Enhancing Data Discoverability and Analysis for Understanding Space Radiation in Earth Environment with Radiation Data Portal

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Introduction to Radiation Data Portal

The impact of radiation dramatically increases at high altitudes in the Earth's atmosphere and in space. Therefore, monitoring and access to radiation environment measurements are critical for estimating the radiation exposure risks of aircraft and spacecraft crews and the impact of space weather disturbances on electronics. Addressing these needs requires reliable access to multi-source radiation environment data and enhanced visualization and search capabilities. The Radiation Data Portal provides an interactive web-based application for convenient search and visualization of in-flight radiation measurements.

Access the Radiation Data Portal at https://data.nas.nasa.gov/helio/portals/rdp/ or use a QR-code above

Radiation Portal Data Sources:

- The Automated Radiation Measurements for Aerospace Safety (ARMAS) data, augmented with the integrated flight parameters and environment. The ARMAS project utilizes a micro-dosimeter integrated into a data processing and communication package to measure and report the absorbed dose rates at a 1 min cadence.
- GOES Soft X-ray (SXR) radiation in the 0.5-4 Å and 1-8 Å channels. The Radiation Portal currently uses calibrated 1-min averaged soft X-ray fluxes measured by Geostationary Operational Environmental Satellite (GOES). Each measurement during the flight is connected to the nearest-time SXR measurement.
- Integrated GOES proton flux measurements. The Portal utilizes 5-min integrated calibrated measurements of the proton fluxes above the 1 MeV - 100 MeV. Each measurement during the flight is connected to the closest-in-time GOES measurement.

Radiation Data Portal Features:

- The back-end MySQL relational database is optimized for fast data retrieval.
- The Application Programming Interface (API) and Python routines have been developed to retrieve the database records directly, without interaction with the web interface.
- The application search engine contains a variety of filters (flight location and timing, environmental and dosimetric properties) allowing a user to customize flight selection.
- The search process and flight summary are supported by dynamic histograms of the flight parameters implemented with the Google Charts API and OpenLayers map API.

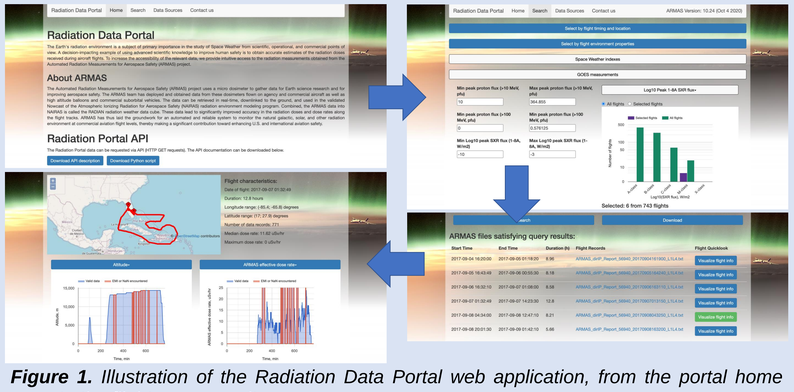


Figure 1. *Illustration of the Radiation Data Portal web application, from the portal home page to the flight query result.*

Prediction of Solar Energetic Particle Events

Solar Energetic Particle (SEP) are one of the major contributors to the radiation environment in Earth's upper atmosphere, magnetosphere, and space. Within the NASA ESI project "Machine Learning Tools for Predicting Solar Energetic Particle Hazards" we are enhancing the predictive capabilities of the SEPs by:

- Developing an online-accessible database that integrates the solar and heliospheric data, metadata, and descriptors related to SEPs
- Developing "all-clear" forecasts of SEPs with low false-alarm rates using a state-of-art machine learning approaches and several-cycle-long series of data

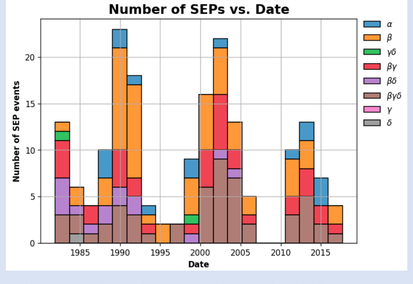


Figure 11. *The number of SEP events produced from the active regions of different Hale classes as a function of time.*

See poster by Aatiya Ali and the recent publications/preprints: Marroquin et al. (2023), ApJ, 952, 97; Ali et al. (2023), ApJ (review), arXiv:2303.05446; O'Keefe et al. (2023), ASR (review), arXiv:2303.08092

Radiation Data Portal Expansion

Expansion of Radiation Data Portal

Within the NASA HITS 2022 program grant, we are expanding the portal. Our specific goals are:

- Inclusion of additional radiation measurement sources (NASA ACE & DSCOVR, NASA CDAWeb geomagnetic activity data, ground-based neutron monitor measurements, measurements of cosmic ray muons, etc.). See Figure 2 for the entity relationship diagram.
- Expansion of ARMAS flight data catalog and enhancement of NAIRAS dose rate modeling by using run-on-request flight trajectory tool
- Adaptation of the existing data visualization capabilities to the new data sets and improving the search engine
- Creation of the ML-ready data set for in-flight radiation prediction.

