Comparative Analysis of Solar Proton Events at Lagrange Point-1 and the Geostationary Orbit

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INTRODUCTION

Solar proton events (SPEs), a solar energetic particle (SEP) event subclass, are characterized by increased fluxes of protons ≥10 MeV, elevating space radiation levels and posing risks to astronauts and equipment.

We investigate concurrent SPE differences between L1 and the geostationary orbit (GEO), exploring magnetospheric transport impacts on proton variations.

We previously cataloged SPEs at GEO using GOES flux data and extend this to L1, with data from SOHO-EPHIN as a cis-lunar proxy beyond Earth's magnetosphere.

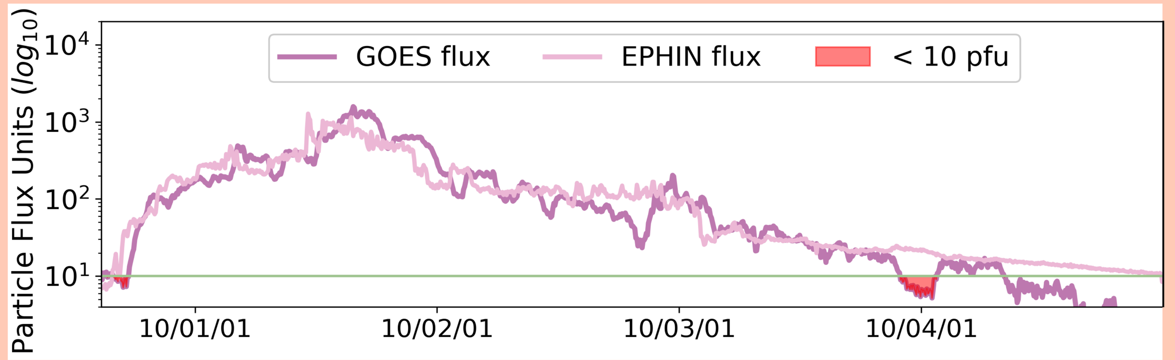

Figure 1: Example of a concurrent event and merged GOES-SPE from Table 1.

MOTIVATION

SPE variations between GEO and L1 may reveal conditions modulating fluxes reaching lunar or terrestrial surfaces.

Understanding SPE precipitation into Earth's magnetosphere is essential for accurate forecasting, particularly when localized data may be insufficient for predictions elsewhere.

With missions like Artemis, we must prioritize safe lunar operations and further understand SEP dynamics.

PROCESSING DATA

EPHIN's discrete channels differ from GOES' integrated and differential channels . A power-law fit is used to isolate 10 – 53 MeV fluxes from EPHIN for analysis.

Events ≤10 minutes apart as well as consecutive SPEs are merged into a single event if identified as such by the other instrument *(see Table 1 & Fig. 1)*.

		Start of SPE	Peak-flux time	End of SPE
EPHIN SPE	1.	10/1/01 12:40	10/2/01 4:10	10/4/01 23:55
Overlapping GOES SPEs	i.	10/1/01 11:55	10/1/01 12:10	10/1/01 12:45
	ii.	10/1/01 14:00	10/2/01 7:45	10/4/01 3:10
	iii.	10/4/01 6:05	10/4/01 6:40	10/4/01 11:25
GOES SPE	1.	10/1/01 11:55	10/2/01 7:45	10/4/01 11:25

Table 1: Merging 3 GOES-detected SPEs into 1 as they all occur during a single event detected by EPHIN.

COMPARING SPEs

Our analysis produced an SPE catalog of,
Concurrent events at L1 and GO:
SC 23: 74 & SC 24: 41

❖ We analyzed SPE differences across solar cycles (SCs) 23 & 24, including start times, duration, etc. *(e.g. Fig. 2)*.

❖ We find that GOES often detects SPEs earlier than EPHIN, a counter-intuitive result linked to high-energy particle fluxes in GOES contaminating low-energy channels during 25 strong events *(e.g. Fig 3)*.

❖ Resulting faulty early detections skew SPE parameters, affecting peak fluxes, fluence, and more.

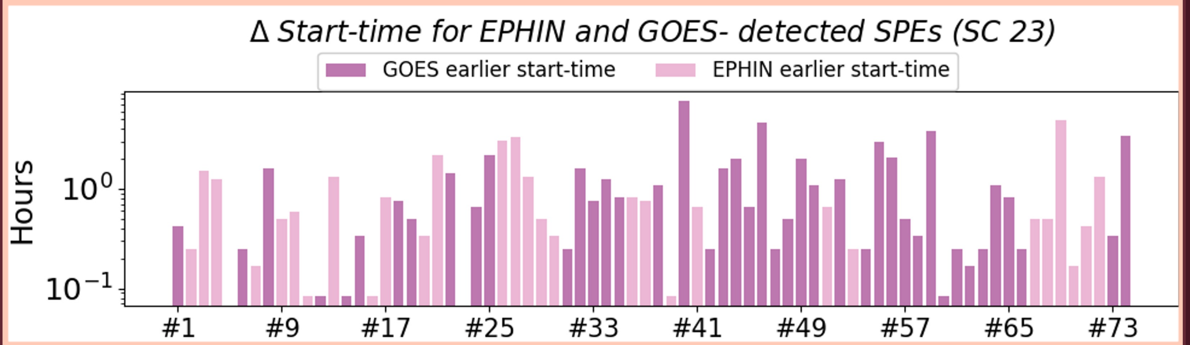

Fig 2: Difference in SPE start times as detected by GOES and EPHIN in SC 23.

