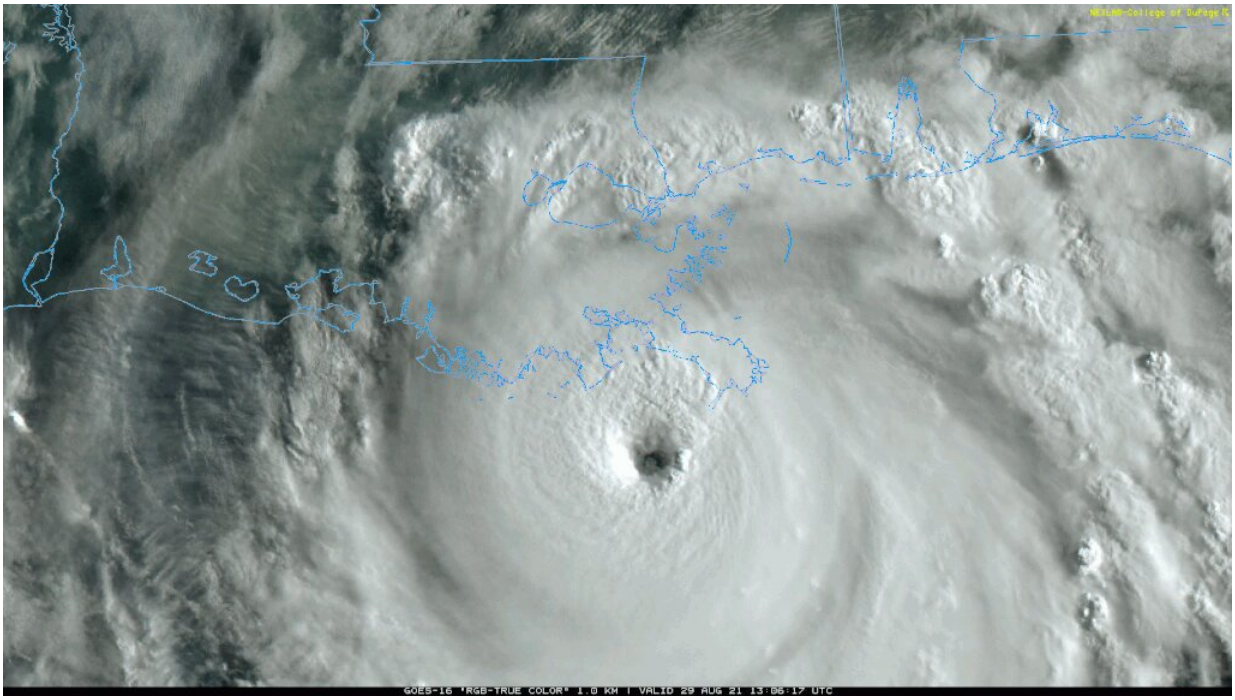
Attribution science: Linking climate change to extreme weather

October 5 2021, by Renee Cho



Hurricane Ida intensifying before landfall. Credit: Photo: College of Du Page

At the end of August, category four Hurricane Ida ravaged Louisiana and caused enormous damage in the Northeast due to flooding. Many homes in both regions were destroyed and prolonged power outages occurred. As Ida moved north, it spawned tornadoes, record rainfall, extensive flooding, and resulted in 82 deaths. Is it possible to determine how much climate change influenced an extreme event like Ida?

Today, as extreme weather events happen more frequently, people are routinely asking if they are caused by climate change. Ten years ago, scientists would have had a hard time answering this question. Today a new type of research called attribution science can determine, not if climate change caused an event, but if climate change made some extreme events more severe and more likely to occur, and if so, by how much. There have always been extreme weather events caused by numerous natural factors, but climate change is increasing the number and strength of these events. Now, it's possible to quantify climate change's influence more precisely, however, determining that climate change contributed to an event does not mean it caused the event.

What can attribution science tell us?

A 2004 paper entitled "Human Contribution to the European Heat Wave of 2003" is generally considered to be the first attribution science study. It modeled how much human-induced greenhouse gases increased the likelihood of the historic 2003 heat wave in Europe.

