ASLO Summer Meeting
Santiago de Compostela
19-24 June 2005

Do we have enough pieces of the jigsaw to integrate CO_2 fluxes in the Coastal Ocean ?

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Carboocean (FP6 511176-2)

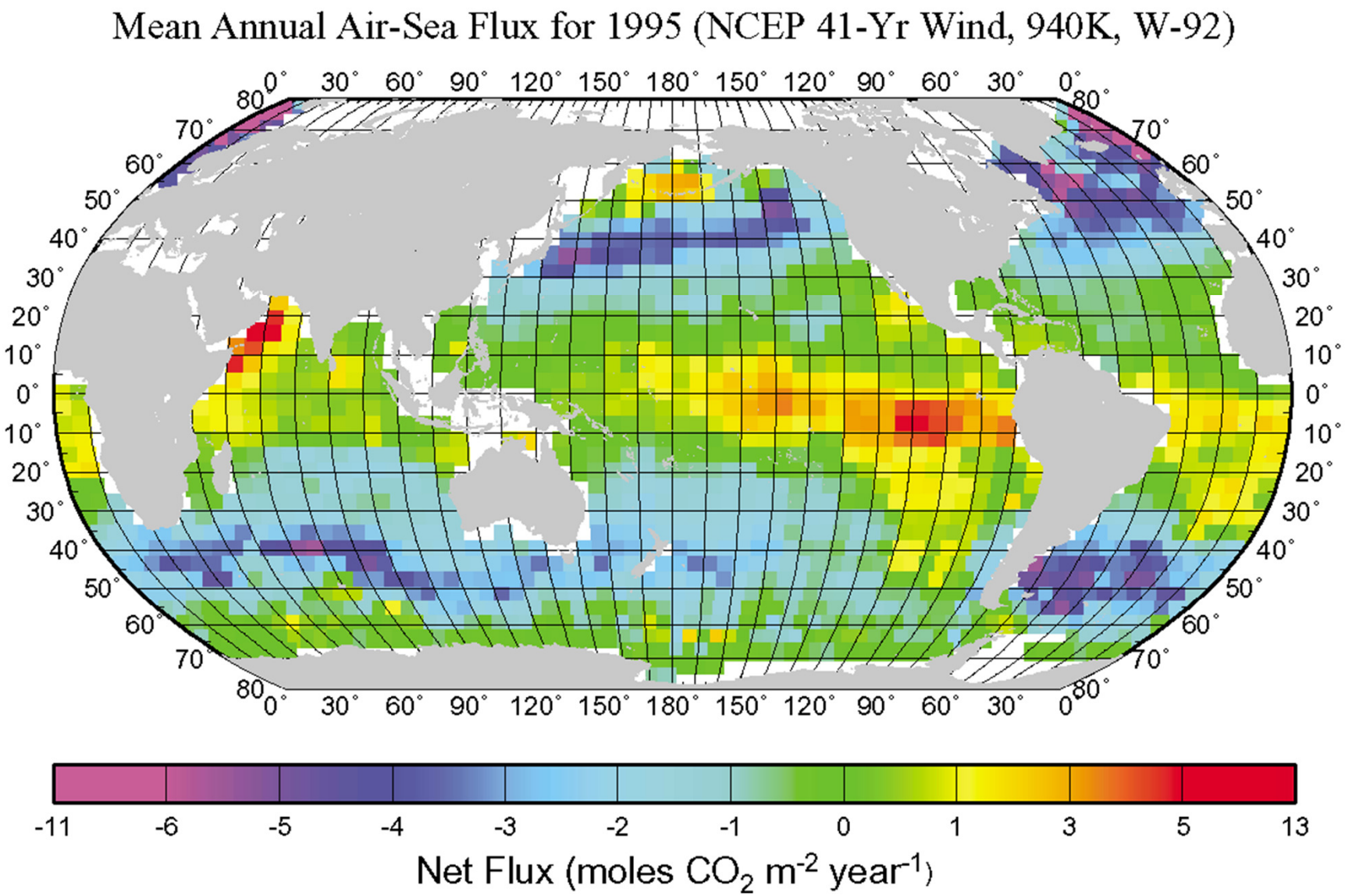
Belcanto (BSP EV/12/7E)

Eurotroph (FP5 EVK3-CT-2000-00040)

Canopy (BSP EV/12/20C)

http://www.ulg.ac.be/oceanbio/co2

Issue



What would happen if we tried to fill the white pixels ?

http://www.ulg.ac.be/oceanbio/co2

Approach

- Climatology approach not possible (too much heterogeneity, not enough data).
- Just about enough data to attempt an up-scaling approach (reasonable flux value for each ecosystem * respective surface area)
- Compilation of CO_2 fluxes in 44 coastal environments, gathered in 6 major coastal ecosystems.