EPHIN also faces challenges during high-energy storms, where detector adjustments trigger abrupt variations in flux measurements. This cannot be corrected by a single factor, impacting SPE parameters such as fluence.

Unfortunately, there is currently no correction algorithm that can fully account for this.

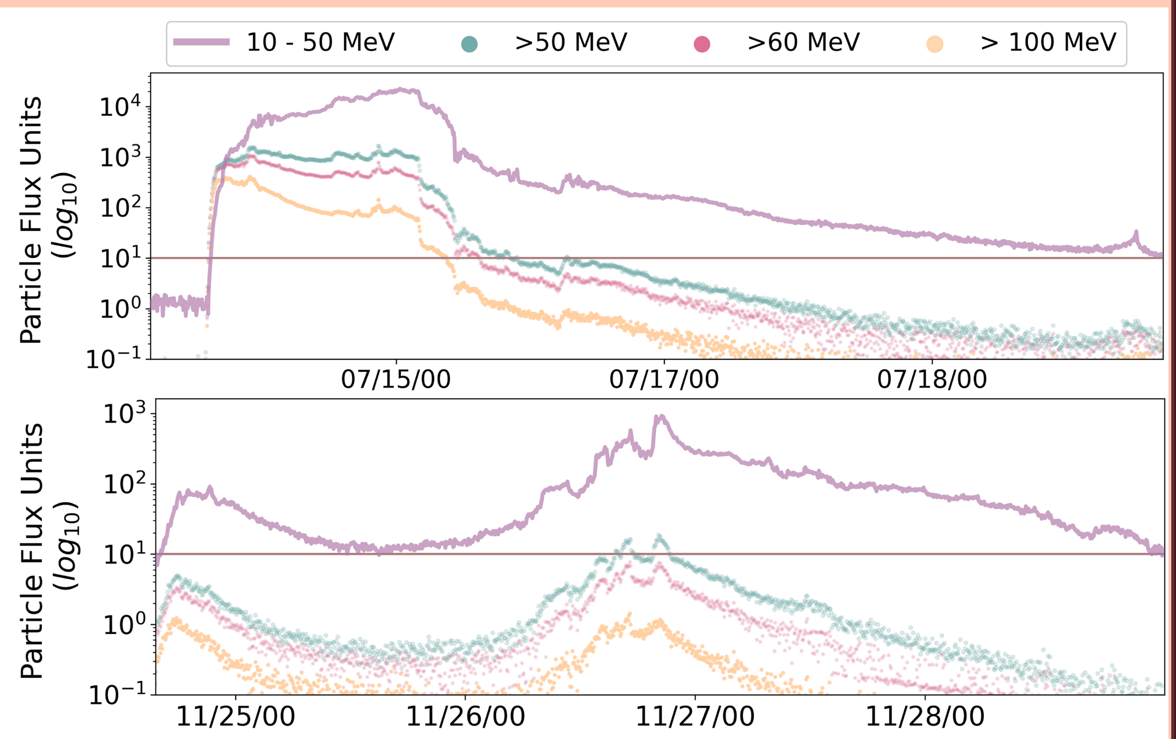

Fig 3: Examples of (top) contaminated and (bottom) non-contaminated GOES SPE flux data.

	PCC		Kτ	
	SC 23	SC 24	SC 23	SC 24
i	-0.13	-0.19	0.12	0.11
ii	0.14	0.30	0.14	0.33
iii	0.12	0.08	0.08	0.05

Table 2: PCC and Kτ for each relationship; none indicate a significant relationship between variables.

