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Seasonal and inter-annual variability of air-sea CO2 fluxes and seawater carbonate chemistry in the Southern North Sea

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A 3D coupled biogeochemical-hydrodynamic model (MIRO-CO2&CO) is implemented in the English Channel (ECH) and the Southern Bight of the North Sea (SBNS) to estimate the present-day spatio-temporal distribution of air-sea CO2 fluxes, surface water partial pressure of CO2 (pCO2) and other components of the carbonate system (pH, saturation state of calcite (Ωca) and of aragonite (Ωar)), and the main drivers of their variability. Over the 1994-2004 period, air-sea CO2 fluxes show significant inter-annual variability, with oscillations between net annual CO2 sinks and sources. The inter-annual variability of air-sea CO2 fluxes simulated in the SBNS is controlled primarily by river loads and changes of biological activities (net autotrophy in spring and early summer, and net heterotrophy in winter and autumn), while in areas less influenced by river inputs such as the ECH, the inter-annual variations of air-sea CO2 fluxes are mainly due to changes in sea surface temperature and in near-surface wind strength and direction. In the ECH, the decrease of pH, of Ωca and of Ωar follows the one expected from the increase of atmospheric CO2 (ocean acidification), but the decrease of these quantities in the SBNS during the considered time period is faster than the one expected from ocean acidification alone. This seems to be related to a general pattern of decreasing nutrient river loads and net ecosystem production (NEP) in the SBNS. Annually, the combined effect of carbon and nutrient loads leads to an increase of the sink of CO2 in the ECH and the SBNS, but the impact of the river loads varies spatially and is stronger in river plumes and nearshore waters than in offshore waters. The impact of organic and inorganic carbon (C) inputs is mainly confined to the coast and generates a source of CO2 to the atmosphere and low pH, of Ωca and of Ωar values in estuarine plumes, while the impact of nutrient loads, highest than the effect of C inputs in coastal nearshore waters, also propagates offshore and, by stimulating primary production, drives a sink of atmospheric CO2 and higher values of pH, of Ωca and of Ωar.