

Wildfires Force Trees to Pull Up Roots

QUESTION:

Climate change is causing some plant species to shift their geographical ranges of distribution to survive. In forests of the western United States, why do some trees leap ahead of others when making this migration?

ANSWER:

A new study suggests wildfires may be causing some species to accelerate this range shift through competition.

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— Avery Hill and Christopher Field of Stanford University looked at U.S. Forest Service data for more than 74,000 plots across nine western U.S. states, focusing on eight tree species that have been migrating to cooler, wetter locations at higher elevations because of climate change. By comparing areas affected by wildfires to unaffected locations, they found evidence that wildfires caused two species—Douglas fir and canyon live oak—to have larger range shifts in burned areas than in locations that had not burned. According to their study, which was published in *Nature Communications*, this suggests “that fire can accelerate climate-related range shifts and that fire and fire management will play a role in the rate of vegetation redistribution in response to climate change.” Hill and Field believe that wildfires influence the range shifts for the two species because the open canopies and scorched ground in burned areas prevent native species from becoming established, thus reducing the competition among plants. “This study highlights a natural mechanism that can help forests remain healthy, even in the face of small amounts of climate change,” Field says. “It also illustrates the way that ecosystem processes often have several layers of controls, a feature that emphasizes the value of detailed understanding for effective management.” [SOURCE: Stanford University]

HIGHS AND LOWS

A Most **Mighty** Wind

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200 MPH—

Wind-speed capability of a planned testing facility at Florida International University (FIU) that the National Science Foundation recently awarded a \$12.8 million grant. The space will also have a water basin that can replicate

wave activity and storm surge, making it the first facility of its kind with such water and wind components. The new resource will be part of FIU's Extreme Events Institute (EEI), which already has a 12-fan facility called the Wall of Wind that is capable of producing 157-mph winds—equivalent to a Category 5 hurricane. But as a changing climate generates stronger storms that rapidly intensify, researchers need new tools to keep up. "The scientific consensus is that we're going to see more intense storms, so we have to research and test for more intense storms," says EEI Director Richard Olson. "Otherwise, nature's going to keep hitting us with harder stuff than we're ready for." The new facility will give researchers insight into how stronger storms will affect buildings and infrastructure—Olson notes that "because the famous Saffir-Simpson Hurricane Wind Scale only goes to Category 5, internally we call this our 'Cat 6 project.'" Researchers from FIU and eight other universities will partner to design the facility, which is scheduled to open in 2026. "We can start putting all of these components together to get a much better picture of what nature is going to be hitting us with," Olson says.

[SOURCES: Florida International University, cnn.com]

