

Summary Report: ISEST WG-4 on Campaign Events

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ISEST 2018 Workshop

Hvar, Croatia

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WG-4 Goals

- Integrate observations, theory and simulations to understand chain of cause-effect dynamics from Sun to Earth/1 AU for carefully selected events.
- Develop/improve the prediction capability for these transients' arrival and their potential impacts at Earth.
- Textbook cases are provided for the community, but a focus is on less well understood events, such as stealth & problem CMEs.
 - WG 4 wiki: http://solar.gmu.edu/heliophysics/index.php/Working_Group_4
- **Textbook** cases: Complete chain of a well-observed event from solar source, through IP propagation, to geoeffects.
- Not Textbook but **Understood** cases: Something is missing in the chain of a well-observed event but, *in retrospect*, we understand why.
- **Problem** cases: The chain is not complete and we still do *not* understand why.

ISEST / MiniMax WG-4 Event List

Dates	Source	Geo-response*	Dst *	Kp/G Level	Forecast Success (SWPC)
VarSITI-wide Campaign Study Events					
1) 2012 July 12-14	X1 flare, wave, fast CME	Shock, MC, Strong storm	-127	7/G3	Mostly successful
2) 2012 October 4-8	CME; weak surface signs.	Shock, MC, HSS, Moderate stm	-105	6+/G2	Under-predicted
3) 2013 March 15-17	M1 fl, wave, EF, IV, fast halo	Shock, MC? SEP, Strong storm	-132	6+/G2	
4) 2013 June 1	Slow CME on 27 May? CH influence?	Cause of Strong stm unclear; CIR?	-119	7/G3	Failed-not pred.
5) 2015 March 15-17	C9;C2 fl, wave, EF, fast CME	Shock, sheath, MC, Severe storm	-222	8+/G4	Under-predicted
6) 2015 June 22-24	2 M-fls, waves, fast halo CMEs	Shock, sheath, MC, SEP, Severe storm	-204	8+/G4	Mostly successful
Other ISEST/MiniMax Study Events					
7) 2012 March 7-9	X5 flare, wave, fast CME	Shock, MC, Strong storm	-131	8/G4	
8) 2012 July 23-24	2 flares? Wave, EFs	Extreme ST-A event; " Strong storm " (Carr.-type)	---		
9) 2014 January 6	CME <2000 km/s, over WL	GLE at Earth	No	---	
10) 2014 January 7-9	X1 fl, wave, fast asym halo	Shock, SEP. No storm- CH deflection; AR channeling?	No	≤3	Failed-pred.;no str
11) 2014 Sept. 10-13	X2 flare, wave, sym halo	Shock, MC, Moderate storm	-88	7/G3	Over-predicted
12) 2015 January 3-7	Slow CME	Brief ICME, MC, HSS, Mod. stm	-99	6+/G2	
13) 2016 October 8-12	Slow CME	Shock, MC, HSS, Moderate stm	-104	6+/G2	
14) 2017 Sept 4-10	Series; M5,X9,X8, etc.	Shocks, MCs, Strong stm(s) , FD	-124	8/G4	

CME = coronal mass ejection; AR = active region; EF = erupting filament; CH = coronal hole; MC = magnetic cloud; SEP = solar energetic particle event; CIR = corotating interaction region; GLE = ground-level event; HSS = high speed stream
 Dst* = Kyoto Dst as of 19 Sept. 2018

xx) Events featured in Webb & Nitta (2017)

xx) Problem events featured in Nitta & Mulligan (2017)

Campaign Event Issues Studied by WG-4

- Why do forecasts fail and how can we improve them?
- Complications linking CMEs to ICMEs:
 - Field line reconnection (e.g., interchange)
 - Interactions in low corona or solar wind (other CMEs; ambient fields),
 - Deflections (e.g., CHs)
 - Rotations of CMEs/Flux ropes
 - Predicting out-of-ecliptic magnetic fields is difficult
 - ~20% of important geostorms have CMEs-ICMEs but no *compelling* low corona signatures (LCS) or at Sun's surface
 - 10% are due to CIR-HSSs
- Combinations of events with IP shocks, including within CMEs, sheaths and multistep storms → “compound events”.
 - Studies of *shock sheaths* in particular need more attention
 - Includes coronal loops/plasma ahead of CME and ambient solar wind
Difficult to predict these magnetic fields

