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Estimation of global and regional precipitation and anthropogenic climate change using scaling fluctuation analysis

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A basic problem in hydro-climatology is to measure trends at decadal and longer scales and to distinguish anthropogenic and natural variability in the precipitation record and to quantify both as functions of scale. The fundamental framework for understanding this problem has been clarified using scaling analyses of Haar fluctuations defined by the differences of the averages of the first and second halves of an interval. This technique has shown that at scales beyond about ten days, positive fluctuations in atmospheric variables - including rain - tend to be followed by (partially) cancelling negative ones. The converging regime is called "macroweather"; however, at long enough time scales – if only from paleodata and because of the existence of ice ages – we know that macroweather gives way to climate variations where on the contrary, fluctuations increase once again with scale.

Anthropogenic changes over the last century also increase the low frequency variability so that it is hard to disentangle them from natural variability. However, as long as we are still in the scaling macroweather regime the natural variability is dominant. For precipitation, this is true for scales at least up 20 - 40 yrs: we must search for anthropogenic influences only at longer scales. This explains why the usual approaches estimating precipitation trends using only 10 year segments are statistically significant. Similarly, the usual approach uses precipitation data on grids (e.g. the Global Historical Climate Network, GHCN at 5ºx5º, from 1900) estimated from station precipitation series with much higher resolutions. From the space-time scaling properties of precipitation, this leads to a serious mismatch in scales; and can explain the large difference in monthly precipitation fluctuation amplitudes (a factor 2.228) for the GHCN estimates compared to the 20th Century Reanalysis (20CR, at 2ºx2º, since 1871).

We have recently shown that anthropogenic effects can be estimated by using the CO_2 radiative forcings as a surrogate for all the anthropogenic effects. This is quite accurate and works because due to economic activity, the anthropogenic effects are highly correlated. We find that over the oceans and for a CO_2 doubling, we can ascribe 4.5 ± 1.9, 9.8 ± 3.1 mm/month ($\approx$5, 10%) of increased rain rate (depending on whether we relate the precipitation to the forcing without a time lag or with a 20 year time lag respectively). Over the period 1900-2005, these values correspond to 1.73 ± 0.72, 3.73 ± 1.16 mm/decade of annual increase. This is not only larger than the (land only) IPCC estimate (1.08 ± 1.87 mm/decade of annual precipitation for the GHCN data), but unlike the IPCC estimate it also shows a statistically significant trend.

These issues are examined in a regional context using long precipitation station data, with the help of spatial scaling properties. We discuss the implications.