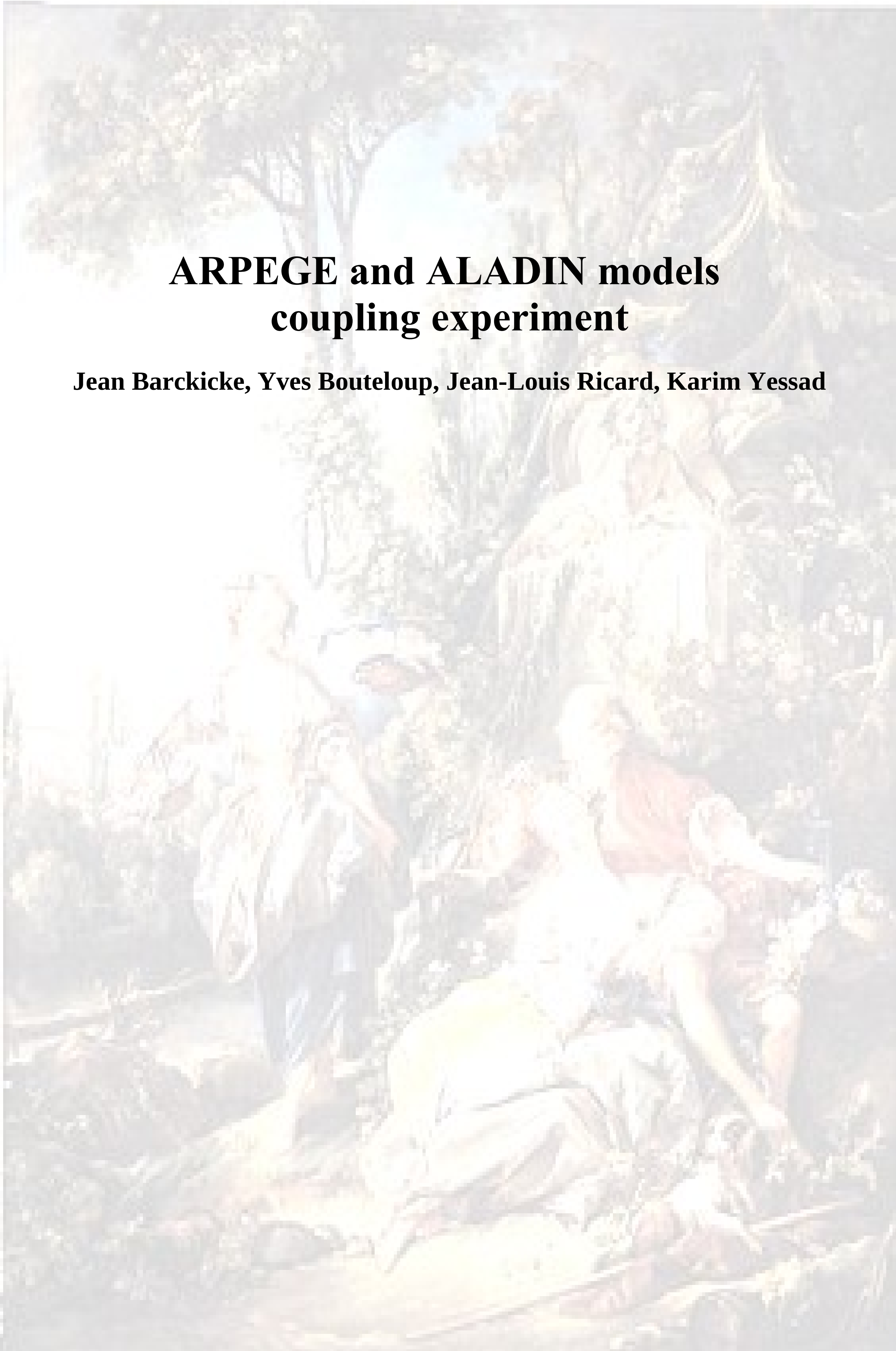

ARPEGE and ALADIN models coupling experiment

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1. Abstract

A two-way coupling experiment between the operational models has been carried out. By using the existing software, the independence between the models is kept, and they are coupled through a full-duplex transfer of data. The comparison between the experiment and the operational ones shows an important noise due to the method. Reference uncoupled experiments which take into account this noise have then been done. With respect to these references, the impact of the coupling is strong and spreads far beyond the small scale model domain. The coupling experiment has been run on two winter and one summer situations. The objective scores are neutral for the winter situations. For the summer situation, we note a small degradation of the global scores, and a clear degradation of the scores over the domain of the small scale model. It is worth continuing the coupling experiment by improving the coupling technique and by using a better small scale model.

