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Carbon dioxide and methane dynamics in estuaries

Treatise on Estuarine and Coastal Science *

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* Due in 2011 if all goes well…

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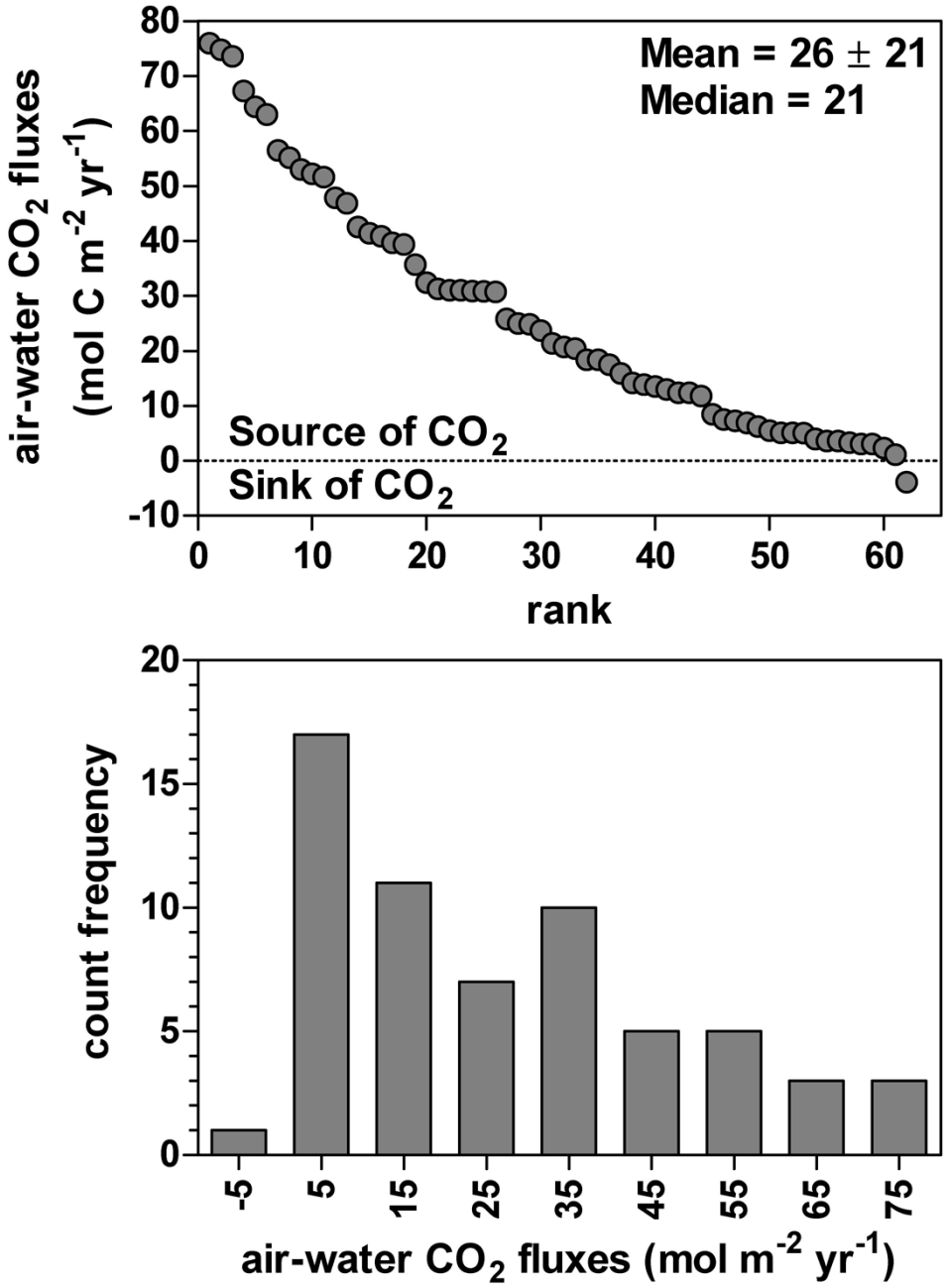
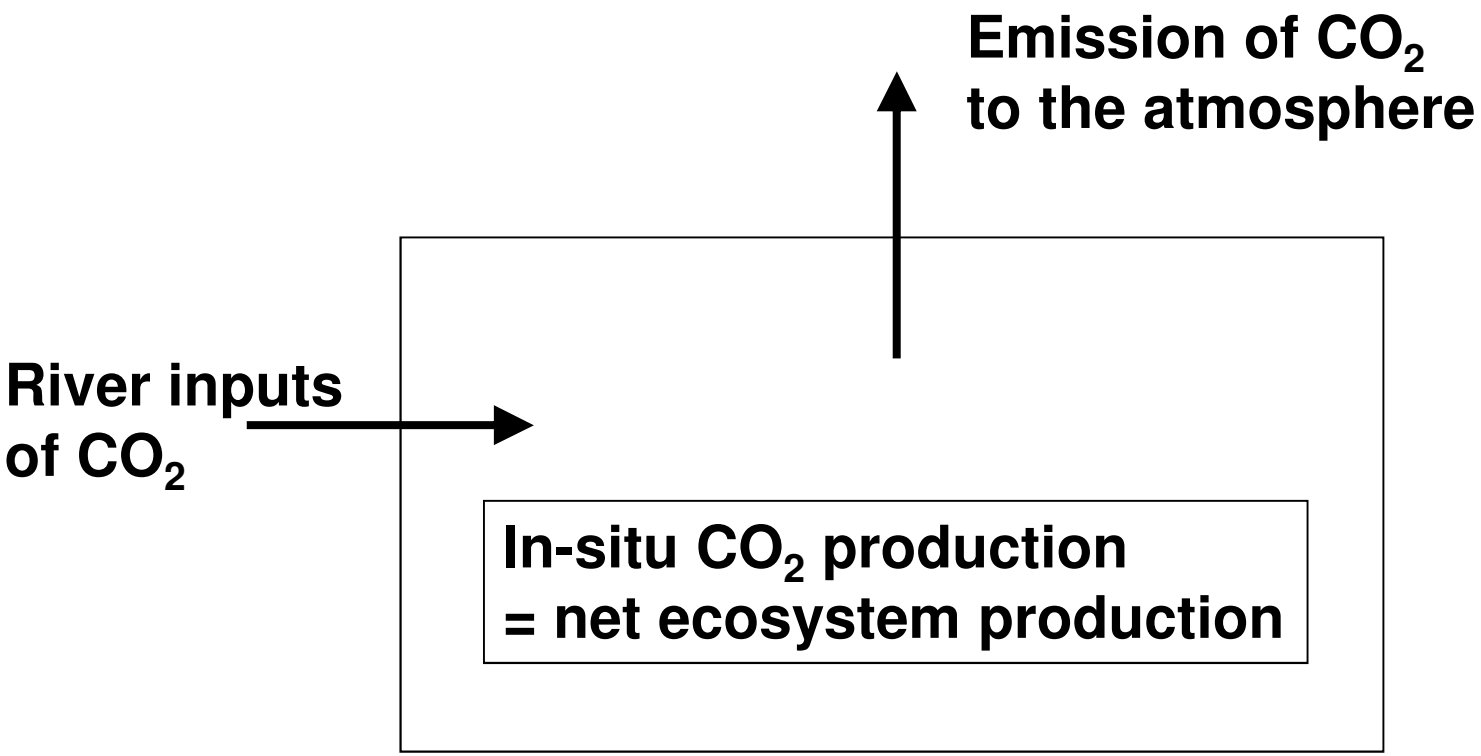
CO_2 emissions from estuaries



CO_2 emissions from estuaries



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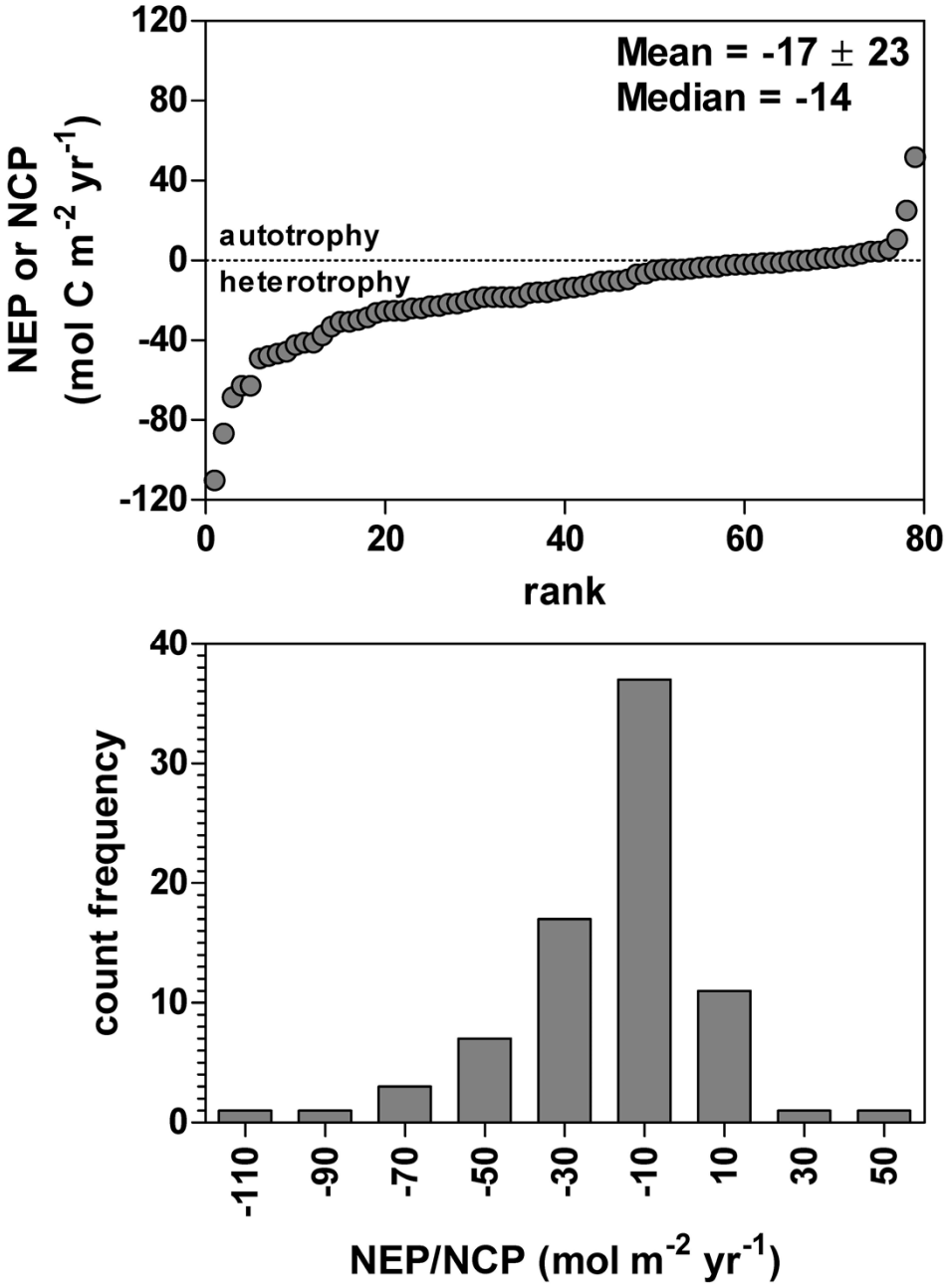
Net community production in estuaries



