Evaluating AROME runs at different degraded analysis resolutions

Stay Report By

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Contents:

1. INTRODUCTION

The actual AROME model is characterized by 1.3 km for the horizontal resolution and 90 levels for the vertical resolution and 1h for the data assimilation cycle, which makes it a costly model in terms of computational resources.

Given that reducing computing costs and keeping the same quality of the forecast or even obtaining an improvement is one of the challenges of the Numerical Weather Prediction Systems, especially when we are dealing with very expensive methods like the 4D-Var or the Envar, in this context this study presents the impact of a possible degradation in the resolution of the AROME analysis on the forecasts derived from it, knowing that these forecasts remain at the finest resolution 1.3km.

Making a lower horizontal resolution analysis has two effects:

- All the model scales at 1.3 km are not analyzed in the initial conditions.
- The network observations cannot be used at the same horizontal density: taking too closely observations from each other implies taking into account correlations of the horizontals observations errors but this is not possible because the observation error covariance matrix R is diagonal.

After evaluating the impact of the degradation of the analysis in the first part, we tried in a second part to understand and diagnose the problem of spin-up.

2. SOME EVENTS ON THE AUTUMN OF 2014

In the autumn of 2014 heavy rainfall events were occurring at an exceptional rate in the Mediterranean Languedoc regions. Main causes can be seen in: (i) the key-role of Mediterranean Sea as a reservoir of energy and moisture; (ii) a southwest flow driven by upper-level cold troughs on the North Atlantic which advect the Mediterranean warm and moist air masses; (iii) the pronounced relief of this region, with the Alps, Pyrenees and Massif Central Mountains, encourages convection phenomena when synoptic conditions are destabilizing (Delrieu and al., 2005).

- From 16 to 20 September, in this flash flood event precipitations exceeded 400 mm (figure 1), many localities were submerged causing the death of 5 people.
- 29 September, precipitations exceeded 300 mm, (253 in 3 hours), the Lez rises 5 meters in the afternoon and floods the city.
- 6 and 7 October : 262 mm were registered (224,7mm in 3 hours), the Lez is again flooded (650 m3 / s) as well as the Mosson.
- from 9 to 13 October : 653 mm were registered (274 mm on the 12 at “La Souche”)...
- From 24 to 26 November: heavy rainfall affecting first the Eastern Pyrenees, Aude (169.5 mm in 3 hours on the 24 at St-André-de-Roquelongue) and Hérault, then Provence (251 mm in Collobrières, 214 in Luc and 211 in Vidauban).

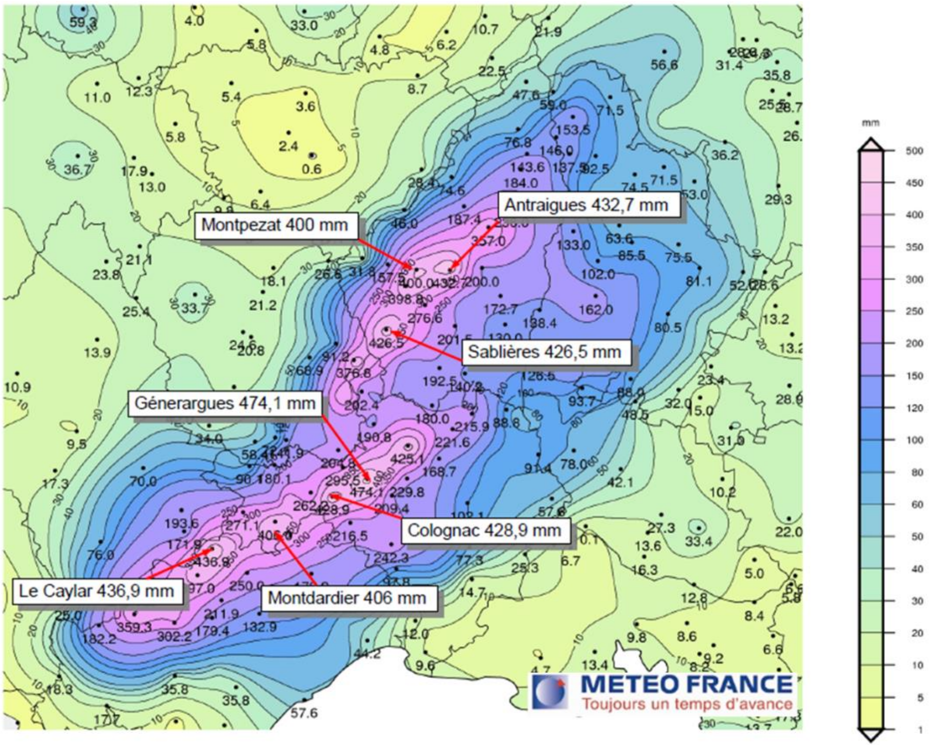


Figure 1. cumulative rainfall between 09/16/2014 and 09/20/2014 [BDEM]

3. METHODOLOGY & EXPERIENCES

To study the impact of the degradation in the resolution of the AROME analysis on the forecasts derived from it in this region “the south-est of France” during these dates, our simulations are based on a configuration of the AROME model which was implemented by Wafa Khalfaoui called “AROME TOY”. It's a data assimilation configuration on a reduced area located in the south-est of France over a domain called “Sude” (469 points x 469 points). This domain represents one tenth of the whole domain "France" (1429 points x 1525 points).

It has been proved that this configuration is able to reproduce quite faithfully the results obtained on the large domain.

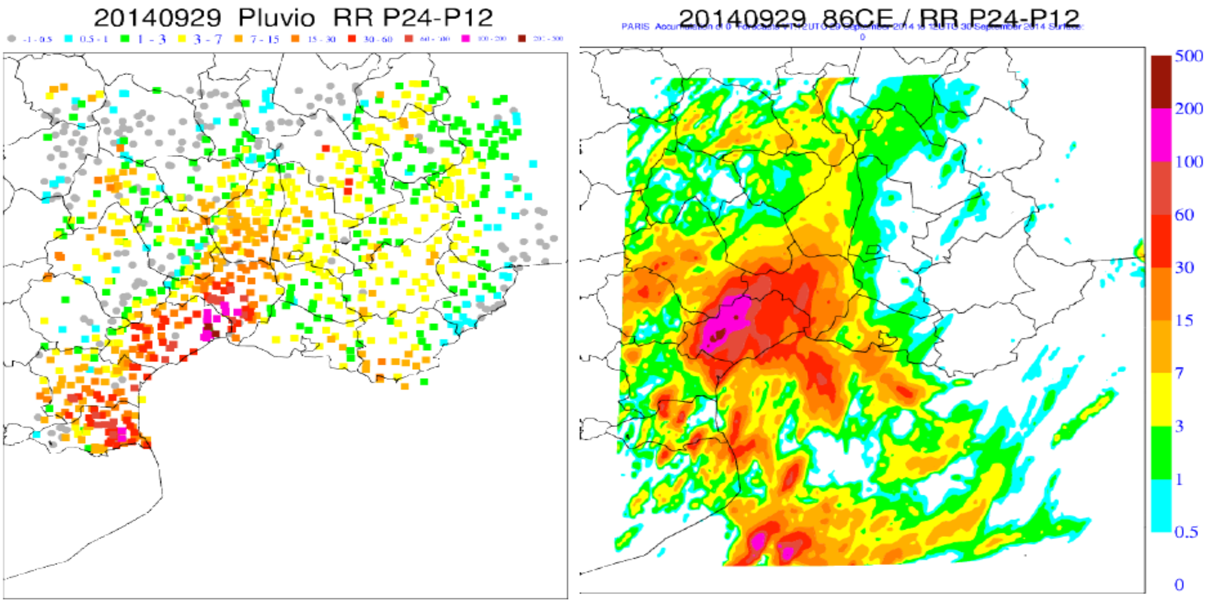


Figure 2. 24-hours cumulated precipitation over Sude domain on 29 September 2014, corresponding raingauge observations are plotted on the right

Three configurations of degraded resolutions were performed respectively at 2.6 km, 4 km and 5.2 km. Technically, 3D-Var configuration under the OLIVE tool has been modified in order to i) project the background at high resolution on the lower resolution grid using FULLPOS tools, ii) perform the analysis at the low resolution iii) interpolate the low resolution analysis on the high resolution grid using FULLPOS. The characteristics of the low resolution grid used are provided by variables modified in the head of the experience like shown in the table.1 modifying variables in the FULLPOS namelist. On the other hand these configurations involve some modifications of the thinning of Radar and AIREP observations. This thinning is performed in the screening step in which the observations are controlled against the background, to verify their vertical consistency, and then thinned when their spatial density is too high compared to the resolution of the analysis.

- high resolution experience (Reference) : forecast 1.3 km, analysis 1.3 km (that is what is done in AROME oper actually) and radar observations assimilated every 8 km but this is still not running in the operational suite, they are assimilated every 15 km, otherwise in the double suite (the research suite in meteo France) they are assimilated avery 8 km, our experiences are based on the operational suite (we use the binaries of this suite), that's for why we modify the screening namelist to assimilate the radar observations every 8 km.
- Degraded resolution experience 1: forecast 1.3 km, analysis 2.6 km and radar observations assimilated every 15 km, there is no need to modify the screening namelist, the default values are convenient.
- Degraded resolution experience 2: forecast 1.3 km, analysis 4 km and radar observations assimilated every 25 km
- Degraded resolution experience 3: forecast 1.3 km, analysis 5.2 km and radar and AIREP observations assimilated every 35 km

It was necessary to increase the thinning of the RADAR and AIREP observations to avoid the correlation issues.

The different realized experiences with the above mentioned configuration of AROME are described in the following table.

