STATE OF THE CLIMATE IN 2022

GLOBAL CLIMATE

R. J. H. Dunn, J. B Miller, K. M. Willett, and N. Gobron, Eds.

Special Online Supplement to the *Bulletin of the American Meteorological Society* Vol. 104, No. 9, September, 2023

https://doi.org/10.1175/BAMS-D-23-0090.1

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Cover Credit:
Photo by Taaniela Kula, Tongan Geological Services (TGS).

Eruption at Hunga Tonga–Hunga Haʻapai, witnessed by TGS observer team, a 5-kilometer wide plume rises over 18 kilometers above sea level, 14 January 2022, 5:14 pm local time.

How to cite this document:
Global Climate is one chapter from the *State of the Climate in 2022* annual report and is available from https://doi.org/10.1175/BAMS-D-23-0090.1. Compiled by NOAA’s National Centers for Environmental Information, *State of the Climate in 2022* is based on contributions from scientists from around the world. It provides a detailed update on global climate indicators, notable weather events, and other data collected by environmental monitoring stations and instruments located on land, water, ice, and in space. The full report is available from https://doi.org/10.1175/2023BAMSStateoftheClimate.1.

Citing the complete report:
Blunden, J., T. Boyer, and E. Bartow-Gillies, Eds., 2023: “State of the Climate in 2022”. Bull. Amer. Meteor. Soc., 104 (9), Si–S501 https://doi.org/10.1175/2023BAMSStateoftheClimate.1.

Citing this chapter:
Dunn, R. J. H., J. B Miller, K. M. Willett, and N. Gobron, Eds., 2023: Global Climate [in “State of the Climate in 2022”]. Bull. Amer. Meteor. Soc., 104 (9), S11–S145, https://doi.org/10.1175/BAMS-D-23-0090.1.

Citing a section (example):
Füllekrug, M., E. Williams, C. Price, S. Goodman, R. Holzworth, K. Virts, D. Buechler, T. Lang, and Y. Liu, 2023: Lightning [in “State of the Climate in 2022”]. Bull. Amer. Meteor. Soc., 104 (9), S76–S78, https://doi.org/10.1175/BAMS-D-23-0090.1.

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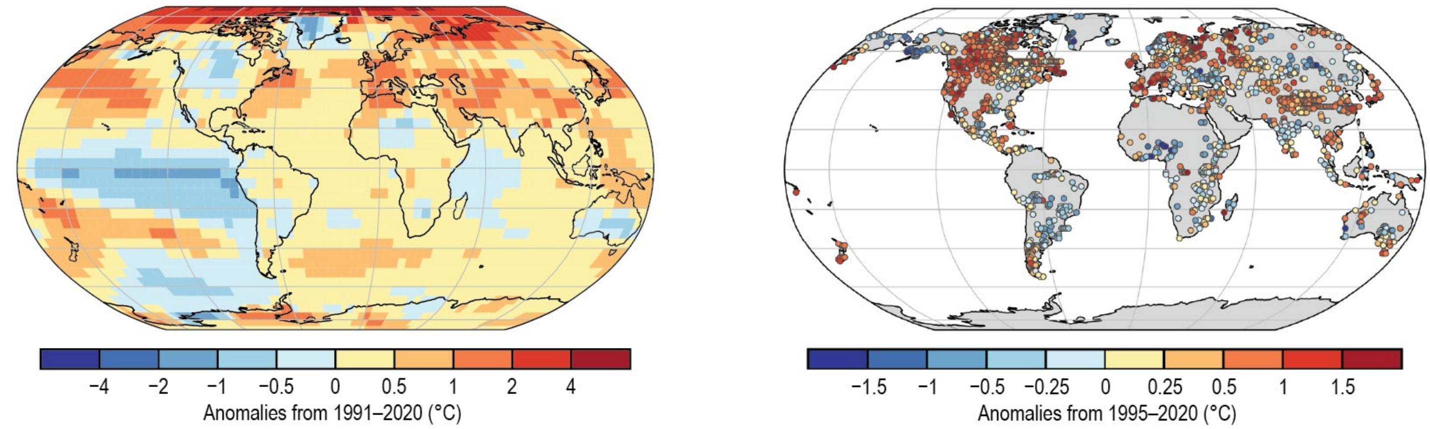
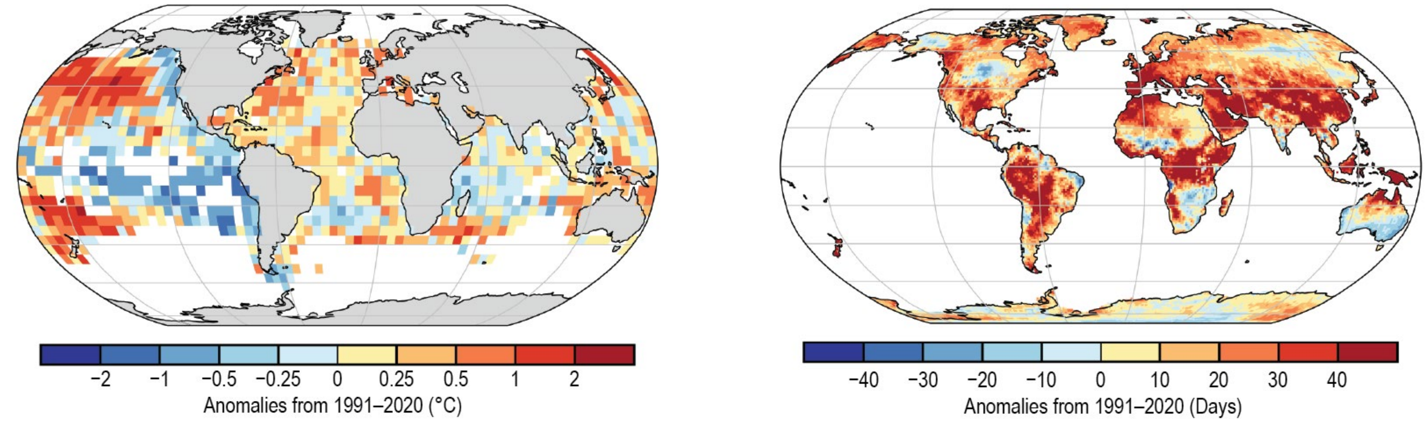
Please refer to Chapter 8 (Relevant Datasets and Sources) for a list of all climate variables and datasets used in this chapter for analyses, along with their websites for more information and access to the data.



