CO_2 fluxes in the Coastal Ocean : a short synthesis

Alberto Vieira Borges

UNIVERSITÉ de Liège

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Why the Coastal Ocean ?

Facts and figures from Gattuso et al. (1998)

- **covers 7% of surface of global ocean**
- **massive inputs of terrestrial organic matter & nutrients**
- **intense exchange of energy and matter with open ocean**
- **one of most biogeochemically active areas of the biosphere**

- **14-30% of oceanic primary production**
- **80% of oceanic organic matter burial**
- **90% of oceanic sedimentary mineralization**
- **75-90% of oceanic sink of suspended river load**
- **50% of oceanic $CaCO_3$ deposition**

- **37% of human population live within 100km of the coastline**

Gas transfer velocity in estuaries

$F = a\ k\ dpCO_2$

F = air-water flux of pCO_2

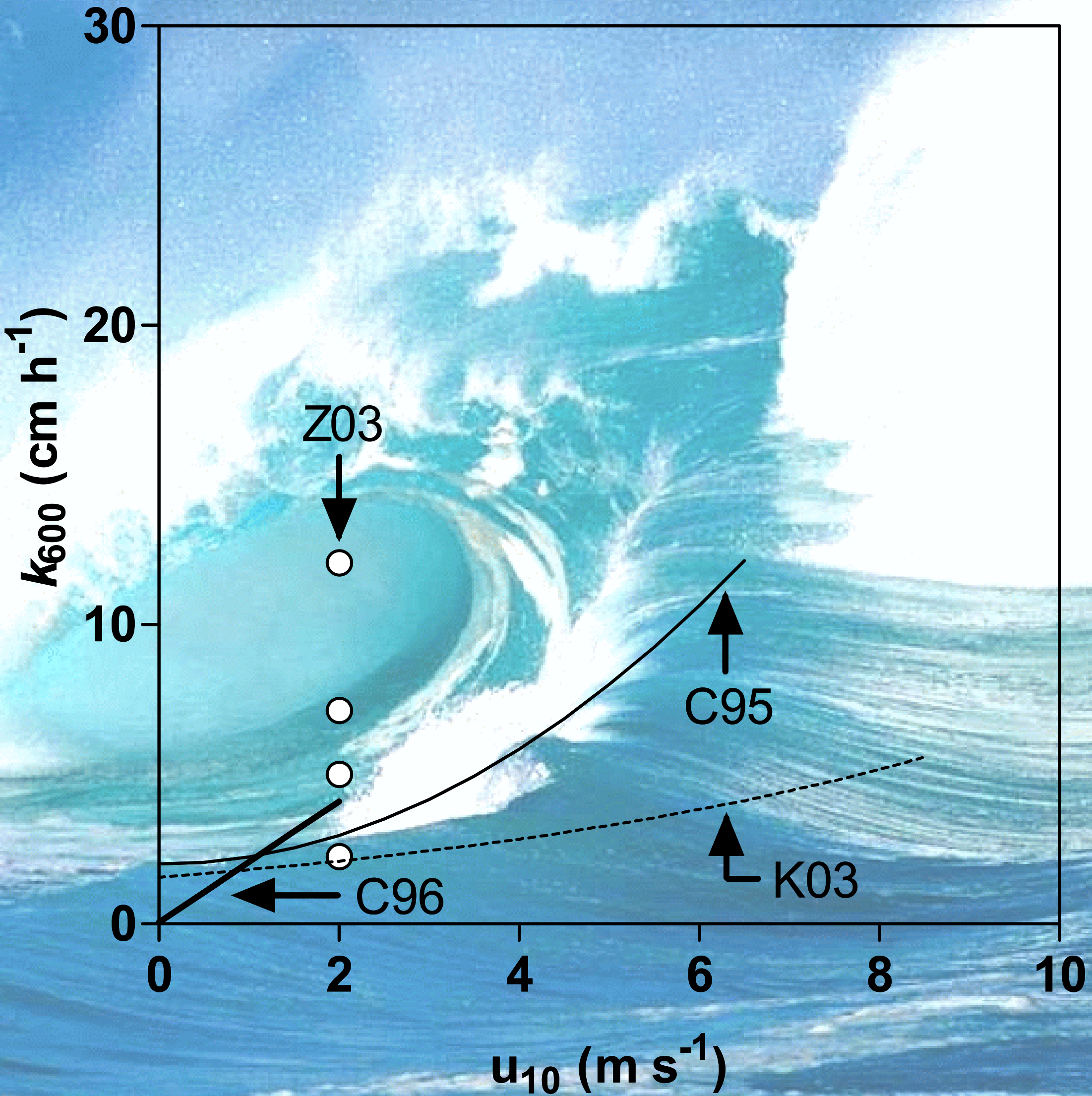
a = CO_2 solubility coefficient

$dpCO_2$ = air-water gradient of CO_2

k = gas transfer velocity of CO_2

Gas transfer velocity in estuaries

$F = a\,k\,dpCO_2$



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Gas transfer velocity in estuaries

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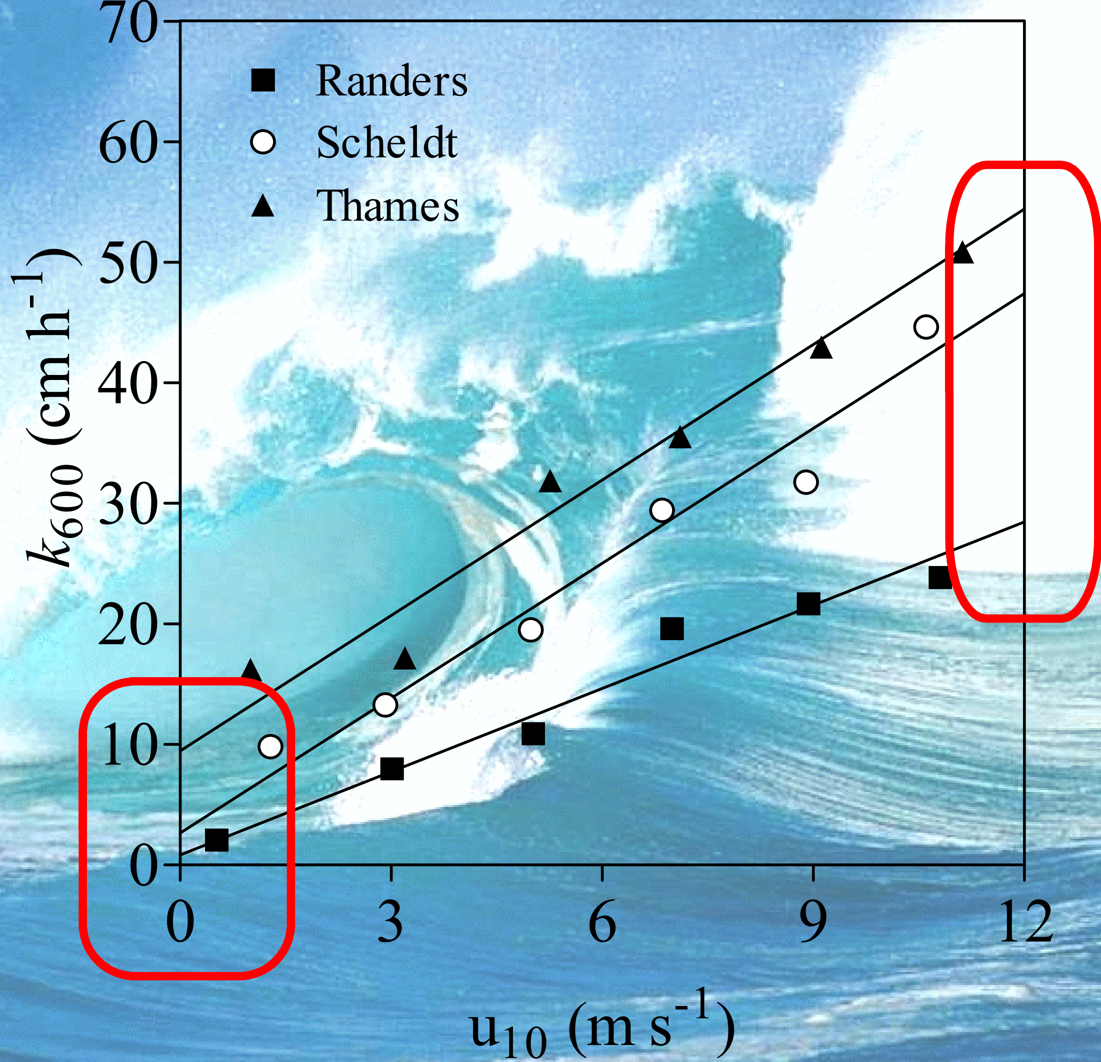

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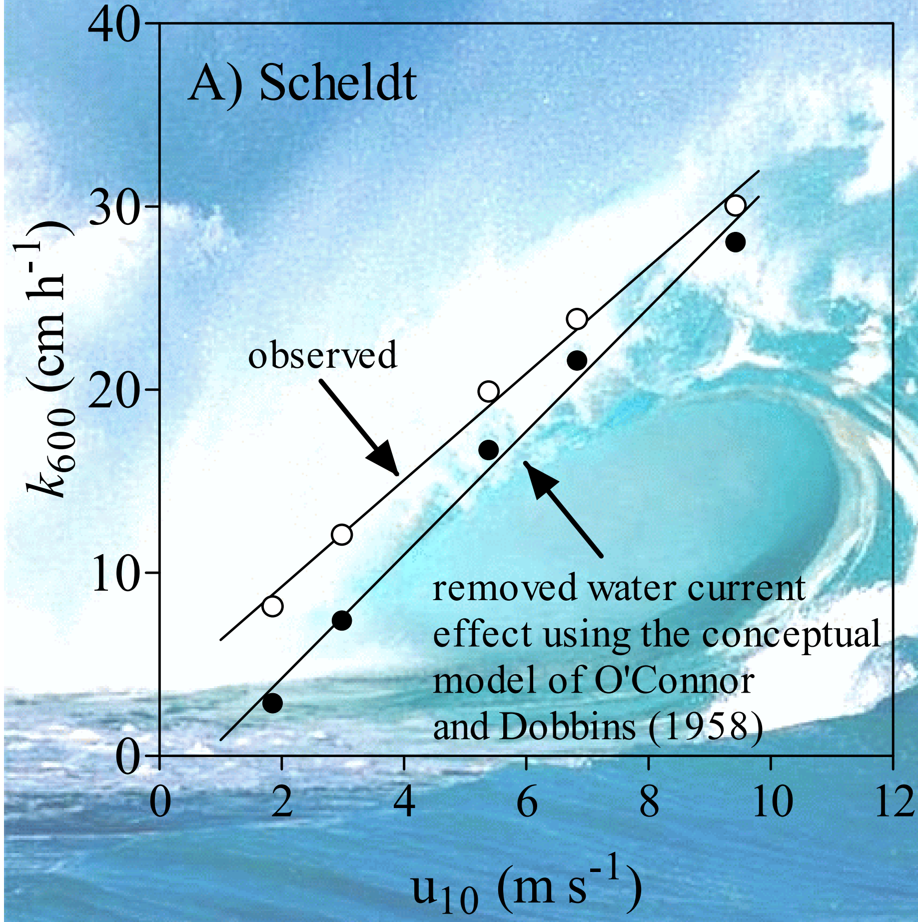

