The Great August 1972 Heliospheric Disturbance: What We Know Now
Critical Challenges and Progress

McMath Region, 11976, Ca-II

Hourly averaged X-ray Intensity for McMath Region, 11976, Aug 1972

Delores Knipp, University of Colorado, Boulder & HAO NCAR; Brian Fraser, Centre for Space Physics, University of Newcastle;
Margaret Shea & Don Smart Retired US AF Research Laboratory

Overview

- One of the most intense intervals of solar/geospace activity during the space age
- Extraordinary effects in geospace
  - Solar activity
  - SEPs & GLE
  - GICs & $dB/dt$
- New insights
  - Drivers of Carrington-class storms

McMath 11976 Magnetogram BBSO, Aug 1972
Initial Perspectives

- **Active Region**
  Single large penumbra;
  Delta configuration
  1200 millionths of hemisphere
  Light bridge

- **Extraordinary solar flares**
  2 Aug: (2), X class & WLF
  4 Aug: (1), X-20 + Gamma-rays
  7 Aug: (1) X class & WLF

- **Flare level 4 Aug 0630 UT**
  - 3B H-alpha
  - X-ray – LDE flare
  - Combined Flare Index = 17
At Earth: 4 August 1972

- Radio Propagation Disturbance & Blackout
  - Dayside & then Polar Cap

- Forbush Decrease

- Rapid Rise of SEPs
  - Then onset of Ground Level Event (GLE24)
  - Spacecraft solar panels deteriorated
  - Sensors overwhelmed with particles
  - Long-lasting ozone depletion

- Extreme Forbush Decrease

- Sudden Storm Commencements & Extraordinary Sudden Impulse

Hakura (1974)
X-ray Flare (reconstructed)

- Space-based SOLRAD 9 & 10 X-ray detectors
  Saturated at X5.1

- ~X-20 flare, Long Duration Event, > 16 hr

- Radio bursts also observed; indicative of plasma cloud motion

- 3 hr dayside radio blackout

- Filament ~ 0.6 R_S disappears

- Largest Forbush Decrease in last 6 solar cycles -28%
SEPs (reconstructed)

- The most intense flux of low and moderate energy SEPs in the space-age

- Significant enhancements ahead of CMEs--Energetic Storm Particles

- Solar Panels on spacecraft lost 5% of power generation capability in three days

Fig. 1. Integral fluxes from the IMP-5 spacecraft measured during the large August 1972 SPE. These have been manually corrected for spacecraft motion and small data gaps have been filled using a 3rd-order polynomial.

Jiggens et al. (2014)
Solar Wind (reconstructed) from Prognoz & Prognoz 2

- Significant solar wind density enhancements from previous CMEs
  - Preconditioning of geospace?

- Path-clearing events prior to shock arrival at 2054 UT on 4 August

- Fastest CME on record—14.6 hrs to 1 AU
  - Average CME transit speed: 2850 km/s

- Shock & structures within sheath?

IMF at Geosynchronous Orbit

- ATS 5 (GEO S/C) in the magnetosheath
  - Clear magnetopause compression

- Rapid IMF fluctuations
  - In sheath ahead of ICME?
    - Extreme southward field
    - -300 nT in sheath
      - -75 – -100 nT in SW

Sheath field (behind IP shock, ahead of ICME)

Indices from Ground Measurements

After SSC

- $AE > 1500 \text{ nT (hr avg)}$
- $|AU| > |AL|$
- $Dst$ Index: $-125 \text{ nT}$
- Extreme $ASY$ Index $> Dst$
High & Mid-latitude Ground Sudden Impulse dB/dt

- 2238-2242 UT Large voltage swings in northern tier US states.
- The Manitoba Hydro Company recorded 120 MW drops in power supplied to Minnesota in only a few minutes.
- Outage on the L4 (AT&T) cable in the US Midwest states
  - Induced electric field of 7.0 V/km, exceeded shutdown threshold for high current, accompanied magnetic field variations (dB/dt) of ~ 800 nT/min at 2240-2242 UT (the time of the L4 outage).
  - dB/dT = 2000 nT/min in northern Canada
- Newfoundland, Canada, GICs activated protective relays many times on 4-5 August.
- Strong GIC effects reported in Ohio and Maryland

