Heliospheric current sheet as a factor of geomagnetic activity floor variation

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Main goals

What is the reason of the geomagnetic disturbances when our planet “floats” in the relatively “quiet” space?

What is the Heliospheric current sheet role in the geomagnetic activity “floor”?

Solar activity

- The sum of all variable, short and long-lived disturbances on the Sun
- sunspot, coronal holes, prominences, solar flares, CME, HSS, etc.

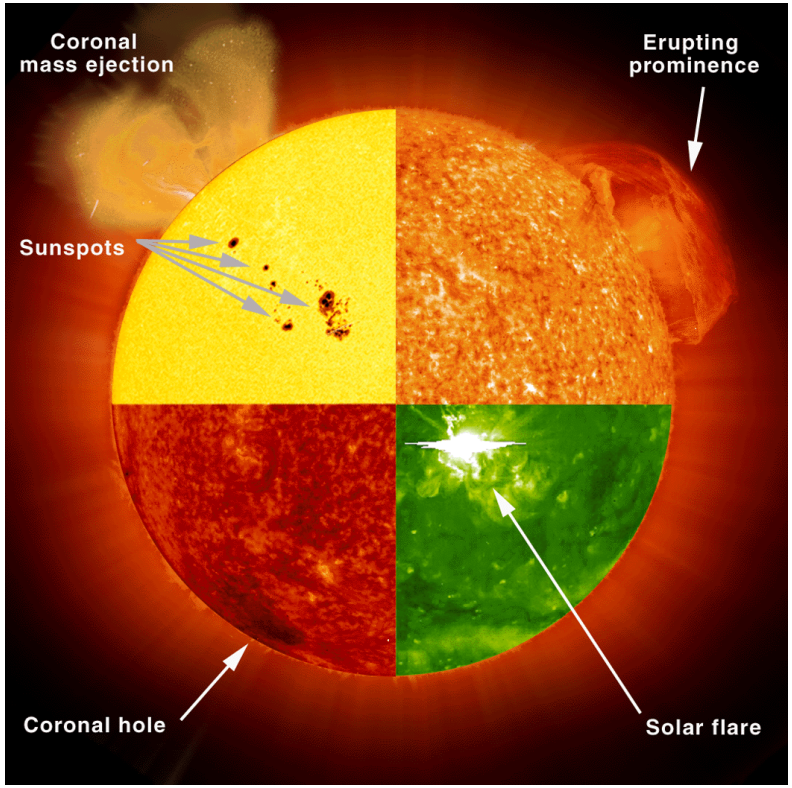


Figure 1: Solar activity

Solar cycle variation

- Solar magnetic activity cycle is the nearly periodic 11-year change in the Sun's activity
- At solar minimum, solar magnetic field is closed to dipole nearly aligned with the rotation axis
- At solar maximum, solar magnetic field is much more complicated

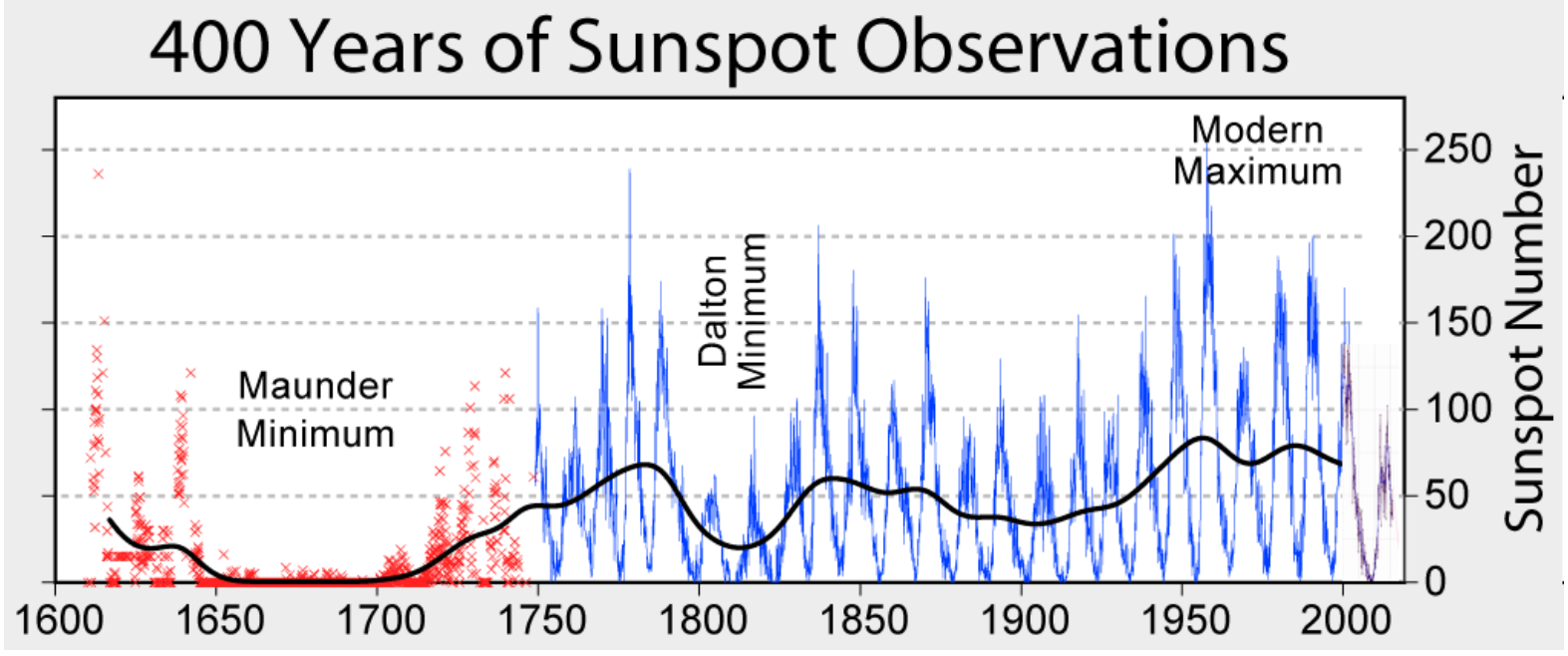


Figure 2: Solar cycle variation

Heliospheric current sheet

- dynamic object modulated by solar activity
- separating the heliosphere into two regions according to the polarity of the interplanetary magnetic field
- large scale variation through the 11-year solar cycle
  - at minimum has minimal inclination and almost matches with solar equatorial plane
  - at maximum becomes much more inclined

