NOAA Center for AI: AI-Ready Capacity Building to Solve Earth and Space Science Challenges

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National Centers for Environmental Information (NCEI)
NOAA Center for Artificial Intelligence (NCAI)

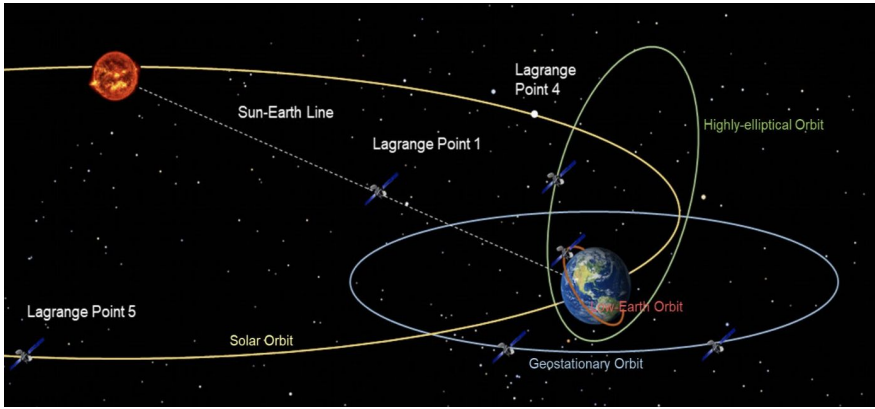
January 31, 2024
104th AMS Annual Meeting
"Session 9: E Pluribus Unum: Synergistic Approaches That Realize the Full Promise of Space Weather Next"

Contributions from the NCAI Development Team,
NOAA AI Executive Committee, and NOAA AI Working Group
Special Thanks: Chris Bethge, Fadil Inceoglu, Alison Jarvis, Paul Loto'aniu, Manoj Nair
https://www.noaa.gov/ai/about

Agenda

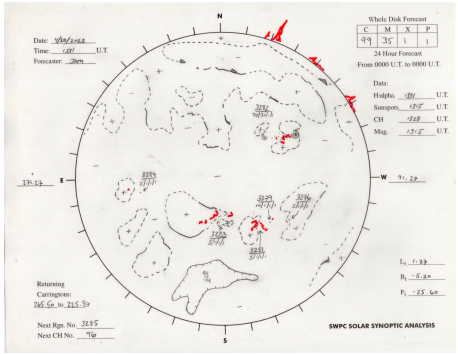
Motivation and Scene Setting

- NOAA's AI Strategic Approach



NOAA Center for AI

- Ethical AI Innovation
- Community of Practice
- AI-ready Data Standard
- Training the Workforce
- SWX Example Use Cases



Connect with NOAA's 800+ member Community of Practice around AI for Earth system science to develop synergies and partnerships
NCAI Monthly Newsletter: tinyurl.com/y2ehvhfg

NOAA AI Strategic Approach

National AI Initiative Act of 2020:
"The Administrator of NOAA [...] shall establish,
a Center for Artificial Intelligence"
"There are authorized to be appropriated to the Administrator to carry out this section $10,000,000 for fiscal year 2021"

Several Executive Orders, including:

- "Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence" (EO 14110)
- "Maintaining American Leadership in Artificial Intelligence" (EO 13859)
- "Promoting the Use of Trustworthy Artificial Intelligence in the Federal Government" (EO 13960)

sciencecouncil.noaa.gov

Related NOAA Strategic Plan Goals & Objectives

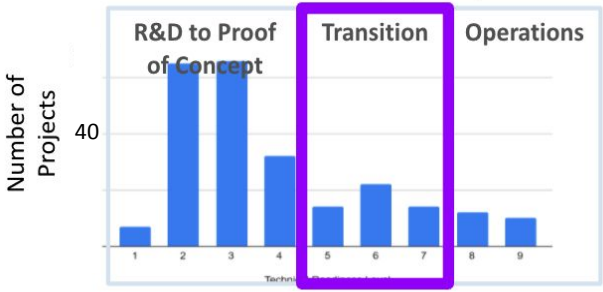
Foster an Information-Based Blue Economy:

NOAA will introduce innovation to data collection through various methods for species detection and explore AI/ML and data visualization technologies...

