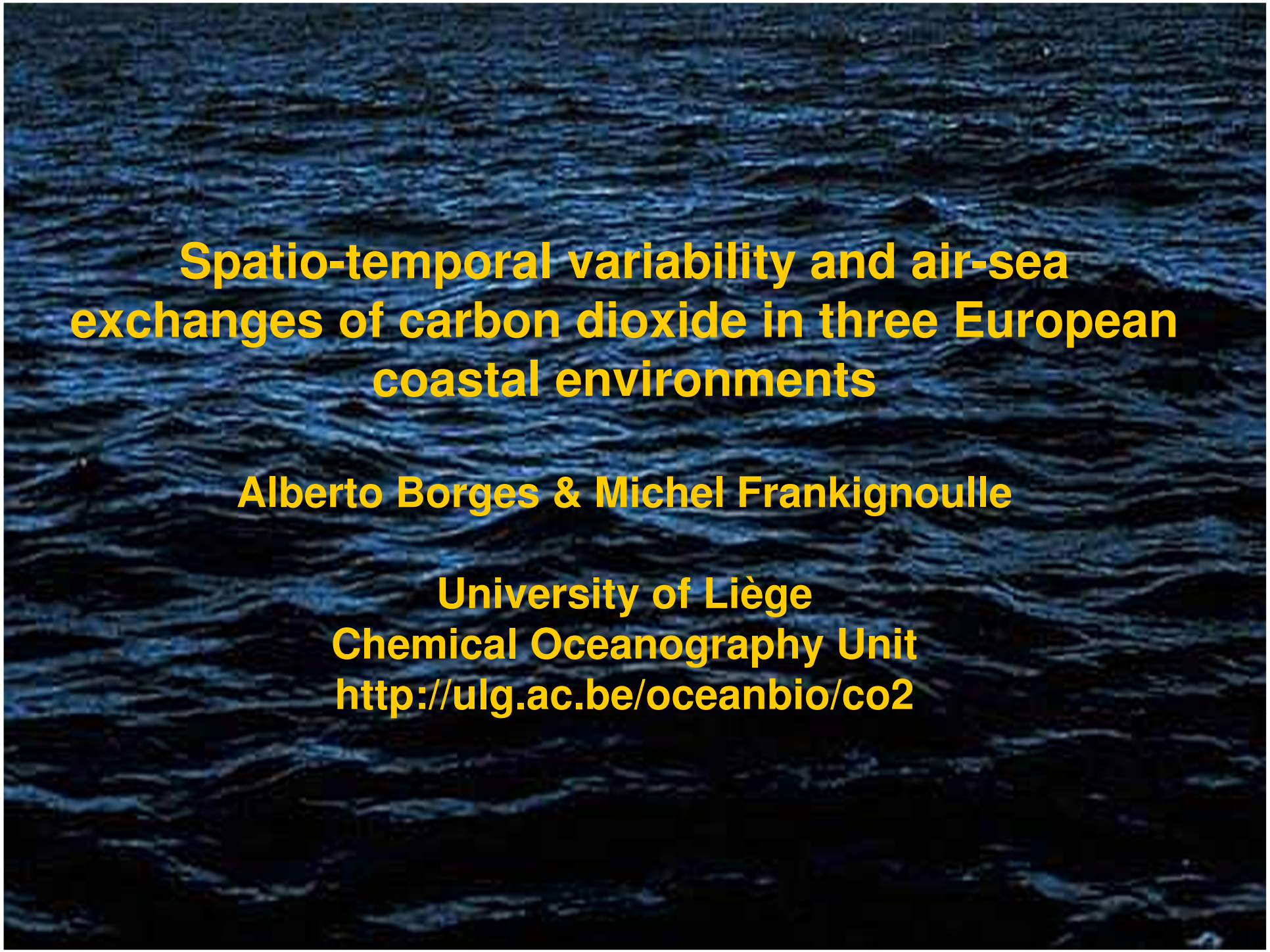
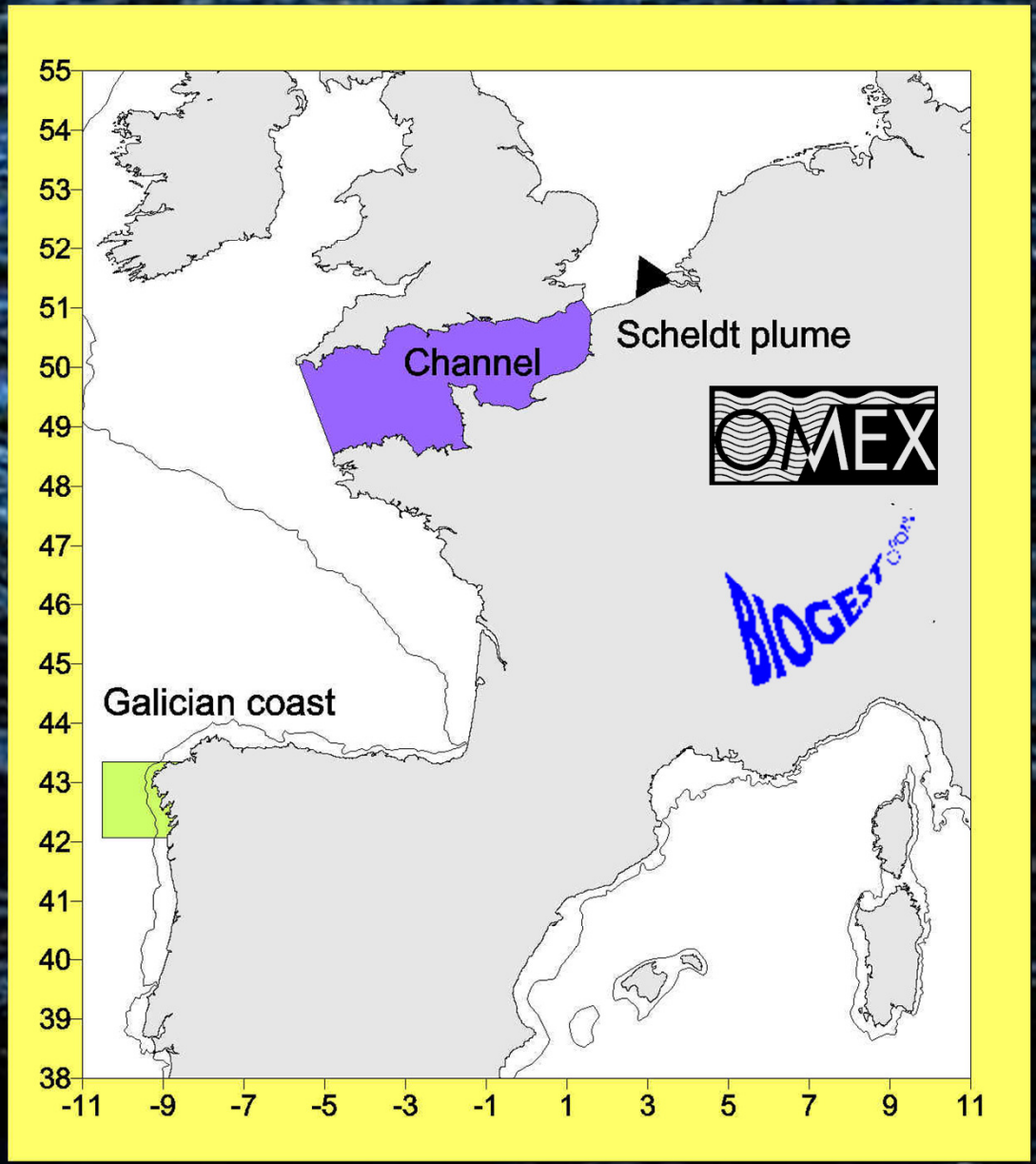
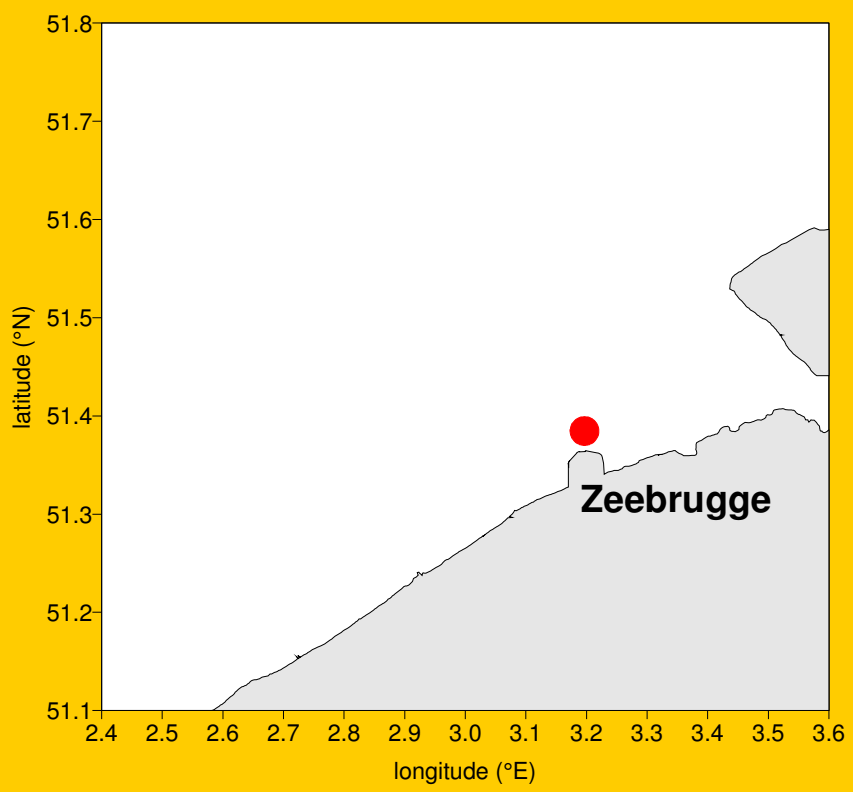
