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], George H. Allen[2], Cédric Morana[1,3], Thibault Lambert[1], Cristian R. Teodoru[3], Steven Bouillon[3]

1 LIÈGE université Chemical Oceanography

2 TAMU GEOGRAPHY

3 DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES KU Leuven - BELGIUM

CO_2 emissions from rivers

Introduction

River CO_2 global emission
1.8 PgC yr^{-1} (Raymond et al. 2013)

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]

Introduction

River CO_2 global emission
1.8 PgC yr^{-1} (Raymond et al. 2013)
0.7 PgC yr^{-1} (Lauerwald et al. 2015)

Global carbon dioxide emissions from inland waters

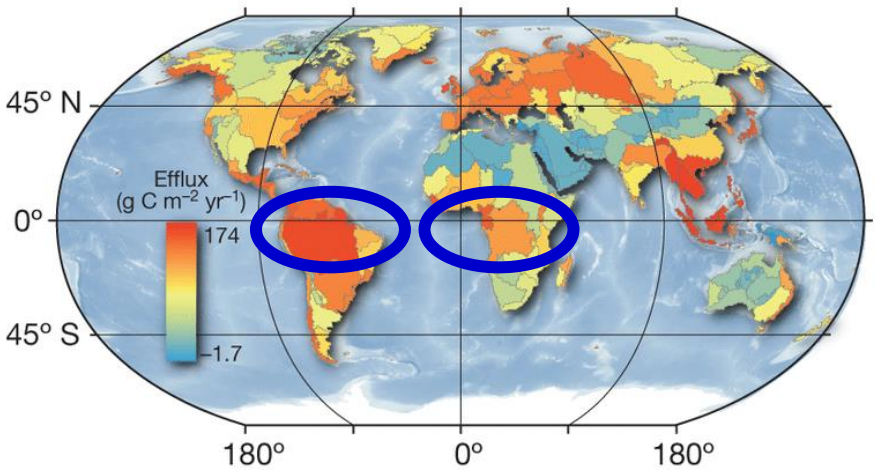
Peter A. Raymond[1], Jens Hartmann[2]*, Ronny Lauerwald[2,3]*, Sebastian Sobek[4]*, Cory McDonald[5], Mark Hoover[1], David Butman[1,6], Robert Striegl[6], Emilio Mayorga[7], Christoph Humborg[8], Pirkko Kortelainen[9], Hans Dürr[10], Michel Meybeck[11], Philippe Ciais[12] & Peter Guth[13]

Spatial patterns in CO_2 evasion from the global river network

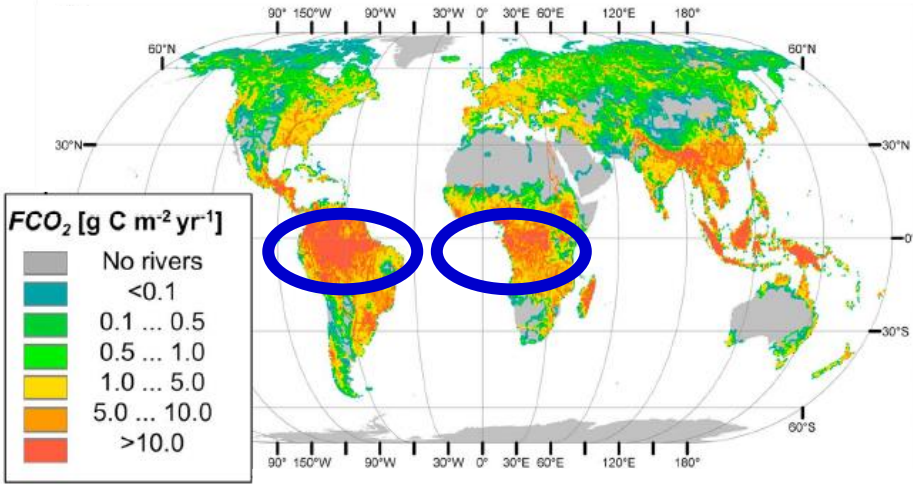
Ronny Lauerwald[1,2,3], Goulven G. Laruelle[1,4], Jens Hartmann[3], Philippe Ciais[5], and Pierre A. G. Regnier[1]

Introduction

Raymond et al. (2013)



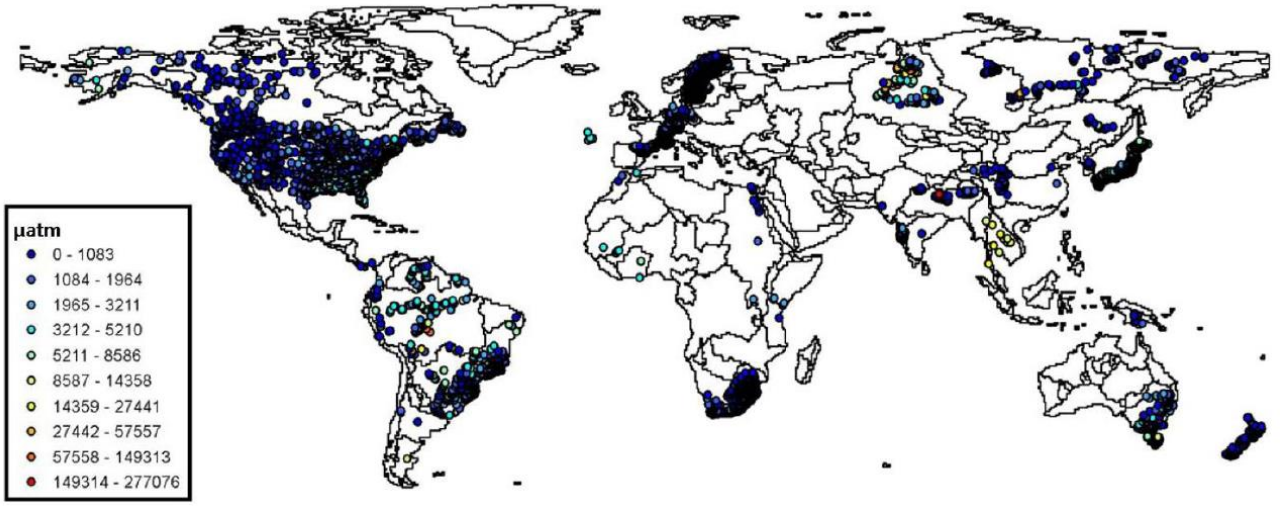
Lauerwald et al. (2015)



