Buckling of elastic layers: Wavelength selection, strain rate dependency, and post-shortening coarsening

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Folding of layered rocks is one of the primary mechanisms that accommodate shortening. Despite the importance of elastic layer buckling in viscous media, from small scale folding to subducting slabs, the available analytical theories present us expressions that contain unknowns, namely σ_{xx}, the layer parallel driving stress. σ_{xx} is not a constant as it evolves during the shortening and buckling of elastic layers; as a thought experiment one can refer to an elastic spring that gets progressively shortened. Motivated by analogue experiments, where condoms were subjected to pure shear shortening in a PDMS matrix, we present a new analytical theory that accounts for the evolution of folds in elastic layers, from the initial to the large strain states.

We show that the dominant wavelength in elastic layer buckling is a function of the shortening rate, $\dot{\epsilon}$, and give an explanation for the locking amplitude, where the dominant wavelength selection freezes. In addition, we present the phenomenon of post-shortening folding where the amplitudes and wavelengths increase during a stage of stress relaxation. Based on mathematical similarities we establish the relationship between the observed fold coarsening and classical coarsening mechanisms such as Ostwald ripening. Our results imply that folded elastic layers cannot be considered static but evolve with time, are more dynamic than previously anticipated, and are sensitive to the rate at which the system is driven.