ALADIN : What's new ? Group Report 2001-2002

A. LIFE OF THE PROJECT

The ALADIN project is addressing a new medium-term research plan, covering 2002-2004, while moving towards a new organization of research : more decentralization balanced by an enhanced coordination (both thematic and transversal) and a strict management of source code, to limit divergence between applications.
Three major training courses were or will be organized along 2002 :

- *"Numerical Methods and NWP Applications"* (ALATNET), 27-31 / 05 (*Si*)
- *"Physics"* (LACE), 16 / 09 - 04 / 10 (*Cz*)
- *"Code Maintenance"* (LACE), 25 - 29 / 11 (*Hu*)

The present status of the 15 operational suites is described in national presentations and in the latest ALADIN Newsletter, available on the web site :

http://www.cnrm.meteo.fr/aladin/

B. HIGH-RESOLUTION DYNAMICS

New NH prognostic variables

Linear stability analyses led to the following proposals for the replacement of the two additional non-hydrostatic prognostic variables :

pressure departure :

$$\mathcal{P}_0 = \frac{p-\pi}{\pi^*} \quad \Rightarrow \quad \mathcal{P} = \frac{p-\pi}{\pi} \quad \text{or} \quad q = \ln\left(\frac{p}{\pi}\right) = \ln(1+\mathcal{P}) \quad \Rightarrow \quad q = \ln\left(\frac{p}{\pi}\right)$$

pseudo-vertical divergence :

$$d_0 = -g\,\frac{\pi^*}{m^* R T^*}\,\frac{\partial w}{\partial \eta} \Rightarrow d_3 = -g\,\frac{p}{mRT}\,\frac{\partial w}{\partial \eta}\left(= \frac{\partial w}{\partial z}\right) \Rightarrow d_4 = d_3 + \frac{p}{mRT}\nabla_\eta \phi \cdot \frac{\partial V}{\partial \eta} = D_3 - \nabla_\eta \cdot V$$

$$(m = \partial\pi / \partial\eta)$$

Semi-implicit three-time-level semi-Lagrangian dynamics was proved to be unstable with the initial choice $(d_0\ \mathcal{P}_0)$ whenever the background flow differs from the semi-implicit values, denoted by a * in equations. Suppressing the reference to semi-implicit parameters in the definition of prognostic variables, i.e. using $(d_3\ q)$, significantly improves the situation, but is not enough in the presence of orography. The preliminary tests performed with $(d_4\ q)$ are quite convincing.

Predictor-corrector scheme

To ensure the stability of two-time-level semi-Lagrangian dynamics, a predictor-corrector approach, involving iterations of the semi-implicit scheme, is required. This was designed in cooperation with the IFS team, and is now available with the old and the first new sets of NH variables

Lower-boundary condition and vertical discretisation *(cf. LACE report)*

Smoothing of orography

A new and flexible method to smooth orography, damping the smallest scales, was proposed : adding a new spectral term to the cost-function used for the optimization of spectral orography.

High-resolution (quasi-)academic validation experiments

A large set of experimental frameworks was used to validate new developments and evaluate the skill of dynamics at high resolution.

2D academic cases

- nonlinear quasi-hydrostatic flow *(Héreil and Laprise, MWR, 1996)*
- various regimes with constant (U, h, a) for Agnesi mountain (from linear hydrostatic to nonlinear non-hydrostatic)
- potential flow
- steady trapped lee-waves with uniform wind-shear and Brunt-Vaisala frequency *(Keller, JAS, 1994)*

2D (quasi-)academic cases used for intercomparison

- nonlinear non-hydrostatic flow (breaking waves)
- non-steady trapped lee-waves : real profiles of wind and temperature, at 2 or 5 km *(Shutts and Broad, QJRMS, 1993)*

3D quasi-academic case **"ALPIA"** (following "SCANIA")

- uniform wind, constant Coriolis parameter, ICAO-like temperature profile
- 4 embedded domains over the French Alps :

Δx	10 km	5 km	2.5 km	1.25 km
vertical levels	30	42	60	85
Δt "safe" (NH)	200 s	60 s	25 s	10 s

- comparing options : Eulerian versus semi-Lagrangian (three-time-level), explicit versus semi-implicit, hydrostatic versus non-hydrostatic.
- searching the maximum "safe" time-step, with a still preliminary version, i.e. the intermediate choice for NH variables and no predictor-corrector scheme.

C. COUPLING PROBLEMS

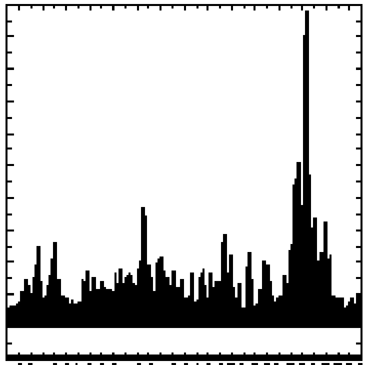
Search for new time-interpolation methods

Further experiments were performed to evaluate the impact of the coupling frequency (6h, 3h, 1h), or the time-interpolation method (linear, quadratic, linear accelerated). Besides, new decompositions of fields were tested : phase / amplitude, growing / moving parts.

