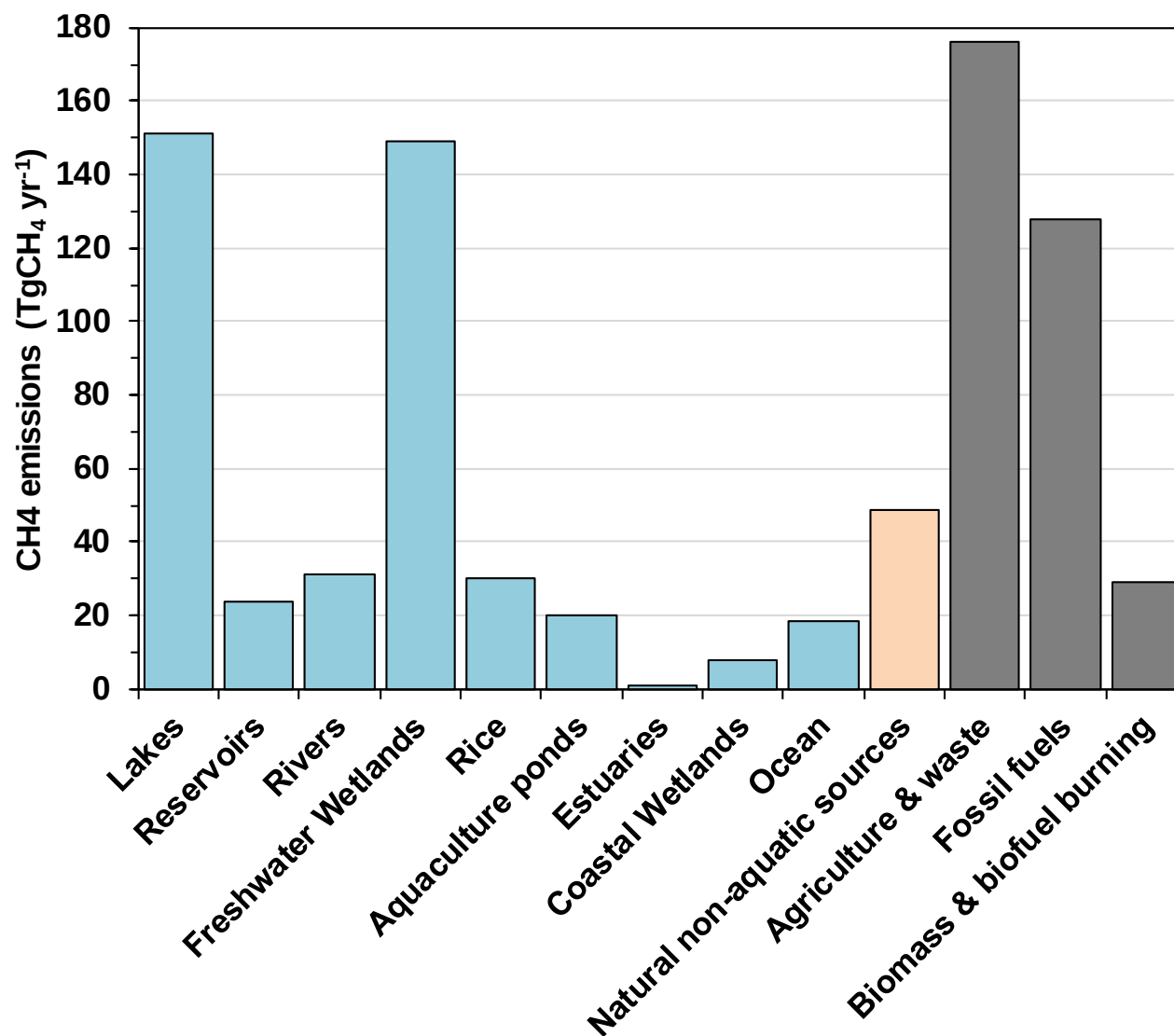


GHG emissions from African lakes and headwaters of the Amazon River

Alberto Borges

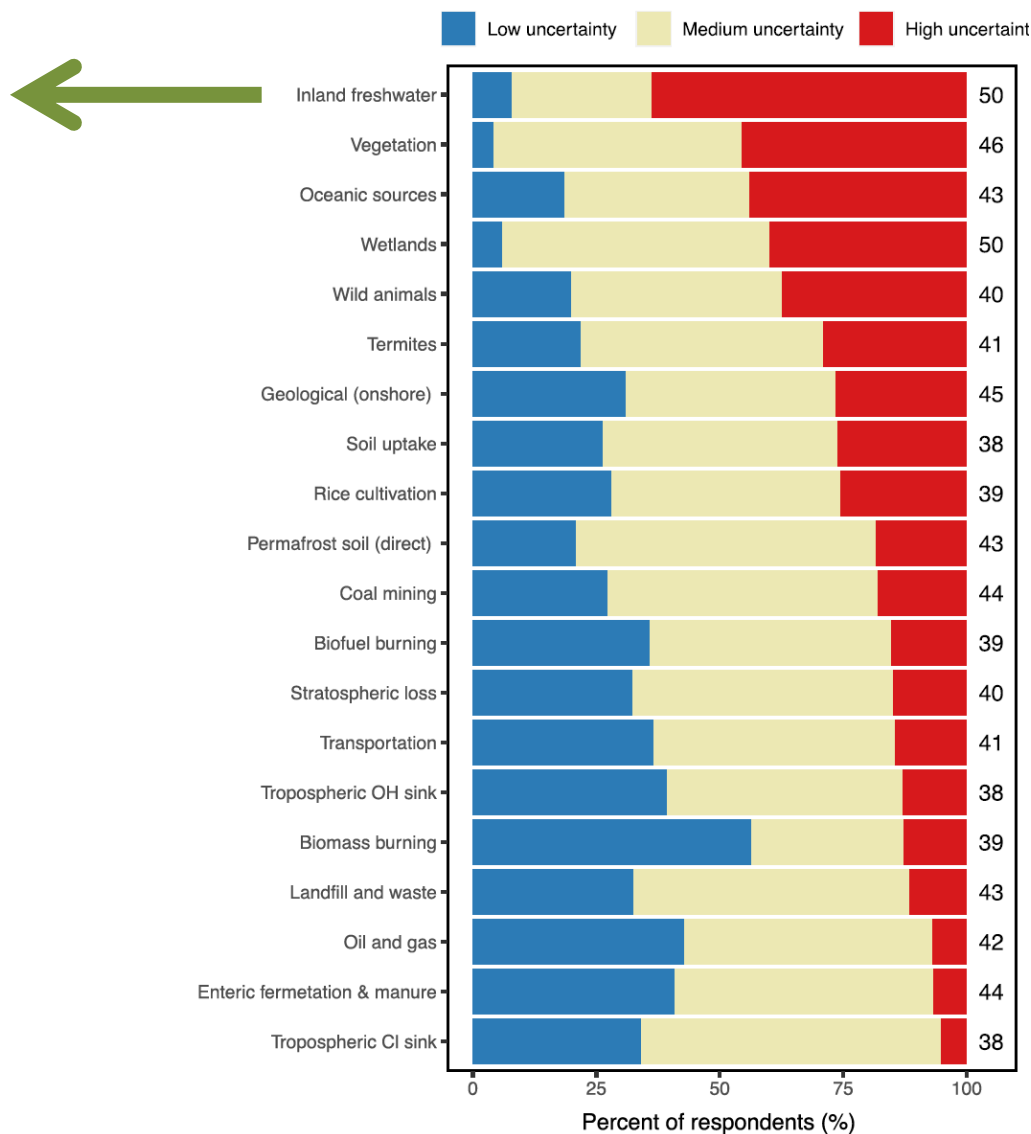
co2.uliege.be

CH₄ emissions from lakes & rivers are significant

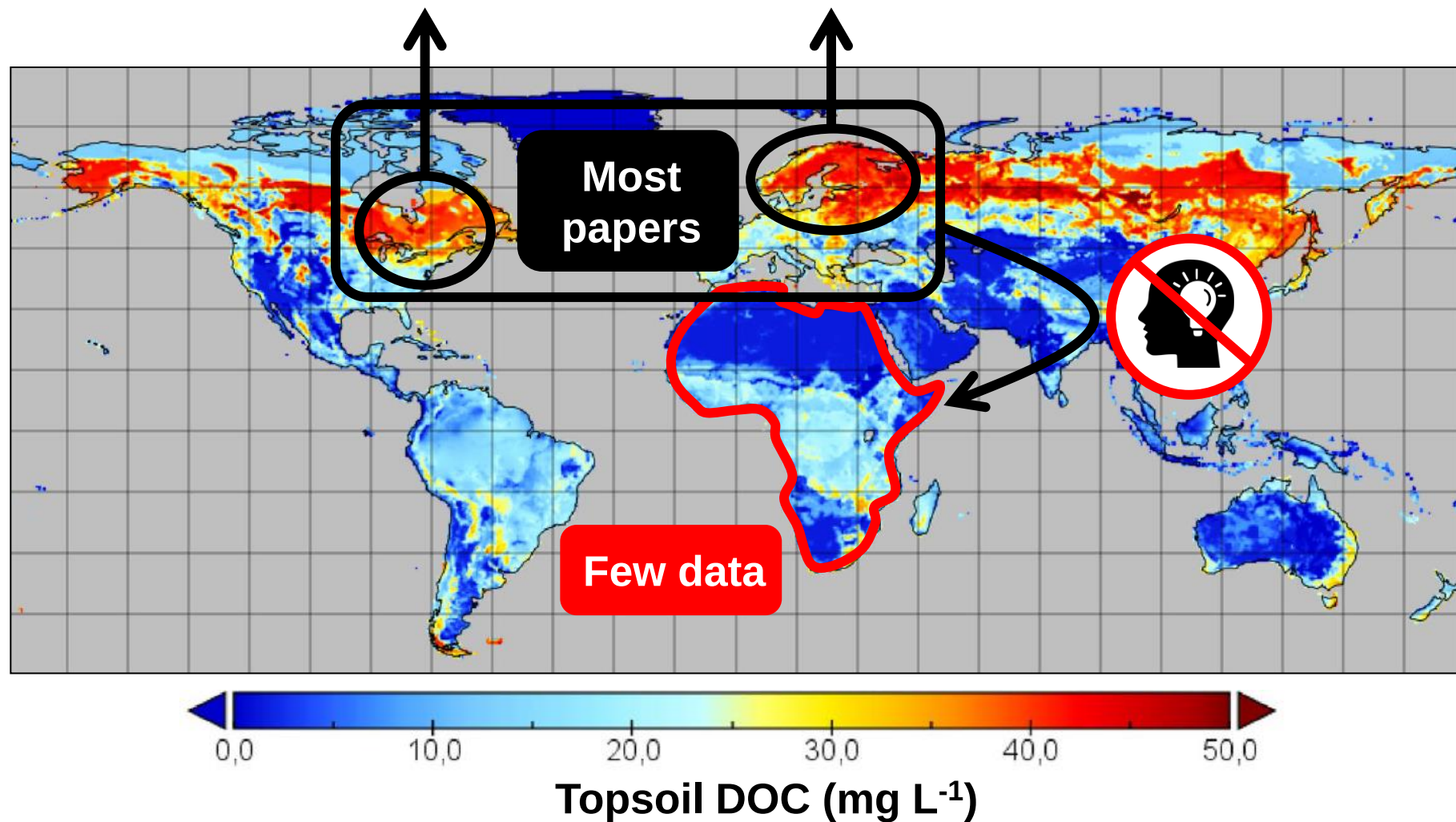


CH₄ emissions from lakes & rivers are significant but highly uncertain

Inland freshwater



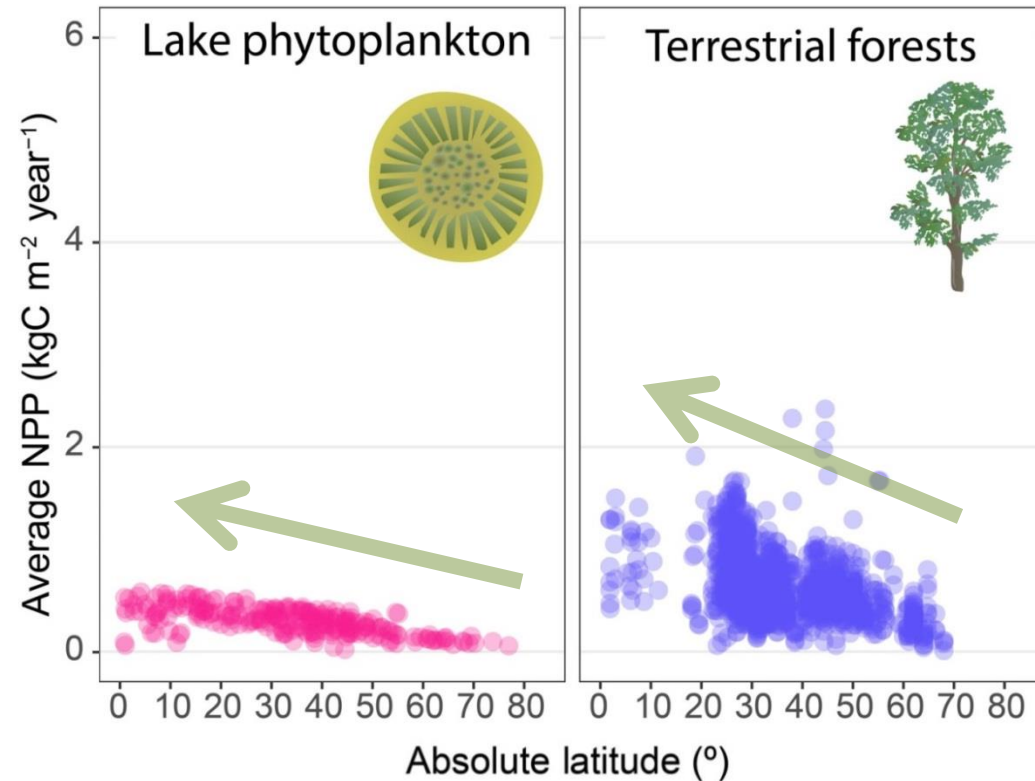
« Humic-centric » of view of C cycling in lakes



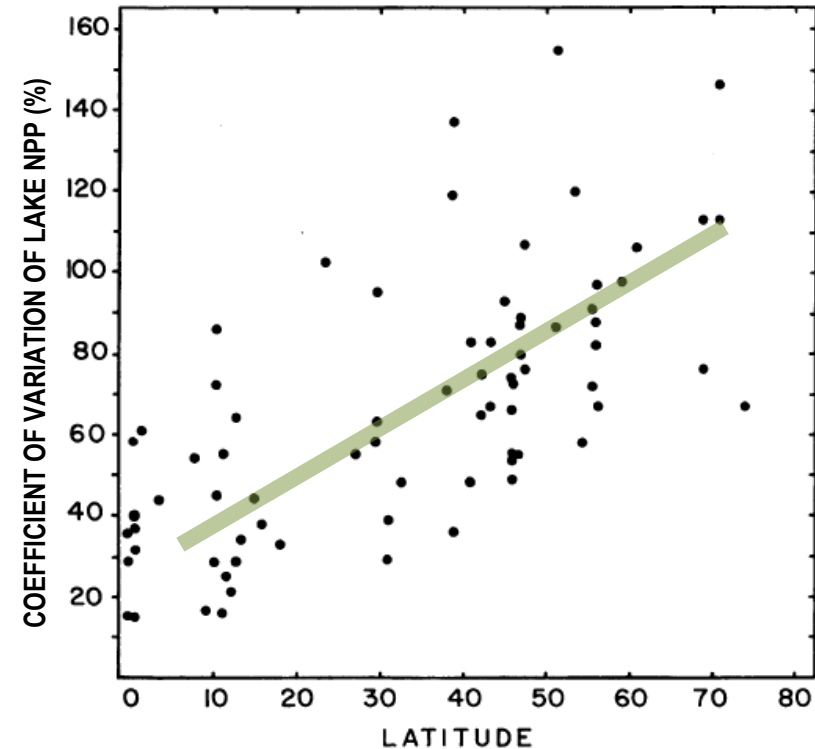
Why tropical lakes ?

Warm (obviously) and productive

Primary production less variable seasonally



Pessarrodona et al. (2022)
doi: [10.1126/sciadv.abn2465](https://doi.org/10.1126/sciadv.abn2465)

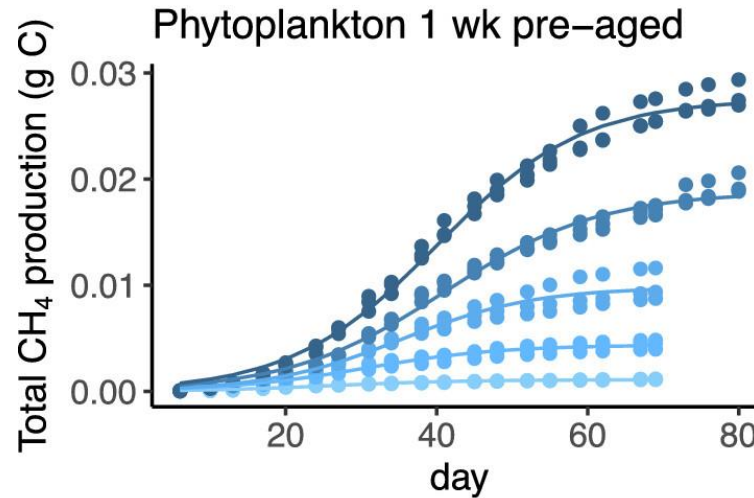


Melack (1979)
doi: [10.1007/BF00346388](https://doi.org/10.1007/BF00346388)

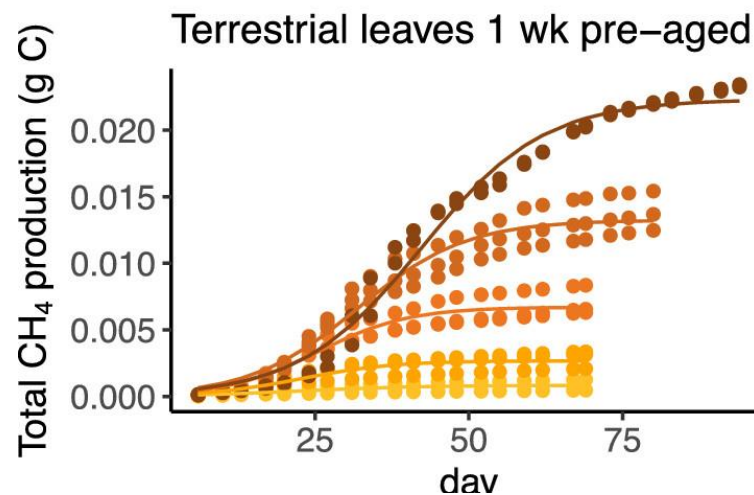
Why tropical lakes ?

