2025 Space Weather Workshop Poster Abstract Booklet
Boulder, CO

Organized by day and poster number.

Poster Lightning Talks:

Tuesday Posters: Tuesday March 18 ***2:45 PM – 3:15 PM***

Wednesday Posters: Tuesday March 18 ***5:15 PM – 5:45 PM***

Thursday Posters: Wednesday March 19 ***5:00 PM – 5:30 PM***

Tuesday, 18 March

Solar and Interplanetary Research and Applications

*Posters can be viewed all day, with dedicated times **9:55 AM – 10:45 AM** and **3:15 PM – 4:00 PM***

1. **Aatiya Ali** (Georgia State University)
Comparative Analysis of Solar Proton Events at Lagrange Point- 1 and the Geostationary Orbit
Co-authors: Viacheslav Sadykov, Georgia State University

Solar energetic particles (SEPs) travel through the heliosphere and interact with Earth's environment, posing risks to astronaut health and satellite operations. Solar proton events (SPEs), a SEP subclass, consist of protons with energies ≥10 MeVs exceeding 10 particle flux units. Accurate prediction of these events is essential to mitigate space weather impacts. Building on previous analyses of SPE flux data from the NOAA GOES series at geostationary orbit, this study compares event properties with those detected by SOHO-EPHIN at L1— beyond Earth's magnetosphere and representative of cislunar space. During Solar Cycles 23 and 24, we find that GOES often registers earlier event onsets, peak fluxes, and end times, primarily due to contamination from high-energy particles, whereas EPHIN typically records higher fluxes and longer durations. Despite these discrepancies, peak flux and fluence measurements between the instruments show a strong correlation, particularly during intense events. Further, environmental factors such as local magnetic pressure and interplanetary shock arrivals show minimal influence on flux discrepancies. However, GOES contamination affects 25 /115 concurrent SPEs, making event analysis less reliable. We are currently refining data correction techniques to address this and compare events more accurately. Our findings shed light on the complexities of SEP dynamics across space environments and highlight the need to account for location- and instrument-specific discrepancies in SPE detections. These insights are beneficial for advancing SPE forecasting models and ensuring the safety and success of future lunar missions, like Artemis, and other operations in near-Earth and cislunar regions.

2. **Mary Aronne** (NASA GSFC/GMU)
The Latest Updates of Moon to Mars Space Weather Analysis Office Activities: Collaborations, Validation, and Support
Co-authors: Teresa Nieves-Chinchilla, NASA GSFC; Michelangelo Romano, NASA GSFC; Anna Chulaki, NASA GSFC/CUA; Carina Alden, NASA GSFC/CUA; Madeleine Anastopulos, NASA GSFC/CUA; Mary Pasanen, ADNET LLC; Hannah Hermann, NASA GSFC/CUA; Anthony Iampietro, NASA GSFC/CUA; Melissa Kane, NASA GSFC/CUA; Christopher Stubenrauch, NASA GSFC/CUA Elizabeth Juelfs, NASA GSFC/GMU

The Moon to Mars Space Weather Analysis Office (M2M SWAO) is located within the Heliophysics Science Division (HSD) at NASA Goddard Space Flight Center (GSFC). The M2M SWAO supports NASA's Space Radiation Analysis Group (SRAG) and works very closely with the Community Coordinated Modeling Center (CCMC) and NOAA's Space Weather Prediction Center (SWPC). The office’s efforts focus on conducting real-time human-in-the-loop space weather analysis in support of NASA robotic missions and exploration activities. The office supports validation of solar energetic particle (SEP) research models in support of the transition from research to operations, provides anomaly assessments for NASA robotic missions, and makes event analysis available to the research community. We will present the latest updates on the office, including the significant events of Solar Cycle 25, and future prospects for Moon to Mars exploration and beyond.

3. **Daniel Brandt** (Michigan Technological University)
Statistical Methods for Solar Cycle Forecasting: Application to Solar Cycle 25
Co-authors: Erick Vega, Michigan Technological University; Brian Thelen, Michigan Technological University

Prediction of the timing and amplitude of future Solar Cycle peaks remains a challenge due to various factors that include lack of sufficient historical data to make predictions of statistical significance and open questions regarding the most relevant features (and combinations thereof) that impact predictions; these questions derive from unresolved modeling issues regarding the physics of the solar atmosphere, such as the problem of unphysical transport coefficients being necessary to produce realistic outputs of solar dynamo models. Accurate prediction of the behavior of the future Solar Cycle provides critical information regarding anticipated solar activity that can significantly impact technologies on which society increasingly depends, but prediction techniques, even when entirely data-driven, ideally must incorporate known behavior and provide insight into the underlying physics of the system they are predicting. To address this need, we present a new statistical technique for Solar Cycle forecasting that involves the assembling of a large suite of physics-motivated Solar Cycle statistical features which are down-selected based on information content, with the result that the selected features are inputs to Generalized Additive Models that predict the behavior of future Solar Cycles as nonlinear functions of these features. The technique provides a statistical estimate of future Solar Cycle behavior, along with insights into how different processes represented by each feature impact future solar behavior. We validate our technique by comparing forecasted maximum amplitude and timing of the Solar Cycle 25 peak with other approaches. We also assess the uncertainty of our forecasts with those of companion techniques.

4. **Juan Camilo Buitrago Casas** (Space Sciences Laboratory - UC Berkeley)
Real-Time Solar Flare Duration Forecasting with X-TOFF: Integrating GOES and SDO/EVE Data
Co-authors: Andrea Lizeth Lopez-Rodriguez (OAN/Unal), Juliana Vievering (APL/JHU), Marianne Peterson (UMN), Lindsay Glesener (UMN), Matthew Choquette (UMN)

We present the X-ray Time of Flare Forecast (X-TOFF) tool, a real-time forecasting system designed to predict the remaining duration of solar flares as they unfold. Building upon the methods described in Reep et al. (2021), the original X-TOFF ingested continuous GOES X-ray data to determine key flare parameters—such as start time, time of maximum derivative, and peak time—which are dynamically marked on an interactive display. This display features two plots that update at a one-minute cadence, one showing the GOES X-ray flux and the other its time derivative, providing updated predictions of flare end times as new data arrive.

The operational utility of X-TOFF was clearly demonstrated during the Hi-C and FOXSI-4 rocket launch campaign. The tool's accurate flare duration forecasts, particularly of the decay phase, provided the necessary confidence for the Hi-C team to capture critical phases of a large solar flare, thereby underscoring its value in real-time observational decision-making.
In our latest development, we have successfully integrated data from the Extreme Ultraviolet Variability Experiment (EVE) on the Solar Dynamics Observatory (SDO) into the X-TOFF system. Covering the 0.1–7.0 nm range, the EVE data offer improved latency over GOES XRS data and have significantly enhanced the timeliness and precision of our flare duration forecasts. We will present a comprehensive evaluation of the upgraded X-TOFF tool, comparing its performance with the previous GOES-only configuration and discussing the implications for future space weather forecasting.
Our results demonstrate the benefits of low-latency multi-instrument integration for real-time solar flare prediction and offer promising advancements for operational forecasting in future solar observational campaigns.

5. **Joan Burkepile** (National Center for Atmospheric Research (NCAR)/ HAO)
Near-real-time CME alerts for Solar Energetic Particle Forecasting
Co-authors: Michael Galloy, National Center for Atmospheric Research (NCAR) / HAO; Ben Berkey, NCAR / HAO; O.C. St. Cyr NASA Goddard Space Flight Center (GSFC), retired; Ian Richardson, NASA GSFC; William Thompson, NASA GSFC; Leila Mays, NASA Community Coordinated Modeling Center (CCMC); Joycelyn Jones, NASA CCMC; Philip Quinn, NASA Space Radiation Analysis Group (SRAG) Ricky Egeland, NASA SRAG

The NCAR Mauna Loa Solar Observatory (MLSO) COSMO K-Coronagraph (K-Cor) issues near-real-time coronal mass ejection (CME) alerts (when MLSO is operating) to the community and to NASA's Community Coordinated Modeling Center Solar Energetic Particle (SEP) scoreboard. K-Cor has a field-of-view (FOV) of 1.05 to 3 solar radii and 15-second cadence images. Data are fully processed in ~2 minutes which includes analysis of the data by a CME detection code developed by William Thompson. This makes K-Cor ideally suited to provide early warning CME detection as part of a Solar Energetic Particle (SEP) forecasting system.
Most K-Cor alerts are issued before the CME enters the LASCO field-of-view. K-Cor alerts provide the first warning of in-progress CMEs and can provide tens of minutes to an hour warning before the CME is seen in available LASCO data (includes LASCO data latency). The new NOAA CCOR coronagraph has lower data latency than LASCO, but an inner field-of-view that is ~1.5 solar radii higher than LASCO. CMEs must travel farther to be visible in CCOR. K-Cor CME alerts will continue to provide early detection of in-progress CMEs and complement observations from CCOR.
We discuss how observations from the low and middle corona provide important information on CME dynamics and acceleration that can help improve SEP forecasting. We highlight the forecasting benefit of a ground-based coronagraph network (I.e. ngGONG mission).

6. **Brittany Cavin (**Aerodyne Industries / Amentum Space Exploration Division)
Natural Space Environments Important to NASA HLS Program

Understanding and accounting for natural space environments is crucial for successful space exploration missions. The Design Specification for Natural Environments (DSNE) details the natural environment conditions that NASA Exploration Systems Development (ESD) programs must address. The Human Landing System (HLS) is required to meet all safety, functional, performance, utilization, and operational requirements during and after exposure to the natural environments defined in DSNE.
Natural environments refer to conditions that exist prior to or regardless of human or robotic activity. These include ionizing radiation, meteoroids, orbital debris encountered during Earth orbit and departure phases, plasma interactions, natural thermal and gravitational environments. Determining the effects of these environments is critical for ensuring the robustness and reliability of space systems.
The Natural Environments Branch at NASA's Marshall Space Flight Center is the Office of Primary Responsibility (OPR) of the DSNE.

7. **Phillip Chamberlin** (U of Colorado/LASP)
The Mars Space Weather Collaboration
Co-authors: Phillip Chamberlin, CU/LASP; Gina DiBraccio, NASA/GSFC; Yaireska Collado-Vega, NOAA/NESDIS; Christina Lee, UC/Berkeley; And the Mars Space Weather Collaboration team

Space Weather has traditionally explored the Sun's immediate influence on the Earth system and its technology, including the direct impact on humans. With increasing missions to Mars and beyond, as well as future plans to send humans to Mars, space weather has recently expanded to include not only Mars, but also the entire heliosphere. One critical asset that has made studying space weather at Mars possible is NASA's Mars Atmosphere and Volatile Evolution mission (MAVEN). MAVEN has instruments on board to not only study the solar irradiance, solar wind, and energetic particles, but also the in-situ and remote sensing instruments to directly measure the Sun's impact, and its variability, on the Martian environment. Additionally, the well-established personnel, tools, and methods of NASA's Community Coordinated Modeling Center (CCMC) and Moon-to-Mars (M2M) Space Weather Analysis Office make a perfect pairing to provide the assets capable of real-time space weather monitoring and data serving of the space weather at Mars. At its initial stage, the Mars Space Weather Collaboration effort is focusing on proof-of-concepts to explore what planetary data are available and if it is possible to implement near real time space weather information at Mars. The ultimate goal of the team is to understand the gaps in space weather research and monitoring at Mars and beyond with emphases on open collaboration with others to fill in those gaps. This presentation will provide an overview of the current efforts of the Mars Space Weather Collaboration, as well as present some of the open-access tools developed for the community to monitor space weather at Mars.

8. **Jean-Baptiste Dakeyo** (Space Science Laboratory (SSL))
BipolySolarWind open source code - a Python code for 1D Parker's like solar wind solutions
Co-authors: Pascal Démoulin (LIRA), Rouillard (IRAP), Samuel Badman (CFA), Milan Maksimovic (LIRA), Aliche Chapiron (IRAP), Stuart Bale (SSL)

One of the fundamental models in heliophysics is the Parker solution, which describes the hydrodynamic equilibrium of the solar corona, producing an outwardly propagating solar wind (Parker, 1958, 1960). One of the recent refinements of Parker's equations, the two-thermal regime Isopoly model embedding an isothermal until the radius Riso, followed, 3/19 by a polytropic evolution (Dakeyo, 2022, 2024), provides a simple modeling consistent with the observed bulk velocity while accounting for in-situ temperature observations (i.e., interplanetary heating). The later refinement of the Bipoly model generalizing the isothermal first regime to a polytropic one, allows to also fit coronal temperature (Tp and Te) from charge state ratios. Although Isopoly underlying physics and equations are well described and already used by the space weather community, Bipoly constitutes a new step in solar wind low complexity modeling, especially regarding its ability to fit coronal and interplanetary observations. Here is the purpose of BipolySolarWind, an open source Python code that provides a simple solver for 1D bipoly solar wind solutions with plotting capabilities. This code follow a series of open source codes such as ParkerSolarWind (https://github.com/STBadman/ParkerSolarWind) and IsopolySolarWind (https://github.com/jbdakeyo/Isopoly) , developed in the same thought of providing to community Parker's like wind solution (Isothermal, Polytropic and Isopoly). BipolySolarWind open code have been built to be used easily, with very low numerical cost, making it ideal for short time computation, wind evolution properties numerical exploration or solar wind background for wind interaction purpose. We present the different types of solar wind solution profiles that can be obtained. The BipolySolarWind significantly enhances the capabilities of low complexity wind modeling.

9. **Aspen Davis** (CU/CIRES - NOAA/NCEI)
The Upcoming SWFO-L Magnetometer Science Products: Opportunities for Collaboration and Coordination
Co-authors: Alison Jarvis, CU/CIRES-NOAA/NCEI; Sarah Auriemma, CU/CIRES-NOAA/NCEI; Paul Loto'aniu, CU/CIRES-NOAA/NCEI

In-situ observations of the interplanetary magnetic field (IMF) at Lagrange 1 (L1) are vital for space weather forecasting at the Space Weather Prediction Center (SWPC), solar wind research and driving magnetic field models. The upcoming SWFO-L1 mission, which will rideshare with the Interstellar Mapping And Probe (IMAP), offers an unprecedented opportunity for coordinated efforts in calibrating / validating data products during commissioning and for research collaborations with legacy missions (DSCOVR, ACE and Wind). SWFO-1 has two boom-mounted vector magnetometers (64 Hz resolution) that will help bridge the gap in continuous, good quality measurements of the IMF at L1. These magnetometers will be calibrated for zero-level offsets using a combination of monthly active rotational maneuvers and the passive Davis-Smith method, which leverages Alfvenic rotations of the magnetic field. The low nano-Tesla magnetic field at L1 presents challenges in zero-level offset determination, and therefore we plan to additionally assess the accuracy of the magnetometer measurements using intersatellite comparisons. Due to the complex variability of the structure of the IMF at L1, studies suggest that these comparisons are most valid when spacecraft are within 26 Re radial distance of each other. Since SWFO-L1 and IMAP will be in close proximity during cruise and their initial halo orbits at L1, there will be unprecedented opportunities for close proximity cross-calibrations. We will discuss plans for coordinated data product validation during commissioning, including calibrations, bias trending and thermal stability. We will also discuss the plans for public scientific datasets, including propagated solar wind parameters, and ideas for collaborative research with the L1 constellation.

10. **Giuliana de Toma** (NCAR/HAO)
Coronal observations at MLSO and their relevance for space weather research
Co-authors: Joan Burkepile, HAO/NCAR

The Mauna Loa Solar Observatory (MLSO) is an NSF observing facility operated by HAO since 1965, which has collected the longest record of coronal observations. There are two coronagraphs at MLSO, which observe the low and middle corona the COSMO K-Coronagraph (K-Cor) and the Updated Coronal Multi-Channel Polarimeter (UCoMP) which is the prototype for the proposed 1.5m COSMO large coronagraph.
K-Cor observes the corona from ~1.05 to 3 solar radii in polarized visible light. It was designed to study the formation and early acceleration of CMEs with a high temporal cadence of 15s. K-Cor data are calibrated and made publicly available in near-real time within 2-3m from acquisition. K-Cor can provide the first detection of an in-progress CME even before the CME enters the LASCO field of view.
UCoMP is an imaging spectropolarimeter that operates in the 530-10830nm range from ~1.03 to 2 solar radii. UCoMP level2 science products include intensity, line of sight velocity, line width, linear polarization, and radial azimuth. Coronal densities, plane of sky magnetic field, and coronal waves can be derived from level2 data. UCoMP provide unique information on the magnetic and plasma structure of the solar corona. While not specifically designed to study solar eruptions, UCoMP captured several CMEs, including halos and partial halos.
We illustrate the current capabilities for space weather research and forecasts of the existing MLSO instruments, show examples of observations taken at MLSO, including eruptive events, and present plans for future instruments and upgrades.

11. **Anthony DeStefano** (NASA)
The History and Performance of MSFC's Modified McNish & Lincoln Solar Activity Prediction Model
Co-authors: Jenna Martin, Amentum

The MSFC Solar Activity Forecast Estimation (MSAFE) model has been in use by NASA programs since the Skylab era. Currently, the Trajectory Operations & Planning Officer (TOPO) uses monthly predictions by MSAFE for ISS orbit maintenance planning. The driving mechanism for developing MSAFE was to provide solar activity inputs (e.g., F10 and Ap index) for thermosphere models such as the Marshall Engineering Thermosphere (MET) model and the Mass Spectrometer Incoherent Scatter Radar (MSIS) model. In this work, we will discuss the history of the development of the MSAFE model, its use during Skylab and the ISS programs, and a review of the performance of the model predictions at various times throughout a given solar cycle.

12. **Karin Dissauer** (NorthWest Research Associates, Boulder CO, USA)
Exploring the magnetic origin and environments of precursor activity in search of causal links to solar energetic events
Co-authors: Graham Barnes, NorthWest Research Associates, Boulder CO, USA; KD Leka, NorthWest Research Associates, Boulder CO, USA, Nagoya University Japan; Eric L. Wagner, NorthWest Research Associates, Boulder CO, USA

The physical role played by small-scale activity, such as transient brightenings (TBs), that occur before the sudden onset of solar energetic events (SEEs, i.e., flares and CMEs) remains in question, especially regarding SEE initiation and early evolution.
We explore the origin of TBs and their potential connection to the main flare by examining their magnetic environment and the photospheric footprints of the coronal topological skeleton, including spines and separatrices of coronal null points, open field footpoints, and bald patches - all topological features that can be key to enable magnetic reconnection. We investigate whether specific topologies are more strongly linked to pre-flare TBs compared to similar activity during non-flaring times of the same active regions. Additionally, we analyze magnetic field characteristics, such as locations of strong-gradient polarity inversion lines (PILs) and areas of free magnetic energy, both crucial for flare processes.
For an initial set of pre-flare/quiet epoch pairs, we find that prior to flares, TBs 1) tend to occur in one large cluster close to the future flare ribbon location and below the separatrix surface of a null point, 2) are co-spatial with reconnection signatures, i.e., bald patches and null point fan traces and 3) cluster in the vicinity of strong-gradient PILs and regions of increased excess magnetic energy density. TBs are also observed during quiet epochs but appear in smaller clusters without a clear spatial pattern, predominantly away from strong-gradient PILs in areas with low excess energy density, although sometimes linked to spatially-intermittent bald patches and fan traces.

13. **Bent Ehresmann** (Southwest Research Institute Boulder)
Analyzing MSL/RAD data to prepare for human exploration of Mars
Co-authors: D. M. Hassler, Southwest Research Institute Boulder
J. L. Loewe, University of Kiel, Germany; C. Zeitlin, Leidos Innovations Corporation; Robert F. Wimmer-Schweingruber, University of Kiel, Germany

Understanding and mitigating the radiation exposure encountered on the surface of Mars remains one of the major challenge in preparation for future human exploration of the Red Planet.
Since Mars possesses only a thin atmosphere high-energy particles (e.g., galactic cosmic protons with energies greater than ~ 150 MeV) can penetrate deep into the atmosphere and the subsurface. Therefore, the Martian surface radiation environment is mainly consisting of Galactic Cosmic Radiation (GCR) and secondary particles created by their interactions with nuclei in the atmosphere or soil, with additional contributions from spontaneous Solar Energetic Particles (SEPs), emitted from the Sun during solar storms.
Here, we focus on two main subjects aimed at understanding the Martian surface radiation field. Firstly, we present updated analysis on how the natural terrain on Mars, e.g. provided by buttes or steep cliff and canyon walls influences the radiation dose as measured by Curiosity's Radiation Assessment Detector

(RAD). The presence of any large natural terrain feature might aid in reducing the local exposure to the prevalent radiation encountered on the surface. We will provided analysis on all identified cases where decreases in RAD radiation dose measurements can be attributed to influence of the surrounding terrain; Secondly, we present initial analysis on how a radiation detector, such as RAD, might be employed to serve as an in-situ, real-time solar-storm warning monitor on Mars and how such an instrument could help to reduce the radiation exposure to future human explorers during such solar storms.

14. **Heather Elliott** (Southwest Research Institute)
What Other Quantities Can Be Forecasted Using Solar Wind Speed Forecasts/Tracking, and With What Accuracies?
Co-authors: Maher Dayeh- Southwest Research Institute; Craig DeForest - Southwest Research Institute; Raphael Attie -George Mason University and NASA GSFC

The correlations between the solar wind speed and other solar wind and IMF parameters results from a combination of differences in the source properties from given source regions and the dynamic interaction that occurs en route from the Sun to Earth. Solar wind associated with coronal holes, streamers, and transient events such as Coronal Mass Ejections have different properties. Additionally, the solar wind parameters evolve in a systematic way as the solar wind parcels propagate from the Sun to Earth producing additional relationships between amongst the solar wind and IMF properties as compressions (rarefactions) and form when fast wind parcels run into (away from) slower wind parcels emitted earlier (later).
We can leverage these known statistical correlations and relationships between the solar wind speed and other parameters such as the density, temperature, field strength, geomagnetic Kp index, and SEP flux to forecast additional quantities using the speeds estimated from coronagraphs and heliospheric imagers like those on PUNCH.
The nature of the relationships between the solar wind speed and the quantity for which you are trying to forecast is important for determining how accurately we can estimate that given quantity using the solar wind speeds derived from the coronagraph and heliospheric imagers.
For example, the formulas for solar wind temperature have a power law exponent of ~1 for the speed term, and the formula for the density has an exponent of about -1.5 for the speed term. Therefore, a given error in the speed will produce a larger error for the solar wind density than it will for the solar wind temperature.

15. **Nicholas Furioso** (University of Florida)
Innovative Global Mapping Techniques for Navigating Space Weather Hazards in Low Earth Orbit
Co-authors: Faraz Abed Azad, University of Florida; Christopher Petersen, University of Florida; Alicia Petersen, University of Florida

Spacecraft are particularly vulnerable to space weather events; solar energetic particles (SEPs) discharge large amounts of energy to spacecraft electronics, degrading system performance, causing malfunctioning software, and physically damaging hardware. Astronauts face health risks from radiation exposure in space. To protect high-value assets and human lives, we present a methodology for creating global space radiation risk maps for spacecraft guidance, navigation, and control (GNC). We aim to improve

operational spacecraft GNC and onboard autonomous capabilities for mitigating the effects of space weather through global space environment risk mapping for use in navigating space weather hazards.