Experience Characteristics	Header of the experience	Modifications screening namelist

High resolution experience (Reference) :
Analysis: 1.3 km
RADAR : 8 km
Forecast: 1.3 km
		`&NAMSCC`
		`RMIND_RADAR = 4167.,`
		`RFIND_RADAR = 8334.,`
		`/`
		`&NAMNPROF`
		`NOBSPROFS(13)=225,`
		`/`

Degraded resolution experience 1: **Analysis: 2.6 km** **RADAR : 15 km** **Forecast: 1.3 km**	INC_NDLUXG="235" INC_NDGUXG="235" INC_NDGLG="250" INC_NDLON="250" INC_NSMAX="124" INC_NMSMAX="124" INC_RES="2600.0" INC_ZONL="8" INC_ZONG="8"	Default values

Degraded resolution experience 2:
Analysis: 4 km
	INC_NDLUXG=152,
	NDGUXG=152,
	NDGLG=180,
		`&NAMNPROF`
		`NOBSPROFS(13)=225,`
		`/`
		`&NAMSCC`
		`RMIND_RADAR=12504.,`
		`RFIND_RADAR=25008.,`

RADAR : 25 km **Forecast: 1.3 km**	NDLON=180, NSMAX=89, NMSMAX=89, INC_RES=4000, INC_ZONL=4, INC_ZONG=4	`RFIND_AIREP=35000.,` `/`

Degraded resolution experience 3:
Analysis: 5.2 km
RADAR : 35 km
Forecast: 1.3 km
	INC_NDLUXG=117,
	NDGUXG=117,
	NDGLG=128,
	NDLON=128,
	NSMAX=63,
	NMSMAX=63,
	INC_RES=5200,
	INC_ZONL=4,
	INC_ZONG=4
		`NOBSPROFS(13)=225,`
		`/`
		`&NAMSCC`
		`RMIND_RADAR=16672.,`
		`RFIND_RADAR=33344.,`
		`RFIND_AIREP=35000.,`
		`/`

For these changes to take effect and on the advice of Eric Wattrelot, it was necessary to recompile the binaries MASTERODB and BATOR taking into considerations the modifications contained in these routines on beaufix:

For MASTERODB:

- /home/gmap/mrpa/wattrelote/pack/cy40_op1.05.IMPI411IFC1301.2x.pack/src/local/arpifs/obs_preproc/defrun.F90
- /home/gmap/mrpa/wattrelote/pack/cy40_op1.05.IMPI411IFC1301.2x.pack/src/local/arpifs/obs_preproc/radar_profs.F90
- /home/gmap/mrpa/wattrelote/pack/cy40_op1.05.IMPI411IFC1301.2x.pack/src/local/arpifs/op_obs/inv_refl1dstat.F90

For BATOR: edit bator_ecritures_mod.F90 as follows:

- ```
  ! DOPPLER WIND
      ELSEIF ((iotp == NRADAR).AND.(iovnm == NVNUMB(93))) THEN
        ROBODY(iwagon,MDBOER) = (2._JPRB/3._JPRB)*&
  &       (2._JPRB/250000._JPRB*ZDATAWAG(iwagon,4) + 1._JPRB)
  ```

➢ Thinning of the radar observations:

