Clemson mathematician helps deepen understanding of Earth's mysterious mantle

MEDIA RELEASE

Laura Schmitt, College of Science
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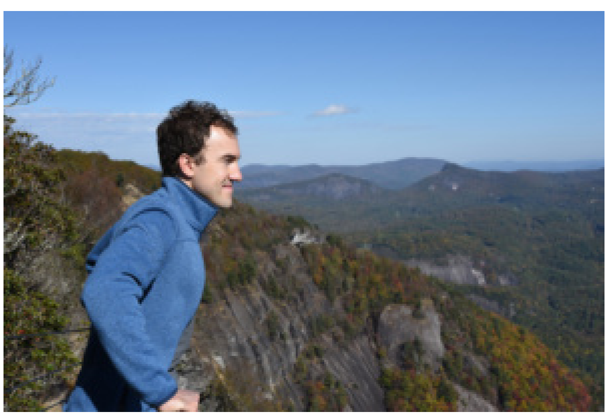
CLEMSON, South Carolina — More than 1,800 miles thick and sandwiched between the Earth's surface and its super-hot core, the mantle is made up of hot, iron-rich rock that slowly moves upward to cool. Known as convection, this process of heat transfer causes a cascade of geological events that lead to earthquakes, volcanic eruptions, or the formation of mountains.

Researchers want to better understand the convection process and other geodynamic activities, but it's impossible to drill into the mantle to see what's happening because the pressure and temperature are too high. Instead, scientists infer information using seismic imaging and speculate about what's happening well below the Earth's surface by relying on computational models that simulate the slow movement of rocks and tectonic plates on time scales from thousands to millions of years.



Clemson mathematical sciences associate professor Timo Heister is part of a multi-institutional team that received a $2.5 million NSF grant to simulate the Earth's mantle.
Image Credit: Courtesy of Timo Heister

College of Science researcher Timo Heister is part of a multi-institutional team of Earth scientists and mathematicians that recently received a $2.5 million National Science Foundation grant to develop a new framework for integrated geodynamic models that will provide realistic simulations from our planet's mantle boundary to its surface.

"Most physical phenomena can be described by partial differential equations that explain energy balances or loss," said Heister, an associate professor of mathematical sciences who will receive $393,000 of the overall funding. "My geoscience colleagues will develop the equations to describe the phenomena and I'll write the algorithms that solve their equations quickly and accurately."

The framework will be based on an open-source software tool that Heister and other team members created over the past eight years. The Advanced Solver for Problems in Earth's Convection (ASPECT) simulates processes in the Earth's mantle, and it is widely used by Earth science researchers worldwide.

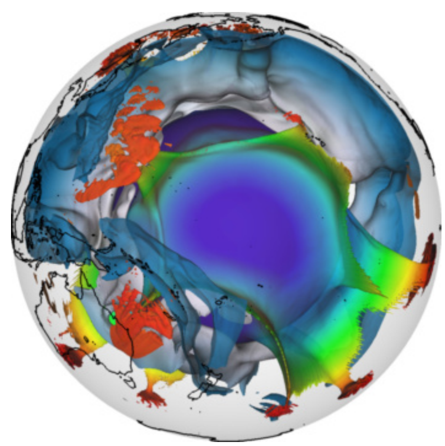
ASPECT's simulations have the potential to provide enormous insight into a wide range of topics, including time and space variations in the motion and deformation of tectonic plates, the flow of magma and the cycling of water through the Earth's interior, the structure of deep Earth, and surface evolution.

According to Heister, he'll use seismic activity, tectonic plate movement, core temperature, and other data generated by seismologists and Earth and planetary scientists as input into ASPECT. He'll run the ASPECT simulations on high-performance computing tools like Clemson University's Palmetto Cluster and other supercomputers.

"We use ASPECT to compute a reference state that helps us understand the current conditions in the mantle as best as we can," he said. "Scientists can then use this framework to do their own simulations."

On the one hand, scientists can use the reference state to perform regional high-resolution simulations. On the other hand, scientists can perform their own global simulations to determine how rock below the Earth's surface responds to stress, particularly at tectonic plate boundaries.

In fact, one of Heister's collaborators on this project, University of California-Davis project scientist Rene Gassmoeller, has used ASPECT to run a simulation of major mantle hotspots — volcanic formations that are created by hot plumes rising from the core-mantle boundary. Examples include Hawaii, Iceland and Yellowstone.



The final state of a global mantle convection simulation after 250 Ma of model time. Isosurfaces of -150 K (white to blue) and +300 K (rainbow colored) temperature deviation from an adiabatic temperature profile for the African Pacific hemisphere. Colors visualize height above the core-mantle boundary, and coastlines are shown in black outlines. Simulation image produced with

Heister and the team will also produce images and video of the current state simulations that they'll make available to the community of Earth science researchers, as well as to high school and college students through education outreach initiatives.

In addition to Heister and Gassmoeller, other team members include principal investigator and mathematician Wolfgang Bangerth and Earth scientist Derek Schutt at Colorado State University; geological scientists Juliane Dannberg and Paul Brenner at the University of Florida; Earth scientist John Naliboff at New Mexico Tech University; and geoscientist Anthony Lowry at Utah State University.

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ASPECT software.
Image Credit: Courtesy of Timo Heister

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More information on the ASPECT simulation software can be found at https://aspect.geodynamics.org/.

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