Globally significant greenhouse-gas emissions from African inland waters

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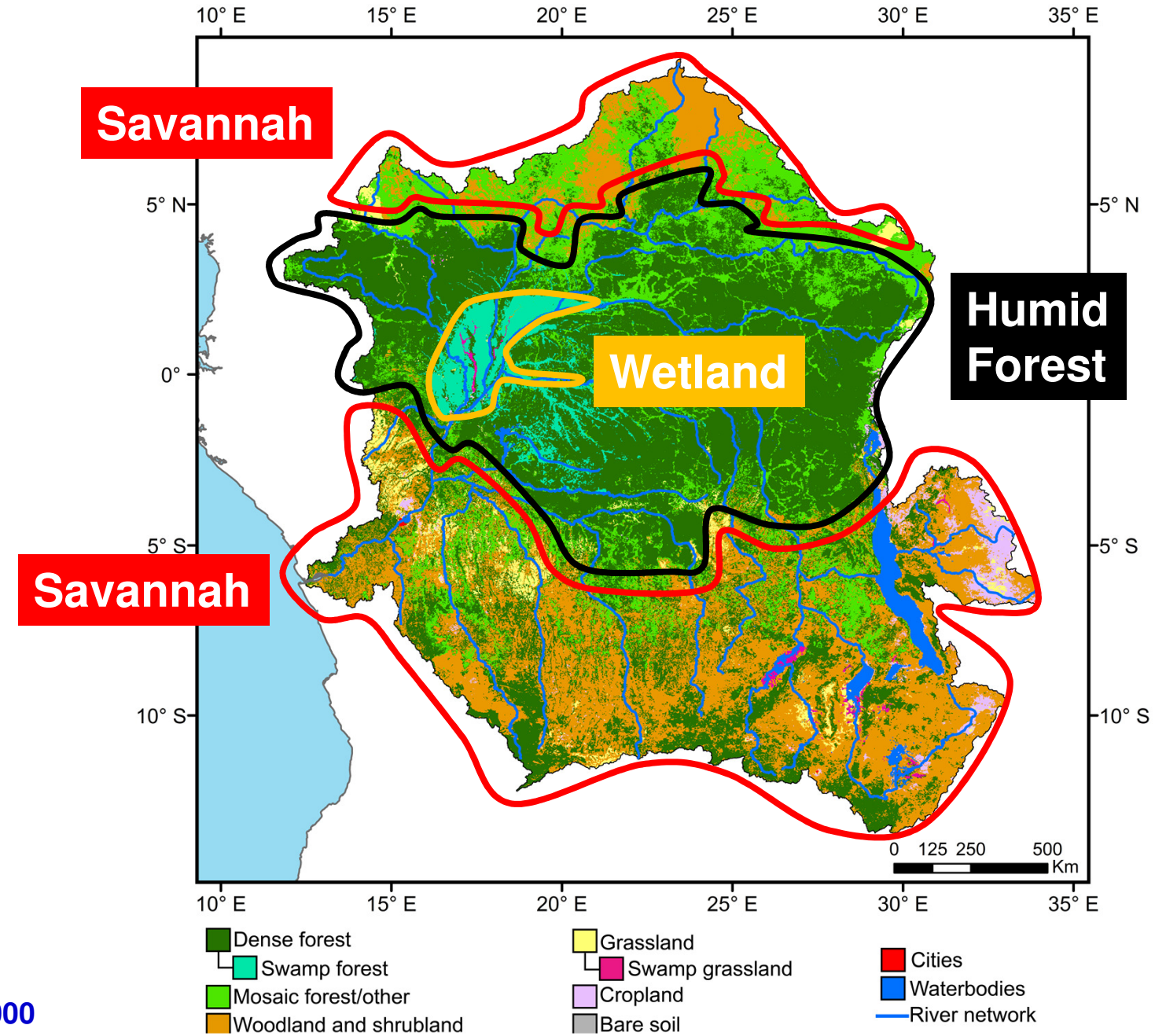
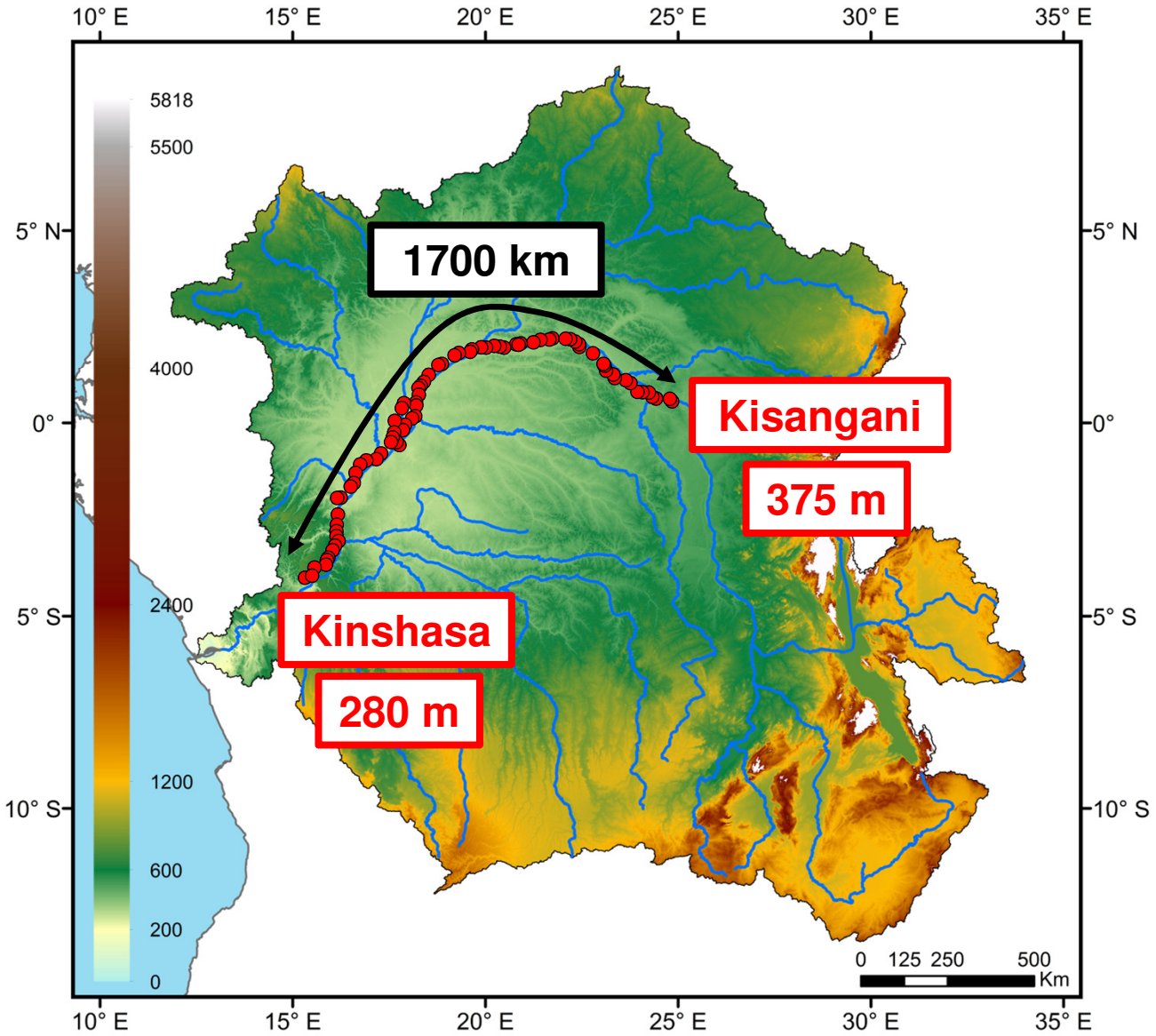
Congo river

