High-Resolution Imaging of O_2, pH, and pCO_2 in Bioirrigated Sediments

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Permeable marine surface sediments often exhibit heterogeneous and dynamic biogeochemical conditions, caused, e.g., by the activity of benthic animals that pump oxygen-rich, high-pH overlying water into their burrows and the surrounding sediment.

To determine the scale, pattern, and magnitude of biogeochemical changes, we constructed sealed transparent chambers ("optocosms") which were partially filled with muddy sand sediment. Peristaltic pumps connected to ports allowed injection of overlying water into the sediment at depth with controlled rate and pattern of water delivery, simulating the activities of bioirrigators. Using planar optode imaging, we obtained quasi co-registered 2-D data of O_2, pH, and pCO_2 with minute resolution.

In our experiments we simulated a wide range of irrigation patterns including continuous, intermittent and low frequency irrigation, represented by constant pumping (at 0.75mL/min), 30min on/30min off at 1.5mL/min, and 12h on/12h off at 1.5mL/min, respectively, complemented by a non-irrigated control. In the low frequency irrigation treatment the entire subsurface oxic area became anoxic during the resting period of each cycle, while in the intermittent irrigation treatment an oxic-anoxic oscillatory region established around a zone with permanently oxic conditions. Oxic-anoxic oscillatory regions were characterized by strong pH and pCO_2 fluctuations with ΔpH = 0.2 and 0.7 and ΔpCO_2 = 5 and 20 matm in the intermittent and slow irrigation treatments, respectively. Our data suggest that intermittently irrigated sediment may swing between super- and under-satutared conditions with respect to $CaCO_3$ and highlight the need and potential for multi-optode imaging to study biogeochemcial processes in marine sediments.