Regional Cooperation for
Limited Area Modeling in Central Europe

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DA cycling and initialization

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Data assimilation cycling

- Observation & quality control
- Objective analysis (3DVAR, 4DVAR, ...)
- Initialization
- Short model integration (background = first guess)

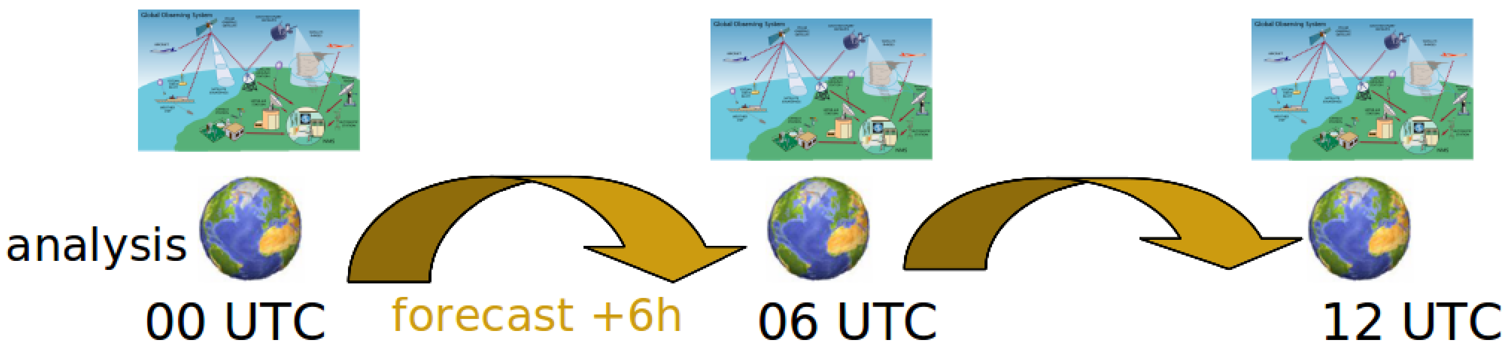

Fig: *intermittent, sequential assimilation cycle*

Data assimilation cycling

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- **DA methods analyze only some prognostic variables:** *T, q, wind, surface pressure*
- **What about other model prognostic variables ?**
  - non-hydrostatic prognostic variables
  - hydrometeors, etc *rain, snow, liquid/solid cloud water, TKE, ...*
- **Option 1: Copy non-analyzed variables from the first guess**
  - using various tools (ADDSURF, BLEND ...)

```
# input file (guess) and output file (analysis)
ln -sf ICMRFMINI0000 fort.12
ln -sf MXMINI999+0000 fort.11
# namelist
cat > fort.4 <<END     &NAML
NBC=number of fields to copy,
CDPREFM(1)='S',CDSUFM(1)='LIQUID_WATER',NBNIV(1)=number of vertical levels,LOPC(1)=.T.,
CDPREFM(2)='S',CDSUFM(2)='SOLID_WATER',NBNIV(2)=number of vertical levels,LOPC(2)=.T.,
...      /
END
mpirun -np 1 ./ADDSURF
```

- **Option 2: Set non-analyzed variables to zero**
  - if no other way, e g. in case of a cold start (for a new scheme for global model or when a different set of prognostic variables used in global and LAM model)

Initialization

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- aim to remove the imbalances introduced during the analysis (or downscaling)
- period of time needed by the model to adjust its initial fields with respect to all, discretized, model equations is called ”spinup” (Fischer and Auger, 2011)
- spinup contains processes related to
  - dynamical adjustment (geostrophy)
  - excess energy radiated away by inertia-gravity waves
  - diabatic adjustment (physics tendencies)
- typical manifestation
  - oscillations, e.g. in MSLP, video credit B. Strajnar
  - precipitation quality issues
- initialization methods:
  - Normal Mode Initialisation (NMI)
    Machenhauer, 1977, Daley, 1979, Temperton and Williams,
  - (Incremental) Digital Filter Initialisation (DFI)
    Lynch, 1997, Lynch et al, 1997
  - extra term in the cost function (J_c-DFI)
    Gustafsson, 1992, Gauthier and Thepaut, 2001
  - Incremental Analysis Update (IAU)
    Bloom et al., 1996

