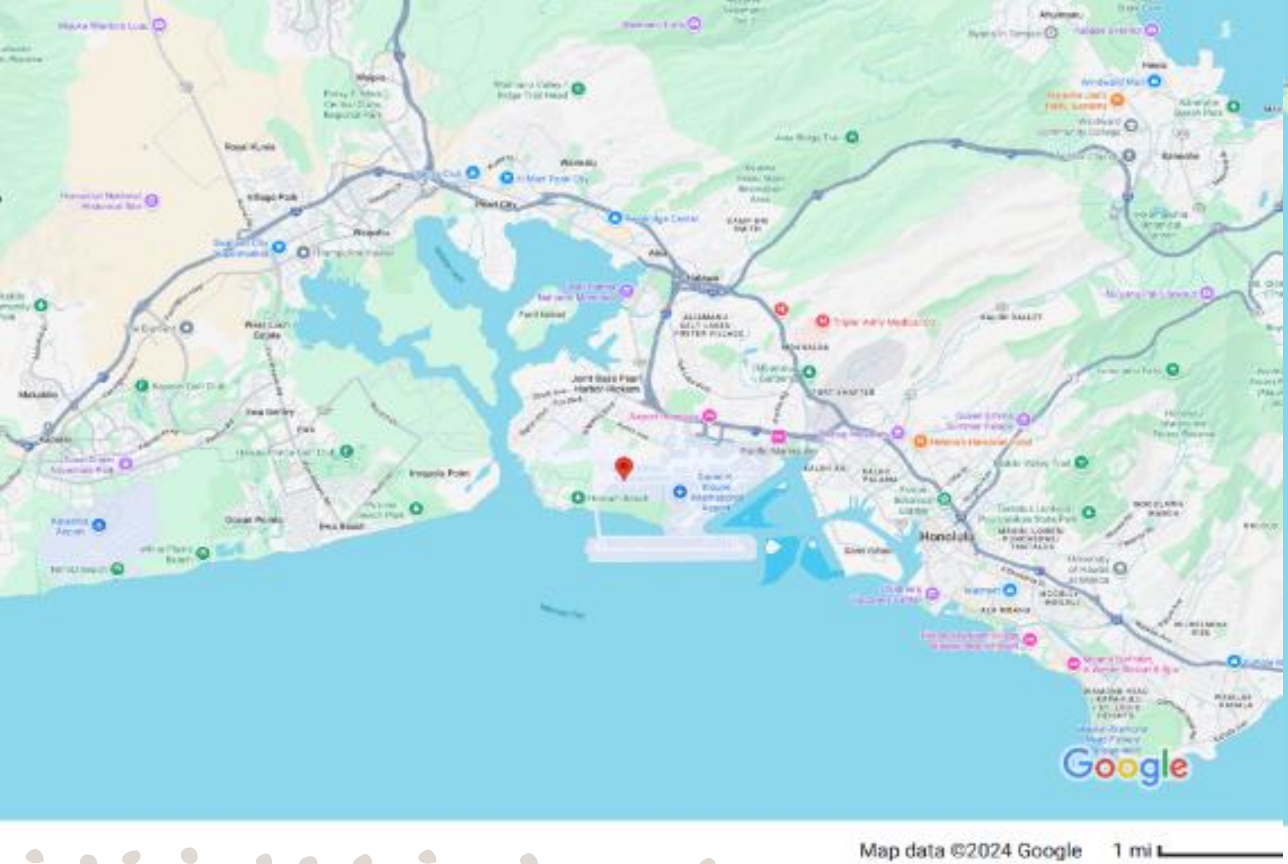
# Climatological Analysis of Honolulu, Hawaii

By: Jason Haley


Bering Sea
KAMCHATKA PENINSULA
Gulf of Alaska
Alexander Archipelago
ALASKA PENINSULA
Sea of Okhotsk
Queen Charlotte Islands
ASIA
SAKHALIN
NORTH AMERICA
KURIL ISLANDS
HOKKAIDO
Sea of Japan
JAPAN
KOREA
Yellow Sea
HONSHU
East China Sea
TAIWAN
HAWAIIAN ISLANDS
Philippine Sea
Islas Revillagigedo
PHILIPPINES
CENTRAL AMERICA
GUAM
MARSHALL ISLANDS
PACIFIC OCEAN
PALAU
MICRONESIA
GALAPAGOS
SOUTH AMERICA
NAURU
KIRIBATI
NEW GUINEA
SOLOMON ISLANDS
TUVALU
SAMOA
FIJI
COOK ISLANDS
VANUATU
Coral Sea
NIUE
FRENCH POLYNESIA
PITCAIRN
New Caledonia
TONGA
AUSTRALIA





# Weather Station Location:
# Honolulu International AAirport

Coordinates: (21.234°N, 157.939° W)

# Weather Station Google Earth Images

# Missing Data

Monthly Data:

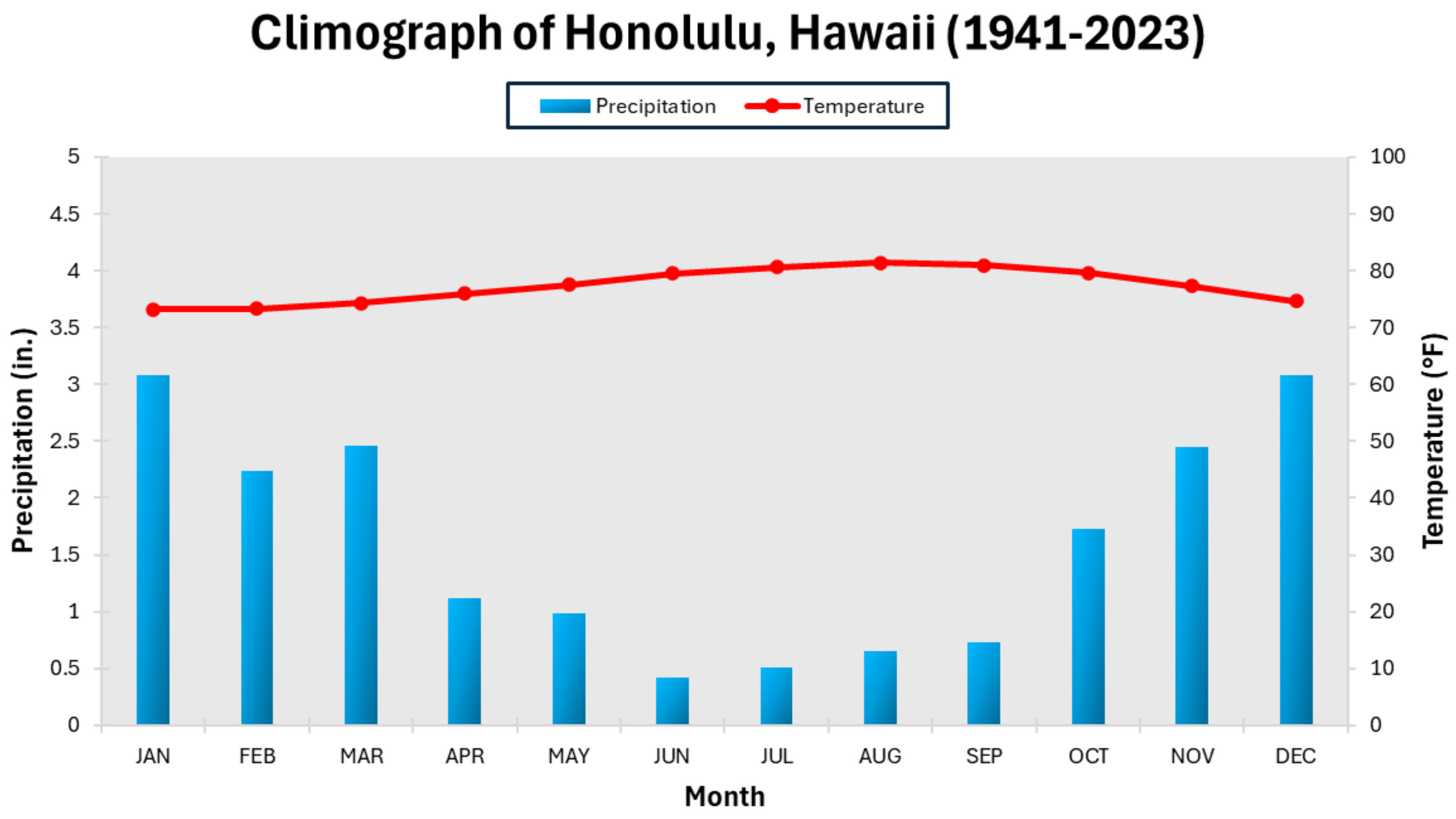
- If less than half the values were recorded the year was deleted (temp: 1940, 1942; precip: 1940)
- If only a few values were missing, average of previous and subsequent month were taken (temp: 1943-1946)
- For some years, there were consecutive years missing, so estimation was not feasible. Those years were deleted (temp: 1947, 1948, 1949; precip: 1942)

Daily Data:

- Missing precipitation data from 1941-1949 and after 2012, so daily analyses were only from 1950-2012

# Climate Overview

- "As" climate – Tropical Wet & Dry
- Winter wet season and Summer dry season (small annual variation)
- Fairly consistent annual temperature



# Climate Controls + Influence

Main Climate Controls:

1. Latitude
2. Proximity to a large water body
3. Orographic influence + atmospheric circulation → rain shadow effect
4. ENSO effects (not shown on climograph)

Influences:

1. Small annual temp variation
2. Small annual temp and precipitation variation
3. Little amount of precipitation despite close to a large body of water
4. Several year precipitation variation
   - El Niño: Less rainfall
   - La Niña: More rainfall


Mokulē'ia
Schofield Barracks Military Reservation
Wahiawā
Mililani
Wai'anae
Kāne'ohe
Kailua
Nānākuli
Waipahu
Aiea
Waimanalo
Kapolei
Honolulu
East Honolulu
3,999 ft
3,702 ft
3,411 ft
3,127 ft
2,851 ft
2,583 ft
2,323 ft
2,071 ft
1,828 ft
1,595 ft
1,371 ft
1,158 ft
955 ft
765 ft
588 ft
426 ft
280 ft
154 ft
53 ft
-7 ft
Elevation database | Elevation API | OpenStreetMa

