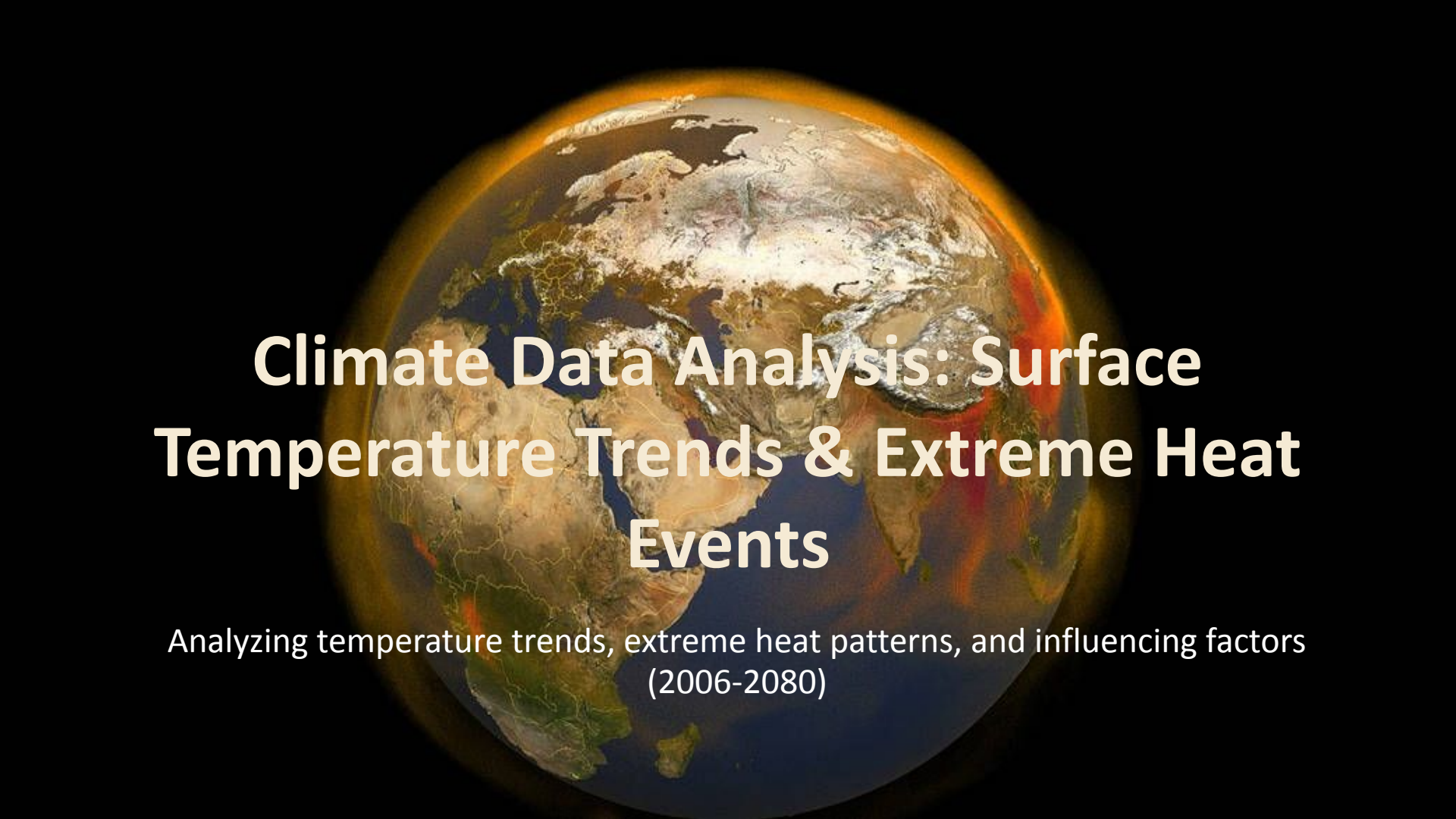
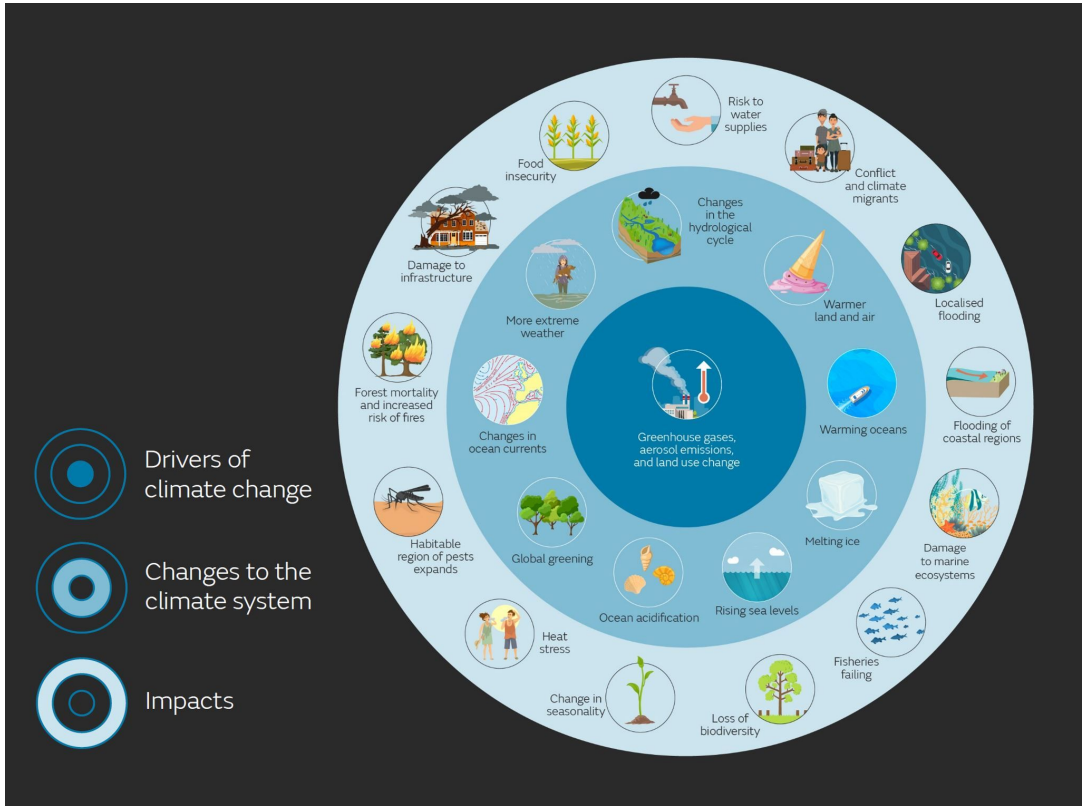


