# Summary of ISEST Working Group 4 on Campaign Events

**David Webb & Nariaki Nitta**

***Co-leaders***

BOSTON COLLEGE
ISR
INSTITUTE FOR SCIENTIFIC RESEARCH

**ISEST 2018 Workshop**

**Hvar, Croatia**

**24-28 September 2018**

# 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.**

# WG-4 Participants

**David Webb: WG-4 Leader**
**Nariaki Nitta: WG-4 Co-Leader**

***WG-4 Participants:***

**A. Asai, D. Biesecker, V. Bothmer, P. Gallagher, N. Gopalswamy, P. Hess, B. Jackson, E. Kilpua, Y. Liu, N. Lugaz, K. Marubashi, L. Mays, C. Moestl, Monga, T. Mulligan, T. Nieves-Chinchila, D. Odstrcil, S. Patsourakos, L. Rodriguez, B. Schmieder, K. Shiokawa, T. Skov, N. Srivastava, M. Temmer, B. Thompson, Y. Wang, C.-C. Wu, J. Zhang**

# WG-4 Progress

- **Papers:**
  - About 10 WG-4-related papers published on Campaign events – since ISEST established in 2013.
  - Earth-affecting Solar Transients; 2017 Topical Collection of 34 papers in Solar Physics (*Editors: J. Zhang, X. Blanco-Cano, N. Nitta, N. Srivastava*) ~ 6 papers by WG-4 members

- **Presentations:**
  - Initially focused on 1 Textbook (12-14 July 2012) & 1 Problem (4-8 Oct. 2012) event. Now have 14 events posing interesting challenges.
  - Meetings:

| | | |
|---|---|---|
| ISEST #1 | June 2013 | Hvar, Croatia |
| CAWSES-II Sym. | Nov. 2013 | Nagoya, Japan |
| STP13 + ISEST #2 | Oct. 2014 | Xi'an, China |
| SHINE | July 2015 | Stowe, VT, USA |
| ISEST #3 | Oct. 2015 | Mexico City, Mexico |
| VarSITI #1 + ISEST #4 | June 2016 | Albena, Bulgaria |
| VarSITI #2 | July 2017 | Irkutsk, Russia |
| ISEST #5 | Sept. 2017 | Jeju Island, S. Korea |

- Continuing discussion/analysis of events and interpretations:
  - Add comments, data, simulations, etc. to wiki event page - for all WG pages.
  - Update references (Is there a master reference list of ISEST papers?)

# 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? | | | | Failed-not pred. |
| | CH influence? | Cause of Strong stm unclear;CIR? | -119 | 7/G3 | |
| 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?**
  - **Which/whose forecasts should we use for comparisons of event "predictions?**
  - **Solar-heliospheric forecast models (NOAA SWPC, CCMC, UK Met, COMESEP, Affects, 3DMHD, Cone/WSA/Enlil [UCSD])**
  - **Models that try to incorporate magnetic fields (UMICH, SUSANOO, Cone/WSA/Enlil w/spheromaks, etc.)**

- **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**

  - **Interpreting remote sensing observatons: combining views from coronagraphs with Heliospheric Imaging or InterPlanetary Scintillation obs.**

- **Combinations of events with IP shocks, including within CMEs, sheaths and multistep storms → "compound events".**
  - **Studies of shock sheaths in particular need more attention**

- **Flux Rope fitting: intercompare models for events**
  - **Marubashi correlations with source orientation and polarity (tilt)**
  - **PIL or arcade?**
  - **Double ARs**
  - **Trans-equatorial loops/footpoints**
  - **Savani's "model"**

- **Use of other kinds of data: eg, NMs, Cherenkov water detectors, IPS, waves ahead of shocks (SOHO; Posner, etc.)**

# Improving Forecasts *(after Webb & Nitta, SP, 2017)*

- **"Textbook" Event: 12-14 July 2012** *Mostly successful*
  - **Complete chain of well-observed Sun-to-Earth event → from solar source, through IP propagation, to its geoeffects.**

- **Problem Event: 17-18 March 2015** *Under-predicted*
  - **Strength of this first "super storm" under-predicted, but we now understand why.**
  - **2 flares/CMEs occurred at Sun but somewhat offset. CMEs may have interacted.**
  - **During transport there was interaction with a CIR & deflection toward Earth.**

