Utrecht University

ETH zürich | D ERDW EARTH SCIENCES

The effects of intrusive magmatism and water on the tectonic regime of Venus

Marla Metternich[1*]; Paul Tackley[2]; Diogo L. Lourenço[2]; Cedric Thieulot[1]

1: Department of Earth Sciences, Faculty of Geosciences, Utrecht University, **2:** Institute of Geophysics, Department of Earth Sciences, ETH Zürich

*m.a.metternich@students.uu.nl

1 Introduction

Modelling the interior dynamics may provide insight as to why Earth and Venus have such **different surface conditions**.

Two end-member models (**episodic lid** / **stagnant lid**) fail to fully explain the constraints regarding **volcanism** & **tectonics**.

New tectonic regimes were observed if **intrusive magmatism** is included [1] and a more realistic **"weak" crustal rheology** is considered [2].

Water possibly exists in Venus' interior. In this case it would affect the rheology and thermal evolution. Water has never been implemented for models of Venus' interior before.

Aim: explore the effects of intrusive magmatism and water presence on the tectonic regime of Venus.

2 Methodology

Numerical model

Mantle convection is modelled using StagYY in a 2D annulus geometry [3]. A "weak" crust rheology with dislocation creep is used [5]. Partial melting produces melt that will intrude or erupt according to a fixed ratio (0.8 / 0.2). Melt segregation and eruption of harzburgite is allowed for. However, only shallow melt may intrude/erupt.

Water treatment

Water is implemented using a relative concentration and is advected on tracers. The effect it has on viscosity goes according to an Arrhenius law.

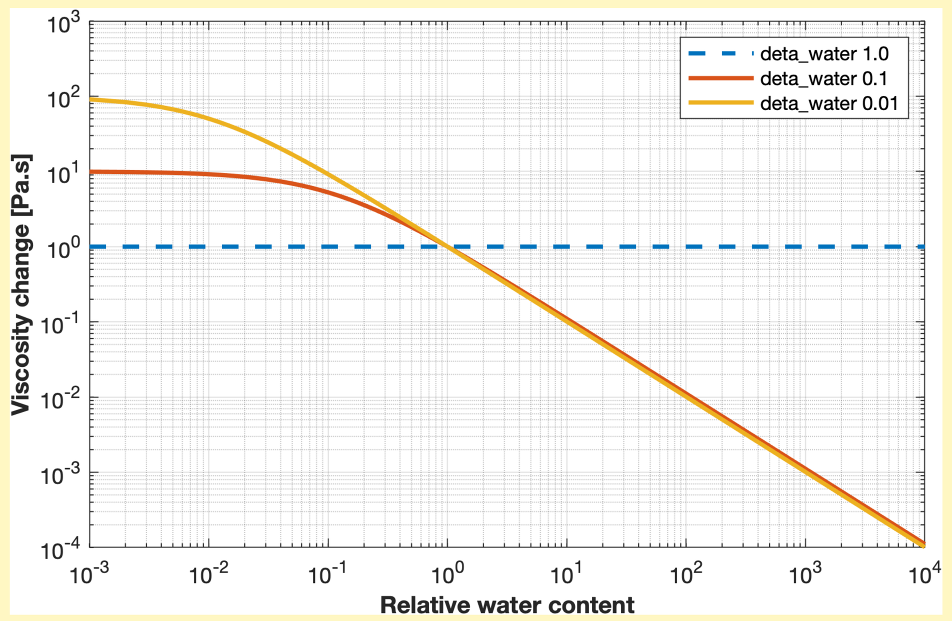

Fig. 1: Viscosity change as a function of relative water content.