16. **David Galarza** (University of Florida)

HelioSTET: Modeling Suprathermal Electron Transport through the Heliospheric Magnetic Field

A major limitation in current space weather forecasting lies in the lack accuracy in modeling the heliospheric magnetic field (HMF), which significantly impacts the prediction of solar energetic particles (SEPs), coronal mass ejections (CMEs), and other transient solar phenomena. These inaccuracies have direct implications for spacecraft operations, satellite communications, GPS navigation, and other critical infrastructure. Suprathermal electrons (SEs), due to their ability to travel along HMF lines, serve as valuable tracers of the magnetic field's properties and dynamics. Their pitch angle distributions (PADs) encode essential information about the HMF and the surrounding plasma, yet the mechanisms connecting observed PADs to specific HMF features remain poorly understood. This research focuses on addressing this challenge by developing the Heliospheric Suprathermal Electron Transport (HelioSTET) model, a novel framework that leverages SE observations to identify and characterize key HMF features. By linking SE PADs to variations in the HMF, this work aims to provide new tools for tracing transient solar events to their origins and enhancing the understanding of solar wind dynamics.

17. **Griffin Goodwin** (Georgia State University)

Assessing the Impacts of Magnetogram Projection Effects on Solar Flare Forecasting and Extending the SWAN-SF Dataset

Co-authors: Viacheslav Sadykov, Georgia State University; Petrus Martens, Georgia State University; Reet Gupta, Georgia State University; Dustin Kempton, Georgia State University

Active region (AR) vector magnetograms are frequently used to forecast solar flares as they provide an excellent source of preflare features that can be easily integrated into machine learning models. However, as ARs traverse farther from the solar disk center, the quality of magnetic field data degrades substantially. Near the limbs, magnetograms suffer from projection effects, which introduce observed long-term systematic trends to the data, unrelated to the evolution of the AR itself. These artificial variations complicate forecasting and may even introduce unnecessary false positive and negative predictions. To study the impacts of this issue on forecasting, we utilize a methodology proposed by Falconer et al. (2016) to correct for projection effects present in Georgia State University's Space Weather Analytics for Solar Flares (SWAN-SF) benchmark data set. We then compare performance metrics across the corrected and uncorrected data. Our analysis shows that both the true positive and false positive prediction rates only increase slightly after corrections are applied, averaging a few percent. This suggests that projection effects do not have a large impact on forecasting, or a more complicated correction methodology may be needed to see improvements. It may also indicate that there are inherent limitations when using magnetogram data for flare forecasting. Therefore, our current efforts are focused on extending the data products of SWAN-SF by incorporating extreme ultraviolet (EUV) descriptors of ARs, with the hope of improving forecasting near the limb. Preliminary results for this project will also be reported on.

18. **Briley Griffin** (Rock Creek High School)
Determining the Best Time to Send Humans to Mars to Avoid Space Weather

Crews are set to return to the Moon with Artemis II in April 2026, but the next major milestone in space exploration lies beyond the Moon: crewed, 3/19 missions to Mars. The environment during the journey to Mars poses significant risks to astronaut health outside of the Earth's protection. Space weather that may be encountered can be broken into two types based on whether they are created from within or outside our solar system. This poster focuses on solar storm occurrence and changes in galactic cosmic ray intensities. Understanding and forecasting when space weather hazards occur on the journey to Mars is important not only to astronauts, space agencies, mission planners, and system engineers, but is also of interest to space weather professionals, and enthusiasts. There are a number of factors to be considered when determining the impact of solar storms or cosmic rays on a Mars mission such as: intensity of radiation, spacecraft position relative to the sun, solar cycles, and the length of the events. This poster presents an overview of some of the factors that should be considered, specifically, the ones related to radiation-associated space weather events such as increased presence of cosmic rays and solar storms. Then, a more detailed examination of two factors, a spacecraft's position relative to the sun and solar cycle, is presented. Information similar to what is presented here can assist in on-going efforts to improve space weather forecast models supporting human space flight.

20. **Kiran Jain** (National Solar Observatory, Boulder USA)
Improved GONG Far side Helioseismic Maps – A Crucial Data Set for Space Weather Forecasting Models
Co-authors: Mitchell Creelman, National Solar Observatory, Boulder, USA; Amr Hamada, National Solar Observatory, Boulder, USA; Niles Oien, National Solar Observatory, Boulder, USA; Alexei Pevtsov, National Solar Observatory, Boulder, USA; Sushanta C. Tripathy, National Solar Observatory, Boulder, USA; Thomas M. Wentzel, National Solar Observatory, Boulder, USA

National Science Foundation's Global Oscillations Network Group (GONG) has been providing helioseismic maps of medium-to-large active regions of the far (invisible from Earth) hemisphere for about two decades. These maps have proven their capability as an important space weather forecasting tool by providing information about the arrival of active regions that were either born on the far side or continued to survive after crossing the west limb about two weeks ago. For example, the models based on observations of the hemisphere facing the Earth, and the lack of information from the far hemisphere introduce severe gaps in the data stream with consequent errors in their forecasts. In recent years, several studies have shown that the inclusion of far side active regions, particularly near limbs, can significantly refine the model predictions by improving estimates of the global magnetic flux distribution. Here we present revamped GONG far side helioseismic maps with better detection near limbs and improved signal-to noise in a more user-friendly format than the previous versions.
This work is partially supported by the NSF' Windows of the Universe grant to the National Solar Observatory and NASA grant 80NSSC22K0778.

21. **Timothy Keebler** (University of Michigan)
Validation of coronal mass ejections generated using the Gibson-Low flux rope model
Co-authors: Lulu Zhao, University of Michigan; Meng Jin, Lockheed Martin Solar and Astrophysics Lab; Igor Sokolov, University of Michigan; Nishtha Sachdeva, University of Michigan

The Eruptive Event Generator – Gibson-Low (EEGGL) uses a synoptic solar magnetogram to generate an unstable 3D flux rope, which is then inserted into magnetohydrodynamic (MHD) simulations of the solar corona. EEGGL uses an empirical fitting of test events to find the relationship between the magnetogram, CME parameters, and flux rope geometry and strength. From this point, the resulting flux rope initiates a coronal mass ejection (CME) that can propagate into the heliosphere. Combined with the AWSoM-R solar and heliosphere model at the University of Michigan, EEGGL has been used extensively for CME simulation, studying the evolution of the CME and the resulting generation of solar energetic particles (SEPs). As part of the CLEAR NASA Center of Excellence at the University of Michigan, validation and enhancement of EEGGL is a key deliverable. We provide results from the updated EEGGL model with improvements to enhance the robust nature of the code. A statistical validation is performed comparing synthetic white-light coronal images generated by the simulation to coronagraph observations, focusing on CME speed and strength. While past publications have occasionally optimized the flux rope based on a priori knowledge, we use larger statistics from agnostic runs to evaluate model performance. Such steps prepare the model for running in a fully automated low-latency configuration.

23. **Robert Leamon** (Lynker Space)
The Downsides to (of) Odd Cycles, and What it Means for Operators
Co-authors: Scott McIntosh, Lynker Space

It is important to understand that sunspot number maximum, solar eruptive activity maximum and geomagnetic effectiveness maximum are not one and the same.
The difference between odd and even numbered Schwabe (11-year) Cycles -- halves of the {\bf Hale Cycle} -- in terms of cosmic rays (global solar dipole being parallel or anti-parallel to the local ISM field) is well known. That is, a difference external to the sun and heliosphere.
Here we show that differences exist in various other activity measures and proxies, including flare occurrence rates, solar wind parameters and geomagnetic indices. These differences between odd and even cycles are intrinsic to the sun, or even internal to the sun.
Odd cycles, of which Cycle 25 is one, tend to produce X-class solar flares for longer after polar field reversal/ sunspot maximum than even cycles. Current expectations of the ""last best flare"" for Cycle 25 is late 2027. Further, following the polar field reversal, the alignment of the sun's and the earth's large-scale dipoles is such that the most geo-effective storms in odd cycles (think Halloween 2003) occur on their Downsides.
We discuss the implications of this for Operators and SWx End Users: While the ""Gannon Storm"" of May 2024 may end up being the single largest event of Cycle 25, it will not be a ""once in a lifetime"" event; we expect that it would not even be the only event with significant geo-effective consequences (GNSS degradations, etc.) of Cycle 25.

24. **KD Leka** (NWRA and ISEE/Nagoya University)
Beyond the HMI ""SHARP parameters"": the Photospheric Magnetic Field Properties of Flaring vs. Flare-Quiet Active Regions
Co-authors: Graham Barnes, NWRA; Eric Wagner, NWRA; Sara Petty, NWRA

The Solar Dynamics Observatory / Helioseismic and Magnetic Imager (HMI) Active Region Patches (HARPs) provide meta-data (the SHARP parameters) that represent a small sample of ways to describe the photospheric magnetic fields in active regions. The SHARP parameters were selected based on decades of research into the question of what drives a solar active region to flare (c.f., Bobra et al 2014 and references therein). We present here an expansive study of additional approaches for characterizing active region magnetic fields in this context (c.f. Leka et al 2018). Beyond additional parameterizations of the surface magnetic field as provided by the HMI vector field maps, we examine the ability of a coronal-field model (from the Magnetic Charge Topology analysis, c.f. Barnes and Leka 2006) and parameters derived from them, to distinguish between flare-imminent and flare-quiet epochs -- with the motivation that the solar coronal magnetic field both stores the requisite energy to power energetic events, and is a candidate for trigger mechanisms as well. We perform these analyses of all HARPs, on a daily basis -- and compare the information provided by the short-term evolution to ""snapshot"" or static parameters. For all, the NWRA Classification Infrastructure (NCI), a facility based on nonparametric discriminant analysis, enables a quantitative evaluation from this large-sample analysis, of which characterizations can best distinguish regions in imminent likelihood of flaring. We present a summary of physical insights from this expanded analysis.

25. **KD Leka** (NWRA and ISEE/Nagoya University)
Beyond the HMI ""SHARP"" parameters: Coupling the Photospheric Magnetic Field with the Chromosphere, Transition-Region, and Coronal Properties of Flaring vs. Flare-Quiet Active Regions
Co-authors: Karin Dissauer, NWRA; Graham Barnes, NWRA; Eric Wagner, NWRA; Sara Petty, NWRA

Recent work has shown that small-scale short-lived variation in the solar corona is statistically indicative of upcoming flare activity (Leka et al. 2023), even while studies based on static images or low spatial resolution images from the Chromosphere, Transition Region, and Coronal (CTRC) regime has not yet proven any significant insights to this question. Long-held knowledge of the photospheric magnetic field has thus far guided most efforts into identifying flare-imminent magnetic field configurations, but evidence for the role of the upper atmosphere is both expected (in terms of energy storage, possible trigger mechanisms) and elusive. To that end, we now investigate the question of distinguishing flare-imminent active regions by evaluating both magnetic characteristics from the Solar Dynamics Observatory/Helioseismic and Magnetic Imager (beyond the SHARP parameters, see accompanying poster) as compared to, and combined with, the characteristics of the CTRC regime as parameterized using SDO/AIA Active Region Patches (Dissauer et al. 2023). To gain physical insight from a large-sample analysis, we use the NWRA Classification Infrastructure (NCI), a facility based on nonparametric discriminant analysis, which enables a quantitative evaluation of which descriptions can best distinguish regions in imminent likelihood of flaring. We present a summary of physical insights from this expanded analysis.

26. **Ying Liu** (CIRES, CU Boulder, and NOAA NCEI)
A Pileup of Coronal Mass Ejections Produced the Largest Geomagnetic Storm in Two Decades

The largest geomagnetic storm in two decades occurred in 2024 May with a minimum Dst of −412 nT. We examine its solar and interplanetary origins by combining multipoint imaging and in situ observations. The source active region, NOAA AR 13664, exhibited extraordinary activity and produced successive halo eruptions, which were responsible for two complex ejecta observed at the Earth. In situ measurements from STEREO A, which was 12°.6 apart, allow us to compare the "geo-effectiveness" at the Earth and STEREO A. We obtain key findings concerning the formation of solar superstorms and how mesoscale variations of coronal mass ejections affect geo- effectiveness: (1) the 2024 May storm supports the hypothesis that solar superstorms are "perfect storms" in nature, i.e., a combination of circumstances resulting in an event of an unusual magnitude; (2) the first complex ejecta, which caused the geomagnetic superstorm, shows considerable differences in the magnetic field and associated "geo-effectiveness" between the Earth and STEREO A, despite a mesoscale separation; and (3) two contrasting cases of complex ejecta are found in terms of the geo-effectiveness at the Earth, which is largely due to different magnetic field configurations within the same active region. Implications for future measurements at sub-L1 will also be discussed.

27. **Greg Lucas** (LASP/SWx TREC)
From Research to Operations: The Success of H3lioViz in Space Weather Visualization
Co-authors: Chris Pankratz, LASP; Jenny Knuth, LASP; Brian McClellan, LASP; Thomas Berger, SWx TREC

Creating advanced tools for operational space weather forecasting relies on a robust Research to Operations to Research (R2O2R) pipeline. The H3lioViz project has focused on enhancing the interface between tool developers, researchers, and operators to foster more productive collaboration. This presentation illustrates a successful, collaborative framework for developing a production-class visualization capability for space weather forecasting.
H3lioViz, found at https://swx-trec.com/h3lioviz, integrates a sophisticated 3D heliosphere visualization engine with an easy-to-use interface and is available from any browser. It enables the interactive exploration of operational space weather model runs from NOAA's Space Weather Prediction Center (SWPC), NASA's Community Coordinated Modeling Center (CCMC), and the UK Met Office.
To maximize user interaction and experimentation, the project eliminated the need for software installation and data transfers by containerizing the tool and leveraging a cloud environment, in this case AWS. This robust, transportable system streamlined collaboration by enabling multiple parallel sessions, worldwide users, and the ability to quickly point to new data cubes with minimal latency and high uptime. Forecasters and researchers are able to use the tool in their own time, allowing the developers to take a back seat to the subject matter experts who drive the design with thoughtful, informed feedback.
Our experience highlights the importance of strong collaboration, effective communication, and innovative deployment strategies in advancing operational space weather forecasting tools. The success of

our visualization capability and the collaborative framework supporting it underscores the value of the R2O2R process in enhancing operational efficacy and scientific understanding.

28. **Katlego Makgatle** (Prof Martin Snow)
Solar flare duration forecast: Will you be there in the morning?

Solar flares are powerful, sudden bursts of energy from the Sun than can disrupt the Earth's ionosphere, affecting communication systems. Precisely predicting the duration of the solar flares is important for reducing their impacts on high-frequency radio communications. This research focuses on developing a Python based analytical tool to estimate solar flare duration using data from the GOES-16 satellite. The study involves extracting and processing X-ray flux data, identifying individual flare events, and applying exponential fitting techniques to model flare decay. By comparing different statistical and machine learning methods, this research aims to improve the accuracy of flare duration predictions and contribute to real-time space weather forecasting.

29. **George Millward** (NOAA/SWPC CU/CIRES)
The Next-Generation NOAA/SWPC CME Analysis Tool, PyCAT
Co-authors: Anders Englyst, UK Meteorological Office; Michael Marsh, UK Meteorological Office; Manasi Gopala, NOAA/SWPC; Mark Miesch, CU/CIRES NOAA/SWPC; Charlotte Martinkus, CU/CIRES NOAA/SWPC; Scott Burns, NOAA/SWPC; Richard Lee, BJSS Consultancy, UK

At NOAA's Space Weather Prediction Center (SWPC), one of the key tools for space weather forecasting is the WSA-Enlil model—a time-dependent, three-dimensional Magnetohydrodynamic (MHD) model of the heliosphere. Running operationally on National Weather Service (NWS) supercomputers since 2011, WSA-Enlil provides five-day forecasts of solar wind conditions at Earth. A crucial aspect of this forecasting is estimating the likelihood and timing of Coronal Mass Ejections (CMEs) impacting Earth, as these events are the primary drivers of significant geomagnetic storms.
A vital component of the WSA-Enlil system is the estimation of CME parameters, including their size, propagation direction, and speed. To support this, an R2O project at SWPC in 2010–2011 led to the development of the CME Analysis Tool (CAT), an IDL-based system that derives these parameters using concurrent coronagraph images from SOHO and STEREO. Over the years, CAT has become an essential part of the WSA-Enlil workflow, playing a key role in daily space weather forecasts.
With the emergence of a new generation of coronal observatories—including the operational CCOR-1 and CCOR-2 coronagraphs on NOAA's GOES-19 and the upcoming SWFO-L1 satellite—there is now a need to modernize CAT. This modernization will enable the integration of these new data sources while also leveraging cutting-edge web-based technologies.
To meet this need, SWPC and the UK Met Office are developing PyCAT, a next-generation CME analysis tool. PyCAT features an interactive JavaScript-based browser front end and a Python-powered back end; all containerized using Docker for flexibility and scalability. In addition to supporting SOHO and STEREO-A coronagraph imagery, PyCAT will incorporate data from CCOR-1, CCOR-2, and future coronagraphs on the PUNCH mission, as well as CCOR-3, which will be deployed at the L5 point aboard the VIGIL satellite.

30. **J. Grant Mitchell** (NASA/GSFC)
Development of the High Energy Proton SSD Telescope and chErenkov Radiator (HEPSTER) to Fill a Critical SWx Measurement Gap
Co-authors: Ashley Greeley, NASA/GSFC; Brent Randol, NASA/GSFC; Georgia de Nolfo, ASA/GSFC; Eric Christian, NASA/GSFC; Shrikanth Kanekal, NASA/GSFC; George Suarez, NASA/GSFC; Jeffrey Dumonthier, NASA/GSFC

Large Solar Energetic Particle (SEP) events are some of the most dangerous sources of radiation contribution to space weather (SWx). Currently, the Heliophysics System Observatory does not currently have any instruments capable of measuring SEP protons with energies greater than ~100 MeV as noted in the recent NASA SWx Gap Analysis document as well as NOAA NESDIS-REQ-4500.3. To address these needs the Energetic Particle Laboratory at NASA/GSFC is developing a high-energy proton spectrometer consisting of a traditional silicon solid-state detector stack folloWed, 3/19 by a light integrating Cherenkov detector. The primary instrument is surrounded by a cylindrical anti-coincidence detector to remove measurements of particles that come from outside the aperture (or those that escape out the side of the instrument). HEPSTER will measure protons from 50 MeV – 1 GeV to answer the following science questions: 1) What is the source of high-energy SEPs? 2) What processes contribute to the spectral features observed in SEPs, especially the rollover at high energies? 3) What processes dominate in the transport of high-energy SEPs through the heliosphere? 4) Are the highest energy SEP electrons accelerated by the same mechanism as SEP protons? HEPSTER will fill a critical SWx role to characterize the high radiation dose imparted by high-energy protons and improve forecasting due to the prompt signal of these particles. We discuss the development of HEPSTER and plans for potential future spaceflight.

31. **Abigail Mthethwa** (South African National Space Agency)
Can Geostationary Operational Environmental Satellite (GOES) ultraviolet measurements predict the X-ray properties of flares?
Co-authors: Martin Snow, South African National Space Agency

Solar flares are powerful phenomena with significant implications for space weather. Understanding their characteristics and predicting their behavior is crucial for mitigating potential risks and ensuring the safety of space-based operations. This research project aims to investigate whether ultraviolet (UV) measurements obtained from the Geostationary Operational Environmental Satellite (GOES) can be used to predict the X-ray properties of solar flares. By analyzing high-cadence UV solar spectral irradiance data from the GOES Extreme Ultraviolet and X-ray Sensors (EXIS) instrument, the study seeks to establish a reliable relationship between UV observations and X-ray flare behavior. The ultimate goal is to develop a model that enables real-time prediction and interpretation of solar flares, empowering space weather forecasters to make accurate forecasts and take necessary precautions.

32. **Syed Raza** (The University of Alabama in Huntsville)
The Effect of Ambient Solar Wind on the Propagation of Coronal Mass Ejections towards Earth
Co-authors: Nikolai Pogorelov, The University of Alabama in Huntsville; Talwinder Singh, Georgia State University

Coronal Mass Ejections (CMEs) are the major drivers of Space Weather (SWx), so predicting their arrival at Earth is one of the major aspects of SWx forecasting. Despite increasingly complex models proposed over the past decades, the mean absolute error (MAE) for predictions of CME arrival is still surpasses 10 hours. In this study, we use machine learning (ML) techniques trained on the errors between observed and modeled solar wind (SW) at the L1 point, upstream of CMEs, to improve CME time of arrival (TOA) predictions. For our investigation, we use CME data from the Database Of Notifications, Knowledge, Information (DONKI) developed by the NASA Community Coordinated Modeling center (CCMC). The WSA-ENLIL-Cone (WEC) model inputs and outputs are available on DONKI for each CME, along with the associated forecast errors. The dataset consists of 122 CME events observed with in the time period of March 2012 to March 2023. The recorded MAE for CME TOA for these events is 12.31 hours. OMNI data for the SW properties at L1 and publicly available simulation results based on the WEC model are obtained. Three machine learning (ML) models are employed: 1) k-nearest neighbors (KNN), 2) support vector machine (SVM), and 3) linear regression (LR) in our analysis. These ML techniques use the observed and modeled SW properties at 1 AU as input parameters, also called the features, and the WEC output quantities, also called the target, to quantify the forecast (or prediction) errors. Our models are set up to quantify and "correct" the errors in CME TOA associated with inaccuracies in the modeled SW properties at 1 AU. The errors in reproducing the properties of the ambient SW are tracked from the time of CME insertion to their arrival at Earth. Together with CME Cone, model parameters they are used as features in our ML models. Univariate and multivariate ML schemes were developed to examine how individual features and their combinations contribute to reducing the MAE in CME TOA forecasts. While most ML runs reduced the TOA MAE, the best univariate and multivariate models improved the forecast by 36.6 and 46.8 minutes, respectively. Our results suggest that uncertainties in the SW background have a minimal impact on the TOA MAE in the WEC model, with the primary source of errors being associated with uncertainties in the initial CME parameters.

33. **Kathy Reeves** (Center for Astrophysics | Harvard & Smithsonian)
Supporting Space Weather Forecasting with Quick ECCCO
Co-authors: K. Reeves(1), D. Seaton (2), S. Athiray(7), L. Golub(1), P. Cheimets(1), E. DeLuca(1), C. DeForest(2), G. Del Zanna1(1,3), C. Downs(4), N. Karna(1), W. Liu(5), C. Madsen(1), C. Moore(1), J. Plowman(2), J. Redfern (2), Y. Rivera(1), J. Samra(1), P. Testa(1), M. West(2), A. Winebarger(6)
(1)CfA, (2) SwRI, (3) U. Cambridge, (4) PSI, (5) BAERI/LMSAL, (6) MSFC, (7) UAH

EUV CME and Coronal Connectivity Observatory (ECCCO) is a proposed NASA Heliophysics SMEX mission currently in Phase A. ECCCO will take EUV observations to the next level, providing for the first time dedicated, global spectral and imaging measurements of the Middle Corona (1.5–3 Rs), a previously underexplored part of the solar atmosphere. The ECCCO imager naturally complements the GOES Solar

Ultraviolet Imagers, extending their FOV in overlapping passbands to meet the CCor FOV. The QuickECCCO Science Enhancement Option delivers low-latency ECCCO observations to NOAA's Space Weather Prediction Center to improve flare and eruption tracking, refine arrival time and impact forecasts for energetic solar events, and track shock structures associated with solar energetic particles, which lack strong forecast constraints. An additional Research-to-Operations activity will generate 3D reconstructions to drive the development of forecasts of eruption and flare onset.

34. **Viacheslav Sadykov (**Georgia State University)
Machine Learning for Space Weather: Overview of Research Efforts at Georgia State University
Co-authors: Berkay Aydin, Georgia State University; Dustin Kempton, Georgia State University; Piet Martens, Georgia State University; Talwinder Singh, Georgia State University; Rafal Angryk, Georgia State University

Over the past decade, the Heliophysics community has increasingly explored machine learning (ML) techniques, as reflected in the exponential growth of peer-reviewed, 3/19 publications, conference presentations, and funding opportunities. Among the key areas of ML application, space weather forecasting stands out as a field with tremendous potential for data-driven decision-making. This poster highlights some of the ongoing ML research efforts at Georgia State University, including (1) ML-driven forecasting of solar transient events such as solar flares, coronal mass ejections (CMEs), and solar energetic particles (SEPs); (2) integration of ML with physics-based simulations to further enhance predictions of solar transient events; (3) the development of ML-ready datasets for improved forecasting of solar transient events and radiation exposure at aviation altitudes, etc.

