GHG emissions from African lakes and headwaters of the Amazon River

Alberto Borges

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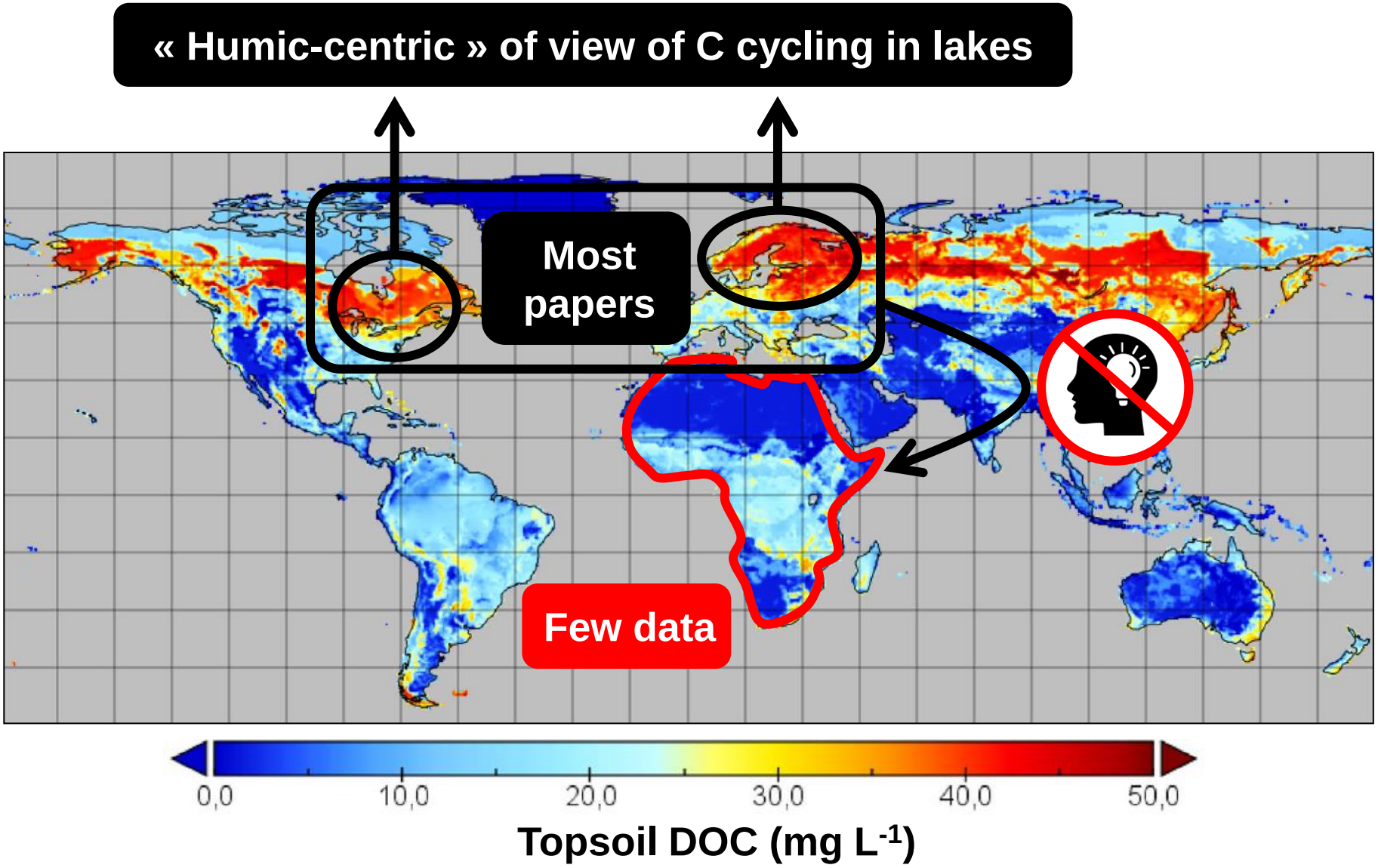
Introduction

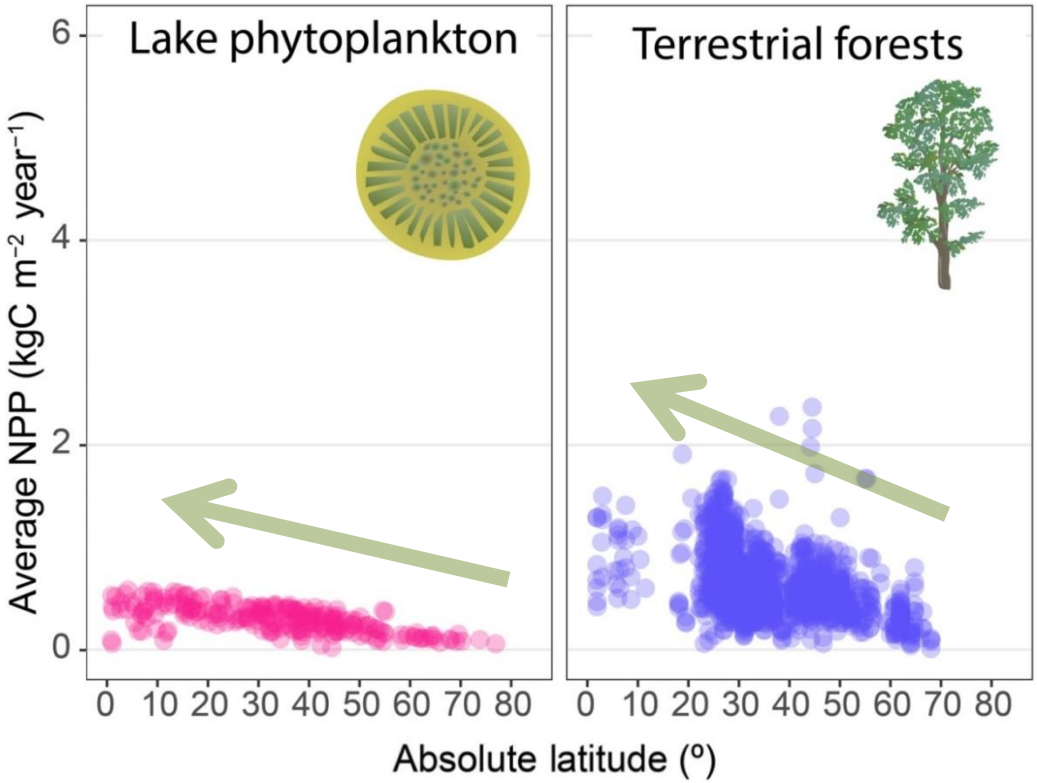


Langeveld et al. (2020)
doi: 10.1007/s42452-020-03290-0

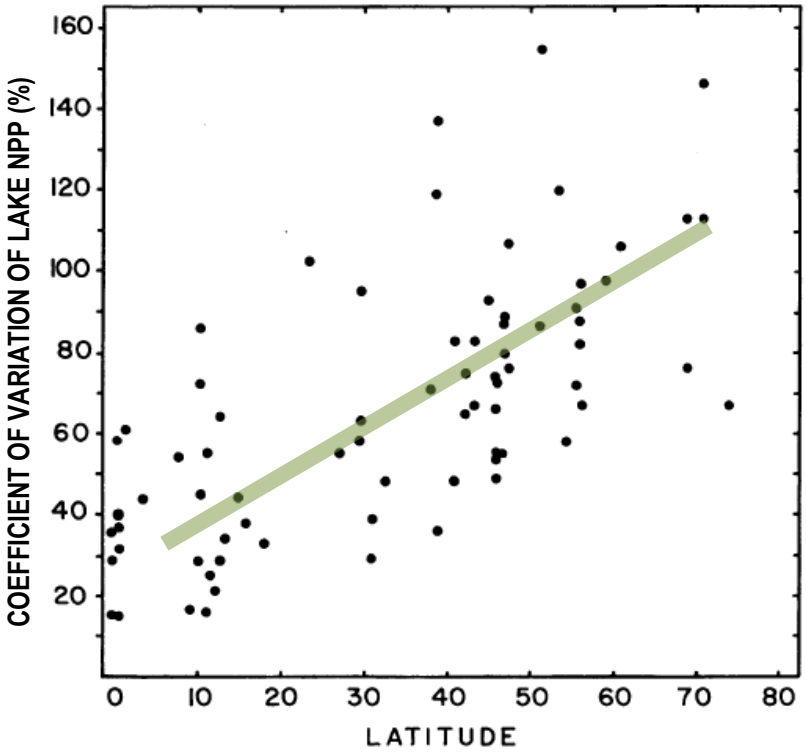
Introduction

Why tropical lakes ?

- Warm (obviously) and productive
- Primary production less variable seasonally



Pessarrodona et al. (2022)
doi: 10.1126/sciadv.abn2465



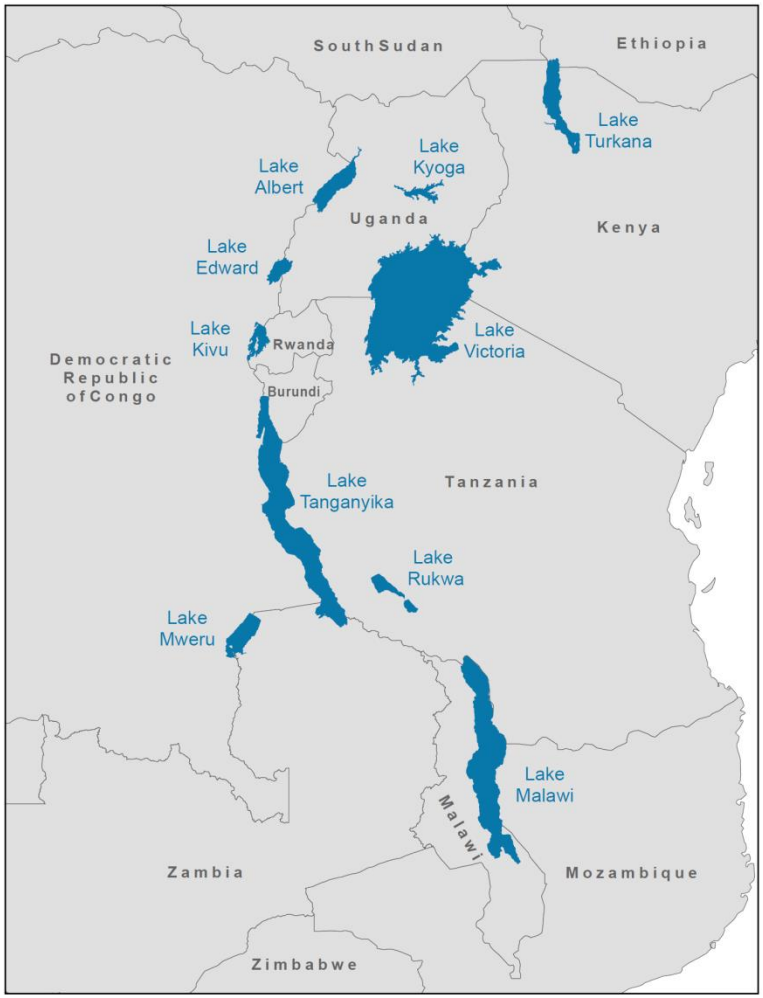
Melack (1979)
doi: 10.1007/BF00346388

African lakes

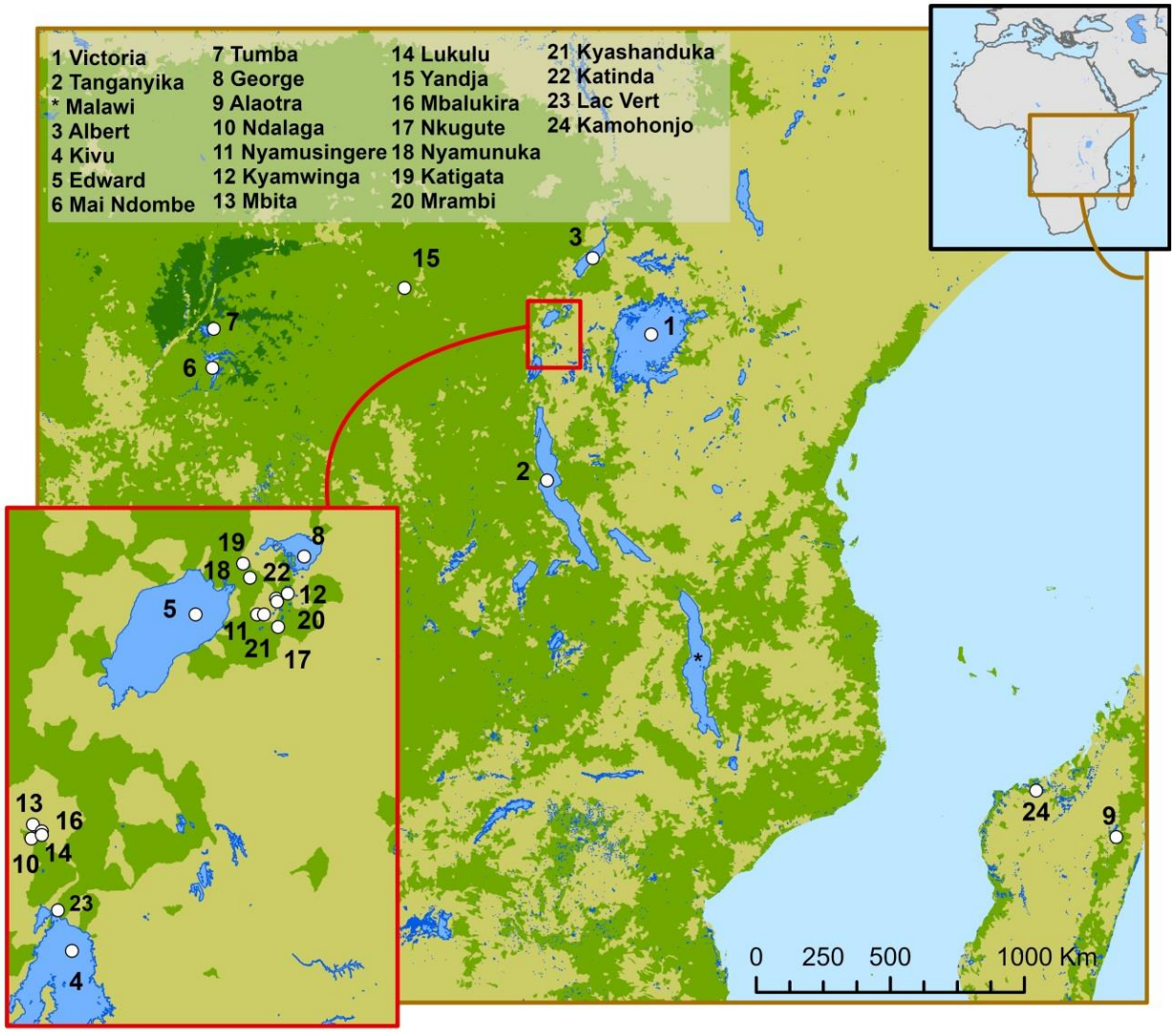
Why Africa ?

Biggest concentration of large lakes after Laurentian Great Lakes

66% of the total surface area of tropical lakes (>0.1 km^2)



