Turning SDO Noise Into Van Allen Radiation Belt Characterization Data

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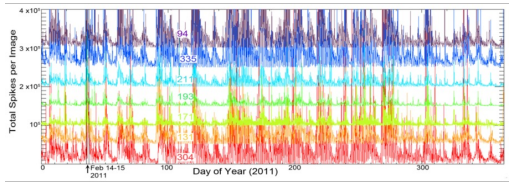
AIA Spike Data Overview

VISION

The Solar Dynamics Observatory (SDO) satellite can be used for characterizing the Van Allen radiation belt, especially at areas where other satellites cannot.

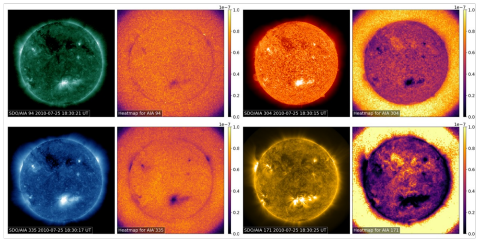
KEY POINTS

- More than 3 trillion "spiked pixels" attributed to magnetospheric particle impacts have been removed from the SDO/AIA images so far.
- The SDO spike rate was compared to particle measurements from GOES-14 during close orbital conjunctions occurring twice daily over 27 months.
- High correlation between AIA spikes and GOES-14 electrons is found, therefore SDO can provide proxy measurements for radiation belt electrons.



Number of AIA despiked pixels per 16-megapixel image for the year 2011. The 304Å numbers are to scale; other wavelengths are offset by multiples of 50,000.

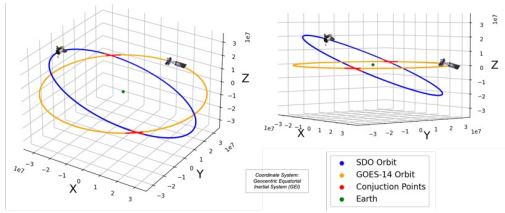
Normalized Detection Density (35x35 px binning)



NSPIKES detection density maps alongside four of the AIA EUV wavelengths on 2010-07-25, to indicate the non-uniformity of NSPIKES detection in the images. The detection density maps are assembled from one hour of NSPIKES data, then normalized so that the total integrated NSPIKES flux is equal to unity on the map.

Kasapis, S., Thompson, B.J., Rodriguez, J.V., Attie, R., Cucho-Padin, G., da Silva, D., Jin, M. and Pesnell, W.D., 2023. Turning noise into data: Characterization of the Van Allen radiation belt using SDO spikes data. Space Weather, 21(3), p.e2022SW003310.

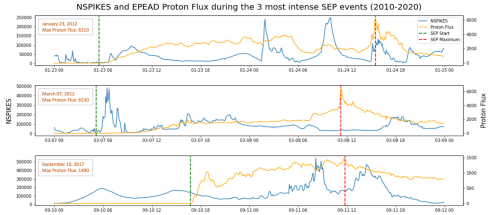
SDO and GOES-14 Conjunction Points



NSPIKES Correlation with Protons

MAGPD Proton Flux	95 keV	140 keV	210 keV	300 keV	575 keV
	Spearman Correlation (ρ)				
Equator	0.326 ± 0.052	0.357 ± 0.052	0.423 ± 0.050	0.467 ± 0.0476	0.447 ± 0.042
Non-Equator	0.306 ± 0.019	0.329 ± 0.018	0.370 ± 0.017	0.389 ± 0.016	0.345 ± 0.014
Full Orbit	0.305 ± 0.020	0.328 ± 0.019	0.370 ± 0.018	0.390 ± 0.017	0.347 ± 0.015

Pearson and Spearman correlation values for NSPIKES and MAGPD Proton Flux data for the five different MAGPD energy channels, calculated for the same period of 27 months. The nine different MAGPD telescopes and seven different AIA wavelengths are accounted for by presenting the mean and standard deviation of all possible combinations (similarly to previous electron studies).



