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A TOWERING EXPERIMENT

An ambitious project to track greenhouse gases from a perch high above the Amazon forest will provide crucial data — but only if scientists can get it built.

BY JEFF TOLLEFSON

Meinrat Andreae walked into a clearing where a fallen paricá tree had torn a hole in the canopy of the rainforest. He recorded the location on his Global Positioning System device and then paused to marvel at a blue Morpho butterfly that fluttered past. In place of the fallen giant, Andreae and a team of scientists from Germany and Brazil will soon plant more than 100 tonnes of steel that will dwarf even the largest trees, offering scientists an unprecedented perch above the rolling hills of the central Brazilian Amazon.

Once complete, the 320-metre-high structure — roughly as tall as the Eiffel Tower — will help to plug a vast gap in terrestrial greenhouse-gas monitoring. Europe and the United States have dozens of tall towers, and Germany's Max Planck Society erected a 300-metre facility in Siberia several years ago. But the Amazonian Tall Tower Observatory (ATTO) project, consisting of one giant and several smaller towers, would be unique in the tropics and Southern Hemisphere. More importantly, says Andreae, an atmospheric chemist at the Max Planck Institute for Chemistry in Mainz, Germany, it would provide the first long-term monitoring capacity in an ecosystem that processes more carbon than anywhere else on Earth.

"It's a beautiful project," comments Carlos Nobre, a climate modeller at the National Institute for Space Research (INPE) in São José dos Campos, Brazil.

Scientists already use smaller flux towers to measure how much carbon dioxide gets sucked up and released every day by small patches of forest. Among the trees, CO_2 levels can drop to 360 parts per million (p.p.m.) during the day owing to photosynthesis, and rise to 500–600 p.p.m. at night because of respiration. But those swings weaken higher up, where air from the forest mixes with trade winds from the Atlantic Ocean, and CO_2 levels remain much closer to the global average of about 387 p.p.m. With ATTO sticking far above the 35-metre-high forest canopy, the tower will provide large-scale measurements that reflect conditions across much of the eastern Amazon, says Nobre. "We are going to be able to say significant things about 50% of the Amazon Basin."

Jointly funded by Brazil and Germany, the tower will monitor air blowing from an elongated area that extends 850 kilometres towards the coast (see map). The data will help scientists to quantify how much CO_2 flows through the forest and how that flux changes year by year, which is crucial to understanding and projecting the effects of global warming. Without that kind of long view of the forest, researchers can't tell for certain whether the Amazon is sponging up CO_2 overall, or releasing it into the atmosphere.

The budget for the study, including initial operations, is €8.4 million (US$10.9 million). The project includes several towers that will monitor air chemistry and interactions between soil, forest and sky, making

the facility one of the most sophisticated atmospheric-monitoring stations in the world. But first the team needs to start building the towers.

Andreae, one of the world's leading experts in atmospheric aerosols, developed a hankering for the tropics early in his career. Over the years, he has witnessed a shoot out in the Amazon and got lost in a plane above the Congo Basin. But ATTO represents one of his most ambitious efforts yet.

The project grew out of governmental meetings in 2007, and has encountered considerable red tape and logistical difficulties. Andreae says he often feels more like a real-estate developer than a scientist. "The logistics, the infrastructure and the politics are more foreign and difficult terrain for us," he says.

Pieter Tans at the National Oceanic and Atmospheric Administration in Boulder, Colorado, who runs the US carbon-monitoring system, says that building a giant monitoring tower in the middle of the jungle "is an impressive undertaking". Because data from this region are so scarce, he says, the tower project "could be very significant".

The first challenge for the German and Brazilian researchers was to choose a site, and they settled on a plateau 155 kilometres upwind of Manaus, a sprawling metropolis of almost 2 million people in the centre of the Amazon. At that distance, the tower would be far enough from the city's pollution to avoid contamination but close enough to allow relatively easy access. Brazilian researchers hope that the facility will help to improve local science by serving as a base camp for many types of study. "We need to have the capacity to do this science here in the Amazon," says Antônio Manzi, a researcher at the National Institute of Amazonian Research in Manaus.

On a visit in August, Andreae and his team drove north and then east from Manaus, then took boats down the Uatumã River for two hours before making a final trek nine kilometres inland to a base camp. From there, they hiked another five kilometres up a steep dirt road to the plateau, where the towers would be located.

