"THE ROLE OF RIVERS ON THE REGIONAL CARBON CYCLE"


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Our time line

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70'S CENA - EVATRANSPIRATION
80's - 00's CAMREX
90'S - 00's - LBA
TODAY: RRRGG AND ROCA

FAPESP TEMATIC PROJECT RBG AND LUCC
FAPESP TEMATIC PROJECT HYDROLOGY AND CARBON CYCLE
FAPESP TEMATIC PROJECT PFPMC
Amazon River - Earth largest and longest fluvial system:

- Average Discharge = 209,000 m$^3$s$^{-1}$
- Basin Drainage Area = 6.1 millions km$^2$
- Maximum depth = 65 meters at Obidos
- Maximum width = 24 km at the mouth (30 m depth)
- Floodplain area = 300,000 km$^2$
**CO₂ Evasion from the Amazon Rivers is Substantial**

- In Amazonia, CO₂ evasion from aquatic ecosystems to the atmosphere is about 0.5 Gt C y⁻¹
- Source: respiration of labile young (~5 years old) organic matter

- 13 times more C than discharged to the ocean (TOC 0.036 and DIC - 0.035 Gt.y⁻¹) and is higher than the amount released by deforestation (0.38 GtC y⁻¹, ~25,000 km². y⁻¹)

Nature, 2002 and 2005
Small rivers (channel width < 100 m)

- CO$_2$ outgassing was the main carbon export pathway: 289 Gg C yr$^{-1}$.
- about 2.4 times the amount of carbon exported as dissolved inorganic carbon (121 Gg C yr$^{-1}$) and 1.6 times the dissolved organic carbon export (185 Gg C yr$^{-1}$)

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Rasera et al., 2008

Figure 4. Average CO$_2$ flux in tributaries and the Ji-Paraná River main stem at low and high water periods. The numbers correspond to rivers: 25 = Comemoração, 26 = Pimenta Bueno, 27 = Urupá, 28 = first site at Ji-Paraná, and 29 = second site at Ji-Paraná.
~92% of the Amazon River network is composed of small rivers: surface area is $0.3 \pm 0.05$ million km$^2$.

Generally supersaturated in CO$_2$ potentially evading to the atmosphere $0.086 \pm 0.047$ Gg C yr$^{-1}$ as CO$_2$.

These ecosystems play an important role in the regional carbon balance.
Develop the tools to describe comprehensively the biogeochemistry of fluvial systems of the Amazon and Pantanal and their role in regional and global carbon cycle, in order to predict their responses to a changing climate.

Produce scientific information about the functioning of rivers in the Amazon and Pantanal with the necessary accuracy to feed basin-scale heuristic models linked to regional carbon cycle, in order to predict their responses to global climate change.
Specific Objectives:

1. Obtain detailed information on C and nutrients distribution and processing at different spatial/temporal scales to define common sets of drivers in the functioning of rivers (pristine and impacted conditions).
2. Adjust and validate hydro-biogeochemical models.
3. Reduce the uncertainties in CO$_2$ evasive fluxes.
4. Obtain detailed information on C and nutrients distribution and processing at different spatial/temporal scales to define common sets of drivers in the functioning of rivers (pristine and impacted conditions).

Role of rivers in the carbon cycle and associated nutrients.
Acquiring long-term data at 11 bases and 20 extensive sampling sites (Rede Beija-Rio), spread over the Amazon and Pantanal
Sampling/analysis kits and protocol + training short courses on the various required techniques,

Intensive surveys based on recent technological advances and laboratory tests to monitor diel patterns in all nodules of the network, at least one at each representative period of the hydrograph
Controls of the biogeochemistry (and ultimately the fate) of carbon in fluvial systems

Regardless of any scale or basin characteristic, the distribution of biogenic species show the same seasonal patterns, tightly connected to the hydrograph

Richey et al., 2010; Rasera, 2010
Higher values were found at the high water period

Seasonal cycle of CO₂ fluxes
This pattern is directly associated with the $pCO_2$ seasonal cycle.
• Other parameters such as DOC, pH and Dissolved Oxygen, also present the same seasonal trend associated with the hydrograph.
• These patterns were found at the majority of the sampled rivers, regardless of any scale or basin biogeochemical characteristics.
Small scale basins: with pronounced dry season: in-stream processes parallel those in adjacent terrestrial systems.

Extremely important to develop adequate models to describe C cycle in these systems: a common seasonal pattern tied to the hydrograph might simplify significantly the up-scaling.
Looking at altered systems as proxies for expected future responses.

Both land cover changes and recent extreme climate events have offered us opportunities to look at some of these responses.

Example: 2004 - 2007 Madeira river data showed that although a severe drought that occurred in southern Amazon in 2005 affected total annual discharge both in 2005 and 2006 it was only when a 25% reduction was reached in 2005 that changes in distribution of sediments and dissolved inorganic carbon were significant.

Leite et al., in press
Land cover change (class area %)

Sawakushi & Ballester, 2010
Responses to land cover and land use change: water and energy balances

Surface Temperature

Emited Long wave radiation

Net radiation

Soil heat calculated by SEBAL model for a region of the Ji-Paraná River Basin

(Furlan & Ballester, 2011)
Hydrological and biogeochemical responses to land cover changes are not so evident.

Small rivers: replacement of forest by pasture alters hydrological flow paths and the amounts, pathways and quality of land-water nutrient transfers.

Higher DOC concentrations were related to higher values of TSS originated in pasture areas, where soil is compacted, there is less infiltration and higher surface run off promoting the leaching of soil superficial layers caring more DOC to the stream.
Relatively recent changes in land cover have already impacted the composition of riverine OM indicating that, as in natural ecosystems, the vegetation plays a key role in the composition of the riverine OM in agricultural ecosystems.
Wide, shallow channel
Sandy banks, no vegetation in channel
Fast water velocity
Low transient storage
Low organic matter loading
High dissolved oxygen
High $\text{NO}_3^-$
Low $\text{Fe}$
High dissolved inorganic N:P ratios
Long $\text{NO}_3^-$ uptake lengths and low uptake rates
Long $\text{PO}_4^{3-}$ uptake lengths and low uptake rates
higher run off and DOC fluxes (36 times) and N storage and transport

Deegan et al., in press

Gouveia Neto et al., 2005;
Effects in aquatic biodiversity

<table>
<thead>
<tr>
<th>Invertebrate community</th>
<th>Nº. of individuals/sample</th>
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<tr>
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<td>Coleoptera</td>
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<tr>
<td>Gastropodos</td>
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</tbody>
</table>

Fish community
- 35 species in 800 m of forest stream
- 1 species in 500 m of pasture stream
Long-term data as we are acquiring in this project will allow us to establish the types of thresholds essential to environmental global change modeling.