The 2010 Amazon Drought

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Several global circulation models (GCMs) project an increase in the frequency and severity of drought events affecting the Amazon region as a consequence of anthropogenic greenhouse gas emissions (*1*). The proximate cause is twofold, increasing Pacific sea surface temperatures (SSTs), which may intensify El Niño Southern Oscillation events and associated periodic Amazon droughts, and an increase in the frequency of historically rarer droughts associated with high Atlantic SSTs and northwest displacement of the intertropical convergence zone (*1*, *2*). Such droughts may lead to a loss of some Amazon forests, which would accelerate climate change (*3*). In 2005, a major Atlantic SST–associated drought occurred, identified as a 1-in-100-year event (*2*). Here, we report on a second drought in 2010, when Atlantic SSTs were again high.

We calculated standardized anomalies from a decade of satellite-derived dry-season rainfall data (Tropical Rainfall Measuring Mission, 0.25° resolution) across 5.3 million km^2 of Amazonia for 2010 and 2005 (*4*). We used identical reference periods to allow a strict comparison of both drought events (*4*). On the basis of this index, the 2010 drought was more spatially extensive than the 2005 drought (rainfall anomalies ≤ -1 SD over 3.0 million km^2 and 1.9 million km^2 in 2010 and 2005, respectively; Fig. 1 and fig. S1). Because dry-season anomalies do not necessarily correlate with water stress for forest trees, we also calculated the maximum climatological water deficit (MCWD) for each year as the most negative cumulative value of water input minus estimated forest evapotranspiration (*5*). This measure of drought intensity correlates with Amazon forest tree mortality (*6*). In 2010, the difference in MCWD from the decadal mean that significantly increases tree mortality (≤ -25 mm) spanned 3.2 million km^2, compared with 2.5 million km^2 in 2005. The 2010 drought had three identifiable epicenters in southwestern Amazonia, north-central Bolivia, and Brazil's Mato Grosso state. In 2005 only a single southwestern Amazonia epicenter was detectable (fig. S1).

The relationship between the change in MCWD and changes in aboveground carbon storage derived from forest inventory plots affected by the 2005 drought (*6*) provides a first approximation of the biomass carbon impact of the 2010 event. Summing the change in carbon storage predicted by the 2010 MCWD difference across Amazonia gives a total impact of 2.2 Pg C [95% confidence intervals (CI) 1.2 and 3.4], compared with 1.6 Pg C for the 2005 event (CI 0.8, 2.6). These values are relative to the predrought carbon uptake and represent the sum of (*1*) the temporary cessation of biomass increases over the 2-year drought measurement interval (~0.8 Pg C) and (*2*) biomass lost via tree mortality, a committed carbon flux from decomposition over several years (~1.4 Pg C after the 2010 drought). In most years, these forests are a carbon sink; drought reverses this sink.

Considerable uncertainty remains, related to the soil characteristics within the epicenters of the 2010 drought, which could moderate or exacerbate climatic drying, whether a second drought will kill more trees (i.e., those damaged by the initial drought) or fewer (i.e., if most drought-susceptible trees are already dead), and whether drought slows soil respiration (temporarily offsetting the biomass carbon source). New field measurements will be required to refine our initial estimates.

The two recent Amazon droughts demonstrate a mechanism by which remaining intact tropical forests of South America can shift from buffering the increase in atmospheric carbon dioxide to accelerating it. Indeed, two major droughts in a decade may largely offset the net gains of ~0.4 Pg C year^{-1} in intact Amazon forest aboveground biomass in nondrought years. Thus, repeated droughts may have important decadal-scale impacts on the global carbon cycle.

Droughts co-occur with peaks of fire activity (*5*). Such interactions among climatic changes, human actions, and forest responses represent potential positive feedbacks that could lead to widespread Amazon forest degradation or loss (*7*). The significance of these processes will depend on the growth response of tropical trees to increases in atmospheric carbon dioxide concentration, fire management, and deforestation trends (*3*, *7*). Nevertheless, any shift to drier conditions would favor drought-adapted species, and drier forests store less carbon (*8*). If drought events continue, the era of intact Amazon forests buffering the increase in atmospheric carbon dioxide may have passed.

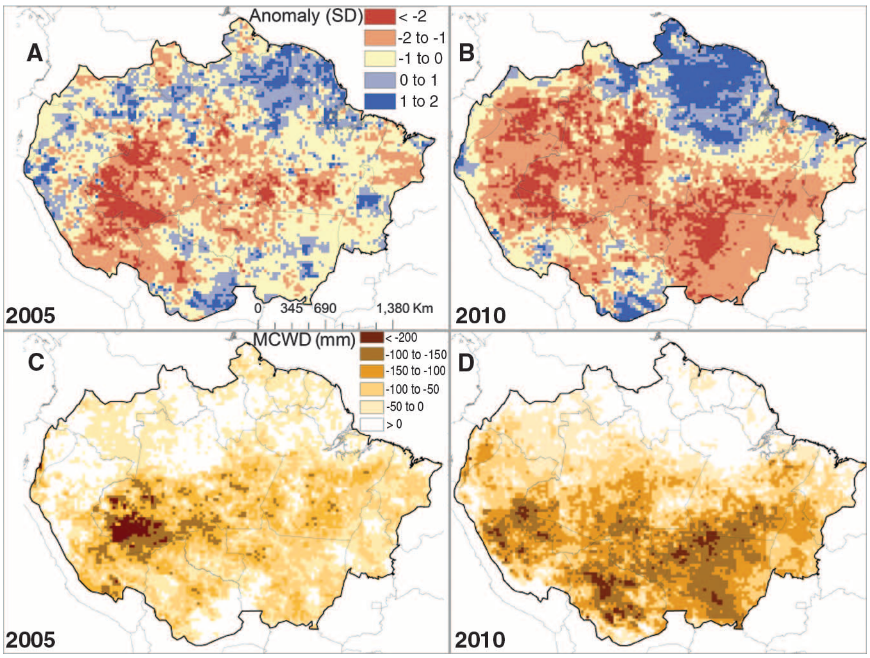

Fig. 1. (**A** and **B**) Satellite-derived standardized anomalies for dry-season rainfall for the two most extensive droughts of the 21st century in Amazonia. (**C** and **D**) The difference in the 12-month (October to September) MCWD from the decadal mean (excluding 2005 and 2010), a measure of drought intensity that correlates with tree mortality. (A) and (C) show the 2005 drought; (B) and (D) show the 2010 drought.

References and Notes

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Supporting Online Material

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Materials and Methods
Fig. S1
References

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