African lakes



Land cover

Flooded forest
Rain forest
Savannah

Surface area

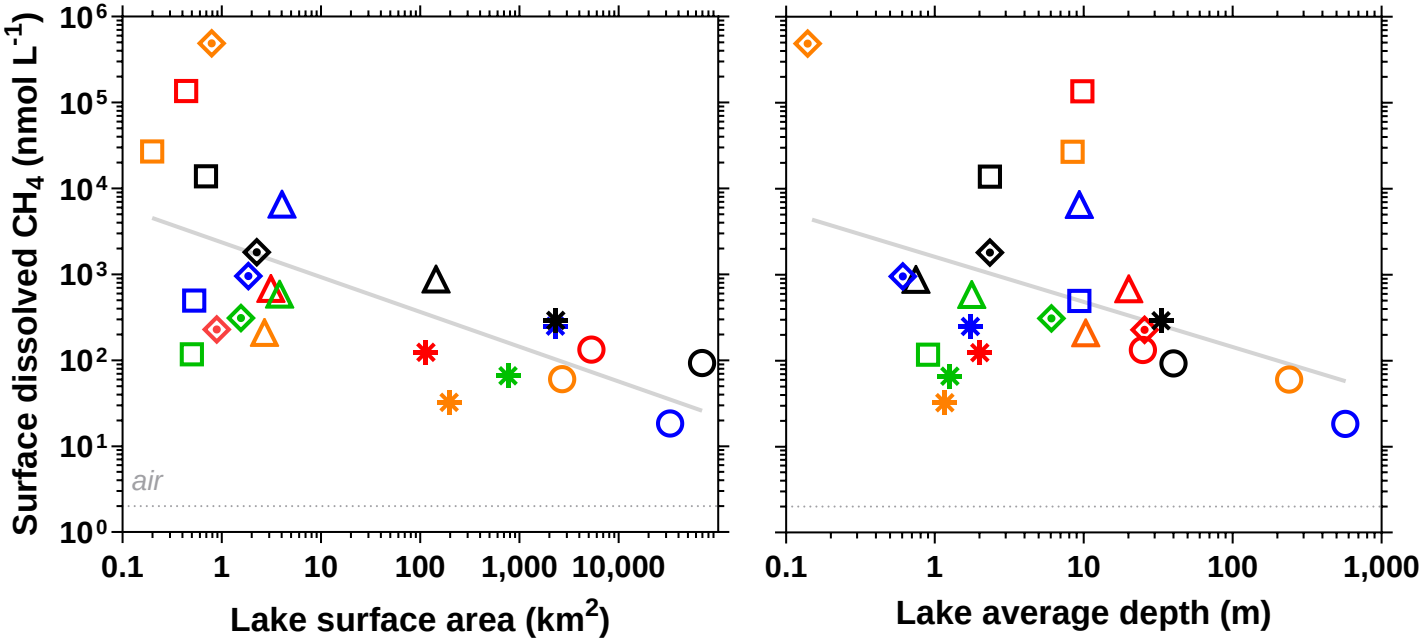
Victoria 67,000 km^2
Lac Vert 0.2 km^2

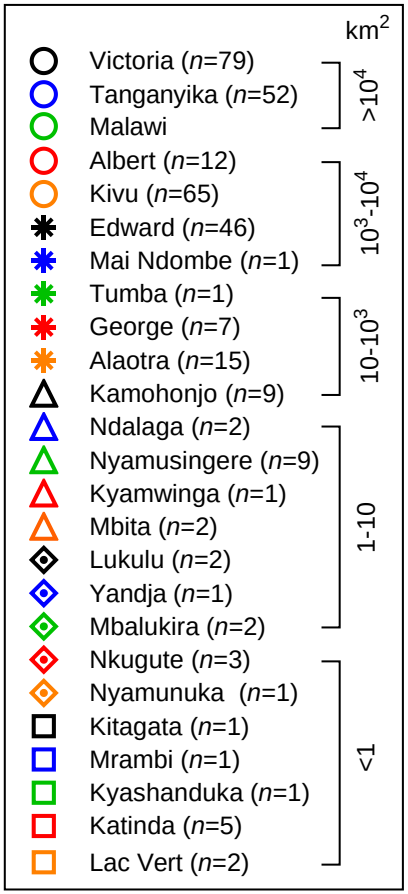
Max depth

Tanganyika 1,470 m
Nyamunuka 0.1 m

Borges et al. (2022) https://doi.org/10.1126/sciadv.abi8716

Surface CH_4 in African lakes

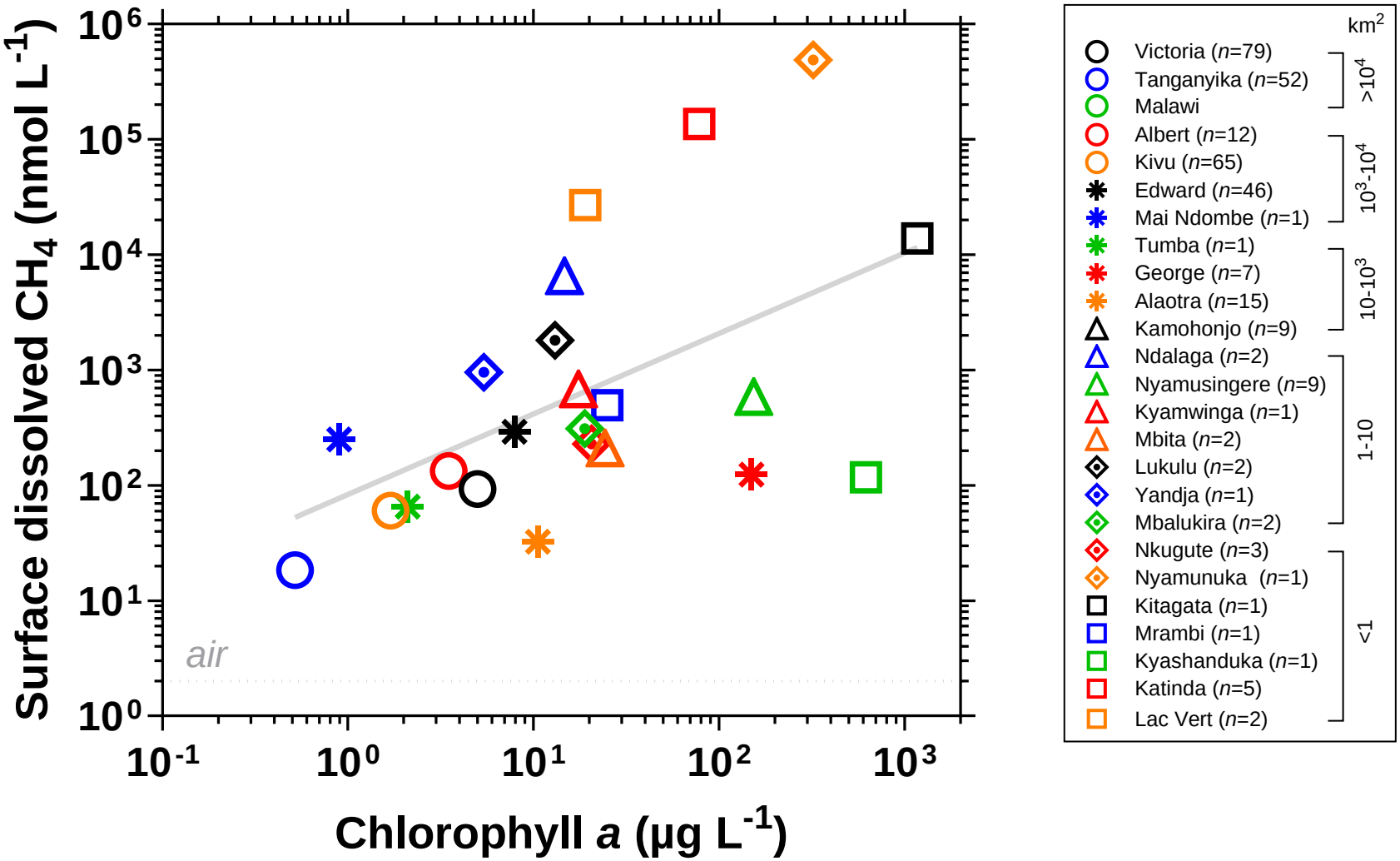




Borges et al. (2022) https://doi.org/10.1126/sciadv.abi8716

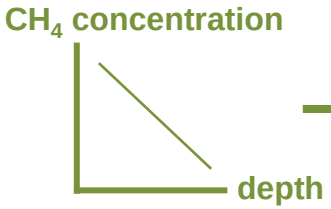
African lakes

Surface CH_4 in African lakes



Borges et al. (2022) https://doi.org/10.1126/sciadv.abi8716

Upscaling diffusive CH_4 emissions in African lakes



HydroLAKES → CH_4 concentration in individual lakes

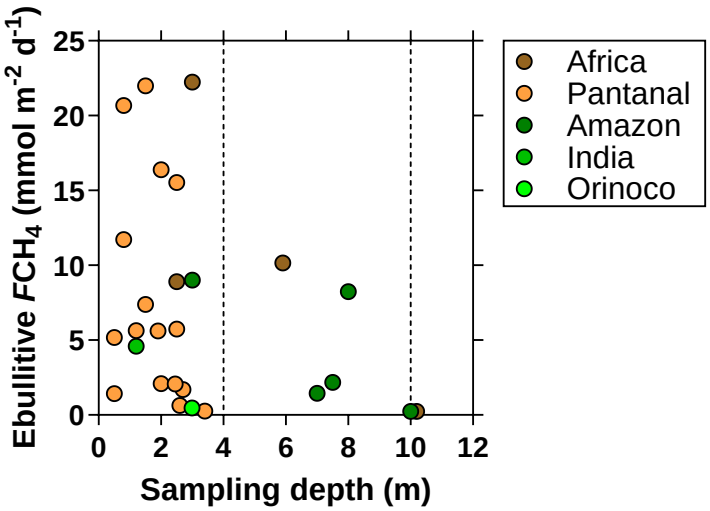
WorldClim wind → Cole & Caraco (98) Gas transfer velocity in individual lakes

CH_4 concentration in individual lakes + Cole & Caraco (98) Gas transfer velocity in individual lakes → Diffusive CH_4 emissions in individual lakes (m^{-2})

HydroLAKES + Diffusive CH_4 emissions in individual lakes (m^{-2}) → Total diffusive CH_4 emissions ($TgCH_4\ yr^{-1}$)

Borges et al. (2022) doi: 10.1126/sciadv.abi8716

African lakes



Upscaling ebullitive CH_4 emissions in African lakes

Depth 0-4m : CH_4 ebullition = 5.7 mmol m^{-2} d^{-1}
Depth 4-10m : CH_4 ebullition = 5.2 mmol m^{-2} d^{-1}
Depth >10m : CH_4 ebullition = 0 mmol m^{-2} d^{-1}

Depth 0-4m : Surface area of individual lake
Depth 4-10m : Surface area of individual lake
Depth >10m : Surface area of individual lake

→ Total ebullitive CH_4 emissions

↑ HydroLAKES ←

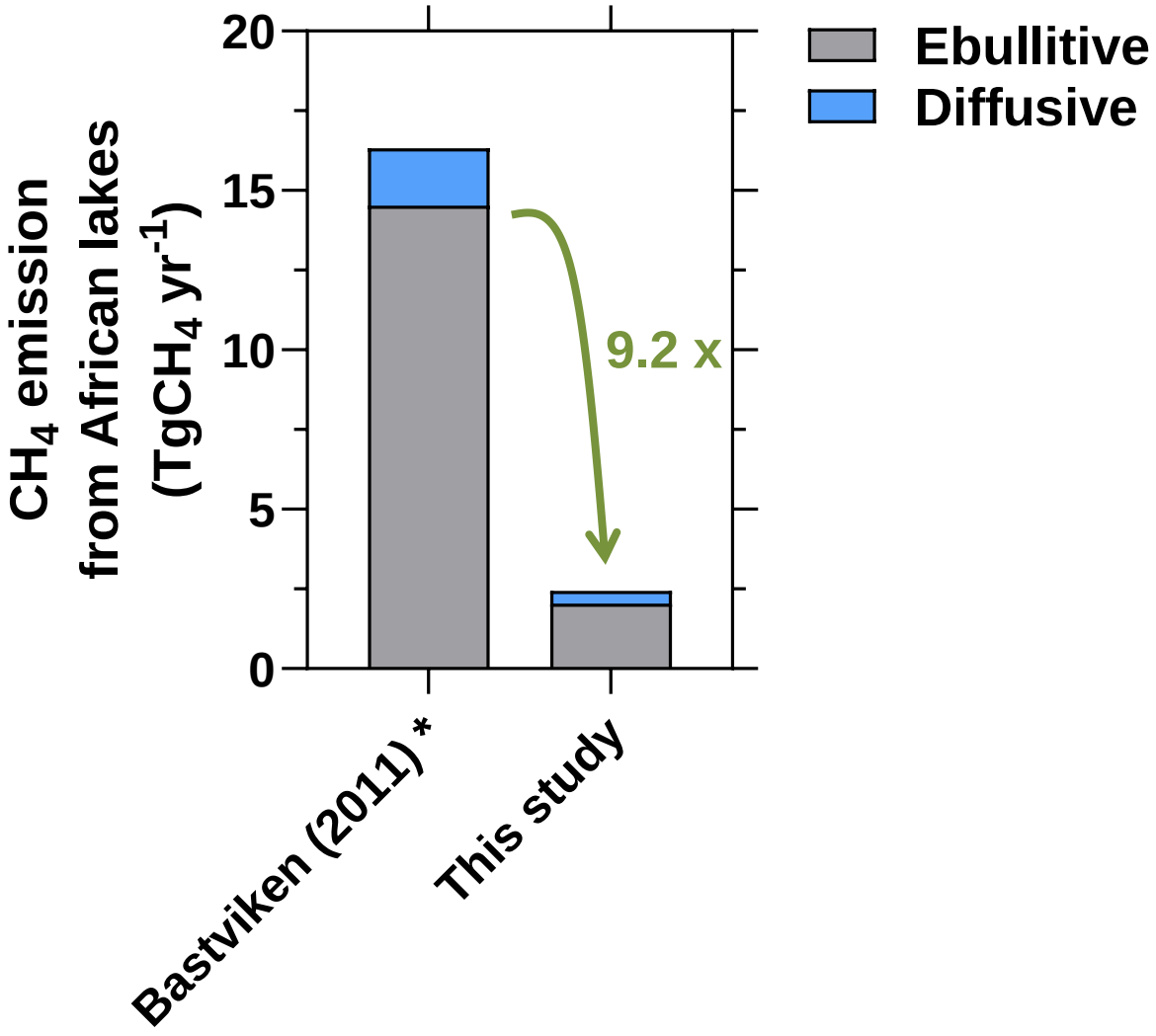
Environ Model Assess (2007) 12:213–228
DOI 10.1007/s10666-006-9069-z

New Approaches to the Modelling of Lake Basin Morphometry

Håkan Johansson · A. Angelica Brolin · Lars Håkanson

Borges et al. (2022) doi: 10.1126/sciadv.abi8716

African lakes



* rescaled as African lakes = 66% of tropical lakes

Borges et al. (2022) doi: 10.1126/sciadv.abi8716

CH_4 emissions from African lakes

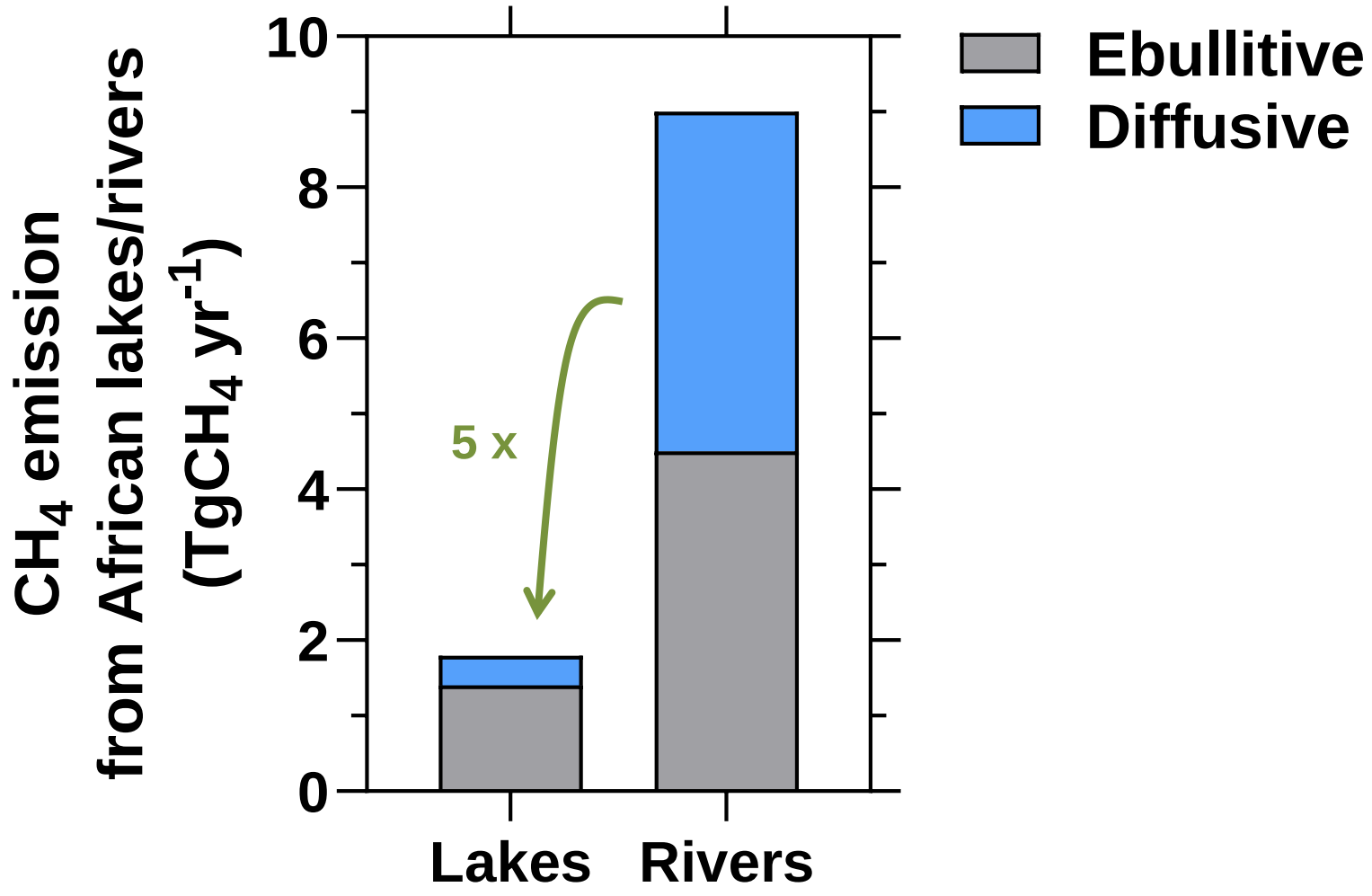
This study	Ebullitive	1.4	$TgCH_4/yr$	25.0	$gCH_4/m^2/yr$
	Diffusive	0.4	$TgCH_4/yr$	2.1	$gCH_4/m^2/yr$
	Total	1.8	$TgCH_4/yr$		
	Total lake surface area	209,394	km^2		
	Littoral zone (<10m)	56,063	km^2		
Bastviken et al (2011)	Ebullitive	14.5	$TgCH_4/yr$	38.9	$gCH_4/m^2/yr$
	Diffusive	2.0	$TgCH_4/yr$	5.5	$gCH_4/m^2/yr$
	Total	16.6	$TgCH_4/yr$		
	Total lake surface area *	373,254	km^2		

* rescaled as African lakes = 66% of tropical lakes

Borges et al. (2022) doi: 10.1126/sciadv.abi8716

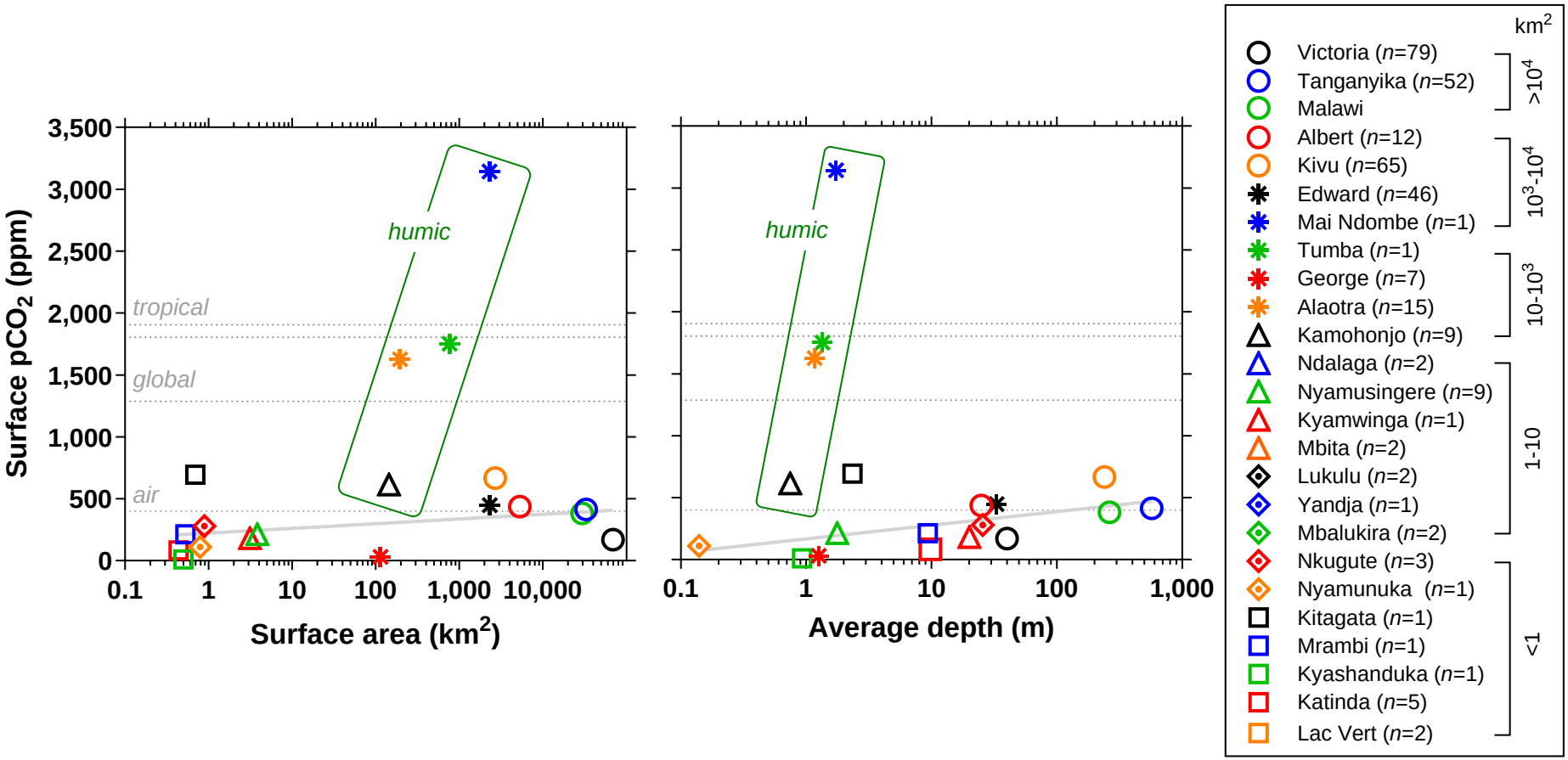
African lakes

CH_4 emissions from African lakes/rivers



Borges et al. (2022) doi: 10.1126/sciadv.abi8716

Surface pCO_2 in African lakes



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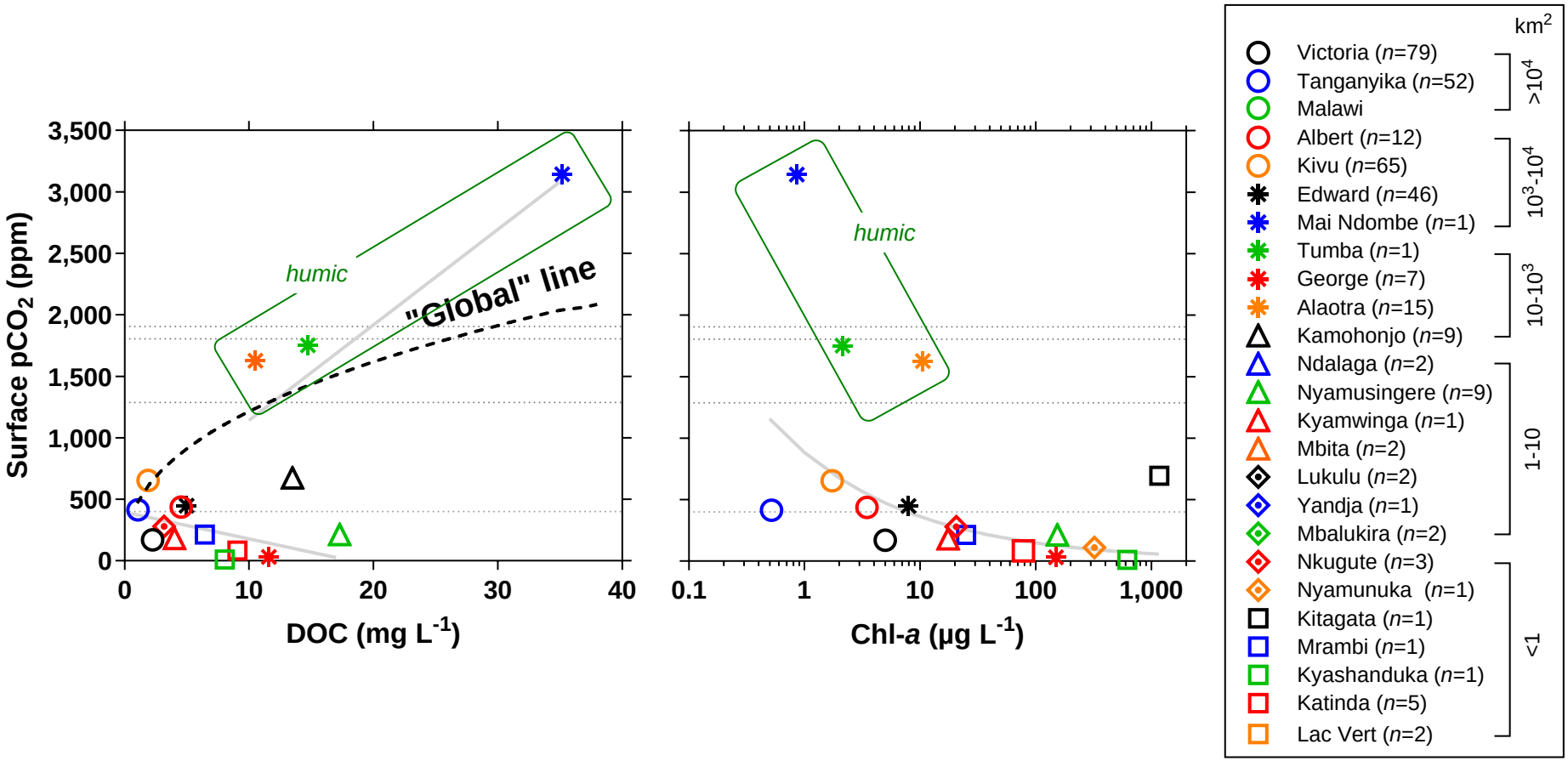