Presentations noted this Week that included WG-4 & Other Specific Events

- Talks
 - C. Shen (invited): Modeling CME interactions and their effects on space weather (**Sept. 2017** event)
 - O. Malandraki (WG6): SEP events incl. **Sept. 2017**
 - J. Guo: **Sept. 2017**, 1st GLE seen at 2 planets! Modeled interactions and transport of 3 Cmes over 2+ days
 - Meng Jin (invited): Sun-Earth modeling & forecasting of 4 CMEs, inc. **Sept. 2017**. SWMF + Gibson-Low FR models.
 - I. Dammasch: LYRA spectra of X9.3 flare on **6 Sept. 2017**
 - S. Heinemann: CH-AR interaction with 21 June 2011 CME
 - Camilla Scolini: (invited): Observations & modelling with EUHFORIA of geoeffective 3 Campaign CMEs: 12 July 2012, 13 Mar 2013, **10 Sept 2017**. Modeling even “textbook” events have problems, esp. FR.
 - T. Podladchikova: Kinematics of EUV wave, dimmings and bubble of CME and X8.2 flare on **10 Sept. 2017**. Fast lateral expansion.
 - J. Seibeleder: Dynamics of slow, limb 13 June 2010 CME
- Posters
 - B. Heber: GLE from the X8.2 Flare on **10 Sept. 2017**
 - M. Savic: Forbush decrease on **8 March 2012**

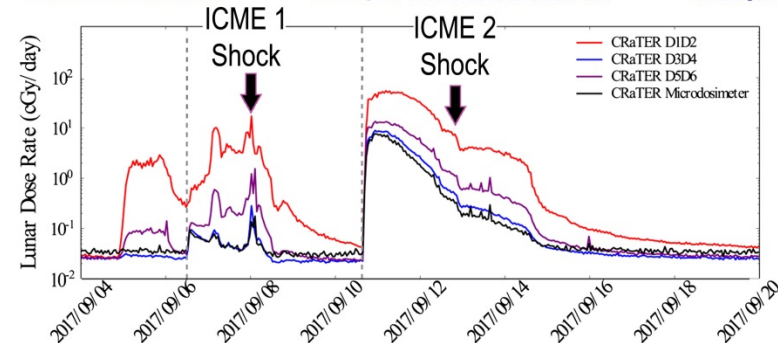
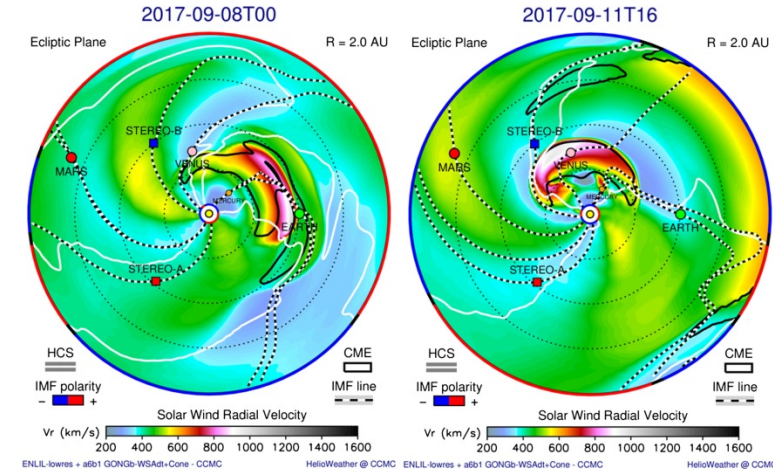
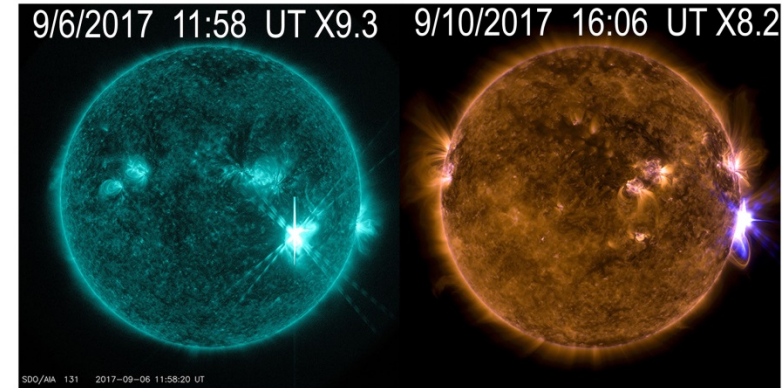
SWx Events of 4-12 September 2017

