STATE OF THE CLIMATE IN 2021

GLOBAL CLIMATE

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

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Corresponding author: Robert Dunn / robert.dunn@metoffice.gov.uk

STATE OF THE CLIMATE IN 2021
Global Climate

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Caption: Lightning discharges appear in various colours depending on the scatter of light inside the thundercloud and in the atmosphere. The intracloud lightning discharges in the centre of the thundercloud appear to be white with a bluish tint, and the cloud-to-ground discharge below appears to be orange. The right hand side of the thundercloud exhibits a green tint that is attributed to the unique composition of hydrometeors inside the thundercloud.

The photo was taken in the late evening of 10 September 2013, near Tarragona in northeastern Spain.

Global Climate is one chapter from the State of the Climate in 2021 annual report and is available from https://doi.org/10.1175/BAMS-D-22-0092.1. Compiled by NOAA's National Centers for Environmental Information, *State of the Climate in 2021* 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.
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Editor and Author Affiliations (alphabetical by name)

Ades, Melanie, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
Adler, Robert, CMNS-Earth System Science Interdisciplinary Center, University of Maryland, College Park, Maryland
Aldred, Freya, Met Office Hadley Centre, Exeter, United Kingdom
Allan, R. P., Department of Meteorology and National Centre for Earth Observation, University of Reading, Reading, United Kingdom
Anderson, John, Department of Atmospheric and Planetary Science, Hampton University, Hampton, Virginia
Anneville, Orlane, National Research Institute for Agriculture, Food and Environment (INRAE), CARRTEL, Université Savoie Mont Blanc, Thonon les Bains, France
Aono, Yasuyuki, Graduate School of Life and Environmental Sciences, Osaka Prefecture University, Sakai, Osaka, Japan
Argüez, Anthony, NOAA/NESDIS National Centers for Environmental Information, Asheville, North Carolina
Arosio, Carlo, University of Bremen, Bremen, Germany
Augustine, John A., NOAA Global Monitoring Laboratory, Boulder, Colorado
Azorin-Molina, Cesar, Centro de Investigaciones sobre Desertificación, Spanish National Research Council (CIDE, CSIC-UV-Generalitat Valenciana), Climate, Atmosphere and Ocean Laboratory (Climatoc-Lab), Moncada, Valencia, Spain
Barichivich, Jonathan, Instituto de Geografía, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile and Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom
Basu, Aman, York University, Toronto, Canada
Beck, Hylke E., Joint Research Centre of the European Commission, Ispra, Italy and GloH2O, Almere, the Netherlands
Bellouin, Nicolas, University of Reading, Reading, United Kingdom
Benedetti, Angela, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
Blagrave, Kevin, York University, Toronto, Canada
Blenkinsop, Stephen, School of Engineering, Newcastle University, Newcastle-upon-Tyne, United Kingdom
Bock, Olivier, Université de Paris Cité, Institut de physique du globe de Paris, CNRS, IGN, F-7500 Paris, France
Bodin, Xavier, Laboratoire EDYTEM, CNRS/Université Savoie Mont-Blanc, Le Bourget-du-Lac, France
Bosilovich, Michael G., Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, Maryland
Boucher, Olivier, Sorbonne Université, Paris, France
Bove, Gerald, University of the Virgin Islands, St. Thomas, U.S. Virgin Islands
Buechler, Dennis, University of Huntsville Alabama, Huntsville, Alabama
Buehler, Stefan A., Meteorologisches Institut, Centrum für Erdsystem- und Nachhaltigkeitsforschung (CEN), Fachbereich Erdsystemwissenschaften, Universität Hamburg, Hamburg, Germany
