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In situ measurements of advective solute transport in permeable shelf sands

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Abstract:

Solute transport rates within the uppermost 2 cm of a rippled continental shelf sand deposit, with a mean grain size of 400–500 µm and permeabilities of 2.0–2.4 x 10^{-11}m^2, have been measured in situ by detecting the breakthrough of a pulse of iodide after its injection into the bottom water. These tracer experiments were conducted on the USA Middle Atlantic Bight shelf at a water depth of ~13m using a small tethered tripod that carried a close-up video camera, acoustic current meter, motorized 1.5 liter "syringe", and a microprofiling system for positioning and operating a solidstate voltammetric microelectrode. When triggered on shipboard, the syringe delivered a 0.21 M solution of potassium iodide and red dye through five nozzles positioned around and above the buried tip of the voltammetric sensor for 0.65–5 min. Bottom turbulence rapidly mixed and dispersed the tracer, which then was carried into the bed by interfacial water flows associated with ripple topography. The advective downward transport to the sensor tip was timed by a sequence of repetitive voltammetric scans. The distance-averaged vertical velocity, expressed as the depth of the sensor tip in the sand divided by the time to iodide breakthrough, was found to vary from 6 to 53 cm h^{-1} and generally to decrease with sediment depth. Because of episodic pumping and dispersion associated with the greatest 5% of wave heights and current speeds recorded, some concentration vs. time responses showed evidence of uneven solute migration. For reasons of mass balance, the advective flow field in the surface layers of permeable beds includes regions of water intrusion, horizontal pore-water flow and upwelling which also may explain some of the observed uneven migration. Pore-water advection was also evident in oxygen profiles measured before and after tracer injection with the voltammetric sensor. These profiles showed irregular distributions and oxygen penetration depths of 4–4.5 cm. Sand cores from the study site subjected to continuous pore fluid pumping showed that oxygen consumption was positively correlated with flow rate. The effect was calculated to be equivalent to increasing the benthic oxygen flux by 0.029 mmol m^{-2} d^{-1} for every 1 liter m^{-2} d^{-1} flushed through a 4 cm thick oxic zone. Thus, it is concluded that in situ oxygen consumption rates must be highly variable and dependent on the prevalent wave and current conditions.

Key-words: Advection, voltammetric electrode, permeable sediments, sand ripples, oxygen consumption, inner shelf