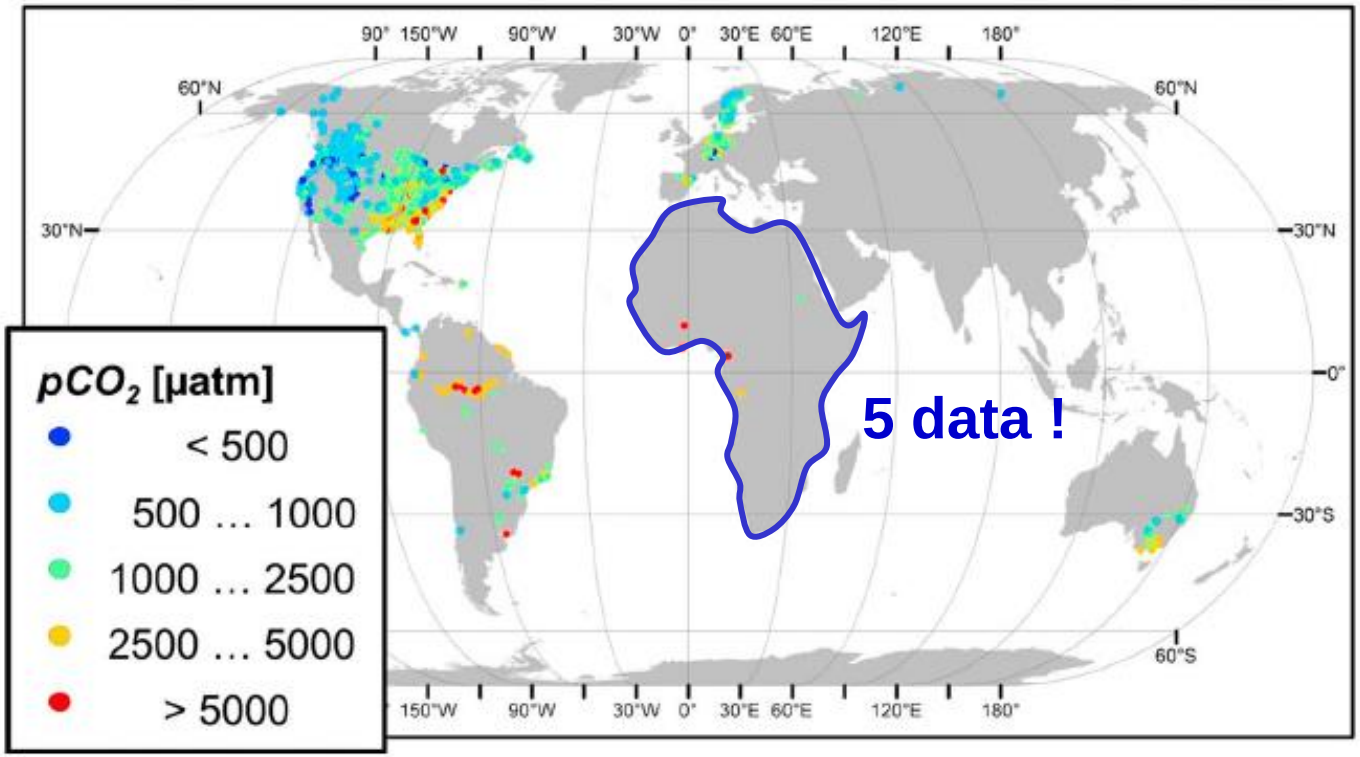
High CO_2 emissions in the tropics (Amazon & Congo)

Introduction

Raymond et al. (2013)

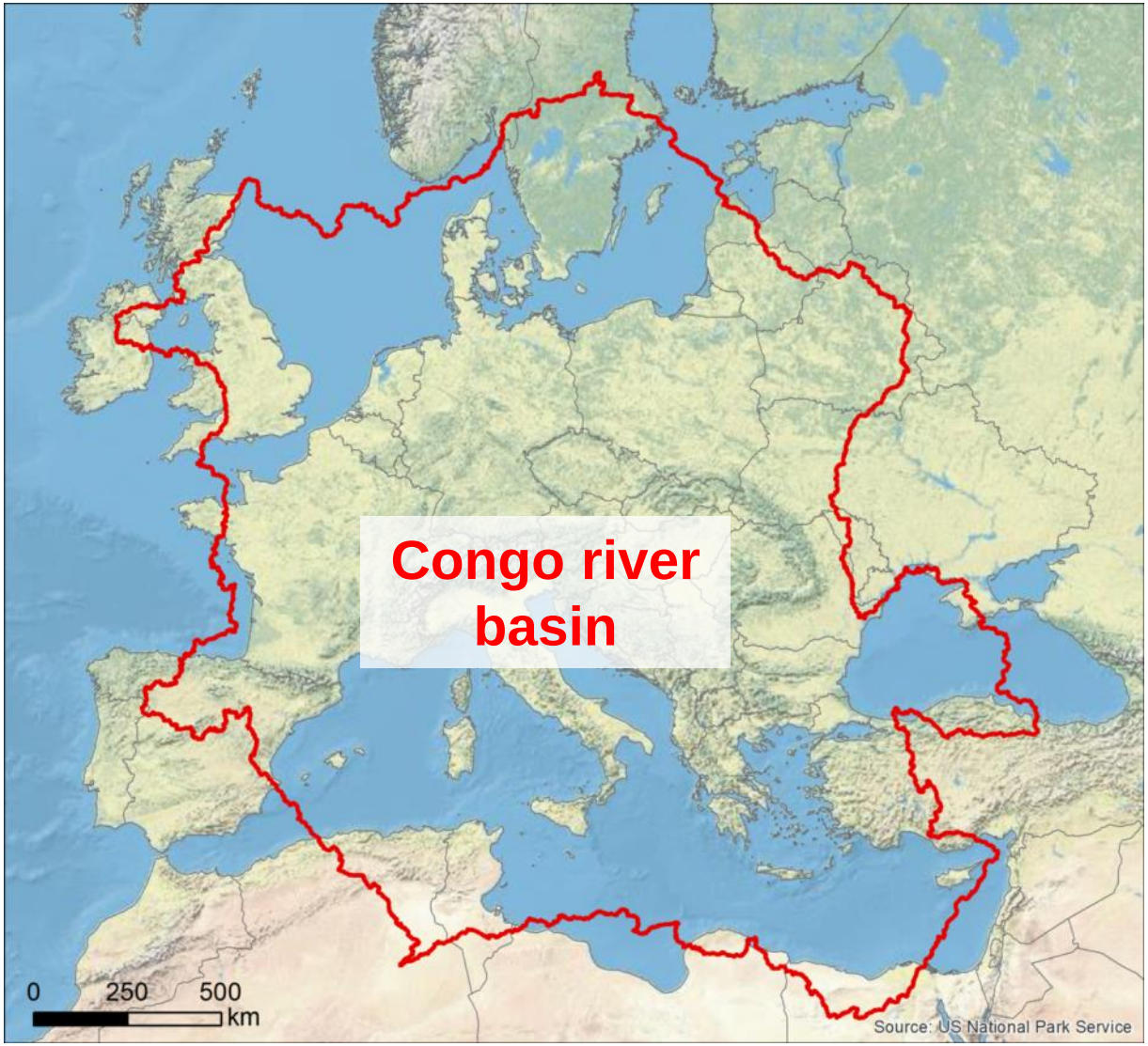


Lauerwald et al. (2015)