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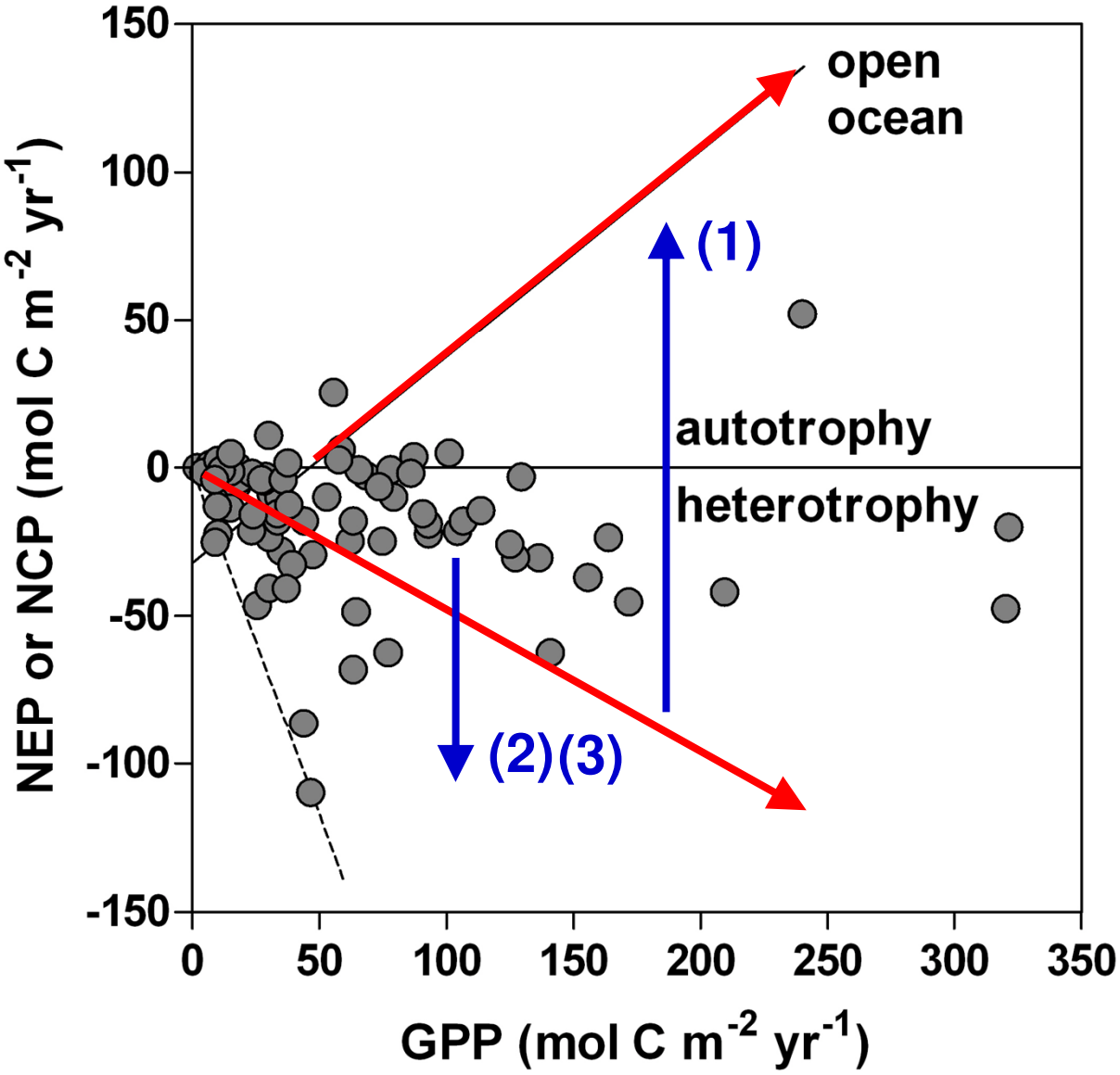
Net community production in estuaries



(1) Increasing ratio of allochtonous inputs of inorganic nutrients : organic matter

(2) Decreasing size

(3) increasing light limitation

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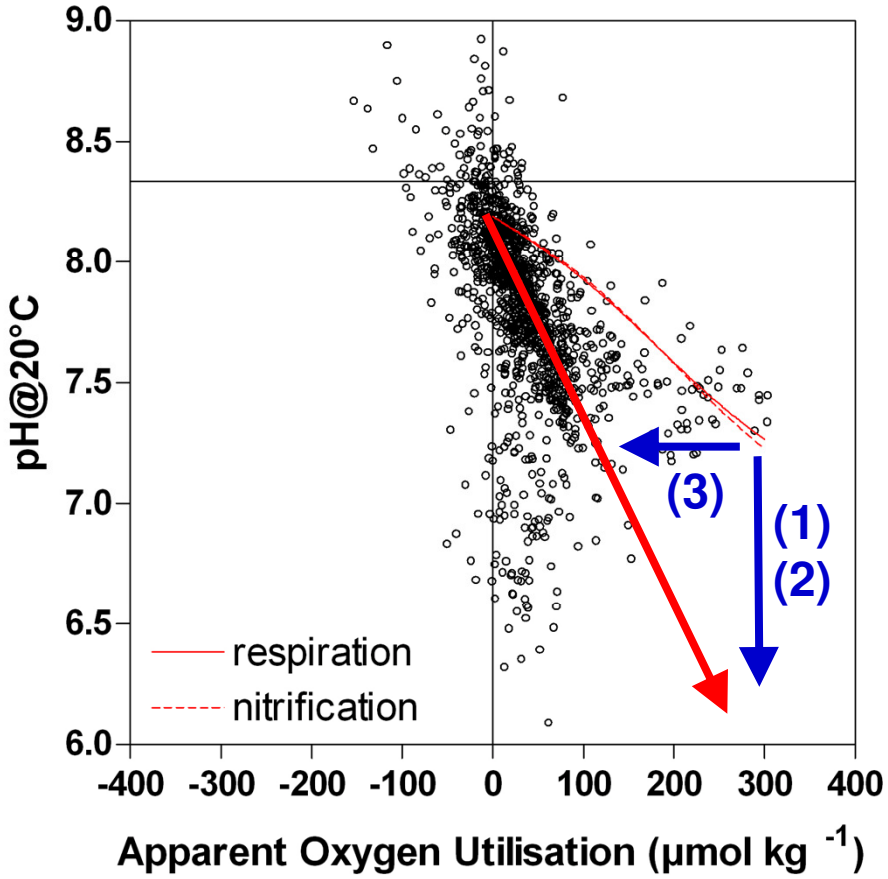
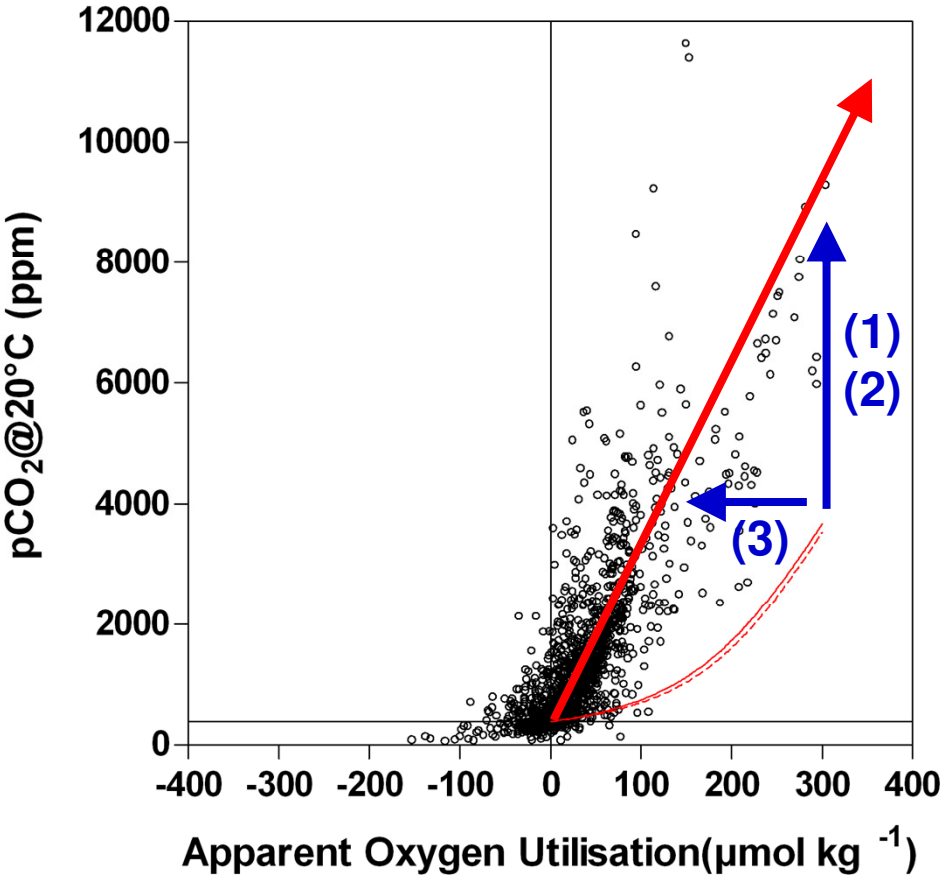
Net community production in estuaries

