A New Index to Describe the Response of Geomagnetic Disturbance to the Energy Injection from the Solar Wind

National Satellite Meteorological Center
(National Center for Space Weather)

Ming-Xian Zhao, Jing-Song Wang*, and Xiao-Wei Zhao

CONTENT

I. Introduction

- Interaction between solar wind and magnetosphere bring geomagnetic storms
- The Dst index is often used to classify the intensity of the geomagnetic storm.
- Compare the relationship between the interplanetary disturbances and the responses in the M-I-A system.
- The existing geomagnetic indices cannot perfectly describe the coupling process between the solar wind and the magnetosphere.

II. Data and Methods

- Spectral Whitening Method (SWM)
  - Proposed by Wang et al., Ann. Geophys, 2014
- SWM was used to design ionospheric single-station index J_s and global index J_p
  - Chen et al. JGR, 2014

$$g_{\mathrm{d}}^{*}(t)=\int_{-\infty}^{+\infty}\left[\int_{-\infty}^{+\infty} g(t)\cdot e^{-2\pi i t\xi}dt\right]\cdot\frac{P_0}{P_{env}(\xi)}\cdot \mathrm{e}^{2\pi i t\xi}d\xi$$

$$g_s(t_m)=\frac{1}{3}\sum_{j=0}^{2} g_{\mathrm{d}}^{*}(t_{m+j-1})$$

$$J_{\mathrm{s}}(t)=\frac{g_s(t)}{\sigma_g}$$

$$J_{\mathrm{p}}(t)=\frac{1}{m}\sum_{i=1}^{m} J_{s_i}(t)$$

II. Data and Methods

- We use SWM to design station index and global index of geomagnetic disturbance
- Geomagnetic data: Intermagnet, from 1991—2004
- Solar wind/IMF/Dst: OMNI dataset
- We Define:
  - Station geomagnetic index, J_s^G
  - Global geomagnetic index, J_p^G

III. Results and Discussion

3.1 The Ability of Geomagnetic Disturbance Extraction

3.2 Influence of the Number of Stations

3.3 Case Study of Magnetic Storm Events

3.4 Statistical Analysis of Magnetic Storm Events

3.1 The Ability of Geomagnetic Disturbance Extraction

- J_p^G index vs Dst index
  - Similar change pattern
  - Minimum value at close time
- SWM can extract geomagnetic disturbance variations
- J_p^G index can describe geomagnetic storms