Congo river

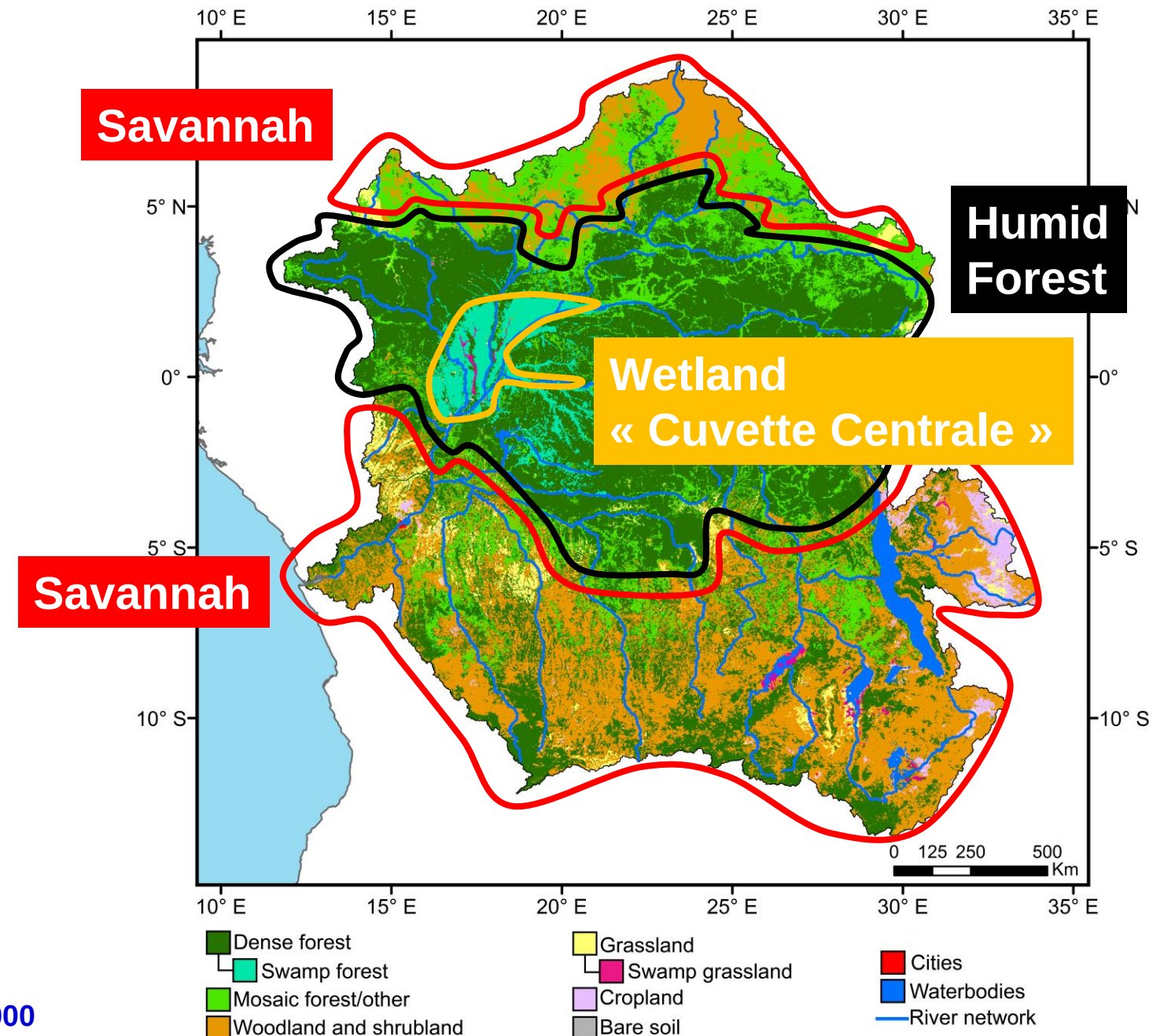
Congo


Congo river basin
0
250
500
km
Source: US National Park Service

Congo

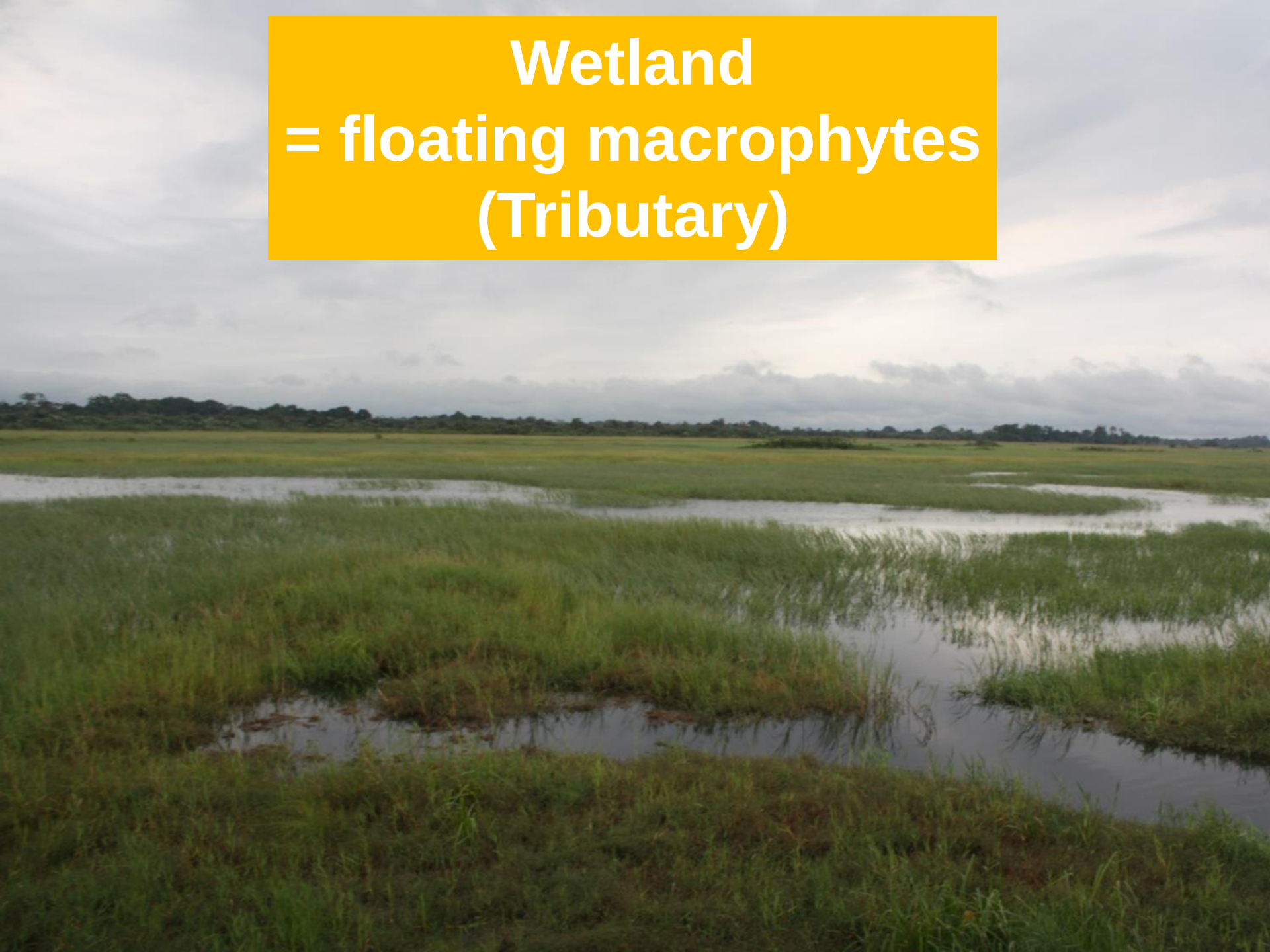

Congo river basin
0
250
500
km
Source: US National Park Service

Congo

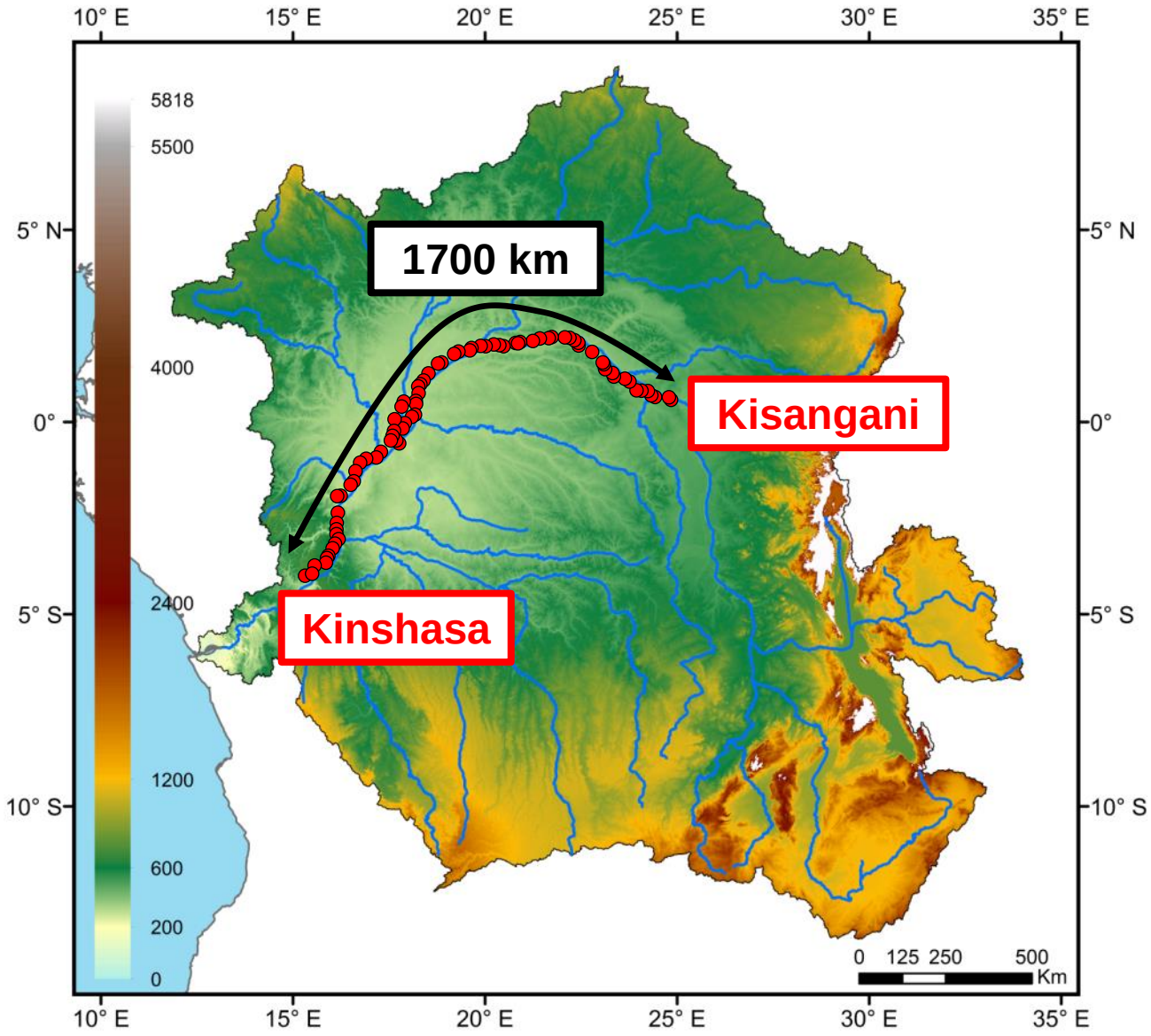


GLC 2000

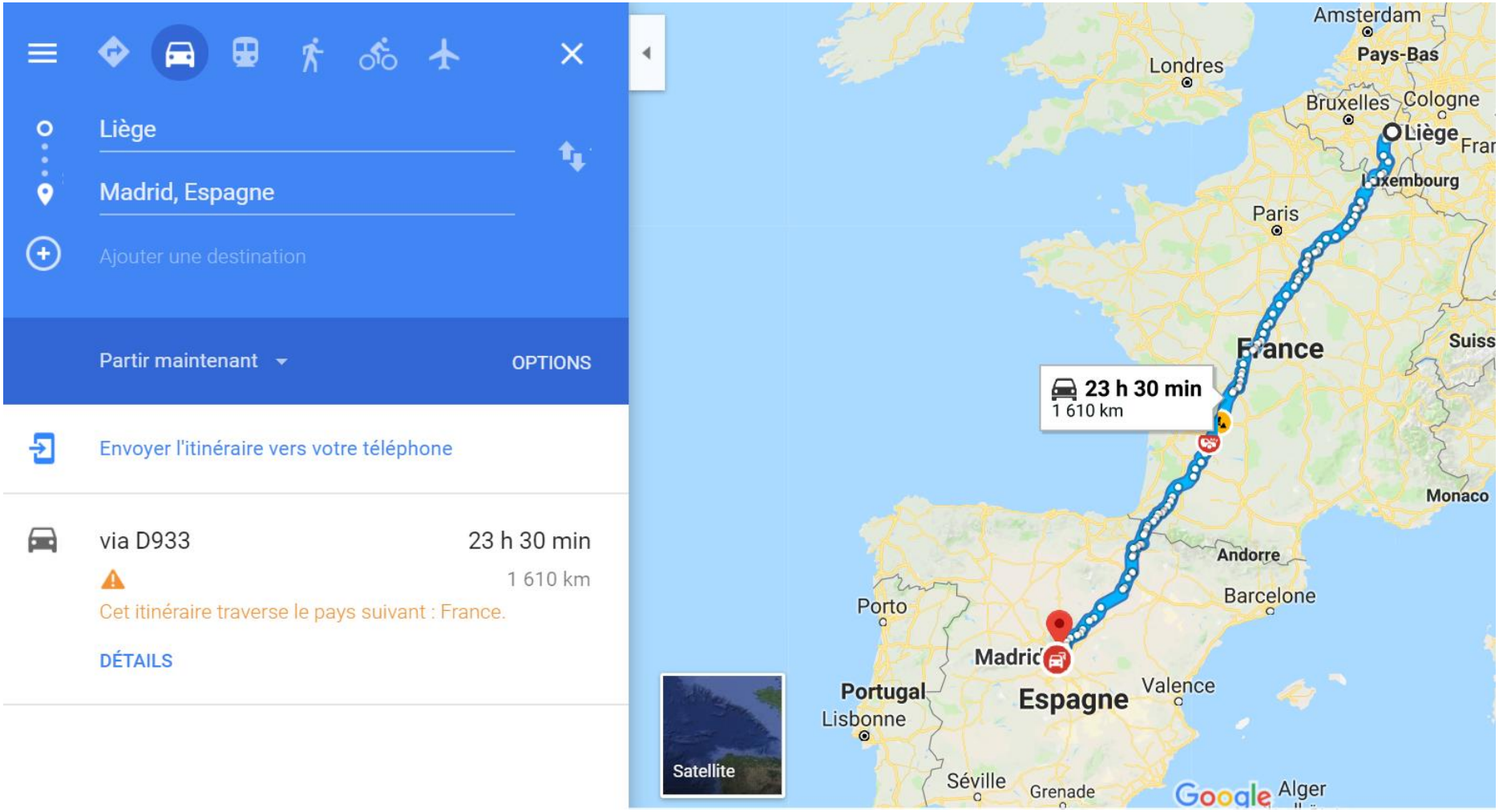

Wetland
= flooded forest
(Tributary)


Wetland
