Mid-year activity report 2013

30 April 2013

Piet Termonia

ALADIN Program Manager

This report represents my personal view on the current status of the activities within the ALADIN consortium. It is written soon after the ALADIN workshop/HIRLAM All Staff Meeting (AMS) in Reykjavik (15-18 April 2013) and taking into account the outcome of that meeting as well as other outcomes since the previous PAC meeting of last year in 2012. This report does not claim to be exhaustive but focuses on some strategic issues following the recent scientific and technical developments within the consortium:

- What does HARMONIE mean? Top-down vs. bottom-up;
- a trend toward finite elements in dynamics: (a) a remarkable breakthrough in vertical finite elements and (b) first steps to consider horizontal finite elements;
- the PREP part of SURFEX: expertise building in profiling and optimization;
- 4DensVAR for the convection permitting scales?
- Radar data assimilation in small countries;
- a new momentum in verification and birth of HARP;
- validation of the cycles using the HIRLAM tools: *this will not be discussed in this report since I consider it to be the key part of the analysis for further merging between the HIRLAM and the ALADIN consortium, and this is explained in the note prepared by the Task Force.*
- Lessons to learn from the COST ES0905 action.

What does HARMONIE mean?

This question was asked during the workshop in Reykjavik and the participants expressed quite some concern during that session.

To answer it we should distinguish between the scientific and the managerial aspects. For the latter, we know that there are different model names in circulation; HARMONIE, ALARO, AROME. It is sometimes not clear to a non-scientist if one is speaking about the same model.

However this question was raised during the workshop by scientists. The scientific reality is that we run a system that allows to use many different configurations the are “drawn” from a system by making choices of the scientific options implemented as physics schemes in the code. This scientific literature is, in many cases, not univocal on how to correctly formulate the physical processes; scientific knowledge being by definition always ad-hoc.

It is up to the scientist to specify what scientific choices are made in his/her model configuration. For instance, I find it important that scientific papers and presentations state clearly what the used scientific options are. Of course there exist a number of particular configurations of special nature; for instance the AROME version running in Toulouse, and also a recent version created in Prague called the ALARO-0 baseline. Any configuration that has not been documented should be called a priori HARMONIE.

Over the past few years there has been a strong scientific eagerness by the scientists to implement new schemes in the model, here is a (non-exhaustive) list:

- testing of alternative radiation schemes,
- two deep-convection schemes: PCMT and CSD,

- cellular automata,
- more sophisticated microphysics (to improve the low clouds),
- many choices for turbulence; QNSE, CCH02, TOMS, and recently there is also a wish for EFB,
- a major scientific progress in the treatment of entropy and enthalpy in moist thermodynamics through the new variable of P. Marquet (2011),
- two-moment schemes,
- aerosols/chemistry.

So there is a bottom-up wish/demand by the scientists to see more diversity implemented in the code.

At the same time Fig. 1 shows that there is only about 4% of reported efforts on code design in the code-related activities in the consortium, which could be interpreted as a very low concern for how the new developments are implemented in the code.