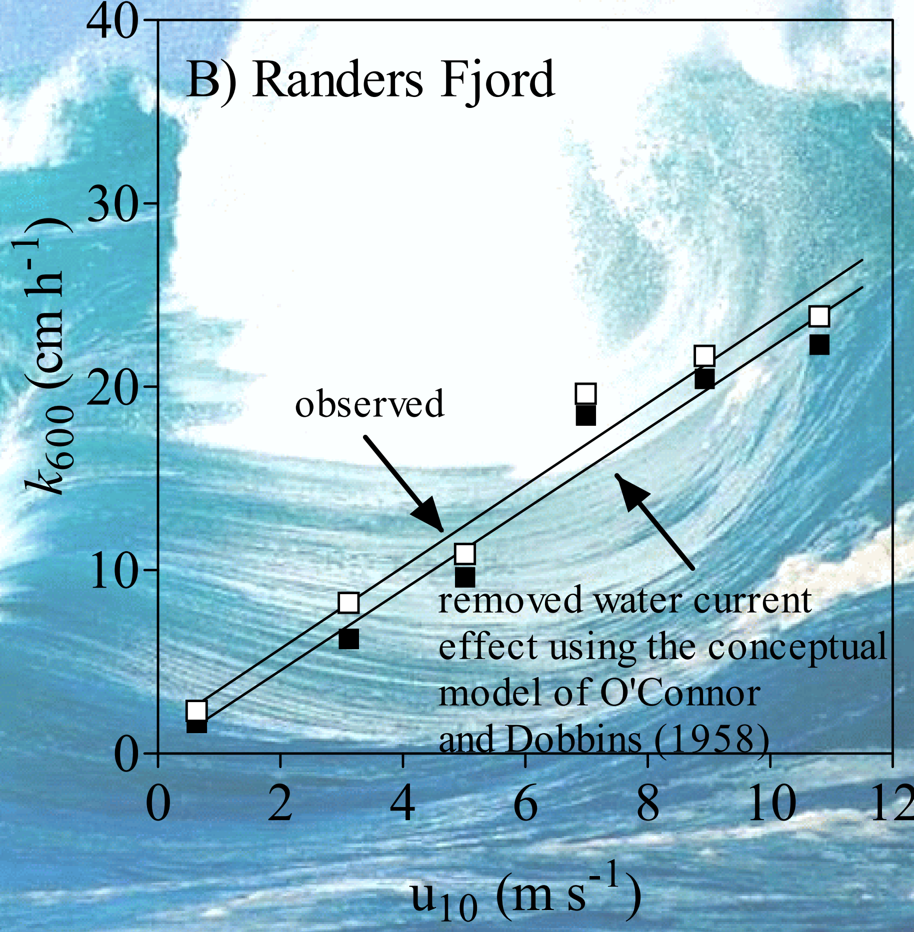

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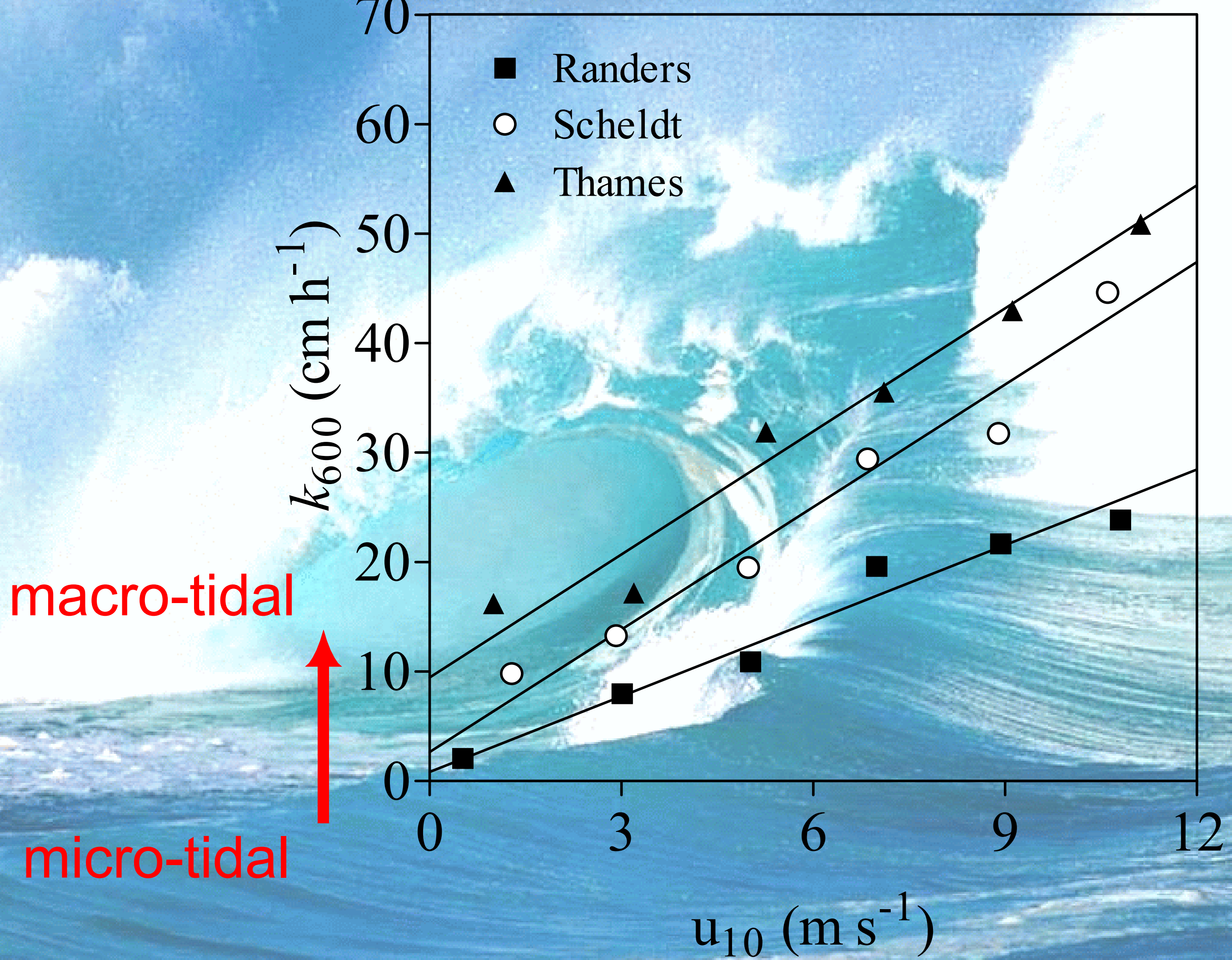

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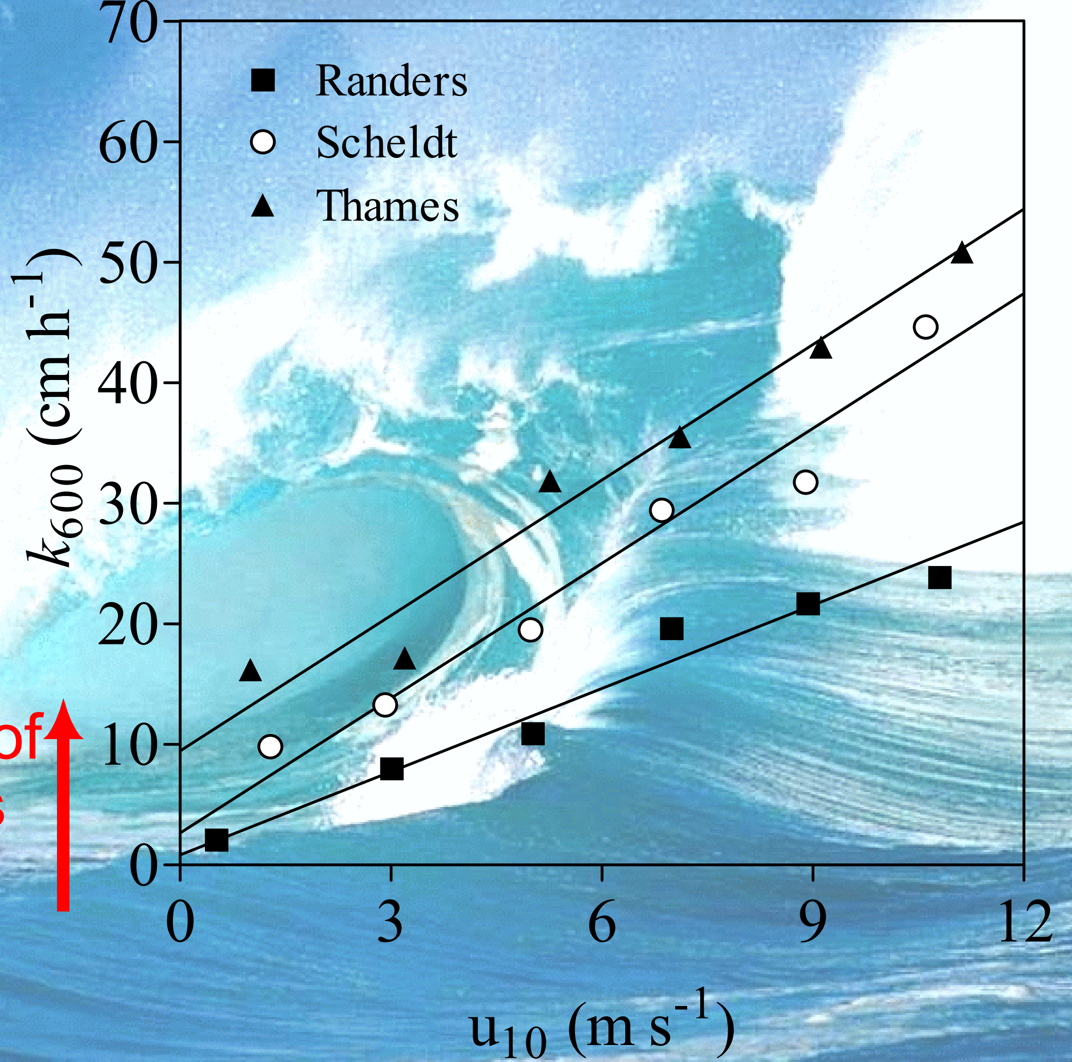
Gas transfer velocity in estuaries