= floating macrophytes
(Tributary)

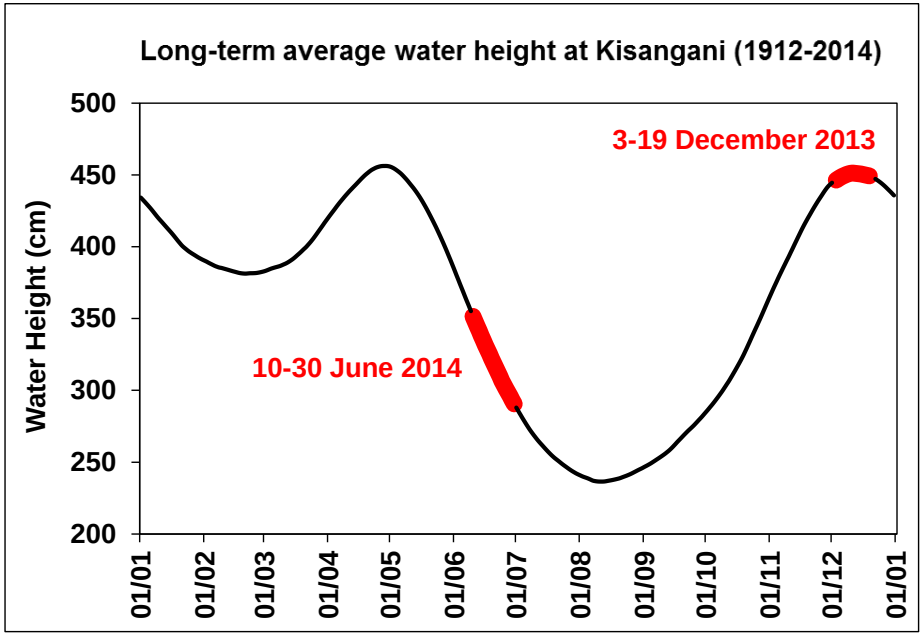
Congo


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
Kinshasa
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
23 h 30 min
1 610 km
Amsterdam
Pays-Bas
Londres
Bruxelles
Cologne
Liège
Luxembourg
Paris
France
Monaco
Andorre
Barcelone
Porto
Madrid
Portugal
Lisbonne
Espagne
Valence
Séville
Grenade
Alger
Satellite
Google

