

1 11th January 2016.

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3 Dear Editor,

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5 Attached please find the revised version of the manuscript “Temperature-dependence of
6 the relationship between $p\text{CO}_2$ and dissolved organic carbon in lakes” to be reconsidered for
7 publication in *Biogeosciences*. To address valuable criticisms from the Reviewer 4, we have
8 included here a point-by-point response with details of the actions.

9 Our main purpose remains to show that the significant global relationship between $p\text{CO}_2$
10 and DOC previously reported in lake waters is not found after including tropical ecosystems.
11 This novel finding improves our knowledge of the C cycling in inland waters, highlighting the
12 role of the latitudinal temperature gradient to increase predictability of $p\text{CO}_2$ under different
13 DOC in lakes.

14 We thank the reviewer 1 to accept the article as fit for publication, the reviewer 4 for his
15 suggestions and the editor for managing all revision process. We believe that all reviewers have
16 led to an improved manuscript, which could be suitable to be published in *Biogeosciences*.

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19 Sincerely,

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22 Luana Pinho on behalf of the co-authors

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**Interactive comment on “Temperature-dependence of the relationship
between $p\text{CO}_2$ and dissolved organic carbon in lakes” by L. Pinho et al.**

Response to Anonymous Referee #4

1) Comments from referee #4

General comments

The manuscript by Pinho et al set out to examine the effect of temperature on the relationship between $p\text{CO}_2$ and dissolved organic carbon (DOC) in lake waters. $p\text{CO}_2$ data were collected from 194 Brazilian lakes in low-latitude and tropical regions in South American. The authors found no significant correlation between $p\text{CO}_2$ and DOC in low-latitude lakes, which is different from those observed in temperate regions. They then concluded the temperature dependence of the $p\text{CO}_2$ and DOC relation. However, this work is solely based on the comparison with those reported by Sobek et al. (2005). No further discussion was made in the manuscript.

Author’s response:

First, we would like to thank the referee #4 for the very constructive comments.

In the larger dataset already published in the literature, Sobek et al. [2005] analyzed 4902 lakes globally distributed (CO_2 data), but only one warm tropical lake with $p\text{CO}_2$ and DOC data. Our aim was to add new data and insights after including warm-low latitude tropical lakes in global compilations.

Now, we have better discussed our results with those reported in other regional reviews on high-latitude lake waters (e.g. Larsen et al 2010, Lapierre and Del Giorgio 2012).

Lines 213 to 219:

The text now reads:

In this way, the inclusion of warm tropical data in our study revealed novel increases in the variability of the DOC- $p\text{CO}_2$ relationship in lakes over the latitudinal gradient. One explanation for this pattern is that even similar DOC concentrations, representing the total pool of DOC, may show different mixtures between origins from aquatic primary producers and terrestrial sources [Kritzberg et al., 2006]. The autochthonous DOC (i.e. produced in the lake) is related to the net CO_2 uptake [Staehr and Sand Jansen 2007], while the allochthonous DOC (i.e. produced in the catchment) is resource to the net CO_2 release in lake waters [Sobek et al., 2007].”

First of all, DOC is not the only parameter regulating the $p\text{CO}_2$ abundance in the water column. Depending on the sources of DOC, $p\text{CO}_2$ could be positively or negatively correlated with DOC when DOC is mostly derived from terrestrial input or mostly produced in situ. Secondly,

temperature could be a master parameter affecting $p\text{CO}_2$ abundance only when all other environmental settings, biological, chemical and physical parameters, remain the same. Now, the question is then “so what” and why $p\text{CO}_2$ has to be correlated with DOC or why temperature has to be a factor affecting this correlation?

Author’s response:

Our study design does not allow testing causes of the non-significant relationship found between DOC and $p\text{CO}_2$. However, we agree with suggestions from the reviewer to improve discussion, and included the following sentences:

Lines 220 to 225:

The text now reads:

“The increased DOC release from aquatic primary producers into waters under tropical conditions, especially warmer annual conditions and higher solar incidence, can offset any positive relationship between $p\text{CO}_2$ and the terrestrial DOC that subsidizes the net aquatic heterotrophy [Marotta et al., 2010; 2012]. This contributes to explain non-significant relationships reported here (Figure 3), suggesting a temperature dependence of the DOC- $p\text{CO}_2$ relationship in global lakes”

Most importantly, instead of using DIC, their $p\text{CO}_2$ data were derived from total alkalinity, which includes additional contributions from dissolved organic ligands (DOC), but was not even mentioned or corrected. Overestimation of TA values cannot be ignored when DOC concentration is high especially in lake waters (up to >100 ppm in some samples, see Fig. 2). Therefore, $p\text{CO}_2$ reported in this manuscript could be questionable.

Overall, I suggest that the authors exploit their data set further, teasing out different factors that could regulate $p\text{CO}_2$, and produce additional meaningful conclusions.

Author’s response:

We agree and had corrected the potential contribution of DOC to total alkalinity (TA), using data reported in Abril et al (2015). This point was clarified in the main text and supplementary information.

The text now reads:

Lines 151 to 156:

“In order to address the potential contribution of DOC to TA, which is especially important in DOC-enriched acid freshwaters, we used the data set from Abril et al., [2015] to correct $p\text{CO}_2$ values calculated from pH and TA after the corrections for temperature, altitude and ionic strength [Cole et al., 1994]. Full details on fitted regression equations to

117 correct $p\text{CO}_2$ in function of the DOC and pH are described in the supplementary
118 information section. (Figure S3).”

119
120

121 Lines 179 to 190:

122 “The same absence of positive significance pattern was found comparing at
123 corrected data. Negative (Linear regression, $p < 0.05$, $R^2 = 0.02$, $p\text{CO}_2 = -95.96 (\pm 39.89) \times$
124 $\text{DOC} + 6526 (\pm 640.7)$ or non significant (Linear regression, $p > 0.05$) DOC- $p\text{CO}_2$
125 relationship for tropical lakes ($N = 194$, DOC and pH corrected, respectively (figure S3a
126 and c) contrasting with a significant positive relationship for those at other latitudes ($N =$
127 $4,433$) (Linear regression, $p < 0.05$, $R^2 = 0.20$, $p\text{CO}_2 = 80.24 (\pm 2.36) \times \text{DOC} + 721.6 (\pm 24.10)$
128 for DOC corrected data and $R^2 = 0.12$, $p\text{CO}_2 = 45.70 (\pm 1.84) \times \text{DOC} + 623.7 (\pm 18.83)$ for
129 pH corrected data, respectively) (Figure S3b and d, full details on corrections in the
130 supplementary information).”

