Dissolved inorganic carbon dynamics and CO_2 atmospheric exchanges in the inner and outer Scheldt estuary

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&

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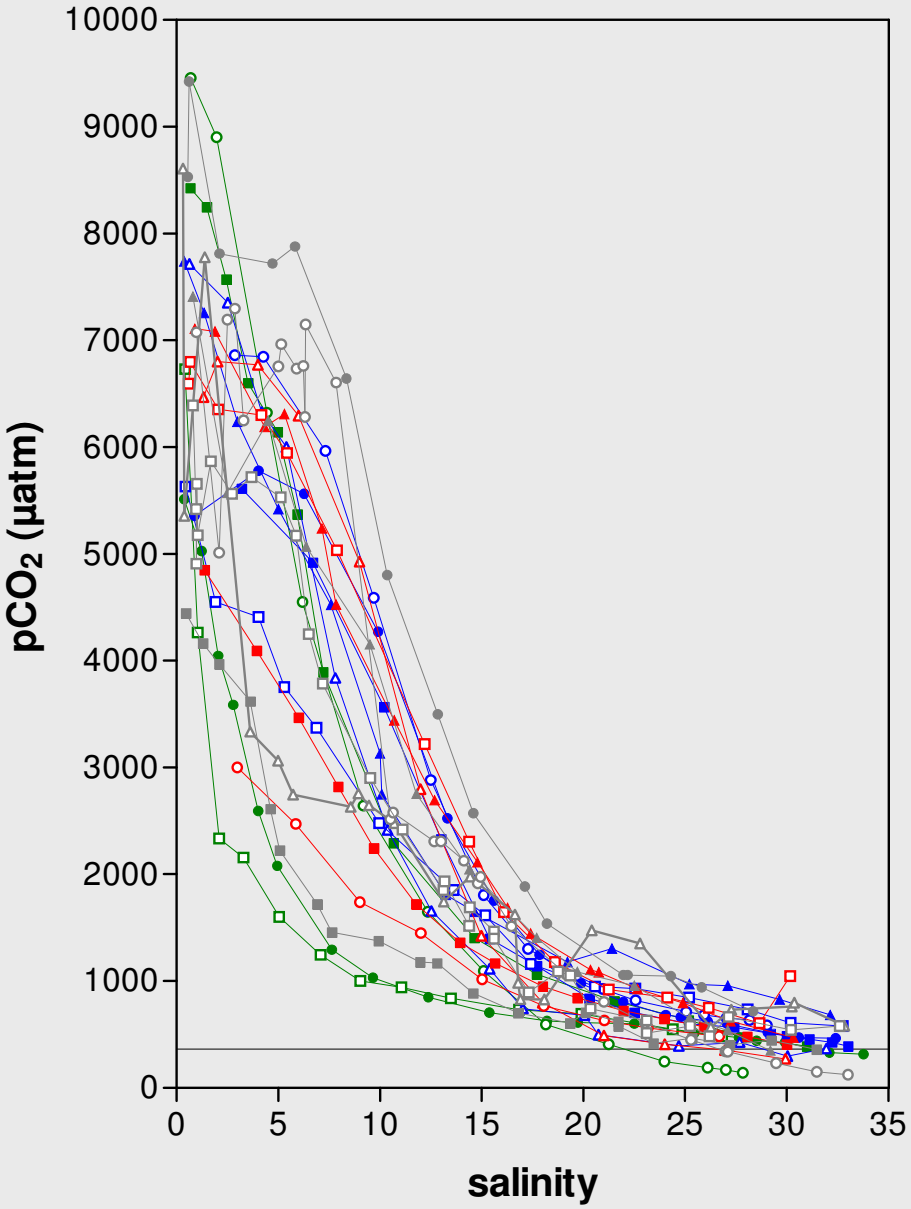
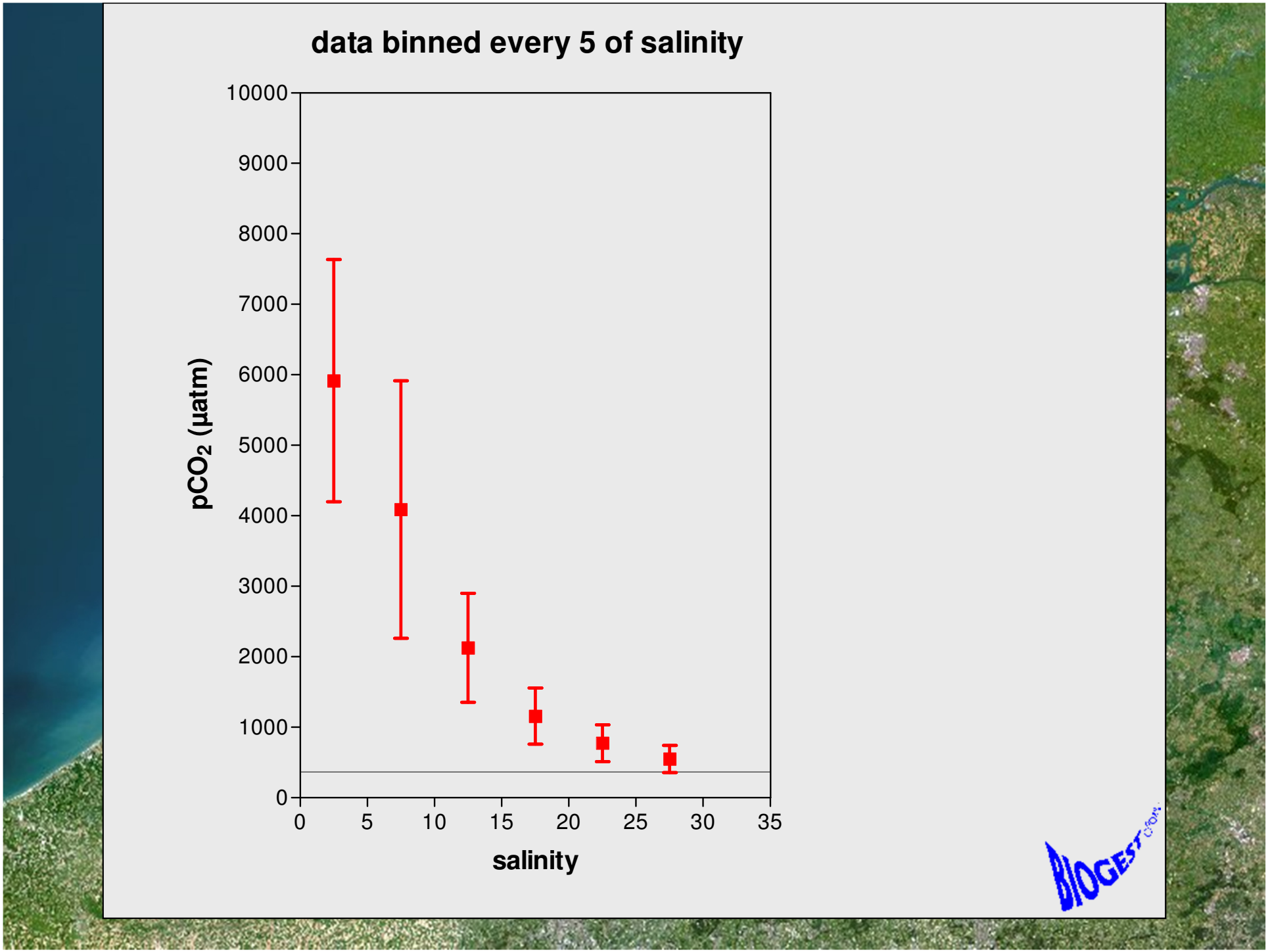
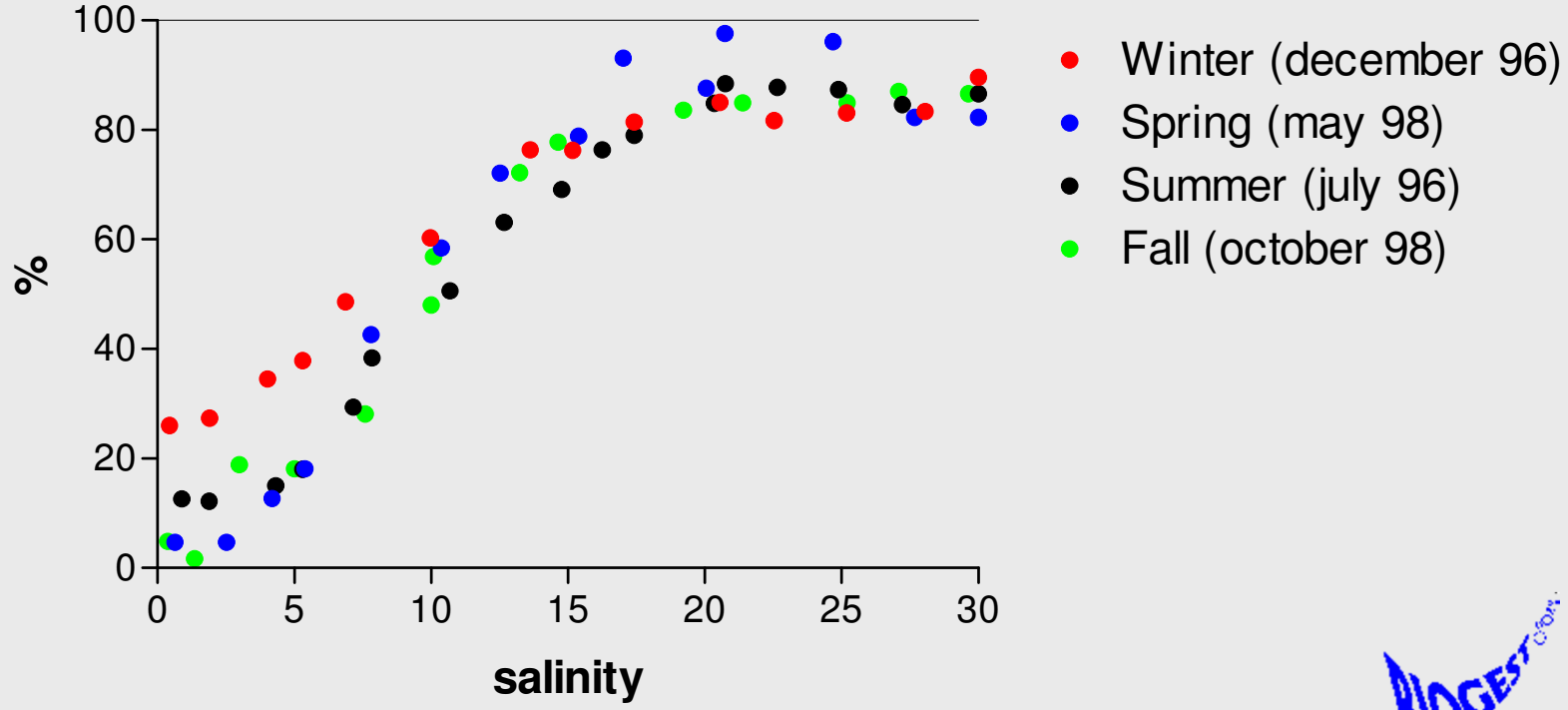
http://www.ulg.ac.be/oceanbio/co2

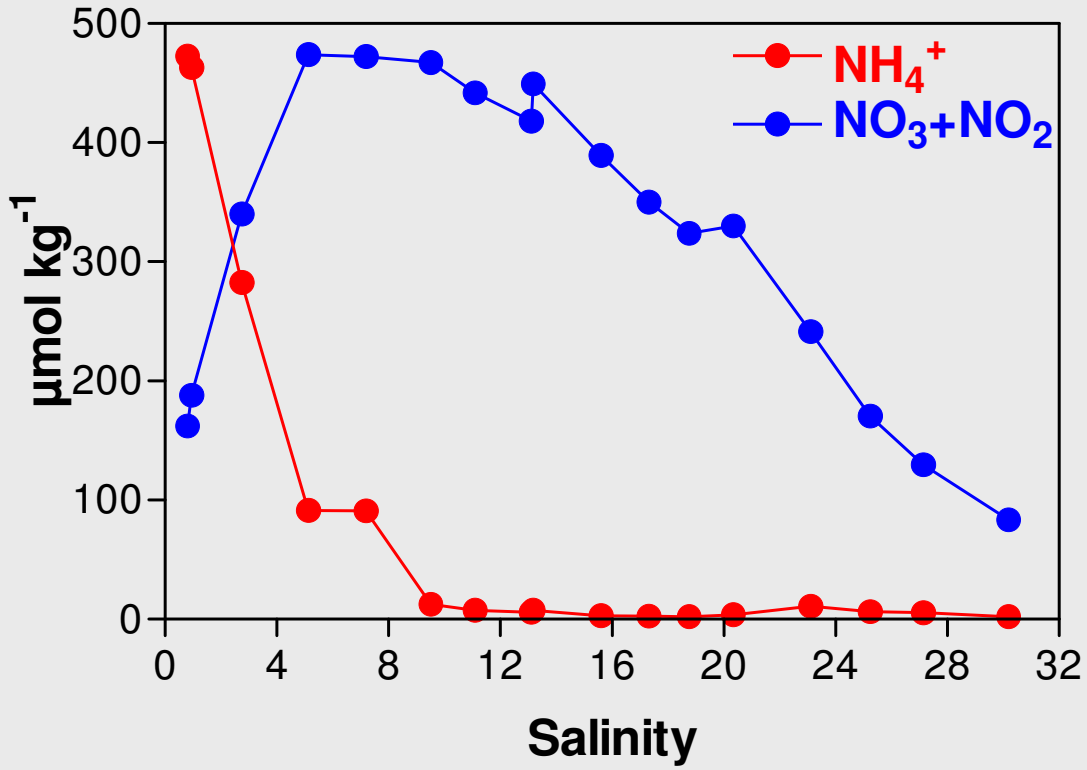

10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
pCO2 (µatm)
0
5
10
15
20
25
30
35
salinity
Mar 93
Jun 93
Mar 94
Nov 94
Jan 95
Aug 95
Nov 95
Jan 96
Mar 96
May 96
July 96
Dec 96
Oct 97
Nov 97
Dec 97
May 98
Oct 98
Feb 99
May 99
Jul 00
Nov 00


data binned every 5 of salinity
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
pCO2 (µatm)
0
5
10
15
20
25
30
35
salinity