Warm (obviously) and productive

Primary production less variable seasonally



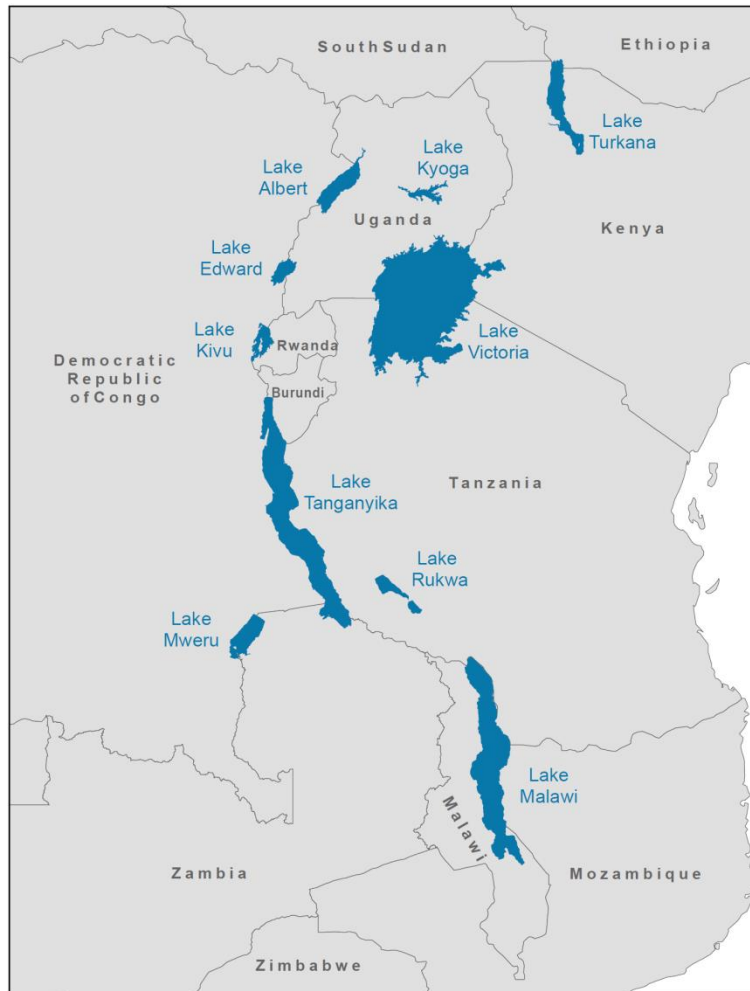
Addition of
organic matter

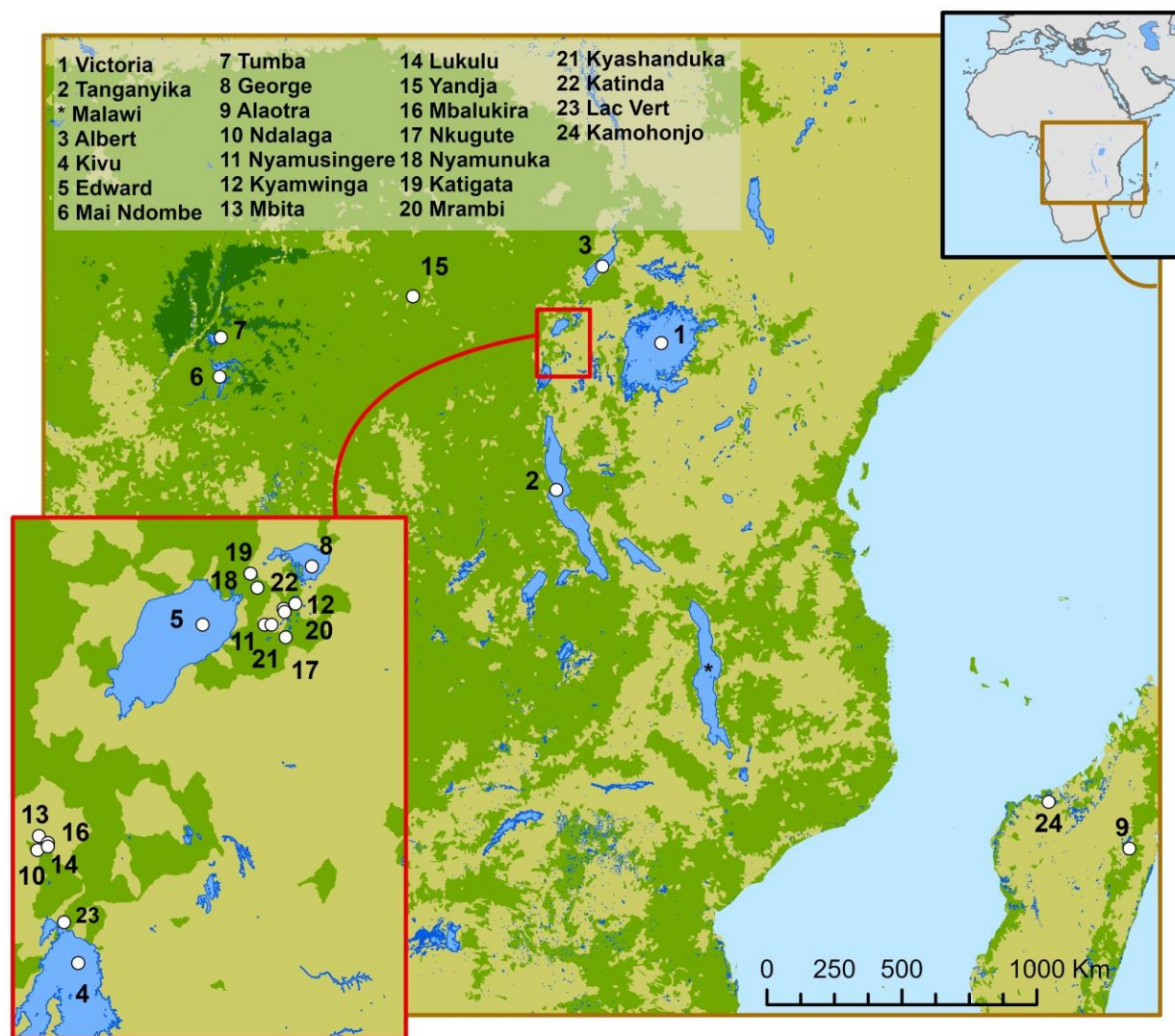


Addition of
organic matter

Why Africa ?

Biggest concentration of large lakes after Laurentian Great Lakes
66% of the total surface area of tropical lakes (>0.1 km²)





Land cover



Flooded forest

Rain forest

Savannah

Surface area



Victoria 67,000 km²

Lac Vert 0.2 km²

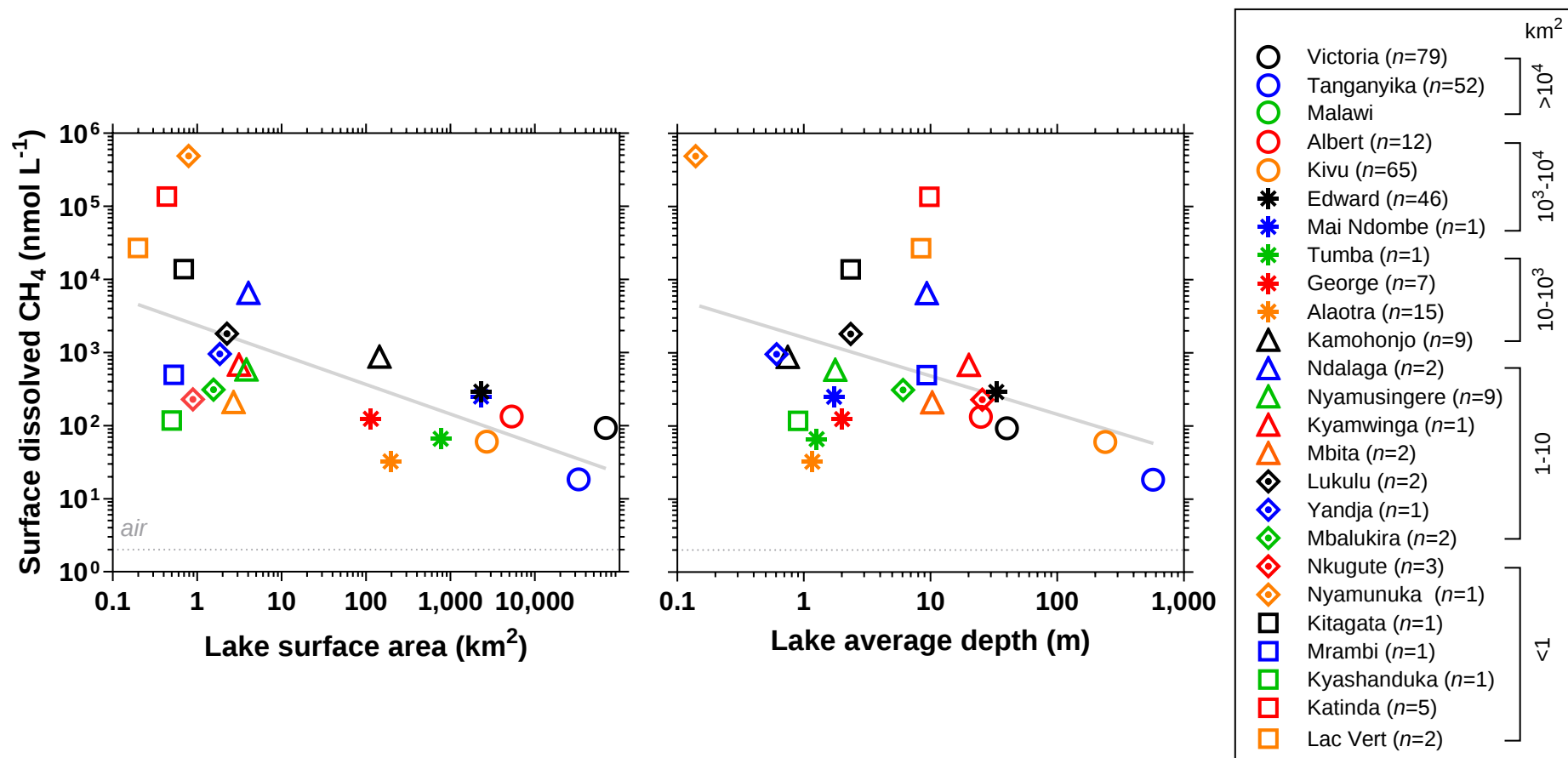
Max depth



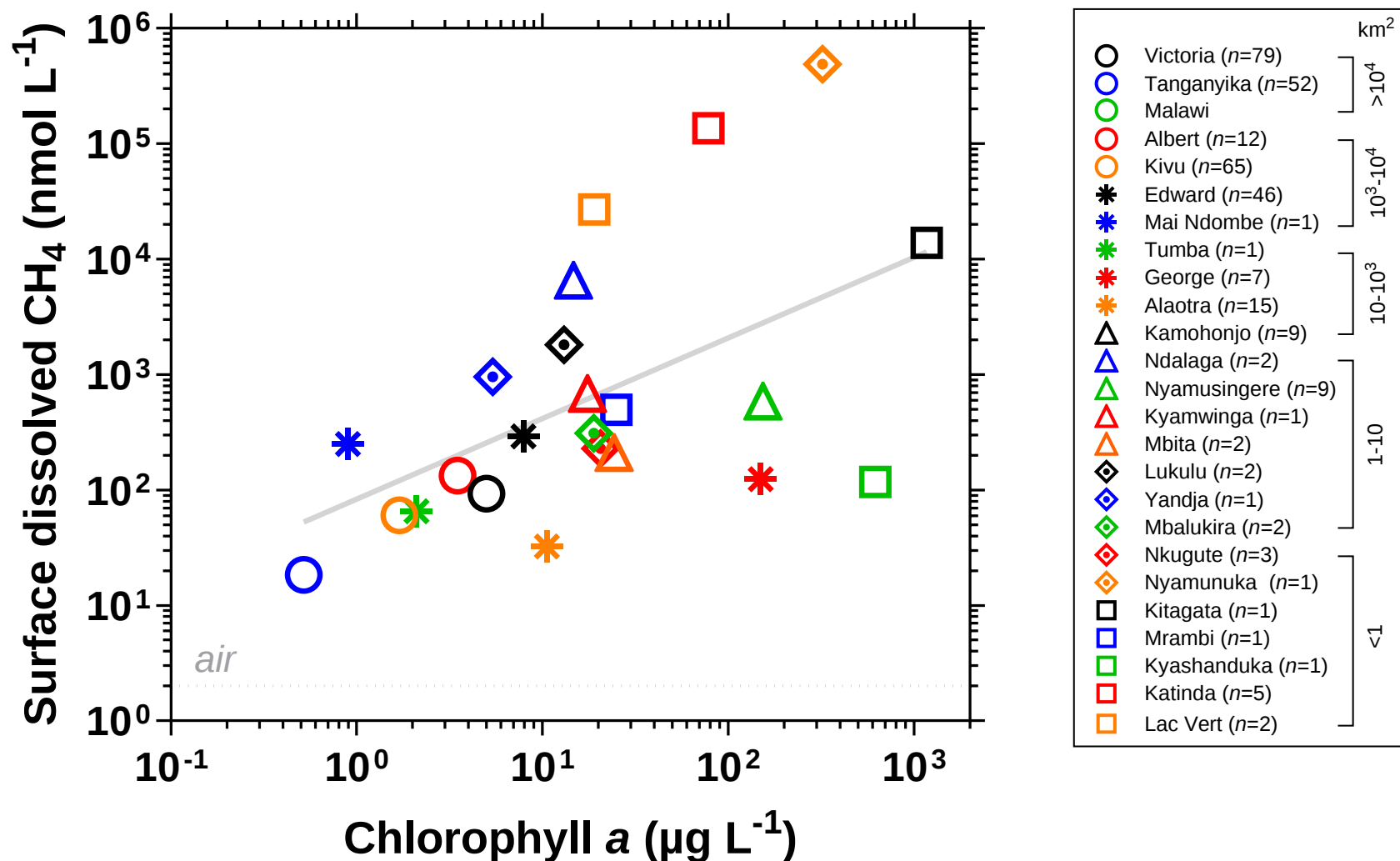
Tanganyika 1,470 m

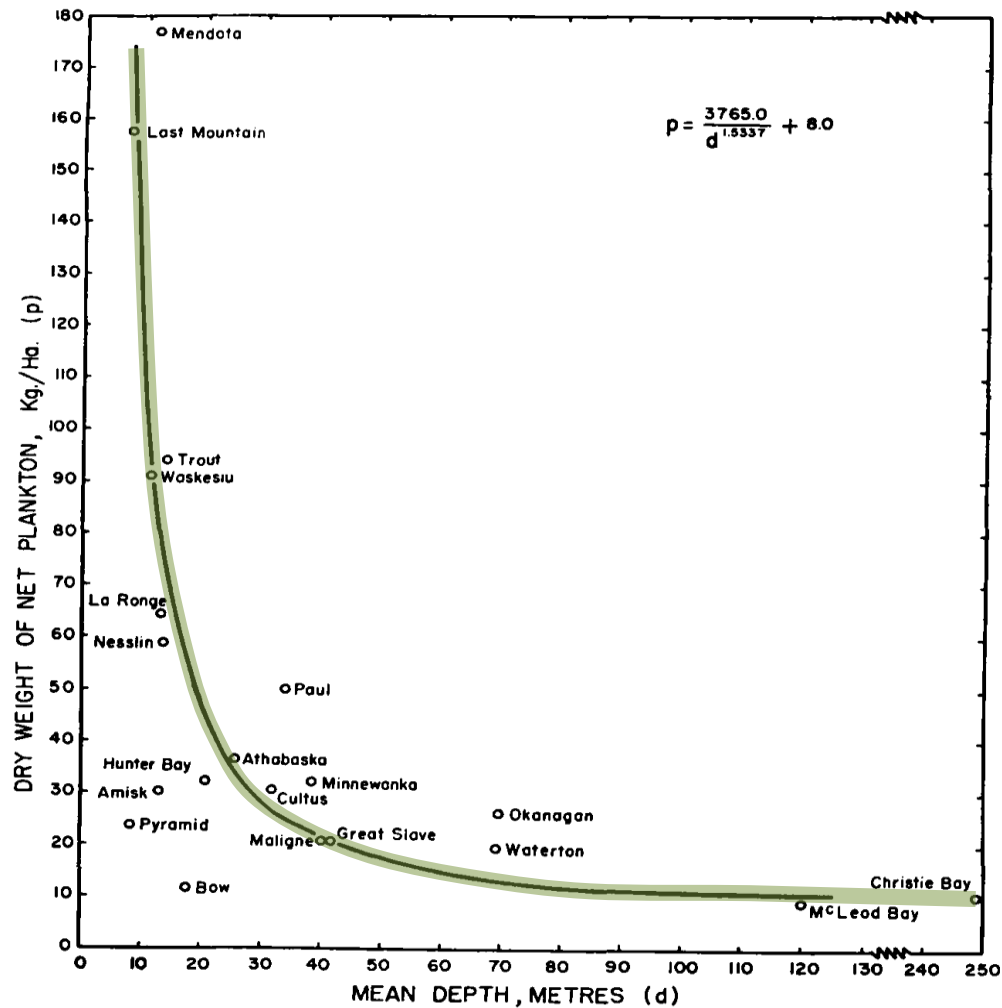
Nyamunuka 0.1 m

Surface CH₄ in African lakes



Surface CH₄ in African lakes

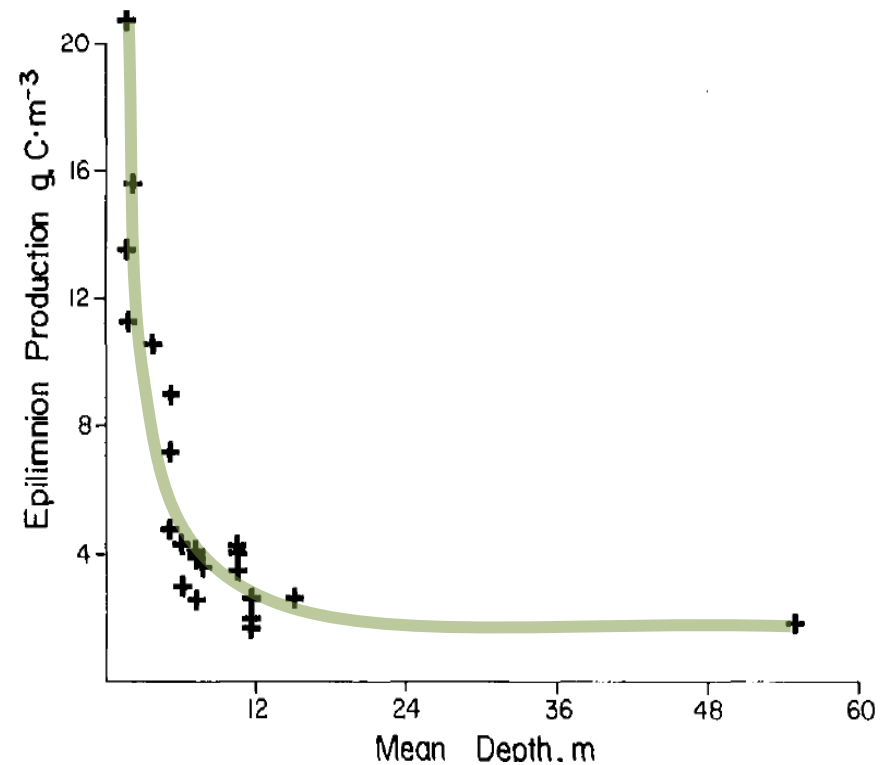




Rawson (1953)

doi:10.1080/03680770.1950.11895282

Shallow = productive
Productive = high CH₄



Fee (1979)