131

132 Supplementary information: “In order to correct the potential contribution of organic
133 acids on $p\text{CO}_2$ values, we used the linear relationship between DOC concentrations and the
134 log of difference of calculated and measured $p\text{CO}_2$ from Abril et al. 2015; (for both
135 variables were used medians, Supplementary Figure 1). The same procedure was
136 performed between pH and the log of difference of calculated and measured $p\text{CO}_2$
137 (Supplementary Figure 2). Using both equations, we corrected each $p\text{CO}_2$ value used in
138 Figure S3”

139

140 Figure S3: “The relationship between $p\text{CO}_2$ values and DOC concentrations for surface
141 lake waters after correcting the contribution of organic acids on TA and
142 subsequent $p\text{CO}_2$ data for the low latitude lakes (a and c) and Sobek lakes (b and d). The
143 fitted linear regression of the relative difference between calculated and measured $p\text{CO}_2$
144 with ranked DOC (a and b) and pH (c and d) according Abril et al. 2015. A non-significant
145 linear regression was observed for pH corrected data of low-latitude lakes (figure S3c, $p >$
146 0.05 , $n = 194$). The solid line represents the fitted linear regression for negative relationship
147 between $p\text{CO}_2$ values and DOC concentrations for DOC corrected data of low-
148 latitude lakes (Linear regression, $p < 0.05$, $R^2 = 0.03$, $n = 194$, $p\text{CO}_2 = -98.76 (\pm 39.92) \times$

149 DOC + 6529 (\pm 641.1), Figure S3a) and positive relationship between $p\text{CO}_2$ values and
150 DOC concentrations for other latitudes showed in Sobek's data (Linear regression, $p <$
151 0.05 , $R^2 = 0.20$, $p\text{CO}_2 = 64.43 (\pm 2.04) \times \text{DOC} + 625.1 (\pm 20.87)$ and $R^2 = 0.12$, $p\text{CO}_2 = 45.70 (\pm$
152 $1.84) \times \text{DOC} + 623.8 (\pm 18.83)$) for DOC corrected data and pH corrected data (S3c and
153 S3d, respectively, $N = 4,433$ for both).”

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157 Specific comments:

158 Methods: The authors should add more detailed information on the methods, such as QA&QC
159 for DOC and total alkalinity measurements, including the use of certified reference materials and
160 the diluted HCl for titration.

161

162 Author's response: We agree and change the sentence.

163

164 The text now reads:

165 Lines 136 to 138:

166 “pH was determined using a pH meter (Digimed – DM2) with reference standards certified
167 by Mettler Toledo (4.00 ± 0.01 and 7.00 ± 0.01 units) before each sampling hour.”

168

169 Lines 146 to 148:

170 “In the lab, DOC was determined by high-temperature catalytic oxidation using a TOC-
171 5000 Shimadzu Analyzer, quality control was checked with calibration curve made with
172 potassium hydrogen phthalate before each sample battery analysis.”

173

174 2. Line 152-153: Delete the repeated equation.

175 2. Author's response: We agree and corrected the equation.

176

177 The text now reads:

178 Lines 179 to 190: “The same absence of positive significance pattern was found comparing
179 at corrected data. Negative (Linear regression, $p < 0.05$, $R^2 = 0.02$, $p\text{CO}_2 = -95.96 (\pm 39.89) \times$
180 $\text{DOC} + 6526 (\pm 640.7)$ or non significant (Linear regression, $p > 0.05$) DOC- $p\text{CO}_2$
181 relationship for tropical lakes ($N = 194$, DOC and pH corrected, respectively (figure S1a
182 and c) contrasting with a significant positive relationship for those at other latitudes ($N =$
183 $4,433$) (Linear regression, $p < 0.05$, $R^2 = 0.20$, $p\text{CO}_2 = 80.24 (\pm 2.36) \times \text{DOC} + 721.6 (\pm 24.10)$
184 for DOC corrected data and $R^2 = 0.12$, $p\text{CO}_2 = 45.70 (\pm 1.84) \times \text{DOC} + 623.7 (\pm 18.83)$ for
185 pH corrected data, respectively) (Figure S1 b and d, full details on corrections in the
186 supplementary information). The range of $p\text{CO}_2$ for a similar DOC range in Brazilian lakes
187 was larger than that reported by Sobek et al., [2005] for the dataset dominated by high-
188 latitude cold lakes, despite the number of lakes in their dataset being much larger (more
189 details in supplementary information section, figure S1).”

190

191

192 3. Line 152-153: Is this equation applicable to all DOC concentrations or for a specific range of
193 DOC concentrations?

194
195 **3.Author's response: We clarified the sentence and rewrote the paragraph as cited above.**

196
197 4. Line 220-224: High temperature and solar radiation may increase primary production and the
198 uptake of CO₂, resulting in a negative correlation between pCO₂ and DOC assuming DOC is
199 positively related to biomass or Chl-a. However, if the degradation of terrestrial DOC prevails in
200 lake waters under high temperature/solar radiation, could pCO₂ be positively correlated to
201 terrestrial DOC?

202
203 **4.Author's response:**
204 **We rewrote the sentence.**

205
206 **The text now reads:**

207 **Lines 213 to 225: "In this way, the inclusion of warm tropical data in our study**
208 **revealed novel increases in the variability of the DOC-*p*CO₂ relationship in lakes over the**
209 **latitudinal gradient. One explanation for this pattern is that even similar DOC**
210 **concentrations, representing the total pool of DOC, may show different mixtures between**
211 **origins from aquatic primary producers and terrestrial sources [Kritzberg et al., 2006].**
212 **The autochthonous DOC (i.e. produced in the lake) is related to the net CO₂ uptake [Staehr**
213 **and Sand Jansen 2007], while the allochthonous DOC (i.e. produced in the catchment) is**
214 **resource to the net CO₂ release in lake waters [Sobek et al., 2007]. The increased DOC**
215 **release from aquatic primary producers into waters under tropical conditions, especially**
216 **warmer annual conditions and higher solar incidence, can offset any positive relationship**
217 **between *p*CO₂ and the terrestrial DOC that subsidizes the net aquatic heterotrophy [Marotta**
218 **et al., 2010; 2012]. This contributes to explain non-significant relationships reported here**
219 **(Figure 3), suggesting a temperature dependence of the DOC-*p*CO₂ relationship in global**
220 **lakes."**

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227 Temperature-dependence of the relationship between $p\text{CO}_2$ and dissolved organic carbon in
228 lakes

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247

248 Abstract

249 **The relationship between the partial pressure of carbon dioxide ($p\text{CO}_2$) and dissolved**
250 **organic carbon (DOC) concentration in Brazilian lakes, encompassing 194 lakes across a**
251 **wide latitudinal range in the tropics, was tested. Unlike the positive relationship reported**
252 **for lake waters, which was largely based on temperate lakes, we found no significant**

Luana Queiroz Pinho 11/1/16 14:14

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Eliminado: 4. Faculty of Marine Sciences, King
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Jeddah, Saudi Arabia. ... [1]

relationship for low-latitude lakes ($< 33^{\circ}$), despite very broad ranges in both $p\text{CO}_2$ and DOC levels. These results suggest substantial differences in the carbon cycling of low latitude lakes, which must be considered when up scaling limnetic carbon cycling to global scales.

1. Introduction

Lakes cover less than 2% of the continent's surface [Downing et al., 2006; McDonald, 2012] but play a significant role in the global carbon (C) cycle [Cole et al., 1994; 2007; Tranvik et al., 2009], contributing significantly to C burial and emissions to the atmosphere [Cole et al., 2007; Downing et al., 2008 and Tranvik et al., 2009]. Dissolved organic carbon (DOC) represents a major C pool in lakes, with both autochthonous and allochthonous contributions [Duarte and Prairie, 2005; Cole et al., 2007; Prairie 2008; Tranvik et al., 2009], supporting heterotrophy [Sobek et al., 2007] and affecting key biological and physico-chemical processes involved in C cycling [Steinberg et al., 2006]. Large inputs of terrestrial organic C and its subsequent mineralization have been suggested to be a major driver of CO_2 supersaturation commonly encountered in lakes [Duarte and Prairie, 2005; Cole et al., 2007; Prairie 2008; Marotta et al., 2009].

