A critical look at studying the reaction of the magnetosphere to interplanetary drivers

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EGU General Assembly 2020

Abstract

One of the most promising areas of research in solar-terrestrial physics is the comparison of the responses of the magnetosphere-ionosphere-atmosphere system to various interplanetary disturbances (the so-called "interplanetary dravers"). Numerous studies show that different types of drivers cause a different reaction of the system for identical IMF variations. At the same time, the number of incorrect approaches in this direction of research has increased. These errors can be attributed to 4 large classes. (1) The first class includes works whose authors uncritically reacted to previously published works with incorrect driver identification and use incorrect results in their work. (2) Some authors used the wrong criteria and incorrectly determined the types of drivers. (3) Very often, authors associate the diturbance of the magnetosphere-ionosphere-atmosphere system caused by a complex driver (by a sequence of single drivers) with one of the drivers, ignoring the complex nature. For example, magnetic storm are often caused by compression region Sheath in front of the interplanetary CME (ICME), but the authors consider this events as so-called “CME-induced” storm, not “Sheath-induced” storm. (4) Finally, there is a “lost driver” of magnetospheric disturbances: some authors simply do not consider the compression region Sheath before ICME if there is no interplanetary shock (IS) before Sheath, although this type of driver, “Sheath without IS”, generates about 10% of moderate and strong magnetic storms.

Data and Methods

We use the same database and methods as in our previous works (Yermolaev *et al.*, 2015):

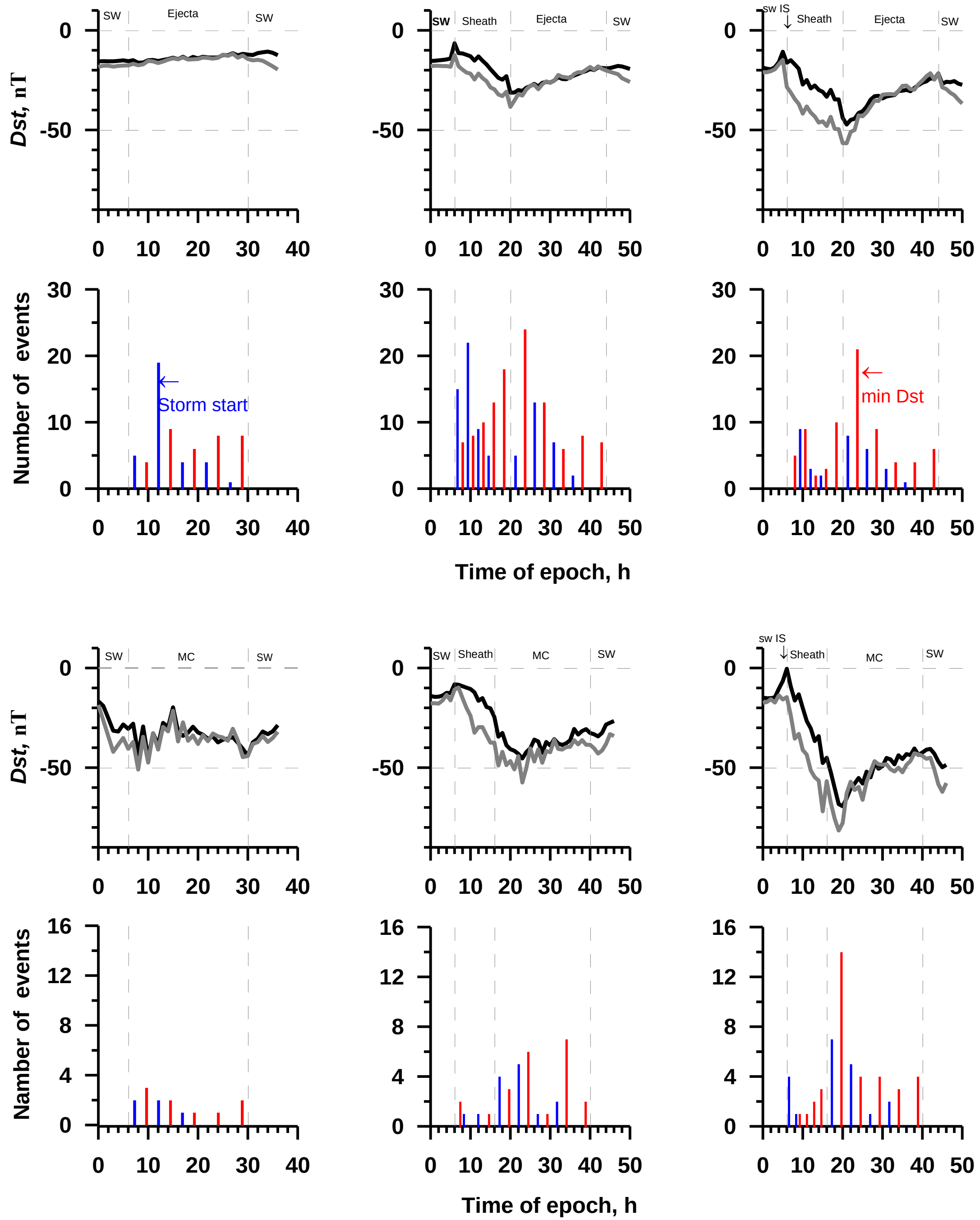
(1) the one hour (1-h) interplanetary plasma and magnetic field data of the OMNI2 database (http://omniweb.gsfc.nasa.gov (King and Papitashvili, 2004)),

