EGU22-3634
https://doi.org/10.5194/egusphere-egu22-3634
EGU General Assembly 2022

Drivers of the air-sea CO_2 flux variability in the North Sea

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Identifying the mechanisms driving the variability of the air-sea exchange of carbon dioxide (CO_2) in the North Sea is necessary to evaluate the consequences of human interventions such as coastal alkalinity enhancement (OAE) on this societally important ecosystem. For this purpose, the three-dimensional coupled physical-biological model SCHISM-ECOSMO, encompassing a carbonate chemistry module, is employed to present the local physical-biogeochemical processes as well as the exchange processes across scales and compartments. Here we present model results for a 5-year simulation (2002-2004), which are shown to agree well with the observations, indicating a net CO_2 uptake in the northern North Sea (NNS) over the year while a net source of CO_2 to the air in summer in the southern North Sea (SNS). In the NNS, the 'Continental Shelf Pump' mechanism, attributing to the seasonal stratification and efficient carbon export, determines the CO_2 exchange, making the ocean a net sink despite the high temperature in summer that contributes to an enhancement of the CO_2 release. In contrast, the temperature-driven release of CO_2 outcompetes the biological CO_2 drawdown in the shallower SNS. In this region, the tidal mixing prevents seasonal stratification. As a result, the CO_2 generated via remineralization gets quickly in contact with the atmosphere. In addition, the interannual variability of the CO_2 flux is assessed based on the 5-year simulation, which is mainly associated with the variations of the hydrodynamic conditions and productions induced by changes of meteorological conditions.