The Source & Precursors of the September 2017 SEP events

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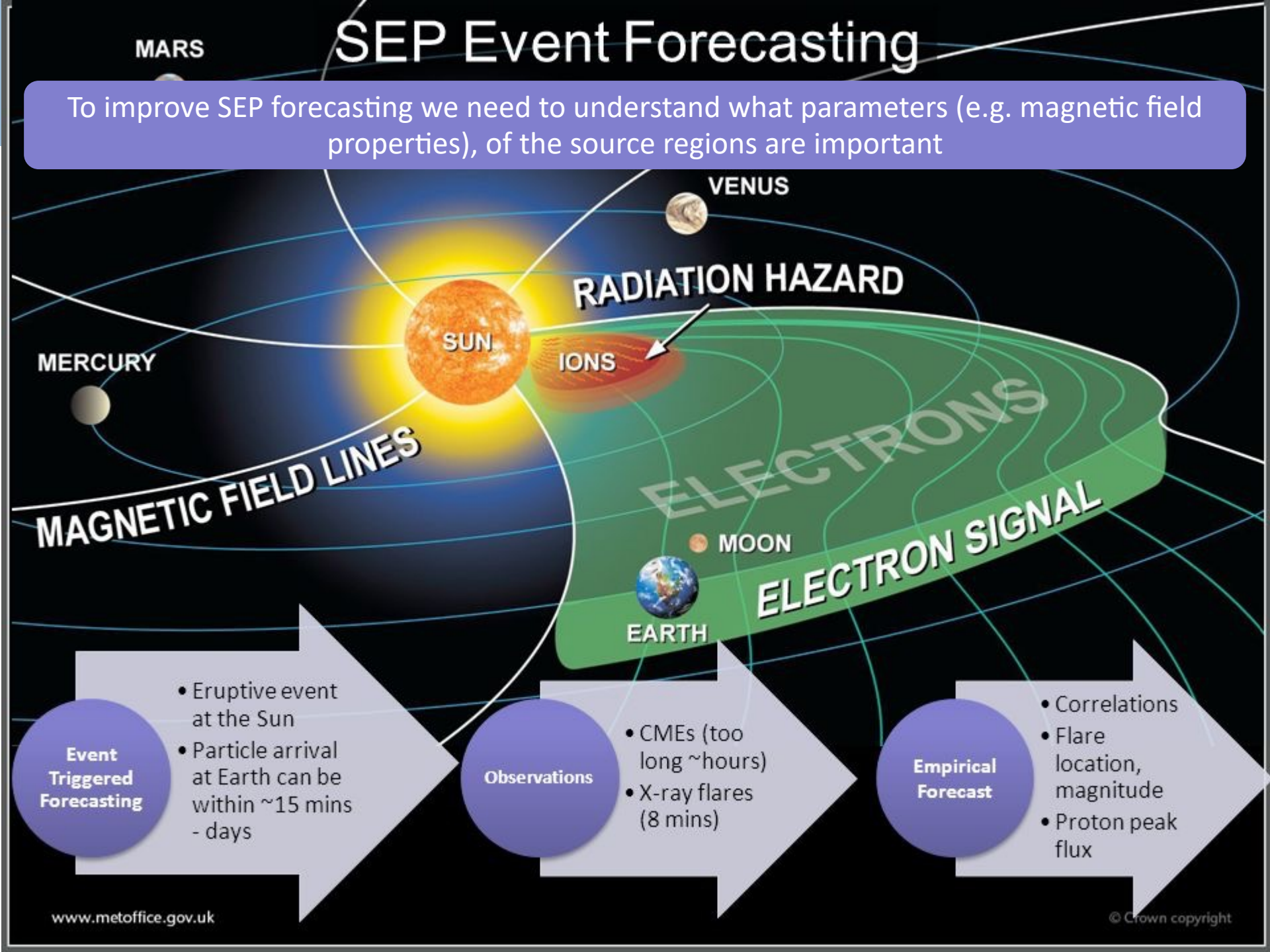
SEP Event Forecasting

