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Data-driven quantification of subterranean estuaries role in ocean chemistry

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The phenomena of submarine groundwater discharge (SGD) through subterranean estuaries is acknowledged as an important process affecting coastal geochemistry and ecology. However, we are still several steps away from quantifying the actual global fluxes of several fundamental major elements and isotope systems such as calcium, potassium and strontium, and other particle-reactive elements. The main challenge stems from the complexity of groundwater flow in coastal aquifers that includes several seawater circulation mechanisms. These mechanisms vary by their spatial and temporal scales from small-scale/short-term mechanisms driven by tides and waves, and up to large-scale/long-term density-driven circulation. The key for quantifying solute transport into the ocean through SGD lies in quantifying water fluxes and understanding the effect of each one of these mechanisms on the geochemical composition of the groundwater.

We present here a bottom-up approach based on a local field site and a top-down approach based on global ocean budgets for quantifying major elements fluxes through SGD. These approaches are based on the notion that major elements are affected mainly by the long-term density-driven circulation process, where calcium and strontium are enriched, and sodium and potassium are depleted (Sola and Vallejos, 2021). Based on Ca^{2}, K^{+}, and Sr^{2} budgets, the long-term component flux in Indian River Bay, Delaware is 9±4% of the total flux. Extrapolating this flux globally using groundwater models and taking into account benthic exchange result in a relative flux of ~1%, which is 1200-3600km^3.

The figure below presents the calculated global long-term circulating seawater (LTC) flux based on a Monte-Carlo simulation of the global budgets of calcium, potassium, strontium, and strontium isotopes taking into account all sources and sinks and their uncertainties. The figure also shows in a black line the range calculated from upscaling Indian River Bay long-term component flux. The calculated LTC flux is 2340±1250km^3, which is ~2% of the total SGD. This results in a Ca flux of $1.5\pm0.2\cdot10^{13}$mol/y, a K removal of $2.8\pm0.5\cdot10^{12}$mol/y, and a Sr flux of $8.2\pm0.5\cdot10^{10}$mol/y. These values are on the same order of magnitude as river fluxes, and thus are crucial for ocean budgets.