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On the feasibility and effectivity of genetic algorithm to VDA with discontinuous "on-of " switches

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A conditional nonlinear optimal perturbation (CNOP) is an extension of the linear singular vector to the nonlinear case. For a nonlinear model, searching its CNOP is a constrained nonlinear optimization problem, and the optimal algorithm used is mainly based on the gradient descent method, in which the gradient information is usually provided by integrating backward the associated adjoint model. This kind of optimization method is named as ADJ hereafter. But in real atmospheric and oceanic models, "on-off" switches often occur due to various parameterization processes, which induce the gradient of the associated objective function with respect to some control variables not to exist, and finally result in the failure of the optimal algorithm to catch the global CNOP effectively. In this study, a constrained genetic algorithm (CGA) effectively tracking CNOPs is proposed, which is based on both advantages of genetic algorithms (GAs) in solving non-smooth optimization problems and the characteristic of the constraint condition of CNOPs. Compared with traditional constraint handling methods, such as the penalty function method, the treatment of the constraint condition in the CGA is not only easily implemented, but also has no requirement of adjusting indefinite parameters just as in the penalty function method. In addition, the CGA improves effectively the performance of GAs by using a hybrid crossover operator and a multi-ply mutation operator. In order to demonstrate the capability of the CGA to capture CNOPs in non-smooth situations, a partial differential equation with discontinuous "on-off" switches in its forcing term is adopted as the nonlinear model, and numerical experiments respectively using the CGA, the ADJ and a GA configuring tournament selection mechanism and niching strategy (named as GA-DEB hereinafter) are conducted to search global CNOPs of the nonlinear model. All results for different initial reference states show that in smooth cases (without the “on-off” influence), three optimization methods can capture global CNOPs. However, in non-smooth cases (with the “on-off” influence), most of CNOPs gained from the ADJ are local. Compared with the ADJ, although the GA-DEB has considerable improvement, its performance is far below the one of the CGA. The CGA is most effective among the three optimization methods and almost all of CNOPs attained by it are global.