CORRESPONDENCE:

Opposing local precipitation extremes

To the Editor — Increases in atmospheric temperature are expected to result in a greater intensity of extreme precipitation in most mid-latitude land masses[1,2]. It is increasingly acknowledged that the changing intensity of extreme precipitation will depend on the geographic location[1]; here we identify a mechanism that can cause very different — or even opposing — trends at the same location.

Precipitation trends in the Greater Sydney region were investigated using 69 rainfall gauges (Supplementary Fig. 1) with sub-daily records from 1966–2012, for durations from 5 minutes to 48 hours. The focus was on trends in annual and seasonal maxima, which are commonly used as the basis for understanding flood risk[3]. The analysis was conducted using a non-stationary extreme value model[4] and the average extreme precipitation trends across all sites are presented. Statistical significance was assessed using a resampling approach[5].

Annual maximum precipitation increased in intensity for durations less than two hours (Fig. 1). Trends were statistically significant (10% significance level) at a rate of 6.5–8.0% per decade for durations of 15 minutes or less. Conversely, precipitation extremes with timescales greater than 3 hours decreased, although only the 12-hour storm-burst duration was statistically significant.

Compared with the annual maximum results, summer extremes exhibited greater increases across all timescales, with statistically significant upward trends for durations of 15 minutes or less and 6 hours or greater. In contrast, autumn and winter decreased over all timescales, with statistically significant autumn decreases for durations of two hours or longer. No apparent changes could be observed during spring for any timescale. These seasonal features are largely consistent with climate modelling projections of seasonal average rainfall in this region[6,7].

The differing trends in annual maximum precipitation for different durations can be explained by the role of the season in which the annual maximum event takes place (Fig. 2). Approximately 50% of the sub-hourly precipitation extremes occurred in summer, reducing to 28% for 48-hour storms. Longer extreme precipitation events were more likely to occur in autumn and winter. Combining Figs 1 and 2, we deduce that the significant increases in the intensity of annual precipitation extremes at short durations are largely contributed by the upward trends in summer storms, while the downward trends of extreme precipitation in autumn and winter exert a stronger influence on annual maximum precipitation intensity at longer timescales.

These findings build on an expanding body of work highlighting the important role of storm-burst duration on the magnitude of changes in extreme precipitation[2]. Recent research on this topic has focused on the contribution of mechanism that triggers the extreme precipitation, with the intensity of

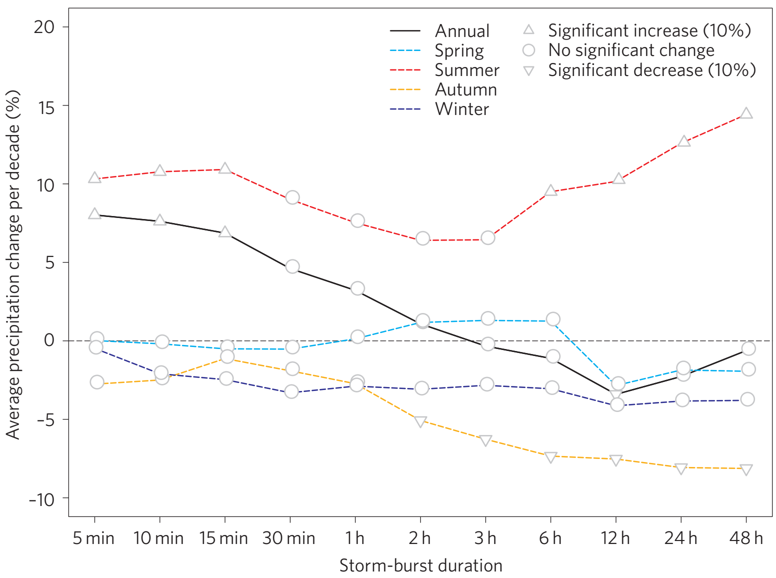

Figure 1 | Average decadal changes in precipitation for the Greater Sydney region over 1966–2012. Note the nonlinear *x*-axis scale.

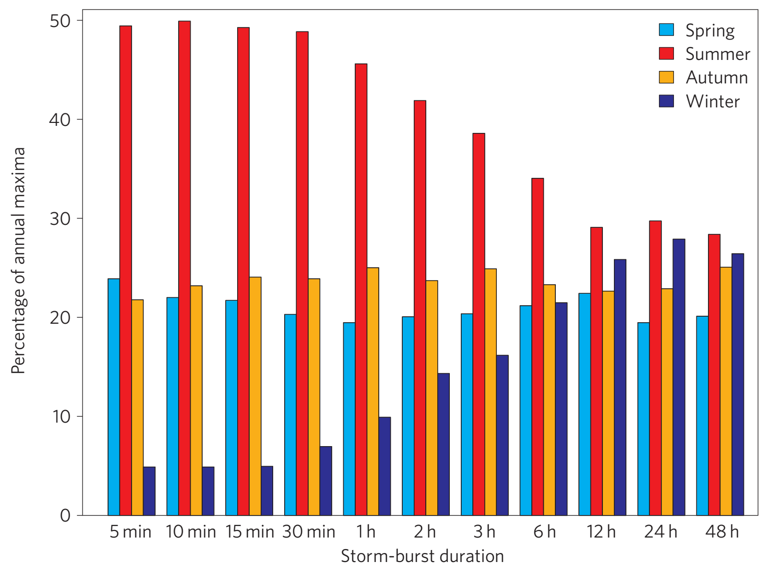

Figure 2 | Seasonal distribution of annual precipitation maxima averaged over 1966–2012.

