OPERATIONAL MODES OF THE CONTINENTAL SHELF PUMP: EVIDENCE FROM CARBON BUDGETS IN THE NORTH SEA AND THE BALTIC SEA

Helmuth Thomas[#] and the CANOBA team:

Wilfried Kühn
Hermann Lenhart
Andreas Moll
Johannes Pätsch
Günther Radach
Institute of Oceanography
University Hamburg
Troplowitzstraße 7
D-22529 Hamburg
Germany

Alberto Borges
Michel Frankignoulle
Laure-Sophie Schiettecatte
Department of Chemical Oceanography,
Institut de Physique (B5)
B-4000 Liege, Belgium

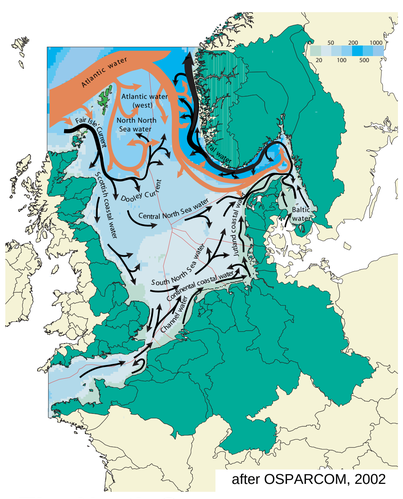
Helmuth Thomas
Yann Bozec
Hein de Baar
Khalid Elkalay
[#]Royal Netherlands Institute for Sea Research (NIOZ) Department of Marine Chemistry and Geology P.O. Box 59, NL-1790 AB Den Burg, Texel, The Netherlands
Email: hthomas@nioz.nl

Janusz Pempkowiak
Department of Marine Chemistry and Biochemistry
Institute of Oceanology
Polish Academy of Sciences
P.O. Box 197
Sopot, Poland

Klaus Nagel
Department of Marine Chemistry
Institute for Baltic Sea Research Warnemünde
Seestr. 15
D-18119 Rostock
Germany

Fred Wulff
Department of Systems Ecology
Stockholm University
106 91 Stockolm
Sweden

Figure 1:
Main circulation pattern, drainage area and topography of the North Sea.



Introduction

Coastal and marginal seas are thought to act as a continental shelf pump transporting CO_2 from the atmosphere to the open oceans. The CO_2 uptake in coastal seas is triggered by high biological activity increasing the CO_2 concentrations of their waters which finally are transported to the open ocean. The efficiency of this "continental shelf pump" will be investigated for the North Sea and the Baltic Sea.

Table 1: Hydrography of the North Sea

surface area [km^2]	575300
Water budget (Eisma and Kalf, 1987) [$km^3 a^{-1}$]	
from the Baltic Sea	500
from the Atlantic Ocean:	
Via English Channel	4900
Via Faire Island and Pentland Firth	9000
Via Shetland Chanel	42000
Rivers	300
Outflow to the North Sea via Norwegian Trench	-56700

Table 2: Hydrography of the Baltic Sea

Surface area [km^2]	415240
Riverine input to [km^3 a^{-1}]:	
Bothnian Bay	98
Bothnian Sea	95
Gulf of Finland	113
Gulf of Riga	29
Baltic Proper	100
Danish Straits	8
Kattegat	29
Outflow to the North Sea	-516

Figure 3:
The Baltic Sea and its drainage area.

The North Sea

The North Sea (Fig. 1) is located on the northwestern European continental shelf with open northern and southern boundaries to the Atlantic Ocean. The deeper northern part reveals depth up to approximately 150m on the shelf and down to 400m in the Norwegian Channel and 700m in the Skagerrak. In the south of the Dogger Bank the depths are less than 50m, near the coasts even less than 20m. The continuous water exchange across the northern boundary dominates the water budget (Tab. 1). Wind and tidal motion is the main driver for the anticlockwise circulation in the North Sea.