1641 measurements in 24 estuarine environments





(1) allochtonous inputs of CO_2 (riverine and lateral)

(2) anoxic production of CO_2

(3) more rapid equilibration of O_2 than CO_2

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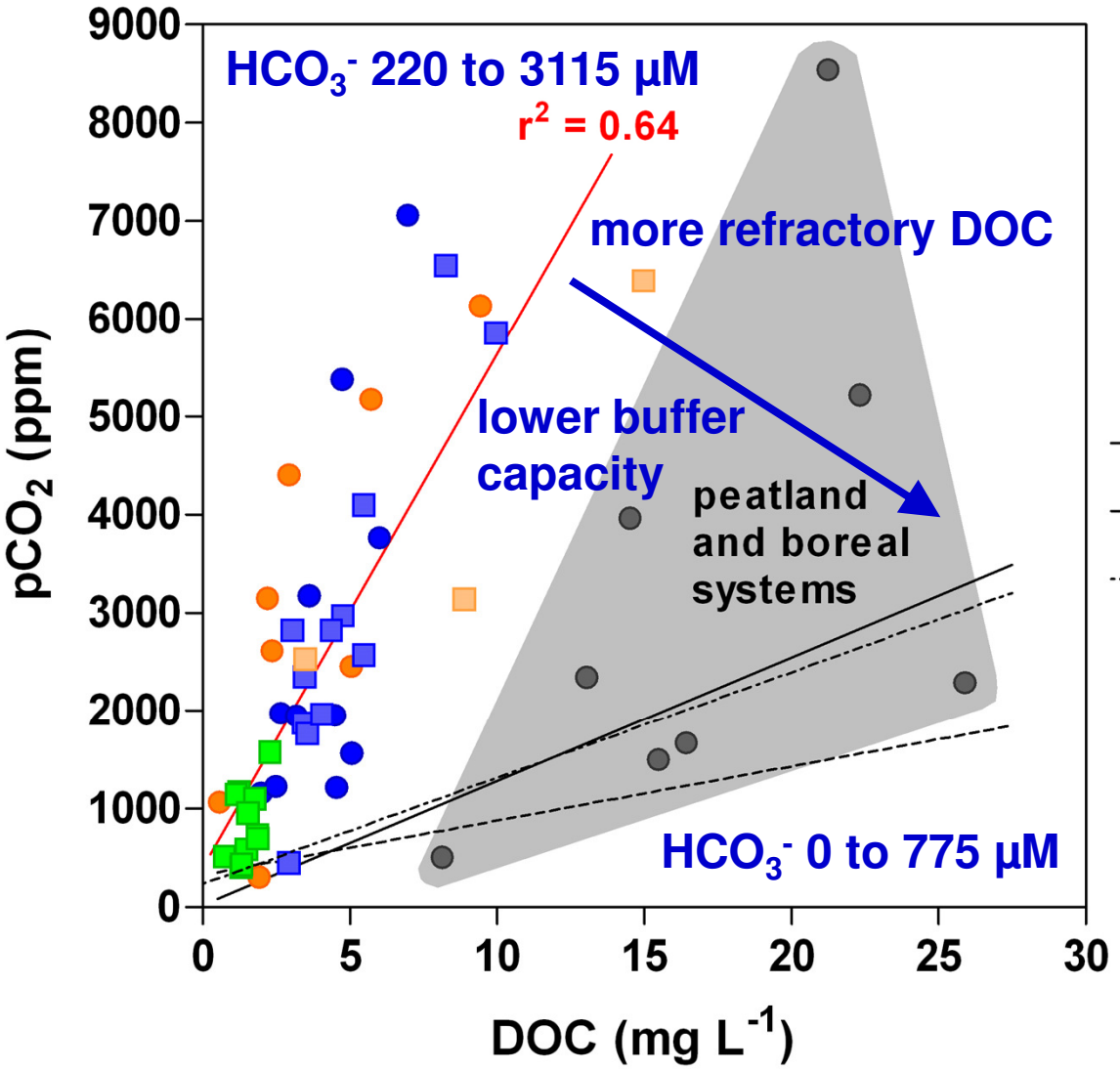
CO_2 River inputs



- EU Tidal rivers
- Tropical Tidal rivers
- UK rivers
- Tropical rivers
- Kivu streams
- Peatland rivers
- Quebec streams & rivers
- Lakes (global)
- Lakes (boreal)

• terrestrial organic matter inputs (DOC) sustaining net heterotrophy in the rivers (pCO_2)

• Inputs of both DOC and CO_2 from soils by ground-waters and surface run-off

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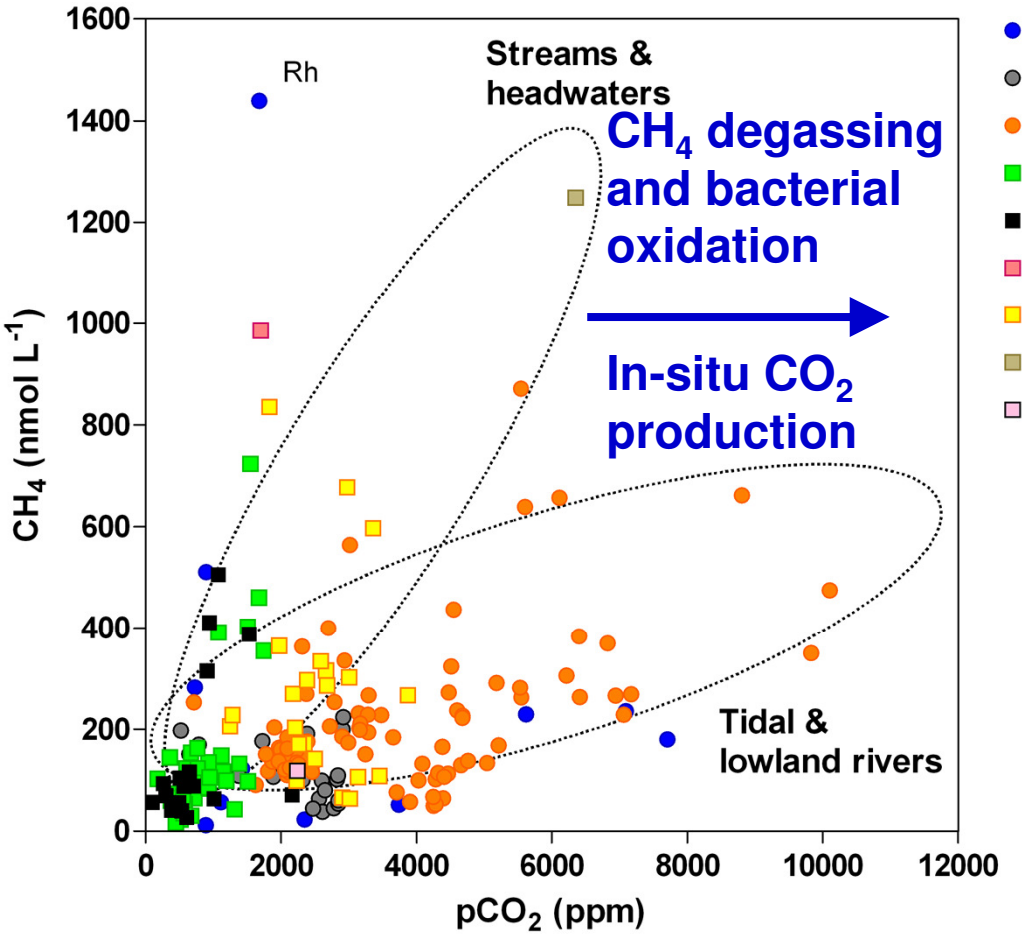
CO_2 River inputs



- EU tidal rivers
- Mekong tidal river
- Ivory Coast lowland rivers
- Kivu streams
- Tana streams
- Temmesjoki River
- Little River & Little Pigeon River
- Great Smoky Mountains National park (headwater)
- Pearl River

