Abstract

This study analyzes the impact of the El Niño phenomenon on rainfall, temperature, and humidity in Bogotá, Colombia, using trends and anomalies observed in 2024 in comparison to other years, such as 2016. The research questions are how El Niño impacts these climatic variables and how 2024 conditions are different from the past. The hypotheses presume that El Niño events result in less rainfall, higher temperatures, and lower humidity in Bogotá, with 2024 presenting significant differences from other years. Contrary to this, using data from a meteorological station, NASA Global Data, and Looker Studio, the research determines that El Niño years are associated with greater rainfall (112% more than La Niña) and comparatively warmer temperatures (0.89°C warmer). The humidities are variable, with El Niño having stronger precipitation and humidity correlations. The study shows that El Niño enhances normal precipitation cycles while maintaining elevated temperatures. Bogotá underwent anomalous tendencies in 2024, with decreased reservoir levels due to reduced rainfall and a delayed timing of extreme rainfall totals, which reveals the susceptibility of the city to climatic change. These results underscore the importance of understanding the regional impacts of El Niño for the effective management of water resources and disaster preparedness.

Impacts of El Niño on Precipitation, Temperature, and Humidity in Bogotá, Colombia: Trends, Anomalies, and Comparative Analysis of 2024 Climatic Shifts

Martin Ramirez- Student

Julian Andres Melo- Student

Tomas Chaves- Student

Matthew Douglas Reis- GLOBE Advisor

March 5, 2025

Research question and Hypothesis

The first research question stated was “How is the phenomenon El Niño affecting the amount of precipitation, outside temperature and humidity in Bogotá, Colombia in terms of trends and anomalies”

The second research question stated was “How do the levels of precipitation, outside temperature, and humidity in 2024 compare to those in previous years (e.g., 2016) in terms of trends and anomalies?” We proposed the first hypothesis:

Null Hypothesis: There is no difference in trends

Alternative Hypothesis: There are differences in the trends.

The hypothesis that was created is "During the El Niño event in 2024, Bogotá, Colombia will experience reduced precipitation, higher-than-average temperatures, and lower humidity levels compared to previous years.”

The second hypothesis that was created “In 2024, the levels of precipitation will be significantly lower, the outside temperature will be higher, and the humidity levels will be more variable compared to 2023, reflecting anomalous trends associated with climatic shifts such as El Niño or other regional factors.”

Background Information. El Niño is a naturally occurring phenomenon that fishermen off the coast of Peru discovered with unusually warm water. According to National Geographic “El Niño is a climate pattern that describes the unusual warming of surface waters in the eastern tropical Pacific Ocean. El Niño is the “warm phase” of a larger phenomenon called the El Niño-Southern Oscillation (ENSO).” El Niño has an impact on the ocean temperatures, the speed and strength, the health of fish life and the local weather from South America. El Niño occurs at 2 to 7 year intervals, it's not a predictable phenomenon. La Niña is defined as the climate pattern that describes the cooling of the surface ocean water which can be the considered the cold part of the ENSO, this happens due to the decrease in the temperature of the waters in the tropical pacific, this happens when unusually strong winds coming from the east bring the water to the surface. Both climate patterns have recently affected Colombia, and Bogota, in this year because of the high temperatures in the pacific coast it also reduced the amount of water that reached its end in may 2024 still affects Bogota, due to the lack of rainfall the city had, depleting the reservoirs of water. To put this into perspective the reservoir San Rafael fell from 60% to 16% in this time span. In order to ration the water usage by dividing the city into 9 areas that are cut from water supply for 24 hours. After this event, in November large amounts of rain have affected the traffic in the city causing schools to evacuate or shut down for days at a time, there were schools that had to keep students in the school because it was impossible to take them home.

Materials and Methods

- Meteorological station
- Computers
- NASA Global Data
- Looker Studio by Google

To collect information of temperature, humidity, wind speed, wind direction, bar, rain, solar radiation, solar energy, air densityAll the information collected was organized in a spreadsheet document by a graph. The spreadsheet document was connected to Google Looker Studio, that way a graph could be made. A graph for humidity, temperature and precipitation was created. After creating the graphs in looker studio we accessed the data to compare our information to the information they have.

