Improving the surface initialization of Aladin (ISBA) from IFS (HTessel) Analysis

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Report of the work done in Meteo-France Headquarters in Toulouse
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1. Introduction

This is the report of the work done by the author in Toulouse Meteo-France Headquarters from 22 of February to 9 of April 2009 which was preceded by another work also done in Toulouse in November 2008. During this first stay, several problems regarding the use of HTessel soil wetness in ISBA were pointed out and solutions were proposed (Ferreira, J 2008). However, despite the major improvement of the new scheme relatively to the 901 old scheme, the final solution described in the November 2008 report was still too crude to be satisfactory, namely in the Rsmin/LAI scaling.

First of all, in the first attempt, the only revised parameter was Wp, through SWI equalisation. In this work, several soil parameters were revised, namely Tp, Wsi, Ws, Wpi and Wp.

2. Objective

In ARPEGE Configuration 901, the routine responsible for initializing surface prognostic variables, from IFS-Tessel to Aladin-ISBA, is *cprep1.F90.* The objective of this work is to change this routine in order to use a more physically based assumption than the one currently used.

3. Methodology

Several important changes were made to the 901 cprep1 code, regarding soil parameters:

Tp change:

The ISBA Tp is no longer taken as the average temperature of HTessel layers 3 and 4. It was substituted by the average temperature of HTessel layers 2 and 3. This is expected to be more close to the optimum ISBA Tp, which is more representative of a 50 cm depth temperature.

Wsi change:

The IFS superficial ice content is calculated first, according to the formula:

$$
\begin{aligned}
&Wsi = f_{fr}(T)SWL_1 \\
&f_{fr}(T) = \begin{cases} 0 & \Leftarrow T > T_{f1} \\ 0.5\left[1-\sin\left(\dfrac{\pi\left(T-0.5T_{f1}-0.5T_{f2}\right)}{T_{f1}-T_{f2}}\right)\right] & \Leftarrow T_{f2} \le T \le T_{f1} \\ 1 & \Leftarrow T < T_{f2} \end{cases} \\
&T_{f2} = 270.15K \\
&T_{f1} = 274.15K \\
&T = T_1 = Temperature\ of\ the\ first\ layer
\end{aligned}
\tag{3.1}
$$

The ISBA superficial ice is made equal to the IFS superficial ice.

Ws change:
The IFS superficial liquid water is:

$$Ws_{IFS} = SWL_1 - Wsi \qquad (3.2)$$

The ISBA superficial liquid water is:

$$Ws_{ISBA} = \frac{W_{capISBA}}{W_{capIFC}} * Ws_{IFS} \qquad (3.3)$$

Wpi change:
The IFS deep ice content is calculated for each of the four layers, according to the formula:

$$\begin{aligned}
&Wpi_i = f_{fr}(T_i)SWL_i \quad i = 1,4 \\
&f_{fr}(T_i) = \begin{cases} 0 & \Leftarrow T_i > T_{f1} \\ 0.5\left[1 - \sin\left(\dfrac{\pi(T_i - 0.5T_{f1} - 0.5T_{f2})}{T_{f1} - T_{f2}}\right)\right] & \Leftarrow T_{f2} \le T_i \le T_{f1} \\ 1 & \Leftarrow T_i < T_{f2} \end{cases} \\
&T_{f2} = 270.15K \\
&T_{f1} = 274.15K \\
&T_i = Temperature\ of\ each\ layer
\end{aligned} \qquad (3.4)$$

The IFS total deep ice content is the weighted mean with the depth of each layer:

$$Wpi = \frac{\sum_{i=1}^{4} Wpi_i * z_i}{\sum_{i=1}^{4} z_i} \qquad (3.5)$$

$$z_1 = 0.07;\ z_2 = 0.21;\ z_3 = 0.72;\ z_4 = 1.89$$

The ISBA deep ice is made equal to the IFS deep ice.

Wp change:
The Wp calculation was massively recoded in cprep1. The idea was to keep the SWI IFS and SWI ISBA equalisation, but with the SWI of both models calculated more correctly, introducing the percentage of roots in each layer and the high and low vegetation type and cover in IFS. In ISBA, the vegetation cover was also taken into account.

The IFS liquid water for each layer is:

$$Liq_{i\,IFS} = SWL_i - Wpi_i \qquad (3.6)$$

The weighted average of unfrozen soil water is given by:

$$\bar{\theta} = \sum_{i=1}^{4} R_i \max\left[Liq_{i\,IFS}, PWP\right] \qquad (3.7)$$

with PWP depending on soil type according to Table 1 of (Ferreira, J 2008) and R_i the fraction of roots in layer i, which depends on vegetation type according to Table 1.

Table 1

Vegetation Index	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**13**	**16**	**17**	**18**	**19**
Layer 1	24	35	26	26	24	25	27	100	47	24	17	25	23	23	19	19
Layer 2	41	38	39	38	38	34	36	0	45	41	31	34	36	36	35	35
Layer 3	31	23	29	29	31	27	27	0	8	31	33	27	30	30	36	36
Layer 4	4	4	6	7	7	14	10	0	0	4	19	14	11	11	10	10

These values are accessed in cprep1 through the call of SURF_INQ module, which varies from the ones given in IFS Documentation – Cy31r1 in vegetation type 7 and 13. Investigating the discrepancy, the conclusion was that SURF_INQ is correct.

The weighted average of unfrozen soil water is calculated for high and low vegetation using equation 3.7 giving a high and low vegetation SWI

$$SWI_{H,L} = \begin{cases} 0 \Leftarrow \bar{\theta}_{H,L} \leq PWP \\ \dfrac{\bar{\theta}_{H,L} - PWP}{CAP - PWP} \Leftarrow PWP < \bar{\theta}_{H,L} < CAP \\ 1 \Leftarrow \bar{\theta}_{H,L} \geq CAP \end{cases} \qquad (3.8)$$

The high and low vegetation percentages are given by

$$VEG_{H,L} = CV_{H,L} * cveg_{H,L} \qquad (3.9)$$

with $CV_{H,L}$ is high and low vegetation cover (respectively gribcodes 28 and 27) and $cveg_{H,L}$ is a coefficient depending on vegetation type and given by Table 2 of (Ferreira, J 2008)..

The total IFS SWI is

$$SWI_{IFS} = \frac{VEG_H SWI_H + VEG_L * SWI_L + (LSM - VEG_H - VEG_L) SWI_1}{LSM}$$
$$with \qquad (3.10)$$
$$SWI_1 = \begin{cases} 0 \Leftarrow Liq_{1_{IFS}} \leq PWP \\ \dfrac{Liq_{1_{IFS}} - PWP}{CAP - PWP} \Leftarrow \ PWP < Liq_{1_{IFS}} < CAP \\ 1 \Leftarrow Liq_{1_{IFS}} \geq CAP \end{cases}$$

LSM is the land sea mask and it is equal to 1 if only bare soil and high and low vegetation exist in the grid box.

Concerning ISBA SWI calculation there are 3 options, leading to 3 different experiments, namely:

(FC and Wilt are functions of clay percentage as explained in (Ferreira, J 2008))

Option 1: Standard SWI

The ISBA SWI is

$$SWI_{ISBA} = \frac{W_p - Wilt}{FC - Wilt} veg + \frac{W_p}{FC}(1 - veg) \qquad (3.11)$$

IFS and ISBA SWI equalisation gives

$$W_p = \frac{(SWI_{IFS}\left(FC - Wilt\right) + veg * Wilt)FC}{FC + (veg - 1)Wilt} \qquad (3.12)$$

Option 2: Optimum Interpolation (OI) SWI

As proposed by Jean François Mahfouf and described for example in (Giard and Bazile, 2000) the ISBA SWI can be written as

$$SWI_{ISBA} = \frac{W_p - veg.Wilt}{FC - veg.Wilt} \qquad (3.13)$$

IFS and ISBA SWI equalisation gives

$$W_p = SWI_{IFS}\left(FC - veg.Wilt\right) + veg.Wilt \qquad (3.14)$$

Option 3: Standard SWI with Rsmin/LAI scaling

In (Ferreira, J 2008) it was pointed out that the big difference in Rsmin and LAI between IFS and ISBA, will produce an important evaporation difference between the two models, when using one of the above options, even thinking that now they use roots percentage and ISBA vegetation. This will be demonstrated in the next pages. So, since ISBA evaporation is still too high in Summer particularly over France, the Rsmin/LAI scaling was introduced in (3.11).

The ISBA SWI is

$$\begin{aligned} SWI_{ISBA} &= LAIscal \frac{W_p - Wilt}{FC - Wilt} veg + \frac{W_p}{FC}(1 - veg) \\ LAIscal &= \frac{\left(\frac{Rs\min}{LAI}\right)_{IFS}}{\frac{Rs\min_{ISBA}}{LAI_{ISBA}}} \\ \left(\frac{Rs\min}{LAI}\right)_{IFS} &= \frac{\frac{Rs\min(TVH)}{LAI(TVH)} VEG_H + \frac{Rs\min(TVL)}{LAI(TVL)} VEG_L}{\left(VEG_H + VEG_L\right)}; \quad \textit{given by Table 2 of Ferreira, J 2008} \end{aligned} \qquad (3.15)$$

