# Blending of initial fields in ALADIN

*(a tentative synthesis of previous contributions)*

Toulouse, March 2001

## 1. INTRODUCTION

In dynamical adaptation mode, the initial conditions for ALADIN short-range forecasts are simply interpolated from those of the coupling model (ARPEGE hereafter). Whatever the quality of the interpolation method the resulting fields are smooth with respect to the higher resolution surface forcing in the coupled model. This leads at least to some spin-up during the early hours of forecast. Moreover, sometimes, some important small-scale features produced by the previous ALADIN forecast are lost and one may face situations when a 24 h forecast is better than the 12 h forecast valid at the same time and based on more recent observations.

The idea of blending is to combine the "large scales" resolved by the ARPEGE analysis with the "meso-scale" features provided by the short-range ALADIN forecast. The underlying hypothesis is that the short-wave part of the guess is more realistic than the short-wave part of the interpolated ARPEGE analysis, thanks to a better balance with the high-resolution surface forcing (orography, soil and vegetation characteristics). This might be considered as a meso-scale data assimilation without (directly) using observations.

## 2. BLENDING OF SPECTRAL FIELDS BY DIGITAL FILTERING

### 2.a Scale selection in the global assimilation of spectral fields

*Incremental approach*

The variational assimilation of spectral fields implemented in ARPEGE is a (multi-)incremental one, where the adjustment of analysis increments is performed at increasing spectral resolutions, till the model (forecast) one.

3d-var assimilation was used till summer 2000. At that time the distance to observations, the surface analysis and the incremental initialization were performed at the nominal resolution, i.e. spectral truncation T199, with a quadratic grid, a stretching factor of 3.5, and the pole of interest over France. The minimization was performed at a lower resolution, i.e. spectral truncation T127, with a semi-linear regular grid.

Within the current multi-incremental 4d-var assimilation, the distance to observations is computed similarly at the nominal resolution, but the computation of increments involves three successive spectral truncations : T42, T63 and T95 (with quadratic regular grids). Surface analysis is still performed at the nominal resolution.

The corresponding gridpoint resolutions are detailed in appendix 1. In this report, "nominal resolution" refers to the resolution of the operational forecast, for ARPEGE or ALADIN.

*Digital filtering in ARPEGE*

The attenuation of high-frequency components within the assimilation process is based on incremental digital filtering, using three different methods.

An external incremental digital filter initialization was performed after 3d-var assimilation and the subsequent surface analyses. It was based on a double-filtering scheme, using a Dolph-Chebyshev filter of fixed stop-band edge and ripple ratio. The time span was chosen as the associated minimum one, so as to minimize costs. This was tuned with the older optimal interpolation analysis.

Within 4d-var assimilation, incremental digital filtering is fully embedded in the analysis of spectral fields, and performed in two steps :

- ♦ a Jc-dfi control : an additional constraint is added to the variational cost-function, to relax the trajectory towards a filtered one at each minimization step, i.e. at low resolution. It is designed so as to act on analysis increments. A Dolph-Chebyshev filter of fixed time-span, equal to the time-window of 4d-var assimilation, is used. Its stop-band edge and ripple ratio are tuned to optimize the response at high or very low frequencies.
- ♦ a semi-internal incremental digital filter initialization performed at the full resolution and with the full physics : it is designed so as to use the first (screening) and last (update) 6h-forecasts performed in 4d-var assimilation (hence the additional cost is negligible). Again, a Dolph-Chebyshev filter of fixed time-span is used, and applied once. Contrary to the 3d-var case, surface analysis is performed after initialization.

The characteristics and the effective response functions of the implied filters are detailed in appendix 2.

2.b Principles of digital filter blending

For spectral fields, the design of a blending procedure involves the definition, first of a transition zone between the longest waves to be taken from ARPEGE and the shortest waves to be kept from ALADIN, and second of an algorithm to combine fields in this intermediate range. The limit resolution of the ARPEGE analysis increments, the location and size of the ALADIN domain and its own resolution provide a first estimate of the "blending cut" spectral truncation for ALADIN, denoted *Tc* hereafter. The method used up to now is detailed in part 2c.

However it would be an error to combine fields using a step function, i.e. to take the ARPEGE information up to truncation *Tc* and the ALADIN ones for the smallest scales, above *Tc*. It is more natural to think about a smooth transition between the two spectra, centred around *Tc*, so as to prevent an initial shock (and to be more consistent with the physical processes of downscale / upscale energy cascades in geophysical fluids). Certainly one could build an explicit blending function by setting a spectral interval centred at *Tc* and a smooth monotonous weighting function to avoid discontinuities. This was tried in fact in ALADIN some years ago. The disadvantage of such an explicit blending is an unknown degree of balance between the spectral fields, and a very delicate choice of both the transition interval and the weights.

To avoid this problem a new strategy was designed, very similar in fact to the one used in ARPEGE assimilation : the use of an incremental digital filter initialization. Thus it is called the digital filter blending (or DFI blending) method. A digital filtering is applied on both ARPEGE analysis and ALADIN forecast (or guess), on the final ALADIN grid but at a lower spectral resolution, *Tc*. The difference between the filtered fields provides a blending large-scale increment, which is added on the final grid, i.e. at the full spectral resolution, to the ALADIN forecast. The choice of the (frequency) filter determines the implicit blending interval and weights.

The resulting initial spectral fields are likely to be well balanced, as a sum of the balanced ALADIN guess and fields filtered using the full model. However an additional digital filter initialization, with a narrow stop-band, may be applied afterwards. The whole procedure is schematized in appendix 3 (a), and may be written as :

$$\mathbf{x}^i_{ALD} = \mathbf{x}^g_{ALD} + \Psi_{L\to H}\left[\overline{\Psi_{G\to L}\left(\mathbf{x}^a_{ARP}\right)}\right] - \Psi_{L\to H}\left[\overline{\Psi_{H\to L}\left(\mathbf{x}^g_{ALD}\right)}\right] \quad \text{instead of} \quad \mathbf{x}^i_{ALD} = \overline{\overline{\Psi_{G\to H}\left(\mathbf{x}^a_{ARP}\right)}}$$

$\mathbf{x}^i$ : initial state  $\mathbf{x}^a$ : analysis  $\mathbf{x}^g$ : guess
$\mathbf{x}_{ALD}$ : ALADIN field  $\mathbf{x}_{ARP}$ : ARPEGE field

$\Psi_{X\to Y}$ : change of geometry ( $G$ - ARPEGE, $H$ - ALADIN nominal, $L$ - ALADIN low truncation)
In practice, $\Psi_{G\to L} = \Psi_{H\to L} \circ \Psi_{G\to H}$, since intermediate files are required for coupling. These transformations are achieved using configuration 927 ( E927 for $G\to H$, EE927 for $H \leftrightarrow L$ ).

Bars denote a digital filter initialization :
- simple bar for the internal filter, applied at low spectral resolution,
- double bar for the external filter, applied at full spectral resolution.

Examples of the corresponding combination of spectra are shown in appendix 4.

## 2.c Tunings

*"Blending cut" truncation*

A first approximation of the "blending cut" or "low" truncation may be obtained as follows :

♦ computation of the average resolution of the ARPEGE forecast model over the ALADIN domain :

$$T^{fa}_{ARP} = T^{f}_{ARP} \times m, \quad \text{where } m \text{ is the average mapping factor over the domain.}$$

♦ computation of the mean resolution of ARPEGE analysis increments over the ALADIN domain, taken as the geometric mean between the average resolution of the forecast model and the highest resolution of the minimization model :

$$T^{a}_{ARP} = \sqrt{(T^{fa}_{ARP} \times T^{m}_{ARP})}, \text{ or } \qquad ln T^{a}_{ARP} = 1/2.\, ln T^{fa}_{ARP} + 1/2.\, ln\, T^{m}_{ARP}$$

♦ computation of the equivalent-ARPEGE truncation for ALADIN :

$$T^{f}_{ALD} = L / 3.dx, \quad \text{where } dx \text{ is the mesh-size and } L = 40\,000 \text{ km.}$$

♦ computation of ARPEGE-equivalent blending-cut truncation :

$$T^{c}_{ALD} = \sqrt[3]{(T^{a}_{ARP}{}^{2} \times T^{f}_{ALD})}, \text{ or } \qquad ln T^{c}_{ALD} = 2/3.\, ln T^{a}_{ARP} + 1/3.\, ln\, T^{f}_{ALD}$$

and the resolution ratio between "high" and "low" spectral resolutions : $r_b = T^{f}_{ALD} / T^{c}_{ALD}$ ,

which should be larger than the coupling ratio : $r_c = T^{f}_{ALD} / T^{fa}_{ARP}$ .

These different steps are detailed for the ALADIN / LACE and ALADIN / France test suites in appendix 1.

*"Internal" digital filter*

The internal digital filter must have a stop-band equal to or larger than those of the various filters used in ARPEGE data assimilation, so as to damp higher frequency components introduced by the interpolation onto the ALADIN grid. The choice is to be refined through the evaluation of very short range forecasts (0 - 6 h).

The first tunings, performed with the LACE model when 3d-var assimilation was still operational, lead to the choice of a filter very similar to the one used in ARPEGE for the external incremental initialization, with a stop-band edge period of 5 hours (see appendix 2). However it leads to some damping of low frequency components of 4d-var assimilation increments, since the involved filters have a stop-band edge period of only 3 hours.

