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Modeling present-day spatial and seasonal variability of carbon dioxide in surface waters of the Southern Bight of the North Sea

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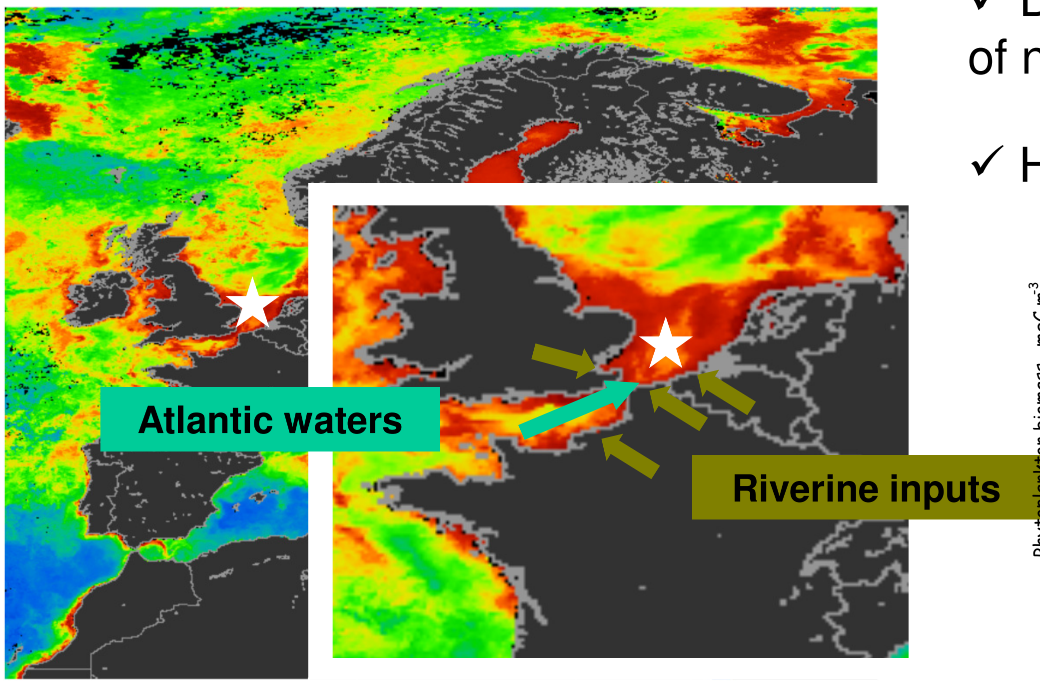
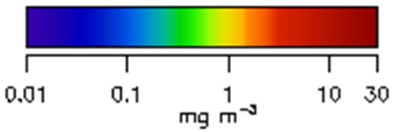
esa ECOLOGIE DES SYSTEMES AQUATIQUES

Studied area

Southern Bight of the North Sea



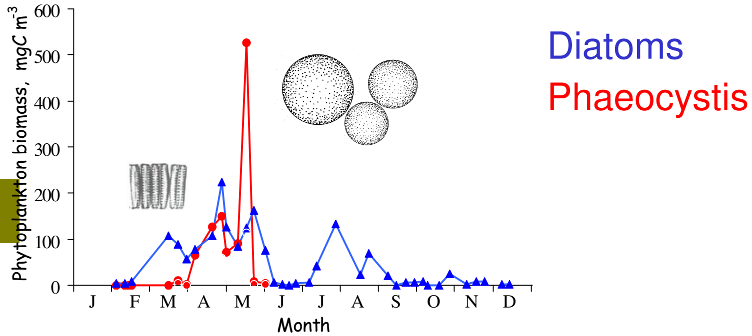
Chl *a* in 2005 May



Source:
ECOMAR
GEM-IES

✓ Direct and transboundary loads of nutrients

✓ High primary production



✓ High interannual variability of phytoplankton blooms related to:

-Atlantic vs riverine waters contribution

-nutrient river loads

Objective

- What is the spatial and seasonal distribution of surface pCO_2?

- What the annual role as CO_2 sink or source?

- How do this vary between years?

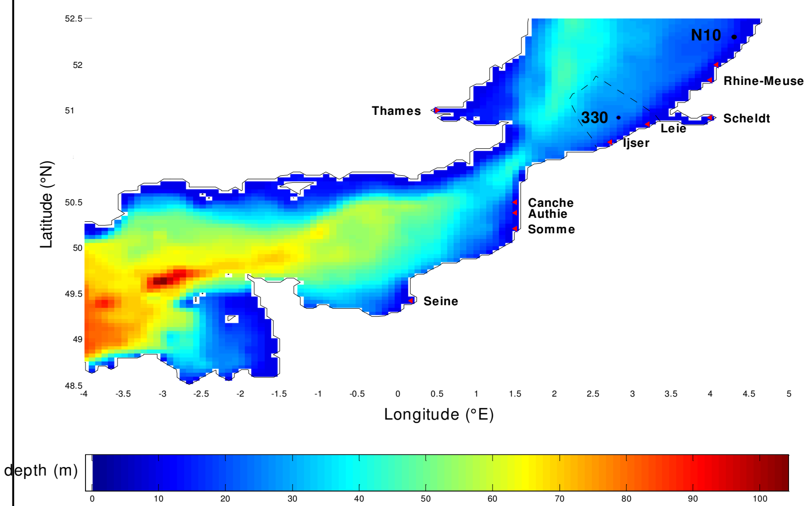
- What the role of carbon and nutrient river loads? Does it change the sign of the annual CO_2 source/sink?

