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Cloud to cloud: Forecasting storm severity with lightning [1]

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Summertime in northern Alabama means sunny family picnics and lazy afternoons by the pool. But clear skies often rapidly fill with storm clouds that produce tornadoes, hail, and lightning. While the sudden eruption of severe weather may thrill a storm chaser, it can make a forecaster cringe. Weather conditions can worsen rapidly, sometimes giving forecasters little time to assess a situation and even less time to issue a warning. Forecasters must monitor a variety of constantly changing factors affecting storm formation, but researchers have discovered that observing one of the components of severe weather, lightning, can reveal clues about an impending storm's severity.

Forecasters find that lightning may help predict whether developing storms will become severe.

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Mapping the frequency of lightning

Richard Blakeslee has studied the relationship between lightning and storm development for more than twenty-five years. As a senior research scientist at the Global Hydrology and Climate Center (GHCC) in Huntsville, Alabama, Blakeslee has relied on a variety of methods to research lightning, and has helped develop satellite sensors to monitor lightning on a global scale. But to better understand how lightning can help make storm forecasting more accurate, he also conducts research in his own neighborhood, incorporating data from the North Alabama Lightning Mapping Array (LMA), a set of sensors that began operating in 2001.

"The Lightning Mapping Array maps out lightning discharges within the clouds, providing a three-dimensional map of the lightning as it develops," Blakeslee said. The network consists of eleven receivers that capture detailed lightning observations. The LMA was initially deployed to validate the Lightning Imaging Sensor aboard the Tropical Rainforest Measuring Mission (TRMM) satellite, but LMA data are also proving useful to regional forecasters on the ground. Every two minutes, data from this network are forwarded to the National Weather Service office in Huntsville responsible for forecasting in eleven northern Alabama counties and three southern Tennessee counties. The data are also provided to nearby forecast offices in Nashville, Tennessee; Birmingham, Alabama; and Jackson, Mississippi.

Using the new LMA data, Blakeslee and his colleagues studied two thunderstorms that occurred over northern Alabama in 2002, and discovered that lightning activity increased dramatically just before the storms intensified and became severe. The researchers also incorporated cloud-to-ground lightning data from the National Lightning Detection Network (NLDN). NLDN data are acquired by the Global Hydrology Resource Center (GHRC) from Vaisala, Incorporated, and made available to approved NASA Earth Observing System (EOS) and TRMM investigators. This combination of data allowed the team to observe the total lightning flash rate, including cloud-to-ground, intracloud, and cloud-to-cloud lightning.

By looking at the flash rate maps, the researchers discovered a pattern: an increase in total lightning activity followed by a dramatic decline often indicated the development of strong storms. This pattern of lightning activity often even preceded the occurrence of cloud-to-ground lightning strikes by several minutes--information forecasters could use to issue earlier warnings to communities and airports in a storm's path.

Lightning illuminates a funnel cloud forming during a storm near Huntsville, Alabama, in April 2006. Alabama's turbulent weather gives scientists frequent opportunities to study lightning and storm development. (Image above and in title graphic © Wes Thomas Photography)