- *Space Weather Journal Special Section (2018)*
- One of most flare-productive periods of SC 24.
- Solar ARs 2673 and 2674 both matured to complex magnetic configurations as they crossed disk. AR 2673 → simple sunspot on 2 Sept. to complex AR with rapid growth on 4 Sept. ARs had 4 X-class flares, multiple partial halo CMEs, & both ARs > dozen M-class flares.

Table 1
Summary of Space Weather 4–13 September 2017^a

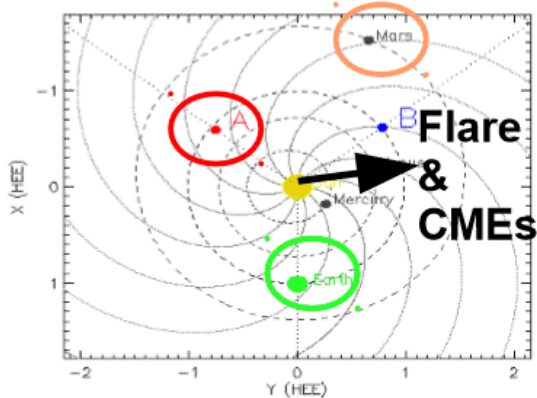
(1) date	(2) Flares ≥M5 (begin)	SWPC storm scales alerts					(7) CME earthward
		(3) Radio (1–5)	(4) SEP (1–5)	(5) G (1–5)	(6) 2 MeV e-		
4 September	M5.5 (20:28)	R2			Yes	Ejected (CME0)	
5 September			S2	G1	Yes		
6 September	X2.2 (08:57) X9.3 (11:53)	R3	S2		Yes	Arrived (CME0) Ejected (CME1)	
7 September	M7.3 (10:11) X1.3 (14:20)	R3	S2	G3	Yes		
8 September	M8.1 (07:40)	R2	S2	G4	Yes	Arrived (CME1)	
9 September					Yes		
10 September	X8.2 (15:35)	R3	S3, Yes GLE72		Yes	Ejected (CME2)	
11 September					Yes		
12 September			S2	G1	Yes	Arrived (CME2)	
13 September			S1	G1			

