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Recent advances in data assimilation in computational geodynamic models

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To restore dynamics of mantle structures in the geological past, data assimilation can be used to constrain the initial conditions for the mantle temperature and velocity from their present observations and estimations. The initial conditions so obtained can then be used to run forward models of mantle dynamics to restore the evolution of mantle structures. If heat diffusion is neglected, the present mantle temperature and flow can be assimilated using the backward advection (BAD) into the past. Two- and three-dimensional numerical approaches to the solution of the inverse problem of the Rayleigh-Taylor instability were developed for a dynamic restoration of diapiric structures to their earlier stages (e.g., Ismail-Zadeh et al., 1998, 2001, 2004; Kaus and Podladchikov, 2001). The mantle flow was modelled backwards in time from present-day mantle density heterogeneities inferred from seismic observations (e.g., Steinberger and O'Connell, 1998; Conrad and Gurnis, 2003). The variational (VAR) (or also called adjoint) data assimilation has been pioneered by meteorologists and widely used in oceanography and in hydrological studies. The use of VAR data assimilation in models of geodynamics has been put forward by Bunge et al. (2003) and Ismail-Zadeh et al. (2003). The VAR data assimilation algorithm was employed to restore numerically models of mantle plumes (Ismail-Zadeh et al., 2004, 2006; Hier-Majumder et al., 2005; Liu and Gurnis, 2008; Liu et al., 2008). The use of the quasi-reversibility (QRV) technique (more robust computationally) implies the introduction into the backward heat equation of the additional term involving the product of a small regularization parameter and a higher order temperature derivative (the resulting regularized heat equation is based on the Riemann law of heat conduction). The data assimilation in this case is based on a search of the best fit between the forecast model state and the observations by minimizing the regularization parameter. The QRV method was most recently introduced in geodynamic modelling (Ismail-Zadeh et al., 2007, 2008; Tantsyrev, 2008; Glisovic et al., 2009). The advances in computational geodynamics and in data assimilation attract an interest of the community dealing with lithosphere, mantle and core dynamics.