Summary of ISEST Working Group 4 on Campaign Events

David Webb & Nariaki Nitta
Co-leaders

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.

  - **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.
    ~ 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

### VarSITI-wide Campaign Study Events

<table>
<thead>
<tr>
<th>Dates</th>
<th>Source</th>
<th>Geo-response*</th>
<th>Kp/G Dst * Level</th>
<th>Forecast Success (SWPC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) 2012 July 12-14</td>
<td>X1 flare, wave, fast CME</td>
<td>Shock, MC, Strong storm</td>
<td>-127 7/G3</td>
<td>Mostly successful</td>
</tr>
<tr>
<td>2) 2012 October 4-8</td>
<td>CME; weak surface signs.</td>
<td>Shock, MC, HSS, Moderate stm</td>
<td>-105 6+/G2</td>
<td>Under-predicted</td>
</tr>
<tr>
<td>4) 2013 June 1</td>
<td>Slow CME on 27 May?</td>
<td>CH influence?</td>
<td></td>
<td>Failed-not pred.</td>
</tr>
<tr>
<td>5) 2015 March 15-17</td>
<td>C9;C2 fl, wave, EF, fast CME</td>
<td>Shock, sheath, MC, Severe storm</td>
<td>-222 8+/G4</td>
<td>Under-predicted</td>
</tr>
<tr>
<td>6) 2015 June 22-24</td>
<td>2 M-fls, waves, fast halo CMEs</td>
<td>Shock, sheath, MC, SEP,</td>
<td>-204 8+/G4</td>
<td>Mostly successful</td>
</tr>
</tbody>
</table>

### Other ISEST/MiniMax Study Events

<table>
<thead>
<tr>
<th>Dates</th>
<th>Source</th>
<th>Geo-response*</th>
<th>Kp/G Dst * Level</th>
<th>Forecast Success (SWPC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7) 2012 March 7-9</td>
<td>X5 flare, wave, fast CME</td>
<td>Shock, MC, Strong storm</td>
<td>-131 8/G4</td>
<td></td>
</tr>
<tr>
<td>8) 2012 July 23-24</td>
<td>2 flares? Wave, EFs</td>
<td>Extreme ST-A event; “Strong storm“ (Carr.-type) ---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9) 2014 January 6</td>
<td>CME &lt;2000 km/s, over WL</td>
<td>GLE at Earth</td>
<td></td>
<td>Failed-pred.;no str</td>
</tr>
<tr>
<td>10) 2014 January 7-9</td>
<td>X1 fl, wave, fast asym halo</td>
<td>Shock, SEP. No storm- CH deflection; AR channeling?</td>
<td>No ≤3</td>
<td></td>
</tr>
<tr>
<td>11) 2014 Sept. 10-13</td>
<td>X2 flare, wave, sym halo</td>
<td>Shock, MC, Moderate storm</td>
<td>-88 7/G3</td>
<td>Over-predicted</td>
</tr>
<tr>
<td>12) 2015 January 3-7</td>
<td>Slow CME</td>
<td>Brief ICME, MC, HSS. Mod. stm</td>
<td>-99 6+/G2</td>
<td></td>
</tr>
<tr>
<td>13) 2016 October 8-12</td>
<td>Slow CME</td>
<td>Shock, MC, HSS, Moderate stm</td>
<td>-104 6+/G2</td>
<td></td>
</tr>
<tr>
<td>14) 2017 Sept 4-10</td>
<td>Series; M5,X9,X8, etc.</td>
<td>Shocks, MCs, Strong stm(s), FD</td>
<td>-124 8/G4</td>
<td></td>
</tr>
</tbody>
</table>

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) 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 observations: 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<sub>S</sub> 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
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>
<thead>
<tr>
<th>Date</th>
<th>Flares</th>
<th>Radio</th>
<th>SEP</th>
<th>G</th>
<th>2 MeV e-</th>
<th>CME Earthward</th>
</tr>
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<tbody>
<tr>
<td>4 Sept.</td>
<td>M5.5 (20:28)</td>
<td>R2</td>
<td></td>
<td></td>
<td></td>
<td>Ejected (CME0)</td>
</tr>
<tr>
<td>5 Sept.</td>
<td>X2.2 (08:57)</td>
<td>S2</td>
<td>G1</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>6 Sept.</td>
<td>X9.3 (11:53)</td>
<td>R3</td>
<td>S2</td>
<td>G1</td>
<td></td>
<td>Arrived (CME0) Ejected (CME1)</td>
</tr>
<tr>
<td>7 Sept.</td>
<td>M7.3 (10:11)</td>
<td>R3</td>
<td>S2</td>
<td>G3</td>
<td>Yes</td>
<td>Arrived (CME1)</td>
</tr>
<tr>
<td>8 Sept.</td>
<td>M8.1 (07:40)</td>
<td>R2</td>
<td>S2</td>
<td>G4</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>9 Sept.</td>
<td>X8.2 (15:35)</td>
<td>R3</td>
<td></td>
<td></td>
<td>Yes</td>
<td>Ejected (CME2)</td>
</tr>
<tr>
<td>10 Sept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>11 Sept.</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 Sept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 Sept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Redmon 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.


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 Roso: 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!
# Possible Interactions with Other Groups

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