Redmon et al., SWx, 2018



Schwadron et al., SWx, 2018

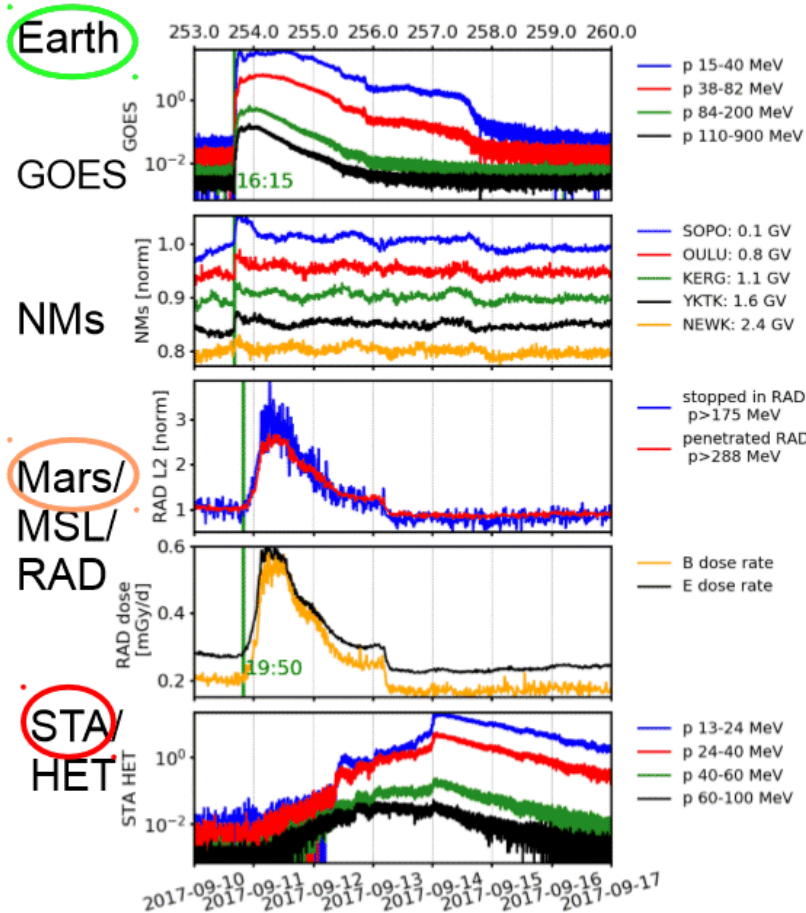
J. Guo talk



The first GLE observed on two planets: 2017-09-10 event with SEPs (>100 MeV) arriving at Earth, Mars and STEREO-A

Earth

- The onset of protons > 100 MeV seen by GOES at Earth is at about **16:15** on 2017-09-10.
- SEPs were also registered as a ground level enhancement (GLE) seen by multiple neutron monitors with cutoff rigidities of about 3 GV (~2 GeV protons)



Mars

- Mars magnetic foot point is ~150 degrees from the flare.
- The earliest onset at Mars is about **19:50** and this has been the biggest GLE at Mars seen by the Radiation Assessment Detector (RAD) since the landing of the Curiosity rover.
- Considering the atmospheric cutoff and the RAD detector response function, particles with > ~300 MeV arrived at Mars.
- *We are working on retrieving the SEP spectra at Mars on top of the atmosphere from surface measurement.*

