

Understanding Superstorms by Harnessing the Power of Aurorasaurus Open Citizen Science

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ABSTRACT

Citizen scientists fill crucial gaps in advancing our understanding of space weather by contributing valuable observational data that complement traditional scientific methods. This poster presents ongoing efforts to clean, verify, and publish citizen science data collected through the Aurorasaurus participatory science project, ensuring readiness for scientific use. Focusing on major auroral events such as the 2024 geomagnetic superstorms, our work establishes protocols to enhance the quality and accessibility of these crowd-sourced observations.

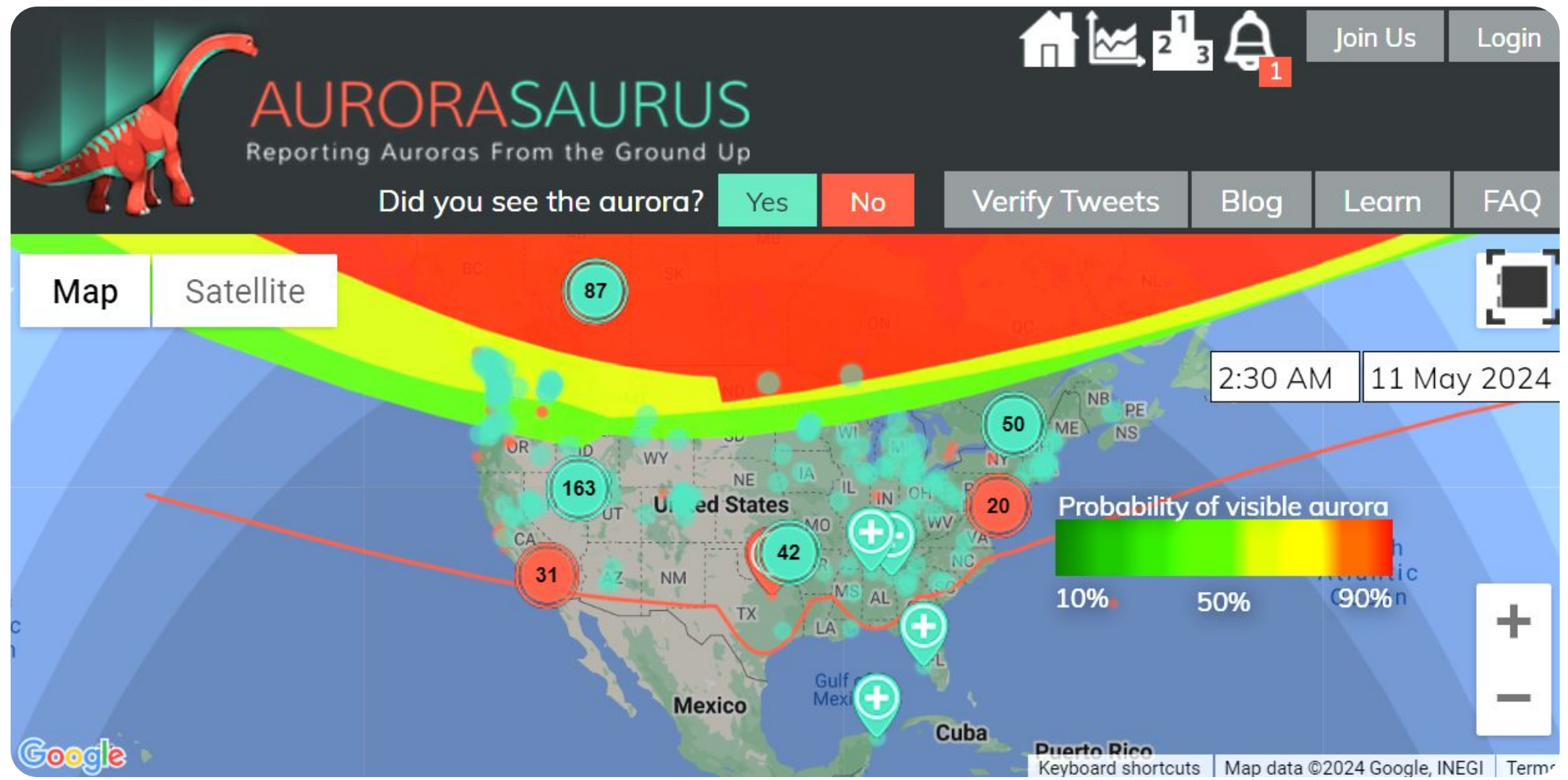
In addition, the Eclipse to Aurora Winter Field School, held in Fairbanks, Alaska, provided a transformative opportunity to supplement this effort by incorporating student-led optical and magnetometer measurements alongside citizen science auroral observations. Students and community members demonstrated collecting scientifically valuable data that support the intercalibration of diverse datasets. Together, these efforts highlight the agility and potential of citizen science to provide impactful contributions to heliophysics education and space weather research.