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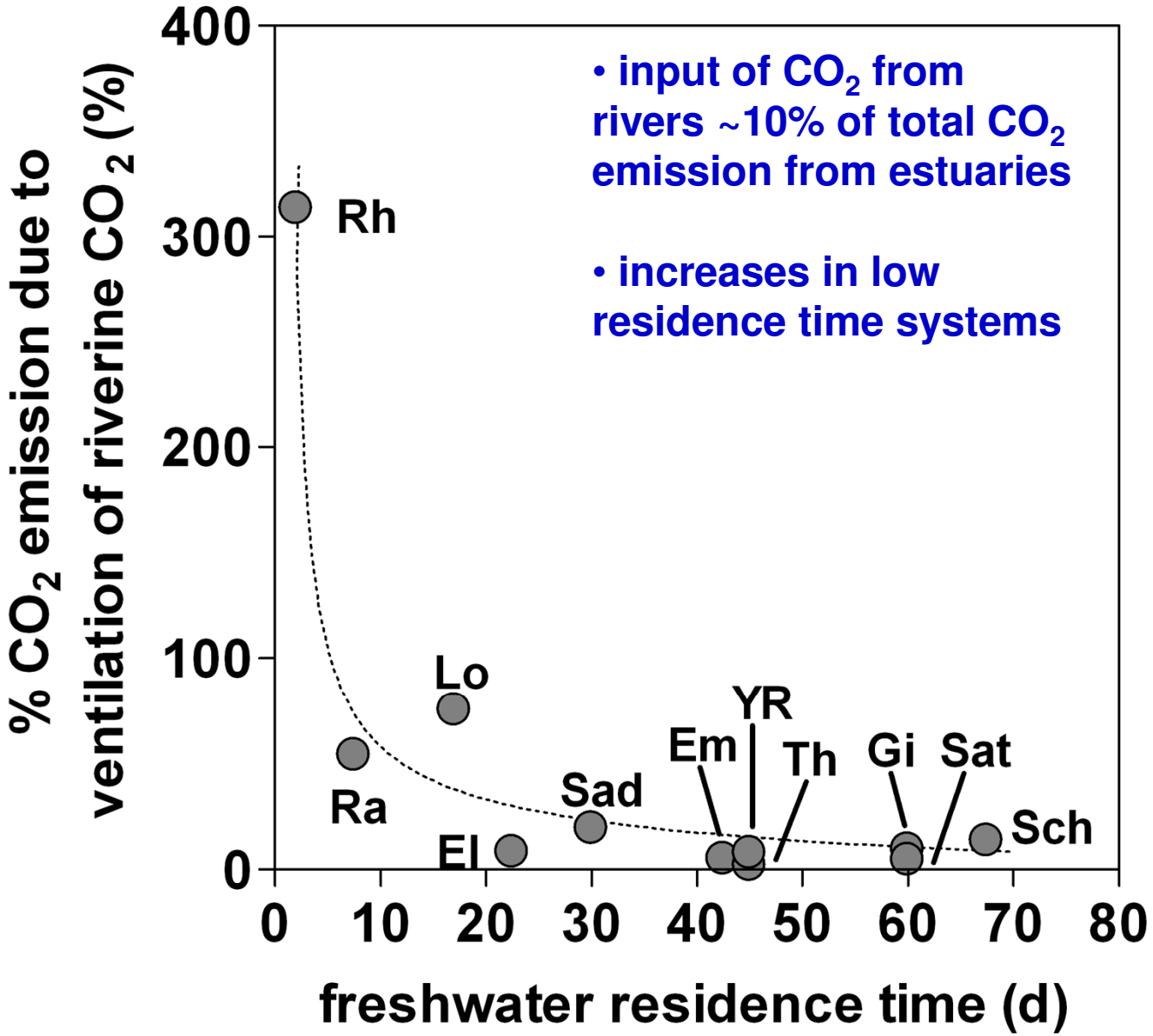
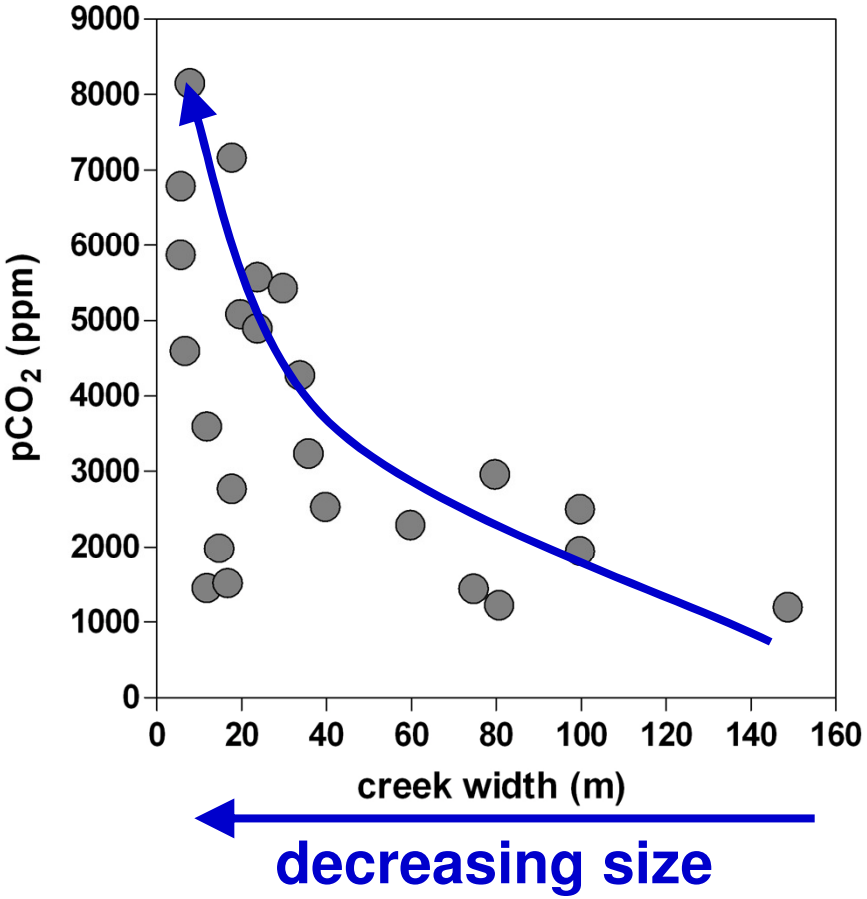
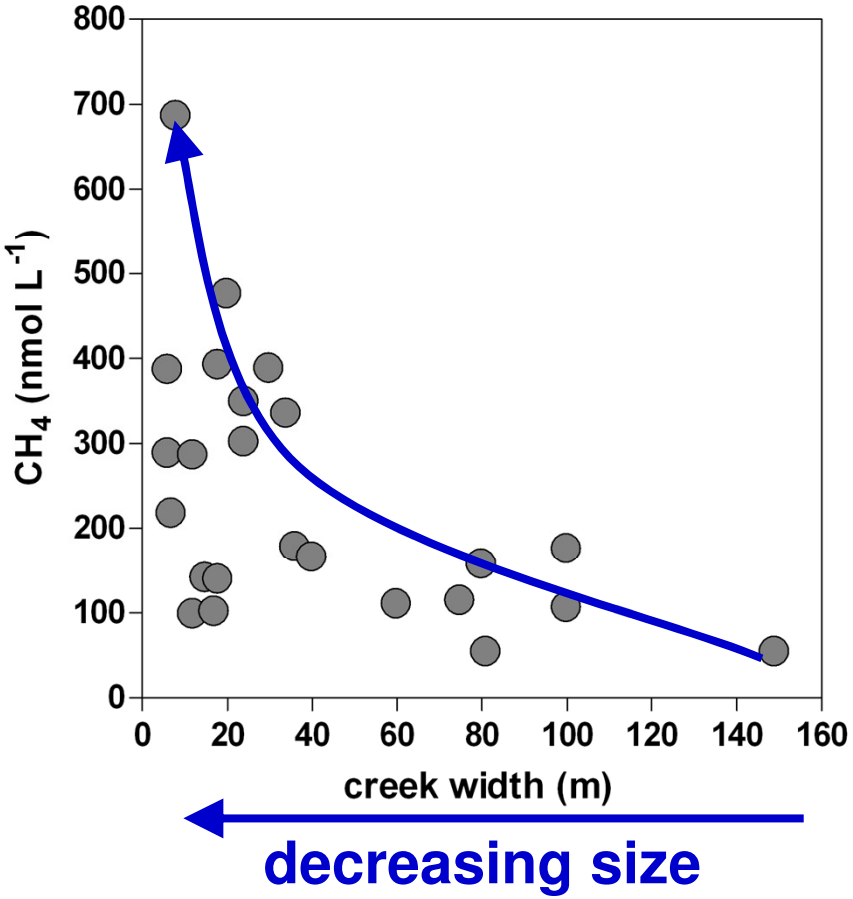
CO_2 River inputs



Physical settings - size

Mangrove creeks of Ca Mau (Vietnam)





- Larger impact on smaller systems of inputs of pore waters rich in CO_2 & CH_4

- Higher production of CO_2 and CH_4 in the water column and sediments sustained by allochtonous organic carbon inputs (higher ratio of inputs to volume)

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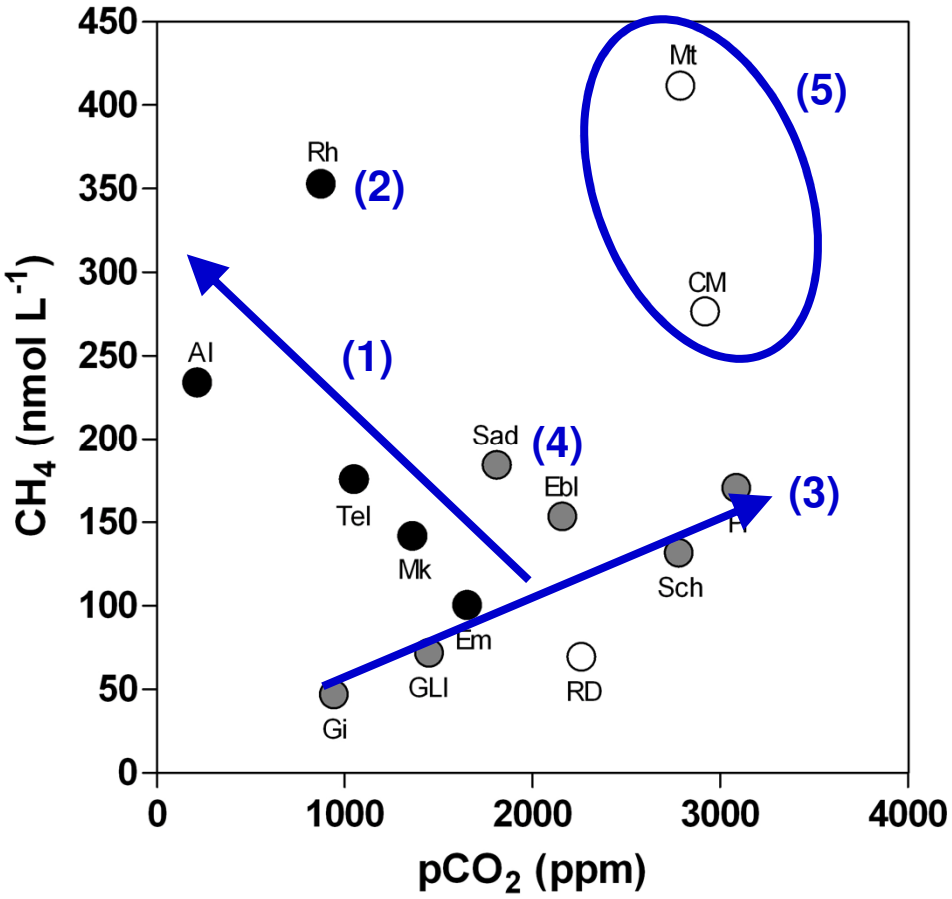
Physical settings - stratification



- Large stratified
- Large mixed
- Small mixed

(1) Stratified systems
= transfer of O.M. across the pycnocline
= decrease of CO_2 in surface waters
= promoting anoxia in bottom waters
= favourable for methanogenesis

