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Low Reynolds-number hydrodynamics of immersed fluid sheets

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Low Reynolds-number flows of thin bodies of viscous fluid immersed in an external fluid with a different viscosity occur in contexts ranging from microfluidics to global geophysics. Here we study the buoyancy-driven motion of a two-dimensional sheet with thickness h and viscosity η_2 in a less dense fluid with viscosity η_1, starting from an initial geometry that corresponds to subduction of oceanic lithosphere in Earth's mantle. We work with two different representations of the flow: a full boundary-integral formulation, and a new "hybrid" integral equation that combines asymptotic thin-sheet theory with a boundary-integral representation of the external flow. In both cases, the time-dependent motion of the sheet is obtained by updating the geometry after each instantaneous flow solution. A scaling analysis shows that the sheet's velocity is controlled by its dimensionless "stiffness" $S \equiv (\eta_2/\eta_1)(h/\ell_b)^3$, where the "bending length" ℓ_b is the length of the portion of the sheet's midsurface where bending moments are significant. We will present illustrative simulations of the evolving sheet as a function of the viscosity ratio η_2/η_1, and will assess the relative efficiencies of the full boundary-integral and hybrid approaches.

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