Data Summary

	Date	In Hum
1.	6 oct 2023	57,64
2.	7 oct 2023	58,71
3.	8 oct 2023	56,48
4.	9 oct 2023	55,73
5.	10 oct 2023	56,44
6.	11 oct 2023	56,83
7.	12 oct 2023	58,9
8.	13 oct 2023	57,13

1 - 100 / 220

	Date	Out Hum
1.	6 oct 2023	84,82
2.	7 oct 2023	88,85
3.	8 oct 2023	83,27
4.	9 oct 2023	87,52
5.	10 oct 2023	88,92
6.	11 oct 2023	90
7.	12 oct 2023	87,33
8.	13 oct 2023	90,98

1 - 100 / 220

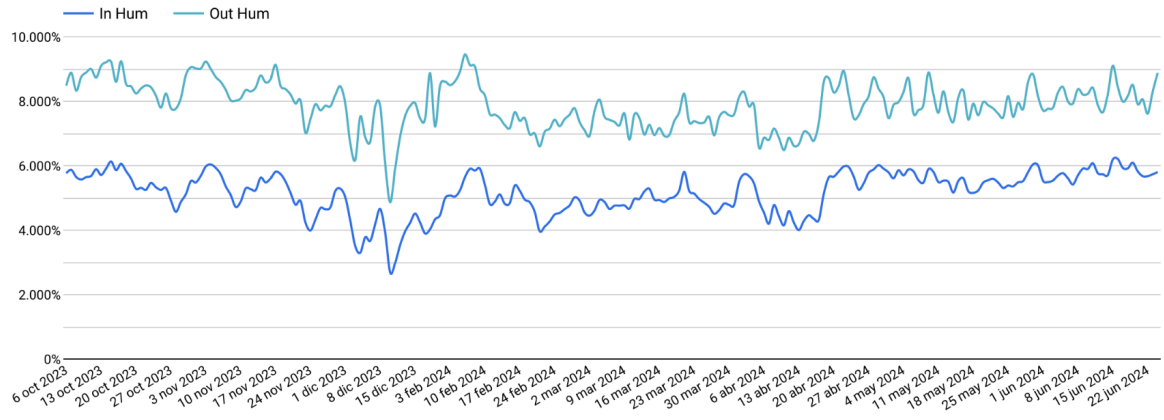


Figure 1. The change in humidity inside and outside of Rochester Rochester School from 2023 to 2024. Data accesses from school meteorological station on campus.

