



Diagnosing Possible Anthropogenic Contributions to Heavy Colorado Rainfall in September 2013

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Unusually heavy rainfall occurred over the Colorado Front Range during early September 2013, with record or near-record totals recorded in several locations. It was associated predominantly with a stationary large-scale weather pattern (akin to the North American Monsoon, which occurs earlier in the year) that drove a strong plume of deep moisture inland from the Gulf of Mexico against the Front Range foothills. The resulting floods across the South Platte River basin impacted several thousands of people and many homes, roads, and businesses. To diagnose possible anthropogenic contributions to the odds of such heavy rainfall, we adapt an existing event attribution paradigm of modelling an ‘event that was’ for September 2013 and comparing it to a modelled ‘event that might have been’ for that same time but for the absence of historical anthropogenic drivers of climate. Specifically, we first perform ‘event that was’ simulations with the regional Weather Research and Forecasting (WRF) model at 12 km resolution over North America, driven by NCEP2 re-analysis. We then re-simulate, having adjusted the re-analysis to ‘event that might have been conditions’ by modifying atmospheric greenhouse gas and other pollutant concentrations, temperature, humidity, and winds, as well as sea ice coverage, and sea-surface temperatures – all according to estimates from global climate model simulations. Thus our findings are highly conditional on the driving re-analysis and adjustments therein, but the setup allows us to elucidate possible mechanisms responsible for heavy Colorado rainfall in September 2013. Our model results suggests that, given an insignificant change in the pattern of large-scale driving weather, there is an increase in atmospheric water vapour under anthropogenic climate warming leading to a substantial increase in the probability of heavy rainfall occurring over the South Platte River basin in September 2013.