Greenhouse gases in African inland waters

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Lab presentation

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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 analysers (Li-Cor & LGR)
- Continuous (surface) and discrete (profiles)
- Methane (CH_4) by gas chromatography (GC) & lazer analyser (LGR)
- Nitrous oxide (N_2O) concentration by GC
- N_2O isotopes by lazer spectrometry (LGR)
- Dimethylsulfide (DMS) by GC



Lab presentation

1) CO_2 in European coastal waters (1996-2001)

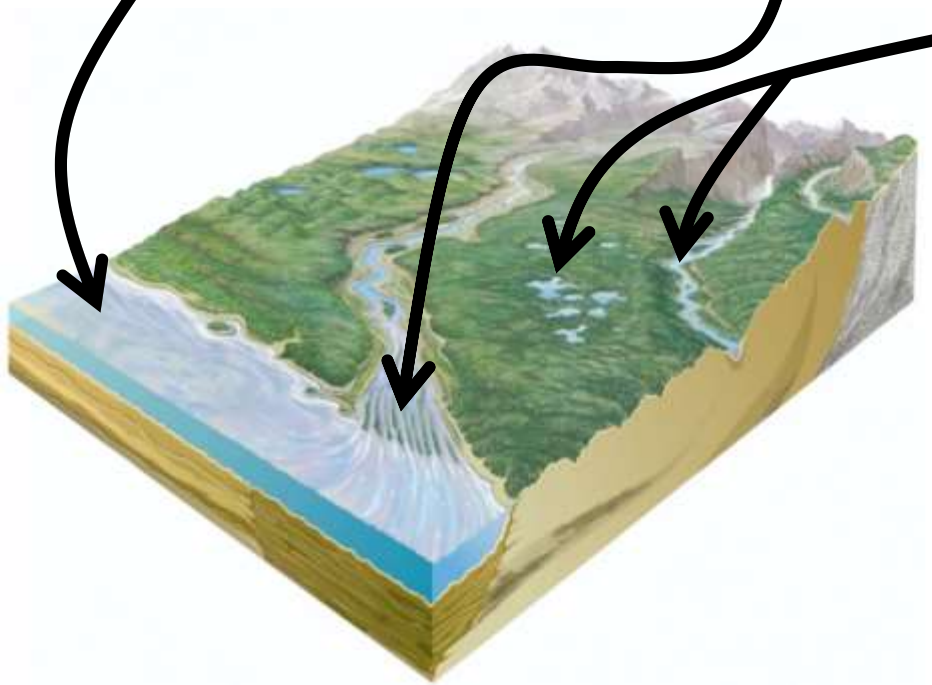
CO_2 fluxes in European continental shelves (North Sea, English Channel, Celtic Sea, Iberian coast)

2) CO_2 in tropical estuaries (2001-2007)

CO_2 data in India, Vietnam, Kenya, and Ivory Coast.

3) CO_2, CH_4 & N_2O in freshwaters (2007-present)

African lakes & rivers



1 – Climate change & global cycles of CO_2 & CH_4
2 – Production of CO_2 et CH_4 in rivers
3 – CO_2 & CH_4 in African rivers
4 – Comparaison with Meuse
5 – A few words on African Lakes

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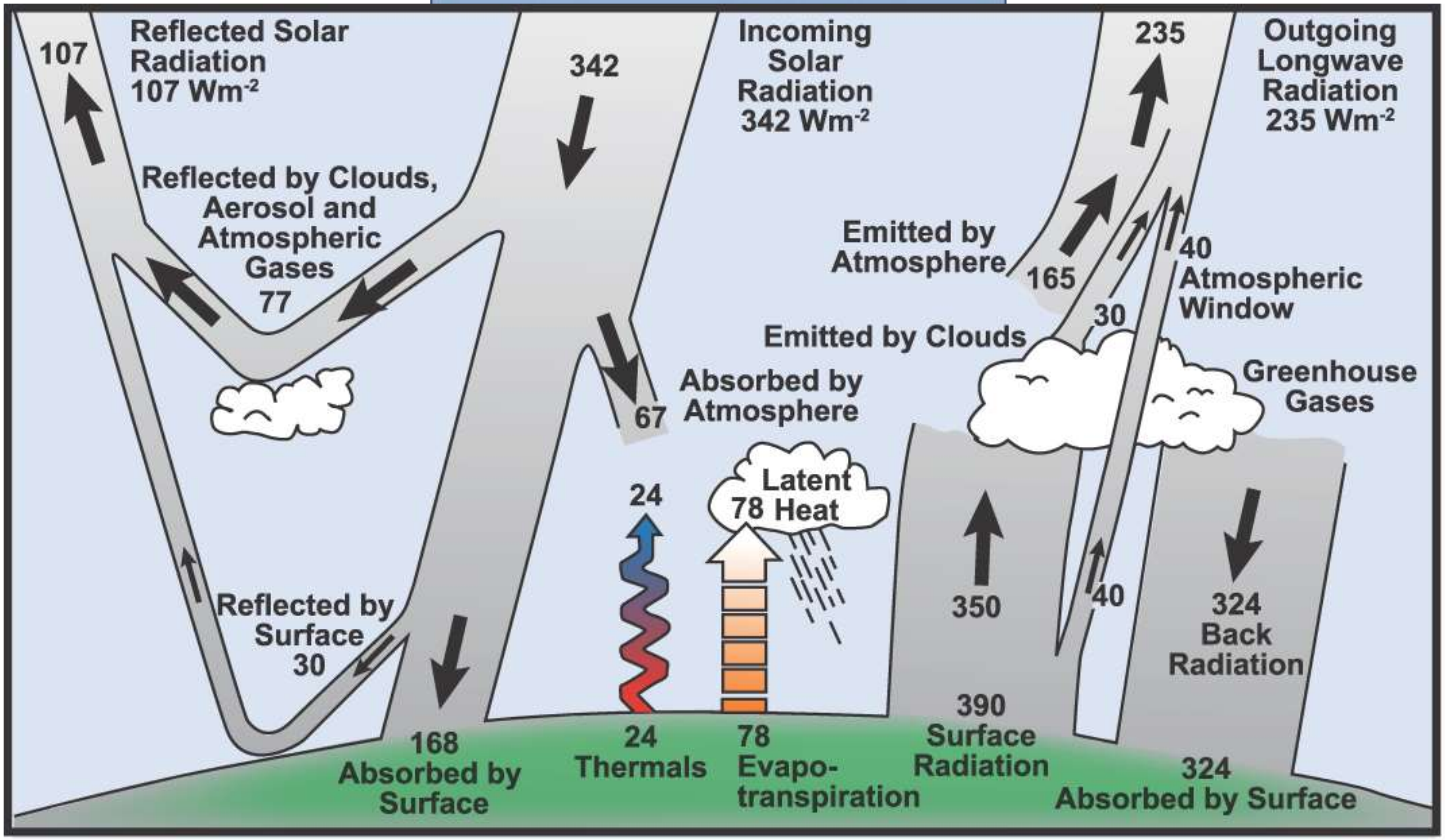
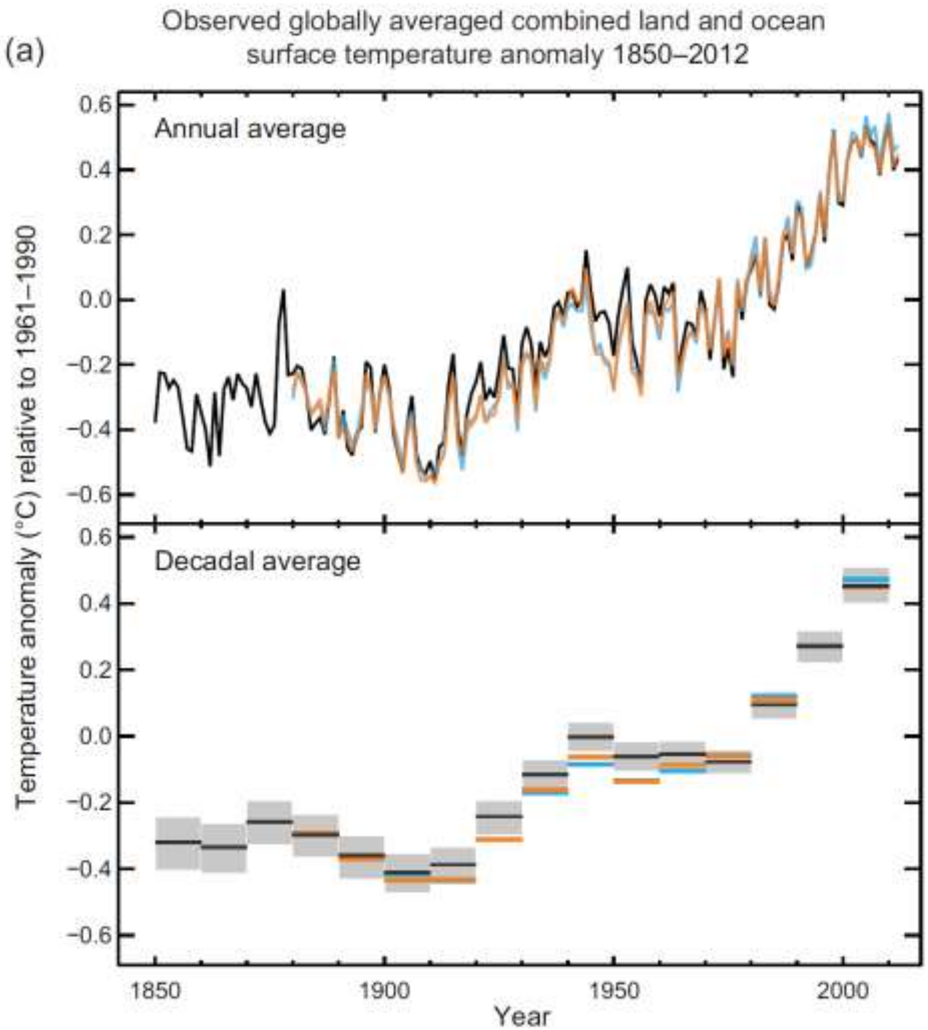
Introduction



Introduction



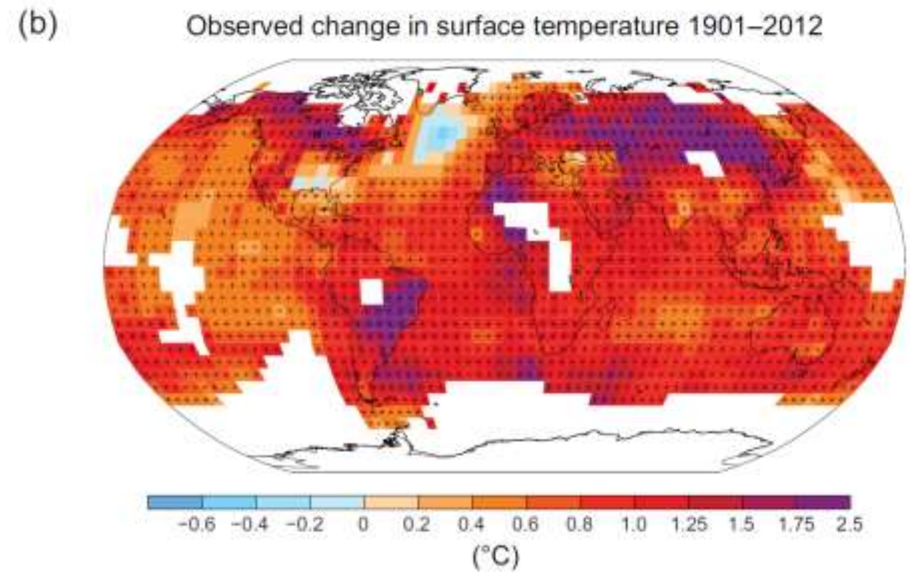
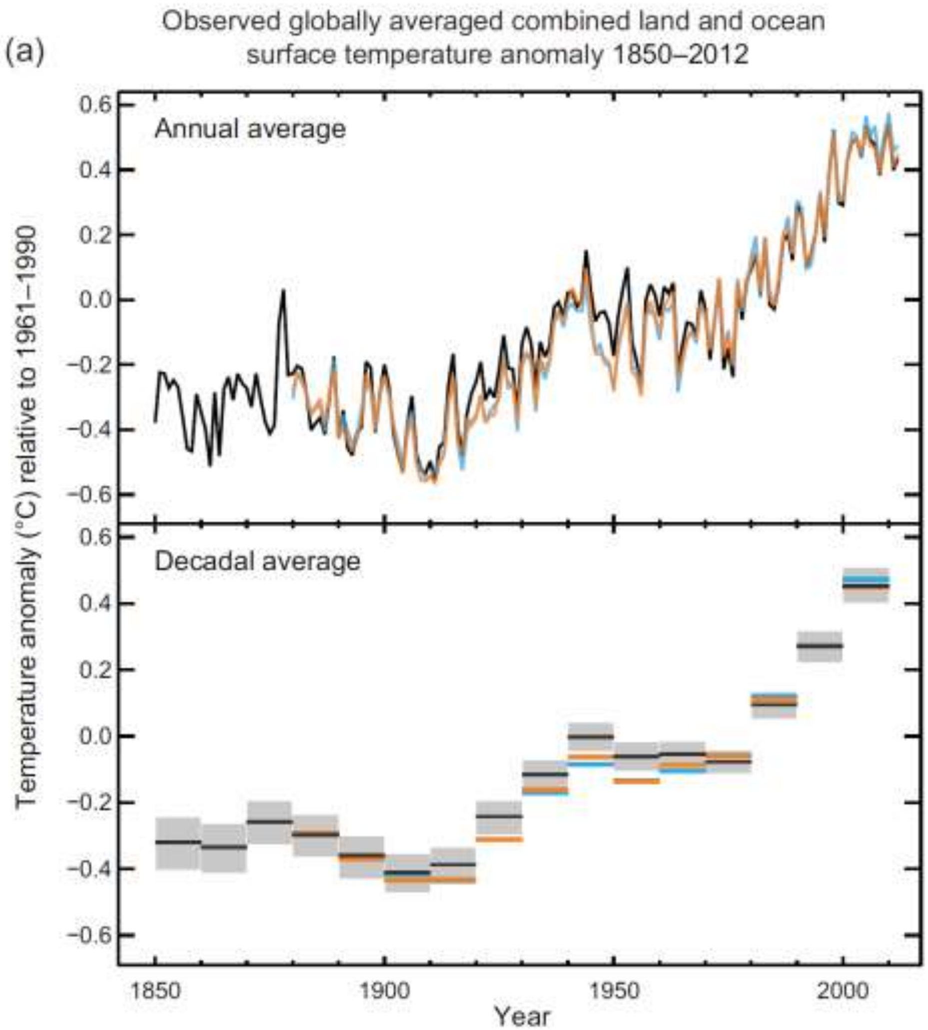
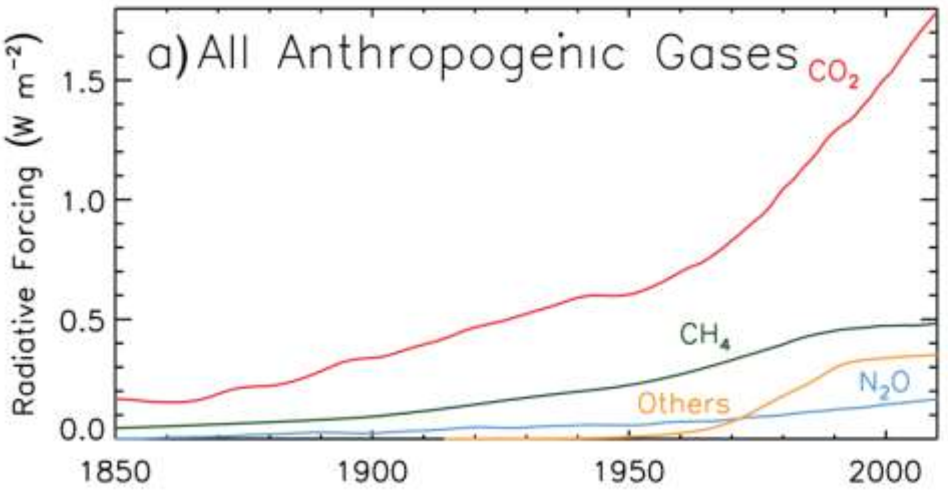


Figure SPM.1 | (a) Observed global mean combined land and ocean surface temperature anomalies, from 1850 to 2012 from three data sets. Top panel: annual mean values. Bottom panel: decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961–1990. (b) Map of the observed surface temperature change from 1901 to 2012 derived from temperature trends determined by linear regression from one dataset (orange line in panel a). Trends have been calculated where data availability permits a robust estimate (i.e., only for grid boxes with greater than 70% complete records and more than 20% data availability in the first and last 10% of the time period). Other areas are white. Grid boxes where the trend is significant at the 10% level are indicated by a + sign. For a listing of the datasets and further technical details see the Technical Summary Supplementary Material. {Figures 2.19–2.21; Figure TS.2}





CO_2 = 56%

CH_4 = 32%

HaloC = 6%

N_2O = 6%

Figure SPM.1 | (a) Observed global mean combined land and ocean surface temperature anomalies, from 1850 to 2012 from three data sets. Top panel: annual mean values. Bottom panel: decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961–1990. (b) Map of the observed surface temperature change from 1901 to 2012 derived from temperature trends determined by linear regression from one dataset (orange line in panel a). Trends have been calculated where data availability permits a robust estimate (i.e., only for grid boxes with greater than 70% complete records and more than 20% data availability in the first and last 10% of the time period). Other areas are white. Grid boxes where the trend is significant at the 10% level are indicated by a + sign. For a listing of the datasets and further technical details see the Technical Summary Supplementary Material. {Figures 2.19–2.21; Figure TS.2}

Introduction

Carbon dioxide (CO_2)

