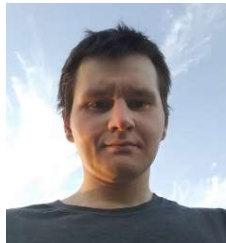


Radiation Data Portal: Connection of Radiation Measurements on Airplane Flights with Observations of Solar-Terrestrial Environment

Viacheslav M Sadykov, Irina N Kitiashvili, W Kent Tobiska, Madhulika Guhathakurta

NASA Ames Research Center, Bay Area Environmental Research Institute, Space Environment Technologies, NASA Headquarters



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INTRODUCTION

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 (RDP) provides an interactive web-based application for convenient search and visualization of in-flight radiation measurements.

DATA SOURCES

The Radiation Data Portal currently integrates the following data sources:

- **The Automated Radiation Measurements for Aerospace Safety (ARMAS)** augmented with the integrated properties of the flight and environment. The ARMAS project utilizes a micro-dosimeter integrated into a data processing and communication electronics package to measure and report the absorbed dose rates with a one-minute cadence. The doses are converted to the effective dose rates. Currently, the ARMAS data are publicly available from Space Environment Technologies (SET) as individual files for each flight (https://sol.spacenvironment.net/ARMAS_Archive/) (https://sol.spacenvironment.net/ARMAS_Archive/)
- **Geostationary Operational Environmental Satellite (GOES) Soft X-ray (SXR) radiation measurements** in the 0.5-4 Å and 1-8 Å channels. The Radiation Data Portal currently utilizes calibrated 1-min averaged GOES fluxes available from the National Oceanic and Atmospheric Administration National Centers for Environmental Information archive (NOAA NCEI, <https://satdat.ngdc.noaa.gov/> (<https://satdat.ngdc.noaa.gov/>)). Each measurement during the flight is connected to the nearest-time SXR measurement.
- **Integrated GOES proton flux measurements.** The Portal utilizes 5-min calibrated and integrated measurements of the proton fluxes above the following thresholds: 1 MeV, 5 MeV, 10 MeV, 30 MeV, 50 MeV, 60 MeV, and 100 MeV. These data are also available via the NOAA NCEI archive (<https://satdat.ngdc.noaa.gov/> (<https://satdat.ngdc.noaa.gov/>)). Each measurement during the ARMAS flight is connected to the closest-in-time GOES measurement.

DATA PORTAL BACK-END

MySQL Database.

The data sources are loaded to MySQL relational database. The database structure, illustrated in Figure 1, represents an interaction between three entities: 1) integrated ARMAS flight properties, 2) measured time-series during a flight, and 3) GOES measurements. In the present time, the ARMAS flight measurements update is performed manually using the developed update scripts.

