Supporting information for

Spatially resolved measurements of CO_2 and CH_4 concentration and gas exchange velocity highly influence carbon emission estimates of reservoirs

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Supporting information

The supporting information has 14 pages, with 10 figures and 3 tables.

Experimental section

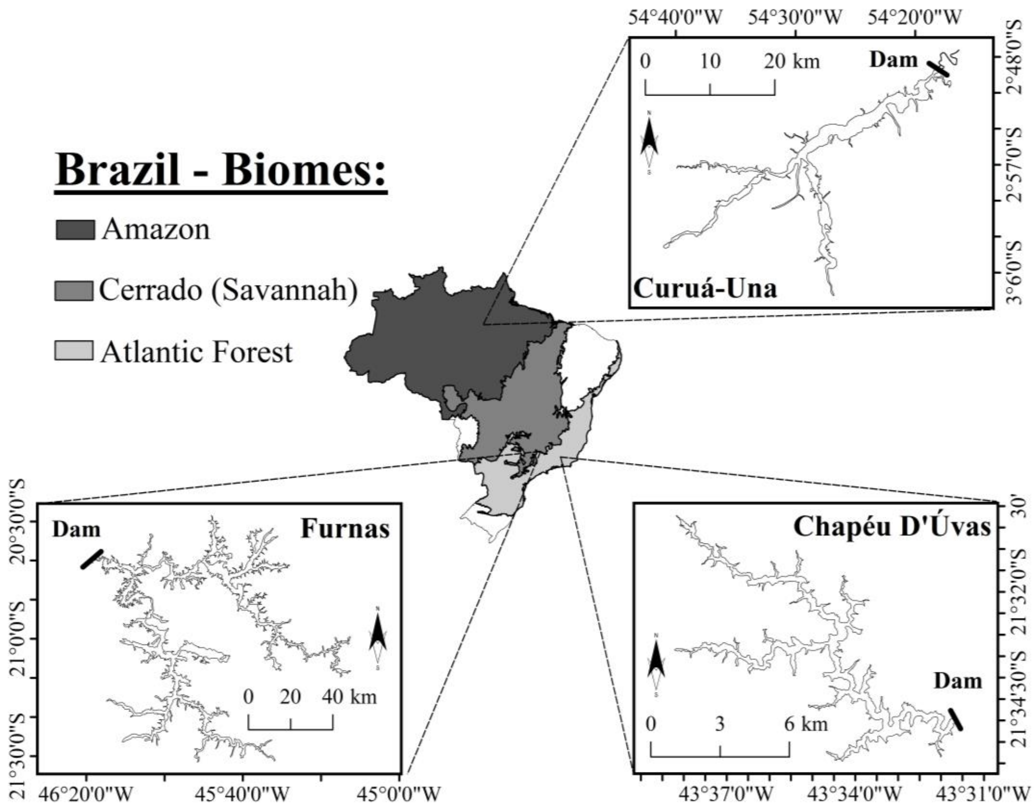

Figure S1: Location of the studied reservoirs. Source: Instituto Brasileiro de Geografia e Estatística (IBGE), 2017.