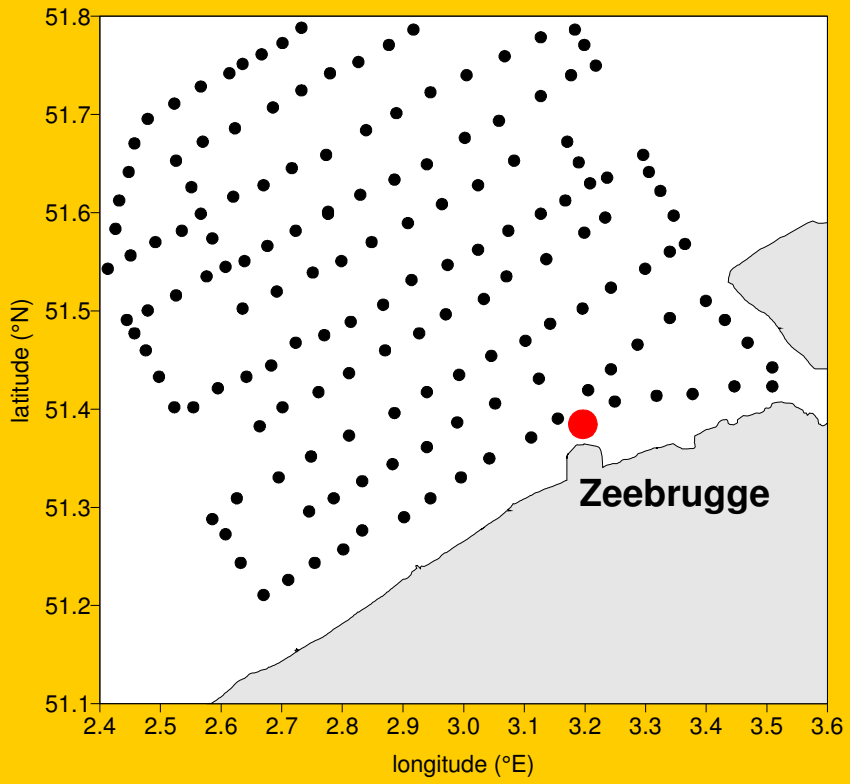
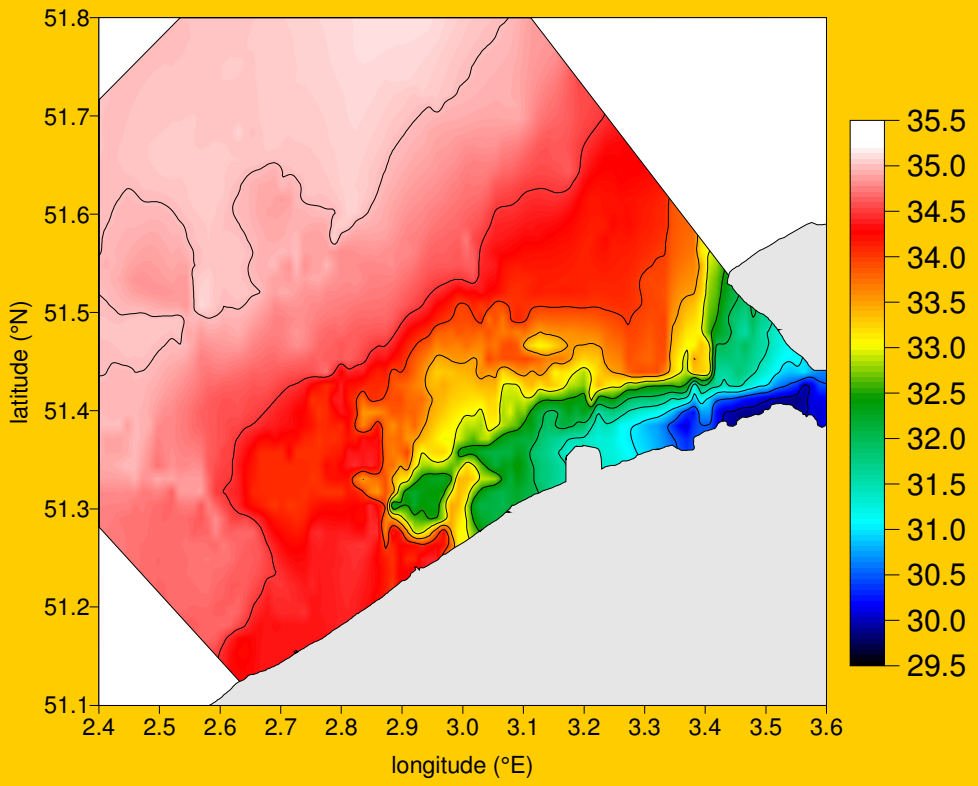