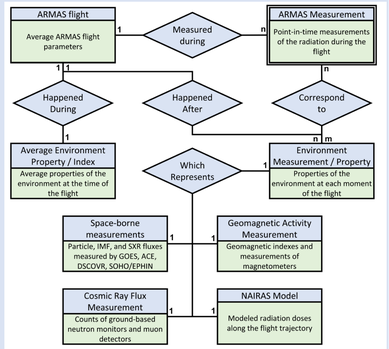


Figure 2. *The entity relationship diagram of the enhanced Radiation Data Portal*

Description of New Data Sources

Python routines created to cross reference dated collected data and update if data from sources has been revised. The routines for the following data sources are implemented:

- Deep Space Climate Observatory (DSCOVR) measurements. The Radiation Portal uses data collected by the Faraday Cup of 1-minute averaged measurements of the solar wind proton density, speed, velocity, temperature, etc., obtained near L1 point.
- Neutron Monitor Database (NMDB) measurements. The Portal utilizes data from the closest neutron monitor station each with its own varying time averaged neutron flux measurements. Each measurement is collected in UTC time format. Currently, OULU and DOMC stations are utilized.
- Ground based Magnetometer measurements. The data is collected from various magnetometer stations around the world with 1-minute averaged magnetic north, magnetic east, local down measurements. HOV and PG2 stations are utilized.
- OMNI Web data set. The data set represents the curated 1-hour-cadence measurements of the solar wind, energetic particle, and geomagnetic activity parameters. The measurements are obtained from several spacecraft at L1 / Geostationary orbits.

Cosmic Ray Muon Measurements on an Airplane Flight

- We recorded cosmic ray muon flux using a cubeSat prototype detector (3 scintillator stack, scintillator size 9cm x 9cm x 1cm) onboard the Colombo (Sri Lanka) -> Doha (Qatar) -> Atlanta (USA) flight
- Our measurements indicate the variations of the muon particle counts with the flight altitude and route, and confirm the functionality of the developed cubeSat prototype
- Credits: Xiaochun He and Ashwin Ashok

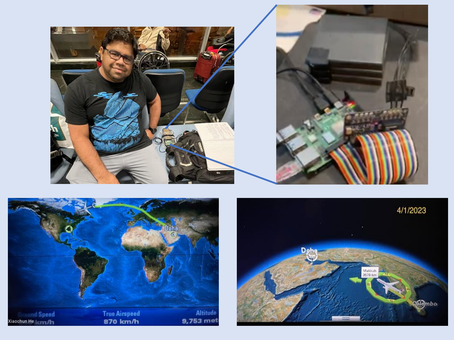


Figure 9. *Setup of the cubeSat prototype detector (top) and the illustrations of the flight route (bottom).*

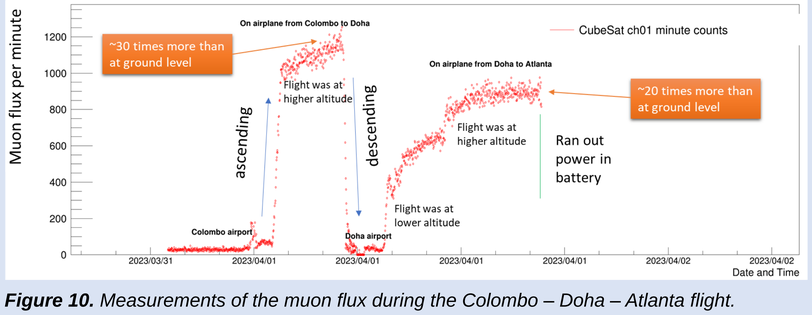


Figure 10. *Measurements of the muon flux during the Colombo – Doha – Atlanta flight.*

See poster by Arfa Mubashir to find more results from the ground-based network of portable muon detectors developed in GSU and their sensitivity to space weather events

Preparation of ML-Ready Data Sets

The ML-Ready data sets are designed to allow the partitioning of ARMAS flight data and the related background measurements to efficiently train/test an ML model to be able to predict / nowcast the ARMAS measurements given environmental factors (Figure 3). We plan to develop the data sets that contain both the instantaneous and prehistory properties of the environment.