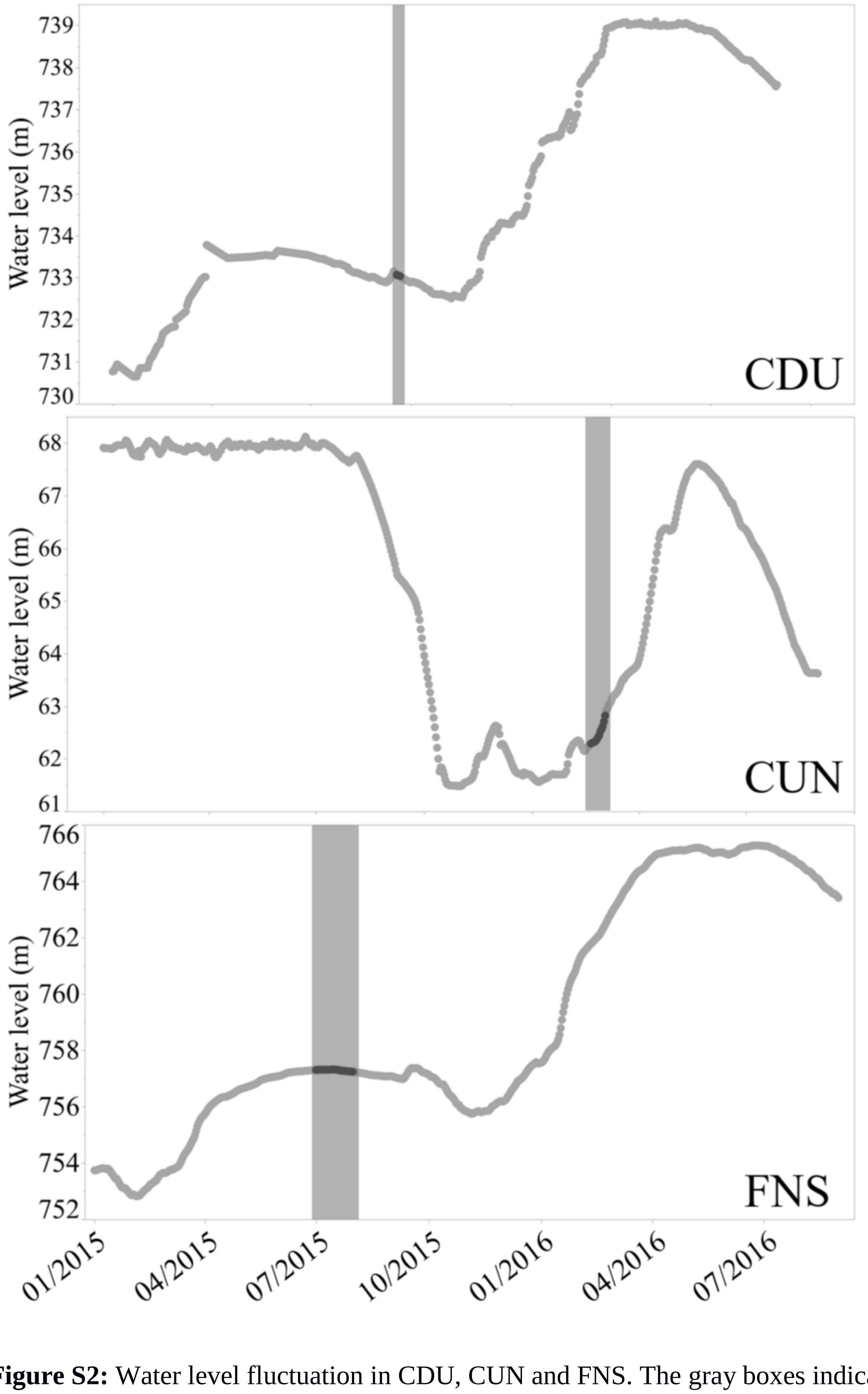

Figure S2: Water level fluctuation in CDU, CUN and FNS. The gray boxes indicate fieldwork periods.

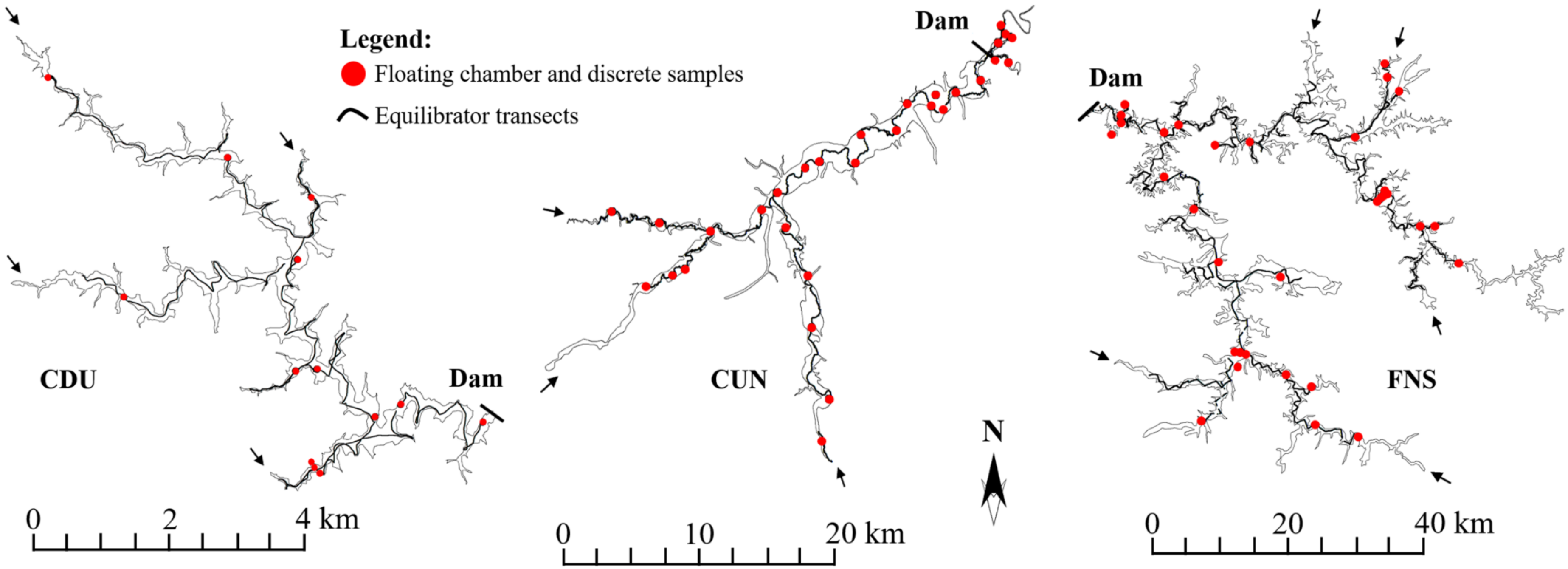

Figure S3: Sampling strategy performed in CDU, CUN and FNS. The solid black line shows the travelled boat transects during equilibrator-based on-line measurement of pCO_2 and pCH_4, and the red circles shows locations of floating chamber and other discrete sample measurements.

