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# Role of carbon and climate in forming the Páramo, an Andean evolutionary hotspot

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According to a number of genetic diversification measures the Páramo grasslands of the high equatorial Andes show the greatest rates of speciation on the planet. This is probably driven by contrasting ranges of the ecosystem between glacial and interglacial periods of the Pleistocene. During the warm interglacial periods the treeline is high in the Andes restricting the Páramos to the highest regions of the Andean mountain chain, while in the cool glacial periods the Páramo areas expand and probably coalesce, bringing isolated populations into contact with each other. The origin of the Páramo ecosystem is placed close to the end of the Pliocene and has been related to the finale of regional Andean mountain building. However, this formation date is also coincident with the global cooling at the end of the Pliocene, as Northern Hemisphere glaciation and the bipolar Pleistocene ice ages begin. Furthermore, it is estimated that atmospheric $CO_2$ concentrations dropped from the 400 ppmv typical of the Pliocene to values more typical of the Pleistocene at around this time.

Global climate model simulations, coupled with a high resolution biome model, give us the opportunity to test these competing hypotheses for the formation of the Páramo ecosystem. A series of HadCM3 climate model simulations are presented here varying the height of the highest altitude Andes and the global climate from its pre-industrial state to the Pliocene. The climate are topographic changes are varied both independently and together. These climatologies are then used to drive a high-resolution biome model, BIOME4, and simulate the impact on Andean vegetation. These models seem to reproduce the observed changes in high altitude grassland biomes during the Pliocene.

The climate and biome modelling presented here show that the climate changes associated with the Plio-Pleistocene boundary are the primary cause of the initial formation of this unique and important ecosystem. Although the reduction of the highest altitude Andean regions reduces the available area for grassland biomes, the effect is significantly smaller than the impact of Plio-Pleistocene climate change. By individually introducing the Pliocene changes (atmospheric carbon dioxide levels, mean temperature, minimum temperatures, precipitation and direct sunlight) to the BIOME4 simulations, it is shown that the primary driver of these changes is atmospheric carbon dioxide levels. The higher Pliocene levels favour the expansion of the forest biomes, increasing the altitude of the treeline and replacing grassland biomes. This suggests that in such areas prediction of future changes and plans to preserve these important ecosystems must consider the impact of both climate change and $CO_2$ fertilization.