By cleaning and analyzing thousands of citizen science reports and integrating them with heliophysics datasets, we further demonstrate the reliability and scientific value of crowd-sourced observations during large, rare events at unusually low latitudes. This poster details our methodologies for data verification, the unique challenges of handling heterogeneous crowd-sourced data, and how citizen scientists and students contribute to advancing our understanding of rare superstorms with new technologies.

DATA-DRIVEN DISCOVERIES

The **Aurorasaurus project** harnesses public observations of the aurora, integrating them with scientific data to improve real-time aurora predictions and enhance space weather models

- Combining collaborative science reports with a traditional solar wind-driven auroral precipitation model enables greater spatial resolution of auroral visibility and the ability to generate localized alerts (Case et al., 2016a)
- A structure recognized by citizen scientists but unidentified by science associated with subauroral ion drift (SAID) is now known as Strong Thermal Emission Velocity Enhancement: STEVE (MacDonald et al., 2018; Hunnekuhl et al., 2020; Semeter et al., 2020)



OBJECTIVES

The 2024 Geomagnetic Superstorms (May 10–13 & October 10–13) witnessed significant citizen science participation

- Thousands of real-time and backdated aurora sightings were submitted from unusually low latitudes, providing a rare opportunity to examine auroral visibility during severe geomagnetic activity

This project aims to transform these crowd-sourced observations into a high-quality, scientifically-usable dataset

- Process 8000+ citizen science reports from all 7 continents
- Develop a reproducible pipeline to clean and analyze observations
- Support scientific investigations into when, where, and how auroras appear during major geomagnetic storms
- Investigate auroral extent, color, structure, and storm-time evolution
- Integrate cleaned reports with geophysical indices (e.g., SYM-H, Kp)
- Support Open Science principles through reproducible data handling

