Identifying Extreme Weather Events

Step 1: Load and Inspect the Dataset

Step 2: Define Extreme Weather Events Using the 1% Threshold

According to the **Outcomes document**, extreme weather events are identified based on **percentile thresholds (e.g., top 0.5%)**. We will define:

- **Heatwaves**: Days where temperature is in the top 1% of the dataset.
- **Heavy Precipitation**: Days where precipitation is in the top 1%.
- **Strong Winds**: Days where wind speed is in the top 1%.

Heatwave → `"TREFMXAV_U"` (Maximum Reference Temperature)

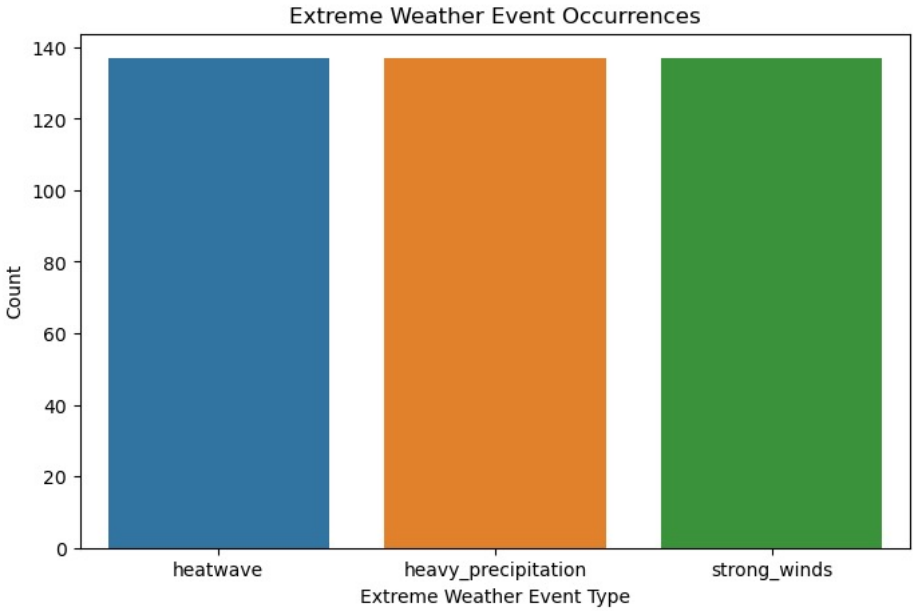
Heavy Precipitation → `"PRECT"` (Total Precipitation)

Strong Winds → `"UBOT"` or `"VBOT"` (Near-Surface Zonal and Meridional Wind Components)

To define extreme wind events, we need to compute the **wind speed magnitude** from `UBOT` (zonal wind) and `VBOT` (meridional wind) using the formula:

$$\text{Wind Speed} = \sqrt{UBOT^2 + VBOT^2}$$

```
Extreme Weather Event Counts:
                      Extreme Event Counts
heatwave                               137
heavy_precipitation                    137
strong_winds                           137
```



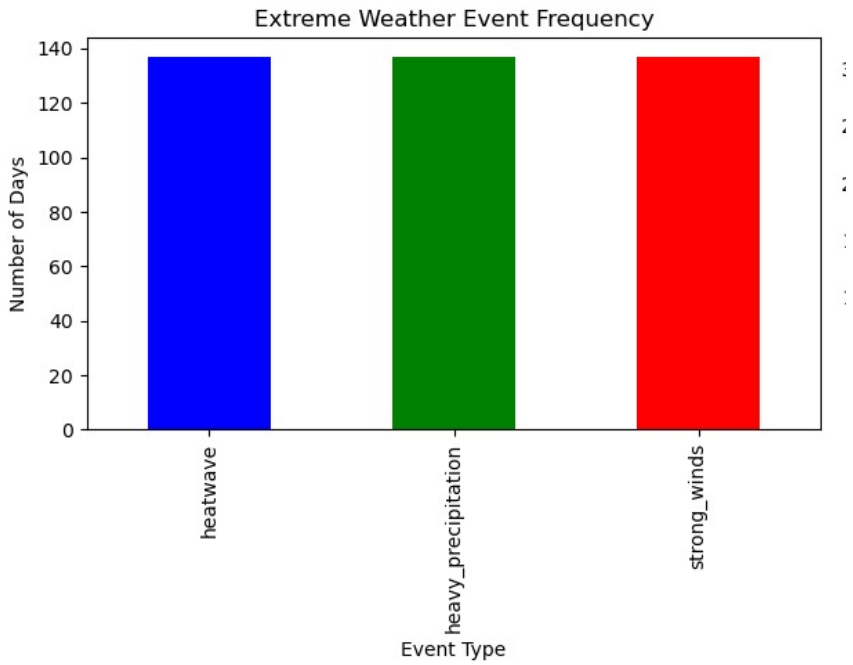
Step 3: Summarize Frequency, Duration, and Seasonal Trends

