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Evaluating North Sea carbon sources using radiogenic (224Ra and 228Ra) and stable carbon isotope (DI13C) tracers

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In the North Sea, much uncertainty still exists regarding the role of boundary fluxes (e.g. benthic input from sediments or lateral inputs from the coastline) in the overall biogeochemical cycling of the system. The stable carbon isotope signature of dissolved inorganic carbon (δ13C-DIC) is a common tool for following transformations of carbon in the water column and identifying carbon sources and sinks. Here, analyses of the first basin-wide observations of δ13C-DIC reveal that a balance between biological production and respiration, as well as a freshwater input near the European continental coast, predominantly control surface distributions in the North Sea. A strong relationship between the biological component of DIC (DICbio) and δ13C-DIC is then used to quantify the metabolic DIC flux associated with changes in the carbon isotopic signature. Correlations are also found between δ13C-DIC and naturally-occurring Radium isotopes (224Ra and 228Ra), which have well-identified sources from the seafloor and coastal boundaries. The relationship between δ13C-DIC and the longer-lived 228Ra isotope (half-life = 5.8 years) is used to derive a metabolic DIC flux from the European continental coastline. 228Ra is also shown to be a highly effective tracer of North Sea total alkalinity (TA) compared to the more conventional use of salinity as a tracer. Coastal alkalinity inputs are calculated using relationships with 228Ra, and ratios of DIC and TA suggest denitrification as the main metabolic pathway for the formation of these coastal inputs. Finally, coastal TA inputs are translated into inputs of protons to quantify their impact on the buffering capacity of the Southern North Sea.