Carrea, Laura, Department of Meteorology, University of Reading, Reading, United Kingdom
Chang, Kai-Lan, Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder; and NOAA Chemical Sciences Laboratory, Boulder, Colorado
Christiansen, Hanne H., Geology Department, University Centre in Svalbard, Longyearbyen, Norway
Christy, John R., The University of Alabama in Huntsville, Huntsville, Alabama
Chung, Eui-Seok, IBS Center for Climate Physics, South Korea
Ciasto, Laura M., NOAA Climate Prediction Center, College Park, Maryland
Coldewey-Egbers, Melanie, DLR (German Aerospace Center) Oberpfaffenhofen, Wessling, Germany
Cooper, Owen R., Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado; and NOAA Chemical Sciences Laboratory, Boulder, Colorado
Cornes, Richard C., National Oceanography Centre, Southampton, United Kingdom
Covey, Curt, Lawrence Livermore National Laboratory, Livermore California
Cropper, Thomas, National Oceanography Centre, Southampton, United Kingdom
Crotwell, Molly, Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado; and NOAA Global Monitoring Laboratory, Boulder, Colorado
Cusicanqui, Diego, Université Grenoble Alpes, Institut de Géosciences de l'Environnement (IGE), Grenoble, France
Davis, Sean M., NOAA Chemical Sciences Laboratory, Boulder, Colorado
de Jeu, Richard A. M., Planet Labs, Haarlem, The Netherlands
Degenstein, Doug, University of Saskatchewan, Saskatoon, Saskatchewan, Canada
Delaloye, Reynald, Department of Geosciences, University of Fribourg, Fribourg, Switzerland
Donat, Markus G., Barcelona Supercomputing Centre, Barcelona, Spain and Catalan Institution for Research and Advanced Studies (ICREA), Barcelona, Spain
Dorigo, Wouter A., TU Wien, Vienna, Austria
Dunn, Robert J. H., Met Office Hadley Centre, Exeter, United Kingdom
Durre, Imke, NOAA/NESDIS National Centers for Environmental Information, Asheville, North Carolina
Dutton, Geoff S., Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado; and NOAA Global Monitoring Laboratory, Boulder, Colorado
Duveiller, Gregory, Max Planck Institute for Biogeochemistry, Jena , Germany
Elkins, James W., NOAA Global Monitoring Laboratory, Boulder, Colorado
Estilow, Thomas W., Rutgers University, Piscataway, New Jersey
Fedaeff, Nava, National Institute of Water and Atmospheric Research (NIWA), New Zealand
Fereday, David, Met Office Hadley Centre, Exeter, United Kingdom
Fioletov, Vitali E., Environment and Climate Change Canada, Toronto, Canada
Flemming, Johannes, Copernicus Department, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
Foster, Michael J., Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, University of Wisconsin-Madison, Madison, Wisconsin
Frith, Stacey M., Science Systems and Applications, Inc., Lanham, Maryland; and NASA Goddard Space Flight Center, Greenbelt, Maryland
Froidevaux, Lucien, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
Füllekrug, Martin, University of Bath, Bath, United Kingdom
Garforth, Judith, Woodland Trust, Grantham, United Kingdom
Garg, Jay, SSAI, Hampton, Virginia
Gentry, Matthew, Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado; and NOAA Global Monitoring Laboratory, Boulder, Colorado
Gobron, Nadine, European Commission Joint Research Centre, Ispra, Italy
Goodman, Steven, Thunderbolt Global Analytics, Huntsville, Alabama
Gou, Qiqi, Hydro-Climate Extremes Lab (H-CEL), Ghent University, Ghent, Belgium
Granin, Nikolay, Siberian Branch of Russian Academy of Sciences, Irkutsk, Russia
Guglielmin, Mauro, Department of Theoretical and Applied Science, Insubria University, Italy
Hahn, Sebastian, TU Wien, Vienna, Austria
Haimberger, Leopold, Department of Meteorology and Geophysics, University of Vienna, Vienna, Austria

Editor and Author Affiliations (alphabetical by name)

