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Poster 1
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Undoubtedly, solar flare activity acts as a trigger for strong earthquakes

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1 Early and recent publications indicating a solar action on seismicity. Studies reveal diurnal, seasonal and 11-years earthquake cycles.

Pliny the Elder (79 A.D. died eruption Mt.Vesuvius)
F. Omori, 1902, 1904-08 (Tokyo) - strong events in Japan
N.F. Drake, 1912 (BSSA) - strongest events in China
V. Conrad, 1909, 1926, 1935 (Vienna) - European regions
E. Tams, 1925 (Zeitschr. Ang. Geoph.) - Vogtland
E. Wanner, 1928 (Zürich) - Switzerland
Ch. Davison, 1928 (BSSA) - worldwide
M. Shimshoni, 1972 (Geo.J.R.Astr.S.) - worldwide
A.D. Sytinskiy 1989 (Izvestiya) - worlwide, solar cycle
G. Duma & G.Vilardo, 1998 (Phys.Chem..Earth) - Mt.Vesuvius

T. Lipovics, 2000, 2005 (EGU) - N- and S-America
G. Duma & Y.Ruzhin, 2003 - Several regions, model
A.Yu. Schekotov & O.A.Molchanov, 2005 - Kamchatka, Japan, USA
D.R. Choi, 2010 (New Concepts in GTN) - Seismic Synchronicity
G. Duma, F. Freund, P. Kosovichev, 2005 (Geo.Res.Abstr.) - Major seismic zones
S. Mukherjee, L. Kortvellyessy, 2005 (Geo..Res.Abstr.) - Fluctuations in Kp Trigger
G. Anagnostopoulos, A. Papandreou, P. Antoniou, 2010 (Cornell Univ.) - Solar wind
V. Straser, G. Cataldi, D. Cataldi, 2015 (New Concepts in GTJ) - Chile quake Md8.3
N. Urata, G. Duma, F. Freund, 2018 (OJER) - Kp Index and Earthquakes

2 Disturbances of the Earth's magnetic field by solar activity

The disturbances are measured by geomagnetic observatories - and published as Geomagnetic Indices Kp and Dst since mid 20th century.

Kp and Dst reflect the impact of varying intensity of solar plasma radiation on the Earth's geomagnetic field as a whole ("Planetary Indices").

Dst is the "Equatorial index horizontal component" , H disturbances are caused by the magnetospheric ring currents, flowing at 2-3 R_E .
Dst (nT) is named: "Disturbance storm time" . By magnetic storms, a dipol field acting against the Earth's dipol (axis-parallel) is generated, H is depressed. Dst is the amount of decrease of H(in Nanotesla, nT). The

The current study focuses on Index Dst which reflects the storm disturbances.

Kp: measured in 3-hr intervals, UT, average of 13 observatories worldwide, published since 1932, by ISGI, France and GFZ Potsdam, Germany

Dst : measured in 1-hr intervals, UT, average of 4 observatories worldwide, published since 1957, by ISGI, France and WDC for Geomagnetism, Kyoto, Japan

Fig. 1 and Fig. 2: Solar flares vary in number and intensity in the short term as well as in the long term.
Note that Dst reacts invers to solar flare activity variations compared to Kp (Fig. 2).