Boteler and Jansen van Beek (1999)
Albertson & Thorson, (1974),
Low-Latitude Ground Magnetic Perturbations

• SSC 2054 UT
• SI 2038-2242 UT
• 168 nT/min Manila, Philippines
  • Near dawn Local Time
  • 7 deg MLAT
• Subsequent Giant Pulsations

Hai Phong Mine Field ‘swept’ by a Solar Magnetic Storm on 4 August 1972

“... the HaiPhong Destructor (mine) Field was actually swept by a solar magnetic storm in August of 1972.” Hartmann & Truver (1991)

“During the first few weeks of August, a series of extremely strong solar flares caused a fluctuation of the magnetic fields, in and around, South East Asia. The resulting chain of events caused the premature detonation of over 4,000 magnetically sensitive DSTs (Destructor mines)"
Gonzales, https://www.angelo.edu/content/files/21974-a

Mine explosion during Sweeping Haiphong Harbor 1973

Progress in Understanding Extreme Shocks & CMEs (1)

- Tousey (1973): Coronal Transients (CMEs) observed by OSO-7

- Agrawal et al. (1974) Shocks and CMEs ‘organize’ GCRs
  - Piles up and Depletions
- Early idea about ‘path-clearing’ by CMEs
- Developing ideas about Forbush Decreases

Agrawal, et al. (1974)
• Illing and Hundhausen (1983) three-part CME

• Shea and Smart (1992) Particles accelerated between fast moving interplanetary (IP) structures
  • Seed particles in IP medium
  • Modify earlier ideas about sources of SEP events and “Proton flares’
  • August 72 primary example of combined Forbush Decrease and Enhanced SEPs

• Gosling (1993) CMEs (rather than flares) are primary driving of geomagnetic activity

http://nevod.mephi.ru
Progress in Understanding Extreme Shocks & CMEs (3)

- Gopalswamy (2001) ‘cannibal’ and interacting CMEs

- Liu et al. (2014) Path-clearing CMEs permit even faster subsequent homologous CMEs
  - July 2012 Ultrafast STEREO-A shock/CME


Liu et al (2014) Observations of an extreme storm in interplanetary space caused by successive coronal mass ejections, Nature Communications
Progress in Understanding Extreme Shocks & CMEs (4)

- Kozyra et al (2013) Filament material originally behind CME moves through CME to interact with shock
  - Produces extreme effects on 21 Jan 2005
- Chatterjee (2018) demonstrate formation of a delta sunspot
  - From the collision of two or more young flux emerging regions developing in close vicinity.
  - Formation of dense filament in overlying region

Progress in Understanding Extreme Shocks & CMEs Effects at Earth—Carrington-class storms

- Saiz et al. (2015) & Cid et al. (2105)
  - high solar wind pressure and abrupt reversals of the IMF appear as the interplanetary trigger of sharp geomagnetic field perturbations in extreme storms.
  - Possible roots of impulsive field-aligned

Fig. 5. Fitting results superposed to $LD_i$ for those analysed events (ABG, BOX, THY). Different colours indicate different time intervals in the fitting procedure; #1 (#2) results in Table 1 corresponds to red (blue) solid line.
Summary: From Sun to Mud

A Extreme Event Struck Earth 4 Aug 72
- SEP s disrupted spacecraft/missions
- Destabilized some of the North American Power Grid
- dB/dt detonated Sea Mines in Southeast Asia

- Rooted in reverse polarity delta spot
- Eruption
  - moved through clear-path
  - Carried solar filament material
  - produced GLE and Forbush Decrease
  - Impulsive magnetopause compression and FACs
- We are on the verge of understanding these extreme events
- Models will be challenged