(2) our extended catalog of large-scale solar-wind phenomena for 1976–2017 (ftp://ftp.iki.rssi.ru/pub/omni/ (Yermolaev *et al.*, 2009)) and

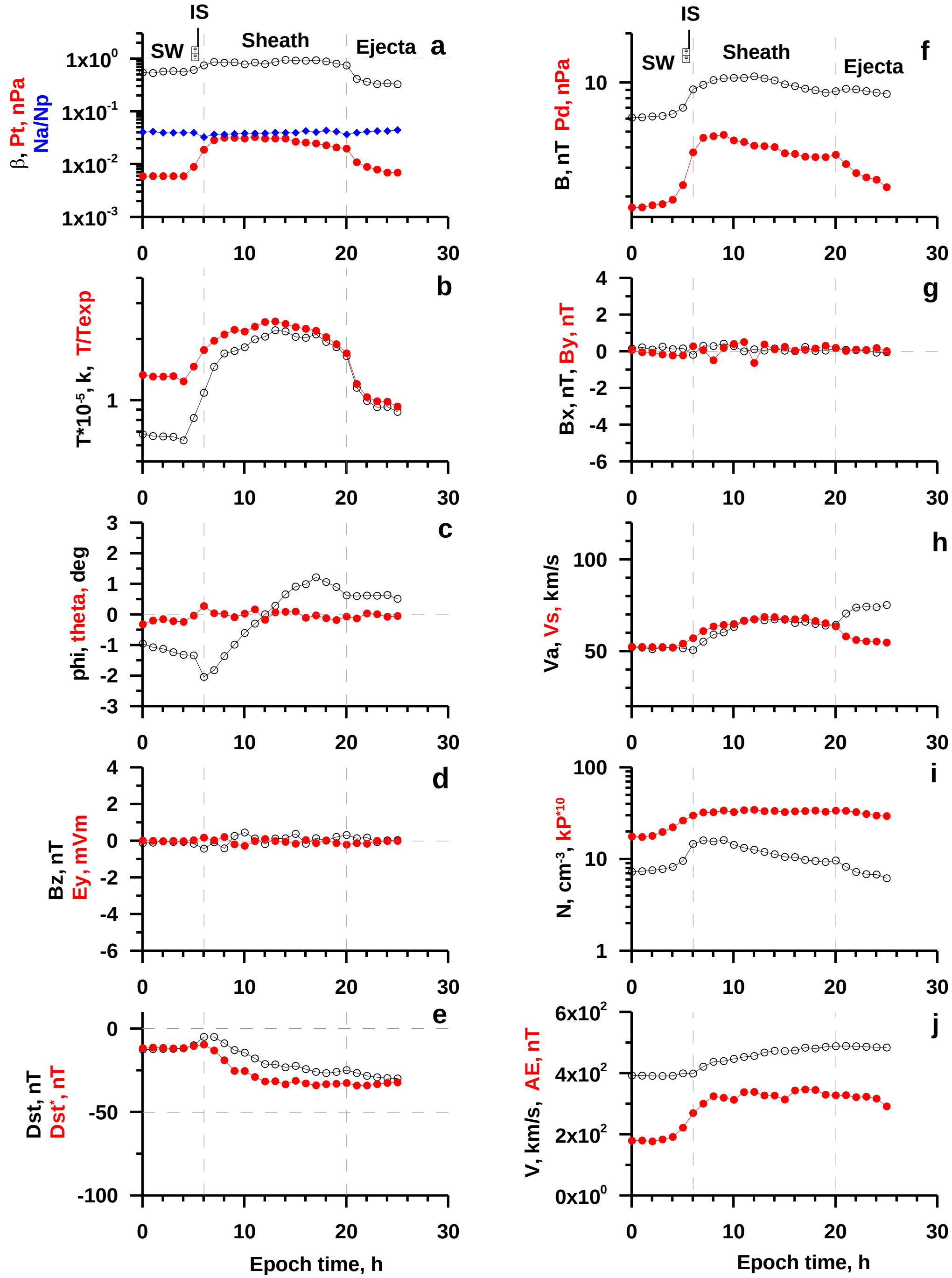
(3) the method of double superposed epoch analysis (DSEA) (Yermolaev *et al.*, 2010).