Fig. 1

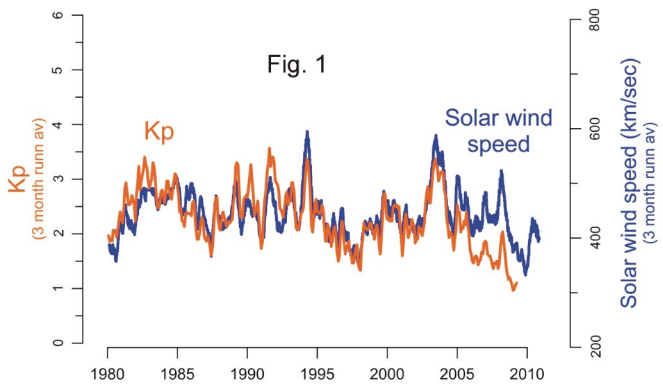
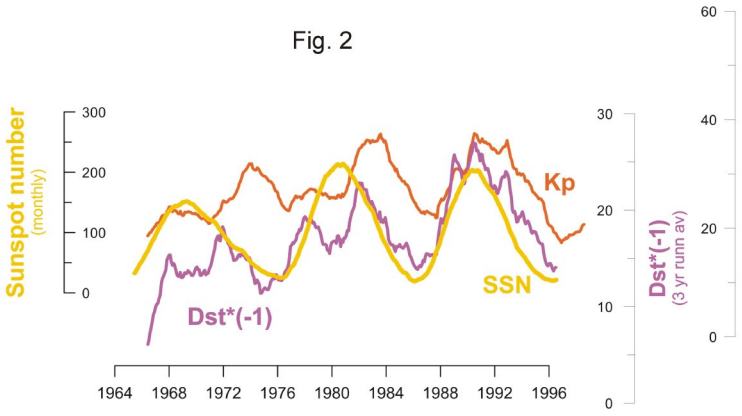


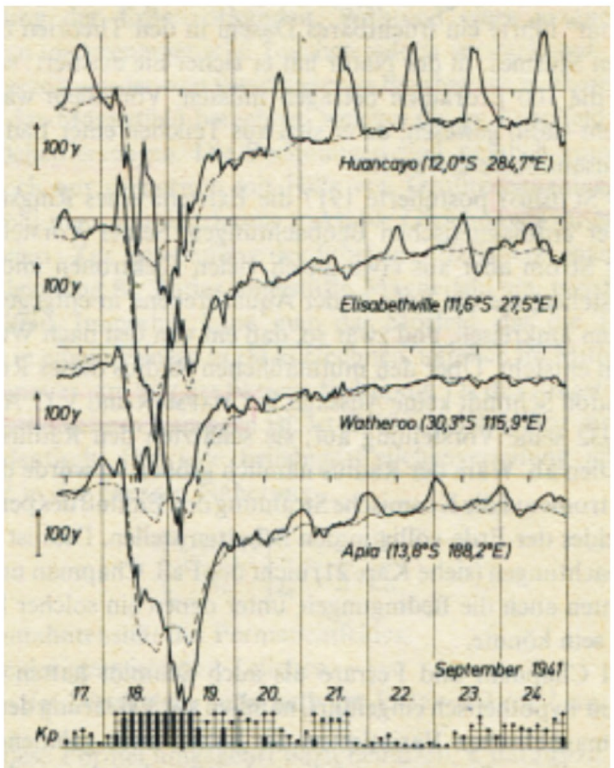
Fig. 2



3 Do magnetic storms trigger strong earthquakes ?

Index Dst reflects magnetic storm variations.

Dst displays the magnetospheric ring current variation DR during magnetic storms, which are solar induced. Fig. 3 shows the horizontal intensity H of the Earth's magnetic field, as it decreases down to very low values, the sharp minimum.



magnetograms of 4 low latitude observatories

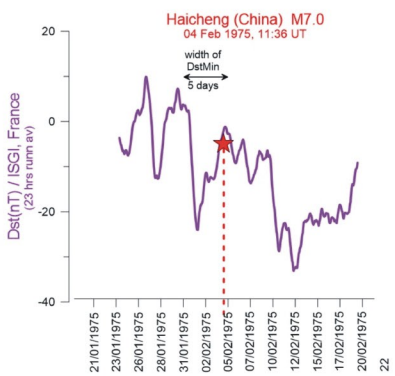
'storm main phase' with minimum of H and 'post-perturbation' (recovering of H can take several days and even weeks)

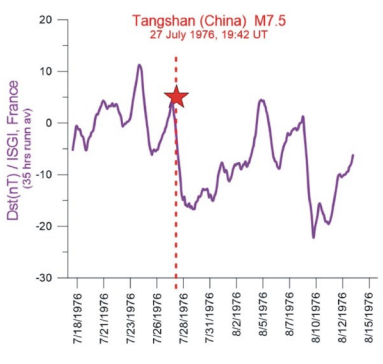
(after W. Kertz, 1968)