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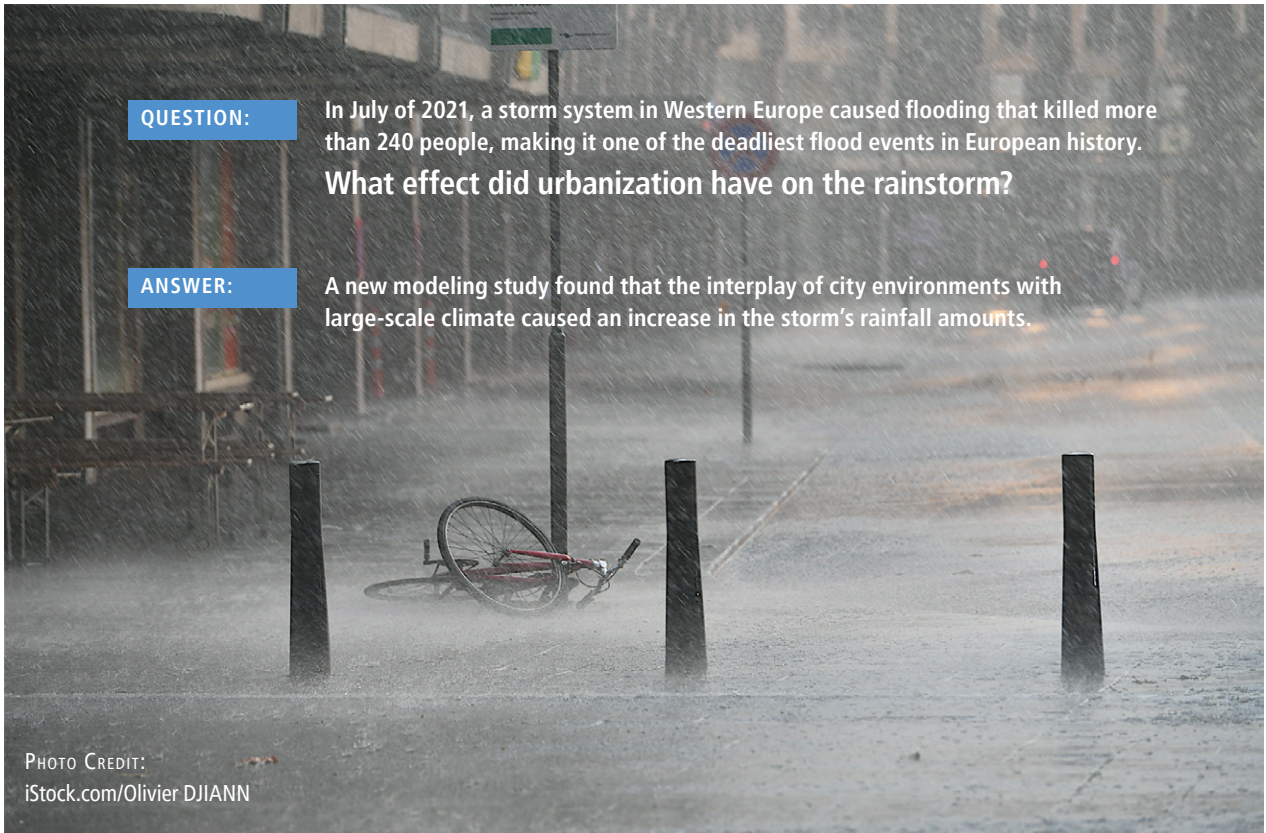
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We Built This City...and Then **It Rained**



QUESTION:

In July of 2021, a storm system in Western Europe caused flooding that killed more than 240 people, making it one of the deadliest flood events in European history.

What effect did urbanization have on the rainstorm?

ANSWER:

A new modeling study found that the interplay of city environments with large-scale climate caused an increase in the storm's rainfall amounts.

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Researchers created a storm model that incorporated effects of urban environments and climate, and also developed simulation models that replaced the cities with undeveloped land and converted temperatures to preindustrial levels. They found that the combination of a warmer climate and an urban setting intensified storm activity over suburban areas of the Rotterdam–Brussels–Cologne metropolitan region and increased rainfall amounts by 50% compared solely to urban effects. The study, which was published in *Geophysical Research Letters*, is also the first to show that “the regional impacts through land–atmosphere interactions on extreme rainfall [are] comparable or more critical than that induced by climate-scale processes,” according to lead author Long Yang of Nanjing University. The research noted that the rainfall amounts were the result of both dynamical and thermodynamical feedbacks from urban roughness, heat, and the mesoscale convergence. While focused on the European storm, the findings could be applied across climate models and help to protect cities from flooding and other influences of a changing climate. “At more local scales, there are immediate ways to develop climate resiliency where you don’t have to wait for 100-plus nations signing on to declarations,” notes coauthor Dev Niyogi of the University of Texas. “It’s something you can do at the city scale, the regional scale.” [SOURCE: University of Texas at Austin]

