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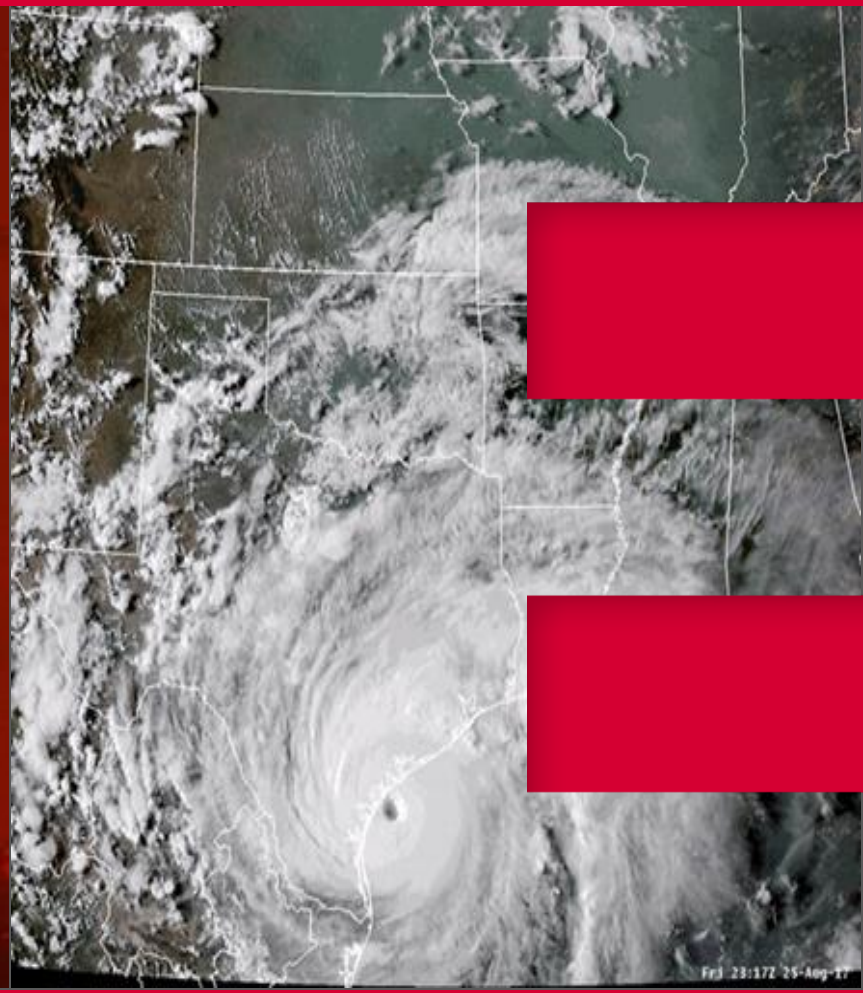

Taster Lecture

Natural Hazards

Weather and climate-related hazards

This is an extract of a lecture taken from the course “Natural Hazards”.
The course is an option taken by many students in Year 1 or Year 2.
The course covers hazards from volcanoes, earthquakes, and weather/climate.

David Stevenson

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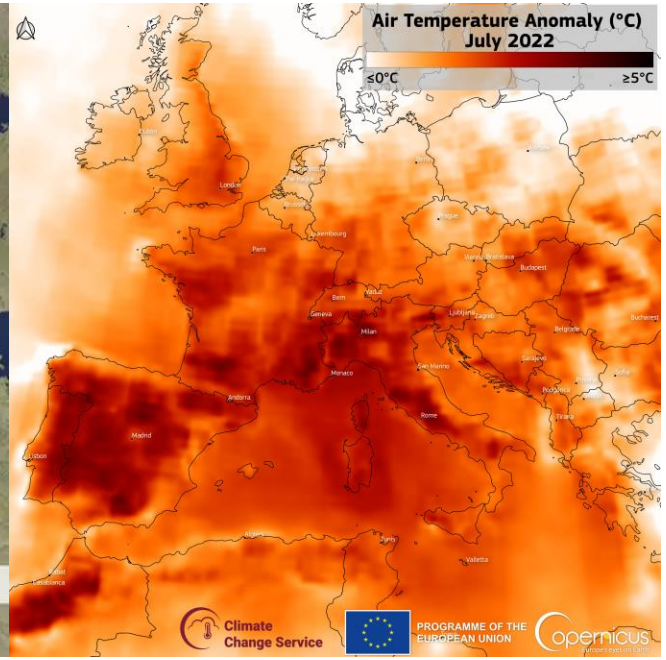
xtraordinary futures await