O_2 saturation level in the Scheldt estuary Biogest cruises

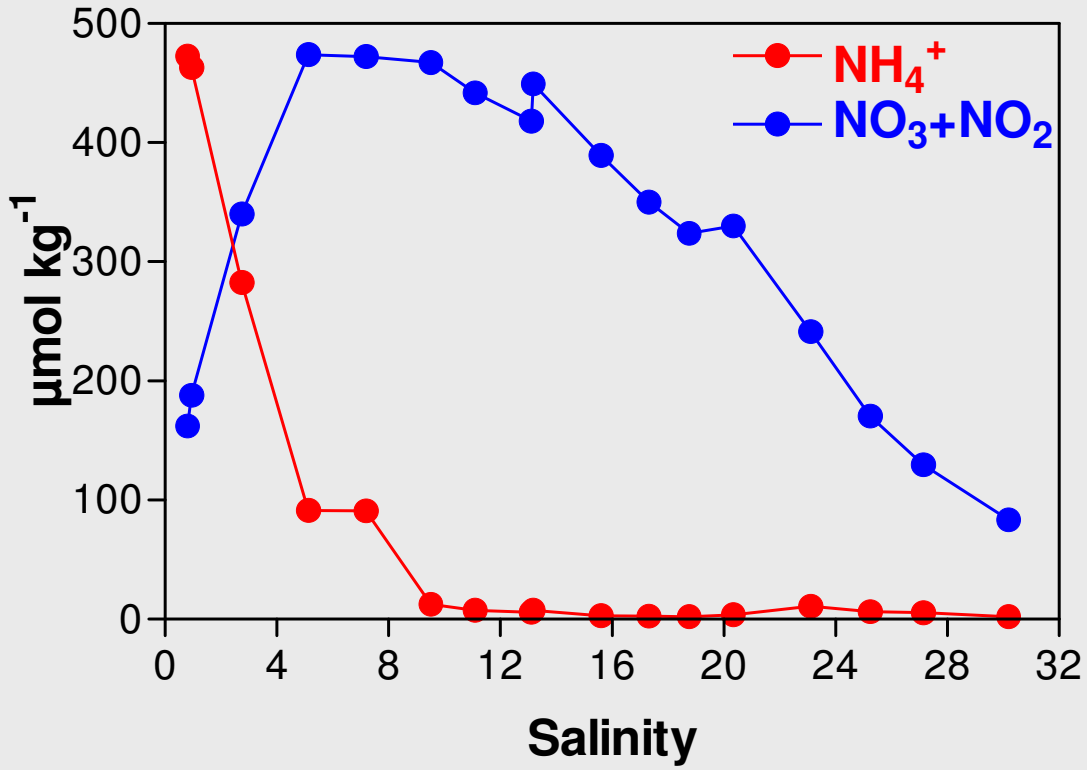


March 1993



$$NH_4^+ + 2O_2 + H_2O \Leftrightarrow NO_3^- + 2H_3O^+$$

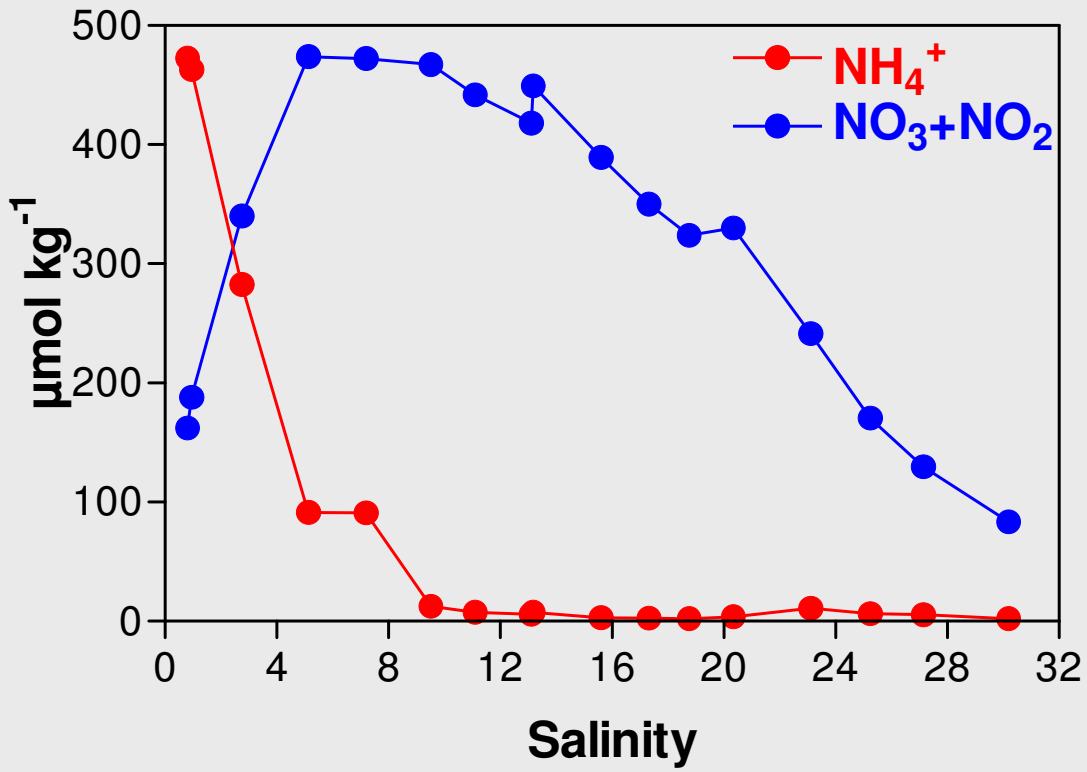
March 1993



$$NH_4^+ + 2O_2 + H_2O \Leftrightarrow NO_3^- + 2H_3O^+$$

$$TAlk = 2[CO_3^{2-}] + [CO_3^-] + [minor] + [OH^-] - [H_3O^+]$$

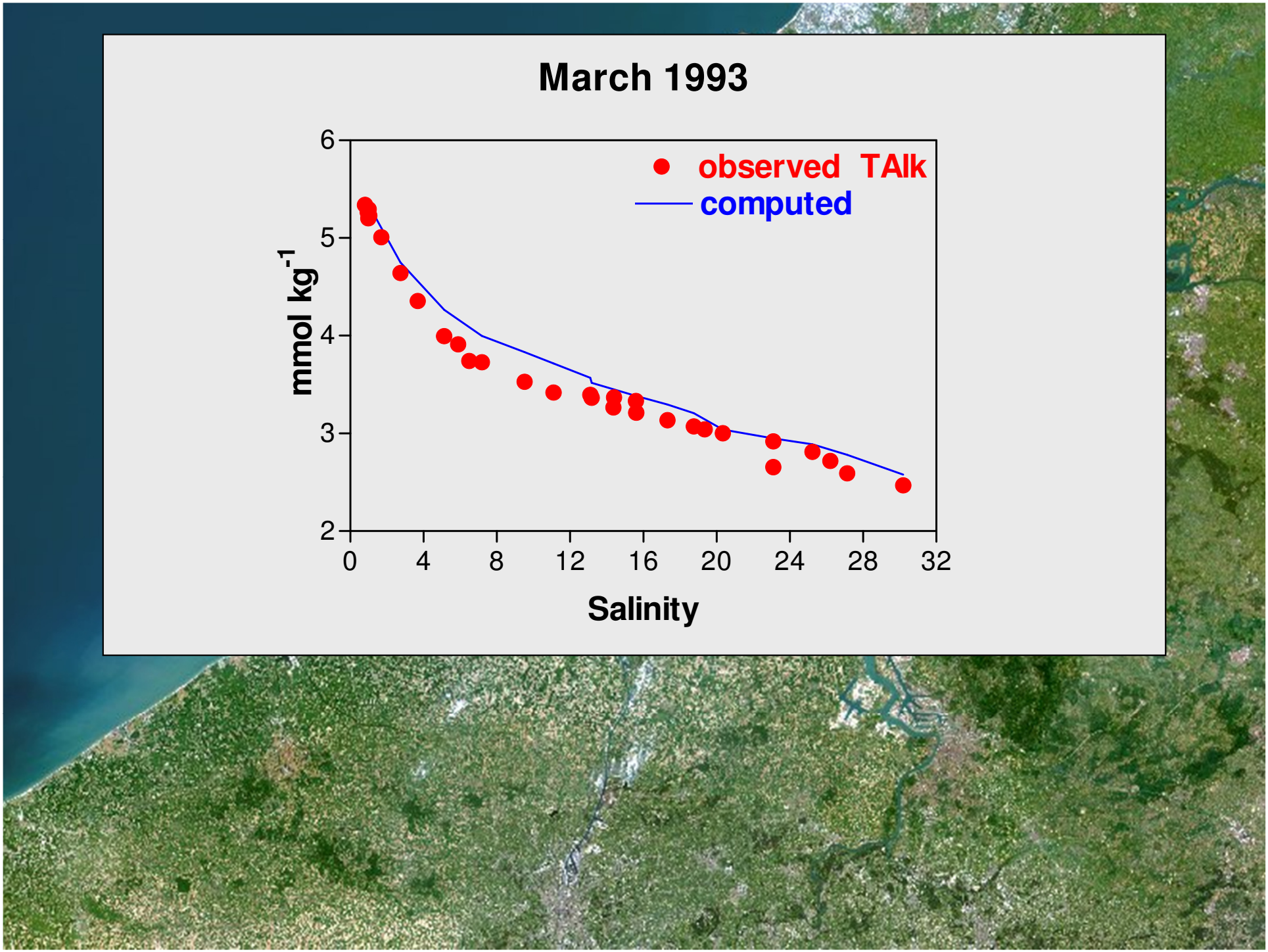
March 1993

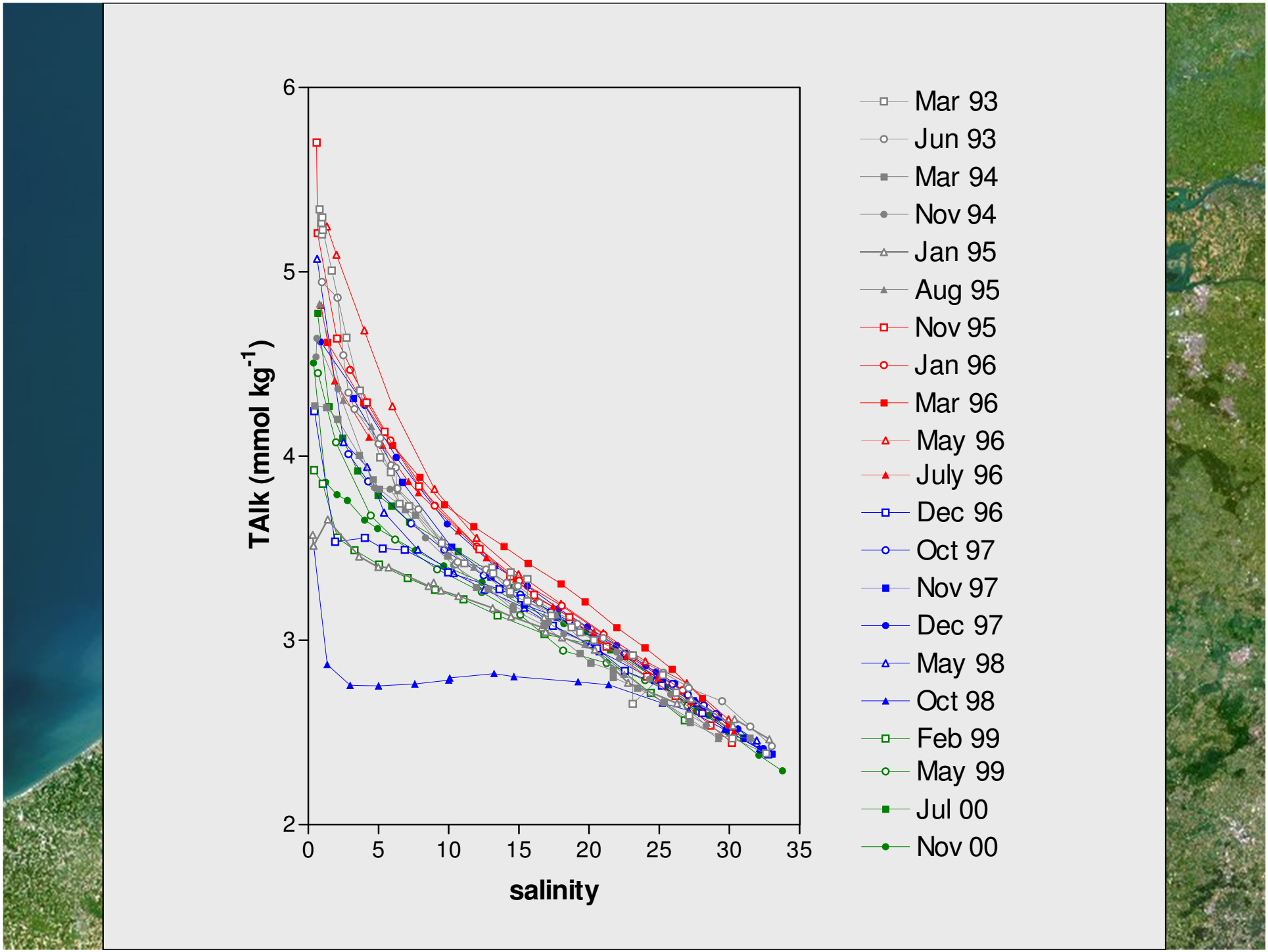


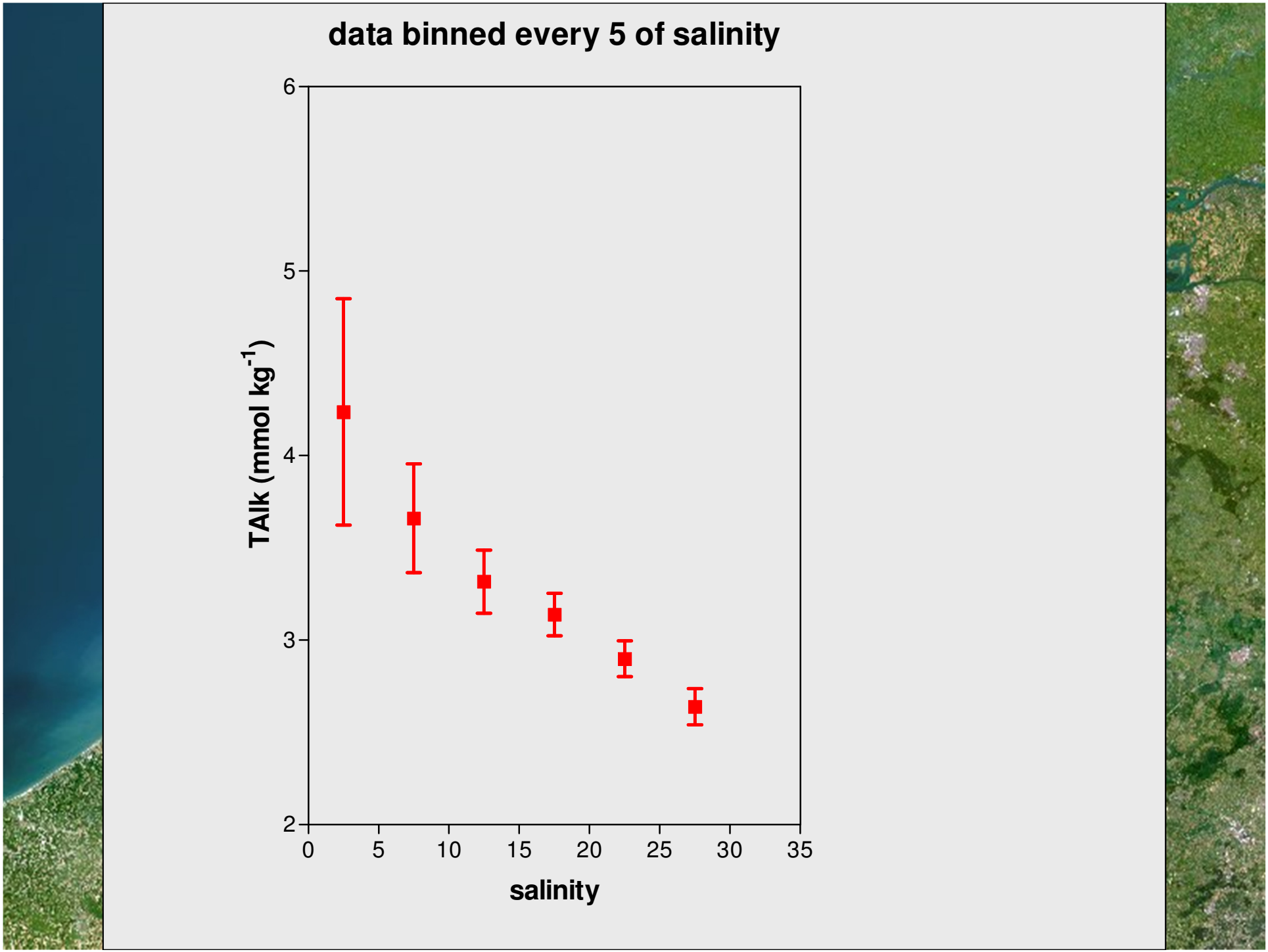
$NH_4^+ + 2O_2 + H_2O \Leftrightarrow NO_3^- + 2H_3O^+$

$TAlk = 2[CO_3^{2-}] + [CO_3^-] + [minor] + [OH^-] - [H_3O^+]$

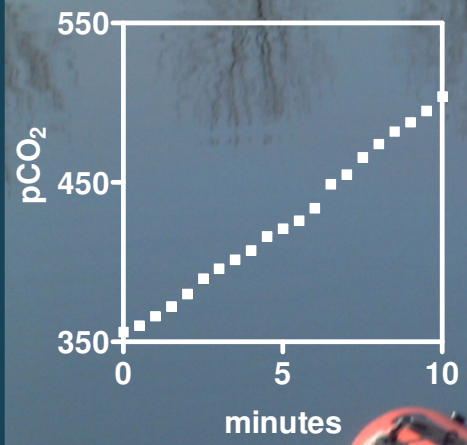
$pH = -\log [H_3O^+]$


March 1993
observed TAlk
computed
mmol kg-1
6
5
4
3
2
0
4
8
12
16
20
24
28
32
Salinity