- **Possibly a textbook event: 21-24 June 2015** *Mostly successful*
  - **Forecast of a severe storm was accurate but probably not to superstorm levels.**
  - **Multiple shocks & sheaths, strong $B_S$ MC axial fields, HSS: compound event**

- **Problem Event: 10-12 September 2014** *Over-predicted*
  - **But we think we now understand why.**
  - **Major storm was predicted → strong long-duration MC shock hit Earth.**
  - **However storm was minor → sheath and MC B field were northward**

    ***(Source FR orientation is hard to predict at Sun)***

- **Problem Event: 4-9 October 2012** *Under-predicted*
  - **Source apparently a CME and resulting ICME that drove a small geostorm.**
  - **But there were only weak and multiple surface signatures.**

- **Problem Event: 27 May – 1 June 2013** *Failed prediction*
  - **An unforecasted brief, but strong storm.**
  - **Possible slow CME but surface features unclear**
  - **Interaction with CIR/HSS and embedded ICME at Earth.**

# Reasons for forecasting errors

- **The 12–14 July 2012 and 21-24 June 2015 cases were considered mostly textbook events, and successful forecasts.**

- **The 27 May–1 June 2013 case was a problem event that we still do not fully understand.**

- **All the other events had problems with the forecasts, but we now understand why. These reasons include:**

  **1) compound CME/ICMEs**
  **2) interactions or deflections either near the Sun or during transit, some with SIR/HSSs**
  **3) deflection by a CH and/or "channeling" by active region fields**
  **4) northward ICME/MC fields**
  **5) weak and/or multiple surface signatures**

# Studies of Recent Campaign Events

**Next: # 14) 2017 September 4-10**

**Series of M, X-class flares/CMEs; 9/6 X2.2, X9.3 at sun center drove geoeffects; 9/8 Forbush decrease = 5%; 9/10 X8.2 fl. at WL, fast CME, wave, reconnection details, GLE**

**Then two Problem ("Stealth") events discussed by *Nitta & Mulligan (Solar Phys., 2017)*:**

**# 12) 2015 January 3-7**

**Slow, diffuse CME → Brief ICME, HSS, moderate storm**

**# 13) 2016 October 8-12**

**Slow, diffuse CME → Shock, long magnetic cloud, HSS, moderate storm**
**- also simulation by *He et al. (ApJ, 2018)***

# SWx Events of 4-12 September 2017

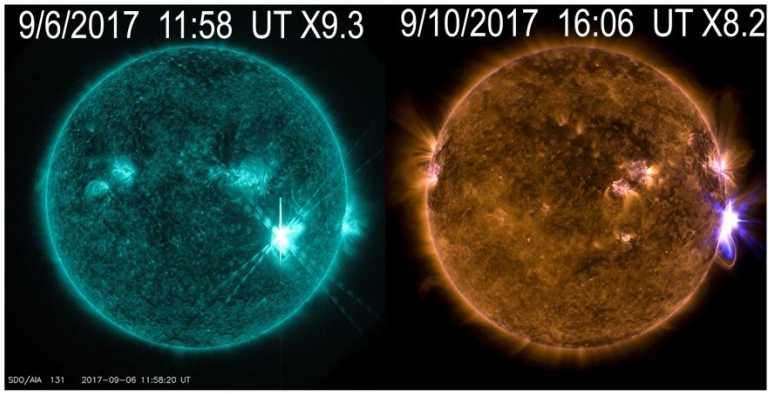
- *Space Weather Journal Special Section (2018)*