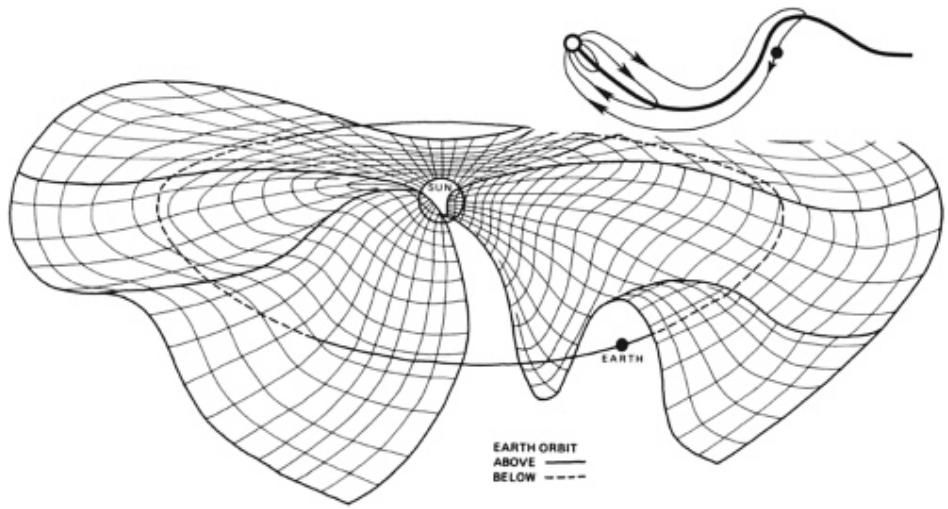


Figure 3: 3D HCS

(*Hoeksema, 1995; Forsyth et al., 1997; Smith et al., 2001*)

Heliospheric current sheet

- magnetic sector structure with alternating positive (away from the Sun) and negative (toward the Sun) polarity

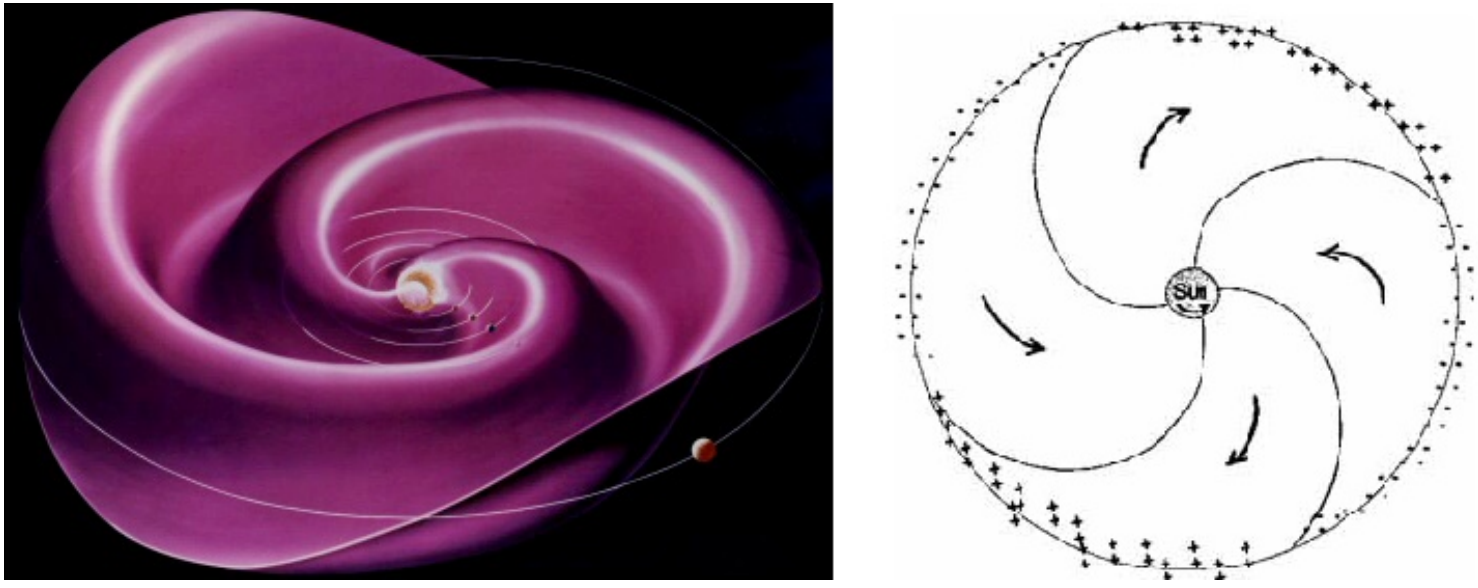


Figure 4: IMF polarity

Geomagnetic activity

- geomagnetic field is modulated by solar activity agents (*Sabine, 1852*)
- two maxima in the ∼11-year sunspot cycle: one corresponding to the sunspot maximum and a second one about two years later during the sunspot declining phase (*Gonzalez et al., 1990*)