(2) Rhine
= high freshwater discharge
= short residence time
= low loss of riverine CH_4 by evasion to the atmosphere and by bacterial oxidation
= lesser CO_2 production due net heterotrophy

(3) Well-mixed systems
= increase of allochtonous carbon inputs
= increase of both CO_2 & CH_4 production

(4) Sado
= very extensive inter-tidal areas and marshes
= higher lateral inputs of CH_4 from pore waters

(5) Small mixed systems
= lateral inputs of CH_4 from pore waters
= high allochtonous inputs sustaining methanogenesis

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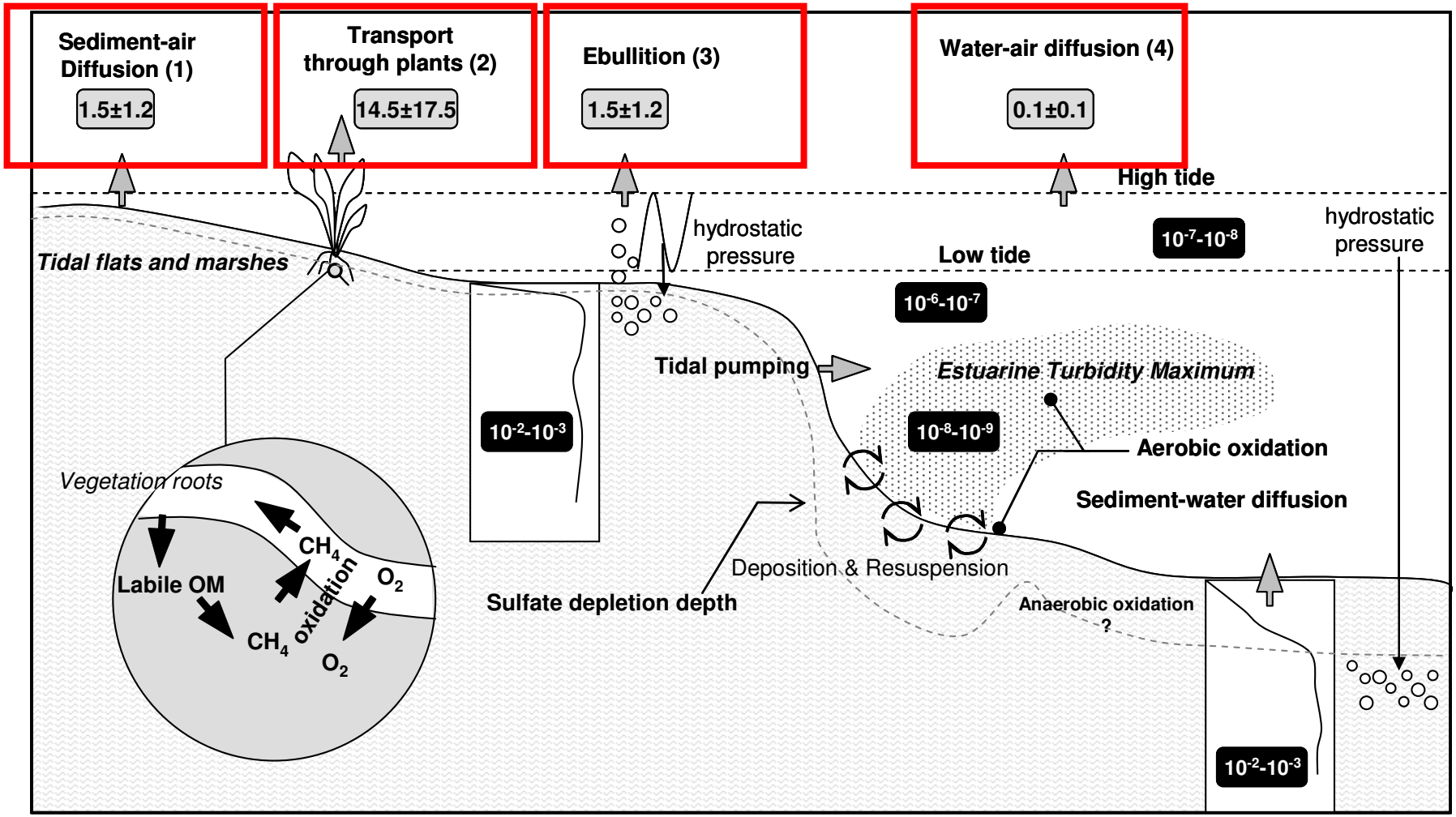
CH_4 fluxes

A. Freshwaters and low salinity regions



mmol m^{-2} d^{-1} | mol L^{-1}

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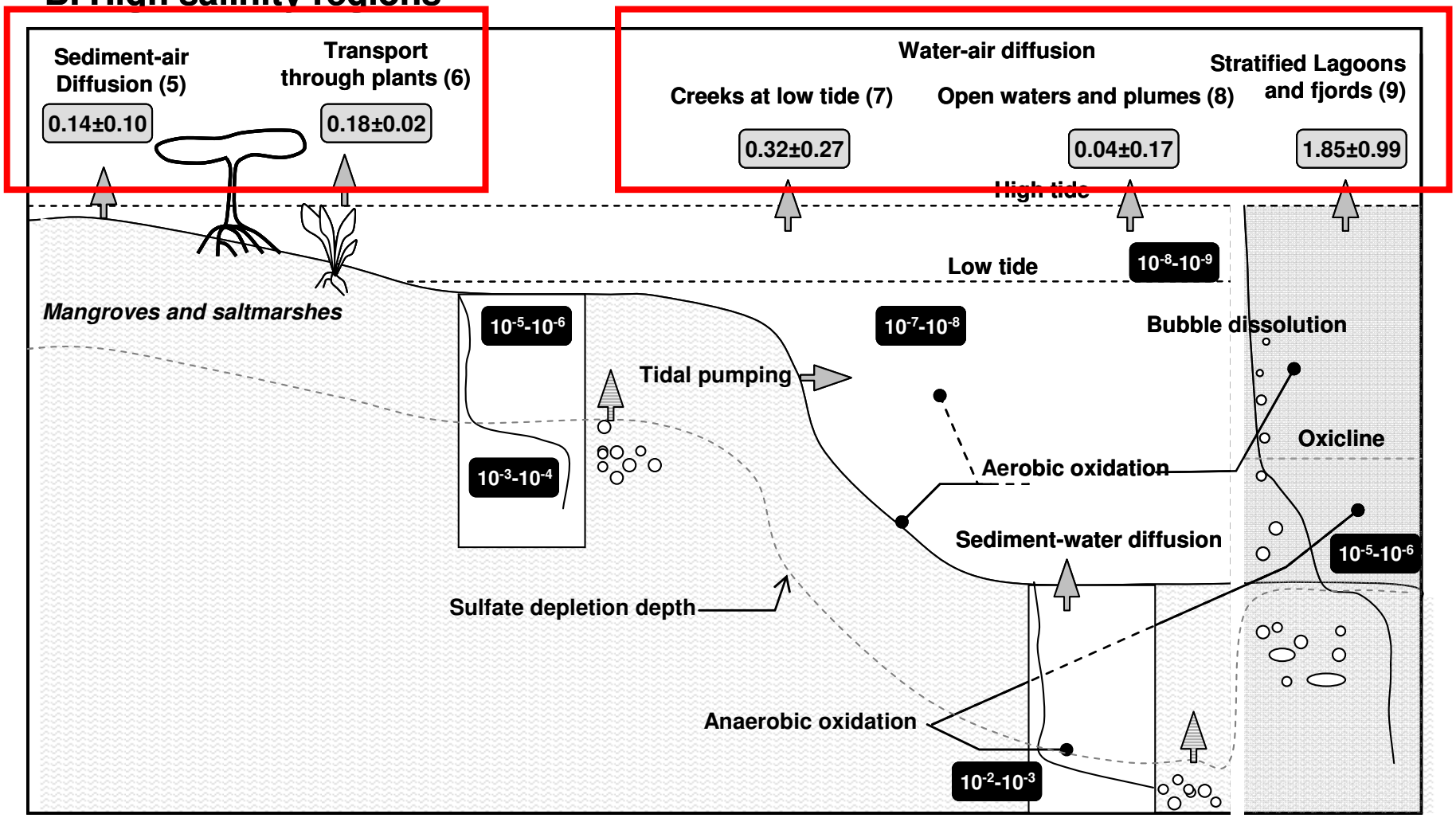
CH_4 fluxes

