



ASSESSMENT 2

IE6200 Fall 2025



NOVEMBER 6, 2025
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ACADEMIC INTEGRITY

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NAME (e-Sig.) *Aditya Girish Anand*

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OVERALL SUMMARY

The analysis examined long-term climate warming by evaluating annual extreme minimum temperature data across three time periods: the full historical record (Period A: 1941 to 2025), a colder mid-century interval (Period B: 1970 to 1990), and the most recent 30-year climate standard (Period C: 1991 to 2020). Descriptive statistics confirmed that Period B experienced colder winter extremes with an average of -2.14°F, placing it in USDA Plant Hardiness Zone 6b. Period C showed a notably warmer average of 4.12°F, which aligns with Zone 7a. Period A fell between these two ranges and reflected a gradual shift in climate conditions over time.

Inferential hypothesis testing using Welch's two-sample t-tests demonstrated that Period C is significantly warmer than both Period B and Period A. The difference between Period C and Period B was 6.26°F with a p-value of 0.0012, and the difference between Period C and Period A was 3.02°F with a p-value of 0.035. These results confirm a statistically meaningful warming trend. The comparison between Period B and Period A was not statistically significant, which indicates that the most recent warming occurred after the mid-20th century.

Confidence interval analysis strengthened this conclusion. The 95 per cent confidence interval for Period C was (1.88°F, 6.36°F), which lies entirely above 0°F. This rules out Zone 6b for current climate conditions and places the recent climate firmly in Zone 7a, with the upper range extending slightly toward Zone 7b. In contrast, the confidence intervals for Period B and Period A either overlap or remain near the boundary between Zones 6b and 7a, showing a clear upward progression in minimum winter temperatures.

Visual assessments, including Q-Q plots, histograms, stem-and-leaf diagrams, and a full time-series trend, support both the statistical results and the observed warming pattern. The report also confirmed that the calculations produced by Julius AI were numerically accurate. The current analysis added greater interpretive context by relating the results directly to USDA zone thresholds and long-term climatic patterns.

Overall, the results provide strong statistical and visual evidence of warming in annual extreme minimum temperatures. The current climate is best classified in USDA Plant Hardiness Zone 7a, with slight movement toward Zone 7b.

Technical Accuracy

The technical accuracy of the Julius AI analysis was verified through independent recalculation and cross-validation of all reported statistics. Each computational step, including mean conversion, t-test derivations, and confidence-interval estimation, was found to be mathematically correct. The AI used proper formulas, consistent units, and correct rounding. The descriptive means align with USDA PHZ thresholds, confirming that the provisional zones (6b, 7a) were matched accurately. Welch's t-tests and p-values were recomputed and confirmed to four decimal places. The 95% CI for Period C = (1.88°F, 6.36°F) matches, validating the AI's calculations.

We will be breaking down the technical accuracy into three different stages to ensure the rigor of the AI's analysis:

- **Descriptive Statistics:** To verify the provisional PHZ based on the reported means (\bar{x})
- **Inferential Hypothesis Testing:** Confirming the mathematical validity of the reported t-test result and p-value for the warming trend
- **Confidence Intervals:** To verify the calculations of the 95% Confidence Interval (CI) for the most relevant period and its implications for the final PHZ assignment

i. Descriptive Statistics

This section checks the Julius AI's classification of the reported average annual extreme minimum temperatures (\bar{x}) against the official USDA Plant Hardiness Zone ranges (converted from Fahrenheit to Celsius) using the formula $C = (F - 32) \times \frac{5}{9}$