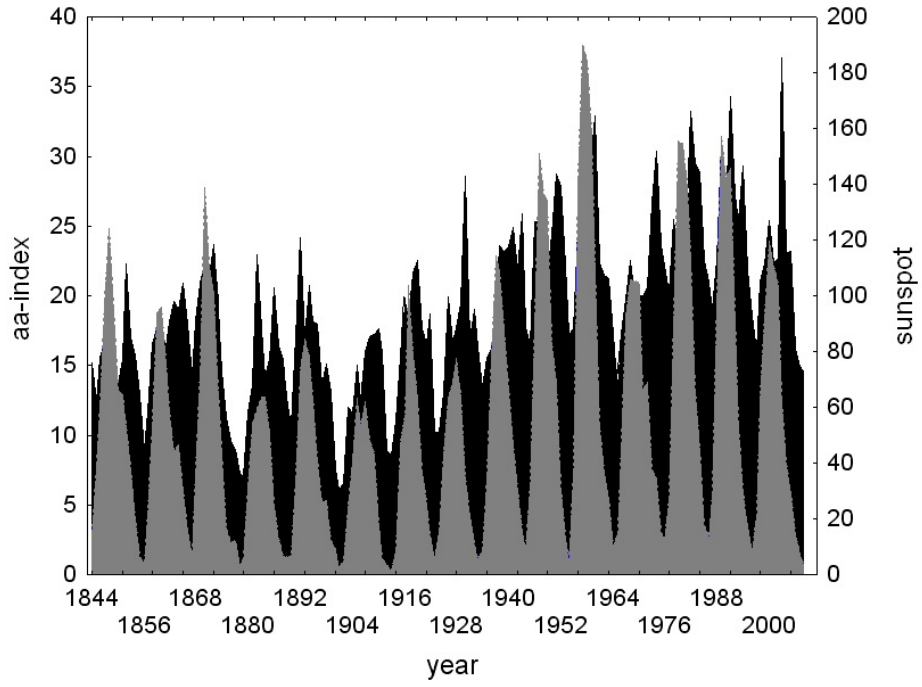


Figure 5: Sunspot number (grey areas) and aa-index of geomagnetic activity (black areas)

Geomagnetic activity and CME

- The geomagnetic activity maximum in sunspot maximum is due to the big number of coronal mass ejections (CMEs) at that time.
- The strong sporadic storms during maximum are caused by CMEs (*Tsurutani et al., 1992; Echer et al., 2008*), and especially by magnetic clouds with strong and smoothly rotating magnetic field inside the structure providing prolonged periods of southward Bz (*Georgieva et al., 2006*)
- Because both CMEs and sunspots are related to solar active regions, the occurrence of the CME-related storms follows the solar cycle (*Gonzalez et al., 1994*)

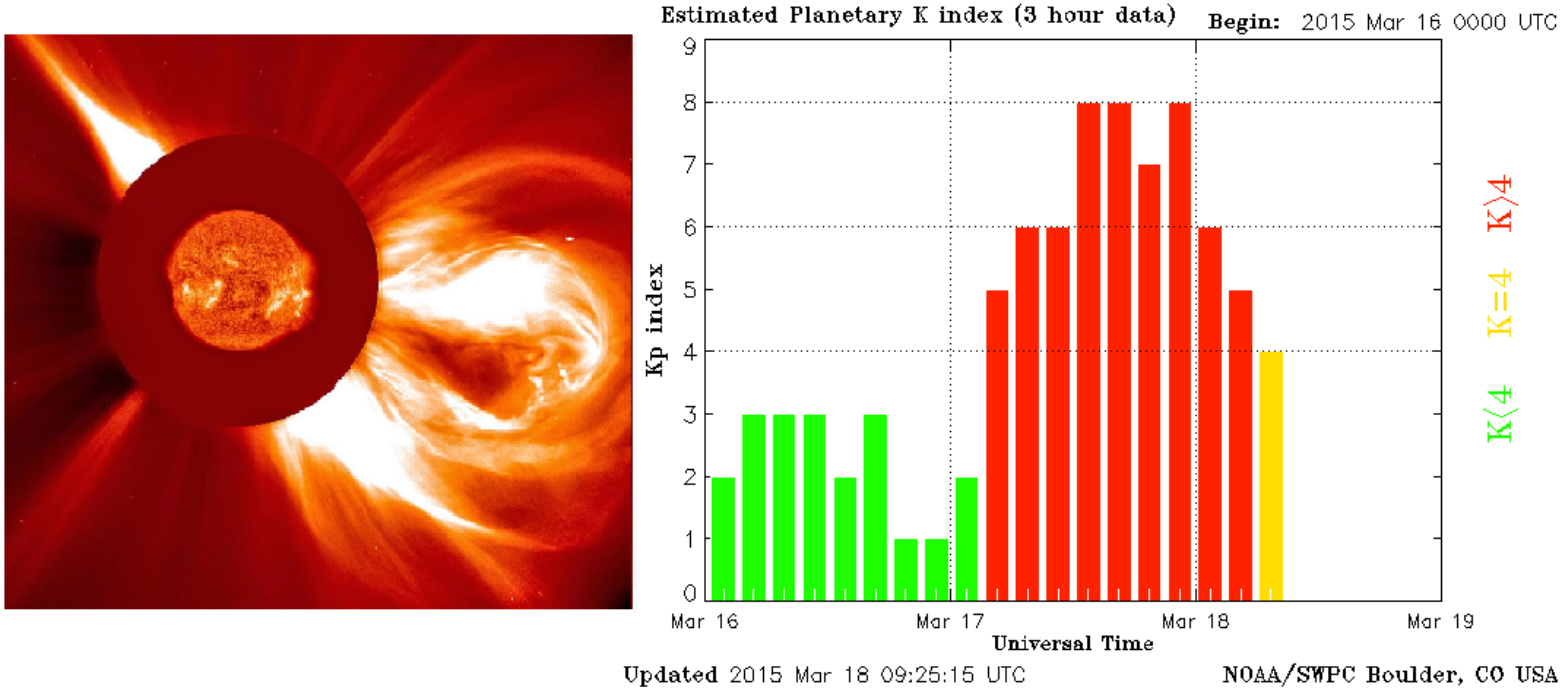


Figure 6: CME related geomagnetic storm

Geomagnetic activity and HSS

- The second maximum of geomagnetic activity is due to high speed solar wind streams (HSS), which originate from coronal holes - unipolar open magnetic field areas (*Kriger et al., 1973; Sheeley Jr. et al, 1996; Tsurutani et al., 1995, 2006*)
- These geomagnetic storms are relatively weaker, but recurrent and of longer duration (*Borovsky and Denton, 2006*)
- Coronal holes are biggest and in most geoeffective position during the sunspot declining phase (*Phillips et al., 1995*), when the second maximum in the geomagnetic activity is observed.