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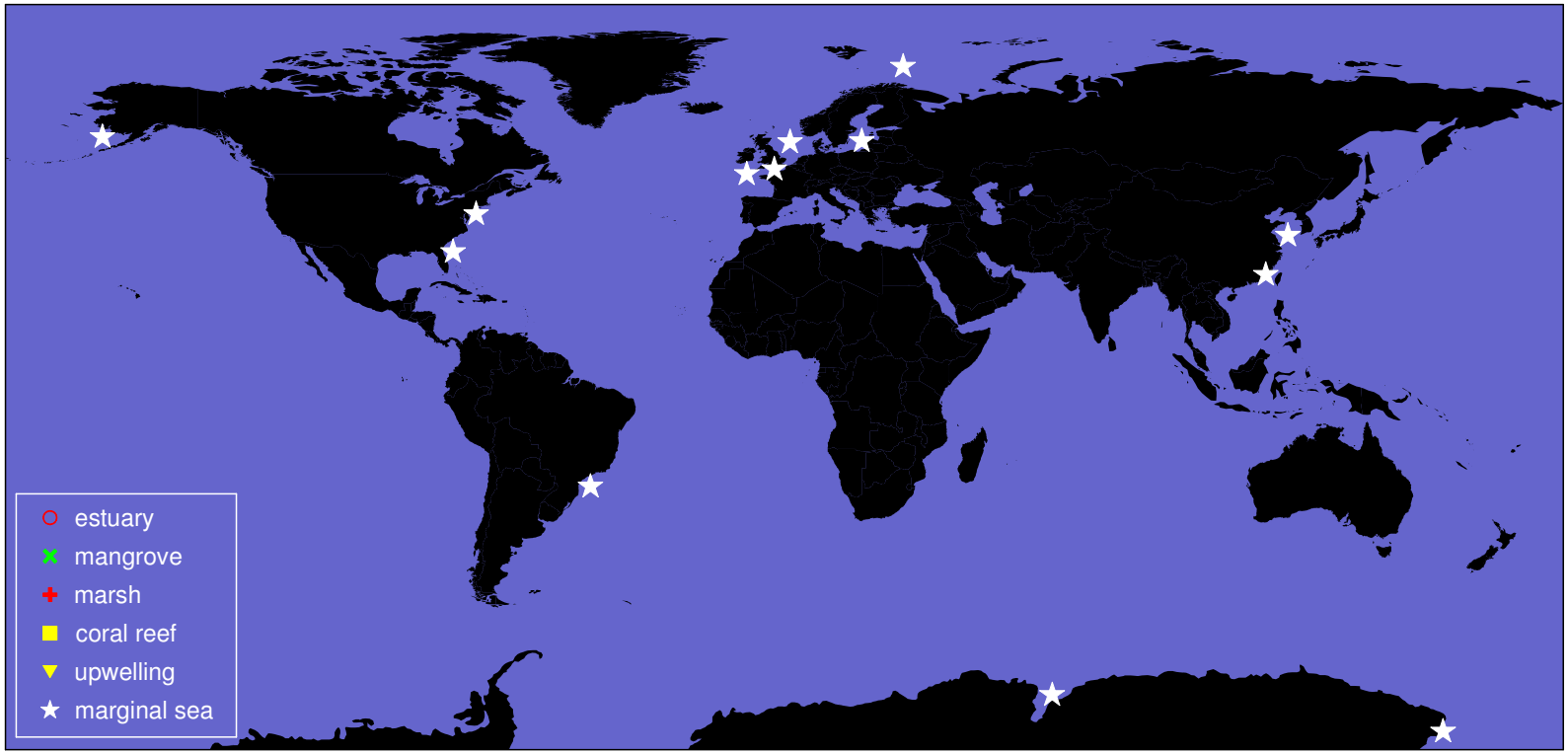
Marginal seas (Fluxes in mol C m^{-2} yr^{-1})



High latitude:	
Barents Sea	-3.6
Bristol Bay	-0.2
Pryzd Bay	-2.2
Ross Sea	-1.8

Temperate latitudes:	
Baltic Sea	-0.8
North Sea	-1.4
English Channel	0.0
Gulf of Biscay	-2.9
US Middle Atlantic Bight	-1.2
East China Sea	-2.1

Sub-tropical & tropical latitudes:	
US South Atlantic Bight	+2.5
South China Sea	+1.8
Southwest Brazilian coast	+1.3

