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Mean bedrock-to-saprolite conversion and erosion rates during mountain growth and decline

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Weathering and associated atmospheric CO_2 consumption are thought to increase during the erosion of uplifting mountain ranges, but the effect of enhanced erosion on weathering is still the subject of active debate. Among the recent criticisms, 1D models coupling erosion and weathering suggest that weathering first increases but then decrease when uplift increases. Moreover, it seems that for the last 12 Ma, global erosion increased while weathering and atmospheric CO_2 stayed constant. Nevertheless, it is possible that erosion heterogeneity in uplifting landscapes leads to time lags between mean uplift, erosion and weathering, without contradicting the fact that erosion does enhance weathering. We explore this possibility by using a 3D land- scape evolution model applied to a synthetic surface with different uplift and climate scenarios. Although we do not strictly simulate the weathering outflux of the mountain, we analyze the weathering response through the evolution of the mountain-mean saprolite production rate and compare it to the mountain-mean erosion rate through time. The parametrical analysis shows that the temporal relationship between mean erosion and saprolite production rates depends mainly on the ratio of the maximum saprolite production rate and the uplift rate wm/U. When wm/U > 1, which corresponds to mountain ranges under hot and humid climate, mean erosion and sapro- lite production rates vary at the same rate during uplift and after, once the uplift is stopped. When the uplift is stopped, mean saprolite production rate decreases monotonically, although locally, saprolite production rates pass by maxima. These maxima occur at different times, which produces a mono- tonic decrease at large scale. When wm/U < 1, which corresponds to most of the mountain ranges at mid-latitudes, mean production rate peaks early and then remains constant, while erosion keeps on increasing and reaches a steady-state $\sim$10 Myrs later. When uplift is stopped, erosion and saprolite production rates decrease also at different rates with time lags of millions years in model time. These results illustrate that a causal relationship be- tween erosion and saprolite production can lead to asynchronous evolutions of their mean values at the global scale. Furthermore, the model suggests that the weathering of large flat continental surfaces may be considered in the geological carbon budget because their size may compensate for their low weathering rate.