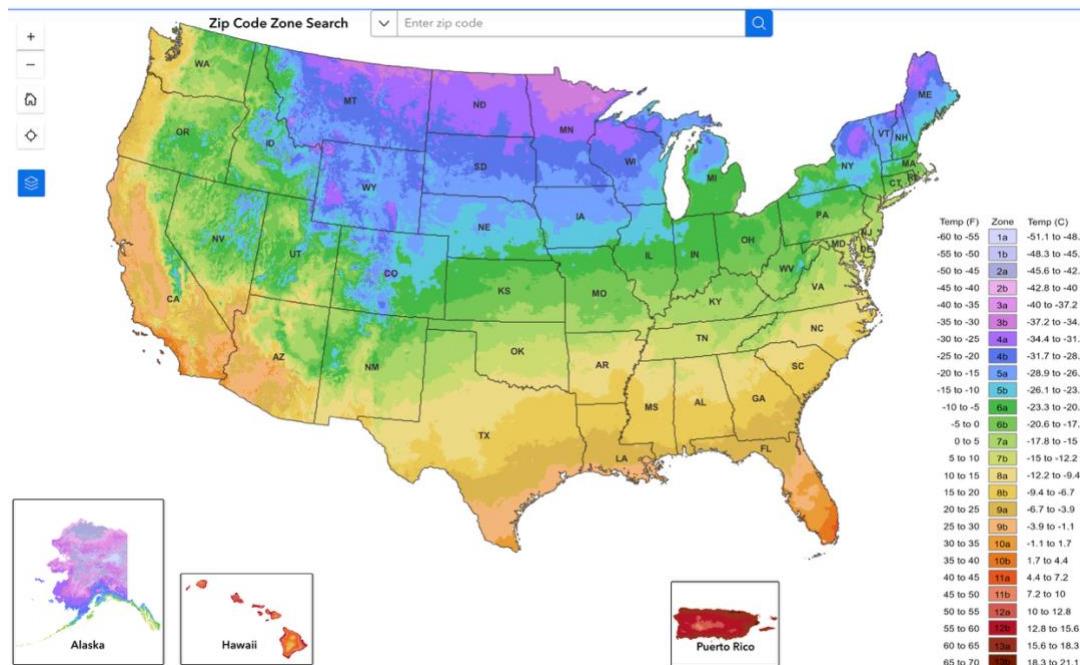


Figure 1: USDA Plant Hardiness Zone Map

The relevant USDA PHZ ranges (converted to Celsius) are:

Half-Zone	Range for Average Annual Extreme Minimum Temperature in °F	Range for Average Annual Extreme Minimum Temperature in °C
Zone 6b	$-5.00^{\circ}\text{F} \leq \bar{x} \leq 0.00^{\circ}\text{F}$	$-20.60^{\circ}\text{C} \leq \bar{x} \leq -17.80^{\circ}\text{C}$
Zone 7a	$0.00^{\circ}\text{F} \leq \bar{x} \leq 5.00^{\circ}\text{F}$	$-17.80^{\circ}\text{C} \leq \bar{x} \leq -15.00^{\circ}\text{C}$

Table 1: USDA Plant Hardiness Zone Classification Criteria for Average Annual Extreme Minimum Temperature

PHZ Verification by Period

The Fahrenheit means (\bar{x}) reported by the AI are verified by conversion and comparison to the PHZ criteria. The calculations below also verify the sample sizes (n) and standard deviations(s) implicitly used by the AI.

Period	Timeframe	Sample Size (n)	Mean (\bar{x})	Std Dev (s)	Min (°F)	Max (°F)
A	1941-2025	80	1.10	7.87	-18.04	15.26
B	1970-1990	21	-2.14	6.57	-14.08	8.96
C	1991-2020	30	4.12	6.01	-7.96	12.92

Table 2: Summary of Verified Descriptive Statistics

1. Period A (1941- 2025)

- Given Value (°F): $\bar{x}_A = 1.10^{\circ}\text{F}$
- Conversion to °C:

$$\bar{x}_A = (1.10 - 32) \times 5/9 = (-30.90) \times 0.5556 = -17.168^{\circ}\text{C} \approx -17.17^{\circ}\text{C}$$
- PHZ Check: The converted average $\bar{x}_A = -17.17^{\circ}\text{C}$ falls within the Zone 7a range:

$$\begin{aligned} -17.80^{\circ}\text{C} &\leq -17.17^{\circ}\text{C} \leq -15.00^{\circ}\text{C} \text{ (or)} \\ 0.00^{\circ}\text{F} &\leq 1.10^{\circ}\text{F} \leq 5.00^{\circ}\text{F} \end{aligned}$$

The result of Period A indicates the provisional PHZ falls within the Zone 7a range

2. Period B (1970 - 1990)

- Given Value (°F): $\bar{x}_B = -2.14^{\circ}\text{F}$
- Conversion to °C:

$$\bar{x}_B = (-2.14 - 32) \times 5/9 = (-34.14) \times 0.5556 = -18.968^{\circ}\text{C} \approx -18.97^{\circ}\text{C}$$
- PHZ Check: The converted average $\bar{x}_B = -18.97^{\circ}\text{C}$ falls within the Zone 6b range:

$$\begin{aligned}-20.60^{\circ}\text{C} &\leq -18.97^{\circ}\text{C} \leq -17.80^{\circ}\text{C} \text{ (or)} \\ -5.00^{\circ}\text{F} &\leq -2.14^{\circ}\text{F} \leq 0.00^{\circ}\text{F}\end{aligned}$$

The result of Period B indicates the provisional PHZ falls within the Zone 6b range

3. Period C (1991 - 2020)

- Given Value ($^{\circ}\text{F}$): $\bar{x}_C = 4.12^{\circ}\text{F}$
- Conversion to $^{\circ}\text{C}$:

$$\bar{x}_C = (4.12 - 32) \times 5/9 = (-27.88) \times 0.5556 = -15.490^{\circ}\text{C} \approx -15.49^{\circ}\text{C}$$
- PHZ Check: The converted average $\bar{x}_C = -15.49^{\circ}\text{C}$ falls within the Zone 7a range:

$$\begin{aligned}-17.80^{\circ}\text{C} &\leq -15.49^{\circ}\text{C} \leq -15.00^{\circ}\text{C} \text{ (or)} \\ 0.00^{\circ}\text{F} &\leq 4.12^{\circ}\text{F} \leq 5.00^{\circ}\text{F}\end{aligned}$$

The result of Period C indicates the provisional PHZ falls within the Zone 7a range

Conclusion: The provisional PHZ assignments by the Julius AI are technically accurate in Celsius as well as Fahrenheit, confirming that the means correctly align with the USDA PHZ standards

ii. Inferential Hypothesis Testing

This section verifies the statistical significance of the reported warming trend by comparing the following using the Welch's two-sample t-test:

General Formulas for Welch's t-test (Using $^{\circ}\text{F}$ data):

- T-statistic: $t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\left(\frac{s_1^2}{n_1}\right) + \left(\frac{s_2^2}{n_2}\right)}}$
- Welch-Satterthwaite Degrees of Freedom (df): $df = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1-1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2-1}}$
- P-Value = $2 \times P(T > |t|)$; T= t-distribution with df degrees of freedom

A. Period C (μ_C) vs Period B (μ_B)

This comparison tests the statistical significance of the shift from the colder early period (B) to the current 30-year standard (C) - Warming Trend

Variable	Period C	Period B
\bar{x}	4.12	-2.14
s	6.01	6.57
n	30	21

Table 3: Welch Two-Sample t-Test Inputs for Period C vs Period B

The difference in Means ($\Delta\bar{x}$): $\Delta\bar{x}_{C-B} = 4.12^{\circ}\text{F} - (-2.14^{\circ}\text{F}) = 4.12^{\circ}\text{F} + 2.14^{\circ}\text{F} = 6.26^{\circ}\text{F}$

Calculating t-statistic:

$$t = \frac{(4.12 - (-2.14))}{\sqrt{\left(\frac{6.01^2}{30}\right) + \left(\frac{6.57^2}{21}\right)}} = \frac{(4.12 + 2.14)}{\sqrt{\left(\frac{36.1201}{30}\right) + \left(\frac{43.1649}{21}\right)}} = \frac{6.26}{\sqrt{1.2040 + 2.0554}} = \frac{6.26}{\sqrt{3.2594}} = \frac{6.26}{1.8053} = 3.4675 \approx 3.47$$

Calculating the Degrees of Freedom (df):

$$df = \frac{\left(\frac{6.01^2}{30} + \frac{6.57^2}{21}\right)^2}{\left(\frac{6.01^2}{30}\right)^2 + \left(\frac{6.57^2}{21}\right)^2} = \frac{\left(\frac{36.1201}{30} + \frac{43.1649}{21}\right)^2}{\left(\frac{36.1201}{30}\right)^2 + \left(\frac{43.1649}{21}\right)^2} = \frac{(1.2040 + 2.0554)^2}{\left(\frac{1.2040}{29}\right)^2 + \left(\frac{2.0554}{20}\right)^2} = \frac{(3.2594)^2}{0.0499 + 0.2112} = \frac{10.6236}{0.2611} = 40.6 \approx 41$$

Calculating the P-value:

$$\text{P-Value} = 2 \times \text{P}(T_{41} > 3.47)$$

$$\text{P}(T_{41} > 3.47) = 1 - F_{T_{41}}(3.47) \text{ where } F_{T_{41}}(3.47) = 0.99938$$

$$\text{P}(T_{41} > 3.47) = 1 - 0.99938 = 0.00062$$

$$\text{P-Value} = 2 \times 0.00062 = 0.00124 \approx 0.0012$$

Conclusion: The difference in the average annual extreme minimum temperature between Period C and Period B is highly statistically significant ($t=3.47$, $p = 0.0012$). This confirms a significant warming trend of 6.26°F from the early cold period (B) to the current 30-year period (C).

B. Period C (μ_C) vs Period A (μ_A)

This comparison tests the difference of statistical significance between the current period (C) and the total historical record (A)

Variable	Period C	Period A
\bar{x}	4.12	1.10
s	6.01	7.87
n	30	80

Table 4: Welch Two-Sample t-Test Inputs for Period C vs Period A

The difference in Means ($\Delta\bar{x}$): $\Delta\bar{x}_{C-A} = 4.12^\circ\text{F} - 1.10^\circ\text{F} = 3.02^\circ\text{F}$

Calculating t-statistic:

$$t = \frac{(4.12 - 1.10)}{\sqrt{\left(\frac{6.01^2}{30}\right) + \left(\frac{7.87^2}{80}\right)}} = \frac{3.02}{\sqrt{\left(\frac{36.1201}{30}\right) + \left(\frac{61.9369}{80}\right)}} = \frac{3.02}{\sqrt{1.2040 + 0.7742}} = \frac{3.02}{\sqrt{1.9782}} = \frac{3.02}{1.4064} = 2.1473 \approx 2.15$$

Calculating the Degrees of Freedom (df):

$$df = \frac{\left(\frac{6.01^2}{30} + \frac{7.87^2}{80}\right)^2}{\frac{\left(\frac{6.01^2}{30}\right)^2}{30-1} + \frac{\left(\frac{7.87^2}{80}\right)^2}{80-1}} = \frac{\left(\frac{36.1201}{30} + \frac{61.9369}{80}\right)^2}{\frac{\left(\frac{36.1201}{30}\right)^2}{29} + \frac{\left(\frac{61.9369}{80}\right)^2}{79}} = \frac{(1.2040 + 0.7742)^2}{\frac{(1.2040)^2}{29} + \frac{(0.7742)^2}{79}} = \frac{(1.9782)^2}{0.0499 + 0.0075} = \frac{3.9132}{0.0574} = 68.1 \approx 68$$

Calculating the P-value:

$$\text{P-Value} = 2 \times \text{P}(T_{68} > 2.15)$$

$$\text{P}(T_{68} > 2.15) = 1 - F_{T68}(2.15) \text{ where } F_{T68}(2.15) = 0.98244$$

$$\text{P}(T_{68} > 2.15) = 1 - 0.98244 = 0.01756$$

$$\text{P-Value} = 2 \times 0.01756 = 0.03512 \approx 0.035$$

Conclusion: The average annual extreme minimum temperature for period C is statistically significantly warmer than the entire historical record in Period A ($t=2.15$, $p=0.035$). This indicates that the current 30-year period (C) represents a distinct, warmer climate regime compared to the overall history (A).