Congo

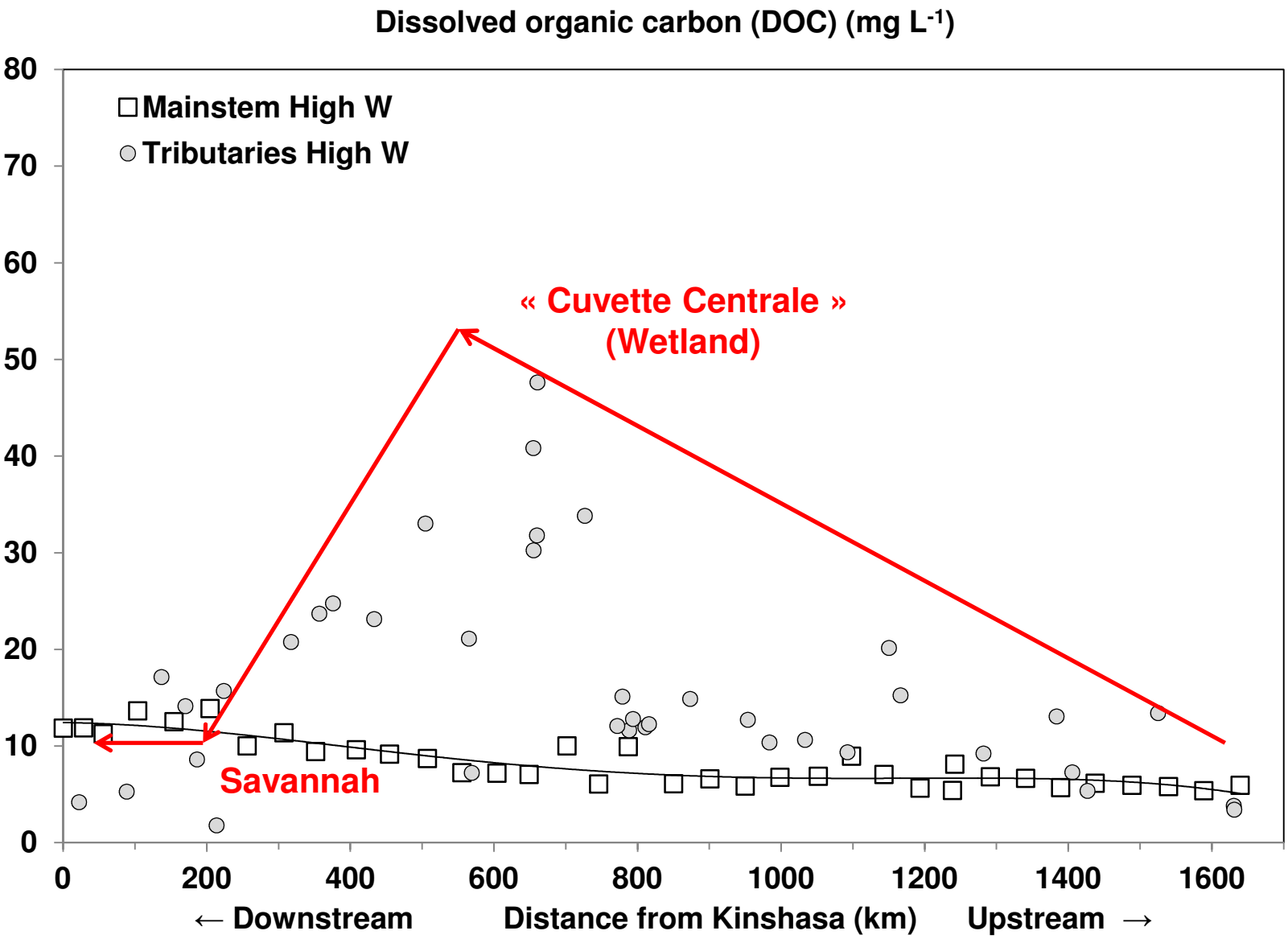


GLC 2000

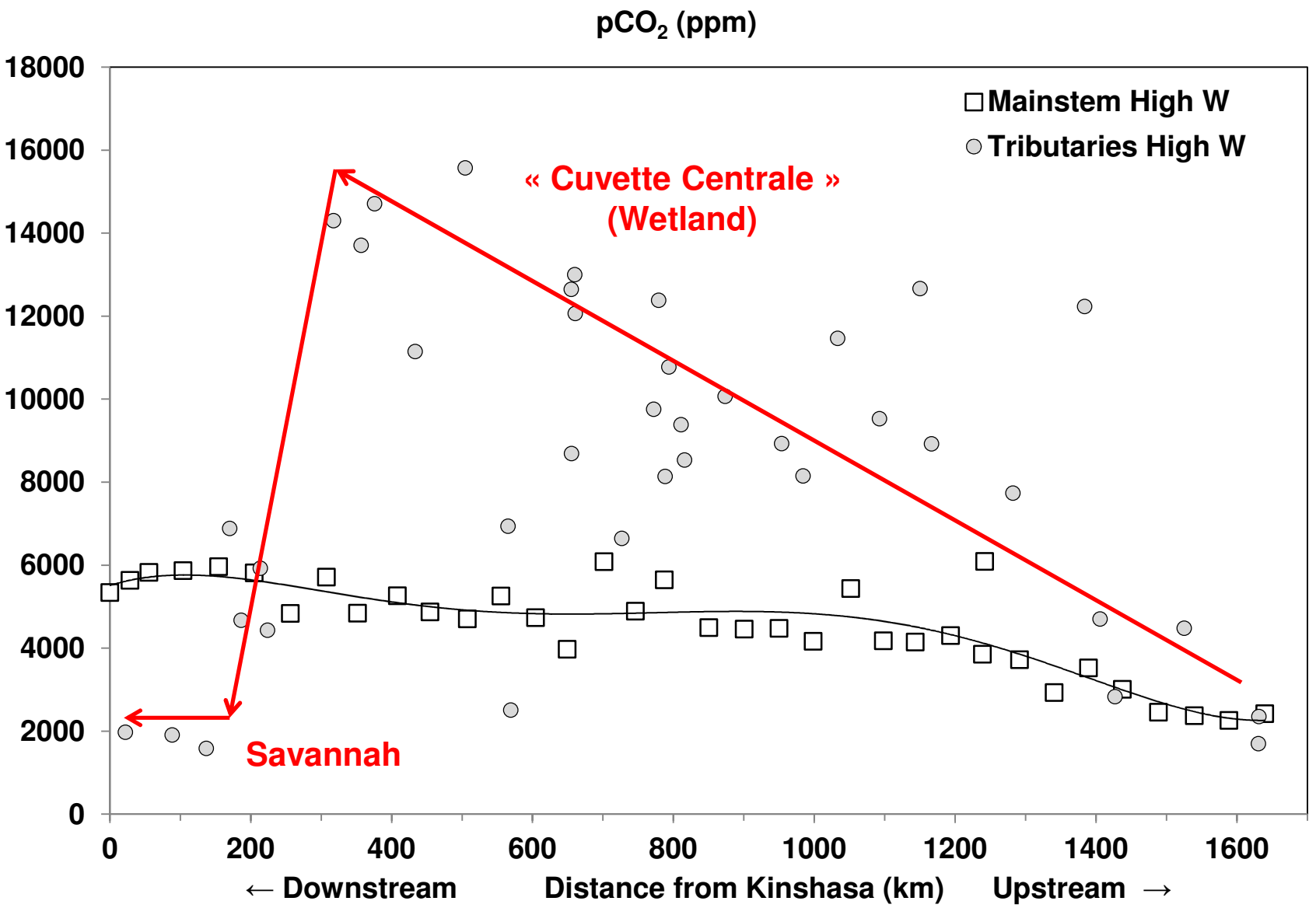
Congo


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

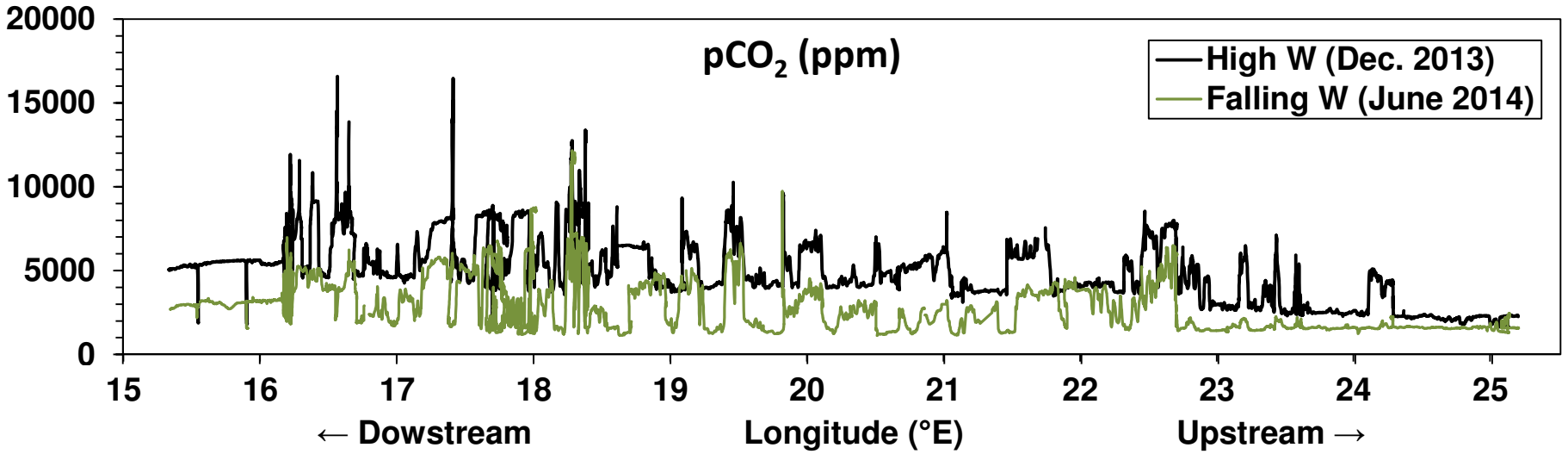
Congo


Dissolved organic carbon (DOC) (mg L-1)
Mainstem High W
Tributaries High W
« Cuvette Centrale »
(Wetland)
Savannah
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
← Downstream
Distance from Kinshasa (km)
Upstream →

