Probing the Maximum CME Speed as Geoactivity Indicator

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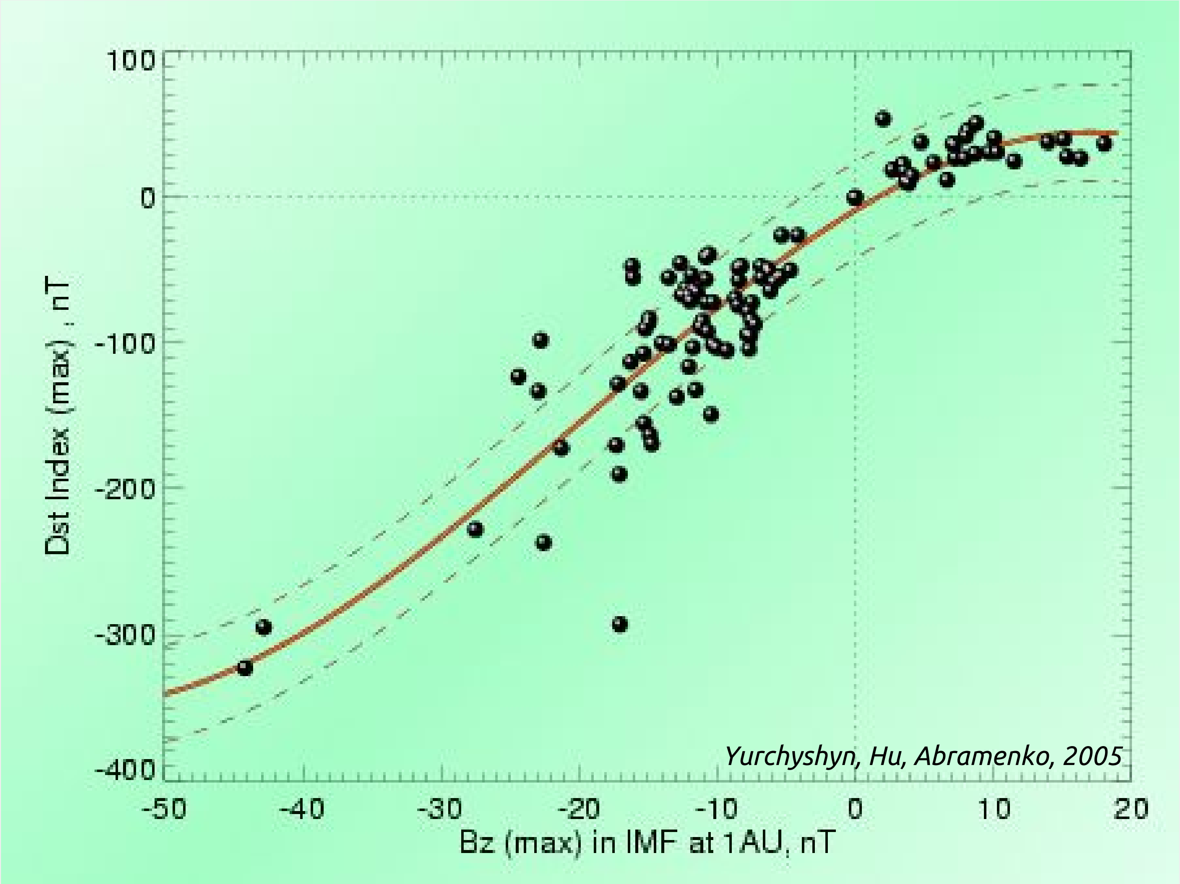
Why New Index?

- Disturbances of the near-Earth environment are measured by various parameters, such as ***aa*** (Mayaud 1972), ***Ap*** (Bartels et al.1939), and ***Dst*** (Sugiura 1964) indices, to name a few. Variations in solar activity are traced by measuring sunspot numbers (Hoyt & Schatten 1998), solar flare indices (Kilcik et al. 2010), and total solar irradiance (Lean et al.1995).

- Sunspot numbers not always accurately reflect the overall intensity of solar eruptions, since not all sunspot groups are equally capable of producing powerful energetic events (Shi & Wang 1994; Abramenko 2005). Moon et al. (2002), reported only a weak correlation between time-integrated X-ray flux of CME associated flares and CME speeds.