$F = a\,k\,\mathrm{dpCO_2}$

contribution of tidal currents to *k*



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Gas transfer velocity in estuaries

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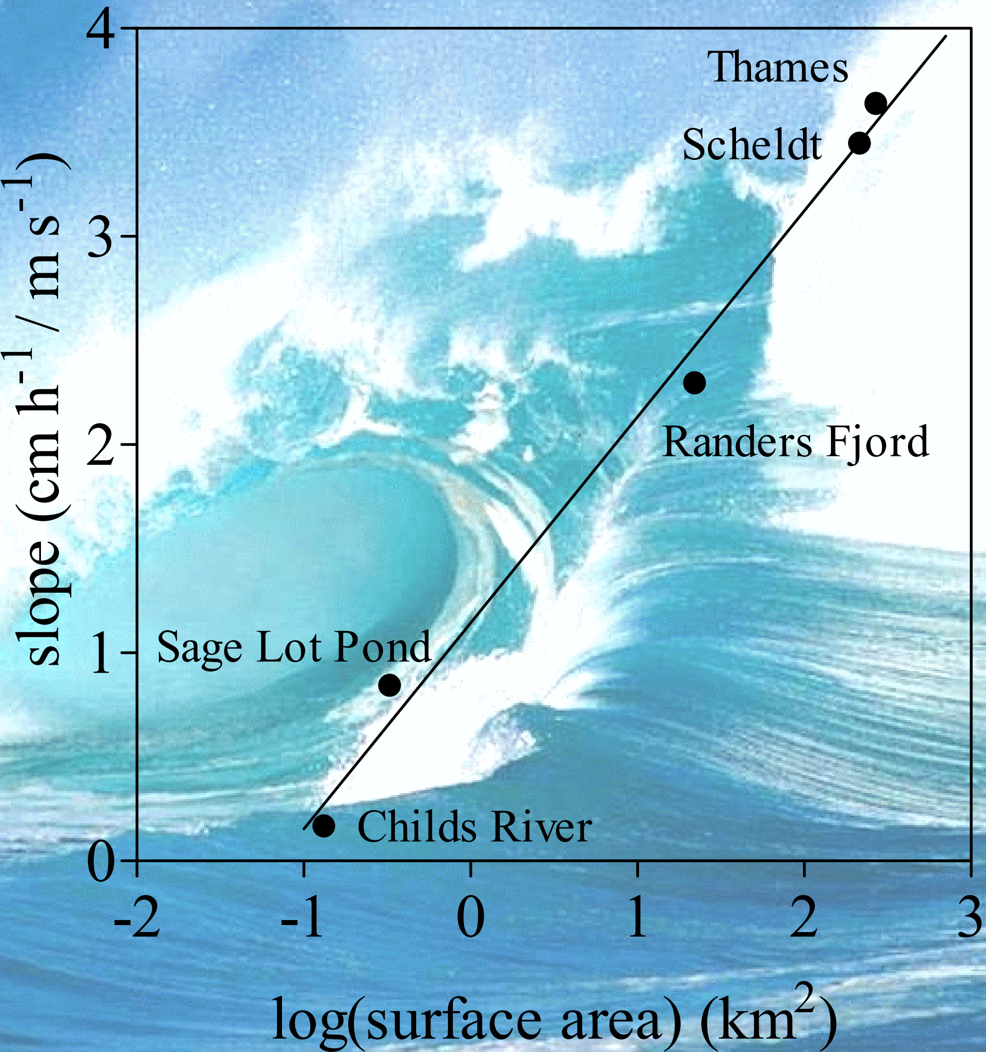

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Gas transfer velocity in estuaries

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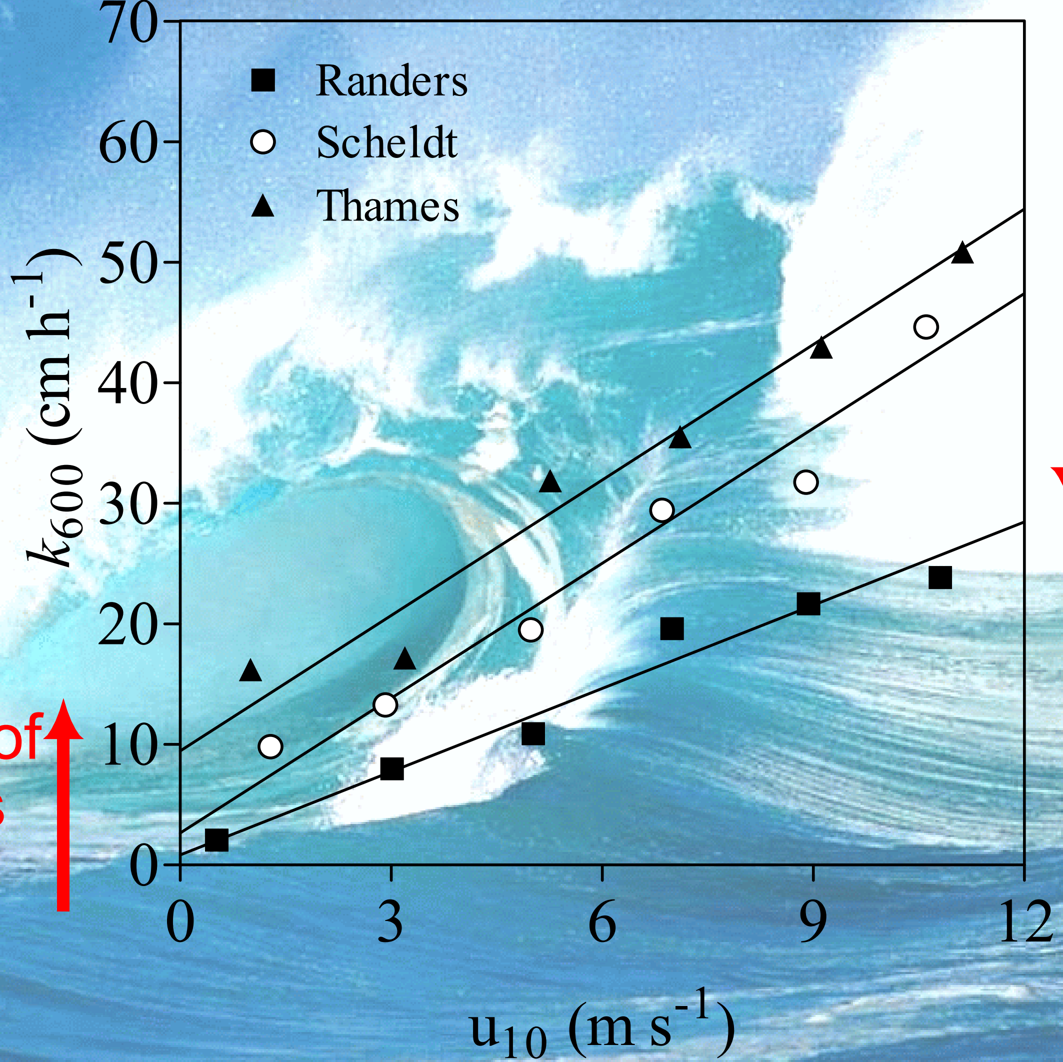
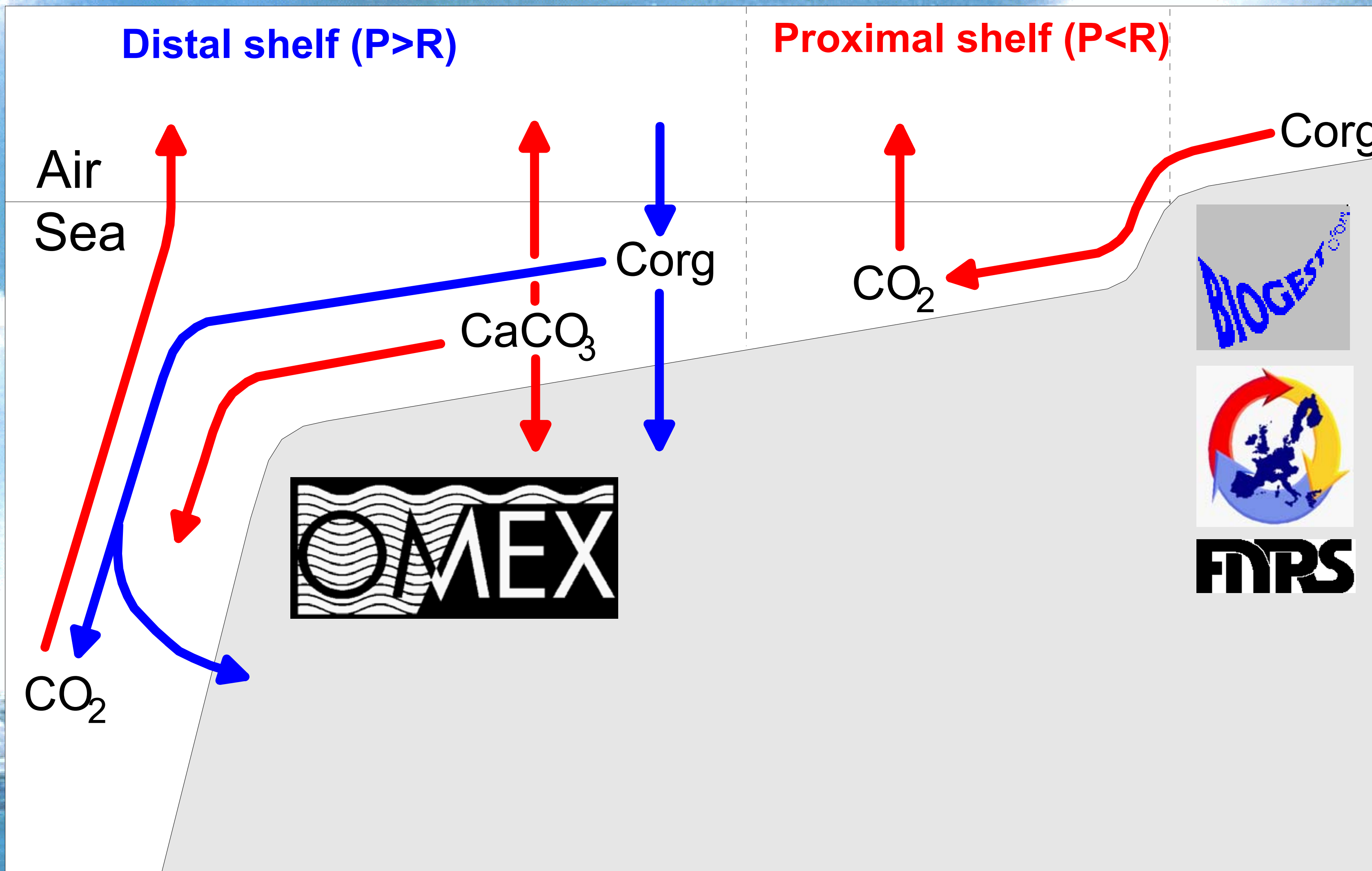