19th July 2022

- UK exceeds 40 °C for the first time
- Parts of mainland Europe top 47 °C



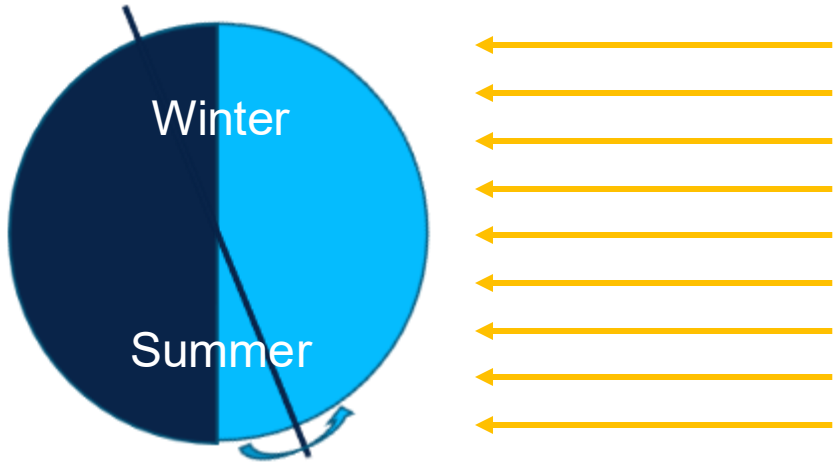
BBC weather presenters make the link to climate change – and receive unprecedented online abuse…

Climate change and weather-related “natural” hazards

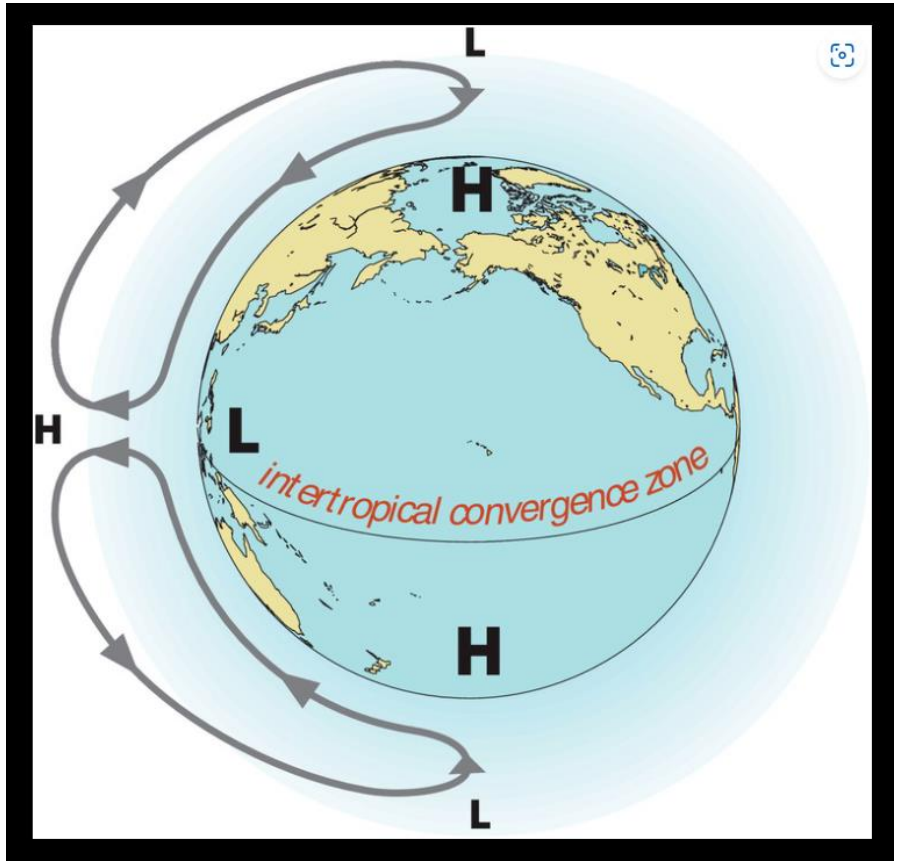
- Natural hazards such as heatwaves and floods arise because the Earth’s climate naturally varies
- Common questions when an event occurs are:
  - Did climate change cause it?
  - Did climate change make it worse?
- As human-induced climate change accelerates, hazard likelihoods are rapidly changing, with major implications for society
- Understanding the fundamental science behind climate variability and change is crucial for understanding how such hazards are evolving
- This lecture introduces the topic

Weather

- Energy from the Sun drives weather on the Earth
- More energy arrives at Equator than Poles
  - Solar radiation arrives directly at Equator, on a slant at poles
  - This generates an Equator-Pole temperature gradient
  - Heat flows from hot towards cold
  - This transfer of energy from Equator to Pole generates weather
  - In addition:
    - Rotation drives a diurnal cycle
    - Tilt of rotation axis drives seasonal cycle