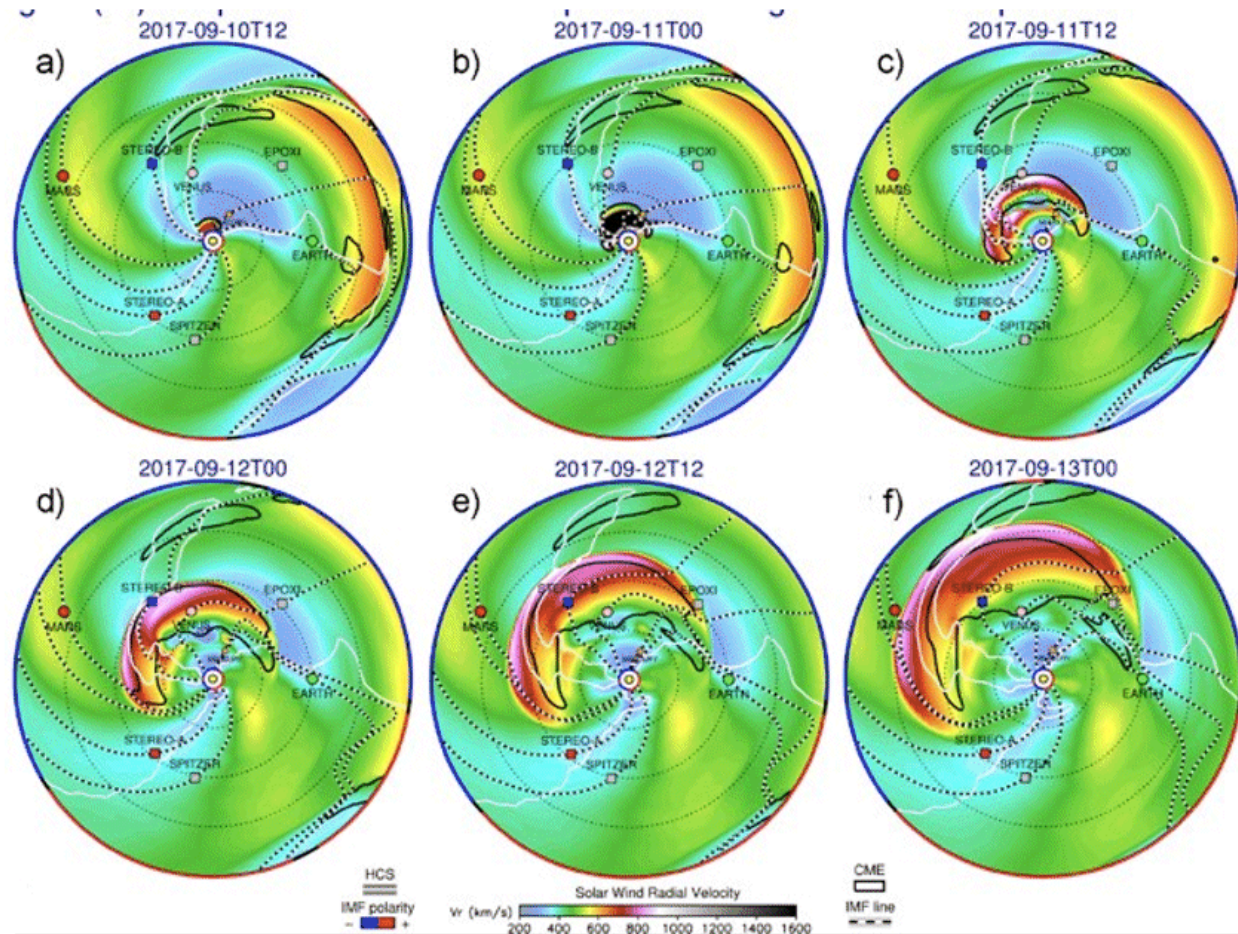
STEREO-A

- STA foot point is >~200 degrees away from flare and still detected particles ~ 100 MeV.
- The SEPs arriving at STA are likely transported there across Interplanetary Magnetic Field (IMF) lines via diffusion and scattering as STA was at the back side of the flare and CME shock.

J. Guo talk

Modeling the Propagation of the ICME event

- The ICME driven shock reached Earth at 18:30 on 12 September ~50.5hr after launch.
- The ICME hit Mars ~59 hr after launch at 02:50 UT on 13 September 2017
- Using input parameters of only the 3rd (the one associated with the GLE event), neither WSA ENLIL+Cone nor DBM could predict the correct arrival time at both planets.
 - The interplanetary propagation conditions (SW speed and the drag force) are different in two directions.
 - In particular, the interaction of the 3 CMEs in the direction of Mars changed the kinematics of the ICME propagation.
 - Towards Earth, the shock is not driven by an ejecta.

