Seasonal variability in concentration, composition, age, and fluxes of particulate organic carbon exchanged between the floodplain and Amazon River

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[1] The composition, sources, and age of particulate organic matter were determined in an Amazonian river-floodplain system during rising, high, falling, and low water periods over 7 yr (1999–2006), and a mass balance for total organic carbon (dissolved and particulate) was estimated. The Curuai floodplain, composed of several temporally interconnected lakes, is permanently connected to the Amazon River via channels. Organic matter (OM) is imported to the floodplain from the Amazon River mainly during the rising water period and produced in the floodplain and exported to the river during high and falling water periods. No significant exchanges occurred during low water periods. The OM produced in the floodplain is characterized by low C/N ratios and by high chlorophyll a concentrations (Chl-a). The $\delta^{13}C$ signature has a seasonal trend, with more negative $\delta^{13}C$ values during the high water period than other periods. $\Delta^{14}C$ results indicate that the bulk OM present in floodplain lakes is predominantly post-bomb (i.e., post-1950). Particulate organic carbon (POC) and dissolved organic carbon (DOC) fluxes exported by the Curuai floodplain represent 1.3% and 0.1%, respectively, of the POC and DOC annual fluxes in the mainstem Amazon River at Óbidos but may reach up to 3.3% and 0.8% during falling water. Based on $\Delta^{14}C$, $\delta^{13}C$, Chl-a, and elemental analysis of the particulate organic matter, we demonstrate that floodplain lakes have intense phytoplankton and macrophyte primary production, which is partly exported to the main river channel. Floodplains are thus a significant source of modern and labile organic carbon to the river mainstem, where it can be rapidly degraded and recycled back to the atmosphere.

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1. Introduction

[2] Riverine and, more generally, inland water systems are important components of the global carbon cycle, linking terrestrial, atmospheric, and oceanic carbon pools. These systems have historically been considered as passive pipelines in global and regional carbon balance computations, but it is now recognized that a significant proportion of the carbon entering these systems from terrestrial ecosystems does not reach the ocean [*Aufdenkampe et al*., 2011; *Battin et al*., 2009; *Cole et al*., 2007; *Tranvik et al*., 2009]. Some of the entering carbon (C) is returned to the atmosphere as carbon dioxide (CO_2) [*Richey et al*., 2002] and, to a lesser extent, as methane [*Melack et al*., 2004; *Tranvik et al*., 2009] or stored in the river corridor as sedimentary organic carbon [*Alin and Johnson*, 2007]. Annual carbon dioxide emissions from inland waters are similar to oceanic carbon dioxide uptake, while global organic carbon burial in inland waters exceeds oceanic organic carbon sequestration [*Tranvik et al*., 2009]. Understanding carbon metabolism and its controlling factors in inland waters is thus crucial for evaluating their roles in the global climate and future trends in climate change and land use conversion.

[3] In this context, the Amazon River system, which is unique in terms of drainage extent and global water and biogeochemical fluxes, has been the focus of numerous studies to quantify lateral and vertical carbon fluxes. Inland Amazon waters are sites of sediment carbon burial [*Devol et al*., 1984; *Smith-Morrill*, 1987; *Melack and Forsberg*, 2001; *Smith et al*., 2003; *Moreira-Turcq et al*., 2004]. The annual CO_2 outgassing is estimated at $0.47\,Gt\,Cyr^{-1}$ [*Richey et al*., 2002] and is an order of magnitude greater than fluvial export of organic carbon to the ocean [*Richey et al*., 1990].

All Supporting Information may be found in the online version of this article.

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The ratio between inland burial and ocean delivery contrasts with findings from temperate rivers, where both fluxes have the same order of magnitude [*Cole and Caraco*, 2001]. This interesting finding raises questions on the carbon sources that could support carbon respiration in Amazonian rivers and why temperate and tropical rivers behave differently.

[4] Several studies have evaluated mechanisms controlling the origin, composition, transport, and flux of OM in Amazon aquatic systems [*Ertel et al*., 1986; *Hedges et al*., 1986a, 1994; *Quay et al*., 1992; *Richey et al*., 2002; *Aufdenkampe et al*., 2007]. These studies mostly present significant differences in source, composition, and age of OM fractions (coarse and fine particulate and dissolved organic matter). The dissolved fraction appears to be richer in C, more degraded, and more recent than the particulate fraction [*Ertel et al*., 1986; *Hedges et al*., 1986a; *Raymond and Bauer*, 2001b; *Mayorga et al*., 2005]. The coarse particulate organic fraction is composed of tree leaves and vascular plant detritus, while the fine particulate organic matter may be an association of mineral particles and organic molecules [*Moreira-Turcq et al*., 2003a; *Aufdenkampe et al*., 2001; *Perez et al*., 2011]. In summary, organic carbon (OC) transported by the Amazon and its tributaries is slightly reactive and highly degraded [*Hedges et al*., 1986a; *Aufdenkampe et al*., 2007]. Additionally, *Mayorga et al*. [2005] reported the presence of a small, recent (i.e., less than 5 yr old) pool of organic C in the Amazon and showed that respiration of this contemporary OM is the dominant source of the excess carbon dioxide driving outgassing in medium to large Amazonian rivers [*Richey et al*., 2002; *Raymond*, 2005]. *Ellis et al*. [2012] note that elevated respiration rates are associated with fine particulate organic carbon (FPOC) derived from algal sources in rivers of the Amazon Basin.

[5] In lowlands of the Amazon Basin, large floodplains are associated with the mainstem of the Amazon and its tributaries. These floodplains are among the most productive systems in the world. Flooded forests, aquatic herbaceous plants, phytoplankton, and periphyton [*Junk*, 1997; *Melack and Forsberg*, 2001] are the main primary producers, and floodplains are also an important site for sequestration of sedimentary organic carbon [*Moreira-Turcq et al*., 2004]. A major challenge in understanding the Amazon fluvial system is to evaluate how and to what extent biogeochemical floodplain processes influence the OM dynamics of rivers. As an interface between terrestrial and aquatic realms, they receive different sources of carbon from the mainstem and the terrestrial local upland, ensuring biogeochemical transformations and export of a mixture of allochthonous and autochthonous carbon to the mainstem. This study is one of few recent studies focusing on floodplain OM composition and sources. In particular, *Richey et al*. [1990] and *Quay et al*. [1992] first showed that aquatic and terrestrial macrophytes and flooded forests in floodplains were very likely sources of labile organic C for the mainstem. *Quay et al*. [1992] proposed that 40% of the OM being respired in the Amazon River and its tributaries is C4 plant material. *Engle et al*. [2008] identified very high net primary production rates for aquatic macrophytes in floodplains and stated that the respiration of this carbon may comprise about half (46%) of annual CO_2 emissions from surface waters in central Amazonia. *Melack and Engle* [2009] note the importance of floating macrophytes in the Calado floodplain, a small, dentritic lake characterized by very low Chl-a concentrations (<10 μg/l) [*Melack and Fisher*, 1990], as a source of labile organic carbon to the Amazon River during an annual cycle. *Martinelli et al*. [2003] used ^{13}C isotopes to show that approximately 36% of the carbon in floodplain sediments was derived locally, mainly from phytoplankton, with riverine POC accounting for the remainder (64%).

[6] We hypothesize that the origin, composition, and concentration of OM in the floodplain, and the subsequent composition of the OM exported to the mainstem, follow a seasonal pattern, with phytoplankton comprising a significant proportion of the OM exported to the mainstem. These hypotheses consider the strong hydrological pattern of floodplains, which affects the distribution and proportions of primary producers (especially aquatic herbaceous plants and phytoplankton). Hydrology also impacts the residence time in floodplains, which influences biogeochemical processing of OM.

