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TYPE:	Article CC:CCG
JOURNAL TITLE:	Nature reviews. Earth & environment
USER JOURNAL TITLE:	Nature Reviews Earth & Environment
ARTICLE TITLE:	Extreme terrestrial heat in 2024
ARTICLE AUTHOR:	Jha, Roshan
VOLUME:	6
ISSUE:	4
MONTH:	
YEAR:	2025-04
PAGES:	234 - 236
ISSN:	2662-138X
OCLC #:	

Processed by RapidX: 7/23/2025 12:31:59 AM

Climate chronicles

https://doi.org/10.1038/s43017-025-00661-2

Extreme terrestrial heat in 2024

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2024 shattered temperature records, surpassing 2023's historic highs to become the warmest year ever recorded. Extreme heatwaves hit West Africa in February, South America and Eastern Europe in March, Southeast Asia in April, and Mexico in June.

2024 marked an unprecedented milestone for global temperature. Global average air temperature reached 1.55 °C above pre-industrial levels (1850–1900)[1], surpassing 2023's record by 0.1 °C (ref. 2). Each of the first six months of the year consecutively broke its respective historical temperature record, while August matched its 2023 record and September–December ranked second. These record temperatures resulted from an unprecedented energy imbalance (0.86 W/m^2), largely driven by greenhouse gases and amplified by El Niño conditions[3]. Terrestrial temperatures were particularly exceptional. They reached 2.28 °C above pre-industrial levels[3], contributing to ~32% of land surfaces experiencing record-breaking annual average temperatures which impacted ~3.3 billion people[3]. This dramatic intensification of terrestrial heat manifested through persistent heat extremes across all major continents particularly over Central and South America, Africa, and Southeast Asia[4].

Here, we assess 2024 extreme terrestrial heat across different continents, using heatwave days[5] from the ERA5-Land[6] global dataset as a basis for discussion. Given the abundance of heatwave events, not all are discussed.

Africa

Temperatures in Africa soared in 2024. Continental-scale temperatures surpassed the 2023 record to reach 1.65 °C above the 1910–2000 average—the 48th consecutive year of above-average warmth[4]. Monthly anomalies also exceeded 1.0 °C, with May recording the highest anomaly at 2.20 °C (ref. 4). As expected, these record levels of warmth also translate to above-average numbers of heatwave days. For instance, continental-average heatwaves days reached 70, 55 days above the 1991–2020 climatology. The most heatwave days on record were observed across large swathes of western and central Africa (Fig. 1a), exceeding 170 days (120 above the climatology; Supplementary Fig. 1). Southern Africa also recorded record numbers of heatwave days (Fig. 1a).

Various heatwave events occurred throughout Africa in 2024. For example, the Guinea zone in West Africa experienced record heat from 11 to 15 February, with daily maximum temperature anomalies reaching 3–4 °C (Fig. 1b). A heatwave spanning Botswana, Namibia, Mozambique, South Africa, Zambia and Zimbabwe also occurred during mid-February, with anomalies of 4–5 °C above the 1991–2020 average. Temperatures ≥45 °C were subsequently observed in South Sudan and the wider East Africa region in the third week of March (7–8 °C above normal), and in the Sahel and West Africa from 31 March to 4 April (4 °C above normal); during the latter event, minimum temperatures were 32 °C in Burkina Faso and maximum temperatures were 48.5 °C in Mali. Later, two heatwave events hit Morocco from 14 to 19 July and 22 to 25 July; during the second period, temperatures of 41.7 °C and 47.6 °C were recorded in in Nouasseur and Marrakech, respectively.

Asia

Asia also sweltered during 2024, recording its second warmest year after 2023. Annual mean anomalies were 2.17 °C above 1910–2000 (ref. 4). Multiple nations broke long-standing records: India and Japan experienced their warmest years since 1901 and 1898, with anomalies reaching 0.65°C and 1.48°C above the 1991–2020 average, respectively; and China recorded the highest average annual mean temperature of 10.9 °C since 1961 and suffered the warmest July on record. Southeast Asian nations experienced unprecedented warmth during the spring of 2024. Although average warming was at or near record levels, average heatwave days across Asia was fairly standard at 31 days (Fig. 1a; Supplementary Fig. 1).

