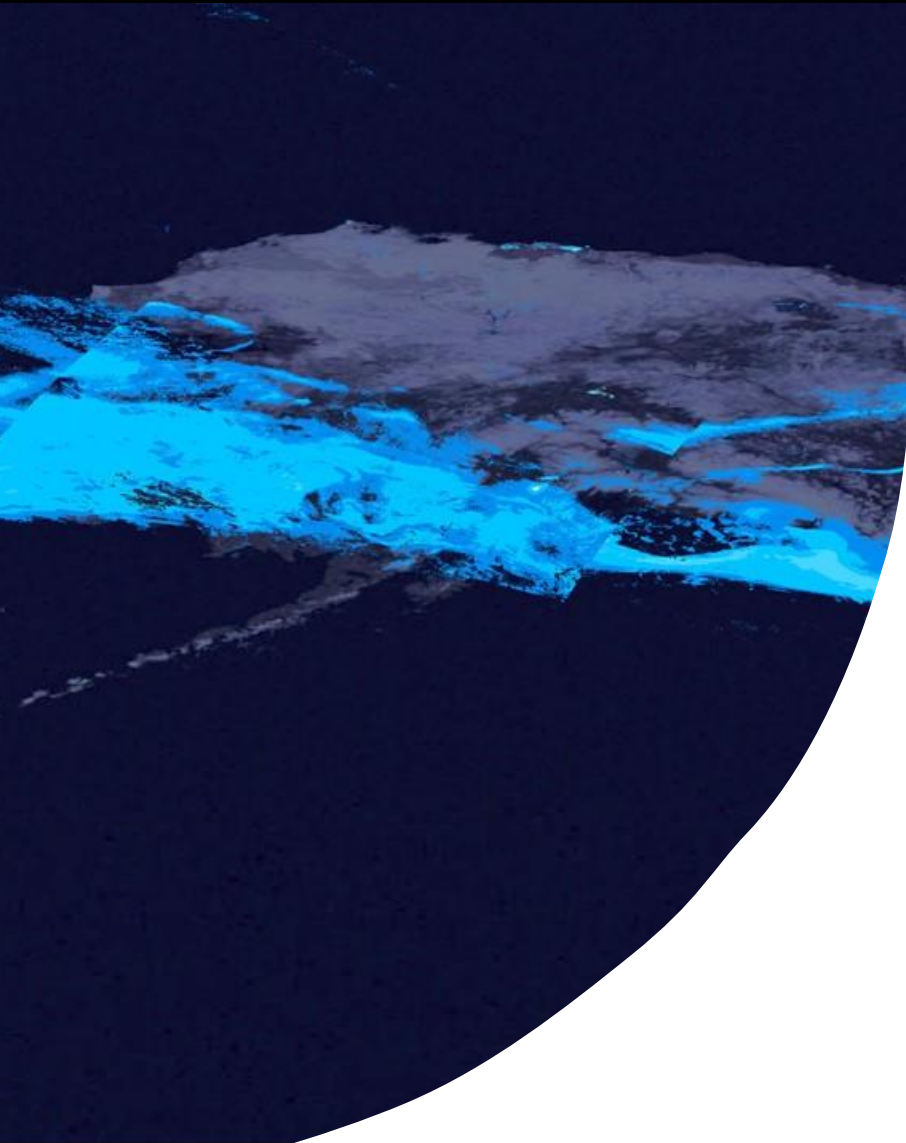




National Aeronautics and
Space Administration



Arctic Space Weather

Enhancing Aurora Watch Planning of Arctic
Cruises During Peak Seasons for Polar
Tourism

Sayona Turner, Lorryn McKaig, Phoebe Mahlin, &
Christopher Ramos (Analytical Mechanics Associates)

Virginia – Langley | Summer 2025



Meet the Team



Sayona Turner



Lorryn McKaig



Phoebe Mahlin



Christopher Ramos



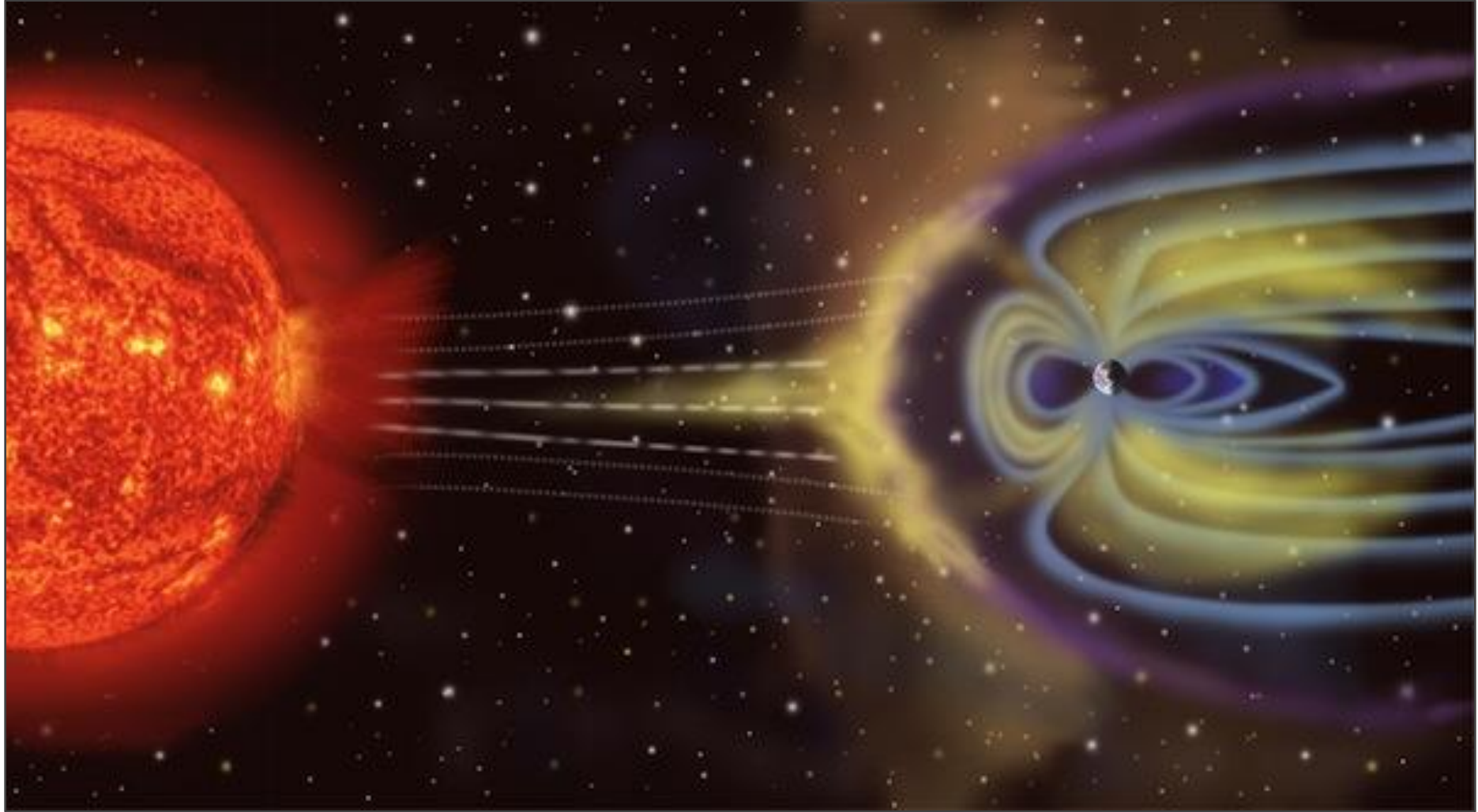
Origins of the Aurora Borealis

Sun

- Coronal Mass Ejections, High Speed Streams

Earth

- Magnetosphere
- Ionosphere



The Polar Adventure Company

About the Partner

- 50 years of experience
 - Relies solely on guides' experiences on observing biodiversity and viewing aurora
- 196 cruises in 2025
 - Arctic: Aug-Oct
 - Antarctic: Mar-Apr
 - 6 cruises advertise viewing aurora

Passenger Demographics + Impact

- Typical Tour Participant
 - Age: 40+
 - Possess secondary education
 - American
 - Interested in observing aurora
- Polar tourism market was \$11.2 billion in 2024, expected to reach \$17.8 billion by 2031

Source: Clayton Anderson (TPAC)



Community Concern

Partner Concern

Our partner relies on guide's past experiences with aurora. The incorporation of scientific input will aid accurate planning and promotion for aurora experiences.