RMIND_RADAR and RFIND_RADAR allow changing the size of thinning boxes in namelist, RMIND corresponds to the small box of thinning, so for the thinning of 8 km:
  ```

RMIND_RADAR=0.0375 * RA/RDEGREES = 0.0375 * 6371 229 *3.14 / 180 = 4167 meters
RFIND corresponds to the large final box: RFIND= RMIND*2= 8334 meters

We have just to multiply respectively by 3 and 4 to obtain an approximately thinning distance of 25 km and 35 km.

In the minimization step, it was necessary to adapt the NPROC parameter which could be modified under the Setup Profiles, indeed degrading the resolution implies reducing the number of calculation point while taking into consideration that the number of tasks per node=12.

NPROC=168: minim for analysis at 1.3 km works (at 2.6 km, 4 km and 5.2 km crashes)

NPROC=168/2=84: minim for analysis at 2.6 km and 4 km works (at 5.2 km crashes)

NPROC=168/3=56: minim for analysis at 5.2 km crashes (but it takes only 48, because 56 is not multiple of 12 the number of tasks per node), and we used 36 which works.

In first time multiple runs were performed for these configurations in the different selected periods of autumn 2014, then for every configuration we run a long forecast based on the produced analysis like shown in the next 2 tables.

Period / Analysis	16/09/2014 20/09/2014	09/10/2014 13/10/2014	24/11/2014 28/11/2014	29/09/2014 01/10/2014	06/10/2014 08/10/2014
1.3 km	86BM	86BV	86DV	86E0	86E4
2.6 km	86BP	86BW	86DW	86E2	86E6
4 km	86BS	86BX	86DX	86E3	86E5
5 km	86BT	86BY	86DY	86E1	86E7

Table.1: The different analysis simulations in the different periods

long experience	reference experiences
86CE	86BM-86BV-86DV-86E0-86E4
86D6	86BP-86BX-86DW-86E2-86E6
86D7	86BS-86BW-86DX-86E3-86E5
86D8	86BT-86BY-86DY-86E1-86E7

Table.2: The different produced forecasts based on the obtained analysis

Olive swapp environment was used for all the experiences which can be found under this path:
http://sxcoope1.cnrm.meteo.fr:8181/swapp_entry/chico/Olive/Browse/home/coope/anis/experiments/

4. RESULTS

To compare the quality of the analysis at different resolutions 2.6 km, 4 km and 5.2 km against the reference analysis at a resolution of 1.3 km, it was used the OBSTAT tool which computes and plots statistics of observation minus background and observation minus analysis quantities.

Impact on analyses

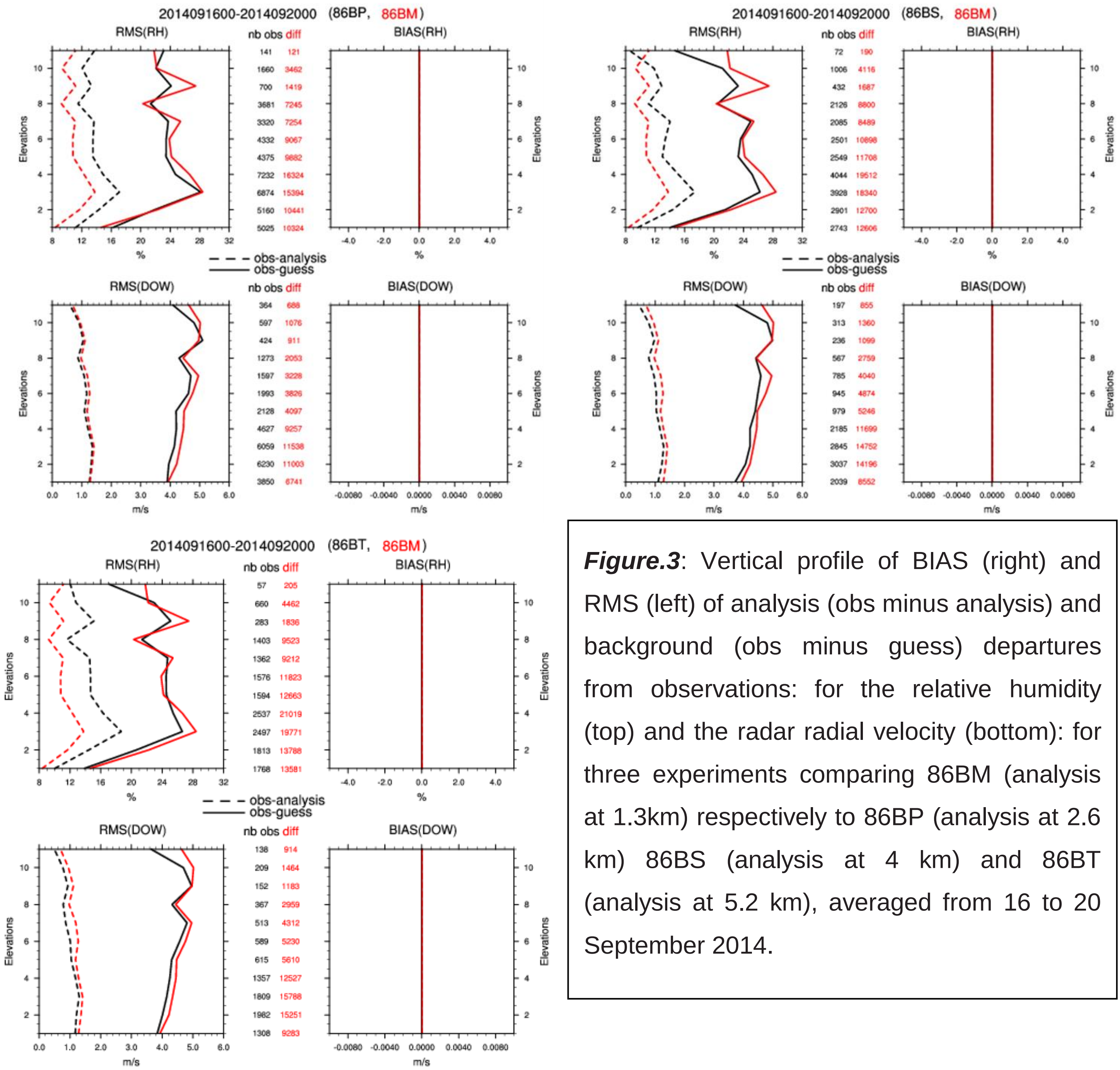


Figure.3: Vertical profile of BIAS (right) and RMS (left) of analysis (obs minus analysis) and background (obs minus guess) departures from observations: for the relative humidity (top) and the radar radial velocity (bottom): for three experiments comparing 86BM (analysis at 1.3km) respectively to 86BP (analysis at 2.6 km) 86BS (analysis at 4 km) and 86BT (analysis at 5.2 km), averaged from 16 to 20 September 2014.

