OCCURRENCE RATE AND CAUSAL RELATIONSHIP OF EXTREME SPACE WEATHER EVENTS

ROSITSA MITEVA

rmiteva@astro.bas.bg   rmiteva@nao-rozhen.org

Institute of Astronomy and National Astronomical Observatory

Bulgarian Academy of Sciences

INSTITUTE OF ASTRONOMY AND NATIONAL ASTRONOMICAL OBSERVATORY

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X-ray Arrival time to the Earth 8min.

Solar Energetic Particles (SEPs)

Flare

30min.~2days

Coronal mass ejection (CME)

Solar wind

Colonal hole

Interplanetary Disturbances
2~3days

Astronaut's exposure

Malfunction of artificial satellites

GPS malfunction

Satellite orbit fluctuation

Reroute of airline flights

Ionospheric disturbances

Changes in radiation belt

Thermospheric disturbances

Aurora

Communications trouble

Electrical powergrid trouble

Geomagnetic disturbances

SPACE WEATHER
Related to Social Infrastructure

http://swc.nict.go.jp/en/knowledge/relation.html

Aim

To calculate the occurrence of extreme space weather (SW) events, to study their inter-relationship in terms of cause and effect in order to estimate their forecasting potential.

Data analysis

- 4 types of data, utilized here:

Solar flare (**SF**): September/1975–present (GOES)
Coronal mass ejection (**CME**): January/1996–present (gaps; SOHO/LASCO)
Solar energetic particles (**SEP**): November/1973–March/2013 (SEPEM)
  [January/1997–December/2019, Miteva et al. 2018]
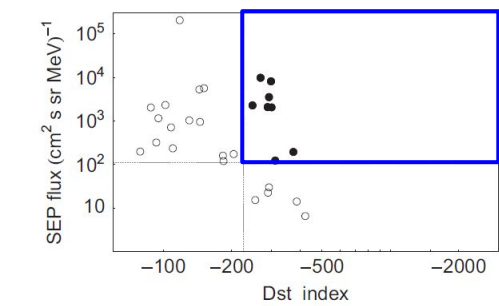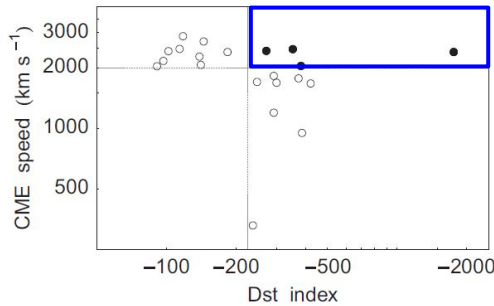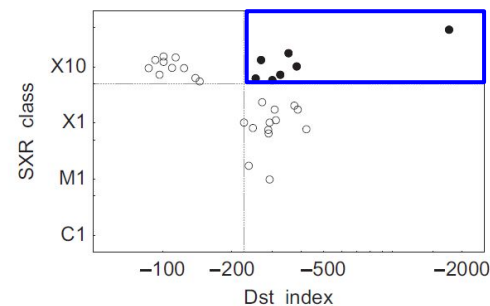Geomagnetic storm (**GS**): January/1957–present (Kyoto)

- Association procedures (time, strength, position) to interlink the solar activity events (SFs, CMEs, SEPs: ~ 1 day) and the geo-magnetospheric disturbances (3-day time window).
- Adopted definition for 'extreme': **top 50** of all observed events in a category

extreme pairs

(SXR class vs CME speed (km s^{-1}) scatter plot)

Results

Tables with all inter-relations are completed.