To improve SEP forecasting we need to understand what parameters (e.g. magnetic field properties), of the source regions are important



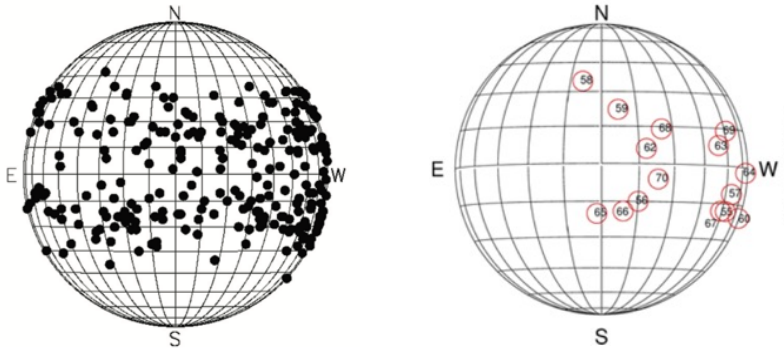
Source Regions: What do we know so far?

	GLE regions	SEP regions	δ regions (no SEP)
Sunspot area (microhemispheres)	1102 ± 621	633 ± 476	646 ± 303
Total USF (AR) (10^{22} Mx)	11.9 ± 5.1	9.0 ± 4.4	9.5 ± 3.5
Total USF (PIL) (10^{21} Mx)	4.9 ± 2.8	3.5 ± 2.4	2.7 ± 1.3
Net flux (AR) (10^{22} Mx)	1.5 ± 0.7	1.7 ± 1.6	1.2 ± 1.0
Separation (10^{9} cm)	3.8 ± 2.1	4.7 ± 2.6	7.0 ± 2.7

Nitta et al. 2012

Higher frequency
Western SEP events
W70-90

Papaioannou et al. (2016)



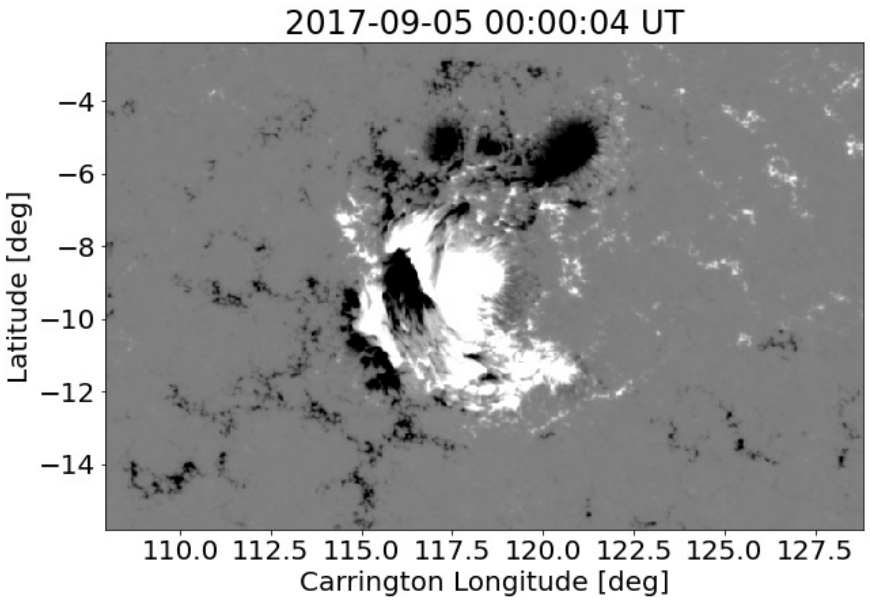
Highest fluence
GLEs
E20-W100

Gopalswamy et al. (2012)

GLEs: super ARs, larger but more compact ARs, larger initial CME acceleration
Significant radiation risk: strong, long duration flares, CME speed, central source