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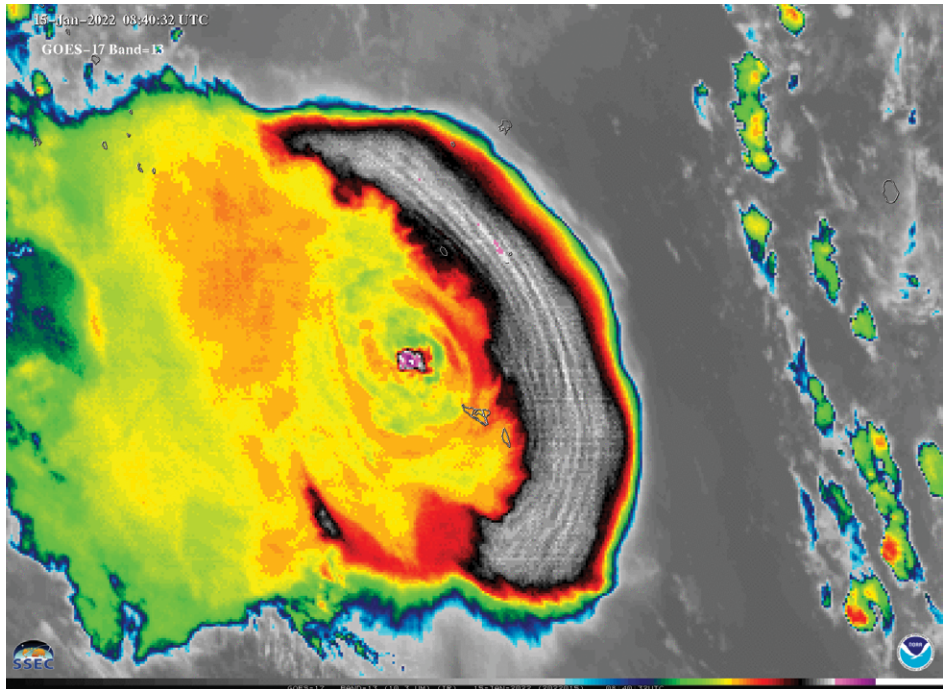
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Grave Waves

ECHOES

The plume emitted by the Hunga Tonga–Hunga Ha’apai volcano in January exhibited a pronounced arc of cloud-top gravity waves along its eastern edge as the bulk of the cloud material drifted westward. Pulsing concentric shock waves were also seen in the infrared imagery, taken by NOAA’s *GOES-West* satellite. [IMAGE CREDIT: Tim Schmit, NOAA/NESDIS/ASPB]

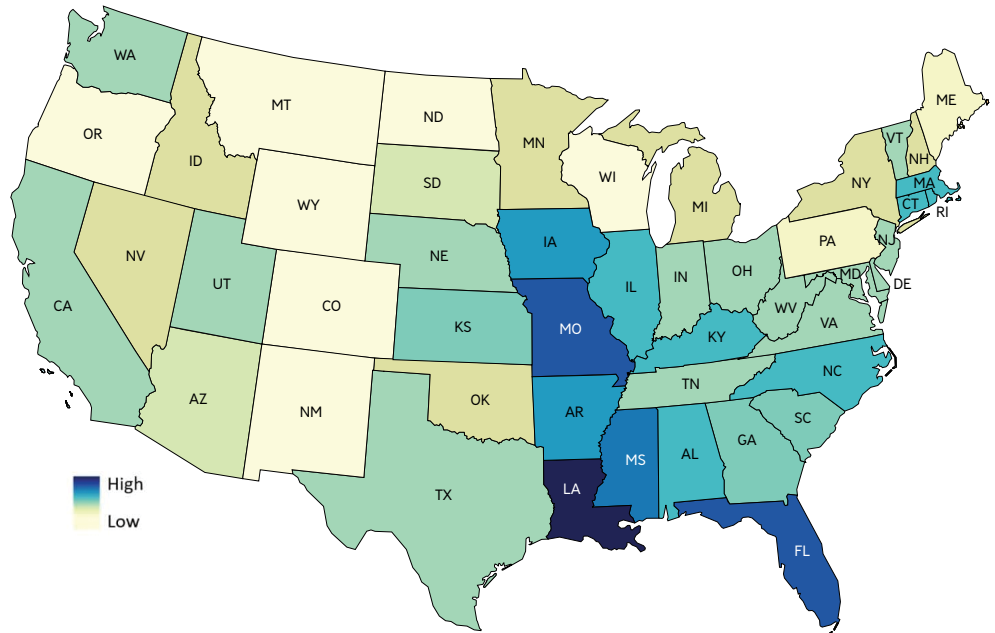


“It’s really unique. We have never seen anything like this in the data before.”

