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TITLE: Evaluating the fate of freshwater lenses on atoll islands after eustatic sea-level rise and cyclone-driven inundation: A modelling approach

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ABSTRACT:

Dispersed human populations inhabiting remote atolls across the tropical Pacific Ocean are reliant on the viability of thin freshwater lenses (FWLs) contained within the island coralline sediments for their survival. Yet FWLs are uniquely fragile and easily damaged by saline intrusion. Eustatic sea-level rise (SLR) and sea flooding generated by intense tropical cyclones therefore pose special perils for continued existence on atolls. In this work, mathematical modelling is used to examine the effects on an atoll freshwater lens of various projected long-term SLR scenarios (10, 20, and 40 cm). A cyclone-driven wave washover event is then simulated in order to observe the responses and recovery of the FWL, subsequent to the SLR scenarios imposed. A key attribute of our model design is the inclusion of a topographic depression containing a low-lying fresh swamp in the atoll islet interior (which is often ignored), where seawater accumulates during inundation. Results indicate that a 40 cm SLR produces a major impact: the FWL decreases in thickness by approximately 50%, develops a brackish centre and contracts to a shrunken 'doughnut' morphology. Following cyclone inundation, observed salinity profiles are illuminating. Steep salinity gradients show how a strong saline plume forms at shallow depths, but also reveal the existence of an undisturbed fresh horizon beneath the salt plume under both present conditions and the modest 10 cm SLR scenario. Within the preserved fresh horizon, salt concentrations are maintained below 1.5 g/L (i.e. within usable limits) for at least a year. In contrast, the diminished freshwater lenses that exist after 20 and 40 cm SLR then exhibit far less resilience to saline damage over comparable post-cyclone timeframes. The findings point towards Pacific atolls becoming increasingly uninhabitable long before their complete submergence by sea-level rise, owing to irrecoverable groundwater salinisation seriously reducing the availability of freshwater.

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