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Satellite data show frequency of intense Mesoscale Convective Systems in the Sahel tripled since 1982

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The hydrological cycle is expected to intensify under global warming, with studies reporting more frequent extreme rain events in many regions of the world, accompanied by expected increases in future flood frequency. An important question is the extent to which changes in extreme rainfall will scale with temperature according the Clausius-Clapeyron relationship. Rising temperatures may also intensify storm-scale dynamics, enhancing moisture inflow and the overall precipitation efficiency of rain events; features which are not well-captured by GCMs. The importance of these processes for extreme rainfall likely depends on specific features of the local and regional environment.

Here we look at cloud-top temperature data over the Sahel provided by the Meteosat series of geostationary satellites since 1982. These data provide observational insight into how Mesoscale Convective Systems (MCS), embedded within the West African Monsoon circulation, have evolved over the last 35 years, as the global climate has warmed. We define MCS as contiguous cold cloud features larger than 25,000 km2 using different temperature thresholds. The strong interannual variability in seasonal rainfall, and indeed the so-called recovery from the drought years of the 1980s, is well-captured by the number of MCS at a threshold of -40C. Superimposed on this however, is a remarkably strong downward trend in cloud-top temperatures within MCS. When considering a temperature threshold of -70C, we find a tripling in the frequency of MCS observed over the Sahel during this period. At the same time we see modest positive trends in the size of MCS only when using lower temperature thresholds (-60C and below). We interpret these features as a tendency towards more intense convection in late afternoon and evening, in turn creating larger, longer-lived systems overnight.

Whilst the trend towards more intense MCS is well-correlated with rising global land temperatures (r=0.81), it is inconsistent with a relationship between convective intensity and Sahelian temperature; during the monsoon the local temperature trend has been slightly negative over this period. We argue that the rapidly warming Sahara may provide the regional link to global warming, via changes in wind shear and in the properties of the Saharan Air Layer. The meridional temperature gradient spanning the Sahel has increased in recent decades, consistent with anthropogenic emissions in the CMIP5 ensemble, and is set to continue throughout the 21st century. This suggests that the Sahel will experience particularly marked increases in extreme rain. The rapid intensification of Sahelian MCSs since the 1980s sheds new light on the response of organised tropical convection to global warming, and challenges conventional GCM projections.