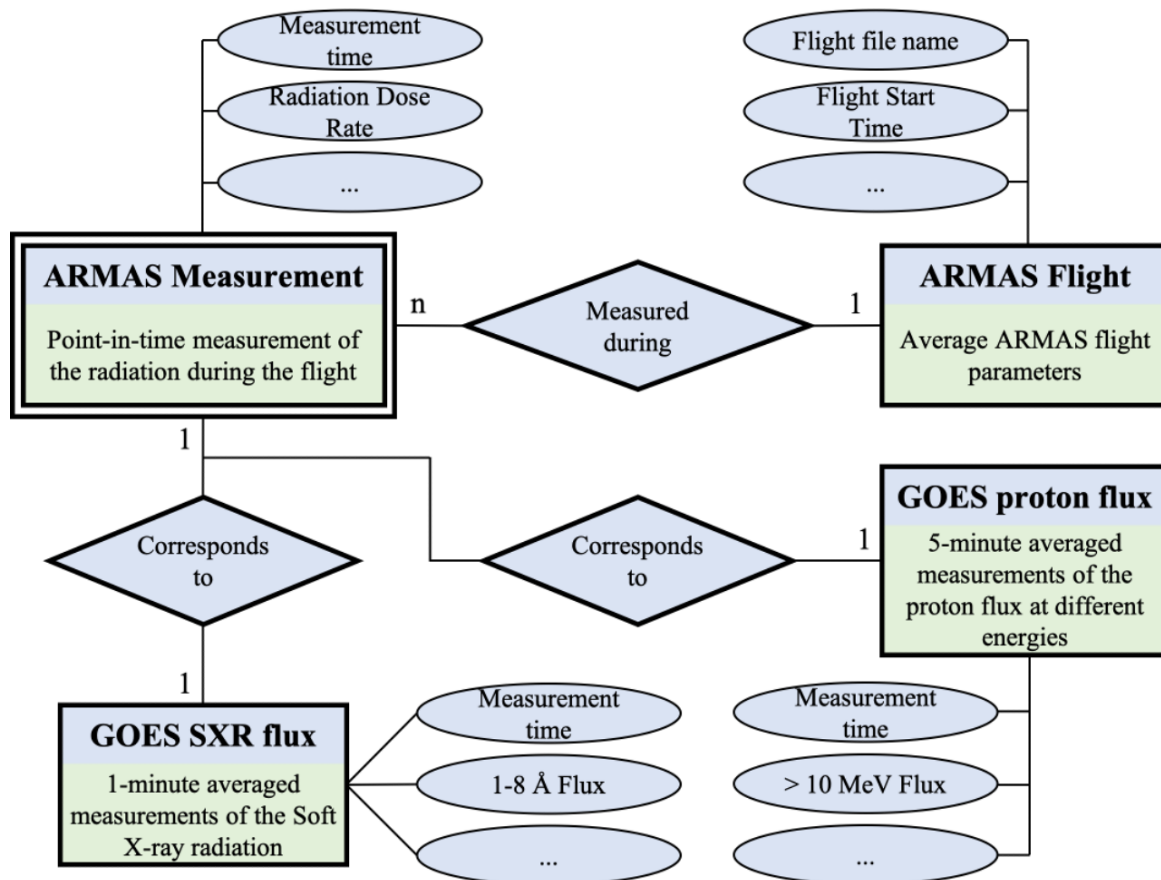


Figure 1. The Entity Relationship Diagram of the Radiation Data Portal.

Application Programming Interface (API).

The API developed for the Radiation Data Portal at present handles the following two types of requests: 1) properties of ARMAS flights, and 2) measurements during a flight. The requests are implemented as HTTP GET requests. The web API documentation (the description of functions and related Python routines) are available from the Radiation Data Portal web page (<https://solarflare.njit.edu/RDP/> (<https://solarflare.njit.edu/RDP/>)). As an example, a request for measurements during the ARMAS flight for September 7, 2017, is available via the following URL: <https://tinyurl.com/rdp-api> (<https://tinyurl.com/rdp-api>)

DATA PORTAL FRONT-END

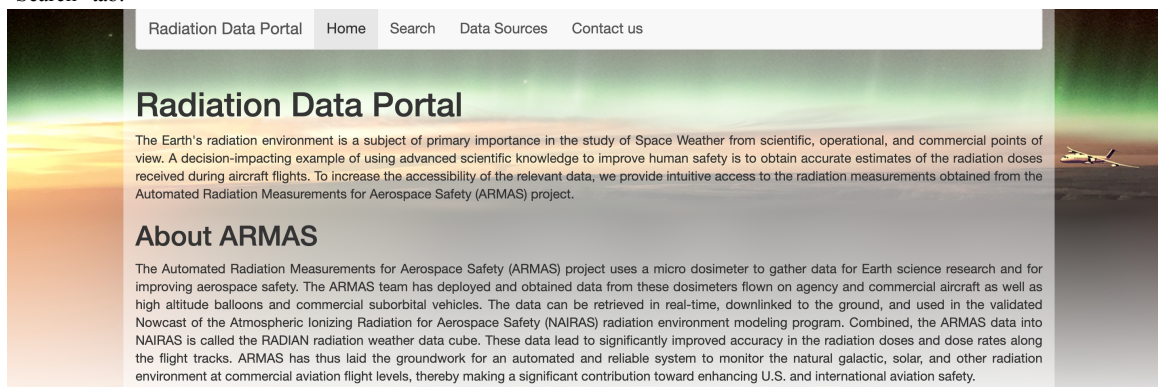
A comprehensive front-end web application is currently available at <https://solarflare.njit.edu/RDP/> (<https://solarflare.njit.edu/RDP/>). Portal deployment at NASA Advanced Supercomputing (NAS) facilities is in progress. The search filters are organized into three categories:

- **Flight time and location properties:** dates when flights were performed, flight duration, location of flight routes in ordinary and geomagnetic coordinates;
- **Environment characteristics:** space weather and geomagnetic indexes such as Kp, Ap, D, Dst, G-level, peak values of SXR and proton fluxes during the flight;
- **Dosimetry measurements:** total, averaged, and median dose measurements obtained during ARMAS flights and predicted by the NAIRAS v1 model, median geomagnetic cutoff rigidity and quality factor during the flight;

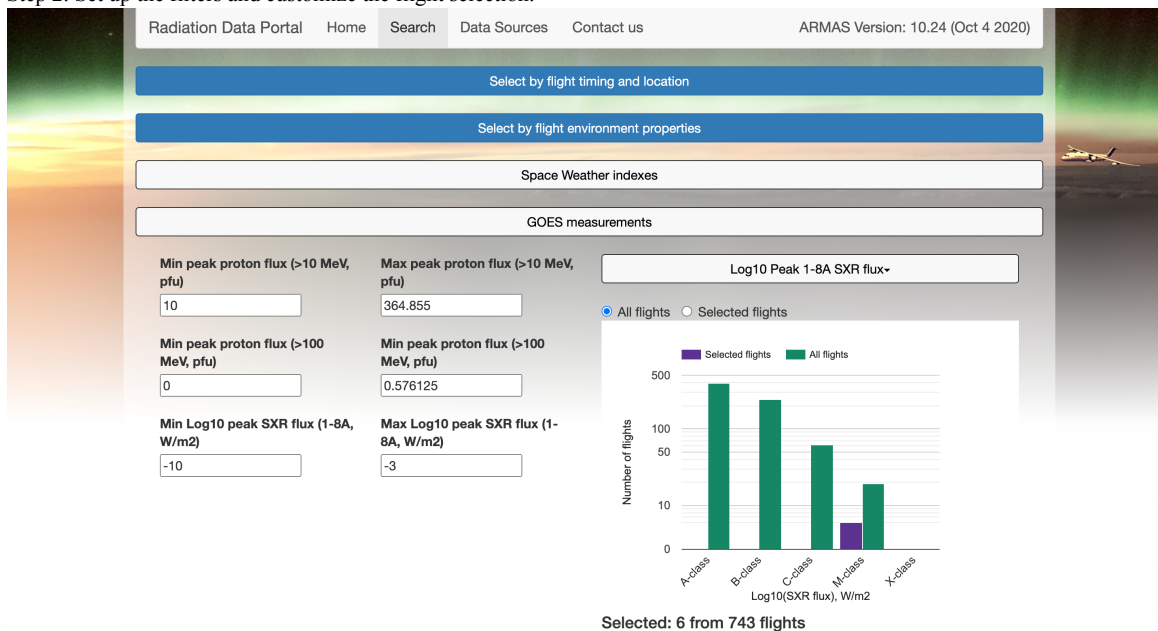
The search results are visualized in the form of dynamic histograms implemented using the Google Charts API. Each selected flight is supported by a quick-look visualization that includes a flight route on the map, summary of the key properties of the flight, and two dynamic charts presenting the flight parameters as functions of time.

Working with RDP step-by-step.

Step 1. Visit the Radiation Data Portal (<https://solarflare.njit.edu/RDP/> (<https://solarflare.njit.edu/RDP/>)) and click on the "Search" tab.



Step 2. Set up the filters and customize the flight selection.



Step 3. Generate the list of the flights satisfying the filters.