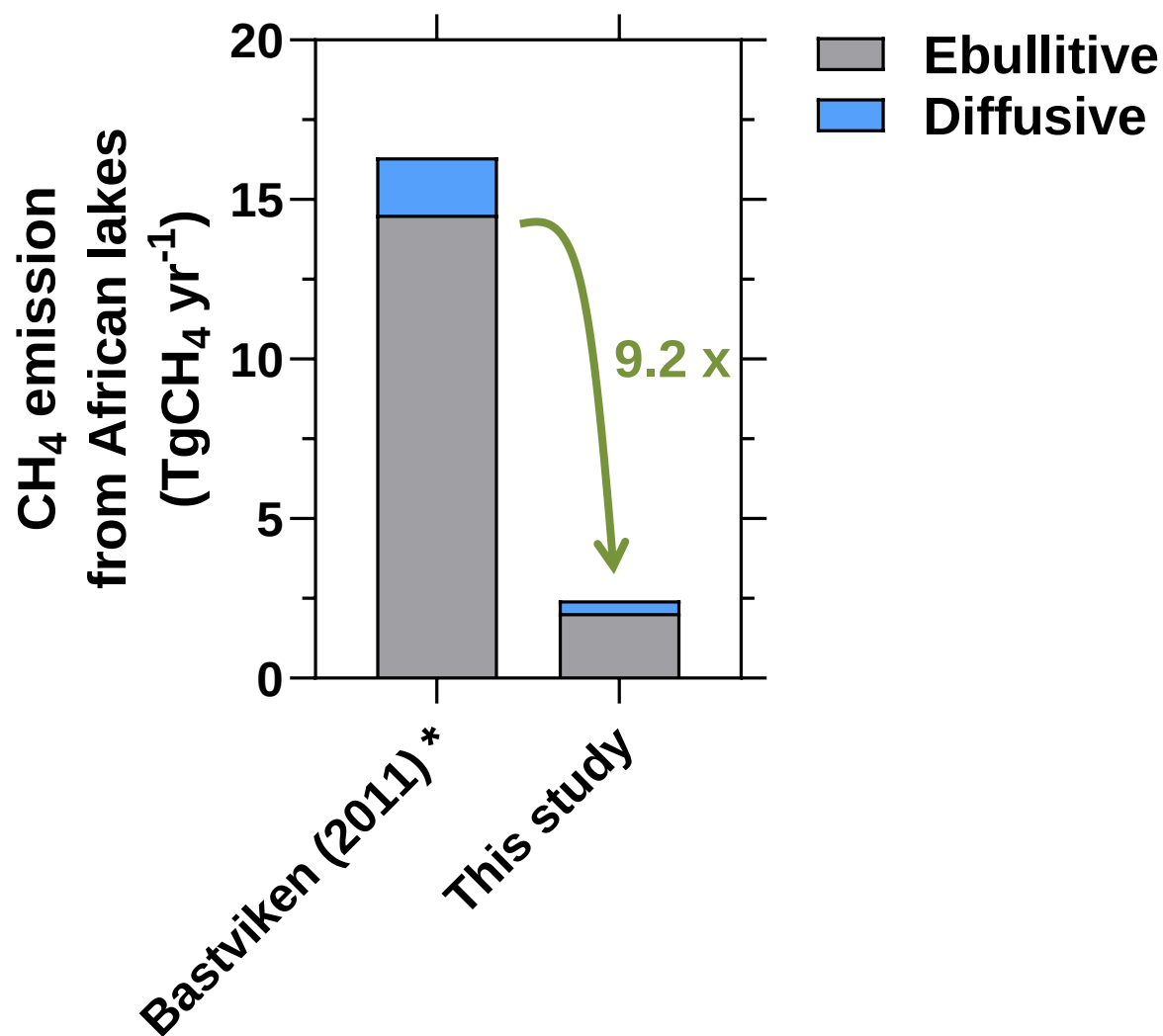
doi:10.4319/lo.1979.24.3.0401

Upscaling diffusive CH_4 emissions in African lakes



Upscaling ebullitive CH_4 emissions in African lakes





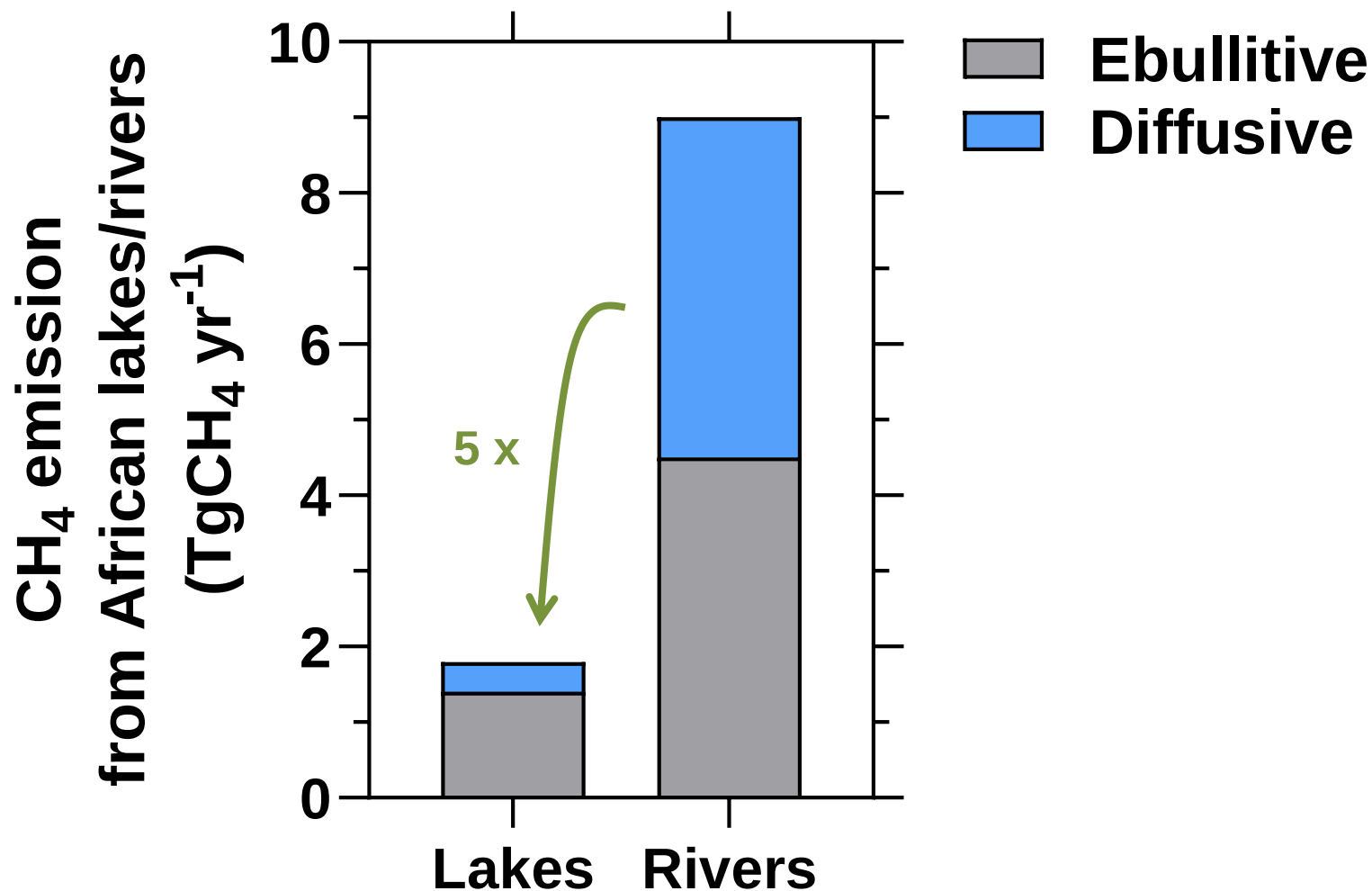
* rescaled as African lakes = 66% of tropical lakes

CH₄ emissions from African lakes

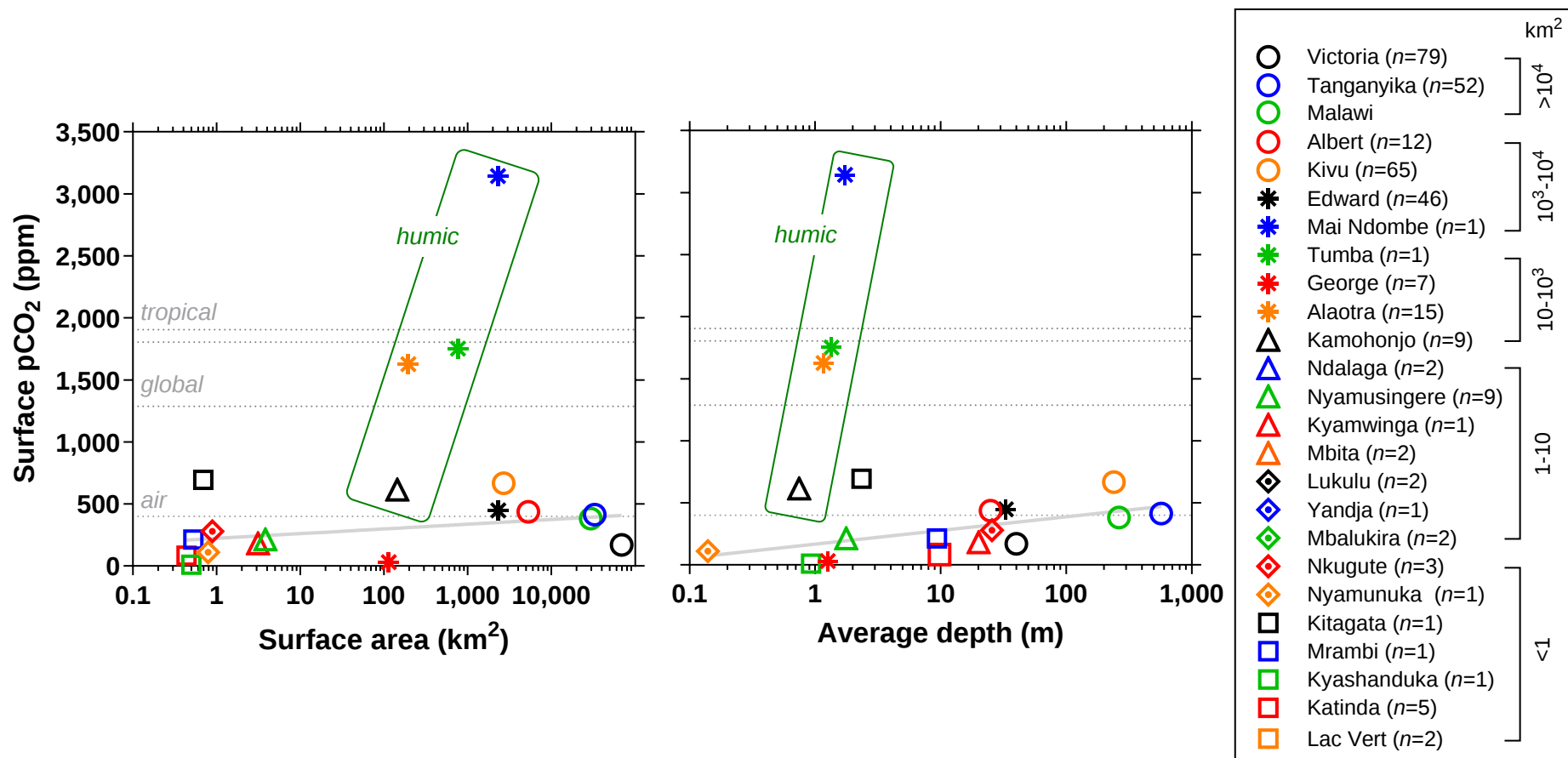
This study	Ebullitive	1.4	TgCH ₄ /yr	25.0	gCH ₄ /m ² /yr
	Diffusive	0.4	TgCH ₄ /yr	2.1	gCH ₄ /m ² /yr
	Total	1.8	TgCH ₄ /yr		
	Total lake surface area	209,394	km ²		
	Littoral zone (<10m)	56,063	km ²		
Bastviken et al (2011)	Ebullitive	14.5	TgCH ₄ /yr	38.9	gCH ₄ /m ² /yr
	Diffusive	2.0	TgCH ₄ /yr	5.5	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