- The CME speed index as a measure of geoeffective solar activity may have advantages over the sunspot numbers in that it is more objective and better reflects the intensity of Earth-directed solar eruptions.

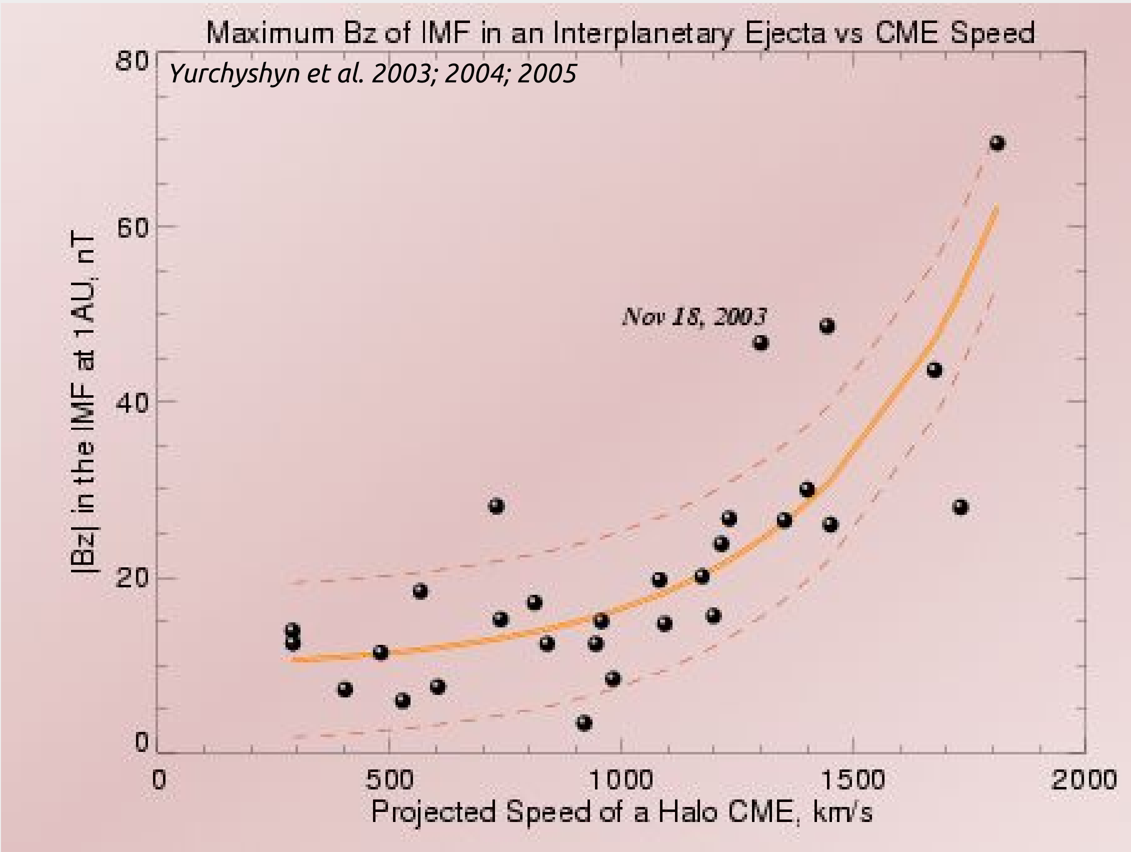
Correlation b/w Bz in Magnetic Clouds and the Dst Index



Hourly averaged extremum of the final Dst index vs extremum values of the ACE hourly Bz in the IMF

Gonzalez & Tsurutani, 1987
Cane et al., 2000
Wu & Lepping, 2002
Yurchyshyn et al., 2004