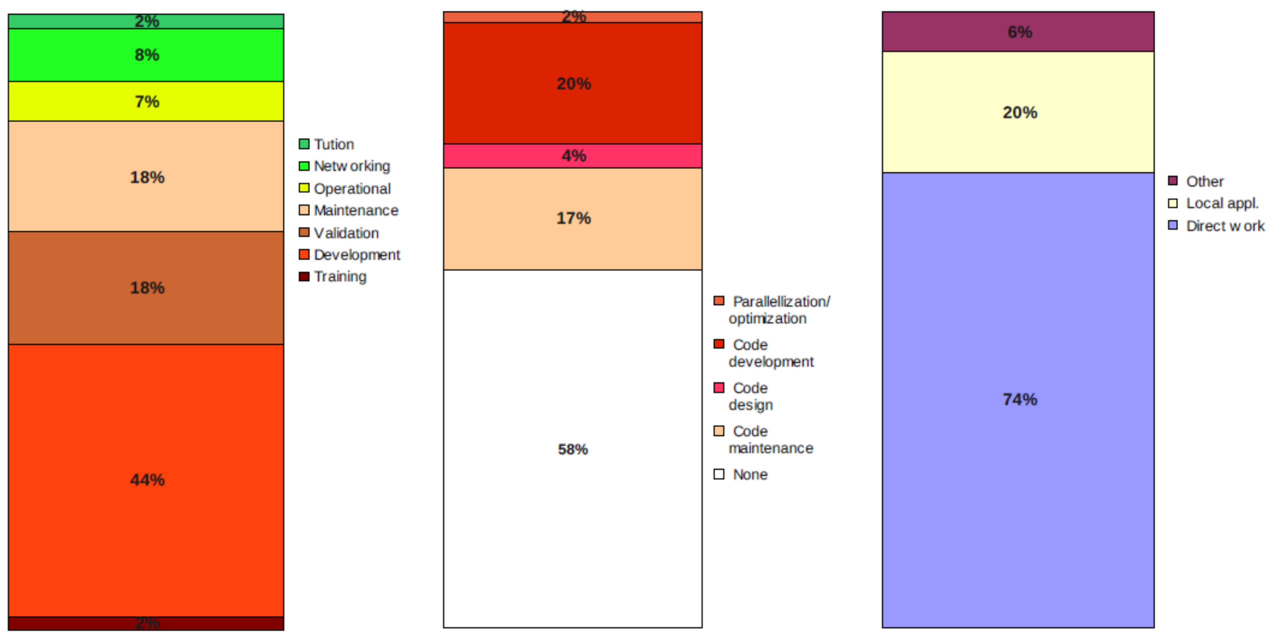


Figure 1: Statistics from the reported manpower contributing to the ALADIN program. The middle column represents the activities related to code work, split up in different aspects. Courtesy Patricia Pottier.

From the above three points, one could recognize a certain incoherence in this, namely (a) there is a scientific bottom-up desire to have new developments implemented in the model code ASAP, (b) one can observe a certain lack of concern for top-down organization of the code design to accommodate this diversity and then (c) to express the concern that there is no definition of what model we are running.

It should be noted here that already the action to implement the Catry et al. (2007) interface was started as a way to (re)structure the coordination to address these issues. Some work was planned last year during the ALARO meeting in Ljubljana, but in practice this did not reach full completion so far, due to a lack of prioritization. A first version of the Catry et. al (2007) interface has been coded and some first tests showed good results in terms of reproducibility with AROME, but this work got delayed. In June this year a meeting is planned in Brussels, with two invited experts from Hungary and Turkey to speed up the impact study of the interface on the AROME performance and to then validate the outcomes. Given the discussions during the past ALADIN workshop this year, this should get highest priority now.

This validation can open the possibility to exchange physics schemes developed in the ARPEGE/ALARO part of the code into the context of AROME or vice versa, provided we analyze the calls of the schemes in relation to the underlying data flows in the two model configurations.

