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The Nordic Seas carbon budget: Sources, sinks, and uncertainties

Emil Jeansson,[1,2] Are Olsen,[1,2,3] Tor Eldevik,[4,5] Ingunn Skjelvan,[1,2,4] Abdirahman M. Omar,[1,2] Siv K. Lauvset,[4,5] Jan Even Ø. Nilsen,[6] Richard G. J. Bellerby,[1,2,4] Truls Johannessen,[4,5,7] and Eva Falck[1,2,8]

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[1] A carbon budget for the Nordic Seas is derived by combining recent inorganic carbon data from the CARINA database with relevant volume transports. Values of organic carbon in the Nordic Seas' water masses, the amount of carbon input from river runoff, and the removal through sediment burial are taken from the literature. The largest source of carbon to the Nordic Seas is the Atlantic Water that enters the area across the Greenland-Scotland Ridge; this is in particular true for the anthropogenic CO_2. The dense overflows into the deep North Atlantic are the main sinks of carbon from the Nordic Seas. The budget show that presently 12.3 ± 1.4 Gt C yr^{-1} is transported into the Nordic Seas and that 12.5 ± 0.9 Gt C yr^{-1} is transported out, resulting in a net advective carbon transport out of the Nordic Seas of 0.17 ± 0.06 Gt C yr^{-1}. Taking storage into account, this implies a net air-to-sea CO_2 transfer of 0.19 ± 0.06 Gt C yr^{-1} into the Nordic Seas. The horizontal transport of carbon through the Nordic Seas is thus approximately two orders of magnitude larger than the CO_2 uptake from the atmosphere. No difference in CO_2 uptake was found between 2002 and the preindustrial period, but the net advective export of carbon from the Nordic Seas is smaller at present due to the accumulation of anthropogenic CO_2.

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1. Introduction

[2] Identifying sources and sinks of carbon in the ocean, and their temporal and spatial variability, is vital to understanding the past, present, and future oceanic carbon system. Key questions are: How does the system respond to changes in climate, and to the increasing load of CO_2 in the atmosphere? The carbon cycle of the preindustrial times is understood to have been in balance and thus operated in steady state [e.g., *Sarmiento et al.*, 2000]. However, because of the anthropogenic CO_2 (C_{ant}) released to the atmosphere since the industrial revolution [*Sabine et al.*, 2004], the present carbon system is not in steady state. The oceans have taken up about half of the C_{ant} emitted from the burning of fossil fuels [*Sabine et al.,* 2004], and changes in the net uptake can have a large effect on future global climate change as projected by earth system models [e.g., *Sarmiento and Gruber*, 2002]. There is evidence of a reduced North Atlantic CO_2 uptake during the last decade [*Schuster et al.*, 2009], however, the interannual variability in the North Atlantic CO_2 uptake is large [e.g., *Watson et al.,* 2009] and is probably affected by regional ocean-atmosphere variability such as the North Atlantic Oscillation (NAO) [e.g., *Gruber et al.*, 2002; *Thomas et al.,* 2008; *Herbaut and Houssais*, 2009; *Ullman et al.,* 2009].

[3] The Nordic Seas (the collective term for the Greenland, Iceland and Norwegian Seas) host the northern limb of the Atlantic Ocean's thermohaline circulation (THC) and are the North Atlantic Ocean's gateway to the Arctic Ocean. Some of the world's densest waters are formed at the source of the THC's northern overturning. This ventilation transports carbon from the surface layer to the intermediate and deep waters of the ocean. Thus the Nordic Seas acts as a channel for atmospheric CO_2 from surface to depth, a process that sustains the global ocean carbon sink [e.g., *Sabine et al.,* 2004]. *Olsen et al.* [2010] recently estimated the inventory of C_{ant} in the Nordic Seas to be in the range 0.9–1.4 Gt C (1 Gt = 10^{15} g), which is approximately 1% of the global ocean C_{ant} inventory [*Sabine et al.,* 2004]. Considering that the Nordic Seas only comprise ~0.3% of the global ocean volume, the area stores a relatively large amount of C_{ant}.

[4] In this study we evaluate present (2002) and preindustrial carbon transport through the gateways connecting the Nordic Seas with the North Atlantic and the Arctic Ocean. The only published carbon budget of the Nordic Seas

[1]Uni Bjerknes Centre, Uni Research AS, Bergen, Norway.
[2]Bjerknes Centre for Climate Research, Bergen, Norway.
[3]Now at Institute for Marine Research, Bergen, Norway.
[4]Geophysical Institute, University of Bergen, Bergen, Norway.
[5]Also at Bjerknes Centre for Climate Research, Bergen, Norway.
[6]Nansen Environmental and Remote Sensing Centre, Bergen, Norway.
[7]Also at Uni Bjerknes Centre, Uni Research AS, Bergen, Norway.
[8]Now at Geophysical Institute, University of Bergen, Bergen, Norway.

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