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Influence of Regional Crustal Variations on the Global Temperature Field of Mars

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Introduction: Although Mars is a terrestrial planet, its internal dynamics differ drastically from the Earth's. As Mars does not exhibit plate tectonics but instead possess a stagnant lid, its ability to loose heat is controlled by the layers forming this stagnant lid. The topmost of these layers is the crust, which - like the stagnant lid in general - has been in place essentially unaltered for the largest part of the planet's history. The main feature of the crust is the dichotomy which divides the planet into the northern lowlands and the southern highlands. But in addition to this prominent global crustal variation, there are also variations on a more regional scale like the thinning of the crust underneath impact basins or its thickening beneath volcanic provinces.

Although the influence of crustal variations on recent volcanism has recently been analyzed [1], so far no attention has been spend on the global effects of regional crustal variations. As the crust has a lower thermal conductivity than the mantle with about 2 $Wm^{-1}K^{-1}$ [2] compared to an average of about 3.3 $Wm^{-1}K^{-1}$, even relatively small crustal variations can lead to significant changes of internal temperatures. Interestingly, these effects can not just be observed on a regional but also on a global scale.

Models: For the analysis two-dimensional models have been developed using the commercial COMSOL Multiphysics© package. The models take present-day Martian conditions into account (e.g. amount of radioactive heat sources) but are still highly time-dependent due to the convection within the mantle. To ascertain that thermal anomalies observed in the results are not caused by convection cells, the models have been averaged over a time representing 24 Ga. Thereby it can be guaranteed that possible thermal effects of mantle convection are averaged out. To compare the effects of different crustal variations, several crustal set-ups have been modeled.

The regional variation has a diameter of 1000 km and a maximum additional thickness of 20 km as the excess crust thins to the edges of the region. This variation compares in size to the Elysium area or the main part of the Tharsis bulge.

Results: The most striking result of all models is that temperatures are not only increased underneath the area of higher crustal thickness but that areas of increased temperatures can be found globally. In addition, there are also areas of significantly reduced temperatures within the stagnant lid. These thermal anomalies are not due to convection patterns as the influence of mantle convection has been eliminated from the results. Thus, merely the regional crustal variation is responsible for the generation of globally distributed thermal anomalies.

While the mantle temperatures stay nearly the same, temperature differences of more than 200 K can be observed for certain areas within the stagnant lid. This is far more than some authors have found for the effects of a potential mantle plume [3, 4]. Thus, comparatively small regional variations in crustal thickness can have a significant global impact on the internal temperature distribution of Mars which rivals and even surpasses that of a potential present-day mantle plume

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