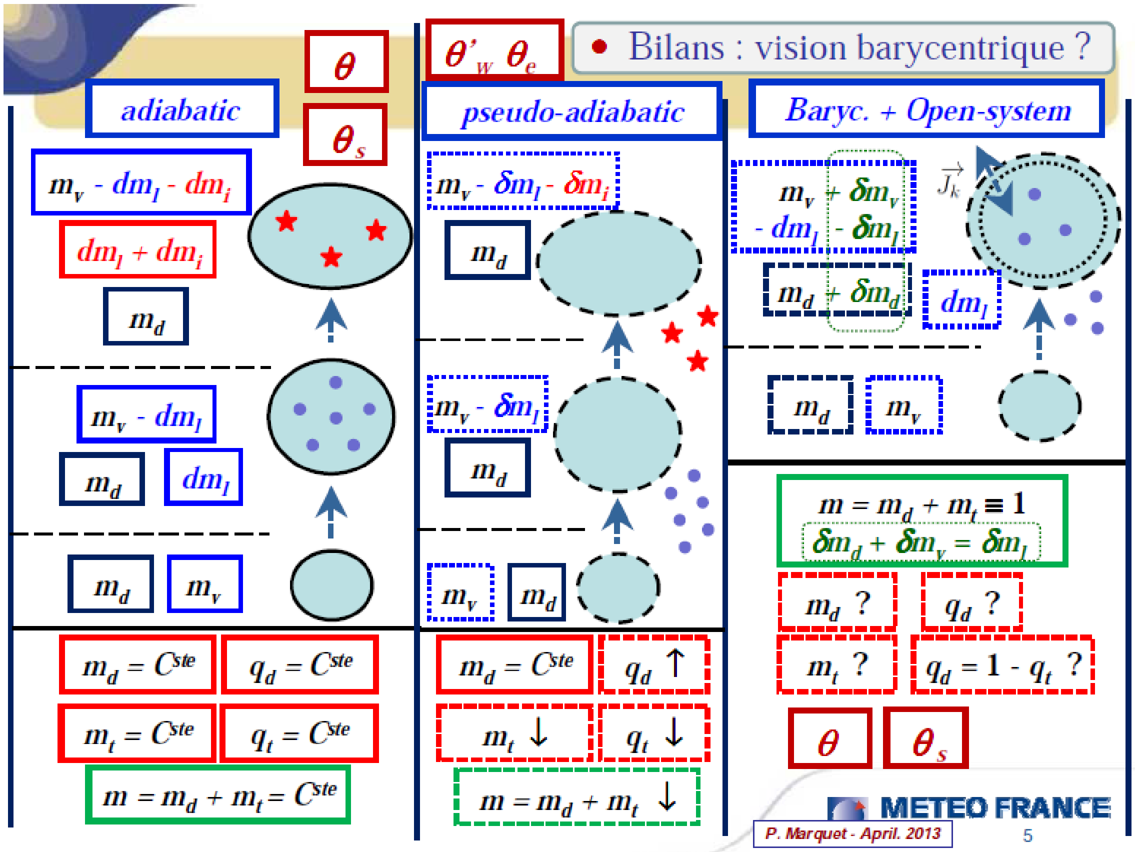


Figure 2: Schematic representation of two ways to treat the air parcel: barycentric vs. the standard pseudo-adiabatic. The theta_s formulation is based on work of Haus and Höller (1987) in a barycentric frame and provides a variable that is both conservative and that can be interpreted as an the entropy of the system. Courtesy Pascal Marquet.

From all the developments of the past few years, perhaps the most scientifically innovative one is the work of P. Marquet (2011), allowing for a treatment of both conservativeness and entropy in one single moist thermodynamic variable, called theta_s. Unexpectedly, this reinforces the usefulness for a barycentric approach (that is also included in the Catry et al. interface), as explained by P. Marquet in the included slide in Fig. 2.

In fact, as can be seen from the diagram in the Fig. 2, adopting P. Marquet's theta_s variable defines partly "what we are computing". Indeed, the diagram represents different choices of the air parcel. One can accept different choices to compute the physics parameterization (after all the scientific literature is not exclusive in most areas, see for instance, on turbulence, but also on deep convection, see the COST ES0905 action described below), but the key is that the final results of the individual schemes are aggregated all of them to the same air parcel. For this we need a decision about "which parcel" will be affected.

For the strategic prioritizing for next year I have the following proposal:

The planned impact study and validation of the physics-dynamics interface will get highest priority now. The rather recent scientific innovation in thermodynamics can be an opportunity to define what the model is and how the physics schemes should respond to the underlying data flow, provided the developers agree on the underlying scientific basis. PAC and/or HAC can then reflect on the terminology of the model later.

A trend toward finite elements and a renewed activity on dynamics

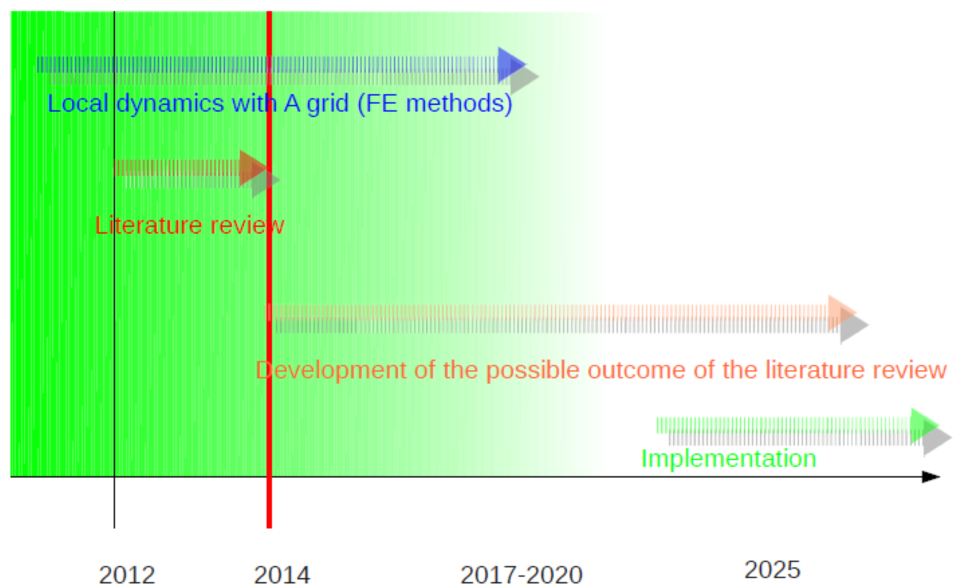
LACE made a major effort last year and a step forward in the longstanding developments in the formulation of the vertical discretization of the dynamics in terms of vertical finite elements in mass based coordinates. This work can now be considered sufficiently mature to claim that we may expect to have a solution in the full 3D model. The scheme has been tested for its stability in linear, and non linear regimes in 2D and 3D, and some first tests in the full model have been carried out. The next step is to phase this to a recent cycle (the science was carried out in cy36t1). Subsequently an optimization of the code is planned and the accuracy of the scheme will be investigated. It is fair to say that most of the developments were carried out in the LACE consortium.

