CURRENT INVESTIGATIONS AT METEO-FRANCE ABOUT DEEP CONVECTION AND CYCLOGENESIS IN NUMERICAL WEATHER PREDICTION

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ABSTRACT

This presentation is a short overview of the present quality and on going improvements for operational Numerical Weather Prediction at METEO-FRANCE: model control, role of a multi-scale approach in research and validation processes, quality of the Limited Area Models, march towards higher resolution, role of the European collaborations in our NWP development step.

Introduction

The French global model ARPEGE and its limited area model (LAM) ALADIN both are the result of European cooperations: the data assimilation and the dynamics of the global model have been developped jointly with ECMWF (partners underlined on figure 1), while dynamical and physical aspects of ALADIN are the result of a wide european collaboration involving up to 16 countries (shaded on the same map).

The models resulting from these collaborations are presented in figure 2: the grid of the global ARPEGE model is in the upper part of the figure; this spectral model uses a stretched grid, truncation T199; the resolution varies from about 20 km over Europe to 200 km at the antipode. Below on the right is shown the grid of another ARPEGE global model, designed to perform tropical cyclones predictions over the Indian Ocean; this model differs from the first one by a rotation of the grid, in order to put the high resolution area over the Indian Ocean. Both global models are run in France. In the middle of the figure one can see several versions of the limited area model ALADIN, coupled with the ARPEGE Europe global model. These LAMs differ both by their geographical location and their resolution, but share the same physico-dynamical formulation. Each model is run by the relevant country from the project; resolutions are between 7 km and 12 km.

Cyclogenesis sensitivity

Let us now enumerate the main components of a typical NWP system (figure 3):

1. The initial conditions are given both by the data assimilation and coupling methods for the LAMs.

2. Starting from these initial conditions the prediction model can be split in two main parts:

    (a) The dynamics, in which one can change the formulation of advection, the number and repartition of vertical levels, horizontal resolution, or expression of horizontal diffusion.

    (b) The physics comprises four main parts: radiation, friction and evaporation processes, cloud and precipitation schemes, and gravity wave drag.