The most innovative approaches were not so successful in real case experiments, but may be used to design "warning indices". Such quantities, introduced at the level of the coupling model, could help controlling the coupling frequency in the case of linear time-interpolation. For instance, the following index ("truncation error") was deduced from the linear-accelerated method :

$$e = \frac{1}{4} \left\| \left(\partial_t X(t_2) - \partial_t X(t_1) \right) (t_2 - t_1) \Big/ \left(X(t_2) + X(t_1) \right) \right\| = \left\| 1 - X\left(\frac{t_1 + t_2}{2}\right) \Big/ \left(\frac{X(t_1) + X(t_2)}{2} \right) \right\|$$

and proved quite efficient for ALADIN-Belgium and the 99 Christmas' storm :



"***e***", computed on msl-pressure over the whole coupling domain

minor ticks each 3 hours,
forecast ranges : +6h, +9h, ..., +27h

Tendency-coupling for surface pressure

The coupling of tendencies, rather than fields, was proposed to handle the problem of large discrepancies in the orography between the coupling and the coupled models near the boundaries (still within Davies' relaxation scheme). It was first experimented with surface pressure, the most sensitive field. The new scheme is now running in 3D, but more targeted impact studies are required.

Spectral coupling

Spectral coupling was considered as an alternative / complementary method to Davies' one, allowing to extract more information from the coupling files. It is now coded in the 3D model, and the first experiments show a reasonable behaviour.

D. PHYSICAL PARAMETERIZATIONS

Trying to set up an efficient networking

That's not so easy ! However the several meetings organized along the first semester of 2002 allowed useful discussions and the emergence of new ideas (e.g. a renewal of convection schemes).

Solving problems in operations :

Most efforts, in physics, were dedicated to the cure of the many problems encountered in operations :

- towards a safer code (debugging, safety locks, reproducibility)
- strong oscillations : horizontally, on the vertical, in time ... *(cf. LACE report)*
- instable behaviours, such as spurious cyclogenesis (or even blow-up !) : This was addressed through changes in the convection schemes, retunings for PBL

parameterizations, etc. But more understanding is required to find the most appropriate solution. For instance, a problem of spurious cyclogenesis in the western Mediterranean sea may be cured either by changing the dependency on resolution within the present convection scheme or introducing a new "shear-linked" convection parameterization.

- underestimation of low-level cloudiness : This led to an investigation of the respective parts of shallow convection, vertical diffusion, ... and the proposal of a new parameterization, based on *Xu and Randall* and first tested in the EUROCS framework.

This list is far from exhaustive and the situation is evolving very quickly !

Restarting work on :

Going to more positive aspects, research restarted in the following domains :

- orographic forcing : That's just the beginning, goals look more clear.

- radiation : There is now a (small) dedicated ALADIN team ! The first steps were the introduction of a geographical and seasonal dependency for ozone profiles, and new tests using improved optical depths (especially near the surface), with unexpected good results.

- functional boxes for handling liquid water and ice : Work is at the stage of 3D experiments, and many of the problems encountered were shown to come from outside, i.e. from the fluxes provided by other physical parameterizations.

Validation and diagnostics

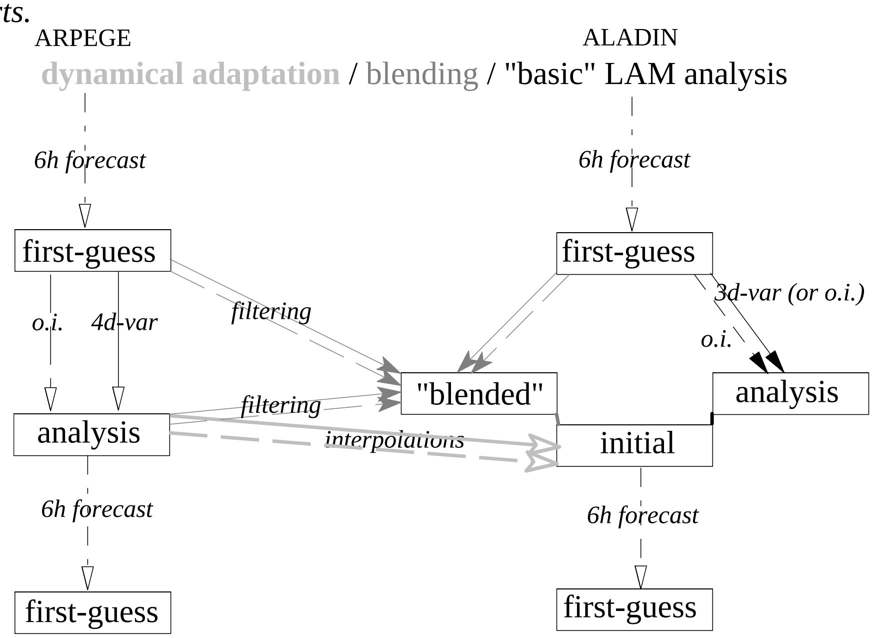
A "model to satellite" application was developed, with an expensive but complete version, using the Morcrette radiation code followed by a channel selection, and a cheap one, based on the RT-TOV7 code. It includes the decoding and filtering of GRIB data, to allow easier comparisons. "Cloudy" and "clear sky", "infrared" and "water vapour" pictures may be produced.
Besides the SCM version of ALADIN is more and more widely used and was interfaced with new field experiments.