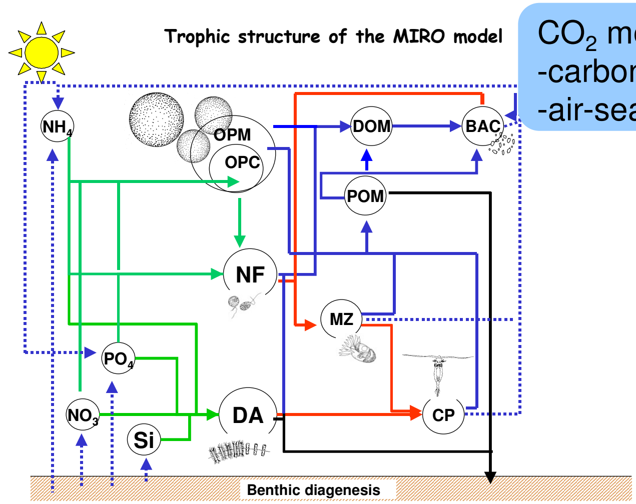
Mathematical tool

Hydrodynamic model
COHERENS-3D (MUMM)

coupling

Ecosystem model
MIRO-CO_2





CO_2 module:
-carbonate system
-air-sea CO_2 fluxes

(Lacroix et al. 2004. JSR)

(Gypens et al. 2004 Biogeosciences)

Surface Forcing:
- 6h meteo RF (UKMO)
-Weekly SST (BSH)
-Monthly atm. CO_2

Rivers:
Actual daily flow &
(bi-)monthly carbon and nutrient loads

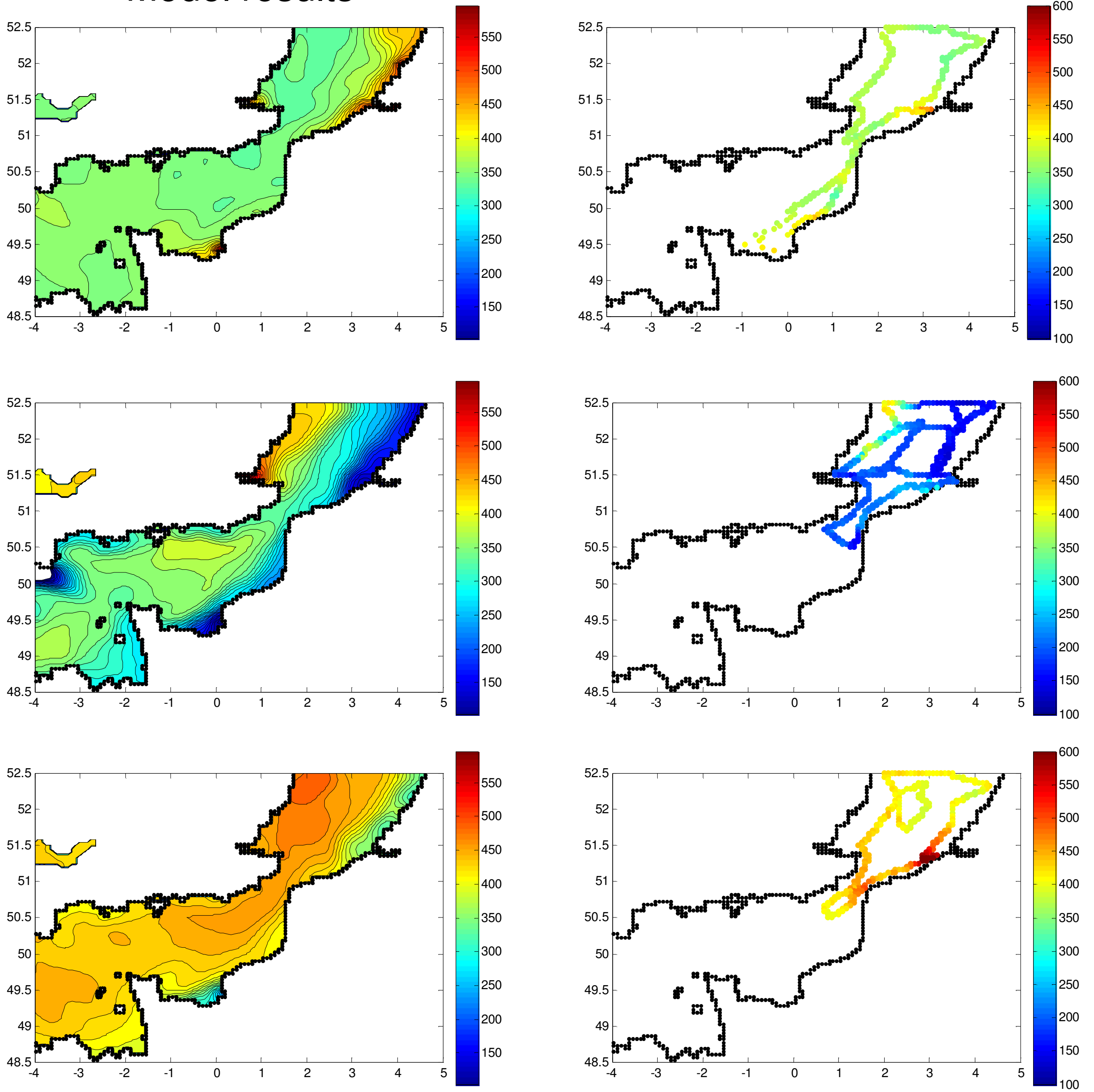
Grid:
- 5.8 km long. x 4.6 km lat.
- 5 σ layers

Period:
-1991-2004 (3y spin up)