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

$9.1 \pm 0.5\ PgC\ y^{-1}$

+

$0.9 \pm 0.7\ PgC\ y^{-1}$

$5.0 \pm 0.2\ PgC\ y^{-1}$
50%

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

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

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Introduction

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

9.1 ± 0.5 PgC y^{-1}

United Nations
Framework Convention on
Climate Change

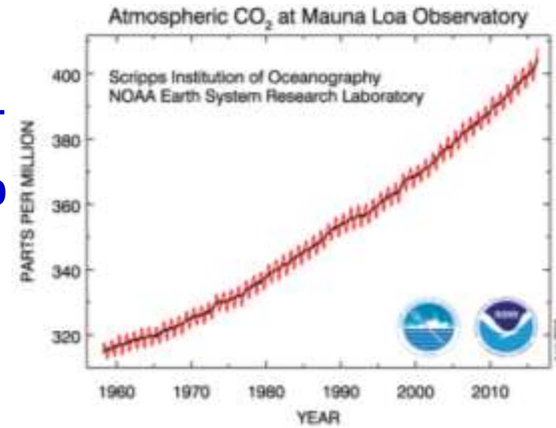
National Reports

+

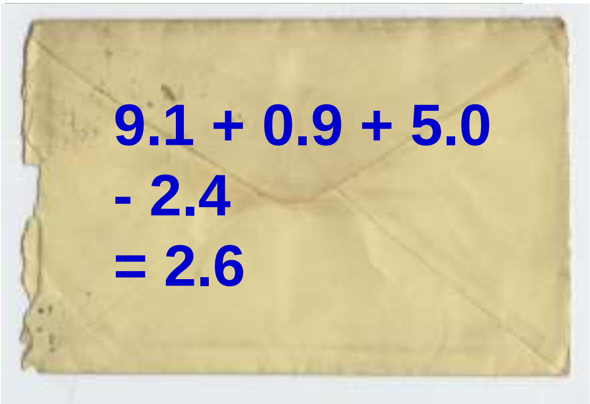
0.9 ± 0.7 PgC y^{-1}

Food and Agriculture
Organization of the
United Nations

5.0 ± 0.2 PgC y^{-1}
50%

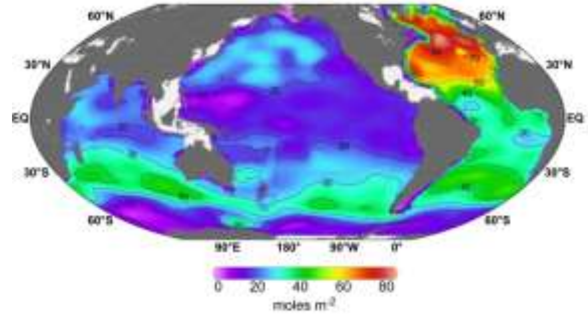


2.6 ± 1.0 PgC y^{-1}
26%
Calculated as the residual
of all other flux components



9.1 + 0.9 + 5.0
- 2.4
= 2.6

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



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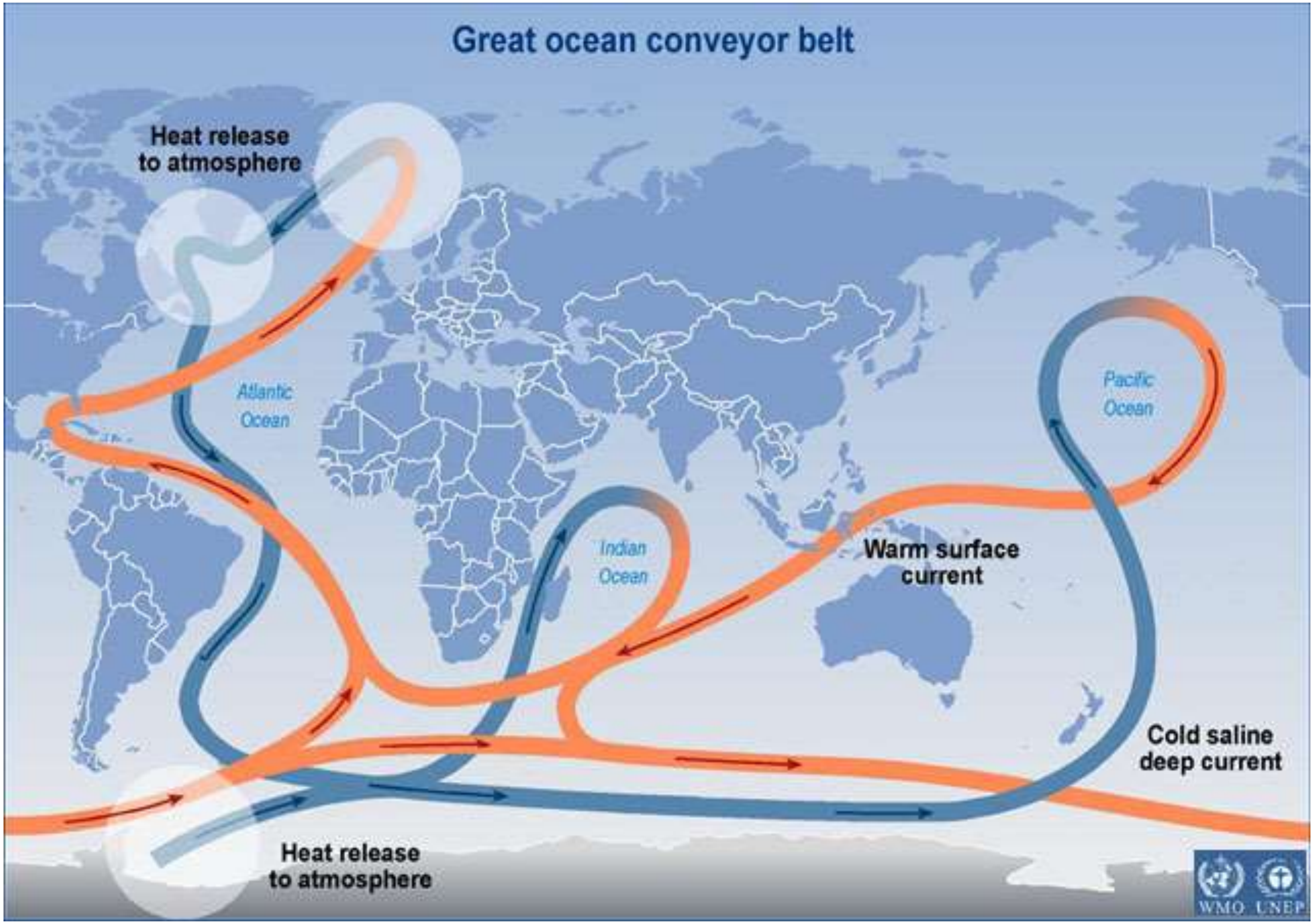
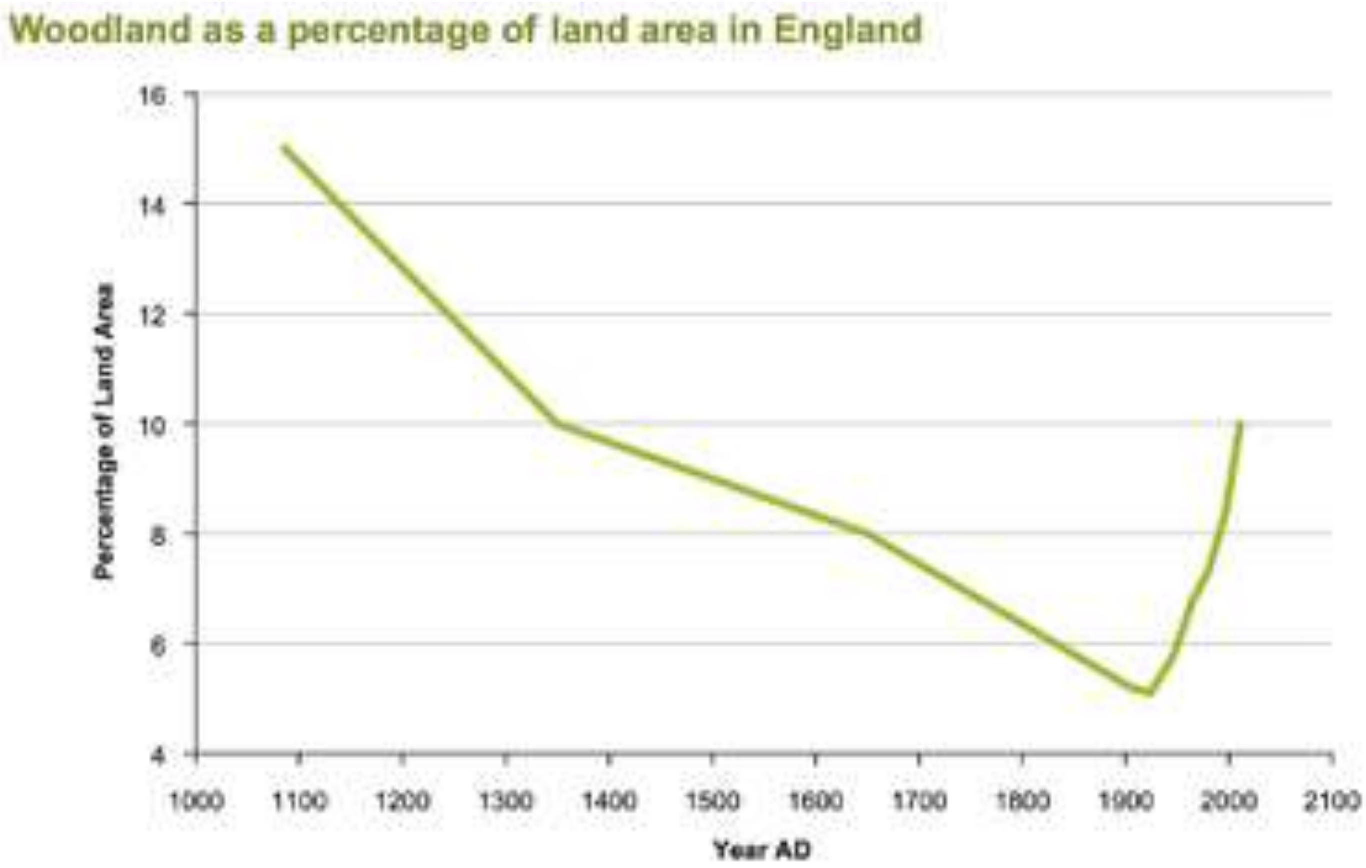
Introduction

Cold water	**=**	**absorption of CO_2 (Henry's Law)**
	=	**dense (deep-water formation)**
	=	**long-term storage (coupled to $CaCO_3$ dissol.)**

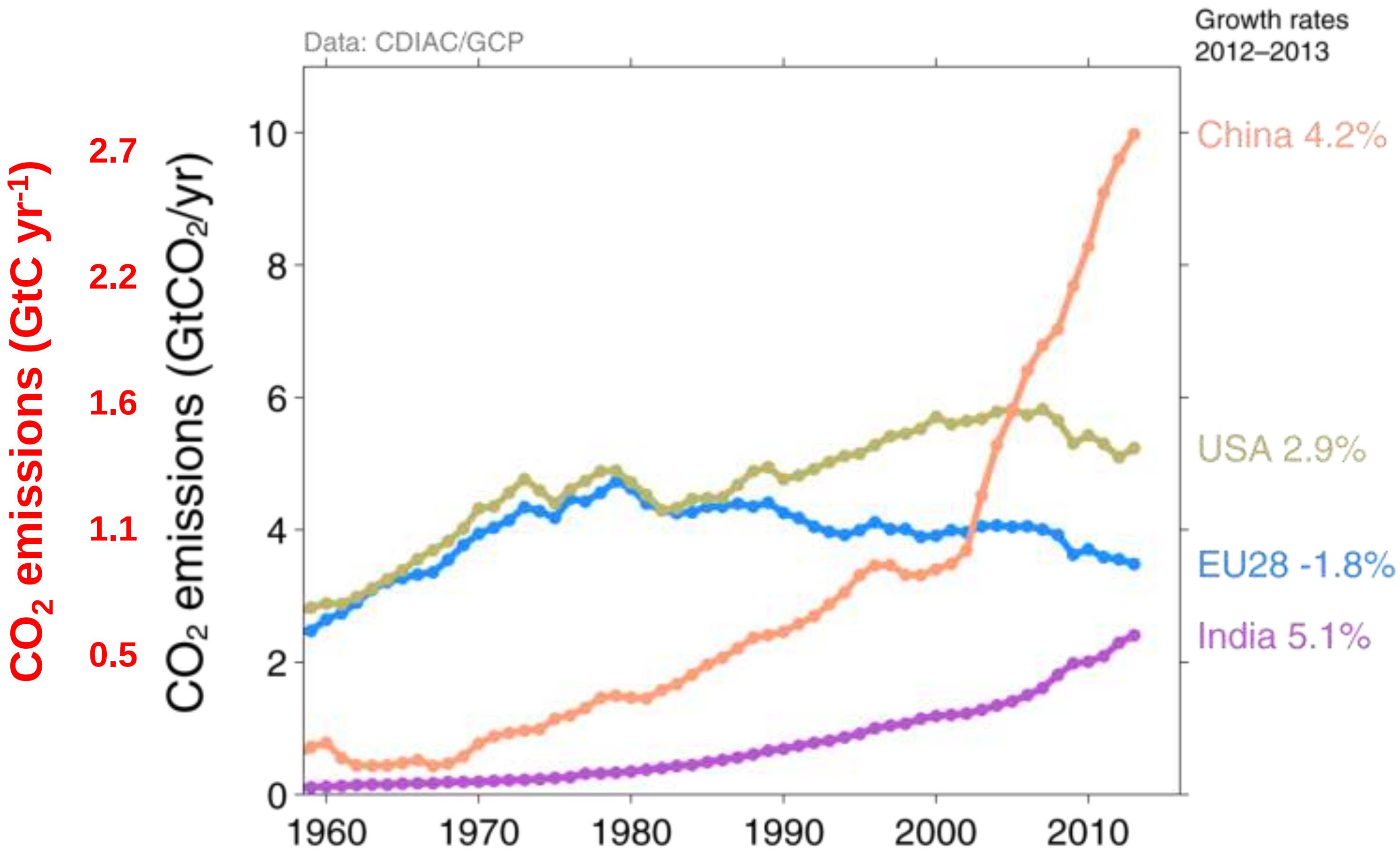


Why is the terrestrial biosphere a CO_2 sink ?
= reforestation



Introduction

The top four emitters in 2013 covered 58% of global emissions
China (28%), United States (14%), EU28 (10%), India (7%)



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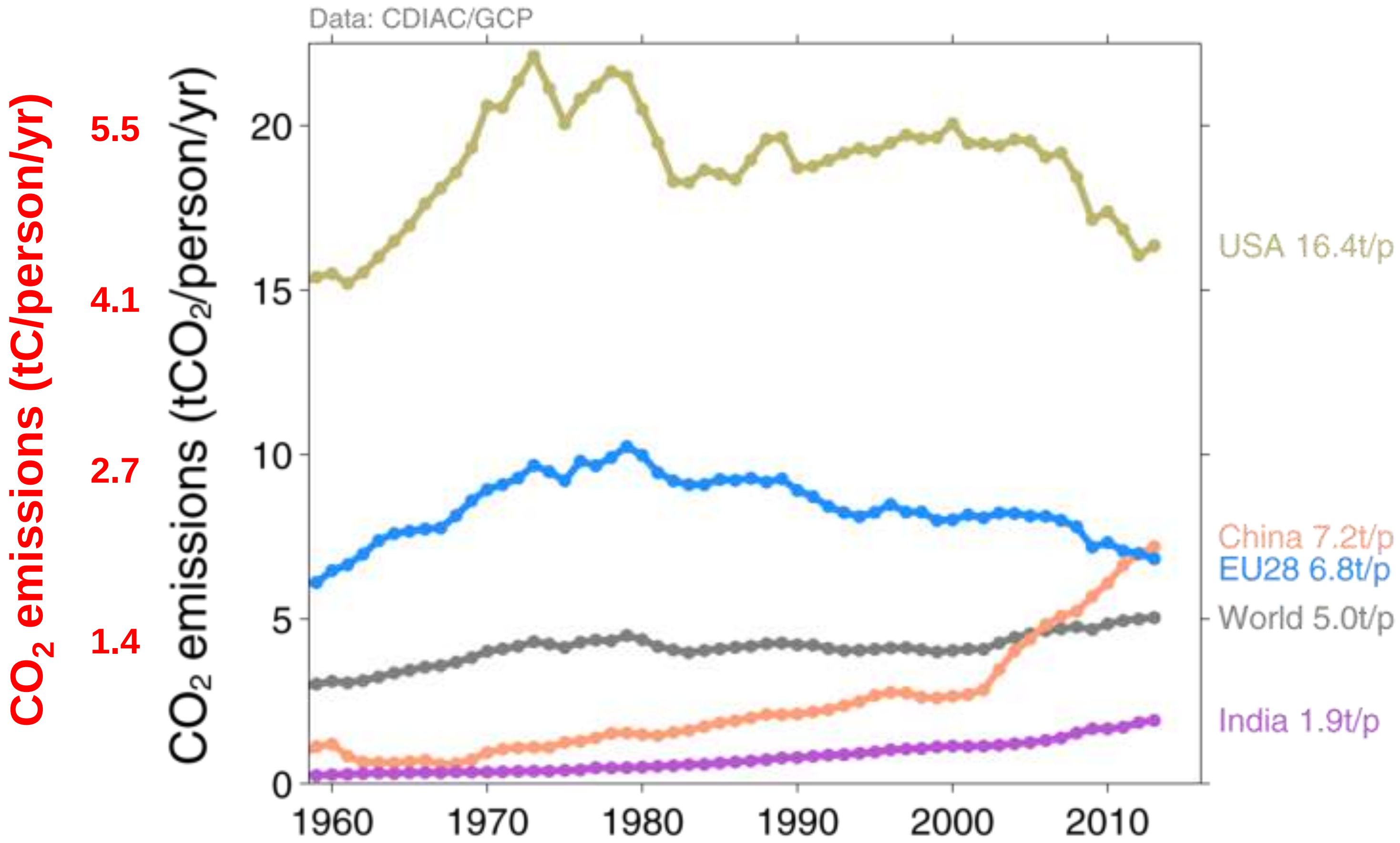
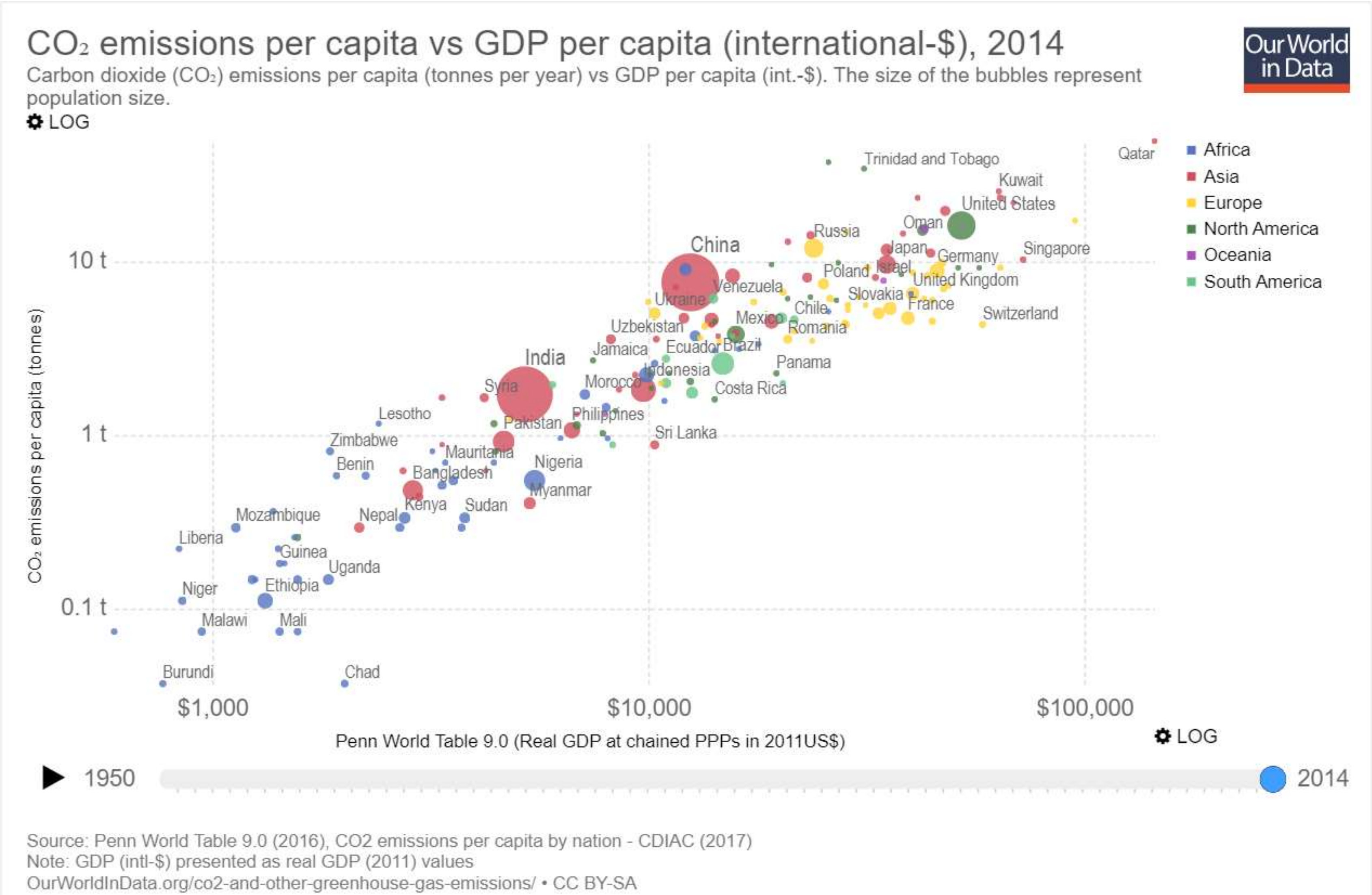
China's per capita emissions have passed the EU28 and are 45% above the global average



www.globalcarbonproject.org/

Introduction



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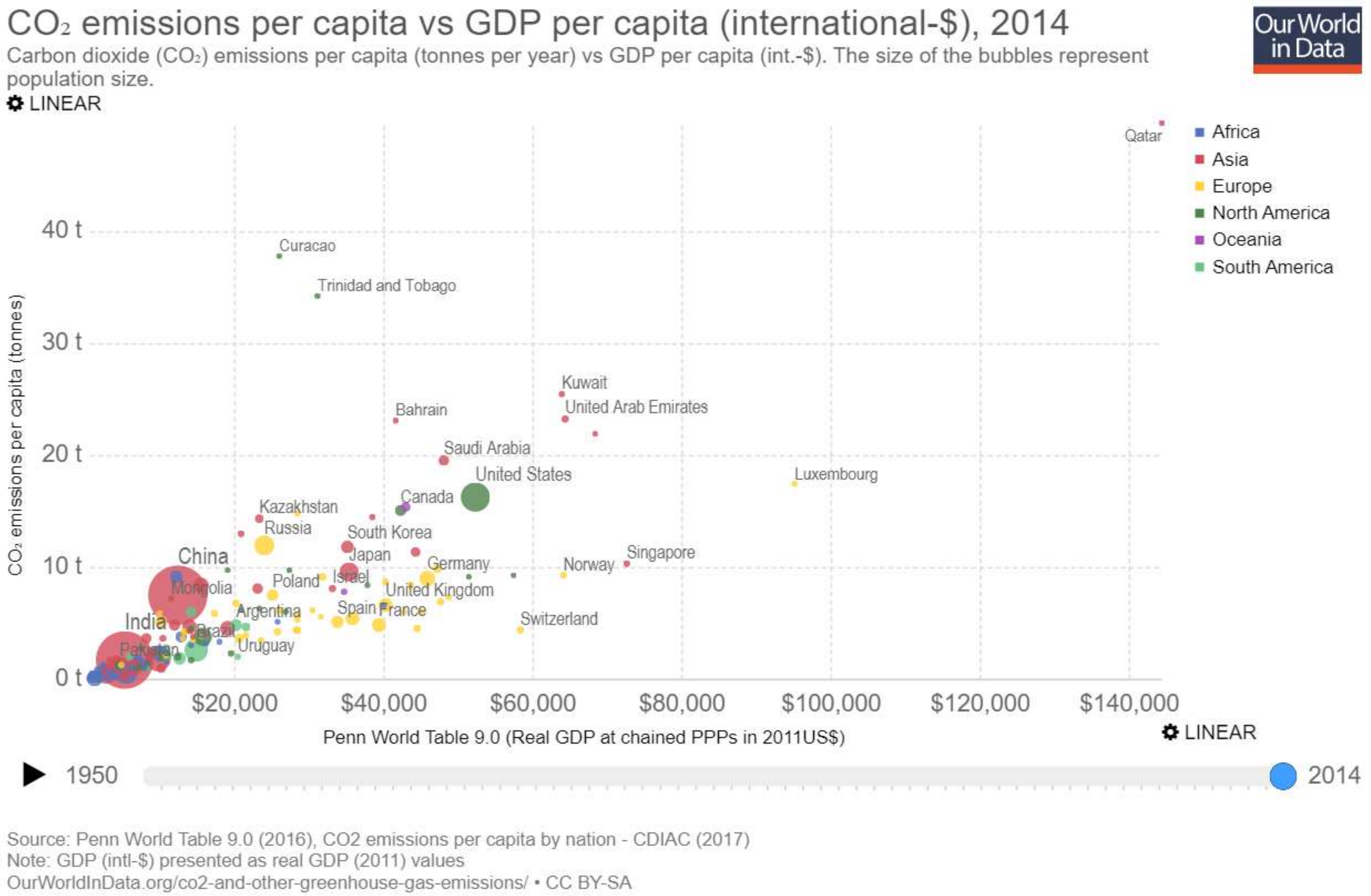