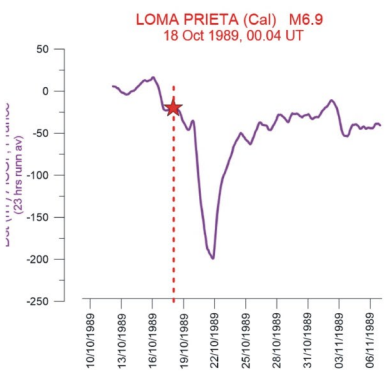
Fig.3 Records of a magnetic ring current variation DR

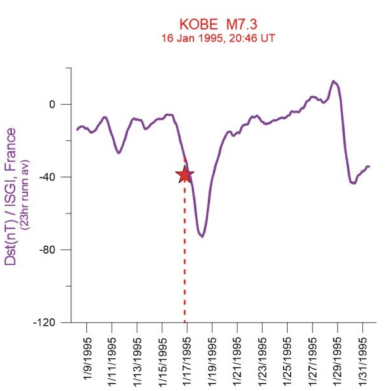
A first inventory of coincidence of earthquake times and magnetic storms

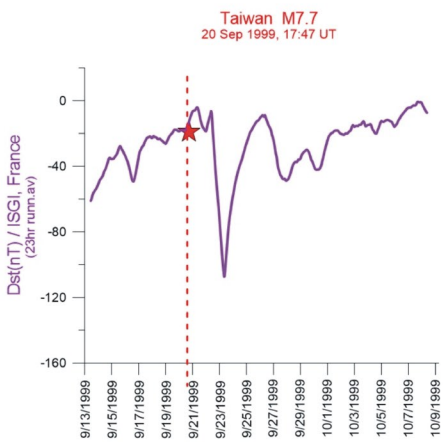
Note: All earthquakes happen close to the storm phase of strong H depression and the H-minima.