Ensure accessibility and enable an enterprise climate information framework to meet the needs of NOAA's users:

NOAA will leverage the lasting value of its observational holdings to create robust, sustainable and scientifically sound analysis and AI-ready climate records with the longevity, consistency and continuity needed to understand climate variability and change.

2022 Data Call included 261 projects (188 in 2020)



NOAA Center for AI as a Tech Hub

NCAI Program Office & Tech Hub

Ethical AI Innovation
Why, What, How

Training
Responsible AI

AI-Ready Data
Standards

Partnerships
&
Engagement

Communities of
Practice
Coordination

Dynamic
Workspaces

or Similar

Communities of Practice

Savvy AI Trained Workforce

Fisheries Research Surveys

Digital Twins for Fire Wx

Multi-lingual Climate / Wx

Rule Making for Bycatch Limits

Optimizing Workflows ◎ **Sharing Knowledge** ◎ **Obtaining Results**

NOAA Leadership in Using and Enabling AI

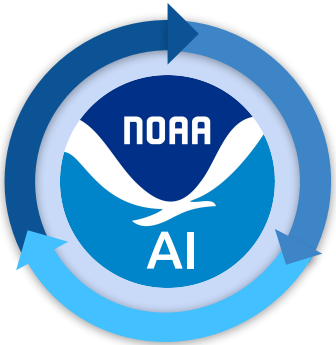
NOAA **uses** AI to advance our mission, from weather forecasting, fisheries management, to space weather prediction.

NOAA **enables** AI applications by turning our Earth system observations into AI-ready data that can drive AI for the NOAA mission, the private sector, research, and other uses.

Rip currents

Ecosystem monitoring

Space weather forecasts

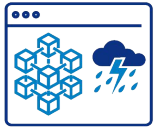


AI ready data

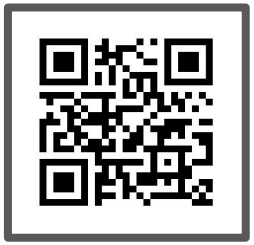
Community of practice

Reanalysis data sets

Wildfires



Numerical weather prediction

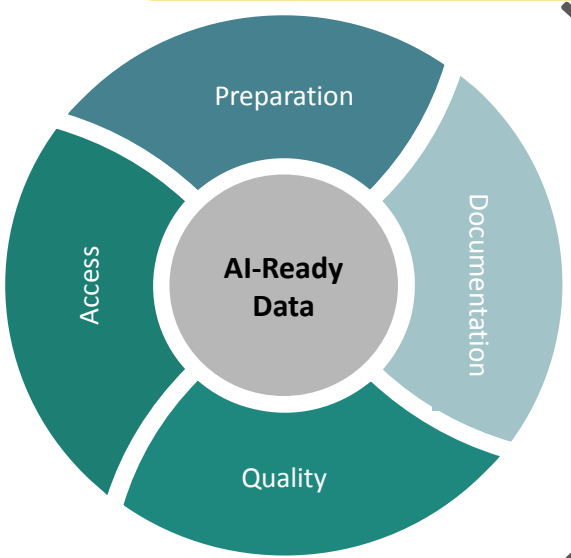


Scientific stewardship (QA/QC)

Repository of 60 PB of data

Community-Driven AI-Ready Data Initiative

Increasing Earth and SWX Science AI-Readiness



Documentation enables users to understand the contents of a data set and should provide information and tools to ***increase data usability***.

Quality **information** determines the dataset's "***fit-for-purpose***" for AI & affects the trustworthiness of AI applications.

Access affects the ***efficiency & reproducibility*** for AI R&D process.