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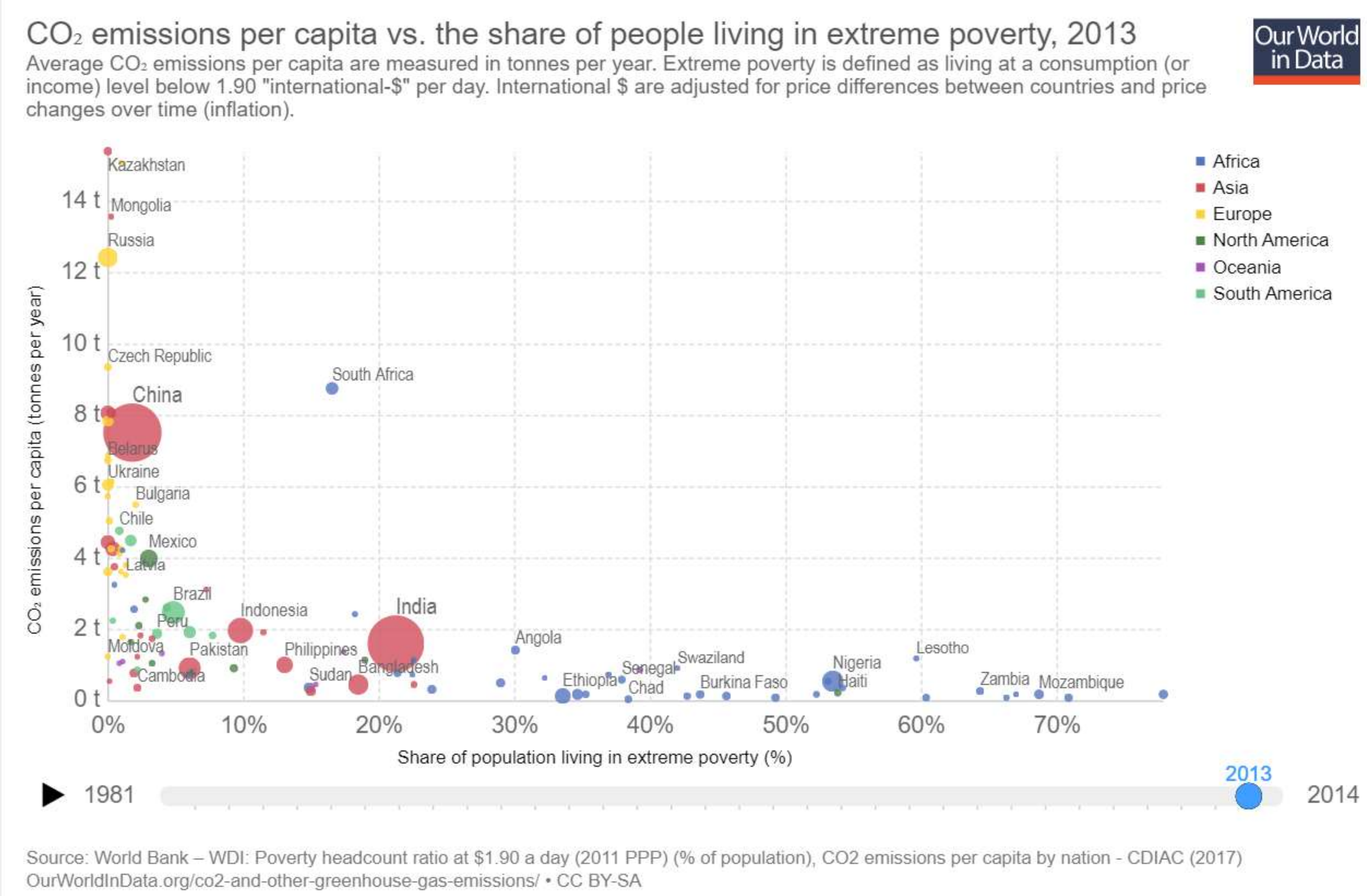
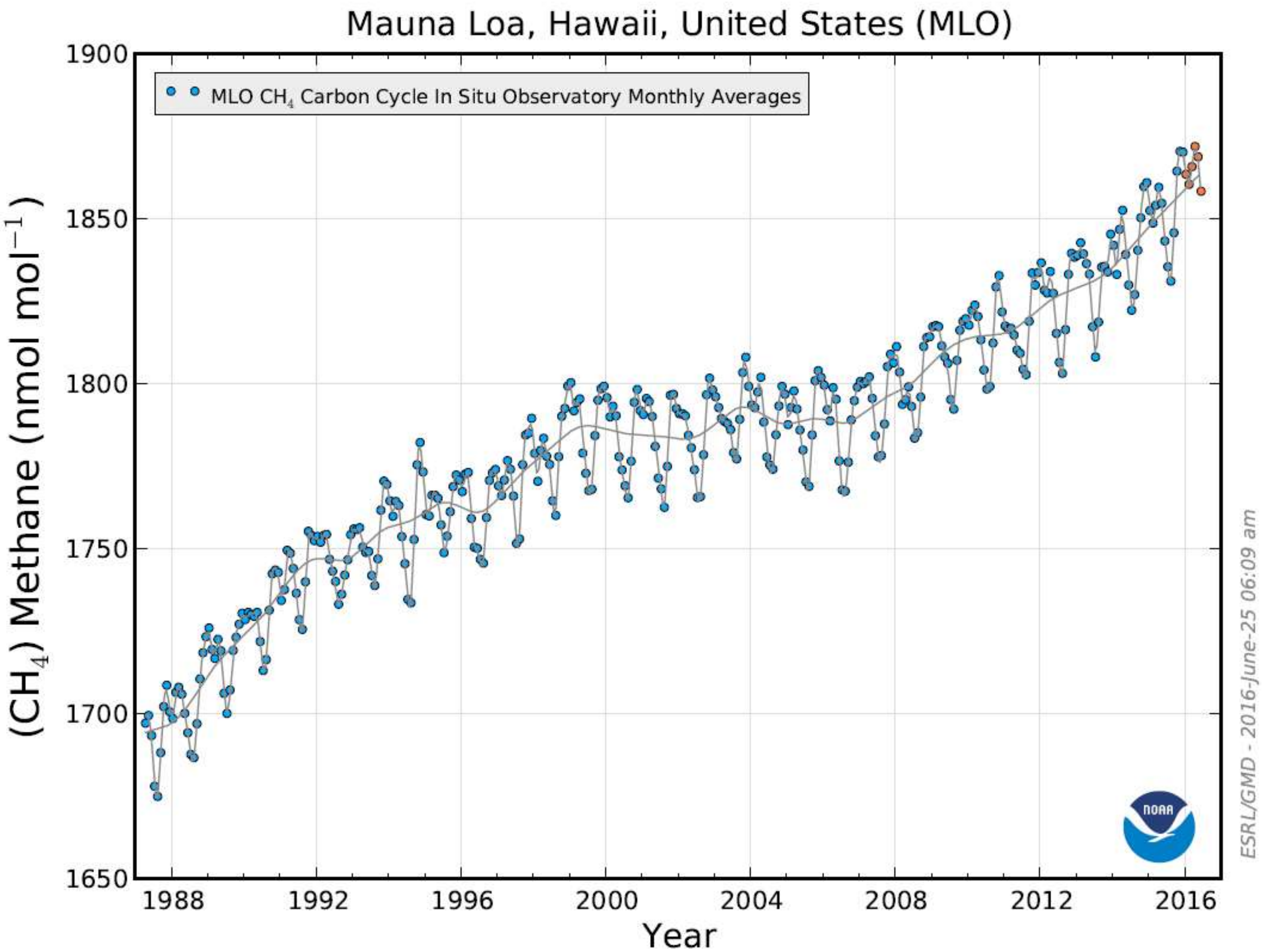
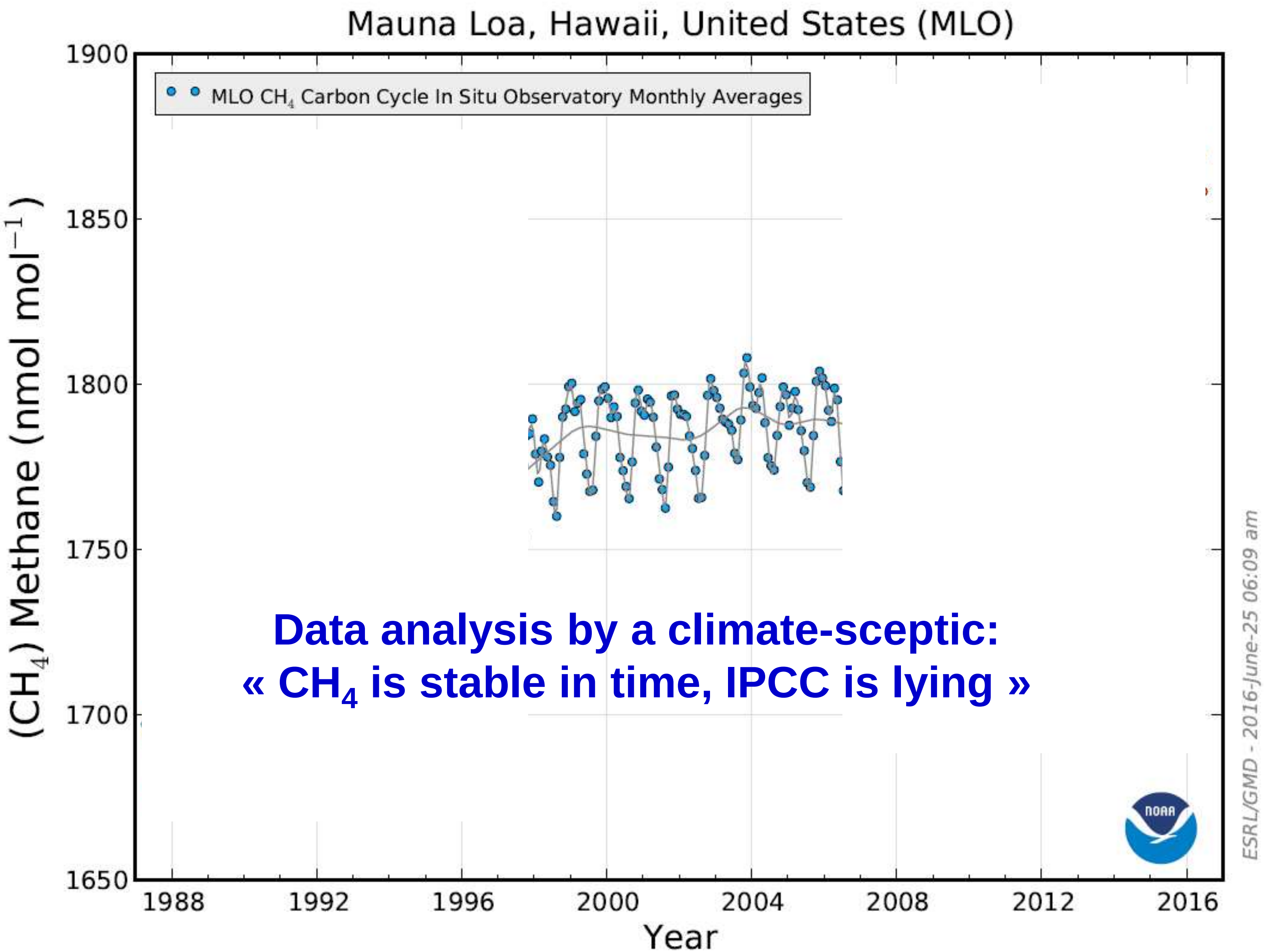


Methane (CH_4)

Introduction

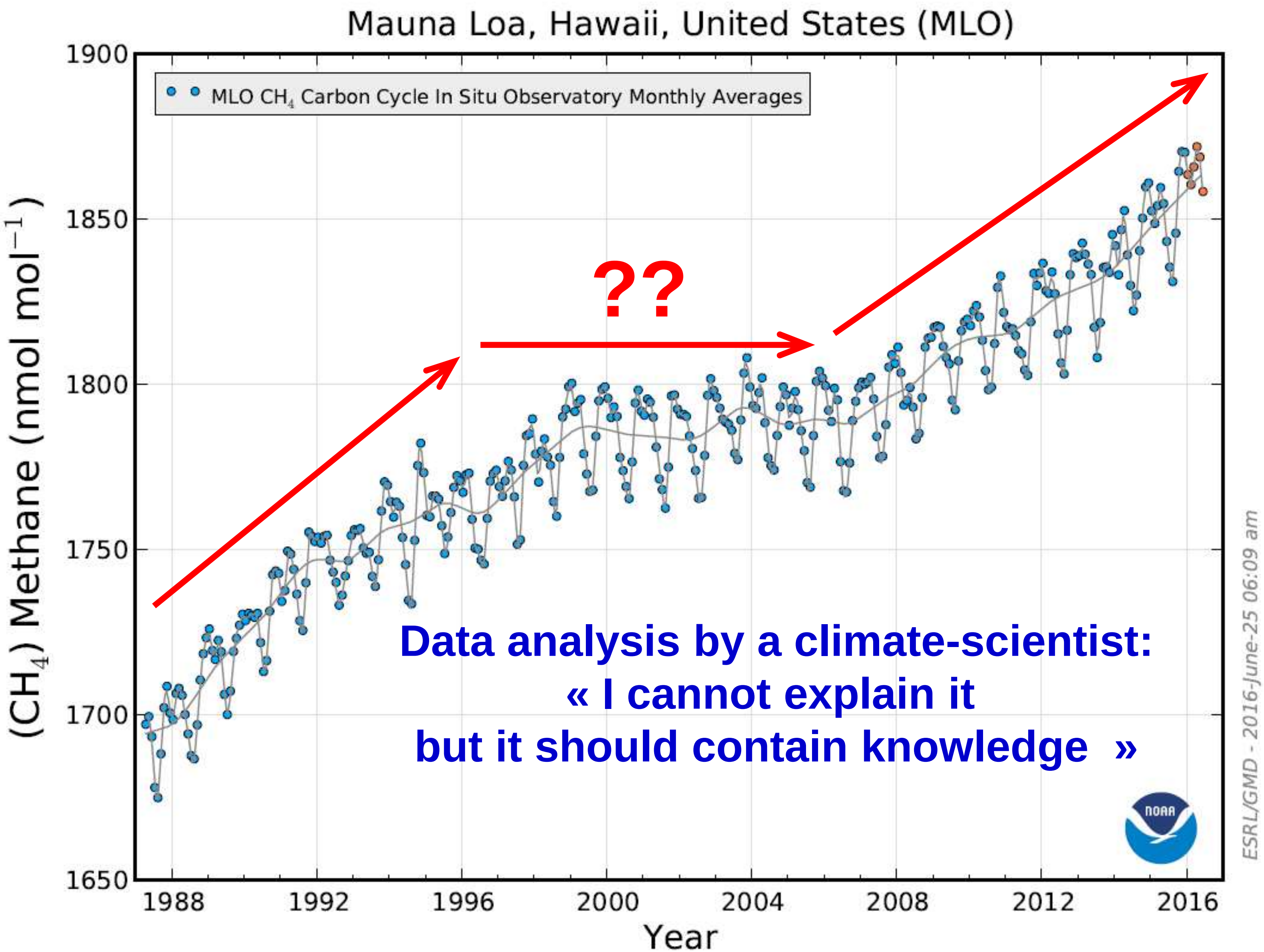


Introduction

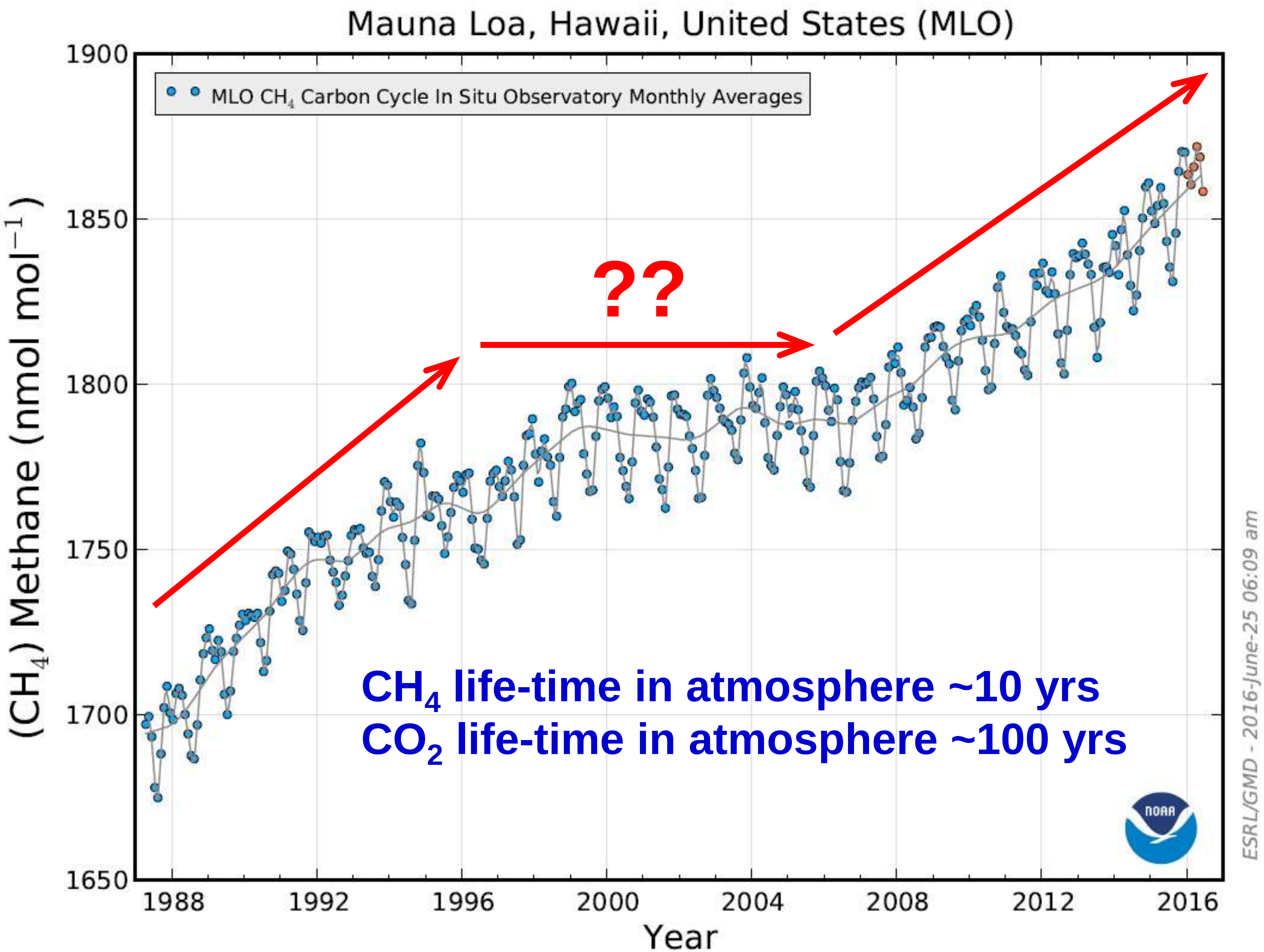


Data analysis by a climate-sceptic:
« CH_4 is stable in time, IPCC is lying »

Introduction

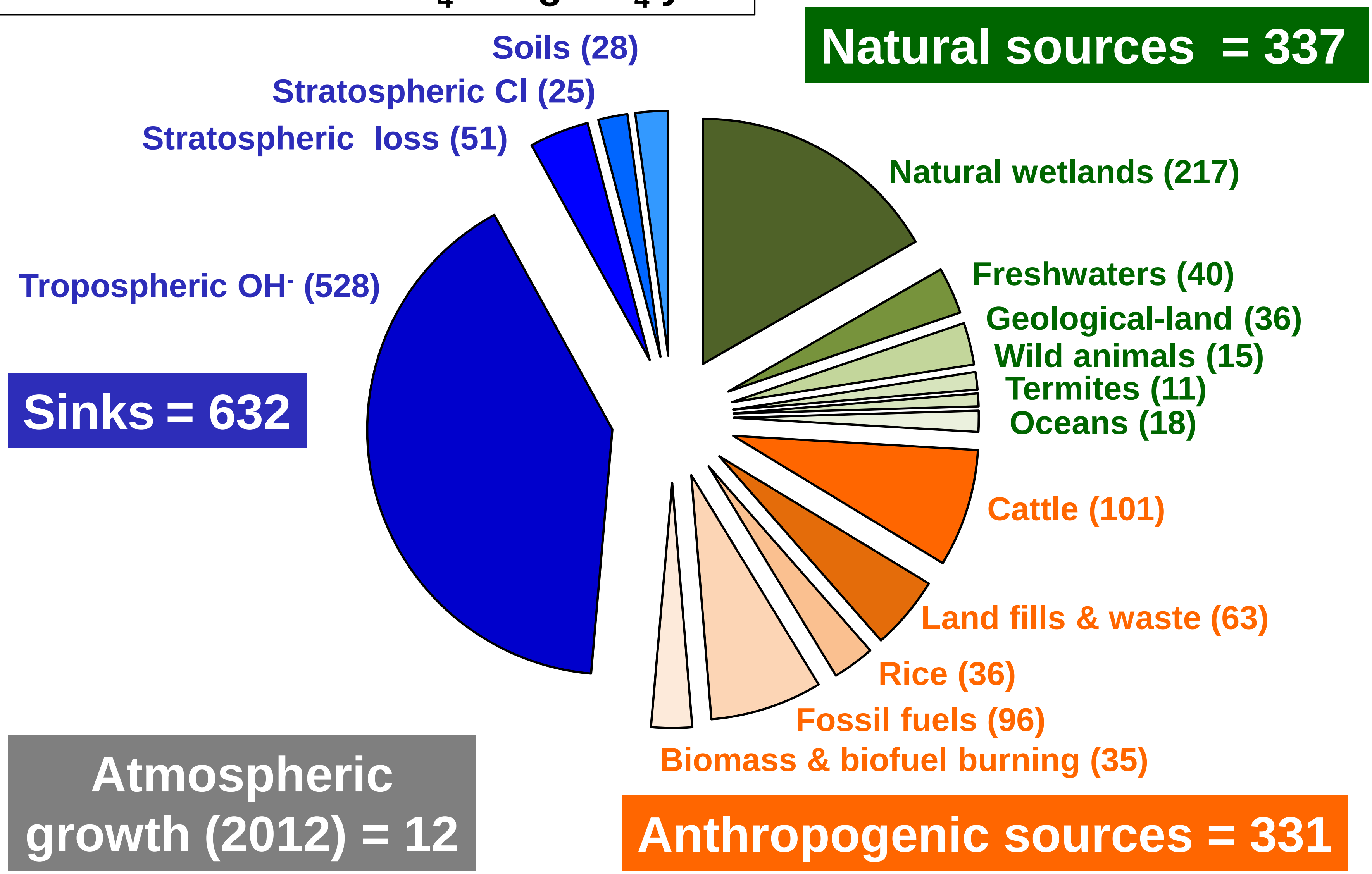


Introduction



CH_4 life-time in atmosphere ~10 yrs
CO_2 life-time in atmosphere ~100 yrs

Sources and sinks of CH_4 in Tg CH_4 yr^{-1}



Kirschke et al. (2013) Nature Geoscience, 6, 813-823

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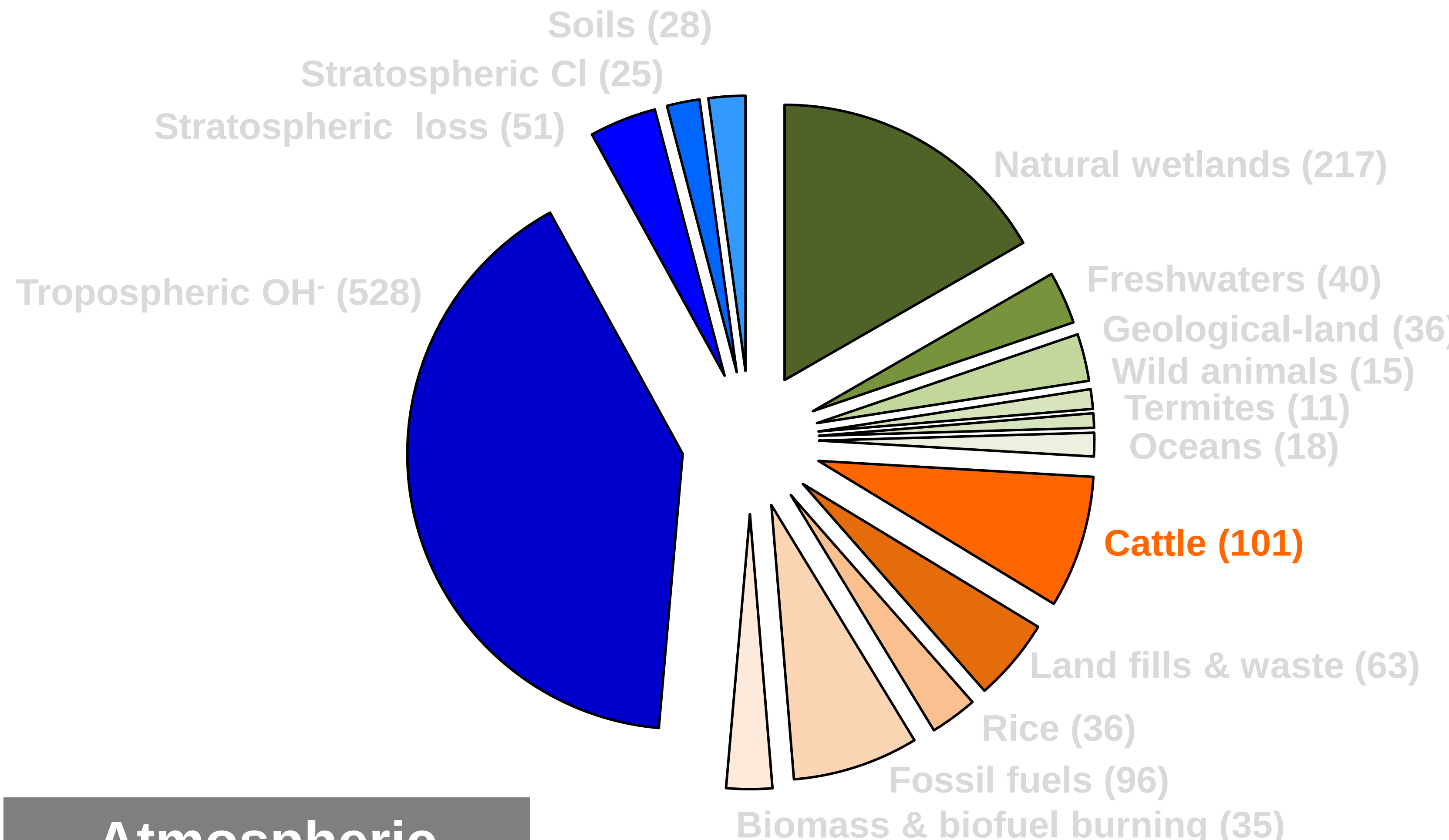
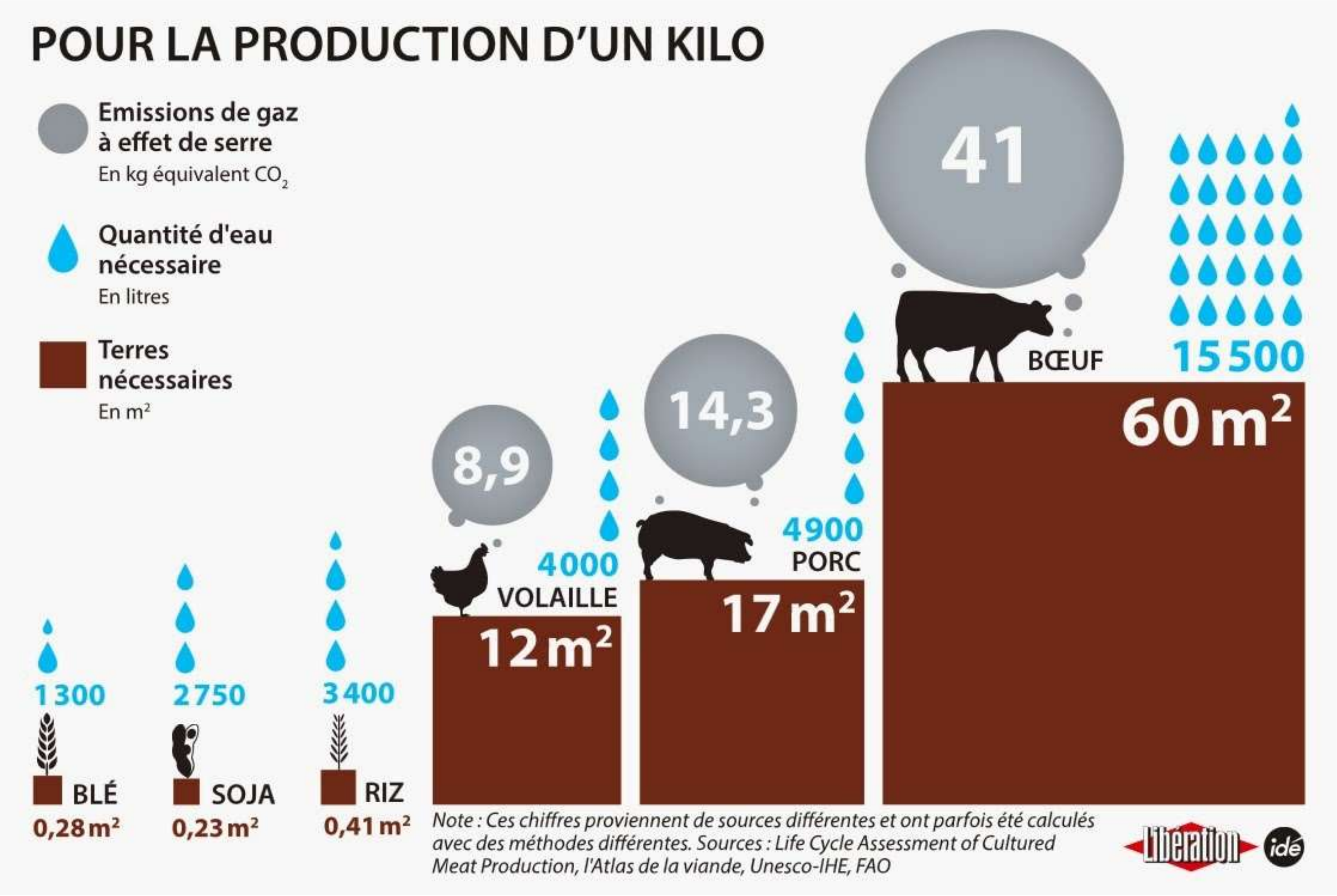


