Twin Experiment of 4DVar Capable of Uncertainty Quantification Based on Seismic Wavefield Propagation

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The four-dimensional variational method (4DVar) is a data assimilation technique widely used especially in the case of a massive numerical simulation model such as weather forecasting. The conventional 4DVar only optimizes parameters and initial conditions of time series but never evaluates their uncertainties. We proposed a new 4DVar that evaluated the uncertainties after obtaining the optima [Ito, Nagao et al., Phys. Rev. E, 2016]. The key technique in the new 4DVar is the second-order adjoint method, which obtains the product of a Hessian matrix and a given vector avoiding a direct computation of the Hessian matrix.

We verify this new 4DVar by applying it to an issue of seismic wave propagation in the two-dimensional field. The forward computation based on the wave equation is done by the finite volume method in space and the velocity Verlet method in time, which conserves the total energy during the time evolution. The periodic boundary conditions are assumed for the both horizontal boundaries of the computational domain, and the fixed boundaries are assumed for the top and bottom of the domain. The set of adjoint models is solved by a time integrator that enables an exact computation of Hessian-vector product without any discretization errors [Ito et al., 2019].

We report the result of this verification through a twin experiment that checks whether the new 4DVar properly estimates true values of parameters assumed in advance and quantifies their uncertainties.

Keywords: data assimilation, seismic wave propagation, uncertainty quantification, adjoint method

