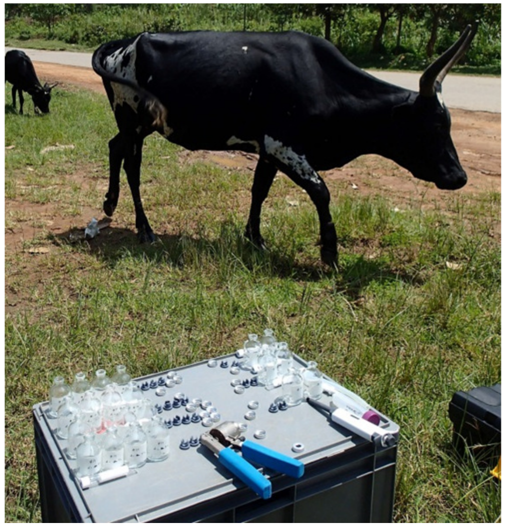
Variations of dissolved greenhouse gases (CO_2, CH_4, N_2O) in the Congo River network overwhelmingly driven by fluvial wetland connectivity

Alberto V. Borges

LIÈGE université
Astrophysique, Géophysique et Océanographie

Lab presentation

- Measurements of greenhouse gases in aquatic enviroments
- Inland waters, coastal waters, oceanic waters & marine cryosphere
- Versatile, compact and rugged equipment for harsh environments
- Carbon dioxide (CO_2) by infra-red & lazer gas analysers (Li-Cor & LGR)
- Continuous (surface) and discrete (profiles)
- Methane (CH_4) by gas chromatography (GC) & lazer gas analyser (LGR)
- Nitrous oxide (N_2O) concentration by GC
- N_2O isotopes by lazer spectrometry (LGR)
- Dimethylsulfide (DMS) by GC



Introduction

How important are emissions of greenhouse-gas from inland waters ?

Global carbon dioxide emissions from inland waters

Peter A. Raymond[1], Jens Hartmann[2*], Ronny Lauerwald[2,3*], Sebastian Sobek[4*], Cory McDonald[5], Mark Hoover[1], David Butman[1,6], Robert Striegl[6], Emilio Mayorga[7], Christoph Humborg[8], Pirkko Kortelainen[9], Hans Dürr[10], Michel Meybeck[11], Philippe Ciais[12] & Peter Guth[13]

Carbon dioxide (CO_2) transfer from inland waters to the atmosphere, known as CO_2 evasion, is a component of the global carbon cycle. Global estimates of CO_2 evasion have been hampered, however, by the lack of a framework for estimating the inland water surface area and gas transfer velocity and by the absence of a global CO_2 database. Here we report regional variations in global inland water surface area, dissolved CO_2 and gas transfer velocity. We obtain global CO_2 evasion rates of $1.8^{+0.25}_{-0.25}$ petagrams of carbon (Pg C) per year from streams and rivers and $0.32^{+0.52}_{-0.26}$ Pg C yr^{-1} from lakes and reservoirs, where the upper and lower limits are respectively the 5th and 95th confidence interval percentiles. The resulting global evasion rate of 2.1 Pg C yr^{-1} is higher than previous estimates owing to a larger stream and river evasion rate. Our analysis predicts global hotspots in stream and river evasion, with about 70 per cent of the flux occurring over just 20 per cent of the land surface. The source of inland water CO_2 is still not known with certainty and new studies are needed to research the mechanisms controlling CO_2 evasion globally.

Raymond et al. (2013)

Introduction

Global anthropogenic CO_2 fluxes in 2010 ($PgC\ y^{-1} = 10^{15}\ gC\ y^{-1}$)

9.1±0.5 $PgC\ y^{-1}$

0.9±0.7 $PgC\ y^{-1}$ +

5.0±0.2 $PgC\ y^{-1}$
50%

2.6±1.0 $PgC\ y^{-1}$
26%
Calculated as the residual
of all other flux components

24%
2.4±0.5 $PgC\ y^{-1}$
Average of 5 models

www.globalcarbonproject.org/

Introduction

Spatial patterns in CO_2 evasion from the global river network

Ronny Lauerwald[1,2,3], Goulven G. Laruelle[1,4], Jens Hartmann[3], Philippe Ciais[5], and Pierre A. G. Regnier[1]

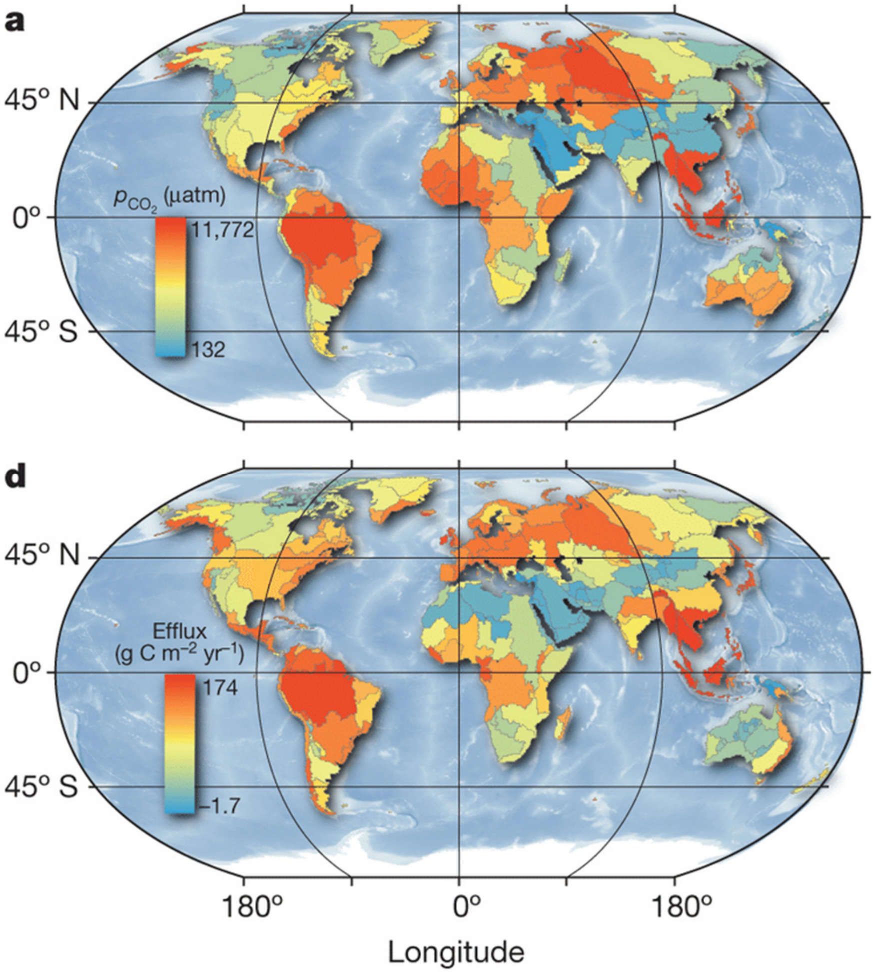
[1]Department of Earth and Environmental Sciences, Université Libre de Bruxelles, Brussels, Belgium, [2]Institut Pierre-Simon Laplace, Paris, France, [3]Institute for Geology, University of Hamburg, Hamburg, Germany, [4]Department of Earth Sciences-Geochemistry, Utrecht University, Utrecht, Netherlands, [5]LSCE IPSL, Gif Sur Yvette, France

Abstract CO_2 evasion from rivers (FCO_2) is an important component of the global carbon budget. Here we present the first global maps of CO_2 partial pressures (pCO_2) in rivers of stream orders 3 and higher and the resulting FCO_2 at 0.5° resolution constructed with a statistical model. A geographic information system based approach is used to derive a pCO_2 prediction function trained on data from 1182 sampling locations. While data from Asia and Africa are scarce and the training data set is dominated by sampling locations from the Americas, Europe, and Australia, the sampling locations cover the full spectrum from high to low latitudes. The predictors of pCO_2 are net primary production, population density, and slope gradient within the river catchment as well as mean air temperature at the sampling location ($r^2 = 0.47$). The predicted pCO_2 map was then combined with spatially explicit estimates of stream surface area A_{river} and gas exchange velocity k calculated from published empirical equations and data sets to derive the FCO_2 map. Using Monte Carlo simulations, we assessed the uncertainties of our estimates. At the global scale, we estimate an average river pCO_2 of 2400 (2019–2826) µatm and a FCO_2 of 650 (483–846) Tg C yr^{-1} (5th and 95th percentiles of confidence interval). Our global CO_2 evasion is substantially lower than the recent estimate of 1800 Tg C yr^{-1} although the training set of pCO_2 is very similar in both studies, mainly due to lower tropical pCO_2 estimates in the present study. Our maps reveal strong latitudinal gradients in pCO_2, A_{river}, and FCO_2. The zone between 10°N and 10°S contributes about half of the global CO_2 evasion. Collection of pCO_2 data in this zone, in particular, for African and Southeast Asian rivers is a high priority to reduce uncertainty on FCO_2.

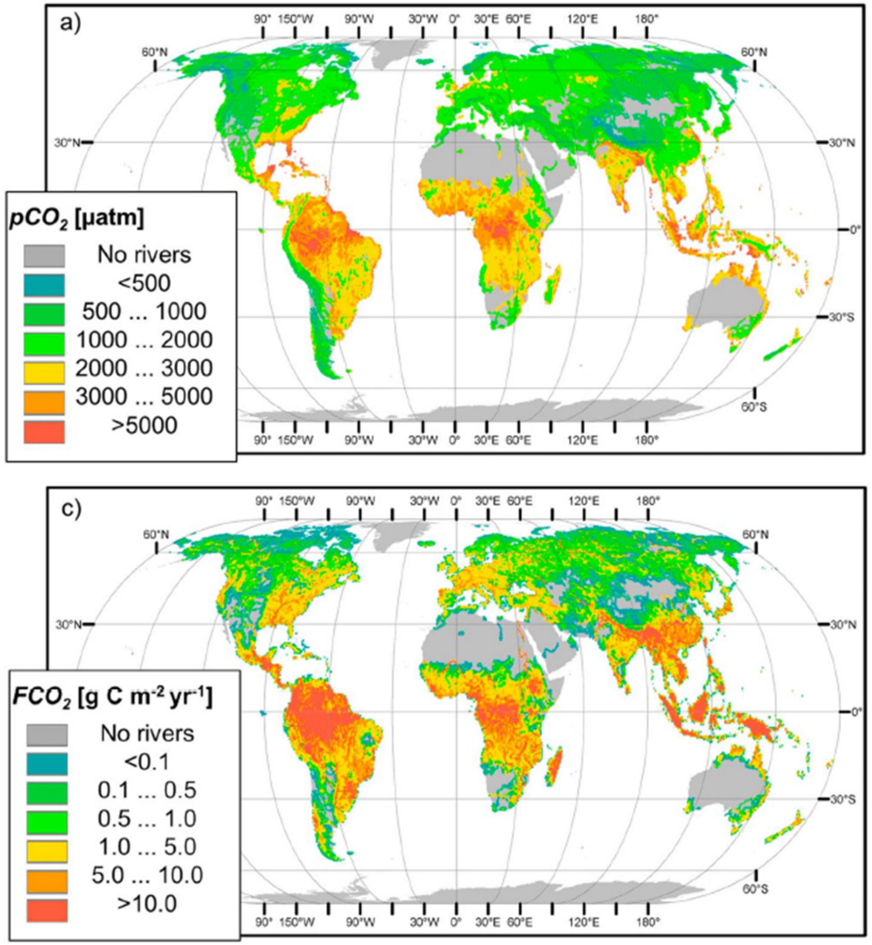
Lauerwald et al. (2015)

Introduction

Raymond et al. (2013)

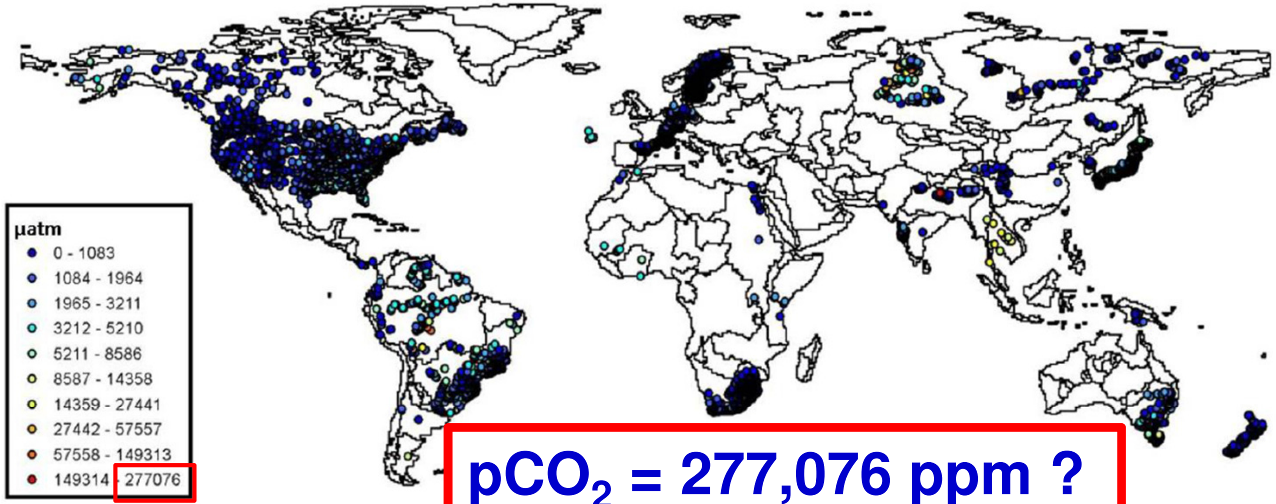


Lauerwald et al. (2015)



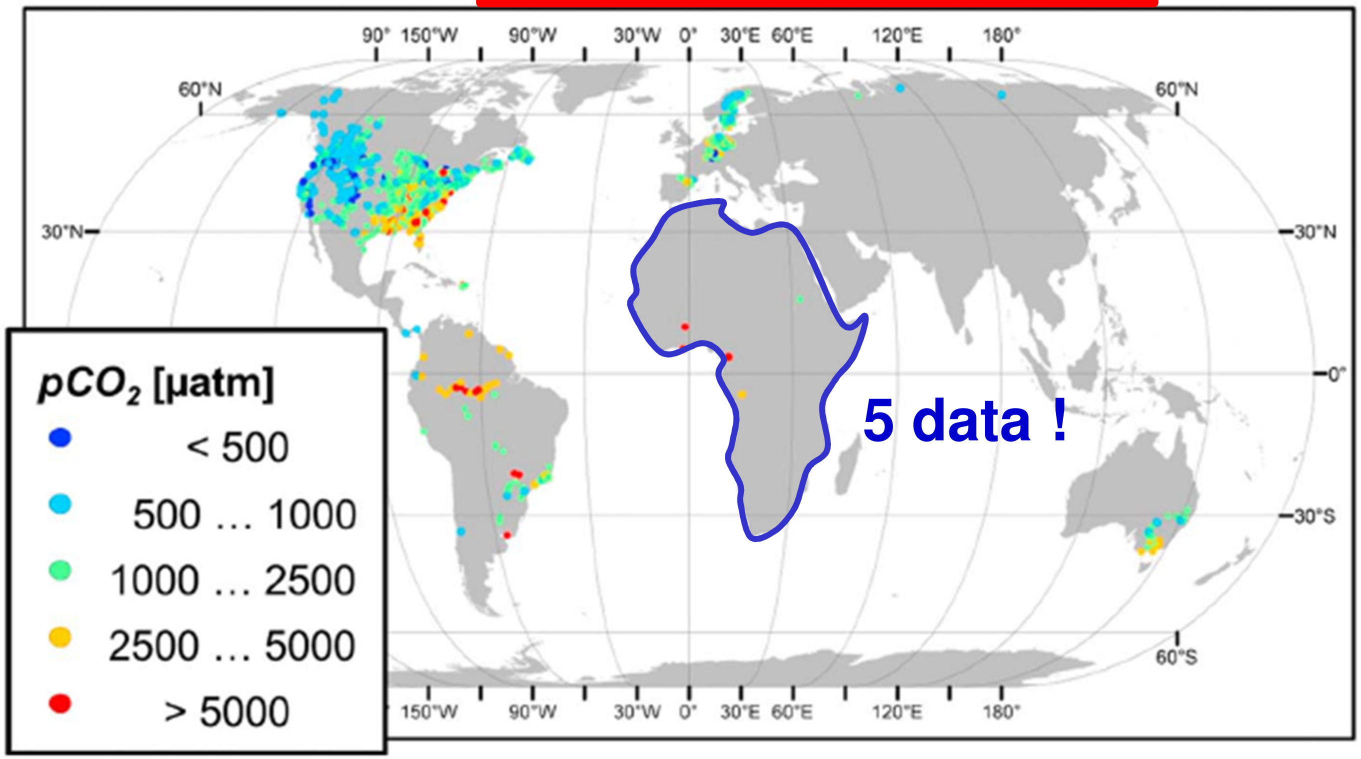
Introduction

Raymond et al. (2013)



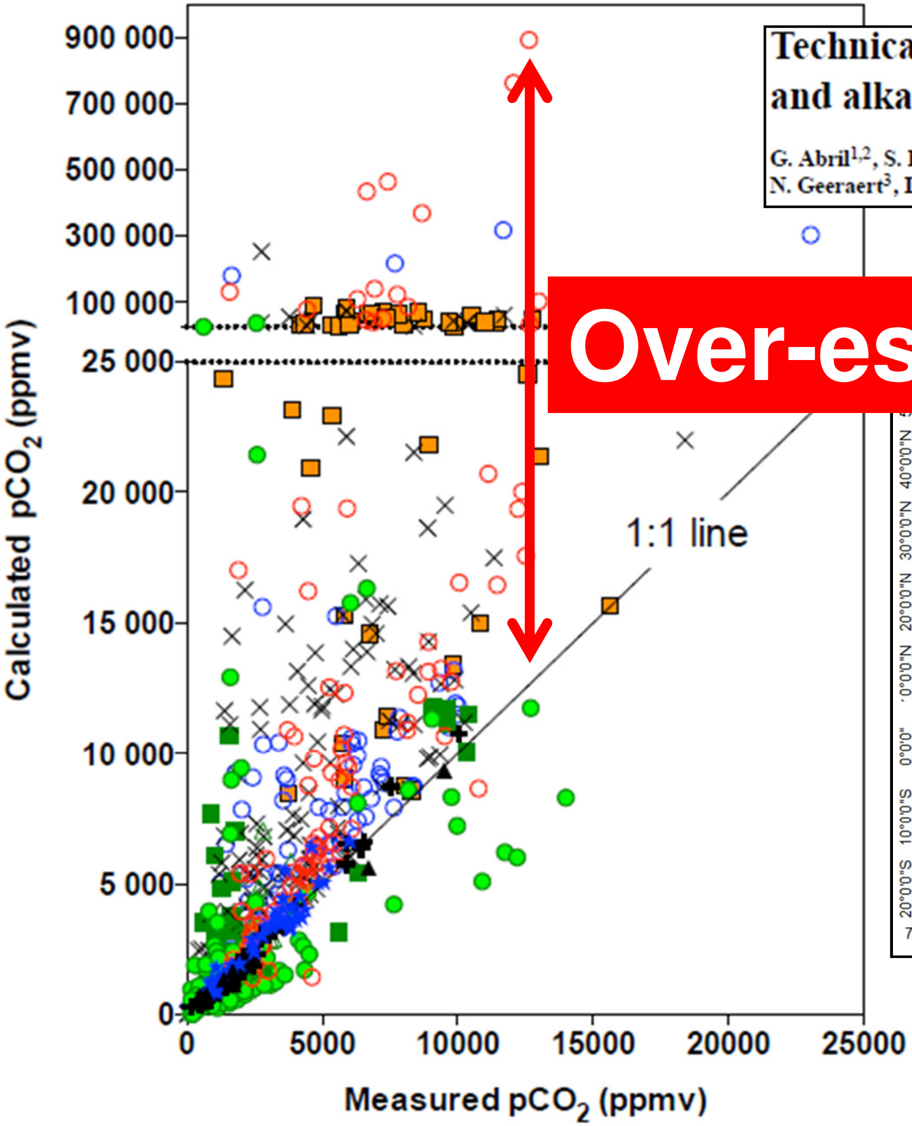
pCO_2 = 277,076 ppm ?

Lauerwald et al. (2015)



5 data !

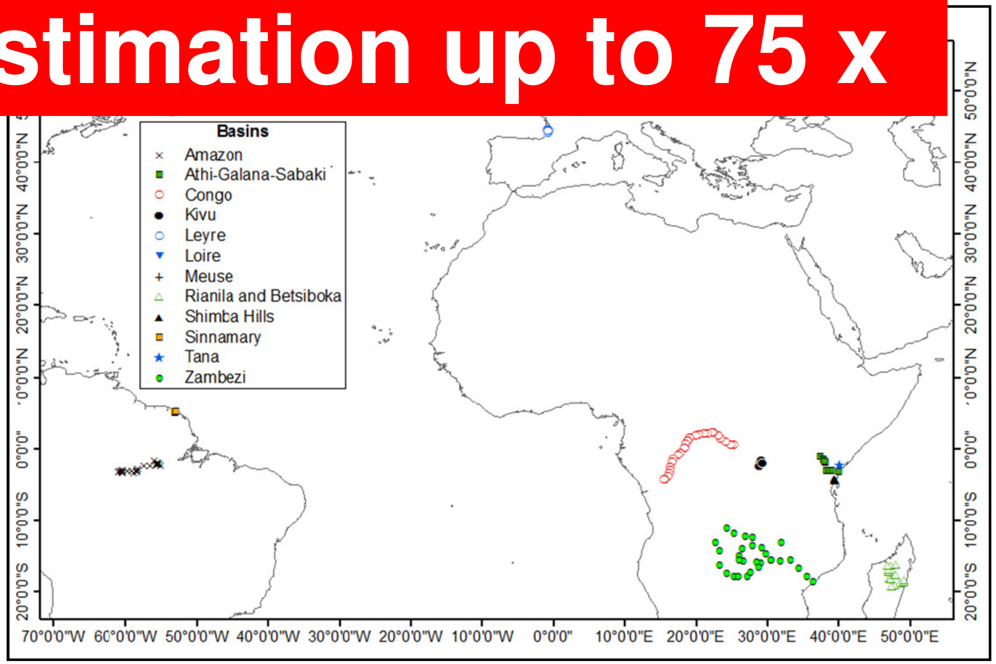
Raymond et al. (2013) & Lauerwald et al. (2015) used pCO_2 computed from pH and total alkalinity



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



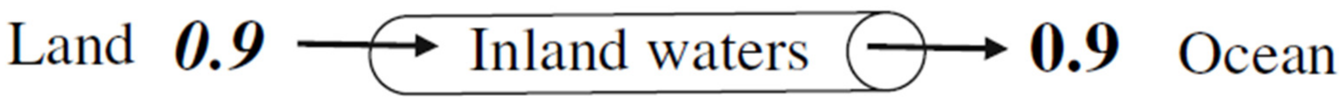
Introduction

Where's the river/lake CO_2 coming from ?