Atmospheric growth (2012) = 12

Kirschke et al. (2013) Nature Geoscience, 6, 813-823

Introduction



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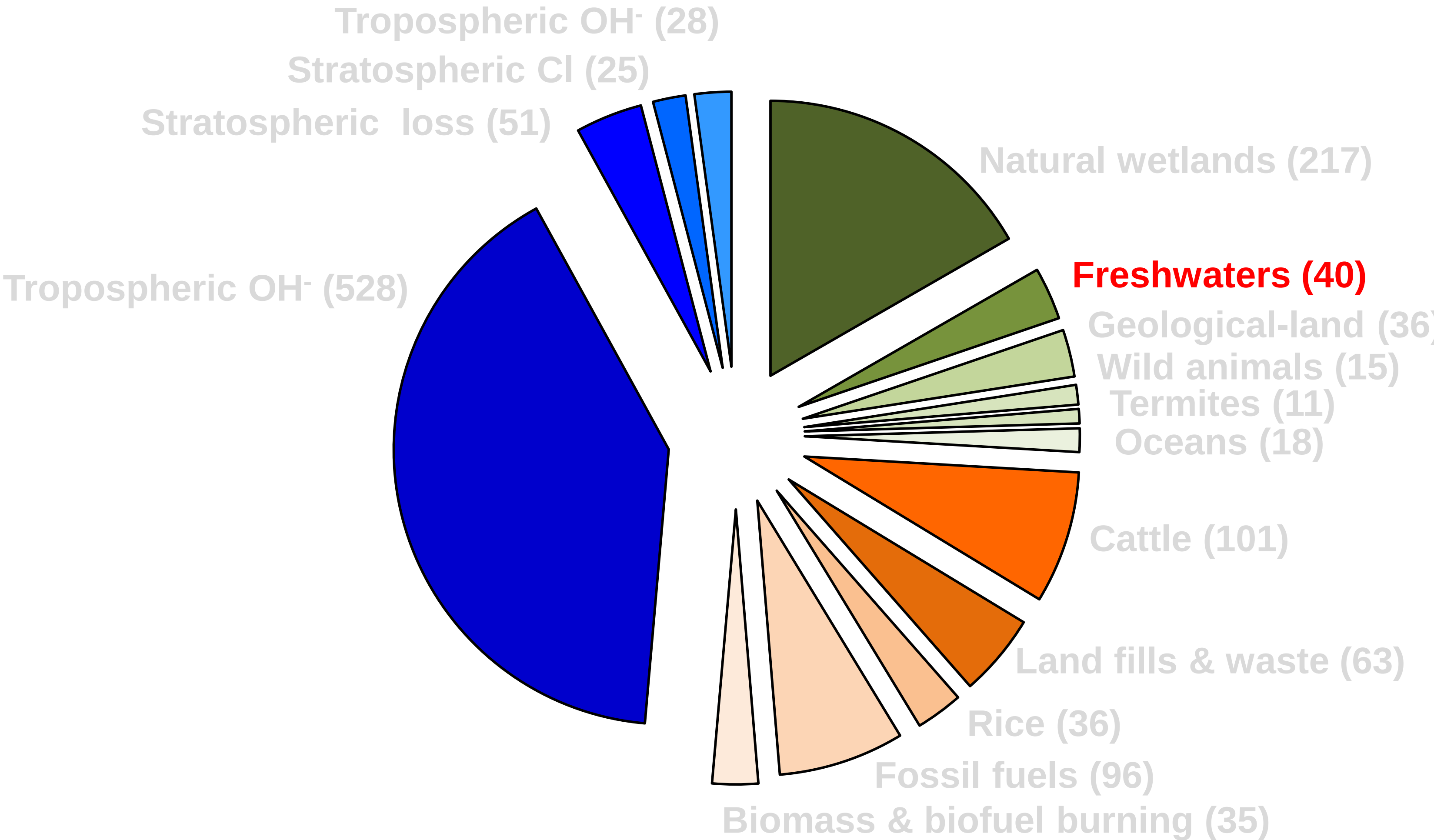

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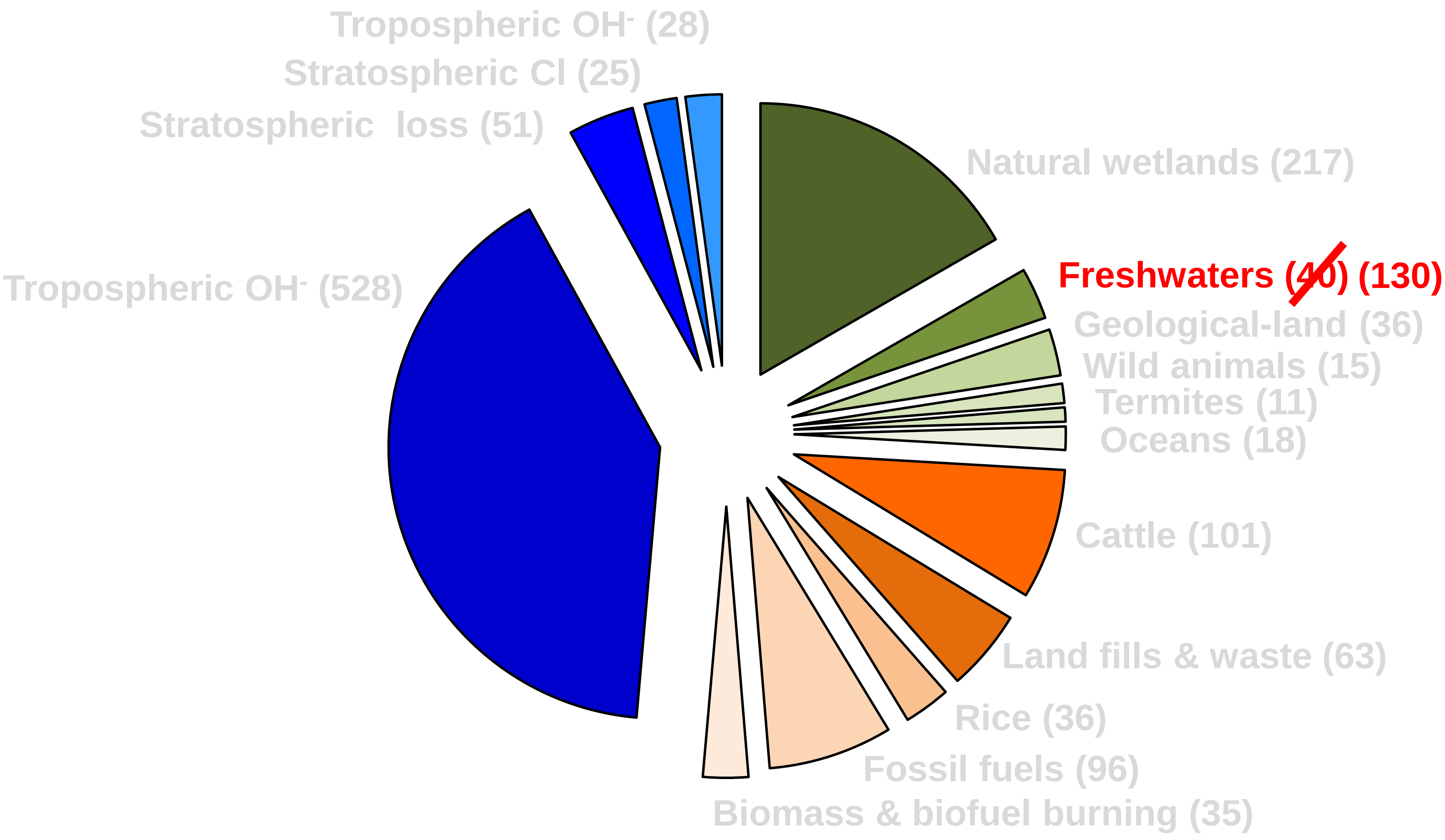

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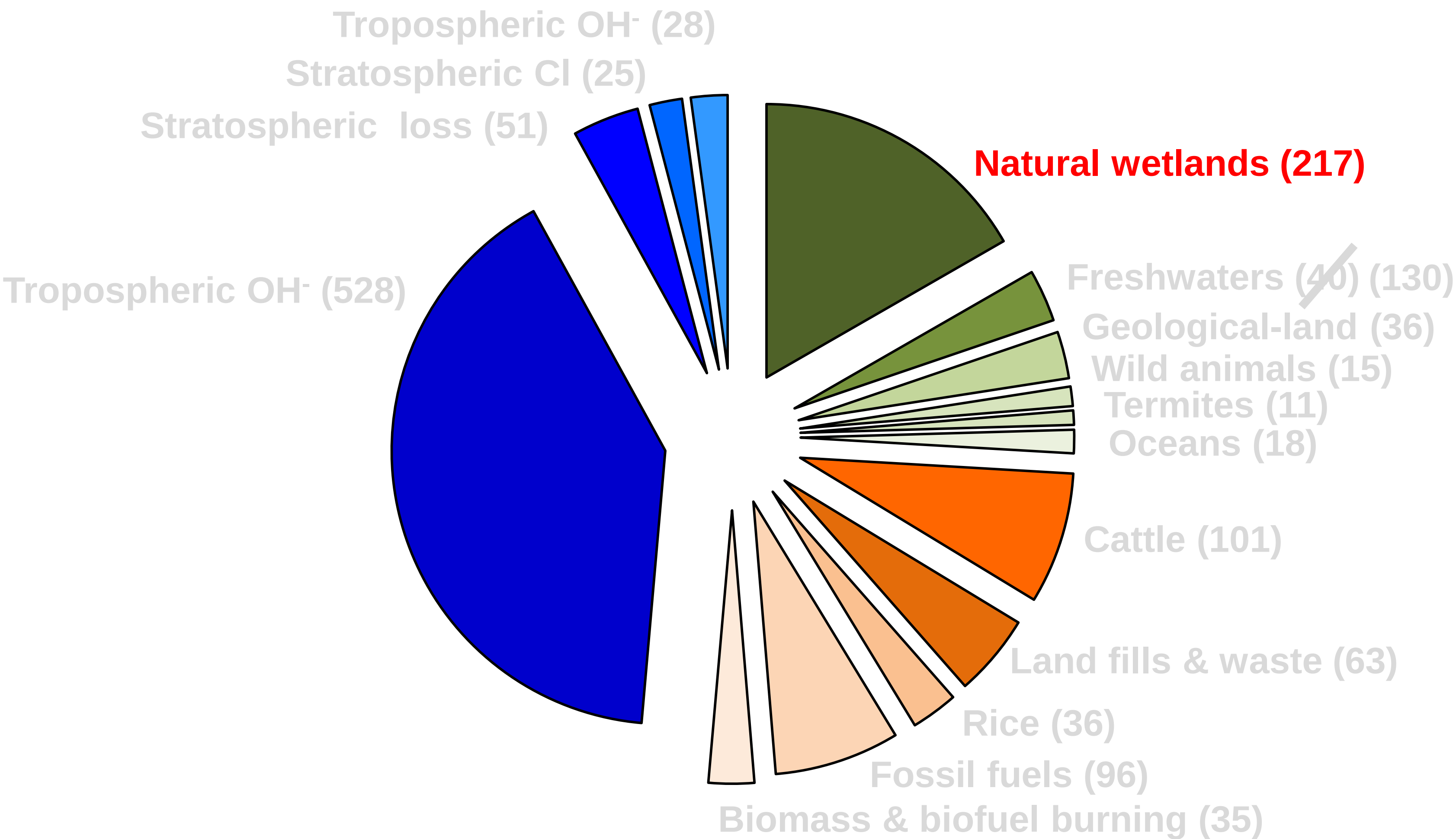

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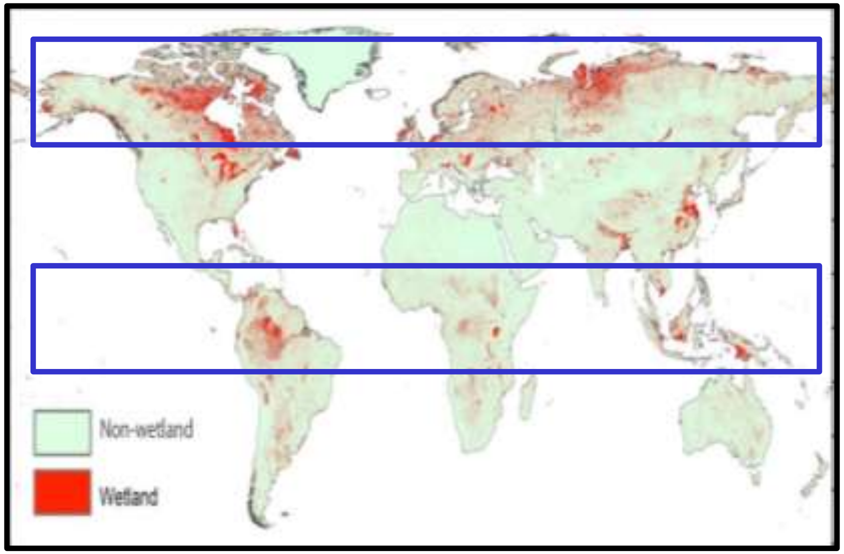
Introduction

peatlands



aquatic macrophytes

flooded forest - swamps

Introduction

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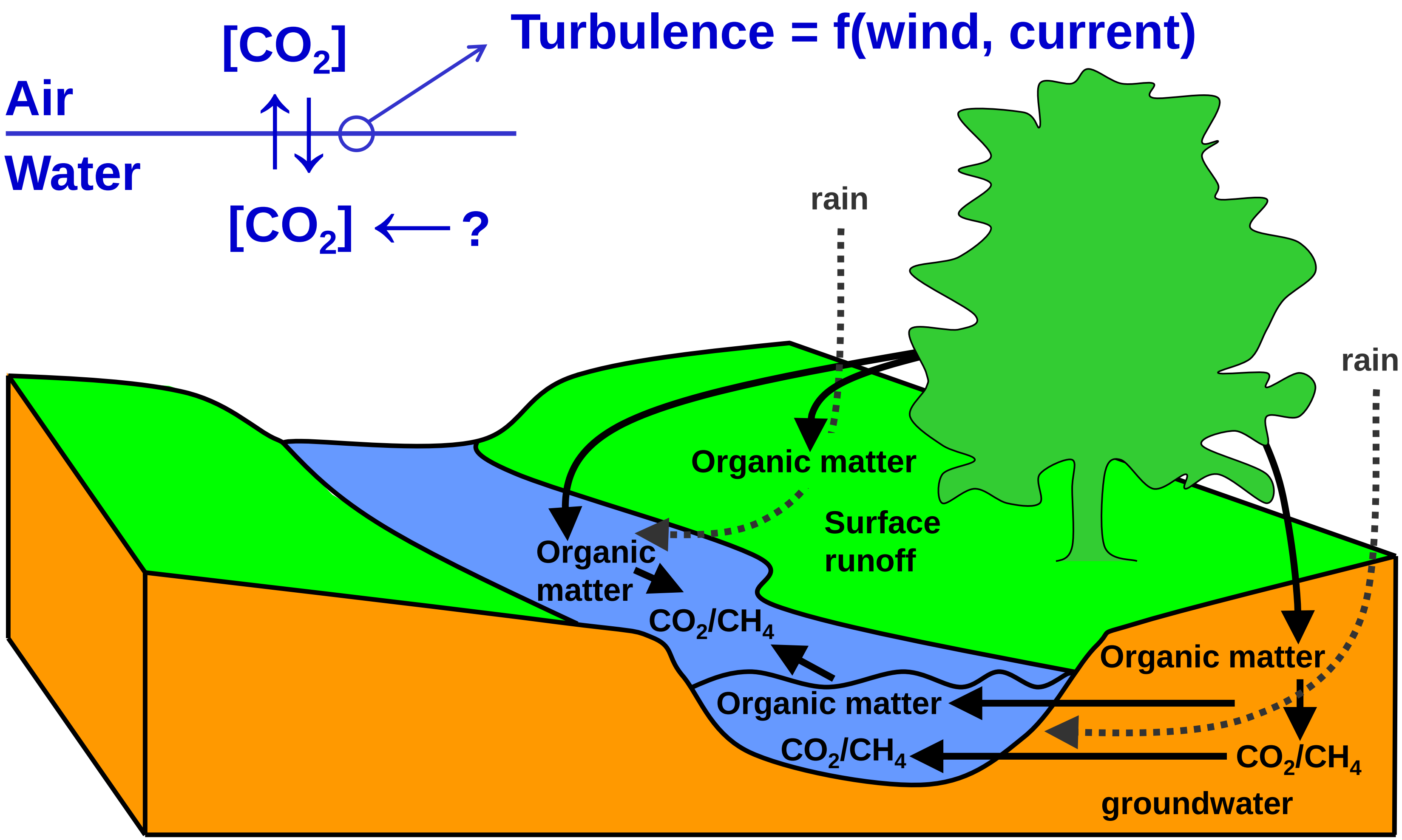
Introduction

- CO_2 and CH_4 come from the degradation of organic matter
- Occurs in the river or in soils
- Transport by surface runoff and groundwater



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]

CO_2 emissions from rivers = 0.6 PgC yr^{-1}

Introduction

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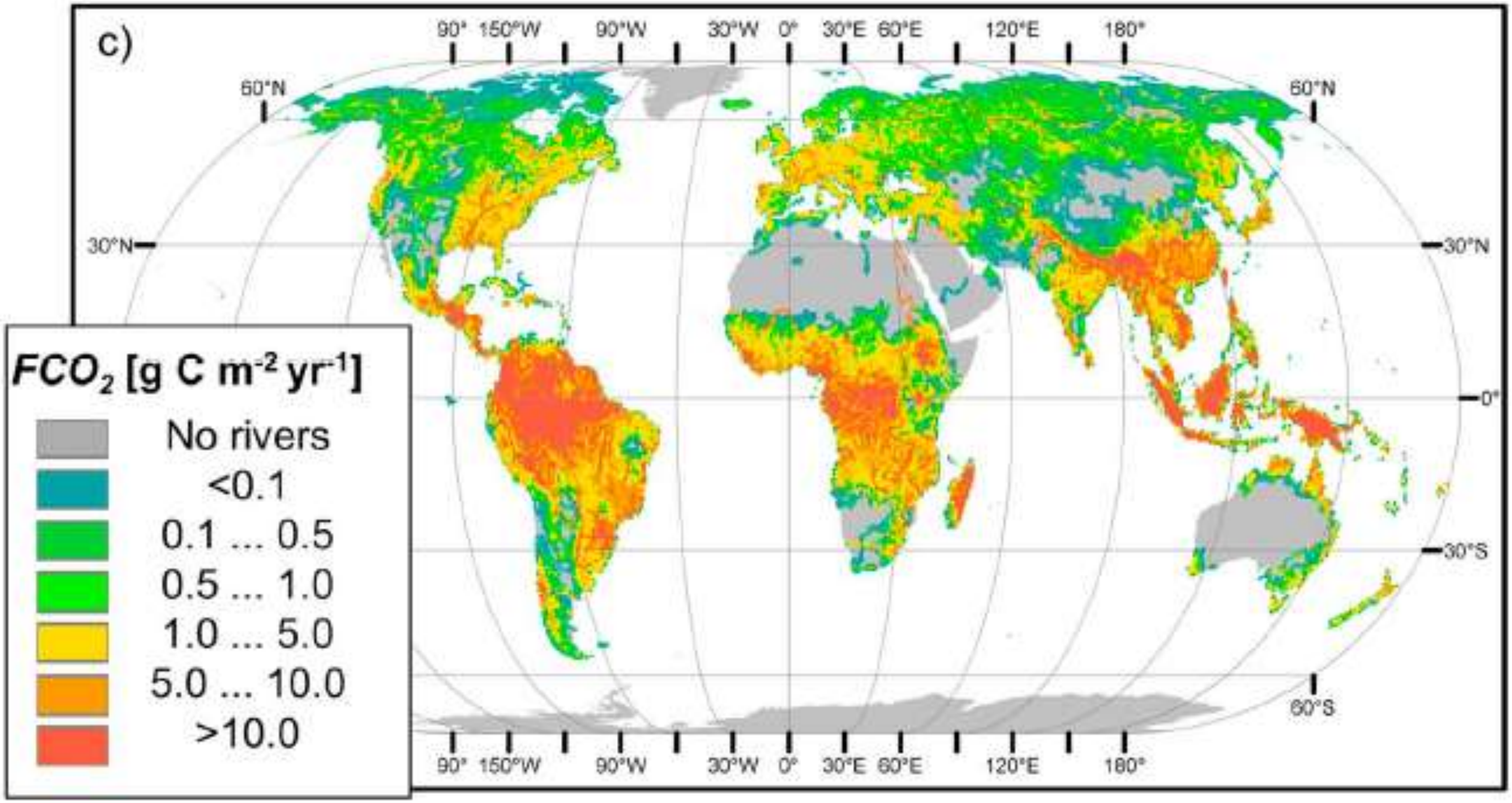