Results

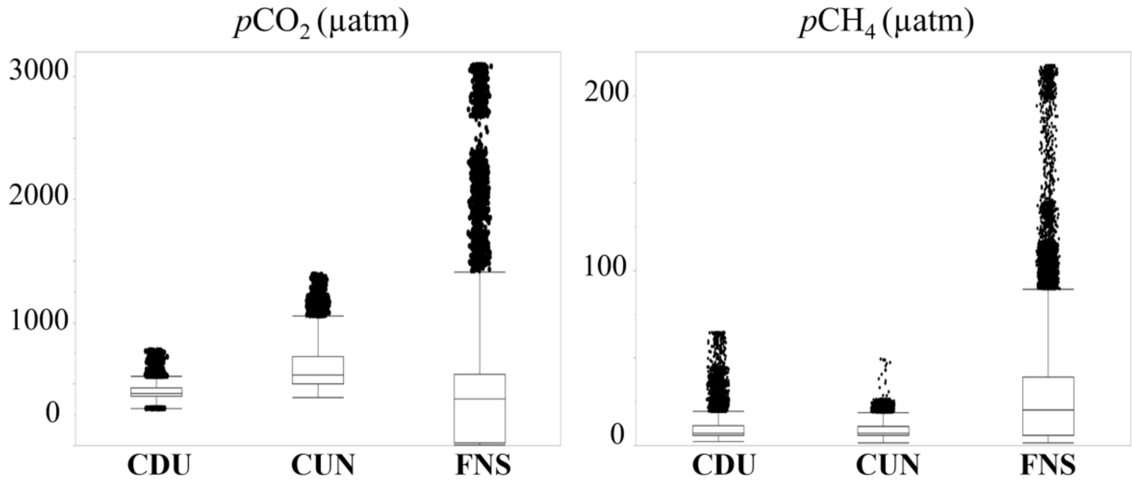

Figure S4: Box plot of pCO_2 and pCH_4 (µatm) from equilibrator-based measurements of CDU, CUN and FNS reservoirs. Average of atmospheric equilibrium of pCO_2 and pCH_4 were 399 µatm and 1.8 µatm, respectively, in all reservoirs.

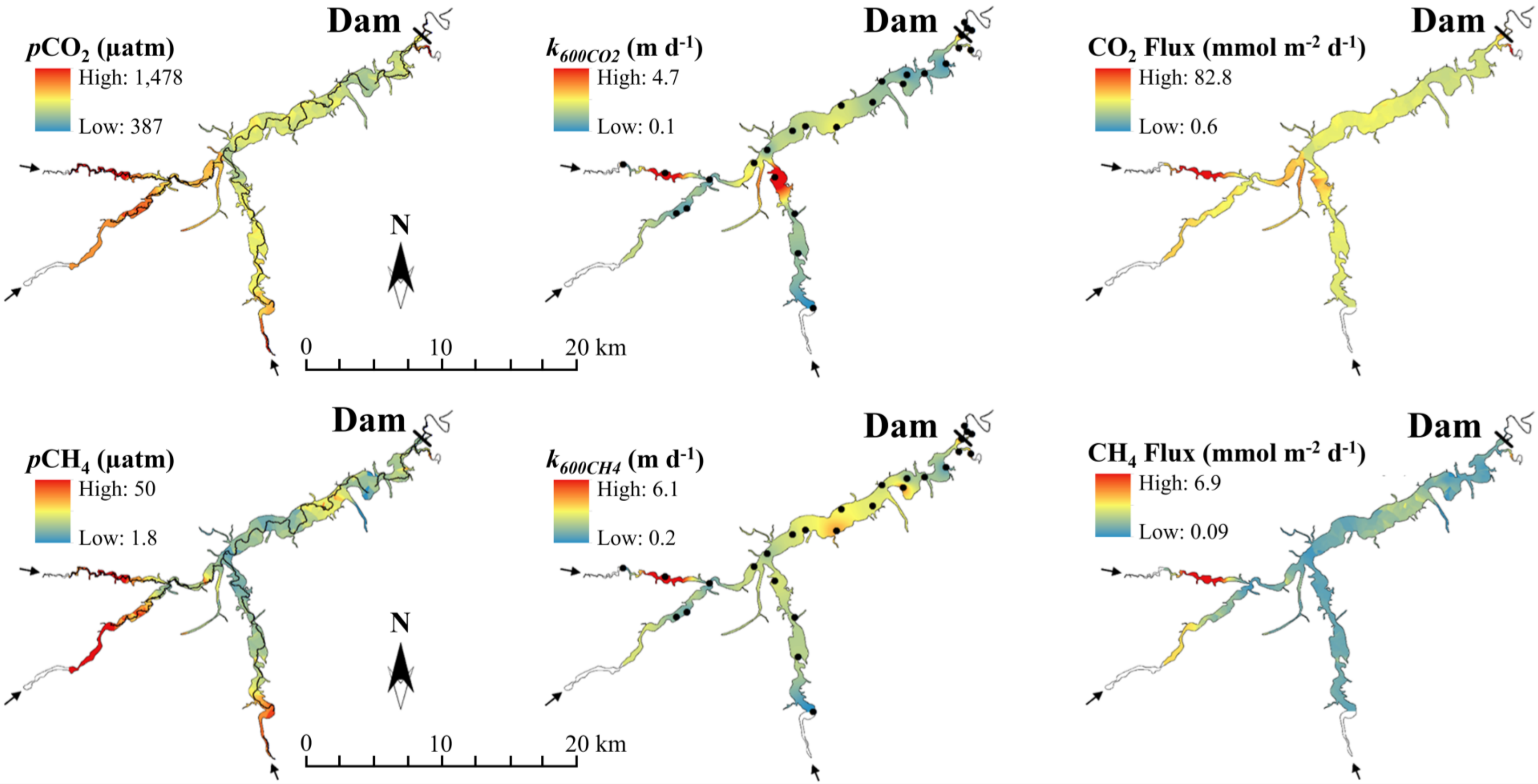

Figure S5: pCO_2 and pCH_4 (µatm), k_{600CO_2} and k_{600CH_4} (m d^{-1}), and diffusive flux of CO_2 and CH_4 (mmol m^{-2} d^{-1}) from IDW interpolation in CUN. The black arrows on the maps indicate river entrances. The black lines represent the equilibrator transects and each black dots represent three measurements of floating chamber and discrete sample.

