A COMPARISON OF SUPER-MATSUNO SCHEME AND DIGITAL FILTERING INITIALIZATIONS IN THE ETA MODEL

Lazar Lazic
Department of Meteorology, University of Belgrade, Serbia (lazar@ff.bg.ac.yu)

An iterative Matsuno or a "super-Matsuno" style scheme and digital filtering are applied as a filters in the Eta Model. The both initialization techniques are applied for the model’s adiabatic part only. We are focusing on the impact of the use of initialization methods in a short-range forecasting environment/time-scale.

The super-Matsuno scheme (Fox-Rabinovitz, 1996) is a generalization of the Euler backward (Matsuno) scheme (Matsuno, 1966), to include more than one corrector step, that is, to include additional corrector iterations. Applying this scheme for the adjustment process in the Eta Model (Lazic, 2000), along with the backward scheme for the Coriolis terms, we have

- predictor:

$$\begin{aligned} u_*^{n+1} &= u^n - \Delta t g \delta_x h^n + \Delta t f v_*^{n+1} \\ v_*^{n+1} &= v^n - \Delta t g \delta_y h^n - \Delta t f u_*^{n+1} \\ h_*^{n+1} &= h^n - \Delta t H\left(\delta_x u + \delta_y v\right)^n \end{aligned} \tag{1}$$

- corrector:

$$\begin{aligned} u_1^{n+1} &= u^n - \Delta t g \delta_x h_*^{n+1} + \Delta t f v_1^{n+1} \\ v_1^{n+1} &= v^n - \Delta t g \delta_y h_*^{n+1} - \Delta t f u_1^{n+1} \\ h_1^{n+1} &= h^n - \Delta t H\left(\delta_x u_* + \delta_y v_*\right)^{n+1} \end{aligned}$$

along with *iterations of the corrector step*

$$\begin{aligned} u_2^{n+1} &= u^n - \Delta t g \delta_x h_1^{n+1} + \Delta t f v_2^{n+1} \\ v_2^{n+1} &= v^n - \Delta t g \delta_y h_1^{n+1} - \Delta t f u_2^{n+1} \\ h_2^{n+1} &= h^n - \Delta t H\left(\delta_x u_1 + \delta_y v_1\right)^{n+1} \\ &\cdots \\ u_k^{n+1} &= u^n - \Delta t g \delta_x h_{k-1}^{n+1} + \Delta t f v_k^{n+1} \\ v_k^{n+1} &= v^n - \Delta t g \delta_y h_{k-1}^{n+1} - \Delta t f u_k^{n+1} \\ h_k^{n+1} &= h^n - \Delta t H\left(\delta_x u_{k-1} + \delta_y v_{k-1}\right)^{n+1} \end{aligned} \tag{2}$$

where k is the *iteration number*. These corrector iterations can be continued until convergence takes place, namely, when

$$\| u_k^{n+1} - u_{k-1}^{n+1} \| < \varepsilon_1, \ \| v_k^{n+1} - v_{k-1}^{n+1} \| < \varepsilon_1, \ \| h_k^{n+1} - h_{k-1}^{n+1} \| < \varepsilon_2, \tag{3}$$

where ε_1 and ε_2 are prescribed small values and $\| \ \|$ is the maximum value norm.

This super-Matsuno-like time differencing scheme with iteration number $k=3$ is applied to the adjustment stage of the Eta Model as an ÒinitializationÓ procedure during the Ò*-1h backward and +1h forward*Ó *adiabatic integration*.

Applying digital filter (Huang and Lynch, 1993) in the Eta Model an adiabatic integration is carried out backward in time for N time steps to produce a model state $X_d(n)$ at $t=-n\Delta t$. Here the N-step numerical integration covers half of the total filter span $T_s=2N\Delta t=4h$, which extends from $-N\Delta t$ to $+N\Delta t$. From $t=0$, the model then integrated forward in time to $+N\Delta t$, giving model variables $X_d(n)$ at $t=+n\Delta t$. The digital filter is then applied to $X_d(n)$, yielding a filtered field X_d^*

$$X_d^* = \sum_{n=-N}^{N} h(-n) X_d(n), \tag{4}$$

where $h(n)$ are the filter coefficients

$$h(n) = \left\{ \frac{\sin[n\pi/(N+1)]}{n\pi/(N+1)} \right\} \frac{\sin\theta_c}{n\pi}. \tag{5}$$

Here θ_c is the cutoff digital frequency, which is related to the cutoff period $\tau_c = \pi T_s / N\theta_c$.

Initial conditions for a sensitivity experiment we ran are those of 0000 UTC 18 January 1987, selected in an earlier study for their featuring the tropical cyclones *Connie* and *Irma* from the Australian Monsoon Experiment (AMEX).

A common way to demonstrate the performance of an initialization scheme is to show the time evolution of the surface pressure and a midlevel vertical velocity at a model grid point. The surface pressure is sensitive to noise in a vertically integrated sense, while the midlevel vertical velocity indicates the internal noise.