[7] Our study focuses on a large floodplain system (the Curuai floodplain) located in the downstream course of the Amazon River. We present the results of multi-annual monitoring, with a focus on the seasonal variability of particulate organic carbon concentration (expressed as carbon content of TSS), Chl-a, $\delta^{13}C$, elemental analysis, and OM age expressed as $\Delta^{14}C$. Additionally, we estimate DOC and POC fluxes exchanged between the river and floodplain based on a simple mass-balance computation. Our data and analysis show the importance of seasonality in the floodplain OM composition. Our findings also have implications for carbon cycling studies in the Amazon Basin. First, we underline the necessity to consider floodplains in a representative way along the river corridor because these systems clearly behave differently from the main stem. Second, we emphasize the importance of seasonality, which must be precisely captured to realistically estimate lateral and vertical carbon fluxes.

2. Study Area

[8] The floodplain "Várzea do Lago Grande de Curuai" (Figure 1) is located on the right bank of the Amazon River, 900 km from the river's mouth near the city of Óbidos. It represents a 120 km long floodplain segment, composed of a complex system of more than 30 interconnected lakes. It has a maximum flooded area of 2430 km^2. The open water area of the lake system ranges from 760 to 1377 km^2, with a 6.7 m variation in water level. Flooded meadows, savanna, and forests (during high water) can cover 570, 450, and over 560 km^2, respectively [*Martinez and Le Toan*, 2007].

[9] The watershed is approximately 3660 km^2, including open water areas. The major lake, "Lago Grande de Curuai", is a white-water lake of approximately 359 km^2 and is located between 56°00′W and 55°03′W and 2°17′S and 1°55′S. It is permanently connected to the Amazon River by two channels: the "Foz Sul" (FS) and the "Foz Norte" (FN) (Figure 1). Other lakes in the Curuai floodplain vary in their amounts and proportions of suspended sediments and dissolved organic carbon and in their connections to the river [*Barbosa et al*., 2010].

[10] The lowest and highest water levels recorded at the Curuai gauging station from 1999 to 2006 were 3.03 m and

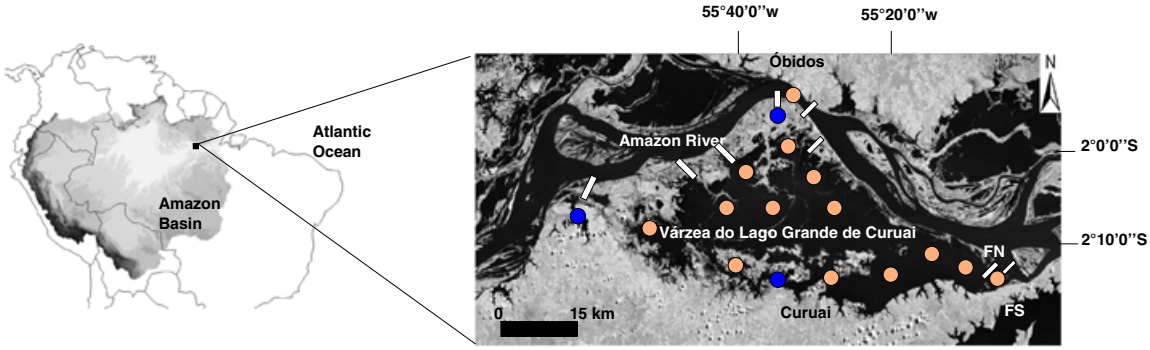

Figure 1. Location of the study area and sampling stations in the Curuai floodplain and Amazon River (Óbidos). Orange circles correspond to stations under direct influence of the Amazon River (white water lakes), and gray circles correspond to stations under more influence from basin drainage (black water lakes). The main channels between floodplain lakes and the Amazon River and gauging stations in the river and floodplain are identified by white bars.

9.61 m, respectively, corresponding to a maximum water level variation of 6.7 m. The annual water-level fluctuations are approximately synchronous with those of the Amazon River. Maximum and minimum levels occur during May-June and November-December, respectively. Generally, water flows from the Amazon River into the floodplain in January, flows in or out from February to late April, and flows out from late April to late October. Flows between the Amazon River and the floodplain at the FS and FN channels (on the western side) are driven by small differences in the rates of water-level rise occurring in the floodplain and the river; the direction and discharge are variable [*Bonnet et al*., 2005; *Bonnet et al*., 2008]. The mean annual residence time of water on the floodplain is approximately 3 months [*Bonnet et al*., 2008].

3. Materials and Methods

3.1. Sample Collection

[11] Water samples were collected from multiple stations on the floodplain and in the Amazon River (Figure 1) during 14 periods at different water levels (Figure 2). Generally, samples were collected at 0.10 m beneath the water surface in acid-washed, black glass bottles rinsed with river water. Transparency was estimated using a Secchi disk (20 cm diameter).

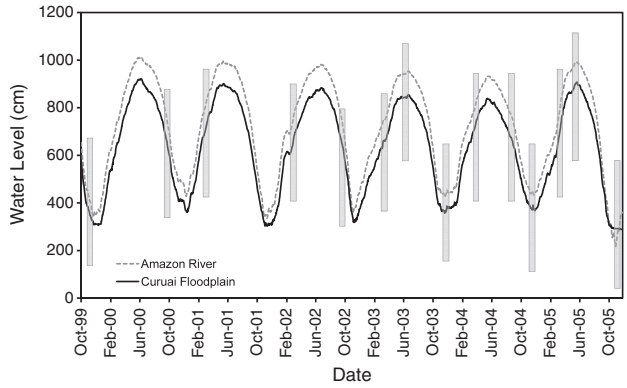

Figure 2. Hydrographs of the Amazon River at Óbidos and the Curuai floodplain. Vertical bars indicate sampling times.

[12] Temperature, pH, and conductivity were measured *in situ* using routine conventional techniques: a WTW instrument and a multiparameter probe (®YSI 600XLM). Temperature and conductivity were measured using the same 6560 sensor with an accuracy of ±0.15°C for temperature and ±0.001 mS/cm for conductivity.

[13] Between 0.5 and 1 l of water were filtered onto ashed (450°C, overnight) and preweighed glass fiber filters (Whatman GF-F, 0.7 µm) under moderate pressure using an all-glass filter holder (Millipore). Samples were filtered to separate particulate organic matter (POM) from dissolved organic matter (DOM). After filtration, the filters were dried for 24 h at 50 °C.

3.2. Analytical Methods

[14] Total suspended sediments (TSS) concentration was determined gravimetrically using the dry weight of the filtered material on the same glass filter. POC and total nitrogen (TN) were analyzed using an elemental analyzer (C/H/N FISONS NA-2000). Stable isotopic composition ($\delta^{13}C$) was analyzed using a Europe Hydra 20/20 mass spectrometer equipped with a continuous flow IRM. The analytical precision (as the standard deviation of repeated internal standard measurements) for the stable isotope measurements was 0.06‰ and 0.13‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively. During phytoplankton blooms in the floodplain waters, we analyzed samples without separating live cells and detritus, thus assuming that the phytoplankton contribution corresponded to live cells "plus" detritus. Chl-a was extracted using acetone (90%) and determined using a spectrophotometer, and the concentrations were calculated using Lorenzen equations [*Lorenzen*, 1967]. DOC concentrations were measured using a Shimadzu TOC-V_{CSH} analyzer. The detection limit for carbon was 4 µg/l.

