CORRESPONDENCE:

Wetter then drier in some tropical areas

To the Editor — Projected changes in precipitation are generally assumed to be monotonic with respect to global temperature changes: rainfall will either increase or decrease as the climate warms. However, using an example in South America, we demonstrate that, under a high emissions scenario, rainfall changes in some regions can actually be non-monotonic, which has important implications for biodiversity, the carbon cycle and long-term climate policy.

The latitudinal position of the Intertropical Convergence Zone (ITCZ) is projected to move equatorwards in response to a warming climate[1–3], although there is uncertainty as to how far and how fast. As it moves, some low-latitude regions may find that the rainfall they receive first increases in accordance with the 'wet get wetter' paradigm, but then decreases as the ITCZ moves over and past them; such regions will experience non-monotonic changes in precipitation with time. We examine this phenomenon using multi-centennial projections of precipitation from different global climate models (GCMs) (see Supplementary Information).

According to the models, non-monotonic changes in precipitation are pronounced over the oceans after the year 2100 — especially in the tropical Atlantic (Supplementary Fig. 1) and Pacific — but they also occur over land regions where impacts on infrastructure and ecosystems will be far more significant. As an example, several GCMs display evidence of non-monotonic changes for tropical South America (Fig. 1). Specifically, several simulations suggest an increase in precipitation near latitude 5° N until the year 2100, followed by a decrease. In contrast, temperatures exhibit a monotonic increase in this region (Supplementary Fig. 2).

Interestingly, the two finest resolution models available (HadGEM2-ES and NCAR CCSM4) show clear non-monotonic precipitation signals, suggesting that the effect may be somewhat dependent on model resolution. However, IPSL-CM5A-LR also shows a similarly clear signal. In any case, this effect would be overlooked by simply averaging a multi-model ensemble. Uncertainties in precipitation projections for the next century on regional spatial scales are dominated by model response uncertainty and internal climate variability, rather than emission scenario uncertainty[4].

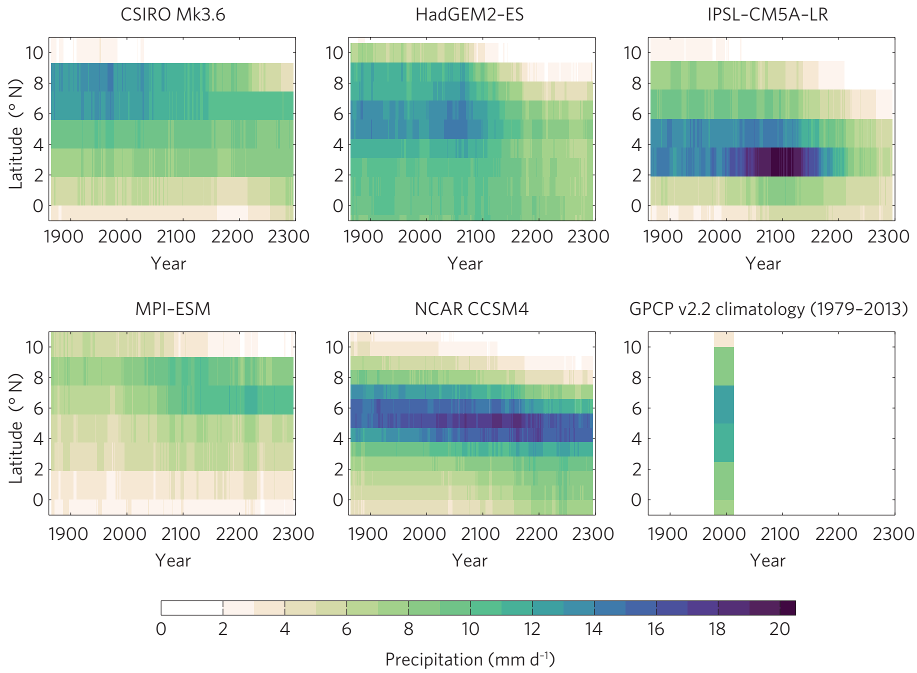

Figure 1 | Non-monotonic precipitation projections. Simulated precipitation for boreal summer (determined from running decadal means for June, July and August) averaged over land regions in northern South America (80° W–65° W) from five global climate models using the historical (1860–2005) and RCP8.5 (2006–2300) forcing pathways. A climatological estimate from the GPCP v2.2 observations[12] for 1979–2013 is shown for the same region (bottom right).

