

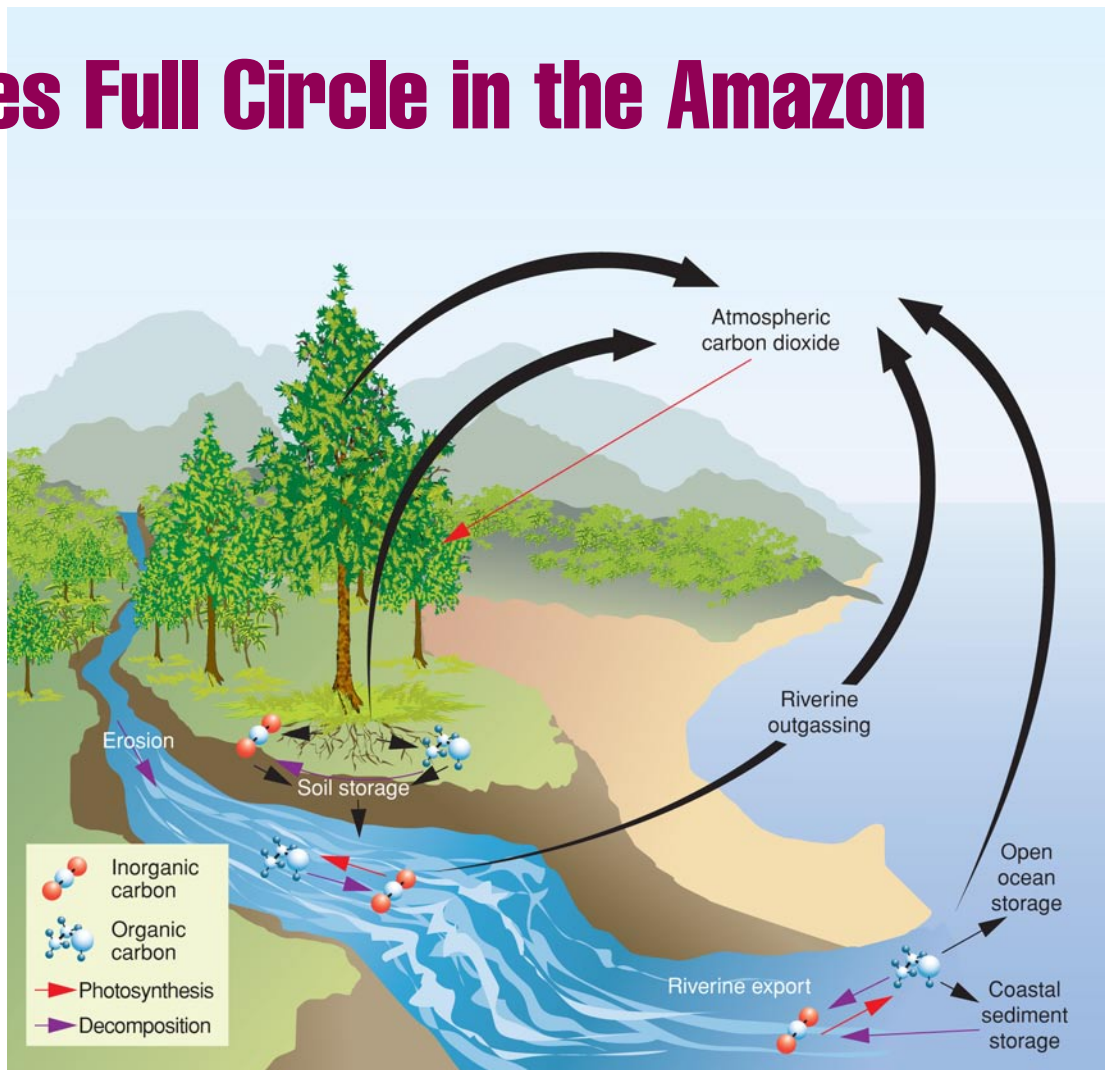
# Carbon Goes Full Circle in the Amazon

**I**n studying Earth’s carbon cycle—the exchange of carbon between the planet’s land, atmosphere, and oceans—scientists are trying to understand the role played by huge tropical rainforests such as the Amazon River basin. In particular, they want to determine how long an ecosystem stores atmospheric carbon dioxide in its plants, soils, and rivers.

Many scientists hope that such ecosystems might sequester this greenhouse gas, produced in excess by human activities, for decades or even centuries. However, results from a collaboration involving researchers from the University of Washington (UW), the Stroud Water Research Center, Livermore’s Center for Accelerator Mass Spectrometry (CAMS), and the University of São Paulo, Brazil, indicate that carbon cycling in the Amazon River basin may be much faster than predicted. Measurements of river water samples showed that the carbon had been stored in the surrounding landscape of the 6.2-million-square-kilometer basin for only about 5 years before being returned to the atmosphere as carbon dioxide.

