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Variability of North Sea pH and CO_2 pumping in response to North Atlantic Oscillation forcing

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High biological activity causes a distinct seasonality of surface water pH in the North Sea, which has been identified as a strong sink for atmospheric CO_2 via an effective shelf pump. The intimate connection between the North Sea and the North Atlantic suggests that the variability of the CO_2 system of the North Atlantic Ocean, may, in part be responsible for the observed variability of pH and CO_2 in the North Sea. The North Atlantic Oscillation (NAO) is the dominant mode of atmospheric variability in the North Atlantic, the index of which describes the difference of atmospheric pressure at sea level between the Icelandic low and the Azores high. Based on three extensive observational records covering the relevant levels of the NAO index, we provide evidence that the North Sea pH and CO_2 system strongly responds to external and internal expressions of the NAO. Under NAO+ higher rates of inflow of water from the North Atlantic Ocean and the Baltic outflow leads to a strengthened north-south biogeochemical divide. This is evident in notably higher salinity and DIC inventories in the northern North Sea and lower salinity and DIC inventories in the Baltic outflow region. The divide between the northern North Sea and southern North Sea limits mixing between the two regimes causing a significantly steeper gradient in pH and partial pressure of CO_2 (pCO_2) in the productive period. This is exacerbated further when coinciding with higher sea surface temperatures, which concentrates the net community production in the north through a shallower summer thermocline. These clear patterns are obscured by changing properties of the North Sea waters, masking or enforcing, the difference between the two regimes on various time scales. Such controls indicate that inter-annual trends in the North Sea CO_2 system must be carefully examined with consideration to the variability caused by NAO.