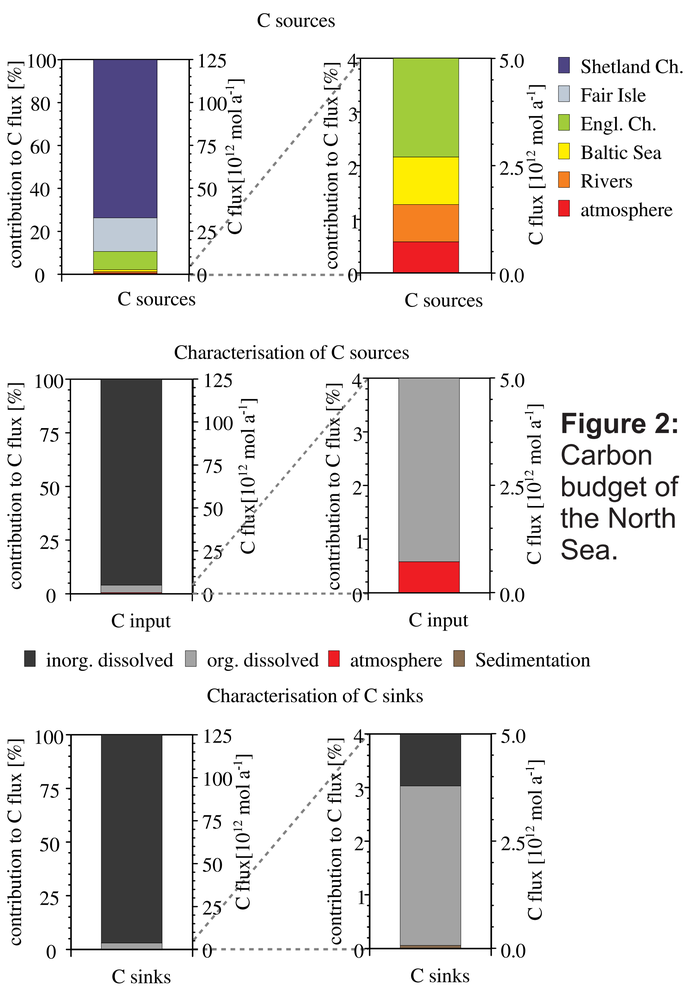


Figure 2:
Carbon budget of the North Sea.

Results for the North Sea

The carbon budget is dominated by the circulation of Atlantic Ocean water through the North Sea (Fig. 2), which finally triggers the uptake of atmospheric CO_2. The initial carbon content of the Atlantic Ocean water is increased from the atmosphere (25%), the Baltic Sea (42%) and the rivers (33%). The uptake of atmospheric CO_2 of $724.000*10^6$ mol C a^{-1} converts to a flux of 1.3 mol C m^{-2} a^{-1} into the North Sea, whereof 10% are transferred to the sediments and 90% to the North Atlantic Ocean constituting the continental shelf pump.

The Baltic Sea

The Baltic Sea (Fig. 3) is almost entirely enclosed and located in the North-western part of Europe. The brackish and stratified system is established by an interaction between both the high annual fresh water inputs (approx. 4% its water volume, Tab. 2) and the sporadic inputs of saline North Sea water. Thus, the Baltic Sea might be seen as a large estuary, of which drainage area is approx. three to four times larger than the surface of the Baltic Sea.

Conclusions

The continental shelf pump operates in two different modes mainly controlled by bottom topography. The North Sea reveals almost no sedimentation but short flushing times. This ultimately implies that the entire CO_2 draw-down caused by biological activity is available for export to the Atlantic Ocean. The North Sea thus can be seen as a strong continental shelf pump acting in a bypass mode (Fig. 5a), which increases the carbon content of Atlantic Ocean while it is circulated through the North Sea. In contrast, the brackish Baltic Sea serves as a collector for riverine carbon inputs, which finally are transported following a "one-way road" to the North Sea. The stratification enables effective export of organic matter from the surface to the deeper layers. The atmospheric CO_2 replenishing the biological CO_2 uptake is thus most notably exported to the deeper layers and the sediments rather than being exported to the North Sea. The Baltic Sea acts as an injection pump (Fig. 5b) for terrestrial carbon, however as a weak continental shelf pump for atmospheric CO_2 .

