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The Importance of Long Wavelength Processes in Generating Landscapes

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The processes responsible for generating landscapes observed on Earth and elsewhere are poorly understood. For example, the relative importance of long (>10 km) and short wavelength erosional processes in determining the evolution of topography is debated. Much work has focused on developing an observational and theoretical framework for evolution of longitudinal river profiles (i.e. elevation as a function of streamwise distance), which probably sets the pace of erosion in low-mid latitude continents. A large number of geomorphic studies emphasis the importance of short wavelength processes in sculpting topography (e.g. waterfall migration, interaction of biota and the solid Earth, hill slope evolution). However, it is not clear if these processes scale to generate topography observed at longer (>10 km) wavelengths. At wavelengths of tens to thousands of kilometers topography is generated by modification of the lithosphere (e.g. shortening, extension, flexure) and by sub-plate processes (e.g. dynamic support). Inversion of drainage patterns suggests that uplift rate histories can be reliably recovered at these long wavelengths using simple erosional models (e.g. stream power). Calculated uplift and erosion rate histories are insensitive to short wavelength (<10 km) or rapid (<100 ka) environmental changes (e.g. biota, precipitation, lithology). One way to examine the relative importance of short and long wavelength processes in generating topography is to transform river profiles into distance-frequency space. We calculate the wavelet power spectrum of a suite of river profiles and examine their spectral content. Big rivers in North America (e.g. Colorado, Rio Grande) and Africa (e.g. Niger, Orange) have a red noise spectrum (i.e. power inversely proportional to wavenumber-squared) at wavelengths > 100 km. More than 90% of river profile elevations in our inventory are determined at these wavelengths. At shorter wavelengths spectra more closely resemble pink noise (power inversely proportional to wavenumber). These observations suggest that short wavelength processes do not simply scale to generate the long wavelength changes in elevation. Instead we suggest that long wavelength processes (e.g. regional uplift, knickzone migration) determine the shape and evolution of nearly all topography. These results suggest that the erosional complexity observed in local geomorphic studies and the relative simplicity of erosional models required to fit continental-scale drainage patterns are not mutually exclusive. Rather that the problem of fluvial erosion is being tackled at different and probably unrelated scales.