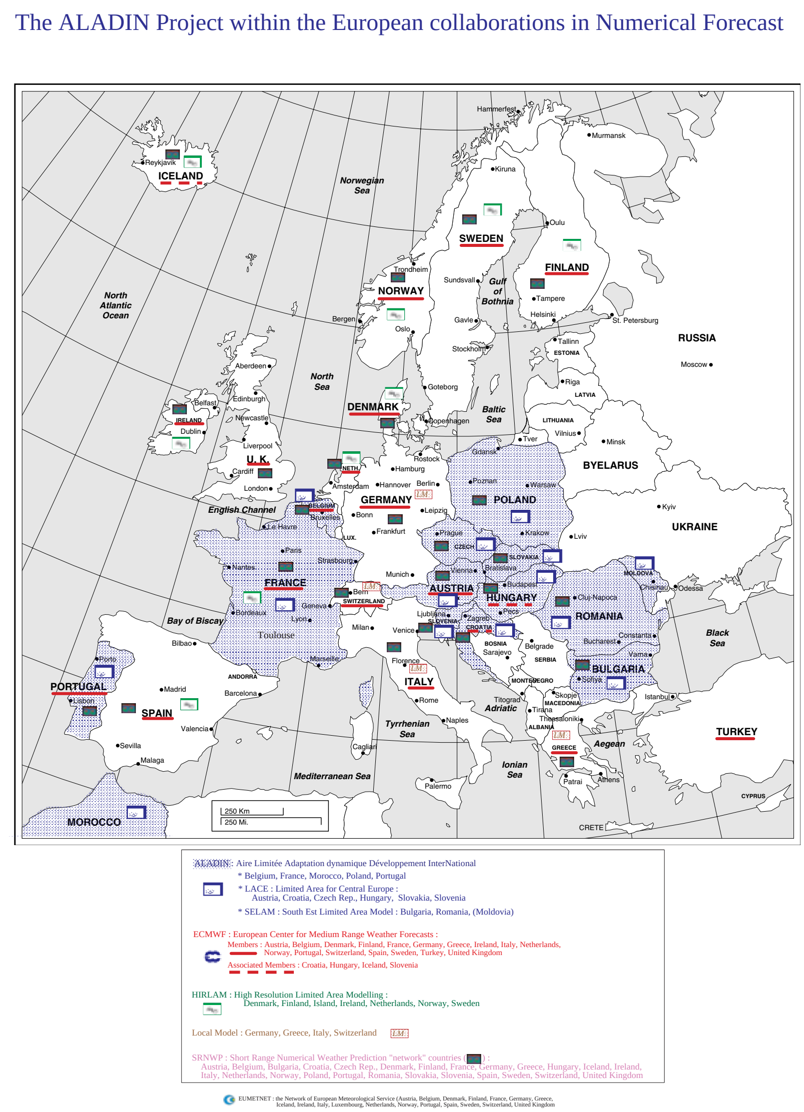

Figure 1: French collaborations for the operational NWP. Source: Patricia Pottier, METEO-FRANCE.

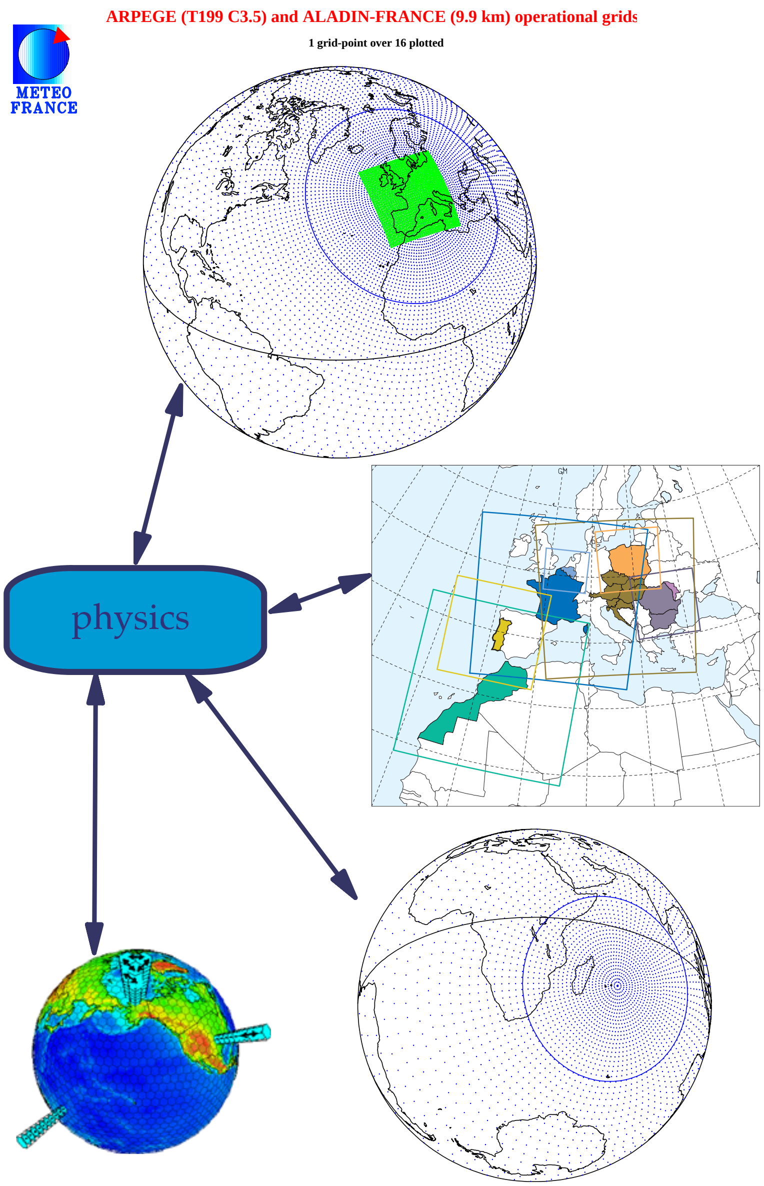

Figure 2: Grids of some models used in operations at MÉTÉO-FRANCE. The image below on the left is by courtesy of the Colorado State University.