The mechanistic connection between DOC and heterotrophic CO_2 production is believed to underpin the significant positive relationship between $p\text{CO}_2$ and DOC reported in comparative analyses [Houle, 1995; Sobek et al., 2005; Larsen et al., 2012]. However, recent analyses have revealed that the relationship between $p\text{CO}_2$ and DOC in lake waters is regionally variable and not universal [Lapierre and del Giorgio, 2012]. Hence, the relationship between $p\text{CO}_2$ and DOC reported in comparative analyses based on datasets dominated by temperate and high-latitude lakes ($> 33^{\circ}$) may not be extrapolated for all types of lakes, mainly because the tropical low latitude lakes ($< 33^{\circ}$) are generally underrepresented in global datasets [Raymond et al., 2013].

One priority of comparative studies is the latitudinal variance, where lake temperature, ice cover and mixing regime will differ and these climatically driven processes, in turn, should strongly influence OC cycling [Hanson et al., 2015]. At low latitudes, warm conditions over the whole year may increase the metabolic rates involved in the C cycling in terrestrial [Ometto et al., 2005] and aquatic [Marotta et al., 2009; 2010] ecosystems on an annual basis compared to the high latitude lakes. High temperatures affect heterotrophic activity and the associated

290 mineralization rates of organic matter in soils [Davidson et al., 2006], waters [López-Urrutia et
291 al., 2007; Wohlers et al., 2008; Regaudie-de-Gioux and Duarte 2012] and aquatic sediments
292 [Wadham et al., 2012; Gudas et al., 2010; Marotta et al., 2014]. Enhanced heterotrophic activity
293 in warm ecosystems would support high aquatic CO₂ production and subsidize high CO₂ evasion
294 from global lake water to the atmosphere.

295 The largest previous comparative analysis already published in the literature for global lake
296 waters [Sobek et al., 2005] reported a significant positive relationship between DOC and *p*CO₂
297 and a non-significant variation of *p*CO₂ among lakes with changing temperature. However, both
298 analyses were characterized by a paucity of low latitude data. A strong positive relationship
299 between temperature and *p*CO₂ was observed when subtropical and tropical ecosystems were
300 included in the dataset [Marotta et al., 2009], likely caused by the potential increase in metabolic
301 rates under warmer conditions [Brown et al., 2004; López-Urrutia et al., 2006]. Hence, the
302 relationship between lake *p*CO₂ and DOC could also be temperature-dependent and, therefore,
303 may differ between temperate and tropical lakes. The extensive low latitude territory of Brazil,
304 which has a high density of lakes and ponds [Downing et al., 2006], is appropriate to examine
305 general patterns in the tropics [e.g., Marotta et al., 2009; Kosten et al., 2010]. Here, we test the
306 applicability of the relationship between *p*CO₂ and DOC using inputs derived from a high
307 latitude dataset [Sobek et al., 2005] with added tropical and subtropical data of low latitude lakes
308 from Brazil.

309

310 2.Methods

311 2.1.Study area and Lakes

312 Brazil extends from 5° 16' 20" North to 33° 44' 42" South, showing an area of
313 approximately 8,547,000 km², constituting half of South America and encompasses a high
314 diversity of low-latitude landscapes [Ab'Saber, 2003] that are predominantly located within
315 tropical latitudes. We conducted a survey of pH, alkalinity and DOC between 2003 and 2011 in
316 surface waters of 166 permanent lakes from 0 to 33° of south latitude across Brazil (Figure 1),
317 yielding a total of 225 water samples. The lakes were sampled in representative biomes of Brazil:
318 (1) the Amazonia Forest (Amazonia Biome, n = 65), (2) the Pantanal Floodplain (Pantanal
319 Biome, n = 29) and (3) the Tropical (< 24° of latitude) and (4) Subtropical (> 24° and < 33° of
320 south latitude) Coasts, both in the Atlantic Forest Biome (n = 35 and n = 37 lakes, respectively;

321 Figure 1). These biomes follow the classification of the Brazilian Institute of Geography and
322 Statistics for biomes (IBGE 2004,
323 ftp://geofpt.ibge.gov.br/mapas_tematicos/mapas_murais/biomas.pdf). Our dataset encompasses a
324 broad inter-lake heterogeneity (n=166) for pH, alkalinity and DOC simultaneously sampled
325 among Brazilian biomes and along the latitudinal gradient, independent of the year's season.

326 The Amazonian Forest biome is formed by the most extensive hydrographic network on the
327 globe: the Amazon River basin, which occupies a total area of approximately 6.11 million km²
328 from its headwaters in the Peruvian Andes to its mouth in the Atlantic Ocean (ANA –
329 www.ana.gov.br). The Amazon Forest is the Brazilian biome with the highest mean annual
330 precipitation (approximately 2200 mm) and has warm mean air temperatures, approximately
331 25°C, high cloud coverage and high humidity with low fluctuations over the whole year
332 [Chambers, 1999]. We sampled a wide variety of lakes, characteristic of different areas of the
333 Amazonian Forest, encompassing “clear” (low DOC and suspended solids), “white” (low DOC
334 and high suspended solids) and “dark” (high DOC and low suspended solids) lakes.

335 The Pantanal Floodplain is the world's largest tropical freshwater wetland, extending
336 across an area of approximately 150,000 km² between 16° and 20° S and 58° and 55° W [Por,
337 1995]. The annual average temperature and precipitation are approximately 22°C and 1,000 mm,
338 respectively [Mariot et al., 2007], with a strong seasonality and subsequent variation in the
339 flooded area [Junk and Nunes da Cunha, 2005]. The high-water period occurs during the rainy
340 summer (usually from September to December), and low waters typically occur during the dry
341 winter (from March to July) [Hamilton, 2002].

342 The Atlantic Forest biome extends along a broad latitudinal belt, between 5° and 30° S
343 from the subtropics to tropics and a narrow longitudinal section between 55° and 56° W, and
344 occupies an area of 1.11 million km² along the Brazilian coast (IBGE-www.ibge.gov.br). This
345 biome is characterized by numerous shallow coastal lakes receiving high inputs of refractory
346 organic matter [Farjalla et al., 2009] derived from the typical open xerophytic vegetation on
347 sandy soils, where water retention is low [Scarano, 2002]. The mean air temperatures vary from
348 27°C in winter to 30°C in summer at the tropical coast [$< 24^\circ$ of latitude; Chellappa et al., 2009]
349 and from 17 and 20°C at the subtropical coast [$> 24^\circ$ of latitude; Waechter, 1998]. The mean
350 annual precipitation reaches 1,164 mm [Henriques et al., 1986] and 1,700 mm [Waechter, 1998]
351 in the tropical and subtropical Brazilian coast, respectively. This biome is also characterized by
352 strong seasonality, with rainy summers and dry winters [Chellappa et al., 2009].

353

354 2.2 Sampling Design and Analytical Methods

355 Our sampling design encompassed the most representative Brazilian biomes from tropical
356 and subtropical coastal areas to tropical and subtropical forests (Amazon and Atlantic Forest)
357 and inland wetlands (Pantanal), with the intra-lake heterogeneity and seasonal fluctuations
358 randomly assessed and further integrated by means of each ecosystem. To analyze the
359 relationship between $p\text{CO}_2$ and DOC in tropical lake waters, we joined data on 194 lakes ($< 33^\circ$
360 of latitude) with both variables sampled at the same time, including 166 data samples from our
361 own survey and 28 from the literature compilation (Table S1). The values reported here
362 represented, gathered in an opportunistic manner, represent daily averages ($N= 4$ or 5 samples)
363 for a given year's season or/and one sampling time over different seasons, which were also both
364 integrated by means of each lake. To test the global importance of the relationship between $p\text{CO}_2$
365 and DOC, we added our low latitude data (225) to the Sobek et al. [2005] dataset (4902 lakes) as
366 this dataset had a paucity of tropical ecosystem data (148 tropical lakes, but only one with $p\text{CO}_2$
367 and DOC sampled at the same time).

