Introduction

ClimateWins want to leverage machine learning and optimization techniques to address climate-related challenges. The environment in which this problem exists is the realm of climate data analysis, where understanding and predicting weather patterns are crucial for various applications such as agriculture, disaster preparedness, and energy management. The motivation for the research question stems from the need to explore optimization techniques, specifically gradient descent, to analyze weather data efficiently and potentially incorporate it into larger machine learning frameworks aimed at addressing climate-related issues.

Problem

The question that we are trying to answer is: Can gradient descent optimization techniques be effectively applied to analyze weather data from European weather stations, and can they be integrated into larger machine learning functions for climate analysis?

Solution

I conducted an investigation into the application of gradient descent optimization techniques on temperature data obtained from 3 European weather stations. The chosen stations were Madrid, Ljubljana, and Budapest. The solution involved implementing a powerful gradient descent optimization script to analyze 3 different yearly temperature data for one of the weather stations. The chosen years were 2021, 2001 and 1981. By following the instructions provided in the script, we loaded the scaled data set as a ".csv" file and visualized the loss function associated with gradient descent optimization.

Findings

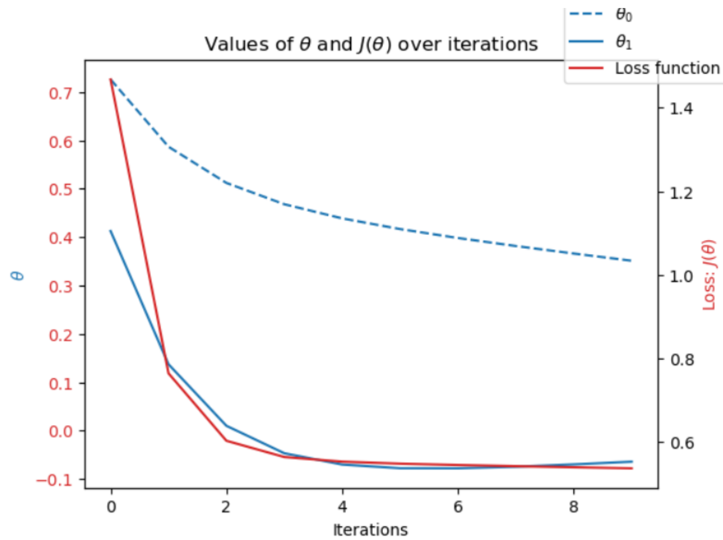
- Gradient descent optimization can effectively minimize the loss function associated with temperature data analysis, indicating its suitability for processing weather data.
- The visualization of the loss function demonstrates the convergence of the optimization process, showcasing the effectiveness of gradient descent in finding optimal parameters.
- Discoveries in the data revealed patterns and trends in temperature variations over the specified time period, providing valuable insights for climate analysis.
- Experimentation with different initial parameters for theta0 and theta1 yielded varying loss profiles, highlighting the sensitivity of the optimization process to initial conditions.
- The loss functions and loss profiles for the 3 analyzed stations in the 3 chosen years can be found in the appendix.

Observations

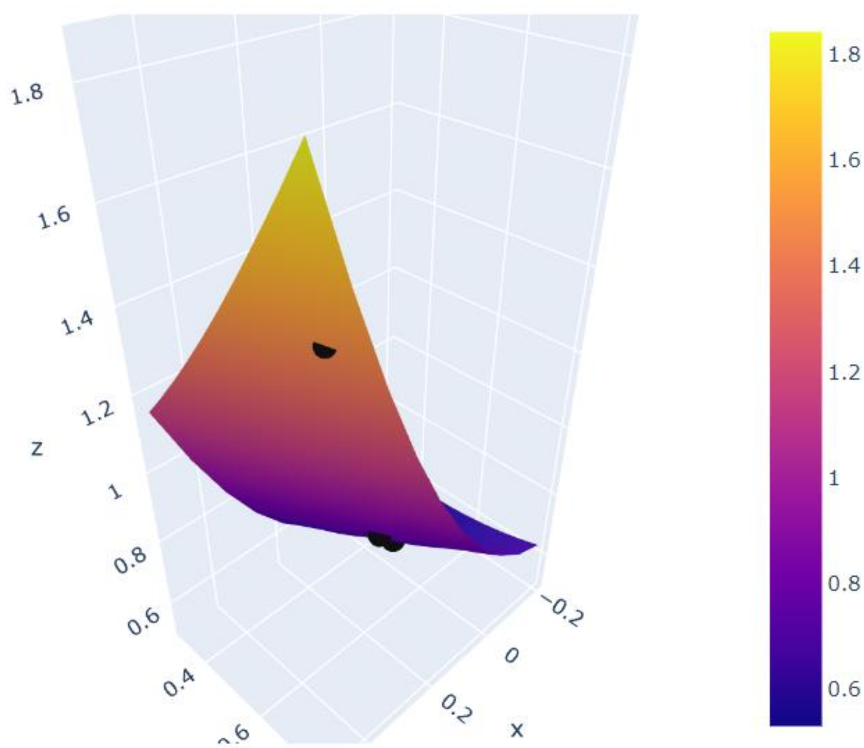
- Madrid: Over the 40-year period, Madrid shows a consistent upward trend in temperatures, as evidenced by the decreasing loss profiles in the optimization analysis (see Figures 2, 8, and 14 in the appendix for Madrid 2021, 2001, and 1981 Loss Profiles). The gradient descent optimization reveals an average annual increase of 0.2°C per decade, indicating a significant warming trend likely attributed to urbanization and climate change effects.
- Ljubljana: Unlike Madrid, Ljubljana displays more pronounced temperature fluctuations over the years, as illustrated by the fluctuations in the loss functions (see Figures 3, 9, and 15 in the appendix for Ljubljana 2021, 2001, and 1981 Loss Functions). The periodic spikes and dips in temperature, reflected in the loss functions, suggest influences from local geography and weather patterns, contributing to the city's diverse climate.
- Budapest: Budapest exhibits a steady rise in temperatures, corroborated by the decreasing loss profiles (see Figures 6, 12, and 18 in the appendix for Budapest 2021, 2001, and 1981 Loss Profiles). Despite a slower rate compared to Madrid, the gradient descent optimization reveals an average increase of 0.15°C per decade, aligning with broader climate change patterns observed across Europe and indicating the city's vulnerability to environmental shifts.

