

What Drives a Warming Climate? Exploring the Physical Mechanisms Behind Regional Climate Change

EART60702 Earth and Environmental Data Science

Group 4

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Study Area & Research Question

The coordinate of study area is **53.246° N, 2.5° W**, which are located in **Cheshire**, UK, in northwest England , near Manchester and Liverpool..

The region has a typical **temperate maritime climate**. The climate is mild and humid year-round (Minobe, Kuwano-Yoshida et al. 2008, Palter 2015).

However, the frequency of extreme weathers events are increasing in europe (Weilnhammer, Schmid et al. 2021)



**How does the weather change with time,
and their potential controlling factors?**

Trend Analysis—Temperature Trend & Seasonal Distribution

Temperature Trend Line Plot

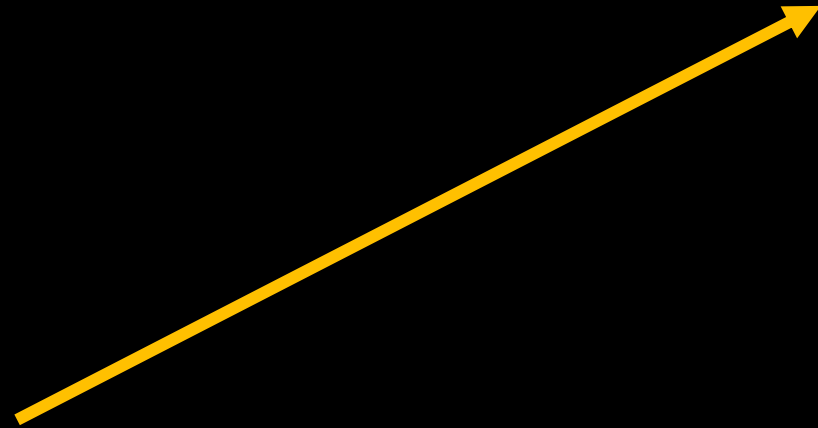
Key findings:

The data shows a significant upward trend in linear regression.

- Mean annual temperature: 10–13.5°C
- Strong upward trend ($R \approx 0.92$)
- Approx. 0.4°C per decade

Physical significance:

- The region is experiencing long-term climate warming
- Showing the potential influence of greenhouse effect (Manabe 2019).



Clear regional warming signal

Trend Analysis—Temperature Trend & Seasonal Distribution

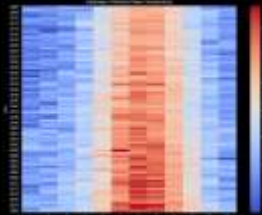
Heatmap of Monthly Mean Temperature

Key findings:

- In the mid-to-late 21st century, “deep red spots” (extreme high temperatures) frequently appear in summer.
- The frequency and intensity increase over time

Physical significance:

- Non-uniform global warming
- Regional seasonal climate structures may potentially being reshaped (Qin, Xie et al. 2024).

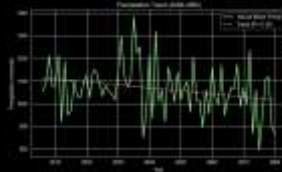


Trend Analysis—Precipitation Trend & Seasonal Distribution

Precipitation Trend Line Plot

Key findings: The line shows sharp, jagged oscillations, lacking a smooth, monotonous trend.

Physical significance: This illustrates that precipitation systems exhibit extremely high interannual variability and inherent uncertainty.

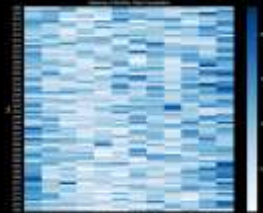


Trend Analysis—Precipitation Trend & Seasonal Distribution

Heatmap of Monthly Total Precipitation

Key findings: Clearly outlines the local precipitation pattern of "more rain in autumn and winter, and relatively less rain in spring and summer".

Physical significance: As shown in the temperature thermogram, the combination of "extreme high temperatures in summer" and "relatively low precipitation" will significantly increase the risk of seasonal drought in the region.