Results

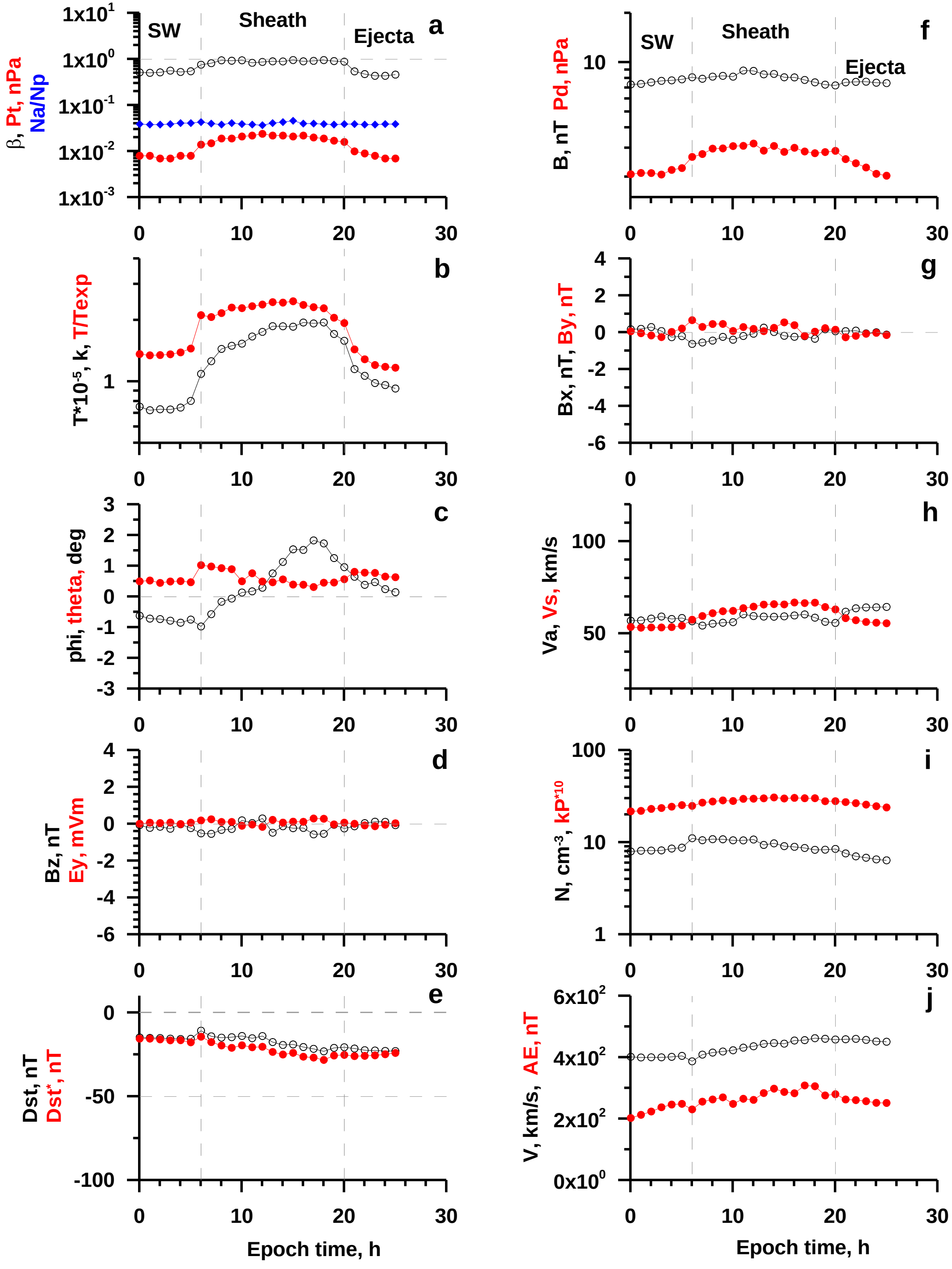
Fig. 1. *Temporal profile of Dst (black) and Dst* (gray) indices for six different sequences of solar wind phenomena. Vertical dashed lines indicate (from right to left): 1. last point of the Ejecta/MC intervals; 2. first point of the Ejecta/MC intervals; 3. (in the presence of Sheath) first point of the Sheath intervals. Panels of second and fourth rows show the distributions, in Sheath or Ejecta/MC time interval, number of beginnings of storms (blue columns) and number of maxima (Dst index minima) of storms (red columns).*