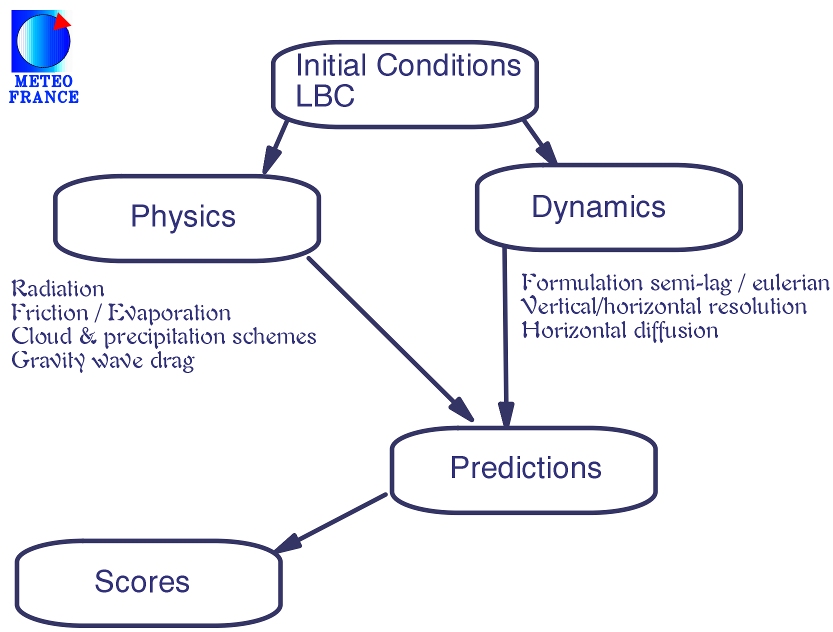

Figure 3: Main components of a Numerical Weather Prediction system.

To which items from that list are strong cyclogenesis events sensitive to? The bad news are that these events are unfortunately sensitive to *all* items!... The good news however are that the space and time scales involved by those items are different: for example, if one is interested by very short range forecasts, like in nowcasting, the atmosphere is mainly inertial, so that one can focus on analysis and dynamical formulations of the model. For 24 hours forecasts of cyclogenesis, friction and evaporation / precipitation are the main additional components from physics to focus on. Stormtracks in the model are finally deeply dependent on pole-equator differential heating due to radiation, and to gravity wave drag, which governs blocking non-blocking periods in the model.

So the crucial point is: on which items from such a long list put human and computer power, to improve the prediction of strong cyclogenesis events? Two examples giving answers to that question will be shown.

The first example is a study of cyclogenesis over the Adriatic Sea: extensive sensitivity tests have been done in the ALADIN frame on lateral boundary conditions, resolution, representation of orography, role of the physics, etc... They have shown that deep lows over this region are mainly adiabatic, and orographically driven: it is possible to get good predictions even at 24 hours, while switching off the physics, as shown on the March 29, 1995 case!... To get right predictions high resolution is required (good predictions were obtained with a 7 km grid), and special attention has to be paid on the representation of orography.

The second example is a score diagram, intended to split good and bad scores of a given model into weather regimes. This diagram, shown on figure 4, is useful to diagnose for which type of weather regimes a given model is bad, or worse than another model. Since weather regimes address particular items from the sensitivity list proposed before, one can select the actions having priority over the others.

Multi-scale approach

It is quite easy to tune a model on a given situation to produce an observed field, like precipitation or pressure value at the center of a given low. But while doing this, the danger is to create compensating errors: a lack of heating due to an underestimatation of vertical turbulent processes can be compensated for example by an overestimation of condensation processes.

