Evaluation of HARMONIE-AROME cycle 46h1 at AEMET

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1 Introduction

In June 2023, cy46h1rc1 was released for testing to potentially become the new reference version of the HARMONIE-AROME model. A common test configuration of the deterministic model was agreed upon by HIRLAM members to be run in the different operational domains. After a thorough benchmarking exercise, some conclusions were reached regarding the relevance of adopting cy46 as the operational version. This report presents a description of the main characteristics of the new version and comparasion to the reference version cy43h2.2bf is done. An objective evaluation is then performed based on the results obtained from the AEMET's domain runs.

2 Experimental set up

The experimental setup was prescribed the same for all the domains based on HARMONIE-AROME CY46h1rc1 and conducted by MetCoOp, UWC-W and AEMET. The resolution is 2.5 km, with four cycles per day and hourly output up to 48 hours of forecast. All the experiments had an initial 15-day warm-up period with 3-hour cycling. It was agreed a whole month verification in each one of the four seasons.
Data assimilation was 3DVar analysis with 3hr cycle includes SAPP pre-processing for conventional observations, RADAR reflectivities, GNSS ZTD, AMSUA, MHS, IASI, ASCAT. IFS humidity enters in the blending process (LSMIX) with the ECMWF forecasts. SEVIRI DA was not included in the tests because when the integrations started the cycle 46 was not prepared to assimilate these data.

The experiments were run in local AEMET-ATOS computer system composed of two cluster each with 140 computed nodes mounted on Bull Sequana X440 A5 chasis. Each node with 2 AMD EPYC™7742 processors (64 cores). The peak performance of the system is 1350 TFlops.

SAPP preprocessing is used for conventional observations. Radar data comes from OPERA using BALRAD preprocesing and including Spanish, Portuguese and French radars. The control of the HARMONIE-AROME operational suite is based on ecflow.

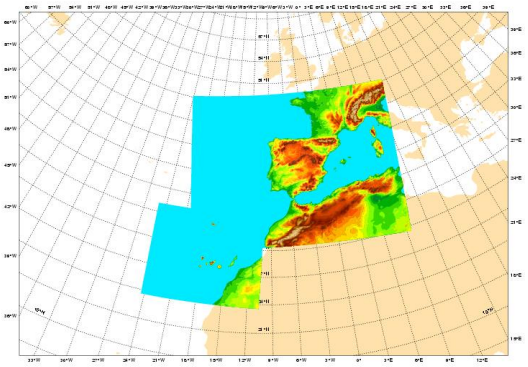

Figure 1: AEMET's operational domain

Cy43h2.2_bf is used as reference (although in AEMET the operational version is based on 43h2.1.1) to allow a cleaner comparison with Metcoop and UWC-W results.

3 Major changes in cycle 46h1

The major changes of cycle 46h1rc1 compared to cycle 43h2_bf are:

- Move back to ECUME instead of ECUME6
- Deactivate FAKETREES for Boreal grassland (not relevant for our domains)
- A more realistic melting of thin snow
- Better initialization of surface fields from IFS BCs taking into account the host model's fraction of land in addition to the land sea mask.
- Use of improved ECOCLIMAP-SG ALBEDO and LAI maps without gaps
- RFRMIN(24)=1 instead of RFRMIN(24)=2.5. A decrease in RFRMIN(24) implies a reduction of the variance term in the statistical cloud scheme producing a reduction of cloud cover (especially in low clouds).

It should be mentioned that HARMONIE-AROME cy46h1 includes the possibility of running the new surface and surface DA schemes: Diffusion Scheme (DIF), Multi Energy Balance (MEB), Multi-layer Snow Scheme (ES), Simplified Extended Kalman Filter (SEKF) and Python API to SURFEX (pysurfex) which are expected to substitute the current Force Restore (FR), Douville95 snow scheme and CANARI in the future. These new options are being intensively tested by members of the surface team and have not been the subject of the validation tests described in this article. Besides, there are a number of improvements in the use of observations in the DA which do not apply to observations included in our operational setup and therefore have not been tested.

