**ISEST-MiniMax WG4 Primary Study Events**

Collected by D. Webb; ISEST Chair WG4

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* VarSITI-wide campaign study events:

1. **2012 July 12-14** **(many)** CME. This event is selected by ISEST.

This is a textbook (TB) style event, with a clear chain of activity signatures all the way from the solar surface, inner corona and outer corona (X1.4 flare and fast CME), to in-situ near the Earth (a shock and magnetic cloud [MC]). Also of interest are the 2012 July 23-24 and other events from the same active region.

It produced an intense geomagnetic storm, Dst = -127 nT. In a prior ISEST workshop, we agreed to study this event extensively.

URL: <http://solar.gmu.edu/heliophysics/index.php/07/14/2012_17:00:00_UTC>

References:

- Dudik, J. et al., ApJ, 2014

- Cheng, X. et al., ApJ, 2014

- Moestl, C. et al., ApJ, 787, 119, 2014

- Hess, P. & Zhang, J., ApJ, 792, 49, 2014 [http://adsabs.harvard.edu/abs/2014ApJ...792...49H Stereoscopic Study of the Kinematic Evolution of a Coronal Mass Ejection and Its Driven Shock from the Sun to the Earth and the Prediction of Their Arrival Times]

- Shen, F. et al., JGR, 119, 7128, 2014

- Wang, R.; Liu, Y. D.; Wiegelmann, T.; Cheng, X.; Hu, H.; Yang, Z., Relationship between Sunspot Rotation and a Major Solar Eruption on 2012 July 12, 2016, Solar Phys., DOI: 10.1007/s11207-016-0881-6 (http://dx.doi.org/10.1007/s11207-016-0881-6)

2. **2012 October 4-8** **(DW; KM)** CME. This event has been recommended by ISEST and SPeCIMEN.

This is an example of a “problem” CME, i.e., a strong CME in the inner corona and ICME, but the solar disk signatures are multiple and weak, and it had slow propagation to Earth. At Earth a smaller storm, Dst = -105nT. Electron acceleration in the radiation belt has been studied by Reeves, G.D. et al (2013). (P)roblem event.

URL: <http://solar.gmu.edu/heliophysics/index.php/10/08/2012_05:00:00_UTC>

References:

3. **2013 March 15-17** **(MT; DW; KM: KS)** CME. Recommended by ISEST and SPeCIMEN.

At the Sun an M1.1 flare, erupting filament, type IV radio burst, fast halo CME. At Earth a shock, possible MC, SEP, and strong storm, Dst = -132nT. TB case. Modeled by C-C Wu.

URL: <http://solar.gmu.edu/heliophysics/index.php/03/17/2013_05:30:00_UTC>

References:

- Wu, Chin-Chun, Kan Liou, Angelos Vourlidas, Simon Plunkett, Murray Dryer, S. T. Wu,

and Richard A. Mewald, Global Magnetohydrodynamic Simulation of the March 15, 2013 Coronal Mass Ejection Event - Interpretation of the 30-80 Mev Proton Flux, JGR, 121, doi:10.1002/2015JA021051, 2016.

- Wu, Chin-Chun, Kan Liou, S. T. Wu, Murray Dryer, and Simon Plunkett, Radial Dependence of Solar Energetic Particles Derived from the 15 March 2013 Solar Energetic Particle Event and Global MHD Simulation, in Proceedings of Solar Wind 14, held in Shandong University, 22-26 June 2015, AIP Conf. Proc. 1720, 070008, doi: 10.1063/1.4943845, 2016. <http://scitation.aip.org/content/aip/proceeding/aipcp/10.1063/1.4943845>.

4**. 2013 June 1** **(NN; MT; KS; KM)** CME. Recommended by ISEST and ROSMIC.

Possibly due to a slow CME on May 27 Coronal hole influence? Cause of big storm unclear, Dst = -119nT. P.

URL: <http://solar.gmu.edu/heliophysics/index.php/05/31/2013_15:30:00_UTC>

References:

5. **2015 March 15-17 (Many)** CME. This event is selected by ISEST. This is also a special Joint GEM-CEDAR campaign event.