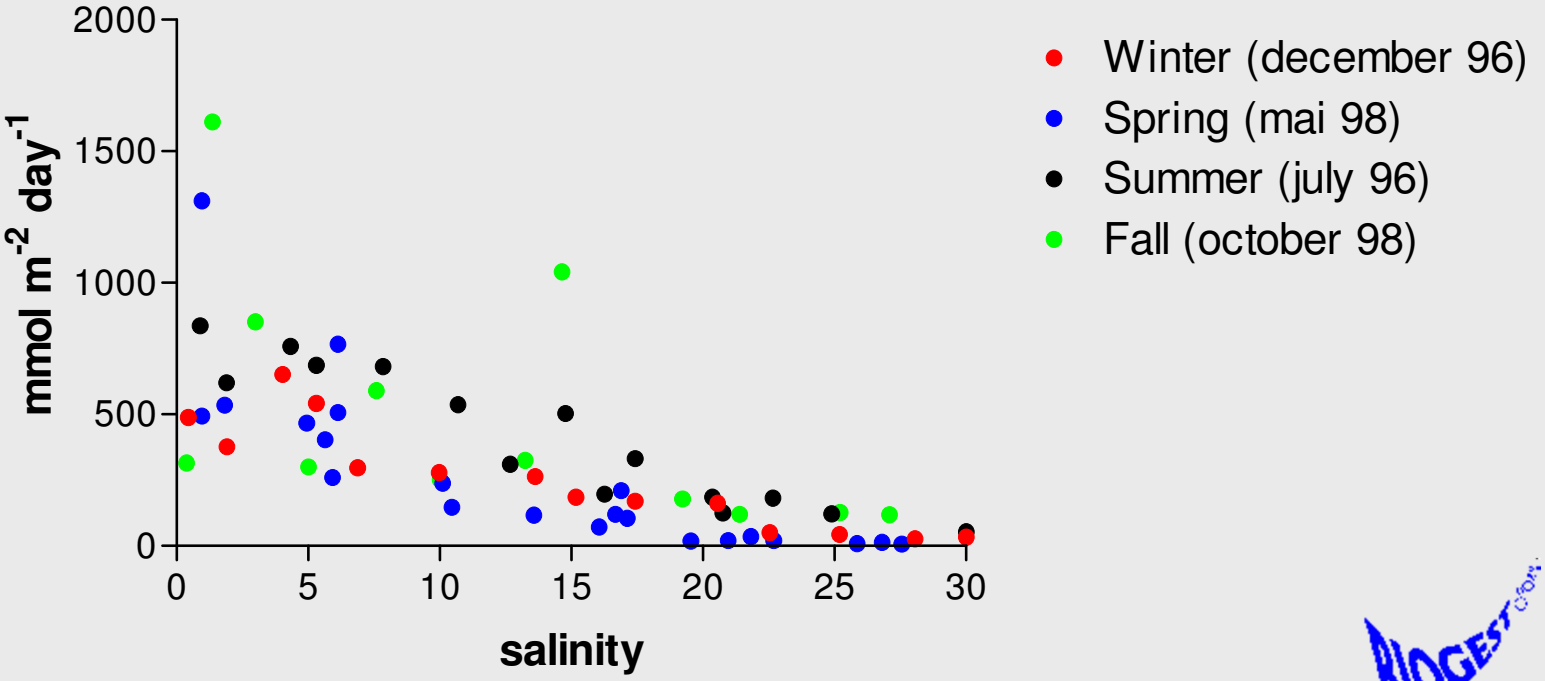

TAlk (mmol kg-1)
salinity
6
5
4
3
2
0
5
10
15
20
25
30
35
Mar 93
Jun 93
Mar 94
Nov 94
Jan 95
Aug 95
Nov 95
Jan 96
Mar 96
May 96
July 96
Dec 96
Oct 97
Nov 97
Dec 97
May 98
Oct 98
Feb 99
May 99
Jul 00
Nov 00

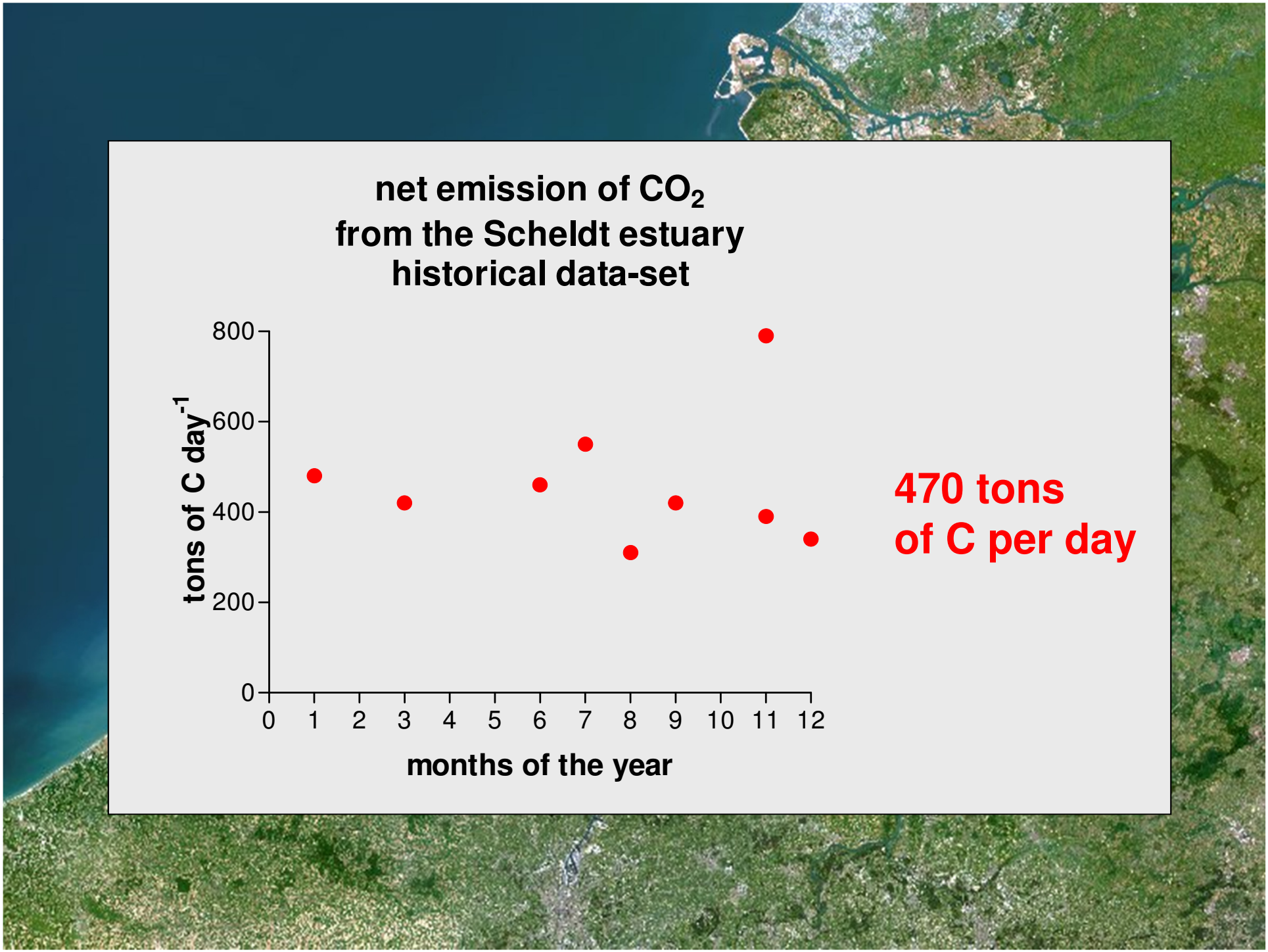

data binned every 5 of salinity
TAlk (mmol kg-1)
6
5
4
3
2
0
5
10
15
20
25
30
35
salinity

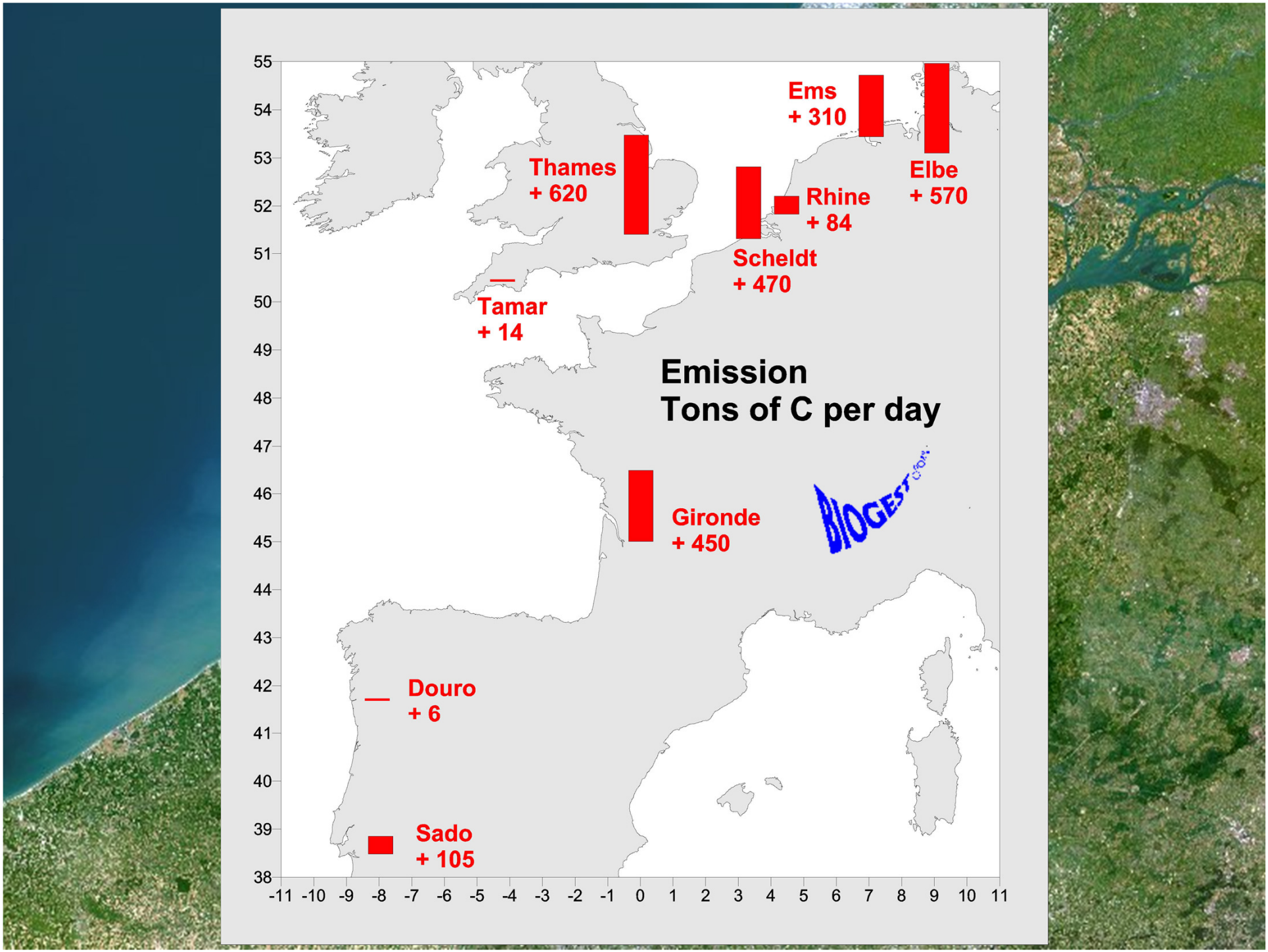
CO_2 air-water fluxes



CO_2 atmospheric fluxes in the Scheldt estuary Biogest cruises




net emission of CO_2
from the Scheldt estuary
historical data-set
tons of C day^{-1}
800
600
400
200
0
0 1 2 3 4 5 6 7 8 9 10 11 12
months of the year
470 tons
of C per day


Ems
+ 310
Thames
+ 620
Elbe
+ 570
Rhine
+ 84
Scheldt
+ 470
Tamar
+ 14
Emission
Tons of C per day
Gironde
+ 450
Douro
+ 6
Sado
+ 105
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
-11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11

Back of the envelope CO_2 budget for the Scheldt ($tC\ day^{-1}$)

Inputs

CO_2 from the tributaries	50[a]
Respiration – primary production	270[b,c]
Acidification from nitrification	250[c,d]

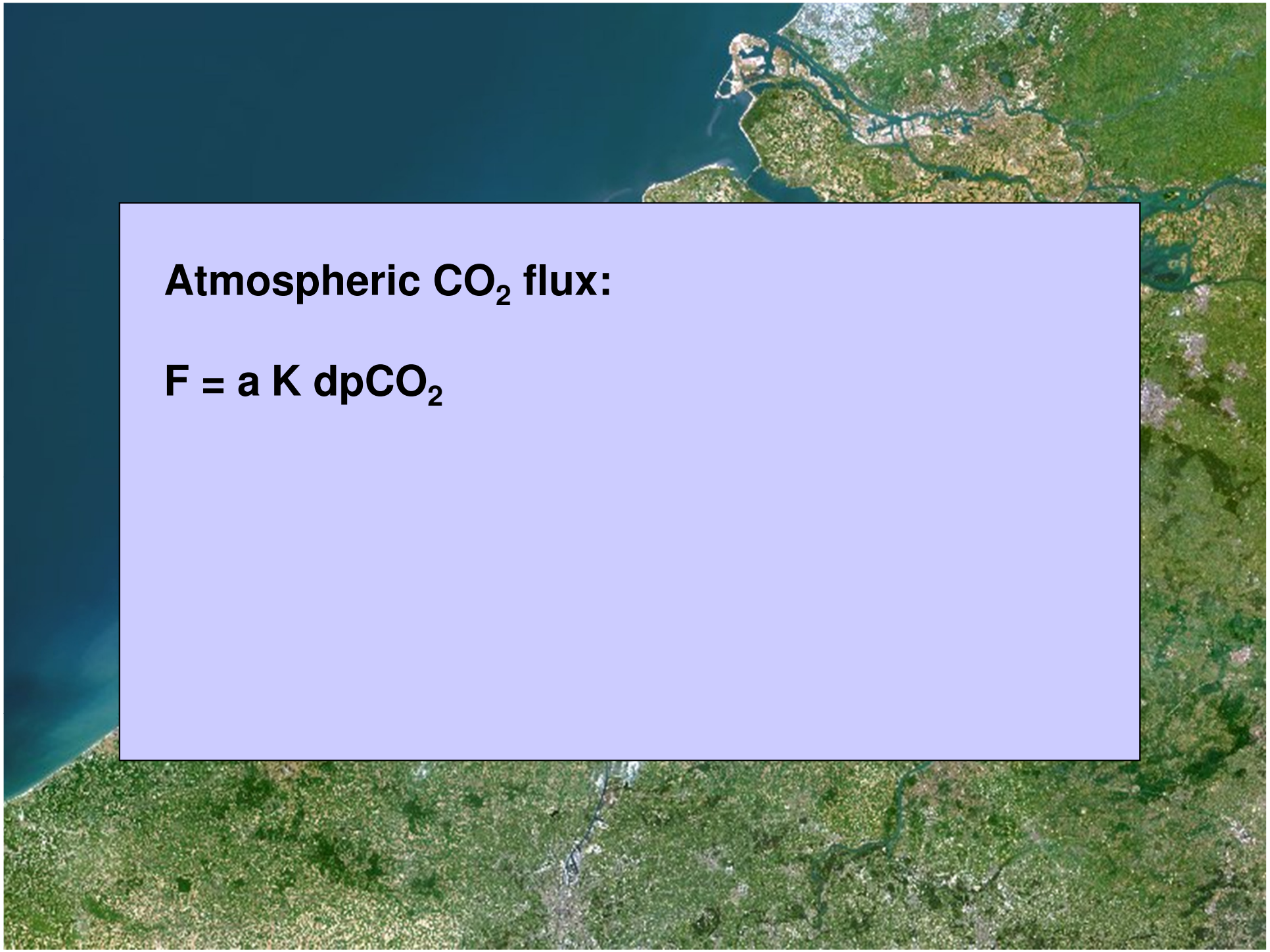
Outputs

CO_2 emission to the atmosphere	470[e]
CO_2 transfert to North Sea	35[f]