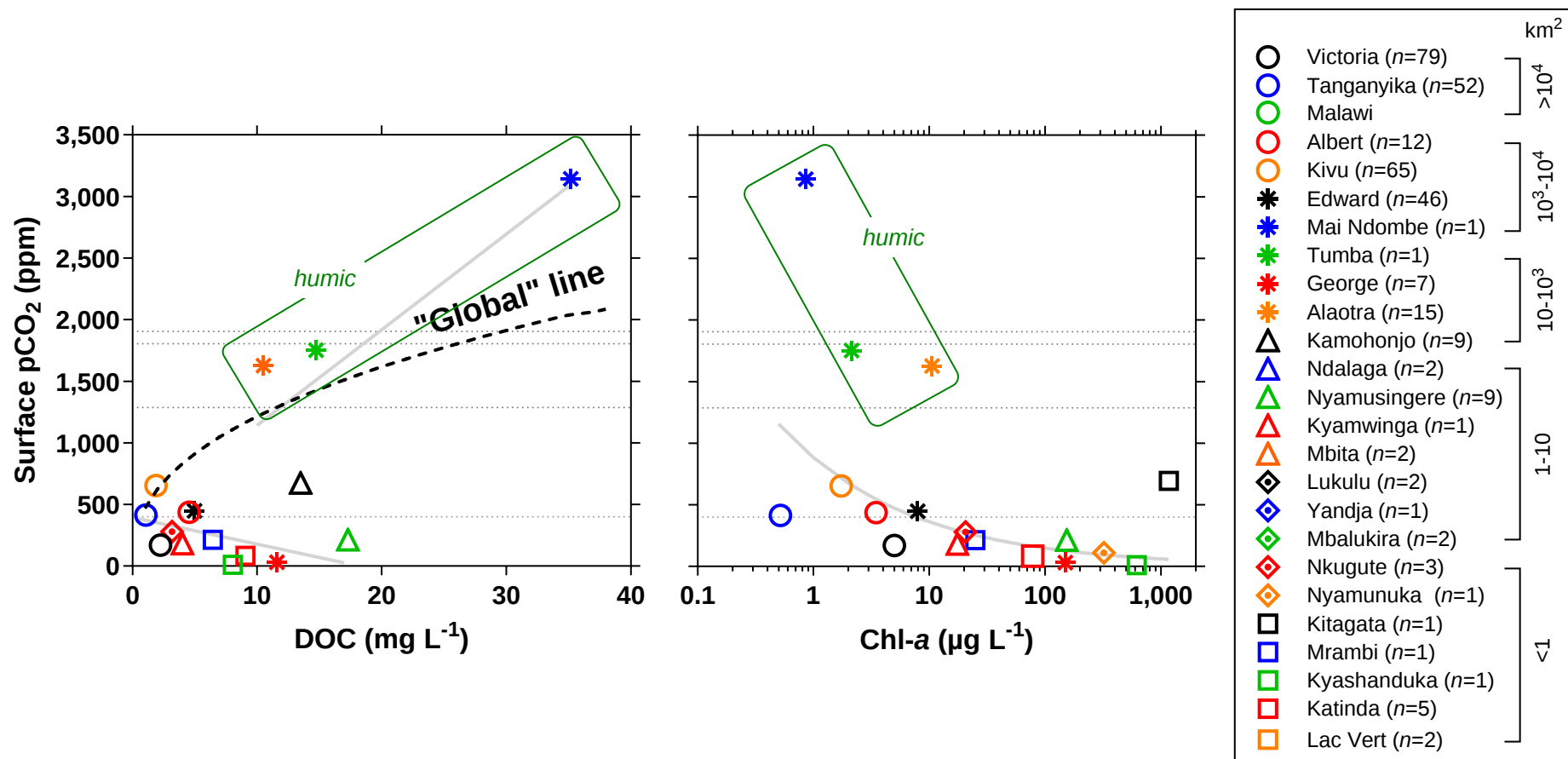
CH₄ emissions from African lakes/ivers

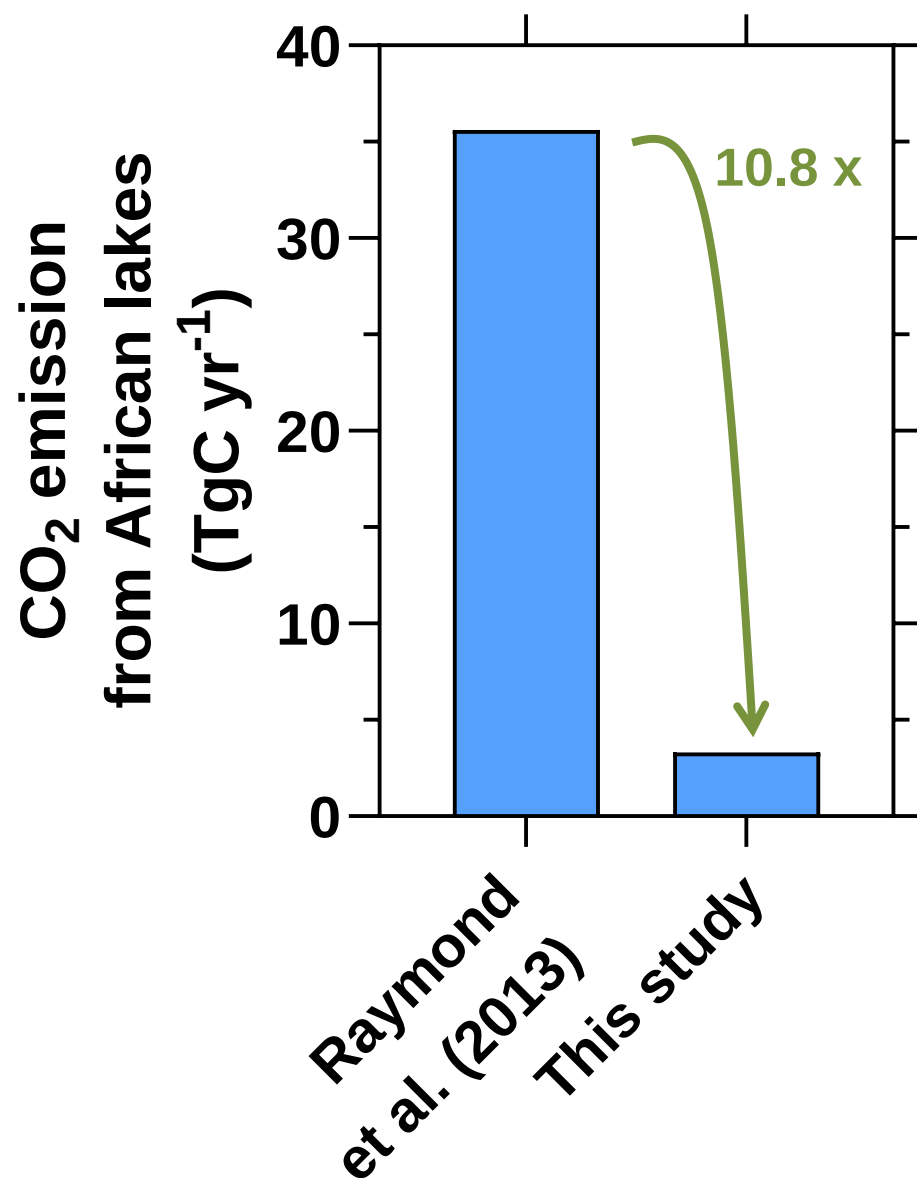


Surface pCO₂ in African lakes



Surface pCO₂ in African lakes





CO₂ emissions from African lakes

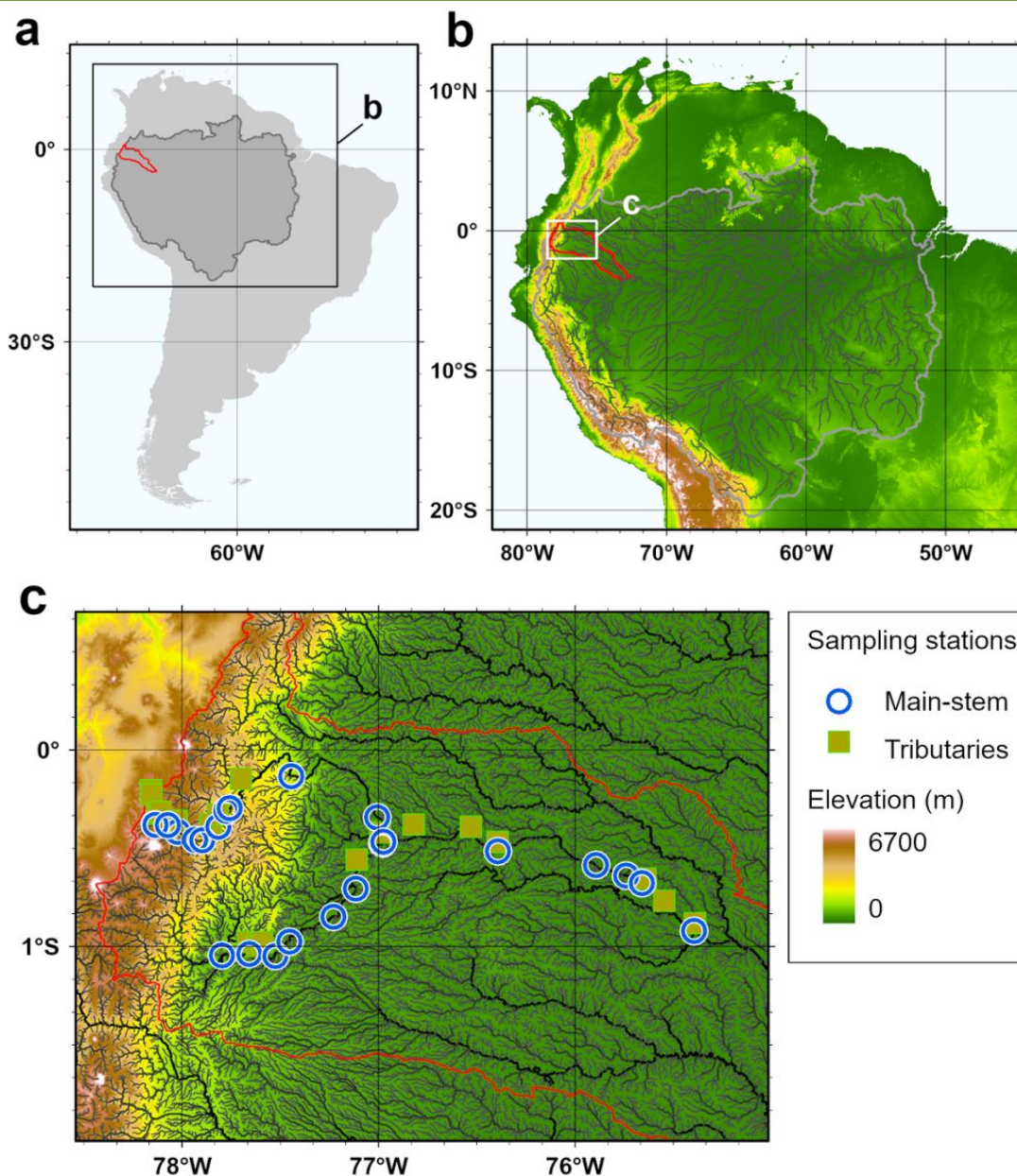
This study	Diffusive Flux	3.3	TgC/yr	15.9	gC/m2/yr
	Average pCO ₂	530	ppm		
	Total lake surface area	209,394	km ²		
Raymond et al (2013)	Diffusive Flux	35.6	TgC/yr	160.3	gC/m2/yr
	Average pCO ₂	934	ppm		
	Total lake surface area	222,062	km ²		

Napo River

Elevation

~ 4000m

~ 170m



Flat terrain (lowlands)

Low turbulence

High temperature

Thick soils

Riparian wetlands

High CO₂
High CH₄

Steep terrain (highlands)

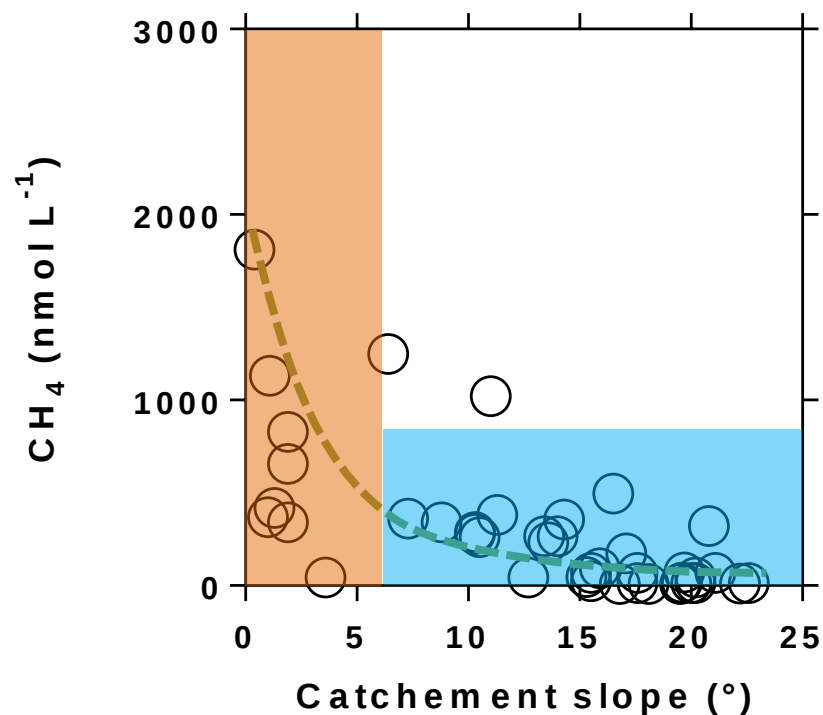
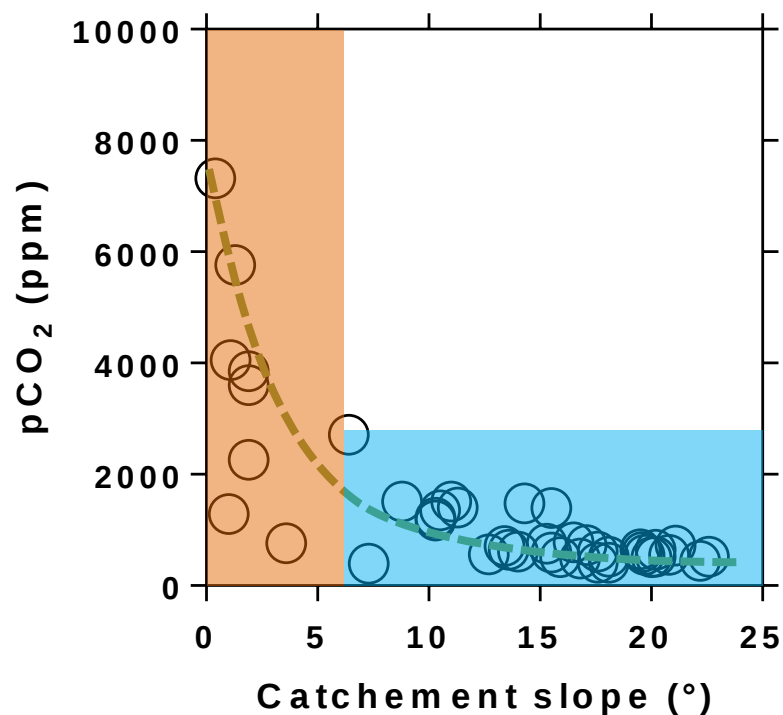
High turbulence

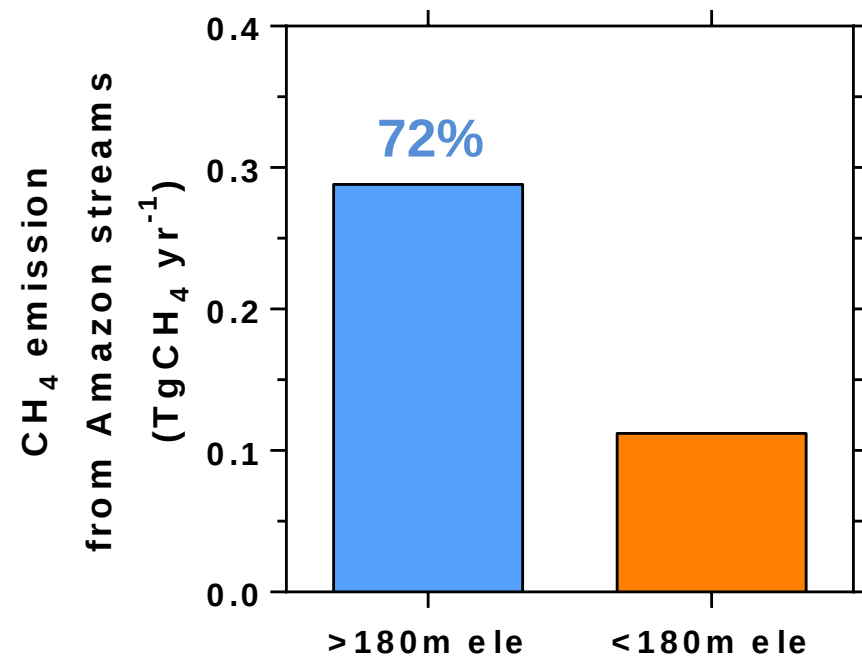
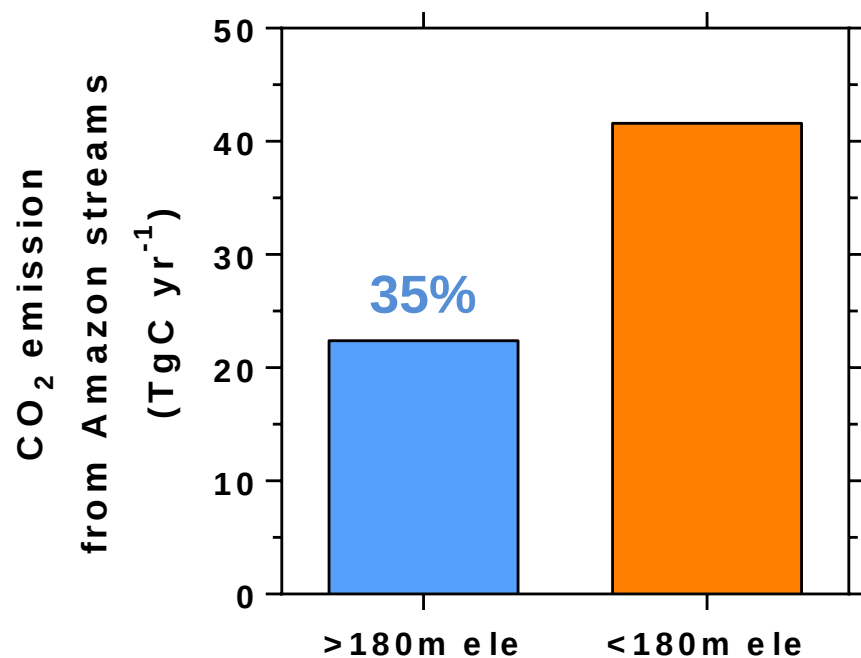
Low temperature

Shallow soils

No lateral flooding

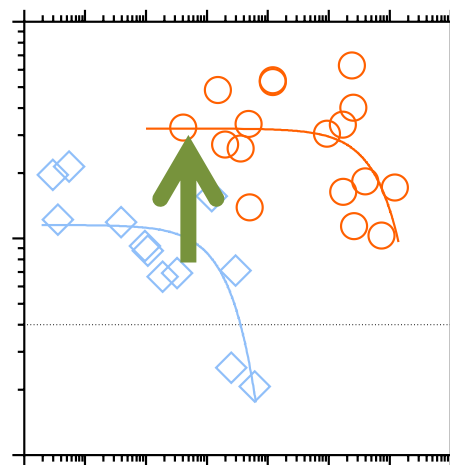
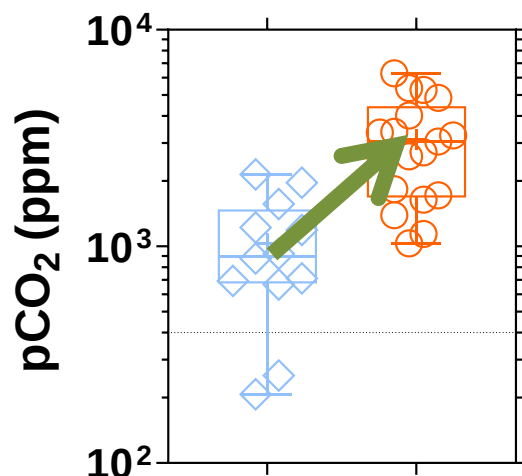
Low CO₂
Low CH₄



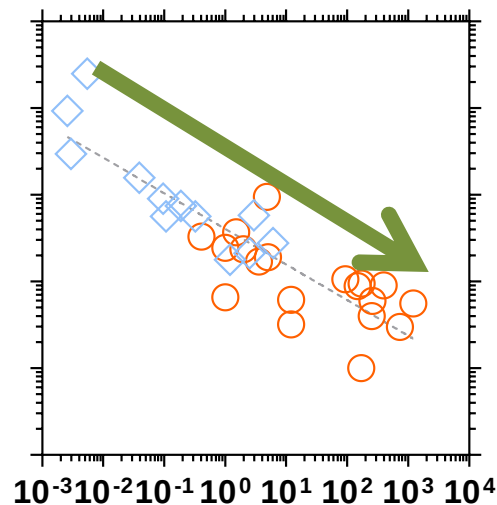
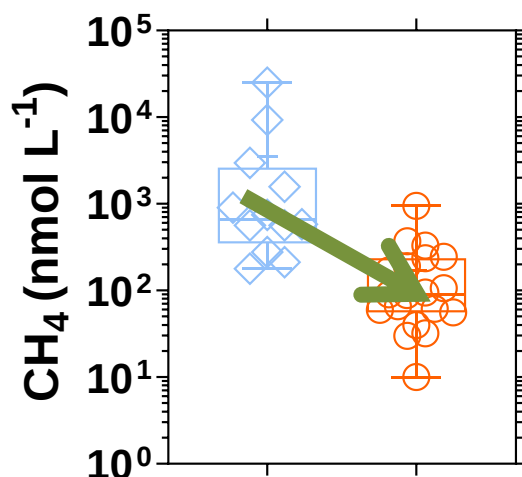