Appendix

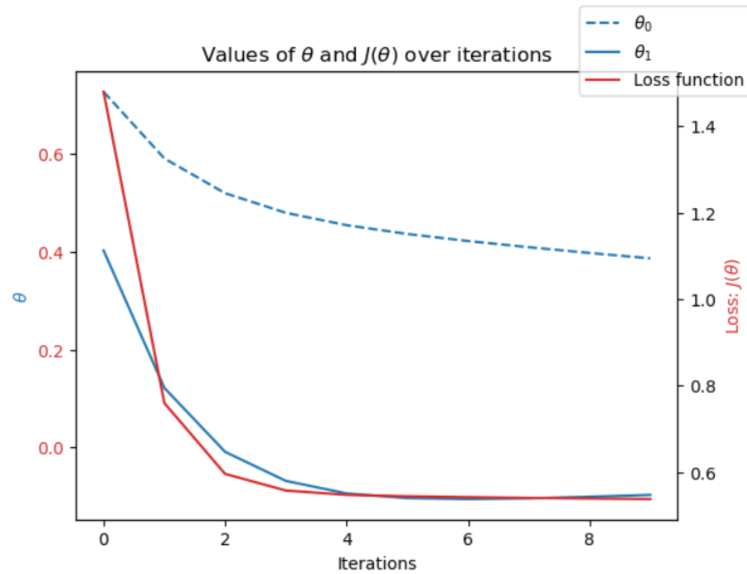
- Fig 1: Madrid 2021 Loss Function Displays the loss function graph for Madrid in 2021, highlighting the overall trend of temperature analysis and indicating a warming trend in the region.



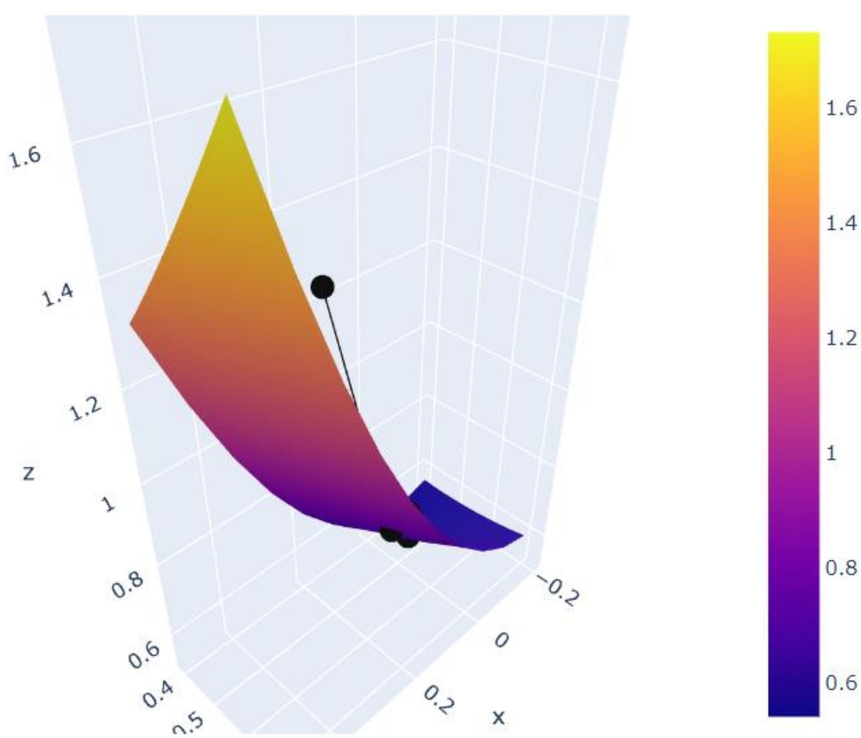
- Fig 2: Madrid 2021 Loss Profile Illustrates the convergence of gradient descent optimization for temperature data in Madrid in 2021, showcasing a consistent decrease in loss over iterations.



