Analysis of Rainfall Variability in Maizales -Santa Fe, Argentina- (2000-2025)

Integration of Citizen Science Records, GLOBE Protocols, and NASA Satellite Validation for Agricultural Resilience.

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ABSTRACT

This research project analyzes the evolution of precipitation in the town of Maizales, Santa Fe, over a 26-year period. The study originates from the enhancement and systematic analysis of a historical rainfall record started by Mr. Martino in the year 2000, which was digitized and analyzed for this purpose. During the 2025 cycle, GLOBE Atmosphere Protocols were incorporated to standardize current measurements, and data from NASA Worldview were utilized for validation.

The study reveals a historical average of 956.58 mm, but with a significant standard deviation that highlights the alternation between extreme dry cycles (such as the minimum of 430.5 mm in 2022) and wet cycles (maximum of 1498 mm in 2012). The analysis demonstrates that citizen science provides critical spatial resolution that complements satellite data. These results allow for a better understanding of water anomalies in a core production area for corn and soybeans, facilitating decision-making based on local climatic evidence.

RESEARCH QUESTIONS

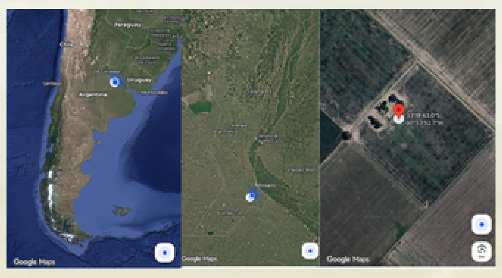
- What are the climate variability trends observed in the 26-year record in Maizales, and how do historical extreme events compare with the 2025 data?
- What is the correlation level between the intensity of storms recorded locally with the rain gauge and the reflectivity observed in NASA satellite data?
- How does "Proximity Citizen Science" (Mr. Martino's records) benefit the accuracy of climate monitoring in rural areas compared to global models?

OBJETIVE

To determine the precipitation variability patterns in Maizales, Santa Fe, through the integration of historical family records, GLOBE scientific protocols, and NASA remote sensing tools to evaluate changes in the local water regime.

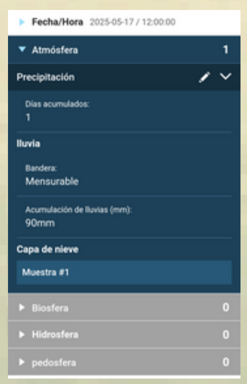
HYPOTHESIS

Precipitation variability in Maizales, Santa Fe, has shown a trend toward the intensification of extreme events (severe droughts and concentrated torrential rains) in the last decade (2015-2025) compared to the initial historical record (2000-2010). This trend is reflected in a higher frequency of anomalies detected by both Mr. Martino's ground records and NASA satellite imagery.

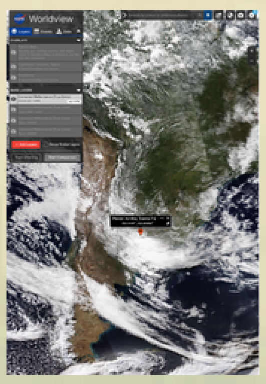


Geographic location and satellite view of the study site.

Historical handwritten rainfall records by Mr. Martino.



2025 Data entry in the GLOBE Observer App.



NASA Worldview screenshot.

INTRODUCTION AND LITERATURE REVIEW

The Argentine Pampas region is one of the world's most complex natural laboratories regarding hydroclimatology. The town of Maizales, located in southern Santa Fe province, sits within one of the most productive agricultural areas globally. However, its economy depends critically on precipitation patterns, which exhibit high variability influenced by macro-climatic drivers such as the ENSO (El Niño/La Niña) phenomenon.

Recent research by Argentine authors, such as Camilloni (2020), indicates that certain regions in Argentina have experienced an increase in the frequency of extreme precipitation events. Furthermore, a report by Magrín et al. (2014) highlights that climate change in Argentina has primarily benefited soybean expansion due to variations in rainfall and temperature, although it warns of the constant need for monitoring. The greatest risks include the increase of extreme events (floods and droughts) and the necessity of adapting agricultural management to an uncertain climate.