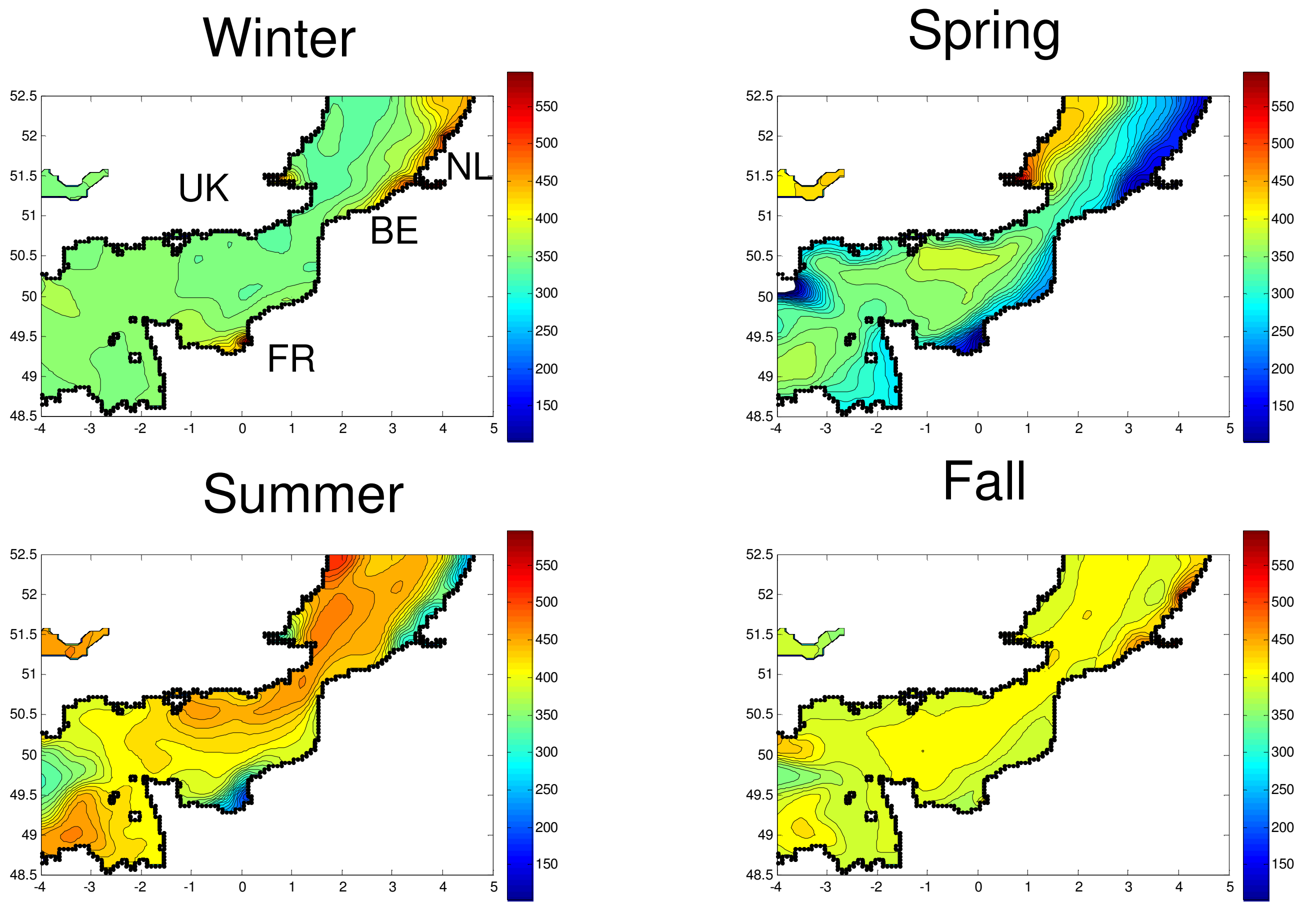
Model validation

2003-2004

	Model results	Field data
February		
May		
August		



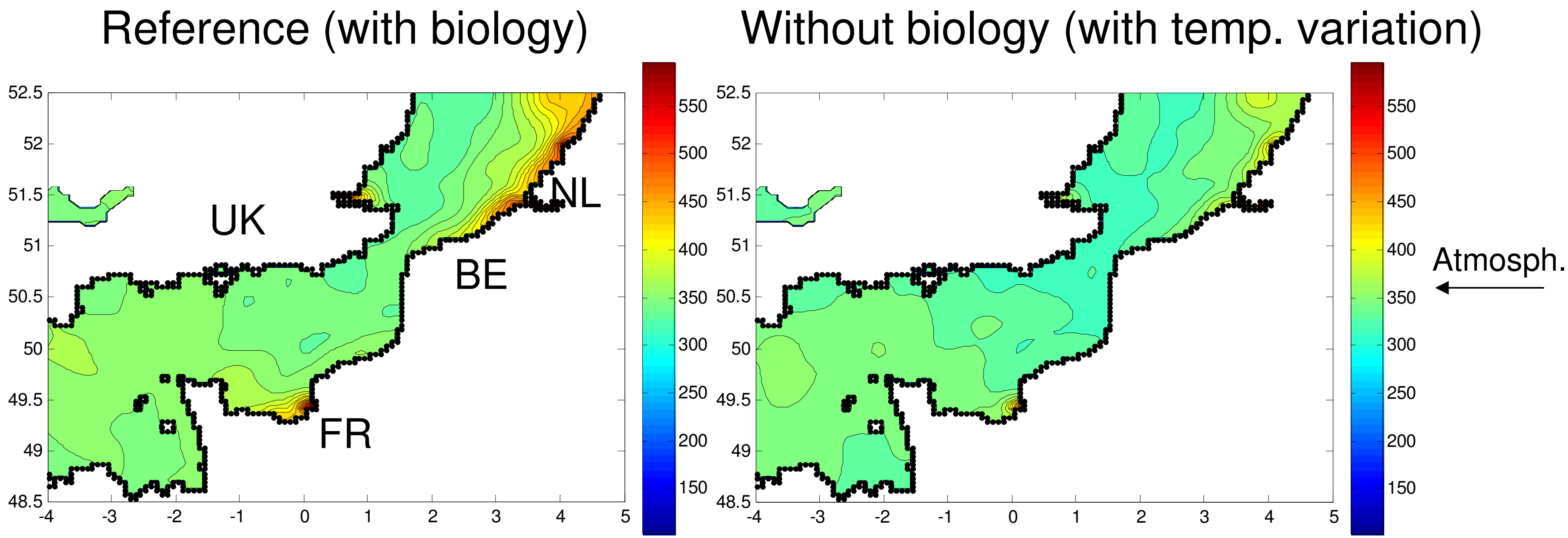
Seasonal variability



Important spatial and seasonal variability of surface pCO_2:
from 100 ppm to 600 ppm

Seasonal variability

Surface pCO_2 (Winter)

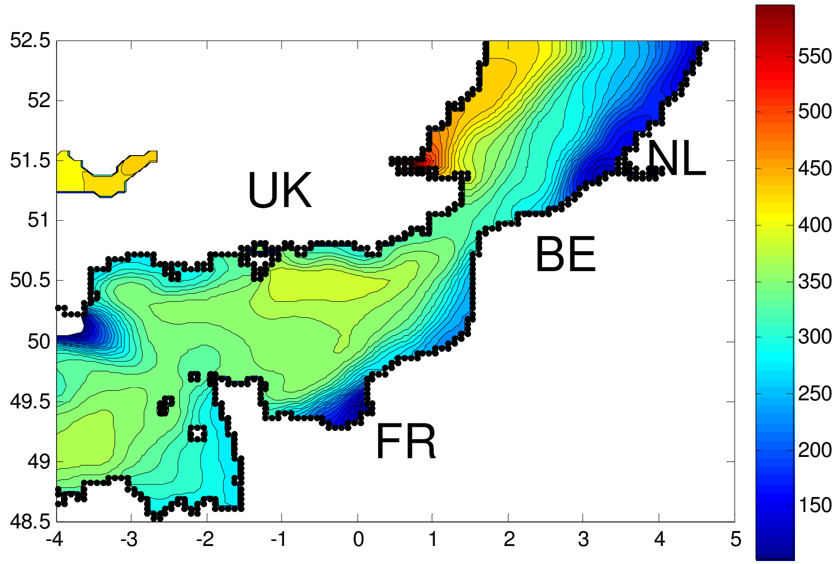


•Surface waters are close to atmospheric pCO_2 except in the vicinity of river mouths characterized by high oversaturation.
•Low primary production, dominance of organic matter degradation in the nearshor water
•Control by temperature in offshore waters