[15] Surficial sedimentary OM was collected (using an Ekman sampler) from multiple stations in the floodplain and analyzed for POC, PON, and $\delta^{13}C$. In addition, samples of representative herbaceous plants present in the floodplain were sampled (i.e., leaf, stem, and root) and analyzed for POC, PON, and $\delta^{13}C$.

[16] Fifty liters of water samples for ^{14}C dating were collected in the Amazon River and floodplain lakes. Samples were processed onboard using tangential filtration (TFU,

Millipore Pelicon device and Durapore membrane with a nominal cutoff of 0.2 μm [e.g., *Allard et al*., 2011]). Samples for ^{14}C dating were also collected in floodplain lakes using sediment traps [e.g., *Moreira-Turcq et al*., 2004]. The ^{14}C measurements were performed using an Artemis accelerator mass spectrometry system based on a 3 MV Pelletron (NEC, Middleton, Wisconsin, United States) at the "Laboratoire de Mesure du Carbone 14 (LMC14) - UMS 2572 (CEA/DSM CNRS IRD IRSN – Ministère de la Culture et de la Communication)" at Gif sur Yvette (France). More information about Artemis and the sample preparation methods can be found in *Cottereau et al.* [2007]. The ^{14}C measurements are reported as percent modern carbon and $\Delta^{14}C$ (‰) after correction for ^{13}C fractionation (normalization to a $\delta^{13}C$ of −25‰). Using $\Delta^{14}C$ notation, positive values indicate greater ^{14}C activity in the sample than in carbon fixed in 1950, signifying the influence of ^{14}C derived from atmospheric weapons testing. Negative $\Delta^{14}C$ values indicate that the average residence time of carbon is sufficiently long for significant radioactive decay to have occurred. The radiocarbon ages were estimated following *Mook and Van der Plicht* [1999] after correction for ^{13}C fractionation.

3.3. Carbon Flux Modeling

[17] Flow rates were measured in channels connecting the floodplain and the Amazon River (Figure 1) using a 1200 Hz or 600 Hz Acoustic Doppler Current Profiler (ADCP; RDI Instruments) and in the Amazon River at Óbidos using a 30 Hz or 600 Hz ADCP. Discharge was estimated from at least four cross-sectional measurements with an error of approximately 5%. The annual POC and DOC mass balances were obtained from model computations. First, the daily river-floodplain exchanged water fluxes were computed from river flooding, direct precipitation, local watershed runoff, and groundwater exchange according to the hydrological model described in *Bonnet et al*. [2008]. The monthly carbon (POC and DOC) data set was obtained from the network installed in the Curuai floodplain (2002–2003) and Amazon River (Óbidos). This hydrological year was chosen because it represented an average in terms of water and sediment discharges at Óbidos. Daily modeled discharges in each connecting channel were multiplied by the corresponding monthly POC and DOC concentrations using Amazon River concentrations at Óbidos for incoming fluxes and floodplain station concentrations for outgoing fluxes; stations located in the outlet channels (FN and FS accounting for 30% of the total water flux to FN [*Maurice-Bourgoin et al*., 2007; Figure 1] were used. Both incoming and outgoing fluxes were calculated from surficial concentrations. In the Curuai floodplain, the vertical stratification is very weak (data not shown) because, even during the high water period, depth remains shallow (approximately 7 m maximum). The water column is regularly mixed by wind-induced waves and free convection at night. In the Amazon River, there is a vertical stratification [*Maurice Bourgoin et al*., 2007; *Richey et al*., 1990] of TSS, POC, and DOC. However, only the surficial layer of the Amazon River (0–7 m) enters the floodplain due to channel topography and flood amplitude [*Maurice-Bourgoin et al*., 2007]. Finally, monthly POC and DOC fluxes were summed to obtain the monthly incoming (Óbidos) and outgoing (floodplain) cumulative POC and DOC masses.

3.4. Statistical Methods

[18] For all parameters (except $\Delta^{14}C$), the statistical significance of temporal variation between water stages and spatial variation among stations at each water stage were evaluated using the Kruskal-Wallis nonparametric test (at 95% level of confidence) with Dunn's post-test comparing all water stages (GraphPad Prism version 4.00 for Macintosh Leopard 10.6, GraphPad Software, San Diego, California, Unites States, www.graphpad.com). In the floodplain and at the Óbidos location, data were pooled for water stages independent of the acquisition year. The low water stage regroups data from November and December. The rising water stage regroups data from January to March. The high water stage regroups data from June and July, and the falling water stage regroups data from August to October. Each group contains a minimum of 20 samples in the floodplain, but the number of observations may be lower for the Amazon River as a function of the parameters (the number in these cases is mentioned in the text—see section 4). The Kruskal-Wallis test was also used to determine the statistical significance of the OM pools by grouping the data by OM type rather than by water periods. Finally, we evaluated the significance of the differences between floodplain and Amazon River pools for all of the considered parameters.

4. Results

4.1. Concentration and Distribution of Total Suspended Solids and Particulate Organic Carbon

4.1.1. Amazon River

[19] Superficial TSS ranged from 50 to 250 mg/l ($n = 62$), with a mean of 67 mg/l. The seasonal pattern was statistically significant ($p = 0.0025$), with the highest difference observed between the rising and falling water periods (Dunn's test; $p < 0.01$). The lowest concentrations were found during falling and low water periods, with the highest concentrations observed during rising water periods (Figure 3). POC (expressed as the percent of organic carbon (%OC) in TSS) varied between 1.1 and 4.2%, rarely reaching 6%. The mean %OC was 2.5% (Figure 4). As observed for TSS, the %OC seasonal pattern was statistically significant ($p = 0.0045$), with the largest difference observed between the rising and falling water stages (Dunn's test; $p < 0.01$).

4.1.2. Floodplain Waters

[20] The mean TSS combining all periods and stations was 135 mg/l ($n = 250$). The seasonal pattern was obvious and statistically significant ($p < 0.0001$) (Figure S1a in the Supporting Information). All water stages significantly differed from each other (Dunn's test, $p < 0.01$). The highest concentrations (up to 800 mg/l) were observed during low water periods (early November; Figure 3). The mean %OC was approximately 8.2% ($n = 250$) and ranged from 1.7 to 45.0% (Figure 4). The mean %OC in the floodplain was 10.9% during rising water and 4.1% during the low water period. Similar %OC values of 8.5 and 8.6% were observed during the high and falling water periods, respectively (Figure 4). The seasonal pattern was highly significant ($p < 0.0001$) (Figure S1b in the Supporting Information). The low water stage contrasted significantly with other water periods (Dunn's test, $p < 0.01$). Spatial variations within the floodplain for each water period were not statistically significant ($p > 0.05$). Both TSS concentration and %OC in the