Plumbing the Global Carbon Cycle: Integrating Inland Waters into the Terrestrial Carbon Budget

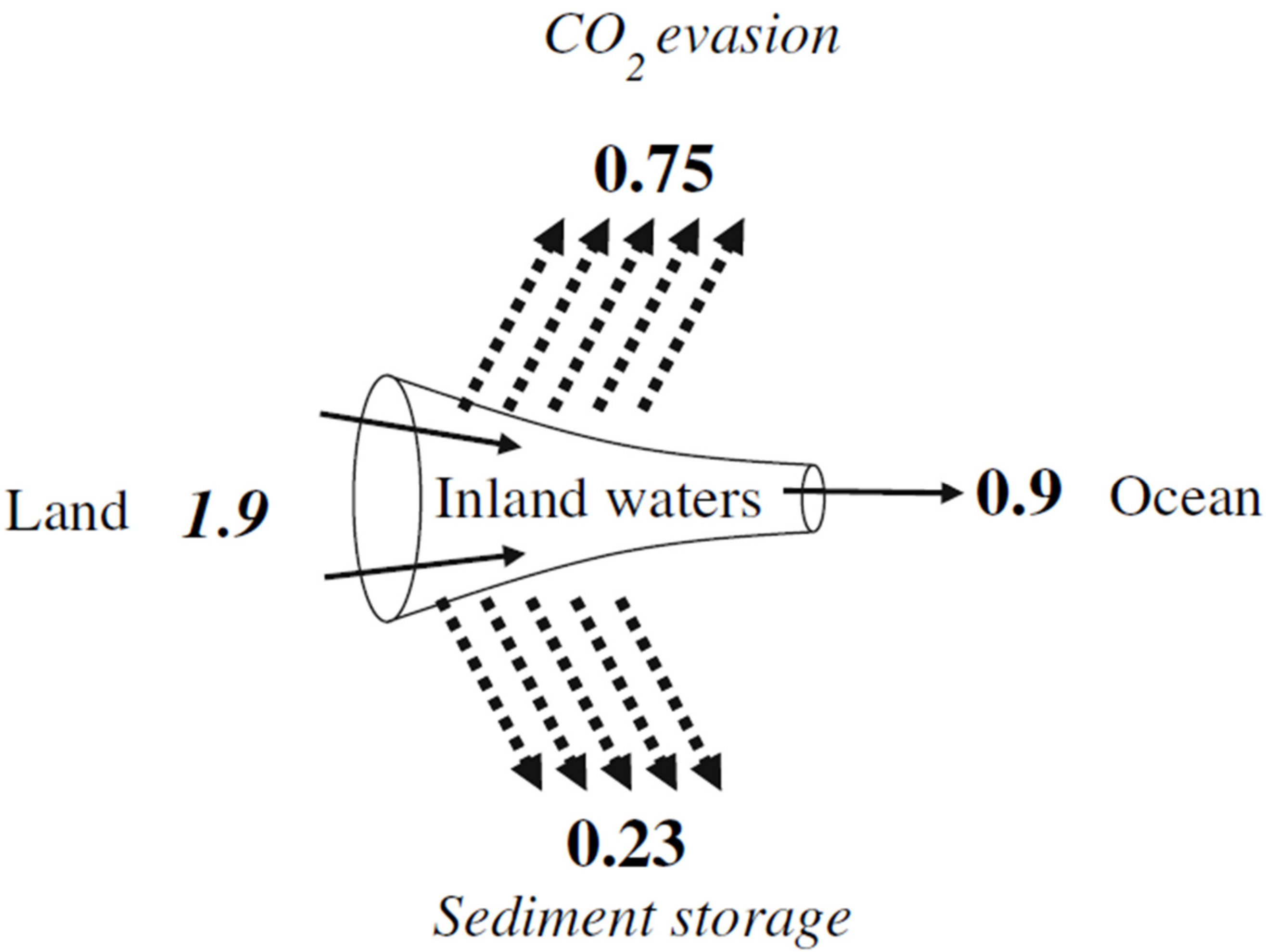
J. J. Cole,[1] Y. T. Prairie,[2,*] N. F. Caraco,[1] W. H. McDowell,[3] L. J. Tranvik,[4] R. G. Striegl,[5] C. M. Duarte,[6] P. Kortelainen,[7] J. A. Downing,[8] J. J. Middelburg,[9] and J. Melack,[10]

Introduction



Fluxes in PgC yr^{-1}

Introduction



Fluxes in PgC yr^{-1}

Introduction

Biogeosciences, 16, 769–784, 2019
https://doi.org/10.5194/bg-16-769-2019

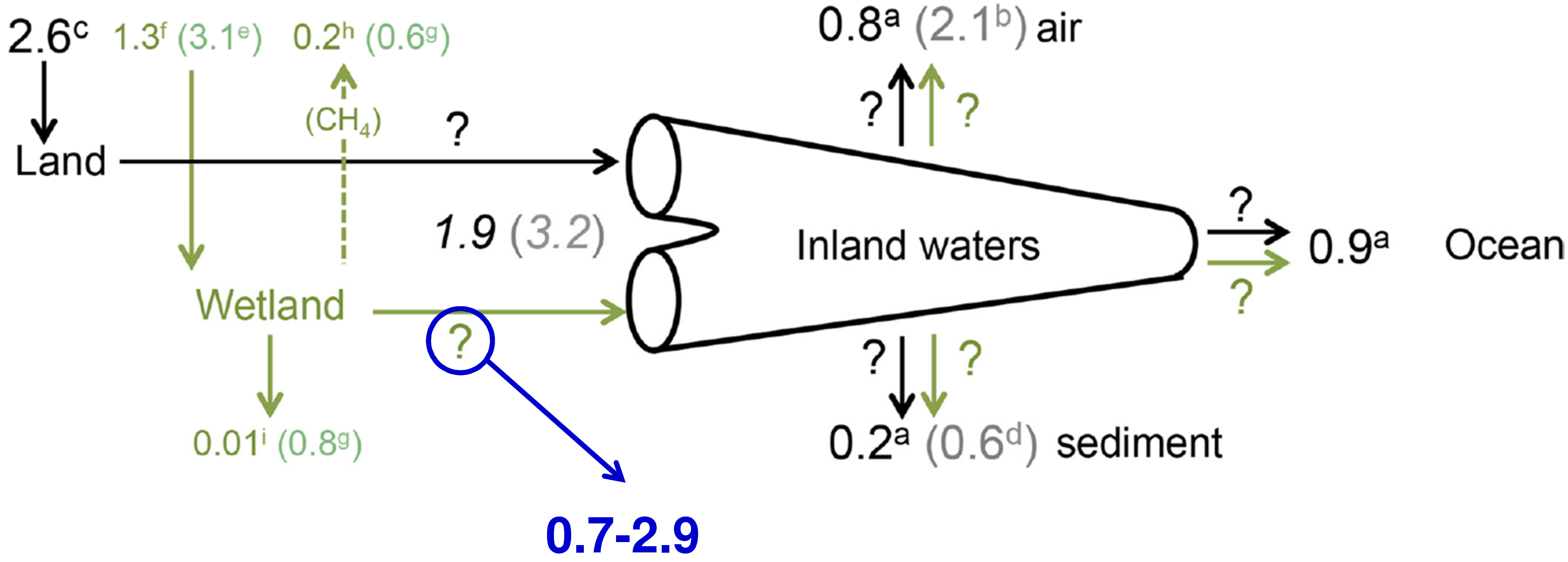
Biogeosciences Open Access EGU

Ideas and perspectives: Carbon leaks from flooded land: do we need to replumb the inland water active pipe?

Gwenaël Abril[1,2] and Alberto V. Borges[3]

Introduction

Replumbed active pipe

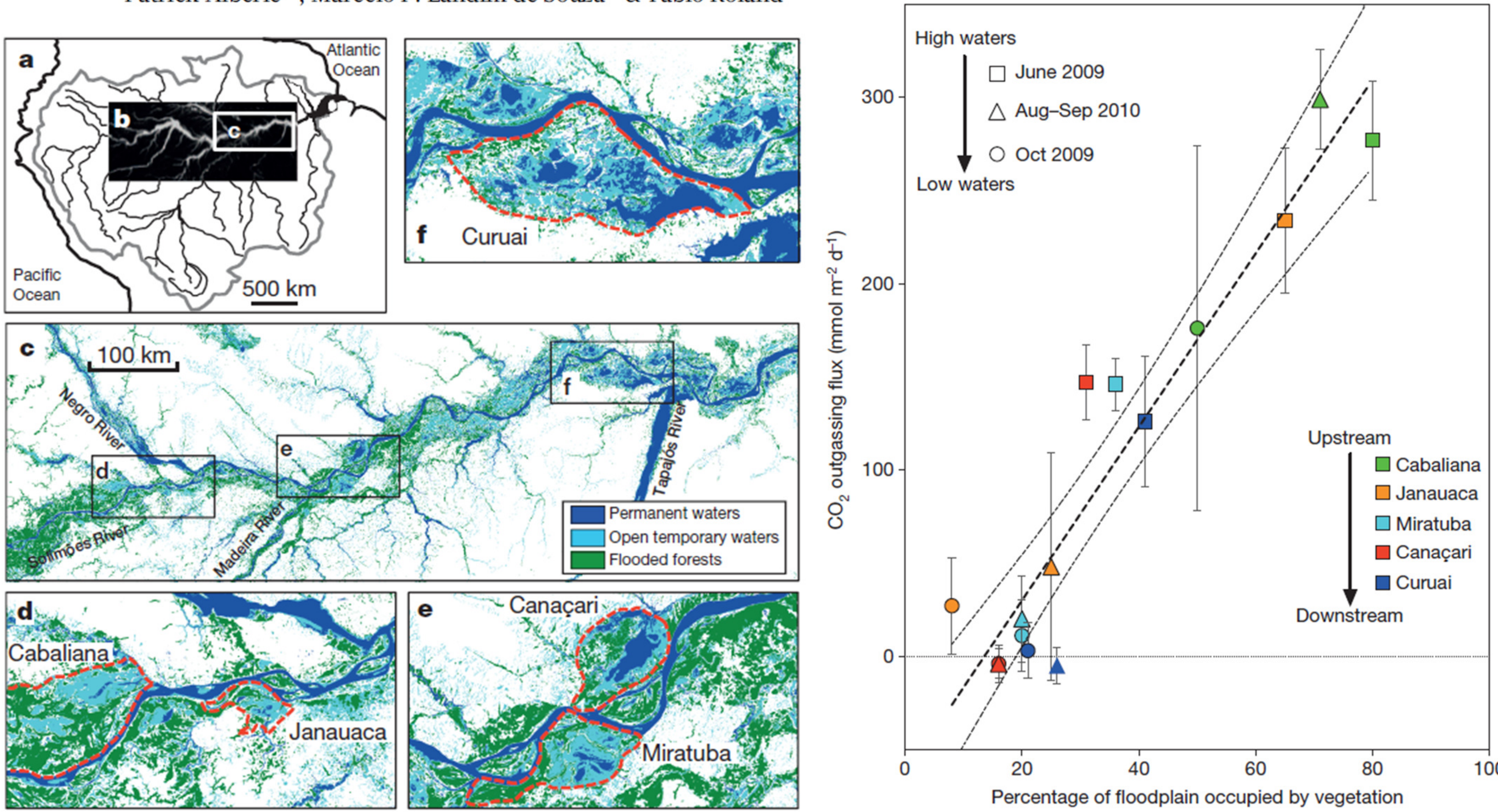


Fluxes in PgC yr^{-1}

Introduction

Amazon River carbon dioxide outgassing fuelled by wetlands

Gwenaël Abril[1,2], Jean-Michel Martinez[2], L. Felipe Artigas[3], Patricia Moreira-Turcq[2], Marc F. Benedetti[4], Luciana Vidal[5], Tarik Meziane[6], Jung-Hyun Kim[7], Marcelo C. Bernardes[8], Nicolas Savoye[1], Jonathan Deborde[1], Edivaldo Lima Souza[9], Patrick Albéric[10], Marcelo F. Landim de Souza[11] & Fabio Roland[5]



Introduction

nature geoscience

ARTICLES

PUBLISHED ONLINE: 20 JULY 2015 | DOI: 10.1038/NGEO2486

Globally significant greenhouse-gas emissions from African inland waters

Alberto V. Borges[1*], François Darchambeau[1], Cristian R. Teodoru[2], Trent R. Marwick[2], Fredrick Tamooh[2,3], Naomi Geeraert[2], Fredrick O. Omengo[2], Frédéric Guérin[4], Thibault Lambert[1], Cédric Morana[2], Eric Okuku[2,5] and Steven Bouillon[2]

Biogeosciences Discuss., https://doi.org/10.5194/bg-2019-68
Manuscript under review for journal Biogeosciences
This is just a preview and not the published paper.

Biogeosciences
Discussions
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Variations of dissolved greenhouse gases (CO_2, CH_4, N_2O) in the Congo River network overwhelmingly driven by fluvial-wetland connectivity

Alberto V. Borges[1,*], François Darchambeau[1,**], Thibault Lambert[1,***], Cédric Morana[2], George Allen[3], Ernest Tambwe[4], Alfred Toengaho Sembaito[4], Taylor Mambo[4], José Nlandu Wabakhangazi[5], Jean-Pierre Descy[1], Cristian R. Teodoru[2,****], Steven Bouillon[2]

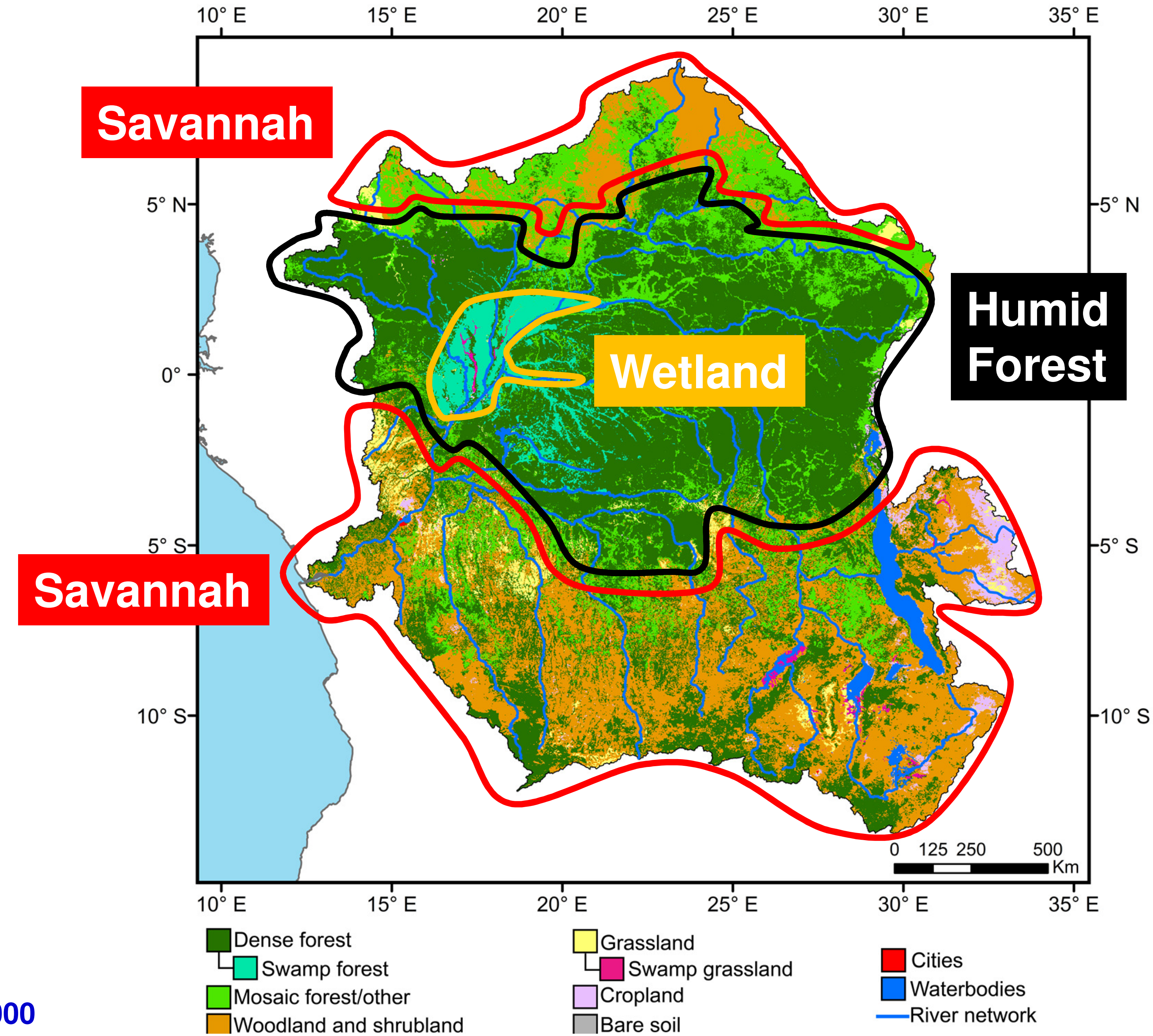
Introduction

Congo river

Congo

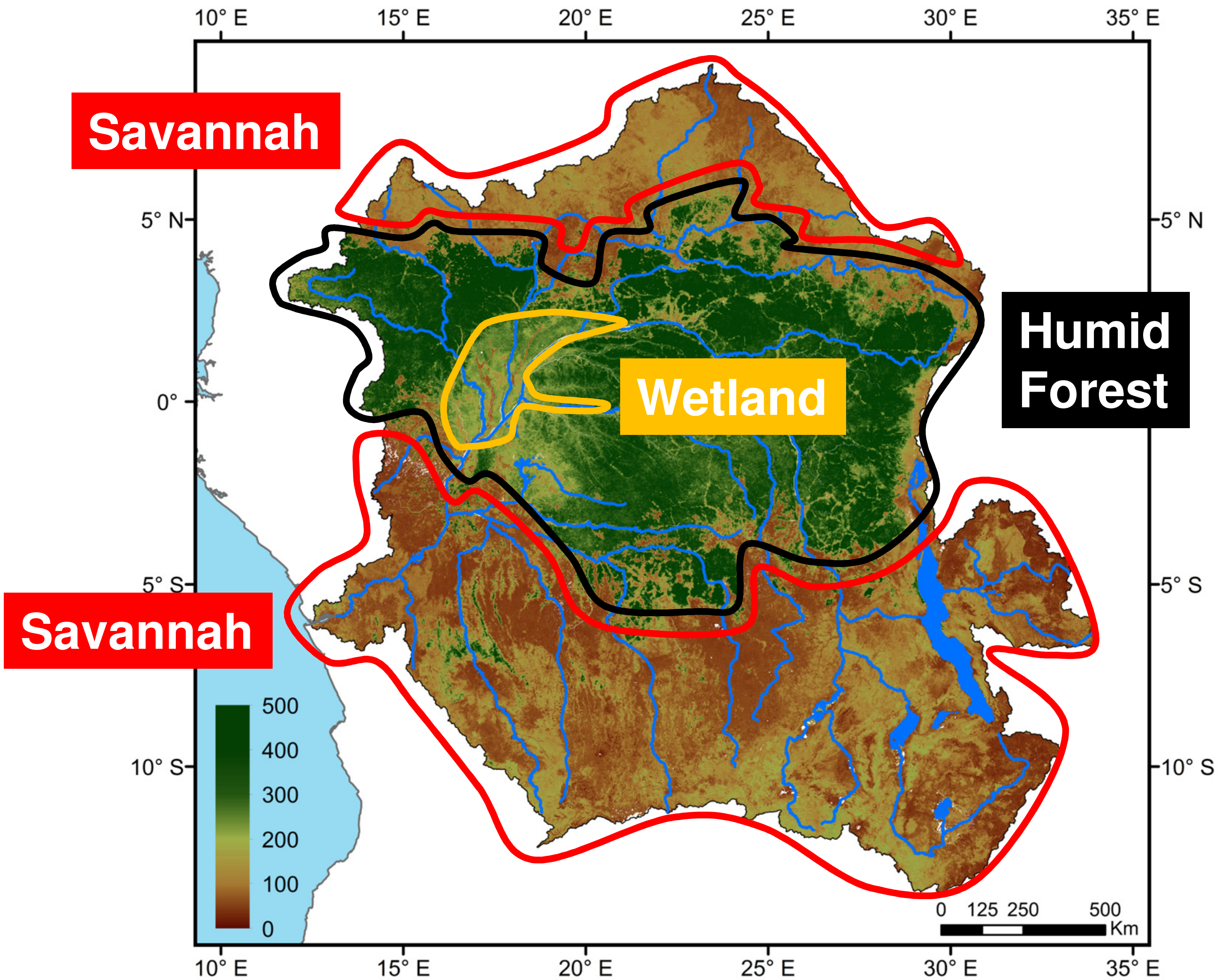
Congo

Congo



GLC 2000

Congo



Aboveground live woody biomass (Mg ha^{-1})