4 Meteorological impact

This section discusses the impacts of cy46h1 for the winter season (1st January to 9th February 2021) and the autumn season (11th September to 15th October 2022). The Spring and Summer tests are not analysed here because they include some local deviations from the original release.

In general, the impact is rather neutral. In table 1 it can be seen a summary of the verification results for main surface variables.

Table 1: Summary of the verification results comparing cycle 46h1rc1 with cycle 43h22_bf. Filled triangles mean 90% confidence.

	Winter	Autumn
MSLP		△
T 2m	▼	
10m wind	△	
10m gust	△	
Td 2m	▽	
Precipitation	△	

The impact on upper air variables is also neutral, improving in some periods/variables and degrading in others (Fig. 2 as an example). Probably, the most remarkable feature is the negative bias in wind speed in cy46h1.

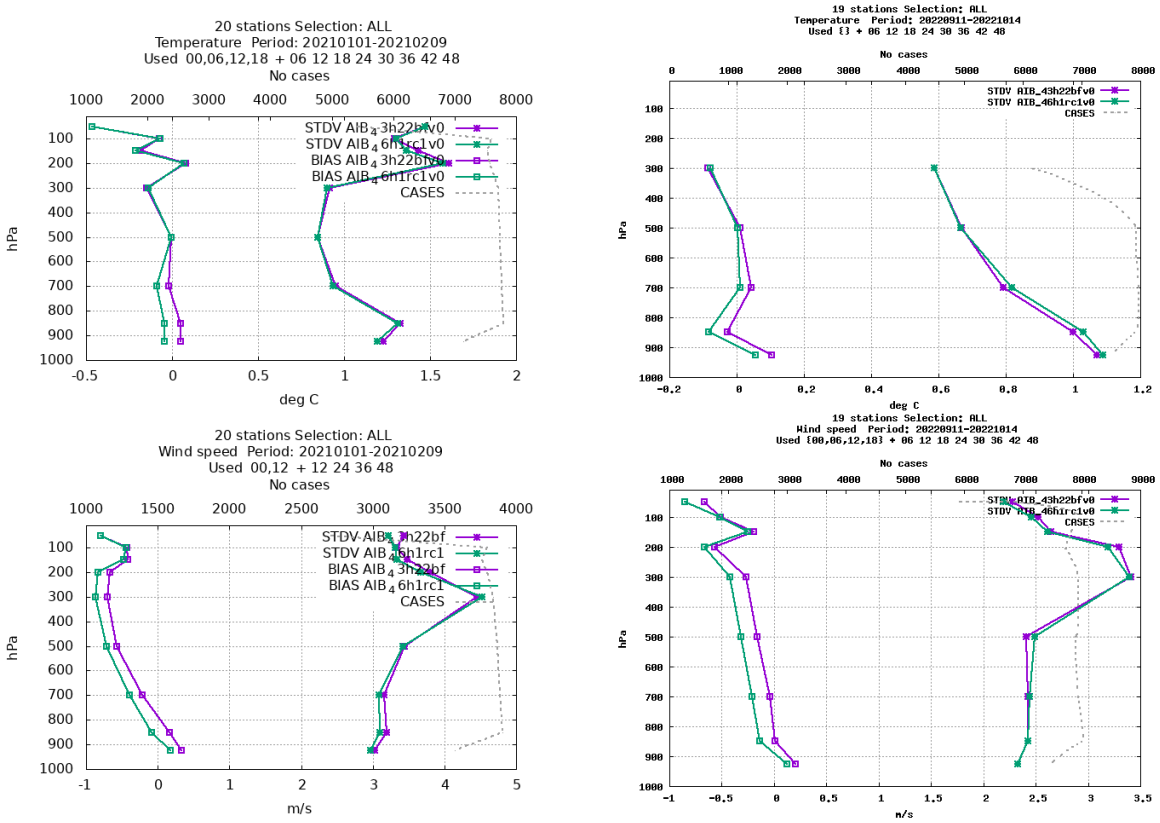

Figure 2. Upper verification at different pressure levels for temperature (upper) and wind speed (lower). Winter period (left) and autumn period (right). Cy43h2.2bf in purple and cy46h.1 in green.

