Geophysical Research Abstracts, Vol. 7, 01898, 2005
SRef-ID: 1607-7962/gra/EGU05-A-01898

The effect of the model errors generated by discretization of "On-Off" processes on VDA

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Abstract Through an idealized model of a partial differential equation with discontinuous "on-off" switches in the forcing term, this study investigates the effect of the model errors generated by discretization of discontinuous physical "on-off" processes on the variational data assimilation (VDA) in detail. Meanwhile, the validity of the adjoint approach in the VDA with "on-off" switches is also examined. The theoretical analyses demonstrate that in the analytic case, the gradient of the associated cost function (CF) with respect to the initial condition (IC) exists everywhere provided the IC does not trigger the threshold condition. But in the discrete case, if the "on-off" switches in the forward model are straightforwardly assigned the nearest time level when the threshold condition is exceeded as the usual treatment, the discrete CF gradient does not exist with respect to some ICs due to the model error, which is the difference between the analytic and discrete solutions to the governing equation, and the solution of the tangent linear model (TLM) obtained by the conventional approach, that is, to linearize the nonlinear forward model around the basic state at every time step while keeping the "on-off" switches the same as in the nonlinear forward model, would not be a good first-order linear approximation to the nonlinear perturbation solution of the governing equation. Consequently, the validity of the adjoint approach in VDA with parameterization physical processes could not be guaranteed. Furthermore, the identical-twin numerical experiments are conducted to illustrate the influences of these problems on VDA when using the adjoint method. The results show that the VDA results are quite sensitive to the first guesses of the IC, and the minimization processes in the optimization algorithm often fail to converge as well as the poor optimization retrievals would be generated.