The dirt on tornadoes

"Why would something that is one season away affect something as specific as tornadoes?"

Dev Niyogi
Purdue University

by Laura Naranjo

On the night of March 15, 2008, a massive tornado tore through downtown Atlanta. Winds of up to 130 miles per hour uprooted trees, shattered glass windows, and ripped roofs off buildings. Tornadoes occur every year in the southeastern United States, but they do not frequently strike urban areas. The 2008 twister took city residents by surprise, prompting researchers to take a closer look at the forces that contributed to this particular storm.

The United States averages about 1,000 tornadoes per year, and less than one percent of these tornadoes are strong enough to cause damage. However, the rare violent tornadoes can be both deadly and costly: the 2008 Atlanta tornado killed three people, injured dozens, and cost the city hundreds of millions of dollars in repairs. While tornadoes require specific local weather events to occur, scientists also wonder whether long-term changes in weather events played a role. Marshall Shepherd, a meteorologist at the University of Georgia, and Dev Niyogi, a climatologist at

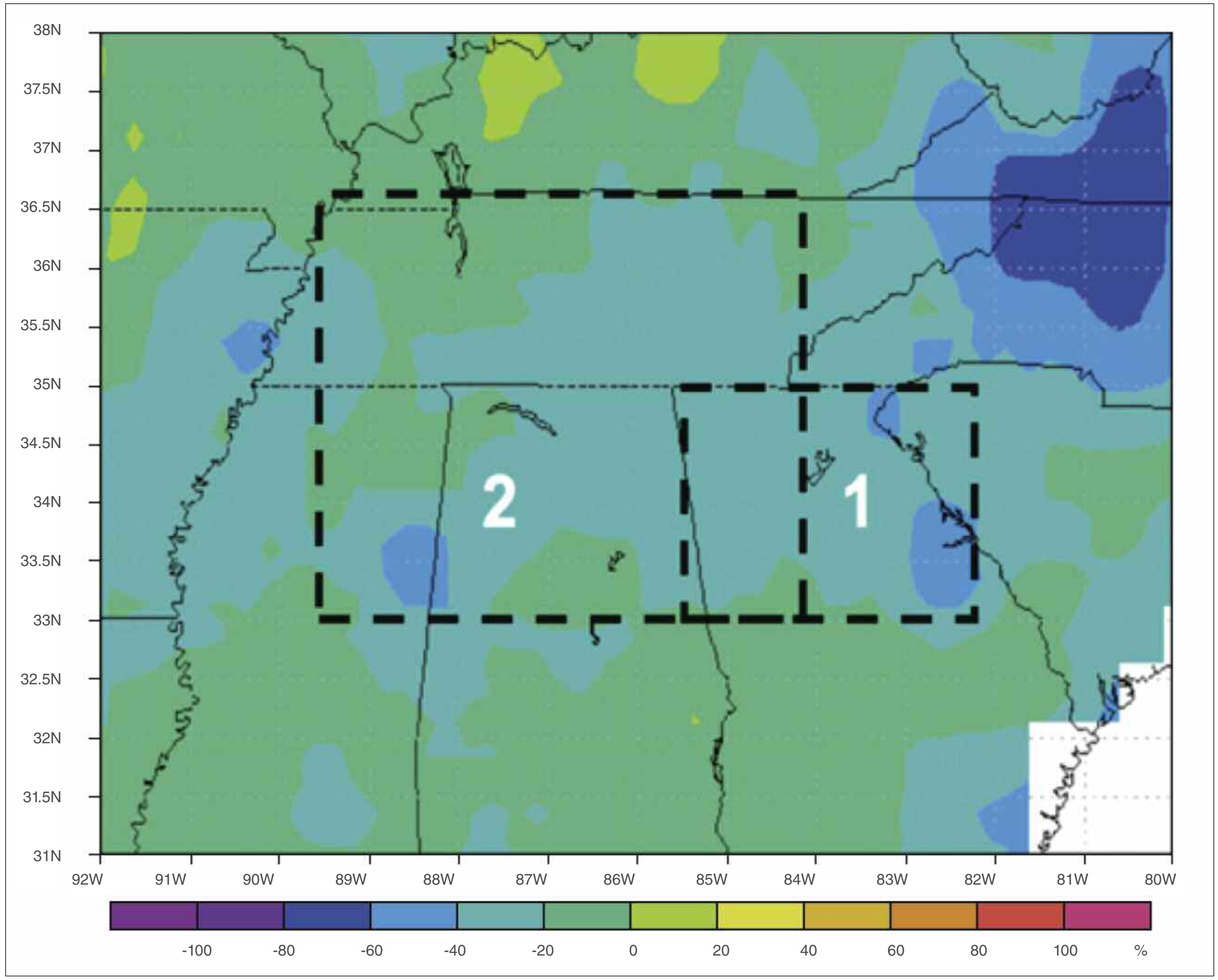
This stovepipe tornado formed on May 31, 2010, near the border between Colorado and Oklahoma. Scientists are investigating how soil moisture might influence tornadoes—rotating columns of air that extend from storm clouds down to the ground. (Courtesy W. Owen)