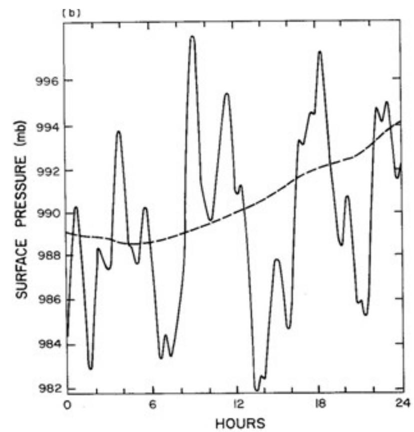

Figure 10.1 Time evolution of surface pressure during a 24 hour model integration for (a) linear and (b) nonlinear normal mode initialization. Solid curves, uninitialized; dashed curves, initialized. (After Williamson and Temperton, *Mon. Wea. Rev.* **109**: 745, 1981. The American Meteorological Society.)

DFI in ALADIN/HIRLAM system

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- **Digital Filter introduced following** Lynch and Huang, 1992, Lynch et al. 1997
- **Principle: considering a function of time** $f(t)$
  1. **calculate a Fourier transform** $F(\omega)$ **of** $f(t)$
  2. **set the coefficients of the high frequencies to zero, e.g.** $F(\omega) * H(\omega)$ **where**

$$H(\omega) = \begin{cases} 1 & |\omega| \leq |\omega_c|; \\ 0 & |\omega| \geq |\omega_c|, \end{cases}$$

     and ω_c **is a cut-off frequency**
  3. **calculate the inverse Fourier transform**

- **These three steps are equivalent to a convolution of** $f(t)$ **with** $h(t) = sin(\frac{\omega_c t}{\pi t})$
- **Solution: To filter function** $f(t)$ **one calculates:**

$$\overline{f(t)} = (h * f)(t) \int_{-\infty}^{\infty} h(\tau) f(t-\tau) d\tau$$

for simple function can be computed analytically, but in general approximation methods are used.

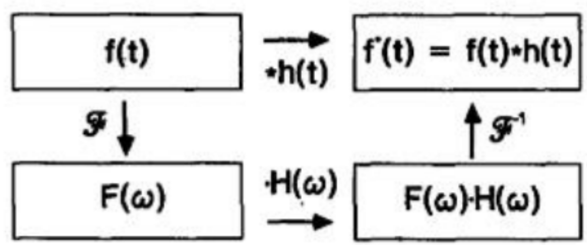


FIG. 1. Schematic representation of the equivalence between convolution and filtering in Fourier space.

Credit: Lynch and Huang,1992

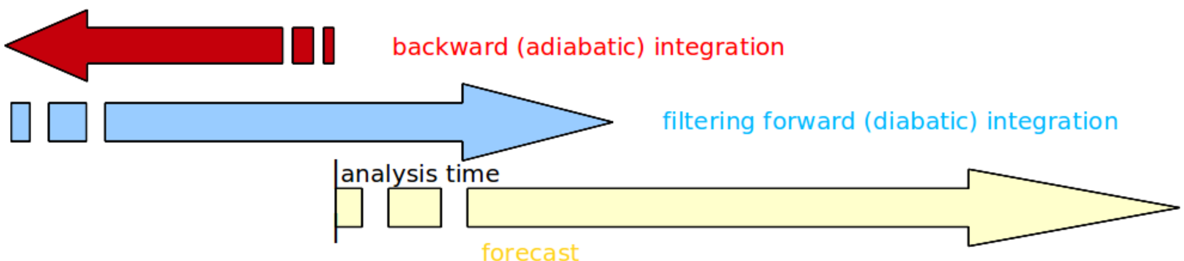
DFI in ALADIN/HIRLAM system

- **Digital Filter introduced following** Lynch and Huang, 1992, Lynch et al. 1997
- **considering a discrete function (of model state x_n at moments $t_n = n\Delta t$)**
- **purpose is to provide a filtered state** valid at initial time
- **non-recursive filtering requires both past and future model states**