Feedback

From data to forecasts

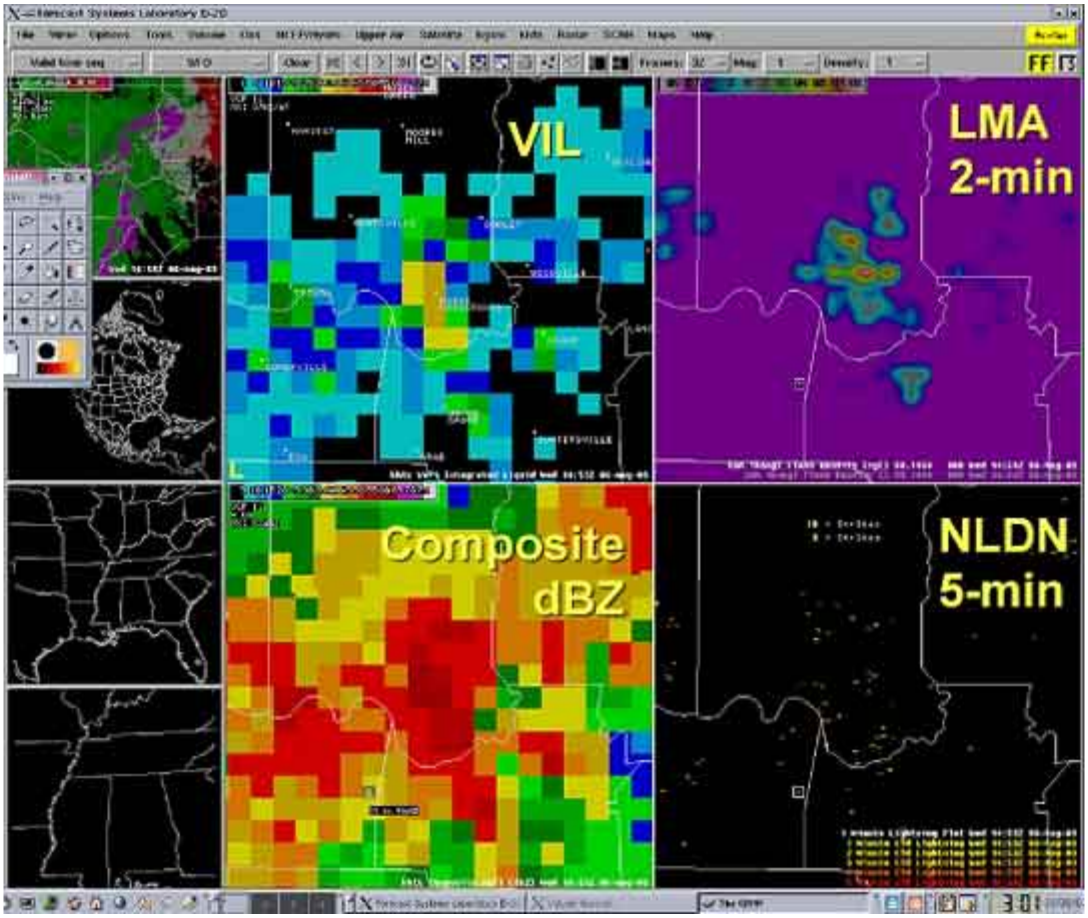
One of the challenges, however, was making the lightning maps accessible to forecasters. "Forecasters do not actually look at the data that the researchers look at. We had to get the data into a format that forecasters could understand," Blakeslee said. Weather service forecasters rely on the Advanced Weather Interactive Processing System (AWIPS), an interactive computer system that integrates meteorological, satellite, radar, and other data, often all in one display screen. "When the weather gets severe, forecasters are glued to their AWIPS displays. If the lightning data are not available there, they're not going to be used," Blakeslee said.

To develop a solution, the lightning team collaborated with Chris Darden, science operations officer at the Huntsville National Weather Service office, which is co-located with GHCC. Darden was familiar with northern Alabama's unruly weather and understood the need for data that forecasters could use quickly and easily. Darden said, "The goal of the weather service is the protection of life and property, and that ties right back into the warning aspects for severe thunderstorms and tornadoes."

In addition, scientists at the Short-Term Prediction Research and Transition (SPoRT) Center, which is co-located with GHCC and the Huntsville National Weather Service Office, partnered in the project. Researchers at SPoRT focus on improving short-term weather forecasts by integrating NASA Earth science data. Darden said, "I worked with the SPoRT researchers and developers to look at the technology and data sets that they had available, and how the National Weather Service might use them operationally."

Together, they designed products from LMA data that could be used in the AWIPS displays. Although forecasters often prefer a single gridded graphic of lightning density that conveys a lot of information, they can choose other ways to view the lightning data. "We can view the summary by itself or overlay it directly onto our radar or satellite data. Or, we can look at individual levels, ranging from ground level to 17 kilometers (10.5 miles) above the surface," Darden said. Each of these levels is like looking at a "slice" of a storm. This allows forecasters to see lightning density at different altitudes and help them assess a storm's development. "We now utilize the LMA maps a lot when developing our early warning decisions," Darden said.

The lightning maps are also useful for weather prediction because their coverage overlaps that of radar and other data sources that forecasters rely on. Storms do not always develop neatly within the circular sweep of radar beams. Blakeslee said, "Where a storm is located relative to the radar system may make it difficult for the forecasters to know exactly what's going on, meaning that they miss some of the details. But the lightning data can help compensate for some of that."



Weather forecasters rely on the Advanced Weather Interactive Processing System (AWIPS) display. This AWIPS includes Lightning Mapping Array (LMA) data (upper right corner) as a single gridded graphic showing lightning flash density. The display also shows National Lightning Data Network (NLDN) data, vertically integrated liquid (VIL) measurements, and radar reflectivity composites. (Courtesy SPoRT)

Predicting severity, protecting lives

Even with the most advanced equipment and data, however, summertime weather often poses special problems for forecasters. Not only are more people likely to be outdoors and vulnerable to severe weather, but short-lived storms, called pulse storms, are more common. Pulse storms are small, isolated storms that last less than thirty minutes. Darden said, "Pulse storms can develop and diminish quite rapidly. They evolve so quickly that it's difficult to provide much warning or lead time." Although pulse storms pose the greatest danger to aircraft, they can also produce hail, heavy rainfall, and weak tornadoes, endangering people and property on the ground. "On a particular day, forecasters may have to track twenty or thirty storms, but only one or two of them will produce severe weather," Darden said. Forecasters need an indicator to tell them which storms might become dangerous.