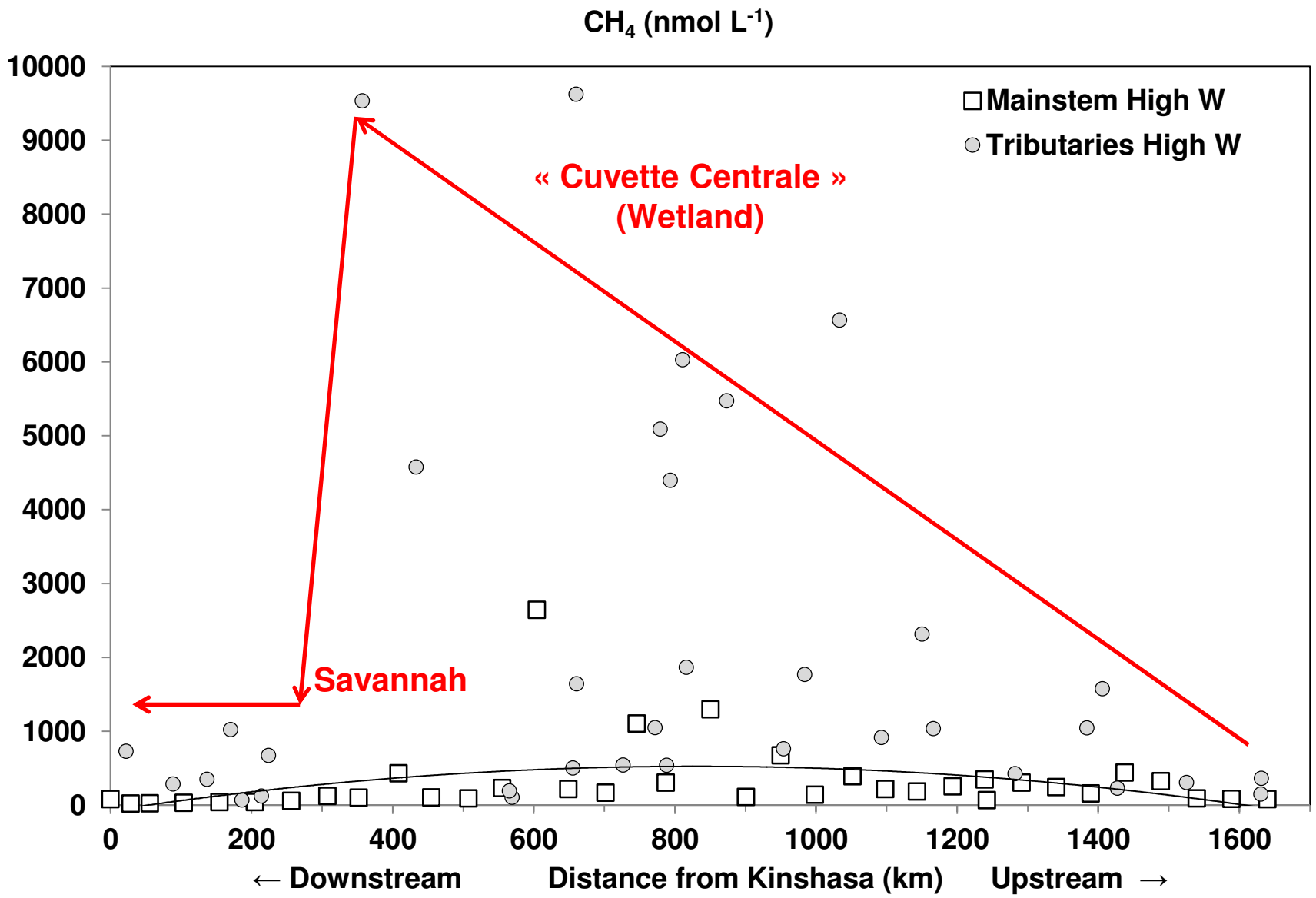
Congo


pCO2 (ppm)
18000
16000
14000
12000
10000
8000
6000
4000
2000
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 →

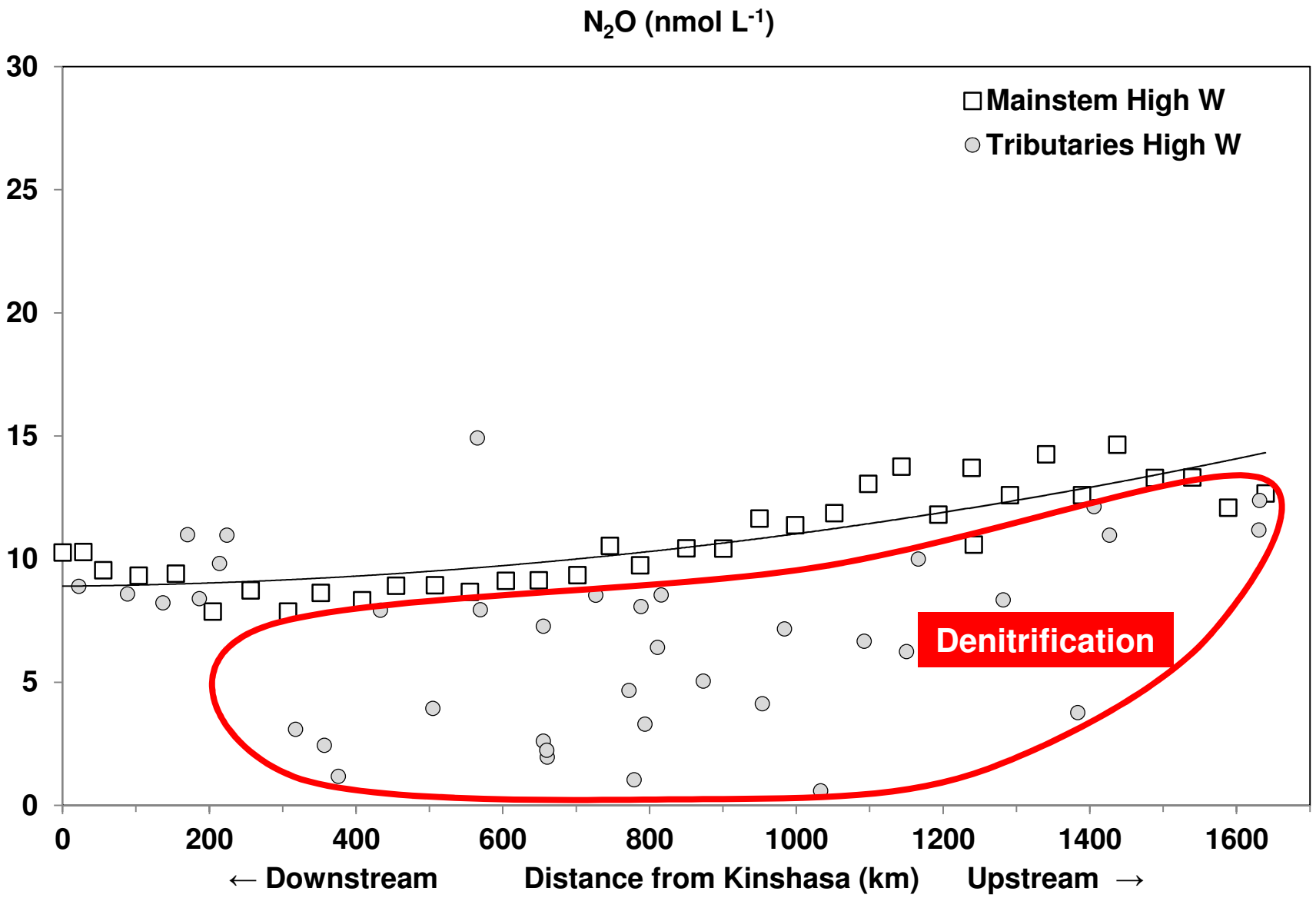
Congo


20000
15000
10000
5000
0
pCO2 (ppm)
High W (Dec. 2013)
Falling W (June 2014)
15
16
17
18
19
20
21
22
23
24
25
← Dowstream
Longitude (°E)
Upstream →