Search
Download

ARMAS files satisfying query results:

Start Time	End Time	Duration (h)	Flight Records	Flight Quicklook
2017-09-04 16:20:00	2017-09-05 01:18:20	8.96	ARMAS_dirIP_Report_56940_20170904161900_L1L4.txt	Visualize flight info
2017-09-05 16:43:49	2017-09-06 00:55:30	8.18	ARMAS_dirIP_Report_56940_20170905164240_L1L4.txt	Visualize flight info
2017-09-06 16:32:10	2017-09-07 01:08:00	8.58	ARMAS_dirIP_Report_56940_20170906163110_L1L4.txt	Visualize flight info
2017-09-07 01:32:49	2017-09-07 14:23:30	12.8	ARMAS_dirIP_Report_56940_20170907013150_L1L4.txt	Visualize flight info
2017-09-08 04:34:00	2017-09-08 12:47:10	8.21	ARMAS_dirIP_Report_56940_20170908043250_L1L4.txt	Visualize flight info
2017-09-08 20:01:30	2017-09-09 01:42:10	5.66	ARMAS_dirIP_Report_56940_20170908163200_L1L4.txt	Visualize flight info

Step 4. Visualize the flight route and measurements for each selected flight and download the data.

Flight characteristics:

- Date of flight: 2017-09-08 04:34:00
- Duration: 8.21 hours
- Longitude range: (-85.3; -71.2) degrees
- Latitude range: (18.9; 29) degrees
- Number of data records: 493
- Median dose rate: 10.98 uSv/hr
- Maximum dose rate: 21.96 uSv/hr

ARMAS effective dose rate-

Download flight data

NAIRAS modeled dose rate-

Change layout

USE CASE EXAMPLE: ARMAS MEASUREMENTS IN AN ENHANCED SOLAR PROTON ENVIRONMENT

There are six ARMAS flights that occurred during Solar Proton events (SP-enhanced conditions). An SP event is defined as an increase of the >10 MeV proton flux above the 10 pfu (particle flux unit) level.

