



PROGRAMME OF
THE EUROPEAN UNION



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Data visualisation for climate science

Dr Anna Lombardi

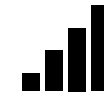
Copernicus Climate Change Service C3S – ECMWF

NMHS Workshop • Ljubljana, September 9th 2025





1. The power of data visualisation



2. Visualising climate data

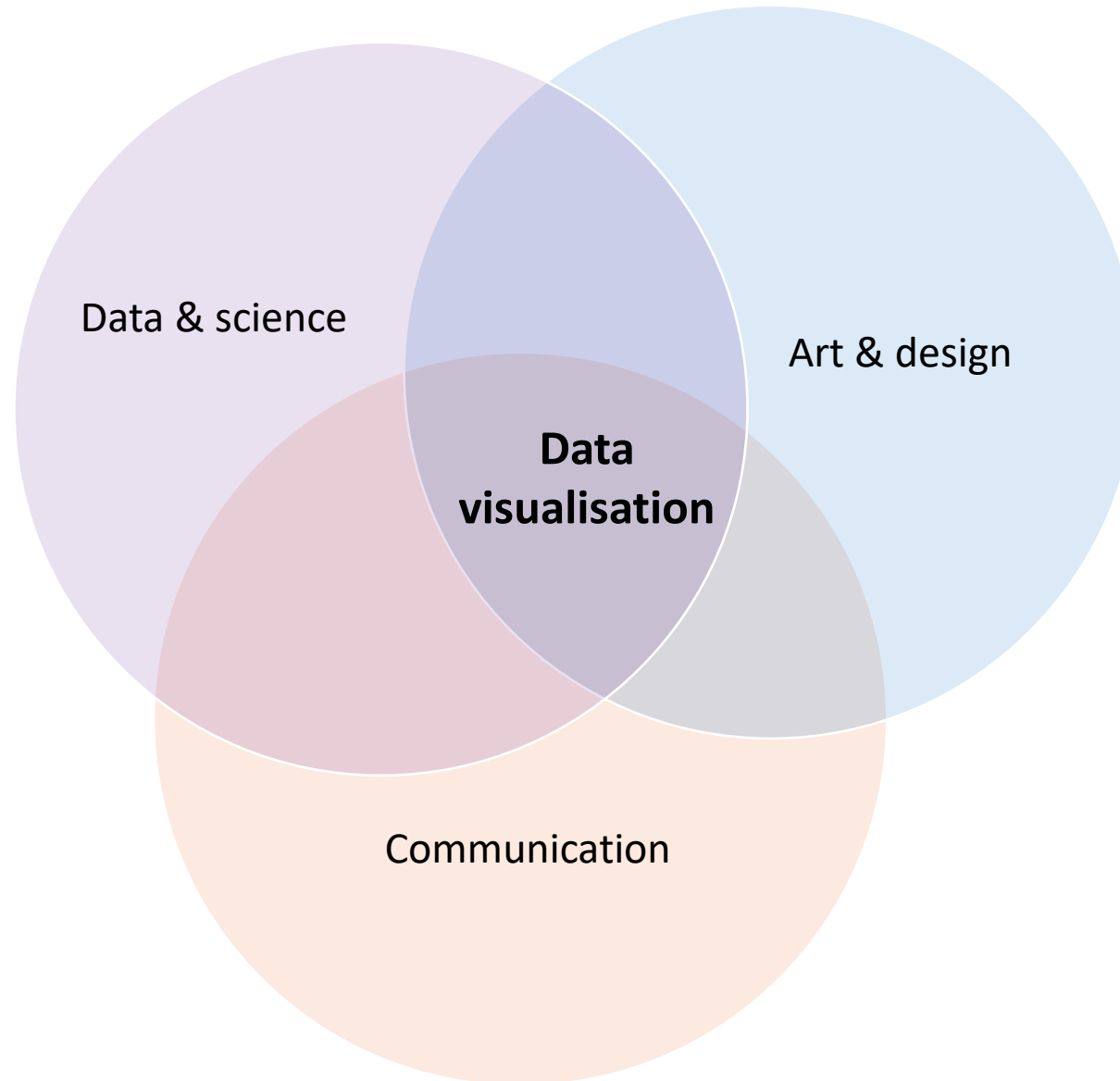


3. What makes a good chart?



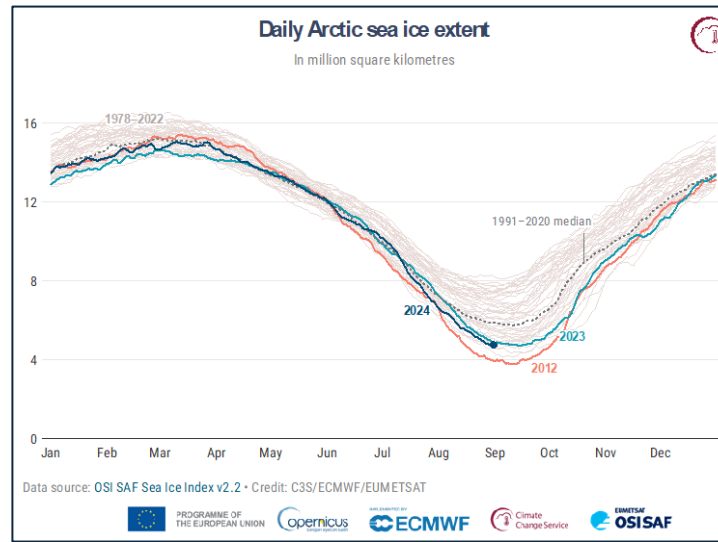
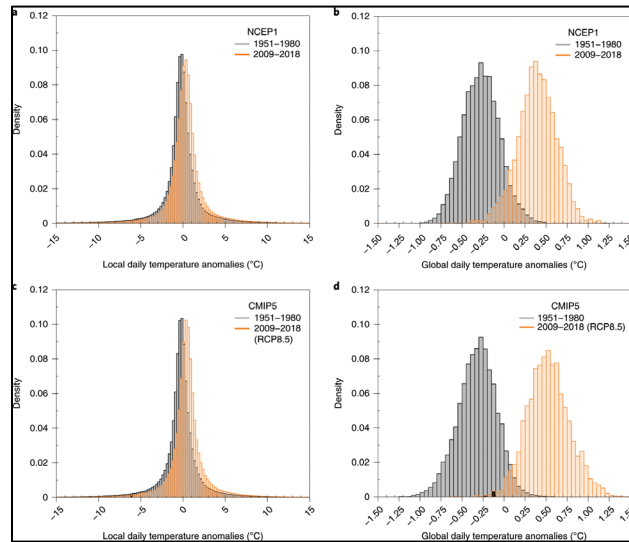


What is data visualisation?



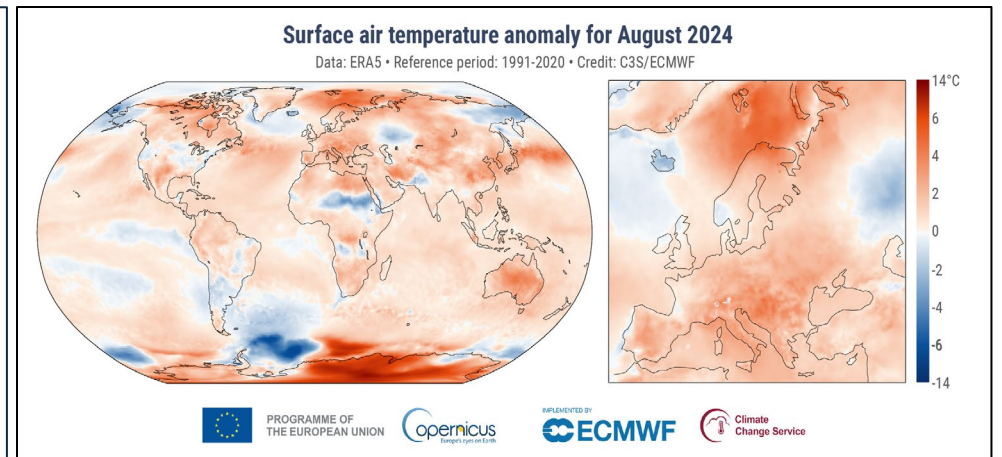
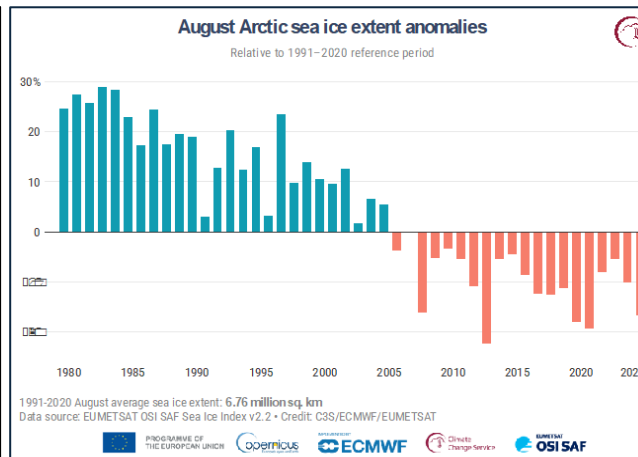
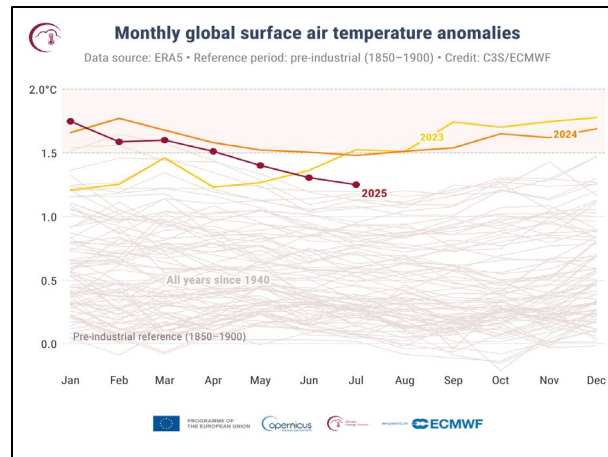
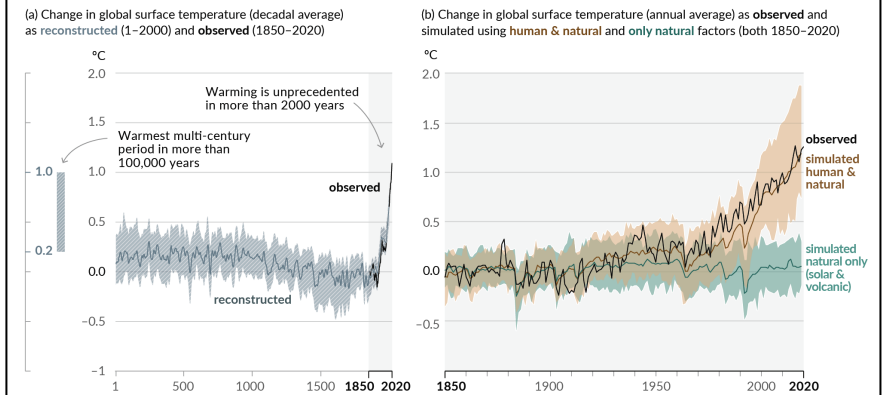


In scientific papers and reports..



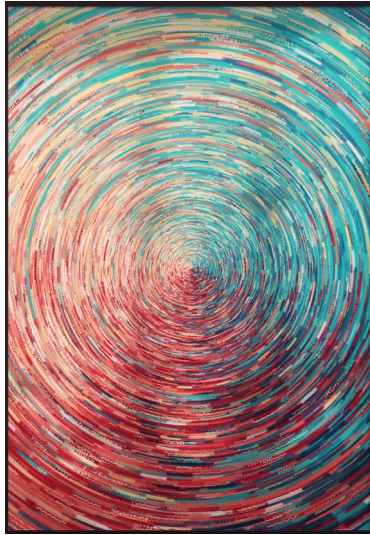
Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Changes in global surface temperature relative to 1850-1900

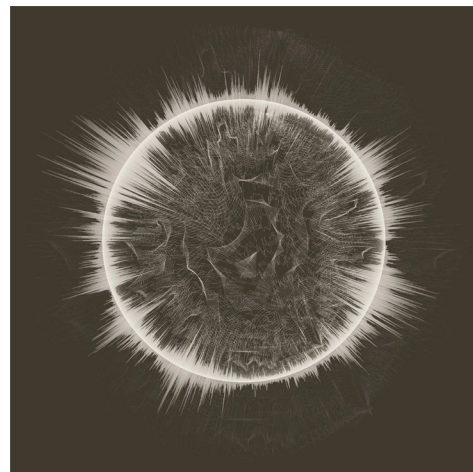
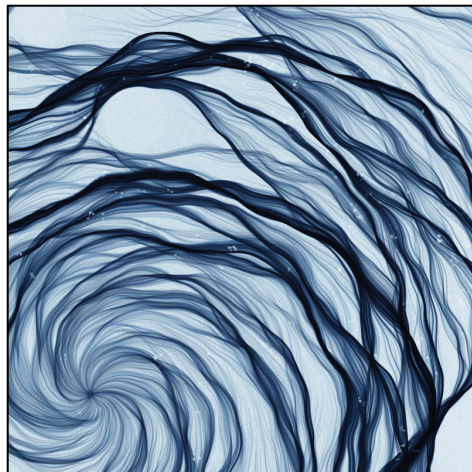
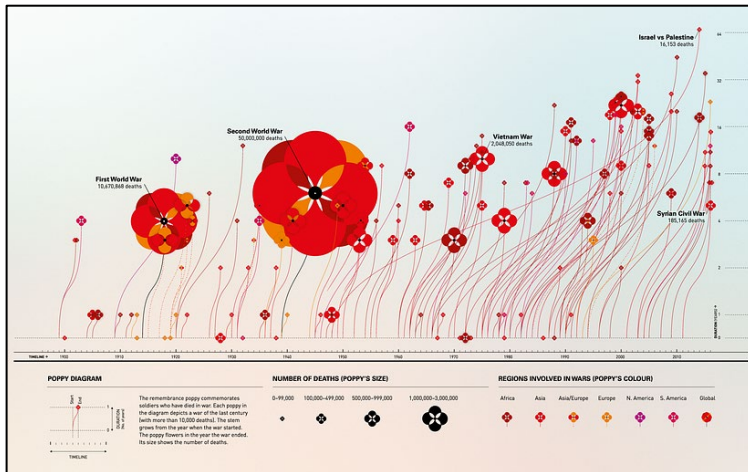
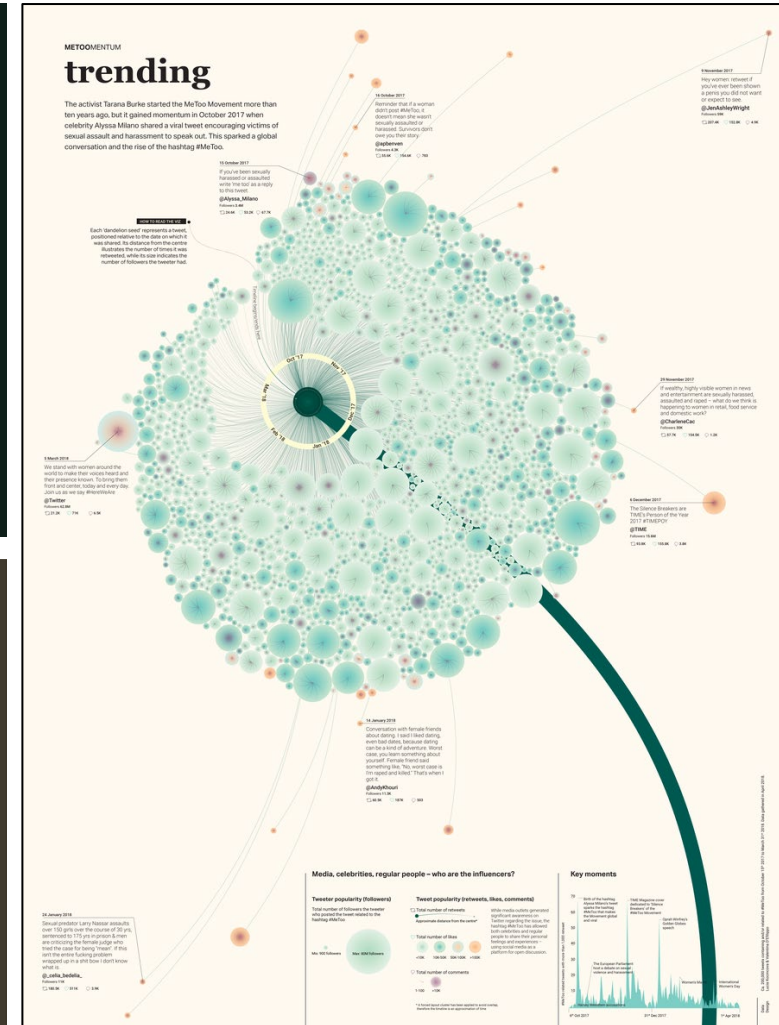




In art galleries..

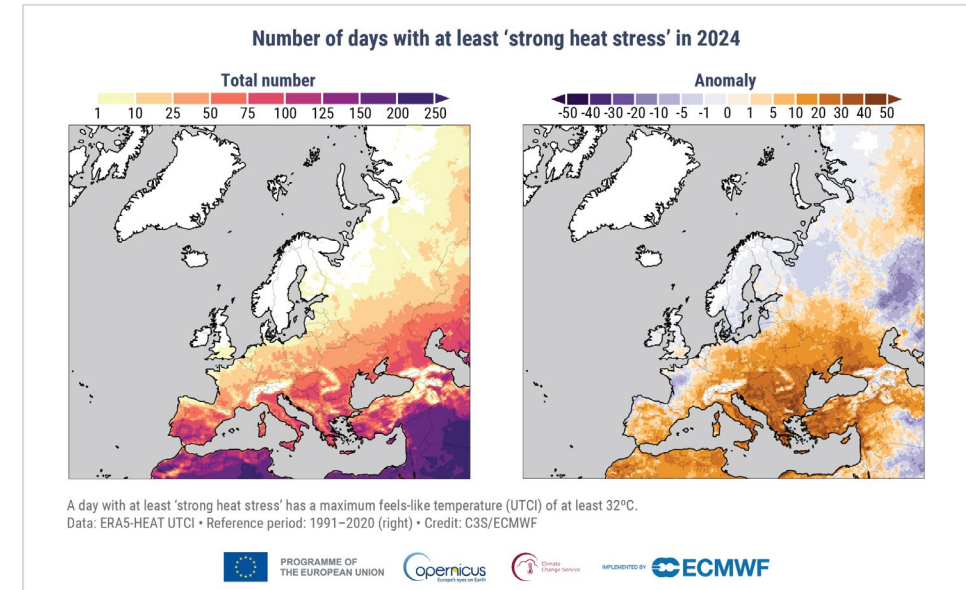
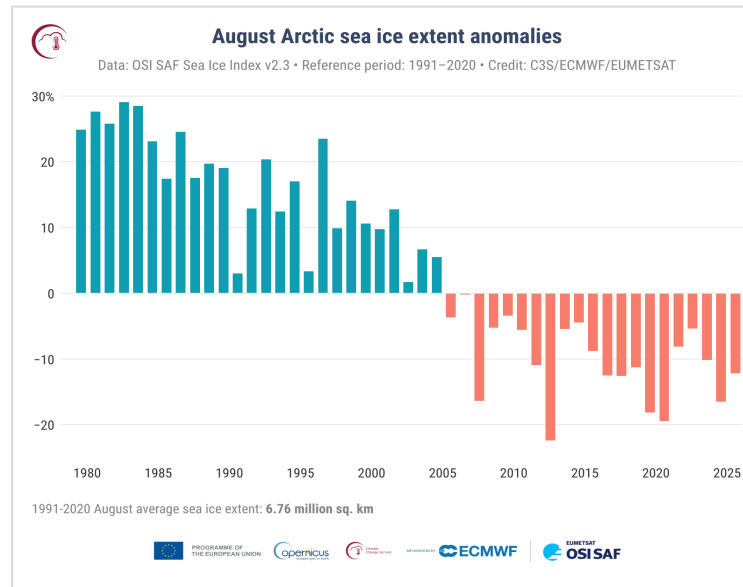
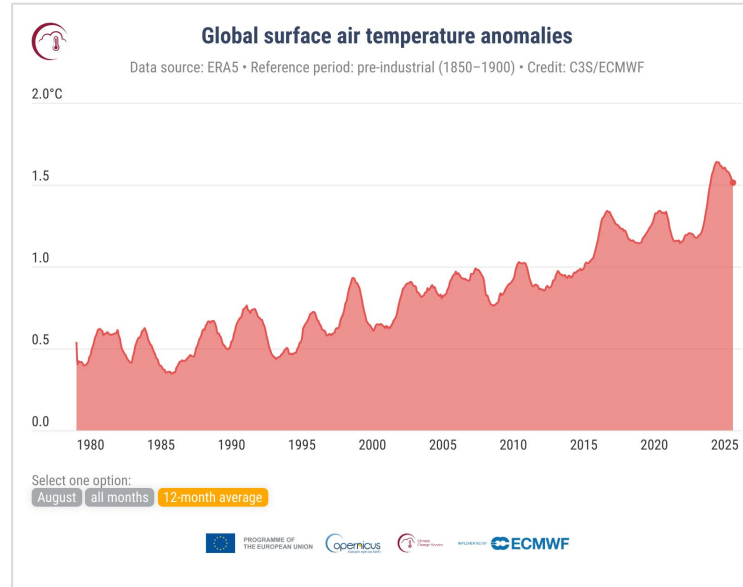


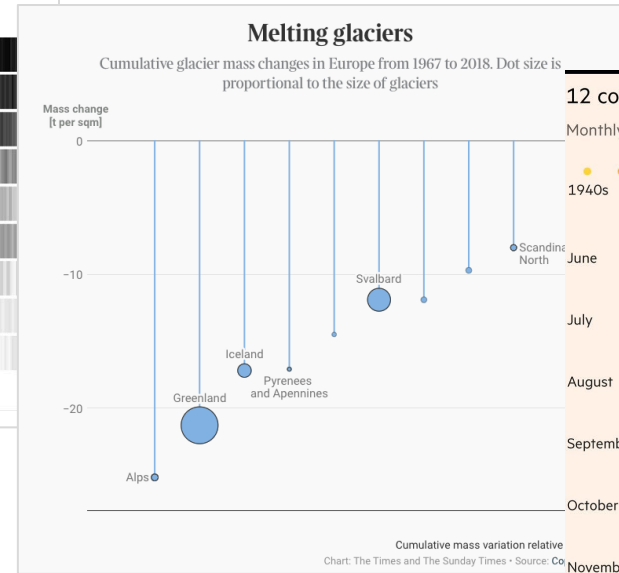
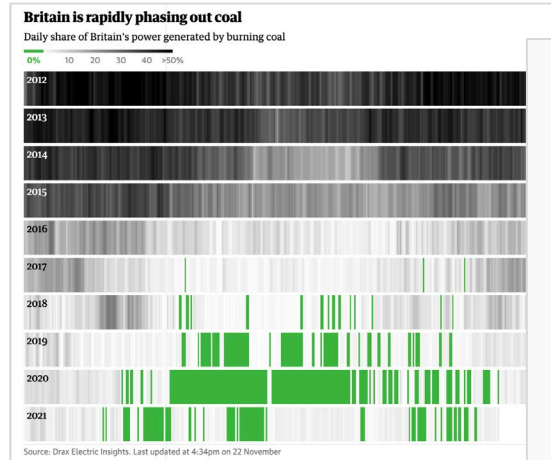
Patterns of Violence in Brazil
The average proportion and number of environmental defender deaths in Brazil from 2015 to 2019 by state