Climate Data Analysis: Surface Temperature Trends & Extreme Heat Events

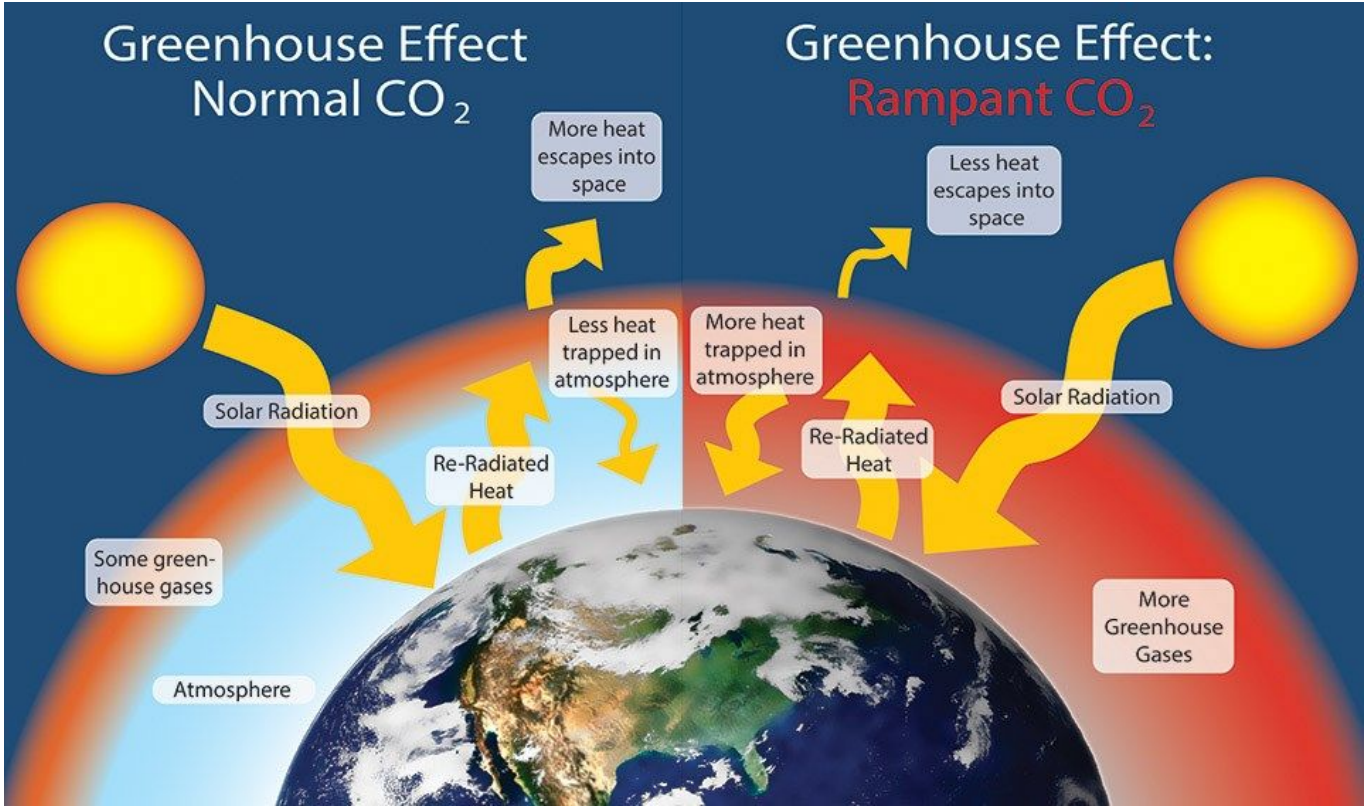
Analyzing temperature trends, extreme heat patterns, and influencing factors (2006-2080)

Background

- Rising earth temperature is a major global challenge affecting weather, ecosystems, human health, and economy
- Projection by IPCC = 4.8C increase in global temperature
- Threshold = 1.5C
- Understanding temperature trends, identifying extreme heat days, and assessing factors influencing surface temperature variations are crucial for climate mitigation and adaptation strategies



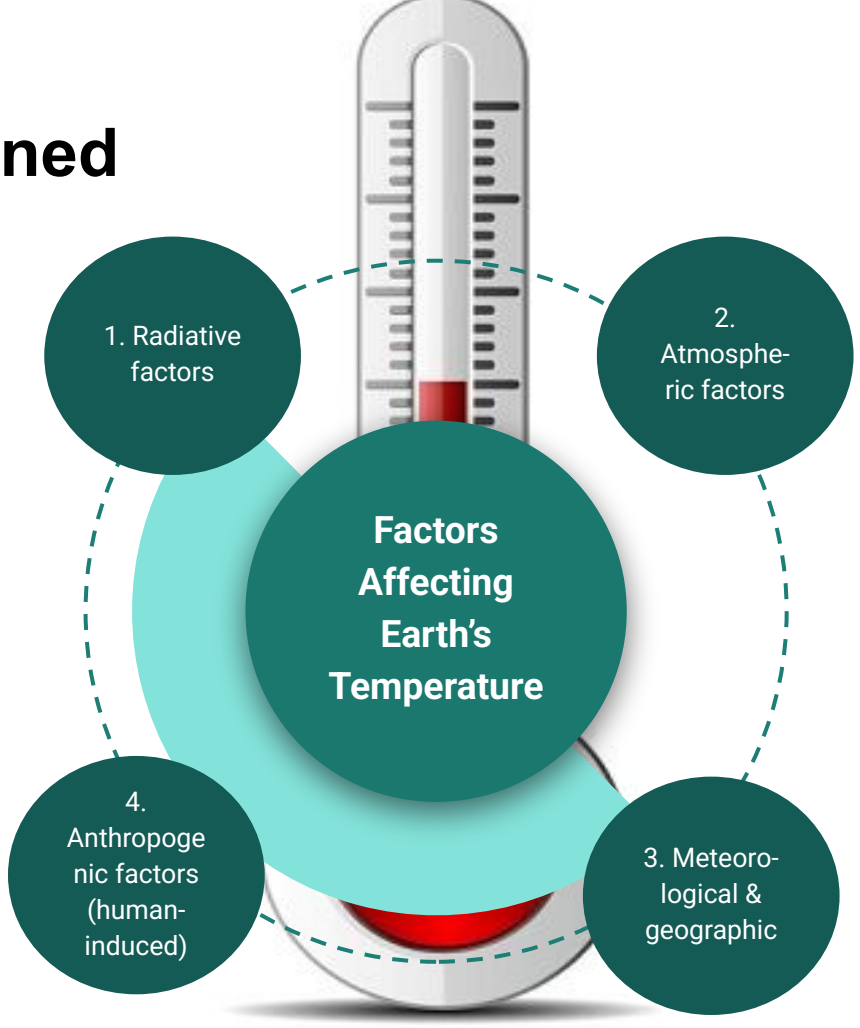
The Earths is Warming



Is this true?

Theory Explained

- Solar radiation
- Longwave radiation
- Albedo effects



- Cloud
- Humidity
- GHG (CO_2, CH_4, H_2O)

- Fossil fuel combustion
- Deforestation
- Urban heat

- Wind patterns
- Precipitation
- Geographical features (ocean, land, altitude, etc.)