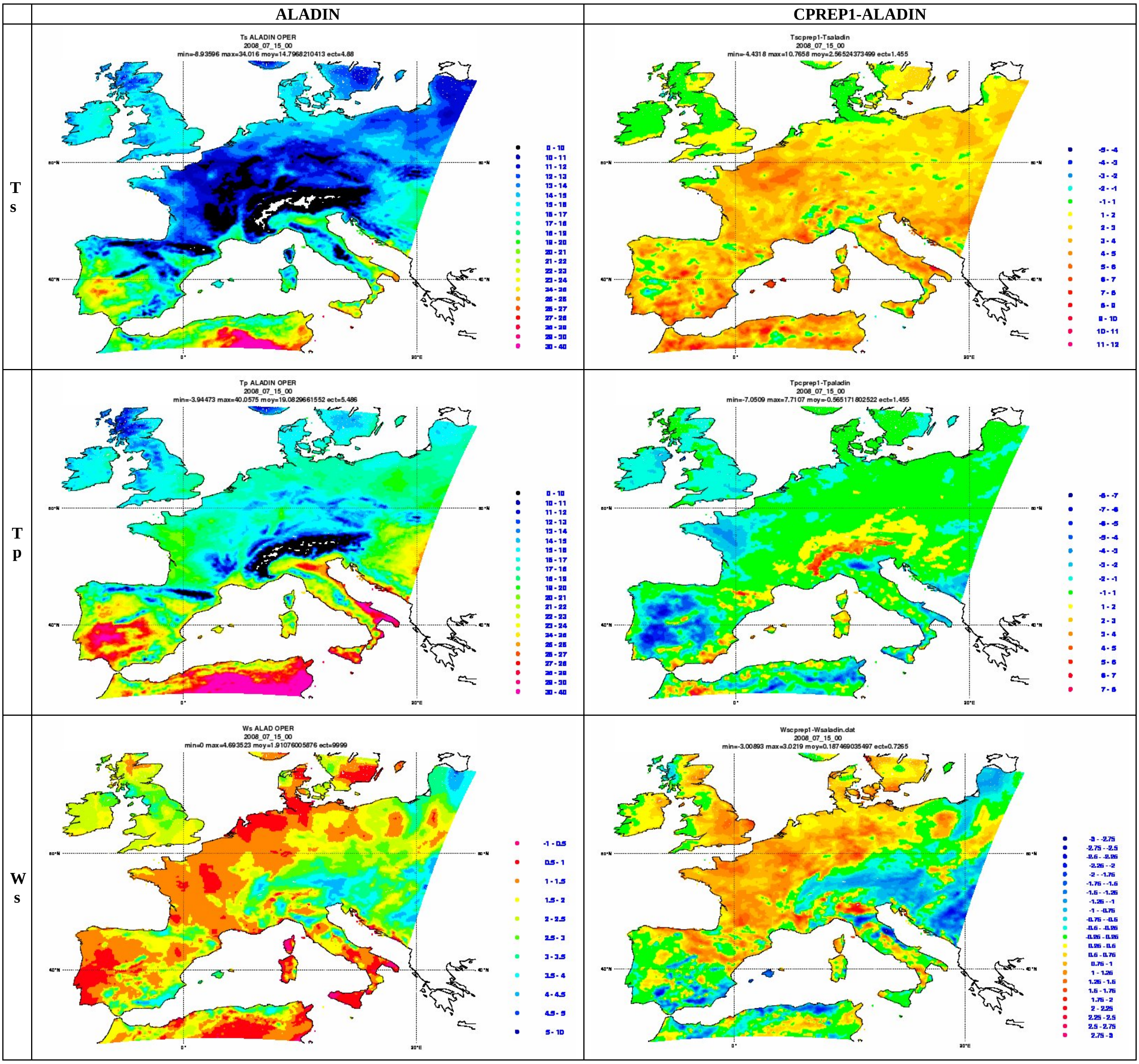
where TVH and TVL is type of vegetation high and low

IFS and ISBA SWI equalisation gives

$$W_p = \frac{(SWI_{IFS}(FC - Wilt) + LAIscal * veg * Wilt)FC}{veg * FC * (LAIscal - 1.0) + FC + (veg - 1)Wilt} \quad (3.12)$$

4. Analysis of results

For a Summer situation, 15th of July 2008, Fig. 1 shows six ALADIN OPER soil parameters and the difference to those obtained with cprep1 modifications in configuration 901. Since Wp calculation is proposed with 3 different methods, the SWI differences are showed apart in Fig.2.



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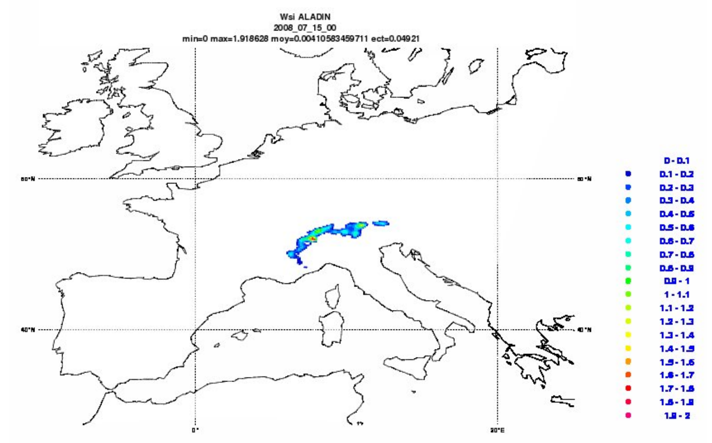
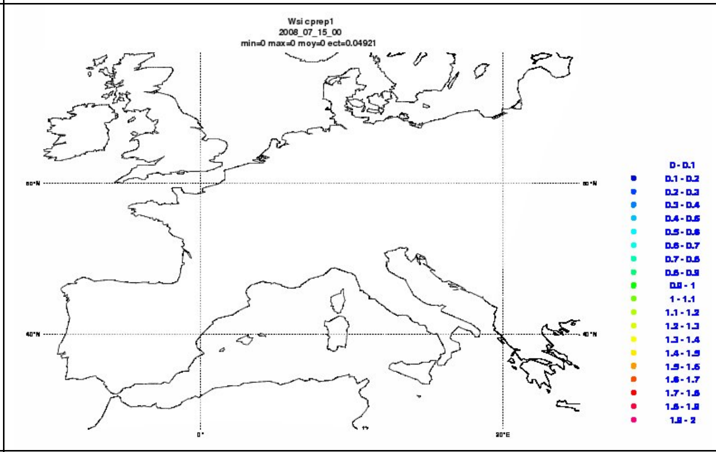
si</td><td>
</td><td>
</td></tr>
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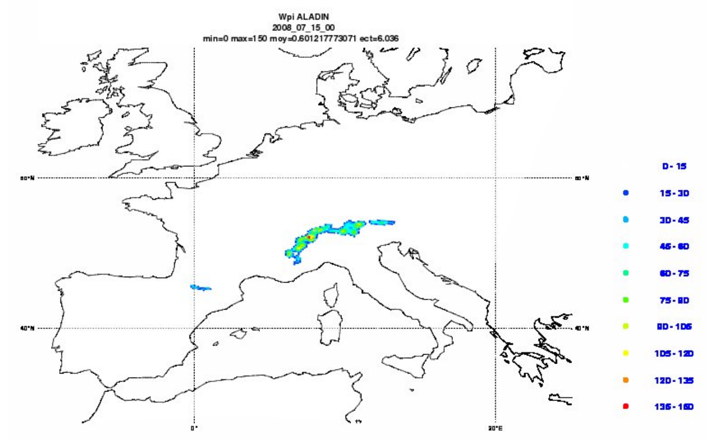
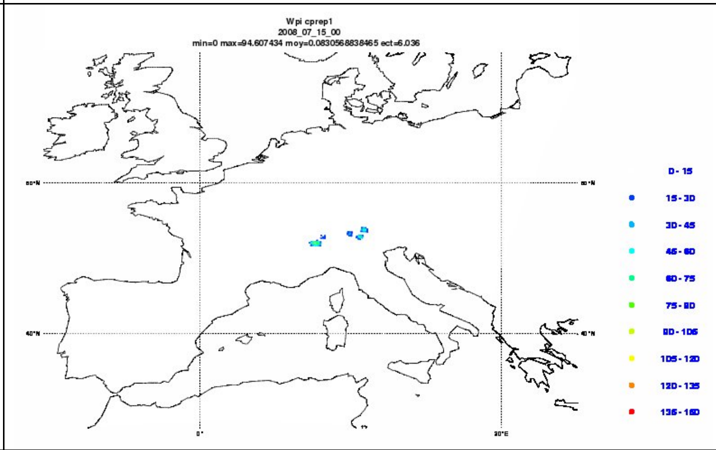
pi</td><td>
</td><td>
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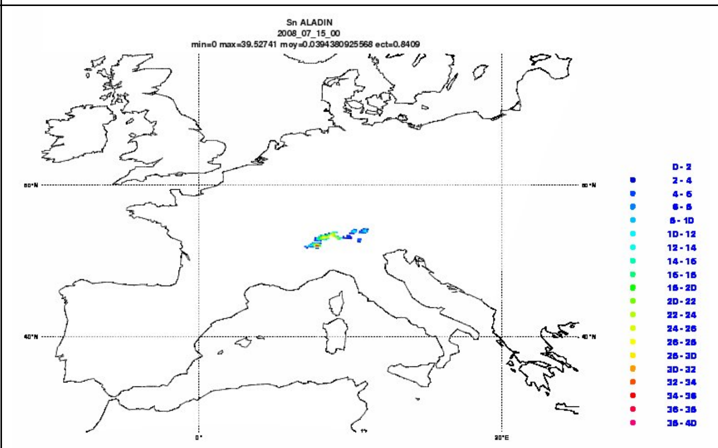
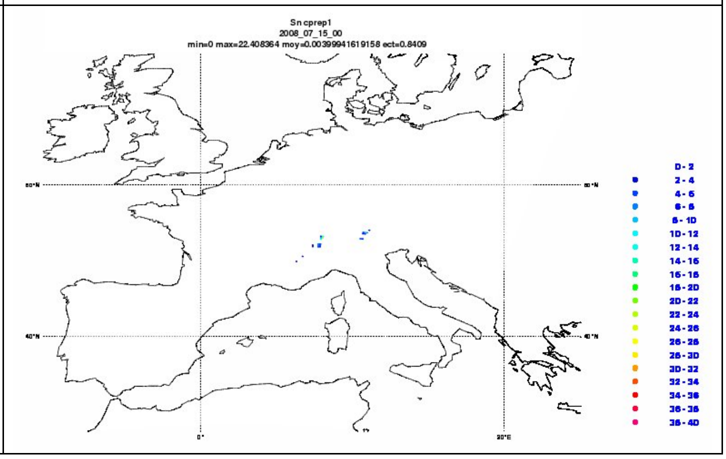
n</td><td>
</td><td>
</td></tr>
</table>

Fig.1 – Soil parameters for the 15th of July 2008 at 0h UTC, obtained with ALADIN Oper and with cprep1 modifications