*"External" digital filter*

The external filter is applied on the blending fields to damp the residual noise after the combination of the various components, which are assumed to be well balanced. It acts on model fields, not on increments. The filter used in the case of dynamical adaptation, to damp the noise introduced by interpolations, is close to those used presently in ARPEGE assimilation. As shown in appendix 2,

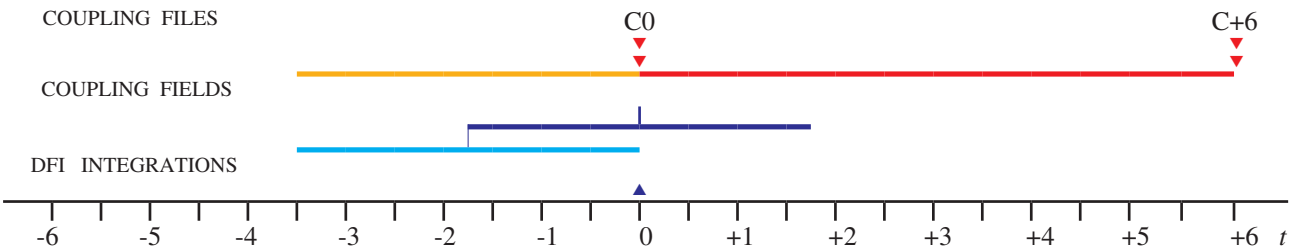
the stop-band edge period is the same, 3 hours, even if the damping is less. It was likely to be a little too strong in dynamical adaptation mode, and the situation may be more critical for blending.

The LACE tunings lead to a suppression of the external initialization in the 6 h-forecasts of the assimilation cycle (described in part 4) and a drastic reduction, to 1.5 h, of the stop-band edge period for short-range (48 h) forecasts. In practice, a further reduction would not be possible with such a long time-step.

*Coupling along DFI*

Since no time-lag is allowed between initial and filtered fields, DFI involves a backward, adiabatic, integration followed by a forward integration using the full model, as described hereafter. Consequently coupling fields must be computed for positive and negative timesteps, though coupling files are usually available at initial time (initial file) and either past or future, never both.

Illustration of standard DFI in ALADIN




The time-span of the filter (Ts) is 3.5 hours here, a non-recursive filter is used, and the coupling period is 6 hours.

In cyan (–), the backward integration is performed from $t=0$ to $t$=-Ts , and filtered. The filtered fields are valid at $t$=-Ts/2 .
In blue (–), the forward integration is run from $t$=-Ts/2 to $t$=+Ts/2, and filtered. The resulting fields are valid at half the time-span, i.e. at initial time.

C0 is the coupling file at $t=0$ , equal to the initial ALADIN file. C+6 is the coupling file at $t$=+6 h.
In red (–), the coupling fields for positive time-steps ($t>0$) are interpolated from C0 and C+6.
In orange (–), the coupling fields for negative timesteps ($t<0$) are extrapolated from C0 and C+6.
When C-6 is available instead of C+6, these two colours are exchanged.

The main question is usually : which choice for C±6 ?

When initialization is performed in the same run as the forecasts, and applies on model fields, coupling fields for positive timesteps are computed as in the forecast, while those for past are extrapolated backward. This is required for simplicity of course, but mainly to ensure a better consistency between filtering and forecast. In this case C+6 is the coupling file at +6 h used for forecast, usually the 6h-forecast from the coupling model interpolated onto the ALADIN domain. The external digital filter initialization in blending mode and the standard initialization in dynamical adaptation mode are concerned by this approach.

The question is to be considered for internal DFI, since it is performed alone and in fact applies on increments. The problem splits into two main alternatives, which may be extended to any use of incremental DFI in ALADIN :
(1) Constant or time-varying coupling ?

With such short time-spans as those used presently, when the time-interpolation of coupling fields benefits to a forecast of maximum length 2 hours, the choice of constant lateral boundary conditions is to be considered. Especially when a 6 hours coupling period is used, and all the more since the associated backward extrapolation may lead to problems in some extreme situations. For instance, the experiments performed within HIRLAM led to the choice of a constant coupling.

(2) Same or different choices for the two parts of the incremental initialization ?

This question is irrelevant in the case of constant coupling fields, of course. In the first experiments with incremental DFI in ALADIN, it was decided to filter the guess using the same coupling files as for the forecast leading to this guess (i.e. taking for C-6 the corresponding initial state), and the analysis with the subsequent forecast, as in a standard initialization. The main alternative choice is to use the same coupling files for both (except at initial time).

In the LACE blending suite, the following was chosen first for internal filtering :

- time-varying coupling fields, with a 6 h period.
- same coupling file at +6 h, corresponding to the subsequent 6 hours ALADIN forecast,

but constant lateral boundary conditions were used afterwards.

## 3. BLENDING OF GRIDPOINT FIELDS

### 3.a Gridpoint fields in ARPEGE / ALADIN

*Surface (2d) variables*

9 surface variables are handled by the present surface scheme or likely to be introduced soon :

| Variable | Symbol | Unit | Official name | Buffer name | Limits |
|---|---|---|---|---|---|
| mean (soil) temperature | Tp | K | *'PROFTEMPERATURE '* | SOILB(:,1,1) | |
| total liquid soil water content | Wp | kg/m2 | *'PROFRESERV.EAU '* | SOILB(:,1,2) | $0. \leq \leq$ Wp*x*(:) |
| total frozen soil water content | Wpi | kg/m2 | *'PROFRESERV.GLACE'* | SOILB(:,1,3) | $0. \leq \leq$ Wpi*x*(:) |
| surface temperature | Ts | K | *'SURFTEMPERATURE '* | RESVR(:,1) | |
| superficial liquid water content | Ws | kg/m2 | *'SURFRESERV.EAU '* | RESVR(:,2) | $0. \leq \leq$ Ws*x*(:) |
| superficial frozen water content | Wsi | kg/m2 | *'SURFRESERV.GLACE'* | RESVR(:,4) | $0. \leq \leq$ Wsi*x*(:) |
| interception water content | Wl | kg/m2 | *'SURFRESERV.INTER'* | RESVR(:,3) | $0. \leq \leq$ Wl*x*(:) |
| snow water content | Sn | kg/m2 | *'SURFRESERV.NEIGE'* | SNOWG(:,1) | $0. \leq$ |
| . . . snow albedo | $\alpha$n | | *'SURFALBEDO.NEIGE'* | SNOWG(:,2) | $\alpha$n*n* $\leq \leq \alpha$n*x* |

Their use depends on the following keys of physics (defined in *YOMPHY*) :

- Tp, Wp, Ts, Ws, Wl, Sn — LSOLV=.TRUE. — (basic ISBA scheme)
- Wpi — LSOLV=LFGEL=.TRUE. — (basic soil freezing)
- Wsi — LSOLV=LFGEL=LFGELS=.TRUE. — (improved soil freezing)
- $\alpha$n — LSOLV=LVGSN=.TRUE. — (improved snow scheme)

The maxima and minima are defined as follows by the physics (*SUPHY1, ACSOLW, ACVEG*) :

- Wp*x* and Ws*x* are computed by *ACSOLW* from the following fields : land-sea mask, land-use type, useful soil depth, percentage of sand, and constants in *YOMPHY1*.
- Wsi*x* = Ws*x*
- Wpi*x* = min (Wp*x* - Wp, GWPIMX)
- Wl*x* = GWLMX $\times$ veg $\times$ LAI
- $\alpha$n*n* = ALBMIN, $\alpha$n*x* = ALBMAX

The constraints are sometimes more strict :

- on sea :
  - Wp $\equiv$ Wp*x* $\equiv$ d2 $\times \rho_l \equiv$ RD2MER $\times$ GCONV
  - Ws $\equiv$ Ws*x* $\equiv$ d1 $\times \rho_l \equiv$ RD1 $\times$ GCONV
  - Wpi $\equiv$ 0.
  - Wsi $\equiv$ 0.
  - Wl $\equiv$ 0.
  - Sn $\equiv$ 0.
  - $\alpha$n $\equiv$ ALBMIN (useless)
- on lakes (whenever identified **and** parameterized, else handled as open sea) :
  - Wp + Wpi $\equiv$ Wp*x* $\equiv$ d2 $\times$ GCONV
  - Wl $\equiv$ 0.

• on ice-cap (land) :

Wpi ≡ Wpi*x* ≡ d2 × GCONV < GWPIMX with the current choices

Wsi ≡ Wsi*x* ≡ RD1 × GCONV

Wp ≡ 0.

Ws ≡ 0.

Wl ≡ 0.