Spatio-temporal variability and air-sea exchanges of carbon dioxide in three European coastal environments
Alberto Borges & Michel Frankignoulle
University of Liège
Chemical Oceanography Unit
http://ulg.ac.be/oceanbio/co2


55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
-11
-9
-7
-5
-3
-1
1
3
5
7
9
11
Channel
Scheldt plume
OMEX
BIOGEST
Galician coast

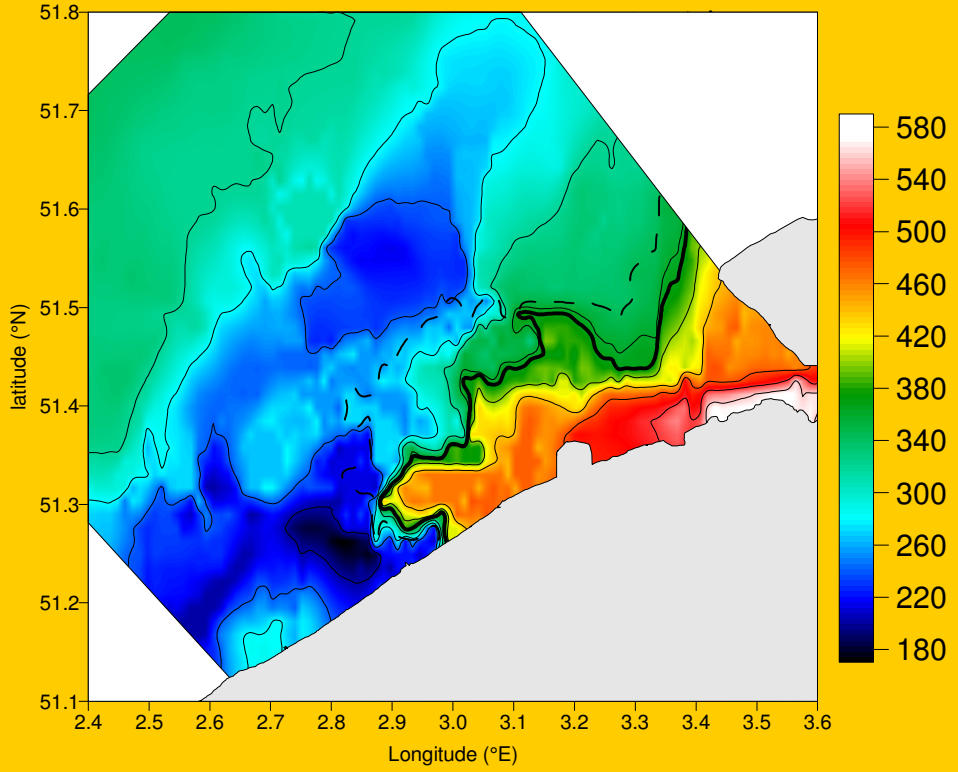

51.8
51.7
51.6
51.5
51.4
51.3
51.2
51.1
latitude (°N)
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
longitude (°E)
Zeebrugge

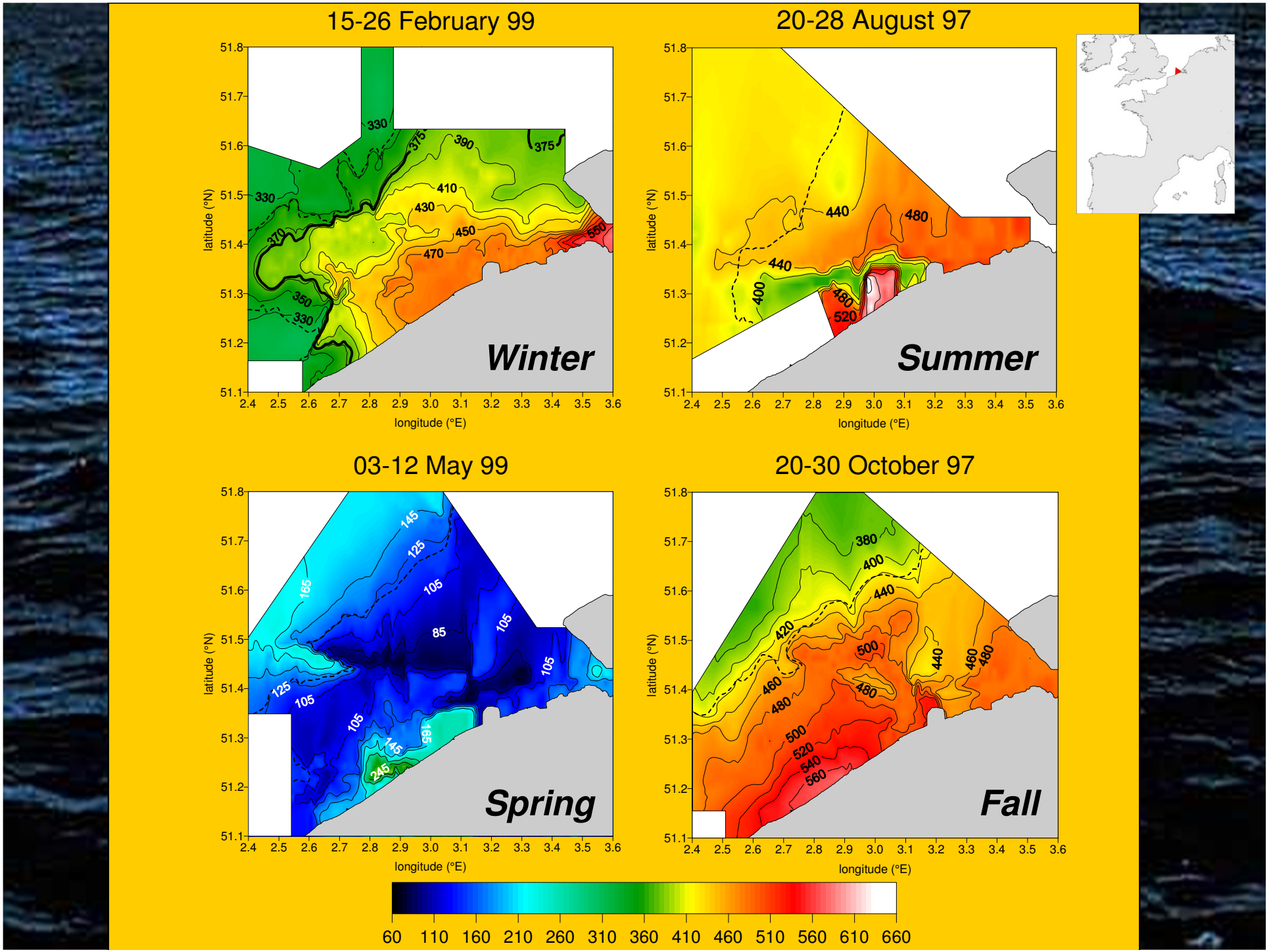

51.8
51.7
51.6
51.5
51.4
51.3
51.2
51.1
latitude (°N)
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
longitude (°E)
Zeebrugge