Since the strategy meeting in Brussels in 2011, a research was started to investigate the question of the feasibility to replace the horizontal spectral discretizations by horizontal finite elements (see blue line in the road map diagram). One of the main critiques in the past has been that abandoning the spectral techniques would necessarily imply that we need to reorganize to code to work on a C grid. These arguments can be traced back to the paper of Mesinger and Arakawa already published in 1976, stating that the formulations on the A grid lead to the propagation of the gravity-wave energy in the wrong direction, which may give rise to unphysical adjustment properties. One well-known way out of this is to reformulate the equations in terms of vorticity and divergence. In the past year we have shown that this can be avoided with a hybrid formulation of the dynamical equation; partly in terms of u and v and partly in terms of vorticity divergence. This can be done in a way that does not force us to change the algorithmic structure of the computation of the current model code; in particular leaving the existing call to the physics and the semi-Lagrangian computation of the advection entirely intact.

Additionally there are some renewed activities on the issue of the lateral-boundary conditions (LBCs). The paper of the implementation of Boyd's periodization method was published last year. New tests were carried out using the MCUF method to deal with the temporal coupling updates and some validations were carried out within the HIRLAM consortium of the Davies coupling scheme. The latter activities and the corresponding test bed could become important when going to higher resolutions. For instance in recent tests carried out with AROME at a resolution of 1.3 km, the question is now raised again of the what is the optimal width of the relaxation zone.

A FR stay is planned this year in Brussels about the literature review part of the road map.

Dynamics: road map



Eliminitating the A grid means we have to overhaul the whole system.
We stay with the current system at least for the term of the current strategy plan (green area).

> There is a fresh activity in the domain of dynamics largely driven by the opportunity to go to finite element formulations. This is a positive impulse in the consortium for the creation of expertise, builds further on a past legacy of the ALADIN NH dynamics and serves as a motivator for ALADIN experts to work on this topic. The literature study mentioned in the road map should get extra attention this year .

The PREP part of SURFEX

During the SURFEX WW in Brussels in 2011, a problem was found with the PREP part of surface (this is the part of the software that allows to create the initial files by interpolating the fields coming from the coupling model). In the Turkish set up, the creation of such files took a very long time (roughly half an hour). This is very unrealistic for a tool to be used in operational applications. In March 2013, two experts (Daan Degrauwe and Tayfun Dalkilic) looked deeper into this problem, by a stepwise approach of profiling, adding open MP directives and by avoiding of a few computations that are not directly needed for the NWP applications. They showed that this problem can be solved. Additionally they looked at the memory consumption (see Fig. 3) and found some limits that may be attained when we will increase the resolution of the HARMONIE configurations in the future while staying on a domain of the same geographical size. For instance the 50 GB limit in the diagram in Fig. 3 can be considered as the type of memory limit that ECMWF can currently afford. All of this was reported to the SURFEX SC and appreciated by its members. The proposed solutions will enter the code and, importantly, will benefit all SURFEX users, not only the NWP community.