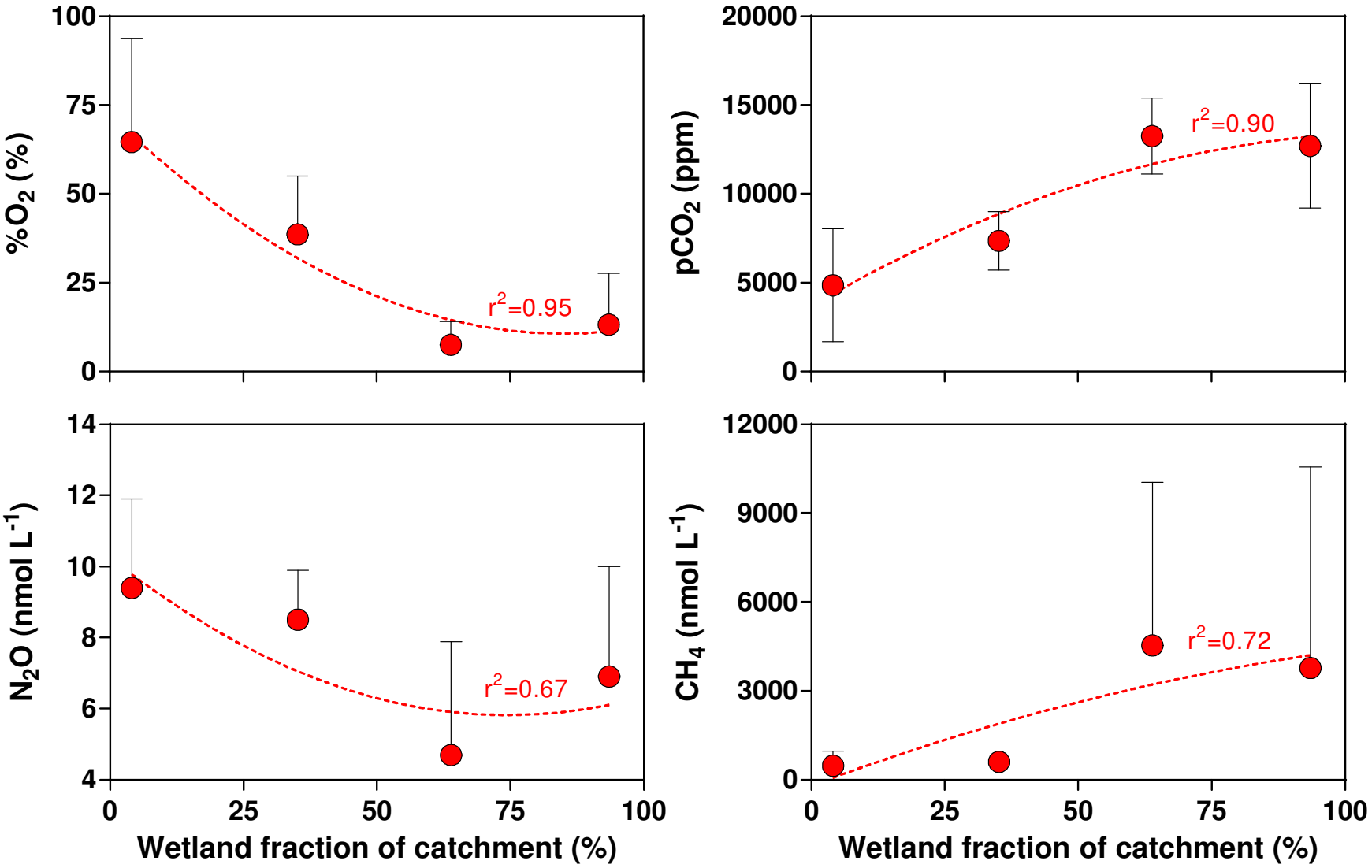
Congo


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

Congo

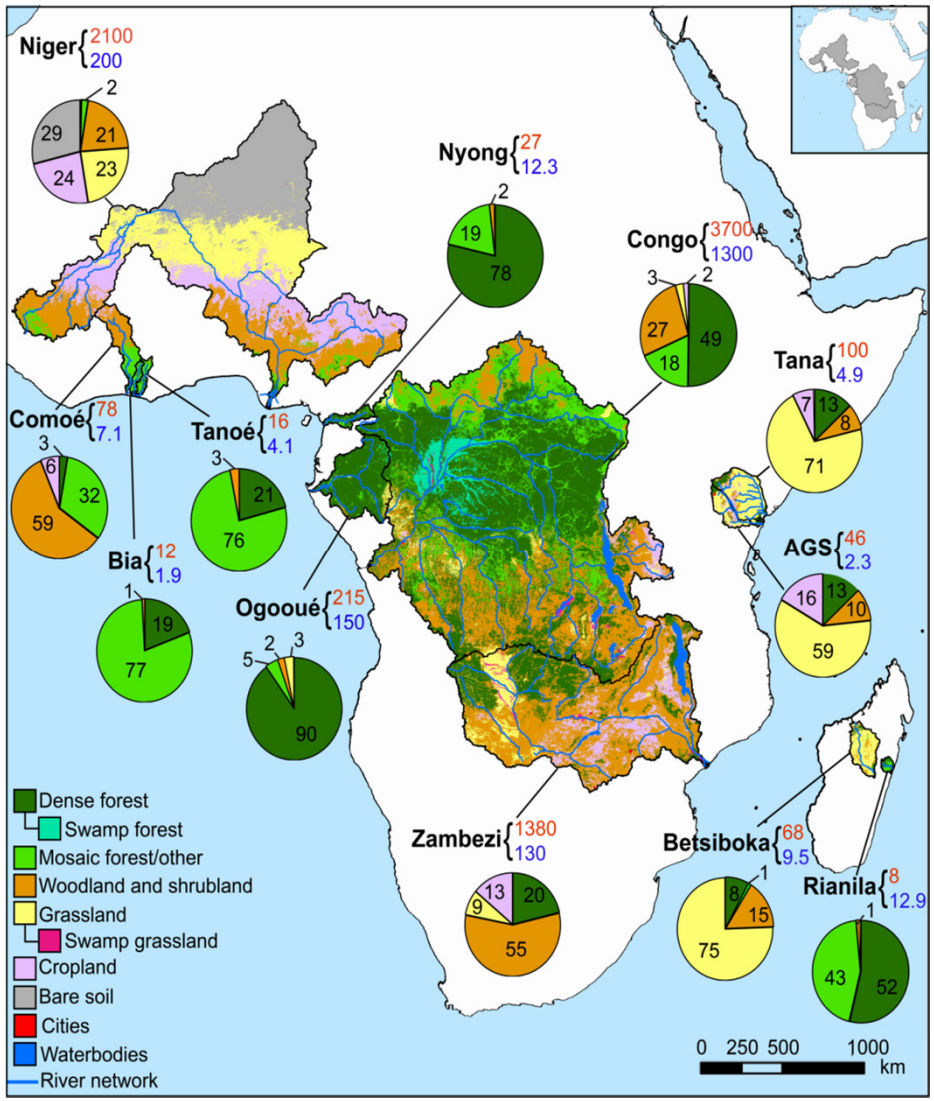

N2O (nmol L-1)
30
25
20
15
10
5
0
Mainstem High W
Tributaries High W
Denitrification
0
200
400
600
800
1000
1200
1400
1600
← Downstream
Distance from Kinshasa (km)
Upstream →