2. Introduction

Météo-France uses a stretched global model and a limited-area model in order to obtain better results over its interest domain. But the results supplied by this method at small-scale are not as good as expected. Some improvements could occur by resolving the complicated problems due to the stretched grid. Another way is to use the information given by the small scale model in the global model. Our attempt will consist in simulating the grid-nesting technique, under the constraint to run experiments at an equivalent cost to the one of the current operational models.

Two kinds of improvements are expected. For the small-scale model, we hope that the fact to periodically inject its own data into the global-scale model will allow to especially improve the trajectory of the coupling area, and then to improve the boundary conditions which force the small-scale model. These boundary conditions would be closer to the small-scale model state, and by taking into account its characteristics, would allow a more soft evolution of this model. For the global-scale model, improvement are expected over the coupling area, but they could be transported beyond, improving more globally the large-scale results.

Part II describes the technique used, part III explains the tests over a first situation and part IV shows the experiments and the results. Part V gives the final interpretations and the perspectives.

3. The coupling method and the technical background

3.1 General principles

An ARPEGE forecast supplies results (historical files) and coupling files (called hereafter forcing files) every 3 hours. The ALADIN forecast uses these forcing files as initial and coupling files with a 3 hours interval. Once the ALADIN forecast done, an information which takes into account the small scale is available, and we wish to inject it into the state of the large-scale model before it runs toward the next steps. For example, the exchanges within the 6 h and 9 h forecast ranges are described in Figure 1.

The "bogussing" term used for the Full-Pos process which replaces, in a historical ARPEGE file, the ARPEGE data by ALADIN data, over the ALADIN domain. The historical ARPEGE file first is put in grid points. The difference between the ALADIN and ARPEGE historical files supplies increments which take into account the ALADIN contribution. These increments are interpolated over the ARPEGE grid-points and added to the data of the ARPEGE grid-point file built before. The ARPEGE file is put in spectral. This process is repeated every 3 hours in order to periodically refresh the ARPEGE state over the area where ALADIN data are available.

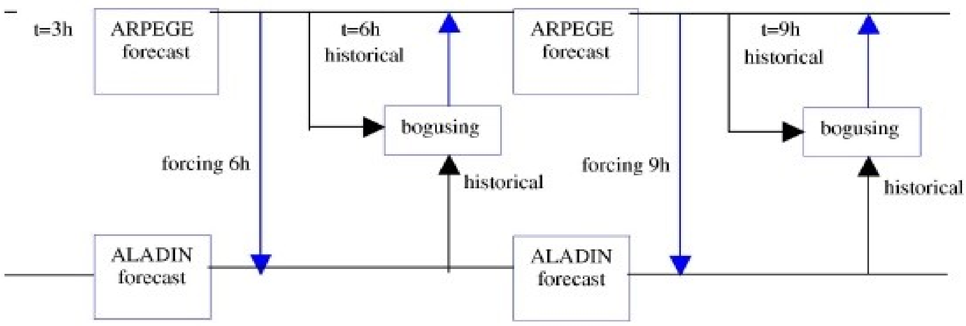

Figure 1 : bogussing procedure

3.2 The technical frame

This experiment consist in scheduling a lot of elementary tasks, work for which OLIVE is particularly adapted. After some modifications of the OLIVE software, updating and integration under OLIVE of the bogussing scripts, the tools were available. A new OLIVE configuration was created : bogussing.

4. <u>Coupling test for a first situation</u>

Three dates were selected for the experiments: 3d December 2003 (situation of winter blocking with a minimum centered over Spain), 13th January 2004 (winter situation with a westerly disturbed flow) and 6th August 2003 (extremely hot summer over France). Each forecast is run until 48 h with bogussing every 3 hours.