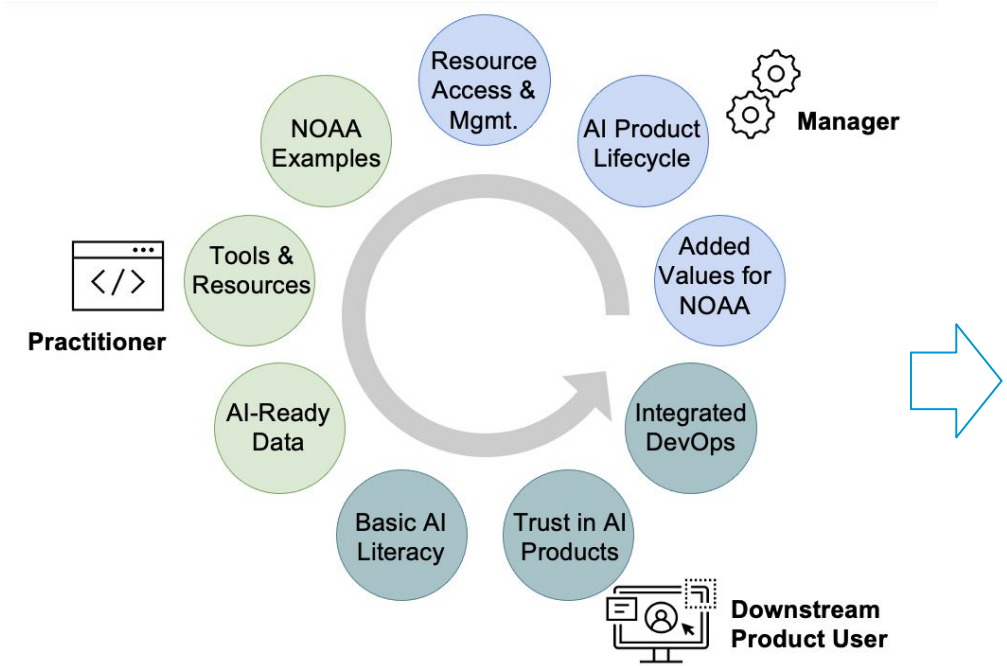
Preparation help identify common ***data services and tools*** to reduce preprocessing burden for users including AI practitioners.

Earth Science Information Partners (ESIP) Data Readiness Cluster is a forum for agencies (NOAA, NASA, USGS, DOE, USAF, etc.), private sectors, and academia to:

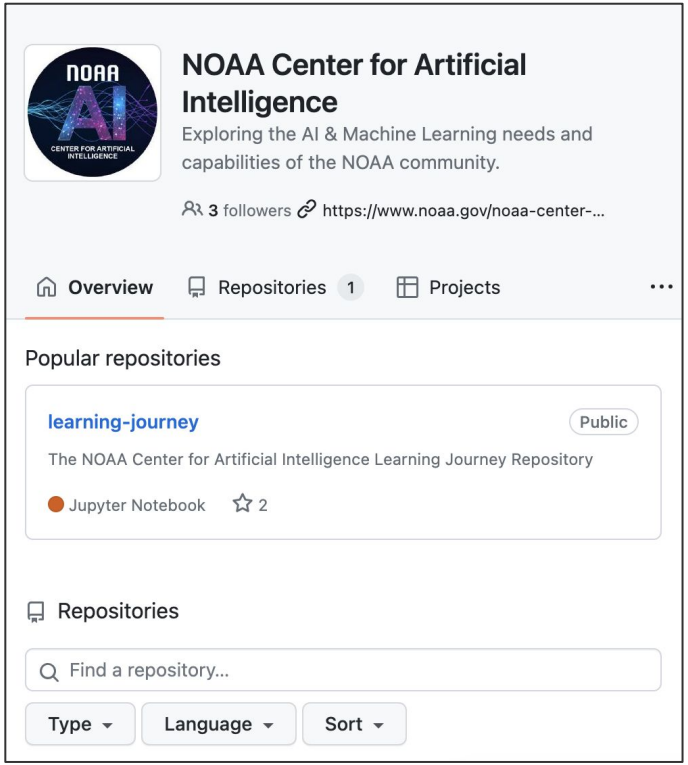
- Understand user needs for AI/ML R&D with environmental data
- Develop community standards, leading practices and tools for AI-ready data
- Open collaboration via Github for AI-ready data checklist - github.com/ESIPFed/data-readiness