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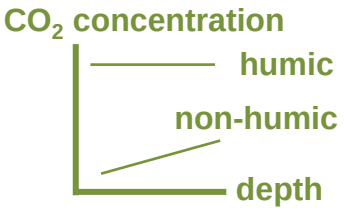
African lakes

Humic lakes

Non-humic lakes

Wetland cover (GIESM)



HydroLAKES

CO_2 concentration in individual lakes

WorldClim wind

Cole & Caraco (98) Gas transfer velocity in individual lakes

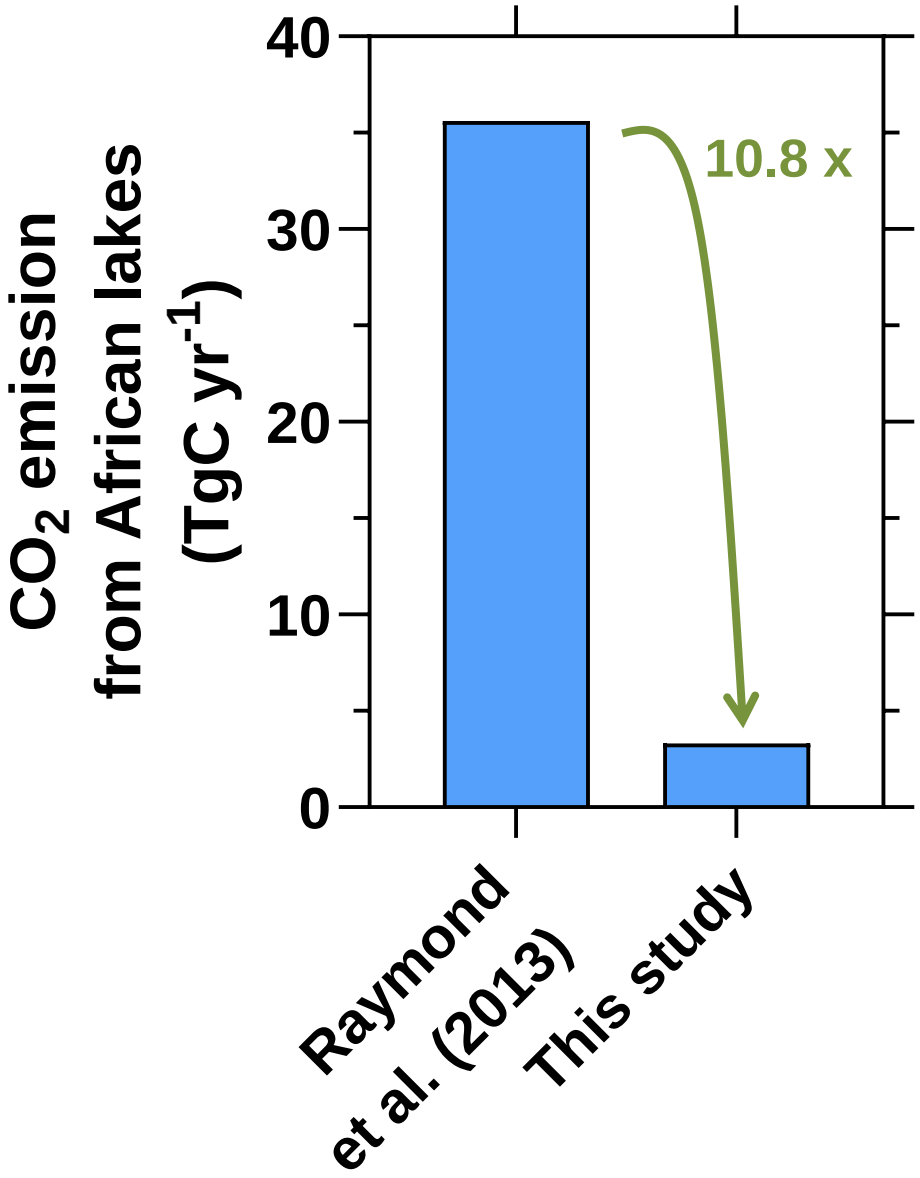
Diffusive CO_2 emissions in individual lakes (m^{-2})

HydroLAKES

Total diffusive CO_2 emissions ($TgC\ yr^{-1}$)

Borges et al. (2022) doi: 10.1126/sciadv.abi8716

African lakes



Borges et al. (2022) doi: 10.1126/sciadv.abi8716

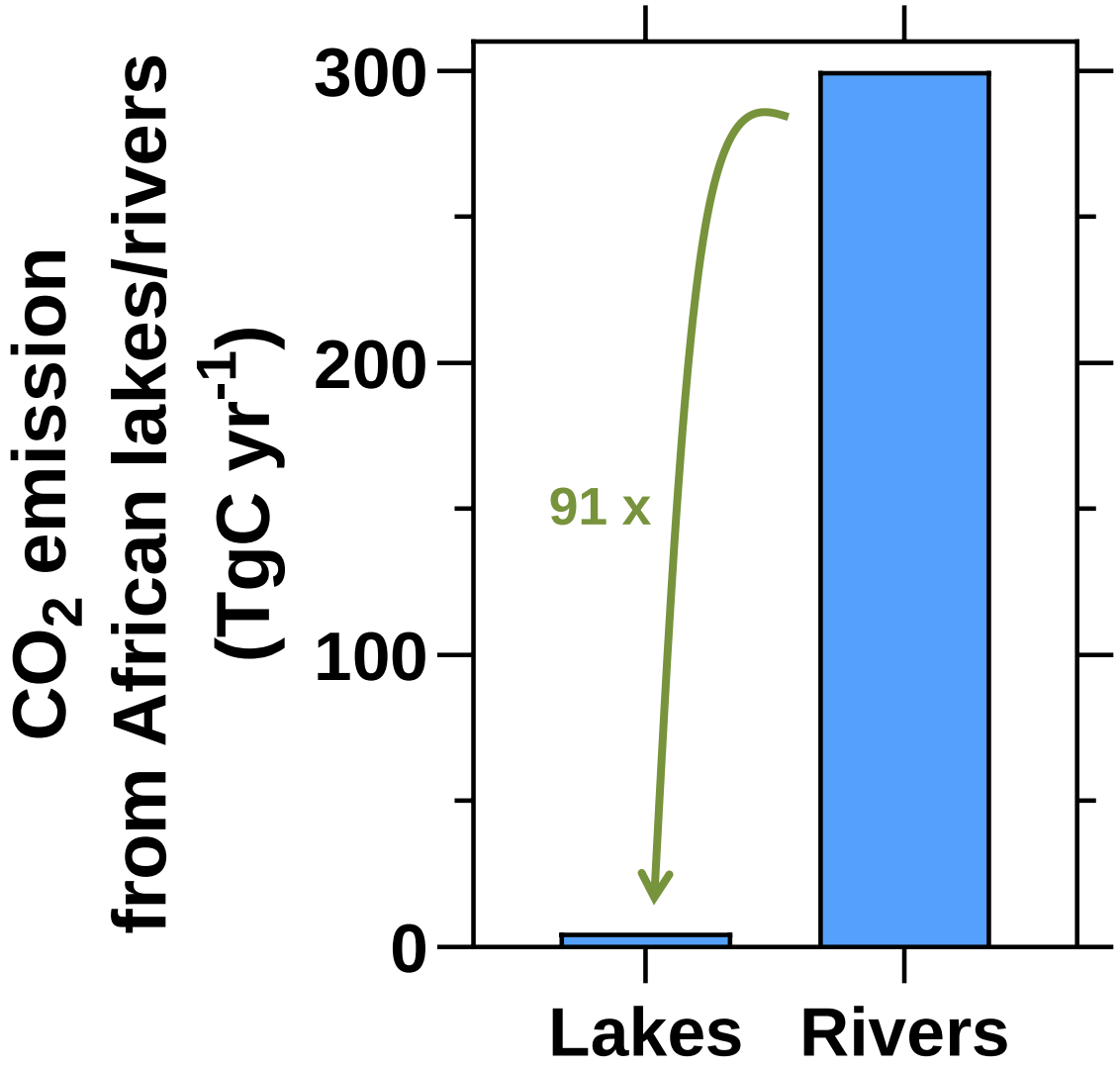
CO_2 emissions from African lakes

This study	Diffusive Flux	3.3	TgC/yr	15.9	gC/m2/yr
	Average pCO_2	530	ppm		
	Total lake surface area	209,394	km^2		
Raymond et al (2013)	Diffusive Flux	35.6	TgC/yr	160.3	gC/m2/yr
	Average pCO_2	934	ppm		
	Total lake surface area	222,062	km^2		

Borges et al. (2022) doi: 10.1126/sciadv.abi8716

African lakes

CO_2 emissions from African lakes/rivers

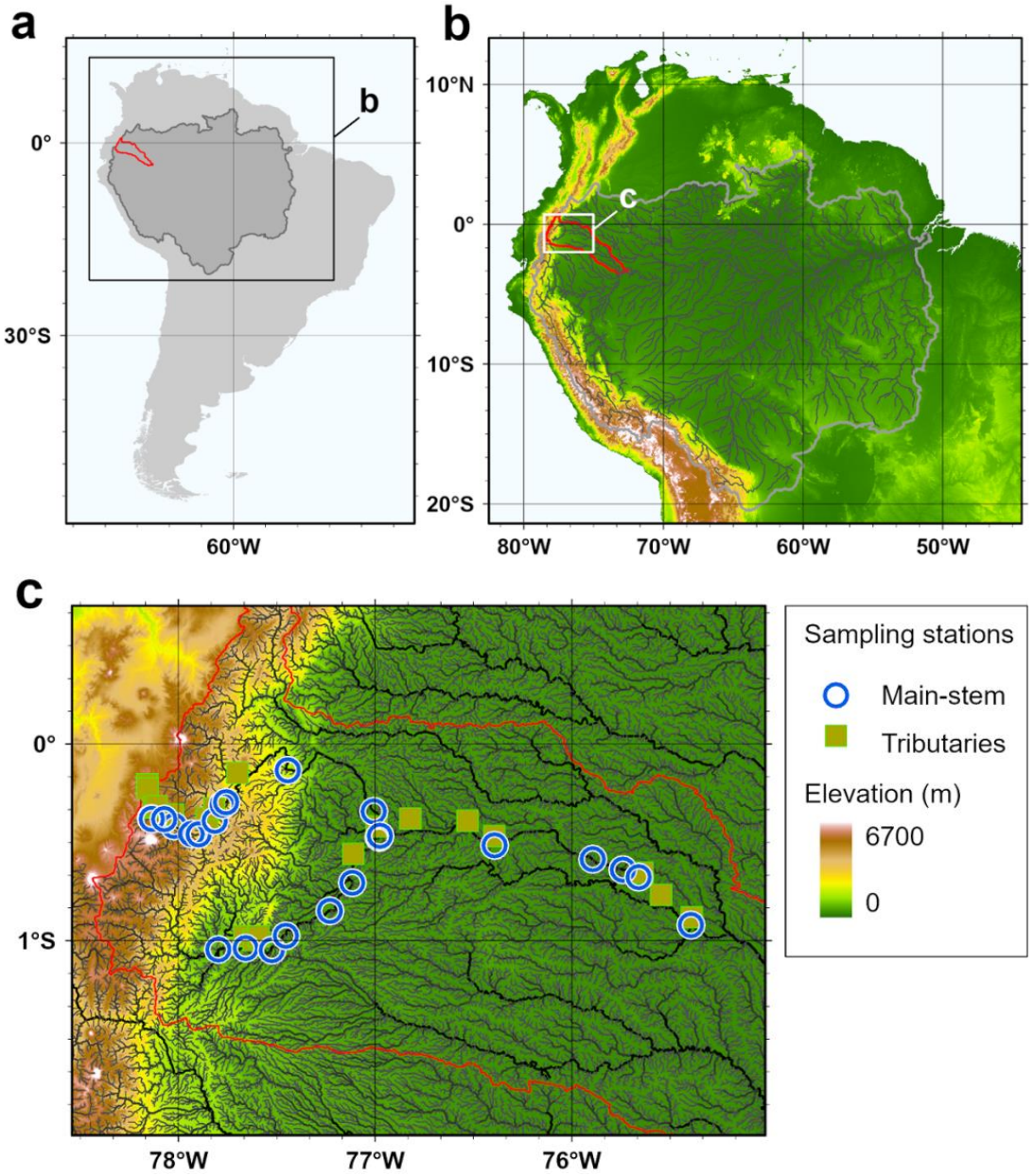


Borges et al. (2022) doi: 10.1126/sciadv.abi8716

Amazon headwaters

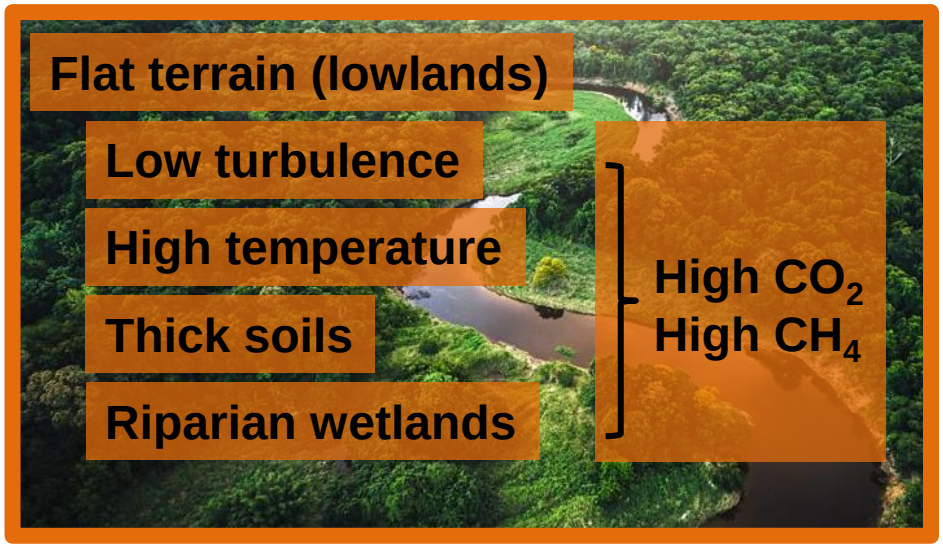
Napo River

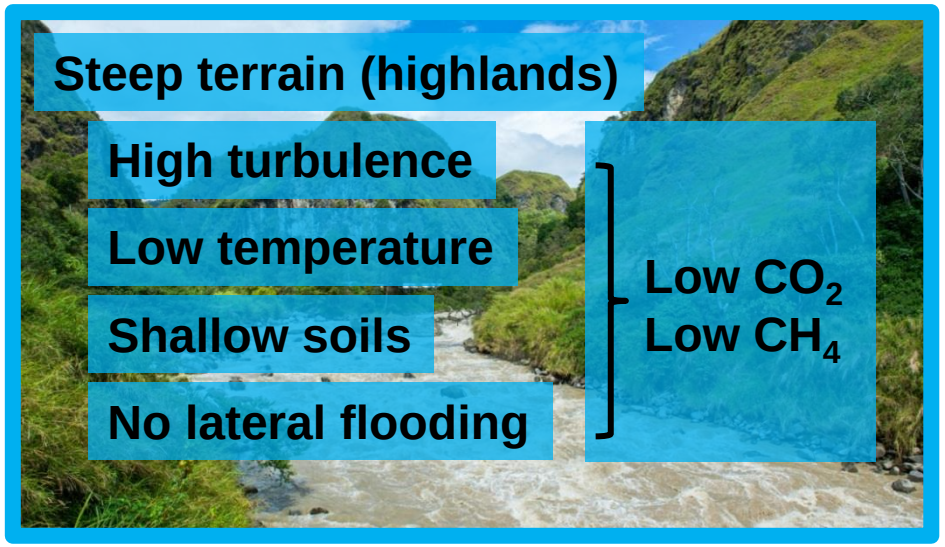
Elevation
~ 4000m
~ 170m

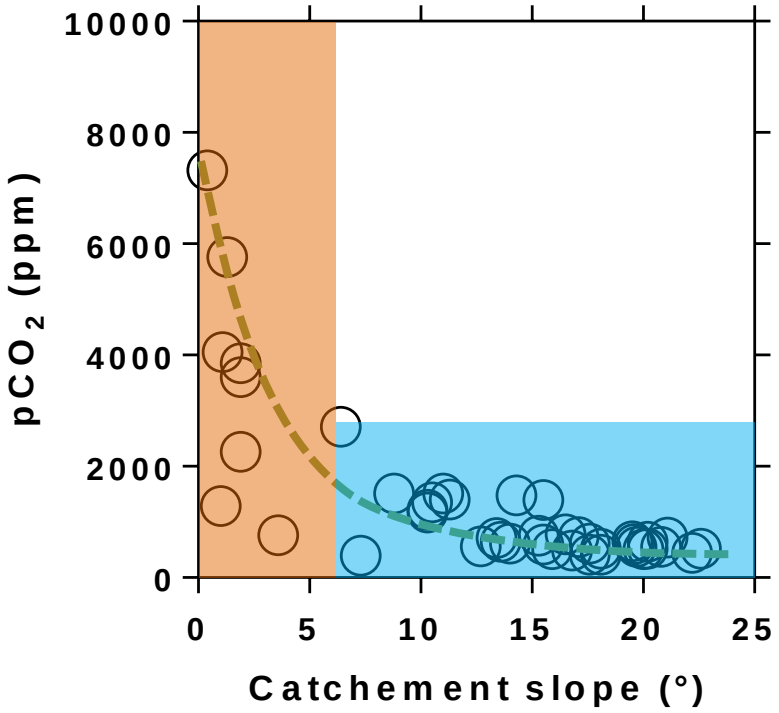


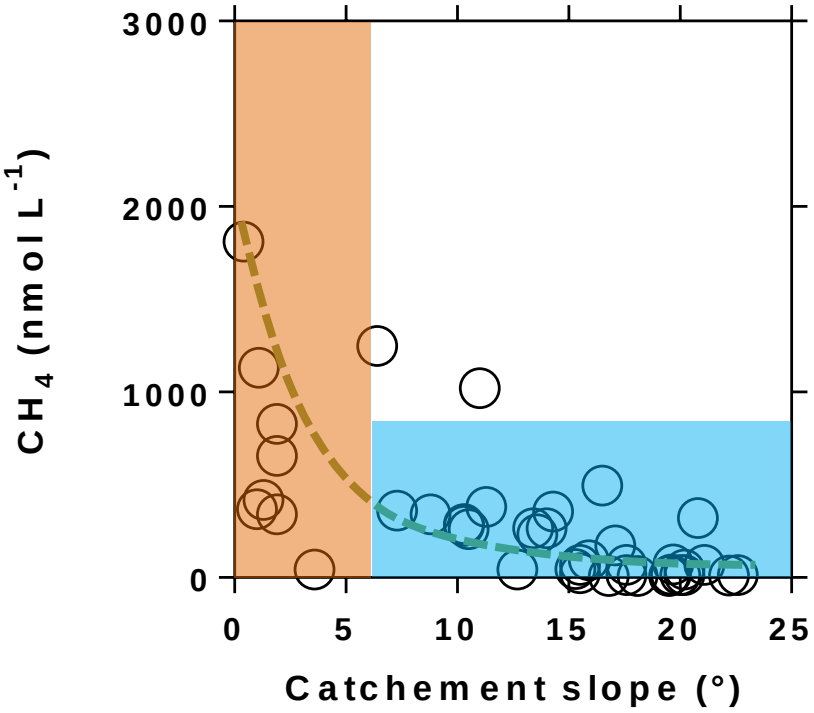
Chiriboga & Borges et al. (2023) doi: 10.1038/s43247-023-00745-1