Cruises & Methods



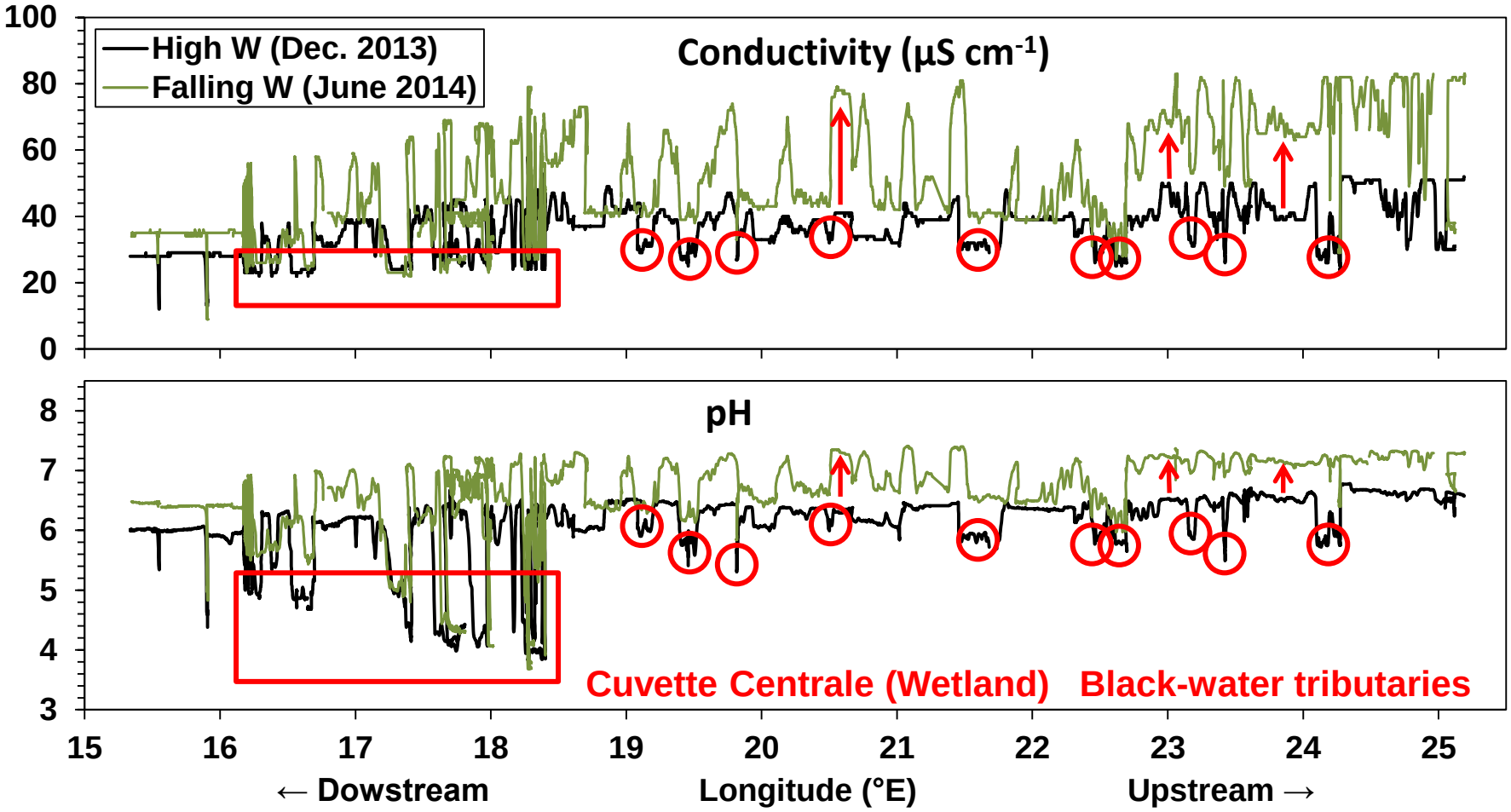
164 stations
29 variables

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

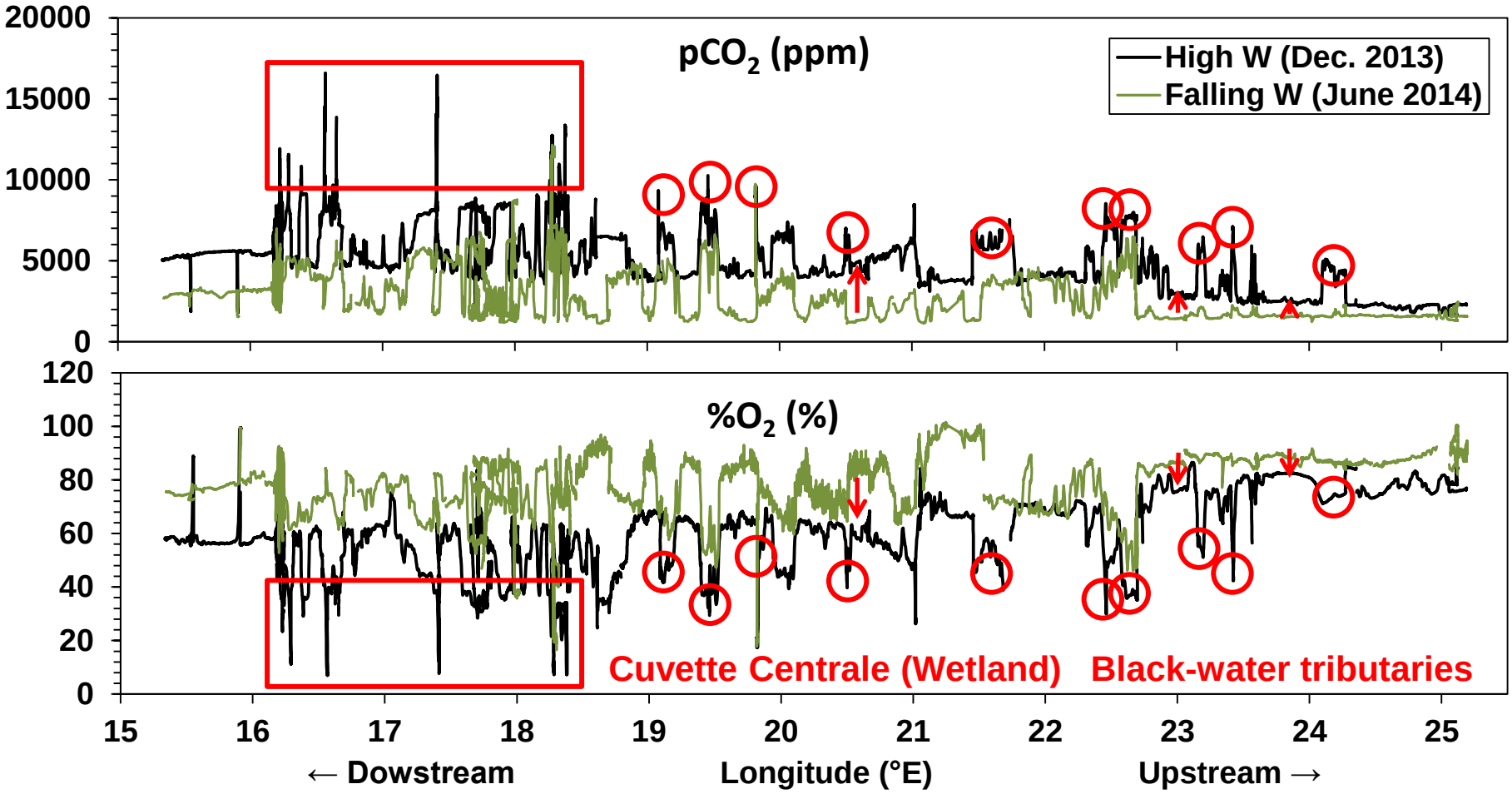
Results

Spatial variations of CO_2

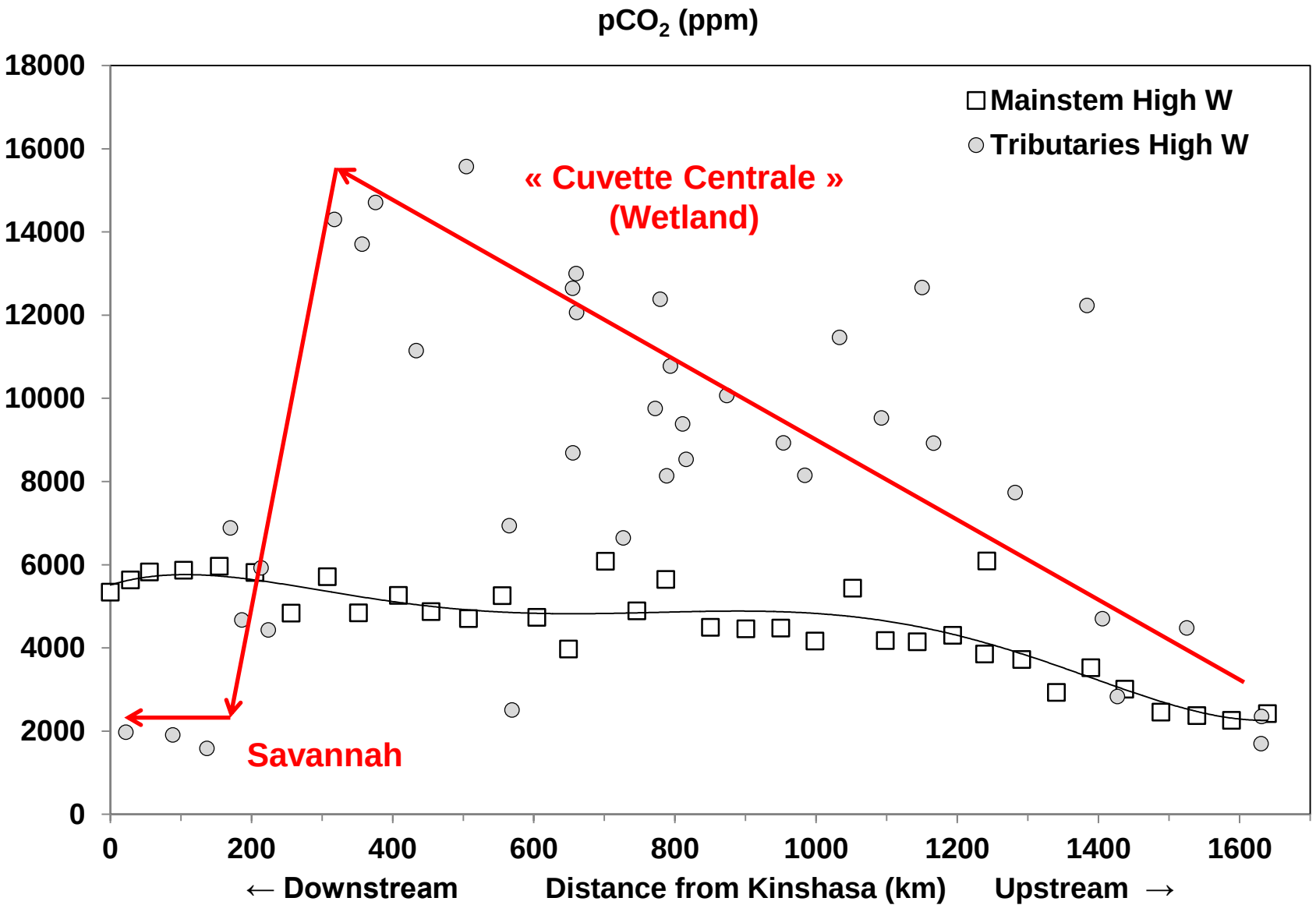
Results


High W (Dec. 2013)
Falling W (June 2014)
Conductivity (µS cm-1)
pH
Cuvette Centrale (Wetland)
Black-water tributaries
← Dowstream
Longitude (°E)
Upstream →

