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Changing rainfall patterns over the Amazon rainforest

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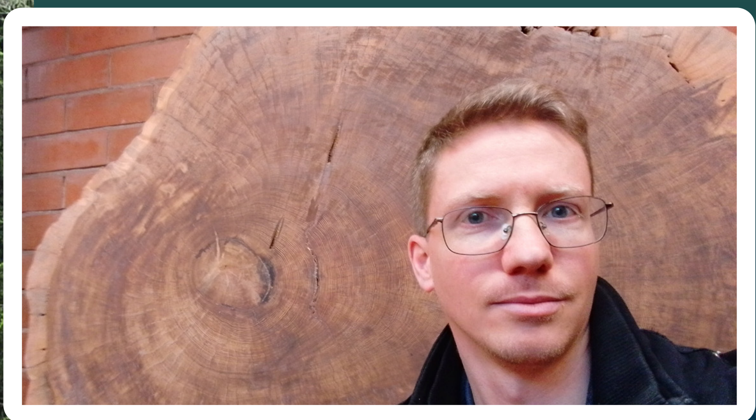
I have always been interested in tropical forests and I am now studying these ecosystems as a climate scientist. You have probably already heard about climate change and increasing temperatures in the news or at school. But what you have heard is not the complete story; climate change also leads to changes in rainfall patterns, which can result in droughts or floods in tropical forests. I find it exciting that we can learn about the past climate from tree rings. In this article, I will take you on a journey to the Amazon forest and share how we can use tree rings to improve projections of the future climate.



Gerbrand Koren in front of a tree cross-section with visible tree rings in the Ramon Margalef building (Barcelona).

Photo by Conscious Design, Unsplash

The Amazon in a changing climate

The Amazon forest is the largest tropical forest on our planet. It is home to many different plant and animal species that live together in this ecosystem. The trees and other plants in the Amazon forest contain a lot of carbon. All this carbon was once in the form of CO_2 in the atmosphere and was then taken up via photosynthesis. Photosynthesis can be measured from space using satellite proxies. In the map in Figure 1, you can see the highly productive tropical forest regions.

Because of climate change, the conditions in the Amazon are changing. We are seeing more floods and droughts in the region. You can also detect more extreme dry and wet periods in river-flow measurements in Figure 1. The maximum monthly flow rate for each year shows an increase, whereas the minimum monthly flow rate shows a decreasing trend for the region.

During droughts, fires can ignite more easily, and the fires also tend to be more intense. Through these fires, the carbon that was stored in the plants is released back into the atmosphere. Dry conditions can also reduce the photosynthetic uptake of carbon. This happened in the Amazon during the severe 2015/2016 and 2023/24 droughts. The increased fires and reduction of photosynthesis during these droughts in the Amazon forest led to further increases of CO_2 concentrations in the atmosphere.