Highland and lowland lakes of the Amazon

River CO₂
input to
floodplain
lakes



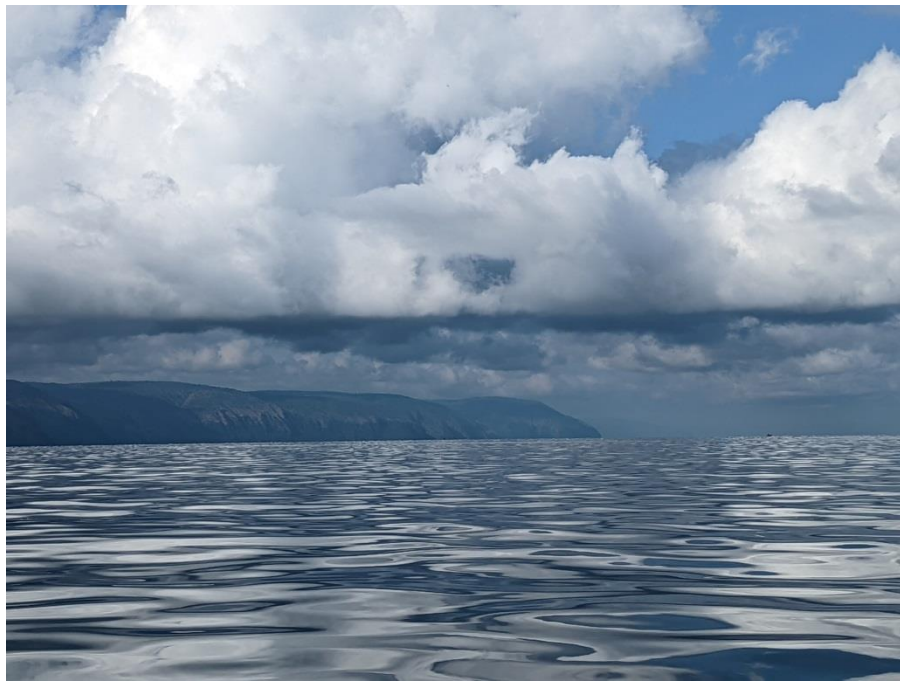
Lake size
increase

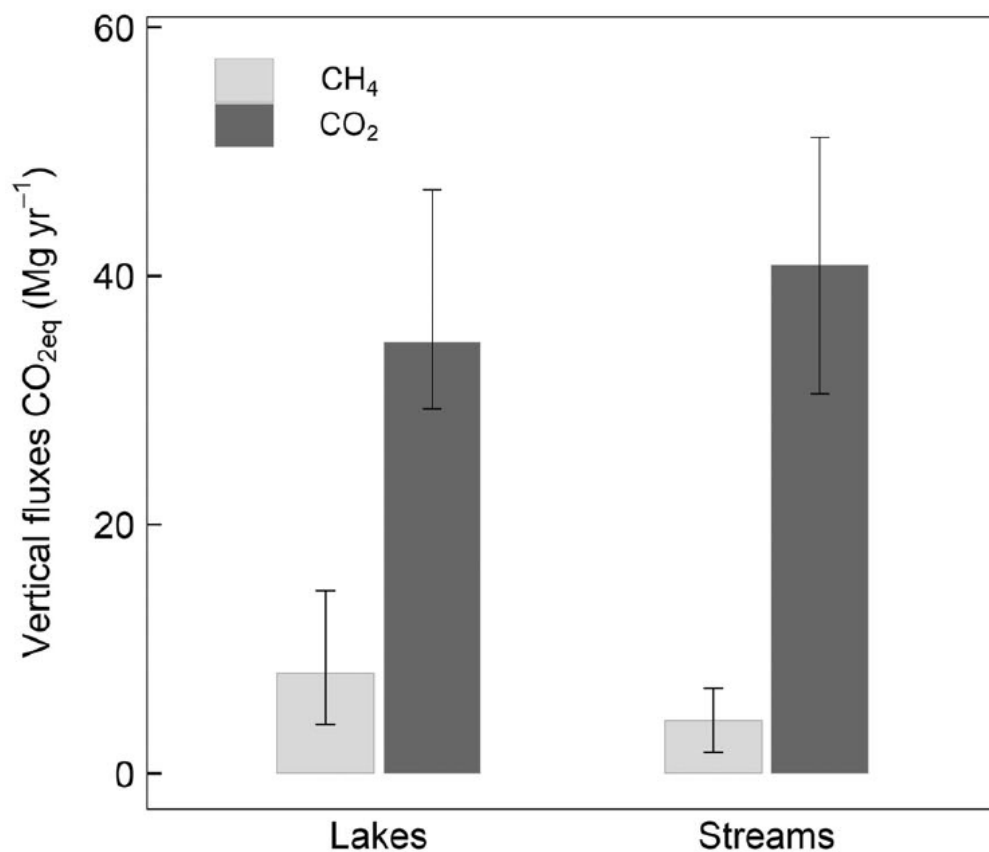


Highland

Lowland

Surface area (km²)

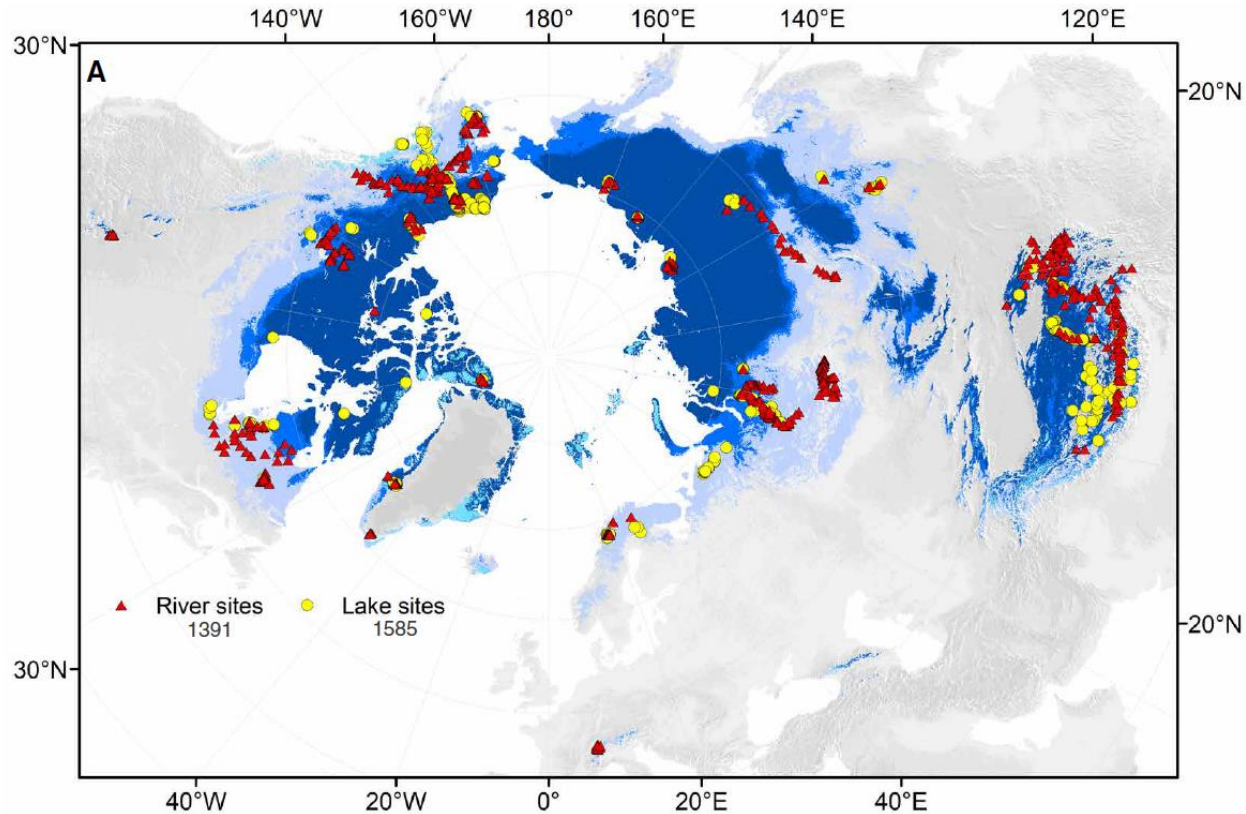




Skogaryd Research Catchment (SRC) ~ 7 km²

River CH_4 emissions < Lake CH_4 emissions (2 x)

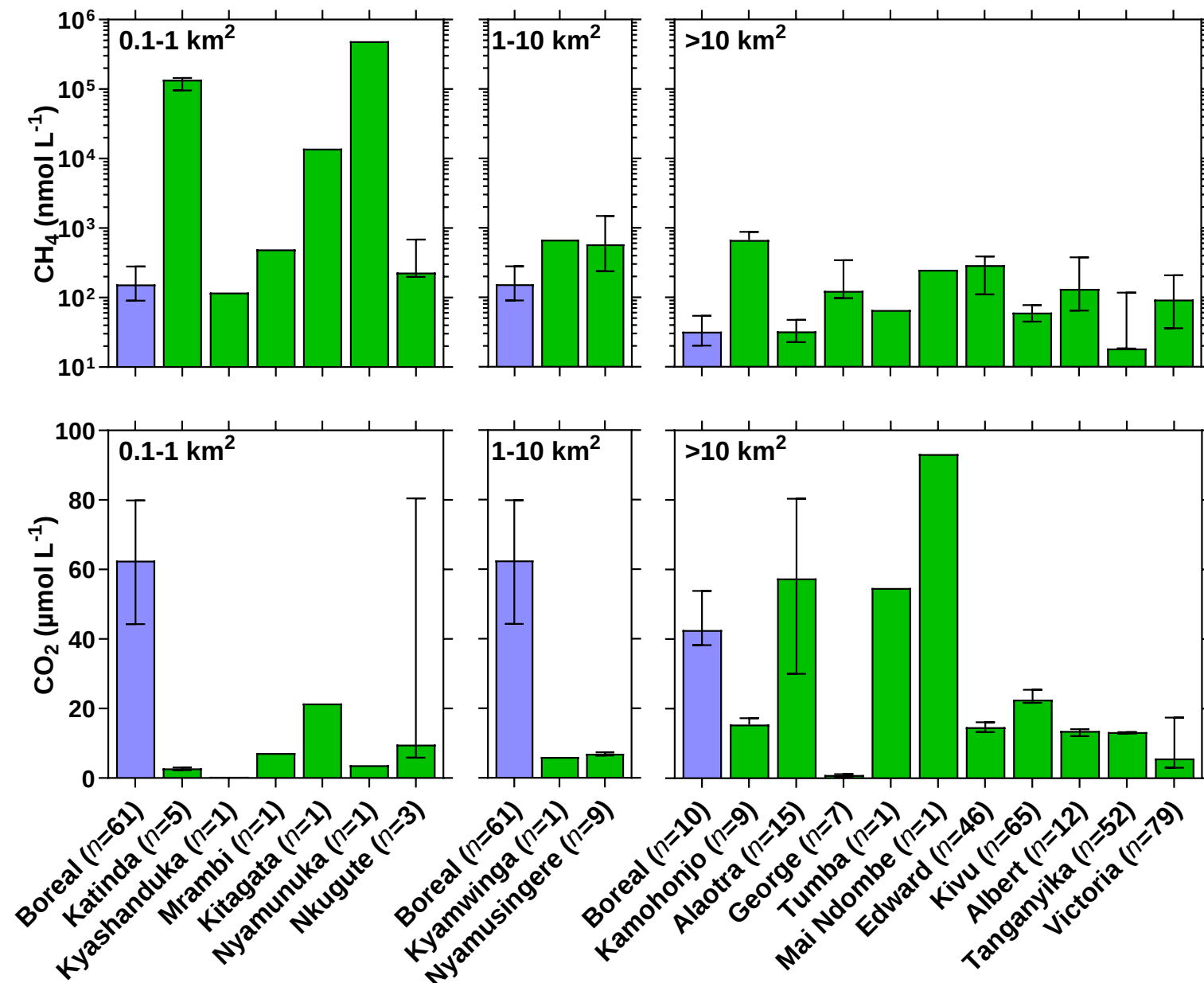
River CO_2 emissions $\geq$ Lake CO_2 emissions (1.2 x)