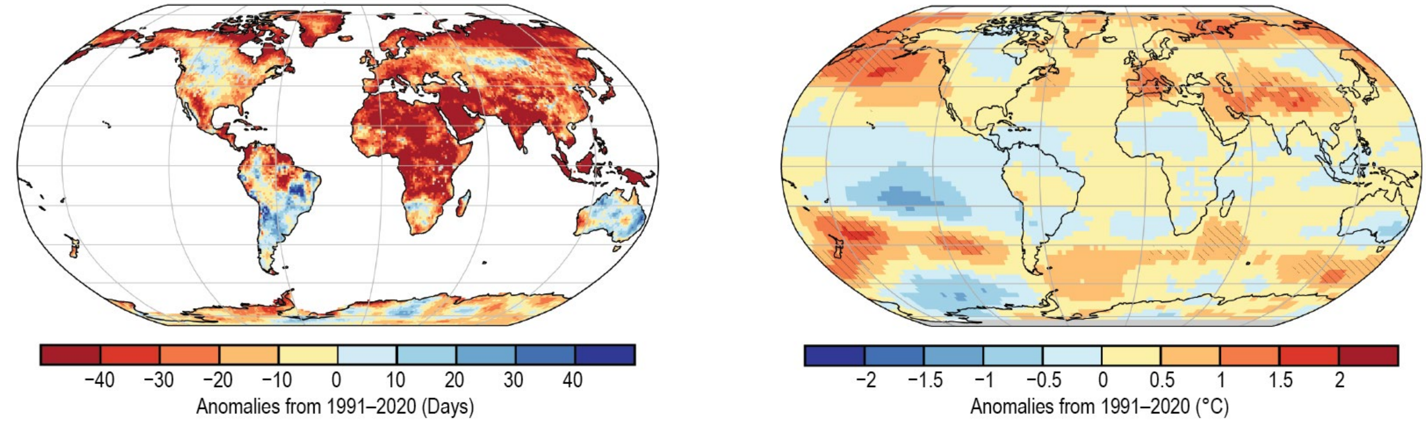
(a) Surface Temperature

(b) Lake Temperature



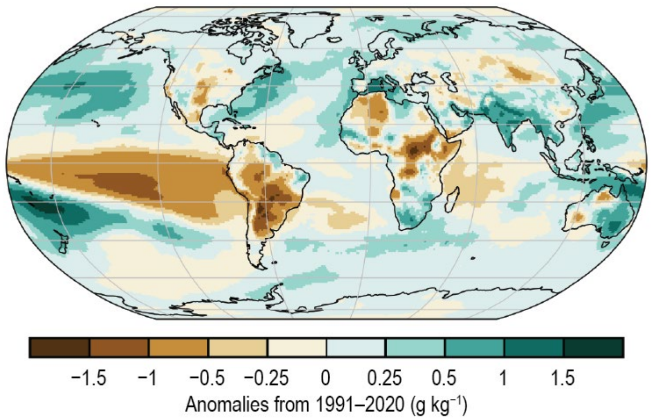
(c) Night Marine Air Temperature

(d) Warm Days



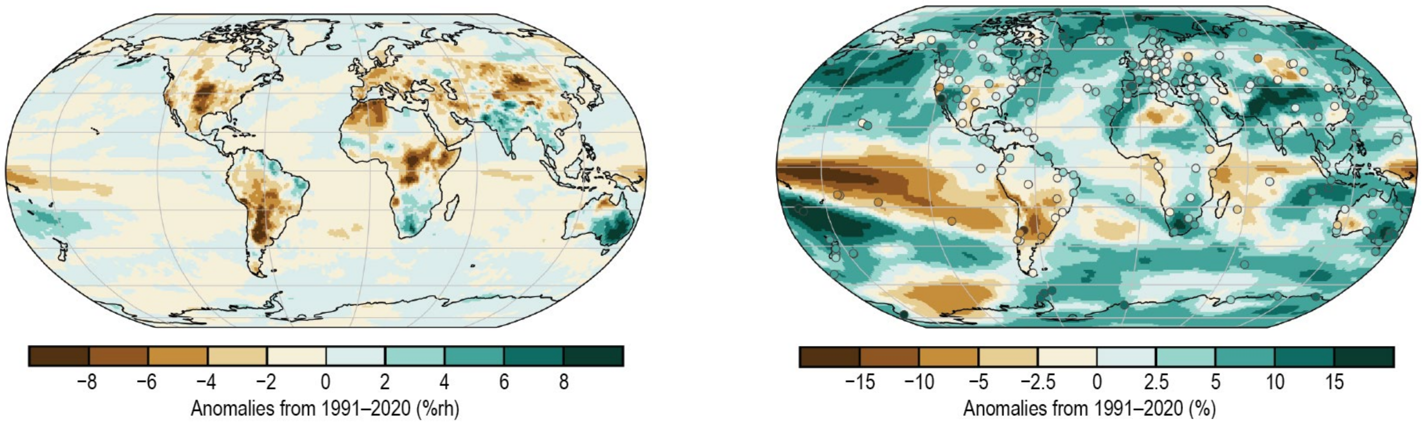
(e) Cool Nights

(f) Lower Tropospheric Temperature

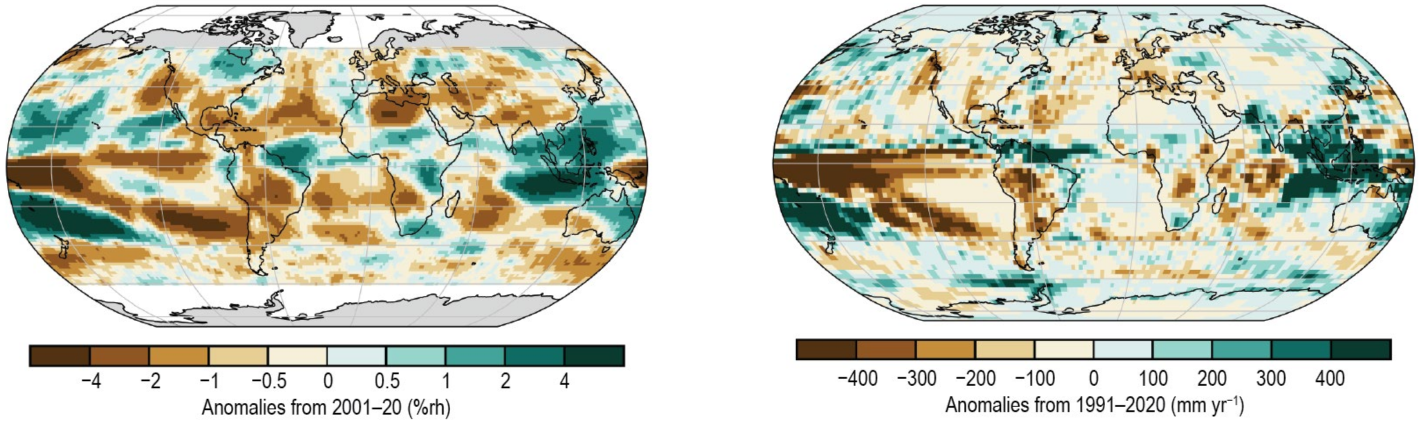


(g) Surface Specific Humidity

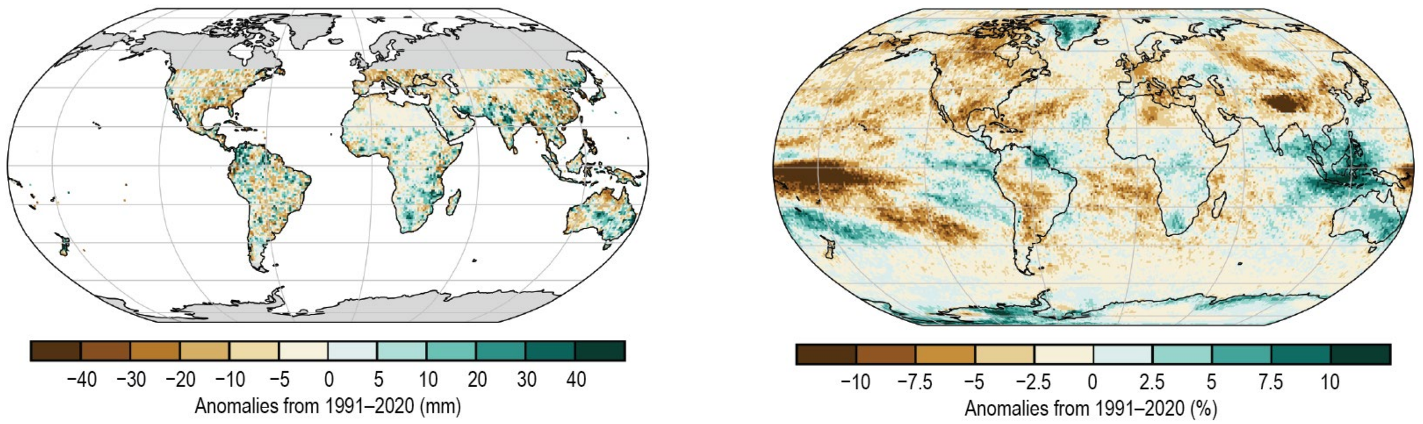
Plate 2.1. (a) NOAA NCEI Global land and ocean surface annual temperature anomalies (°C); (b) Satellite-derived lake surface water temperature anomalies, from ESA CCI LAKES/Copernicus C3S (°C); (c) CLASSnmat night marine air temperature annual average anomalies (°C); (d) ERA5 warm day threshold exceedance (TX90p); (e) ERA5 cool night threshold exceedance (TN10p); (f) Average of RSS and UAH lower-tropospheric temperature anomalies (°C). Hatching denotes regions in which 2022 was the warmest year on record; (g) ERA5 surface specific humidity anomalies (g kg^{-1});


