EGU21-7311, updated on 21 May 2022
https://doi.org/10.5194/egusphere-egu21-7311
EGU General Assembly 2021

Thermal evolution of terrestrial planets with 2D and 3D geometries

Aymeric Fleury, Ana-Catalina Plesa, and Christian Hüttig
DLR, Institute of Planetary Research, Berlin, Germany (aymeric.fleury@dlr.de)

In mantle convection studies, two-dimensional geometry calculations are predominantly used, due to their reduced computational costs when compared to full 3-D spherical shell models. Although various 3-D grid formulations [e.g. 1, 2] have been employed in studies using complex scenarios of thermal evolution [e.g., 3, 4], simulations with these geometries remain highly expensive in terms of computational power and thus 2-D geometries are still preferred in most of the exploratory studies involving broader ranges of parameters. However, these 2-D geometries still present drawbacks for modeling thermal convection. Although scaling and approximations can be applied to better match the average quantities obtained with 3D models [5], in particular, the convection pattern that in turn is critical to estimate melt production and distribution during the thermal evolution is difficult to reproduce with a 2D cylindrical geometry. In this scope, another 2D geometry called “spherical annulus” has been proposed by Hernlund and Tackley, 2008 [6]. Although steady state comparison between 2D cylindrical, spherical annulus and 3D geometry exist [6], so far no systematic study of the effects of these geometries in a thermal evolution scenario is available.

In this study we implemented a 2-D spherical annulus geometry in the mantle convection code GAIA [7] and used it along 2-D cylindrical and 3-D geometries to model the thermal evolution of 3 terrestrial bodies, respectively Mercury, the Moon and Mars.

First, we have performed steady state calculations in various geometries and compared the results obtained with GAIA with results from other mantle convection codes [6,8,9]. For this comparison we used several scenarios with increasing complexity in the Boussinesq approximation (BA).

In a second step we run thermal evolution simulations for Mars, Mercury, and the Moon using GAIA with 2D scaled cylinder, spherical annulus and 3D spherical shell geometries.In this case we considered the extended Boussinesq approximation (EBA), an Arrhenius law for the viscosity, a variable thermal conductivity between the crust and the mantle, while taking into account the heat source decay and the cooling of the core, as appropriate for modeling the thermal evolution. A detailed comparison between all geometries and planets will be presented focussing on the convection pattern and melt production. In particular, we aim to determine which 2D geometry reproduces most accurately the results obtained in a 3D spherical shell model.

Aknowledgments: The authors gratefully acknowledges the financial support and endorsement from the DLR Management Board Young Research Group Leader Program and the Executive

Board Member for Space Research and Technology.

References: [1] Kageyama and Sato, G3, 2004; [2] Hüttig and Stemmer, G3, 2008; [3] Crameri & Tackley, Progress Planet. Sci., 2016; [4] Plesa et al., GRL (2018); [5] Van Keken, PEPI, 2001; [6] Hernlund and Tackley, PEPI, 2008; [7] Hüttig et al, PEPI 2013; [8] Kronbichler et al., GJI, 2012; [9] Noack et al., INFOCOMP 2015.