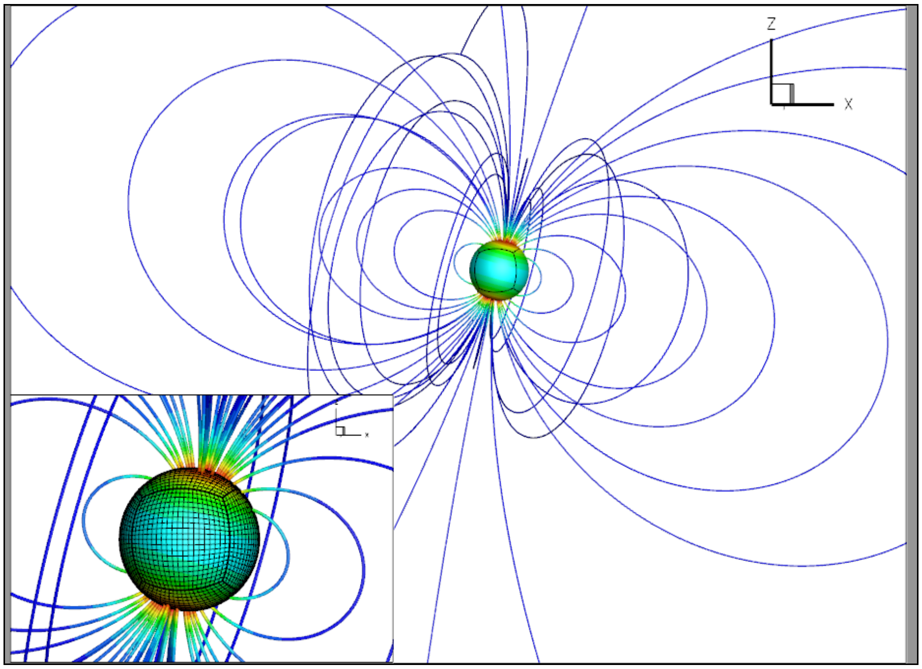
Research Profiles



A Forecaster’s Guide to Weather in Space:

Researchers use computational models to better understand solar disturbances of Earth’s magnetic environment

Each month, several eruptions on the Sun’s surface, associated with solar flares, travel 150 million kilometres across space to reach Earth. They may cause geomagnetic storms that disrupt our planet’s electromagnetic field, interfering with satellites, communication technology and power grids.

Aircraft navigation and communication systems are especially vulnerable, and airlines often re-route flights that pass over the polar region to avoid these storms. But to do so, they currently rely on oversimplified, primitive forecasting models and have no reliable way to predict this ‘space weather’.

University of Waterloo Prof. Hans De Sterck and postdoc Lucian Ivan, Department of Applied Mathematics, are developing mathematical models to simulate components of space weather. With support from the Canadian Space Agency, they build large-scale computational models that will one day make accurate space weather forecasting possible.

De Sterck and Ivan have created a fully adaptive, three-dimensional cubed-sphere grid framework for space plasma simulation. The grid can be scaled up to simulate huge domains, such as the space between the Sun and Earth. Within the grid, an inner sphere represents the Sun while an outer sphere marks the location of our planet. Each cell in the grid corresponds to an area in space.

“The grid divides space into ‘computational cells’ that allow us to simulate space weather events,” says de Sterck. “Performing these calculations with uniform resolution from here to the Sun would be impossible, so we designed our grids to be adaptive.”

By “adaptive,” he means that the size of grid cells can be adapted and adjusted according to space weather patterns. Cells positioned in more relevant areas of space, where significant space weather events occur, have higher resolution. Cells in less active regions have lower resolution.

And although this model sets the stage for simulating the complex physical phenomena of space weather, many factors, known and unknown, remain to be taken into account.

Space is filled with plasma, a gas-like matter found throughout our universe. Plasma is also present on Earth, in nuclear fusion reactors. De Sterck and Ivan simulate interplanetary plasma using differential equations similar to those used for nuclear fusion plasmas.

A constant stream of charged molecules travel at supersonic speeds in interplanetary space. These molecules are emanating in all directions outward from the sun. This is known as 'solar wind', and it's a driving force in space weather.

"We're interested in disturbances in this continuous flow of solar wind that are related to solar flares or eruptions and might affect Earth's magnetic field," says De Sterck. "When an event like this happens, we want high resolution cells available to track the movement of the disturbance as it travels towards Earth."

Although it's adaptive, the grid model still requires enormous processing power. That's where SHARCNET and other Compute Canada resources come in. De Sterck and his team use hundreds to thousands of parallel processors on SHARCNET and SciNet systems. Eventually, they plan to expand this number to tens of thousands to increase their models' accuracy.

They'll need them. Because the domain of space weather is so enormous, researchers need extremely powerful computers to handle all the calculations. Another challenge is the lack of observational data to plug into the models. Terrestrial weather forecasting models are supplied with a wealth of information from sensors all over the world. Space weather forecasters must rely on observational data collected from a handful of satellites describing only a few areas of space.

What's more, our sun--the source of solar flares and eruptions—is in some ways still shrouded in mystery. Researchers have limited information on what's going on within it or on its other side. That makes predicting the sun's behaviour a challenge.

"Our focus now is to develop accurate, efficient numerical methods and software that can help to improve our understanding of the solar wind and flares," says De Sterck. "In the future we hope these models will contribute to more accurate predictions of space weather."

Prof. Clinton Groth, University of Toronto, is collaborating on this research. Funding is provided by the Canadian Space Agency and the Natural Sciences and Engineering Research Council.

For more information on Dr. De Sterck or his research please visit
http://www.math.uwaterloo.ca/~hdesterc/