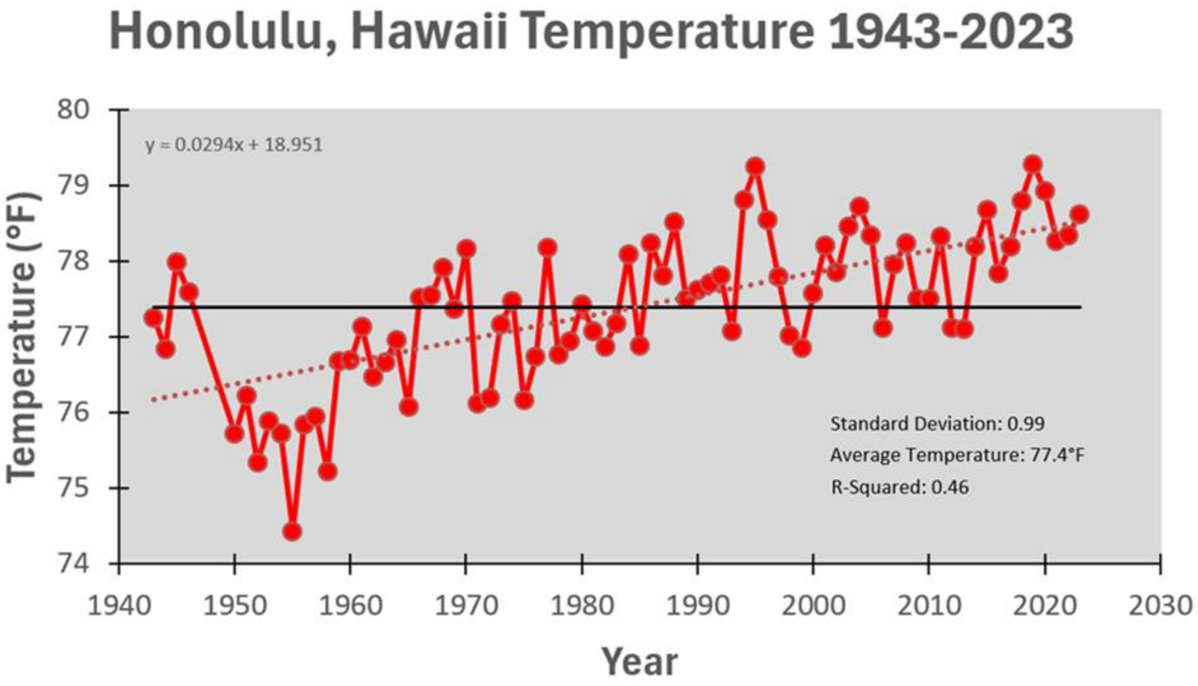
# Trends in Annual Temperature and Precipitation

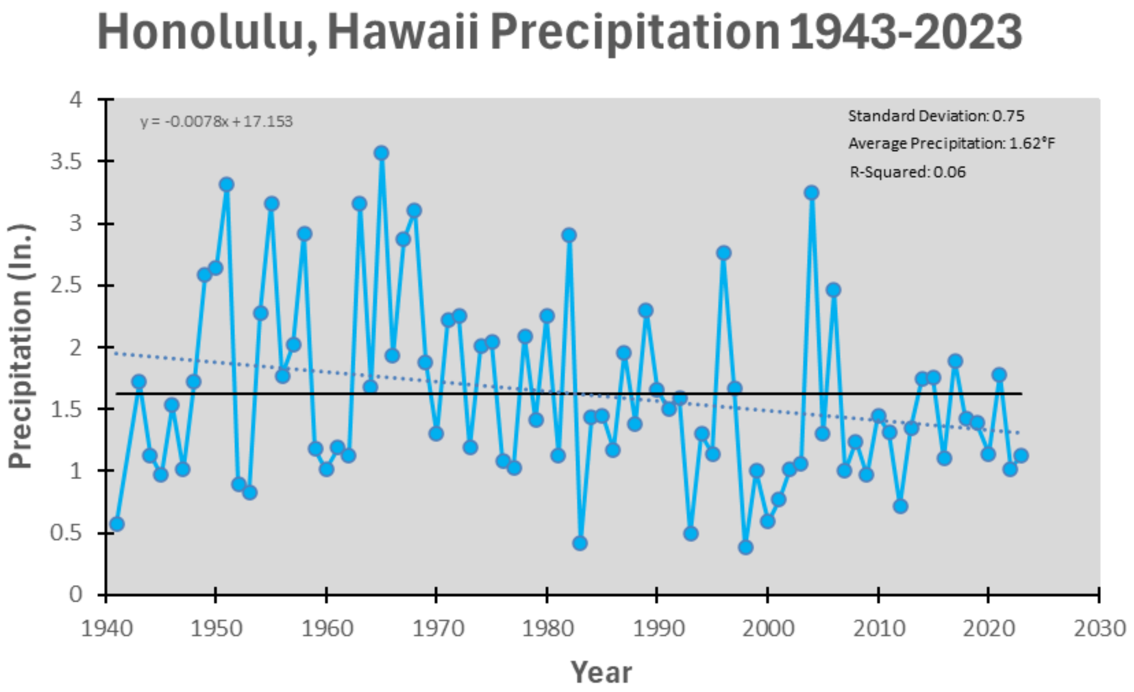
Temperature trend:

- Warming of nearly 0.03° F per year
- Moderately strong correlation (R-squared = 0.46)

Rainfall trend:

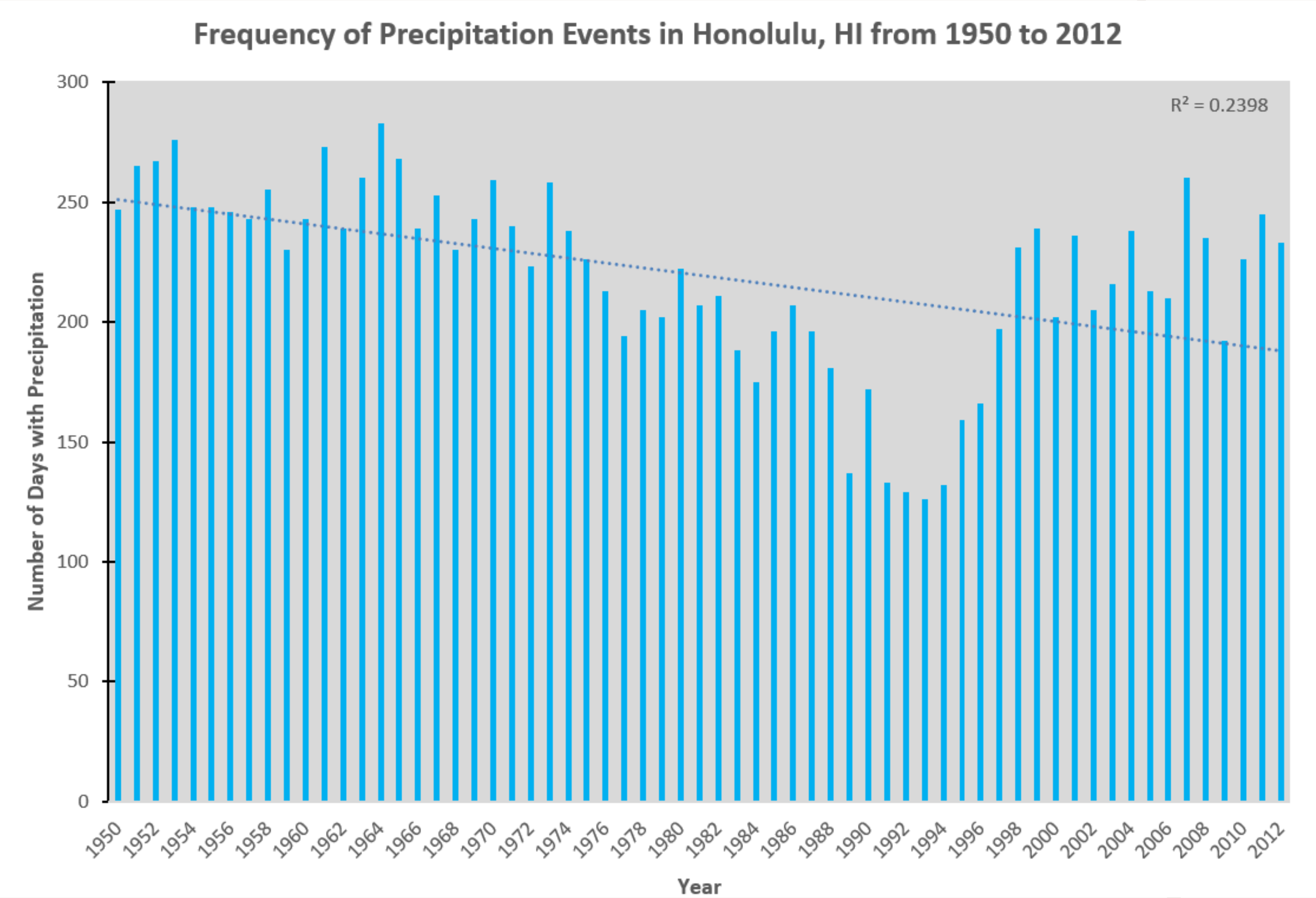
- No noticeable trend in rainfall (very small slope)
- Very weak correlation (R-squared = 0.06)
- Speculation: Less extreme rainfall events?



# Frequency: Yearly Precipitation Events

- Chose since there was not much evidence about how/if precipitation is changing over time
- Perhaps a slight decrease of precipitation events per year
- Somewhat weak correlation of the data with the trend line (R-Squared = 0.2398)
- Could just be natural variability
- Further analysis needed to figure out what is actually going on with precipitation in Honolulu



