Geophysical Research Abstracts
Vol. 21, EGU2019-1583, 2019
EGU General Assembly 2019

The role of dynamic vegetation in erosional response of semi-arid landscapes to climate change

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The interplay between the erosive power of runoff and the protective effect of vegetation against erosion shapes the landscapes. Climate change causes changes in both runoff production and vegetation cover. This delicate balance between these effects becomes more pronounced in semi-arid ecosystems due to the dependency of vegetation growth on water availability. The nonlinear character of climate-vegetation interactions in semi-arid regions challenges our interpretation of the erosional response of landscapes to past climates. To elucidate the role of climate change on sediment export, we use the CHILD landscape evolution model coupled with vegetation dynamics and surface hydrology in a semiarid Southwest US setting. Climate change is represented with two different settings. The first one is an abrupt change in climate (step change), the second one is sinusoidal change in climate. In the first setting, mean annual precipitation (MAP) is increased from 200 mm to 600 or vice versa. In the second setting MAP fluctuates sinusoidally between 200 mm and 600 mm with 100-kiloyear period. To elucidate the role of vegetation, landform evolution and erosional response were investigated for bare soil (no vegetation cover) and dynamic vegetation cases (vegetation grows as a function of available soil moisture which is dependent of given climatic state). Results show that the sediment yield is in-phase with climate forcing when the surface is bare, and therefore an increase in precipitation leads to higher runoff production and higher sediment export. However, when vegetation dynamics is driven by climate, sediment production becomes out-of-phase with climate. In this case, erosion increases during dry periods and topography builds up during wet periods. This reversed behaviour is driven by the protective effect of vegetation cover that increases (decreases) due to vegetation growth (loss) during the wet (dry) periods, counteracting the contribution of increased (decreased) erosion due to runoff production. The comparison between given climate change models reveals that the tempo in the landscape response to sinusoidal climate forcing leads topography closer to the dry state for bare soil case. On the other hand, in dynamic vegetation case, landscape is in close to dynamic equilibrium for both forcing.