Correlation b/w CME Speed and the Bz



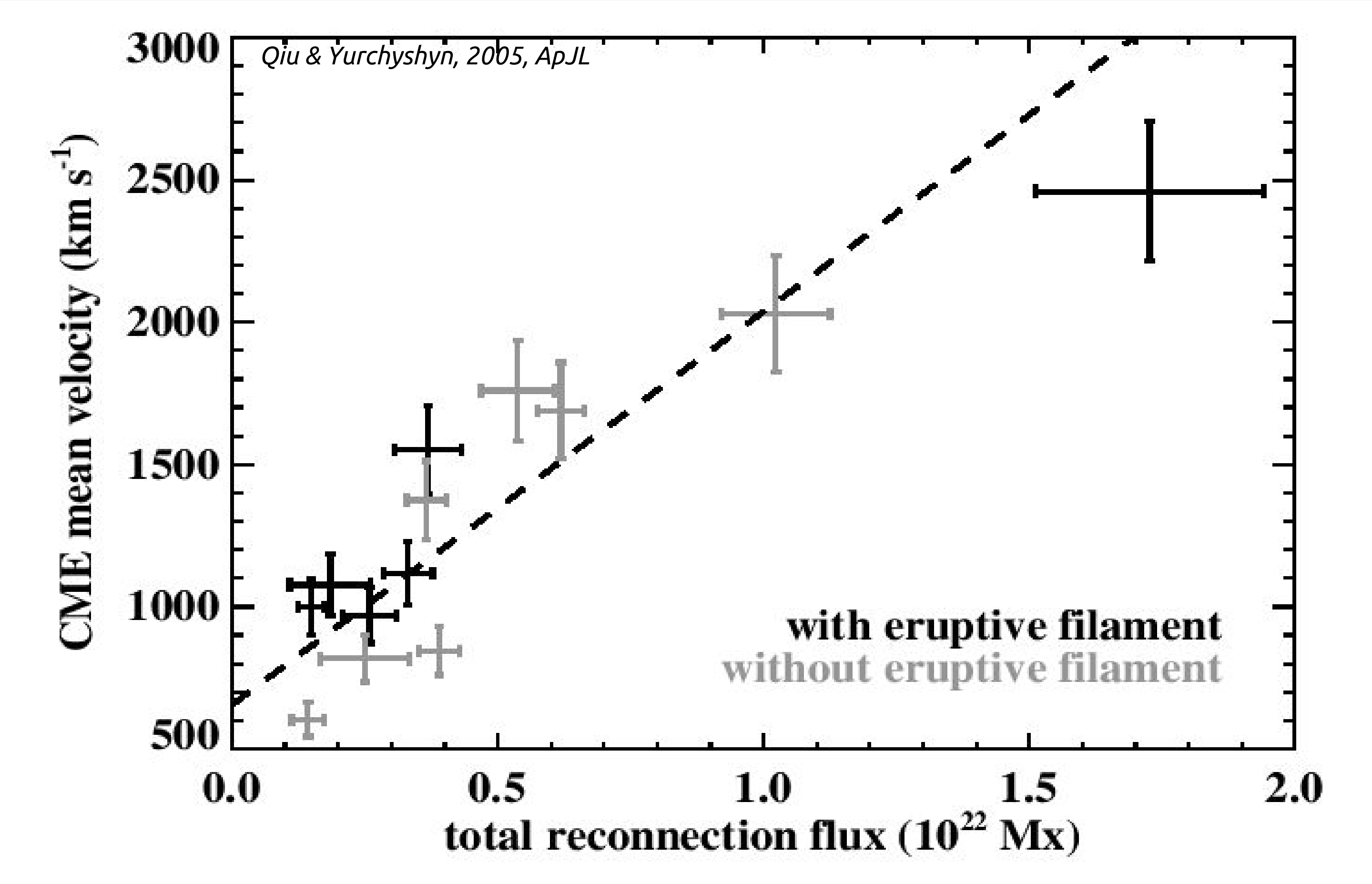
The hourly ACE Bz in the IMF vs the LASCO projected CME's speeds

Yurchyshyn et al, 2003; 2004
Gonzalez et al. 2004
Srivastava & Venkatakrishnan 2004

This relationship might reflect the fact that an eruption is driven by the Lorentz force, which is directly related to the amount of the magnetic flux confined in the flux rope.

Other factors can contribute to the scatter (e.g., Liu & Hayashi 2006)

Speed of CMEs vs Magnetic Flux



The higher the total amount of reconnected flux the higher the speed of that eruption.

Why This Index?

- Numerous severe storms occur during the maximum phase of the solar cycle, and they are mostly associated with CMEs (Gopalswamy et al. 2007; Zhang et al. 2007).