Some problem with the efficiency of the code was reported running SURFEX on a very large domain. So in my opinion the Brussels action of March 2013 should be repeated next year, but for the SURFEX part of the code, i.e. for running the SURFEX scheme within the model execution . The past action proves that manpower is available in the partner countries that master the standard techniques of profiling, open MP optimization, and scientific code optimization (i.e. ask what needs to be computed and organize it optimally). The issue of distributed memory use has not been addressed in this action.

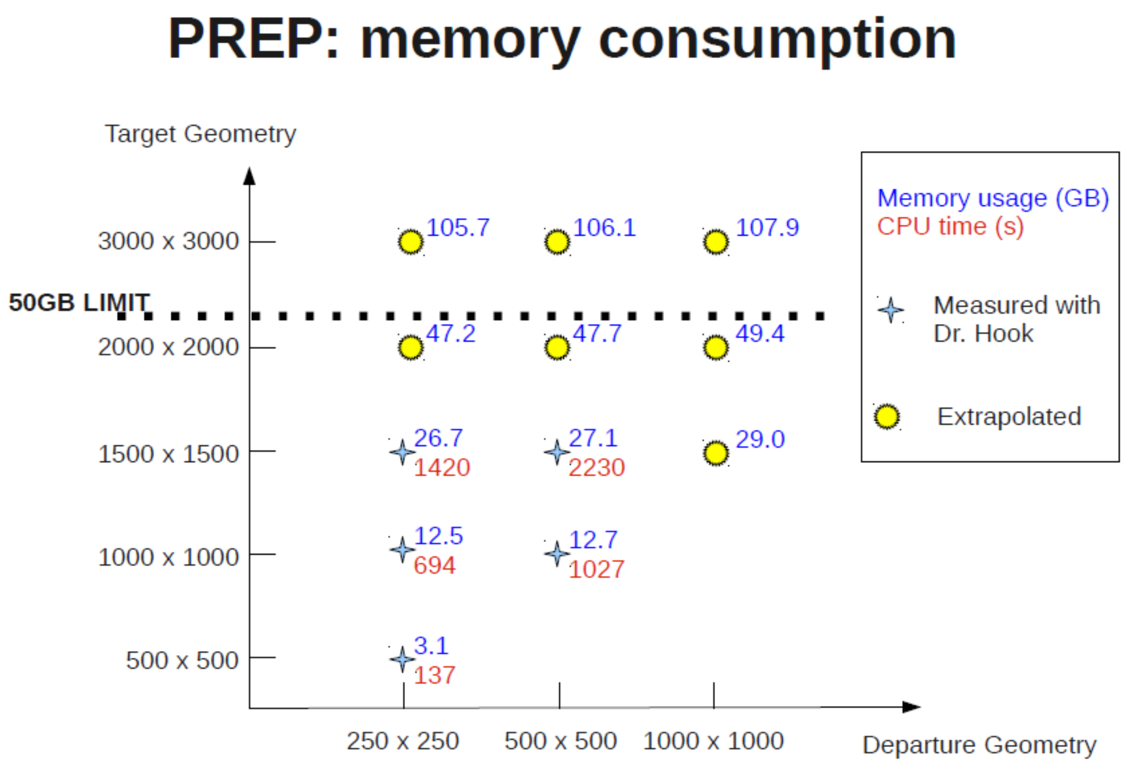


Figure 3: Profiling of the PREP performance in terms of CPU time and memory usage for different sizes of the departure domain and the target domain. Courtesy Tayfun Dalkilic and Daan Degrauwe.

There is a lot of potential for optimizing the PREP code. This action solves the problem of the partners with PREP reported in 2011. A plan for more optimal memory use is needed. The SURFEX SC has demonstrated to play channeling a role in this. The next step is to look at SURFEX itself. It might be beneficial to reflect on a long term strategy.

4DensVAR as a candidate for the convection permitting scales

Every year the possible choice between the variety of data assimilation techniques, 3Dvar, 4Dvar, ETKF, hybrid methods, EDA, is being discussed. This year in Reykjavik, there was an interesting presentation about 4DensVAR. This has a number of appealing properties:

- there is no need for a TL/AD and simplified physics,
- it includes an EPS component, which makes it more attractive from the point of view of scalability.