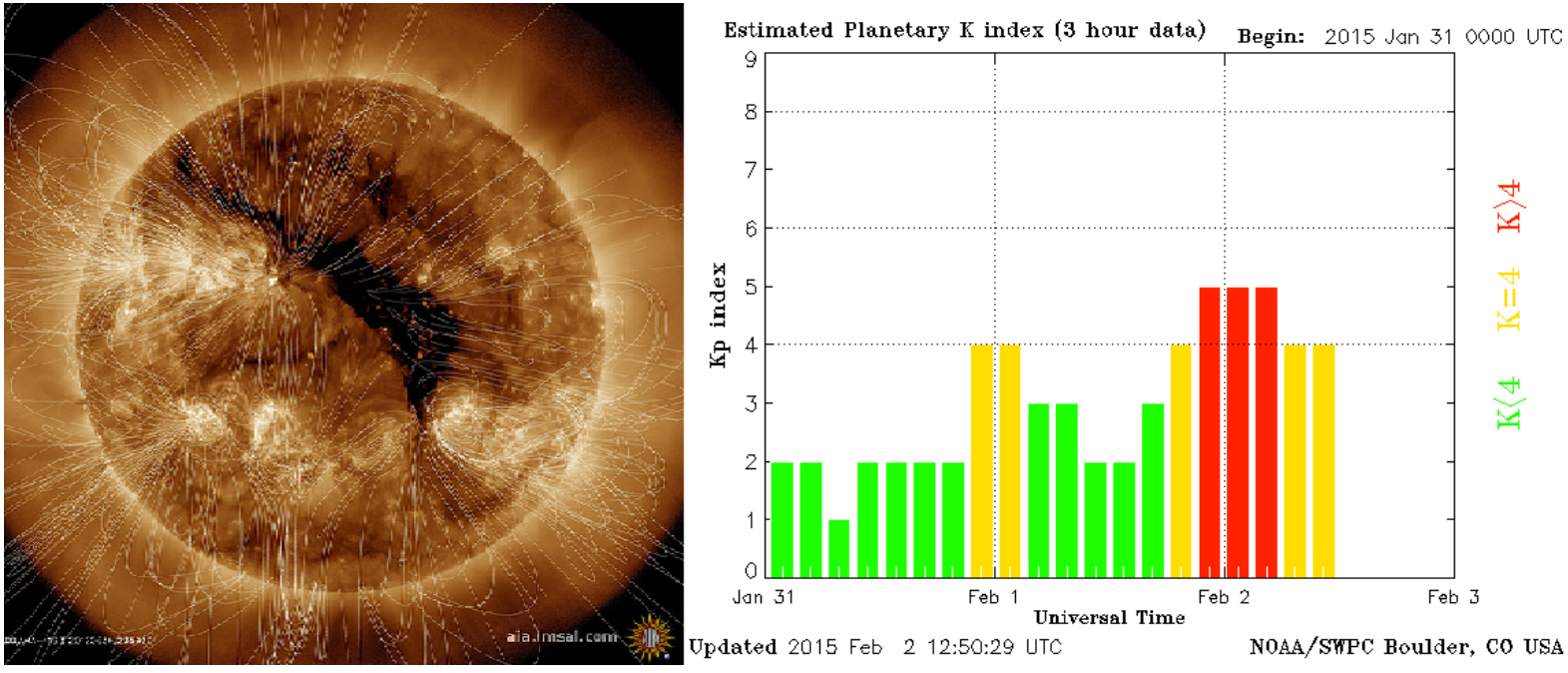
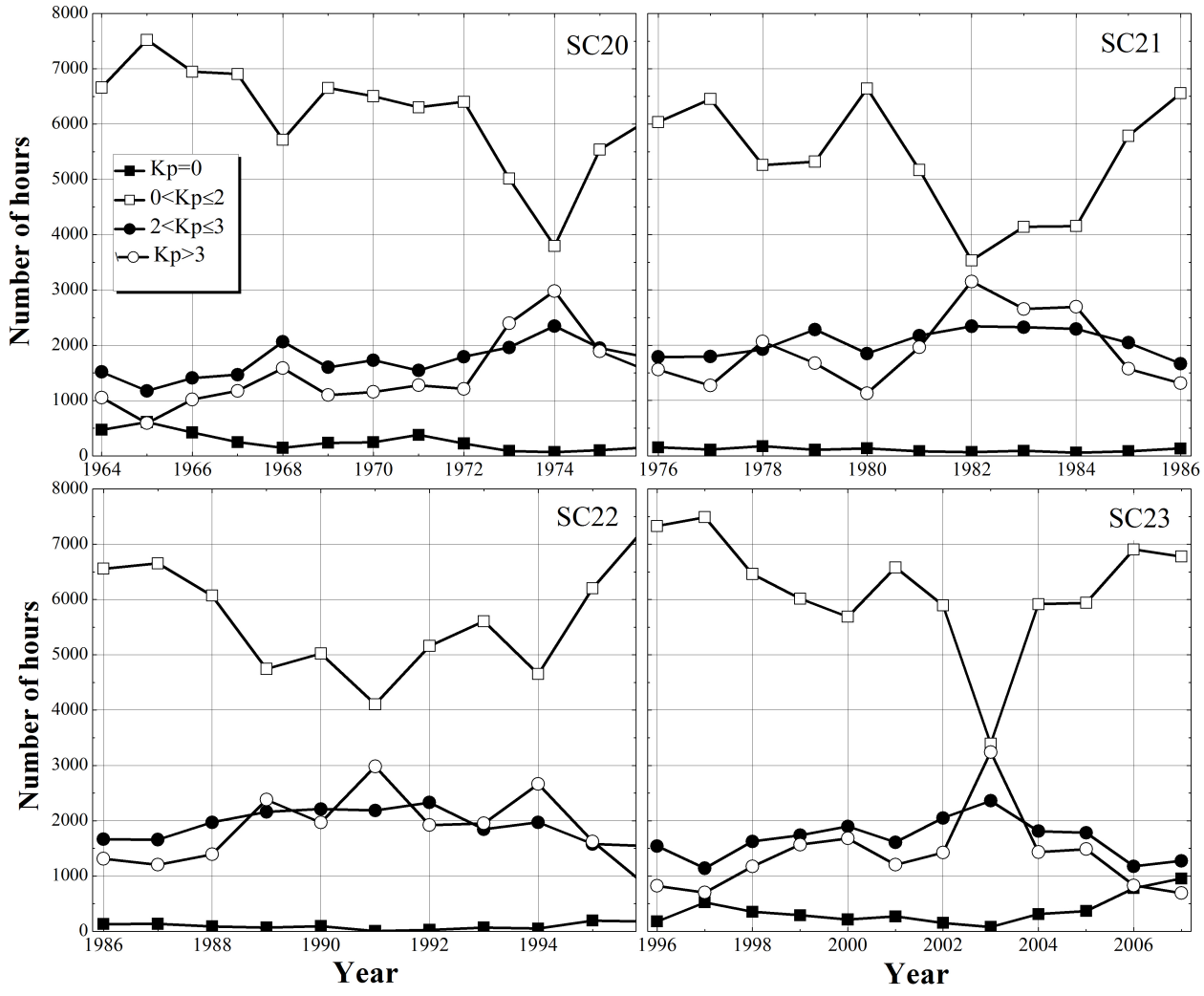