Amazon headwaters

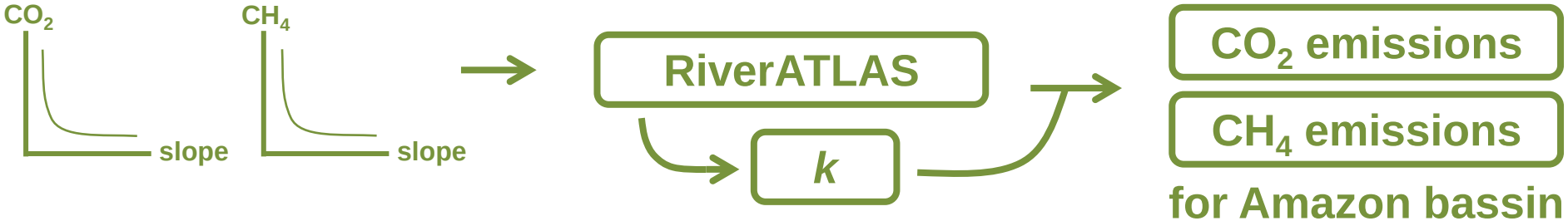


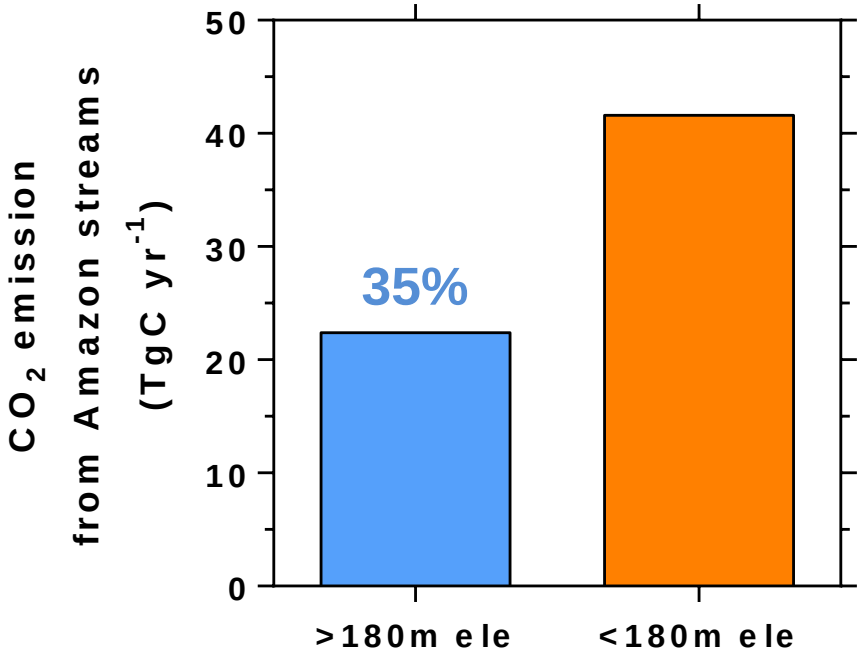


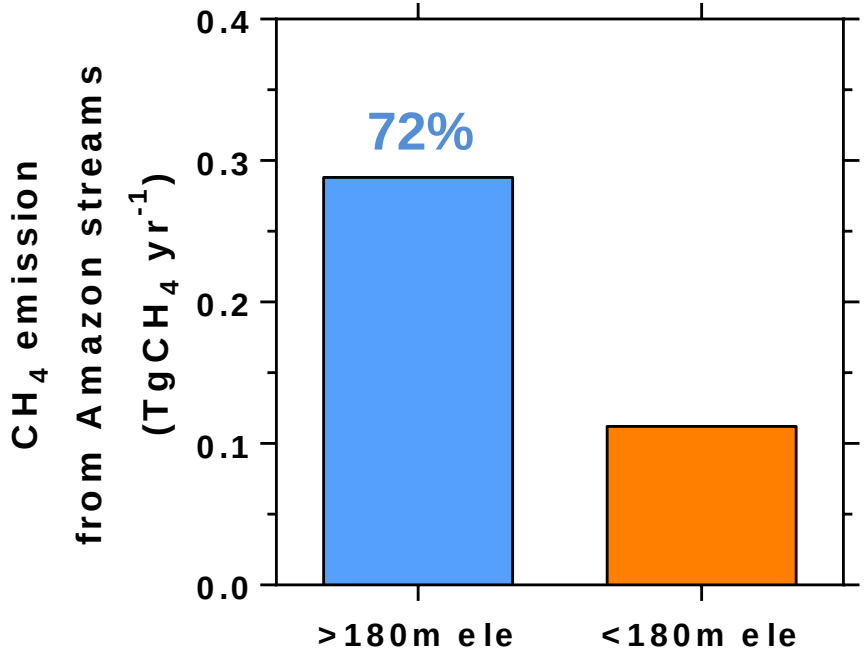


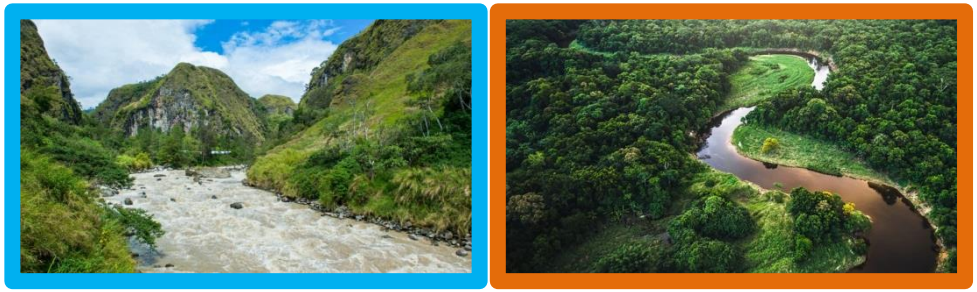


Amazon headwaters







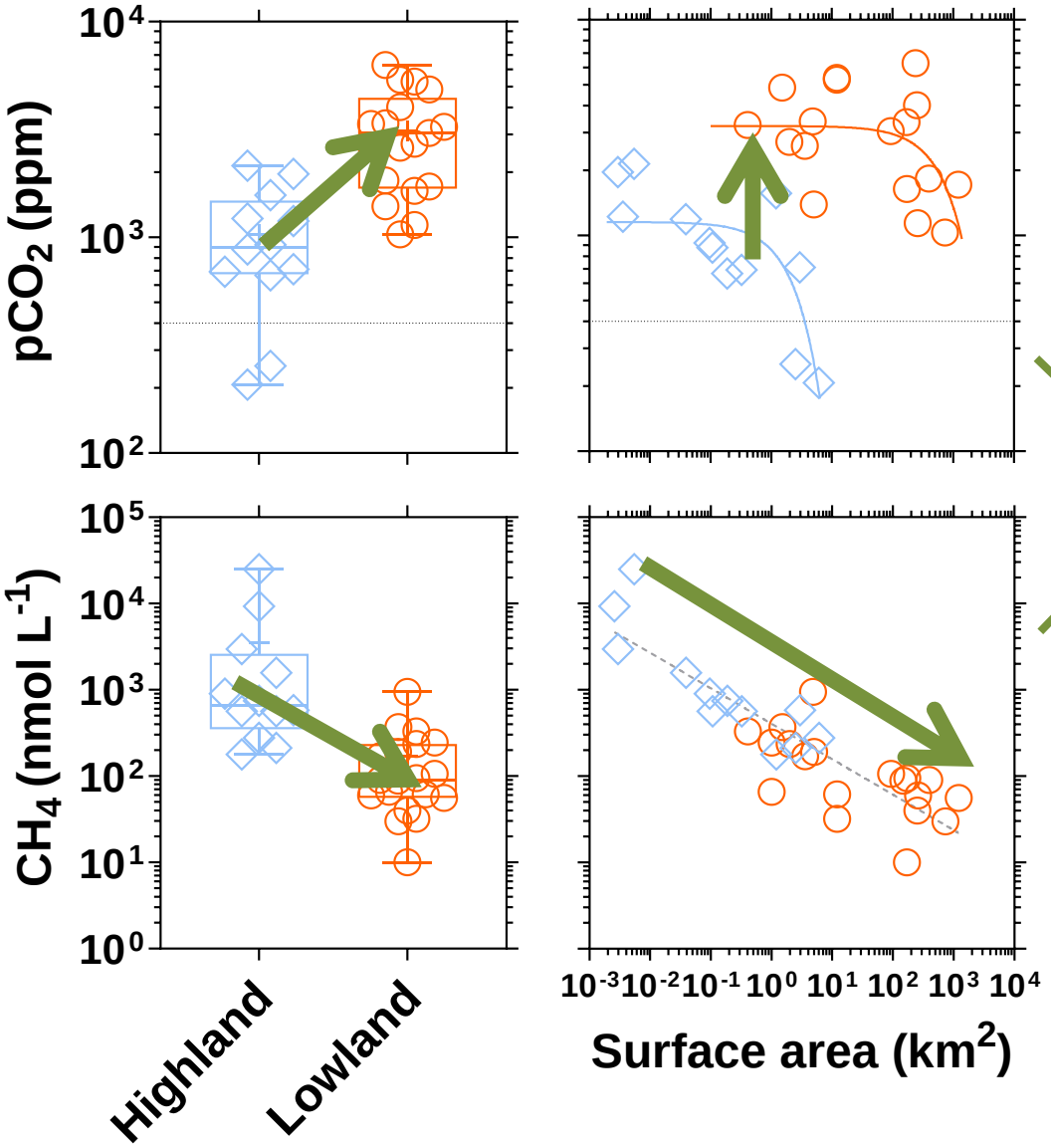


Chiriboga & Borges et al. (2023) doi: 10.1038/s43247-023-00745-1

Highland and lowland lakes of the Amazon

River CO_2 input to floodplain lakes

Lake size increase



HydroLAKES

CO_2 emissions

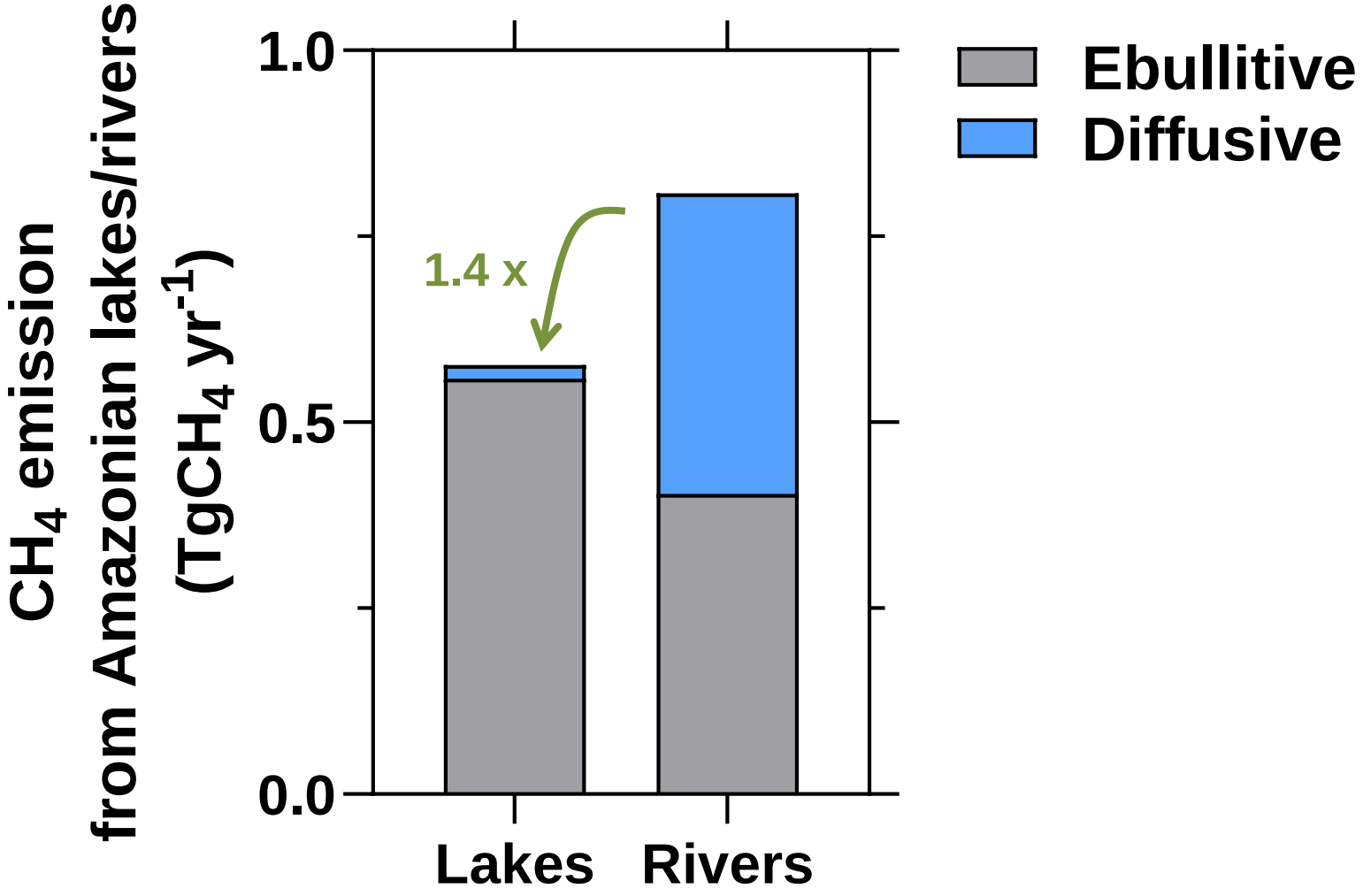
CH_4 emissions

for Amazon bassin

Chiriboga et al. (2024) doi: 10.1007/s00027-023-01039-6

Amazon headwaters

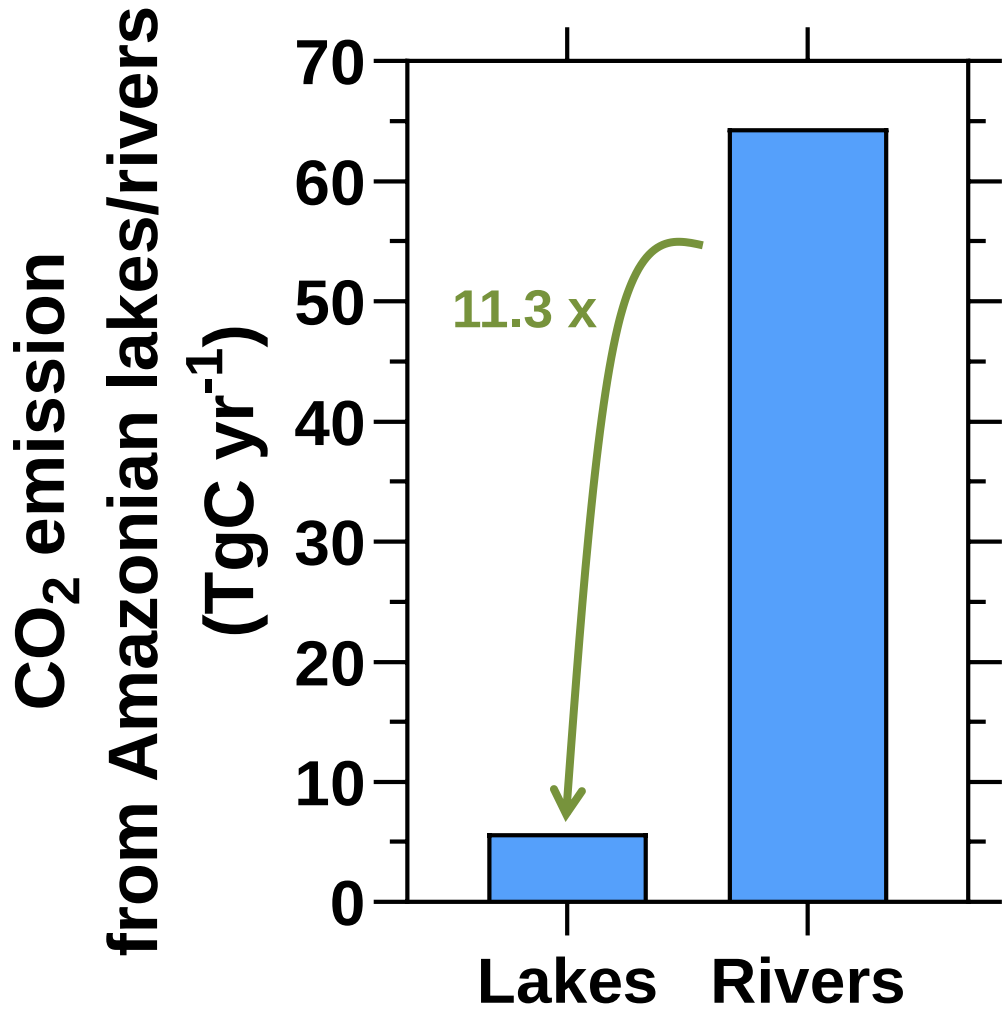
CH_4 emissions from Amazonian lakes/rivers