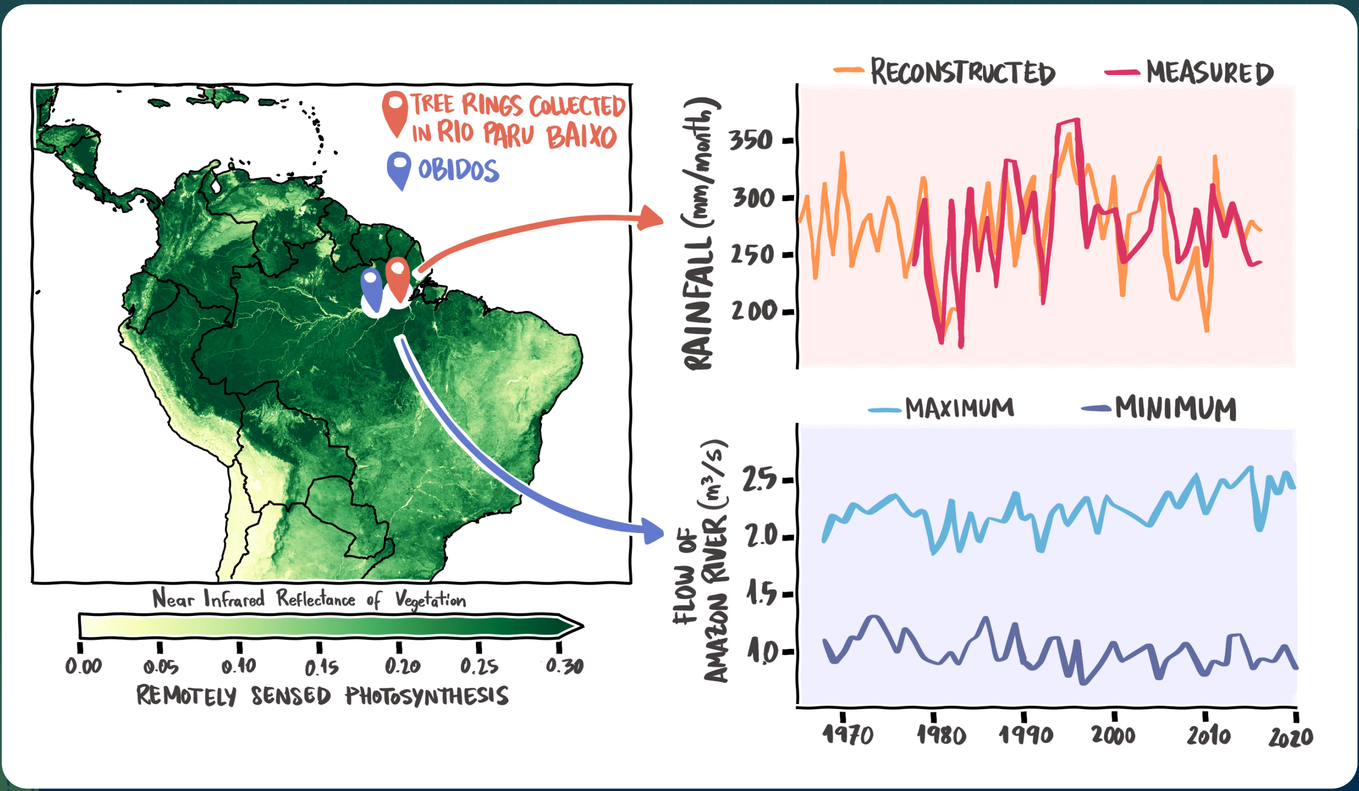


Figure 1:
Measurements of hydrology and vegetation activity in the Amazon forest. Left: Map of a remotely sensed photosynthesis proxy *(Data source: MODIS).*

Top right: Precipitation during the wet season (February to July) for the eastern Amazon, inferred from tree-ring growth ("reconstructed", orange line) and measured precipitation ("measured", red line) *(Data source: Granato-Souza et al. 2020).*

Bottom right: River-flow measurements from the Óbidos station along the Amazon river *(Data source: National Water and Sanitation Agency, ANA, Brazil).*

Tree-ring measurements from the Amazon

The width of tree rings tells us how much a tree has grown in a year. This also gives us information about the climate during those years. For instance, tree rings can be used to estimate how much the amount of rainfall varied from year to year. Figure 1 shows a comparison between precipitation reconstructed from tree-ring data and direct measurements made with instruments. The agreement between data sets for the overlapping years suggests that the reconstructed precipitation from tree rings, which covers ~250 years (not shown), is a reliable indicator of past precipitation.

Besides the width of the tree ring, we can also measure its isotopic composition. Measurements of oxygen isotopes in tree rings from the Amazon have indicated a decrease in dry season precipitation. This agrees with the negative trend in river flow rate for the driest months shown in figure 1.

However, isotopes in tree rings do not only record past rainfall, but can also reveal how vegetation responded to this changing rainfall. A strategy of vegetation to reduce its water loss during droughts is to close openings ("stomata") in their leaves. This can result in higher water-use efficiency (amount of carbon fixed divided by the amount of water lost via transpiration). This change can be detected from the ratio of carbon-13 and carbon-12 isotopes in the tree rings.