— **LARS HOFFMANN** of Germany’s Jülich Supercomputing Centre, commenting on satellite images showing a pattern of atmospheric gravity waves after the climax of the eruption of the Hunga Tonga–Hunga Ha’apai volcano in the South Pacific in mid-January. The images, which showed the waves as concentric circles extending from the ocean surface to the ionosphere, were captured by the Atmospheric Infrared Sounder, and Hoffmann noted that the instrument “has been operating for something like 20 years now and we have never seen such nice concentric wave patterns.” The waves formed when the volcano explosively erupted, emitting a plume of ash, smoke, and hot gases that created an overshooting top when it stopped rising through the lower atmosphere. The settling of the plume pushed the gravity waves outward in undulations, propelling them around the world in less than 24 hours. The waves demonstrated the “almost unimaginable amount of energy” released by the volcano, notes Mathew Barlow of the University of Massachusetts Lowell: they caused meteotsunamis and influenced local air pressure, and it is believed that they briefly cleared out fog in Seattle. “As this wave moved around the world, it essentially gave a little shove or a jiggle to the whole atmosphere,” says Barlow, who also looked at imagery taken by NOAA’s *GOES-West* satellite to reveal the full extent of the waves. NASA researchers utilized satellite imagery to calculate that the plume rose 58 kilometers into the air, making it the highest known plume in the satellite era (surpassing the 1991 eruption of Mount Pinatubo in the Philippines). “The intensity of this event far exceeds that of any storm cloud I have ever studied,” notes Kristopher Bedka of NASA’s Langley Research Center. [SOURCES: *Nature*, NASA Earth Observatory]

HIGHS AND LOWS

Floods Across America



Predicted average flood damage risk by state or district.
[IMAGE CREDIT: Elyssa Collins]

1.01 Million—

The number of square miles in the United States that have a high probability of flood damage, according to models developed recently by a team of researchers. By comparison, the Federal Emergency

Management Agency (FEMA)'s 100-year floodplain maps comprise only 221,000 square miles, suggesting that the agency is potentially "underestimating flood damage exposure," according to the study's lead author, Elyssa Collins of North Carolina State University. Collins and colleagues trained their models using historical NOAA flood damage data for the years 2006–20 as well as variables such as topography, soil type, precipitation, and the proximity of land to rivers or streams. "Our models are not based in physics or the mechanics of how water flows; we're machine learning methods to create predictions," Collins explains. While FEMA's floodplain maps only account for storms that have a 1% chance of occurring in any given year, the new models looked at damage from floods of any frequency. The team created a model for every watershed in the United States and found that Louisiana, Missouri, the District of Columbia, Florida, and Mississippi were the five states/districts with the highest flood risk in the continental United States. The findings could be useful in land-use planning. "There is still work to be done to make this model more dynamic," Collins notes. "But it's part of a shift in thinking about how we approach these problems in a more cost-effective and computationally efficient manner." The research was published in *Environmental Research Letters*. [SOURCE: North Carolina State University].