Young, large, complex ARs (usually $\beta\gamma\delta$, Mcintosh "K" class)
> M class flares
Fast, wide CMEs (1000 km/s+, Full Halos)
Prior activity i.e. multiple CMEs in quick succession
Longitudinal preference
Well-connected longitudes

Case Study AR 12673: Eruptive Events



SEP productive events: 4th & 6th September 2017

GLE: 10th September 2017

Non-SEP productive events

SHARPs quantities showed no obvious trend

(previously used for flare & CME forecasting e.g. Bobra & Couvidat 2015; Bobra & Illondis 2016)

SEPs/GLE associated with:

Halo CMEs, v > 2000 km/s

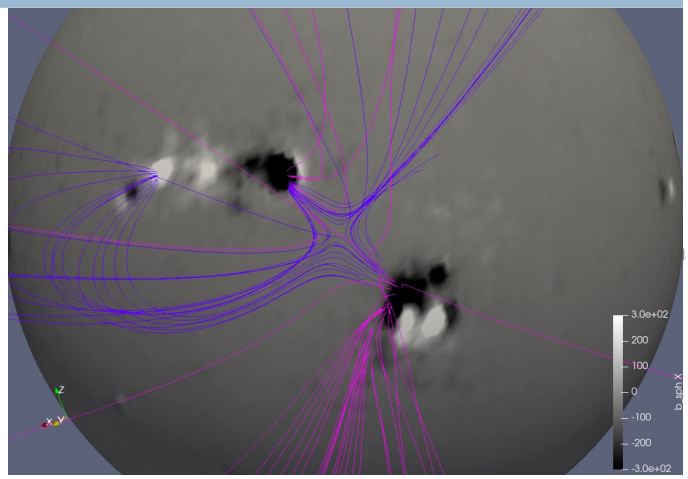
M> class flares

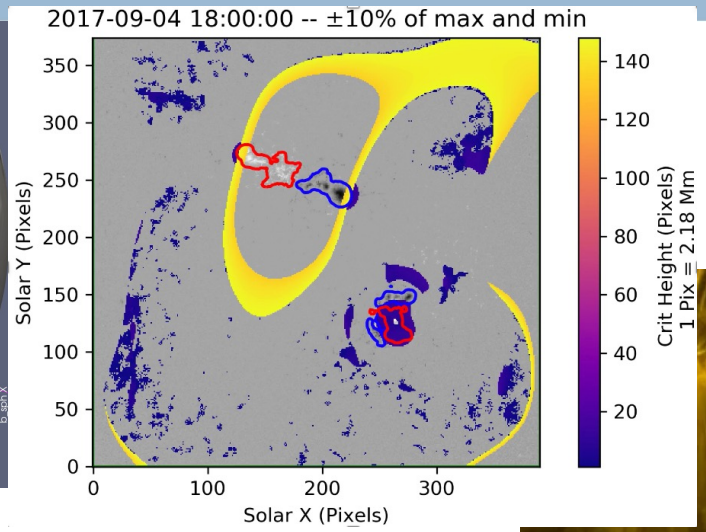
Large-scale coronal disturbances

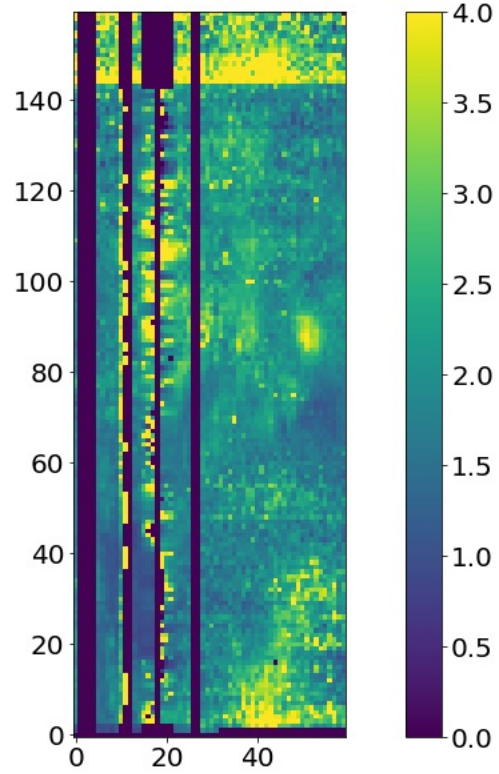
< 60 degrees