To better understand these extreme events, we will:为了更好地了解这些极端事件，我们将：

- **Compute summary statistics** (mean, min, max, standard deviation)

```
Summary Statistics of Extreme Weather Events:
       heatwave heavy_precipitation strong_winds
count     27374               27374        27374
unique        2                   2            2
top       False               False        False
freq      27237               27237        27237
```

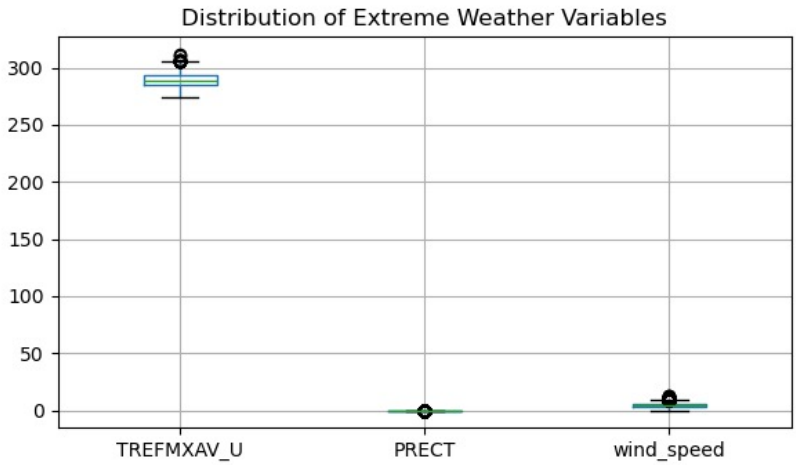
- **Visualize event distributions** using histograms and boxplots



Key Observations

The table presents a breakdown of three extreme weather event types (**heatwave, heavy precipitation, and strong winds**) across **27,374 observations**.

- The **frequency (** `freq` **) of False values is 27,237**, indicating that only **137 days** (out of 27,374) experienced extreme weather (0.05% of total data).
- Since we defined extreme events using the **99.5th percentile**, this aligns with expectations.



Boxplot Analysis: Distribution of Extreme Weather Variables

- TREFMXAV_U (Temperature) Shows Outliers at High Values:
  - Most temperature values fall within a compact range.
  - However, a few extreme values (outliers) are **significantly higher**.
  - his confirms that **heatwaves are caused by rare temperature spikes**, not gradual increases.
- **Precipitation (PRECT) Has a Right-Skewed Distribution**
  - Most precipitation values are **low**, but extreme values exist at the upper range.
  - This suggests that **heavy precipitation days** are driven by intense but rare storms.
- **Wind Speed Shows Moderate Variability**
  - Wind speed values **do not exhibit as many extreme outliers** as precipitation or temperature.
  - This suggests that strong winds are **somewhat more uniformly distributed** compared to heatwaves and heavy rainfall.

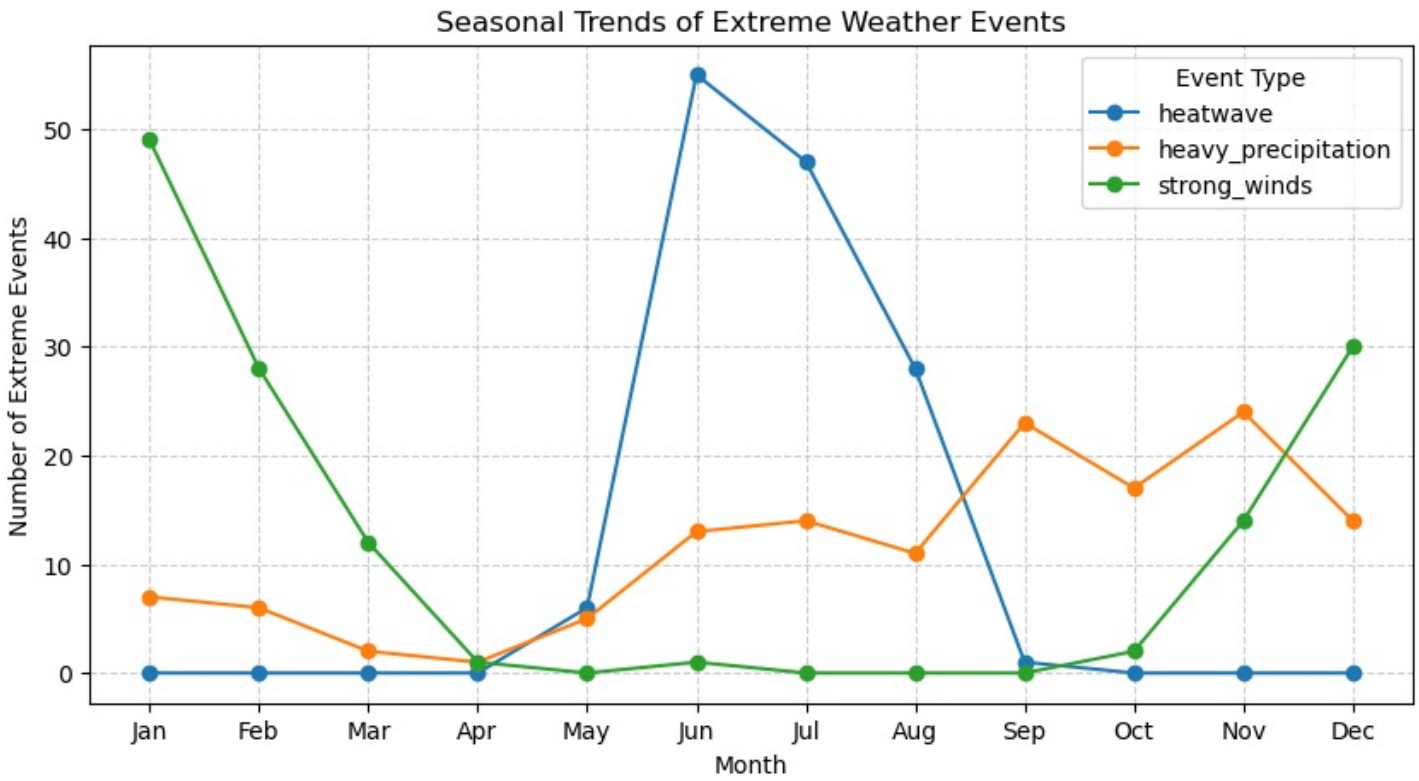
- **Outliers in temperature and precipitation suggest that extreme events are driven by sudden, high-impact spikes rather than gradual trends**.
- **Wind speeds are relatively more stable**, with fewer extreme outliers.