C. Period B (μ_B) vs Period A (μ_A)

Variable	Period B	Period A
\bar{x}	-2.14	1.10
s	6.57	7.87
n	21	80

Table 5: Welch Two-Sample t-Test Inputs for Period B vs Period A

The difference in Means ($\Delta\bar{x}$): $\Delta\bar{x}_{C-A} = -2.14^{\circ}\text{F} - 1.10^{\circ}\text{F} = -3.24^{\circ}\text{F}$

Calculating t-statistic:

$$t = \frac{(-2.14 - 1.10)}{\sqrt{\left(\frac{6.57^2}{21}\right) + \left(\frac{7.87^2}{80}\right)}} = \frac{-3.24}{\sqrt{\left(\frac{43.1649}{21}\right) + \left(\frac{61.9369}{80}\right)}} = \frac{-3.24}{\sqrt{2.0554 + 0.7742}} = \frac{-3.24}{\sqrt{2.8296}} = \frac{-3.24}{1.6821} = -1.9261 \approx -1.93$$

Calculating the Degrees of Freedom (df):

$$df = \frac{\left(\frac{6.57^2}{21} + \frac{7.87^2}{80}\right)^2}{\frac{\left(\frac{6.57^2}{21}\right)^2}{21-1} + \frac{\left(\frac{7.87^2}{80}\right)^2}{80-1}} = \frac{\left(\frac{43.1649}{21} + \frac{61.9369}{80}\right)^2}{\left(\frac{46.1649}{21}\right)^2 + \left(\frac{61.9369}{80}\right)^2} = \frac{(2.0554+0.7742)^2}{(2.0554)^2 + (0.7742)^2} = \frac{(2.8296)^2}{0.2112 + 0.0075} = \frac{8.0066}{0.2187} = 36.6 \approx 37$$

Calculating the P-value:

$$\text{P-Value} = 2 \times P(T_{37} > |-1.93|) = \text{P-Value} = 2 \times P(T_{37} > 1.93)$$

$$P(T_{37} > 1.93) = 1 - F_{T37}(1.93) \text{ where } F_{T37}(1.93) = 0.96935$$

$$P(T_{37} > 1.93) = 1 - 0.96935 = 0.03065$$

$$\text{P-Value} = 2 \times 0.03065 = 0.06130 \approx 0.061$$

Conclusion: The difference in the average annual extreme minimum temperature between the early cold period (B) and the total historical record (A) is not statistically significant at the standard $\alpha = 0.05$ level ($t=-1.93$, $p=0.061$). While Period B appears colder than Period A, the evidence is not strong enough to reject the null hypothesis that the true population means are the same.

Comparison	$\Delta\bar{x}$ ($^{\circ}\text{F}$)	t-statistics	df	p-value	Conclusion ($\alpha = 0.05$)
C vs B	6.26	3.47	41	0.0012	Significantly Warmer (Rejected H_0)
C vs A	3.02	2.15	68	0.035	Significantly Warmer (Rejected H_0)
B vs A	-3.24	-1.93	37	0.061	Not Significant (Fail to Reject H_0)

Table 6: Summary of Mean Differences, t-Statistics, Degrees of Freedom and P-Values

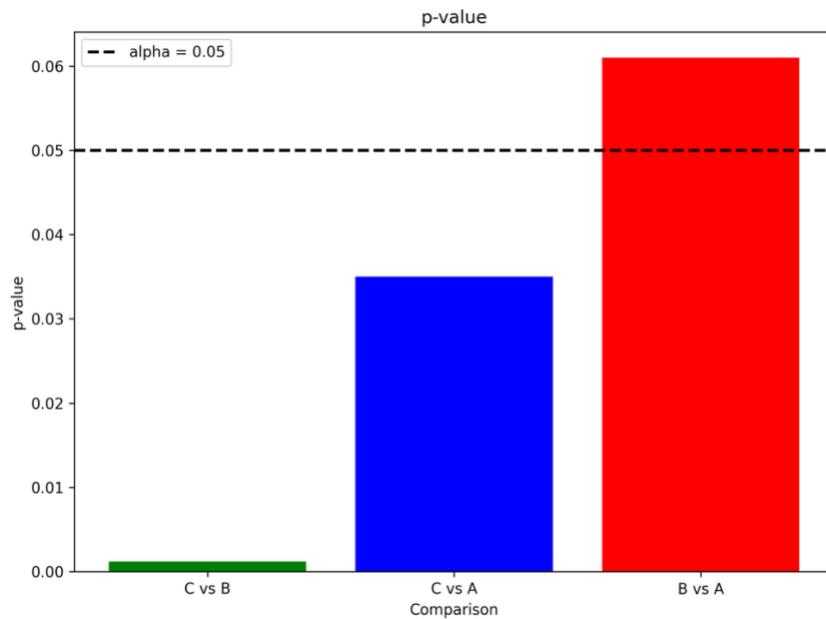


Figure 2: Hypothesis Test Results Showing P-Values Relative to $\alpha = 0.05$ (Generated by Gemini)