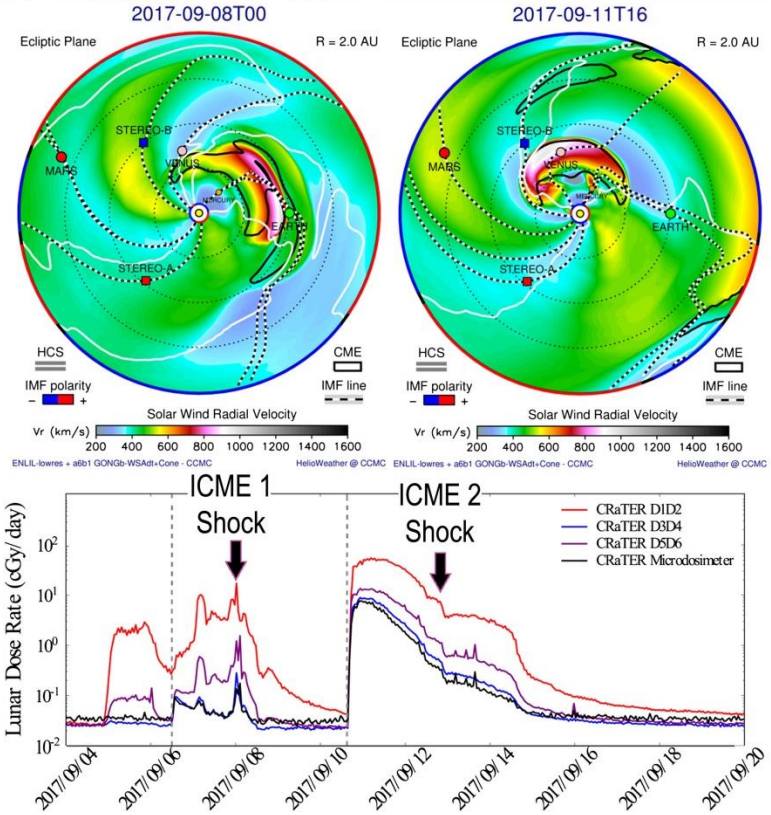
- One of most flare-productive periods of SC 24.
- Solar ARs 2673 and 2674 both matured to complex magnetic configurations as they crossed disk. AR 2673 → simple sunspot on 2 Sept. to complex AR with rapid growth on 4 Sept. ARs had 4 X-class flares, multiple partial halo CMEs, & both ARs > dozen M-class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

**Table 1**
*Summary of Space Weather 4–13 September 2017*[a]

| | | SWPC storm scales alerts | | | | |
|---|---|---|---|---|---|---|
| (1) date | (2) Flares ≥M5 (begin) | (3) Radio (1–5) | (4) SEP (1–5) | (5) G (1–5) | (6) 2 MeV e- | (7) CME earthward |
| 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***

