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A numerical study of subduction zone dynamics using linear viscous to thermo-mechanical model setups including (de)hydration processes

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This thesis documents a series of numerical modelling experiments devised to explore the influence of lateral boundary conditions in modelling subduction zone processes, to compare and contrast the behaviour of a set of test models run on different numerical codes, and finally to test different water migration implementations on subduction zone model behaviour.

Numerical models are commonly used to provide insight into different types of geological process, and models that attempt to explain subduction zone processes are particularly influential. Model codes are becoming increasingly complex, and it is not always straightforward to compare and contrast the results of different models – which behaviours are code-specific and which actually provide insight into geological/tectonic processes? This thesis therefore documents a number of important findings.

Firstly, different lateral boundary conditions in the models critically affect subduction behaviour (e.g. slab retreat, slab behaviour at the 660km discontinuity). This means that different subduction settings need to be modelled in different ways – an important insight into model interpretation.

Secondly, a series of numerical model tests of increasing complexity were run on up to seven different codes. The simplest models, run with a linear-viscous rheology, showed <5% difference in different quantifiable model outputs compared to each other, and that this variation was probably due to model resolution. Importantly, however, model results increasingly diverge as the model setup becomes more complicated, including the addition of brittle behaviour and pressure and/or temperature-dependent viscosity. This has important implications for the interpretation of model results, as fine-scale behaviour may be an artifact of the numerical methodology rather than contributing to tectonic understanding.

Lastly, the effect on the model results of three different water-migration schemes was tested: element-wise vertical migration, imposed vertical water-flow velocity and a density-driven velocity. Dehydration appeared to exert an influence on model results but the manner in which water migration was applied was not that important, especially for large-scale models. The experiments did find that the local or wider distribution of free water was influenced by the scheme applied, and that this may have implications for the wider distribution of water in the mantle.

This thesis was extremely well-written, and presented in a coherent and logical fashion. One paper is already published, and two more in preparation. I have no doubt that these chapters will turn into well-received contributions to the scientific literature. The motivation behind the study and the results/conclusions were clearly laid out and easy to follow. The thesis clearly demonstrates Mr Quniquis' scientific maturity and proves his ability to carry out creative scientific work.

I would like to ask Mr Quinquis a few questions about his progress through his PhD and the implications of his results.

1. How did the project evolve from what was set out to investigate in the beginning and what ended up as the end result? How did your ideas develop from those of your supervisors?

2. How were the codes chosen for the comparison tests? Were there any difficulties in getting people to run the tests? Is there a bias towards the simpler codes or were the tests run on more complex codes as well?

3. What are the implications of the divergence in test model results due to increasing complexity or changes in boundary conditions for developing further models to understand tectonic processes?

4. Clearly the choice of water migration scheme has a big influence on the amount of water in different places in the models, even if the different schemes don't have a big effect on model evolution. What information do you need from the 'mantle geology' community in order to provide the best possible modelling insight into subduction (de)hydration processes and effects?

5. It would be interesting to discuss which inputs have the biggest effects on model outputs, and how the influence of uncertainty in these parameters might best be mitigated.

6. Finally what are the take-home messages of this work for the non-modelling geological community? What new insight do these models provide on understanding processes, and what should the non-modelling community look for in modelling papers in order to help them understand and interpret the results in terms of real-world behaviour?

Congratulations, Matthieu, for a very well-written, logical and coherent thesis, and all the best for your future career.

With best wishes,

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