The time evolution for the first 6 h of the forecast of the surface pressure p_s and 500 hPa vertical velocity $\omega = dp/dt$ at a model grid point I=25, J=18, without and with initialization, are shown in Fig. 1

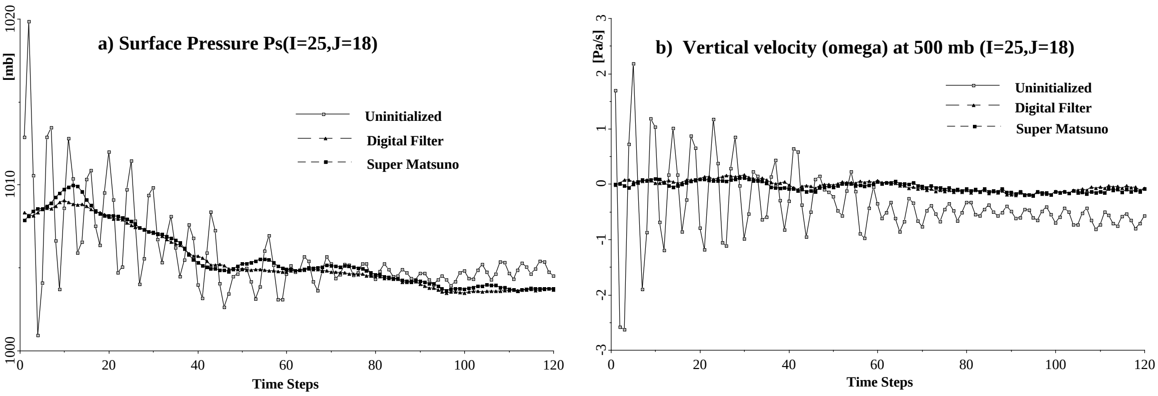

Fig. 1 Time evolution of: a) surface pressure ***p***$_s$ *[hPa]; b) 500 hPa vertical velocity* ω *[Pa/s]; at a model grid point I=25, J=18, without and with initialization, during 6 h (120 time steps) of integration.*

Uninitialized and initialized sea level pressure fields at the initial time are shown in Fig. 2. A high level of noise can be seen on uninitialized map, and no noise to be seen on initialized maps at the same time.

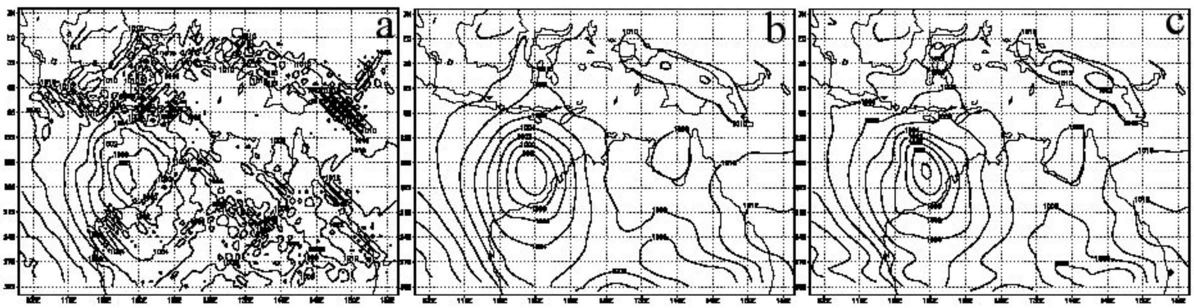

Fig. 2 Uninitialized (a), digital filter (b) super-Matsuno scheme (c) initialized sea level pressure [hPa]; at the initial time 0000 UTC 18 January 1987.

The super-Matsuno style time differencing scheme and digital filtering initializations remove the spurious high-frequency oscillations from the forecast *very efficiently*. After initializations fields are adjusted and without noise. It results in a lower noise level and a structure in the surface pressure tendency and 500 hPa vertical velocity at 1 h of integration significantly smoother than in the control case. In the control case fields still display a high level of noise.

The all integration results with and without initialization after 6 h are very similar. They are very similar also after 12 h and later until the end of the 48-h integration performed. Even so, it is to be expected that small differences, given that they have resulted from the removal of spurious initial noise have to be beneficial.

References

Fox-Rabinovitz, M.S., 1996: Diabatic dynamic initialization with an iterative time integration scheme as a filter. *Mon. Wea. Rev.*, **124**, 1544-1557.

Huang, X., and P. Lynch, 1993: Diabatic digital-filtering initialization: Application to the HIRLAM model. *Mon. Wea. Rev.*, **121**, 589-603.

Lazic, L., 2000: "Initialization" using an iterative Matsuno style scheme in the Eta Model adjustment stage. *Meteor. Atmos. Phys.*, **75**, 121-130.

Matsuno, T., 1966: Numerical integrations of the primitive equations by simulated backward difference scheme. *J. Meteor. Soc. Japan*, **44**, 76-84.