(h) Surface Relative Humidity

(i) Total Column Water Vapor


(j) Upper Tropospheric Humidity

(k) Precipitation


(l) Maximum 1 Day Precipitation Amount

(m) Cloudiness

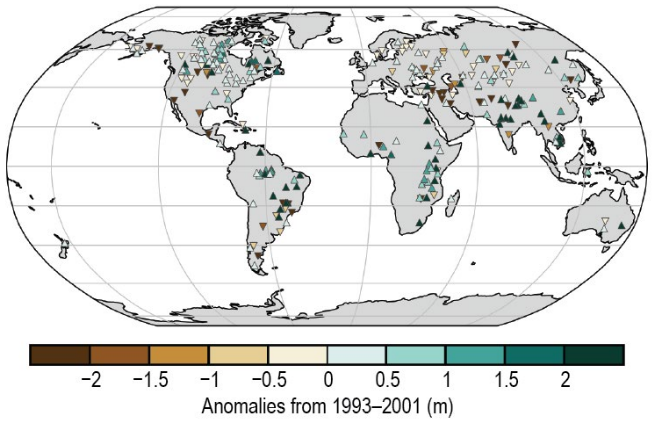
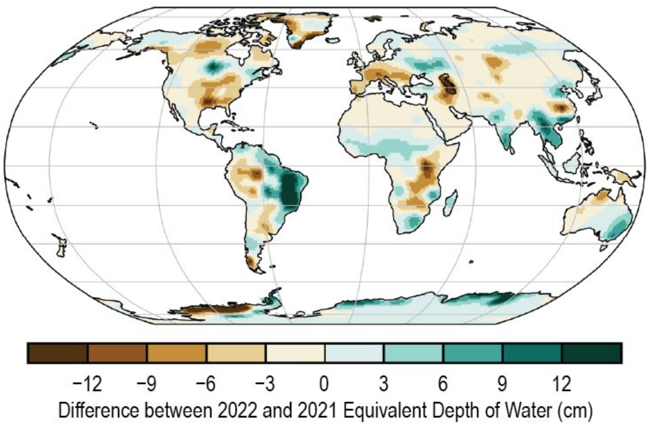
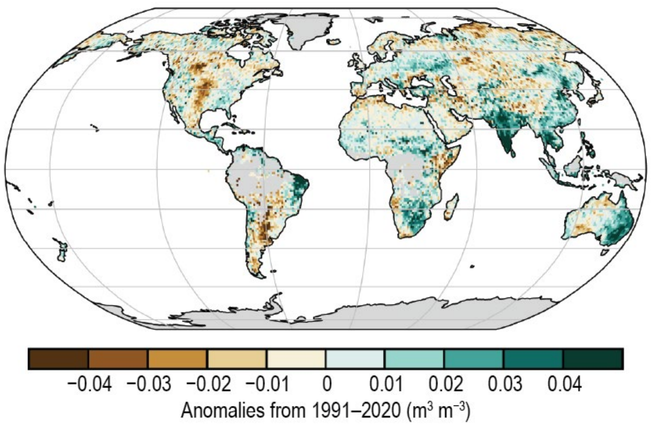

(n) Lake Water Level

Plate 2.1 (cont.) (h) ERA5 surface relative humidity anomalies (%rh); (i) ERA5 TCWV anomalies (%). Data from GNSS stations are plotted as filled circles; (j) Annual microwave-based UTH anomalies (%rh); (k) GPCP v2.3 annual mean precipitation anomalies (mm yr^{-1}); (l) CHIRPS maximum 1-day (Rx1day) annual precipitation anomalies (mm); (m) PATMOS-x 6.0 cloud fraction annual anomalies (%); (n) G_REALM lake water level anomalies. Triangles pointing upward indicate positive anomalies, and triangles pointing down indicate negative anomalies;