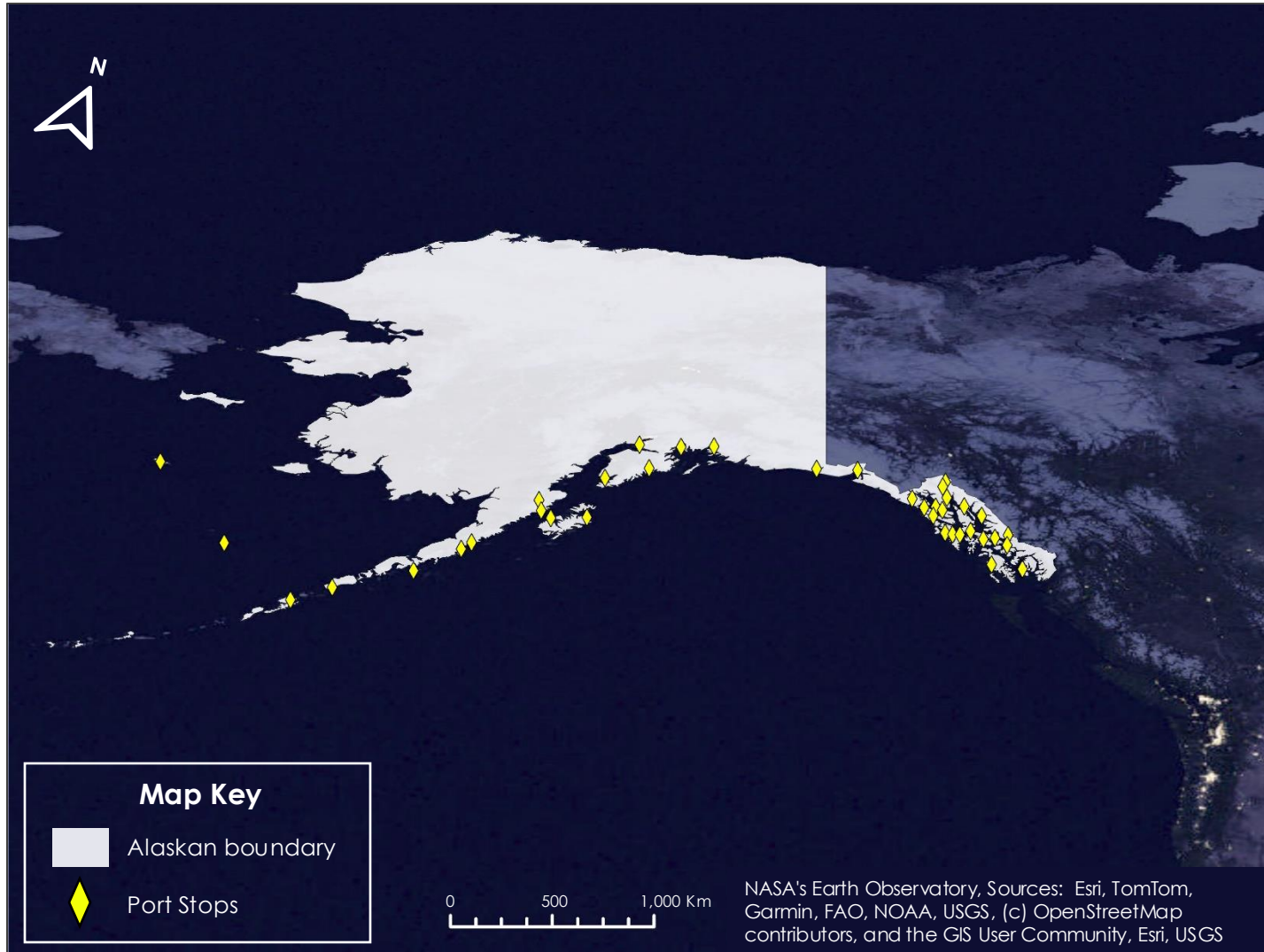
Passenger Concern

The darkness that is essential for aurora viewing is limited during peak tourism season for Arctic Voyages.

Source: Clayton Anderson (TPAC)



Study Area



Study Period

**Solar Cycles 24
(2008-2019)**

&

**Solar Cycle 25
(2020-Present)**

- Peak Arctic voyage months:
August – October
- 9 PM – 5 AM Alaska local time

Forecasts

August – October
2026 – 2028



Observational Data

Ground Based

- Planetary K (Kp) Index
- Auroral Electrojet (AE) Index
- Sunspot Number
- Aurorasaurus

Satellite Instrumentation

- Suomi National Polar-Orbiting Partnership (Suomi NPP) Visible Infrared Imaging Radiometer Suite (VIIRS)
- Advanced Composition Explorer (ACE)