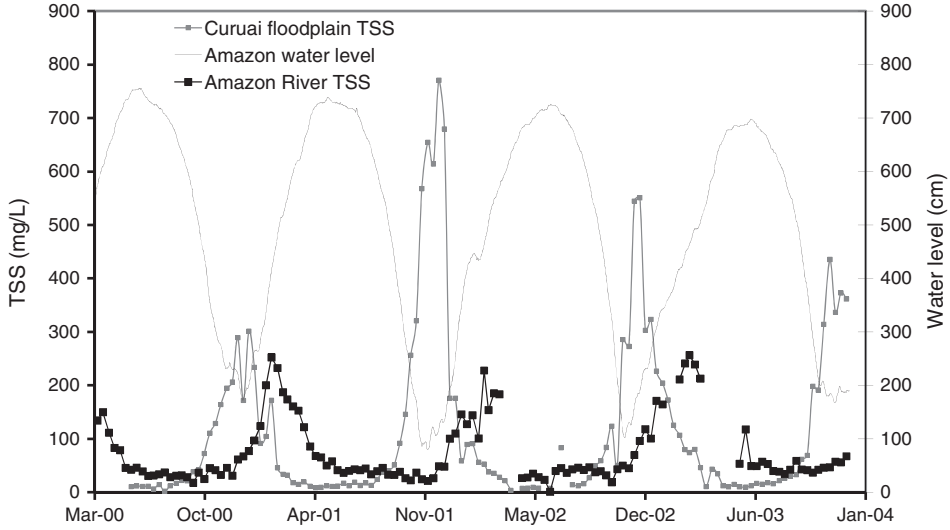

Figure 3. Temporal variations in total suspended sediments (TSS) in the Amazon River and the Curuai floodplain based on data from repeated sampling in the floodplain at the FS location [e.g., *Maurice-Bourgoin et al.*, 2007] and monthly sampling in the Amazon River at Óbidos.

Amazon mainstem contrasted significantly with the floodplain data ($p < 0.0001$). In the Amazon River and the Curuai floodplain, %OC was inversely correlated to TSS (Figure 4).

4.2. C/N Ratios, Chl-a, C/Chl-a Ratios, and C Isotopic Composition of Particulate Organic Matter

4.2.1. Amazon River

[21] C/N ratios of POM ranged from 6 to 18 (Figure 5) with a mean value of 11.6. These ratios were slightly higher during rising and high water periods. The seasonal pattern was significant ($p = 0.0028$), as was the difference between rising and falling water stages ($p < 0.01$, Dunn's test).

4.2.2. Floodplain Waters

[22] Spatial variations in C/N ratios were not statistically significant within the dataset. The seasonal pattern was strongly significant ($p < 0.0001$), with significant differences between low water and rising and high water stages (Dunn's test, $p < 0.001$), between rising and falling stages (Dunn's test, $p < 0.01$) and between falling and high water stages ($p < 0.05$) (Figure S1c in the Supporting Information). Mean C/N ratios were equivalent (equal to 6.8) during falling and low water periods (Figure 5). During rising and high waters, the floodplain OM had higher C/N ratios (mean of 8.4 and 9, respectively), with values closer to those of the Amazon River. However, the C/N ratios in the Amazon River and floodplain were significantly different ($p < 0.0001$).

4.2.3. Amazon River

[23] Low concentrations of Chl-a (mean of 5 µg/l) were observed in the Amazon River.

4.2.4. Floodplain Waters

[24] The mean Chl-a concentration ranged from 30 to 50 µg/l in the floodplain lakes. Spatial variations within the floodplain were not statistically significant. There was a significant seasonal pattern ($p < 0.0001$) and significant differences between low and high water stages ($p < 0.05$, Dunn's test), between rising and falling water stages and between falling and high water stages ($p < 0.001$, Dunn's test) (Figure S1d in the Supporting Information). The Secchi

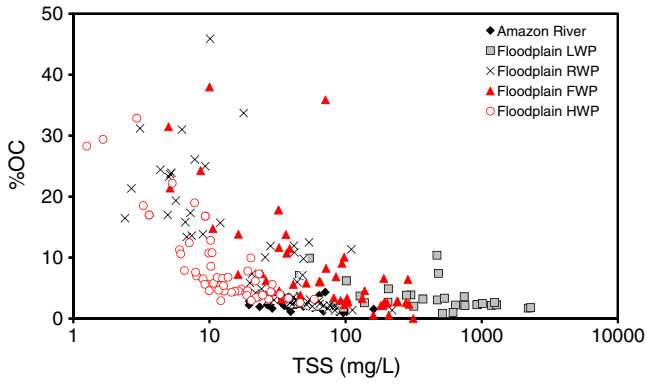

Figure 4. Percent weight of particulate organic carbon (% OC) versus total suspended sediments (TSS) for the Amazon River (black diamonds) and the Curuai floodplain during different water levels: low water period (LWP), rising water period (RWP), falling water period (FWP), and high water period (HWP).

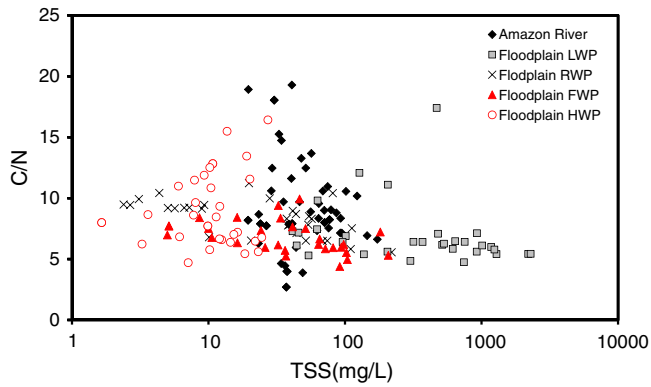

Figure 5. C/N ratios versus total suspended sediments (TSS) for the Amazon River (black diamonds) and the Curuai floodplain during different water levels: low water period (LWP), rising water period (RWP), falling water period (FWP), and high water period (HWP).

depth in the water column ranged from 0.10 m (low water) to 1.35 m (high water). High Chl-a concentrations were observed during rising and falling water, when Chl-a reached 111 µg/l and 186 µg/l, respectively. In the Amazon River at Óbidos, the C/Chl-a ratio ranged from 150 to 1300 (Figure 6), with lower values during low water and higher values during rising water. In floodplain waters, the mean ratio decreased from 630 during low water to 340 during rising water to 289 during high water and was minimal at 219 during falling water. The same range was observed in the Amazon River, but values were generally lower. The seasonal pattern was highly significant ($p < 0.0001$), and the low water period was significantly different from the other water periods ($p < 0.001$, Dunn's test) (Figure S1e in the Supporting Information).

4.2.5. Amazon River

[25] The $\delta^{13}C$ for the Amazon River (Óbidos) ranged from −29.9 to −26.6‰, with an average of -28.0 ± 0.8‰ ($n = 16$) (Figure 7).

4.2.6. Floodplain Waters

[26] The $\delta^{13}C$ seasonal pattern was statistically significant ($p = 0.0003$) in the floodplain waters. The high water period differed significantly from the rising and falling periods ($p < 0.01$, Dunn's test) (Figure S1f in the Supporting Information). Mean values ranged from -27.9 ± 1.5‰ during rising water to -26.2 ± 2.6‰ during falling water. In white water lakes (more influenced by River waters), the $\delta^{13}C$ ($n = 165$) varied from −28.4 to −17.7‰. Maximum values in white water lakes (−21.0 to −17.7‰; $n = 7$) were found during extensive phytoplankton blooms, when Chl-a and POC (%) were at their maximal values (140–186 µg/l and 30–45%, respectively). These data represent the particulate organic matter pool (live cells and detritus) found in the water. In contrast, the $\delta^{13}C$ levels of lakes more influenced by black water in the drainage basin ($n = 38$) were more negative than those of the Amazon River and ranged from −34.1 to −29.6‰ (Figure 7). The mean $\delta^{13}C$ was −25.4‰ in white water lakes and −30.4‰ in lakes more influenced by black waters.