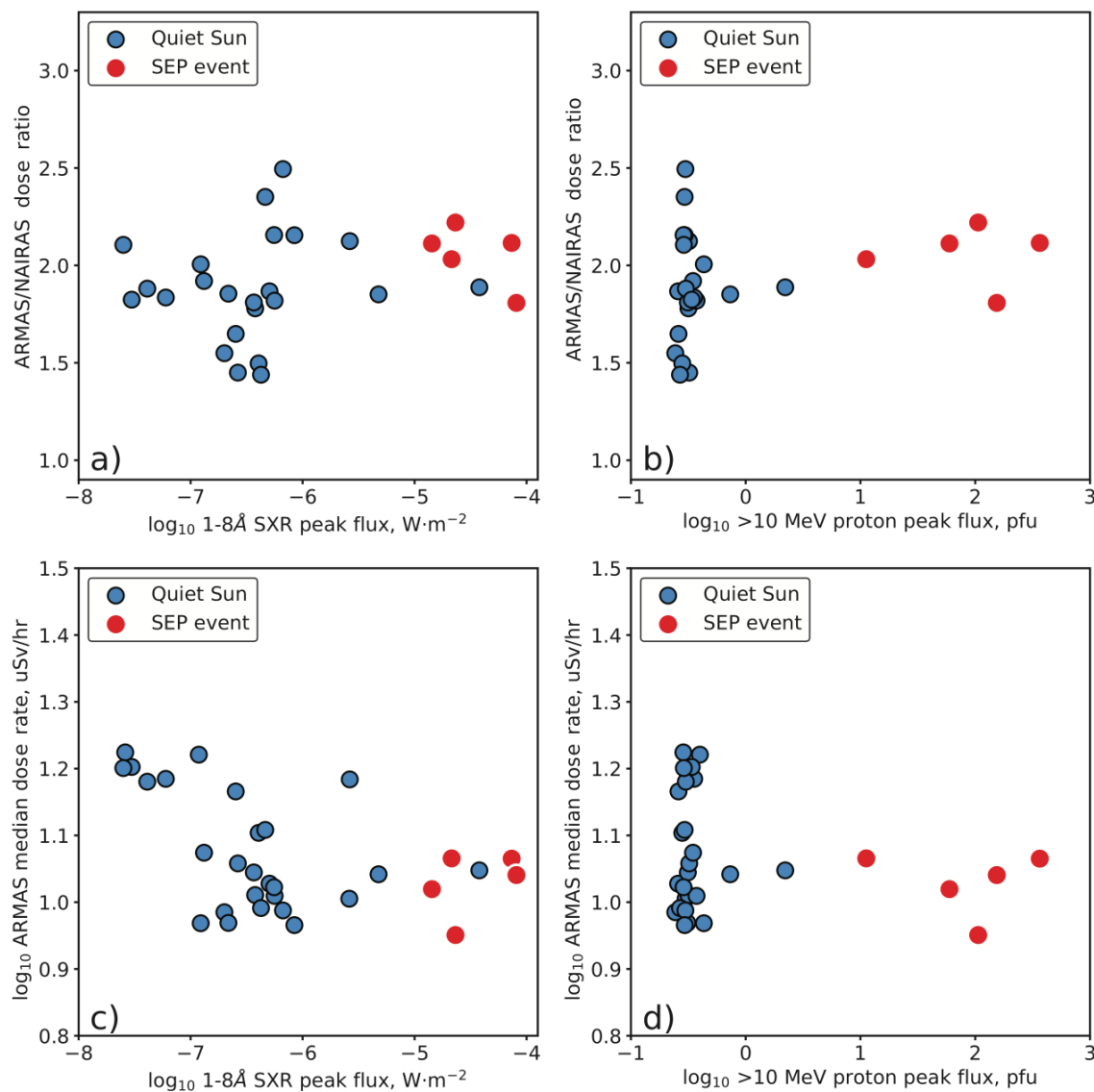


Figure 2. Correlations between the total dose ratios of ARMAS to NAIIRAS to X-ray flux (panel a) and proton flux above 10 MeV (b). Dependence of the ARMAS median effective dose rate from the X-ray flux (panel c) and proton flux above 10 MeV (d). Red circles correspond to the flights when the peak value of > 10 MeV proton flux exceeded 10 pfu; blue circles indicate the flights when the flux was less than 10 pfu.

The selected flights have the following properties:

- All SP-enhanced flights were performed in September 2017 in a confined geographic region. We collected the flights that happened in the same region during September 2016 – September 2018 when no SP events were observed (SP-low group).
- The Student's and Welch's t-tests demonstrate that there is no statistically-significant difference between the ARMAS/NAIIRAS* ratios and median effective dose rates for SP-enhanced and SP-low groups of flights (see Figure 3 for distributions). *NAIIRAS: Nowcast of Aerospace Ionizing Radiation System.
- Possible explanations: 1) most of energetic protons were in the low-energy tail and did not penetrate deep into the atmosphere; 2) the data-driven NAIIRAS model captures much of what ARMAS is measuring.

PLANS AND BROADER IMPACT

The Radiation Data Portal will be expanded by including additional radiation measurement sources, adapting the existing data visualization capabilities, and adapting and improving the search engine to the new data sets. In particular, we plan to include measurements of ion flux and magnetic field in-situ measurements from the NASA Advanced Composition Explorer (ACE), Geomagnetic activity data from NASA's Coordinated Data Analysis Web (CDAWeb), the data from ground-based neutron monitors, and add more space-based measurements of energetic particles. We envision that the Radiation Data Portal will enhance our knowledge of solar-terrestrial interactions and Space Weather and grow further into a comprehensive collaborative effort involving many aspects of the aerospace radiation environment and the broader community.

ABSTRACT

The impact of solar radiation dramatically increases at high altitudes in the Earth's atmosphere and in space. Therefore, continuous monitoring of the radiation environment is critical for the safety of aircraft and spacecraft crews and passengers. Addressing the problem requires a complex approach of integration of different data sources and enhancement of the visualization and search capabilities. The Radiation Portal Database represents an interactive web-based application for convenient search and visualization of in-flight radiation measurements and exploration of various properties related to the radiation environment. The primary element of the Radiation Portal back-end is a MySQL relational database that currently contains the radiation measurements obtained from the Automated Radiation Measurements for Aerospace Safety (ARMAS) device, and soft X-ray and proton fluxes from Geostationary Orbiting Environmental Satellite (GOES). The developed Application Programming Interface (API) and related Python routines allow a user to retrieve the database records directly and efficiently, without interaction with the web interface. As a use case of the Radiation Portal, we examine the properties of the ARMAS flights taken during the enhanced Solar Proton (SP) fluxes and compare them to the flights of similar time and location taken during SP-quiet periods.