Global warming is likely to increase severe thunderstorm conditions in US, researchers find

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In 2012, 11 weather disasters in the United States crossed the billion-dollar threshold in economic losses. Seven of those events were related to severe thunderstorms. New climate analyses led by Stanford scientists indicate that global warming is likely to cause a robust increase in the conditions that produce these types of storms across much of the country over the next century.

Severe thunderstorms are one of the primary causes of catastrophic losses in the United States and often exhibit the conditions that generate heavy rainfall, damaging winds, hail and tornadoes.

Sparse historical data describing the atmospheric conditions that cause severe thunderstorms has limited scientists' ability to project the long-term effects of global warming on storm frequency. But, using a complex ensemble of physics-based climate models, researchers led by Noah Diffenbaugh, an associate professor of environmental Earth system science at Stanford, have produced the most comprehensive projections of severe storm conditions for the next century.

Scientists have identified two main ingredients involved in generating a severe thunderstorm. The first is that the atmosphere must contain a significant amount of what scientists call convective available potential energy (CAPE), created as the air in the low atmosphere warms. The warm air rises, carrying with it moisture to higher altitudes.

To transform into a severe thunderstorm, CAPE must also interact with strong vertical wind shear – essentially a moving wind current that organizes the atmospheric energy and moisture such that it can sustain a storm.

Climate researchers have previously hypothesized that global warming will increase CAPE and cause an overall decrease in wind shear, which created uncertainty about the net effect.

The new climate model experiment that Diffenbaugh and his co-authors analyzed, called the Coupled Model Intercomparison Project (CMIP5), confirms these competing effects, but in a different way than previously believed.

Although the climate model experiment does indicate an overall decrease in the average amount of wind shear, the researchers found that the bulk of that decrease occurs on days that produce levels of CAPE that are much lower than is normally seen during severe storms.

The net effect is that the increases in CAPE on other days drive increases in the occurrence of severe thunderstorm environments.

"We're seeing that global warming produces more days with high CAPE and sufficient shear to form severe thunderstorms," said Diffenbaugh, who is also a senior fellow at the Stanford Woods Institute for the Environment.

Stormy springs ahead

The analysis carved the United States into boxes that were roughly 60 miles on a side and assessed the climate conditions that could emerge over the next century. The analysis showed the biggest changes occurring in the spring season, with each box in the central United States

experiencing about two-and-a-half additional storm days per spring by the late 21st century.

The researchers also reported that sustained global warming is likely to cause robust increases in storm days over large areas of the eastern United States not only in spring but also in winter and autumn. While the summer season also showed increases over the region as a whole, those increases were the least robust within the region and across the different climate models.

An additional few days of severe storm conditions might not seem like a large change, but Diffenbaugh emphasized that the projected increases are in fact substantial compared to the frequency of occurrence in the current climate.

"We are looking at the conditions that produce severe events, which are relatively rare at present," Diffenbaugh said. "For example, the changes during spring represent an increase of about 40 percent over the eastern U.S. by the late 21st century."

Diffenbaugh also emphasized even a single severe storm can cause very high levels of damage.

"The severe thunderstorms we experience now can result in very high economic losses," Diffenbaugh said. "Sadly, we have many examples of cases where a single storm has had disastrous impact. So a 25 or 30 percent increase in the annual occurrence represents a substantial increase in the overall risk."

Potential for more tornadoes

Such storms also create conditions that can lead to tornado formation, although the researchers stress caution in drawing conclusions

specifically about the effect of global warming on tornadoes.

"We have tried to analyze the atmospheric conditions that are associated with tornadoes," Diffenbaugh said. "Although we do see that those conditions increase in occurrence in response to global warming, it is important to bear in mind that we are not resolving tornadoes in these experiments."

Diffenbaugh hopes to build on this research to improve the understanding of the atmospheric dynamics that lead to the development of severe thunderstorms, and to better incorporate those processes into climate models.

The study is published in the current issue of *Proceedings of the National Academy of Sciences*.

"These are rare but significant events," Diffenbaugh said. "This new set of global climate model experiments has provided some important new insights. What we need to do next is develop ways to better represent the processes that produce individual storms in the real atmosphere."

More information: Robust increases in severe thunderstorm environments in response to greenhouse forcing, *PNAS*, www.pnas.org/cgi/doi/10.1073/pnas.1307758110

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