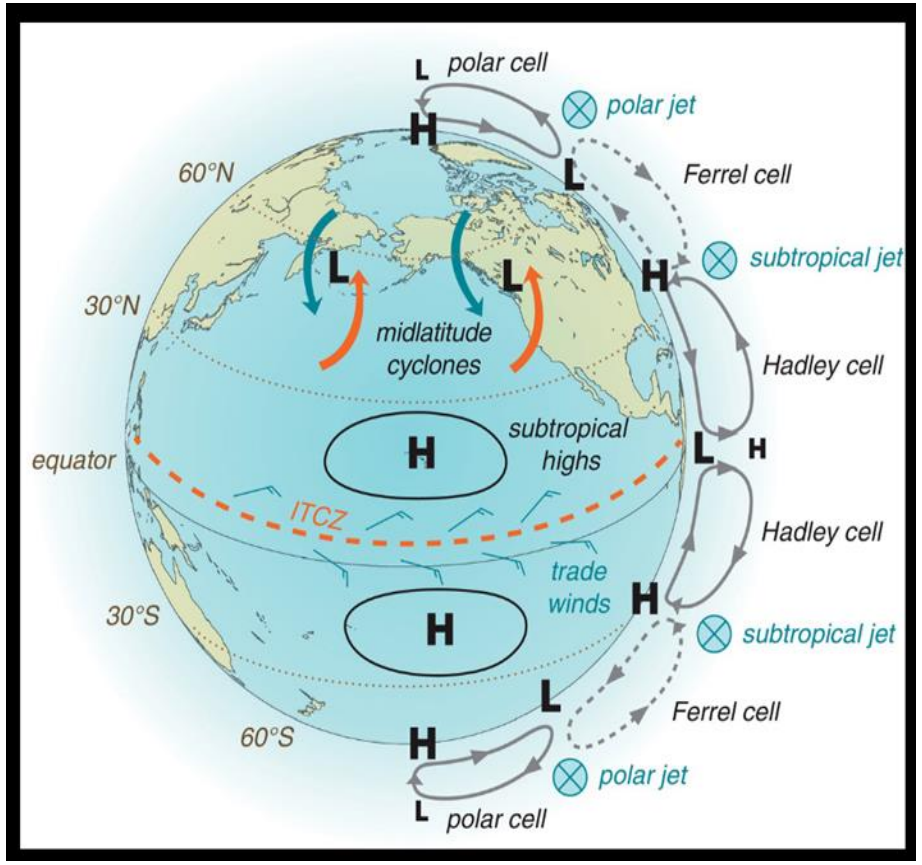
Single cell model



Hakim & Patoux (2021) Weather: A concise introduction (2nd edition), Section 9.2

- Convection cell
- Hot air (less dense) rises at Equator, moves towards poles at high altitude, then cools and sinks at the Pole
- Circulation completed by cold air moving towards Equator near surface
  - This is partly correct, but is too simplified
  - This configuration of the global circulation is unstable
- Earth's rotation means we need to include the Coriolis Force

Three-cell model



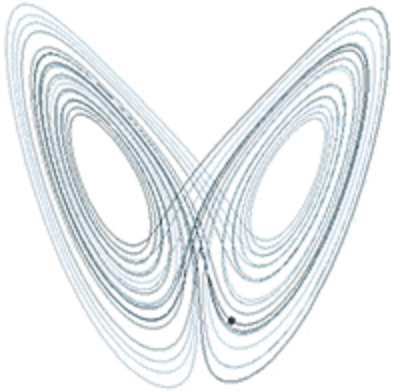
Hakim & Patoux (2021) Weather: A concise introduction (2nd edition), Section 9.3

- The Coriolis force deflects flows to the right in the Northern Hemisphere (and to the left in the SH)
- This disrupts the single cell model, and leads to something more like the three cell (in each hemisphere) model
- Hadley cell in the tropics and Polar cell at high latitudes have same sense of circulation as single cell model
- 'Ferrel cell' in mid-latitudes in opposite sense
- Westerly (flow from West to East) jet streams (at ~10 km altitude) between cells
- Easterly surface winds in the tropics
- This configuration is more stable, but is not completely stable, and produces weather variability