WHRC

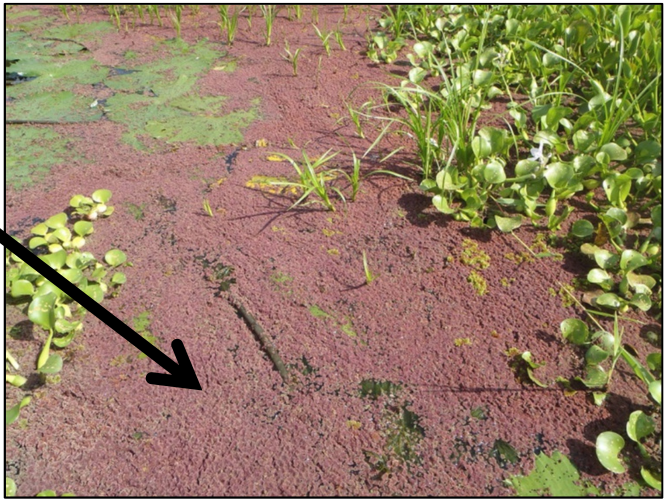

Wetland
= flooded forest
(Tributary)


Wetland
= floating macrophytes
(Tributary)


Wetland
= floating macrophytes
(Congo mainstem)

Congo

Azolla pinnata

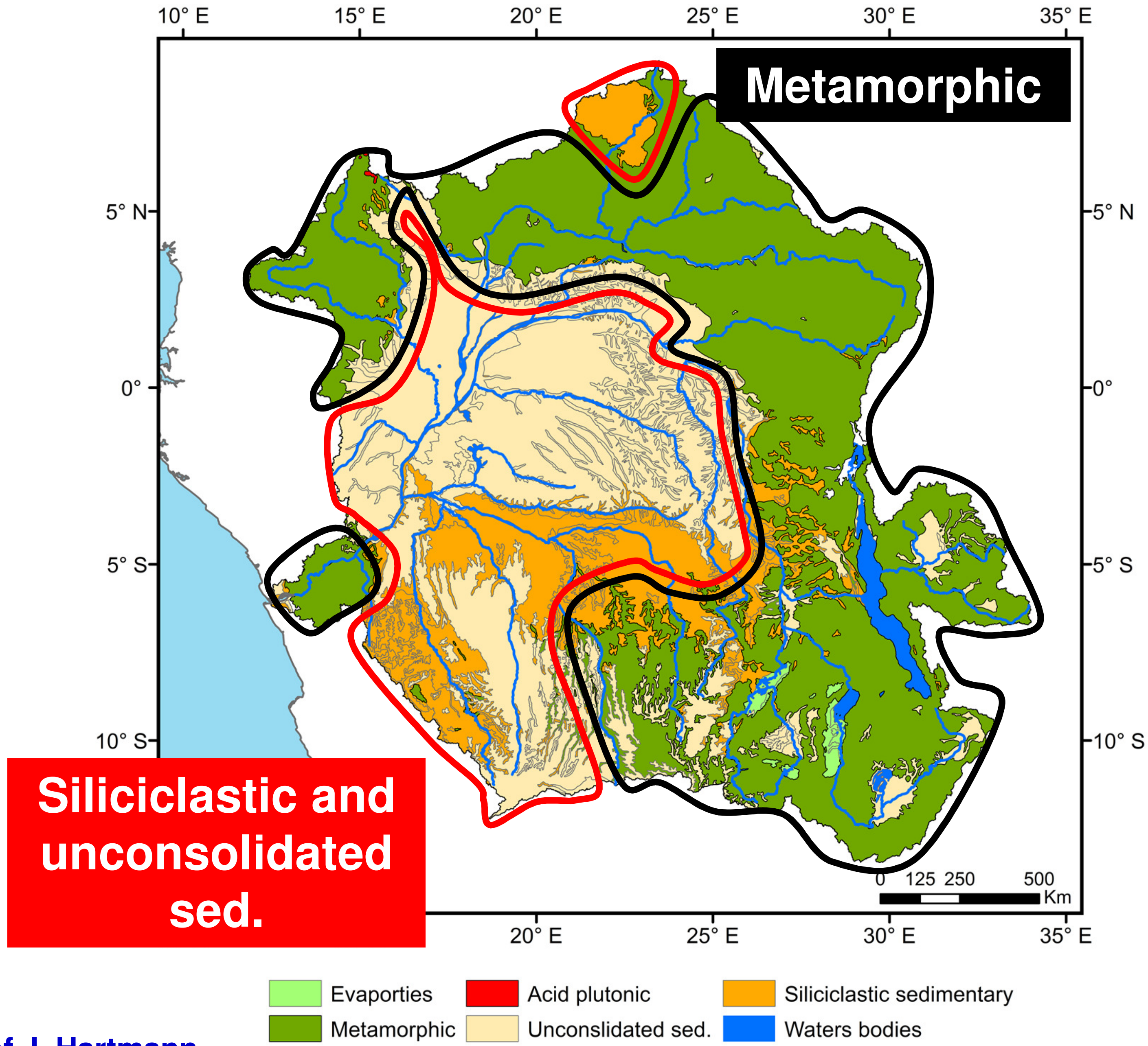


Vossia cuspidata
« Hippo grass »

Eichhornia crassipes
« water hyacinth »

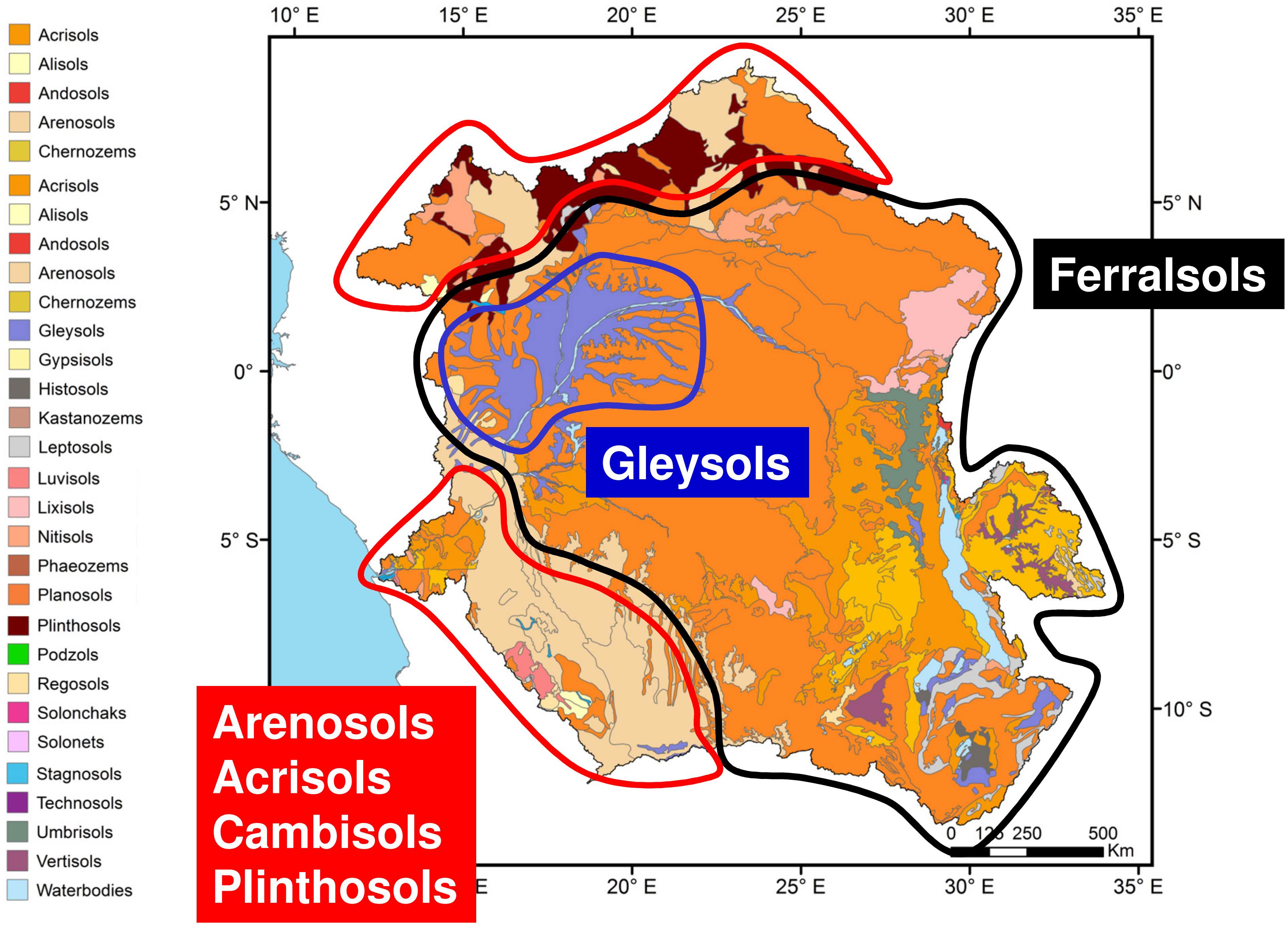
Salvinia auriculata

Congo

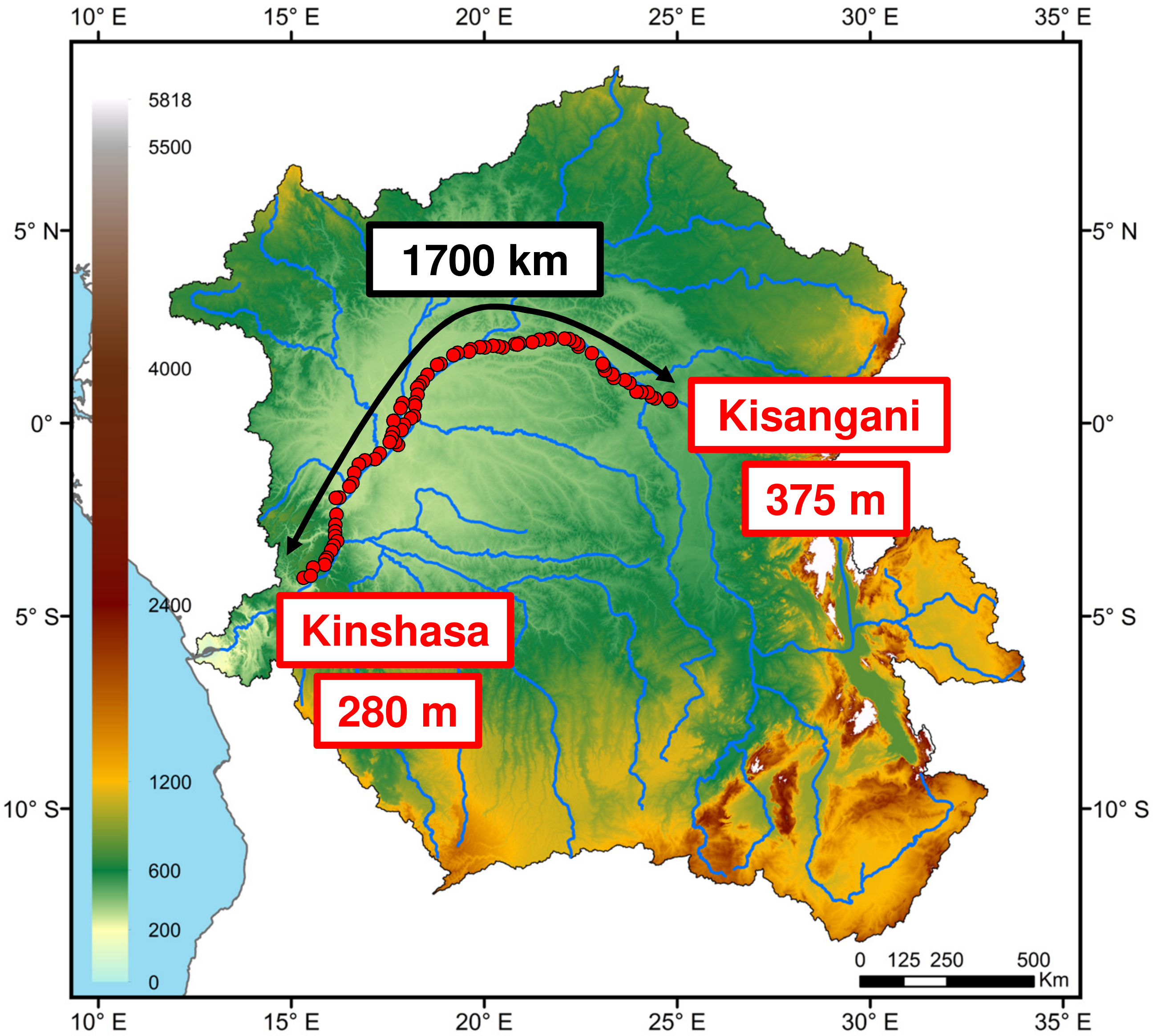


Courtesy of J. Hartmann

Congo

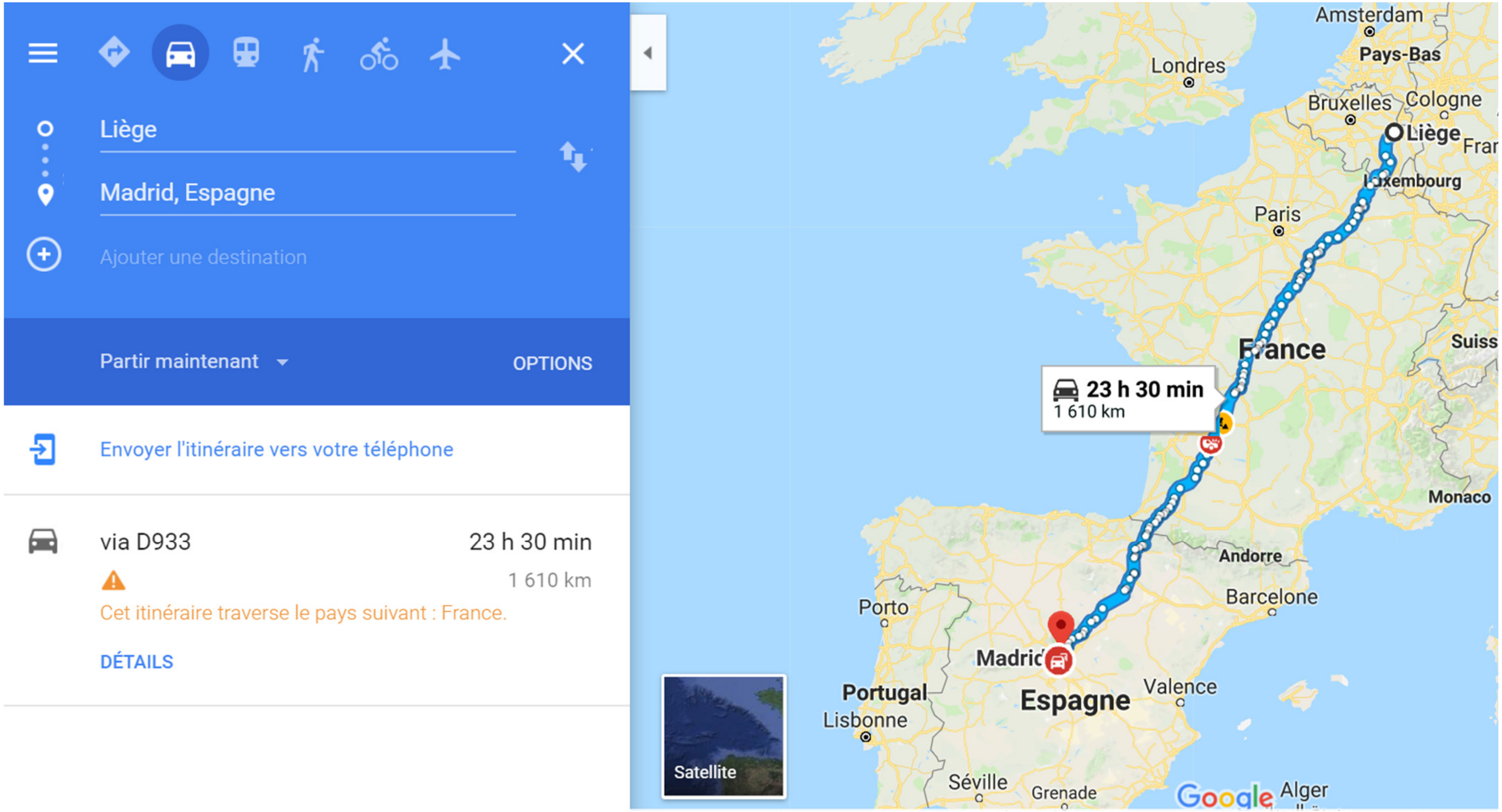

Acrisols
Alisols
Andosols
Arenosols
Chernozems
Acrisols
Alisols
Andosols
Arenosols
Chernozems
Gleysols
Gypsisols
Histosols
Kastanozems
Leptosols
Luvisols
Lixisols
Nitisols
Phaeozems
Planosols
Plinthosols
Podzols
Regosols
Solonchaks
Solonets
Stagnosols
Technosols
Umbrisols
Vertisols
Waterbodies
10° E
15° E
20° E
25° E
30° E
35° E
5° N
0°
5° S
10° S
Ferralsols
Gleysols
Arenosols
Acrisols
Cambisols
Plinthosols
Km

Congo

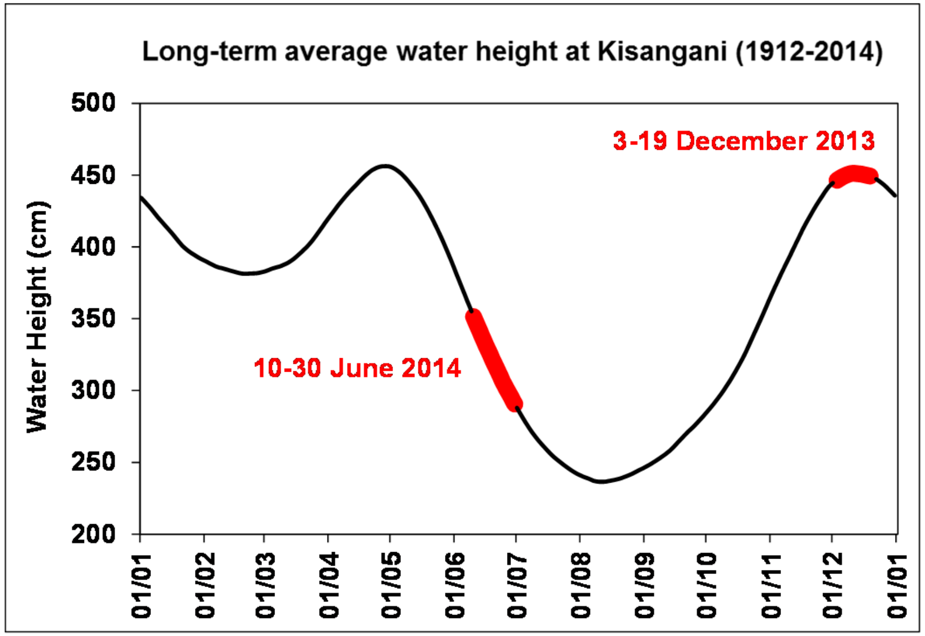


10° E
15° E
20° E
25° E
30° E
35° E
5° N
0°
5° S
10° S
5818
5500
4000
2400
1200
600
200
0
1700 km
Kisangani
375 m
Kinshasa
280 m
0 125 250 500
Km

Congo

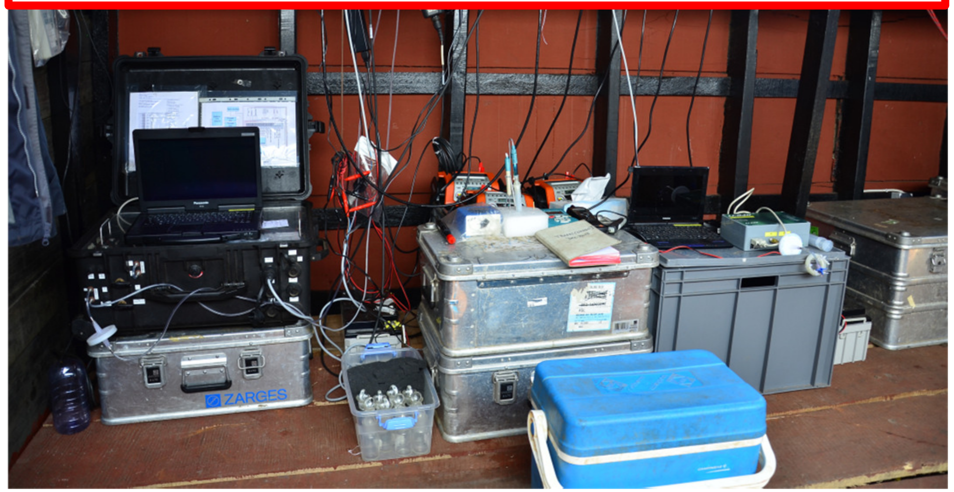

Liège
Madrid, Espagne
Ajouter une destination
Partir maintenant
OPTIONS
Envoyer l'itinéraire vers votre téléphone
via D933
23 h 30 min
1 610 km
Cet itinéraire traverse le pays suivant : France.
DÉTAILS
Amsterdam
Pays-Bas
Londres
Bruxelles
Cologne
Liège
Paris
France
Suiss
23 h 30 min
1 610 km
Monaco
Andorre
Barcelone
Porto
Madrid
Portugal
Espagne
Valence
Lisbonne
Séville
Grenade
Alger
Satellite
Google