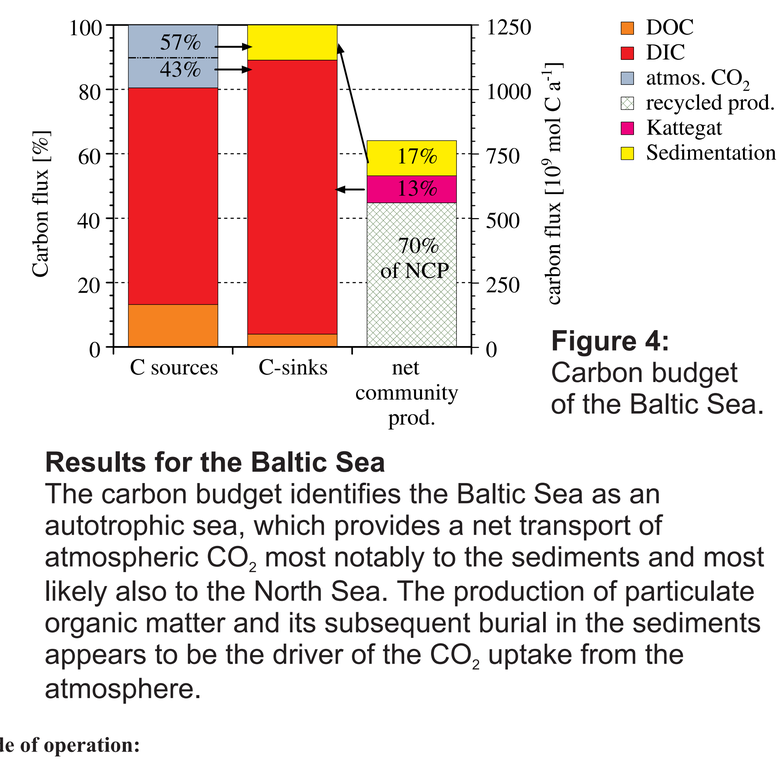


Figure 4:
Carbon budget of the Baltic Sea.

Results for the Baltic Sea

The carbon budget identifies the Baltic Sea as an autotrophic sea, which provides a net transport of atmospheric CO_2 most notably to the sediments and most likely also to the North Sea. The production of particulate organic matter and its subsequent burial in the sediments appears to be the driver of the CO_2 uptake from the atmosphere.

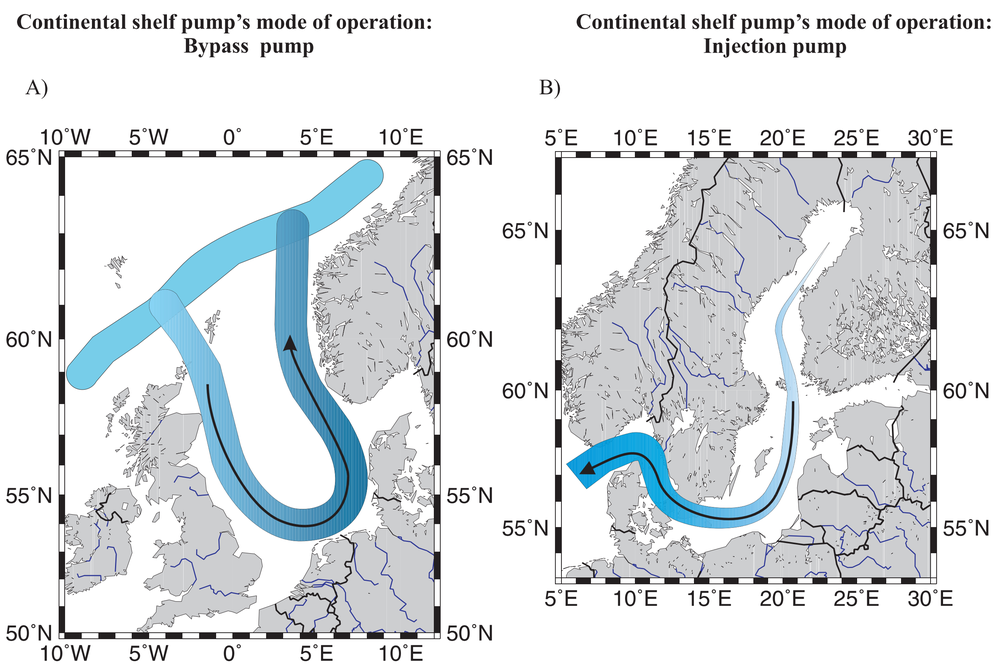


Figure 5:
Operational modes of the "continental shelf pump" in the North Sea and the Baltic Sea.