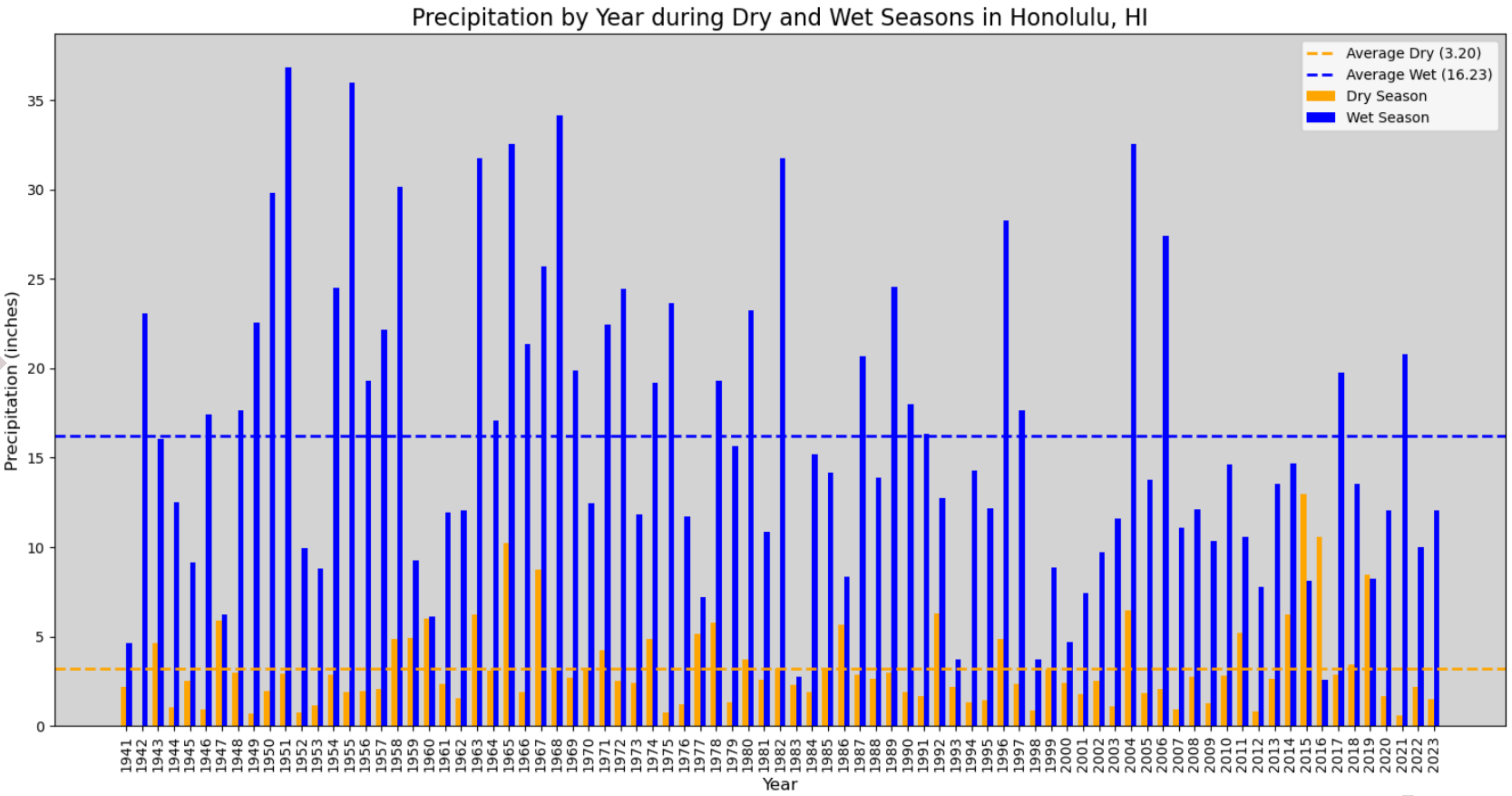
# Precipitation by Year – Wet vs. Dry Season