35. **Laura Sandoval** (Laboratory for Atmospheric and Space Physics (LASP))
I-ALiRT: Improving SWx Forecasting Capabilities with IMAP
Co-authors: Greg Lucas, LASP; Tori Marbois, LASP; Melissa Mantey, LASP; Evan Brooken, LASP Steve Monk, LASP; Kristopher Larsen, LASP; Christina O. Lee, University of California, Berkeley; Eric R. Christian, NASA Goddard Space Flight Center; David J. McComas, Princeton University; Arik Posner, NASA Headquarters

The Interstellar Mapping and Acceleration Probe (IMAP) mission includes the Active Link for Real-Time (I-ALiRT) system to provide continuous real-time data products for use in space weather forecasting. IMAP I-ALiRT will broadcast real-time data 24/7 from the IMAP observatory via NASA's Deep Space Network (DSN) and international ground stations. The Laboratory for Atmospheric and Space Physics (LASP) will play a critical role in the I-ALiRT architecture, receiving telemetered I-ALiRT data from ground stations, implementing a low-latency processing pipeline in real time, and providing the data via the IMAP website and a publicly accessible API. To achieve this, I-ALiRT will leverage the Amazon Web Services (AWS) cloud resources for efficient data ingestion and processing. The resulting data products will be distributed through the IMAP Science Data Center, ensuring accessibility by forecasting centers and the broader scientific community. We will present our Cloud Architecture plans, highlighting how this cutting-edge technology enables the delivery of real-time space weather data products to the public and operational forecasting centers.

36. **Martin Snow** (South African National Space Agency)
Once is not enough: why high-cadence MgII is important
Co-authors: Janet Machol, University of Colorado Boulder/CIRES and NOAA/NCEI

The magnesium II core-to-wing ratio has been measured on a daily basis since 1978. It is a widely used proxy for solar chromospheric activity, essential for satellite drag calculations as well as the model that is the NOAA Climate Data Record for solar spectral irradiance. In 2017, this measurement became available operationally from GOES-16/EXIS at three-second cadence with high signal-to-noise. While the Earth's atmosphere may not respond to ultraviolet irradiance changes on such short timescales, it does respond to the time-integrated irradiance variation. Using a once-a-day measurement as was available before GOES-16 introduces a systematic bias in the estimated facular brightening that gets worse as solar activity increases. Using data from solar cycle 24, we can estimate a correction factor for the daily magnesium II index for previous solar cycles. In this presentation, we will discuss the magnesium II index and provide details of the instrumentation as well as how to retrieve the data from the NOAA web page.

38. **Valeriy Tenishev** (Heliophysics and Planetary Science Branch, NASA Marshall Space Flight Center, Huntsville, AL)
Effect of turbulence on transport and in the Heliosphere

Solar energetic particles (SEPs) are high-energy particles originating from the Sun and accelerated at the front of a CME-driven shock. They pose potential risks to space missions, especially those outside Earth's protective magnetosphere. Understanding their behavior in both the heliosphere and Earth's magnetosphere is vital for the safety and functionality of space exploration. The study focuses on how pitch angle scattering impacts the overall SEP population during various phases of SEP events.
The presentation compares two transport models that capture different aspects of the SEP dynamics. The Parker transport equation describes the evolution of the nearly isotropic particle population and effectively incorporates large-scale processes, including spatial diffusion and convection by the solar wind. However, by averaging over the particle pitch angle, the Parker equation inherently smooths over details of pitch-angle scattering and magnetic focusing. In contrast, the focused transport equation retains the pitch-angle dependence of the particle distribution function, enabling one to characterize the effects of scattering and the impact of magnetic focusing on the particle transport in the heliosphere. The presentation discusses the impact of accounting for anisotropy when modeling the SEP population during various stages of a SEP event.

39. **Juliana Vievering** (Johns Hopkins Applied Physics Laboratory)
Toward Early and Actionable Flare Alerts
Co-authors: Juan Camilo Buitrago-Casas, Space Sciences Laboratory at the University of California Berkeley; Marianne Peterson, University of Minnesota Twin Cities; Kristopher Cooper, University of Minnesota Twin Cities; Lindsay Glesener, University of Minnesota Twin Cities; Sabrina Savage, NASA Headquarters; Gordon Emslie, Western Kentucky University; Paolo Massa, University of Applied Sciences and Arts Northwestern Switzerland; Vicki Herde, BAE Systems; Hugh Hudson, Space Sciences Laboratory at the University of California Berkeley; Noriyuki Narukage, National Astronomical Observatory of Japan; Yoshiaki Sato, SOKENDAI ; P. S. Athiray, University of Alabama Huntsville; Phillip Chamberlin, Laboratory for Atmospheric and Space Physics at the University of Colorado Boulder Katharine K. Reeves, Harvard-Smithsonian Center for Astrophysics; Amy Winebarger, NASA Marshall Space Flight Center

Solar flares are some of the most energetic phenomena in the Solar System, producing bursts of radiation across the electromagnetic spectrum, which can lead to space weather impacts, including radio blackouts and increased satellite drag. Operational products for flares have typically included long-term probabilistic forecasts (e.g., probability that a flare of a given size will occur over a given time period) and flare alerts (e.g., notification when the flare flux has already reached a high level), leaving a gap in the forecast horizon. For a variety of research and operational purposes, there is a need for predictions that are more actionable than long-term probabilistic forecasts and provide earlier notice than current flare alerts. In addition to potential space weather applications, having earlier notice of impactful flares can support triggered observations of scientifically interesting events. To address this gap, we are working to develop a real-time early solar flare alert, with the goal of leveraging flare onset signatures to predict the magnitude and duration of an ensuing eruptive event. Here we describe this concept and the implementation of a preliminary early flare alert system to support a successful and unprecedented solar-flare-triggered sounding rocket launch in April 2024 to observe a large flare with novel solar instrumentation. We additionally discuss the observational needs for improving this flare alert system in the future.

40. **Nai-Yu Wang** (NOAA NESDIS SWO)
Uses, Needs, and Plans for off Sun-Earth Line Lagrange Point 5 Observations
Co-authors: Jeff Newmark; V. Pizzo; E. Adamson; R. Steenburgh

The L5 Project within the joint program between the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) and the National Aeronautics and Space Administration (NASA) will supply the Compact Coronagraph 3 (CCOR-3), built by the Naval Research Laboratory (NRL), to the European Space Agency's (ESA) Vigil mission to the Lagrange 5 (L5) point mission. In addition, the L5 project will obtain, distribute, and archive all Vigil products. The off SEL coronagraph data from CCOR-3 is expected to improve space weather forecasting of the coronal mass ejections (CMEs) from Wang-Sheeley-Arge (WSA)-Enlil predictions of CME arrival at Earth. The in-situ plasma and magnetic field data from L5 can be used to monitor the evolution of co-

rotating structures with lead times of days before any potential impact on Earth. Previous Research has shown pathways to using particle data and heliospheric imaging data to further improve forecasting of space weather. NOAA is also interested in the planned Vigil magnetograph for improved solar wind modeling and for the longer lead time solar flare, predictions it will enable. We will present the NOAA current uses of data from STEREO and plans for future observations and space weather product improvements from CCOR-3 and Vigil mission products.

41. **Chin-Chun WU** (US Naval Research Laboratory, Washington, D.C., USA)
Magnetohydrodynamic Simulation of the Inner Heliospheric Solar Wind within 7 AU: A Comparison With Ulysses Observations During 1990-2009
Co-authors: Kan LIOU, Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA; Brian E. Wood, US Naval Research Laboratory, Washington D. C. , USA; Y. M. Wang, US Naval Research Laboratory, Washington D. C. , USA

The purpose of this work is to test the performance of the G3DMHD model [Wu et al., 2020, 2024]. G3DMHD is a data driven, time-dependent, global 3-D magnetohydrodynamic (MHD) model. The model has been proven to be effective in simulating the solar wind at and within 1 AU using the solar wind data from Wind and Parker Space Probe. In this work, we extend the G3DMHD model simulation domain out to 7 AU and perform three simulations. The simulated solar winds are compared with the Ulysses observations. Ulysses was the first (and still the only) spacecraft to orbit the Sun with a high inclination angle (~80º), monitoring the solar wind from pole to pole. Therefore, its data provide a stringent test of the G3DMHD model. Specifically, we use a sequence of source surface (2.5 $R_\odot$) maps, which are extrapolated from the (Mount Wilson Observatory) photospheric magnetic field maps using the potential field model, from 1990 to 2009 continuously covering two solar minima (1996 & 2008) and one solar maximum (2000), to drive G3DMHD. We consider the following three different inner boundary conditions: Case-A: Vr = 150 +500 fs km/s and $\gamma = 1.67$; Case-B: Vr = 150 +650 fs km/s and $\gamma = 1.46$; and Case-C: Vr = 150 +650 fs km/s and $\gamma = 1.30$, where Vr is the radial speed at 18 $R_\odot$, γ is the specific heat ratio, and fs is expansion factor. After comparing with the Ulysses observations (density, speed, temperature and magnetic intensity), the following results are found: (a) None of the three cases can lead to a satisfactory result for the four solar wind plasma and field parameters for all region/period being considered; (b) the solar wind speed is under-estimated in the pole region during solar minima for Case-A; (b) the solar wind temperature is under-estimated for Case-A for the entire time period and Case-B in solar minima; is over-estimated during 1997-2001 for Case-C; (c) the solar wind speed is over-estimated in solar maximum (2000) for both Case-B & Case-C; (d) the Case-C results in a better agreement for both solar wind density (Pearson correlation coefficient (cc) = 0.58; mean absolute squared error (MASE) = 0.64) and the solar wind velocity (cc = 0.56; MASE = 0.75) than for the solar wind magnetic intensity (cc = 0.40; MASE = 1.97) and temperature (cc = 0.38; MASE = 1.28). This simulation work suggests that the initial solar wind speed at the inner boundary, which is still difficult to measured, plays an important role. It is also suggested that a proper heating (controlled by γ) in the solar wind will need to be considered.

42. **Dimitrios Vassiliadis** (NOAA/NESDIS/SWO)

Space Weather Follow On: Release of CCOR-1 Imagery and Readiness for the SWFO-L1 Launch

Co-authors: M. Aubrey(2), M. Burek(2), M. Devaney(1), Steven Hill(2), Jacob Inskeep(1), Jeff Johnson(2), Elizabeth Kline(4), Brian Kress(3), Paul T.M. Lotoaniu(3), J. Marshall(1), Nazila Merati, N. Miles(2), G. Millward(2), M. Nakasone(2), Alessandra Pacini(3), C. Pagan(1), Laurel Rachmeler(3), Robert Redmon(3), Juan V. Rodriguez(3), William Rowland(3), Donald Schmit(3)
(1) NOAA/Space Weather Observations, (2) NOAA/Space Weather Prediction Center, (3) NOAA/National Centers of Environmental Information, (4) NOAA/Geostationary Earth-Orbit Observations

In March 2025, the Space Weather Follow-On (SWFO) program will start making operational solar-coronal images by the Compact Coronagraph 1 (CCOR-1) available to the space weather community. Later in the year, it will provide first light, non-operational data from an observatory at the Sun-Earth Lagrange 1 (L1) point.
We first give status updates on CCOR-1 flying on the Geostationary Operational Environmental Satellite 19 (GOES-19) since the June 25, 2024 launch and subsequent Post-Launch Test (PLT). Product quality was reviewed, 3/19 twice, in the beta-maturity and provisional maturity reviews of January and February 2025, respectively. CCOR-1 imagery is now ready to be shared publicly, in real time through SWPC and retrospectively at NCEI. We show representative observations of CMEs, streamers, and other structures obtained during PLT, before summarizing the advantages of the coronagraph relative to the legacy LASCO/C3 on board SOHO. Product validation involves monitoring issues such as earthshine and eclipses, and applying mitigations in acquisition and processing. Finally, we outline plans for intercalibration with LASCO and scenarios for synergistic observations with other coronagraphs from space- and ground-based platforms.

Next, the Space Weather Follow On at Lagrange 1 (SWFO-L1) mission is planned to launch to L1 in the fall of 2025. It will carry a second coronagraph, CCOR-2, and instrumentation for plasma (SWiPS), suprathermal-particle flux (STIS), and magnetic-field measurements (MAG). The data will be used to improve on the operational components of the ACE, DSCOVR, and SOHO missions. SWFO-L1 will be a rideshare with NASA’s Interstellar Mapping and Acceleration Probe (IMAP). Together with other new and legacy spacecraft at L1, SWFO-L1 will provide multipoint measurements of the background solar wind and geoeffective structures.

Data from CCOR-1 and SWFO-L1 will be made available through the Space Weather Portal (SPOT) developed at the National Centers for Environmental Information (NCEI) for SWFO and other missions. We briefly describe the data products, outlining types and levels, formats, and documentation in terms of algorithm descriptions, calibration plans, and user guides.

Wednesday, 19 March

Ionosphere and Thermosphere Research and Applications

Aviation Radiation Research and Applications

Geospace/Magnetosphere Research and Applications

Posters can be viewed all day, with dedicated times from ***10:15 AM – 11:00 AM*** *and* ***2:45 PM – 3:40 PM***

1. **Muyiwa Paul Ajakaiye** (Ariel University Israel)
Investigation and Modeling of VLF Transmitter Signal Variability Driven by Solar and Geomagnetic Activity in Israel
Co-authors: Yuval Reuveni / Eastern R&D Center, Ariel University, Ariel, Israel, Astrophysics; Geophysics and Space Science Research Center, Ariel University, Israel (yuvalr@ariel.ac.il); Ben Romano, Department of Physics, Ariel University, Israel

Critical infrastructures, such as satellite communication systems, are significantly affected by the state of the ionosphere, the region between the Earth's atmosphere, and satellite orbits. Extreme space weather events that pose risks to these systems can be analyzed through their impacts on the ionosphere, necessitating a comprehensive understanding of ionospheric dynamics. Among the ionospheric layers, the D-region remains poorly studied due to its challenging altitude, which is inaccessible to space-based measurements and beyond the reach of ground- and air-based instruments. Very Low Frequency (VLF) radio waves, which propagate between the Earth and the ionosphere in a guided manner, offer a valuable tool for investigating this region. However, the limited availability of VLF receivers, particularly in the Middle East, underscores the urgency of expanding VLF monitoring capabilities, especially during the rising phase of solar cycle 25. To address this gap, a VLF receiver - an AWESOME (Atmospheric Weather Electromagnetic System for Observation Modeling and Education) system from Georgia Tech - was installed at the summit of Samaria Hill to facilitate routine monitoring of anticipated solar and geomagnetic events predicted by current models. This study presents an analysis and modeling of VLF signal amplitude and phase variations during selected X-class solar flares and intense geomagnetic storms. The findings aim to advance the understanding of the D-region ionosphere within the Mediterranean sector and contribute to improved modeling of space weather impacts on critical technological systems.

2. **Dr. Ogwala Aghogho** (Eko University of Medicine and Health Sciences, Lagos, Nigeria)
Temporal Variations of Nighttime Scintillation Near the MUF Communication Link at the Equatorial Ionization Anomaly
Co-authors: Dr. Olugbenga Olumodimu, Institute of Cosmology and Gravitation, University of Portsmouth, United Kingdom; Dr. Oyedokun Oluwole Johnson, Department of Physics, University of Lagos, Lagos, Nigeria; Dr. Becky Canning, Institute of Cosmology and Gravitation, University of Portsmouth, United Kingdom

Scintillation is a phenomenon caused by ionospheric irregularities that disrupt the propagation of High Frequency (HF) radio communication signals, including those near the Maximum Usable Frequency (MUF) band. This effect is particularly pronounced in the equatorial region due to the Equatorial Ionization Anomaly (EIA) and at high latitudes due to auroral activities. The variability of scintillation near the MUF is influenced by ionospheric dynamics and electrodynamics, particularly from post-sunset to midnight. This study examines the relationship between the Maximum Usable Frequency (MUF) and scintillation (S4) index to assess the potential correlation between these parameters over time. Results of our preliminary analysis reveals weak and inconsistent correlations between both parameters, with alternating negative and positive values depending on the month and year. Some other interesting results have also been noted due to the significant influence of the variations in MUF and S4 index.

3. **Katarzyna Beser** (New Jersey Institute of Technology)
The Impact of Polar Cap Patches on Over-The-Horizon Radar Systems
Co-authors: Gareth W. Perry, New Jersey Institute of Technology

A polar cap patch is defined operationally as an enhancement in plasma density within the high-latitude F-region of the ionosphere, having spatial scales of the order of 100 km and featuring a density that exceeds twice that of the surrounding ionosphere. The occurrence of these patches at high latitudes is important for two main reasons. Firstly, they arise from complex interactions among the interplanetary magnetic field, magnetosphere, ionosphere, and thermosphere. Secondly, polar cap patches create plasma density irregularities that affect the propagation of radio waves in the high-latitude ionosphere. Substantial evidence indicates that polar cap patches pose a hazard related to space weather. For instance, they can cause deviations from direct great-circle paths and increase scattering for radio transmissions operating in the high frequency (HF) spectrum at high latitudes. Despite the clear need to monitor polar cap patches actively, an automated method for detecting them using HF instruments has not yet been developed.
In this study, we present the progress made towards understanding the patches' signature within HF backscatter signal obtained by the Super Dual Auroral Radar Network (SuperDARN), a radar system that provides real-time observations across northern and southern high- and mid-latitudes.

4. **James Cannon** (University of Colorado Boulder)
Ground-based VLF Remote Sensing and the October 10-11 Geomagnetic Storm
Co-authors: Ryan Dick, University of Colorado Boulder; Robert Marshall, University of Colorado Boulder

The Earth's ionosphere is classically broken into 3 distinct regions: the D-region (50-90 km), the E-region (90-150 km), and the F-region (150-500 km). Radio signals propagating through the ionosphere can, depending on frequency, become attenuated, refracted, or in the case of signals in the Very Low Frequency (VLF) range of 3-30 kHz, reflect off of the ionospheric plasma. These VLF signals also reflect off the Earth's surface, causing efficient propagation inside the Earth-Ionosphere (EI) waveguide over thousands of kilometers. The structure of this wave propagation is dependent on the height of the D-region and, to a lesser extent, the electron density gradient within the D-region. During geomagnetically quiet days, measurements of VLF waves reveal a diurnal variation within the D-region. This is because the primary source of ionization in the D-region is solar Lyman-α radiation. However, during geomagnetically active times, the D-region density can be enhanced by X-ray flux from solar flares or by highly energetic particles from the solar wind at Auroral latitudes or precipitating from Earth's radiation belts at mid-latitudes. The October 10-11 2024 severe geomagnetic storm (peaking at KP=8.87, DST = -333 nT) is a perfect example of this. Data are presented of the October storm from a newly operational Array for VLF Imaging of the D-region (AVID) consisting of 11 different VLF receivers covering a mid-latitude region of ~1500 km x 2500 km spanning ~48°N to ~60°N. We show clear spatial variation within the D-region's response to the geomagnetic storm.

5. **Clayton Cantral** (Johns Hopkins University Applied Physics Laboratory)
Space weather impacts on spacecraft position prediction in very Low Earth Orbits
Co-authors: Matthew Zuber – JHUAPL; Patrick Dandenault – JHUAPL; Robert Schaefer – JHUAPL; Larry Paxton – JHUAPL; Yongliang Zhang – JHUAPL; Rafael Mesquita – JHUAPL; Hyosub Kil - JHUAPL

Very Low Earth Orbit (vLEO), spanning altitudes from 100 km to 400 km, much closer to Earth's surface than low Earth orbits (LEO; 400-2000 km), is a challenging yet rapidly evolving space domain with potential advantages for commercial and national security operations. The close proximity to the Earth's surface introduces the challenge of vLEO: mitigating the impacts of the exponentially denser atmosphere on the spacecraft. This requires knowledge of the atmosphere conditions (i.e. weather) within the domain. Unfortunately, observational evidence of the weather in vLEO is currently lacking and models have not been extensively verified and validated within the domain. Here we provide a survey of the current state-of-the-art databases and models that provide atmosphere information within vLEO. We compare model predictions within the domain and assess the impacts of model differences on spacecraft orbit predictions. The results from this study are then used to assess and recommend approaches to ameliorate gaps in our understanding and capabilities to predict weather in vLEO in the context of improved operations and tracking.

6. **Ching-Chung Cheng** (University of Colorado at Boulder, CO, USA)
High-Latitude Ionosphere TEC Mapping using Ground-based and Spire Nanosatellite GNSS Observations
Co-authors: Yang Wang, University of Colorado at Boulder, CO, USA

This study presents a mapping of high-latitude ionospheric total electron content (TEC) during the March 2023 storm period. High latitudes, particularly Polar Regions, are inadequately covered by ground-based GNSS receivers for ionospheric observation. To address this, the study investigates the integration of space-based GNSS measurements from Spire Nanosatellites to improve the 2D mapping of vertical TEC. The data used include line-of-sight (LOS) TEC measurements from the Madrigal database, as well as radio occultation (RO) and grazing-angle GNSS reflectometry (GNSS-R) measurements from Spire Nanosatellites. During the selected period from March 22-24, there were ~13,700 sets of RO data and ~16,300 sets of grazing-angle GNSS-R data available. Using all these measurements, we formulated a 2D TEC mapping problem for high latitudes (e.g., northern hemisphere latitudes > 60 degrees) with a spatial resolution of 2-degrees latitude by 4-degrees longitude. The electron density profiles simulated by the Whole Atmosphere Model are employed to support the use of space-based GNSS. The detailed methodology, mapping results, and some comparative analysis will be presented.

7. **Mihail Codrescu** (Vector Space, LLC, Boulder, CO, USA)
Better global neutral density specification and forecast through the assimilation of COSMIC-2 sTEC measurements
Co-authors: Stefan M. Codrescu, Vector Space, LLC, Boulder, CO, USA; Catalin Negrea, Institute of Space Science, Magurele, Romania; Mariangel Fedrizzi, University of Colorado/CIRES and Space Weather Prediction Center, Boulder, CO, USA

Neutral density measurements are difficult to make, limited in number and coverage and suffer from large biases and uncertainties. This makes the option to improve neutral density specification using the plentiful ionospheric measurements, very attractive for satellite collision avoidance applications. Better neutral density specification and forecast can reduce the uncertainty in satellite and debris positioning, lower satellite fuel consumption, and help prevent the Kessler Syndrome. The main question we answer here using the Thermosphere Ionosphere Data Assimilation (TIDA) model is as follows: Is it possible to improve the global thermosphere neutral density model results by assimilating only ionospheric measurements? To illustrate the case we assimilate only slant TEC (sTEC) measurements from COSMIC-2 and show improvement in neutral density during an 8-day period (January 31 - February 7, 2022) that includes the minor geomagnetic storm that lead to the loss of 48 SpaceX satellites.

8. **Arianna Corry** (University of Hawai'i at Mānoa)
Remote Sensing of the Ionosphere from the Central Pacific
Co-authors: Giuseppe Torri, University of Hawaiʻi at Mānoa

Ground-based ionosondes are an essential tool for investigating ionospheric variability and space weather phenomena. The upper atmosphere over the Central Pacific region is critically under-sampled, limiting our ability to fully characterize regional ionospheric conditions. To address this gap, we deployed a low-cost ionosonde on Oʻahu, Hawaiʻi. Our station is continuously collecting data, regularly detecting signals and generating ionograms from over-the-horizon radars including, the Relocatable Over-the-Horizon Radar (ROTHR) in the continental United States and the Jindalee Operational Radar Network (JORN) in Australia. These observations offer unique insights into ionospheric dynamics and structure, particularly during space weather disturbances. Looking ahead, we intend to enhance our observational platform, including for example, a chirp transmitter, a high-frequency magnetometer to observe the extreme low frequency (ELF) range, and a meteor radar. Our long-term goal is to build a comprehensive observatory for remote sensing of the upper atmosphere at the University of Hawaiʻi.