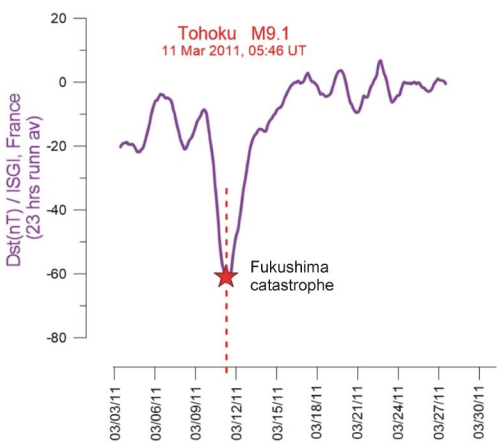


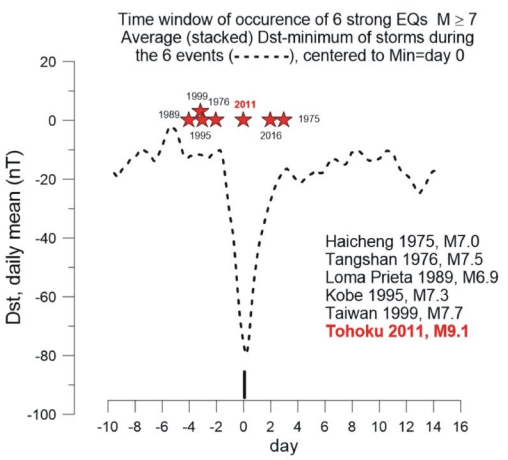




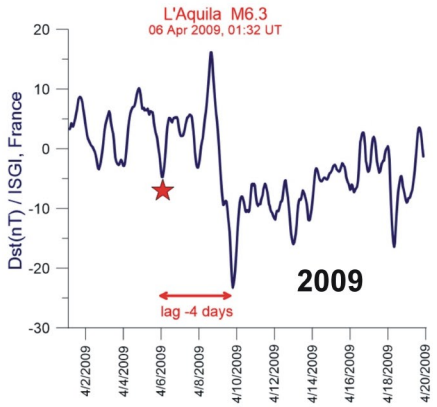


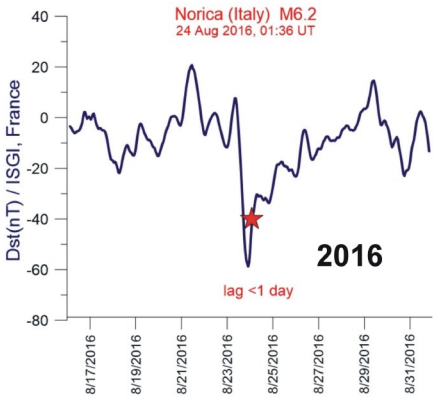






Two more examples for earthquakes M>6 in Italy

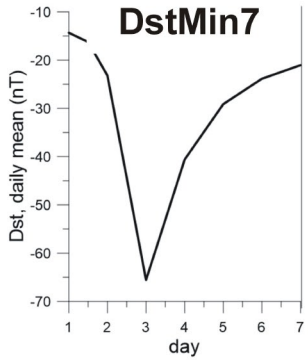




4 A comprehensive case study on all earthquakes 2010 - 2018 on the Earth's N-hemisphere, M ≥ 7

According to the USGS Earthquake Catalogue there happened 36 events M > 7 in that period.

Detection of all strong storm Dst-minima in the period 2010-1018: Compute cross-correlation DstMin7 - DstYear



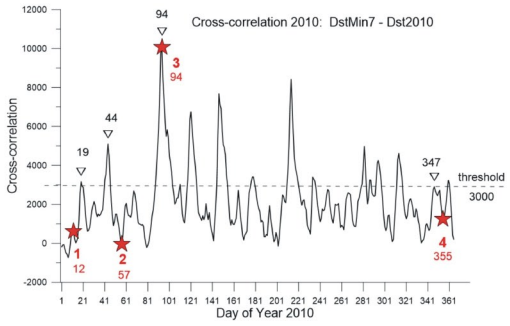
1) An average storm minimum in H was established, derived from the above observations, with a width of 7 days, named DstMin7.
2) The cross-correlation with the entire Dst data 2010-2018 (daily means) were computed.
3) All maxima of cross-correlation with an amplitude bigger than 3000 were compared with the 36 earthquake origin times.

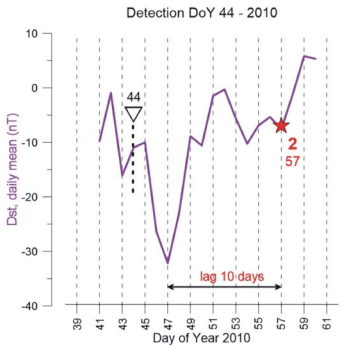
Results of cross-correlation per year and detected Dst-minima

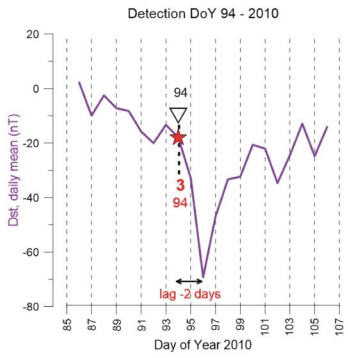
Annual display

Just 2 examples per year of detected Dst-minima and position of earthquakes relative to storm Dst-minimum