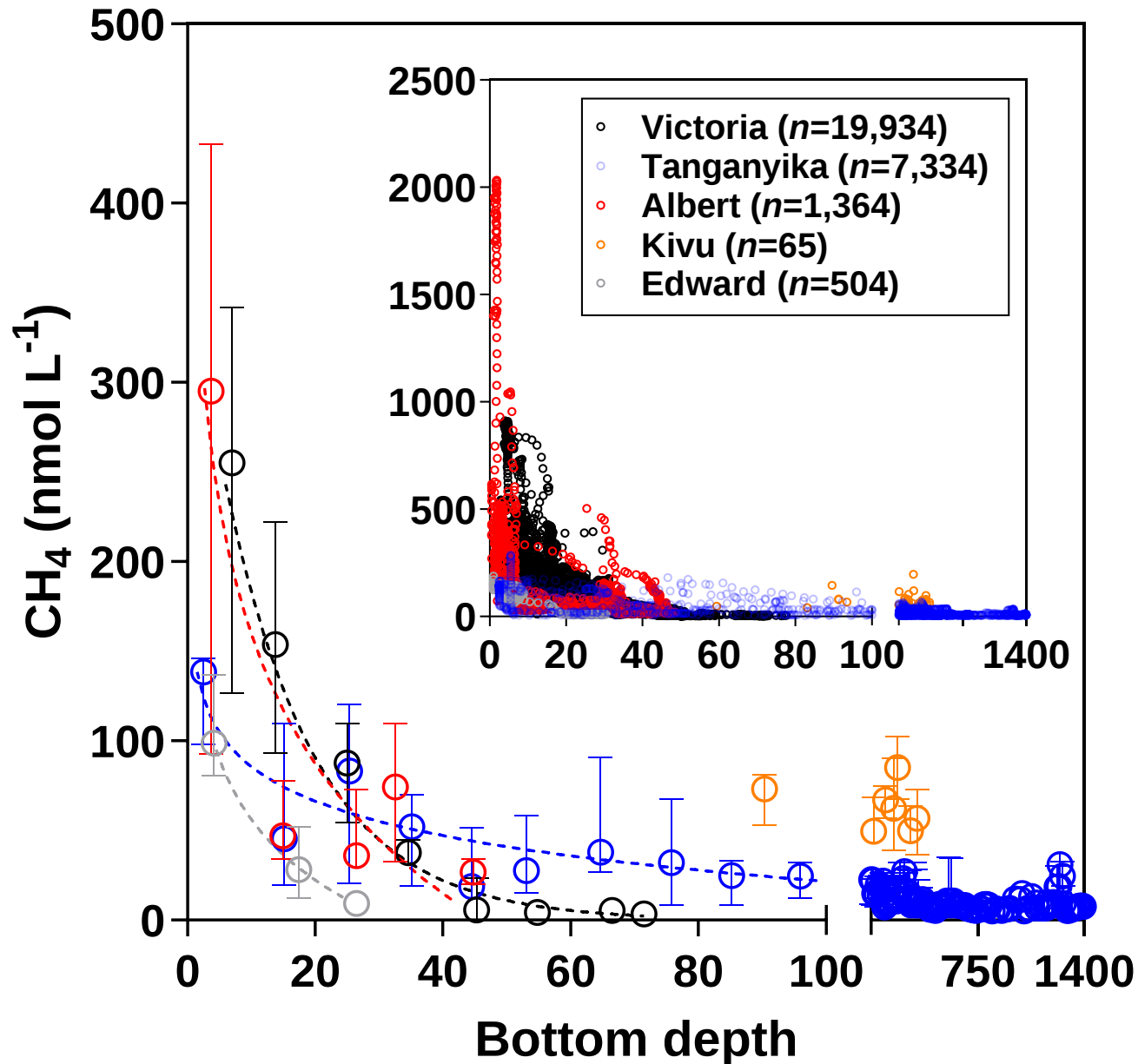


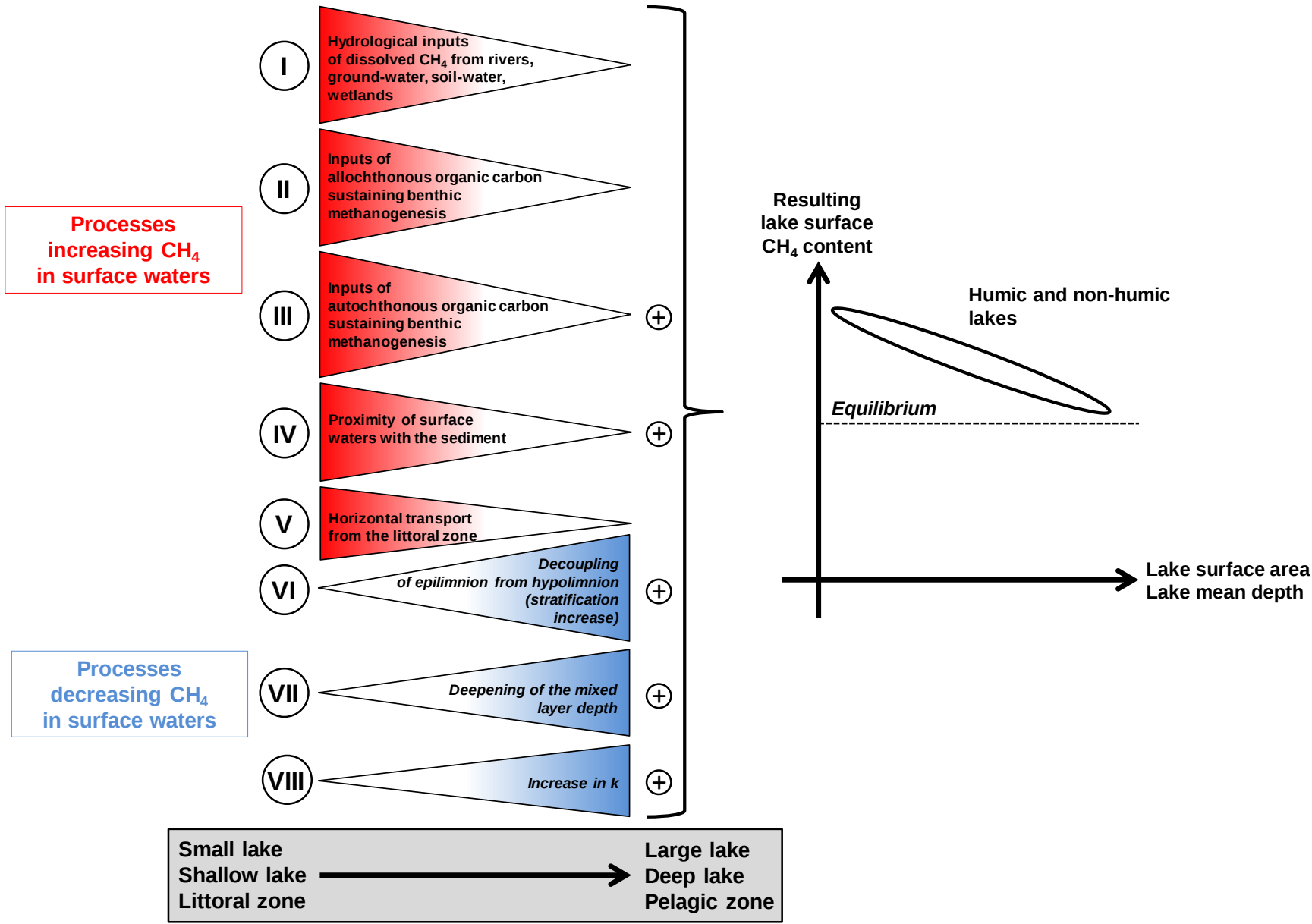
Northern cryosphere

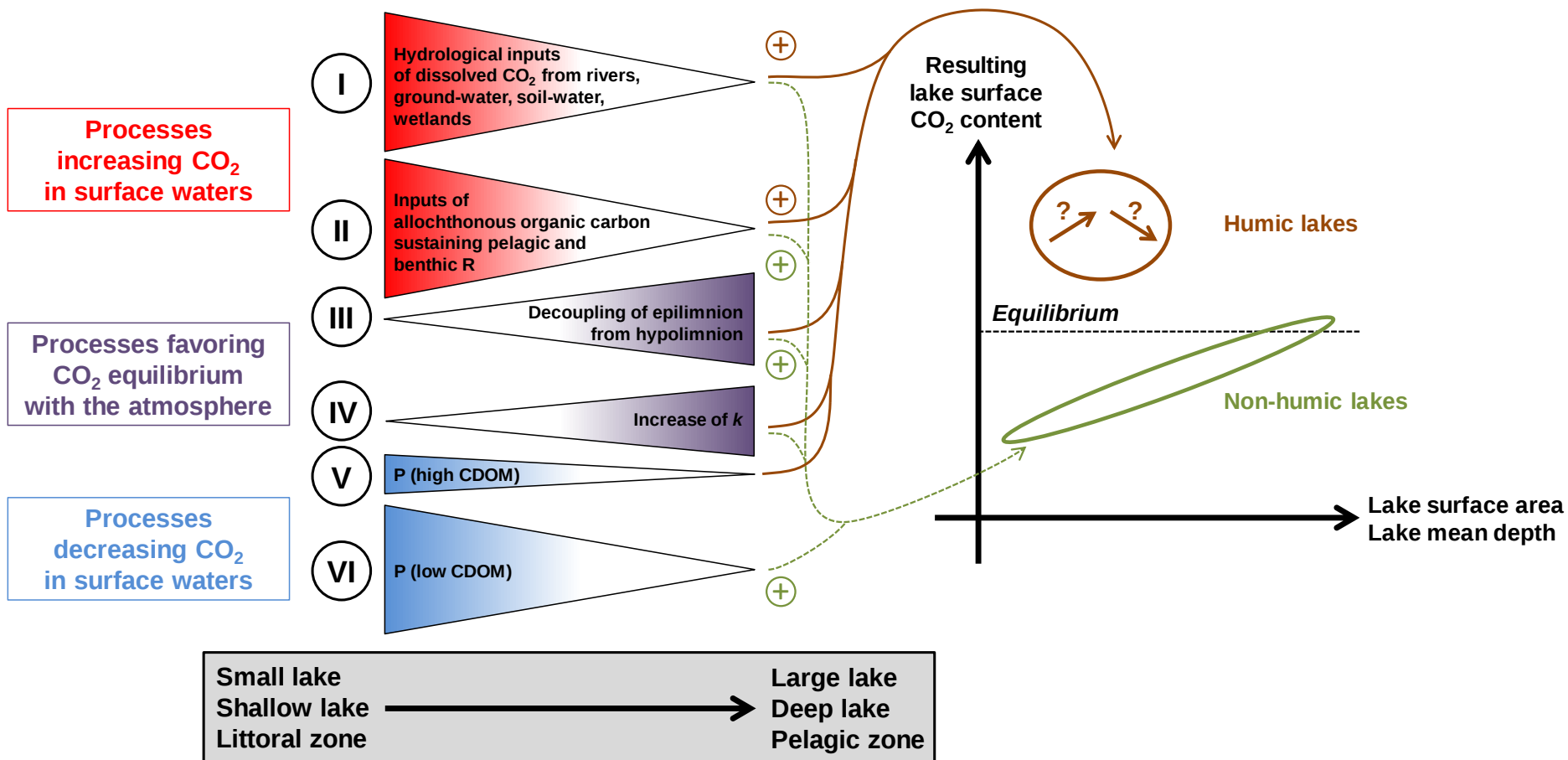
River CH₄ emissions < Lake CH₄ emissions (2.1 x)

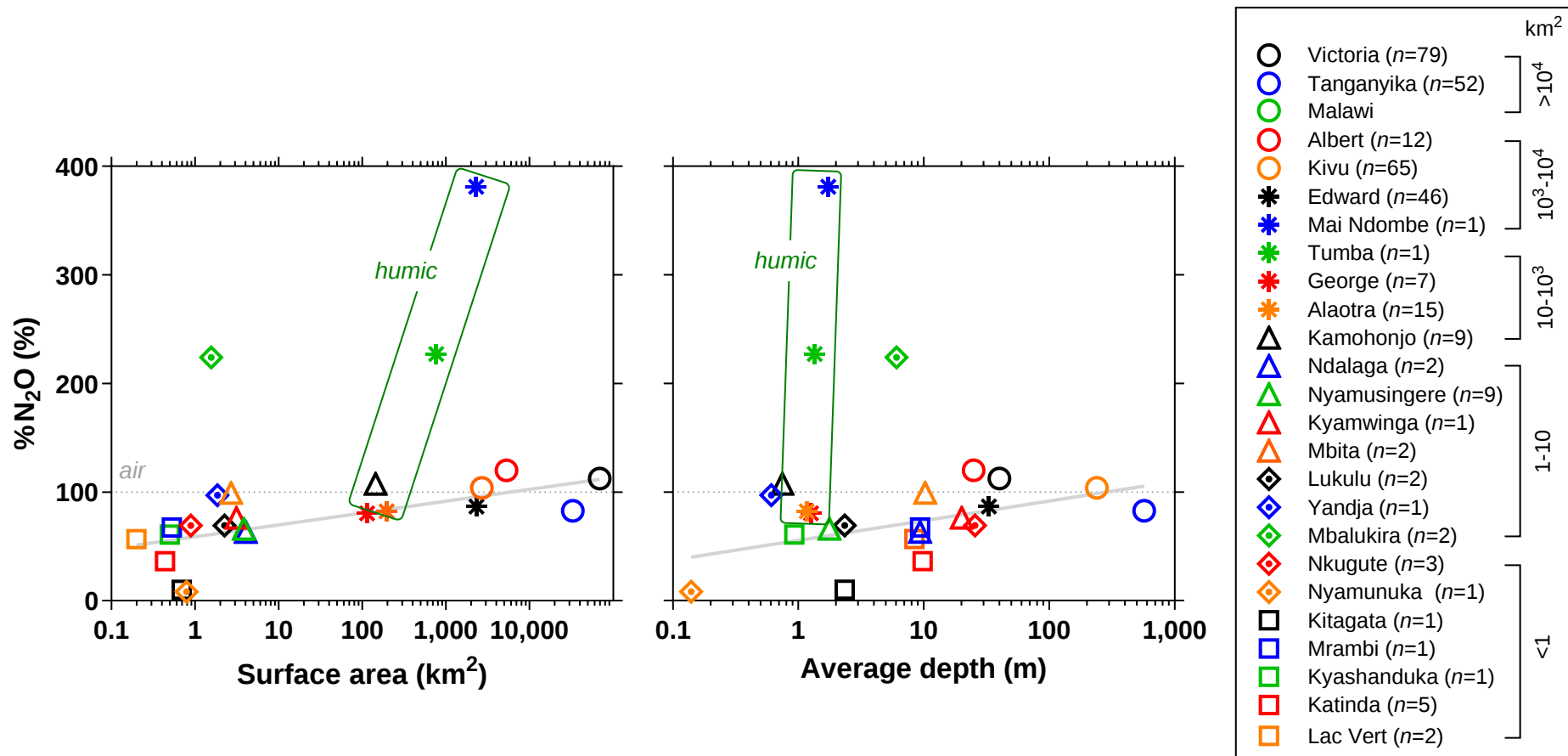
River CO₂ emissions > Lake CO₂ emissions (2.6 x)

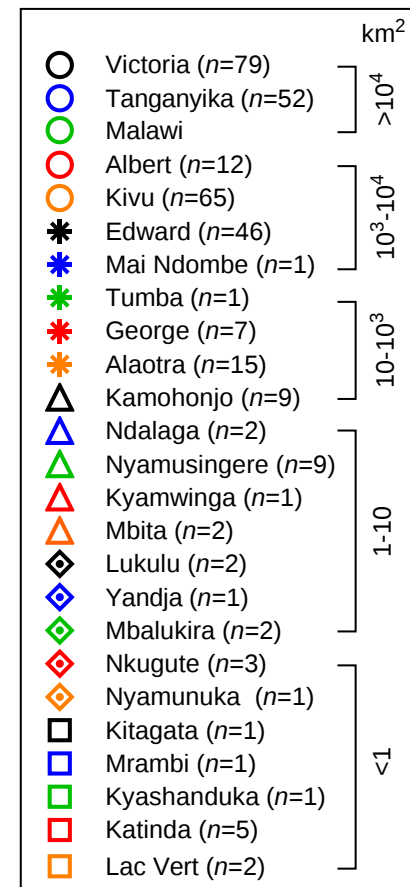
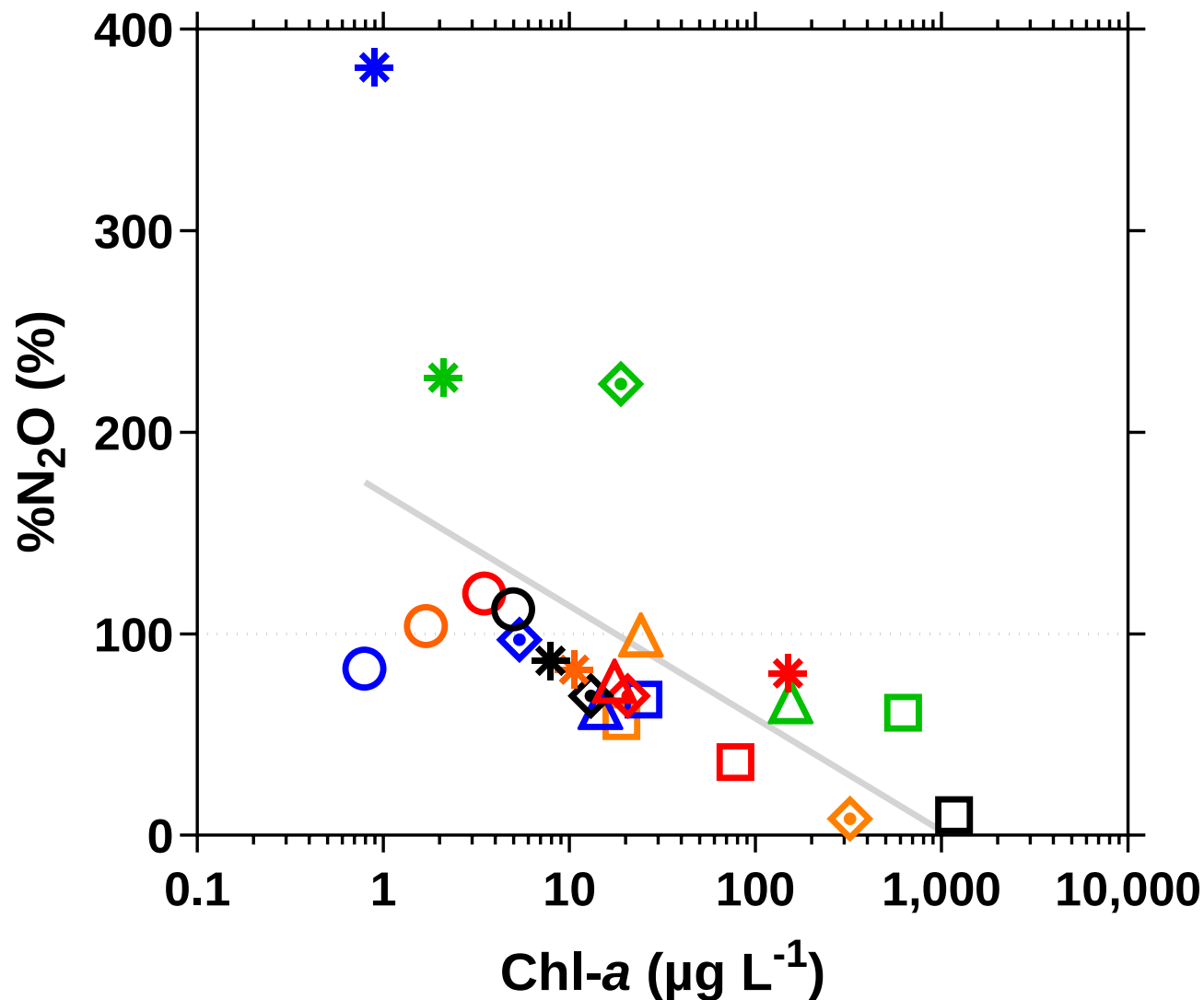




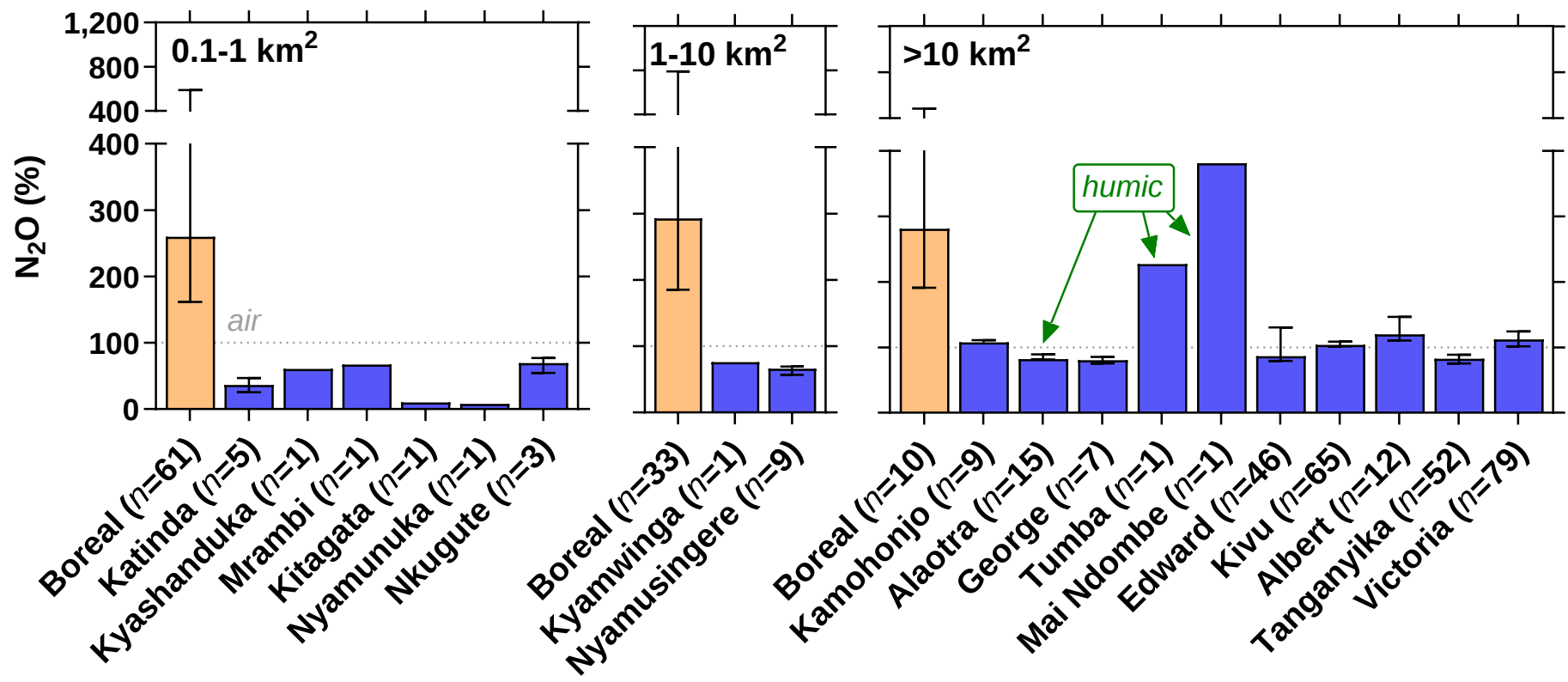








This study	Diffusive Flux	-0.1±0.1	GgN ₂ O/yr	-0.5	mgN ₂ O/m ² /yr
	Total lake surface area	209,394	km ²		
Lauerwald et al (2019)	Diffusive Flux	3.7	GgN ₂ O/yr	16.1	mgN ₂ O/m ² /yr
	Total lake surface area	229,000	km ²		

