Amazon rainforest responds quickly to extreme climate events

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Solimões, the section of the upper Amazon River. Image: Wikipedia.

A new study examining carbon exchange in the Amazon rainforest following extremely hot and dry spells reveals tropical ecosystems might be more sensitive to climate change than previously thought.

The findings, published online on April 28 in the journal *Global Change Biology*, have implications for the fate of the Amazon and other tropical ecosystems if greenhouse gas emissions continue to climb.

"There have been a lot of projections of what might happen in the Amazon in the future as global warming intensifies," said study co-author Noah Diffenbaugh, an associate professor of Earth Systems Science at Stanford's School of Earth, Energy & Environmental Sciences. "In this study, we are bringing together many different data sources to take a more comprehensive and detailed look at how the Amazon has responded to severely hot and dry conditions that happened in the recent past."

Net Biome Exchange

Land ecosystems "breathe" carbon dioxide (CO2) in and out during growth and decay, and the amount of CO2 taken up or released by biomes can offer important insights into how ecosystems could be affected by global warming. Because of their vast potential to store and release carbon, tropical ecosystems play a major role in regulating the Earth's climate. If climate change causes tropical forests to emit large amounts of CO2 into the atmosphere, that carbon loss could amplify the global warming effects of fossil fuel emissions.

The study's lead author, Caroline Alden, began the study at the University of Colorado's Cooperative Institute for Research in Environmental Sciences (CIRES) and continued the research as a postdoctoral researcher working with Diffenbaugh at Stanford.

Alden and her colleagues developed a data analysis that combines weather data with CO2 measurements gathered by airplane surveys to calculate how much atmospheric carbon exchange, also known as net biome exchange (NBE), is happening across the Amazon basin. This new analysis allowed the researchers to track down the sources of CO2 absorption and emission in the rainforest during each month over a three-year period.

"By gathering many observations of CO2 in the atmosphere, we gain a sense of how CO2 is distributed above the Amazon, and how that changes in response to extreme climate events," said Alden, who is currently a research associate at the University of Colorado. "By combining that knowledge of CO2 in the atmosphere with knowledge of where the winds came from in the days preceding the measurements, we can track down the sources of the signals that we see in the air."

The analysis Alden's team developed is the first to look at NBE variations month-by-month on regional scales that cover several million square kilometers, filling in a critical gap between very small-scale and larger-scale studies and helping to improve understanding of Amazon climate-carbon interactions.

Shifting Carbon Balance

For their analysis, the scientists calculated NBE flux in the Amazon for the three-year period spanning 2010 to 2012. In 2010, a major drought and unusually high temperatures affected much of the Amazon basin, but conditions had returned closer to normal by 2011 and 2012.

Alden and her team found evidence of very large shifts toward carbon loss to the atmosphere in the Amazon after periods of extreme heat and drought in 2010. What's more, the shifts were surprisingly fast.

"We see that the carbon balance in the Amazon can change quickly in response to climate events," Alden said, "Heat anomalies during the wet season are strongly correlated with increased carbon loss in the same month, and lower-than-average rainfall during the wet season is correlated with increased carbon loss in the following month."

Increasing Heat Stress

It was already known that the 2010 drought had caused large carbon loss from the Amazon. However, the more detailed information developed in the new study allowed the researchers to analyze both the carbon and climate conditions that occurred in different parts of the Amazon as the drought evolved. This new analysis suggests that the loss of carbon may have preceded the onset of drought conditions, when the climate was unusually hot but not yet unusually dry.

"We have very strong evidence that severe heat has been increasing in the Amazon, and that more global warming will intensify this effect," said Diffenbaugh, who is also a senior fellow at Stanford's Woods Institute for the Environment. "Our findings suggest that regardless of changes in precipitation, the Amazon could be vulnerable to the increasing heat stress that we know is very likely to accompany further global warming."

The group also found that in the eastern Amazon, CO_2 was still being emitted to the atmosphere in large pulses throughout 2011, months after the severe heat and drought events had occurred. This "legacy" effect could indicate that tropical rainforests can take several years to recover from a major drought, Alden said.

Taken together, these results suggest the Amazon may be more sensitive to heat and drought conditions than previously thought - a finding that does not bode well for tropical ecosystems in the coming decades as the effects of climate change are expected to intensify.

"The Amazon ecosystem is a critical part of the global climate and carbon system, and home to unparalleled biodiversity," Alden said. "These findings highlight how much more we still have to learn about tropical carbon-climate interactions, and underscore the importance of continued monitoring of the atmosphere in tropical regions."

The findings also show that carbon emissions from the Amazon have tremendous capability to affect global climate, said John Miller, a study co-author and CIRES researcher at the time of the analysis and now a scientist at the National Oceanic and Atmospheric Administration.

"Better understanding of NBE in the Amazon will continue to help scientists resolve major unknowns in future climate projections," Miller said, "namely how tropical forest sensitivities to future changes in temperature, rainfall and drought patterns may accelerate global climate change."

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