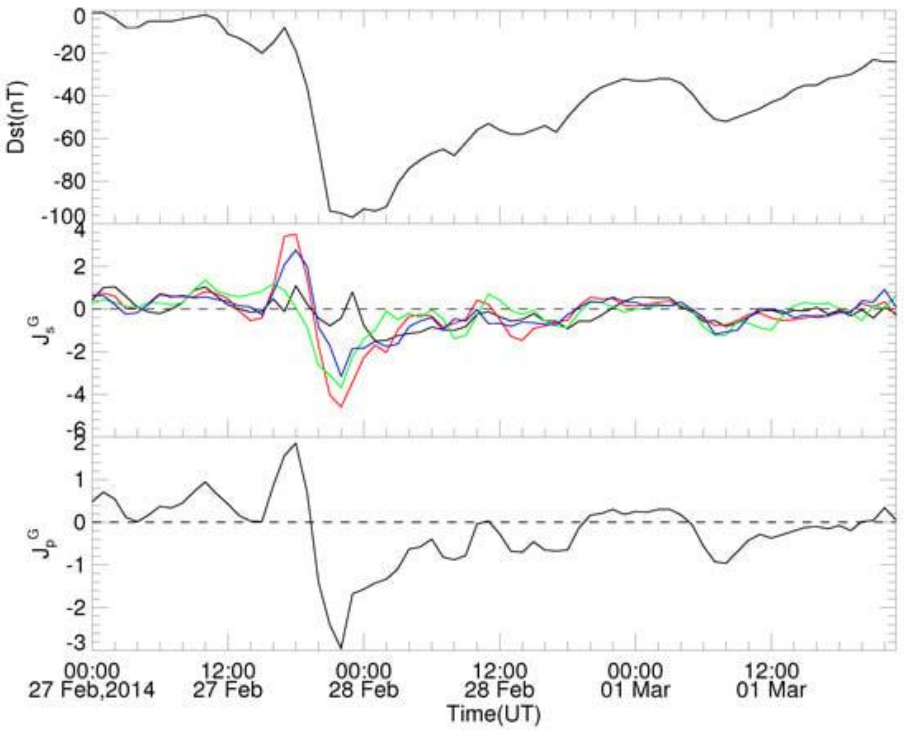


Figure 1. Comparation of the Dst index and our new index during the magnetic storm from 27 February to 1 March 2014. The top panel shows the Dst index. The middle panel shows the J_S^G index for HER (green), KAK (black), HON (blue), and SJG (red) stations. The bottom panel shows the J_p^G index.

3.2 Influence of the Number of Stations

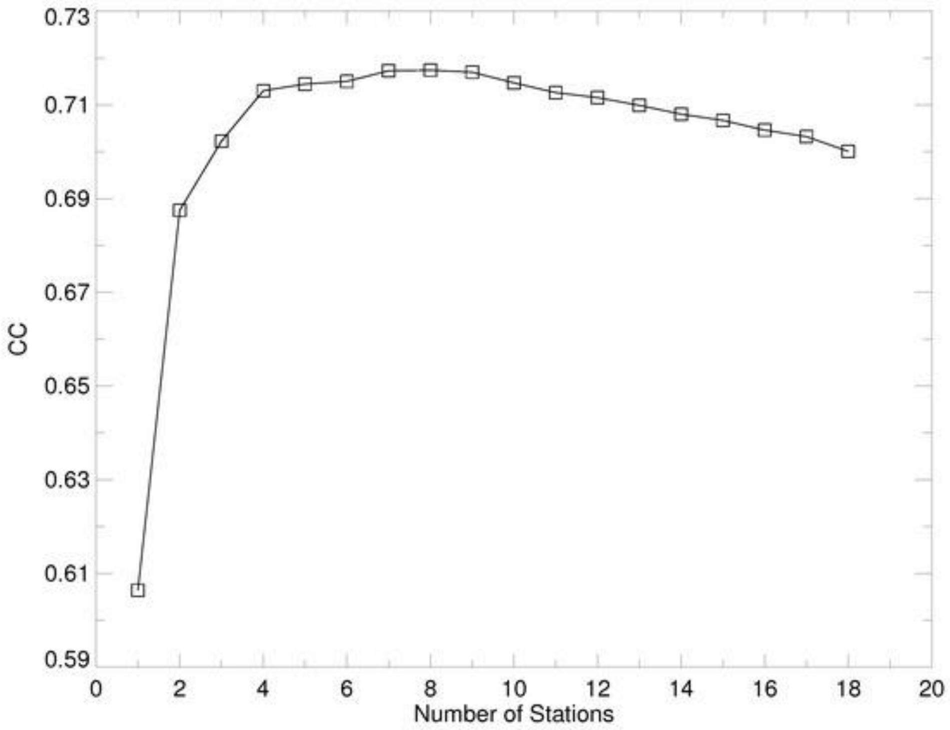


Figure 2. The variation of the CC between the Dst index and the J_p^G index when the number of stations used in the construction of J_p^G varies from 1 to 18.