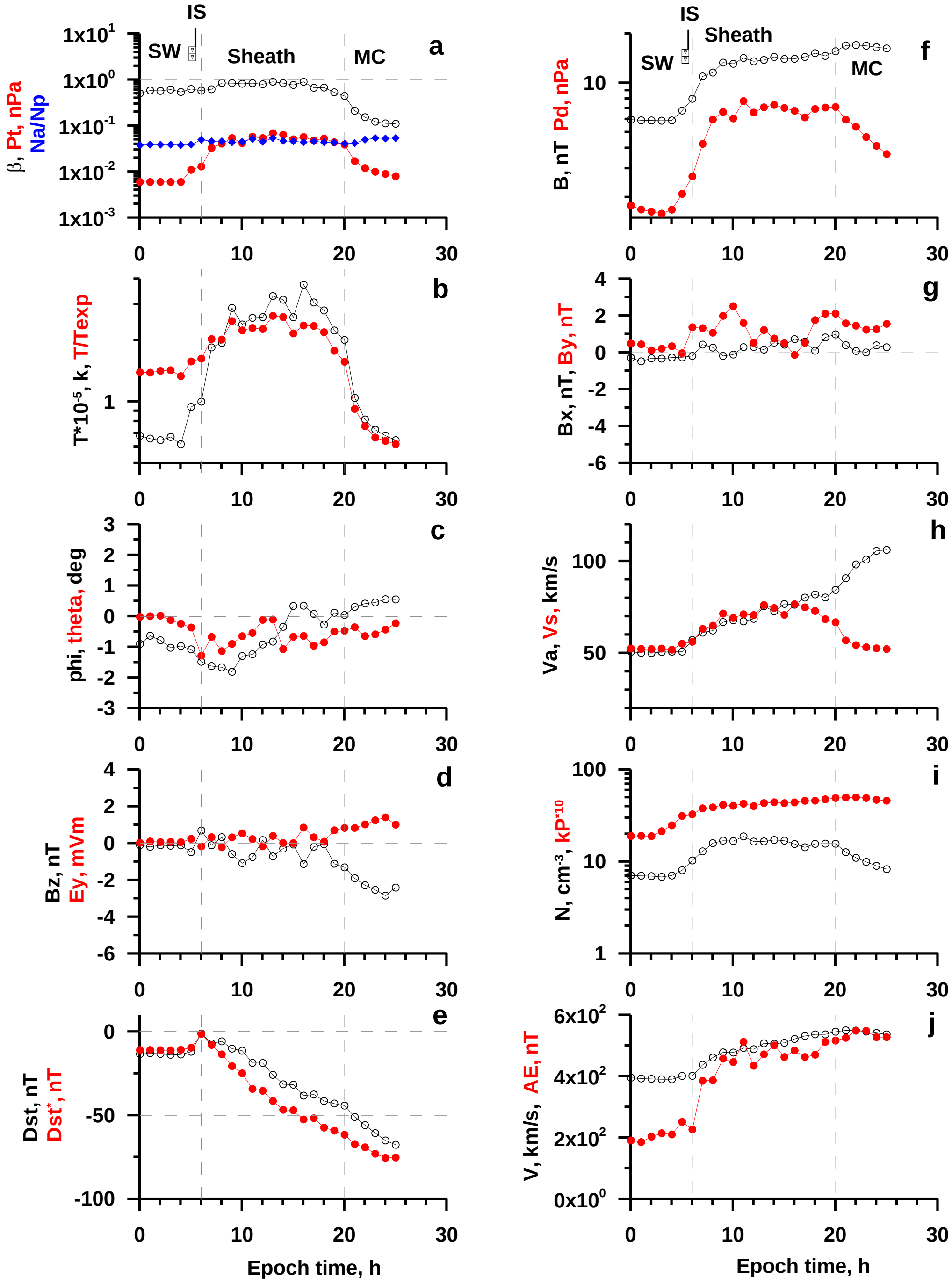
- **Fig.2** *The temporal profiles of the solar wind parameters and magnetospheric indices for the IS/Sheath/Ejecta sequence obtained using the SEA and DSEA methods: from 0 to 5 and 20–25 points, SEA was used without re-scaling; from 6–19 points, DSEA was used with re-scaling up to 14 points*



