"Horizontal and Vertical Fluxes of Carbon in River Corridors of the Amazon Basin"

Team membership

Team ID number: ND-09

Co-PIs: Jeffrey E. Richey and Reynaldo Luiz Victoria

Co-Is: Mª Victoria Ballester; Allan Devol; Alex Krusche; Dennis Lettenmaier

Collaborators: Anthony Aufdenkampe; Jean P.B. Ometto; Marcelo Z. Moreira; Beatriz M. Gomes; Nicolau Priante; Foster Brown; Ricardo Figueiredo; Mercedes Bustamante; Miles Logson and Marcelo Bernardes

Graduate students: André Toledo; Daniel de Castro Victoria; Gelson de Macedo; Kellie Balster; Lais Hanada; Michelle Cogo; Nei Kamagushi Leite; Nilton Bonelle; Sonya Remington.

Undergraduate students: Marcos Alexandre Bolson; Renata Marcondes;Sergio Candido de Gouveia Neto

Abstract

Our proposed research addresses the overall role rivers and periodically inundated environments play in the biogeochemical cycles of the Amazon Basin. Recent evidence suggests that outgassing of CO_2 is of comparable magnitude to the lower estimates of carbon sequestration by forests. We will address our objectives by: (1) Conducting fieldwork in characteristic sub-basins to complete water chemistry and to obtain an extensive suite of *p*CO2 distribution measurements over the hydrologic regime, and to use proven geochemical techniques (gas flux measurements, isotopic tracers, remineralization rates) to quantify the rates of the lateral transfer and cycling of water and bioactive organic matter from the land, through riparian environments and to the river system and (2) Using a terrestrial source/river transport and reaction model to synthesize and extrapolate the site-specific CO_2 evasion rate measurements to a basin-wide estimate of CO_2 evasion rate. The rationale for expanding the research on gas evasion is that our Phase 1 calculations on outgassing suggested that this process was much greater than previously expected, to the extent that it may help resolve the current "imbalances" in the estimates of carbon sequestration. Direct evasion of CO_2 of such magnitude from drainage waters would force us to revise our concept of the mechanisms coupling terrestrial and aquatic environments at regional scales. Linkages between land and water would be stronger than previously thought, with river corridors representing a significant downstream translocation of carbon (in both space and time) originally fixed by the forest.

Scientific objectives

Objective 1. Complete research on the question of land-use change and its consequences for water chemistry in the Ji-Paraná River Basin

Objective 2. Expand research on the fluxes of gases between wetlands and the atmosphere, by testing the **working hypothesis** that **"CO_2 evasion returns as much carbon to the atmosphere as is sequestered in upland forests on an interannual basis. Export of organic material from upland and riparian forests to fluvial environments is the primary source of carbon that is eventually respired in rivers and evaded as CO_2."**

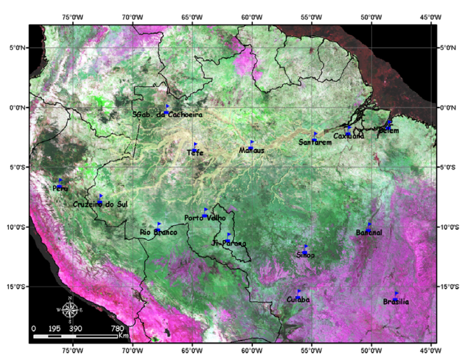
Technical Approach

Functionally, our two main objectives are closely related, and can be broken into their respective constituents. The nutrient dynamics is part of the sequence of processes that are ultimately expressed as excess CO_2. Sampling is done on the same expeditions. The CO_2 evasion is the product of the areal extent of open water (which is the product of the hydrologic regime and landscape), surface CO_2 concentrations (the product of a complex series of biological and transport processes), and the gas exchange rate (controlled by dynamic processes across the air-water interface). Given the realities of Amazon logistics and our requirement to characterize diverse environments, we propose to pursue a nested sampling and modeling strategy. We will focus our sampling on sub-regions that are both representative of the diversity of Amazon environments, and feasible to sample. The fieldwork will be both intensive (involving more detailed studies on both patterns and processes at a smaller number of sites, primarily in the Ji-Paraná) and extensive (involving defining the variability of *p*CO2 by habitat type at a wider variety of sites). For the extensive sites, we will focus on areas of other LBA investigations, particularly in the Tapajós and lower Negro/greater Manaus regions. We also hope to work in collaboration with LBA colleagues. The parameters to be measured are selected explicitly as those necessary to develop and validate the coupled biogeochemistry/hydrology model that will be used for basin-wide extrapolations and ultimately as the basis for a general model to be tested elsewhere.

Using this combination of techniques, we anticipate being able to quantify the CO_2 fluxes and identification of the mechanisms controlling them in humid tropical forests.

More specifically, we will:

1. Complete the studies of land-use change and its consequences for the water chemistry of the Ji-Parana River basin.
2. Determine Spatial (Multiple Environments and Soil Types) and Temporal (Seasonal) Distributions and Potential Sources of Dissolved Gases
3. Evaluate models of gas exchange and CO_2 accumulation in the lower boundary layer.
4. Determine seasonality of Inundation and Terrestrial Runoff.
5. Modeling regional dynamics of flow regimes and gas transfer



Our role in integration and synthesis

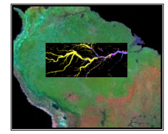
The overall research here is relevant to a series of the LBA-ECO Science questions:

- Land use in Rondonia: is relevant to questions LC-Q1 and LC-Q2.
- Evasion work bears directly on CD-Q1, CD-Q3, TG-Q1, and TG-Q2.
- Water chemistry works is relevant to ND-Q4 and particularly ND-Q5.