## What Goes around Comes Around

The term carbon cycle describes the complex processes carbon undergoes as it is transformed from organic carbon—the form found in living organisms such as plants and trees—to inorganic carbon and back again. Most of the carbon in rivers originates as atmospheric carbon dioxide and either cycles back to the atmosphere or settles in sediments of the coastal ocean where it is eventually buried.



In Earth’s carbon cycle, carbon is exchanged between the planet’s land, atmosphere, and oceans. In the process, it is transformed from inorganic carbon to organic carbon and back again.

For example, in the Amazon basin, tropical forests “breathe in” carbon dioxide from the atmosphere and during photosynthesis transform this inorganic carbon into organic carbon. As plants die and decay, they carry carbon into the soil. Decomposition then begins to transform organic carbon back again into inorganic carbon. Rain and groundwater transport carbon from soil, decomposing woody debris, leaf litter, and other organic matter in the waterways, where it is digested by microorganisms, insects, and fish. The carbon dioxide they generate and the dissolved inorganic carbon carried into the rivers from on land then return to the atmosphere.

Determining the sources of carbon in a river, how long it was on land, and when it changed forms are difficult problems because

so many plants and soils contribute to the carbon cycle. Previous measurements in the downstream section of the Amazon basin indicated that the carbon there was 40 to more than 1,000 years old. Researchers reasoned that tropical forest regions might sequester carbon for decades or even centuries, thus serving as a potential site for the long-term storage of atmospheric carbon dioxide.

According to Livermore scientist Tom Brown, who worked on the carbon-aging project, such earlier estimates had not included the amount of carbon dioxide returned to the atmosphere by riverine outgassing. Characterizing this carbon dioxide—for example, determining its average age—is an important step if scientists are to accurately determine the amount of carbon being exchanged between the biosphere and the atmosphere in the Amazon River basin.

### Taking Stock of Carbon

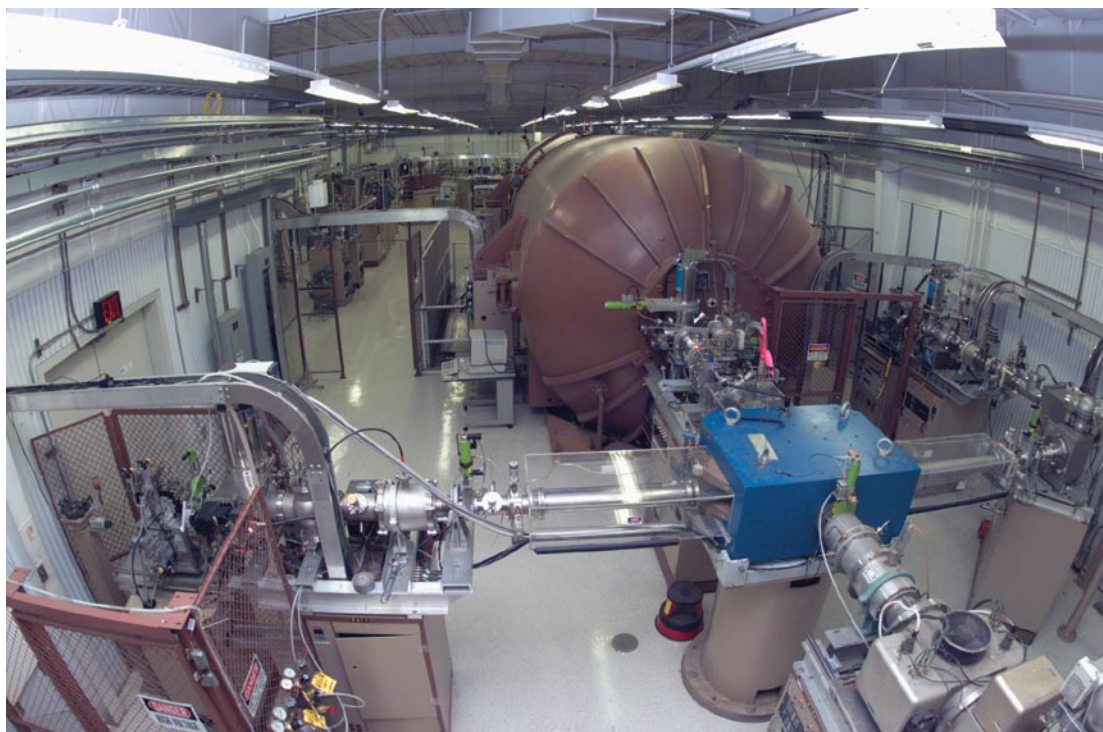
For the carbon-aging study, the project team, led by UW graduate students Emilio Mayorga and Anthony Aufdenkampe, used samples from the Carbon in the Amazon River Experiment (CAMREX), a long-term collaboration to examine the processes that control the distribution and transformation of water and bioactive elements such as carbon, nitrogen, and oxygen in the Amazon River system. With funding from Livermore's University Relations Program and CAMS, Mayorga and Aufdenkampe worked with Brown and Laboratory postdoctoral researcher Carrie Masiello (now an assistant professor at

Rice University) to analyze the river water samples. Using Livermore's accelerator mass spectrometer, they measured the radiocarbon, or carbon-14, in over 150 samples—more than double the number of existing river radiocarbon measurements from that area. According to Mayorga, these measurements represent the largest and most comprehensive radiocarbon data set to date for any river system in the world.