Figure 7: HSS related geomagnetic storm

Geomagnetic activity in the last four SC

- Considering the global picture of the geomagnetic disturbances most of the time (up to 60 %) during any 11-years SC, Kp is less than 5 BUT different from zero
- Even in the absence of CME and HSS there is some non-zero geomagnetic activity



Geomagnetic activity floor

- Feynman (1982) linked geomagnetic activity and sunspots, in a way to show that the annual average aa index can be decomposed into two functions - short (CME) and long (HSS) lived related
- Kirov et al., (2013) supplies additional component expressing the geomagnetic activity in the absence of sunspots, i.e. geomagnetic activity "floor"
- Geomagnetic activity "floor" - minimal value of an averaged geomagnetic index under which the geomagnetic activity cannot fall

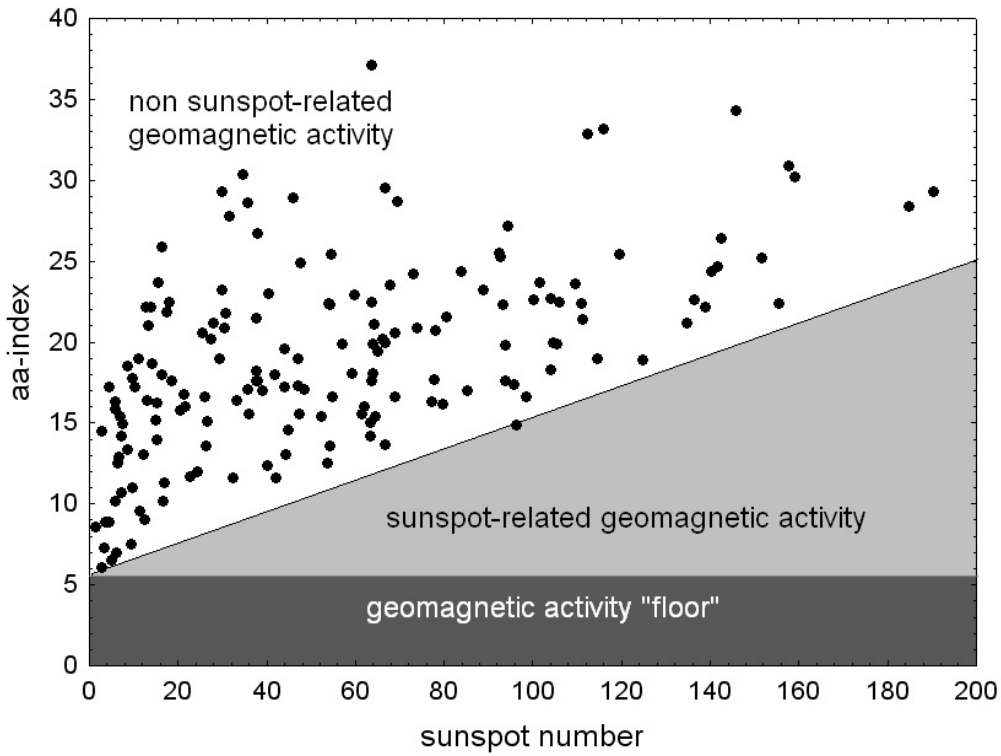


Figure 9: Dependence of the geomagnetic activity on the sunspot number

What is the reason of the geomagnetic disturbances when our planet "floats" in the relatively "quiet" space?

- Properties of the slow solar wind (which originate from regions near equatorial coronal streamers)
- Properties of the fast solar wind (coming from polar coronal holes)
- Conditions inside the magnetosphere
- **Heliospheric current sheet**

