Comparison of real-time and historical solar flare catalogs

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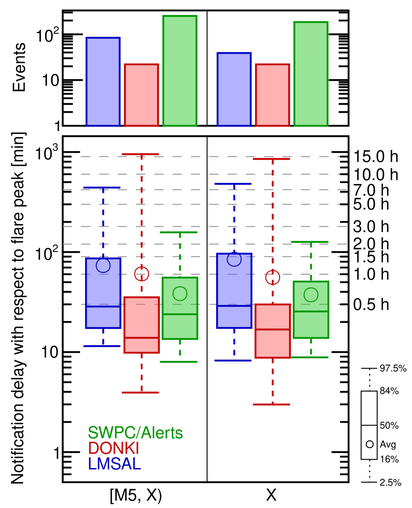
Timely forecasts of solar energetic particles (SEPs) at various locations are crucial to improve the protection of astronauts from radiation hazards during deep space missions.
Solar flare properties are one of the key input to SEP forecast models.
For this reason, prompt flare detection and characterization are needed to ensure astronauts have enough time to take shelter in their spacecraft/habitat before the bulk of the SEPs reach their location.
In this work, we review and compare various publicly accessible services providing near real-time flare alerts and summaries.
We analyze the delay between the time of the flare occurrence and the time its information is published.
We also study the accuracy of various flare properties required for SEP forecasting, such as peak flux intensity and location on the solar surface, by comparing their near real-time estimates derived from operational-ready data with measurements performed on science-quality data.

Catalogs used in this study

Provider	Product	Flare Time Start, Peak, Stop	Issue Time	Flare GOES Class	Active Region	Flare Location	Type	Format	Date Range
SWPC	Events	X-rays	No	Yes	≈65%	Hα ≈35%	Real time	txt	2023/01/25 – 2023/04/14
							Historical	txt	1996/07/31 – 2023/04/14
	Edited Events	X-rays	No	Yes	≈80% 2023 only	Hα ≈45%	Real time	JSON	2023/01/25 – 2023/04/14
	Alerts	X-rays	Yes	⩾M5	No	Hα Summary only	Real time	JSON-wrapped txt	2023/03/21 – 2023/04/14
							Historical	txt, HTML	1997/09/24 – 2023/04/14
	L2 GOES-16	X-rays	No	Yes	No	GOES-R XRS ≈75%	Real time	NetCDF	2023/03/21 – 2023/04/14
							Historical	NetCDF	2017/02/09 – 2023/04/14
	L2 GOES-17	X-rays	No	Yes	No	GOES-R XRS ≈80%	Real time	NetCDF	–
							Historical	NetCDF	2018/06/01 – 2023/01/10
LMSAL	Latest Events webpage	X-rays	No	Yes	≈80% 2023 only	EUV	Real time	HTML	2023/01/25 – 2023/04/14
	HER API	X-rays	Yes	Yes	≈75%	EUV	Real time	JSON	2023/01/25 – 2023/04/14
							Historical	JSON	2003/09/25 – 2023/04/14
DONKI	Events API	X-rays	Yes	Yes	≈75%	EUV ≈90%	Real time	JSON	2023/01/25 – 2023/04/14
							Historical	JSON	2010/04/03 – 2023/04/14
SIDC	Solar Demon webpage	EUV + X-ray peak	No	EUV-derived + GOES	≈70%	EUV ≈80%	Real time	HTML	2023/01/25 – 2023/04/14
							Historical	HTML	2010/05/13 – 2023/04/14
	Solar Demon ESA-SWE	EUV	No	EUV-derived	No	EUV	Real time	JSON	2023/03/21 – 2023/04/14
							Historical	JSON	2022/10/05 – 2023/04/14

Flare delay from historical catalogs



Flare peak observation is needed to determine the peak flux, hence the relevant delay for SEP modeling is between the peak time and issue time.
There is a clear decreasing trend in the delay as function of increasing flare class: weaker flares have median delays of around 1 hour or more. However, these flares are associated with small low-energy SEPs, which are not a source of radiation hazard.
No significant trend is observed in the delay as function of flare latitude and longitude.

	A	B	C	M	[M5, X)	X
SWPC Alerts[a]	# flares median delay 68% interval	–	–	–	252 24m 14m – 53m	185 25m 14m – 52m
DONKI[b]	–	12 51m 30m – 19h 46m	63 3h 41m 44m – 19h 25m	218 50m 12m – 8h 54m	22 14m 10m – 34m	22 17m 9m – 29m
LMSAL[c]	1364 4h 38m 2h 8m – 9h 21m	9097 1h 10m 25m – 4h 34m	9496 41m 20m – 3h 36m	780 27m 18m – 1h 53m	84 27m 17m – 1h 22m	39 27m 17m – 1h 31m

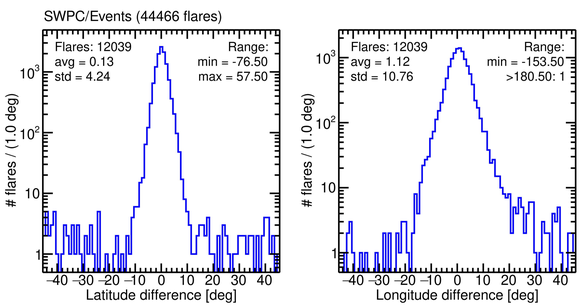
[a] Flare selection: only summaries.
[b] Flare selection: flare time within DONKI operators working hours; delay less than 1 day.
[c] Flare selection: delay less than 1 day.