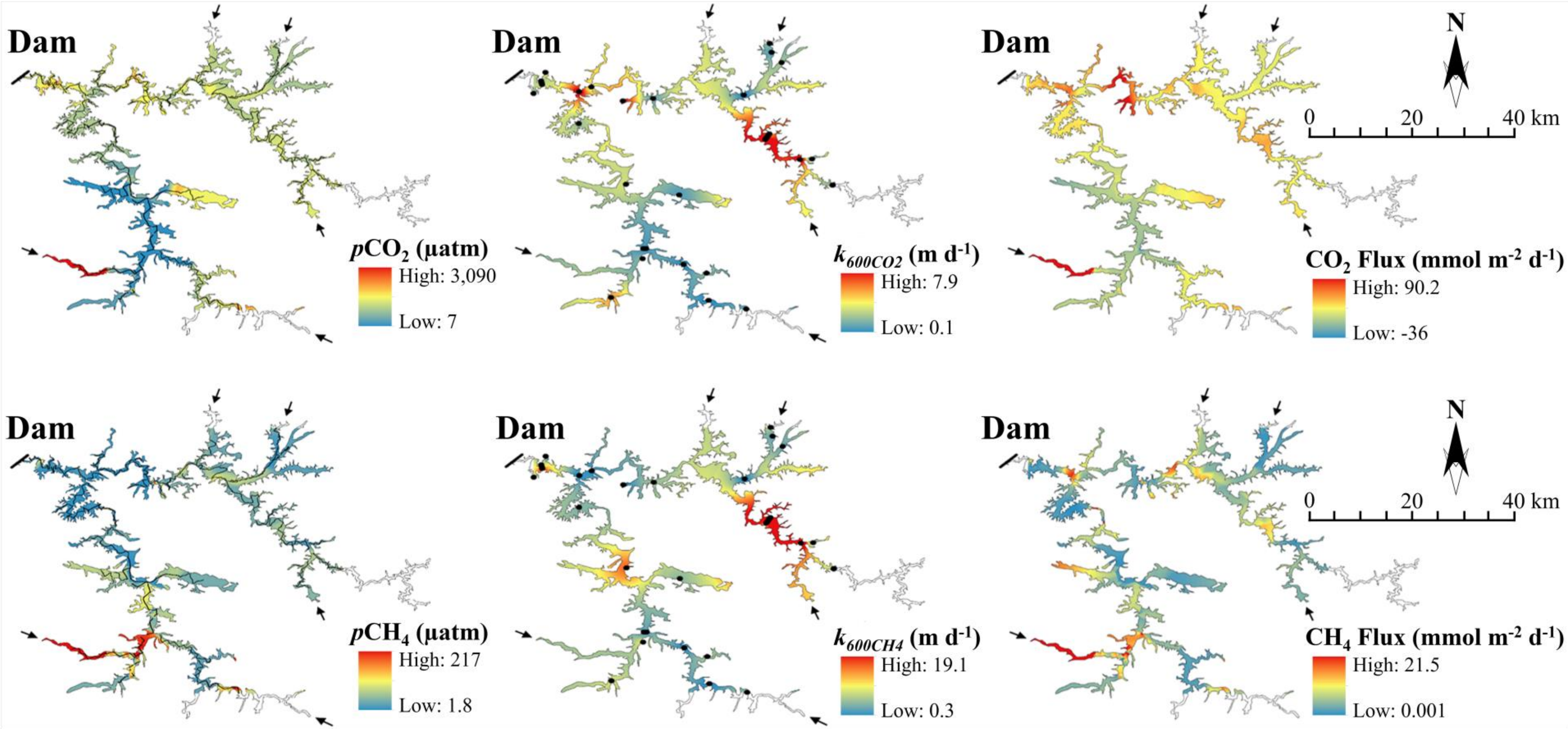

Figure S6: pCO$_2$ and pCH$_4$ (µatm), k_{600CO2} and k_{600CH4} (m d^{-1}), and diffusive flux of CO_2 and CH_4 (mmol m^{-2} d^{-1}) from IDW interpolation in FNS. The black arrows on the maps indicate river entrances. The black lines represent the equilibrator transects and each black dots represent three measurements of floating chamber and discrete sample.

