Hot topic: How heat flow affects the Earth's magnetic field

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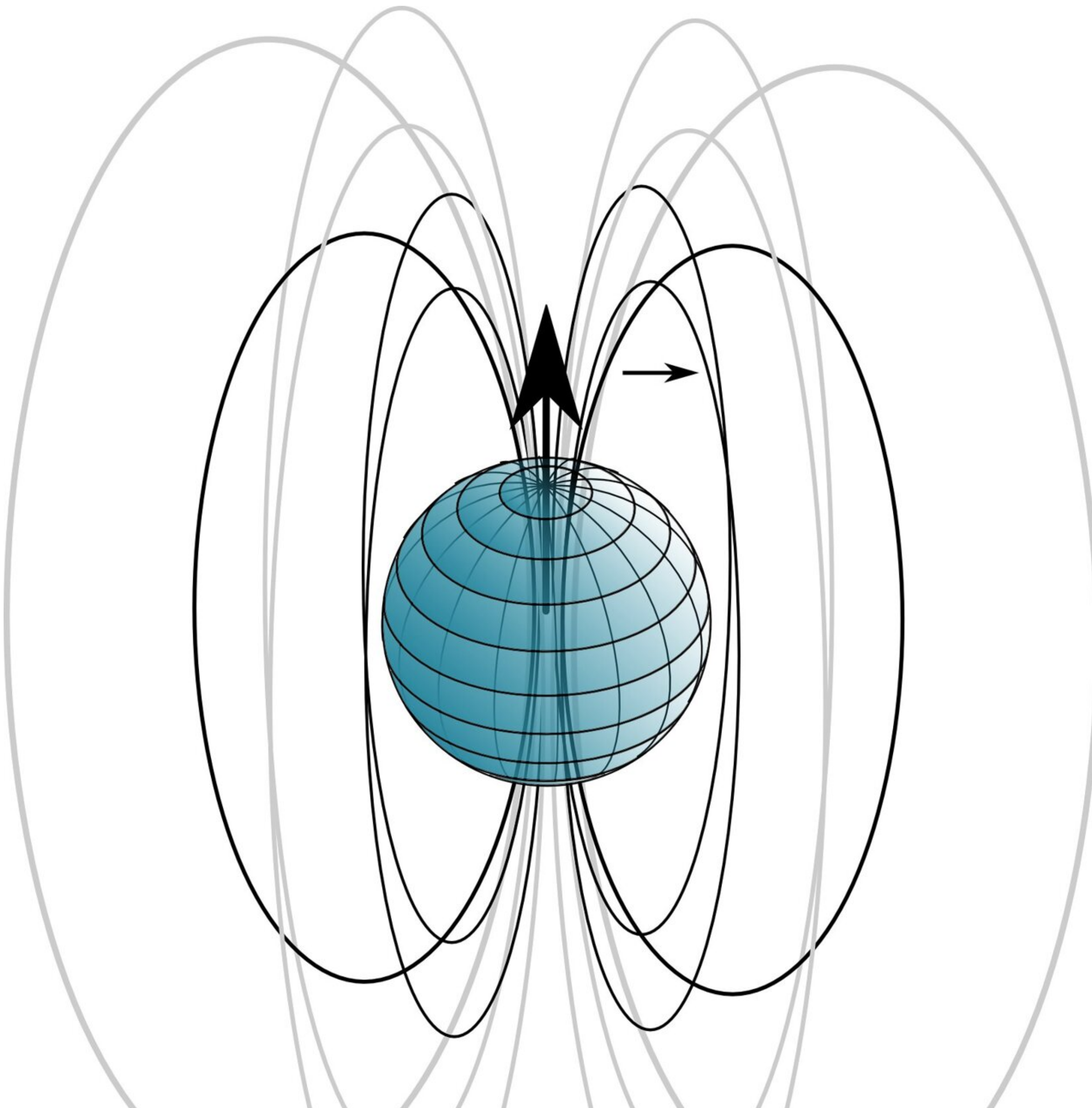

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Compass readings that do not show the direction of true north and interference with the operations of satellites are a few of the problems caused by peculiarities of the Earth's magnetic field.

The magnetic field radiates around the world and far into space, but it is set by processes that happen deep within the Earth's core, where temperatures exceed 5,000 degrees Celsius.

New research from geophysicists at the University of Leeds suggests that the way this super-hot core is cooled is key to understanding the causes of the peculiarities—or anomalies, as scientists call them—of the Earth's magnetic field.

Dynamo at the center of the Earth

In the extremely hot temperatures found deep in the Earth, the core is a mass of swirling, molten iron which acts as a dynamo. As the molten iron moves, it generates the Earth's global magnetic field.

Convective currents keep the dynamo turning as heat flows out of the core and into the mantle, a rock layer that extends 2,900 kilometers up to the Earth's crust.

Research by Dr. Jonathan Mound and Professor Christopher Davies, from the School of Earth and Environment at Leeds, has found that this cooling process does not happen in a uniform way across the Earth—and these variations cause anomalies in the Earth's magnetic field.

Variations in Earth's magnetic field

Seismic analysis has identified that there are regions of the mantle, under Africa and the Pacific for instance, that are particularly hot.

Computer simulations by the researchers have revealed that these hot zones reduce the cooling effect on the core—and this causes regional or localized changes to the properties of the magnetic field.

For example, where the mantle is hotter, the magnetic field at the top of the core is likely to be weaker.

And this results in a weaker magnetic field which is projected into space above the South Atlantic, which causes problems for orbiting satellites.

Interference with space technology

Dr. Mound, who led the study, said, "One of the things that the magnetic field in space does is deflect charged particles emitted from the sun. When the magnetic field is weaker, this protective shield is not so effective.

"So, when satellites pass over that area, these charged particles can disrupt and interfere with their operations."

Scientists have known about the anomaly over the South Atlantic since they started monitoring and observing the magnetic field, but it is not known if it is a long-lived feature or something that has happened more recently in the history of the Earth.

As the study at Leeds has revealed, the anomalies are likely to be caused by differences in the rate at which heat is flowing from the Earth's core into the mantle. Whereabouts in the Earth's inner structure these heat flow differences happen is likely to dictate how long they could last.

Dr. Mound added, "Processes in the mantle happen very slowly, so we can expect the temperature anomalies in the lower mantle will have stayed the same for tens of millions of years. Therefore, we would expect the properties of the magnetic field they create also to have been similar over tens of millions of years.

"But the hotter, outer core is quite a dynamic fluid region. So, the heat flows and the magnetic field properties they cause will probably fluctuate on shorter time scales, perhaps for 100's to 1000's of years."

The paper—Longitudinal structure of Earth's magnetic field controlled by lower mantle heat flow—is published in *Nature Geoscience*.

More information: Jonathan Mound, Longitudinal structure of Earth's magnetic field controlled by lower mantle heat flow, *Nature Geoscience* (2023). DOI: 10.1038/s41561-023-01148-9.
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