Climate change cripples forests

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Southwestern US trees face rising drought stress and mortality as climate warms

LOS ALAMOS, N.M., Oct. 1, 2012—Combine the tree-ring growth record with historic information, climate records and computer-model projections of future climate trends, and you get a grim picture for the future of trees in the southwestern United States. That's the word from a team of scientists from Los Alamos National Laboratory, the U.S. Geological Survey, University of Arizona, and several other partner organizations.

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Tree Death Study's Climate Change Connection

Described in a paper published in *Nature Climate Change* this week, "Temperature as a potent driver of regional forest drought stress and tree mortality," the team concluded

that in the warmer and drier Southwest of the near future, widespread tree mortality will cause forest and species distributions to change substantially.

The researchers aligned about 13,000 tree core samples with known temperature and moisture data, further blending in known historic events such as documented megadroughts that drove the ancient Pueblo Indians out of longtime settlements such as Mesa Verde, Colo.

By comparing the tree-ring record to climate data collected in the Southwest since the late 1800s, scientists were able to identify two climate variables that can be used to estimate annual regional tree-growth variability with exceptional accuracy. Both variables are related to drought: total winter precipitation and average summer-fall atmospheric evaporative demand. Forest growth is best when total winter precipitation is high and summer-fall atmospheric evaporative demand is low -- that is, not too hot.

Warming to continue for foreseeable future due to accumulating greenhouse gases

“These results are very important,” said A. Park Williams of Los Alamos, lead author [and corresponding author] of the study. “Atmospheric evaporative demand is primarily driven by temperature. When air is warmer, it can hold more water vapor, thus increasing the pace at which soil and plants dry out. The air literally sucks the moisture out of the soil and plants.”

This is important, Williams and his colleagues noted, because southwestern U.S. temperatures have been generally increasing for the past century and warming is expected to continue for the foreseeable future due to accumulating greenhouse gases in the atmosphere.

“There will still be wet winters, but they will more often be followed by warm summers, putting stress on trees and limiting their ability to respond to a subsequent wet winter,” Williams said.

The finding that summer-fall atmospheric evaporative demand is just as important as winter precipitation has very important implications for the future of southwestern forests: climate models all agree that atmospheric evaporative demand will continue rising significantly in the coming decades.

“Temperature and evaporation don’t only dictate whether trees grow fast or slow in the Southwest. They also strongly influence the processes that kill trees, such as bark-beetle outbreaks and wildfires,” said Nate McDowell, staff scientist at Los Alamos National Laboratory.

For example, the study points out that very large and severe wildfires, bark-beetle outbreaks and a doubling of the proportion of dead trees in response to early 21st-century heat and drought conditions serve as evidence that a transition of southwestern forest landscapes toward more open and drought-tolerant ecosystems is already underway.

“We can use the past to learn about the future,” Williams notes. “For example, satellite data from the past 30 years show that there has been a strong and exponential relationship between the regional tree-ring record and the area of southwestern forests killed by wildfire each year. This suggests that if drought intensifies, we can expect forests not only to grow more slowly, but also to die more quickly.”

Forest Drought Stress Index proves accurate and predictive about megadroughts

“The new ‘Forest Drought Stress Index’ that Williams devised from seasonal precipitation and temperature-related variables matches the records of changing forest conditions in the Southwest remarkably well,” said co-author Thomas W. Swetnam, director of University of Arizona’s Laboratory of Tree-Ring Research.

“Among all climate variables affecting trees and forests that have ever been studied, this new drought index has the strongest correlation with combined tree growth, tree death from drought and insects, and area burned by forest fires that I have ever seen.”

And while drought conditions in the 2000s so far have been severe, the regional tree-ring record indicates that there have been substantially stronger megadrought events during the past 1,000 years. The strongest megadrought occurred during the second half of the 1200s and is believed to have played a primary role in the abandonment of ancient Puebloan cultural centers throughout the Southwest. The most recent megadrought occurred in the late 1500s and appears to have been strong enough to have killed many trees in the Southwest.

“When we look at our tree-ring record, we see this huge dip in the 1580s when all the tree rings are really tiny, meaning trees didn’t grow much during that period,” Williams said. “Following the 1500s megadrought, tree rings get wider. At the same time, there was a major boom in new trees. The vast majority of trees we see in the Southwest today were established after the late-1500s drought, even though the species we evaluated can easily live longer than 400 years. So that event is a benchmark for us today. If forest drought stress exceeds late 1500 levels, we expect that a lot of trees are going to be dying.”

Future forest drought-stress levels will reach or exceed those associated with the megadroughts of the 1200s and 1500s

But will warming and increased atmospheric evaporative demand cause future forest drought-stress levels to reach or exceed those associated with the megadroughts of the 1200s and 1500s?

“Consistent with many other recent studies, these findings provide compelling additional evidence of emerging global risks of amplified drought-induced tree mortality and extensive forest die-off as the planet warms,” said co-author Craig D. Allen, a research ecologist with the U.S. Geological Survey.

Using climate-model projections of winter precipitation and summer-fall evaporative demand to estimate forest drought stress in the future, the team projects 1200s and 1500s megadrought-type forest drought-stress conditions to be exceeded on a regular basis by the 2050s. If climate models are correct, forest drought-stress levels during even the wettest and coolest years of the late 21st century will still usually be more severe than the driest, warmest years of the 1200s and 1500s megadroughts. In fact, the study forecasted that during the second half of this century, about 80 percent of years are projected to exceed megadrought levels.

Williams says the current drought event, which began in 2000, can be used as an indicator of what to expect from projected climate scenarios. While average winter precipitation totals have not been exceptionally low, average summer-fall evaporative

demand has been the highest on record. And trees, he says, are paying the price. The team concluded that forest drought stress during about 30 percent of the past 13 years, including 2011 and 2012, matched or exceeded megadrought-type levels of the 1200s and the 1500s. For comparison, 4.8 percent of years in the past millennium qualified as megadrought-type years.

By the end of this century, forecast shows southwestern forest-drought stress to exceed megadrought-type levels even during years with abnormally wet winters

While we cannot observe future climate, Williams said, we can consider projections of future climate trends produced by a collection of global climate models. “Considering a scenario where greenhouse gases continue to accumulate in the atmosphere along a ‘business-as-usual’ trajectory, summer-fall atmospheric evaporative demand is projected to be 18 percent higher than the 20th century average by 2050 and 41 percent higher by 2100. By the end of this century, we forecast southwestern forest-drought stress to exceed megadrought-type levels even during years with abnormally wet winters.”

“Of course,” Williams says, “you can only have forest drought stress if you have forests. The ultimate conclusion of our study is that in a warmer world, we won’t be able to have forests in many places where they exist today. Continued warming will cause forest distributions to change substantially in the southwestern United States.”

For first time, a solid prediction of future drought conditions from forest's perspective

McDowell adds, “This paper is a breakthrough because, for the first time, we have a solid prediction of future drought conditions from the perspective of the forests. There is no question, southwestern forests are not likely to be growing well in the next few decades.”

The researchers drew on worldwide scientific resources to conduct this study, starting with a vast tree-ring data library maintained by the NOAA Paleoclimatology Program and World Data Center for Paleoclimatology. Additional data were from a network of southwestern US tree-ring data developed under the leadership of UA co-author Connie Woodhouse and funded by the National Science Foundation. In addition, the models used for the 2007 IPCC report were used to make projections of precipitation and evaporative demand. One of the models includes code developed at Los Alamos.

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