*Surface (2d) constants*

18 "constant" surface fields are handled by the present surface scheme or likely to be introduced soon :

| Field | Symbol | Unit | Official name | Buffer name | Time-variations |
|---|---|---|---|---|---|
| g*dynamical roughness length | $g*z0_d$ | m2/s2 | 'SURFZ0.FOIS.G ' | VARSF(:,1) | (1) |
| snow-free albedo | $\alpha$ | | 'SURFALBEDO ' | VARSF(:,2) | monthly |
| emissivity | $\varepsilon$ | | 'SURFEMISSIVITE ' | VARSF(:,3) | constant |
| std dev of surface geopotential | | m2/s2 | 'SURFET.GEOPOTENT' | VARSF(:,4) | constant |
| land-sea mask | itm | | 'SURFIND.TERREMER' | VARSF(:,5) | constant |
| vegetation fraction | veg | | 'SURFPROP.VEGETAT' | VARSF(:,6) | monthly |
| anisotropy coef. of orography | | | 'SURFVAR.GEOP.ANI' | VARSF(:,7) | constant |
| principal dir. of orography | | radian | 'SURFVAR.GEOP.DIR' | VARSF(:,8) | constant |
| land-use type | itp | | 'SURFIND.VEG.DOMI' | VCLIV(:,1) | constant |
| min. surface resistance | Rsmin | m/s | 'SURFRESI.STO.MIN' | VCLIV(:,2) | monthly |
| percentage of clay | | % | 'SURFPROP.ARGILE ' | VCLIV(:,3) | constant |
| percentage of sand | | % | 'SURFPROP.SABLE ' | VCLIV(:,4) | constant |
| useful soil depth | d2 | m | 'SURFEPAIS.SOL ' | VCLIV(:,5) | constant |
| leaf area index | LAI | m2/m2 | 'SURFIND.FOLIAIRE' | VCLIV(:,6) | monthly |
| resistance to evapotranspiration | $h_v$ | | 'SURFRES.EVAPOTRA' | VCLIV(:,7) | (2) |
| g*thermal roughness length | $g*z0_t$ | m2/s2 | 'SURFGZ0.THERM ' | VCLIV(:,8) | (1) |
| . . . albedo of bare ground | $\alpha s$ | | 'SURFALBEDO.SOLNU' | VCLIV(:,9) | constant |
| . . . albedo of vegetation | $\alpha v$ | | 'SURFALBEDO.VEG ' | VCLIV(:,10) | monthly |

(1) : monthly on land (as vegetation), constant on permanent sea-ice, computed by the physics at each time-step over ice-free sea (as a function of wind)
(2) : computed by the physics at each time-step over land, constant over sea (useless)

The maxima, minima and specific values are defined in configuration 923.

*Upperair (3d) fields*

The following fields may be concerned : liquid water, ice, ozone. However none of them is used in ALADIN up to now.

## 3.b Standard initialization of gridpoint variables in ARPEGE

*Assimilation*

There is an assimilation scheme for surface variables in ARPEGE, which differs between land and sea as does the forecast.

• sea surface :

An analysis of SST (sea-surface temperature, Ts ≡ Tp) is performed every 6 h. The temperature is kept constant along the forecast afterwards. The other fields are meaningless here.

• land surface :

An assimilation of Ts, Tp, Ws, Wp is performed every 6 hours, using observations of temperature and relative humidity at 2m. The basic corrections read :

$$\Delta Ts = \Delta T2m \qquad \Delta Tp = \Delta T2m / 2\pi,$$

$$\Delta Ws = \rho_l \, d1 \, [ \, a_S^T \, \Delta T2m + a_S^H \, \Delta H2m \, ] \qquad \Delta Wp = \rho_l \, d2 \, [ \, a_p^T \, \Delta T2m + a_p^H \, \Delta H2m \, ]$$

and depend on vegetation, soil characteristics, cloudiness, time, ... The increments for soil moisture may vanish, according to the situation, and are smoothed. To avoid large deviations in case of too few observations, weak relaxations towards climatology are introduced for Tp and Wp.
An assimilation of Sn based on snow-height observations is likely to be introduced soon. Up to now, the only corrections are a relaxation towards climatology and some melting according to T2m. The interception water content is not corrected. The albedo of snow has not been considered yet.

At the beginning of each month, the monthly varying surface constants are updated just after the correction of surface variables.

The assimilation of upperair gridpoint fields is still a free research topic.

*Initialization*

No digital filtering of gridpoint fields is available in ARPEGE/ALADIN. However a few previous studies, performed in the framework of ARPEGE, ALADIN or HIRLAM, showed it is not useful.

*Configuration 927*

The following derived variables are interpolated along changes of geometry :

- Ts - $Ts^c$ , instead of Ts
- Tp - $Tp^c$ , instead of Tp
- Ws / Ws*x* - $Ws^c$ , instead of Ws
- Wsi / Ws*x* , instead of Wsi
- Wp / Wp*x* - $Wp^c$ , instead of Wp
- Wpi / Wp*x* , instead of Wpi
- Sn - $Sn^c$ , instead of Sn
- Wl / Wl*x* , instead of Wl (previously, Wl was simply set to 0.)
- $\alpha n$

A 12-points interpolation method is used, which may be modified to avoid overshooting ("monotone quadratic" interpolations).

$Ts^c$, $Tp^c$, $Ws^c$, $Wp^c$ and $Sn^c$ are the climatological values of Ts, Tp, Ws+Wsi, Wp+Wpi and Sn, respectively. In practice, $Ts^c \equiv Tp^c$ and $Ws^c \equiv Wp^c$. The reference to climatology is expected to avoid a height-correction, assuming climatological fields are consistent.
The maxima, minima, and specific values are checked afterwards. The snow cover is corrected according to surface temperature : $Sn = 0.$ if $Ts > Tt$ (triple point, `RTT`),
while $Sn^c = 0.$ if $Ts^c > Tt + \delta T$ in ARPEGE ($\delta T$ is a namelist variable). Oppositely, stricter constraints are applied to the climatological soil moistures (limitation to field capacity).

The roughness lengths over sea and the resistance to evapotranspiration are also interpolated then checked. The other surface constants are simply read from climatological files, which ensures a monthly update.

Unrealistic values of surface fields may be obtained when new lakes or islands are created along the change of geometry (i.e. when none of the 12 neighbouring points in the initial grid has the same land-sea index). This may be avoided (on demand) provided realistic climatological values are available : the climatology is used instead of the interpolated fields.

### 3.c Blending of surface variables

*Principles*

- The information from observations must be used, which is possible only via ARPEGE surface analysis.
- The resolution of the observation network is usually lower than that of the ALADIN grid.
- The structure of surface fields is mostly dictated by the physiography of the model surface boundary (orography, vegetation, ...), but not so well known.
- The ALADIN guess provides useful fine-scale information.

The suggested solution takes the difference of the ARPEGE guess and analysis projected to the ALADIN grid, giving a filtered projected ARPEGE analysis increment, and adds this increment to the ALADIN guess.

*Cautions*

- The ARPEGE and ALADIN cycles must not diverge. Therefore a weak relaxation to ARPEGE analysis (and hence to climatology) has to be applied.
- The physical limits and consistency of the blended surface fields must be checked afterwards.
- Blending must be performed only for land points, for :
    - ♦ SST is updated only through ARPEGE surface assimilation, ARPEGE and ALADIN forecasts bring older fields (by at least 6h);
    - ♦ a regular update of SST was shown to have a positive and significant impact on ALADIN forecasts;
    - ♦ the problem of the initialization of lakes due to configuration 927 got even worse along the designed blending procedure.

• Initial surface variables (temperature in practice) on water (sea or lake) points must be derived from the ARPEGE analysis, as for a standard initialization.
• Date and geometry must be checked of course.

*Formulation*

$x^b_{ALD} = check_limits \{ (1 - r) . [ x^g_{ALD} + x^a_{ARP} - x^g_{ARP} ] + r . x^a_{ARP} \}$ , instead of $x^b_{ALD} = x^a_{ARP}$

$x^b$ : blended (initial) field $x^a$ : analysed field $x^g$ : forecasted field (guess)
$x_{ALD}$ : ALADIN field $x_{ARP}$ : ARPEGE field interpolated onto the ALADIN grid

$r$ : relaxation constant, differing for sea and land points :
$r \equiv 1.$ over sea, $0. < r < 1.$ over land ($r = .05$ in the present tunings)
*check-limits* : control of consistency

The procedure is performed in 5 steps :
1: take ARPEGE guess and project it to the ALADIN grid using configuration 927 ($\rightarrow x^g_{ARP}$ )
2: take ARPEGE analysis and project it to the ALADIN grid using configuration 927 ($\rightarrow x^a_{ARP}$ )
3: combine both with ALADIN guess ( $x^g_{ALD}$), checking that :
$x^a_{ARP} - x^g_{ARP} \equiv 0.$ for fields not corrected by ARPEGE assimilation (Wl, Sn, αn up to now)
4: introduce the relaxation towards ARPEGE analysis
5: check the consistency with the program *check_limits*
which can be schematized as shown in appendix 3b.

Once a parameterisation of lakes implemented in ALADIN, lake points should be handled as land points not analysed in ARPEGE, rather than as sea points.

### 3.d Management of other gridpoint fields

The "constant" surface fields must be derived from the ARPEGE climatology through configuration 927, i.e. read in the current monthly climatological file. This is necessary to preserve the annual cycle of vegetation characteristics.
This might not be the optimal solution for the roughness lengths over sea and the resistance to evapotranspiration, when compared to using the ALADIN forecast. However taking this into account would make procedures far more complicated and, since these fields are recomputed at the first time-step, the impact would be very small.

The case of upperair gridpoint fields has not be considered up to now.

## 4. THE BLENDING ASSIMILATION SUITE

In the simplest configuration, the ALADIN suite with blending is very close to the standard one, based on dynamical adaptation, as shown in appendix 5 (b,c). The cycling period, or the span between two successive updates of ALADIN fields using observations, is the same : 12 hours, as for ALADIN / LACE, or 6 hours, as for ALADIN / France.

However blending provides an opportunity to update ALADIN fields more frequently (i.e. every 6 hours instead of every 12 hours) and/or using more observations (i.e. using ARPEGE analyses with long, instead of short, cut-off), building an assimilation suite parallel to the ARPEGE data assimilation suite. This was done at once for the first LACE test suite, and kept for subsequent attempts.

