

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

**EART60702 Earth and Environmental Data Science**

**Group 4**

**Members: Ruiqi Huang, Kedi Li, Yuhui Duan**

# 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

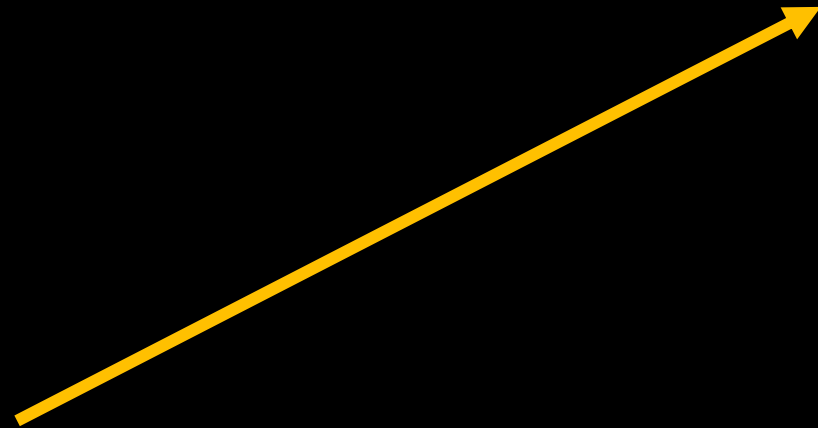
### Key findings:

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

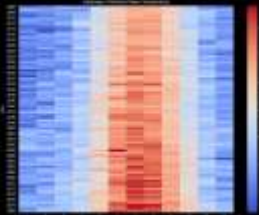
## Heatmap of Monthly Mean Temperature

### 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

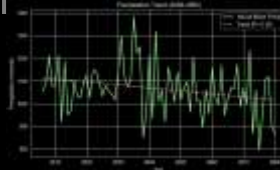
## Precipitation Trend Line Plot

### Key findings:

The line shows sharp, jagged **fluctuations**, 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

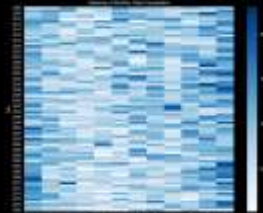
## Heatmap of Monthly Total Precipitation

### 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 heatmap, 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)