No	CME Start Time	LASCO Start Time	PA width	v	v_r	a	Lat	Lon	Flare Start Time	Flare Peak Time	Flare End Time	GOES Flare Class	Large-scale Disturb.	SEPs
1	2017/09/04 18:05	19:00	205>	597	1133	52.9	-7	11	18:12	18:21	18:28	M1.0	N	N
2	2017/09/04 20:00	20:36	Halo	1418	2061	47.5	-10	11	20:12	20:32	20:37	M5.5	Y	Y
3	2017/09/06 11:56	12:24	Halo	1571	2328	-0.3	-9	34	11:52	12:01	12:10	X9.3	Y	Y
4	2017/09/07 14:33	15:12	58	433	436	-9.9	-8	48	14:31	14:36	14:53	X1.3	Y	N
5	2017/09/09 22:18	23:12	138	1019	1031	-18.6	-9	88	22:02	23:53	00:40	M1.2	Y	N
6	2017/09/10 15:38	16:00	Halo	3163	3708	-232	-9	88	15:38	16:05	16:30	X8.2	Y	Y

Case Study AR 12673: Coronal Configuration





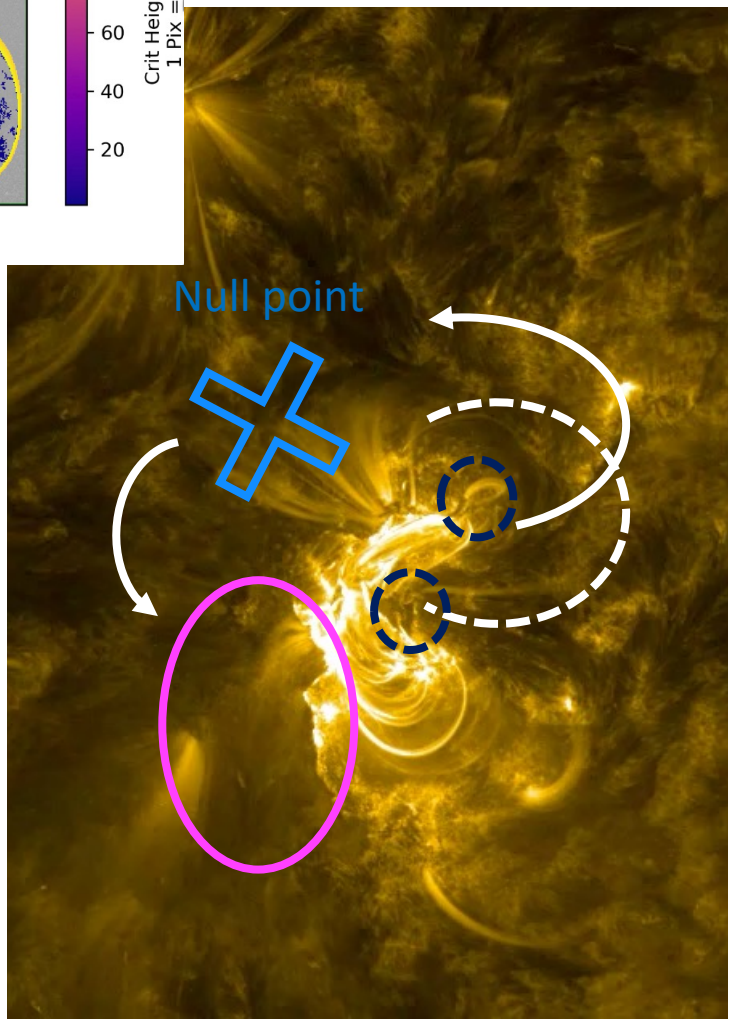


SEP eruptions originate from regions where there is an elevated Si/S abundance ratio (see Brooks & Yardley, 2021)