Dry Season: May – September

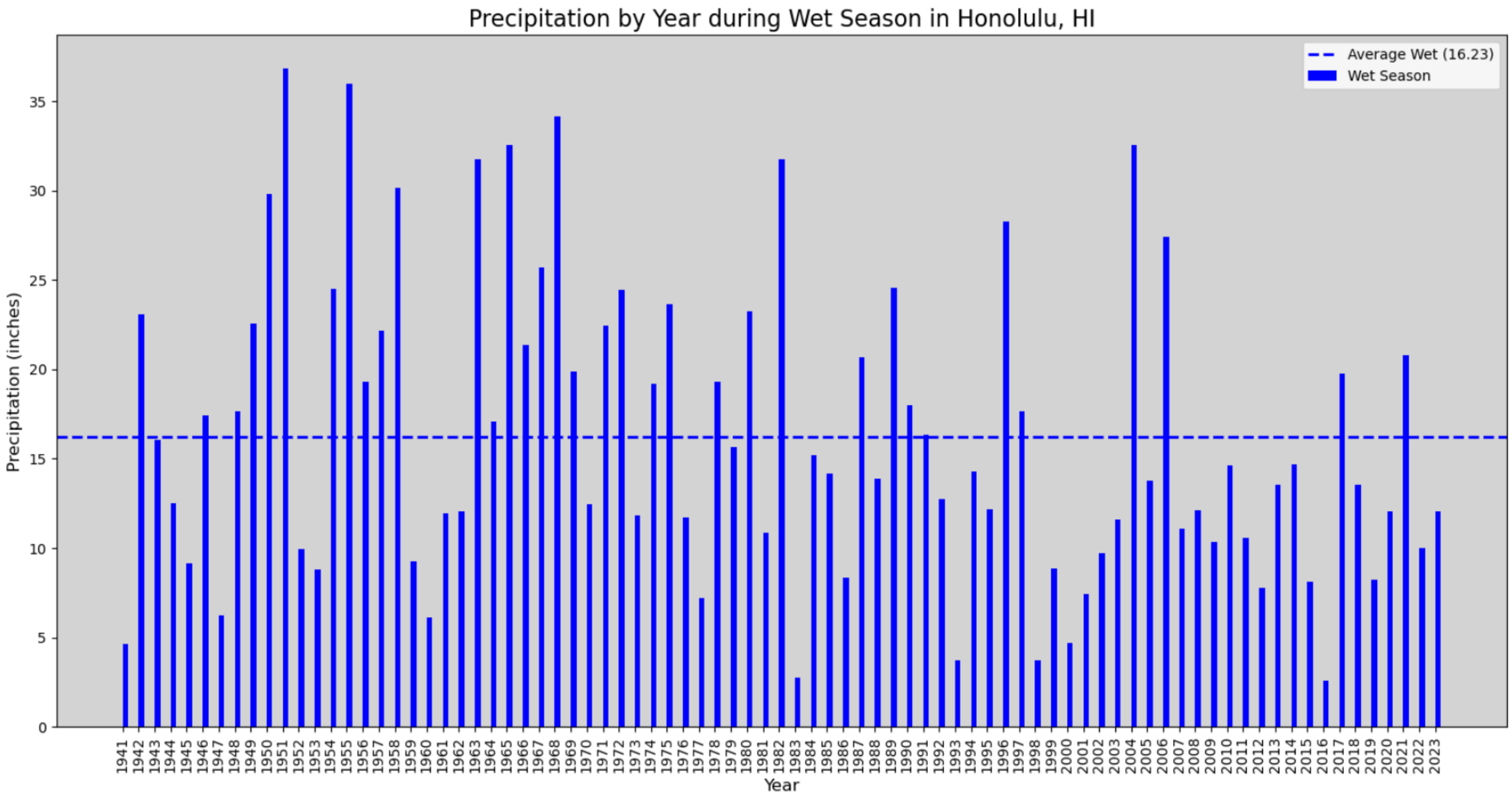
Wet Season: October – April

Calculated the amount of precipitation per year by season

Average precipitation calculated for each season



# What's going on with the wet season?



# Difference of Proportions Statistical Significance Test

- There seems to be a greater number of years that fall above the annual wet season precipitation amount average in years further in the past than in recent years
- Split the data into 2 groups: annual precipitation amounts before 1982 and after 1982
- For each group, calculated the number of years where the annual precipitation amount is greater than the precipitation average for the given time period
- **Statistical Question:** Is there a statistically significant difference between the proportion of wet season precipitation years before 1982 that are above the average precipitation and the proportion of years after 1982 that are above the average precipitation?

```
# Separate data into before and after 1982
before_1982 = seasonal_precip_sorted_reset[seasonal_precip_sorted_reset['YEAR'] < 1982]
after_1982 = seasonal_precip_sorted_reset[seasonal_precip_sorted_reset['YEAR'] >= 1982]

# Wet season: Count years above the average
wet_above_before_1982 = (before_1982['Wet'] > average_wet).sum() # Answer = 24
wet_above_after_1982 = (after_1982['Wet'] > average_wet).sum() # Answer = 11

# Print these values to provide context
print('Number of years before 1982 with observed precipitation > average value:', wet_above_before_1982)
print('Number of years after 1982 with observed precipitation > average value:', wet_above_after_1982)


# Conduct statistical significance test for Difference of Proportions
# Is there a statistical significant difference between
# the proportion of wet season precipitation years before 1982 that are above the average precipitation
# and the proportion of years after 1982 that are above the average precipitation?

import math
import scipy.stats as stats
import statistics

# Data values
n_before_1982 = 40
n_after_1982 = 40
p_before_1982 = 24/40
p_after_1982 = 11/40
standard_error = math.sqrt((p_before_1982 * (1 - p_before_1982) / n_before_1982) +
                           (p_after_1982 * (1 - p_after_1982) / n_after_1982))


# Conditions:

print('\nChecking for Conditions:\n')

# 10 successes and failures for each
if n_before_1982 * p_before_1982 >= 5 and n_after_1982 * p_after_1982 >= 5:
    print('Large Counts Condition: There are enough successes both samples to conduct the statistical significance test.')
else:
    print('Large Counts Condition: There are not enough successes in at least one sample to conduct the statistical significance test.')

if n_before_1982 * (1-p_before_1982) >= 5 and n_after_1982 * (1-p_after_1982) >= 5:
    print('Large Counts Condition: There are enough failures in one or both samples to conduct the statistical significance test.')
else:
    print('Large Counts Condition: There are not enough failures in at least one sample to conduct the statistical significance test.')


# Large enough sample size
if n_before_1982 >= 30 and n_after_1982 >= 30:
    print('Sample Size Conditon: The sample sizes in each sample are sufficiently large to conduct the statistical significance test')

else:
    print('Sample Size Conditon: The sample size in at least one sample is not sufficiently large to conduct the statistical significance test')


# Independence of Samples
print('Independence Condition: Precipitation for one year does not affect the precipitation for other years, so we consider these samples independent.')


# Test calculations
z = (p_before_1982 - p_after_1982) / standard_error
p_value = 2 * (1 - stats.norm.cdf(z))
print('\nResult:')
print('Z-score:', round(z, 5))
print("P-value:", round(p_value, 4))
```

```
Number of years before 1982 with observed precipitation > average value: 24
Number of years after 1982 with observed precipitation > average value: 11

Checking for Conditions:

Large Counts Condition: There are enough successes both samples to conduct the statistical significance test.
Large Counts Condition: There are enough failures in one or both samples to conduct the statistical significance test.
Sample Size Conditon: The sample sizes in each sample are sufficiently large to conduct the statistical significance test
Independence Condition: Precipitation for one year does not affect the precipitation for other years, so we consider these samples independent.

Result:
Z-score: 3.10096
P-value: 0.0019
```

