Status of the AROME project in MF in winter 2006

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1. Introduction: AROME documentation

The AROME project has been presented numerous times in this Newsletter series. Some presentations can be found online on the Aladin website,

http://www.cnrm.meteo.fr/aladin/aladin2.html which features an up-to-date technical documentation of the AROME model. The AROME R&D on data assimilation is currently identical to the ALADIN 3D-Var assimilation, which is documented in the Newsletters and on the Aladin website. The most recent AROME (very short) publication is:

Bouttier, F., G. Hello, Y. Seity and S. Malardel, 2006: Progress of the AROME mesoscale NWP project. *CAS/JSC WGNE "Blue Book" annual report "Research Activities in Atmospheric and Ocean Modelling"*, Ed. J. Côté, 2pp.

A major AROME international event took place in late November 2005: the ALADIN/HIRLAM first AROME training course, in Poiana Brasov, Romania, whose program and presentations are available as links through the Aladin website.

The AROME project itself has mostly been managed through monthly meetings at CNRM in Toulouse, the substance of these meeting reports (in French) is summarized below.

2. Daily runs and case studies

The AROME 2.5-km model has been run for several months over 400km-wide domains, usually on SW and SE France in near real time, and for some case studies over Paris or Brittany, which included convective systems, orographic and coastal effects, synoptic storms and fronts, mediterranean, temperate and cold wintertime weather. The plots from the daily runs are available to the ALADIN partners in a password-protected area of the Aladin website (known to the local Aladin correspondents).

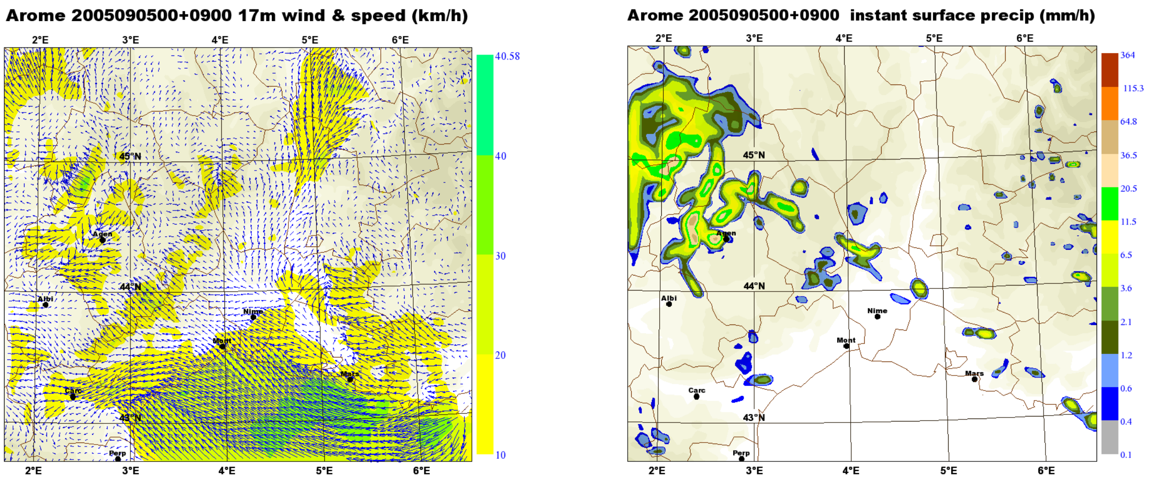
The AROME performance was subjectively assessed with reference to in-situ routine data, radar and satellite imagery, and human forecasters. The performance is good, both in absolute terms and relatively to the lower-resolution ALADIN model. The added value (over ALADIN-France and other available models on the area) is very clear on low-level wind and temperature forecasts, thanks to the dynamical adaptation to complex orography and physiography. The sensible depiction of urban heat effects was a good surprise. The most spectacular improvements were experienced in convective situations, where AROME was able to depict realistic details (anvils, gust fronts, texture and maximum of the precipitation field) of the weather which are completely absent from lower resolution models. The positioning of convective cells is still imprecise due to the lack of a fine-scale assimilation, and the added value is mostly in the information on the probabilistic distribution of weather features at scales of the order of 50km, i.e. much larger than the actual model grid size. In some situations, the location and timing of rain and convective cells are spectacularly precise, presumably because they are the result of orographically-driven wind circulations, which are highly predictable when the model has sufficient resolution.