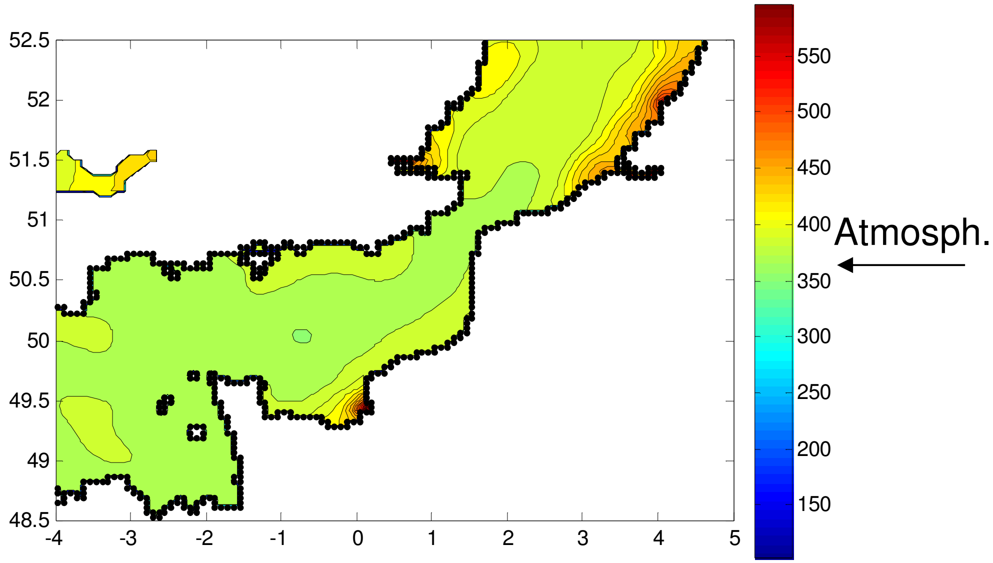
Seasonal variability

Surface pCO_2 (Spring)

Reference (with biology)



Without biology (with temp. variation)

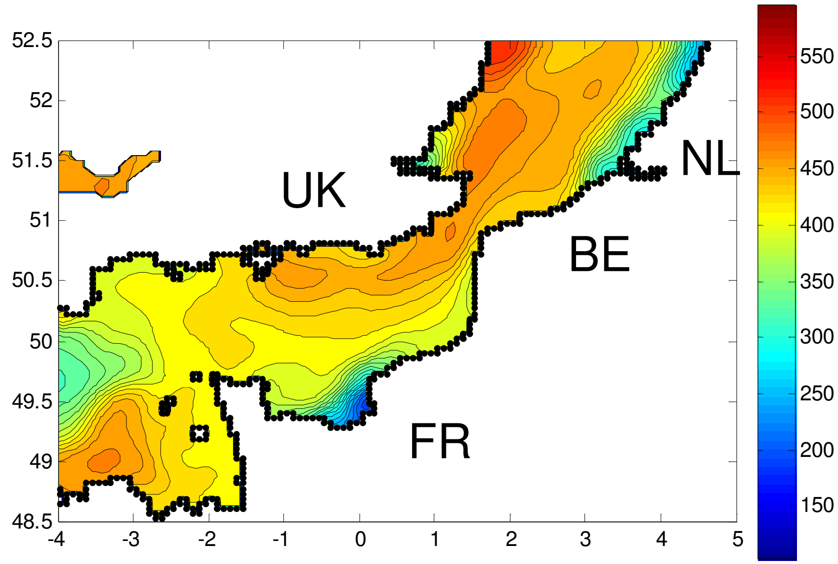


- Increase of primary production
- undersaturation except in the Thames plume
- Biological control>>>Temperature
- Dominance of primary production to organic matter degradation

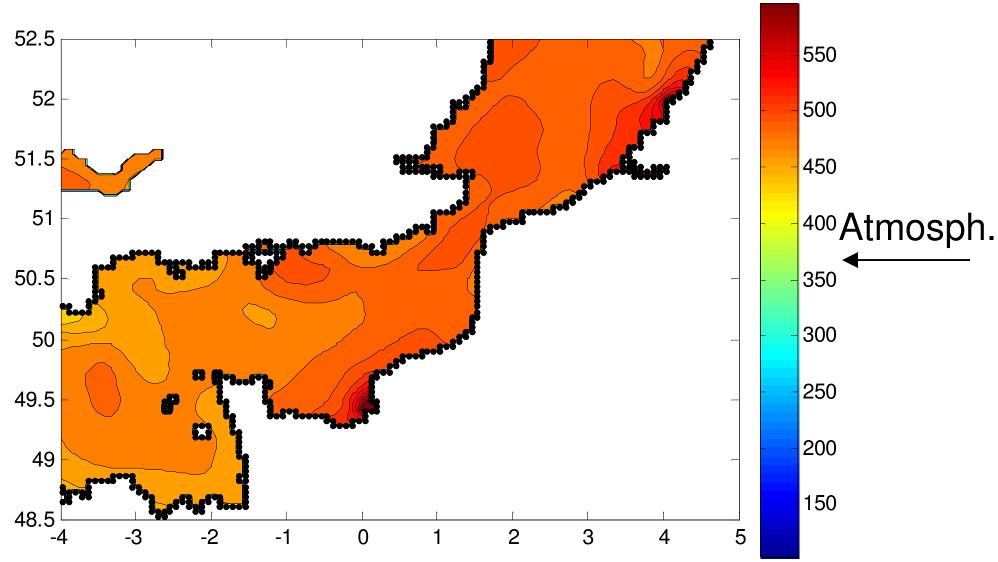
Seasonal variability

Surface pCO_2 (Summer)

Reference (with biology)