EXTREME WEATHER

New WMO Certified Megaflash Lightning Extremes for Flash Distance and Duration Recorded from Space

Michael J. Peterson, Timothy J. Lang, Timothy Logan, Cheong Wee Kiong, Morne Gijben, Ron Holle, Ivana Kolmasova, Martino Marisaldi, Joan Montanya, Sunil D. Pawar, Daile Zhang, Manola Brunet, and Randall S. Cerveny

Initial global extremes in lightning duration and horizontal distance were established in 2017 (Lang et al. 2016) by an international panel of atmospheric lightning scientists and engineers assembled by the WMO. The subsequent launch of NOAA's latest *GOES-16* and *GOES-17* with their Geostationary Lightning Mappers (GLMs) enabled extreme lightning to be monitored continuously over the Western Hemisphere up to 55° latitude for the first time. As a result, the former lightning extremes were more than doubled in 2019 to 709 km for distance and 16.730 s for duration (Peterson et al. 2020). Continued detection and analysis of lightning “megaflashes” (American Meteorological Society 2021) has now revealed two flashes that even exceed those 2019 records. As part of the ongoing work of the WMO in detection and documentation of global weather extremes (e.g., El Fadli et al. 2013; Merlone et al. 2019), an international WMO evaluation committee was created to critically adjudicate these two GLM megaflash cases as new records for extreme lightning.

Megaflashes do not occur in ordinary thunderstorms. They require expansive electrified clouds that discharge at sufficiently low rates to facilitate single horizontal flashes spanning extraordinary distances. The overhanging anvils and raining stratiform regions in mesoscale convective systems (MCSs) meet these criteria. However, few MCSs produce lightning at extreme scales, and such storms have

only been observed in the Great Plains of North America and the La Plata basin in South America (Peterson 2021). This is largely due to the availability of observations although the Lightning Mapping Imager (LMI) on the *Fengyun-4A* satellite can partially observe northeastern India (Fig. 1 from Cao et al. 2021). Future platforms like the Meteosat Third Generation (MTG) Lightning Imager will allow us to observe extreme lightning in more regions across the globe.

Both hotspot regions were represented in the new extreme lightning candidate flashes submitted to the current WMO evaluation committee. The geographic locations and extents of these flashes (red lines) are mapped in Fig. 1. The longest-duration candidate flash was reported by GLM to have developed continuously over a 17.102 s period along the Argentina–Uruguay border starting at 0648:58.822 UTC 18 June 2020. The longest-distance candidate flash was observed to extend over a 768-km (477-mi) distance between Texas and Mississippi starting at 1432:39.016 UTC 29 April 2020.

• *Megaflashes... require expansive electrified clouds that discharge at sufficiently low rates to facilitate single horizontal flashes spanning extraordinary distances.*

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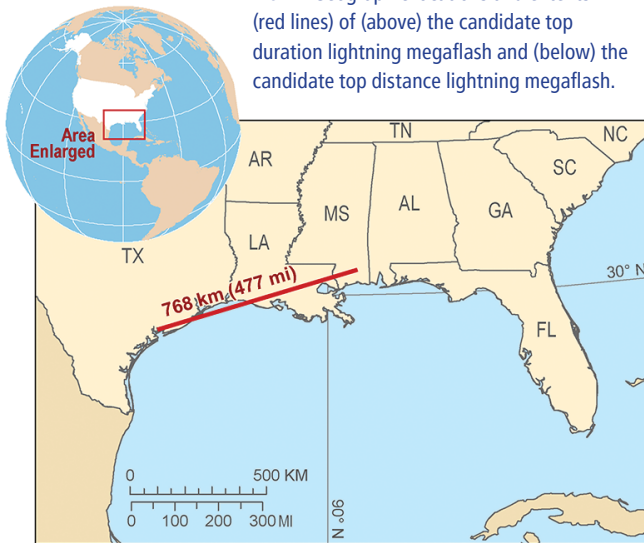
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FIG. 1. Geographic locations and extents (red lines) of (above) the candidate top duration lightning megaflash and (below) the candidate top distance lightning megaflash.