3 Intrusive magmatism

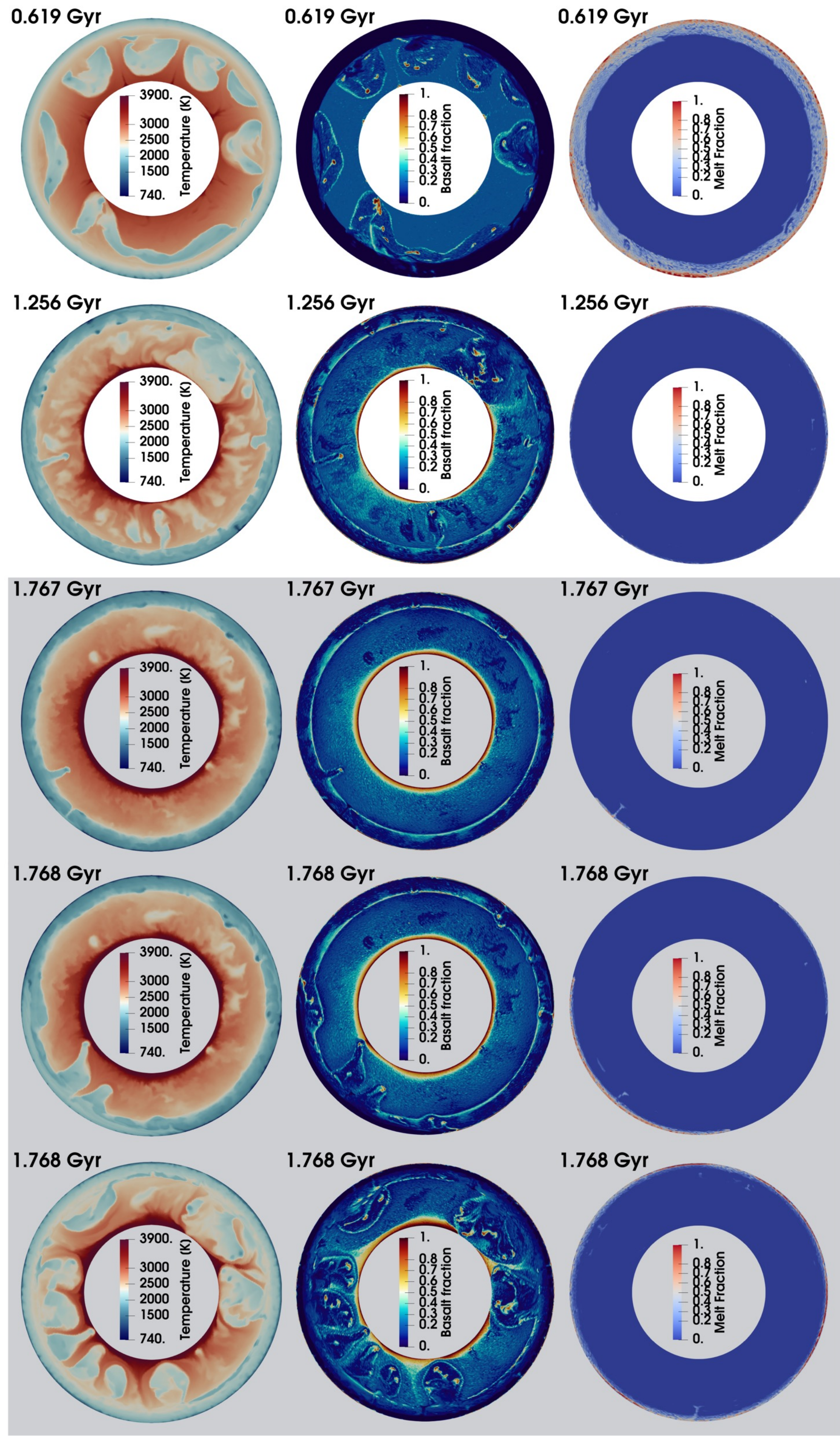

Fig. 2: Temperature field, basalt fraction and viscosity field at moments of global overturns.