Specific heatwave events were more anomalous in nature. Indeed, several severe heatwaves spanned Asia in April, including: the eastern and south peninsular regions in India from 18 to 30 April (Fig. 1c), where temperatures reached 46 °C, 4–6 °C above average[7]; in much of southeast Asia from 15 to 29 April, with national April temperature records being broken in Myanmar (48.2 °C), Laos (43.2 °C) and Vietnam (44 °C), and heat index values being broken in the Philippines (53 °C); and in much of western Asia during 24–26 April, with temperatures reaching 40.7 °C in Tel-Aviv (breaking an 85-year-old record) and 37.7 °C in Gaza. India subsequently endured another severe heatwave from 18 May to 2 June, with temperatures exceeding 45 °C across northwest India, including a peak of over 49 °C in Delhi on 29 May. Severe heat

Key points

- A record number of heatwave days occurred in central, western and southern Africa (Botswana, Namibia, Mozambique, Zambia, Zimbabwe, and South Africa); events during 11–15 February and 31 March–4 April brought temperature anomalies of ~4 °C.
- Large swathes of South America (Brazil, Bolivia, Paraguay, Peru, Venezuela, Colombia) experienced a record >150 heatwave days; the 11–18 March and 22–25 August events experienced temperature anomalies of 8 °C and 7.5 °C, respectively.
- Temperature records were smashed across the remainder of the land surface, including an unprecedented April heatwave in southeast Asia (>43 °C), and severe June heat in southern USA and Mexico (reaching up to 48 °C) and the Eastern Mediterranean (>45 °C).