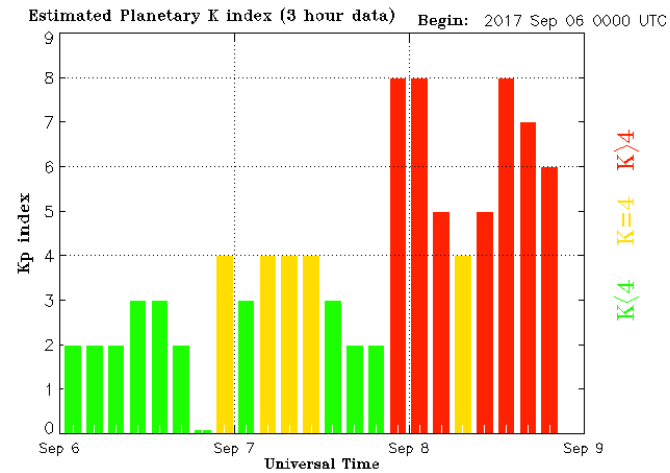


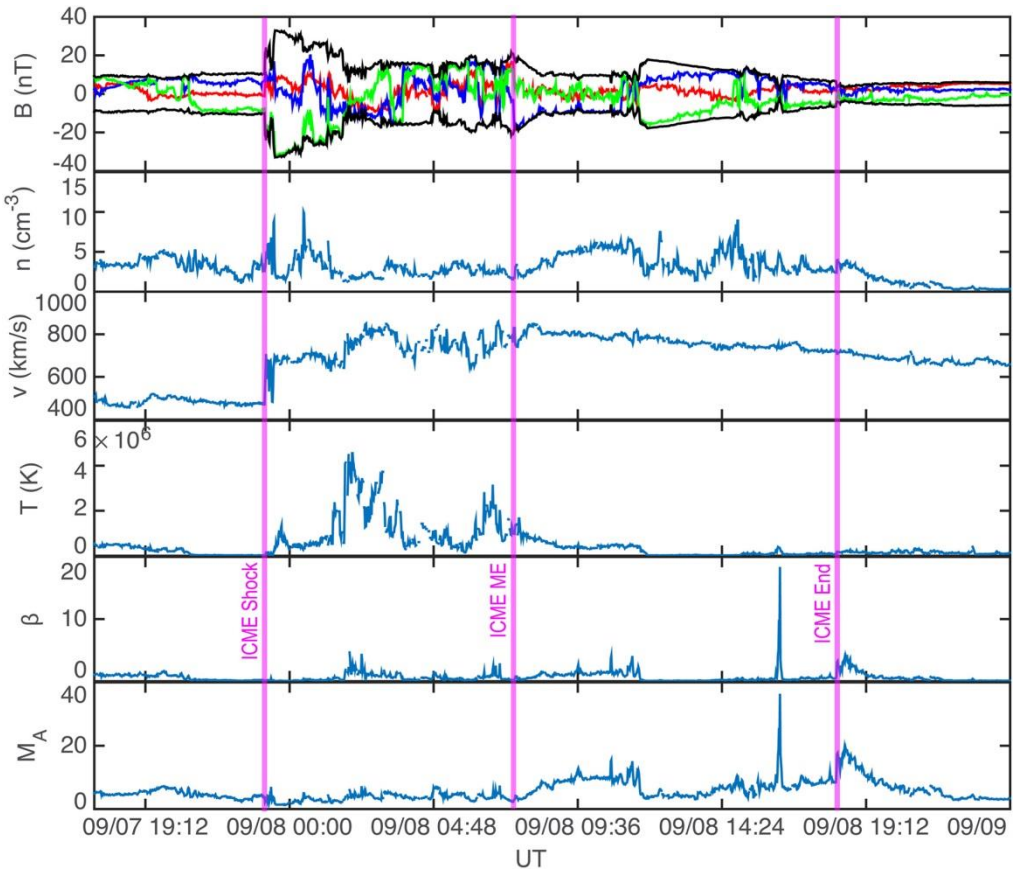




***Schwadron et al., SWx, 2018***

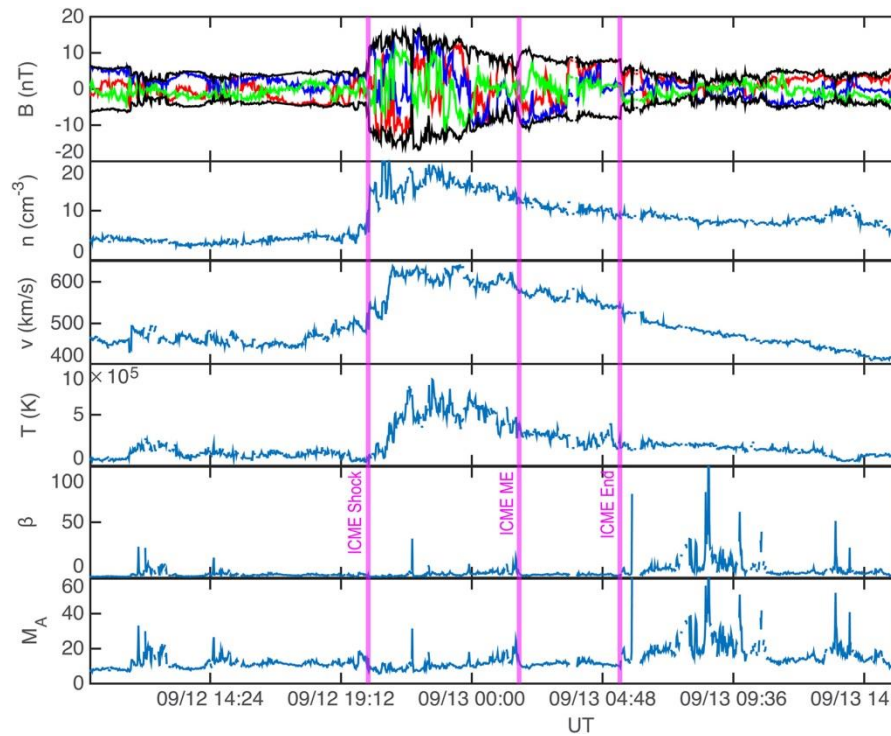
- X2.2 & X9.3 flares on 6 Sept. produced CMEs assoc. with severe geostorm (Dst = -124 nT) on 7 and 8 Sept. The events also assoc. with a 5% Forbush decrease and HSSs that produced geo-activity.

- At west limb on 10 Sept. AR 2673 produced: 1) an X8.2 flare, 2) an assoc. moderate SEP event, & 3) a GLE.