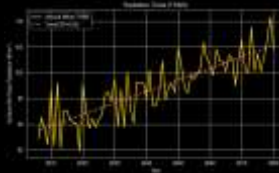


Trend Analysis—Surface Net Shortwave Radiation Trend (FSNS)

Radiation Trend Line Plot

Key findings: Tracked the changing trajectory of solar energy as it penetrates the atmosphere to reach the Earth's surface.

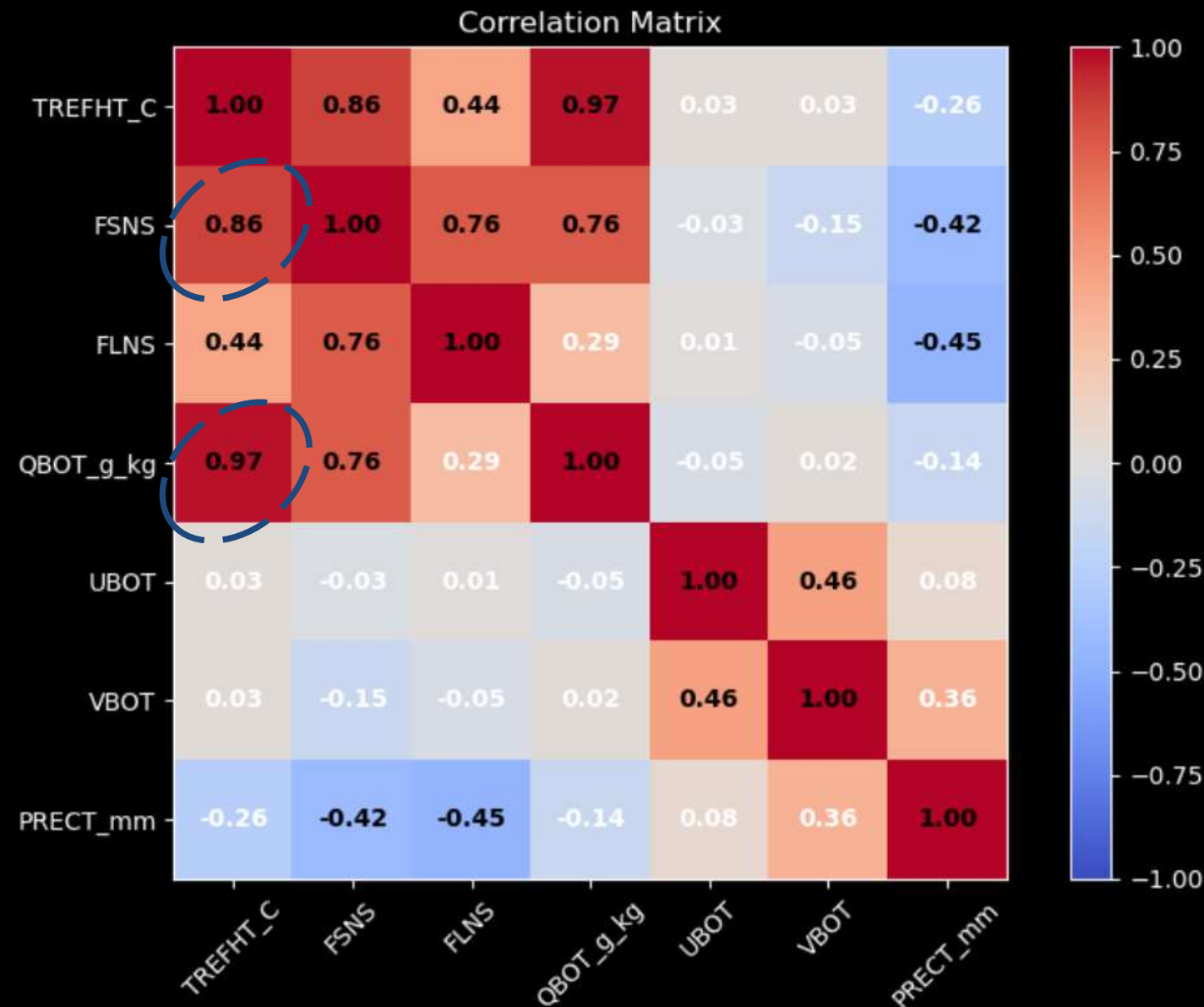
Physical significance: Fluctuations in radiation are directly affected by local cloud cover and atmospheric transparency, serving as the direct "fuel" and energy source driving abnormal fluctuations in surface temperature.



