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Data assimilation in models of Earth's mantle dynamics

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Rapid progress in imaging deep Earth structures using seismic tomography and in studies of physical and chemical properties of mantle rocks facilitates research in assimilation of data related to mantle dynamics. We present a numerical approach for data assimilation, which allows for incorporating observations (at present) and unknown initial conditions (in the past) for mantle temperature and flow into a three-dimensional dynamic model in order to determine the initial conditions. The dynamic model is described by the backward heat, motion and continuity equations. The use of the quasi-reversibility (QR) method implies the introduction of the additional term of higher order of temperature differentiation, multiplied by a small regularization parameter, into the backward heat equation. 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. We apply the QR data assimilation to restore the evolution of mantle plumes and the lithospheric slab imaged by teleseismic body-wave tomography in the southeastern Carpathians. The present temperature and mantle flow have been assimilated to the geological past, and the prominent features of mantle structures have been recovered. The results of the QR data assimilation have been compared to that obtained by the variational (VAR) and backward advection methods. Although the accuracy of the QR data assimilation is lower compared to the VAR data assimilation, the QR method does not require any additional smoothing of the input data and filtering of temperature noise as the VAR method does.