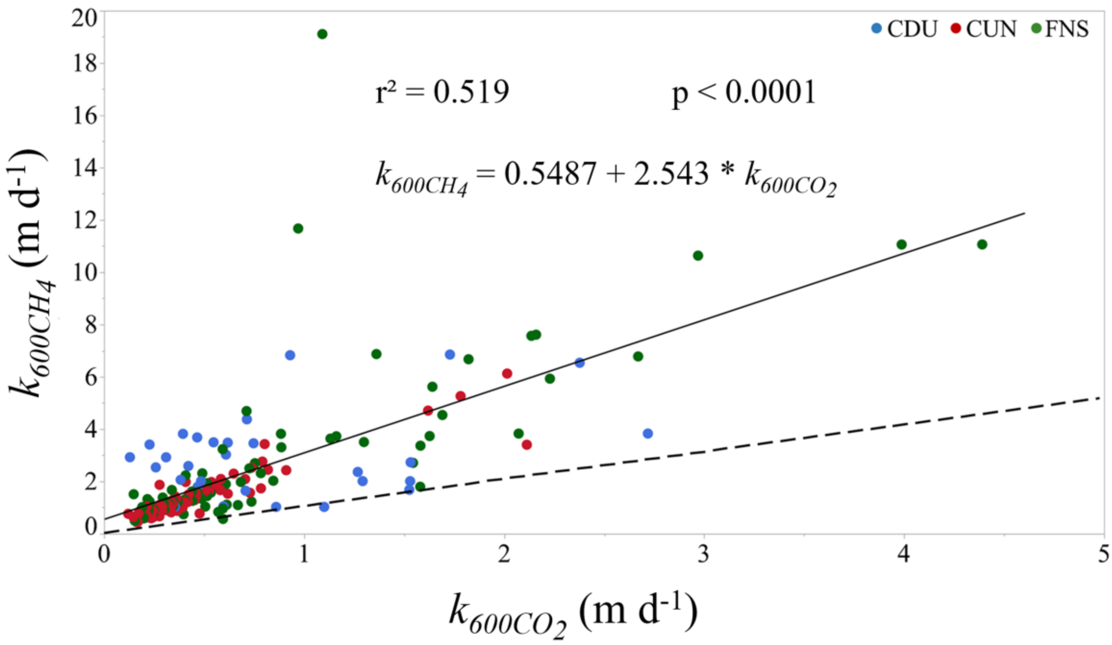

Figure S7: Relationship between the gas exchange velocity calculated from diffusive CH_4 flux measurements (k_{600CH4}) and the gas exchange velocity calculated from diffusive CO_2 flux measurements (k_{600CO2}) for CDU, CUN and FNS. The dashed line represents the 1:1 line. Every point represents the mean of 3 chamber deployments at each measurement location.

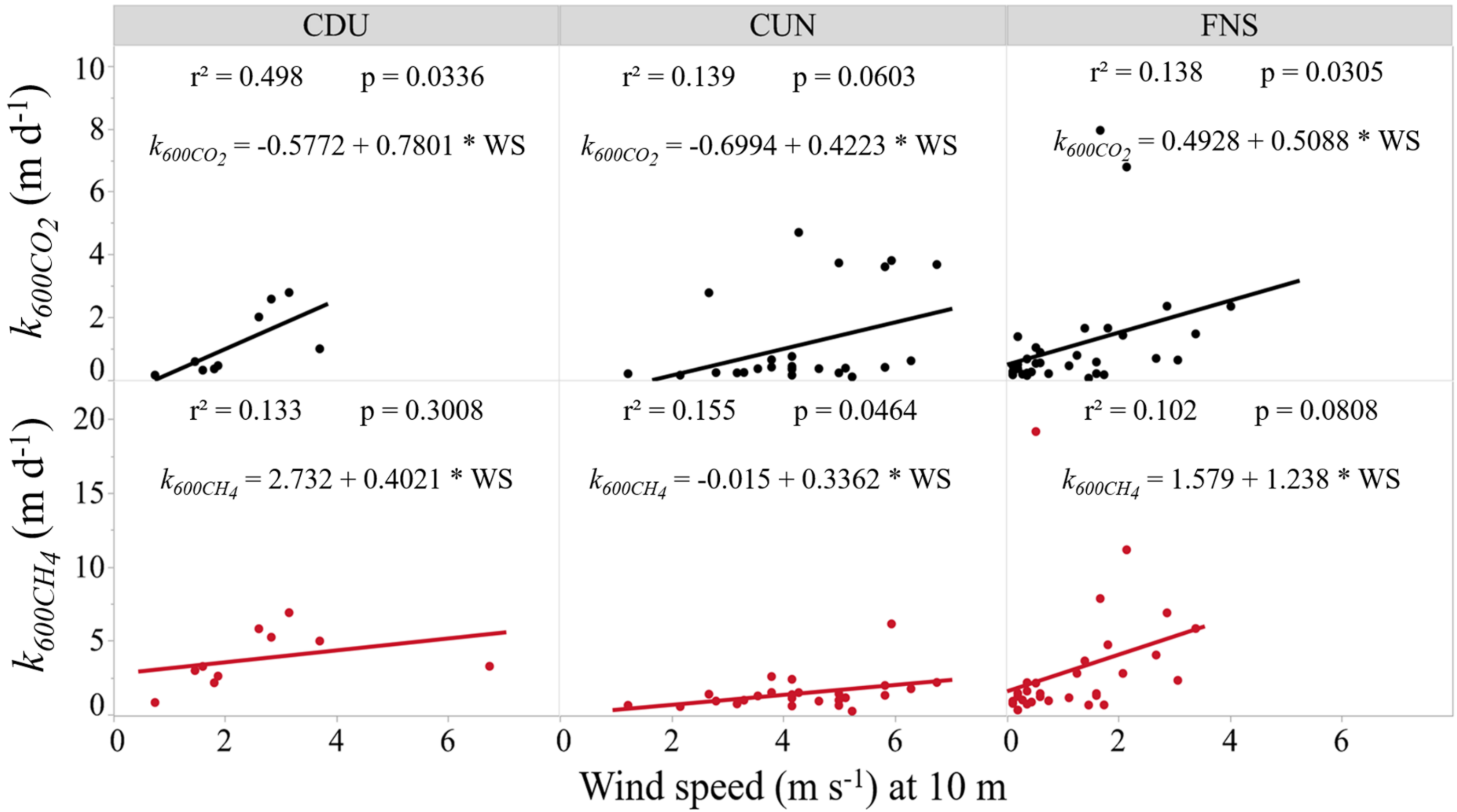

Figure S8: Relationship between wind speed and k_{600CO_2} *and* k_{600CH_4} measured by floating chambers. Every point represents the mean of 3 chamber deployments at each measurement location.