[27] Significant differences in $\delta^{13}C$ values were observed between the groups presented in Figure 7 ($p < 0.0001$, Kruskal-Wallis test). The Dunn's post-test indicates that only differences between black waters and Amazonian OM and between phytoplankton bloom and macrophytes were significant. Floodplain OM versus sedimentary OM and Amazonian OM versus sedimentary OM were not significantly different ($p > 0.05$).

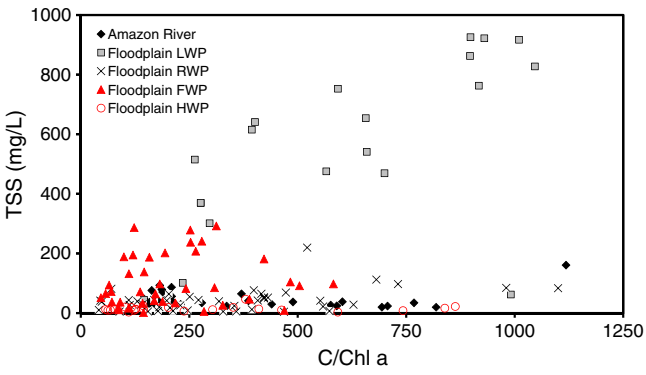

Figure 6. Total suspended sediments (TSS) versus particulate organic carbon/chlorophyll a ratio (C/Chl-a) for the Amazon River (black diamonds) and the Curuai floodplain during different water levels: low water period (LWP), rising water period (RWP), falling water period (FWP), and high water period (HWP).

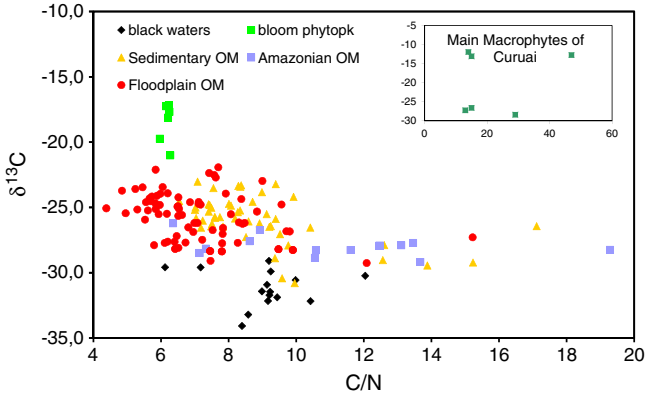

Figure 7. Isotopic carbon (^{13}C) versus carbon/nitrogen ratios (C/N) for all samples (large plot) in the Curuai floodplain: black waters (black diamonds), phytoplankton blooms (grey squares), sedimentary organic matter (white triangles), pelagic organic matter (grey circles), and Amazonian pelagic organic matter (white squares). The inset plot shows ^{13}C versus C/N ratios for the main macrophytes present in the Curuai floodplain.

[28] The $\Delta^{14}C$ results (12 samples) are presented in Table 1. These data show that all floodplain suspended matter samples were characterized by the presence of modern (i.e., ^{14}C-enriched) OM. Older, ^{14}C-depleted material was found only in the Amazon River sample and in settling particles (obtained from sediment traps in the floodplain).

4.3. Carbon Content, C/N Ratios and Isotopic Composition of Sedimentary Organic Matter and the Main Primary Producers in Floodplain Lakes

[29] The carbon content (%) of surficial sediments in fractions <63 µm ranged from 1.1 to 12% ($n = 40$). The highest values were found in the sediments of black water lakes (6–12 %), and the lowest values (1.5–5%) were found in the sediments of white water lakes. The C/N ratios of surficial sediments in the various lakes ranged from 7.0 to 15.2, and the mean C/N ratio was 8.7 (significantly lower than

Table 1. ^{14}C concentration as Percentage of Modern (1950) Atmospheric CO_2, $\Delta^{14}C$ Values and Radiocarbon Age From the Amazon River and Floodplain Samples During Different Water Levels

Laboratory Code	Sample	Water Level	Modern Carbon (%)	$\Delta^{14}C$ (‰)	Radio Carbon Age (yr BP)
Sac 5573	floodplain	rising	100	1.2 ± 3.7	modern
Sac 5574	floodplain	rising	102	15 ± 3.7	modern
Sac 5580	bloom phytoplankton	rising	101	14 ± 3.6	modern
Sac 5581	floodplain	rising	103	29 ± 3.8	modern
Sac 5582	floodplain	rising	102	23 ± 5	modern
Sac 2078	floodplain	low	101	8 ± 4.8	modern
Sac 2079	floodplain	low	102	21 ± 3.7	modern
Sac 2080	floodplain trap	falling	98	-23 ± 3.5	old
Sac 2081	floodplain trap	falling	73	-270 ± 3.5	old
Sac 2082	floodplain	rising	100	4 ± 3.5	modern
Sac 2083	floodplain trap	rising	72	-276 ± 7	old
Sac 8763	Amazon River	rising	80	-195 ± 3.1	old

TSS in the Amazon River (C/N = 11.6)). The $\delta^{13}C$ of surficial sediments ranged from −29.4 to −23.0‰ in white water lakes and from −30.8 to −26.2‰ in black water lakes (Figure 7).

[30] Table 2 presents relative abundance, C/N ratios, and $\delta^{13}C$ levels for representative herbaceous plants and for two periphyton samples collected from the Curuai floodplain. For all herbaceous plants except *Echinochloa polystachya* and *Eichornia crassipes*, C/N ratios were relatively consistent among the different parts of the plant. These two dominant species were characterized by high $\delta^{13}C$ values (approximately −13.0‰).

4.4. Water and Carbon Mass Balances in the Curuai Floodplain and the Amazon River

[31] We used the results of the hydrological model from *Bonnet et al*. [2008], which was developed for the Curuai system, to estimate the carbon mass balance. Based on 6 yr of hydrological data, this model shows that Amazon River water starts invading the floodplain at the end of November-December and continues to increase until May-June. From July to November, the lake water discharges into the Amazon River. The largest exported volume occurs from August to October during the falling water phase. Annually, the floodplain represents a source of water to the Amazon River. The net annual output of water from the Curuai floodplain to the Amazon River ranges from 0.2 to 0.5 km^3. The highest output water fluxes occurred between May and October.

[32] The carbon mass balance was computed using the hydrological model results obtained for the 2002–2003 water-year and the corresponding carbon (dissolved and particulate) data obtained from the monitoring network installed in the Curuai varzea. This water-year was chosen because a complete time series of carbon data was also available at Óbidos, and this year was also an average year for water and sediment discharges at Óbidos. DOC concentrations measured at Óbidos varied from 4.4 to 6.4 mg/l during the 2002–2003 hydrological year, and POC concentrations varied from 0.9 to 1.7 mg/l during the same period (Table S1 in the Supporting Information). In the Amazon River, POC represented between 15 and 25% of the TOC, while POC contributed 30 to 50% of the TOC at Curuai. The DOC and POC concentrations were measured at the output station at the eastern mouth of the Curuai floodplain (stations FN and FS, Figure 1). DOC ranged from 3.7 to 5.9 mg/l. The POC concentrations varied from 2.4 mg/l during high water to 4.6 mg/l during falling and low water. According to the model results, DOC flowing into the floodplain ranged from 0.6 to 29 Gg C per month, and POC inflows varied from 0.15 to 6 Gg C per month. The higher input fluxes occurred during high water periods, when water from the Amazon River entered the lakes. DOC outflows ranged from 0.09 Gg C in January to 28 Gg C in June. Outflowing POC fluxes were minimal in January (0.06 Gg C) and maximal in August (16 Gg C). POC and DOC balances were negative (i.e., TOC export from the floodplain) except during December and January for POC and December, January, May, and June for DOC. Annually, the total DOC export was 26 ± 2.6 Gg C, and POC export was 66 ± 6.6 Gg C (Table S1 in the Supporting Information).