Workforce Training – Responsible AI

Learning Journeys – Advancing O2R2O



NOAA training action priority lifecycle highlighted by workforce role and relationship to AI



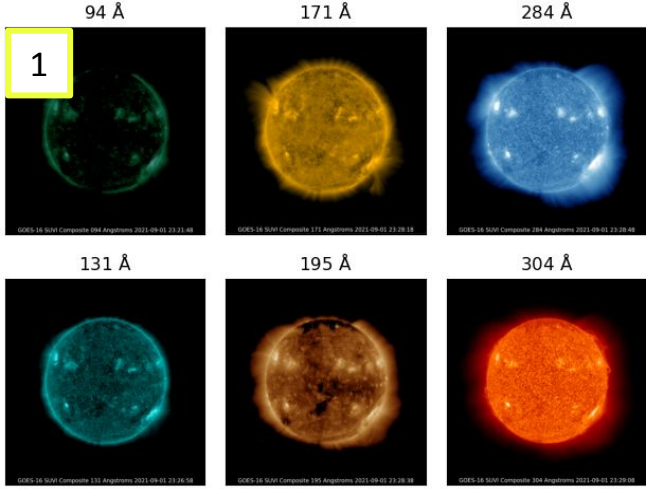
Learning Journey release via NCAI GitHub: github.com/noaa-ncai/learning-journey

Solar – Classifying Space Weather Regions of the Sun

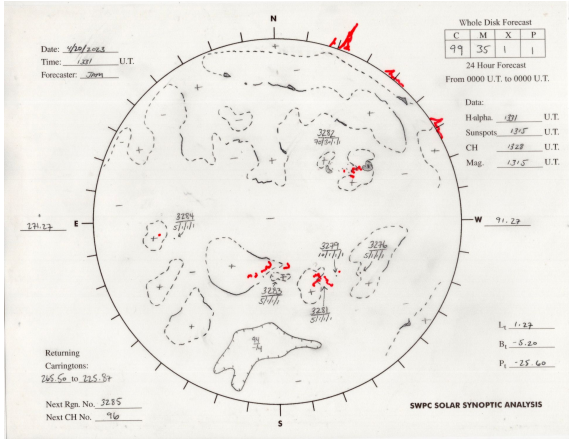
Space Weather is powered by the energy released from explosive eruptions on the Sun. The National Academies has estimated that the cost of an extreme solar eruption could exceed several Trillion USD.

- **Forecasters have created hand annotated "synoptic" maps of the sun since 1972.**
- GOES-R – we are empowering the forecaster, and SWX application development (R2O2R) with automation.