$$\overline{x_0} = \sum_{n=-N}^{n=+N} h_n x_n = \sum_{n=0}^{n=-N} h_n x_n + \sum_{n=-N}^{n=+N} h_n x_n$$

where n is model time step and x_n is model state

- **usual response function** $H(\omega) = \frac{T_n\left[\frac{cos(\frac{\omega\Delta t}{2})}{cos(\frac{\omega_s \Delta t}{2})}\right]}{T_n\left[\frac{1}{cos(\frac{\omega_s \Delta t}{2})}\right]}$ **where $T_n[.]$ is n-Dolph-Chebyshev polynomials, $\omega_s = \frac{2\pi}{\tau_s}$ with τ_s the filter stop-band edge period**



DFI in ALADIN/HIRLAM system

- **efficiency of the filter can be decreased when the time span is decreased** *(2*NSTDFI*RTDFI)* **and/or by decrease of the stop-band edge** *(TAU/3600)*
- **due to the backward adiabatic integration** *bias is generated in the filtered state* **with respect to the original analysis state** **(Fischer and Auger, 2011)**
- **NAMELIST**

```
&NAMINI
  LDFI ! TRUE if digital filter initialization
  LBIAS ! COMPUTING INITIALIZATION INCREMENT (Xi-Xa)
  LINCR ! INCREMENTAL INITIALIZATION ( -> Xi-Z , Z=Yi-Ya )
/
&NAMDFI ! default values
  LADIFH=.T., !  HORIZONTAL DIFFUSION IN ADIABATIC INTEGRATIONS
  NEDFI=7, !  BACKWARD+FORWARD DFI FOR INITIAL FIELDS
  NSTDFI=21, !  NUMBER OF ADIABATIC DFI TIMESTEPS IN ONE DIRECTION (2*NSTDFIA)
  NTPDFI=4, !  no recursive filter (A DOLPH-CHEBYSHEV FILTER IS USED)
  TAUS=10800., !  STOP-BAND EDGE (TAUS/3600)= 3.000h
/
```

