VARPACK – A diagnostic Tool , based on the 3DVar/ALADIN surface scheme

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1. Introduction

The purpose of this work on Varpack was to study the possibility of implementation of the ALADIN/3DVar scheme for diagnostic and nowcasting purposes. Such a software would have been an analogue of Diagpack, based on the CANARI OI scheme. The first tests with the Varpack software have been performed early 2004 and a comparison with Diagpack has been done. The results have shown that Diagpack and Varpack give similar meteorological fields and there is a possibility to improve the application of the ALADIN 3D-Var scheme as a diagnostic tool (Auger, 2004; Taseva and Auger 2004). During the Summer of 2004, the ALADIN/3Dvar scheme has been modified by introducing the difference (T_s – T_N) where N is the lowest model-level, as a new control variable (Auger 2004b). The tests with Varpack performed late 2004 have shown that there is a significant advantage of the new Varpack with respect to the old one (Taseva and.Auger 2004b).

In Section I the results of the comparison between Diagpack and Varpack are presented, while the results of the experiments with Varpack are presented in Section II.

2. Section I – Basic features of Diagpack and Varpack

2.1. Diagpack

With Diagpack an operational hourly CANARI OI analysis is performed with:

- a first guess field from ALADIN forecasts (from 3 to 8 h ones)
- surface data, obtained from manual and automatic land and ship SYNOP stations.

When running Diagpack, some constrains are applied:

- only the stations below the altitude of 1500 m are used in the analysis;
- the stations, for which the difference between the model orography and the altitude at the observation point is bigger than 800 m, are not assimilated.

The observation operators allow performing an upper-air analysis of geopotential, temperature and humidity at the model levels up to approx. 1500m only with SYNOP observations and a direct analysis of T2m, RH2m, V10m. Those fields together with the diagnostic parameters CAPE and MOCON, computed by specific post-processing options, are used afterwards for nowcasting purposes (CAPE computed from analysed 2m fields, mainly NFCAPE=4, MOCON calculated as div($q_{2m}V_{10m}$).

2.2. Varpack (2004)

We used all the SYNOP data that passed through ALADIN screening to perform temperature, wind and specific humidity analysis on model levels only.

Three different modifications of the basic 3DVarc onfiguration scheme were tested :

- The value of the model standard deviation error (i.e. The scaling factor REDNMC) has been increased to better fit observations, this version is referred as Varpack/bas3D.
- Another modification on top of bas3D has been included, with the artificial update of the surface temperature Ts according to the temperature at the lowest model level 41 approx. 17 m) at each step of the minimization. This modification has been done to

enable more meaningful physical to fit to the 2m temperature through the observation operator (version referred as Varpack/mod3D);

- In addition mod3D has been modified, giving bigger values of the model error variances in the PBL (planetary boundary layer) and keeping the initial ones on the upper levels (REDNMC = 7, 7, 5, 3, 1, …1) (version referred as Varpack/sod3D).

2.3. Validation tests

The comparison between the Diagpack and the Varpack focussed on:

- the meteorological fields (T, RH, wind on the last model levels)
- the distribution of the derived parameters CAPE and MOCON, used for nowcasting purposes, after post processing on the FRAN X 01 domain.

The validation tests described in Taseva and Auger (2004) have been done for two cases: on the 09/10/2001 at 10h UTC; 09/10/2001 at 15h UTC and on the 18/08/2001 at 00h UTC; 18/08/2001 at15h UTC, with a run every hour over the ALADIN/FRANCE domain.

Radar echoes for that situation and results of the experiment at 14H00 are presented in Fig.1, Fig.2 and Fig.3.