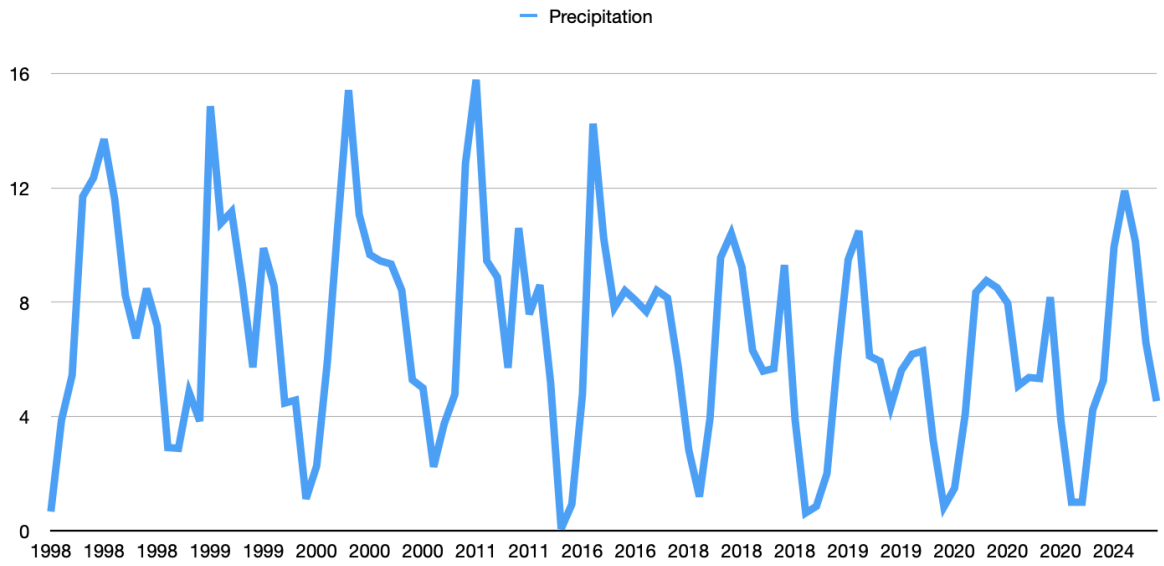


Figure 2. Change in average yearly precipitation (mL) in Bogota, Colombia from 1998 to 2024. Data accessed from mynasadata.org.

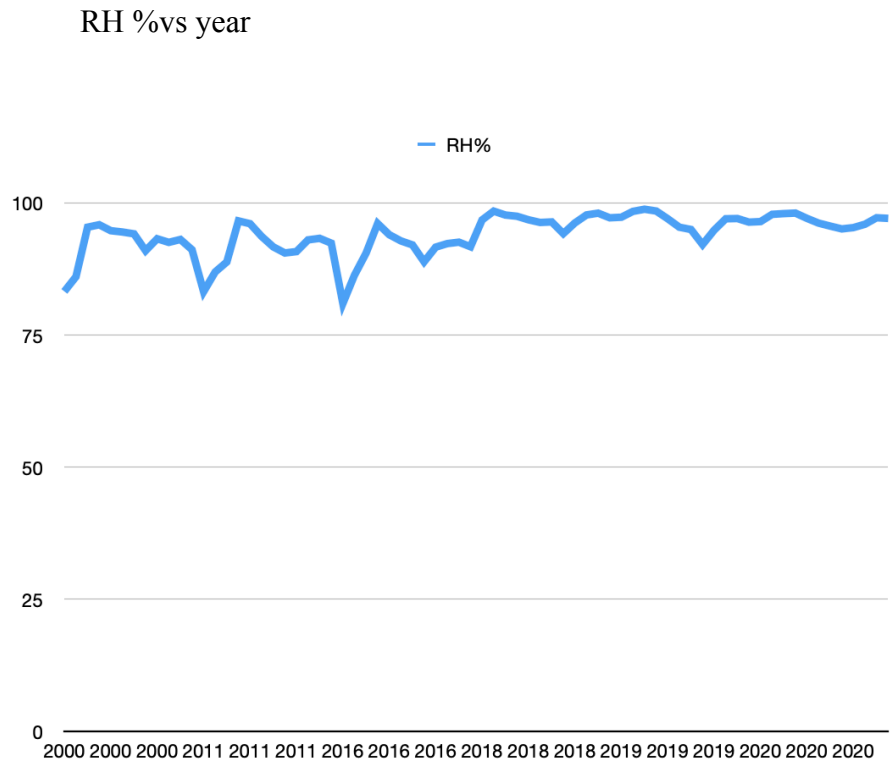


Figure 3. Change in relative humidity from 2000 to 2020 in Bogota, Colombia. Data accessed from mynasadata.org.