Chaos Theory and the Lorenz attractor

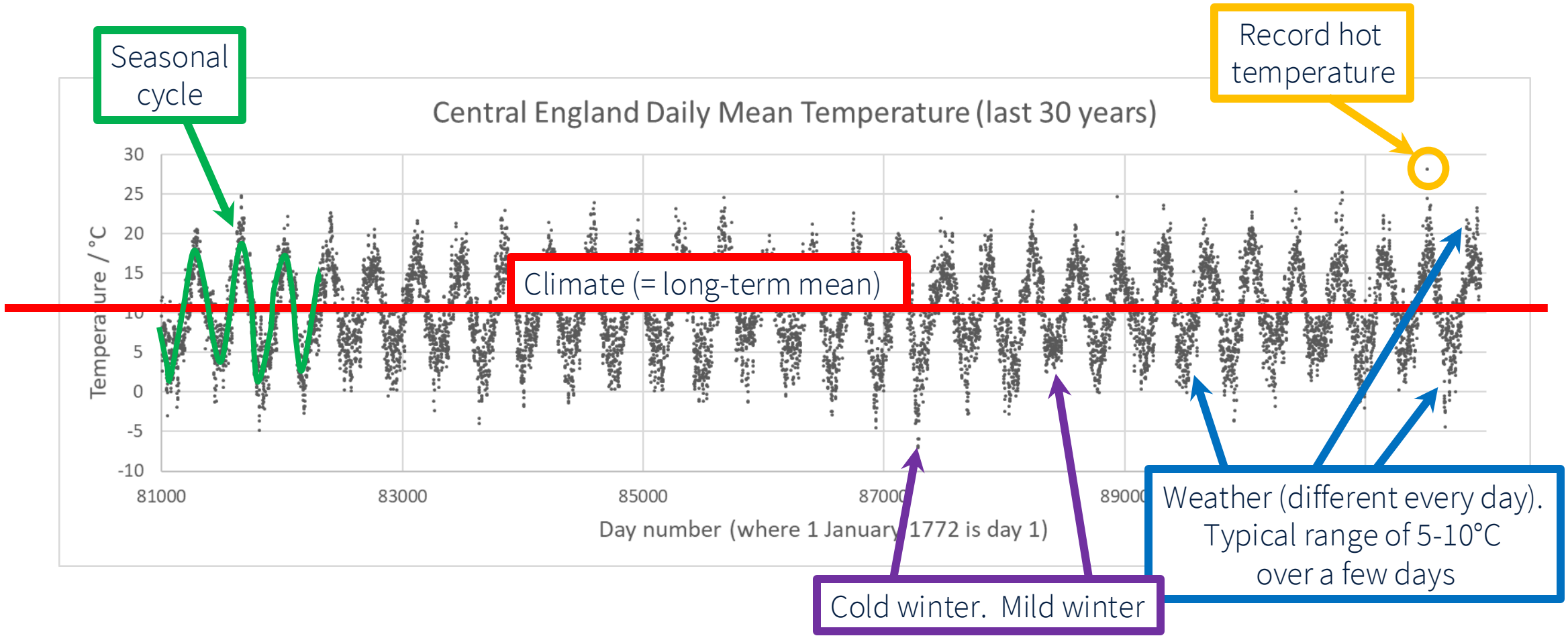
Edward Norton Lorenz

Introduction to chaos, predictability and ensemble forecasts



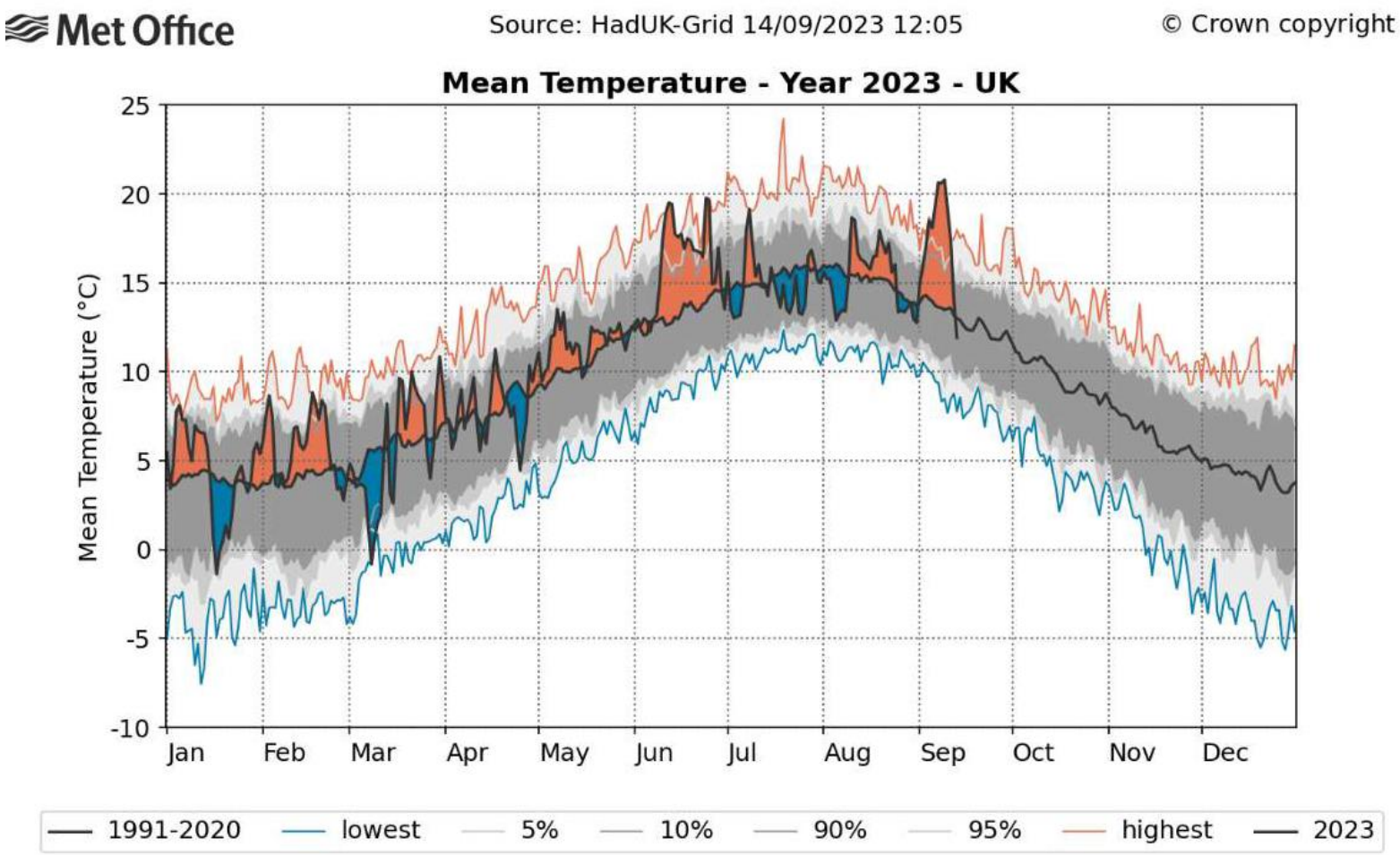
- We can write down a set of physical equations that describe the weather (I'm not going to do this here!)
- These are non-linear and have sensitive dependence on the initial conditions
- They behave chaotically – the Lorenz attractor is one graphical example of this sort of system (discovered by Ed Lorenz in 1961)
- This is a physical explanation for the variability of the weather (it is random but constrained within limits)