Stronger fetch limitation in small estuaries

contribution of tidal currents to *k*

Conceptual model of C cycling in shelves



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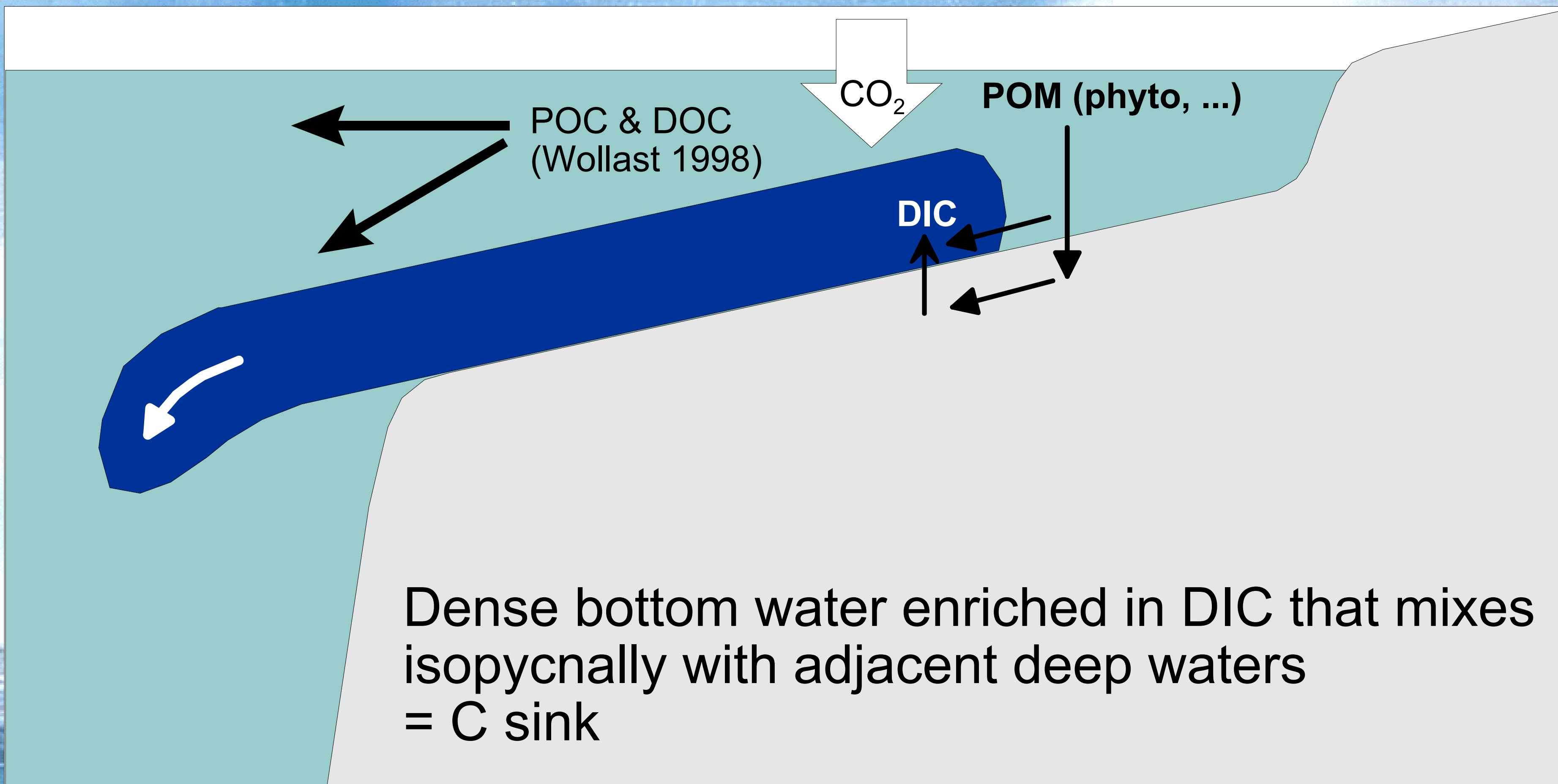
Continental shelf pump hypothesis
Tsunogai et al. (1999)



Continental shelf pump hypothesis
Tsunogai et al. (1999)

5 cruises in the East China Sea

pCO_2 measurements
<) pCO_2 = -55 ppm
< CO_2 flux of - 8 mmol m^{-2} d^{-1}

< global shelf surface area = 26 10^6 km^2

< 1 PgC yr^{-1} (10^{15} gC yr^{-1})

Open oceanic waters (Takahashi et al. 2002)
< 2.2 PgC yr^{-1} (10^{15} gC yr^{-1})

< Major revision of oceanic CO_2 pump !!

Continental shelf pump hypothesis

East China Sea	-8 mmol m^{-2} d^{-1}	Tsunogai et al. (1999)
Gulf of Biscay	-5 to -8 mmol m^{-2} d^{-1}	Frankignoulle & Borges (2001)
US MAB	-2 to -3 mmol m^{-2} d^{-1}	DeGranpre et al. (2002)
North Sea	-4 mmol m^{-2} d^{-1}	Thomas al. (2004)

However :

< Temperate systems

< Non-upwelling

< Little influence of terrestrial inputs

CO_2 fluxes in :

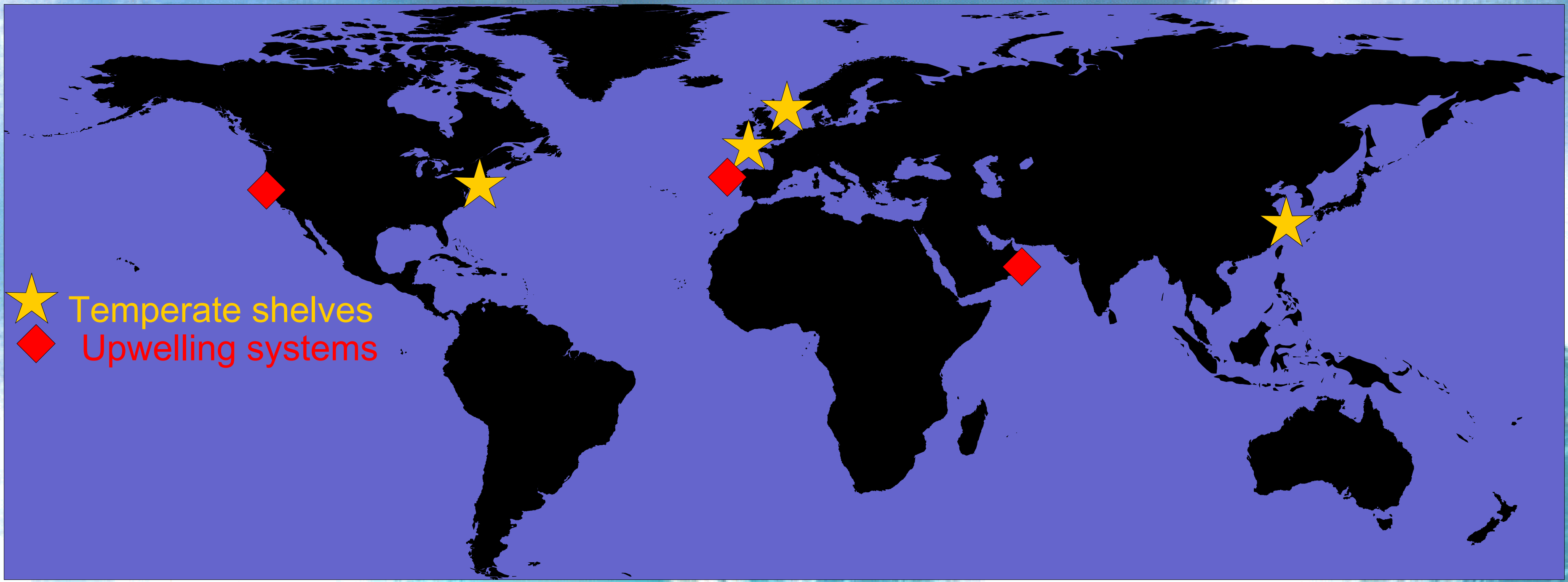
- Upwelling systems } DIC inputs
- Estuaries
- River plumes