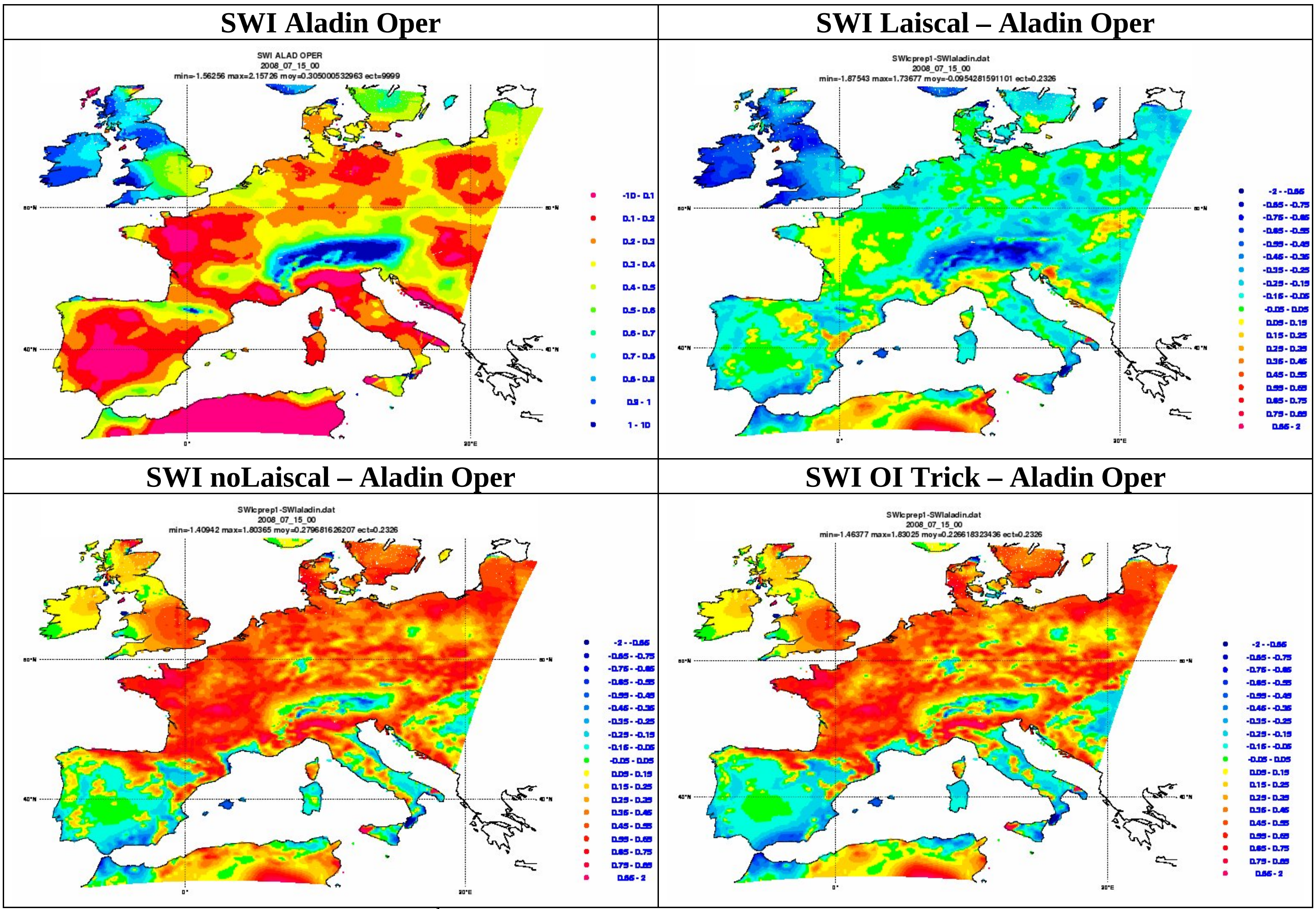


Fig.2 – SWI for the 15th of July 2008 at 0h UTC, obtained with ALADIN Oper and with the 3 proposed cprep1 modifications concerning Wp

Fig. 1 shows a big discrepancy in Ts over large regions, with a mean difference of +2.6 C and a maximum difference of +10.8 C. The IFS temperature of the first layer (gribcode 139), used in cprep1, is too warm during night when compared with the surface temperature used in ISBA which is a combination of a skin temperature and the superficial layer temperature. However, this discrepancy in Ts is not very important because, as it is shown in the score analysis section, the impact in the 2 metre temperature vanishes before 6 hours integration time. Nevertheless, one possibility of improving Ts would be to take a linear combination of the IFS temperature of the first layer (gribcode 139) and the IFS Skin temperature (gribcode 235).

The Tp has a mean difference of -0.6 C and it is warmer in mountainous regions. The option of using the average temperature of layers 2 and 3 is good enough and has more physical meaning than the average temperature of layers 3 and 4.

The Ws has a mean difference of 0.19 Kg/m2 which is acceptable. However, over some regions, the field is not very comparable. For example over France we have ISBA Ws between 1.0 and 1.5 Kg/m2 and cprep1 Ws is between 2.0 and 3.0 Kg/m2.

The Wsi fields are much different. IFS does not give superficial frozen soil for this day, not even over the Alps, while ISBA gives substantial superficial frozen soil in a wide region over the Alps that reaches 1.9 Kg/m2. This difference can be important and deserves further investigation.

The IFS Wpi reaches the maximum value of 94 Kg/m2 over the Alps, while ISBA Wpi reaches the maximum value of 150 Kg/m2 and spreads over a much wider region, including part of the Pyrenees. Again, this difference can be important and deserves further investigation but as a preliminary comment one could say that ISBA Wpi is probably too high for the 15th of July.

ISBA Snow is higher in ISBA than IFS as it was expected from the latest statements.

Fig.2 shows a ALADIN Oper SWI that is probably too dry compared to the “real” SIM SWI, as it was already stated in (Ferreira, J 2008). However, this SWI produces good quality accumulated evaporation which leads to good quality 2 metre temperature and relative humidity inside the ALADIN code. So, the IFS derived SWI should not be very different from the ISBA SWI.

Fig.2 also shows how the 3 proposed SWI deviate from ISBA SWI.

No_LAIscal and OI_Trick SWI:

Both have similar patterns with a SWI mean difference of +0.280 for No_Laiscal and +0.227 for OI_Trick. Almost the whole domain is wetter than ISBA SWI.

LAIscal SWI:

The SWI has a mean difference of –0.095 and so, as a whole, the domain is now slightly dryer than the ISBA SWI. However, over large part of France it is still too wet. The regions where Laiscal is significantly dryer than ISBA SWI are over the Alps and the British Islands. The scaling is roughly neutral over regions with less vegetation as the centre of the Iberian Peninsula, not changing much from the solutions without scaling.

Fig.3 shows the Aladin Oper H+12 forecast of 2 metre temperature, relative humidity and accumulated evaporation and the difference to the Laiscal and the Blended Forecasts for the 15th of July 2008 at 12h UTC.

The “blended” forecast is obtained with IFS upper air initial conditions, but does not use the surface fields from cprep1. The surface initial conditions are obtained from Aladin Oper, “blending” them with the IFS upper air fields. So, the Blended forecast discrepancy show the impact of using a different upper air initial condition with exactly the same surface as Aladin Oper and it is useful to isolate the impact of a different surface initialization (coming from cprep1) with IFS upper air.

It can be seen that the blended forecast already has some discrepancies to the Aladin Oper forecast, namely in the centre of Spain , south of Italy, north of Africa, northwest of France, Holland, northeast of Germany and centre of Poland. The Laiscal discrepancies are also present at those places with some amplification particularly in the northwest of France, but the major Laiscal T2m difference reaches +13 C over the Alps, where there is no discrepancy in the blended forecast. So, this difference is not related to IFS upper air but rather it should be caused only by surface initialization.

Fig. 4 is a zoom of Fig. 1, 2 and 3 over the Alps. Cprep1 discrepancy in T2m is coherent with soil parameter discrepancies, with almost all of them leading to a warm T2m forecast. So, with cprep1, Ts and Tp are warmer and SWI is dryer. But the most important is Wpi. The biggest difference in 2 metre temperature occurs when there is almost no deep frozen soil in IFS and a substantial amount of deep frozen soil in Aladin Oper.

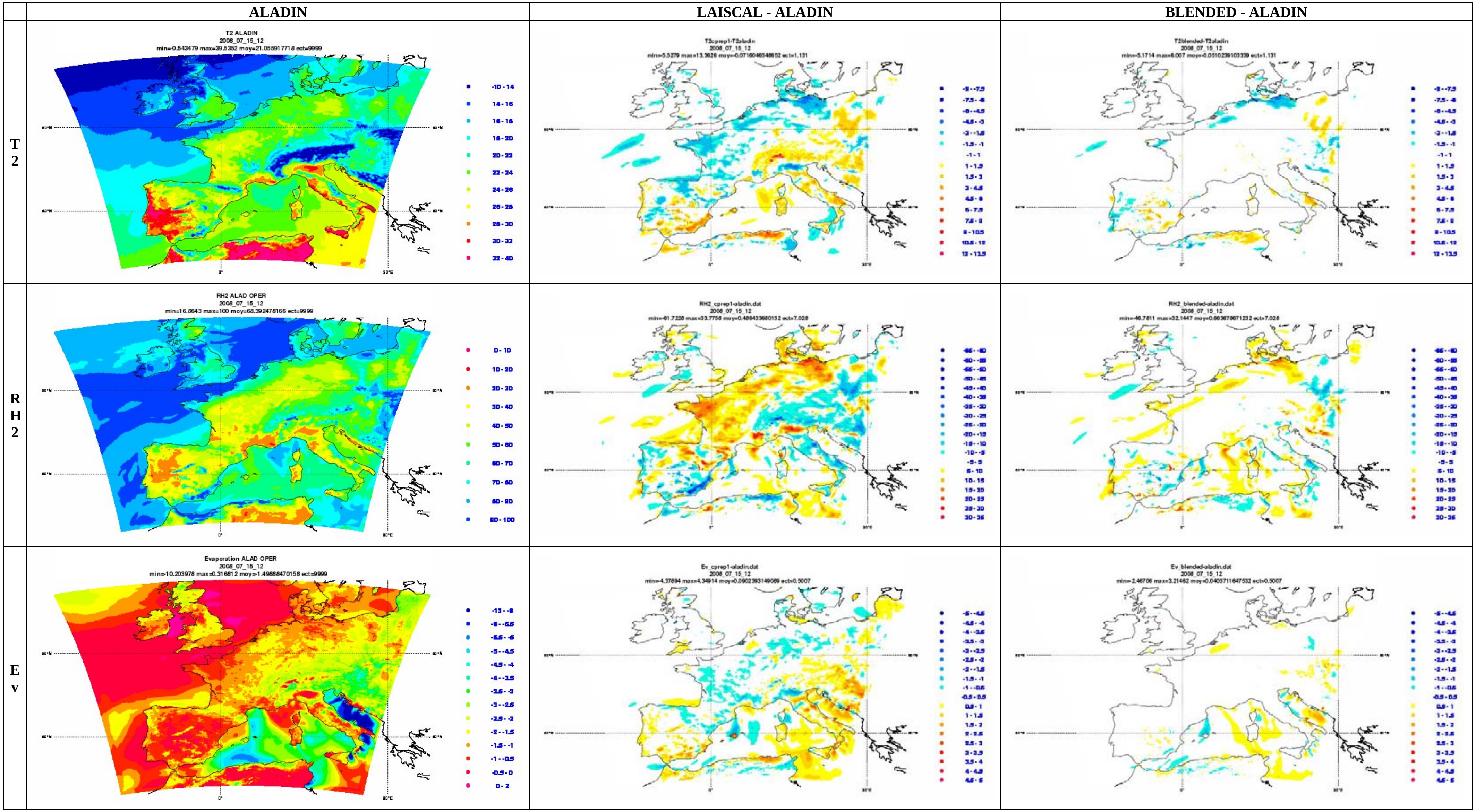


Fig. 3 – Aladin Oper H+12 forecast of 2 metre temperature, relative humidity and accumulated evaporation and difference to the Laiscal and Blended Forecast for the 15th of July 2008 at 12h UTC