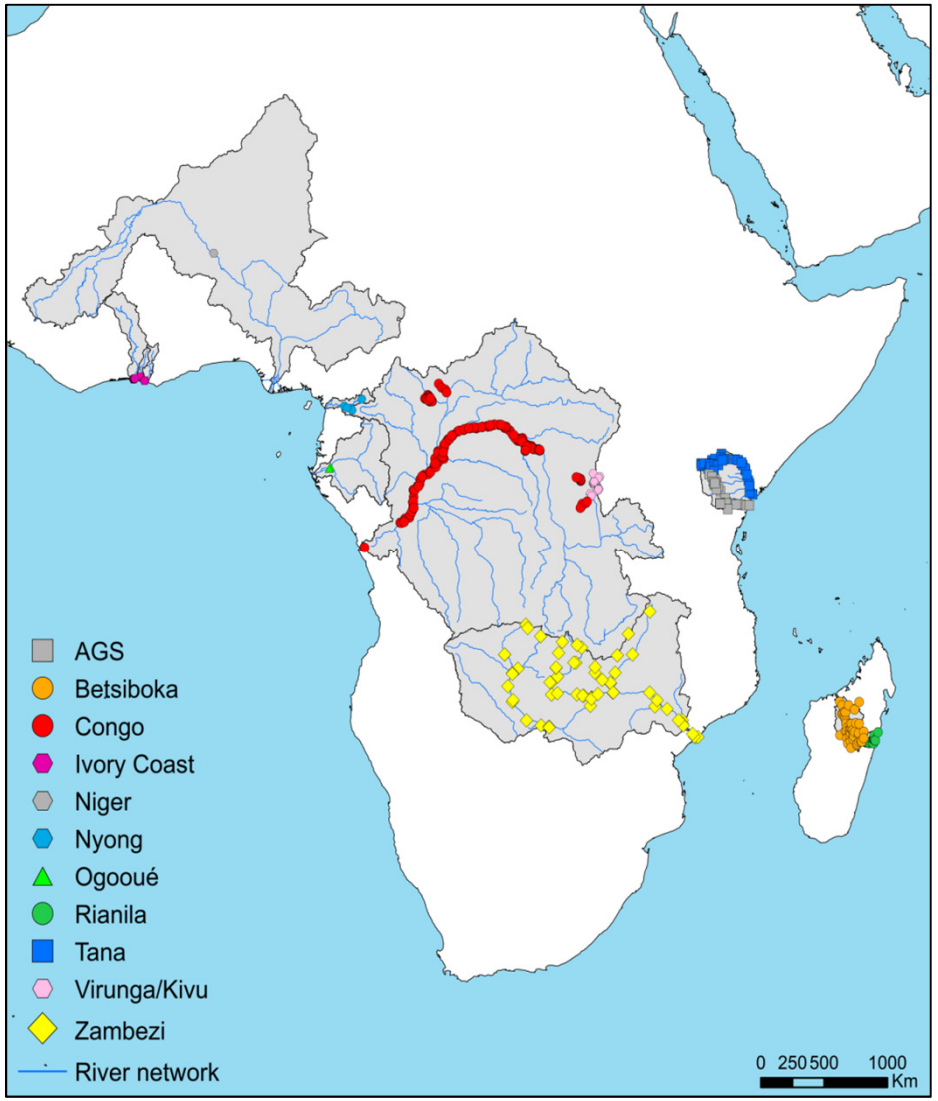
Congo


%O2 (%)
r2=0.95
pCO2 (ppm)
r2=0.90
N2O (nmol L-1)
r2=0.67
CH4 (nmol L-1)
r2=0.72
Wetland fraction of catchment (%)
Wetland fraction of catchment (%)

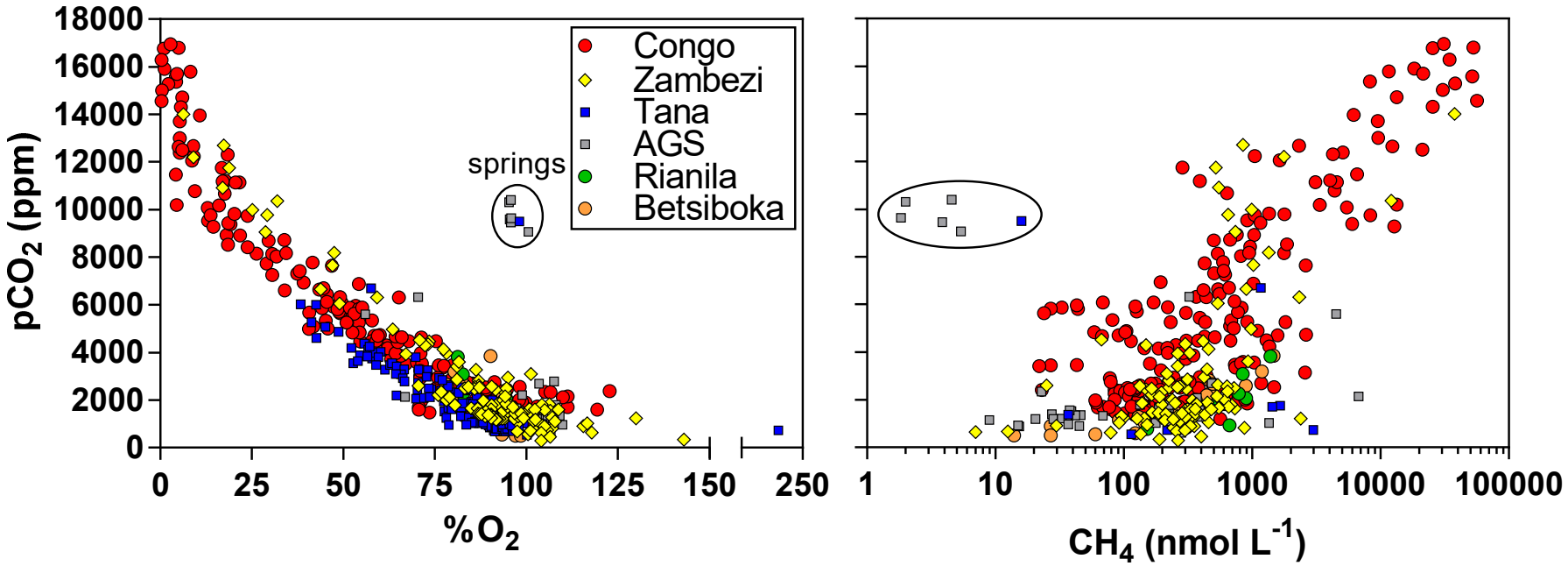
Congo & other Sub-Saharan African (SSA) rivers

SSA rivers

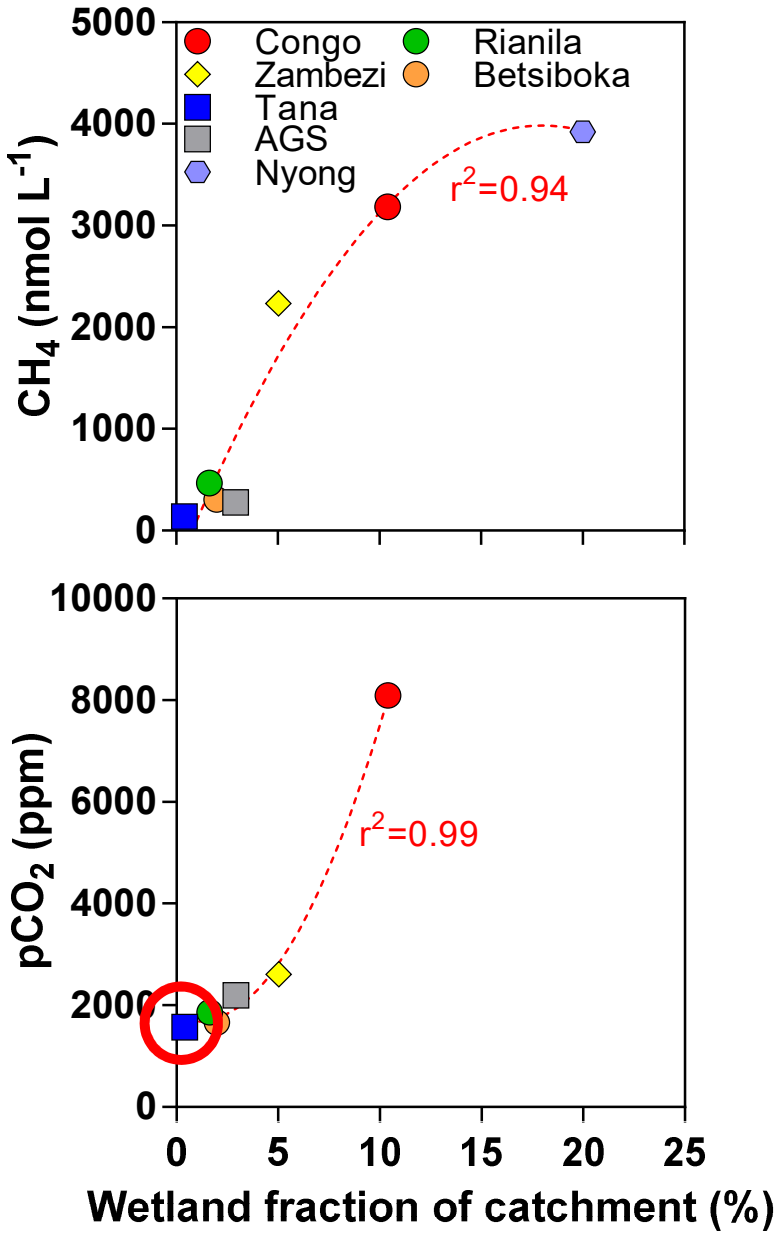

Niger 2100 200
Nyong 27 12.3
Congo 3700 1300
Tana 100 4.9
Comoé 78 7.1
Tanoé 16 4.1
Bia 12 1.9
Ogooué 215 150
AGS 46 2.3
Zambezi 1380 130
Betsiboka 68 9.5
Rianila 8 12.9
Dense forest
Swamp forest
Mosaic forest/other
Woodland and shrubland
Grassland
Swamp grassland
Cropland
Bare soil
Cities
Waterbodies
River network
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