9. **Patrick Dandenault** (JHU/APL)
HAWK-I: High-Latitude Atmospheric WorKbox for the Ionosphere
Co-authors: Robert Schaefer, JHU/APL; Clayton Cantrall, JHU/APL; Sebastijan Mrak, JHU/APL; Jim Conroy, JHU/APL; Giuseppe Romeo, JHU/APL; Lisa Knowles, JHU/APL; Cathryn Mitchell, U of Bath; Gary Bust, GSBust, LLC

Advances in space weather modeling, data assimilation, instrumentation, and the growth in real-time observational networks enable the simulation of the ionosphere in 3D across wide spatial regions in near real time. Here, we present HAWK-I: High-latitude Atmospheric WorKbox for the Ionosphere, which is designed to provide a near-real-time specification of the high-latitude ionosphere in near real time and generate tailored operational products for Users. The framework is being developed and optimized for use in a real-time operational environment (R2O2R). HAWK-I uses multiple background models of Earth's ionosphere along with the data assimilation algorithm H-IDA4D (High latitude Ionospheric Data Assimilation 4D). H-IDA4D is an advanced version of IDA4D, tailored for use in the high-latitudes. It produces 4D time-dependent electron-density maps through variational analysis.
Three models are used to provide background ionospheres for HAWK-I. Real-time (NTRIP) data from GNSS ground stations and satellite Radio Occultation (RO) data from COSMIC-2, Spire, and PlanetiQ are assimilated to generate near-real-time Nowcast products. An included High frequency Ionosphere Interface Tool box (HIIT) creates 2D and 3D ray-trace output products using the modeled ionospheres (i.e., using the IRI ionosphere vs. SAMI3 vs. E-CHAIM). Near-real-time Ionospheric Scintillation and Rate of TEC Index (ROTI) products are also generated. Observational data from the Poker Flat Incoherent Scatter Radar (PFISR) and are used to validate the results. Since the current focus is the high latitudes, where the dynamics and chemistry can change very quickly, we use a 5-minute modeling + data assimilation cadence and we only ingest near-real-time data that can be automatically processed.

10. **Marouane El Bahraoui** (Oukaimeden Observatory, High Energy Physics and Astrophysics Laboratory, FSSM, Cadi Ayyad University, Marrakech, Morocco.)

The first multi-year analysis of TEC results obtained at Oukaimeden Observatory. Study of the solar and geomagnetic activities on TEC behavior.

Co-authors: 1: Zouhir Benkhaldoun; 1 and 2: Mohemed Kaab
1: Oukaimeden Observatory, High Energy Physics and Astrophysics Laboratory, FSSM, Cadi Ayyad University, Marrakech, Morocco.
2: National School of Applied Sciences Beni Mellal, Sultan Moulay Sliman University, Beni Mellal, Morocco.

One of the main parameters that characterize the ionosphere is the electron density showing changes regarding solar activity, geomagnetic activity, position, season, ...etc.
The quality of radio signals passing through this mysterious area of our Earth's atmosphere is affected by the behavior and state of the electron density. Hence there is a need to understand its evolution as a function not only of time but also of solar and geomagnetic activity.
One of the key parameters making it possible to identify this behavior and its connection with the degradation of radio signals used in radio telecommunications is the measurement of the total electron content (TEC). Variations in TEC can cause signal delays, phase distortions, and scintillations, impacting the accuracy and reliability of telecommunications systems.
This study aims to represent the first multi-year analysis of TEC results obtained from a GPS station installed at the Oukaimden Observatory, located at an altitude of about 2700 meters on the High Atlas mountain range, about 78 kilometers south of Marrakech, Morocco.
We are going to present the evolution of total electron content (TEC) as a function of time and of solar and geomagnetic parameters: in this context, F10.7 solar flux and Interplanetary Magnetic Fields (IMF) as solar proxies and Kp and Dst indices as geomagnetic activity proxies are considered.

11. **Katherine Garcia-Sage** (NASA GSFC)

Space Weather Applications of the Geospace Dynamics Constellation: A Comprehensive Look at Ionosphere-Thermosphere Variability and Its Geomagnetic Drivers

Co-authors: Doug Rowland, NASA GSFC; Rebecca Bishop, Aerospace Corp; Marcin Pilinski, CU Boulder; Eric Sutton, CU Boulder; Jeff Thayer, CU Boulder; Larry Kepko, NASA GSFC

An overwhelming number of space weather effects take place in or are driven by the thermosphere and ionosphere. Society's increasing dependence on space for defense and commercial needs requires a new, comprehensive examination of the ionosphere-thermosphere (IT) region, in order to improve our fundamental understanding of these space weather processes. The Geospace Dynamics Constellation (GDC) mission will provide the first comprehensive look at IT. GDC will track multiscale measurements of energy input from the magnetosphere to the ionosphere-thermosphere, its effects in the IT region, and internal processes throughout the IT system. GDC's six satellites will characterize the IT system and its geomagnetic drivers from ~375 km altitude. This mission will make unprecedented multi-point orbital measurements of ionosphere/thermosphere density, composition, and temperature, magnetic and electric fields, and ionospheric variability. The measurements and science advancements will inform our understanding of the processes that change atmospheric densities, cause ionospheric scintillation, and

drive ionospheric currents, with effects on satellite drag, navigation/communication, and geomagnetically induced currents.
GDC's contribution to our understanding will enable improvements in nowcasting and forecasting of IT variability and its effects. Further, GDC will transmit low-latency space weather-relevant data that will be available for our operational partners, allowing GDC to demonstrate a near real-time data pipeline to evaluate and prioritize the highest-impact measurement parameters and spatio-temporal scales. GDC's comprehensive, multipoint picture of IT variability and its drivers will establish the understanding of fundamental space weather processes and the operational pipeline that we need for our increasing reliance on space.

12. **Josemaria Gomez Socola** (University of Texas at Dallas - W. B. Hanson Center for Space Sciences)
ScintPi: Advancing ground-based observational capabilities for space weather monitoring and studies
Co-authors: Fabiano Rodrigues, University of Texas at Dallas - W. B. Hanson Center for Space Sciences

Ionospheric scintillation refers to rapid fluctuations in the phase and/or amplitude of radio signals as they propagate through plasma irregularities in the Earth's ionosphere. Scintillation can affect, for instance, the performance of systems that use transionospheric signals for remote sensing, communication, and navigation. Signals from Global Navigation Satellite Systems (GNSS) have been used by advanced receivers to monitor L-Band scintillation and ionospheric total electron content (TEC).
Rodrigues and Moraes (2019) showed, 3/19 that commercial off-the-shelf (COTS) GPS receivers could be combined with single-board computers (e.g., Raspberry Pi) to create low-cost ionospheric scintillation monitors (ScintPi 1.0). More recently, Gomez Socola and Rodrigues (2022) presented results of more advanced monitors (ScintPi 3.0) capable of making measurements of ionospheric scintillation and TEC using signals from multiple GNSS constellations.
While ScintPi monitors are not intended to fully replace more advanced commercial monitors, they have been shown to be adequate for many research investigations related to space weather and fundamental geospace science. In this presentation, we summarize the design of ScintPi monitors and highlight their benefits. We also present the status of collaborative deployments at low, middle, and high latitudes. Finally, we present examples of observations and results of collaborative studies that highlight the adequacy and benefits of ScintPi observations. These include for instance, magnetic conjugate observations of low latitude scintillation, spaced-receiver measurements of ionospheric irregularity drifts, and detection of strong L-Band scintillation by a receiver located in the US.

13. **Austin Griffin** (Kansas State University)
GNSS Outages and Space Weather

One of the demonstrations shown via space weather that directly affects the Earth is displayed as the aurora borealis. Another way that space weather indirectly affects crop growth and development on Earth is by preventing satellite signals from going through the Earth's ionosphere to reach farm equipment. Since 1932, geomagnetic disturbances have been charted to visualize the frequency of events before and during the GNSS era. Crop yields can be estimated by comparing planting proficiency during years with intense geomagnetic disturbances throughout most active planting and harvest dates.

Geomagnetic disturbances directly affect GNSS satellite signals from traveling through the ionosphere as predicted disturbances affect the ability of precision agricultural technology from obtaining its current location and in turn makes crop planting and harvesting less accurate.
Two graphs, one over space weather levels vs. the aurora borealis and the other on crop yield/planting in the northern United States, show how space weather from the sun affects crop yield/planting.

14. **Florian Günzkofer** (German Aerospace Center (DLR), Institute for Solar-Terrestrial Physics)
Joule heating scaling in thermosphere-ionosphere models compared to EISCAT incoherent scatter radar measurements
Co-authors: Hanli Liu, National Center for Atmospheric Research (NCAR); Huixin Liu, Kyushu University; Gunter Stober, University of Bern; Gang Lu, National Center for Atmospheric Research (NCAR); Frank Heymann, German Aerospace Center (DLR); Claudia Borries, German Aerospace Center (DLR)

The polar plasma convection originates from the interaction between the interplanetary magnetic field and the Earth's magnetic field. To model the atmosphere-ionosphere system, the resulting polar electric potential is taken as an upper boundary condition using empirical convection models. These empirical models cannot represent short-term variations of the electric field, which has been shown to cause a systematic underestimation of ionospheric Joule heating rates at high latitudes. Commonly, atmosphere-ionosphere models apply a Joule heating scaling factor for compensation. For example, a constant scaling factor of 1.5 is applied in the Thermosphere Ionosphere Electrodynamics General Circulation Model (TIE-GCM).
We evaluate the accuracy of this constant scaling factor by comparing Joule heating rates calculated from the TIE-GCM with those estimated from measurements by the EISCAT incoherent scatter radar in Tromsø, Norway (69.6°N, 19.2°E). We investigate TIE-GCM runs driven with the Heelis, Weimer, and AMIE convection models, as well as WACCM-X model runs in standard and high resolution. We show that the required scaling factor varies significantly with geomagnetic activity, solar wind energy input, magnetic local time, and the applied plasma convection model. The impact of the spatial and temporal model resolution on the Joule heating rates is studied as well.

15. **Frank Heymann** (German Aerospace Center (DLR))
Synthetic study of ionosphere lower boundary forcing using TIEGCM
Co-authors: Florian Günzkofer, German Aerospace Center (DLR)

In this study, we use the general circulation model TIE-GCM as well as different synthetic lower boundary forcing conditions to investigate the behavior of the lower Thermosphere Ionosphere (TI) system. The lower boundary forcing is synthetically generated to artificially mimic different atmospheric conditions and then used as input for TIE-GCM. The influence of these conditions on the TI system will be analyzed by investigating different thermosphere as well as ionosphere parameters. The goal of this study is to improve the understanding of the importance of the different (internal vs. external) driving mechanisms in the TI system.

16. **Nate Holland** (University of Colorado at Boulder)
Towards using SDO/HMI helioseismic far-side images to improve solar irradiance prediction
Co-authors: Natasha Flyer, University of Colorado at Boulder and Flyer Research LLC; Thomas Berger, University of Colorado at Boulder Space Weather Technology, Research, and Education Center (SWx TREC); Shea Hess-Webber, Stanford University; Mark Vincent, MAVerick Analysis LLC

Predicting the solar EUV irradiance is a key element of thermospheric density modeling used in Low Earth Orbit satellite navigation and collision avoidance planning. Current methods rely only on solar nearside observations or flux transport approximations for far-side estimations of magnetic activity (the underlying cause of EUV irradiance variability). Here we outline our plan for using machine learning (ML) models trained on SDO/HMI far-side helioseismic phase maps along with SDO/AIA EUV images to infer global solar EUV irradiance. This global irradiance approximation can then be virtually rotated to give more accurate 1--7 day forecasts of solar EUV inputs to the thermosphere. We demonstrate the first stage of our ML models, which regresses SDO/AIA images to the radio F10.7 index that is commonly used in current thermospheric density models, capturing the nonlinear relationship between EUV irradiance and the F10.7 index.

17. **Chali Idosa Uga** (University of Alabama in Huntsville, Department of Space Science)
TEC disturbances caused by CME-triggered geomagnetic storm of September 6–9, 2017
Co-authors: Sujan Prasad Gautum and Ephrem Beshir Seba; University of Alabama in Huntsville, Department of Space Science and KU Leuven, Department Wiskunde, Centre for Mathematical Plasma-Astrophysics, Leuven, Belgium

This study investigates the ionospheric response to a geomagnetic storm triggered by a Coronal Mass Ejection (CME) during 6–9 September 2017, across GPS stations located in diverse geographical regions. We analyze the changes in the magnetic field component (ΔH), the Prompt Penetration Electric Fields (PPEF), and the Total Electron Content (TEC). We find that ΔH exhibits latitude-dependent responses during the storm, with high-latitude stations experiencing more significant reductions compared to low-latitude stations. The PPEF behavior is found to be directly correlated with solar wind disturbances. Particularly during the main phase of the storm, fluctuations in PPEF were clearly associated with negative values in the Dst index. The KIRU station, located at a high latitude, shows the most pronounced PPEF effects, indicating the increased susceptibility of high-latitude regions to solar wind interactions. The time series plot of TEC, covering a full month at different stations, shows a distinct diurnal pattern driven by solar ionization. Equatorial stations such as HYDE, BOU, HON (HNLC), and DODM exhibit the highest daily TEC values. During the geomagnetic storm, TEC disturbances are evident across all stations, with significant disturbances and varying trends in TEC depletion rate observed at different locations. The TEC values differ by 5–25 TECU during the storm period, suggesting intricate ionospheric responses to geomagnetic storms at different stations. This highlights the importance of considering different geographical regions to fully understand the ionospheric dynamics related to solar activities.

18. **Christopher Jeffery** (Los Alamos National Laboratory, Los Alamos, NM, USA)
Extending SWPC's D-RAP algorithm: A Vertically-Resolved Model for D-Region Chemistry and HF Impacts
Co-authors: Anton Goertz, Frankfurt University, Frankfurt, Germany

Under the auspices of the Space Weather Research-to-Operations-to-Research (SWR2O2R) program, we are developing a new forecast tool that extends and improves SWPC's D-RAP product for HF absorption during solar proton events. We are pursuing this goal by extending the empirical and presently operational relations of Sauer and Wilkinson (2008), predicting a square-root dependence of HF absorption on GOES proton flux, using a vertically resolved model with D-Region chemistry. In a recent publication (in review), we demonstrate that this new approach has greater predictive accuracy than D-RAP for the September 2017 solar proton event. In addition, our new approach shares analytic similarities to D-RAP. Under certain conditions, for example proton absorption confined to the upper D-Region, our approach also predicts a similar square-root dependence in the quasi-steady limit. However, our vertically-resolved models allows for generalized weighting factors for the contribution of separate GOES proton energy channels to total HF absorption. In this poster, we summarize the current status of our new model, and our plans for validation using a large set of storms observed by the Canadian Riometer Array

19. **Tyler Karasinski** (Arizona State University)
Gravity Wave Zoo: Engaging Citizen Science to Analyze Atmospheric Gravity Wave Activity over Poker Flat, Alaska
Co-authors: Katrina Bossert, Arizona State University; Jessica Berkheimer, Arizona State University; Jessica Norrell, Arizona State University; Sophie Phillips, Arizona State University; Karina Muñoz, Arizona State University; Pierre-Dominique Pautet, Utah State University

The Mesosphere and Lower Thermosphere (MLT), also known as the spacecraft reentry region, is a critical atmospheric region ranging from ~80-140 km. A main driver of momentum transport, density perturbations, temperature variations, and background winds in this region are high-altitude atmospheric gravity waves (GWs) which are not well accounted for in many models of the thermosphere and near-space region. Additionally, models that do include GWs fail to resolve small-scale activity (<200km). We utilize our OH imager located in Poker Flat, Alaska (65°N 147°W) to leverage our ongoing citizen science initiative, Gravity Wave Zoo, expanding the breadth of available GW, aurora, and Kelvin-Helmholtz Instability (KHI) data. To-date, more than 2,000 Gravity Wave Zoo participants have classified over 66,000 near-infrared video clips (6.6 million images), allowing for the emergence of behavioral trends on the scale of weeks, months, or seasons and aiding in a more cohesive understanding of regular MLT variabilities. We focus on a short-term study between December 27th, 2023, and February 4th, 2024, and report on recent Gravity Wave Zoo progress and accuracy, presenting preliminary statistics on both overall participation and citizen classification types of GW, KHI, and auroral events. Additionally, we compare the novel use of citizen science to conventional analysis as a means of data validation and later speculate on future studies that may be enabled by this work. Through case studies and validation of citizen science data, we demonstrate both initial findings, as well as the potential uses of this extensive citizen science dataset.

20. **Delores Knipp** (Smead Aerospace Engineering Sciences, University of Colorado Boulder)

Low Earth Orbit Challenges During the 10-14 May 2024 'Gannon' Storm

Co-authors: Eric Sutton, Space Weather Technology Research and Education Center, University of Colorado Boulder

We present a collection of anecdotal reports and statistical information related to satellite operations in the Low Earth Environment (LEO) during the 10-14 May 2024 storm. Several High LEO operators (altitudes > 650 km) reported challenges with pointing and altitude maintenance. In mid-LEO (400-600 km) where neutral density increased by a factor 5 above background values, autonomous orbit maneuvers by thousands of satellites occurred during the peak of the storm, vs the October 2003 storm during which the bulk of orbit maneuvering was in the post-storm phase. In Very Low Earth Orbit (VLEO < 400 km) reports show that active and inactive 'CubeSat's' met an early orbit demise. Many space operators paused normal activities or noted that data products had to be reprocessed because of storm. Although not comprehensive, we believe this collection of reports is illustrative of future storm-time operations and challenges in the statistically more 'active' declining phase of odd-numbered solar cycles.

21. **I-Te Lee** (Taiwan Space Agency, Taiwan)

Relationship of FORMOSAT-7 Orbital Decay and Space Weather Conditions

Co-authors: Cheng-Yung Huang, Taiwan Space Agency, Taiwan; Jyun-Ying Huang, Central Weather Administration, Taiwan; Hsu-Hui Ho, Central Weather Administration, Taiwan

The orbit of an artificial satellite would be perturbed by various forces, especially affected by the aerodynamic drag, which depends on the thermospheric density. The thermospheric density varies with solar activities and flux as well as geomagnetic activities. The enhancements of atmospheric drag under geomagnetic disturbed conditions and higher solar radio flux period might bring difficulties for predicting the trajectories of satellites and further cause communication anomalies between satellite and ground stations such as command failures, data missing, and/or contact losing. The Taiwan Space Agency (TASA) operates a constellation mission named FORMOSAT-7/COSMIC-2 (F7/C2) to provide the global navigation satellite system radio occultation data for meteorology, ionosphere, climatology, and space weather. F7/C2 consists of 6 identical small satellites, which are orbiting with an inclination angle to acquire more observations at middle and lower latitudes. The precise F7/C2 spacecraft orbits are provided by the Taiwan Data Processing Center (TDPC) of the Taiwan Analysis Center for COSMIC (TACC). The daily mean semi-major axis indicates a day-to-day gradual descending, approximately 50 to 80 meters per day responding to solar activities. Under the geomagnetic disturbed conditions, the air drag would increase at higher latitude due to the particle precipitation and Joule heating. Therefore, the daily change of these six satellites also reveal a sudden decay simultaneously during the strong geomagnetic storm condition ($Kp > 7$). The orbital altitude decreased more than 100 meters per day during the geomagnetic storm, which occurred on 10-12 May 2024. In this study, the orbital data of all six FORMOSAT-7/COSMIC-2 satellites in 2024 are comprehensively analyzed to report the response of the satellite orbit to solar radio flux and geomagnetic conditions.

22. **Po-Han Lee** (Central Weather Administration, Taiwan)
Operational Space Weather Monitoring and Forecasting in Taiwan
Co-authors: Huei-Wen Siao, Central Weather Administration, Taiwan; Wei-Chen Kuo, Central Weather Administration, Taiwan; Jyun-Ying Huang, Central Weather Administration, Taiwan; Hsu-Hui Ho, Central Weather Administration, Taiwan; Yu-Ming Tsai, Central Weather Administration, Taiwan; I-Te Lee, Taiwan Space Agency, Taiwan; Jing-Shan Hong, Central Weather Administration, Taiwan

Taiwan's geographic location subjects it to the influence of the Equatorial Ionization Anomaly, where rapid plasma density variations, plasma bubbles, and irregularities severely impact high frequency and satellite communications, as well as navigation systems. To address these challenges, the Central Weather Administration (CWA) has collaborated with the Taiwan Space Agency and domestic research teams since 2013 to provide real-time space weather monitoring and forecasts. Currently, CWA operates a range of observational systems, including solar images in visible light, H-alpha, and Calcium K-Line, along with sunspot drawings for sunspot number estimation. In addition, ionograms, real-time global and regional total electron content (TEC) data, scintillation indices, rate of TEC variations, and ionospheric radio occultation profiles provide valuable insights into ionospheric behavior. CWA also runs the Global Ionospheric Specification, which generates 3D electron density structures for the ionosphere. Regarding geomagnetic field monitoring, CWA computes local geomagnetic disturbances, known as Taiwan Disturbance Index (TWDI), to estimate the local impact of space weather events. . To enhance space weather awareness, CWA issues forecasts twice daily, with automated reports triggered by space weather events and special warnings issued for severe disturbances. These forecasts and alerts are publicly accessible via the Space Weather Operational Office website, which recorded approximately 470 thousand page views and 55 thousand users in 2024. Over 1,600 updates were provided throughout the year, including both automated event reports and manually updated space weather summaries and forecasts. Further details on these CWA products will be presented and discussed.

23. **Diana Loucks** (United States Military Academy)
West Point Distributed Space Weather Array
Co-authors: Dr Jason Derr, USMA; Cadet Daniel Klotz, USMA; Cadet Joanna Halfhill, USMA; Cadet Aaron Jerobimo-Monarca, USMA; Cadet Sidharth Hegde, USMA; Cadet Preston Poirier, USMA

A variety of sensors and measuring devices, including GNSS receivers, ground magnetometers, radios, electrometers, and seismometers, are used to study ionospheric and geomagnetic variations caused by space weather. While research has primarily focused on polar and equatorial regions, mid-latitude regions have been less studied. At the United States Military Academy (USMA) in West Point, NY, a distributed network of these instruments is being deployed within a 3 x 3 km area of the West Point Military Reservation to investigate mid-latitude space weather effects. Observations from CASES GPS receivers will help infer total electron content variations, amplitude scintillation, and phase scintillation. Ground magnetometers will provide data on ground-induced currents, field-aligned currents, and local magnetic perturbations. This information will be used to characterize structures and causal pathways in the regional ionosphere and underground. During the workshop, any collected data on geomagnetic storms and other events using collocated receivers will be presented. This data will inform future analyses of expected phenomena recorded with the distributed operational system. The project aims to contribute valuable ionospheric data and a novel methodology to mid-latitude studies, document a method for creating a low-cost instrumentation network, and establish a distributed laboratory for future space weather and operational coursework at USMA.