For the different configurations, all the degraded resolutions decrease the RMS of the background (obs - guess) departures from observations for both the relative humidity and the radar radial velocity, also we note a slight improvement of the analysis (obs – analysis) for the radar radial velocity: The fact that the differences (obs - guess) are more hollow at 1.3 km is explained by the fact that the network of the observations is denser at this scale (the difference of the number of observations is very important), by the way we notice a remarkable degradation of the analysis (obs – analysis) for the relative humidity at the different resolutions.

Comparing the experiences for each selected period, we find almost the same answers for Radar observations; the various plotted statistics could be found in the annex.

As the number of other types of observations is not important, we decided to assemble the statistics of all the periods for each resolution to get more meaningful results, otherwise in the next 3 figures we compare the analysis at 1.3 km 86ref:(86BM-86BV-86DV-86E0-86E4) vs 86exp:(86BS-86BW-86DX-86E3-86E5) the analysis at 4 km.

The Obstat of the radiosonde data (temp), AIREP and SEVIRI: like the obstat RADAR, we notice an increased fit at all levels for most of observation types but this generally does not cause improved fit of first guesses. Contrariwise, The SYNOP data of the relative humidity and the 2m temperature present a significant degradation: as a first point, we can say that the analysis at 1.3 km represents better the in-situ data.

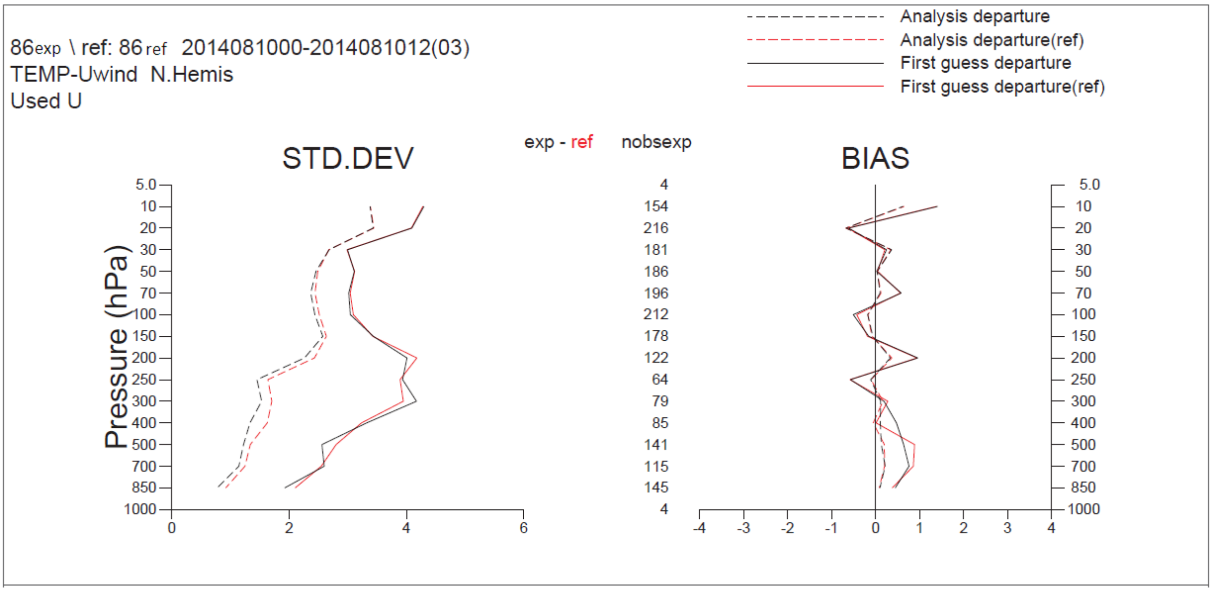


Figure.4: Obstat statistics for TEMP data (obs - analysis) and (obs - guess)

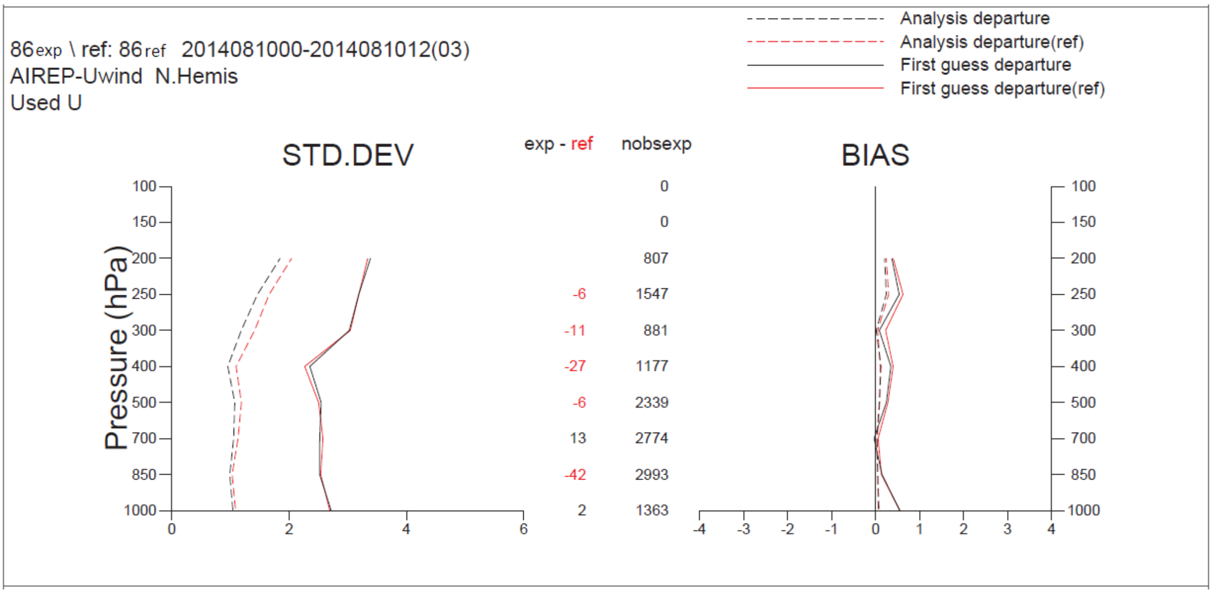


Figure.5: Obstat statistics for AIREP data (obs - analysis) and (obs - guess)

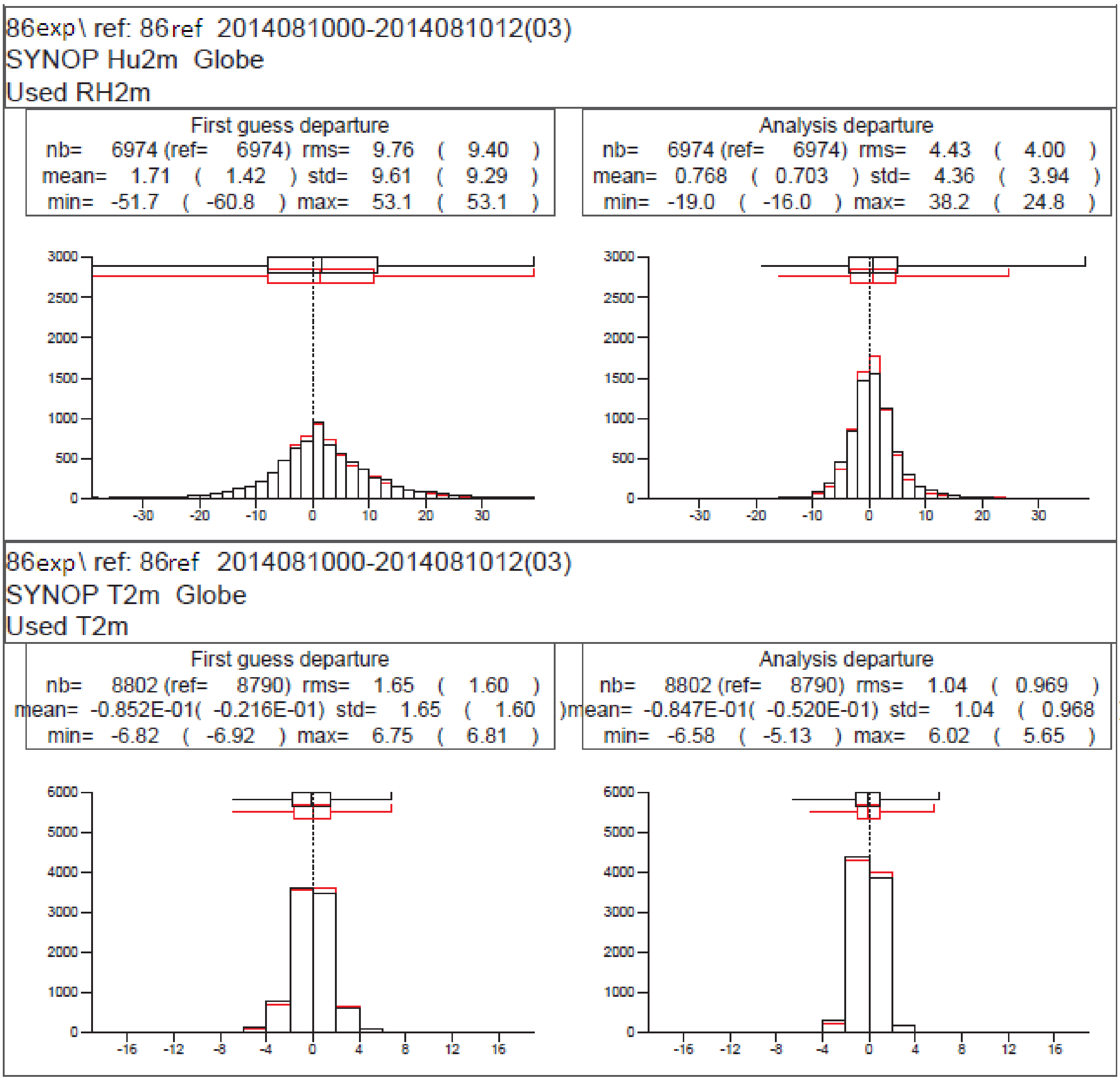


Figure.6: Obstat statistics for SYNOP data (obs - analysis) and (obs - guess)

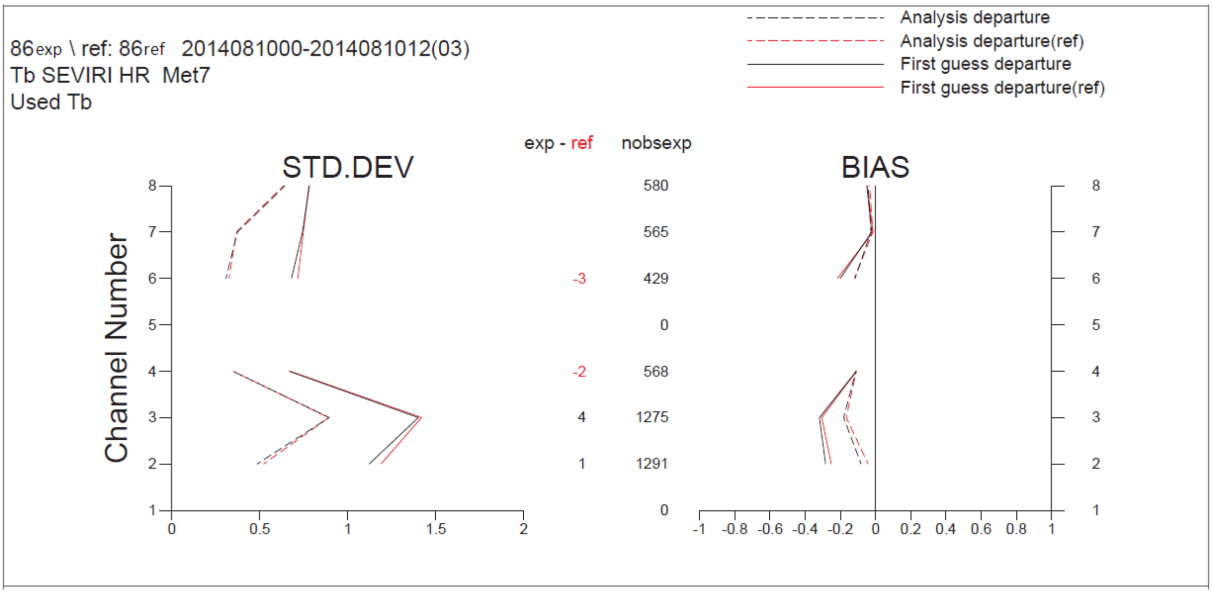


Figure.7: Obstat statistics for SEVIRI data (obs - analysis) and (obs - guess)

Impact on precipitation forecasts

The comparison of the driven forecasts have been carried out using FAR (false alarm rate: it is probability that if there is no precipitation observed, it was predicted) vs POD (Probability of Detection) statistics: they help in understanding the trends of the experiments and provide more rigorous evidences.

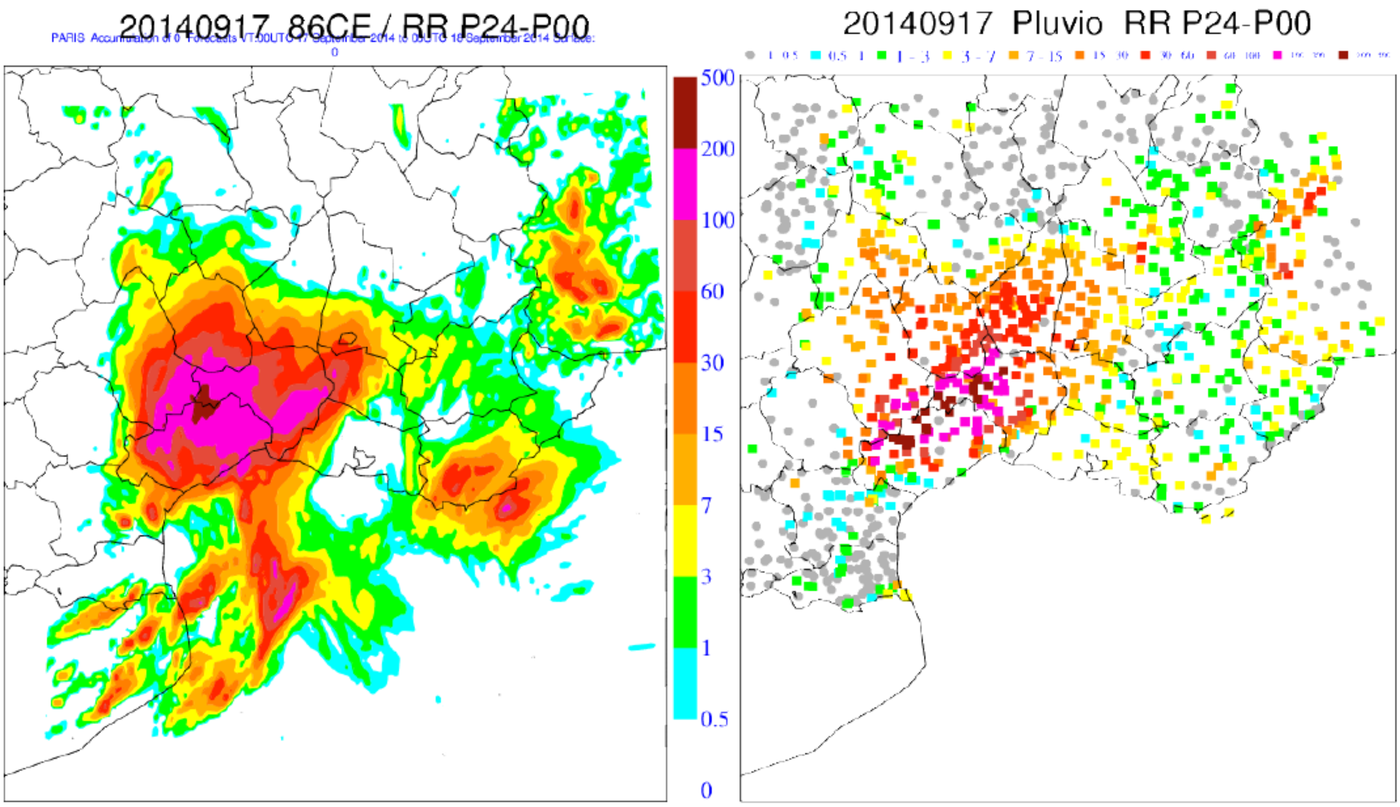


Figure.8: 24-hours cumulated precipitation over Sude domain on 17 September 2014 based on analysis at 1.3 km, corresponding raingauge observations are plotted on the right

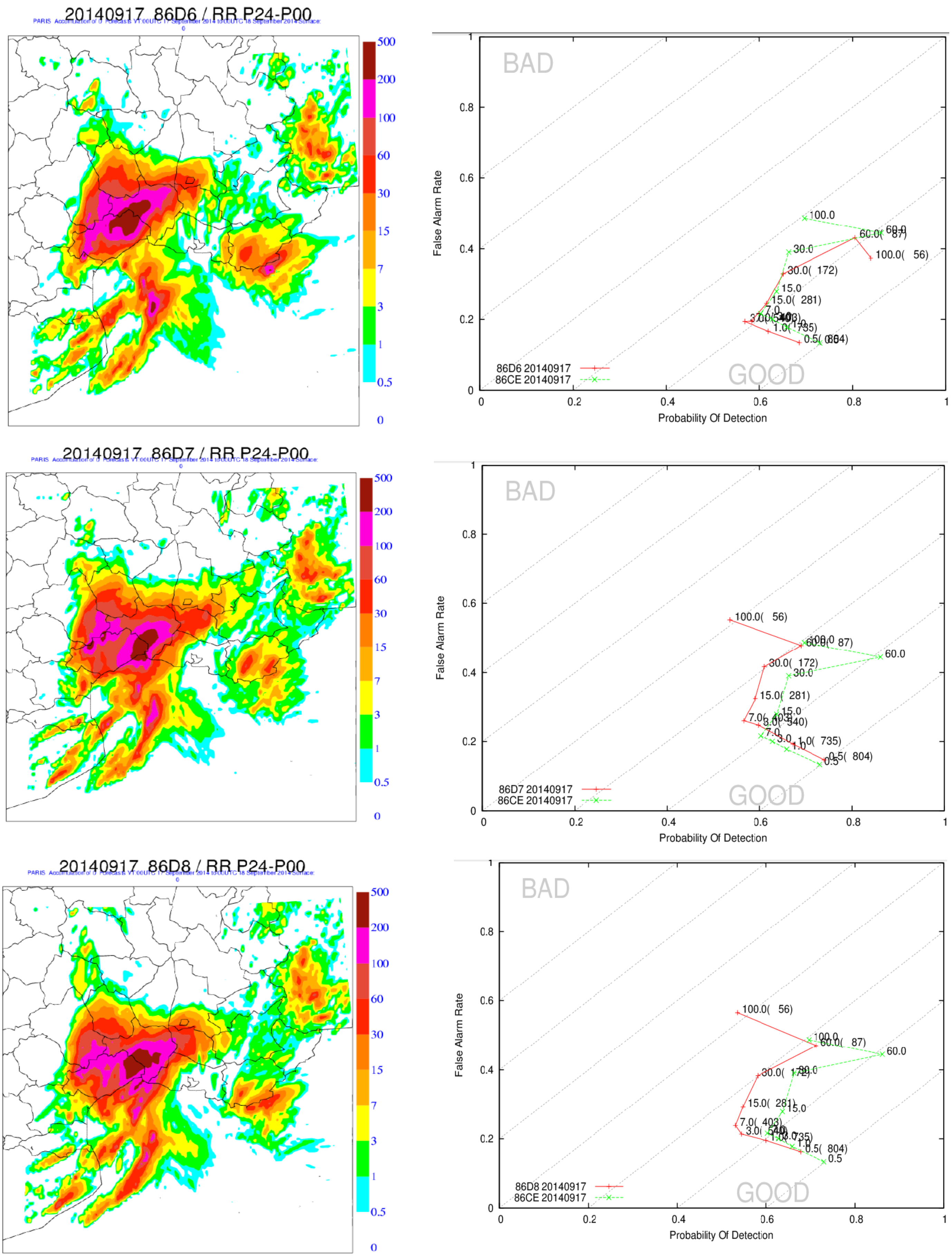