B. High salinity regions

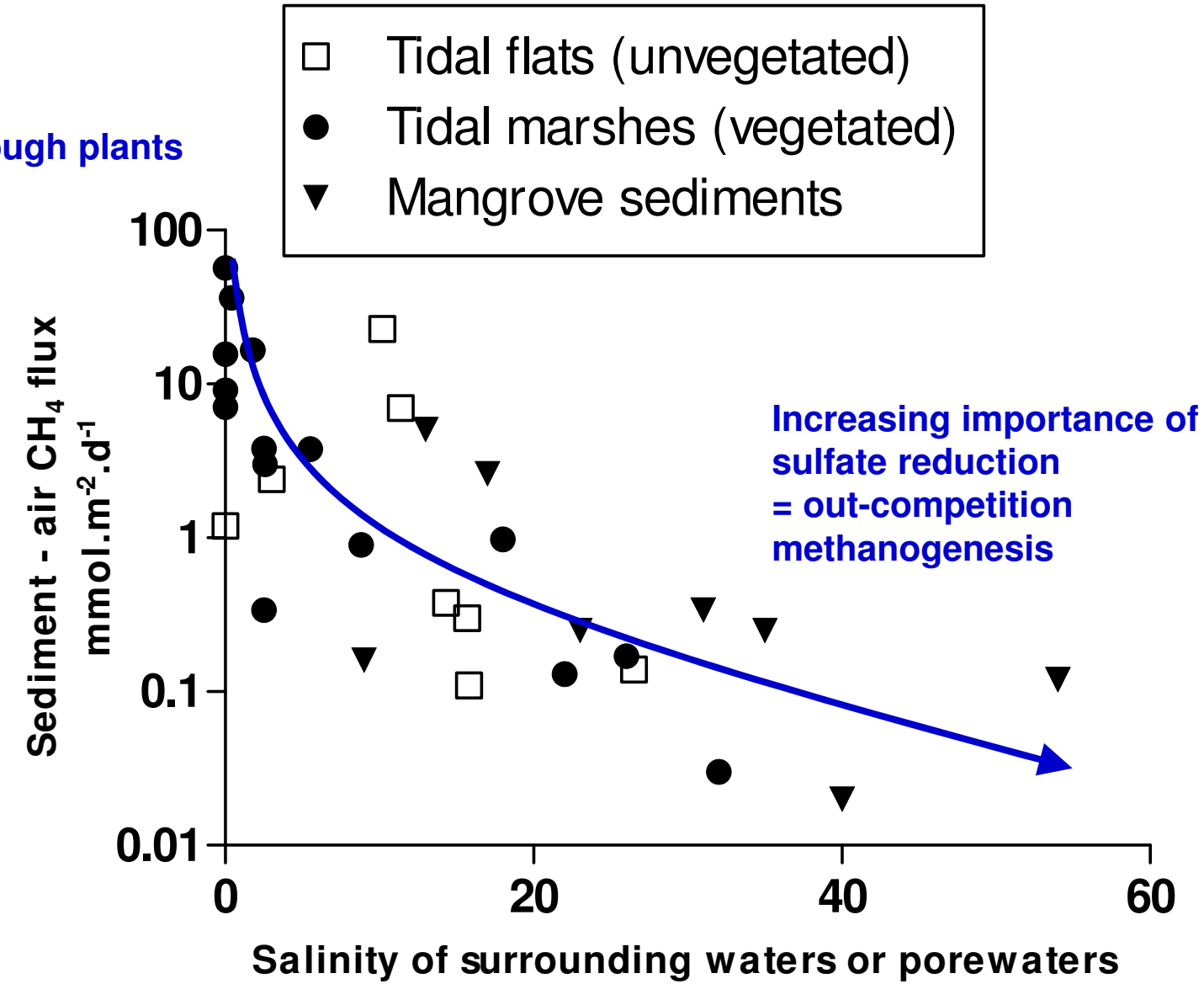


mmol m^{-2} d^{-1}

mol L^{-1}

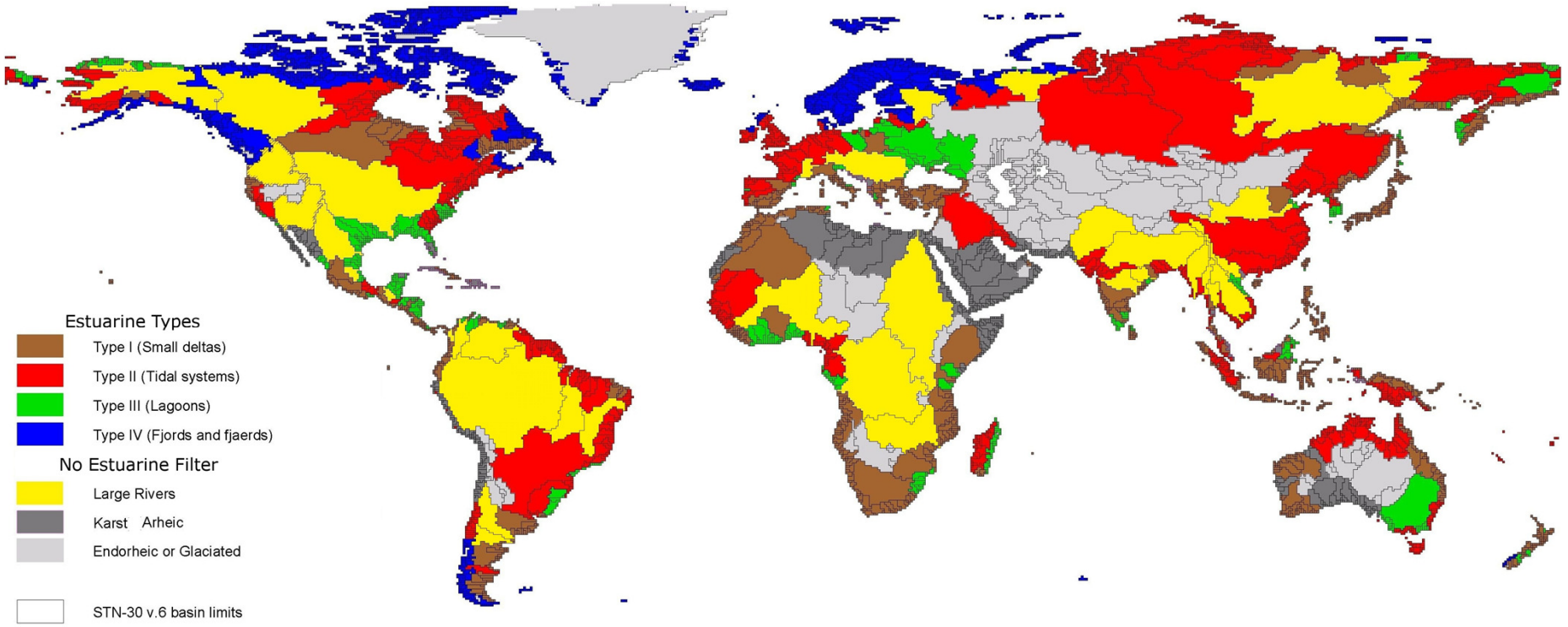
CH_4 fluxes

diffusion
ebullition
transport through plants



Global scaling of CO_2 & CH_4 fluxes

Typology of estuaries of Dürr et al. (2010)



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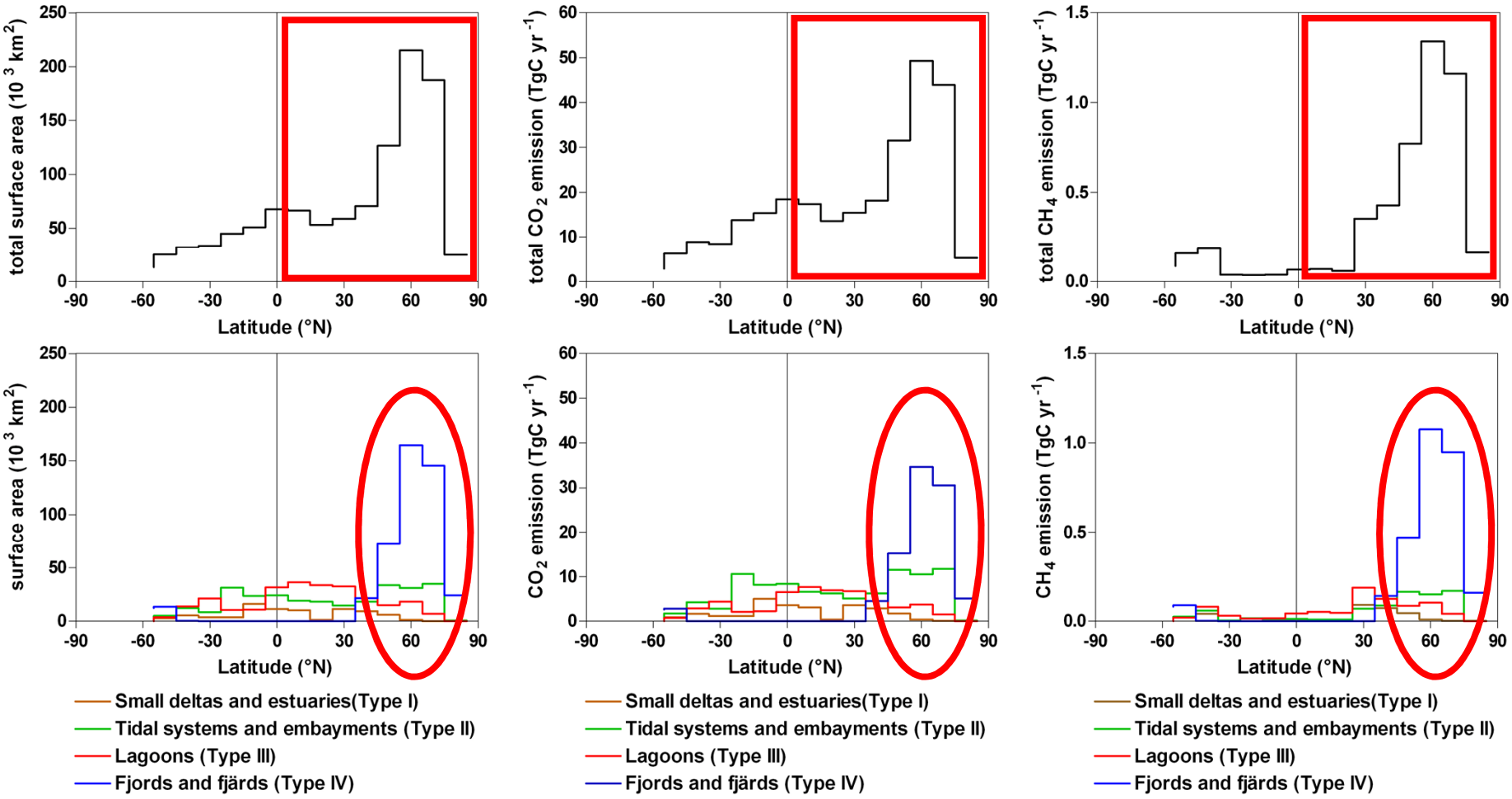
Global scaling of CO_2 & CH_4 fluxes



Larger emission of CO_2 and CH_4 in the Northern Hemisphere

Related to surface area

Dominance by fjords and fjärds

Global scaling of CO_2 & CH_4 fluxes

CO_2 emissions

PgC yr^{-1}	mol m^{-2} yr^{-1}	10^6 km^2	Reference
0.60	36.5	1.40*	Abril and Borges (2004)
0.43	38.2	0.94**	Borges (2005)
0.32	28.6	0.94**	Borges et al. (2005)
0.36	32.1	0.94**	Chen and Borges (2009)
0.27	21.0	1.10***	this study

* Woodwell et al. (1973) including intertidal areas
** Woodwell et al. (1973) excluding intertidal areas
*** Dürr et al. (2010)

