Statistical properties of the most powerful perturbations on the Sun and in the heliosphere

Yakovchouk O.S. Veselovsky I.S.

Institute of Nuclear Physics, Moscow State University

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Strongest perturbations on the Sun

- flares and coronal mass ejections

and their transient manifestations
in the heliosphere

- solar wind plasma,
  radiation and electromagnetic fields

are of great practical interest from the point of view of the space weather evaluation and forecast

Several difficulties exist in their study:

- 1) the statistics of such events is rare by definition of extreme events
- 2) the reliable theoretical models are still not available

We discuss some common and specific properties of extreme events

At present time, the conditions of space weather in the near-Earth space can be estimated sometimes using a five-point scale:

- extreme (5)
- severe (4)
- strong (3)
- moderate (2)
- minor (1)

www.sec.noaa.gov/NOAAscales/

The scales describe the environmental disturbances for three event types:

- radio blackouts (R1-R5)
- solar proton radiation storms (S1-S5)
- geomagnetic storms (G1-G5)

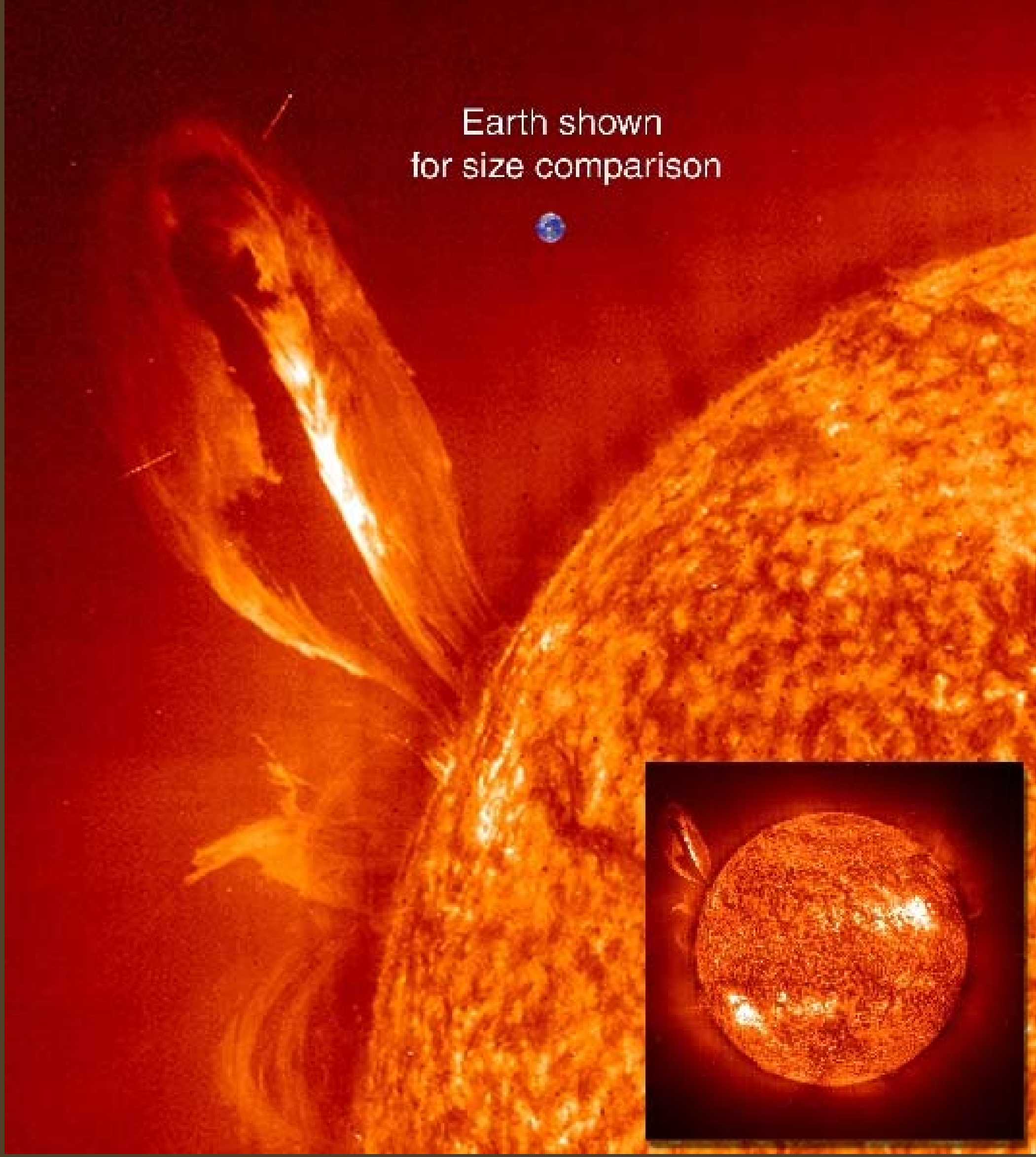
Radio blackouts

Disturbance of the ionosphere caused by X-ray emissions from the Sun that can lead to high frequency radio blackout and navigation errors