Cruises & Methods



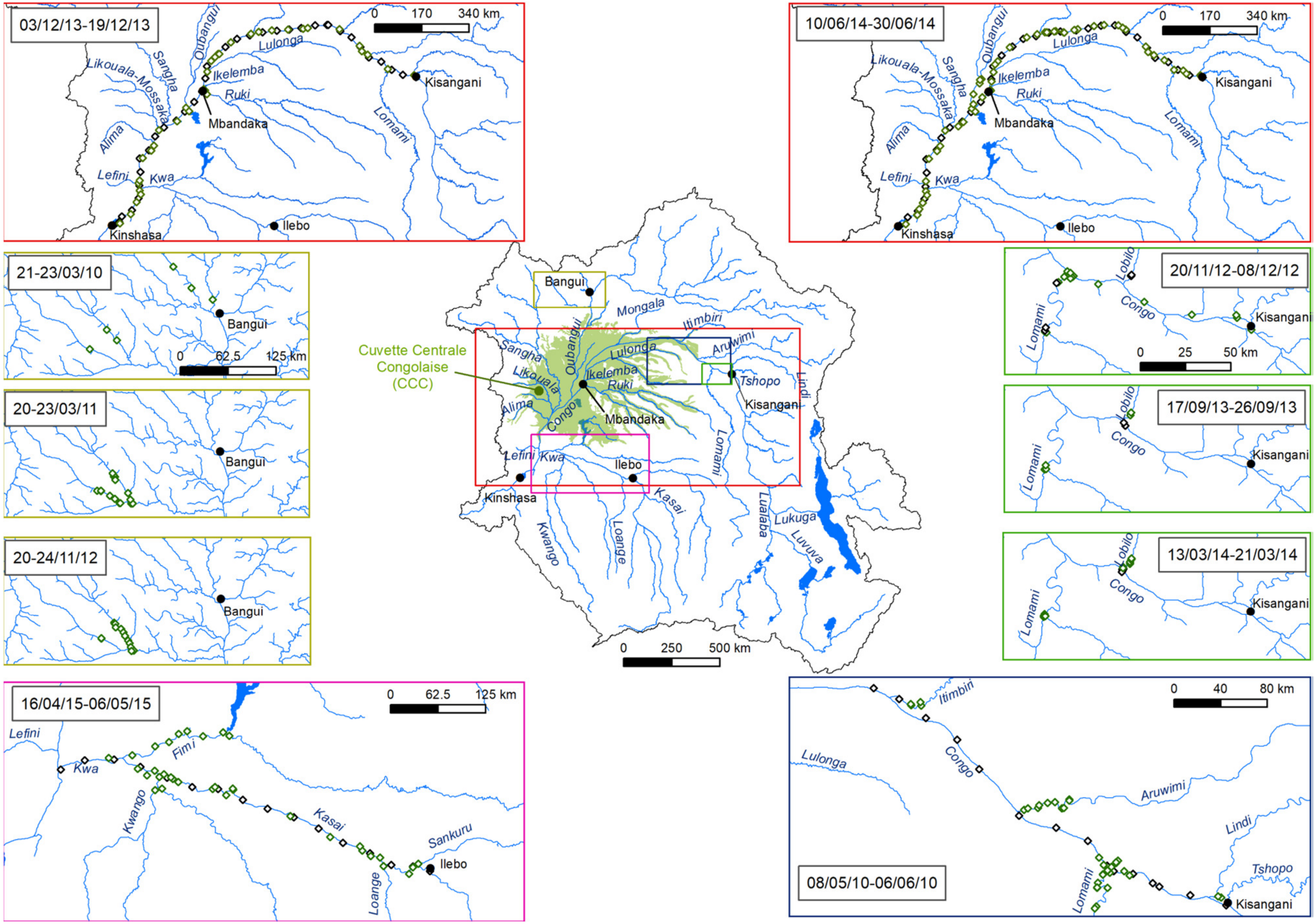
164 stations
29 variables

> 23,000 continuous measurements
pCO_2, cond, temp, pH, O_2, TSM, cDOM

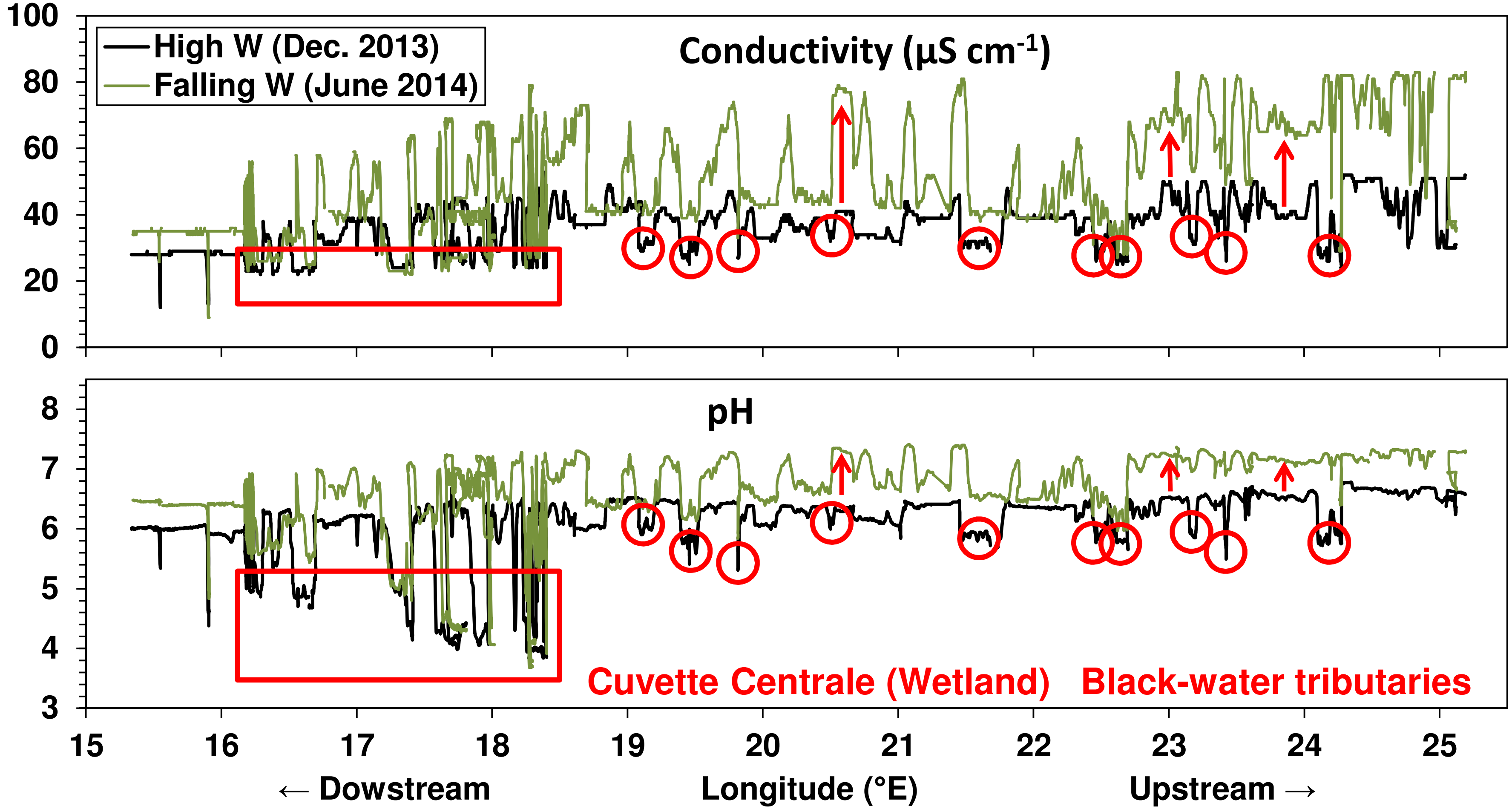


Cruises & Methods

Cruises & Methods

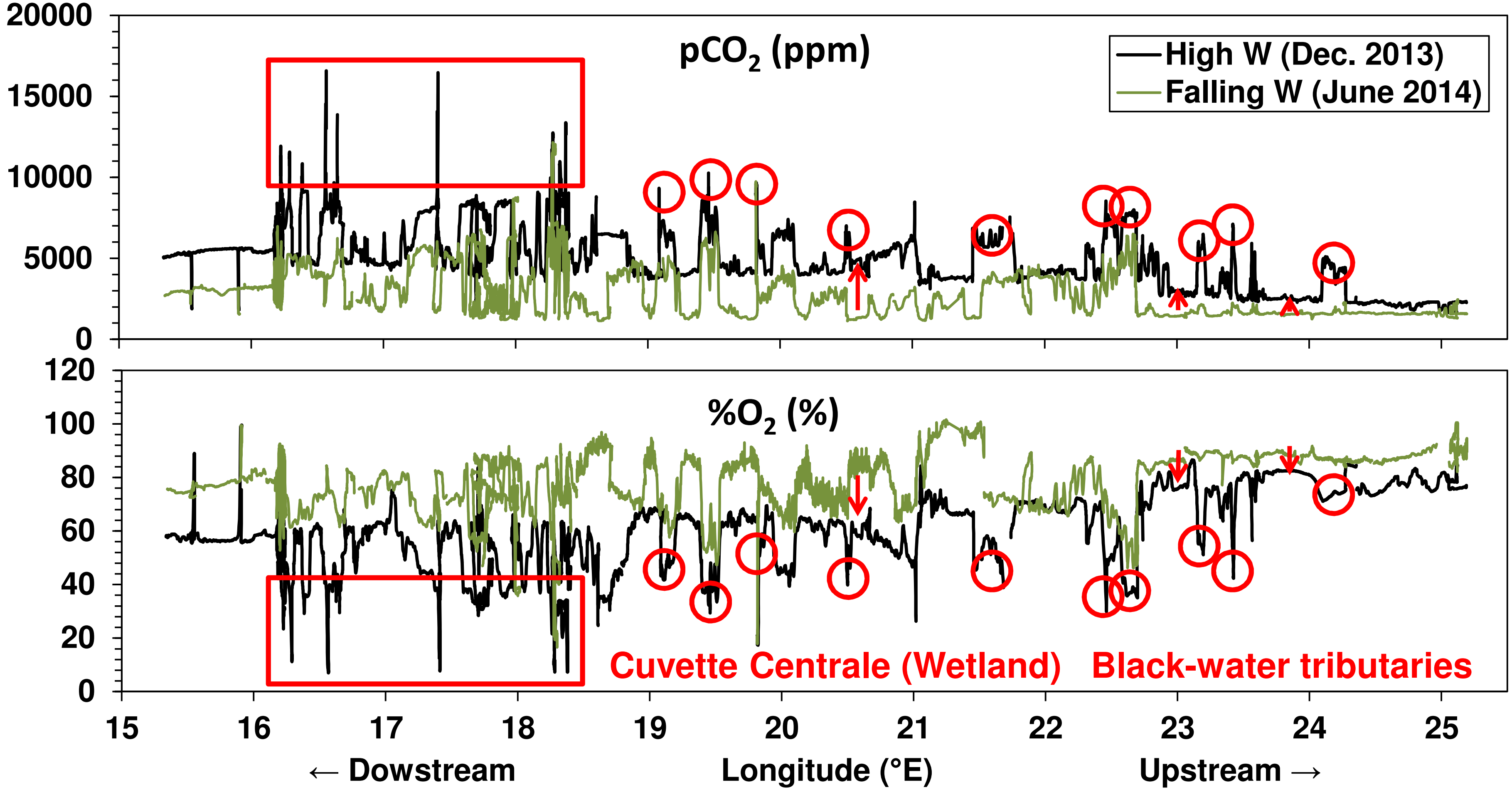


Results



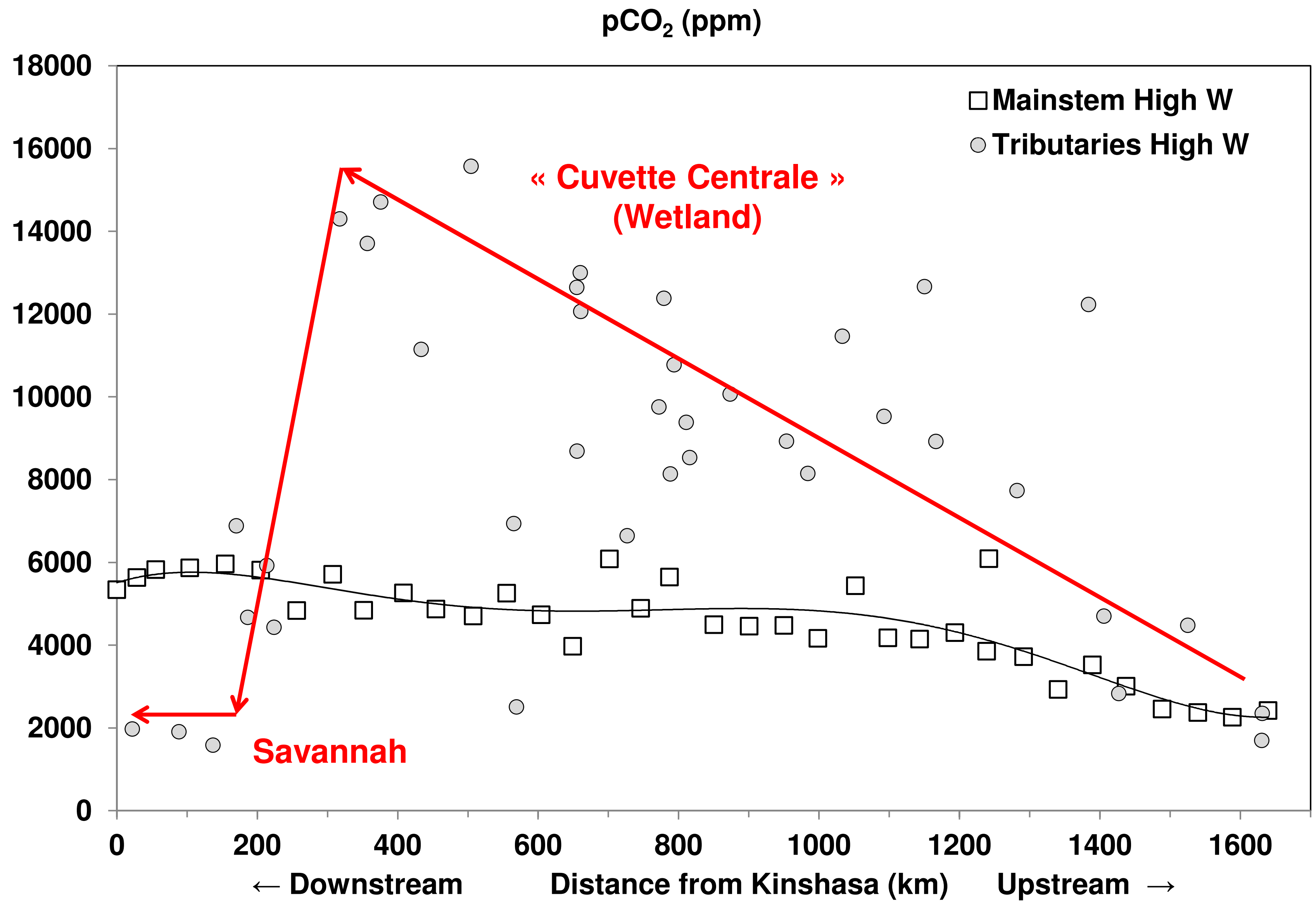
100
80
60
40
20
0
High W (Dec. 2013)
Falling W (June 2014)
Conductivity (µS cm-1)
8
7
6
5
4
3
pH
Cuvette Centrale (Wetland)
Black-water tributaries
15
16
17
18
19
20
21
22
23
24
25
← Dowstream
Longitude (°E)
Upstream →

Results



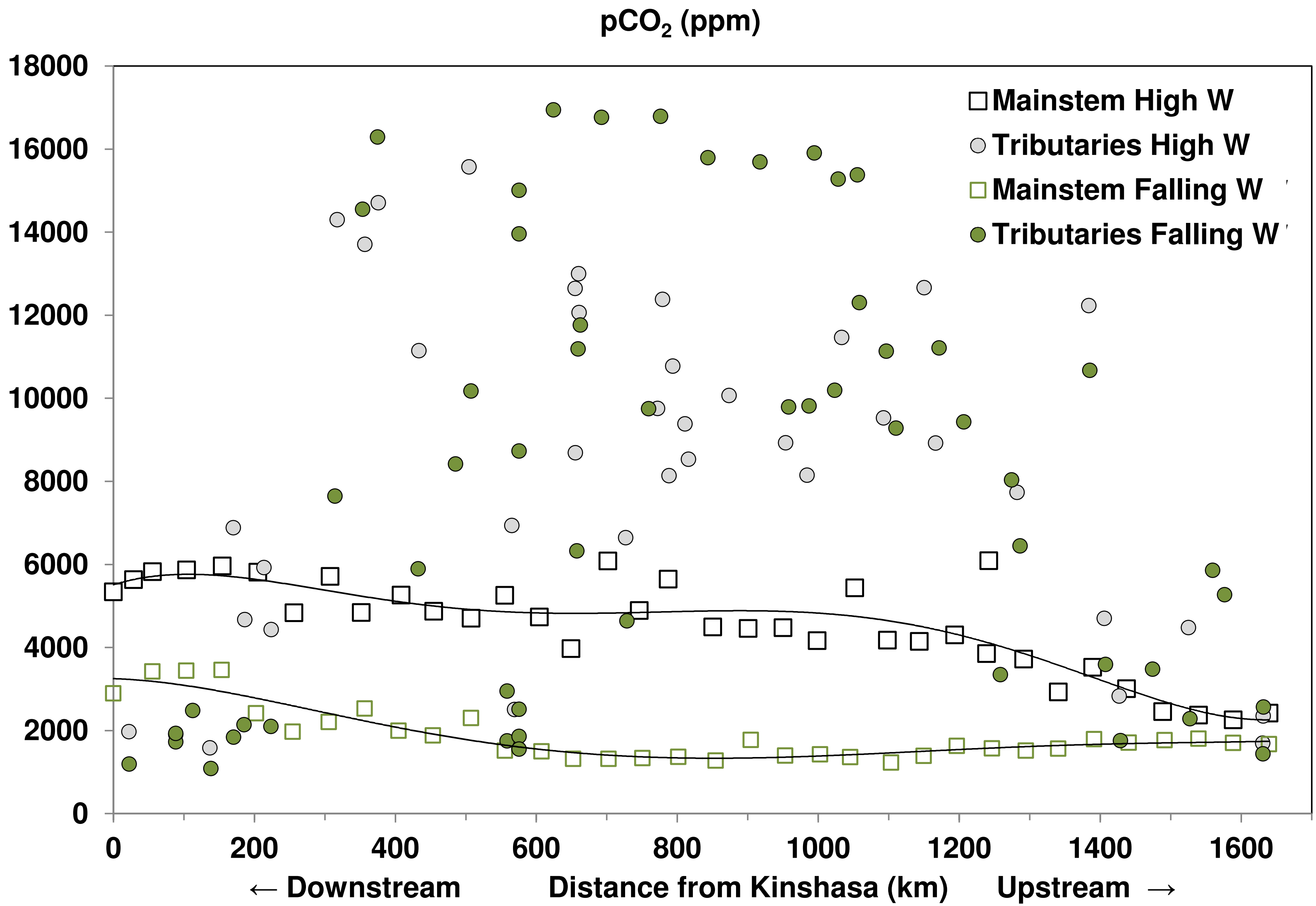
pCO2 (ppm)
High W (Dec. 2013)
Falling W (June 2014)
20000
15000
10000
5000
0
%O2 (%)
120
100
80
60
40
20
0
Cuvette Centrale (Wetland)
Black-water tributaries
15
16
17
18
19
20
21
22
23
24
25
← Dowstream
Longitude (°E)
Upstream →

Results

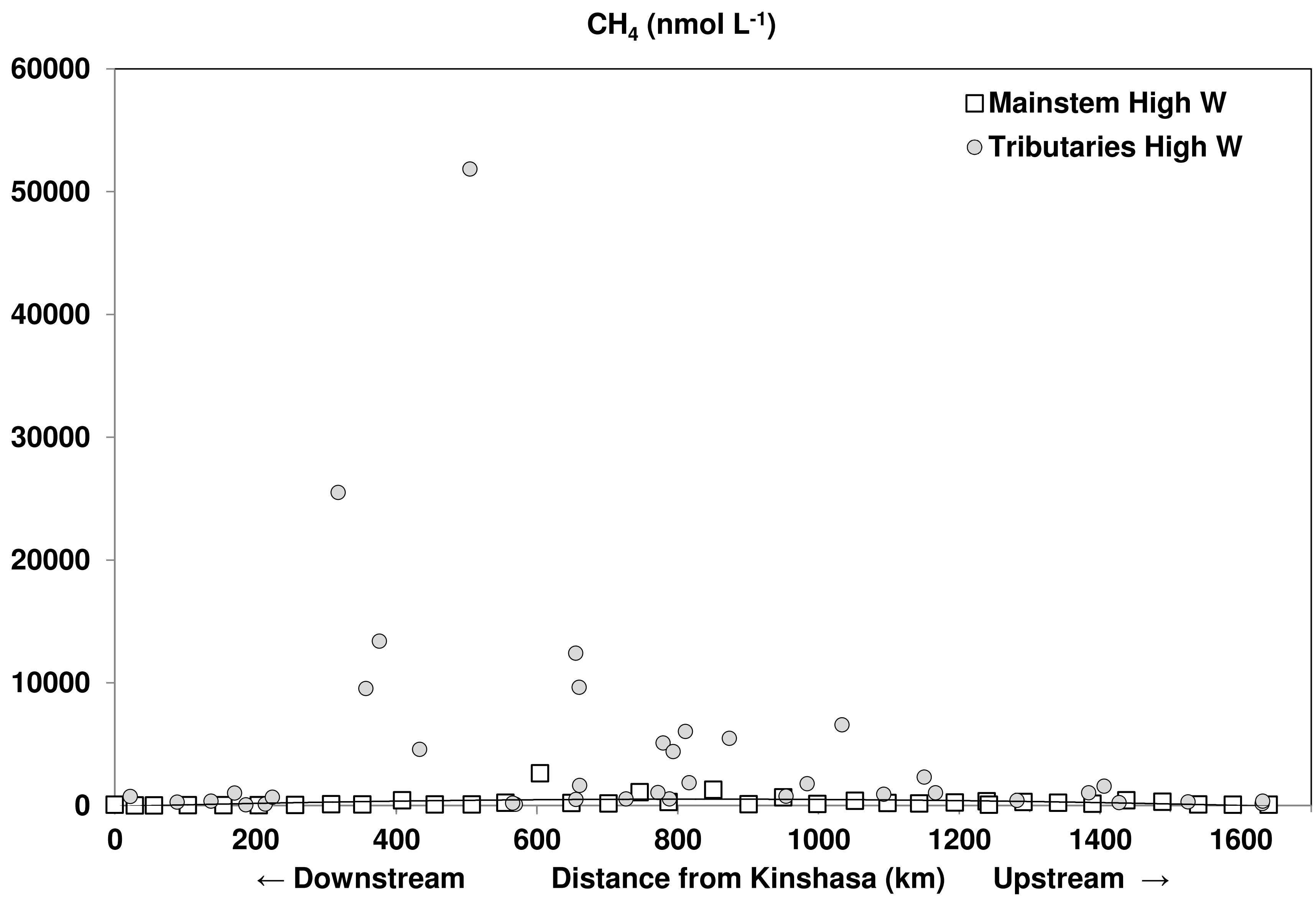


pCO2 (ppm)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
200
400
600
800
1000
1200
1400
1600
← Downstream
Distance from Kinshasa (km)
Upstream →
Mainstem High W
Tributaries High W
« Cuvette Centrale »
(Wetland)
Savannah

