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Tidal creeks as hot spots for submarine groundwater discharge on barrier islands: an example from Spiekeroog

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Submarine groundwater discharge can be a controlling factor in water and nutrient cycles in coastal ecosystems. Groundwater discharge and associated nutrient fluxes are controlled by both geomorphology of coastal catchments as well as dynamics at the land-ocean interface e.g. tidal magnitude. The Wadden Sea of Northern Germany is one of the largest regions shaped by tides in the world as well as having active biogeochemistry in the organic-rich mud flats. The aim of this work was to characterize and quantify groundwater discharge to the coastal zone in space and time, with a particular focus on tidal creeks, using the noble gas 222Rn. We have conducted two field campaigns on the barrier island Spiekeroog, which is an ideal field laboratory due to its well defined hydrological boundary conditions. The investigations took place from February 22 to 26 2016, and from March 14 to 20 2016 in a selected branched tidal creek and its catchment in the eastern part of the island (Ostplate). We have mapped the tidal creek using 222Rn activities as well as biogeochemical parameters (e.g. EC, DOC, Fe, SO42-). A continuous measurement station was set-up at the creek mouth and measured 222Rn, O_2 and EC in 15 min resolution for 5 days. The mapping results show that groundwater discharge is highest in areas closed to the dune systems and decreases towards the tidal flat areas. While all samples in the creek had a high salt concentration (EC>30 ms/cm), the samples were also close to the dunes had the largest proportion of salt compared to areas close to the mud flats. The continuous 222Rn measurements showed that the largest groundwater discharge occurred during low tide, when hydrological gradients are likely to be largest towards the sea. While the discharge could be very high over short periods ($\sim$1 m/d), which is likely due to the large tidal amplitude in the Norther German sea, when averaged over the whole tidal cycle it was similar to previous studies (15-26 cm/d). Our work on Spiekeroog suggests that the tidal creek systems are areas of preferential groundwater discharge, particularly from the fresh to brackish groundwater lens that develops under the islands dune system and that this discharge is very dynamic.