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convective precipitation likely to increase more rapidly than stratiform precipitation[8,9]. However, other changes — such as shifts in large-scale circulation patterns — may have different responses to climate change in different seasons[10], and this can also influence trends in extreme precipitation intensity, as observed here. Simulating the combined effect of all of these processes remains a major challenge in climate modelling. Although some recent modelling studies have emphasized sub-daily precipitation[11], more work is needed to understand the dominant processes that govern changes in extreme precipitation at both short (sub-daily and sub-hourly) and long timescales.

Given the fundamental relationship between catchment size, the duration of an extreme precipitation event and flood magnitude[12], the finding that extreme precipitation is changing at different timescales has potentially surprising implications for flood risk. Our results show that different or even opposing trends in flood risk are possible within a single geographic region, such as neighbouring catchments of different sizes, or even smaller sub-catchments within the same larger basin. This will be of interest to those involved in land-use planning, water infrastructure design (for example dams, levees, bridges and storm-water drainage networks), floodplain management, emergency response, as well as to the insurance industry. ❐

References

1. Boucher, O. *et al.* in *Climate Change 2013: The Physical Science Basis* (eds Stocker, T. F. *et al.*) Ch. 7 (IPCC, Cambridge Univ. Press, 2013).
2. Westra, S. *et al. Rev. Geophys.* **52,** 522–555 (2014).
3. Field, C. B. *et al.* (eds) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (IPCC, Cambridge Univ. Press, 2012).
4. Westra, S. & Sisson, S. *J. Hydrol.* **406,** 119–128 (2011).
5. Westra, S. *et al. J. Clim.* **26,** 3904–3918 (2013).
6. Delworth, T. L. & Zeng, F. *Nature Geosci.* **7,** 583–587 (2014).
7. *Summary of Climate Change Impacts Sydney Region* (Department of Environment and Climate Change New South Wales, 2008); http://www.environment.nsw.gov.au/resources/climatechange/08519Sydney.pdf
8. Lenderink, G. & Van Meijgaard, E. *Nature Geosci.* **1,** 511–514 (2008).
9. Berg, P., Moseley, C. & Haerter, J. O. *Nature Geosci.* **6,** 181–185 (2013).
10. Grose, M. *et al. Clim. Dynam.* **39,** 445–459 (2012).
11. Kendon, E. J. *et al. Nature Clim. Change* **4,** 570–576 (2014).
12. Brutsaert, W. *Hydrology — An Introduction* (Cambridge Univ. Press, 2005).

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Additional information

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

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CORRESPONDENCE:

IAMs and peer review

To the Editor — Integrated assessment models (IAMs) have provided the bulk of the evidence relied on by prominent documents — such as the Stern Report[1] and the contributions of Working Group III to the IPCC Assessment Reports[2,3] — as well as numerous research articles on the economics of climate change mitigation and related issues. I am concerned, however, that many published IAM-based research articles fail to adequately explain the basis for their findings, and do not justify these findings carefully based on sound scientific and logical argumentation, analysis, and data presented in the article itself (or in published appendices). Often the details of how the IAMs were used to derive the basic results are not described, meaning that reviewers cannot credibly assess the reliability of the results.

One major flaw of most, if not all, peer reviews of IAM-based research reports is that the models relied upon have not been reviewed in themselves. And yet such articles cannot be adequately reviewed without carefully critiquing the underlying models. All too often the original models, and subsequent versions, have never been formally peer reviewed publicly. Due to these shortcomings, even the recent 'model intercomparison projects'[4] are, I would argue, of limited value.

Because economics claims to be a science, and because economists have developed many different IAMs, peer reviewers of IAM-based research articles should, in my view, assess: (1) the theory behind each model in light of model's intended purpose; (2) the structure of the model to determine if the theory was properly implemented; (3) the way in which various structural parameters were estimated based on historical data; and (4) the way in which the values of various input parameters were estimated or derived, especially those for the future. The last point is a particular problem because many IAM-based studies involve very long-term, multi-decadal projections. In addition, I believe that peer reviewers must especially assess how the model is being used in relation to the particular research questions being addressed, and what sensitivity analyses have been performed that might illuminate the answers to these questions. If any of these steps are skipped, then confidence in the reported findings is reduced. Of course, if some of these steps have been undertaken for previously published articles using the same IAM, and if the model has not significantly changed since these reviews were completed, then some of the above steps could be deemed to be complete prior to the current review. It would be helpful in this regard if past reviews of the particular IAM were made available in some format. But this is almost never done.

In 2013, the IAM Consortium — which was set up at the request of the IPCC after the Fourth Assessment Report and of which I am a member — set up scientific working groups intending to establish community-wide standards on IAM documentation and the inclusion of key input assumptions in research publications. There has been little or no progress since. It is my contention that this situation should be rectified, so as to usher in a new era for peer reviews in this field. ❐

References

1. Stern, N. *The Economics of Climate Change – The Stern Review* (Cambridge Univ. Press, 2007).
2. IPCC *Climate Change 2007: Mitigation of Climate Change* (eds Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. & Meyer, L.A.) (Cambridge Univ. Press, 2007).
3. IPCC *Climate Change 2014: Mitigation of Climate Change* (eds Edenhofer, O. *et al.*) (Cambridge Univ. Press, 2014).
4. Rosen, R. A. *Technol. Forecast. Soc. Change* http://dx.doi.org/10.1016/j.techfore.2015.01.019 (2015).

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