Today, the World Weather Attribution (WWA) initiative, a collaboration of scientists around the world, does real-time analyses of extreme events right after they occur to figure out how much climate change played a role in them. Attribution science figures out the likelihood or severity of a particular event happening today compared to how it might have unfolded in an imaginary world that humans have not warmed. But because natural variability always plays a role too, even if an extreme event is found to have been made more likely by climate change, it doesn't necessarily mean that the chance of this type of event occurring each year will increase.

How does it work?

When there is an extreme weather event, scientists first determine how frequently an event of that magnitude might occur based on historical and observational data. Having good observational data that goes back a long way is important. WWA says the dataset should go back to the 1950s at least, ideally to the 19th century. Some types of extreme events can be more accurately analyzed than others. Those with long observational records that can be simulated by computer models, especially those connected to temperature, such as heat waves, deliver the most certainty in attribution studies.

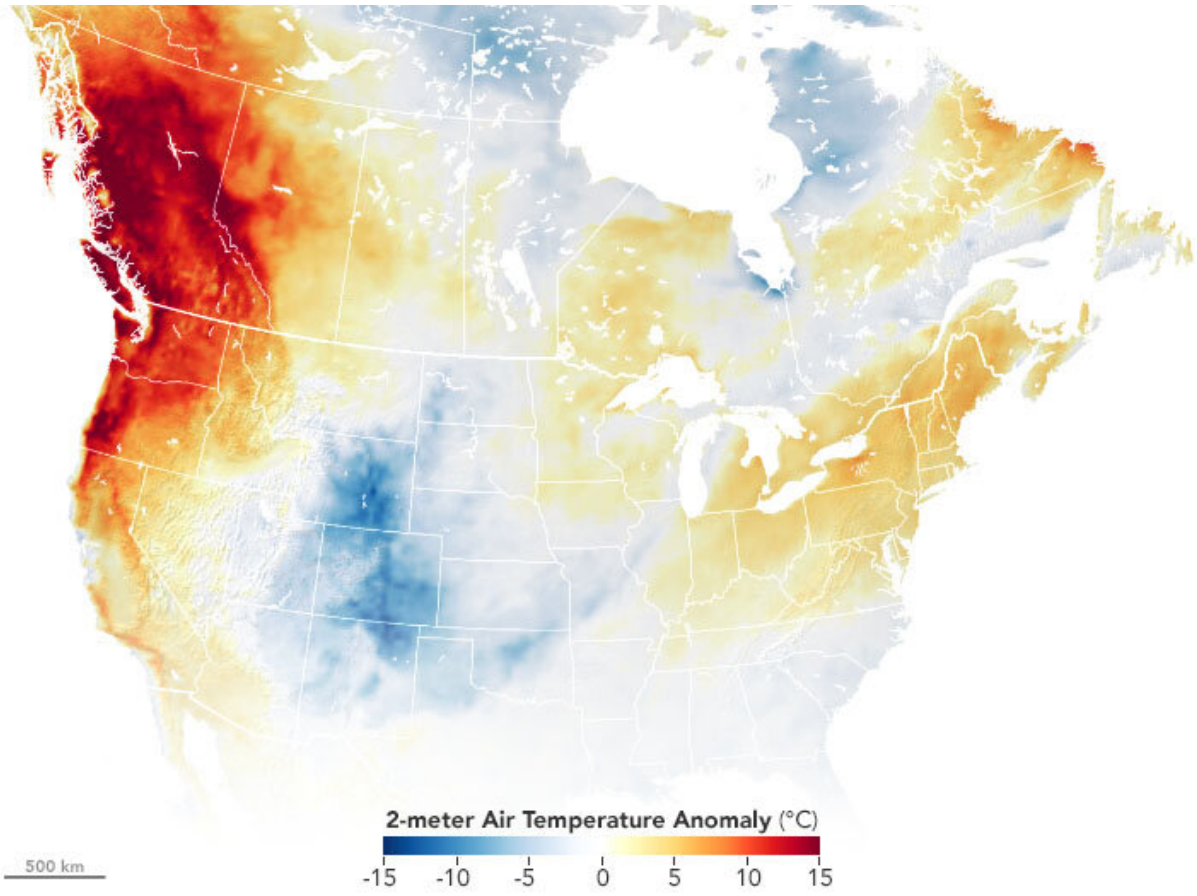
Attribution studies then run identical climate models under two scenarios. In the first, greenhouse gas concentrations are kept constant at some level from the past before humans started burning fossil fuels, and the climate model is run over, say, a 150-year period. This is called the "counterfactual world"—the world that might have been. For the second scenario, the climate model goes back in time again, plugging in the actual greenhouse gas concentrations for each year as they increased over time. By comparing the results from the two modeled scenarios, scientists can estimate how much human emissions from fossil fuel activity have shifted the odds. Statistical methods are then used to quantify the differences in severity and frequency of the event.