First “super” storm of SC24 was caused by an Earth-directed CME that erupted on 15 March 2015 from near disk center (S18W39) with a speed of 1120 km/s in the sky plane. N. Gopalswamy – this can be converted to an earthward speed of ~1025 km/s based on the source location on the Sun. The CME arrived with a MC on March 17 at 13:38 UT with a large southward field in the sheath (-15 nT) and in the front of the cloud (-25 nT). There were Dst dips corresponding to the sheath and cloud portions, with the deepest minimum Dst of 223 nT occurring at 23:00 UT on March 17. The speed of the MC was ~600 km/s, considerably smaller than the white-light CME speed of 1025 km/s.

URL: <http://solar.gmu.edu/heliophysics/index.php/03/17/2015_04:00:00_UTC>

References:

- Gopalswamy et al., Proc. 14th International Ionospheric Effects Symposium, May 12-14, 2015, Alexandria, VA.

- Wu et al., abs. for the SCOSTEP-WDS Workshop at NICT, Japan, Sept, 2015

- Jackson, priv. comm.

- Kamide, Y & K. Kusano, Space Weather, 13, 2015

- Liu, Y. at al., Plasma and Magnetic Field Characteristics of Solar Coronal Mass Ejections in Relation to Geomagnetic Storm Intensity and Variability, ApJL, 809, L34 (<http://iopscience.iop.org/article/10.1088/2041-8205/809/2/L34/pdf>)

- Kataoka, R., D. Shiota, E. Kilpua, and K. Keika (2015), Pileup accident hypothesis of magnetic storm on 17 March 2015, GRL, 42, 5155–5161, doi:10.1002/2015GL064816.

- P. Gallagher press release: <http://files.mail-list.com/m/iswinewsletter/2015-07-space-weather-scans-solar-storms.pdf>.

- Wang, Y. et al., On the Propagation of a Geoeffective Coronal Mass Ejection during March 15 – 17, 2015, subm. JGR, 2016.

- Jakosky, B. M., J. M. Grebowsky, J. G. Luhmann, D. A. Brain, Initial results from the MAVEN mission to Mars. Geophys. Res. Lett. 10.1002/2015GL065271 (2015).

- Cherniak, I., I. Zakharenkova, and R. J. Redmon (2015), Dynamics of the high-latitude ionospheric irregularities during the 17 March 2015 St. Patrick’s Day storm: Ground-based GPS measurements, Space Weather, 13, 585–597,doi:10.1002/2015SW001237.

- Le, G., et al. (2016), Magnetopause erosion during the 17 March 2015 magnetic storm: Combined field-aligned currents, auroral oval, and magnetopause observations, GRL, 43, 2396–2404, doi:10.1002/2016GL068257.

**6. 2015 June 22-24 (Many)** CME. This event is selected by ISEST.

Second “super” storm of SC24, and this year, was caused by at least 2 Earth-directed CMEs that erupted on 21 and 22 June 2015 from AR 12371 near disk center with speeds of 1315 and 1075 km/s, resp. Compound event with a series of shocks arriving over a 3-day span, and one likely magnetic cloud arriving around midnight on the 23rd, corresponding to a clear, symmetric halo CME on the 21st which drove the strongest of the shocks with a highly compressed magnetic field. Drove a powerful geomagnetic storm with a Dst = -204nT.

N. Lugaz: The first dip on June 22nd (~-150 nT) is clearly due to a shock propagating in preceding CME... The larger dip on the 23rd is due to the following CME... There are three probable fast forward shocks in 30 hours from 06/21 at 15UT to 06/22 at 18UT. The third shock combines a very large increase in dynamic pressure and a large short-duration southward Bz; it must have really compressed the magnetosphere like crazy. The CME on the 23rd had extremely low density and back of the envelope estimate shows that the solar wind may have had a Mach number of ~1.

N. Nitta: There were at least four eruptions during 18-22 June and the third one (associated with a M2 flare on 21 June) was a quite impressively circular CME, which I think contributed the most to the geo-space effects (the CME arrived much earlier than I had thought). Three CMEs seemed to have arrived without merging,.. The M6.5 flare on 22 June was not associated with a very geo-effective CME even though it arrived fast.