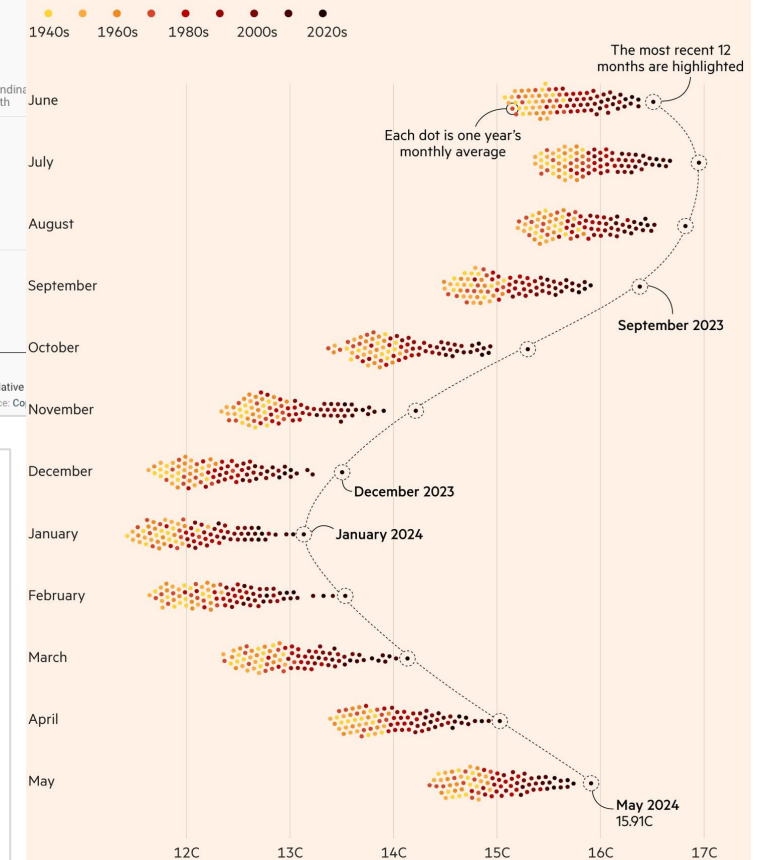
It can be standard



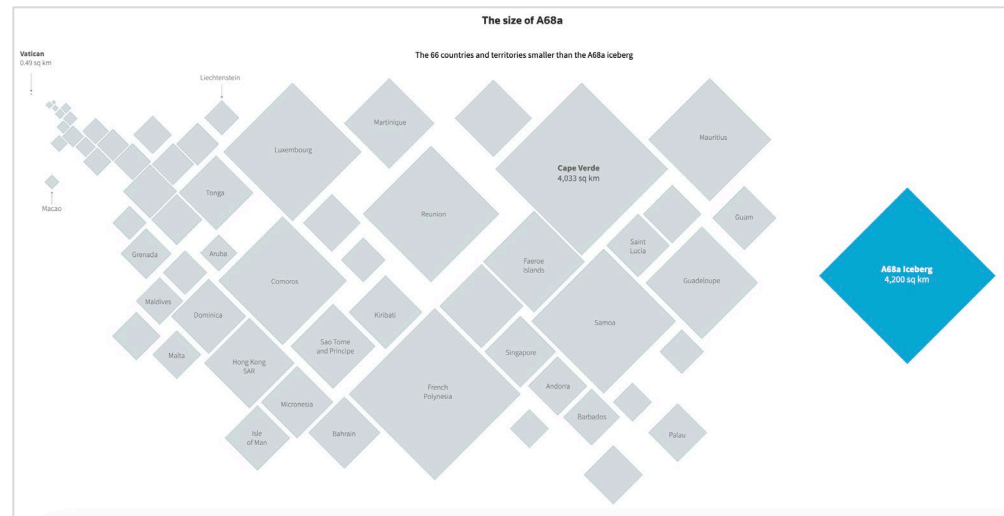


12 consecutive months of record-breaking temperatures

Monthly global average temperature by year, 1940-2024

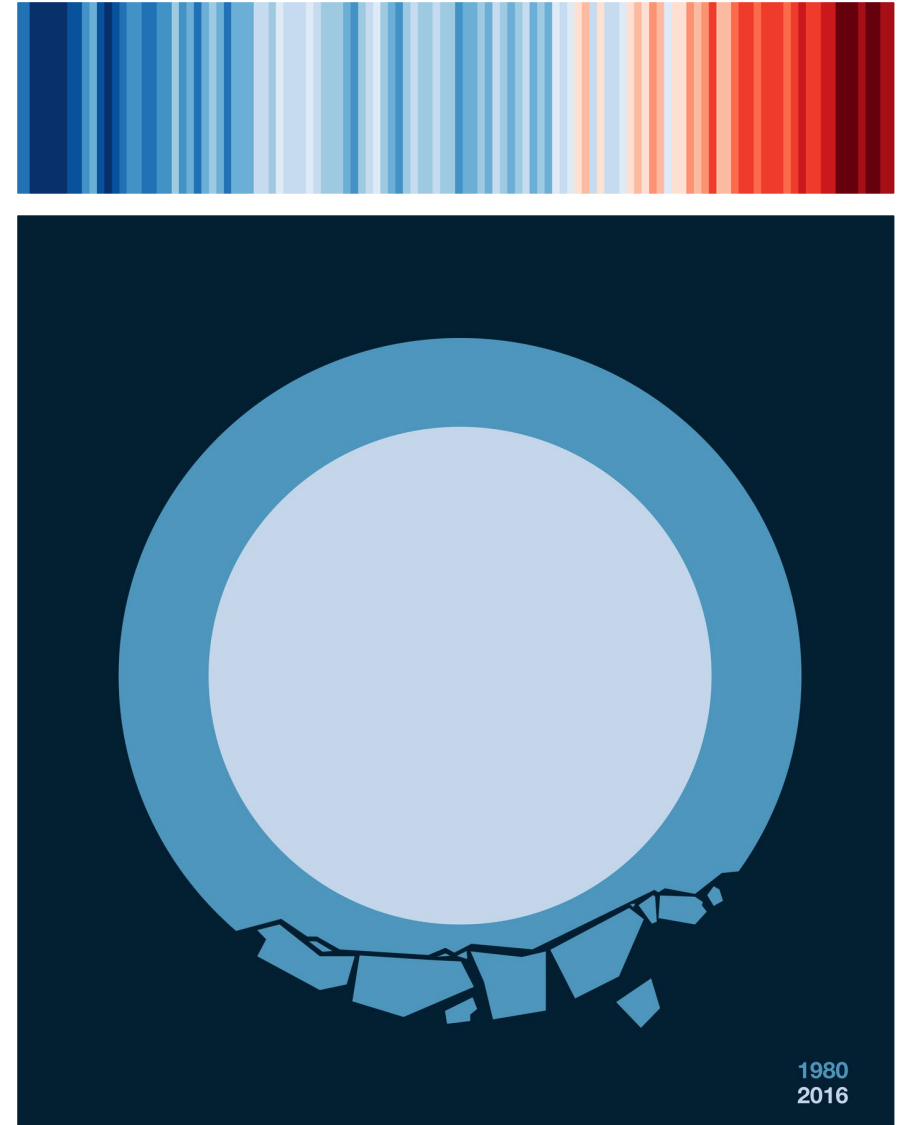


Slightly less conventional





Totally abstract





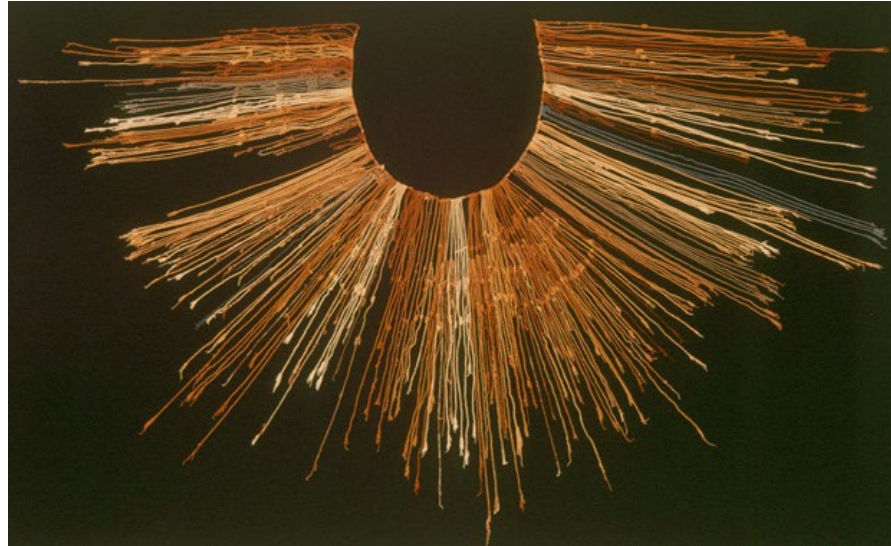
Dataviz is not a modern invention

An ancient spreadsheet



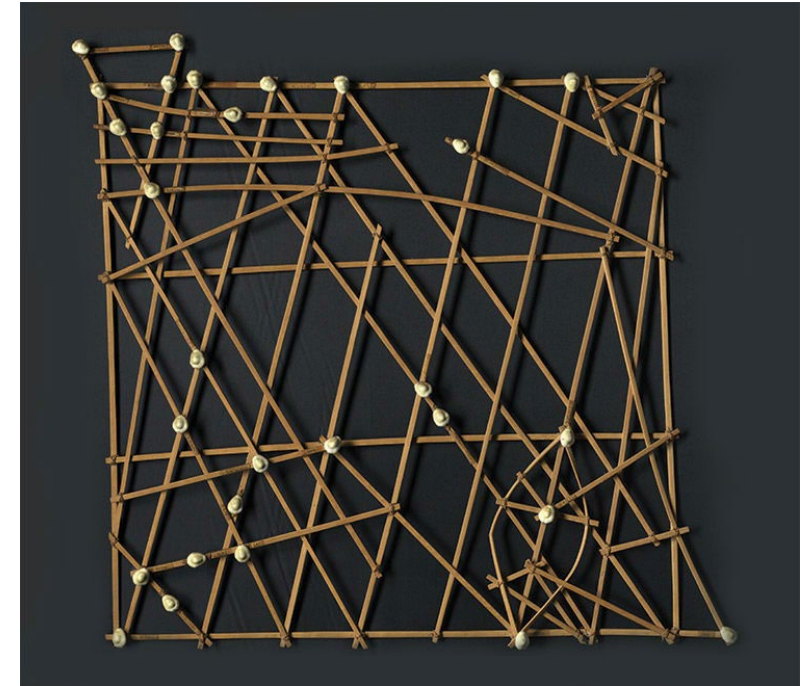
Mesopotamia, **2000 BC**
Tablet to survey silver available

An ancient plot

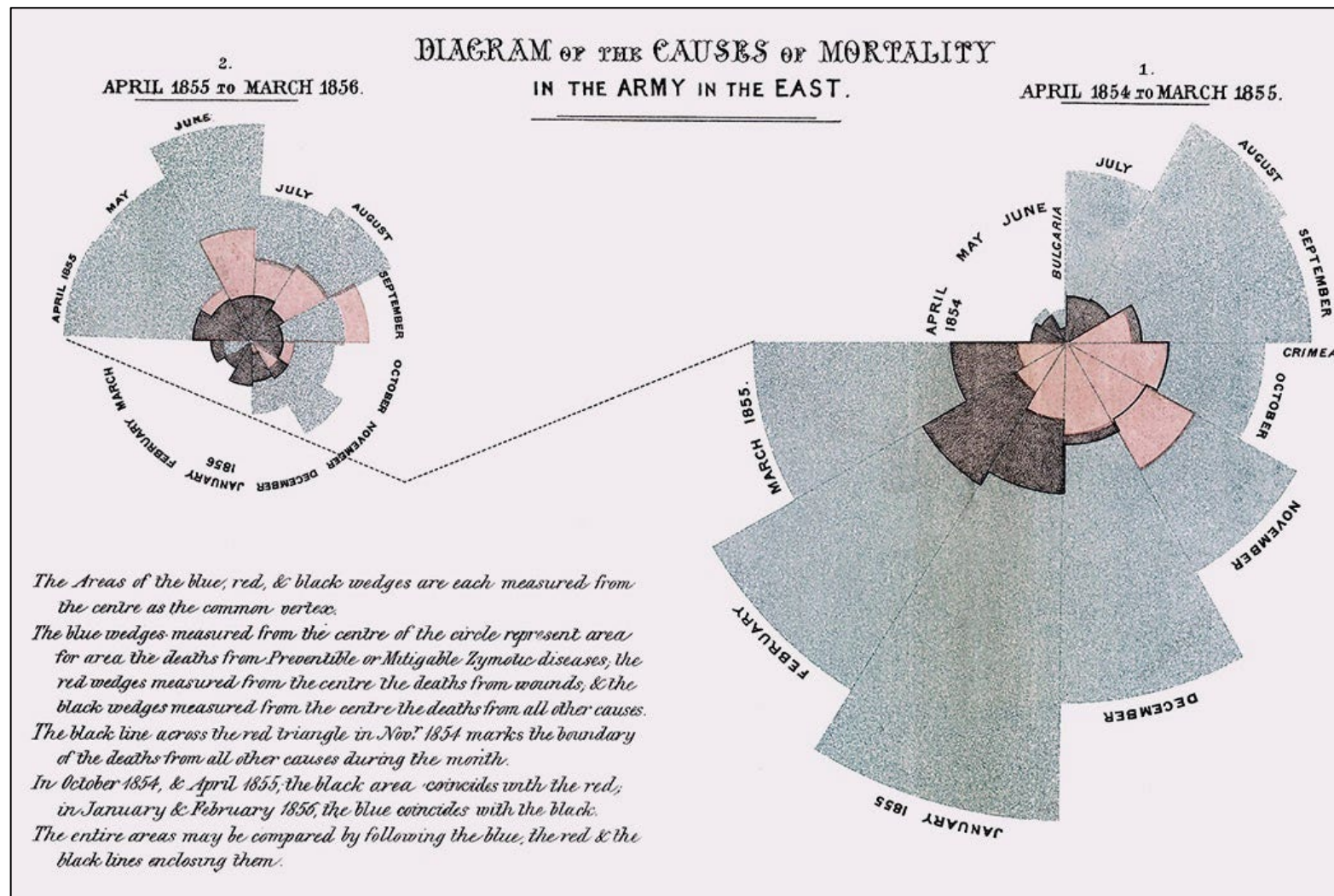
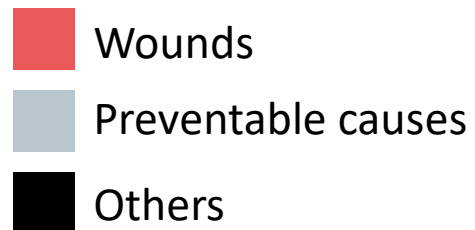


Inca Empire, **2500 BC**
Record keeping devices from knotted cords.
Information is categorised based on color, order, number of knots.

An ancient map



Marshall Islands, **1000 BC**
Navigation system made up of sticks and
shells to show islands, currents, waves





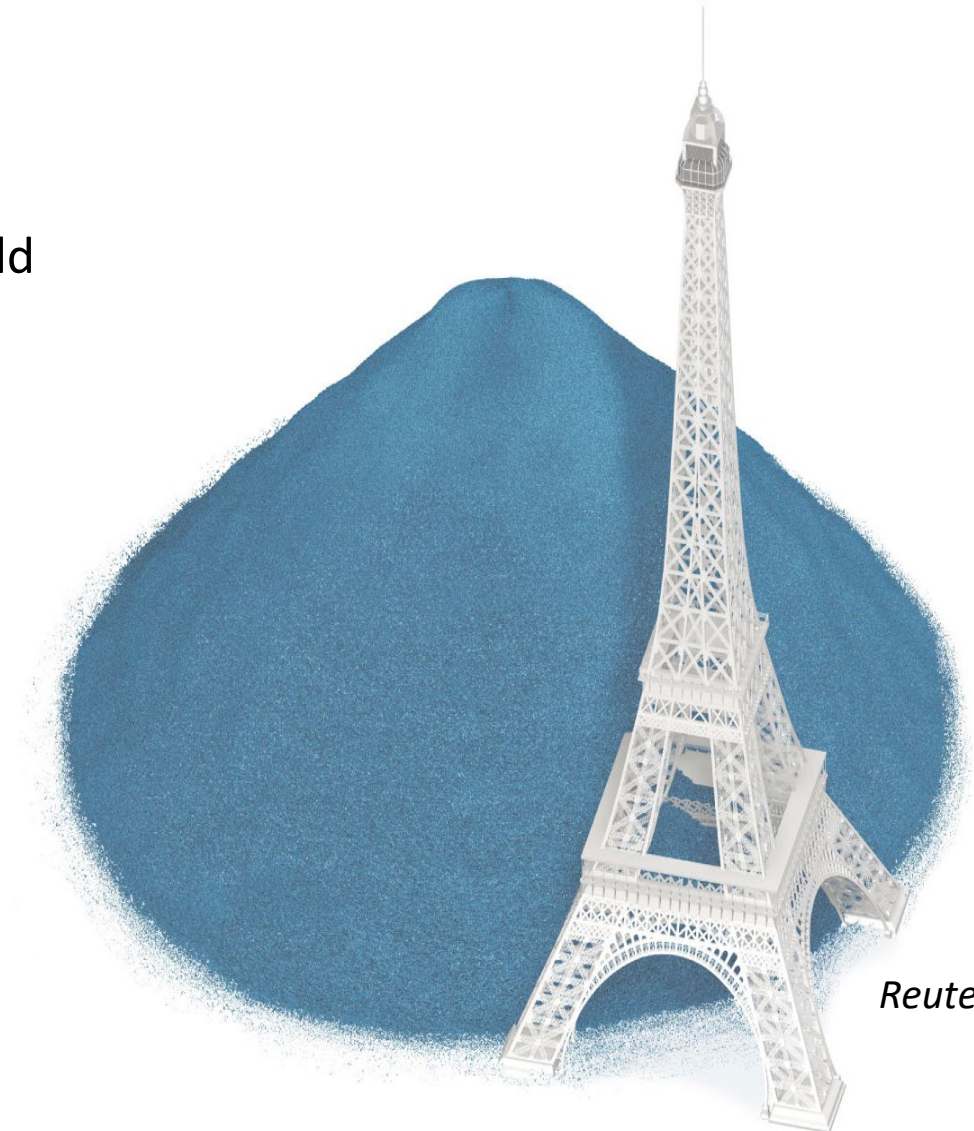
1. The power of data visualisation



1.3bn plastic bottles are sold **in a day** around the world



1.3bn plastic bottles are sold **in a day** around the world



Reuters (2019)



Visual impact

Processing visual information **60,000 times faster** compared to text-based information



Lasting impression

Data visualization engages multiple areas of the brain, making it more memorable, easier to recall



Translate information

Complex information more accessible,
easier to identify trends/outliers, reduced misperceptions



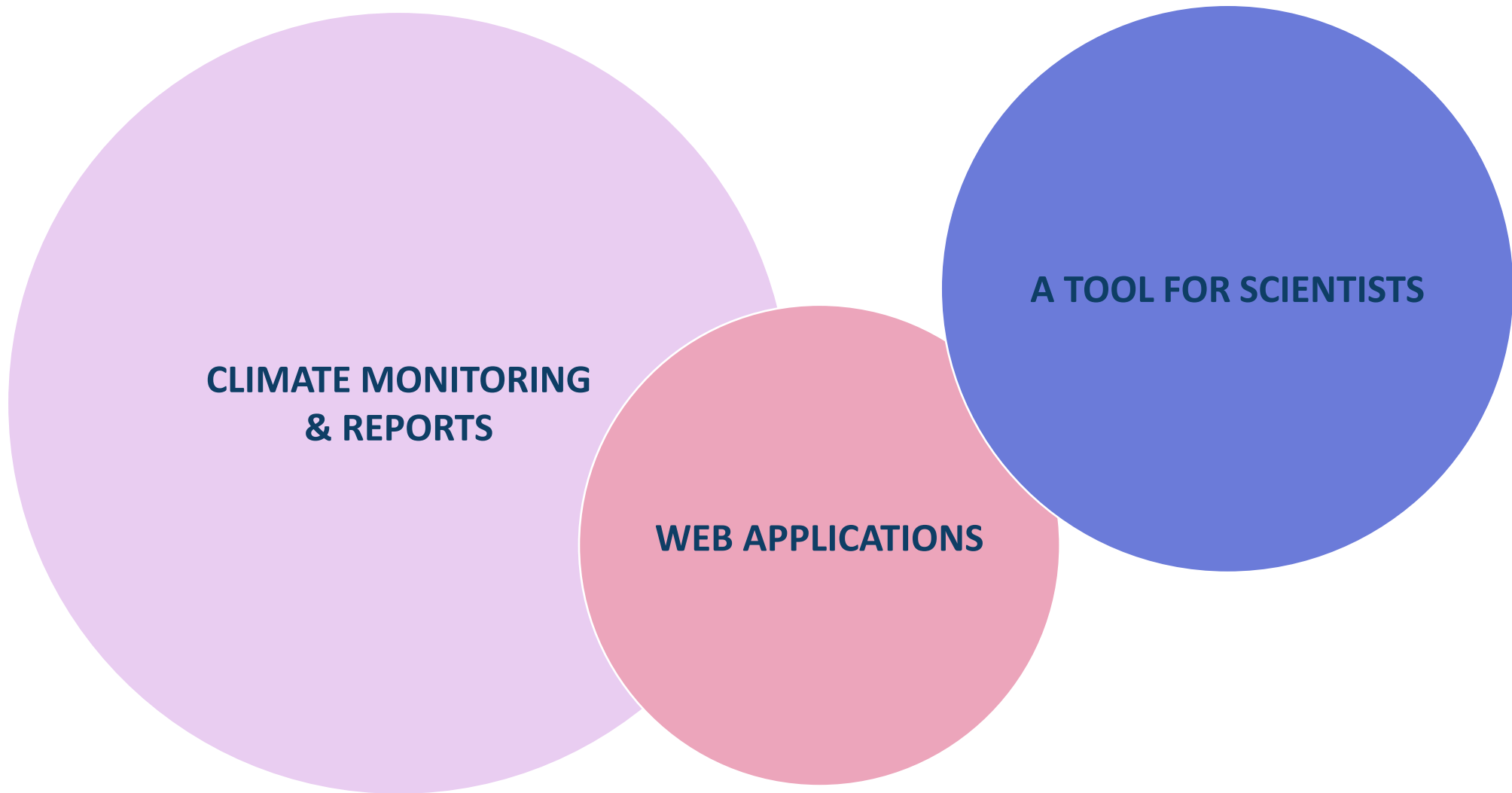
Trigger conversation

Engaging, easy to share





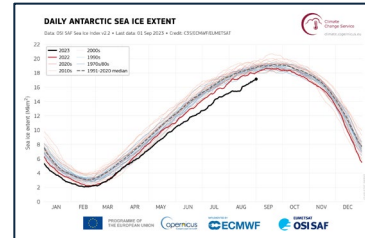
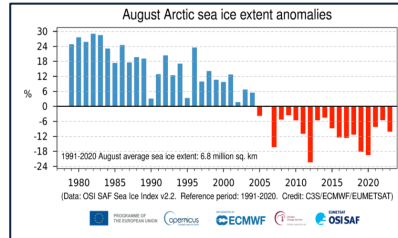
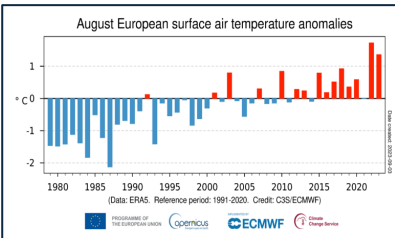
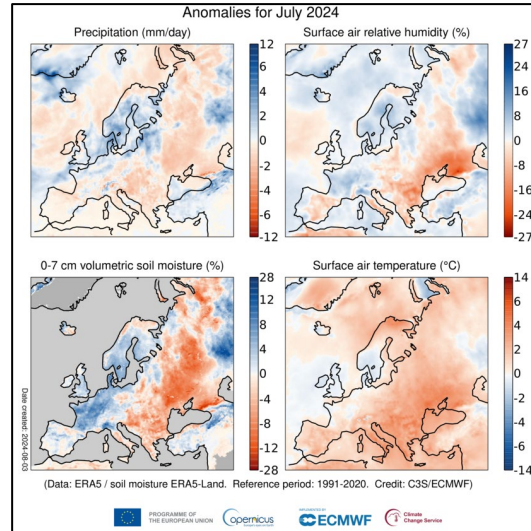
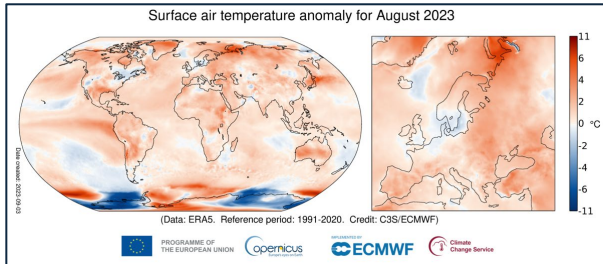
2. Visualising climate data