Citizen science, defined as public participation in scientific research, is key when long-term records are required in areas where official stations of the National Meteorological Service (SMN) are far away. Mr. Martino's data represents a "proximity record" that satellite networks sometimes fail to capture with millimeter precision due to the spatial resolution of their sensors. According to Rivera et al. (2018), local historical records are essential for reconstructing Argentina's climate history and understanding the intensification of the hydrological cycle.

The integration of satellite data is now the standard for validating these ground observations. NASA satellite imagery offers global products that, when cross-referenced with ground data like those in this project, allow for the adjustment of rain detection algorithms in lowland areas. On the other hand, Barros et al. (2015) suggest that satellite remote sensing is an indispensable complementary

RESEARCH METHODS

Study Site: The study area is located at Mr. Martino's field, coordinates -33.311939, -60.897958, in Maizales, Santa Fe. The landscape consists of a gently undulating plain with a humid temperate climate. The soil is highly fertile with a high water-retention capacity, making the monitoring of accumulated rainfall vital for groundwater and crop management.

Data Collection: To ensure scientific validity, the GLOBE Atmosphere (Precipitation) Protocol was followed throughout 2025:

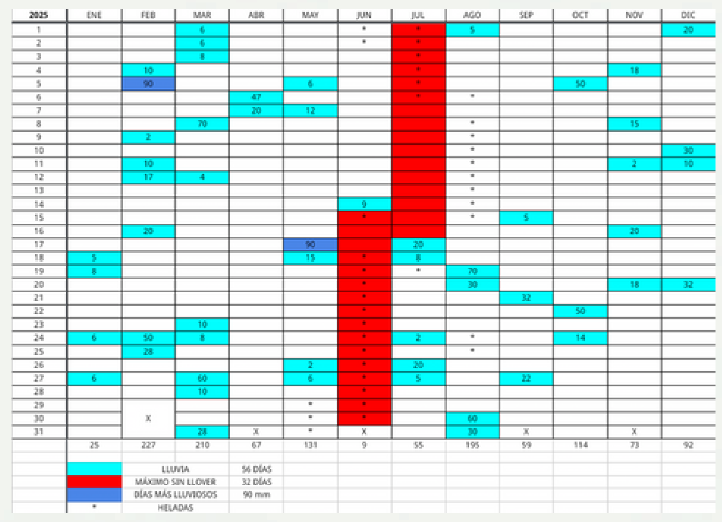
1. Instrument: A standardized cylindrical rain gauge was used, installed in an open area away from trees or buildings that could cause a "shadow effect" or wind turbulence. The instrument was placed 1 meter above the ground on a leveled post.
2. Measurement Procedure: Readings are taken daily at the same time (local solar time).
   - The base of the water meniscus is observed on the millimeter scale.
   - The exact amount is recorded in mm (e.g., 12.5 mm).
   - In the event of heavy rainfall, the gauge is checked to ensure no overflow occurred.
   - After the reading, the rain gauge is emptied and cleaned to prevent sediment buildup or errors due to residual evaporation.
3. Recording: The 2025 data were uploaded to the GLOBE database, while historical data (2000-2024) were tabulated from Mr. Martino's original field notebooks.

Satellite Data Integration: The NASA Worldview platform was accessed to investigate atmospheric dynamics. For every rainfall event exceeding 40 mm recorded by Mr. Martino, the corresponding satellite imagery was downloaded. This allowed for the observation of Mesoscale Convective Systems (MCS) and cold fronts over the province of Santa Fe, confirming that the rain gauge data coincide with the phenomenology observed from space.

RESULTS

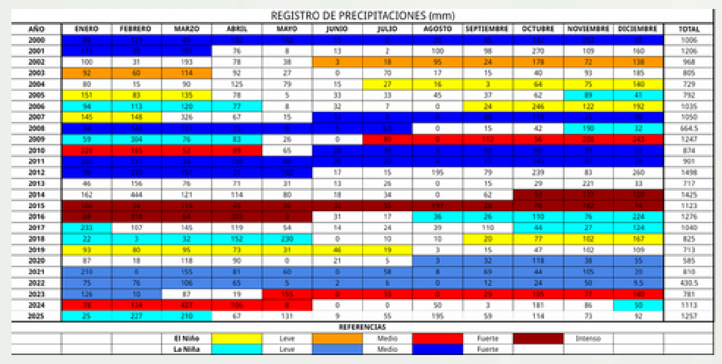
Tabulated precipitation dataset (2000-2025).