Figure.9: 24-hours cumulated precipitation over Sude domain on 17 September 2014 based respectively (from top to bottom) on analysis at 2.6 km, 4 km and 5.2 km, on the right FAR vs POD for each configuration against 86CE: the forecast based on the analysis at 1.3 km.

Fig. 8 and 9 demonstrate the better ability of the forecast based on analysis at 1.3 km, in evaluating cumulated precipitation, in terms of both localization and amplitude.

In comparison with the raingauge the different experiments doesn't perform correctly the quantity of precipitation, since it produces an overestimate for all the precipitation thresholds, while the three experiments present very similar behaviors and generally overestimate rain quantities, keeping a higher rate of false alarms, and a lower rate of POD, except the threshold 100 for the forecast based on the analysis at 2.6 km where we notice a slight improvement of the FAR and POD.

For this date and this particular area, overestimate precipitation quantities is too penalizing: for a forecaster, foresee such amount of rain on the plain, causes without doubt a disaster, in spite of that the largest amount of precipitation was on the mountain, where there is not a major risk.

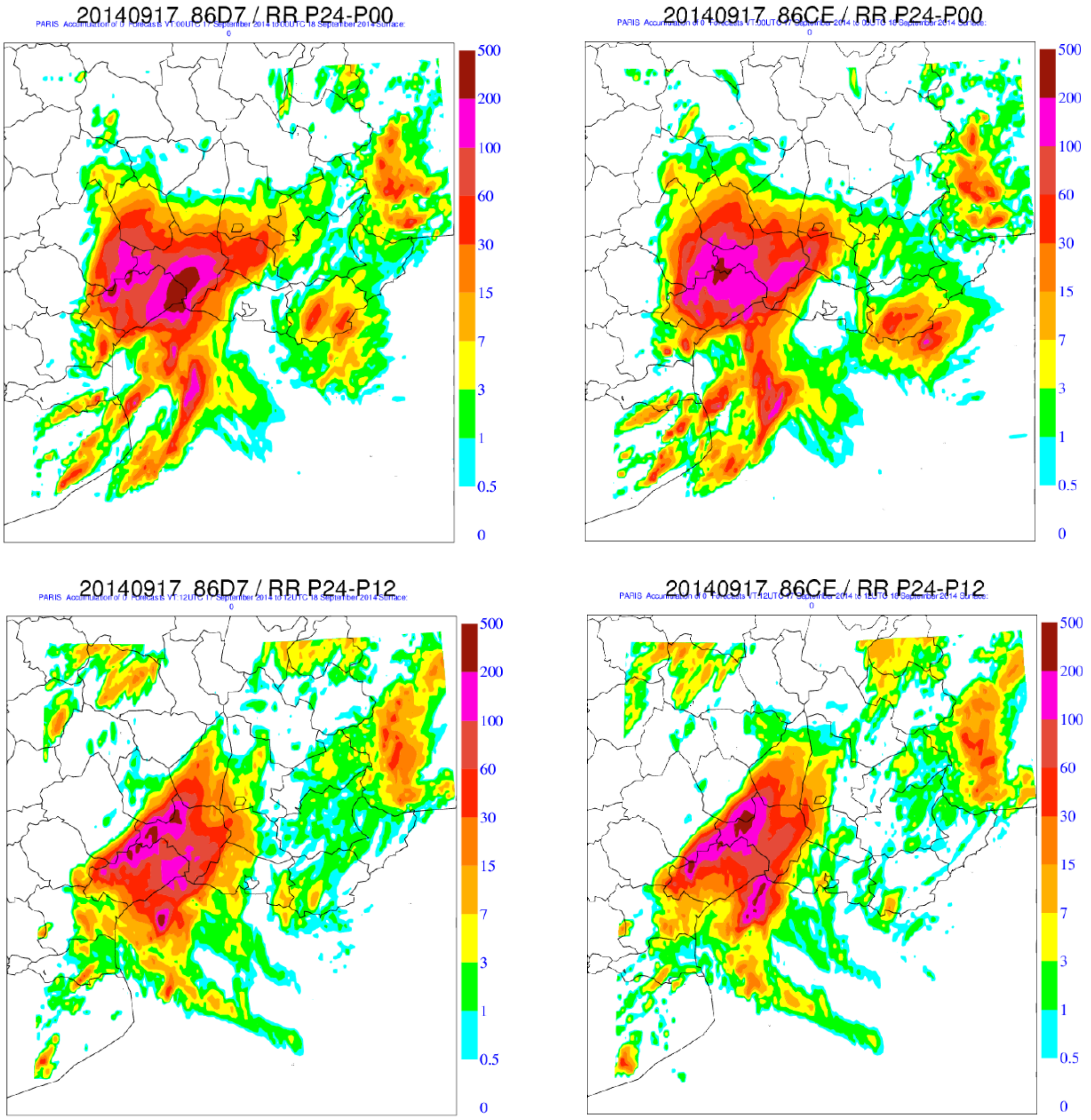


Figure.10: 24-hours cumulated precipitation over Sude domain on 17 September 2014 based on analysis at 4 km (left) and 1.3 km (right), issued from 00 UTC network (top) and 12 UTC (bottom).

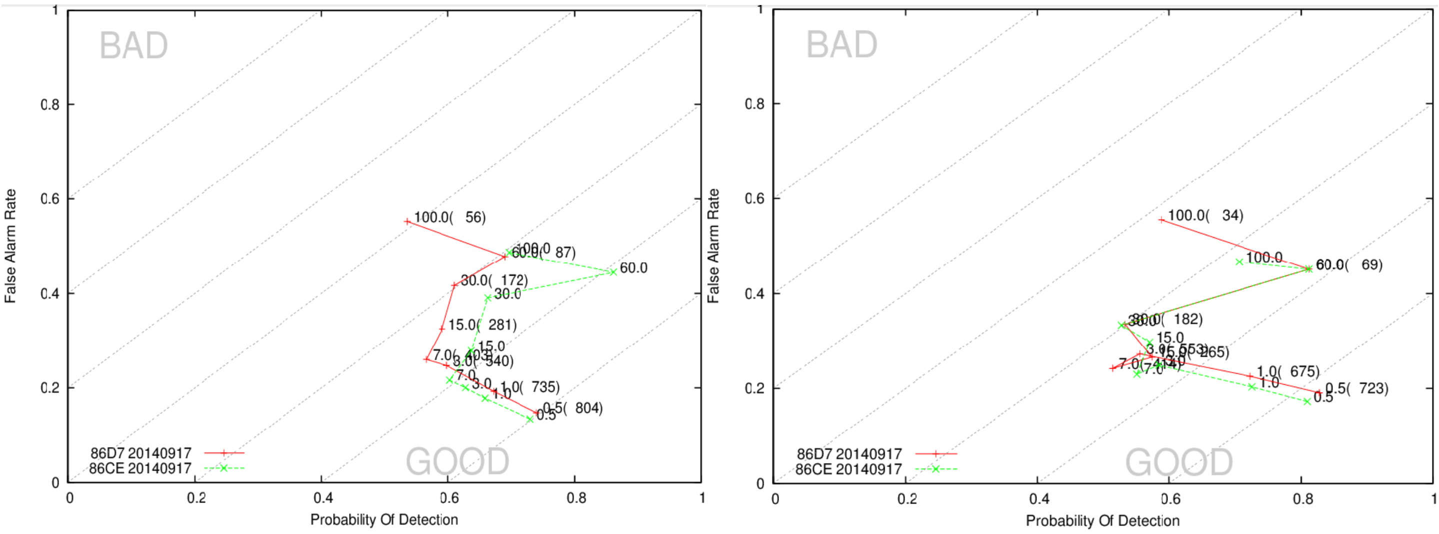


Figure.11: POD vs FAR diagrams for 24-hours cumulated precipitation over Sude domain on 17 September 2014 based on analysis 4 km vs 1.3 km, issued from 00 UTC network (right) and 12 UTC (left).

If we look into the impact of the degradation of the resolution of the analysis on the dynamics of the system; comparing 24-hours cumulated precipitation based on analysis at 4 km and the analysis at 1.3 km issued from 00 UTC and 12 UTC networks, plus the POD vs FAR diagrams: within the first forecast hours, we see well the difference between the forecast issued from the analysis at 1.3km and that issued from the analysis at 4km (the one issued from the analysis at 1.3km is significantly better), by against the impact of the degradation of the increment is no more visible after a few hours of forecast.

On the other periods, we have almost the same type of responses for the FAR and POD, which is still more pronounced on this date, in other words, the degradation of the resolution of the analysis tends to overestimate the cumulated precipitation, in terms of both localization and amplitude.

Generally, the forecast based on the analysis at 1.3 km overestimate the cumulated precipitation and yet, this overestimation is more accentuated with the degradation of the resolution of the analysis.

