ABSTRACT

Propagation of viscous gravity currents on porous substrates

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Abstract:

Thin horizontal flows, driven by the buoyancy difference between an intruding and an ambient fluids, also known as gravity currents, occur in a wide range of natural and industrial flows. When such flows propagate on a porous bed, some fluid can leak into the ground and consequently a sub-surface current can develop. Such flows could occur, for example, when honey spreads on a slice of bread, when waves break on a sandy beach, and following the sequestration of CO2 in deep aquifers.

Gravity currents on impermeable substrates are known to have self-similar solutions, in which the nose-front position is power law in time. On permeable beds, the flux out through the substrate grows with the radius of the front of the sub-surface current (the drainage front), and the flow reaches a steady state when the nose and drainage fronts coincide.

We study an intermediate situation, where the nose-front separates from the drainage front, which becomes an internal boundary between draining and non-draining regimes. In this case, percolation of the propagating current into the substrate is inhibited unless a critical pressure, specified by capillary forces, is exceeded. We analyse this flow using numerical and analytical techniques combined with laboratory experiments. In contrast with the case in which capillary forces are absent and the flow becomes steady, we find that the asymptotic propagation of the fronts is quasi-self-similar, having identical structure to the solution of gravity currents on impermeable substrate, only with time-dependent influx.