4.1 Coupling impact and comparison with the operational.

We worked on the first situation, and studied the results focussing on the following fields particularly: 200 hPa geopotential, 500 hPa geopotential, mean-sea-level pressure, 850 hPa temperature and humidity.

For about all fields, the comparison to the operational outputs shows very "noisy" fields, everywhere around the earth. Compared to the operational analysis, scores giving neither clear improvement or degradation (only some biases are clearly degraded) are obtained. More precisely, the "noise" presented the form of many well identified structures, but these structures were linked neither to physical phenomena nor to ALADIN domain properties. The noisy shapes and the degradation of biases warned us about a unphysical behavior of our system. The next experiments were carried out to understand the origin of the problem and to solve it.

4.2 Test of restart absence and of the bogussing technique.

We try to quantify the noise due to the method itself. The sources of noise are the restart of the model from an historical ARPEGE file instead of a restart file, and the modification of the historical ARPEGE file by the bogussing technique.

It was easy to build two degraded configurations of the experiment under OLIVE. The first one only consists in restarting ARPEGE every 3 hours from the historical instead of the restart file (ALADIN is not used). Like that, the first source of noise is tested. The second one consists in doing the bogussing, but with the ALADIN forcing file instead of the ALADIN historical file as input. This version is a "go and back bogussing". It allows to test the impact of the absence of restart file and of the bogussing (but not the impact of the small-scale data).

By using the first degraded configuration, we obtained about a half of the so-called noisy structures, as they were visible on the maps discussed above in II.A. In that case, let us recall that the model restarts with information over one time-step only, and starts its run with a SL2TL scheme (equality of the values at t-dt and t) instead of the two-steps scheme used with a restart file or during a run (no stop).

By using the second degraded configuration, we obtain the previously unexpected structures (the same as in discussed in II.A), but only the ones that were not supplied by the first degraded configuration. So the "mechanic" of the bogussing (spectral transforms and interpolations) produces the second half of the so-called noisy structures obtained in our coupling experiment. Only the structures present over or close to the ALADIN domain were not produced by the degraded configuration.

In conclusion we decided to test the impact of the ALADIN data on the ARPEGE/ALADIN system by using a reference experiment. This reference is obtained by using the ALADIN forcing file (that contains ARPEGE data) as input of the bogussing instead of the ALADIN historical file. Like that the only difference between the reference and the coupling experiment will stand in the "physical" ALADIN contribution.

5. <u>Coupling results</u>

5.1 Experiment of the 3 December 2003 with winter blocking.

The first experiment, explained in III, is here compared to its reference.

- All structures that were not explained by a contribution of the small-scale model have disappeared. The impact starts always over the ALADIN domain, then spreads outside with time, depending on the flow.
- Transport and amplification of a departure to the reference (called "increment" hereafter) by the flow turning around the minimum centered over Spain. For the geopotential at 200 hPa, the increment is clear at 24 h (reaching 16 m) and centered over an area spreading from the Bay of Biscay to the Britain. At 42 h, it is centered over 20°W /40°N, still out of the ALADIN domain. At 48 h, it is 5° more towards the west. A second maximum of increment upstream the wind approaches Corogne. The one which appears over Persic gulf increases at 48 h (reaching 12 m) and fills the thalweg located over the north of Red Sea. Figure 2 shows this field at 500 hPa level where the rotation around the minimum is less clear, but the impact also strong.
- A negative increment goes northward upstream the flow and reaches at 48 h North America. It comes in phase with the thalweg located between USA and Greenland and digs it.
- These structures are present at 500 hPa. For the mean-sea-level pressure, a structure which fills by 3 hPa the low-pressure system centered over the Portugal is associated.
- The humidity is increased by 32 % in the perturbation located over Spain at 48 h.
- The impact of the small-scale data is clear, spreading outside the coupling area as expected. Moreover, it is remarkable that the impact goes upstream the wind too.