it is clear that degrading the analysis resolution, we have worse forecasts, for against what is outstanding, that it does not degrade linearly depending on the increment: while we have similar behavior of the RMSE for relative humidity for different resolutions (fig.12), we note a deterioration much weighty of the BIAS for the humidity forecast issued from the analysis at 2.6km in comparison with those issued from the analysis at 4km and 5.2km, it seems that the results obtained from the analysis at 2.6 are the worst, an observation that needs more investigation to recognize a concrete conclusion.

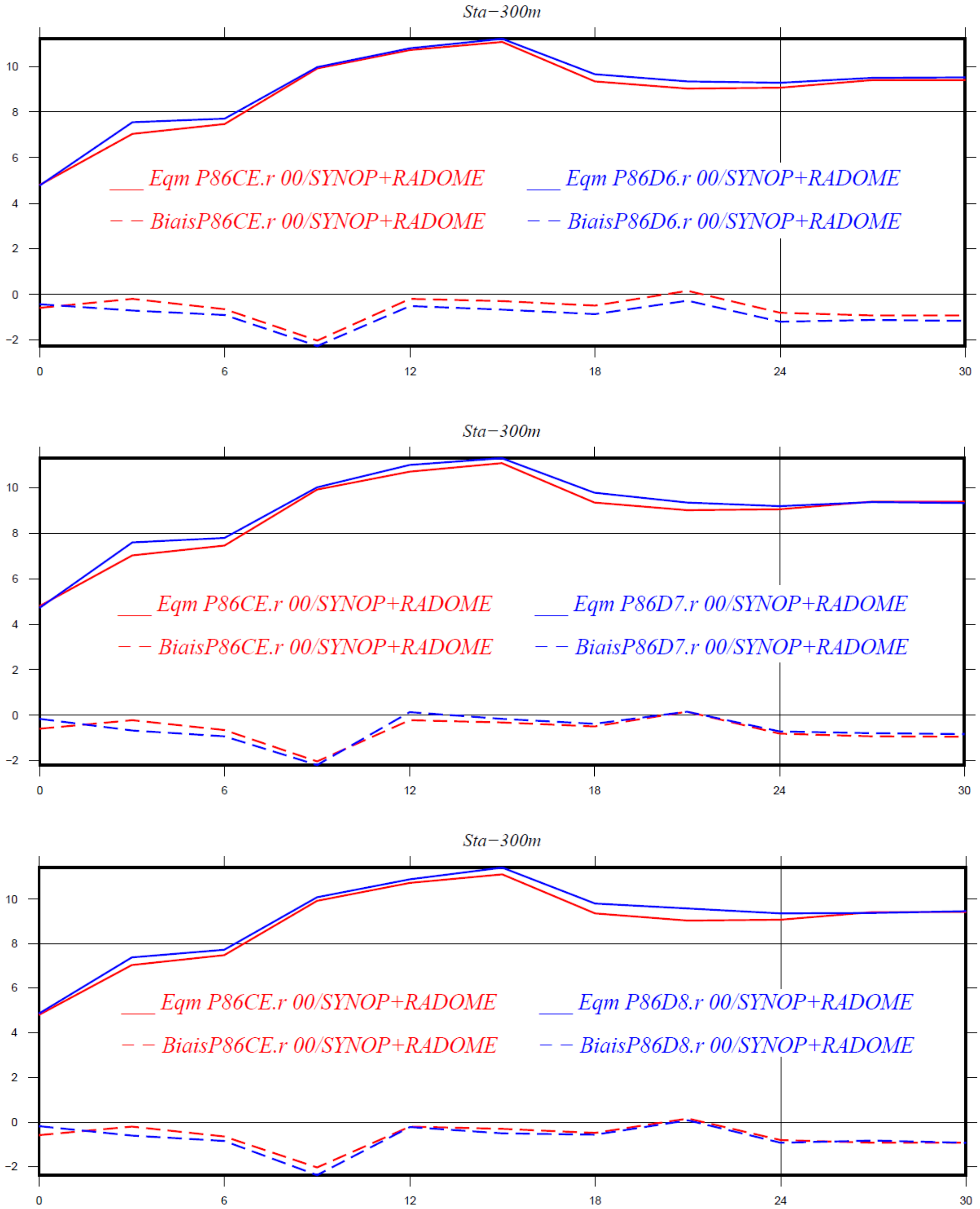


Figure.12: Comparative scores of bias (dashed lines) and rmse (solid lines) for Relative Humidity in altitudes under 300m, based respectively (from top to bottom) on analysis at 2.6 km, 4 km and 5.2 km, against 86CE: the forecast based on the analysis at 1.3 km. issued from 00 UTC network forecasts, valid for 30 hours, between 17 September and 29 November 2014.

5. SPIN-UP

During the run of the different experiences we got several times this error "MPI_ABORT: !V WIND TOO STRONG, EXPLOSION NUMERIQUE", for some experiences it was sufficient to reduce the time step from 45 to 30 to overpass this error, for other experiences it was not sufficient, they require further investigation. Nevertheless we thought it would be interesting to diagnose the problem of spin-up.

The spin-up problem is a numerical noise which occurs in the first ranges of the model integration, it provokes accumulation of noises and imbalances through the assimilation cycle decreasing the system performances.

We started by plotting some differences of some fields from the "ICMSH ..." files, for this purpose we used the epygram tool, for instance to plot the differences of temperature:

fa_plot.py analysis1 -D analysis2 -F 'S030TEMPERATURE'

add the option -o png, to get a .png output file.

The Option --diffminmax '-5, 5' eg: allows to impose limits -5 and 5.

We plotted some analysis increments (analysis-guess) for the different experiences for various analyzed fields (temperature, wind, humidity) at various levels to see what is the effect:

- To make an analysis at a lower resolution: do we see with the naked eye differences of increments between the different resolution.
- To change the resolution by cpl_h2l and cpl_l2h (two scripts that we added before and after the analysis step, to pass from high to low resolution and then from low to high resolution) especially in the lower layers with perhaps a bad effect of the relief.

Effectively our uncertainties are confirmed as shown in the next figures: the increment of the analysis obtained at 4 km, which is converted to the resolution 1.3km (by the script cpl_l2h), lets see that the change of the resolution introduces noise, which increases with altitude.