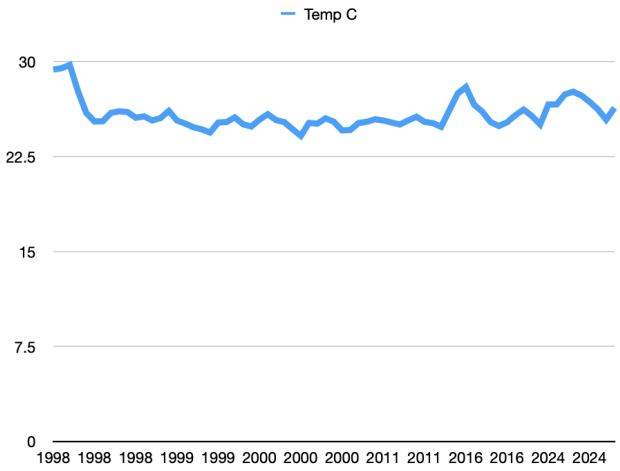
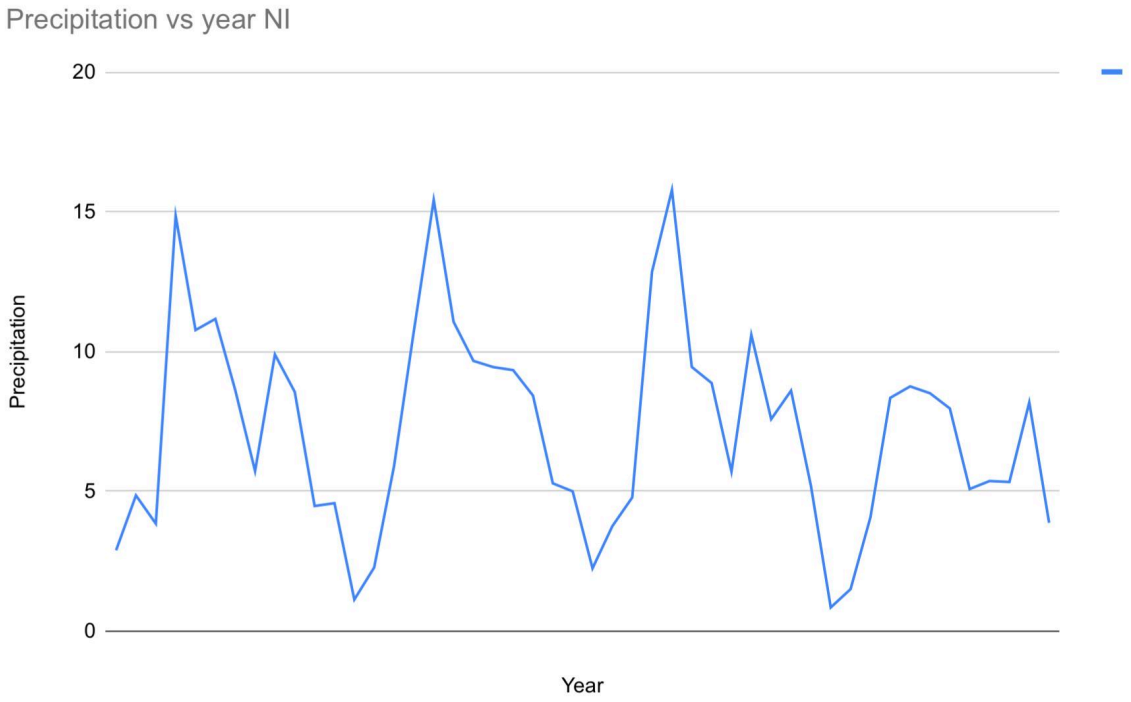


Figure 4. Change in temperature from 1998 to 2024 in Bogota, Colombia. Data accessed from mynasadata.org.


