Scientists use cosmic rays to study twisters and other severe storms

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Cosmic rays could offer scientists another way to track and study violent tornadoes and other severe weather phenomena, a new study suggests.

By combining local weather data with complex astrophysics simulations, researchers explored whether a device that typically detects high-energy particles called muons could be used to remotely measure tornado-producing supercell thunderstorms.

Conventional tornado-tracking instrumentation relies on measurements made by technologies like drones or weather balloons, but those methods often require humans to get dangerously close to the path of an oncoming storm.

Yet through studying how these storms affect muons, which are heavier than electrons and travel through matter at nearly the speed of light, these findings can act as another tool for scientists to gain a more accurate picture of underlying weather conditions.

"The thing about atmospheric muons is that they're sensitive to the properties of the atmosphere that they travel through," said William Luszczak, lead author of the study and a fellow at the Center for Cosmology and AstroParticle Physics at The Ohio State University.

"If you have a group of muons that traveled through a thunderstorm, the amount you're going to measure on the other side is different from a bundle of muons that traveled through a pretty day."

The study is published on the preprint server *arXiv*.

Compared to other cosmic particles, muons have many unique real-world applications, including helping scientists to peer inside large, dense objects like the pyramids or detecting hazardous nuclear material. Now, Luszczak's simulations in this paper imply that supercell thunderstorms cause very slight changes in the number, direction and intensity of these particles.

To determine this, the researchers applied a three-dimensional cloud model that could account for multiple variables, including wind, potential temperature, rain, snow and hail. Then, using atmospheric observations gathered from the 2011 supercell that passed through El Reno, Oklahoma, and spawned a tornado outbreak, Luszczak applied that information to measure variations in air pressure in the region around a simulated storm over the span of an hour.

Overall, their results found that muons are indeed affected by the pressure field inside tornadoes, though more research is needed to learn more about the process.

In terms of how well it could work in the field, the concept is especially appealing, as utilizing muons to predict and analyze future weather patterns would also mean scientists wouldn't necessarily have to try to place instruments very near a tornado to gain these pressure measurements, said Luszczak.

Still, the type of muon particle detector that Luszczak's paper considers is much smaller than other more well-known cosmic ray projects, such as the Pierre Auger Observatory in Argentina and the University of Utah's Telescope Array.

Unfortunately, these detectors don't reside in places where they can study tornadoes, said Luszczak, but if placed in a region like Tornado Alley in the United States, researchers imagine that the device could easily complement typical meteorological and barometric measurements for tornadic activity.

That said, the device's size also influences how precise its measurements are, as scaling it up enhances the number of particles it can detect, said Luszczak.

The smallest detector researchers describe in this paper is 50 meters across, or about the size of five buses. But while such a tool would be portable enough to ensure scientists could place it near many different types of storm systems, being so small would likely cause it to face some errors in its data-gathering, said Luszczak.

Despite these potential setbacks, as supercell thunderstorms typically form and disappear in short periods, the paper emphasizes it may be well worth future scientists' time to consider implementing a large detector in some regions—one that would likely be a permanent stationary establishment to catch as many muons as possible during severe weather events.

More importantly, because current weather modeling systems are directly linked to when and where severe weather alerts are issued, using cosmic rays to strengthen those models would give the public a more detailed sense of a storm's various twists and turns as well as more time to prepare for the phenomenon.

"By having better measurements of the atmosphere surrounding a tornado, our modeling improves, which then improves the accuracy of our warnings," said Luszczak. "This concept has a lot of promise, and it's a really exciting idea to try to put into action."

More information: William Luszczak et al, The Effect of Tornadic Supercell Thunderstorms on the Atmospheric Muon Flux, *arXiv* (2024). DOI: 10.48550/arxiv.2405.19311

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