Given the discussions that took place in the past, in particular during the ALADIN workshop in Krakow in 2010, the EPS approach seems to be a natural one for dealing with the inherently stochastic nature of the deep convection at the convection-permitting scales. Additionally the EPS approach allows for a multi-resolution approach. For instance, it could be investigated whether the members of the included EPS perturbation could be run at lower resolutions than the deterministic component, for instance the convection-permitting resolution could have a resolution of 2.5 km, while the perturbed members could run at 5-km resolution and it could be investigated whether the computing resources are better spent on increasing the ensemble size instead of the resolution.

4DensVAR is an very attractive candidate for a remotely future data assimilation systems for the high-resolution models. While we can not hope to have this in a near future as an application in the ALADIN partner countries, this is a promising scientific evolution that should certainly be followed up very closely.

Radar data assimilation

As an example of a common work between the ALADIN and the HIRLAM consortium radar data assimilation cycles were installed and tested in Hungary and Norway, after common efforts on the radar data converter software called CONRAD. The systems differ in several aspects, for instance in Norway only reflectivities were assimilated whereas in Hungary both reflectivities and radial winds were assimilated. The radars are also of different types. The used radar data assimilation techniques were adopted from the data assimilation team of Météo France. Significant improvements were found in Norway (Fig. 4), whereas the tests in Hungary currently give encouraging, but mixed results (Fig. 5); a small degradation early in the forecast but good improvements later were found. In the Hungarian case, a significant spin up was observed and it will be investigated if this is responsible for the small degradation and how to deal with it.

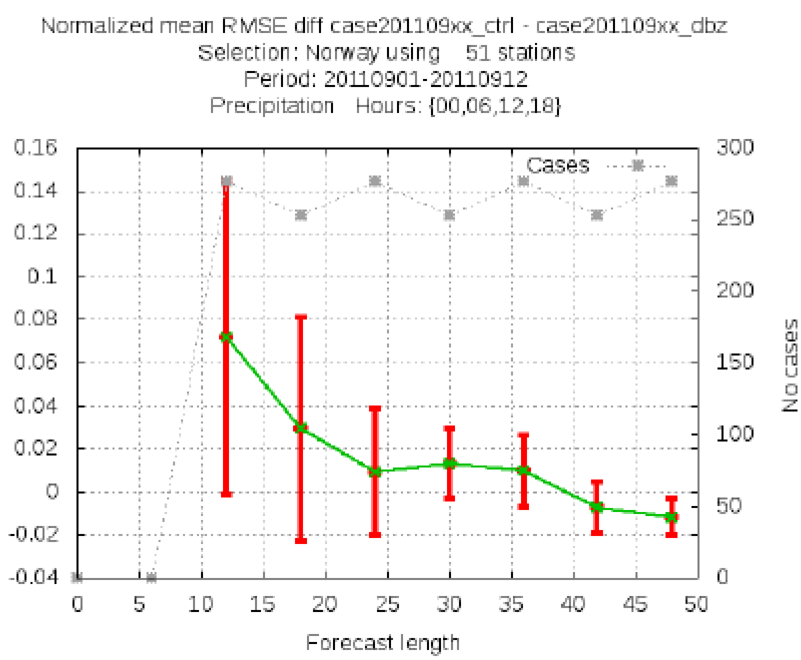


Figure 4: Root-mean-square error difference between the data assimilation without radar DA and with radar DA in Norway. Positive values represent improvements.