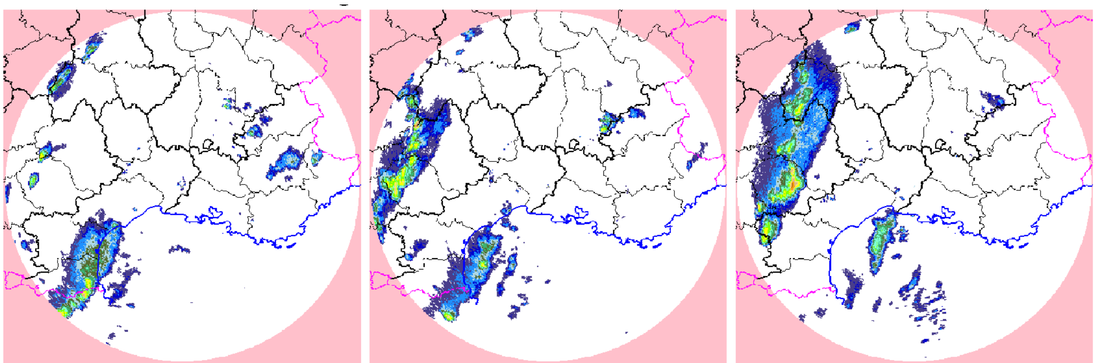

Fig. 1 Radar images for the 18/08/2001, 16H00,17H00,18H00

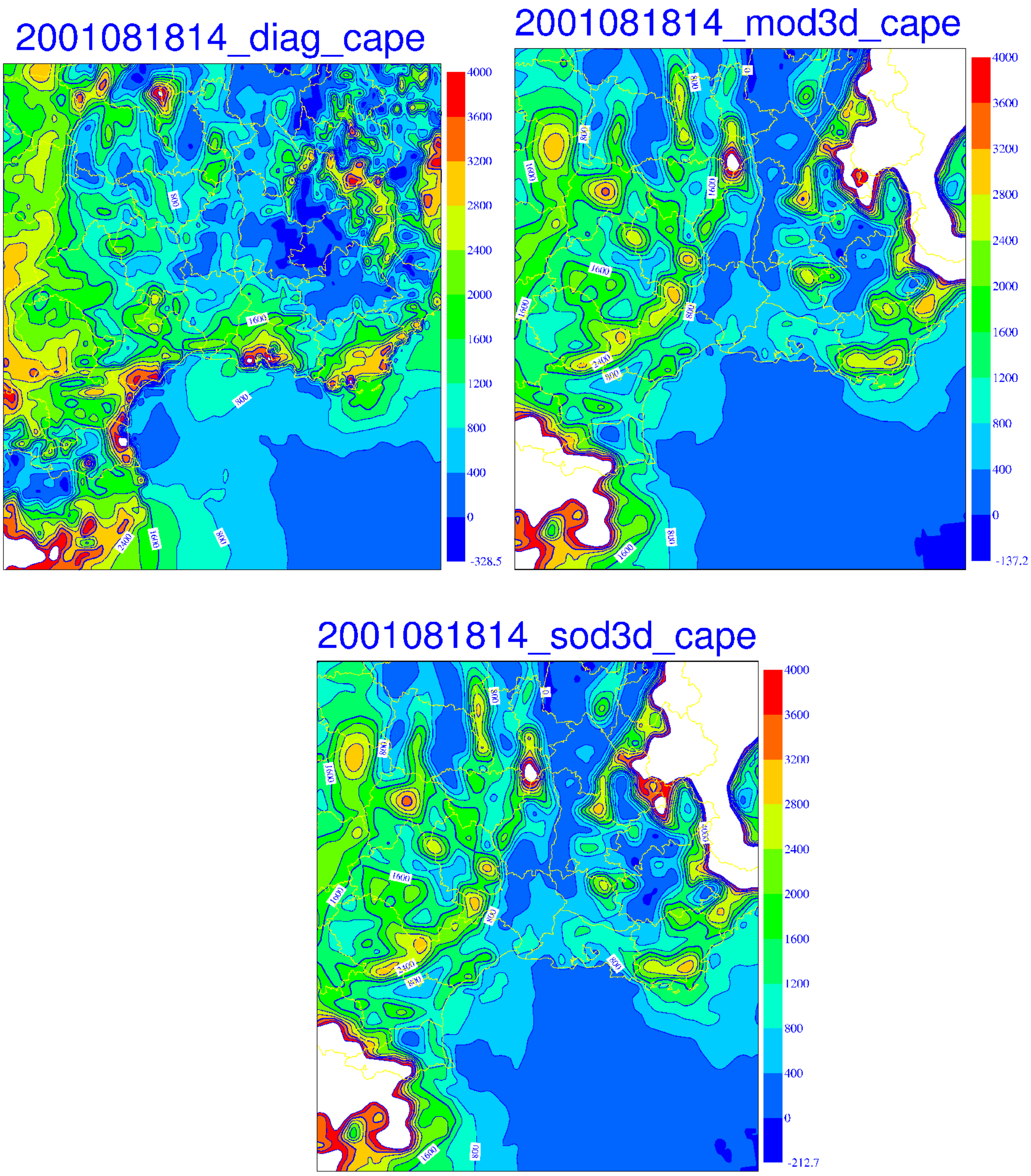

Fig. 2 : Cape for Diagpack (top left), Varpack experiment mod3d (top right) and Varpack experiment sod3d (bottom) for the 18/08/2001 at 14H00.