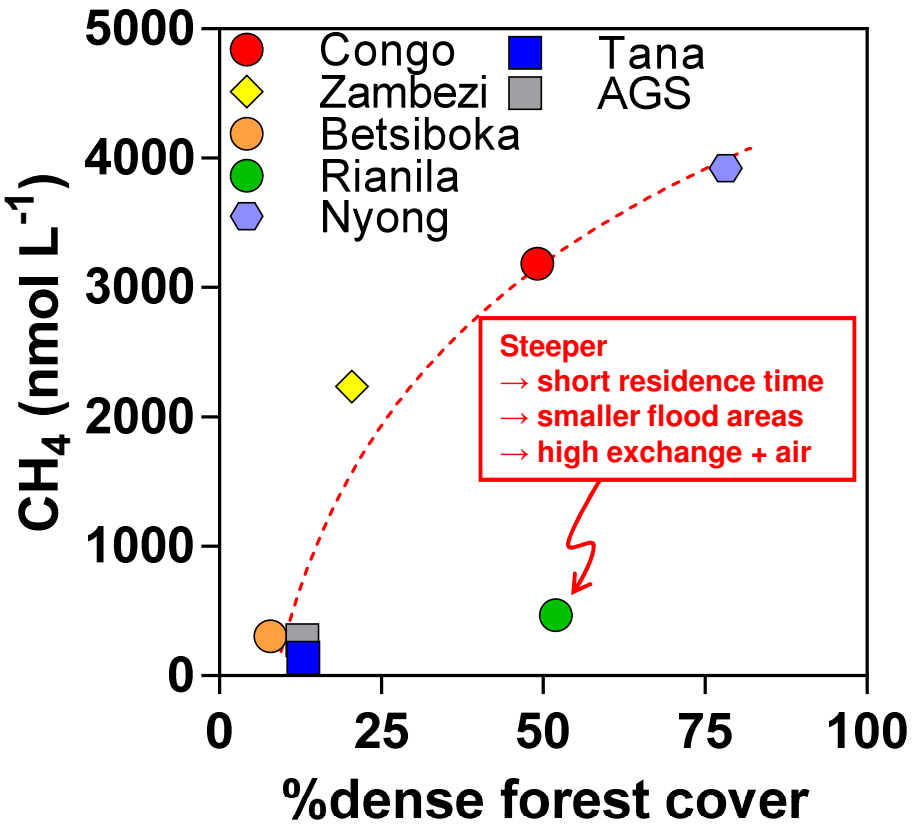
SSA rivers

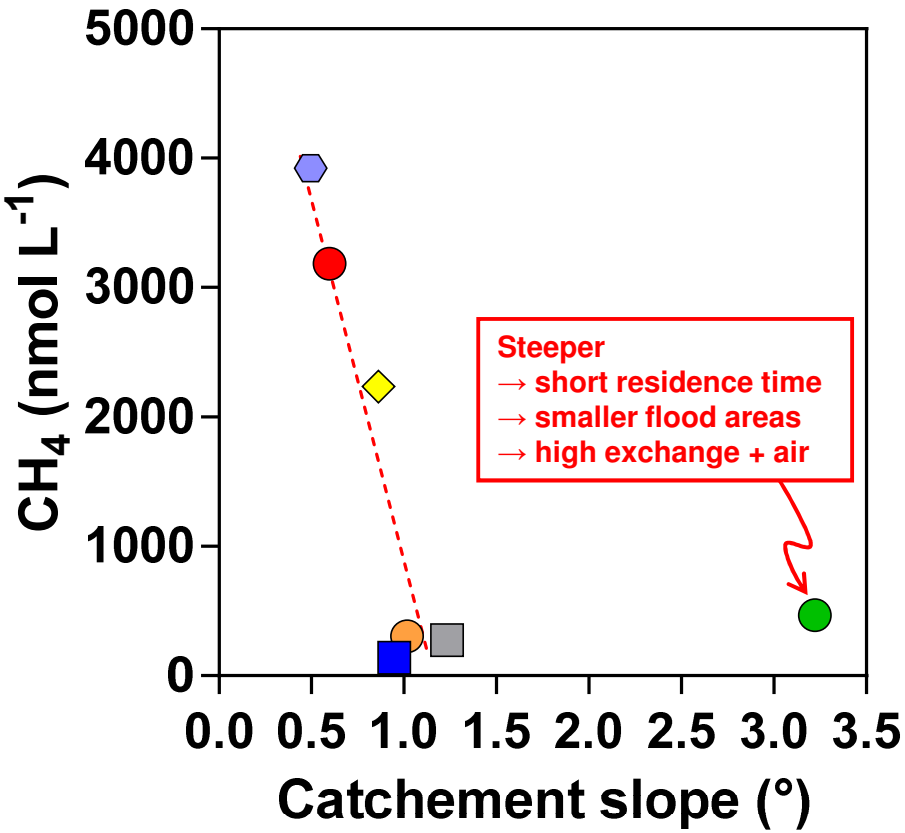

18000
16000
14000
12000
10000
8000
6000
4000
2000
0
pCO2 (ppm)
0
25
50
75
100
125
150
250
%O2
springs
Congo
Zambezi
Tana
AGS
Rianila
Betsiboka
1
10
100
1000
10000
100000
CH4 (nmol L-1)

SSA rivers

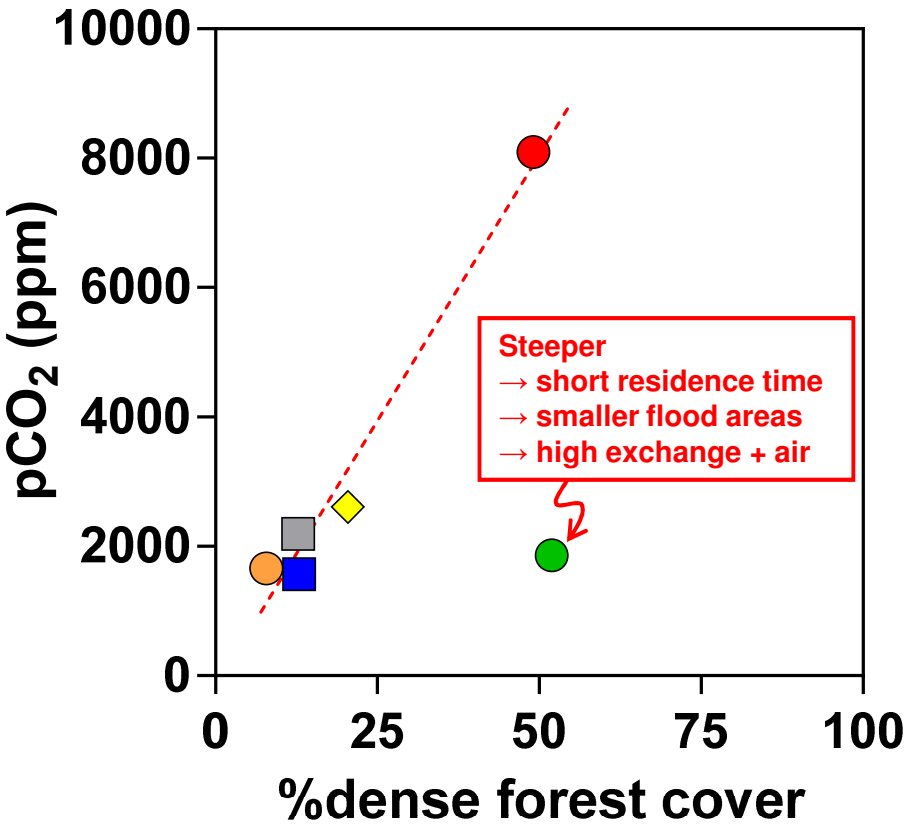

Congo
Zambezi
Tana
AGS
Nyong
Rianila
Betsiboka
r^2=0.94
r^2=0.99
CH_4 (nmol L^{-1})
pCO_2 (ppm)
Wetland fraction of catchment (%)
0
1000
2000
3000
4000
5000
6000
8000
10000
0
5
10
15
20
25