The region identified in Fig. 1 is a biodiversity hotspot with several "irreplaceable protected areas"[5], and is home to many threatened species (including terrestrial mammals, amphibians, birds and plants[6]), all of which may be directly or indirectly sensitive to changes in precipitation[7,8]. For instance, an eventual reduction in precipitation could result in accelerated decreases in net primary productivity (NPP) and vegetation cover in regions where NPP is already projected to decrease during the twenty-first century[9], whereas it could cause non-monotonic changes in NPP elsewhere. Profound and surprising changes in local habitats, as well as changes in both the local and global carbon budgets during the twenty-first century[10] could therefore be driven by non-monotonicity in precipitation change.

Evidence for non-monotonically changing climate variables exists in climate model projections for tropical South America. Many projections of impacts and vulnerabilities resulting from climate change, such as those produced by integrated assessment models[11], can be expected to fail to capture the type of dynamic effects described here, especially if they are based on linear regressions, pattern scaling or snapshots of future patterns of change at a specific point in the future (such as the year 2100). Decision makers should be aware that long-term changes may oppose or even reverse near-term changes, driving potentially unexpected impacts in some of the most unique and irreplaceable habitats in the world. ❐

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Additional information

Supplementary Information is available in the online version of the paper.

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CORRESPONDENCE:

A note of caution about the excess winter deaths measure

To the Editor — The Letter by Staddon *et al.*[1] draws the emphatic conclusion that "climate warming will not decrease winter mortality" based on an analysis of the determinants of annual excess winter deaths (EWDs) — a measure derived by considering the number of deaths occurring during the period December–March compared with other periods during the year. Although there is value in characterizing interannual variations in cold-risk, to attempt this using EWDs is flawed as it is an inappropriate metric with which to draw conclusions about weather-related health impacts associated with either current or future climate.

As the authors report, not all EWDs are due to cold weather; but it is also the case that not all deaths due to cold weather are restricted to these four months. Cold-related deaths also occur on days with moderate temperatures falling outside this period, and these deaths bias the EWD measure because they unavoidably contribute to the comparison months in the calculation. Owing to the greater frequency of moderate temperature days, the number of cold-related deaths associated with these days is far from small — for example, in London over 70% of all cold-related deaths occur on days warmer than 5 °C, based on models adjusted for seasonal factors[2]. The calculation of EWDs is also sensitive to unusual mortality patterns occurring at other times of the year; this is particularly pertinent for any statements about future climate change because increasing heat-related deaths in the summer months would mean that a winter mortality index ostensibly reduces even if the true winter burden remains the same. Furthermore, winter and summer burdens may not be independent[3].

For these reasons, epidemiologists use more sophisticated techniques that account for seasonal factors and quantify the specific contribution of weather variables, rather than a seasonal excess. There may have been some confusion about this distinction, as Staddon *et al.* quoted studies that did not assess EWDs[4,5], incorrectly stating that they did. The authors also note similarities in EWDs across regions, although regional differences in cold-related risk are well established[6]. Typically, day-to-day associations are analysed using these epidemiologic methods, but for sufficiently long series the analysis can be applied to annual data to assess longer-term impacts. So, for a credible assessment of changes in population response to cold over time, quantification of cold-specific risk for each year being studied is needed rather than calculations of EWDs — analysis of the latter shouldn't be used to draw conclusions about the former.

Studies analysing relatively recent data confirm that most of the seasonal excess in mortality is related to cold, with a smaller component attributable to influenza and other factors[7]. Moreover, empirically-based assessments of future climate change impacts for the UK, which consider specific characterizations of cold-risk, project a reduction in future cold-related health burdens due to milder winters[8–10]. Indeed, a look at the supplementary material of a more recent *Nature Climate Change* Letter reveals the same finding[11]. Climate change is an important public health challenge for the UK and elsewhere and policymakers need to be informed by the best available evidence on the probable harms and benefits to human health. ❐

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