Correlation Analysis—Correlation Matrix

Correlation Matrix

Key findings: Surface temperature (TREFHT) shows a strong positive correlation with shortwave radiation (FSNS) and bottom specific moisture (QBOT) (deep red block).

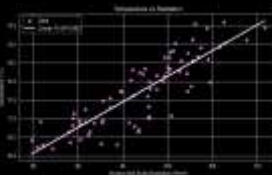


Relationship Analysis—Temperature–Radiation Relationship

Scatter Regression Plot of Temperature vs. Radiation

Key findings: Net shortwave radiation reaching the Earth's surface shows a clear positive linear fit with surface temperature.

Less cloud → More sunshine →
Ground warms up



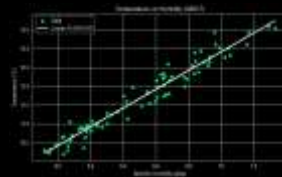
The chart reveals the first physical driver of global warming: radiative forcing.

Relationship Analysis—Temperature–QBOT Relationship

Scatter Regression Plot of Temperature vs. Specific Humidity (QBOT)

Key finding: The actual water content (specific humidity) of the atmosphere shows a very close, synchronous increase with rising temperature.

Warming → **increased water vapor**
→ **stronger warming.**



Conclusions and Key Findings

A

**Evolution of the phenomenon:
Warming and hydrological
extremes**

Summer mean temperatures show a significant upward trend, while precipitation does not exhibit a statistically significant long-term change but displays notable interannual variability.

B

Core Driver: Radiative Forcing

Enhanced net downward shortwave surface flux, largely controlled by atmospheric (cloud) variations, contributes to regional anomalous warming.(Loeb, Wang et al. 2019).

C

**Mechanism Scale-Up:
Thermodynamic Feedback**

This illustrates the Clausius-Clapeyron effect: rising temperatures force the atmosphere to absorb more water vapor, which in turn locks in more heat (Pall, Allen et al. 2007, O’Gorman and Muller 2010).

D

**Final Conclusion: The New
Normal of Climate Change**

Driven by rigorous thermodynamics, the region is irreversibly moving toward a high-energy climate state characterized by warmer, wetter, and more extreme fluctuations.

Reference

1. Loeb, N. G., et al. (2019). "Decomposing shortwave top-of-atmosphere and surface radiative flux variations in terms of surface and atmospheric contributions." Journal of Climate **32**(16): 5003-5019.
2. Manabe, S. (2019). "Role of greenhouse gas in climate change." *Tellus A: Dynamic Meteorology and Oceanography* 71(1): 1620078.
3. Minobe, S., et al. (2008). "Influence of the Gulf Stream on the troposphere." Nature **452**(7184): 206-209.
4. O'Gorman, P. A. and C. J. Muller (2010). "How closely do changes in surface and column water vapor follow Clausius–Clapeyron scaling in climate change simulations?" Environmental Research Letters **5**(2): 025207.
5. Pall, P., et al. (2007). "Testing the Clausius–Clapeyron constraint on changes in extreme precipitation under CO₂ warming." Climate Dynamics **28**(4): 351-363.
6. Palter, J. B. (2015). "The role of the Gulf Stream in European climate." Annual review of marine science **7**(1): 113-137.
7. Qin, P., et al. (2024). "Characteristics of population exposure to climate extremes from regional to global 1.5° C and 2.0° C warming in CMIP6 models." *Environmental Research Letters* 19(1): 014018.
8. Weilhhammer, V., et al. (2021). "Extreme weather events in europe and their health consequences—A systematic review." *International Journal of Hygiene and Environmental Health* 233: 113688.

Team Task Distribution Table

Group members	Student ID	Main responsibilities
Ruiqi Huang	14180111	Drawing annual trend charts and scatter plots, integrating code, writing README, and creating PPT presentations.
Kedi Li	14200199	Creating monthly average trend charts (Heatmap) and creating a PowerPoint presentation.
Yuhui Duan	14219275	Drawing a correlation matrix and creating a PowerPoint presentation.