Wind speed

In Fig. 3, the scores for 10m wind can be seen. The problems with wind bias traditionally seen in Aemet domains, remain in this version. The bias is significantly reduced by activating OROTUR (Rontu, 2006) orographic scheme (Fig. 4).

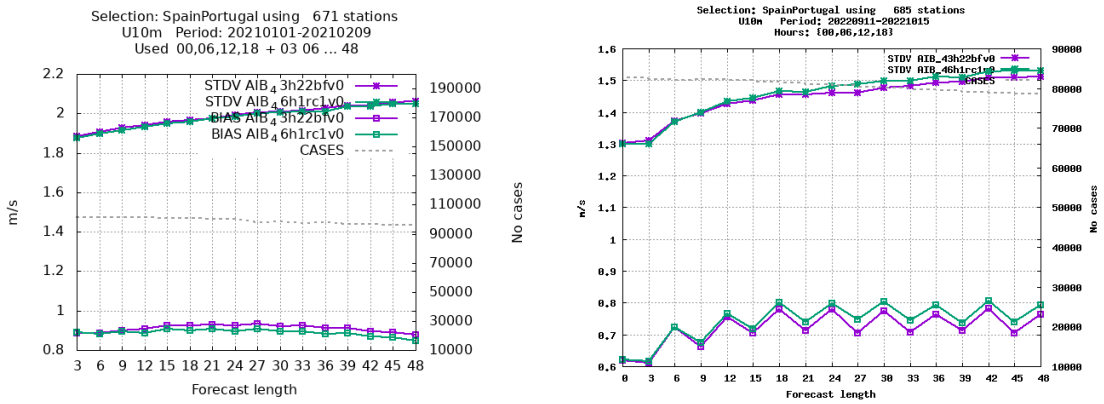

Figure 3. STDV and Bias of 10 *m* wind *function of the forecast length for winter period (left) and* autumn (right). Cy43h22 *in purple and cy*46h*1 in green.*

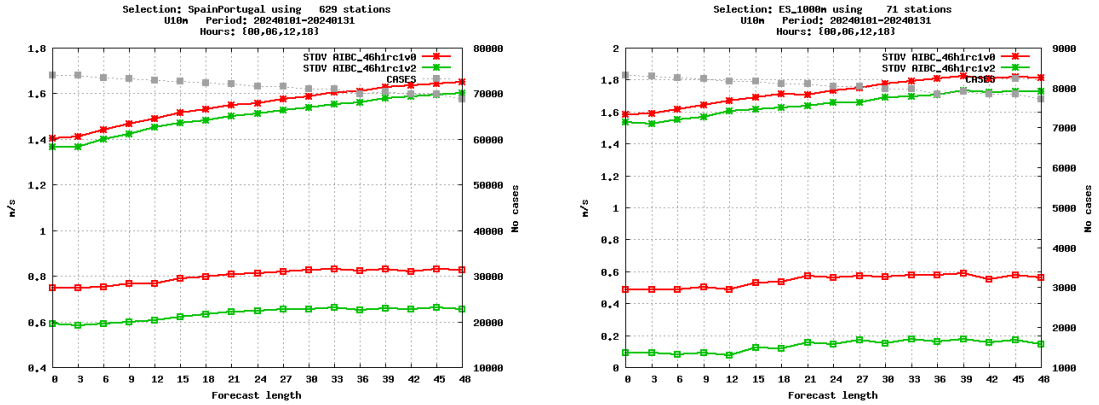

Figure 4. STDV and Bias of 10 m wind function of the forecast length for all Iberain stations (left) and only stations above 1000 m (right). Reference cy46h1 in red and activating OROTUR in green. Evaluation for January 2024 (different period).

Cloud cover and fog

The major impact of the version update is a decrease in cloud cover, especially in low clouds, as can be seen in the verification against SYNOPs (Fig. 5). This is due to a change in the variance term of the cloud scheme. The increase in the STDV can be explained by the impact of the variance term. On the other hand, the bias is much lower in cy46h1.