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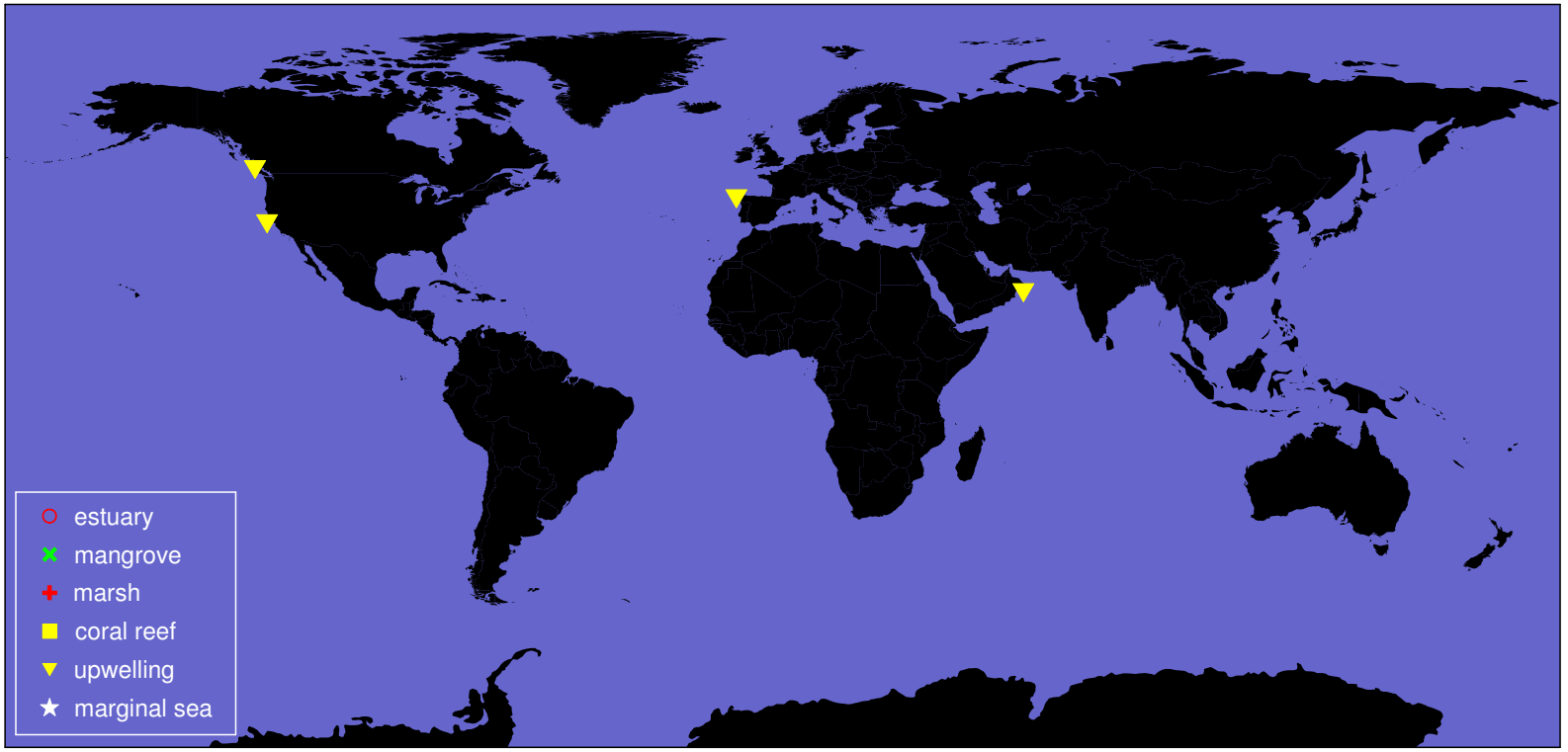
Coastal upwelling (Fluxes in mol C m^{-2} yr^{-1})



Galician coast	-2.2
Vancouver Island	-1.2
Californian coast	+0.5
Oman coast	+0.9

High Upwelling Index systems (California and Oman coasts)
= inputs of nutrients and DIC so intense that primary production "does not have enough time" to deplete surface waters in nutrients and create under-saturation of CO_2 OVER THE SHELF.
= sources of CO_2

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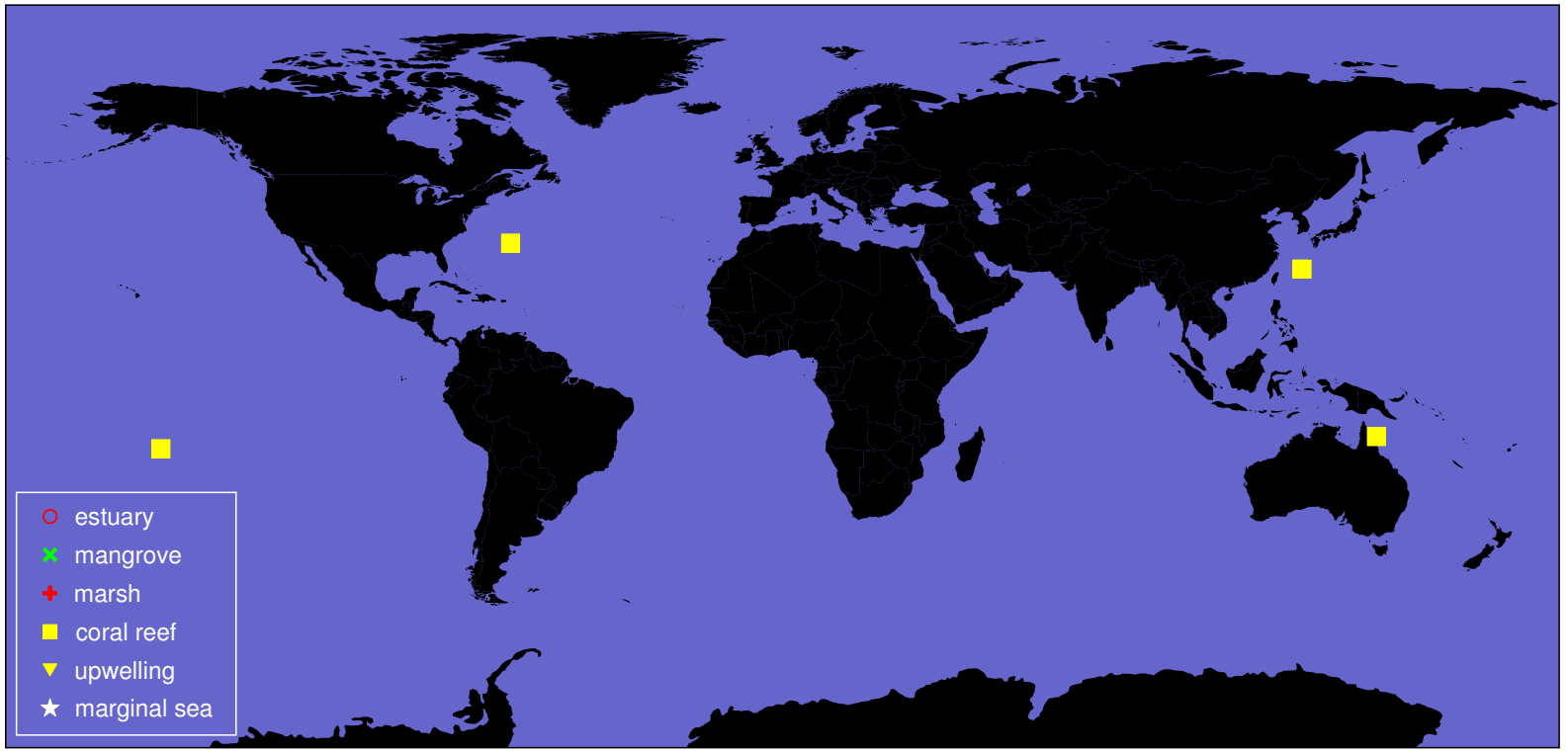
Coral Reefs (Fluxes in mol C m^{-2} yr^{-1})



