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Spontaneous formation of waves, channels and levees in geophysical mass flows

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Geophysical mass flows often break down into large amplitude wave pulses and/or spontaneously form channels with static levees in the arrest zone, enhancing overall run-out. This talk reviews recent depth-averaged models that are able to capture the formation of:- (i) rollwaves, (ii) erosion-deposition waves (which exchange mass with an erodible substrate) and (iii) channel and levee formation, within a single framework. The key is the inclusion of frictional hysteresis, which allows static and moving zones to coexist, as well as depth-averaged viscous terms that incorporate further details of the granular rheology. As well as being able to compute time-dependent spatially evolving solutions numerically, the resulting model allows steady-state solutions to be constructed for the height, width and depth-averaged velocity profile across a leveed channel, which are in good quantitative agreement with small scale analogue experiments using monodisperse dry sand. Colour change experiments are used to show that erosion-deposition waves really do propagate downslope as a wave, rather than a coherent body of grains, and that the presence of the erodible substrate gives them surprising mobility over very long distances. Photos and videos of the similar effects at field scale will be shown to emphasize the importance of these ideas for a wide range of geophysical mass flows. There are, however, still many open challenges in how to generalize these results to multiphase mixtures with broad grain size distributions.