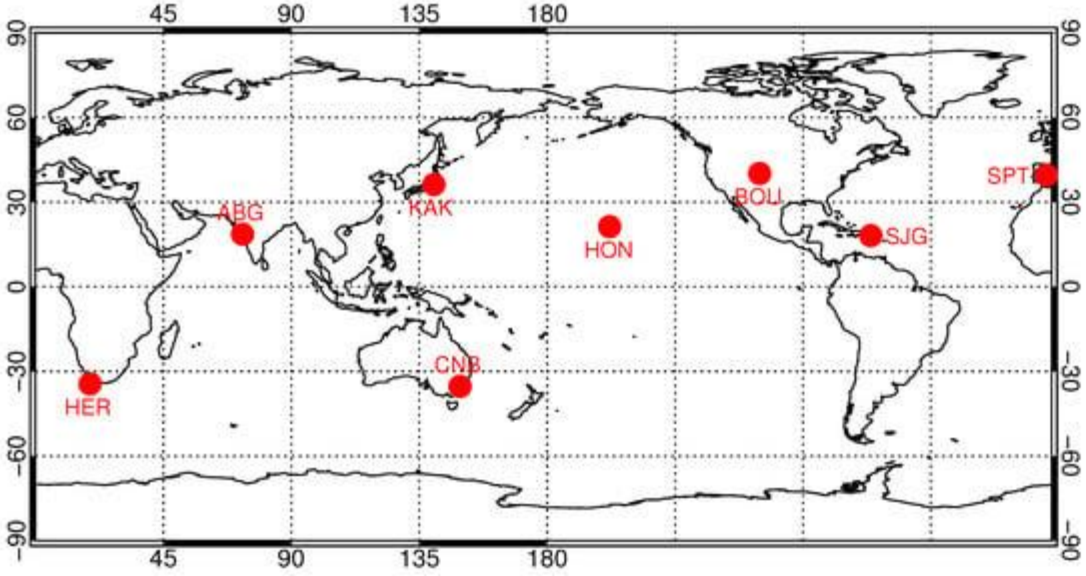
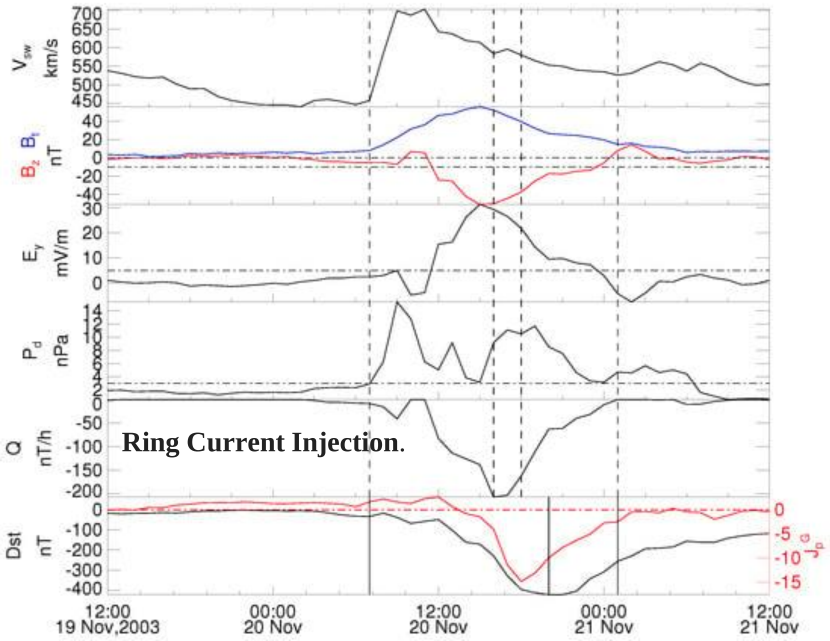