Monitoring and reporting: monthly bulletins

Before

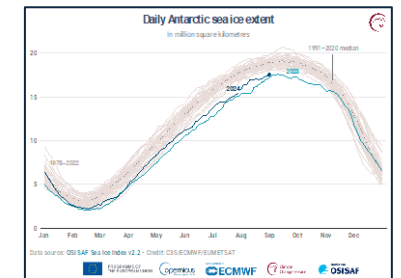
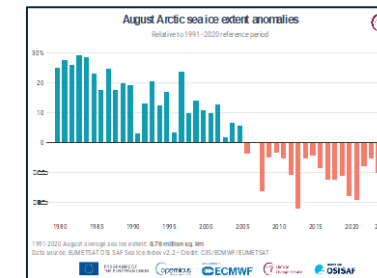
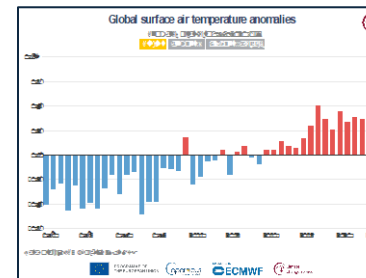
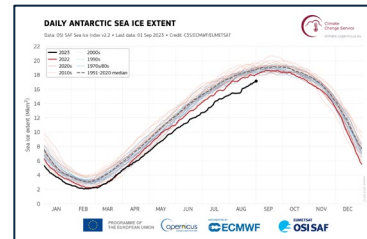
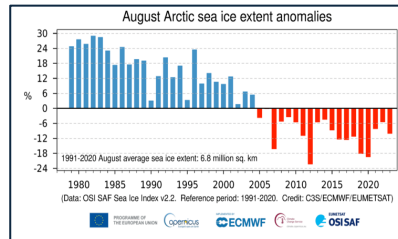
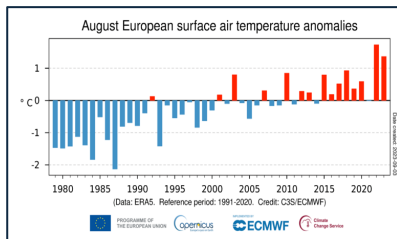
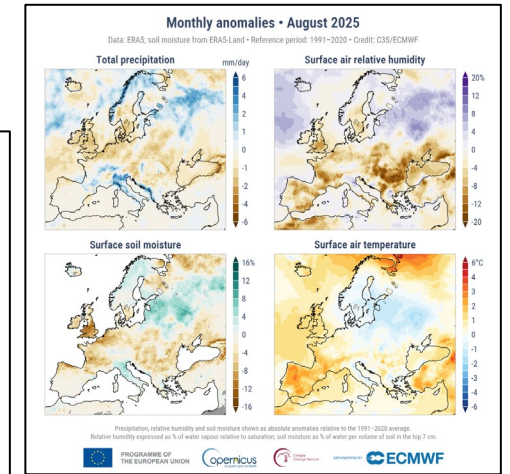
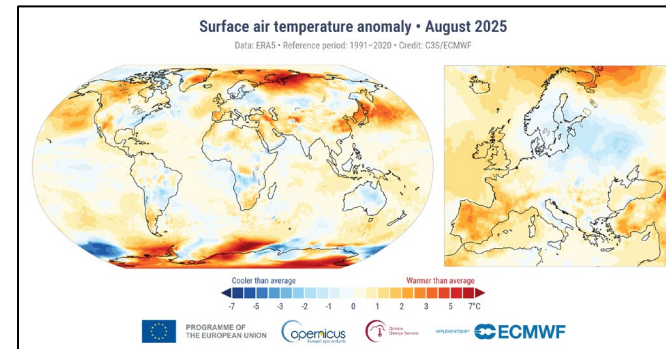
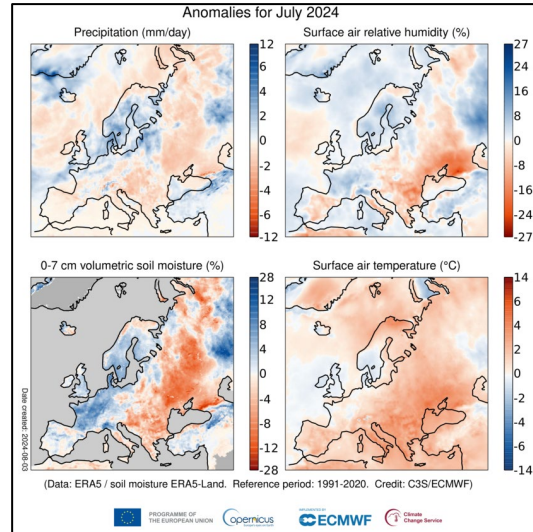
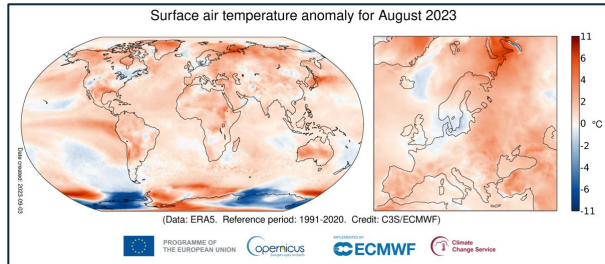


Monitoring and reporting: monthly bulletins

Before

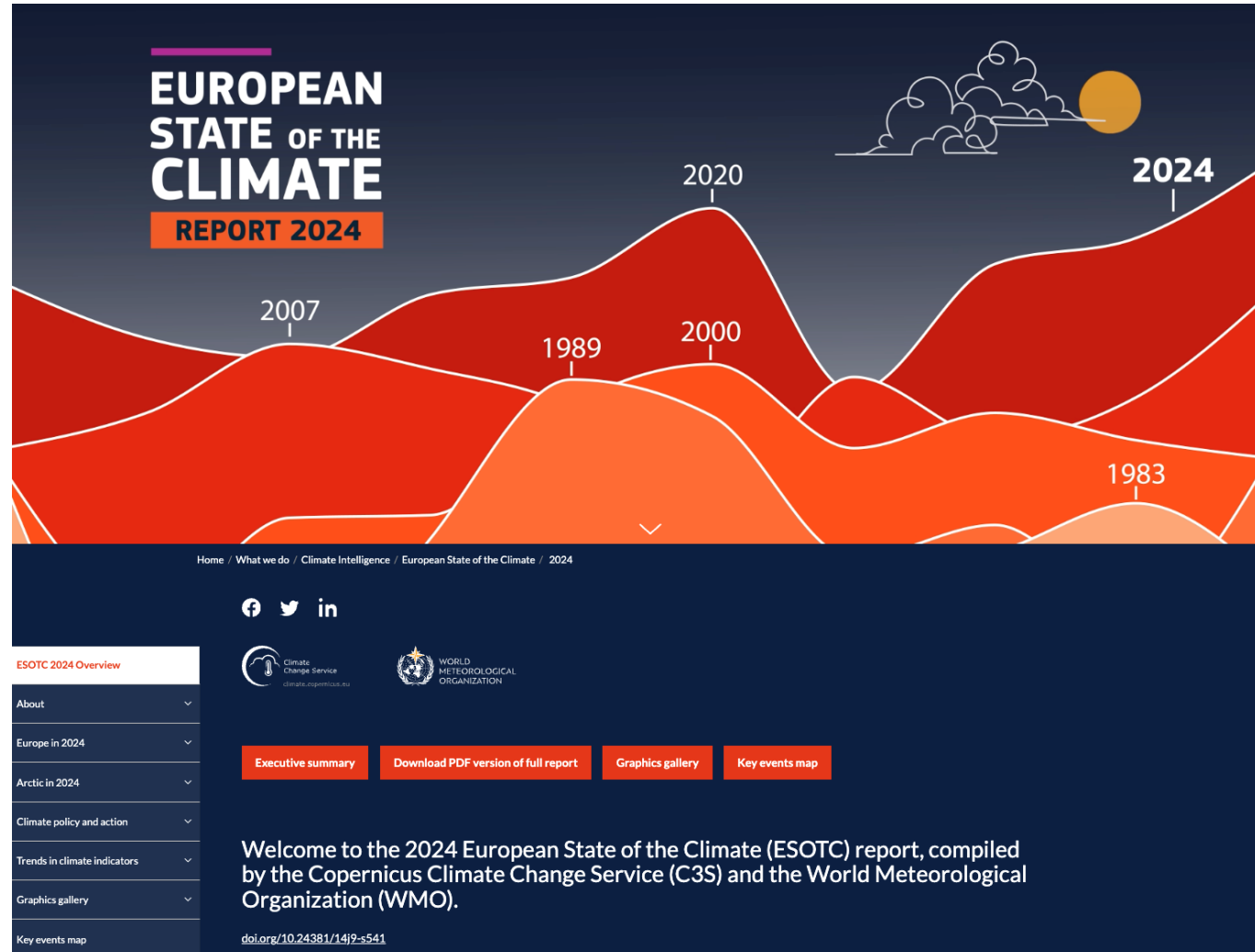
After

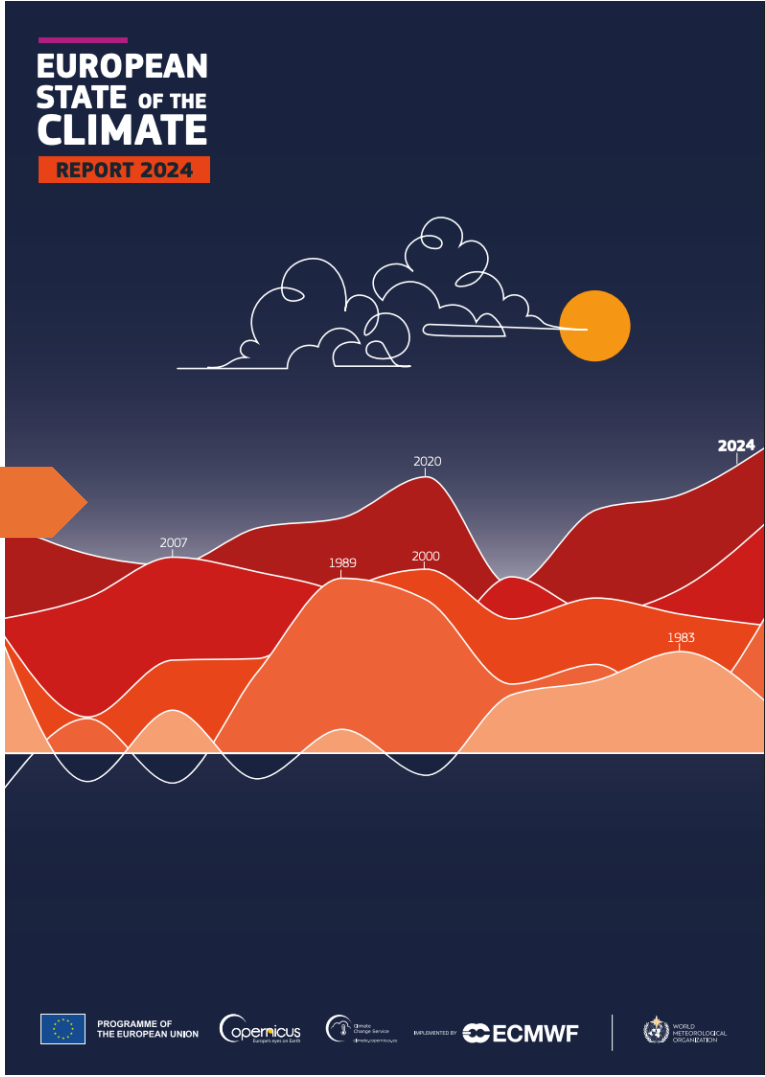
1. Uniform design
2. Unique colours
3. Interactivity
4. Data download



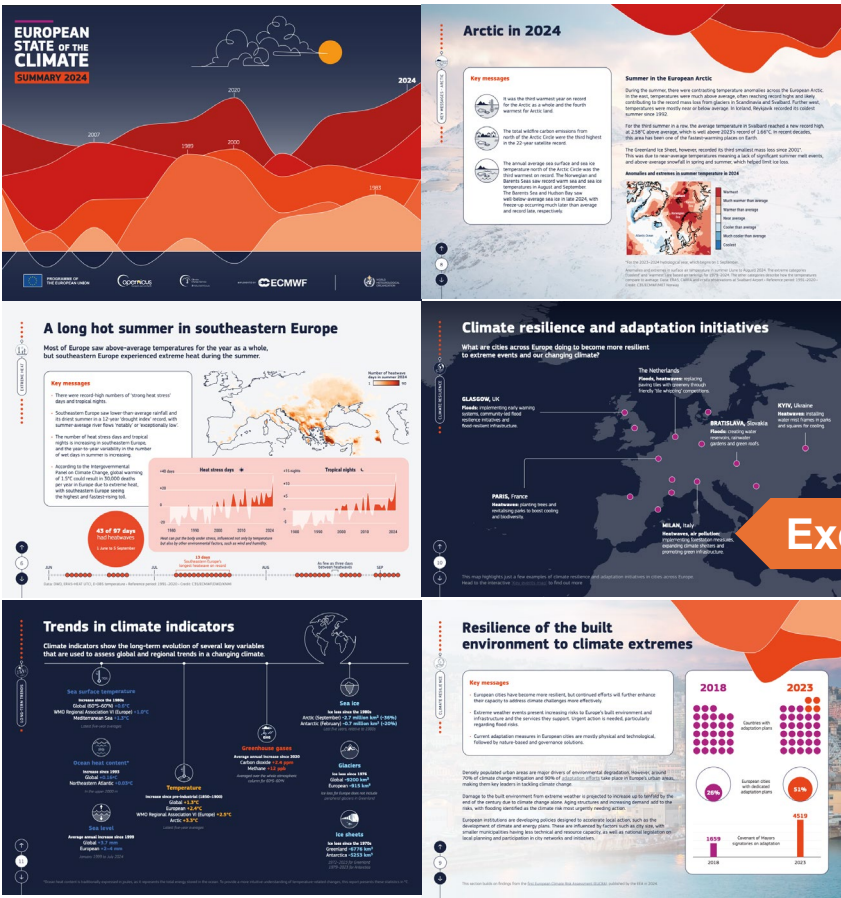


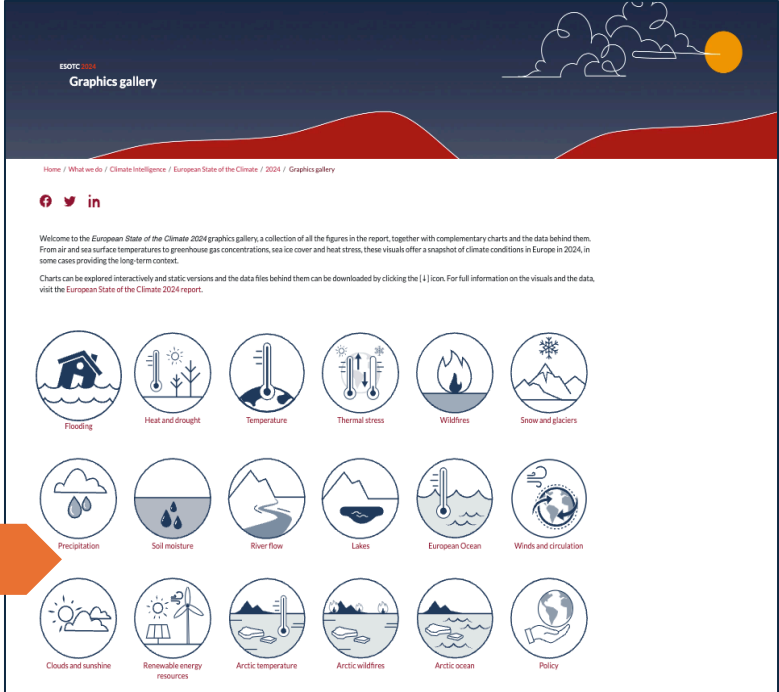
Monitoring and reporting: European State of the Climate Report





PDF full report

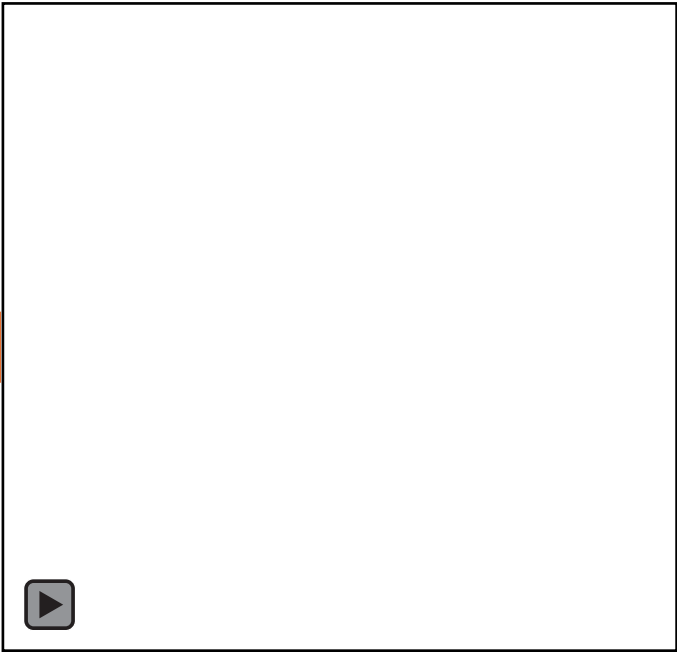




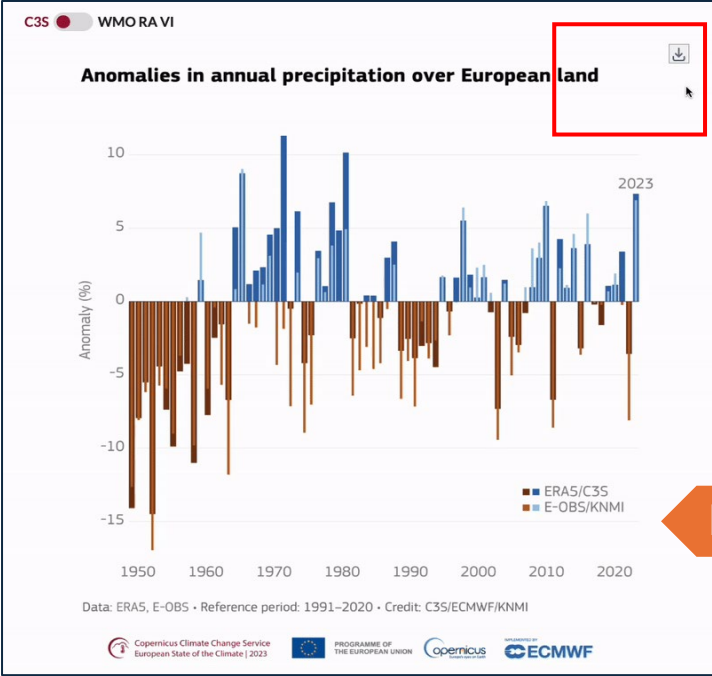
Graphics gallery



Interactive key events map



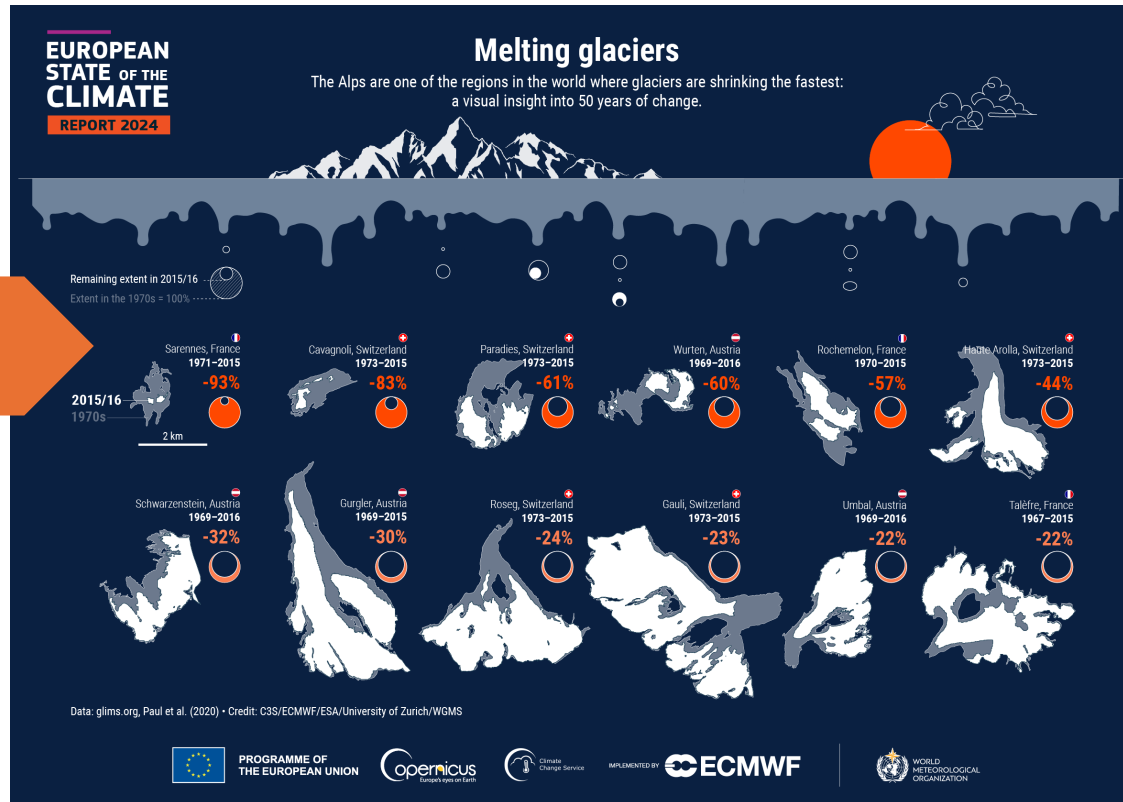
Interactive features



Easy data download option



Bespoke
infographics



Widespread flooding in Europe in 2024

According to the Intergovernmental Panel on Climate Change, Europe is one of the regions with the largest projected increase in flood risk.