368 pH, salinity and temperature were measured *in situ*. pH was determined using a pH meter
369 (Digimed – DM2) with reference standards certified by Mettler Toledo (4.00 ± 0.01 and $7.00 \pm$
370 0.01 units) before each sampling hour. Temperature and salinity were measured using a
371 Thermosalinometer (Mettler Toledo - SevenGo SG3) coupled to a probe in Lab 737 previously
372 calibrated with 0.01 M KCl. Surface lake water was collected for total alkalinity and DOC
373 analyses, taking care to avoid bubbles at approximately 0.5 m of depth using a 1 L Van Dorn
374 bottle. Total alkalinity (TA) was determined in the field by the Gran's titration method with
375 0.0125 M HCl immediately after sampling [Stumm and Morgan, 1996]. Water samples for DOC
376 were pre-filtered ($0.7 \mu\text{m}$, Whatman GF/F) and preserved by acidification with 85% H_3PO_4 to
377 reach a $\text{pH} < 2.0$ in sealed glass vials [Spyres et al., 2000]. In the lab, DOC was determined by
378 high-temperature catalytic oxidation using a TOC-5000 Shimadzu Analyzer, checked with a
379 calibration curve made with xxx before each analysis. $p\text{CO}_2$ concentrations in surface waters
380 were calculated from pH and alkalinity following Weiss [1974], after corrections for
381 temperature, altitude and ionic strength according to Cole et al. [1994].

Luana Queiroz Pinho 7/1/16 17:21

Eliminado: a precision of 0.01 calibrated with standard solutions (Mettler Toledo) of pH 4.01 and 7.00 units

Luana Queiroz Pinho 6/1/16 14:02

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386 In order to address the potential contribution of DOC to TA, which is especially
387 important in DOC-enriched acid freshwaters, we used the data set from Abril et al., [2015]
388 to correct $p\text{CO}_2$ values calculated from pH and TA after the corrections for temperature,
389 altitude and ionic strength [Cole et al., 1994]. Full details on fitted regression equations to
390 correct $p\text{CO}_2$ in function of the DOC and pH are described in the supplementary
391 information section, (Figure S3).

392 2.3. Statistical Analyses

393 The variables $p\text{CO}_2$ and DOC did not meet the assumptions of parametric tests even after
394 logarithmic transformations [Zar, 1996] as the data were not normally distributed (Kolmogorov-
395 Smirnov, $p < 0.05$) and the variances were heterogeneous (Bartlett, $p > 0.05$). Therefore, we used
396 medians and non-parametric tests to compare these variables among biomes (Kruskal-Wallis
397 followed by Dunn's multiple comparison post hoc test, $p < 0.05$). The linear regression equations
398 were fitted to compare our results with those of previous studies from Sobek et al., [2005].
399 Statistical analyses were performed using the software Graphpad Prism version 4.0 for
400 Macintosh (GraphPad Software, San Diego, CA).

401 3. Results

402 The lake waters surveyed were warm across all biomes (median 25-75% interquartile
403 range = 27.5°C , $25.2 - 30.1$) but colder in subtropical coastal lakes (23.4°C , $20.0 - 26.2$) than in
404 Pantanal and Amazonian lakes (29.5°C , $27.7 - 31.4$ and 29.4°C , $27.6 - 31.0$, respectively;
405 Dunn's test, $p < 0.05$, Figure 2a). DOC concentrations were consistently high (6.3 mg C L^{-1} , 4.3
406 $- 11.9$) for all Brazilian biomes but significant lower in the Amazonian Forest (3.8 mg C L^{-1} , 2.7
407 $- 5.8$) than in the tropical coast (13.4 mg C L^{-1} , $6.1 - 32.8$; Figure 2b; Dunn's test, $p < 0.05$).
408 Most lakes (approximately 83% of raw data) showed surface waters supersaturated in CO_2
409 relative to the atmospheric equilibrium ($p\text{CO}_2$ in atmospheric equilibrium is $400.83\text{ }\mu\text{atm}$, 2015
410 annual mean; data available in www.esrl.noaa.gov/gmd/ccgg/trends), with much higher $p\text{CO}_2$
411 values in Amazonian lakes ($7,956\text{ }\mu\text{atm}$, $3,033 - 11,346$) than in subtropical coastal lakes (900
412 μatm , $391.3 - 3,212$; Figure 2c; Dunn's test, $p < 0.05$).

413 The $p\text{CO}_2$ in the surface waters of Brazilian lakes was independent of DOC
414 concentrations (Linear regression for raw data, $p > 0.05$, Figure 3). The same absence of
415 positive significance pattern was found comparing at corrected data. Negative Linear

Luana Queiroz Pinho 5/1/16 15:12

Eliminado: We used additional corrections to address concerns about $p\text{CO}_2$ calculated from pH and TA (Gran titration) especially in low salinity or highly organic enriched DOC lake waters, even after corrections for temperature, altitude and ionic strength [Cole et al., 1994]. From the dataset of

Luana Queiroz Pinho 5/1/16 15:12

Eliminado: Abril et al. [2015], we calculated fitted regression equations for the median pH or DOC and respective % of $p\text{CO}_2$ corrections ($\text{Log } p\text{CO}_2 \text{ correction (\%)} = -0.9638 * \text{pH} + 7.755$; $R^2 = 0.9752$, $p < 0.005$; $\text{Log } p\text{CO}_2 \text{ correction (\%)} = -0.9638 * \text{pH} + 7.755$; $R^2 = 0.9752$, $p < 0.005$). Statistical analyses were performed using raw and corrected data

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Eliminado: according to Tans and Keeling 2014

432 regression, $p < 0.05$, $R^2 = 0.03$, $n = 194$, $p\text{CO}_2 = -98.76 (\pm 39.92) \times \text{DOC} + 6529 (\pm 641.1)$ or non
 433 significant (Linear regression, $p > 0.05$) DOC- $p\text{CO}_2$ relationship for tropical lakes ($N = 194$,
 434 DOC and pH corrected, respectively (figure S3a and c) contrasting with a significant
 435 positive relationship for those at other latitudes ($N = 4,433$) (Linear regression, $p < 0.05$, $R^2 =$
 436 0.20 , $p\text{CO}_2 = 64.43 (\pm 2.04) \times \text{DOC} + 625.1 (\pm 20.87)$) for DOC corrected data and $R^2 = 0.12$,
 437 $p\text{CO}_2 = 45.70 (\pm 1.84) \times \text{DOC} + 623.8 (\pm 18.83)$ for pH corrected data, respectively) (Figure
 438 S3 b and d, full details on corrections in the supplementary information). The range of $p\text{CO}_2$
 439 for a similar DOC range in Brazilian lakes was larger than that reported by Sobek et al., [2005]
 440 for the dataset dominated by high-latitude cold lakes, despite the number of lakes in their dataset
 441 being much larger (more details in supplementary information section, figure S3).