Solar radiation storms

Elevated levels of radiation that occur when the number of energetic particles increase.

SEP, accelerated to near-relativistic energies during major solar storms arrive at the Earth's orbit within minutes and may severely endanger astronauts and passengers and crew in high-flying aircraft at high latitudes



Geomagnetic Storms

Disturbances in the geomagnetic field caused by e.g. CME, ejected into interplanetary space as gigantic clouds of ionized gas, that after a few hours or day may hit the Earth. Geomagnetic storms can e.g. get broken the power systems, spacecraft orientations

NOAA Space Weather Scale

NOAA scale	**R** Radio Blackouts (X-ray flux)	**S** SEP (Flux level of E>10MeV Particles)	**G** Geomagnetic Storm (Kp value)
5 - Extreme	>X20 ($2x10^{-3} Wm^{-2}$)	>100 000 pfu	9
4 - Sever	>X10 ($10^{-3} Wm^{-2}$)	>10 000 pfu	8 и 9-
3 - Strong	>X1 ($10^{-4} Wm^{-2}$)	>1000 pfu	7
2 - Moderate	>M5 ($5x10^{-5} Wm^{-2}$)	>100 pfu	6
1 - Minor	>M1 ($10^{-5} Wm^{-2}$)	>10 pfu	5

Extreme events:

Major Solar Flares

+

(as a result)

Strongest perturbations in near-Earth space

R4,R5; S3,S4; G4,G5

↓

The database was compiled, which contains 85 strongest events for the period since 1859 to 2007

28.10.2003

X17.2/4B

SEP = 33600 p.f.u.