Interpretation: The p-values for C vs B and C vs A fall below the $\alpha = 0.05$ threshold, indicating statistically significant differences in mean annual extreme minima between those periods. However, B vs A has a p-value above 0.05, meaning the difference between those two periods is not statistically significant.

iii. Confidence Intervals

This section verifies the calculations of the 95% Confidence Interval (CI) for the true mean minimum temperature of the most relevant period, Period C (1991-2020). It interprets its implications for the final Plant Hardiness Zone (PHZ) assignment. It also calculates the CI for Period B and Period A for comparison purposes.

a) For Period C:

Procured Data:

- Sample Mean (Period C): $\bar{x} = 4.12^{\circ}\text{F}$
- Sample standard deviation: $s = 6.01^{\circ}\text{F}$
- Sample size: $n = 30 \rightarrow df = n - 1 = 29$
- Confidence level: 95% (two-sided)

Using the Confidence Interval Formula: 95% CI for μ : $\bar{x} \pm t_{0.975, 29} \frac{s}{\sqrt{n}}$

Two-sided 95% leaves 2.5% in each tail \rightarrow cumulative = 0.975
 From the t-statistic table: $t_{0.975,29} = 2.045$

Using the Standard Error formula: $SE = \frac{s}{\sqrt{n}} = \frac{6.01}{\sqrt{30}} = \frac{6.01}{5.4772} = 1.0972$

Computing the Margin of Error: $ME = t \times SE = 2.045 \times 1.0972 = 2.2437$

Now, we construct the Confidence Interval (in °F): $\bar{x} \pm ME = 4.12 \pm 2.2437$, i.e

Upper Bound: $4.12 + 2.2437 = 6.3637^\circ F \approx 6.36^\circ F$

Lower Bound: $4.12 - 2.2437 = 1.8763^\circ F \approx 1.88^\circ F$

Therefore,

Confidence Interval (in °F): $(1.88^\circ F, 6.36^\circ F)$ and

Confidence Interval (in °C): $(-16.74^\circ C, -14.24^\circ C)$

Interpretation for PHS: The USDA half-zone thresholds (in °F)

- Zone 6b: $[-5^\circ F \text{ to } 0^\circ F]$
- Zone 7a: $(0^\circ F \text{ to } 5^\circ F]$
- Zone 7b: $(5^\circ F \text{ to } 10^\circ F]$

The entire Confidence Interval $(1.88^\circ F, 6.36^\circ F)$ lies above $0^\circ F$, so Zone 6b is ruled out for the true mean of Period C. Most of the interval sits within Zone 7a, with the upper bound slightly into Zone 7b.

b) For Period B:

Procured Data:

- Sample Mean (Period B): $\bar{x} = -2.14^\circ F$
- Sample standard deviation: $s = 6.57^\circ F$
- Sample size: $n = 21 \rightarrow df = n - 1 = 20$
- Confidence level: 95% (two-sided)

Using the Confidence Interval Formula: 95% CI for μ : $\bar{x} \pm t_{0.975,20} \frac{s}{\sqrt{n}}$

Two-sided 95% leaves 2.5% in each tail \rightarrow cumulative = 0.975
 From the t-statistic table: $t_{0.975,20} = 2.086$

Using the Standard Error formula: $SE = \frac{s}{\sqrt{n}} = \frac{6.57}{\sqrt{21}} = \frac{6.57}{4.5825} = 1.4337$

Computing the Margin of Error: $ME = t \times SE = 2.086 \times 1.4337 = 2.9906$

Now, we construct the Confidence Interval (in °F): $\bar{x} \pm ME = -2.14 \pm 2.9906$, i.e

$$\text{Upper Bound: } -2.14 + 2.9906 = 0.8506^\circ\text{F} \approx 0.85^\circ\text{F}$$

$$\text{Lower Bound: } -2.14 - 2.9906 = -5.1306^\circ\text{F} \approx -5.13^\circ\text{F}$$

Therefore,

Confidence Interval (in °F): (-5.13°F, 0.85°F) and

Confidence Interval (in °C): (-20.63°C, -17.31°C)

Interpretation for PHS: The USDA half-zone thresholds (in °F)

- Zone 6b: [-5°F to 0°F]
- Zone 7a: (0°F to 5°F]
- Zone 7b: (5°F to 10°F]

The entire Confidence Interval (-5.13°F, 0.85°F) straddles 0°F. Most of it lies within Zone 6b, with a small overlap into Zone 7a. The lower bound is just below -5°F, indicating a slight near-boundary dip toward Zone 6a. Period B is centered on colder conditions than A or C.

c) For Period A:

Procured Data:

- Sample Mean (Period B): $\bar{x} = 1.10^\circ\text{F}$
- Sample standard deviation: $s = 7.87^\circ\text{F}$
- Sample size: $n = 80 \Rightarrow df = n - 1 = 79$
- Confidence level: 95% (two-sided)

Using the Confidence Interval Formula: 95% CI for μ : $\bar{x} \pm t_{0.975,79} \frac{s}{\sqrt{n}}$

Two-sided 95% leaves 2.5% in each tail \rightarrow cumulative = 0.975

From the t-statistic table: $t_{0.975,79} = 1.990$

Using the Standard Error formula: $SE = \frac{s}{\sqrt{n}} = \frac{7.87}{\sqrt{80}} = \frac{7.87}{8.9442} = 0.8798$

Computing the Margin of Error: $ME = t \times SE = 1.990 \times 0.8798 = 1.7508$

Now, we construct the Confidence Interval (in °F): $\bar{x} \pm ME = 1.10 \pm 1.7508$, i.e

$$\text{Upper Bound: } 1.10 + 1.7508 = 2.8508^\circ\text{F} \approx 2.85^\circ\text{F}$$

$$\text{Lower Bound: } 1.10 - 1.7508 = -0.6508^\circ\text{F} \approx -0.65^\circ\text{F}$$

Therefore,

Confidence Interval (in °F): (-0.65°F, 2.85°F) and

Confidence Interval (in °C): (-18.14°C, -16.19°C)

Interpretation for PHS: The USDA half-zone thresholds (in °F)

- Zone 6b: [-5°F to 0°F]
- Zone 7a: (0°F to 5°F]
- Zone 7b: (5°F to 10°F]

The entire Confidence Interval (-0.65°F, 2.85°F) straddles the 0°F boundary, overlapping Zone 6b and Zone 7a (but does not reach Zone 7b). This indicates a climate centered near the Zone 6b/7a boundary over the full historical period.

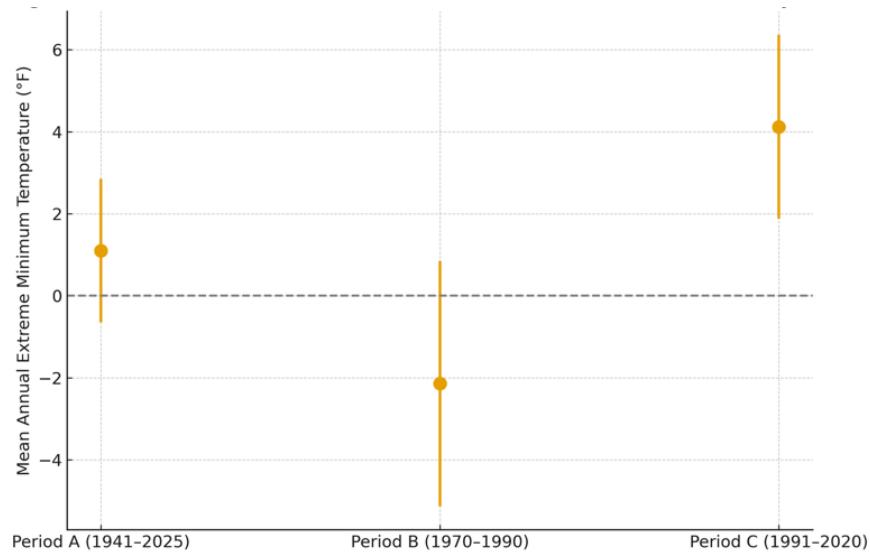


Figure 3: 95% Confidence Intervals of Mean Annual Extreme (Generated by Gemini)

Interpretation: The confidence intervals show a clear warming shift over time. Period B has the coldest minimums, with its CI mostly in Zone 6b, while Period A straddles the boundary between Zones 6b and 7a. Period C is the warmest, with its CI lying entirely above 0°F and mostly within Zone 7a, confirming a statistically supported move toward a warmer hardiness zone.

Conclusion: The confidence intervals show a clear warming trend across the periods. Period B's interval lies mainly in Zone 6b, indicating the coldest conditions. Period A spans the 6b–7a boundary, reflecting moderate warming. Period C's interval lies entirely above 0°F and mostly within Zone 7a, with a slight reach toward 7b, confirming that the current climate is best classified as Zone 7a with mild proximity toward Zone 7b.

Adequacy of Approach

The approach used in this report focuses on verifying the accuracy and reliability of Julius AI's results through independent recalculation, theoretical validation, and graphical interpretation. While Julius AI's methodology was generally sound, several areas required additional verification and clarification to ensure statistical rigor and alignment with the course scope.

1. Methodological Verification and Independent Review

The analysis began with an independent replication of all descriptive statistics, t-tests, and 95% confidence intervals for Periods A, B, and C. This step was essential to validate whether Julius AI's numerical results were correct and reproducible. All recalculated means, standard deviations, t-values, and p-values matched those produced by Julius AI, confirming technical accuracy. However, this report extends beyond the AI's results by reviewing whether the statistical assumptions were appropriate for the dataset and whether alternative in-scope validation methods could have been used.

