

Volume 99

Number 6

June 2018

# BAMS



Bulletin of the American Meteorological Society

*PLUME—WILDFIRE INTERACTIONS*

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## Air Time

Investigating  
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## SAHARA DESERT EXPANDS IN THE TWENTIETH CENTURY

The Sahara Desert is the largest warm desert on the planet, with an area comparable to that of the contiguous United States. It is located in North Africa, bounded to the south by the Sahel – the semiarid transition zone between approximately 10° and 20°N that receives most of its rainfall in summer. Not surprisingly, the Sahara Desert appears more expansive in winter than summer in satellite imagery. Meteorologically, however, deserts are defined using annual rainfall. This study focuses on twentieth-century trends in surface air temperature and precipitation over the African continent, analyzing both

annual and seasonally stratified trends in observational datasets and historical climate simulations. Our analysis of seasonal precipitation trends finds that the Sahara Desert has expanded significantly in the last century, due both to natural variability and anthropogenic climate change, and it identifies the desert advance as well as retreat regions in the agriculturally important seasons, which should help the regional agricultural economies with adaptation and mitigation planning.

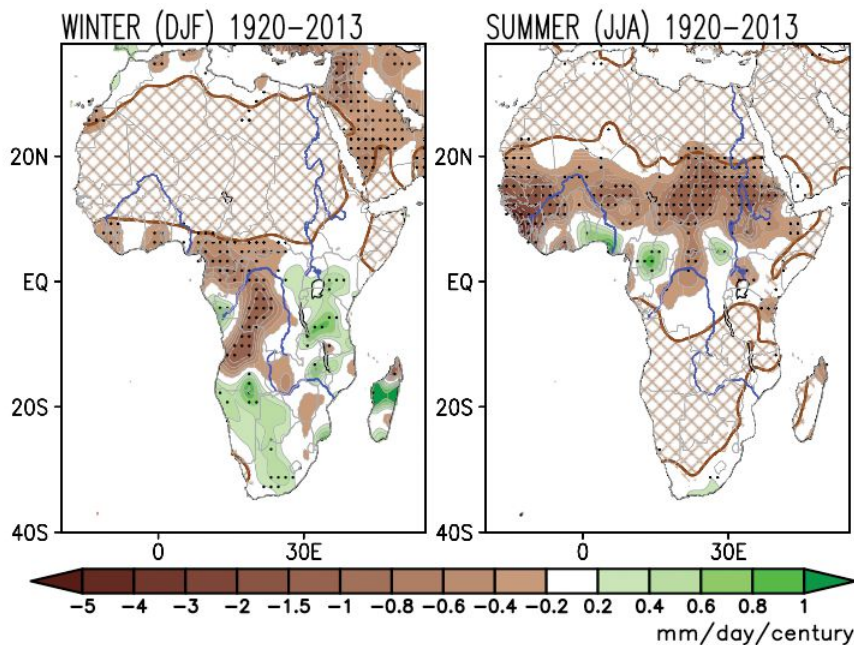
Our research is the first to analyze trends in the size of the Sahara Desert over a century-long time scale. The full-century period (1902–2013) was examined, but

particular attention is paid to the recent 93-yr period (1920–2013) when the rain gauge network is relatively more stable.