**Notable flood events occurred throughout the year. See the ESOTC 'Flooding' section and the interactive 'Key events map' for more details.*

— River network
— High flood threshold
— Severe flood threshold

Valencia, Spain

From 28 October to 4 November, the national records for total rainfall in one, six and 12 hours were all broken.

The maximum 24-hour total reached 771.8 mm – the second highest amount on record for Spain.

The rainfall and flooding had devastating impacts, with at least 232 people killed in the province of Valencia and fatalities in three other provinces.

Storm Boris

In September, persistent rainfall from Storm Boris caused flooding in eight countries in central and eastern Europe. Flows reached at least twice the annual maximum along 8500 km of rivers.

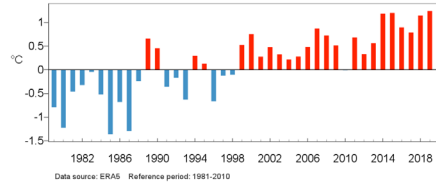
The percentage of the river network that flooded during the year was the **fifth-largest in a 32-year record** and the **largest since 2013**.

Data: EFAS • Credit: CEMS/C3S/ECMWF

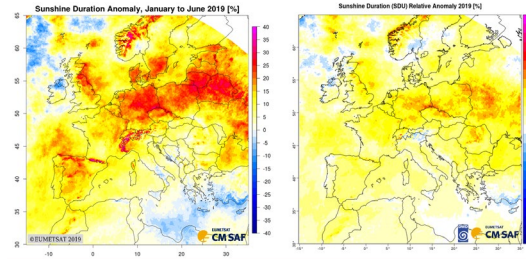
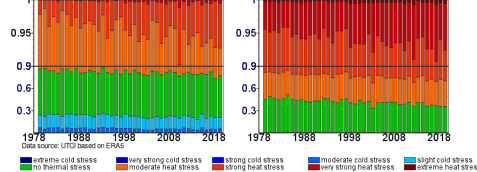


Examples from an early edition of the report

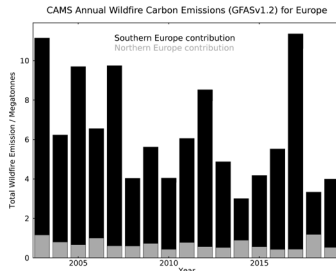
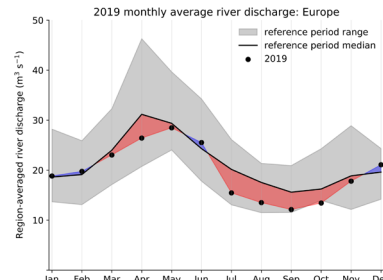
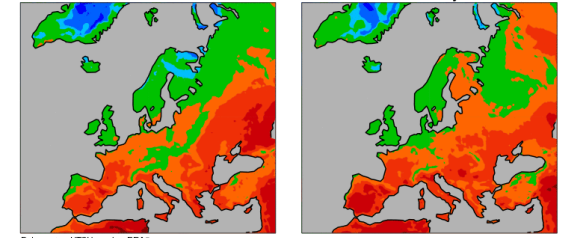
Europe annual temperature anomalies 1979-2019



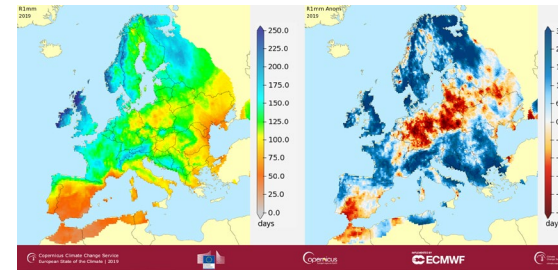
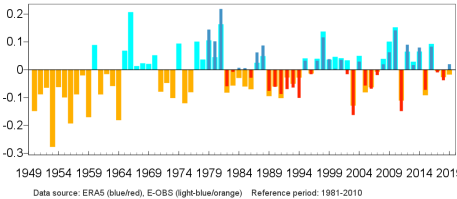
Fraction of days during summer (JJA) with max UTCI in respective category
Northern Europe Southern Europe



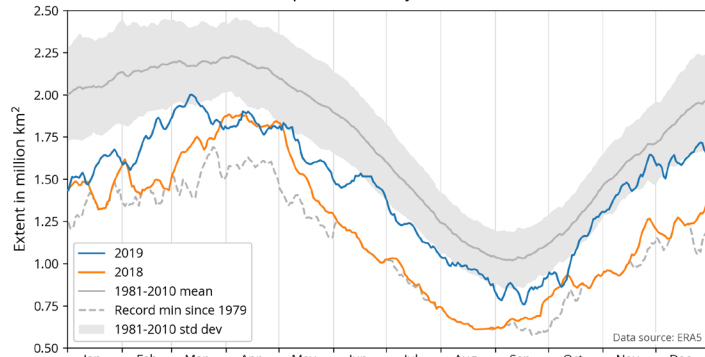
Daily maximum UTCI during 2019 summer heatwaves
23 June 21 July



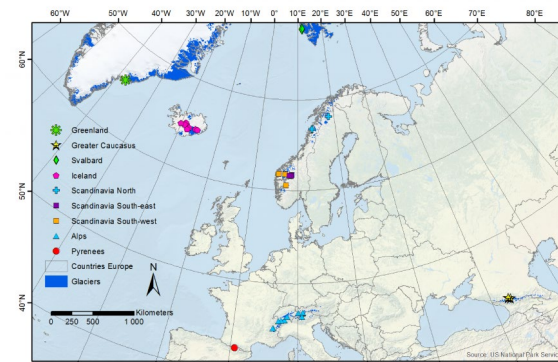
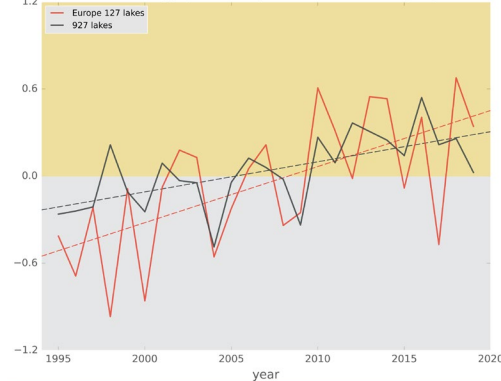
Europe annual precipitation anomalies (mm/day) 1979-2019



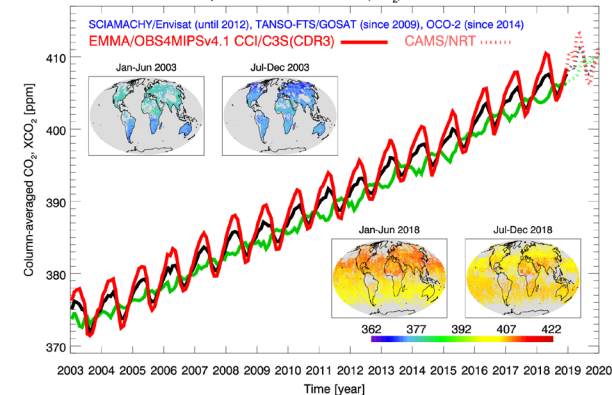
European Arctic daily sea ice extent



Summer (JJA) lake temperature anomalies (°C)



Atmospheric Carbon Dioxide (CO₂) from Satellites





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EUROPEAN STATE OF THE CLIMATE REPORT 2024



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Style Guidelines

Palettes

Layout

Logolines

Basemaps

Fonts

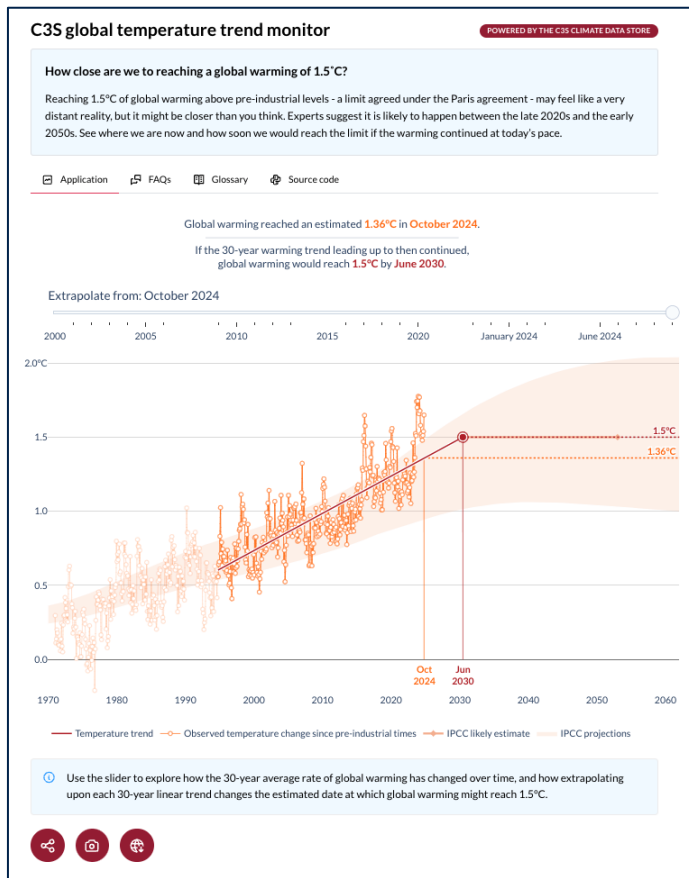


Applications

Temp. trend monitor

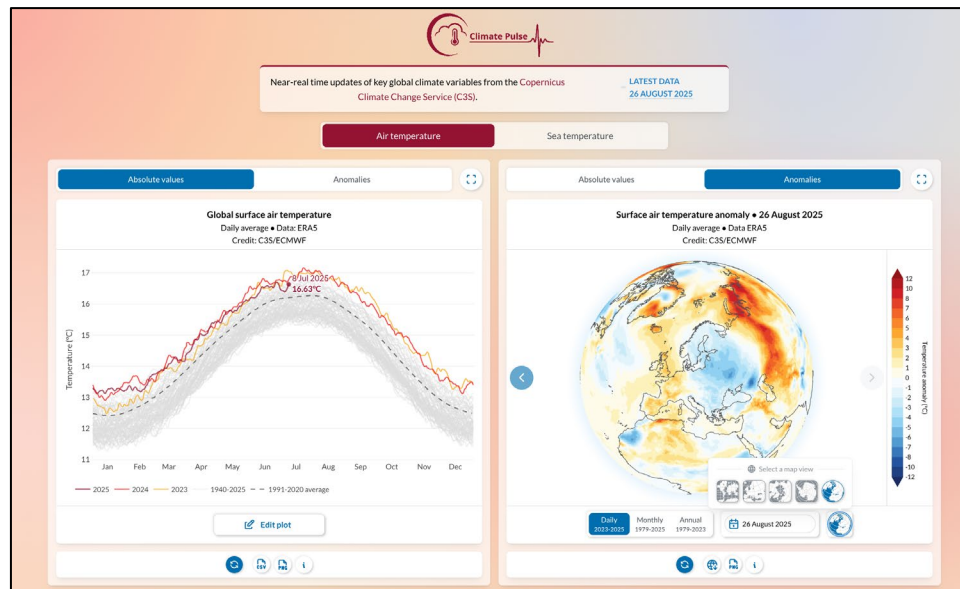


<https://apps.climate.copernicus.eu/global-temperature-trend-monitor>



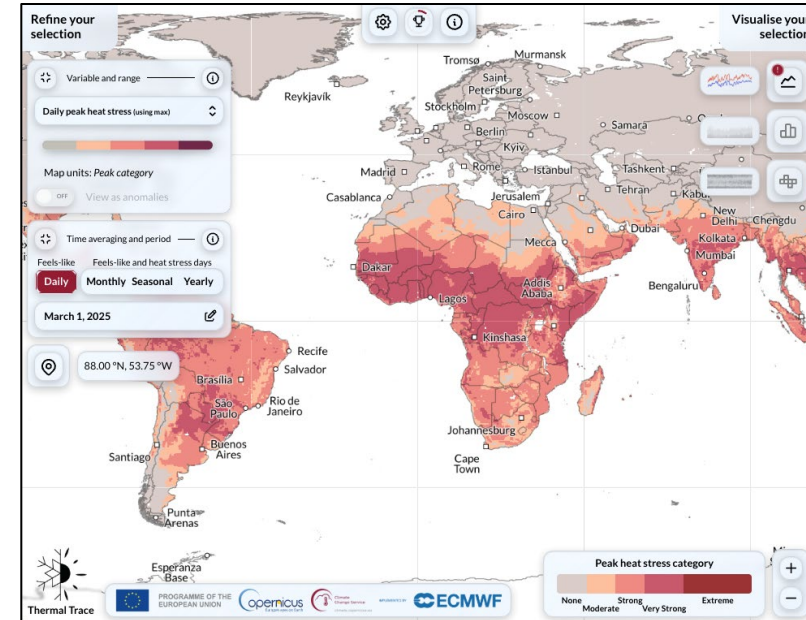
Climate Pulse

<https://pulse.climate.copernicus.eu/>



Thermal Trace

<https://thermaltrace.climate.copernicus.eu/>





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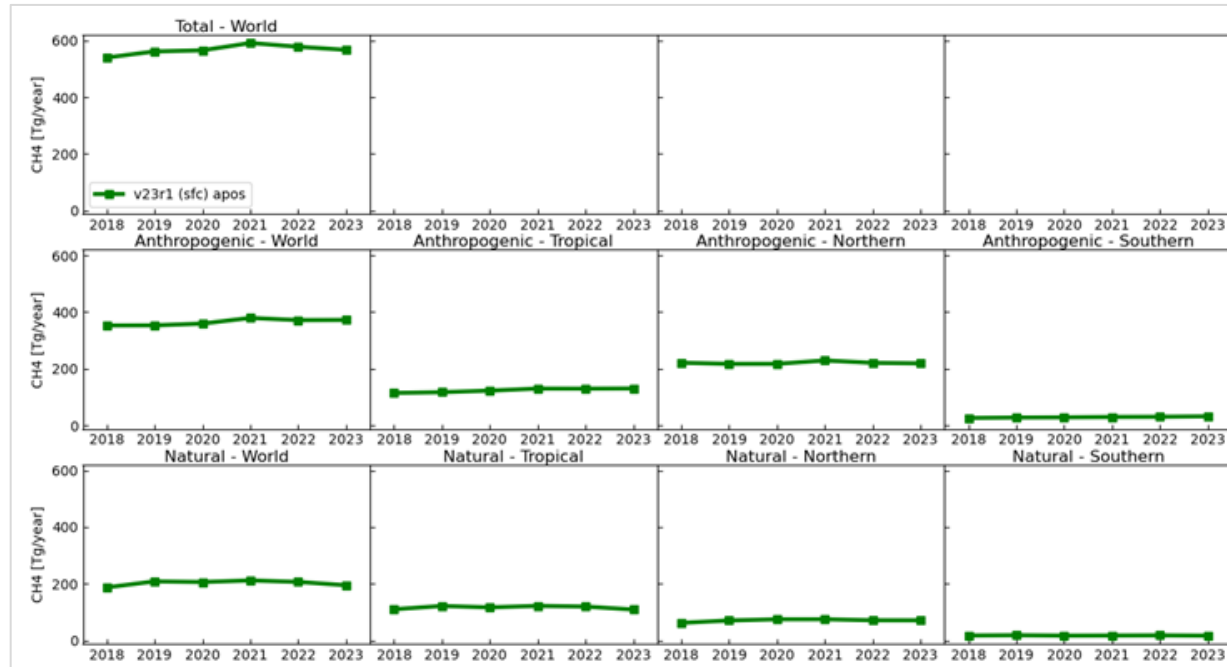
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A tool for scientists: gain insights

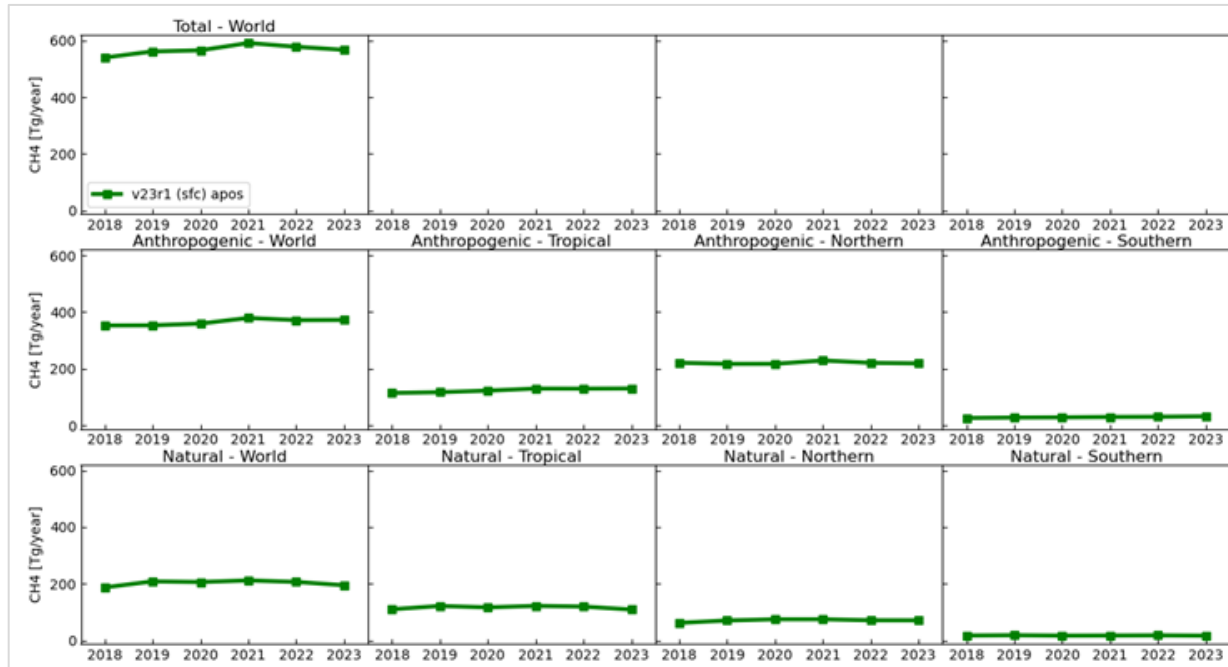


A tool for scientists: gain insights



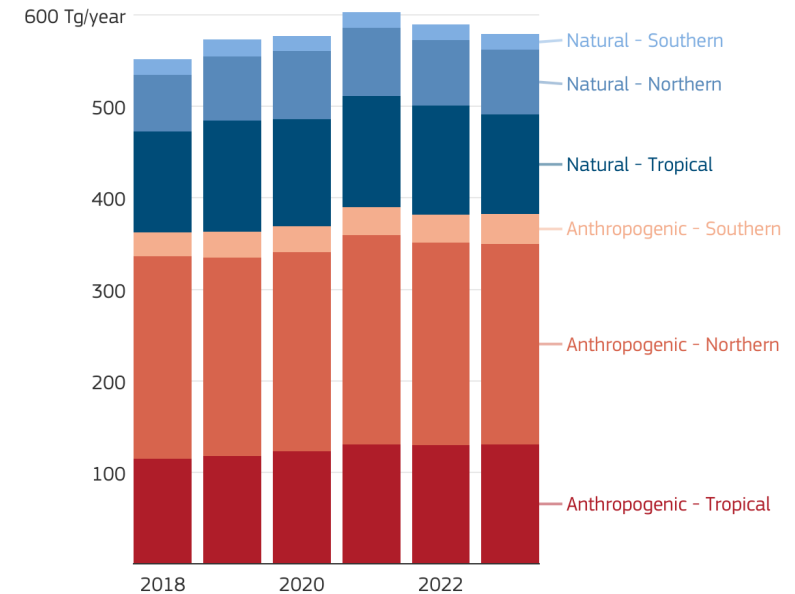


A tool for scientists: gain insights



Net annual fluxes of CH₄ into the atmosphere

Data in teragram per year



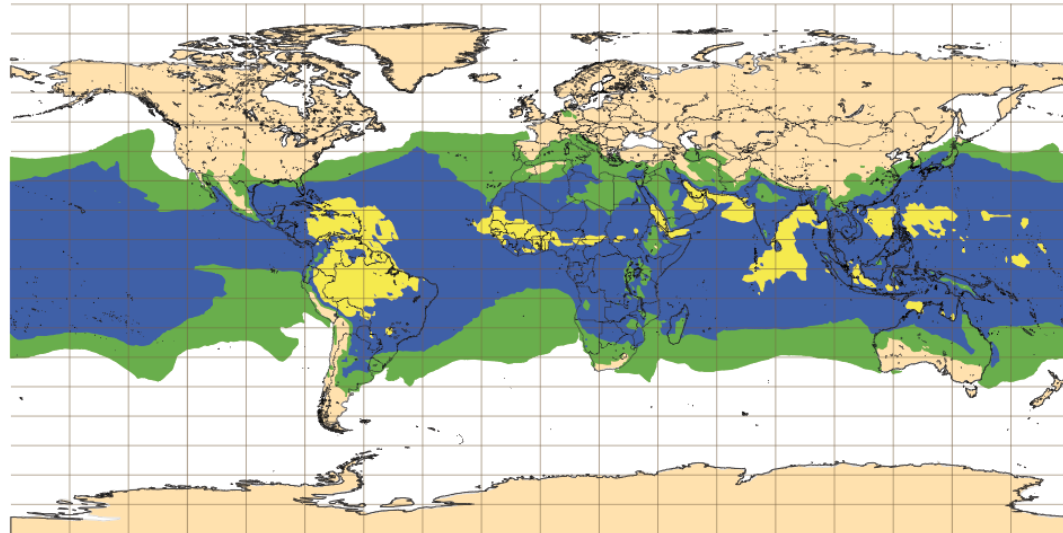
Data: CAMS greenhouse gas flux data estimated from in situ measurements • Credit: CAMS/ECMWF/TNO/VU



A tool for scientists: gain insights

Thermal stress (Thermofeel) • Humidity index

Sun 13 Oct 2024 12 UTC - Area: Global



Humidity index (Thermofeel parameter)

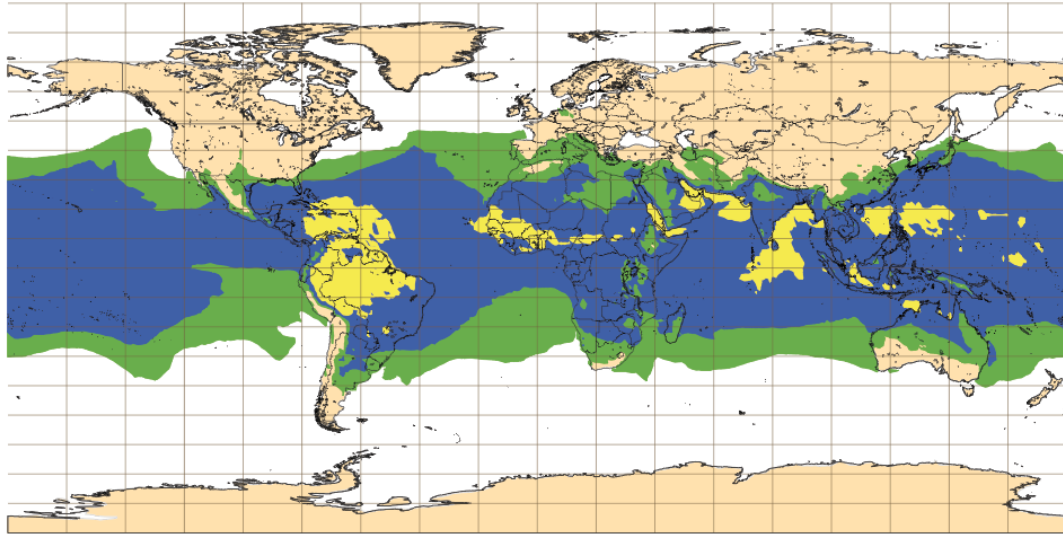
Little discomfort Some discomfort Great discomfort Dangerous