Hog Reef	+1.2
Okinawa Reef	+1.8
Yonge Reef	+1.5
Moorea	+0.1

By definition, intense calcification

$Ca^{2+} + 2\ HCO_3^- = CaCO_3 + CO_2 + H_2O$

At community level, GPP = R

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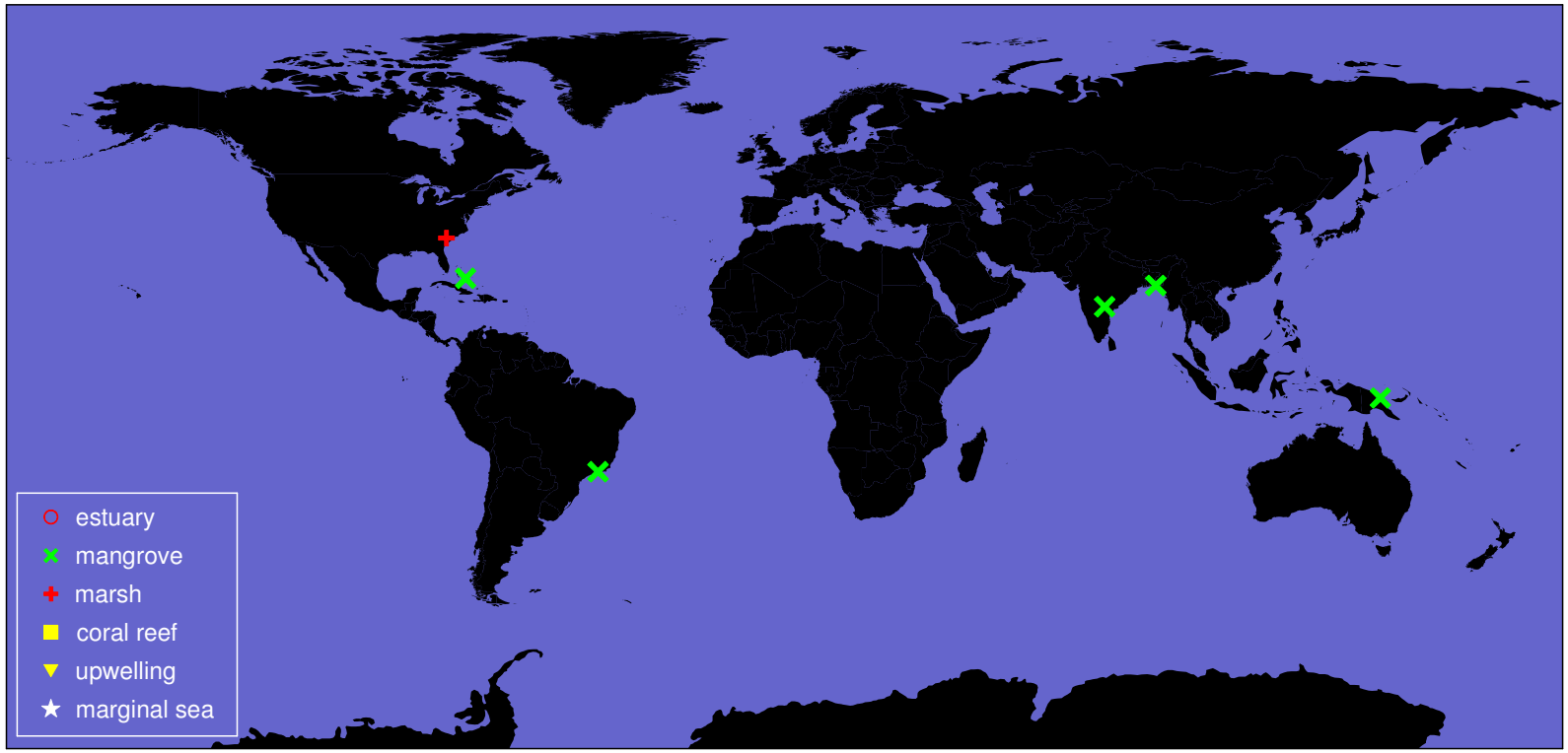
Mangrove & saltmarsh (Fluxes in mol C m^{-2} yr^{-1})



