NASA Finds Lightning Clears Safe Zone in Earth's Radiation Belt

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Lightning in clouds, only a few miles above the ground, clears a safe zone in the radiation belts thousands of miles above the Earth, according to NASA-funded researchers. The unexpected result resolves a forty-year-old debate as to how the safe zone is formed, and it illuminates how the region is cleared after it is filled with radiation during magnetic storms.

The safe zone, called the Van Allen Belt slot, is a potential haven offering reduced radiation dosages for satellites that require Middle Earth Orbits (MEOs). The research may eventually be applied to remove radiation belts around the Earth and other worlds, reducing the hazards of the space environment.

"The multi-billion-dollar Global Positioning System satellites skirt the edge of the safe zone," said Dr. James Green of NASA's Goddard Space Flight Center, Greenbelt, Md. He is the lead author of the paper about the research published in the Journal of Geophysical Research. "Without the cleansing effect from lightning, there would be just one big radiation belt, with no easily accessible place to put satellites," he said.

If the Van Allen radiation belts were visible from space, they would resemble a pair of donuts around the Earth, one inside the other, with the planet in the hole of the innermost. The Van Allen Belt slot would appear as a space between the inner and outer donut. The belts are comprised of high-speed electrically charged particles (electrons and atomic nuclei) trapped in the Earth's magnetic field. The Earth's magnetic field has invisible lines of magnetic force emerging from the South Polar Region, out into space and back into the North Polar Region. Because the radiation belt particles are electrically charged, they respond to magnetic forces. The particles spiral around the Earth's magnetic field lines, bouncing from pole to pole where the planet's magnetic field is concentrated.

Scientists debated two theories to explain how the safe zone was cleared. The prominent theory stated radio waves from space, generated by turbulence in the zone, cleared it. An alternate theory, confirmed by this research, stated radio waves generated by lightning were responsible. "We were fascinated to discover evidence that strongly supported the lightning theory, because we usually think about how the space environment affects the Earth, not the reverse," Green said.

The flash we see from lightning is just part of the total radiation it produces. Lightning also generates radio waves. In the same way visible light is bent by a prism, these radio waves are bent by electrically charged gas trapped in the Earth's magnetic field. That causes the waves to flow out into space along the Earth's magnetic field lines.

According to the lightning theory, radio waves clear the safe zone by interacting with the radiation belt particles, removing a little of their energy and changing their direction. This lowers the mirror point, the place above the polar regions where the particles bounce. Eventually, the mirror point becomes so low; it is in the Earth's atmosphere. When this happens, the radiation belt particles can no longer bounce back into space, because they collide with atmospheric particles and dissipate their energy.

To confirm the theory, the team used a global map of lightning activity made with the Micro Lab 1 spacecraft. They used radio wave data from the Radio Plasma Imager on the Imager for Magnetopause to Aurora Global Exploration (IMAGE) spacecraft, combined with archival data from the Dynamics Explorer spacecraft. IMAGE and Dynamics Explorer showed the radio wave activity in the safe zone closely followed terrestrial lightning patterns observed by Micro Lab 1.

According to the team, there would not be a correlation if the radio waves came from space instead of Earth. They concluded when magnetic storms, caused by violent solar activity, inject a new supply of high-speed particles into the safe zone, lightning clears them away in a few days.

Engineers may eventually design spacecraft to generate radio waves at the correct frequency and location to clear radiation belts around other planets. This could be useful for human exploration of interesting bodies like Jupiter's moon Europa, which orbits within the giant planet's intense radiation belt.

The research team included Drs. Scott Boardsen, Leonard Garcia, William Taylor, and Shing Fung from Goddard; and Dr. Bodo Reinisch, University of Massachusetts, Lowell.

Source: NASA

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