Application of Physical Filter Initialization Scheme on WRFVAR

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The 3DVar and 4DVar has come a long way since its beginning in the late 1980s and early 1990s. In variational data assimilation scheme, usually, the analysis fields are not in balance because of poorly defined background error covariance, insufficient observations, imperfect modal, and observation error. Some researches have been focused on using weak constraints to reduce the dynamic imbalance between model variables based on the idea that unbalanced initial conditions often generate high-frequency oscillations with amplitude larger than those observed in nature. One of the approaches is digital-filter initialization (DFI) proposed by Lynch and Huang (1992)[1]. Another approach is to use some physical constraint such as temporal and spatial smoothness penalty functions. Liang et al. (2007)[2] proposed a model constrained 3DVar (MC-3DVar) technique to apply the full physics and dynamics of numerical model as constraints in 3DVar. In MC-3DVar, the full physics and dynamics of numerical model act as low-pass filter (physical filter) which can dramatically reduce the high frequency oscillations in the analyses fields. In this study, the physical filter initialization (PFI) scheme used in 3DVar is extended to four-dimension and implemented in WRF-4DVar system with the cost function as

$$J_4 = [\mathbf{x}-\mathbf{x}_b]^T \mathbf{B}^{-1}[\mathbf{x}-\mathbf{x}_b] + \sum_i^N [\mathrm{H}(\mathbf{x}_i)-\mathbf{y}_i]^T \mathbf{O}^{-1}[\mathrm{H}(\mathbf{x}_i)-\mathbf{y}_i] + \sigma \sum_j^M [\frac{\Delta \mathbf{x}_j}{\Delta t}]^T \mathbf{R}^{-1}[\frac{\Delta \mathbf{x}_j}{\Delta t}] \quad (1).$$

The first term of Eq.1 is as same as that in 3DVar. The second term is for distance between analysis and observations at time $i = 1,2...N$. The third term is the penalty defined at time $j = 1,2...M$.

Idealized experiment and real case study were performed in this study using WRF-4DVar with PFI scheme. The results indicate that the high frequency oscillations are obviously eliminated using PFI scheme and the spin-up time is shortened. The analysis and forecast fields are analyzed carefully and comparision with general 4DVar and 4DVar with DFI scheme in this study.

References

[1]Lynch P, Huang XY. Initialization of the HIRLAM model using a digital filter. *Mon. Wea. Rev.* **120**, 1019–1034, 1992.

[2]Liang Xudong, B. Wang, CL Chan, et al. Tropical cyclone forecasting with model-constrained 3D-Var. I: Description. *Quart. J. Roy. Meteor Soc.*, **133**, 147-153, 2007.