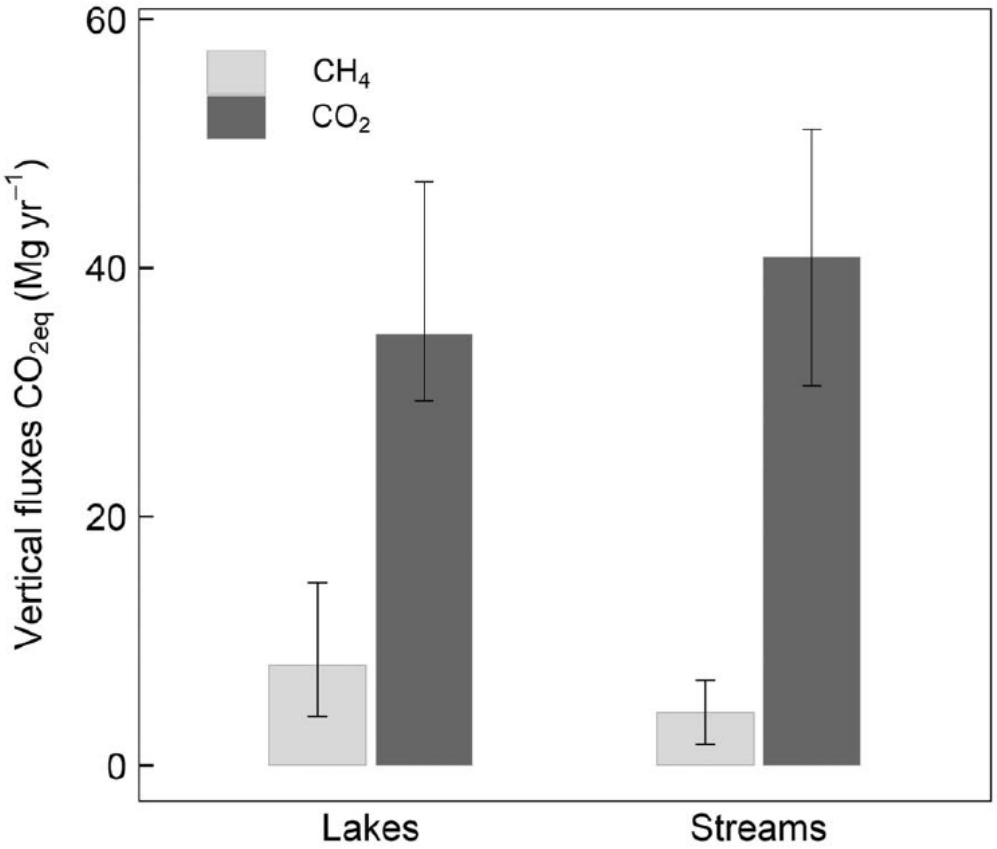
Chiriboga et al. (2024) doi: 10.1007/s00027-023-01039-6

Amazon headwaters

CO_2 emissions from Amazonian lakes/rivers



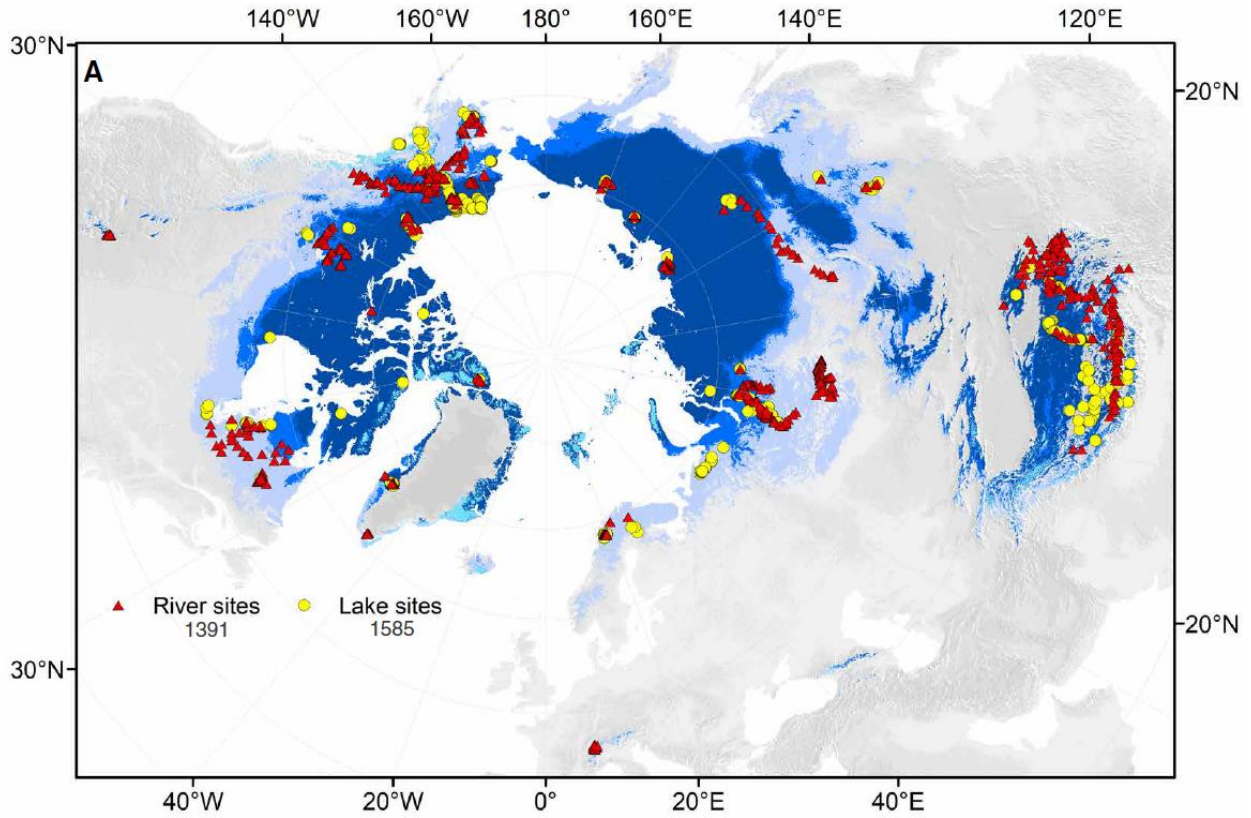
Chiriboga et al. (2024) doi: 10.1007/s00027-023-01039-6



Skogaryd Research Catchment (SRC) ~ 7 km²

River CH_4 emissions < Lake CH_4 emissions (2 x)
River CO_2 emissions ≥ Lake CO_2 emissions (1.2 x)

Balathandayuthabani et al. (2023) doi: 10.1002/lol2.10312

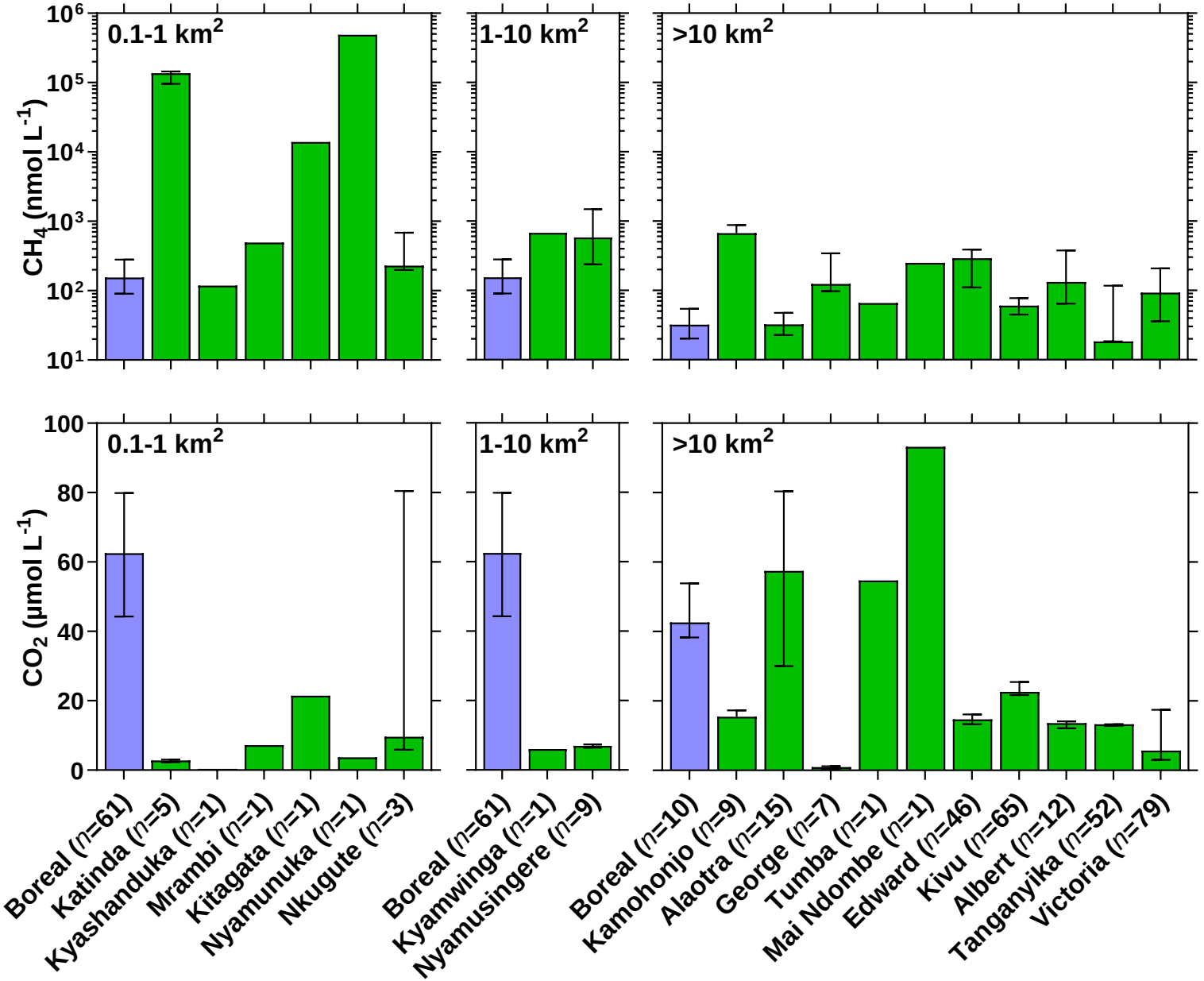


Northern cryosphere

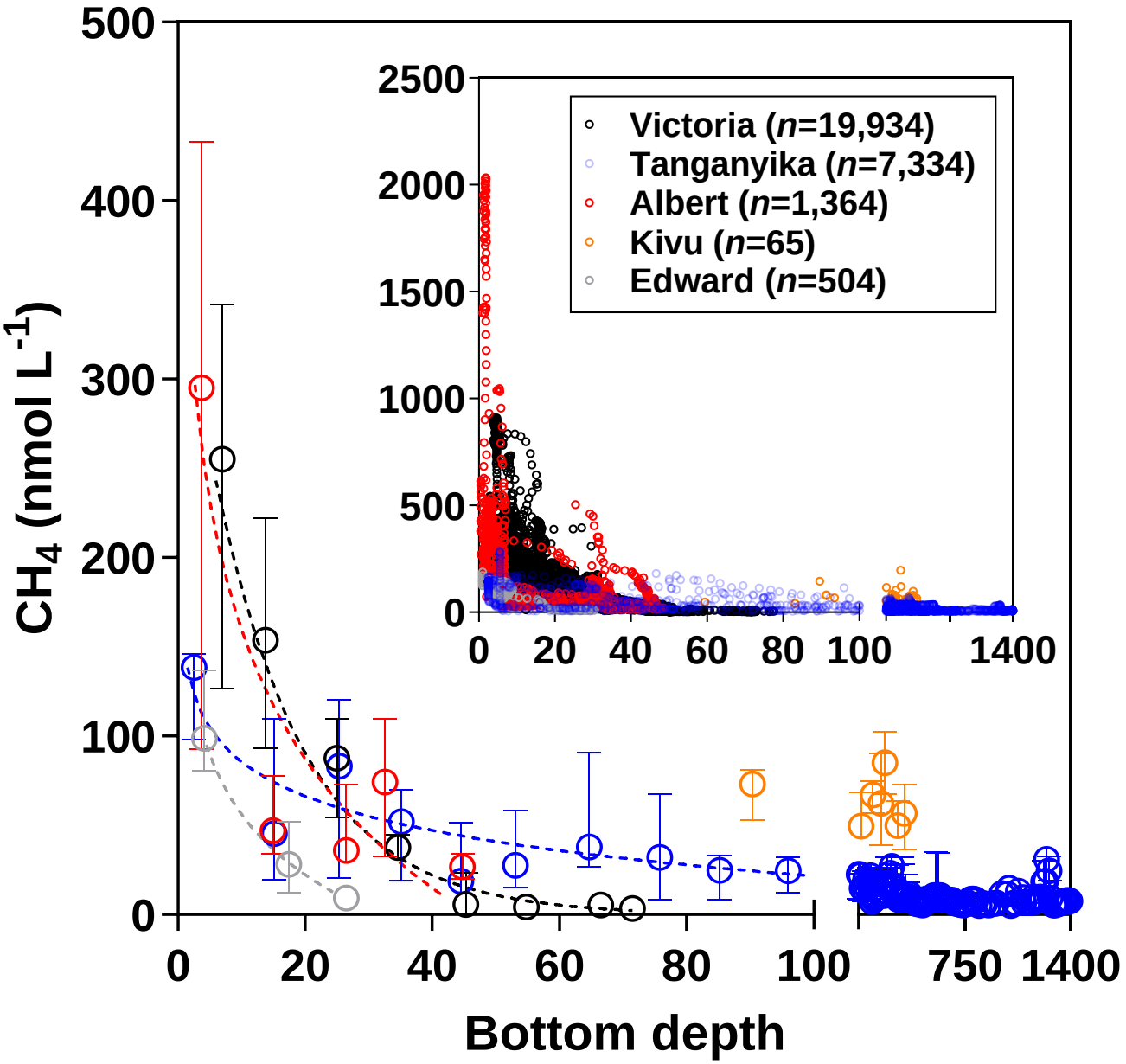
River CH_4 emissions < Lake CH_4 emissions (2.1 x)
River CO_2 emissions > Lake CO_2 emissions (2.6 x)

Song et al. (2024) doi: 10.1126/sciadv.adp0024

Q&A



Borges et al. (2022) doi: 10.1126/sciadv.abi8716



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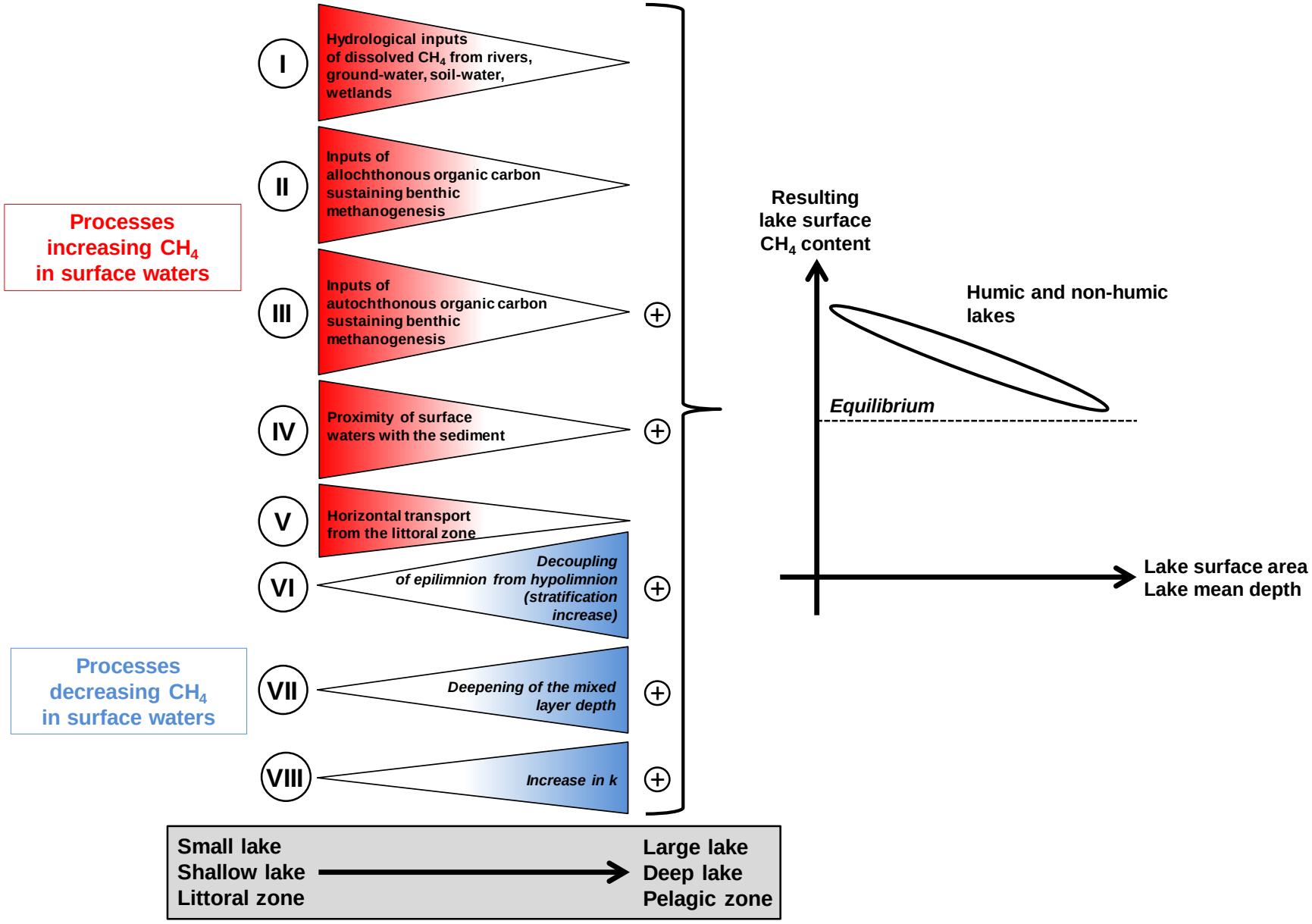
Q&A



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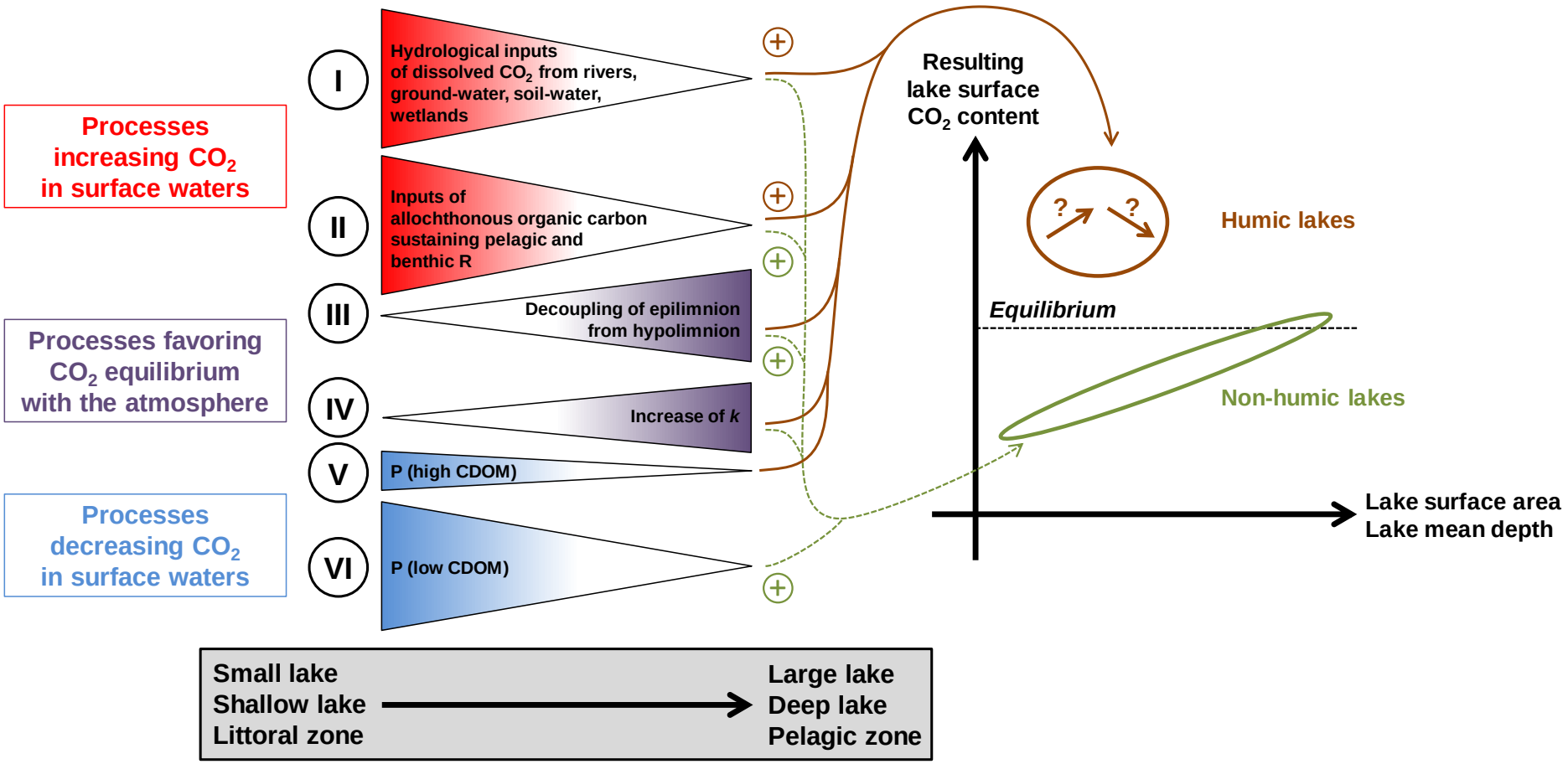

