Recently, a group of climate scientists set out to determine how likely it was that human-induced climate change had played a role in the devastating floods that struck England and Wales in the fall of 2000, damaging nearly 10,000 properties, severely disrupting services and causing an estimated $2 billion in losses.

Their answer: very likely.

``You have to look at these events in terms of probability,'' says Pardeep Pall, lead author of the study, which appeared in the journal *Nature* in 2011. ``Think of the weather as a roll of the dice, and flood as being a six. If you roll the dice, you will have a one- in- six chance of a six happening. But imagine if the dice is somehow loaded toward more sixes. We've loaded the climate toward more sixes, so when we roll the dice, we're more likely to roll a six.''

Pall and his colleagues, in a novel approach, used a detailed computer climate model from the UK Met Office to simulate fall 2000 weather, first, in a world as it actually was at that time, and then in a parallel world without twentieth century greenhouse gases.

They ran the simulations thousands of times and found that the odds of the England/Wales floods occurring increased by double - or more - in a world that had been altered by climate change.

``In nine out of ten cases, the models indicated that climate change raised the risk by more than 20% and in two out of three cases, by more than 90%,’’ says Pall, a computer systems engineer with the Lawrence Berkeley National Laboratory.

The world is growing hotter due to human activities, and it is reconfiguring the Earth’s climate, prompting extreme weather events, including more intense rain, which raises the risk of floods. Last fall, the U.N. Intergovernmental Panel on Climate Change (IPCC) predicted that global warming would bring much heavier rainfall and more floods, especially in the high latitudes and tropical regions, and in winter in the northern mid-latitudes.

``The rainfall will be more intense for a given event,'' says Gerald ``Jerry'' Meehl, a senior scientist at the National Center for Atmospheric Research (NCAR). ``We've already seen it. It's been happening and is projected to continue to happen as we get warmer in the future. And, if there is more rainfall coming out of a given storm, it just increases the risk for flooding.''

World-wide, floods cause billions of dollars in damage, with thousands of lives lost. In fact, flooding causes more deaths in the United States than any other weather event except heat.

There has been no letup in serious floods. Last summer, the UK and Wales again were hit hard, as were vulnerable areas of China and the Philippines. Russia's Krasnodar region - scheduled to host the 2014 Winter Olympic Games in the Black Sea resort of Sochi - experienced floods in July that killed more than 170 people.

In the United States - and seven years to the day Hurricane Katrina made landfall there - Hurricane Isaac slammed into Louisiana with 70 mile-per-hour winds and heavy rain, causing widespread flooding, and leaving at least 200,000 without power, and thousands of people in shelters. In 2011, catastrophic flooding from Hurricane Irene decimated areas of New York, Connecticut, Vermont and elsewhere.

To be sure, it is still unclear to what extent climate change was involved in any of these individual events. But climate experts agree that global warming has ``a direct influence…on precipitation,’’ says Kevin E. Trenberth, distinguished senior scientist in the climate analysis section at NCAR.

Increased heating leads to great water evaporation; the water-holding capacity of the air rise about 7% with each Celsius degree of warming, resulting in air that becomes super-saturated with water. This brings rainfall that often is heavy and intense.

Thus, ``when it rains, it's going to pour,'' says Michael Oppenheimer, professor of geosciences and international affairs at Princeton University, and a long time participant in IPCC. ``We will be getting more of those, and those are the types of events that can be highly damaging, very disruptive and can cause real trouble.''

Donald J. Wuebbles, professor of atmospheric sciences at the University of Illinois at Urbana-Champaign, agrees. ``In general, the U.S. is seeing more precipitation coming as larger events when it does rain,'' says Wuebbles, a lead author on the first and second international assessments of climate change sponsored by the IPCC. ``In the Midwest, for example, the heaviest 1% of rainfalls historically have increased by 46% over the last 50 years.''

Trenberth, who was among the first to attribute seasonal U.S. weather changes to El Niño (the warming of water in the equatorial Pacific) and La Niña (the cooling of water in the equatorial Pacific), estimates that from 5 to 10% of Katrina’s precipitation was due to climate change, adding: ``That’s probably conservative.’’