- **Fig.3.** The *same as in Fig. 2 for the Sheath/Ejecta sequence*



- **Fig.4.** The *same as in Fig. 2 for the IS/Sheath/MC sequence.*



- **Fig.5.** The *same as in Fig. 2 for the Sheath/MC sequence*.

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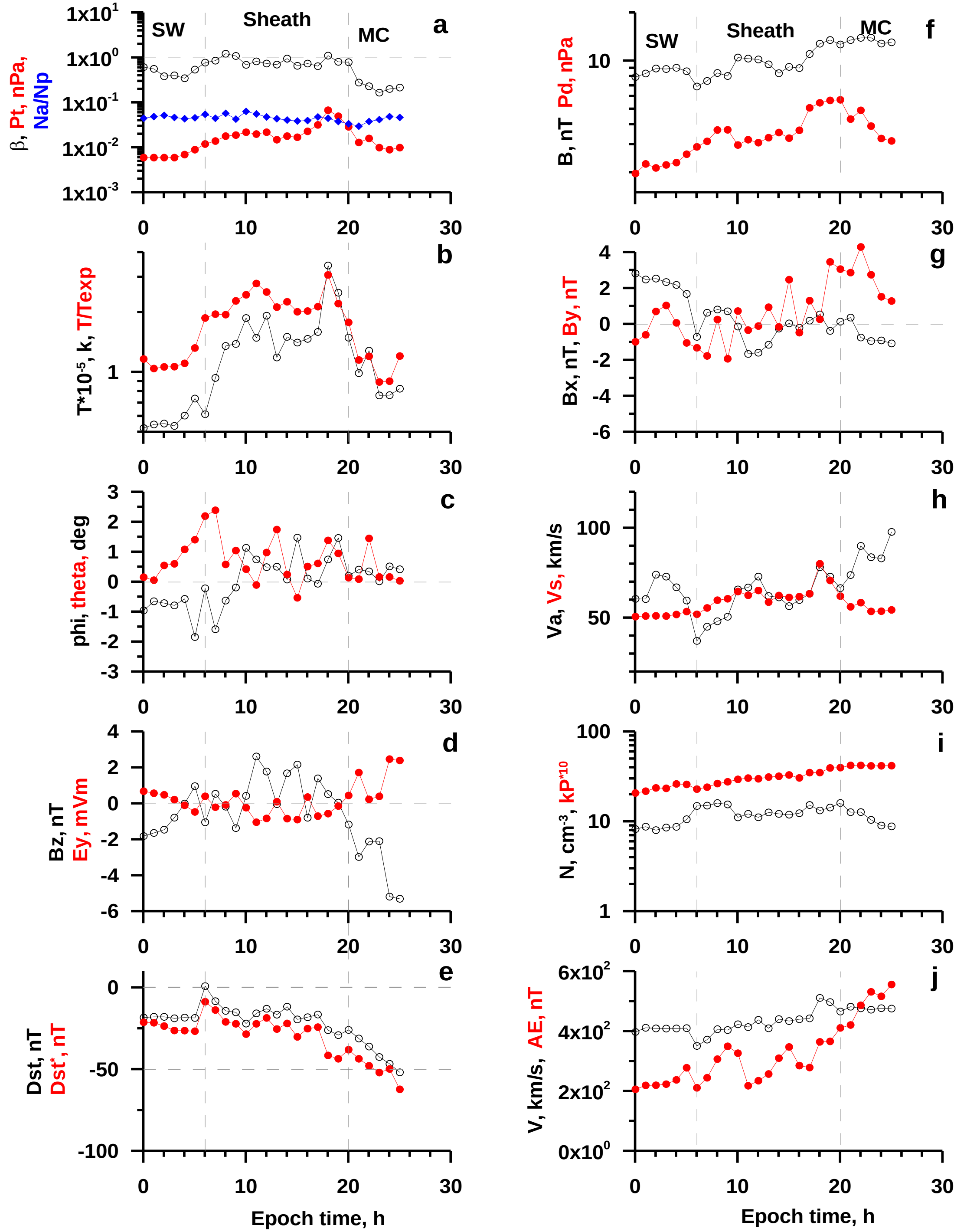

Discussion and conclusions

- Many studies investigated so-called “CME-induced" storms (or other types of magnetospheric disturbances) as an independent type of storms. In our opinion, there are no CME-induced disturbances, but there are Sheath-induced and MC/Ejecta-induced disturbances, as well as multi-step disturbances, which are excited by a sequence of Sheath/MC or Sheath/Ejecta events. The presented data indicate that the CME-induced disturbances of the magnetosphere can represent the response to absolutely different interplanetary drivers or their successive impact. The region “Sheath without shock” is observed before ICME almost as often as the Sheath region with IS, is sufficiently geoeffective and is the driver of about 10% of all storms. These drivers have different physical natures, possess different efficiencies of the impact on the magnetosphere and may lead to the implementation of different mechanisms of this impact.
- The following experimental facts should be mentioned. (1) The average magnitude of IMF B in Sheaths is higher than B in Ejecta and is close to B in MCs (Yermolaev et al., 2015). (2) The efficiency of magnetic storm generation is 50% higher for Sheath than for ICME (MC and Ejecta) (Nikolaeva et al., 2013, 2015; Dremukhina et al., 2018, 2019), i.e. at identical southward components of the interplanetary magnetic field, the magnetic storms are generated ~1.5 times more strongly by Sheaths than by ICMEs.

Discussion and conclusions -2

- The contribution of compression regions Sheath (including “lost driver”: Sheath without shock) in the generation of storms is often not taken into account and their role is often underestimated, and this erroneous approach often results in incorrect conclusions during studying the solar-terrestrial links.

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