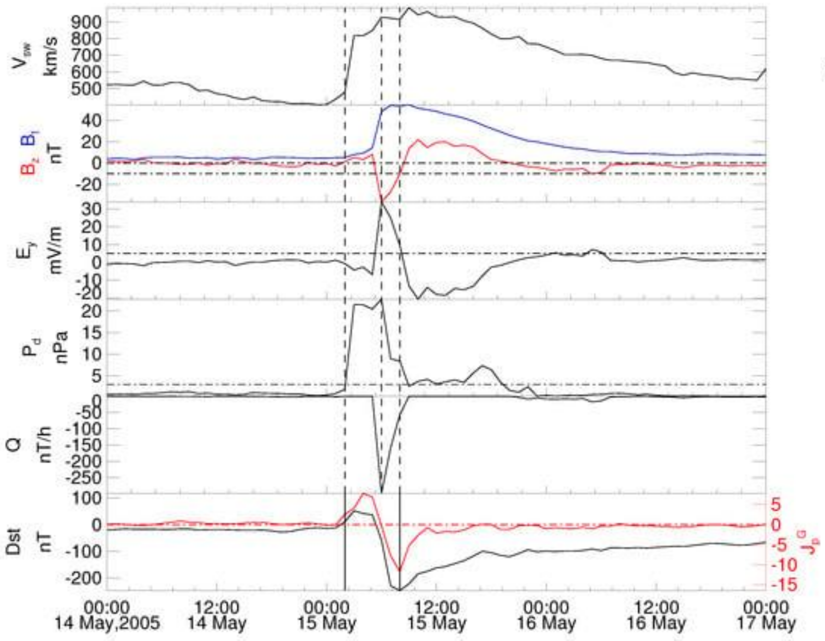
Figure 3. The global map with these eight stations locations marked as red circle..

3.3 Case Study of Magnetic Storm Events

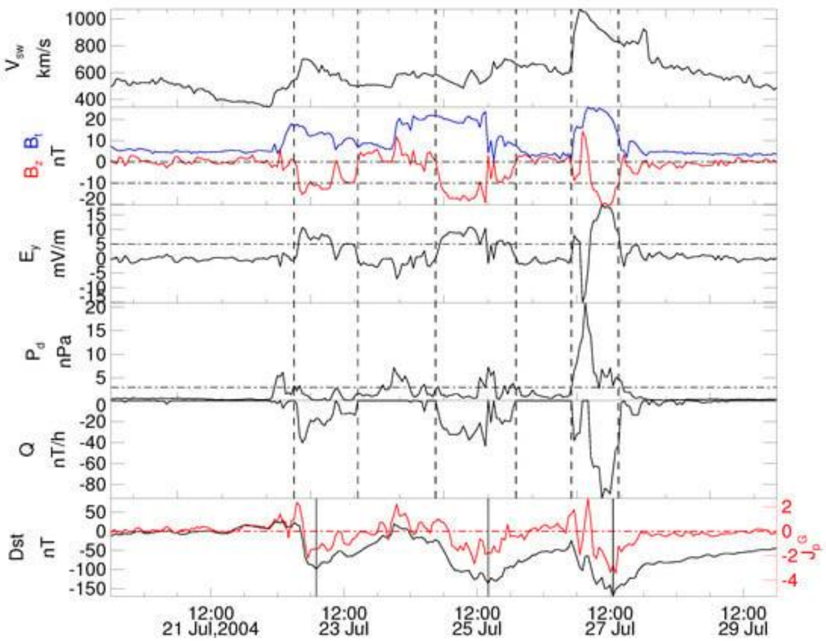
Three typical magnetic storm events



Without sudden commencement (SC)



With SC



Multi magnetic storms

J_p^G correlate well with the energy injections from the solar wind.

3.4 Statistical Analysis of Magnetic Storm Events

3.4.1 Storm intensity

- Thirty great storms (1998--2014)
- Correlation Q_{min} vs $J_p^G{}_{min}$
  - CC = 0.82
  - p-value = 0.00
- Our new J_p^G index correlates well with the interplanetary source in the amplitude aspect.