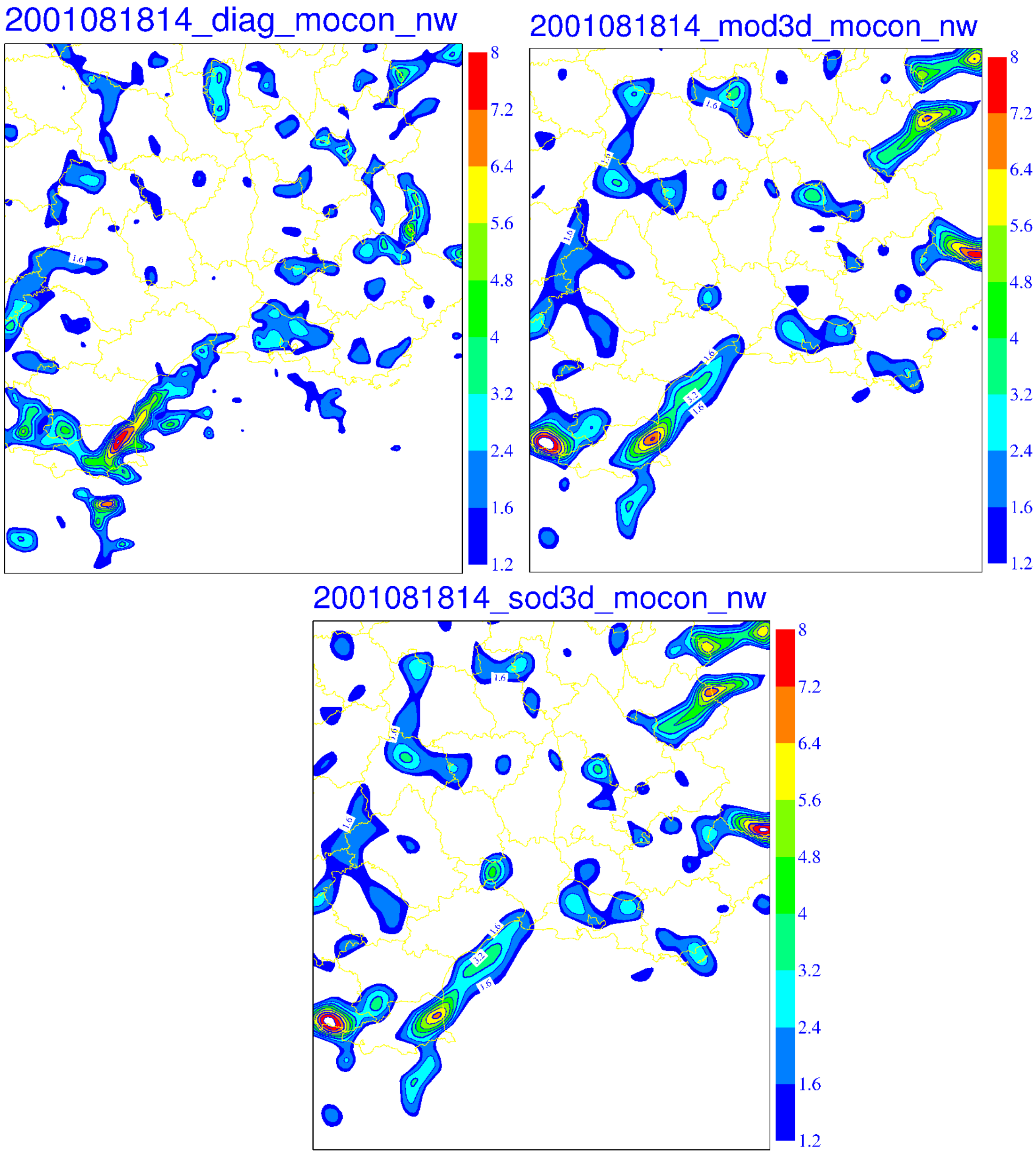

Fig. 3 : MOCON for Diagpack (top left), Varpack experiment mod3d (top right) and Varpack experiment sod3d (bottom) for the 18/08/2001at 14H00.

It can be seen that:

- MOCON fields derived from Varpack, are very similar to those derived from Diagpack, but smoother;
- CAPE fields derived from Diagpack and Varpack are quite different, both giving on that case, a quite poor diagnostic for future convective events.

3. Section II – Experiments with Varpack

During the summer of 2004, the ALADIN 3D-Var surface scheme has been modified by introducing the vertical temperature difference between surface and the lowest model-level ($T_s - T_N$) at the observation point as a new control variable in the vector. This modification, made by L. Auger has been validated by comparison with Diagpack and the previous version of Varpack .

3.1. Basic ideas of the new 3D-VAR/ALADIN surface scheme - surface temperature in the control variable.

In the 3D-VAR formalism, the goal is to minimize a coast function:

$$J = J_b + J_o = \frac{1}{2} \delta x^t B^{-1} \delta x + \frac{1}{2} (H \delta x - d)^t R^{-1} (H \delta x - d)$$

Where: $d = y - H(x^b)$ is the departure between the observation vector y and the model equivalent computed from the background x^b and δx is the control variable.

The goal of the algorithm is to minimize the J cost function with respect to δx .

So far in ALADIN 3D-VAR only upper-air fields were used inside the control variable.