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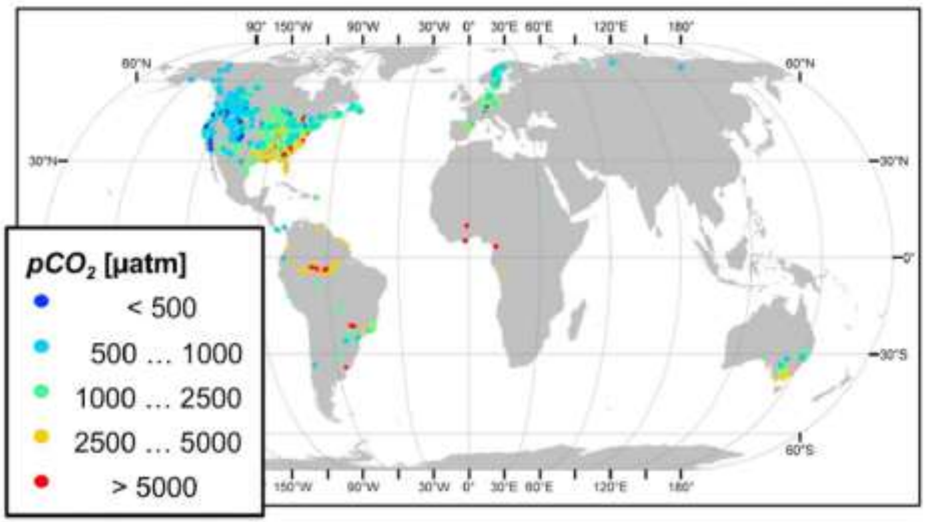
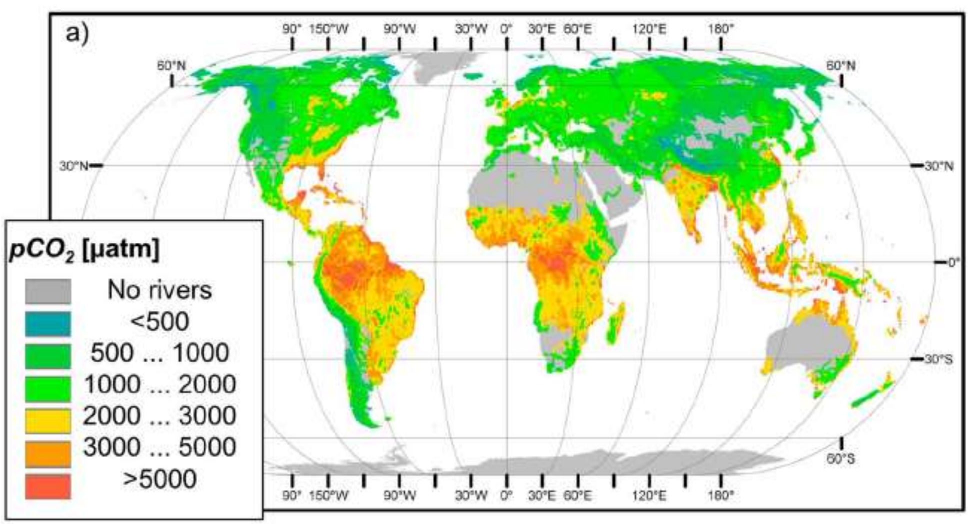
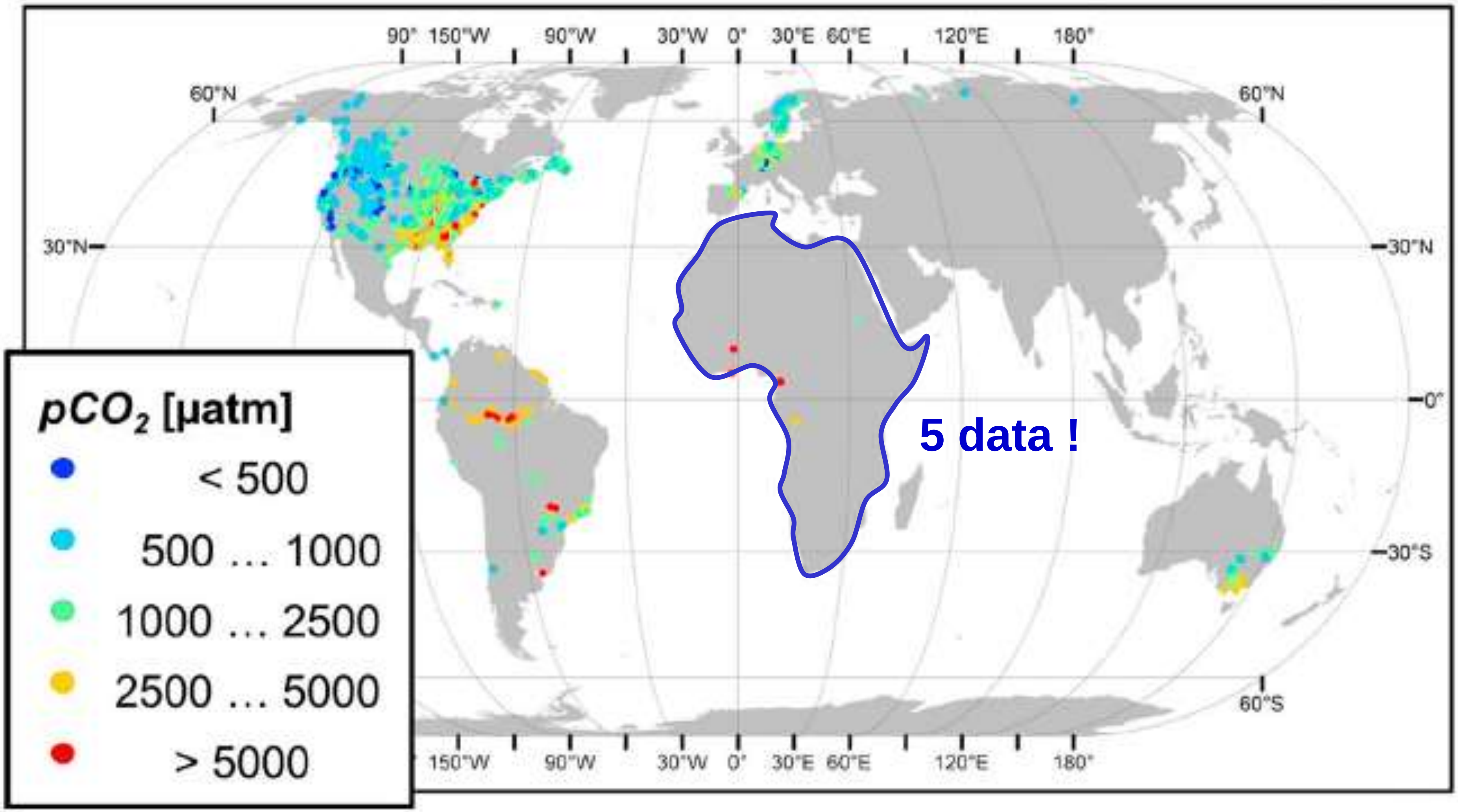


Statistical model of pCO_2 = f(terrestrial net primary Production, human population density, air temperature, slope)

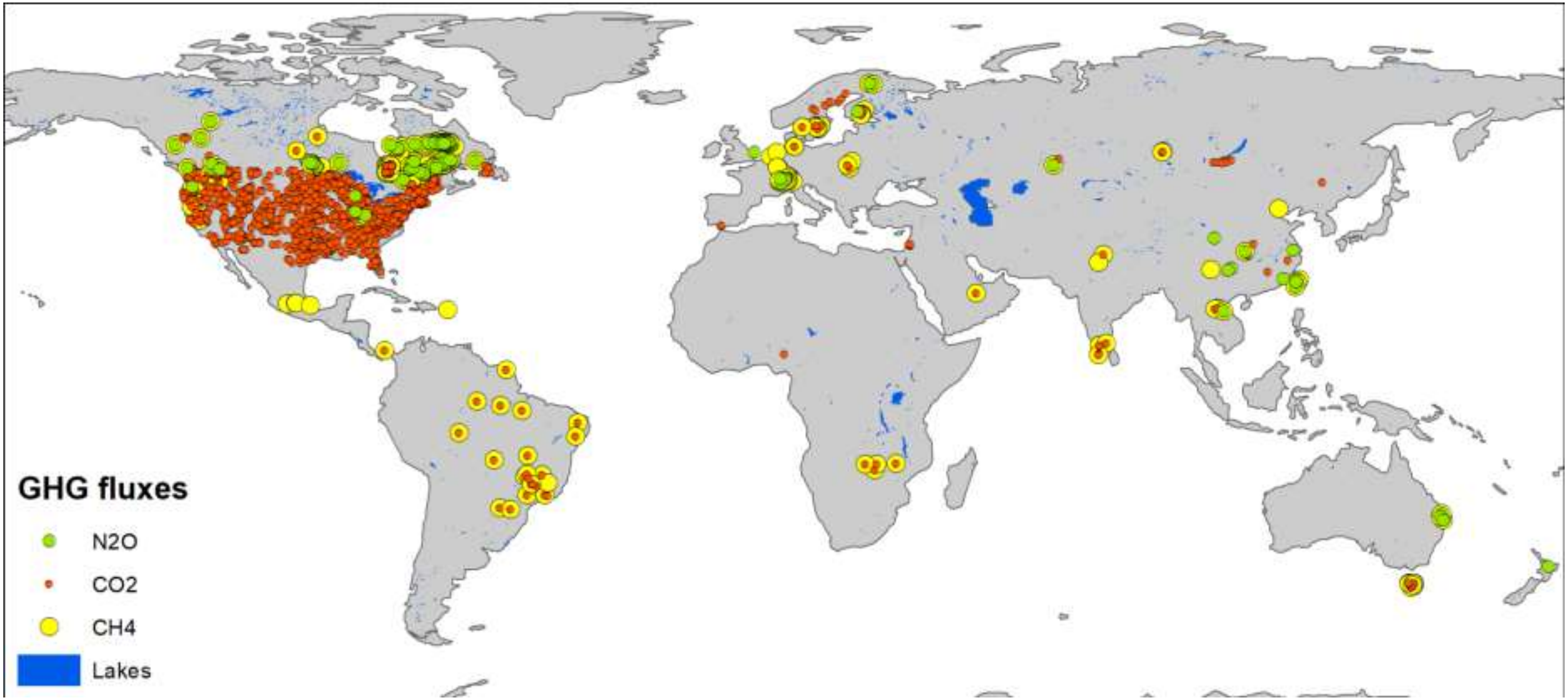
Global maps of terrestrial net primary Production, human population density, air temperature, slope



Introduction



GHGs in lakes



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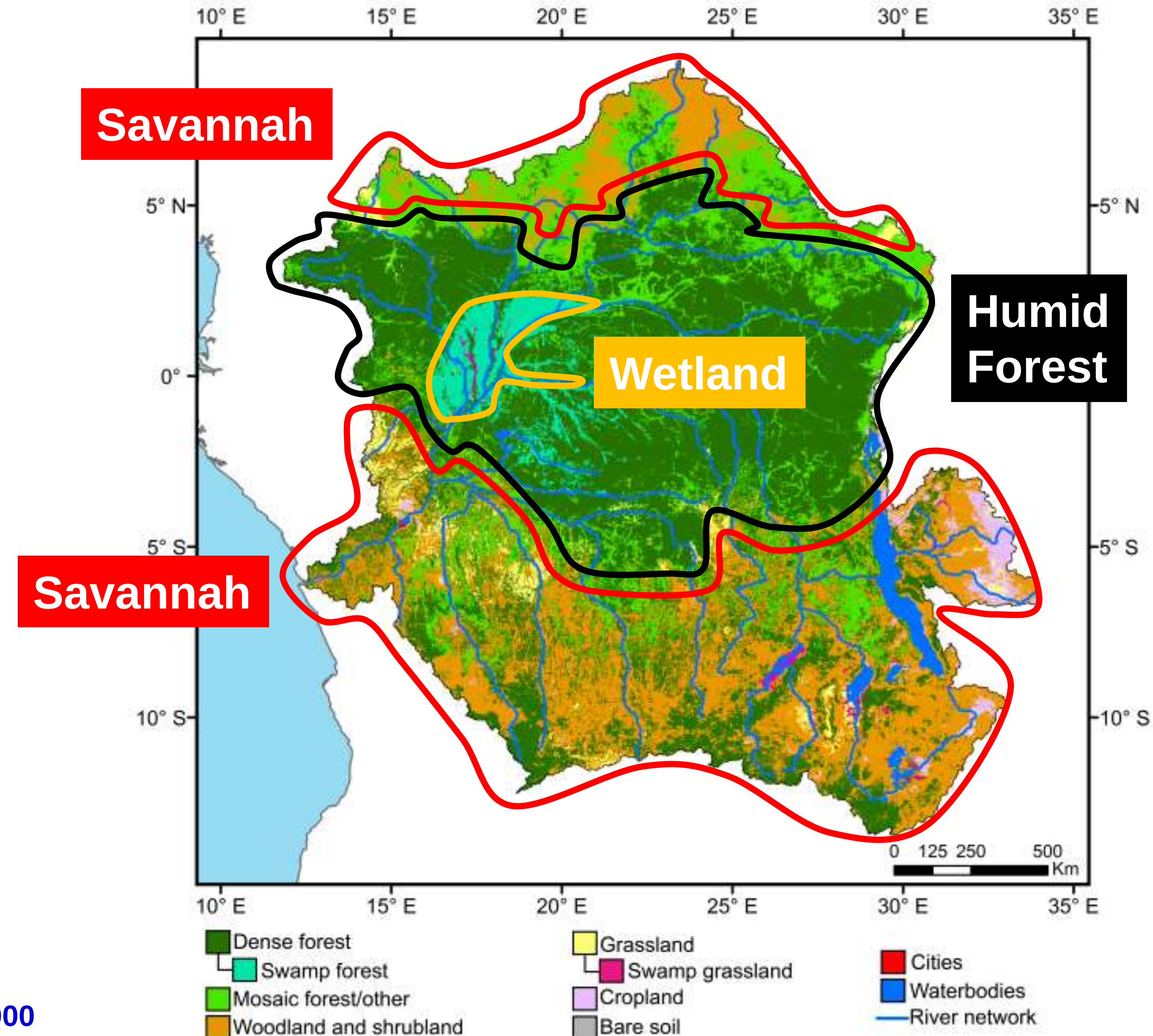
Introduction

Congo river

Congo

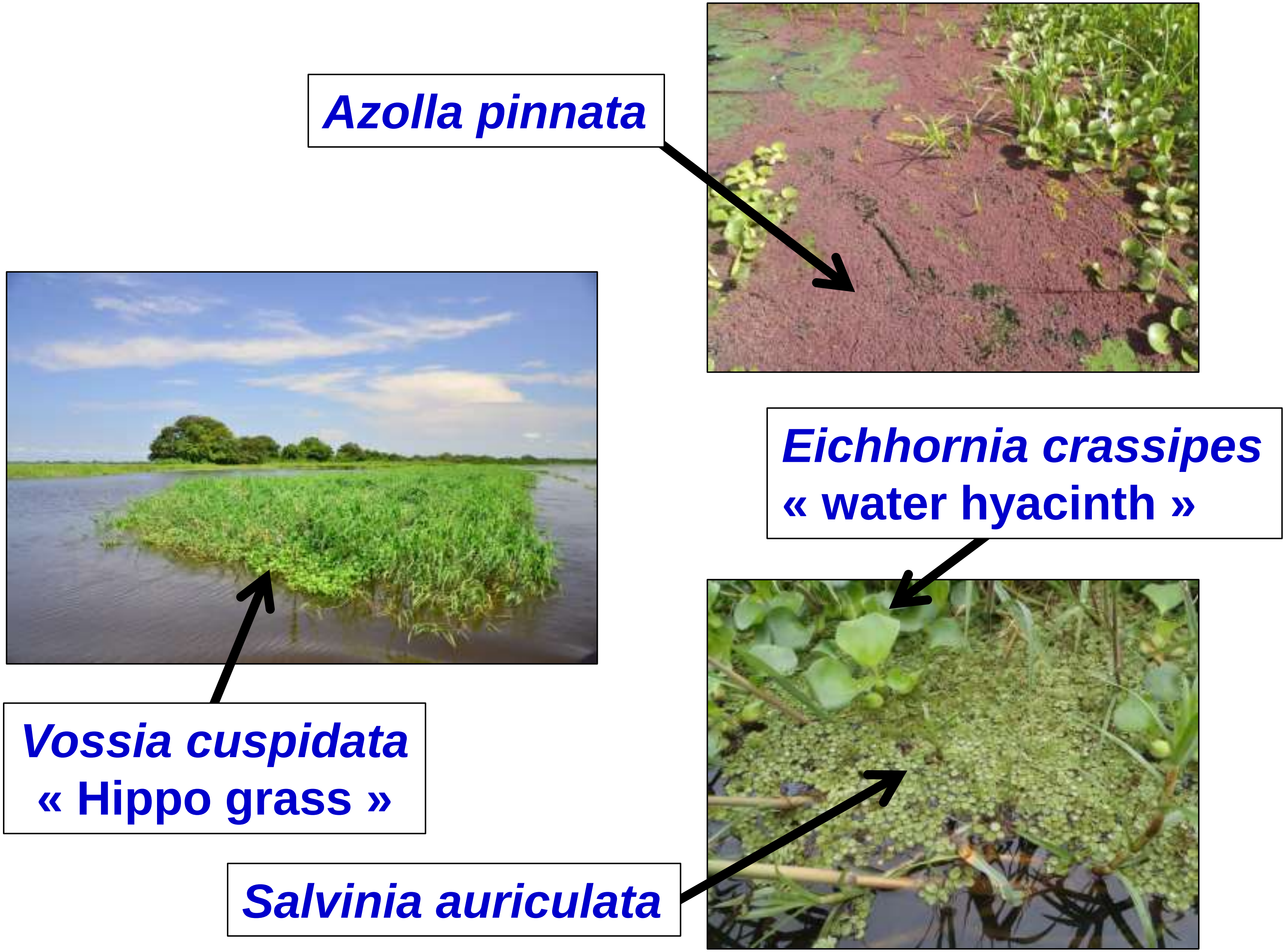


GLC 2000

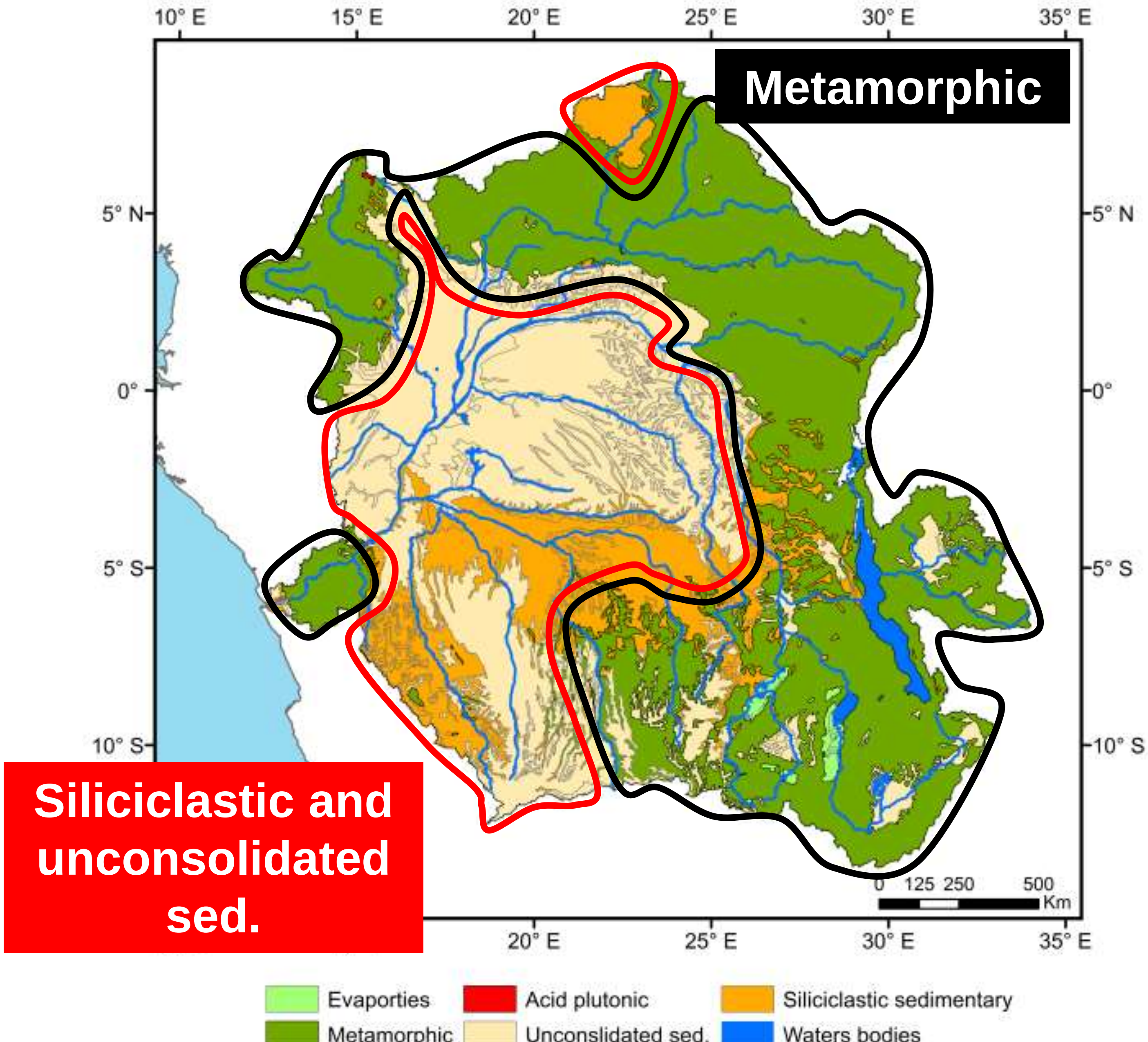

Wetland
= flooded forest
(Tributary)


Wetland
= floating macrophytes
(Tributary)


Wetland
= floating macrophytes
(Congo mainstem)

