Earth Gauge
A National Environmental Education Foundation Program

Climate Change and the Amazon

THE AMAZON BASIN: AN INTRODUCTION

The Amazon Basin is considered a major “flywheel” of Earth’s climate, due to its size (1.7 billion acres), the biomass and soil carbon reserves it holds, and the climate/vegetation feedbacks that can initiate changes in global circulation.

Changes in vegetation cover in the Amazon have been shown to alter rainfall patterns in places as far away as the Arabian Peninsula in the Middle East. The Amazon Basin accounts for between 15 and 20 percent of Earth’s freshwater flow, sending over one trillion cubic meters of water into the Atlantic Ocean annually. The basin hosts half of the world’s remaining tropical rainforest and features some of the most concentrated biodiversity, with this diversity peaking in the Andean foothills in the western part of the basin. About 25 percent of the world’s species can be found here. About 1.4 billion acres of the basin are covered with tropical rainforest, with the northern and southern fringes (which tend to have longer and more intense dry seasons, and greater interannual rainfall variability) being covered with semi-deciduous forests (trees are dormant during the dry season) or savanna. As the planet’s climate fluctuates, the proportion of the basin dominated by these different types of vegetation fluctuates as well.

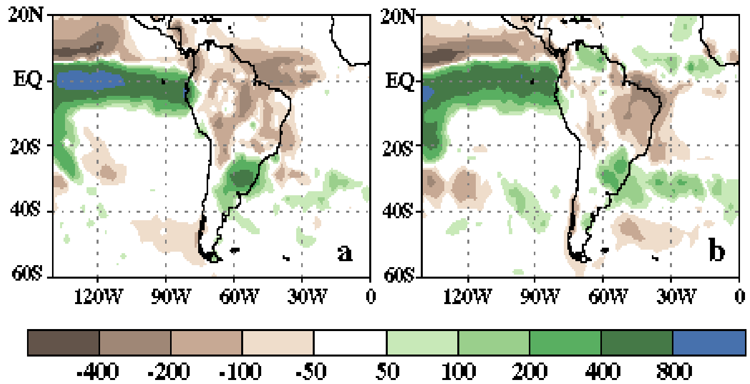
The area within the black line is the Amazon Basin. Notice the transition from the darker rainforest to the lighter savanna/grassland areas on the Basin’s southern fringes. Image Courtesy of NASA.

THE AMAZON BASIN: A BRIEF HISTORY

The Amazon Basin has been in the Earth’s tropics for about 100 million years. As South America and Africa separated at the end of the Cretaceous period (about 65 million years ago), the tropics became much wetter. By about 55 million years ago, most of the major flowering plant families that exist in the Amazon today had established themselves there. Since then, climate fluctuations caused by i) tectonic activity such as changes in atmospheric composition due to volcanic eruptions and ii) cycles in Earth’s orbit and rotational axis, which affect the amount of sunlight the planet receives, have caused fluctuations in the extent of rainforest cover. The world’s rainforests exist in frost-free regions where at least 6.5 feet of rain fall each year and dry seasons (seasons when less than four inches of rain fall each month) are no longer than four months. When the planet cools, as it did during the Oligocene epoch (34-23 million years ago) and the Pleistocene epoch (1.8 million to 10,000 years ago), the tropics are drier overall, dry seasons are longer, and carbon dioxide (CO_2) levels are relatively low. These factors favor the survival of grasses over trees. During the last glacial maximum (21,000 years ago) the extent of the Amazon Basin that was covered with forest was about 20 percent less than it is today, with this 20 percent being replaced with savanna and grassland ecosystems. At least part of the 80 percent of the remaining forested area was covered by semi-deciduous forests (forests that are dormant during the dry season). Most of the Amazon has at least one dry season. The western Amazon has less seasonality and generally receives abundant rainfall even in dry periods, due to the precipitation the Andes Mountains generate as they force moist air blowing in from the Atlantic to rise and precipitate. This makes the western Amazon less susceptible to climate-related vegetation changes. Variations in the Earth’s precession (the movement of the rotational axis) influence seasonality in the tropics and create 11,000-year cycles when annual rainfall decreases and dry seasons extend rapidly. This causes regular shifts from rainforest to savanna and then from savanna to rainforest.

CONTROLS OVER AMAZONIAN RAINFALL
While the Amazon Basin is "ever-warm," it is not "ever-wet." Rainfall variability in the Amazon Basin is controlled by three key variables: northern tropical Atlantic sea-surface temperatures (SSTs); the El Niño-Southern Oscillation (ENSO); and the Tropical Multidecadal Mode (TMM).

Northern Tropical Atlantic SSTs: The seasonality in Amazon rainfall is directly controlled by the seasonal north-south migration of the intertropical convergence zone (ITCZ), or the permanent low-pressure zone that leads to tropical Hadley cell circulation. The ITCZ "lags" behind the sub-solar point (the point of maximum solar intensity) because of the different heat budgets between the land and the ocean. Without this "lag," the eastern equatorial Amazon would have a rainy season during the austral spring as it is directly under the sub-solar point (convective rainfall is maximized there). Instead, the northward displacement of the ITCZ causes an increase in descending air over the region, creating a high pressure cell that drives away rainfall. Also, anomalously warm temperatures in the tropical North Atlantic weaken the trade winds that bring moisture into the southern Amazon during the summer, which can cause drought there. This was the mechanism behind the 2005 drought.