The links between the ARPEGE and ALADIN suites are described in appendix 5 (d,e). In the figures, as in the present test configurations, the coupling period is set to 6 hours for the blending assimilation suite, whatever the coupling period, 3 or 6 hours, for production (i.e. 2-days forecasts). Since ARPEGE fields are now available every 3 hours in the assimilation suite, thanks to 4d-var, this choice might be reconsidered for some models.

## 5. PERSPECTIVES

### 5.a Combination with 3d variational assimilation

While the blending method improves mainly the treatment of surface forcing, the next step is to analyse meso-scale structures which ALADIN is in principle able to describe. Since the long waves cannot be correctly analysed in ALADIN because of insufficient sampling, they should not be re-analysed but taken directly from the global ARPEGE assimilation. For this, DFI blending should be an ideal tool. The blended state, containing the analysed large scales from ARPEGE, appears as a logical first guess for the meso-scale analysis. Or, inversely, the blending step can be used to correct the largest scales once the meso-scale analysis is completed.

### 5.b Combination with soil/surface assimilation

The assimilation of soil and surface gridpoint variables on land is based on the analysis (optimal interpolation) of screen-level fields, mainly temperature and relative humidity at 2 meters. Such an assimilation could be as well performed in ALADIN, independently of the assimilation of upperair fields. This could allow a better tuning of error statistics and a better fit to surface characteristics, but may not be worth the additional cost if the surface observation network is too loose. Analysed SST would still be taken from ARPEGE, which implies careful combinations of fields.

### 5.c Case of nested models

The choice of the transition truncation, the digital filters, the cycling period, as well as the impact of the resolution ratio or the coupling frequency, are to be carefully re-examined in the case of nested ALADIN models, with or without data assimilation. The first tests are likely to be performed with ALADIN / Belgium, coupled to ALADIN / France.

REFERENCES

Brozkova R., D. Klaric, S. Ivatek-Sahdan, J.F. Geleyn, V. Cassé, M. Siroka, G. Radnoti, M. Janousek, K. Stadlbacher and H. Seidl : DFI blending : an alternative tool for preparation of the initial conditions for LAM. CAS-JSC WGNE Report n° , 2001, pp. .-..

Brozkova R. : RC-LACE status report 2000. LAM Newsletter n°30, February 2001, pp. 46-52.

Klaric D. and R. Bubnova : RC-LACE status report 1999. LAM Newsletter n°29, February 2000, pp. 33-37.

Lynch P., D. Giard and V. Ivanovici : Improving the efficiency of a digital filtering scheme for diabatic initialization. Mon. Wea. Rev., vol. 125, n° 8, pp. 1976-1982.

ALADIN Newsletters : RC-LACE reports

APPENDIX 1

a. Resolution of ARPEGE analysis increments

| spectral truncation | smallest wavelength | mesh-size |
|---|---|---|
| T042 (quadratic) | 952 km | 315 km |
| T063 (quadratic) | 635 km | 210 km |
| T095 (quadratic) | 421 km | 140 km |
| T127 (semi-linear) | 315 km | 125 km |
| T199 (quadratic) (1) | 201 km | 67 km |
| T199 (quadratic) (2) | 57 km | 19 km |
| T199 (quadratic) (3) | 704 km | 233 km |

*Notes* :
The spectral resolution may be considered as half the smallest wavelength.

(1) : at the equator (mean)
(2) : at the pole of interest (max.)
(3) : at the opposite pole (min.)

b. Resolution of some ALADIN models

| model | spectral truncations | smallest wavelength | mesh-size |
|---|---|---|---|
| France (f) | E 95-95 (~ T1344) | 30 km | 9.9 km |
| France (l) | E 32-32 (~ T0448) | 89 km | 9.9 km |
| LACE (t) | E 49-44 (~ T0644) | 62 km | 20.7 km |
| LACE (f) | E 79-71 (~ T1079) | 37 km | 12.2 km |
| LACE (l) | E 31-28 (~ T0424) | 94 km | 12.2 km |

*Notes* :
The spectral resolution may be considered as half the smallest wavelength.
The mentioned truncations are the ALADIN ones and an estimated equivalent ARPEGE one.
The largest wavelength well described by the LAM forecast, taken as a quarter of the domain extension, is around 700 km for ALADIN / France and 600 km for ALADIN / LACE.

(t) : transmission domain, i.e. at the mean ARPEGE resolution over the chosen area
(f) : forecast domain, at the full ALADIN resolution
(l) : low resolution domain, used to compute blending increments

c. Detailed computation of the "blending cut" truncation

| parameter | | ALADIN / LACE | ALADIN / France |
|---|---|---|---|
| | $m$ | 3.28 | 3.50 |
| | $T^{fa}_{ARP}$ | 653 | 696 |
| | $T^{f}_{ALD}$ | 1079 | 1344 |
| | $r_c$ | *1.70* | *1.90* |
| 3d var | $T^{m}_{ARP}$ | 127 | |
| | $T^{a}_{ARP}$ | 287 | 297 |
| | $T^{c}_{ALD}$ | 446 | 491 |
| | $r_b$ | *2.42* | *2.74* |
| 4d var | $T^{m}_{ARP}$ | 95 | |
| | $T^{a}_{ARP}$ | 249 | 257 |
| | $T^{c}_{ALD}$ | 405 | 446 |
| | $r_b$ | *2.66* | *3.01* |
| effective $r_b$ | | *2.54* | *2.97* |

♦ Notations are defined in Part 2c.

♦ $m \in [0.29, 3.50]$ i.e. $[1/c, c]$ with $c$=3.5 the stretching factor of the ARPEGE grid.

♦ Various resolution ratios (*3.3*, *2.9*, *2.5*, *2.1* and *1.7*) where tested in the ALADIN / LACE test suites; $r_b$ =*2.5* was retained.

♦ The present ALADIN / France test suites corresponds to the operational resolutions of spring 2000 ($dx$=9.9 km for ALADIN, 3d-var assimilation). With the present operational configuration, the computations lead to :

high resolution : $T^{f}_{ALD}$ = 1400 (*T99-99*) , $dx$ = 9.5 km,
low resolution : $T^{c}_{ALD}$ = 452 (*T32-32*) , $r_b$ = *3.10* ($r_c$ = *1.98*), i.e. the current one ...

APPENDIX 2

## a. Notations

In all cases, non-recursive Dolph-Chebyshev filters are used. Such filters are easy to tune and well suited to "small" time-span/stop-band edge ratios.
"**type**" may be :
*"d"* : applied twice (backward-forward) versus *"s"* : applied once (finalisation)
*"i"* : applied on analysis increments versus *"f"* : applied directly on fields
$\Delta$**t** is the integration timestep (rounded value here).

$\iota$**s** is the stop-band edge period.

***r*** is the ripple-ration, i.e. the maximum value of the response function in the stop-band; ***r* max** is the imposed maximum value (for warnings in the code), ***r* eff** the effective one.
**Ts** is the time-span of the filter; **Ts min** is the minimum integration length associated to r max and the given stop-band edge and time-step, **Ts eff** is the real one, which must be an even number of timesteps and at least Ts min.
The legend corresponds to the graphics in appendix 2e.

## b. Main features of the digital filters used in ARPEGE assimilation

| use | type | $\Delta$t | $\iota$s | *r* max | Ts min | Ts eff | *r* eff | legend |
|---|---|---|---|---|---|---|---|---|
| external | *d* , *i* | 900. s | 5.0 h | .050 | 3.45 h | 3.50 h | .047 | |
| semi-internal | *s* , *i* | 900. s | 3.0 h | .050 | 3.48 h | 6.00 h | .004 | |
| Jc-dfi, T42 | *s* , *i* | 720. s | 3.0 h | .050 | 3.50 h | 6.00 h | .004 | |
| Jc-dfi, T63 | *s* , *i* | 1080. s | 3.0 h | .050 | 3.46 h | 6.00 h | .004 | |
| Jc-dfi, T95 | *s* , *i* | 1543. s | 3.0 h | .050 | 3.40 h | 6.00 h | .004 | |