As an example, if the extreme event occurs twice as often in today's climate model as it does in the counterfactual climate model, then climate change is determined to have made the event twice as likely as it would otherwise have been in a world without human-induced emissions.

The limitations of attribution analyses

Because of natural variability, however, doing attribution analyses of extreme precipitation events like Hurricane Ida is more difficult, according to climate scientist Radley Horton, of Columbia Climate School's Lamont-Doherty Earth Observatory. "It's not easy to do

attribution on extreme rain events like this, though people do it for sure," he said. "This is because the natural variability for extreme precipitation from one year to the next in any one place is much greater, making it harder to see the signal of climate change relative to the noise of variability."



NASA Earth Observatory image of the June 2021 heat wave. Credit: NASA_Joshua Stevens

Climate models are also less reliable for extreme precipitation because they work with grid boxes that cover large spatial areas; for example,

100 miles by 100 miles. For each grid box, there is one number that represents everything—temperature, precipitation, and wind speed—without differentiating between them. Extreme precipitation, however, often falls in relatively narrow geographical bands. The most extreme rainfall, for example, might occur in a band 40 miles wide, and in most climate models, the grid box is bigger than 40 miles.

"The climate model cannot tell you anything on a finer spatial scale than its grid box, so it can't really capture extreme rainfall events," said Horton. He added, "At present, attribution results are more robust for heat waves, gradually changing conditions that cover a large area like sea level rise, global average temperature, or the extent of Arctic Sea ice. Trying to quantify how much climate change increased extreme precipitation is still challenging and is an area of active research."

Climate models currently do not have fine enough spatial resolution to deal with the many aspects of extreme precipitation, largely because they lack sufficient computing power. In addition, they are limited by what scientists still do not know about the relationships between different components in the atmospheric system that climate change can alter in unpredictable ways—key processes that might interact to unleash new behavior as greenhouse gases increase and temperatures rise.

In the future, however, attribution science will likely become more definitive. "Every five to 10 years, we have more years of data, so we're better able to estimate what the baseline risk is, because we're talking about very rare events," said Horton. "We will also have new data products like satellites that can help us look at cloud temperatures and help estimate rainfall in places where there may not be a lot of weather stations. But I think even more important will be that as our computing power grows, those grid boxes will get finer and smaller. We will have higher resolution models."

While attribution studies are constrained when it comes to determining how much climate change affects precipitation events, the bottom line is that climate change has made many types of extreme events more common than they were in the past.

And for any given storm, like Ida, there is strong potential for heavier rainfall since a warming atmosphere holds more moisture. Scientists are confident in their projections that extreme precipitation events are increasing, and that they will be a growing problem in the future because the observed trends have been so large in so many places. But there are still great uncertainties about how severe the upper extremes will be, which is critical for knowing how to plan, avoid economic damage, and save lives.

Other factors, too, play a part in creating a natural disaster. According to the WWA, first are the meteorological conditions. Second is exposure to the event—how many people and how much property are located in danger zones. And finally, vulnerability—the attributes and circumstances of a population or system that make it susceptible to the event's impacts.