Results

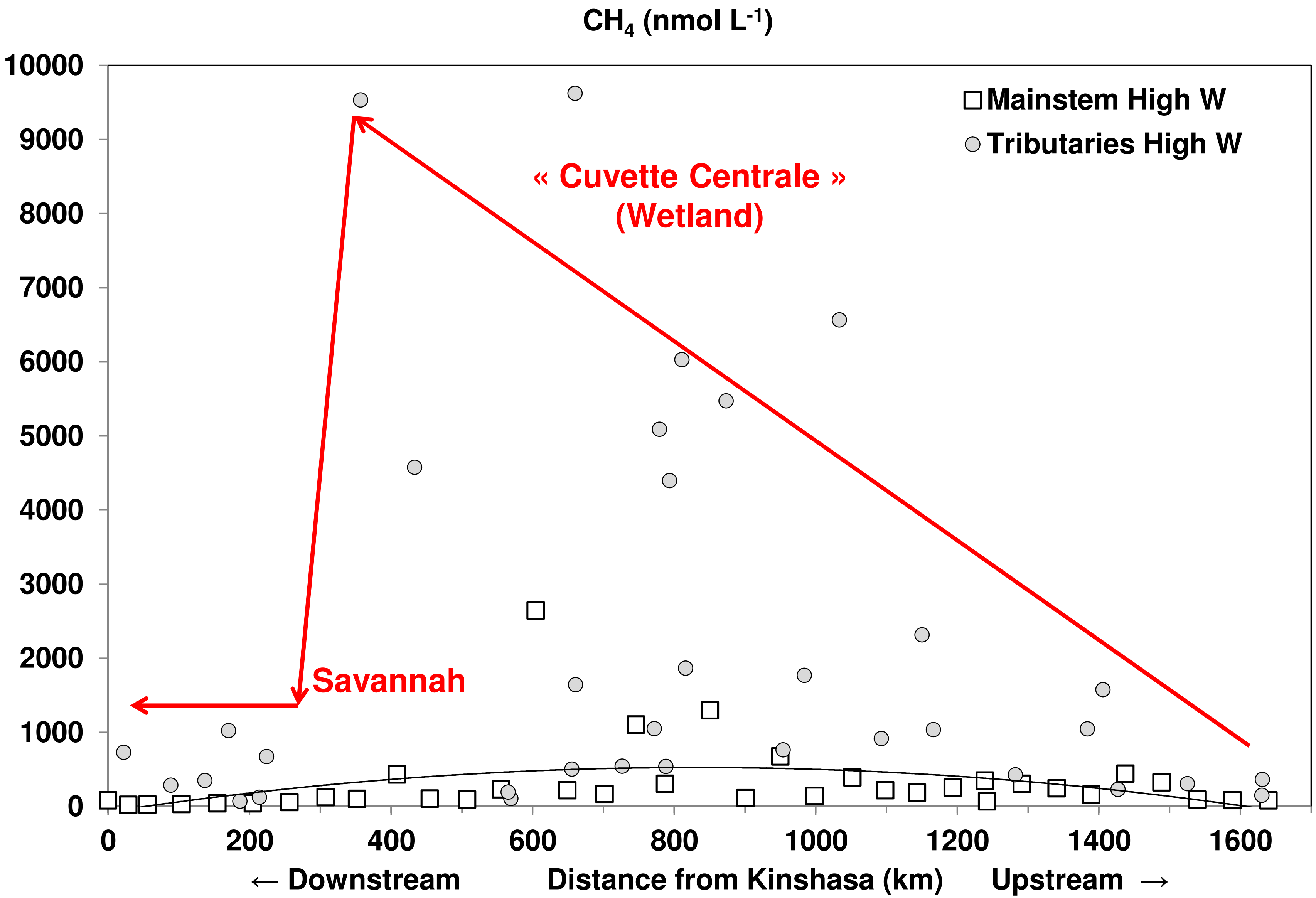

pCO$_2$ (ppm)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Mainstem High W
Tributaries High W
Mainstem Falling W
Tributaries Falling W
0
200
400
600
800
1000
1200
1400
1600
← Downstream
Distance from Kinshasa (km)
Upstream →

Results



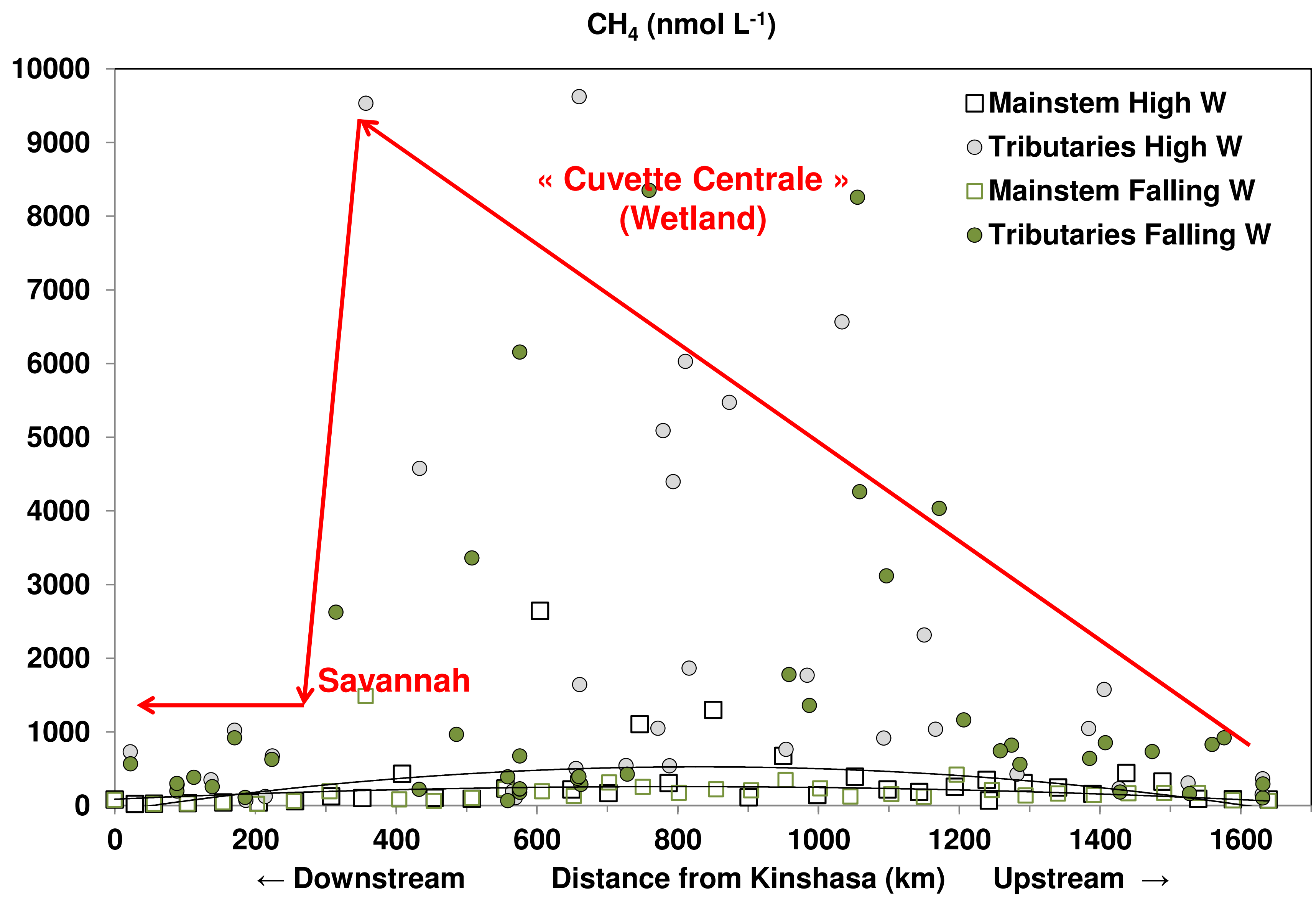
CH4 (nmol L-1)
60000
50000
40000
30000
20000
10000
0
Mainstem High W
Tributaries High W
0
200
400
600
800
1000
1200
1400
1600
← Downstream
Distance from Kinshasa (km)
Upstream →

Results



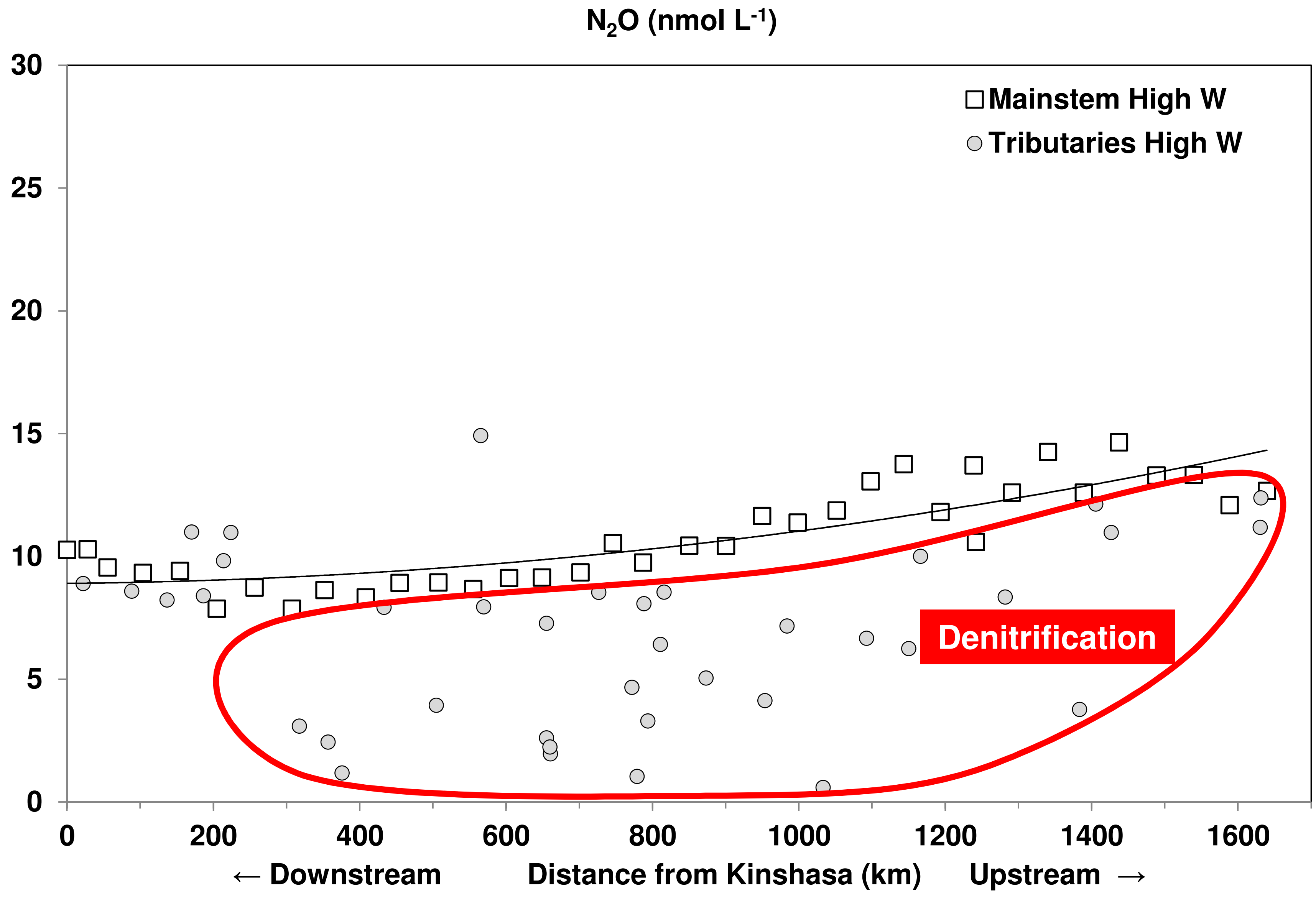
CH4 (nmol L-1)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
200
400
600
800
1000
1200
1400
1600
Mainstem High W
Tributaries High W
« Cuvette Centrale »
(Wetland)
Savannah
← Downstream
Distance from Kinshasa (km)
Upstream →

Results



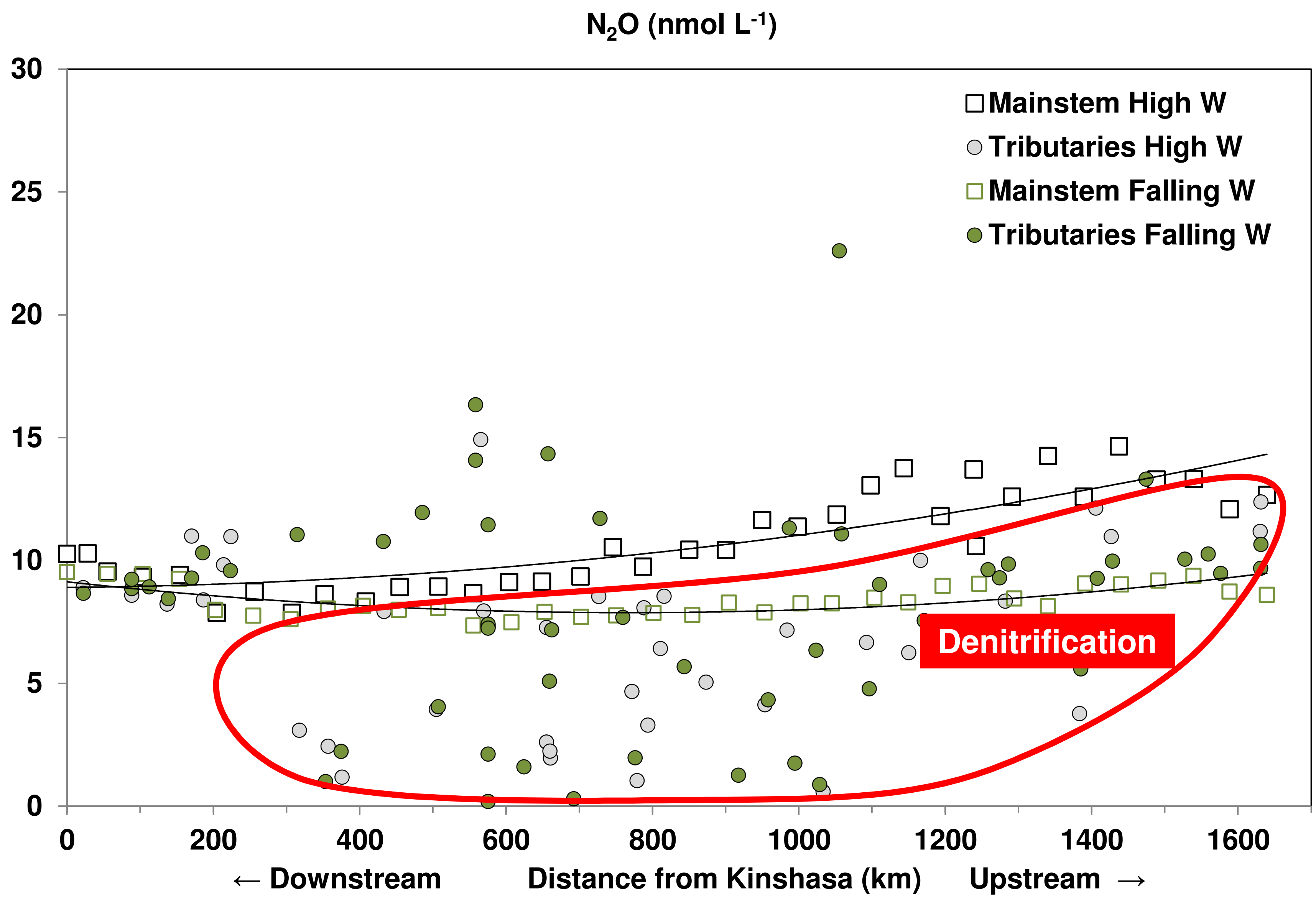
CH4 (nmol L-1)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
200
400
600
800
1000
1200
1400
1600
← Downstream
Distance from Kinshasa (km)
Upstream →
Mainstem High W
Tributaries High W
Mainstem Falling W
Tributaries Falling W
« Cuvette Centrale »
(Wetland)
Savannah

Results



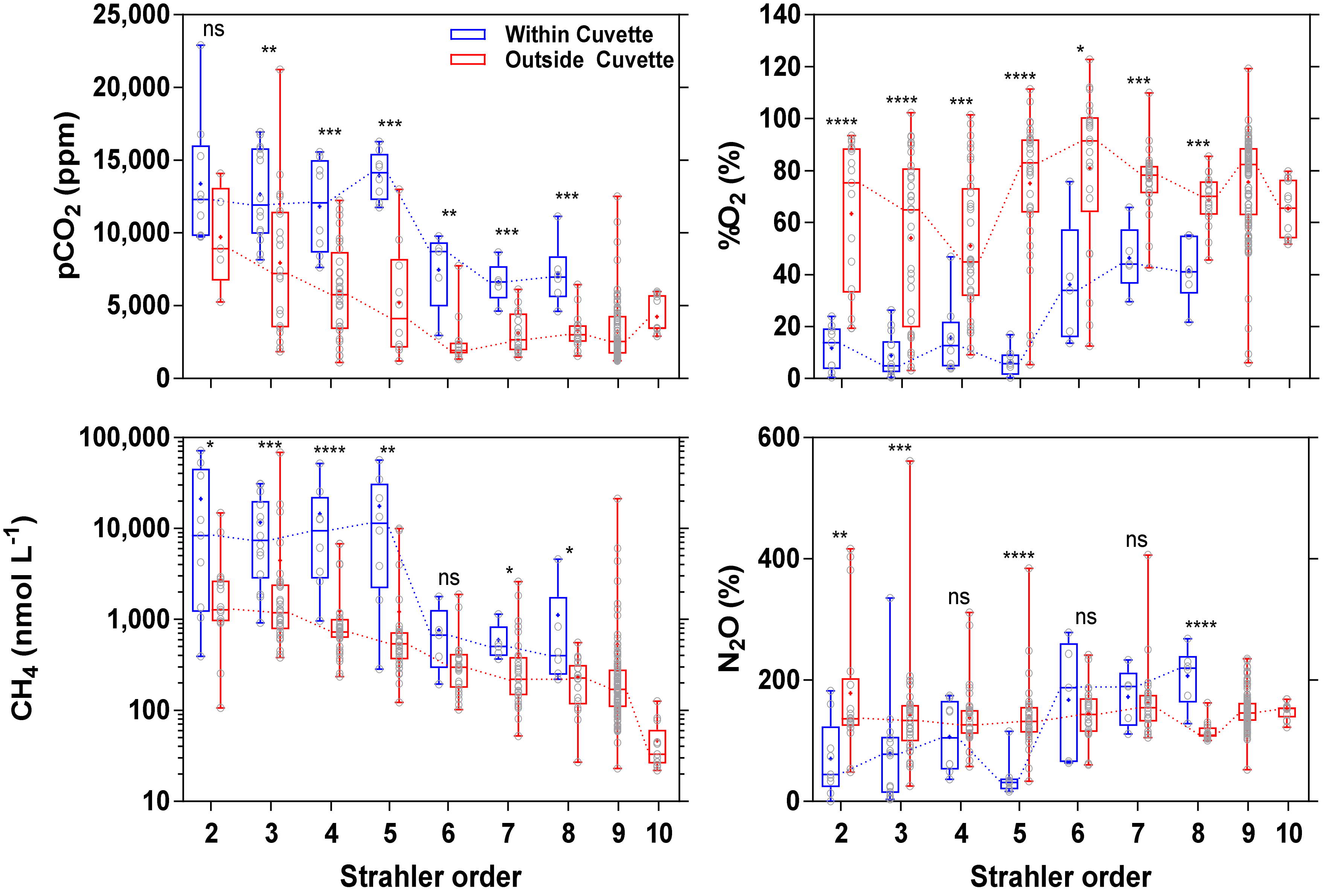
N2O (nmol L-1)
30
25
20
15
10
5
0
Mainstem High W
Tributaries High W
Denitrification
0
200
400
600
800
1000
1200
1400
1600
← Downstream
Distance from Kinshasa (km)
Upstream →