About the Data: *Climate Data from year 2006 - 2080*

	A	B	C	D	E	F	G	H	I	J	K	L
1	time	TREFMXAV_U	FLNS	FSNS	PRECT	PRSN	QBOT	TREFHT	UBOT	VBOT	lat	lon
2	2006-01-02 00:00:00	282.77585	41.92518	25.926952	4.6631348e-09	4.781004e-17	0.004768578	279.14288	3.8785791	1.3941841	53.246075	357.5
3	2006-01-03 00:00:00	284.47113	8.905806	10.94691	8.046593e-08	1.2957259e-16	0.0062706326	281.14865	1.7881572	3.8217027	53.246075	357.5
4	2006-01-04 00:00:00	284.28796	16.511415	6.405902	2.9109355e-09	4.0944472e-16	0.0057817996	281.2238	0.8048447	-2.2991402	53.246075	357.5
5	2006-01-05 00:00:00	282.1211	29.948362	9.315041	7.432505e-11	0.0	0.0042769867	278.39767	-1.1002674	-1.2580292	53.246075	357.5

Only 1 location – an area near Manchester

Number of entries : 27,374

Period : 2 Jan 2006 - 31 Dec 2080

Source: **Community Earth System Model**

TREFMXAV_U (K)： Urban daily maximum of average 2-m temperature

FLNS (W/m2): Net longwave flux at surface

FSNS (W/m2): Net solar flux at surface

PRECT (m/s): Total (convective and large-scale) precipitation rate (liq + ice)

PRSN (kg/m²/s): the snow-only precipitation rate at the surface, excluding rain and other hydrometeors

QBOT (kg/kg): Lowest model level water vapor mixing ratio

TREFHT (K): Reference height temperature

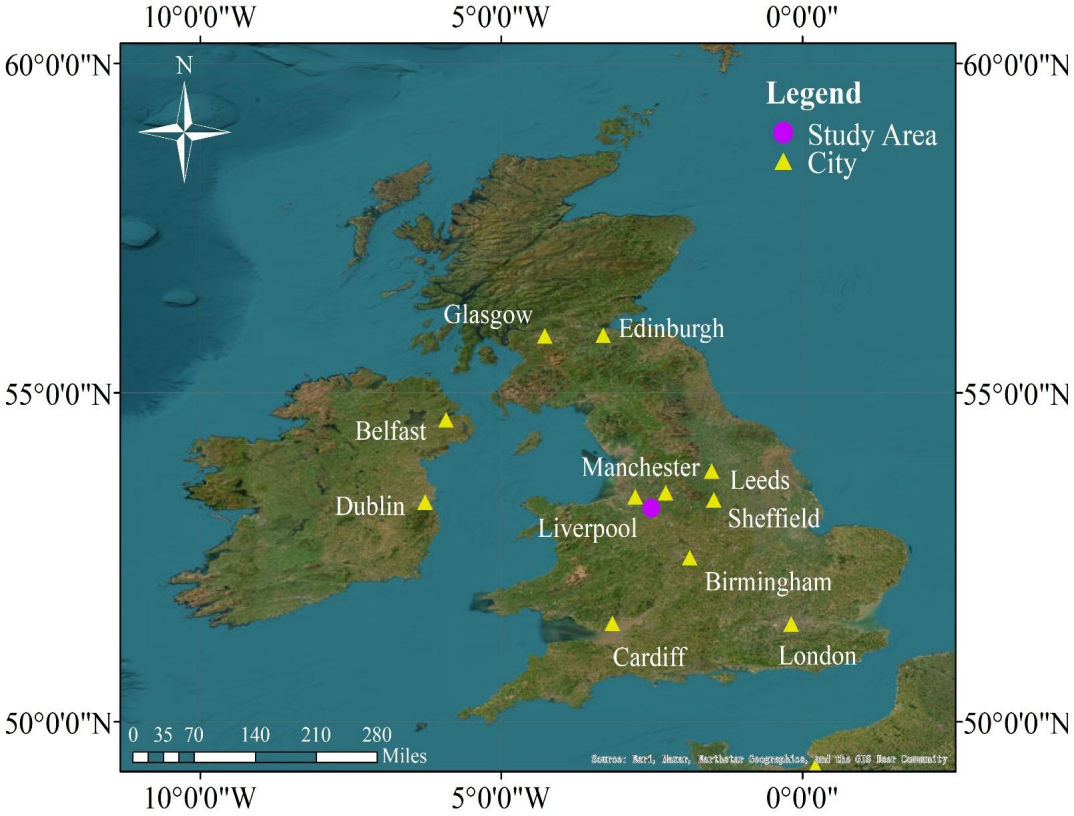
UBOT (m/s): Lowest model level zonal wind. Positive value: Wind blows eastward (westerly wind); Negative value : Wind blows westward (easterly wind)

VBOT (m/s): Lowest model level meridional wind. Positive value: Wind blows northward (southerly wind); Negative value : Wind blows southward (northerly wind)

lat: latitude

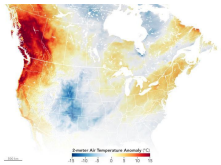
lon: longitude

About the Data: *Climate Data from year 2006 - 2080*



- Temperate oceanic climate
- The climate is mild and humid (~80%)
- Small temperature variations, with annual avg ~284K
- Evenly distributed precipitation with annual avg ~800mm
- Westerly winds are common (influence from irish sea and atlantic ocean)

Project Scope



Does the earth experience extreme heat?

Identify extreme heat days (305K - moderate heat risk, 308K - extreme heat risk)

Does the overall trend of earth's temperature increases?

Investigate Earth's surface temperature trends (TREFHT, TREFMXAV_U)

What are the key factors affecting earth's temperature?

Analyze factors affecting temperature across seasons and between extreme vs. normal days

Methodology

Initial Data Analysis

- Summary statistics
- EDA and visualization

Data Preprocessing

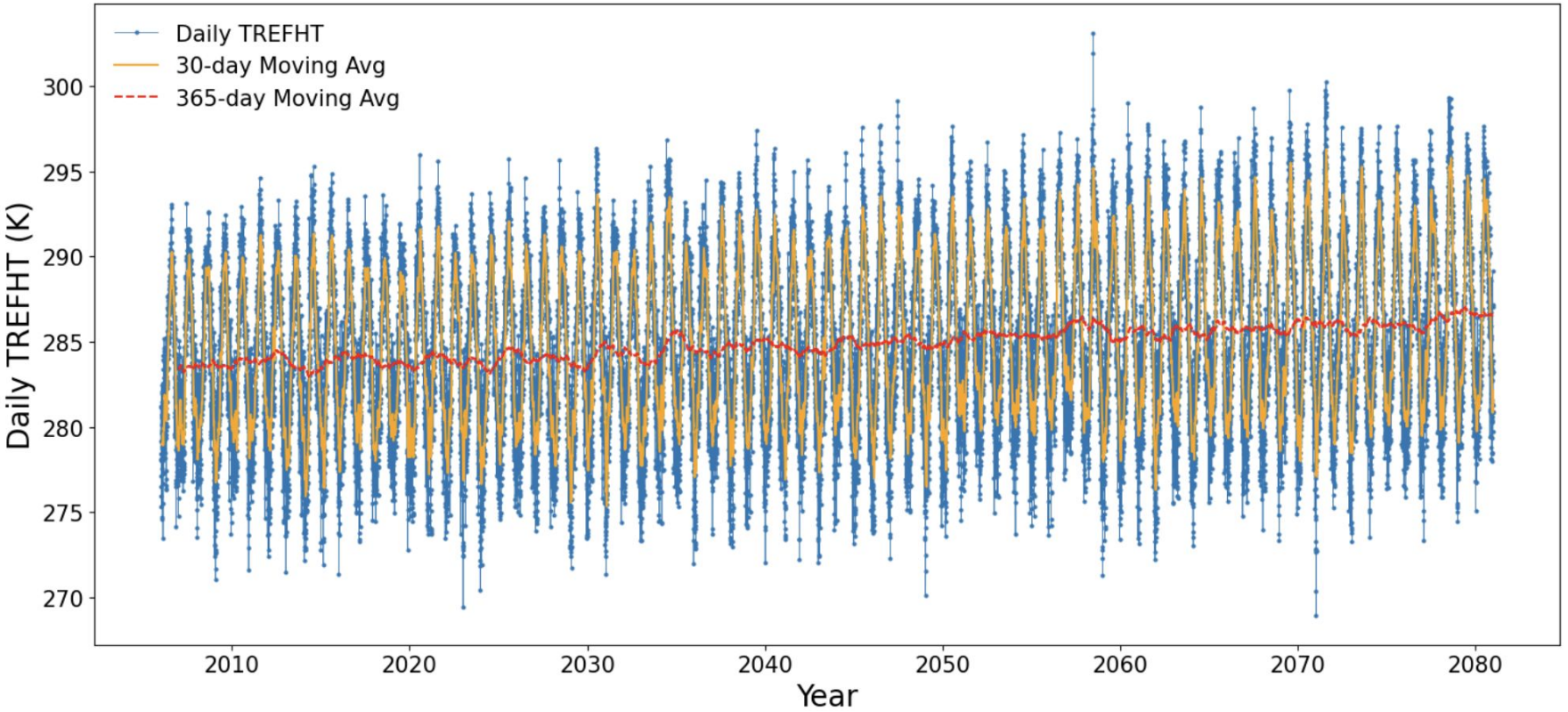
- Correct datatype (time from object → datetime)
- Missing values
- Duplicates
- Feature engineering (extract year, month from time, extreme heat threshold)
- Incorrect data (PRECT, PRSN, FSNS can't be <0)
- Standardisation (minmax)