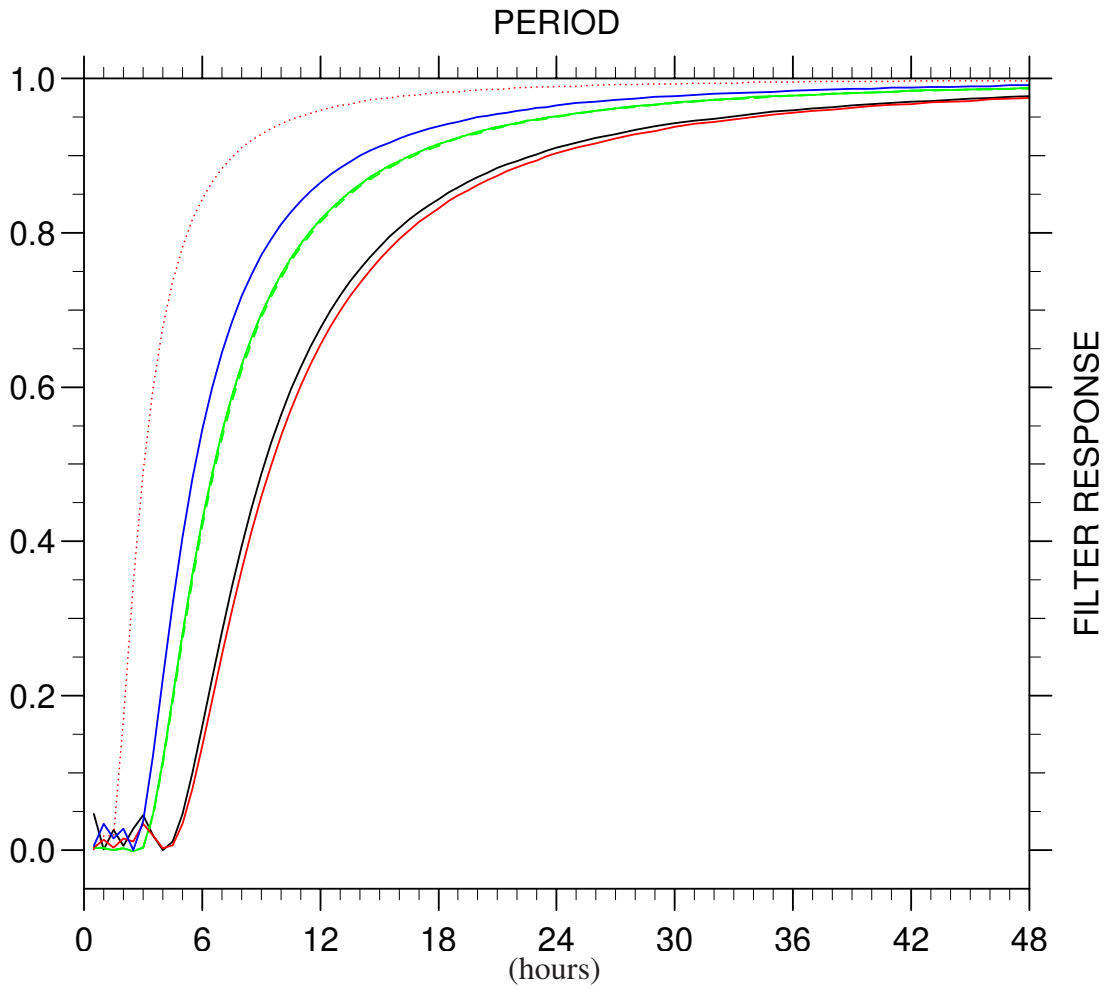
## c. Main features of the digital filters used in the test blending suite for ALADIN / France

| use | type | $\Delta$t | $\iota$s | *r* max | Ts min | Ts eff | *r* eff | legend |
|---|---|---|---|---|---|---|---|---|
| external, oper. | *d* , *f* | 470. s | 3.0 h | .050 | 2.07 h | 2.09 h | .049 | |
| ext., forecast, blend. | *d* , *f* | 470. s | 3.0 h | .050 | 2.07 h | 2.09 h | .049 | |
| ext., assim., blend. | *NO* | | | | | | | |
| internal, blending | *d* , *i* | 1350. s | 5.0 h | .050 | 3.43 h | 3.75 h | .034 | |

d. Main features of the digital filters used in the parallel blending suite for ALADIN / LACE

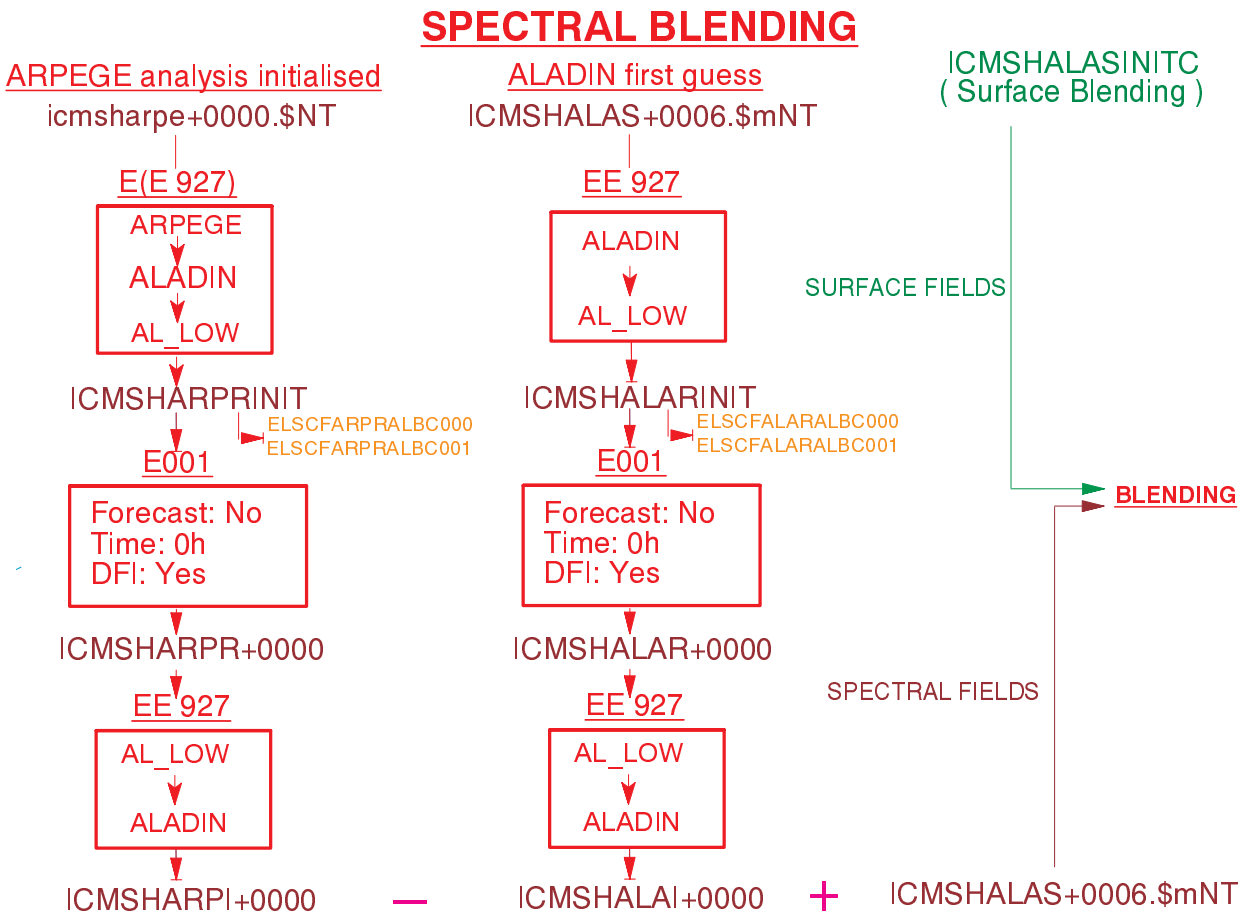
| use | type | Δt | ιs | *r* max | Ts min | Ts eff | *r* eff | legend |
|---|---|---|---|---|---|---|---|---|
| external, oper. | *d* , *f* | 568. s | 3.0 h | .050 | 2.07 h | 2.21 h | .038 | |
| ext., forecast, blend. | *d* , *f* | 568. s | 1.5 h | .050 | 1.02 h | 1.26 h | .018 | |
| ext., assim., blend. | *NO* | | | | | | | |
| internal, blending | *d* , *i* | 1350. s | 5.0 h | .050 | 3.43 h | 3.75 h | .034 | |

e. Response function for some of the previous filters



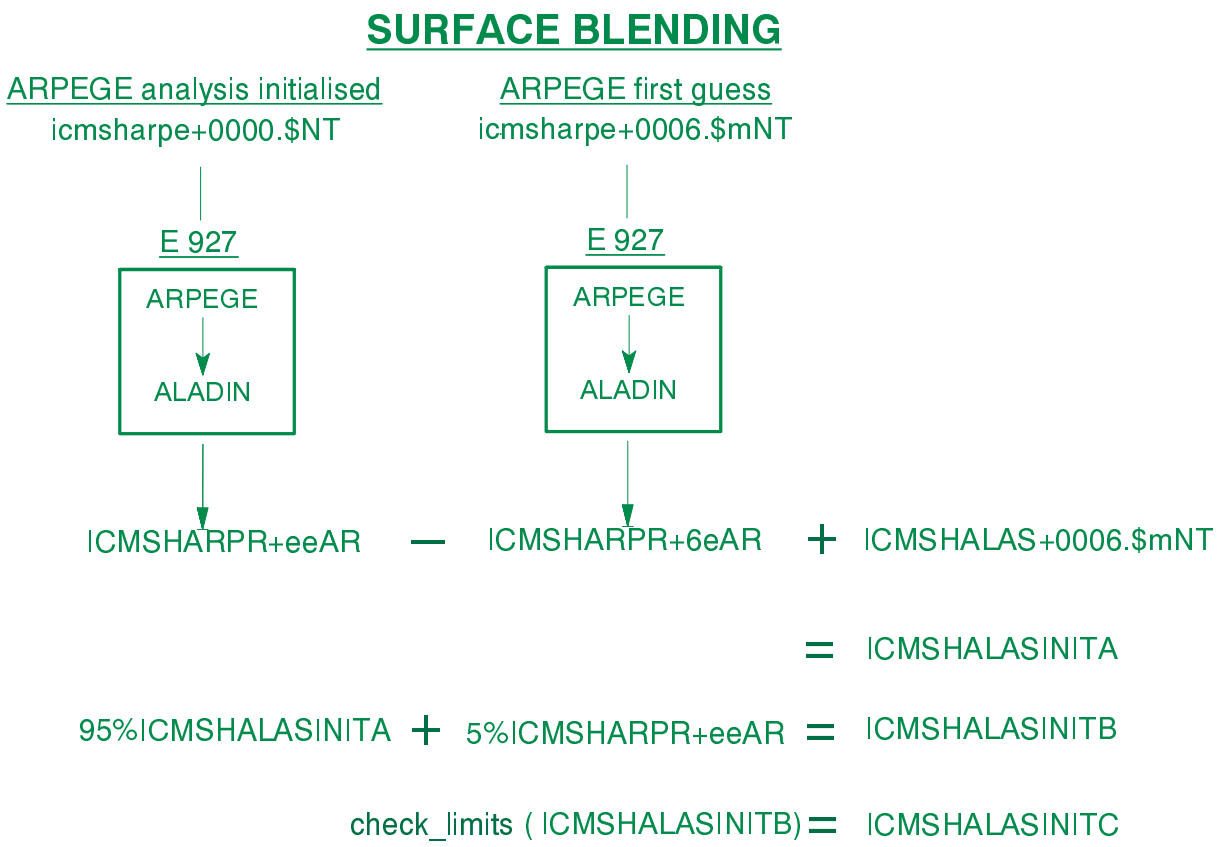
APPENDIX 3

a. Description of the spectral dfi blending procedure




The naming is that of the script available at Météo-France.