24. **Jeffrey Marino** (Ensemble Space Labs)
ML Model Forecasting High and Mid Latitude Ionospheric Scintillation
Co-authors: Dr. Luisa Capannolo, Boston University; Dr. Jackson McCormick, Ensemble Space Labs; Elyse Schetty, Ensemble Space Labs; Benjamin McCrossan, Ensemble Space Labs

Ensemble Space Labs, in collaboration with Boston University, has developed a proof-of-concept machine-learning model that forecasts high and mid latitude ionospheric scintillation over North America funded by a NASA Phase I SBIR. The training datasets were compiled from multiple sparse sources, including UNAVCO and CHAIN receivers, with temporal resolutions up to 5 minutes and spatial resolution of 1° by 1°, spanning North America (approx. 25° to 80° latitude) over the period 2015–2018. Ensemble implemented proxy indices to facilitate using geodetic receiver observations to mitigate the limited number of scintillation observations. The model's convolutional architecture captured spatiotemporal dependencies of TEC, space weather drivers, and receiver data in order to forecast probabilistic output of phase and amplitude scintillation. The model generates probabilistic forecasts for phase and amplitude scintillations one hour into the future, achieving True Skill Scores (TSS) of 0.53 and 0.44, respectively. The phase scintillation forecast outperforms the baseline persistence model TSS of .27 by nearly 100%.
The model is deployed on an AWS-hosted cloud environment that visualizes the model outputs via heat map that depicts scintillation probabilities at a 1° by 1° resolution. Analysis of different training data combinations (UNAVCO vs. CHAIN) revealed modest performance variations, supporting the model's robustness and capacity to integrate auxiliary data without degradation in performance.

25. **Shaylah Mutschler** (Space Environment Technologies)
Solari — a Commercial Data Assimilative Thermospheric Density Model
Co-authors: Marcin Pilinski, CUB LASP; Steve Casali, Omitron Inc.; Kent Tobiska, Space Environment Technologies; Brandon DiLorenzo, Space Environment Technologies

Because the state-of-the-art in density estimation, the High Accuracy Satellite Drag Model (HASDM), is restricted to use within the US Government, there is a critical need for a commercial data assimilation tool that can deliver operational nowcast and forecast densities to satellite operators for routine operations. Solari, our new data-assimilative density model, is designed to meet this need. Solari assimilates LeoLabs radar tracking data and Space Force Energy Dissipation Rates (EDRs) of calibration satellites to correct a background density model and produce a global density state. The flexible architecture of Solari allows the tool to be easily extended to include additional measurement types (i.e., satellite GNSS, nitric oxide). The first version of Solari will utilize two background density models: MSIS-00 and JB2008. The use of two background models enables the concurrent application of two widely used data assimilation approaches: space weather index estimation and exospheric temperature estimation. The end goal is an operational commercial density nowcast and forecast data stream that offers accuracy equal to or surpassing that of HASDM.

The six-month NASA SBIR Phase I results will be presented, which include a feasibility study of the radar tracking data processing tool and the transition of the Space Force EDR processing tool from a TRL 4 to a TRL 5. Details on the Solari algorithm architecture and plans for future work will also be shared.

28. **Marcin Pilinski** (CU/LASP)
Neutral Density and Satellite Drag Forecast Using Data Assimilative Models
Co-authors: Marcin Pilinski, University of Colorado Boulder, SWx-TREC; Eric Sutton, University of Colorado Boulder, SWx-TREC; Shaylah Mutschler, Space Environment Technologies; Weijia Zhang, University of Colorado Boulder, SWx-TREC; Jeff Steward, Orion Space Solutions

Satellite drag predictions continue to be one of the main challenges facing operators of satellites in Low Earth Orbit (LEO). One of the main impediments to accurate satellite drag predictions results from uncertainties in the air density of the highly variable upper atmosphere, also known as the thermosphere. Drag-validated data assimilation (DA) techniques such as IDEA [Sutton 2018], and Dragster [Pilinski et al. 2016] now have the ability to determine the thermospheric model forcing that is most compatible with the observed satellite drag, effectively making a “driver correction” to the atmospheric models at each time step. These methods have been the only ones so far shown to match or outperform the current state of the art in density specification, which is the High Accuracy Satellite Drag Model (HASDM) operated by the Department of Defense. We present the nowcast results from one year of Dragster and IDEA runs and compare these with HASDM as well as a few non-assimilative models. This includes the estimated forcing parameters, their comparison to existing indices and proxies, and the validation of neutral density outputs. We also evaluate several methods of launching forecasts based on these nowcasts. The overall goal is to determine how best to make thermospheric forecasts using the best validated and most operationally ready DA techniques.

29. **Robert Schaefer** (Johns Hopkins U. Applied Physics Laboratory)
Tuning Ionospheric Data Assimilation for Optimal Performance
Co-authors: Gary Bust, GSBust, LLC; Clayton Cantrall, JHU/APL; James Conroy, JHU/APL; Patrick Dandenault, JHU/APL; Lisa Knowles, JHU/APL; Cathryn Mitchell, University of Bath; Sebastijan Mrak, JHU/APL; Giuseppe Romeo, JHU/APL

Empirical and first principles models of the atmosphere and ionosphere can be improved through the use of data assimilation (DA). However, the most common form of data assimilation is the variational approach, which uses linear estimation theory. In linear estimation theory, each type of information is given a weight proportional to the inverse of its specified error covariance. Analysis systems are therefore dependent on appropriate estimates of observation and modeling errors. Unfortunately, those statistics are not easy to obtain perfectly and remain a major challenge for assimilation systems. In ionospheric data assimilation, a major source of information comes from Total Electron Content (TEC) observations. For errors on these observations, one can estimate the phase leveling errors, but other sources of error, e.g. multipath and forward modeling errors, are much more difficult to estimate. Here we consider ways to estimate the appropriateness of the errors using statistical metrics derived for terrestrial weather models (Desroziers and Ivanov, 2001; Desroziers, et al., 2005; Daley and Barker, 2001) and apply them to ionospheric assimilation. We will show how these can be used to tune the error sizes in assimilation to optimize the ionosphere specification. We consider here both ground GPS and Radio Occultation measurements of TEC and find optimum estimates of error for the variational data assimilation program IDA4D (Bust and Datta-Barua. 2014).

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30. **Liam Smith** (Georgia Institute of Technology)

Using Transformers to Improve Ionospheric Modeling and Enable a Wider Input Space

Co-authors: Morris Cohen, Georgia Institute of Technology

Understanding the ionosphere is crucial for many aspects of modern life, especially regarding communications. However, the impact of the ionosphere depends heavily on the electron density, which is difficult to measure densely, leading to a need for models. While using correlated solar activity metrics can help, using direct measurements is challenging due to inconsistently structured data, such as ungridded or arbitrary-length formats, which hinder the use of many machine-learning techniques. This applies to electron density measurements, which are sparse and scattered, as well as Total Electron Content (TEC) (the integral of electron density) measurements, which are inconsistent in amount and location at any one time.

Such drawbacks could be addressed by transitioning data into standardized sizes, for which we have developed a technique. By using transformer-like architectures, we can embed arbitrary lengths of sequences into fixed-length vectors that can be further used in other models. Our work has demonstrated that we are able to capture details of inconsistent data, especially TEC, which enables us to use recent TEC history to drive improved 3D electron density predictions. We also compare our approach with more traditional masked CNNs and highlight the benefits of using an attention-based approach like ours. Since our approach is not confined to a grid, we can even use recent electron density history measurements from moving spacecraft, an input previously unexplored.

31. **Eric Sutton** (Univ. of Colorado / SWx TREC)

Satellite Constellation Data to Drive Thermospheric Density Forecasting Capabilities

Co-authors: David Fitzpatrick, Univ. of Colorado / Aerospace Dept.; Nai-Yu Wang, NOAA / NESDIS; Tzu-Wei Fang, NOAA / SWPC

Interactions between resident space objects in low-Earth orbit (LEO, i.e., orbits below ~1,000 km altitude) and the ambient atmospheric environment cause significant orbital perturbations. While LEO is a most desirable orbital regime from the standpoint of debris disposal, the uncertainty of an object's orbital trajectory is often a limiting factor in the accuracy of conjunction assessments used to determine when and if a collision-avoidance maneuver is needed. At the same time, the increasing population of LEO over the last 5 years has compounded the overall risk of collisions. By combining tracking data from recently launched small satellites, often in the form of high-rate GNSS observables or quantities derived thereof, with attitude and satellite geometry information, the thermosphere can be observed with unprecedented coverage. The necessary information is available, in various forms, from several mega constellations, including Starlink, Spire, and others. This talk will outline the progress, challenges, and limitations of working with commercial datasets as well as the promise of scientifically instrumented, targeted missions.

33**. Weijia Zhan** (University of Colorado Boulder)
Validation of ICON Satellite Measurements of Neutral and Plasma Parameters Using WAM-IPE Model Simulations: A Comparative Study of Climatological and Day-to-Day Variabilities
Co-authors: Eric Sutton, University of Colorado Boulder

The validation of Ionospheric Connection Explorer (ICON) satellite measurements of neutral and plasma parameters is critical for understanding the complex dynamics of the Earth's upper atmosphere. This study leverages simulations from the Whole Atmosphere Model coupled with the Ionosphere-Plasmasphere Electrodynamics (WAM-IPE) model to validate ICON observations, focusing on both climatological patterns and day-to-day variabilities. By comparing ICON measurements with WAM-IPE outputs, we assess the accuracy and reliability of the satellite data in capturing key thermospheric and ionospheric parameters, such as neutral winds, densities, and plasma densities. The analysis reveals both similarities and differences between the observed and modeled datasets, highlighting the strengths and limitations of each approach. Such validation is essential for improving the fidelity of space weather models, enhancing our understanding of the coupling between the neutral and plasma environments, and refining predictive capabilities for space weather impacts on communication and navigation systems. This study underscores the importance of cross-validating observational and modeling frameworks to advance our knowledge of upper atmospheric processes and their variability.

34. **Weijia Zhan** (University of Colorado Boulder)
A Comparative Framework for Index Mapping in Forecasting: Leveraging Data-Assimilated Ap and F10.7 for Enhanced Ap and F10.7 Forecasting
Co-authors: Marcin Pilinski, University of Colorado Boulder; Eric Sutton, University of Colorado Boulder

This work introduces and evaluates an index mapping strategy aimed at improving the forecast accuracy of estimated Ap and F10.7—key geomagnetic activity and solar flux indices, respectively—by jointly leveraging Issued Ap, F10.7, and time-lagged values of the estimated indices. The estimated Ap and F10.7 are the result of data assimilation methods that are described in another poster. We conduct a comprehensive exploration of time-series modeling approaches—including linear regressions with lagged features, ARIMAX, NARX, and machine learning methods such as long short-term memory (LSTM) neural networks—to illustrate how effectively harnessing combinations of time-lagged, data-assimilated solar and geomagnetic drivers (each forecasted separately) alongside issued indices leads to more precise predictions. Methodological steps for data preparation, feature construction, model training, and systematic performance comparisons (via RMSE and other key metrics) are detailed. Our results underscore the importance of integrating assimilation-based estimates of geomagnetic and solar flux data

into robust forecasting solutions, ultimately guiding practitioners toward achieving higher predictive accuracy and enhanced interpretability in space weather modeling.

35. **Eric Benton** (Oklahoma State University)
Progress on Development of Dosimetry Instrumentation for Monitoring Ionizing Radiation in the Upper Atmosphere
Co-authors: Kyle Copeland, FAA; Buddy Gersey, OSU; Alex Hands, TRIUMF; Conner Heffernan, OSU; Garrett Thornton, OSU

The Radiation Physics Laboratory at OSU with support from NASA SWR2O2R program is developing ionizing radiation dosimeters for use aboard aircraft, UAVs and high altitude balloons. The Atmospheric Ionizing Radiation Tissue Equivalent Dosimeter (AirTED) is a low cost, compact ionizing radiation detector consists of a tissue equivalent proportional counter (TEPC) to measure high LET radiation including secondary neutrons, primary and secondary protons and heavy ions, and a Si PIN photodiode to measure low LET radiation including x-/gamma-rays, electrons and positrons. The Atmospheric ionizing Radiation Silicon Dosimeter (AirSiD) is a lightweight, battery-powered radiation spectrometer using only a Si PIN photodiode. A space-flight qualified version of AirTED (SpaceTED) recently completed a one year experiment aboard the ISS and results from this experiment is being used to develop and refine methods of combining the data measured by the TEPC and Si diode into a single lineal energy spectrum in order to determine total absorbed dose and dose equivalent. Three test flights of the AirSiD dosimeter aboard stratospheric solar balloons were carried out in summer 2024 over central Oklahoma. Results from these flights were systematically slightly lower than model estimates made using the CARI-7A code, probably due to the lack of inclusion of the neutron component in the AirSiD measurement. Both AirTED and AirSiD were calibrated at the HIMAC heavy ion accelerator in Japan and AirTED was used to characterize the Neutron Irradiation Facility at TRIUMF in Canada.

36. **Georgia de Nolfo** (NASA Goddard Space Flight Center)
High-Energy Lunar Outpost Neutron Spectrometer (Hi-LOONS)
Co-authors: G.A. de Nolfo, J.G. Mitchell, G. Suarez, J. Dumonthier, M. Daehn, R. Ridley, D. Guzman, A. Bruno, L. Williams, J. Ryan, J. Legere

Fast neutrons constitute one of the most hazardous forms of space weather radiation, threatening astronauts and space assets in a variety of contexts. In addition to primary fast neutrons (e.g., from solar flares), secondary fast neutrons can be produced by interactions between high-energy charged particles (e.g., GCRs and SEPs) and the shielding that is intended to protect astronauts from radiation. It has been found that albedo neutrons on the surface of the Moon contribute up to 23% of the total radiation on the lunar surface. Of this population, models suggest that 80% of the total radiation dose comes from neutrons in the energy range between~1-300 MeV. Fully characterizing albedo neutrons is also highlighted as a key gap area in NASA's Space Weather Science and Observation Gap Analysis (2021) and in the recommendations from the Space Weather Advisory Group (SWAG). Albedo neutrons also radiate from the Earth's atmosphere contributing to single event upsets in avionics (Leray2007; Ziegler 1998) and a significant radiation dose to flight crews, particularly important because there is growing evidence of higher cancer rates among flight attendants (McNeeley et al 2018; Dyer 2002). We emphasize that space weather modeling and forecasting has high priority in the recently released Heliophysics 2024

Decadal Survey. The High-energy Lunar Orbiting and On-surface Neutron Spectrometer (Hi-LOONS) is designed to measure fast neutrons (~0.5- to >400 MeV). It is based on its predecessor, an imaging neutron spectrometer, LOONS. Hi-LOONS is a unique configuration, replacing arrays of large monolithic scintillators found in LOONS, with two segmented layers along the instrument axis in Hi-LOONS. Hi-LOONS is a low SWaP instrument (10x10x30-cm3,~10 kg, < 20W) suitable for compact platforms within the aviation industry and future Moon to Mars opportunities where safeguarding astronauts is critical. We discuss the development of LOONS for upcoming Artemis opportunities and Hi-LOONS for future space weather applications.

37. **Georgia de Nolfo** (NASA Goddard Space Flight Center)
High-Energy Lunar Orbiting and On-surface Neutron Spectrometer (Hi-LOONS)
Co-authors: J.G Mitchell, G. Suarez, M. Daehn, J. Dumonthier/ NASA Goddard Space Flight Center
J. Ryan, J. Legere/ University of New Hampshire

Fast neutrons constitute one of the most hazardous forms of space weather radiation, threatening astronauts and space assets in a variety of contexts. In addition to primary fast neutrons (e.g., from solar flares), secondary fast neutrons can be produced by interactions between high-energy charged particles (e.g., GCRs and SEPs) and the shielding that is intended to protect astronauts from radiation. It has been found that albedo neutrons on the surface of the Moon contribute up to 23% of the total radiation on the lunar surface. Of this population, models suggest that 80% of the total radiation dose comes from neutrons in the energy range between~1-300 MeV. Fully characterizing albedo neutrons is also highlighted as a key gap area in NASA's Space Weather Science and Observation Gap Analysis (2021) and in the recommendations from the Space Weather Advisory Group (SWAG). Albedo neutrons also radiate from the Earth's atmosphere contributing to single event upsets in avionics (Leray2007; Ziegler 1998) and a significant radiation dose to flight crews, particularly important because there is growing evidence of higher cancer rates among flight attendants (McNeeley et al 2018; Dyer 2002). We emphasize that space weather modeling and forecasting has high priority in the recently released Heliophysics 2024 Decadal Survey. The High-energy Lunar Orbiting and On-surface Neutron Spectrometer (Hi-LOONS) is designed to measure fast neutrons (~0.5- to >400 MeV). It is based on its predecessor, an imaging neutron spectrometer, LOONS. Hi-LOONS is a unique configuration, replacing arrays of large monolithic scintillators found in LOONS, with two segmented layers along the instrument axis in Hi-LOONS. Hi-LOONS is a low SWaP instrument (10x10x30-cm3, ~10 kg, < 20W) suitable for compact platforms within the aviation industry and future Moon to Mars opportunities where safeguarding astronauts is critical. We discuss the development of LOONS for upcoming Artemis opportunities and Hi-LOONS for future space weather applications.

38. **Sanjib K C** (Georgia State University)
Enhancing Atmospheric Radiation Predictability: A Data-Driven Approach using Multi-Source Observations and Machine Learning
Co-authors: Viacheslav M. Sadykov, Georgia State University
Dustin Kempton, Georgia State University

Radiation from solar and galactic sources impacts Earth's atmosphere and space environment, posing challenges for aviation safety, satellite operations, communication systems, and power grids. Accurate

radiation prediction remains a challenge due to the complex dynamics of radiation variability. Physics-based models do not precisely match experimental observations, suggesting the potential physics effects not yet included in the models.
To address these challenges, this study employs machine learning (ML) techniques to improve nowcasting of radiation dose rates at aviation altitudes and to explore the importance of various Geospace environment factors such as global solar activity, solar wind properties, and geomagnetic indices. Data used in this research are ML ready datasets prepared by the Radiation Data Portal team which include ARMAS in-flight radiation measurements, NAIRAS V3 model predictions, GOES proton and electron flux, OMNIWeb solar wind and geomagnetic indices, neutron monitor counts, and global solar activity parameters.
Preliminary analysis using linear model with regularization (Lasso regression) and Random Forest regression, demonstrate statistically significant improvement in predictive accuracy, with lower Mean Squared Error (MSE) compared to physics-based model. The average mean squared error (MSE) value for Random Forest regression is 13.09 (μSv/s) ^2 trained over six train-validation-test combinations and Physics-based model is 16.37 (μSv/s) ^2. Both the Lasso regression-based and Random Forest-based feature importance estimations indicate the significant role of the solar wind parameters in radiation environment forecasting. These findings highlight the potential of ML-driven approaches to refine existing models and support development of operational, data-driven frameworks for space weather forecasting.

39. **Christopher Mertens** (NASA Langley Research Center, Hampton, VA, USA)
Forecasting SEP Atmospheric and Space Radiation by Coupling UMASEP and NAIRAS Models
Co-authors: Guillaume Gronoff, Science Systems & Applications, Inc., Hampton, VA, USA; Daniel Phoenix, Analytical Mechanics Associates, Hampton, VA, USA; Yihua Zheng, NASA Goddard Space Flight Center, Greenbelt, MD, USA; Marlon Nunez, University of Malaga, Malaga, Spain

The Nowcast of Aerospace Ionizing RAdiation System (NAIRAS) model predicts the radiation environment from the Earth's surface to free-space. The model output provides dosimetric and particle flux quantities required to assess the radiation impacts to human health and adverse effects on vehicle electronic systems. The four sources of ionizing radiation included in NAIRAS are galactic cosmic rays (GCR), solar energetic particles (SEP), trapped protons (TRP-p), and trapped electrons (TRP-e). The focus of this presentation is the development of a new SEP dose forecast approach by coupling integral proton flux forecast products provided by the University of Malaga Solar particle Event Predictor (UMASEP) model to the input data stream of the NAIRAS model. The UMASEP-NAIRAS SEP dose forecasts approach is demonstrated by analyzing the September 2017 and the recent Jenn Gannon (May 10-11) 2024 SEP events. The model forecast bias is characterized at commercial and military aviation altitudes and at low-Earth orbit (LEO) trajectories similar to the International Space Station (ISS) orbit. The analysis of the two SEP events is encouraging and bolster the viability of this forecast approach. The UMASEP-NAIRAS SEP dose forecast products will soon be available in real-time at the Community Coordinated Modeling Center (CCMC) integrated Space Weather Analysis (iSWA) Web-based dissemination system.

40. **Kai Schennetten** (Institute of Aerospace Medicine, German Aerospace Center (DLR))
Relevance of the Space Weather Events in May 2024 to Radiation Protection in Aviation
Co-authors: Daniel Matthiä, Institute of Aerospace Medicine, German Aerospace Center (DLR); Matthias M. Meier, Institute of Aerospace Medicine, German Aerospace Center (DLR); Thomas Berger, Institute of Aerospace Medicine, German Aerospace Center (DLR)

A number of space weather events occurred during a very active phase of the Sun in May 2024 including several strong M and X class X-ray flares. Following these flares and the associated coronal mass ejections elevated levels of highly energetic protons were measured in Low-Earth Orbit that have the potential to increase the dose rate at aviation altitudes. However, one of the events also caused a temporary reduction of the intensity of galactic cosmic radiation (GCR) measured by ground-based neutron monitors during a Forbush decrease. During this period of temporary decreased intensity of cosmic radiation, another event in turn led to a small increase in neutron monitor count rates, a ground level enhancement, the first of its kind since October 2021.
The complex evolution of the different components of these space weather events was analyzed with the PANDOCA model, developed at the German Aerospace Center for the assessment of radiation exposure in aviation. The expected impact on the radiation field and the related variations in the effective dose at aviation altitudes were calculated and compared to quiet space weather conditions. The calculations were based on measurements of the integral proton flux by the Geostationary Operational Environmental Satellites (GOES) and count rates of ground-based neutron monitors during the critical phases of the events.

41. **Jay Albert** (Air Force Research Lab)
Wave Properties and Diffusion Rates Associated with Alpha Transmitters
Co-authors: Frantisek Nemec, Charles University,
Ondrej Santolik, Institute of Atmospheric Physics, Czech Academy of Sciences

Radiation belt electrons within the plasmasphere are believed to be strongly affected by cyclotron-resonant interactions with waves from various sources. Such waves include plasmaspheric hiss, lightning-generated whistlers, and VLF waves from large Navy transmitters worldwide. Russian Alpha radio navigation transmissions around 12 kHz may also have to potential to contribute, though this depends on their radiated wave power, which has been poorly documented. Recently, have been comprehensively observed and characterized by the Van Allen Probes, as well as modeled from source to space using a full-wave calculation of trans-ionospheric propagation coupled to 3D ray-and-power tracing, allowing detailed comparisons of field amplitudes and wave normal angles. We find the nominal, frequently quoted radiated power for these transmitters to be a large overestimate, and survey other evidence supporting this. We also present quasi-linear pitch angle and energy diffusion coefficients for these waves. By comparing to previously considered wave sources, we show where the effects are expected to be significant, and also where they may be serve as useful diagnostics for other aspects of wave-particle interactions, such as the prevalence of wave ducting.