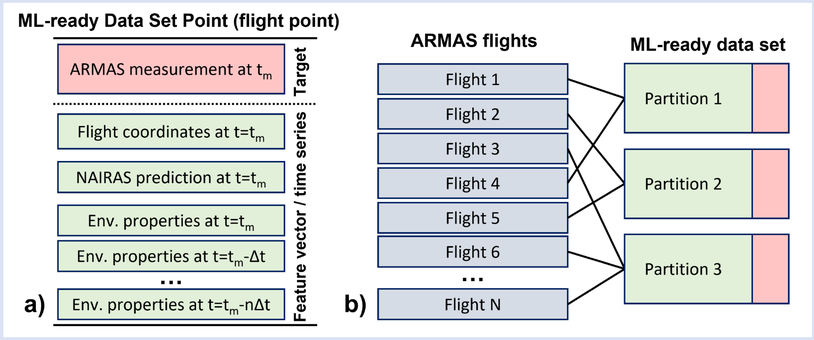
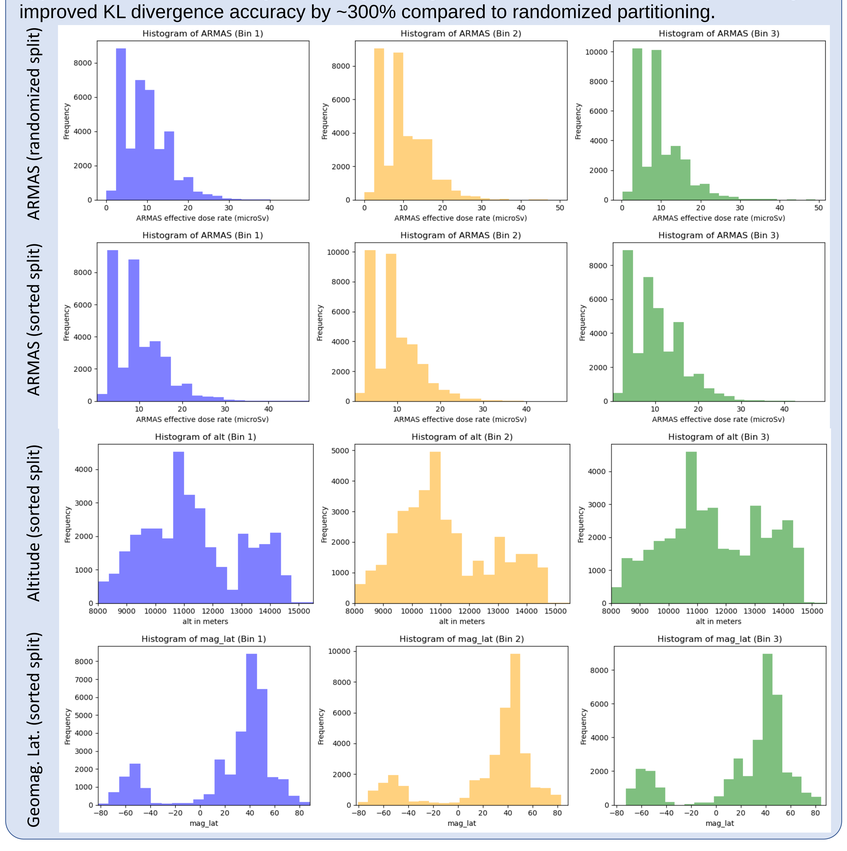


Figure 3. *a) Schematic structure of the ML-ready data set entity (a target corresponding to the measurement of radiation dose rate during the ARMAS flight, and the feature vector representing the flight timing and coordinates, NAIRAS predictions, and prehistory of the measurements of the environment); b) Illustration of subdivision of ARMAS into the partitions.*

The data was grouped by flight so that data collected by a single flight could not be separated. To save computational power, the mean and standard deviation were calculated for each flight, then the normalized absolute distance of the mean and standard deviation were calculated. The data was then sorted into partitions, such that the distance for each flight has minimum differences. The partitions were then analyzed using KL divergence to see if one could properly approximate the other. Though KL divergence agreement was not a goal of this partitioning, it improved KL divergence accuracy by ~300% compared to randomized partitioning.



Acknowledgements

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