Analysis

- Further EDA to capture trends & patterns
- Pearson corr.
- Spearman corr.
- Factor influence analysis
- Seasonal variation in influencing factors
    - 4 seasons
    - Extreme vs normal days

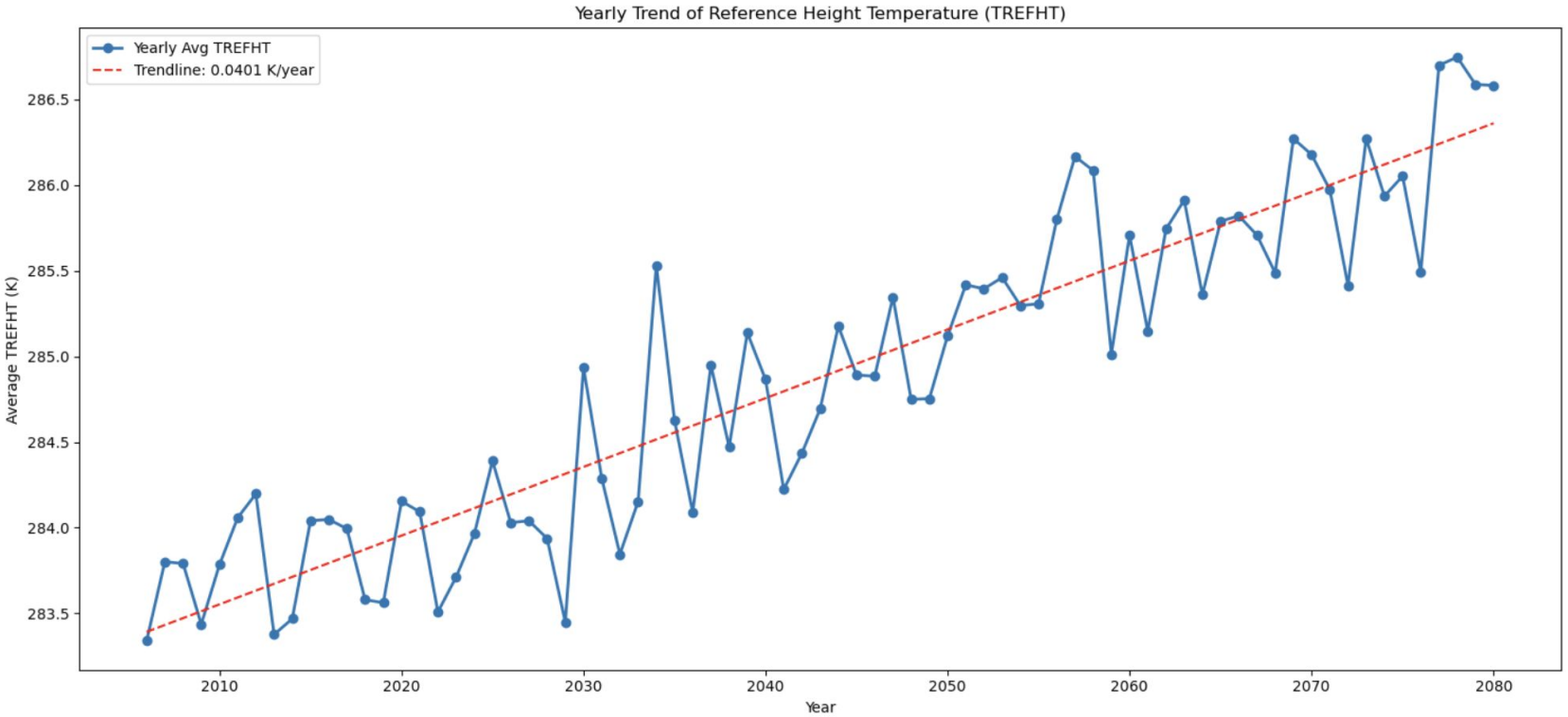
Scope 1

Result Analysis: Trend of Avg Daily Temperature



Scope 1

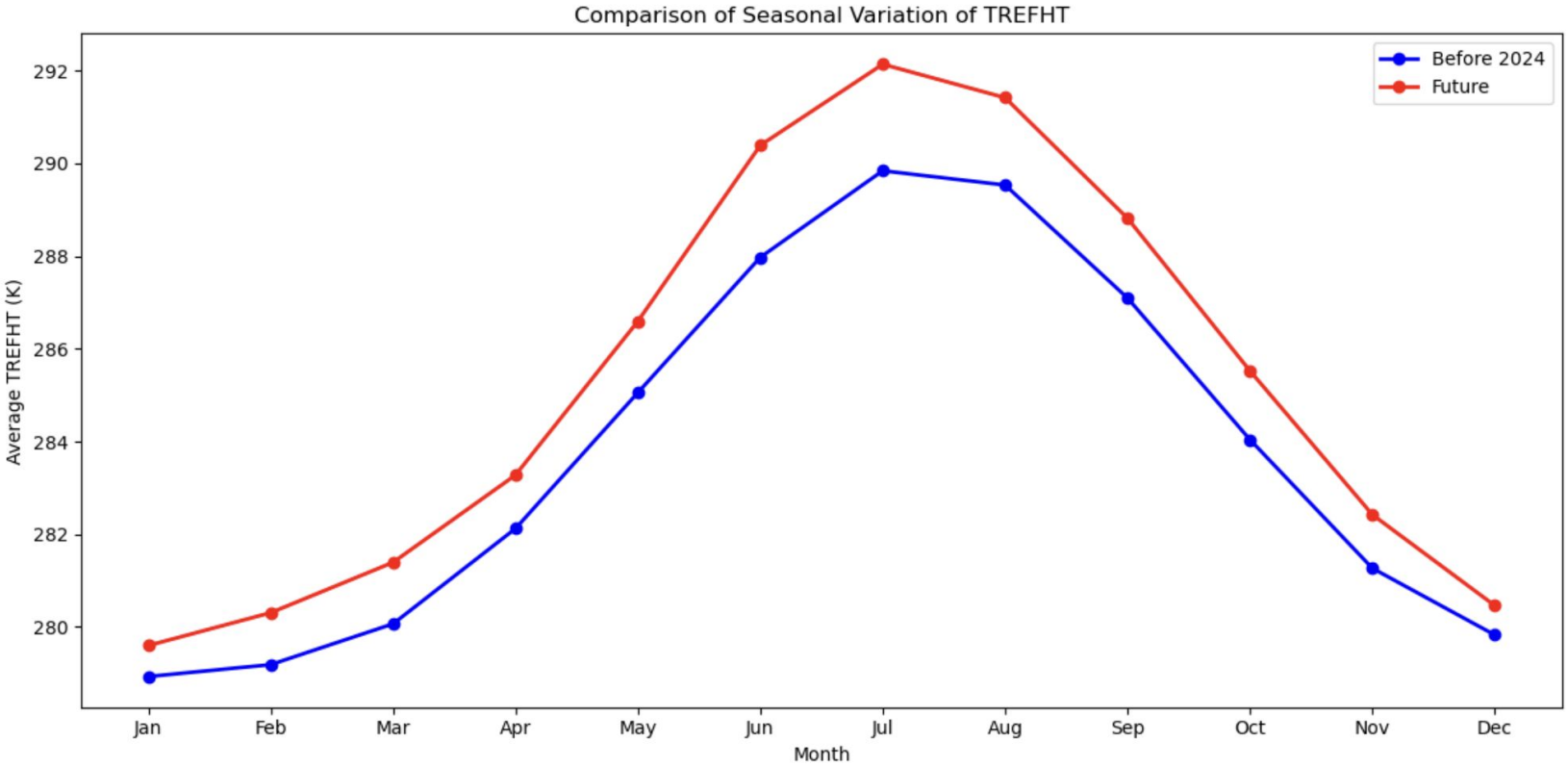
Result Analysis: Avg Daily Temperature is Increasing YoY



Estimated Temperature Change Rate for Daily TREFHT: 0.0401 K/year