Flare delay from real-time catalogs

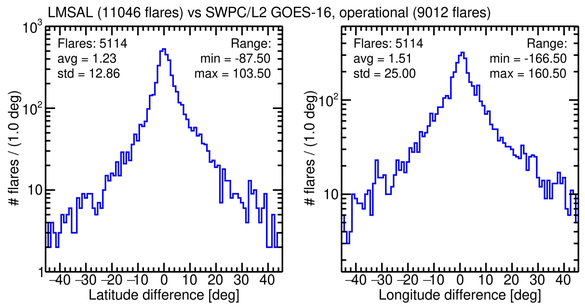
	All classes			⩾M5		
	# flares	Median	68%	# flares	Median	68%
SWPC/Events	567	1h 25m	32m – 3h 51m	10	33m	17m – 1h 4m
SWPC/Edited Events	633	1h 28m	32m – 4h 5m	11	32m	17m – 1h 26m
SWPC/Alerts	2	29m	–	2	29m	–
SWPC/L2 GOES-16	162	22h 50m	15h 11m – 1d 13h	2	1d 10h	–
LMSAL/Web	1044	23m	15m – 3h 9m	13	19m	13m – 1h 3m
LMSAL/API	1021	1h 13m	17m – 5h 34m	12	1h 4m	13m – 10h 58m
DONKI	52	25m	13m – 16h 33m	8	15m	13m - 16m
SIDC/Web	1291	20m	17m - 34m	7	18m	16m - 33m
SIDC/ESA-SWE	345	46m	35m – 1h 2m	1	44m	–

Flare location

SWPC Events and Edited Events provide a location derived from Hα for less than half of the flares. However, most of the flares are associated with an active region. The flare location can then be derived by rotating the active region center (published by SWPC at midnight) to the position corresponding to the flare time.
This procedure yields an almost unbiased location with a precision of 4 deg in latitude and 11 deg in longitude.

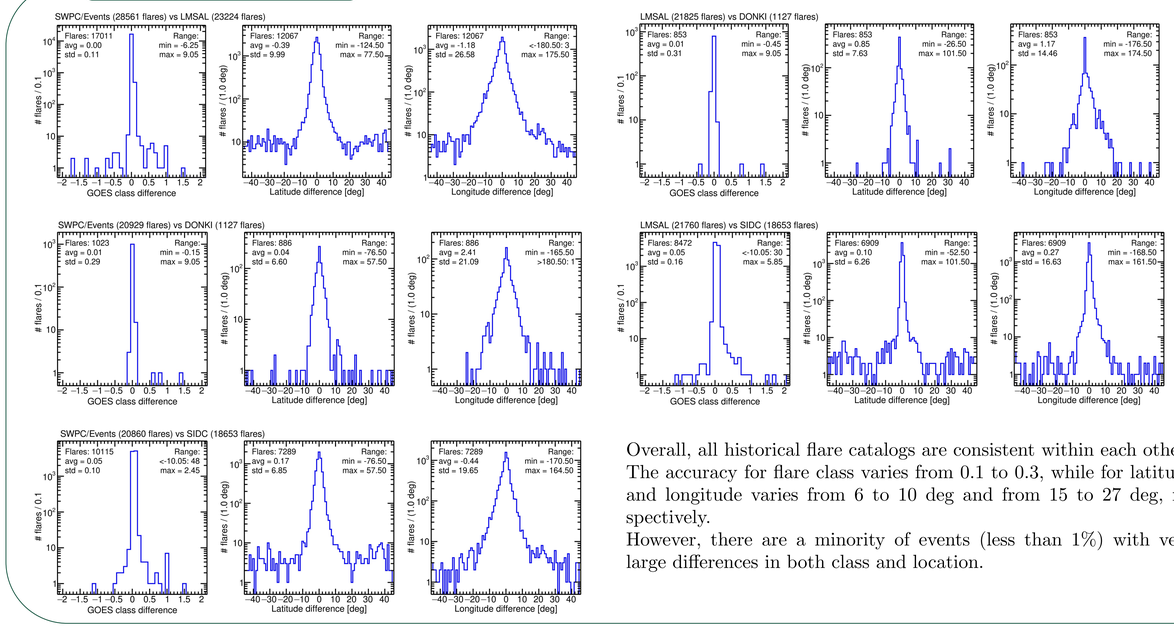


LMSAL catalog was mainly developed to associate a location to all SWPC Events flares, using SDO/AIA as a primary imaging source.
GOES-R XRS L2 data products include the location estimated by the quad diode of the X-ray sensor. The calibration of this product was done on LMSAL catalog.
The agreement between the XRS- and SDO-derived latitude and longitude is 13 and 25 deg, respectively.



Note: flares are matched by requiring that the peak time in LMSAL and SWPC are the same. The figure doesn't qualitatively change by using a narrow temporal window (up to 3 min), by using L2 science data, and by using GOES-17.

Cross-catalog comparisons



Overall, all historical flare catalogs are consistent within each other.
The accuracy for flare class varies from 0.1 to 0.3, while for latitude and longitude varies from 6 to 10 deg and from 15 to 27 deg, respectively.
However, there are a minority of events (less than 1%) with very large differences in both class and location.