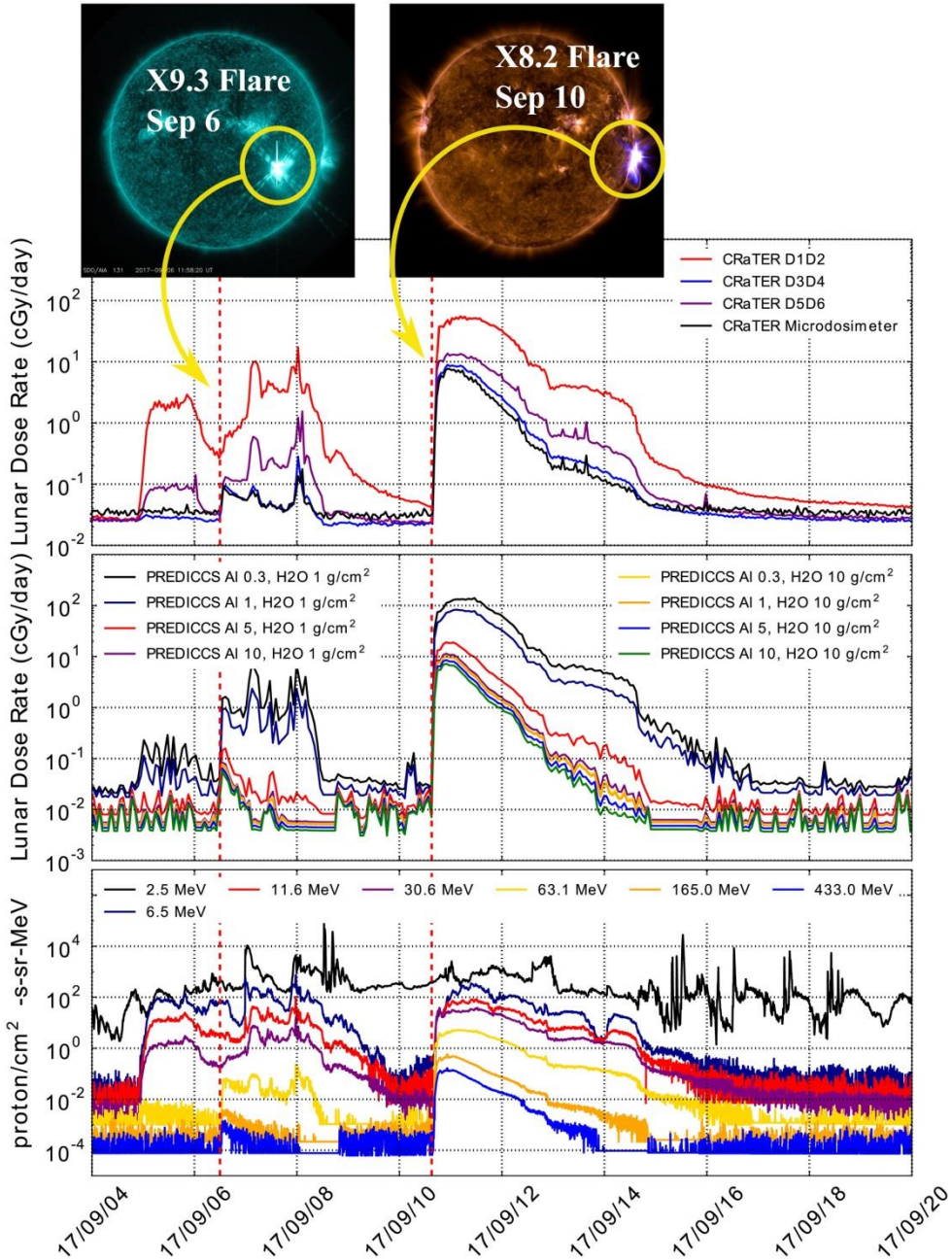




**7-9 Sept. 2017** ***(Schwadron et al., SWx, 2018)***



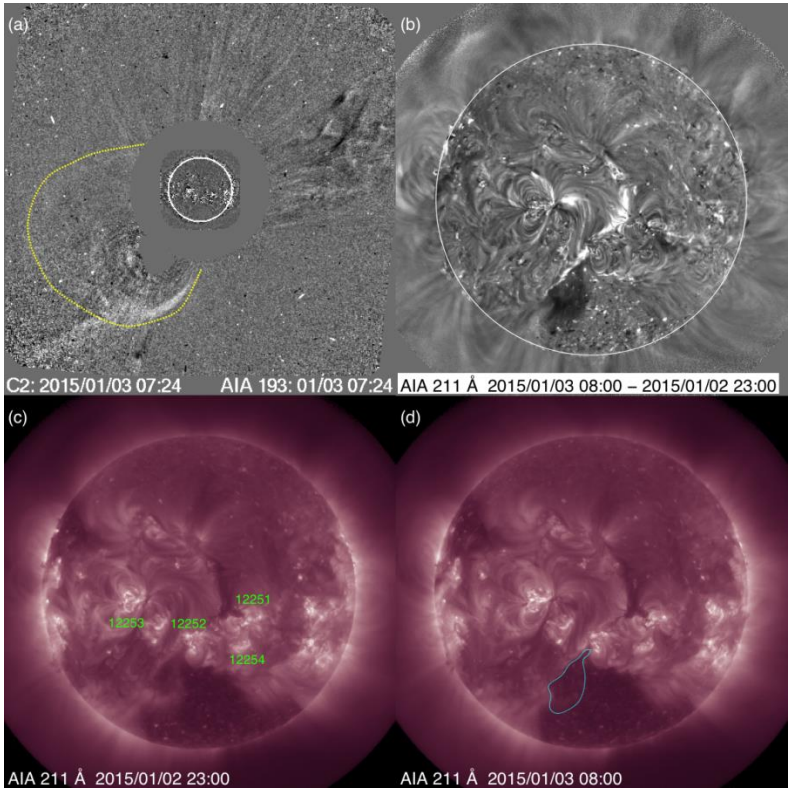

**12-14 Sept. 2017** ***(Schwadron et al., 2018)***

- From 4 -16 September the radiation environment at geosync. was at minor storm level with 100 MeV protons in geostationary orbit. At moon LRO CRaTER revealed a hard spectrum, large fluxes >400 MeV, and large dose rates. *(Schwadron et al., SWx, 2018)*