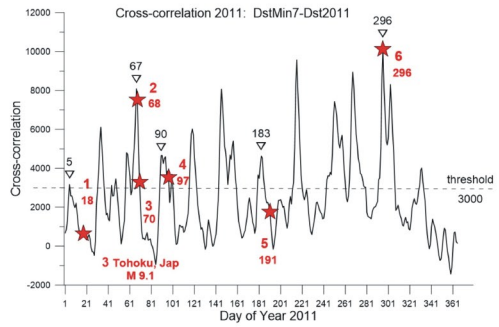
2010

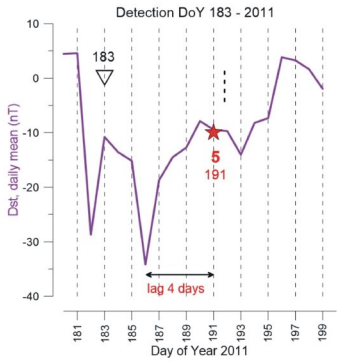


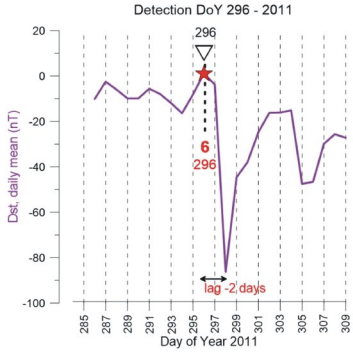




2011



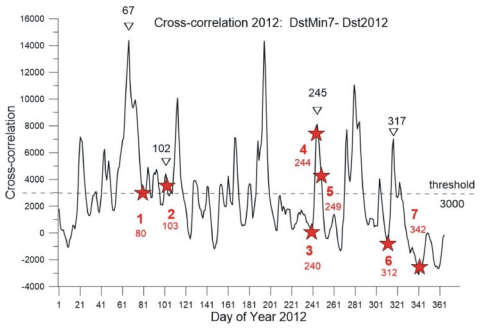


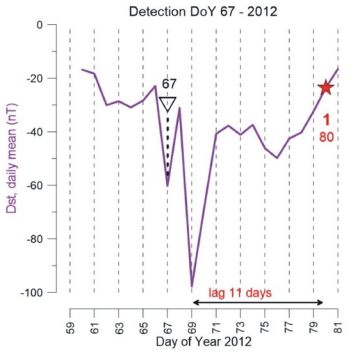


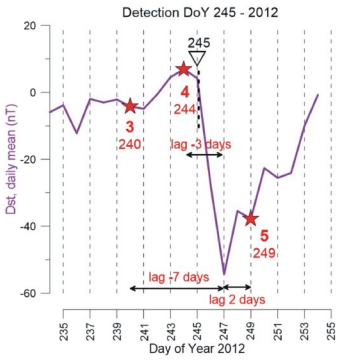
Results continued on next page

Results continued

2012

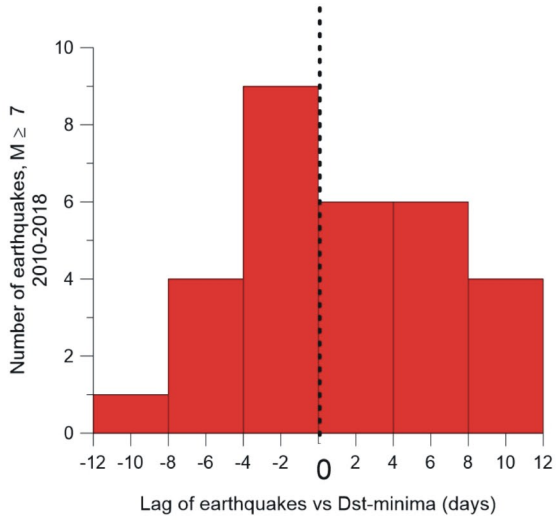






Similar results are obtained for remaining years 2013 - 2018.

5 Summary on earthquake times relative to storm Dst-minima, period 2010 - 2018



Period 2010-2018:
30 earthquakes M ≥ 7 happened within an interval of [-12,+12] days relative to the storm Dst-minimum.
They all were associated with cross-correlation maxima bigger than threshold 3000.

Significance of statistical result for 30 strong earthquake times within a magnetic storm window [+12,-12] days

1. In the 9 years 2010 - 2018 we counted about 117 detections with a cross-correlation (DstMin7 vs 9 years Dst data) peak amplitude more than 3000, which we took as lower threshold. Every peak identified a magnetic storm minimum.

2. To each Dst-minimum we assigned a "storm window" of [+12,-12] days, with the minimum centered at day 0. This coincides with the time interval in which 30 earthquakes occured around a minimum (see histogram in chapter 4.)

3. Thus, the 117 minima cover 117 x 24 = 2808 days in period 2010 - 2018. The whole number of days 2010-2019 is 3287.

4. Consequently, the chance that 1 earthquake fits with one of the 117 "storm windows" is:
p1 = 2808/3287 = 0.85, i.e. 85%.
According to basic statistics, the probabilty that 30 earthquakes fit with any of the "storm windows" is than p30 = p1^30, which makes p30 = 0,007.

Result

The chance that 30 earthquakes fit with any "storm window" of 24 days width, in the period 2010 - 2018, by accident is only 0,7% .

This is far below the common threshold of significance of 5%.