The image displays the complete raw data matrix digitized from Mr. Martino's field notebooks. This spreadsheet organizes 26 years of monthly and annual rainfall records in Maizales, Santa Fe. It serves as the primary evidence for the longitudinal statistical analysis, identifying the historical average of 956.58 mm and the interannual fluctuations that characterize the regional hydrological regime. Source: Own elaboration based on primary records.



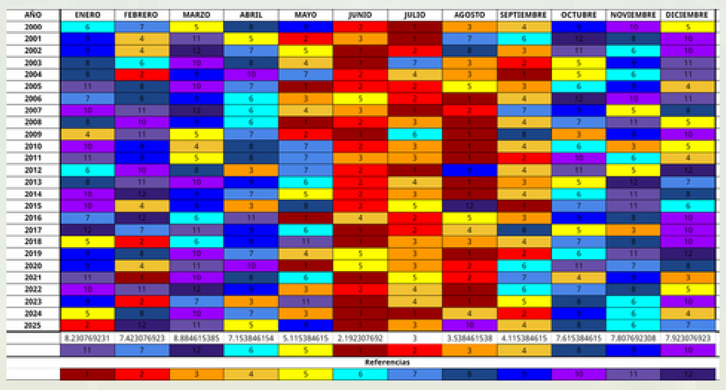
2025 Primary digital record for GLOBE Observer integration.

This spreadsheet illustrates the detailed monitoring performed during 2025. It tracks specific rainfall days, the maximum consecutive dry days, and the highest precipitation events. Additionally, an asterisk (*) was used to incorporate frost days, expanding the atmospheric analysis beyond rainfall. This dataset served as the preliminary quality control before uploading the measurements to the GLOBE Observer App. Source: Own elaboration.



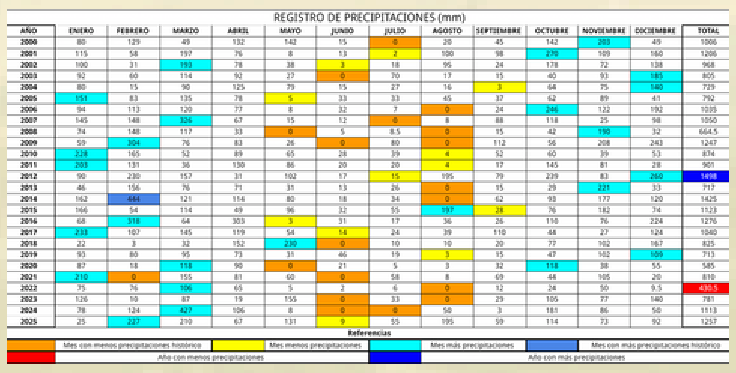
Correlation between local rainfall and El Niño/La Niña phenomena.

This thematic matrix categorizes the monthly and annual records based on the influence of the El Niño-Southern Oscillation (ENSO). The color-coded references identify periods of El Niño (warm phase, associated with higher rainfall in the region) and La Niña (cold phase, associated with droughts), categorized by intensity from "Weak" to "Very Strong." This visualization allows for the identification of how global macro-climatic patterns directly dictated the hydrological extremes recorded in Maizales over the last 26 years. Source: Own elaboration.



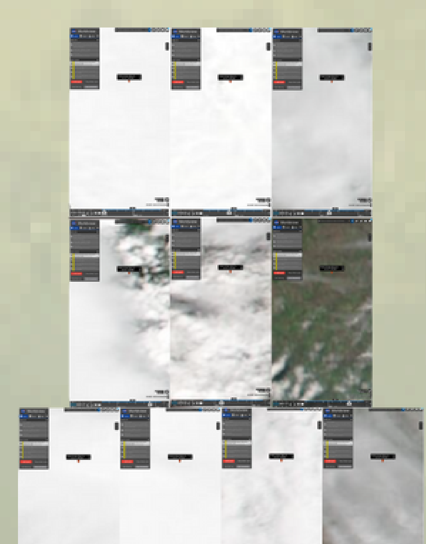
Monthly precipitation hierarchy (Ranked from wettest to driest).

