CLIMATE CHANGE

Dichotomy of drought and deluge

Freshwater deficits and heavy rainfall have been projected to intensify in a warming climate. An analysis of hydrological data suggests that past changes in wet and dry extremes were more complex than a simple amplification of existing patterns.

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Severe drought conditions across California over the past year have led to wildfires and the restriction of water-use. At the same time, parts of Europe were affected by flooding and infrastructure damage from torrential, and at times sustained, rainfall. These impacts of unusual weather patterns underscore the precarious nature of societal reliance on just the right quantity of water: not too much at once, not too little over a few seasons. Climate model projections for the twenty-first century suggest that wet regions will generally experience more and heavier rainfall, whereas many arid parts of the planet will dry out further as the Earth warms[1]. However, writing in *Nature Geoscience*, Greve and colleagues[2] suggest that it is premature to apply this simplified expectation to data from the past six decades. They find that only about 11% of the global land area has followed this 'wet get wetter, dry get drier' pattern since 1948.

Extremes of weather are generated randomly by the fickle nature of the complex, interconnected system that links Earth's atmosphere, oceans and land surface. Yet basic physics also determines how these extremes may evolve in a warming world. Most of the water in the air exists in its invisible gaseous form, water vapour, which provides the fuel for precipitation including rain, snow and hail. As atmospheric temperatures rise, the concentration of water vapour in the atmosphere increases, as observed and as predicted by computer simulations[3]. One consequence of this effect is an intensification of extreme precipitation[4].

Higher levels of water vapour in the atmosphere also mean that the winds blow more water vapour that evaporated from the sub-tropical oceans toward the wet regions of the planet, such as the equatorial rainbelt of the inter-tropical convergence zone and the bands of mid-latitudes storms. The simple balance — incoming moisture approximately equals outgoing moisture — results in an increased freshwater flux to the surface over wet regions, in terms of precipitation minus evaporation, as atmospheric water vapour concentrations rise[5]. The source regions for the moisture, by contrast, dry out further, so that, at least over the oceans, more water evaporates than is received from precipitation. This signal has already been detected using measurements of sea surface salinity[6]. Yet, over land, where humans rely on usable fresh water, the picture is more complex: because there is no infinite water source over land, broadly speaking only water that fell as precipitation previously can evaporate. The simple division into arid and humid regions depending on whether more water evaporates or falls as rain is therefore less meaningful.

Greve and colleagues[2] circumvent this problem by defining arid and humid regions on land according to an impact-relevant aridity index that takes into account not only precipitation and evaporation, but also potential evaporation, that is, the amount of evaporation that would result from an unlimited supply of surface water. They find that between the 1948–1968 and 1985–2005 periods, robust changes in the expected sense of wet regions getting wetter or dry areas becoming drier, were found in only 10.8% of the global land area. In fact, only about a quarter of the global land area displays robust changes in aridity.

These findings for the past few decades contrast with future projections, as well as with analyses of precipitation trends alone[1,5,7,8]. This apparent discrepancy is partly a result of Greve and colleagues' consideration of evaporation and potential evaporation, in addition to precipitation. Their measure of dryness is more physically meaningful, and also more relevant to climate impacts; yet it is more detached from the simple constraints of water vapour being swept around the globe by the wind. Their analysis also relies upon the construction of high-quality observations

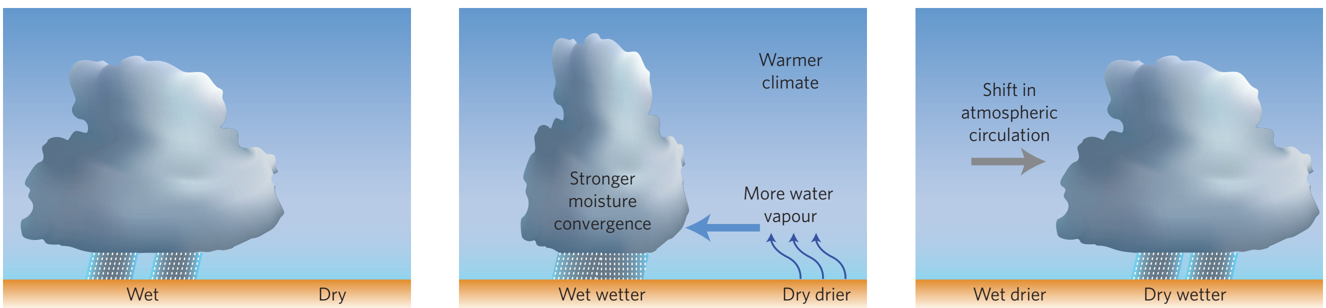

Figure 1 | Patterns of precipitation define the wet and dry regions. As the climate warms, the atmosphere can hold more water vapour and more water vapour is transported from dry to wet regions by the wind, causing humid regions to become wetter, while dry regions dry out further. Greve and colleagues[2] analyse observational records and find that this pattern has only been apparent in about 11% of the global land area between 1948 and 2005. One complicating factor lies in the variability of atmospheric circulation patterns that also shift naturally or as part of global warming[11,12]: shifts in the circulation can lead to opposite shifts in precipitation patterns.

that are homogeneous over time, which is a great challenge since spurious drifts or jumps in the data record can mask real signals. A further reason for the discrepancy may relate to the changing geographical positions of the wet and dry branches of the global atmospheric circulation. These vary in response to internal fluctuations of the ocean as well as to natural and human influences on climate, such as volcanic eruptions, changes in the Sun, anthropogenic emissions of greenhouse gases and aerosol pollution. As a result, normally wet regions can receive less rainfall whereas drier regions would receive more, the opposite of the anticipated response to a warming climate (Fig. 1).

Such large-scale shifts in atmospheric circulation patterns have been documented during the past six decades. Over Europe and North America, previously high levels of aerosol pollution have been implicated[9] in drought in the Sahel during the 1980s. A subsequent reduction in this pollution has coincided with a recovery in African rainfall[10]. Other anthropogenic factors such as greenhouse gas emissions or stratospheric ozone depletion can also alter rainfall by influencing circulation patterns[11,12], as can natural decadal alterations in ocean circulation and its link to atmospheric conditions through El Niño/Southern Oscillation[7].

Changes in the global water cycle are unlikely to run smoothly with so many contrasting influences operating from one decade to the next. Circulation-related changes in dryness[7,12] must therefore be taken into account. And annual average changes, as investigated by Greve and colleagues, may disguise contrasting trends on shorter timescales, for example in the wet and dry season at a particular location[1,8], which can be equally important for flood risk and water supply.

The analysis by Greve and colleagues[2] indicates that only about a quarter of the global land area has been exposed to robust changes in dryness over the course of the past 60 years or so, and often not in the sense expected by a wet get wetter, dry get drier pattern. Future changes in the wettest and driest continental regions are therefore uncertain, because they depend upon shifts in atmospheric circulation patterns[11,12] in addition to the influence of the more robust changes in atmospheric concentrations of water vapour. ❐

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