Global scaling of CO_2 & CH_4 fluxes

CH_4 emissions

$TgCH_4\ yr^{-1}$	mmol C $m^{-2}\ yr^{-1}$	$10^6\ km^2$	Reference
0.8-1.3	36-59	1.40*	Bange et al. (1994)
1.8-3.0	79-132	1.40*	Middelburg et al. (2002)
6.8	385	1.10**	this study

* Woodwell et al. (1973) including intertidal areas
** Dürr et al. (2010)

Global scaling of CO_2 & CH_4 fluxes

CH_4 emissions

Natural sources ($TgCH_4\ yr^{-1}$)	
Wetlands	100-231
Termites	20-29
Ocean	4-15
Hydrates	4-5
Geological sources	4-14
Wild animals	15
Wildfires	2-5
Estuaries	7

Global scaling of CO_2 & CH_4 fluxes

CH_4 emissions

Aquatic sources ($TgCH_4\ yr^{-1}$)	
Wetlands	100-231
Rice paddies	31-112
Hydroelectric reservoirs	70
Lakes	8-48
Ocean	4-15
Estuaries	7

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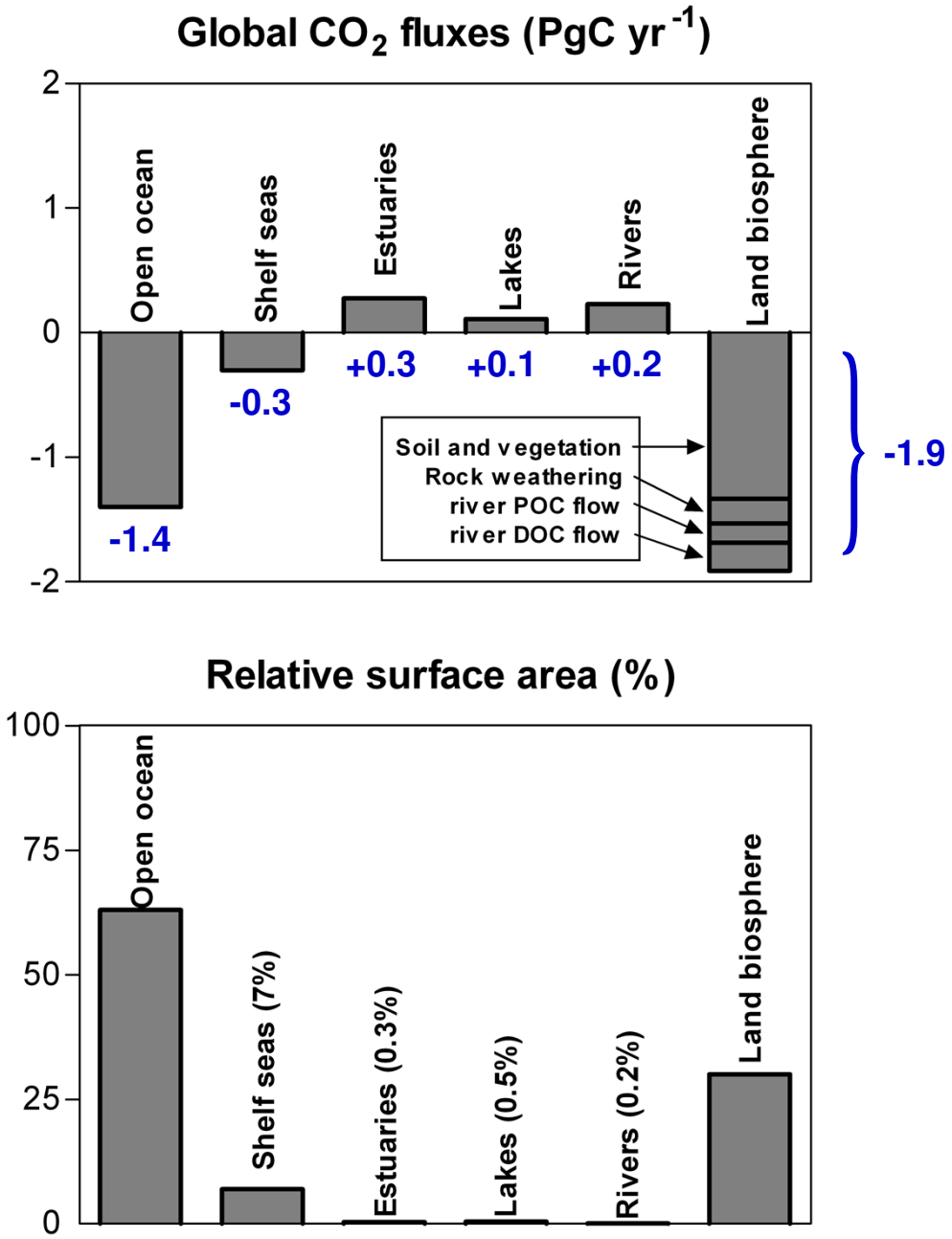
Global scaling of CO_2 & CH_4 fluxes



Conclusions

- **Need of observations in more estuaries worldwide**

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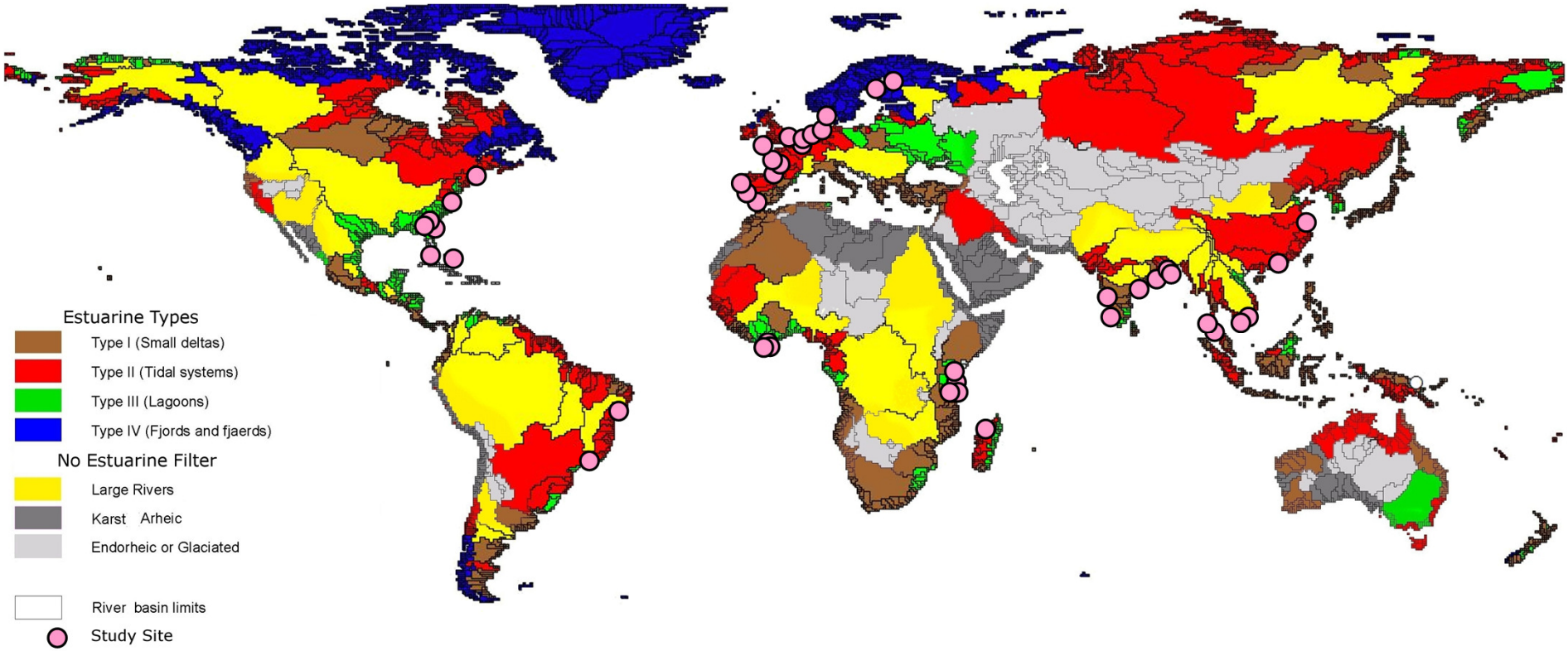
Conclusions