442 4. Discussion

444 The Brazilian lakes sampled here were characterized by a prevalence of CO_2
 445 supersaturation, consistent with general trends previously reported for global lakes [e.g.,
 446 Raymond et al., 2013; Cole et al., 1994; 2007], including those at tropical latitudes [Marotta et al.,
 447 2009]. The very high $p\text{CO}_2$ levels observed here, with a median of 900 and 8,300 μatm for
 448 subtropical and Amazon lake waters, respectively, are consistent with those reported previously
 449 for the Amazon River and tributaries (2,000-12,000 μatm ; Richey et al., [2002]), Amazon
 450 floodplain lakes (3,000 - 4,898 μatm ; Rudorff et al., [2012]), Pantanal lakes and wetlands (2,732-
 451 10,620 μatm ; Hamilton et al., [1995]), and coastal lakes (768 - 9,866 μatm ; Kosten et al., [2010];
 452 361-20,037 μatm ; Marotta et al., [2010]) and for global values for tropical lakes (1,255-35,278
 453 μatm ; Marotta et al., [2009]), reservoirs (1,840 μatm ; Aufdenkampe et al., [2011]) and wetlands
 454 (3,080-6,170 μatm ; Aufdenkampe et al., [2011]).

455 The non-significant or weakly negative relationship (Figure S3) between DOC and $p\text{CO}_2$
 456 reported here for warm low-latitude lakes contrasted with significant positive relationships
 457 derived from previous datasets dominated by high-latitude lakes [Houle, 1995; Prairie et al.,
 458 2002; Jonsson et al., 2003; Sobek et al., 2005; Roehm et al., 2009; Lapiere and del Giorgio,
 459 2012; Larsen et al., 2012]. The results presented show that warm low-latitude lakes range widely
 460 in $p\text{CO}_2$, reaching very high and low values, but tend to have comparatively more uniform DOC
 461 concentrations (Figure 3). More intense metabolic processes that uptake and release CO_2 in lake
 462 waters, respectively autotrophy and heterotrophy, could determine an enhanced variability in lake
 463 $p\text{CO}_2$ with decreasing latitude [Marotta et al., 2009].

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Eliminado: After correcting our data and the Sobek data with the contribution of organic acids on total alkalinity (TA) and subsequent $p\text{CO}_2$ data, using the fitted linear regression for the median values of the relative difference between calculated and measured $p\text{CO}_2$ with pH, both groups continued with the same pattern observed before (not a significant relationship for Tropical data ($p > 0.05$, $n = 194$) and a positive relationship for the Sobek dataset ($p\text{CO}_2 = 45.70 (\pm 1.84) \times \text{DOC} + 623.7 (\pm 18.83)$, $R^2 = 0.12$, $p < 0.0001$, $n = 4433$), figure S2 a and b).

We also calculated the DOC- $p\text{CO}_2$ relationship for two separate groups ($\text{DOC} > \text{ and } < 10 \text{ mg L}^{-1}$), and the observed pattern was the same. We found non-significant relationships between DOC and $p\text{CO}_2$ using all data or only the data from low latitude ($< 33^\circ$) lakes (linear regression, $p > 0.05$), and we found significant positive linear regressions for those at high latitudes ($> 33^\circ$) in each DOC group, despite low R^2 values ($R^2 = 0.08$ and 0.03 , $p < \dots$ [2]

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Eliminado: We also calculated the DOC- $p\text{CO}_2$ two separate groups ($\text{DOC} > \text{ and } < 10 \text{ mg L}^{-1}$) [3]

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In this way, the inclusion of warm tropical data in our study revealed novel increases in the variability of the DOC- $p\text{CO}_2$ relationship in lakes over the latitudinal gradient. One explanation for this pattern is that even similar DOC concentrations, representing the total pool of DOC, may show different mixtures between origins from aquatic primary producers and terrestrial sources [Kritzberg et al., 2006]. The autochthonous DOC (i.e. produced in the lake) is related to the net CO_2 uptake [Staehr and Sand Jansen 2007], while the allochthonous DOC (i.e. produced in the catchment) is resource to the net CO_2 release in lake waters [Sobek et al., 2007]. The increased DOC release from aquatic primary producers into waters under tropical conditions, especially warmer annual conditions and higher solar incidence, can offset any positive relationship between $p\text{CO}_2$ and the terrestrial DOC that subsidizes the net aquatic heterotrophy [Marotta et al., 2010; 2012]. This contributes to explain non-significant relationships reported here (Figure 3), suggesting a temperature dependence of the DOC- $p\text{CO}_2$ relationship in global lakes.

In conclusion, the finding that $p\text{CO}_2$ does not increase with DOC concentration in Brazilian tropical lakes rejects the hypothesis that DOC serves as a universal predictor for $p\text{CO}_2$ in lake waters [Larsen et al., 2012]. Even discounting a possible artifact of the method that could be causing an overestimation in the values of $p\text{CO}_2$ or considering the contribution of organic acids on the alkalinity, the pattern of no relationship between DOC and $p\text{CO}_2$ in the Tropical lakes was strongly confirmed (Figure S3). Therefore, our results contributing to fill the tropical gap suggest potentially important latitudinal differences for depositional aquatic environments, whose causes still need to be better addressed to improve accuracy of global C cycle models.

Authors Contribution

All authors contributed to the study design, data interpretation and preparation or refinement of the manuscript. L. P. and H. M. performed the sampling and sample analyses.

Acknowledgments

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Luana Queiroz Pinho 8/1/16 14:05

Eliminado: Tropical conditions based on higher annual temperatures and solar incidence typically

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Eliminado: increase the aquatic primary productivity activity [Paerl and Huisman 2008] that releases into waters the DOC produced by the CO_2 uptake of algae and submerged plants [Staehr and Sand Jansen 2007], which can withstand a negative variation in the $p\text{CO}_2$ with an increase in the DOC concentration [Marotta et al., 2010; 2012; Hanson et al., 2015]. The contrasting non-significant or weak negative relationship between $p\text{CO}_2$ and DOC in warm Brazilian lakes observed here, with respect to the positive relationship for cold lake waters from the dataset of Sobek al. [2005], suggests a temperature dependence of the $p\text{CO}_2$ and DOC correlation in global lakes.

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Eliminado: Despite the limitations of our methodology, our work contributes data to the literature from tropical lakes that is frequently missing from global calculations.

595 from FAPERJ (Programa Jovem Cientista do Nosso Estado), and a research grant from CNPq

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597 References

598 Abril, G., Bouillon, S., Darchambeau, F., Teodoru, C., Marwick, T., Tammooh, F., Ochieng
599 Omengo, F., Geeraert, N., Deirmendjian, L., Polsenaere, P., and Borges, A.: Large
600 overestimation of $p\text{CO}_2$ calculated from pH and alkalinity in acidic, organic-rich freshwaters.
601 Biogeoscience, 12, 67-78, 2015.

602 Ab'Saber, A.: Os Domínios de Natureza no Brasil: Potencialidades paisagísticas, Ateliê editorial
603 Brazil, 2003.

604 Aufdenkampe, A., Mayorga, E., Raymond, P., Melack, J. and Doney, S.: Riverine coupling of
605 biogeochemical cycles between land, oceans, and atmosphere, Front. Ecol. Environ., 9, 1, 53-60,
606 2011.

607 Brow, J., Gillooly, J., Allen, A., Savage, V., West, G.: Toward a metabolic theory of ecology,
608 Ecology, 85 (7), 1771-1789, 2004.