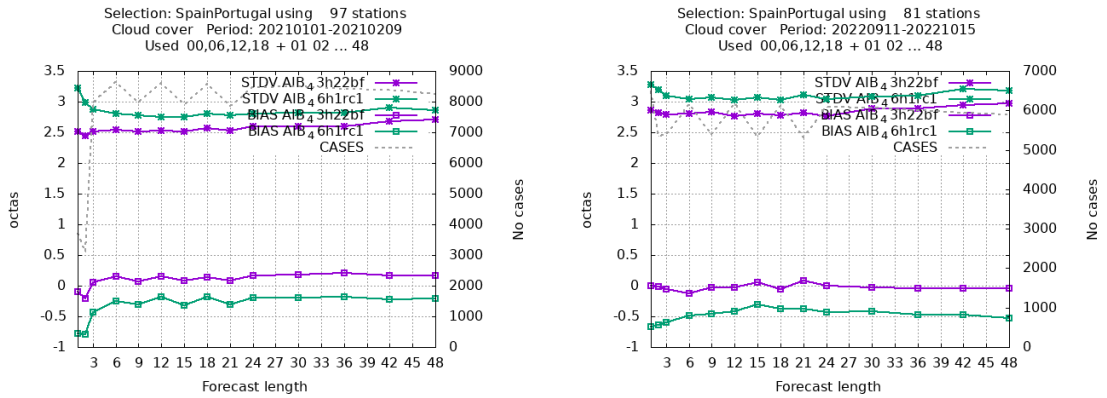

Figure 5. STDV and Bias of cloud cover as a function of the forecast length for winter (left) and autumn (right). cy43h22 in purple and cy46h1 in green.

Whether this decrease of the cloud cover is good or bad is a matter of debate. Besides, objective verification of cloud cover is a difficult task. SYNOP observations tend to overestimate cloud cover when compared with the model variables, which represent a mean value in each grid. We believe that radiation can provide a more accurate assessment of the quality of the model cloud cover. Fig. 6 shows the diurnal cycle of the Direct Normal radiation. Mean values of cy46h1 are closer to the observed values, which suggests a better cloud cover distribution in cy46h1.

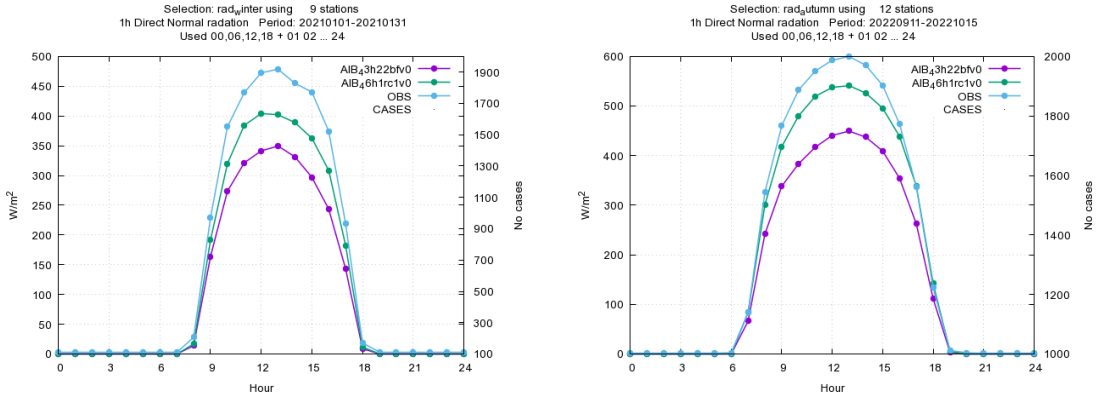

Figure 6. Daily cycle of the Direct Normal Radiation for winter (left) and autumn (right). Cy43h22 *in purple and cy46h.1 in green.*

A sensitivity test was conducted by changing RFRMIN(24) in cy46h1. The results confirm that the decrease in cloud cover seen in cy46h1 is almost exclusively due to the decrease in this parameter (refer to Figure 7).