GOES-16 measurements of the top duration candidate are displayed in Fig. 2. The horizontal structure of the flash (white line segments) and maximum spatial extent (gold X symbols) are overlaid on top of GLM Flash Extent Density (FED) imagery (color contours) showing spatial variations in flash rate across the storm and Advanced Baseline Imager (ABI) visible–infrared–composite cloud imagery. GLM reported that the megaflash developed laterally throughout the low-flash-rate trailing stratiform region of an MCS. Its measured 17.102-s duration would be more than 1/3 of a second longer than the previous flash duration record.

Similar *GOES-16* observations are shown for the top distance candidate in Fig. 3. This megaflash was produced

by an MCS that originated over the Great Plains and moved southward before migrating offshore over the Gulf of Mexico. The megaflash occurred after the storm had moved offshore and it extended throughout the trailing stratiform region stretching along the Gulf Coast between Texas and Mississippi. Its 768-km (477-mi) extent mapped by GLM would be 59 km (37 mi) greater than the previous flash distance record.

These two flashes were analyzed independently by members of the WMO evaluation committee using available coincident data. A slightly longer-duration of 17.2 s was proposed for the top duration case. This difference was determined to be within the expected error for the analyses, and the lower GLM-reported duration of 17.102 s was ultimately selected as the reported value. The top distance case happened to occur completely within the domains of the GLM instruments on both *GOES-16* and *-17*, allowing each GLM to provide an independent measurement of flash size. Even though the *GOES-17* GLM viewed the flash near the edge of its field of view where pixels are larger and triggering thresholds are particularly high, it still reported the same flash extent as the *GOES-16* GLM to within 1 km. As with duration, the slightly smaller distance (768 km from *GOES-17*) was accepted as the reported value.

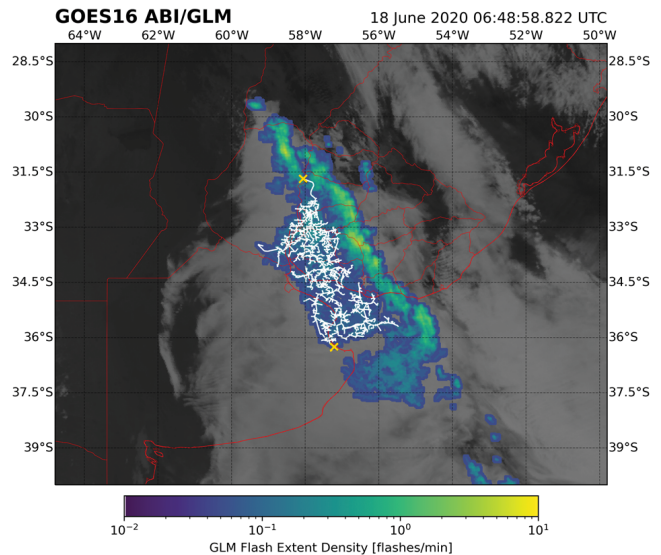
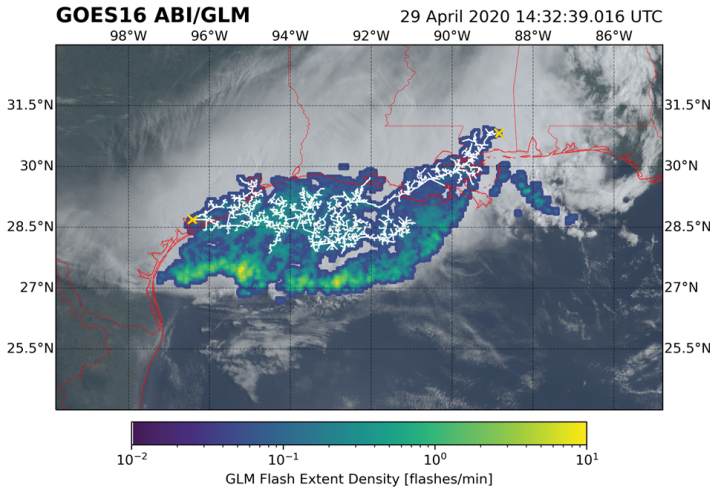


FIG. 2. *GOES-16* GLM Flash Extent Density (color contours) flash rate imagery and ABI composite visible/infrared imagery of the thunderstorm that produced a megaflash that GLM recorded as having a 17.102 s duration. The horizontal structure (white line segments) and maximum extent (gold X symbols) of this megaflash are overlaid.