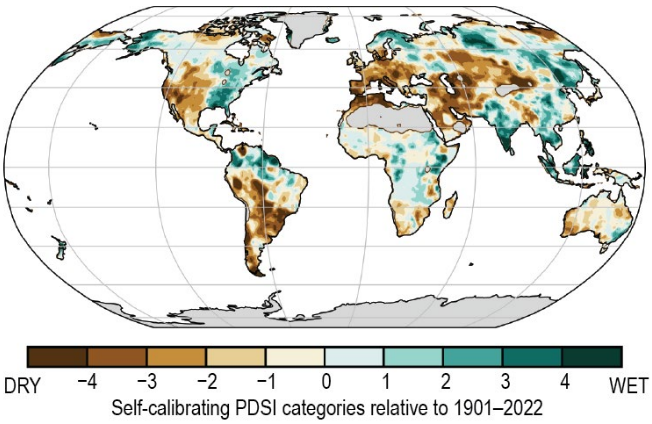
(o) Terrestrial Water Storage



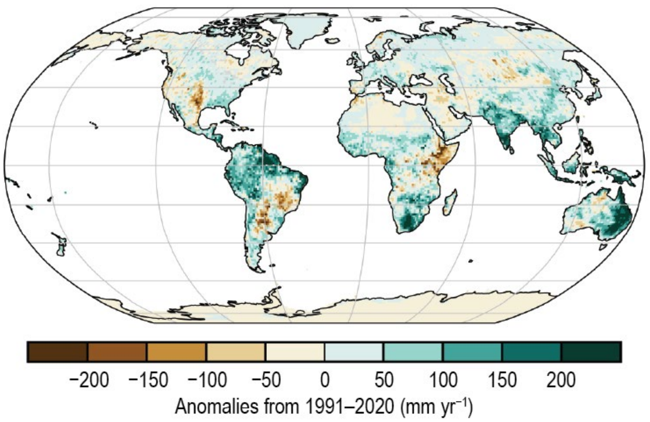
(p) Soil Moisture



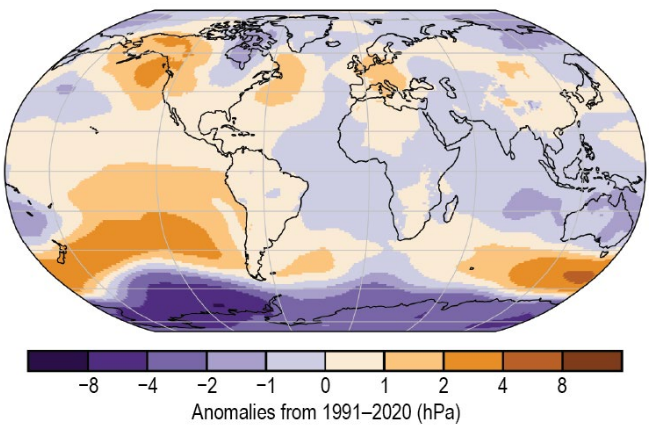
(q) Drought



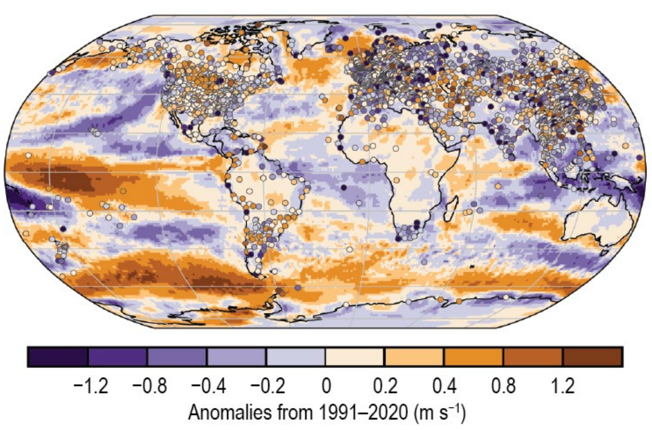
(r) Land Evaporation



(s) Sea Level Pressure



(t) Surface Winds



(u) Upper Air (850-hPa) Eastward Winds

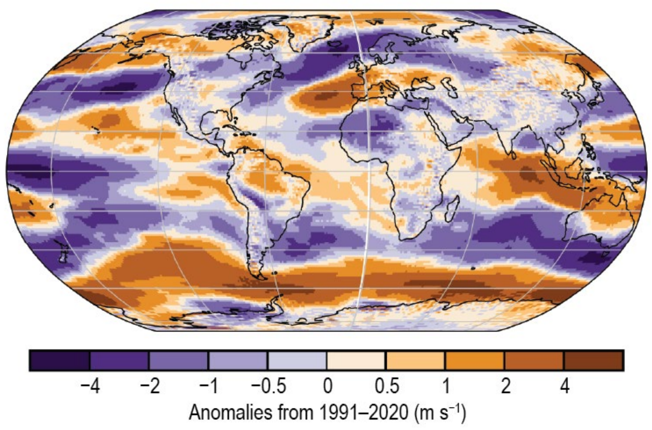
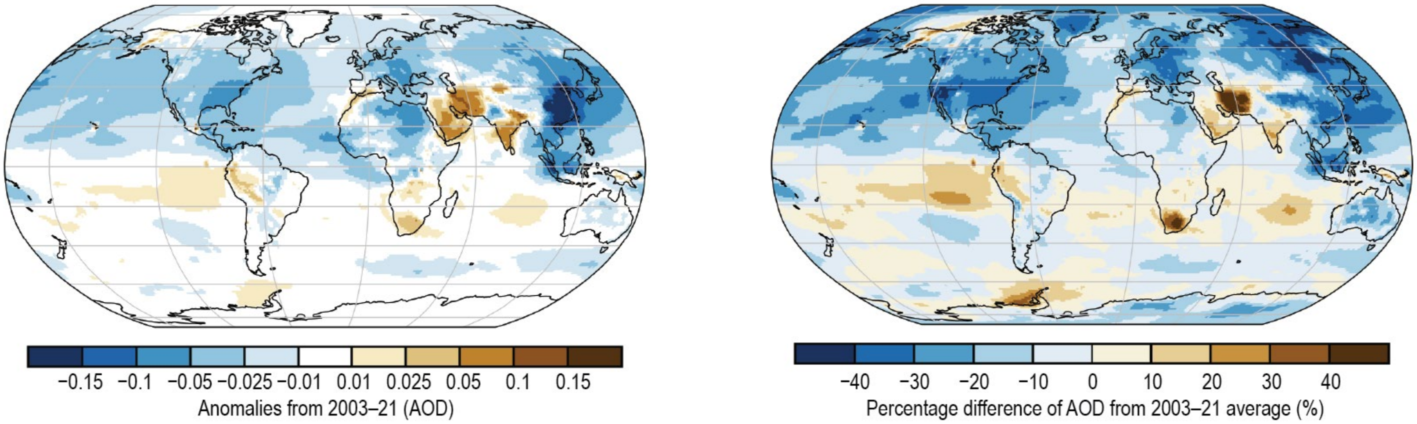
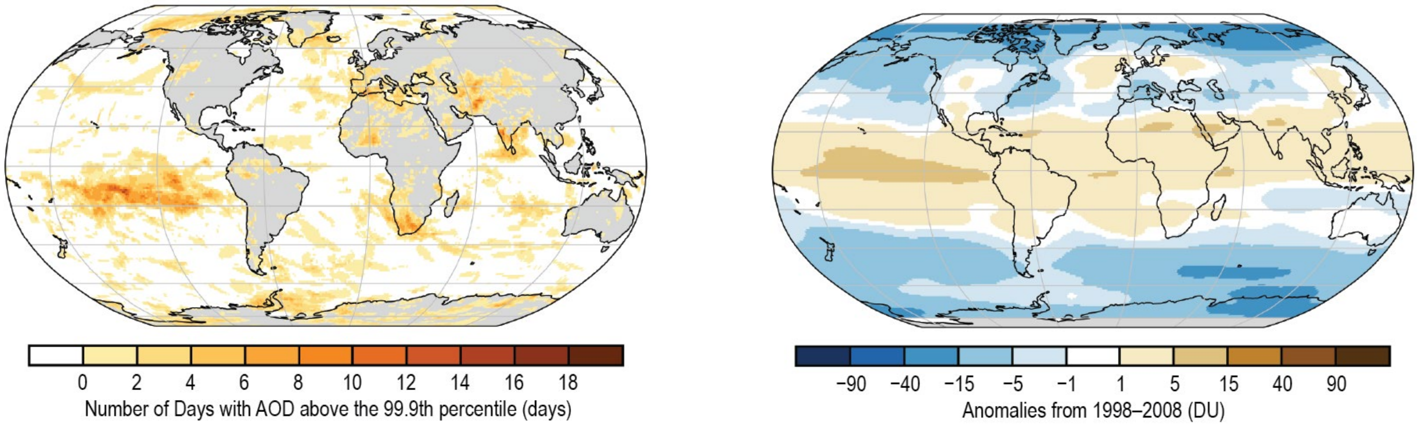


