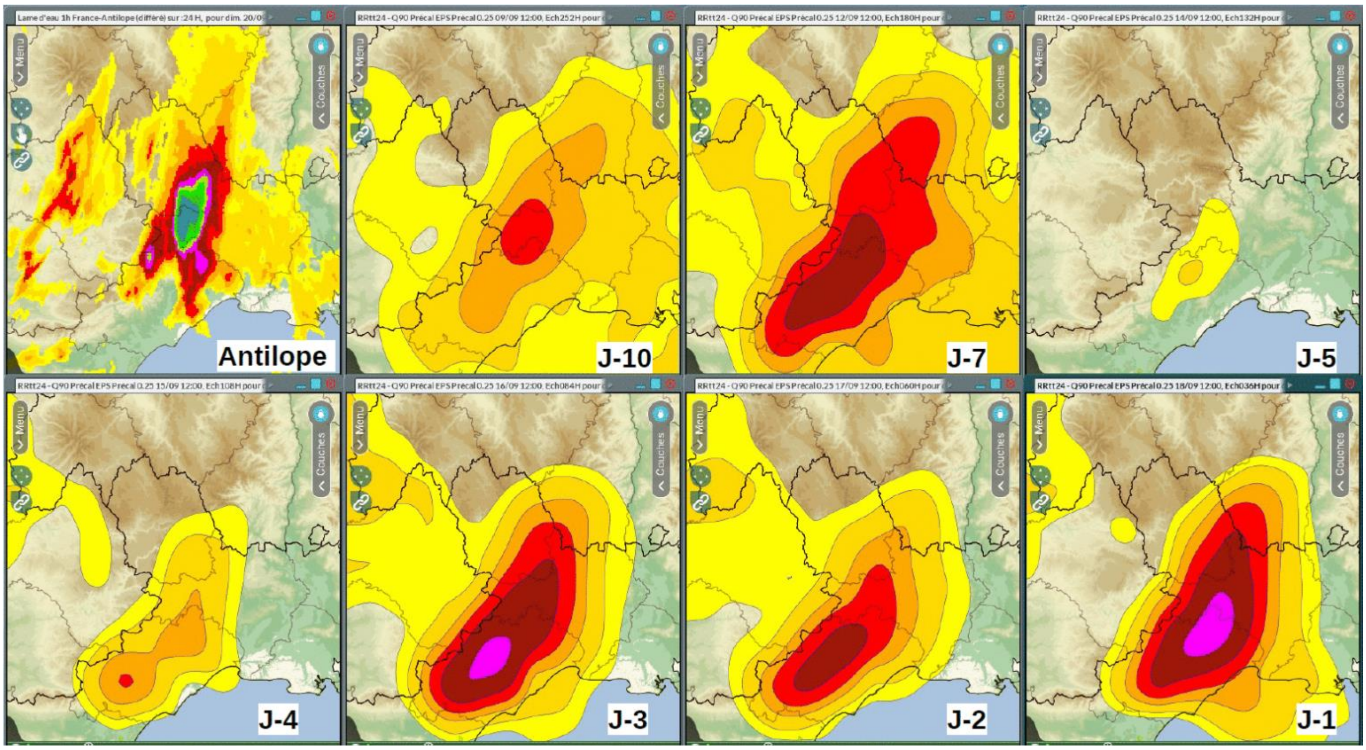

Figure 8: QPE analysis for the 19th September 2020 (top left). 24-h QPE for the 19th September forecast for the Q90 of IFS-ENS (basetime: 0UTC) from Day-10 (J-10) to Day-1 (J-1) (left to right, top to bottom)

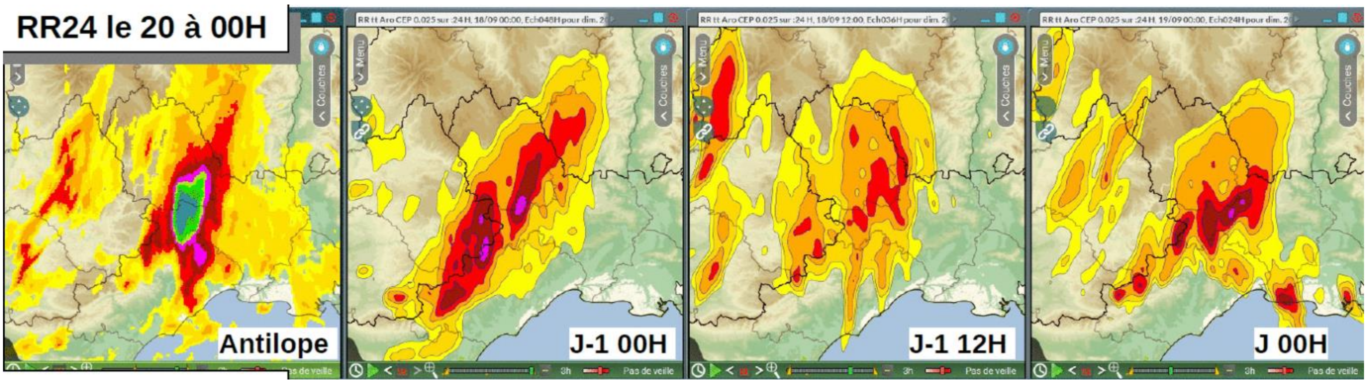

Figure 9: QPE analysis for the 19th September 2020 (top left). 24-h QPF for the 19th September forecast by AROME-IFS from Day-1 (J-1) at 0UTC to Day (J) at 0UTC (left to right)

3. Requests for additional output

4. Feedback on ECMWF "forecast user" initiatives

6. References to relevant publications

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(7. Structure of these Reports)