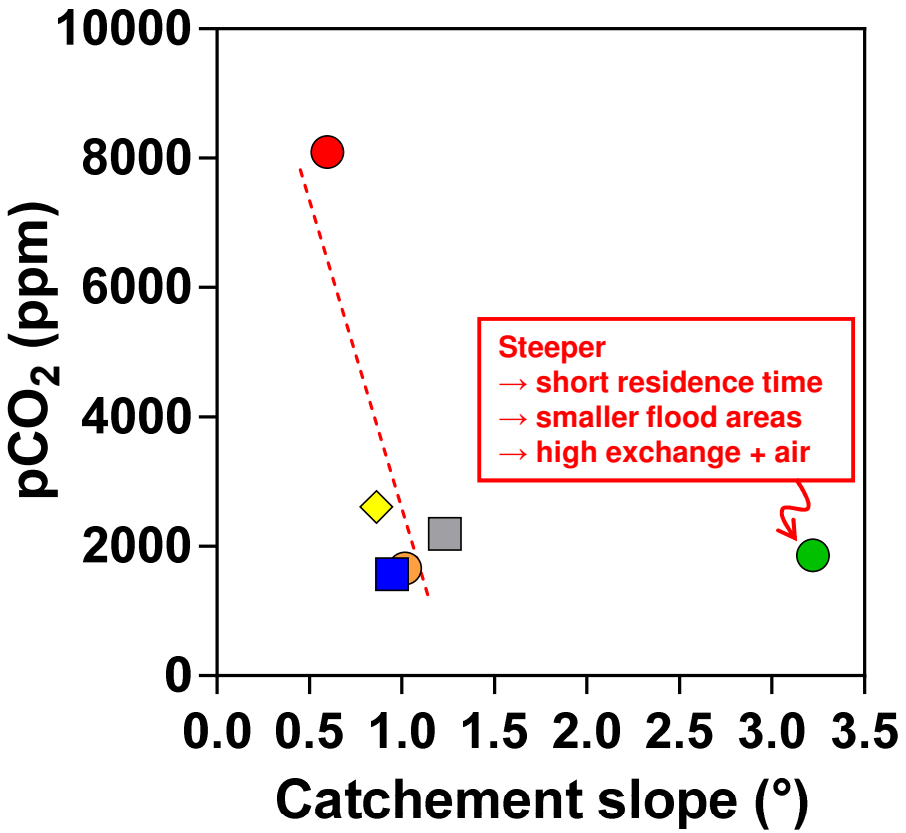
SSA rivers


5000
4000
3000
2000
1000
0
CH_4 (nmol L^{-1})
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


5000
4000
3000
2000
1000
0
CH_4 (nmol L^{-1})
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 (°)

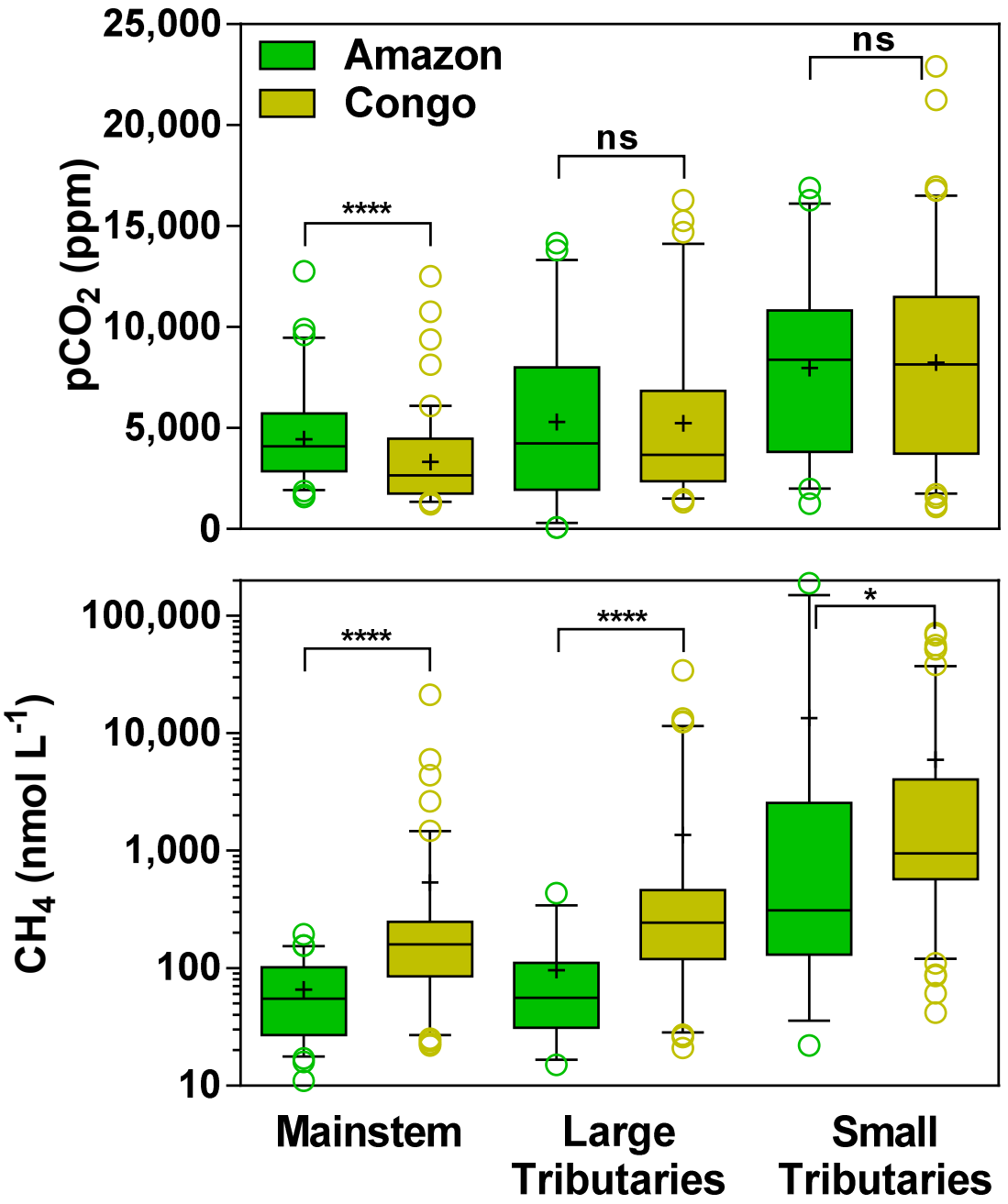
SSA rivers


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

Congo versus Amazon

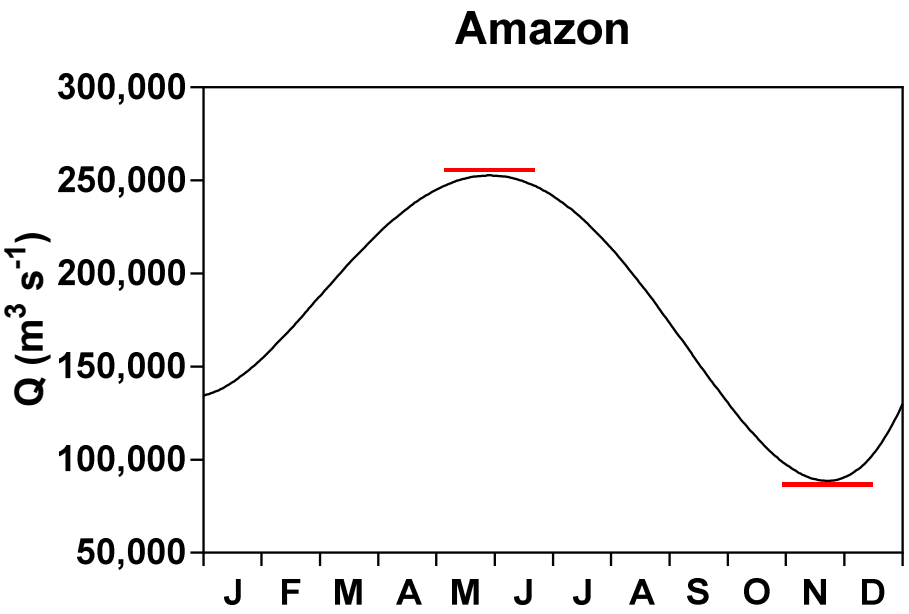
Congo *vs* Amazon

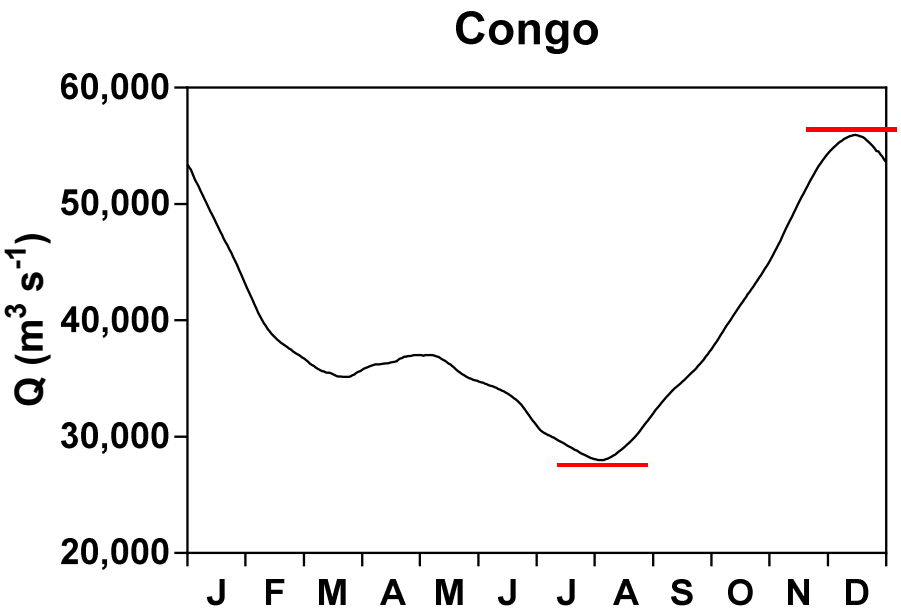


pCO_2 is ± similar

CH_4 is 3-4 times higher in Congo

Congo *vs* Amazon





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

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

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

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

Congo *vs* Amazon

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

Congo *vs* Amazon

Amazon	Congo
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Congo *vs* Amazon