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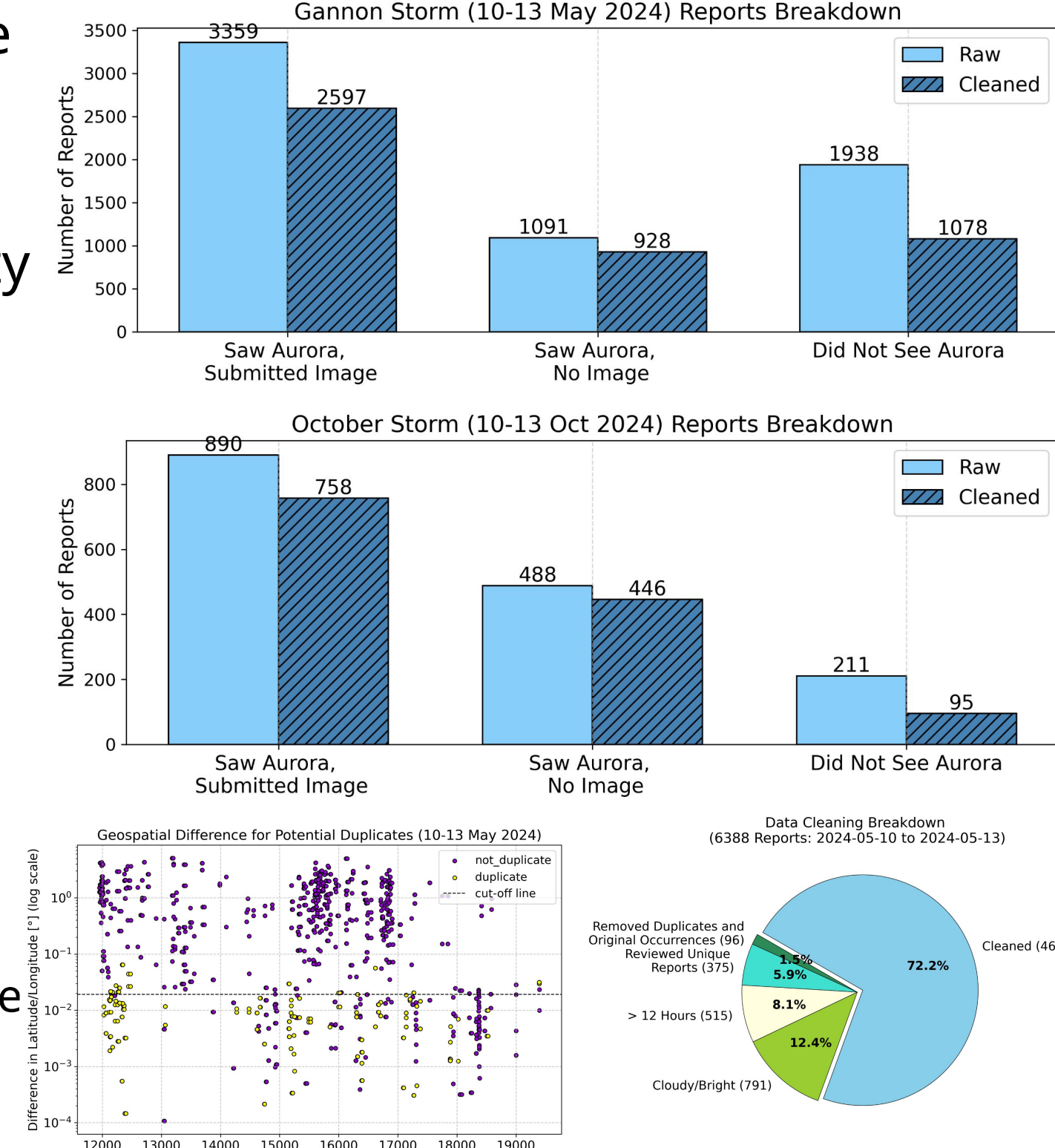
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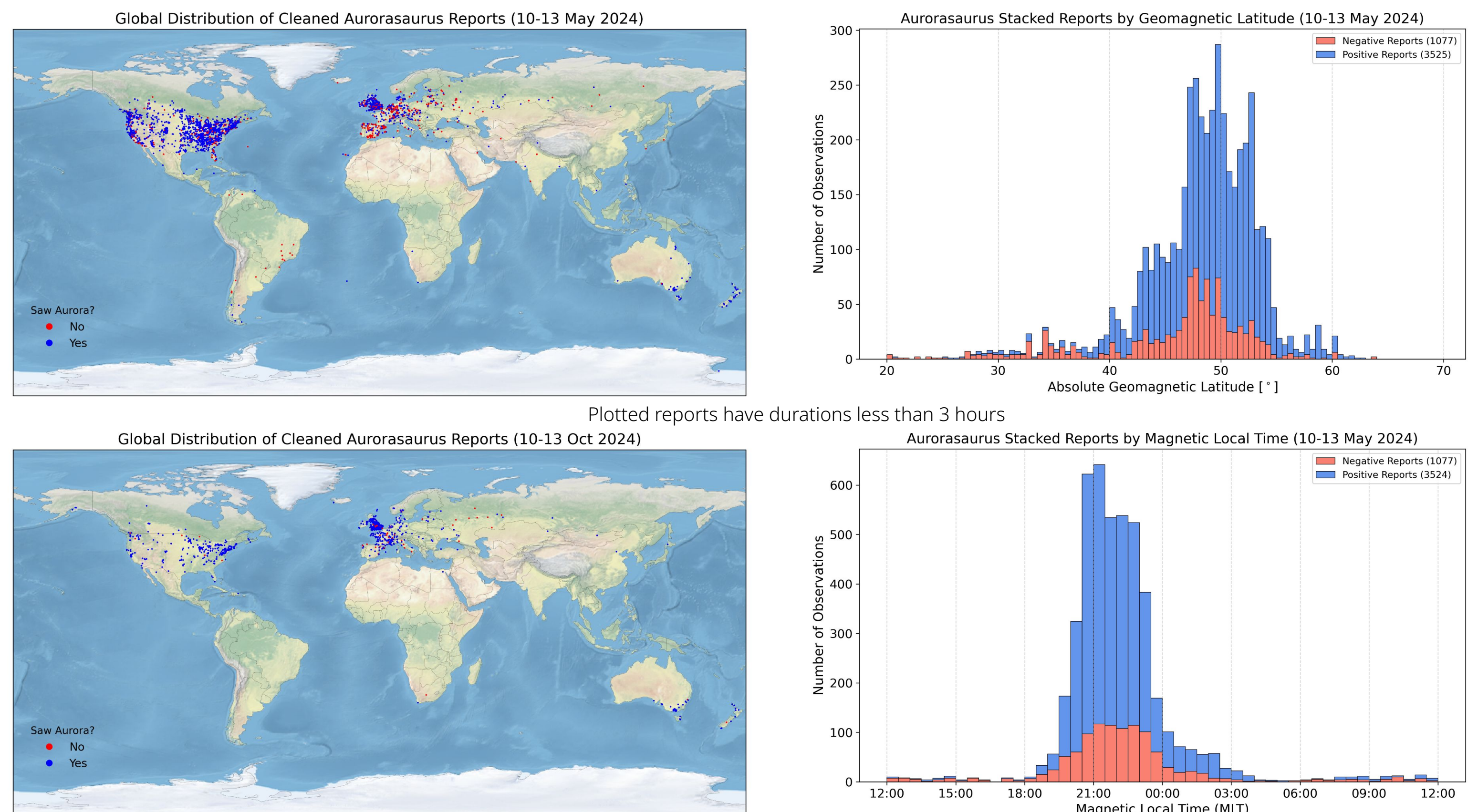
DATA CLEANING