The Thickness of the Heliospheric current sheet

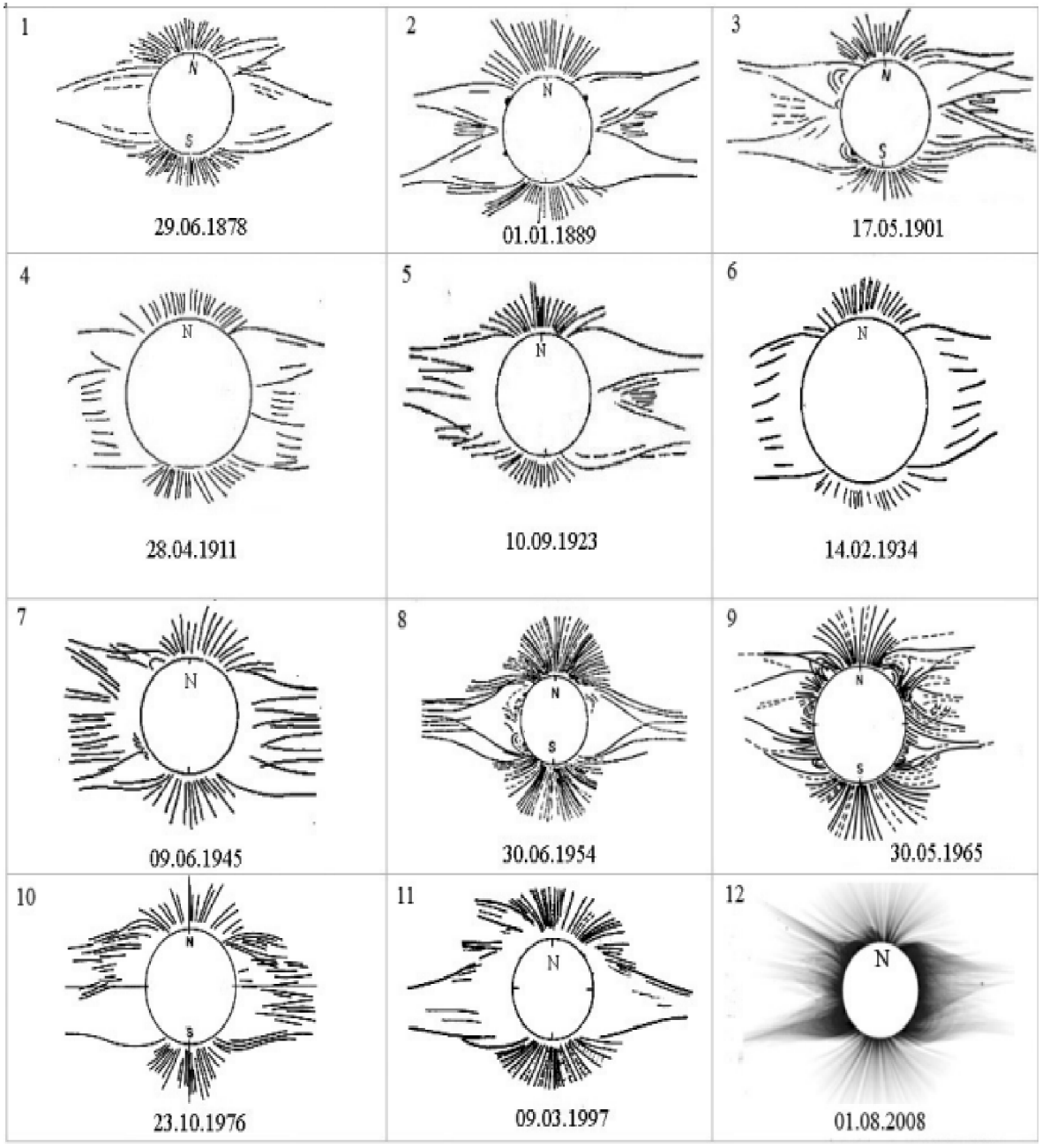


Figure 10: Eclipses close to the minima of cycles 12–24 (*Tlatov, 2010*)

Solar wind speed vs. Helio coordinates

- Considering the CME and HSS free periods for the last four solar cycles
- The angle between the equator of the Sun, and the plane of the Earth's orbit is approximately 7,2°
- The thickness of the Heliospheic current sheet is defined as the angle between high-latitude boundaries of the large coronal streamers (*Tlatov, 2010*)

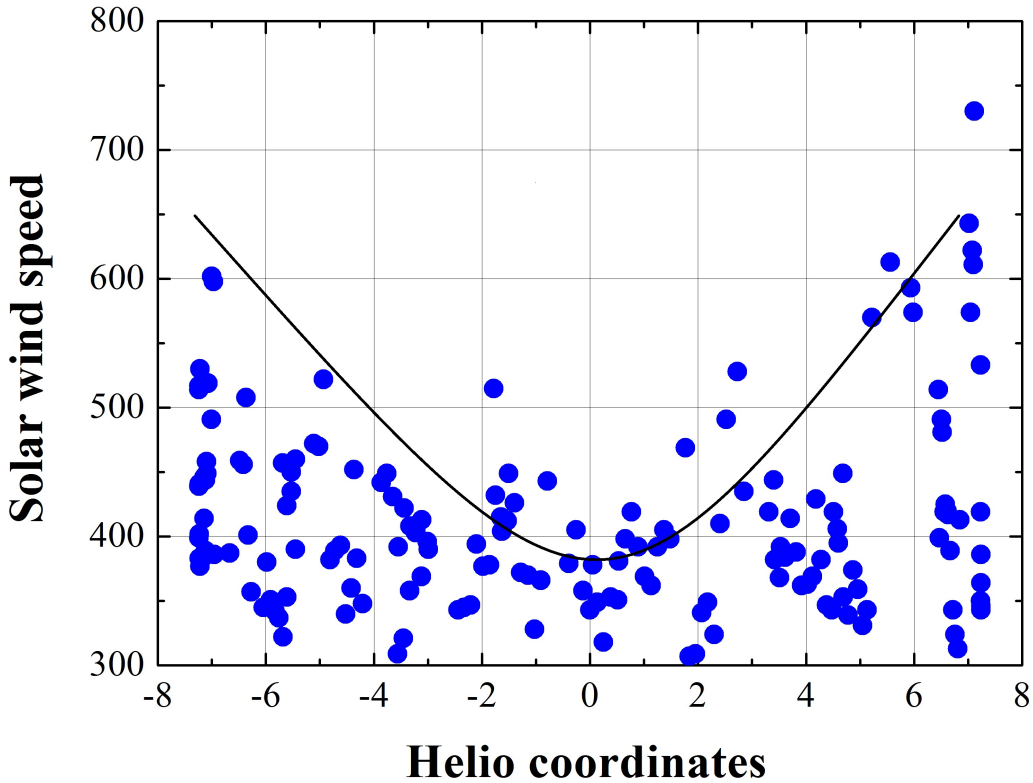


Figure 11: Solar wind speed as a function of the Heliospheric coordinates during SC22 minima

Solar wind speed vs. Helio coordinates

- Varying thickness of the heliosheet cause variations in the relative exposure of the Earth to different solar wind drivers