Scope 1

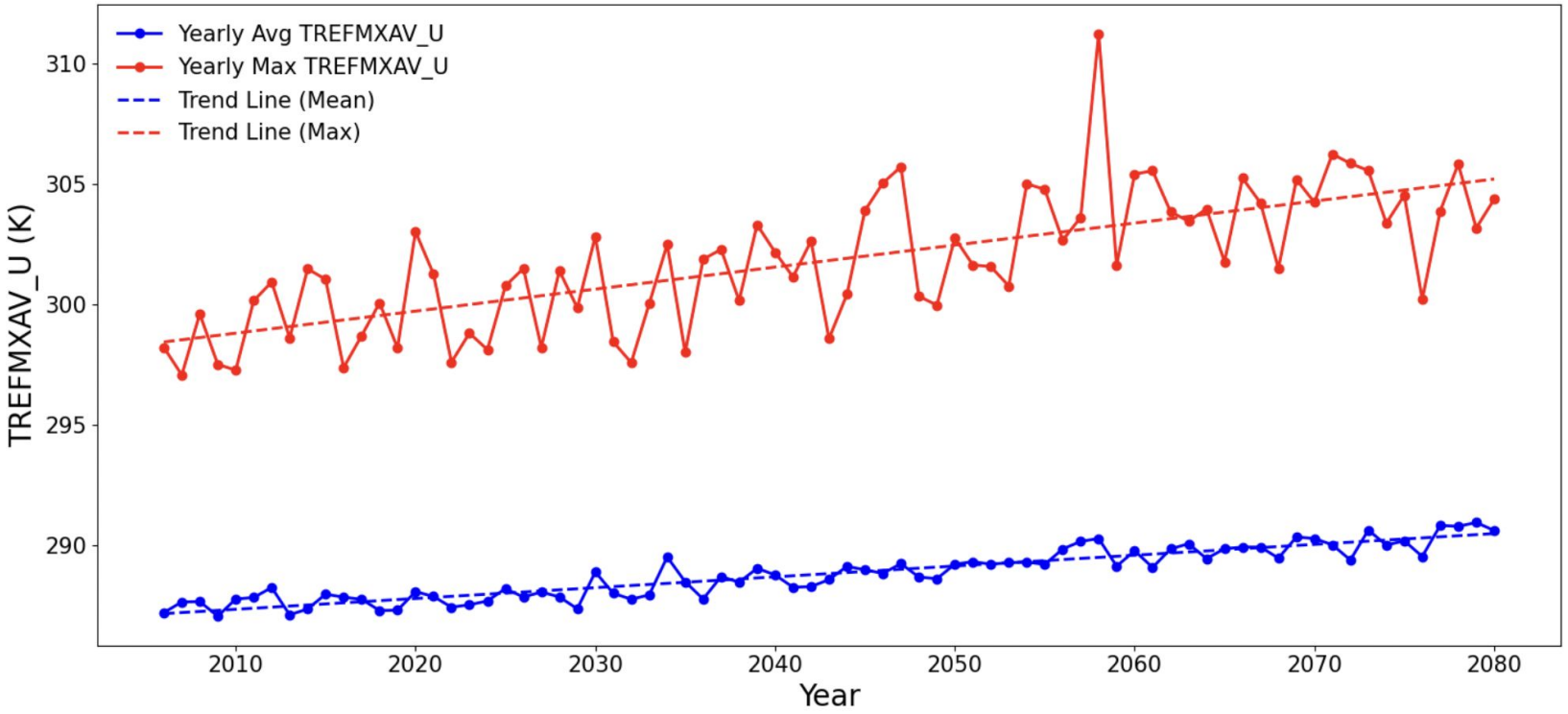
Result Analysis: MoM Temperature Trend



Scope 1

Result Analysis: Max Daily Temperature Follows the Same Trend

Estimated Temperature Change Rate (Yearly Mean): 0.0449 K/year
Estimated Temperature Change Rate (Yearly Max): 0.0914 K/year



Result Analysis: Extreme Heat Events (IPCC)

305K

32°C / Moderate Heat

High risk of heat stress, especially for outdoor workers and vulnerable populations.