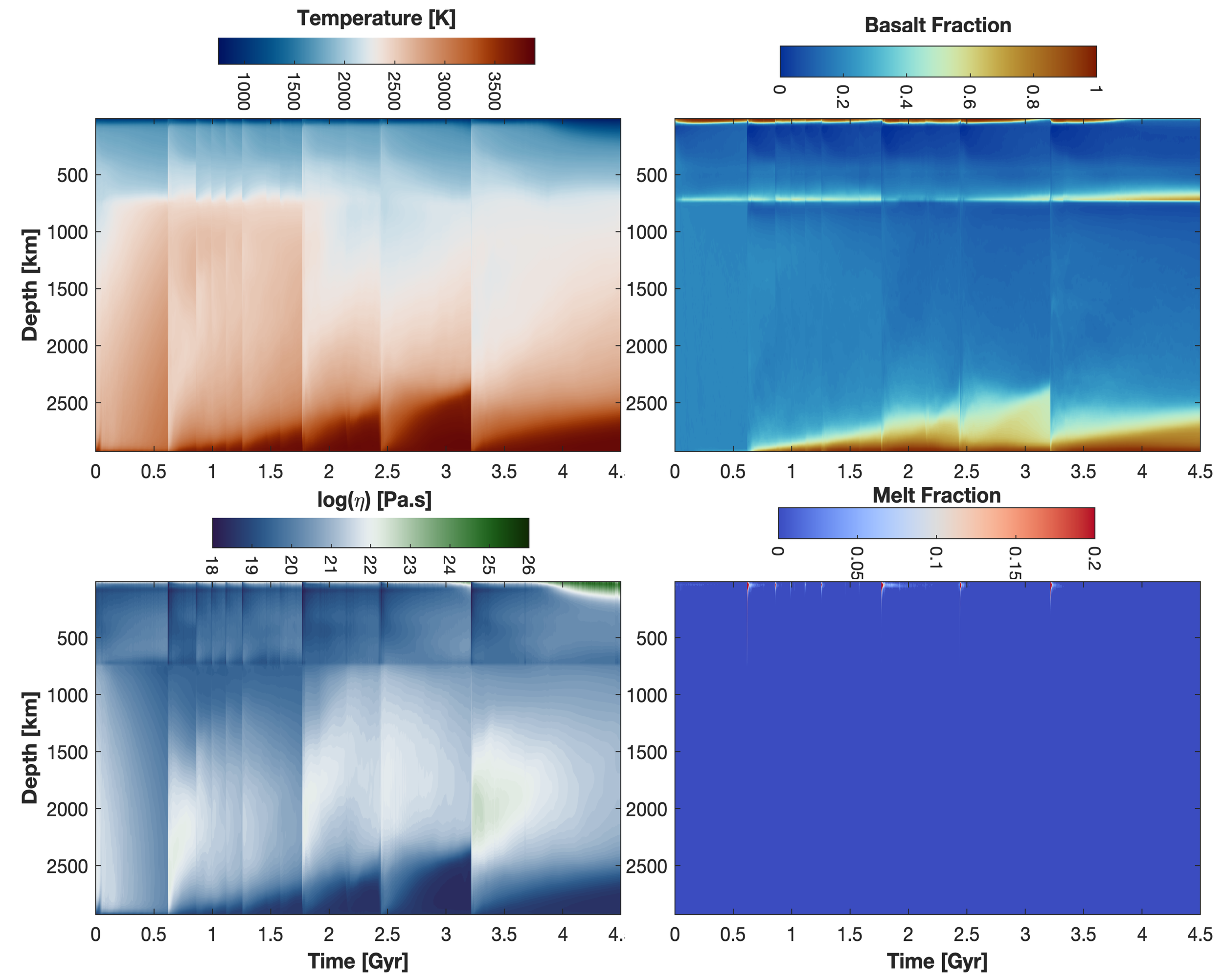

Fig. 3: Evolution of radial profiles of temperature, basalt fraction, viscosity and melt fraction.