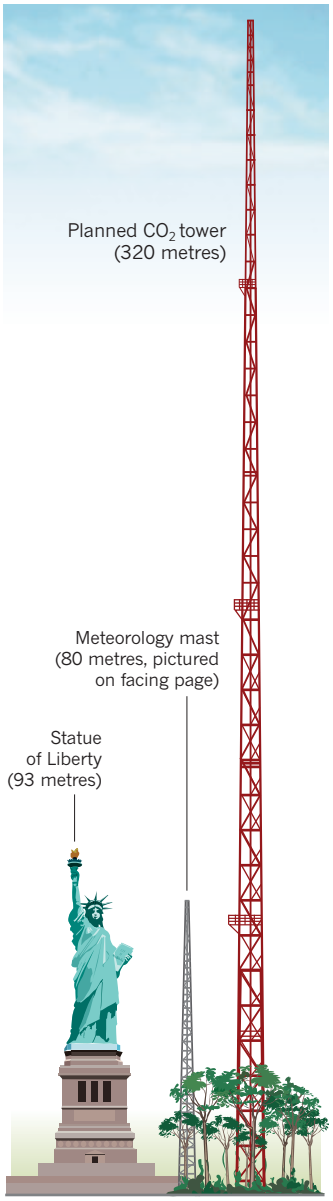
Several problems have slowed down construction. The scientists have been waiting for months for the state of Amazonas to improve the roads for heavy equipment. Because the plan to run a power line to the site proved too expensive, they are now planning to build a diesel-fired generator near the river and run a power line up to the towers, also a costly scheme. Similarly, high cost estimates from local companies for the towers themselves have Andreae and his team thinking about buying the entire set-up in Europe and then shipping it to Brazil.

As he toured the study site on the plateau, Andreae encountered another problem. The team had already installed an 80-metre-tall tower to monitor local meteorology (see 'The height of research') but the crew cut down one tree too many, knocking down a second and opening up a huge hole in the canopy. The opening would heat the soil and promote updrafts, rendering the tower's readings meaningless, explains Andreae. The tower would have to be moved.

"It's a sort of fog-of-war situation," Andreae says. "Shit happens."

But the August trip also brought some positive news. "It looks as if there will be a road constructed during this dry season," says Jürgen Kesselmeier, a plant physiologist at the Max Planck Institute for Chemistry who heads the ATTO project as part of Andreae's team.

The main ATTO tower will measure CO_2, methane and other atmospheric constituents; a series of four smaller satellite towers will be used to track local air currents. All the data will be plugged into a computer model that calculates atmospheric trends in an effort to determine where the gases come from and how the forest influences them. The team hopes to complete construction of the towers by next year.



THE HEIGHT OF RESEARCH

At 320 metres, the Amazonian tower will stand tall enough to monitor greenhouse gases over a vast section of the Amazon forest. That sample area, shown in yellow (below), shifts with the prevailing winds throughout the year.

TOO MUCH DIVERSITY

Studies in small plots[1,2] show that tropical forests are accumulating CO_2, and these data have been used to suggest that the entire Amazon is acting as a sink for the greenhouse gas. But such local studies may not tell the full story because the Amazon is a patchwork of myriad ecosystems. The path from the river to the site crossed clay bogs and a desert-like area dominated by shrubs, lichens and white sands before reaching the terra-firma forest of the plateau. Such diversity makes it hard to extrapolate local measurements to the whole forest.

Local measurements also miss some crucial processes. Recent work by Peter Raymond and David Butman, biogeochemists at Yale University in New Haven, Connecticut, presented at an American Geophysical Union (AGU) meeting last month in Foz do Iguaçu, Brazil, suggests that some carbon escapes from the forest through rivers and streams. And extreme events — such as the 2005 drought or the violent storm that knocked down more than half a billion trees the same year — could wipe out decades' worth of local carbon accumulation.

Initial results from a 2008–09 aircraft campaign conducted by Andreae in conjunction with a team of scientists in the United States and Brazil suggest that the Amazon Basin is more or less carbon neutral. But those data, presented at the AGU meeting, are just a snapshot. Only a tall tower can provide detailed measurements of a large area of forest over time.

Nobre is looking forward to analysing the CO_2 concentrations over the course of a year. If CO_2 levels at the tower are consistently lower than known concentrations in ocean air that gets blown inland, then the forest is taking up CO_2 as the air passes through.

Further down the line, Andreae wants to know how the situation will change. Could extra CO_2 stimulate forest growth? Will the forest recede in a warmer climate, pumping more CO_2 into the atmosphere? What about the effects of deforestation and development? "What we want to see over this 10- to 20- to 30-year timescale is if there is a change in the carbon greenhouse-gas budget," says Andreae, who is 61 and recognizes that he will hand over the reins long before answering some of these questions. "This is a long-term effort." ■

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1. Baker, T. R. *et al. Phil. Trans. R. Soc. Lond. B* **359,** 353–365 (2004).
2. Lewis, S. L. *et al. Nature* **457,** 1003–1006 (2009).