Incorporating complementary ecological and biogeochemical information into quantitative bioirrigation models

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Macrofaunal activties including burrow construction and ventilation lead to enhanced solute transport, termed bioirrigation, in the upper layers of organic-rich sediments. This solute transport has a significant impact on fluxes of nutrients and redox-sensitive chemical species across the sediment-water interface, creates unique microbial habitats, and increases the lateral heterogeneity of sediments. A variety of models have been proposed to quantify the impact of burrow ventilation on solute transport. Most such models either ignore available ecological information regarding animal behavior and burrow networks, or greatly simplify such data.

We have developed an ecologically-based, stochastic approach so that available burrow network data can be used to estimate 1D nonlocal bioirrigation coefficients $\alpha_i(x)$ and their likely variability. Burrow networks are parameterized with respect to size, shape and density, and simulated using appropriate probability functions. The mean burrow density (r_1) and mean burrow separation distance (r_2) is used to estimate $\alpha_i(x)$ according to:

$$\alpha_i(x) = 2\left(D_i r_1\right)/\left(\left(r_2^2 - r_1^2\right)\left(\bar{r} - r_1\right)\right)$$

where D_i is the diffusion coefficient of solute i, and rbar is the time-averaged lateral-distance from the burrow wall at which solute i reaches its laterally-averaged concentration. Nonlocal bioirrigation coefficients derived using this approach for a saltmarsh sediment containing polychaete worms, fiddler crabs, mud crabs and shrimps are in good agreement with coefficients derived using an inverse model with biogeochemical data (sulfate concentration and reaction rates) from the same site (Meile et al. 2001, Limnol & Ocean 46, 164-177). This approach shows promise for extraction of bioirrigation data from paleosediments with well-preserved burrow network structures.