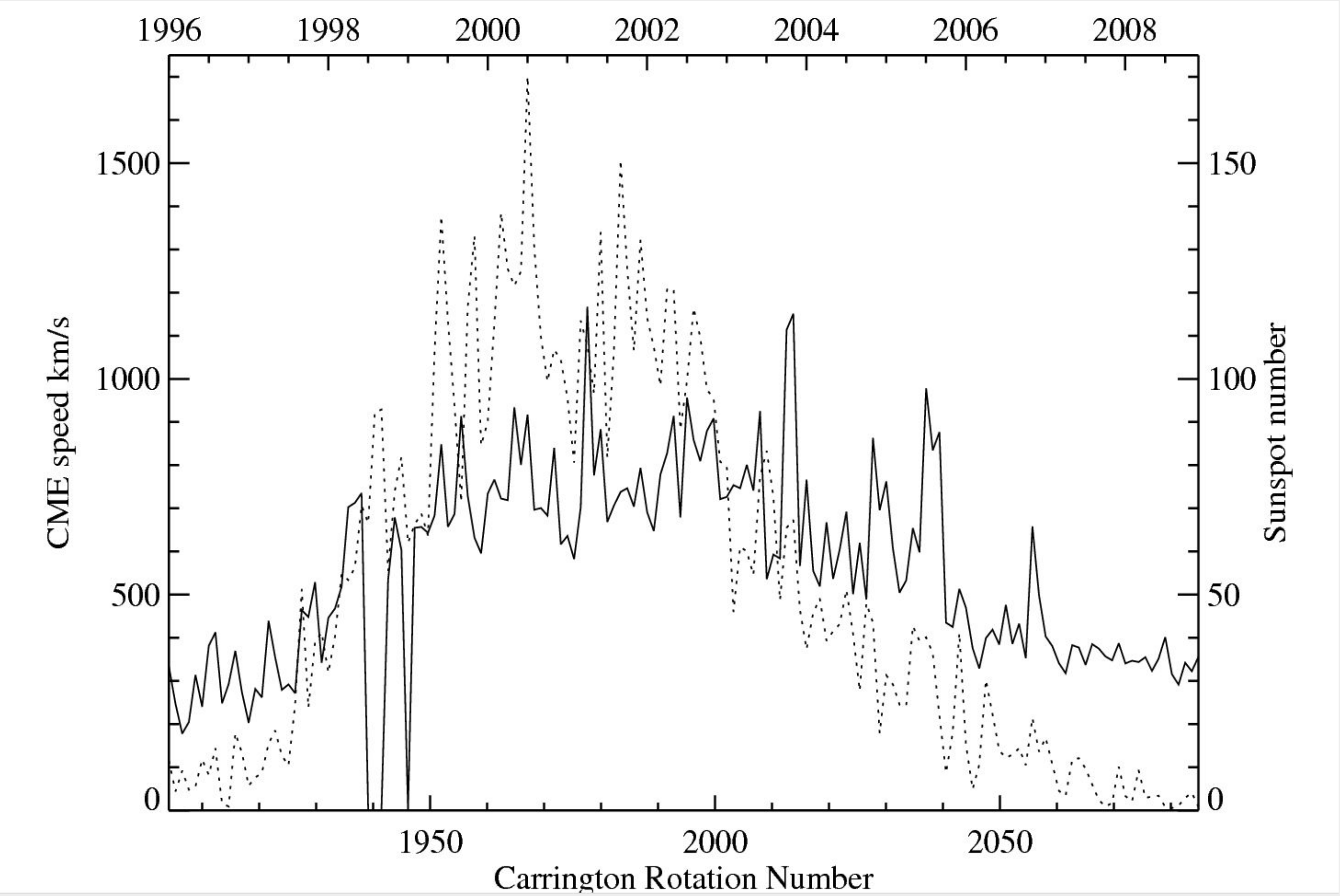
- Gopalswamy (2006) introduced CME daily rate as a new solar activity indicator closely correlated to the geomagnetic activity. All these indices display correlative relationships with one another. Although the relationship between the solar and geomagnetic activity indices has been extensively studied (e.g., Stamper et al.1999), it still eludes satisfactory explanation (Echer et al. 2004).