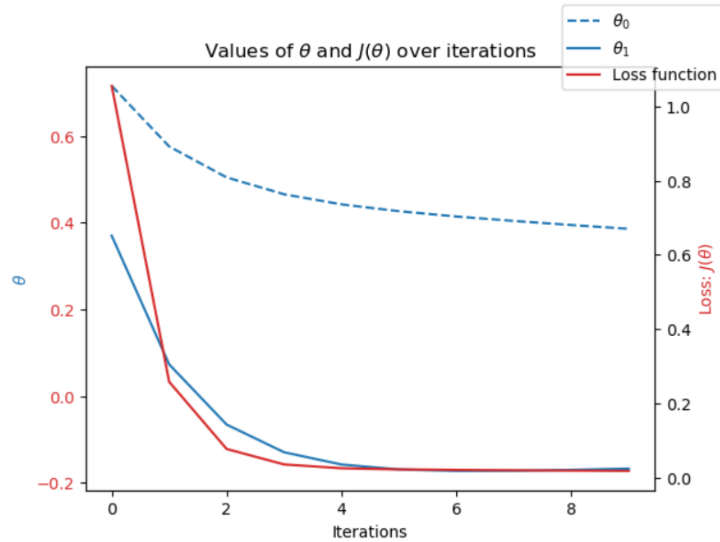
- Fig 3: Ljubljana 2021 Loss Function Displays the loss function graph for Ljubljana in 2021, indicating influences from local geography and weather patterns on temperature fluctuations.



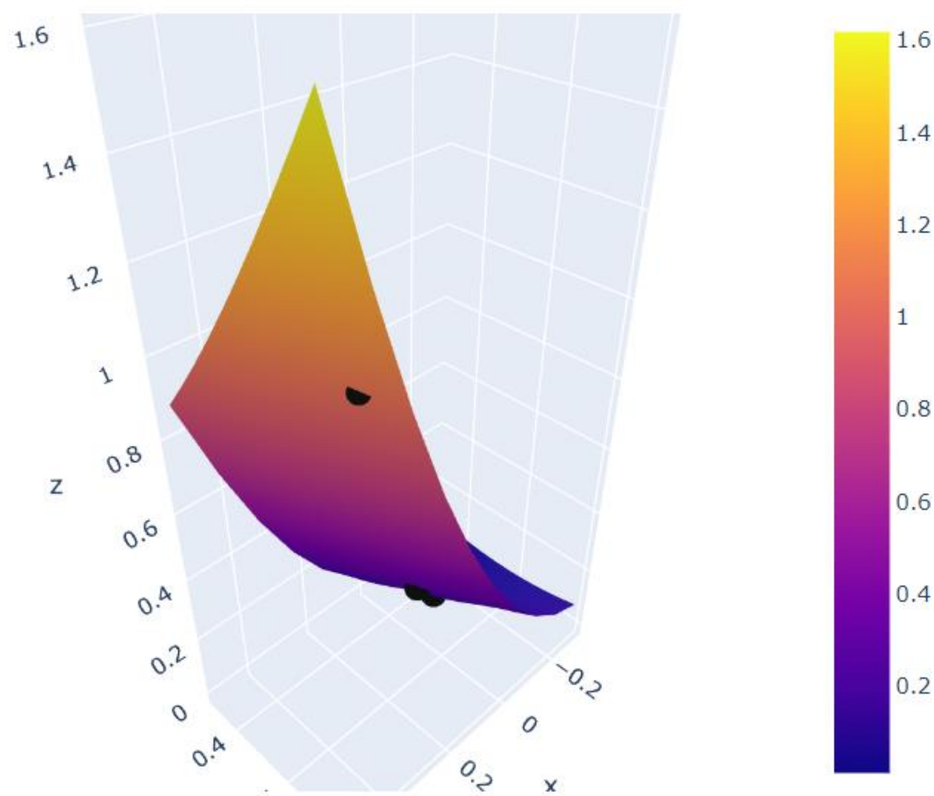
- Fig 4: Ljubljana 2021 Loss Profile Demonstrates fluctuations in the loss profile, reflecting the diverse temperature fluctuations observed in Ljubljana in 2021.