Sum

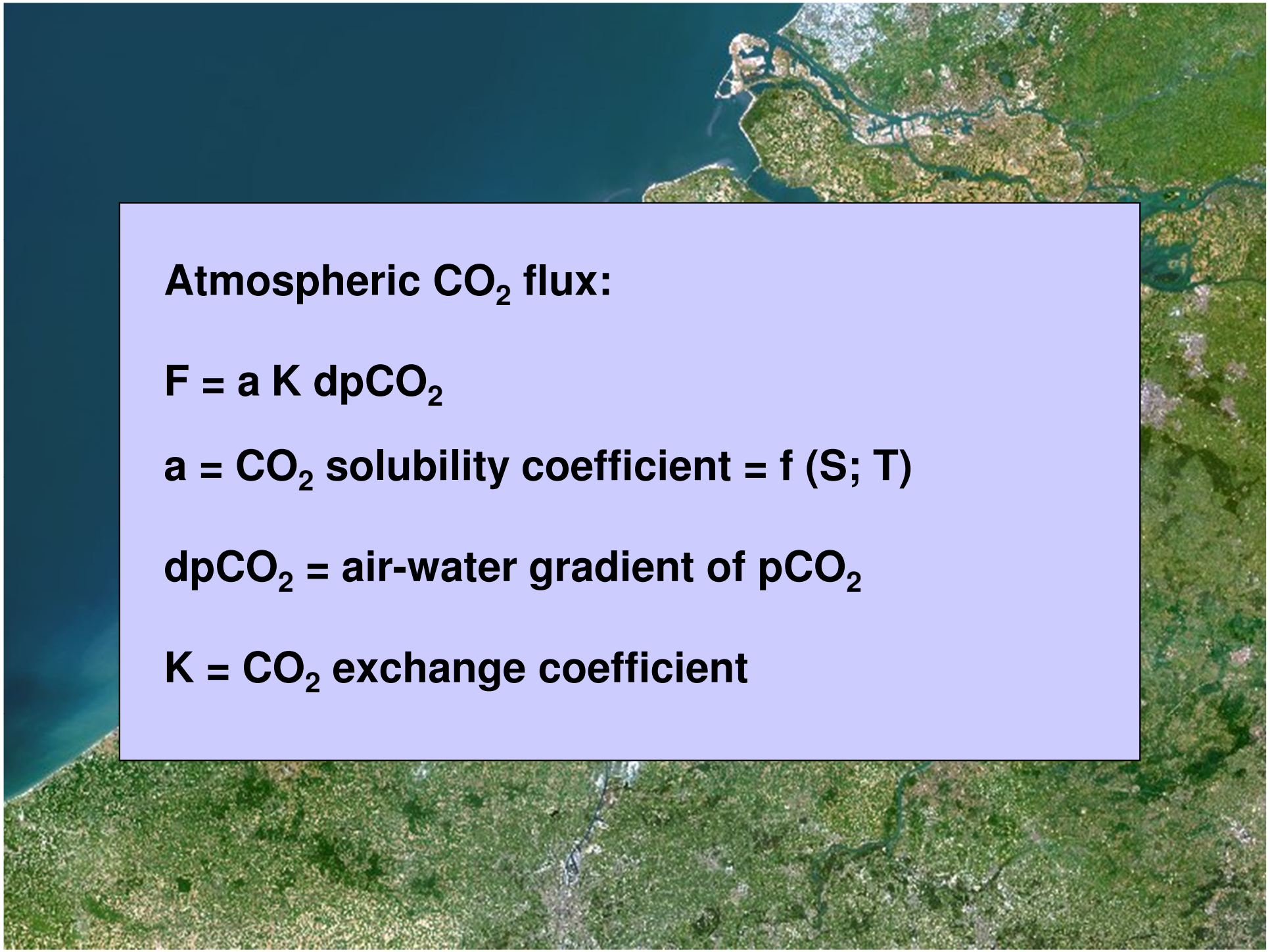
570	**505**

[a] Abril et al. (2000)
[b] Soetaert & Herman (1995)
[c] Wollast (1988)
[d] Regnier et al. (1997)
[e] Frankignoulle et al. (1998)
[f] Borges and Frankignoulle (2002)



Atmospheric CO_2 flux:

$F = a\ K\ dpCO_2$



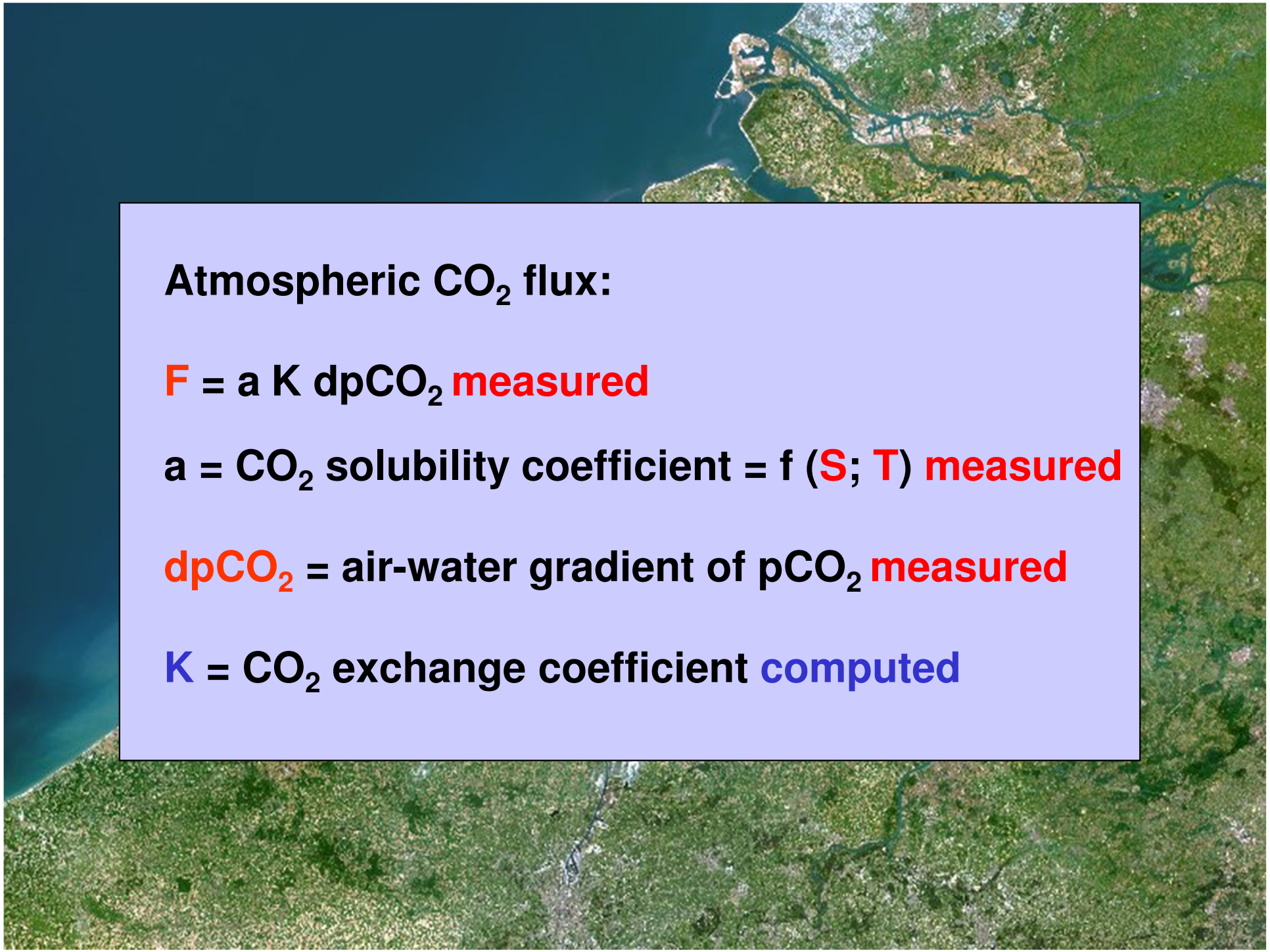
Atmospheric CO_2 flux:

$F = a\ K\ dpCO_2$

a = CO_2 solubility coefficient = f (S; T)

$dpCO_2$ = air-water gradient of pCO_2

K = CO_2 exchange coefficient



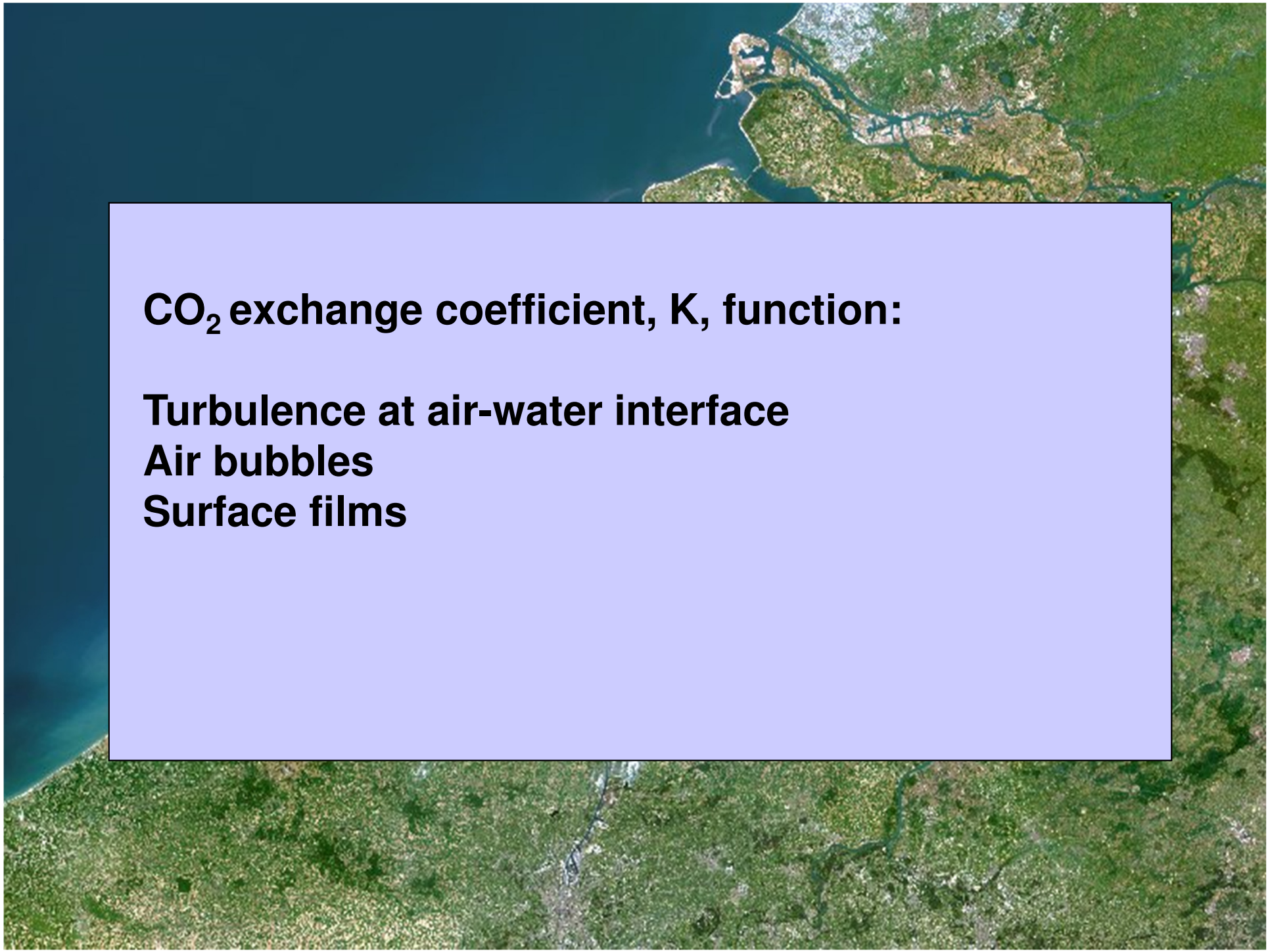
Atmospheric CO_2 flux:

$F = a\ K\ dpCO_2$ measured

a = CO_2 solubility coefficient = f (S; T) measured

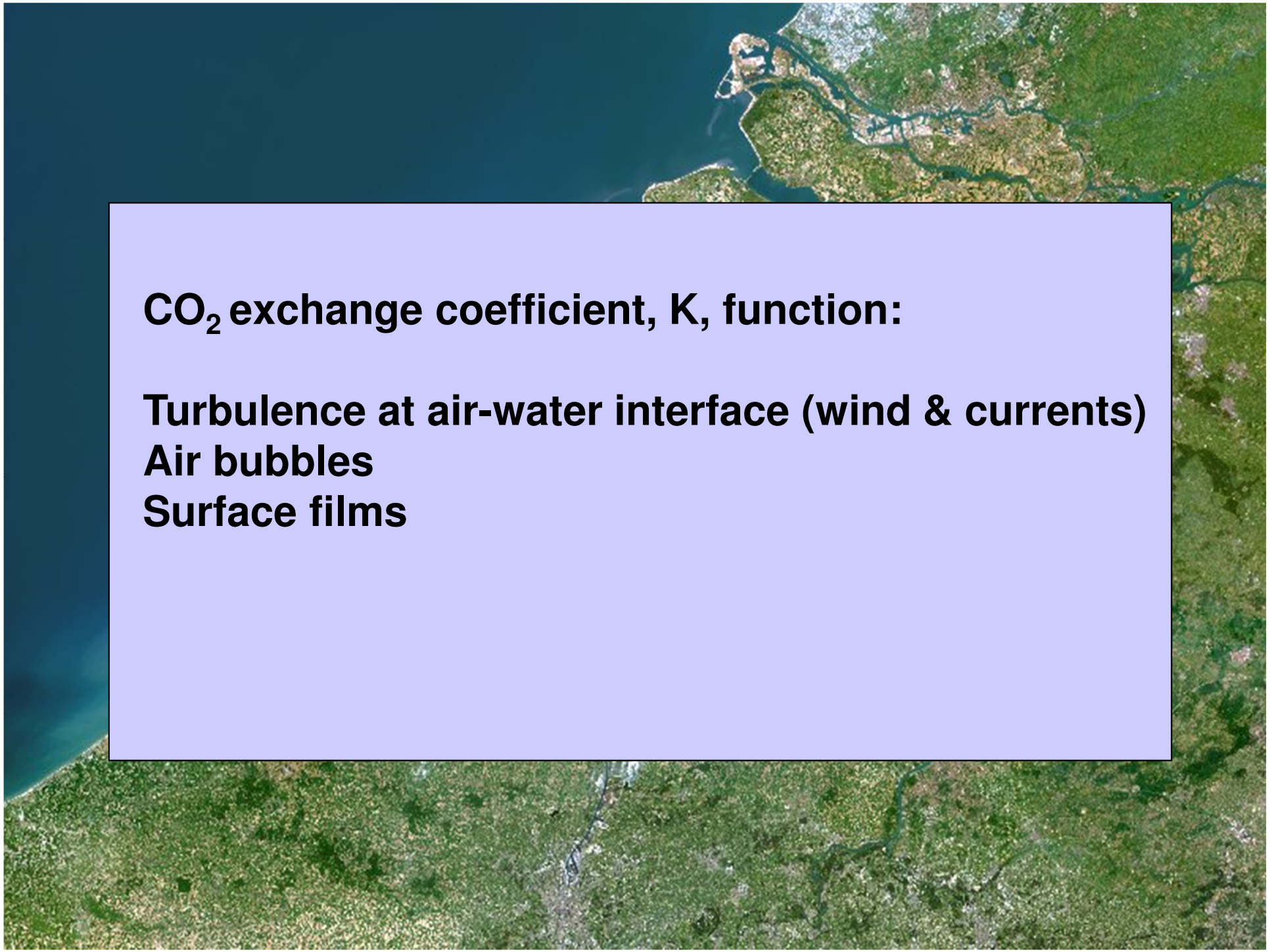
$dpCO_2$ = air-water gradient of pCO_2 measured