But, when analysing 2 meters observations, one needs to be able to modify during the minimization cycle also the surface variables, because the observation operator H is using surface parameters to compute the model equivalent at 2 meters or 10 meters.

Let's call T_S the surface temperature departure (actual temperature minus background temperature) and T_N the lowest level temperature departure.

The difference $T_S - T_N$ was introduced as a new control variable. To this new control variable was associated a forecast error standard deviation $\sigma_{T_S - T_N}$ representing the error made by model on this parameter. So the new model error cost function reads:

$$J_b = \frac{1}{2} \delta x^t B^{-1} \delta x + (T_S - T_N)^t \sigma_{T_S - T_N}^{-2} (T_S - T_N)$$

Introducing $T_S - T_N$ as a control variable, provides a correlation between the surface and the lowest level temperature without having to modify the B matrix structure (model forecast covariances error). The main problem when using a B matrix which would include surface parameters is that in ALADIN, upper-air fields are specified in spectral space whereas surface fields are specified as gridpoint ones. It also seems difficult to compute a reliable B matrix near the ground because the model forecast error inside the boundary layer might be quite important.

More details are given in Auger (2004b).

Only this new version will be considered hereafter.

3.2. Results of the experiments for the case study 2004/10/09

That case has been chosen because the CAPE obtained by Diagpack at 12H00 indicated a potential for a storm, that developed in the following hours.