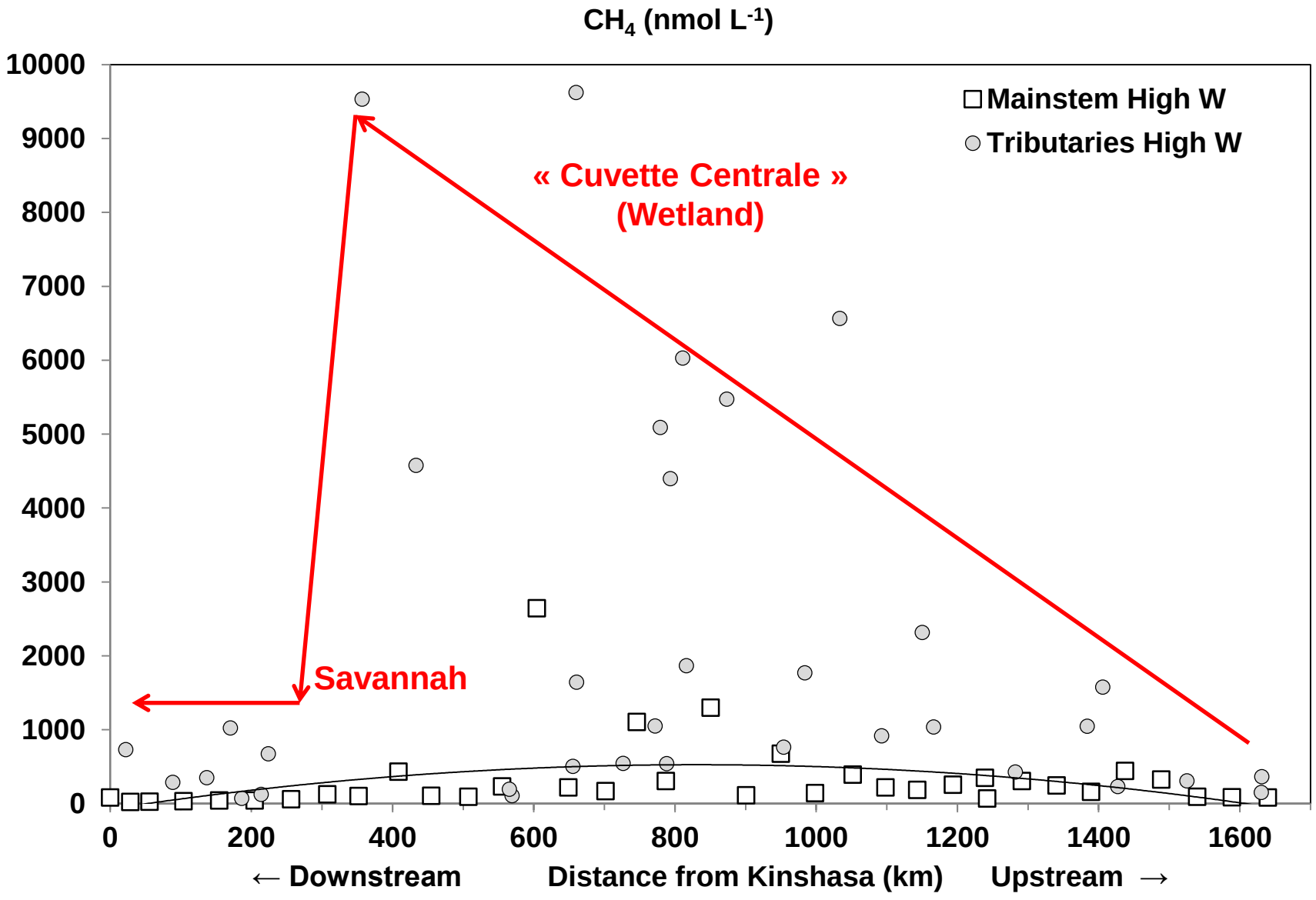
Results


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 →

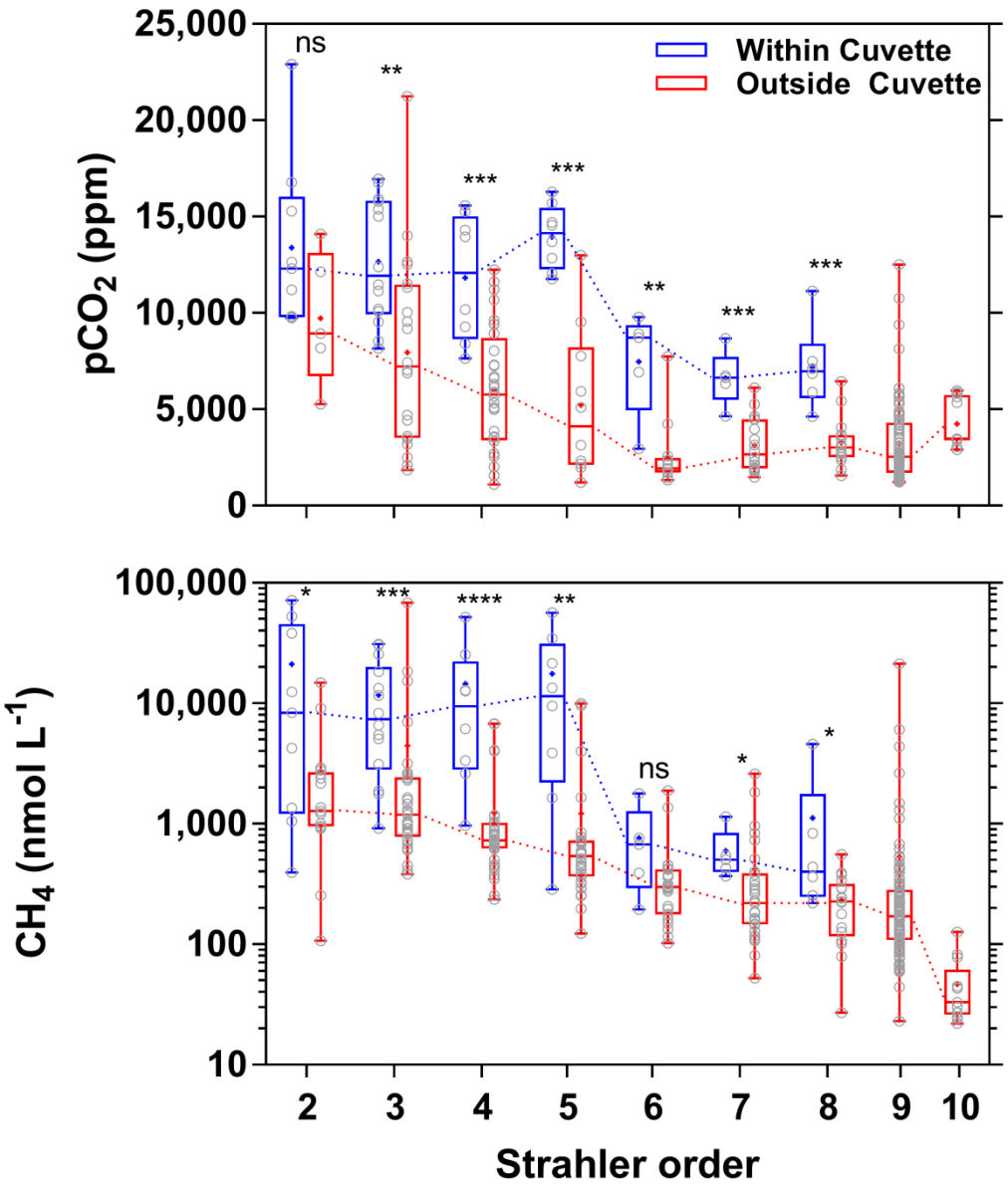
Results


pCO2 (ppm)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
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 →

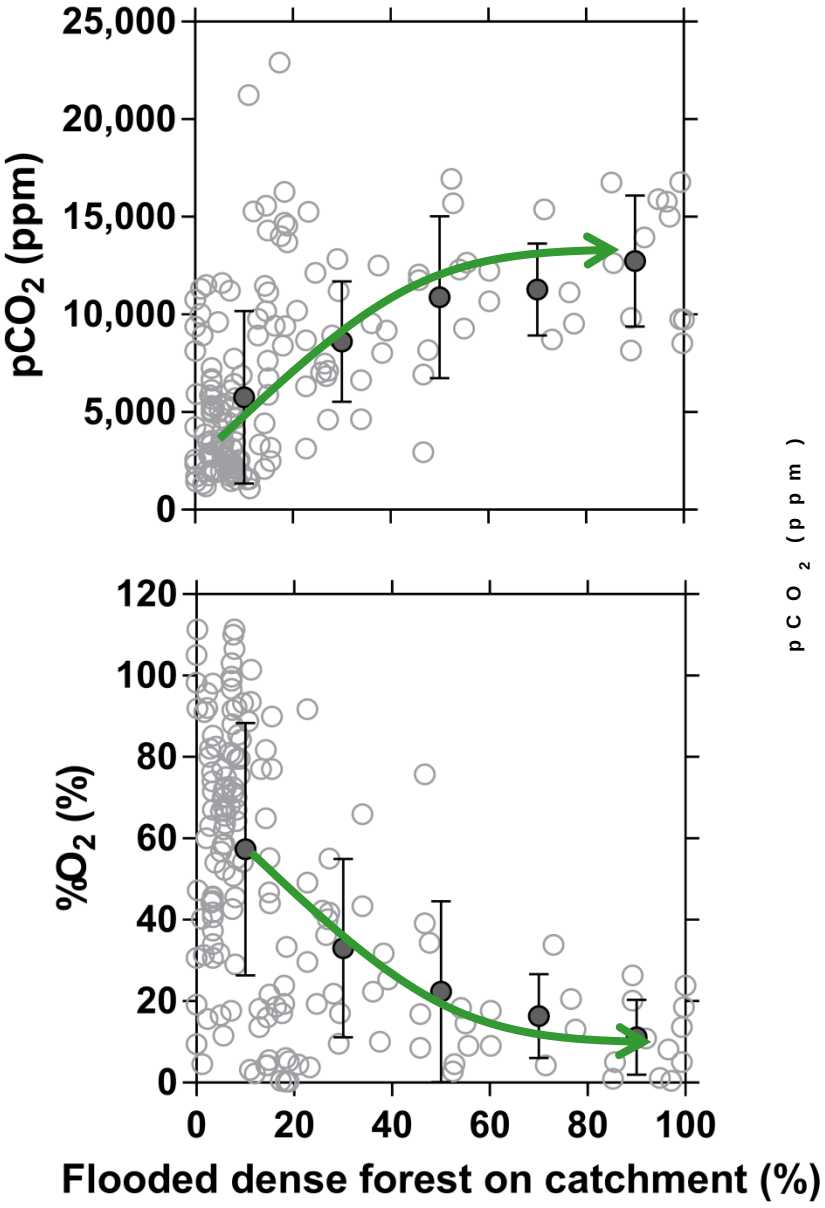