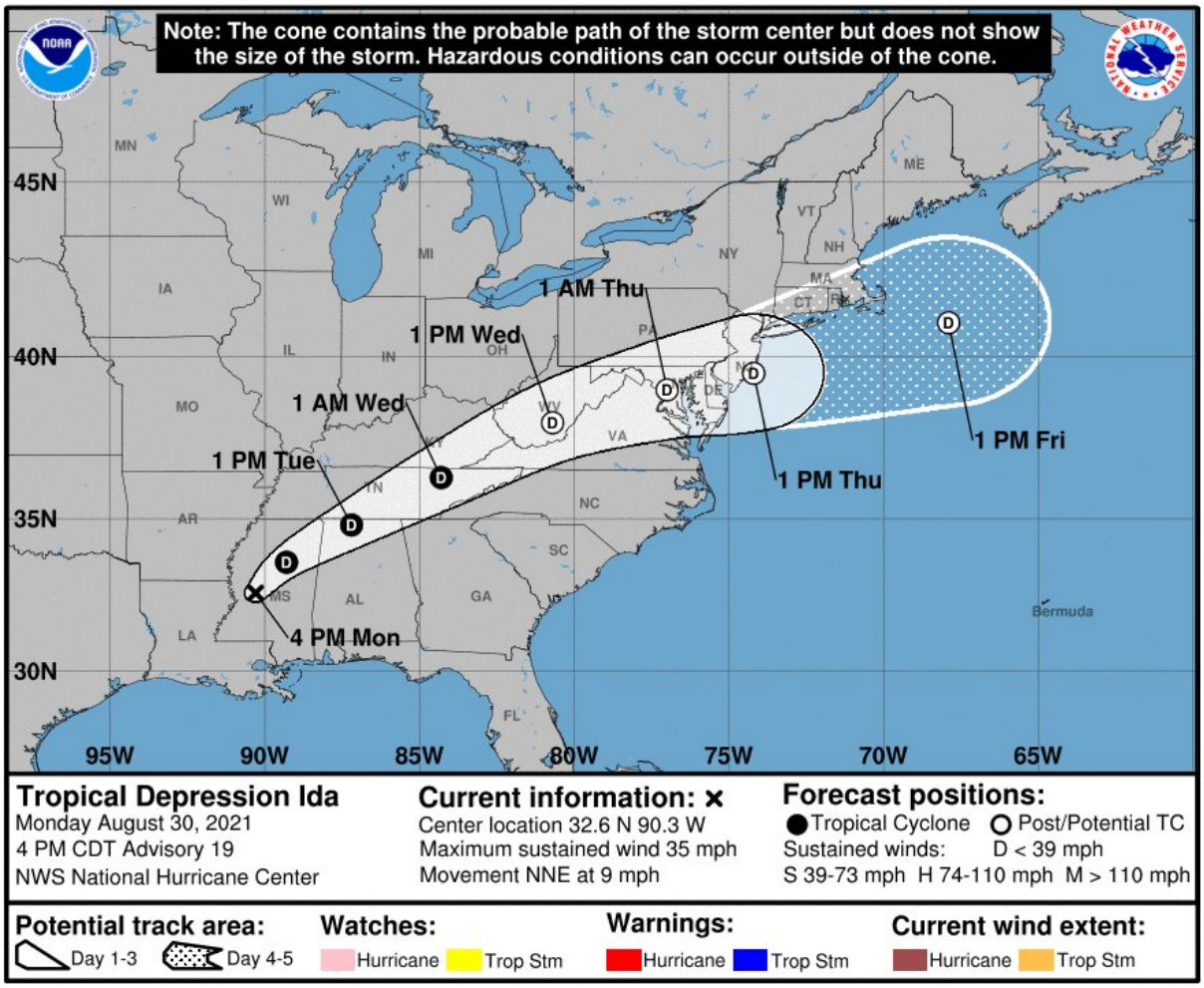
Sometimes attribution analyses find that extreme events have not necessarily been exacerbated by climate change, but rather by the exposure and vulnerability of the population. For instance, as more and more Americans build homes in areas at high risk for floods and wildfires, the catastrophic damage that occurs is due to a confluence of factors—such as hotter drier summers that increase wildfire risk or a lack of governmental regulations for building in flood plains.

Attribution science at work

In July, Germany, Belgium, Luxembourg, and the Netherlands experienced catastrophic flooding due to record rainfall during a storm

that killed 220 people. According to the history of the region, there was a 1 in 400 chance of that much rainfall falling in any given year. But an attribution analysis by WWA found that human-induced climate change made the event 1.2 to 9 times more likely than it would have been 100 years ago. Warming temperatures also increased the amount of rainfall by three to 19 percent.

The heat wave that hit the Pacific Northwest in June brought temperatures higher than ever previously recorded in that region. The event was estimated to be a 1 in 1000-year event and might never have happened without climate change, according to the WWA.