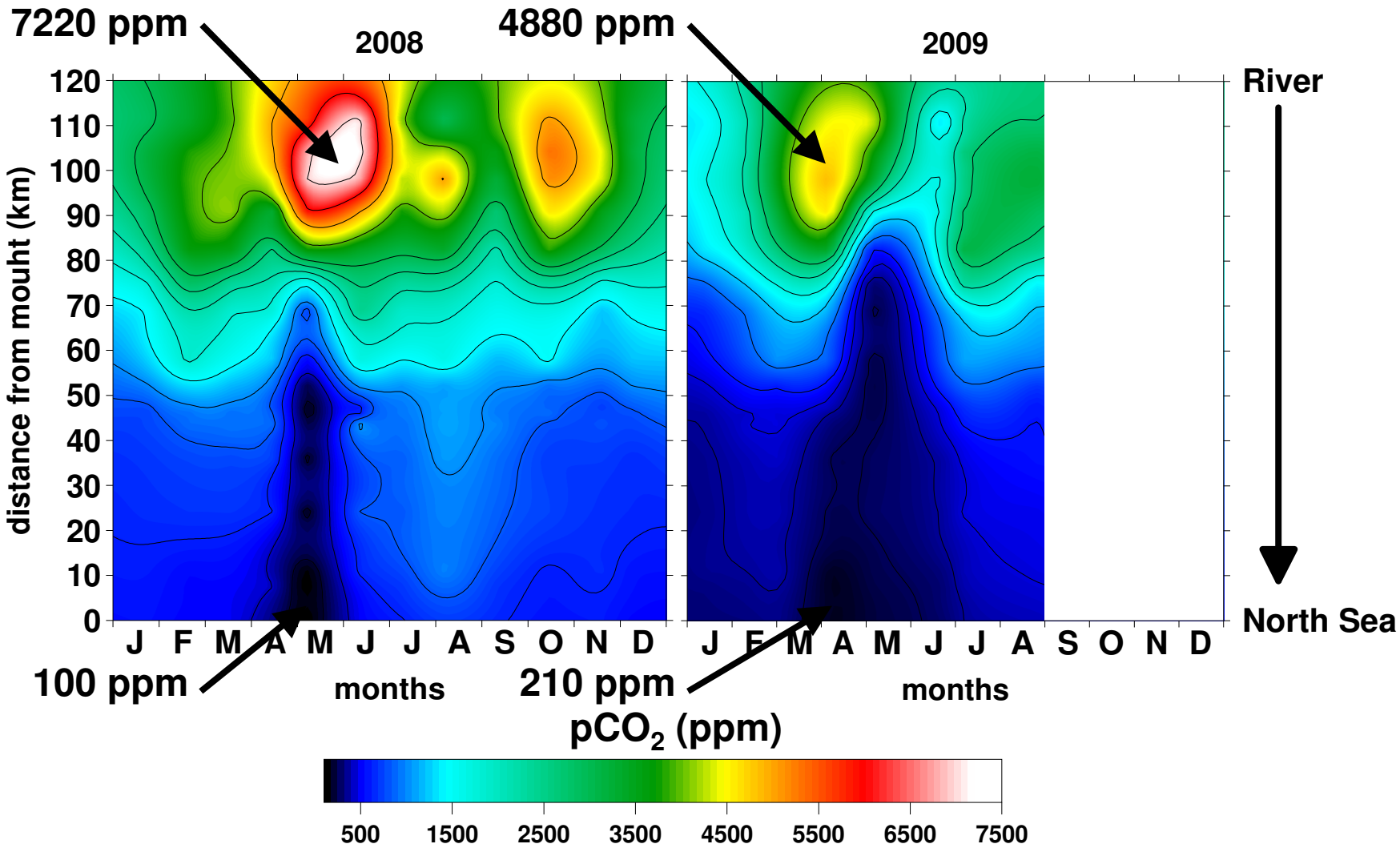


Conclusions

- Need of observations in more estuaries worldwide
- Need of sustained observations to unravel inter-annual variations

Conclusions

Scheldt estuary

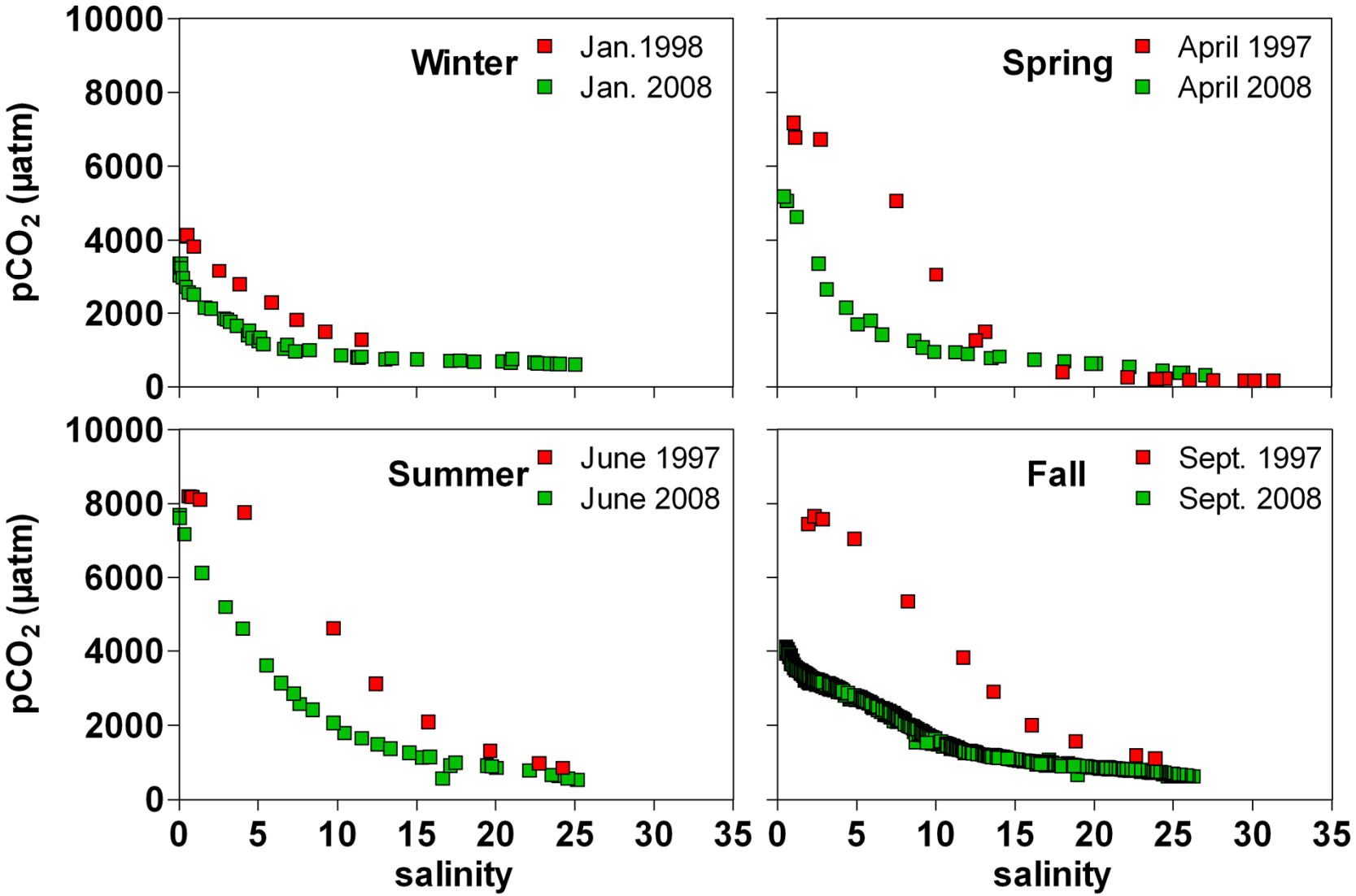


Conclusions

- Need of observations in more estuaries worldwide
- Need of sustained observations to unravel inter-annual variations
- Need of sustained observations to unravel long term changes

Conclusions

Scheldt estuary



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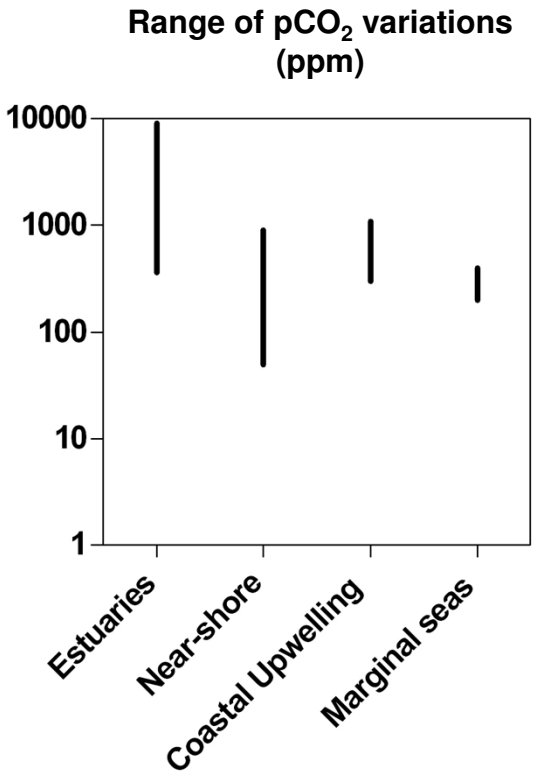
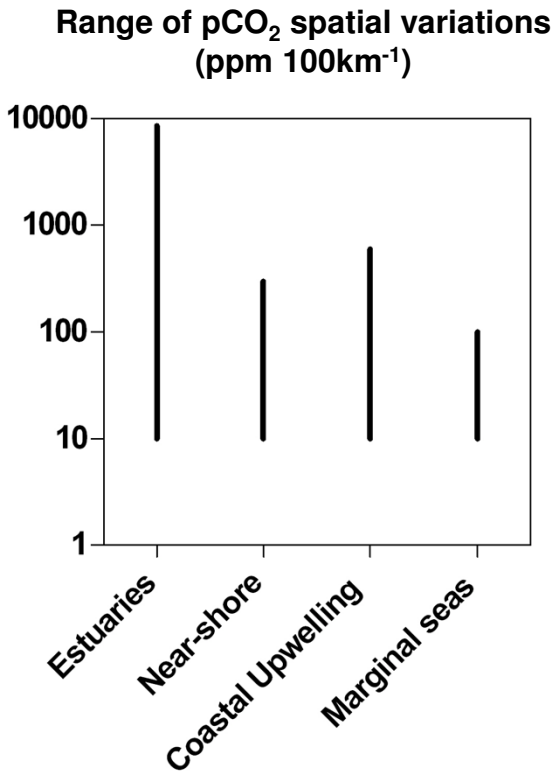
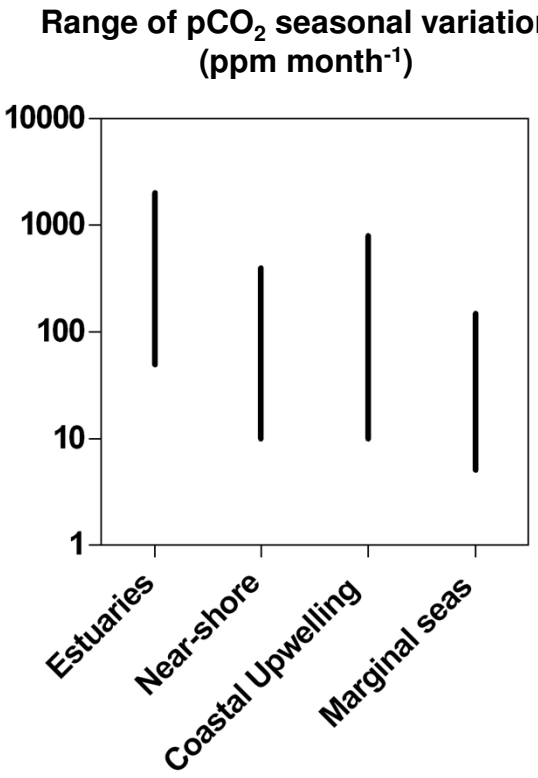
Dynamic range in estuaries







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Dynamic range in estuaries