Hall, Brad D., NOAA Global Monitoring Laboratory, Boulder, Colorado
Harris, Ian, National Centre for Atmospheric Science (NCAS), University of East Anglia, Norwich, United Kingdom; and Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom
Hemming, Debbie L., Met Office Hadley Centre, Exeter, United Kingdom; and Birmingham Institute of Forest Research, Birmingham University, Birmingham, United Kingdom
Hirschi, Martin, ETH Zürich, Zürich, Switzerland
Ho, Shu-pen (Ben), Center for Satellite Applications and Research, NOAA, College Park, Maryland
Holzworth, Robert, University of Washington, Seattle, Washington
Hrbáček, Filip, Department of Geography, Masaryk University, Brno, Czech Republic
Hubert, Daan, Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium
Hulsman, Petra, Hydro-Climate Extremes Lab (H-CEL), Ghent University, Ghent, Belgium
Hurst, Dale F., Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, Colorado; NOAA Global Monitoring Laboratory, Boulder, Colorado
Inness, Antje, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
Isaksen, Ketil, Norwegian Meteorological Institute, Oslo, Norway
John, Viju O., EUMETSAT, Darmstadt, Germany
Jones, Philip D., Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom
Junod, Robert, Earth System Science Center (ESSC), University of Alabama in Huntsville, Huntsville, Alabama
Kääb, Andreas, Department of Geosciences, University of Oslo, Norway
Kaiser, Johannes W., Centre for Agrometeorological Research (ZAMF), German Meteorological Service (DWD), Braunschweig, Germany
Kaufmann, Viktor, Institute of Geodesy, Working Group Remote Sensing and Photogrammetry, Graz University of Technology, Graz, Austria
Kellerer-Pirklbauer, Andreas, Institute of Geography and Regional Science, Cascade – The Mountain Processes and Mountain Hazards Group, University of Graz, Graz, Austria
Kent, Elizabeth C., National Oceanography Centre, Southampton, United Kingdom
Kidd, Richard, Earth Observation Data Centre (EODC), Vienna, Austria
Kim, Hyungjun, Moon Soul Graduate School of Future Strategy and Department of Civil and Environmental Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Korea
Kipling, Zak, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
Koppa, Akash, Hydro-Climate Extremes Lab (H-CEL), Ghent University, Ghent, Belgium
L'Abée-Lund, Jan Henning, Norwegian Water Resources and Energy Directorate, Oslo, Norway
Lan, Xin, Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado; NOAA Global Monitoring Laboratory, Boulder, Colorado
Lantz, Kathleen O., NOAA Global Monitoring Laboratory, Boulder, Colorado
Lavers, David, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
Loeb, Norman G., NASA Langley Research Center, Hampton, Virginia
Loyola, Diego, DLR (German Aerospace Center) Oberpfaffenhofen, Wessling, Germany
Madelon, Remi, CESBIO (Université Toulouse 3, CNES, CNRS, INRAE, IRD), Toulouse, France
Malmquist, Hilmar J., Icelandic Museum of Natural History, Reykjavík, Iceland
Marszelewski, Wlodzimierz, Nicolaus Copernicus University in Toruń, Toruń, Poland
Mayer, Michael, University of Vienna, Vienna, Austria; and European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
McCabe, Matthew F., Division of Biological and Environmental Sciences and Engineering, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia
McVicar, Tim R., CSIRO Land and Water, Canberra, Australian Capital Territory; and Australian Research Council Centre of Excellence for Climate Extremes, Sydney, New South Wales, Australia
Mears, Carl A., Remote Sensing Systems, Santa Rosa, California
Menzel, Annette, TUM School of Life Sciences, Technical University of Munich, Freising, Germany; and Institute for Advanced Study, Technical University of Munich, Garching, Germany
Merchant, Christopher J., Department of Meteorology, University of Reading, Reading, United Kingdom
Miller, John B., NOAA Global Monitoring Laboratory, Boulder, Colorado
Miralles, Diego G., Hydro-Climate Extremes Lab (H-CEL), Ghent University, Ghent, Belgium
Montzka, Stephen A., NOAA Global Monitoring Laboratory, Boulder, Colorado
Morice, Colin, Met Office Hadley Centre, Exeter, United Kingdom
Mösinger, Leander, TU Wien, Vienna, Austria
Mühle, Jens, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California
Nicolas, Julien P., European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
Noetzli, Jeannette, WSL Institute for Snow and Avalanche Research SLF, Davos-Dorf, Switzerland and Climate Change, Extremes and Natural Hazards in Alpine Regions Research Center CERC, Davos Dorf, Switzerland
Nõges, Tiina, Estonian University of Life Sciences, Tartu, Estonia
Noll, Ben, National Institute of Water and Atmospheric Research (NIWA), New Zealand
O'Keefe, John, The Harvard Forest, Harvard University, Petersham, Massachusetts
Osborn, Tim J., Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom
Park, Taejin, NASA Ames Research Center, Moffett Field, California; Bay Area Environmental Research Institute, Moffett Field, California
Pellet, Cecile, Department of Geosciences, University of Fribourg, Fribourg, Switzerland
Pelto, Maury S., Nichols College, Dudley, Massachusetts
Perkins-Kirkpatrick, Sarah E., University of New South Wales, Canberra, Australia
Phillips, Coda, Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, University of Wisconsin-Madison, Madison, Wisconsin
Po-Chedley, Stephen, Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, Livermore, California
Polvani, Lorenzo, Columbia University, New York, New York
Preimesberger, Wolfgang, TU Wien, Vienna, Austria
Price, Colin, Tel Aviv University, Tel Aviv, Israel
Pulkkanen, Merja, Finnish Environment Institute SYKE, Helsinki, Finland
Rains, Dominik G., Hydro-Climate Extremes Lab (H-CEL), Ghent University, Ghent, Belgium
Randel, William J., National Center for Atmospheric Research (NCAR), Boulder, Colorado

