Geophysical Research Abstracts, Vol. 8, 05559, 2006
SRef-ID: 1607-7962/gra/EGU06-A-05559

A Model Constrained 3D-Var Data Assimilation Scheme

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More recently, some researches are focused on using weak constraints to reduce the dynamic imbalance between model variables based on the idea that unbalanced initial conditions often generates high-frequency oscillations with amplitude larger than those observed in nature. There are two main approaches including digital-filter initialization (DFI) and physical constraints.

DFI was proposed by Lynch and Huang (1992) and was used in 4DVar system by Gustafsson (1992), Gauthier and Thepaut (2001), Polavarapu et al. (2000), Wee and Kuo (2004). They showed that the imposed weak constraint controlled the emergence of high-frequency oscillations effectively, while maintaining a closer fit to the observations. Another way is using some physical constraints such as temporal and spatial smoothness penalty function in Sun and Crook (1994, 1997, 1998, 2001), mass continuity and smoothness in Gao et al. (1999), steady advective-diffusive equation in McIntosh and Veronis (1993), dynamical constraint in Brausseur (1991), Brausseur and Haus (1991) and Ishikawa et al. (2001).

In this study, a new 3DVar method is proposed with full dynamics and physics in the numerical model as constraints following Ishikawa et al. (2001). The Model Constrained 3DVar (MC-3DVar) scheme can be resolved without time integrating but ensuring the balance between variables in the initial conditions. The cost function of

MC-3DVar is given as:

$$\left\{ \begin{array}{c} J(x_a, x_b, y_0) = \underset{x}{Min}\, J(x, x_b, y_0) \\ J(x, x_b, y_0) = J_3(x, x_b, y_0) + \delta \left(\frac{\partial x}{\partial t}\right)^T \left(\frac{\partial x}{\partial t}\right) \ (\delta > 0) \end{array} \right. \quad (1)$$

Where x is the analysis field, x_b the background, y_o the observation and δ a given weighting. The inclusion of the model constraints introduced by term $\left(\frac{\partial x}{\partial t}\right)^T \left(\frac{\partial x}{\partial t}\right)$ not only requires the optimal IC to satisfy the model equations as possible, but also makes the minimization more stable.

In this study, a MC-3DVar scheme is fulfilled using MM5V3 and its adjoint and validated by a set of ideal experiments.

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