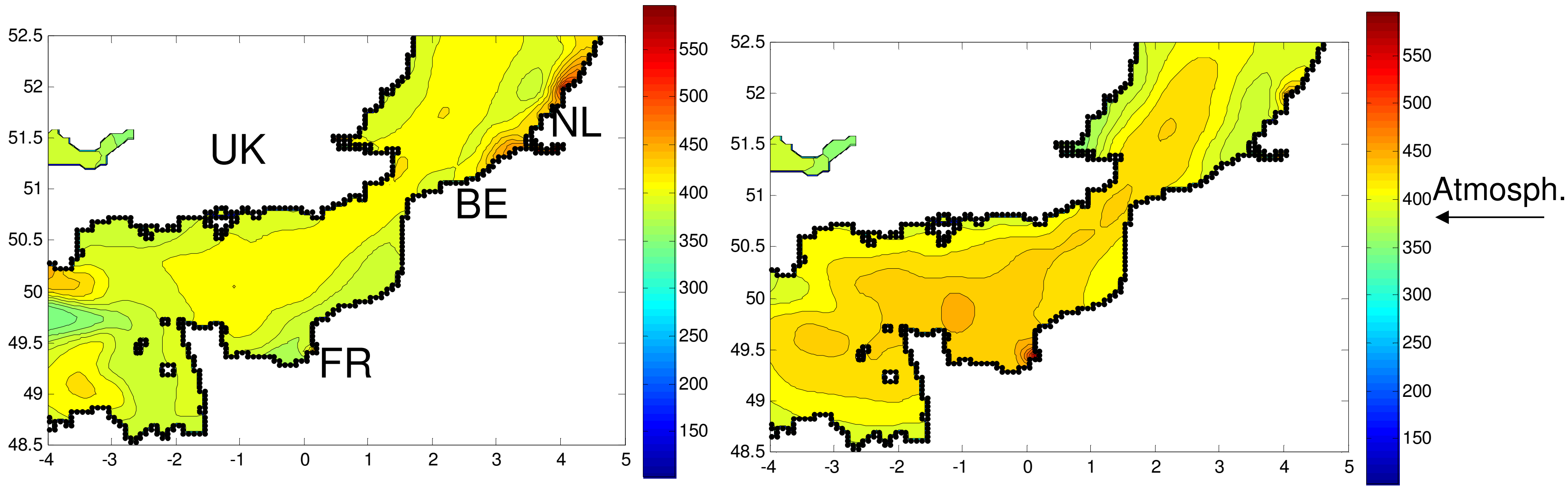
Without biology (with temp. variation)



- Decrease of primary production and increase of heterotrophic activities
- Surface waters oversaturated in most of the domain
- Close to or below atmospheric CO_2 near shore where autotrophic activities stay significant
- Biology>>Temperature

Surface pCO_2 (Autumn)

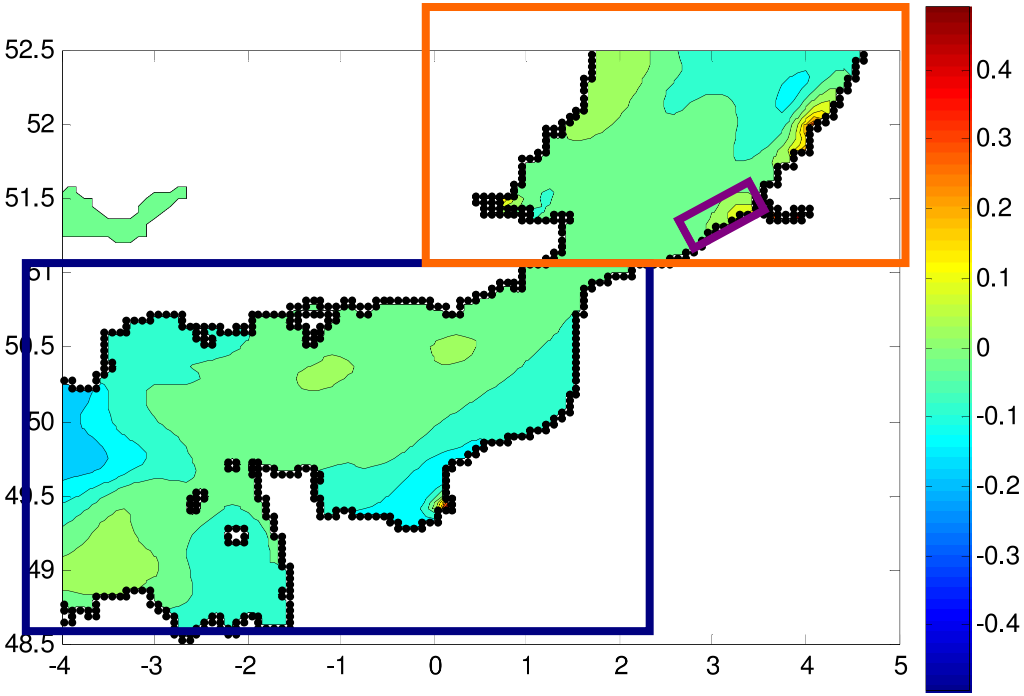
Reference (with biology) | Without biology (with temp. variation)



- Decrease of heterotrophy
- Oversaturation in the whole domain with highest values near the river mouths (especially Rhine and Scheldt river)
- Temperature control excepted in nearshore coastal waters

Annual air-sea CO_2 flux

2004 annual air-sea CO_2 fluxes



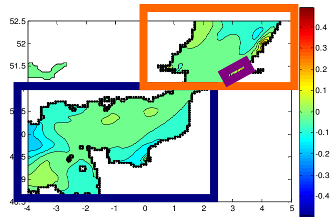
Spatial variability:
- sources near estuaries
- zero or moderate sink nearshore and offshore

Spatially integrated flux (mol m^{-2} y^{-1})