Impact to humans:

- Dehydration
- Fatigue
- Thunderstorm

308K

35°C / Extreme Heat

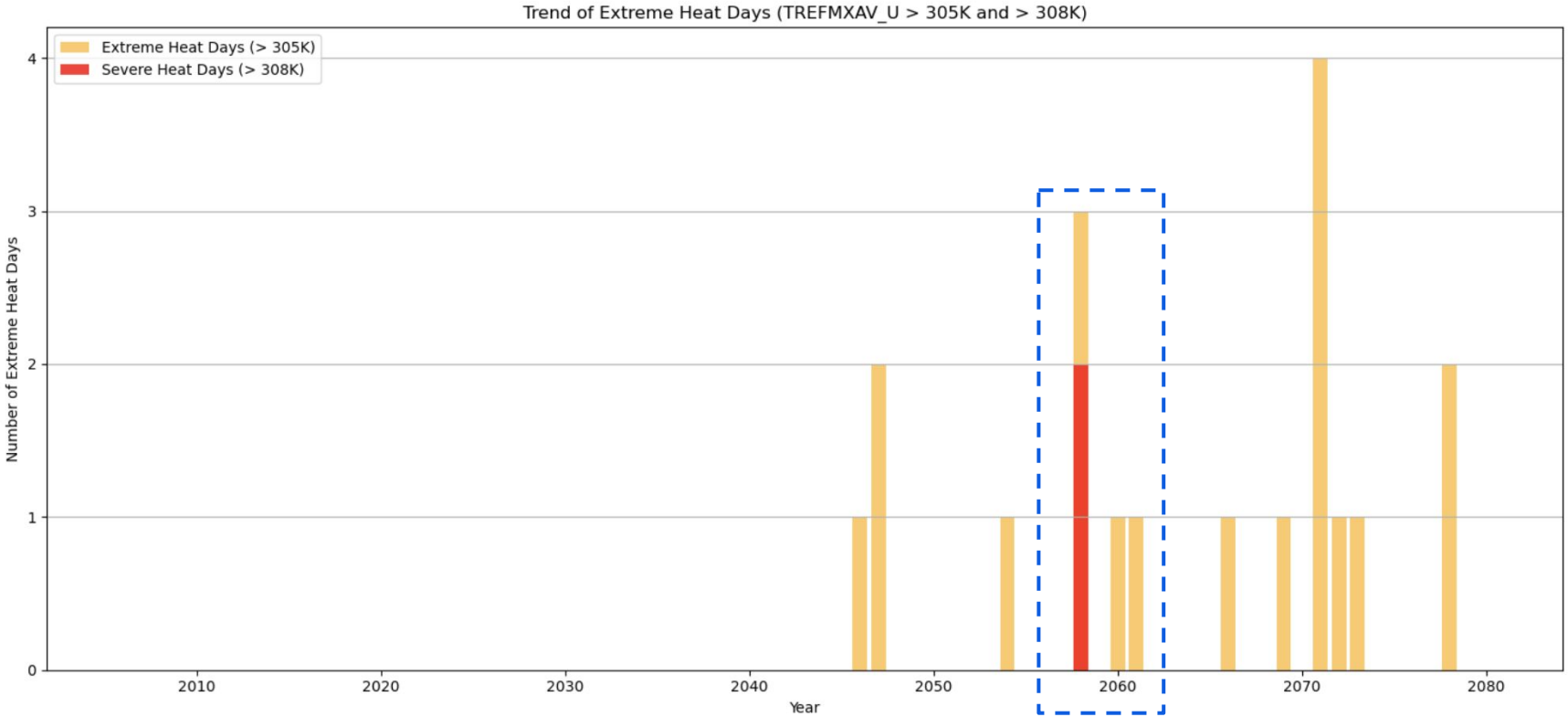
Dangerous heat levels, increasing risk of heat-related illnesses and reduced outdoor activity.

Impact to humans:

- Heatwave
- May be lethal

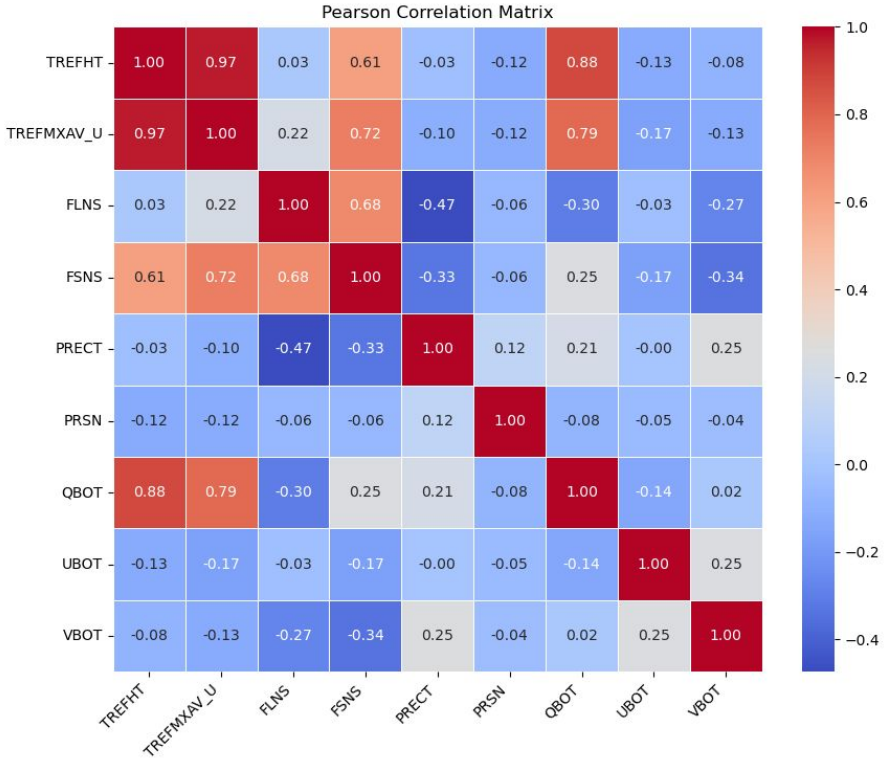
Scope 2

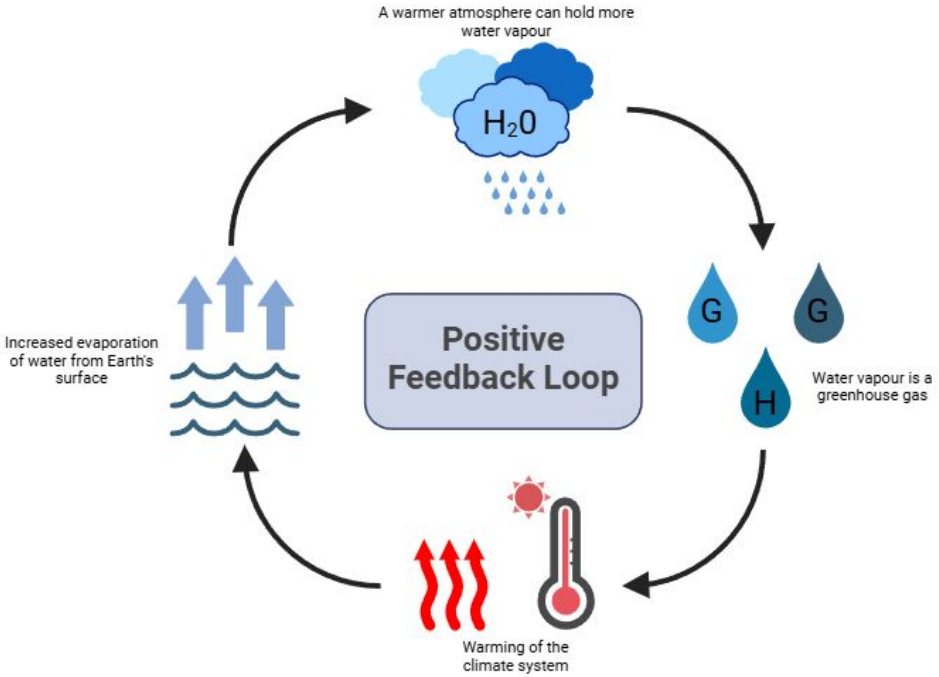
Result Analysis: Extreme Heat Events



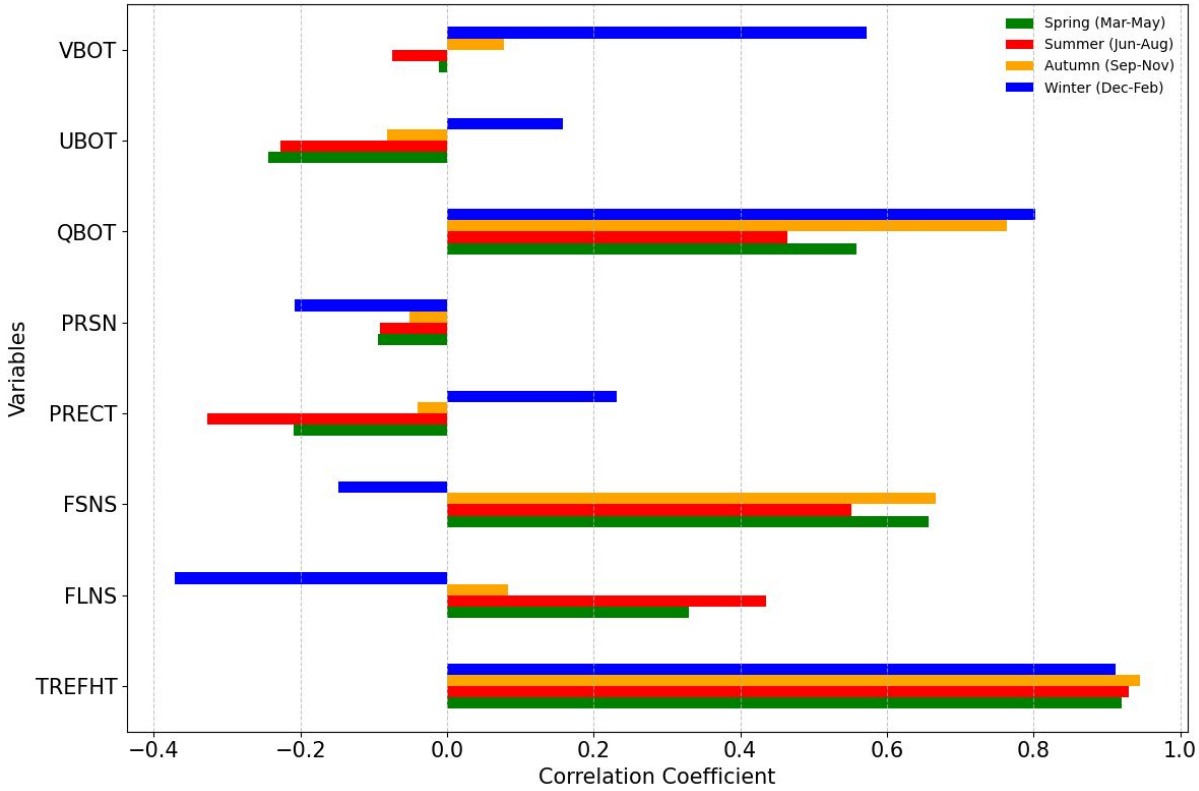
Scope 3

Result Analysis: Key Factors - Correlation Matrix





Result Analysis: Key Factors - Seasonal Variations

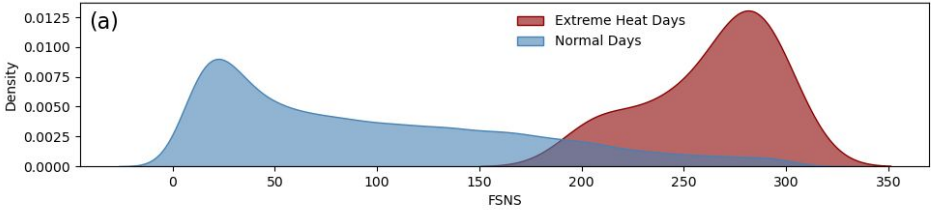


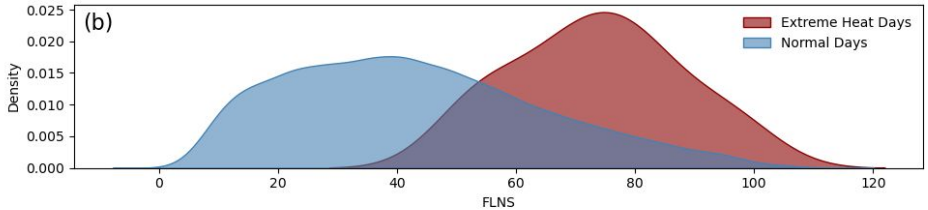
In summer, daily maximum temperature is primarily controlled by QBOT, FLNS and FSNS.

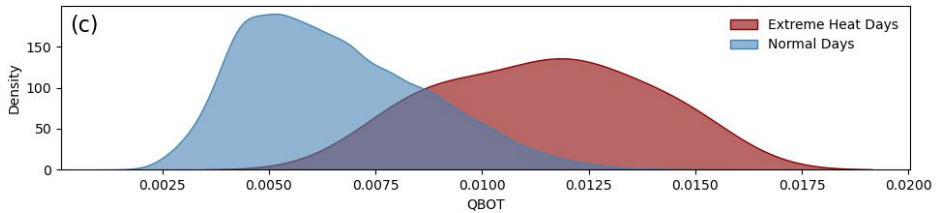
In winter, daily maximum temperature is more influenced by QBOT, FLNS, and VBOT.

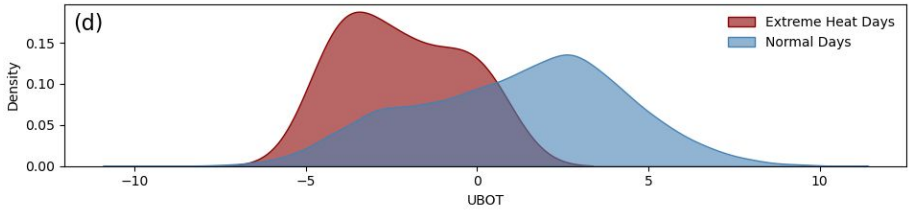
Scope 3

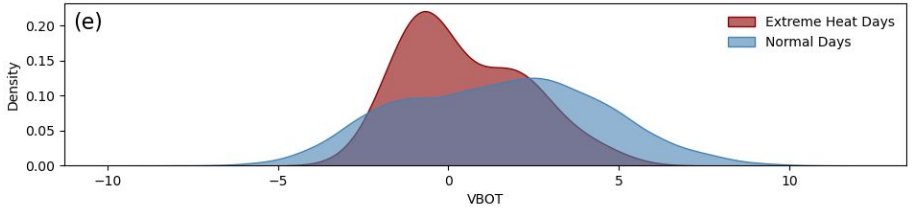
Result Analysis: Key Factors - Extreme Heat Days vs Normal Days

