certainty that anthropogenic climate change is up for debate, when in fact outside of this echo chamber there is overwhelming evidence and scientific agreement about climate change.

This study has several implications for future research. First, and most significantly, while we know a lot about individual-level climate change attitudes, we need much more research that links these attitudes quantitatively to the larger institutional structures within which US climate politics has developed. Jasny *et al.* take a crucial step by formalizing and testing one such approach, but much more empirical work along these lines is needed to understand the social relationships within which attitudes are generated and reinforced in the first place.

Second, while this study identifies the structure of the echo chamber, it leaves future research to document the sources of the information itself — who gets to decide what information makes it into the 'chamber' to begin with? A complex mix of political, scientific, and industry interests — which also have particular social network structures and reverberate certain information and ideas — will need to be considered.

Third, the potential for echo chambers has seemingly increased with the proliferation of social media and online news, and thus researchers might examine how and why something in the climate politics arena goes viral and what, if any, connection this has to the echo chamber concept.

Lastly, Jasny and colleagues remind us that despite being perceived as a negative phenomenon, echo chambers are inherently neutral, and their normative appraisal is dependent on the context and subjective value of the information being communicated. So, on a more hopeful note, future research might examine how the echo chamber phenomenon could be reinterpreted and utilized as a positive force in democratic society, especially around issues like climate change, where information diffusion and ideological entrenchment continue to have important consequences. ❐

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References

1. Akerlof, K., Rowan, K. E., Fitzgerald, D. & Cedeno, A. Y. *Nature Clim. Change* **2,** 648–654 (2012).
2. Jacques, P. J., Dunlap, R. E. & Freeman, M. *Environ. Polit.* **17,** 349–385 (2008).
3. Fisher, D. R., Waggle, J. & Liefeld, P. *Am. Behav. Sci.* **57,** 70–92 (2013).
4. Jasny, L., Waggle, J. & Fisher, D. *Nature Clim. Change* **5,** 782–786 (2015).

HYDROLOGY

Climate change comes to the Sahel

Persistent drought in the Sahel in the 1970s and 1980s was caused by subtle changes in global sea surface temperatures. Now model results show that the direct effect of increasing greenhouse-gas concentrations led to the subsequent recovery.

Alessandra Giannini

The Sahel is the semi-arid southern shore of the Saharan 'sea of sand'. It holds a special place in climate science, because of the long-standing debate on the causes of persistent drought in the 1970s and 1980s. Since the driest mid-1980s, which include 1984 — the year of the Ethiopian famine made famous by Live Aid — there has been a recovery in rainfall[1], provoking further questions on what controls precipitation in the region. Writing in *Nature Climate Change*, Buwen Dong and Rowan Sutton[2] suggest that higher atmospheric concentrations of greenhouse gases, and the consequent atmospheric temperature increase known as the direct effect, were primarily responsible for the recovery. Given the high climatic vulnerability of the region, this study[2] is sure to captivate a broader audience, including development practitioners. This presents an opportunity to synthesize current understanding of the dynamics of future climate change in the context of past drought persistence.

The twentieth-century evolution of Sahel rainfall — including the decades of anomalously abundant rains that preceded the long-term drought — has been attributed to sea surface temperature (SST) variations. This was conclusively demonstrated only in 2003[3], freeing Sahelian farmers and pastoralists from blame[4]. Prior attempts to attribute variations in Sahel rainfall to emissions from industrialization presented arguments for indirect effects, whereby emissions, both greenhouse gases (GHGs) and aerosols, affect rainfall by inducing persistent SST anomalies[5]. For example, the cooling effect of sulphate aerosols on the surface temperature of the North Atlantic, the moisture source for the West African monsoon, has long been recognized as a key component of late 20th century Sahelian drought[6]. The generalized warming of the oceans attributed to GHGs, that emerged around 1970, is understood to have exacerbated drought persistence in the 1970s and 1980s[3,7,8]. Comparison to El Niño events[9] is illustrative: warming of the oceans locally favours the rising motions in deep convection that cause the air to cool, and water vapour in it to condense and fall in precipitation. At the same time, it raises the bar for the same processes to occur globally, because convection communicates the surface warming to the upper levels of the troposphere. As the upper-tropospheric warming spreads, it stabilizes columns of air remote from the surface warming itself. When this "upped ante for convection" cannot be met, tropical land dries[7], as in the case of the Sahel[10].