The percentage difference from average rainfall levels during the strong 1997-1998 El Niño event. The December, January, and February mean is on the left, and the March, April, May mean is on the right. Image Courtesy of NOAA: Climate Prediction Center.

ENSO: During El Niño phases, the increased strength of the rising air over the warm water that collects off the west coast of South America leads to an increase in the descending air on the east side of the Andes and higher-than-average atmospheric pressure in the eastern Amazon, which reduces precipitation there. The ENSO cycle explains between 22-24 percent of interannual rainfall variability in the tropics.

TMM: The TMM is the dominant mode of variability in the global tropics, accounting for between 50-60 percent of observed variability in tropical rainfall. During positive phases, which were seen during the 1980's and 1990's, convection in the Amazon Basin is enhanced, resulting in above average precipitation. During negative phases, as were seen during the 1950's and 1960's, global circulation favors more descending air over the Amazon, and diminished convection and rainfall.

RECENT CLIMATE TRENDS

The Canopy of the Brazilian Amazon. NASA

The average temperature of the world's tropical forests has been increasing at a rate of 0.47 degrees Fahrenheit per decade since the mid-1970's. During this period, the southeast Amazon (considered to be the region most sensitive to climate fluctuations) warmed at a rate of 0.72 degrees Fahrenheit per decade. The more stable northwest Amazon warmed at a rate of 0.27 degrees Fahrenheit per decade. Annual precipitation trends over the last four decades of the 20th century were almost non-existent, with only the southeast Amazon receiving noticeably less rainfall (about 1.5 percent per decade less). There has, however, been a slight negative trend in dry season river discharge since the 1970's, implying that dry seasons are more intense than they were several decades ago.

Higher atmospheric CO_2 levels, which have increased from about 280 parts per million in pre-industrial times to about 386 parts per million today, have made the Amazon more "dynamic." Increases in atmospheric CO_2 can promote photosynthesis, especially in trees and herbs. Analysis conducted on Amazonian forest plots since the 1970's show that trees are growing more stems and growing their trunks faster. As a result, the rate at which each 2.5 acre plot in the Amazon absorbs carbon is growing by half ton each year. This change is favoring some types of species over others. For example, lianas, or climbing vines, are becoming increasingly dominant, and are expanding their average area of leaf cover (which is already around 40 percent of the total leaf cover in the Amazon) at a rate of 1.7-4.6 percent each year.

Sources

Bush, MB et al. "Fire, climate change and biodiversity in Amazonia: a Late-Holocene perspective." Philosophical Transactions of the Royal Society of London B 363 (2008): 1795-1802.

Chagnon, FJF and Bras, RL. "Contemporary climate change in the Amazon." Geophysical Research Letters 32 (2005): L13703.

Chelliah, M and Bell, GD. "Tropical Multidecadal and Interannual Climate Variability in the NCEP-NCAR Reanalysis." Journal of Climate 17 (2004): 1777-1803.

Fu, R et al. "How do Tropical Sea Surface Temperatures Influence the Seasonal Distribution of Precipitation in the Equatorial Amazon?" Journal of Climate 14 (2001): 4003-4026.

Grimm, AM. "The El Niño Impact on the Summer Monsoon in Brazil: Regional Processes versus Remote Influences." Journal of Climate 16 (2003): 263-280.

Harris, PP et al. "Amazon Basin climate under global warming: the role of the sea surface temperature." Philosophical Transactions of the Royal Society of London B 363 (2008): 1753-1759.

Hooghiemstra, H. "The Dynamic Rainforest Ecosystem on Geologic, Quaternary and Human Time Scales." Understanding and capturing the multiples values of tropical forest. Proceedings of the International Seminar on Valuation and Innovative Financing Mechanisms in support of Conservation and sustainable management of tropical forest. Ed. P. Verweij. Tropenbos International: Wageningen, the Netherlands, 2001. 7-20.

Lewis, SL. "Tropical forests and the changing earth system." Philosophical Transactions of the Royal Society 361 (2006): 195-210.

Liebmann, B and Marengo, JA. "Interannual Variability of the Rainy Season and Rainfall in the Brazilian Amazon Basin." Journal of Climate 14 (2001): 4308-4318.

Malhi, Y and Wright, J. "Spatial patterns and recent trends in the climate of tropical rainforest regions." Philosophical Transactions of the Royal Society of London 359 (2004): 311-329.

Malhi, T and Phillips, OL. "Tropical forests and global atmospheric change: a synthesis." Philosophical Transactions of the Royal Society of London 359 (2004): 549-555.

Marengo, JA et al. "Hydro-climatic and ecological behaviour of the drought of Amazonia in 2005." Philosophical Transactions of the Royal Society of London B 363 (2008): 1773-1778.

Maslin, M et al. "New views on an old forest: assessing the longevity, resilience and future of the Amazon rainforest." Transactions of the Institute of British Geographers 30 (2005): 477-499.

Phillips, OL et al. "The changing Amazon forest." Philosophical Transactions of the Royal Society of London 363 (2008): 1819-1827.