42. **Corey Cochrane** (Jet Propulsion Laboratory, California Institute of Technology)

Compact Vector Helium Magnetometer for Space Weather Monitoring of the Interplanetary Magnetic Field

Co-authors: David Peirce, Jet Propulsion Laboratory, California Institute of Technology; Hannes Kraus, Jet Propulsion Laboratory, California Institute of Technology; Nicholas Tallarida, Jet Propulsion Laboratory, California Institute of Technology; Matthew Klein, Jet Propulsion Laboratory, California Institute of Technology; Giacomo Mariani, Jet Propulsion Laboratory, California Institute of Technology Aspen Davis, University of Colorado Boulder-CIRES / NOAA-NCEI; Paul Lotoaniu, University of Colorado Boulder-CIRES / NOAA-NCEI; Nai-Yu Wang, NOAA-NESDIS Office of Space Weather Observations

JPL's Compact Vector Helium Magnetometer (CVHM), with has heritage from those flown on the Ulysses and Cassini missions, represents an evolution in space borne magnetometry. Initially developed for NASA Dynamo sounding rocket experiment to study Earth's dayside ionospheric dynamo, the CVHM was also developed for the Interplanetary NanoSpacecraft Pathfinder In a Relevant Environment (INSPIRE) mission. Most recently, the CVHM flew on the CubeSat for Solar Particles (CuSP) mission, a secondary payload aboard Artemis I in November 2022, where it was intended to measure the interplanetary magnetic field (IMF) carried by the solar wind, advancing our understanding of space weather phenomena. Here, we report on the design and development of the CVHM for potential use on a solar sail mission intended to make magnetic field measurements at L1 for space weather monitoring, where the instrument's attractive SWaP (size, weight, and power) and flat noise floor provide a significant advantage over heritage designs. In this presentation, we will provide an overview of the instrument's operational principles, its architecture, and the testing the instrument will eventually undergo in the two-year development cycle. This work is supported by the NOAA NESDIS FY24 Systems Architecture and Engineering Joint Venture Partnerships (SAE JVP) Technology Exploitation Program and managed by NESDIS Office of Space Weather Observations, an interagency collaboration between NOAA, CU, and JPL.

43. **Jonathan Fisher** (Fifth Gait Technologies, Inc.)

The SIRE2 Family of Tools

Co-authors: Zachary D. Robinson, Fifth Gait Technologies, Inc.; James H. Adams Jr., Fifth Gait Technologies, Inc.; Paul R. Boberg, Fifth Gait Technologies, Inc.; Jonathan Z. Fisher, Fifth Gait Technologies, Inc.; Jeren Suzuki1, Fifth Gait Technologies, Inc.; Wally D. Westlake, Fifth Gait Technologies, Inc.; Joseph H. Nonnast, Fifth Gait Technologies, Inc.; Haley M. H. Cole, Fifth Gait Technologies, Inc.; Adam Smith, Fifth Gait Technologies, Inc.; Don F. Smart, SSSRC Inc. Margaret A. Shea, SSSRC Inc.; David Hope, Fifth Gait Technologies, Inc.; Robert Reed, Institute for Space and Defense Electronics Vanderbilt University; Brian Sierawski, Institute for Space and Defense Electronics Vanderbilt University; Vladimir Kolobov, CFD Research Corporation; Ashok Ramon, CFD Research Corporation; Robert Arslanbekov, CFD Research Corporation; Carter Grimmeisen, CFD Research Corporation; Alec Engell, NextGen Federal Systems

The Space Ionizing Radiation Environment and Effects (SIRE2) toolkit was designed to provide state-of-the-art environment models for satellites and arbitrary trajectories in space. SIRE2 also has single event effects modeling capabilities that utilize the SIRE2 environments. SIRE2 is free-to-use, ITAR-restricted toolkit that can be used as a standalone application on secure computer systems.

In recent years, Fifth Gait Technologies has expanded the SIRE2 toolkit with premium capabilities, leading to the creation of the SIRE2 family of tools. The SIRE2 advanced climatology (SIRE2-AC) expands the SIRE2 environment modeling to the inner Solar System. SIRE2-Real provide historical solar energetic particle (SEP) data and geomagnetic indices to provide historical environments for anomaly assessment. SIRE2-Now include real-time, nowcasting, and forecasting environments in the SIRE2 environment workflow. At the conference, we plan to showcase the entire SIRE2 family of tools.

Thursday, 20 March

Geospace/Magnetosphere Research and Applications

Space Weather Policy and General Space Weather Contributions

Posters can be viewed all day, with dedicated times from ***9:45 AM – 10:45 AM*** *and* ***2:30 PM – 3:30 PM***

1. **Athanasios Boudouridis** (University of Colorado Boulder/NOAA)
Association of the GOES 16-19 MPS-HI sensor high-energy electron channel backgrounds with Galactic Cosmic Ray fluxes
Co-authors: Juan Rodriguez, University of Colorado Boulder/NOAA; Brian Kress, University of Colorado Boulder/NOAA

The Space Environment In-Situ Suite (SEISS) on GOES 16-19 includes the Magnetospheric Particle Sensor – High Energy (MPS-HI), an instrument designed for measuring radiation belt electrons and protons that have energies responsible for charging of internal spacecraft elements, that can lead to disruptive or damaging electrostatic discharges. The four high energy electron channels, two differential channels with effective energies 2.0 MeV (E9) and 2.9 MeV (E10), and two integral channels with threshold energies $\gtrsim$2.0 MeV (E11, used by SWPC for its real-time alerts) and $\gtrsim$4.1 MeV (E10A), require background removal due to penetrating high energy protons. The background removal is essential for accurate flux specification of the high-energy electron channels. The first step in this process is the assumption that the high-energy protons responsible for the elevated electron backgrounds are due to Galactic Cosmic Rays (GCRs). We use high-energy GCR proton fluxes from the Solar and Galactic Proton Sensor (SGPS) instrument (also onboard the GOES satellites), to estimate the level of contamination of the MPS-HI E9-E11 channels. We examine nearly 8 years of MPS-HI E9-E11 electron fluxes and SGPS P9 (150-275 MeV), P10 (275-500 MeV) and P11 (>500 MeV) proton fluxes from GOES-16 (2017-2024). We calculate the electron channel backgrounds by modeling the peak of the electron distribution and the background counts below the peak as a Gaussian distribution. We do the same for the SGPS P9-P11 counts, and use the means of the distributions to estimate the "background removal coefficients" used in real time to remove the GCR background counts from the electron channels. We perform this process periodically, every few months, to assess the stability of the resulting "background removal coefficients" over time, and thus evaluate the validity of our methodology in which the E9-E11 backgrounds, assumed to be due to the GCR fluxes, are accurately captured by the SGPS P9-P11 fluxes.

2. **Luisa Capannolo** (Boston University)
Preliminary Results on A novel Machine learning technique to Parametrize Energetic Electron maps (AMPERE)
Co-authors: Joshua Pettit, George Mason University; Sadie Elliot, University of Minnesota; Hyunju Connor, NASA Goddard; Gowtam Valluri, NASA Goddard; Wen Li, Boston University

The Earth's outer belt is populated by energetic electrons (tens of keV to multi-MeV), which can be trapped by the magnetic field or precipitate into the atmosphere (energetic electron precipitation, EEP), depositing energy at altitudes of a few tens to a few hundred km. These electrons shape the near-Earth radiation environment and influence atmospheric energy input. However, global electron flux maps are limited by sparse continuous observations at LEO and MEO.
We leverage observations by the long-term NOAA POES and EUMETSAT MetOp LEO constellation to develop a machine learning model that nowcasts (and potentially forecasts) energetic electron conditions in LEO, including trapped and precipitating populations. The model is driven by geomagnetic indices such as AL and Sym-H, applied regionally to capture the local-time-dependent characteristics of electron dynamics. We demonstrate preliminary results that our model reproduces expected precipitation and trapped flux patterns under both quiet and active geomagnetic conditions.
These electron maps enhance space weather monitoring, aiding in the assessment of energy input into the atmosphere. Radiation belt electrons can induce adverse effects on satellites, including charging, electronic degradation, and increased instrument noise. Monitoring trapped electrons, helps identify high-flux regions that may impact satellite performance. Additionally, precipitating electrons influence atmospheric chemistry (e.g., ozone depletion) and ionospheric conductance, which affects communication systems. Our model serves as a pilot study for electron dynamics in LEO, paving the way for applications in proton modeling and coupling electron/proton precipitation with atmospheric and ionospheric effects.

3. **Hyunju Connor** (NASA GSFC)
Harnessing AI for Geospace Science: The AIMFAHR Project
Co-authors: Bayane Michotte de Welle, NASA GSFC; Gonzalo Cucho-Padin, NASA GSFC/CUA; Valluri Sai Gowtam, NASA GSFC; Kyle Murphy, CUA; Alexa Halford, NASA GSFC; Chris Bard, NASA GSFC; Emily Berndt, NASA MSFC; Chris Schultz, NASA MSFC

Artificial Intelligence (AI) techniques, particularly Machine Learning (ML), have undergone significant growth in heliophysics research in recent years. Various ML models have emerged, some outperforming empirical and physics-based models while significantly reducing computational time. The Artificial Intelligence Modeling Framework for Advancing Heliophysics Research (AHR) project is an initiative aimed at integrating community-wide AI efforts into a unified AI modeling framework, advancing system-of-systems science in Sun-Earth interactions and enhancing the predictability of space weather hazards. This presentation highlights our initial efforts under the AIMFAHR project. We selected data-driven models of the magnetosheath, cusps, auroral precipitation, field-aligned currents (FACs), ionospheric electrodynamics, and thermospheric density as the initial set of AIMFAHR base models. As part of the MLGEM Challenge Storm study, we simulated geomagnetic storms on 4 Jan 2023, 6 May 2023, and 11 May 2024, selected by the Machine Learning-based Geospace Environment Modeling (MLGEM) resource group at the Geospace Environment Modeling (GEM) workshop. The AIMFAHR models reveal the storm responses of various geospace systems from a data-driven respective, including the spatiotemporal variation of the magnetopause reconnection line and its global dayside reconnection rate; cusp motions and the evolution of cusp ion energy dispersions; auroral boundary motions and variation in global auroral spectrums; increases in FACs and ionospheric potentials; and enhanced Joule heating in the upper atmosphere. These initial efforts provide valuable insights for future AIMFAHR activities, including ML model coupling, knowledge transfer between models, uncertainty quantification, and research-to-operation transitions.

4. **Eelco Doornbos** (Royal Netherlands Meteorological Institute (KNMI))
Space Weather Timeline Viewer - application to 2024's active space weather events
Co-authors: Kasper van Dam, Royal Netherlands Meteorological Institute (KNMI); Kevin De Hulsters, Royal Netherlands Meteorological Institute (KNMI); Mark ter Linden, Royal Netherlands Meteorological Institute (KNMI); Eelco Verduijn, Royal Netherlands Meteorological Institute (KNMI); Bert van den Oord, Royal Netherlands Meteorological Institute (KNMI)

The Space Weather Timeline Viewer, available at https://spaceweather.knmi.nl/viewer/, can be used to give a visual overview of a wide variety of space weather data sources. During the last year of active space weather, the timeline viewer tool has proven to be very useful, not only for monitoring real-time data streams as events unfolded, but also for post-event assessment of forecast products, and for assessments of less-often used scientific observations. The flexibility of the timeline viewer also contributes to making comparisons between events across the years, and helps to illustrate observational gaps.
Data from the May 10-11 and October 10-11 2024 geomagnetic storms shows the timing and locations of peak magnetic field perturbations, overhead aurora reaching 40 degrees magnetic latitude as seen in VIIRS Day-Night-Band satellite remote sensing in relation to citizen scientist observations, strong heating and cooling of the upper atmosphere seen in measurements of satellite drag, as well as extreme variations in the ionosphere.

6. **Espen Fredrick** (The University of Texas at Arlington)
Analysis of OMNI High-Speed Stream and Coronal Mass Ejection Propagation Reliability to Earth's Bow Shock
Co-authors: Ramon Lopez, The University of Texas at Arlington

High-speed streams (HSSs) and coronal mass ejections (CMEs) are primary drivers of geomagnetic storms within Earth’s magnetosphere. Accurate forecasting of such events is critical, and physics-based global magnetosphere-ionosphere-thermosphere models have been developed to accomplish this task. In an operational scenario, solar wind and the large structures contained within are monitored upstream and propagated downstream to the model boundary placed just outside Earth’s bow shock. This data is most often provided by the OMNI dataset, a set of observations of the solar wind typically collected near the L1 Lagrange point and ballistically propagated to Earth’s bow shock nose. Occasionally, the actual solar wind conditions outside the bow shock may differ from the OMNI data, leading to erroneous model inputs and forecasts not faithfully reflecting reality. One such case may be HSSs, which contain large magnetic fluctuations traveling at the Alfvén velocity not advected with the bulk solar wind flow and may therefore appear drastically different to the propagated OMNI data. In contrast, CMEs are large, relatively unchanging structures and may be more accurately represented near Earth. We investigate the reliability of OMNI to propagate HSSs and CMEs to the bow shock by taking correlation coefficients of the OMNI data with data from near-Earth satellites along the Earth-Sun line and discuss the implications of prediction reliability on space weather models."

7. **Longzhi Gan** (Boston University)
Numerical simulations of dual-component microbursts observed by BARREL: effects of atmospheric backscattering
Co-authors: K. Cantwell, Dartmouth College; R. Millan, Dartmouth College; W. Li, Boston University
G. Berland, APL; R. Marshall, University of Colorado, Boulder

Electron microbursts are rapid, fluctuating precipitation of energetic electrons with timescales of about 100 ms. The energy of precipitating electrons ranges from tens of keV to several MeV. Collisions between these energetic electrons and the neutral atmosphere create Bremsstrahlung X-rays, which can subsequently be observed by balloons at lower altitudes. In this study, we utilize observations from the Balloon Array for Radiation Belt Relativistic Electron Losses (BARREL), where microbursts are observed with burst and smooth components. The burst components exhibit much higher count rates and shorter durations than the smooth components. Using test particle simulations, we show that the burst components are directly driven by resonant interactions with discrete chorus wave elements, while the smooth components are prolonged precipitation due to atmospheric backscattering. We further demonstrate that observations by BARREL can be used as a low-altitude proxy to quantify the atmospheric backscattering ratio. Our results provide insights into the interpretation of microburst observations and are crucial for quantifying radiation belt dynamics using low-altitude observations."

8. **Jonathan Hanson** (GNS Science Te Pū Ao, NZ)
Revolutionizing New Zealand Geomagnetic Data for Space Weather Monitoring
Co-authors: Tanja Petersen, GNS Science Te Pū Ao, NZ; Craig Rodger, University of Otago, NZ; Luke Easterbrook-Clarke, GNS Science Te Pū Ao, NZ
Stewart Hardie, University of Canterbury, NZ
Johnny Malone-Leigh, University of Otago, NZ

In Aotearoa New Zealand (NZ), geomagnetic waveform data has been recorded since 1916. The Eyrewell Geomagnetic Observatory (EYR), a member of INTERMAGNET since 1994, and has contributed to the global Kp index since its early years. However, it is only in recent years that this data has gained prominence in space weather research and monitoring.
Historical magnetograms, recorded on photographic paper from 1916 to 1991, offer valuable insights that enhance statistical models for predicting extreme geomagnetic storm scenarios in NZ. These pre-digital-era records have been painstakingly maintained by the NZ Geomagnetic Database – a long-term program aimed at safeguarding and providing current and historic geomag data. As part of the ""Solar Tsunamis"" research programme, we have digitized key portions of this dataset, producing 1-minute resolution data for major storms since 1951, and will present the 4th August 1972 storm as an example here.
We have developed a real-time magnetic field monitoring tool for EYR, delivering rate of change information to support space weather monitoring, leveraging correlations between GICs (geomagnetically induced currents) and magnetic field measurements. This tool powers a dashboard

(https://www.geonet.org.nz/data/geomag/dashboard) and API, providing openly available 1-minute and 1-second resolution data streams.
Additionally, the Solar Tsunamis programme established the Magnetometer Array for New Zealand Aotearoa (MANA), adding five new sites to the national network. The May 2024 ""Gannon"" geomagnetic storm, which exhibited a maximum rate of change of 320 nT/min at EYR, highlighted NZ's enhanced ability to capture and characterize geomagnetic events across the country."

9. **Michael Hartinger** (Space Science Institute)
SCUBAS: A python-based numerical model to estimate electrical surges in submarine cables during geomagnetic disturbances
Co-authors: Shibaji Chakraborty, Embry-Riddle Aeronautical University; Xueling Shi, Virginia Tech David Boteler, Natural Resources Canada; Joseph Baker, Virginia Tech

Submarine cables are crucial for global internet connectivity, but their vulnerability to extreme space weather events remains uncertain. Understanding and mitigating this risk is essential for maintaining reliable communication infrastructure. This study aims to develop a computational model to assess the induced voltages in submarine cables during geomagnetic disturbances. The model, implemented in Python, utilizes parameters such as ocean and Earth conductivity, cable length, and magnetic observatory data to estimate induced voltages. By providing a user-friendly software tool, researchers and engineers can evaluate the impact of geomagnetic events on submarine cables. Through theoretical explanations and practical demonstrations, this study enhances our understanding of submarine cable behavior under extreme space weather conditions. Ultimately, this research contributes to the preparation and mitigation of potential disruptions to submarine cable systems, ensuring the resilience of global communication.

10. **Richard Horne** (British Antarctic Survey)
A comparison between radiation belt models and observations during the May 2024 (Gannon) storm
Co-authors: Sarah Glauert, British Antarctic Survey; Pak Yin Lam, British Antarctic Survey; Peter Kirsch, British Antarctic Survey; Matthew Lang, British Antarctic Survey; Alex Lozinski, University of California Los Angeles; Hugh Evans, European Space Agency; Ingmar Sandberg, SPARC Greece; David Pitchford, CarringtonSpace

We review what happened to the electron and proton radiation belts during the May 2024 (Gannon) storm using results from the SWIMMR N1 forecasting system. The BAS radiation belt model (BAS-RBM) predicted that the magnetopause was “pushed” inside geostationary orbit. This was confirmed by observations by GOES 16 and 18. The model also predicted that the outer belt would be depleted and re-formed much closer to the Earth affecting satellites in the slot region. This was also confirmed by satellites in low earth orbit (LEO). The flux in the slot region increased by over 4 orders of magnitude and charging currents (behind 0.5 mm of Al shielding) exceeded NASA design guidelines. We show that it took between a few weeks to a month for this high level of flux to decay. Charging currents also reached high levels where Galileo and GPS satellites orbit. The BAS proton radiation belt model showed, 3/19 that the outer proton belt region decreased during the storm. This was confirmed by satellite data and is consistent with a reduction in single event upsets reported by some spacecraft in medium Earth orbit (MEO). Data show that proton belt was enhanced at lower L but this was not reflected in the model. We discuss the need to revise the models. We conclude that the changes in the electron and proton belts would have increased radiation exposure to satellites undergoing electric orbit raising for a few months following the storm.

11. **Thomas J. Immel** (Univ of California, Berkeley)
Spectrographic Imagers for Space Weather Applications
Co-authors: B. J. Harding, Univ of California, Berkeley; S. B. Mende, Univ of California, Berkeley
K. A. Rider, Univ of California, Berkeley; J. B. McPhate, Univ of California, Berkeley; M. W. Liemohn, Univ of Michigan; A. J. Ridley, Univ of Michigan

The Spectrographic Ultraviolet Imager is an innovative, dual-wavelength, 2D imaging design that has been used for a range of critical measurements on NASA missions. Its utility has been proven on NASA IMAGE and NASA ICON with a combined 8 years of on-orbit observations. Both CCD cameras and cross-delay line event-counting detector systems have been used successfully. Optical gratings and coatings from a range of different vendors have been implemented. The systems are low noise, with photon traps and field masks throughout each implementation, yielding a system that reduces out-of-field stray light and in-field contaminating emissions by factors of 10^4 to 10^6. The dual band system implemented for previous missions is adapted to the purpose of the MAAX mission to retrieve FUV images of the auroral N_2 band emissions at 144 nm and 173 nm, the ratio of which is directly related to the altitude profile of the emissions and the auroral ionospheric conductivity. The recent Phase A study for the NASA MAAX mission concept yielded new performance metrics for the retrieval of auroral conductances, and the sensitivity of the retrieval to many adverse factors. This historically known sensitivity of the retrieval to a contaminating line emission of atomic nitrogen (at 149 nm) is addressed, showing the actual insensitivity of the retrieval to this auroral feature. For diffuse aurora, we show the retrieval is insensitive to view angle. These attributes provide the two MAAX observatories key capability from their vantage point of a 6 R_E altitude circular polar orbit. With continuous imaging of the terrestrial aurorae with better than 50 km resolution, MAAX provides new capability for space weather research and operations. Here we also discuss additional capability that comes with mounting the grating on a rotatable stage. This provides access to emission lines of atomic oxygen, with application for broader thermospheric and ionospheric measurement objectives. Specifically, the precise determination of thermospheric composition ratios and nighttime ionospheric densities become easy targets for a MAAX-type instrument with a movable grating.

12. **Ricardo Jimenez Martinez** (FieldLine Industries, Louisville, CO 80027, USA)
Scalable Ground-Based Magnetometry: A 64-Sensor Optically Pumped Magnetometer Array
Co-authors: Matt Liss, FieldLine Industries, Louisville, CO 80027, USA; Ezra Godfrey, FieldLine Inc, Louisville, CO 80027, USA; K. Jeramy Hughes, FieldLine Industries, Louisville, CO 80027, USA

Magnetometry is a fundamental tool for studying Earth's space environment. Among the different techniques for measuring Earth's magnetic field, optically pumped magnetometers (OPMs) have recently gained increased interest. OPMs use the optical properties of alkali vapors to detect minute variations in Earth's magnetic field with high sensitivity and speed, without requiring external calibration. Over the past decade, advancements in OPM technology have enabled the production of high-performance, compact sensors at scale, facilitating the deployment of large sensor arrays. Here, we present the development and deployment of a ground-based array of 64 scalar OPMs and highlight space weather events recorded during its first months of operation. Installed at the Edgar Experimental Mine in Idaho Springs, CO, the array has been continuously operating since June 2024, enduring Colorado's summer, fall, and winter conditions. The sensors are synchronized via GPS-based time references, allowing for increased spacing between nodes to establish a regional OPM sensor network.

13. **Caitlin LaNeve** (George Mason University)
Critical Infrastructure Operator Space Weather Mitigation Decisions over the 2024 Solar Maximum
Co-authors: Edward Oughton, George Mason University; Robert Weigel, George Mason University; Noah Rivera, George Mason University; Trevor Gaunt, George Mason University

The Gannon geomagnetic storm of 10-13 May 2024 was the first time that the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center issued an Extreme G5 geomagnetic event warning since the 2003 Halloween storms. Although the May 2024 space weather events produced beautiful aurora in lower latitudes (as low as southern Florida), the reality is that these were challenging operational conditions for critical infrastructure operators, particularly for electricity transmission and satellite networks. Scientists and engineers modeling space weather impacts urgently need new data to advance our fundamental scientific understanding of these operational hazards as highlighted by the US National Space Weather Strategy and Action Plan. Therefore, it is imperative to collect perishable operational decision data from critical infrastructure operators. Firstly, this poster reports the range of mitigation options identified for power and satellite networks from a systematic literature review, broken down chronologically. Secondly, we gather mitigation decision data to provide a historical log of the steps taken to protect critical infrastructure during solar cycle 25. This involves contacting over 160 distinct power and satellite entities for information related to actions taken prior to, during, and following recent events. Data has been recorded through interviews and targeted surveys of over 30 electricity transmission and satellite operators, including via the ChronoStorm survey (www.chrono-storm.com). This study enables future generations of scientists and engineers to better understand how to mitigate space weather hazards, and further inform critical infrastructure protection decisions, ensuring national security.