E. DATA ASSIMILATION

Cycling

Many experiments aimed at testing and comparing various combinations of the following initialization methods :
- for upperair fields : dynamical adaptation, dfi-blending, O.I., 3d-var
- for soil and surface : dynamical adaptation, surface blending, O.I.
using various background error statistics and coupling methods, and different model configurations : ALADIN-Morocco, -LACE, -Hu, -France, -Belgium.

The figure below illustrates the basic configurations : pure data assimilation (operational in Morocco), blending (operational for LACE) and simple dynamical adaptation (used everywhere else). Other possible combinations were tested, e.g. between 3d-var and dfi-blending for upperair fields (blendvar and varblend) or between dfi-blending for upperair and O.I. for soil and surface fields (canblend and blendcan). *More details are available in other ALADIN reports.*



Besides, the work on 3D-FGAT is progressing, 4D-screening is now ready.

<u>3D-var : refinements for background error statistics</u>

The requirements for LAM background error statistics were formalized and the presently used "NMC-lagged" method justified. Some refinements are on the way, trying to better represent geographical dependency.
Besides, other methods are tried, such as the use of "wavelet" functions or the "ensemble analyses" approach.

<u>3d-var : intensive validation</u>

A detailed case study was performed with ALADIN-France on "MAP IOP 14" (02-03/11/1999). *It is described in a dedicated presentation.*

<u>Soil/surface assimilation</u>

A new statistical model was designed for the O.I. analysis of 2m temperature and relative humidity. Statistics were first computed using the Lönnberg-Hollingsworth method, and considering geographical and seasonal variations. An improved formulation of the coefficient of correlation was proposed :

$$\rho_{T/H} = \exp(-r^2 / 2a^2_{T/H}) \quad \Rightarrow \quad \rho_{T/H} = \exp(-r / 2a_{T/H})$$

together with retunings of standard deviations and characteristic lengths.

A spatial smoothing of the soil-wetness-index (soil moisture) was introduced within diagnostic analyses first, within soil moisture assimilation afterwards. It enables to reduce horizontal heterogeneity and subsequent forecast errors.

A few combinations of the (O.I. based) assimilation of soil and surface fields with dfi-blending for upperair spectral fields were tested with ALADIN-LACE.

To end with, a prototype version of 2d-var assimilation for mean soil moisture is now ready. The underlying hypotheses : "linear variations" and "gridpoint decoupling" were carefully checked, and a "double chess" approach chosen for the computation of the gain matrix. The next step is now the introduction of a spatial smoothing of soil moisture, as for O.I. .

Observations

The interfacing of the model with ODB is very slowly progressing, due to portability problems and the lack of documentation. Help from IFS is needed (and was asked, with a negative answer).

The first 3D-var experiments using raw radiances (ATOVS data) are running. The above-mentioned case study gave the opportunity to use pseudo-profiles of humidity, derived (a posteriori) from satellite data. Research on the use of IASI data over land is going on, background error matrix and emissivity maps are ready.

Simplified physics

Modifications in the simplified parameterization of large-scale precipitations were proposed (and successfully tested) in the framework of sensitivity studies using the adjoint model. This was done at a resolution of about 10 km.
Besides, the consistency between vertical diffusion schemes, in the full and simplified physics, was improved.

A posteriori validation and retuning of assimilation algorithms

More understanding of the method (validation, limitations, applications) was acquired along thess summer months. The main validation diagnostics are :

- "Talagrand index" :

$E(J_{min} / P)$, with : $J_{min} = min(Jb+Jo)$, P= number of observational data

- "estimated global error variance rescaling", for background and observations :

$Sb = Jb_{min} / Tr(KH)$ and $So = Jo_{min} / Tr(I_p - HK)$

with H= observation operator, K= gain matrix

And the main remarks are the following. (1) These diagnostics provide a global information on the system. (2) There is a clear need to compare these "a posteriori" results with independent diagnostics (here output of a Lönnberg-Hollingsworth method, both for variances and correlation length-scales). (3) Since a posteriori validation contains all the scales, there is a fundamental difficulty in assessing the amount of scale-selective error variances. (4) The diagnostics exhibit clearly case-dependent behaviours, which indicates that the error statistics in the LAM are sensitive to weather systems. (5) Working with real data implies the design of tractable pragmatical applications, and a small departure from the theoretical framework.

Predictability

First explicit mention in the research plan !