Crowd-sourced aurora observations offer valuable scientific insights. To maximize the scientific value of this database, a rigorous data cleaning and analysis pipeline was developed to ensure usability and reproducibility

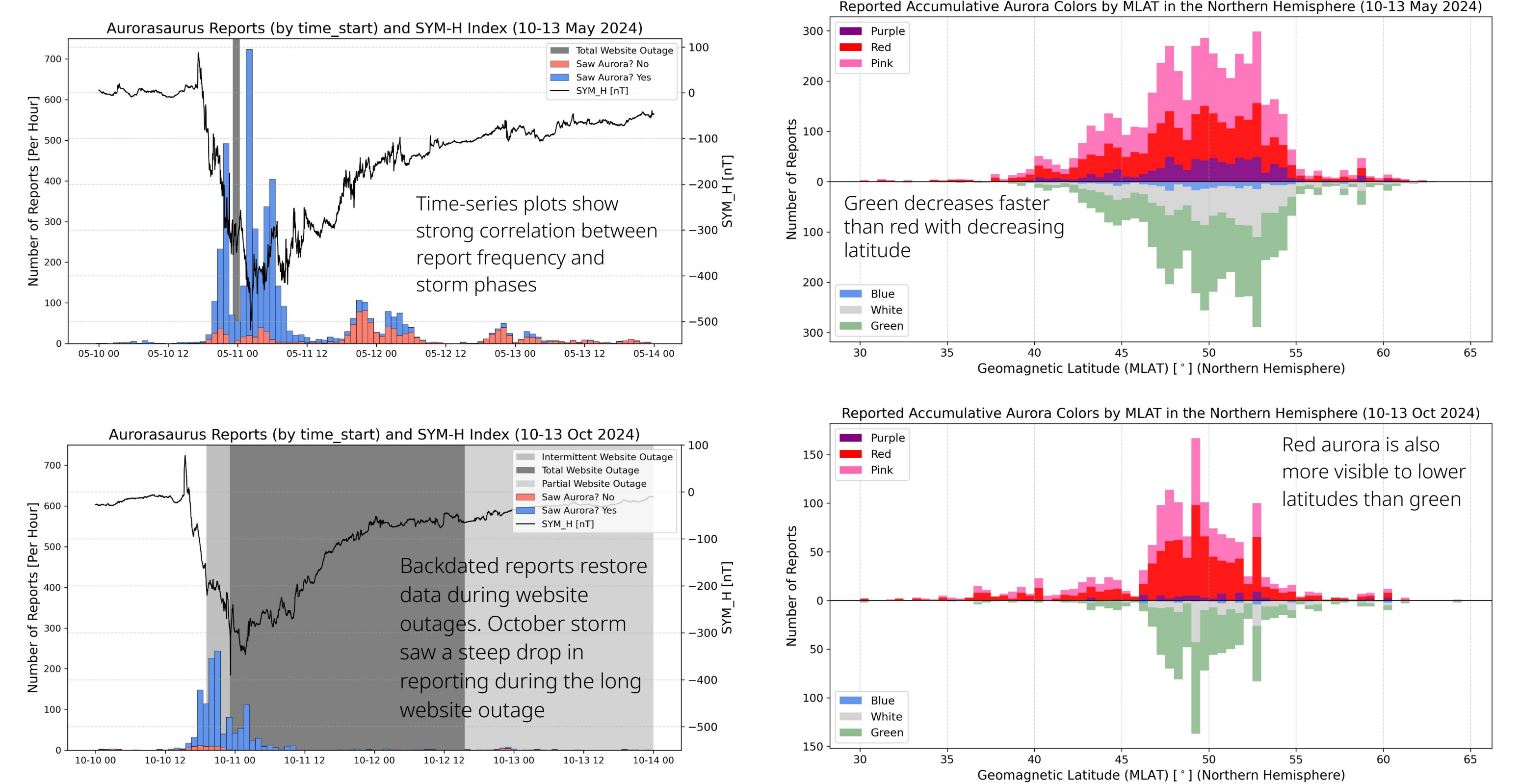
- Gannon storm:
 - 6,388 **raw** reports → 4,603 **cleaned** reports (72.1%)
 - 77% of cleaned reports were positive sightings
 - Duplicate reports were resolved by examining all parameters between similar reports
- October storm:
 - 1,589 **raw** reports → 1,299 **cleaned** reports (81.8%)
 - 93% of cleaned reports were positive sightings
 - No manual duplicate review was performed for October. Potential duplicates were still flagged for consistency