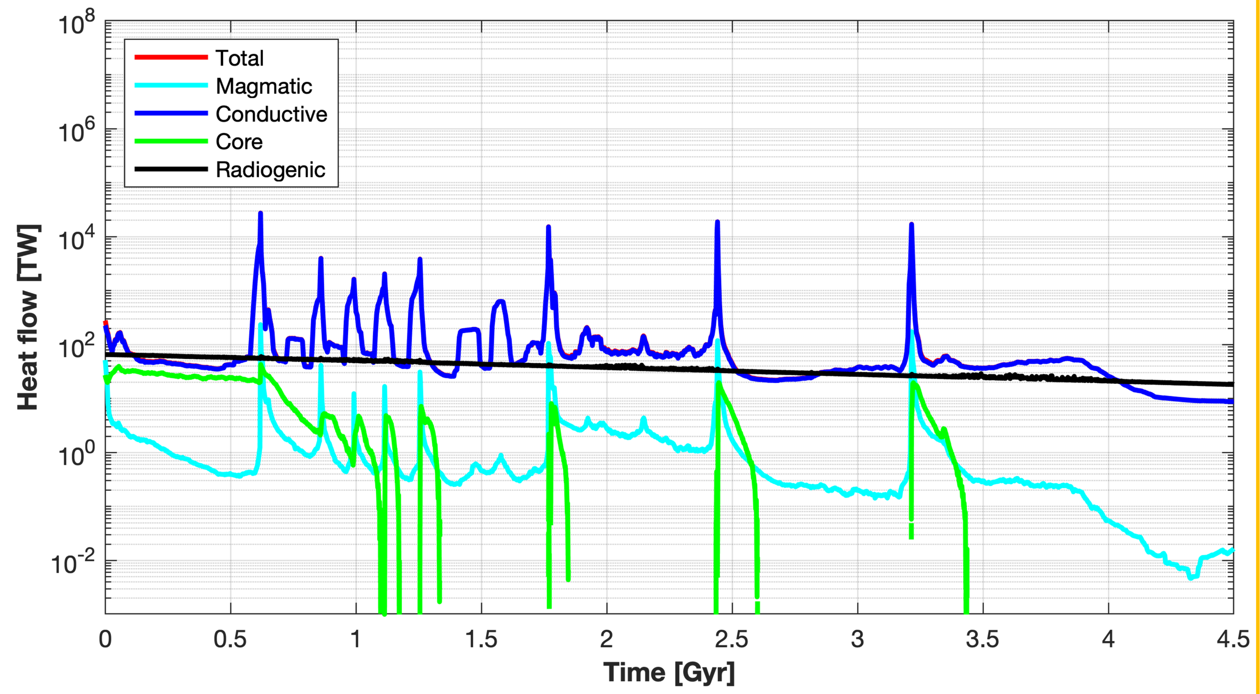

Fig. 4: Contributions of radiogenic heating, core cooling, conductive heat flow and magmatic heat flow over time.