To create a reference run, the new ALADIN/3D-VAR surface scheme has been modified to be consistent with the settings of Diagpack :

- the data base included only the observations within the 10 minutes interval around the observation time,
- the old blacklist was modified by excluding the French RADOME observations from it,
- smaller values of the observation errors were set,
- the operational 6-hour ALADIN forecast was taken as first guess,
- the ALADIN/3D-VAR surface scheme was modified with a complete de-correlation of the temperature and humidity, and a new executable had been created,
- in screening and minimization the default values of RGBQC were taken,
- in minimization with LTSCV=. T. (LTSCV is the new logical flag for activating the Ts control variable) the value TSCVER=0.5 was used,
- in minimization model error covariances were inversed in PBL;
- in forecast no DFI were applied,
- in FullPos CAPE was computed from the lowest model-level (NFPCAPE=1) or from meteorological standard height after the computation (NFPCAPE=3).

The analysis of the diagnostic JOT tables before screening, before and after minimization have shown that :

- screening had rejected mainly U10 observations for all subtypes of SYNOP data (11-land manual report, 14-land automatic report, 15-French automatic land report, 16-French RADOME);
- the result of the minimization is a state, close to the observations – the values of the normalized JO/n have decreased an order of magnitude for all SYNOP subtypes and all variables.

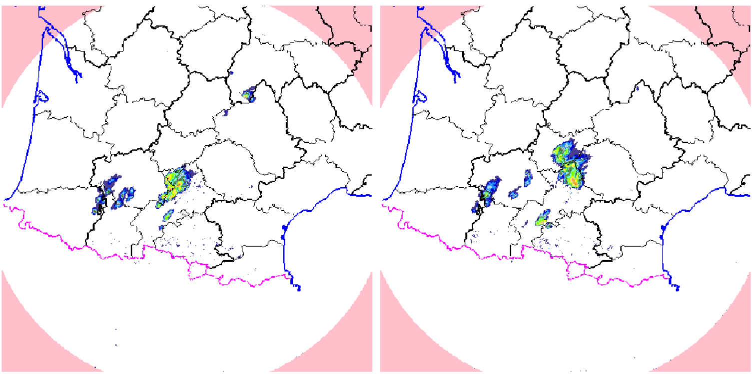

Fig.4 : Radar data for 20041009, 16H00 and 17H00.