2024 SUPERSTORMS COMPARISONS



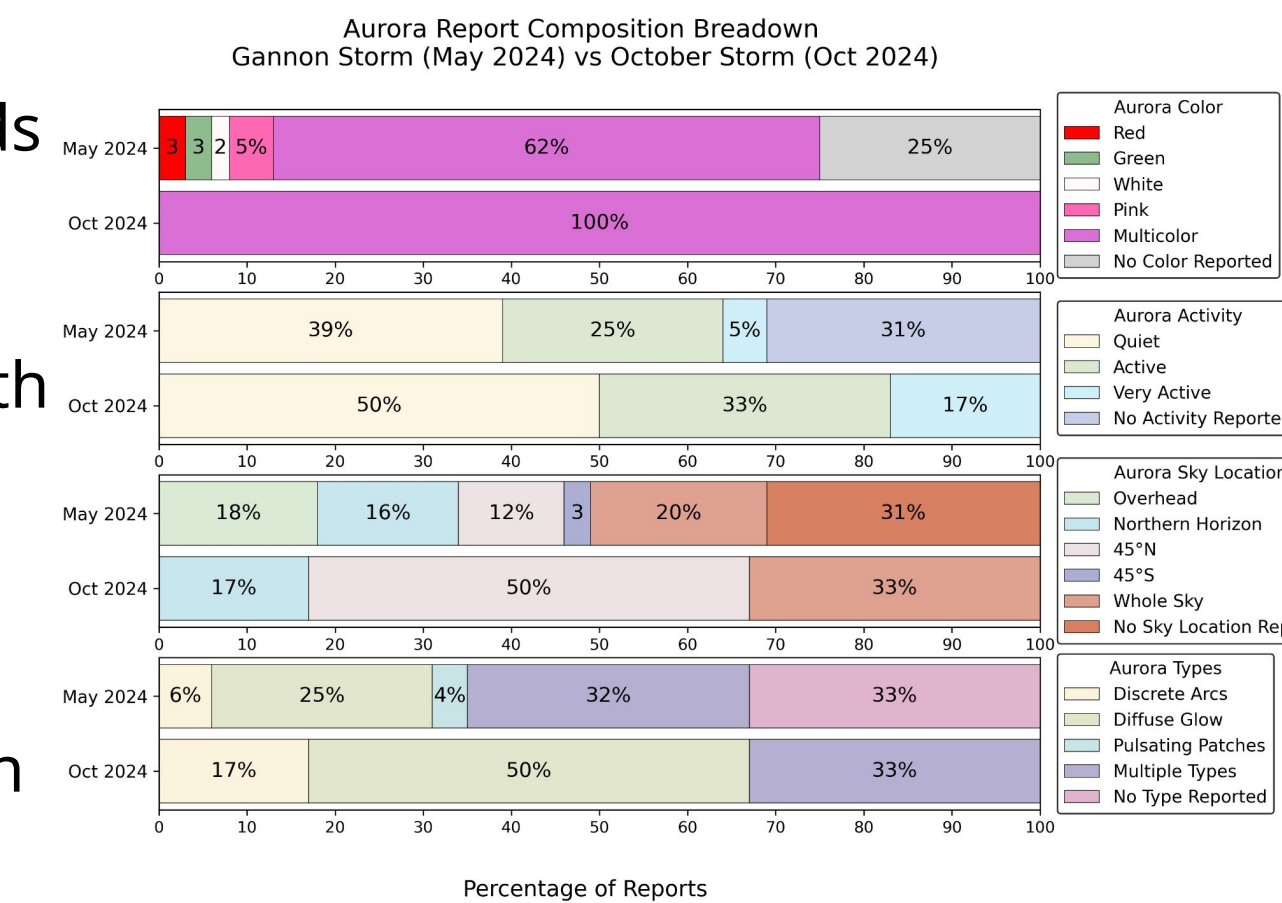
- Global maps show widespread visibility across mid- and low-latitude regions
- Nanjo et al. (2024), Kataoka et al. (2024), and Grandin et al. (2024) investigate unusual colors for May 2024 storm (fewer data). We look at Northern Hemisphere (NH) reports for both storms
- Seasonally, we expect:
 - May (more ☀️ in NH):
 - Oct (less ☀️ in NH):
- Activity wise, May should have a wider auroral oval than October since it was a larger storm
- Big storms can have unusual aurora, especially SAR arcs (red) and great red aurora (blood red)
- Separating out which red is due to which cause is still complicated