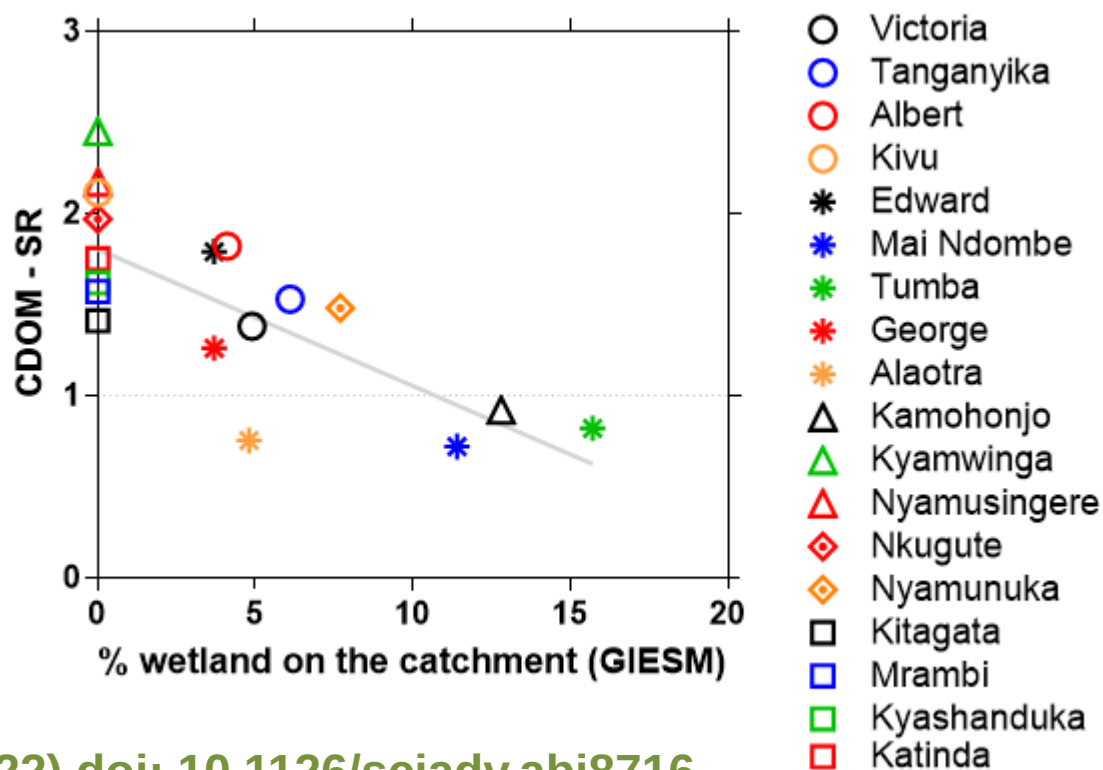


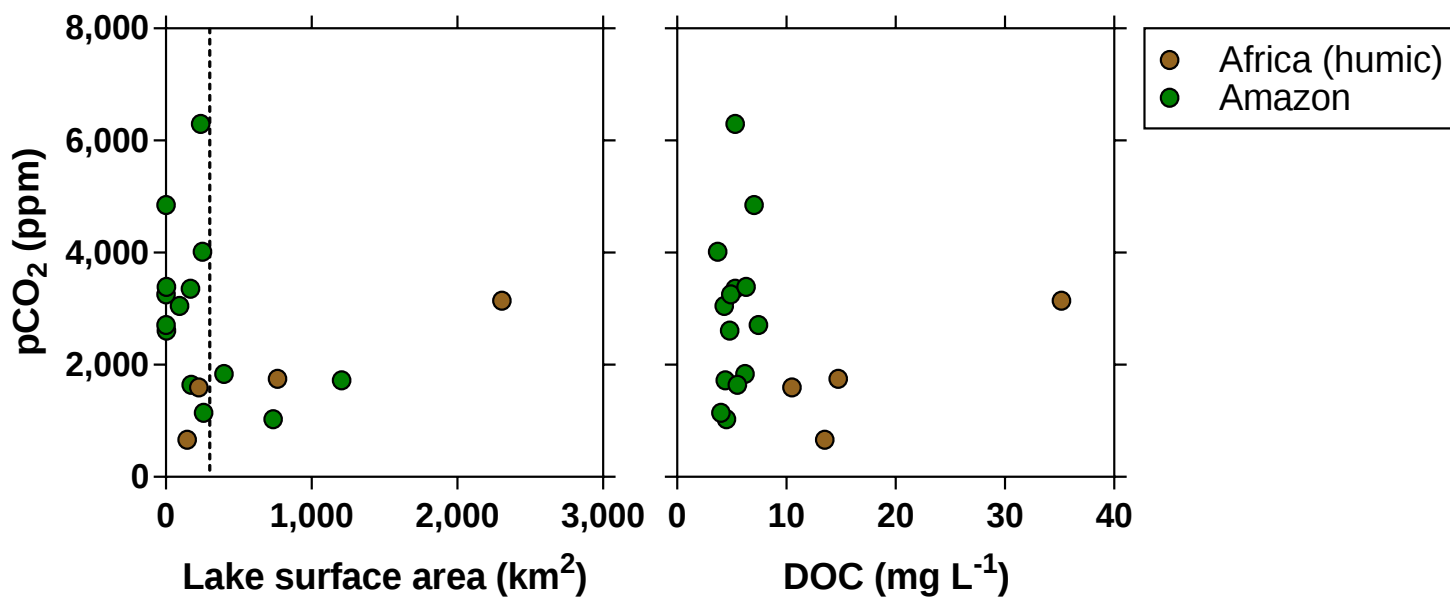
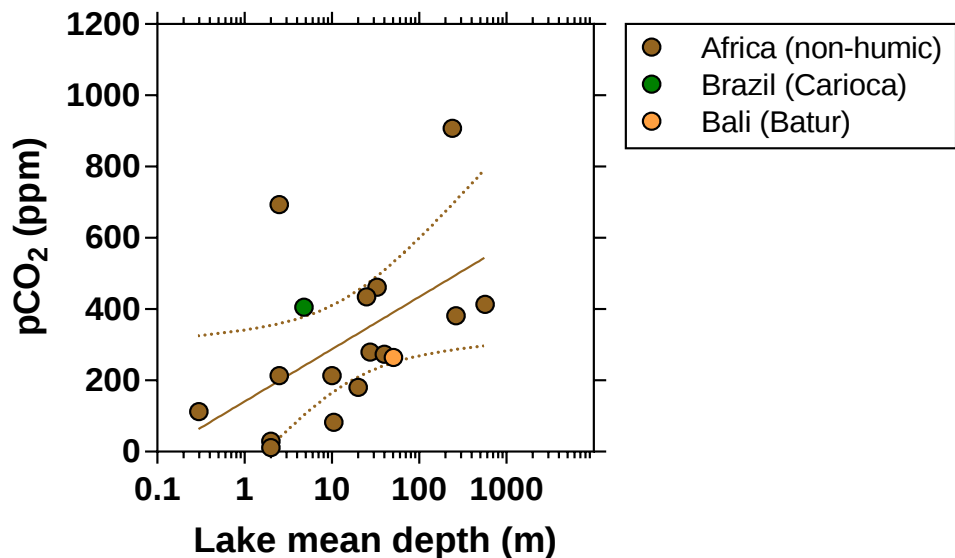
CDOM SR was negatively related with wetland presence on the catchment extracted from GIEMS-D15

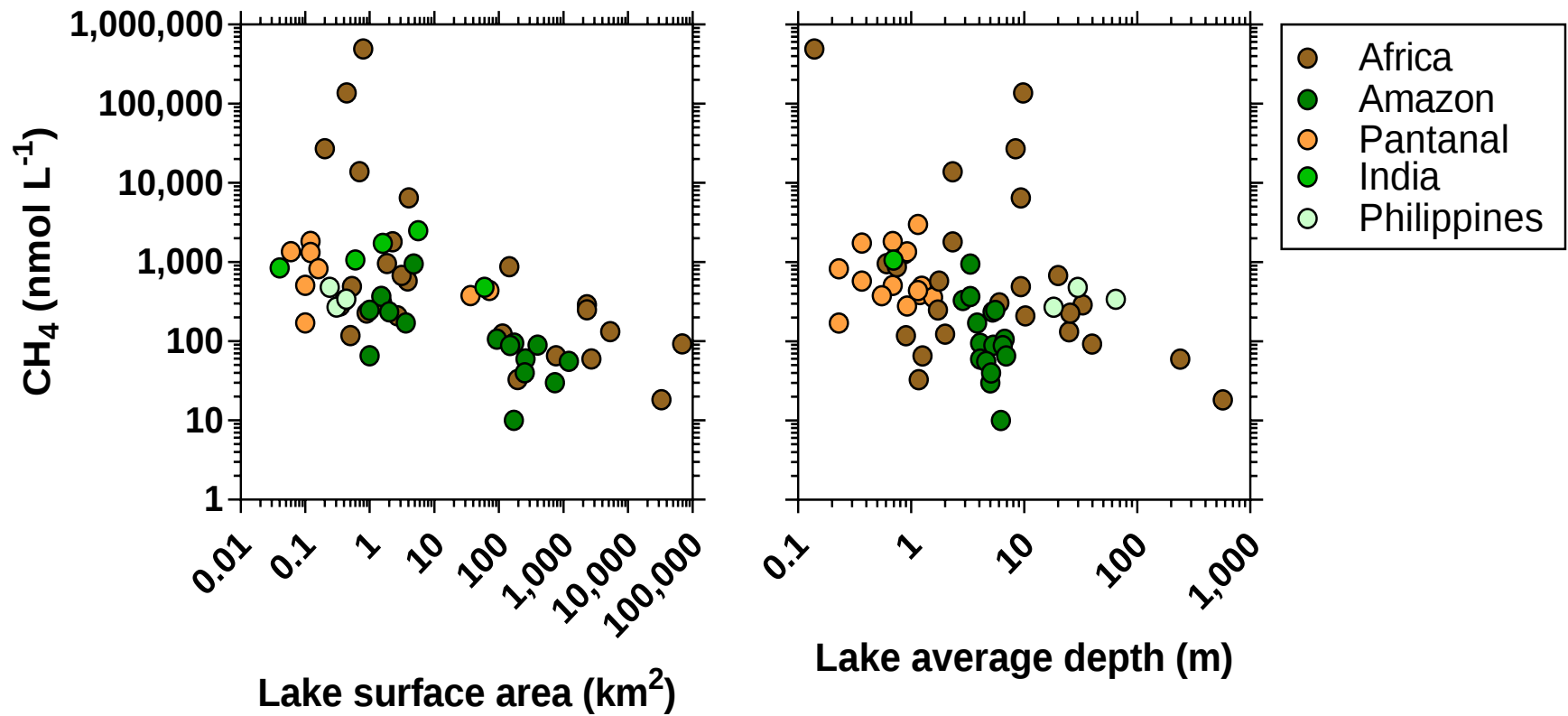
$$\text{CDOM SR} = 1.85 - 0.0765 \times \% \text{wetland} \quad (r^2 = 0.57, p=0.0003, n=18)$$

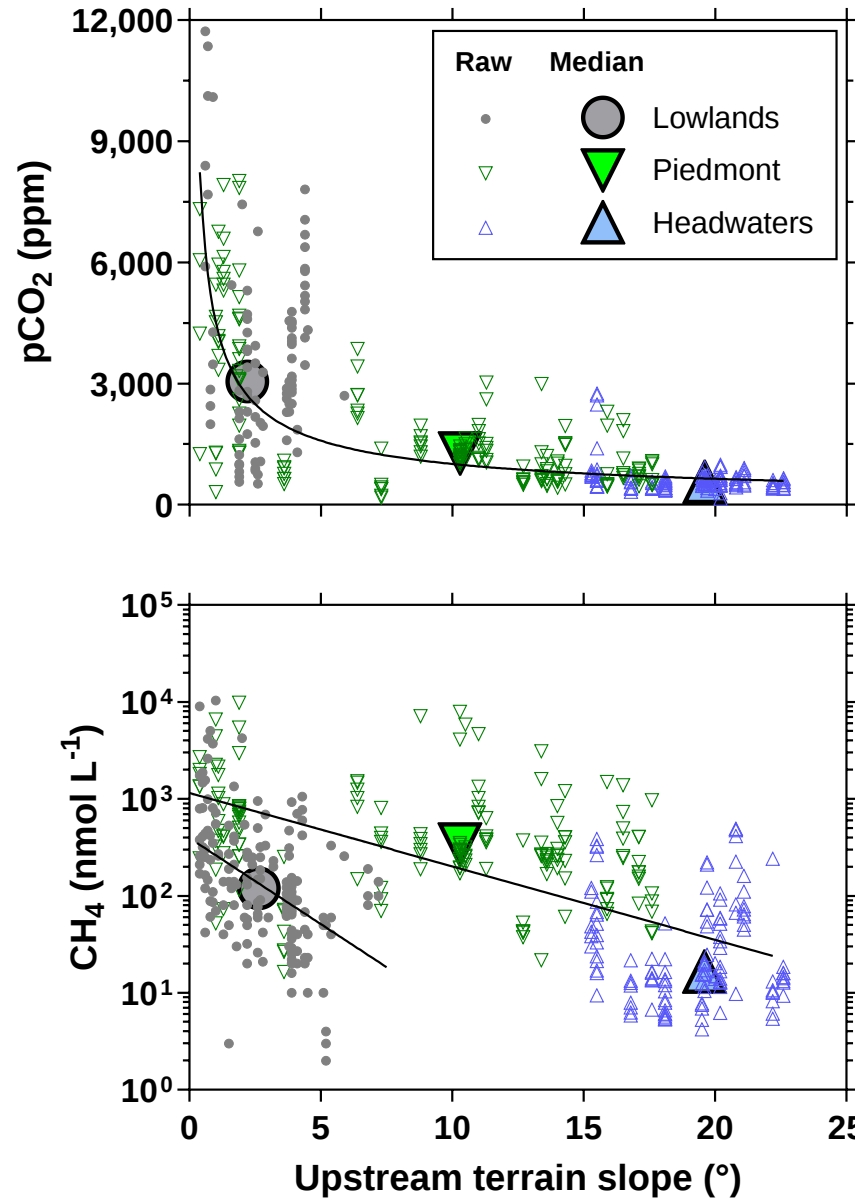
Threshold value of wetland coverage of 8.1%

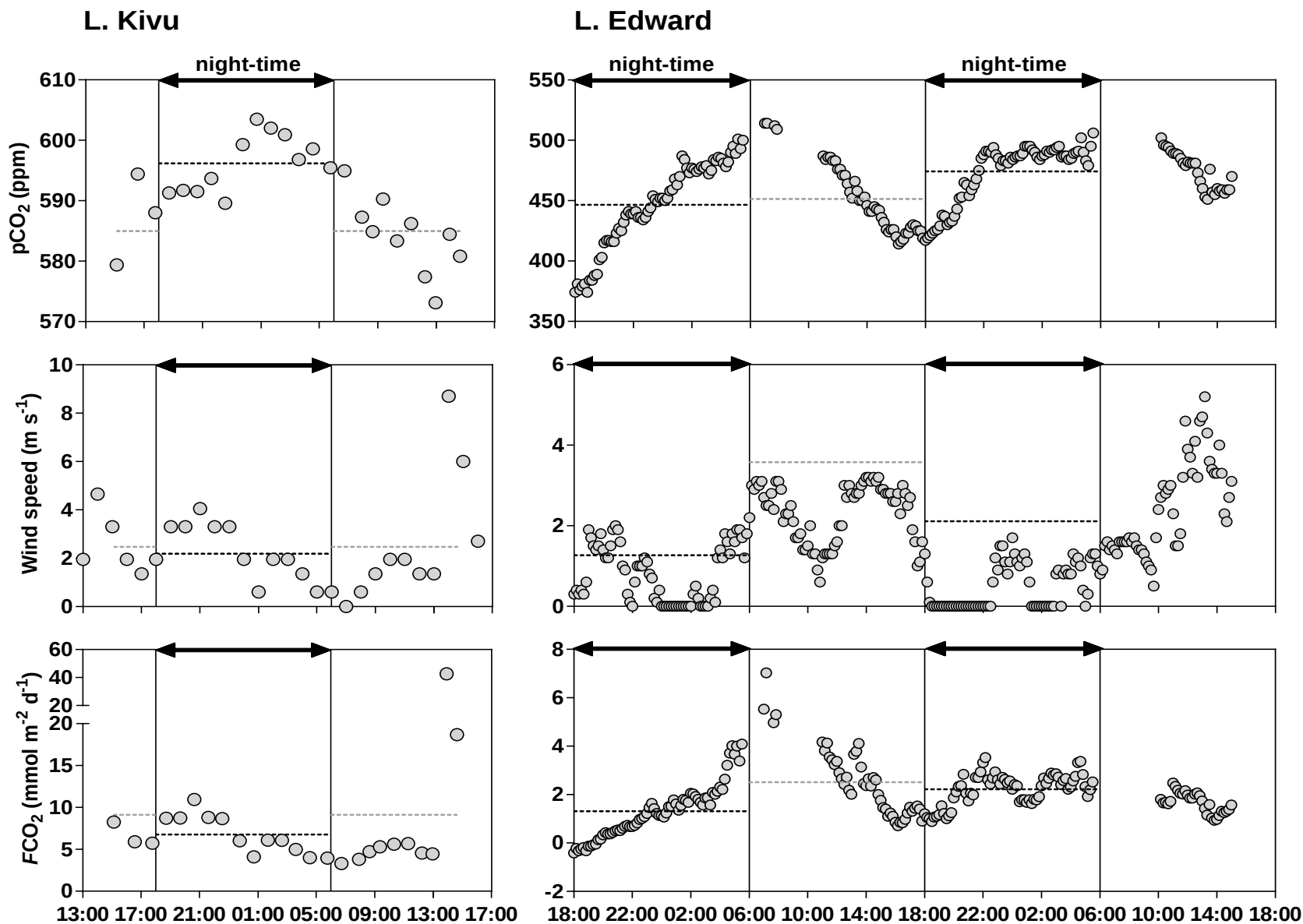
to classify humic (CDOM SR <1) and non-humic (CDOM SR >1) lakes.