GOES-R Solar Ultraviolet Imager (SUVI) images the Sun in 6 UV bands

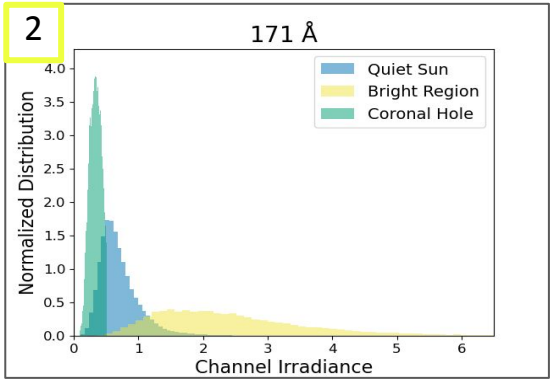


Synoptic Maps - Critical Forecaster tool since 1972



Credit: NOAA SWPC

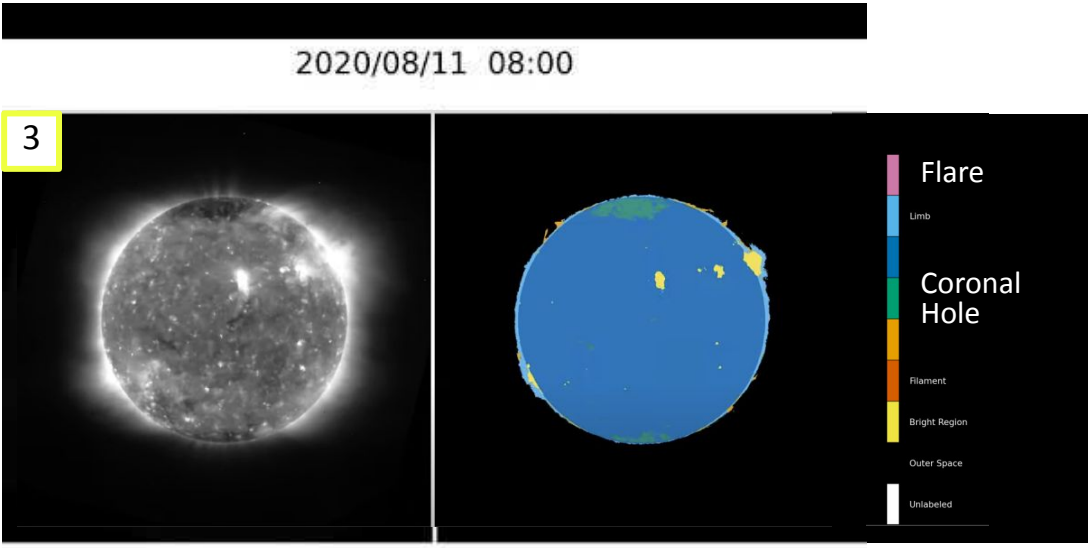
Feature Engineering – bands distinguish solar phenomena



Solar – Classifying Space Weather Regions of the Sun

Space Weather is powered by the energy released from explosive eruptions on the Sun. The National Academies has estimated that the cost of an extreme solar eruption could exceed several Trillion USD.

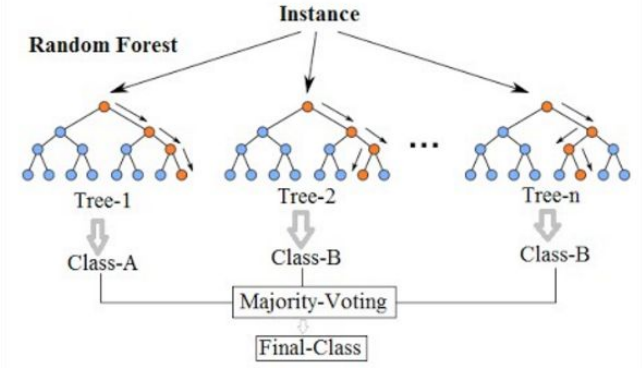
- **Thematic maps provide automatic, real-time classification of solar features,**
- These maps enable both real-time event monitoring / prediction and long-term statistical studies.



Thematic Maps: GOES-R Space Weather / example display code. See Hughes et al. for a description of original algorithms. See here for code used to produce these results.
Contacts: Alison.Jarvis@noaa.gov, Christian.Bethge@noaa.gov

How?

GOES-16 Solar Ultraviolet Imager (SUVI) composite images, observed in six extreme ultraviolet wavelengths, are input to a random forest algorithm to generate a thematic map.