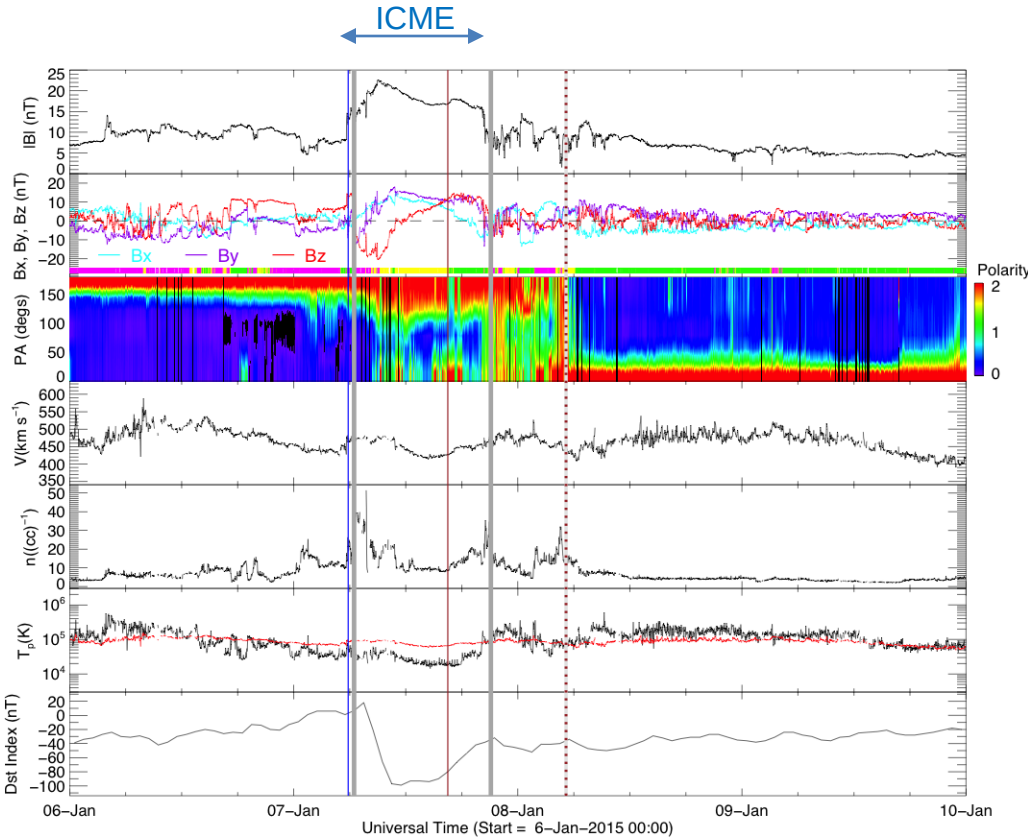


# New Campaign Event: 3 – 8 January 2015

**One of 3 "stealthy" Campaign events studied by *Nitta & Mulligan* which have been problematic in identifying a Lower Coronal Source (LCS). However, each resulted in moderate storms (Dst ~ -99 nT) *that were not predicted*. Thus, these were "Problem" storms!**