K = CO_2 exchange coefficient computed



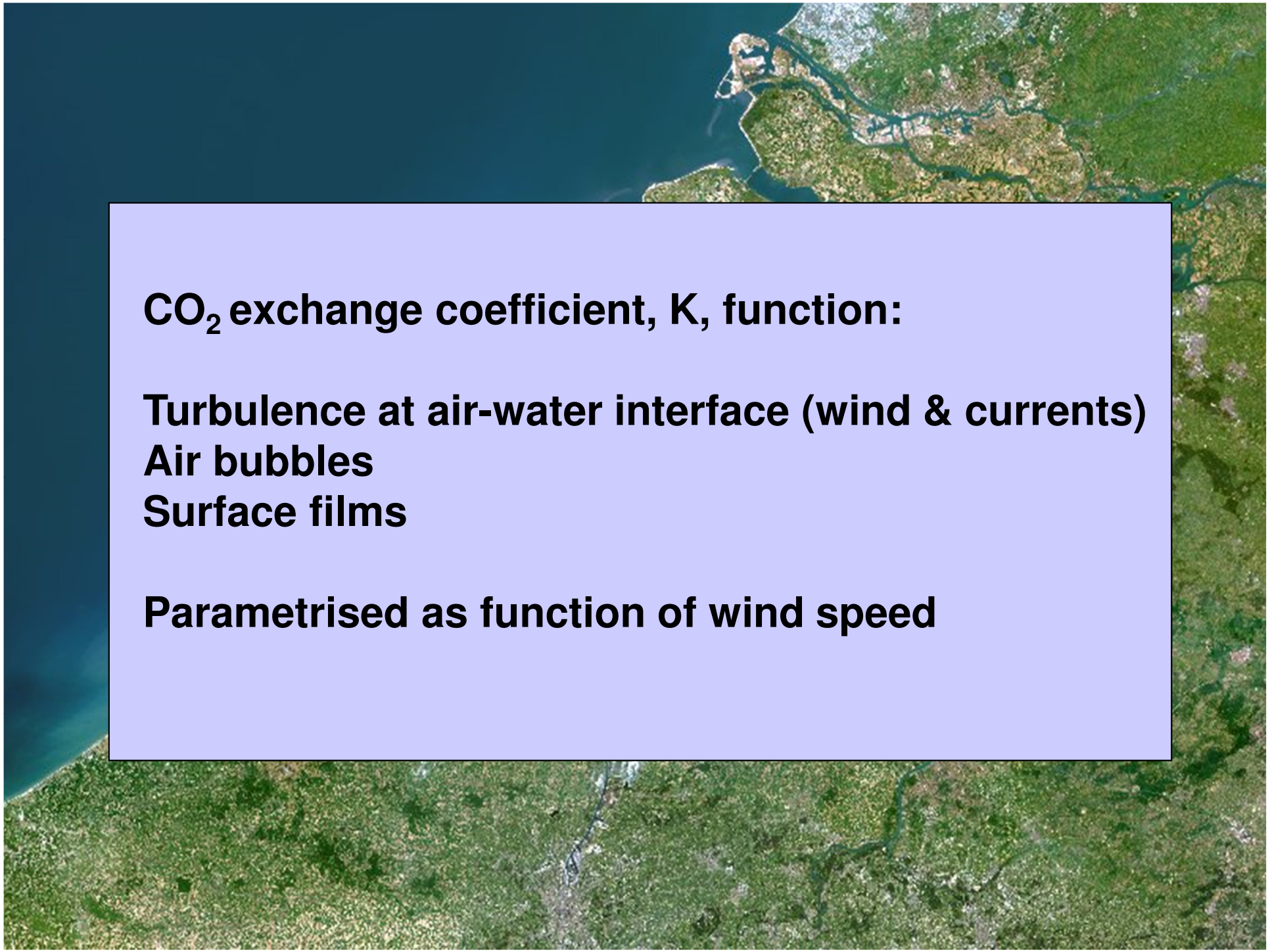
CO_2 exchange coefficient, K, function:

Turbulence at air-water interface
Air bubbles
Surface films



CO_2 exchange coefficient, K, function:

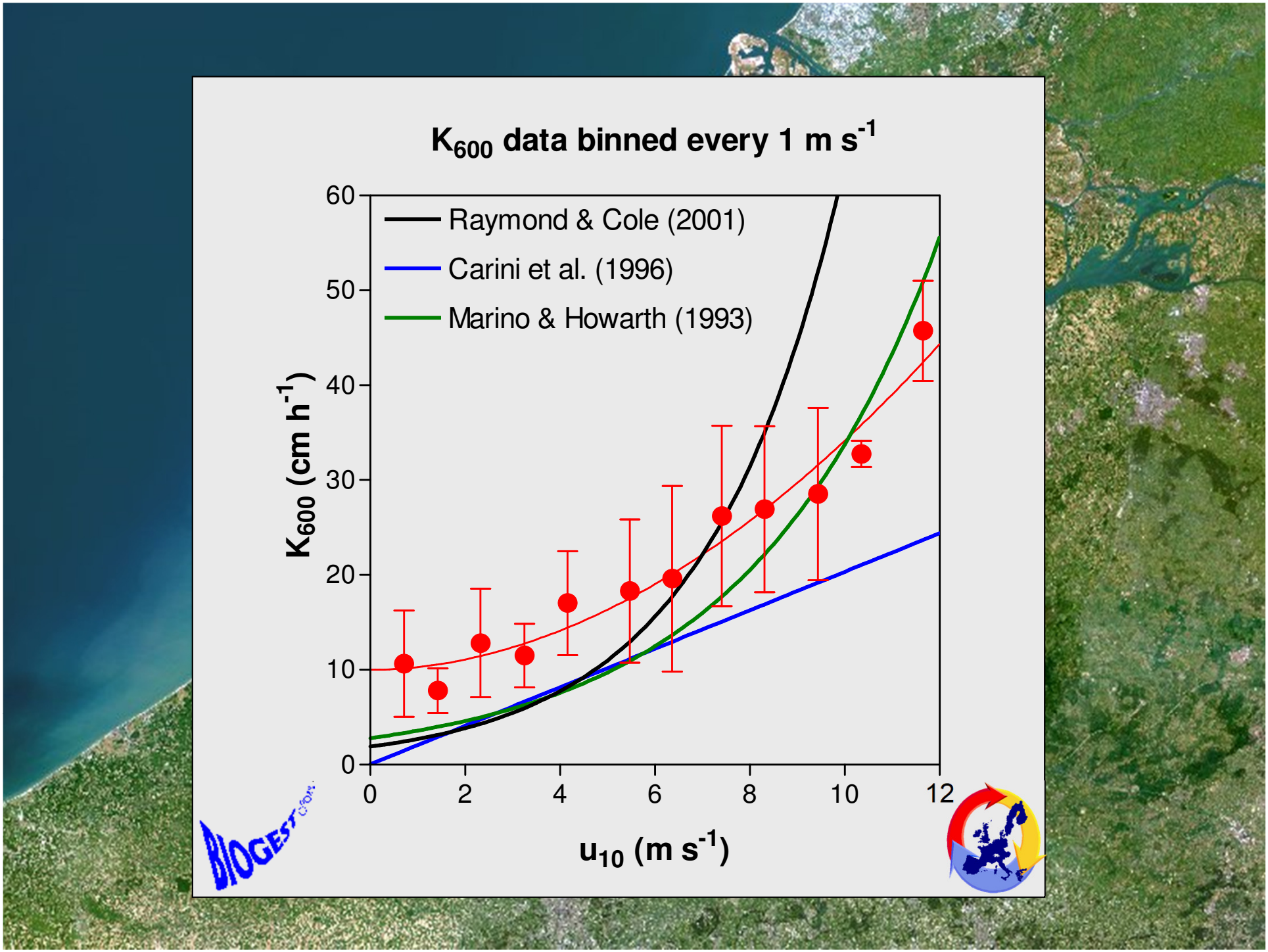
Turbulence at air-water interface (wind & currents)
Air bubbles
Surface films

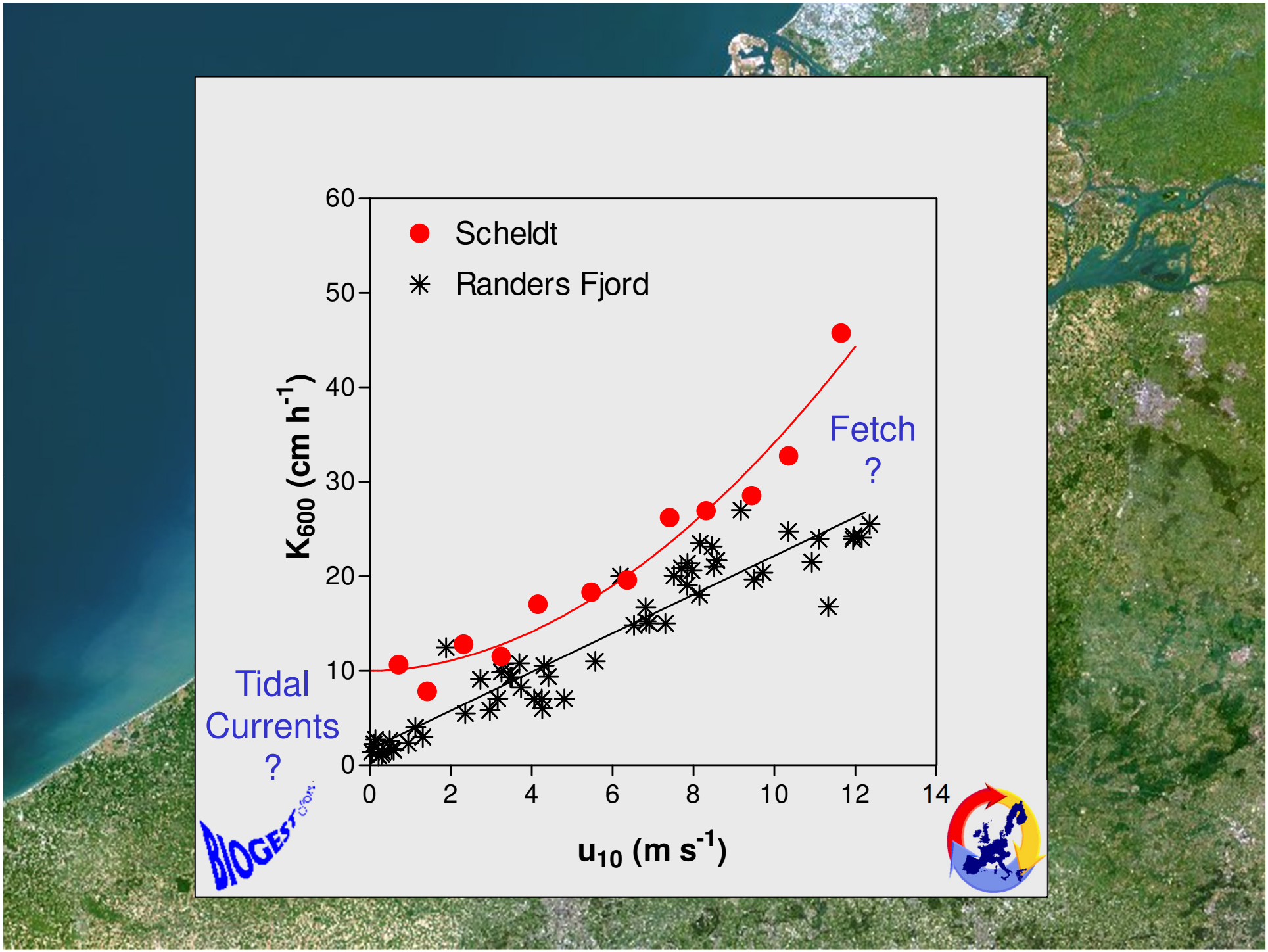


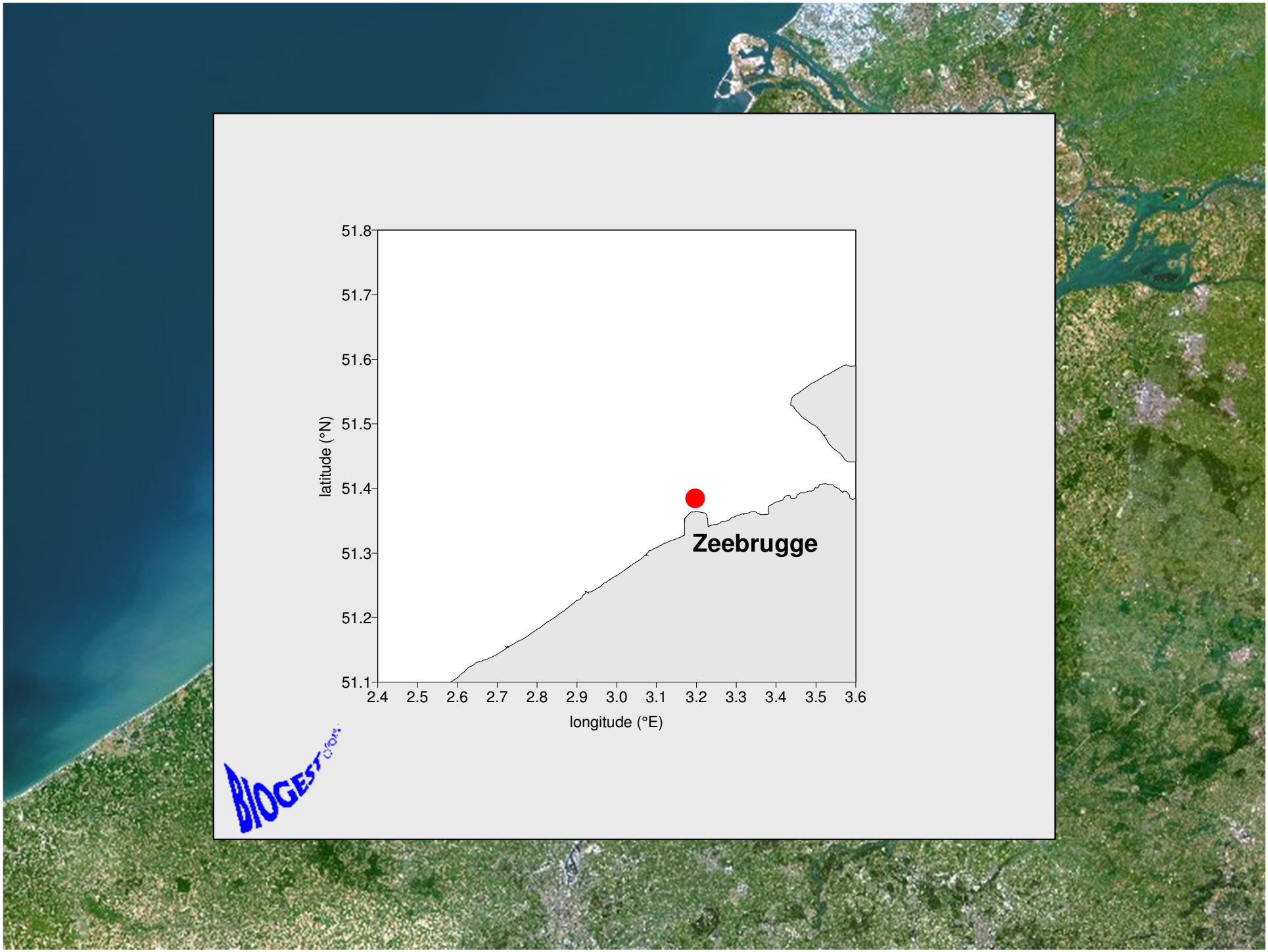
CO_2 exchange coefficient, K, function:

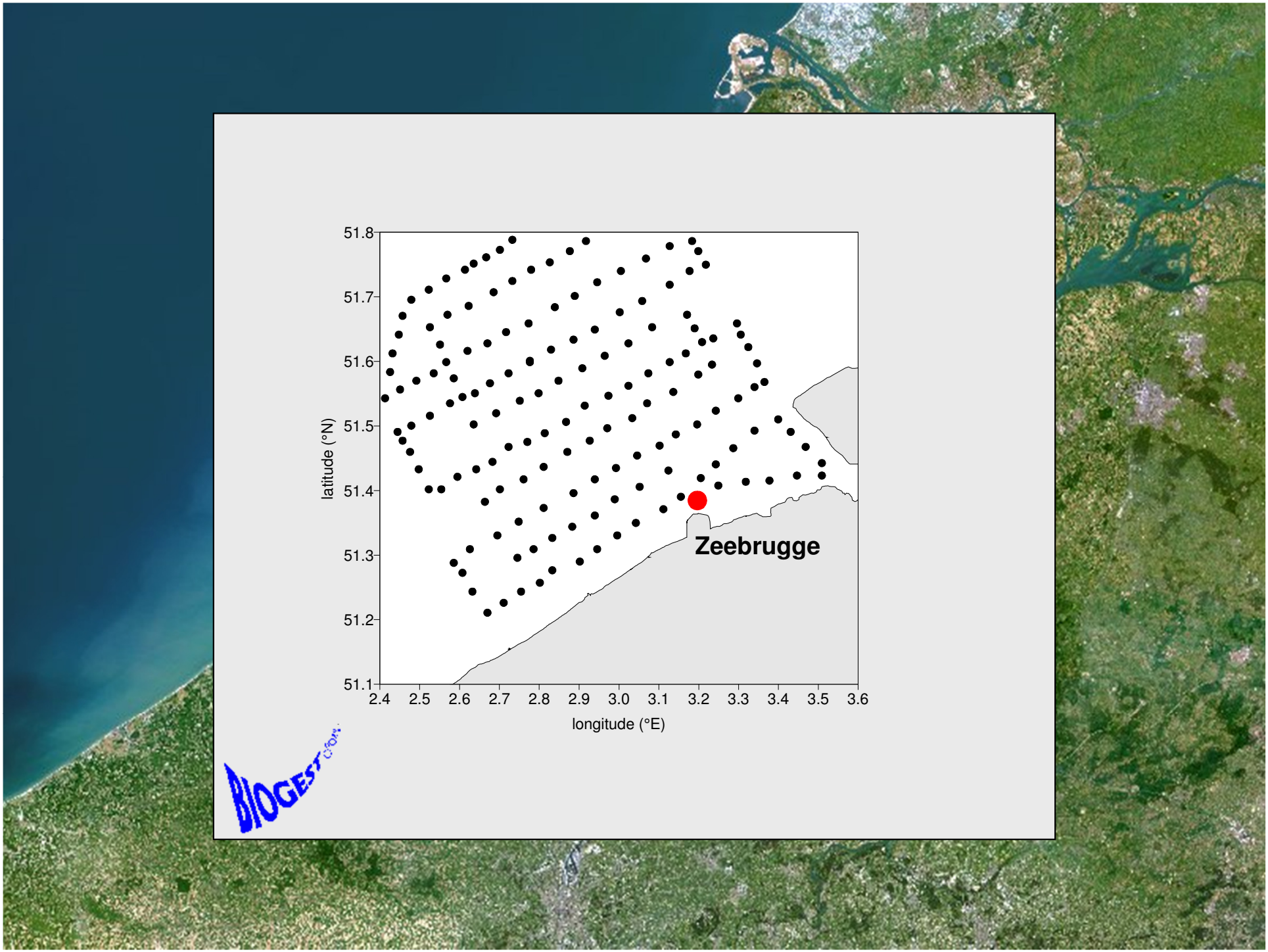
Turbulence at air-water interface (wind & currents)
Air bubbles
Surface films

Parametrised as function of wind speed

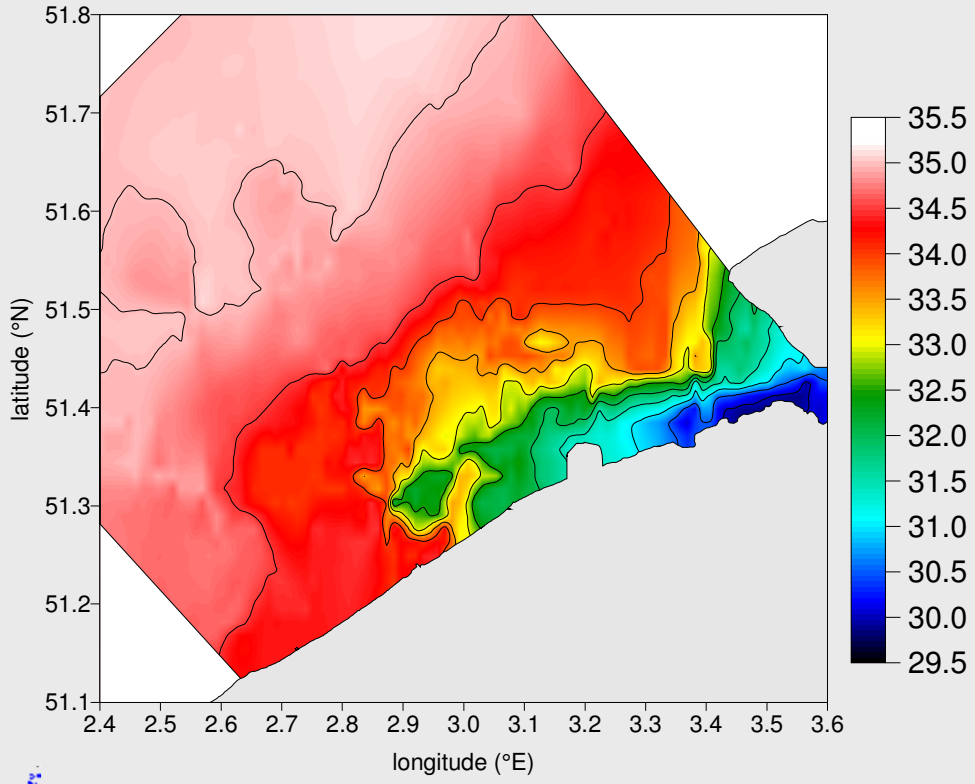

K600 data binned every 1 m s-1
Raymond & Cole (2001)
Carini et al. (1996)
Marino & Howarth (1993)
K600 (cm h-1)
u10 (m s-1)
0
10
20
30
40
50
60
0
2
4
6
8
10
12


Scheldt
Randers Fjord
K_{600} (cm h^{-1})
u_{10} (m s^{-1})
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
Fetch
?
Tidal
Currents
?

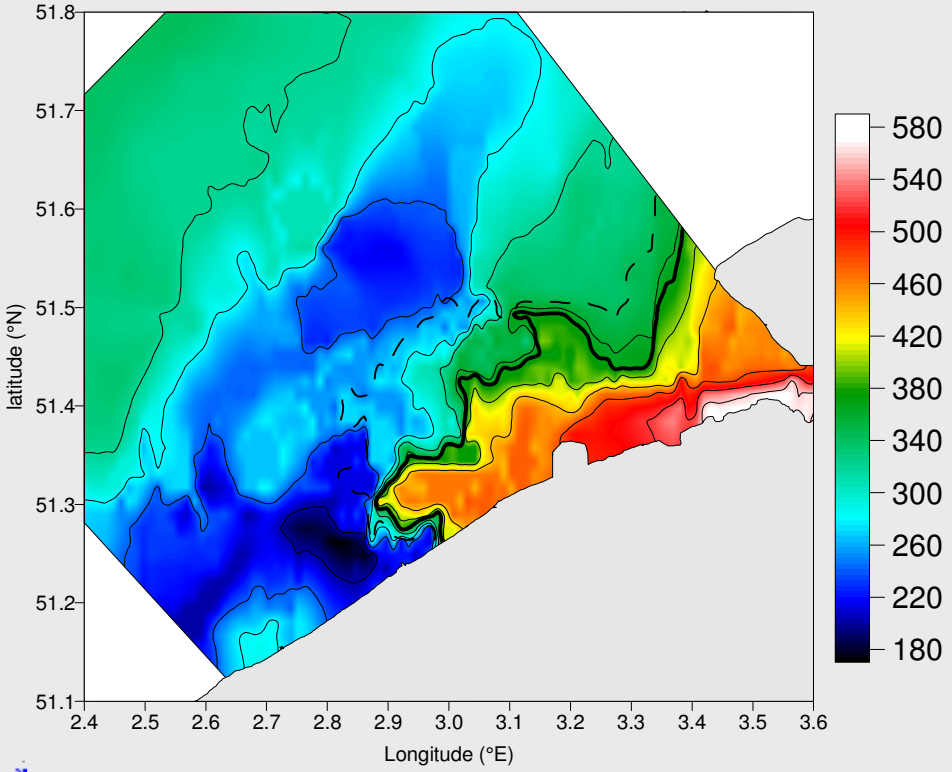

51.8
51.7
51.6
51.5
51.4
51.3
51.2
51.1
latitude (°N)
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
longitude (°E)
Zeebrugge

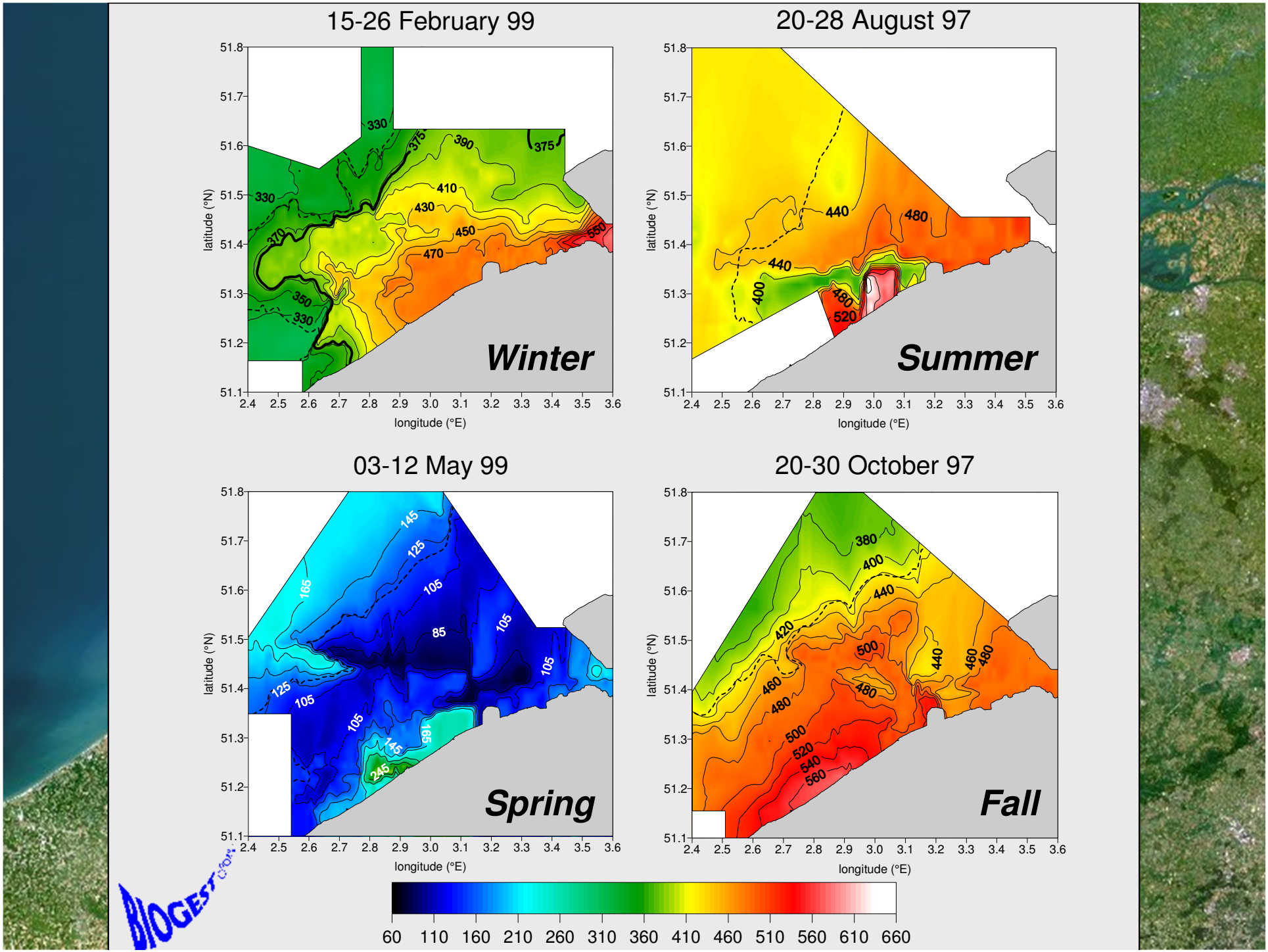

51.8
51.7
51.6
51.5
51.4
51.3
51.2
51.1
latitude (°N)
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
longitude (°E)
Zeebrugge