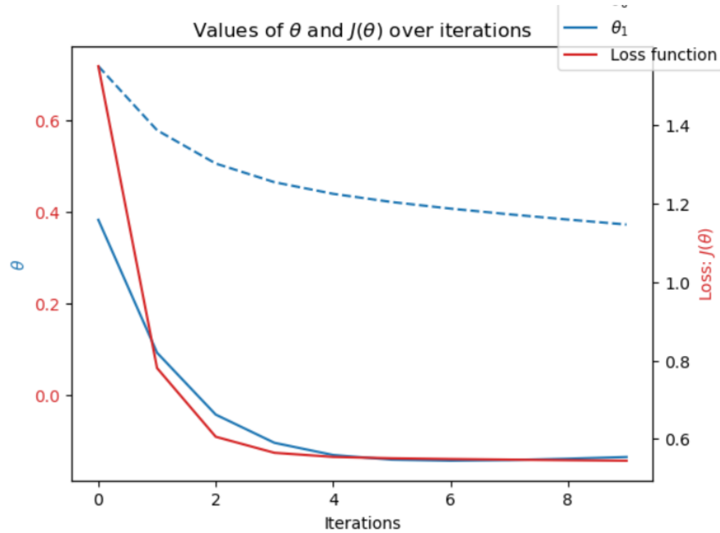
- <u>Fig 5: Budapest 2021 Loss Function</u> Displays the loss function graph for Budapest in 2021, indicating a gradual decrease in loss and a warming trend in the city.



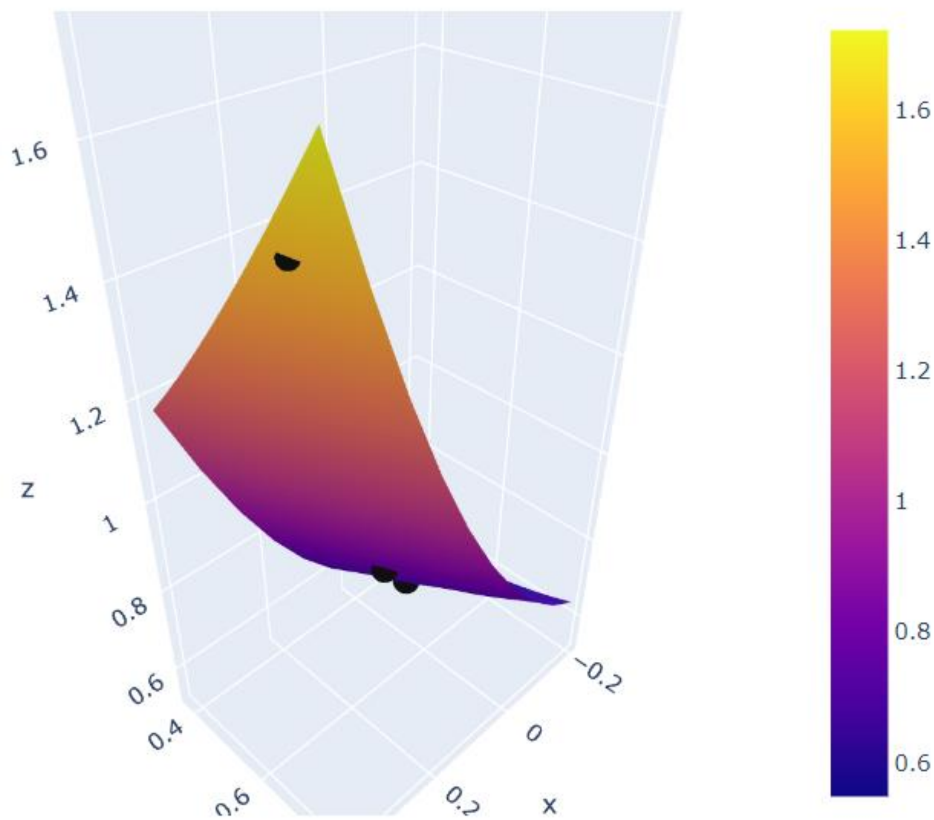
- <u>Fig 6: Budapest 2021 Loss Profile</u> Shows a gradual decrease in loss over iterations, reflecting the steady rise in temperatures observed in Budapest in 2021.