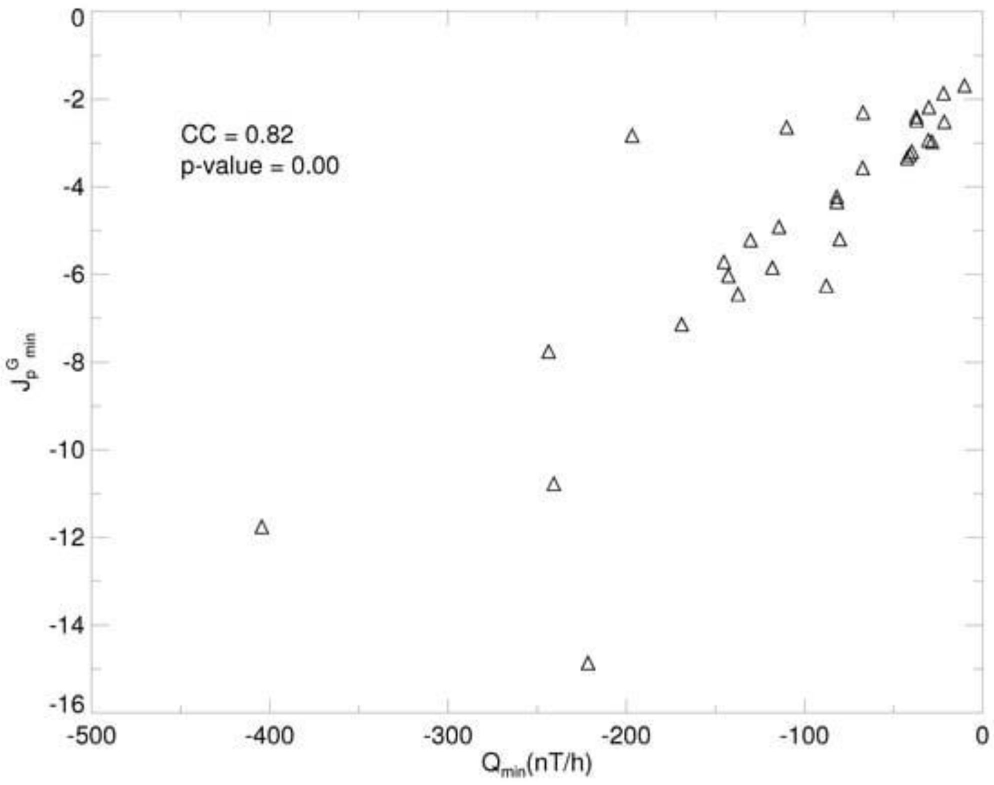


Figure 7. Correlation between Q minimum and J_p^G minimum for 30 great magnetic storm events from 1998 to 2014.

3.4 Statistical Analysis of Magnetic Storm Events

3.4.2 Delay time

- The delay time between Q minimum and Dst or J_p^G minimum
- $\Delta t(Q_{min} \sim Dst_{min})$
  - Mainly between 1~7 h
  - Average delay time: 4.00 h
- $\Delta t(Q_{min} \sim {J_p^G}_{min})$
  - Mainly between 0~3 h
  - Average delay time: 2.17 h

