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Two-dimensional backward modeling of mantle plumes

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Forward (in time) modeling of mantle plumes has been done excessively by previous authors and has provided useful insights into mantle dynamics. Forward modeling requires starting from generic initial temperature distributions in the mantle and follows the evolution of arising mantle plumes. Yet, geodynamicists are most interested in reconstructing mantle plume evolution backwards in time starting from the actual temperature state of the mantle as derived from geophysical measurements. Backward modeling produces significant numerical instabilities though; this is due to the heat diffusion term. We are dealing here with an ill-posed problem in the sense that initial imperfections, even very small, will amplify during backwards evolution in time. The advection term, in contrast, produces no instabilities. In order to stabilize the solution of the diffusion term, we need to regularize it using special techniques, like iterative and reversibility methods. The iterative method consists of a sequence of solutions of well-posed forward problems. In order to get a good initial guess for the iterative method, we need to apply reversibility methods (for example, approximations of Lattes & Lions, Tiba, Samarskii). These methods are based on the approximation of our ill-posed problem by a well-posed problem through addition of a regularization term. In addition, initial stages of temperature evolution are physically unstable for forward in time in certain range of frequencies. However backward modeling in the same range of frequencies is stable. Therefore the backward convection problem is relatively more stable then backward heat conduction problem.