Results



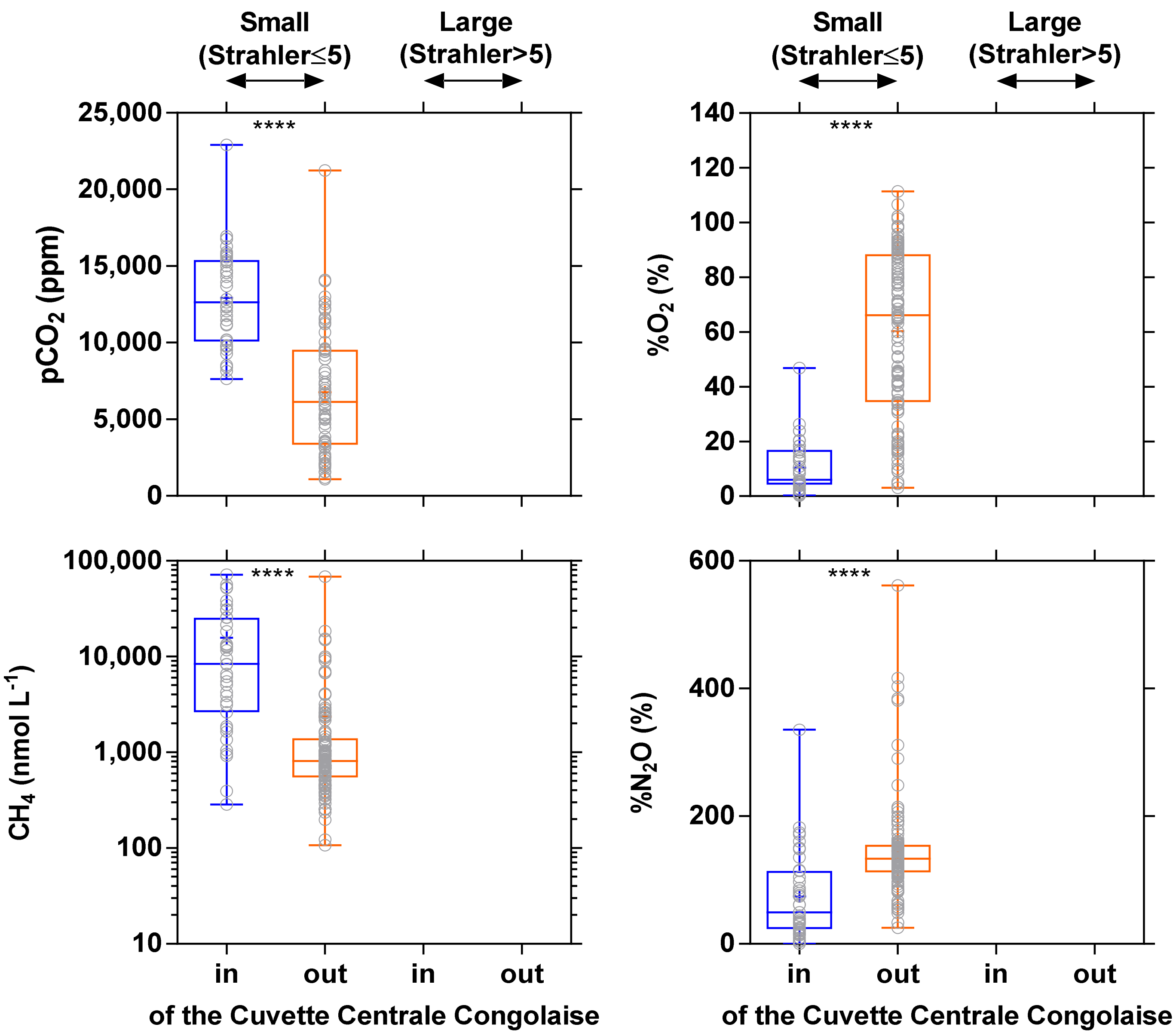
N$_2$O (nmol L^{-1})
30
25
20
15
10
5
0
Mainstem High W
Tributaries High W
Mainstem Falling W
Tributaries Falling W
Denitrification
0
200
400
600
800
1000
1200
1400
1600
← Downstream
Distance from Kinshasa (km)
Upstream →

Results



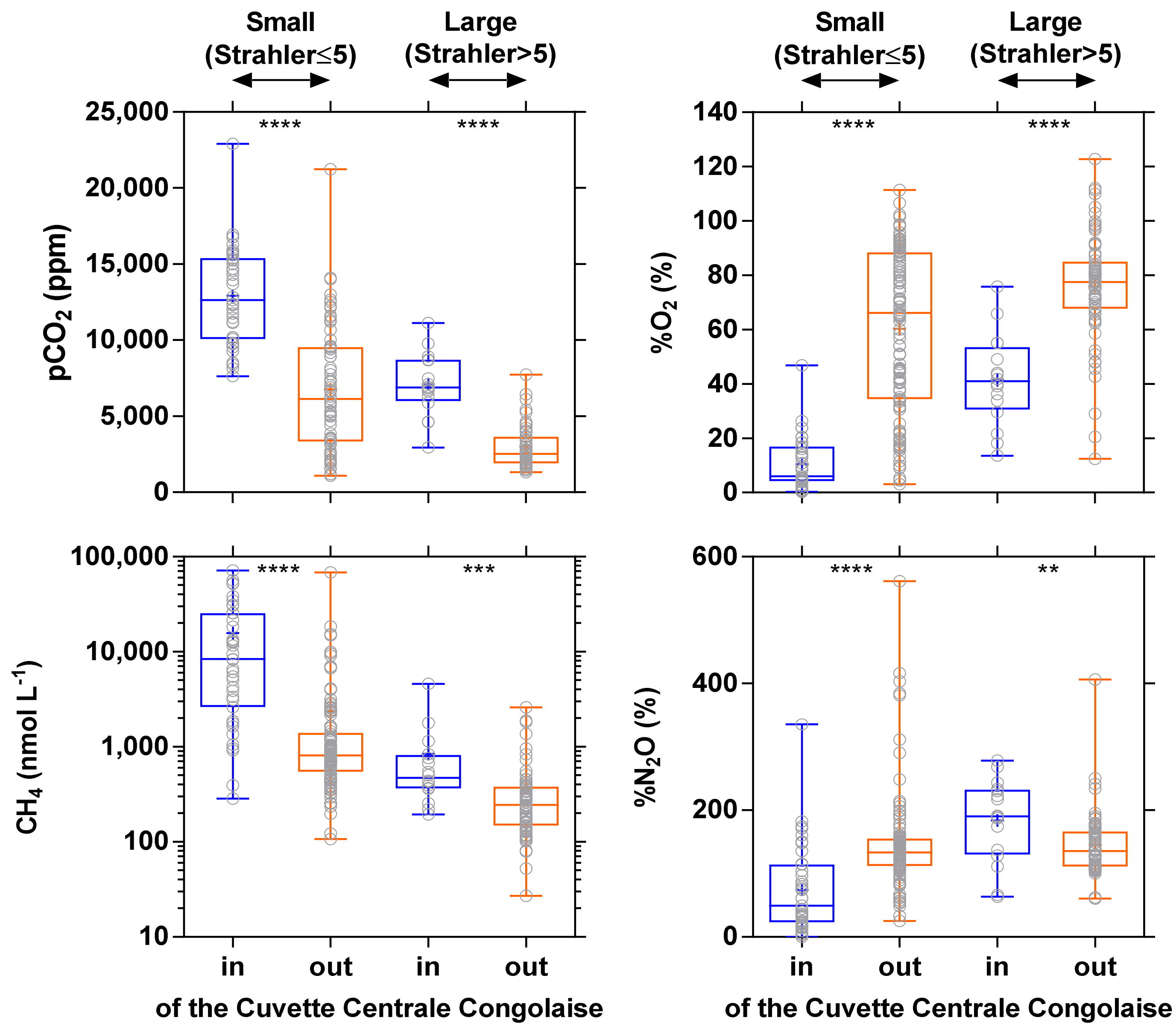
Within Cuvette
Outside Cuvette
pCO2 (ppm)
%O2 (%)
CH4 (nmol L-1)
N2O (%)
Strahler order
Strahler order

Results



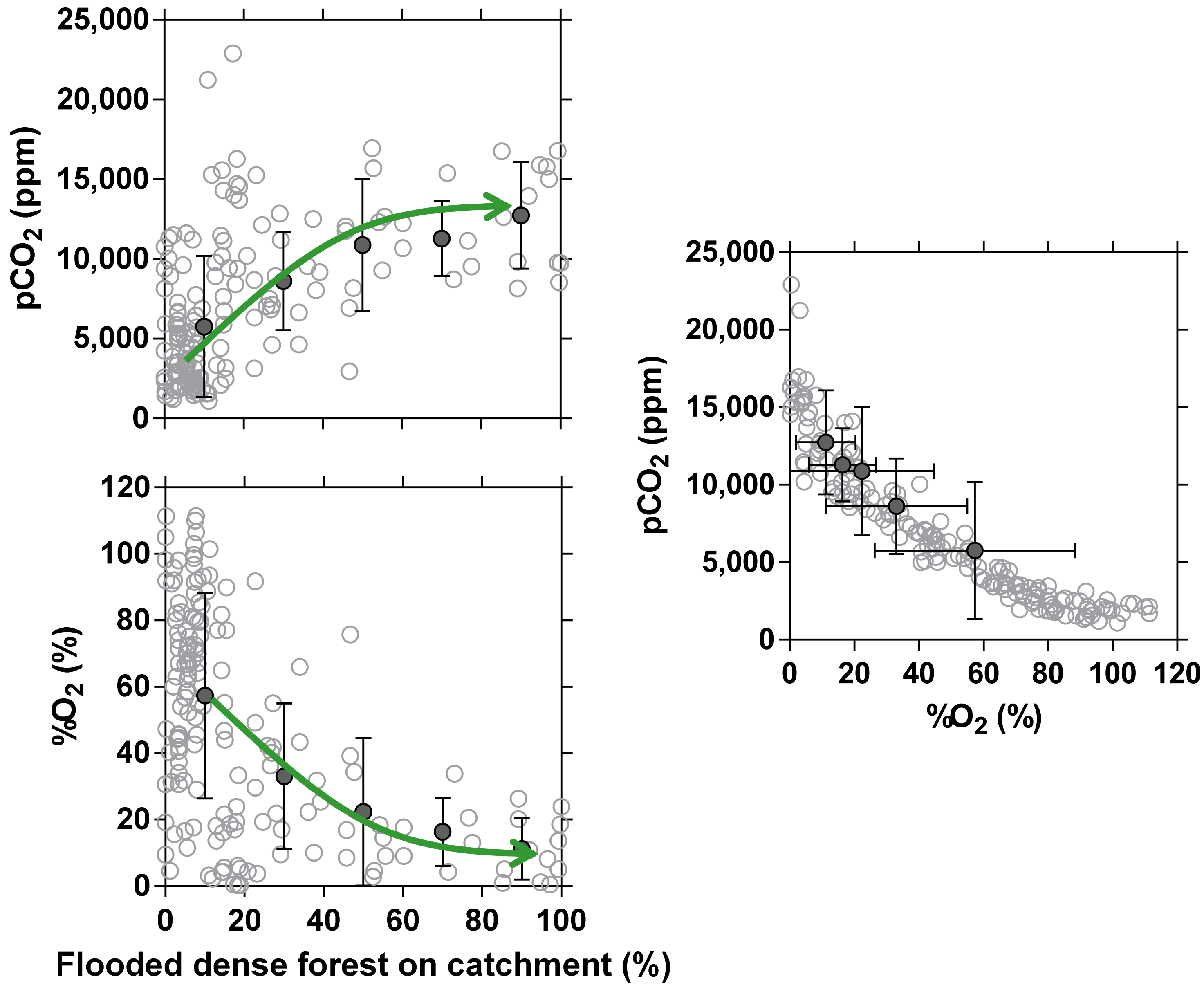
Small (Strahler≤5)
Large (Strahler>5)
25,000
20,000
15,000
10,000
5,000
0
pCO2 (ppm)
****
140
120
100
80
60
40
20
0
%O2 (%)
****
100,000
10,000
1,000
100
10
CH4 (nmol L-1)
****
600
400
200
0
%N2O (%)
****
in
out
in
out
of the Cuvette Centrale Congolaise

Results



Small (Strahler≤5)
Large (Strahler>5)
pCO2 (ppm)
25,000
20,000
15,000
10,000
5,000
0
****
****
%O2 (%)
140
120
100
80
60
40
20
0
****
****
CH4 (nmol L-1)
100,000
10,000
1,000
100
10
****
***
%N2O (%)
600
400
200
0
****
**
in
out
in
out
of the Cuvette Centrale Congolaise

Results



pCO2 (ppm)
25,000
20,000
15,000
10,000
5,000
0
%O2 (%)
120
100
80
60
40
20
0
0
20
40
60
80
100
Flooded dense forest on catchment (%)
pCO2 (ppm)
25,000
20,000
15,000
10,000
5,000
0
0
20
40
60
80
100
120
%O2 (%)

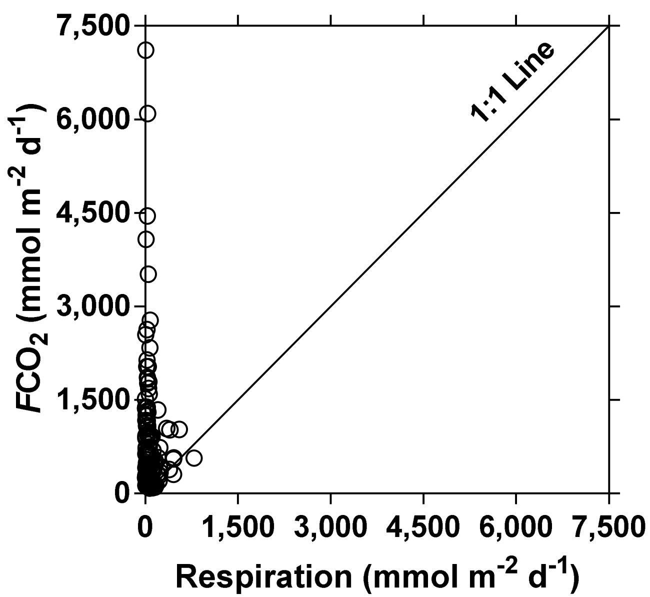
Results

Freshwater Biology

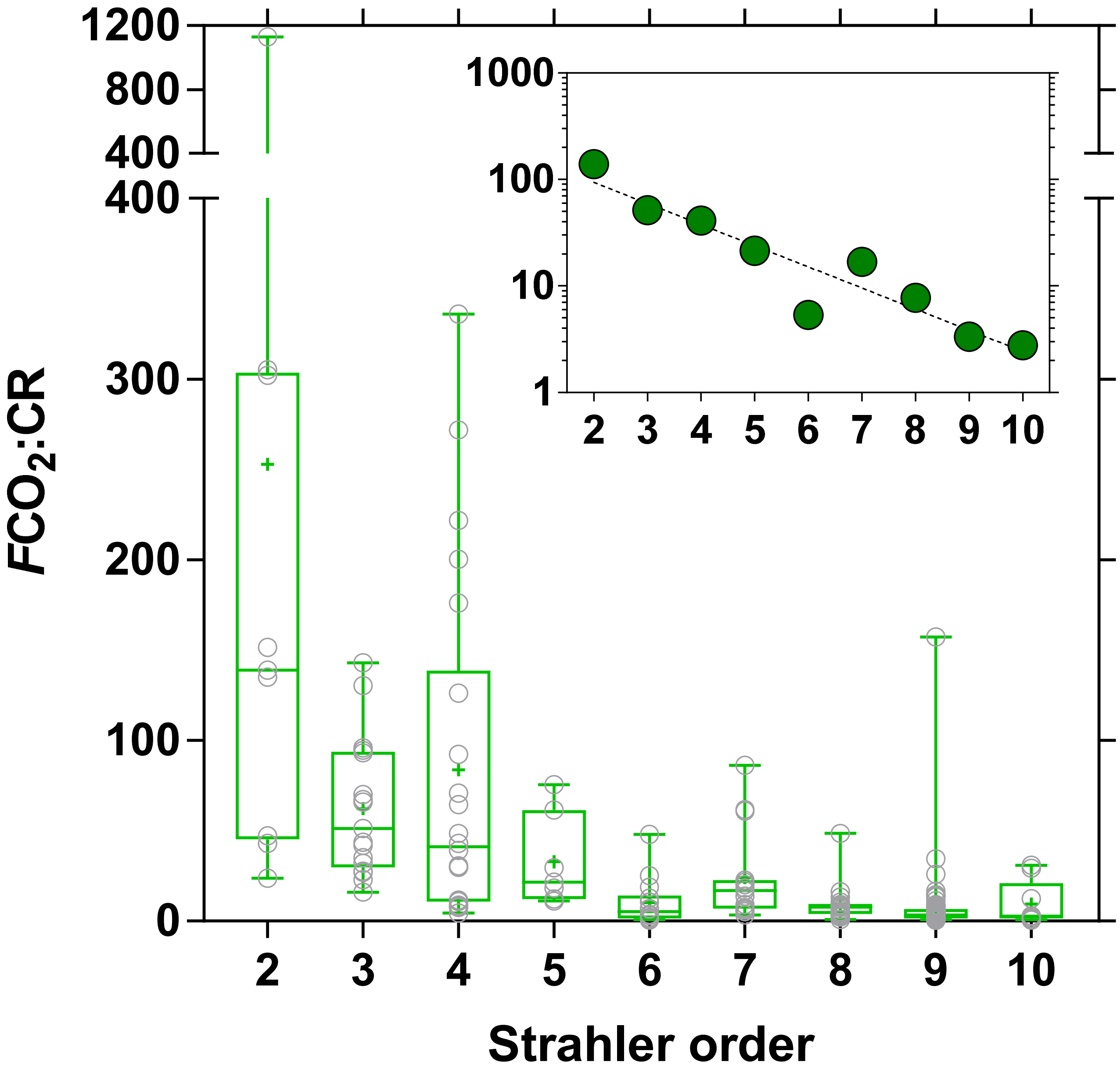
Freshwater Biology (2017) **62**, 87–101 doi:10.1111/fwb.12851

Phytoplankton dynamics in the Congo River

JEAN-PIERRE DESCY*,†, FRANÇOIS DARCHAMBEAU†, THIBAULT LAMBERT†,
MAYA P. STOYNEVA-GAERTNER‡, STEVEN BOUILLON§ AND ALBERTO V. BORGES†

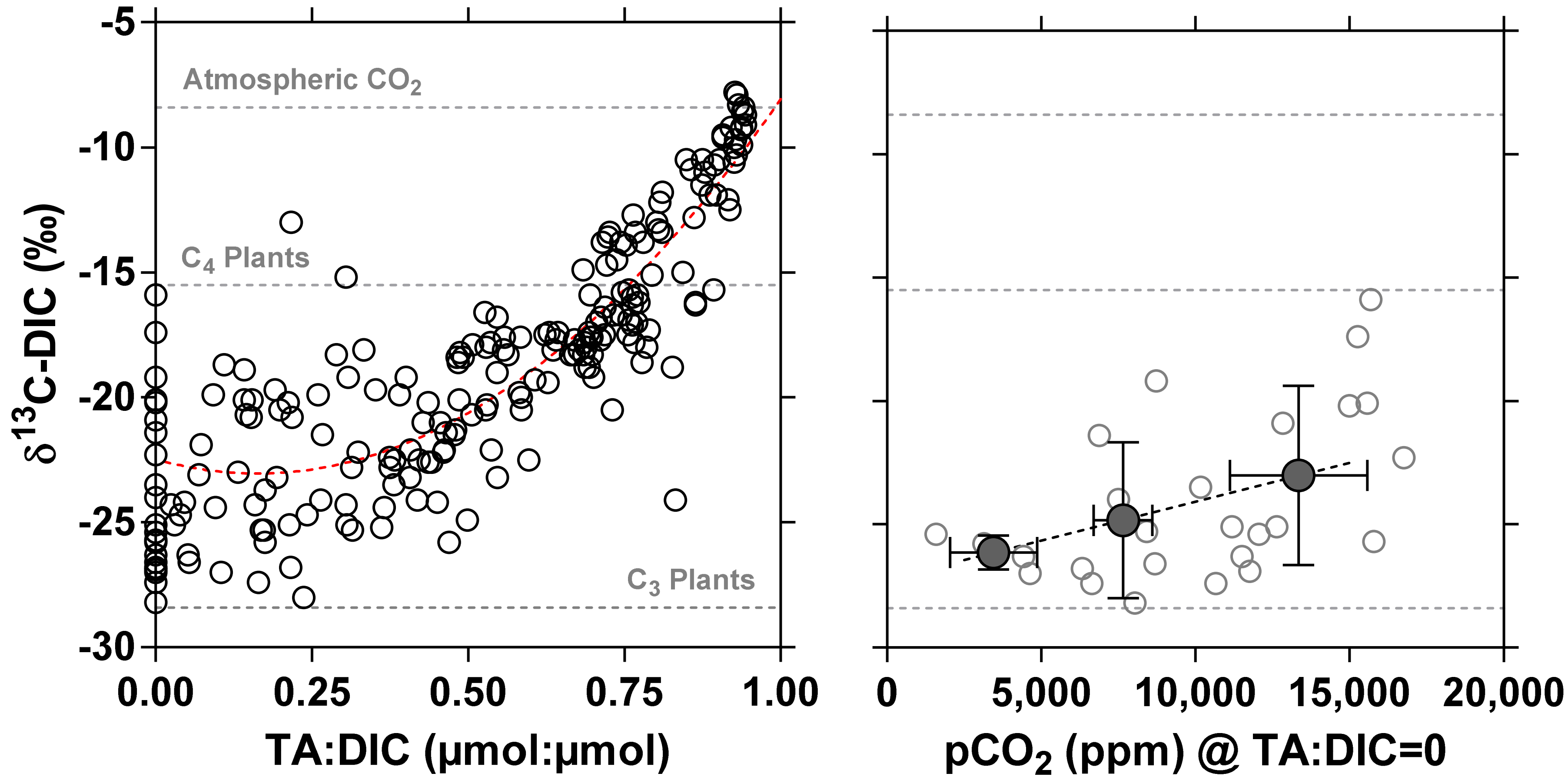


Results



1200
800
400
400
300
200
100
0
FCO2:CR
2
3
4
5
6
7
8
9
10
Strahler order
1000
100
10
1
2
3
4
5
6
7
8
9
10

Results



-5
-10
-15
-20
-25
-30
Atmospheric CO2
C4 Plants
C3 Plants
δ13C-DIC (‰)
0.00
0.25
0.50
0.75
1.00
TA:DIC (µmol:µmol)
0
5,000
10,000
15,000
20,000
pCO2 (ppm) @ TA:DIC=0

Results

CO_2 emission from Congo rivers-streams

$FCO_2 = k\ H\ \Delta pCO_2$

FCO_2 air-water CO_2 flux
H Henry's constant = f(temperature)
ΔpCO_2 = air-water gradient of pCO_2 (measured)
k = gas transfer velocity

k = f (flow velocity; slope)