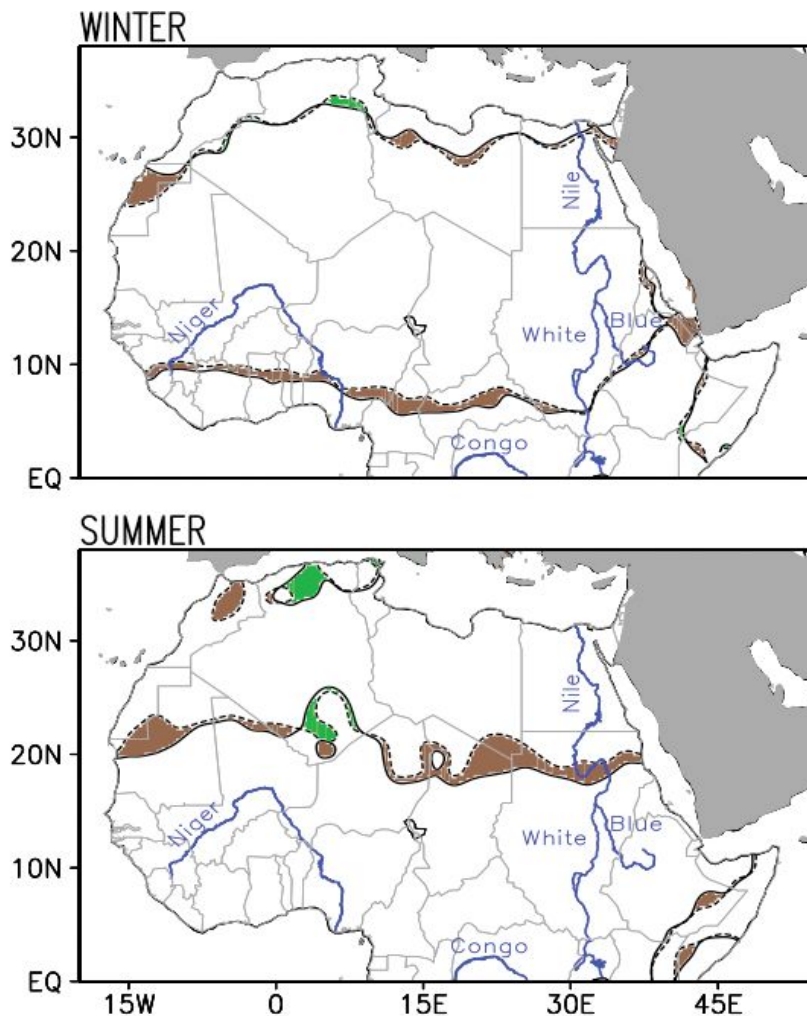
Examination of linear trends in seasonal surface air temperature (SAT) shows that heat stress has increased in several regions, including Sudan and northern Africa, where SAT trends are largest in the warm season. Seasonal precipitation trends show notable twentieth-century drying in the source region of the Niger River in West Africa, the Congo River basin, countries along the Gulf of Guinea, and the Sahel. During summer (June, July, and August; the growing season in Northern Hemisphere Africa), the Sahara Desert expanded significantly, by ~8.5% over 1920–2013, with most of the expansion to the south. The southward creep was partly related to natural cycles of climate variability, such as the Atlantic multidecadal oscillation (AMO) and Pacific decadal oscillation (PDO). These cycles affect the hydroclimate in both near and far-away regions, including the Sahel; the cold phase of the AMO, for example, is linked to decreased Sahel rainfall (and thus a southward expanded Sahara).

In the annual mean, the areal extent of the Sahara Desert increased by ~10% over 1920–2013. The analysis indicates that cycles of natural variability (the AMO and PDO) were responsible for roughly two-thirds of the annual-mean expansion over this time period, with the remaining one-third attributed to anthropogenic climate change. The countries bearing the brunt of the southward desert advance in summer are Mauritania, Chad, and Sudan.

Finally, the study shows that leading global climate models used in the Fifth Assessment



**Widespread drying.** Linear trends in seasonal precipitation over the African continent during 1920–2013, from the 0.5° resolution precipitation analysis in version 7 of the Global Precipitation Climatology Centre (GPCC, v7), in units of  $\text{mm day}^{-1} \text{century}^{-1}$ . The nonuniform contouring and shading interval is indicated via the color bar. Thick solid brown contours mark the  $0.274 \text{ mm day}^{-1}$  climatological precipitation isoline, and brown hatching indicates regions where climatological precipitation is below  $0.274 \text{ mm day}^{-1}$  (or  $100 \text{ mm year}^{-1}$ )—a precipitation threshold used for defining the Sahara Desert. Trends significant at the 95% confidence level are denoted with black dots. Major rivers are shown in thin blue lines and country boundaries in thin gray lines.



Report of the Intergovernmental Panel on Climate Change (IPCC AR5) are unable to capture the notable features of the observed twentieth-century hydroclimate trends. —NATALIE THOMAS (UNIVERSITY OF MARYLAND), AND S. NIGAM, “Twentieth-century climate change over Africa: Seasonal hydroclimate trends and Sahara Desert expansion,” in the 1 May 2018 issue of the *Journal of Climate*.

**Sahara Desert’s larger footprint. Advance/Retreat of the Sahara Desert over the 1920–2013 period, seasonally. The dashed (solid) brown lines denote the 0.274 mm day<sup>-1</sup> precipitation isolines in the synthetic 1902 (2013) precipitation map obtained from the endpoint analysis. The brown (green) shaded areas denote desert advance (retreat). Note the observed precipitation distribution at the period endpoints cannot be directly used as it includes both interannual and decadal–multidecadal variability components and the sought-after linear trend.**