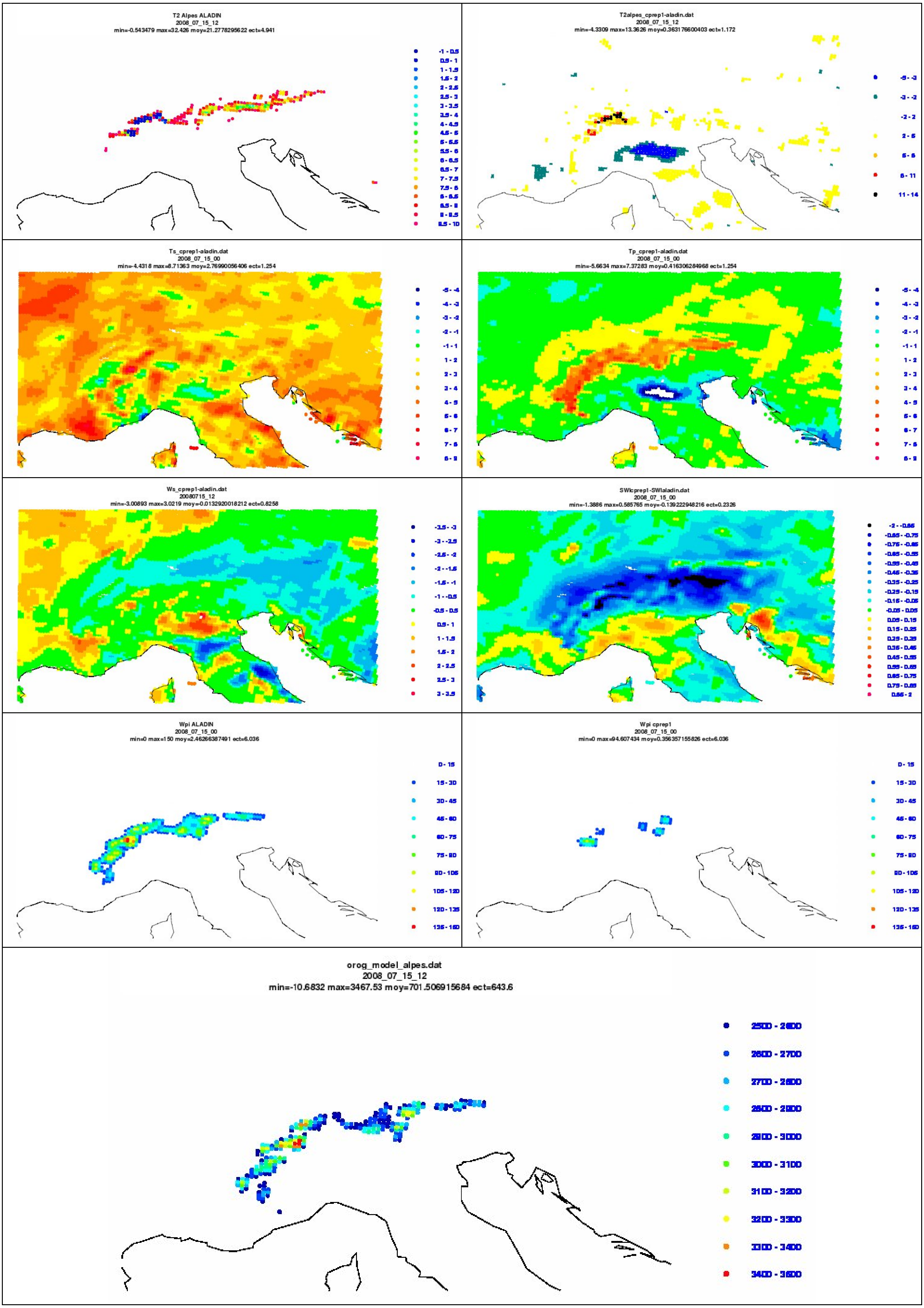


Fig. 4 – Zoom over the Alpes region

For the 15th of July 2008 at 12h UTC, Aladin Oper forecasted a T2m bellow 0 C over some grid points with an altitude around 2500 metres, while Laiscal forecasted a temperature above 10 C at the same grid points. Fig. 5 shows the available observations and their altitude for this date. It is true that only one station reported a temperature bellow 10 C (and in a different location where laiscal doesn't have a significant discrepancy) but it is also true that none of them is located above 2500 metres.

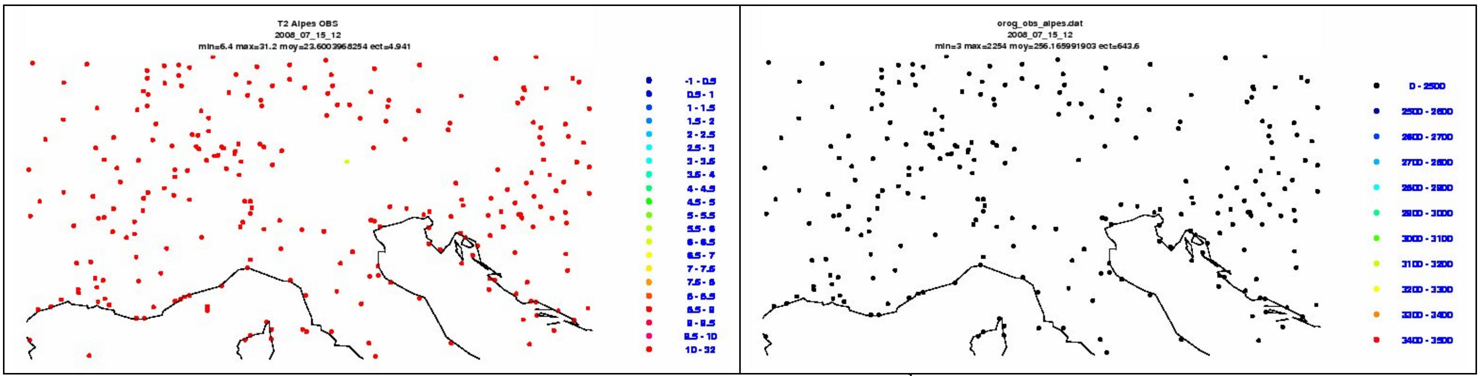


Fig. 5 – Observations over the Alps for the 15th of July 2008 at 12h UTC

As it was already stated, the ice problem is important and deserves further investigation.

Apart from that, the spatial mean T2m discrepancy is 0.07 C and the spatial mean RH2 discrepancy is 0.5% which are very satisfactory values. Of course there are still differences between the Aladin Oper forecasts and cprep1 forecasts, but the objective of this work was not to have the same output with IFS and Aladin Oper, because then what would be the point of using IFS? Both models have their strengths and to know for sure which one is closer to reality is not an easy task. The next session will present computed scores over a month (July 2008) to see if the new cprep1 is ready to be implemented substituting the actual blended solution and will help to decide which one of the 3 proposed SWI should be adopted: Laiscal, No_Laiscal or OI_Trick.

5. Analysis of scores

Meteo France has a very nice web tool called Olive, that easily allows to run experiments and compute scores. For each experiment, Olive will produce a label identifying it. Six experiments were done for the period from the 1st of July 2008 to the 31th of July 2008:

Olive Label	Description of experiment
74MB	Full Aladin Oper
74MF	Cprep1 with Rsmin/Lai scaling (Laiscal)
74N3	Cprep1 without Rsmin/Lai scaling (No_Laiscal)
74N4	Cprep1 without Rsmin/Lai scaling (OI_Trick)
74N5	Original Cprep1
74N6	Blended

The experiments run in "tori" via sms and the scores are computed in the Meteo France machine "serran", producing a pair of experiments in postscript format reporting rmse and bias from 0 to 54 hours forecast with a 6 hours time step.

The first pair of experiences to analyse is 74MB and 74N6. This will measure the impact of using IFS upper air, but with the same surface as Aladin Oper. The second pair of experiences is 74MB and 74MF. This will measure the impact of using both IFS upper air and surface. Fig. 6 shows the T2m scores for these experiences.