Salinity 10-21 march 97

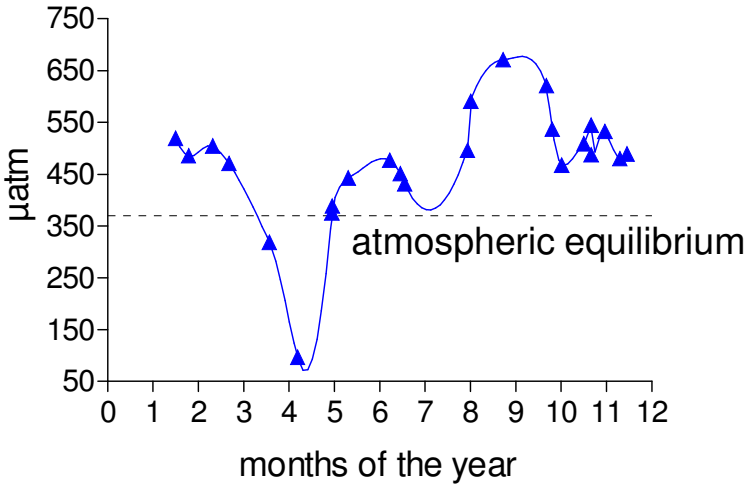


Partial pressure of CO_2 (pCO_2)
10-21 march 97

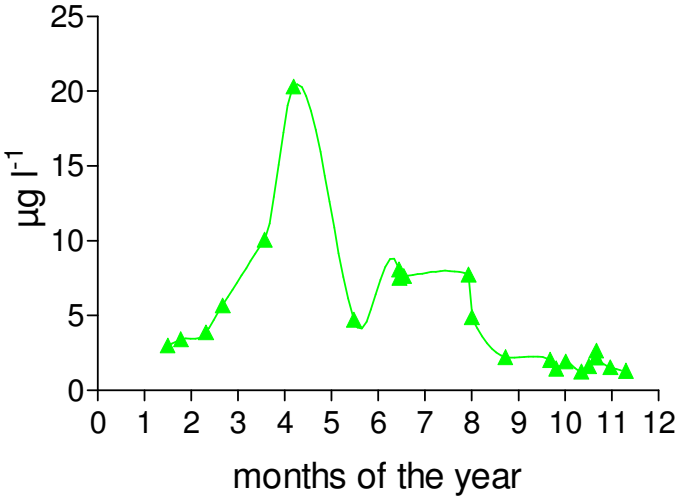



15-26 February 99
20-28 August 97
03-12 May 99
20-30 October 97
Winter
Summer
Spring
Fall
latitude (°N)
longitude (°E)
51.8
51.7
51.6
51.5
51.4
51.3
51.2
51.1
2.4 2.5 2.6 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5 3.6
330 375 390 375 410 430 450 470 550 330 370 350 330
440 480 440 400 480 520
145 125 105 165 105 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

pCO_2
Zeebrugge Station



chlorophyll a



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

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Surface of the Scheldt plume: 2100 km^2

Annual emission of CO_2: 112 tC day^{-1}

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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

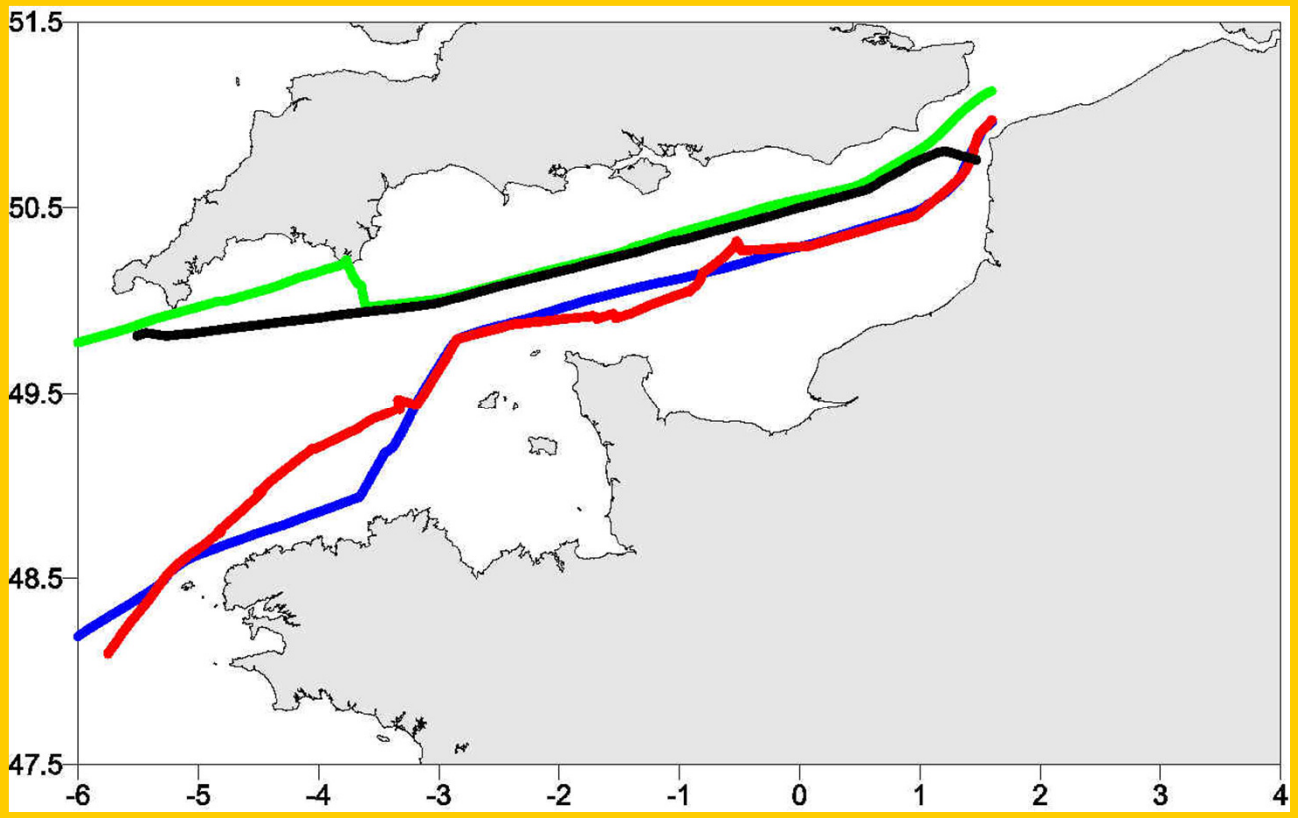
Organic carbon preservation in sediments	62[c]
CO_2 emission	112[a]