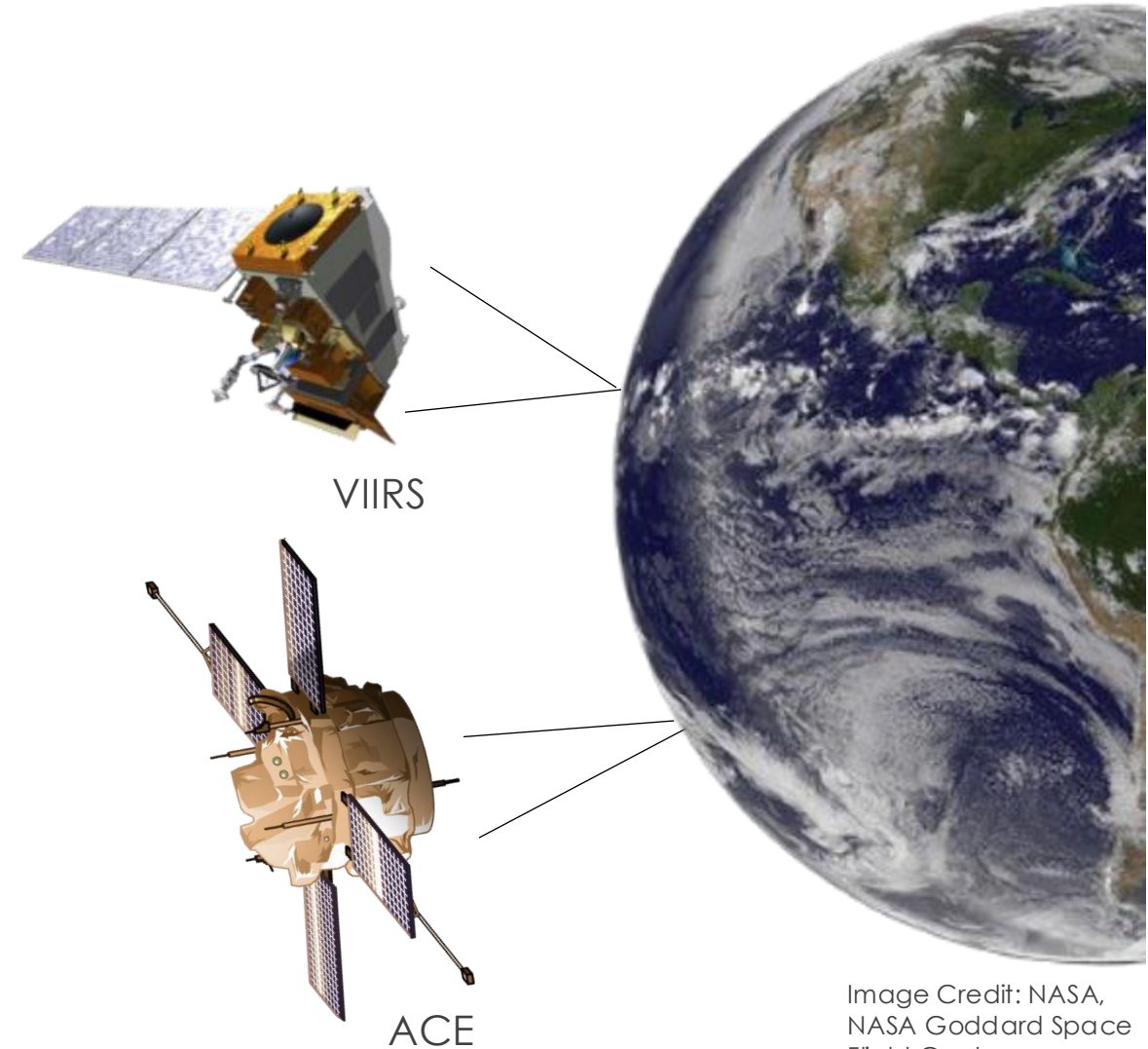


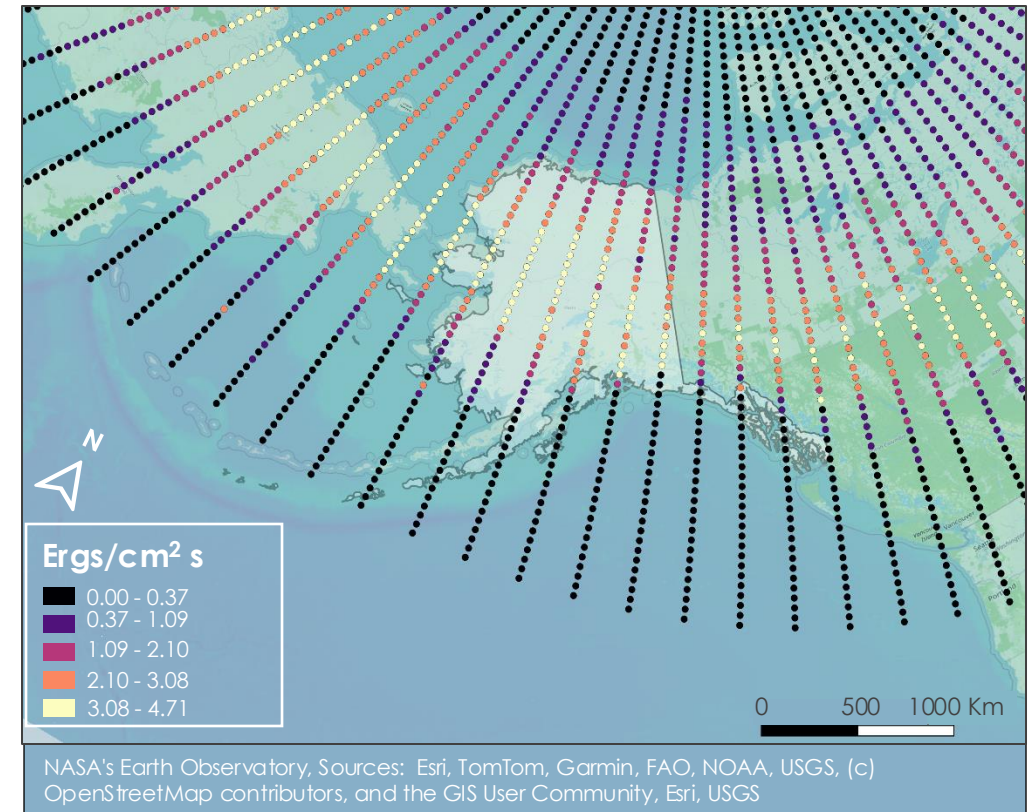
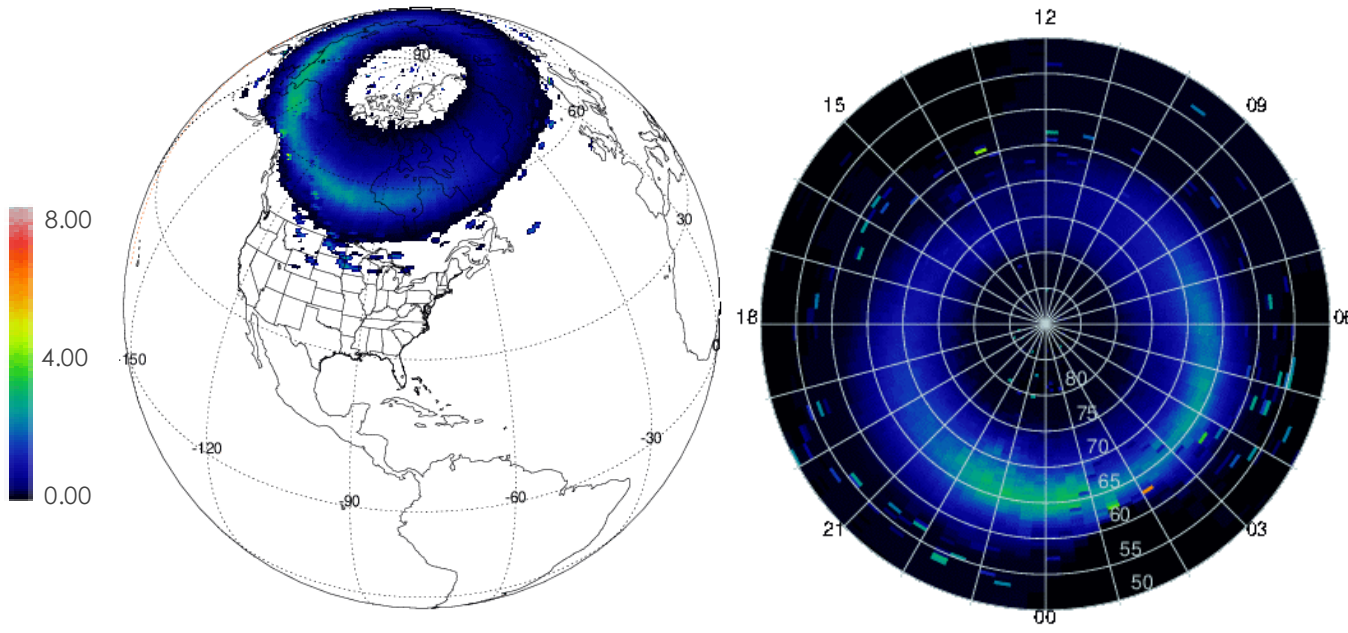
Image Credit: NASA,
NASA Goddard Space
Flight Center



OVATION Prime (OP) Model

- Modeling auroral precipitation by parameterizing solar wind data from ACE
- Widely utilized by operation centers and research institutes

Aurora precipitation, 2023/09/20 11:45:00



Objectives

1.

Validate OP output with auroral Earth observations for case study date

2.

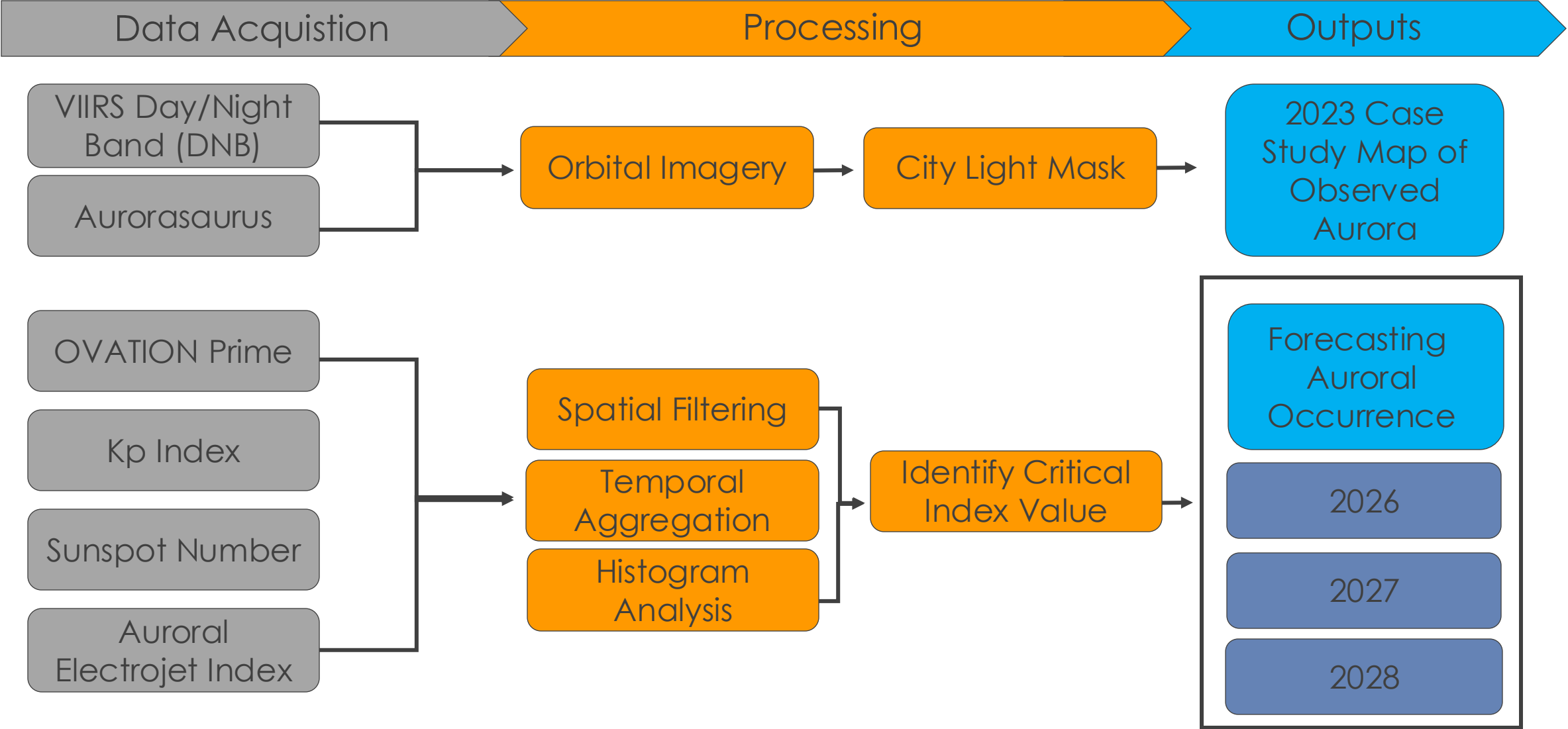
Utilize historical data to analyze trends and estimate the activity for upcoming decline phase

3.