Results

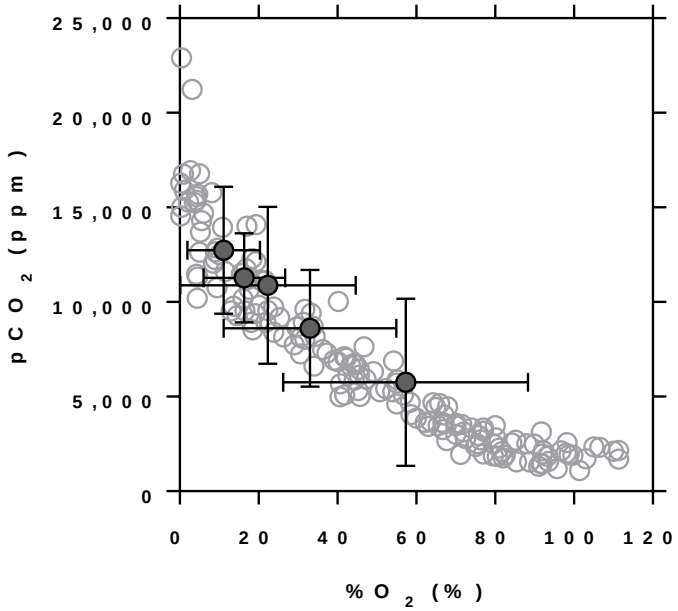

CH4 (nmol L-1)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Mainstem High W
Tributaries High W
« Cuvette Centrale »
(Wetland)
Savannah
0
200
400
600
800
1000
1200
1400
1600
← Downstream
Distance from Kinshasa (km)
Upstream →