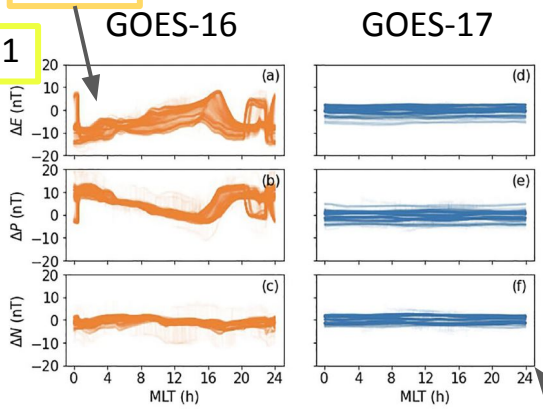
Credit: Wikipedia, notional random forest.

Earth's Magnetic Field from Satellite Observations - Debiasing

Correcting Geosynchronous Magnetic Field using Transfer Learning

Errors

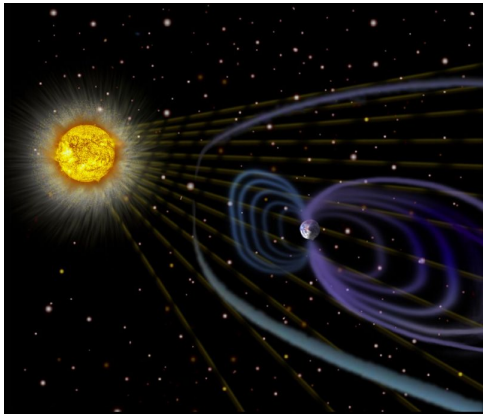
1



Outboard - Inboard time series for the E-component (ΔE), the P-component (ΔP), and the N-component (ΔN) for GOES-16 (a–c) and GOES-17 (d–f)

Inceoglu and Loto'aniu, Space Weather, 2021
https://doi.org/10.1029/2021SW002892

Earth's Magnetic Shield
Protects Us from the Solar Wind

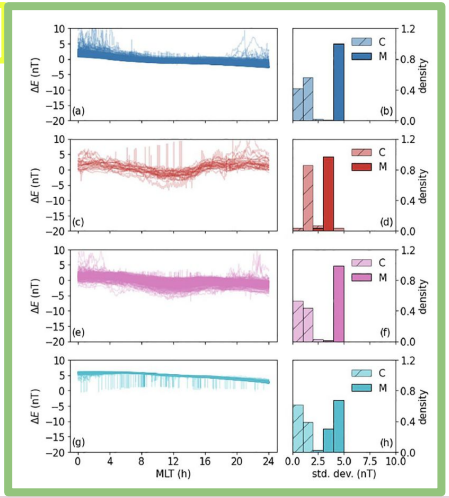


Credit: NASA and GOES-R

2 **Four clusters** of anomalous data detected in the magnetic field data… **due to Earth shadowing of the spacecraft during eclipse seasons**

Transfer Learning

3



Correction via LSTMs using transfer learning from GOES-17. The left panel shows the difference between GOES-16 measured OB and corrected IB E-component magnetic field values for each cluster. On the right panel, we show the standard deviations calculated for the offsets between the measured OB and IB (darker colors) and also the standard variations in the differences between the measured OB and corrected IB (hatched bars).