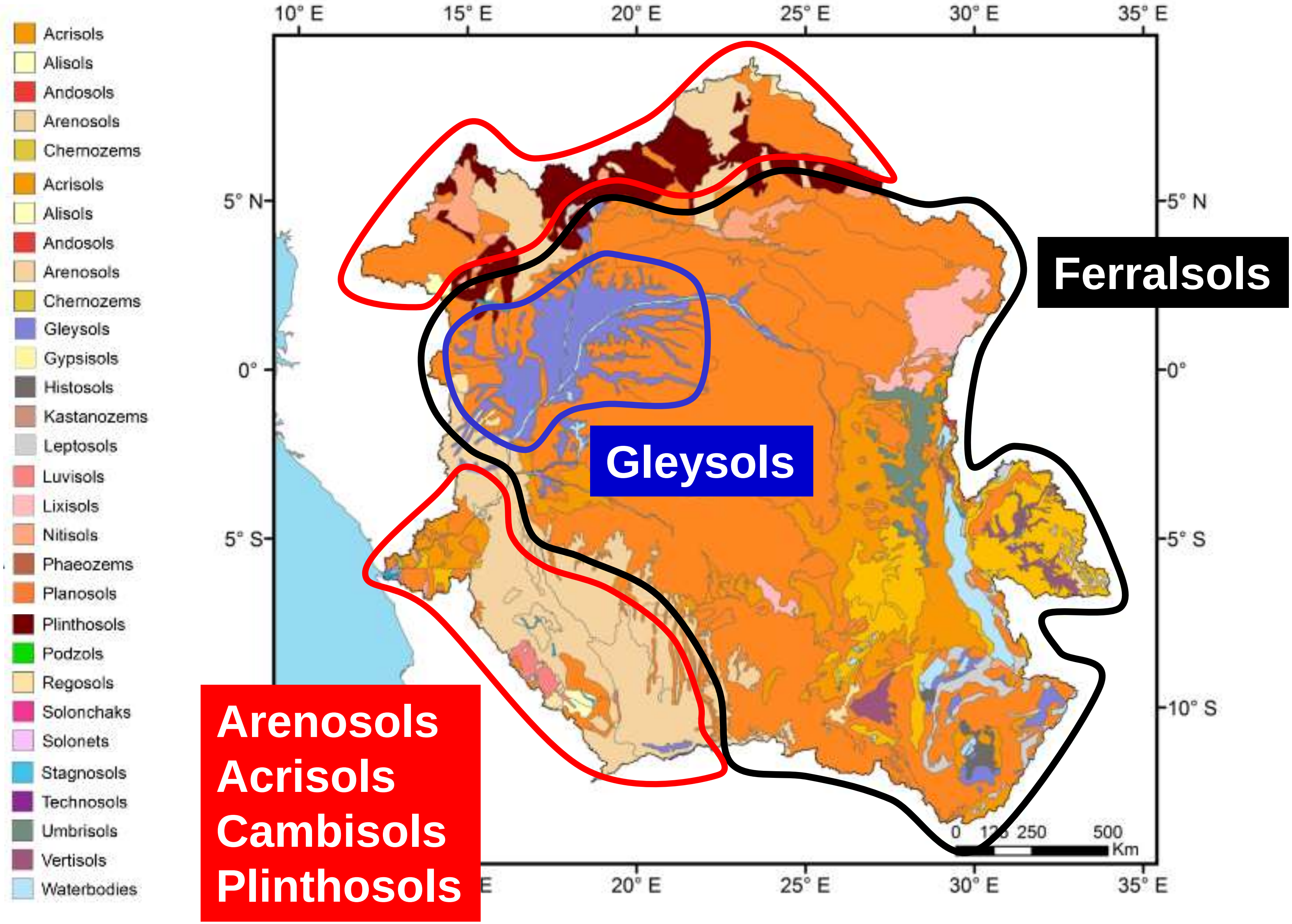

Azolla pinnata
Eichhornia crassipes
« water hyacinth »
Vossia cuspidata
« Hippo grass »
Salvinia auriculata

Congo



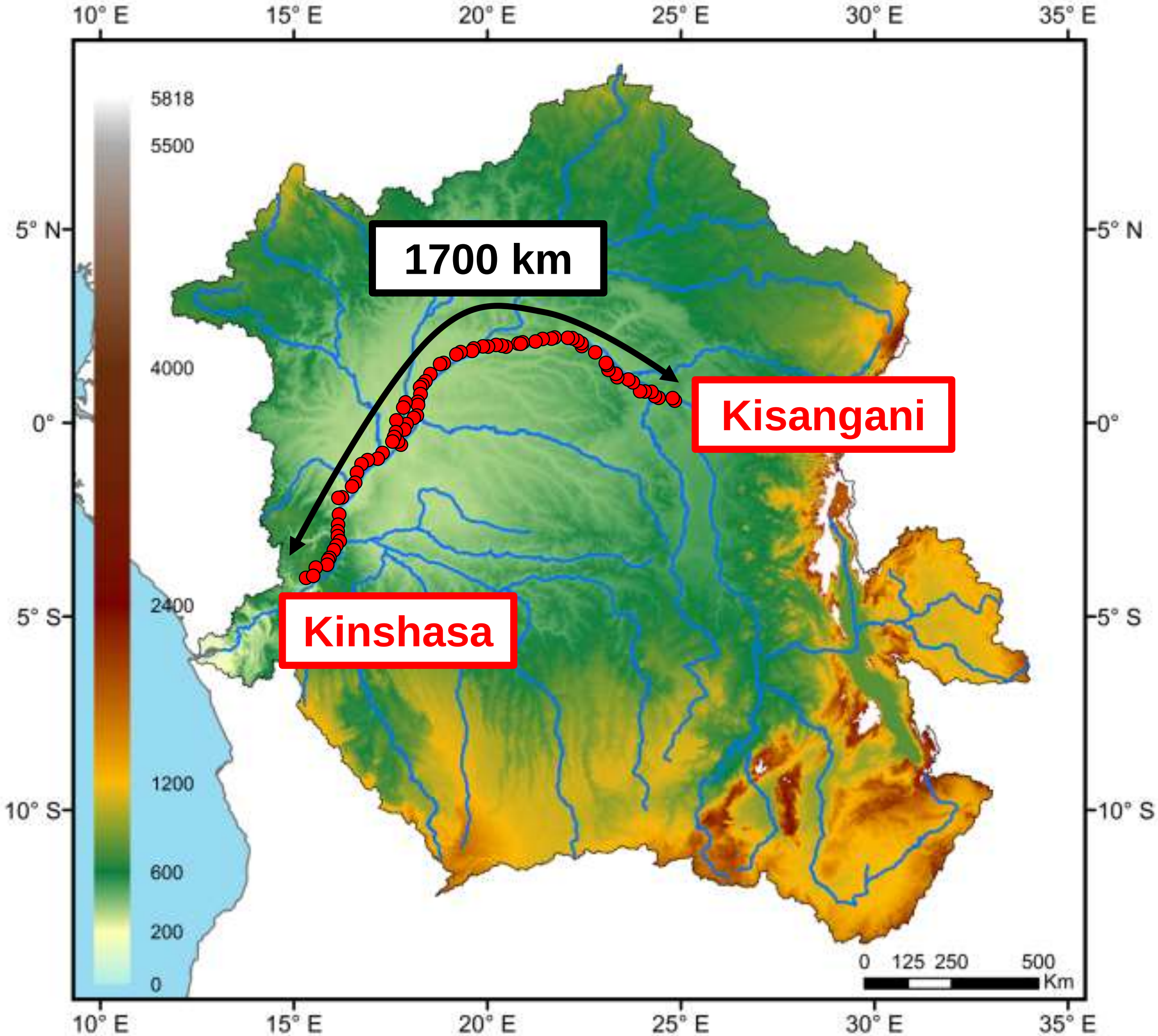
Courtesy of J. Hartmann

Congo



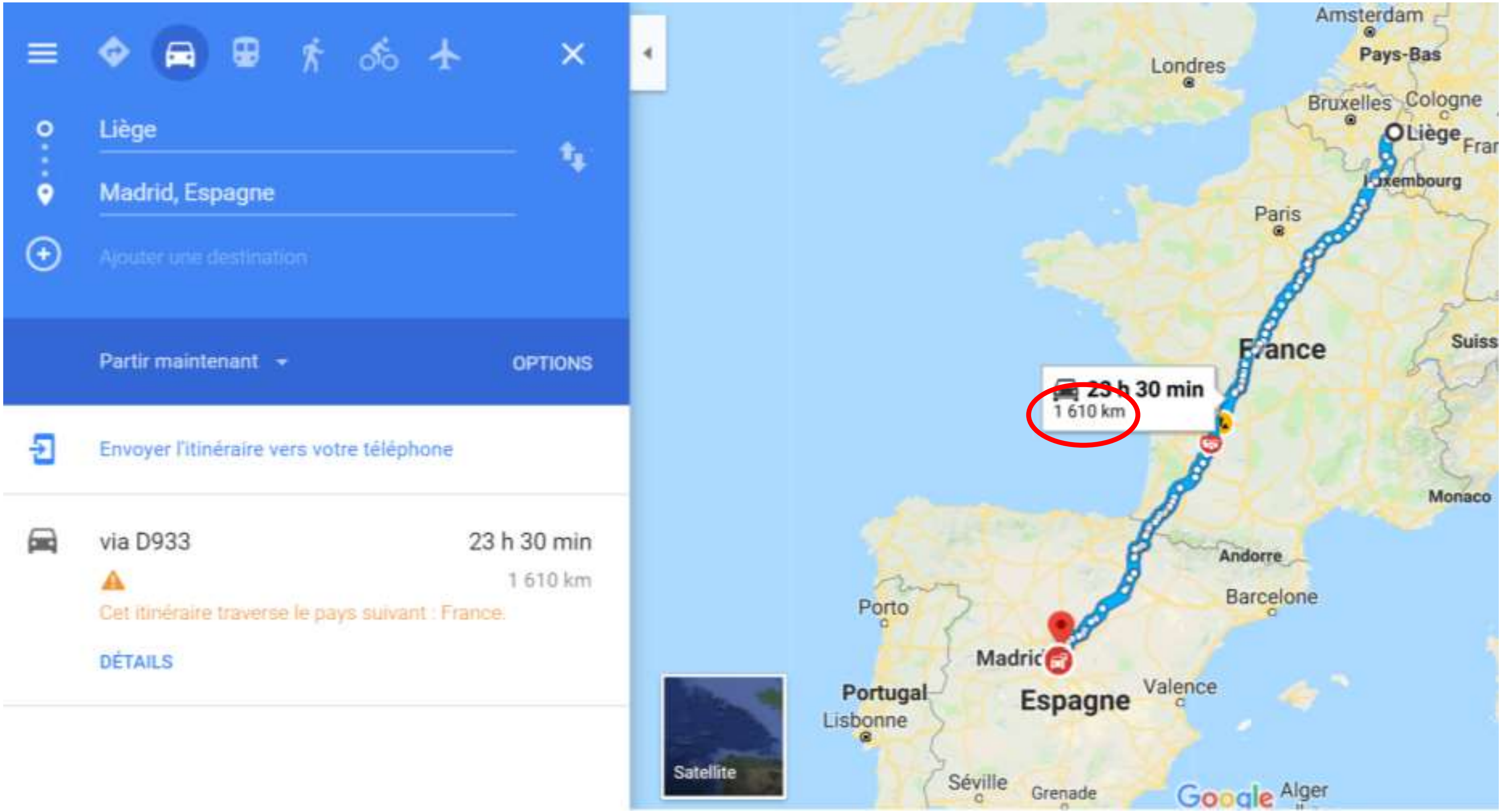
Acrisols
Alisols
Andosols
Arenosols
Chemozems
Acrisols
Alisols
Andosols
Arenosols
Chemozems
Gleysols
Gypsisols
Histosols
Kastanozems
Leptosols
Luvisols
Lixisols
Nitisols
Phaeozems
Planosols
Plinthosols
Podzols
Regosols
Solonchaks
Solonets
Stagnosols
Technosols
Umbrisols
Vertisols
Waterbodies
10° E
15° E
20° E
25° E
30° E
35° E
5° N
0°
5° S
10° S
Ferralsols
Gleysols
Arenosols
Acrisols
Cambisols
Plinthosols
0
250
500
Km

Congo

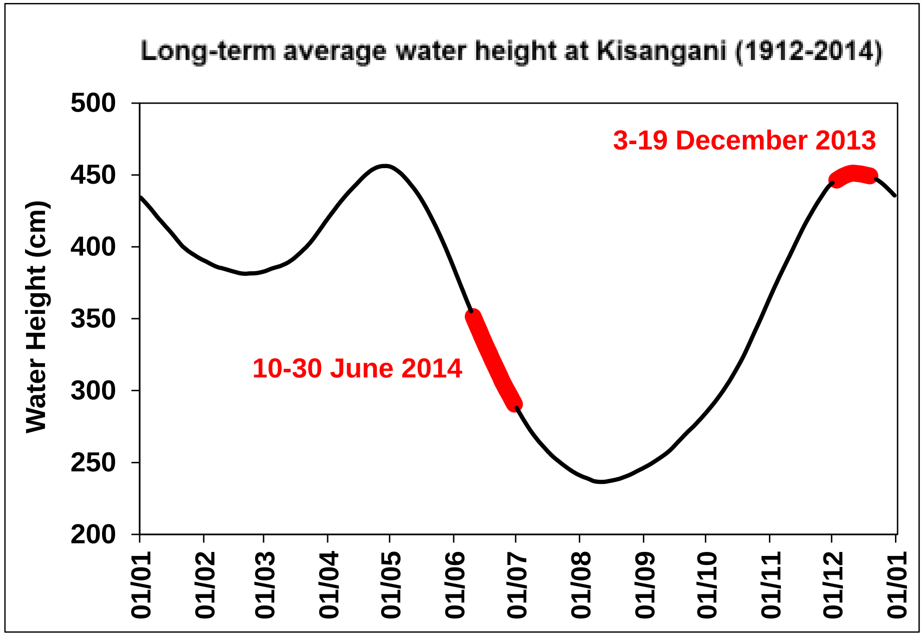


10° E
15° E
20° E
25° E
30° E
35° E
5° N
0°
5° S
10° S
5818
5500
4000
2400
1200
600
200
0
1700 km
Kisangani
Kinshasa
0 125 250 500
Km

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
Suiss
Monaco
Andorre
Barcelone
Porto
Madrid
Portugal
Lisbonne
Espagne
Valence
Séville
Grenade
Alger
Satellite
Google

Cruises & Methods



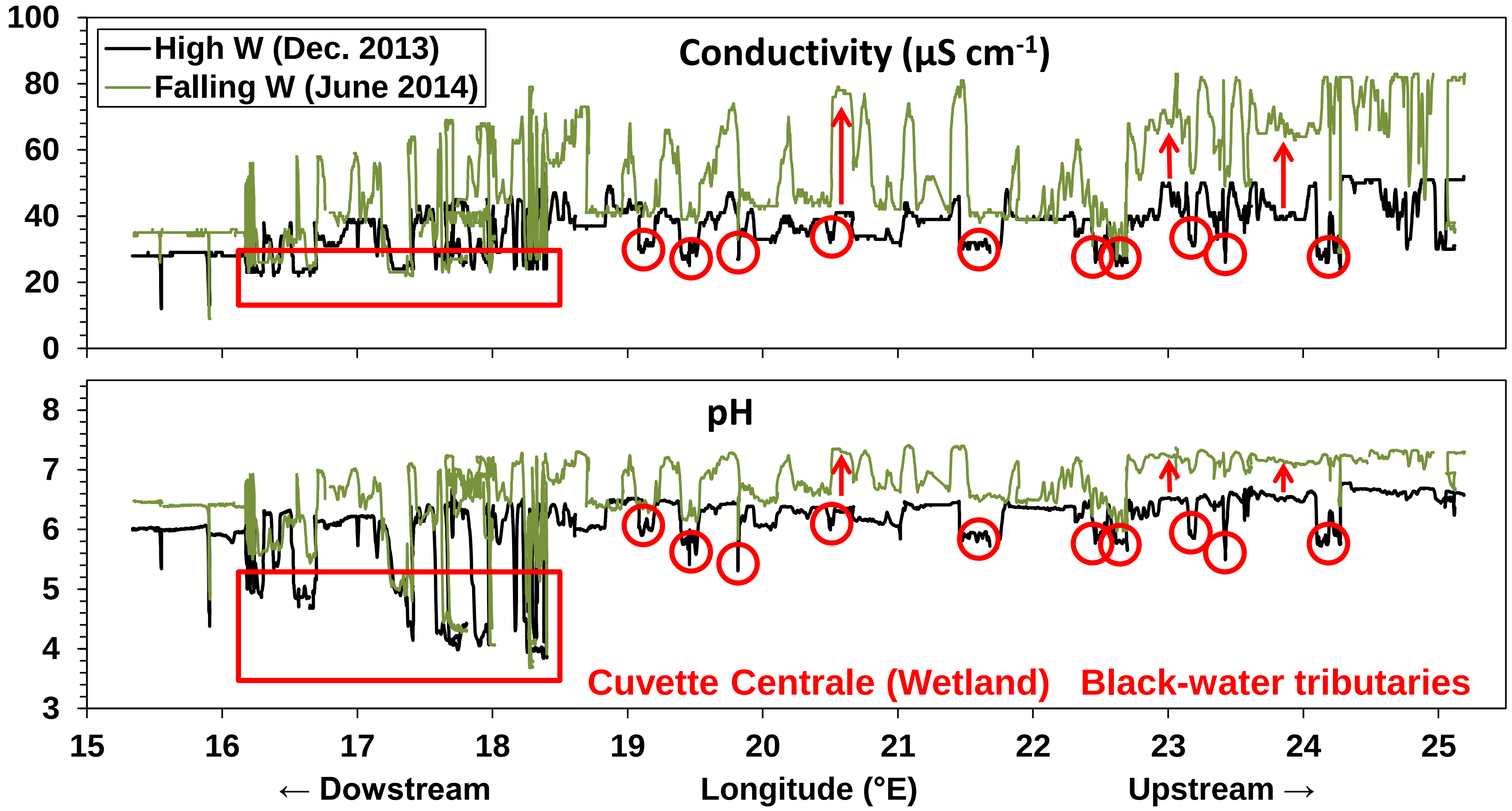
164 stations
29 variables

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

Cruises & Methods

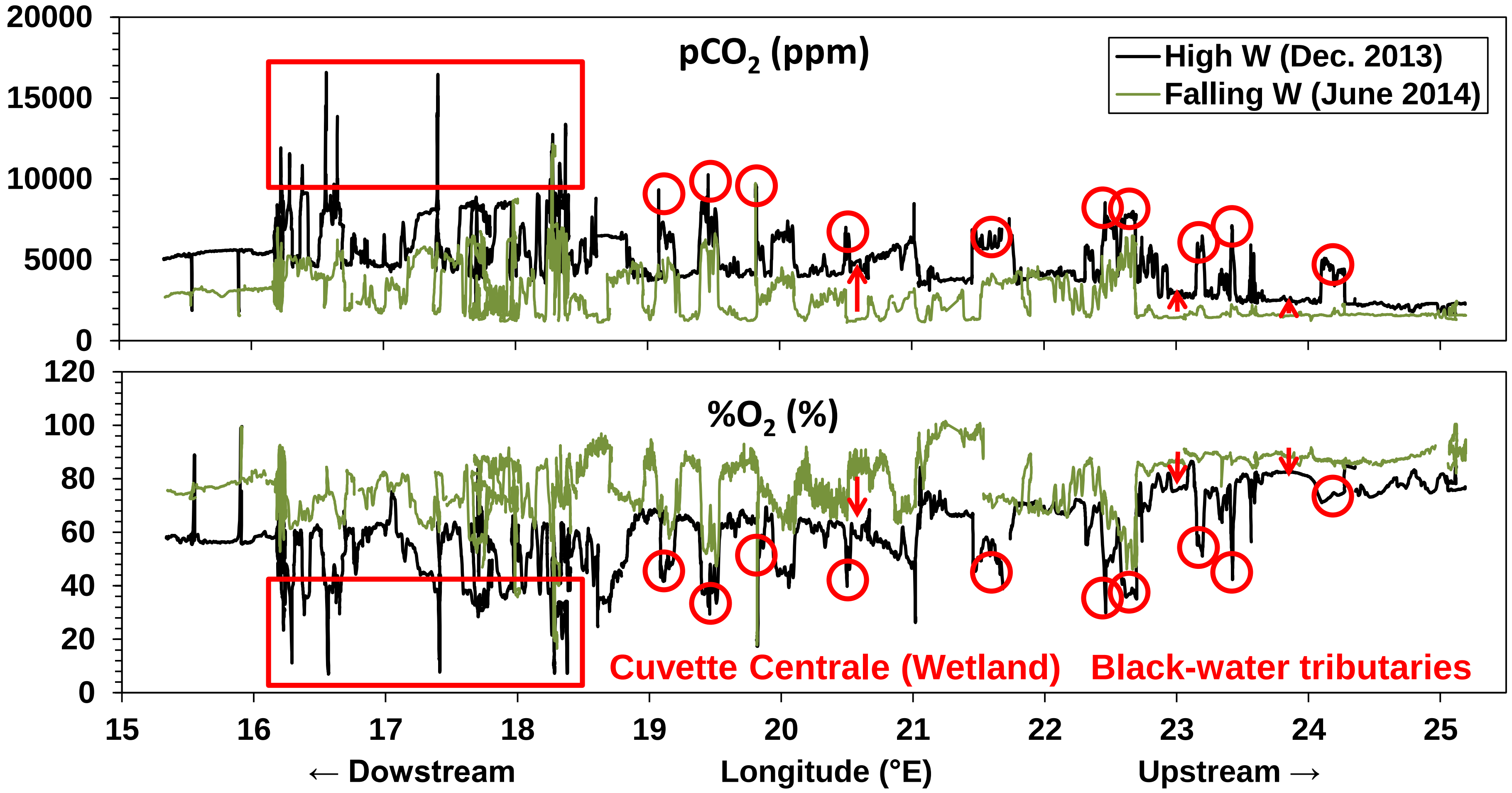
Cruises & Methods

Results



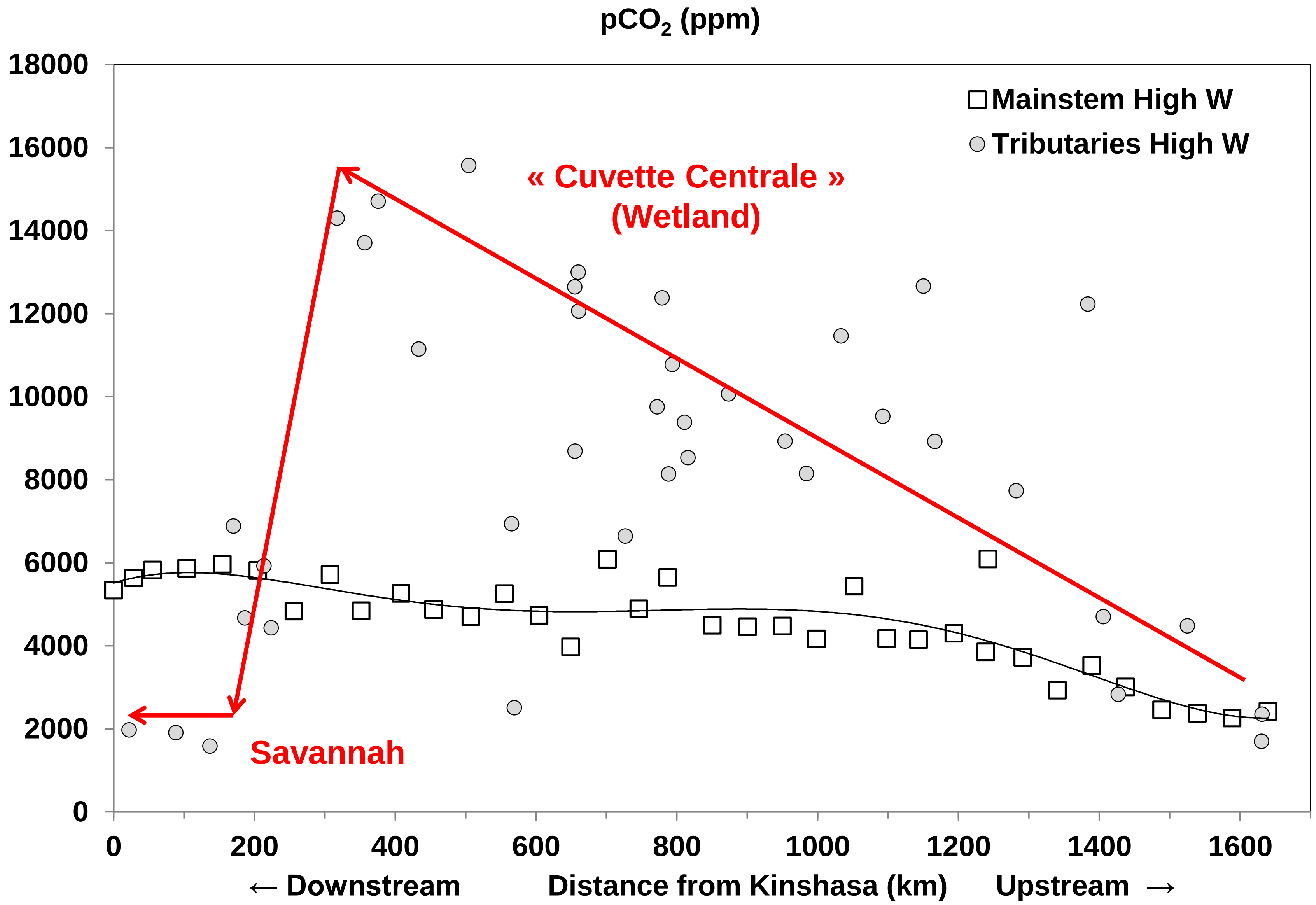
Conductivity (µS cm-1)
High W (Dec. 2013)
Falling W (June 2014)
pH
Cuvette Centrale (Wetland)
Black-water tributaries
100
80
60
40
20
0
8
7
6
5
4
3
15
16
17
18
19
20
21
22
23
24
25
← Dowstream
Longitude (°E)
Upstream →