Figure 2: Conceptual overview of the main processes described in this article. The changing environmental conditions result in impacts on vegetation that are recorded in tree rings which can improve climate models, and therefore, the reliability of their projections. This illustrates how measurements of the past can improve our predictions for the future.

Improving vegetation models

What will the climate be like in 2050, or 2100? And will the Amazon forest still exist as we know it today? To answer these questions, researchers use climate models. These models are based on mathematical equations that describe the complex processes of the climate system. You can imagine that the more realistic these models are, the more reliable their output is. That is why a lot of time and energy is spent on further improving these climate models.

The tree-ring width and the isotopic (carbon and oxygen) composition of tree rings contain information about the past climate and the response of vegetation. Untangling this information is difficult, but will ultimately provide us with a better understanding of plant behavior. If we know how plants have responded to a changing climate in the past, we can use this information to improve vegetation models or climate models as summarized in figure 2, leading to more reliable climate projections.

Beyond tree rings

Besides tree rings, there are other records that can inform us on climate and vegetation, summarized in figure 3. Combining these different methods helps us to understand past climate changes and improve projections for future climate.

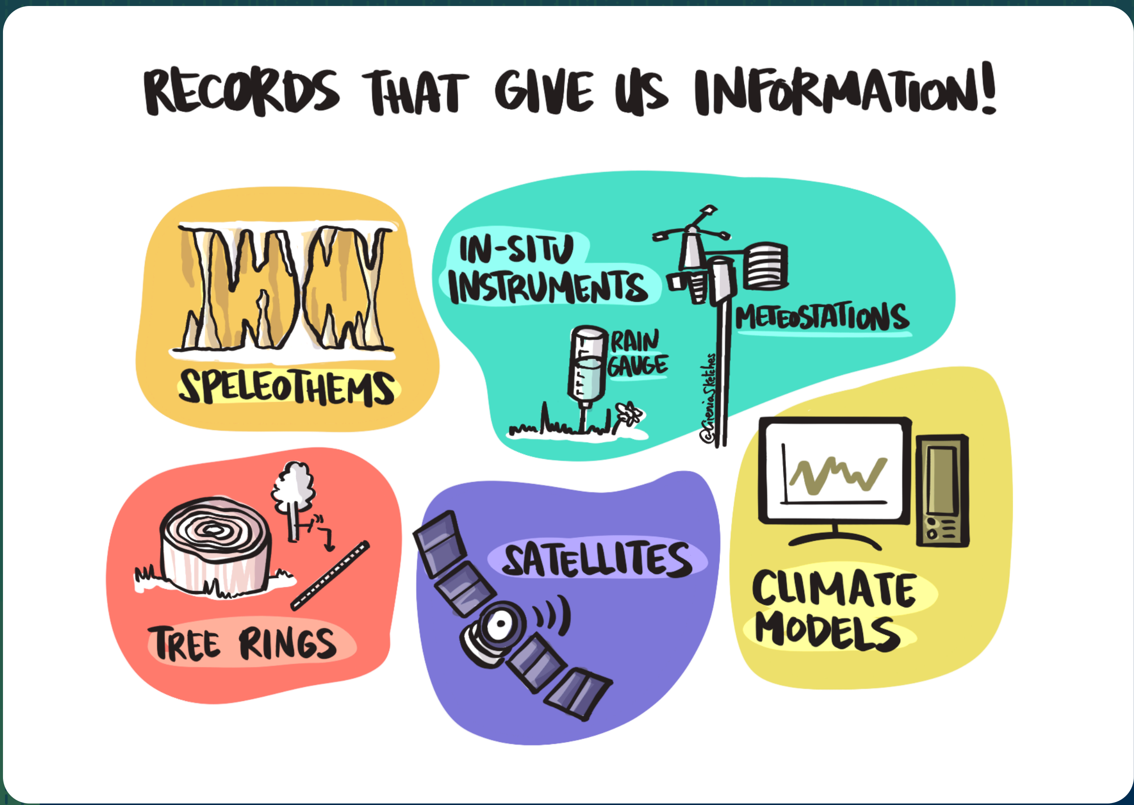


Figure 3: Overview of paleorecords, measurement instruments and models.

Further reading

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