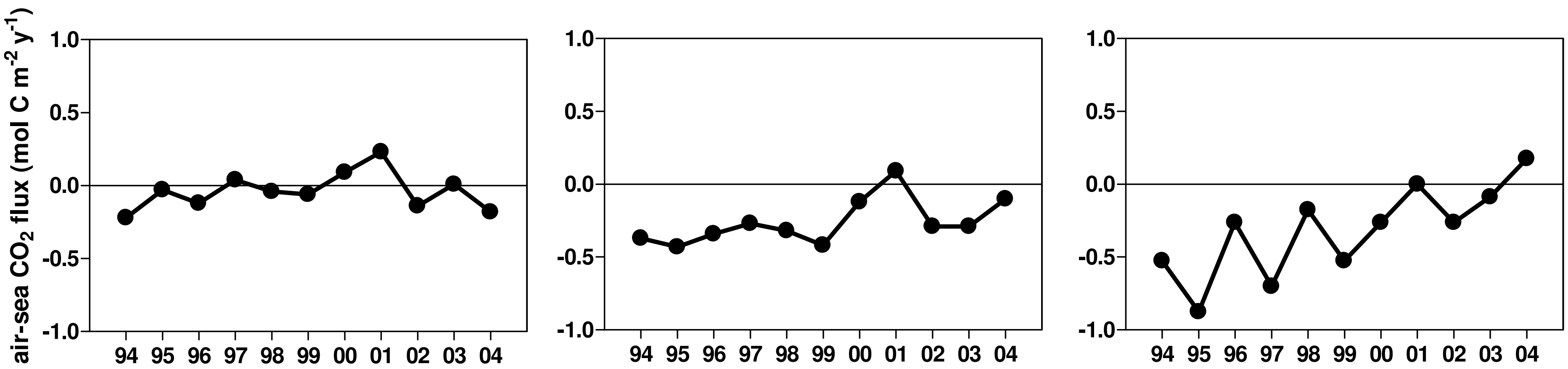
Western Channel	Southern Bight	Belgian waters
-0.2	-0.1	0.2

Interannual variability

Air-sea CO_2 flux (mol m^{-2} y^{-1})



Western Channel | **Southern Bight** | **Belgian waters**



Important interannual variability of annual air-sea CO_2 fluxes

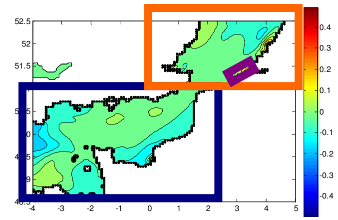
- From –0.2 to 0.2 molC m^{-2} y^{-1}
- No trends

- From –0.4 to 0.1 molC m^{-2} y^{-1}
- Sink tends to decreases

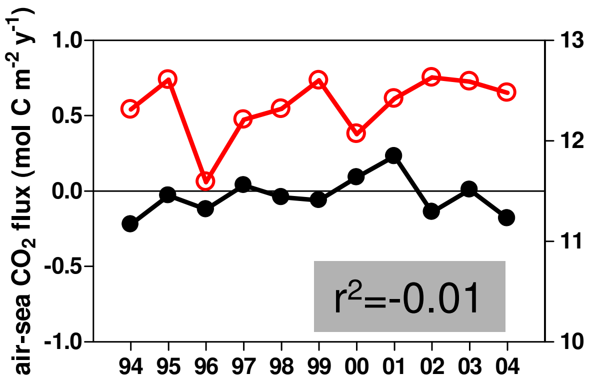
- From –0.9 to 0.2 molC m^{-2} y^{-1}
- Shift from sink to source

Interannual variability

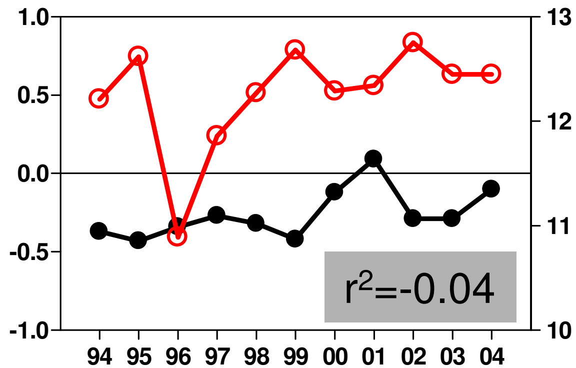
Air-sea CO_2 flux (mol m^{-2} y^{-1}) *vs* Temperature



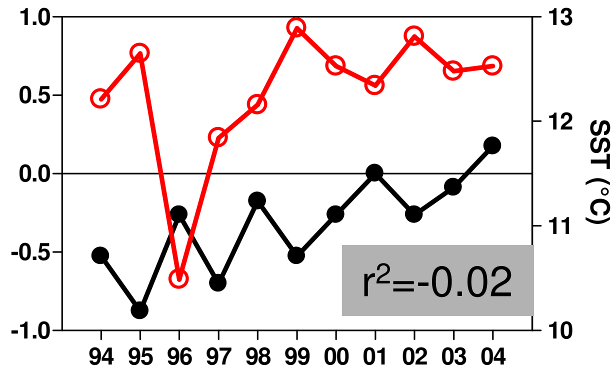
Western Channel



Southern Bight



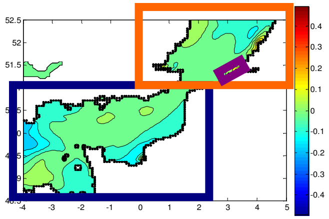
Belgian waters



No relationship between annual air-sea CO_2 fluxes variability and annual SST

Interannual variability

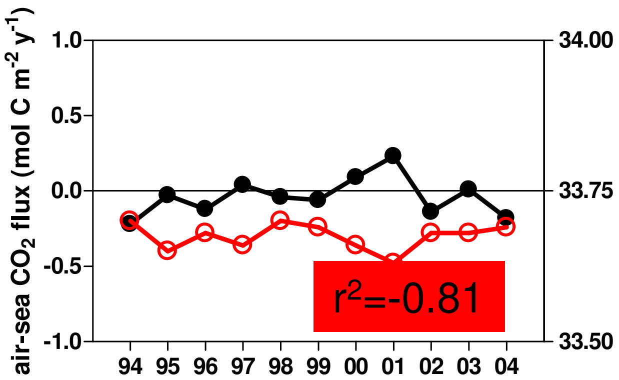
Air-sea CO_2 flux (mol m^{-2} y^{-1}) *vs* Salinity