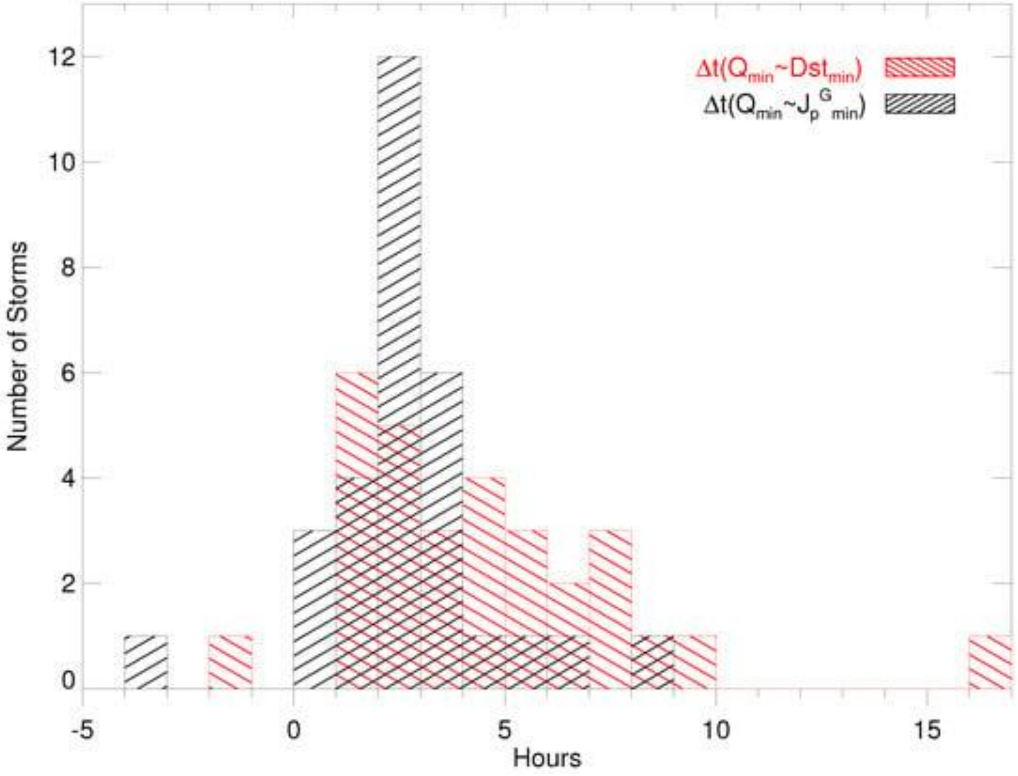


Figure 8. The distribution of delay times between Q minimum and Dst minimum (red), denoted as $\Delta t(Q_{min}\text{\textasciitilde}Dst_{min})$, and delay times between Q minimum and J_p^G minimum (black), denoted as $\Delta t(Q_{min} \sim {J_p^G}_{min})$.

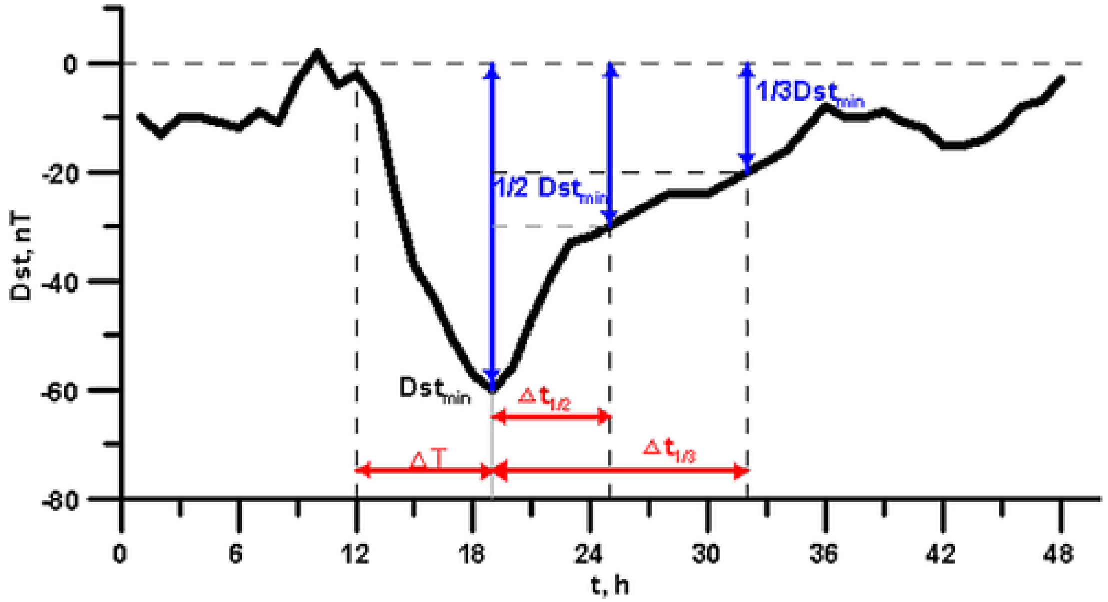
3.4 Statistical Analysis of Magnetic Storm Events