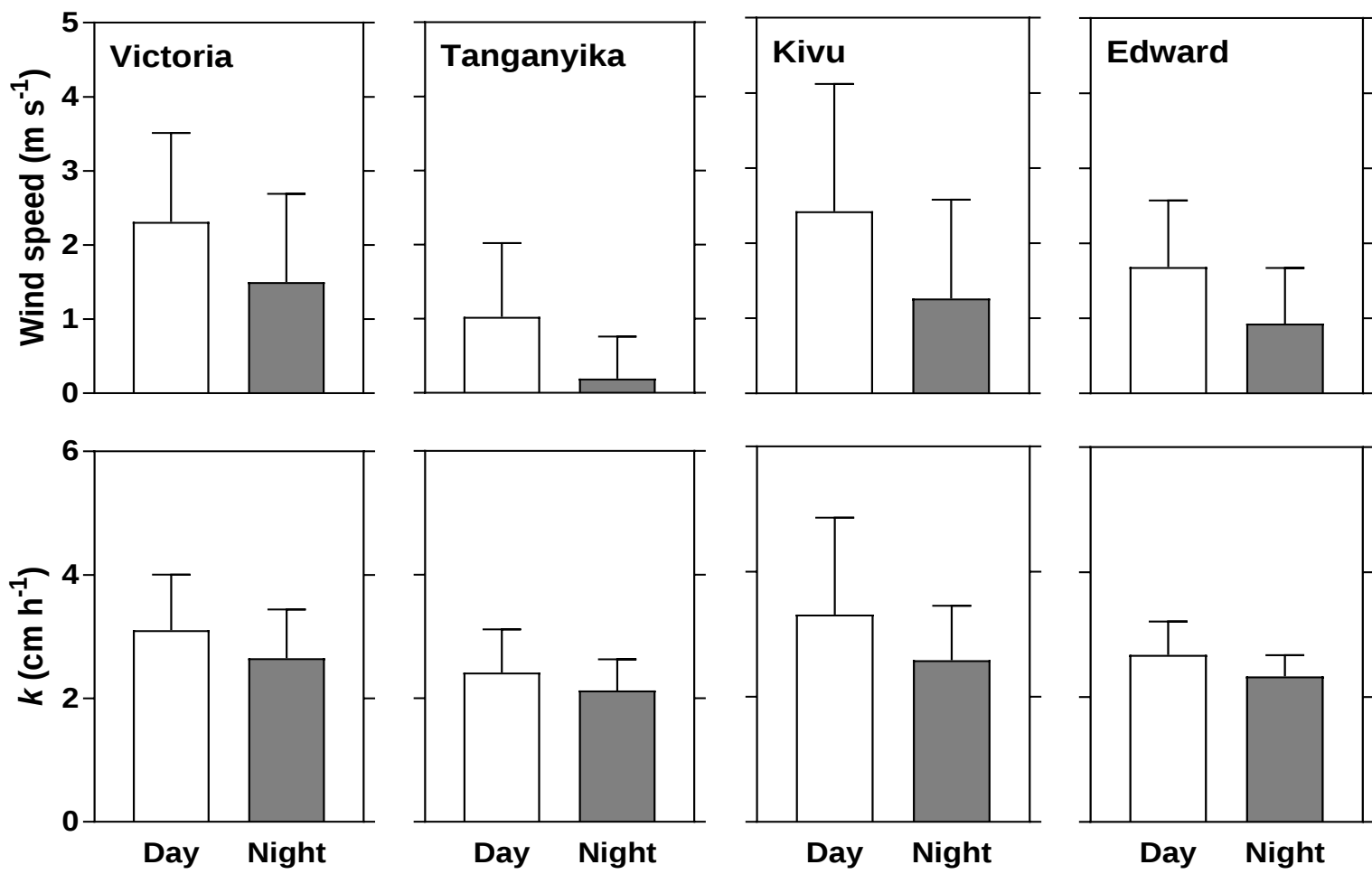


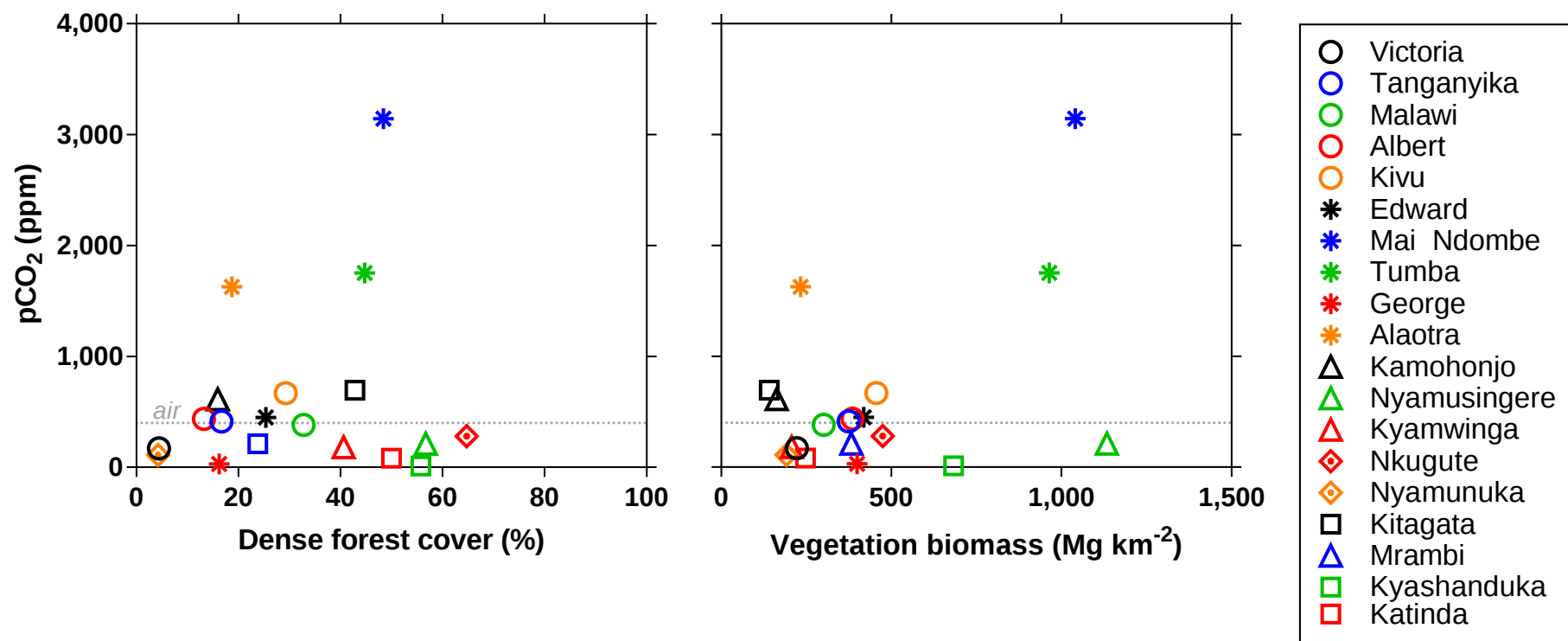










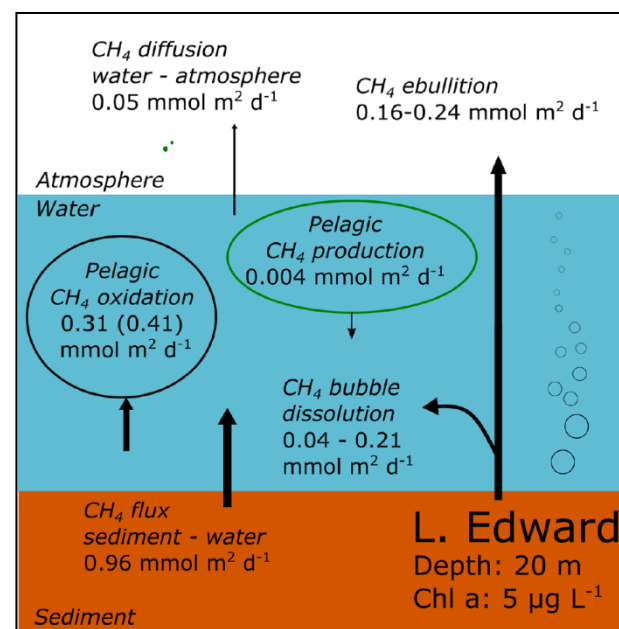
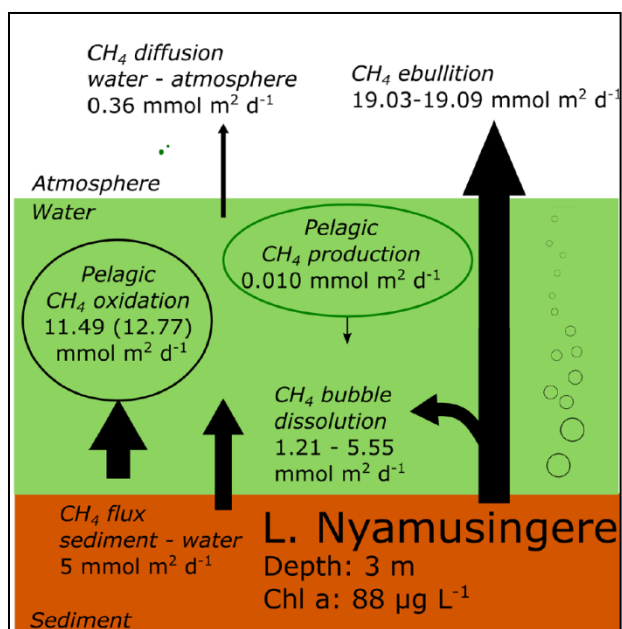
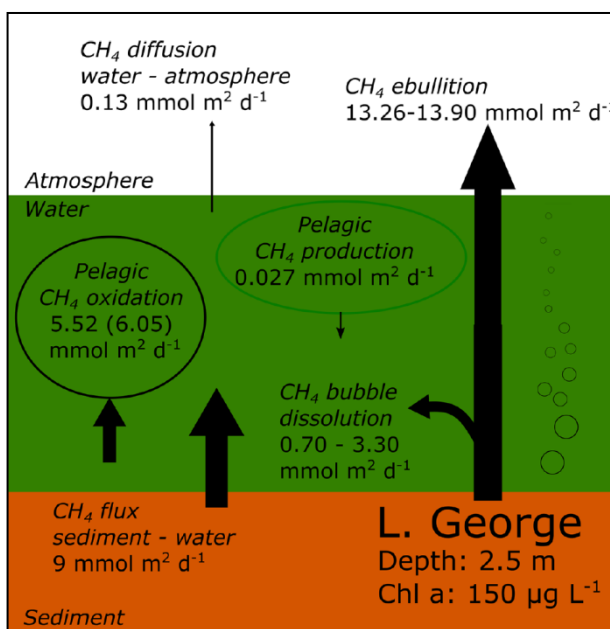


Methane aerobic production (MAP) based on tracer incubations

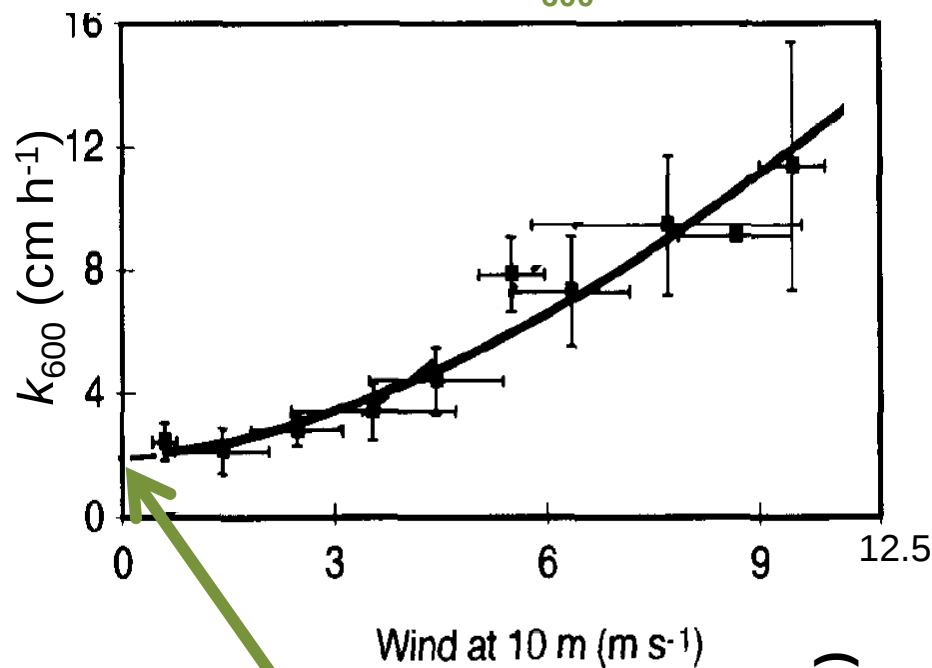
Diff. = 5 x MAP
MOX = 205 x MAP

= 36 x MAP
= 1150 x MAP

= 13 x MAP
= 78 x MAP



Cole and Caraco (1998)
 $k_{600} = 2.07 + 0.215 \times u_{10}^{0.17}$

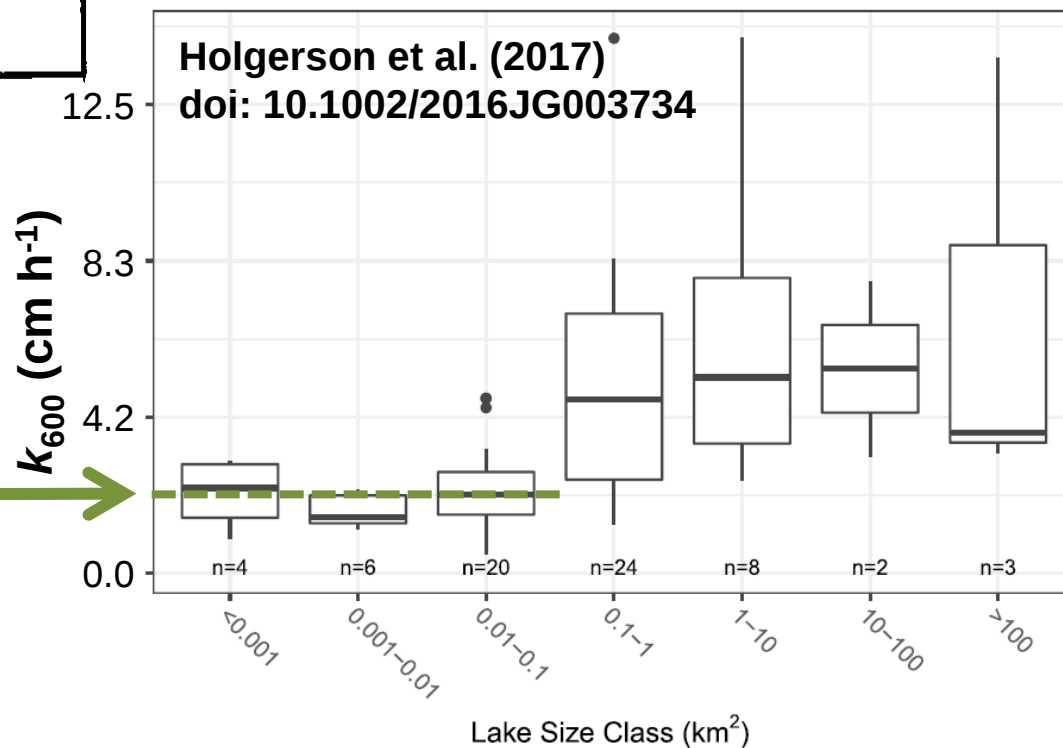


Compilation in 11 lakes

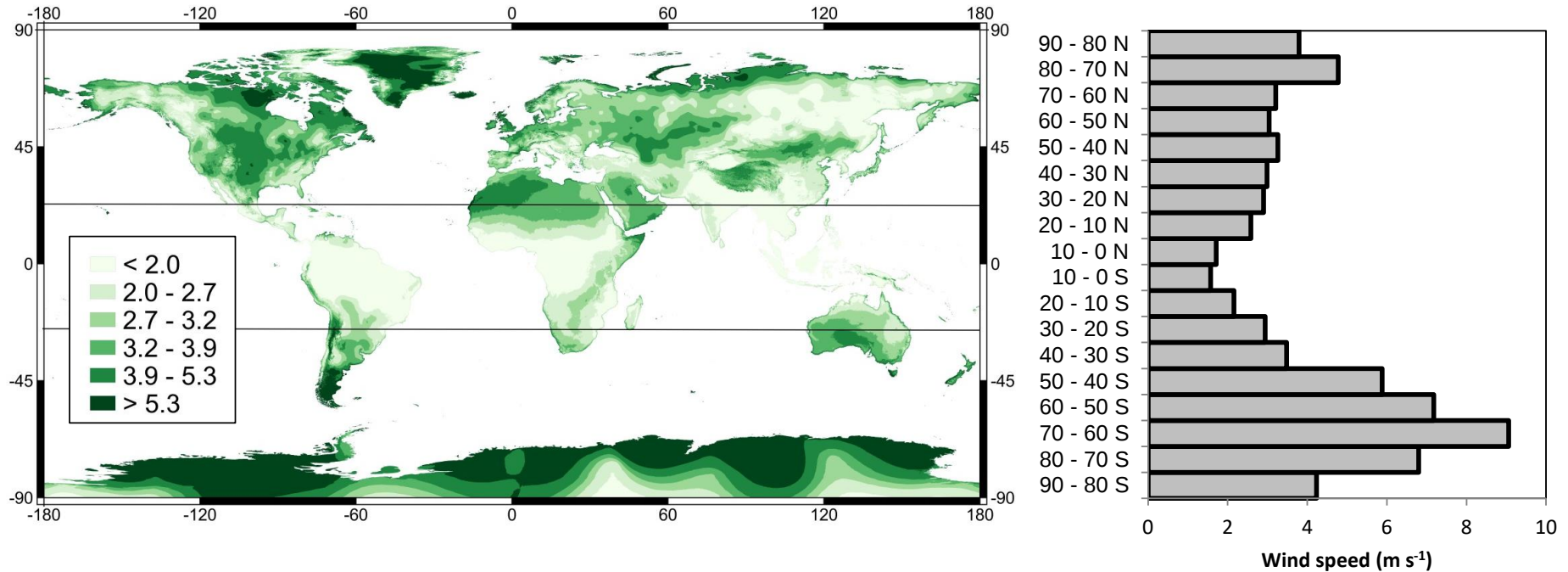
Range of maximum depth
0.7 to 109 m

Range of surface area
0.14 to 487 km²

Holgerson et al. (2017)*
doi: 10.1002/2016JG003734



2.1 cm h⁻¹



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

pCO₂ calculated from pH and total alkalinity *versus* pCO₂ measured direct

