Fingering convection in double-diffusive, sediment-laden flows

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Abstract

We study double-diffusive instabilities in environments where the fluid density depends on both temperature and sediment concentration. The motivation for this research is to understand the double-diffusive transport mechanisms of sediment in river plumes. Under some conditions, such stably stratified sediment-laden systems give rise to fingering instabilities, which in the presence of horizontal bases state gradients can result in the formation of large-scale structures such as near-horizontal intrusions (cf. Figure 1). The primary double-diffusive instability operates on a small scale (few centimeters), but can evolve to much larger scales (kilometers).

We present linear stability analysis and direct numerical simulation (DNS) results of the instabilities in a stratified sediment-laden system with uniform linear vertical and horizontal background gradients. The linear growth rates of the primary fingering instability are seen to agree with the early stages of the DNS simulations. The particle settling velocity has a significant effect on the strength and dominant length scale of the double-diffusive instability, as well as on the formation of the horizontal intrusions and staircases, so that strong differences emerge as compared to the traditional oceanic case of a heat-salt system.
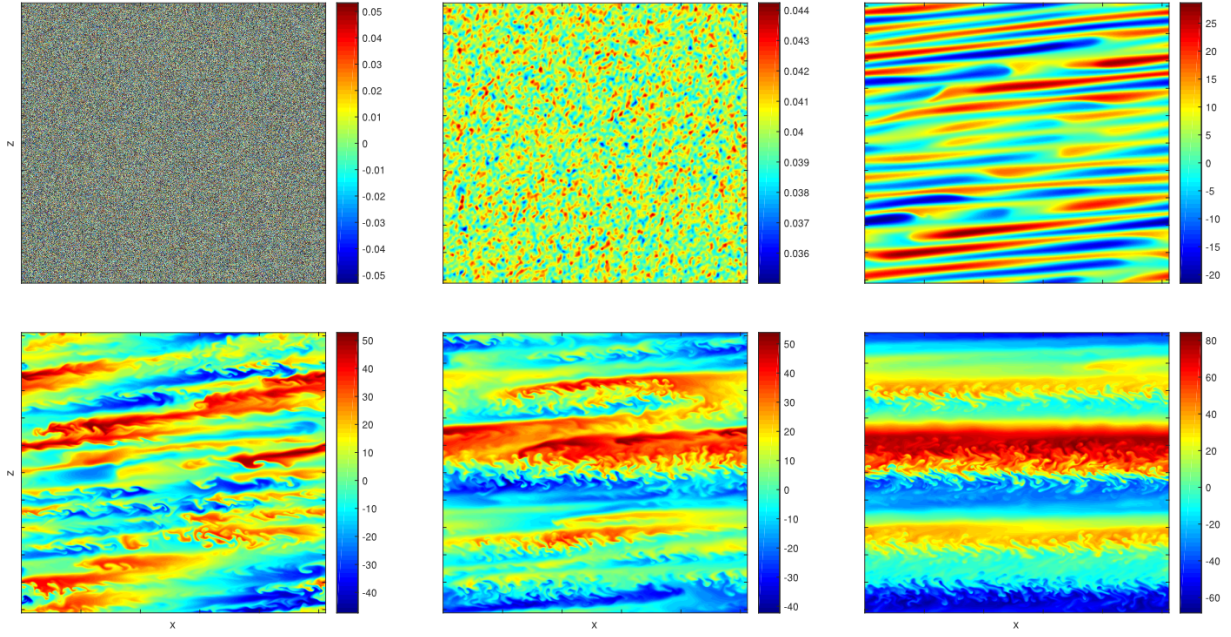
Figure 1: Snapshots of the particle perturbations at times t=0, t=20, t=900, t=1000, t=1200 and t=1490 in a sediment-laden system (particle settling velocity $W_{st} = 0.02$). Fingers start to show at $t = 20$ an then evolve to form near-horizontal intrusions, which start to appear around t=900.