Editor and Author Affiliations (alphabetical by name)

Rémy, Samuel, HYGEOS, Lille, France
Ricciardulli, Lucrezia, Remote Sensing Systems, Santa Rosa, California
Richardson, Andrew D., School of Informatics, Computing, and Cyber Systems and Center for Ecosystem Science and Society, Northern Arizona University, Flagstaff, Arizona
Robinson, David A., Rutgers University, Piscataway, New Jersey
Rodell, Matthew, Hydrological Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, Maryland
Rodríguez-Fernández, Nemesio J., CESBIO, Université Toulouse 3, CNES, CNRS, INRAE, IRD, Toulouse, France
Rosenlof, Karen H., NOAA Chemical Sciences Laboratory, Boulder, Colorado
Roth, Chris, University of Saskatchewan, Saskatoon, Canada
Rozanov, Alexei, University of Bremen, Bremen, Germany
Rutishäuser, This, Swiss Academy of Sciences (SCNAT), Bern, Switzerland
Sánchez-Lugo, Ahira, NOAA/NESDIS National Centers for Environmental Information, Asheville, North Carolina
Sawaengphokhai, Parnchai, Science Systems and Applications, Inc. (SSAI), Hampton, Virginia
Schenzinger, Verena, Medical University of Innsbruck, Innsbruck, Austria
Schlegel, Robert W., Sorbonne Université, CNRS, Villefranche-sur-mer, France
Schneider, Udo, Global Precipitation Climatology Centre, Deutscher Wetterdienst, Offenbach, Germany
Sharma, Sapna, York University, Toronto, Ontario, Canada
Shi, Lei, NOAA/NESDIS National Centers for Environmental Information, Asheville, North Carolina
Simmons, Adrian J., European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
Siso, Carolina, Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder CO USA, and NOAA Global Monitoring Laboratory, Boulder, Colorado
Smith, Sharon L., Geological Survey of Canada, Natural Resources Canada, Ottawa, Canada
Soden, Brian J., University of Miami Rosenstiel School of Marine and Atmospheric Science (RSMAS), Key Biscayne, Florida
Sofieva, Viktoria, Finnish Meteorological Institute (FMI), Helsinki, Finland
Sparks, Tim H., Poznań University of Life Sciences, Poznań, Poland
Stackhouse, Jr., Paul W., NASA Langley Research Center, Hampton, Virginia
Stauffer, Ryan, NASA Goddard Space Flight Center, Greenbelt, Maryland
Steinbrecht, Wolfgang, German Weather Service (DWD), Hohenpeissenberg, Germany
Steiner, Andrea K., Wegener Center for Climate and Global Change, University of Graz, Graz, Austria
Stewart, Kenton, State University of New York at Buffalo, Buffalo, New York
Stradiotti, Pietro, TU Wien, Vienna, Austria
Streletskiy, Dimitri A., George Washington University, Washington, D.C.
Telg, Hagen, Cooperative Institute for Research in the Environmental Sciences, University of Colorado, Boulder, Colorado
Thackeray, Stephen J., Centre for Ecology and Hydrology, Lancaster, United Kingdom
Thibert, Emmanuel, Université Grenoble Alpes, INRAE, UR ETGR, Grenoble, France