} DIC and OM inputs

- Sub-tropical shelves
- Coral reefs
- Mangroves

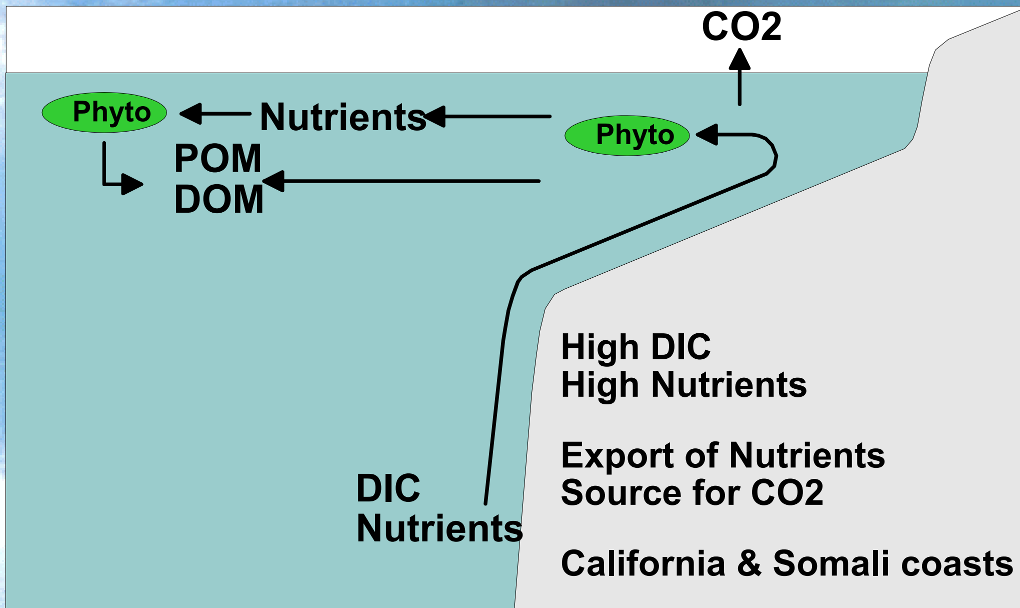
} Non-temperate systems

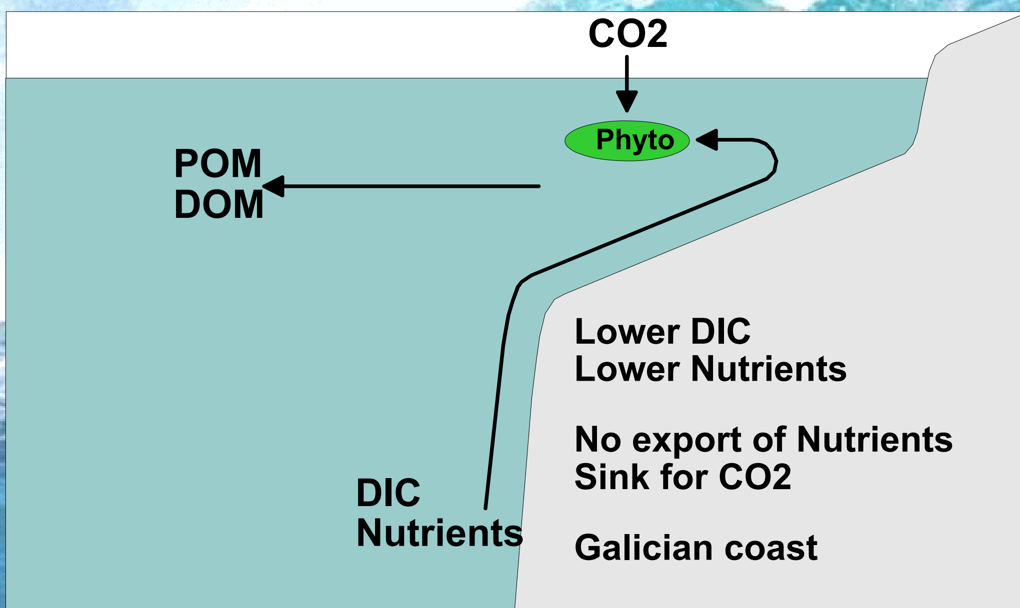
Upwelling systems



Somali coast	+2.5 mmol m^{-2} d^{-1}	Goyet et al. (1998)
Galician coast	-3.5 to -7.0 mmol m^{-2} d^{-1}	Borges & Frankignoulle (2002)
California coast	+4.1 to +6.0 mmol m^{-2} d^{-1}	Friederich et al. (2002)

Upwelling systems





California coast
(Friederich et al. 2002)

El Nina
< 4.1 to 6.0 mmol m^{-2} d^{-1}

El Nino
< -1 to -2.0 mmol m^{-2} d^{-1}

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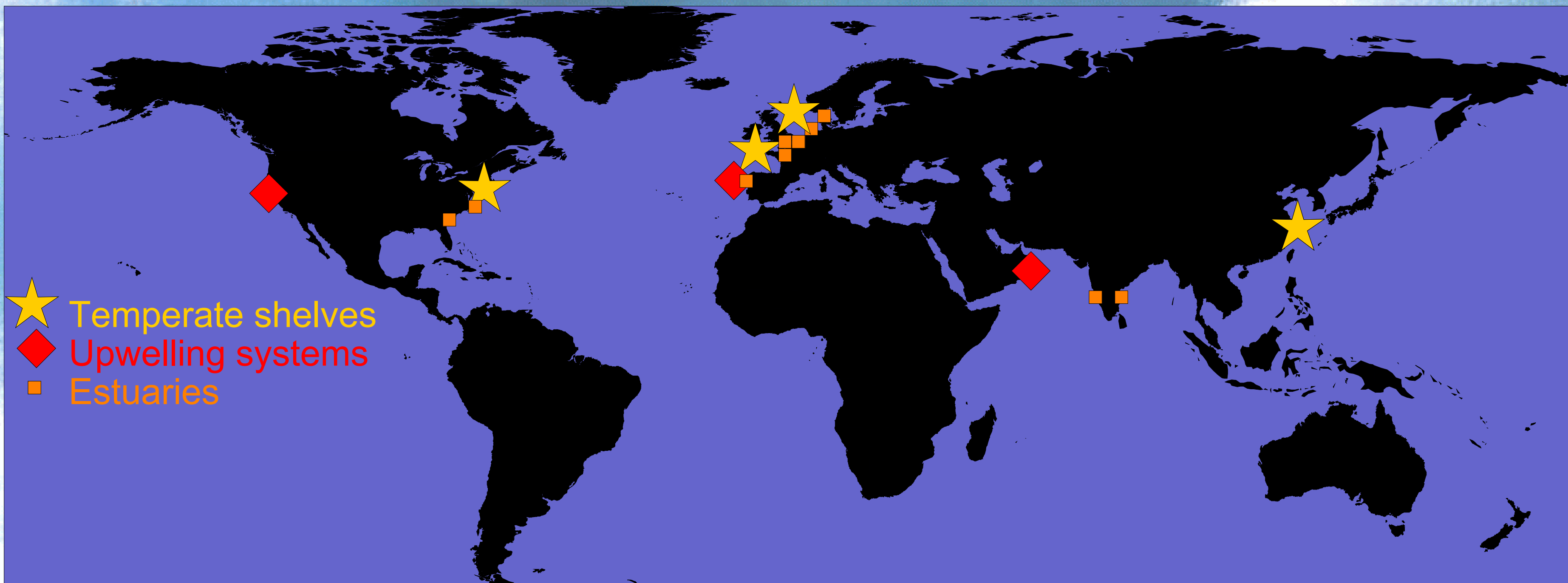
Estuaries

< Receive massive inputs (riverine and lateral) of dissolved inorganic carbon, organic matter and nutrients

< Long residence time promotes biogeochemical transformations during estuarine transit

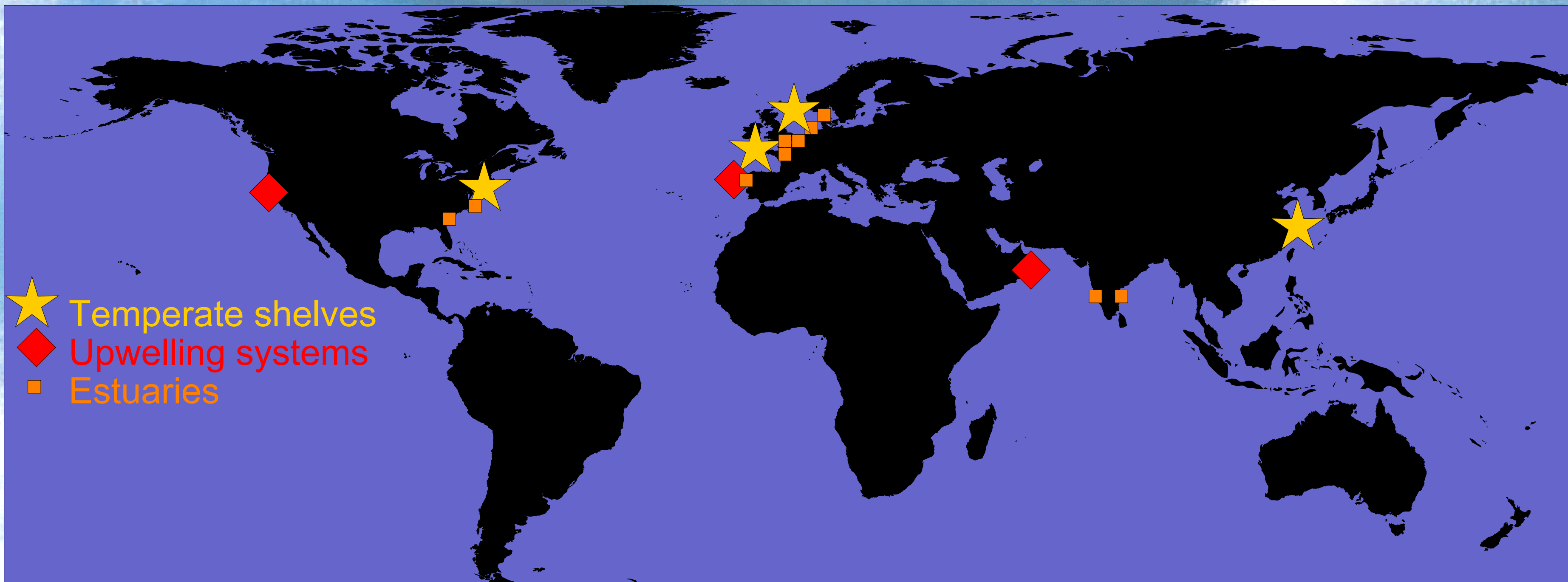
< Residence time is highly variable (days to months) !