Plate 2.1 (cont.) (o) GRACE and GRACE-FO difference in annual-mean terrestrial water storage between 2020 and 2021 (cm); (p) C3S average surface soil moisture anomalies (m^3 m^{-3}). Data are masked where no retrieval is possible or where the quality is not assured and flagged, for example due to dense vegetation, frozen soil, or radio frequency interference; (q) Mean scPDSI for 2021. Droughts are indicated by negative values (brown), wet episodes by positive values (green); (r) GLEAM land evaporation anomalies (mm yr^{-1}); (s) ERA5 mean sea-level pressure anomalies (hPa); (t) Surface wind speed anomalies (m s^{-1}) from the observational HadISD3 dataset (land, circles), the ERA5 reanalysis output (land, shaded areas), and RSS satellite observations (ocean, shaded areas); (u) ERA5 850-hPa eastward wind speed anomalies (m s^{-1});



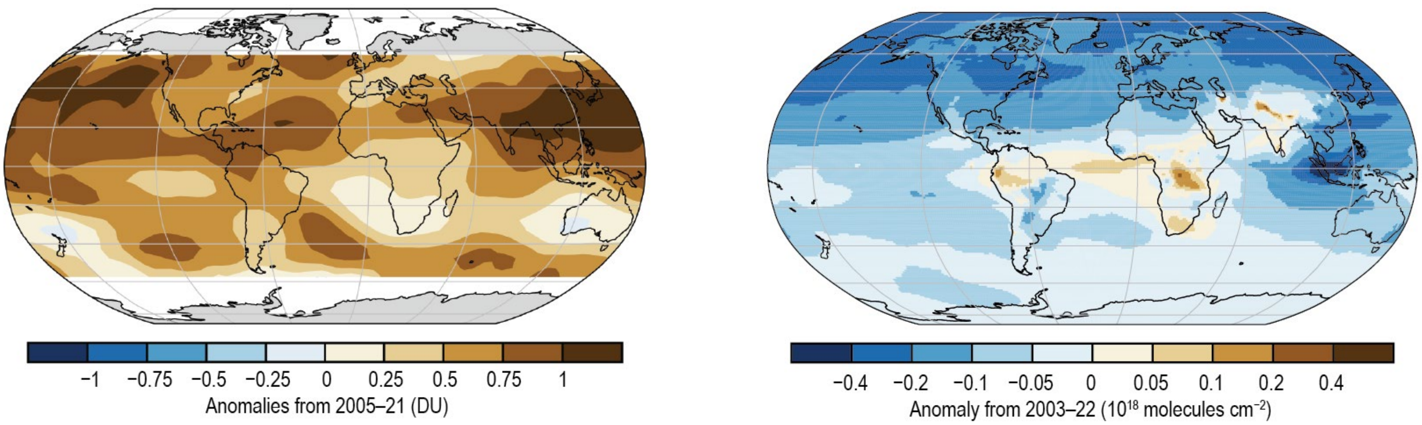
(v) Total Aerosol

(w) AOD Percentage Anomaly



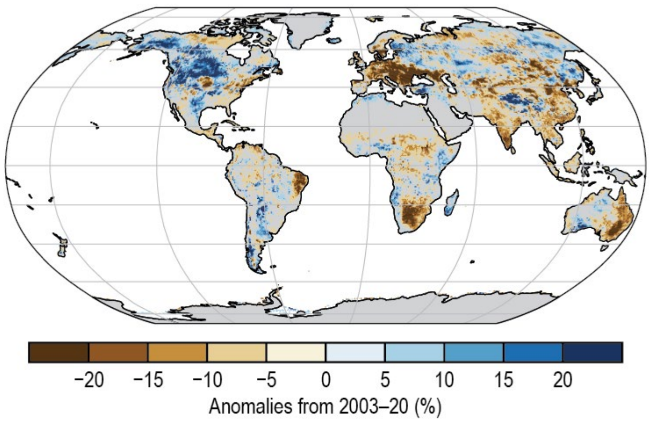