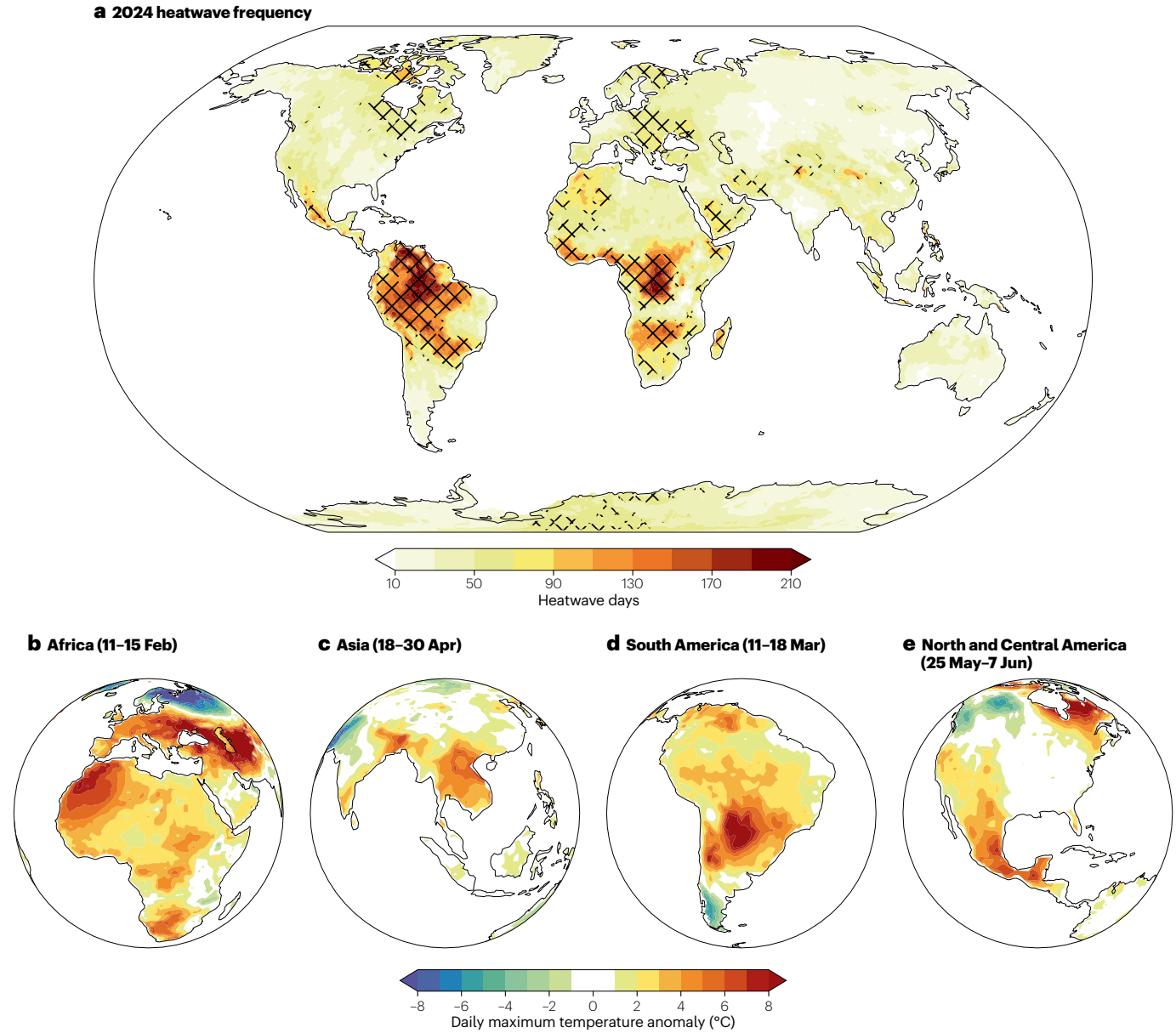

Fig. 1 | Heatwave statistics for 2024. a, Number of heatwave days (≥3 days in a row where daily maximum temperature anomaly is >90th percentile, based on a 15-day moving window during 1991 to 2020)[5] in 2024 from ERA5-Land[6]. Hatching outlines the regions that experienced the highest number of heatwave days in 2024 since 1979. For anomalies of heatwave days, see Supplementary Fig. 1. **b**, Daily maximum temperature anomalies for a heatwave event over Africa from 11 to 15 February 2024. **c**, As in panel **b**, but over Asia during 18–30 April 2024. **d**, As in panel **b**, but over South America during 11–18 March 2024. **e**, As in panel **b**, but over North and Central America during 25 May–7 June. The unprecedented frequency of heatwaves across multiple regions in 2024 underscores an accelerating pattern of extreme temperature events, particularly affecting tropical and subtropical regions.

also hit Saudi Arabia on 16–18 June (during the Hajj pilgrimage)[8], with temperatures in Mecca reaching 51.8 °C (about 7 °C above normal), and Pakistan on 20–26 June, with temperatures in Karachi reaching 47.2 °C. In China, multiple provinces also recorded temperatures up to 43.9 °C in early August.

South America

In South America, 2024 tied with 2023 for the warmest year on record. Continental-average temperatures reached 1.78 °C above the 1910–2000 mean, marking the 48th consecutive year of above-average heat[4]. Six months set new records, including in September when temperatures were 2.55 °C above average[4]. Across the continent, about 90 average heatwaves days occurred in 2024, 75 days above the 1991–2020 climatology (Fig. 1a; Supplementary Fig. 1). The most heatwave days were recorded in central and northern South America (>150 days; Fig. 1a); Gran Chaco, the Pantanal wetlands and the Amazon basin were most affected.

As in other continents, heatwave events occurred throughout the year and across the entire continent. For example, extreme heat spanned much of Argentina and Uruguay from 11 to 18 March (Fig. 1d), peaking at 38.6 °C in Buenos Aires and 40.5 °C in Mercedes, Uruguay, on 11 March, approximately 8–10 °C above average. Brazil also experienced several events: from 11 to 18 March in central-southern Brazil, where temperatures reached 42 °C in Rio de Janeiro; and from 22 to 25 August in central-western Brazil, where temperatures reached 42.2 °C in Cuiabá for three consecutive days, shattering existing records. The year ended with a prolonged heatwave across Venezuela, Guyana and northern Brazil during first half of November.

North and Central America

North America experienced its warmest year on record in 2024. Average temperatures over the contiguous United States, Canada and Mexico were 2.22 °C above the 1910–2000 average[4], the warmest on record. February and December stood out as the warmest anomalies of the year at 3.29 °C and 3.32 °C above the 1991–2020 average, respectively. Average heatwave days reached 46 days (+26 compared to the 1991–2020 average), setting new records for parts of Canada and Mexico (Fig. 1a; Supplementary Fig. 1).