Table 2. Main Characteristics of Macrophytes and Periphyton in the Curuai Floodplain

Sample	Parts	Habitat	Abundance	C/N	$\delta^{13}C$
Pistia stratiotes	leaf	aquatic	low	12	−27.3
Pistia stratiotes	stem	aquatic	low	14	−27.3
Pistia stratiotes	root	aquatic	low	14	−27. 1
	mean			**13**	**−27.2**
Paspalum fasciculatum	leaf	terrestrial	moderate	12	−11.3
Paspalum fasciculatum	stem	terrestrial	moderate	14	−12.2
Paspalum fasciculatum	root	terrestrial	moderate	17	−12.3
	mean			**14**	**−11.9**
Echinochloa polystachya	leaf	semiaquatic	dominant	47	−11.8
Echinochloa polystachya	stem	semiaquatic	dominant	80	−11.9
Echinochloa polystachya	root	semiaquatic	dominant	15	−14.5
	mean			**47**	**−12.7**
Eichornia crassipes	leaf	aquatic	moderate	25	−28.2
Eichornia crassipes	stem	aquatic	moderate	47	−28.0
Eichornia crassipes	root	aquatic	moderate	12	−29.9
Eichornia crassipes	flower	aquatic	moderate	31	−27.4
	mean			**29**	**−28.4**
Paspalum repens	leaf	semiaquatic	dominant	13	−12.3
Paspalum repens	stem	semiaquatic	dominant	13	−13.0
Paspalum repens	root	semiaquatic	dominant	11	−14.9
Paspalum repens	flower	semiaquatic	dominant	21	−12.0
	mean			**15**	**−13.1**
Salvínia auriculata	total	aquatic	low	15	−26.6
Periphyton	total	aquatic	-	8	−25.8
Periphyton	total	aquatic	-	15	−17.5

5. Discussion

[33] This study highlights the high seasonal variability of particulate organic matter composition exchanged between floodplain lakes and the Amazon River during an annual hydrological cycle. Our results indicate that primary production occurring in floodplain lakes (mainly phytoplankton primary production) can be an important source of labile OM to the Amazon River, especially during falling water, when the lake discharge to the River influences river metabolism. This finding is in contrast to previous work, which has assumed a minor role for phytoplankton in floodplain lakes.

5.1. Aquatic Phytoplankton Activity

[34] Chl-a in the Amazon River is low [*Saliot et al*., 2001]. Assuming a C/Chl-a ratio of 40 for phytoplankton cells [*Meybeck*, 1982; *Saliot et al*., 2001], algal material represents only 2 to 8% of the POC in the Amazon River. Some studies in major rivers have found that the fine fraction of POM is dominated by nonreactive, soil-derived materials [*Hedges et al*., 1986a; *Mariotti et al*., 1991; *Quay et al*., 1992], but recent findings [*Ellis et al*., 2012] show the presence of OM derivatives from autochthonous production in Amazon waters. Other studies (particularly those in rivers that drain lakes or reservoirs) have found that algae are the major component [*Angradi*, 1994; *Barth et al*., 1998; *Thorp et al*., 1998; *Kendall et al*., 2001]. Amazonian floodplain lakes can be sites of extensive phytoplankton activity, where Chl-a concentrations can reach 186 μg/l. In the Curuai floodplain, the C/Chl-a ratio was variable throughout the hydrological cycle and was related to TSS concentration. The highest concentration of TSS (Figure 6) was found during the low water stage, likely due to sediment resuspension caused by high winds and low depth [*Alcantâra et al*., 2010; *Barbosa et al*., 2010, *Maurice-Bourgoin et al*., 2007]. During this period, OM is dominated by detritus (high C/

Chl-a ratio). TSS concentration has a direct impact on water transparency, which influences photosynthetic activity and, consequently, affects the C/Chl-a ratio and particulate organic matter composition in the lakes. During rising water, when TSS was below 100 mg/l and the C/Chl-a ratio was high, detritus from the Amazon River was still abundant. Early in the falling water period (August), when the concentration of TSS was relatively low (between 30 and150 mg/l), the C/Chl-a ratio was also low (<200), indicating an increase in photosynthetic activity. *Barbosa et al*. [2010] also note the importance of TSS as a limiting factor for phytoplankton growth in the Curuai floodplain. TSS concentration thus appears to be one of the most important parameters influencing seasonal composition and sources of organic particulate matter in the Amazon floodplain lakes and, thus, the particulate organic matter exported to the Amazon River.

5.2. The Nature of POM Exchanged Between Floodplain Lakes and the Amazon River Mainstem

[35] Organic matter imported from the river has a low carbon content (~1.6%), higher C/N ratios (9–18), low algal contributions (~5 μg/l of Chl-a), ^{14}C-depleted material (-195 ± 3.1‰), and δ^{13}C levels from −29.2 to −26.7‰. These results suggest that OM transported by the Amazon is old and characterized by low autochthonous production. The δ^{13}C indicated a mixture of C3 and C4 plants. These ^{13}C values are similar to those reported for the lower Amazon River by *Hedges et al*. [1986a] (-27.8 ± 0.7‰ for the >63 μm fraction (CPOC) and -27.0 ± 0.8‰ for the <63 μm fraction (FPOC)) and by *Cai et al*. [1988] (−27.9 to 30.1‰). *Bird et al*. [1992] reported values of approximately −28.0‰, and *Quay et al*. [1992] reported a mean FPOC of -27.2 ± 0.5‰ and a mean CPOC of −27.9 0.4‰. Despite these relatively uniform δ^{13}C values, a seasonal trend occurs in the lower Amazon River, with more negative δ^{13}C values occurring during rising water (mean δ^{13}C of −29.2‰) than during falling water (mean δ^{13}C of −28.2‰); this pattern is likely due to floodplain inputs. The mean C/N ratio reported here for the Amazon River (approximately 12) is also similar to that found by *Hedges et al*. [1986a] for fine (<63 μm) particulate organic matter (FPOM), indicating a soil source. The broader range of our results is likely due to our use of a longer time series, which would have been influenced by floodplain OM inputs, particularly during falling water. *Hedges et al*. [1986a, 1994] demonstrated that the FPOM suspended in the Amazon River consists primarily of refractory, lignin-bearing, soil humic material, which is strongly associated with fine minerals. *Cecanho* [2007] and *Zocatelli et al*. [2011] have characterized surficial sediments from the Curuai floodplain using lignin phenols. They showed that these sediments have a high Ad/Al (v) > 0.4 [*Hedges et al*., 1986a], indicating high degradation.

[36] Organic matter produced in floodplain lakes has higher carbon contents, lower C/N ratios (approximately 7), higher algal contributions (10–180 μg/l of Chl-a), is ^{14}C enriched (post-bomb), and exhibits more variable δ^{13}C (−17.0 to −34.0‰) than OM in the Amazon River. The highest δ^{13}C was found during phytoplankton blooms, and more negative δ^{13}C was measured in black waters. *Martinelli et al*. [2003] estimated that 36% of the organic carbon present in floodplain sediments (along the Solimões/Amazon River) originates from *in situ* production and that riverine POC provides the remaining 64%. *Junk and Piedade* [1997] and *Melack and Engle* [2009] studied other Amazonian floodplains (e.g., Marchantaria and Calado in the Solimões River) and demonstrated that aquatic macrophytes and phytoplankton were the primary sources of organic carbon.