Results



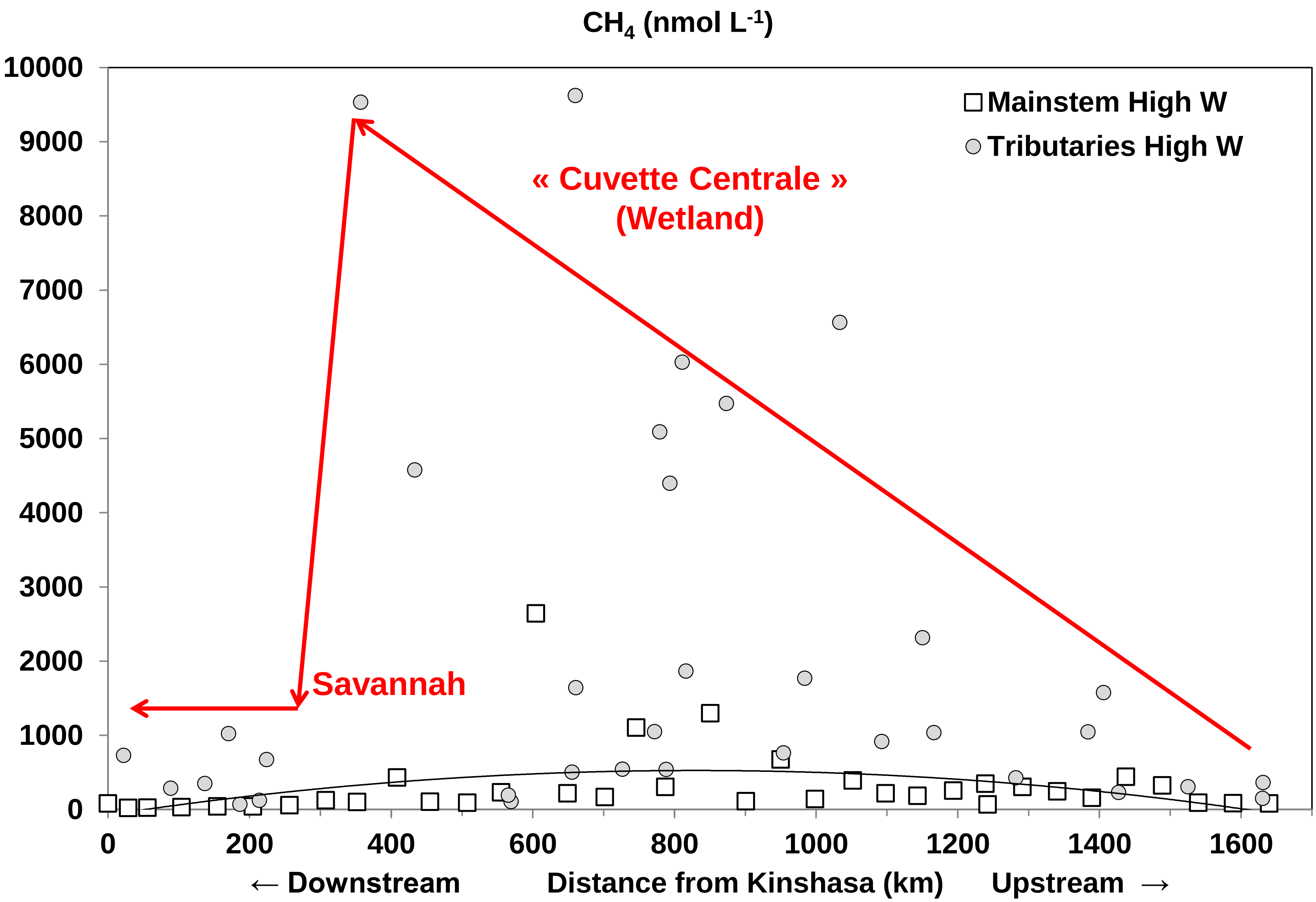
pCO2 (ppm)
High W (Dec. 2013)
Falling W (June 2014)
20000
15000
10000
5000
0
%O2 (%)
120
100
80
60
40
20
0
Cuvette Centrale (Wetland)
Black-water tributaries
15
16
17
18
19
20
21
22
23
24
25
← Dowstream
Longitude (°E)
Upstream →

Results



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

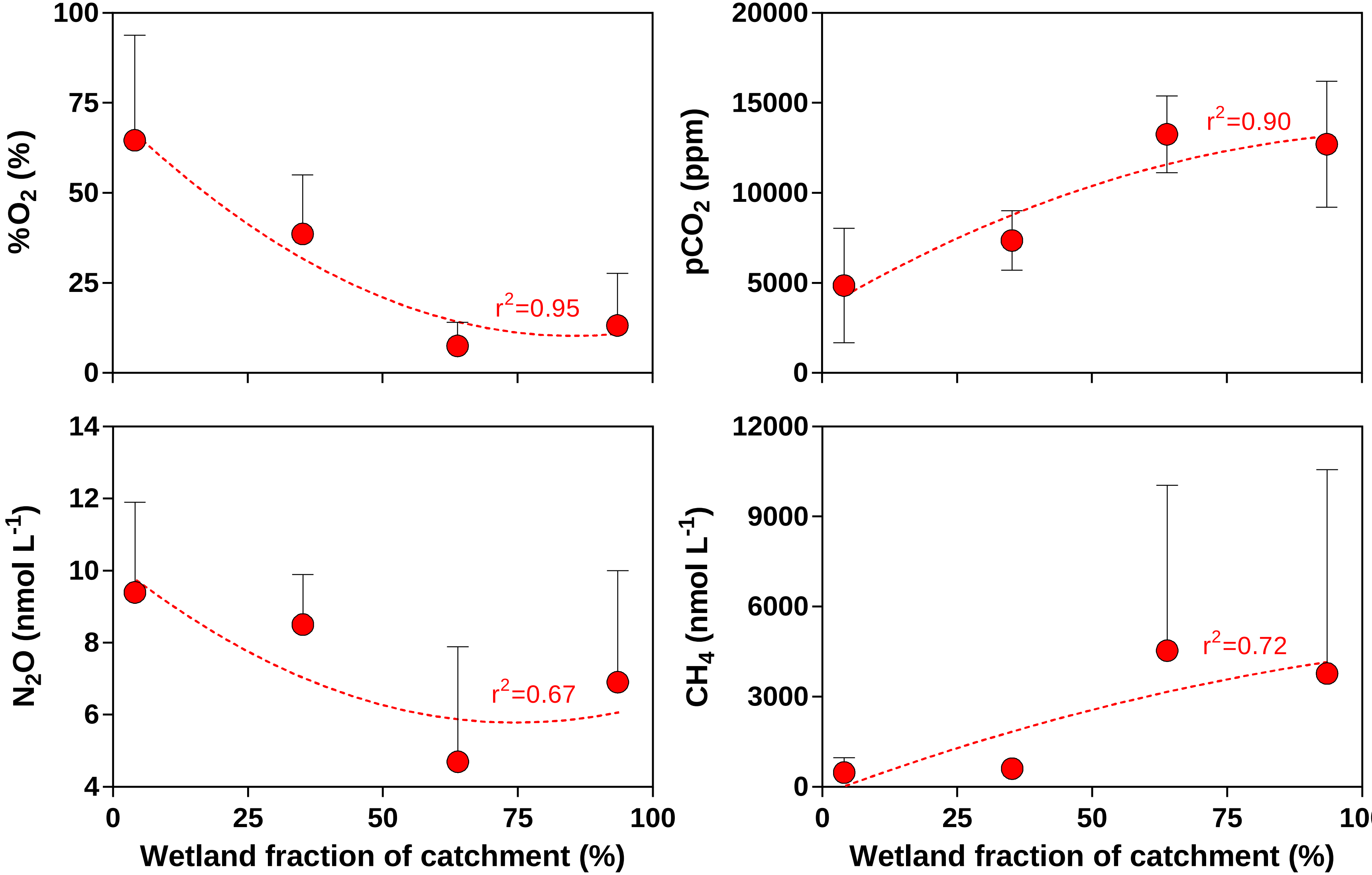
Results



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 →

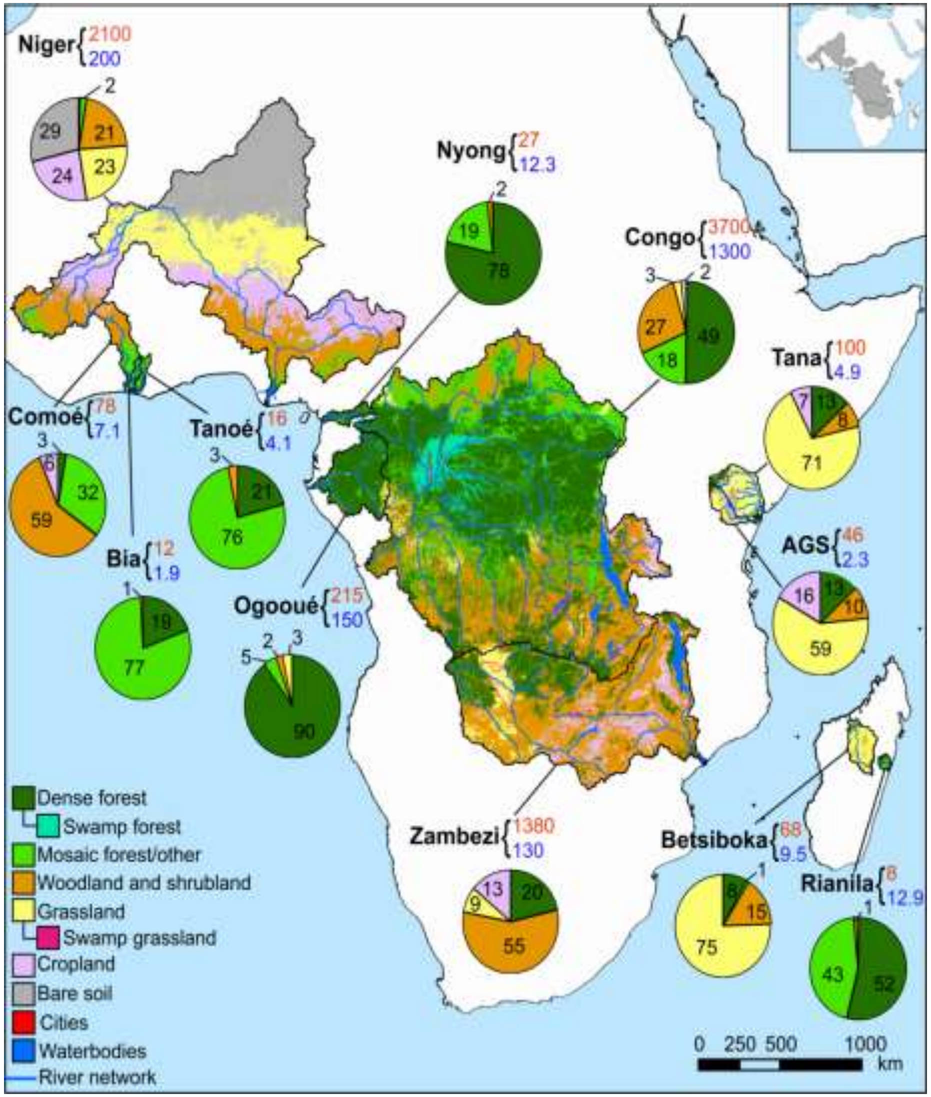
Results

All streams/rivers vs catchement characteristics

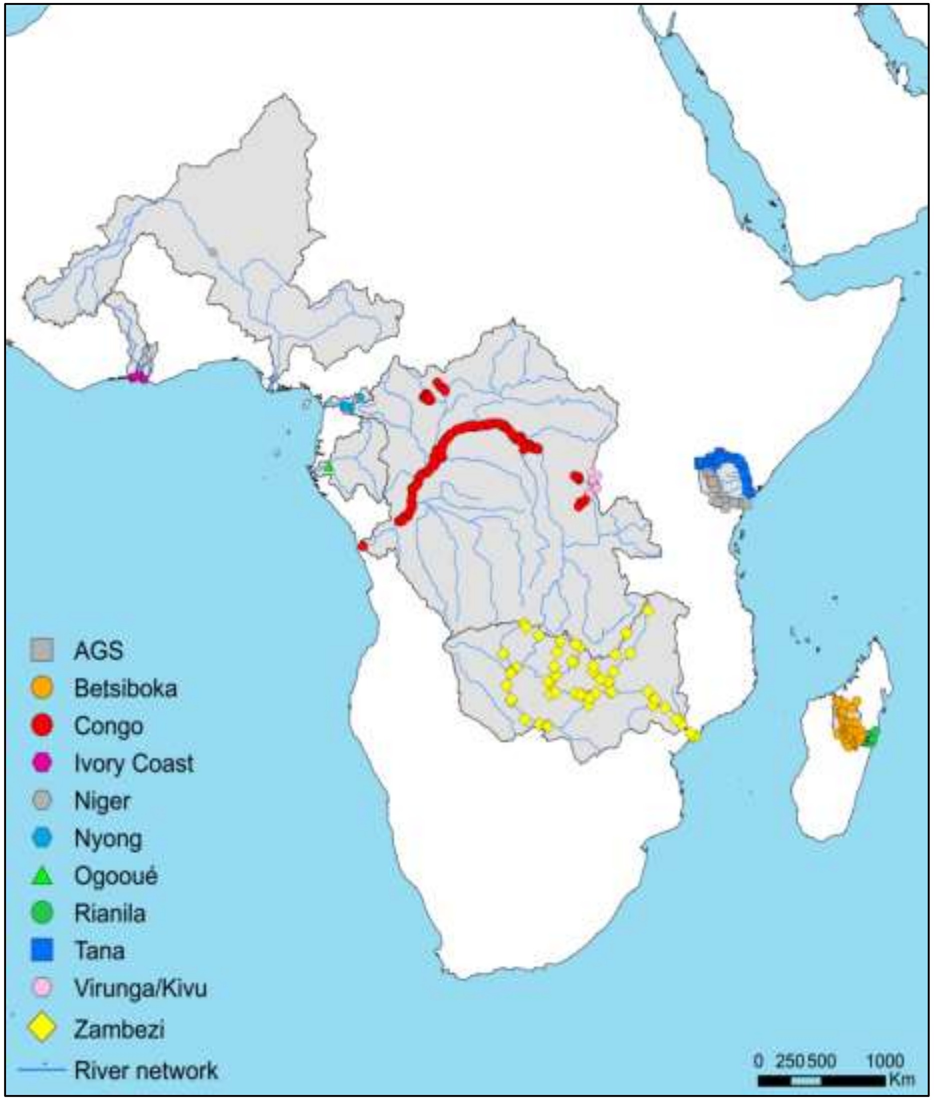


Congo & other African rivers

Results

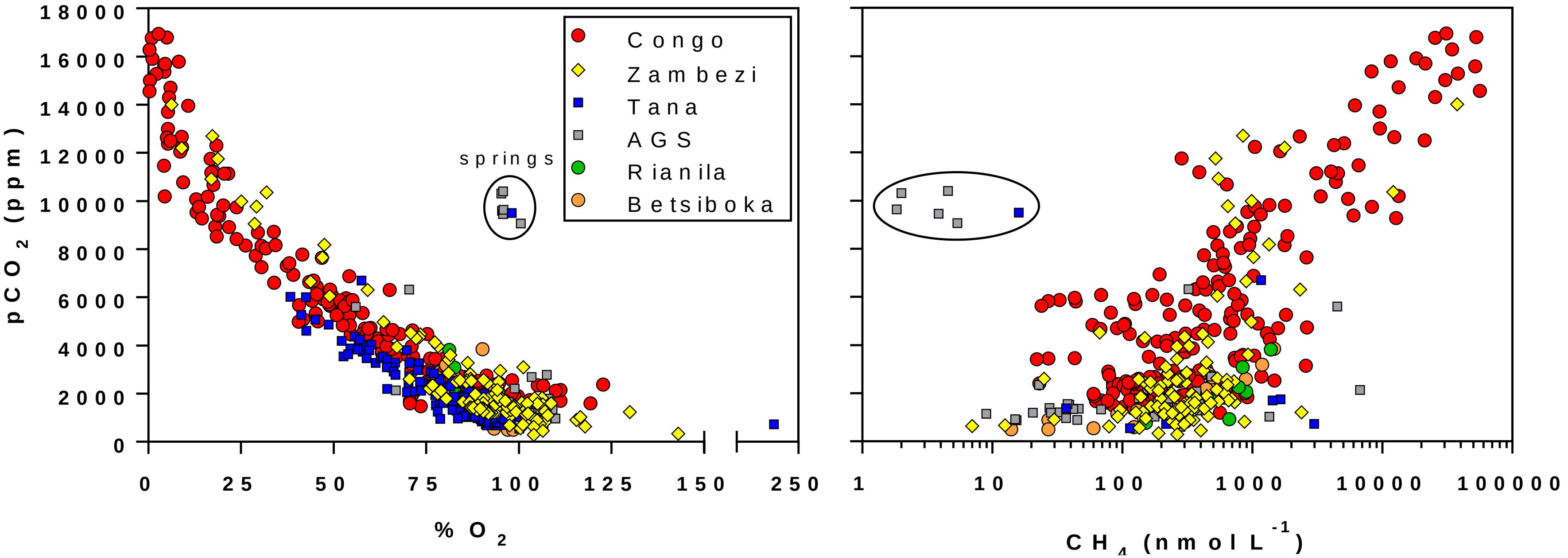


Niger 2100 200
Nyong 27 12.3
Congo 3700 1300
Tana 100 4.9
Comoé 78 7.1
Tanoé 16 4.1
Bia 12 1.9
Ogooué 215 150
AGS 46 2.3
Zambezi 1380 130
Betsiboka 68 9.5
Rianila 8 12.9
Dense forest
Swamp forest
Mosaic forest/other
Woodland and shrubland
Grassland
Swamp grassland
Cropland
Bare soil
Cities
Waterbodies
River network
0 250 500 1000 km



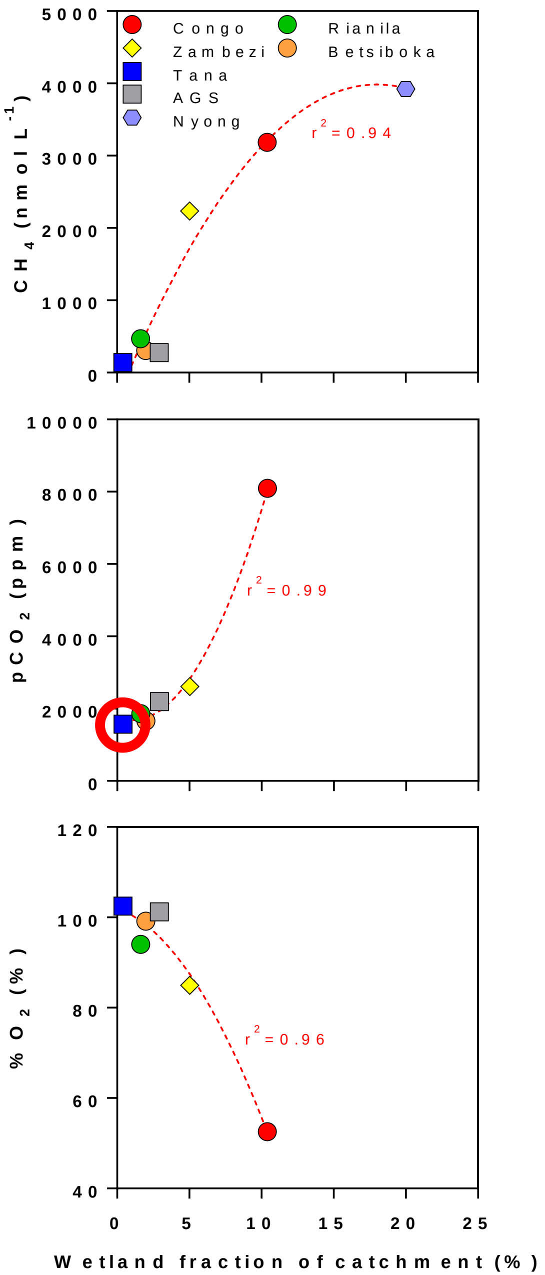
AGS
Betsiboka
Congo
Ivory Coast
Niger
Nyong
Ogooué
Rianila
Tana
Virunga/Kivu
Zambezi
River network
0 250 500 1000 Km