Limnology and Oceanography
FLUIDS & ENVIRONMENTS

ORIGINAL ARTICLE

Scaling the gas transfer velocity and hydraulic geometry in streams and small rivers

Peter A. Raymond,[1] Christopher J. Zappa,[2] David Butman,[1] Thomas L. Bott,[3] Jody Potter,[4] Patrick Mulholland,[5] Andrew E. Laursen,[6] William H. McDowell,[4] and Denis Newbold[3]

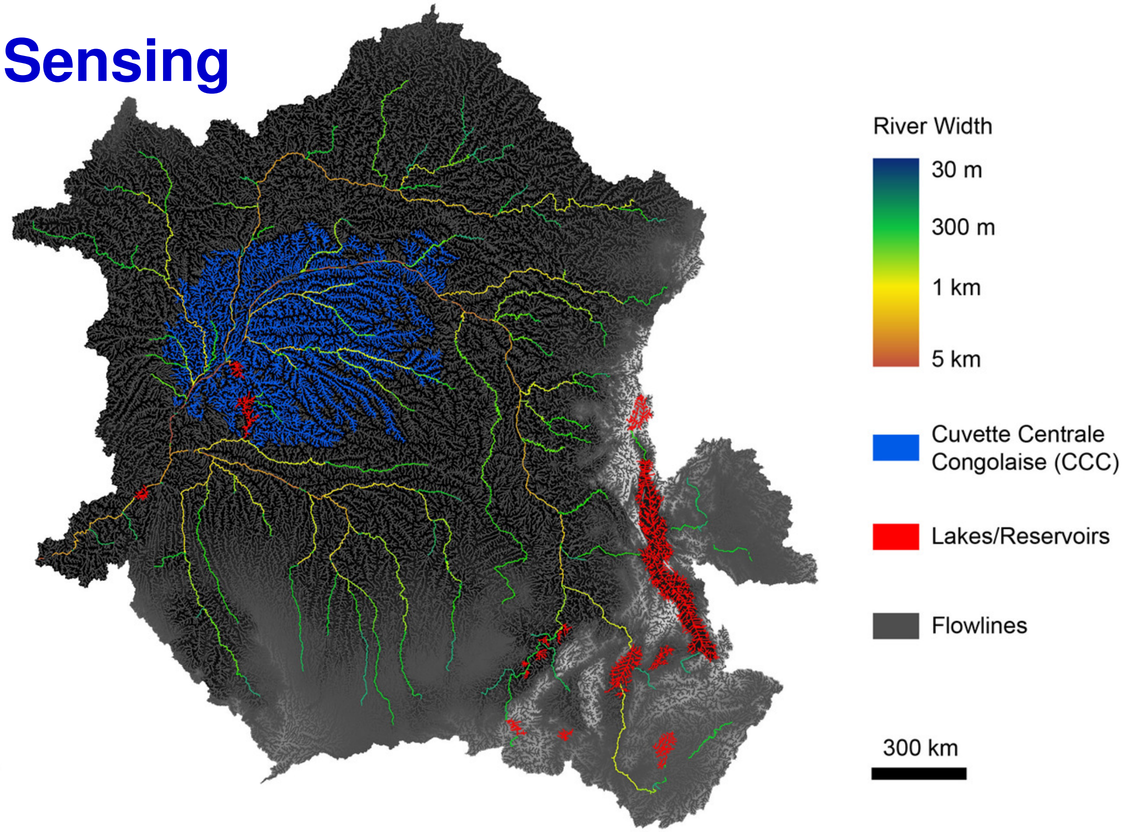
Results

CO_2 emission from Congo rivers-streams

Stream surface area = length x width

length = Hydrosheds

width = Remote Sensing



Science

Global extent of rivers and streams

George H. Allen*† and Tamlin M. Pavelsky

Results

CO_2 emission from Congo rivers-streams
= 251 TgC yr^{-1}

Net ecosystem exchange (NEE) Congo forests + savannahs
= 77 TgC yr^{-1}

???

Export of C from soils to rivers
= 2-3% of NEE
for *terra firme* forests

??????

Global Change Biology

Global Change Biology (2011) **17**, 1167–1185, doi: 10.1111/j.1365-2486.2010.02282.x

Dissolved carbon leaching from soil is a crucial component of the net ecosystem carbon balance

REIMO KINDLER*‡[1,2], JAN SIEMENS*§[2,3], KLAUS KAISER†, DAVID C. WALMSLEY‡
CHRISTIAN BERNHOFER§, NINA BUCHMANN¶, PIERRE CELLIER||,
WERNER EUGSTER¶, GERD GLEIXNER**, THOMAS GRŨNWALD§,
ALEXANDER HEIM††, ANDREAS IBROM‡‡, STEPHANIE K. JONES§§, MIKE JONES¶¶,
KATJA KLUMPP|||, WERNER KUTSCH***, KLAUS STEENBERG LARSEN‡‡,
SIMON LEHUGER||, BENJAMIN LOUBET||, REBECCA MCKENZIE†††, EDDY MOORS‡‡‡,
BRUCE OSBORNE‡, KIM PILEGAARD‡‡, CORINNA REBMANN§§§,
MATTHEW SAUNDERS‡, MICHAEL W. I. SCHMIDT††, MARION SCHRUMPF**,
JANINE SEYFFERTH**, UTE SKIBA§§, JEAN-FRANCOIS SOUSSANA|||,
MARK A. SUTTON§§, CINDY TEFS**, BERNHARD VOWINCKEL§,
MATTHIAS J. ZEEMAN¶ and MARTIN KAUPENJOHANN*

Results

CO_2 emission from Congo rivers-streams
= 251 TgC yr^{-1}

Mostly sustained by C leaked from wetlands ?

Export C from flooded forest in Amazon (Abril et al.)

+

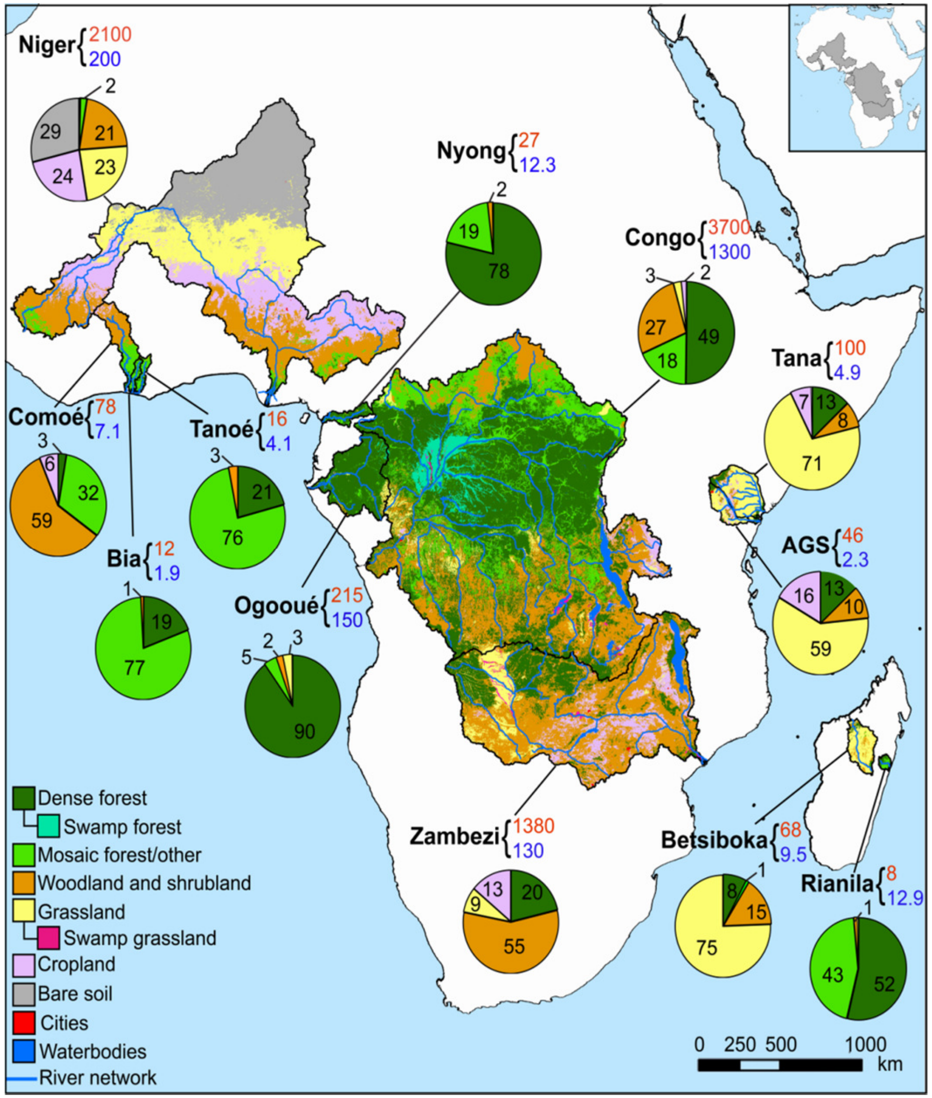
Surface of flooded forest in Congo

= 400 TgC yr^{-1}

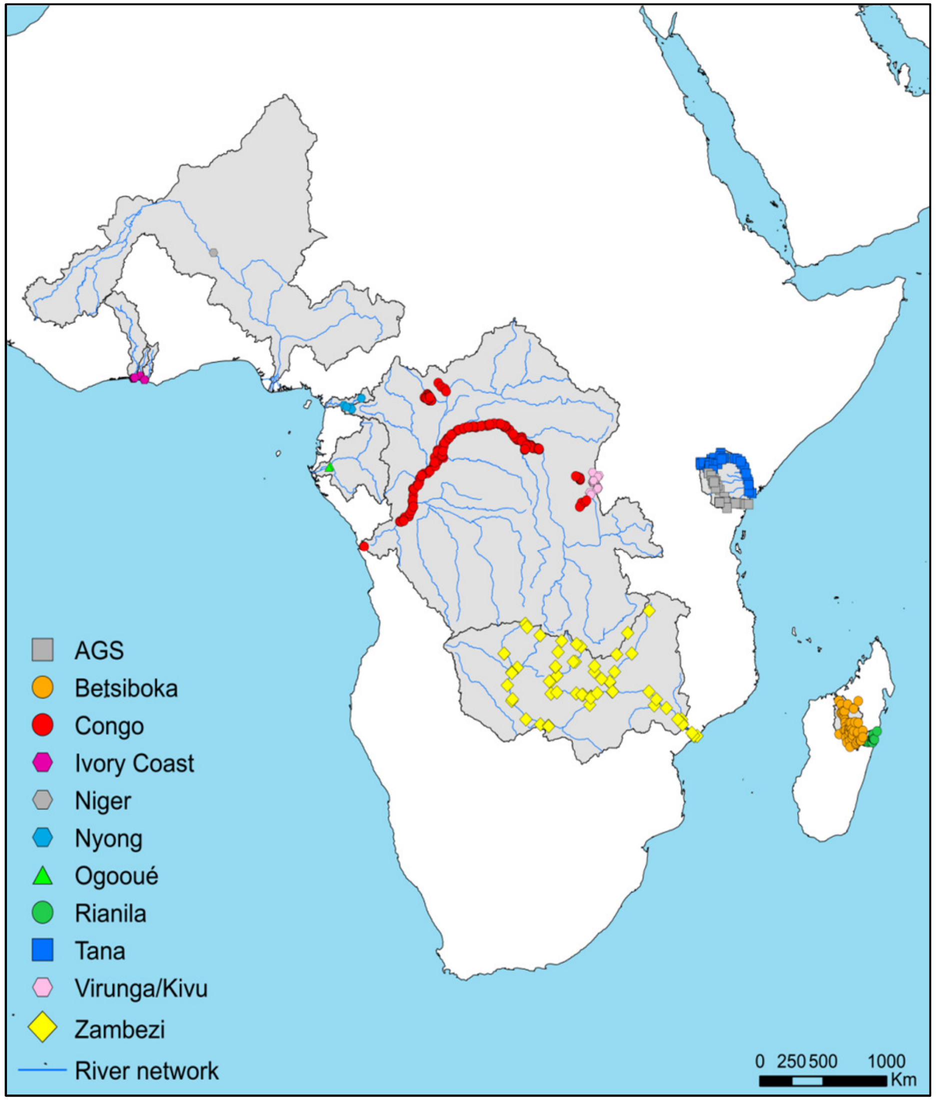
Results

Congo & other African rivers

Results

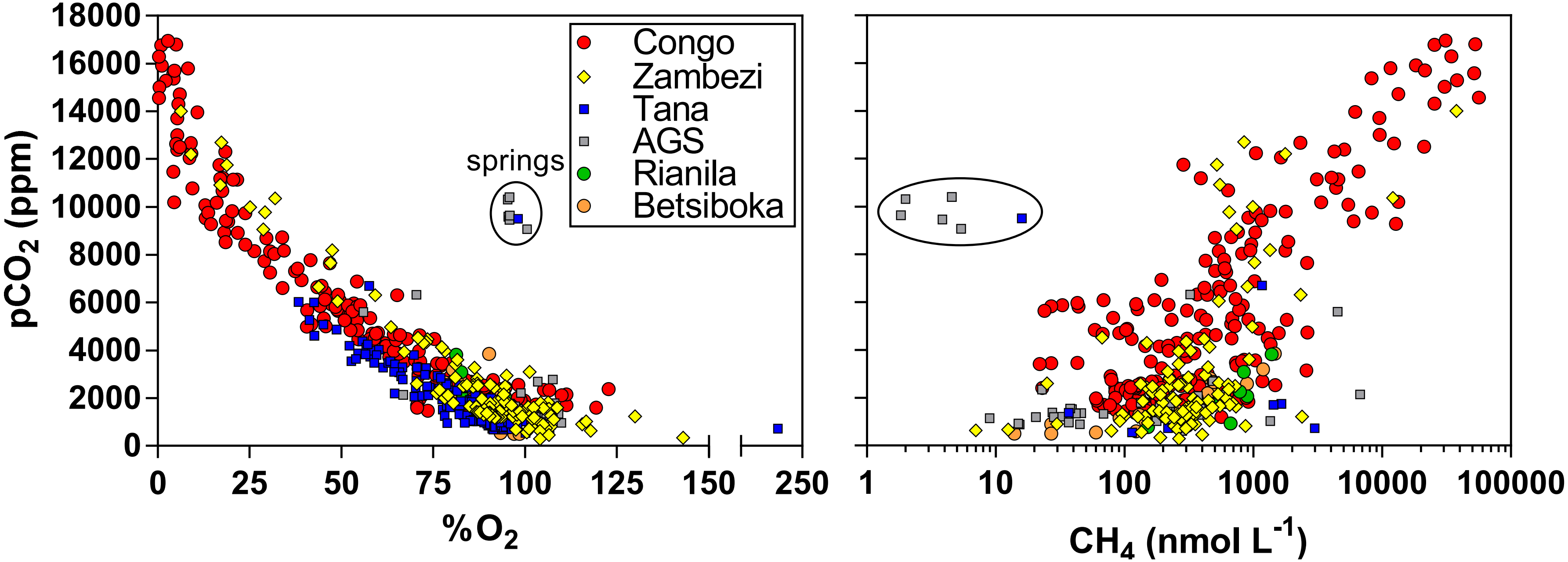


Niger{2100 200
2
29
21
24
23
Nyong{27 12.3
2
19
78
Congo{3700 1300
3
2
27
49
18
Tana{100 4.9
7
13
8
71
Comoé{78 7.1
3
6
32
59
Tanoé{16 4.1
3
21
76
Bia{12 1.9
1
19
77
Ogooué{215 150
5
2
3
90
AGS{46 2.3
16
13
10
59
Dense forest
Swamp forest
Mosaic forest/other
Woodland and shrubland
Grassland
Swamp grassland
Cropland
Bare soil
Cities
Waterbodies
River network
Zambezi{1380 130
13
20
9
55
Betsiboka{68 9.5
1
8
15
75
Rianila{8 12.9
1
43
52
0 250 500 1000
km



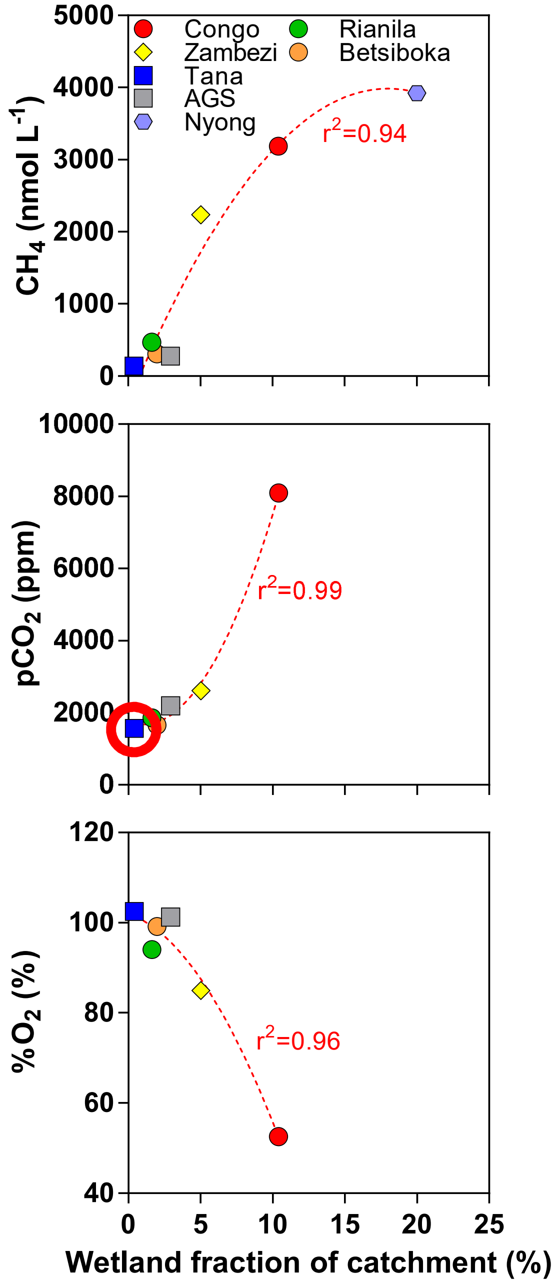
AGS
Betsiboka
Congo
Ivory Coast
Niger
Nyong
Ogooué
Rianila
Tana
Virunga/Kivu
Zambezi
River network
0 250 500 1000
Km

Results



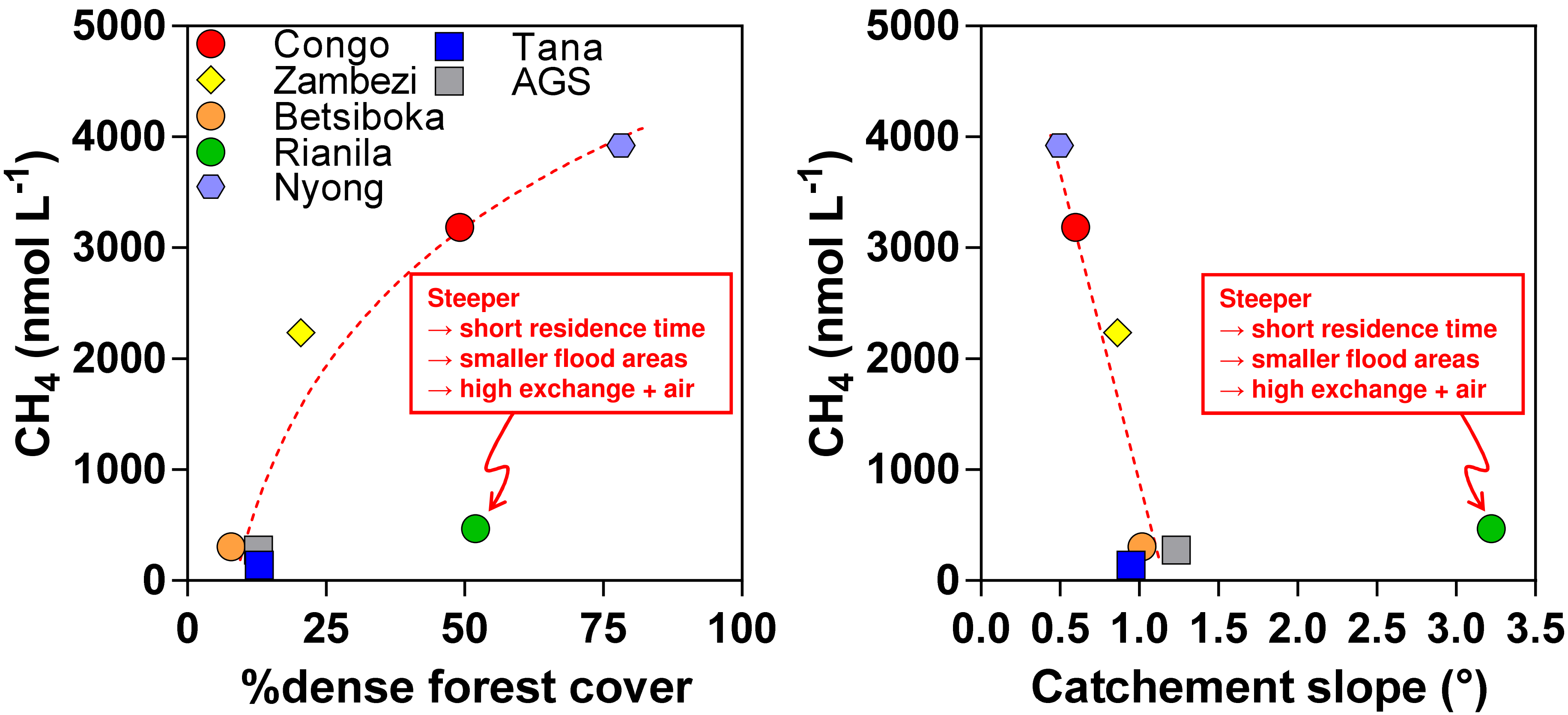
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
pCO2 (ppm)
0
25
50
75
100
125
150
250
%O2
springs
Congo
Zambezi
Tana
AGS
Rianila
Betsiboka
1
10
100
1000
10000
100000
CH4 (nmol L-1)