[37] The two main macrophytes present in the Curuai floodplain (*Echinochloa polystachya* and *Paspalum repens*) have mean C/N ratios of 47 and 15 (Table 1), respectively, and a δ^{13}C of −13.0‰. Consequently, contributions from these macrophytes cannot explain the observed composition of the bulk POM in the floodplain (i.e., low C/N). When comparing the δ^{13}C of the two main macrophytes and the floodplain OM (Figure 7), there is no evidence of a significant contribution of these macrophytes to the suspended and sedimentary OM in the Curuai floodplain. As reported by *Piedade et al*. [1994] and *Melack and Engle* [2009], these macrophytes have a high biomass in other Amazonian floodplains. Therefore, a significant contribution of this biomass source in the POC and sediments from the Curuai floodplain could be expected. However, we observed that macrophytes were mainly concentrated along the connecting channels. This spatial distribution, which differs from that in smaller floodplains, may result from the large open water area of the Curuai floodplain. During falling water, a large portion of this biomass is directly exported to the Amazon River, and only a small portion is degraded and can be buried in the lakes. *Junk and Piedade* [1997] also observed that stands of *Paspalum repens* and *Echinochloa polystachya* that grow in exposed locations are frequently carried away by the current.

[38] The C/N ratios of phytoplankton blooms (living cells and detritus) occurring in the Curuai floodplain ranged from 5.8 to 7.4 (Figure 7). The carbon isotopic composition of the POM (composed mainly of phytoplankton cells and detritus) during these phytoplankton blooms, which formed a scum in the surface waters, ranged from −17.68 to −22.11‰. These results differ from those reported by *Araujo-Lima et al*. [1986] for Amazonian phytoplankton (approximately −34.0 to −38.0‰) and for Orinoco phytoplankton [*Hamilton and Lewis*, 1992].

[39] The isotopic signatures of phytoplankton are determined both by the isotopic signatures of assimilated DIC [*Gu and Alexander*, 1996] and by their isotopic fractionation during assimilation [*Vuori et al*., 2006]. In general, the carbon isotope fractionation between DIC and plants is maximal when DIC is abundant relative to demand, resulting in low δ^{13}C values in aquatic vegetation. Conversely, minimum fractionation occurs when DIC concentrations are low relative to demand, which is very high during phytoplankton blooms. Assimilation is the rate-determining step in carbon consumption, resulting in higher δ^{13}C values [*Kendall et al*., 2001]. This appears to be the case in the Curuai floodplain during the blooms. During nonbloom periods in Curuai floodplain lakes, the δ^{13}C of DIC varies from approximately −11.0 to −14.0‰ (G. Abril, unpublished data). However, the δ^{13}C of DIC was approximately −5.0‰ during bloom periods (P. Alberic, unpublished data). We hypothesize that extensive phytoplankton blooms, dominated by cyanobacteria (e.g., *Microcystis*, unpublished data), occurring in the Curuai floodplain are responsible for the higher δ^{13}C values of bulk OM (due to reduced C

fractionation), lower C/N ratios and may represent from 30 to 45% of the total suspended solids present in the floodplain during these periods. However, we can also consider the possibility of carbonate assimilation when CO_2 concentrations are very low and pH is high (approximately 8.0).

[40] Consequently, if only two main sources of OM are considered (e.g., the Amazon River and the phytoplankton sources), it is possible to quantify the contribution of these two sources based on their respective carbon isotopic compositions. The contribution of different OM sources during the annual hydrological cycle can be determined using an isotopic mixing model (equations (1) and (2)) proposed by *Martinelli et al*. [2003].

$$\text{POM auto (\%)} + \text{POM amaz (\%)} = 100\% \quad (1)$$

$$\text{POM auto (\%)} = \left[\left(\delta^{13}C_{\text{sample}} - \delta^{13}C_{\text{POMamaz}}\right)/\left(\delta^{13}C_{\text{POMauto}} - \delta^{13}C_{\text{POMamaz}}\right)\right] * 100 \quad (2)$$

where POM auto (%) is the percentage contribution of *in situ* production to the floodplain suspended organic matter; POM amaz (%) is the percentage contribution of the Amazon particulate organic matter; $\delta^{13}C_{\text{sample}}$ is the sample carbon isotopic composition; $\delta^{13}C_{\text{POMauto}}$ is the carbon isotopic composition of *in situ* production (range: −21.9 to −17.7‰) during the different sampling expeditions; and $\delta^{13}C_{\text{POMamaz}}$ is the carbon isotopic composition of Amazon particulate organic matter (range: −29.3 to −27.2‰, depending on the period). The results of this mixing model (Figure S2 in the Supporting Information) reveal that OM from the Amazon dominates the floodplain POM during rising water, reaching 68 % in February. This contribution decreases progressively from 61% during high water to 48% during the early falling water period and reaches a minimum of 37% in October, when autochthonous phytoplankton sources dominate. In December, Amazon River waters begin to rise, and their contribution to OM is 55%.

[41] The C/N ratio and $\delta^{13}C$ data from the floodplain surficial sediments (Figure 7) also reveal that OM settled in the floodplains is a mixture of material from the Amazon River and the floodplain.

[42] Several studies conclude that POM transported by the Amazon River is old because soils are the main source of riverine OM [*Raymond and Bauer*, 2001a, 2001b]. Riverine POC contains a significant quantity of old, nonhydrolyzable, recalcitrant soil OM originating from soil transported to rivers via erosion [*Hedges et al.*, 1986b; *Raymond and Bauer*, 2001a]. This finding suggests that most of the POM transported by the Amazon River was fixed by terrestrial photosynthesis hundreds to thousands of years ago [*Raymond and Bauer*, 2001a]. However, recent studies in the Amazon River [e.g., *Mayorga et al*., 2005] have shown that respiration of contemporary (i.e., less than 5 yr old) OM is the dominant source of excess carbon dioxide, which drives outgassing in medium to large Amazonian rivers [*Richey et al*., 2002; *Raymond*, 2005]. This discrepancy in the ages of POM and CO_2 suggests the occurrence of two superimposed carbon cycles in the system: (i) the transport of an old, refractory POM from land to ocean with little or no degradation; and (ii) the transport and mineralization in the river of modern and labile POM, which is transformed to CO_2 and recycled into the atmosphere [*Mayorga et al*., 2005]. This latter source of labile and modern organic carbon is not well identified. *Engle et al.* [2008] note the importance of net primary production of macrophytes (*Paspalum repens* and *Echinochloa polystachya*) and showed that respiration of this carbon potentially accounts for about half (46%) of the annual CO_2 emissions from surface waters in the central Amazon. We suggest that phytoplankton decomposition and respiration in the lower Amazonian floodplains can also contribute to this labile and modern C source. Our results show that all POC samples from the Curuai floodplain were characterized by post-bomb (^{14}C enriched) OM and by high Chl-a concentrations. Extremely dense phytoplankton biomasses covered the surface of these lakes during a large part of the annual hydrological cycle. Together with phytoplankton, macrophytes [*Engle et al.*, 2008] are also a potential source of modern aquatic carbon in floodplain lakes. During falling water, this post-bomb and highly biodegradable POM produced in floodplains is exported to the Amazon mainstem, where it is then respired by bacteria and subsequently escapes to the atmosphere as modern CO_2. During rising water, floodplain lakes receive old and refractory POM from the Amazon River that is partly buried in sediments. Our $\Delta^{14}C$-POC data from the Amazon River (−195‰) are older than those (−145‰) found by *Raymond and Bauer* [2001a, 2001b]. Seasonal variations in the nature and age [*Mayorga et al*., 2005] of OM transported by the River may explain this discrepancy, but more data are needed to better understand these variations.

