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Co-evolution of climate and topography

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In considering the response of landscapes to climate change it is interesting to note that topography exerts a strong influence on spatial variability in climate and that, even in the absence of external drivers of climate change, topography and regional climate evolve together over timescale of thousands to millions of years. Spatial variability in precipitation is a common feature of mountain climates. Measurements and models of orographic precipitation document persistent precipitation gradients of 150-500% over spatial scales of 5-30 km. These precipitation gradients are shaped by topography, and, because precipitation fundamentally affects the ability of rivers and glaciers to erode, these same precipitation gradients directly influence topographic development.

A coupled model of landscape evolution and orographic precipitation is used to explore the co-evolution of climate and topography under a range of climatic conditions. The CASCADE landscape evolution model simulates fluvial erosion with a threshold slope condition over a uniformly uplifting surface. Modeled climates vary in the moisture availability (wetter vs. drier on average) and in the delay time from condensation of water vapor to precipitation hitting the ground. Short delay times are interpreted to represent the fast fallout of rain with longer delay times simulating slower-falling snow.

In the case of a dominant wind direction, an asymmetric topography and a rain shadow develop. Both moisture availability and delay time influence the strength of the rain shadow and the extent of divide migration away from the wet windward side. In cases with no preferred wind direction, moisture availability controls the mean elevation and precipitation of the steady-state climate and topography. Delay time controls the peak elevation, hypsometric integral, channel concavity and ridge-valley relief in these same cases. These results indicate that in addition to the clear impact of precipitation

amounts on topography, spatial patterns of precipitation – which are controlled by delay time – also strongly influence topography. A transition from a rain-dominated to a snow-dominated climate is predicted to decrease peak elevation and channel concavity. This behavior is simply due to a shift in the spatial pattern of precipitation and lacks consideration of a transition from fluvial to glacial erosion. More study of the climatic controls on spatial patterns of precipitation is needed to understand the links between climate and topography at sub-mountain range spatial scales.