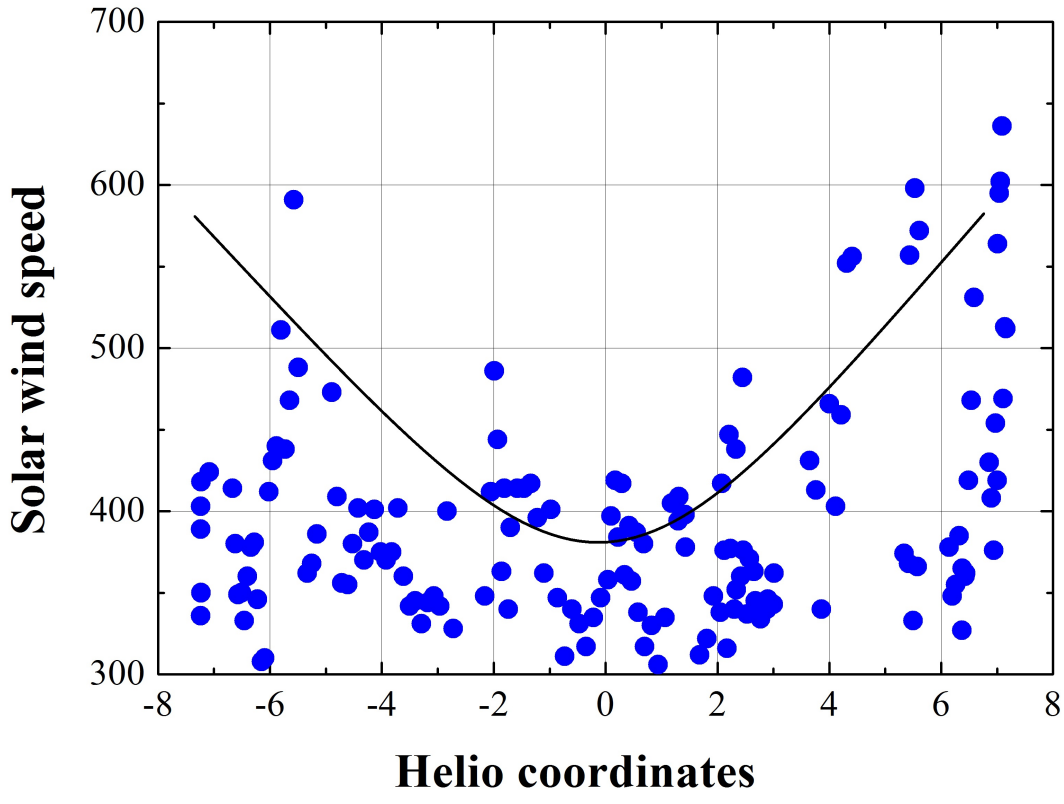


Figure 12: Solar wind speed as a function of the Heliospheric coordinates during SC23 minima