Mangrove waters	Norman's Pond	+5.0
	Mooringanga Creek	+8.5
	Saptamukhi Creek	+20.7
	Gaderu Creek	+20.4
	Nagada Creek	+15.9
	Itacuraça Creek	+41.4
Saltmarsh waters	Duplin River	+23.5

Massive terrestrial organic matter iputs
= strong heterotrophy of water column and sediments
= CO_2 production

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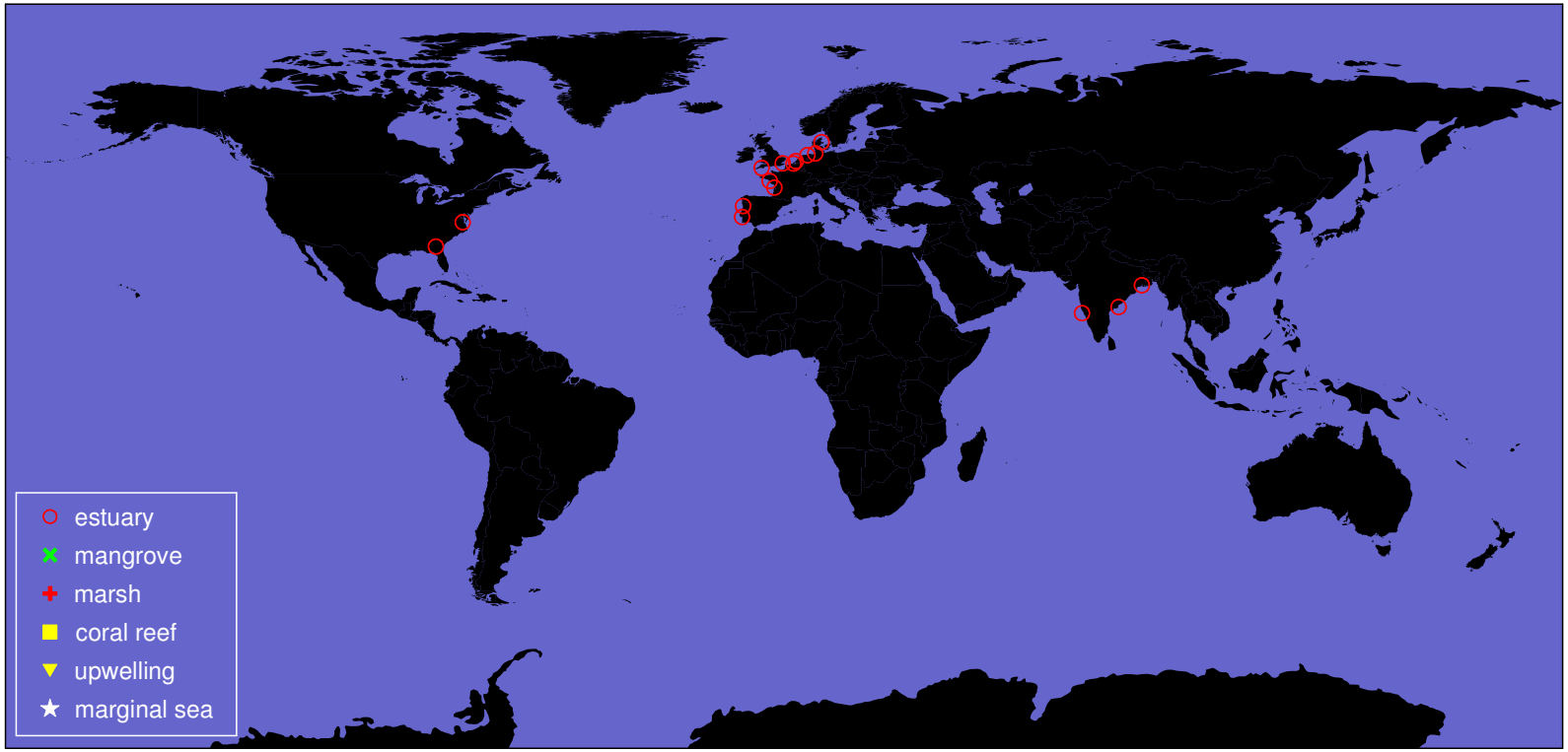
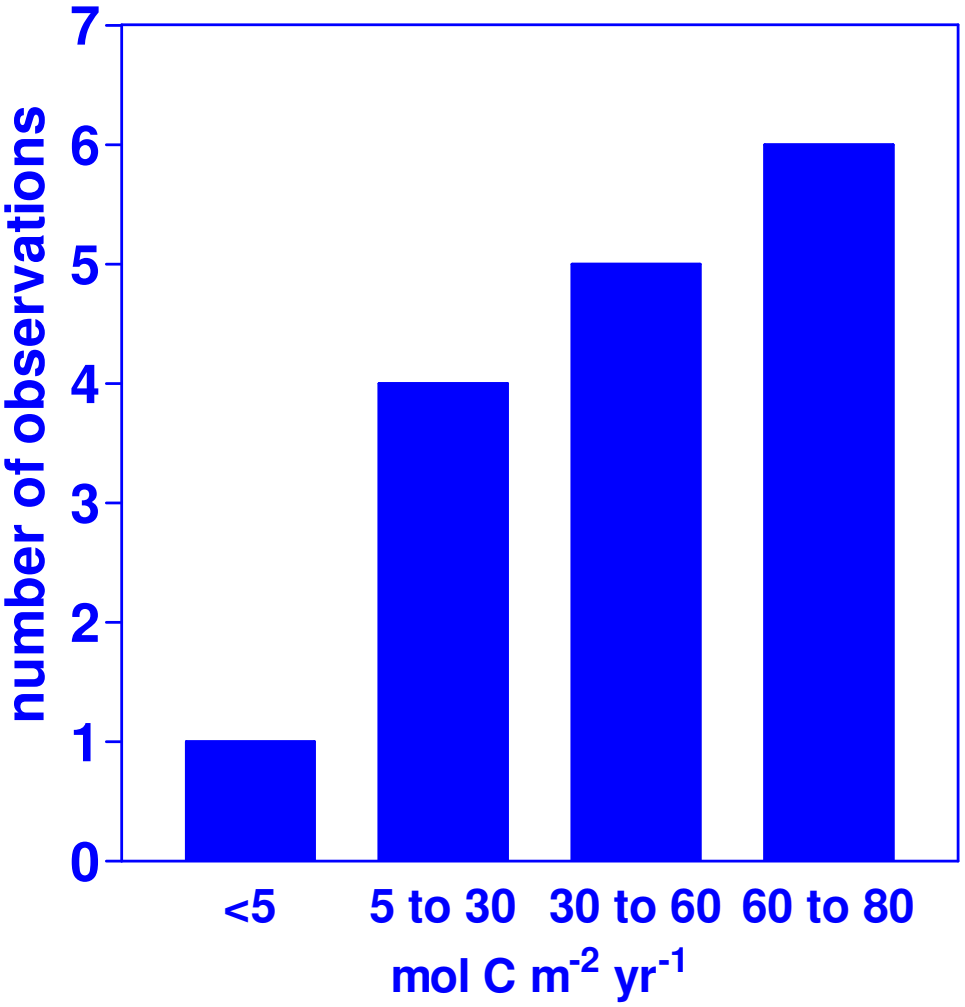
Estuaries



