Supplementary Equations:

Rate of surface uplift from a simple analytic model

By performing a flux balance of material accreted to a doubly vergent wedge, assuming critical wedge taper angles, the long term evolution of wedge geometry can be determined.

The area of a wedge of height H, pro-wedge taper angle α and retro-wedge taper angle β is given by:

$$A_{wedge} = \frac{H^2}{2\tan\alpha} + \frac{H^2}{2\tan\beta}$$

The total area of material accreted to a 2d cross-section is the integration of the thickness of the material accreted over the convergence interval 0 to *S*:

$$A_{accreted} = \int_0^S h(S)dS$$

Taking a constant thickness of accreted material h_0:

$$A_{accreted} = Sh_0$$

The non-erosive flux balance,

$$A_{accreted} = A_{wedge}$$

Thus the rate of surface uplift of the wedge, assuming constant wedge taper, is proportional to the square root of the convergence accommodated.

$$\frac{H}{h_0} = \sqrt{\frac{2\tan\alpha\tan\beta}{\tan\alpha + \tan\beta} S}$$

Consequently, both deformation fronts also advance at a rate proportional to square root of the convergence accommodated. For a constant convergence rate, the total amount of shortening accommodated is proportional to the time duration over which the model has been run. Thus the height of the wedge is also proportional to the square root of time elapsed.

Values and references used in construction of Figure 4

Orogen	**References**	**Thrust length (km)**	**Convergence Rate (km/Myr)**	**Timescale (Myr)**
South Central Pyrenees	(*1*)	24	6	4
Western Alps	(*2, 3*)	3.7	5	0.74
Southwestern Taiwan	(*4*)	12	80	0.2
Western Nepal	(*5*)	25	21	1.2
Central Nepal	(*5*)	12	21	0.6
Makran	(*6*)	6	31-47	0.1-0. 2

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Video 1 (VideoDR1.avi) - Non-erosive model - Evolution of a non-erosive DEM doubly-vergent wedge. The data from this run has been used to construct Figure 2. This animation consists of a subset of time slices from the entire model run. The lower panel shows the time evolution of initially horizontal horizons. Material in the lightly coloured horizons, initially to the left of the S-point (pro-side) is coloured in orange and material to the right (retro-side) is coloured brown. Material is fluxed into the system at a constant convergence rate from the left. The wedge grows above the basal velocity discontinuity. The pro-wedge is shallower and more active than the retro-wedge. The upper panel is coloured by relative displacement of adjacent particles to highlight zones of localised displacement, i.e. structures. This clearly demonstrates the punctuated nature of deformation within the wedge.

Video 2 (VideoDR2.avi) - Erosive model - In order to investigate the effects of the tectonic variability on geological proxies of cumulative erosion and thermochronometric age, this second animation incorporates a simple erosive scheme removing material above a threshold elevation, exposing more deeply derived material. The panels depict the same information as described for Animation 1. The wedge initially grows similar to Animation 1 until the wedge starts to erode. The upper part of the wedge then broadens until a time averaged flux steady state is attained. At this point the wedge fluctuates through the tectonic variability. Material is fluxed to the surface in intermittent pulses of internal thickening. Periods of quiescence within the main part of the wedge are associated with convergence being accommodated through frontal accretion. Once the flux steady state has been attained, deformation of the retro-side is inhibited.