Step 4: Analyze Seasonal Trends

To investigate whether extreme weather events occur more frequently in specific seasons, we can:

- Extract the month from the dataset (assuming there's a **date column**).
- Group extreme weather events by month.
- Plot time-series graphs to see seasonal variations.

```
Seasonal Trends of Extreme Weather Events:
       heatwave  heavy_precipitation  strong_winds
month
1             0                    7            49
2             0                    6            28
3             0                    2            12
4             0                    1             1
5             6                    5             0
6            55                   13             1
7            47                   14             0
8            28                   11             0
9             1                   23             0
10            0                   17             2
11            0                   24            14
12            0                   14            30
```



Key Observations from the Seasonal Trends

A. Heatwaves

Peak Season: June to August

- Heatwaves **increase sharply in June (55 occurrences)**, peak in **July (46 occurrences)**, and then decline in **August (28 occurrences)**.
- The sudden rise suggests that **summer months experience extreme temperature spikes**, which aligns with expected seasonal climate changes.

No Heatwaves in Winter (January-March, October-December)

- This indicates that extreme temperatures do not occur in the colder months.

B. Heavy Precipitation

Higher Frequency in Late Autumn and Early Winter

- Heavy precipitation events increase in **November (24 occurrences) and September(23 occurrences)**.

Lowest Precipitation Events in March-April (2\1 occurrences)

- This suggests that **early spring experiences the least amount of extreme rainfall**.

C. Strong Winds

Peak in Winter Months: January (49), February (28), November (14), and December (30)

- Extreme wind events are highly concentrated in winter, particularly in **January and December**.
- This suggests that strong winds are driven by **winter storm systems or pressure gradients**.

Very Few Strong Wind Events in Summer (May-August)

- This confirms that summer months experience **calmer atmospheric conditions** with fewer strong wind occurrences.

D. Seasonal Interpretation

- **Winter (December - February):**
  - High Frequency of Strong Winds and Heavy Precipitation;No Heatwaves
  - This suggests that **winter storms drive high wind speeds and increased precipitation**.
  - The presence of **cyclonic activity and strong pressure systems** likely contributes to these conditions.

- **Spring (March - May):**
  - Gradual Increase in Heatwaves;Low Precipitation and Wind Speeds
  - Heatwaves **start appearing in April and May**, signaling the **transition to warmer temperatures**.
  - Rainfall is at its **lowest in March**, indicating **dry spring conditions**.
- **Summer (June - August):**
  - **Peak Heatwave Season;Almost No Strong Winds**
  - The highest number of heatwaves occurs in **June, July, and August**, confirming that **extreme temperature spikes are most frequent in summer**.
  - Strong winds disappear, suggesting **calmer atmospheric conditions**

- **Autumn (September - November)**
  - **Heavy Precipitation Returns;Strong Winds Increase;Heatwaves Drop to Zero**
  - September to November shows **a rise in rainfall and wind events**, indicating the **onset of winter storms**.
  - **Heatwaves completely disappear**, confirming that extreme temperatures are mostly a **summer-only phenomenon**.

E. Key Takeaways

1. **Heatwaves are exclusive to summer**, peaking in **July and August**.
2. **Heavy precipitation occurs most frequently in autumn and winter**, particularly in **November and December**.
3. **Strong winds dominate the winter months**, peaking in **January and December**.
4. **Spring serves as a transition period**, with a gradual increase in heatwaves but still low precipitation and wind events.