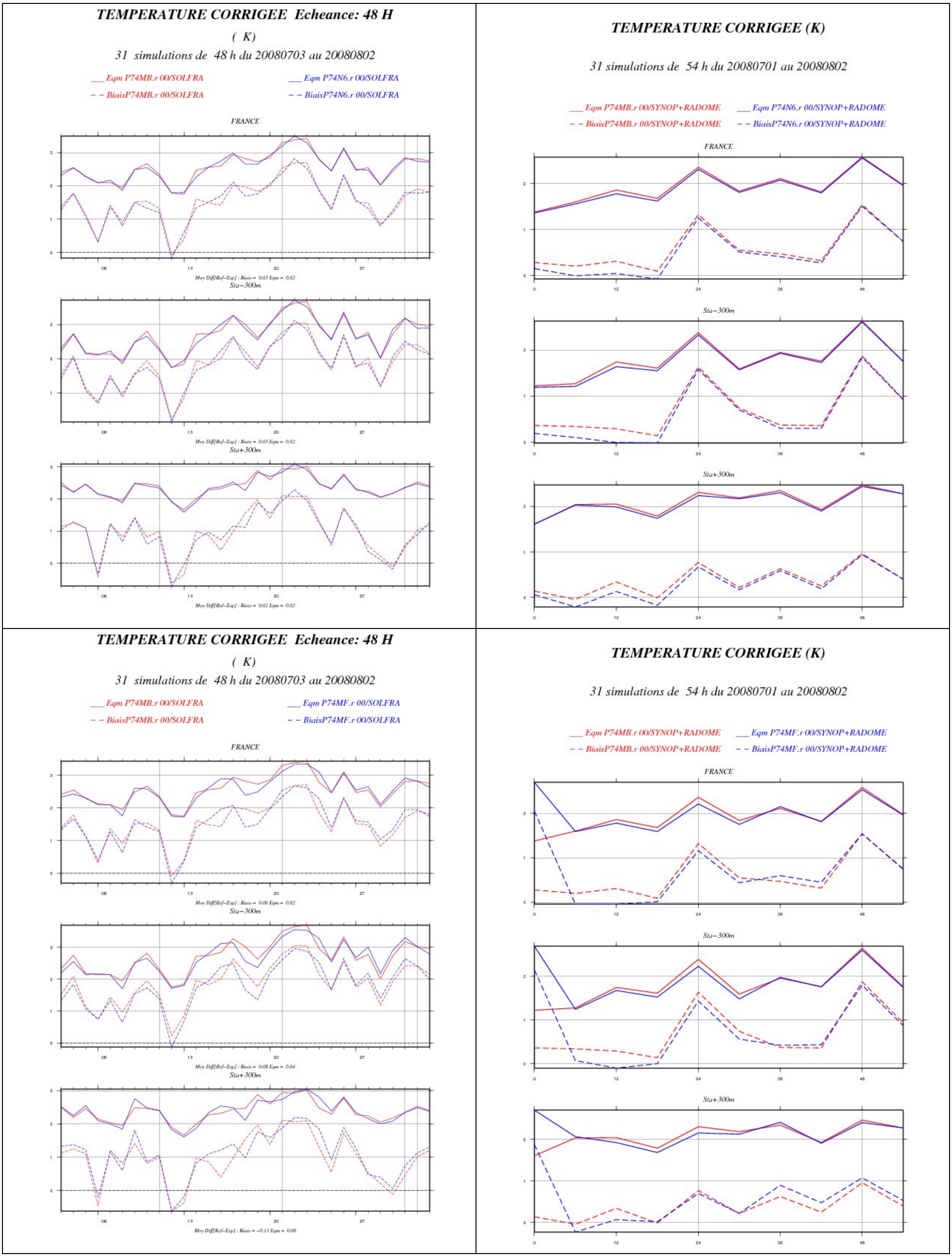


Fig.6 - T2m scores for experiences 74MB (Full Aladin), 74MF (Laiscal) and 74N6 (Blended) during summer

The direct comparison between 74MF and 74N6 for several surface parameters is in Fig.7