Todt, Michael, Cooperative Institute for Research in the Environmental Sciences, University of Colorado, Boulder
Tokuda, Daisuke, Institute of Industrial Science, The University of Tokyo, Tokyo, Japan
Tourpali, Kleareti, Aristotle University, Thessaloniki, Greece
Tye, Mari R., National Center for Atmospheric Research, Boulder, Colorado
van der A, Ronald, Royal Netherlands Meteorological Institute (KNMI), DeBilt, The Netherlands
van der Schalie, Robin, Planet Labs, Haarlem, The Netherlands
van der Schrier, Gerard, Royal Netherlands Meteorological Institute, De Bilt, The Netherlands
van der Vliet, Mendy, Planet Labs, Haarlem, The Netherlands
van der Werf, Guido R., Faculty of Science, Vrije Universiteit Amsterdam, Amsterdam, Netherlands
van Vliet, Arnold., Environmental Systems Analysis Group, Wageningen University & Research, the Netherlands
Vernier, Jean-Paul, National Institute of Aerospace/NASA Langley Research Center, Hampton, Virginia
Vimont, Isaac J., Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder; and NOAA Global Monitoring Laboratory, Boulder, Colorado
Virts, Katrina, University of Huntsville, Huntsville, Alabama
Vivero, Sebastiàn, Department of Geosciences, University of Fribourg, Fribourg, Switzerland
Vömel, Holger, Earth Observing Laboratory, National Center for Atmospheric Research, Boulder, Colorado
Vose, Russell S., NOAA National Centers for Environmental Information, Asheville, North Carolina
Wang, Ray H. J., Georgia Institute of Technology, Atlanta, Georgia
Weber, Markus, University of Bremen, Bremen, Germany
Wiese, David, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
Wild, Jeanette D., ESSIC/University of Maryland, College Park, Maryland; and NOAA Climate Prediction Center, College Park, Maryland
Willett, Kate M., Met Office Hadley Centre, Exeter, United Kingdom
Williams, Earle, Massachusetts Institute of Technology, Cambridge, Massachusetts
Wong, Takmeng, NASA Langley Research Center, Hampton, Virginia
Woolway, R. I., School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, Wales
Yin, Xungang, NOAA National Centers for Environmental Information, Asheville, North Carolina
Yuan, Ye, TUM School of Life Sciences, Technical University of Munich, Freising, Germany
Zhao, Lin, School of Geographical Sciences, Nanjing University of Information Science and Technology, Nanjing, China
Zhou, Xinjia, Center for Satellite Applications and Research, NOAA, College Park, Maryland
Ziemke, Jerry R., Goddard Earth Sciences Technology and Research, Morgan State University, Baltimore, Maryland; and NASA Goddard Space Flight Center, Greenbelt, Maryland
Ziese, Markus, Global Precipitation Climatology Centre, Deutscher Wetterdienst, Offenbach am Main, Germany
Zotta, Ruxandra M., TU Wien, Vienna, Austria