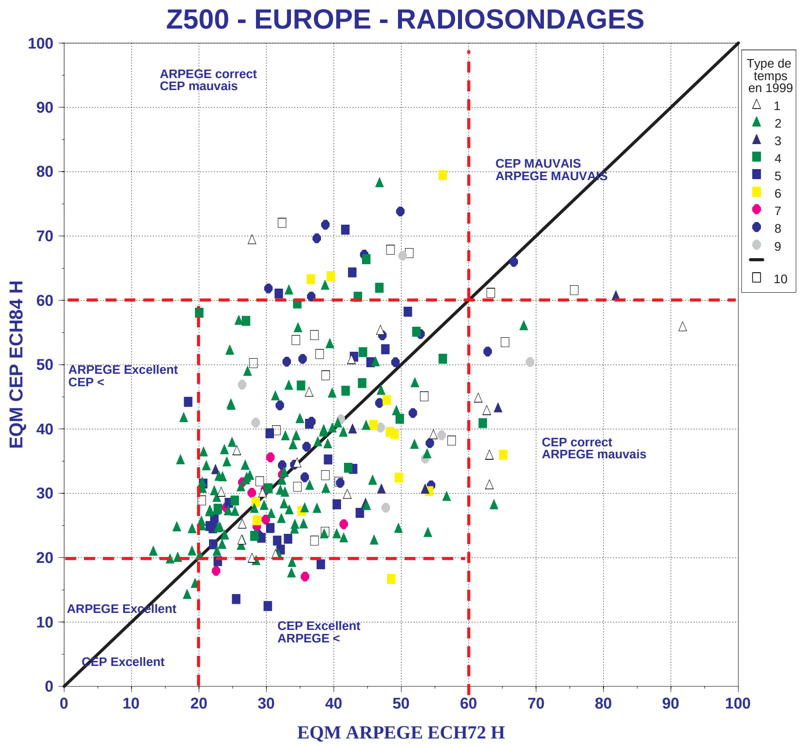

Figure 4: "Scattering scores" on a 9 months period. On X axis: RMS error of 500 hPa geopotential from the French ARPEGE model over Europe (in meters). On Y axis: same for the ECMWF model (12 hours lag). One dot per day; the marker is related to a given weather regime from an automatic classification, like shown on figure 5. Source: Marc Tardy, METEO-FRANCE.

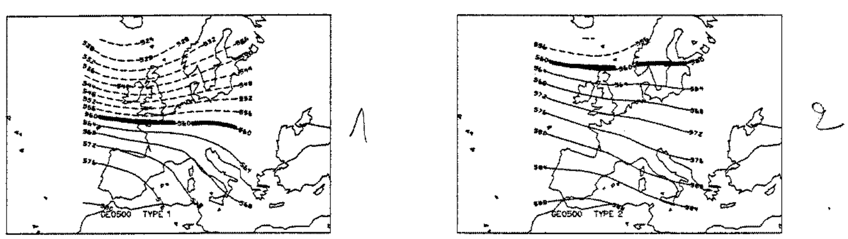

Figure 5: Two of the ten weather regimes used in the automatic classification of weather events over France. The field is here the 500 hPa geopotential. Source: Patrick Bénichou, METEO-FRANCE.

One can thus get the right results for the wrong reason. This can occur every time the validation of the model modifications are done on a too small set of situations, or if those are correlated (same region, or weather regime, or resolution, etc...).

The two global ARPEGE models and the LAMs used in operations, already shown on figure 2, share the same physics. One of the reasons for this choice is that this allows through operational scores to have an idea of advantages and drawbacks of the same physics at different places like mid-latitudes, tropics, polar regions, or over a given area with different model resolutions.

For example, as we introduced some weeks ago modifications in the deep convection scheme, we made tests both at high resolution in ALADIN, looking at low level flow convergence compared to METEOSAT cloud images, and at larger scale in the global model to look at the impact on the Hadley cell or at cloud fields in zonal mean.

4D-VAR analysis

Just a word about 4D-VAR analysis: data assimilation would be a subject in itself!... Figure 6 shows how beneficial 4D-VAR is with respect to cyclogenesis predictions: in an optimal interpolation (OI) or a 3D-VAR analysis, information from an isolated observation is added to the guess in a way which is isotropic in the horizontal and barotropic in the vertical (top panel). But in active baroclinic systems, the structure of the errors should be more complex, and become anisotropic and baroclinic, as it is in the 4D-VAR approach for observations which are not right at the starting point of the so-called trajectory for the assimilation window. The influence of dynamics will be greater for observations towards the end of the assimilation window. For instance, one can see on bottom panel (+6 hours) that the increments are more distorted than in the middle panel (+3 hours). So 4D-VAR increments are done consistently with the 3D dynamics of the model, and will better update the existing baroclinic structures from the previous model forecast for the considered time range.