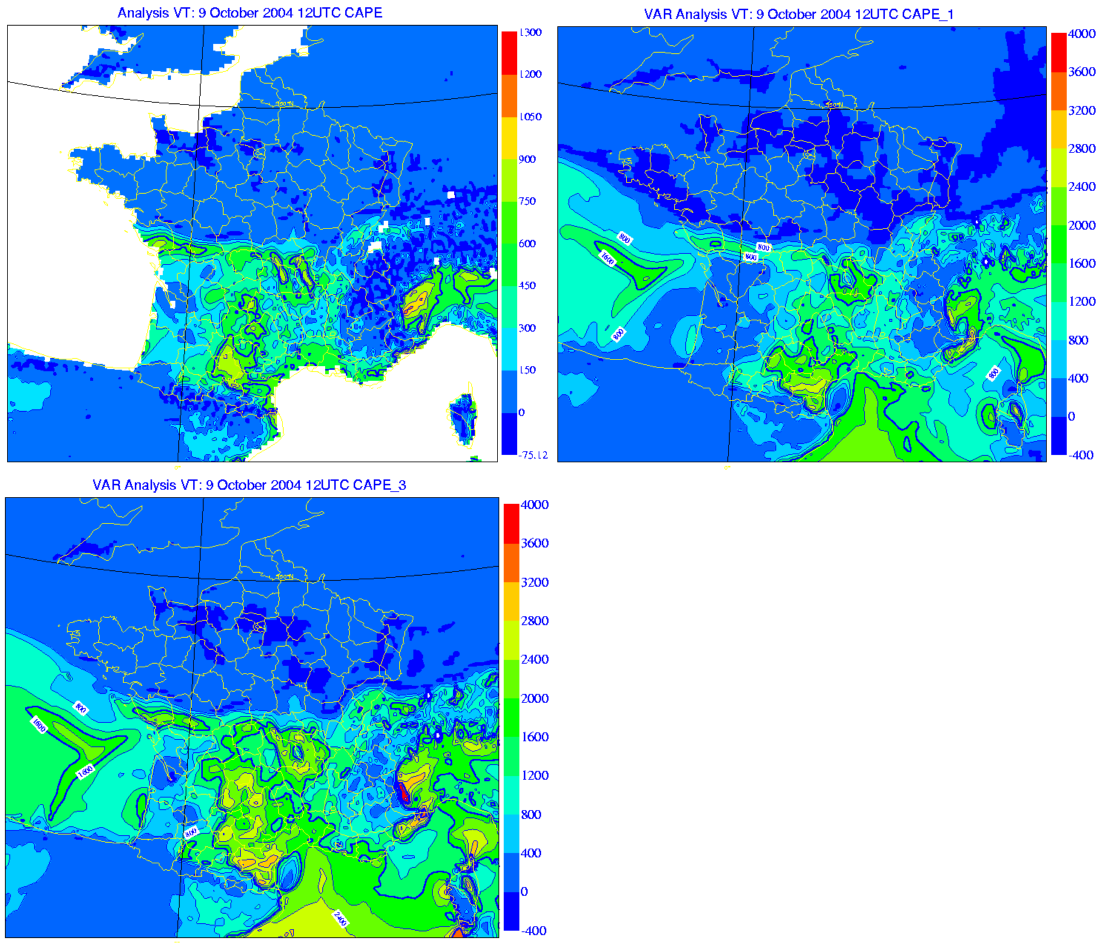

Fig. 5 : Time evolution of CAPE, derived by Diagpack (top left), new Varpack with NFPCAPE=1 (top right) and with NFPCAPE=3 (bottom)

On radar images (Fig. 4) we can see that a strong convective event starts at 16H00 UTC on the South-West part of the domain. On the CAPE diagnostic from Diagpack (Figure 5), we have a strong signal at 12H00 at the same location, proving the convective capacity of the atmosphere at that place, leading to the development of the storm a few hours later.

On Figure 5 (top right and bottom panel), the Varpack diagnostic is not so good, it shows more maxima at some places where no rain event was observed later.

We can also observe that the CAPE computation with NFPCAPE=1 and NFPCAPE=3 gives somehow different CAPE fields, although there is a lot of common pattern between the two pictures.

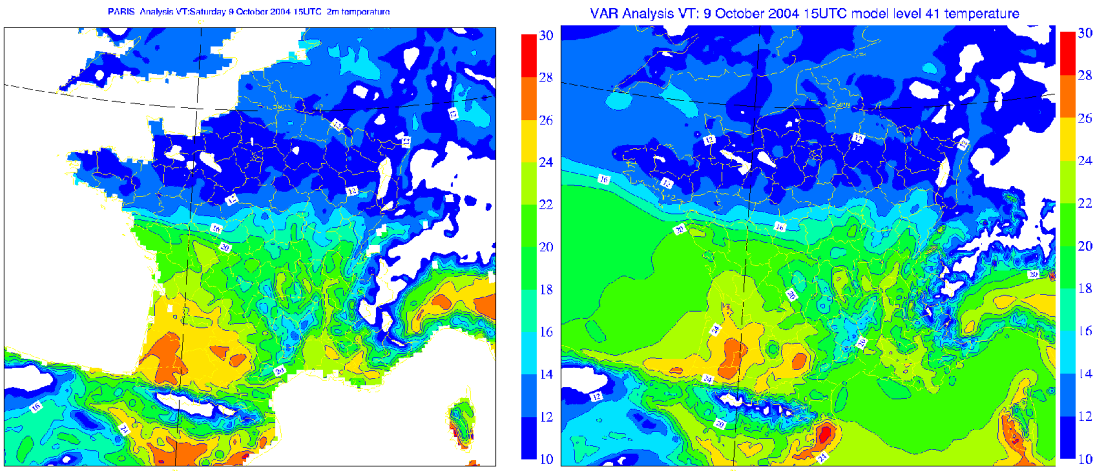

Fig.6 : 2m temperature analysis by Diagpack (left) and temperature at the last model level for Varpack.