SEP eruptions propagate into null point and open field

Minimum critical height at location of eruptions, null point and open magnetic field

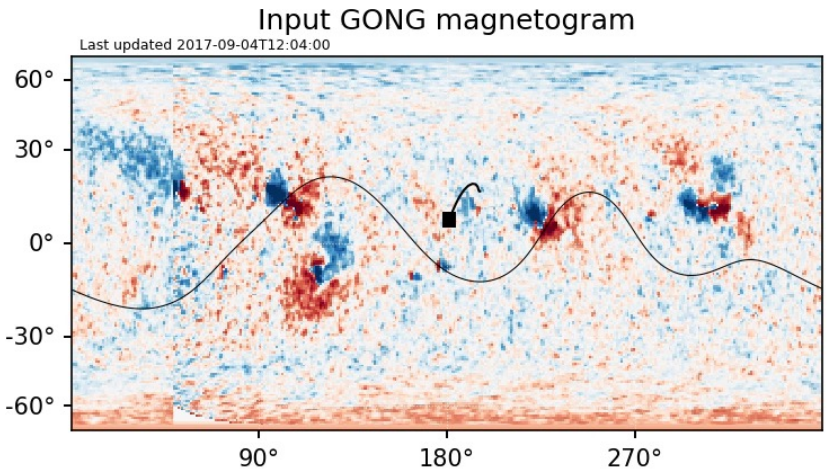
Example: SEP Event on 04/09/2017 at 20 UT