Multiple heatwave events struck these areas. For instance, a heat dome brought a series of back-to-back heatwaves across North and Central America from May to June (Fig. 1e), including severe heat from 24 to 26 May, which caused temperatures to reach 44 °C in Del Rio, Texas, 48 °C in San Juan Bautista Valle Nacional, Mexico, and 42 °C in parts of Guatemala and Honduras. The peak summer months brought even more extreme conditions. A severe heatwave spanned the eastern USA from 18 to 23 June, matching all-time highs of 36 °C in Caribou, Maine. Much of the island of Puerto Rico also experienced heat index values reaching 46 °C on 24 June, resulting in the first island-wide heat advisory. Later, an intense heatwave struck the western USA from 5 to 7 July, driving record-high temperatures of 51 °C in Palm Springs, 49 °C in Las Vegas, and 54 °C in Death Valley's Furnace Creek[9]. Also, Deadhorse, Alaska, broke its previous hottest record, recording the hottest temperatures anywhere in the Arctic circle at 31.7 °C on 6 August.

Europe

Europe also experienced its warmest year in recorded history. Here, annual mean temperature reached 2.45 °C above the 1910–2000 average[4]. February, July, and August set new temperature records, with February exhibiting the highest monthly anomaly at 4.12 °C above average. Average heatwave days were 44 days for the continent (Fig. 1a), with records numbers in eastern Europe (60 days) and Fennoscandia (50 days). Accordingly, several European nations set records: Austria experienced its warmest year since the 1700s; Germany surpassed its 2023 record by 0.3 °C, reaching 1.6 °C above the 1990–2020 average[4]; and Greece, Italy, Spain, Portugal and France all experienced record-high summer temperatures.

Substantial events dominated eastern and Mediterranean Europe. In the first week of March, for example, temperatures hit 29.7 °C in Moldova, 29.6 °C in Albania, 29 °C in Croatia and 27.2 °C in Belarus, about 10–15 °C above normal for this time of the year, shattering eastern European heat records. A severe heatwave also gripped southeastern Europe from 11 to 14 June, bringing temperatures of 44.5 °C in Greece and 45 °C in Cyprus, reaching up to +10 °C above average[10]. A subsequent event from 10 to 24 July brought 2 weeks of > 40 °C temperatures in Greece, peak temperatures of 40 °C in coastal regions of Turkey, and put fourteen cities on 'red alert' in Italy.

Australia

Like Europe, Australia also experienced its second warmest year. Annual mean temperatures were 1.46 °C above the 1961–1990 average. These warming patterns were apparent across most months of the year, but record seasonal temperatures were observed in austral winter (1.45 °C above average) and spring (1.76 °C above average). Despite record temperatures, no records were set with the number of heatwave days, which averaged 20 days (Fig. 1a; Supplementary Fig. 1).

Heatwave conditions ranging from mild to severe intensity affected extensive regions of Australia. In February 2024, Western Australia experienced three successive heatwaves on 31 Jan–3 Feb, 8–12 Feb and 14–21 Feb. The third event was particularly extreme, as temperatures reached 12 °C or more above the February average in many towns, including a record high of 49.9 °C at Carnarvon Airport. Another severe heatwave hit northern Australia in mid-December 2024, with temperatures exceeding 45 °C.

Summary

The unprecedented heat of 2024 marked a critical milestone as global temperatures surpassed the 1.5 °C Paris Agreement threshold. All continents experienced exceptional warming, with unprecedented heatwaves striking simultaneously across multiple regions. The intensity of warming far exceeded typical El Niño responses, with land regions warming twice as much as ocean surfaces and affecting 3.3 billion people. Global temperatures in 2025 are expected to cool relative to 2024 and 2023, with the end of the 2023/2024 El Niño and the transition towards a weak La Niña in early 2025. However, the persistent heat since 2023 suggests that extreme heat events will likely become more frequent and more intense in the future, posing a severe threat to vulnerable populations in developing regions, where limited adaptation resources and gaps in health monitoring hinder efforts to protect communities and assess heat-related impacts.

Data availability

ERA5-Land hourly data are publicly available from the Copernicus Climate Data Store (https://cds.climate.copernicus.eu/datasets/reanalysis-era5-land?tab=overview).

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Published online: 11 April 2025

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Acknowledgements

R.J. acknowledges fellowship support through DAAD In-Region Scholarship Programme South Asia.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s43017-025-00661-2.