Europe	11
U.S.A.	2
India	3

Estuaries

CO_2 emission from 16 inner estuaries



Temperate estuaries (12)
46 mol C m^{-2} yr^{-1}

Tropical estuaries (4)
19 mol C m^{-2} yr^{-1}

High latitude estuaries
= temperate estuaries ?

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Up-scaling

Surface areas:

- marginal seas + upwelling systems from Walsh (1988)
- mangroves from FAO (2003)
- coral reefs from Spalding et al. (2001)
- estuaries : global estimate from Woodwell et al. (1973) partitioned into latitudinal bands (linear dependence on freshwater discharge)

Open ocean CO_2 fluxes from Takahashi et al. (2002) revised climatology

Latitudinal bands of 30°:

- high latitudes (90°-60°)
- temperate latitudes (60°-30°)
- subtropical and tropical latitudes (30°-0°)

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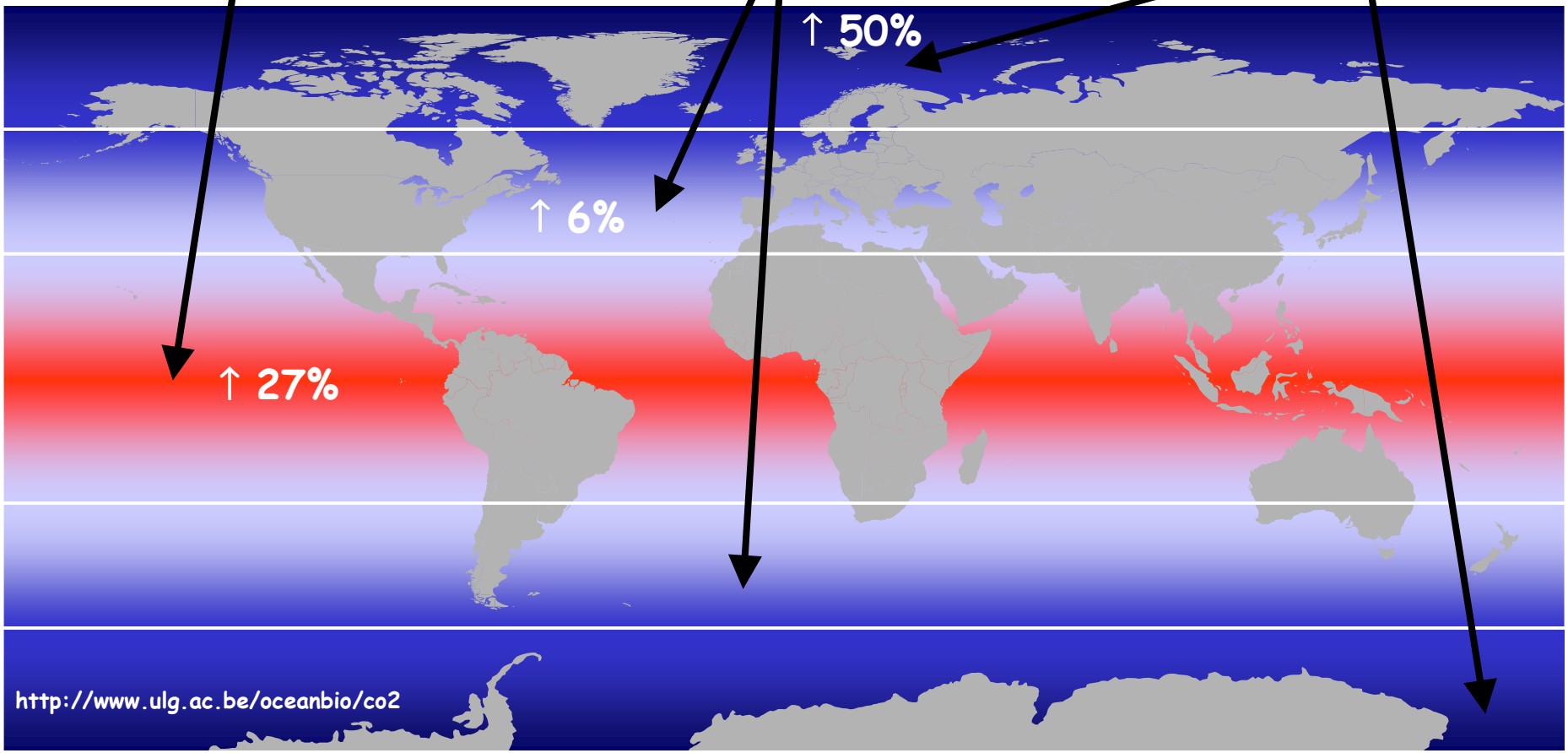
Up-scaling