4 Influence of water

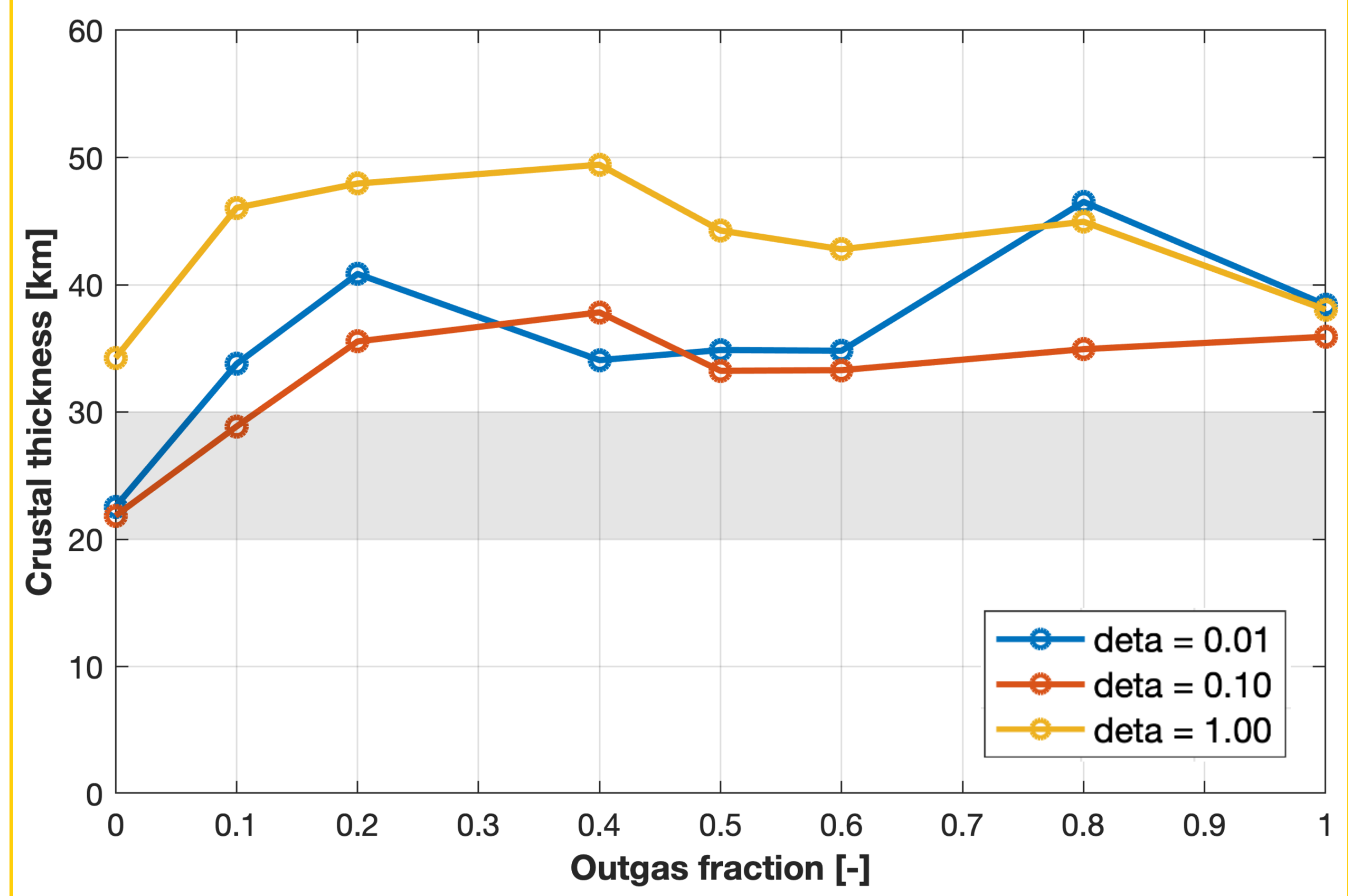

Fig. 5: Crustal thickness averaged over the last 500 Myr for models with ranging outgas fractions and varying influence of water on viscosity.