Estuaries



European estuaries (11):
Randers Fjord, Elbe, Ems, Rhine, Scheldt, Thames, Tamar, Loire, Gironde, Douro & Sado = +40 to +210 mmol m^{-2} d^{-1}
Frankignoulle et al. (1998), Abril et al. (1998) & Borges (unpublished)
York & Satilla Rivers +17 to 116 mmol m^{-2} d^{-1}
Raymond et al. (2000) and Cai & Wang (1998)
Mandovi-Zuari & Godavari +15 to +39 mmol m^{-2} d^{-1}
Sarma et al. (2001) & Bouillon et al. (2003)

Estuaries



CO_2 source (temperate sub-tropical and tropical)

CO_2 fluxes +20 to +200 mmol m^{-2} d^{-1}

CO_2 fluxes one to two orders of magnitude higher than open shelves

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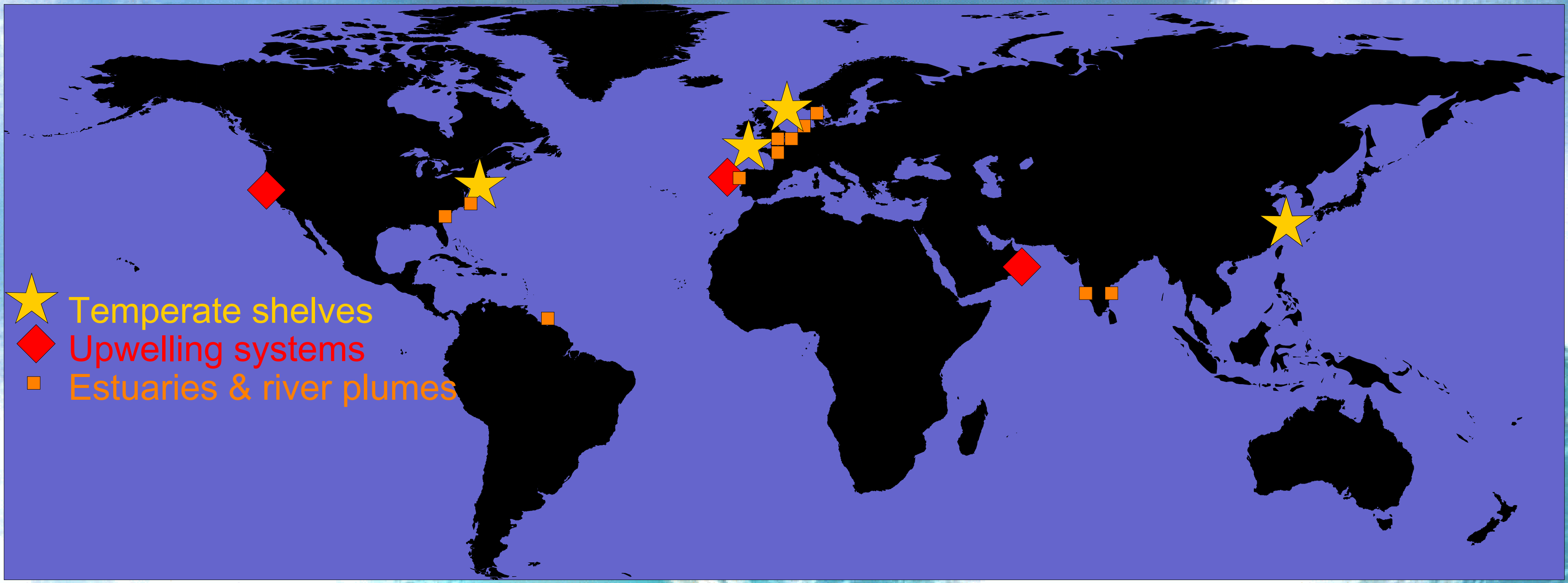
River plumes

- Receive inputs of dissolved inorganic carbon, organic matter and nutrients from inner estuaries
- Lower end of the mixing with seawater end-member
- Decrease of light limitation in relation to inner estuaries
- Biogeochemical processes less intense than inner estuaries

River Plumes



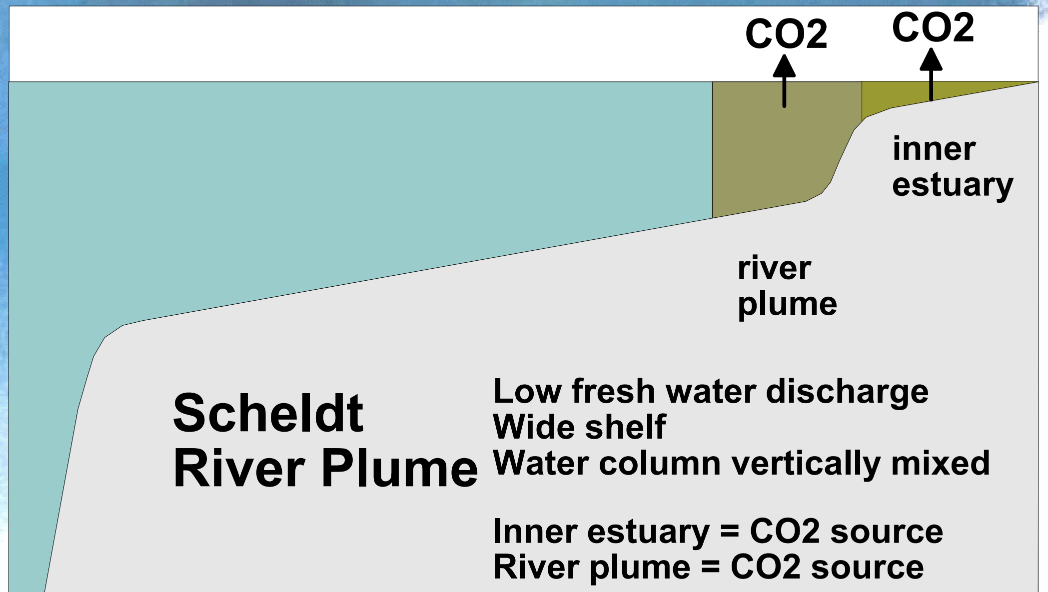
Scheldt river plume
+3 to +5 mmol m^{-2} d^{-1}

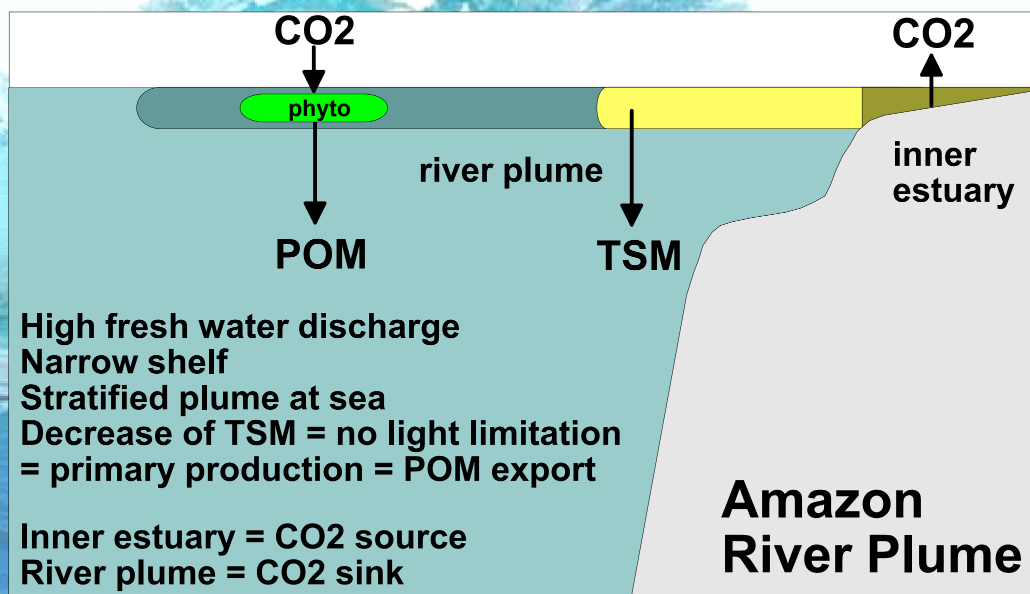
Borges & Frankignoulle (2002)

Amazon river plume
-1.4 mmol m^{-2} d^{-1}

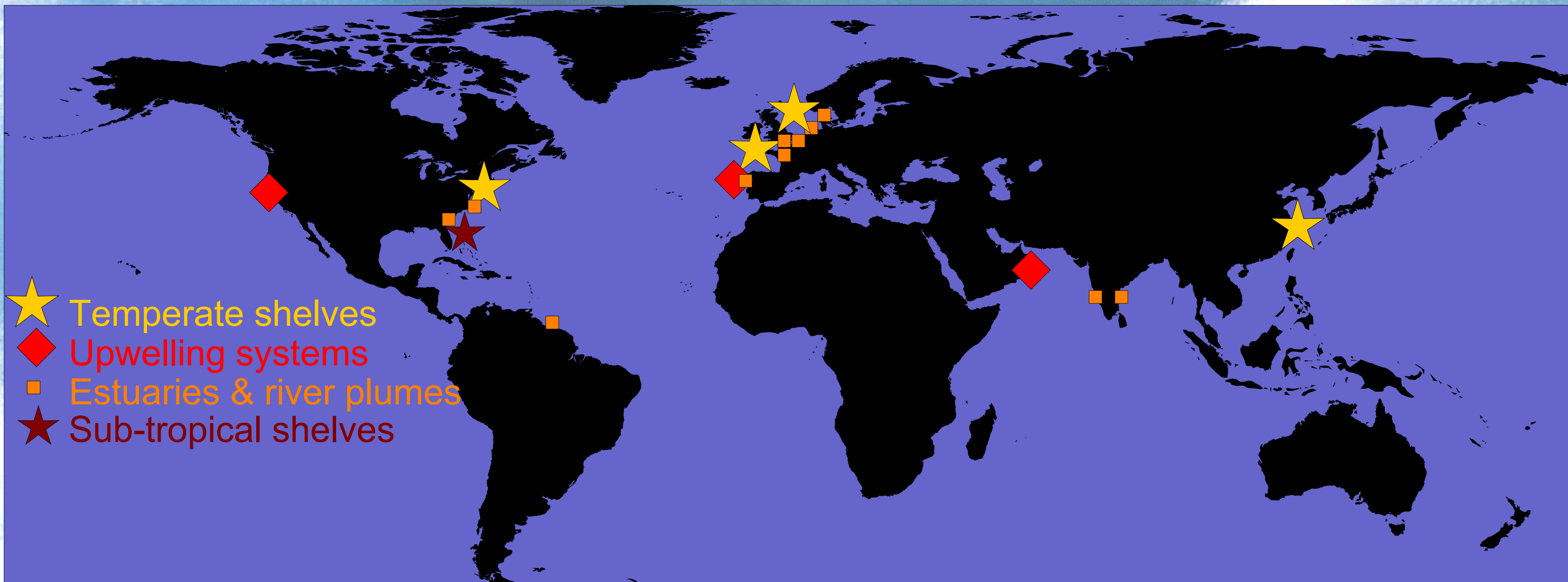
Körtzinger (2003)