[43] The POM transported by the Amazon River to the Atlantic is old and ^{14}C depleted, so modern POM from the floodplains may be preferentially mineralized by bacteria in the river and exported to the atmosphere by outgassing [*Richey et al*., 2002]; thus, the age of the particulate organic matter exported to the ocean is preserved. Our ^{14}C data set is small, but our results show the discrepancies in ages between Amazon POC and floodplain POC. Future studies are needed to better understand this contribution, possible seasonal variation in the riverine age and, finally, to estimate turnover times of POM in the Amazon River.

5.3. Exchanges and Balance of TOC in Floodplain Lakes and in the Amazon River Mainstem

[44] The Curuai floodplain exchanges water and sediment with the Amazon River during a hydrological cycle [*Bonnet et al*., 2008; *Maurice-Bourgoin et al*., 2007]. At the same time, exchanges of OM occur between the Curuai floodplain lakes and the Amazon River. The nature and composition of floodplain OM can be related to the temporal pattern of Amazon River hydrology. Floodplain lakes receive OM from the river for approximately 8 months (from January to August) and supply OM to the Amazon River for approximately 8 months (from March to October). *In situ* flow measurements and the POC and DOC exchange computations demonstrate that carbon from the Amazon River reaches floodplain lakes when waters are rising and during the early maximum water level period. The DOC fraction entering the floodplain represents 75 to 85% of the TOC, which is similar to the fraction found by other studies of carbon transport in the Amazon [*Richey et al*., 1990; *Moreira-Turcq et al*., 2003b]. During these periods, considerable autotrophic activity in the floodplains is associated with increased nutrient inputs from the river and the local watershed at the

beginning of the wet season [*Perez*, 2008]. During the high and early falling water periods, the floodplain exports particulate and dissolved organic carbon to the Amazon River (Figure 8). During the low water period, these exchanges remain weak.

[45] The data and model results showed that carbon export is greater than carbon input. Moreover, *Moreira-Turcq et al*. [2004] and *Maurice-Bourgoin et al*. [2007] showed that the Curuai floodplain acts as a sediment trap. Consequently, a large portion of the particulate organic carbon exported to the river is produced *in situ*, as demonstrated by the isotopic model (Figure S2 in the Supporting Information). These results are also supported by the different carbon partitioning of outflowing OM, in which POC can represent between 30 and 50% of the TOC, thus providing strong evidence of *in situ* organic aquatic production. *Melack and Engle* [2009] observed that Calado Lake is also a net annual source of organic carbon to the river. *Engle et al*. [2008] and *Melack and Engle* [2009] observed that floating macrophytes are the dominant source of organic carbon in the lake. However, in the Curuai floodplain, phytoplankton appears to be the dominant carbon source. The Curuai and Calado floodplains are very different. Calado Lake is a dentritic lake connected to the Solimões River, with a surface area of 2 to 8 km^2. The drainage basin is an important component of this lake. Curuai is located in a dynamic region with a major riverine influence and marked hydrographic changes; it is connected annually to the Amazon River. The catchment of Curuai Lake represents only about half of the total area of the hydrological system. In the Curuai system, the influence of the local upland watershed in terms of water flux (and a fortiori in terms of OM flux) is small (approximately 6% for a normal hydrological year, *Bonnet et al*., 2008), while it is approximately 57% for the Calado system [*Lesack and Melack*, 1995]. However, the Curuai system is much more influenced by the river (more than 70% of the water balance). In addition, the morphology of the two systems is very different. While Calado Lake has a dentritic form and a narrow shape, large open lakes are present in the Curuai floodplain. Numerous studies report that wind-induced mixing is strong in this system, which is not favorable for macrophyte development.

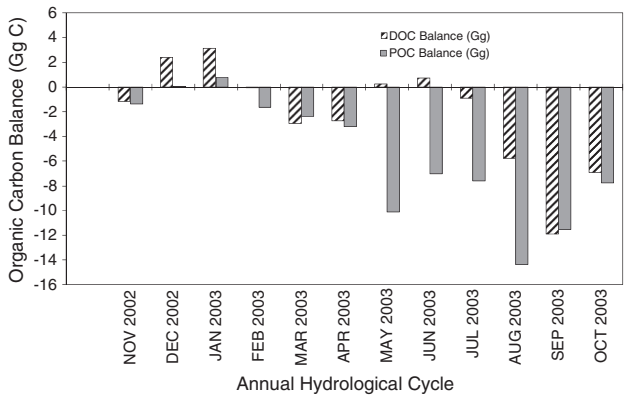

Figure 8. Monthly fluxes of particulate organic carbon (POC) and dissolved organic carbon (DOC) between the Amazon River and the floodplain system for the 2003 hydrological year. Fluxes are positive during filling of the floodplain lakes (inflow) and negative during drainage (outflow).

[46] According to our computations, the efflux of total organic carbon represents approximately 0.3% of the total carbon flux at Óbidos (estimated at 32.7 ± 3.3 Tg yr^{-1} and 36.1 Tg yr^{-1} by *Moreira-Turcq et al*., 2003b and *Richey et al*., 1990, respectively). Particulate organic carbon (POC) and dissolved organic carbon (DOC) fluxes exported by the Curuai floodplain represent 1.3% and 0.1%, respectively, of the POC and DOC annual fluxes at Óbidos, but may reach up to 3.3% and 0.8% during falling water (Table S2 in the Supporting Information). Assuming that all of the floodplains located downstream of Manaus behave similarly to the Curuai floodplain, which has an estimated area of 13,000 km^2, floodplains may contribute up to 17% and 4% of the POC and DOC fluxes passing through Óbidos. These estimates should be taken with caution because they are based on surficial concentrations. A comparison with the integrated flux [*Richey et al*., 1990] indicates that the POC contribution can be overestimated.

6. Conclusions

[47] Floodplain lakes receive OM from the Amazon River during the rising water period and export OM to the mainstem mainly during falling water. Both inflows and outflows of OM occur during high water, and no significant exchange takes place during low water. Annually, the floodplain represents a water and OM source to the Amazon River. The pool of particulate organic matter present in the floodplain is a mixture of Amazonian POM and floodplain POM, whose relative contributions vary throughout the year. At the end of the low water period and during the early rising and high water periods, the main source of OM in the floodplain is the Amazon River. In contrast, at the end of the high water period and during the falling water period, *in situ* production of POM predominates. The floodplain is also a sink for old, refractory particulate organic carbon transported by the Amazon River. The Curuai floodplain is characterized by the presence of an important pool of labile particulate organic matter, which is dominated by phytoplankton biomass. These results differ from some other Amazonian floodplains, such as Calado Lake, where the POM pool is mainly due to aquatic macrophytes.

[48] Our study reveals that floodplains play an important role as contributors of labile OM to the Amazon River. We present data on the nature, composition, and age of particulate organic matter in floodplain lakes. We note that some of this post-bomb organic matter is derived from phytoplankton photosynthesis in floodplain lakes. Finally, our study confirms that floodplains are a nonnegligible source of C for the mainstem.

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