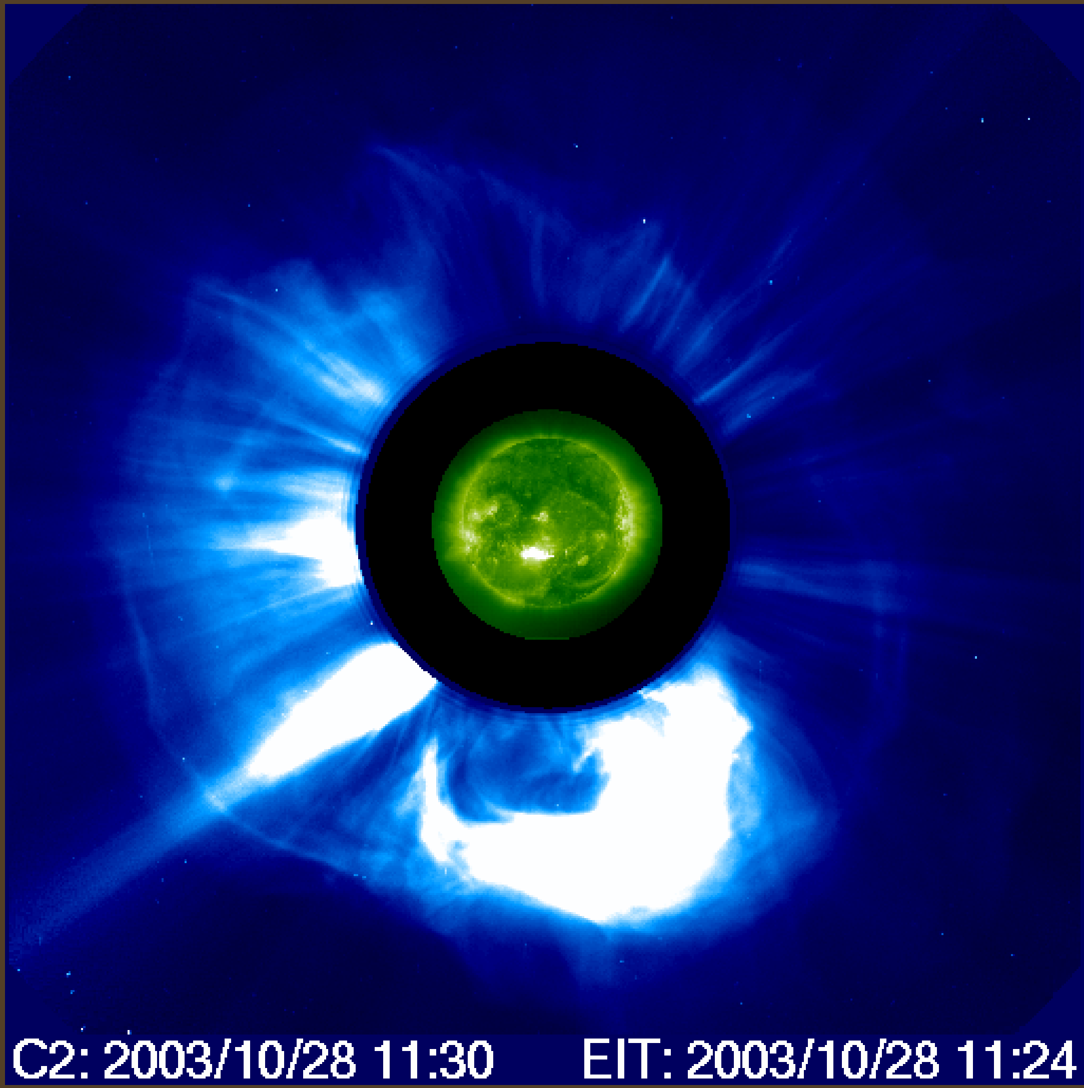
Storm:

29.10. - 1.11(78)