River plumes





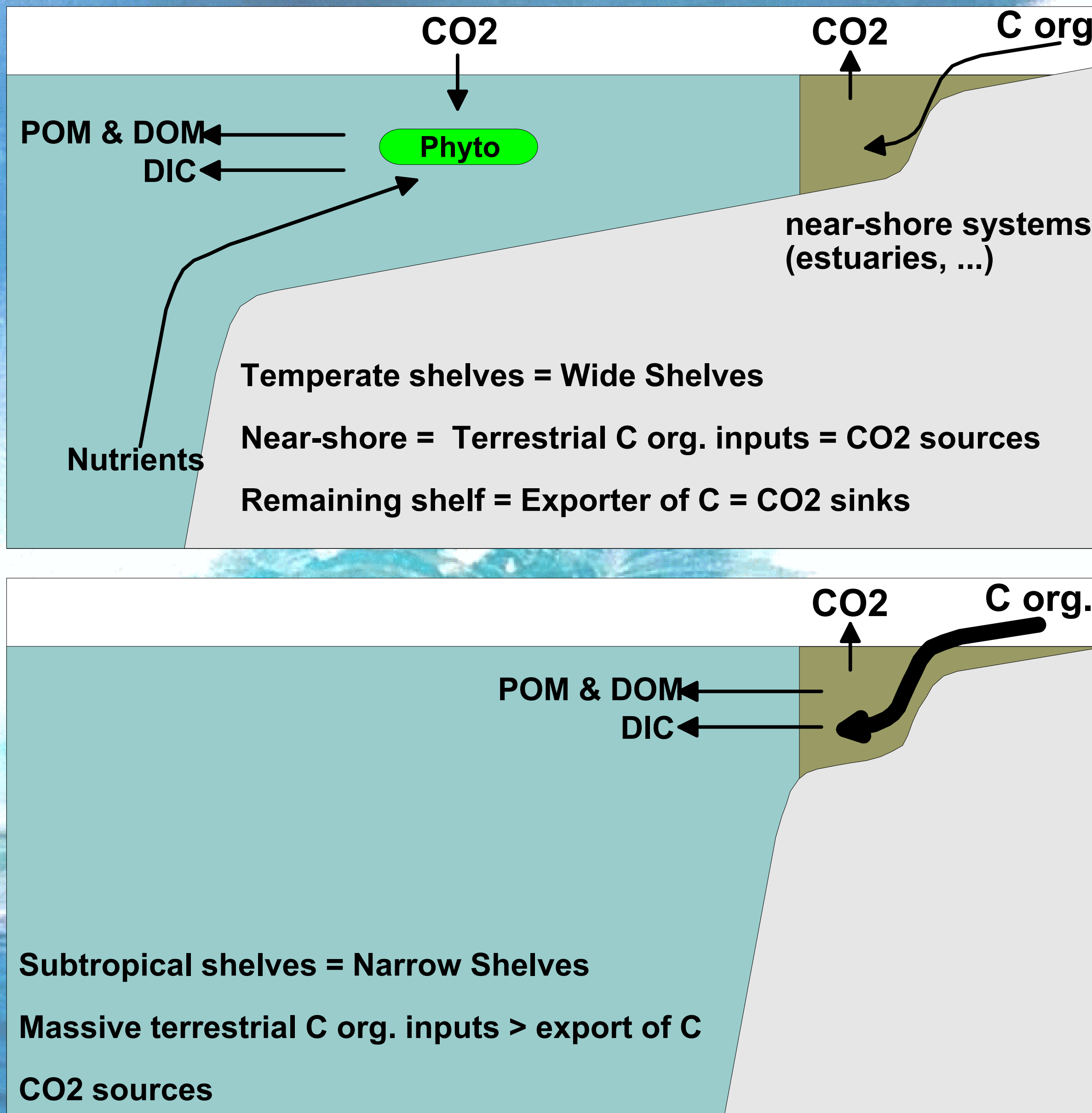
Sub-tropical shelves



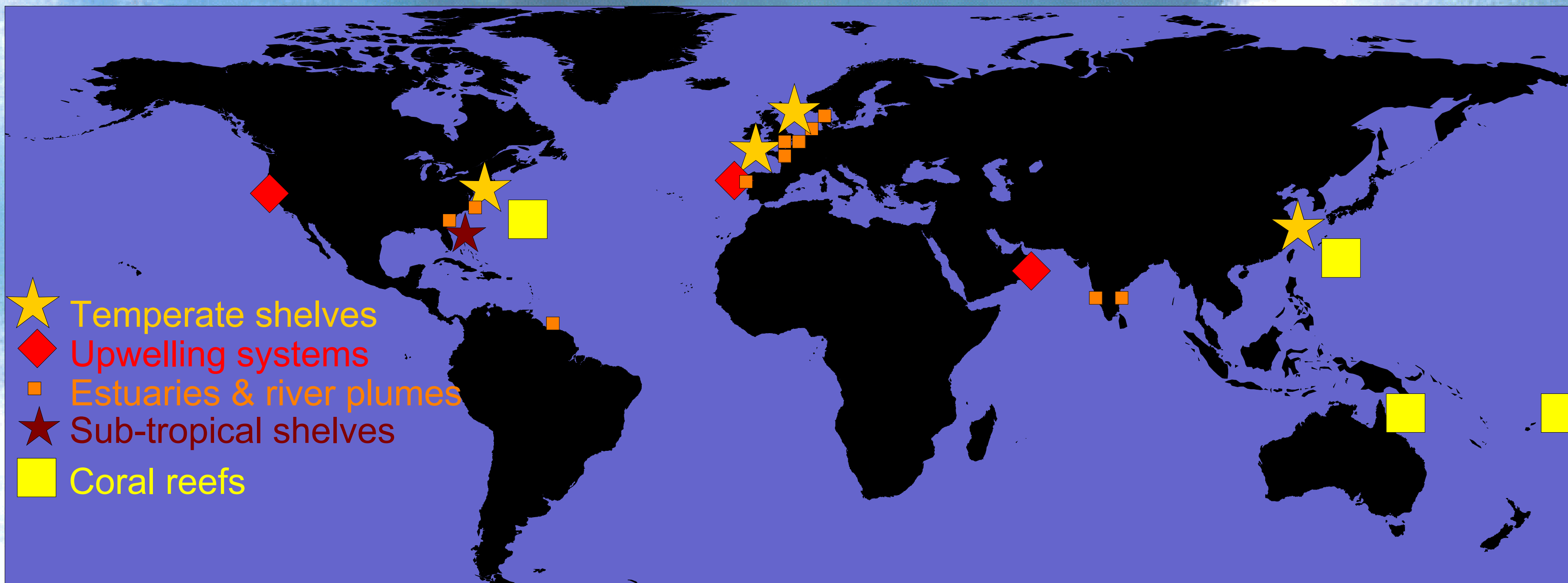
US South Atlantic Bight
+7 mmol m^{-2} d^{-1}
Cai et al. (2003)

CO_2 fluxes of same order of magnitude as temperate shelves but OPPOSITE sign

Sub-tropical shelves

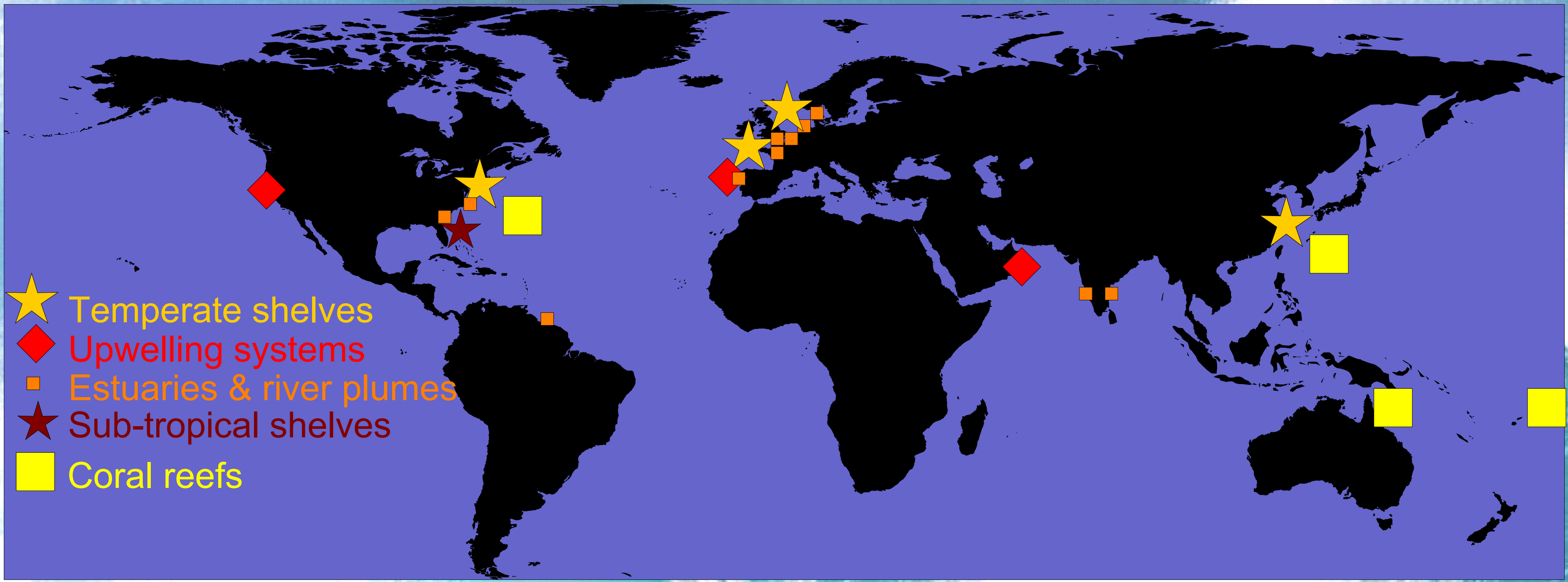


Coral reefs



Moorea	+0.4 mmol m^{-2} d^{-1}	Gattuso et al. (1993; 1997)
Yonge Reef	+4.1 mmol m^{-2} d^{-1}	Frankignoulle (1996)
Okinawa	+5.0 mmol m^{-2} d^{-1}	Ohde & van Woesik (1999)
Hog Reef	+3.3 mmol m^{-2} d^{-1}	Bates et al. (2001)

Coral reefs



Coral reefs are a moderate source of CO_2

Coral Reefs

P : $CO_2 + H_2O = CH_2O + O_2$

R : $CH_2O + O_2 = CO_2 + H_2O$

C : $Ca^{2+} + 2CO_3^{-} = CO_2 + CaCO_3$

P-R . 0

C > 0 (2.2 $gCaCO_3\ m^{-2}\ d^{-1}$)

English Channel

) $pCO_2 = 0$ Borges & Frankignoulle (2003)