Create an auroral probability map over Alaskan port stops for 2026 showcasing predicted aurora occurrences



Methodology



Challenges



Lack of precedence in forecasting models:
OP up to 1 hr & Kp forecast up to 27 days

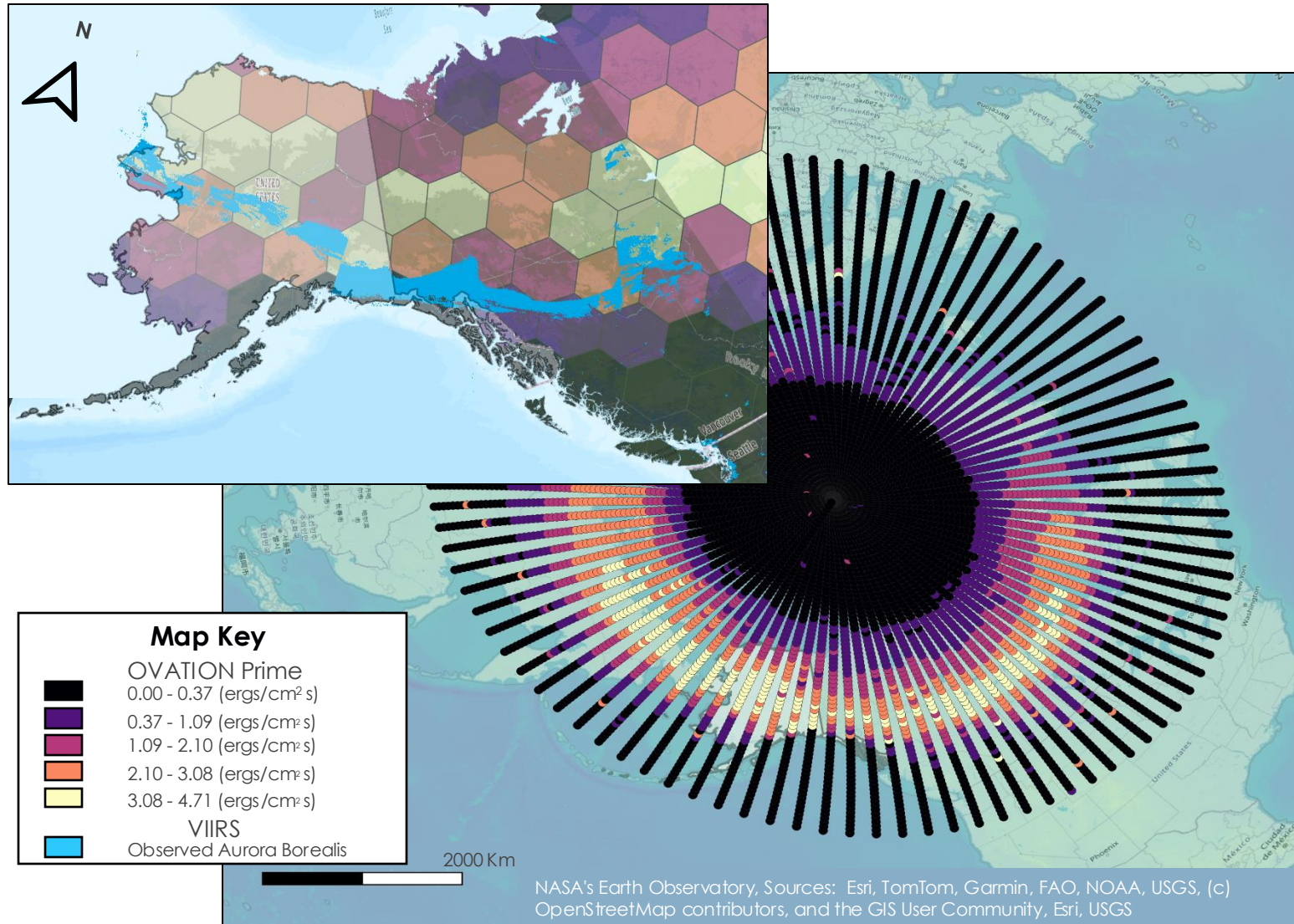


10-week feasibility study

Source: Clayton Anderson (TPAC)



Case Study Map of Observed Aurora

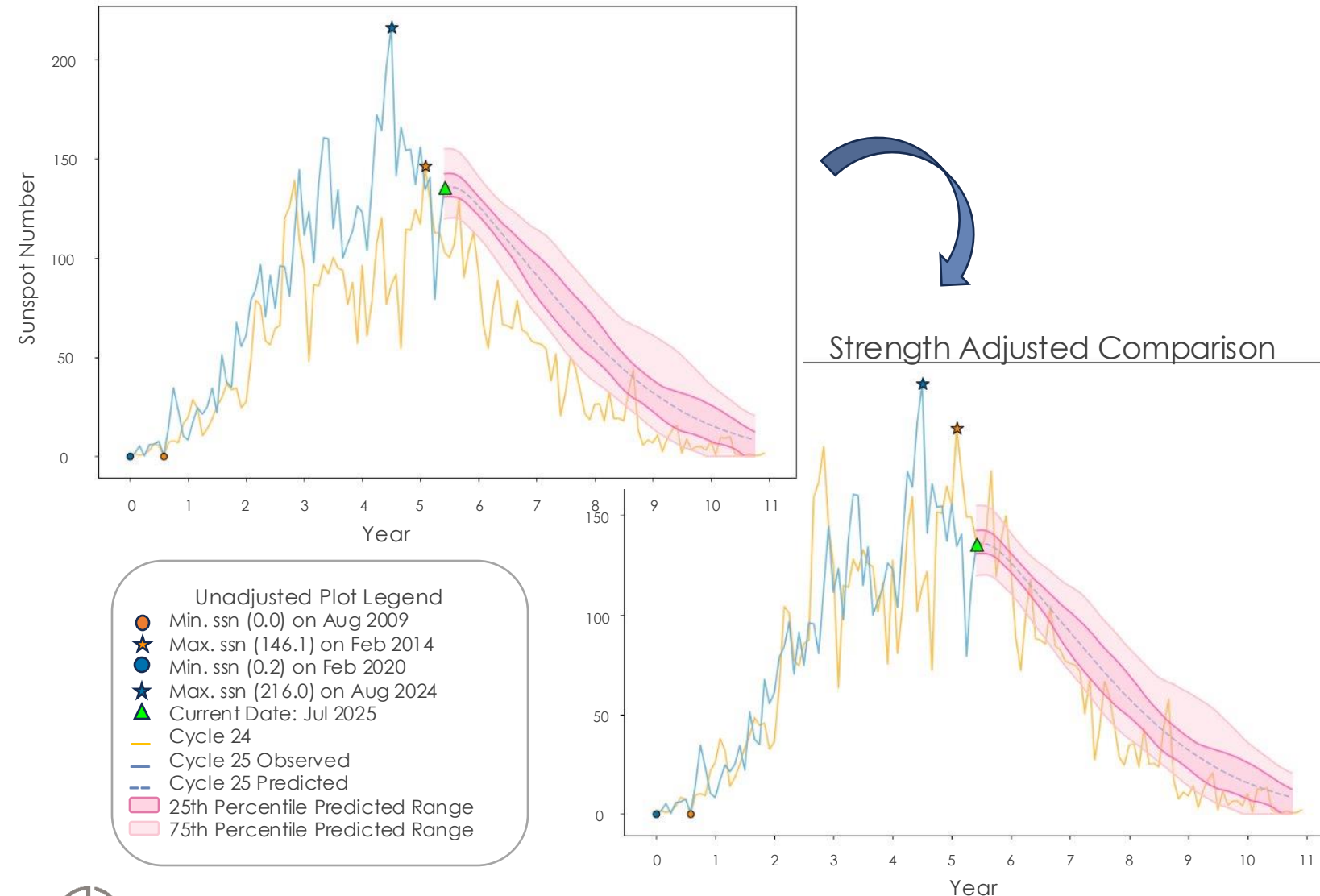


Sept 20th, 2023
3:44 AM local time

Kp 5+; AE 1000nT
High activity storm

Solar Cycle Comparison

Sunspot Number Comparison for Cycles 24 and



Results

- Similar trend for Cycle 24 and 25
 - Double peak unpredictability
- Cycle 25 is 32.56% stronger, longer predicted decay