(x) Extreme Aerosol Days

(y) Stratospheric (Total Column) Ozone



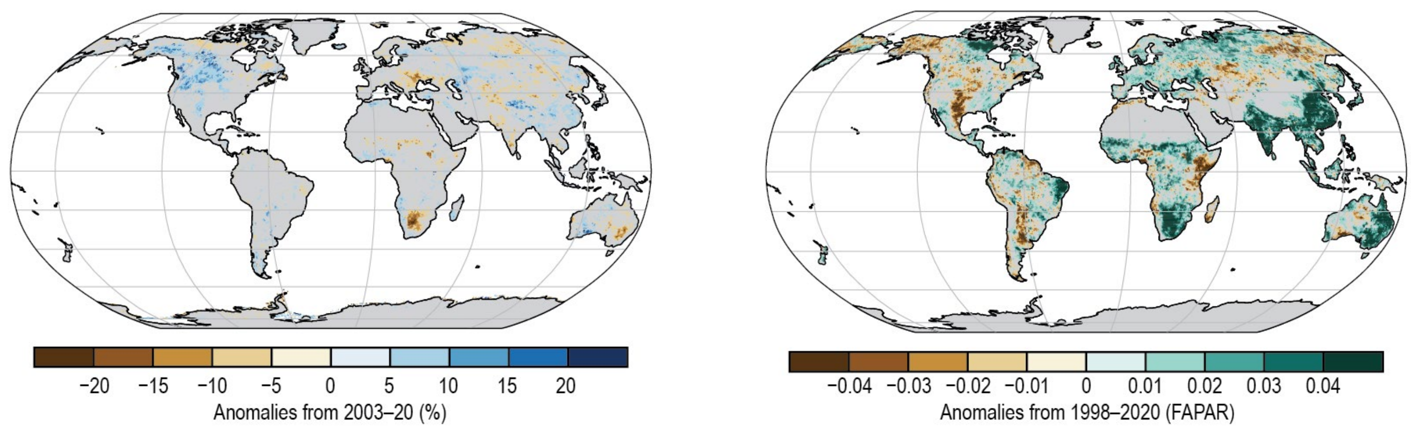
(z) OMI/MLS Tropospheric Column Ozone

(aa) Carbon Monoxide



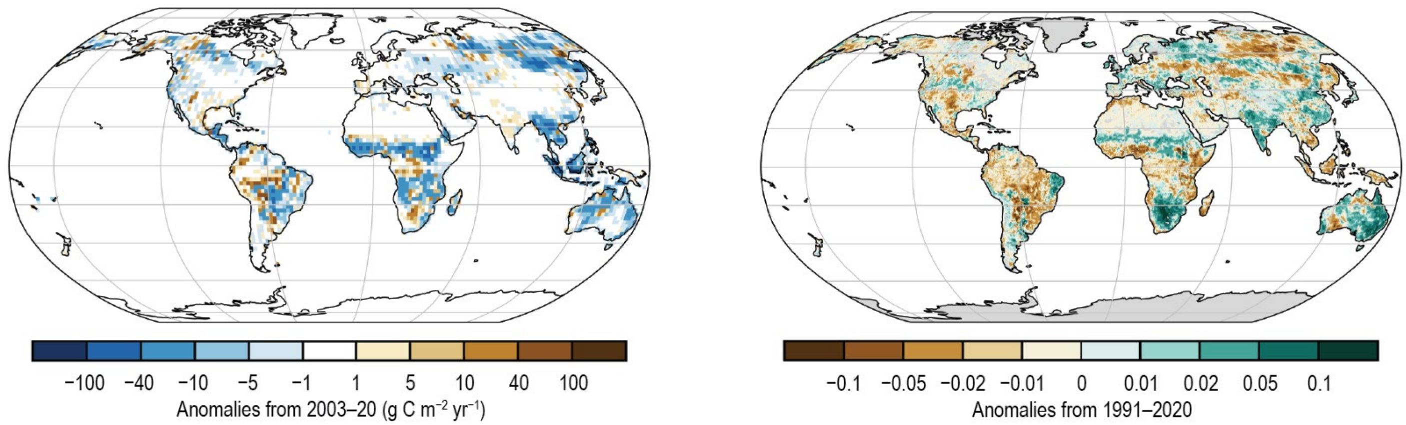
(ab) Land Surface Albedo in the Visible

Plate 2.1 (cont.) (v) Total aerosol optical depth (AOD) anomalies at 550 nm; (w) Percent difference of total AOD at 550 nm in 2022 relative to 2003–21; (x) Number of days with AOD above the 99.9th percentile. Areas with zero days appear as the white/gray background; (y) TROPOMI aboard Sentinel-5 Precursor (S5P) measurements of total column ozone anomalies relative to the 1998–2008 mean from GSG merged dataset (DU); (z) OMI /MLS tropospheric ozone column anomalies for 60°S–60°N (DU); (aa) CAMS reanalysis total column CO anomalies (× 10^{18} molecules cm^{-2}); (ab) Land surface visible broadband albedo anomalies (%);



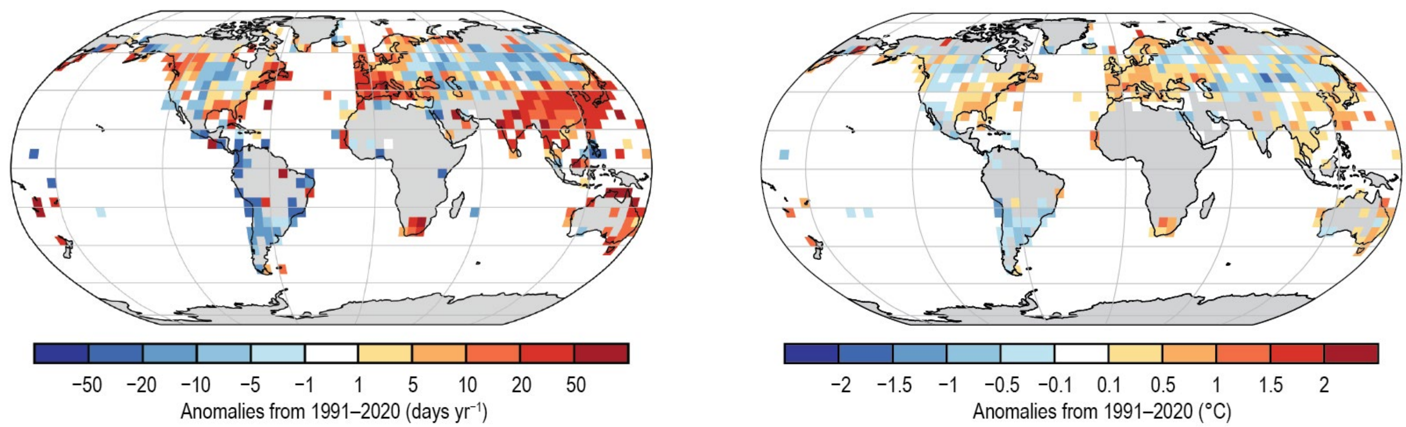
(ac) Land Surface Albedo in the Near-Infrared

