EGU General Assembly 2023

EGU23-9177, updated on 27 Apr 2024
https://doi.org/10.5194/egusphere-egu23-9177
EGU General Assembly 2023

Seasonal dynamics of submarine groundwater discharge from a rewetted coastal peatland

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Most research on submarine groundwater discharge (SGD) focuses on sandy beaches. Less studies have investigated environments with low hydraulic conductivity (K_s) such as coastal peatlands, which are abundant along the southern Baltic Sea coast. Coastal peatlands, which have been drained for agricultural purposes, hold high quantities of carbon, nitrogen, and other compounds that could possibly be released to the sea upon rewetting of these sites. In this study, we simulated groundwater flow from a coastal rewetted fen with a peat layer extending out into the sea to understand the short– and long–term dynamics of SGD, quantify SGD water and matter fluxes, and assess the impact of a storm surge on SGD and seawater intrusion. Five-year (2016 – 2021) daily 2D numerical simulations of groundwater flow were based primarily on monitored groundwater and seawater level data and field-gathered soil hydraulic parameters. Hydraulic conductivities of geological layers were optimized against measured water levels. Manual seepage meter measurements were conducted and water samples were collected. The modeled seepage rates fitted the measured ones well. Our results reveal that SGD and seawater intrusion are highly dynamic and vary spatially and temporally. Two dominant submarine discharge areas were observed: 1) near the beach (up to ~30 m from shore) where mean seepage rates based on nodal water velocities reach up to 12.4 cm d^{-1} with waters originating from the dune dike and recirculated seawater; 2) seeps from the aquifer at about 60 m distance from the coast with discharge rates of 1.1 cm d^{-1} on average. Mean seepage rates from the discharge areas are comparable to other wetland and sandy environments. The low K_s of the peat layer limits water exchange between the peatland and the Baltic Sea to these regions. The groundwater-seawater interface below the dune moves between the beach and the central dune on an hourly to weekly basis. However, the extent of the interface changes at a seasonal scale. Higher SGD fluxes occur in spring and summer while seawater intrusion increases during fall and winter, as a consequence of the seasonal variations of the peatland's water level and the resulting hydraulic gradient. During storm surges, higher seawater intrusion fluxes are expected, while low seawater would lead to

higher SGD fluxes. The mean daily net flux which represents land-derived SGD from the peatland is 0.15 m^2 d^{-1} (range: -6.12 m^2 d^{-1} to 1.63 m^2 d^{-1}), with the highest intrusion occurring during the 2019 storm surge and the highest SGD occurring two days after the surge event. Our mean daily net flux compares well with previous studies but total SGD, which includes recirculated seawater, is likely underestimated. Nearshore carbon and nitrogen SGD concentrations are higher than ambient seawater concentrations demonstrating the potential impact of SGD on local biogeochemistry. Our findings show that SGD is an important coastal process even from low-lying and low K_s coastal peatlands. We emphasize the importance of conducting more interconnection studies between peatland hydrogeology and geochemistry disciplines to better understand SGD processes in these environments.