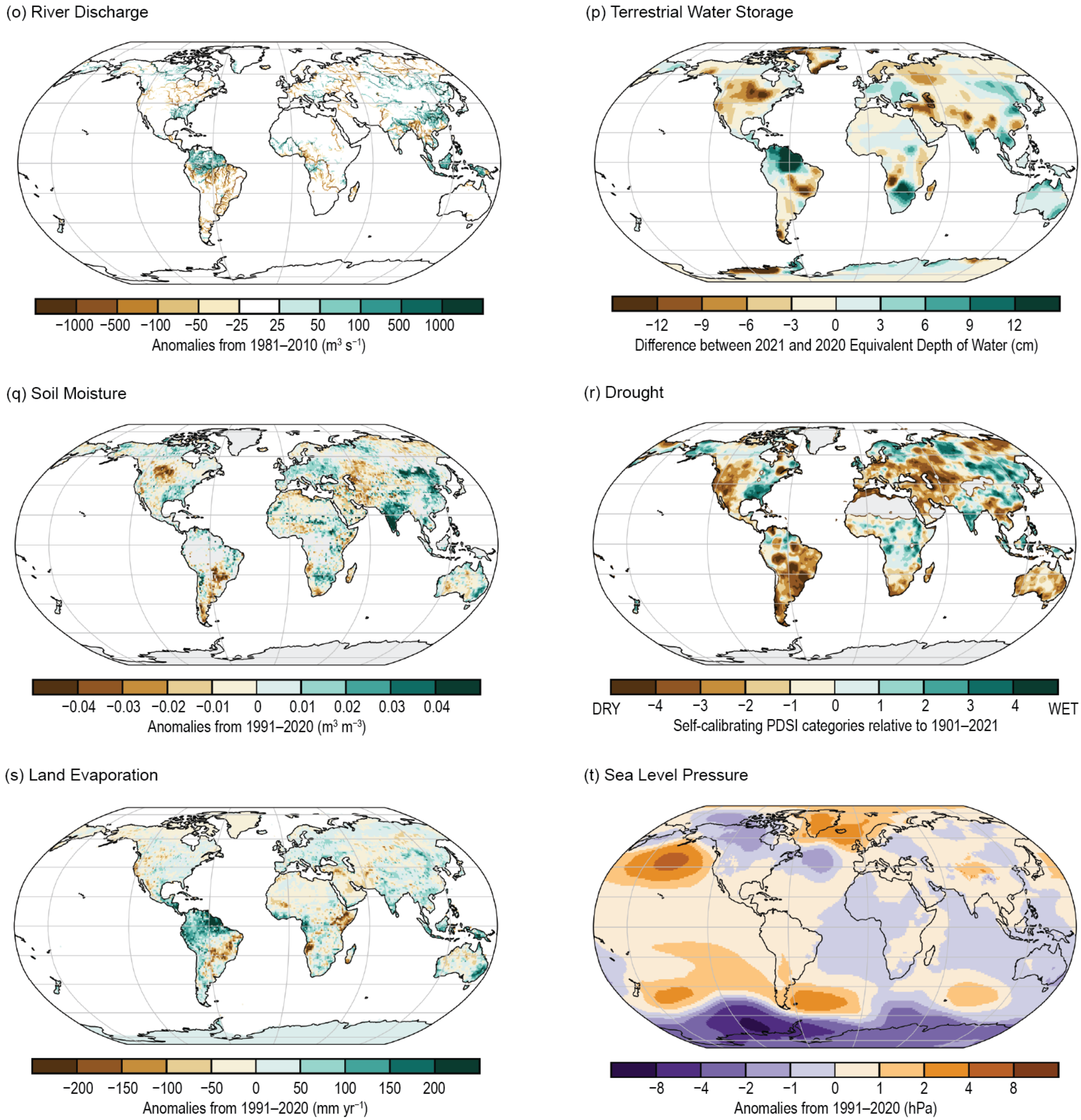

Plate 2.1. (cont.) (o) ELSE global distribution of river discharge anomalies ($m^3\ s^{-1}$); (p) GRACE and GRACE-FO difference in annual-mean terrestrial water storage between 2021 and 2020 (cm); (q) ESA CCI average surface soil moisture anomalies ($m^3\ m^{-3}$); (r) Mean scPDSI for 2021. Droughts are indicated by negative values (brown), wet episodes by positive values (green); (s) GLEAM land evaporation anomalies ($mm\ yr^{-1}$); (t) ERA5 sea level pressure anomalies (hPa);

(section 2d4). In late 2021, drier-than-usual conditions were present in Madagascar and Tanzania, following wetter-than-usual conditions at the beginning of the year.

In Russia, Siberia and surrounding regions experienced low rainfall and high temperatures that continued below-average soil moisture conditions overall. These negative anomalies were widespread throughout much of central Asia, with countries like Kazakhstan, Kyrgyzstan, Turkmenistan, and Uzbekistan experiencing drought events. For Siberia, this was a continuation of 2020 conditions. India, Thailand, Mongolia, and large parts of China observed positive anomalies, caused by above-average precipitation (section 2d4). Northeastern China and southern India are particularly noteworthy, as they recorded the highest wet anomalies globally of 2021, linked to the second highest rainfall totals since 1961 in parts of China (Li et al. 2022) and highest recorded November rainfall since 1901 in southern India (IMD 2022).