Stratiform clouds become electrified via a combination of charged hydrometeors being advected from the thunderstorm core and in situ processes from collisions between local hydrometeors. In either case, the precipitation structure of the surrounding thunderstorm is an important control on the horizontal development of megaflashes.

FIG. 3. GOES-16 imagery as in FIG. 2 showing the candidate top distance megaflash and its parent thunderstorm.

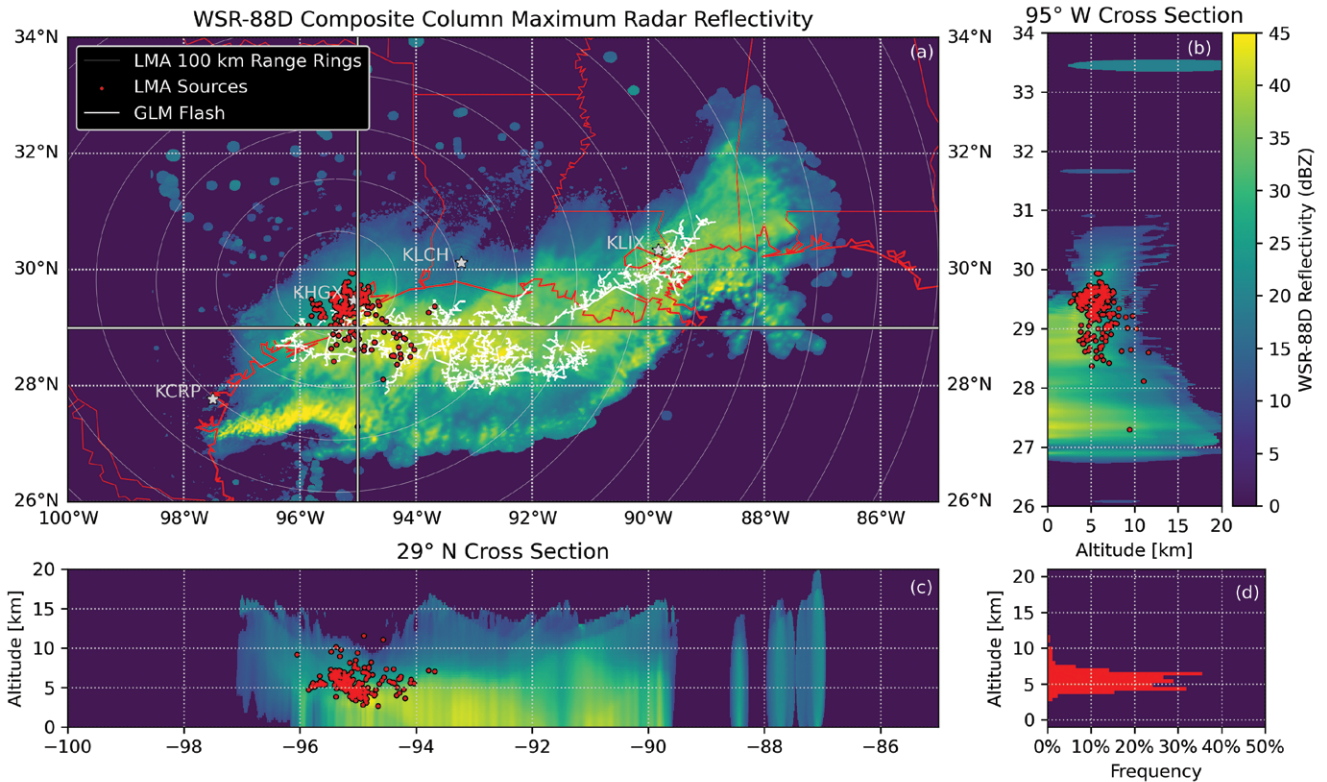


FIG. 4. GLM (white) and HLMA (red) observations of the top distance candidate megaflash overlaid on top of composite NEXRAD radar imagery. (a) Map of flash structure and WSR-88D maximum column reflectivity. (b) Latitude–altitude cross section along the 95°W meridian with all LMA sources overlaid. (c) Longitude–altitude cross section along the 29°N parallel. (d) Histogram of LMA source altitudes.