Figure 6 presents the 2m temperature field, obtained by Diagpack, and the one (at the lowest model level (41), obtained by Varpack at 12H00. It can be seen that there is a good agreement between the two temperature fields even if level 41 corresponds approx. to 17 m height. For that day the boundary layer is quite well mixed so temperature at 17m is not much different from temperature at the ground.

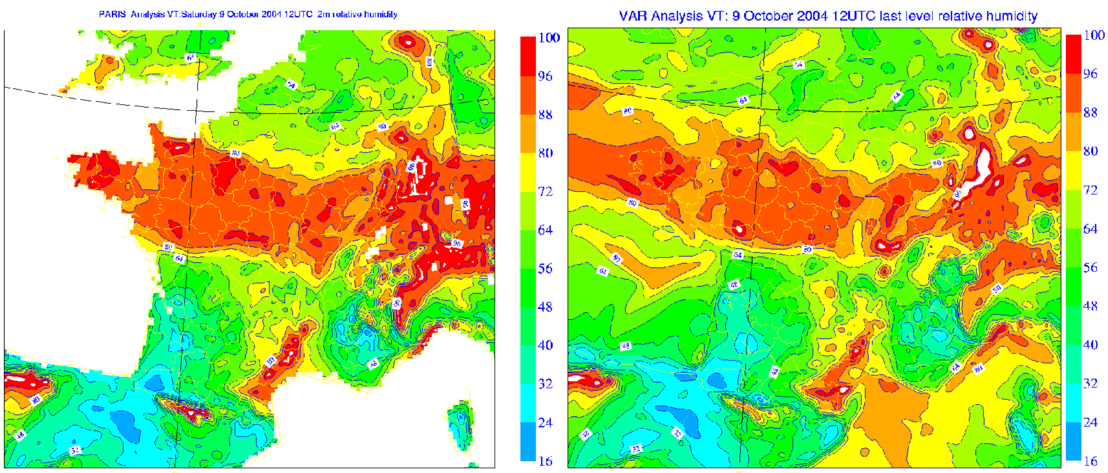

Fig. 7 : Relative humidity at 2m for Diagpack (left panel), relative humidity at the lowest model level, recomputed from temperature and specific humidity, with correction from MSL pressure, obtained by Varpack (2004b) (right panel).

The humidity fields from Diagpack and Varpack (Figure 7) are also very similar, except for mountainous areas.

It is seen that:

- there are small differences for temperature and relative humidity for most part of the domain.

- these minute differences explain the differences between the CAPE fields obtained by Diagpack and Varpack, mainly because CAPE is very sensitive to the temperature and humidity at the starting point in the integral computation.

The comparison with the observed values of 2m relative humidity (Hu 2m)have shown that when there are no observations in an area with a characteristic size of 50 km, Diagpack is giving much importance to the guess and produces a poor diagnostic of Hu 2m, whereas for such cases, the Varpack analysis gives a relative humidity field that seems to be in better agreement with reality.

3.3. Impact of the observations for altitude stations.

On the specific case shown before, the CAPE diagnostic from Diagpack enabled a good forecast of the storm that develops at 16H00 UTC.

Looking more carefully at the temperature and humidity analysis provided by Varpack, we saw that one station at 600 m gave a quite different increment analysis for T2m and Hu2m on the South-East part of the domain.

This is because there is no horizontal correlation between our control variables ($Ts-T_N$) at different observation points. As a matter of fact, unplugging the modification of the control variable in that specific case gave a CAPE diagnostic that is much closer than the Diagpack CAPE (Fig.8).