A 3-day Mediterranean flooding case occurred close to Marseilles in September 2005. Such events are characterized by synoptically-driven convective cells in warm, moist air, that keep regenerating for many hours in a row over coastal orographic features. In this particular case, large-scale models (global models from ECMWF and Météo-France) gave a good depiction of the synoptic context, and AROME improved the quantitative precipitation forecast on scales of the order of 20 to 50km. Interestingly, AROME also improved larger-scale aspects of the precipitation forecasts, compared to ALADIN, presumably because of feedback from the convective cloud microphysics and small-scale turbulence to the generation of cold pools (by rain evaporation), to the triggering of precipitation, and to the humidity and vorticity fields on larger scales.

3. Known problems

The future work will concentrate on adapting the ALADIN 3DVar analysis system to the higher resolution of AROME and to using radar and satellite data. Benefits will need to be assessed not just in terms of the analysis algorithm itself, but also in terms of the interplay of model and observations during assimilation cycles. On the model side, the known weaknesses of the current AROME version are being adressed:

- the representation of non-convective, non-frontal clouds is very poor, which is very harmful in anticyclonic wintertime weather. The introduction of a subgrid shallow convection scheme is expected to improve cloud cover and its feedback with radiation. Interestingly, the AROME explicit production of fog itself currently is rather poor, but the high relative humidities forecast by AROME often are a spectacularly precise predictor of the likelihood of fog.
- the forecasts are adversely affected by lateral boundary effects at up to 80km of the border. The numerics of the lateral boundary coupling are being revisited. One (expected) problem is a spurious perturbation of the convective circulations near the exit border: when one moves the domain, the location and intensity of precipitations near the border are significantly altered. The problem is multivariate and seems an unavoidable consequence of having resolved convective circulations in AROME which do not exist in the forcing model. Another problem is the generation of spurious clouds over high mountains close to the input border, presumably due to a poor vertical interpolation of humidity between the forcing (ALADIN-10km) model and AROME.
- the specification of surface conditions e.g. town heating source term, soil moisture, coastal physiographies, need to be improved. Currently some bugs are visible on the temperature along coastlines.
- the diffusion along terrain-following model surfaces is inappropriate in narrow valleys, in stably stratified atmospheres, which are more horizontal in nature. A case-sensitive formulation of the diffusion is being considered, that plays with the diffusive nature of the semi-Lagrangian advection (based on Filip Vana's SLHD scheme).
- the precipitation field forecast is often poor during the first 2 hours of forecast, which will certainly be much alleviated by the planned introduction of an AROME assimilation cycle to initialize the AROME forecasts.



Examples of fields forecast by the AROME 2.5km model: low-level wind vectors (color shading according to speed), and instantaneous precipitation field, on the SouthEast of France.

4. Highlights of recent internal AROME model meetings

4.1. subgrid convection

Experiments show no sign that a subgrid deep convection scheme is needed in AROME. However, it seems that weaknesses in cloud cover prediction, and in the texture of the rain forecast fields (e.g. too well-structured intense bands), are linked to the lack of a **representation of subgrid shallow convection.** The 3MT convection parametrisation project (cf. JM Piriou, L. Gérard, etc, presented by J-F. Geleyn at an AROME meeting) is a very interesting framework, but is primarily aimed at deep convection and is in a preliminary state (it is incompatible with the current MésoNH model software structure). It will be very interesting to enable it in AROME for experimentation when 3MT is fit for preoperational use. This will take too long for the AROME operational commitments, so interim solutions are sought.

As a short-term fix, the subgrid cloud cover and the shallow part of the Kain-Fritsch Bechtold (KFB) scheme have been activated in the AROME runs around October 2005, with an immediate beneficial impact (work mostly done by S. Malardel). The CNRM contact point on the AROME strategy in convection is Jean-Marcel Piriou.

4.2. Turbulence

According to Méso-NH experimentation (done specially for the benefit of AROME by the CNRM/GMME Méso-NH group) the (1D) turbulence scheme suffers from

(a) the lack of a counter-gradient term in the PBL (planetary boundary layer),

(b) insufficient entrainment at the top of the PBL,

(c) poor cloud representation in the upper part of the PBL.

For dry PBLs, the Méso-NH 1D turbulence scheme has been extended by some TOMs (turbulence third order moments) and a mass-flux scheme (P. Soares), which are being tested (both approaches are somewhat competing so some selection is going to occur). (C. Lac)

For moist PBLs, an improved KFB scheme and the Soares scheme are being tested.