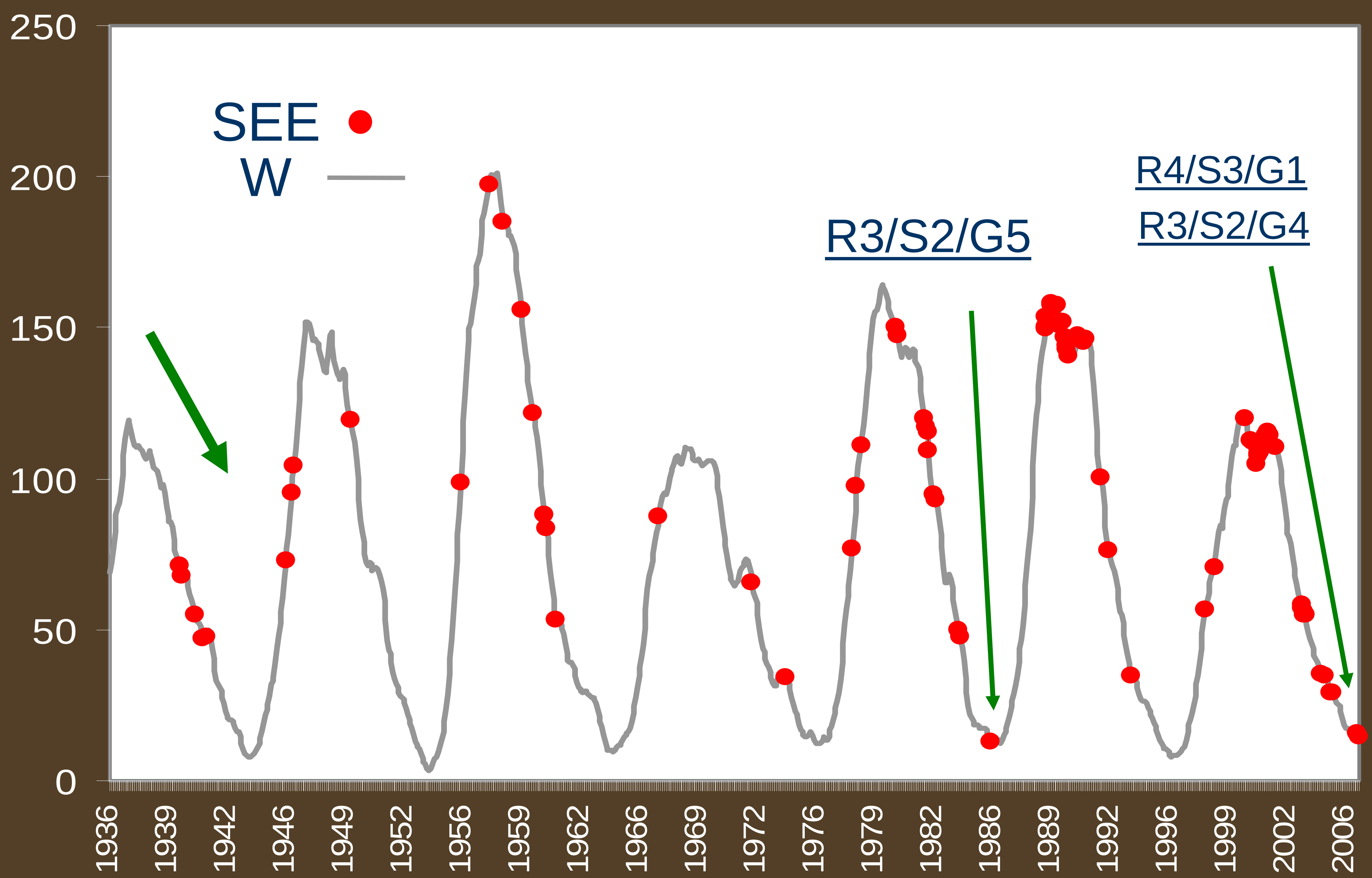
Ap = 252

Dst = -363

R5/S4/G5

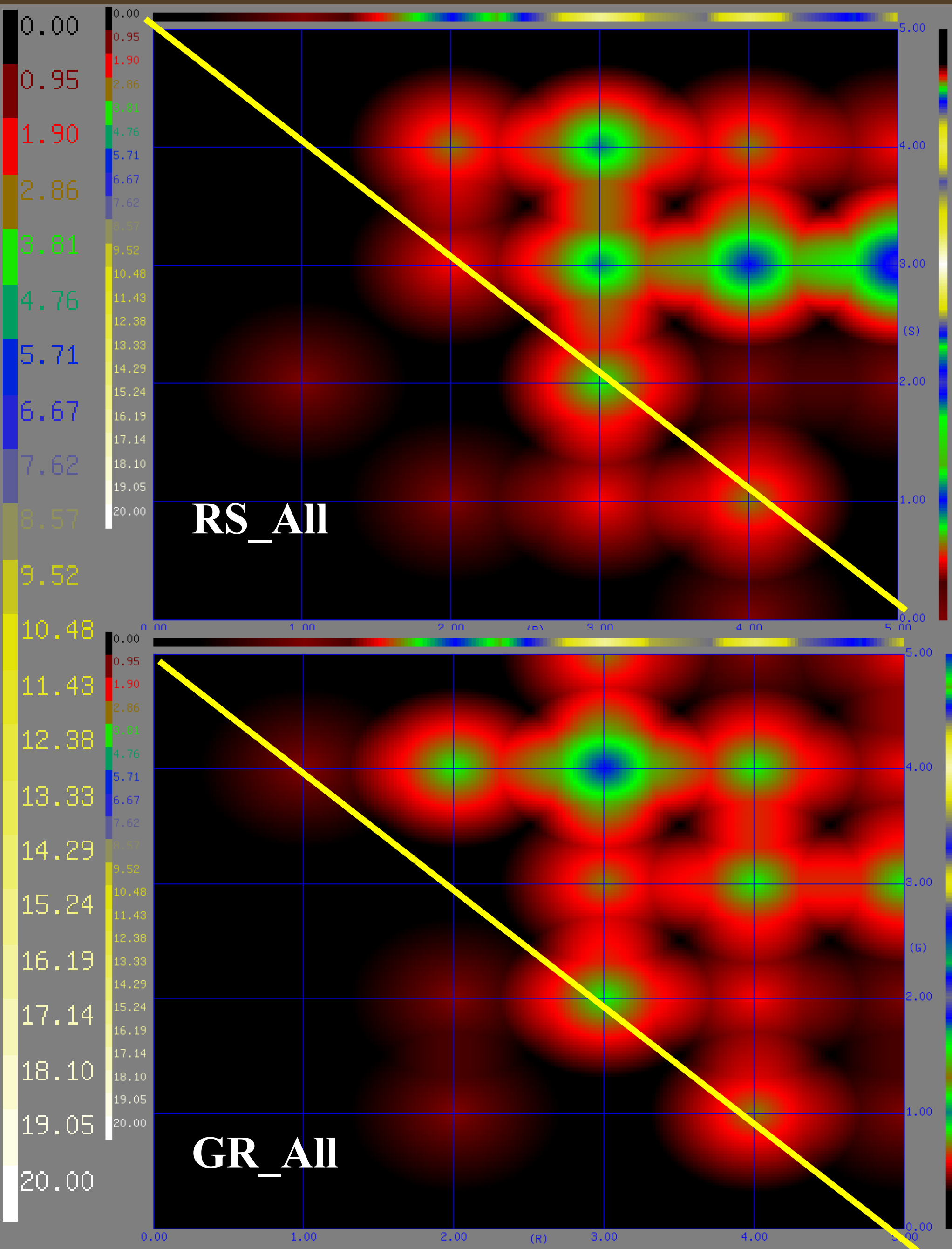


SEEs distribution during the solar cycles



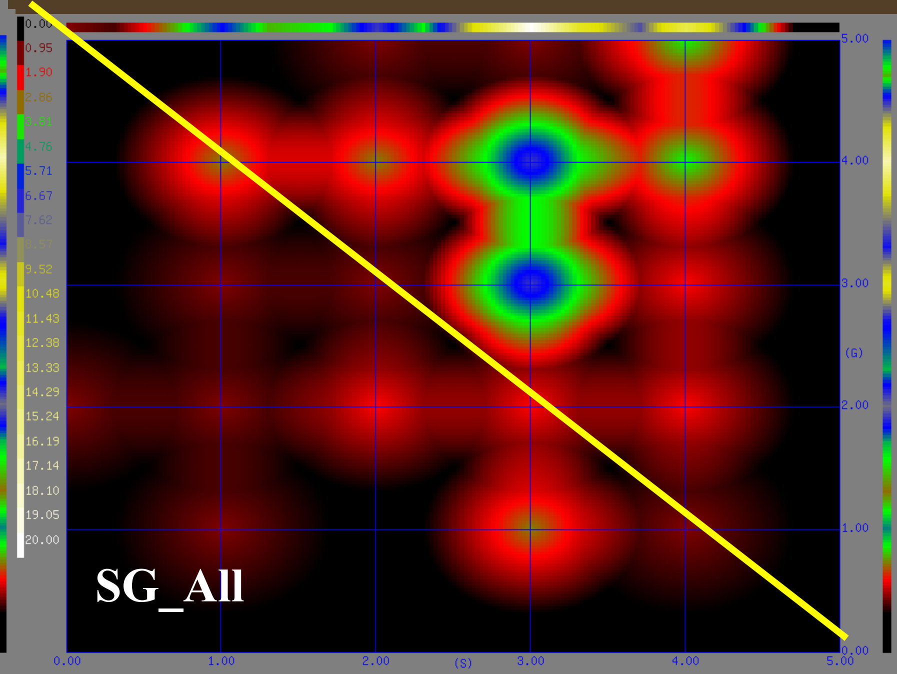
Strongest Solar Extreme Events

Index	Data	Value	Index	Data	Value
X>10	01.06.1991	X> 12.5/1F (26 m)	Dst	10.03.1989	-599
	06.06.1991	X> 12.5/4, (26 m)		18.11.2003	-472
	04.11.2003	X> 17.5/3, (11 m) X28		29.10.2003	-401
	15.06.1991	X> 12.5/1F (22 m)		14.07.1959	-429
	07.09.2005	X> 17.1		29.03.2001	-387
SEP	04.08.1972	86000	Ap	17.09.1941	312
	19.10.1989	39000		10.11.1960	293
	22.03.1991	50000		10.03.1989	285
	14.07.2000	24000		23.03.1940	277
	28.10.2003	33600		28.10.2003	252



