Modelling of the Influence of a Giant Impact and the Resulting Antipodal Anomaly on the Martian Mantle Convection

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Abstract

We have studied the influence of a large impact on the mantle dynamics of Mars. In contrast to earlier studies, we have also considered the antipodal temperature anomaly that is caused due to the superposition of the shock waves.

1. Introduction

Impact processes play an important role in the planetary evolution of terrestrial planets. For instance, it has been suggested that the origin of the Martian hemisphere dichotomy, which is expressed by the change in elevation between the cratered southern highlands and the smooth northern lowlands, is caused by one or several large impacts [1,2,3]. The Hellas basin, which is the largest impact basin on Mars, was formed by an impact during the late heavy bombardment period of the solar system [4]. The massive Hellas strike on one side of Mars is suggested to have triggered the antipodal volcanic region, i.e., Tharsis [5].

The cause for the strong influence of a large impact on the thermal and chemical evolution of the planet is the impact-induced temperature increase. In a very short time, the mantle material is heated above the solidus and possibly even the liquidus.

Here, we investigate the effects of giant impacts on mantle convection and thermal evolution of Mars in a 2D spherical shell. As a starting temperature condition, we use the results of a 2D impact model. We will show the change of temperature distribution and convection pattern with simulation time.

2. Computational Model

For the simulation of the mantle convection, we use the 2D and 3D spherical simulation code *GAIA* [6]. We consider a one-plate planet without a crust. Partial melt is calculated assuming a dry mantle model. The additional temperature in the mantle induced by the giant impact is calculated with the 2D code *iSALE* [7]. We consider an impactor that is perpendicular to the surface.

3. Results

The 2D impact model shows that directly after the impact, a shock wave leads to a strong heating from the impact basin to the interior. The mantle temperature increases due to the high induced pressure. In a very short time, the mantle material is heated above the solidus (and liquidus) curve, such that a high amount of melt is produced and reaches the surface, until the mantle temperature sinks again below the solidus. Still, the mantle temperature is much higher than the temperature of the surrounding material.

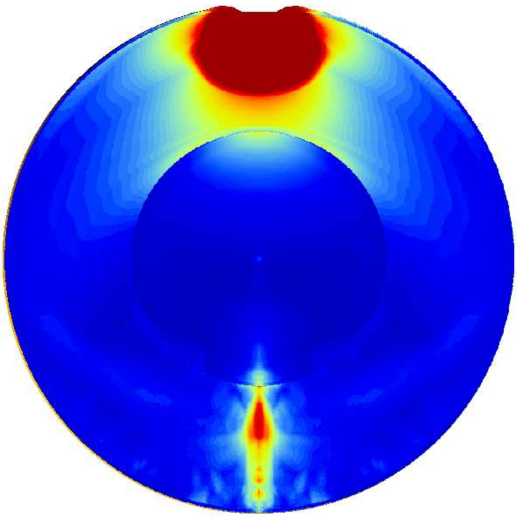

Figure 1: Temperature profile after giant impact.

Depending on the velocity and mass of the impactor, not only the material next to the impact basin heats up. Due to superposition of the shock waves, which reach the opposite site of the mantle and additional waves, which are reflected from the surface, a pipe-like positive temperature anomaly can be seen at the opposite side of the impact, see Figure 1.

The influence of this particular temperature distribution on the mantle dynamics has been compared with a model assuming just a one-sided temperature anomaly.

Also the influence on the convecting mantle has been investigated in two different scenarios where the impact region was located above an upwelling and downwelling plume respectively.

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