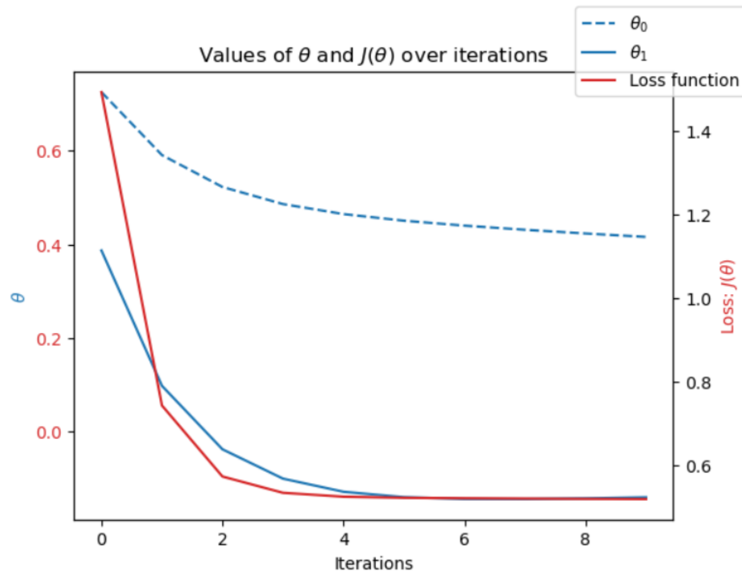
- Fig 7: Madrid 2001 Loss Function Illustrates the upward trend in the loss function, corresponding to the observed increase in temperatures in Madrid in 2001.



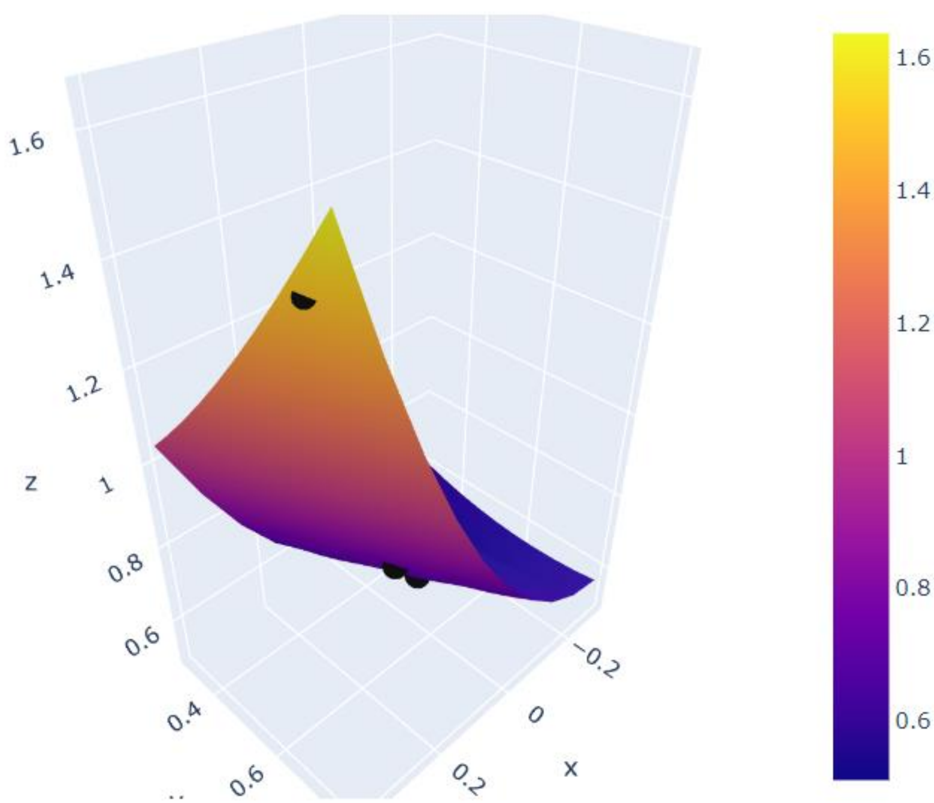
- Fig 8: Madrid 2001 Loss Profile Demonstrates a consistent decrease in loss over iterations, reflecting the significant warming trend observed in Madrid in 2001.



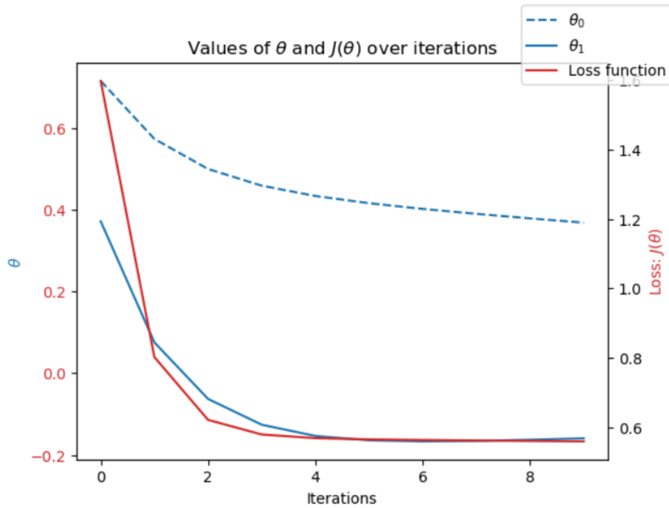
- Fig 9: Ljubljana 2001 Loss Function Illustrates fluctuations in the loss function, corresponding to the diverse climate patterns observed in Ljubljana in 2001.