Magnetic Navigation: MagNet Challenge

X-Prize to Forecast SWX Effects on Magnetic Navigation

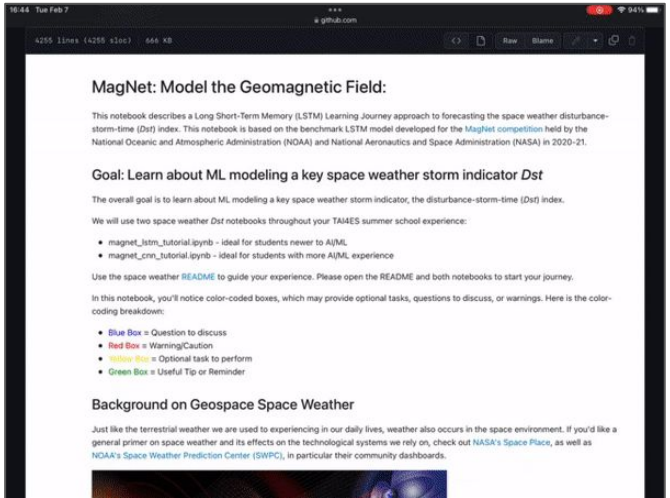
- ***Challenge*** *- to improve precision magnetic navigation during times of heightened space weather, e.g. for efficient critical mineral exploration.*
- ***NCEI Innovates*** - funded a competition to improve an ML model to predict a key Space Weather index from DSCOVR satellite solar-wind data, mitigating impacts on magnetic navigation; *600 participants and ~1200 model submissions*

www.ncei.noaa.gov/products/geomagnetic-data

DRIVENDATA

	User or team		Best private RMSE
	Ammarali32	1	11.1311
	belinda_trotta	2	11.2532
	LosExtraterrestres	3	11.2944
	k_squared	4	11.5293

Dr. Belinda Trotta
Melbourne, Australia
Senior Software Eng.
2nd Place



MagNet: Model the Geomagnetic Field:

This notebook describes a Long Short-Term Memory (LSTM) Learning Journey approach to forecasting the space weather disturbance-storm-time (*Dst*) index. This notebook is based on the benchmark LSTM model developed for the MagNet competition held by the National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA) in 2020-21.

Goal: Learn about ML modeling a key space weather storm indicator *Dst*

The overall goal is to learn about ML modeling a key space weather storm indicator, the disturbance-storm-time (*Dst*) index.

We will use two space weather *Dst* notebooks throughout your TAI4ES summer school experience:

- magnet_lstm_tutorial.ipynb - ideal for students newer to AI/ML
- magnet_cnn_tutorial.ipynb - ideal for students with more AI/ML experience

Use the space weather README to guide your experience. Please open the README and both notebooks to start your journey.

In this notebook, you'll notice color-coded boxes, which may provide optional tasks, questions to discuss, or warnings. Here is the color-coding breakdown:

- Blue Box = Question to discuss
- Red Box = Warning/Caution
- Yellow Box = Optional task to perform
- Green Box = Useful Tip or Reminder

Background on Geospace Space Weather

Just like the terrestrial weather we are used to experiencing in our daily lives, weather also occurs in the space environment. If you'd like a general primer on space weather and its effects on the technological systems we rely on, check out NASA's Space Place, as well as NOAA's Space Weather Prediction Center (SWPC), in particular their community dashboards.

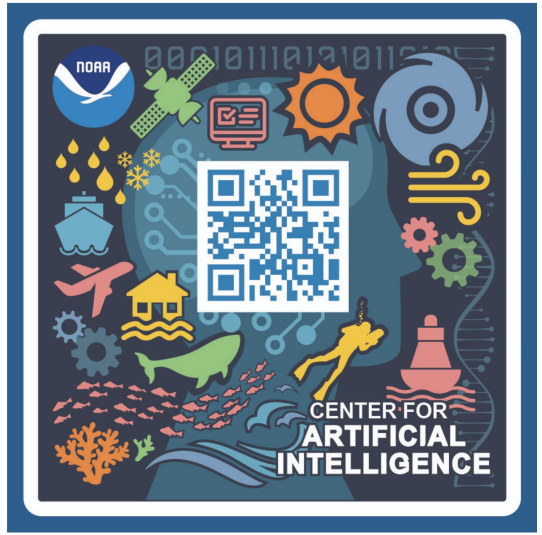
NOAA Center for Artificial Intelligence

SAVE THE DATE
September 16–20, 2024

6th NOAA AI Workshop
Leveraging AI in Environmental Sciences

Our Vision
Benefiting NOAA's mission by proliferating the use of Responsible AI at NOAA.

How?
By lowering the cost of engaging curiosity for our Community of Practice.



noaa.gov/ai