CLIMATE CHANGE

Tropical extremes

Climate model projections of future precipitation extremes in the tropics are highly uncertain. Observations of year-to-year variations in extremes of present-day climate help to narrow down these projections to a rise in extreme rainfall by 6–14% per °C of warming.

Geert Lenderink

Precipitation extremes are expected to increase with global warming. The atmosphere can hold about 6–7% more water vapour per °C of warming before saturation occurs[1], potentially allowing more water to accumulate into a downpour. This dependency follows from basic atmospheric thermodynamics, and is termed the Clausius–Clapeyron relation. To first order, changes in precipitation extremes might be expected to follow Clausius–Clapeyron scaling[2]. However, ample evidence for deviations from this relationship has emerged[3–5]. Writing in this issue, O'Gorman[6] found that the huge range — between close to zero and 25% per °C of warming — of changes in tropical precipitation extremes projected by global climate models can be constrained substantially by using present-day observations.

Narrowing down the uncertainty range in climate model projections with the help of observations is an important challenge in climate research. Obviously, it makes sense to weight model results according to the model's ability to represent pertinent aspects of the observed present-day climate[7,8]. However, such an evaluation of simulations is far from trivial: it is often difficult to identify clear links between the response of a model to enhanced greenhouse gas forcing and its skill in simulating present-day climate. For instance, a model whose simulations of the present-day climate are close to observations may well contain a set of errors that compensate each other today, but may strongly distort the response to climate warming as the balance between errors changes.

In a more sophisticated approach, observations of climate variability (rather than of the climate itself) have been used to constrain projections, for example of the snow albedo feedback[9] and climate sensitivity[10]. This approach usually works in two steps: first, a relationship is established that holds across the models, between an observed variation in the present-day climate (on seasonal or interannual timescales) and the climate change signal. Second, using this relationship provided by the model simulations, observations of present-day variability are translated into information on climate change.

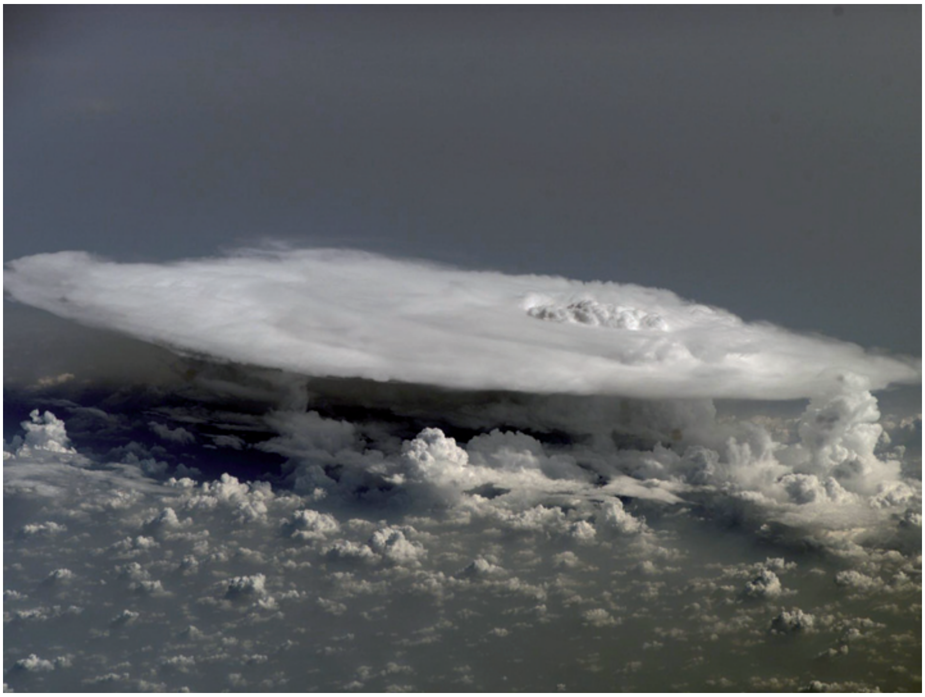

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Figure 1 | Tropical convective cloud. O'Gorman[6] uses observations of present-day interannual variability and climate model simulations to estimate that tropical rainfall in extreme events — usually associated with these convective clouds — will rise by 6–14% per °C of climate warming.

O'Gorman[6] approached the problem of projecting tropical precipitation extremes from this more sophisticated angle. He investigated precipitation extremes in a large number of state-of-the-art global climate model simulations. Noting from these simulations that changes in precipitation extremes between today and the end of the twenty-first century vary in broadly similar ways to their changes between cold and warm years, O'Gorman explores ways to bound the uncertainty range using observations.

In the tropics, this interannual temperature variability is primarily determined by the El Niño-Southern Oscillation (ENSO). From his analysis of the model simulations, it turns out that models with a strong response of precipitation extremes to ENSO variability also have a strong response of these extremes to global warming, and vice versa. On average, the sensitivity to a given temperature rise in a changing climate is approximately 30–40% of the sensitivity to the same temperature rise if it occurs within interannual variability. With the help of this relationship, the observed sensitivity of precipitation extremes to variability derived from satellite observations can be translated into a sensitivity to climate warming. In this way, O'Gorman arrives at a range of 6–14% per °C — a much narrower range than the raw model output.

O'Gorman finds no apparent change in the spread of the model projections between the older simulations from the third phase of the Climate Model Intercomparison Project (CMIP3) and the follow-up CMIP5 simulations that were largely prepared over the past two years for the next Intergovernmental Panel on Climate Change report. It could be considered disappointing that the model predictions are so uncertain, and that there is so little convergence in the results as the climate models are becoming more sophisticated.

Rainfall formation is strongly affected by vertical air motions, whose evolution in a changing climate is particularly poorly constrained in the models. Rising air cools, leading to condensation if the air is sufficiently moist, cloud formation and eventually to precipitation. The precipitation rate is roughly proportional to the amount of water vapour in the near-surface air, multiplied by the strength of the vertical motion. Much of the inter-model spread in the tropics can be accounted for by differences in the response of the vertical motions to climate change[5]. A large part of the vertical motions in the tall, tower-like convective clouds (Fig. 1) that are responsible for most extreme precipitation in the tropics is, however, not explicitly simulated in the climate models with their coarse grids. Instead, models express the effect of convective clouds — such as the amount of moisture going up and the rate of precipitation — by a number of simplified and rather uncertain rules called parameterizations.

The spatial scale of the simulated extremes in present-day climate models, and therefore in O'Gorman's analysis, is coarse, on the order of 300 by 300 km^2. Observations are often not available at higher resolution, either. In many user applications, information on precipitation extremes at smaller spatial and temporal scales is required, and scale dependencies of precipitation extremes are likely to exist[1,4].

O'Gorman's results[6] show how observations can be used to constrain model projections of tropical precipitation extremes. Nevertheless, good quality high-resolution observations, higher-resolution climate models, and improved understanding of small-scale processes in the atmosphere, are still required for further progress. ❐

Geert Lenderink is at the Royal Netherlands Meteorological Institute, PO Box 201, 3730 AE De Bilt, the Netherlands.
e-mail: lenderin@knmi.nl

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