CORRELATION COEFFICIENTS

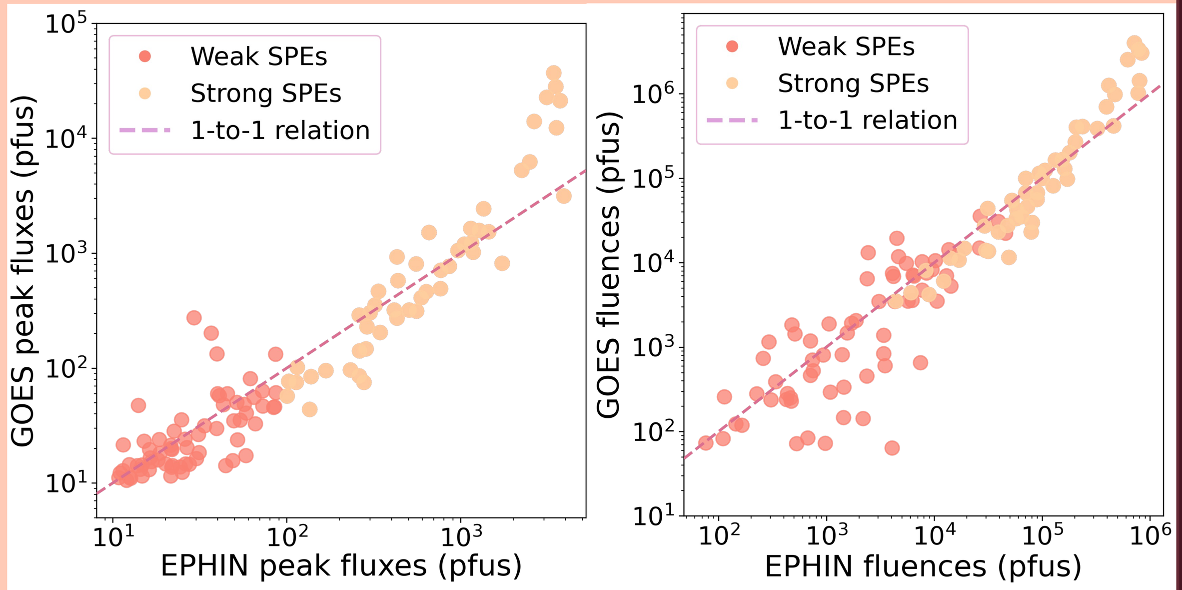

Fig 4: GOES (left) peak flux and (right) fluence detections compared to EPHIN.
'Strong' events are those where SPE peak fluxes > 100 pfu.

Evaluating potential influence of external factors on flux measurements at each location, we calculate (and present in *Table 2*) the Pearson Correlation (PC) and Kendall τ (Kτ) coefficients for:

i. SPE fluence detected by EPHIN relative to GOES.

ii. Local magnetic pressure at GEO relative to particle ratios between GOES and EPHIN.

iii. GOES data contamination relative to its position in the geocentric solar ecliptic system.

Additionally, we examined deviations in SPE measurements following the arrival of interplanetary shocks at L1, but found no significant results.

DISCUSSION

Thus far, our analysis of SPE properties during SCs 23 & 24 comparing cis-lunar and GOES flux data highlight:

❖ Flux contamination often results in GOES detecting SPE onset and peak fluxes earlier than EPHIN.

❖ To assess possible influence, interplanetary shocks from CMEs were examined for selective enhancement of GOES fluxes without affecting EPHIN, but no correlations were identified.

❖ Analyzed GOES locations for flux contamination patterns, but no clear trend was found.

❖ Excluding contaminated GOES events, SPEs detected at L1 and GEO exhibit similar properties and trends across different parameters *(see Table 3)*.

❖ PC and Kτ analyses showed no significant relationship between the variables in Table 2.

DISCUSSION

❖ ~75% of SPEs show a GOES-to-EPHIN peak flux ratio < 1, potentially indicating magnetospheric shielding effects on GOES detections.

		EPHIN	GOES	Greater / Earlier detection
SC 23	Initial flux (~pfu)	11	11	GOES
	Peak flux (~pfu)	63	57	GOES
	Fluence (~pfu)	8,700	7,400	GOES
	Δ Start time (mins)	50		GOES
	Δ Peak time (hrs)	~1.4		GOES
	Δ End time (hrs)	~2		GOES
	Δ Duration (hrs)	~1		EPHIN
SC 24	Initial flux (~pfu)	11	11	EPHIN
	Peak flux (~pfu)	85	60	EPHIN
	Fluence (~pfu)	16,500	12,200	EPHIN
	Δ Start time (hrs)	~1.3		GOES
	Δ Peak time (hrs)	~2.4		GOES
	Δ End time (hrs)	~2.8		GOES
	Δ Duration (hrs)	~4		EPHIN

Table 3: Median Properties of SPEs detected by both GOES and EPHIN across SCs 23 & 24.

GOES FLUX RECONSTRUCTION

Based on the similar SPE trends in *Table 3*, we are developing a proxy for uncontaminated GOES flux data.

We are refining Random Forest and eXtreme Gradient Boosting regressors to reconstruct GOES fluxes where contamination is present, using EPHIN fluxes as the target due to their general similarity.

Our goal is to quantify contamination levels and adapt flux reconstruction model to correct the GOES proton flux data set.

We will also explore dynamic time warping to analyze time shifts in SPE detections between EPHIN and GOES.

Despite a 5-minute data retrieval cadence, these time shifts *are* noticeable in several events and could be utilized to enhance flux reconstructions.

Implementing these adjustments to the GOES flux dataset will enable more accurate event analysis and improve SPE comparisons between EPHIN detections at L1 and GOES detections at GEO.

ACKNOWLEDGEMENTS

We thank Bernd Heber and Arik Posner for their insights and suggestions on adjusting EPHIN data for analysis.

This research is supported by NASA ESI grant 80NSSC20K0302, NASA HITS grant 80NSSC22K1561 & NSF FDSS grant 1936361.