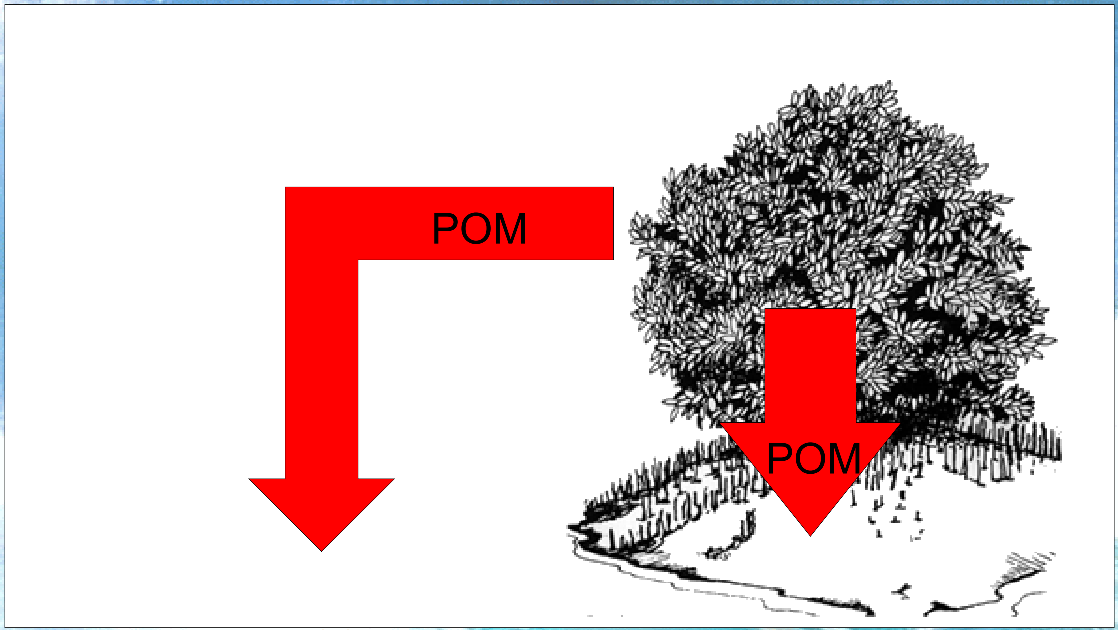
P-R = 1.0 mmol $m^{-2}\ d^{-1}$

Le Corre et al. (1996) L'Helguen et al. (1996)

CO_2 release = 0.9 mmol $m^{-2}\ d^{-1}$

by brittle star populations (Migné et al.1998)

Mangrove surrounding waters

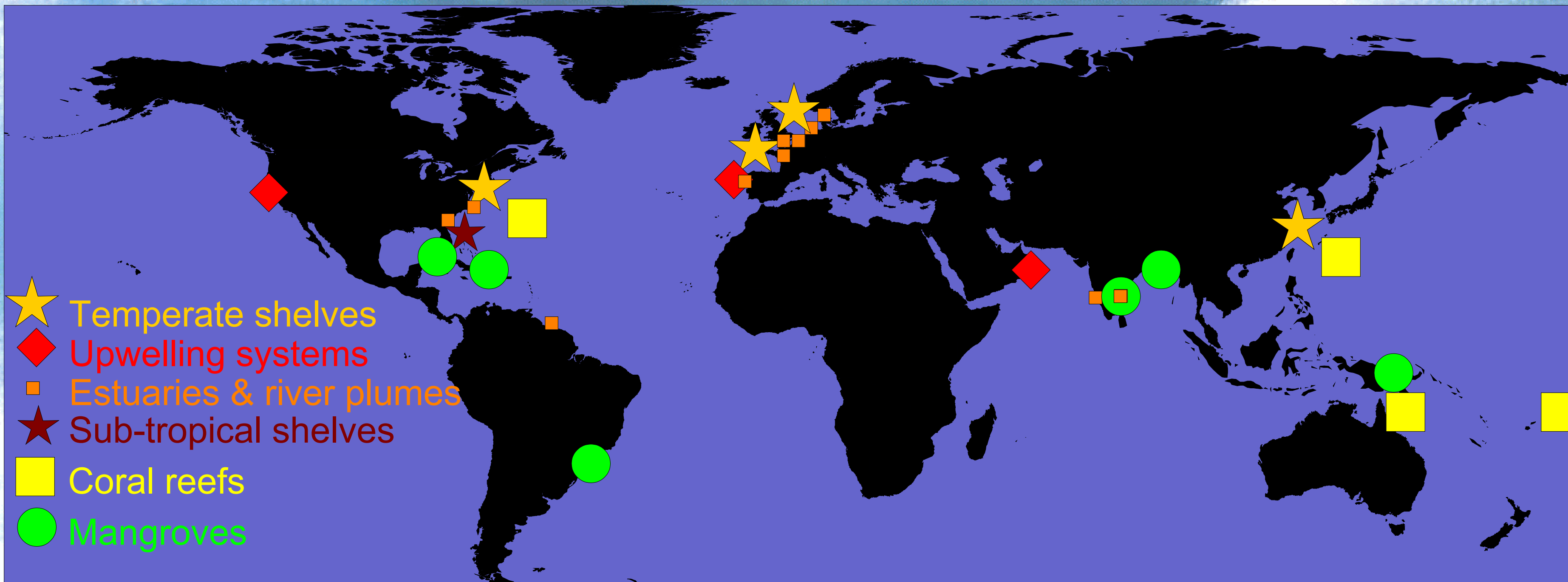


Leaf and wood litter transfer to water and sediments

Thus, water column and sediments metabolisms are net heterotrophic

Thus, water column should be a CO_2 source

Mangrove surrounding waters



Nagada Creek	+44 mmol m^{-2} d^{-1}	Borges et al.(2003)
Saptamukhi Creek	+57 mmol m^{-2} d^{-1}	Borges et al.(2003) based on Ghosh et al.(1987)
Mooringanga Creek	+23 mmol m^{-2} d^{-1}	Borges et al.(2003) based on Ghosh et al.(1987)
Gaderu Creek	+56 mmol m^{-2} d^{-1}	Borges et al.(2003)
Itacuraça Creek	+23 mmol m^{-2} d^{-1}	Borges et al.(2003) based on Ovalle et al.(1991)
Norman's Pond	+14 mmol m^{-2} d^{-1}	Borges et al.(2003)
Florida Bay	+3 mmol m^{-2} d^{-1}	Borges et al.(2003) based on Millero et al.(2001)

Mangrove surrounding waters

< +50 mmol m^{-2} d^{-1}
< 0.2 10^6 km^2
< CO_2 emission of 0.05 PgC yr^{-1}

CO_2 emission in tropical sub-tropical oceanic waters
< 0.43 PgC yr^{-1} (Takahashi et al. 1997)

< Mangrove surrounding waters provide an extra CO_2 emission of 12% at sub-tropical and tropical latitudes for a surface area 1000 times smaller than open oceanic waters !

Conclusions

< Coastal ocean as sink of of CO_2 of 1.0 PgC yr^{-1} as formulated by Tsunogai et al. (1999) would imply a major revision of the oceanic CO_2 pump

< Temperate wide shelves = sink of CO_2 (-2 to - 5 mmol m^{-2} d^{-1})

< Sub-tropical (and tropical ?) shelves = sources of CO_2 (+7 mmol m^{-2} d^{-1})

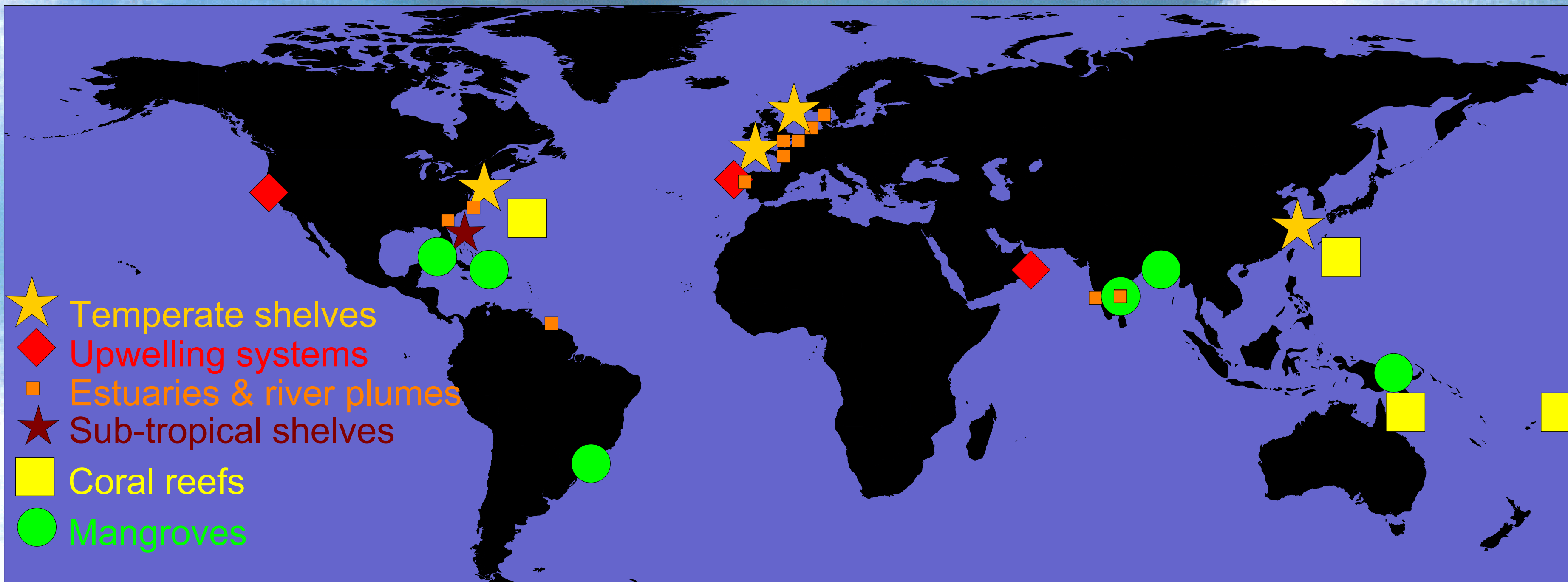
< Temperate, sub-tropical and tropical estuaries
= sources of CO_2 (+20 to +200 mmol m^{-2} d^{-1})

< River plumes = ?

< Coral reefs = sources of CO_2 (+1 to +5 mmol m^{-2} d^{-1})

< Mangrove surrounding waters = sources of CO_2 (+50 mmol m^{-2} d^{-1})

< The geographic and ecological **diversity** of the Coastal Ocean **must** be accounted when integrating at global scale



Thank you

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