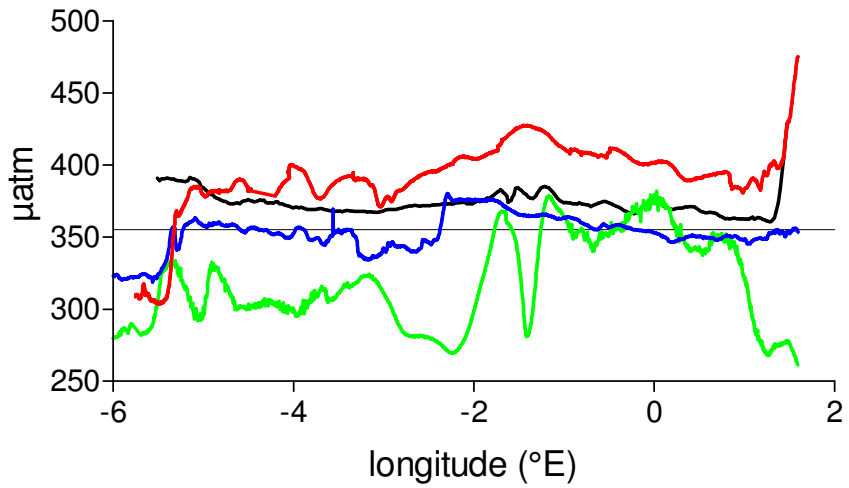
Sum

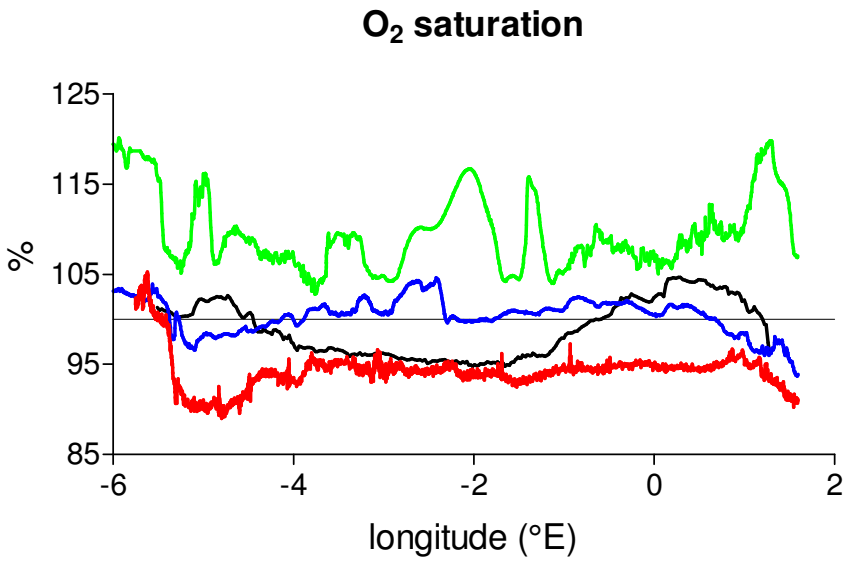
97 - 133	175

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

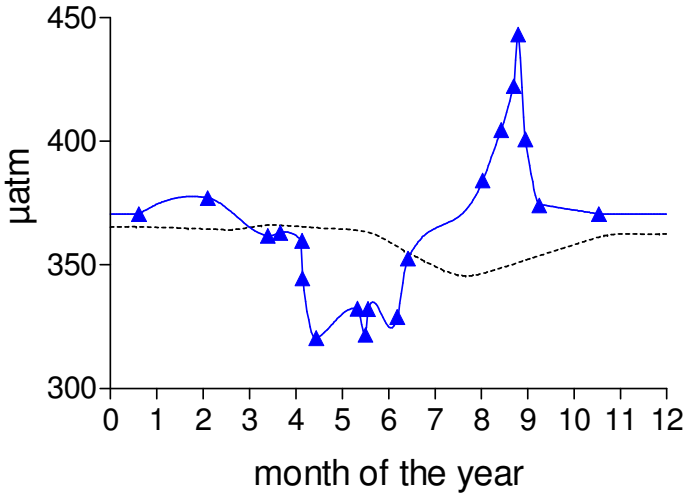
English Channel



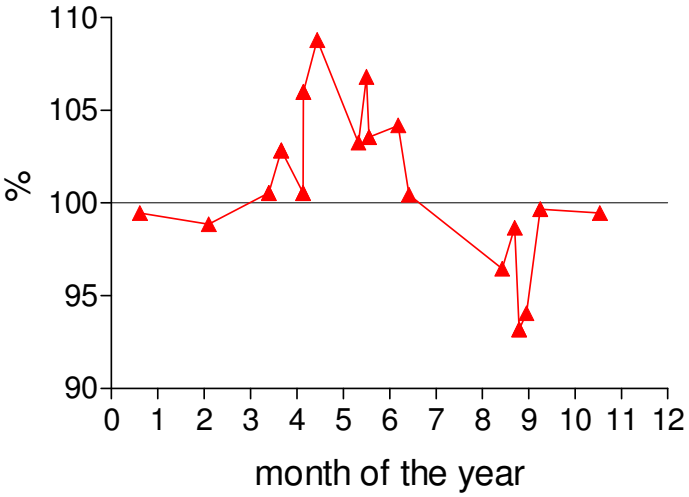

pCO2
English Channel
500
450
400
350
300
250
µatm
-6
-4
-2
0
2
longitude (°E)
Winter (March 95)
Summer (July 98)
Spring (May 97)
Fall (September 95)


O2 saturation
125
115
105
95
85
%
-6
-4
-2
0
2
longitude (°E)

pCO_2
English Channel (1993-1999)



O_2 saturation



Annually integrated $\Delta pCO_2 \approx 0$

Annually integrated ◑pCO_2 ≈ 0

Annually integrated CO_2 air-sea flux ≈ 0

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Annually integrated CO_2 air-sea flux ≈ 0

Why?

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New primary production = 1.0 mmolC m^{-2} day^{-1}
(^{15}N incubations from L'Helguen et al. (1996))

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9 mmolC m^{-2} day^{-1}	**Continental shelf average**
5 mmolC m^{-2} day^{-1}	**Southern Bight of the North Sea**
7 mmolC m^{-2} day^{-1}	**Gulf of Biscay**

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Benthic calcification in Eastern Channel = 19 mmol$CaCO_3$ m^{-2} day^{-1}

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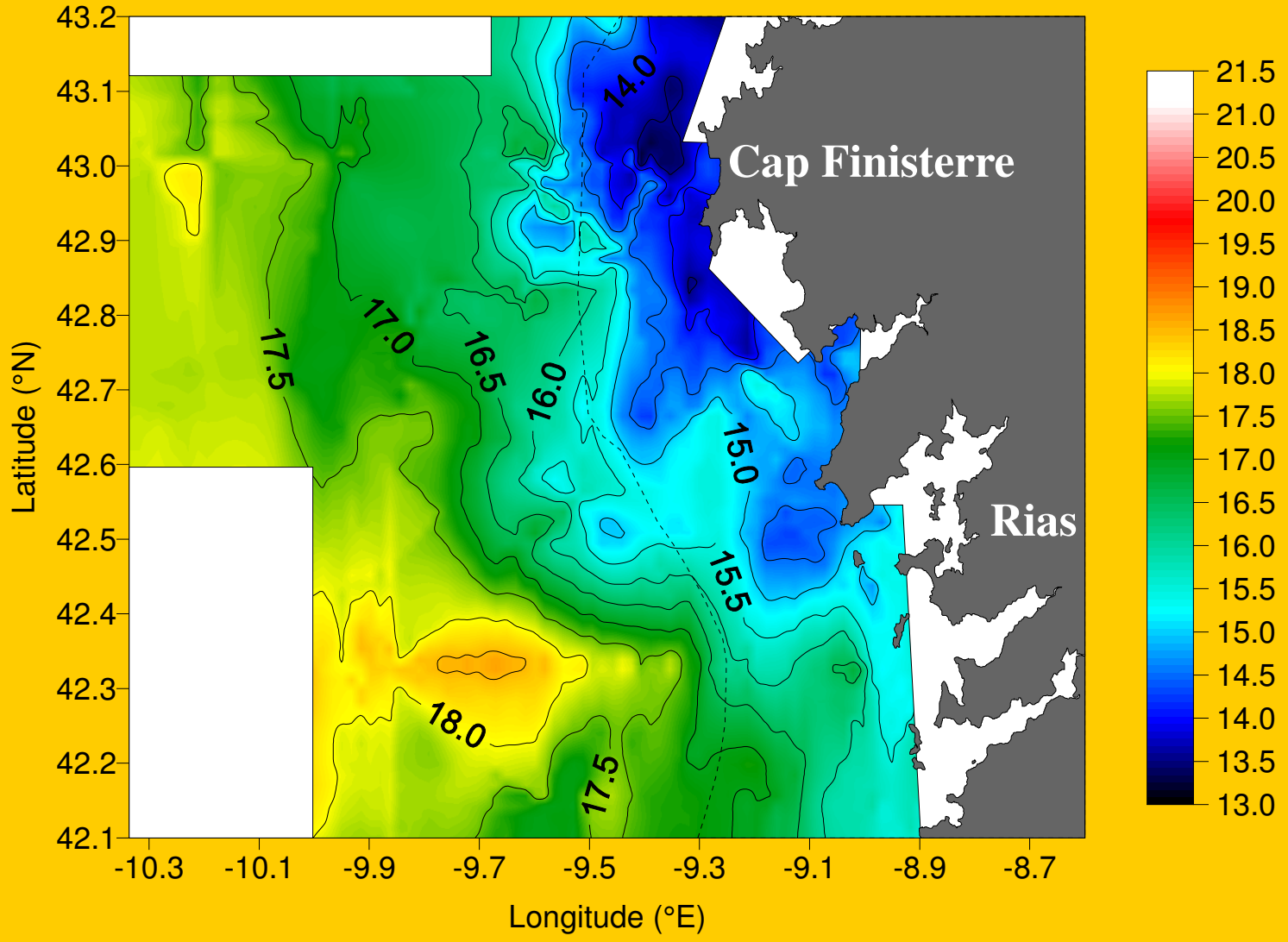
Release of CO_2 = +13 mmolC m^{-2} day^{-1}