Coastal -0.05 Pg C y^{-1} Open -1.57 Pg C y^{-1} Global -1.61 Pg C y^{-1} ↑ 3%

Coastal	+0.18 Pg C y^{-1}
Open	+0.71 Pg C y^{-1}
Global	+0.90 Pg C y^{-1}

Coastal	-0.13 Pg C y^{-1}
Open	-2.06 Pg C y^{-1}
Global	-2.19 Pg C y^{-1}

Coastal	-0.10 Pg C y^{-1}
Open	-0.22 Pg C y^{-1}
Global	-0.33 Pg C y^{-1}



Up-scaling : ecosystem diversity counts !

Overall coastal ocean small CO_2 sink (–0.05 PgC yr^{-1})

Marginal seas strong sink (–0.45 PgC yr^{-1})

Near-shore systems (estuaries, mangroves, marshes, coral reefs, upwelling systems) strong source (0.40 PgC yr^{-1})

Up-scaling : reliability ?

	PgC yr^{-1}	% total
Estuaries	0.324	81.1
Marsh waters	0.036	9.0
Mangroves waters	0.033	8.2
Coral reefs	0.005	1.3
Upwelling	0.002	0.5
Nearshore systems	0.400	100

Up-scaling : reliability ?

CO_2 emission from estuaries of 0.32 Pg C yr^{-1}

- emission of 0.08 Pg C yr^{-1} ☹

  (river POC input from Ludwig et al. 1996; 50% of river POC is degraded and ventilated in estuaries - Abril et al. 2002)