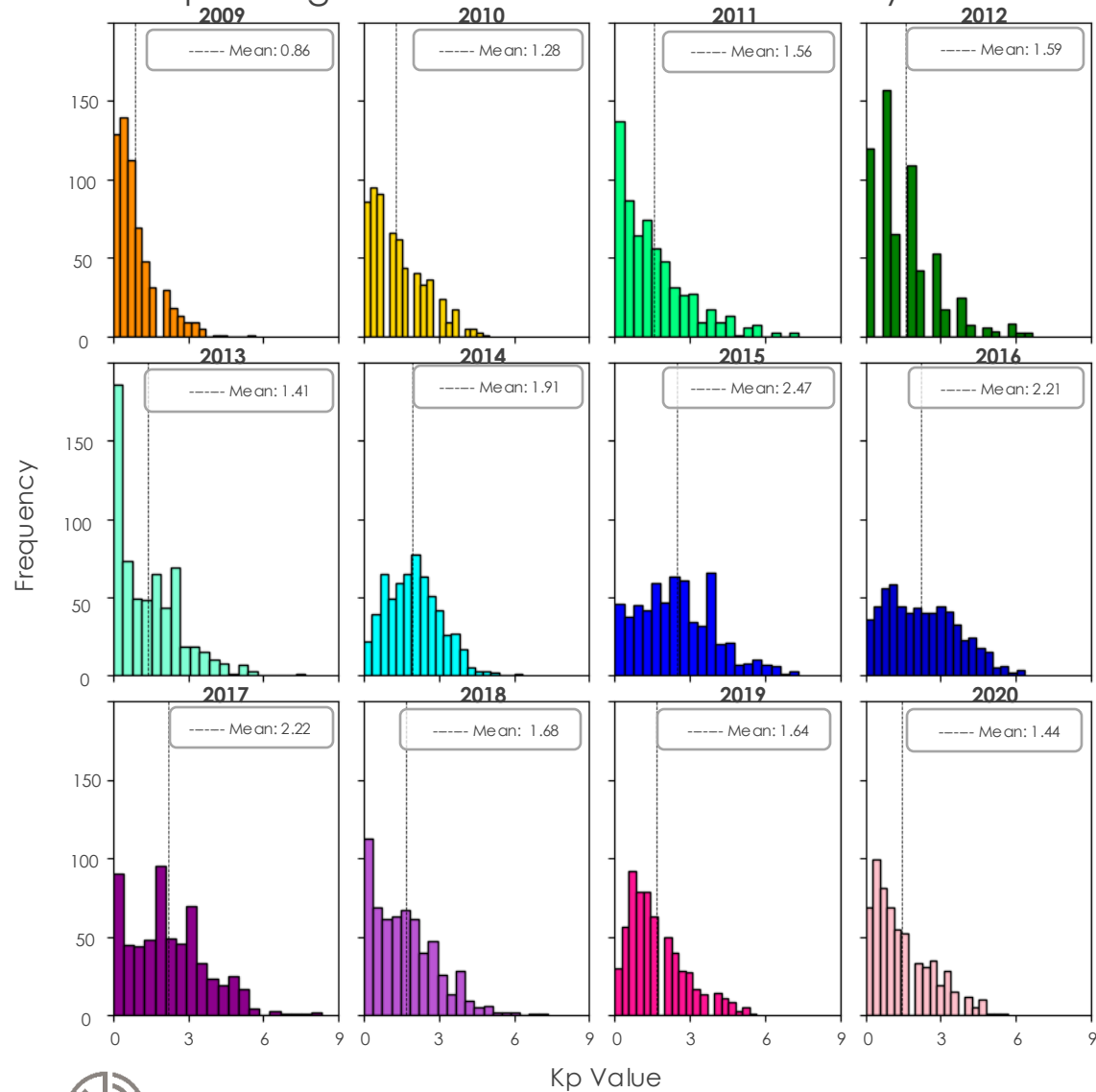
Conclusion

- Strength adjustment on historical data
- Assuming similar solar activity and geospace response, aurora occurrence in 2026 is similar to that in 2015, 2027 to 2016, 2028 to 2017

