Combining multiple electromagnetic methods, direct aquifer measurements, and modeling to inform ecological management on Palmyra Atoll

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Abstract

Assessment and management of limited fresh groundwater resources on remote small islands can be complicated by heterogenous geology, natural climate cycles, and a general lack of data. The Palmyra Atoll National Wildlife Refuge is home to one of the few surviving native stands of *Pisonia grandis* in the central Pacific Ocean, yet these trees face pressure from groundwater salinization, with limited basic groundwater data to guide decision making. Adding to natural complexity, the geology of Palmyra was heavily altered by dredge and fill activities in the 1940s. We combined electromagnetic imaging (EMI) and hydrological field measurements from 2008-2019 with groundwater modeling to map the current distribution of fresh groundwater on the modified main island and a small, more natural islet to better understand potential physical drivers of spatiotemporal variability. Frequency-domain EMI data were collected on the main atoll islands over repeat transects in 2008 following 'strong' La Niña conditions (wet) and 2016 during 'very strong' El Niño conditions (dry). Shallow monitoring wells were installed adjacent to the geophysical transects in 2013 and screened within the fresh/saline groundwater transition zone. Temporal EMI and monitoring well data showed a strong lateral and vertical contraction of the freshwater lens in response to El Niño conditions, and transient EMI data indicated a thicker lens toward the ocean side, an opposite spatial pattern to that observed for many other Pacific islands. On an outer islet where a stand of mature *Pisonia* trees exist, EMI surveys revealed only a thin (<3 m from land surface) layer of brackish groundwater during El Niño. Numerical groundwater simulations were performed for a range of permeability distributions and climate conditions at Palmyra. Results revealed that the observed atypical lens asymmetry is likely due to a combination of lagoon dredging and filling with high-permeability material, allowing for more efficient submarine groundwater discharge on the lagoon side. Simulations also predict large negative changes (approximately 40% decrease) in freshwater lens volume during dry cycles and highlight threats to the *Pisonia* trees, yielding insight for atoll ecosystem management on Palmyra and other small Pacific islands.