``It has been estimated that heavy rains in tropical storms, including Katrina, have increased by 6 to 8% as a result of higher sea surface temperatures and more water vapor in the atmosphere,’’ he says.

Similarly, in August 2011, Hurricane Irene barreled up the East Coast dumping a record rainfall that caused more than $15 billion in damages due to flooding.

``Irene formed over unusually warm waters and picked up a lot of moisture,’’ says Michael Mann, **professor and director of the Earth System Science Center at Pennsylvania State University. ` `Because of those record ocean temperatures, Irene was working with a much higher amount of water vapor in the atmosphere than we normally would have. That’s why we saw the record flooding in New England, Vermont and Massachusetts.''**

**As with Irene, the amount of rainfall delivered by hurricanes is expected to increase. ``Irene was an interesting storm in that it contained a lot of water,'' says** Michael Wehner, a staff scientist at the Lawrence Berkeley National Laboratory, and a leading climate researcher.  **``That's why there was so much damage, because of the water, not because of the wind speed, which was low. Hurricane-induced flooding might statistically become more severe.''**

The average person might find it easier to connect global warming to drought - currently afflicting much of the nation - because ``droughts evolve very slowly and are related to factors like stagnant atmospheric circulation patterns, hot temperatures, and long periods without rain or snow, whereas floods are related directly to weather events,'' says Katherine K. Hirschboeck, associate professor of climatology at the University of Arizona. ``But there are many reasons why climate change could increase the frequency of floods.''

Moreover, ``it depends on where you live and the season,'' Mann says. ``Even in the same place, such as here in Pennsylvania, you may very well expect greater winter rainfall and winter precipitation, and increasing summer drought. Two very different things are going on. Even in regions where there is pronounced drought, it is possible that the precipitation that falls will be more intense. Rainfalls may be farther and fewer between, but there will be a greater tendency, when it rains, for it to pour.''

Generally, floods result when weather events - thunderstorms, tropical storms, or hurricanes, for example - deliver more rain to a drainage basin than it can absorb readily, or store. Also, a midwinter thaw or an early spring can produce large amounts of runoff from melting snow in a short period of time. Ground that still is hard and frozen can't absorb the water, which runs off the surface and into lakes, streams and rivers, causing excess water to spill over the banks.

``The meteorological processes that produce flood-causing precipitation and runoff in the United States occur within a much larger climatic context that is global in extent,'' Hirschboeck says. ``They often are related to the large-scale delivery pathways of atmospheric moisture, and, within a given season, floods often are influenced by unusual or unseasonal regional atmospheric circulation patterns.

``The connection to climate change is related to how the energy and moisture transport in the atmosphere balances out,'' she adds. ``It's these circulation changes that I think are the key to connecting the dots between increased floods and global warming.''

Pall, of the Berkeley lab, says he and his colleagues decided to conduct the computer modeling experiment on the 2000 UK floods because they felt it was important to try to provide an objective answer to whether certain events have become more likely due to human-induced climate change ``as opposed to the speculation and somewhat subjective debate that usually follows in the aftermath of a damaging weather-related event,'' he says.

Moreover, the United Nations Framework Convention on Climate Change (UNFCC) Adaptation Fund, established to support adapation activities for parties affected by climate change, could find the science valuable when deciding claims related to a bout of damaging weather, Pall says, adding: ``We need a method that disentangles whether an event was due to climate change, or just some freak event.''

To be sure, the researchers only investigated a single event during a specific short time period, ``so we aren't saying anything about past or future trends, per se,'' Pall says. But their results, generally, were consistent ``with a well-known basic physical mechanism for increased atmospheric moisture under global warming,'' which might be a harbinger of ``wetter extreme weather of this type under future global warming,'' he says.

He and other scientists plan to expand their work to include other extreme weather events ``as soon as possible after they happen,'' he says. ``We want to make this more systematic and do it on a regular basis for various events across the world.''

-Marlene Cimons