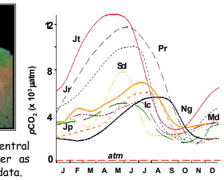
In the aggregate the work is very focused on regional-scale integration and synthesis. The work considers explicitly the effects of changing land use, the relation of surface water chemistry to regional flow patterns, and the role of the extensive wetlands and temporarily inundated or saturated areas in Amazônia. If proven true, the flux of CO_2 via riverine systems will impact considerations of the Amazon and ultimately the global carbon cycle.

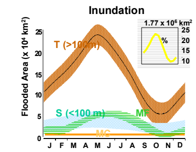
Key past results

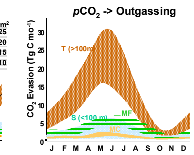
In our work in Phase I of LBA, we evaluated the magnitude and dynamics of the "dissolved *C* leakage" down river corridors. We evaluated the evasion of CO_2 from the fluvial environments of a 1.77 million-km² quadrant of the low-gradient central Amazon basin as a function of seasonal inundation patterns and surface pCO_2 concentrations. The flooded areas derived from radar mosaics and river network were use to calculate pCO_2 outgassing by combining the areal extent of flooding and the distributions of pCO_2 with a simple but widely used gas evasion model. We observed a pronounced seasonality in evasion, corresponding to both the elevated water levels and the increased CO2 concentrations. Integrating over the year, the surface waters of the central Amazon basin (a 1.77 million km2 quadrant) export 210 ± 60 Tg *C* y^{-1} to the atmosphere. This corresponds to a flux of 8.3 ± 2.4 Mg *C* ha^{-1} y^{-1} over the annual mean flooded area of the central basin, or 1.2 ± 0.3 Mg *C* ha^{-1} y^{-1} over the entire quadrant.



Flooded area of the central Amazon basin at high water as mapped from JERS-1 radar data.

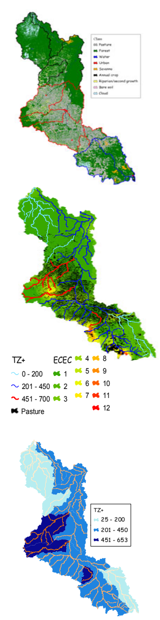






Extrapolating across Amazônia, the total basin evasion is ~ 470 Tg *C* y^{-1}. That is, the waters of the Amazon export ~13 times more carbon via CO_2 evasion to the atmosphere than via the export of total organic carbon (36 Tg *C* y^{-1}) or of DIC (35 Tg *C* y^{-1}) to the ocean. Assuming that the fluxes computed for the Amazon are representative of fluvial environments of lowland humid tropical forests in general, surface water CO2 evasion in the tropics may help explain an anomaly in the current balance of the global carbon cycle. Estimates that the tropics are a net carbon sink are not consistent with recent calculations from global inverse modeling, which imply that the tropics are at least in balance with the atmosphere if not a net source. Extrapolating over the global area covered by humid tropical forests1 with our estimate of areal evasion rates for the Amazon basin yields a flux of roughly 0.9 Gt *C* y^{-1} (three times larger than previous estimates of global evasion). A return flux from water to the atmosphere of this magnitude comes closer to reconciling independent carbon budgets for the tropics. From these findings, we suggest that the overall carbon budget of rainforests, summed across terrestrial and aquatic environments, is more in balance than would be inferred from studies of uplands alone.

For details see: J. Richey, J. Melack, A. Aufdenkampe, V. Ballester, L. Hess ; 2002. Outgassing from Amazonian rivers and wetlands as a large source of atmospheric CO_2. Nature, 416:617-620.



Our results in the Ji-Paraná River show that naturally occurring spatial variability, such as soil cation content is an important determinant of river water quality. However, soil pastures compaction increase the potential for lateral flow, which, when combined with inadequate pasture management or cattle excretions runoff (feces and urine), can also influence the chemical composition of these waters. Pasture was a good predictor of river water composition. The percentage of the basin area covered by pasture was consistently the best predictor of Electrical Conductivity, PO_4^{3}, Na^+, Cl^-, and K^+. For Ca2+ and Mg2+, both ECEC and pasture, explained most of the observed variability. Spatial distribution was heterogeneous along the basin, higher values of all ions analyzed here were associated with sectors dominated by pasture. Concentrations of these elements showed a consistent increase as the river drained areas with an increase in the proportion of this land use. The highest concentrations were found in the central part of the basin, where pasture areas are at a maximum. As the river enters the lower reaches, forests dominate the landscape, and the concentrations drop. Based on the observed pasture establishment patterns, it is not likely that deforestation will occur in the head waters of the basin, due to soils characteristics of this region. Environmental concerns about deforestation should focus instead on the lower reaches of the river, where forest occupies potential agricultural areas. In terms of consequences for river biogeochemistry, little change resulting from forest to pasture conversion should be expected in the headwaters, due to the limitations of soils properties (nutrient limited soils). Simultaneously, if areas located in the lower reaches of the river were deforested and converted into pasture, we would expect changes in river water composition similar to those observed in the central part of the basin.

For details see: Ballester, M.V.R.; Victoria, D. de C.; Krusche, A.V.;Coburn, R.;Victoria, R.L.; Richey, J.E.; Logsdon, M.G.; Mayorga, E. and Matricardi, E. A Remote Sensing/GIS-based physical template to understand the biogeochemistry of the Ji-Paraná River Basin (Western Amazônia). Remote Sensing of the Environment, LBA especial issue, in press.