In contrast to previous periods of persistently abundant or deficient rainfall, the recent recovery in the Sahel is characterized by increased year-to-year variability[1]. This variability can be understood by revisiting the two elements implicated in drought — variations in North Atlantic SSTs, and warming of the tropical oceans. Whether due to a decrease in atmospheric aerosol loading prompted by legislation in the US and Europe, or to a recovery in the strength of the Atlantic Meridional Overturning Circulation[11], the North Atlantic is now also warming.

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North Atlantic SSTs that are warmer than the global tropical mean imply that the “upped ante”[9] associated with warming tropical oceans can be met by the increased moisture supplied in monsoon flow[8]. In years when that happens, the Sahel can receive abundant rains once again. But that is not guaranteed year in, year out, due to the large internal variability in the system: there is concern that this year’s rainy season may be delayed or deficient precisely because the present configuration is that of a relatively cool North Atlantic in the face of a rapidly warming El Niño event in the tropical Pacific (http://go.nature.com/UgPmP8).

The work by Dong and Sutton investigates the three factors — SSTs, GHGs and anthropogenic aerosols — that may contribute to precipitation changes. Based on simulations run with a single model, and testing these in combination and alone, they come to the conclusion that the direct effect of GHGs on the climate of the Sahel is sufficient to explain the rainfall recovery since the driest early to mid-1980s.

The direct and indirect effects of GHGs cannot be easily separated. In models, the sum of their separate effects is different from that of their simultaneous combination[12]. Herein lies the uncertainty in regional projections of precipitation change[5]. Dong and Sutton[2] analyse output from one model (HadGEM2), but do these results hold for other models? Comparison of the model used in the study with others included in the Coupled Model Intercomparison Project Phase 5 (CMIP5) confirms that all models tested make the Sahel wetter when subjected to only the direct effect of GHGs, when SSTs are prevented from warming in response[12]. However, one reason why the model used by Dong and Sutton emphasizes the direct effect of GHGs may be its underperformance in reproducing the effect of historical SST on Sahel rainfall. Testing the version of this model made available in CMIP5 finds it does not reproduce the conclusion of SST influence reported in the literature (see refs 3,13, for example) that provides the scientific basis for seasonal prediction. The correlation between modelled precipitation in a single simulation run with the atmospheric component of HadGEM2 over observed SST, and observed precipitation (from the Global Precipitation Climatology Project, a blend of satellite retrievals and station observations) is not significant for 1979–2008 (Fig. 1). In comparison, the ensemble mean (5 simulations) from another CMIP5 model, GFDL-CM3, which is the current generation of the model used in ref. 13 and 7, shows a robust SST influence.