Ida's hurricane cone. Credit: National Hurricane Center

The heat wave was also found to be 2 degrees Celsius hotter than it would have been had it occurred before the Industrial Revolution. If the world reaches 2 degrees Celsius of global warming (it has currently warmed about 1.1 degrees Celsius but is on track to hit 1.5 degrees Celsius by 2040), this type of 1 in 1000-year heat wave could occur every five to 10 years.

Two attribution studies found that climate change made Hurricane Harvey, which caused floods and over 100 deaths in Texas and Louisiana in 2017, three times more likely and increased the storm's rainfall by 15 percent. Unlike Hurricane Ida, Hurricane Harvey covered a large area with extreme precipitation falling over a longer period of time.

Carbon Brief, a U.K. website reporting the latest developments in climate science, has mapped over 350 peer-reviewed studies of weather extremes around the world and analyzed the trends. Overall, extreme events have increased in the last 10 to 15 years. 70 percent of 405 extreme weather events were made more likely or more intense by human-induced climate change. 92 percent of 122 attribution studies of extreme heat found that climate change made them more likely or more severe. 58 percent of 81 rainfall studies found that human activity made them more probable or intense. And 65 percent of 69 drought events were also exacerbated by climate change.

How else can attribution science be used?

Attribution science is becoming sufficiently recognized and established enough to provide support in some legal disputes. In 2020, the Sabin

Center for Climate Change Law and Lamont-Doherty Earth Observatory established the Climate Attribution Database. It contains 385 scientific resources organized by theme: climate change attribution, extreme event attribution, impact attribution, and source attribution. The database will help scientists understand how attribution research might be applied to laws and policies, enable lawyers to access the latest research to support their cases, and provide policy makers with resources that offer justification for their climate policies. A number of environmental impacts, such as sea level rise, melting permafrost or snowpack, extreme heat, and ocean acidification can quite confidently be attributed to climate change. And once an impact has been determined to be influenced by climate change, it's possible to figure out the proportion to attribute to a specific source of emissions.

Lindene Patton, a partner at Earth & Water Law, told E&E News,"When the science changes, when a body of knowledge to which a responsible professional is expected to keep up with and understand and pay attention to—when that changes, it changes what they have to do to protect people. It changes the standard of care."

Attribution science can thus potentially be used to defend climate regulations that are challenged as being too stringent or to establish standing to sue by showing that certain parties have been harmed by climate change impacts. It can help hold emitters liable and sue governments for not sufficiently regulating greenhouse gas emissions. According to Michael Burger, executive director of the Sabin Center for Climate Change Law at Columbia University, a Dutch court ordered Shell to reduce greenhouse gas emissions associated with the combustion of its fossil fuel products 45 percent by 2030, using a form of "source attribution." And the Philippines' Commission on Human Rights determined that fossil fuel companies have a responsibility under a Philippines human rights law to reduce the emissions that result from their products and services. As yet, however, no fossil fuel or power

company has been held liable for climate-related damages based on an extreme event or a gradual change in environmental conditions. But because attribution science is making it possible to quantify increased risks, it will likely result in more lawsuits in the future.

Attribution science could also be used to help governments determine the right level for an emissions cap or a carbon tax, and eventually could even be used to predict extreme events.

"Already, we're seeing attribution studies being conducted before an event has even happened," said Horton. "Let's say there's a hurricane in the tropical Atlantic. You're seeing that cone of uncertainty about where that storm might go in a week or 10 days. People can link those short-term predictions to models that give us the counterfactual world with no warming versus the world of today, so that before the storm even arrives, there's an estimate of how much more likely you are to get that event."

Because the future is likely to bring extreme weather and impacts in areas that have not experienced as frequent or intense events in the past, attribution science could potentially also help with climate adaptation. For example, cities might decide to install more green infrastructure to absorb a projected increase in stormwater. Or if an area is aware that more extreme weather events will likely occur in the future, residents might be persuaded to relocate rather than rebuild.

Attribution science is providing new insights into the impacts of climate change. As such, it has great potential as a tool to help educate, prepare, and influence global communities as they face the impacts of a warming world.

"My personal feeling about attribution science," said Horton, "is that it's less a revolution in our understanding, and more a revolution in how we apply knowledge to attribute blame and apportion responsibility, and

perhaps most importantly, to inform and motivate communities and stakeholders to take action."

Provided by Columbia University