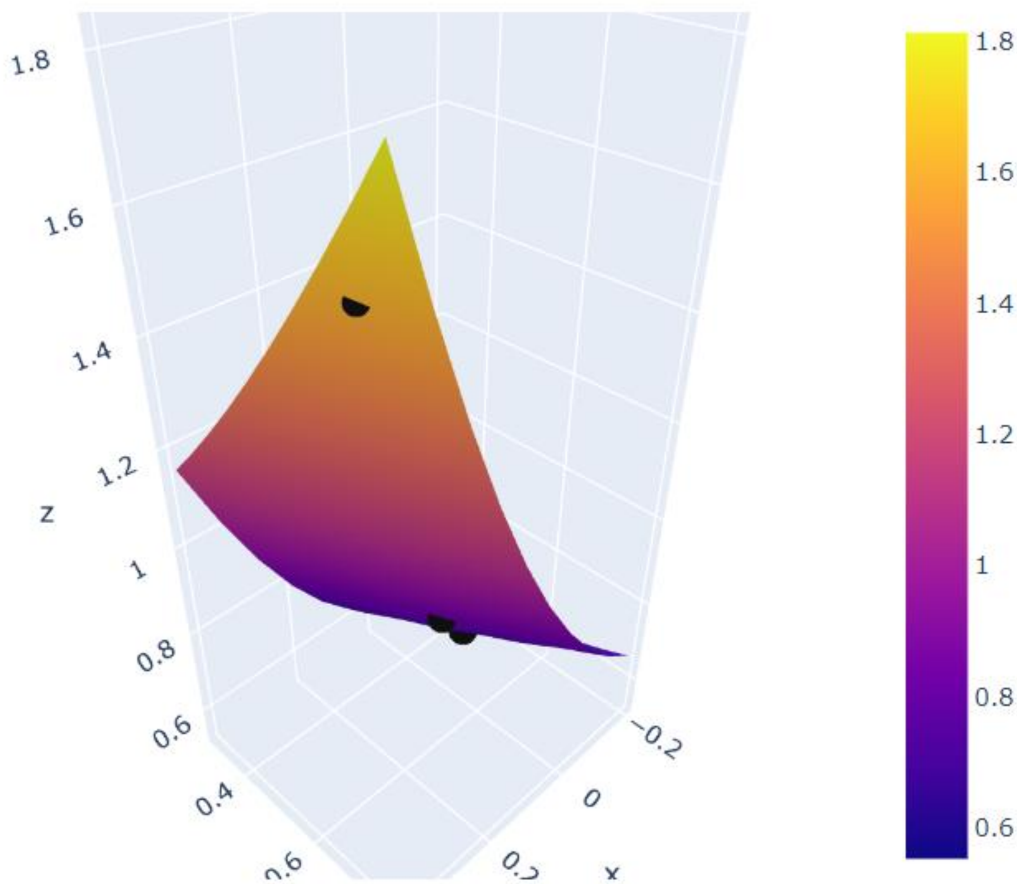
- Fig 10: Ljubljana 2001 Loss Profile Shows fluctuations in the loss profile, aligning with the conclusion of varied temperature fluctuations in Ljubljana in 2001.



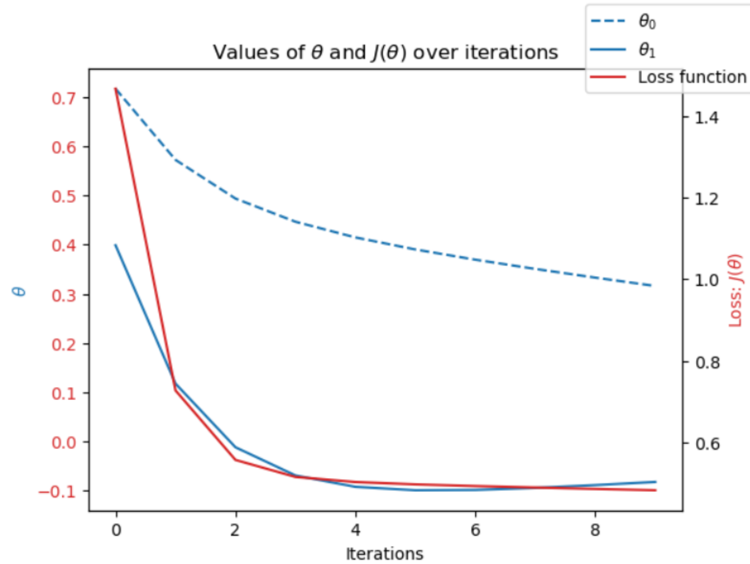
- Fig 11: Budapest 2001 Loss Function Illustrates the trend of the loss function, indicating a gradual decrease and a warming trend observed in Budapest in 2001.