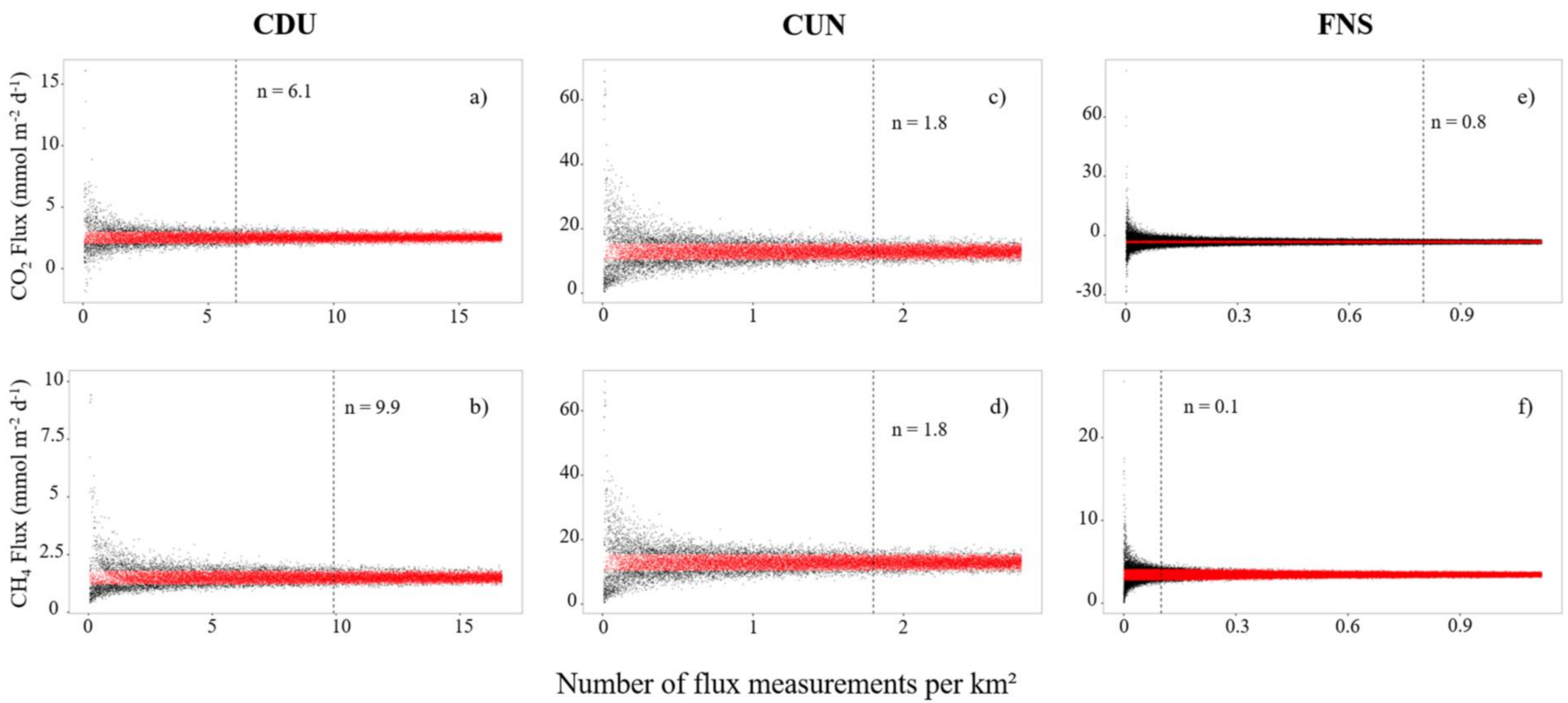

Figure S9: Downsampling simulations to predict how many flux measurements per km^2 would have been enough to reach total flux estimates within ± 20% of our observed mean for each gas in each reservoir (*a, b*: CDU; *c, d*: CUN; *e, f:* FNS). The points inside the red area represent those estimates that fell within the ± 20% criteria. The vertical dashed line indicates the minimum sampling effort per km^2 to reach a probability of 95% of falling within the ± 20% criteria.