609 Chambers, J., Higuchi, N., Schimel, J., Ferreira, L. and Melack, J.: Decomposition and carbon
610 cycling of dead trees in tropical forests of the central Amazon, Oecologia, 122, 380-388, 1999.

611 Chellappa, N., Câmara, F. and Rocha, O.: Phytoplankton community: indicator of water quality
612 in the Armando Ribeiro Gonçalves Reservoir and Pataxó Channel, Rio Grande do Norte, Brazil,
613 Braz. J. Biol., 69, 241-251, 2009.

614 Cole, J. J., Caraco, N. F., Kling, G. W. and Kratz, T. K.: Carbon-Dioxide Supersaturation in the
615 Surface Waters of Lakes, Science, 265, 1568-1570, 1994.

616 Cole, J. J., Prairie, Y. T., Caraco, N. F., McDowell, W. H., Tranvik, L. J., Striegl, R. G., Duarte,
617 C. M., Kortelainen, P., Downing, J. A., Middelburg, J. J. and Melack, J.: Plumbing the global
618 carbon cycle: Integrating inland waters into the terrestrial carbon budget, Ecosystems, 10, 171-
619 184, 2007.

620 Davidson, E. and Janssens, I.: Temperature sensitivity of soil carbon decomposition and
621 feedbacks to climate change, Nature, 440, doi:10.1038/nature04514, 2006.

622 Downing, J.A., Prairie, Y.T., Cole, J.J., Duarte, C.M., Tranvik, L.J., Stiegl, R.G., McDowell,
623 W.H., Kortelainen, P., Caraco, N.F., Melack, J.M. and Middleburg, J.: The global abundance and
624 size distribution of lakes, ponds, and impoundments, Limnol. Oceanogr., 51, 2388-2397, 2006.

Luana Queiroz Pinho 8/1/16 13:59

Eliminado: Algesten, G., Sobek, S., Bergstrom, A., Jonsson, A., Tranvik, L. and Jansson, M.: Contribution of sediment respiration to summer CO_2 emission from low productive boreal and subarctic lakes, Microb. Ecol., 50, 529-535, 2005. [↗](#)

Luana Queiroz Pinho 8/1/16 11:36

Eliminado: Barreto, W.: Interpretation of Seasonal Variation of Metals and Abiotic Properties in a Tropical Lake Using Multivariate Analysis, Anal. Sci., 21 (3), 209-214, 2005. [↗](#)

634 Downing, J. A., Cole, J. J., Middelburg, J. J., Striegl, R. G. and Duarte, C. M.: Sediment organic
 635 carbon burial in agriculturally eutrophic impoundments over the last century, *Glob. Biogeochem.*
 636 *Cy.*, 22, GB1018, doi:10.1029/2006GB002854, 2008.
 637 Duarte, C. M. and Prairie, Y. T.: Prevalence of heterotrophy and atmospheric CO₂ emissions
 638 from aquatic ecosystems, *Ecosystems*, 8, 862-870, 2005.
 639 Farjalla, V. F., Amado, A. M., Suhett, A. L., and Meirelles-Pereira, F.: DOC removal paradigms
 640 in highly humic aquatic ecosystems, *Environm. Sci. and Pol. Res.* 16, 531-538, 2009.
 641 Gudas, C., Bastviken, D., Steger, K., Premke, K. and Sobek, S.: Temperature-controlled organic
 642 carbon mineralization in lake sediments, *Nature*, 466, 478- 481, 2010.
 643 Hamilton, S. K., Sippel, S.J. and Melack, J.M.: Oxygen depletion and carbon dioxide and
 644 methane production in waters of the Pantanal wetland of Brazil. *Biogeochem.* 30, 115-141, 1995.
 645 Hamilton, S. K., Sippel S. J. and Melack, J. M.: Comparison of inundation patterns among major
 646 South American floodplains, *Journ. of Geophysic. Res.*, 107, D20, 8038,
 647 doi:10.1029/2000JD000306, 2002.
 648 Hanson, P., Pace, M., Carpenter, C., Cole, J. and Stanley, E.: Integrating Landscape Carbon
 649 Cycling: Research Needs for Resolving Organic Carbon Budgets of Lakes, *Ecosystems*, DOI:
 650 10.1007/s10021-014-9826-9, 2015.
 651 Henriques, R.P.B., Araújo, D.S.D. and Hay, J.D.: Descrição e classificação dos tipos de
 652 vegetação da restinga de Carapebús, Rio de Janeiro. *Rev. Bras. Bot.* 9: 173 – 189, 1986.
 653 Houle, D., Carigan, R., Lachance, M. and DuPont, J.: Dissolved organic carbon and sulfur in
 654 southwestern Québec lakes: Relationships with catchment and lake properties, *Limnol.*
 655 *Oceanogr.*, 40, 710-710, 1995.
 656 Jonsson, A., Karlsson, J. and Jansson, M.: Sources of carbon dioxide supersaturation in
 657 clearwater and humic lakes in Northern Sweden, *Ecosystems*, 6, 224-235, 2003.
 658 Junk, W. J. and Nunes de Cunha, C.: Pantanal: a large South American wetland at a crossroads,
 659 *Ecol. Eng.*, 24, 391- 401, 2005.
 660 [Kritzberg, E., Cole, J., Pace, M. and Granéli, W.: Bacterial growth on allochthonous carbon in](#)
 661 [humic and nutrient-enriched lakes: Results from whole-lake ¹³C addition experiments,](#)
 662 [Ecosystems, 9, 489-499, 2006.](#)
 663 Kosten, S., Roland, F., Da Motta Marques, D., Van Nes, E., Mazzeo, N., Sternberg, L., Scheffer,
 664 M. and Cole, J.: Climate-dependent CO₂ emissions from lakes, *Glob. Biogeochem.Cy.*, 24,
 665 doi:10.1029/2009GB003618, 2010.