14. **Daniel Mac Manus** (University of Otago)
Demonstrating the power of NZ's R2O collaboration between Academia & Industry in managing GIC from the May 2024 Gannon storm
Co-authors: Craig Rodger, University of Otago; Andrew Renton, Transpower NZ Ltd; Victor Lo, Transpower NZ Ltd; Johnny Malone-Leigh, University of Otago; Tanja Petersen, GNS Science; Matthew Copland, Transpower NZ Ltd; Mark Clilverd, British Antarctica Survey; Gemma Richardson, British Geological Survey

New Zealand's space physics experts have been collaborating with New Zealand's High Voltage power grid owner and operator Transpower for the last 9 years to assess the risks geomagnetic storms pose to the grid. Since 2001, Transpower has recorded and archived the Geomagnetically Induced Currents (GIC) observations from several dozen transformers. This has allowed, 3/19 us to validate our GIC models against a large dataset of real-world observations to reliably model GICs during geomagnetic storms. This

suggests that many New Zealand transformers are at risk of damage when an extreme geomagnetic storm occurs in the future.
In 2022, acknowledging the importance of protecting the grid, Transpower and the University of Otago collaborated to develop an ""All of New Zealand"" GIC mitigation plan. This grid reconfiguration plan strategically disconnects specific lines and transformers with the objective of reducing the magnitude and duration of GICs flowing in the system and the most vulnerable transformers, while ensuring an uninterrupted power supply across the country. After control room staff were trained, the plan became operational in mid-2023.
During the May 2024 “Gannon” storm; Transpower's control room staff activated the mitigation plan according to the established procedure. We saw a considerable reduction in GIC flows, with no disruption to New Zealand's power supply. We will compare GIC observations with modelling to demonstrate the expected outcomes with and without the mitigation plan being implemented. Further mitigation efforts in the form of capacitor blockers are being explored.
This research is part of the New Zealand Solar Tsunamis programme.

15. **Feras Natsheh** (The New Mexico Consortium (NMC) & Whitman College)
Understanding the Gannon Storm by Harnessing the Power of Aurorasaurus Open Citizen Science
Co-authors: Elizabeth MacDonald, NASA Goddard Space Flight Center; Laura Brandt, NASA/NMC; Vincent Ledvina, University of Alaska Fairbanks (UAF)

Citizen scientists play a crucial role 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 their readiness for scientific use. Focusing on major auroral events such as the May and October 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 expand this effort by incorporating optical and magnetometer measurements alongside citizen science auroral observations. Students and community members contributed scientifically valuable data that support the intercalibration of diverse datasets. These combined efforts highlight the agility and potential of citizen scientists to provide high-impact contributions to heliophysics education and space weather research.
By cleaning and analyzing 6000+ citizen science reports, and integrating them with heliophysics datasets, we demonstrate the reliability and scientific value of crowd-sourced observations during large, rare events. This highlights the importance of public engagement in space weather research, and showcases how these data can be utilized to study auroral activity at scale and at much lower than usual latitudes.
This poster will detail the methodologies used for data verification, challenges in handling crowd-sourced heterogeneous data, and the contributions of citizen scientists and students to our understanding of exploring unusual aurora with new technologies.

16. **Anthony Rasca** (CU/CIRES, NOAA/SWPC)
SWPC's Operational Geospace Model: Current/Future Improvements to Serve User Needs
Co-authors: Howard Singer (NOAA/SWPC); Gabor Toth (University of Michigan); Zhenguang Huang (University of Michigan); Christopher Balch (CU/CIRES, NOAA/SWPC); Jordan Guerra (CU/CIRES, NOAA/SWPC); George Millward (CU/CIRES, NOAA/SWPC)

The Geospace model, part of the Space Weather Modeling Framework (SWMF) developed at the University of Michigan has been utilized operationally at NOAA's Space Weather Prediction Center (SWPC) since 2016. Driven by observations at the L1 Lagrange point (1.5 million km upstream from Earth), Geospace provides predictions for the magnetospheric response to incoming solar wind drivers and resulting ground-level magnetic perturbations with a 30-60 minute lead time for geomagnetic disturbances. Operational output from the model--in the form of binary files and product images--is continuously archived and stored internally at NOAA. This poster provides an overview of current and future research and validation aimed at using the Geospace model to improve space weather forecasting and services through innovative ways to increase lead-time and by coupling the Geospace model with the Geoelectric model to create a predictive version of Geoelectric. Additionally, we highlight work to make the Geospace model operational output--such as ground-level magnetic perturbations, plasma properties in the magnetosphere, and model Kp/Dst--more accessible to the research community. By serving the research community with operational data, operations will benefit from their assessments of model output, comparisons with other model results and the development of new innovative techniques for improving model performance.

17. **Juan Rodriguez** (University of Colorado CIRES)
GOES 16-19 Solar Energetic Helium and Heavy Ion Fluxes
Co-authors: Brian Kress, University of Colorado CIRES

Each observatory in the GOES 16-19 series carries three instruments dedicated to solar energetic particle (SEP) measurements: two Solar and Galactic Proton Sensors (SGPS), which are the primary instruments for proton and helium ion (alpha particle) fluxes, and one Energetic Heavy Ion Sensor (EHIS), which is the primary instrument for heavy ion fluxes from carbon to nickel. The SGPS proton differential fluxes are used to derive the integral fluxes upon which NOAA SWPC bases its solar radiation storm alerts. This poster focuses on the SGPS alpha particle and the EHIS heavy ion data sets, which are important as inputs to dose models and indicators of elevated risk of single event effects, among other applications. The instrument energy channels, geometric factors, and look directions are described. Observations during recent SEP events of Solar Cycle 25 serve as the basis for comparisons between GOES satellites and with other missions. The current and planned operational status and retrospective and real-time data availability of these data sets are described.

18. **Neesha Schnepf** (Laboratory for Atmospheric & Space Physics, University of Colorado Boulder, Boulder, CO)
Geomagnetic Storm Power for the March 1989 and October 2003 Events
Co-authors: Jeffrey J. Love, Geomagnetism Program, Geological Hazards Science Center, USGS, Golden, CO; Bhagyashree Waghule, University of Colorado Boulder, Boulder, CO

The 03/13/1989 and 10/29/2003 geomagnetic storms were events that caused power blackouts for people in Québec and in southern SWed, 3/19en, respectively. Many studies have confirmed that geomagnetic storms can cause rapidly varying magnetic fields and ground induced currents, which locally differ dramatically. To better understand this hazard, we analyze data of 10-s resolution from ground magnetometer stations within the International Monitor for Auroral Geomagnetic Effects (IMAGE) array (which is supported by a consortium of European agencies) for both events. For the 03/13/1989 storm, we use data from seven stations located in northern Norway and Finland. The stations have geomagnetic latitudes ranging from 63o to 67o and average ~200 kilometers apart from their nearest neighbor. For the 10/29/2003 storm, we use 26 stations spread throughout Scandinavia. These Scandinavian stations have geomagnetic latitudes ranging from 54o to 75o and are as close as 87 kilometers from their nearest neighbor. We examine the spectral content of the geomagnetic time series to evaluate the spatiotemporal variability in geomagnetic power and the frequency characteristics of the storm. We also evaluate the variability of geomagnetic storm power as a function of geomagnetic latitude and storm time index (e.g., Dst). We find that during quiet times, higher magnetic latitude stations have relatively more power. Meanwhile, during more disturbed storm times, magnetic power increases at lower latitudes such that the peak in storm power occurs at a significantly lower latitude than the peak latitude in power for quiet times."

19. **Huei-Wen Siao** (Central Weather Administration, Taiwan)
Exploring Local Geomagnetic Variations in Taiwan from Historical Data for Space Weather Understanding
Co-authors: I-Te Lee, Taiwan Space Agency, Taiwan; Po-Han Lee, Central Weather Administration, Taiwan; Jia-Sin Kuo, National Central University, Taiwan; Chih-Hsuan Li, National Central University, Taiwan; Jing-Shan Hong, Central Weather Administration, Taiwan

Although common geomagnetic disturbance indices, such as the Kp, Dst, and Ap indices, effectively reflect variations caused by geomagnetic storms, slight differences often exist between the measurements recorded by local magnetometers and the disturbance indices during the same period. In addition to geomagnetic storms, ground-based measurements occasionally show smooth variations of a few tens of nanoteslas (nT) that change with local time. This phenomenon is attributed to the Solar Quiet (Sq) current, an electric current flowing on the sunlit side of the ionosphere. Studies of the Sq current are crucial for advancing our understanding of ionospheric electrodynamics, as its impacts vary with latitude and time. For these reasons, evaluating the local geomagnetic effects is important.
The main aim of this study is to identify potential local geomagnetic influences from historical data. This work comprehensively reviews local geomagnetic field variations in Taiwan from 1965 to 2024. The data were collected by Lunping Observatory (25.0°N, 121.17°E) between July 1965 and December 2000, by a geomagnetic monitoring network hosted by National Central University from November 2002 to October 2005, and by Taiwan Geophysical Networks for Seismology (TGNS) starting in January 2007. These data span solar cycles 20 to 25 (1964–2025) and are capable of calculating high-temporal-resolution local geomagnetic indices that serve as a reference for evaluating future local impacts of space weather. The results show that the local geomagnetic index reflects tiny differences from the Dst index during geomagnetic storms, and the Sq current is roughly consistent with long-term solar activity variations.

20. **Dean Thomas** (George Mason University, Fairfax, VA)

Comparing measured and calculated GIC for the May 2024 geomagnetic storm

Co-authors: Lucy A. Wilkerson, George Mason University, Fairfax, VA; Robert S. Weigel, George Mason University, Fairfax, VA; Dennies Bor, George Mason University, Fairfax, VA; Edward Oughton, George Mason University, Fairfax, VA; Liling Huang, George Mason University, Fairfax, VA; Trevor Gaunt, University of Cape Town, Cape Town, ZA; Christopher C. Balch, NOAA/SWPC, Boulder, CO; Michael J. Wiltberger, NCAR/HAO, Boulder, CO

The 10–13 May 2024 Gannon storm saw some of the most severe geomagnetic activity over the past 20 years, providing a space weather event that scientists and engineers will study for decades. We use the Gannon storm to compare the effectiveness of various simulation models in development. Although geomagnetically induced current (GIC) estimates recorded from the storm can be accessed at any point, the measured values are sensitive to the power network configuration at the time of the event. Unfortunately, power network data, such as power grid configuration, often are lost in the weeks and months after a major Geomagnetic Disturbance (GMD), motivating a rapid study of recent events. This research aims to collect both GIC and magnetic field data (measured and modeled) from the Gannon storm to compare different methods of estimating GIC, ΔB, and the electric field. GIC estimates produced by the Tennessee Valley Authority (TVA) network simulation model for four substation locations, populated with real asset data and parameter values, were obtained, along with measured GIC and ΔB values from TVA. Additional measured GIC and ΔB estimates were accessed through North American Electric Reliability Corporation (NERC)'s ERO Portal. Finally, modeled ΔB data was obtained from the Space Weather Modeling Framework (SWMF) and Multiscale Atmosphere-Geospace Environment Model (MAGE). By comparing these various data sets, we hope to understand the predictive effectiveness of different approaches to GIC estimation.

21. **Bhagyashree Waghule** (University of Colorado Boulder)

Drivers of Co-occurring GICs During the September 2017 Geomagnetic Storm

Co-authors: Delores J. Knipp; University of Colorado Boulder

Geomagnetically induced currents (GICs) were globally recorded during the long-duration geomagnetic storm of September 2017. On September 7th, a 30A GIC spike was recorded at the Eastern US station immediately following the shock arrival. Twelve hours later, sustained GICs lasting over an hour were observed across the US, Finland, and New Zealand. Six hours later, a 30A spike occurred at the Mäntsälä pipeline with no identifiable upstream trigger. We investigated the multiscale magnetospheric drivers of these significant GIC events using wavelet analysis and data fusion.

Our analysis revealed three key findings: (1) The 30A spike in the US was driven by shock-induced injection in the dusk side magnetosphere, likely amplified by under-shielding conditions due to a weak ring current; (2) the sustained GICs were caused by electric field disturbances in the inner magnetosphere driven by substorm injections; and (3) localized dusk side injections drove the 30A spikes in the Mäntsälä pipeline.

This study underscores the importance of considering local time and storm phases to predict significant GIC events and mitigate their impact on infrastructure. Although no damage was reported for the 2017 storm, persistent GICs for a long duration can produce excessive stress on critical ground-based

infrastructure, potentially reducing the lifespan of the power grid components. Hence, there is a need to prepare for long-duration storms like the 2017 event as much as the Carrington event.

22. **Taylor Whitney Aegerter** (Department of Astrophysical and Planetary Sciences, CU Boulder; Laboratory for Atmospheric and Space Physics)

Spatial Extent of Electromagnetic Ion Cyclotron Waves in Earth's Magnetosphere during Geomagnetic Storms

Co-authors: Lauren Blum; Department of Astrophysical and Planetary Sciences, CU Boulder; Laboratory for Atmospheric and Space Physics

Geomagnetic storms often trigger electromagnetic waves in the Earth's magnetosphere that can further influence wave-particle interactions. However, the spatial variability of these wave signatures throughout the magnetosphere is not well understood. This study will characterize the spatial extent of electromagnetic ion cyclotron (EMIC) waves throughout the magnetosphere during periods of geomagnetic storming from March 2015 - October 2019. This will be done using simultaneous magnetic field measurements from the Magnetospheric Multiscale (MMS), Time History of Events and Macroscale Interactions during Substorms (THEMIS), Van Allen probes, and Geostationary Operational Environmental Satellite (GOES) missions. Results of this study reveal the regions of the magnetosphere over which EMIC waves span throughout geomagnetic storms.

23. **Daniel Welling** (University of Michigan)

The Magnetospheric Auroral Asymmetry eXplorer: a Mission Concept to Observe Energy the Complete Aurora

Co-authors: Michael Liemohn, University of Michigan; Aaron Ridley, University of Michigan; Alexa Halford, NASA Goddard Space Flight Center; Tom Immel, University of California, Berkeley

The aurora are a beautiful and inspiring manifestation of heliophysics. They also are one of the most important phenomena to observe if we are to understand the magnetosphere-ionosphere-thermosphere system and its relation to the dynamic solar wind. Further, the ability to monitor the aurora is critical for space weather operations. Despite this, there has not been a mission dedicated to viewing the whole aurora, either northern or southern, for over 18 years.

This poster introduces MAAX: the Magnetospheric Auroral Asymmetry eXplorer. MAAX is a NASA small explorer mission concept currently in Phase A. It consists of two observatories, each with a single instrument: a dual-wavelength ultraviolet imager capable of viewing the entire auroral oval. The mission will achieve two firsts: the first mission to view either complete oval continuously, and the first mission to simultaneously observe both auroral ovals completely from the same altitude using the same instrument. With these observatories, MAAX will be able to determine how magnetosphere - ionosphere electrodynamic coupling regulates multi-scale auroral energy flow through the near-Earth space environment.

24. **Emily Berndt** (NASA MSFC/SPoRT)
20 years of R2O/O2R at NASA's Short-term Prediction Research and Transition Center, Lesson Learned and Emerging Space Weather Partnerships
Co-authors: Anita LeRoy (University of Alabama in Huntsville, NASA MSFC/SPoRT); Christopher Schultz (NASA MSFC/SPoRT)

The NASA Short-term Prediction Research and Transition (SPoRT) center was established in 2002 to transition NASA satellite products and capabilities to the operational weather community to improve short-term weather forecasting. A research-to-operations/operations-to-research (R2O/O2R) paradigm has been the basis for transitioning over 50 satellite products to stakeholders over 20 years. Today SPoRT focuses on applied research and applications in 6 focus areas that span weather, atmospheric, and land surface topics with partnerships across government agencies, academia, and the private sector. An emerging focus area for SPoRT includes partnering with scientists to facilitate space weather R2O and especially the O2R feedback cycle. This presentation will highlight SPoRT's R2O/O2R paradigm, lessons learned, and emerging work to partner with space weather scientists within NASA to foster the translation of research to operations.

25. **Nouhaila Bouhadi** (University Chouaïb Doukkali, Faculty of Science El Jadida)
Hybrid Optimization in Space Weather Forecasting Using Machine Learning: Bridging Astronomy and Computational Science

Space weather forecasting plays a critical role in safeguarding Earth's infrastructure against the adverse effects of solar activity, such as solar flares and coronal mass ejections. This research leverages hybrid optimization techniques, combining Physics-Informed Neural Networks (PINNs) and Explainable AI (XAI), to enhance the prediction accuracy of solar-terrestrial interactions. By integrating physical laws with data-driven models, the study ensures both computational efficiency and physical consistency. This contribution highlights the development and application of a robust framework for space weather parameter prediction, using advanced machine learning techniques. Initial results demonstrate improved accuracy over traditional models, offering actionable insights for heliophysics research and operational forecasting. This project bridges astronomy with computational science, illustrating how interdisciplinary approaches can advance Africa's contribution to global astronomy research.

26. **Jeremy Bundgaard** (Booz Allen Hamilton)
Sun2OD: MLOps Multimodal Foundation Model pipeline of Solar Events, Space Weather, and Orbit Determination for Space Battle Management
Co-authors: Derek Doyle, PhD; Stephen Gerrells

Satellite mission have long been vulnerable to high radiation events caused by solar storms, necessitating the monitoring and forecasting of solar weather. While early methods relied on empirical data, recent advancements now harness vast datasets, complex algorithms, and AI to achieve unprecedented accuracy. Despite these improvements, current models still face challenges, such as high computational demands and difficulties in predicting rare events. At Booz Allen, we are developing a MLOps framework called Sun2OD, which employs cutting-edge deep learning, efficient model architectures, and high-fidelity Space Domain Awareness (SDA) data. This framework enhances our AI-enabled Space Battle

Management (SBM) capability through continuous learning feedback loops on SDA/SBM data streams, leading to improved reliability and precision in predictions crucial for satellite safety and operational functionality.

The most immediate information affecting the space environment is light from the sun. Therefore, the first component of Sun2OD we present is a deep learning-based solar weather forecasting system based on solar imagery. Solar flares and coronal mass ejections (CMEs) can adversely impact satellite electronics, while solar radiation heats the atmosphere, affecting satellite trajectories. Indirect measurements of extreme ultraviolet (EUV) radiation often fail to capture the full spectrum of solar dynamics impacting the atmosphere. These methods typically rely on empirical models and approximations, resulting in forecasts that may not fully account for the complex interactions between solar activity and atmospheric density. Our approach leverages direct observation of high-fidelity EUV imagery from NASA's Solar Dynamics Observatory (SDO), offering a comprehensive and accurate representation of these solar events. This leads to more precise predictions and a deeper understanding of how solar dynamics influence atmospheric conditions.

Inspired by recent successes in deep learning, our approach aims to enhance solar weather forecasting by using SDO data to train a foundational deep learning model of solar activity. By extending the computationally efficient Hierarchical Vision Transformer (HiViT) to ingest 12-channel SDO imagery, which we call SDOViT, we extract an information-dense solar feature space from masked image modeling (MIM) pretraining. This image feature space is combined with atmospheric model drivers, such as F10.7, F30, Dst, F15, Kp, and Ap, augmenting historical model driver data to train a space weather forecast model called SWFCast. Preliminary results show that SWFCast averages a 30% improvement in 27-day forecast accuracy compared to the NOAA 27-day persistence model baseline over a solar cycle. Additionally, we are developing a foundation model using coronagraphs and geomagnetic indices to predict CMEs and solar flares. This model will integrate data from coronagraphs and geomagnetic indices, such as Dst, F15, Kp, and Ap, to provide early warnings and enhance the accuracy of solar weather predictions. By incorporating these additional datasets, we aim to enrich our models and expand the coverage of learned solar dynamics.

The future direction of Sun2OD includes several key advancements. First, we will integrate additional datasets, such as Dst, F15, Kp, Ap, and coronographs, to enrich our models and expand coverage of learned solar dynamics. We will develop solar flare and CME prediction capabilities to provide early warnings to satellite operations. Finally, we will create deep learning models to improve anomaly detection and maneuver planning based on high-fidelity satellite ephemerides, ensuring robust and adaptive space operations. Together, these advancements form a comprehensive AI-enabled Space Battle Management solution for solar weather forecasting.

27. **Ian Cohen** (Johns Hopkins Applied Physics Laboratory)

Results from the 2024 Space Weather Tabletop Exercise

Co-authors: Ian J. Cohen, APL; Dipak Srinivasan, APL; Ruth A. Vogel, APL; John E. Hicks, APL; Anne B. Roberts-Smith, APL; Drew L. Turner, APL; Larry Paxton, APL; Angelos Vourlidas, APL Daniel M. Meidenbauer, APL; Julee Rendon, APL; Megan Toms, APL; Ben Sheppard, APL; Lisa Turner, APL

On 8–9 May 2024, the government held the first-ever end-to-end Space Weather (SWx) Tabletop Exercise (TTX), which provided opportunities for participants to better understand the preparedness and

response challenges associated with the threat of an impending space weather event. Jointly sponsored by NOAA, NASA, NSF, and FEMA, the exercise incorporated federal, state, local, and tribal considerations to improve our nation's whole-of-government preparedness for space weather events.
The TTX scenario involved a series of solar events that drove a range of adverse space weather effects, including i) intense radiation exposure to satellites, astronauts, and commercial aviation; ii) radio communications outages and disruptions; iii) loss of functionality or degraded performance of GPS for precision navigation and timing; iv) degraded ability to communicate with and track on-orbit satellites; and v) local- to regional-scale power outages.
It is important to note that, by chance, the SWx TTX occurred at the same time that a significant real-world space weather event—the largest geomagnetic disturbance in more than 20 years (i.e., the "Gannon Storm")—began. These extraordinary events required key participants to divide their time between the simulated actions of the TTX and real-world needs.
The TTX was designed to provide a low-stress, no-fault environment for generating dialogue about the challenges of preparing for and responding to an impending SWx event. Participants from over thirty government departments and agencies, including senior leaders, interacted at two locations: the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland, and FEMA Region 8 (R8) in Denver, Colorado.

28. **Stephen Gerrells** (Booz Allen)
SWFCast: Fusing Ensembles of Multimodal Foundation Models to Forecast Space Weather
Co-authors: Derek Doyle, PhD, Booz Allen; Jeremy Bundgaard, PhD, Booz Allen

Satellites are vulnerable to high radiation from solar storms, making it essential to monitor and predict solar flares and coronal mass ejections (CMEs) that damage satellite electronics, while solar radiation heats the atmosphere, increasing satellite drag leading to increased orbital uncertainties. AI and machine learning (AI/ML) advancements can significantly enhance empirical methods for solar forecasting by leveraging vast datasets and complex algorithms to dramatically improve accuracy. Despite these advancements, current models still face limitations, such as high computational demands and difficulties in predicting rare events.
Indirect measurements of extreme ultraviolet (EUV) radiation often fail to capture the full spectrum of solar dynamics that impact the atmosphere. These methods typically rely on empirical models and approximations resulting in forecasts that may not fully account for the complex interactions between solar activity and atmospheric density. Our approach, leveraging direct observation of high-fidelity EUV imagery from NASA Solar Dynamics Observatory (SDO), offers a comprehensive and accurate representation of these solar events. This leads to more accurate predictions and a deeper understanding of how solar dynamics influence atmospheric conditions. At Booz Allen, we are developing a MLOps pipeline called Sun2OD that fuses multimodal foundation model ensembles of solar events, Space Weather, and Orbit Determination for Space Battle Management.
The lowest latency information impacting the space environment is light from the sun, therefore the first component of the Sun2OD pipeline that we present is a deep learning-based solar weather foundation model trained on solar imagery, called SDOViT. To achieve this, we successfully developed this vision transformer architecture to extract an information-dense solar feature space from 12-channel SDO imagery. Secondly, we fuse the resultant SDOViT latent space with atmospheric model drivers, such as F10.7, F30, Dst, Kp, and Ap, augmenting historical model driver data to train a multimodal space weather

forecast model called SWFCast. Preliminary SWFCast results showing 30% improvement in accuracy in F10.7, F30, Dst, Kp, Ap, Hp30, and Hp60 compared to the NOAA 27-day forecast over the last solar cycle; and the 27-day forecast accuracy is drastically improved within the 5-day horizon.
The future direction of Sun2OD includes several key model enhancements. First, we will integrate additional datasets, such as radio and particle flux, geomagnetic indices, and coronographs, to enrich our models and expand coverage of learned solar dynamics. We will develop solar flare and CME prediction capabilities to provide early warnings to satellite operations. Finally, we will develop deep learning models to improve anomaly detection and maneuver planning based on high-fidelity satellite ephemerides, ensuring robust and adaptive space operations. Together, these advancements form a comprehensive AI-enabled Space Battle Management solution.