b. Description of the gridpoint blending procedure

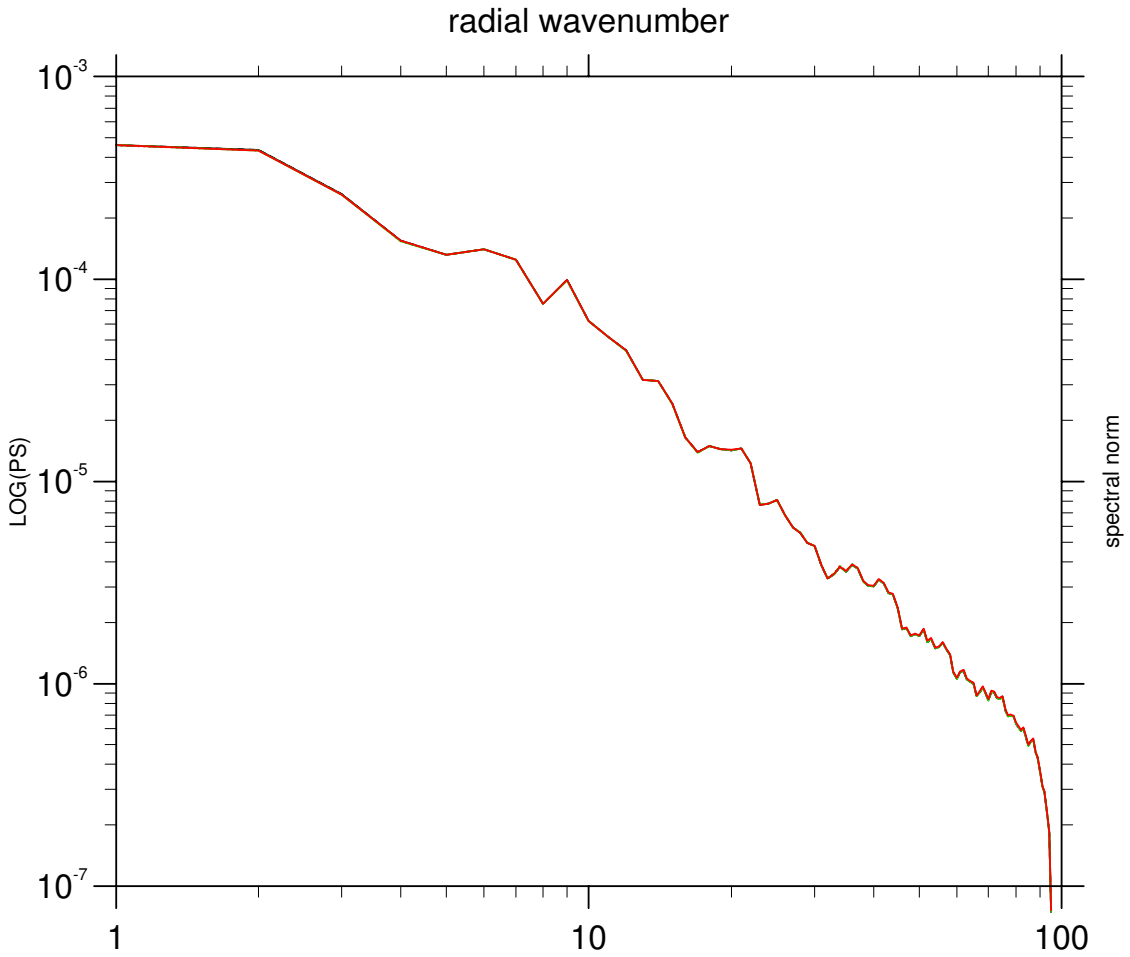



The naming is that of the script available at Météo-France.

Note that surface blending is actually performed before spectral blending.

APPENDIX 4

a. Spectra for surface pressure in ALADIN / France

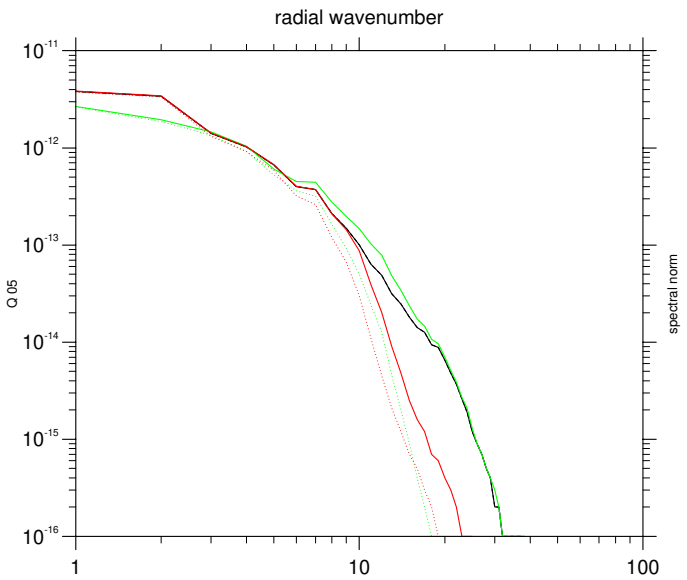



in black : blended initial state
in red : ARPEGE analysis
in green : ALADIN guess
dotted lines : after filtering (internal or external)

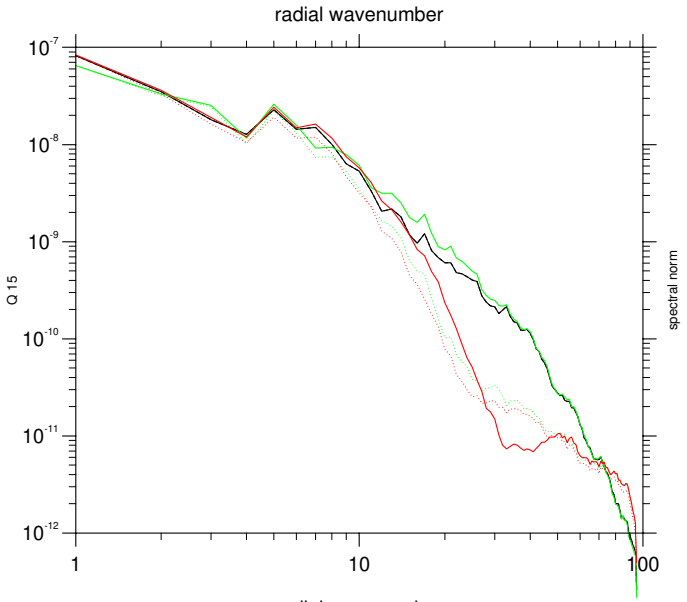
For this particular variable, differences are negligible. It is not always the case, as illustrated hereafter with specific humidity.

b. Spectra for specific humidity in ALADIN / France

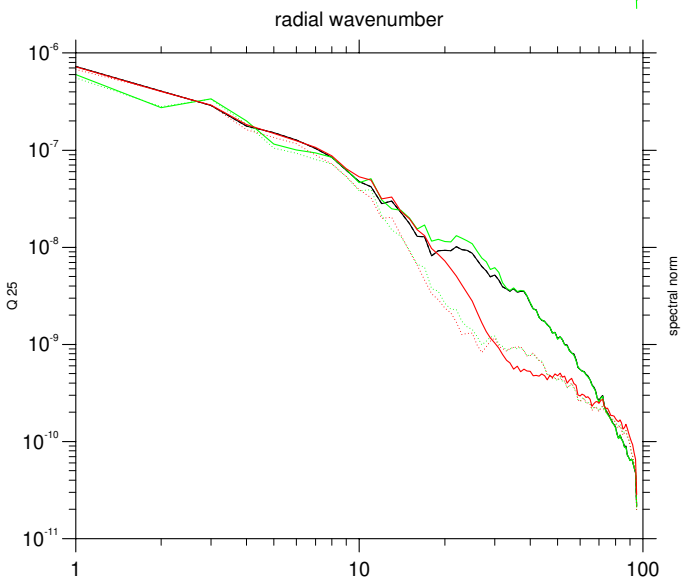
at model level 05
(~ 100 hPa)




at model level 15
(~ 500 hPa)




at model level 25
(~ 900 hPa)



APPENDIX 5

a. Introduction to diagrams

♦ "analysis" stands for initialized analysis or initial (blended) state.

♦ "guess" stands for 6 hours (assimilation mode) or 12 hours (production mode) forecasts. When in italics, the file is used only for subsequent forecasts or coupling.