We also see the noise, looking at the differences within the first forecast range of the first analysis network between the reference (1.3km) and the other configurations (2.6, 4 and 5.2km), we note that this noise is accentuated with the degradation of the analysis.

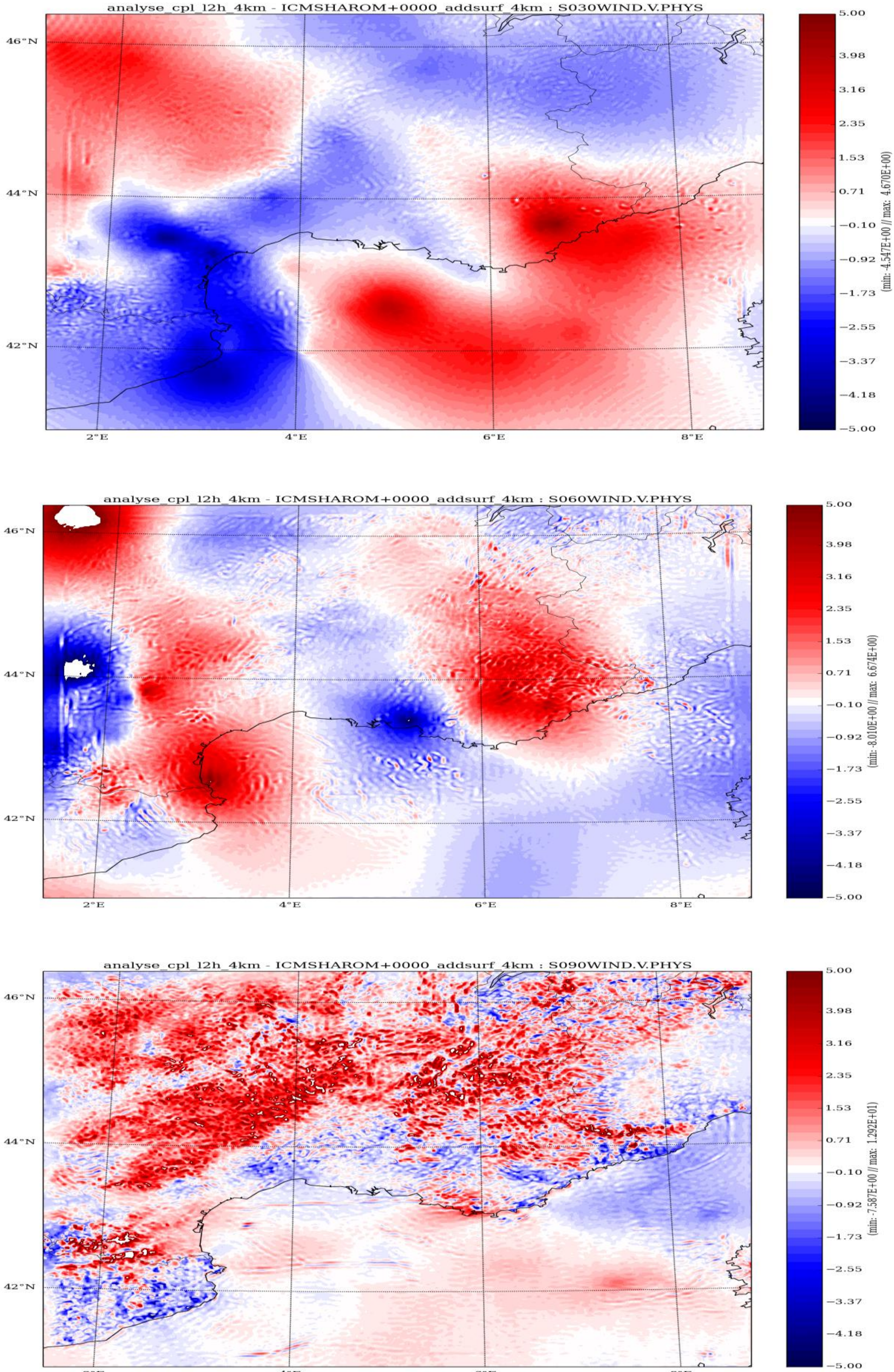


Figure.13: increment analysis obtained at 4 km, and converted to the resolution 1.3km for the wind at different AROME levels 30, 60 and 90.

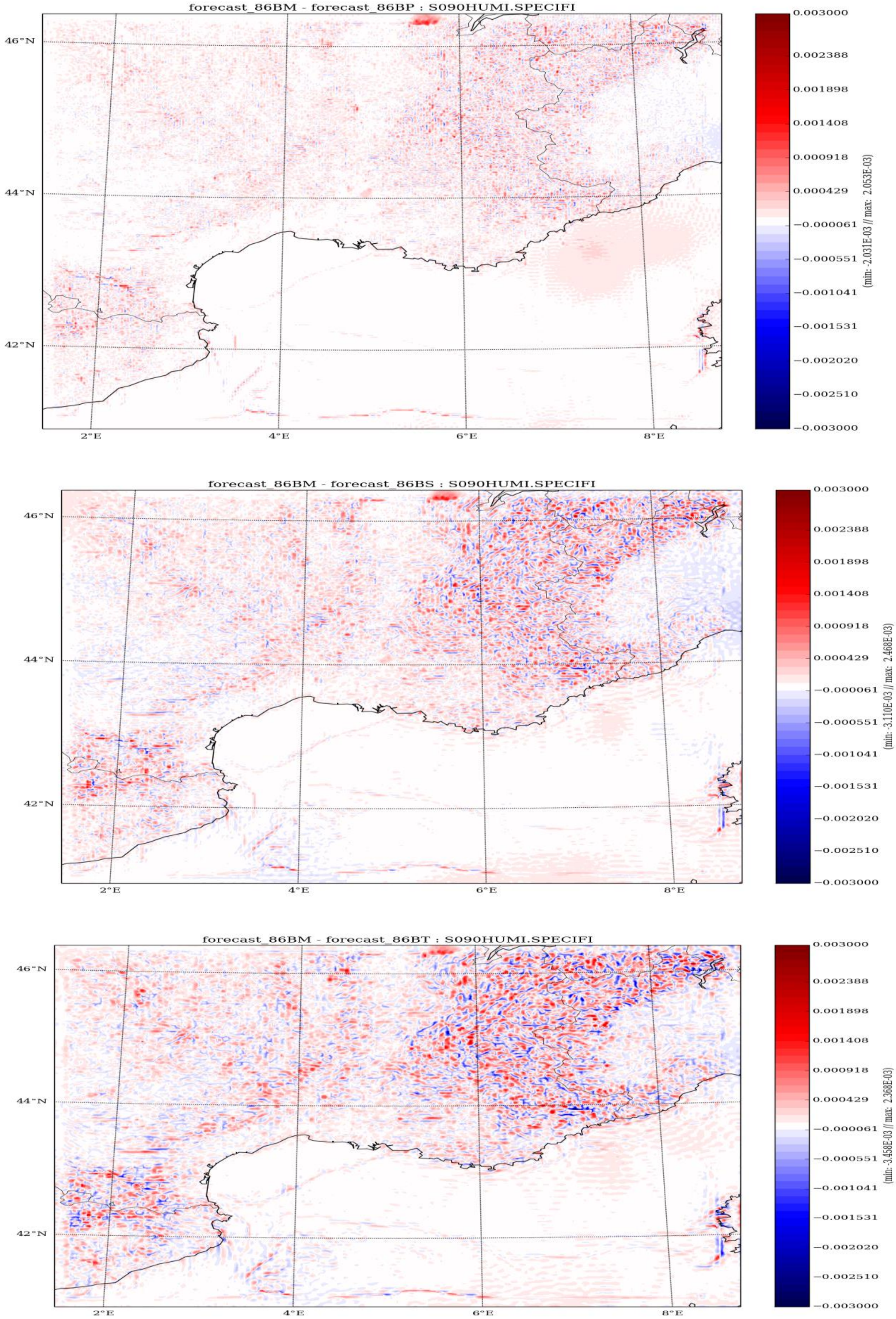


Figure.13: the differences within the first forecast range of the first analysis network between the reference (1.3km) and the other configurations from top to bottom)2.6km, 4km and 5.2km), for the Relative Humidity, at the AROME level 90.

We also see a noise at the boundaries of the domain at the bottom of fig.13 and fig.12, this is explained by the differences in the initial conditions inside the domain, which are the AROME analysis, and in the coupling zone: analysis of the coupling model.

More investigations were done for this numerical explosion using the ECHKEVO diagnostics, which allow studying the temporal evolution of the prognostic variables of the model and particularly in our case the RMS of the pressure tendency over the geographical domain at each time steps.

The increase of the spin-up is evident and more accentuated from a degradation to another, the maximum reduction is achieved in the first 15 minutes, when we start a forecast with an analysis at the same resolution (1.3km) we got less spin-up.

We note that from 3600s (where we record a small oscillation, which corresponds to the injection time of the new coupling files), the 4 curves merge.

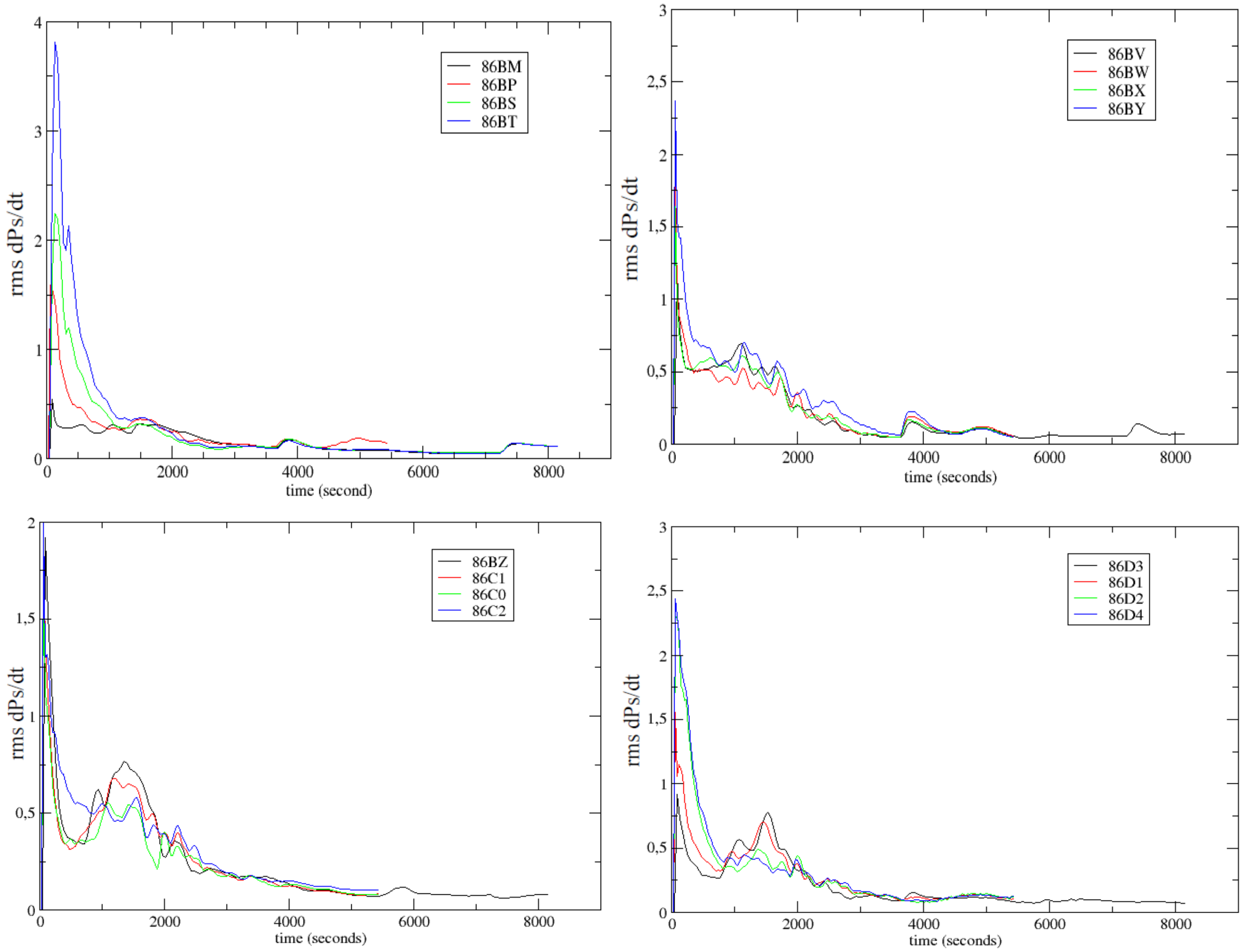
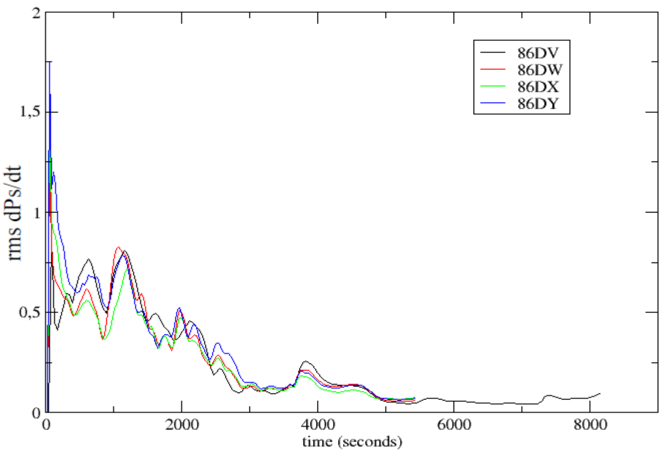
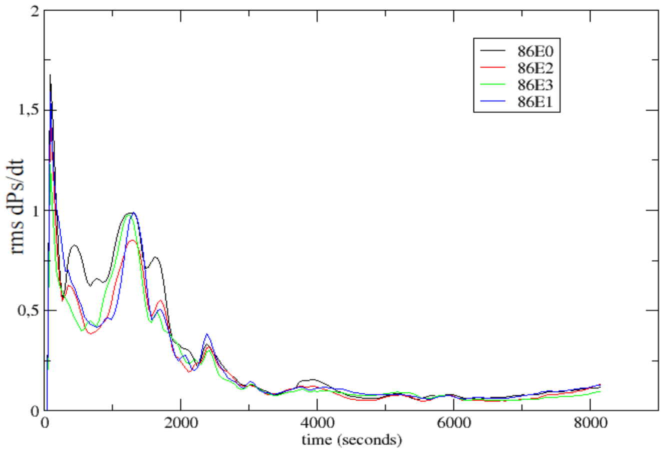


Figure.14: the Echkevo scores: evolution, in function of forecast range, of the RMS of the pressure tendency for the different realized experiences





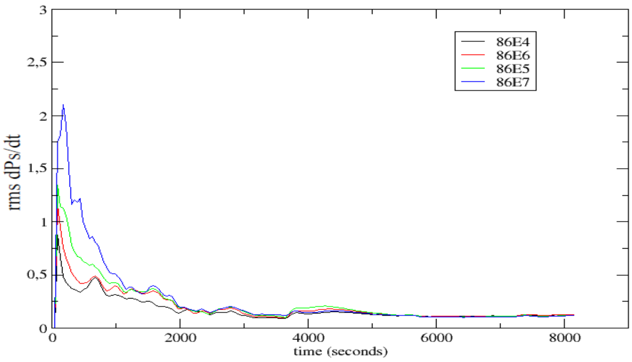


Figure.15: the Echkevo scores: evolution, in function of forecast range, of the RMS of the pressure tendency for the different realized experiences.

6. CONCLUSION & AKNOWLEDGEMENT

The evaluation of the AROME runs at different degraded analysis resolutions required in the first part some technical work, to simulate some strong precipitation event over the French Languedoc region in the autumn of 2014.

It was evident that The best results were obtained with the operational configuration.

The in-situ data emphasize the added value of the analysis at 1.3km, nevertheless it seems that the major added value at this resolution comes from the RADAR observations.

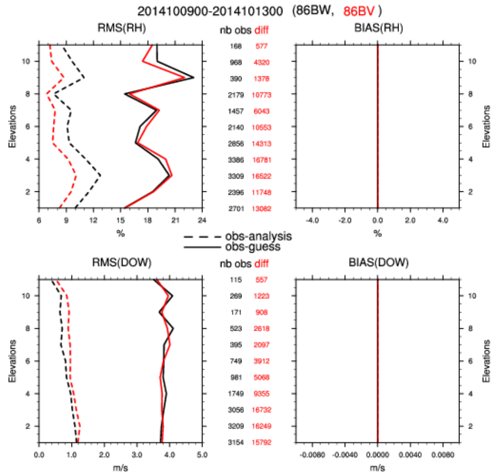
Results show the overestimating tendency in 24-hours cumulated precipitation, in terms of both intensity and location of the forecasts driven from the degraded resolution analysis.