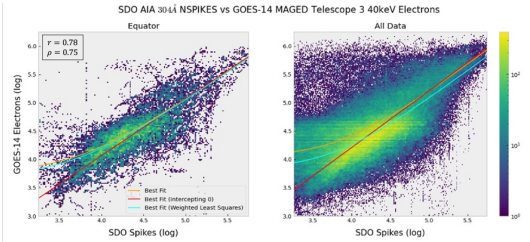
NSPIKES at 304Å (blue) and EPEAD >10 MeV proton (yellow) time profiles for the two-day periods that include the three most significant SEP events recorded by NOAA during the first decade of operation of the SDO.

NSPIKES Correlation with Electrons

The MAGED device aboard the GOES-14 satellite detects high energy ions and electrons in space. The EPEAD instrument, also on GOES-14, further expands this detection, focusing on even higher energy electrons than MAGED.

MAGED ($40keV$)	94	131	171	193	211	304	335
	Spearman Correlation (ρ)						
Equator	0.712	0.713	0.735	0.721	0.729	0.731	0.737
Non-Equator	0.491	0.499	0.532	0.531	0.524	0.532	0.534
Full Orbit	0.501	0.509	0.538	0.536	0.535	0.545	0.541

Spearman correlation values for NSPIKES and MAGED 40keV electron flux data for the seven different AIA wavelengths calculated for Dec 2017 - Feb 2020.



Heatmaps for the Equator and Full Orbit NSPIKES & MAGED Electron data in log scale. The correlation value for the 304Å 40 keV Equator data is r = 0.779.

EPEAD (800 keV)	94	131	171	193	211	304	335
	Spearman Correlation (ρ)						
Equator	0.529	0.534	0.432	0.435	0.456	0.448	0.447
Non-Equator	0.383	0.385	0.350	0.350	0.357	0.350	0.350
Full Orbit	0.387	0.389	0.351	0.352	0.359	0.352	0.352

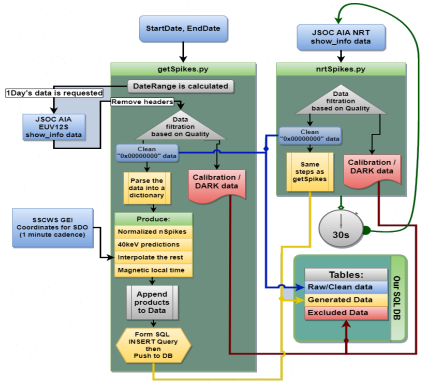
Spearman correlation values for NSPIKES and EPEAD >0.8 MeV (E1) electron flux data for the seven different AIA wavelengths, calculated over the same period. Something about the equation:

$$J_{GOESe,40\text{keV}} = 1.1604 \text{ NSPIKES}$$

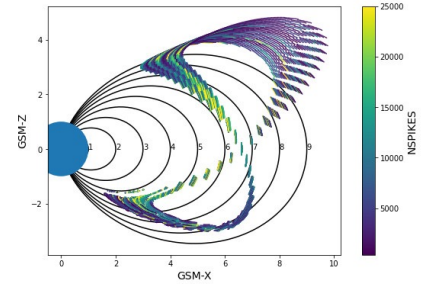
It was found that the correlation was highest (r = 0.78) for GOES-14 MAGED 40 keV electrons, and had a linear relationship as described in the above equation.

Real-Time Radiation Belt Dashboard

Structured an SQL database with three specific tables: One for a) Clean/raw data from JSOC, another for b) Generated data from models/calculations and a third one for c) Rejected/filtered data from JSOC.



Developed "getSpikes.py", a script that fetches and processes high-resolution data from JSOC, generating: Normalized NSPIKES 40keV predictions, interpolated GEI data and magnetic latitude, local time, and L-shell data (work in progress).



Future Work: Creating "nrtSpikes.py", a real-time script that keeps the data up-to-date using near-real time dataseries. A website with real-time information as long as historical data will be released.