Y. Liu: This is actually a multi-step geomagnetic storm… The first dip was produced by the fluctuating southward field components upstream of the third shock, the second one by the southward field components downstream of the third shock, and the major one by the southward field components within the ICME associated with the June 21 M2.0 eruption (01:42 UT). I agree with Nariaki that the June 22 M6.5 eruption didn't produce obvious geo-effectiveness... The fourth shock in the plot was associated with the June 22 M6.5 eruption, and it was beginning to overtake the ICME from behind at 1 AU. Another eruption on June 25 (M7.9) also produced a shock that impacted Earth.., but wasn’t geo-effective either.

E. Kilpua: The strongest Bs intervals and the Dst minimum in the June event are … preceded by a mainly northward IMF and high density in CME sheath. Such conditions combined may have led to particularly dense plasma sheath and enhanced the ring current later when strong Bs related to FR1 (in Ying's plot) arrived.

URL: <http://solar.gmu.edu/heliophysics/index.php/06/21/2015_15:30:00_UTC>

References:

- Liu, Y. at al., Plasma and Magnetic Field Characteristics of Solar Coronal Mass Ejections in Relation to Geomagnetic Storm Intensity and Variability, ApJL, 809, L34 [(http://iopscience.iop.org/article/10.1088/2041-8205/809/2/L34/pdf).]((http:/iopscience.iop.org/article/10.1088/2041-8205/809/2/L34/pdf).%20)

* Other ISEST WG4 events being studied:

**7. 2012 March 7-9 (NN; KS; YL)**. An X5 flare, wave, fast CME. At Earth a shock, magnetic cloud (MC), and strong storm, Dst = -131nT. TB case. Of interest because of the influence of a CH on a relatively modest CME.

References:

- Wang, R., Liu, Y. D., Yang, Z., and Hu, H., Magnetic Field Restructuring Associated with Two Successive Solar Eruptions, 2014, Astrophys. J., 791, 84 (<http://iopscience.iop.org/article/10.1088/0004-637X/791/2/84/pdf>)

- Liu, Y. D., Luhmann, J. G., Lugaz, N., Möstl, C., Davies, J. A., Bale, S. D., and Lin, R. P., On Sun-to-Earth Propagation of Coronal Mass Ejections, 2013, Astrophys. J., 769, 45 (<http://iopscience.iop.org/article/10.1088/0004-637X/769/1/45/pdf>)

- Liu, Y. D., Richardson, J. D., Wang, C., and Luhmann, J. G., Propagation of the 2012 March Coronal Mass Ejections from the Sun to Heliopause, 2014, Astrophys. J. Lett., 788, L28 (<http://iopscience.iop.org/article/10.1088/2041-8205/788/2/L28/pdf>)

**8. 2012 July 23-24 (NN; MT; DW; NG)**

This was the famous energetic, very fast event directed at STEREO-A. There were two consecutive prominence eruption/flares starting about 02:20 UT on July 23, seen best in SOHO and STEREO-B observations. The shock hit STEREO-A on July 23, 20:55 UT, followed by two ICMEs, the first starting about 23:00 UT and the second at 01:51 UT on July 24.

- N. Nitta says “It was not an Earth-affecting event, but it was said to have possibly been as geoeffective as the Carrington event had it occurred 9 days earlier [and been aimed at Earth-DW]. I think it is important to understand the interplanetary conditions as disturbed by AR 11520 over an extended period.”

- M. Temmer: “i am currently working together with Nariaki on the complex (two-step) eruption from July 23, 2012 event aiming to simulate the short arrival time and high impact speed by using the analytical drag-based-model. the low density in interplanetary space as well as the high mass of the CME might be the decisive factors for this event to be so fast. The question remains whether the event from July 19 is able to lower the density over several days and as such is able to change the interplanetary conditions. i had during the process of the analysis nice discussions with Ying Liu and Janet Luhmann. We would like to encourage people to take a closer look on this event. We had subjective interpretations of the white-light structures, but most important found no conclusion on the high magnetic field as measured in-situ for both magnetic structures. Is it maybe something intrinsic to the active region? … it would be good to get modelers involved for gaining some deeper insight into the complex eruption process and its in-situ effects.”