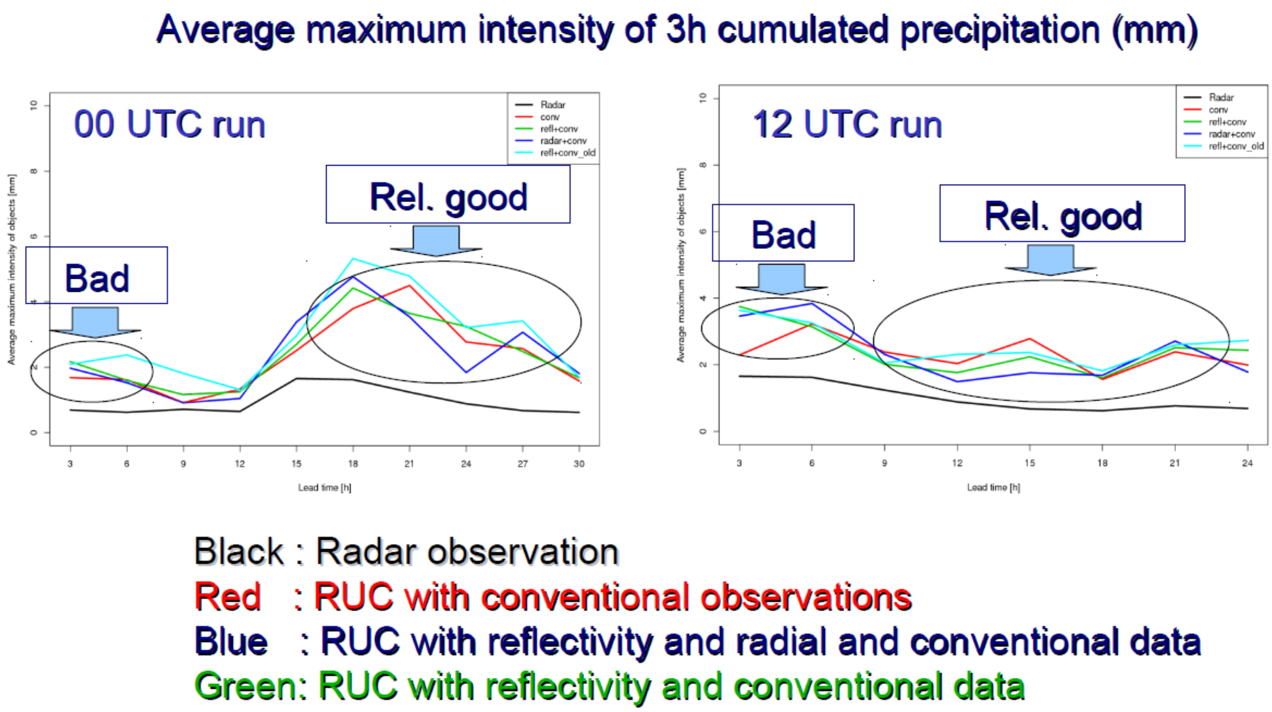


Figure 5: Comparison of the model output with respect to radar observations (black) for three rapid-update cycles in Hungary.

Radar data assimilation can benefit a lot from cooperation (the NWP teams in most of the countries being small). This is to my knowledge the first example of a common action on radar data assimilation crossing the border of ALADIN and HIRLAM. At this stage it is not clear what can be learned from the point of view of the intercomparison between the two systems, but the spin-up issue is a good question to be addressed.

The common HILAM-ALADIN verification package HARP

As discussed during the ALADIN verification meeting in 2011, verification pertains to three issues:

- verification as part of the validation of the new model versions (the so-called cycles),
- verification of part of the monitoring of the forecast quality of the applications, and
- verification as part of model development in research contexts.

In 2011 it was decided that the HIRLAM-ALADIN cooperation could benefit by developing a common toolbox. However a few tools were already existing for the monitoring of the operational applications and HIRLAM also had a very elaborated system to perform the validations of the new cycles. However in both consortia there was an explicit need for an extended verification toolbox to verify the newly developed EPS systems, in particular the commonly developed GLAMEPS system. During the ALADIN workshop/HIRLAM ASM meeting in 2012 in Marrakech it was therefore decided to start to develop such a package together. Last year a first version of this package has been created, known under the name HIRLAM-ALARIN R Package (HARP). And it has been used to demonstrate the GLAMEPS adds forecast skill on top of ECMWF for precipitation, besides the standard variables such as 2m-temperature and wind speed, as can be seen in Fig. 6.

