Report from the HARMONIE 4D-Var working week at Meteo-France 8-12 December 2008

Participants: Bernard Chapnik, Nils Gustafsson, Magnus Lindskog and Ole Vignes with support from other Meteo-France staff members (Claude Fischer, Francois Bouttier, Loik Berre, et al.)

1. Review of the status of the ALADIN 4D-Var from an algorithmic point of view

A first framework for ALADIN 4D-Var has now been constructed and is running including minimization, use of all types of observations, the background error constraint and a weak digital filter constraint. Filip Vanna has done a very good work with the TL and AD versions of the ALADIN model and Bernard Chapnik has very quickly and efficiently put together the 4D-Var framework.

Bernard Chapnik demonstrated the different steps in the ALADIN 4D-Var calculations. The algorithms and the data flow follow very much the ARPEGE 4D-Var, and therefore they differ from the HIRLAM 4D-Var and the ECMWF 4D-Var due to the constraints imposed by the ARPEGE variable resolution (ARPEGE 4D-Var minimizations are carried out in a non-stretched geometry, while the ARPEGE non-linear model integrations are done in stretched geometry). Table 1 summarizes these differences. Some further comments on these differences:

- 2 main differences are clearly related to the ARPEGE stretched geometry: (1) The use of FULLPOS for all geometry changes in ALADIN/ARPEGE, while HIRLAM (and ECMWF) are using simpler spectral truncations and filling in of zeros when going from low to high resolution increments and vice versa. (2) The running of a low resolution trajectory for linearization of the TL and AD models. HIRLAM intends to test the simpler HIRLAM/ECMWF solution also for ALADIN 4D-Var. This issue was raised by Nils in a conversation with Francois Bouttier, who gave his support to such tests by HIRLAM staff. With regard to the ECMWF method for low resolution trajectory linearization, the study of their new technique of "integral preserving" interpolation software should also be considered. Karim Yessad and Gerald Desroziers are Meteo-France contact points on coding issues with regard to trajectory calculation options. With regard to FULLPOS versus simpler techniques based on spectral truncation and zeroing, effects on balances need to be investigated.
- In the first tests of ALADIN 4D-Var by Bernard Chapnik, a fixed size extension zone and a fixed size coupling zone, both in terms of the number of grid distances, were applied. Since the total extended area needs to be exactly the same in low and high resolution, this efficiently means a shrinking inner integration domain with decreasing resolution of increments. This needs to be modified by HIRLAM staff in their continued tests and development.
- The fixed size extension zone in the background error constraint (used also in the contrd vector) and in the TL/AD models (+ observation operators) introduces unnecessary calculation in-efficiency in ALADIN 4D-Var. Claude Fischer has been considering the necessary code modifications to introduce several (two) sizes of the extension zone, but not yet found a "non-ugly" code modification strategy. Claude will come up with a first draft of a report on this issue during January-February 2009, and HIRLAM staff will thereafter continue the investigations and also carry out the necessary code modifications after consultation with Meteo-France and ECMWF staff (Mats Hamrud).
- For multi-incremental minimization, the minimization needs access to the background as well as the first guess model states. It is not clear from the demonstration during the working week how this is handled in ALADIN 4D-Var (HIRLAM staff will keep in contact with Bernard Chapnik and Gerald Desroziers).

ALADIN 4D-Var	HIRLAM 4D-Var
"Lowres": Preparations of LBC and first guess at low resolution for the non-linear model (this is done by FULLPOS)	Not applicable in HIRLAM since all non-linear model calculations are done at full resolution.
"Screening": High resolution non-linear model integration over the assimilation window, calculation of innovations and screening.	Done in the same way as in HIRLAM. However in HIRLAM these calculations are done in two different steps (forecast run by the gridpoint HIRLAM and the rest at the start of HIRVDA)
"Obsccma" Compress the observation data sets after screening (ODB).	Done in a similar way in HIRLAM (CMA and observation modules)
"Trajectory" (first part of the "minimize"): low resolution non-linear model integration over the assimilation window to be used as a basic state for the linearization of the tangent-linear and adjoint models	Not applied in HIRLAM 4D-Var, where the trajectory is obtained by truncation of the output from the high resolution forecast run done by "screening". This truncation is very simple, extraction of the appropriate wave number coefficients in spectral space and horizontal interpolation of surface fields.
"Minimize": One outer loop minimization including the background error constraint, TL and AD model integrations, observation operators and weak digital filter constraint. Differences between HIRLAM and ALADIN - Minimization with respect to the accumulated increment from several outer loop minimizations. - Same extension zone everywhere. - No VarQC	"Minimize": In a broad sense similar to ALADIN 4D-Var. Differences: - Minimization with respect to the partial increment of each outer loop iteration. - Possibilities for different extensions zones in the background error constraint/minimizations and the TL/AD model. - VarQC (leads to non-quadratic problem)
	"TL propagate": Propagation of the assimilation increment by the low resolution TL model (reference option)
"Highres": Construction of high resolution increments and analysis: HR(analysis)=HR(first guess) + fullpos(LR(analysis))-fullpos(LR(first guess))	"Highres": Construction of the high resolution increment by filling out with zeros in spectral space.
"NL propagate": Propagation of the analysis field from the start of the assimilation window to the main analysis hour by the high resolution non-linear forecast model	"NL propagate": Similar to what is done in ALADIN 4D-Var (option)