The tendency confirmed of extreme events to be strong in all parameters

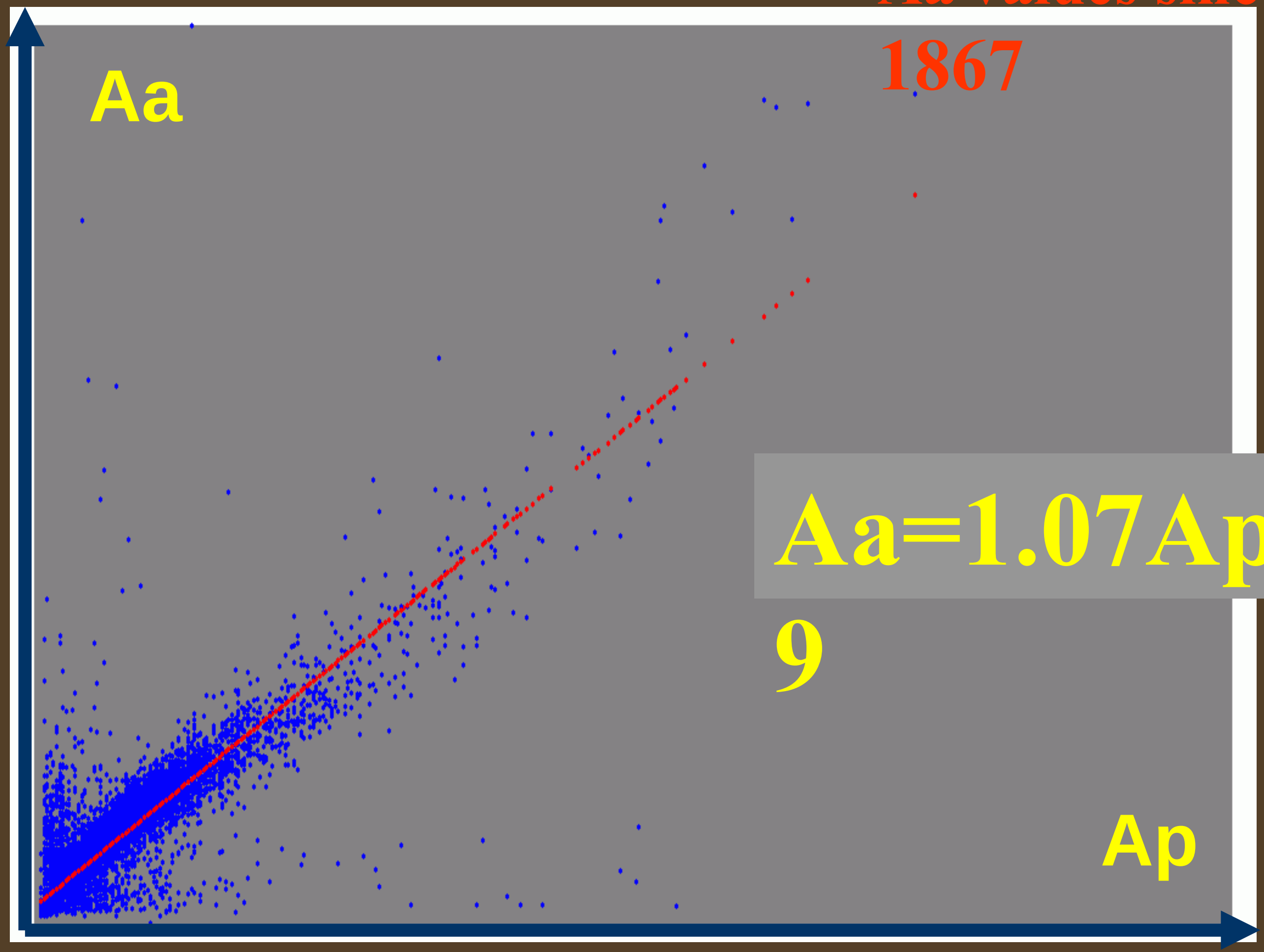
R - radio blackouts
S - solar proton radiation storms
G - geomagnetic storms