29. **Ty Griffin** (Kansas State University)
Sakura and Solar Activity

Solar activity has varying effects on both weather and plants. Solar storms associated with peaks of sunspot cycles may cause greater effects. One such biological effect may be correlation between geomagnetic disturbances and the blooming period of cherry blossoms.
Sakura tree (Prunus serrulata) development has been observed, studied, and recorded over many years. By comparing the development and bloom timing with solar cycles, patterns begin to emerge. The 67 years of Sakura data and 81 years of sunspot cycle data were evaluated.
The bloom time of Sakura trees varies in similar pattern to the solar cycle. During solar cycle maximum, cherry blossoms tended to bloom earlier, while blooming later during solar minimum. Preliminary results indicate some negative or offset out-of-sync correlation between the Sakura and solar cycles.
Geomagnetic storms associated with solar cycles alter the temperature and exposure to radiation that the earth faces daily. The cherry blossoms are sensitive enough to these subtle changes that the bloom dates are either delayed or arrive earlier than normal. The trees continue to bloom sooner as the environment warms and may eventually bloom as early as the beginning of March.

30. **Terry Griffin** (Kansas State University)
Impact of the Gannon Storm on corn: economic assessment of agricultural production and revenue losses due to GNSS signal degradation

The Gannon Storm of 10-12 May 2024 disrupted the global navigation satellite system (GNSS) signals, affecting precision agriculture that resulted in economic losses. Initial assessments conservatively estimated agricultural production losses for the US at $500M. Since then, the half-billion-dollar estimate has been cited multiple times in presentations and popular media outlets. The foundation for this poster is a comprehensive written report with sensitivity analyses over a range of farm assumptions across several representative scenarios. For transparency, the methodology for quantifying economic losses due to delayed corn planting caused by GNSS signal degradation from the foundational report is presented along with one pertinent scenario. Using publicly available United States Department of Agriculture (USDA) data, the proportion of planted acres dependent on GNSS guidance, farm size distributions, and the market share of vulnerable differential correction systems (DGPS) across 12 Midwestern corn-producing states are assessed. Losses were expected to be between $12,000 and $17,000 per farm, depending on local planting progress and effective field capacity of planting equipment. By evaluating various market shares of vulnerable DGPS systems across different equipment sizes, total revenue losses between $53M and $1.29B due to planting delays were estimated across 12 Midwestern states. These findings provide critical insights for development of space weather alert systems, agricultural policymakers, GNSS specialists, precision farming practitioners, space weather professionals and enthusiasts, and GNSS infrastructure stakeholders, emphasizing the need for enhanced resilience in agriculture-dependent satellite services.

31. **Bernard Jackson** (Department of Astronomy and Astrophysics, University of California)
A Kp Forecast Several Days in Advance From Solar Surface Extrapolated GSM Component Fields and Heliospheric-Derived Velocity and Density
Co-authors: Matthew Bracamontes - Department of Astronomy and Astrophysics, University of California; Andrew Buffington - Department of Astronomy and Astrophysics, University of California

Our UCSD group now provides a Kp forecast up to five days ahead of the current time with a 70% chance of an occurrence to predict geomagnetic storms from a Kp enhancement greater than 5. We provide this from first principles using a machine-learning tool and a prediction of GSM magnetic field components, velocity, and density. This forecast is currently made available on the UCSD website https://ips.ucsd.edu and to the NASA Goddard Community Coordinated Modeling Center. Our automatic system operates using near-Earth spacecraft measurements and Interplanetary Scintillation (IPS) data from existing world radio sites to provide the density and velocity forecasts. Magnetic fields using Global Oscillation Network (GONG) data sets provide GSM fields at Earth extrapolated outward from the solar surface. We have known since 2018 that we were able to forecast GSM Bz fields. However, since the summer of 2024 our machine-learning tool has been used to provide the high Kp correlation with geomagnetic storms in advance of our observations. We show past examples and a real time forecast of our analyses in this presentation.

32. **Marybeth Kiczenski** (Millersville University)
Space Weather Unplugged
Co-authors: Tanya Melnik, co-host and also fellow SWEN student; Christian Harris, co-host

The aurora borealis and aurora australis have been a source of inspiration, interest, and mystery to humans since ancient times. However, with the recent advances in technology and space weather awareness, this "once in a lifetime" phenomena has become accessible to anyone. In fact, the May 2024 Gannon Storm boosted Google searches of "northern lights" to an all-time high. While there is plenty of highly scientific information out there on Space Weather topics, the general public may not be aware of available resources or may have difficulties accessing it outside of academia or operations. As a result, mass media as well as social media, websites, and blogs become the primary sources of space weather news. Information shared through those sources are rarely checked for accuracy by the space weather professionals which leads to disappointment and mistrust in science or even fear of space weather events. "Space Weather Unplugged" project was started with the aim to address the existing gap in space weather education for the general public. Short educational videos are streamed and posted on a weekly basis and address both current events and relevant topics in space weather as just-in-time learning opportunities. Learner feedback occurs both formally, with posted surveys, as well as informally, with questions posted in live chat and comments for the posts/recorded sessions. Additional reading is suggested for learners as references to the relevant scientific publications. In addition to weekly short videos, monthly featured talks by academic and operational space weather professionals focus on topics of interest in greater detail, such as the impacts of space weather events on important industries like precision farming."

33. **Jenny Knuth** (SWx TREC, LASP, University of Colorado, Boulder)
Space Weather Applications for Operations, Science, and Society
Co-authors: Greg Lucas, CU Boulder, SWx TREC, LASP; Eelco Doornbos, KNMI; Thomas Berger, CU Boulder, SWx TREC, SWORD Center of Excellence

Space weather missions, data, and models are currently under-utilized. We have an abundance of tools and applications that require expert knowledge, training, webinars, local computing resources, and/or technical know-how just to attempt to use them. This poster will promote a frequently overlooked and historically undervalued approach to making the most of our space weather assets: user-centered web applications.
The poster will outline the current state of the art of modern web applications in space weather such as the SWx TREC Model Staging Platform (https://swx-trec.com) and the KNMI Space Weather Timeline Viewer (https://spaceweather.knmi.nl/viewer)
These applications have separable frontends and back ends and illustrate concrete steps we can take as a community to increase data access and adoption such as unified APIs, established design systems, and usability testing.
Our investment in missions, data, and models can be enhanced when modern web architecture and user input are part of the process and budget from the beginning instead of an afterthought. A relatively small investment in web applications can lead to large dividends in space weather science and space weather communication.
Intuitive and inviting space weather applications—and ideally, a Space Weather Applications Program—can advance space weather operations, science, and public understanding.

34. **Christina Lee** (Space Sciences Laboratory, UC Berkeley)
Near-real-time Space Weather Data from the Interstellar Mapping and Acceleration Probe (IMAP) Mission
Co-authors: Eric Christian, NASA GSFC; David McComas, Princeton University; Nathan Schwadron, University of New Hampshire; Matina Gkioulidou, Johns Hopkins Applied Physics Laboratory; Drew Turner, Johns Hopkins Applied Physics Laboratory; Laura Sandoval, CU Boulder - Laboratory for Atmospheric and Space Physics; Stefano Livi, Southwest Research Institute; Tim Horbury, Imperial College London; Jamie Rankin, Princeton University; Ruth Skoug, Los Alamos National Laboratory

The NASA Interstellar Mapping and Acceleration Probe (IMAP) mission will launch in September 2025 and travel to the Earth-Sun Lagrange 1 (L1) point. In addition to the broad range of excellent science that the ten IMAP instruments will generate, IMAP will continuously telemeter selected data of interest for advancing space weather predictions using five of the in-situ instruments on IMAP. The IMAP space weather system, called I-ALiRT (IMAP Active Link for Real-Time), is based on the very successful Real-Time Solar Wind (RTSW) data from the Advanced Composition Explorer (ACE), with enhanced cadences and including new, additional data products. Furthermore, IMAP, alongside NOAA's SWFO-L1 that launches with it, will contribute to a 6-point constellation of in situ observatories measuring the solar wind and space weather observables at L1. Such an advanced and unprecedented L1-constellation should offer exciting new insight on the nature, structure, and spatiotemporal dynamics of the solar wind and interplanetary magnetic field at 1 au and strategies and errors in propagating the observables from L1 to Earth's magnetosphere. This presentation will highlight the I-ALiRT system and its data products.

35. **Steve Luther** (Millersville University)
National Parks as An Emerging Gateway for Space Weather: Sowing the Seeds for Current and Future Generations of Citizen Scientists, Researchers and Night Sky Enthusiasts
Co-authors: Catherine Lewis, Millersville University, Graduate Student, SWEN Program

National parks play a key role in preserving Earth's most pristine natural wonders and landmarks, offering protection for wildlife and cultural resources while providing affordable public access and offering unparalleled research opportunities. The parks have also increasingly become a haven for the preservation of dark sky environments, not only within their physical boundaries but also for adjacent gateway communities
Public interest in space weather and night sky phenomena has increased exponentially in recent years thanks to the proliferation of social media and affordable technology including mobile phones and digital cameras. Aurora chasing, eclipse viewing, meteor showers and deep space documentation have resultantly seen a similar explosion of interest.
However, with ever-increasing light pollution and the loss of dark sky environments, national parks provide havens for study, research, observation and general enjoyment to all who seek to learn about and understand space weather and night sky phenomena.
In this poster, we aim to show the important role national parks globally do and can play, along with resultant challenges they face and recommendations for future development. Of note, my co-author is a former US national park wilderness ranger. Specific topics covered:
- Best national parks for dark sky observation
- How Yellowstone National Park uses GPS monitoring to predict solar storms
- The many parks, which offer dedicated dark/night sky events and activities
- The proliferation of visitation at parks during large-scale space weather events and resulting challenges
- How collaboration will be key for national parks and the space weather community is crucial going forward

36. **Tori Marbois** (Laboratory for Atmospheric and Space Physics)
Coordinating Ground Station Network for I-ALiRT

The Active Link for Real-Time (I-ALiRT) project, included within the Interstellar Mapping and Acceleration Probe (IMAP) mission, will collect and broadcast real-time space weather data 24/7. The data packets will be received by international ground stations making up a network of dishes that meet requirements designating them capable of providing high-performance participation in the project. The Laboratory for Atmospheric and Space Physics (LASP) is leading the coordination efforts for this network of ground station partners and providing the support the satellite teams need to receive I-ALiRT data. This involved writing code that processes ephemeris data stored in Spice kernels and produces files used as pointing schedules for the satellite dishes and providing the scheduling files via website-embedded API endpoints supported by AWS architecture and python libraries. This poster presents the tools used to create this processing code and provide insight into how the ground station partners will be supported as members of the 24/7 coverage network. We also identify upcoming tasks within the coordinator project that will continue to add functionality to the system (for example, a predictive coverage map that shows the trajectory of the IMAP spacecraft and the reception area of dish partners). We share insights into the creation process of this wide-reaching project that aspires to supplement legacy space weather missions and provide real-time data products that are crucial to the world of forecasting."

37. **Léonel Mba Nkilli** (Civil Aviation Authority of Gabon)
Space weather's training needs in the African aviation

Space weather comprises a set of hazards that threaten life and human activities including electric power, satellite communications and aviation.
According to a survey in the aviation field, Space weather is still unknown by many African countries and the means to face it is still nearly unavailable.
However, in the African continent space weather hazards is likely to occur like in any part of the world. Therefore, decisions have to be made and concrete actions to be taken to tackle this situation as soon as possible.
Among the wide range of solutions that can be suggested, what seems the most urgent can be expressed by this credo ""Training is the key"".
We call for partnerships, training programs, experience sharing and a global collaboration so that no continent be left behind.

38. **Brett McCuen** (The Aerospace Corporation)
Space Environment Architecture Modernization (SEAM) Overview
Co-authors: T. Paul O'Brien, Alexander Boyd, Fekireselassie Beyene, Janet Green

Space Environment Architecture Modernization (SEAM) is a series of web-based tools and applications to determine and predict satellite hazards based on the space weather environment. SEAM tools use various data sources and methods to provide space weather forecasts as well as direct prediction of satellite hazards and/or assessment of satellite anomalies. Here, we provide an overview of the tools currently available and under active development in the SEAM portfolio at The Aerospace Corporation. The services described include the following. Three flow-chart tools for assessment of satellite anomalies or hazards: Spacecraft Environmental Anomalies Expert System – Flow Charts (SEAES-FC), Space Environment Electro-Magnetic Interference - Flow Charts (SEEMI-FC), and Launch and Predicted Impact and Uncorrelated Re-entry - Flow Charts (LPI-FC). The Long-Term Environment and Anomaly Forecast (LEAF) series, which comprises a set of tools that forecast the Kp index, Outer Belt Index (OBI), the energetic electrons at geosynchronous orbit (GEO), and the auroral hazard (Aurora). The satellite hazard (LEAF-HQ) for various orbits is predicted based on the LEAF environment forecasts. Finally, the Specifying High-Altitude Electrons Using Low-Altitude LEO Systems (SHELLS) model for specifying the outer electron belt environment."

39. **Scott McIntosh** (Lynker Space)
Lynker Space: Improving Understanding & Forecast Skill of the Space Environment
Co-authors: Robert J. Leamon [Lynker Space / Lynker]

Space weather is driven by the relentless emission of radiation and plasma from the sun. It can trigger beautiful light displays known as the aurora borealis, but can also disrupt and damage essential technologies and infrastructure. It's the most extreme solar flares and geomagnetic storms that garner the most attention. Yet even mild storms, as well as the ever-present and ever-changing radiation environment, energetic particle streams (originating from the sun and from outside the solar system), can have major impacts on numerous industries and critical services.
Private sector operators across a range of sectors require timely, accurate, and accountable forecasts in support of their mission. Affecting their bottom line, their fundraising capability, their outward strategy, and their day-to-day operations the costs of inaccuracy are easily measured in millions of dollars. Lynker Space's community, forecast, products, and alerts provide highly skilled industry-specific forecasts and warnings to inform operational and strategic decisions from minutes to years in advance.
Accessible via secure web portal or mobile app, our products are tailored to our customer's needs - helping to secure their vulnerable assets and ensure continuity of operations. Are your asset(s) covered?

40. **Tanya Melnik** (Millersville University)
Space Weather Information and Aurora Chasers
Co-authors: Christian L. Harris; MaryBeth Kiczenski, Millersville University; Anthony Williams, Auburn University; Elizabeth A. McDonald, NASA; Michael Cook, Millersville University

General public interest in space weather has increased due to recent significant geomagnetic storms with spectacular northern and southern lights. This trend is reflected in mass and social media coverage of solar events and auroral forecasts, with platforms like Twitter tracking activity for over a decade. However, publications in the media often rely on official forecasts without input from scientific or operational space weather experts. As a result, forecasts designed for industries affected by severe space weather are frequently shared without explanation of their limitations and uncertainties to the general public. This can lead to public disappointment when forecasts do not materialize as predicted, potentially eroding trust in science. While the scientific community is active in social media and space weather communication, little is known about how forecasts are used by aurora chasers and other space weather enthusiasts.
Our team, composed of interdisciplinary academics, citizen scientists, and amateur aurora chasers, is focused on improving the communication of space weather forecasts. To achieve this, we will conduct a targeted survey to explore how aurora chasers use forecasts to plan activities. The survey will capture community views on forecast uncertainty, such as acceptable timing and geomagnetic impact, examine where aurora chasers seek out data sources, and investigate how they apply this information in decision-making. These insights will guide the development of tailored communication strategies for aurora chasers and related non-industry users, while also identifying opportunities for further research into public perceptions of space weather information."

41. **Joachim Raeder** (Space Science Center, UNH)
Regional and Seasonal Effects of Geomagnetic Storms on Terrestrial Weather

It is well known that many local weather variables, such as temperature or precipitation, correlate with the 11-year solar cycle. Total Solar Irradiance (TSI) variations alone cannot explain this, and thus the physical forcing processes remain unknown. Here, we show that geomagnetic storms affect local weather on much shorter time scales much more profoundly than the solar cycle variations. We use the Disturbance Storm-Time (Dst) index to identify storm hours (SH) by requiring that Dst reaches a value below a given threshold (Dst storm values are negative.) We then use ERA5 reanalysis data on a grid across the North American continent for the period 1957-2023. For each Hour Of Year (HOY) we calculate the average (AV) and the standard deviation (STD) for a several weather variables over this 67-year period. For each HOY we then calculate the anomaly as the difference between AV and the SH values, and average those over the 67 year interval. The anomaly values are normalized to the STD, sorted by season, and plotted as heat maps. We find significant anomalies for the variables temperature, pressure, precipitation, wind speed, and direct radiation, which are 2-3 orders of magnitude larger than the corresponding solar cycle variations. The anomalies also show significant regional and seasonal differences. Our results do not favor any particular physical process, but they provide critical constraints for models to explain the physical processes, for example cosmic ray effects on clouds or stratosphere - troposphere coupling.

42. **Elisa Turner** (MITRE Corporation)
Economic Benefit Analysis for NOAA Space Weather Program
Co-authors: Michael Cook (MITRE); Cecilia Wei (MITRE); Michael Cohen (MITRE)

Space weather (SWx) describes variations in the space environment between the sun and the Earth. These solar variations can disrupt critical technology including electric power grid, satellite communications and aviation. NOAA’s mission to build a weather ready nation includes observing, studying, and advising citizens and industry stakeholders of SWx conditions. MITRE is working with NOAA to perform an economic benefits study of their Next Generation space weather program. An extensive literature review to identify benefit mechanisms and understand how observations inform forecasts and alerts. Applying value of information theory, the observations were linked to benefits via value chains, emphasizing the decisions and actions industries can take, based on NOAA information, to mitigate economic impact. These valuations are incorporated into an event-driven model applying the probability of different magnitude events via Monte Carlo simulations. Results will be included in a Cost Benefit Analysis underpinning NOAA’s budget submission.

43. **Jon Vandegriff** (JHU Applied Physics Lab)
Simplifying Access to Space Weather Measurement and Forecast Data using the HAPI Standard
Co-authors: Robert Weigel, George Mason University; Sandy Antunes, JHU Applied Physics Lab; Jeremy Faden, Cottage Systems

As more space weather measurements, models, and forecasts become available, standard ways to access, the resulting data become increasingly important. Unpleasant data wrangling efforts throughout analysis and operations processes can be reduced by leveraging standards. The Heliophysics Application Programming Interface (HAPI) is a COSPAR endorsed and NASA supported standard for accessing time series data, and it is being adopted by both the Space Weather Prediction Center (SWPC) and the National Environmental Satellite, Data, and Information Service (NESDIS). Multiple NASA Heliophysics archives now make their data available using HAPI, as do several international projects and archives with space mission data, ground-based measurements, and space weather indices.

We describe the basics of the HAPI standard, the extent of its adoption, and how existing HAPI-enabled tools can benefit both data providers and data users. We will also showcase some existing and emerging capabilities for data visualization and data fusion, which can be useful for any HAPI data source. The recent Heliophysics Decadal Survey community vision for increased cohesion across Heliophysics is strongly resonant with HAPI's standardization and data fusion capabilities."

44. **Lucy Wilkerson** (George Mason University)
Evaluating GIC-related measurements and model predictions from the May 2024 Gannon storm
Co-authors: Edward Oughton, George Mason University; Robert Weigel, George Mason University; Dean Thomas, George Mason University; Dennies Bor, George Mason University; Antti Pulkkinen, NASA Goddard; Michael Wiltberger, NCAR/HAO; Christopher Balch, NOAA/SWPC; Trevor Gaunt, University of Cape Town

The May 2024 Gannon storm was one of the most severe geomagnetic storms in the past 20 years, making it an event that scientists and engineers will study for decades. Understanding how large geomagnetic disturbances (GMD) impact geomagnetically induced currents (GICs) within power grid networks is key to ensuring the resilience of such systems. However, empirical GIC estimates are sensitive to the network configuration at the time of the event, and this perishable network data is often lost after a GMD. In this work, we present results by combining permissible data from 18 GIC sites and 7 magnetometer sites from the Tennessee Valley Authority with many other data sources. These other data sources are (a) 396 GIC sites and 15 magnetometer sites from the NERC ERO portal, (b) computed virtual magnetometer data at all sites from the MAGE and SWMF simulation models, (c) β scaling factors derived from transfer functions at locations from the NSF IRIS/SAGE/EarthScope Data Services portal, (d) predicted GIC from GMU's Power Grid Model, and (e) transmission line geographic and voltage information from HIFLD. The objective of this work is to collect the largest and most diverse set of data for a geomagnetic storm on record, search for heuristic and empirical relationships between GICs measured at different sites, and compare model predictions with measurements. Preliminary analysis includes a comparison of the correlation between all pairs of GIC sites and its dependence on the intersite distance, the β factor difference between sites, and the voltage level of the line of the GIC monitors. In this poster, we present the initial results from analyzing this synthesized data.

45. **Naoto Nishizuka** (National Institute of Information and Communications Technology (NICT))
Social Implementation of Space Weather Forecasting in NICT for Promotion of Private Sector Use
Co-authors: Chihiro Tao, Takuya Tsugawa, Yuki Kubo (NICT)

NICT provides daily space weather forecasts, develops various forecast models, and discloses the information on its website. At the same time, private-sector use of space weather forecasting and its social implementation have been an issue, and NICT has been studying ways to create private-sector businesses. Over the past year, NICT has interviewed, 3/19 more than 80 companies to investigate their needs for space weather forecasting. As a result, it was found that there is a high need from the private sector for the provision of space weather information data through APIs.
In this R&D, an API data provision platform for space weather information will be established while selecting fields where space weather forecasting is expected to be commercialized and the foundation for the formation of space weather private-sector services will be developed. There are a wide range of fields

where space weather has an impact. While preparing to provide data, we will conduct research by directly interviewing companies to determine which data has high demand interest and high potential for commercialization, and which format is suitable. In addition to (1) the space weather forecast indicator (7 types), we are considering providing the following API data: (2) solar radiation exposure estimation map at aircraft altitude, (3) solar flare AI probability forecast, (4) satellite surface charging risk assessment, (5) aurora forecast map, (6) GEONET GPS total electron count (TEC) map, (7) GEONET GPS ionospheric disturbance index (ROTI) maps.
In addition, this summer, we aim to begin providing data under a joint research agreement with a private company, and will conduct a survey of usability, needs, and other requests. At the same time, the survey results will be used to create guidelines for space weather countermeasures. After this research period, we aim to establish an environment that will lead to license agreements for commercial data use. We will introduce these efforts in this presentation.

46. **Erin Lynch** (NOAA NESDIS SWO)
Formulation of NOAA’s Space Weather Next Program
Co-authors: Joanne Ostroy NOAA NESDIS SWO / MITRE

NOAA’s Office of Space Weather Observations (SWO) is formulating the next generation space weather observing system, Space Weather Next (SW Next). SW Next will provide continuity for the space-based observations needed to sustain operational space weather monitoring and forecasting capabilities at NOAA’s Space Weather Prediction Center (SWPC). It will also provide enhancements beyond current capabilities that better serve the industries impacted by space weather. As part of the formulation of the program, a detailed study to identify the economic and societal benefits associated with SW Next observations is being conducted. Space weather poses a threat to a number of industries including electric power, satellite operations, and civil aviation. To understand how user communities derive value from space weather observations, value chains are constructed by tracing how SW Next sensors will feed into downstream products and services and ultimately user decisions. This trace is key to understanding the value of a program and key to tracing user-needed improvements back to model and sensor performance. Economic and societal benefits are derived from the ability of these end-user communities to mitigate detrimental space weather impacts by utilizing timely and accurate space weather information in their operational decisions. The valuation of these benefits builds upon past studies and incorporates new understanding of space weather impacts."