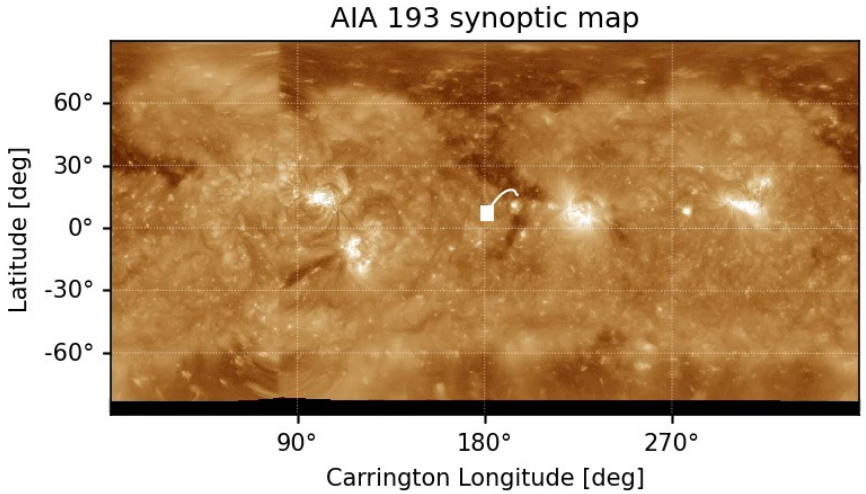


Case Study AR 12673: Magnetic Field Connectivity

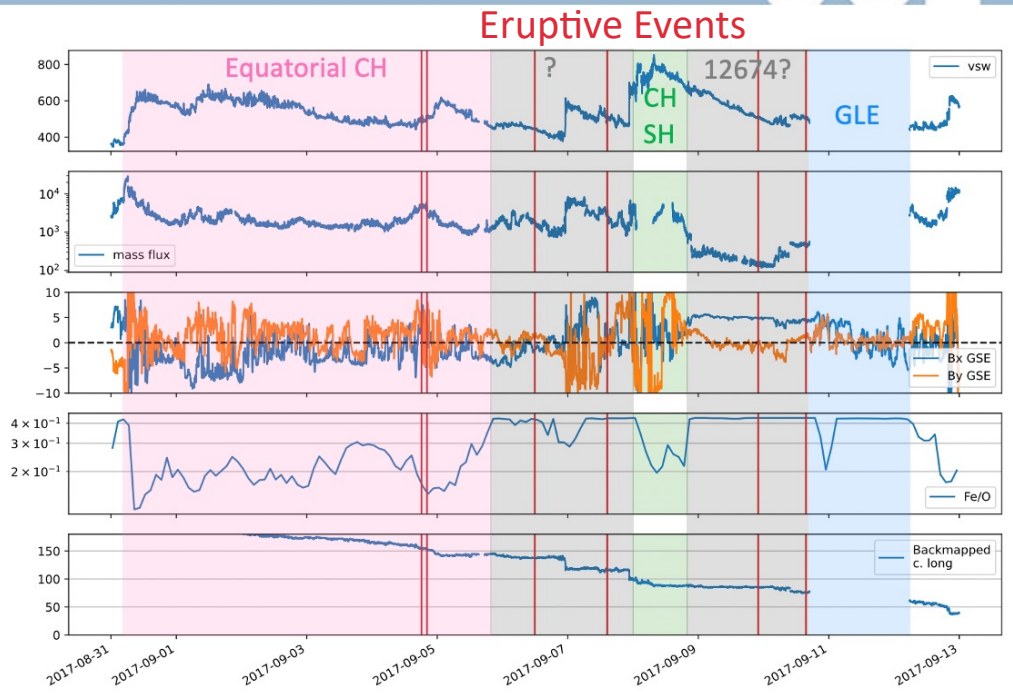
4th - 10th September 2017

2017-09-04 12:00:00





■ Earth



SEP events 4-6th: Earth footpoint connected to coronal hole on farside, CMEs & EUV waves propagate in this direction

GLE on 10th: AR 12674 (north of AR 12673) well connected to Earth

Adjacent to open magnetic field and null point configuration

Summary & Future Work

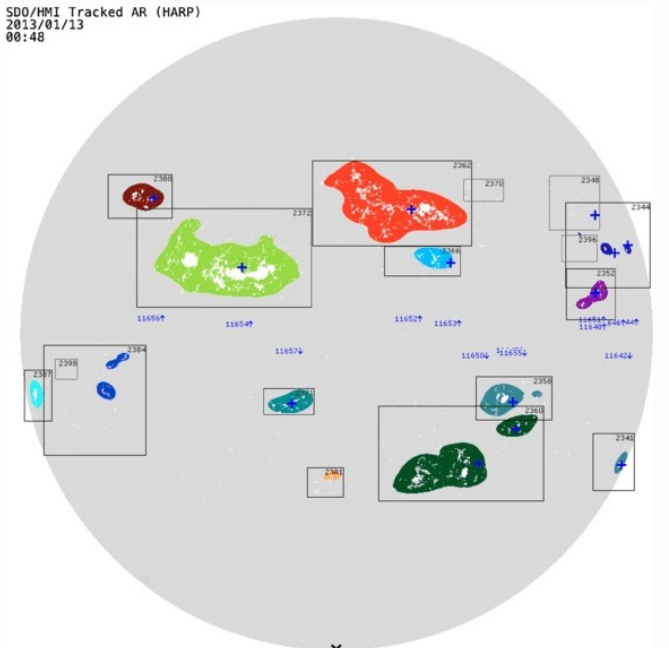
AR 12673 Case Study

Analysed photospheric, coronal magnetic field configuration & connectivity using PFSS modelling

Presence of null point and open field

Earth footpoint connected to coronal hole on farside into which CMEs & EUV waves propagate

Next: EIS composition data, gamma ray & hard x-ray spectra, radio data, EUV Waves/disturbances



Statistical Study

30 source regions from Solar Cycle 24

Assess capabilities SHARPs parameters: are they appropriate for SEP forecasting?

Extend survey to include SC 23 using line-of-sight parameters with SMARPs (SOHO/MDI)