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# Evaluating ocean alkalinity enhancement as a carbon dioxide removal strategy in the North Sea

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**Supplement S1: Passive tracer experiment**

We conduct two passive tracer experiments regarding the different locations of tracer added. The two locations are illustrated in Fig.S1. The tracer is added as a continuous surface flux in the selected ocean regions. The flux is prescribed as 1mmol/m2/s. The tracer in the interior ocean is only subject to hydrodynamic processes. Before the tracer is added, the initial field is set to zero over the whole model domain. The addition of tracer flux starts from 01.01.2005 and the model runs for one year.

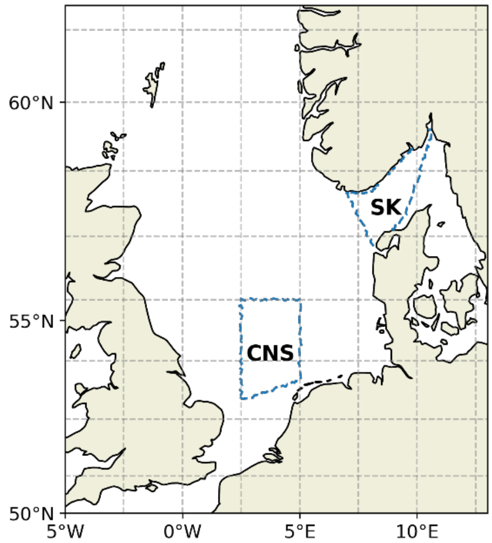


**Figure S1: Locations of passive tracer added.**

**Supplement S2: One-time alkalinity addition experiments**

To test our hypothesis, we conduct three single-instance alkalinity addition experiments, where a fixed amount of alkalinity is added to the three selected locations only in the first month. Following the addition, we monitor the total excess $CO_2$ uptake relative to the CTL simulation. In all three scenarios, the $\eta CO_2$ reaches a plateau of 0.57–0.76 mol $CO_2$ per mol of alkalinity addition after one year, with minimal further $CO_2$ uptake thereafter.

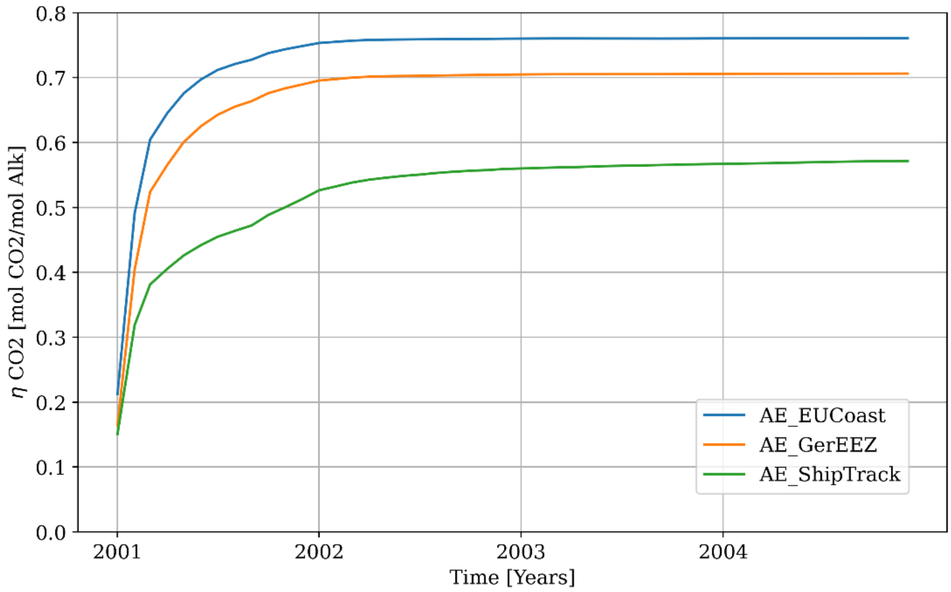


**Figure.S2 Time series of $\eta CO_2$ with one-time alkalinity addition in the three locations.**

Compared to our standard continuous alkalinity addition scenarios, the one-time addition method shows lower $CO_2$ uptake efficiency, even though in the latter case, the seawater with elevated alkalinity is fully equilibrated with the atmosphere. One possible reason is that in the one-time addition scenarios, alkalinity is added during winter, when strong flushing leads to a shorter residence time and consequently poorer equilibration efficiency.