♦ "obs." stands for observations, used by the ARPEGE data assimilation system.

♦ In practice, production forecasts are performed up to 4 days for ARPEGE, 2 days for ALADIN; only the first 12 hours are shown hereafter, for simplicity.

♦ Similarly, the figures correspond to an ALADIN production of 2 runs per day, starting at 00 h TU and 12 h TU, which is the most frequent situation in operations; however ARPEGE and some ALADIN models run 4 times per day, every 6 hours, in production mode.

♦ In blue (➔), ARPEGE and ALADIN forecasts (i.e. configuration 001) and the associated coupling (⇨).

♦ In red (➔), data assimilation in ARPEGE (3d- or 4d-var and surface analysis).

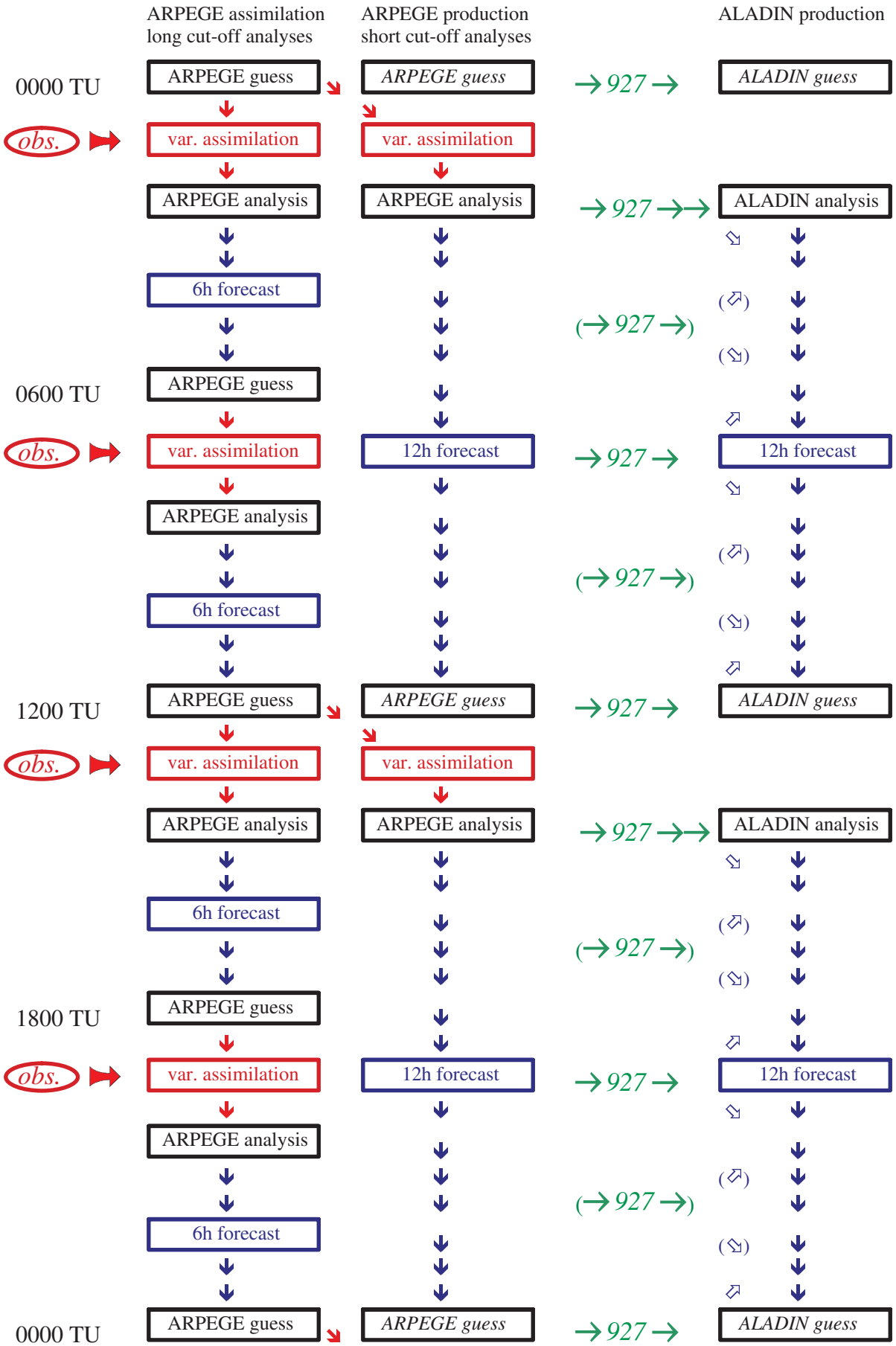
♦ In orange (➔), blending for ALADIN; G means that the input file is used only for the blending of grid-points fields.

♦ In green (➔), changes of geometry, for the production of coupling files, blending, and initialisation of ALADIN in the standard production mode (➔➔).

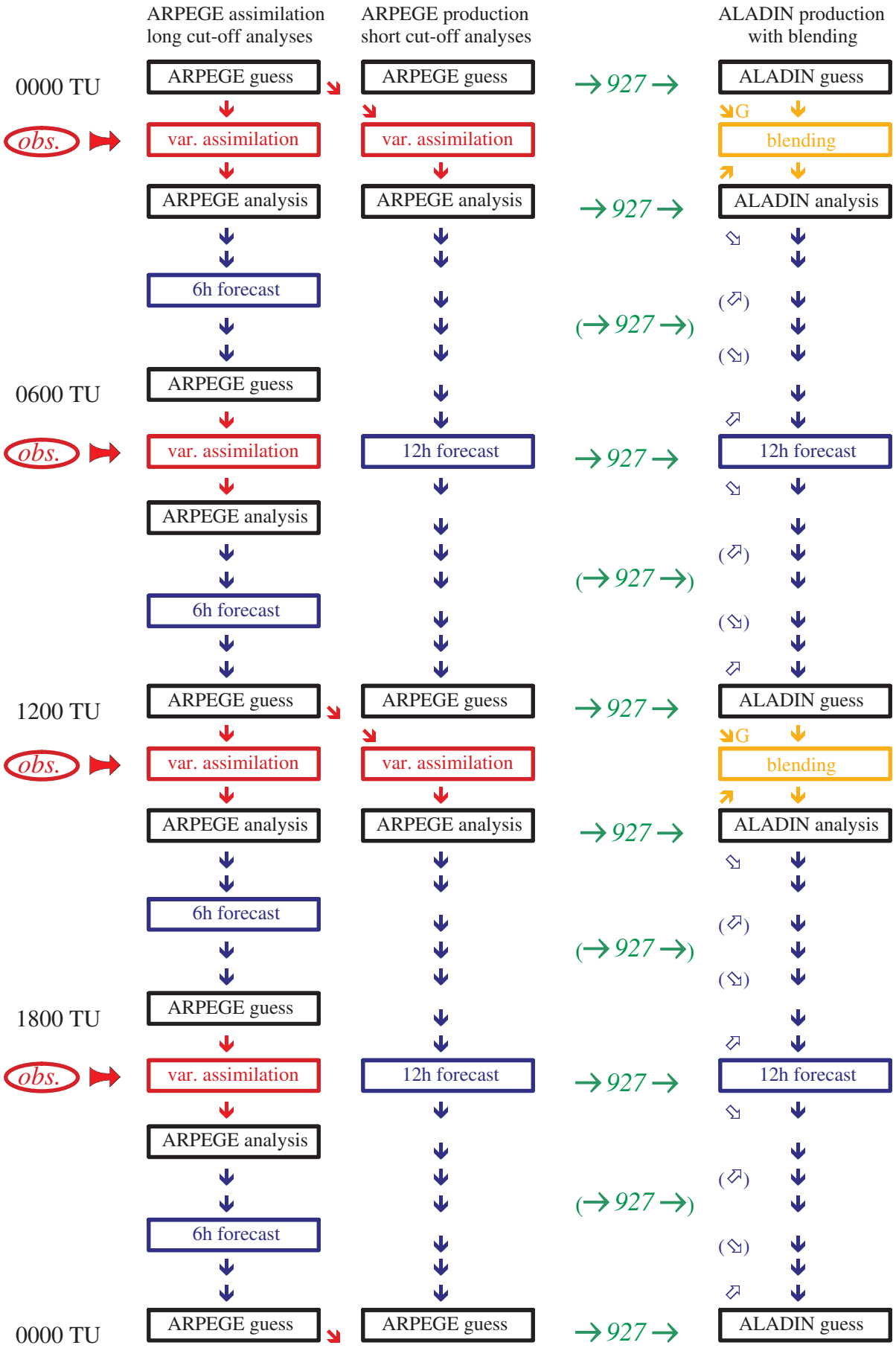
♦ Operations related to a coupling period of 3 hours in production forecasts are between brackets.

♦ In figure e, the ARPEGE assimilation cycle, providing input files to both ARPEGE production (as shown in figures b and c) and ALADIN assimilation with blending (as shown in figure d) is not explicitly shown.

