Geophysical Research Abstracts
Vol. 13, EGU2011-5926, 2011
EGU General Assembly 2011

Topographic thresholds to atmospheric circulation patterns

Andreas Mulch (1,2), Hari Mix (3), Manfred Strecker (4), and C. Page Chamberlain (3)

(1) Biodiversity and Climate Research Centre (BiK-F), Frankfurt, Germany (andreas.mulch@senckenberg.de), (2) Institut für Geowissenschaften, Goethe University, Frankfurt, Germany, (3) Environmental Earth System Science, Stanford University, Stanford, USA, (4) Institut für Erd- und Umweltwissenschaften, Universität Potsdam, Potsdam, Germany

Reconstructing the combined effects of geodynamic and Earth surface processes and their interaction with topography and climate has become an integral part of Earth system science approaches. Terrestrial stable isotope records in particular now play an increasingly important role in recovering the effect of mountain ranges on continental precipitation patterns and ultimately the topography and relief structure of orogens. The underlying principle is seemingly simple: Orographic rainout along the windward side of mountain ranges progressively depletes the residual atmospheric moisture in the heavy isotopes of oxygen and hydrogen and creates a systematic (and recoverable) pattern of isotopes in precipitation, similar to the effect of increased continentality (i.e. the distance to the oceanic moisture source). The systematic relationship between oxygen and hydrogen isotopes in precipitation and elevation may then be used to reconstruct paleoelevation histories of mountain belts. An additional level of complexity arises from topographic scenarios, where climatic or topographic tipping points dominate the overall atmospheric circulation and weather patterns. Here we present examples from the American Cordilleras where large (and significant) changes in rates and isotopic composition of precipitation reflect sudden changes in atmospheric circulation patterns and hence changes in the isotopic composition of precipitation that are far too large and their duration too short to be the direct result of surface uplift. Rather, these very rapid changes in rainfall amount and composition reflect topographic (and possibly additional climatic) thresholds within or adjacent to the internal parts of the orogen(s) that control the overall precipitation regime.

We reconstructed the Cenozoic surface uplift pattern of western North America based on a record of more than 4000 stable isotope proxy data. This data set is consistent with along-strike Eocene north to south surface uplift, culminating in the assembly of an Eocene-Oligocene highland that may have attained 3-4 km in elevation and is therefore too young to be the direct reflection of late Mesozoic crustal shortening, thickening, and associated buoyant rise in surface elevation. More importantly, however, individual records display very rapid (<100 ka) and large (6-8‰ changes in the oxygen isotope ratios of precipitation; changes whose magnitude and rate are beyond possible rates of surface uplift as the sole driver. Similarly, oxygen and carbon isotope ratios in Neogene central Andean foreland basins document almost instantaneous shifts that are coeval with a) increased sedimentation rates, b) headward erosion and growth of the catchment area, and c) increased seasonality of rainfall at a time of proposed surface uplift in the Eastern Cordillera and the internal plateau region. Similar to the North American example, these shifts are too large and too rapid to directly reflect a surface uplift signal.

Both cases document the importance of topographic and associated regional (and possibly global) climatic thresholds and how these may have interfered at various stages of surface uplift. We conclude that in both examples topographic tipping points control the overall pattern of rates and composition of precipitation. Determining the magnitude and spatial extent of such topographic limits will require integration of spatially and temporally resolved data sets that directly feed into global and regional atmospheric circulation models.