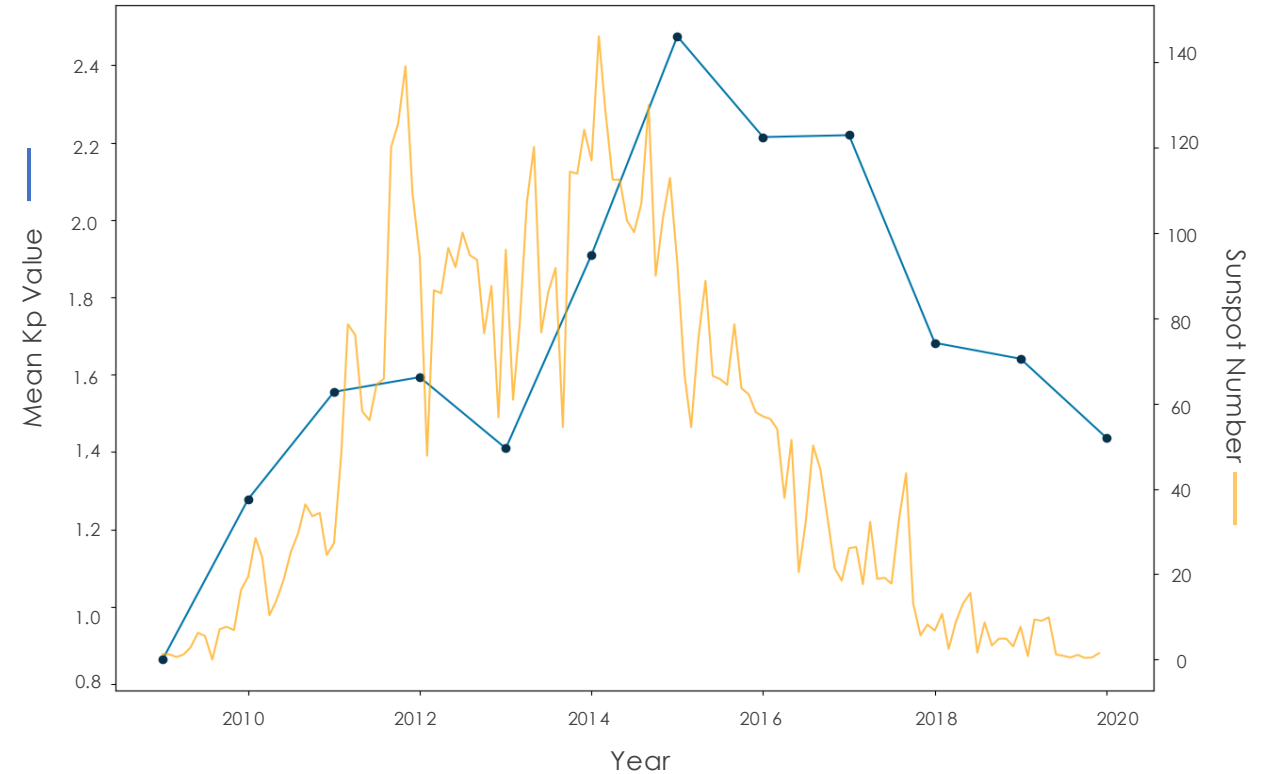


Kp Trends

Kp During Peak Tourism Seasons in Solar Cycle 24



Mean Kp Compared with Sunspot Number in Solar Cycle 24

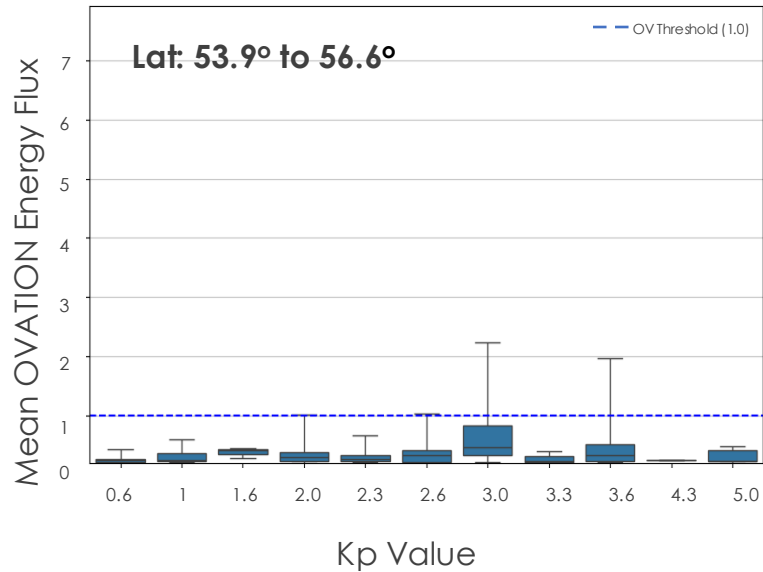


- Mean Kp value follows the solar cycle trend
- Correlation between increasing and decreasing cycle activity



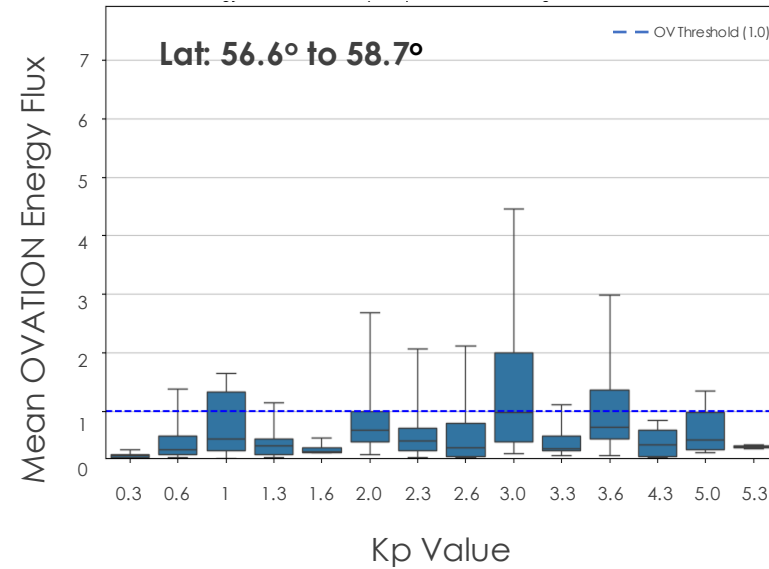
Finding $\overline{K_p}$

Mean OVATION Energy Flux Distribution per Kp Value for Lat Range **53.9° to 56.6°** (Alaska)



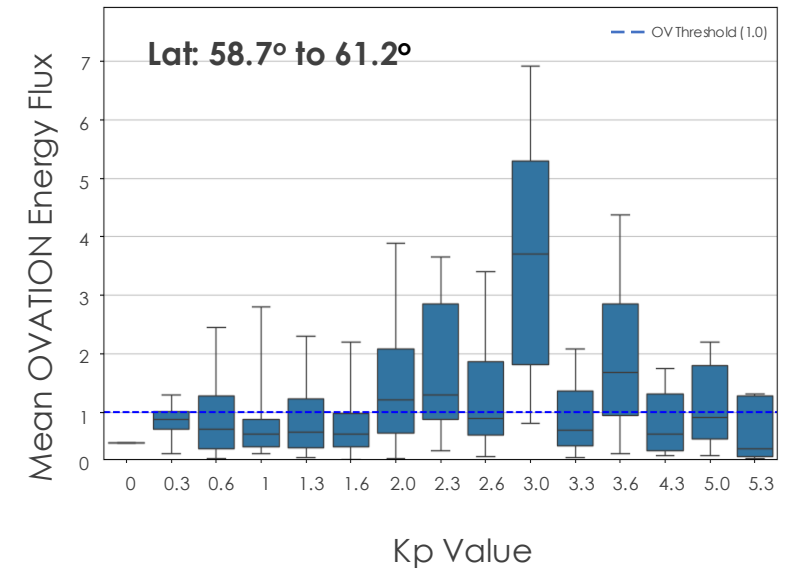
Average Weighted Kp Value: **2.64**

Mean OVATION Energy Flux Distribution per Kp Value for Lat Range **56.6° to 58.7°** (Alaska)



Average Weighted Kp Value: **2.28**

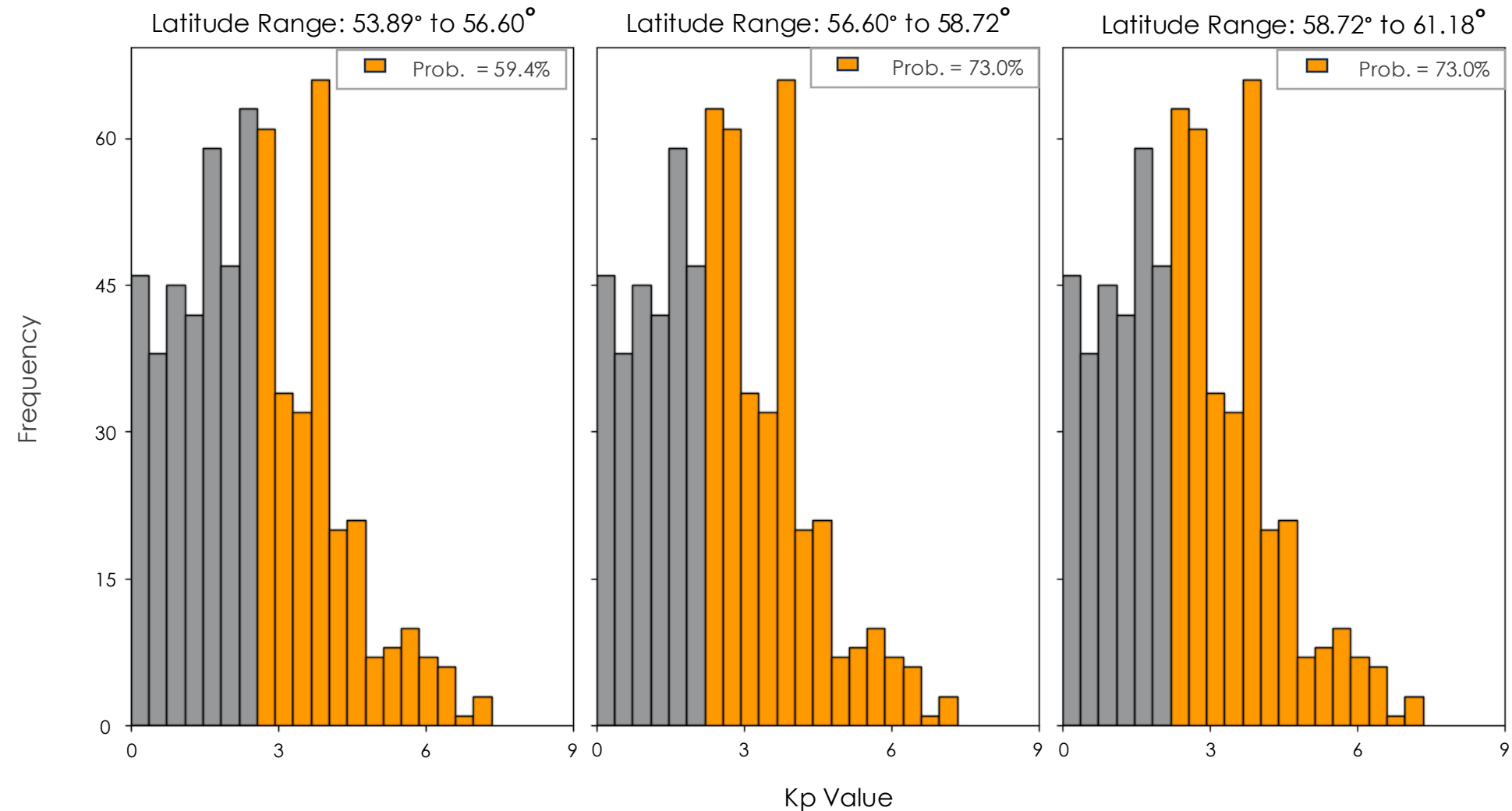
Mean OVATION Energy Flux Distribution per Kp Value for Lat Range **58.7° to 61.2°** (Alaska)

