Progress of the AROME mesoscale NWP project

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1. The model

Launched in 2000, AROME (Applications of Research to Operations at Mesoscale) aims to develop an original mesoscale model and data assimilation system for operational NWP and the scientific community. AROME builds upon ECMWF's IFS software (a global NWP system that was extended by the ALADIN cooperation into a limited area model (LAM) and data assimilation system, and non-hydrostatic (NH) dynamics), and the Méso-NH software, which provides most of AROME's physical parameterizations. The IFS framework ensures good computer optimization on a variety of architectures, and quick pull-through of R&D on data assimilation algorithms and use of satellite data. The link to Méso-NH provides excellent scientific expertise and development workforce from the mesoscale atmospheric research community and universities.

Namely, the AROME model core is a NH LAM with a semi-Lagrangian advection scheme and a spectral (bi-Fourier) semi-implicit solver, that allows e.g. using a timestep of 1 minute with an horizontal resolution of 2km, with perfect stability and very good accuracy. The AROME model physical parametrizations are: a prognostic TKE turbulent mixing scheme, a prognostic cloud microphysics scheme with 5 condensed water species (cloud water and ice, precipitating water and ice, graupel), a tiling surface flux parametrization (with subgrid tiles for soil/vegetation [ISBA scheme] hydrology, town [TEB scheme], lake and sea prognostic mixing layer, multilayer snow), the ECMWF RRTM-IR/FM radiation scheme, a subgrid mass-flux shallow convection scheme, an optional interactive chemistry/aerosol scheme. The model has coupling facilities for mesoscale 3D ocean models and hydrology/flood models. The AROME physical parametrizations are the subject of intense research and development.

After initial validation on selected academic and real test cases, the AROME model has been producing daily real-time 24-hour runs in dynamical adaptation from the French ALADIN model, since June 2005. Real-time testing has been very satisfactory and some results are shown below. AROME has also been configured for local experimentation by the meteorological services of Hungary, Slovenia, Denmark, Sweden, Finland, Norway, and the Czech Republic. Dedicated real-time AROME runs are planned in support of the AMMA (African Monsoon in Western Africa, summer 2006), COPS (Convection in Southwestern Germany, summer 2007), and MAP D-PHASE (MAP hydrology demonstration on the Alps, summer 2007). Exploitation of AROME for operational NWP is scheduled for 2008 in Météo-France (possibly earlier in other institutes).

2. The data assimilation

The AROME data assimilation system is still being built. The development tool is the ALADIN 3D-Var assimilation (the subject of another article in this volume), which is operational. The ALADIN 3D-Var differs from the target AROME assimilation by three aspects: ALADIN is a simpler model (hydrostatic with cruder physics), its horizontal resolution is lower (of the order of dx=10km whereas AROME will use dx=1 to 3km), and the ALADIN 3DVar does not yet observe, analyze or initialize variables such as cloud or precipitating species, which are likely to be useful control variables for AROME. In other respects, the ALADIN 3D-Var is an ideal mesoscale assimilation tool thanks to its low numerical cost. It has been extensively tested in 2005 on a 3000km-wide domain on Western Europe, with the same observations and algorithms (except from the use of 3D-Var instead of 4D-Var, and the horizontal geometry) as the global 4D-Var ARPEGE data assimilation (operational at Météo-France), plus regional low-level observations of temperature and humidity, and cloud-cleared radiances from the SEVIRI imager of the Meteosat-8 (MSG series) satellite. The additional observations noticeably improve the humidity analysis, which in turn improves short-range forecasts of (mainly) precipitation and wind at lead times from 2 to 12 hours, for the time being. This system was declared operational in August 2005 and used since then to provide the initial state to the ALADIN forecasts over Western Europe (and, incidentally, to the AROME 2.5-km daily trial runs over France, which were found to be improved by the ALADIN 10-km assimilation as well)

3. Results so far

The AROME 2.5-km model has been run for several months over 400km-wide domains, usually on SW and SE France, and for some case studies over Paris or Brittany, which included convective systems, orographic

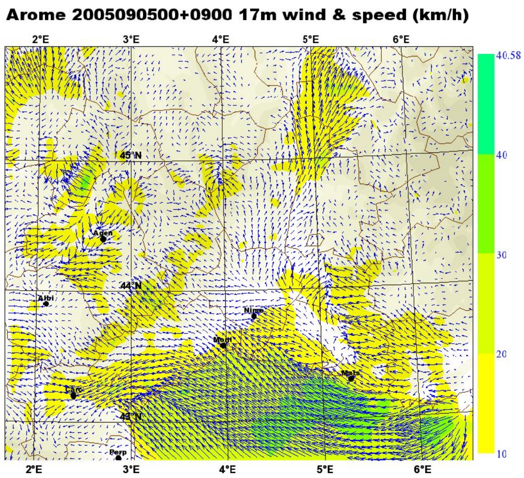
and coastal effects, synoptic storms and fronts, mediterranean, temperate and cold wintertime weather. The AROME performance was assessed with reference to in-situ routine data, radar and satellite imagery, and human forecasters. It is significant, both in absolute terms and relatively to the lower-resolution ALADIN model. The added value 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.

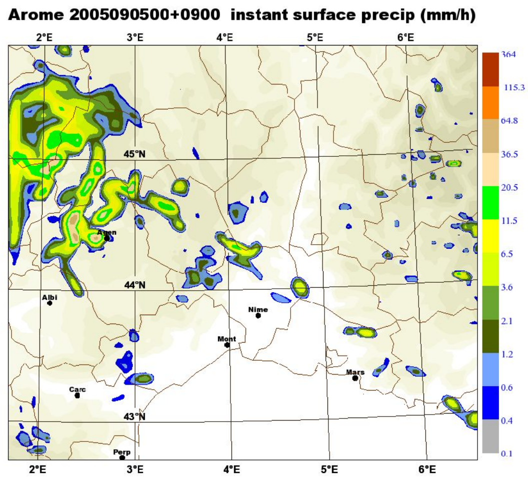
4. Conclusions

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 interpolay 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.
- 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.
- the specification of surface conditions e.g. town heating source term, soil moisture, coastal physiographies, need to be improved.
- 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 developed, that plays with the diffusive nature of the semi-Lagrangian advection.

References: see http://www.cnrm.meteo.fr/arome/





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