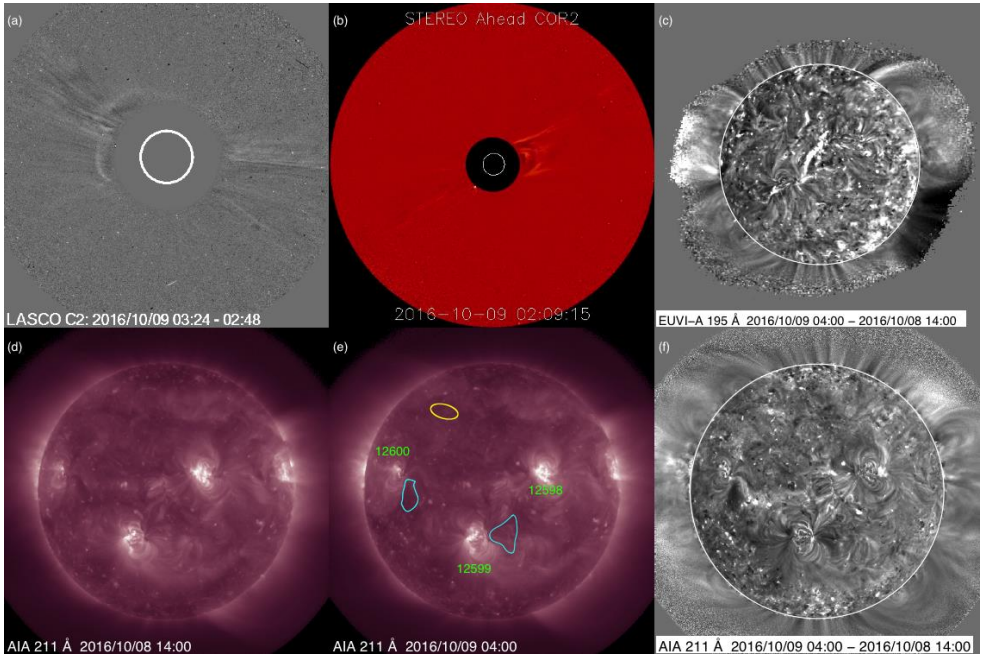

**Slow, diffuse CME on 3 January 2015.**

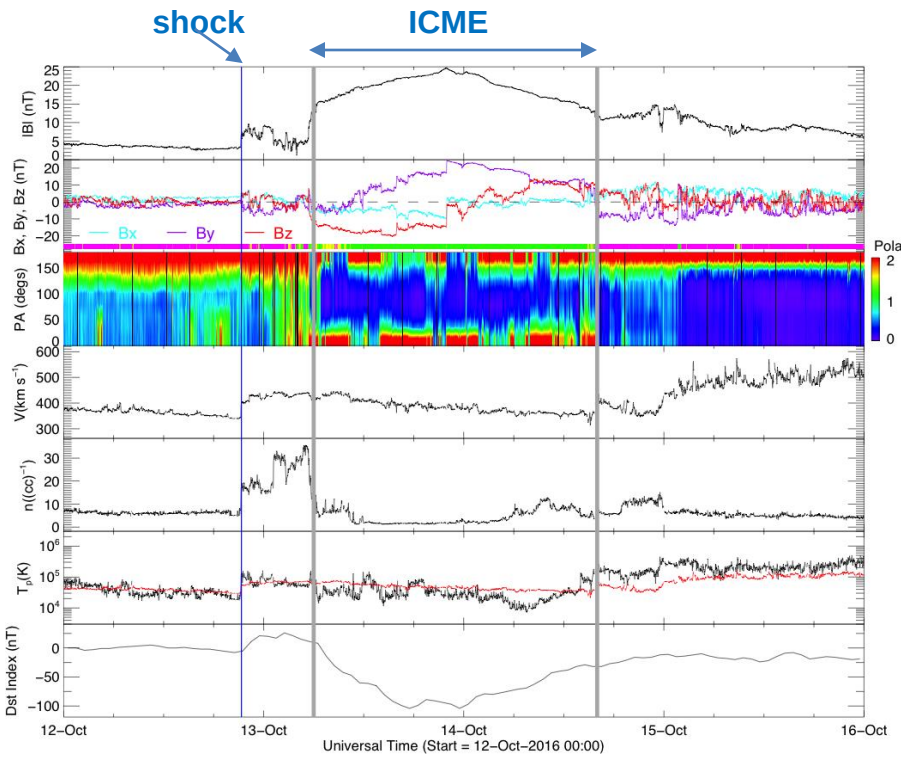



***Wind* solar wind data showing ICME, storm (Dst -99 nT), SB crossing w/ polarity reversals. G3 storm driven by $B_S$ in front half of ICME.**

# New Campaign Event: 8 – 14 October 2016

**Slow, diffuse CME on 8 – 9 October 2016.**




**The CME was very diffuse but a full halo (upper panels). STEREO-A, viewing the "backside", suggested it was Earthward. Small filament eruption in NE (bottom – yellow) too localized and early for the CME. 2 cyan areas mark dimming regions.**

***Nitta & Mulligan (2017); He et al., ApJ (2018)***

**Solar wind data for 12-16 Oct. 2016. *In-situ* signatures → shock late on 12 Oct. ff. by a sheath region & MC lasting for 34 hrs. Surprising → long coherent structure but no obvious LCS! Storm (Dst -104nT) driven by $B_S$ in front half of ICME/MC. Strong MC → compression by trailing HSS.**

# Presentations This Week -

## *Including WG-4 & Other Specific Events*

- **Main WG-4 Session – Thursday morning and afternoon**

- ***Meng Jin*** **(invited): Sun-Earth modeling & forecasting of CMEs**
- ***J. Campos Rozo*****: Flow modeling of AR on 11 April 2011**
- ***I. Dammasch*****: 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 CMEs**