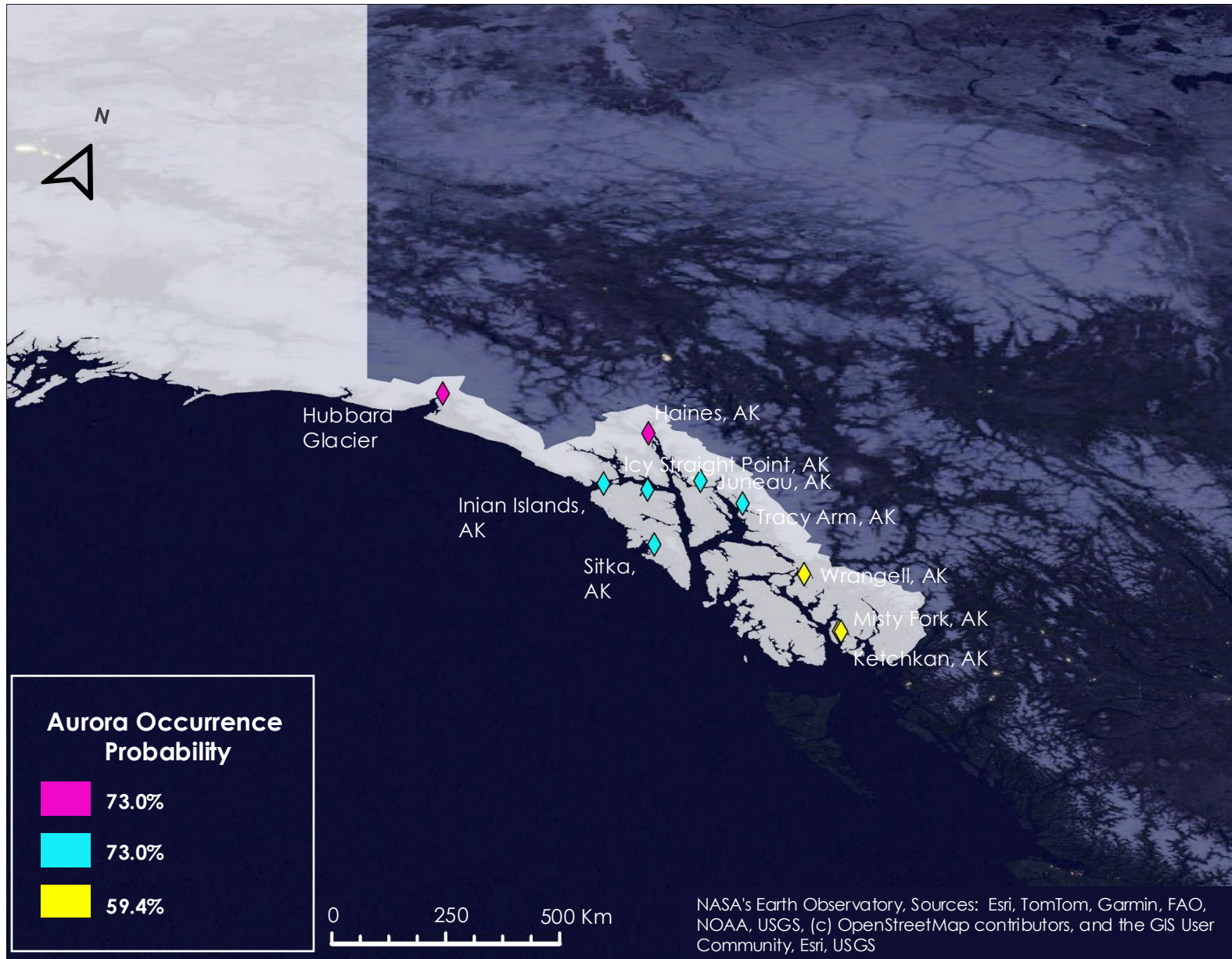


Average Weighted Kp Value: **2.15**

Predicting Aurora Using $\overline{Kp}$

Kp Predictions for Alaska 2026





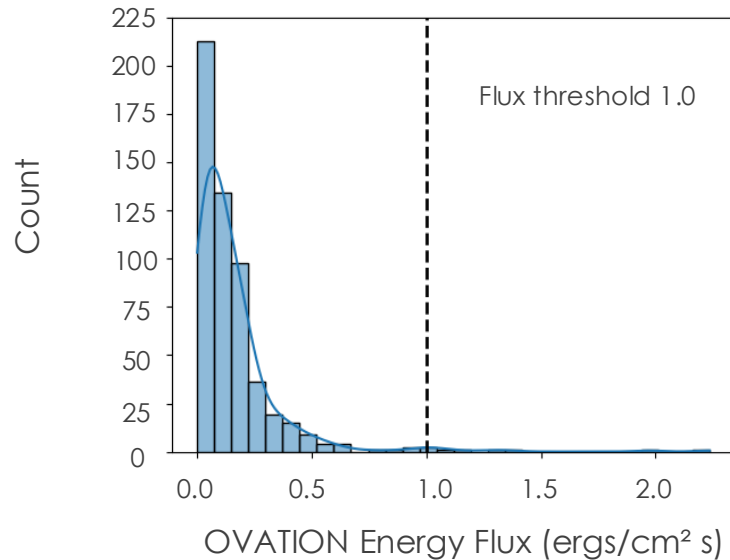
Expedition Cruise (2026)

- Eastern Alaska
- 9 Stops
- 10 Cruise nights
- Depart: August 28th
- Return: September 9th

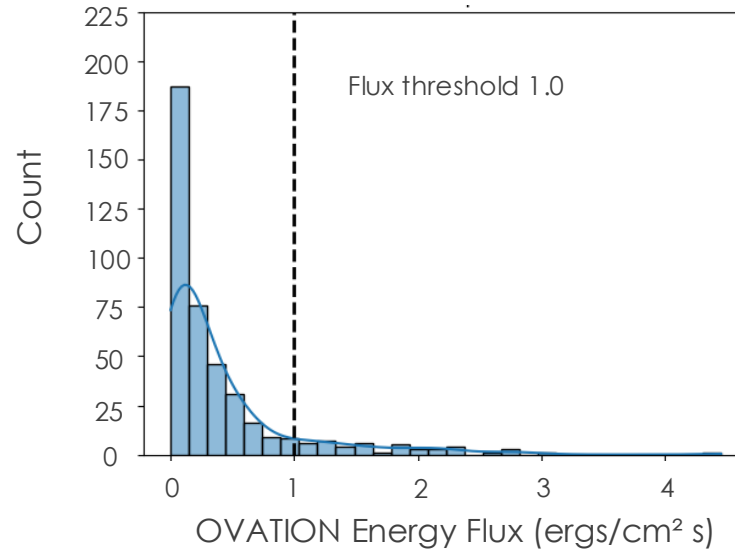


Predicting Aurora Using Precipitation Energy Flux

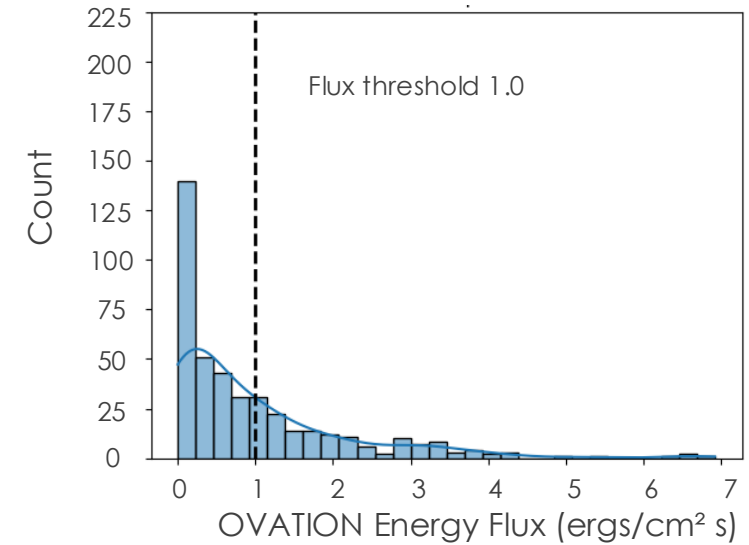
Auroral Intensity for AUG-OCT, 2014-2017
in Latitude Range **53.9° to 56.6°**, Alaska