30 years of daily data: weather vs climate

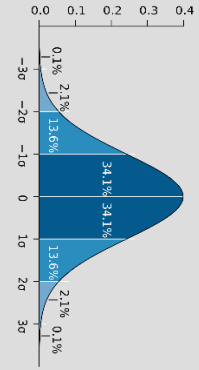


UK: September 2023 heatwave

Met Office, Heatwave September 2023 Report

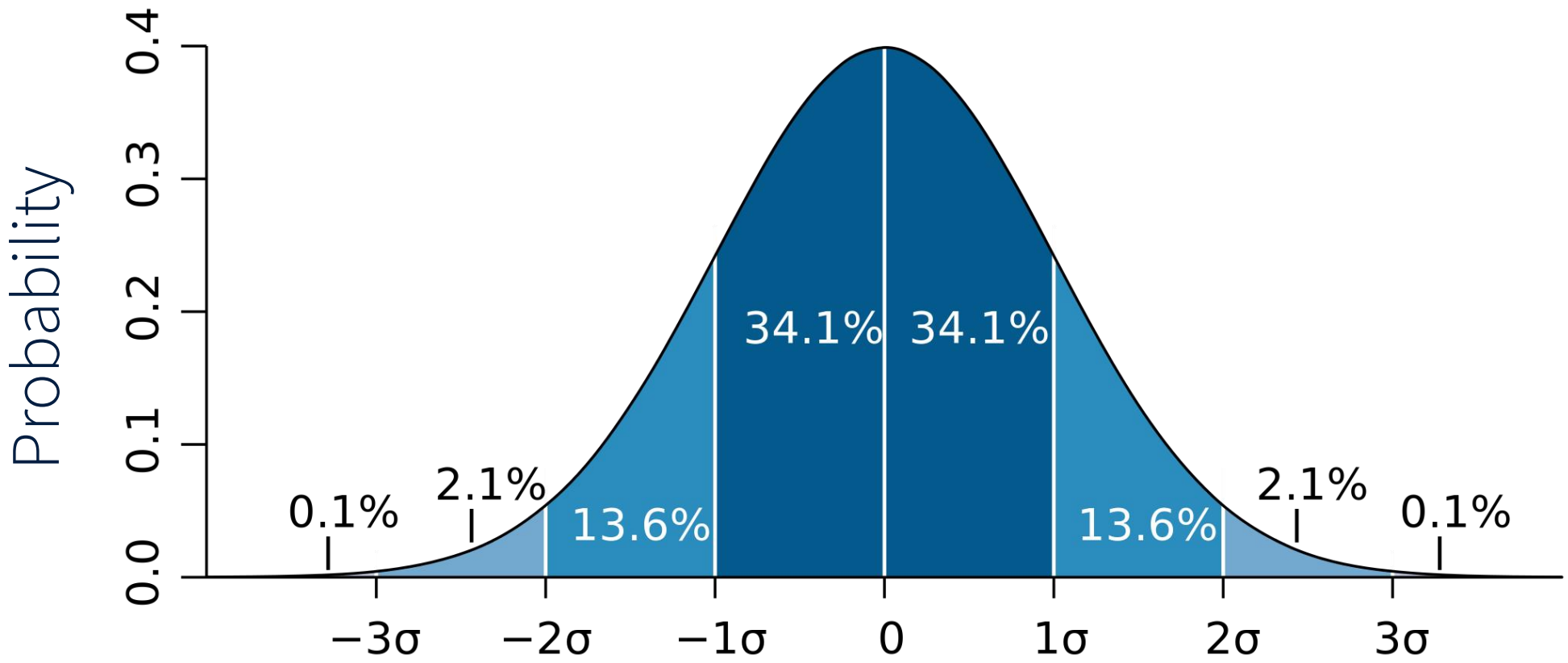


Can describe the distribution of values with a mean and standard deviation:



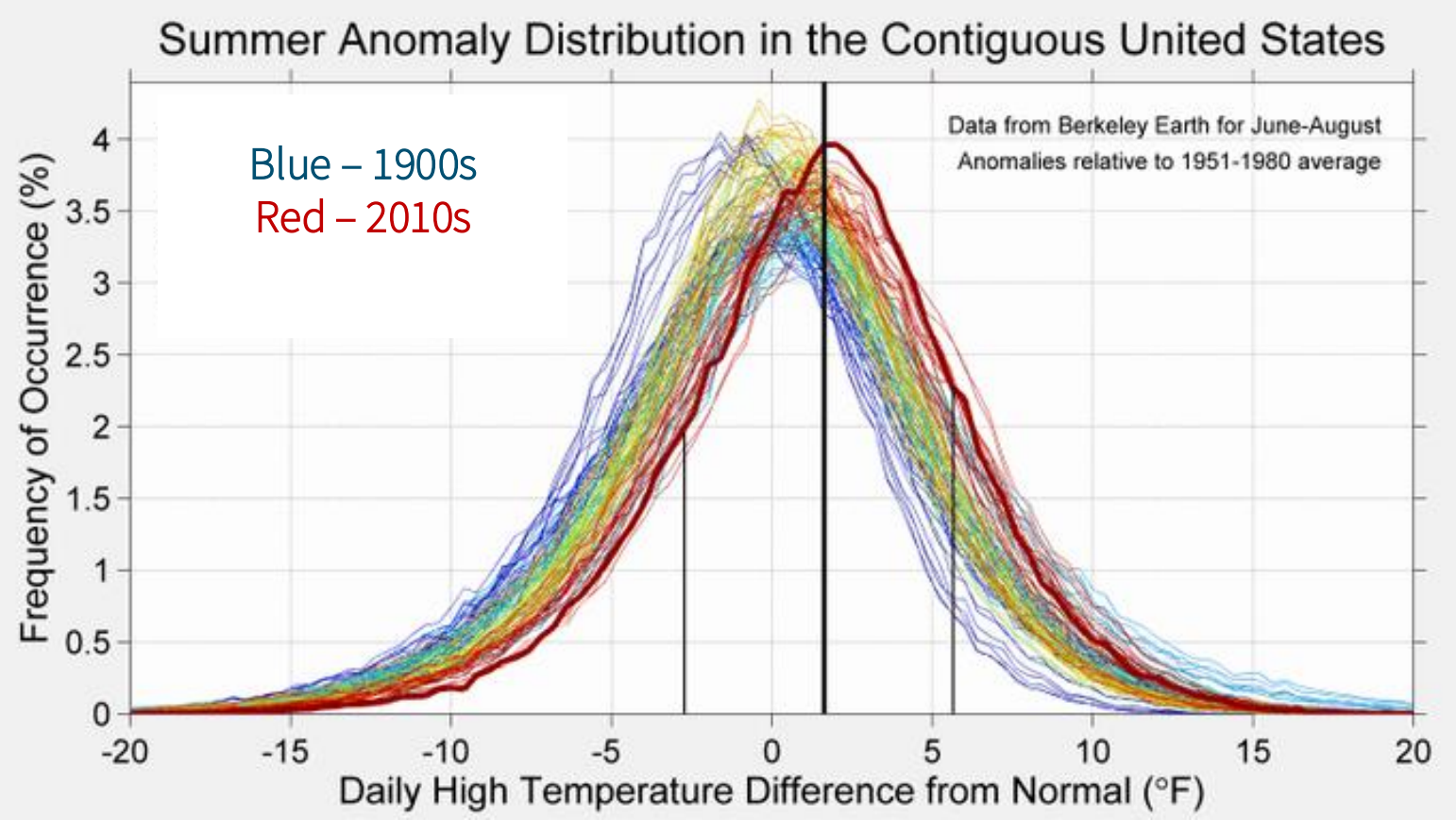
Probability density function (PDF) - mean and standard deviation (σ)