2024 SUPERSTORMS COMPARISONS

The categorical breakdown shows the distributions of answers to the Aurorasaurus web questionnaire that characterizes the aurora based on auroral color, activity, location in the sky, and type

- Comparison between both storms demonstrates trends and differences
- More reports of multicolor auroras during October, with percentage of multicolor being significantly larger than single-color
- A greater fraction of whole sky and overhead reports in May than October



SUMMARY

- Aurorasaurus reports, contributed by the public, fill critical observational gaps over mid- and low-latitude regions not covered by ground- and space-based instruments
 - The 2024 geomagnetic superstorms show how participatory science complements heliophysics research and education
- Data cleaning and statistical visualizations provide insights into our data and compare it to traditional heliophysics models
 - 75% of the entire project's >26,000 reports passed cleaning criteria
 - Automated duplicate screening is largely sufficient, < 0.1% introduced error to the Gannon storm data
- Full database and pipeline will be available on Zenodo as open-access for researchers and the citizen scientist community (late June 2025)
- OpenSpace planetarium visualization of our data which includes geophysical CCMC models will be released to their open hub



RARE AURORA SEEN DURING SUPERSTORMS?

The distribution of STEVEs and SAR arcs is not fully understood

- Quick check for STEVEs and SAR arcs mentions in the texts of cleaned data:
 - Gannon storm: 10 unique STEVE reports, 7 included images
 - Gannon storm: 6 unique SAR arc reports, all included images
 - October storm: 14 unique STEVE reports, 13 included images
 - October storm: 38 unique SAR arcs reports, 31 included images
- Further investigation is needed to determine distribution and cause of rare aurora

Photo Submission to Aurorasaurus from England, UK, Oct 10, 2024 2:00 PM UTC



User said: "The attached photograph was taken towards the end of my observation. The STEVE I saw erupted from the east at around 21.55 and reached westwards. Even through patchy cloud, it was obvious to my eyes as a bright white and fast moving ribbon of light. It turned pink, as in my photograph, towards the end of its outburst. This was looking S.E. at 50.8°N."

ECLIPSES TO AURORA WINTER FIELD SCHOOL

Students, researchers, and citizen scientists in Fairbanks, AK

- Hands-on learning opportunities with Poker Flat Rocket Range, the Museum of the North, aurora chases, and more
- Active participation in citizen science data collection using a variety of instruments, including Aurorasaurus, EZIE-Mag, and AudioMoths



Winter Field School students and instructors. Photo: Andy Witteman

ACKNOWLEDGEMENTS

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