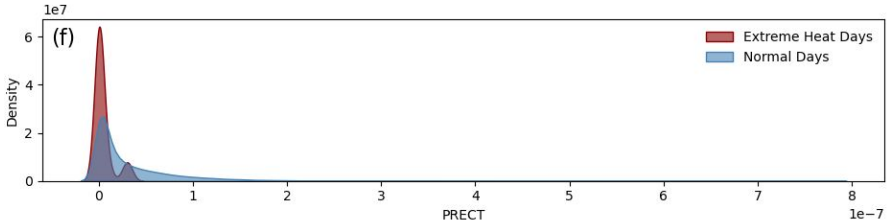






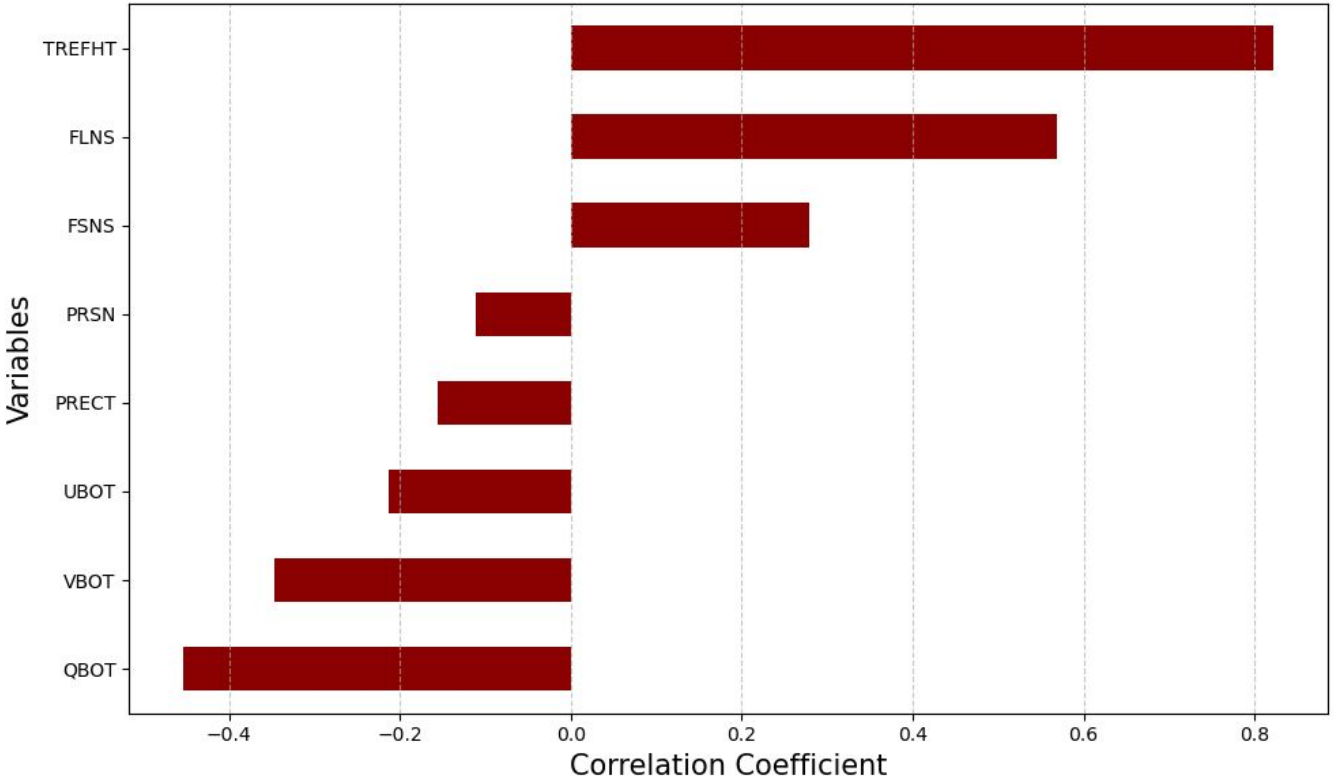






Scope 3

Result Analysis: Key Factors - Extreme Heat Days

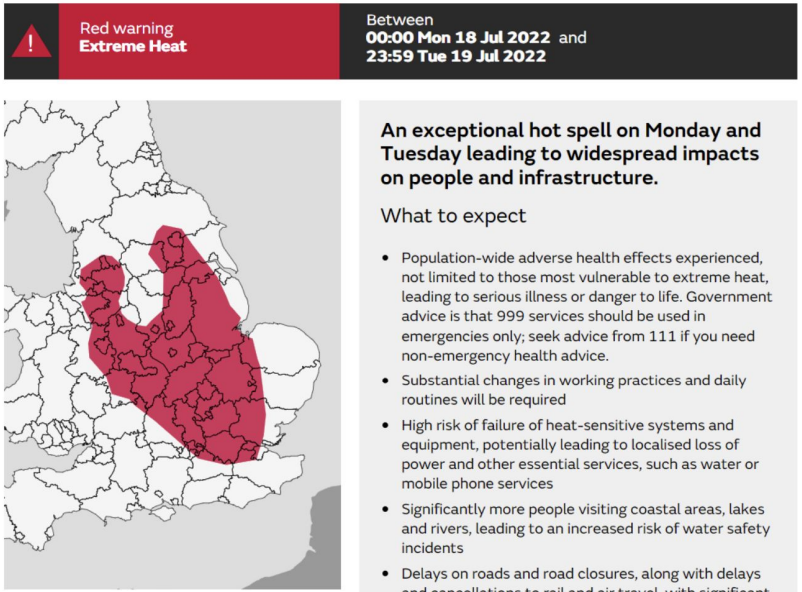


Key Findings

1	2	3	4	5
BOTH TREFHT & TREFMXAV_U EXHIBIT AN INCREASING TREND	**RATE OF INCREASE IN TREFMXAV_U IS TWICE THAT OF TREFHT**	**THE NUMBER OF EXTREME HEAT DAYS WILL INCREASE SIGNIFICANTLY AFTER 2050**	**TREFMXAV_U IS INFLUENCED BY DIFFERENT VARIABLES PER SEASON**	**FSNS, FLNS, QBOT & VBOT ARE THE MAIN DRIVERS OF HIGH TEMPERATURES**
The seasonal pattern of future climate remains unchanged, with the greatest increase in daily average temperature occurring in summer.	Indicating that while the overall temperature is rising, the intensity and frequency of extreme heat events are increasing at a much faster rate.	Suggests that heatwaves will become more frequent in the future. Prolonged heatwaves lasting several days may occur after 2060. However, extreme heatwaves (>308K) may still remain relatively rare.	In summer, the daily maximum temperature is primarily influenced by QBOT, FLNS, and FSNS, whereas in winter, it is predominantly controlled by QBOT, FLNS, and VBOT.	Extreme heat events typically occur under clear-sky conditions (FSNS), with enhanced atmospheric longwave radiation (FLNS), elevated humidity levels (QBOT), stronger westerly winds (UBOT), and reduced precipitation.

Relevance - Why is this useful?

Picture 1 Example of a Met Office Red Warning for Extreme Heat.
Warnings include a specification of the affected area, and an assessment of the likelihood and impact of the event as well as advice and guidance to protect public health from heat impacts at the respective warning level.



Further Research

Regional Variability

- Investigate how different geographical regions experience these trends based on local climatic conditions.

Interactions Between Heatwaves & Other Climate Extremes

- Examine how heatwaves interact with droughts, wildfires, and extreme precipitation.
- Study compound climate events, such as heatwaves followed by severe storms, and their impacts on infrastructure and agiculture.

Machine Learning for Heatwave Prediction

- Develop machine learning models to improve forecasting accuracy using historical climate data and atmospheric predictors.

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