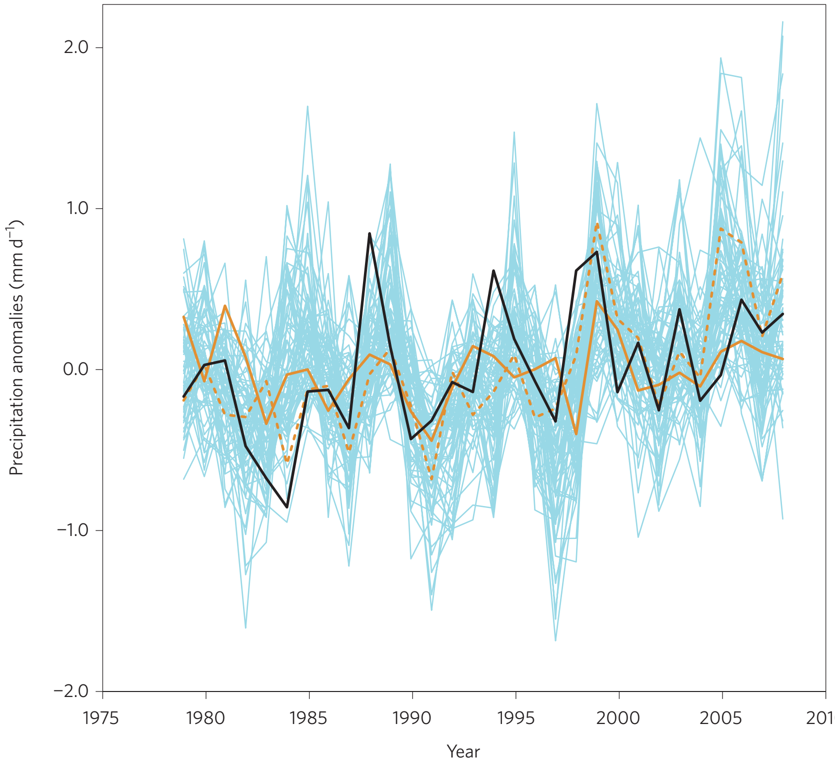

Figure 1 | Sahel precipitation anomalies (10–20° N, 20° W–40° E) for 1979–2008. A total of 72 AMIP simulations (forced with observed SST) covering this period were contributed to CMIP5 by 26 modelling groups (light blue lines). Observations are shown in black. The multi-model ensemble mean correlation with observations is 0.46, significant at the 5% level. The correlation of the single simulation with HadGEM2 (solid orange line) is 0.30, not significant at the 5% level. The correlation of the ensemble mean of 5 simulations with GFDL-CM3 (dashed orange line) is 0.58, significant at the 1% level.

In conclusion, Dong and Sutton do well to focus attention on a gap in research: a complete understanding of the influence of GHGs, direct and indirect, on the climate of the Sahel. This is needed more urgently, not less, as purported in headlines such as those collected here (http://go.nature.com/bovWXw), which go so far as to state that climate change may be beneficial to this region, because current observed trends in the “character of precipitation”[14] are already remarkably consistent with expectation from “global warming”. While precipitation may have recovered in the seasonal total amount, it has done so through more intense, but less frequent precipitation events[15,16]. This state of affairs requires more attention be paid to the climate of the Sahel, to ensure that negotiations around adaptation, such as those taking place in the run-up to the Conference of the Parties of the UN Framework Convention on Climate Change that will be held in Paris at the end of this year, are based on the best science available, and are grounded in this region’s unique experience in building resilience to drought. ❐

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References

1. Ali, A. & Lebel, T. *Int. J. Climatol.* **29,** 1705–1714 (2009).
2. Dong, B. & Sutton, R. *Nature Clim. Change* **5,** 757–760 (2015).
3. Giannini, A., Saravanan, R. & Chang, P. *Science* **302,** 1027–1030 (2003).
4. Mantell, K. Farmers freed of blame for Sahel drought. *SciDev.net* (10 October 2003); http://go.nature.com/HIoJY5
5. Biasutti, M. & Giannini, A. *Geophys. Res. Lett.* **11,** L11706 (2006).
6. Rotstayn, L. & Lohmann, U. *J. Clim.* **15,** 2103–2116 (2002).
7. Held, I. M., Delworth, T. L., Lu, J., Findell, K. & Knutson, T. R. *Proc. Natl Acad. Sci. USA* **102,** 17891–17896 (2005).
8. Giannini, A., Salack, S., Lodoun, T., Ali, A., Gaye, A. T. & Ndiaye, O. *Environ. Res. Lett.* **8,** 024010 (2013).
9. Neelin, J. D., Chou, C. & Su, H. *Geophys. Res. Lett.* **30,** 2275 (2003).
10. Lyon, B. *Geophys. Res. Lett.* **31,** L21204 (2004).
11. Rahmstorf, S. *et al. Nature Clim. Change* **5,** 475–480 (2015).
12. Biasutti, M. *J. Geophys. Res.* **118,** 1613–1623 (2013).
13. Lu, J. & Delworth T. L. *Geophys. Res. Lett.* **32,** L22706 (2005).
14. Trenberth, K. E., Dai, A., Rasmussen, R. M. & Parsons, D. B. *Bull. Am. Meteorol. Soc.* **84,** 1205–1217 (2003).
15. Lodoun, T. *et al. Environ. Dev.* **5,** 96–108 (2013).
16. Salack, S., Giannini, A., Diakhaté, M., Gaye, A. T. & Muller, B. *Clim. Dynam.* **42,** 189–201 (2014).

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