Results



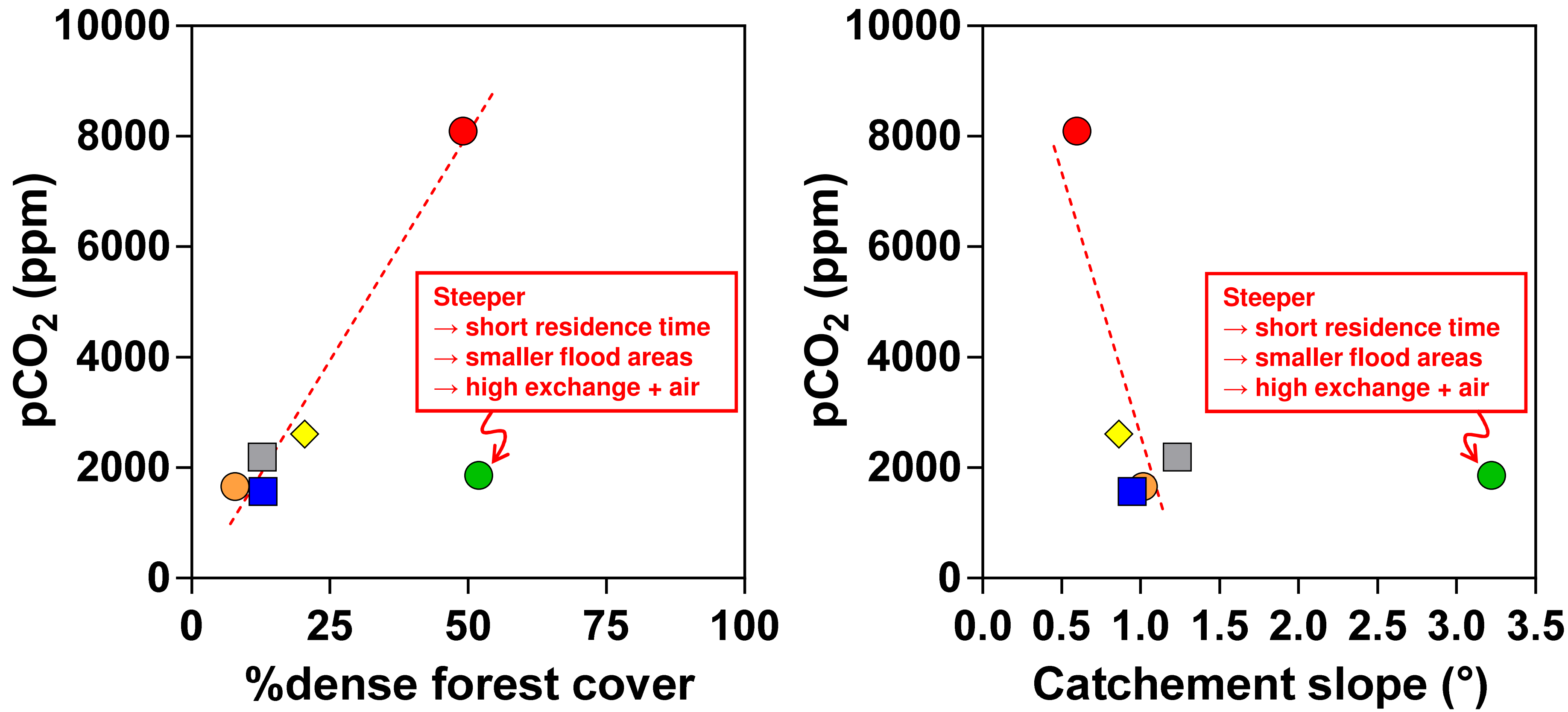
Congo
Zambezi
Tana
AGS
Nyong
Rianila
Betsiboka
CH4 (nmol L-1)
5000
4000
3000
2000
1000
0
r2=0.94
pCO2 (ppm)
10000
8000
6000
4000
2000
0
r2=0.99
%O2 (%)
120
100
80
60
40
r2=0.96
0
5
10
15
20
25
Wetland fraction of catchment (%)

Results



CH$_4$ (nmol L^{-1})
5000
4000
3000
2000
1000
0
Congo
Zambezi
Betsiboka
Rianila
Nyong
Tana
AGS
Steeper
→ short residence time
→ smaller flood areas
→ high exchange + air
0
25
50
75
100
%dense forest cover
CH$_4$ (nmol L^{-1})
5000
4000
3000
2000
1000
0
Steeper
→ short residence time
→ smaller flood areas
→ high exchange + air
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Catchement slope (°)

Results



10000
8000
6000
4000
2000
0
pCO2 (ppm)
0
25
50
75
100
%dense forest cover
Steeper
→ short residence time
→ smaller flood areas
→ high exchange + air
10000
8000
6000
4000
2000
0
pCO2 (ppm)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Catchement slope (°)
Steeper
→ short residence time
→ smaller flood areas
→ high exchange + air

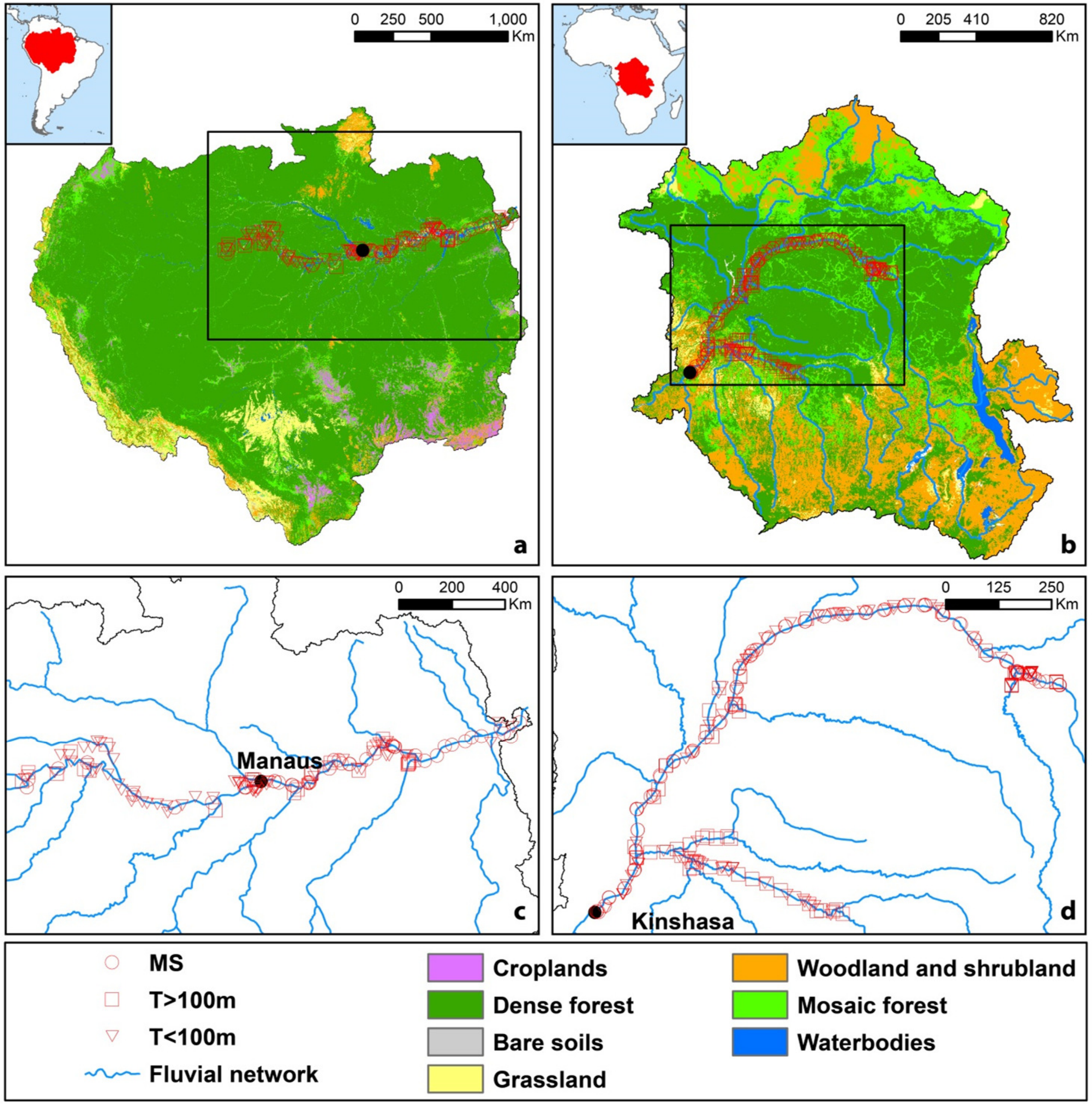
Results

Congo versus Amazon

Results

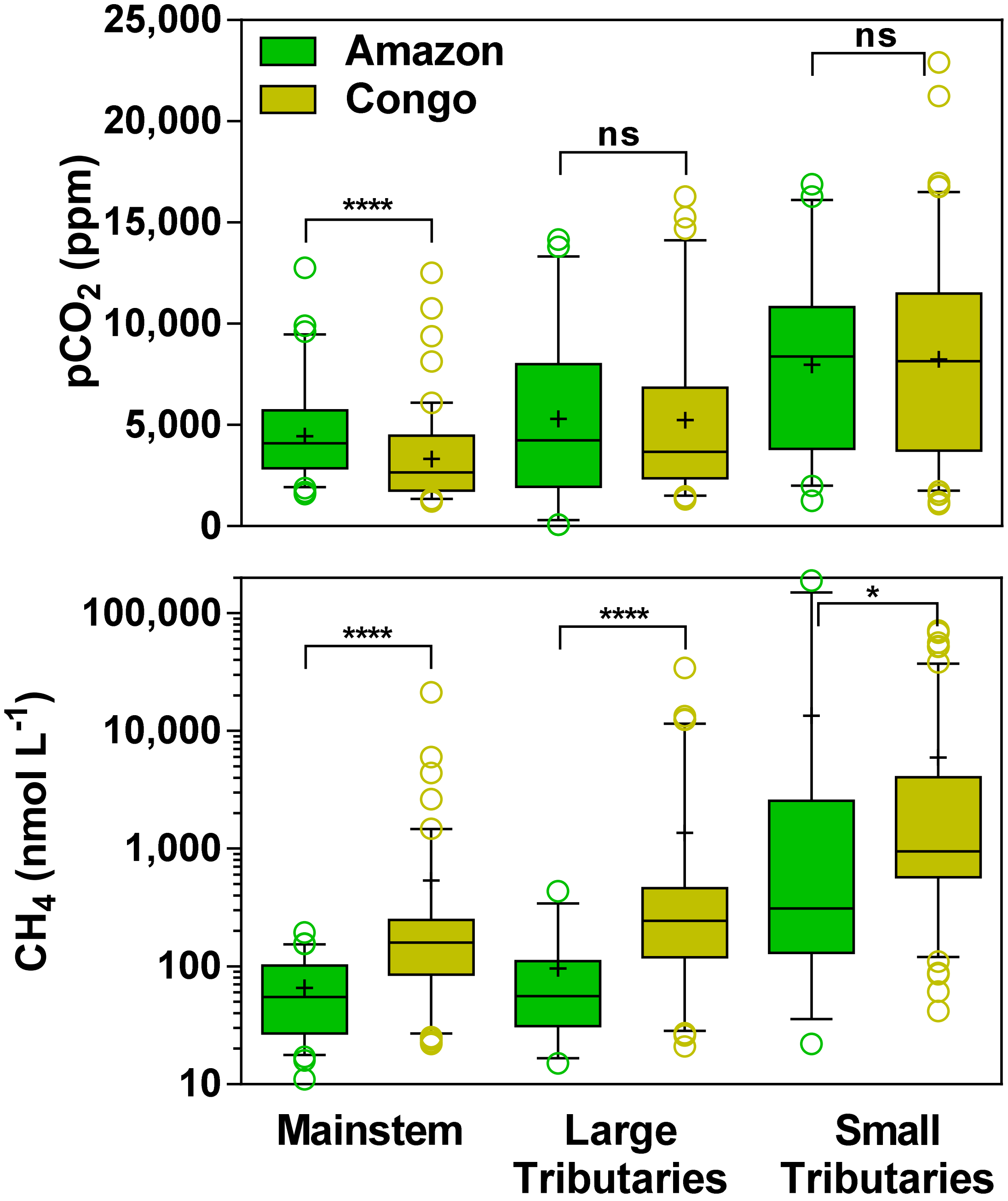
	Amazon		Congo
Catchment area (km^2)	6,025,735	>	3,705,222
Slope (°)	1.4		0.6
Discharge ($km^3\ yr^{-1}$)	5,444		1,270
Specific discharge ($L\ s^{-1}\ km^{-2}$)	29	>	11
Precipitation (mm)	2,147	>	1,527
Air temperature (°C)	24.6		23.7
River-stream surface area (km^2)	74,904		26,517
Wetland surface area (%)	14		10
Above ground biomass ($Mg\ km^{-2}$)	909	>	748
Land cover			
Dense Forest (%)	83	>	49
Mosaic Forest (%)	4		18
Woodland and shrubland (%)	4	<	27
Grassland (%)	5		3
Cropland/Bare soil (%)	4		2

Results



0 250 500 1,000 Km
a
0 205 410 820 Km
b
0 200 400 Km
Manaus
c
0 125 250 Km
Kinshasa
d
MS
T>100m
T<100m
Fluvial network
Croplands
Dense forest
Bare soils
Grassland
Woodland and shrubland
Mosaic forest
Waterbodies

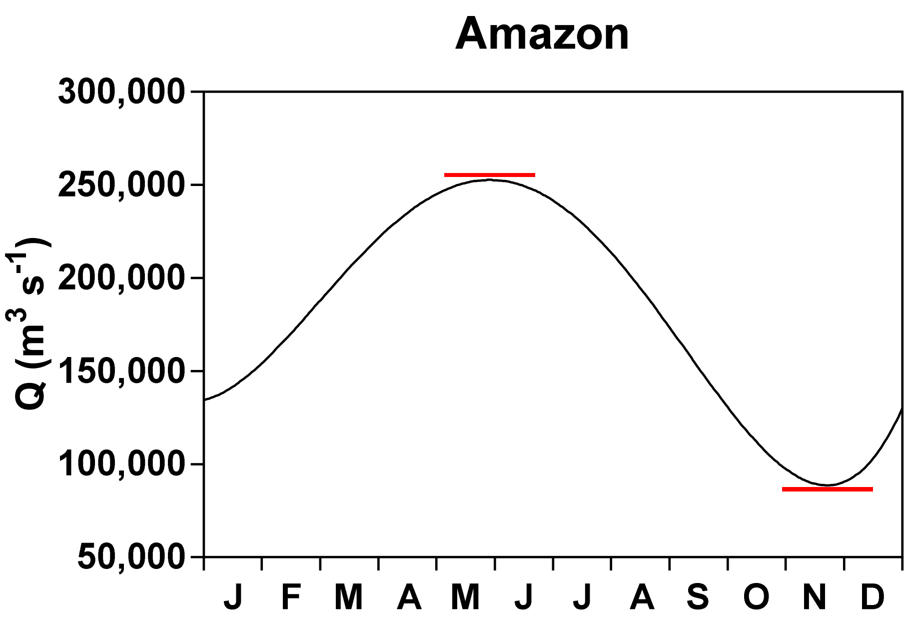
Results

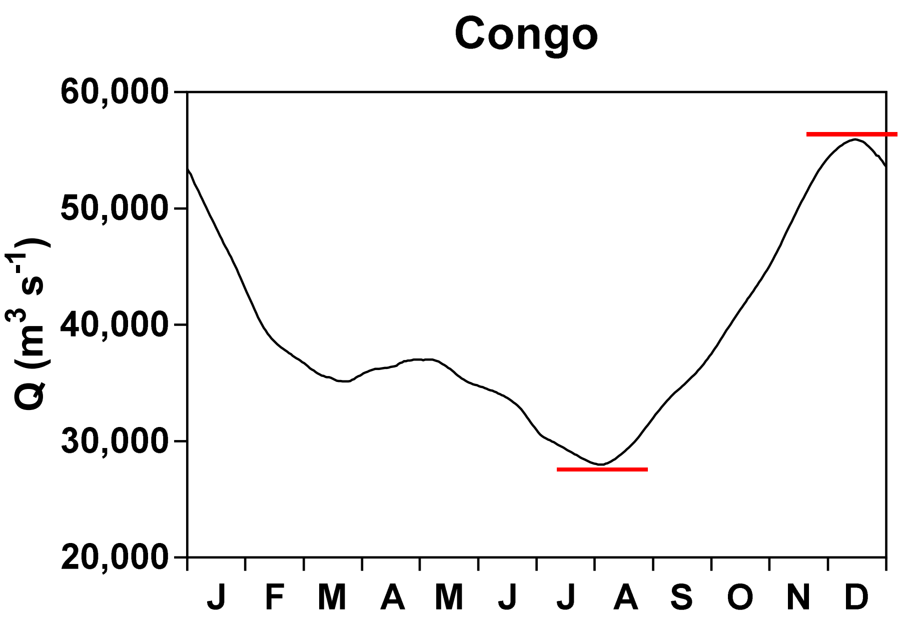


pCO_2 is ± similar

CH_4 is 3-4 times higher in Congo

Results





$Q_{max}:Q_{min} = 2.85$

$H_{max} - H_{min} = 10\text{-}12$ m

$Q_{max}:Q_{min} = 1.99$

$H_{max} - H_{min} = 3\text{-}4$ m

Results

Amazon	Congo
Flooded land = 80 % flooded forest Numerous permanent & temporary lakes	Flooded land = 100 % flooded forest Only a few large permanent lakes

Results

Amazon	Congo
Flooded land = 80 % flooded forest Numerous permanent & temporary lakes	Flooded land = 100 % flooded forest Only a few large permanent lakes
Seasonally inundated wetlands	Permanently inundated flooded forest

Results

Amazon	Congo
Flooded land = 80 % flooded forest Numerous permanent & temporary lakes	Flooded land = 100 % flooded forest Only a few large permanent lakes
Seasonally inundated wetlands	Permanently inundated flooded forest
Flooding from river overflow	Wetland water from upland runoff

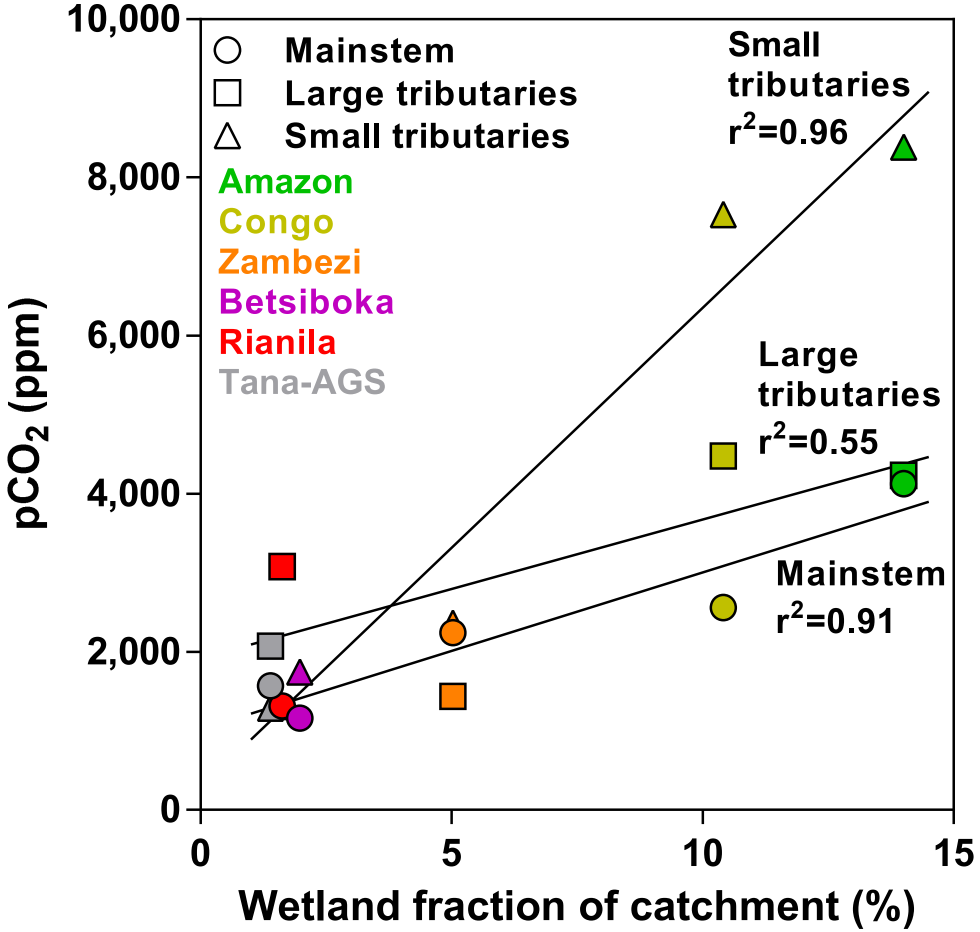
Results

Amazon	Congo
Flooded land = 80 % flooded forest Numerous permanent & temporary lakes	Flooded land = 100 % flooded forest Only a few large permanent lakes
Seasonally inundated wetlands	Permanently inundated flooded forest
Flooding from river overflow	Wetland water from upland runoff
Macrophytes only present in floodplains	Extensive macrophyte meadows in river channels (mainstem + tributaries)

Explains why CH_4 is 3-4 times higher in Congo

Results

Using gas transfer velocity + river/stream areas from GIS of Raymond et al. (2013) + GLWD (Lehner & Döll 2003)



CO_2 emissions from tropical rivers = 1.8 PgC yr^{-1}

Raymond et al. (2013) 1.4 PgC yr^{-1}

Lauerwald et al. (2015) 0.5 PgC yr^{-1}

Further Reading

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Divergent biophysical controls of aquatic CO_2 and CH_4 in the World's two largest rivers

Received: 07 July 2015
Accepted: 29 September 2015
Published: 23 October 2015

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Acknowledgments

erc European Research Council

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