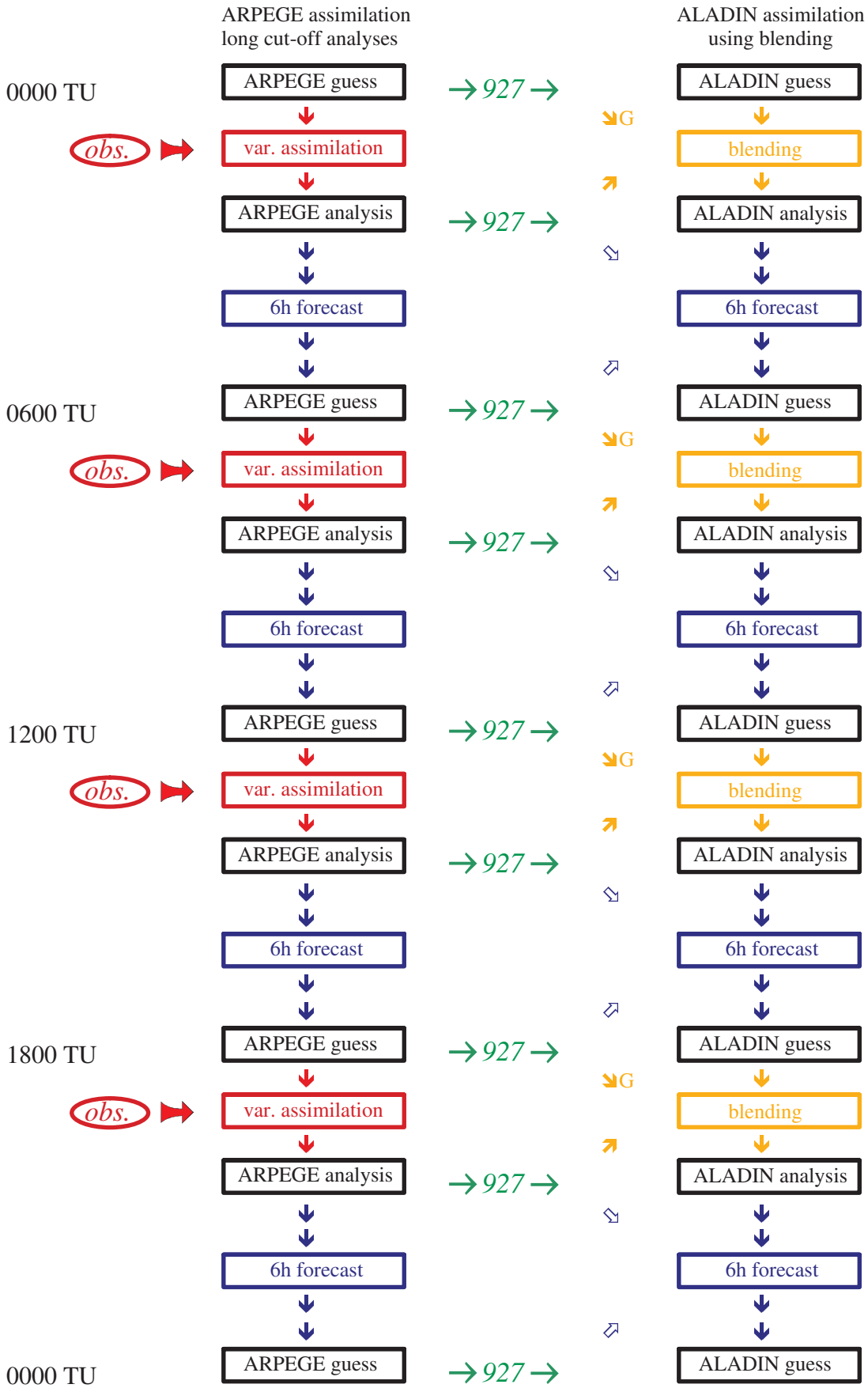
b. Standard coupled ARPEGE and ALADIN suites



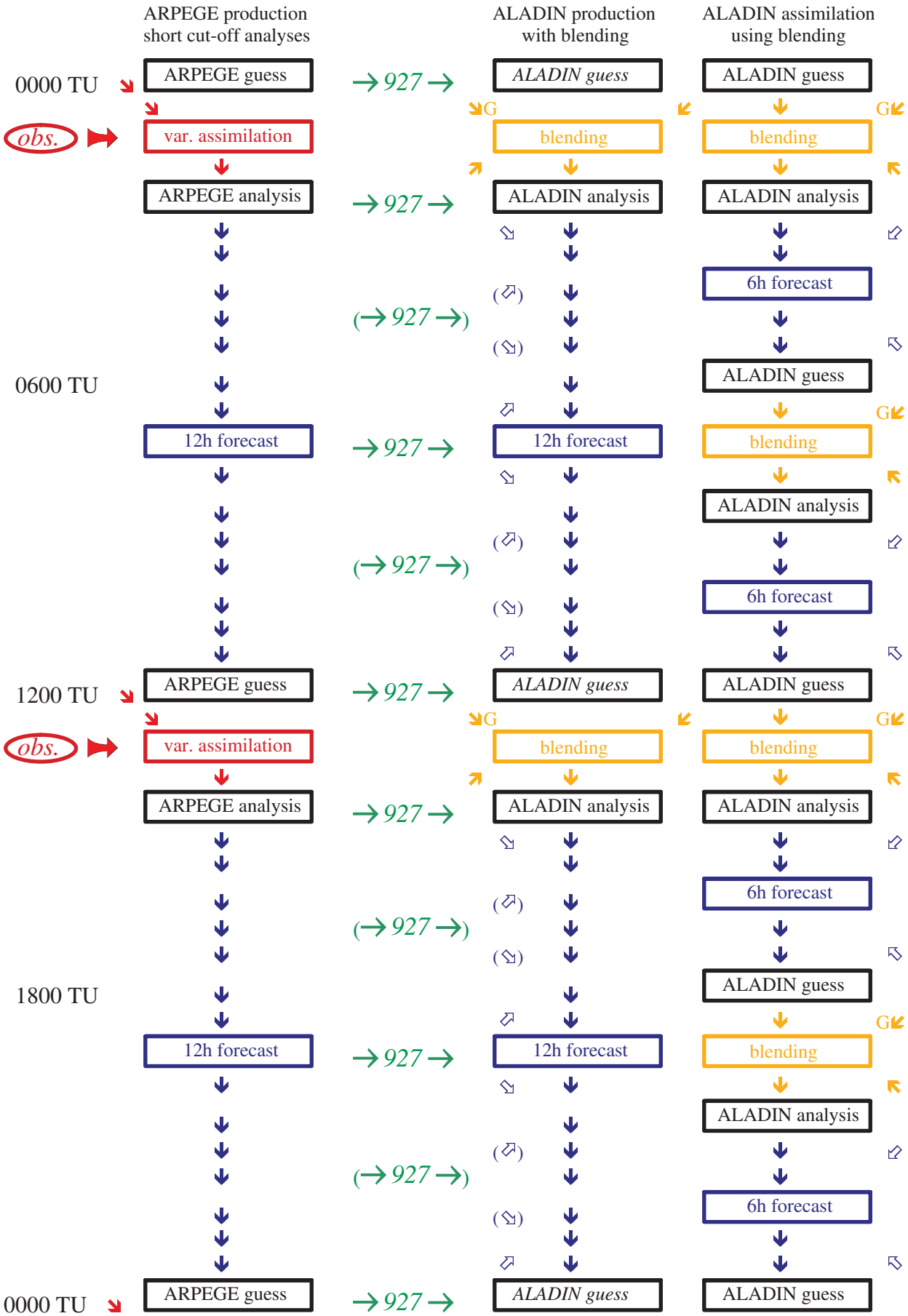
c. Standard coupled ARPEGE and ALADIN suites, using blending



d. Coupled ARPEGE and ALADIN assimilation suites, using blending



e. Coupled ARPEGE and ALADIN production suites, using blending assimilation



CONTENTS

1. INTRODUCTION

2. BLENDING OF SPECTRAL FIELDS BY DIGITAL FILTERING

2.a Scale selection in the global assimilation of spectral fields
*Incremental approach*
*Digital filtering in ARPEGE*

2.b Principles of digital filter initialisation (DFI) blending

2.c Tunings
*"Blending cut" truncation*
*"Internal" digital filter*
*"External" digital filter*
*Coupling along DFI*

3. BLENDING OF GRIDPOINT FIELDS

3.a Gridpoint fields in ARPEGE / ALADIN
*Surface (2d) variables*
*Surface (2d) constants*
*Upperair (3d) fields*

3.b Standard initialization of gridpoint variables in ARPEGE
*Assimilation*
*Initialization*
*Configuration 927*

3.c Blending of surface variables
*Principles*
*Cautions*
*Formulation*

3.d Management of other gridpoint fields

4. THE BLENDING ASSIMILATION SUITE

5. PERSPECTIVES

5.a Combination with 3d variational assimilation

5.b Combination with soil/surface assimilation

5.c Case of nested models

REFERENCES

APPENDIX 1

a. Resolution of ARPEGE analysis increments

b. Resolution of some ALADIN models

APPENDIX 2

a. Notations

b. Main features of the digital filters used in ARPEGE assimilation

c. Main features of the digital filters used in the test blending suite for ALADIN / FRANCE

d. Main features of the digital filters used in the parallel blending suite for ALADIN / LACE

e. Response functions of the previous filters

APPENDIX 3

a. Description of the spectral dfi blending procedure

b. Description of the gridpoint blending procedure

APPENDIX 4

a. Spectra for surface pressure in ALADIN / France

b. Spectra for specific humidity in ALADIN / France

APPENDIX 5

a. Introduction to diagrams

b. Standard coupled ARPEGE and ALADIN suites

c. Standard coupled ARPEGE and ALADIN suites, using blending

d. Coupled ARPEGE and ALADIN assimilation suites, using blending

e. Coupled ARPEGE and ALADIN production suites, using blending assimilation