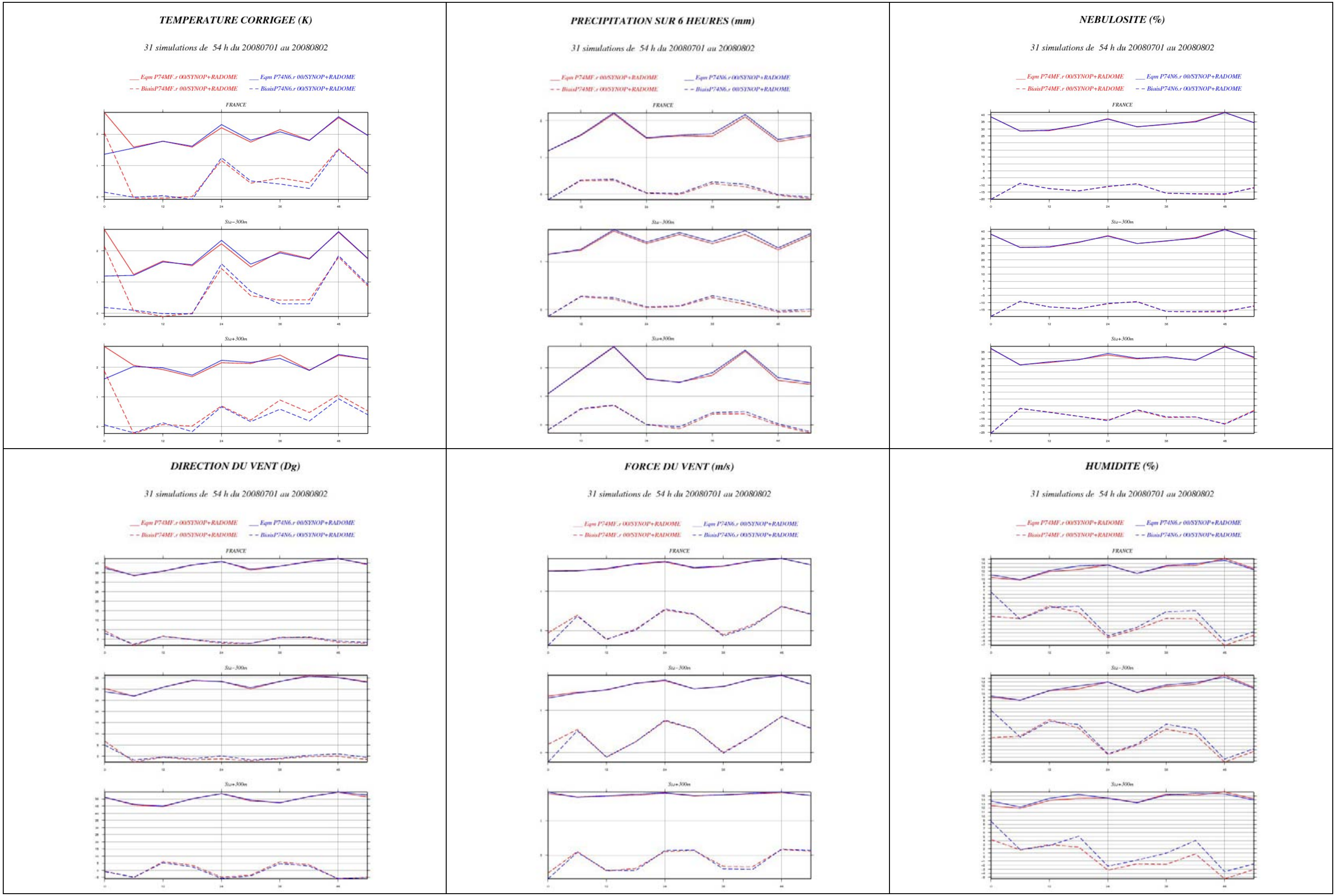


Fig.7 – 74MF (Laiscal in red) and 74N6 (Blended in blue) scores

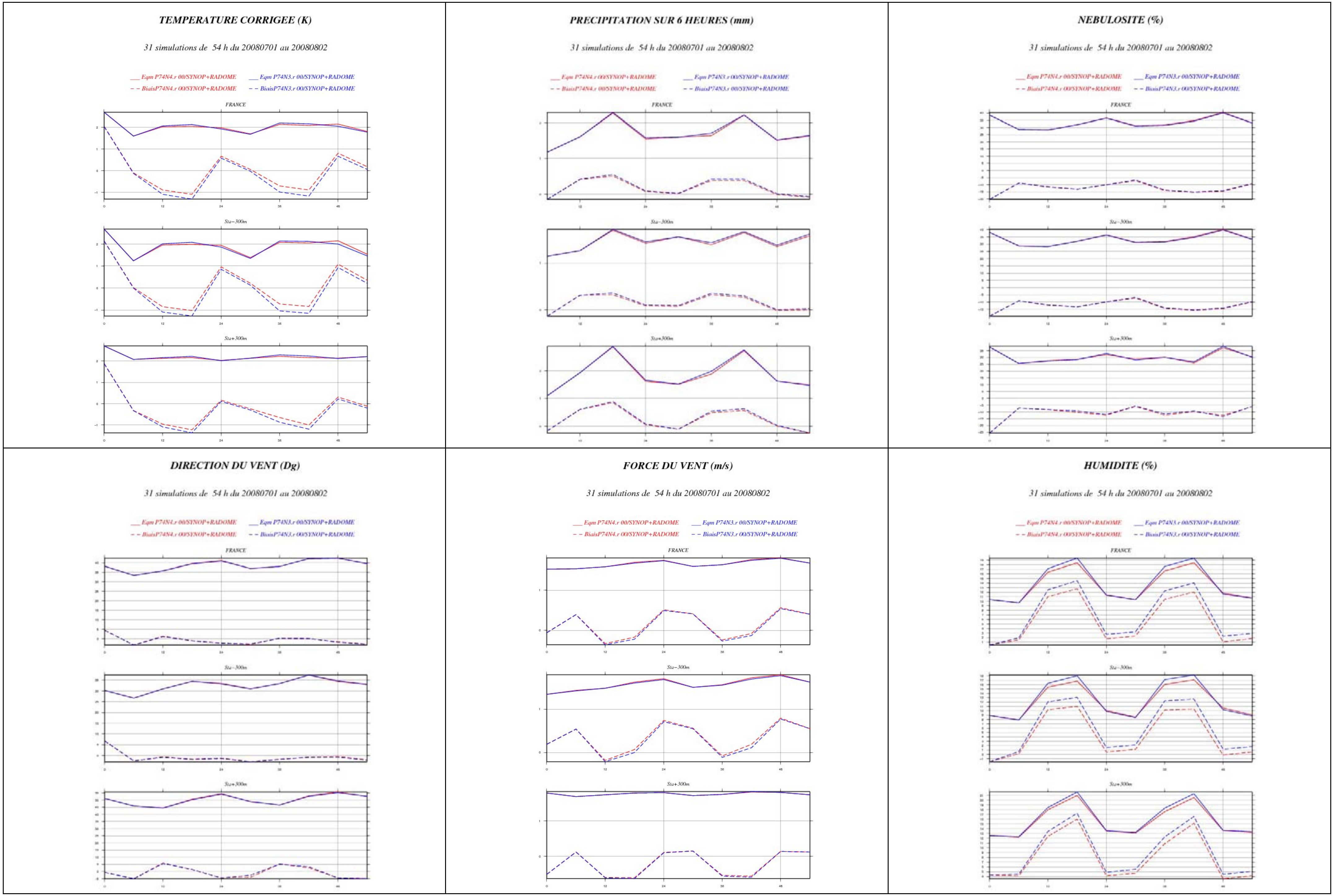


Fig.8 – 74N3 (No_Laiscal in blue) and 74N4 (OI_Trick in red) scores

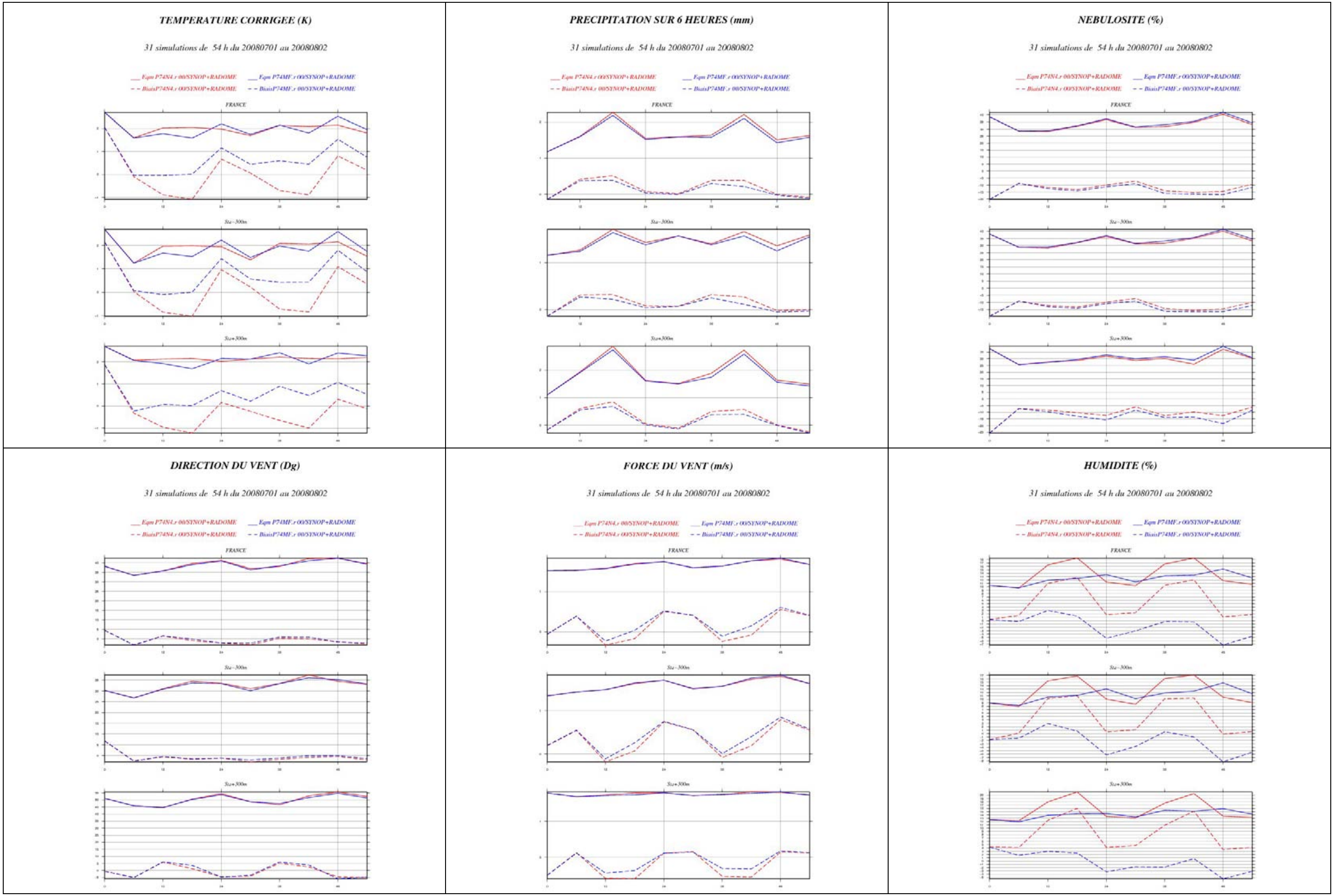


Fig.9 – 74MF (Laiscal in blue) and 74N4 (OI_Trick in red) scores

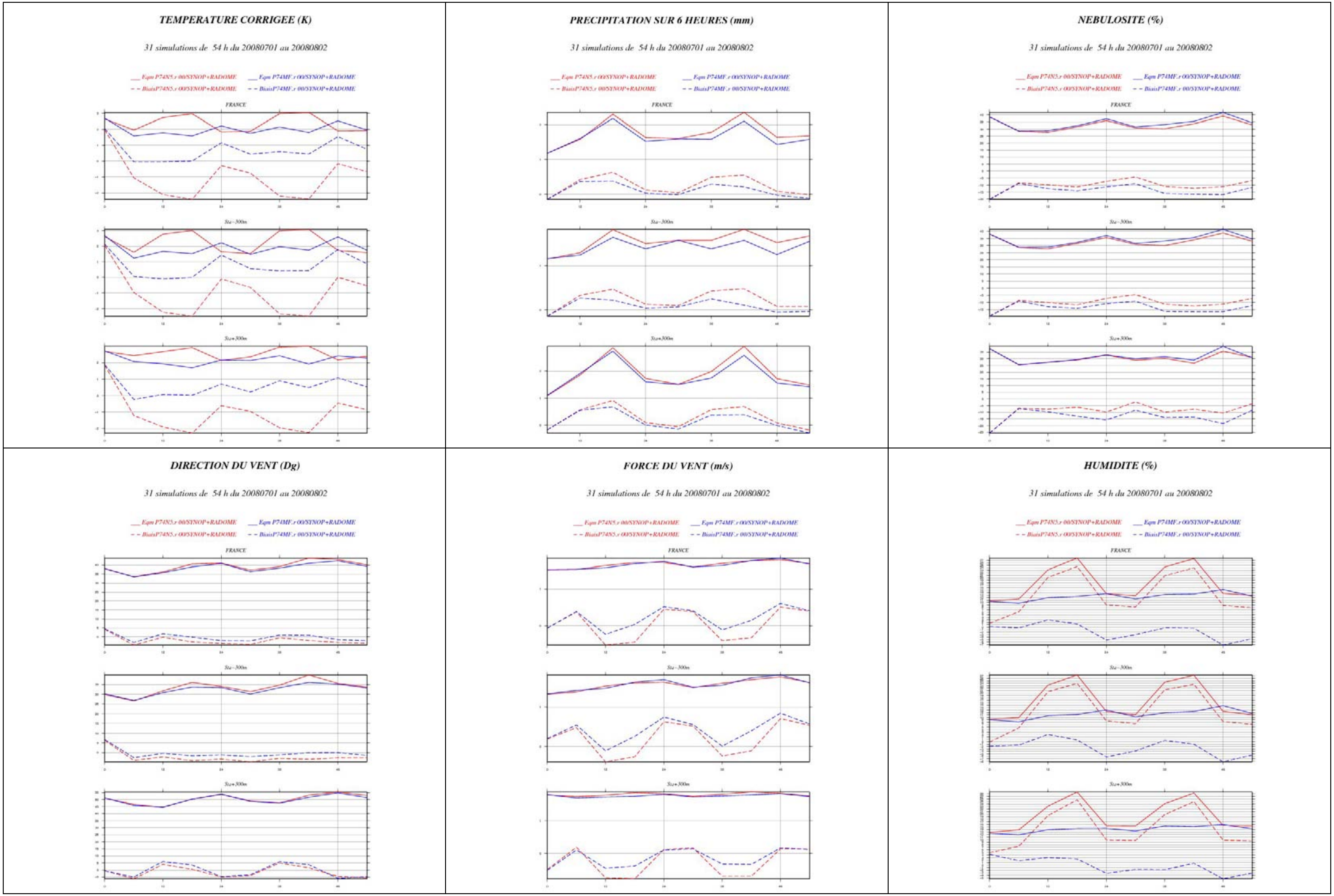


Fig.10 – 74MF (Laiscal in blue) and 74N5 (Original cprep1 in red) scores

Summer analysis:

From Fig. 6, T2m scores of the Blended solution (74N6) are slightly better than Full Aladin (74MB), mainly in the first 24 hours forecast and in the bias. This is the improvement given by IFS upper air. The Laiscal solution (74MF) improves a little bit more the H+18, H+24 and H+30 and mainly in rmse, with a small degradation in the bias at the end of the period. This is what is achieved by using IFS soil in cprep1 with Rsmin/LAI scaling and discarding completely the need of ARPEGE/ALADIN initialization.

From Fig. 7, Laiscal T2m scores are very poor at H+0. This is because Ts has a very warm bias as already stated in the previous section. If using the skin temperature (gribcode 235) this problem would probably disappear. Nevertheless, the problem disappears after a 6 hours integration. Laiscal precipitation scores are slightly better than Blended. Nebulosity and Wind scores are neutral. Humidity scores are equivalent.

From Fig.8, No_Laiscal and OI_Trick have equivalent scores for precipitation, nebulosity and Wind and OI_Trick has better T2m and Humidity scores. Since OI_Trick is also simpler to implement in the code, the choice should be OI_Trick as the alternative to Laiscal.

Fig. 9 is the direct comparison between Laiscal and OI_Trick. The Laiscal T2m scores are better in the short forecast range but there is a degradation at the end of the period. The Laiscal precipitation and humidity scores are better and for wind Laiscal scores are also slightly better.

Finally, Fig.10 is the comparison between Laiscal and the original cprep1. The Laiscal improvement is very clear. T2m rmse decreases about 1 C over cprep1 original and humidity rmse decreases about 15%. The precipitation and wind scores are also clearly better.

The results obtained during the summer of 2008, namely July, are very satisfactory. Six new experiences were done for a winter period between the 1st of February and the 1st of March, with the following labels:

Olive Label	**Description of experiment**
74NF	Full Aladin Oper
74NG	Cprep1 with Rsmin/Lai scaling (Laiscal)
74NH	Cprep1 without Rsmin/Lai scaling (No_Laiscal)
74NI	Cprep1 without Rsmin/Lai scaling (OI_Trick)
74NJ	Original Cprep1
74NK	Blended

The following figures are analogue to the previous ones and show the scores obtained during this winter period.