(ad) Fraction of Absorbed Photosynthetically Active Radiation



(ae) Carbon Emissions from Biomass Burning

(af) Vegetation Optical Depth



(ag) Humid-heat days (TwX90p)

(ah) Maximum T_{wet}

Plate 2.1 (cont.) (ac) Land surface near-infrared albedo anomalies (%); (ad) FAPAR anomalies; (ae) GFASv1.4 carbonaceous emission anomalies (g C m^{-2} yr^{-1}) from biomass burning; (af) VODCA Ku-band VOD anomalies; (ag) HadISDH extremes daily maximum wet bulb temperature 90th percentile exceedances (days yr^{-1}); (ah) HadISDH.extremes annual mean anomaly in daily maximum wet bulb of the month (°C).

in autumn. This aggravated the water deficit of the region for the second consecutive year (van der Schalie et al. 2022). Persistent dry conditions also continued in southern South America and were especially pronounced in the Rio Paranà basin and Patagonia, now in a four-year-long drought spell (Naumann et al. 2021). In eastern Africa, the Indian Ocean dipole (IOD) is one of the main drivers of intra-annual climatic variability along with the El Niño–Southern Oscillation (Nicholson 2017; Marchant et al. 2007; Anderson et al. 2022). The negative IOD mode, which lasted until October 2022 (see section 4f for details), is consistent with the below-average soil moisture observed for most of the Horn of Africa, northern Mozambique, and Madagascar, developing into very dry conditions toward the end of the year. Negative anomalies for the region are a continuation of the severe droughts in recent years (Anderson et al. 2022). Mild negative anomalies remained steady throughout 2022 around the Mediterranean Sea regions (Spain, northern Morocco, Libya, and Tunisia). In large parts of China and northern Asia, widespread negative anomalies persisted and intensified in the eastern Siberian tundra region at the end of the boreal autumn. However, the strong negative water deficit in the Yangtze River basin (section 2d8) is not as visible in the surface layer.

A strong intra-annual variation was observed in western and northern Australia, with average to very dry conditions (below -0.1 m^3 m^{-3}) in the first part of the year giving way to slightly positive anomalies from mid-year. A similar progression was observed for the Arabian Peninsula and the Persian plateau, northern Europe (Scandinavian peninsula), and the southern Sahel regions. In contrast, the Pacific Northwest region started 2022 with above-average conditions, which subsided toward the boreal summer, turning to below-average soil moisture by the end of the year.

Soil moisture was observed by microwave satellite remote sensing of the upper few centimeters of the soil layer, as provided by the COMBINED product of the Copernicus Climate Change Service (C3S) v202012 (Dorigo et al. 2017). C3S combines multi-sensor data in the 1978–2022 period through statistical merging (Gruber et al. 2017, 2019). Wet and dry anomalies here refer to the positive and negative deviations respectively from the 1991–2020 climatological average.

10. MONITORING GLOBAL DROUGHT USING THE SELF-CALIBRATING PALMER DROUGHT SEVERITY INDEX

—J. Barichivich, T. J. Osborn, I. Harris, G. van der Schrier, and P. D. Jones

The self-calibrating Palmer Drought Severity Index (scPDSI) over the period 1950–2022 shows that the ongoing increase in global drought since mid-2019 (Barichivich et al. 2020, 2021) reached a new historical peak in October 2022 (Fig. 2.39), surpassing the peak in August 2021 (Barichivich et al. 2022). A historical maximum of 6.2% of the global land area experienced extreme drought conditions (scPDSI≤−4) in August 2022, slightly greater than the previous maximum in October 1984 (6.1%). The extent of severe plus extreme drought conditions (scPDSI≤−3) in 2022 exceeded 15% of the global land area between July and November, reaching a historical maximum of 15.8% in August. Similarly, moderate or worse drought conditions (scPDSI≤−2) peaked in October at a historical maximum of 29% of the global land area.

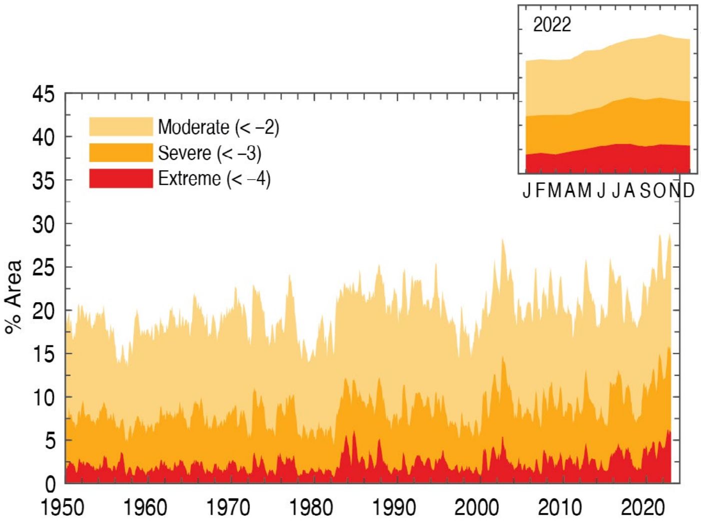


Fig. 2.39. Percentage of global land area (excluding ice sheets and deserts) with the self-calibrating Palmer Drought Severity Index (scPDSI) indicating moderate (<−2), severe (<−3), and extreme (<−4) drought for each month during 1950–2022. Inset: each month of 2022.

The global pattern of regional droughts in 2021 largely persisted through 2022 (Plate 2.1q). Drought severity through western

North America remained mostly unchanged from 2021 to 2022, but worsened in Europe, parts of South America, and the midlatitudes of Asia (Fig. 2.40). Despite persistent drought conditions in western North America, California experienced a milder fire season than in 2021 (section 2h3) but the west–east moisture contrast observed across the United States since 2017 persisted (Plate 2.1q). In South America, earlier drought hot spots through most of Chile and around the El Gran Chaco region in northern Argentina intensified (Barichivich et al. 2022). The record-breaking megadrought of central Chile reached its 13th consecutive year in 2022, and 80-year record-low river levels in northern Argentina and Paraguay (e.g., Bermejo and Paraná) disrupted fluvial transport.

