Uncovering the mechanisms of lightning varieties

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The mechanism behind different types of lightning may now be understood, thanks to a combination of direct observation and computer modeling reported by a team of researchers from New Mexico Tech and Penn State.

"Our explanation provides a unifying view of how lightning escapes from a thundercloud," the researchers report in the April edition of *Nature Geoscience*.

Most people see lightning strikes that go from clouds to the ground, but some lightning goes upward, forming blue jets and gigantic jets. Perhaps the most dangerous lightning appears as "bolts from the blue" – lightning that begins upward, but then moves sideways and then downward to hit the ground as much as three miles from a thunderstorm.

About 90 percent of lightning occurs inside clouds and is not visible to the casual observer. The researchers wondered if lightning that appears within clouds and the lightning that escapes upward or downward shared the same development mechanisms.

"With the help of colleagues from New Mexico Tech, we were able to build a model of lightning and apply it to the various types of lightning," says Jeremy A. Riousset, graduate student in electrical engineering, Penn State. "Thanks to their observations and measurements, we know how lightning like 'bolts from the blue' happen. We know they develop like normal intracloud lightning before escaping the thundercloud at upper

levels and branching toward the ground."

They also discovered that upward and sideward lightning events occurred shortly after normal downward lightning bolts occurred or intracloud lightning produced a local charge imbalance in the cloud.

Harald E. Edens, graduate student in physics, New Mexico Tech, working with Paul R. Krehbiel, professor of physics; Ronald J. Thomas, professor of electrical engineering, and William Rison, professor of electrical engineering, all at New Mexico Tech; and Mark A. Stanley, consultant, obtained detailed pictures of "bolts from the blue" using New Mexico Tech's Lightning Mapping Array, a three-dimensional lightning location system that uses multiple measurement stations to capture and time the VHF signal of the lightning. The Lightning Mapping Array can map lightning within clouds, something that normal optical photography or videography cannot do.

Riousset, working with Victor P. Pasko, associate professor, electrical engineering at Penn State, looked at the images from New Mexico and developed a model that explained the variety of lightning types. Lightning forms in clouds when different areas of the cloud become either positively or negatively charged. Once the electric field near a charged area exceeds a certain propagation level, lightning occurs. The type of lightning depends on where the charge builds and where the imbalance in charge exists in the clouds.

For intracloud lightning, the most common form of lightning, the transfer of charge occurs between the most negatively and most positively charged areas, the middle and upper parts of the cloud, respectively. Lightning that strikes the ground does so because precipitation or the storm's progression creates an excess of net negative charge in the mid-levels of the cloud. This results in either a direct ground strike or a bolt from the blue.

An alternative way to discharge a middle negative charge is through a gigantic jet, which propagates upward. The height of the clouds somewhat controls whether a gigantic jet or bolt from the blue propagates. The higher the top of the cloud, the more likely a gigantic jet will appear.

However, large positive charge in the upper levels of the storm causes blue jets.

"This is the first consistent definition of blue jets and gigantic jets," says Pasko.

In normal thunderstorms, blue jets are positive, originate in the uppermost part of the cloud and propagate continuously upward; while gigantic jets are negative, begin like a normal intracloud flash and propagate stepwise upward. Inverted polarity storms do exist and the charges of the various lightning types would then reverse.

The higher the cloud, the more likely either type of jet becomes. Thunderstorms in the tropics form with very high clouds increasing the chances of jets forming. Thunderstorms in the temperate United States do not have clouds quite so high, allowing a great number of bolts from the blue to occur. Bolts from the blue are very common in continental mid-latitude storms.

Every discharge of lightning from the cloud alters the charge status within the cloud, shifting the locations of the highest negatively or positively charged areas. These shifts along with mixing of the upper areas of the clouds can tip the storm toward bolts from the blue or jets depending on the circumstances.

"We are proposing a self-consistent, unified theory of lightning discharges inside and outside of clouds including blue jets, bolts from

the blue and gigantic jets," says Pasko of Penn State. He adds that while their model can stipulate the requirements of each type of lightning, data collection during storms is too slow for the model to act in any predictive way.

Source: Penn State