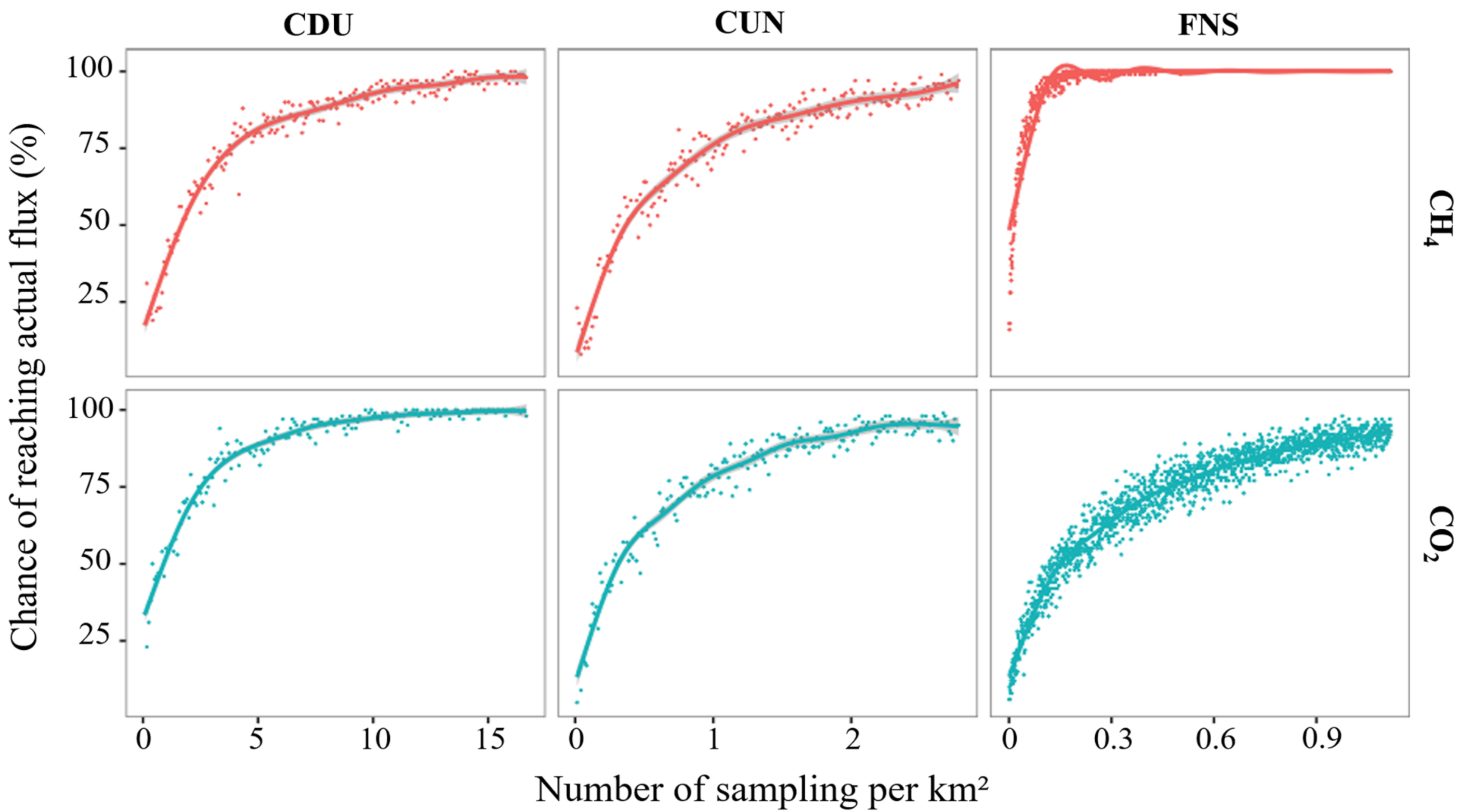

Figure S10: Chance of reaching a whole-system mean flux within ± 20% of our observed mean flux (i.e., considering the entire dataset) for a given number of flux measurements randomly distributed across the reservoir.

Table S1: Descriptive statistics of pCO_2 and pCH_4, TOC concentration, wind speed and the gas exchange velocity calculated from CO_2 flux (k_{600CO2}) and CH_4 flux (k_{600CH4}).

	Reservoirs		
	CDU	**CUN**	**FNS**
pCO_2 (µatm)	439 ± 63	664 ± 221	400 ± 299
median	423	587	380
pCH_4 (µatm)	11 ± 9	9 ± 5	30 ± 20
median	7	7	20
Coefficient of variation of pCO_2	0.1	0.3	0.8
Coefficient of variation of pCH_4	0.8	0.5	0.7
TOC - main tributary (mg C L^{-1})[a]	3.2 ± 0.5	4.3 ± 0.8	3.5 ± 0.4
median	3	4	2.8
TOC - reservoir before the dam (mg C L^{-1})[a]	1.1 ± 0.3	2.1 ± 1	1.4 ± 0.2
median	0.8	1.8	1
Wind speed at 10 m (m s^{-1})	2.7 ± 2.4	4.4 ± 2	1.3 ± 2.1
median	2.4	3.8	1.4
k_{600CO2} value (m d^{-1})	0.9 ± 0.6	0.5 ± 0.6	1.1 ± 1.2
median	0.5	0.4	0.6
k_{600CH4} value (m d^{-1})	2.8 ± 1.6	1.4 ± 1	3 ± 3.3
median	3.4	1.3	1.5
k_{600CH4}/k_{600CO2} ratio	3.1	2.8	2.7

[a] *This study*

Table S2: Average of *k* values (m d^{-1}) calculated by three different approaches: from spatially distributed floating chamber measurements, k_{FC}; from floating chamber measurements close to the dam, k_d; and scaled from wind speed (Cole & Caraco, 1998), k_{ws}; Diffusive fluxes of CO_2 and CH_4 (mmol m^{-2} d^{-1}) and limnological parameters expressed as average ± standard deviation and range. (n.a. represents “not analyzed”).