DFI in ALADIN/HIRLAM system

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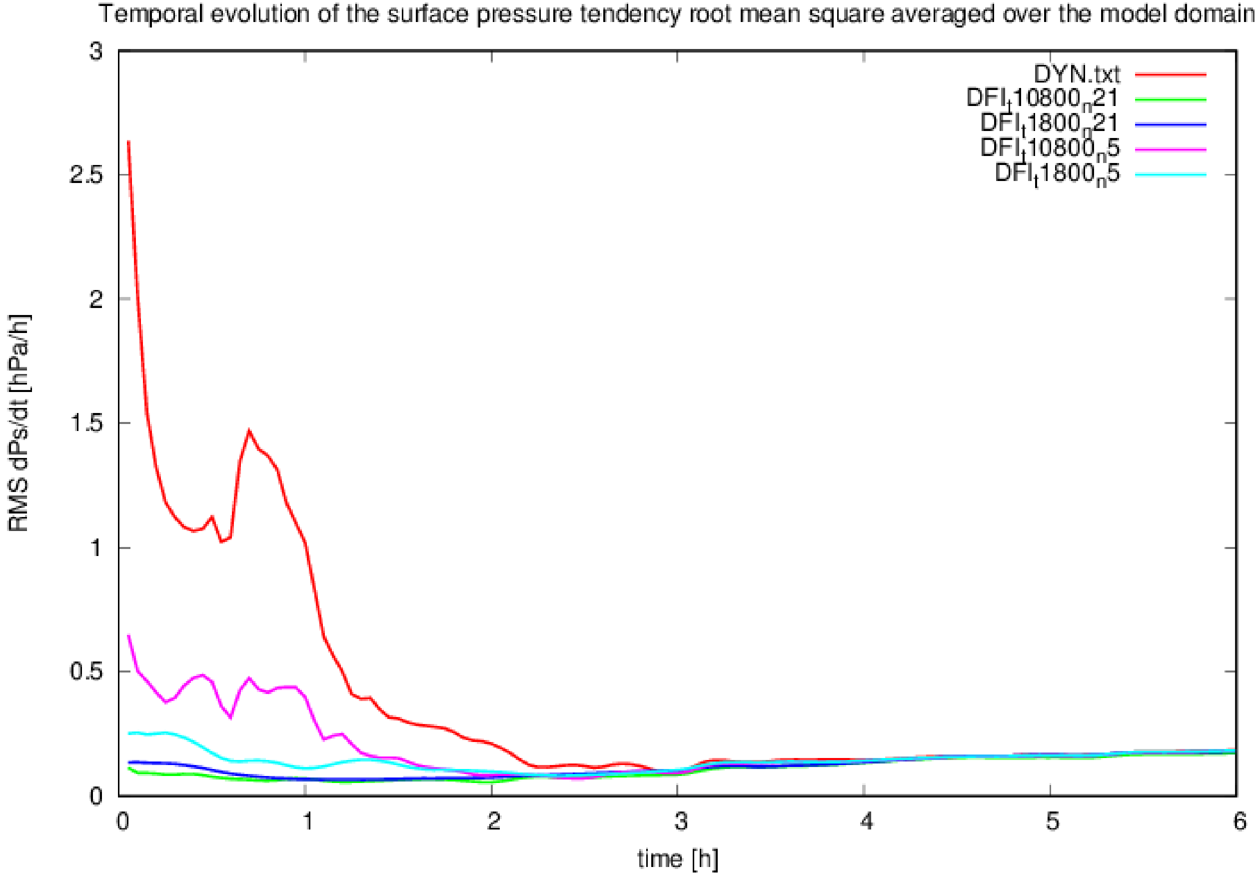

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IDFI in ALADIN/HIRLAM system

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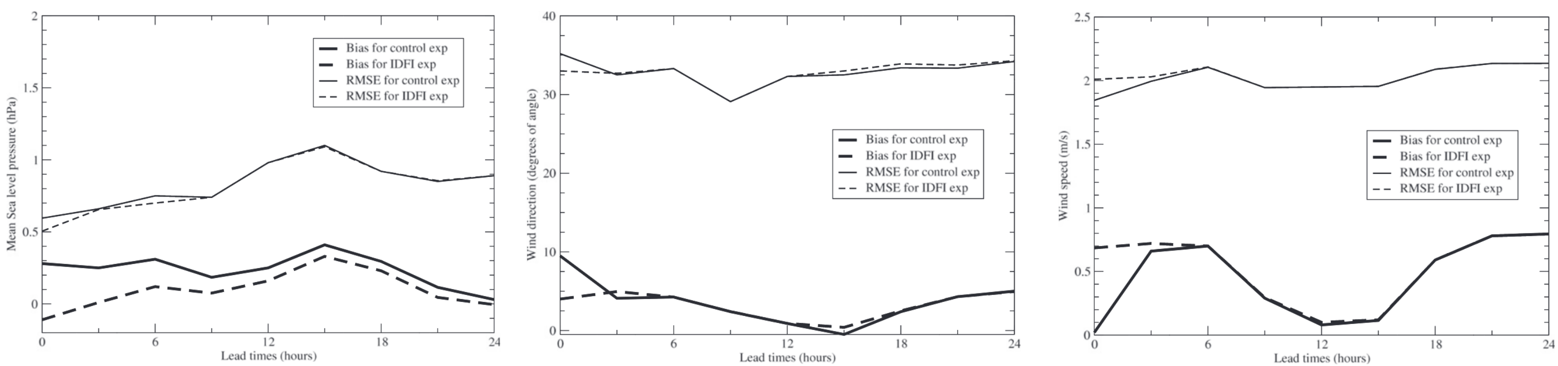
- **DFI does not distinguish the high frequencies related to rapidly evolving meteorological features and in order to keep high frequencies of the first guess for the subsequent forecast Incremental Digital Filter Initialization (IDFI) was proposed**