URL: <http://solar.gmu.edu/heliophysics/index.php/07/23/2012_23:00:00_UTC>

References:

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- Ngwira, C. et al., GRL, 2013

- Baker, D., Space Weather, 11, 585, 2013

- Liu, D.L. et al., NComm., 5, 3481, 2014

- Gopalswamy et al., E,P&S, 66, 104, 2014

- Temmer and Nitta, Solar Phys., 290, 919, 2015

- Liou, K, C.-C. Wu, M. Dryer, S.-T. Wu, N. Rich, S. Plunkett, L. Simpson, C. D. Fry, and K. Schenk, Global Hybrid Simulation of Extremely Fast Coronal Mass Ejection on 23 July 2012, JASTP, 121, 32-41, 2014.

**9. 2014 January 6 (NN; NG)**, 07:30, WL: Produced a GLE (see next).

- N. Gopalswamy reports that the January 6 and 7 CMEs are quite intriguing. The Jan. 6 event produced a GLE even though it had a speed <2000 km/s and originated behind the west limb (Thakur et al. 2014).

URL:

References:

- Thakur et al., ApJL, 2014

**10. 2014 January 7-9 (NN; NG; CM, DW; YL)**

A “problem” event being studied for a Fall 2014 AGU session: SH51E: Challenges to Space Weather Forecasting and Data-Driven Modeling of the Sun Focused on January 2014; 19 Dec. 2014 (e.g., Webb, 2014).

The Jan. 7 CME was assoc. with a X1.2 flare near disk center (S12W08) and was ultrafast (~2400 km/s), but was likely deflected to the south and west so it was not geoefffective. It was a large SEP event, but not a GLE. The shock and sheath were likely detected at Earth (9, 19:40 UT) and Mars (10, 22:30 UT) – Moestl et al. (2015).

URL: <http://solar.gmu.edu/heliophysics/index.php/01/08/2014-01/09/2014>;

<https://agu.confex.com/agu/fm14/meetingapp.cgi#Session/4428>

References:

- Webb, An Overview of the 7 January 2014 X-Class Flare-CME and Space Weather Predictions, AGU SH51E-01, 2014

- Moestl et al., Nat. Commun., 6, 7135, 2015

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- Wang, R., Liu, Y. D., Dai, X., Yang, Z., Huang, C., and Hu, H., The role of active region coronal magnetic field in determining coronal mass ejection propagation direction, 2015, Astrophys. J., 814, 80 (http://iopscience.iop.org/article/10.1088/0004-637X/814/1/80/pdf)

**11. 2014 September 10-13 (NN; MT; DW; KM)**

An X1.6 flare and wave near Sun Center and a nearly symmetric halo CME. The evolution of the source active region (AR 12158) is also of interest.

The ICME at L1 on 12-13 Sept. mostly had strong northward field in the putative flux rope (several models produced). The southward fields, which drove the early storm activity, were in the sheaths trailing two IP shocks, the second one being the strongest. The ICME north field rapidly shut down the auroral and storm activity.

A STEREO SWx Group event. “U” case? B. Jackson runs a real time forecast site, and have included the Rosetta comet mission in the forecasts, currently using IPS data. A density response at Rosetta due to the Sept. 10 event was predicted for IPS and modeled using the ENLIL 3D-MHD code. We are looking for Rosetta solar wind data to confirm an ICME there.

URL: <http://solar.gmu.edu/heliophysics/index.php/09/12/2014_15:26:00_UTC>

References.:

- McKenna-Lawlor et al., Space Weather at Comet 67P/Churyumov–Gerasimenko

Before its Perihelion, EM&P, 117, 1–22, DOI 10.1007/s11038-015-9479-5, 2016

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Some data on these and other events can be found on the ISEST Wiki site:

<http://solar.gmu.edu/heliophysics/index.php/The_ISEST_Event_List>? Contributers are also welcome to add their favorite events and results/papers to that Wiki site.

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