Scientists discover surprise in Earth's upper atmosphere

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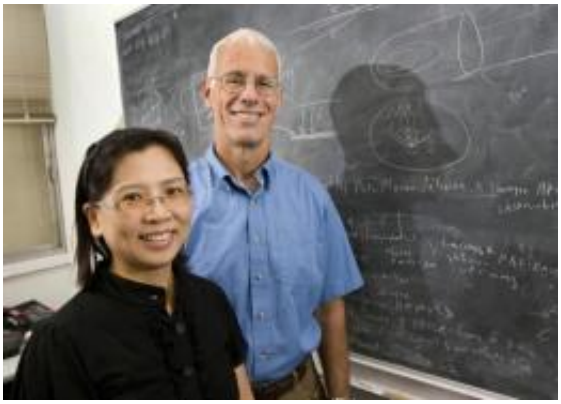

(PhysOrg.com) -- UCLA atmospheric scientists have discovered a previously unknown basic mode of energy transfer from the solar wind to the Earth's magnetosphere. The research, federally funded by the National Science Foundation, could improve the safety and reliability of spacecraft that operate in the upper atmosphere.

"It's like something else is heating the atmosphere besides the sun. This discovery is like finding it got hotter when the sun went down," said Larry Lyons, UCLA professor of atmospheric and oceanic sciences and a co-author of the research, which is in press in two companion papers in the Journal of Geophysical Research.

The sun, in addition to emitting radiation, emits a stream of ionized particles called the solar wind that affects the Earth and other planets in the solar system. The solar wind, which carries the particles from the sun's magnetic field, known as the interplanetary magnetic field, takes about three or four days to reach the Earth. When the charged electrical particles approach the Earth, they carve out a highly magnetized region — the magnetosphere — which surrounds and protects the Earth.

Charged particles carry currents, which cause significant modifications in the Earth's magnetosphere. This region is where communications spacecraft operate and where the energy releases in space known as substorms wreak havoc on satellites, power grids and communications systems.

The rate at which the solar wind transfers energy to the magnetosphere can vary widely, but what determines the rate of energy transfer is unclear.

"We thought it was known, but we came up with a major surprise," said Lyons, who conducted the research with Heejeong Kim, an assistant researcher in the UCLA Department of Atmospheric and Oceanic Sciences, and other colleagues.

"This is where everything gets started," Lyons said. "Any important variations in the magnetosphere occur because there is a transfer of energy from the solar wind to the particles in the magnetosphere. The first critical step is to understand how the energy gets transferred from the solar wind to the magnetosphere."

The interplanetary magnetic field fluctuates greatly in magnitude and direction.

"We all have thought for our entire careers — I learned it as a graduate

student — that this energy transfer rate is primarily controlled by the direction of the interplanetary magnetic field," Lyons said. "The closer to southward-pointing the magnetic field is, the stronger the energy transfer rate is, and the stronger the magnetic field is in that direction. If it is both southward and big, the energy transfer rate is even bigger."

However, Lyons, Kim and their colleagues analyzed radar data that measure the strength of the interaction by measuring flows in the ionosphere, the part of Earth's upper atmosphere ionized by solar radiation. The results surprised them.

"Any space physicist, including me, would have said a year ago there could not be substorms when the interplanetary magnetic field was staying northward, but that's wrong," Lyons said. "Generally, it's correct, but when you have a fluctuating interplanetary magnetic field, you can have substorms going off once per hour.

"Heejeong used detailed statistical analysis to prove this phenomenon is real. Convection in the magnetosphere and ionosphere can be strongly driven by these fluctuations, independent of the direction of the interplanetary magnetic field."

Convection describes the transfer of heat, or thermal energy, from one location to another through the movement of fluids such as liquids, gases or slow-flowing solids.

"The energy of the particles and the fields in the magnetosphere can vary by large amounts. It can be 10 times higher or 10 times lower from day to day, even from half-hour to half-hour. These are huge variations in particle intensities, magnetic field strength and electric field strength," Lyons said.

The magnetosphere was discovered in 1957. By the late 1960s, it had

become accepted among scientists that the energy transfer rate was controlled predominantly by the interplanetary magnetic field.

Lyons and Kim were planning to study something unrelated when they made the discovery.

"We were looking to do something else, when we saw life is not the way we expected it to be," Lyons said. "The most exciting discoveries in science sometimes just drop in your lap. In our field, this finding is pretty earth-shaking. It's an entire new mode of energy transfer, which is step one. The next step is to understand how it works. It must be a completely different process."

The National Science Foundation has funded ground-based radars which send off radio waves that reflect off the ionosphere, allowing scientists to measure the speed at which the ions in the ionosphere are moving.

The radar stations are based in Greenland and Alaska. The NSF recently built the Poker Flat Research Range north of Fairbanks.

"The National Science Foundation's radars have enabled us to make this discovery," Lyons said. "We could not have done this without them."

The direction of the interplanetary magnetic field is important, Lyons said. Is it going in the same direction as the magnetic field going through the Earth? Does the interplanetary magnetic field connect with the Earth's magnetic field?

"We thought there could not be strong convection and that the energy necessary for a substorm could not develop unless the interplanetary magnetic field is southward," Lyons said. "I've said it and taught it. Now I have to say, 'But when you have these fluctuations, which is not a rare occurrence, you can have substorms going off once an hour.'"

Lyons and Kim used the radar measurements to study the strength of the interaction between the solar wind and the Earth's magnetosphere.

One of their papers addresses convection and its affect on substorms to show it is a global phenomenon.

"When the interplanetary magnetic field is pointing northward, there is not much happening, but when the interplanetary magnetic field is southward, the flow speeds in the polar regions of the ionosphere are strong. You see much stronger convection. That is what we expect," Lyons said. "We looked carefully at the data, and said, 'Wait a minute! There are times when the field is northward and there are strong flows in the dayside polar ionosphere.'"

The dayside has the most direct contact with the solar wind.

"It's not supposed to happen that way," Lyons said. "We want to understand why that is."

"Heejeong separated the data into when the solar wind was fluctuating a lot and when it was fluctuating a little," he added. "When the interplanetary magnetic field fluctuations are low, she saw the pattern everyone knows, but when she analyzed the pattern when the interplanetary magnetic field was fluctuating strongly, that pattern completely disappeared. Instead, the strength of the flows depended on the strength of the fluctuations.

"So rather than the picture of the connection between the magnetic field of the sun and the Earth controlling the transfer of energy by the solar wind to the Earth's magnetosphere, something else is happening that is equally interesting. The next question is discovering what that is. We have some ideas of what that may be, which we will test."

Co-authors on the papers include colleagues at Chungbuk National University in South Korea and SRI International in Menlo Park, Calif.

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