This matrix organizes monthly records from 2000 to 2025 according to their rainfall volume. The color scale (1 to 12) identifies the relative rank of each month within a specific year. This visualization is essential for detecting seasonal shifts and determining which months consistently drive the water balance in Maizales. Source: Own elaboration.



Statistical matrix of precipitation extremes (Annual and historical).

This analytical table highlights the wettest and driest months for each specific year, as well as the historical records for the entire 26-year series. The color-coded references allow for a quick identification of absolute minimums (red) and maximums (blue), providing a clear overview of the hydrological volatility in Maizales. It highlights critical periods such as the historical annual maximum in 2012 and the absolute minimum in 2022. Source: Own elaboration based on digitized records



Multi-temporal satellite validation of high-intensity events (Rainfall › 40 mm) during 2025.

This visual correlation confirms that every significant ground-based record at "Campo del Sr. Martino" is backed by satellite-observed atmospheric conditions. Source: NASA Worldview.

DISCUSSION

The data obtained by Mr. Martino serves as a perfect example of mutual benefit in citizen science: the scientist (or student) acquires a historical database that is impossible to purchase, while the citizen (the grandfather) sees years of dedicated work transformed into useful knowledge for his community.

The trend does not show a decrease in total rainfall, but rather a concentration of rainfall. More water falls in less time. This was verified by comparing rainy days in 2005 versus 2025; for a similar accumulated total, fewer precipitation days were required in 2025, suggesting more violent weather events.

The comparison with NASA satellite data confirmed that the storm systems observed on the ground were of a regional scale, validating the precision of Mr. Martino's manual records against remote measurements. A potential source of error was identified in the records if the rain gauge was not emptied immediately after a rainfall event due to evaporation; however, the overall consistency of the data suggests high reliability and fidelity.

CONCLUSION

To arrive at the conclusions of this study, a data triangulation process was conducted, integrating three dimensions: the 25-year historical series of citizen science records from Mr. Martino, standardized data under the GLOBE Atmosphere Protocol during 2025, and NASA remote sensing observations. Through the analysis of digitized spreadsheets, a pattern of increasing water instability was identified. The conclusion arises not only from observing numbers but from comparing local anomalies with regional events recorded by NASA Worldview imagery, confirming that the extremes measured by the Maizales rain gauge are local responses to large-scale climatic dynamics.

The results obtained are of vital importance for local climate science. Identifying an oscillation ranging from a minimum of 430.5 mm (2022) to a maximum of 1,498 mm (2012) places Maizales in a high-vulnerability area. These findings are relevant because they demonstrate that, in the context of global climate change, the region is not necessarily receiving less water on an annual average, but is receiving it in a much more erratic manner. This impact is direct for the agricultural community: the data suggest that planting schedules must adapt to concentrated precipitation events and more acute water stress periods, validating the utility of citizen science as an early warning network that complements NASA satellites.

Despite the robustness of Mr. Martino's data, the research process identified areas for improvement. Manual methods, while reliable, present risks of evaporation error if the reading is not taken immediately after the event. Technical improvements proposed include the incorporation of rain gauges with anti-evaporation systems and the installation of an automated weather station calibrated with the GLOBE protocol to reduce human error and obtain real-time data.

As follow-up actions, we plan to expand the research toward the GLOBE Soil Moisture and Land Cover Characterization Protocols. This is essential for understanding not only how much it rains but how the soil in Maizales absorbs that water. Future research should focus on the correlation between the extreme events documented here and local crop yields, utilizing NASA's SMAP (Soil Moisture Active Passive) mission to deepen satellite data integration.

Working with a project mentor was the catalyst that transformed a family notebook into an international-level scientific research paper. Mentorship provided the necessary methodological framework for data digitization, the interpretation of NASA Worldview satellite layers, and, fundamentally, helped structure the critical thinking required to connect a citizen's observation (the researcher's grandfather) with the major environmental problems that science aims to solve today. This collaboration underscores that science is not an isolated process but a community and academic construction.