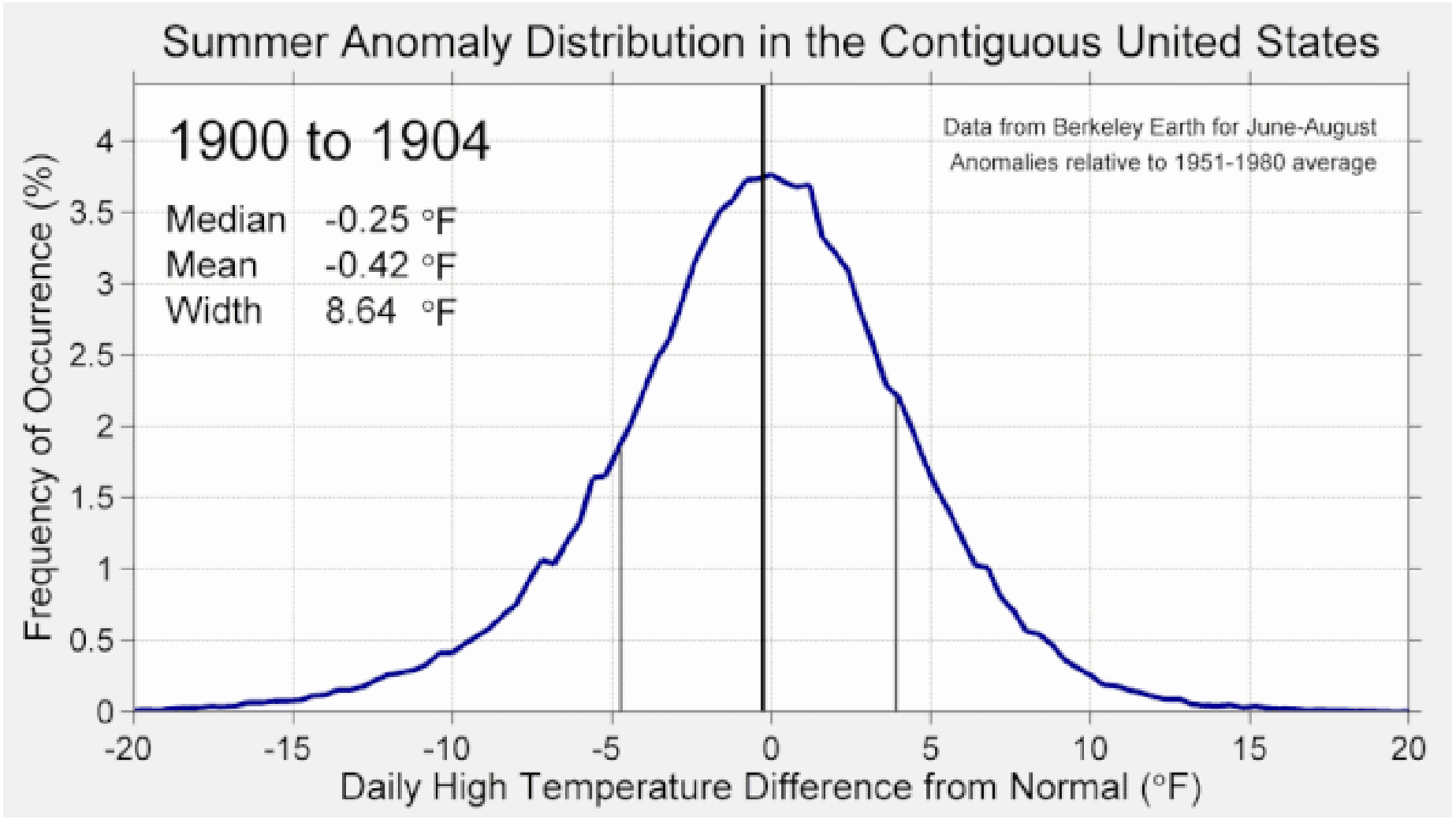
Standard Deviation



Summer US surface temperature PDFs (5 year periods since 1900)