**Supplement S3:**

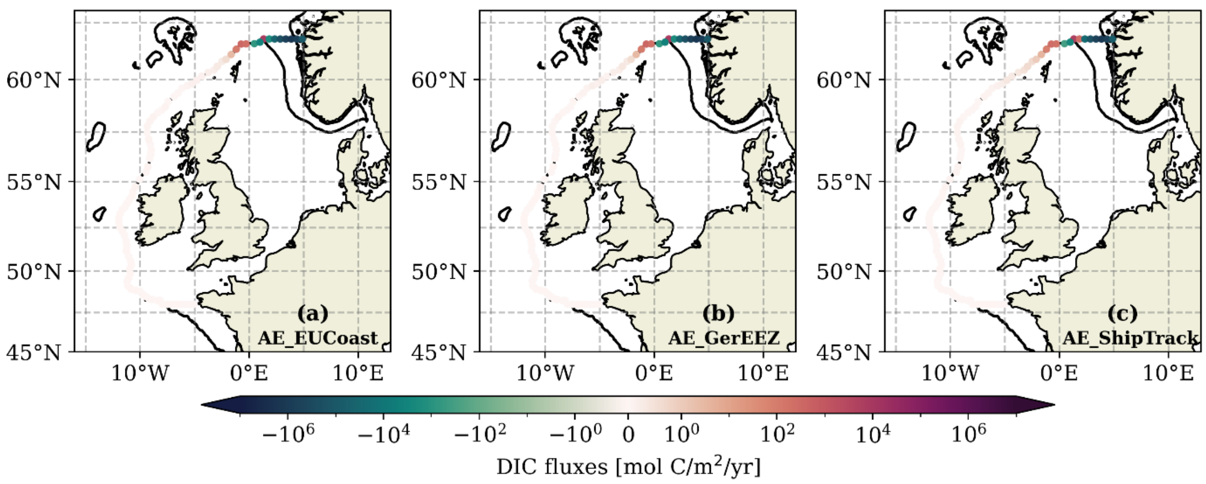


**Figure S3: Difference in the vertically integrated DIC flux per unit horizontal distance across the shelf-break relative to the none-OAE condition for the three scenarios. Black contour shows the 200m isobath.**