Worldview
Layers
Events
Data
OVERLAYS
BASE LAYERS
Corrected Reflectance (True Color)
+ Add Layers
Group Similar Layers
Start Charting
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Pavón Arriba, Santa Fe
-33.3119°, -60.8980°
2025 OCT 05
1 DAY
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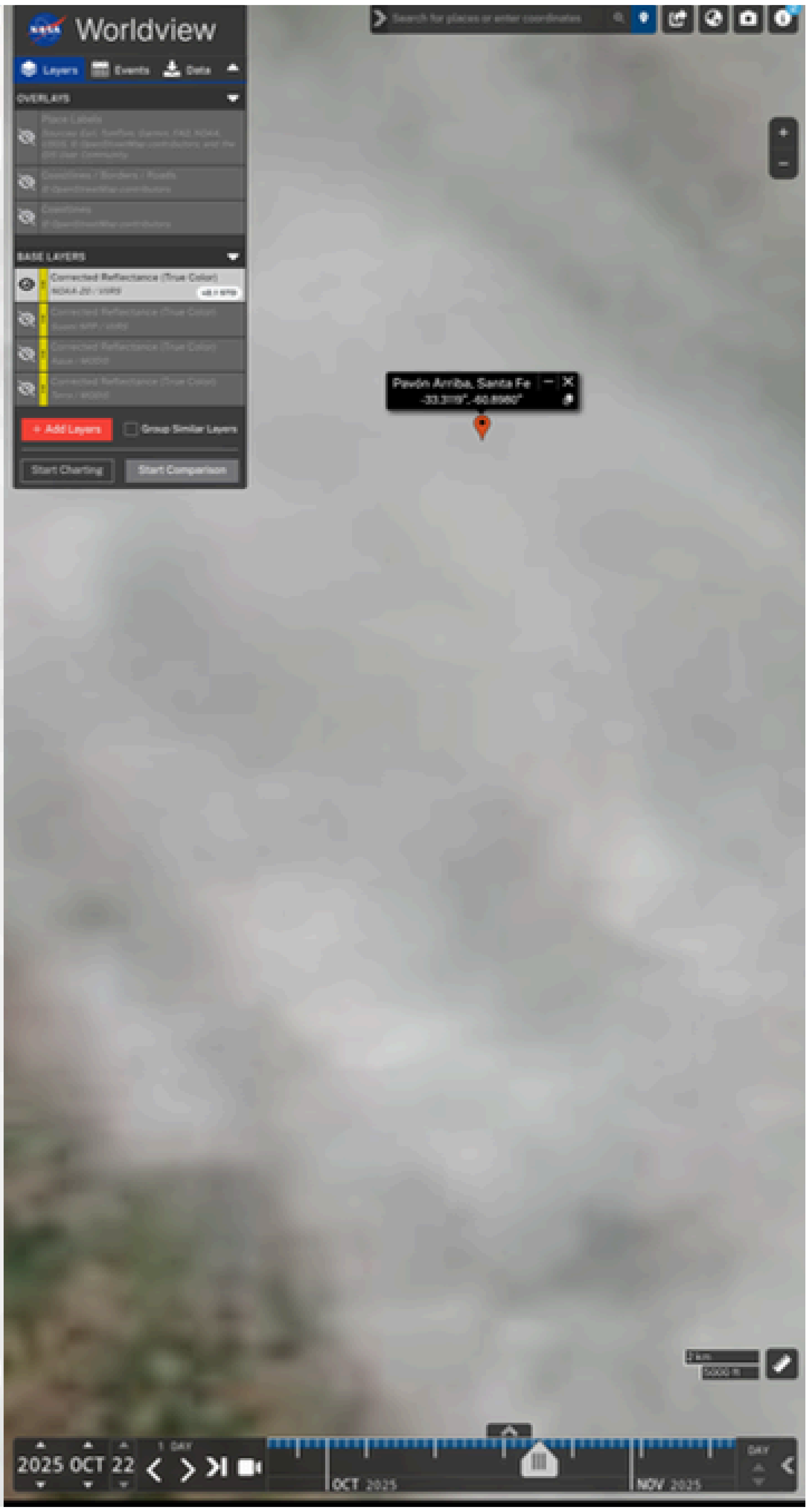
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