- ***T. Tsvetkov*****: Kinematics of prominence eruptions**
- ***T. Podladchikova*****: X8.2 flare on 10 Sept. 2017**
- ***J. Seibezeder*****: Dynamics of 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**
- ***A. Kohlhoff*****: SEP event from STEREO B on 9 August 2011**

# Thank you for your attention!

BOSTON COLLEGE
ISR
INSTITUTE FOR SCIENTIFIC RESEARCH

***david.webb@bc.edu***

***nitta@lmsal.com***

# Possible Interactions with Other Groups

| Event | Storm | WG2, 3, 5 | SPeCIMEN Magnetosp | ROSMIC Ionosp | SEE/WG6 Climate/SEPs |
|---|---|---|---|---|---|
| VarSITI Events | | | | | |
| 1) 2012 July12 | Strong | X | X | | |
| 2) 2012 Oct.4-8 | Mod | X | X | | |
| 3) 2013 March 15 | Strong | X-3 | X | | SEP |
| 4) 2013 June1 | Strong | | | X | |
| 5) 2015 March 15 | Super | X-3 | X | X | 2-step, CIR, deflection |
| 6) 2015 June 22 | Super | X-3 | X | X | SEP 2-step, FD, hi dens. |
| Other ISEST Events | | | | | |
| 7) 2012 March 7 | Strong | X | X | | |
| 8) 2012 July 23 | “Strong“ | X | ---- | ---- | SEP |
| 9) 2014 Jan. 6 | None | ? | | | GLE |
| 10) 2014 Jan. 7 | None | X | | | SEP |
| 11) 2014 Sep. 10 | Mod. | X | X | | FD |
| 12) 2015 Jan 3-7 | Mod. | X | X | | HSS |
| 13) 2016 Oct. 8-12 | Mod. | X | X | | HSS |
| 14) 2017 Sept 4-10 | Strong | X | X | X | SEP, GLE, FD |