Purdue University, are investigating that possibility. Prior to the 2008 Atlanta tornado, the southeastern United States was undergoing a severe drought. Shepherd and Niyogi wondered if the parched soil affected the region's weather patterns. "We tried to look at things from a different perspective. Was there anything inherently related to soil moisture that reflected larger-scale atmospheric patterns that might result in fewer tornadoes?" Shepherd asked.

Matching tornadoes to moisture

Tornadoes form most frequently during spring and summer, when cold fronts, or masses of cool air, move eastward across the country and collide with warm, moist air. This atmospheric mixing creates the storm clouds, high winds, and humidity that often produce thunderstorms. If violent enough, this mixing can also create tornadoes—rotating columns of air that extend from storm clouds down to the ground. Although tornado formation relies in part on moisture in the atmosphere, Shepherd and his colleagues wondered whether moisture in the soil, or the lack of it, might also play a role.

To investigate this hypothesis, he and his colleagues first gathered tornado data ranging from the 1950s to the present over Tennessee and the northern portions of Georgia, Alabama, and Mississippi. But they found tornado-counting methods were not consistent over time. Populations have grown and filled in more of the rural landscape, meaning more people are likely to see and report tornadoes than in the past. And the increased use of Doppler radar made tornadoes easier to spot, skewing the count. To ensure consistency, the researchers chose to use a metric called a tornado day. Shepherd said, "Tornado day is a metric where we've said, 'Okay, on that day, there was a tornado



To investigate how drought might affect tornadoes, scientists looked at rainfall patterns from February 2006 through February 2008, using data from the Tropical Rainfall Measuring Mission (TRMM). The blue and green colors over the study area indicate the region was undergoing a strong drought. Dotted black lines indicate the study area; the researchers first focused on northern Georgia (box number 1), and then expanded to investigate a larger portion of the southeastern United States (box number 2). (Courtesy *Environmental Research Letters* and M. Shepherd)

somewhere in that study region.' That's a safer metric because it's not based on population changes or the advent of radar."

Next, they compared tornado days with drought periods. They identified droughts, or periods when their study area experienced less than 85 percent of normal rainfall, using precipitation measurements from the Global Historical and Climatological Network, and satellite data from the Tropical Rainfall Measuring Mission (TRMM), both available from the NASA

Boat ramps and docks at Lake Lanier, Georgia, were exposed during a severe drought that siphoned water levels to record lows. This photograph was taken in November 2007 from a point normally about 150 yards from the shore. (Courtesy S. Vore)

Goddard Earth Sciences Data and Information Services Center (GES DISC).

When the researchers compared the tornado and precipitation data between 1950 and the present, they did not find a direct link between drought and tornado days. But when they looked for seasonal patterns, they discovered a long-term relationship. Their study identified when droughts occurred during the fall and winter seasons, and then counted how many tornado days occurred during the following spring and summer seasons, primarily during March through June. "When there are drought conditions in the South during the previous winter and fall, there are fewer days the following spring that have tornadoes," Shepherd said. In fact, the number of tornado days decreased by almost half when preceded by fall drought. These findings established a connection between soil moisture and tornado activity. Although the relationship suggests that tornado days are less frequent after drought, severe tornadoes can still occur, such as the 2008 Atlanta tornado.