666 Lapierre, J. F. and del Giorgio, P. A.: Geographical and environmental drivers of regional
 667 differences in the lake $p\text{CO}_2$ versus DOC relationship across northern landscapes,
 668 Biogeosciences., 117, G03015, doi: 10.1029/2012JG001945, 2012.
 669 Larsen, S., Andersen, T. and Hessen, D.: The $p\text{CO}_2$ in boreal lakes: Organic carbon as a
 670 universal predictor?, Glob. Biogeochem. Cy., 25, GB2012, doi:10.1029/2010GB003864, 2012.
 671 López-Urrutia, Á. and Morán, X. A. G.: Resource limitation of bacterial production distorts the
 672 temperature dependence of oceanic carbon cycling, Ecology, 88, 817–822, 2007.
 673 Mariot, M., Dudal, Y., Furian, S., Sakamoto, A., Valles, V., Valls, V., Fort, M. and Barbiero, L.:
 674 Dissolved organic matter fluorescence as a water-flow tracer in the tropical wetland of Pantanal
 675 of Nhecolândia, Brazil, Sci. Total Environ., 388, 184-193, 2007.
 676 Marotta, H., Duarte, C. M., Sobek, S. and Enrich-Prast, A.: Large CO_2 disequilibria in tropical
 677 lakes, Glob. Biogeochem. Cy., 23, doi:10.1029/2008GB003434, 2009.
 678 Marotta, H., Duarte, C. M., Pinho, L. and Enrich-Prast, A.: Rainfall leads to increased $p\text{CO}_2$ in
 679 Brazilian coastal lakes, Biogeosciences, 7, 1607-1614, 2010.
 680 Marotta, H., Duarte, C.M., Guimarães-Souza, B. and Enrich-Prast, A.: 2012 Synergistic control
 681 of CO_2 emissions by fish and nutrients), Oecologia, 168, 3, 839-847, 2012.
 682 Marotta, H., Pinho, L. Gudas, C., Bastviken, D., Tranvik, L. and Enrich-Prast, A.: Greenhouse
 683 gas production in low-latitude lake sediments responds strongly to warming, Nat. Clim. Change,
 684 4, 467-470, 2014.
 685 McDonald, C., Rover, J., Stets, E. and Striegl, R.: The regional abundance and size distribution
 686 of lakes and reservoirs in the United States and implications for estimates of global lake extent,
 687 Limnol. Oceanogr., 57, 597-606, 2012.
 688 Ometto, J. P. H. B., Nobre, A., Rocha, H., Artaxo, P. and Martinelli, L.: Amazonia and the
 689 modern carbon cycle: lessons learned, Oecologia, 143, 483-500, 2005.
 690 Prairie, Y.: The summer metabolic balance in the epilimnion of southeastern Quebec lakes,
 691 Limnol. and Oceanogr., 47, 1, 316-321, 2002.
 692 Prairie, Y. T.: Carbocentric limnology: looking back, looking forward, Canadian Journal of
 693 Fisheries and Aquatic Sci., 65(3), 543-548, 2008.
 694 Raymond, P., Hartmann, J., Lauerwald, R., Sobek, S., McDonald, C., Hoover, M., Butman, D.,
 695 Striegl, R., Mayorga, E., Humborg, C., Kortelainen, P., Durr, H., Meybeck, M., Ciais, P. and
 696 Guth, P.: Global carbon dioxide emissions from inland waters. Nature, 503, 355- 359, 2013.
 697 Regaudie-de-Gioux A and Duarte C.M.: Temperature dependence of planktonic metabolism in

Luana Queiroz Pinho 8/1/16 11:49

Eliminado: Paerl, H. and Huisman, J., Blooms like it hot, Science, 320, 57-58, 2008. -

700 the ocean, Glob. Biogeochem. Cycles, 26, GB1015, 2012.

701 Richey, J. E., Melack, J. M., Aufdenkampe, A. K., Ballester, V. M., and Hess, L. L.: Outgassing
 702 from Amazonian rivers and wetlands as a large tropical source of atmospheric CO₂, Nature,
 703 416(6881), 617–620, 2002.

704 Roehm, C., Prairie, Y. T. and del Giorgio, P.: The pCO₂ dynamics in lakes in the boreal region of
 705 northern Québec, Canada, Global Biogeochem. Cy., 23, GB3013, doi:10.1029/2008GB00329,
 706 2009.

707 Rudorff, C. M., Melack, J. M.; MacIntyre, S.; Barbosa, C. C. F.; and Novo, E. M. L. M.:
 708 Seasonal and spatial variability of CO₂ emission from a large floodplain lake in the lower
 709 Amazon, J. Geophys. Res., 117, G01002, doi: 10.1029/2011JG001699, 2012.

710 Scarano, F.: Structure, function and floristic relationships of plant communities in stressful
 711 habitats marginal to the Brazilian Atlantic rainforest, Annals of botan., 90, 4, 517-524., 2002.

712 Stumm, W. and Morgan, J. J.: Aquatic chemistry: chemical equilibria and rates in natural waters,
 713 vol 3. Wiley, New York, 1996.

714 Sobek, S., Tranvik, L. J. and Cole, J. J.: Temperature independence of carbon dioxide
 715 supersaturation in global lakes, Global Biogeochem. Cy., 19, GB2003,
 716 doi:10.1029/2004GB002264, 2005.

717 Sobek, S., Tranvik, L. J. and Cole, J. J.: Patterns and regulation of dissolved organic carbon: An
 718 analysis of 7,500 widely distributed lakes, 2007.

719 Spyres, G., Nimmo, M., Worsfold, P., Achterberg, E., Miller, A.: Determination of dissolved
 720 organic carbon in seawater using high temperature catalytic oxidation techniques, Trends in
 721 Analytic Chem., 19, 8, 498-506, 2000.

722 Staehr, P. and Sand-Jansen, K.: Temporal dynamics and regulation of lake metabolism, Limnol.
 723 and Oceangr. 52 (1), 108-110, 2007.

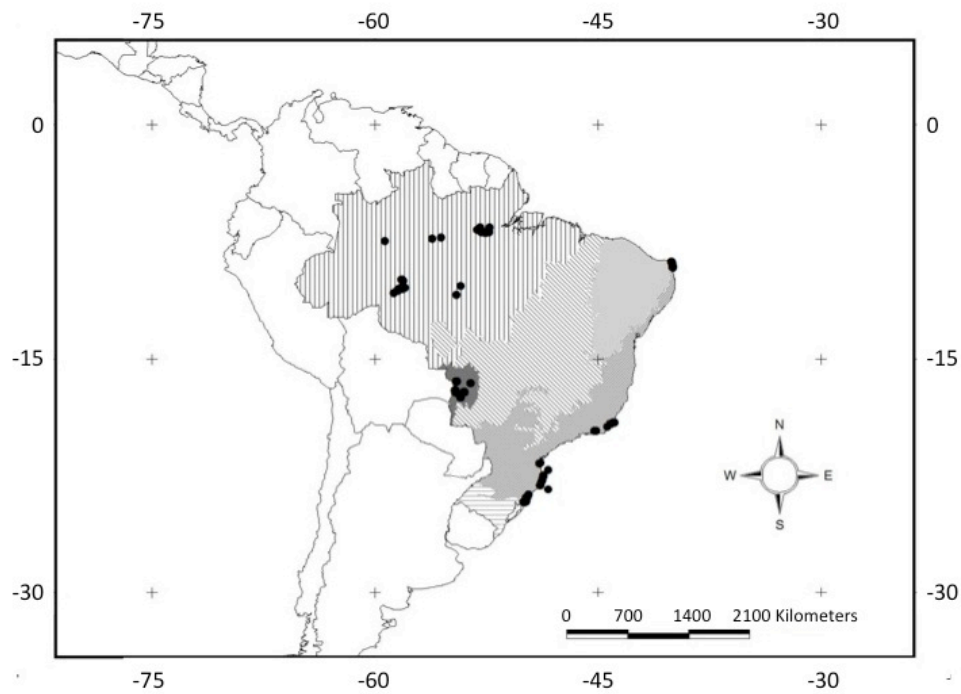
724 Steinberg, C. E. W., Kamara, S., Prokhotskaya, V., Manusadzianas, L., Karasyova, T.,
 725 Timofeyev, M., Jie, Z. Paul, A., Meinelt, T., Farjalla, V., Matsuo, A., Burnison, B. and Menzel,
 726 R.: Humic substances in the environment with an emphasis on freshwater systems, Environm.
 727 Sci. Pollut. Res. Int., 15, 15-16, 2006.

