Progress and plans of the Météo-France NWP system in 2006: ARPEGE, ALADIN and AROME systems

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1. NWP system overview

The operational NWP system of Météo-France mainly comprises two nested models, with their data assimilation system: the global ARPEGE, with a stretched T358c2.4L46 resolution (23km grid on Western Europe) with 6-hourly 4D-Var data assimilation, and the ALADIN-France LAM with a 3000x3000km domain around France at 9.5kmL46 resolution with 6-hourly 3D-Var data assimilation. Extra ARPEGE and ALADIN instances run with other geometries and data cutoffs for various operational purposes. A third nested model, AROME, is under development and aims for operational implementation in 2008 (1200x1200km 2.5kmL46 grid over mainland France).

In 2006 a major supercomputer upgrade took place. The Fujitsu vpp5000 platform was complemented by a 256-processor NEC SX8R machine, which is made of vector processors arranged in shared-memory clusters. Parallelisation can be achieved using OpenMP (inside each 8-processor cluster) or MPI. The upgrade amounts to a total x5 CPU upgrade with respect to the vpp5000 (i.e. 9Tflops peak performance), with an effective sustained speedup of approximately x3 (using the same number of processors) on the main NWP runs. The NEC SX8R will primarily be used to upgrade the ARPEGE and ALADIN resolutions (model and 4D-Var horizontal and vertical resolutions), and to allow a first real-time implementation of the AROME mesoscale model and its data assimilation.

More details are in *http://www.cnrm.meteo.fr/gmap/*

2. ARPEGE and ALADIN models

ARPEGE and ALADIN-France use the same physical parametrisations and model setup, except for the horizontal geometry and resolution. The main model physics upgrades in 2006 have been: an improved orography database and soil wetness climatology (from GSWP), with revised sea albedo and soil emissivity; introduction of a new prognostic cloud/precipitation microphysics scheme (adapted from Lopez 2002, with cloud water, cloud ice, rain and snow); revisions to the turbulence, shallow and subgrid convection (entrainment & cloudiness diagnostic) schemes; change of radiation scheme to use RRTM-IR adapted from ECMWF (16 IR and 2 visible bands).

Also, the vertical resolution has been improved from 41 to 46 levels, with the new levels in the upper stratosphere and above (the model top was raised from 1hPa to 5Pa). Some aspects of the semi-Lagrangian advection have been improved in the main model and in the linearized model used by 4D-Var.

These changes have improved the ARPEGE large-scale scores, e.g. the cloud products, with positive evaluation of ALADIN-France changes by the forecasters.

A very short cutoff 4D-Var analysis and forecast suite has been introduced shortly after 00UTC, on top of the regular 00UTC run (used for international WMO scores intercomparison) whose data cutoff was left unchanged. An extra ALADIN 3D-Var assimilation and forecast suite ran over Western Africa during the AMMA field experiment (June to September 2006).

The plans for 2007 focus on a major ARPEGE resolution upgrade, from T358L46 to T538L60 (with the same horizontal grid stretching factor c=2.5), which brings the resolution over Western Europe from 23km to 15km, and halves the vertical resolution in the upper troposphere and lower stratosphere. In the ARPEGE and ALADIN-France physics, it is planned to revise the subgrid orographic drag scheme, to further upgrade the radiation scheme, to make the Lopez microphysics scheme cheaper using a better sedimentation algorithm, to implement the SLHD adaptive horizontal diffusion scheme developed by the ALADIN consortium, to revise the representation of cirrus clouds and various physical aspects of the microphysics scheme. The AROME surface scheme (SURFEX) will be integrated into the ALADIN code in support of the ALADIN consortium's activities.

3. ARPEGE/ALADIN data assimilation

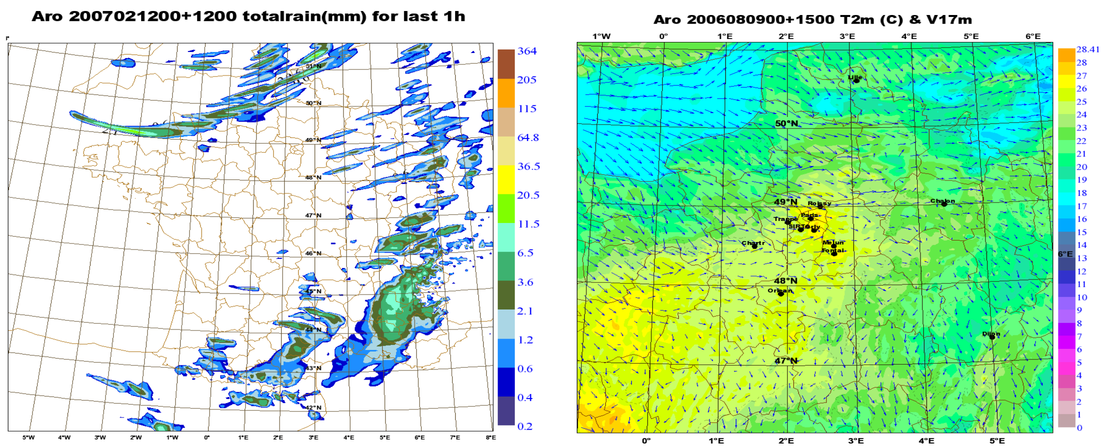
ARPEGE and ALADIN-France use about the same setup, except that ARPEGE uses an incremental 4D-Var analysis algorithm (with coupled OI surface analysis) whereas ALADIN uses nonincremental 3D-Var. Unlike ARPEGE, ALADIN 3D-Var assimilates Meteosat radiances. The major data assimilation upgrades in 2006 have been: assimilation of Quikscat scatterometer winds, of Aqua AMSU radiances, of MTSAT-1R atmospheric motion winds, of MODIS (Aqua and Terra) AMW winds near the poles, of extra AMSU channels, of SSM/I DMSP-F13 clear radiances, of AIRS (Aqua) radiances, of **ground-based GPS zenithal total delays** from European networks, plus upgrades to the radiosonde temperature and Meteosat radiance bias correction schemes, and upgrades to the SATOB and profiler data selection policy.

