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PROJECTION AND PREDICTION: Local noise and global confidence

Markus G. Donat

Analyses of changes in climate extremes at the local scale are affected by large uncertainties related to climate variability. Now research finds that integration over larger areas reveals consistent intensification of heat and precipitation extremes in projections of the near future.

Climate extremes often have the most severe impacts on society, infrastructure and ecosystems. In a warming world, the question of how extreme climate events might change over the coming decades is of high importance for decision-makers to develop and implement adaptation strategies. However, climate projections are characterized by large uncertainties. These uncertainties come from several sources, including imperfect models, internal variability of the climate system and the unknown future of anthropogenic forcings such as greenhouse gas emissions. Uncertainties are particularly large at regional scales¹. In this issue of *Nature Climate Change*, Erich Fischer and colleagues² report that climate variability is the dominant contributor to uncertainty in near-term projections of extremes at the local scale. Although this source of uncertainty is irreducible, robust information about changes in climate extremes over the coming decades can be obtained by averaging over larger spatial scales.

Changes towards more intense heat and heavy precipitation extremes have been observed globally³ (Fig. 1) and are expected to continue over the coming century⁴. Although there is little doubt that these climate extremes will intensify in the longer term^{4,5}, stakeholders and decision-makers often express the need for reliable information on near-term changes. However, climate projections for the next few decades are strongly affected by the internal variability of the climate system, and this may mask long-term trends on decadal timescales¹. Internal variability refers to natural fluctuations within the climate system that occur without any external forcing — the most prominent of which is probably the El Niño/Southern Oscillation (ENSO), which influences the climate in many regions of the world.

Climate projections are commonly produced using computer models that simulate the different physical components of the climate system. All models simulate a particular climate variability, reproducing the characteristics of the Earth's climate with differing success. The state of the climate within the model-specific variability is further determined by the initial conditions of each model simulation. This means that our 'actual climate' is just one possible realization, but climate models represent alternative physically plausible evolutions. Large ensembles of climate model simulations — such as the Coupled Model Intercomparison Project Phase 5 (CMIP5), which forms the basis for statements about future climate changes in the most recent assessment by the Intergovernmental Panel

on Climate Change (IPCC)⁵ — sample a number of known uncertainties and thus indicate a range of possible future evolutions of the climate⁶.

In their study, Fischer and colleagues² demonstrate that projections of extreme annual temperatures and heavy precipitation over the next few decades are associated with very large uncertainties locally. They show that these uncertainties primarily result from internal climate variability. This implies that the uncertainties would persist at a similar magnitude even if a perfect climate model (which captures all aspects of the climate system) were available. The occurrence of daily extremes is particularly sensitive to variability on seasonal to decadal timescales⁷. Fischer *et al.* also argue that the uncertainty induced by internal variability chiefly affects the specific location where certain changes in extremes occur — that is, whether in one particular model grid box or a nearby location. This means that the uncertainty in the magnitude of change decreases when larger regional averages are considered. They show that large fractions of the land area will experience significant increases in annual maximum temperature values and intensity of heavy precipitation over the coming decades. Robust near-term changes can also be identified for large individual countries and at the continental scale.

These results illustrate that it will not be possible to provide the information on local near-term changes in extremes that would be desirable to local stakeholders. However, useful and robust information can be provided for larger areas. The authors employ an analogy to a city: it is not possible to predict the time and location of the next traffic accident, although it is certain that accidents will occur — it thus makes sense to have an ambulance prepared. For climate change adaptation, this means that strategies should cover larger areas (similar to an ambulance station, which is usually responsible for a larger district rather than just the street in which it is located).

Fischer and colleagues base their study on an ensemble of climate simulations that only vary in small random disturbances in the initial atmospheric conditions and evolve differently thereafter. This is slightly different from the experimental design in the model intercomparison initiatives used for the IPCC assessments, for example, where internal variability is addressed by running climate simulations from different initial states of the climate system that represent large-scale modes of variability (including ocean variability). One might argue that this would be a more physical way to account for different phases in internal climate variability, however the ensemble of their atmospheric initial conditions seems to cover a reasonable range of variability.

Assuming that climate variability is realistically reproduced, the study by Fischer and co-workers gives a clear indication of what kind of information on near-term changes in climate extremes is achievable. The results suggest that stakeholders and decision-makers will have to think on larger spatial scales and be prepared to deal with probabilistic information. Alternatively, regional information on near-term changes may also be obtained from so-called initialized decadal

predictions⁸, which are constrained to the real world's climate state within variability. That is, if these predictions prove skilful at the local scale.

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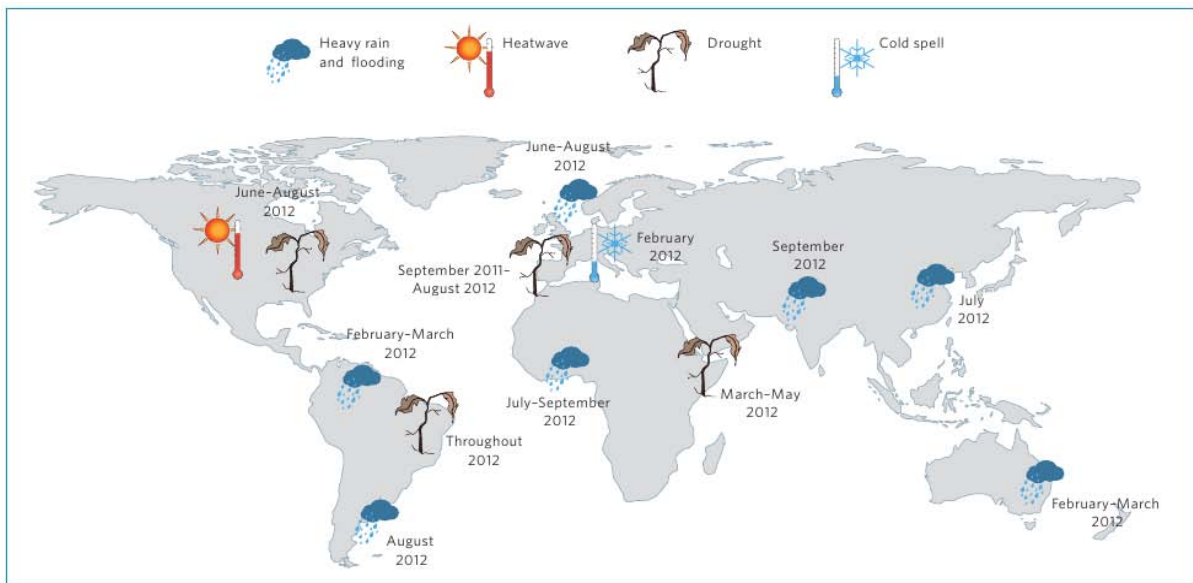


Figure 1: Significant extreme temperature and precipitation events that occurred in 2012. These events are described in refs. 9,10. Fischer and colleagues² suggest robust trends of intensification in both heat and precipitation extremes in the near future over the globe, although it is not possible to predict exactly when and where the extremes will occur.