- SF - CME: **9** X5+ (0.06%) - 2000+ km/s
- SEP - SF: **6** 110+dpfu (20 %) [**10** 2+dpfu] - X5
- SEP - CME: **4** [**15**] SEP - 2000+km/s (0.002%)
- GS - SF: **7** -226 nT(11 % from all 100 nT) - X5+
- GS - CME: **4** -226 nT - 2000+km/s
- GS - SEP: **8** -226 nT - 110+dpfu

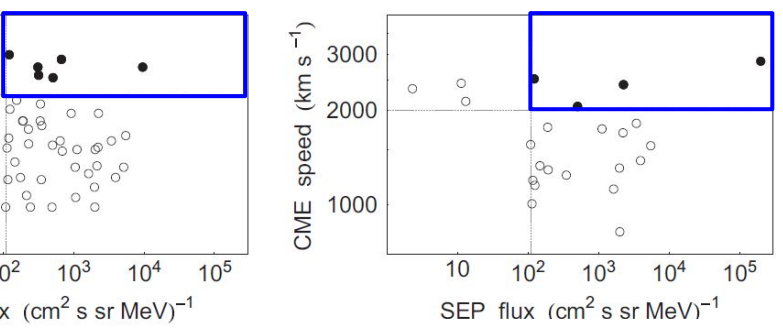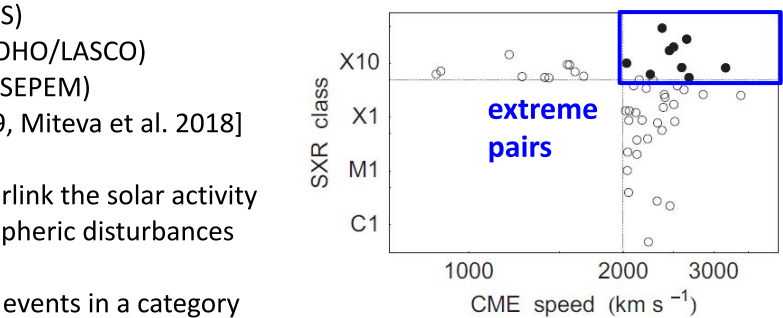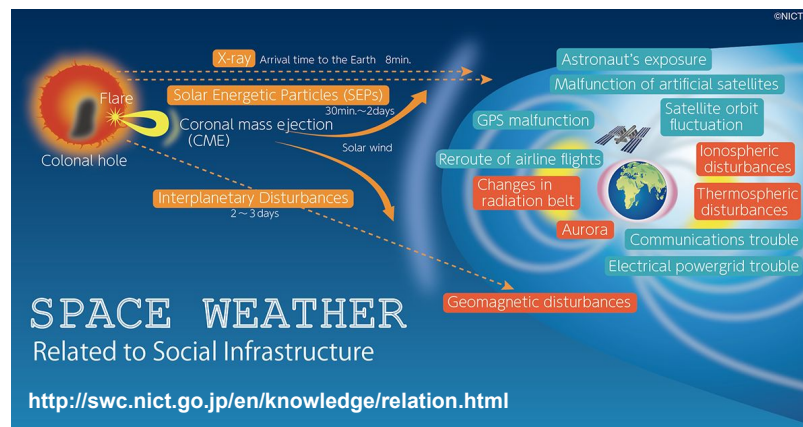% - occurrence rate in the respective database

(SXR class vs SEP flux (cm^2 s sr MeV)$^{-1}$ scatter plot)

(CME speed (km s^{-1}) vs SEP flux (cm^2 s sr MeV)$^{-1}$ scatter plot)

(SXR class vs Dst index scatter plot)

(CME speed (km s^{-1}) vs Dst index scatter plot)

(SEP flux (cm^2 s sr MeV)$^{-1}$ vs Dst index scatter plot)

Primary phenomenon	Extreme/Associated phenomenon				
	SFs	CMEs	SEP flux	SEP fluence	GSs
SFs	–	9/19	6/8 [10/13]	5/8	7/17
CMEs	9/38	–	4/7 [15/27]	4/7	4/13
SEP flux	6/43	4/20	–	46/50	8/23
SEP fluence	5/43	4/21	46/50	–	8/20
GSs	7/20	4/12	8/13	8/13	–

Summary & Discussion

- Minority of extreme pairs (out of top 50 in the respective samples)
- wide range in the parameter space of the correlated events
- The fastest CMEs are not better predictors to GSs compared to SF (although there is a link between large SF and CMEs)
- SEPs are neither good predictors for GS occurrence/strength
- SF/CME-related AR location is not an ordering parameter for GS: IP space could be of a greater importance for a successful forecasting

Acknowledgements

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http://12sbak.matf.bg.ac.rs/index.html