4.3. Microphysics

The representation of cirrus clouds is being looked into, primarily by tuning some autconversion processes. A satellite radiance simulation tool is being developed for AROME as a validation tool.

1D-column tests have proven that the correct representation of **fog and low clouds** requires sedimentation of cloud droplets, which has significant effects. The affordability of increasing the vertical resolution of AROME near the ground is being looked into, in the hope that it can improve the fog prediction.

The numerics of the sedimentation of microphysical fields is being rewritten in order to cope with the timesteps used in AROME (longer than in Méso-NH).

4.4. Radiation

The work is common with Méso-NH and ARPEGE/ALADIN models. There have been some issues with the specification of aerosols, of cloud overlap, of the number of visible bands. The improvements and bugfixes have gone into an ARPEGE/ALADIN parallel suite in February 2006 and are thus available to all partners in the default software configuration.

4.5. Chemistry

An interactive inline chemistry (with aerosols and dust) capability has been plugged into AROME (work mostly done by P. Tulet and Y. Seity). Basically it is a migration of the existing Méso-NH chemistry facility into AROME, which provides vastly superior computational efficiency for more or less the same scientific content. The surface interaction part (which is important, e.g. the dust production on deserts) is going into the SURFEX software and thus will soon be available for ALADIN and ALARO. The chemistry in AROME produced interesting simulations such as the urban ozone in the Marseilles area (ESCOMPTE field experiment case), and Saharian dust plumes.

This feasibility study demonstrated that aerosol/chemistry developments done in Méso-NH (which has an active scientific team in Laboratoire d'Aérologie in Toulouse, and also works on cloud electricity and NOx) will be rather easy to migrate into AROME if and when desired, which is expected in a couple of years, depending on future evolution of the mesoscale chemistry activity in the Méso-NH and MOCAGE groups. The provision of coupling fields to CTMs (chemical transport models) is the preferred option for shorter-term operational applications.

4.6. Interfaces and surface

The AROME/SURFEX interface has been rewritten in order to facilitate the plugging of SURFEX into ALADIN/ALARO, since there where parallelization issues in the I/Os (work by G. Hello). The SURFEX developments for ALARO are well under way, only the ARPEGE global geometry and some les simportant technical features which have received low priority due to lack of manpower. The main action for the INTERFACES project of ALADIN-2 is currently the development of DDH-like physics diagnostics for AROME (work initiated by T. Kovacic, now with a strong implication of J.-. Piriou).

4.7. Dynamics and software

There are intense and diverse activities, mostly for cleaning up the code and its user interface. The entire AROME software is now part of the ALADIN export libraries with very little lag behind the in-house MF version and the latest Méso-NH and SURFEX versions. And the AROME model launch is now available under the OLIVE experimentation preparation tool in MF.

The dynamics configuration used in the AROME daily runs is cy29t4 d4 p/c with one semi-implicit iteration, plus (since Nov 2005) the SLHD and LRDBBC options which significantly improved the precipitation over orography by eliminating the so-called "chimney" spurious numerical artifacts (thanks Radmila and Filip !).

5. Cooperations around AROME

A very intense advertising effort around AROME in 2005 has produced a large number of cooperations, beside the official explicit mention of AROME in the ALADIN and HIRLAM *Memoranda of Understanding*, mostly thanks to the efforts of G. Hello:

- AROME over Hungary (L. Kullman)
- AROME for Slovenia (J. Cedilnik)
- AROME on Austria (contact point in MF: E. Bazile) for quantitative precipitation studies
- AROME for HIRLAM: domains on Sweden (S. Niemela), Denmark (B. H. Sass), South Finland (S. Niemela), installation on ECMWF HPCF (with R. El Khatib)
- AROME for coastal oceanography: optimization of output fields for a 3D ocean model (with the French Navy).
- AROME for air pollution accidents: testbench in the Paris area (with a specialized French Agency) and other customers.
- AROME for wind farms: testbench in the South of France (with a French Electricity Utility).

•AROME on field experiments: ongoing contacts for AMMA (GPS validation and assimilation, with French research labs), COPS and MAP D-PHASE (European experiments)

In 2006, the priority on creating new external cooperations will decrease, and the emphasis will shift towards improving the model numerical efficiency, alleviating its physical weaknesses, and testing the assimilation/forecast interactions.