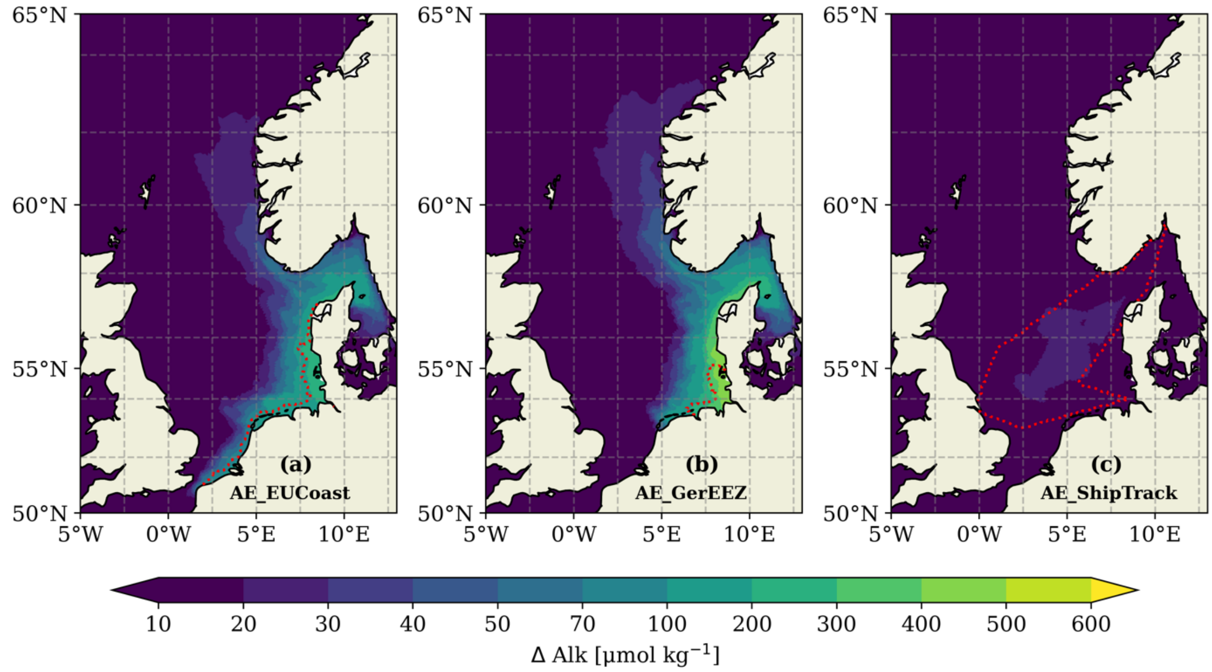


**Figure S4: The maximum changes in surface alkalinity concentration during the OAE periods for each scenario. Overlaid dashed red contour lines indicate the alkalinity addition sites. Note the nonlinear colour bar.**

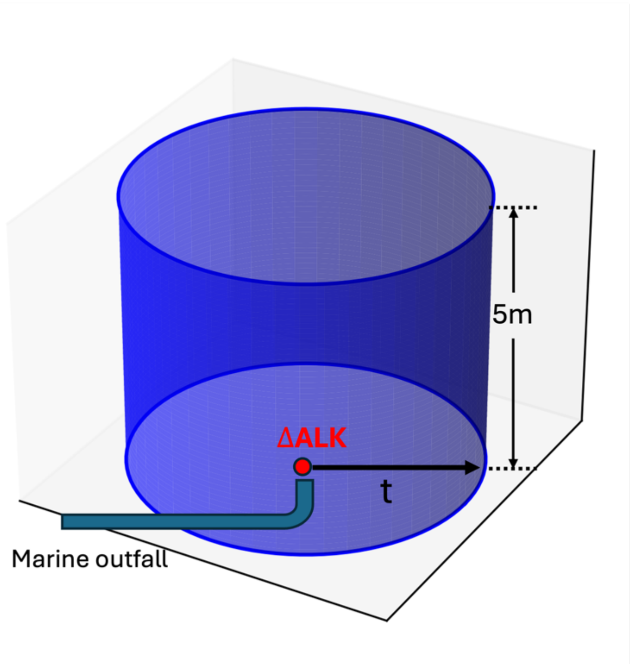


**Figure S5: Schematic showing how the alkalinity is discharged through a marine outfall.**

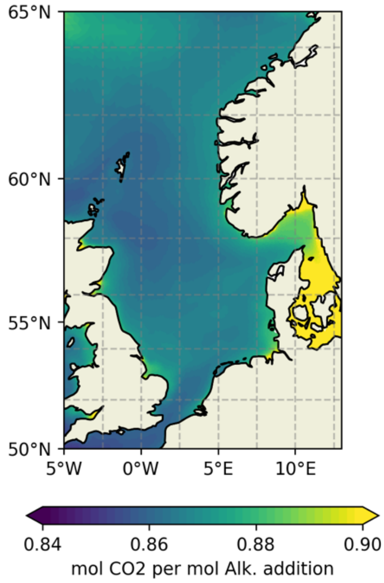


**Figure S6. Map of the maximum attainable $CO_2$ uptake efficiency in the North Sea determined by the mean simulated surface ocean DIC and alkalinity fields.**

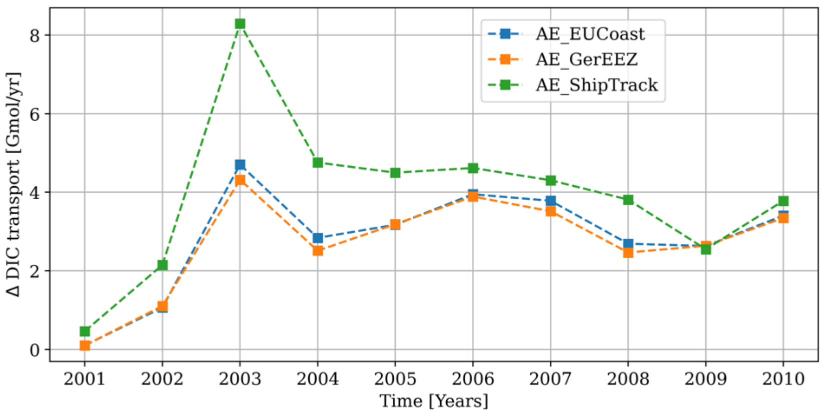


**Figure S7. The yearly total excess DIC export below the permanent pycnocline across the Norwegian Trench for the three scenarios.**