frontiers

Supplementary Material

1 MODEL VALIDATION

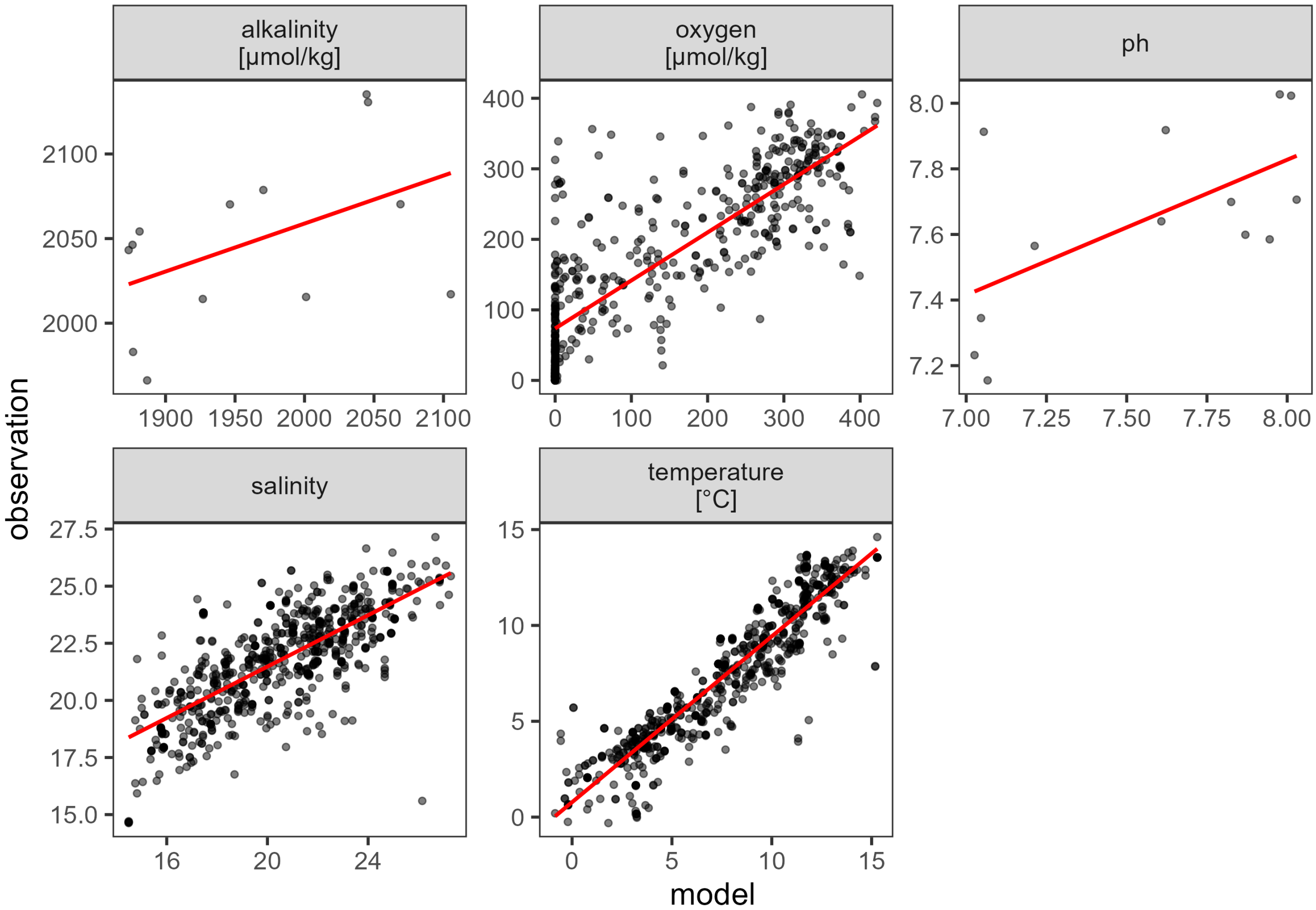

Figure S1. Model data (control run) from the lowermost grid cell and observational data near the bottom at the station Boknis Eck (observational data > 20 m). The observational data was retrieved from the PANGAEA database. For better visibility in high data density, the dots are slightly transparent.