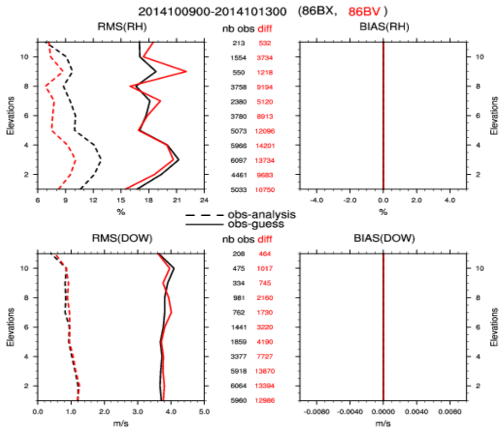
In addition to the negative impact on the forecast, the degradation of the analysis amplifies the problem of spin-up, an issue that we are trying to reduce and not to amplify; the degradation of the analysis is very penalizing, it is not a good track to reduce the costs of calculations.

More investigations should be done for the problem of spin-up for some experiences where the reduction of the time step was not sufficient to overpass this error.

At the end of this report I want to thank Pierre Brousseau for the valuable guidance, advices and entire support during my stay, as well many thanks to the entire GMAP team

ANNEX





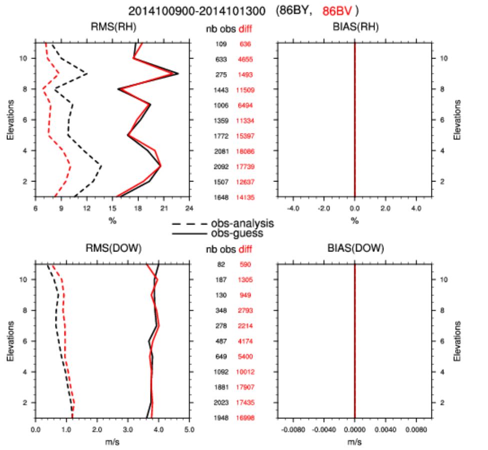
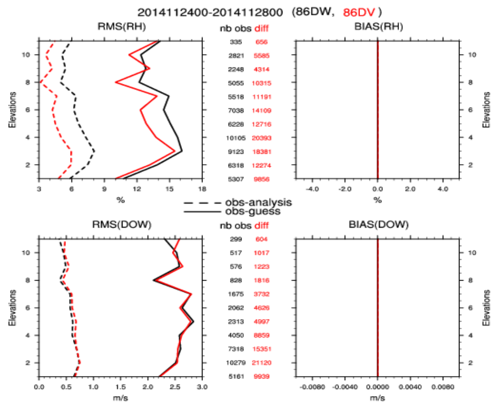
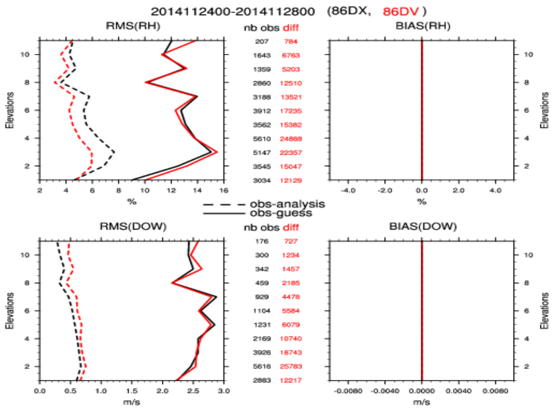


Figure.16: Vertical profile of BIAS (right) and RMS (left) of analysis (obs minus analysis) and background (obs minus guess) departures from observations: for the relative humidity (top) and the radar radial velocity (bottom): for three experiments comparing 86BV (analysis at 1.3km) respectively to 86BW (analysis at 2.6 km) 86BX (analysis at 4 km) and 86BY (analysis at 5.2 km), averaged from 9 to 13 October 2014.





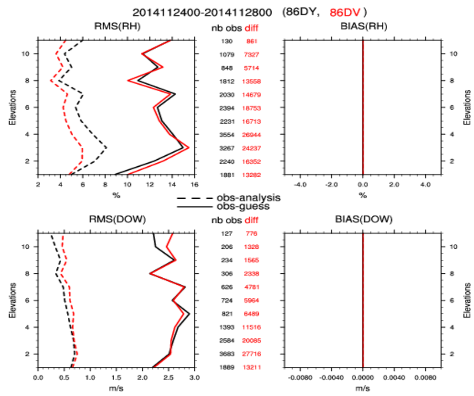
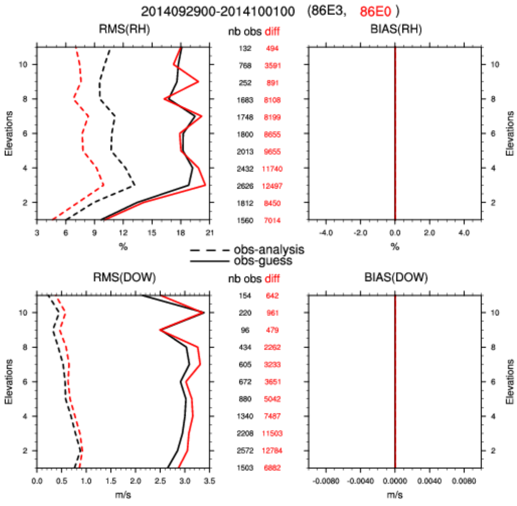
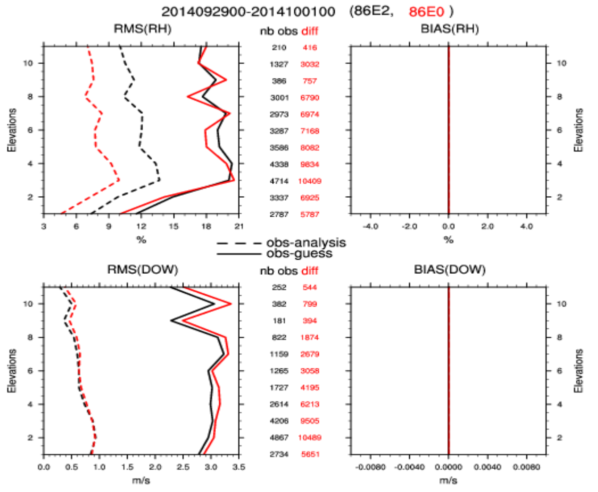


Figure.17: Vertical profile of BIAS (right) and RMS (left) of analysis (obs minus analysis) and background (obs minus guess) departures from observations: for the relative humidity (top) and the radar radial velocity (bottom): for three experiments comparing 86DV (analysis at 1.3km) respectively to 86DW (analysis at 2.6 km) 86DX (analysis at 4 km) and 86DY (analysis at 5.2 km), averaged from 24 to 28 November 2014.





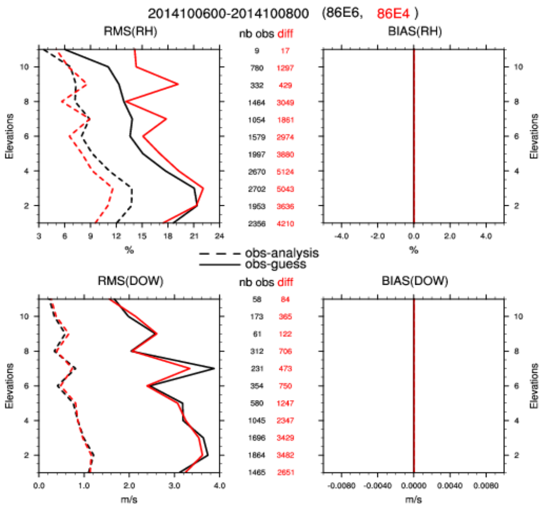
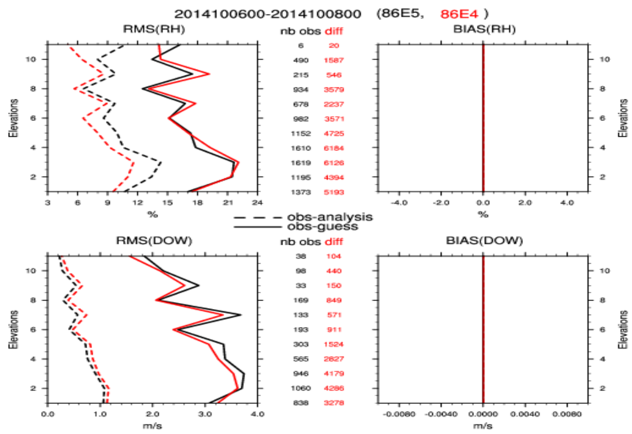
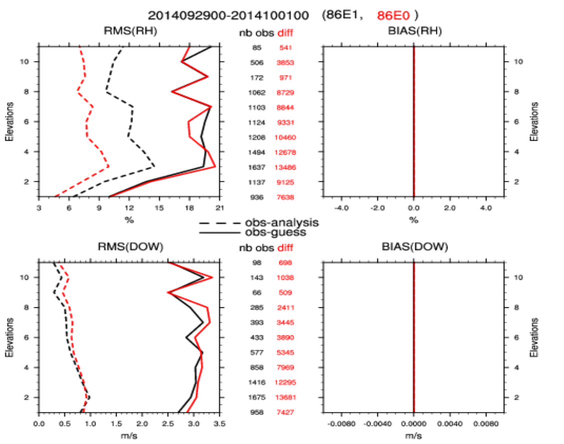


Figure.18: Vertical profile of BIAS (right) and RMS (left) of analysis (obs minus analysis) and background (obs minus guess) departures from observations: for the relative humidity (top) and the radar radial velocity (bottom): for three experiments comparing 86E0 (analysis at 1.3km) respectively to 86E2 (analysis at 2.6 km) 86E3 (analysis at 4 km) and 86E1 (analysis at 5.2 km), averaged from 29 September to 01 October 2014.





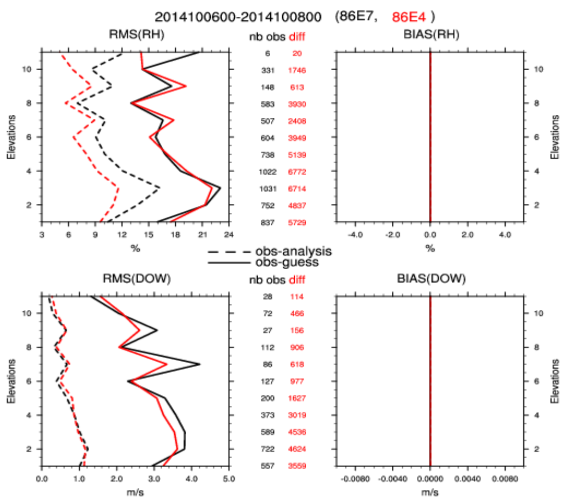


Figure.19: Vertical profile of BIAS (right) and RMS (left) of analysis (obs minus analysis) and background (obs minus guess) departures from observations: for the relative humidity (top) and the radar radial velocity (bottom): for three experiments comparing 86E0 (analysis at 1.3km) respectively to 86E2 (analysis at 2.6 km) 86E3 (analysis at 4 km) and 86E1 (analysis at 5.2 km), averaged from 06 to 08 October 2014.