Results



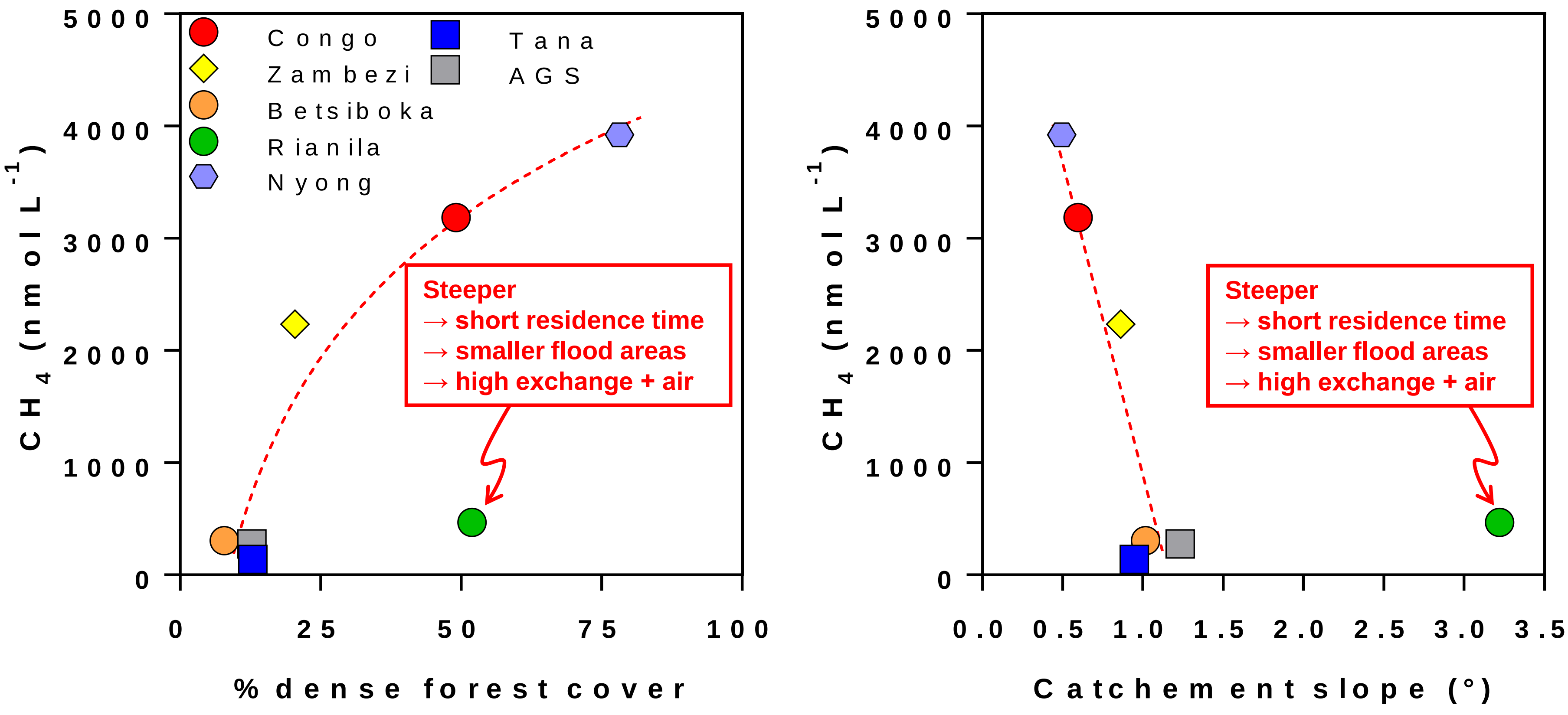
Congo
Zambezi
Tana
AGS
Rianila
Betsiboka
springs
pCO2 (ppm)
% O2
CH4 (nmol L-1)

Results



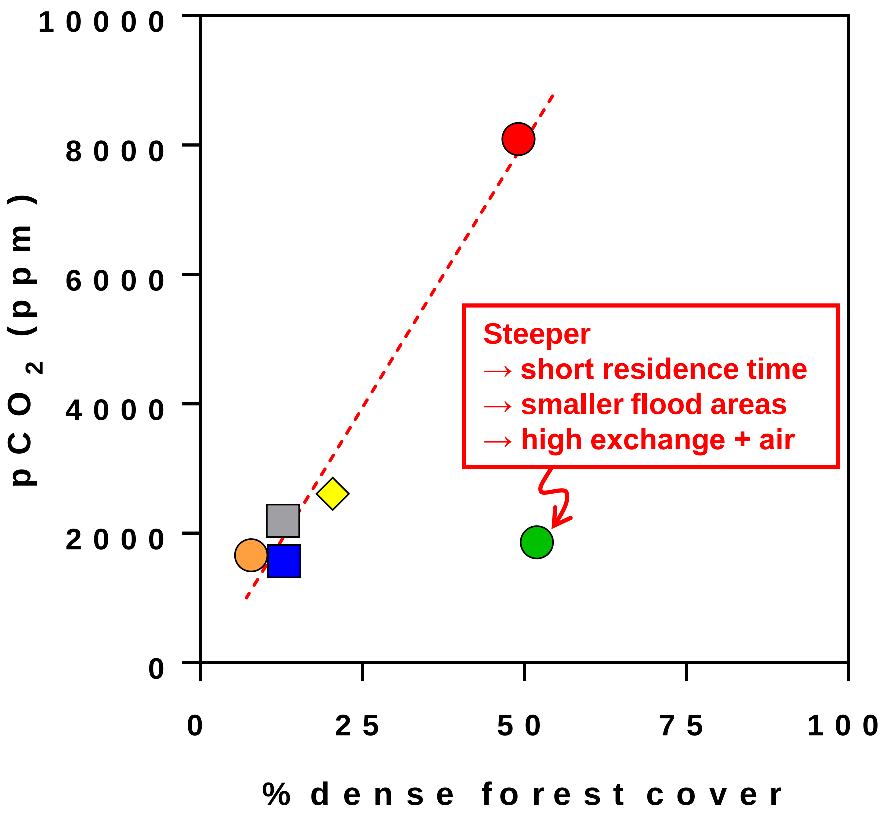
Congo
Rianila
Zambezi
Betsiboka
Tana
AGS
Nyong
CH_4 (nmol L^{-1})
5000
4000
3000
2000
1000
0
r^2 = 0.94
10000
8000
6000
4000
2000
0
pCO_2 (ppm)
r^2 = 0.99
120
100
80
60
40
% O_2 (%)
r^2 = 0.96
0
5
10
15
20
25
Wetland fraction of catchment (%)

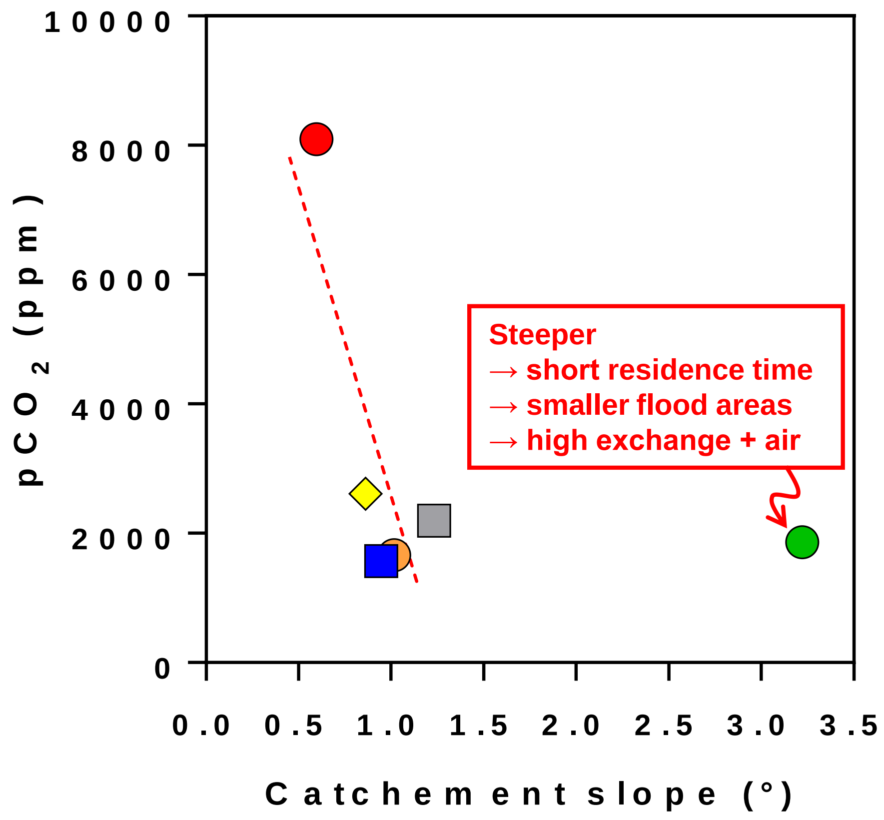
Results



5000
4000
3000
2000
1000
0
CH4 (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
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Catchment 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

African rivers/streams

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

African rivers/streams + Cuvette Centrale Congolaise

$CO_2 + CH_4 = 1.0$ PgC yr^{-1} ($CO_{2\ equivalents}$)

Results

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

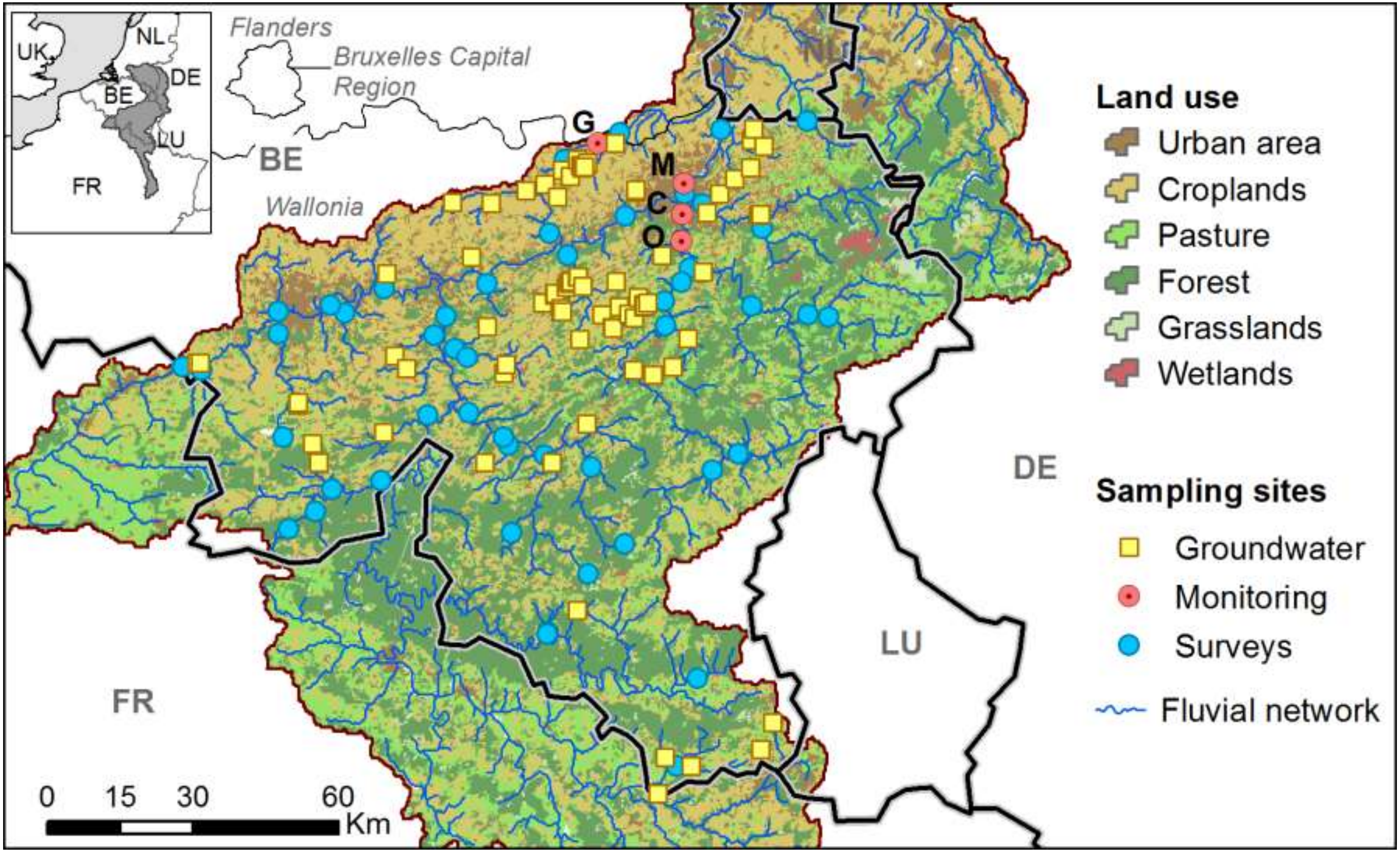
24%
2.4±0.5 $PgC\ y^{-1}$
Average of 5 models

www.globalcarbonproject.org/

Introduction

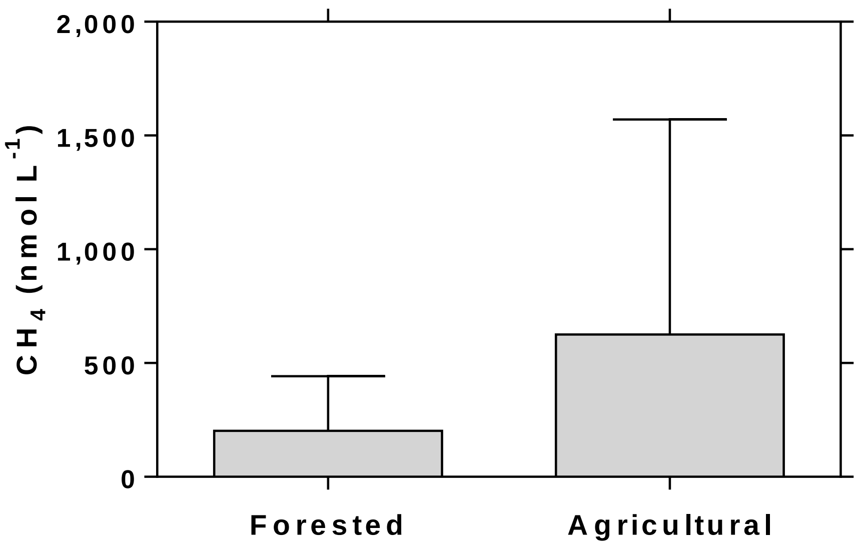
1 – Climate change & global cycles of CO_2 & CH_4
2 – Production of CO_2 et CH_4 in rivers
3 – CO_2 & CH_4 in African rivers
4 – Comparaison with Meuse
5 – A few words on African Lakes

Results

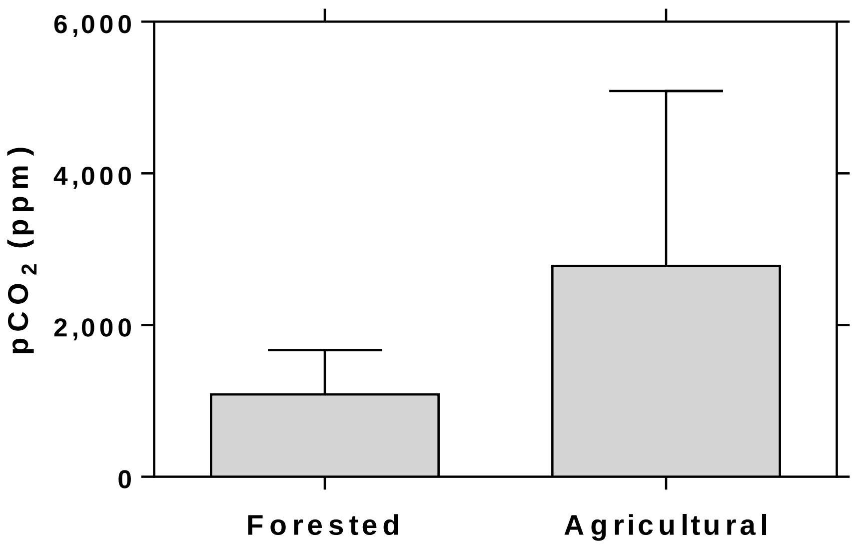


UK
NL
DE
BE
LU
FR
Flanders
Bruxelles Capital
Region
BE
Wallonia
G
M
C
O
NL
DE
LU
FR
0
15
30
60
Km
Land use
Urban area
Croplands
Pasture
Forest
Grasslands
Wetlands
Sampling sites
Groundwater
Monitoring
Surveys
Fluvial network

Results

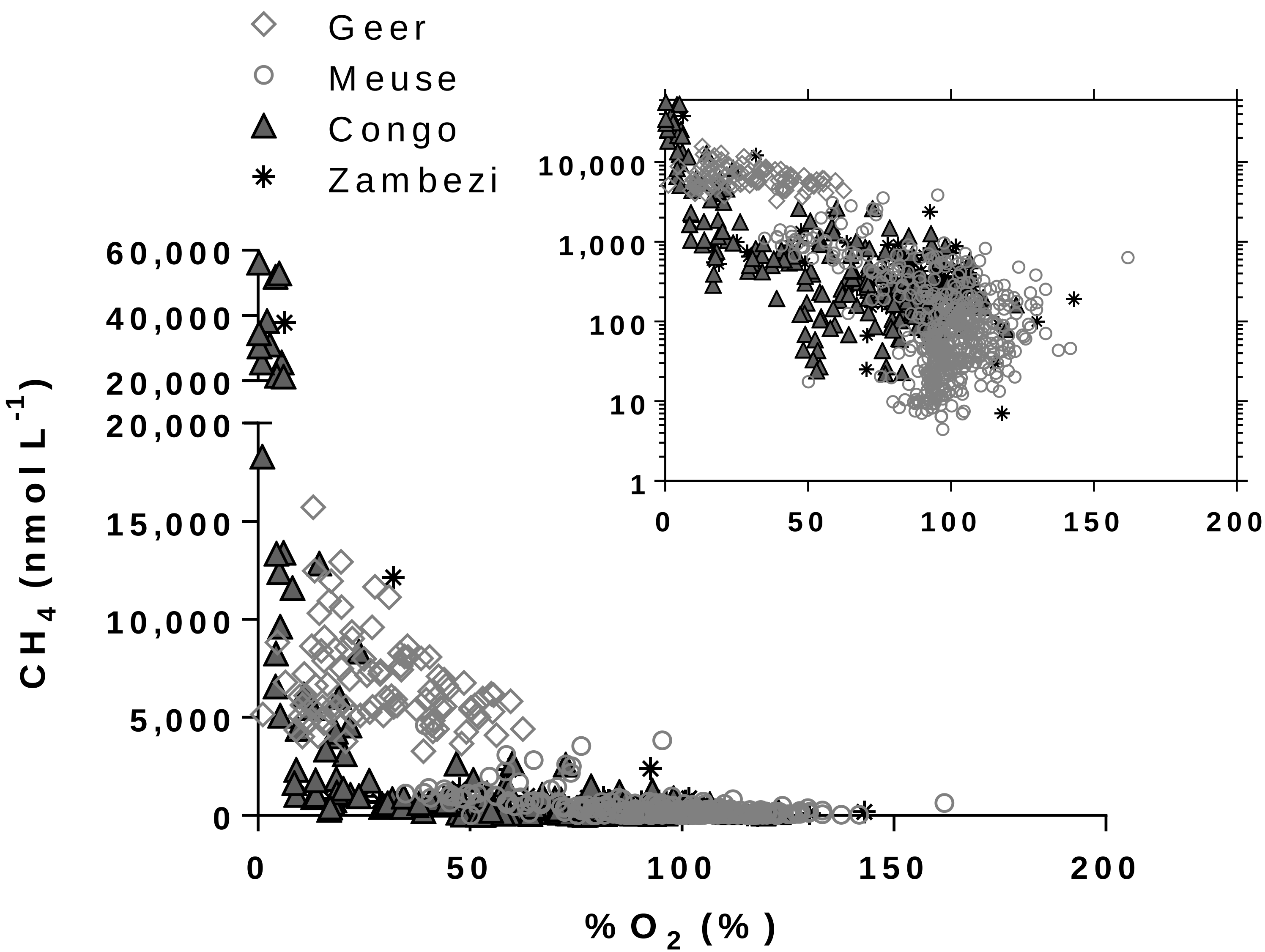


2,000
1,500
1,000
500
0
CH_4 (nmol L^{-1})
Forested
Agricultural



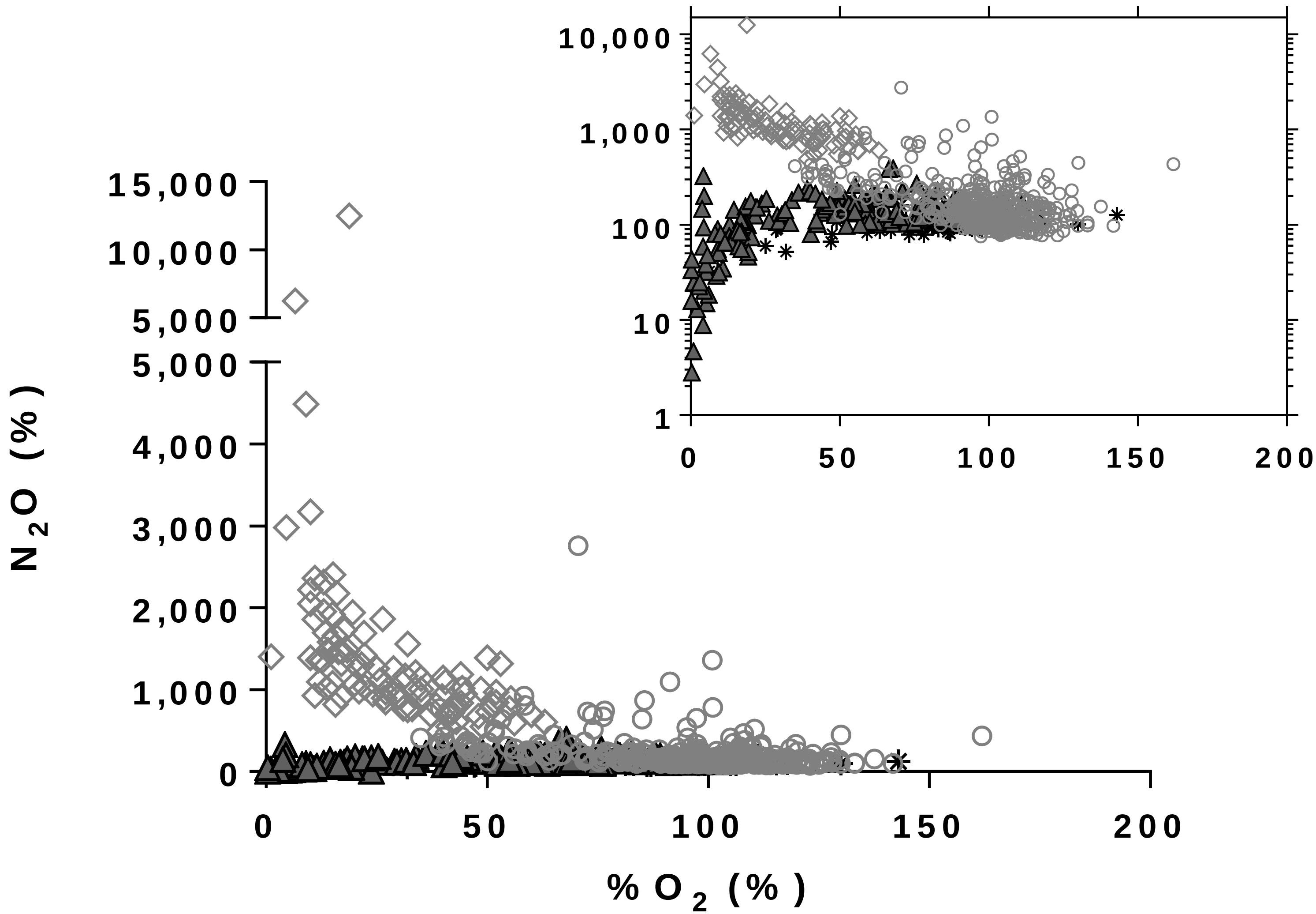
6,000
4,000
2,000
0
pCO_2 (ppm)
Forested
Agricultural

Results



Geer
Meuse
Congo
Zambezi
60,000
40,000
20,000
20,000
15,000
10,000
5,000
0
CH_4 (nmol L^{-1})
0
50
100
150
200
% O_2 (%)
10,000
1,000
100
10
1
0
50
100
150
200

Results



15,000
10,000
5,000
5,000
4,000
3,000
2,000
1,000
0
0
50
100
150
200
N_2O (%)
% O_2 (%)
10,000
1,000
100
10
1
0
50
100
150
200

Results

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Results

On going research in Lakes Edward, George, Victoria, Tanganyika