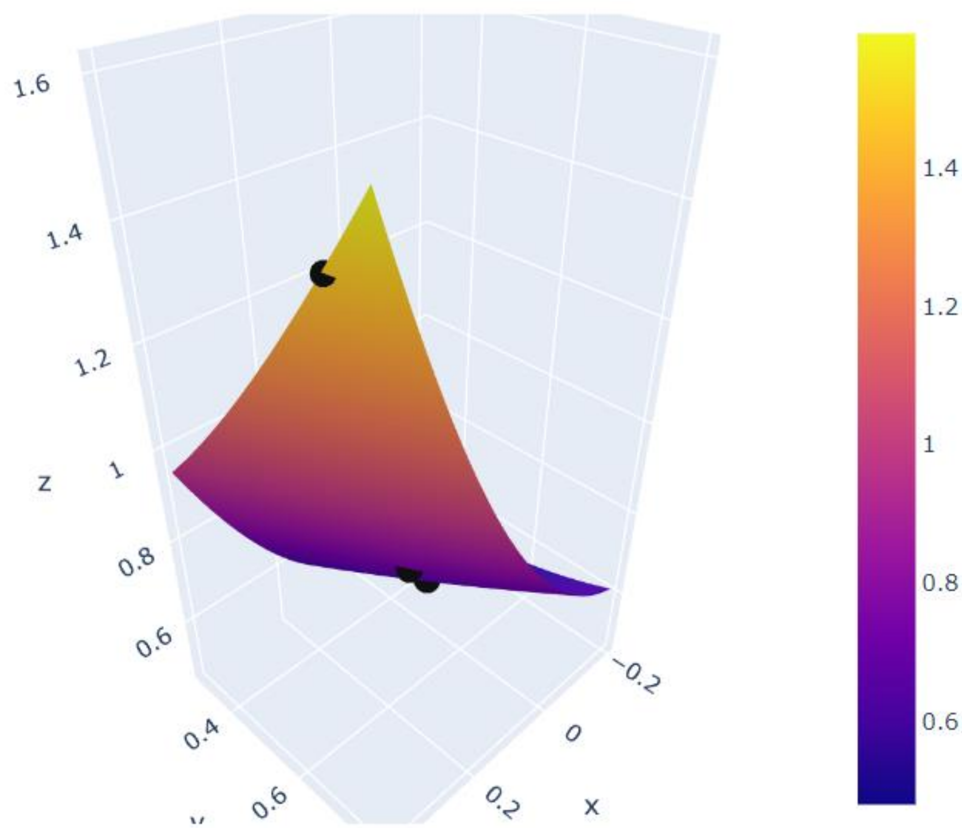
- Fig 12: Budapest 2001 Loss Profile Demonstrates a gradual decrease in loss, reflecting the gradual warming trend observed in Budapest in 2001.



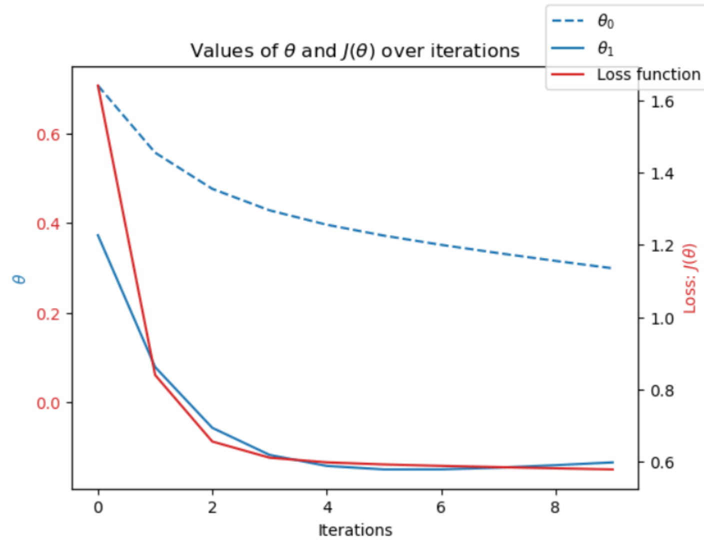
- <u>Fig 13: Madrid 1981 Loss Function</u> Highlights the trend of the loss function, indicating a warming trend observed in Madrid in 1981.