3.4.3 Decay time

- The recovery phase of extreme storms
  - Fast phase: exponential or hyperbolic
  - Slow phase: constant recovery rate

$\Delta t(Dst_{min}/2)$、 $\Delta t({J_p^G}_{min}/2)$

$\Delta t(Dst_{min}/3)$、$\Delta t({J_p^G}_{min}/3)$



Yermolaev et al., JGR, 2014

3.4 Statistical Analysis of Magnetic Storm Events

3.4.3 Decay time (Fast decay)

- $\Delta t(Dst_{min}/2)$
  - Range from 5~40 h
  - Average decay time: 13.97 h
- $\Delta t({J_p^G}_{min}/2)$
  - Range from 1~7 h
  - Average decay time: 2.97 h

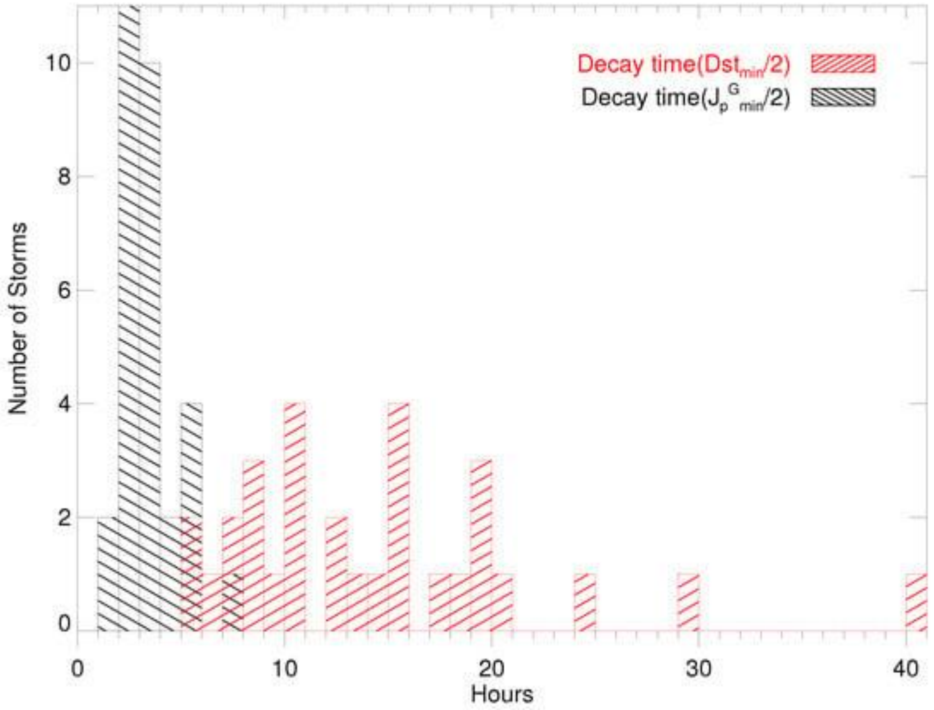


Figure 9. Distributions of magnetic storm recovery durations, the start and end time of the recovery phase are the time when the geomagnetic index is at the minimum value and the time when the geomagnetic index is restored to 1/2 of the minimum value, the red is for the Dst index, and the black is for the J_p^G index.

