Determining scaling laws from geodynamic simulations using adjoint gradients

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Whereas significant progress has been made in modelling of lithospheric and crustal scale processes in recent years, it often remains a challenge to understand which of the many model parameters is of key importance for a particular simulation. Determining this is usually done by manually changing the model input parameters and performing new simulations. For a few cases, such as for folding or Rayleigh-Taylor instabilities, one can use thick-plate stability analysis to derive scaling laws to obtain such insights. Yet, for more general cases, it is not straightforward to do this (apart from running many simulations). Here, we discuss a numerically cheaper approach to compute scaling laws using adjoint gradients. This method determines the gradients of the model solution versus the model parameters, or more precisely, quantifies the influence of a large number of parameters on the simulation. The required computational effort is independent on the number of model parameters, which makes it tractable even for complicated setups. We show how these gradients can be used to derive scaling laws. We test the method by reproducing existing scaling laws for a Rayleigh-Taylor instability problem, as well as that of folding of a single layer over a weaker basement. The results show that this method can, at very little computational overhead, give significant insights in the controlling parameters of geodynamic simulations.