In the 4D-Var algorithm, the linearized stratiform precipitation scheme has been removed (it degrades the forecasts since the introduction of the Lopez physics in the main model); the variational observation quality control of ECMWF has been activated. Flow-dependent quality control thresholds are now used, thanks to a (six-member) randomization technique that estimates background standard errors in the 4D-Var cost function. The 4D-Var minimization now uses 25

iterations in each of the two inner loop minimizations (it was 40+15 previously).
The plans for 2007 include an upgrade to the 4D-Var increment resolution from T149L46 to T224L60, the introduction of a non-linear balance and a new humidity variable in 4D-Var and 3D-Var, the use of GPS COSMIC radio-occultation data, of several instruments onboard the Metop satellite, and SSMI/S radiances.

4. The AROME system

The AROME model has been running daily throughout 2006 without any major problem. Also, it has been tested on various domains, including equatorial Africa (the AMMA field experiment), central Turkey, and several central European and nordic domains (runs by the ALADIN and HIRLAM consortia). All these runs - in research mode and in dynamical adaptation of lower resolution models - gave a broad view of the AROME performance. The model appears to be very robust and gives reasonable results in all weather situations. The model technical setup is still cumbersome and it is being simplified. The most obvious strength of the model is the ability to give strong precipitation warnings in situation of strong deep convection. The most obvious weaknesses have been the low-level parameter biases and the cloud cover forecasts.
Low-level forecast errors, as diagnosed using scores against SYNOP data, have been traced back to bugs in the physiography setup, and to weaknesses in the vertical interpolation formulae used in the PBL below the model's lowest mass level. Improved formulae (e.g. using the Paulsen approach) have alleviated some night-time biases, which improves the AROME T2m/RH2m objective scores to the extent that they now consistenly beat the ALADIN-France scores. A lack in low level cloudiness has been attributed to deficiencies in the representation of shallow convection at the top of the PBL. Thus, a subgrid shallow convection scheme has been introduced in AROME, using a combination of the Kain-Fritsch-Bechtold scheme (shallow part) and a new closure based on an eddy-damped mass-flux approach (P. Soares). This improved the forecast PBL vertical thermodynamical profiles and created more realistic cumulus cloud structures. Work in this area is still ongoing. A third deficiency of AROME is the handling of narrow valleys. The semi-lagrangian formulation of the AROME non-hydrostatic dynamics is rather smoothing, which means that very local features (e.g. pockets of cold air below inversions) are not well represented in valleys where the width is less than twice the model numerical grid size. Experiments have been carried out with various horizontal diffusion schemes (so-called SLHD semi-Lagrangian scheme) to try and minimize this behavior.
Other advances in AROME physics include a better representation of fog (including aerosol dependnecy and sedminetation of fog droplets), the introduction of a prognostic snow scheme, tests of interactive ocean mixed layer schemes, improvements to the cloud/radiation interaction, and the development of an experimental version of AROME with interactive chemistry, dust and aerosols. The physics/dynamics interface is being revised in order to improve code interoperability with other developments of the ALADIN consortium.
The AROME data assimilation is being adapted from the ALADIN 3DVar system to a higher resolution (dx=2.5km). A variational background error term (the so called *Jb*) was computed using AROME ensemble forecasts, forced by ARPEGE ensemble data assimilations. The corresponding structure functions are quite sharp, and sensitive to the vertical stratification: anticyclonic and convective weather produces very different forecast error covariances. Finally, radar processing has been implemented in AROME 3DVar, and first assimilation experiments of Doppler wind components are promising.
The AROME daily runs have been upgraded to cover the whole mainland France and Corsica using daily 30-h forecasts, in January 2007.



Two samples of AROME real-time forecast fields: a winter frontal rain event over France (left panel; the colors represent 1-hourly liquid rainfall), and a summertime afternoon with a heat island effect on Paris (right panel; the colors represent 2m temperature, the arrows represent 10m wind).