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Anthropogenic signals in global and regional precipitation variability and extremes: detection and quantification of change using scaling fluctuation analysis

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Quantifying anthropogenic changes in precipitation is difficult because of a) the low ratio of anthropic (signal) to natural variability (noise), b) due to the serious divergences found between different precipitation products that reflect our limited ability to estimate areal precipitation even when averaged over decades and at global scales, and c) the standard linear trend analysis for assessing changes in precipitation is not optimal.

We suggest several ways forward based on the systematic application of scaling fluctuation analysis to characterizing different precipitation scaling regimes (weather, macroweather, climate) – for example, we find that the scales at which the anthropogenic signal exceeds the natural variability noise is roughly 20 years at global scales, 30-40 years at 5°x5° scales. Following a recent approach for estimating anthropogenic temperature changes that uses CO_2 as a surrogate for all anthropogenic forcings, we directly determine the effective sensitivity of the precipitation rate to a doubling of CO_2. We also show that the extreme probability tails of monthly precipitation are power laws with an exponent $\approx$3.6 (extreme behaviour: 4th and higher order statistical moments diverge), thus extending meteorological scale ($<\approx$10 days) characterizations of extreme precipitation into the longer macroweather regime.

Analysis of three global scale precipitation products (from gauges, reanalyses and a satellite and gauge hybrid) from monthly to centennial scales and in space from planetary down to 5°x5° shows trends with higher statistical significance than when estimated from temporal trends; further improvements are obtained by considering precipitation over the ocean where anthropogenic increases are strongest. This approach gives empirical estimates of anthropic increases in global precipitation with temperature: we find 1.71$\pm$0.62 %/K, close to that found in GCM's (2 - 3%/K) and below the value of $\approx$ 6 - 7%/K predicted on the basis of increases in humidity. We also quantify the anthropic effects regionally (5°x5°) and make multidecadal projections of precipitation rates.