Precipitation vs year NI
20
15
10
5
0
Precipitation
Year

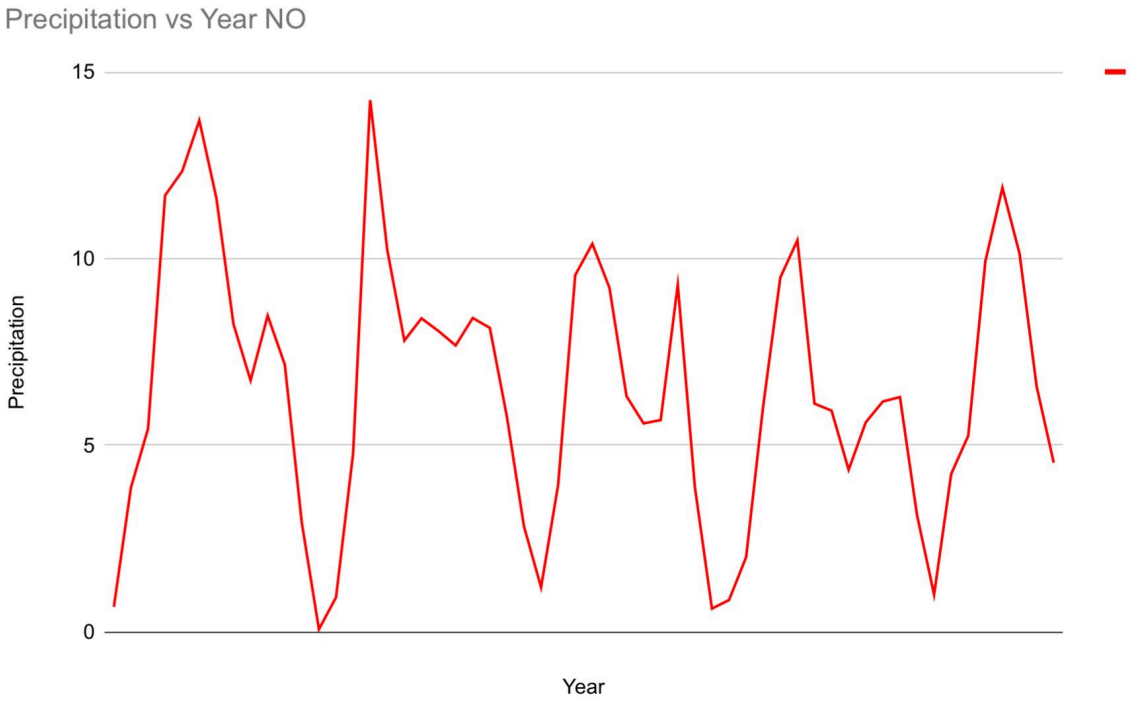

Precipitation vs Year NO
15
10
5
0
Precipitation
Year

Figure 5.

Analysis and Results

The analysis of climate data reveals significant differences between El Niño (NO) and La Niña (NI) conditions. El Niño periods demonstrate substantially higher precipitation with an average of 8.48 mm compared to La Niña's 4.00 mm, representing a 112% increase. Temperature patterns also differ, with El Niño periods being moderately warmer at 17.47°C versus 16.58°C during La Niña events, a difference of 0.89°C or approximately 5.4%. These climate variations are consistent across different humidity levels, with the precipitation difference becoming less pronounced at higher relative humidity ranges (95-99%). Monthly analysis indicates that regardless of El Niño or La Niña conditions, precipitation peaks during April-May and reaches minimum values in January-February. The data shows stronger correlation between relative humidity and precipitation during El Niño periods, suggesting that El Niño conditions amplify normal precipitation patterns while maintaining slightly elevated temperatures throughout the year. Recent years (2018-2020) show higher overall humidity levels and smaller differences between conditions, possibly indicating changing climate patterns. The climate oscillation between El Niño and La Niña conditions follows approximately 3-5 year cycles, with the most significant differences observed in earlier years of the dataset. The information can be further analyzed and compared with the information found by our meteorological station which shows that the information used is similar, with the temperature increasing by 1.21C which since the year is shown as a El Niño year can be seen as another effect of El niño in Bogota.

Conclusions

El Niño's Impact on Precipitation, Temperature, and Humidity:

Research confirms that El Niño significantly impacts Bogotá's climate. El Niño precipitation is 112% greater on average than La Niña precipitation, and temperatures are approximately 0.89°C greater. Humidity is unpredictable, with greater correlations between humidity and precipitation in El Niño, suggesting that El Niño amplifies the normal climatic conditions.

Trends and Anomalies in 2024:

The data for 2024 validates the hypothesis that El Niño precipitates reduced rainfall, higher temperatures, and less stable humidity levels. Compared to other years, such as 2016, 2024 experienced extreme variations, including a sharp decline in reservoir levels predicated on reduced rainfall and eventual unprecedented rainfalls in November. These trends are in agreement with the overall impacts of El Niño on regional climatic conditions.

Monthly and Cyclical Trends:

Precipitation in Bogotá is highest in April-May and lowest in January-February regardless of El Niño or La Niña years. The periodic occurrence of the El Niño and La Niña events every 3-5 years underscores the importance of long-term climate monitoring to be able to detect and predict the events.

Implications for Water Resource Management:

The drastic drop in reservoir levels in 2024 highlights the vulnerability of Bogotá's water supply to El Niño-induced droughts. One of the crucial steps in order to combat this was the implementation of water rationing by the city which demonstrated the need for proactive actions to mitigate the impacts of future El Niño events.