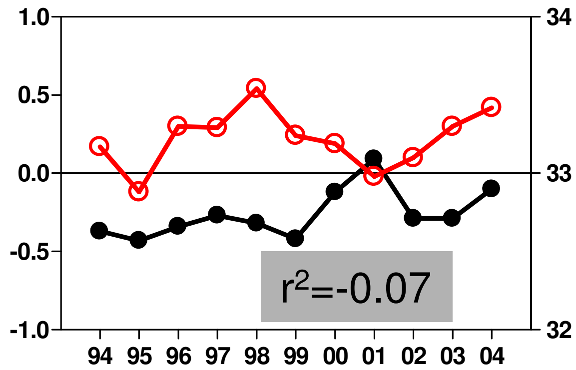


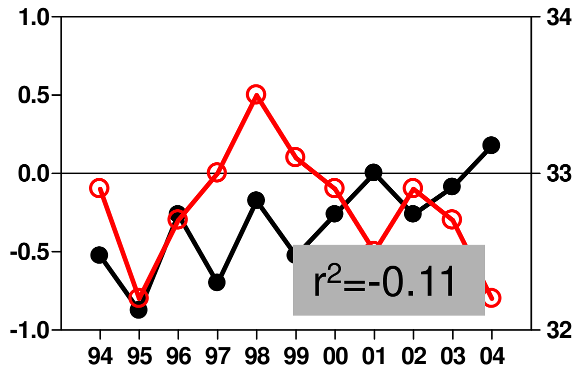
Western Channel

Southern Bight

Belgian waters



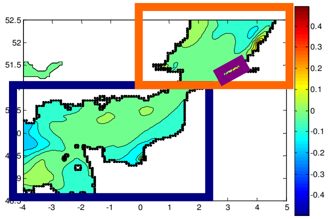




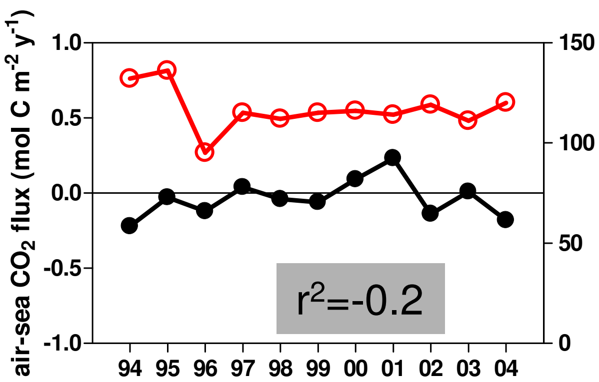
Increase of Atlantic water contribution increases the CO_2 sink in the Western Channel

Interannual variability

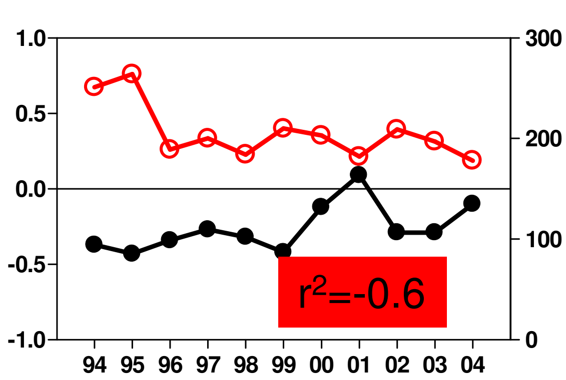
Air-sea CO_2 flux (mol m^{-2} y^{-1}) *vs* primary production



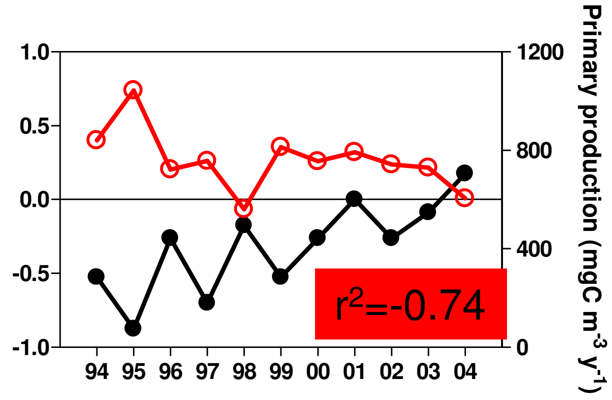
Western Channel



Southern Bight



Belgian waters

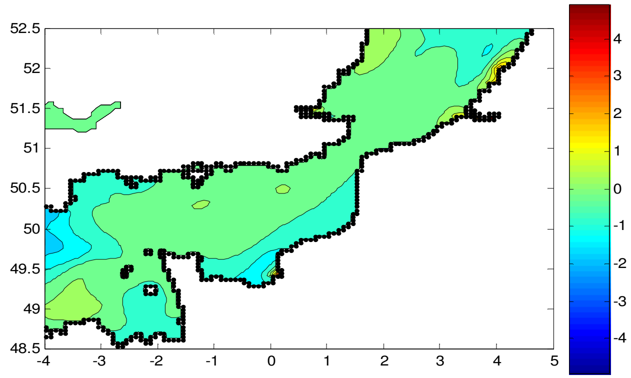


Increased primary production increases (decreases) the annual sink (source) for CO_2 in the Southern Bight and in the Belgian waters. The effect in more pronounced in the Belgian waters du to nutrient river loads.

