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Climate-driven versus tectonic-driven asymmetry of an orogenic wedge under high precipitation conditions: an axample from the northern Andes

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We studied the Eastern Cordillera of the Northern Andes, a two-sided orogenic wedge that in cross-section shows a symmetrical doubly verging tectonic style with an asymmetric topographic profile. This dichotomy between tectonic symmetry and geomorphic asymmetry is not unique among active orogens in the world. However, this mountain belt is a good place to examine and quantify the influence that a strong precipitation gradient may cause in uplift and erosion rates and how it can modify the cross sectional geometry and the tectonic evolution of this cordillera.

Although there are many studies addressing the influence of climatic factors in the large-scale morpho-tectonics of active orogens, there are still questions about the models coupling tectonic and surface processes. One of the biggest hurdles is estimating the climate signature in the landscape and tectonic models. Among the conditions that make this estimation difficult is the high complexity of climate systems and determining the geologic longevity of current climate patterns. However, over relatively short time spans and in places where mountain ranges are high enough to modify climate patterns we can assume that a steady-state condition is valid for a tectonic – surface process model. In our study across the Eastern Andes present climatic conditions show an east-west precipitation gradient that in places may range from 8 m/yr to 2 m/yr. If these climatic conditions have remained similar since the last stage of Andean uplift then we can assume steady-state condition for the present tectonic-geomorphic-climate feedbacks in this cordillera, and that the dichotomy between the tectonic style and the topographic profile is not transient.

Our study compares the spatial distribution of geomorphic indices with mapped faults and strain distributions derived from earthquake and geodetic data. In our geomorphic analyses we use a combination of high resolution Tropical Rainfall Measurement Mission (TRMM) and Shuttle Radar Topography Data (SRTM 30 and 90) to characterize how basic (elevation, relief, slope) and derived (steepness, circularity, curvature) landscape characteristics correlate with precipitation patterns. At a regional scale we found that the eastern side retro-wedge developed a higher, steeper topography that corresponds to higher precipitation. The western pro-wedge is not as homogeneous in its topographic distribution. In the southern end of the pro-wedge, lower precipitation correlates with smaller relief and gentler slopes. However, in the central and northern part, lower precipitation correspond to areas of deep, incised valleys with high relief and steeper slopes.

Average channel steepness is in general much higher in the retro-wedge (east) than in the pro-wedge (west). Nonetheless, in both sides of the orogen river profiles of big streams (10e7 square meters area catchments) are always segmented by major knick points. Knick points are usually aligned parallel to the trend of the orogen, with the average relief of every knick point being much higher in the east than in the west. In contrast, alignments of knick point across basins are much longer in the west than in the east. Knick points seem to be aligned along major faults and folds, with knick points in the west following long structures and knick points in the east aligning with shorter structures.

These distribution of steeper areas and knick points partially coincide with short term strain maps that show elongated high strain concentrated along the frontal folds and faults of the pro-wedge, whereas in the retro-wedge areas with higher strains are clustered and do not always correspond to the frontal fault/ folds. In the middle of the orogen, low-strained areas correspond to low steepness in the high interior plateau. Areas showing high steepness, but not high strain are present along the rivers incising into the northern end of the central plateau.

In summary, we found that along the retro-wedge higher precipitation correlates with stronger distributed deformation and overall intense denudation in this side of the orogen. In the pro-wedge lower precipitation does

not always correlate with the degree of deformation and the intensity of denudation. The highest steepness in this flank correspond to the higher strain areas in the frontal fold/fault where in general precipitation is the lowest. The rougher topography to the north side of the pro-wedge seems related not to changes in precipitation with respect to the southern end, but to the deep incision and southern migration of channel heads into the central interior plateau.