Climate Change and Regional Variability:

Recent years (2018-2020) further indicate greater total humidity percentages and smaller differences between El Niño and La Niña conditions, which may indicate shifting climate patterns. This can indicate the impact of regional factors and global climate change on the intensity and frequency of El Niño and La Niña events.

Discussion

The results of this study confirm earlier studies of the global and regional impacts of El Niño. For instance, the rise in precipitation during El Niño events is consistent with observations revealing the impact of the phenomenon to enhance precipitation in certain regions, such as South American regions (NOAA, 2025). Similarly, the progressively rising temperatures in El Niño follow global patterns of rising heatiness during the phenomenon (NASA, 2025). The unusual climatic features of Bogotá, however, such as its altitude and tropicality, bring regional specificity into play that can be further investigated.

The outlier 2024 rainfall patterns of reduced rain initially and then repeated subsequent instances thereof draw focus toward the double threat of El Niño's capacities for droughts and floods. These are most applicable for cities like Bogotá, where population growth at a rapid rate

and infrastructural constraints enhance the impacts of climatic change. The sharp decline in reservoir levels and imposition of water restriction policies indicate the urgent need for improved water management practices to counteract increasing climate variability.

If this project was recreated, the following adjustments would enhance validity and scope in results:

Increased Data Collection: Integrating additional meteorological data from more stations spread across Bogotá and surrounding regions would offer a comprehensive sense of regional climatic change.

Longer Time Scale: A longer time scale of analysis that includes a few El Niño and La Niña cycles would allow us to determine long-term trends and verify the cyclical nature of these events.

Advanced Modeling Tools: Application of global climate modeling software for projecting future conditions under different ENSO conditions is able to potentially forecast likely impacts and inform adaptation.

The findings of this study have research implications outside the purview of academia, most prominently for policymakers, planners, and environmentalists in Bogotá and similar cities. Drawing attention to the vulnerabilities of water resources and infrastructure to El Niño occurrences, the study urges anticipatory measures such as:

Investment in infrastructures that are resilient to withstanding extreme weather occurrences.

- Development of early warning systems against flood and droughts.

- Promoting water conservation practices, including rainwater harvesting and conservation irrigation systems.

To build on this research, further work could examine the following questions:

- Regional Analyses: Comparison of Bogotá's El Niño climatic responses to those of other South American cities at high elevations could yield more universal trends and inform regional adaptation.
- Interactions with Climate Change: Consideration of the ways in which global climate change is likely altering the intensity and frequency of El Niño and La Niña events would provide useful insights into future climatic threats.
- Community-Based Adaptation: An exploration of the adaptive capacity of local communities to climatic variability, particularly in marginal areas, may raise awareness on emerging solutions and foster resilience.
- Economic Impacts: A consideration of economic costs resulting from El Niño phenomena, such as loss of crops or infrastructure, would infuse an equitable framework into recognizing its effects.

References

"El Niño and La Niña: Frequently Asked Questions." National Oceanic and Atmospheric Administration (NOAA), www.noaa.gov/education/resource-collections/weather-atmosphere/el-nino. Accessed 5 Mar. 2025.

"El Niño: Pacific Wind and Current Changes Bring Warm, Wild Weather." National Geographic, www.nationalgeographic.com/environment/article/el-nino. Accessed 5 Mar. 2025.

"Global Climate Change: Vital Signs of the Planet." NASA, climate.nasa.gov. Accessed 5 Mar. 2025.

"El Niño and La Niña Events in Colombia: Impacts and Adaptation Strategies." IDEAM (Instituto de Hidrología, Meteorología y Estudios Ambientales), www.ideam.gov.co. Accessed 5 Mar. 2025.

"Climate Data Online: Global Historical Climatology Network." National Centers for Environmental Information (NCEI), www.ncei.noaa.gov/access/search/data-search/global-summary-of-the-day. Accessed 5 Mar. 2025.

"El Niño and Its Impact on Colombia's Climate." World Meteorological Organization (WMO), public.wmo.int/en/our-mandate/climate/el-ni%C3%B1ola-ni%C3%B1a-update. Accessed 5 Mar. 2025.

“Bogotá Climate Data and Trends.” World Weather Online, www.worldweatheronline.com/bogota-weather-averages/cundinamarca/co.aspx. Accessed 5 Mar. 2025.