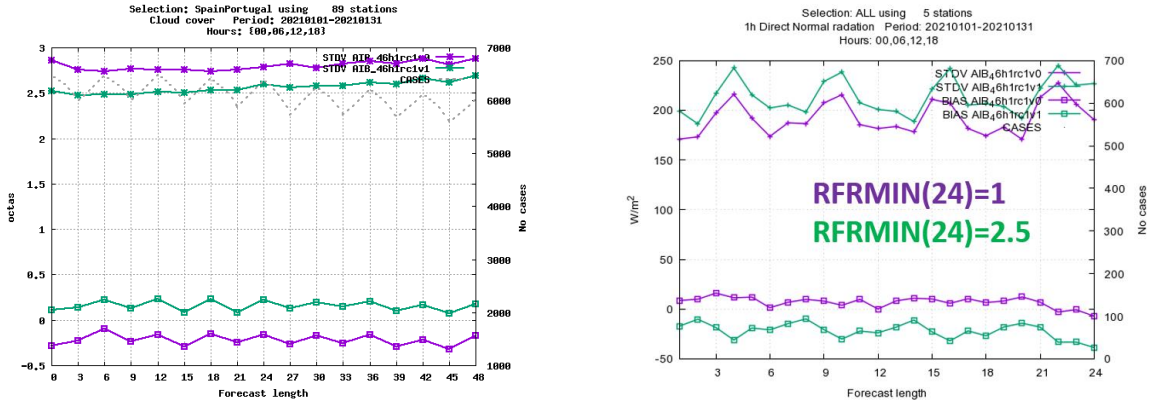

Figure 7. Only for cy64h1, STDV and Bias of Cloud Cover against synops (left) and Direct Normal Radiation as a function of the forecast length (right), for winter season. RFRMIN(24)=1 (pre-defined value) in purple RFRMIN(24)=2.5 in green.

From a subjective evaluation, operational forecasters think that there is an excess of cloud cover in cy43h22, so the decrease in cy46h1 may improve the performance of the model. Although this fact should be verified in the long term, there are evidences that confirm this behaviour from multiple examples analysed in these periods (Fig. 8).

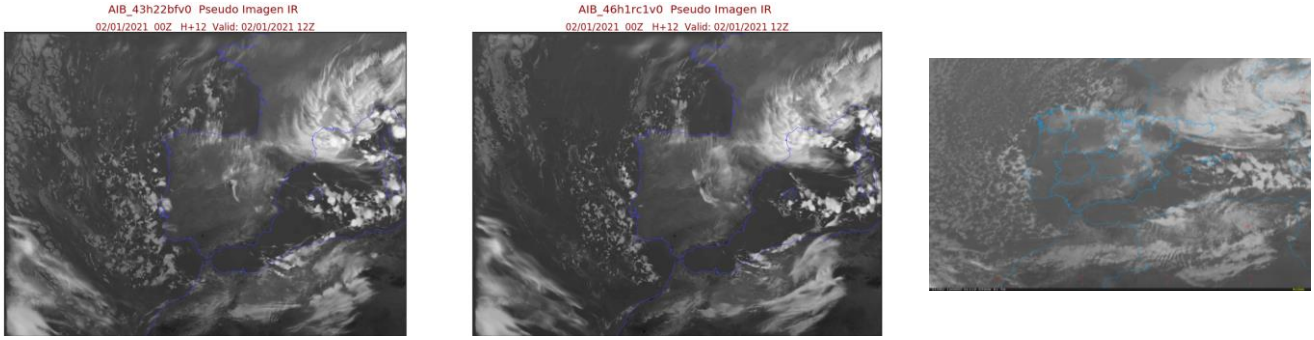

Figure 8. Simulated IR satellite image on the 2nd of January, 2021: cy43h22 (left), cy46h1(middle), Meteosat image (right).

What may be a side effect of reduced cloud cover is the unwanted reduction in fog developed by cy46h1. However, it is difficult to draw conclusions from such a small sample of fog situations that occurred during the periods analysed. As fog has a strong local character, we have found examples where cy46h1 improves the fog performance of the model compared to cy43h22 and vice versa.
In Fig. 9, cy46h1 reduces the extent of fog in the Northern Plateau (black shape) compared to cy43h22 (which is not necessarily wrong). However, the new cycle is able to develop fog tracks along the Ebro basin (north-east of the peninsula), an area where fog typically occurs in winter and where cy43h22 has difficulty generating it and records a significant number of missing events.