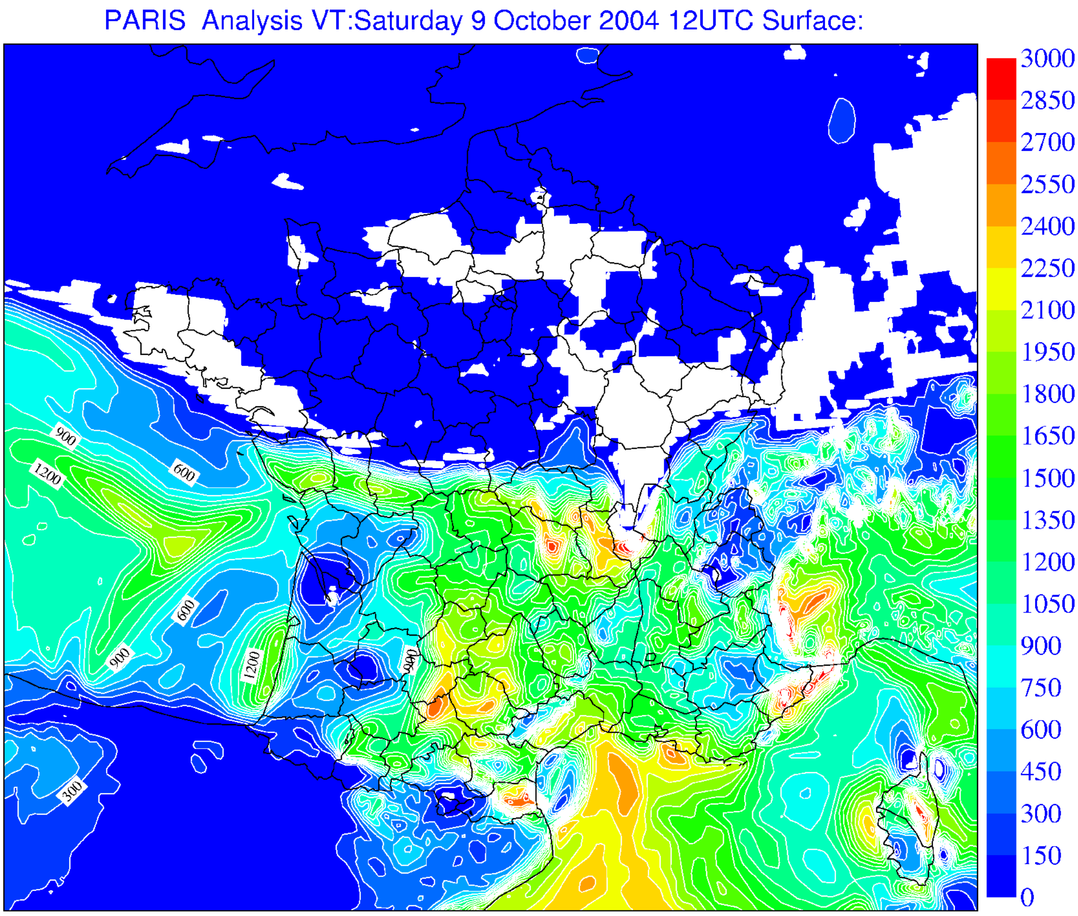

Fig.8 : CAPE diagnostic from Varpack, for the 09/10/2004 at 12H00, without the modification concerning the control variable.

4. Section III. Conclusions and intents for the future work

The main conclusions, reached on the basis of the performed experiments in Section I and Section II are as follow:

- there is a significant advantage of the new Varpack version with respect to the previous one (Auger 2004). Besides, the results are scientifically more satisfying due to the new control variable ($T_s - T_N$),
- The temperature fields obtained by Diagpack and Varpack are similar,
- the humidity fields obtained by Diagpack and Varpack are a little different. For most of the cases we looked at, the ALADIN/3D-VAR humidity analysis seemed at least as good as Diagpack one, in comparison with the 2 m observations,
- the CAPE fields derived from Diagpack and Varpack are still different, mostly because some altitude observations have a different impact But as the CAPE field is used for convective activity diagnostic and is not 100% reliable, it is difficult to evaluate its quality on a few cases,
- MOCON fields derived from Diagpack and Varpack are close.

The further study of Varpack analysis requires

- to study more the Varpack humidity analysis,
- to study the possibility of using new observation types,
- to correct the problem linked with altitude station impacts.

5. Acknowledgements

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6. References

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CONTENTS