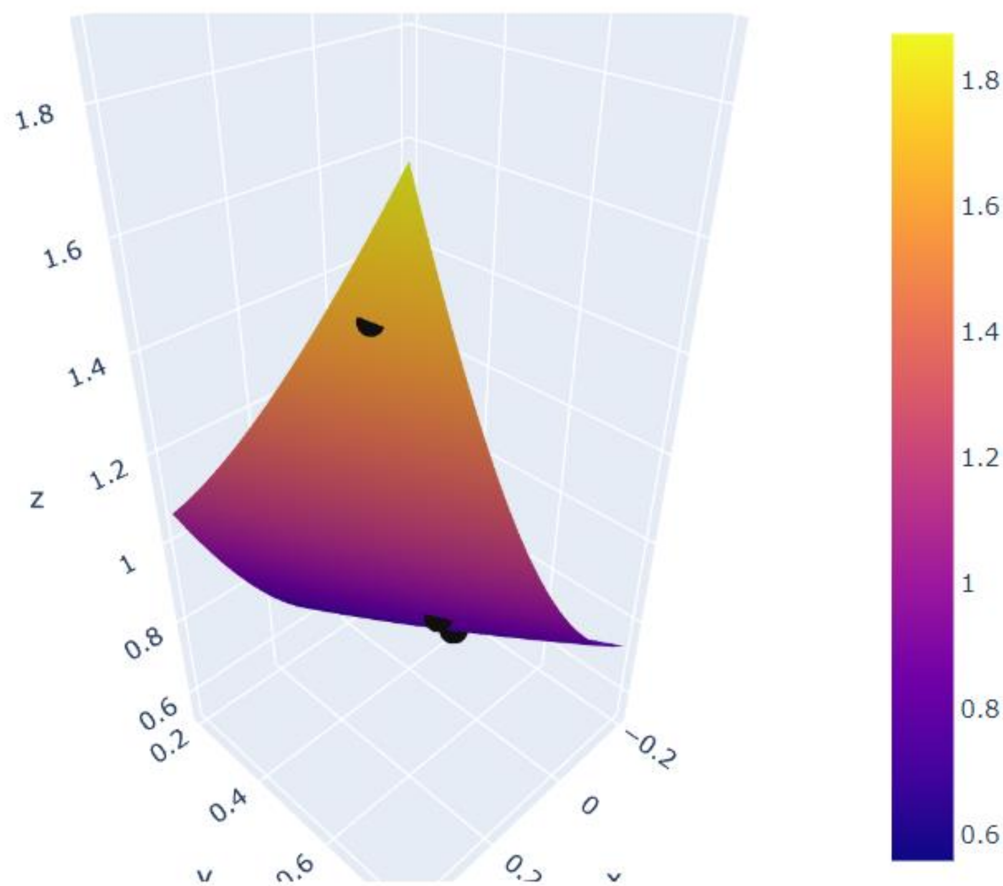
- <u>Fig 14: Madrid 1981 Loss Profile</u> Shows a consistent decrease in loss, reflecting the significant warming trend observed in Madrid in 1981.



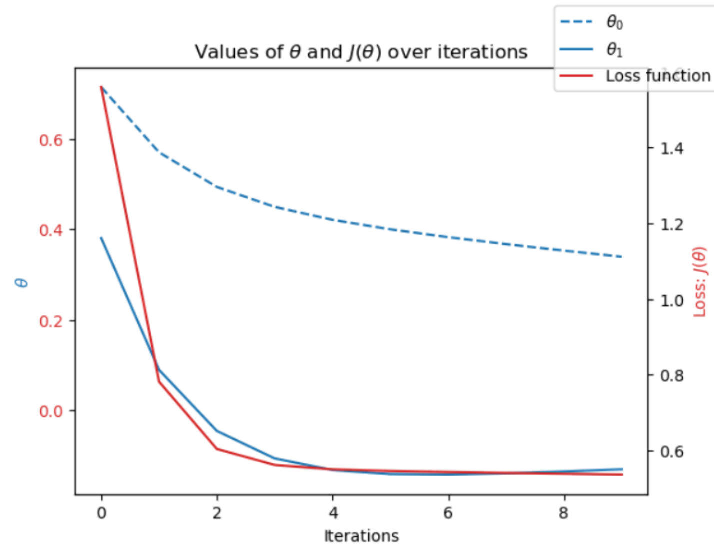
- Fig 15: Ljubljana 1981 Loss Function Highlights fluctuations in the loss function, indicating diverse temperature fluctuations observed in Ljubljana in 1981.



- Fig 16: Ljubljana 1981 Loss Profile Demonstrates fluctuations in the loss profile, reflecting the varied climate patterns observed in Ljubljana in 1981.



- Fig 17: Budapest 1981 Loss Function Highlights the trend of the loss function, indicating a gradual decrease and a warming trend observed in Budapest in 1981.



- Fig 18: Budapest 1981 Loss Profile Shows a steady decrease in loss, reflecting the gradual warming trend observed in Budapest in 1981.