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Carbon uptake sensitivity of the North Atlantic to climate change: A model study with the Bergen Climate Model

Nadine Goris (1,2), Christoph Heinze (1,2), Jerry Tjiputra (2,3), Jörg Schwinger (2,3)

(1) University of Bergen, Geophysical Institute, Bergen, Norway (nadine.goris@gfi.uib.no), (2) Bjerknes Centre for Climate Research, Bergen, Norway, (3) Uni Climate, Uni Research, Bergen, Norway

The efficiency of the world's oceans to take up carbon is expected to decrease with ongoing climate change, thereby increasing the atmospheric burden of carbon. Here, the North Atlantic is a region of special interest as it is one of the most important oceanic carbon sinks, featuring an exceptionally high column inventory of anthropogenic CO_2. Several model studies have identified the carbon uptake of the North Atlantic as highly sensitive to climate change, but these studies are mostly global studies and are not concerned with a detailed attribution of the underlying mechanisms and their regional differences within the North Atlantic. Yet, quantifying the climate change induced CO_2-uptake variability in the North Atlantic and identifying its main drivers is of high relevance for improving climate projections.

In order to assess and understand the climate sensitivity of the CO_2 uptake of the North Atlantic, we investigate the differences between two simulations (denoted as simulation COU and simulation BGC) carried out with the Bergen Earth System Model (BCM-C). While simulation COU features rising atmospheric CO_2 concentrations (based on observed records for 1850-1999 and the IPCC SRES-A2 scenario for 2000-2099) for radiation code and carbon fluxes, simulation BGC uses rising atmospheric concentrations only for the calculation of the carbon fluxes. The differences between those simulations identify climate induced changes. Our analysis confirms the important role of the North Atlantic for carbon uptake and demonstrates that this region is most sensitive to climate change (in comparison to other oceanic regions as defined in Tjiputra et al., 2010). We furthermore identify substantially different responses to climate change in different parts of the North Atlantic. Based on these differing responses, we divide the North Atlantic into 3 regions, namely the subpolar gyre region (SPG), the high latitude region (HL) and the rest of the North Atlantic (rNAT*, covering mostly the subtropical gyre). The uptake reduction takes place mainly in the SPG-region accounting for 64.67% of the uptake differences in the North Atlantic. Further analysis shows that the changing CO_2-flux in both SPG- and rNAT*-region is driven by an increasing oceanic pCO_2, but the underlying mechanisms differ substantially. The pCO_2-changes in the rNAT*-region are dominated by physical processes, that is increasing sea surface temperatures and a reduced freshwater flux. The latter processes are only of secondary importance for the pCO_2 changes in the SPG-region, which are driven by reduced surface concentrations of dissolved inorganic carbon (DIC) and alkalinity. While the DIC concentration is reduced due to a decreasing DIC-transport into the SPG-region and a reduced carbon flux (both processes are counteracted by a declining biological production), the alkalinity concentration is reduced by the decreasing biological production (counteracted by a declining alkalinity-transport out of the SPG-region). The modeled interaction of deep convection (downwelling), high biological production, and surface circulation create the high climate sensitivity of carbon uptake in the SPG-region.