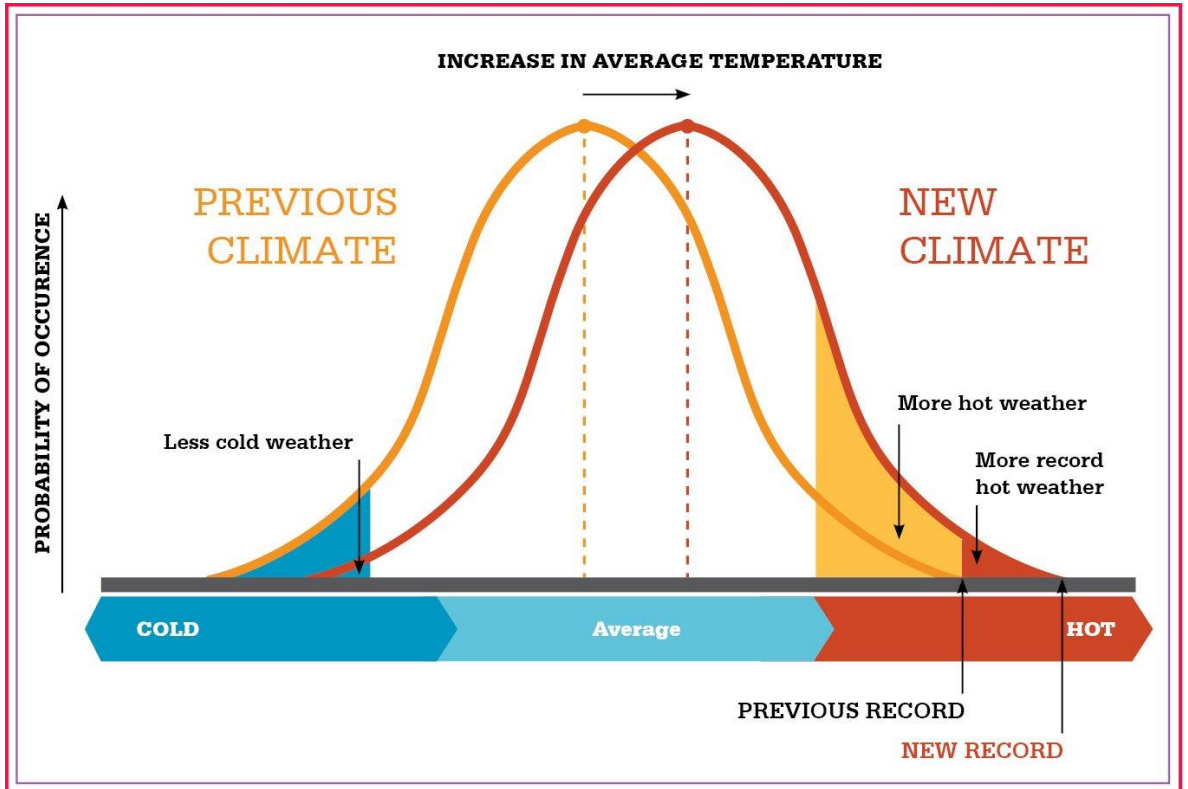
PDF = Probability Density Function





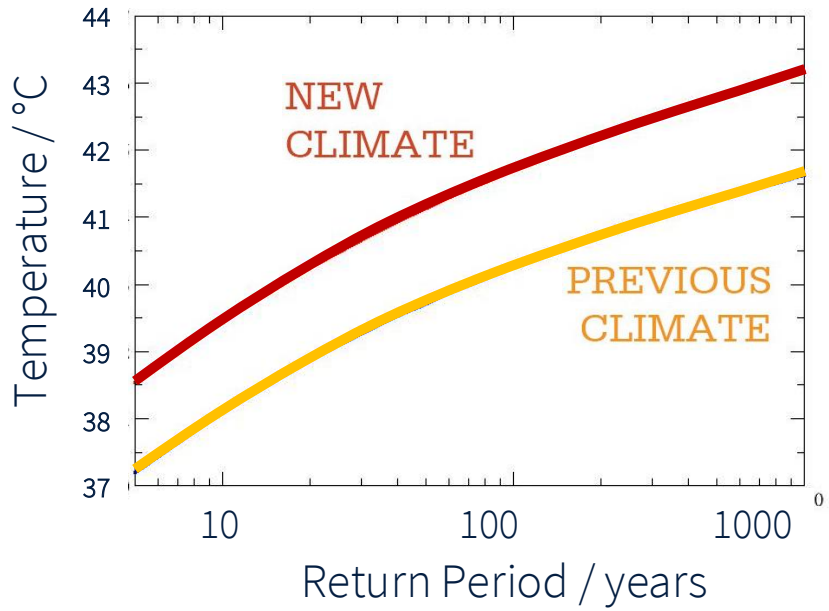
Summer Temperature Anomaly Distribution

Schematic version of last slide



Source: Modified from IPCC, 2007

If you know the probability distribution, you can also express this in terms of a 'return period', e.g.:



We will look at this in the practical on UK heatwaves.

Summary

- Weather varies
  - In obvious ways – seasonal and diurnal cycles
  - But also in less obvious ways – day-to-day and year-to-year
  - Why does weather vary as it does?
  - Weather is chaotic
    - Weather on same date each year is a bit different
    - The range of this variability is important for extremes and resulting natural hazards
- Climate is the long-term (30 year) average of the weather
  - Under 'normal' conditions, climate doesn't change
  - Mean and standard deviation – probability distribution function (PDF)
  - Climate extremes generate hazards – even for an unchanging climate
- But we don't live in normal times… climate is changing (fast)
  - This is changing PDFs, and hence hazard frequencies/magnitudes
  - This is fundamentally different to seismic and volcanic hazards
  - Exposure also increasing as global population rises – this is same for other hazards

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More on attributing the climate change impacts to specific global extreme weather events:

Any questions on this topic or about studying GeoSciences at Edinburgh?

Contact me

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