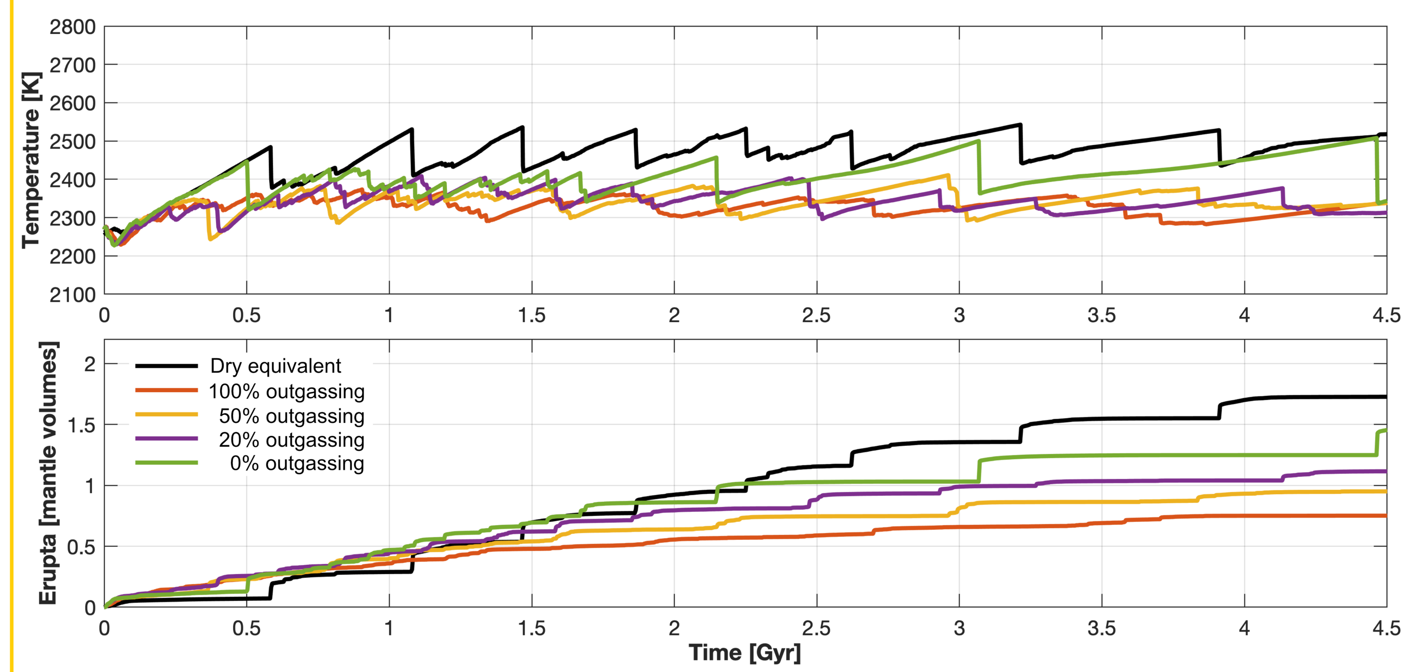

Fig. 6: Global average temperature and erupted volume for models including water and varying outgas fractions.

Bibliography

1. Lourenço, D. L., Rozel, A. B., Ballmer, M. D., & Tackley, P. J. (2020). Plutonic-squishy lid: a new global tectonic regime generated by intrusive magmatism on Earth-like planets. Geochemistry, Geophysics, Geosystems, 21(4), e2019GC008756.
2. Tian, J., Tackley, P. J., & Lourenço, D. L. (2023). The tectonics and volcanism of Venus: New modes facilitated by realistic crustal rheology and intrusive magmatism. Icarus, 115539.
3. Tackley, P. J. (2008). Modelling compressible mantle convection with large viscosity contrasts in a threedimensional spherical shell using the yin-yang grid. Physics of the Earth and Planetary Interiors, 171(1-4):7–18.
4. Lourenço, D. L., Rozel, A., and Tackley, P. J. (2016). Melting-induced crustal production helps plate tectonics on Earth-like planets. Earth and Planetary Science Letters, 439:18–28.
5. Gerya, T. (2014). Plume-induced crustal convection: 3D thermomechanical model and implications for the origin of novae and coronae on Venus. Earth and Planetary Science Letters, 391:183–192.

5 Discussion & Outlook

Mid-crustal intrusions cause weakening of the crust, promoting drippings and regional overturns. The crust remains relatively thin, facilitating efficient mantle cooling through conduction.

Global lithospheric overturns with high surface mobilities in between characterize the evolution, in accordance with the "**deformable episodic lid**" regime [2].

Stronger effect of water on viscosity and **stronger outgassing** have a similar effect on the thermal evolution and tectonics, leading to more **basaltic drippings** & **regional overturns**.

Remaining water accumulates in regions where **basalt** is **abundant**, such as the lower mantle, basalt barrier and crust itself.

Outlook: further testing of the effect of water on the rheology would enhance the water-containing models.