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Ancient dynamos more sensitive to core-mantle boundary heat flows

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The early dynamos of Earth and Mars probably operated without an inner core being present. They were thus exclusively driven by secular cooling and radiogenic heating, whereas the present geodynamo is thought to be predominantly driven by buoyancy fluxes which arise from the release of latent heat and the compositional enrichment associated with inner core solidification.

The impact of the inner core growth on the ancient geodynamo has been discussed extensively but is still controversial. While earlier paleomagnetic and thermal evolution models proposed a large impact, recent numerical dynamo simulations suggest that the effect on field would be rather minor.

As for Mars, the Mars Global Surveyor detected a strong northern-southern dichotomy in the crustal magnetization. A scenario proposed so far is due to such an ancient dynamo, where thermal heterogeneities at the core-mantle boundary (CMB) were imposed by the lower mantle structure. A key question for this scenario is how easily influence of the boundary anomalies emerges.

Here we show that the dynamos without inner core solidification are much more sensitive to the CMB heat flows imposed by the lower mantle structure. We compare three-dimensional convection-driven MHD dynamos either driven by homogeneously distributed internal heat sources or by buoyancy sources at the inner core boundary (ICB). Several different CMB heat-flux patterns are used. In the dynamos driven by internal heating a rather small CMB heat-flux heterogeneity suffices to break symmetries and leads to boundary-induced structures and different field strength. The effect is much smaller for dynamos driven by ICB associated buoyancy sources. The result indicates that the field intensity and morphology of the ancient dynamos of Earth or Mars were more variable and more sensitive to the thermal CMB structure than the geodynamo after onset of inner core growth.