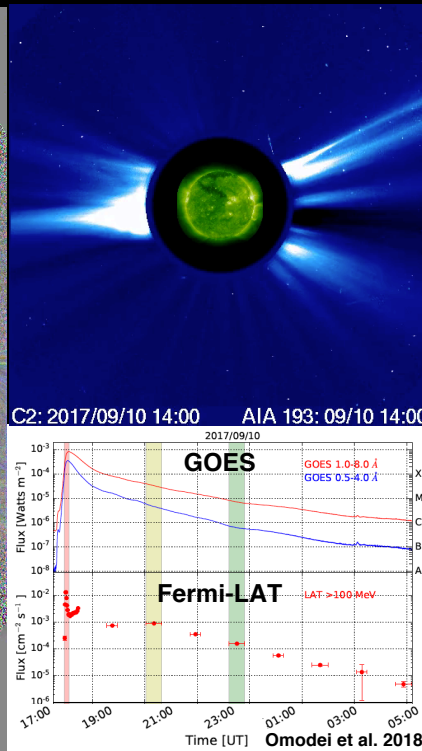
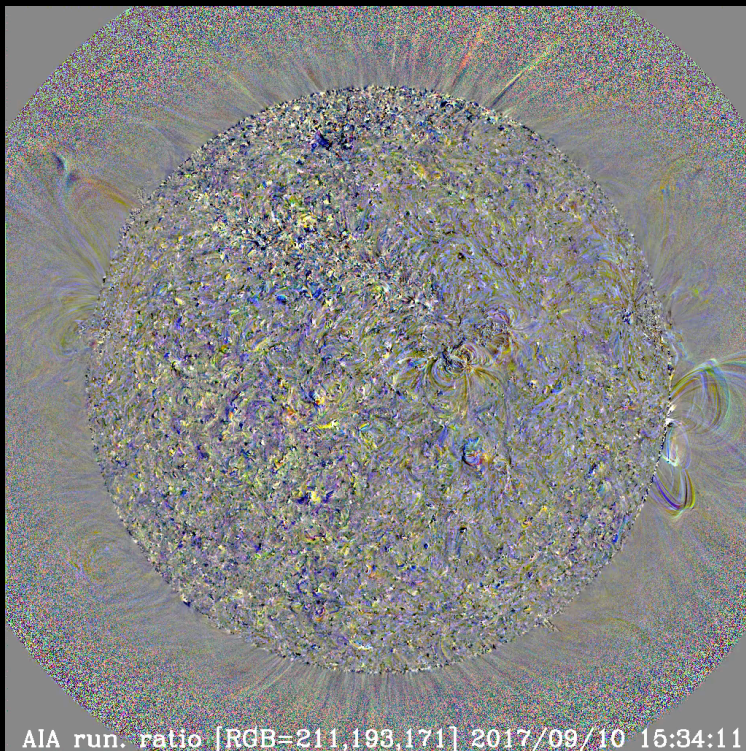


Input 3 CMEs with tweaked SW parameters into the ENLIL model could finally match with in situ obs.

Ming Jin: CME Events

- In this talk, we will present four realistic CME events simulation, following each event, we focus on different physical processes during the CME evolution from the Sun to 1 AU.
- **Event I: 2017 September 10 (New Campaign Event)**
 - Global EUV waves [**Impulsive Phase**]
- **Event II: 2011 February 15**
 - Coronal Dimming [**Impulsive Phase, Residual Phase**]
- **Event III: 2014 September 1 (Fermi Behind-the-limb Event)**
 - CME-driven shocks, Gamma-ray emission [**Impulsive Phase**]
- **Event IV: 2011 March 7**
 - Shock connectivity and in-situ SEP, CME propagation in the heliosphere [**Residual Phase, Propagation Phase**]