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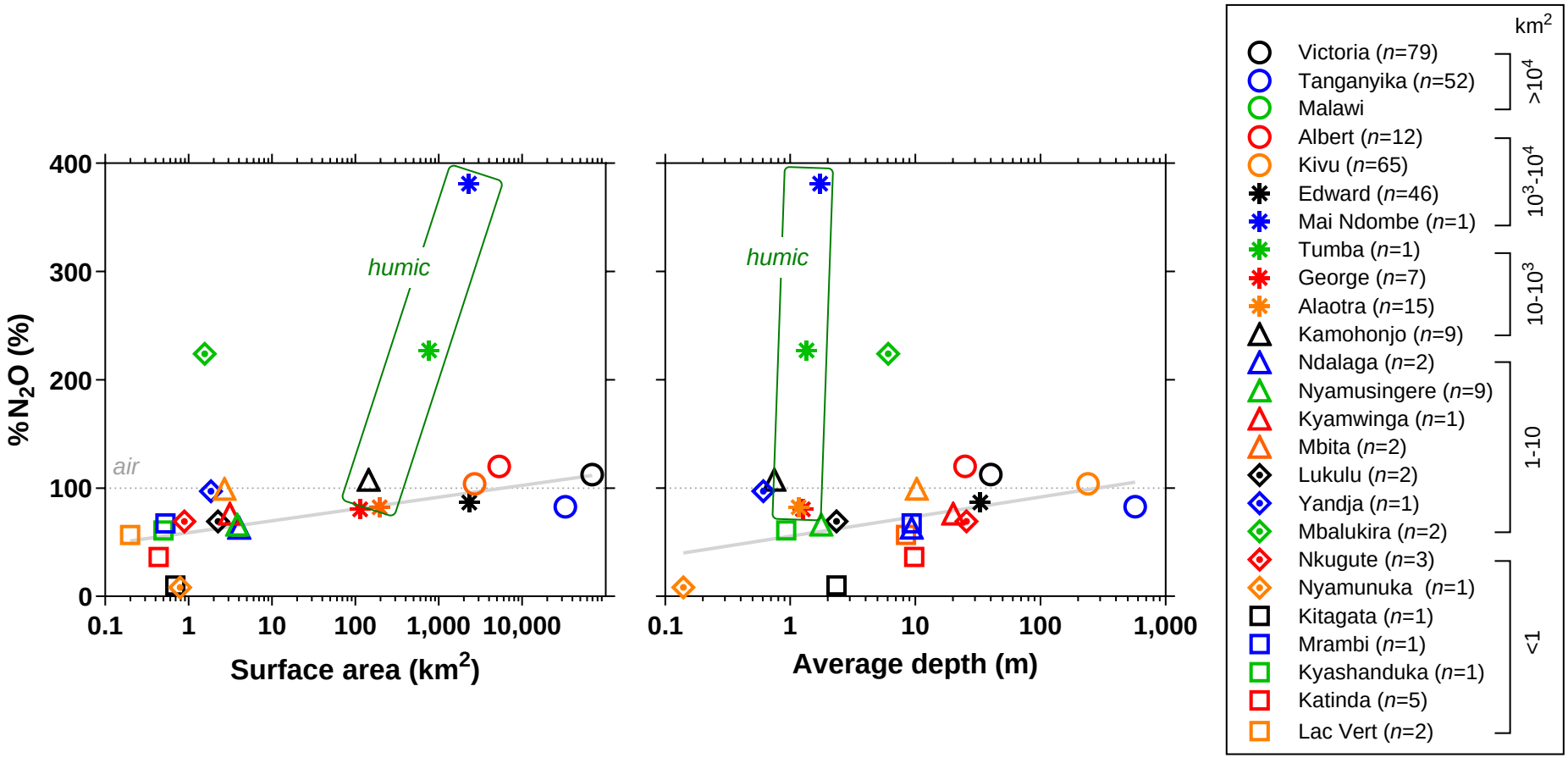

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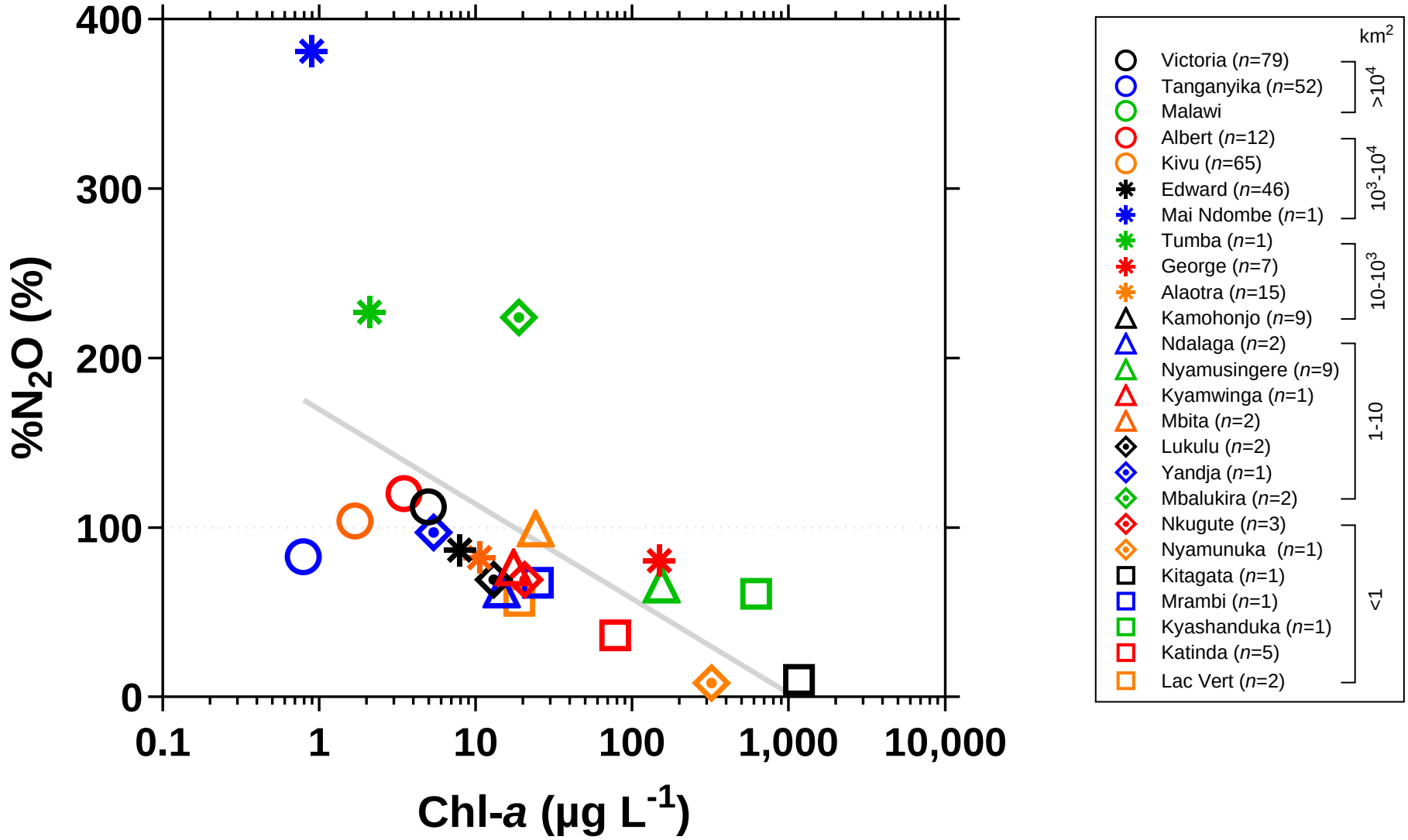
Q&A



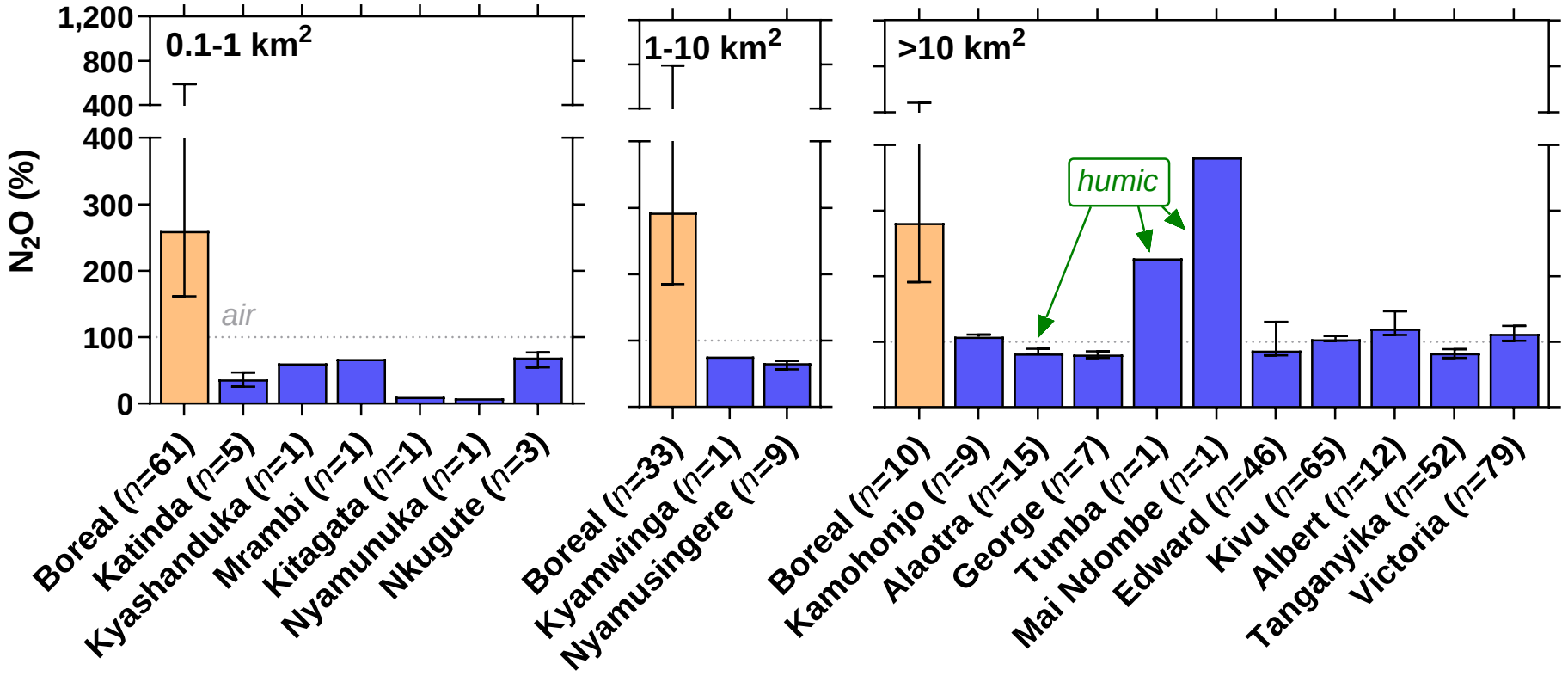
Borges et al. (2022) doi: 10.1126/sciadv.abi8716

Q&A

This study	Diffusive Flux	-0.1±0.1	GgN_2O/yr	-0.5	$mgN_2O/m^2/yr$
	Total lake surface area	209,394	km^2		
Lauerwald et al (2019)	Diffusive Flux	3.7	GgN_2O/yr	16.1	$mgN_2O/m^2/yr$
	Total lake surface area	229,000	km^2		

Borges et al. (2022) doi: 10.1126/sciadv.abi8716

Q&A



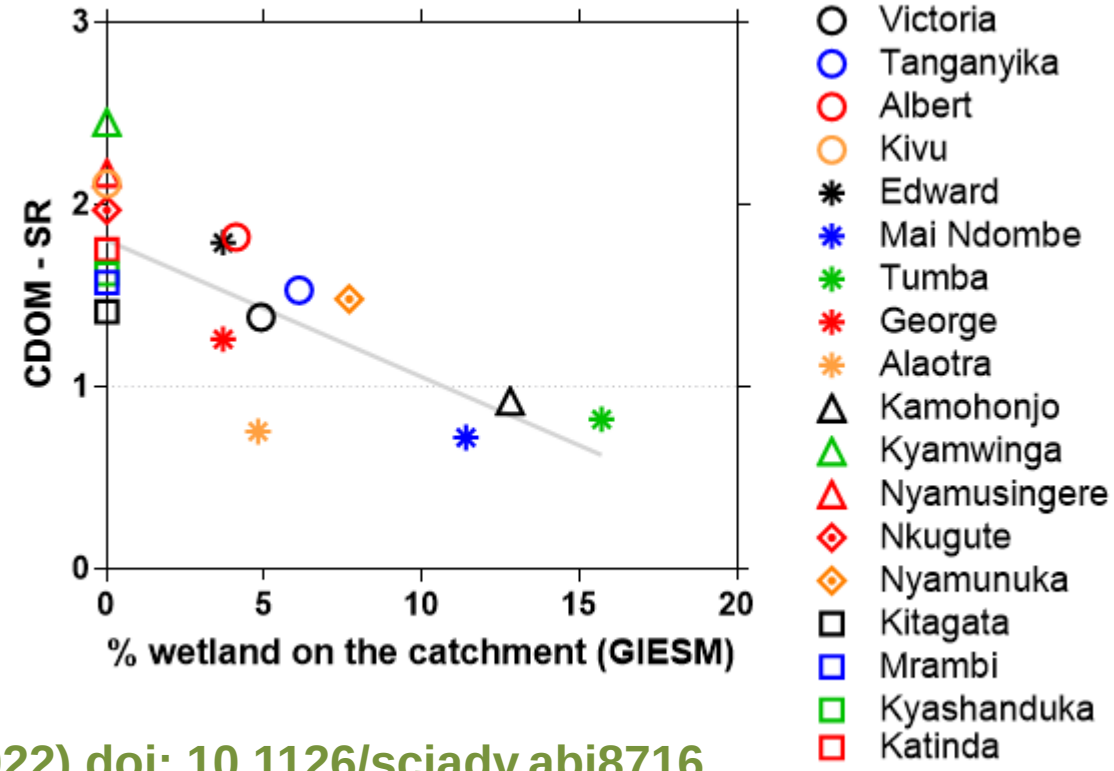
Borges et al. (2022) doi: 10.1126/sciadv.abi8716

CDOM SR was negatively related with wetland presence on the catchment extracted from GIEMS-D15

CDOM SR = 1.85 - 0.0765 x %wetland (r^2 = 0.57, p=0.0003, n=18)

Threshold value of wetland coverage of 8.1%

to classify humic (CDOM SR <1) and non-humic (CDOM SR >1) lakes.



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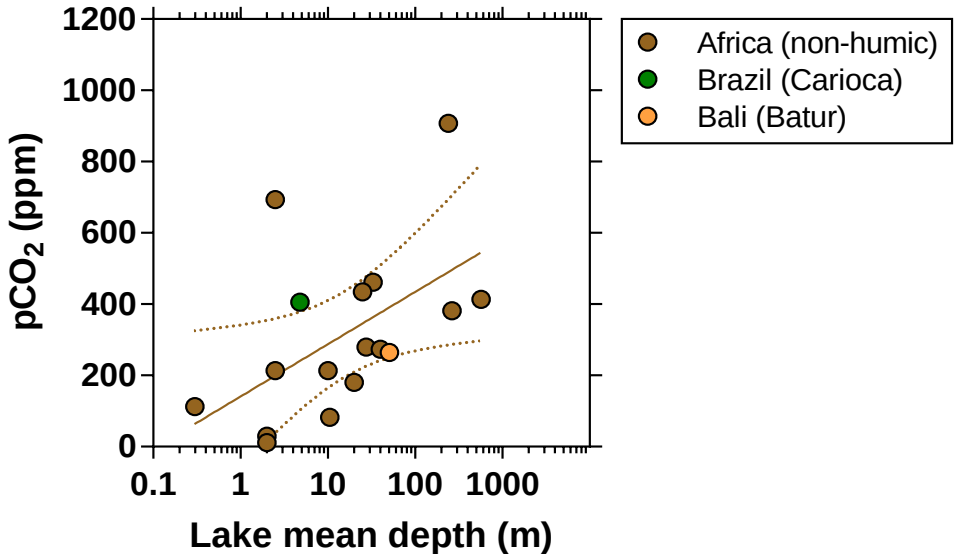