Solar wind speed vs. Helio coordinates

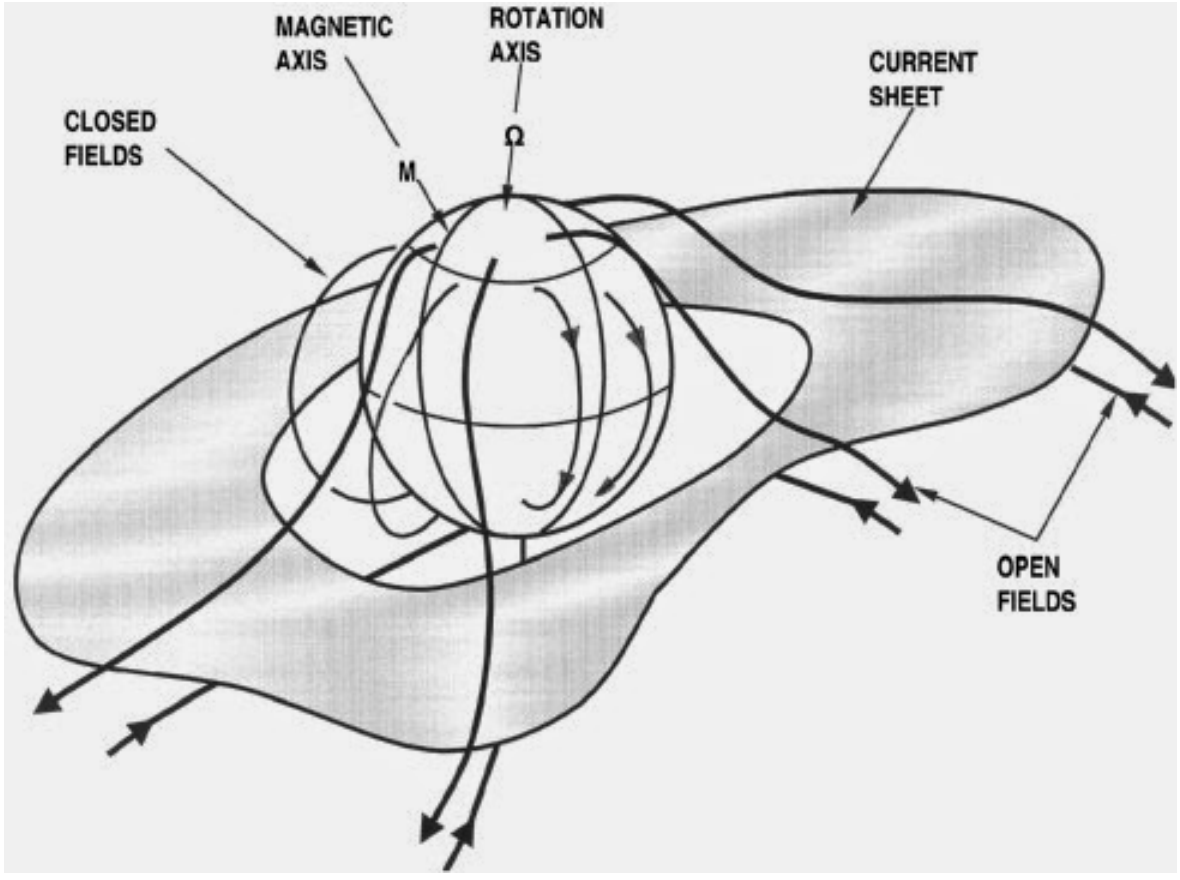


Figure 13: Three-dimensional sketch of the heliospheric current sheet

Solar wind speed vs. geomagnetic activity

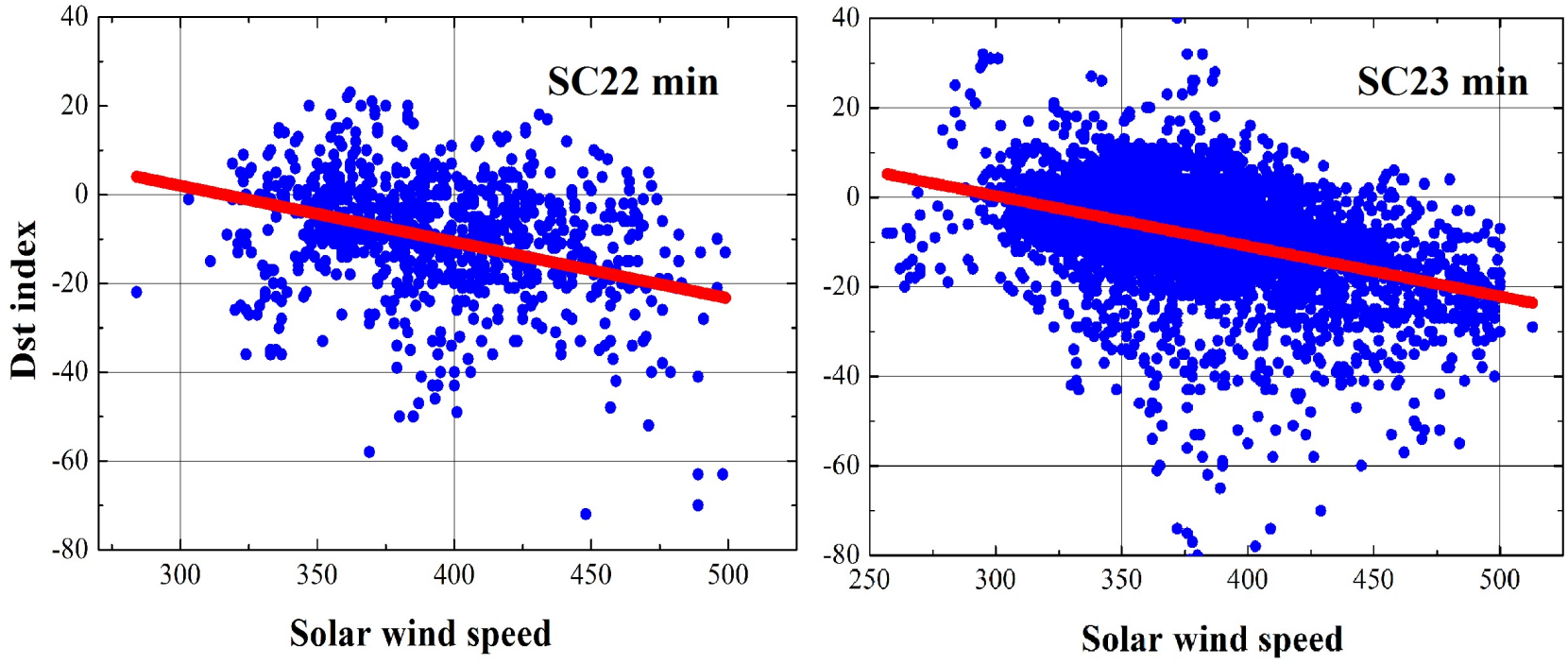


Figure 14: Dst index as a function of the solar wind speed during SC22 minima and SC23 minima

The Sector Structure of the Heliospheric current sheet

Heliospheric current sheet crossing

- Considering the CME and HSS free periods for ten crossing of the Helisopheric current sheet
- Using L. Svalgaard's list of the Sector Boundaries in the Solar Wind

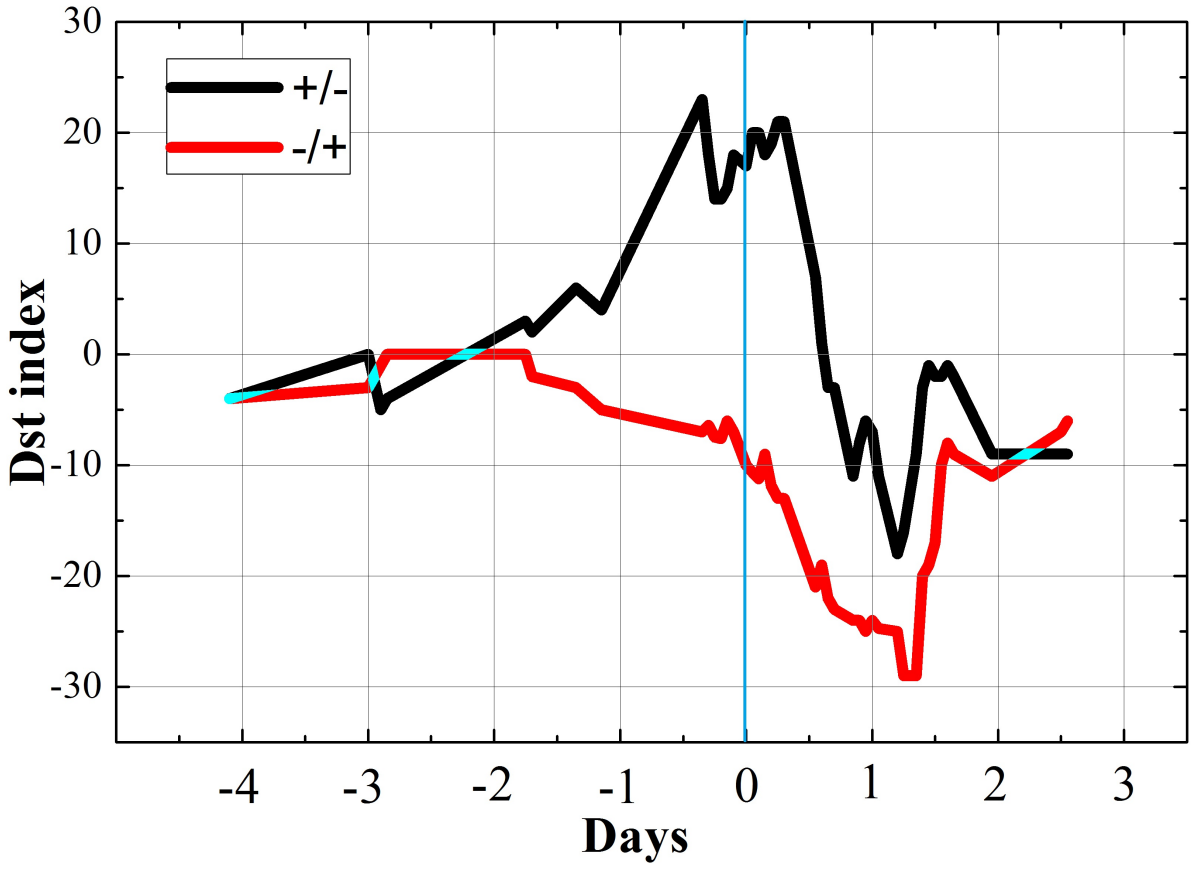


Figure 15: Superposed epochs of the intensity of the Dst index

Conclusion

- Geomagnetic activity "floor" is modified by the heliospheric current sheet in sense of its crossing and shielding