Table 1: Overview of differences between the HIRLAM 4D-Var and the first version of the ALADIN 4D-Var.

2. ALADIN 4D-Var schematics

The following flow diagram (Figure 1) illustrates the main steps in an ALADIN 4D-Var assimilation as presently designed. The illustration is for a data assimilation cycle at 00 UTC, utilizing a background state from 18 UTC. HR means High Resolution and LR means Low Resolution.

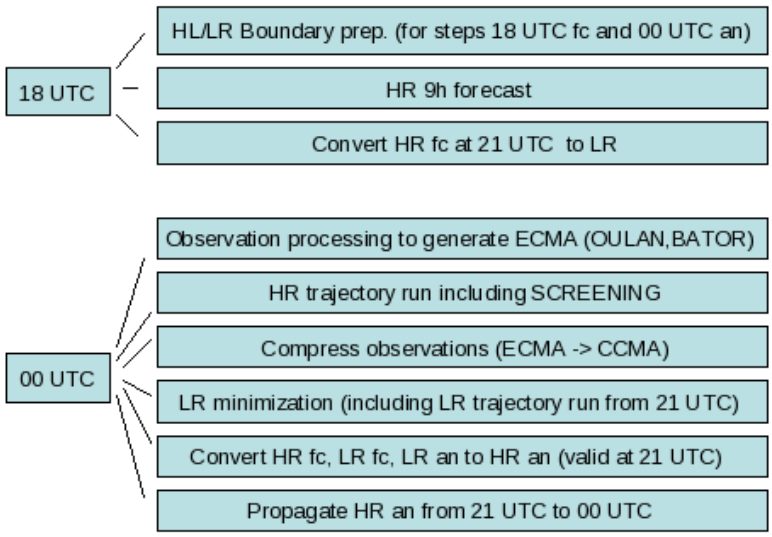

Figure 1. *Flow diagram illustrating the main steps in an ALADIN 4D-Var assimilation for 00 UTC, as presently designed.*

3. A plan for the continued work to develop HARMONIE 4D-Var

The further testing and development of ALADIN 4D-Var will be carried out by HIRLAM staff within the HARMONIE framework. The following most urgent steps are envisaged:

- Dump all files and namelists from the demonstration-run of ALADIN 4D-Var by Bernard Chapnik under OLIVE at Meteo-France to be used for a test-run at ECMWF (done by Magnus).
- Try to run HARMONIE 3D-Var with an extension zone different from 11 gridpoint (done by Nils).
- Introduce the code modifications of Bernard Chapnik into the HARMONIE version 35 (done already), try to compile and try to run HARMONIE 3D-Var with the modifications included (started by Ole).
- Try to repeat the ALADIN 4D-Var test of Bernard Chapnik on the ECMWF computer within a first simplified 4D-Var HARMONIE framework (Magnus with support from Ole).
- Start develop 4D-Var scripts for HARMONIE, based on the algorithms in the test of Bernard and utilizing to the extent possible existing 4D-Var scripts for HIRLAM. (Ole with support from Magnus and Nils)
- Arrange a HARMONIE 4D-Var working week at met.no (April 2009?).
- The ALADIN community will be informed about further activities related to HARMONIE 4D-Var and will also be invited to participate in the suggested 4D-Var working week.

4. Other issues raised during the 4D-Var working week

- The possibility to apply the background error statistics file from a large area to sub-areas included in the large area was discussed during the working week. Claude Fischer gave his support to such a development by HIRLAM staff provided the appropriate "warnings" by the checking software (EDOG?) still will be issued. Nils volunteered to try this code development in order to learn a little bit on dimensioning and allocation in the IFS assimilation software.
- The issue of observation pre-processing was also discussed during the working week, at least informally between Nils and Francois, who both agreed that a future move towards using ECMWF pre-processing and BUFR2ODB would be a productive strategy.