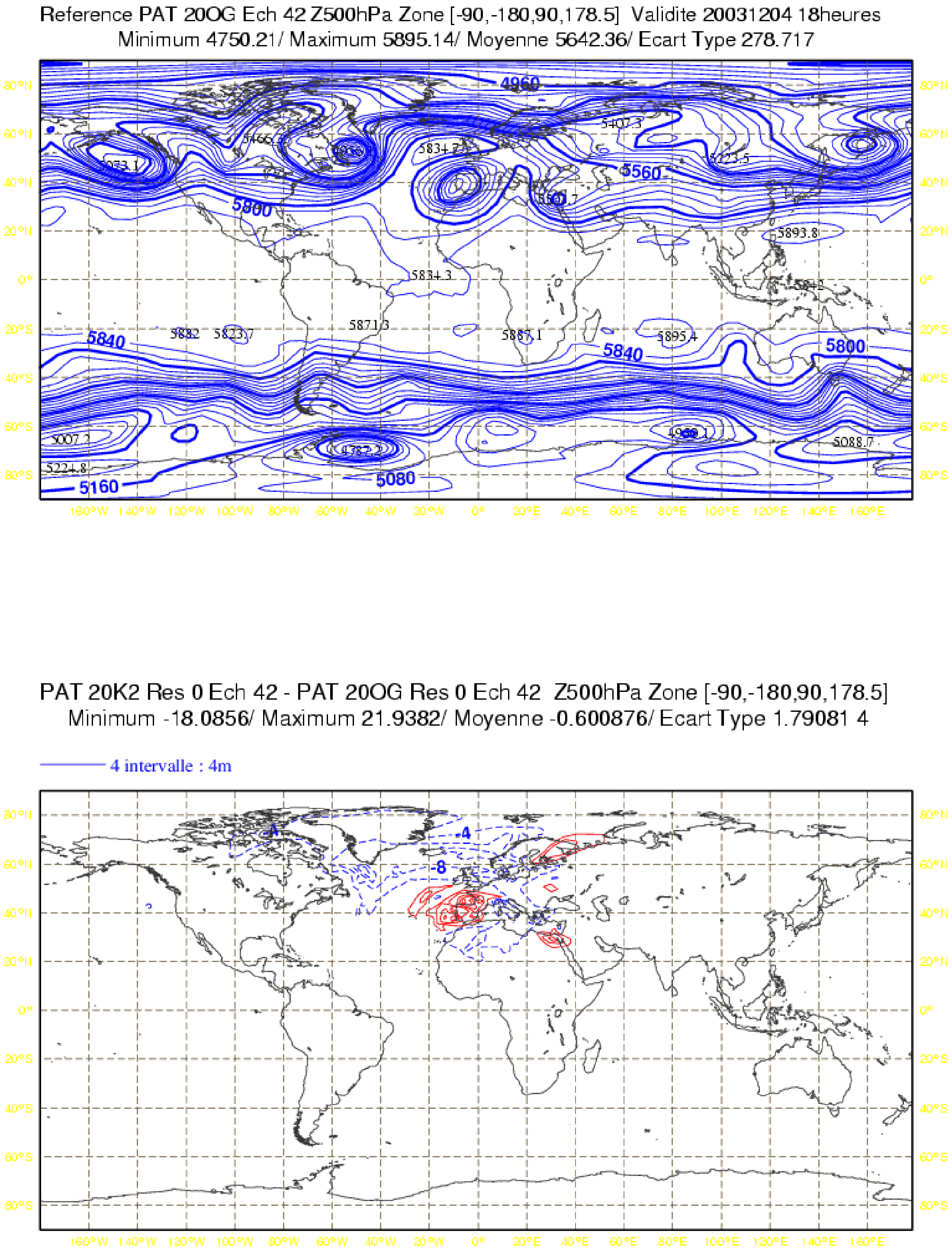

Figure 2 : Impact of the coupling by comparison to the reference experiment for the geopotential at 500 hPa at 42 h (Z500, the 20031203+42h).

Global scores have been computed by comparison to the operational analysis. Biases of the experiment are slightly worse than the reference ones, but nothing significant was found for the standard deviations. The same scores have been computed over the ALADIN domain, from the rather coarse EURAT5 grid. In both cases, no significant contribution due to the small scale data on the scores of the global model has been noted.