A tool for scientists: gain insights

Thermal stress (Thermofeel) • Humidity index

Sun 13 Oct 2024 12 UTC - Area: Global

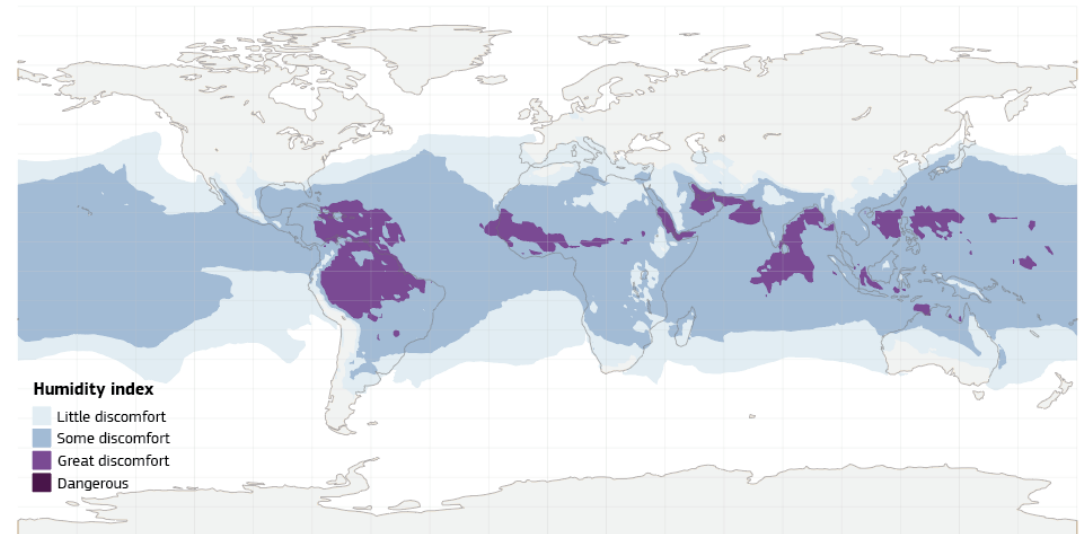


Humidity index (Thermofeel parameter)

Little discomfort Some discomfort Great discomfort Dangerous

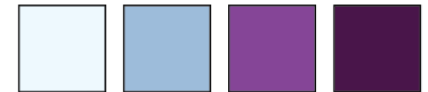
Thermal stress (Thermofeel) • Humidity index

Sun 13 Oct 2024 12 UTC - Area: Global

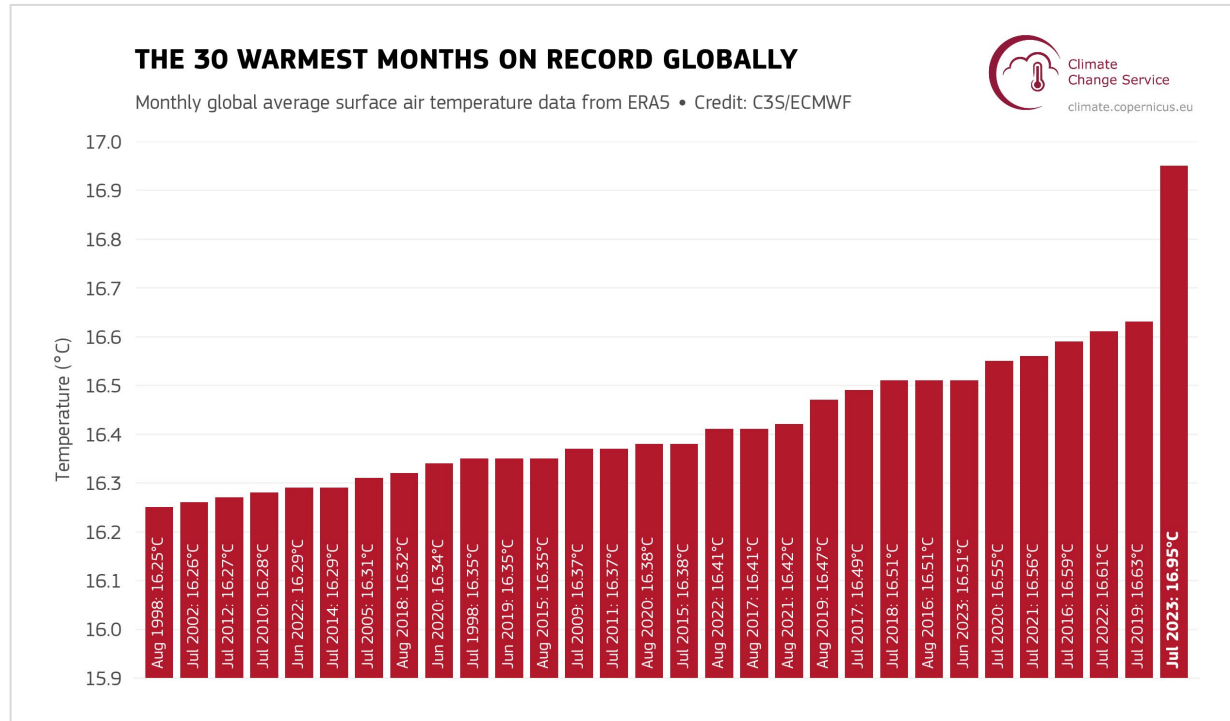


Humidity index

Little discomfort
Some discomfort
Great discomfort
Dangerous



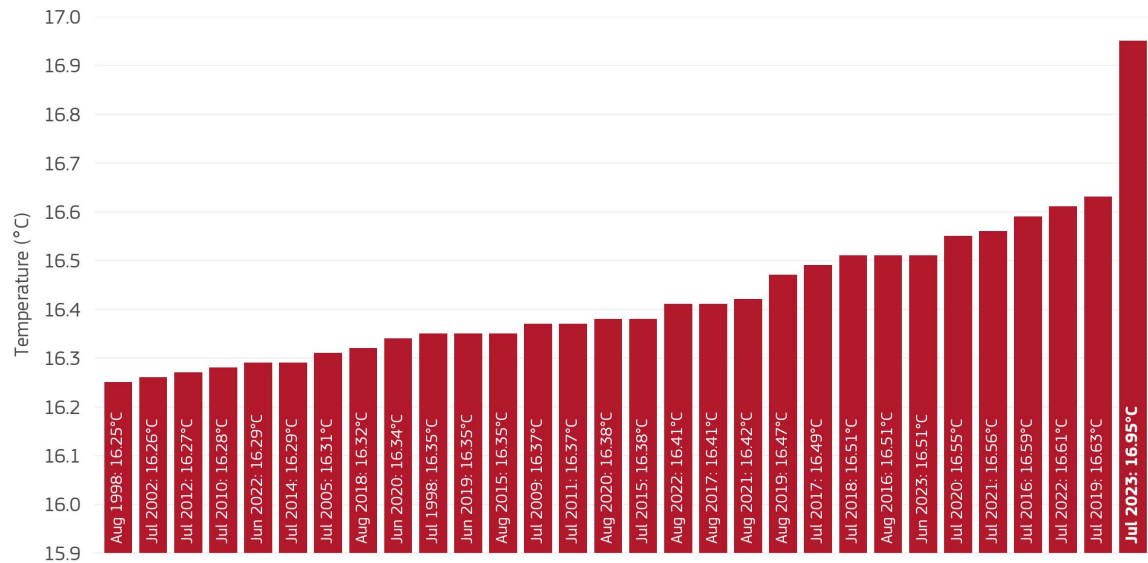
A tool for scientists: gain insights



A tool for scientists: gain insights

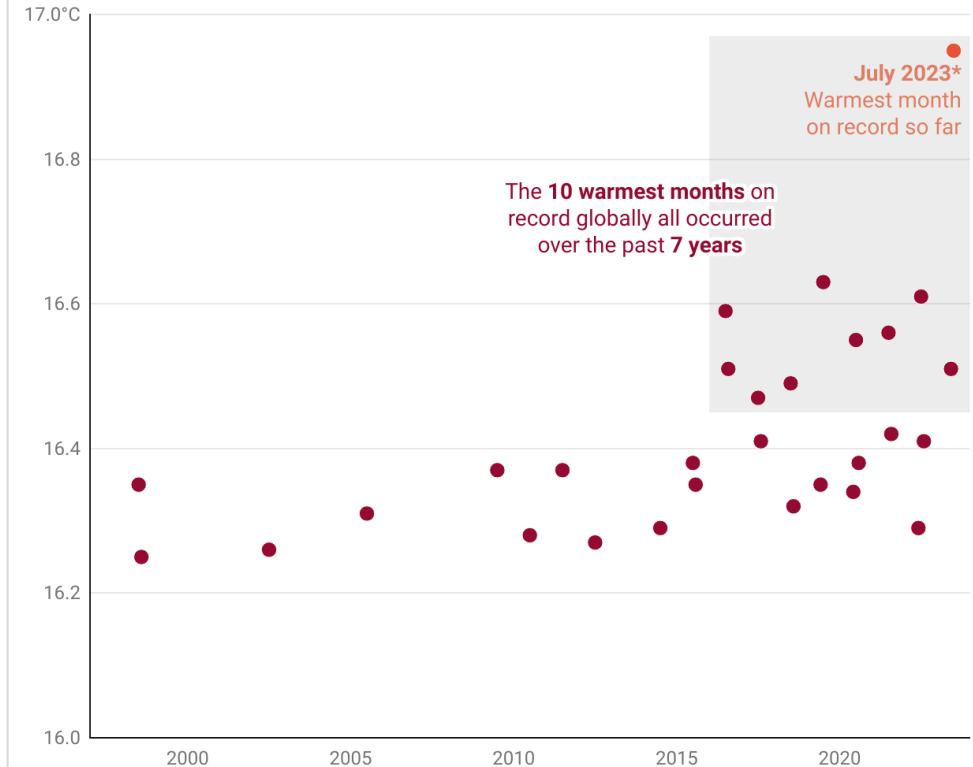
THE 30 WARMEST MONTHS ON RECORD GLOBALLY

Monthly global average surface air temperature data from ERA5 • Credit: C3S/ECMWF



Warmest months on record

Monthly global average surface air temperature



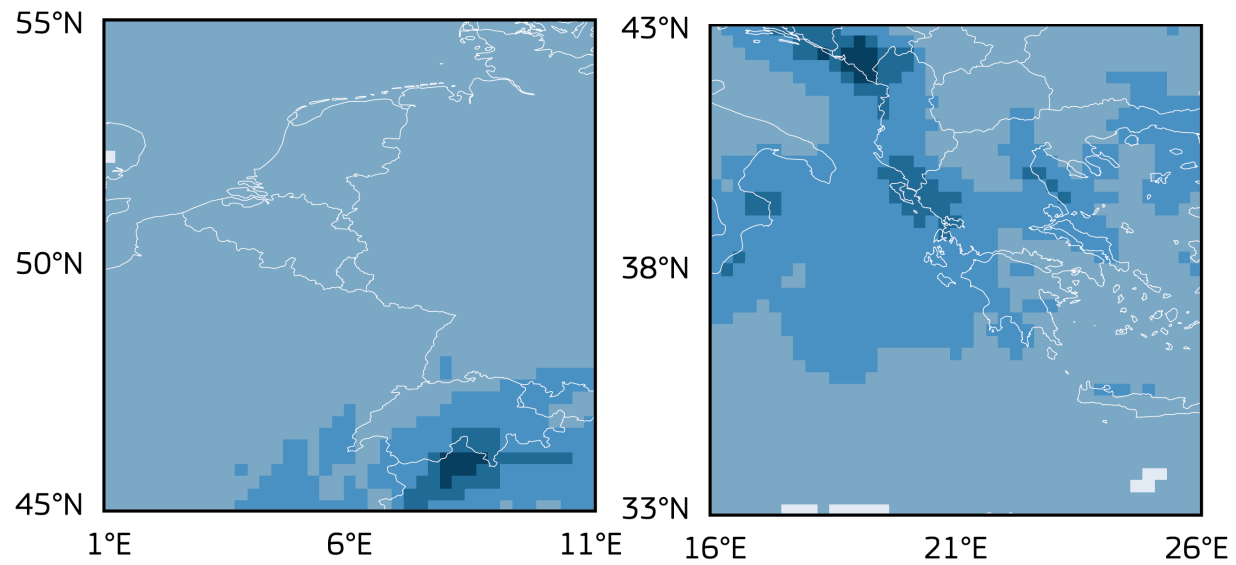
Data for July 2023 is provisional (up to July 23rd)

Source: C3S/ECMWF • Created with Datawrapper

Additional insights!

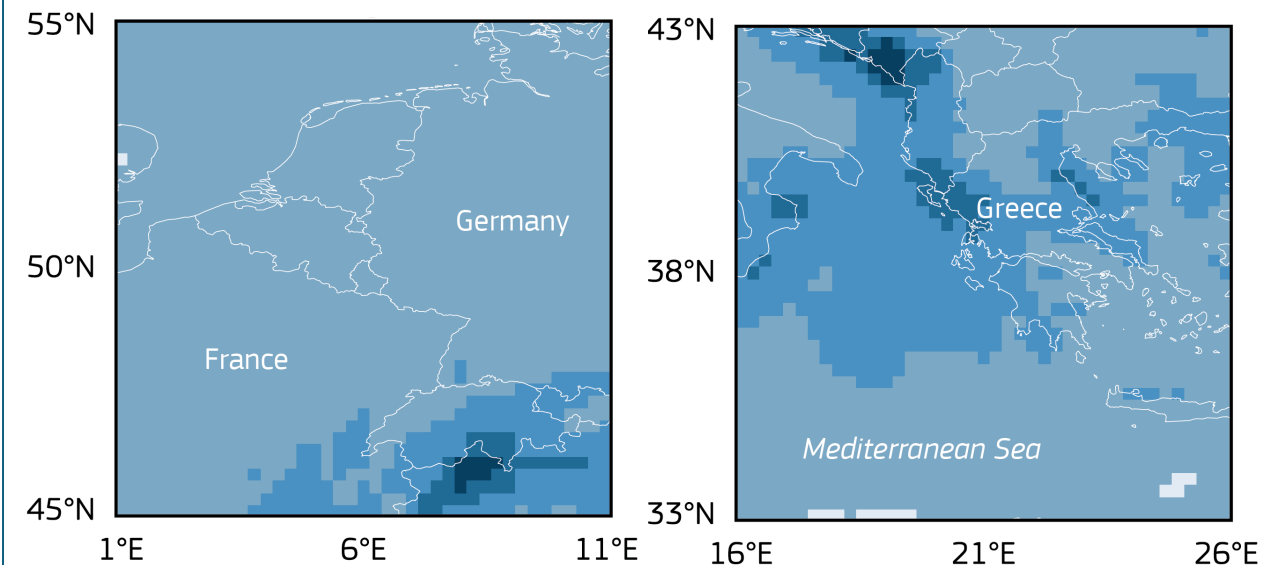
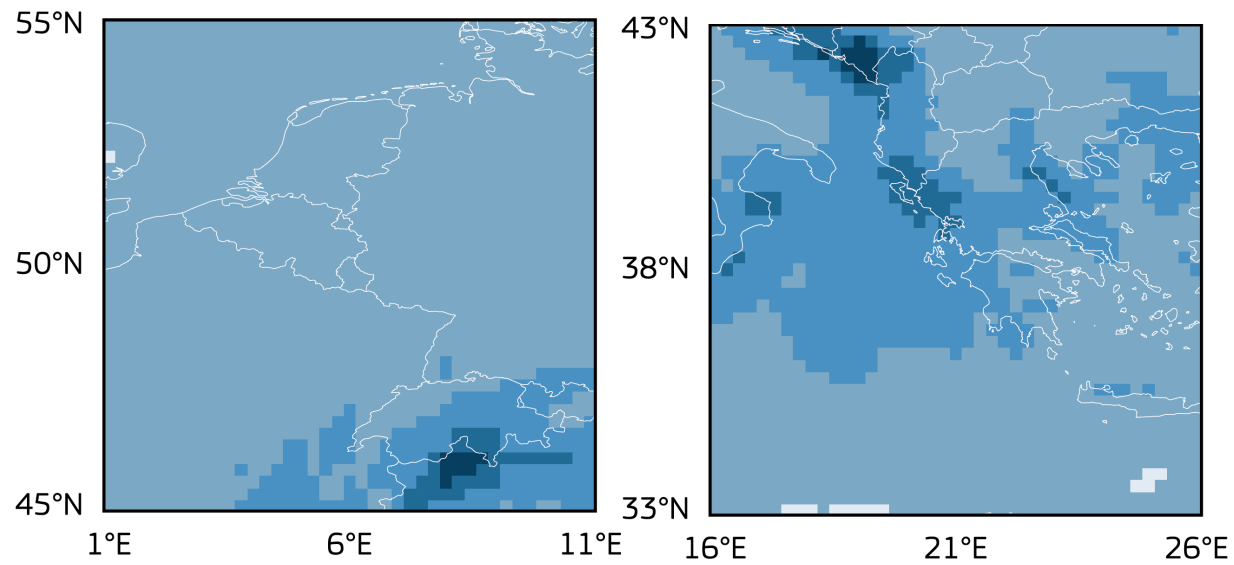


A tool for scientists: better communicate findings





A tool for scientists: better communicate findings





A tool for scientists: better communicate findings

Meteorological Applications Science and Technology for Weather and Climate

RESEARCH ARTICLE | **Open Access** |

How bad is the rain? Applying the extreme rain globally and for climate monitoring activities

David A. Lavers Gabriele Villarini, Hannah L. Cloke, Adrian Simmons, Nigel Samantha N. Burgess, Florian Pappenberger

First published: 12 April 2025 | <https://doi.org/10.1002/met.70031>

Earth System Science

ARTICLES & PREPRINTS SUBMISSION POLICIES PEER REVIEW LIVING DATA PROCESS EDITORIAL BOARD

Article

Articles / Volume 16, Issue 8 / ESSD, 16, 3601–3685, 2024

<https://doi.org/10.5194/essd-16-3601-2024>
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Review article |

State of Wildfires 2023–2024

Matthew W. Jones , Douglas I. Kelley , Chantelle A. Burton , Francesca Di Giuseppe , Maria Lucia F. Barbosa, Esther Brambleby, Andrew J. Hartley, Anna Lombardi, Guilherme Mataveli, Joe R. McNorton, Fiona R. Spuler, Jakob B. Wessel, John T. Abatzoglou, Liana O. Anderson, Niels Andela, Sally Archibald, Dolores Armenteras, Eleanor Burke, Rachel Carmenta, Emilio Chuvieco, Hamish Clarke, Stefan H. Doerr, Paulo M. Fernandes, Louis Giglio, Douglas S. Hamilton, Stijn Hansson, Sarah Harris, Piyush Jain, Crystal A. Kolden, Tiina Kurvits, Seppe Lampe, Sarah Meier, Stacey New, Mark Parrington, Morgane M. G. Perron, Yuquan Qu, Natasha S. Ribeiro, Bambang H. Saharjo, Jesus San-Miguel-Ayanz, Jacquelyn K. Shuman, Veerachai Tanpipat, Guido R. van der Werf, Sander Veraverbeke, and Gavril Xanthopoulos

14 Aug 2024

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Short summary
This inaugural State of Wildfires report catalogues extreme fires of the 2023–2024 fire season....
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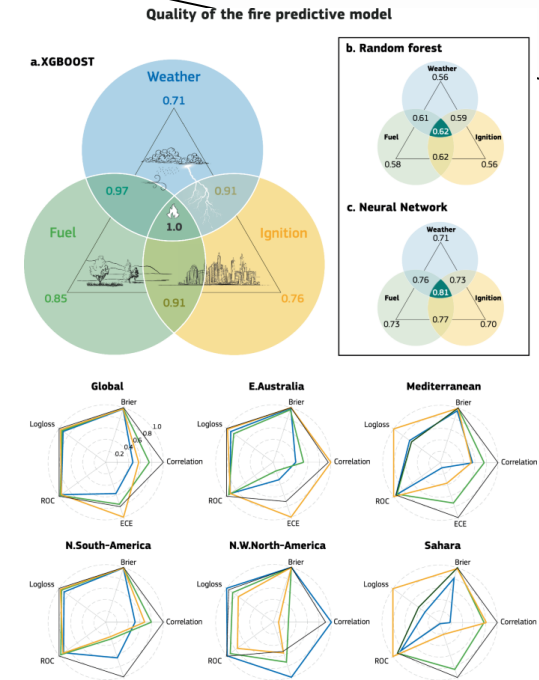
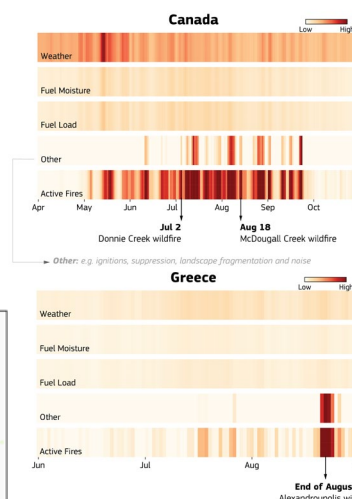
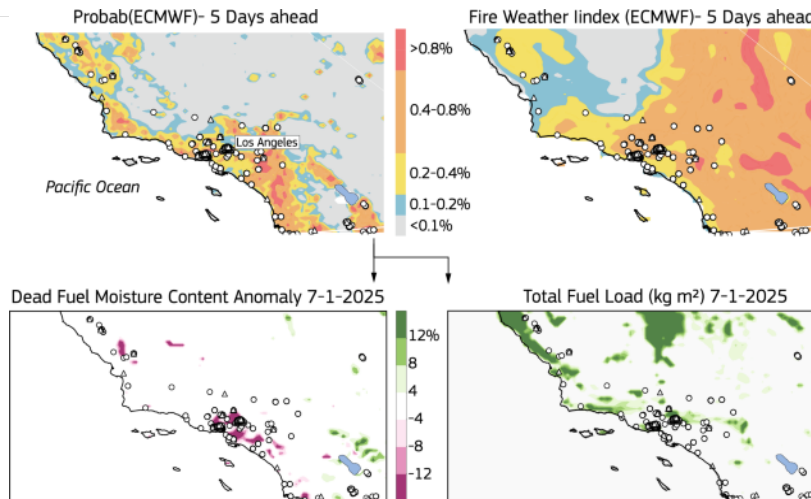
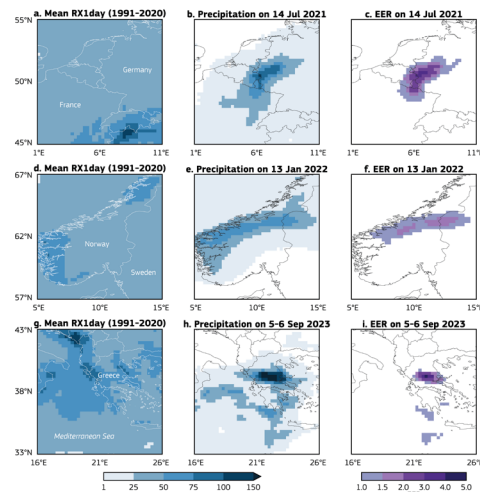
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Article | **Open access** | Published: 01 April 2025

