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Solid Earth
Discussions

Interactive comment on "Breaking supercontinents; no need to choose between passive or active" *by* Martin Wolstencroft and Huw Davies

Anonymous Referee #2

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This paper presents three global mantle convection calculations using a full 3D spherical shell model. The study aims to provide a determination of the cause of supercontinent rifting, arguing that rifting is best explained when both mantle plumes and extensional rifting are present, rather than being attributed to one or the other of these phenomenon. In the context of this study, extensional rifting appears to be adopted as a term to describe rifting that occurs due to a cumulative effect of the tractions associated with convection (e.g., due to the pull associated with distant subduction) on lithospheric stresses (however, this needs clarification). For example, Figure 4b shows downwelling on the margins of a supercontinent, with the suggestion that tractions due to flow towards the subduction zones, below the continent, contribute to intracontinental

'long-range extensional stresses' that cause rifting. The ideas presented are not particularly novel, indeed supercontinent breakup studies have been presented for some 30 years now, including in other much more systematic and comprehensive studies (e.g., Rolf et al., 2014) that also utilized a spherical shell geometry. The newer contribution from this study is the analysis of a mantle avalanche that occurs with the modelling of an endothermic phase change at a depth of 660 km and an argument for the role of avalanches that would contribute to continental rifting to help drive a global supercontinent cycle. This idea is interesting but unfortunately various aspects of the (just) three models presented mean that they are not suitable for modelling the supercontinent cycle or even just continental breakup.

The most fundamental manifestation of mantle convection is the motion of the Earth's tectonic plates. The plates, continent cratons and deep convection comprise a coupled system in which feedback makes it impossible to separate the study of one without the influence of the other. In particular, a global model of terrestrial mantle convection must include plates in order to emulate terrestrial evolution. Moreover, it must include continental cratons in order to model the supercontinent cycle or infer the reasons for its occurrence. The models presented here do not appear to feature plates not incorporate cratons. Indeed, two of the three models presented are isoviscous and the third includes a thermal viscosity contrast of just two orders of magnitude. These parameters do not allow for the generation of plates. Consequently we have to ask what can we learn from models that do not include plates when they are applied to trying to understand a process that affects continental lithosphere (continental rifting).

Although the suggestion that intermittent mantle avalanches may play a role in driving a supercontinent cycle (that necessitates periodic rifting) is worth exploring, in this manuscript the calculations presented for the purpose of supporting this hypothesis are inadequate (in number and sophistication) to adequately address the issue. At a minimum the authors need to demonstrate the surface characteristics of their cases - do they exhibit anything like plate tectonics? The models need to include continental cratons if they are to analyze the effect of convection on cratons (e.g., if cratons were present would there be a connection between their positions and avalanches). Has there ever been a study that found avalanches occur in global models (2D or 3D) that feature plate-like surface motion and evolution?

The bottom line is that plate tectonics is an observed phenomenon but mantle avalanches are a phenomenon that appears in some mantle convection simulations and no concrete evidence for avalanches in the Earth's history exists. A study claiming that avalanches can play a role in supercontinent breakup should at least include model supercontinents and mantle convection observables (plates) as a starting point.

Further comments on presentation:

1. The figures should include some model geotherms (i.e., laterally averaged temperature as a function of depth).

2. A figure of the surface viscosity field of model 3 should be included.

3. Present core heat flow as well as surface (Figure 1 is heat flow, not flux).

4. What is a 'smaller' convective feature (line 88) and why would it have more trouble breaking through the phase change? Specifically, it should be more vigorous in a high Rayleigh number flow.

5. On line 67 a comparison appears to be made between 2D and spherical shells. Is that 2D Cartesian geometry or 2D annuli geometry (please be clear).

6. On line 118 what exactly is meant by inward and outward as they are used here. This doesn't appear to be referring to radial directions but rather lateral. Can more careful wording by offered?

7. There are many previous studies on supercontinent breakup and identification of its causes that have not received adequate referencing. For example, please check and include some of the papers from the 90s, in particular those that discussed passive

versus active mechanisms for supercontinent rifting.

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