Space weather catalogs: energetic particles, radio emissions, flares and geomagnetic storms

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Contents

Open access to a set of analysed space weather events (catalogs):

- Proton events
- X & M class flares
- Electron-related radio bursts
- Major geomagnetic storms
- Type II bursts
“Space weather” refers to conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. [...] can cause disruption of satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socioeconomic losses.

Space weather phenomena

**Solar flare**
- eruption in the solar atmosphere due to magnetic reconnection process
- released energy up to $10^{27}$ J
- *remotely observed* emission from radio to gamma-rays
- occurs in active regions
- acceleration of electrons, protons
- association with mass motions

https://www.solarmonitor.org/
Space weather phenomena

Solar energetic particles (SEPs)
- *in situ* observed electrons, protons and heavy ions
- from keV to GeV
- transport in the interplanetary (IP) space along magnetic field lines
- profiles indicate the location of parent solar activity on the solar disk

https://www.solarmonitor.org/
Space weather phenomena

Radio bursts
- remotely observed emission from accelerated electrons in the corona and IP space
- the shape of the features indicates the type of driver and magnetic field line configuration
  - Type II: shock wave
  - Type III: electron beams along open field lines

Space weather phenomena

Geomagnetic storm
- disturbance in the Earth's magnetic field caused due to CME/shock wave impact on the magnetosphere
- can be given in negative values of the disturbance – storm time ($\text{Dst}$) index: globally averaged change of the horizontal component of the Earth's magnetic field at the magnetic equator based on measurements from a few magnetometer stations
Electron event catalog

The first electron catalog
- ACE/EPAM data 103-175 (175-315) keV
- 12 sec resolution
- 965 (800) events
- parent activity (64% flares, 74% CMEs, 14% none)
- associated protons ~32 (38)%
- Pearson & second-order partial log10-correlations

https://www.nriag.sci.eg/ace_electron_catalog/
Proton event catalog

- SOHO/ERNE HED, 10 energy channels (14-131 MeV)
- 1 min resolution
- 600+ events
- Solar origin, SEE, radio burst associations
- Energy dependent statistical analyses (Pearson & partial)

https://catalogs.astro.bas.bg/

Preliminary version: Miteva et al. (2020) BgAJ (+online list)
X vs. M-class flares: space weather relevance

**X-class flares**
- SC 23 & 24: 175 flares
- X vs. CMEs: 76%
- X vs. type IP IIs/IIs: 55%/75%
- X vs. SEPs/SEEs: 38%/37%
- 14% $\beta$, 11% $\beta-\gamma$, 30% $\beta-\gamma-\delta$

Miteva (2021), Bulgarian Astronomical Journal (+online catalog)

**M-class flares**
- SC 23 & 24: 2177 flares
- M vs. CMEs: 41%
- M vs. type IP IIs/IIs: 25%/50%
- M vs. SEPs/SEEs: 6%/11%
- 30% $\beta$, 22% $\beta-\gamma$, 30% $\beta-\gamma-\delta$

Miteva & Samwel (2022), Universe (+online catalog)

https://catalogs.astro.bas.bg/
Electron vs. proton-associated radio bursts of type II, III, IV

965 electron (SEE) events (Samwel & Miteva 2021, MNRAS): 832 radio bursts (86%)
- type IIIIs are the most numerous burst type in corona/IP space
- Reduced SEE-type IIs in the IP space wrt SEP (Are IP shocks more proton-efficient?)
- Lower occurrence of SEE-type II in IP range for E & W origin
- Clear decrease in IP space for SEE-type II in SC24 compared to SEP-type II

Ranges:
3-1 GHz, 1000-300 MHz, 300-100 MHz, 100-30 MHz, 30 MHz-20 kHz
Black --> certain identification
Dark gray --> uncertain or only observatory reports
Light gray --> no dynamic spectral plots found

Completed
Support: SCOSTEP/PRESTO 2020 grant
‘On the relationship between major space weather phenomena in solar cycles 23 and 24’
Electron vs. proton-associated radio bursts of type II, III, IV

Protons (SEP)-radio bursts: Miteva et al. (2017) JSWSC (+online list)
Electrons (SEE)-radio bursts: Miteva et al. (2022) Universe (+online catalog)

### Catalogs of Solar Energetic Particles and Space Weather Events

**Solar cycle 23 – Radio**

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https://www.astro.gla.ac.uk/users/eduard/cesra/?p=3350
https://catalogs.astro.bas.bg/
**Major geomagnetic storm**

- SC 23 & 24: 107 geo-storms
- Dst < -100 nT
- more GSs in SC23 wrt SC24
- more intense SGs in SC23 wrt SC24
- CME in SC23 are faster & narrower wrt CMEs in SC24
- SXR peak flux is similar for both SCs around X-class flares
- Correlations with electrons in SC23 are larger wrt SC24
- Correlations with low/high energy protons in SC23 are larger/lower wrt SC24.
Type II radio bursts from RSTN data

SC 24 (2009-2019)

RSTN data: 25-180 MHz; 1-sec time resolution; observatory reports used

Total # type II bursts identified: 486 candidates

Majority of type IIs (~67%): 1-5 & 6-10 min

143/486 (or 29%) are newly identified by our team

In progress: associations with space weather events (in situ particles, IP shocks, ICMEs, geomagnetic storms, filaments)

In progress

Collaboration: Lawrence, Devi, Chandra, Miteva, Koleva, Dechev

Support: Bulgarian-Indian Project

KP-06-India/14 (19-Dec-2019)
Outlook

Completed repositories:
- X & M class flares
- Electron-related radio bursts

Catalogs in progress:
- Proton events
- Major geomagnetic storms (list ready)
- Type II bursts (list ready)