5.2 Situation of the 13 January 2004 with rapid westerly flow.

Here too the experiment is compared to its reference.

- The impact always starts over the coupling area, then spreads following the flow, but only downstream.
- The geopotential departures created over the ALADIN domain are spread eastward as a plume. The increments reach the 60th east meridian at 48 hours.
- A negative increment goes downstream northward and is centered over Baltic sea at 48 h.
- Very strong humidity increments are obtained in the coupling area at 48 h.

The impact of the small-scale data is clear, spreading outside the coupling area mainly downstream as expected.

The global scores by comparison to the operational analysis show a small reduction of the mass fields biases but a small degradation of the humidity biases. The result is the opposite concerning the standard deviations. For the scores over EURAT5, the biases are strongly reduced in the coupling experiment, except concerning temperature at 850 hPa. The standard deviations are better only for the mean-sea-level pressure at 24 h and humidity at 850 hPa.

5.3 Situation of the 6 August 2003.

The situation was anticyclonic over France.

- The coupling makes the fields smoother: it fills the minima located on Gibraltar and Caspienne Sea.
- The temperature modifications are clear, with a cooling over North Africa and West Europa, except over Morocco/Gibraltar and the center of Spain (increasing by 2.5 K).
- Note a bug over Antarctic, since strong increments appear from 12 h.

The differences between the global scores with respect to the operational analysis are not significant. The same scores computed over ALADIN domain (from EURAT5 grid) show a degradation of all scores.

6. Conclusion and perspectives

Three situations were selected for the experiments: 3d December 2003 (winter blocking with a minimum centered over Spain), 13th January 2004 (westerly disturbed flow) and 6th August 2003 (« killer summer » in France). Each run was a 48 h forecast with bogussing every 3 hours.

Once the sources of noise identified, due to the simple technique employed, reference experiments having the same noise have been built. A clear and logical impact of the contribution of the small scale model data has been observed. The magnitude of the increments cannot be neglected with respect to the concerned fields, and these increments are generally transported downstream, eventually far from the coupling area, impacting less and less significantly as we leave this area.

Concerning the objective scores, the results of both winter situations are neutral. But for the summer situation a clear negative impact is produced with the introduction of the small-scale model data. The reasons could be :

- An insufficient quality of the small scale model to improve the results of the large-scale model,
- A problem of the reference chosen to computed the objective scores. The analysis could be too close to ARPEGE or of insufficient characteristics,
- A too big noise due to the computing technique. To simplify the experiment, ARPEGE restarts every 3 hours on the basis of the historical file, which induces a noise whose impact has been discussed in III.B. The bogussing, that carries out the interpolations, produces a noise of the

same magnitude (see III.B), which could warn us about an insufficient technique. Maybe the ALADIN data can improve the ARPEGE model state, but it is possible that the noises interacts in a negative way.

- A noise due to the numerical bogussing technique: the adding of the increments on the fields of the global model is done over a limited area, which could induce a physical, particularly thermodynamic, imbalance at the boundaries of this area. The temporal scheme of injection of the small-scale data into the large-scale model is very simple too (adding of the increments every 3 hours). A grid-nesting scheme is generally more complex, with rather a recall toward the small scale model at each time step.

We point out that the two-way coupling idea is for us complementary to the stretched grid. We want to show the impact of the small scale on the large scale, and on the coupling conditions received by the small scale model. We hoped to show the interest of keeping a global model "modifiable by the small scale", instead of "bearing" an external global model and risking to limit the quality of our results at mesoscale. Being aware that the two-way coupling idea is founded on a solid basis, we deduce the following perspectives for next studies:

- This experiment should be pushed further, from a better small-scale model, or from the same one but with improved initial states.
- Scores should be computed from a more objective or better quality reference.
- The noise induced by the absence of restart and the bogussing should be reduced. For example, to build real restart files would not be difficult and would allow to improve the objective scores.
- To reduce the method noise, it is possible to rerun the experiments (without big development) by modifying the historical ARPEGE in an incremental manner, by using the difference between two "bogus" files (the one of this experiment – the one coming from the forcing ARPEGE file).

7. <u>Références</u>

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