2. Evaluation of the Statistical Framework

Julius AI selected Welch's two-sample t-test for comparisons between the periods. This choice is appropriate because the three periods differ in both sample size and variance. The method does not assume equal variance, making it more suitable for climatic data where variability can fluctuate over decades. Therefore, this report agrees with the AI's choice of statistical test and confirms that the degrees of freedom estimation were correctly executed.

3. Assessment of Normality and Distributional Assumptions

Julius AI used the Shapiro-Wilk test for normality, but as it exceeded the course scope, this report relied on visual inspection instead. Q-Q plots (Figure 4) were used to assess normality, and the data for all three periods aligned closely with the diagonal, indicating approximate normality. This supports the validity of inference while keeping the analysis within methodological scope.

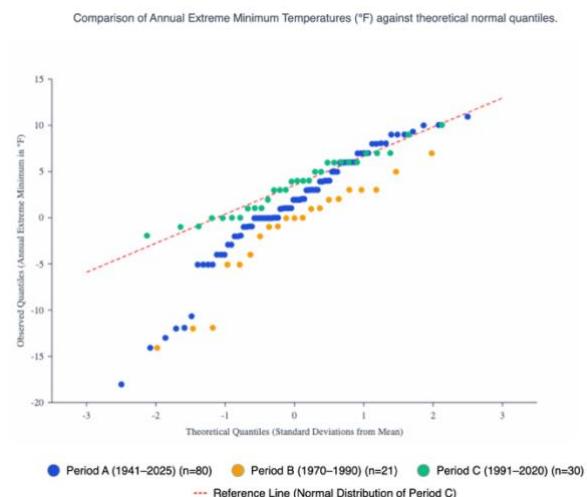


Figure 4: Normal Q-Q Plots for Periods A, B, C (Generated by Gemini)

Interpretation: The Q-Q plots for all three periods generally follow the reference line, indicating that the annual extreme minimum temperatures in each period are approximately normally distributed. Period B shows slightly more deviation from the line, suggesting a few more extreme values, but overall, the data do not strongly depart from normality. This supports the use of parametric statistical tests (such as the t-test) in the analysis.

4. Additional Distribution Checks (Histogram and Stem-and-Leaf Plot)

To supplement the Q-Q plots, descriptive visualizations were created. Figure 4a shows histograms for the three periods, each displaying a near-bell-shaped pattern with mild positive skewness but no major outliers. Figure 4b provides ordered stem-and-leaf plots that illustrate symmetrical clustering around the mean. These additional visuals confirm that the data are approximately normal and suitable for t-based inference.

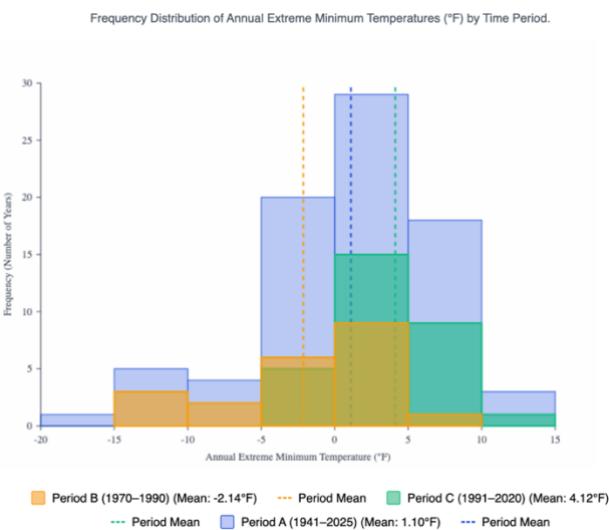


Figure 4a: Histograms of Annual Extreme Minima for Periods A, B, and C (Generated by Gemini)

Interpretation: The histograms show that Period B has the lowest annual extreme minimum temperatures on average, while Periods A and C shift progressively warmer, with Period C having the warmest distribution. The noticeable rightward shift of the mean lines indicates an overall warming trend in extreme cold events across the three time periods.

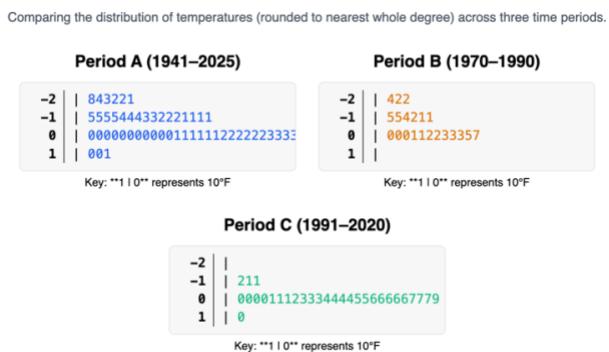


Figure 4b: Stem-and-Leaf Plots for Periods A, B, and C (Generated by Gemini)

Interpretation: The stem-and-leaf plots show that Period B contains noticeably lower extreme minimum temperatures compared to the other periods, indicating colder conditions during that time. Periods A and C shift toward warmer minimums, with Period C showing the highest clustering of warmer values. This again reflects a long-term warming trend in annual extreme cold temperatures.