2 ESTIMATION OF THE POSSIBILITY OF A DECREASE IN PHYTOPLANKTON GROWTH AS A RESULT OF LOWER PCO_2 THROUGH OAE

2.1 Overall idea

If ocean alkalinity enhancement is used to enhance the CO_2 flux from the atmosphere to the sea, this will only work by lowering the surface water pCO_2. A lower pCO_2 may, however, decelerate phytoplankton growth. We want to estimate by how much.

2.2 CO_2 drawdown rates

For the Baltic Sea, a calcite dissolution rate of 2.94 µmol cm^{-2} d^{-1} was suggested by Fuhr et al. (2024), in agreement with model studies by Anschütz et al. Considerung that 1 mol of calcite contributes 2 mol of alkalinity, and assuming a CO_2 drawdown efficiency of 0.85 (Montserrat et al., 2017), this would mean a CO_2 capture of F =5.00 µmol cm^{-2} d^{-1} = 5.78e-7 mol m^{-2} s^{-1}.

2.3 Wanninkhof flux formula

According to Wanninkhof (2014) and their equation (6), the CO_2 flux across the air-sea interface can be approximated by the formula

$$F = k\, K_0\, (pCO_{2,w} - pCO_{2,a})\ , \tag{S1}$$

where F describes the flux, k is the transfer coefficient, K_0 is a solubility, and $pCO_{2,w}$ and $pCO_{2,a}$ are the partial pressures of CO_2 in water and air, respectively. The transfer coefficient k can be calculated as

$$k = 0.251 \cdot \mathrm{cm\,h^{-1}\,s^2\,m^{-2}} u_{av}^2\ , \tag{S2}$$

where u_{av} is the average wind speed. In more useful units, it states

$$k = 9.036 \cdot \mathrm{s\,m^{-1}} u_{av}^2\ . \tag{S3}$$

For wind speeds of 1, 5 and 10 m s^{-1}, this gives

$$k_{1\ m/s} = 9.036\ \mathrm{m\,s^{-1}} \tag{S4}$$

$$k_{5\ m/s} = 225.9\ \mathrm{m\,s^{-1}} \tag{S5}$$

$$k_{10\ m/s} = 903.6\ \mathrm{m\,s^{-1}}\ . \tag{S6}$$

A balance between ocean and atmosphere, i.e. a zero flux, is reached if

$$pCO_{2,w} = pCO_{2,a} \tag{S7}$$

For the given flux F, we obtain

$$pCO_{2,w} = \frac{F}{k \cdot K_0} + pCO_{2,a} \tag{S8}$$

The difference is therefore given by

$$\Delta pCO_{2,w} = \frac{F}{k \cdot K_0}\ . \tag{S9}$$

For sea water with 10 °C, Wanninkhof 2014 gives a solubility of

$$K_0 = 4.45 \cdot 10^{-4}\ \mathrm{mol\,m^{-3}\,Pa^{-1}} \tag{S10}$$

We therefore get

$$\Delta pCO_{2,1\ m/s} = 1.44 \cdot 10^{-4}\ \text{Pa} \tag{S11}$$

$$\Delta pCO_{2,5\ m/s} = 5.75 \cdot 10^{-6}\ \text{Pa} \tag{S12}$$

$$\Delta pCO_{2,10\ m/s} = 1.44 \cdot 10^{-6}\ \text{Pa}\ . \tag{S13}$$

As the atmospheric pCO_2 is around 40 Pa, the expected permanent change in pCO_2 that is required to sustain the desired uptake flux is at least 5 orders of magnitude smaller, so far from being significant.

REFERENCES

Fuhr, M., Wallmann, K., Dale, A. W., Kalapurakkal, H. T., Schmidt, M., Sommer, S., et al. (2024). Alkaline mineral addition to anoxic to hypoxic Baltic Sea sediments as a potentially efficient CO2-removal technique. *Front. Clim.* 6, 1338556. doi:10.3389/fclim.2024.1338556

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