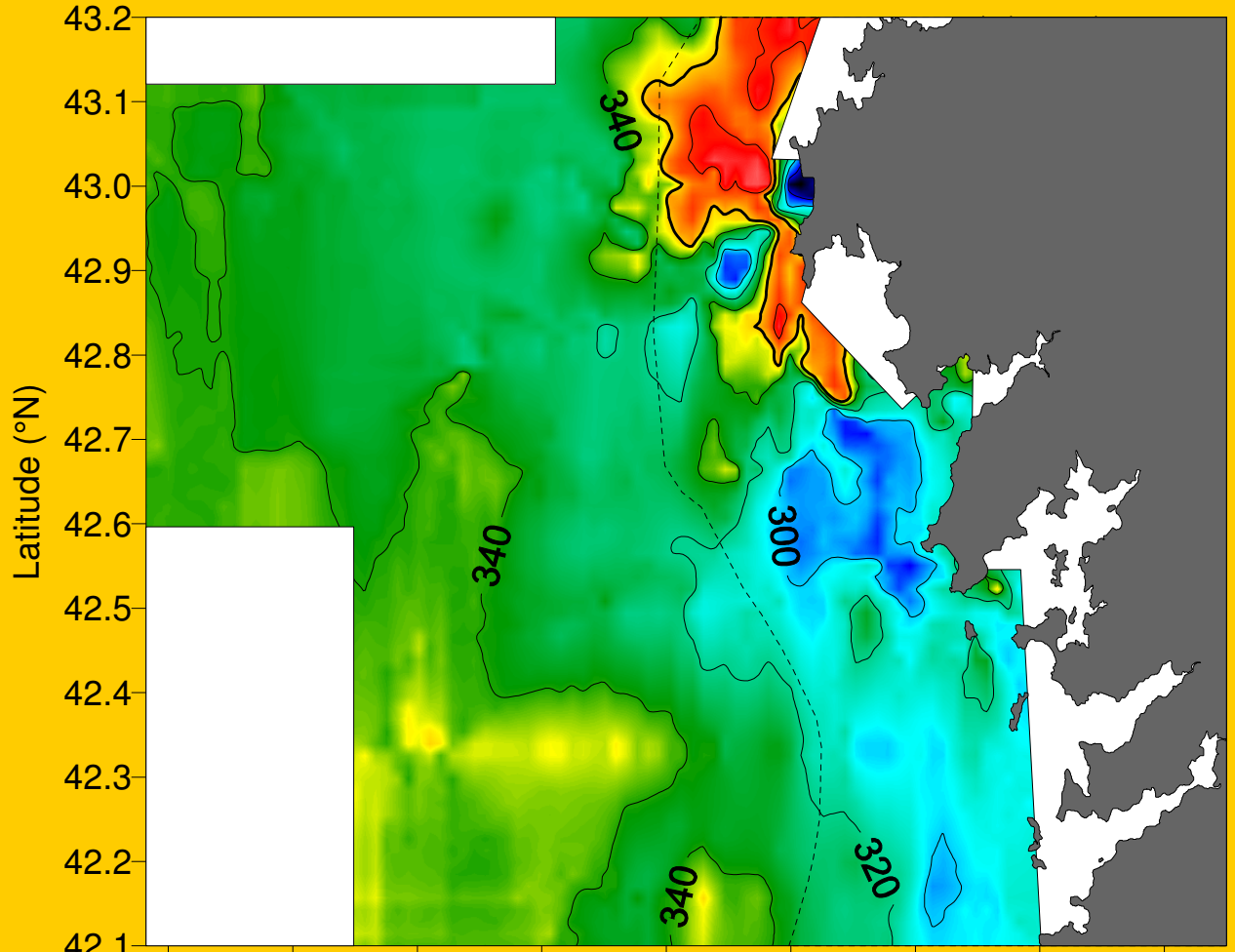
Area 5400 km^2

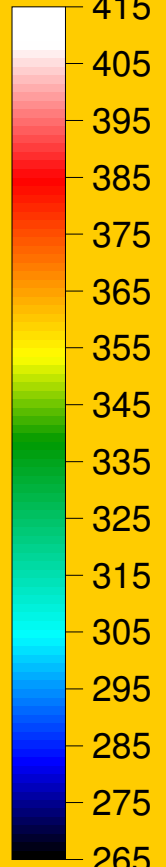
Whole of Channel
Release of CO_2 = +0.9 mmolC m^{-2} day^{-1}