Impact of C and nutrient river loads

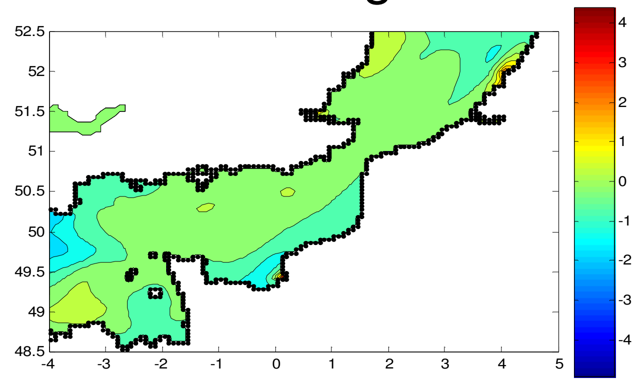
2004 annual air-sea CO_2 fluxes

Reference



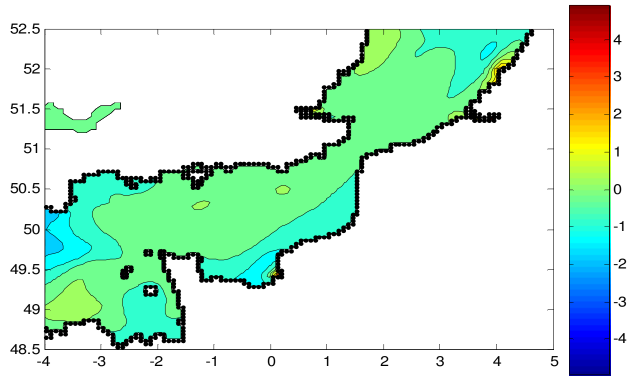
WCH	SBNS	BCZ
-0.18	-0.1	0.2

River inorg C…



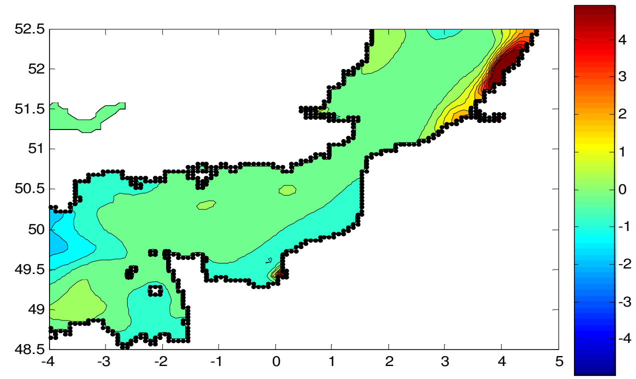
WCH	SBNS	BCZ
-0.18	-0.13	-0.06

No river org C



WCH	SBNS	BCZ
-0.18	-0.13	0.02

No river nutrient

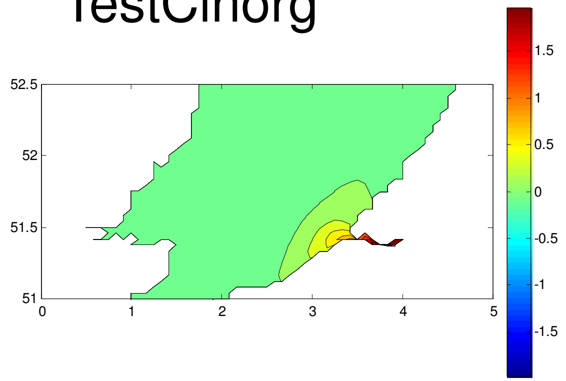


WCH	SBNS	BCZ
-0.18	0.9	0.94

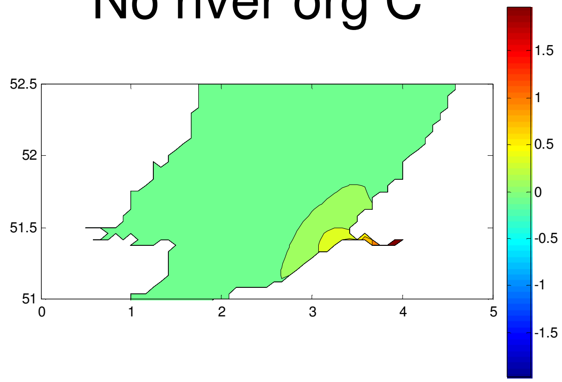
Impact of C and nutrient river loads

Anomaly of the annual air-sea CO_2 fluxes: Reference-Scenario

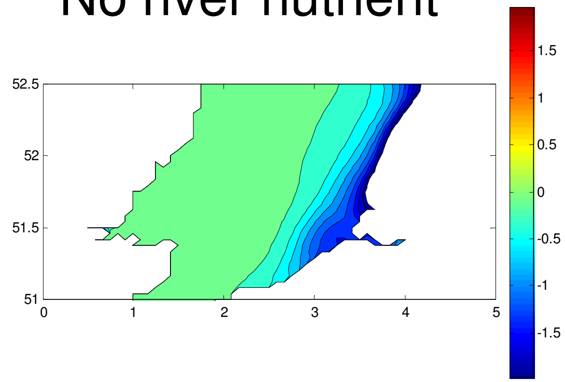
TestCinorg



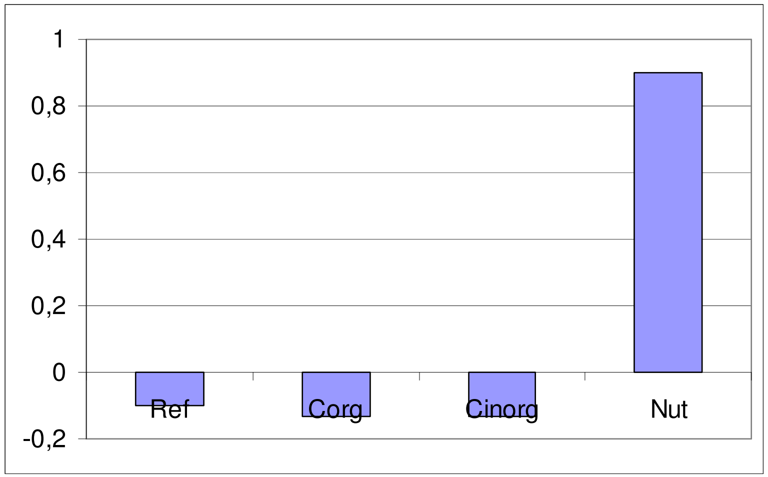
No river org C



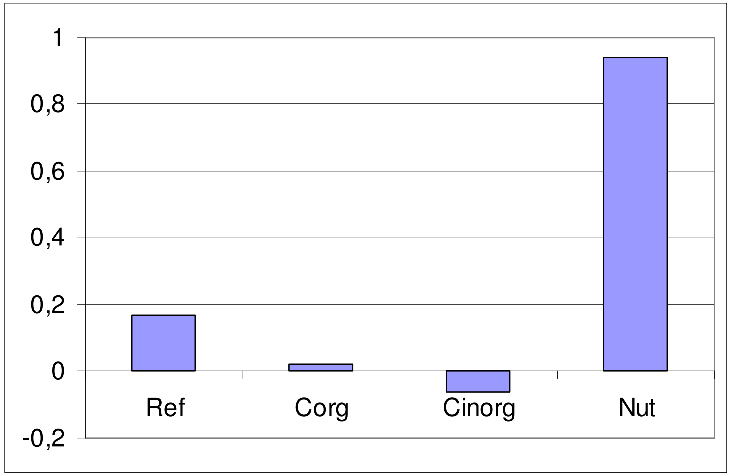
No river nutrient



Southern Bight



Belgian waters



Conclusion

- Important spatial and temporal (seasonal and interannual) variability of surface pCO_2 and air-sea CO_2 fluxes

- Western Channel

  - Annual air-sea CO_2 flux close to zero
  - Interannual variability related to the importance of Atlantic water masse contribution

- Southern North Sea and Belgian waters

  -Annual sink for atmospheric CO_2
  -Decrease of the magnitude of the sink from 1994 to 2004 related to primary production and nutrient river loads

Acknowledgements

Sigle carboocean

CARBOOCEAN

AMORE 3 (**A**dvanced **Mo**deling and **R**esearch on **E**utrophication)

Belgian Science Policy

IAP TIMOTHY (**T**racing and **I**ntegrated **Mo**deling of Natural and Anthropogenic Effec**t**s on **Hy**drosystems (TIMOTHY) Case study:The Scheldt River Basin and Adjacent Coastal North Sea

+ FNRS???