Aa vs Ap

Ap values since 1932

Aa values since 1867



Aa=1.07Ap+1.9

+ 14 events from Aa data base

SEE recurrence time statistics

Recurrence time statistics of extreme events can be described by the following low

$$P(T) \sim T^{-\alpha}$$

For

earthquake α= 2/3

mortality caused by inundations and tornado α= 1,4

Sacrifices of epidemies α= 0,29

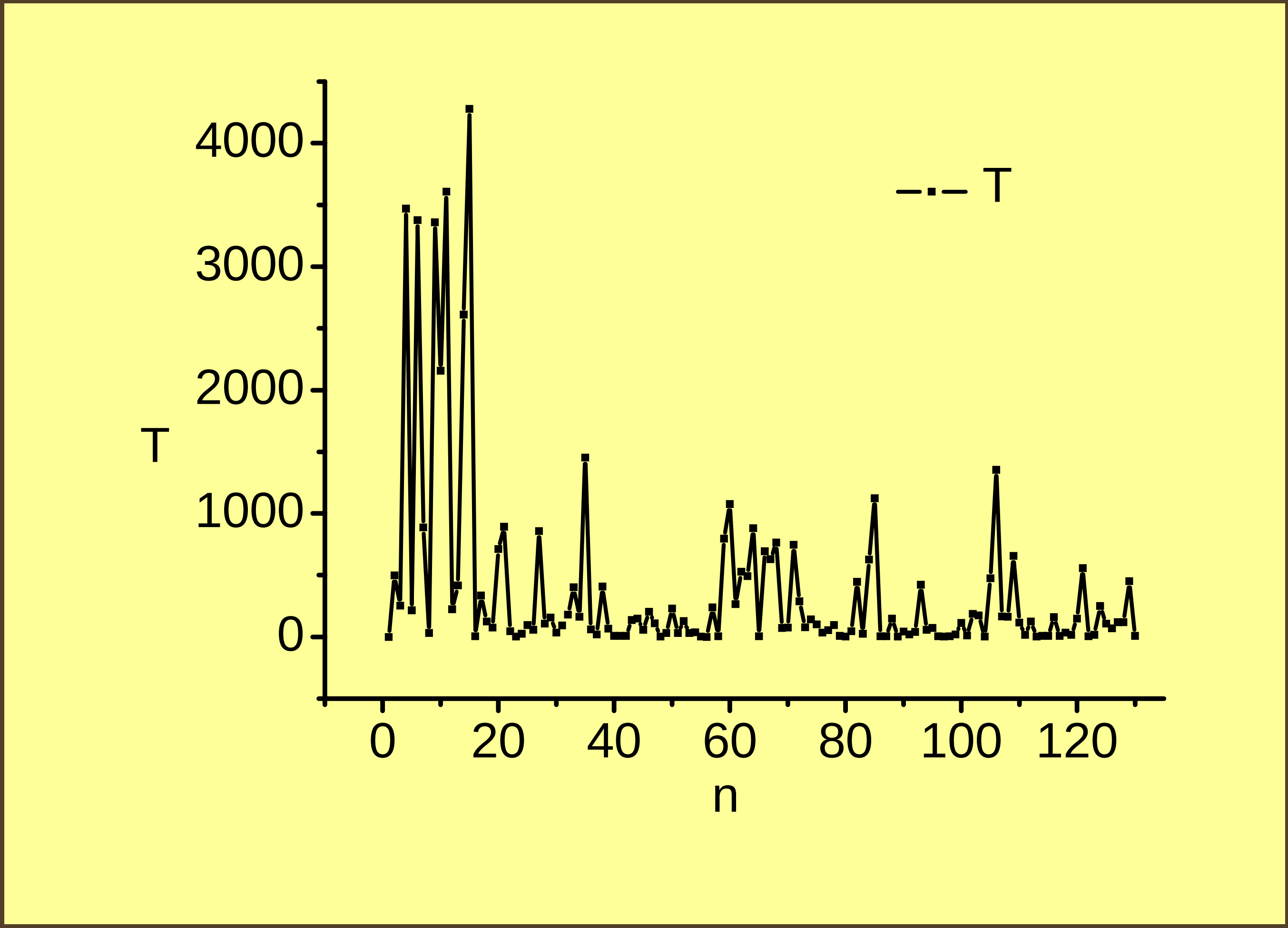
Area of forest fires α= 0,59

Phillip D. Stroud, , Stephen J. Sydoriaka, Jane M. Riesea, James P. Smitha, Susan M. Mniszewskia, Phillip R. Romero Semi-empirical power-law scaling of new infection rate to model epidemic dynamics with inhomogeneous mixing //Mathematical Biosciences Vol. 203, N 2, 2006, P. 301-318

Fausto Guzzetti, Colin P. Stark, Paola Salvati. Evaluation of Flood and Landslide Risk to the Population of Italy// Environmental Management. Vol 36, N.1, 2005, P 15-36