On November 24, 2001, a series of tornadoes swept across Alabama, striking a mobile home community near New Hope. One tornado damaged twenty-one homes, completely destroyed eight, and overturned vehicles. The tornado path was 4.18 kilometers (2.6 miles) long, and as wide as 275 meters (900 feet). While damaging, this tornado caused no fatalities or injuries. Several residents of the damaged mobile home community heard the National Weather Service Tornado Warning on television and were able to take cover in underground storm shelters.(Courtesy Birmingham National Weather Service)

Lightning may be one of those indicators. Blakeslee said, "When forecasters are not quite sure about the severity of a storm, lightning data may tilt the balance one way or the other. Lightning can be that confirming bit of observation that indicates we definitely need to issue a warning."

By taking advantage of the advance notice provided by the LMA lightning maps, forecasters have been able to more accurately predict the onset of severe weather. Darden said, "We can correlate flash rates directly to the strength of a building thunderstorm. In certain cases, we've issued a warning for a storm after seeing a surge in lightning rates." The additional few moments of warning may be especially useful when dangerous weather erupts over populated areas. Blakeslee said, "A tornado warning delivered five or ten minutes early might really make a difference in whether a person is able to get to shelter."

LMA data have also revealed some unexpected characteristics of electrical charges during storms. The data can sometimes indicate lightning in areas where forecasters would not normally expect it to be. "The data are showing occasional cloud-to-ground lightning strikes trailing a system, miles from the front, and well away from the really severe weather activity," Blakeslee said. When forecasters spot this additional lightning hazard, they can now alert people who may otherwise feel safe resuming outdoor activities after the worst part of a storm has passed.

The Huntsville weather forecast office also uses lightning maps to help issue weather warnings for the local airports and to develop aviation and terminal forecasts. "These kinds of systems are only now being explored in terms of how they can help with forecasting ramp and ground operations. I think we're going to see more of that kind of activity in the future," Blakeslee said. One such network is the DC Metro LMA in Washington, D.C., which began operating during the summer of 2006. Washington, D.C., is home to three major international airports, making this a high-profile project for studying lightning and aviation. Lightning and severe weather frequently affect flight schedules, so forecasters are interested in using lightning data to improve airport forecasts, particularly when potentially severe weather begins to develop. Air traffic controllers can use the advance warning to halt departures and detour incoming flights, keeping passengers and crew out of dangerous weather. And advance warning can give ramp workers and other airline ground staff additional time to get to shelter.

Learning from lightning

In addition to northern Alabama and Washington, D.C., lightning mapping networks are operating in Texas, Oklahoma, Florida, and New Mexico. While scientists are still probing the many aspects of lightning, they have gleaned valuable information from studying LMA data. Blakeslee said, "We've learned a lot through the years about how storms generate electricity and how they operate."

Researchers like Blakeslee and Darden will continue to analyze data from a variety of sources, such as the LMA networks and satellite sensors. Whether they learn more about specific storms or about broader aspects of electrical discharges in the atmosphere, each new bit of knowledge about meteorological processes brings forecasters a step closer to more accurate weather predictions and more timely forecasts. And this knowledge might help forecasters and Alabama residents, alike, plan ahead for wayward summertime weather.

Reference

Goodman, S. J., R. Blakeslee, H. Christian, W. Koshak, J. Bailey, J. Hall, E. McCaul, D. Buechler, C. Darden, J. Burks, T. Bradshaw, and P. Gatlin. 2005. The North Alabama Lightning Mapping Array: Recent severe storm observations and future prospects. *Atmospheric Research* 76: 423-437.

Related Links

- NASA Global Hydrology and Climate Center [3]
- NASA Global Hydrology Resource Center [4]
- North Alabama Lightning Mapping Array [5]
- Short-term Prediction Research and Transition Center (SPoRT) [6]

About the remote sensing data used		
Networks	National Lightning Detection Network (NLDN), operated by Vaisala, Incorporated	3-D Lightning Mapping Array (LMA)
Sensors	U.S. NLDN consists of more than 100 remote, ground-based Vaisala IMPACT ESP Lightning Sensors	10 Very High Frequency (VHF) lightning mapping detectors
Data sets	GAI Lightning Ground Strikes	North Alabama LMA
Spatial coverage	Continental United States	11 counties in northern Alabama and 3 counties in southern Tennessee
Parameters	Lightning	Lightning
Data centers	NASA Global Hydrology Resource Center (GHRC [2])	NASA Global Hydrology Resource Center (GHRC [2])
Science funding	NASA	NASA

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