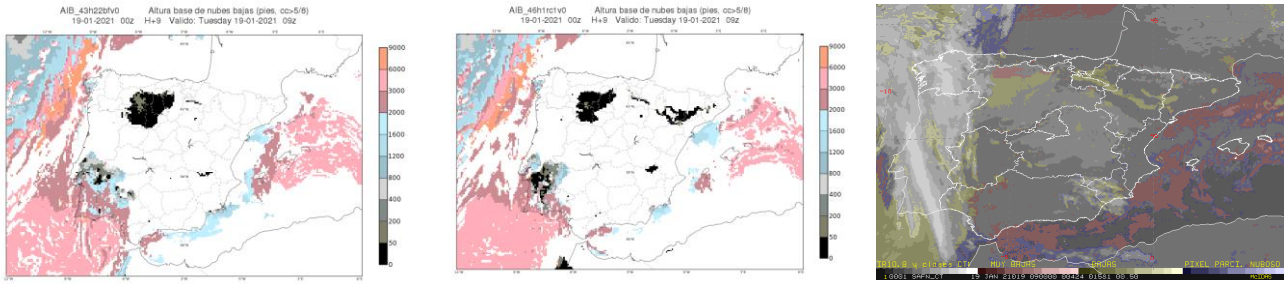

Figure 9. Left and middle, cloud height for cy43h22bf and cy46h1 respectively, where black color (height=0) corresponds to fog. Right, Nowcasting SAF product where orange and yellow patterns represent the fog extension.

Precipitation

Objective verification of precipitation shows a small decrease in cy46h1 what seems to be positive (Figure 10). Anyway the impact on ETS is very small.

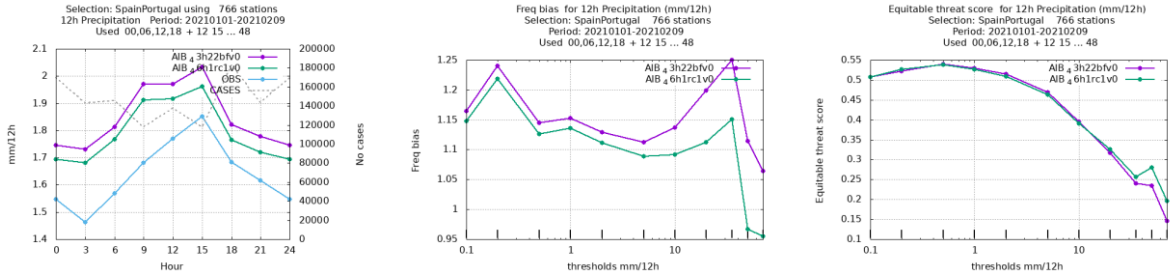

Figure 10. Precipitation acc. in 12hr: daily cycle (left), frequecy bias (middle) and ETS (right) function of precipitation thresholds. Cy43h22 in purple, cy46h1 in green and observations in blue.

An example of one model output from the winter run is seen in Figure 12. The decrease of precipitation in cy46h1 is more evident over sea.