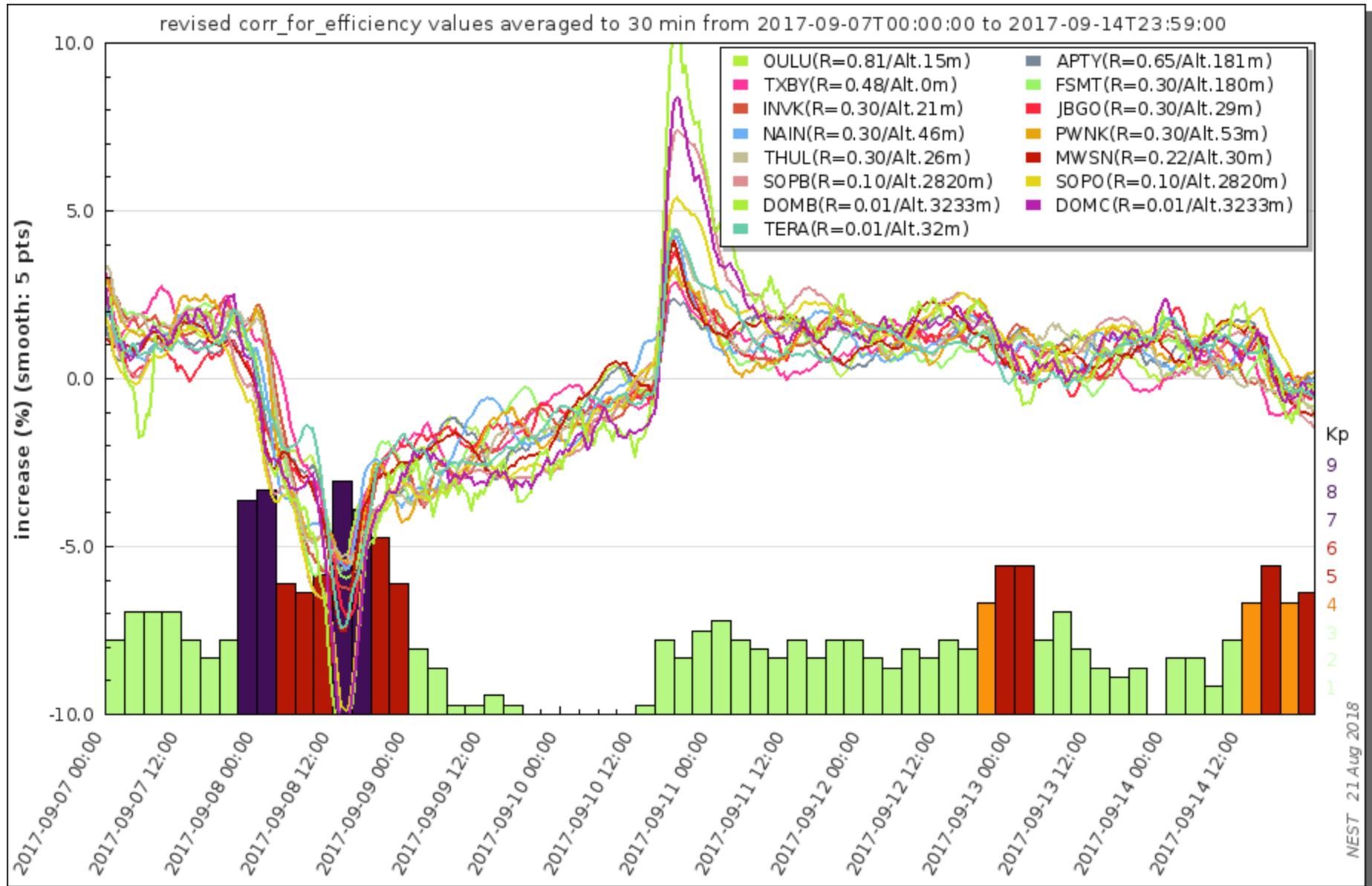
2017 September 10 X8.2 Event



- 2017 September 10 X8.2 flare event is associated with spectacular **global EUV waves** that transverse the **entire** visible solar disk (*Veronig et al. 2018, Liu et al. 2018, Podladchikova et al. 2018*).
- A CME with speed **> 3000 km/s**, which is one of the fastest CMEs ever recorded.
- Solar Energetic Particles (**SEPs**) and Ground Level Enhancement (**GLE**) events at Earth.
- **Fermi-LAT** observed long-duration gamma-ray emission over **12 hours** (*Omodei et al. 2018*).

10-Sep-2017 X-flare ADS list by Peter Young: <https://bit.ly/2Kbzlvb>

B. Haber poster: NM GLE observations of 10 Sept. 2017 event



**Thank all for working on the
Campaign and other events!**



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