Results


25,000
20,000
15,000
10,000
5,000
0
pCO2 (ppm)
ns
**
***
***
**
***
***
Within Cuvette
Outside Cuvette
100,000
10,000
1,000
100
10
CH4 (nmol L-1)
*
***
****
**
ns
*
*
2
3
4
5
6
7
8
9
10
Strahler order

Results

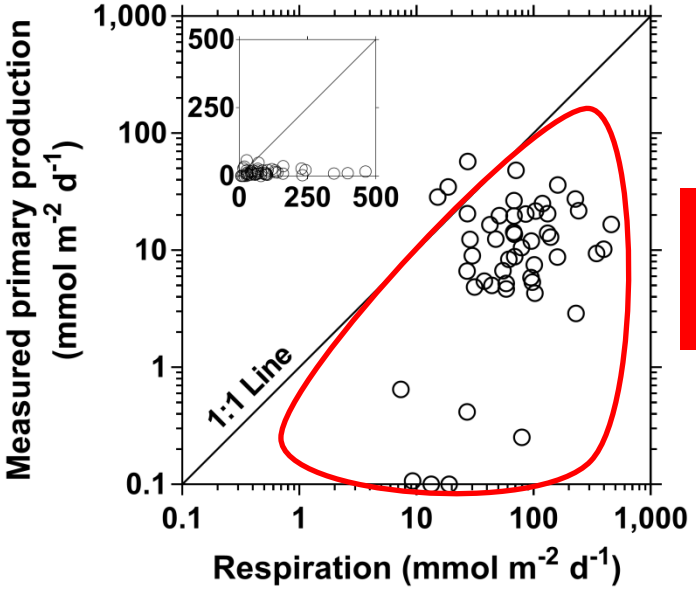

25,000
20,000
15,000
10,000
5,000
0
pCO2 (ppm)
120
100
80
60
40
20
0
%O2 (%)
0
20
40
60
80
100
Flooded dense forest on catchment (%)


25,000
20,000
15,000
10,000
5,000
0
pCO2 (ppm)
0
20
40
60
80
100
120
%O2 (%)

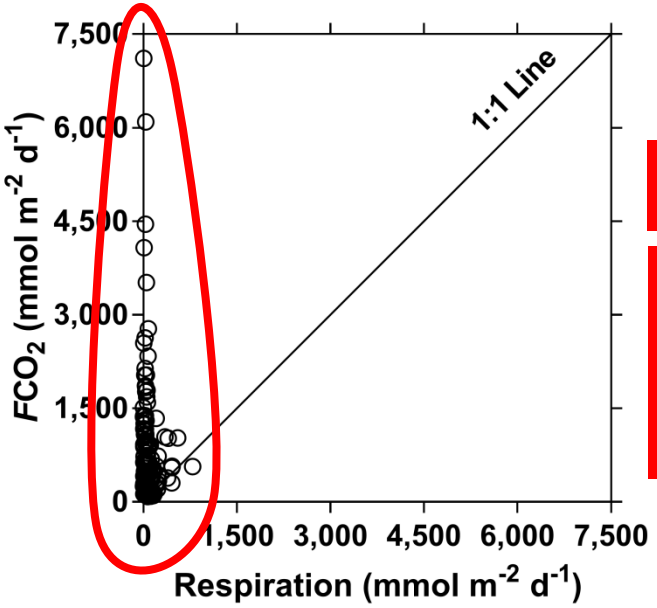
Results

Metabolism versus CO_2 emissions

Results



Net heterotrophic
R >> P



CO_2 emission >> R

Lateral CO_2 inputs
>>
in-stream R

Results

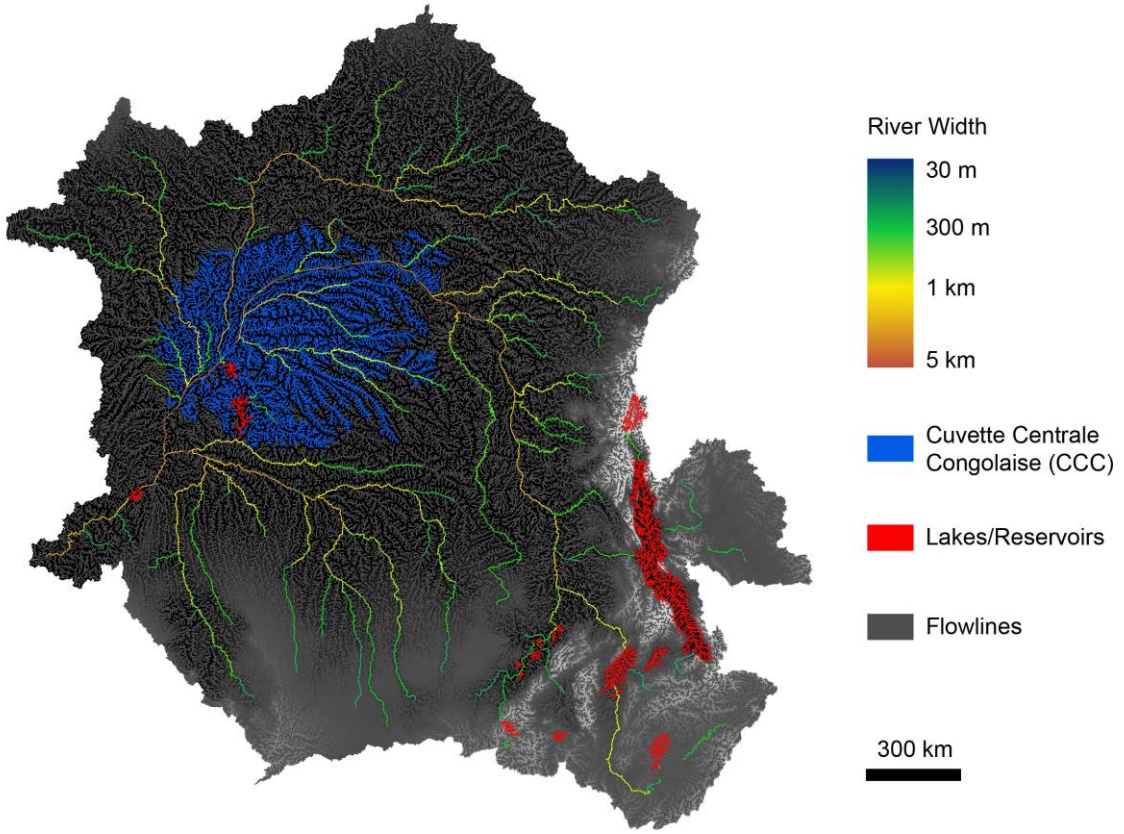
CO_2 and CH_4 in rivers & streams of the Congo seem to be mainly related to wetland inputs

Based on:

- **Spatial patterns (in/out of the Cuvette Centrale)**
- **Metabolic measurements**
- **Stable isotopic composition of DIC (not shown here)**

Results

CO_2 emission from Congo rivers-streams using a lot of GIS



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}

CO_2 emission from rivers 3 times higher than terrestrial NEE ???

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 GRÜNWALD§, 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 ?

Rate of Export C from flooded forest in Amazon (Abril et al.)
+
Surface of flooded forest in Congo

C leaked from wetlands = 400 TgC yr^{-1}

Further Reading

Biogeosciences, 16, 3801–3834, 2019

Variations in 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,a], Thibault Lambert[1,b], Cédric Morana[2], George H. Allen[3], Ernest Tambwe[4], Alfred Toengaho Sembaito[4], Taylor Mambo[4], José Nlandu Wabakhangazi[5], Jean-Pierre Descy[1], Cristian R. Teodoru[2,c], and Steven Bouillon[2]

Acknowledgments

European Research Council

fnrs LA LIBERTÉ DE CHERCHER

Belgian Science Policy Office belspo