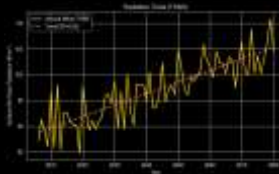
## Radiation Trend Line Plot

### 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.

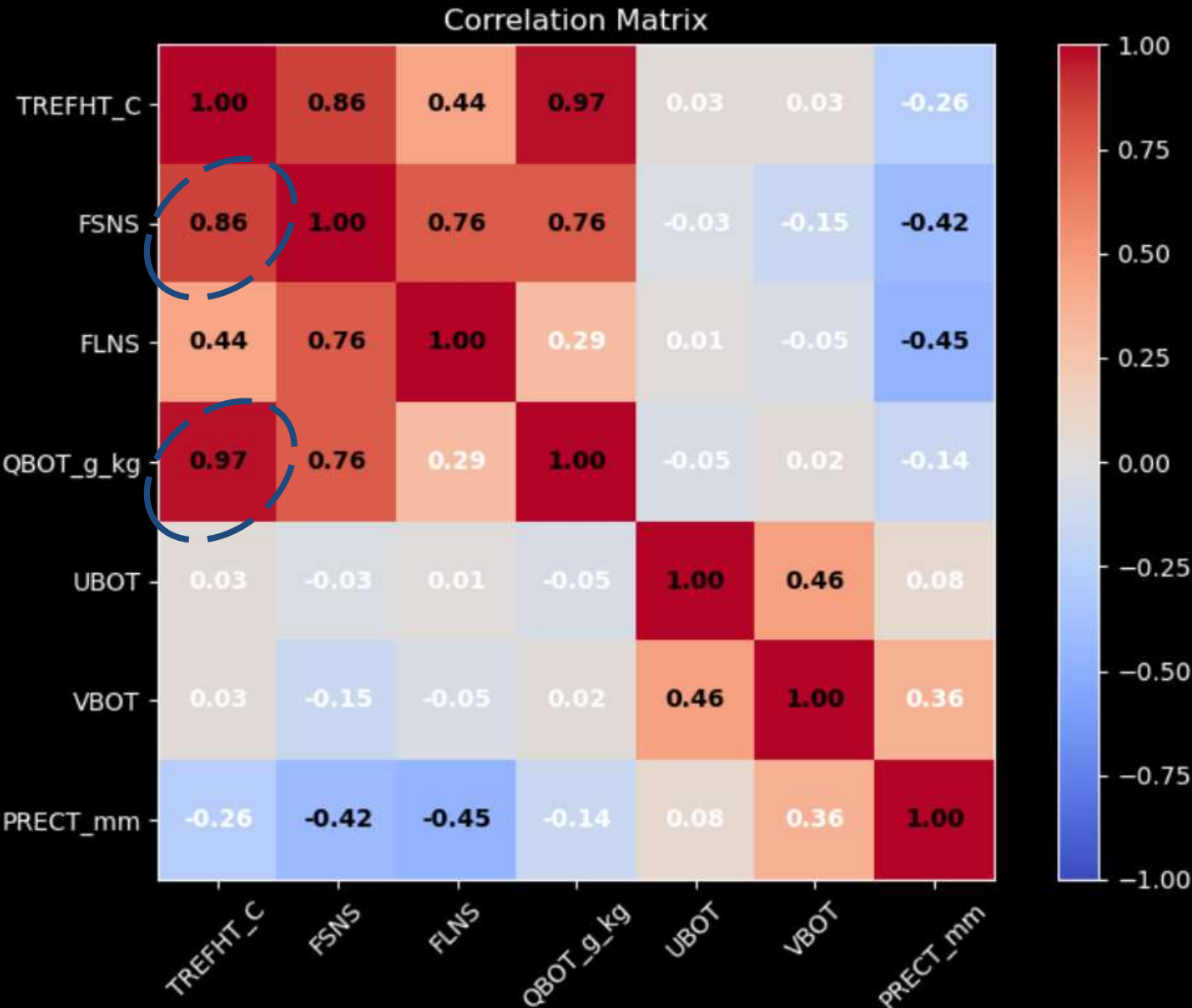


# Correlation Analysis—Correlation Matrix

Correlation Matrix

**Key findings:**

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



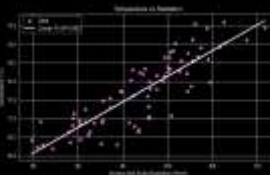
# Relationship Analysis—Temperature–Radiation Relationship

## 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.

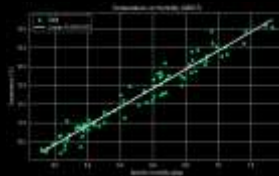
# Relationship Analysis—Temperature–QBOT Relationship

## 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

|   |  |
|---|--|
| <b>A</b><br><b>Evolution of the phenomenon:<br/>Warming and hydrological<br/>extremes</b> | 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>B</b><br><b>Core Driver: Radiative Forcing</b>   | Enhanced net downward shortwave surface flux, largely controlled by atmospheric (cloud) variations, contributes to regional anomalous warming.(Loeb, Wang et al. 2019).  |
| <b>C</b><br><b>Mechanism Scale-Up:<br/>Thermodynamic Feedback</b>                         | This illustrates the <b>Clausius-Clapeyron effect</b> : 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). |
| <b>D</b><br><b>Final Conclusion: The New<br/>Normal of Climate Change</b>                 | Driven by rigorous thermodynamics, the region is irreversibly moving toward a high-energy climate state characterized by warmer, wetter, and more extreme fluctuations.  |

# References

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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.
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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.   |