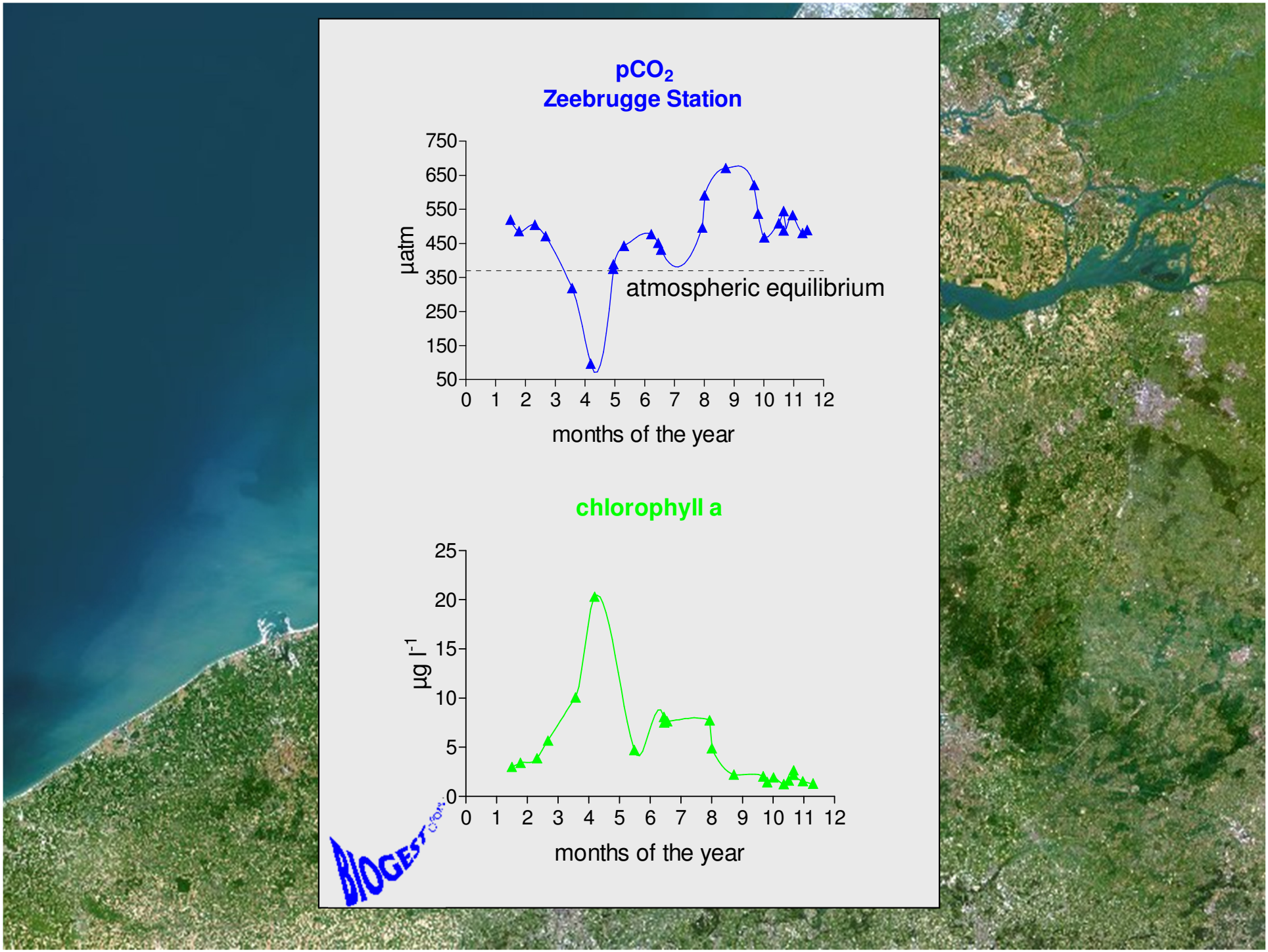
Salinity 10-21 march 97

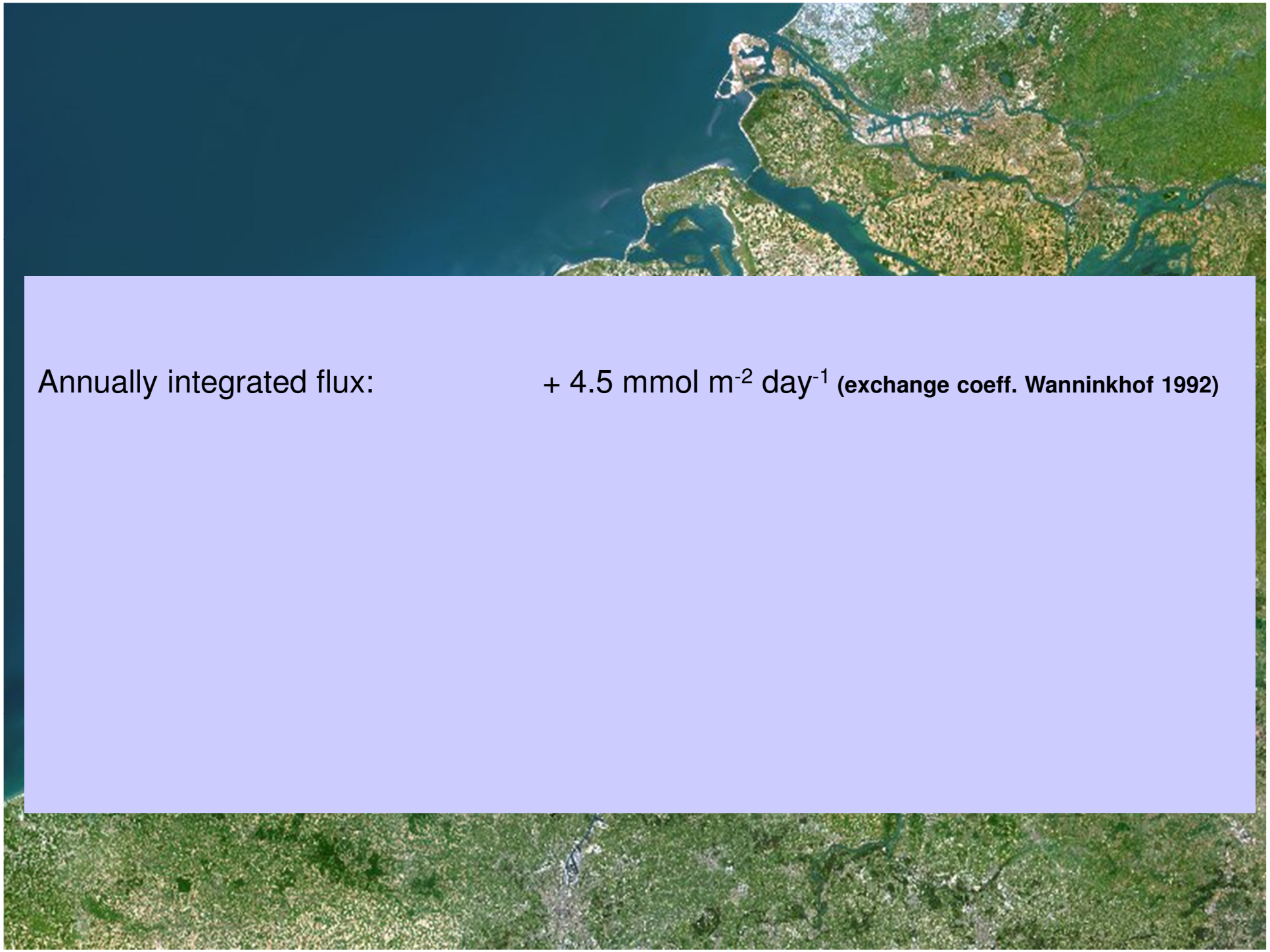


Partial pressure of CO_2 (pCO_2)
10-21 march 97

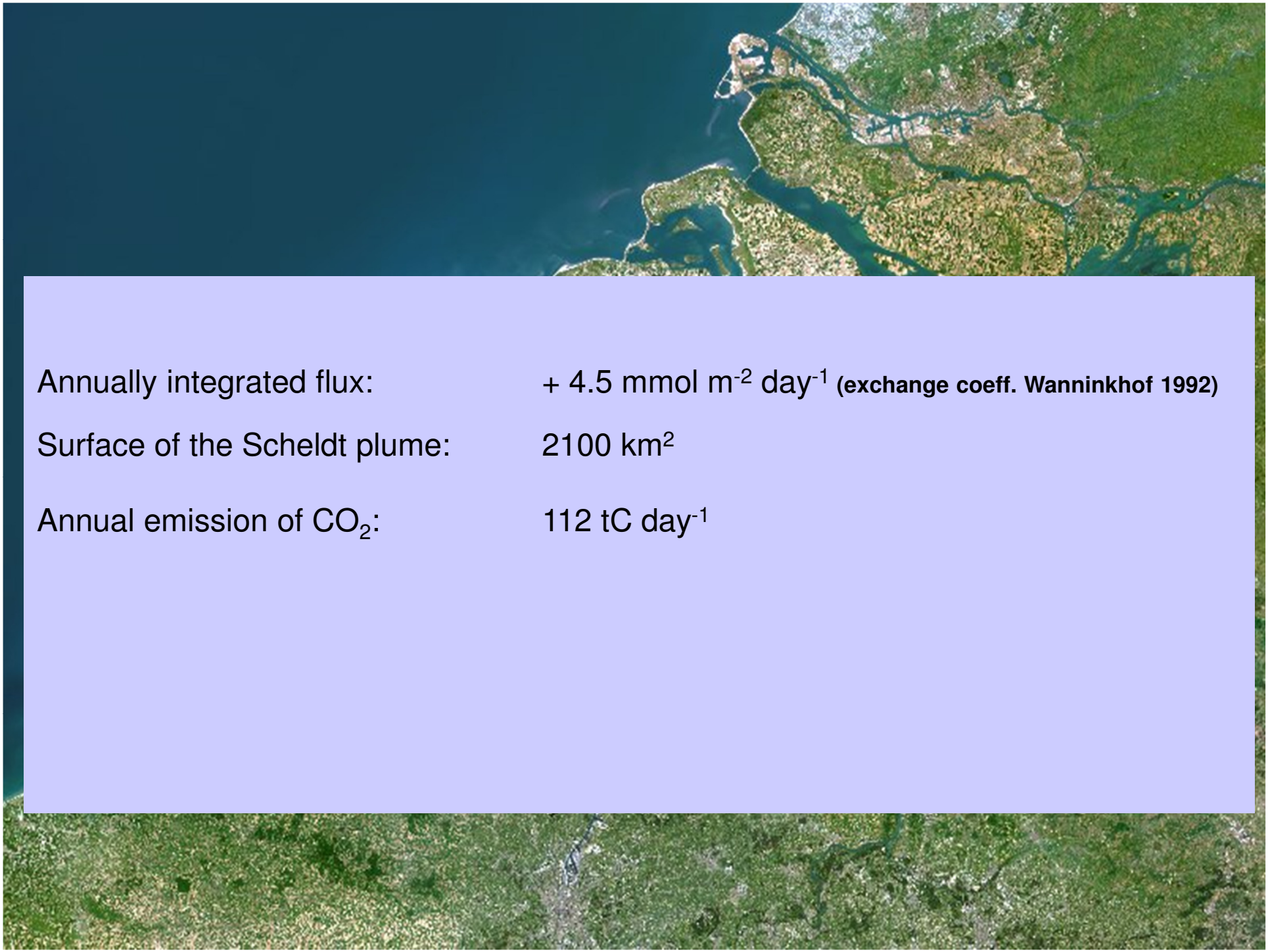



15-26 February 99
20-28 August 97
03-12 May 99
20-30 October 97
Winter
Summer
Spring
Fall
latitude (°N)
longitude (°E)
51.8
51.7
51.6
51.5
51.4
51.3
51.2
51.1
2.4 2.5 2.6 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5 3.6
330 375 390 375 410 430 450 470 550 330 370 350 330
440 480 440 400 480 520
145 125 165 105 85 105 105 125 105 105 165 145 245
380 400 440 420 500 440 460 480 460 480 500 520 540 560
60 110 160 210 260 310 360 410 460 510 560 610 660

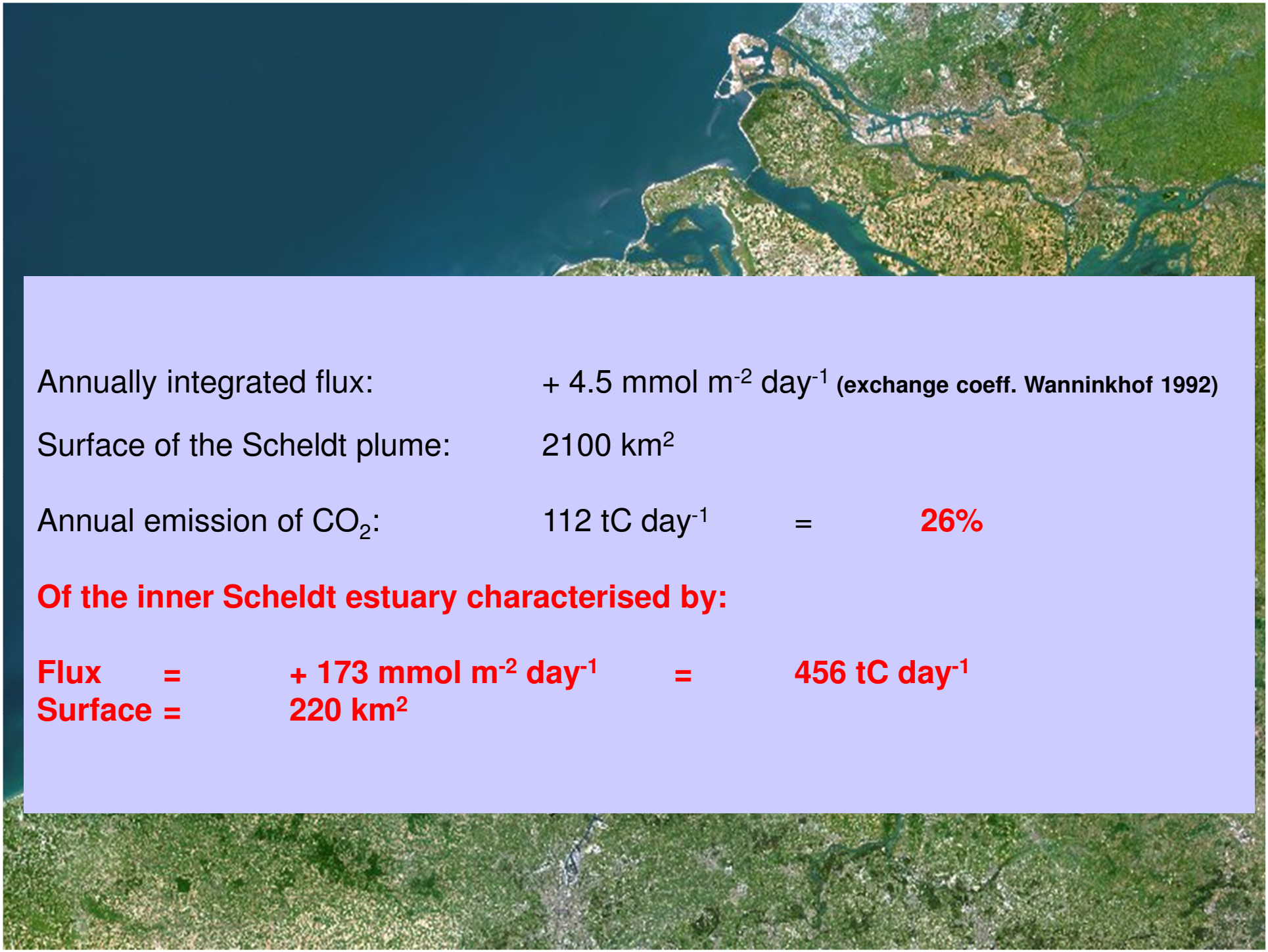

pCO2
Zeebrugge Station
750
650
550
450
350
250
150
50
µatm
atmospheric equilibrium
0 1 2 3 4 5 6 7 8 9 10 11 12
months of the year
chlorophyll a
25
20
15
10
5
0
µg l-1
0 1 2 3 4 5 6 7 8 9 10 11 12
months of the year



Annually integrated flux: + 4.5 mmol m^{-2} day^{-1} **(exchange coeff. Wanninkhof 1992)**



Annually integrated flux:	+ 4.5 mmol m^{-2} day^{-1} **(exchange coeff. Wanninkhof 1992)**
Surface of the Scheldt plume:	2100 km^2
Annual emission of CO_2:	112 tC day^{-1}



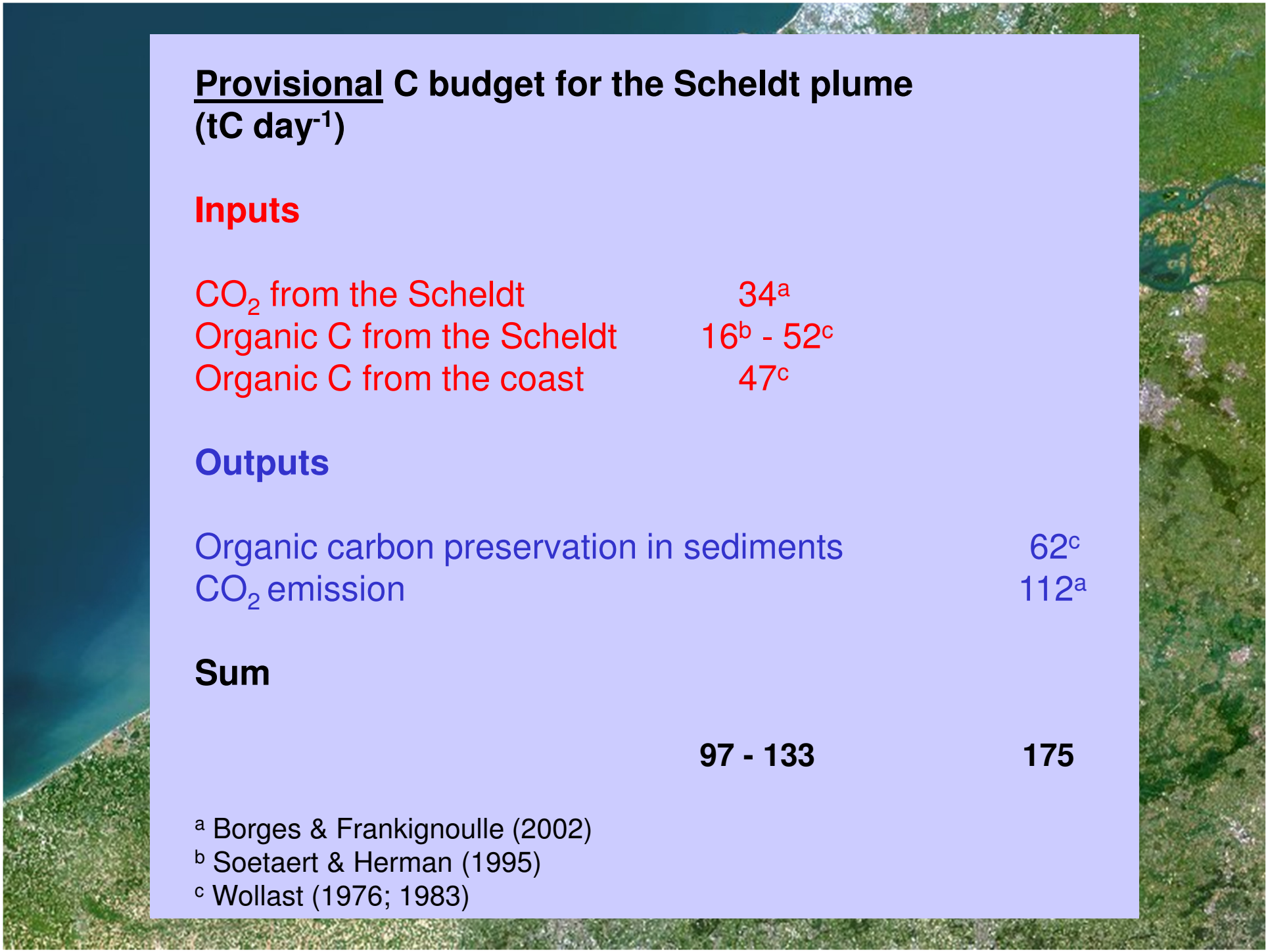
Annually integrated flux: + 4.5 mmol m^{-2} day^{-1} **(exchange coeff. Wanninkhof 1992)**

Surface of the Scheldt plume: 2100 km^2

Annual emission of CO_2: 112 tC day^{-1} = **26%**

Of the inner Scheldt estuary characterised by:

Flux = + 173 mmol m^{-2} day^{-1} = 456 tC day^{-1}
Surface = 220 km^2



<u>Provisional</u> C budget for the Scheldt plume (tC day^{-1})

Inputs

CO_2 from the Scheldt	34[a]
Organic C from the Scheldt	16[b] - 52[c]
Organic C from the coast	47[c]

Outputs

Organic carbon preservation in sediments	62[c]
CO_2 emission	112[a]