	CDU	CUN	FNS
k_{FC-CO2} (m d^{-1})	2.2	0.7	1
k_{FC-CH4} (m d^{-1})	4	1.9	4.5
k_{d-CO2} (m d^{-1})	0.3	0.5	0.9
k_{d-CH4} (m d^{-1})	2.4	1.5	3.3
k_{ws-CO2} (m d^{-1})	0.8	1.2	0.6
k_{ws-CH4} (m d^{-1})	0.8	1.2	0.6
CO_2 Flux using k_{FC-CO2}	4.8 ± 6 (-26.4 - 24.2)	7.7 ± 9.5 (0.6 - 83)	7.1 ± 15.8 (-36 - 90.2)
CH_4 Flux using k_{FC-CH4}	1.7 ± 1.7 (0.04 - 16)	0.6 ± 0.8 (0.1 - 7)	2.6 ± 2.5 (0.001 - 21.5)
CO_2 Flux using k_{d-CO2}	0.7 ± 0.7 (-0.9 - 4.7)	5.5 ± 3.3 (0.9 - 18.5)	6.3 ± 17.3 (-14.3 - 102)
CH_4 Flux using k_{d-CH4}	0.9 ± 0.7 (0.4 - 5.4)	0.5 ± 0.2 (0.1 - 1.5)	2.7 ± 3.4 (0.2 - 29)
CO_2 Flux using k_{ws-CO2}	2.1 ± 2.1 (-2.7 - 13.4)	13 ± 8 (2.2 - 44.3)	4.2 ± 11.6 (-9.7 - 69)
CH_4 Flux using k_{ws-CH4}	0.3 ± 0.2 (0.1 - 1.9)	0.4 ± 0.2 (0.08 - 1.2)	0.5 ± 0.6 (0.04 - 5.5)
Water temperature (^{0}C)	24.2 ± 0.7 (22.5 - 27.2)	30.1 ± 1.4 (27.1 - 37.4)	21.3 ± 0.8 (19.5 - 25)
pH	7.8 ± 0.1 (7.45 - 8.06)	6.1 ± 0.7 (4.5 - 7.25)	8.4 ± 0.9 (7.04 - 11)
Conductivity (µSc cm^{-1})	26.7 ± 0.6 (26 - 29)	16 ± 11 (1 - 40.1)	32 ± 16 (1 - 58.2)
Chlorophyll *a* (µg L^{-1})	11.5 ± 15 (0.2 - 56)	n.a.	7 ± 30.2 (0.5 - 270)
Turbidity (NTU)	19.7 ± 10.3 (7.2 - 88.1)	n.a.	24.6 ± 12.6 (2.7 - 116)
Dissolved oxygen (mg L^{-1})	8.5 ± 0.4 (8.1 - 9)	6.7 ± 1.9 (4.3 - 9.8)	7.1 ± 3.4 (5.6 - 12.5)
Dissolved oxygen saturation (%)	102 ± 1.6 (97.8 - 113.2)	70.1 ± 12.4 (56.4 - 88.9)	81.1 ± 36.1 (70.4 - 146.3)

Table S3: Parameters of PLS models explaining the variability in log_{10}-transformed pCO_2 and pCH_4 in the studied reservoirs. Variable importance in projection (VIP) describes how much a variable contributes to explaining the Y variable. Highly important variables have VIP>1.0 (marked bold), moderately important variables have VIP 0.8-1.0 (marked italic), and unimportant variables have VIP <0.8. Coefficients and intercepts correspond to, and can be used analogous to the slopes and intercepts in an ordinary multiple linear regression. Lacking values for chlorophyll *a* and turbidity were caused by missing data due to instrument failure. (n.a. represents "not analyzed").

Reservoir	**CDU**		**CUN**		**FNS**		**CDU**		**CUN**		**FNS**	
Model	log pCO_2		log pCO_2		log pCO_2		log pCH_4		log pCH_4		log pCH_4	
Components	7		4		5		3		4		3	
r^2Y	0.65		0.83		0.77		0.79		0.65		0.44	
Q^2	0.65		0.83		0.77		0.79		0.65		0.44	
Parameter	VIP	Coefficients	VIP	Coefficients	VIP	Coefficients	VIP	Coefficients	VIP	Coefficients	VIP	Coefficients
Date	**1.11**	0.005	**1.13**	0.03	*0.83*	-0.15	**1.72**	0.06	*0.92*	-0.03	*0.86*	0.01
Time	**1.58**	0.04	0.18	0.01	*0.93*	-0.16	0.53	-0.02	*1*	-0.04	0.59	-0.06
GPS(S)	0.55	0.003	0.67	-0.01	0.66	-0.21	**1.82**	0.08	**1.01**	-0.06	**1.56**	-0.15
GPS(W)	0.67	0.04	**1.11**	0.04	0.47	-0.03	**1.51**	-0.05	*0.97*	-0.02	0.71	-0.01
Water temperature	**1.03**	0.006	0.74	0.003	*0.86*	0.07	0.32	0.01	**1.01**	-0.03	0.56	-0.04
pH	0.48	-0.005	**1.18**	-0.01	**1.62**	-0.39	0.43	0.03	*0.98*	-0.02	**1.21**	0.11
Depth	*0.88*	-0.01	**1.16**	-0.02	0.56	-0.05	**1.56**	-0.05	0.61	-0.02	**1.26**	-0.08
log pCH_4	0.75	0.01	**1.23**	0.06	*0.86*	-0.16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
log pCO_2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.57	-0.002	**1.51**	0.15	**1.45**	-0.21
Conductivity	*1*	-0.003	0.62	-0.01	0.73	0.04	0.30	-0.01	0.67	-0.02	0.53	-0.01
log Chl *a*	0.6	-0.007	n.a.	n.a.	0.61	0.06	0.45	-0.01	n.a.	n.a.	0.78	0.01
log Tubidity	0.72	0.003	n.a.	n.a.	0.41	0.02	0.45	0.01	n.a.	n.a.	**1.05**	0.02
$[O_2]$	**1.69**	-0.005	**1.18**	-0.02	**1.64**	-0.07	0.62	0.04	**1.04**	0.03	*0.84*	-0.07
$\%O_2$ sat	**1.04**	-0.01	**1.19**	-0.03	**1.62**	-0.07	0.52	0.02	**1.03**	0.05	*0.88*	-0.07
Intercept		2.63		2.79		2.1		0.93		0.91		1.31