Carbon-14, which has a radioactive half-life of 5,730 years, can be used to determine the rate of carbon exchange between the atmosphere and the oceans and land. Carbon-14 is produced naturally in the atmosphere when cosmic-ray neutrons hit nitrogen-14. The concentration of carbon-14 in atmospheric carbon dioxide remained fairly constant for thousands of years. However, between 1954 and 1963, when atmospheric nuclear tests were conducted, the carbon-14 in the atmosphere doubled. After the tests were halted, the elevated concentrations began to decrease as atmospheric carbon dioxide—which includes the elevated carbon-14 fraction—exchanged carbon into other not-yet-elevated carbon reservoirs in the oceans and on land.

This infiltration of nuclear-test carbon-14 into carbon reservoirs provides scientists with valuable information on carbon exchange. Once they know the rate at which nuclear-testing carbon-14 moves through the carbon cycle, scientists can determine the rate at which human-induced carbon dioxide is absorbed and released, because the same physical rules govern the transfer processes.

The 10-megavolt spectrometer at Livermore's Center for Accelerator Mass Spectrometry is one of the most precise and high-throughput spectrometers in the world.



According to Brown, the CAMS spectrometer is one of only a few in the world that can measure radiocarbon with the precision and throughput required for a project such as the carbon-aging study. In accelerator mass spectrometry, negative ions generated from an ion source are accelerated across a field of millions of volts. The accelerated ions smash through a thin carbon foil that destroys all molecular species and strips the ions of many electrons. After a second stage of acceleration, the ions pass through a high-energy mass spectrometer and finally slow to a stop in a gas ionization detector. The signals obtained from the detector allow scientists to distinguish and count individual carbon-14 ions and determine the ratio of those ions to ions of other carbon isotopes. (See *S&TR*, July/August 2000, pp. 14–19.)

Because of its sensitivity, the CAMS spectrometer allows scientists to measure concentrations of isotopes in samples less than 1 milligram and the relative abundance of isotopes at very low levels. It can, for example, find one carbon-14 atom among a thousand billion ( $10^{15}$ ) other carbon atoms.

In the Amazon basin study, the project team determined a sample's age by comparing its carbon-14 concentration to atmospheric concentrations over the last 40 years. The team's comparisons showed that in most of the Amazon samples the carbon-14 was only slightly higher than the atmospheric concentration at the time the samples were taken. That is, the level of carbon-14 in most Amazon samples corresponded to the atmospheric level about 5 years prior to the sampling.

To clarify the data on carbon aging, the project team also analyzed the carbon-13 abundance in the Amazon samples. The basin's rivers receive significant drainage from high-elevation areas, which are formed of very old carbonate rock. The amount of dissolved carbon dioxide from carbonate rock may affect the measurements because the carbon-14 concentration in these old formations is essentially zero.

Carbon-13 is a stable isotope, and its concentration in a sample is not affected by radioactive decay. Other processes,

however, influence the carbon-13 concentration in a sample during its formation. For instance, carbonate rocks generally have carbon-13 concentrations about 25 parts per thousand higher than trees, and most grass plants have carbon-13 concentrations about 10 parts per thousand higher than trees. By comparing the abundance of carbon-14 and carbon-13 in the Amazon basin samples, the project team could account for these influences on the apparent carbon-14 ages of affected samples. These measurements indicated that carbon from the carbonate rock was flushed from the water into the atmosphere as it flowed downstream. By the time the water reached the lowlands, most of the carbon had returned to the atmosphere.

### **Balancing the Carbon Budget**

"This detailed study of the Amazon basin gives us a clearer picture of the role played by streams and rivers in the carbon cycles of tropical regions," says Brown. Most of the atmospheric carbon dioxide taken up by the Amazon basin in a given year is not sequestered for decades to centuries but, rather, is returned to the atmosphere as carbon dioxide on a time scale of 5 years. The study also provides information for researching how land use may affect climate. By more precisely measuring the carbon cycle in the Amazon basin, the project team has taken another step in helping scientists understand how atmospheric carbon dioxide concentrations affect the global carbon cycle and the world.

—*Ann Parker*

**Key Words:** Amazon River basin, carbon-14, carbon cycle, carbon dioxide, Center for Accelerator Mass Spectrometry (CAMS), radiocarbon dating, sequestration.

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