Distribution of time intervals between SEE

T – time interval
n – event number

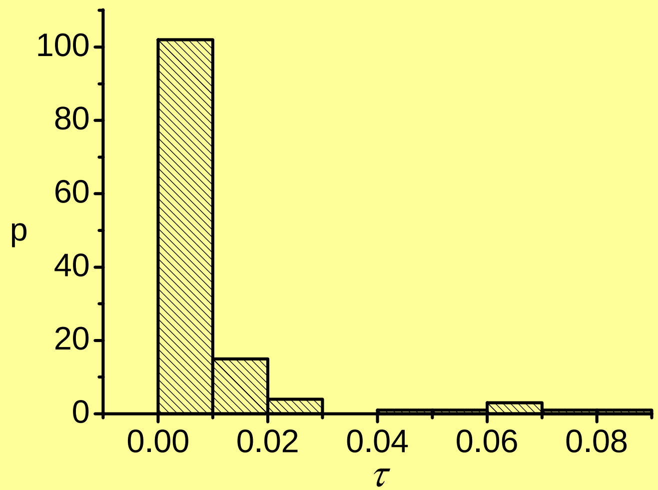


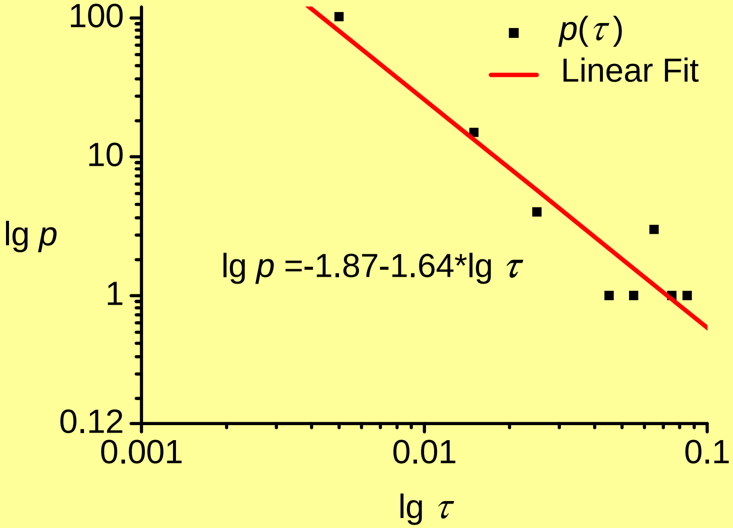
For SEE α=0,64

$$\langle T \rangle = \lim_{N \to \infty} (1/N) \sum_{i=1}^{N} T_i$$

$$p_\tau \sim \tau^{-(1+\alpha)}$$

$$\tau = T_i / \langle T \rangle$$





- Histogram shows how many time intervals are in the each bar
- Estimation of power low index for extreme events recurrence intervals

Conclusions:

- The data base was created, which contains 85 strongest events for the period since 1932 to 2007
- The data base was expended to 1868 using regression connection of Aa and Ap indexes
- We confirmed the tendency of extreme events to be strong in all parameters (‘syndrome of big flares’)
- As a rough approximation, waiting time intervals between SEE can be described by power low with index α=0,64

Thank you!