$$\overline{x_0} = g + f(a) - f(g)$$

where g is the first guess, a is analysis and $f()$ is DFI filter

- **Fischer and Auger (2011) showed that IDFI formulation:**
  - decreases MSLP bias partially linked to an intrinsic property of DFI
  - improves scores of the wind direction
  - degrades scores of the wind intensity



Credit: Fischer and Auger, 2011

Source of imbalances

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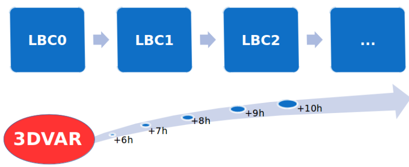
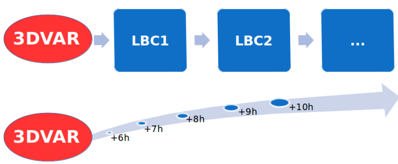
- imbalances introduced during the analysis
  - improve B matrix estimation & its representativness to reduce imbalances in the analysis increments (Brousseau et al, 2016)
  - apply initialization methods (DFI, IDFI, IAU, ...)
- imbalances due to inconsistencies between analyzes state and LBCs (lateral boundary conditions) at the initial time
  - time-consistent coupling

(3DVAR analysis=INIT & LBC0 = ARPEGE/ECMWF analysis)



  - space-consistent coupling reduces spinup

(3DVAR analysis = INIT = LBC0)



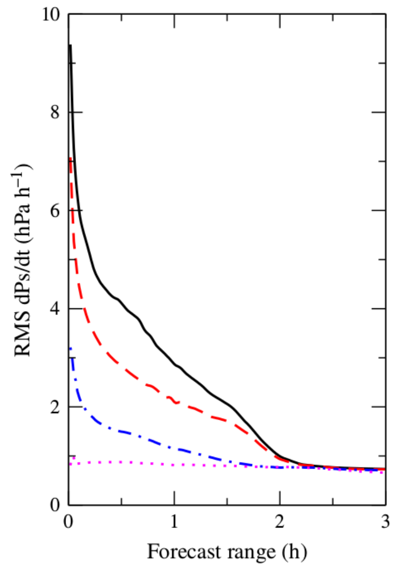


Figure 2. Temporal evolution of the surface pressure tendency root mean square averaged over the model domain and 15 forecasts as a function of the forecast range for different configurations: in restart mode (dotted line), using analysis obtained with the OLD **B** matrix and LBCs at initial time from the host model (solid line), analysis obtained the NEW **B** matrix and LBCs at initial time from the host model (dashed line), and analysis obtained with the new **B** matrix as initial condition but also as LBCs at initial time (dashed-dotted line).

Credit: Brousseau et al, 2016

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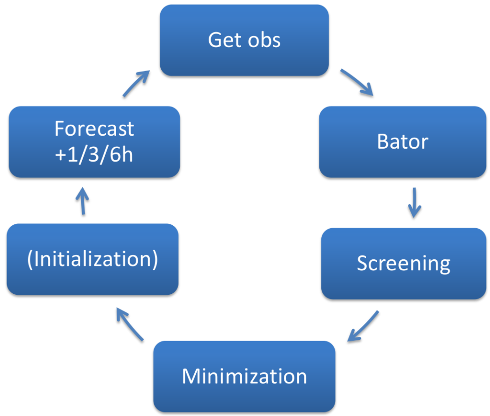
End

Initialization is an important component of DA cycling
& it is essential for a good performance !



Thank you for your attention !