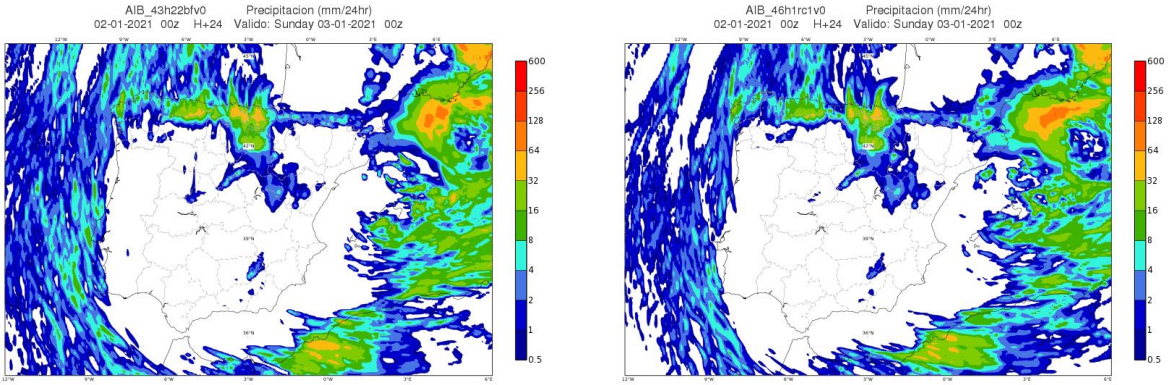

Figure 12. Precipitation in 24h on the 2nd of January, 2021. Cy43h22 (left) and cy46h1(right)

5 Single Precision

A one-month parallel run was performed in January 2024 to assess the impact of using Single Precision (SP) in the Forecast model, in a setup similar to the operational one but with a bigger domain. The scores obtained are almost identical to the Double Precision (DP) ones. See Figure 12 for the variables with bigger differences. The use of SP reduces the Forecast time by 25%.

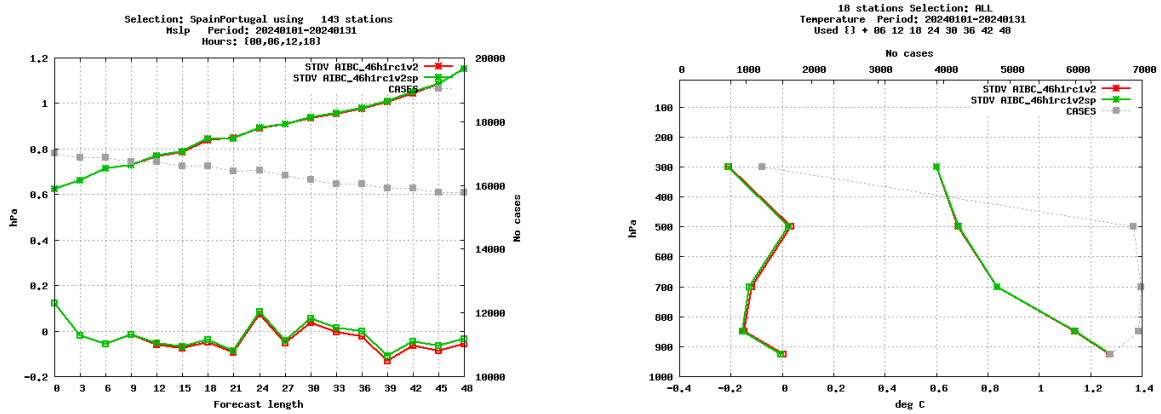

Figure 12. STDV and Bias of MSLP (left) and upper levels temperature (right) for January 2024. SP in green and DP in red.

6 Conclusions

The new version of HARMONIE-AROME cy46h1 shows no major changes in the model behaviour. However, there is a decrease in total cloud cover (mainly low clouds) compared to cycle 43h22bf, which in principle is positive, besides a slight decrease in precipitation.

The overestimation of 10 m wind speed in both cy46h1 and cy43h22bf can be alleviated activating the orographic parameterization OROTUR.

It is difficult to draw definitive conclusions about the performance of fog due to the limited number of cases analysed during the benchmark period. While this new version may not fully capture all fog episodes, it is expected to reduce the number of misses in some areas compared to cycle 43h22bf.

An important novelty in cy46h1 is that it allows for the use of more sophisticated surface schemes (DIF, MEB, Extended Snow) and surface DA (SEKF and pysurfex) to run the model. Currently, a big effort is on-going within the surface team to validate these schemes.

Single precision results are very close to the double precision ones, saving 25% of forecast time. Hence, it will be implemented in the operational suite in the near future.

7 References

Rontu, L. (2006) A study on parametrization of orography-related momentum fluxes in a synoptic-scale NWP model. *Tellus A*: *Dynamic Meteorology and Oceanography*, 58:1, 69-81, doi: 10.1111/j.1600-0870.2006.00162.x