The wetting trend in Australia continued in 2021, partly related to La Niña, with most regions recording average or above-average soil moisture levels. The most intense positive anomaly was detected over New South Wales, which coincides with the above-average rainfall in that region (section 2d4). New Zealand generally saw average soil moisture conditions.

The soil moisture anomalies (representing the top ~5 cm of the soil) used in this analysis were derived from the COMBINED product of ESA's Climate Change Initiative for Soil Moisture v06.2 (https://climate.esa.int/en/projects/soil-moisture/; Dorigo et al. 2017), a merged product based on multiple active (Wagner et al. 2013) and passive microwave (van der Schalie et al. 2017) sensors. Merging is done based on both the quality and the temporal and spatial availability of observations (Gruber et al. 2017, 2019).

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 ongoing increase in global drought area, based on different severities of the self-calibrating Palmer Drought Severity Index (scPDSI), that began in mid-2019 (Barichivich et al. 2020) reached a new historical peak around August 2021 (Fig. 2.36), surpassing the previous high peak in October 2020 (Barichivich et al. 2021). Around 5.9% of the global land area experienced extreme drought conditions in September 2021, matching the earlier historical peak in October 1984. The extent of severe plus extreme drought conditions in 2021 peaked at 17% of the global land area in July and August, surpassing the earlier historical peak of this drought severity in December 2002 (16.6%). Similarly, moderate or worse drought conditions peaked in August at 32% of the global land area, surpassing the earlier historical peak in November 2002 (31.6%).

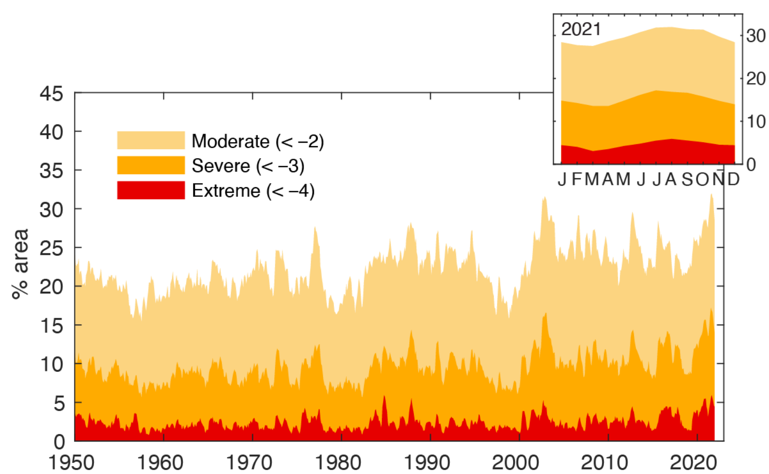

Fig. 2.36. Percentage of global land area (excluding ice sheets and deserts) with scPDSI levels of less than −2, −3, and −4, indicating moderate, severe, and extreme drought, respectively, for each month of 1950–2021.

The most extensive severe-to-extreme drought conditions in 2021 occurred across most of South America and western North America (Plate 2.1r), whereas the most extensive severe-to-extreme drought conditions in 2020 had been in Europe (Barichivich et al. 2021). Widespread drought in South America was mostly due to an intensification of previous drought (Fig. 2.37), leading to the expansion and intensification of earlier drought hotspots in central Chile and the Chaco region in northern Argentina (Barichivich et al. 2021). The ongoing protracted drought in central Chile reached its 12th consecutive year in 2021, becoming the longest drought in the historical record in the region. In