Global data-driven prediction of fire activity

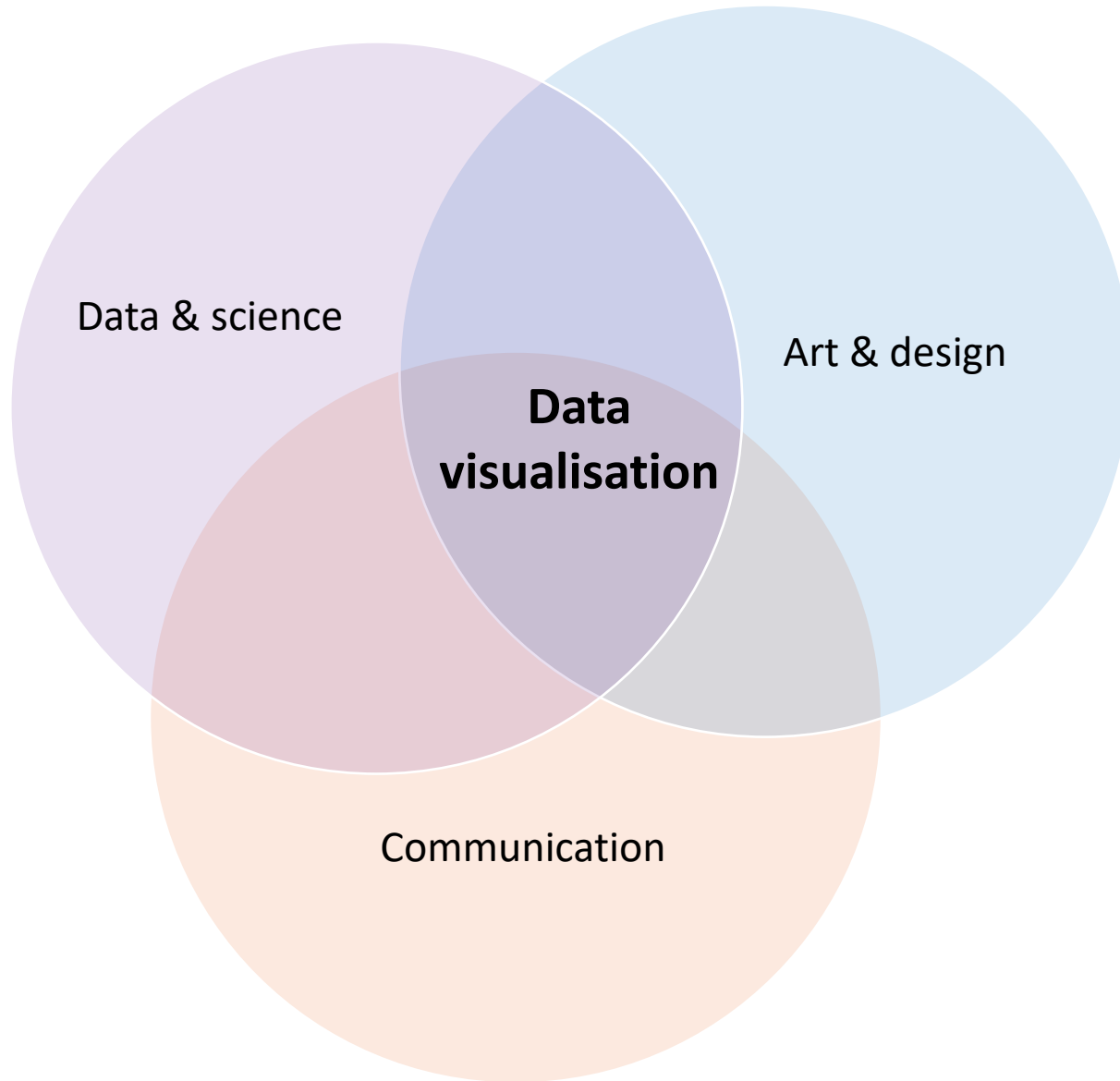
Francesca Di Giuseppe , Joe McNorton , Anna Lombardi & Fredrik Wetterhall

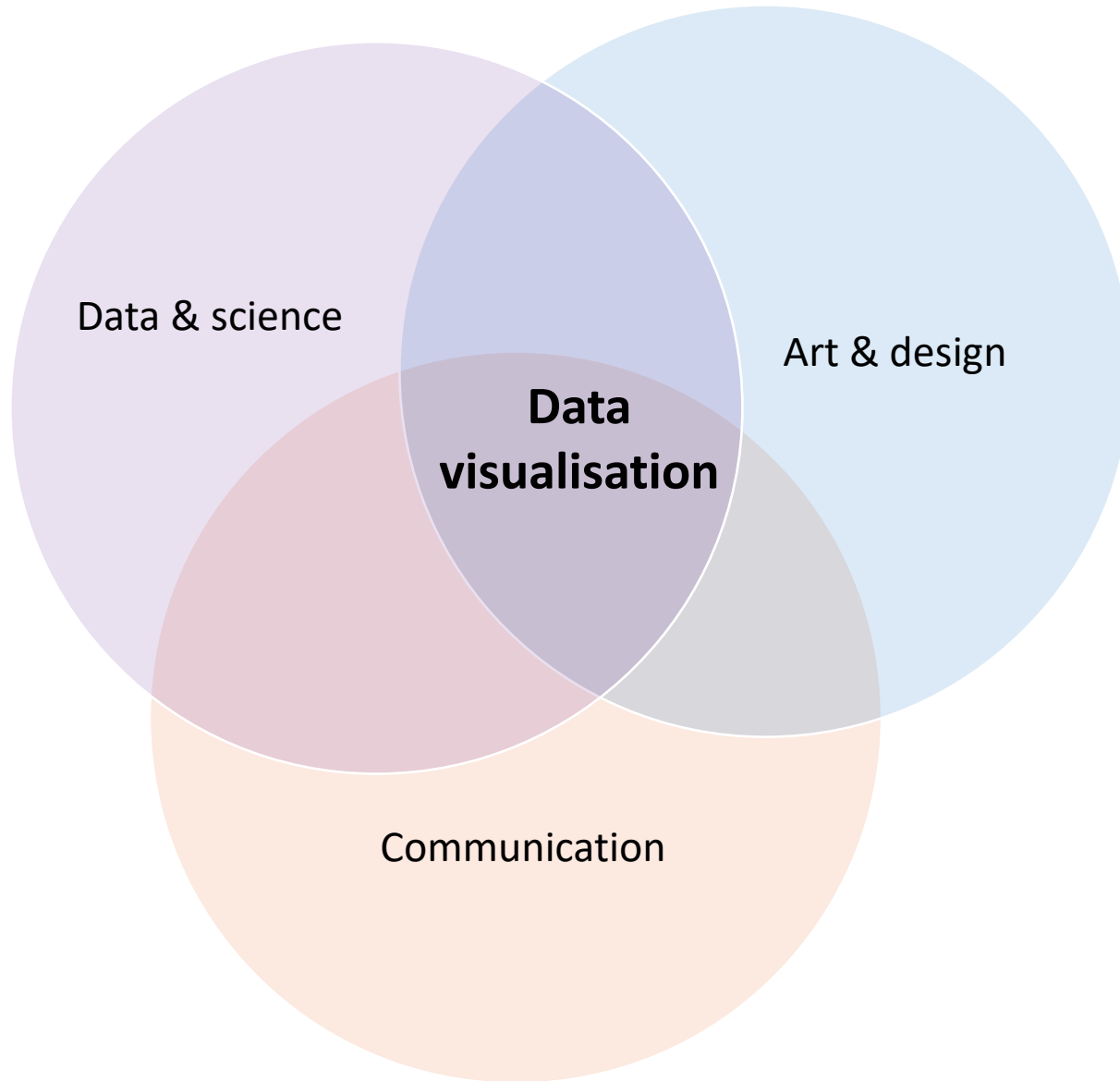
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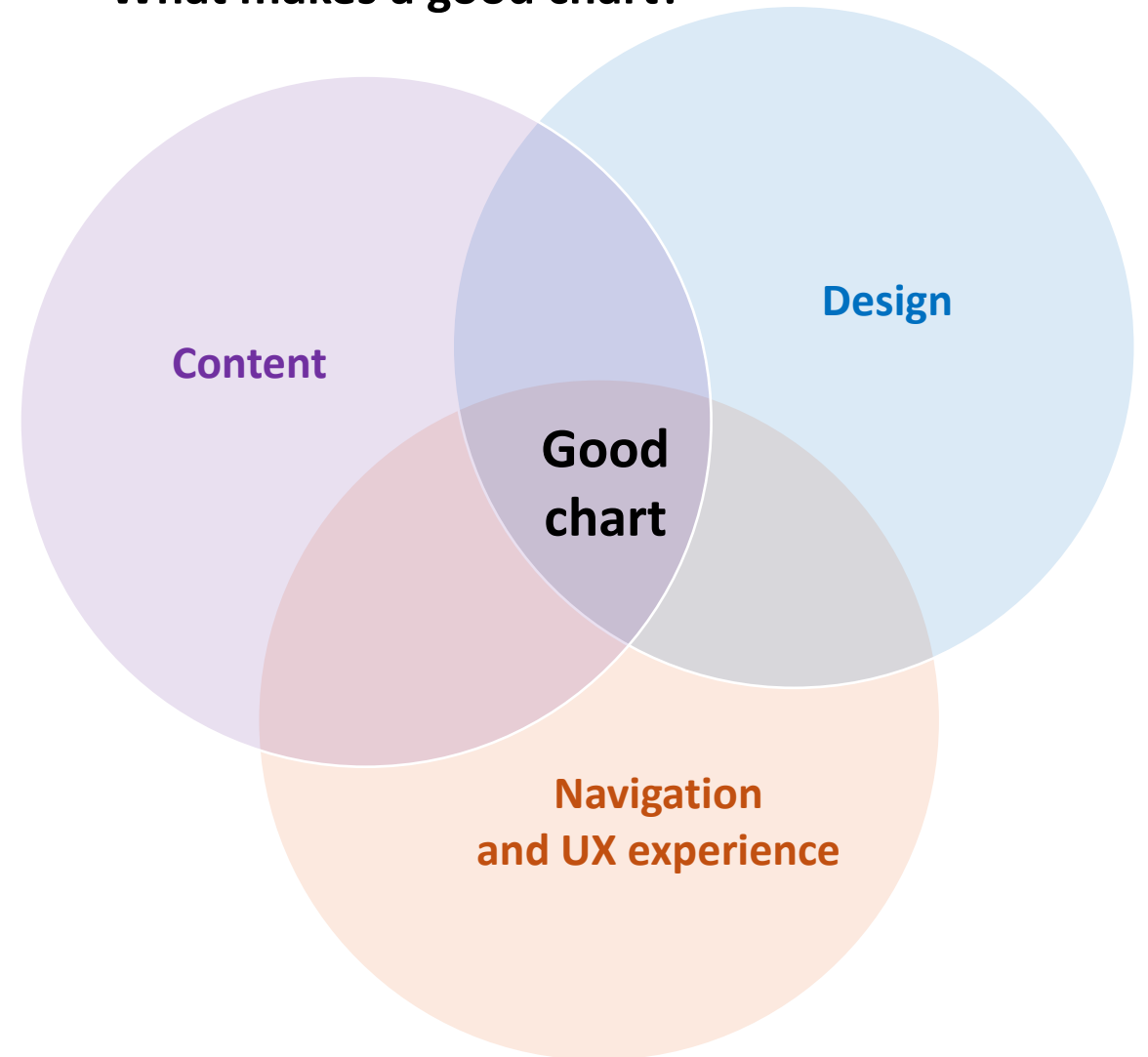


3. What makes a good chart?

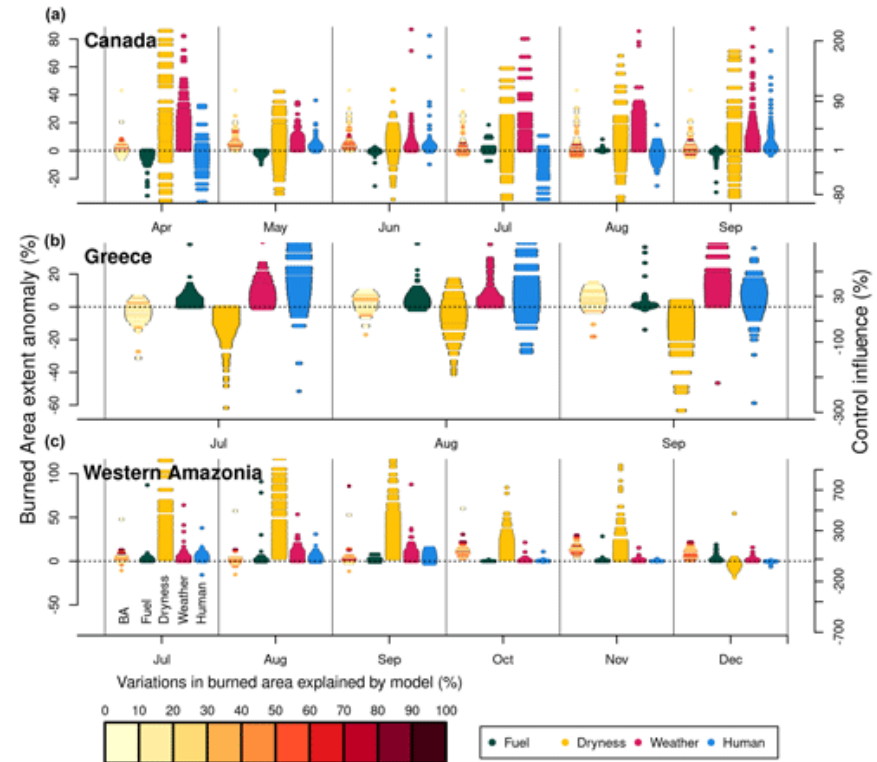
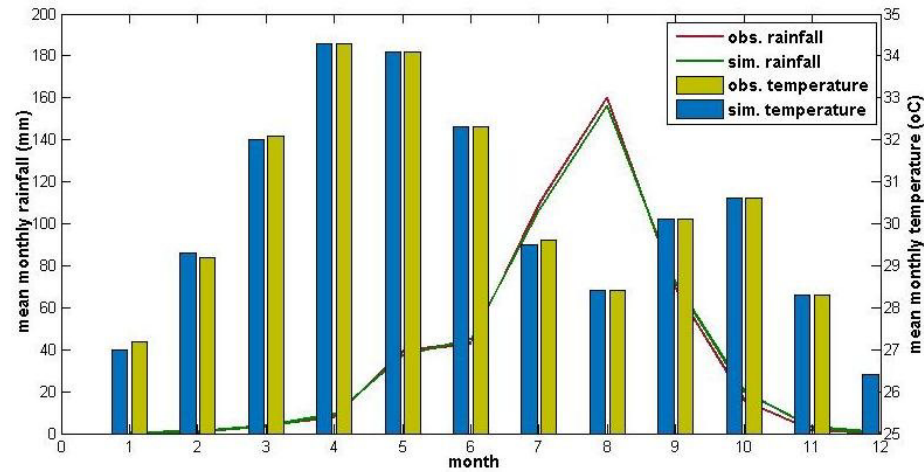




What makes a good chart?

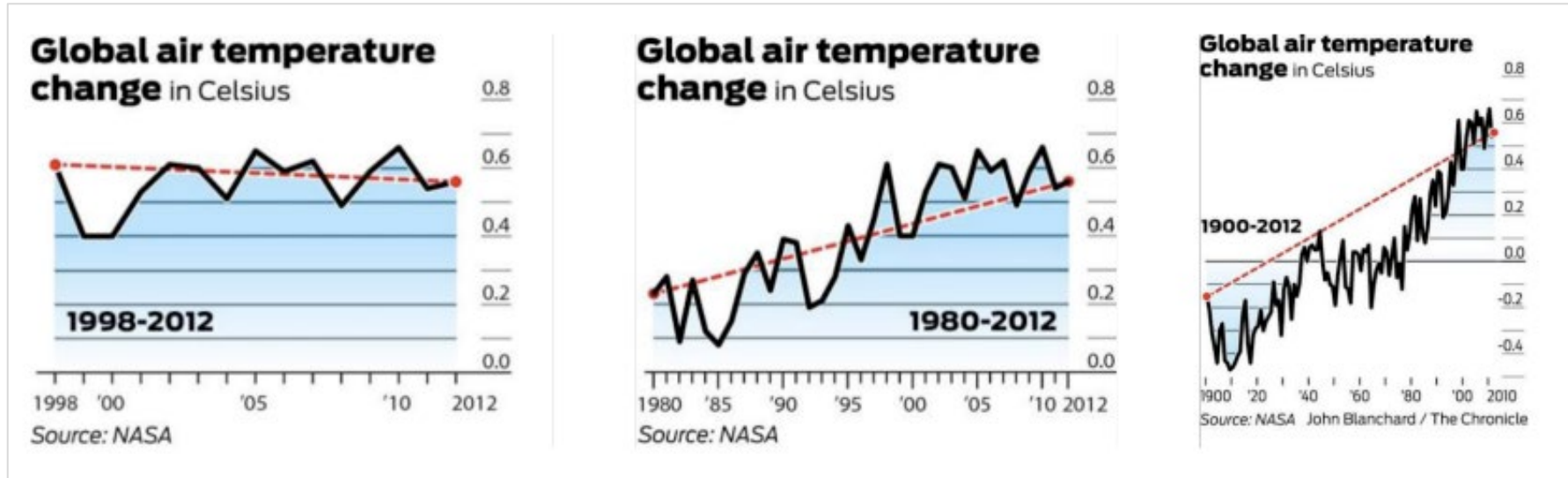


1. Clarity and transparency: don't overload



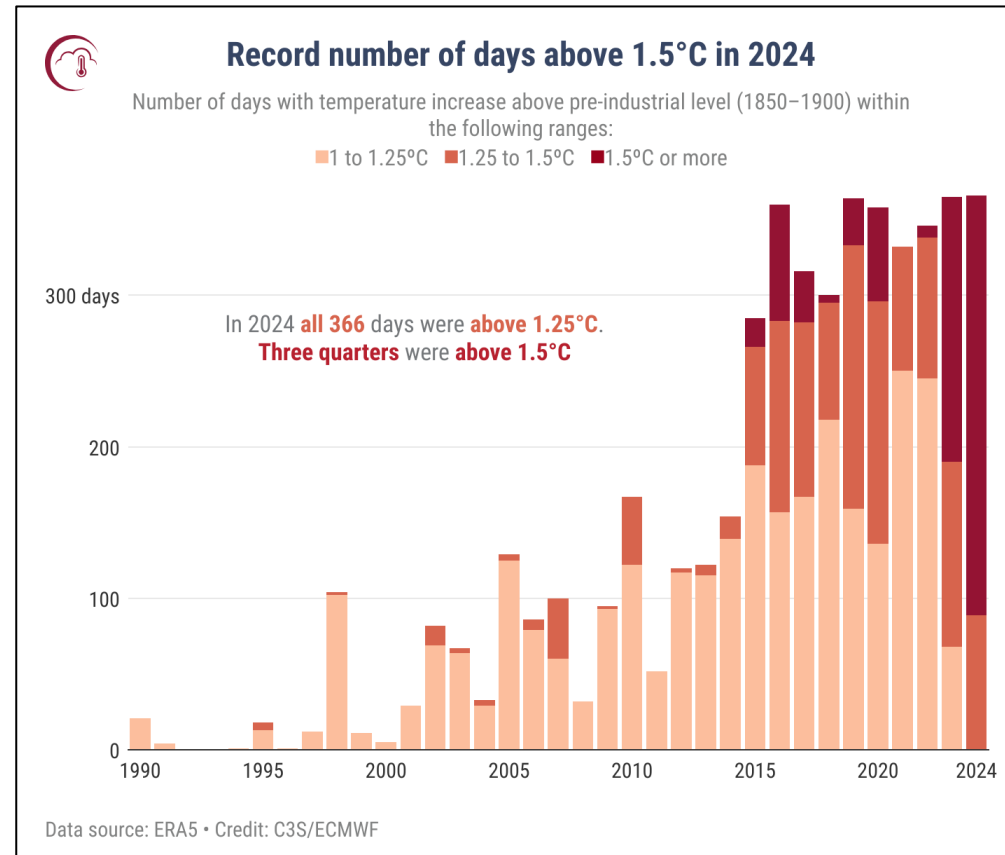


1. Clarity and transparency: no cherry picking





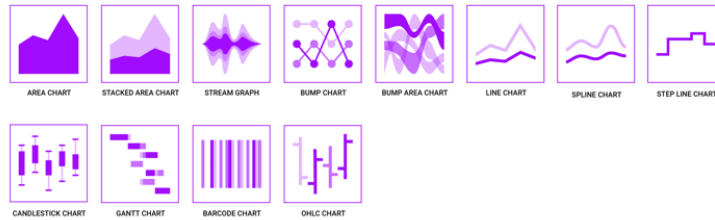
1. Clarity and transparency: spell the message out, be redundant, add annotations, guide the eye



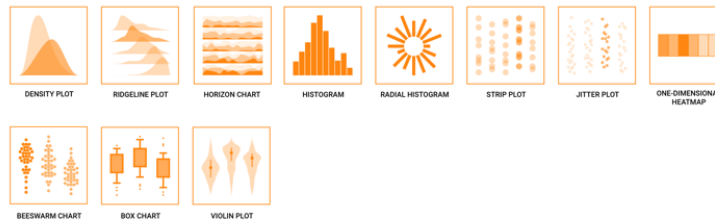


1. Clarity and transparency
2. Pick the best chart for the data

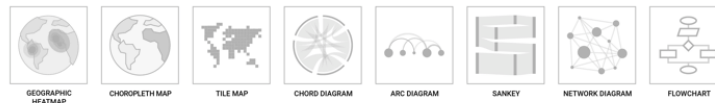
DATA OVER TIME (TEMPORAL)



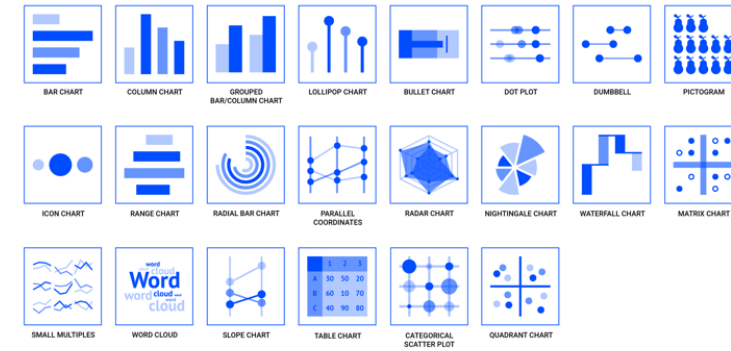
DISTRIBUTION



GEOSPATIAL & OTHER



COMPARISON



CORRELATION



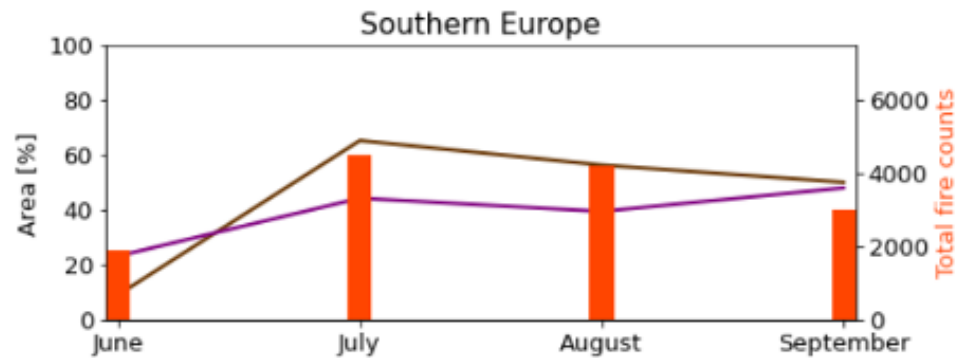
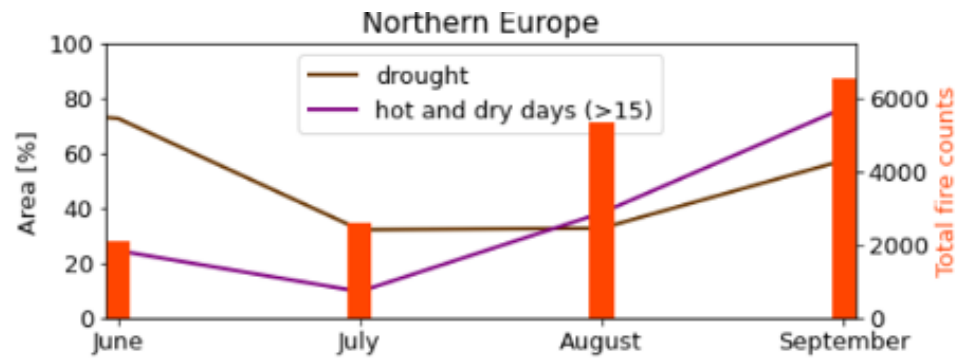
PART-TO-WHOLE & HIERARCHICAL