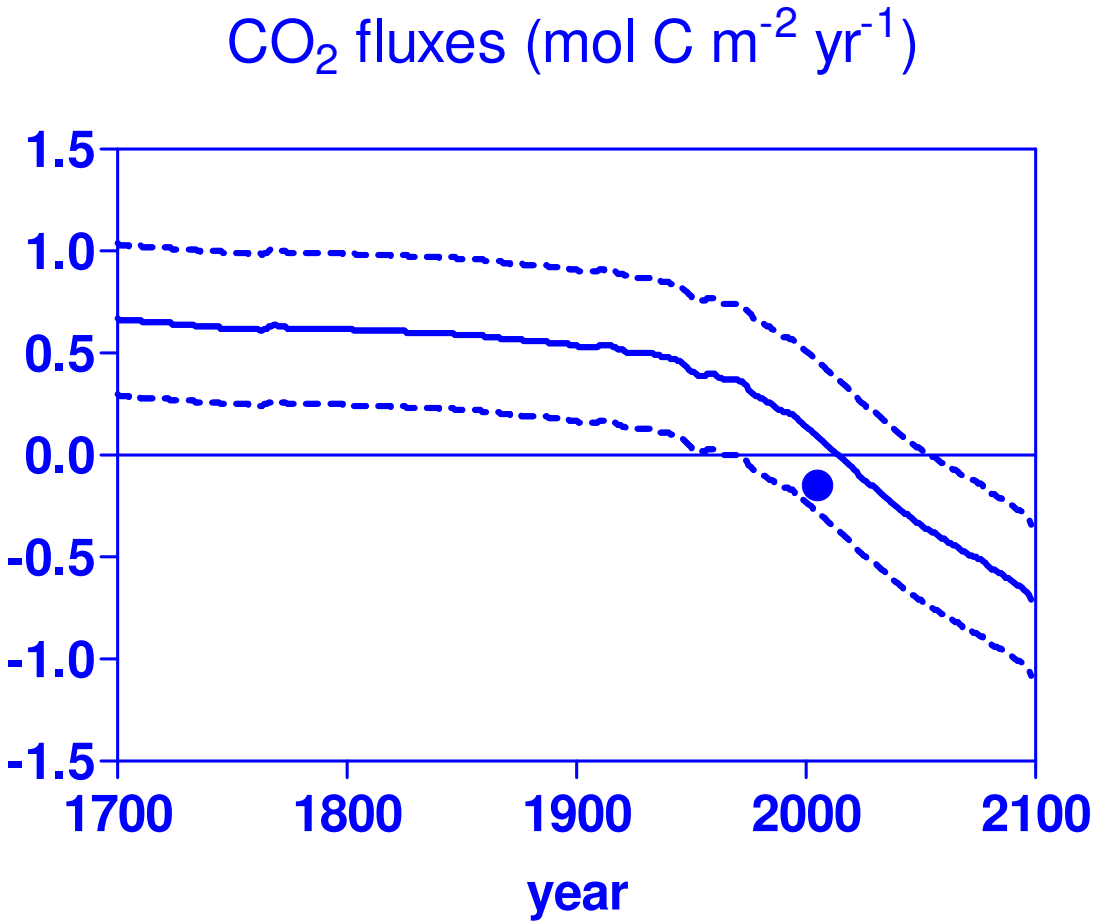
- emission of 0.25 Pg C yr^{-1} ☺

  (river POC input from Richey 2004 ; 50% of river POC is degraded and ventilated in estuaries - Abril et al. 2002)

- emission of 0.35 Pg C yr^{-1} ☺ ☺

  (river POC input from Richey 2004; 70% of river POC is degraded and ventilated in estuaries – Keil et al. 1997)

Up-scaling : reliability ?



—— **Shallow-water Ocean Carbonate Model (SOCM)**
Anderson & Mackenzie (2004)

● **Up-scaled flux values**

Up-scaling : future challenges

- delimitation of near-shore ecosystems
- surface area estimates of near-shore ecosystems
- no CO_2 flux data in high latitude estuaries
- river plumes were not included (no surface area estimate; not enough data)
- no (or little) data in certain ecosystems (segrass beds, lagoons, …)
- coastal ? open ? systems:
  high freshwater discharge estuaries (plumes at sea)
  upwelling filaments

Up-scaling : latitudinal variability counts !

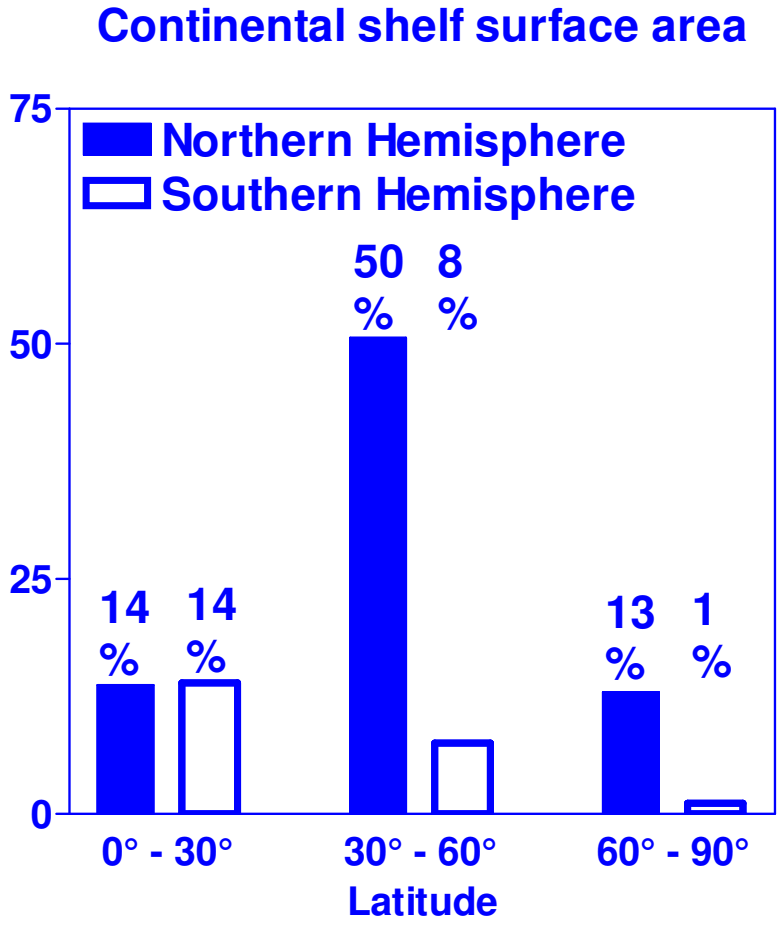
Marginal seas sink of –0.45 PgC yr^{-1} consistent with previous estimates :

-0.43 to –0.96 PgC yr^{-1}
(global extrapolation of data from East China Sea – Wang et al. 2000)

-0.40 PgC yr^{-1}
(global extrapolation of data from North Sea – Thomas et al. 2004)

Marginal seas	PgC yr^{-1}
High latitudes	-0.16
Temperate latitudes	-0.32
Subtropical & tropical latitudes	+0.03

Up-scaling : latitudinal variability counts !



80% of coastal ocean is located in the Northern Hemisphere:
- Relevance of coastal ocean for CO_2 inversion models ?
- Relevance of coastal ocean for CO_2 inter-hemispheric transport ?

Acknowledgments

Borges (2005) Do we have enough pieces of the jigsaw to integrate CO_2 fluxes in the Coastal Ocean ? Estuaries, 28(1): 3-27

Borges, Delille & Frankignoulle (2005) Budgeting sinks and sources of CO_2 in the coastal ocean: Diversity of ecosystems counts, GRL in press

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