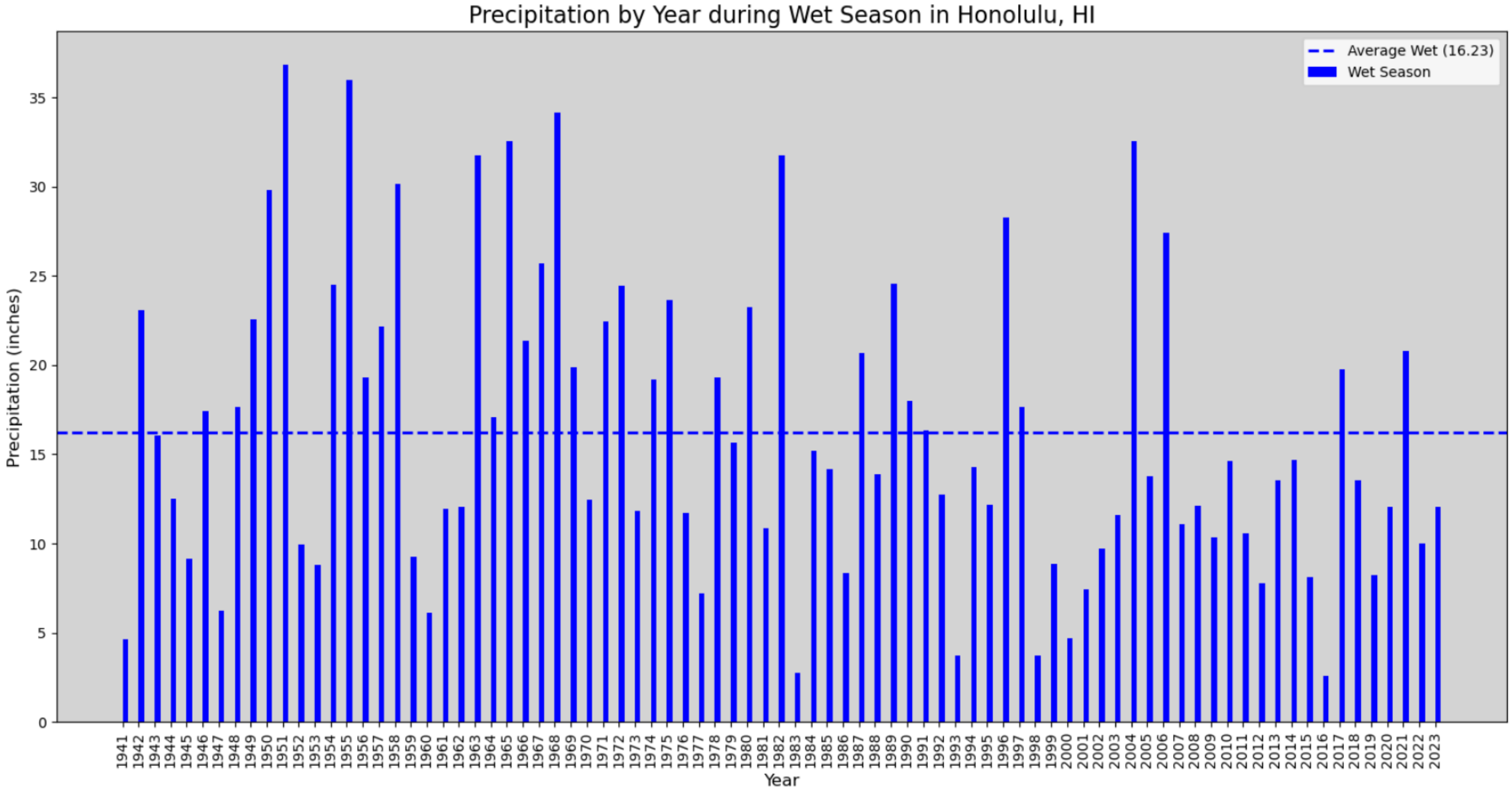
# Difference of Proportions Test Results

- Null Hypothesis ($H_0$): $\pi_{before1982} - \pi_{after1982} = 0 \rightarrow \pi_{before1982} = \pi_{after1982}$
- Alternative Hypothesis ($H_a$): $\pi_{before1982} - \pi_{after1982} > 0 \rightarrow \pi_{before1982} > \pi_{after1982}$
- Prop. of years before 1982 w/ observed precip > avg. value: 24/40
- Prop. of years after 1982 w/ observed precip > avg. value: 11/40

- Z-score: 3.10
- P-value: 0.0019
- Since the p-value is very small (< 0.01), and the z-score is positive, $H_0$ is rejected

- There is statistically significant evidence in favor of the alternative
- This gives us strong evidence that the wet season in Honolulu is getting drier
- But what if those differences from the average wet season value are small?