Emissions of green-house gases from SSA rivers

Emissions of greenhouse-gases from SSA rivers

African rivers/streams

$CO_2 + CH_4 = 0.3 – 0.4$ PgC yr^{-1} ($CO_{2\ equivalents}$)

A full greenhouse gases budget of Africa: synthesis, uncertainties, and vulnerabilities

R. Valentini[1,2], A. Arneth[3], A. Bombelli[2], S. Castaldi[2,4], R. Cazzolla Gatti[1], F. Chevallier[5], P. Ciais[5], E. Grieco[2], J. Hartmann[6], M. Henry[7], R. A. Houghton[8], M. Jung[9], W. L. Kutsch[10], Y. Malhi[11], E. Mayorga[12], L. Merbold[13], G. Murray-Tortarolo[15], D. Papale[1], P. Peylin[5], B. Poulter[5], P. A. Raymond[14], M. Santini[2], S. Sitch[15], G. Vaglio Laurin[2,16], G. R. van der Werf[17], C. A. Williams[18], and R. J. Scholes[19]

Sink of C = 0.6 PgC yr^{-1}

Off-set by 2/3 !

Emissions of greenhouse-gases from SSA rivers

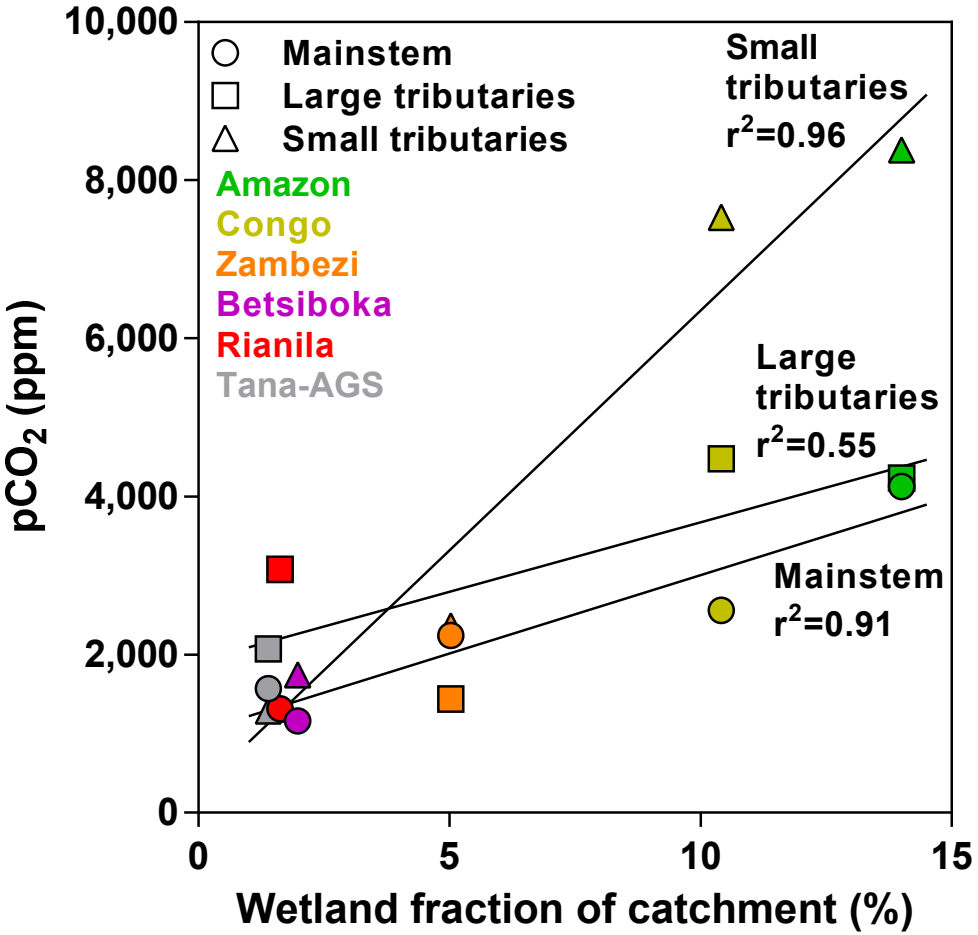
Cuvette Centrale Congolaise + rivers/streams
CO_2 + CH_4 = 0.9 – 1.0 PgC yr^{-1} ($CO_{2\ equivalents}$)

A full greenhouse gases budget of Africa: synthesis, uncertainties, and vulnerabilities

R. Valentini[1,2], A. Arneth[3], A. Bombelli[2], S. Castaldi[2,4], R. Cazzolla Gatti[1], F. Chevallier[5], P. Ciais[5], E. Grieco[2], J. Hartmann[6], M. Henry[7], R. A. Houghton[8], M. Jung[9], W. L. Kutsch[10], Y. Malhi[11], E. Mayorga[12], L. Merbold[13], G. Murray-Tortarolo[15], D. Papale[1], P. Peylin[5], B. Poulter[5], P. A. Raymond[14], M. Santini[2], S. Sitch[15], G. Vaglio Laurin[2,16], G. R. van der Werf[17], C. A. Williams[18], and R. J. Scholes[19]

Sink of C = 0.6 PgC yr^{-1}
Becomes a source of 0.3-0.4 PgC yr^{-1} !

Emissions of greenhouse-gases from tropical rivers



GLWD (Lehner & Döll 2003)

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

Further Reading

nature geoscience

ARTICLES

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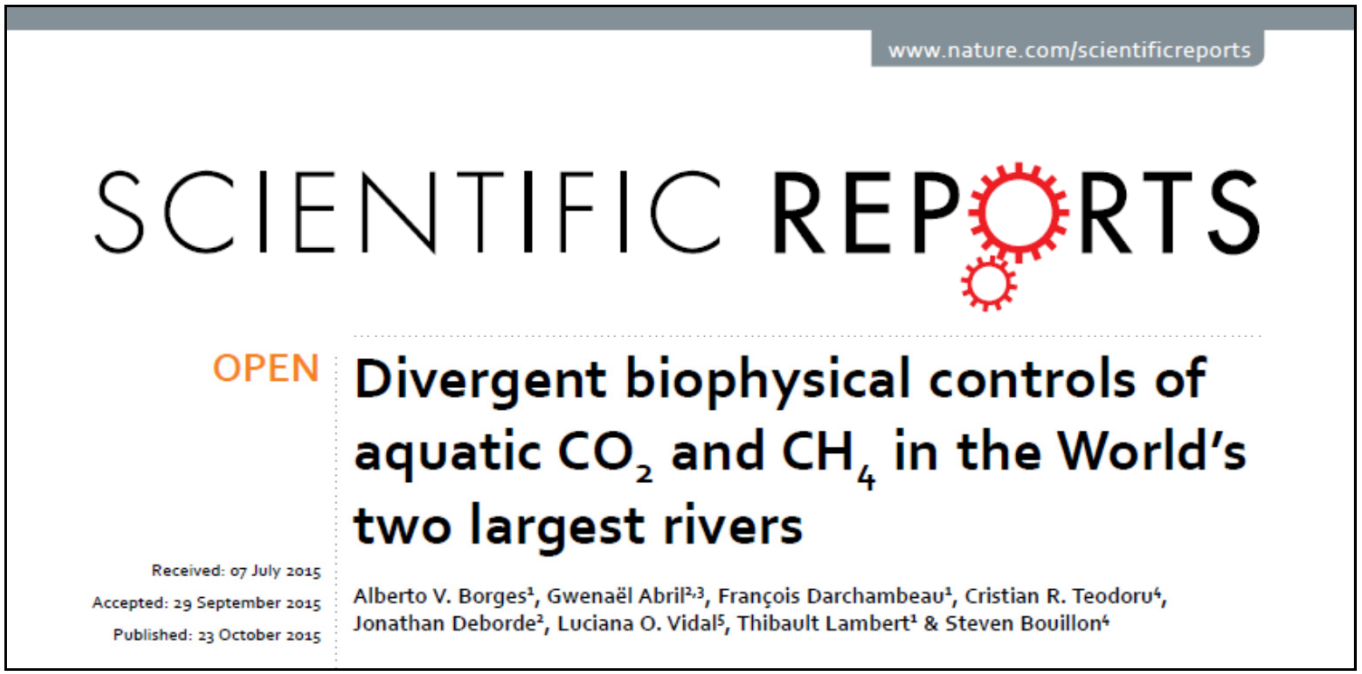

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Divergent biophysical controls of aquatic CO_2 and CH_4 in the World's two largest rivers

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