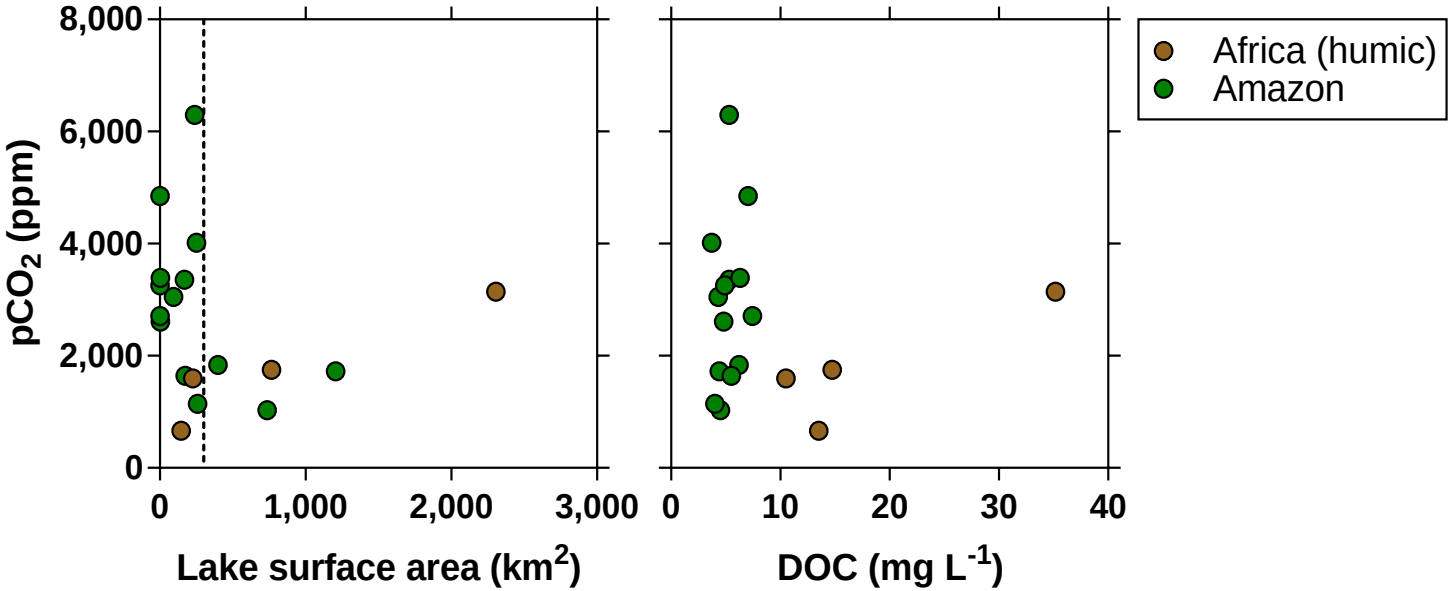

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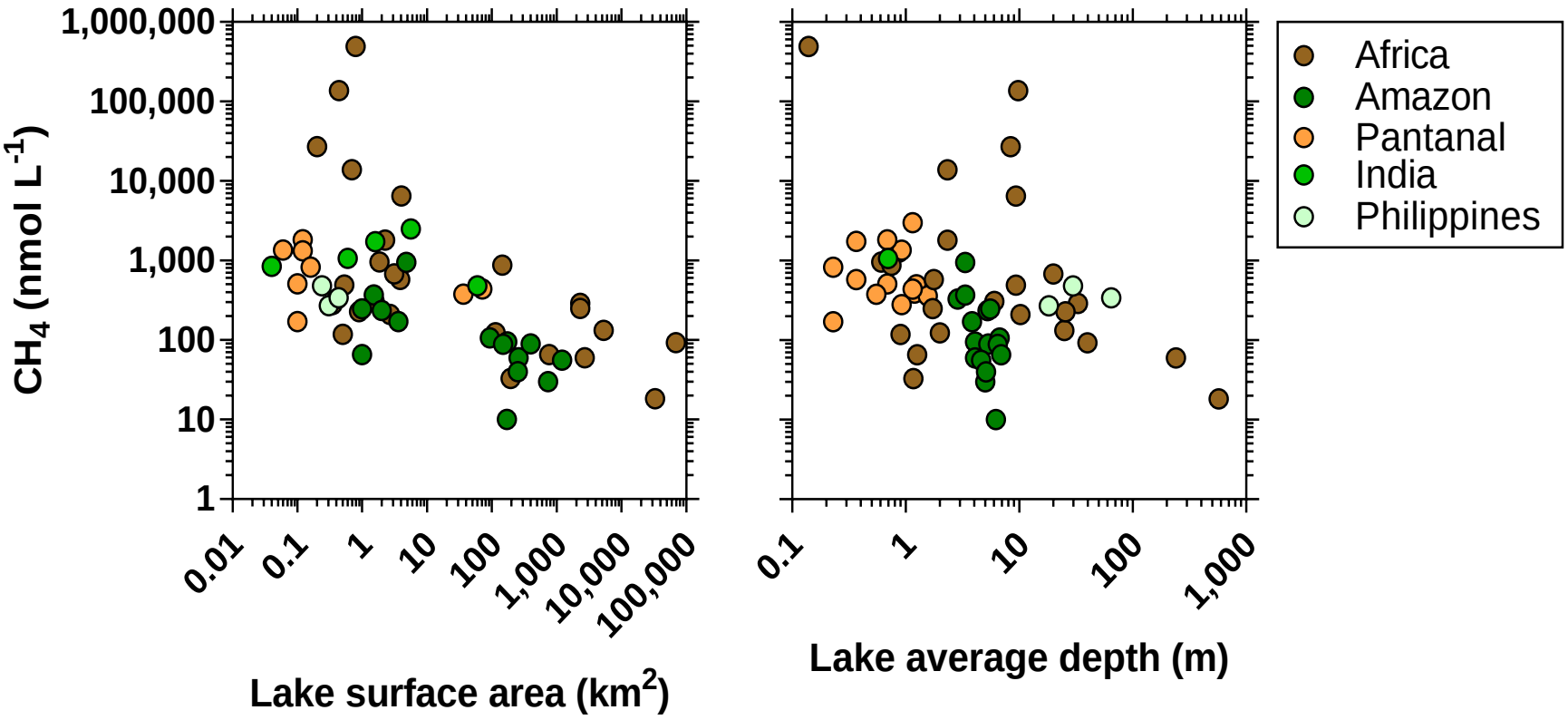

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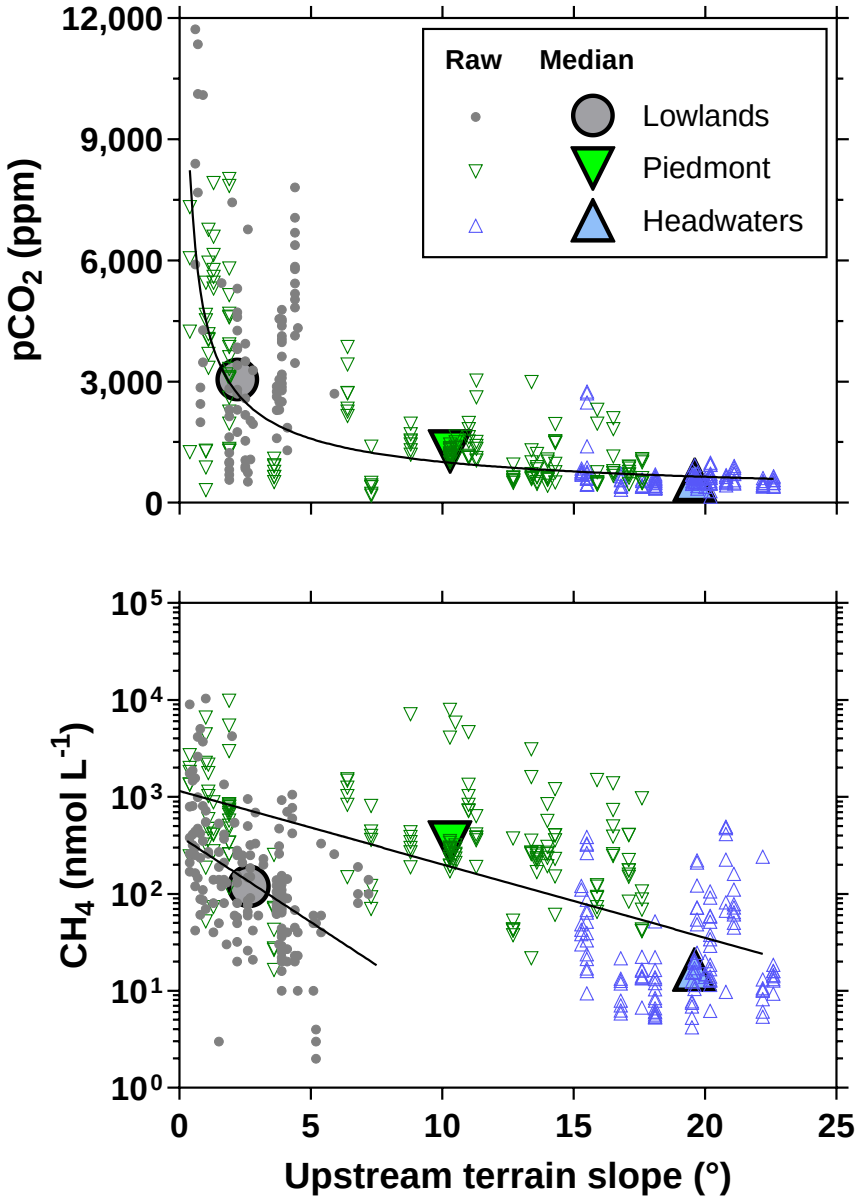
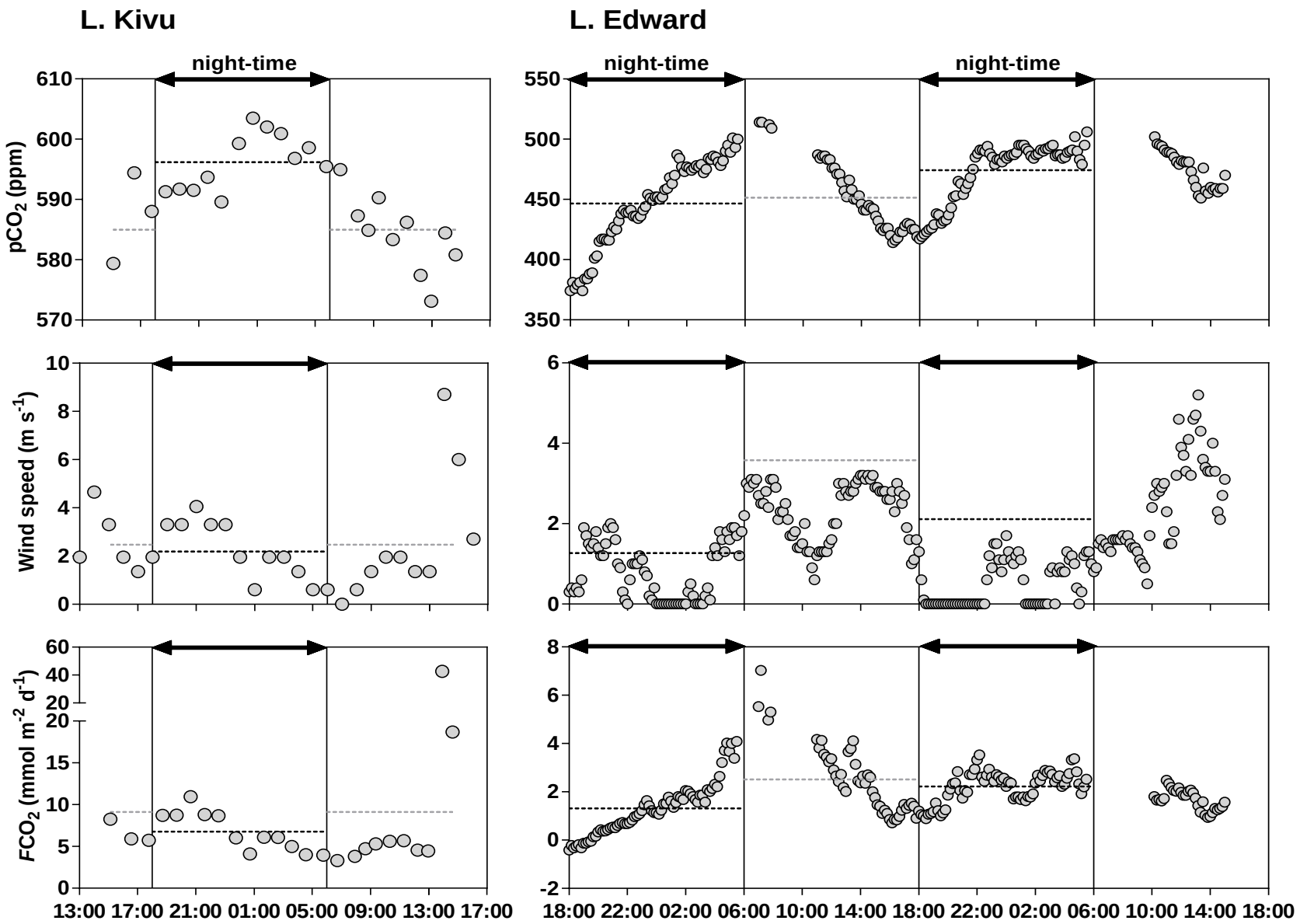
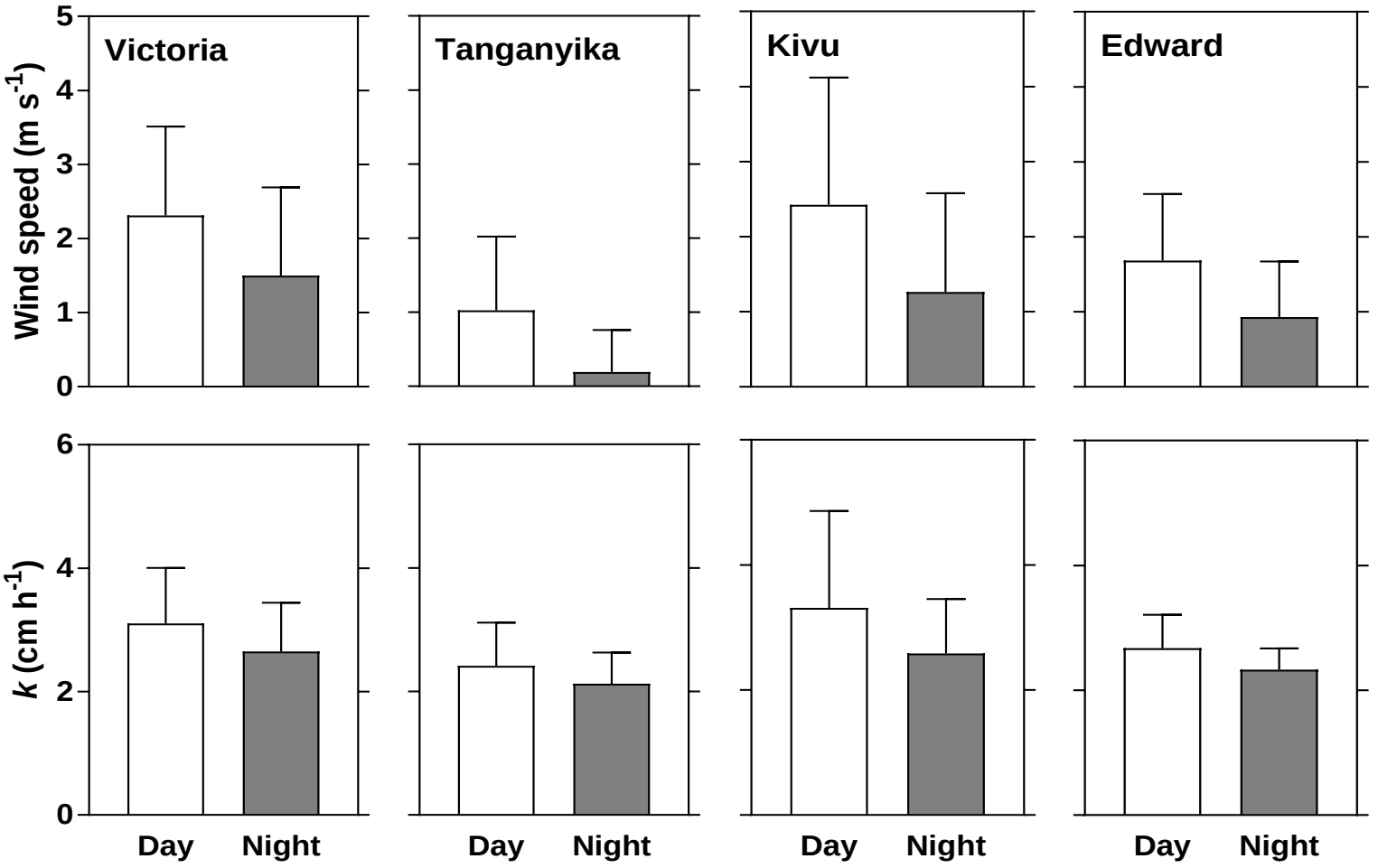


Chiriboga & Borges et al. (2023) doi: 10.1038/s43247-023-00745-1



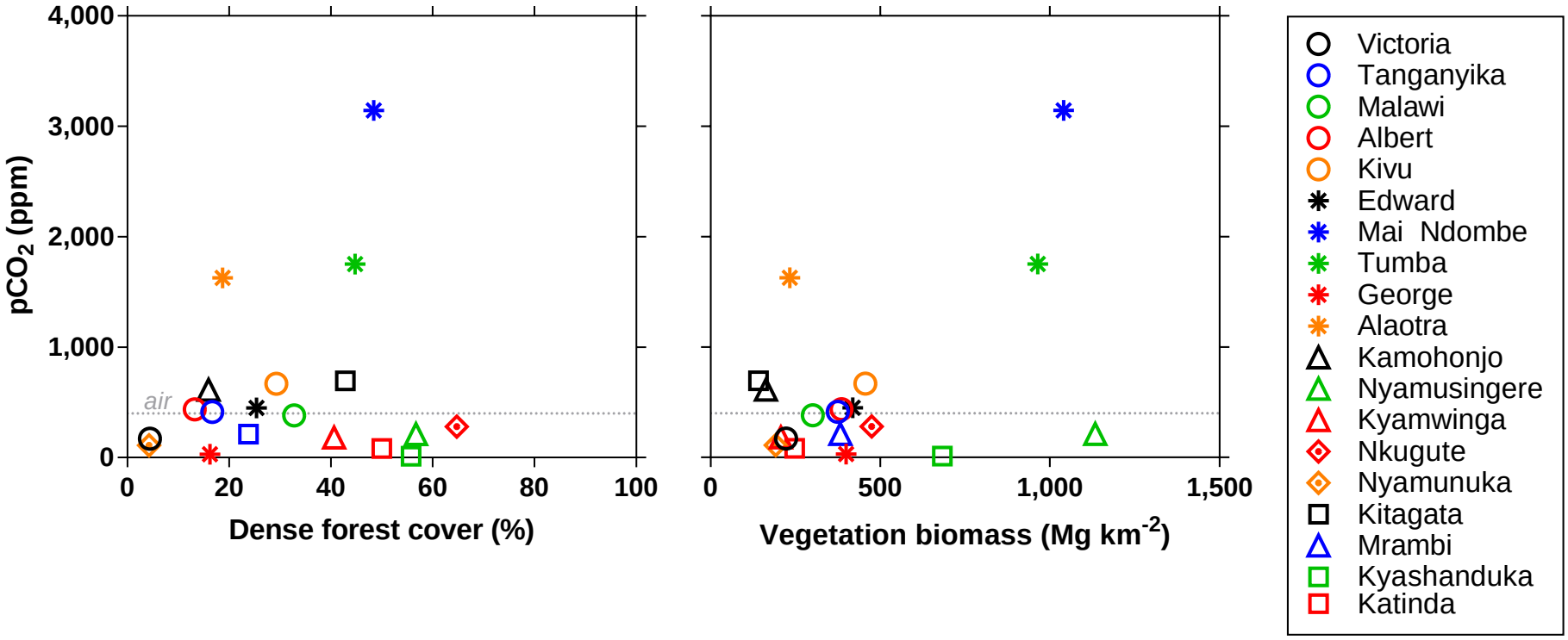
Borges et al. (2022) doi: 10.1126/sciadv.abi8716

Q&A



Borges et al. (2022) doi: 10.1126/sciadv.abi8716

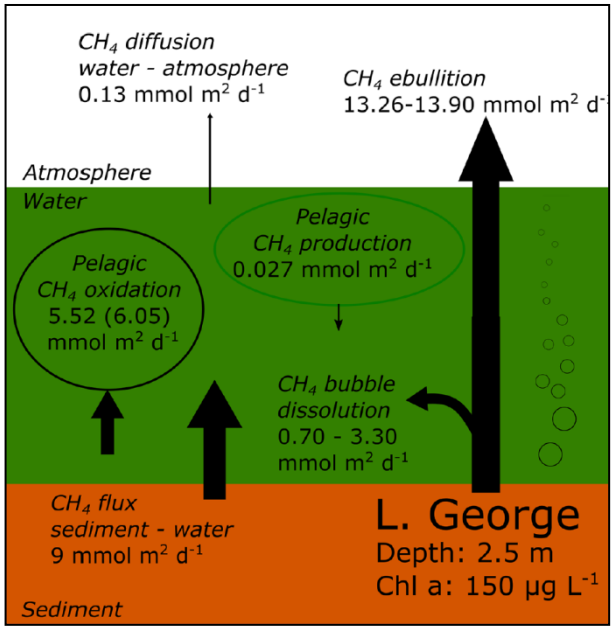
Q&A

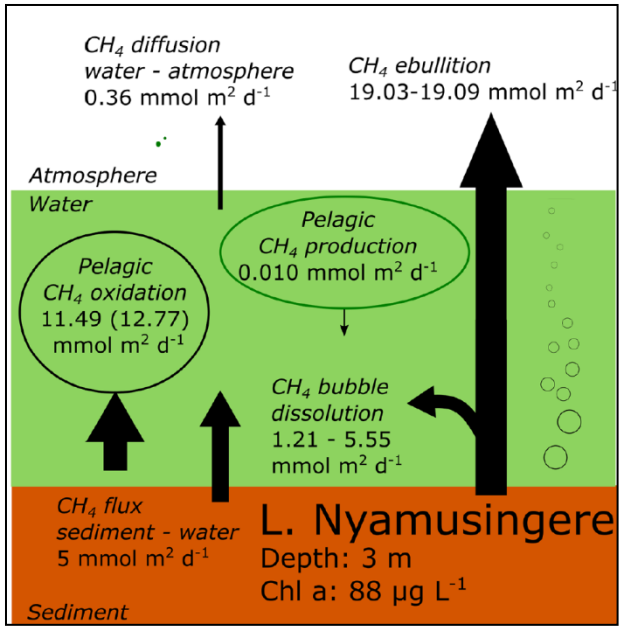


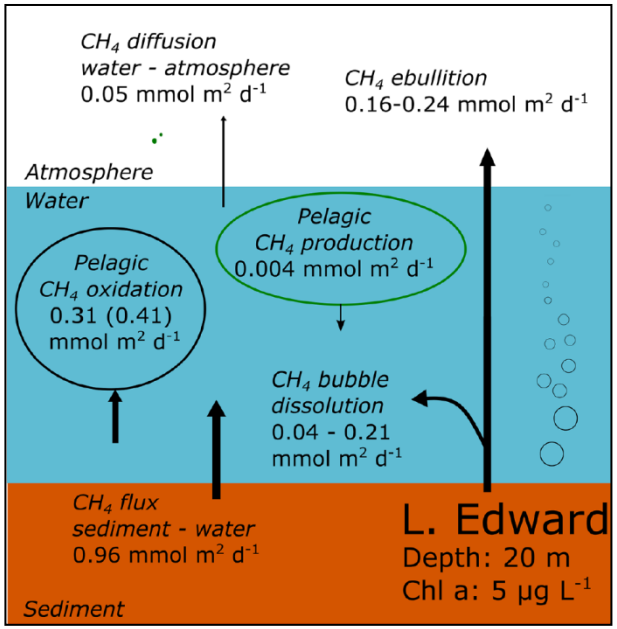
Borges et al. (2022) doi: 10.1126/sciadv.abi8716