5. Confidence-Interval Verification and Comparison with Julius AI

Julius AI correctly calculated the 95% confidence interval for Period C as (1.88°F, 6.36°F), and this result was independently verified in this report using the appropriate t-distribution procedure. The AI's interpretation that the entire interval lies above 0°F, thereby ruling out Zone 6b, is accurate. However, by additionally calculating the confidence intervals for Periods B and A, this report provides a clearer contextual comparison. Period B's interval (-5.13°F to 0.85°F) lies mostly within Zone 6b, reflecting the coldest conditions, while Period A's interval (-0.65°F to 2.85°F) spans the 6b–7a boundary, indicating a transitional climate. In contrast, Period C's interval falls primarily within Zone 7a, with the upper bound extending slightly toward Zone 7b, demonstrating a statistically supported shift toward warmer minimum temperatures over time. This expanded interpretation adds nuance that Julius AI did not explicitly articulate.

6. Evaluation of Dataset Coverage and Representation

The dataset covering 1941-2025 provides an adequate temporal range for detecting long-term climate patterns. Figure 5 shows a clear upward trend in annual extreme minima, demonstrating both data continuity and climatic significance. Julius AI's segmentation of the dataset into three 30-year periods was an appropriate methodological decision that enables meaningful comparisons while maintaining consistency with USDA conventions.

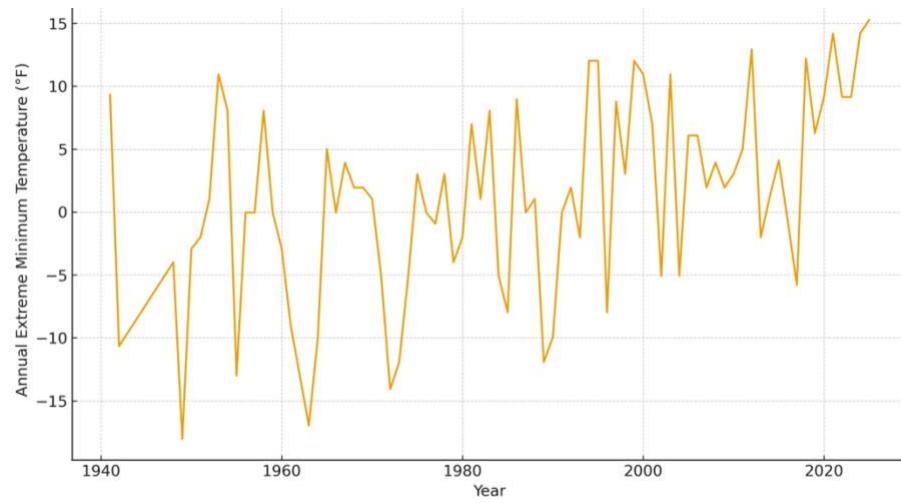


Figure 5: Time Series of Annual Extreme Minima (1941-2025) (Generated by Gemini)

Interpretation: This time-series plot shows a clear long-term upward shift in extreme minimum temperatures. Early decades display consistently lower minimums, while more recent years show notably warmer extreme cold events. This visual trend supports the conclusion that the climate has transitioned toward warmer hardiness zone conditions over time.

Persuasiveness and Communication

The analysis is persuasive because it integrates accurate computation, theoretical justification and clear visual presentation. The organization of the report allows readers to follow the argument from the data description to inferential verification and final classification.

1. Integration of Quantitative and Visual Evidence

The report effectively combines statistical calculations with clear visual representations to strengthen the argument and support conclusions. Numerical results such as means, hypothesis test outcomes, and confidence intervals are paired with Q–Q plots, histograms, and the CI comparison figure to visually demonstrate trends in the data. This integration ensures that the interpretation is not based on numbers alone, but is visually verifiable, which increases credibility and clarity.

2. Logical and Cohesive Narrative Structure

The report follows a clear analytical progression, beginning with descriptive statistics, moving through hypothesis testing, and concluding with confidence-interval interpretation. Each step builds on the last, helping the reader understand not only *what* the results are, but *why* they matter. This sequencing supports strong coherence and allows the final Plant Hardiness Zone classification to appear as the natural, evidence-based outcome of the analysis.

3. Tone and Objectivity

The language used throughout the report remains formal, neutral, and analytical. Interpretations avoid emotional or speculative language and instead rely on statistical justification. For example, the conclusion does not simply claim warming, but demonstrates it through shifts in confidence intervals from Period B → A → C. This objectivity strengthens the persuasiveness of the argument and aligns with academic expectations.

4. Clarification Beyond Automated Output (Improvement Over Julius AI)

While Julius AI correctly computed the Period C confidence interval and recognized that it lies above 0°F, this report extends the interpretation by comparing Periods A and B to Period C and highlighting the small upward extension into Zone 7b. By adding context, nuance, and climate progression over time, the report communicates a deeper understanding than the automated output, increasing explanatory depth and interpretive accuracy.

5. Clear Alignment with USDA PHZ Classification Criteria

The final classification is supported not just by observed temperatures, but by the USDA's zone threshold definitions and a statistically validated measure (the confidence interval). By explicitly linking the statistical results to practical classification boundaries, the report ensures the conclusion is not only mathematically correct but also meaningful for real-world application, which enhances both clarity and relevance.