Estimating tide-induced seawater infiltration rates at a meso-tidal beach by modelling reactive transport of Si and ^{222}Rn

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The upper intertidal recirculation cell (often referred to as upper saline plume – USP) is an important biogeochemical reactor fueled by the delivery of large amounts of reactive organic matter, oxygen and nutrients to benthic and subsurface microbial communities every tidal cycle. Quantification of biogeochemical turnover rates critically depends on the knowledge of water residence times. As conservative tracer tests in the inter-tidal zones of meso- and macro tidal beaches are extremely difficult to carry out, reactive tracers such as dissolved silica (DSi) and radon (^{222}Rn) may serve as a constraint for the calibration of flow and transport models within the infiltration zone of the USP.

In a reactive transport modelling framework, we tested the suitability of these two reactive tracers to quantify residence times in a meso-tidal sandy beach on Spiekeroog Island, Germany. For that we employed a 2D vertical cross-sectional model for unconfined groundwater flow and reactive transport processes along a transect in the intertidal zone from high to low water line. The model accounted for phase-resolved tides, as well as the geochemical processes quartz dissolution and ^{222}Rn production and decay. While only the flow model was calibarated to match the observed hydraulic heads, the reactive transport model was not calibarated. Instead, the quartz dissolution rate constant was taken unmodified from a previous laboratory experiment, and the ^{222}Rn production rate constant was estimated from the ^{222}Rn equilibrium concentration found at the study site.

The modelled concentrations matched the measurements within high-resolution profiles along the transect reasonably well. This suggests that the model-predicted residence times in the infiltration zone can, with some uncertainty of course, be used to quantify the biogeochemical turnover rates of oxygen and nitrate introduced into the beach sediments.