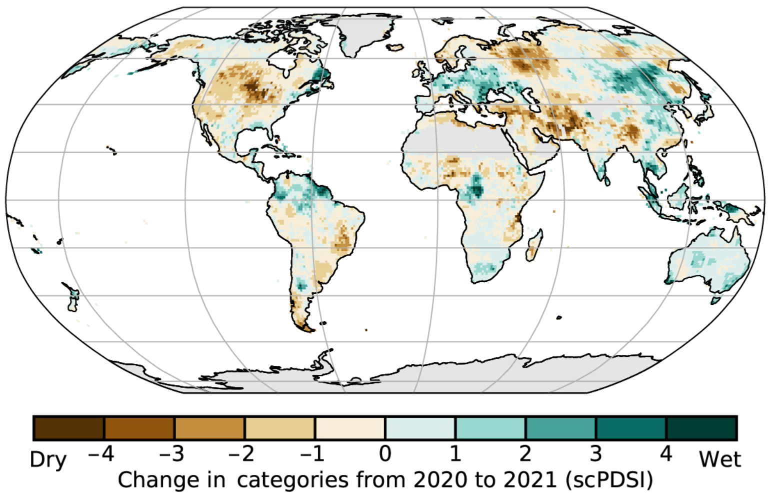

Fig. 2.37. Change in drought categories from 2020 to 2021 (mean scPDSI for 2021 minus mean scPDSI for 2020). Increases in drought severity are indicated by negative values (brown), decreases by positive values (blue). No calculation is made where a drought index is meaningless (gray areas: ice sheets or deserts with approximately zero mean precipitation).

North America, the intensification and expansion of drought through most of the western and formerly wetter central United States in 2021 (Fig. 2.37) weakened the east–west moisture contrast observed across the country since 2017 (Plate 2.1r). Under these persistent drought conditions, California saw another extreme season of wildfires (section 2h3), which was intensified by La Niña conditions.

Previous extensive severe-to-extreme drought across central Europe eased to moderate drought in 2021 (Fig. 2.37). Wet conditions in northern Europe from the British Isles to Scandinavia and western Russia continued through 2021 (Plate 2.1r). In northern Africa, previous drought conditions intensified along the Mediterranean coast. Most of tropical Africa saw a continuation of wet conditions from 2019 (Plate 2.1r), though changes in moisture anomalies in this region are uncertain due to the sparse coverage of meteorological station data. Persistent severe-to-extreme drought conditions in southern Africa since 2018 continued through 2021 but eased slightly compared to 2020 (Fig. 2.37).

In Australia, previous drought eased, but most of the country continued under drought conditions during 2021 (Plate 2.1r). In contrast, the Maritime Continent (Southeast Asia) experienced wet conditions, and previous drought in region eased, particularly across Vietnam. A large stretch along northeastern Siberia and the Far East region of Russia saw an intensification and expansion of severe drought along with extreme heat (Plate 2.1r), which led to unprecedented wildfires. Most of the Middle East from Turkey to Pakistan saw an intensification of drought to moderate-to-severe conditions.

Hydrological drought results from a period of abnormally low precipitation, sometimes exacerbated by a concurrent increase in evapotranspiration (ET). Its occurrence can be apparent in reduced river discharge, soil moisture, and/or groundwater storage, depending on season and duration of the event. Here, a simple estimate of drought called the self-calibrating Palmer Drought Severity Index (Wells et al. 2004; van der Schrier et al. 2013) is presented, using global precipitation and Penman-Monteith Potential ET from an early update of the CRU TS 4.06 dataset (Harris et al. 2020). Moisture categories are calibrated over the complete 1901–2021 period to ensure that "extreme" drought and pluvial (wet periods) relate to events that do not occur more frequently than in approximately 2% of the months. This calibration affects direct comparison with other hydrological cycle variables in Plate 2.1r that use a different baseline period.

This year's update is based on an extensively revised dataset that incorporates new estimates of some variables in CRU TS4.06 compared with CRU TS4.05 used in the report on 2020 (Barichivich et al. 2021). The revisions affect both precipitation (via an improved baseline climatology) and potential ET (all input variables are affected by the improved baseline climatology, and cloud cover is further modified by a new method for estimating it from diurnal temperature range). These revisions modify the scPDSI drought index values throughout, including during the mid-1980s period of extensive drought, which has a reduction in the extent of drought compared to that previously estimated.

2.d.7 Runoff and River Discharge

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2.d.8 Groundwater and Terrestrial Water Storage

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2.d.10 Drought

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2.d.11 Land Evaporation

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2.e.1 Mean Sea Level Pressure and Related Modes of Variability

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2.e.2 Surface Winds

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2.e.3 Upper Air Winds

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