Auroral Intensity for AUG-OCT, 2014-2017
in Latitude Range **56.6° to 58.7°**, Alaska

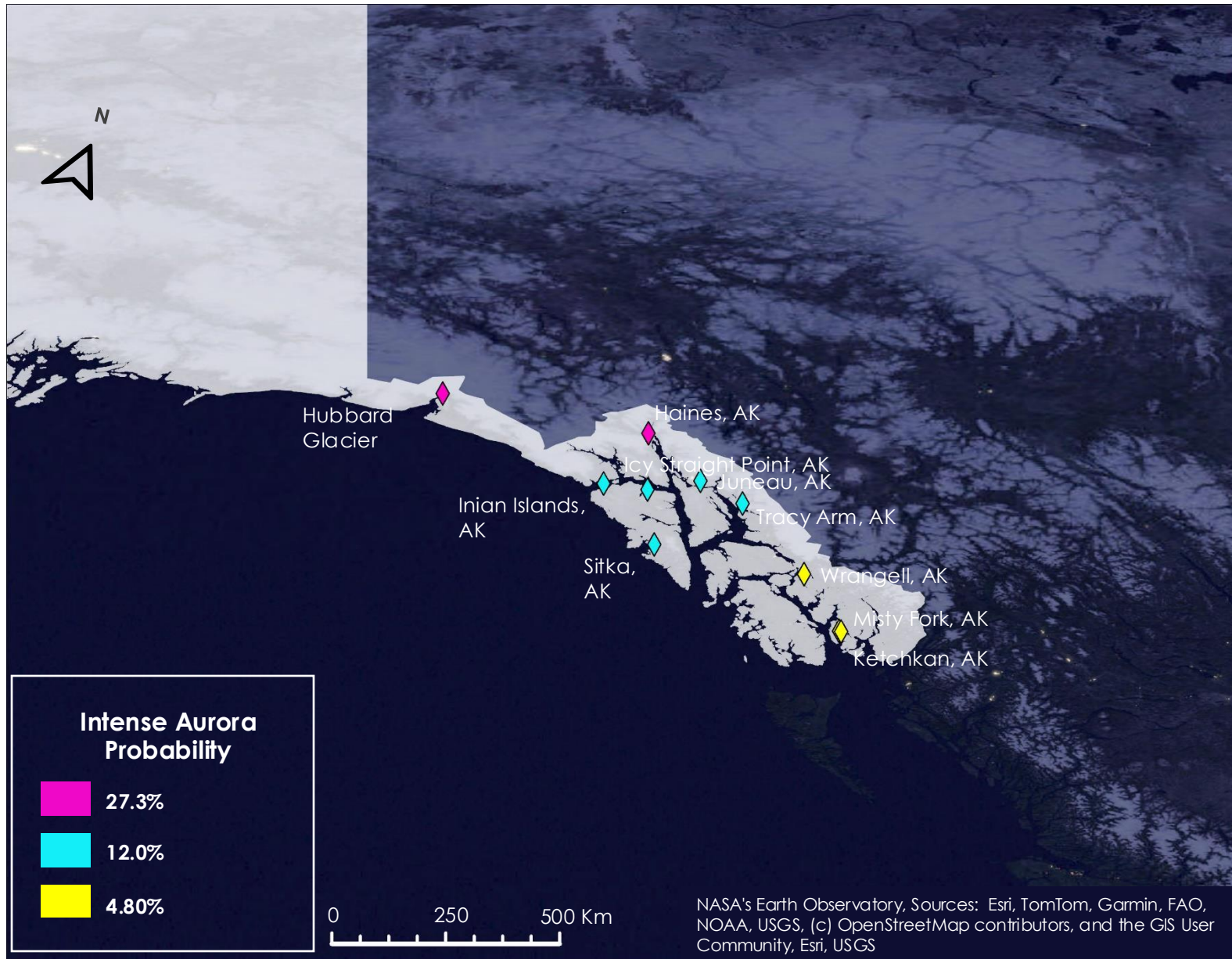


Auroral Intensity for AUG-OCT, 2014-2017
in Latitude Range **58.7° to 61.2°**, Alaska



Higher Latitude → Higher Auroral Intensity Values → Greater Aurora Visibility





Expedition Cruise (2026)

- Eastern Alaska
- 9 Stops
- 10 Cruise nights
- Depart: August 28th
- Return: September 9th



Limitations



Limited data due to cloud contamination



Storage limitations within the study only allotted for computation within Alaska. Cloud storage and computing (e.g., Amazon Web Service) could be a solution.



Auroral activity is monitored by limited number of field instruments, which poses challenges in accurately predicting auroral activity.



Partner Implementation

Provide a guide of when auroral activity is potentially visible

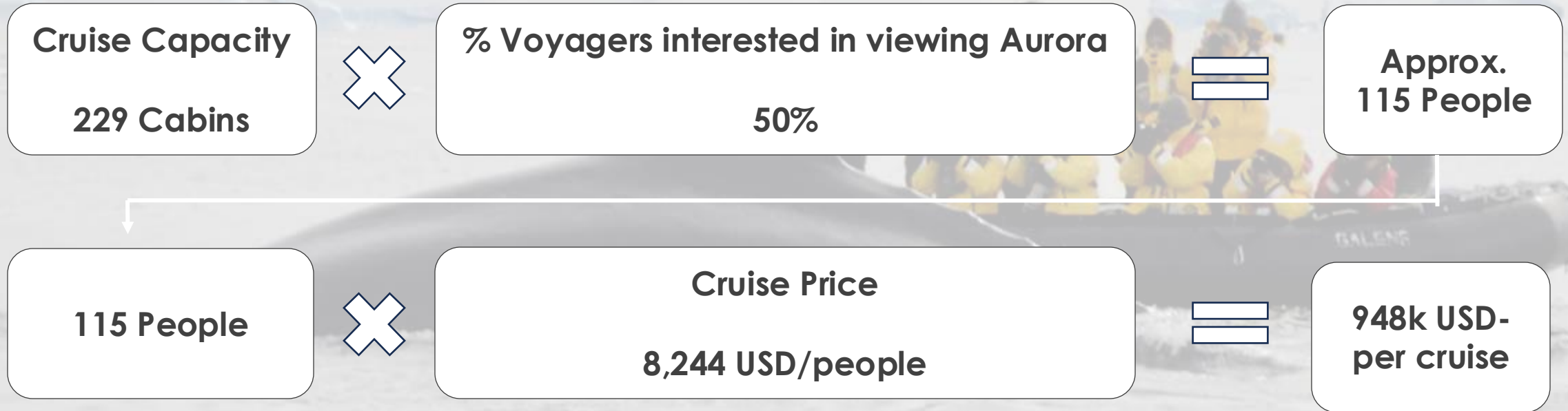
Enhance passenger understanding of auroral phenomena

Source: Clayton Anderson (TPAC)



Potential Economic Impact

2026 Expedition Cruise: 14 nights



Source: Clayton Anderson (TPAC)



Conclusions

Earth observation Suomi-NPP VIIRS can provide aurora observations from space to benefit aurora study and forecasting.

OVATION Prime is a reliable tool for estimation of the likelihood of viewing auroral phenomena in near-term (30 minutes) and short-term (~ 1 day)

OVATION Prime could be a potential tool for long-term (~ 1 year) auroral prediction assuming similar solar wind driving and geospace response at the same solar phase.

Forecasting efforts provide a spatiotemporal guide to potential aurora occurrence on future voyages and may enhance partner and passenger understanding of auroral phenomena.

Source: Clayton Anderson (TPAC)



Acknowledgements

- **Advisors:** Dr. Xia Cai (NASA Langley Research Center), Dr. Elizabeth MacDonald (NASA Goddard Space Flight Center), Dr. Yihua Zheng (NASA Goddard Space Flight Center)
- **Partners:** Clayton Anderson, Lex Harrison, Jason Hilier, Thomas Lennartz (Polar Adventure Company)
- **PC Fellow and Project Lead:** Brent Bowler (Virginia – Langley), Jack Graziano (Virginia – Langley)



This material is based upon work supported by NASA through contract 80LARC23FA024. Any mention of a commercial product, service, or activity in this material does not constitute NASA endorsement. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration and partner organizations.