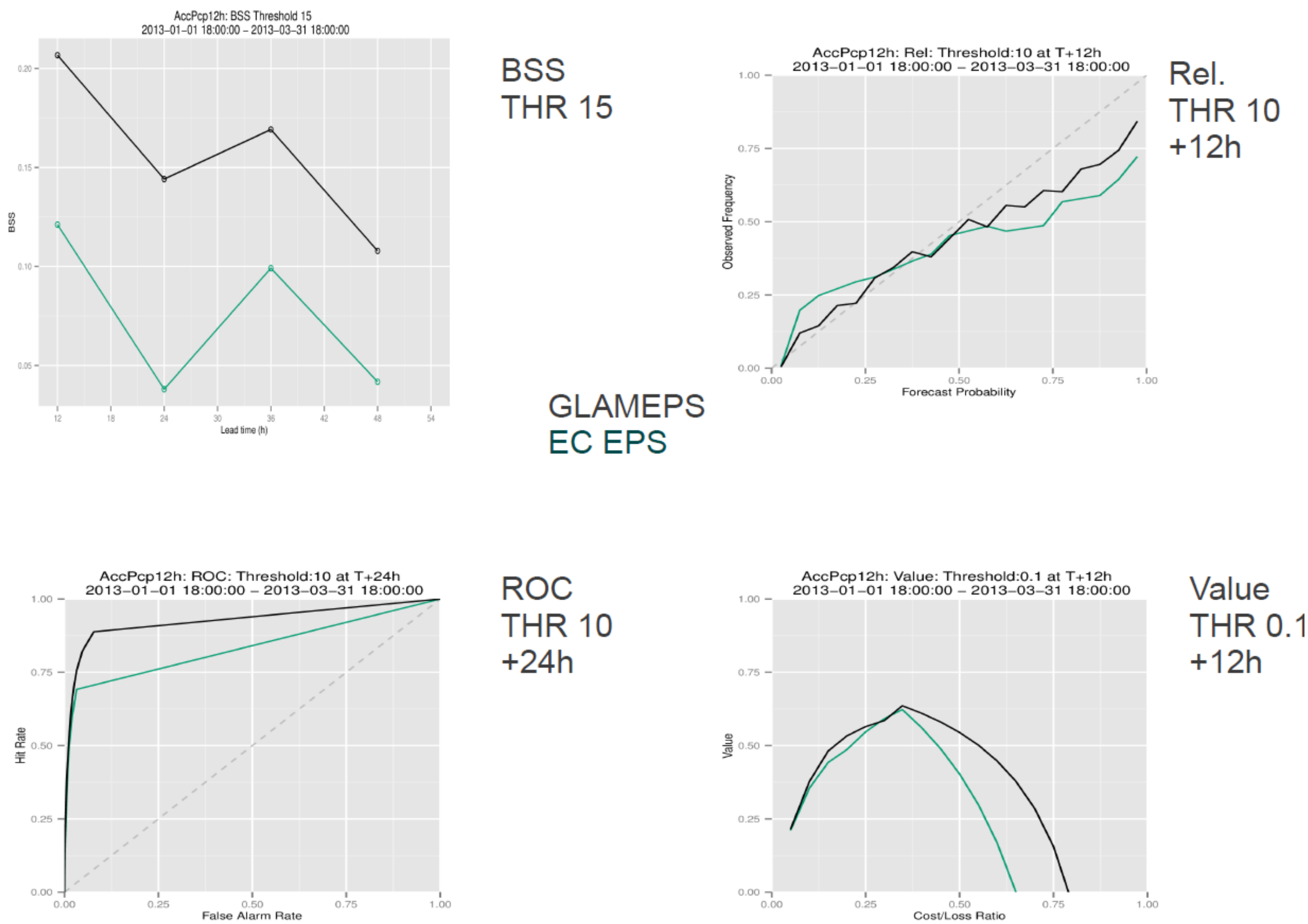


Figure 6: Output of HARP presenting different scores comparing GLAMEPS to ECMWF EPS.

What can be learned from the COST ES0905

There was a meeting of the COST ES 0905 action from 19 to 21 March in Palma, Spain with the title *Generalization*, *Consistency and Unification in the Parameterization*, addressing the problem of choices made for developing parameterization schemes. The meeting showed a keen interest to different approaches within the NWP communities, but also with respect to other scientific communities in fluid dynamics. While the topics of this meeting were expressed in rather general terms, the discussions were very concrete and addressing well-defined scientific problems. The leading manager of this action, J.-I. Yano produced a very instructive summary of the final discussion of that meeting. The starting point of his synthetic paper is the turbulent nature of the sub-grid processes and this was looked upon from the point of view of theory, laboratory experiments, measurement, Large-Eddy Simulation (LES), Cloud-resolving models (CRMs) and even making the link to the synoptic scale notion of the slow manifold. The overview shows that there are many scientific angles to look at the problem. The discussion then finally arrived at the conclusion that: given that there are multiple scientific paths, there is a need for a basic strategy and that model development is largely a matter of doing it in a consistent manner as much as possible .

References:
Yano, J.-I., 2013: Generalization, Consistency and Unification in the Parameterization Problem. Report of the 2013 General COST ES 0905 meeting, Palma, Spain.