Seasonal soil moisture

The study reinforced the theory that long-term weather patterns, such as drought, might influence tornado seasons. But the study raised questions too. "Why would something that is one season away affect something as specific as tornadoes?" asked Dev Niyogi, Indiana's state climatologist and one of Shepherd's colleagues in the study. And why would something seemingly unrelated to severe weather, like drought, affect tornado seasons?

Drought reduces the amount of water available in ways that are obvious, such as receding lakes and dwindling river flow. Drought also dries up the moisture held in the soil, so that less evaporates into the air. Niyogi said, "Soil moisture is a means by which the Earth's atmosphere, particularly the land surface, partitions solar energy." When solar energy, or sunlight, reaches moist soil, most of the energy is used to evaporate some of that moisture. When sunlight reaches dry soil, most of the energy goes into heating the air. Over time, drier soil contributes to drier air.

However, dry soil might have a longer-term influence on atmospheric moisture than previously thought. Shepherd and Niyogi theorized that the effects of droughts might carry over into subsequent seasons, a kind of soil moisture memory, in which drought conditions during the fall and winter lag into the following spring and summer. This lag may help suppress the local weather components, such as moist air, that generate storms and tornadoes. Shepherd said, "During the spring, you can still have a storm, based on the meteorological conditions on that particular day. But if there's an overarching drought condition that is kind of a hangover from the fall and winter, it may reduce the moisture available for storm development if you have all other conditions in place." The researchers also found that dry soil conditions in the fall proved a stronger predictor of spring tornado days than wet fall conditions.

Converging theories

Shepherd and Niyogi are continuing to investigate other questions about soil moisture and tornadoes, including whether pockets of soil moisture can affect the severity of seasonal tornado activity. Pockets occur when bursts of heavy rainfall create areas of moist soil in an otherwise dry region. Niyogi said, "When you have regions of wet versus dry soil next to each other, under certain special conditions, they can create atmospheric circulations where winds are going from dryer soils to wetter soils." This airflow can exacerbate the atmospheric mixing that already occurs during thunderstorms.

"The Atlanta tornado was one possible example where pockets of soil moisture might have played a role in intensifying the thunderstorms, which subsequently produced a tornado," Niyogi added. Prior to the Atlanta tornado, Georgia had been experiencing a severe drought for more than a year. Water in lakes and reservoirs had been drying up, and by December 2007, water levels had reached record lows. But during the spring of 2008, bands of rain may have created localized pockets of wet soil near Atlanta that enhanced already severe weather.

Although Shepherd and Niyogi's findings hint at a connection between drought and seasonal tornado activity, their research is still in the early stages. It cannot predict tornadoes in any way. The researchers are testing their findings against a variety of other data sets to reproduce the results, and are expanding their study area to see if they find similar results in other parts of the United States. In fact, Shepherd and graduate student Theresa Andersen recently confirmed the study's finding over a different portion of the southeastern United States. Shepherd said, "Our theory right now is that the relationship is somehow tied to this notion of soil moisture and soil moisture memory."

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About the remote sensing data used

Satellite	Tropical Rainfall Measuring Mission (TRMM)
Sensor	TRMM Microwave Imager
Data set	Multi-satellite Precipitation Analysis
Resolution	25 degree
Parameter	Precipitation
Data center	NASA Goddard Earth Sciences Data and Information Services Center (GES DISC)

About the scientists

Dev Niyogi is an associate professor of regional climatology at Purdue University and serves as Indiana State Climatologist. He studies land surface processes and the effects of vegetation-atmosphere interactions on environmental processes. NASA Water and Energy Cycle programs, the Department of Energy, and the National Science Foundation supported his research. (Photograph courtesy D. Niyogi)

Marshall Shepherd is a member of the NASA Precipitation Measurement Missions Science Team. He is also an associate professor at the University of Georgia, where he conducts research, teaches, and advises in atmospheric sciences, climatology, water cycle processes, and urban climate systems. NASA Water and Energy Cycle programs, the Department of Energy, and the National Science Foundation supported his research. (Photograph courtesy University of Georgia)

References

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For more information

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