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3D fold growth rates

Marcel Frehner
Geological Institute, ETH Zurich, Switzerland (marcel.frehner@erdw.ethz.ch)

Geological folds are inherently three-dimensional structures. Therefore, a growing fold structure also propagates in three dimensions. In this study, fold growth in all three dimensions is studied and quantified numerically using a finite-element algorithm for simulating three-dimensional deformation of Newtonian materials. To simplify terminology, only upright symmetrical single-layer fold structures are considered here. The horizontal higher-viscous layer exhibits an initial point perturbation. Horizontal compression in one direction (x-direction) leads to a mechanical folding instability, which grows from this perturbation in all three dimensions, described by:

- **Fold amplification** (growth in z-direction)
  The fold growth in z-direction (vertical) is commonly referred to as fold amplification and describes the growth from a fold shape with low limb-dip angle to a shape with higher limb-dip angle.
- **Fold elongation** (growth in y-direction)
  The fold growth in y-direction is parallel to the fold axis and is here referred to as fold elongation. It describes the growth from a dome-shaped (3D) structure to a more cylindrical fold (2D).
- **Sequential fold growth** (growth in x-direction)
  The fold growth in x-direction is parallel to the shortening direction and perpendicular to the fold axis. It describes the growth of secondary (and further) folds adjacent to the initial isolated fold and is here referred to as sequential fold growth.

In existing literature, both fold elongation and sequential fold growth have previously been referred to as lateral fold growth, which is here used as an umbrella term for both.

First results indicate that in the initial folding stage, the fold growth rates in all three dimensions are of the same order. However, after some shortening and fold amplification, the two lateral growth rates first increase significantly and then decrease below the value of the vertical fold amplification. At a later folding stage, the vertical amplification rate of the initial fold also decreases and the sequentially grown secondary folds exhibit higher vertical amplification rates. During the entire modeled folding history, the two lateral directions generally show a very similar growth rate.