The 768-km flash was also partially mapped from the ground by a Lightning Mapping Array centered in Houston, Texas (HLMA). Figure 4 overlays the HLMA sources (red dots) and GLM flash structure (white lines) on top of composite WSR-88D imagery constructed using the Py-ART package (Helmus and Collis 2016) and four NEXRAD sites (gray stars). While most of the flash occurred >200 km from the center of the array, and thus was not mapped, the ground-based network partially detected the northward propagation of the flash and characterized its vertical structure (Fig. 4). LMA sources were clustered at relatively low altitudes centered around 6 km MSL, which is commonly observed with MCS stratiform region lightning (e.g., Carey et al. 2005; Lang and Rutledge 2008).

Stratiform clouds become electrified via a combination of charged hydrometeors being advected from the thunderstorm core and in situ processes from collisions between local hydrometeors (Schurr and Rutledge 2000; Stolzenburg et al. 1994). In either case, the precipitation structure of the surrounding thunderstorm is an important control on the horizontal development of megaflashes. Indeed, the shape of the top distance megaflash case bears a striking resemblance to the 30-dBZ WSR-88D maximum echo region behind the convective line in Fig. 4a, with LMA source altitudes clustered along the upper boundary of the enhanced echo region in Figs. 4b,c. What appears to make this flash exceptional—even compared to other megaflashes in the same MCS thunderstorm—is its unique ability to expand laterally throughout a large fraction of the horizontally extensive stratified charge layer at ~6-km altitude.

Another possible charging mechanism which could have amplified the charge layer noted at ~4–6 km is the melting charging mechanism (Stolzenburg and Marshall 2008; Silveira 2016; Drake 1968). Given the reflectivity cross sections (Fig. 4), it is possible that the charge layer is near the melting layer.

These comparisons also demonstrate the advantage that GLM has for documenting extreme flashes that surpass the traditional range of an LMA. However, GLM might not resolve every branch in a given flash. This can happen, for example, when the optical emissions are too dim to trigger GLM. In these cases, merging GLM and LMA data can provide a more complete picture of the horizontal extent of the flash. While LMA sources can be observed beyond the boundaries of the GLM flash in Fig. 4a, we found that none of them would have increased the overall size of the candidate flash.

It should be noted that the sizes reported by GLM are only a minimum estimate for the true extent and duration of these flashes and the actual flashes may exceed these accepted values. Also, as with all WMO evaluations of extremes (temperature, pressure, wind, etc.), the proposed lightning extremes are identified based on only those events with available quality data that are brought to the WMO's attention by the meteorological community. Environmental extremes are living measurements of the capabilities of nature, as well as markers for scientific progress in being able to make such assessments. It is likely that greater extremes still exist, and that we will be able to observe them as more data are collected and lightning detection technology improves.

The committee unanimously recommended acceptance of these two GLM-identified extremes as new global records employing uncertainty estimates as established in previous lightning extremes analyses (Peterson et al. 2020). Consequently, the longest WMO-recognized lightning flash is the single stratiform flash that covered a horizontal distance of 768 ± 8 km (467.2 ± 5 mi) across parts of the southern United States on 29 April 2020. The greatest WMO-recognized duration for a single lightning flash is 17.102 ± 0.002 s from the flash that developed continuously through the stratiform region of a thunderstorm over Uruguay and northern Argentina on 18 June 2020.

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