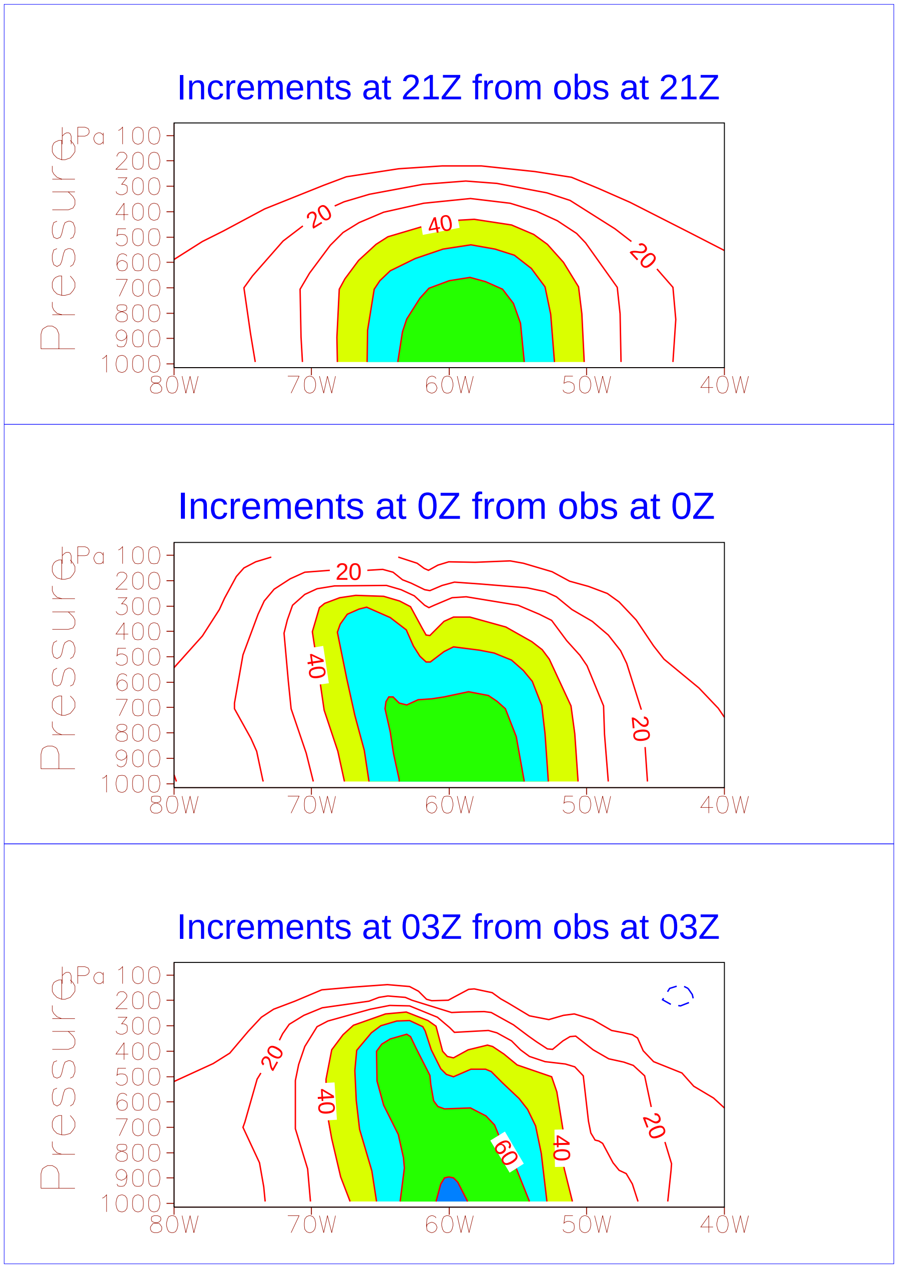

Figure 6: Comparison of 3D and 4D VAR increments of geopotential, in cross-section, for an observation of geopotential at 850 hPa located at 60W. Increments are the quantity added to a guess to produce the corresponding analysis. Above: 3D-VAR or 4D-VAR for an observation at starting point of the minimization trajectory; middle and below: 4D-VAR, for an observation 3 hours or 6 hours after the starting point.

Conclusion

The predictability of cyclogenesis has improved:

- 3D and 4D-VAR produce more realistic initial conditions than OI did.
- Present resolutions catch the orography forcings in the Mediterranean.
- Multi-scale approach is safer than LAMs only or global only.

Perspectives concern all aspects of NWP: analysis, physics , dynamics, scores and validation processes.

Acronyms

ALADIN: Aire Limitée Adaptation Dynamique Initialisation

CNRM: Centre National de Recherches Météorologiques

ECMWF: European Centre for Medium Range Forecasting

LAM: Limited Area Model

NWP: Numerical Weather Prediction

OI: Optimal Interpolation

RMS: Root Mean Squared