<https://www.data-to-viz.com/>
Dataviz Catalogue

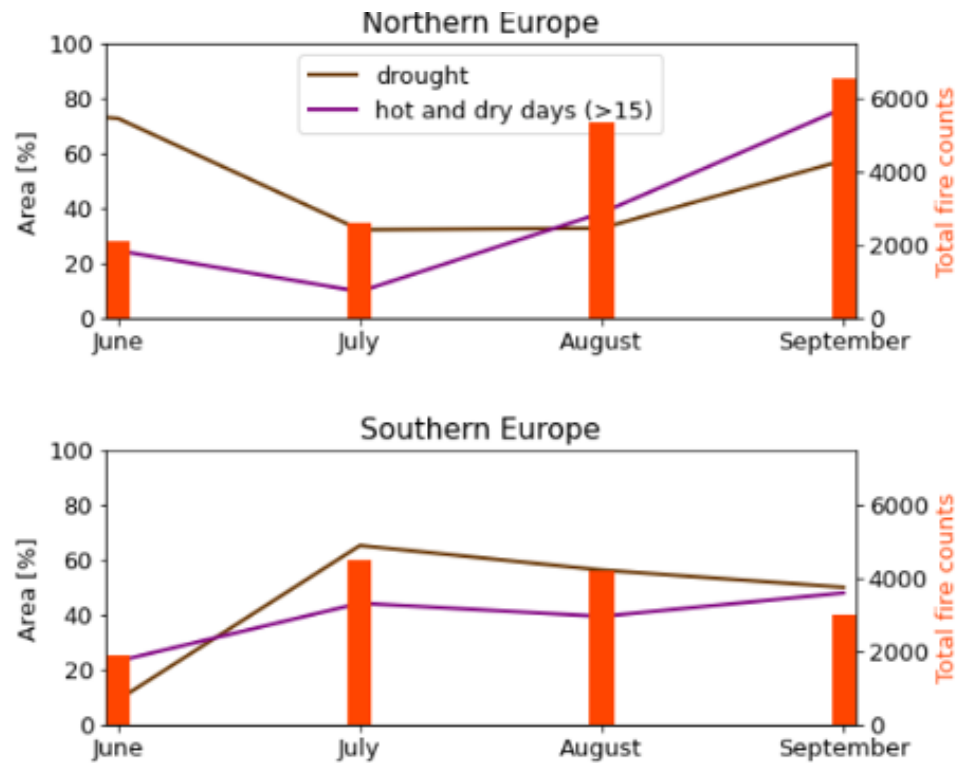


1. Clarity and transparency
2. Pick the best chart for the data





1. Clarity and transparency
2. Pick the best chart for the data



Patterns of drought in Europe during summer 2023

Northern Europe

	Area in drought	Area experiencing more than 15 hot and dry days	Fire count
June	72.4%	24.3%	2,107
July	31.9%	9.5%	2,607
August	32.5%	38.1%	5,350
September	57.2%	76.18%	6,508

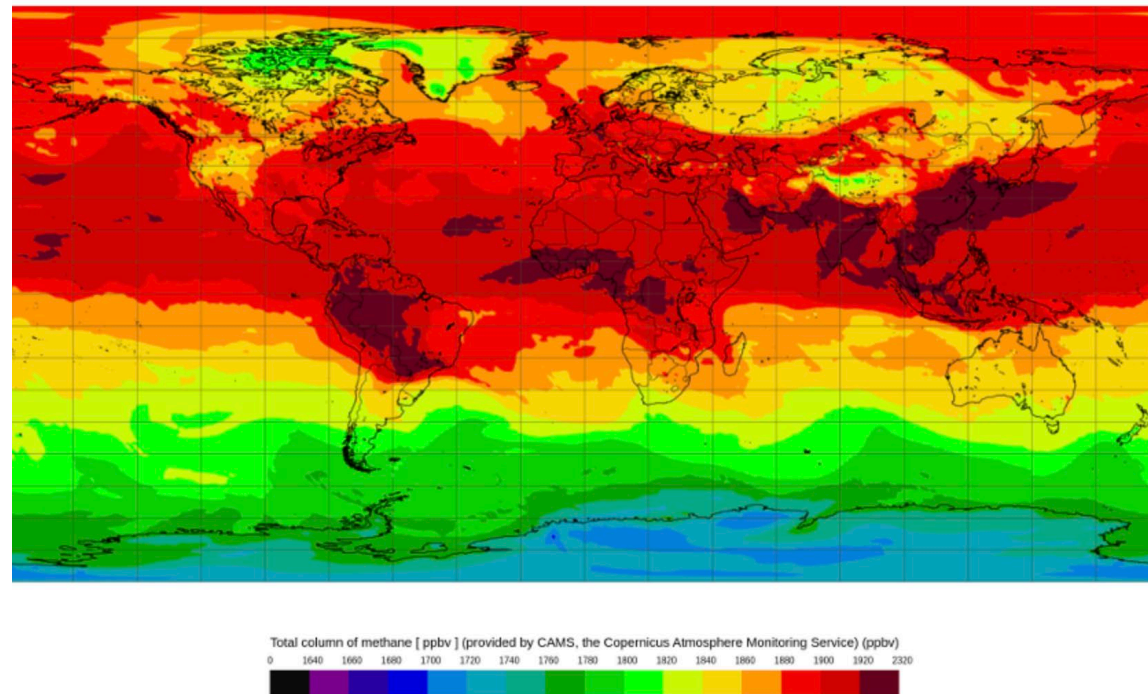
Southern Europe

	Area in drought	Area experiencing more than 15 hot and dry days	Fire count
June	8.9%	23%	1,902
July	65%	44%	4,494
August	56.1%	39.2%	4,193
September	49.8%	47.79%	2,997



1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility

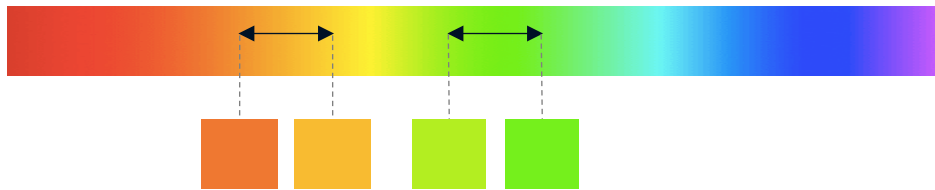
1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility





1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility

Non-uniform distances between hues



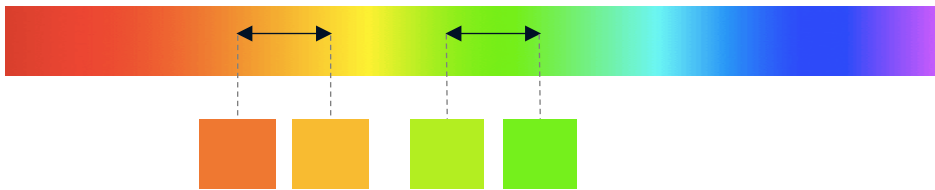
Rainbow palettes are not optimised for human perception:

- **Inaccurate or unreadable for people with colour blindness**
- **Not perceptually uniform:** equal steps in data values don't map to equal steps in perceived colour



1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility

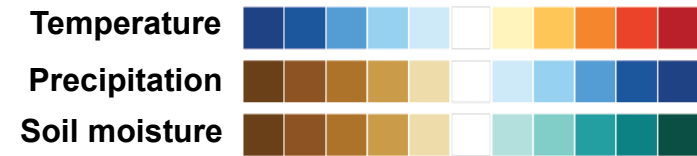
Non-uniform distances between hues



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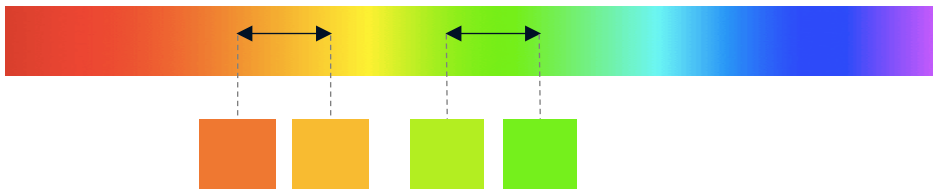
- ✓ *Fewer hues, more shades*
- ✓ *Grey is your friend*
- ✓ *Use intuitive colour associations*





1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility

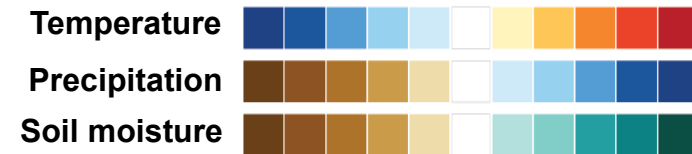
Non-uniform distances between hues



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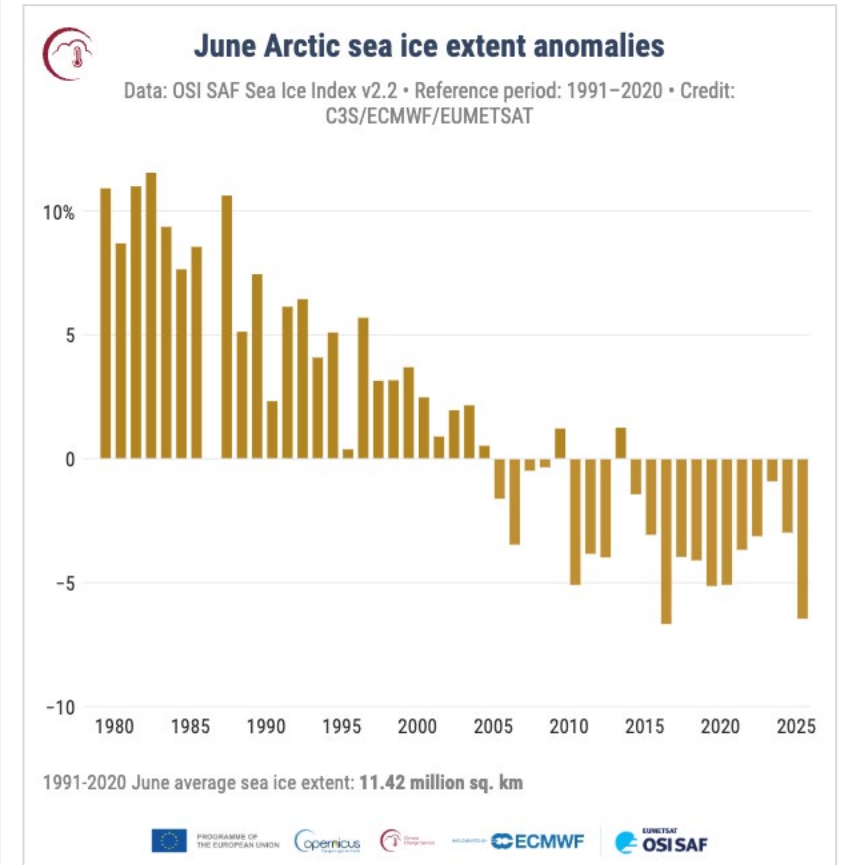
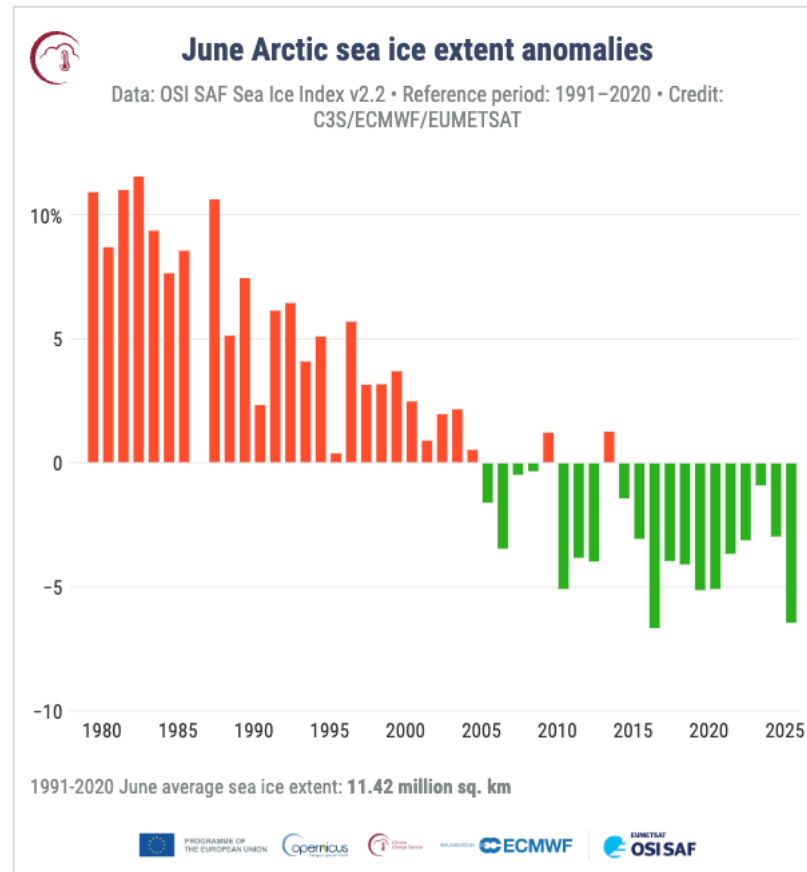
Somewhere Over the Rainbow: How to Make Effective Use of Colours in Meteorological Visualizations

Stauffer et al., BAMS (2015)

<https://doi.org/10.1175/BAMS-D-13-00155.1>

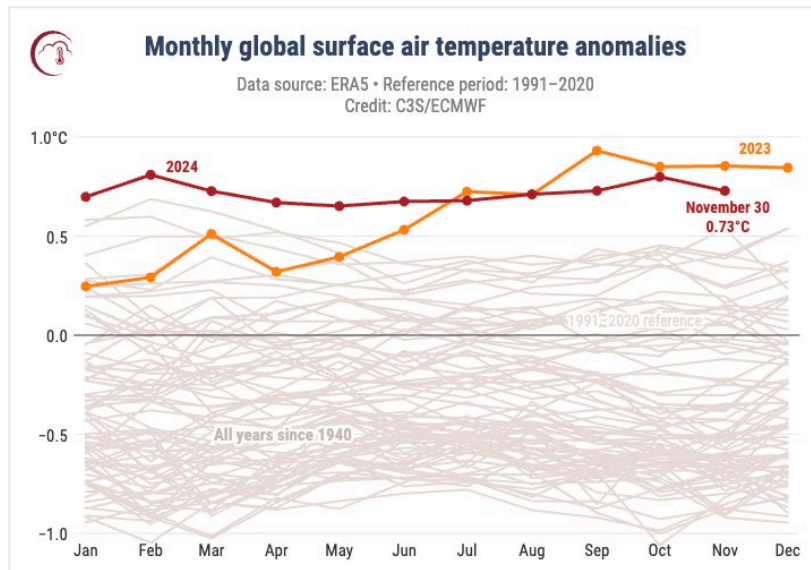


1. Clarity and transparency
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3. Accessibility

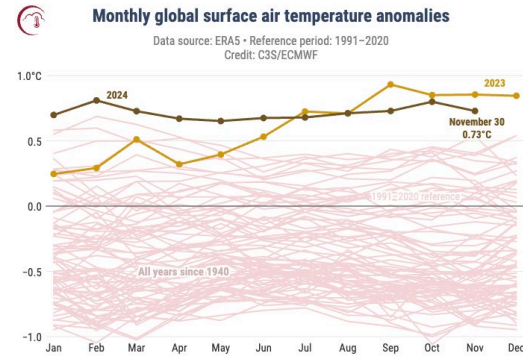




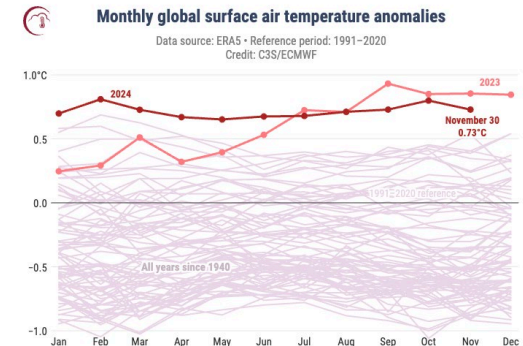
1. Clarity and transparency
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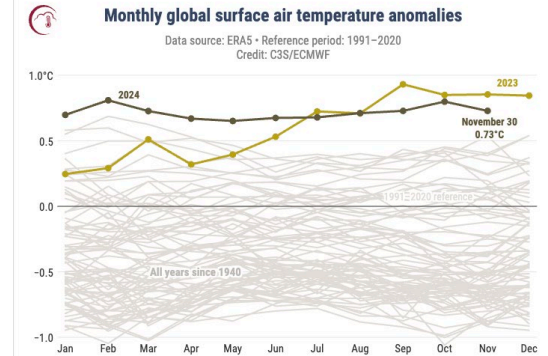
Deuteranopia (red-green blindness)



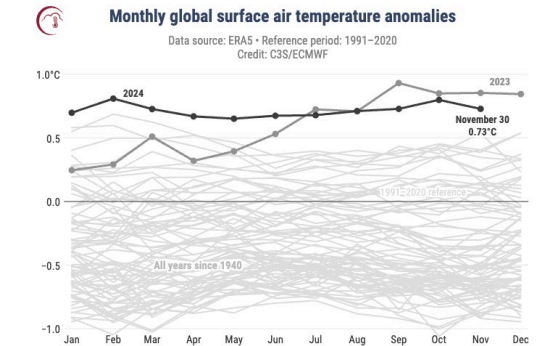
Tritanopia (blue-yellow blindness)



Protanopia (red-green blindness)

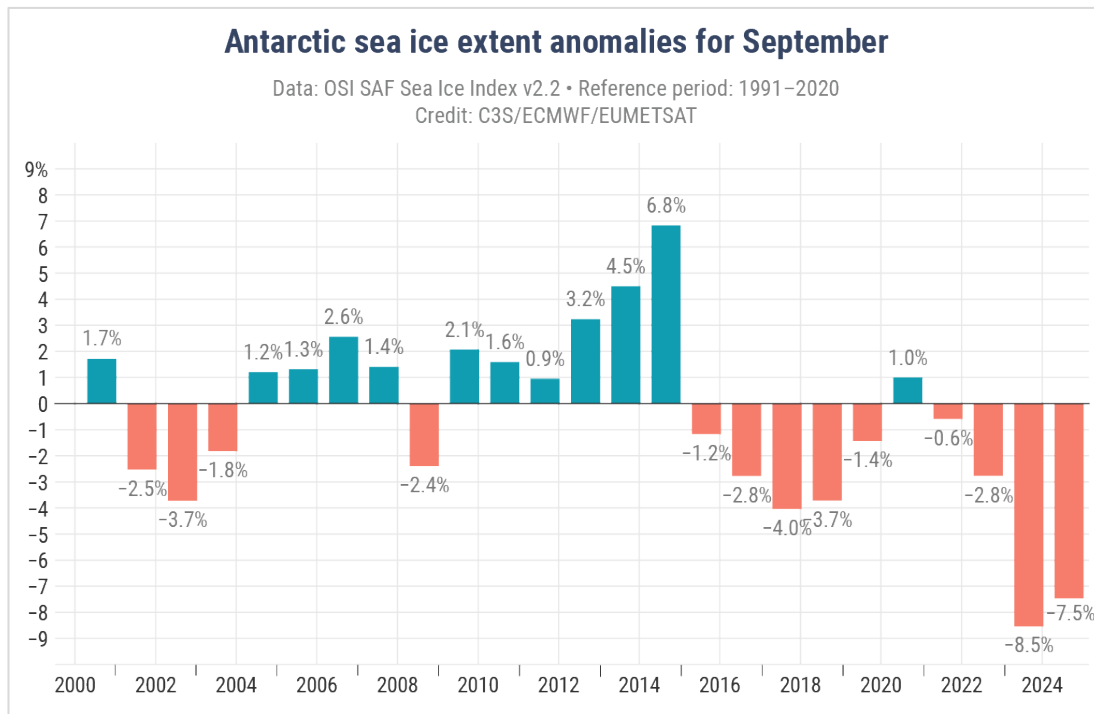


Achromatopsia



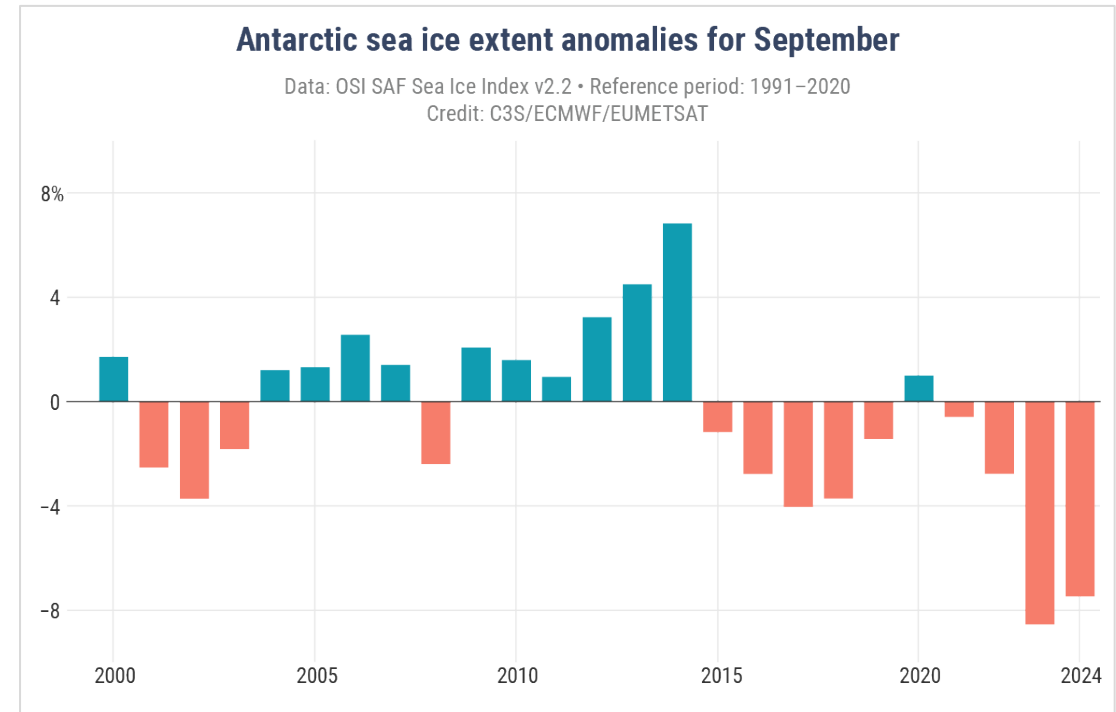
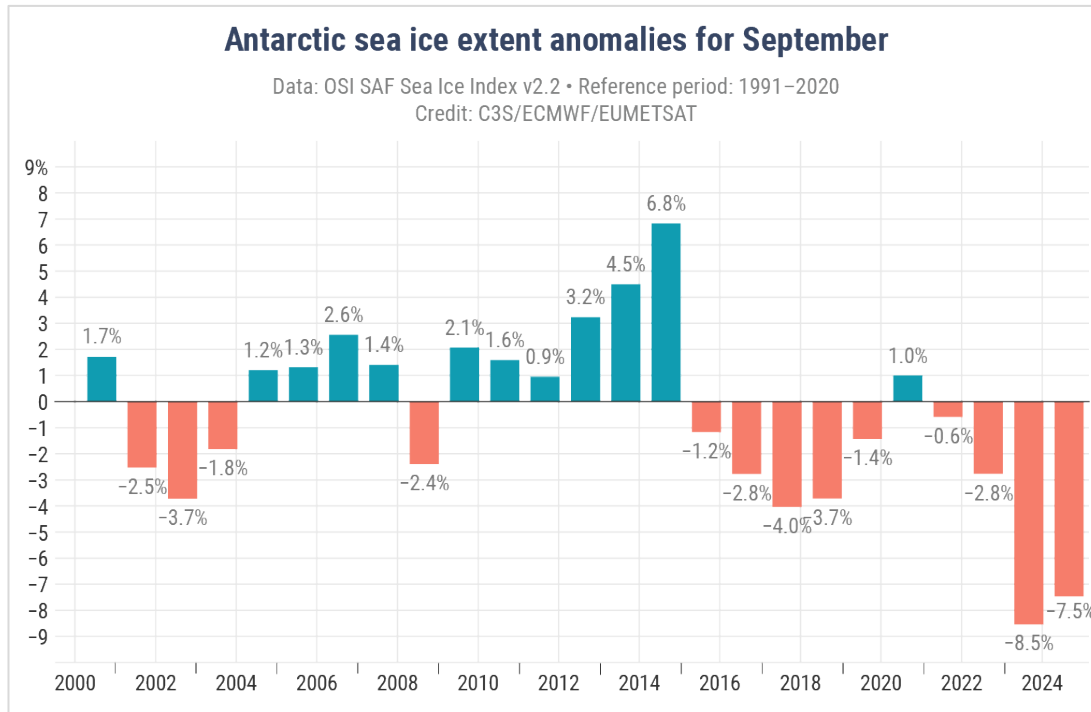