Galician coast
temperature (°C) 27 June - 7 July 98

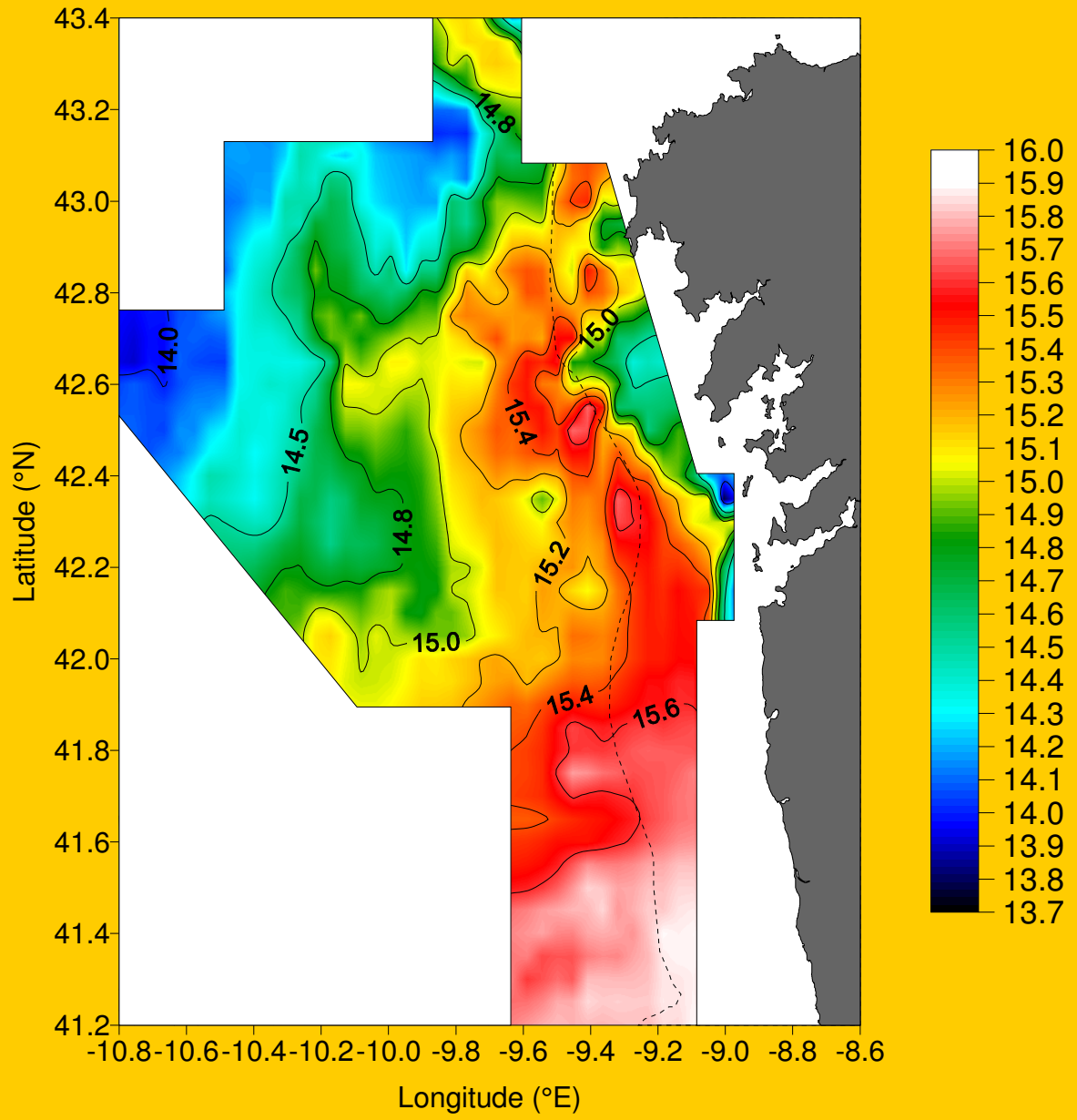


pCO_2 (µatm) 27 June - 7 July 98

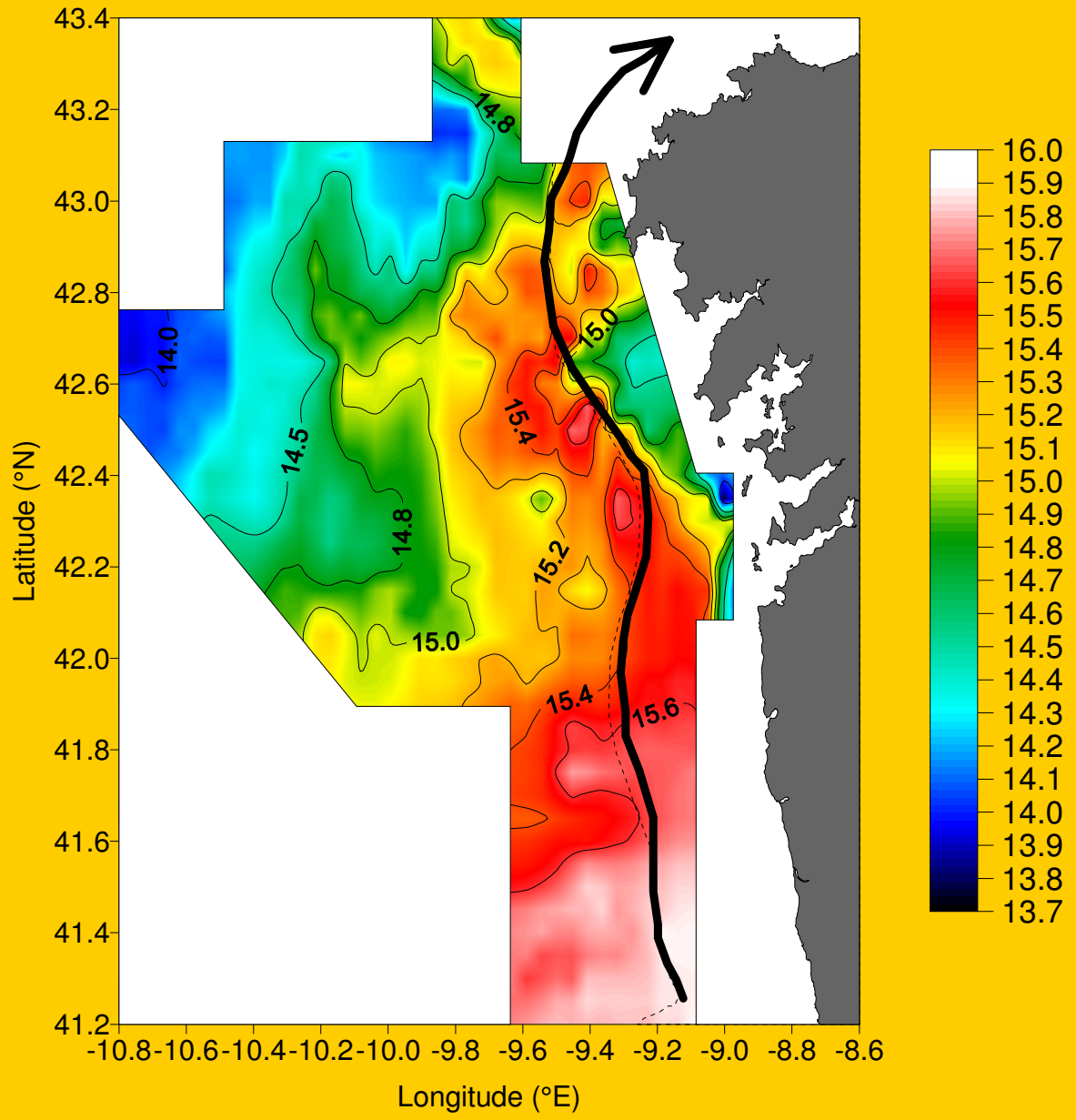




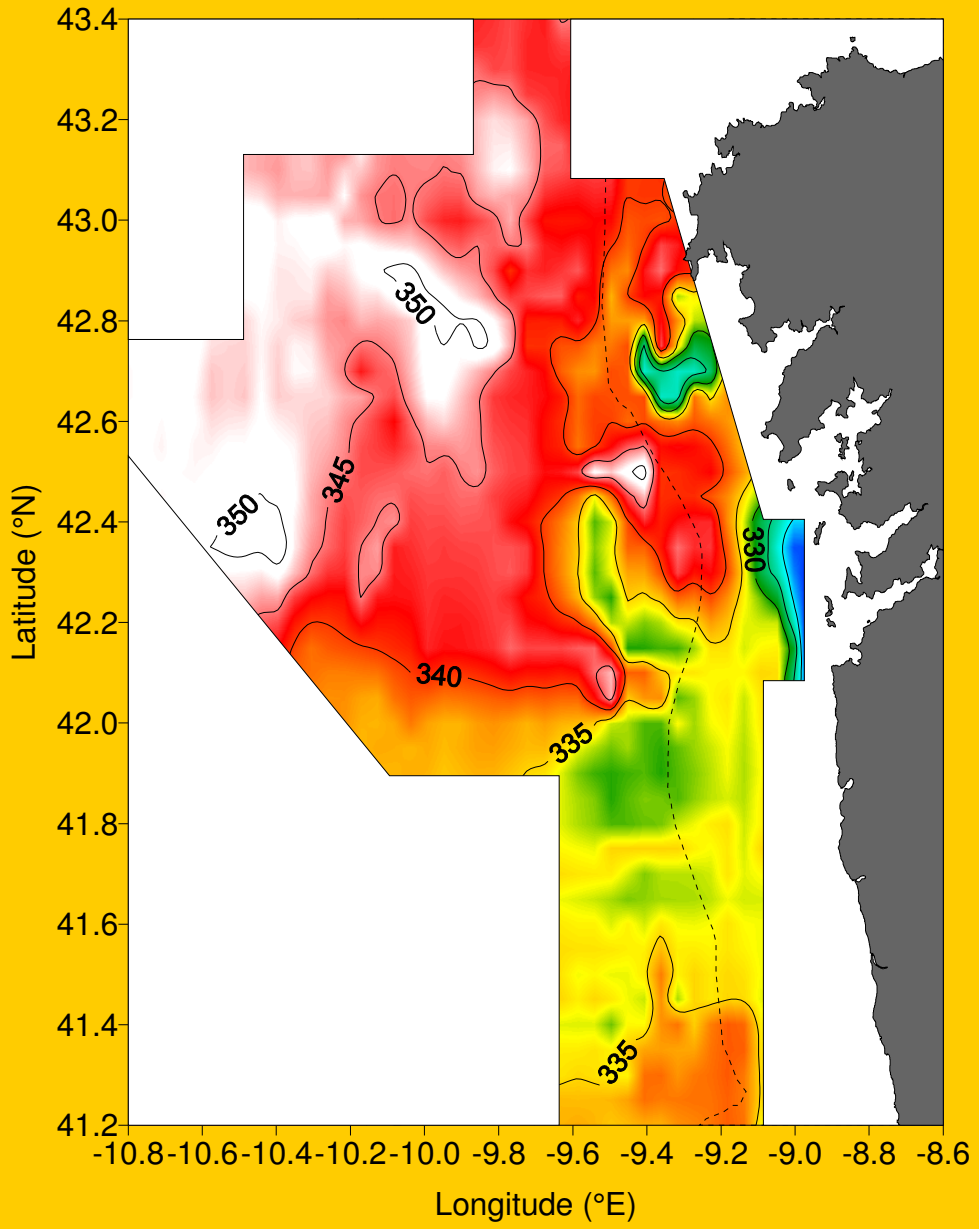
temperature (°C) 6 - 16 January 98



temperature (°C) 6 - 16 January 98



pCO_2 (µatm) 6 - 16 January 98



Annual integration of the air-sea CO_2 fluxes:

June/July 97
june/july 98 upwelling season
August 98
September 99

Annual integration of the air-sea CO_2 fluxes:

June/July 97	
june/july 98	upwelling season
August 98	
September 99	
January 98	downwelling season

Annual integration of the air-sea CO_2 fluxes:

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june/july 98 upwelling season
August 98
September 99
January 98 downwelling season

Upwelling season = March to October = 6 months

Continental shelf:

- 6.1 mmol m^{-2} day^{-1} (exchange coeff. Wanninkhof 1992)

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june/july 98 upwelling season
August 98
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January 98 downwelling season

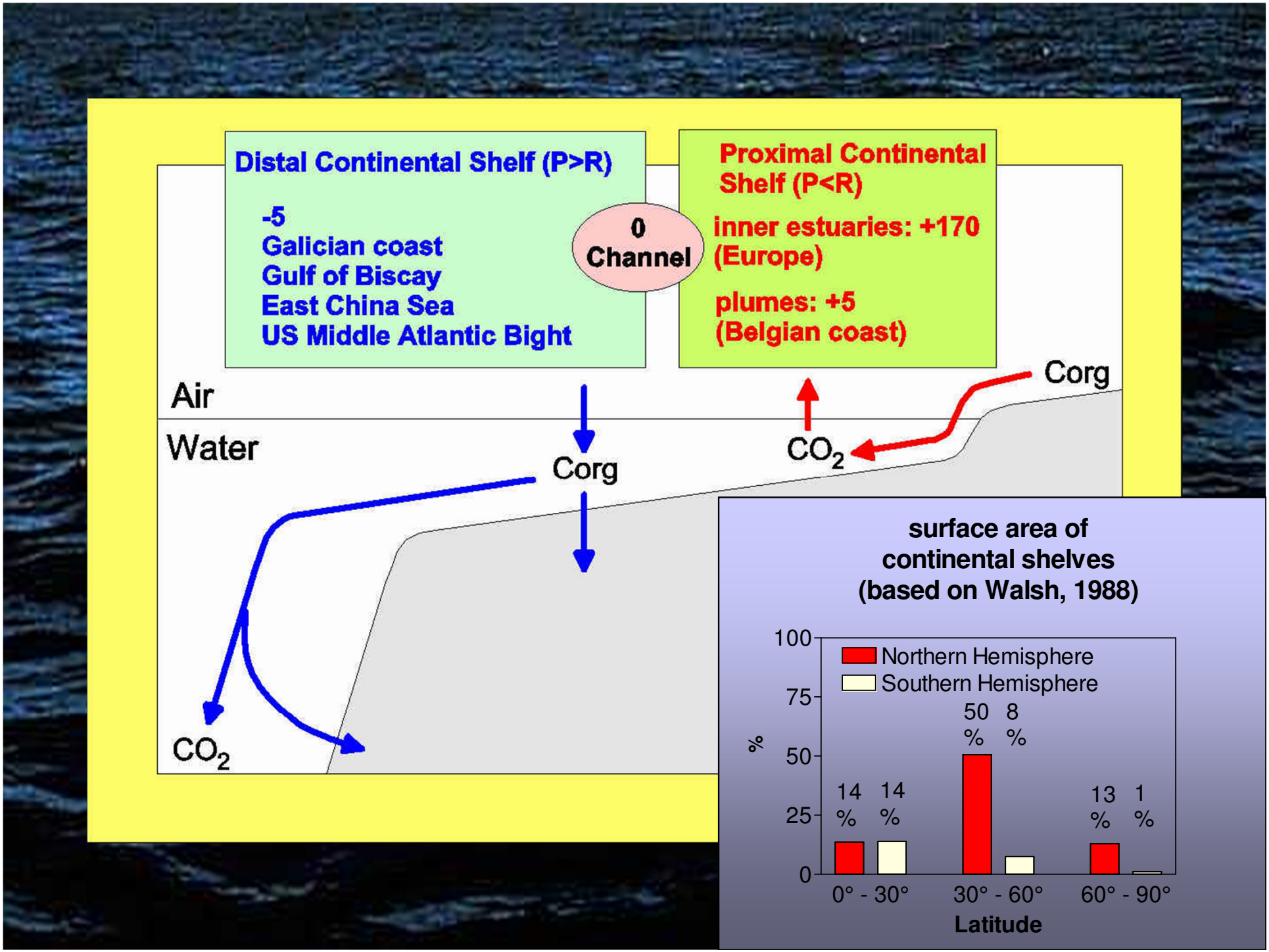
Upwelling season = March to October = 6 months

Continental shelf:

- 6.1 mmol m^{-2} day^{-1} (exchange coeff. Wanninkhof 1992)

Off-shore region:

- 4.4 mmol m^{-2} day^{-1}


Distal Continental Shelf (P>R)
-5
Galician coast
Gulf of Biscay
East China Sea
US Middle Atlantic Bight
0
Channel
Proximal Continental Shelf (P<R)
inner estuaries: +170
(Europe)
plumes: +5
(Belgian coast)
Air
Water
Corg
Corg
CO_2
CO_2
surface area of
continental shelves
(based on Walsh, 1988)
100
75
50
25
0
%
Northern Hemisphere
Southern Hemisphere
14 %
14 %
50 %
8 %
13 %
1 %
0° - 30°
30° - 60°
60° - 90°
Latitude