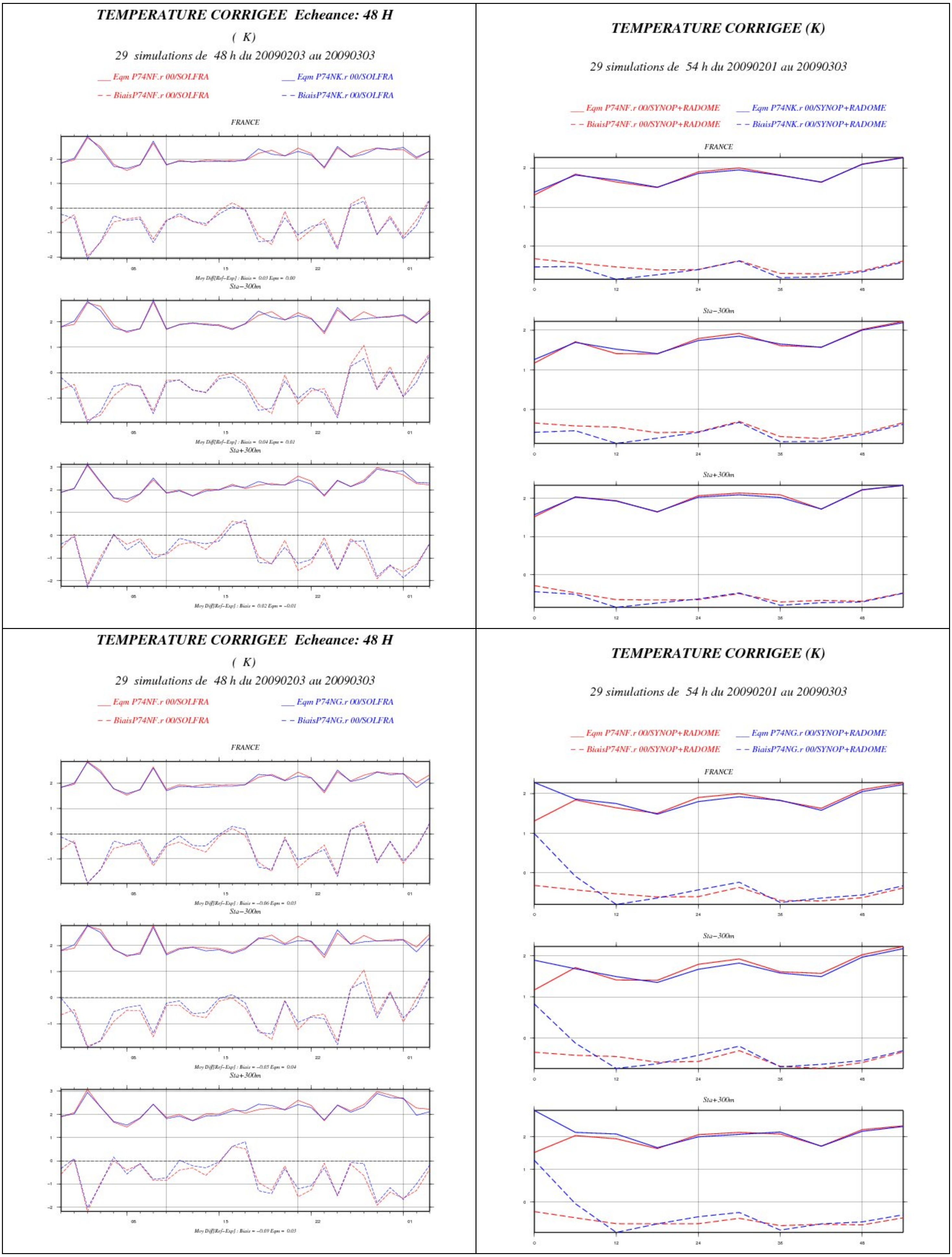


Fig.11 - T2m scores for experiences 74NF, 74NG and 74NK during winter

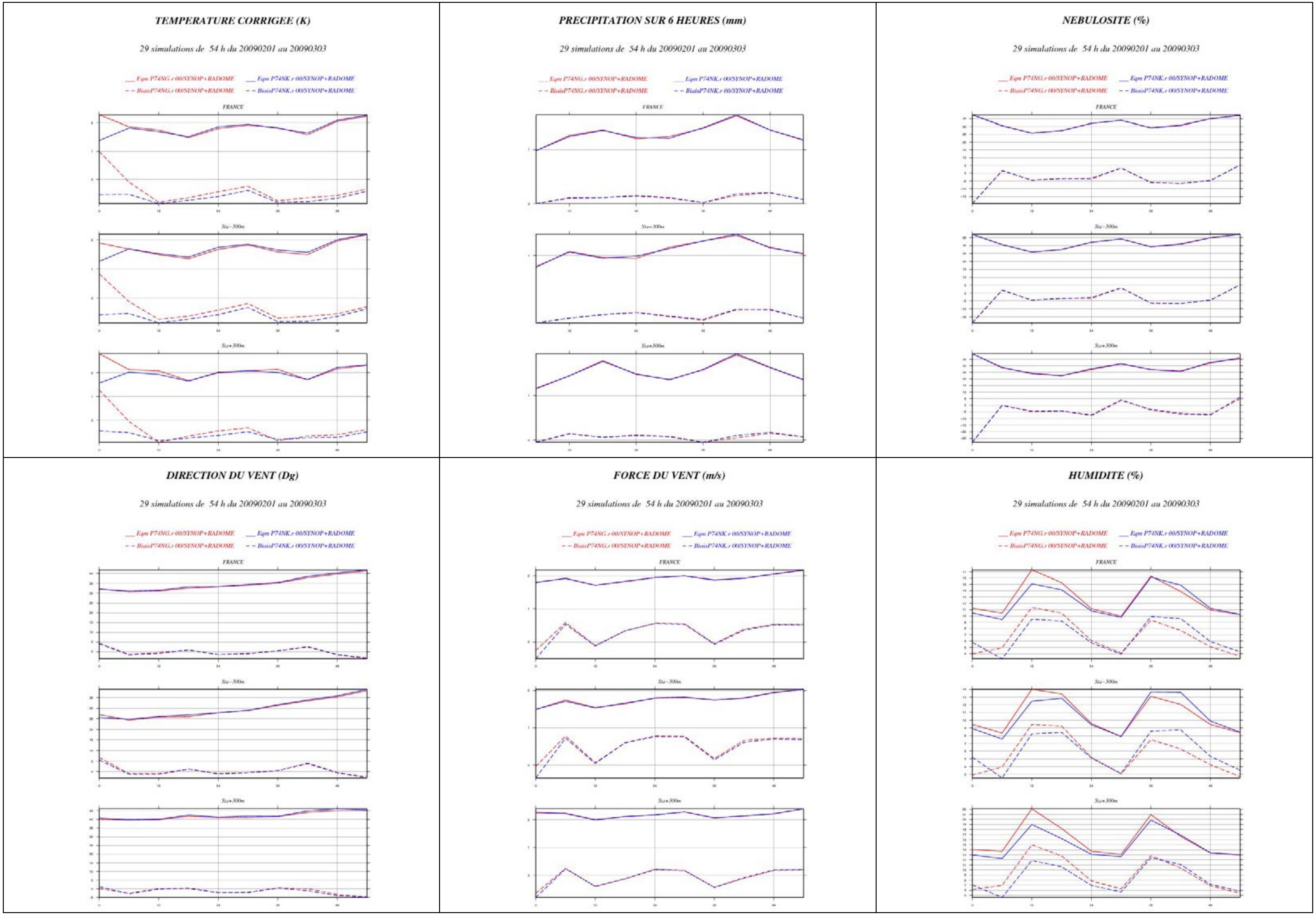


Fig.12 – 74NG (Laiscal in red) and 74NK (Blended in blue) scores for winter

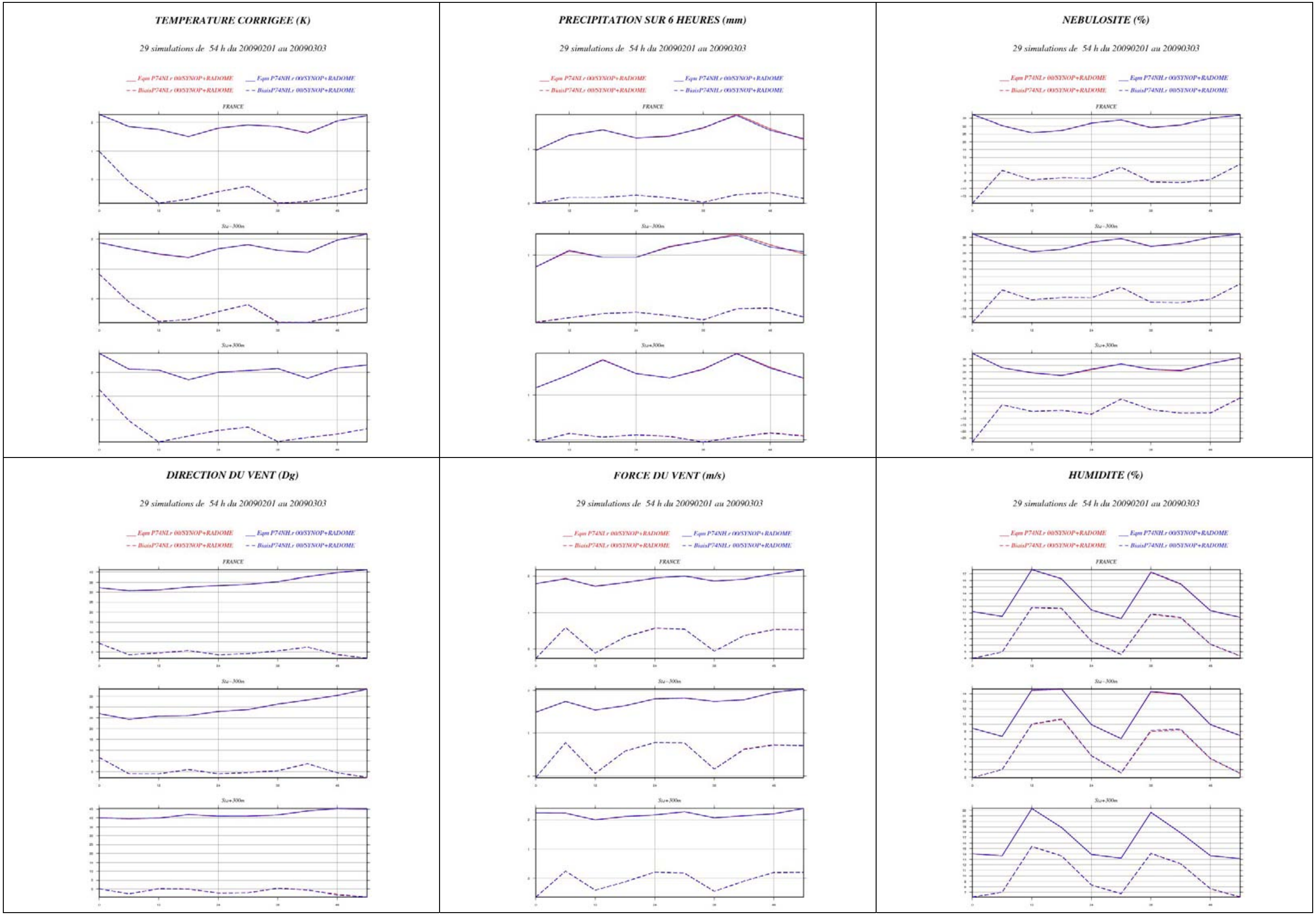


Fig.13 – 74NH (No_Laiscal in blue) and 74NI (OI_Trick in red) scores for winter

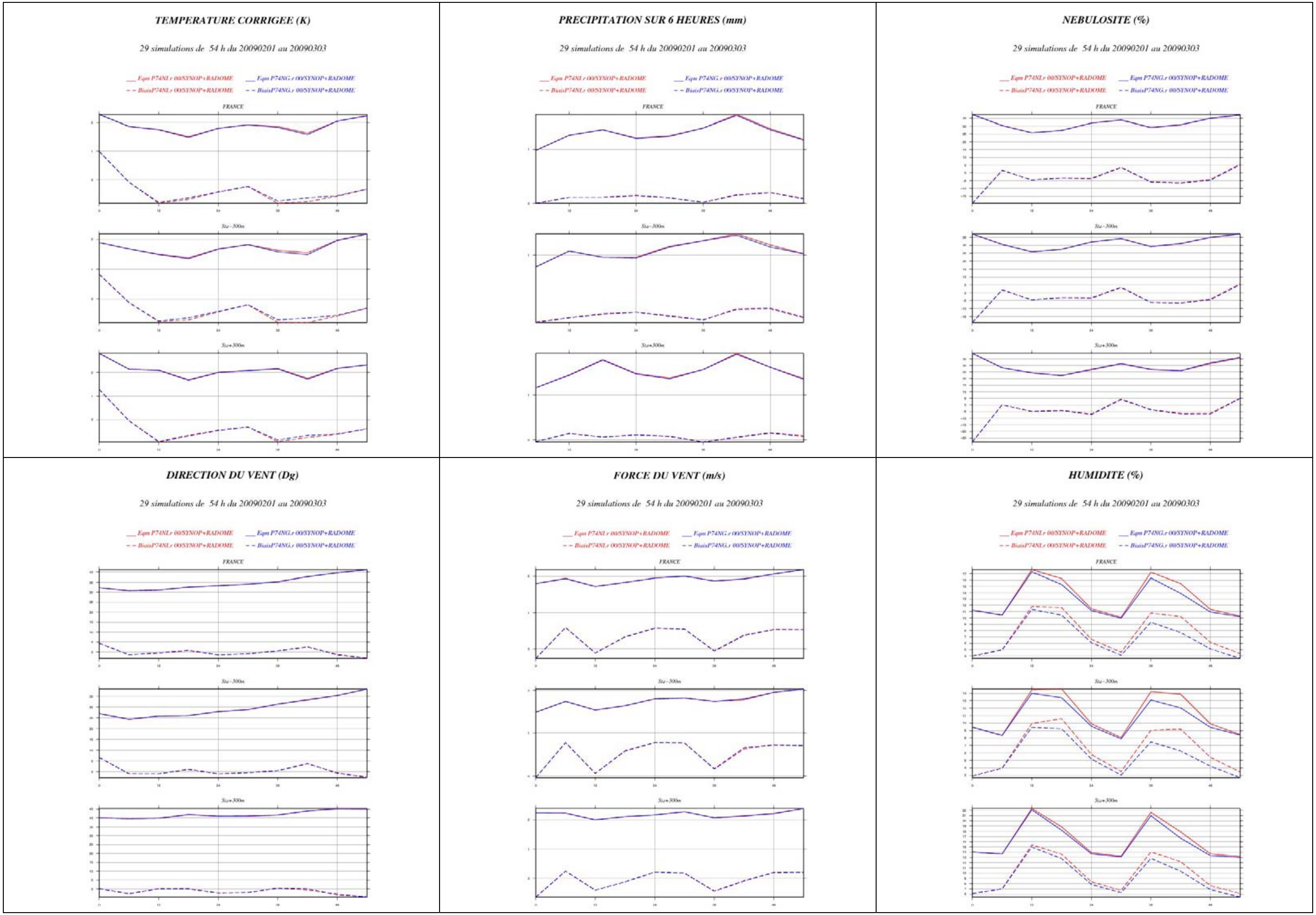


Fig.14 – 74NG (Laiscal in blue) and 74NI (OI_Trick in red) scores

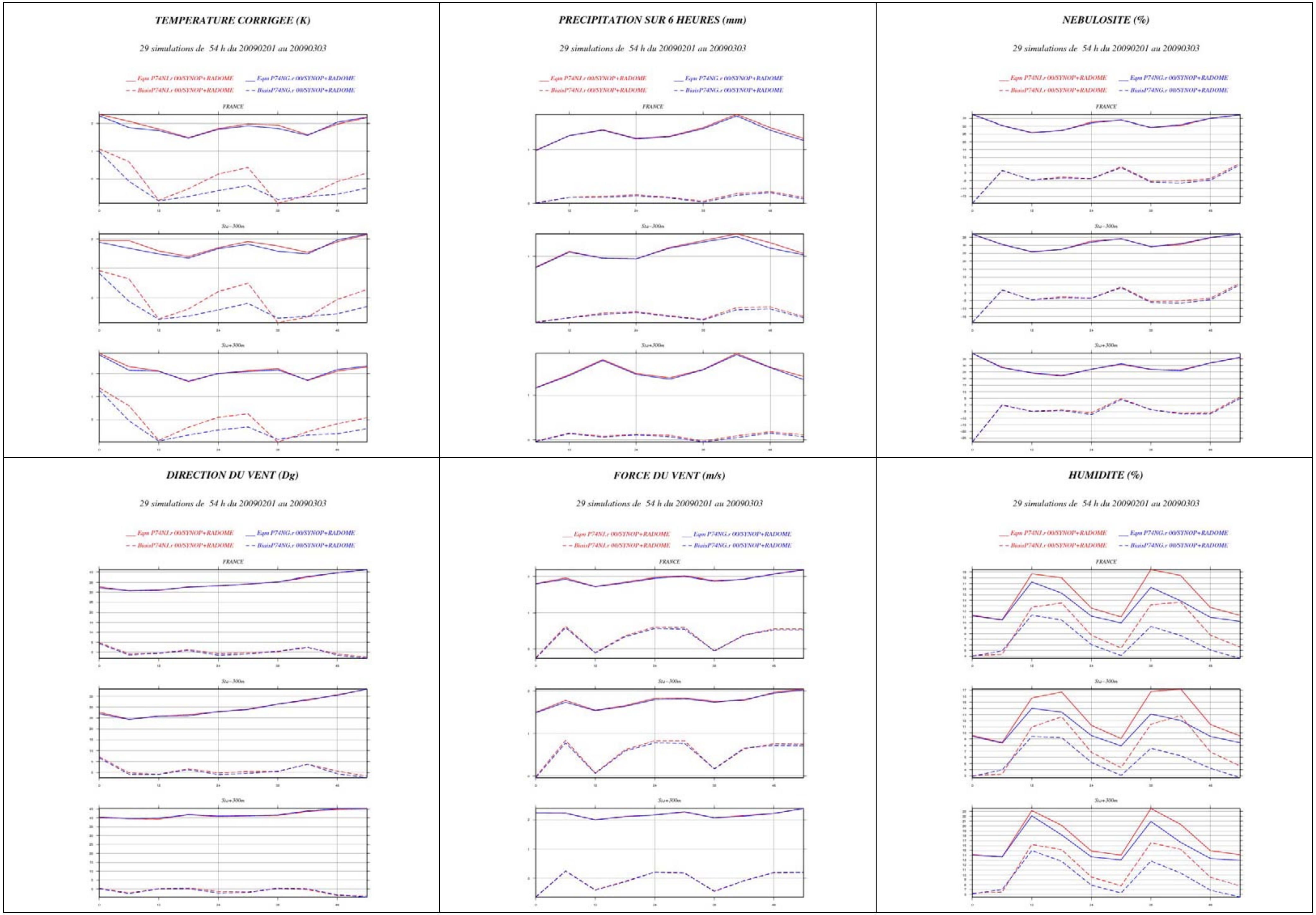


Fig.15 – 74NG (Laiscal in blue) and 74NJ (Original cprep1 in red) scores for winter

Winter analysis:

From Fig. 11, T2m scores of the Blended solution (74NK) are not better than Full Aladin (74NF). So, IFS upper air does not give any improvement over ALADIN upper air initialization. The rmse score is equivalent and the bias score is worse with the Blended solution which is the opposite of what happened in July 2008. Nevertheless, using IFS upper air and IFS surface with the Laiscal solution (74NG) it is possible to beat the Full Aladin scores. This is interesting, because in July 2008 Laiscal only improved a little bit the H+18, H+24 and H+30 forecasts and mainly in rmse, with a small degradation in the bias at the end of the period.

In Fig.12 and as expected from the last paragraph, Laiscal T2m scores are better than Blended T2m scores. The scores of other parameters are equivalent, except humidity scores which are worse with Laiscal until H+30 and afterwards they become better.

From Fig. 13, No_Laiscal and OI_trick scores are very similar. Not even in humidity we see any difference.