3.4 Statistical Analysis of Magnetic Storm Events

3.4.3 Decay time (Fast+slow decay)

- $\Delta t(Dst_{min}/3)$
  - Range from 10~53 h
  - Average decay time: 27.40 h
- $\Delta t({J_p^G}_{min}/3)$
  - Range from 2~12 h
  - Average decay time: 4.90 h
- Slow decay
  - Dst: average time 13.43 h
  - J_p^G: average time 1.93 h

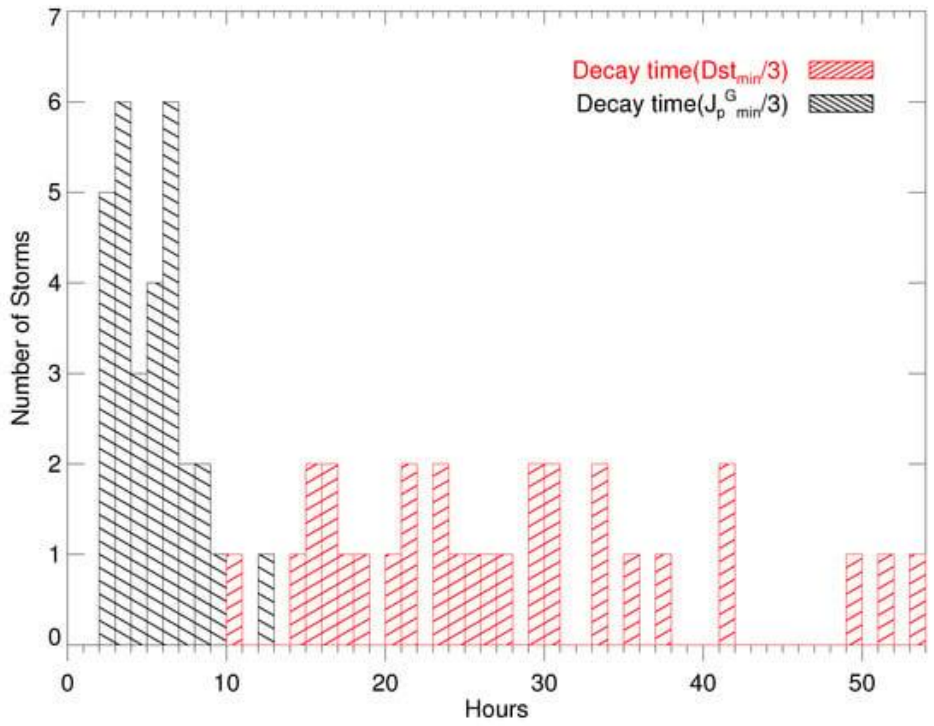
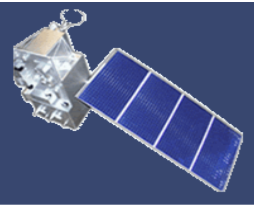


Figure 9. Distributions of magnetic storm recovery durations, the start and end time of the recovery phase are the time when the geomagnetic index is at the minimum value and the time when the geomagnetic index is restored to 1/3 of the minimum value, the red is for the Dst index, and the black is for the J_p^G index.

IV. Summary and Conclusions

- The J_p^G index can describe the development of geomagnetic storms and its relationship with the Dst index has been verified, which gives a CC of about 0.72.
- The variation of J_p^G is similar to the variation of Q, and the recorded Q_{min} and ${J_p^G}_{min}$ for 30 great storms yields a relatively good CC of about 0.82. These results illustrate that J_p^G can effectively depict the storm evolution and is well related to the associated Q in amplitude.
- The delay time between Q_{min} and ${J_p^G}_{min}$, as well as the decay time of J_p^G, are shorter than those of the corresponding Dst index.
- For multiple storms occurred continuously on a short time scale, the recovery of the Dst index to a quiet period level can be affected by the following solar wind energy input, while the J_p^G index does not and exhibits independently.



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Thanks!