Methane aerobic production (MAP) based on tracer incubations

Diff.	= 5 x MAP	= 36 x MAP	= 13 x MAP
MOX	= 205 x MAP	= 1150 x MAP	= 78 x MAP



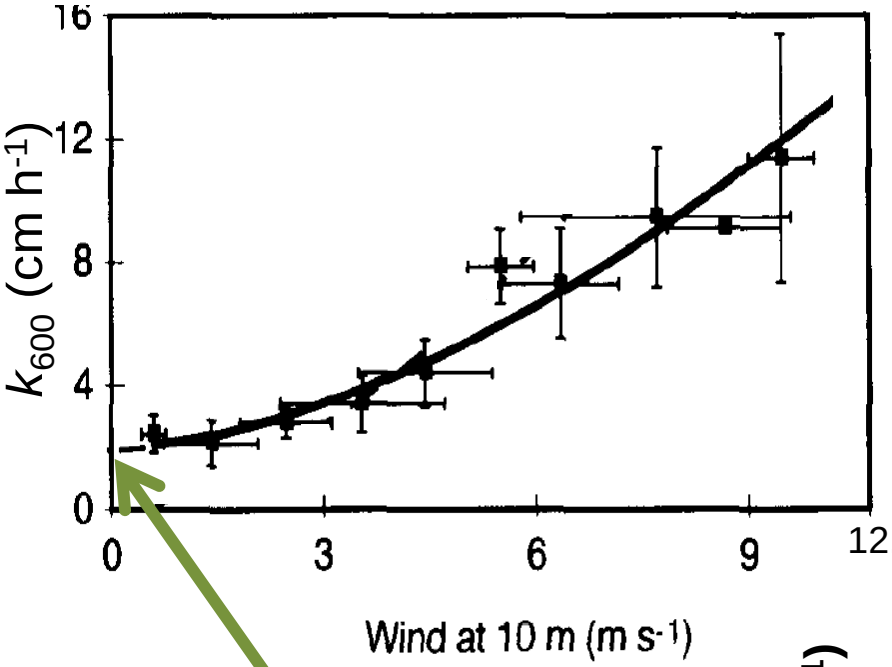




Morana et al. (2020) doi:10.5194/bg-17-5209-2020

Cole and Caraco (1998)

$k_{600} = 2.07 + 0.215 \times u_{10}^{0.17}$

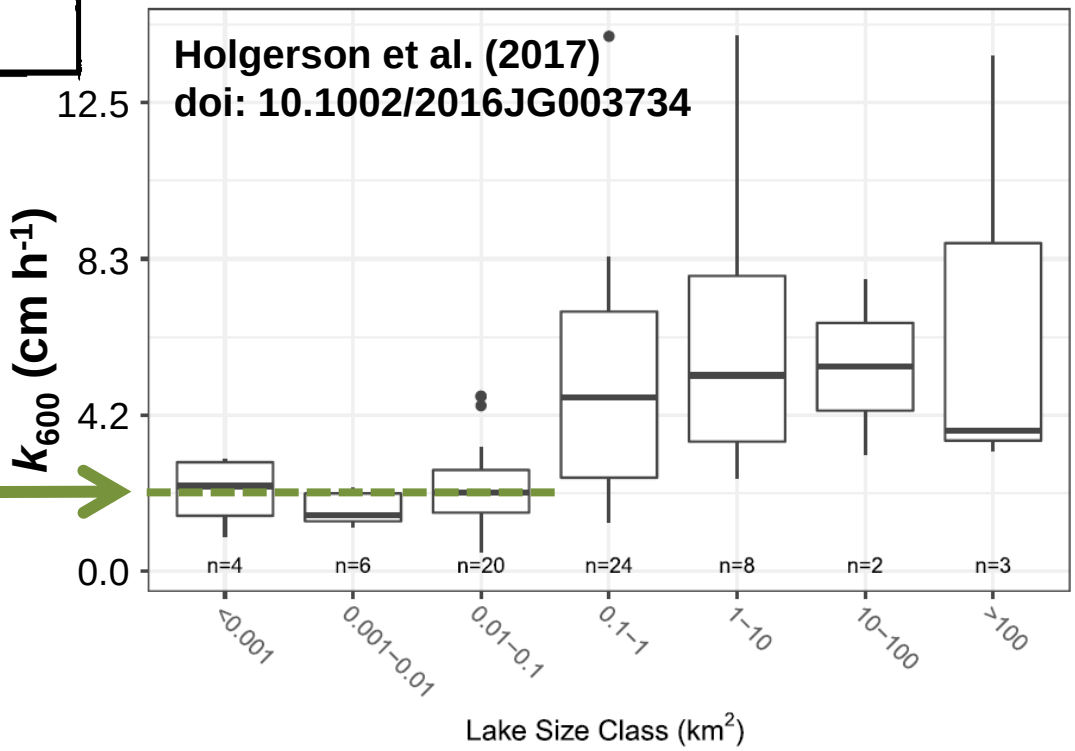


Compilation in 11 lakes

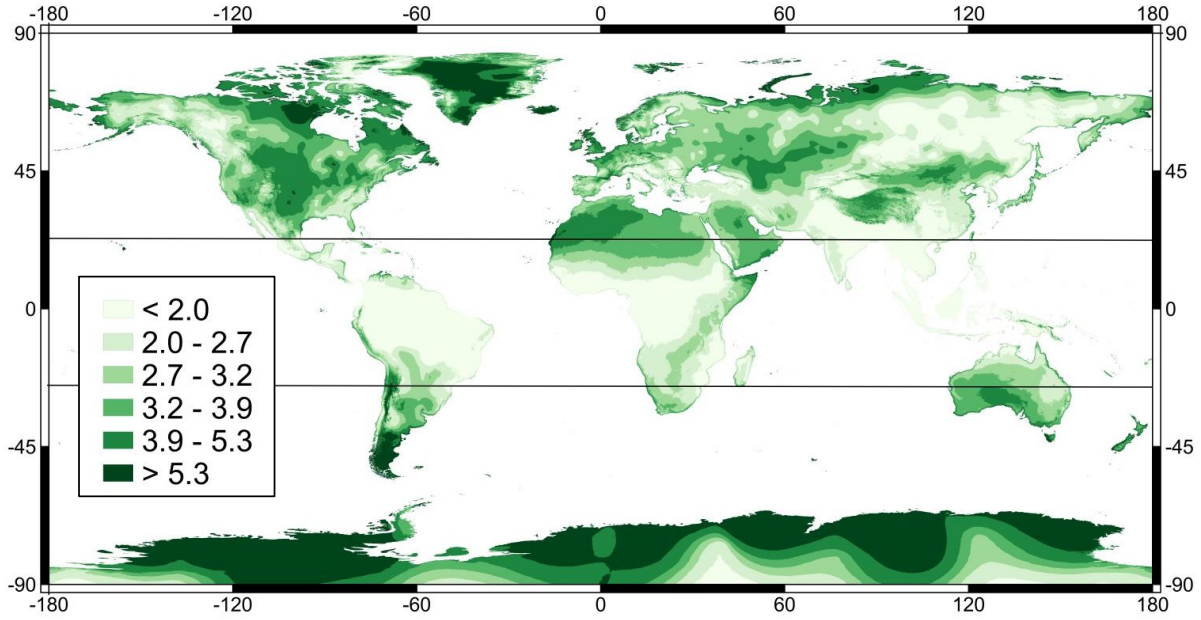
Range of maximum depth
0.7 to 109 m

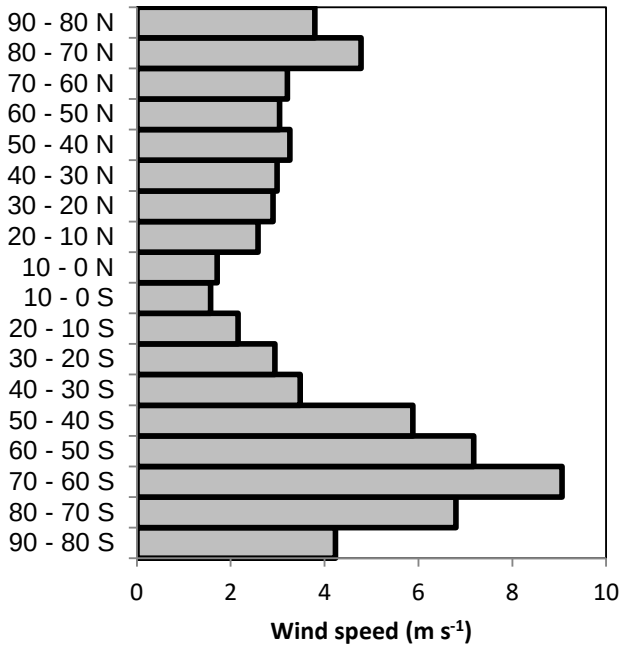
Range of surface area
0.14 to 487 km^2

2.1 cm h^{-1}



Q&A

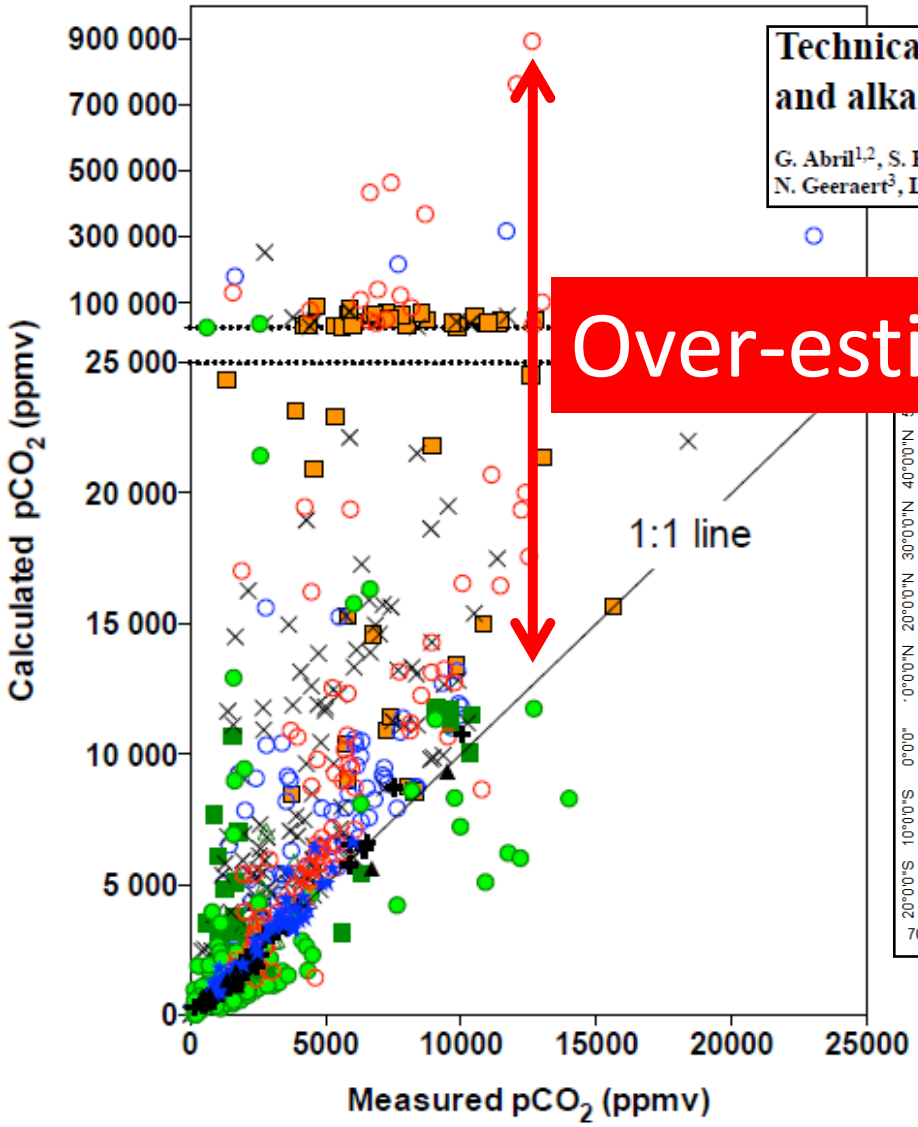




Raymond et al. (2013) lake *k*

Area class (km^2)	Mean gas exchange coefficient *k* ($m\ d^{-1}$)
<0.1	0.57
0.1-1	0.80
1-10	0.85
10-100	1.09
>100	1.15

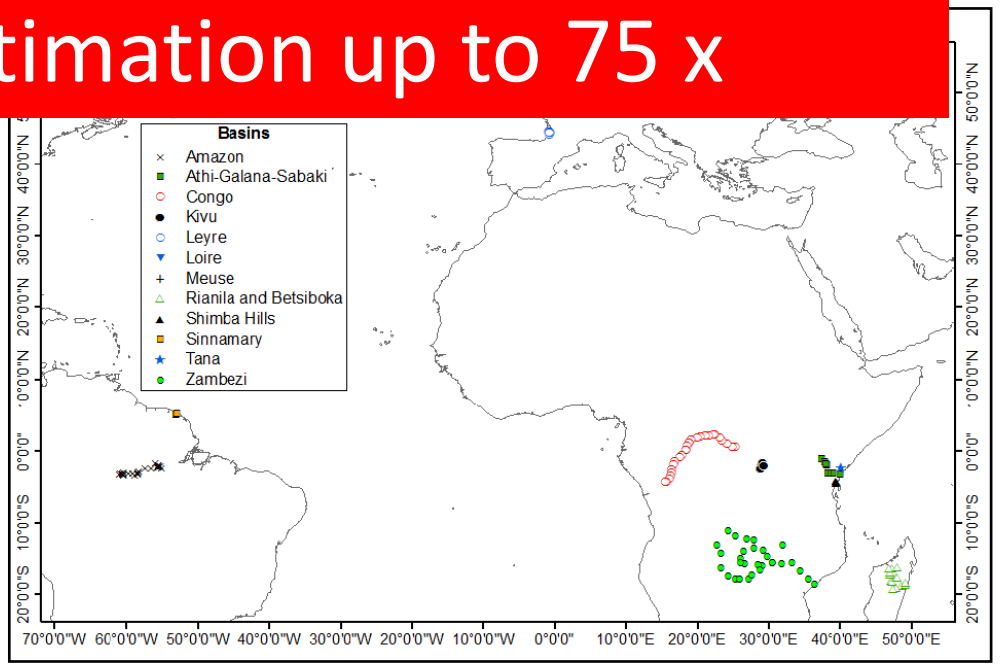
pCO_2 calculated from pH and total alkalinity *versus* pCO_2 measured direct



Technical Note: Large overestimation of pCO_2 calculated from pH and alkalinity in acidic, organic-rich freshwaters

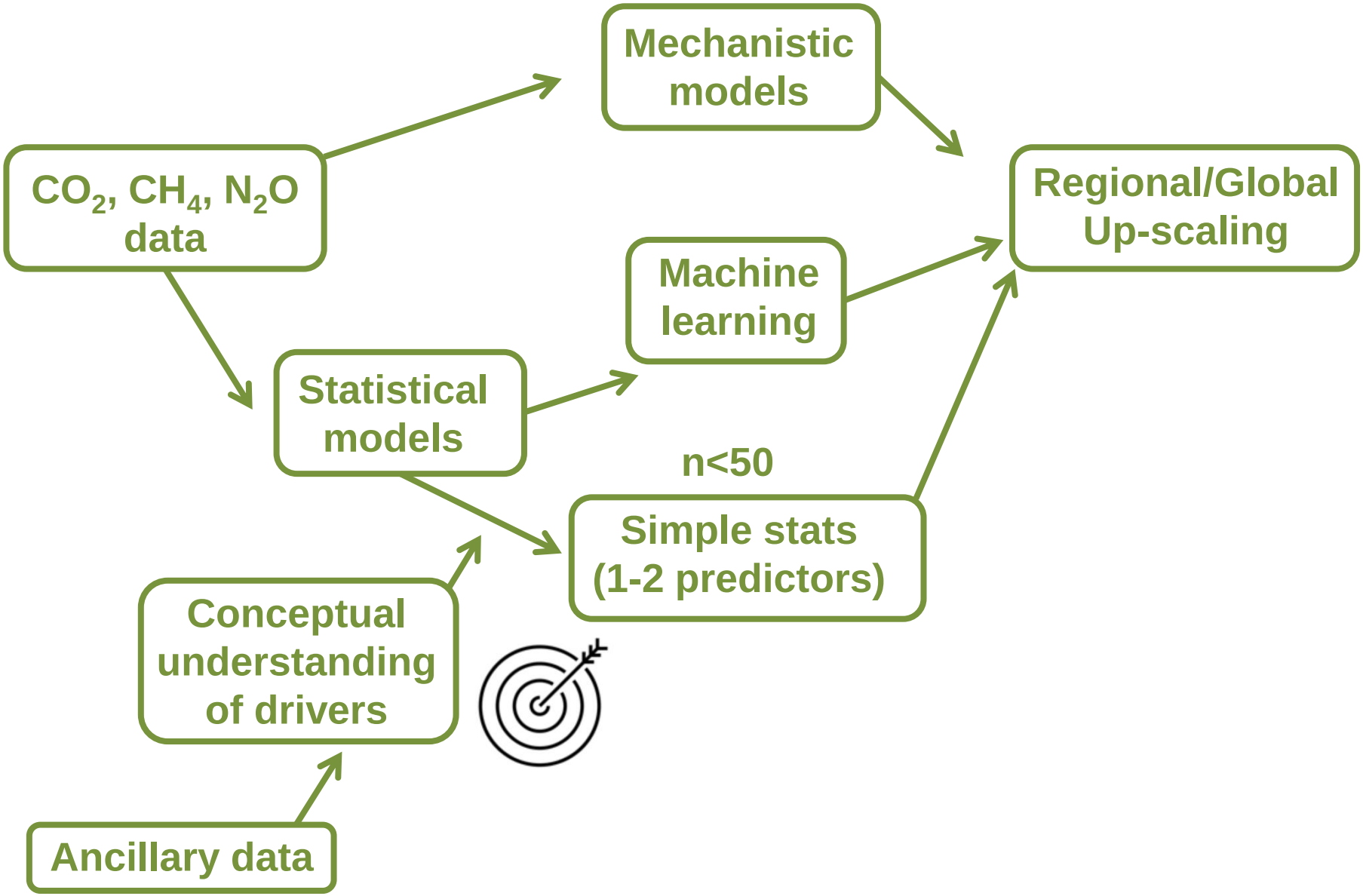
G. Abril[1,2], S. Bouillon[3], F. Darchambeau[4], C. R. Teodoru[3], T. R. Marwick[3], F. Tamooh[3], F. Ochieng Omengo[3], N. Geeraert[3], L. Deirmendjian[1], P. Polsenaere[1], and A. V. Borges[4]

Over-estimation up to 75 x



https://doi.org/10.5194/bg-12-67-2015

Q&A


Mechanistic models
CO_2, CH_4, N_2O data
Regional/Global Up-scaling
Machine learning
Statistical models
n<50
Simple stats (1-2 predictors)
Conceptual understanding of drivers
Ancillary data