From Fig. 14, the difference between Laiscal and OI_Trick is only in T2m and humidity scores with a small advantage of Laiscal.

From Fig.15, the difference between Laiscal and Cprep1_original is mainly in T2m and humidity scores with Laiscal being noticeably better in humidity (both bias and rmse) but in T2m the benefit of using Laiscal is more obvious in rmse, since in bias Laiscal seems cold.

6. Final conclusions and remarks

An important improvement was achieved with the proposed cprep1 modifications, as it can be seen by the analysis of results and scores. The work reached a mature state and the cprep1 modifications can be introduced in Aladin configuration 901.

The introduction of Rsmin/LAI scaling has a strong physical argument related with evaporation and proved to have the best results even in Winter. However, one can argue that if the Laiscal equals 0.3 for example, the ISBA SWI can never be 1 which is unrealistic especially during winter when the soil is saturated. However, during Winter the evaporation is negligible and this seems not to be a problem as it was demonstrated.

However, there is the possibility of not using Rsmin/LAI scaling through namelist control.
If LLLAISCAL = .FALSE. in the namelist, then what is used is the OI_Trick solution.

7. Perspectives

1) The new initialization method should be more intensively tested for different geographical areas (polar, arid, semi-arid regions)
2) This initialization should be implemented in PREP configuration of SURFEX and an extension should be studied for different ISBA