# What's going on with the wet season?



# Difference of Means Statistical Significance Test

- For each year, calculated the difference in observed precipitation for the wet season and the average wet season precipitation amount
- Calculated the average of these statistics for the two groups (before 1982 and after 1982)
- **Statistical Question:** Is there a statistically significant difference between the averaged differences in the average wet season precipitation and the actual values between the years before 1982 and after 1982?

```
# Get the difference in average wet precipitation and the actual years for years before and after 1982

# Get average wet precipitation
average_wet = seasonal_precip_sorted_reset['Wet'].mean()

# Separate data into before and after 1982
before_1982 = seasonal_precip_sorted_reset[seasonal_precip_sorted_reset['YEAR'] < 1982]
after_1982 = seasonal_precip_sorted_reset[seasonal_precip_sorted_reset['YEAR'] > 1982]

# Get copies of the dataframes (so I don't get an error)
before_1982_copy = before_1982.copy()
after_1982_copy = after_1982.copy()

# Calculate the difference between actual and average wet precipitation
before_1982_copy['Difference'] = before_1982['Wet'] - average_wet
after_1982_copy['Difference'] = after_1982['Wet'] - average_wet

# Print these values to provide context
print('Averaged difference in the average wet season precipitation and observed values for years before 1982:', round(before_1982_copy['
print('Averaged difference in the average wet season precipitation and the observed values for years after 1982:', round(after_1982_copy

# Conduct statistical significance test for Difference of Means
# Is there a statistically significant difference between
# the averaged differences in the wet season precipitation anomaly and the actual values
# between the years before 1982 and after 1982?

# Data values
mean_diff_before_1982 = before_1982_copy['Difference'].mean()
mean_diff_after_1982 = after_1982_copy['Difference'].mean()
standard_deviation_diff_before_1982 = statistics.stdev(before_1982_copy['Difference'])
standard_deviation_diff_after_1982 = statistics.stdev(after_1982_copy['Difference'])
sample_size_diff_before_1982 = 40
sample_size_diff_after_1982 = 40
standard_error_diff_of_means = math.sqrt((standard_deviation_diff_before_1982 ** 2) / (sample_size_diff_before_1982)
                                         + (standard_deviation_diff_after_1982 ** 2) / (sample_size_diff_after_1982))

print('\nChecking for Conditions:\n')

# Conditions:

# Sample sizes are both at least 20
if sample_size_diff_before_1982 >= 20 and sample_size_diff_after_1982 >= 20:
    print('Sample Size Condition: The sample sizes in both samples are sufficiently large to conduct the statistical significance test.
else:
    print('Sample Size Condition: The sample size in at least one sample is not sufficiently large to conduct the statistical significa

# Independence of Samples
print('Independence Condition: Precipitation for one year does not affect the precipitation for other years, so we consider these sample

# Test calculations
z = (mean_diff_before_1982 - mean_diff_after_1982) / standard_error_diff_of_means
p_value = 2 * (1 - stats.norm.cdf(abs(z)))
print('\nResult:')
print('Z-score:', round(z, 5))
print('P-value:', round(p_value, 5))
```

```
Averaged difference in the average wet season precipitation and observed values for years before 1982: 2.6 inches
Averaged difference in the average wet season precipitation and the observed values for years after 1982: -2.9 inches

Checking for Conditions:

Sample Size Condition: The sample sizes in both samples are sufficiently large to conduct the statistical significance test.
Independence Condition: Precipitation for one year does not affect the precipitation for other years, so we consider these samples indep

Result:
Z-score: 3.15604
P-value: 0.0016
```

# Difference of Means Test Results

- Null Hypothesis ($H_0$): $\mu_{before1982} - \mu_{after1982} = 0 \rightarrow \mu_{before1982} = \mu_{after1982}$
- Alternative Hypothesis ($H_a$): $\mu_{before1982} - \mu_{after1982} > 0 \rightarrow \mu_{before1982} > \mu_{after1982}$
- Averaged difference in the average wet season precipitation and observed values for years before 1982: 2.6 inches
- Averaged difference in the average wet season precipitation and observed values for years after 1982: -2.9 inches

- Z-score: 3.16
- P-value: 0.0016
- Since the p-value is very small ($< 0.01$), and the z-score is positive, $H_0$ is rejected

- There is statistically significant evidence in favor of the alternative
- This gives us even more evidence that the dry season is getting drier
- Possible confounding variables?: Measurement differences, moving wet season

# Comparison to National Assessment

National Assessment:

- Increased temps and altered rainfall patterns will cause food and water shortage
- Increase in extreme events such as droughts, hurricanes, and heat waves
- Sea level rise will harm infrastructure and economy
- Islands' ecosystem composition are being threatened due to rising temps, ocean acidification, and sea level rise

Comparison to my Analysis:

- My analysis did agree with the fact that temperatures are rising
- The statistical significance tests corroborate with altered rainfall patterns (drier wet season)
- Evidence against extreme events
- Other variables not analyzed

# Future Direction

- In the future, I'd like to travel to Honolulu to study the paleoclimatology of the area
- It would be interesting to see how far back the proxy data goes as the islands were formed recent in geologic time
- For the station itself, figure out why the daily precipitation data isn't being added to dataset
  - It's accounted for since there is monthly data

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