728 Tranvik, L.J., Downing, J.A., Cotner, J.B., Loiselle, S.A., Striegl, R.G., Ballatore, T.J., Dillon,
 729 P., Finlay, K., Fortino, K., Knoll, L.B., Kortelainen, P.L., Kutser, T., Larsen, S., Laurion, I.,
 730 Leech, D.M., McCallister, S.L., McKnight, D.M., Melack, J.M., Overholt, E., Porter, J.A.,
 731 Prairie, Y., Renwick, W.H., Roland, F., Sherman, B.S., Schindler, D.W., Sobek, S., Tremblay,

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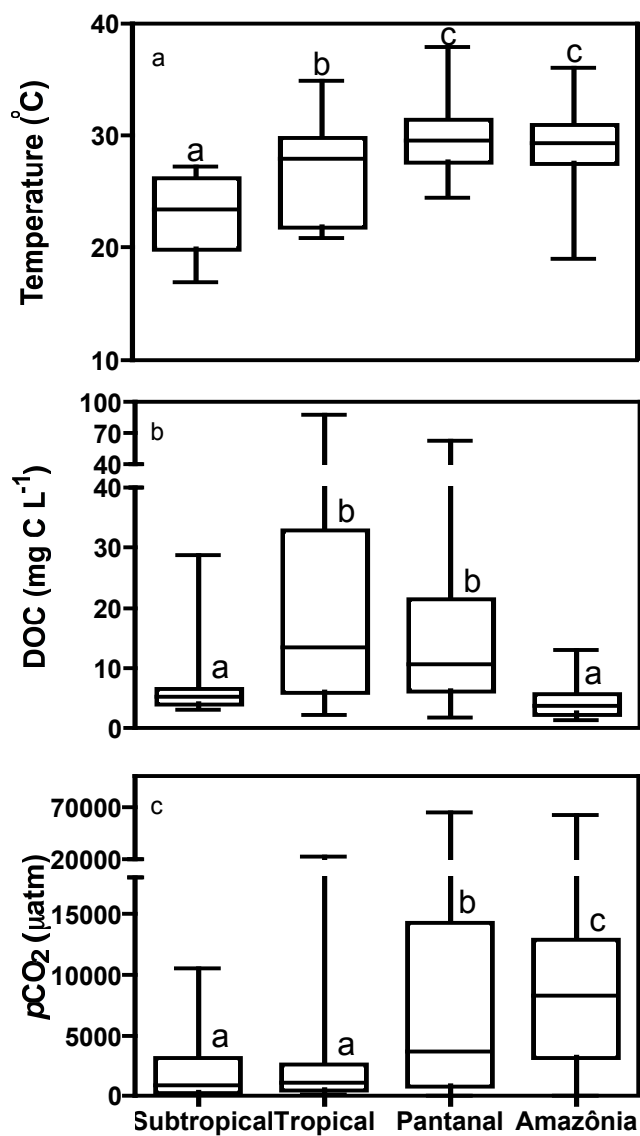
Luana Queiroz Pinho 8/1/16 11:53
Eliminado: Tans, P. and Keeling, R.: Trends in
 Atmospheric Carbon Dioxide. National Oceanic and
 Atmospheric Administration Earth System Research
 Laboratory Global Monitoring Division; Scripps
 Institution of Oceanography.
<http://www.esrl.noaa.gov/gmd/ccgg/trends/>.
 (Accessed 19.05.15).

739 A., Vanni, M.J., Verschoor, A.M., von Wachenfeldt, E. and Weyhenmeyer, G.A.: Lakes and
 740 reservoirs as regulators of carbon cycling and climate. *Limnol. Oceanogr.*, 54, 2298-2314, 2009.
 741 Wadham, J., Arndt, S., Tulaczyk, S., Stibal, M., M. Tranter, M., Telling, J., Lis, G., Lawson, E.,
 742 Ridgwell, A., Dubnick, A., Sharp, M., Anesio, A. and Butler, C.: Potential methane reservoirs
 743 beneath Antarctica, Potential methane reservoirs beneath Antarctica, *Nature*, 488, 633-637, 2012.
 744 Waechter, J. L.: Epiphytic orchids in eastern subtropical South America. *Proc. 15th World Orchid*
 745 *Conference. Naturalia Publications*, pp. 332-341, 1998.
 746 Weiss, R. F.: Carbon Dioxide in water and seawater: The solubility of non-ideal gas, *Mar.*
 747 *Chem.*, 2, 203-215, 1974.
 748 Wohlers, J., Engel, A., Zollner, E., Breithaupt, P., Jurgens, K., Hoppe, H., Sommer, U. and
 749 Riebesell, U.: Changes in biogenic carbon flow in response to sea surface warming. *PNAS*,
 750 106,17, 7067-7072, 2008.
 751 Zar, J. H.: *Biostatistical analysis*, 3 ed., Prentice Hall., New Jersey, 1996.
 752
 753
 754 Figures and subtitles



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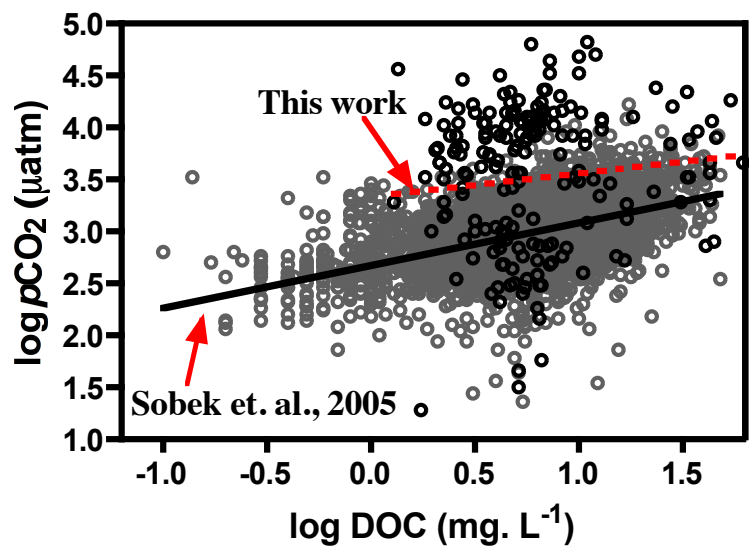
756 Figure 1. Geographic location of Brazilian lakes sampled in different biomes (IBGE 2004,
 757 available in ftp://geofp.ibge.gov.br/mapas_tematicos/mapas_murais/biomas.pdf): Amazonia
 758 Forest (vertical lines), Pantanal Floodplain (dark gray), and Atlantic Forest (gray; Tropical and
 759 Subtropical costal lakes).



760

761 Figure 2. Values of (A) temperature (°C), (B) DOC concentrations (mg C L⁻¹) and (C) pCO₂
 762 concentration (μatm) of Brazilian lakes sampled from different biomes, as defined by (SUBT)
 763 Subtropical Coastal lakes (n = 37), (TROP) Tropical coastal lake (n = 63), (PANT) Pantanal

764 Floodplain (n = 58) and (AMAZ) Amazonia Forest (n = 67). The line depicts the median. The
 765 boxes show the quartiles, and the whiskers mark the 10th and 90th percentiles. Different
 766 lowercase letters near the boxplot indicate significant statistic differences between the groups
 767 (Kruskall-Wallis followed by Dunn's multiple comparison post hoc test, p < 0.05).



768 -
 769 Figure 3. Comparisons of *p*CO₂ against DOC concentrations for lakes from this study (black
 770 circles) and from Sobek et al. [2005] (gray circles). Each point in the plot represents one
 771 measurement. The dashed line represents the linear regression for all Brazilian data points (not
 772 significant; p > 0.05), and the solid line represents the linear regression from Sobek et al. [2005]
 773 (p < 0.05, R² = 0.26, log pCO₂ (µatm) = 2.67 + 0.414 log DOC (mg C L⁻¹)).

Luana Queiroz Pinho 7/1/16 15:06
 Eliminado ; R² = 0.26; p < 0.05