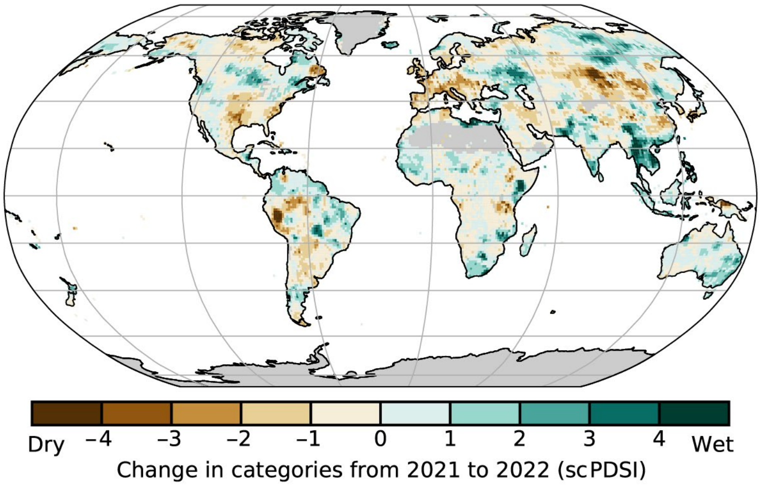


Fig. 2.40. Change in drought (self-calibrating Palmer Drought Severity Index [scPDSI]) from 2021 to 2022 (mean scPDSI for 2022 minus mean scPDSI for 2021). Increases in drought severity are indicated by negative values (brown), decreases by positive values (green). No calculation is made where a drought index is not physically meaningful (gray areas: ice sheets or deserts with approximately zero mean precipitation).

A persistent lack of precipitation in large areas of Europe from winter to summer, together with warmer-than-usual conditions and a sequence of heatwaves (sections 2b4, 7f) triggered a severe-to-extreme drought (Plate 2.1q). At its peak, the drought affected more than two-thirds of Europe, becoming one of the worst historical droughts in France, Spain, Germany, and Italy. In northern Italy, the Po River and canals in Venice reached record-low levels. The drought did not extend into northern Europe, where wet conditions across Fennoscandia continued through 2022. In northern Africa, previous moderate drought intensified to extreme drought along the Mediterranean coast from Morocco to Tunisia (Plate 2.1q). Most of the Middle East from eastern Turkey to Pakistan also saw an intensification of drought to severe or extreme conditions.

Although changes in moisture anomalies through tropical Africa are uncertain due to the sparse coverage of meteorological station data, this region largely saw a continuation of the wet conditions that began in 2019 (Plate 2.1q). In southern Africa, drought conditions seen since 2018 continued through 2022 but eased slightly compared to 2021 (Fig. 2.40). In Australia, previous drought eased in the east but most of the country continued under moderate drought during 2022 (Plate 2.1q). In contrast, India and Southeast Asia experienced predominantly wet conditions. The Yangtze River basin in central-eastern China saw severe drought as a result of precipitation deficit combined with an extreme heatwave, though most of northern China saw wet conditions (see section 7g and Sidebar 7.2 for details). Previous moderate-to-severe drought in parts of northeastern Siberia and the Russian Far East continued in 2022 (Plate 2.1q).

The update of the scPDSI (Wells et al. 2004; van der Schrier et al. 2013) for this year uses global precipitation and Penman-Monteith Potential Evapotranspiration (ET) from an early update of the Climatic Research Unit gridded Time Series (CRU TS) 4.07 dataset (Harris et al. 2020). It incorporates new estimates of some variables in CRU TS4.07 compared with CRU TS4.06 used last year, affecting potential ET via an improved baseline climatology for cloud cover. These revisions modify the scPDSI drought index values throughout, notably a small reduction in the global areas of moderate and severe drought that is consistent throughout the time series.

2.d.7 Lake water level

B. M. Kraemer recognizes support from the grant "SeeWandel: Life in Lake Constance - the Past, Present and Future" within the framework of the Interreg V programme "Alpenrhein-Bodensee-Hochrhein (Germany/Austria/Switzerland/Liechtenstein)" whose funds are provided by the European Regional Development Fund as well as the Swiss Confederation and cantons. M.F. Meyer was supported by a USGS Mendenhall Fellowship from the Water Mission Area. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

2.d.8 Groundwater and terrestrial water storage

Work on the Groundwater and Terrestrial Water Storage section was funded by NASA's GRACE-FO Science Team.

2.d.9 Soil moisture

This study uses satellite soil moisture observations from the Copernicus Climate Change Service (C3S) Climate Data Store (CDS): Soil moisture gridded data from 1978 to present. (Accessed on 19-01-2023), 10.24381/cds.d7782f18

2.d.10 Drought

Jonathan Barichivich was supported by the European Research Council (ERC) under the Horizon Europe research and innovation programme (ERC-starting grant CATES, grant agreement No. 101043214). Tim Osborn received funding from UK NERC (NE/S015582/1). Ian Harris received funding from UK National Centre for Atmospheric Science (NCAS). The research presented in the drought section was carried out on the High-Performance Computing Cluster supported by the Research and Specialist Computing Support service at the University of East Anglia.

2.d.11 Land evaporation

D. G. Miralles acknowledges support from the European Research Council (ERC) under grant agreement no. 101088405 (HEAT). M.F. McCabe and H.E. Beck are supported by the King Abdullah University of Science and Technology.

2.e.2 Surface winds

C. Azorin-Molina was supported by CSIC-UV-GVA and funded by AICO/2021/023, LINCGLOBAL-CSIC ref. INCGLO0023, INTRAMURAL-CSIC ref. 202230I068, and PTI-CLIMA.R. J. H. Dunn was supported by the Met Office Hadley Centre Climate Programme funded by BEIS. L. Ricciardulli was supported by NASA Ocean Vector Wind Science Team grant 80HQTR19C0003. Z. Zeng was supported by the National Natural Science Foundation of China grant 42071022.

2.e.4 Lightning

The work of M. Füllekrug was sponsored by the Royal Society (UK) grant NMG/R1/180252 and the Natural Environment Research Council (UK) under grants NE/L012669/1 and NE/H024921/1.

E. Williams is supported for studies on global circuit response to climate change from the Physical and Dynamic Meteorology Program at the National Science Foundation on grant no. 6942679.

C. Price was supported in his lightning research by the Israel Science Foundation (ISF) grant 2701/17, and the Ministry of Energy grant no. 220-17-002. S. Goodman was supported by NASA Grant 80NSSC21K0923 and NASA Contract 80GSFC20C044. K.Virts is supported in part by the GOES-R Series Science, Demonstration, and Cal/Val Program at Marshall Space Flight Center. D. Buechler is supported by the NASA MSFC/UAH Cooperative Agreement NNM11AA01A. The authors wish to thank Peter Thorne at Maynooth University in Ireland and at the European Centre for Medium Range Weather Forecast (ECMWF) for suggesting and initiating this work and for recommending that lightning be made an essential climate variable. ISS LIS acknowledges support from the NASA Science Mission Directorate.

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