1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility
4. Reduce the visual noise

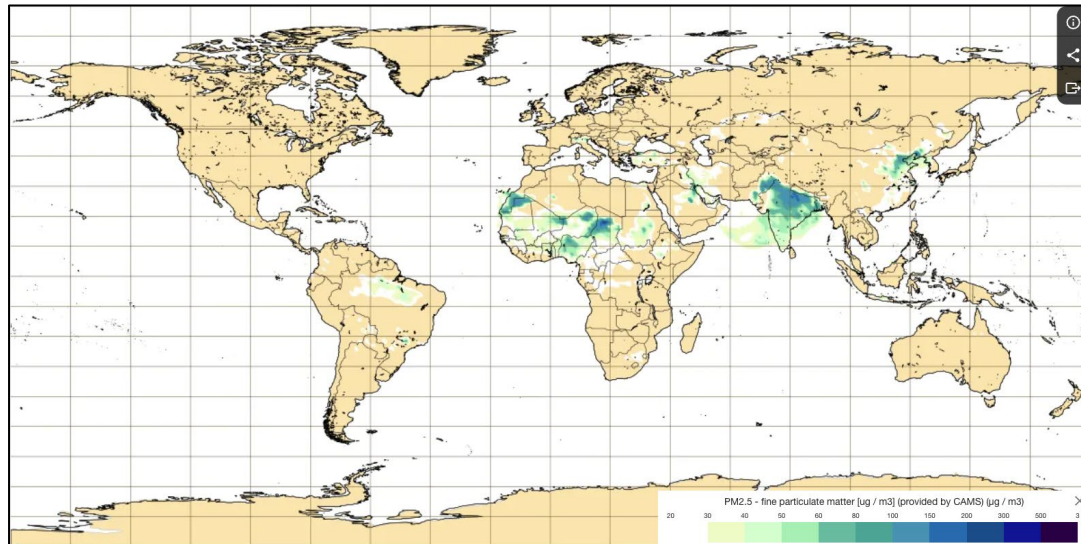




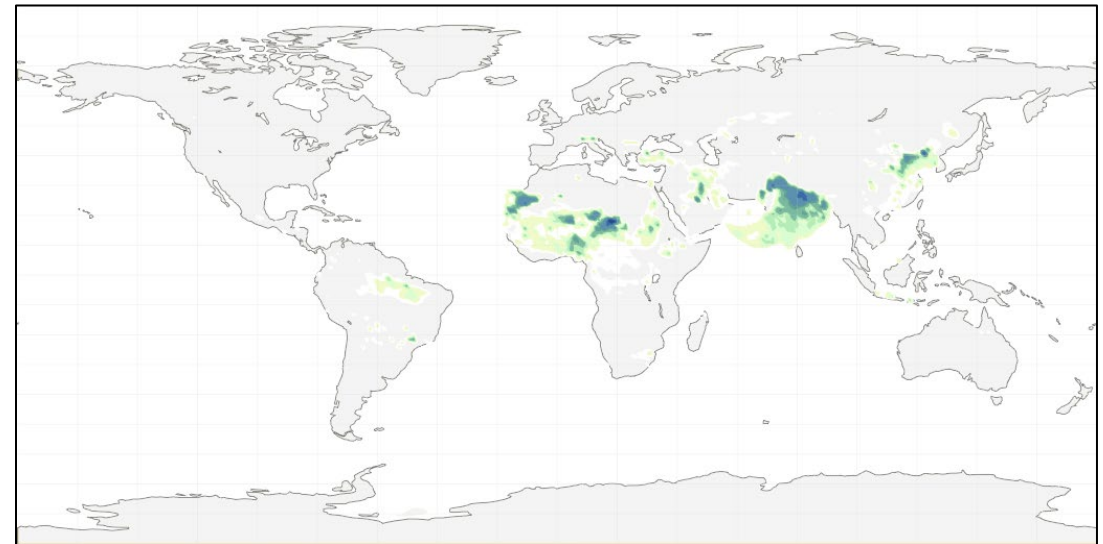
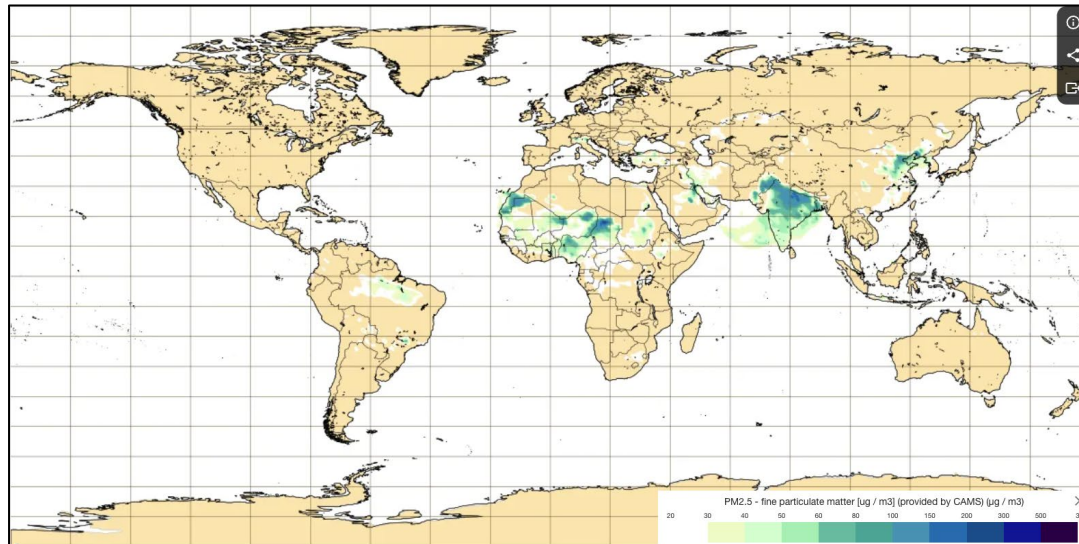
1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility
4. Reduce the visual noise



1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility
4. Reduce the visual noise

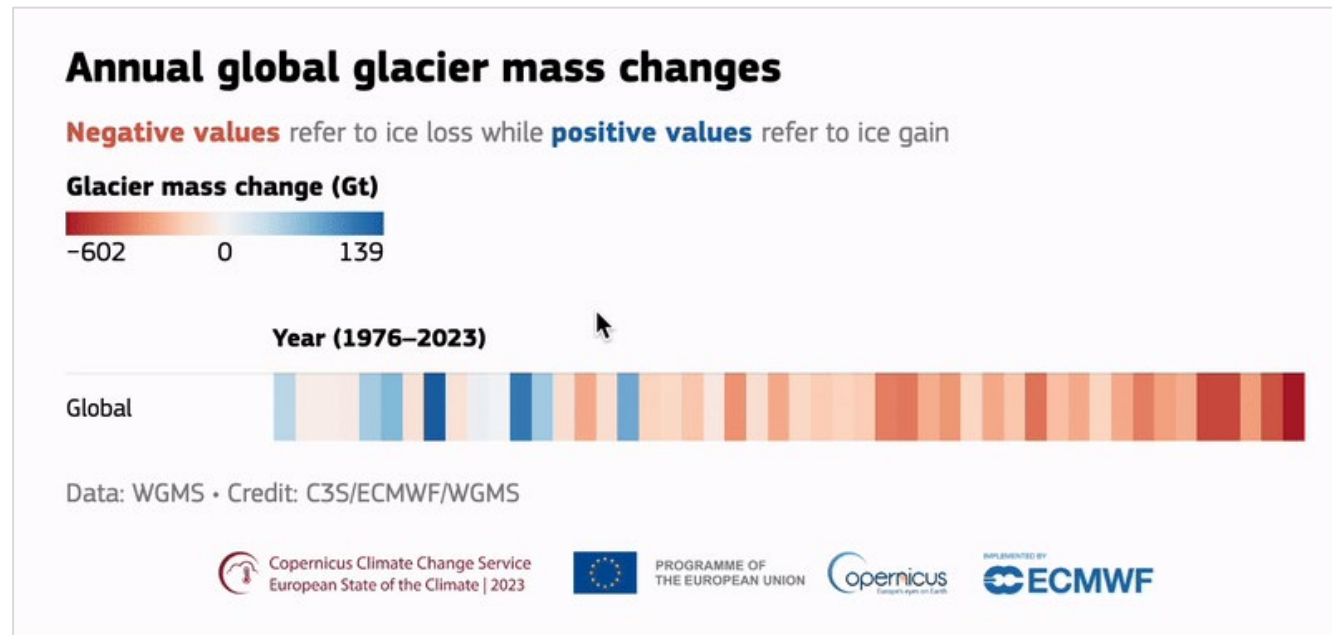


1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility
4. Reduce the visual noise



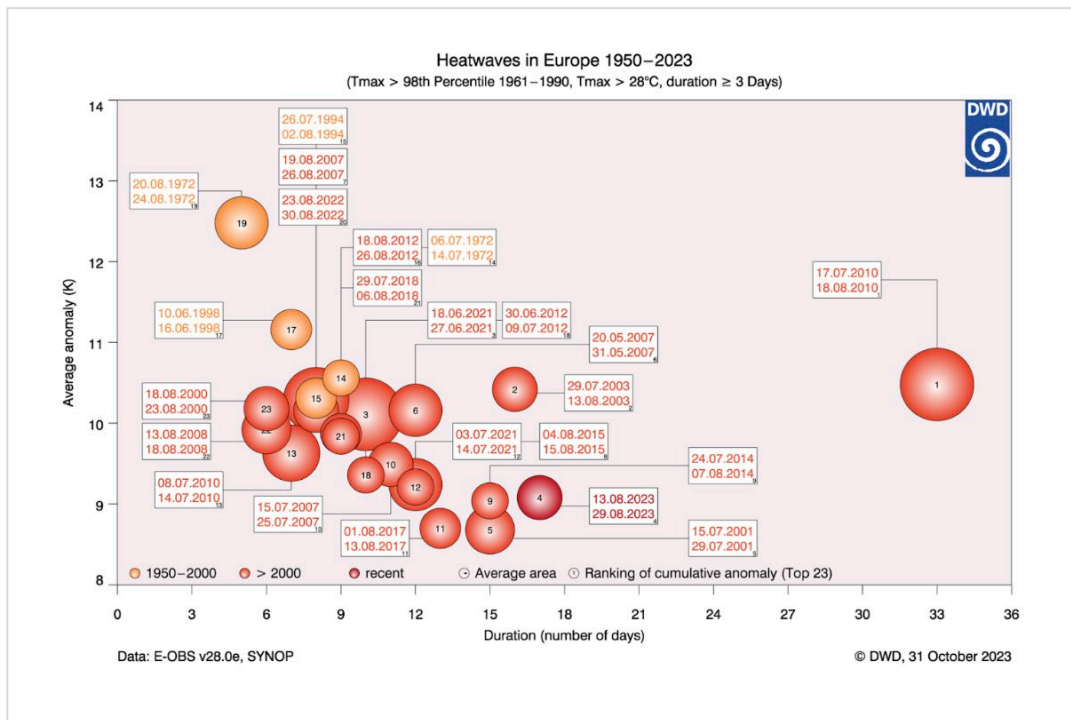


1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility
4. Reduce the visual noise
5. Use interactivity wisely



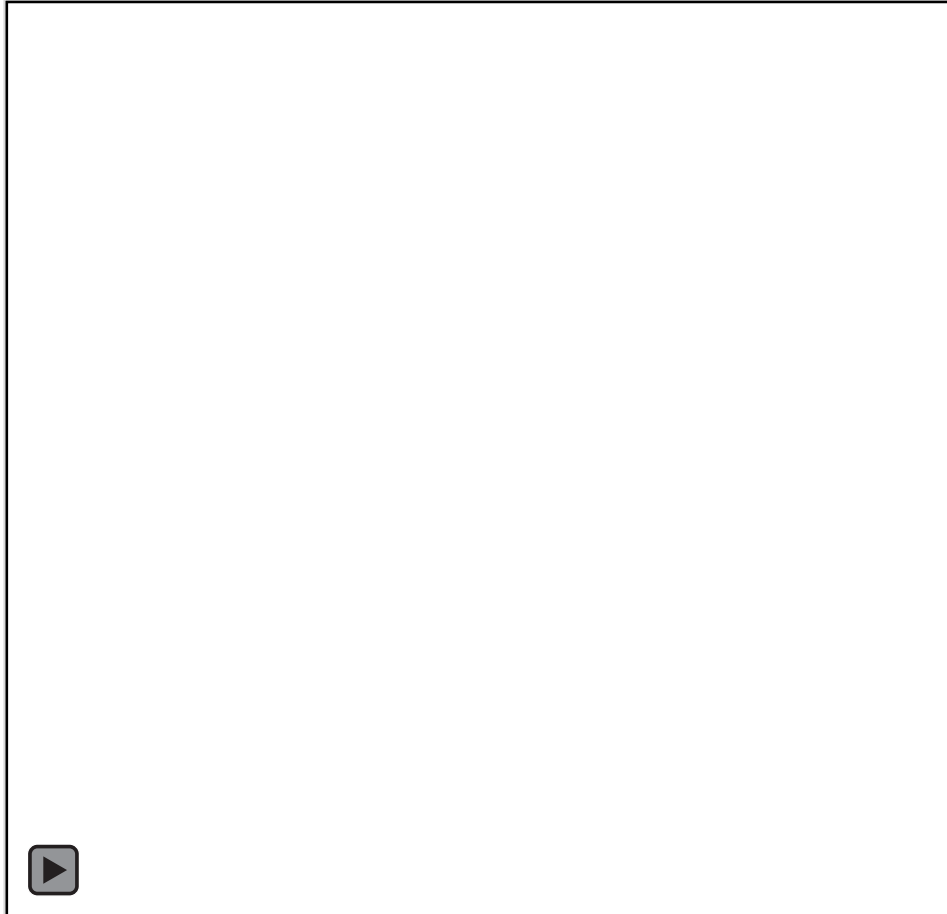
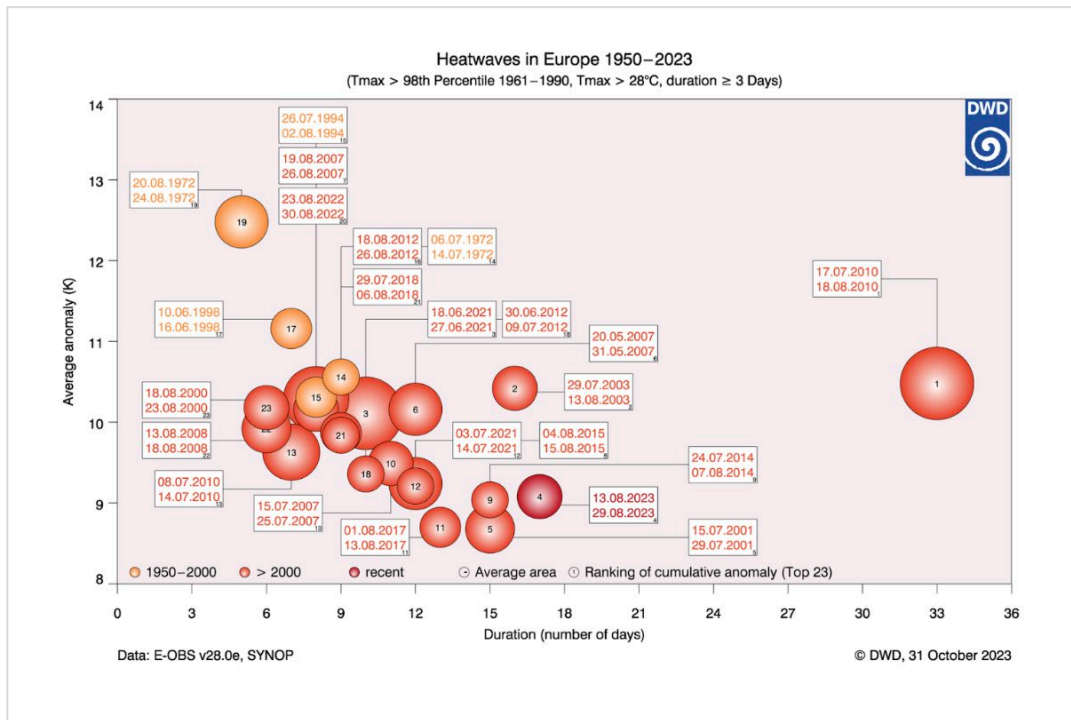


1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility
4. Reduce the visual noise
5. Use interactivity wisely



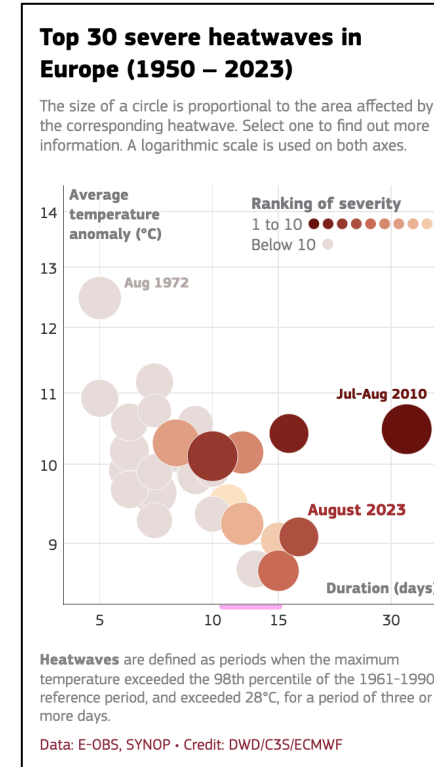
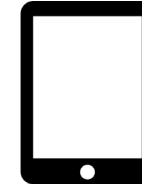
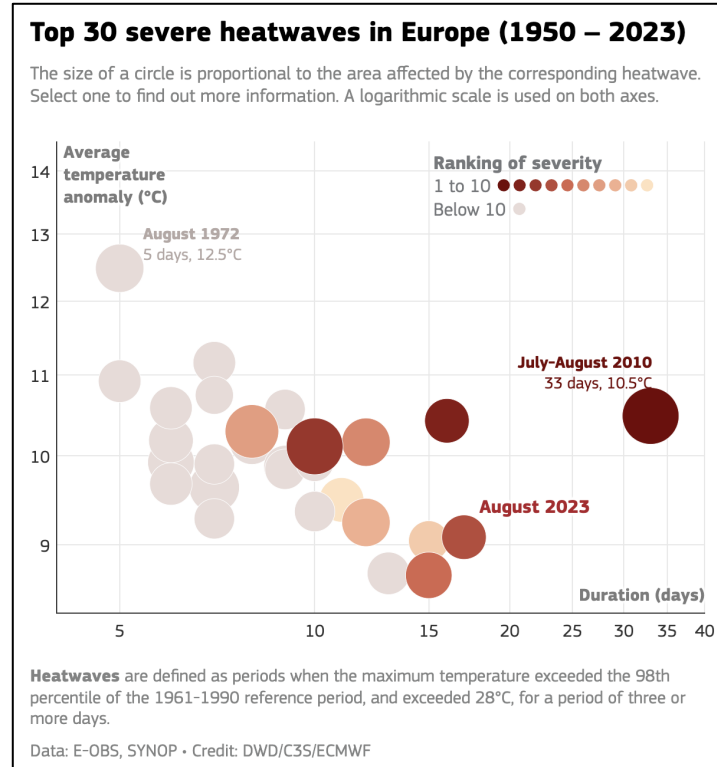
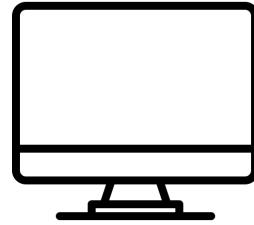


1. Clarity and transparency
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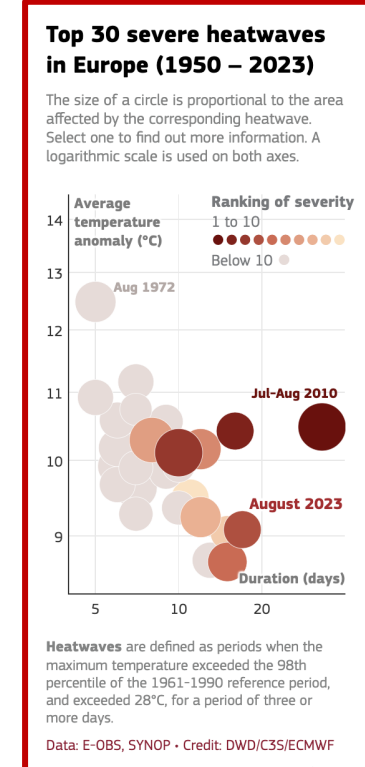




1. Clarity and transparency
2. Pick the best chart for the data
3. Accessibility
4. Reduce the visual noise
5. Use interactivity wisely
6. Responsiveness



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Professor Ben Shneiderman (computer scientist)



Anna Lombardi



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