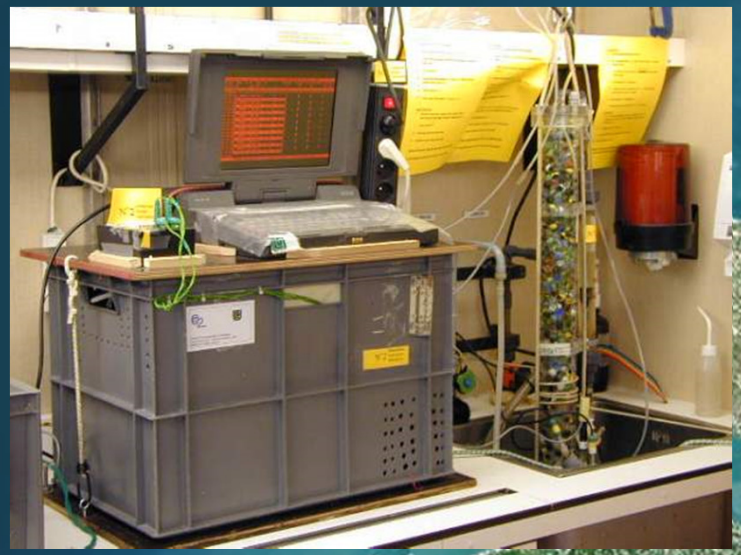
Sum

97 - 133	**175**

[a] Borges & Frankignoulle (2002)
[b] Soetaert & Herman (1995)
[c] Wollast (1976; 1983)

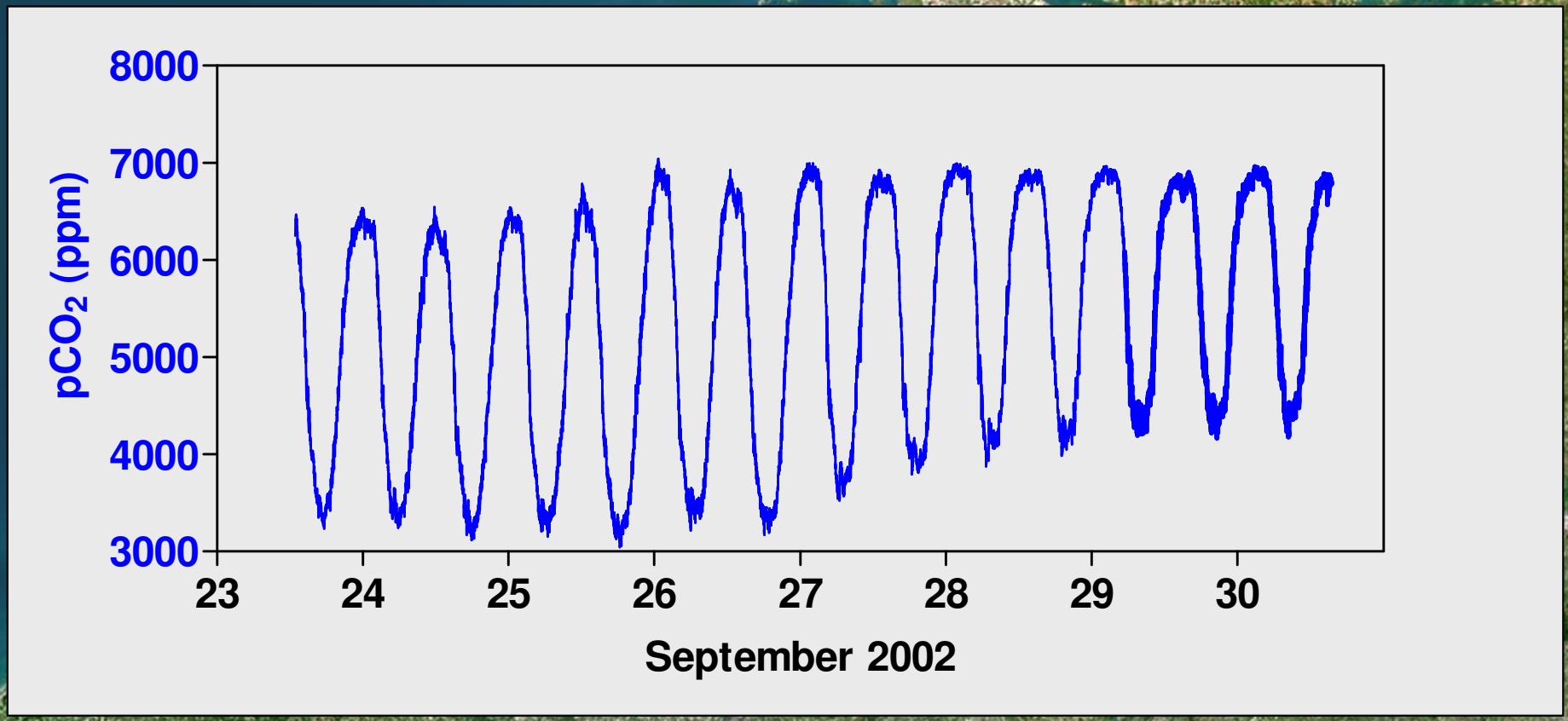
Perspectives

Belgica (North Sea)

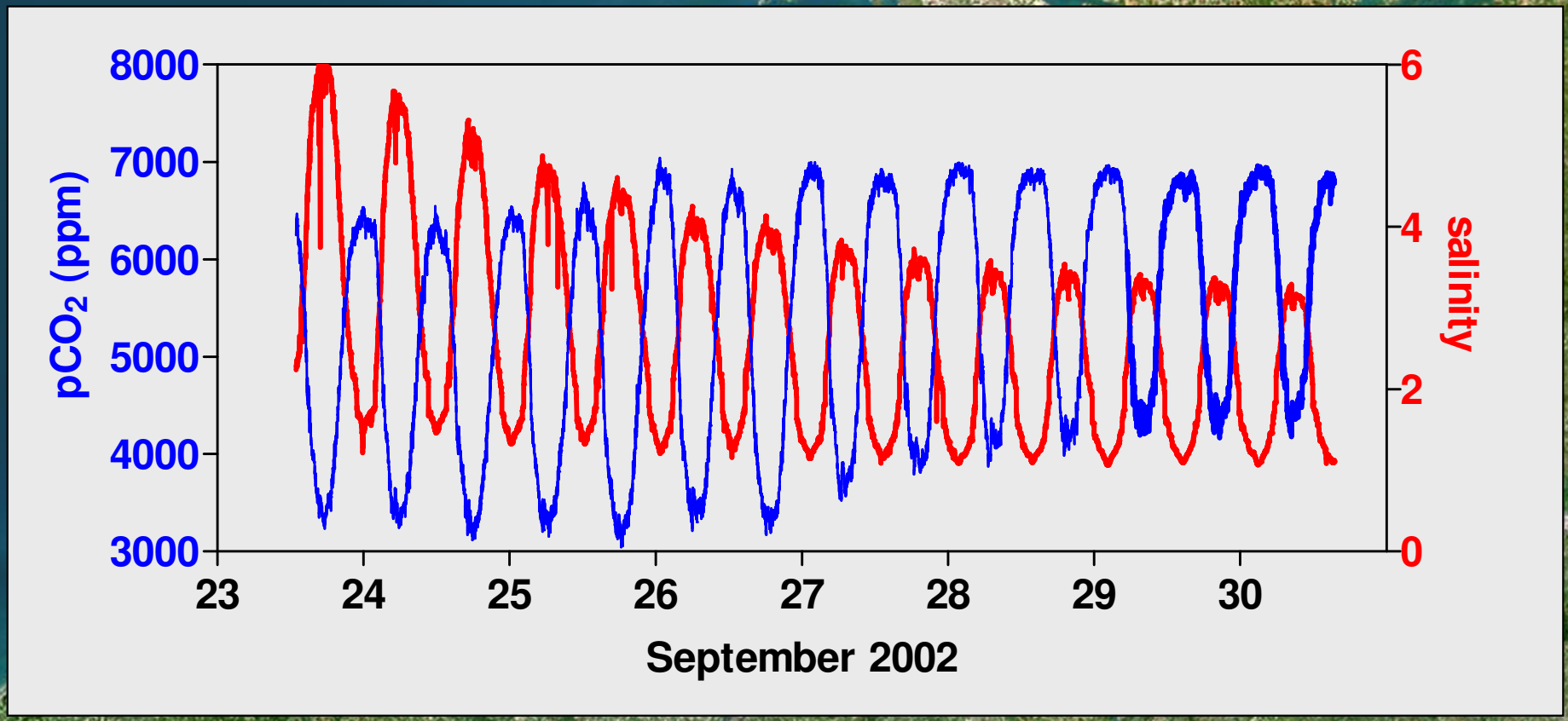


Ste Anna Station (Antwerp)

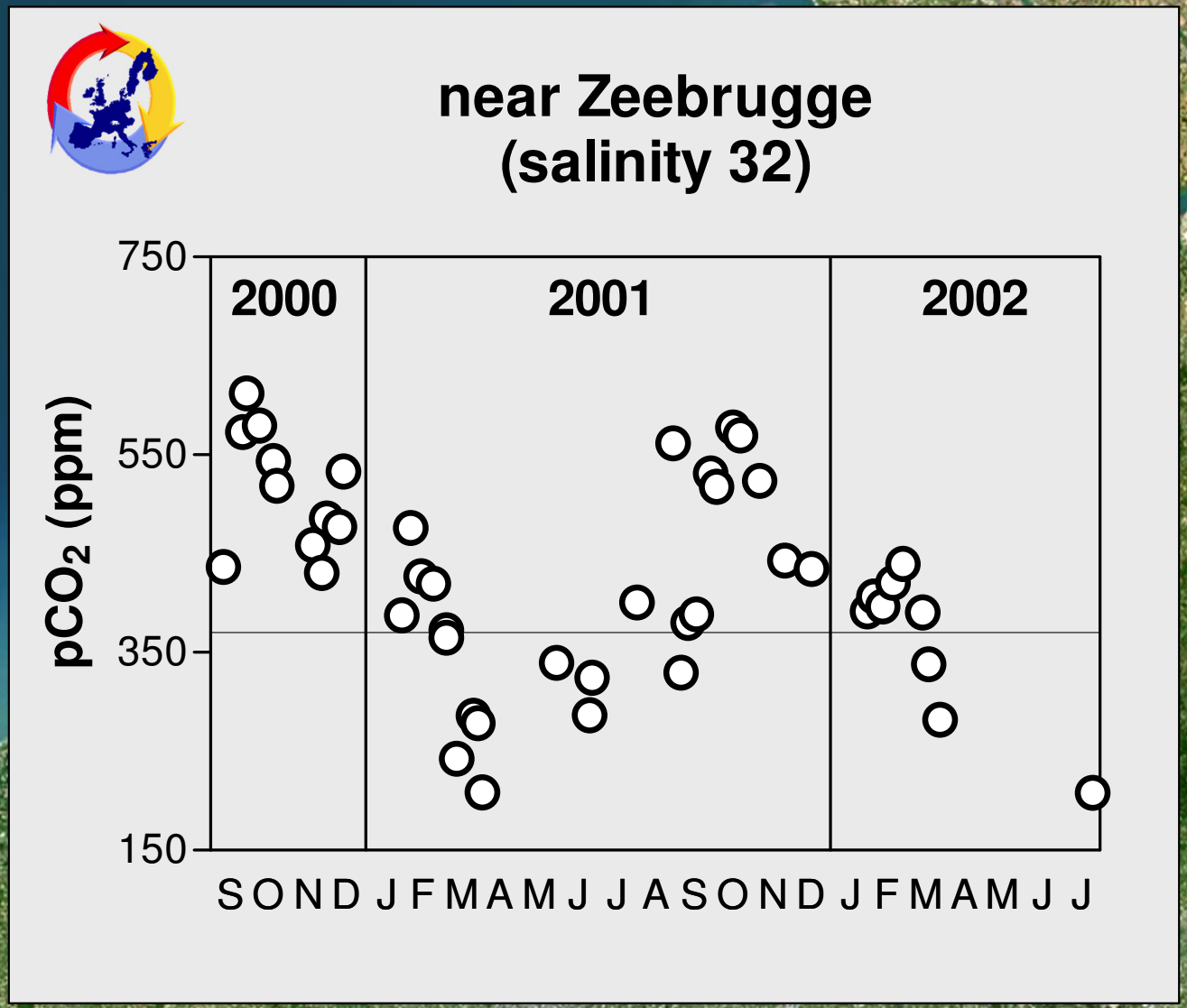
Ste Anna Station (Antwerp)



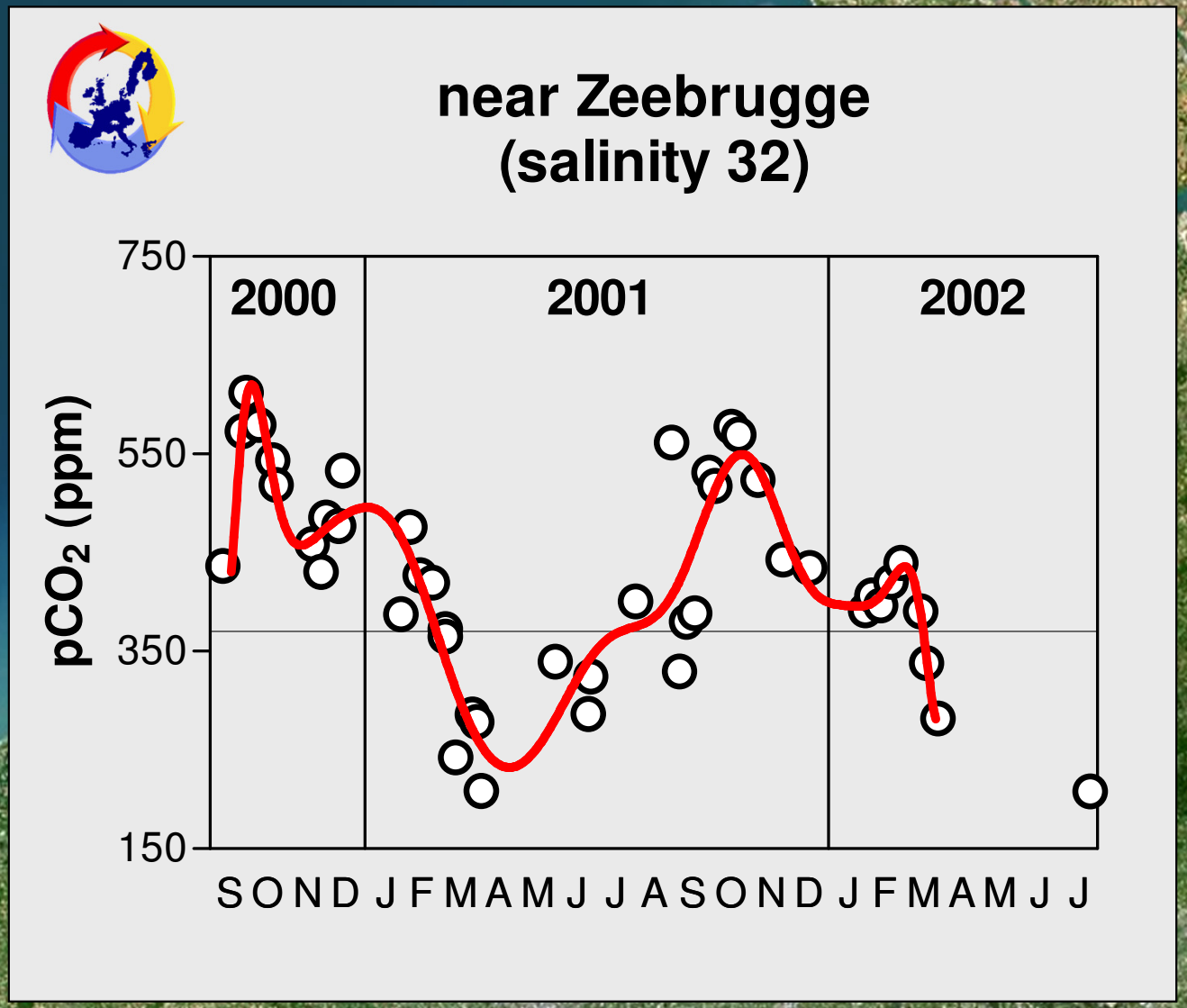
Ste Anna Station (Antwerp)



Belgica (North Sea)



Belgica (North Sea)




www.ulg.ac.be/oceanbio/co2