- Here use the linear CME speeds to explore their contribution to geomagnetic activity. Fast CMEs are very often associated with strong geomagnetic storms (Srivastava & Venkatakrishnan 2004; Yurchyshyn et al. 2004, 2005), and the correlation is best when an earthward CME is associated with a magnetic cloud (Gopalswamy 2010).

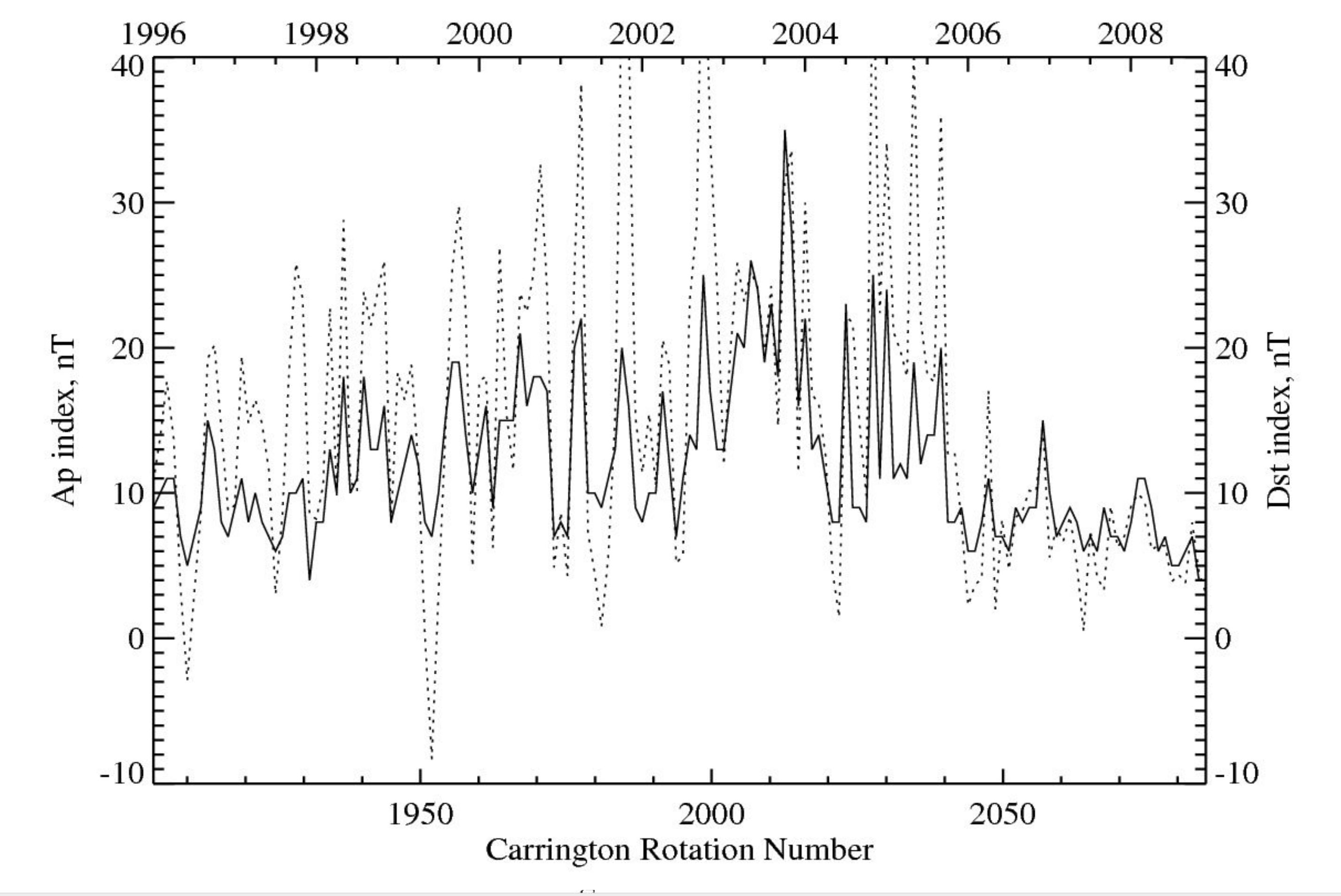
- For each day, we only chose the eruption with the maximum linear fit speed, and the CME speed index was calculated as a monthly averaged maximum CME speed (MCMESI).

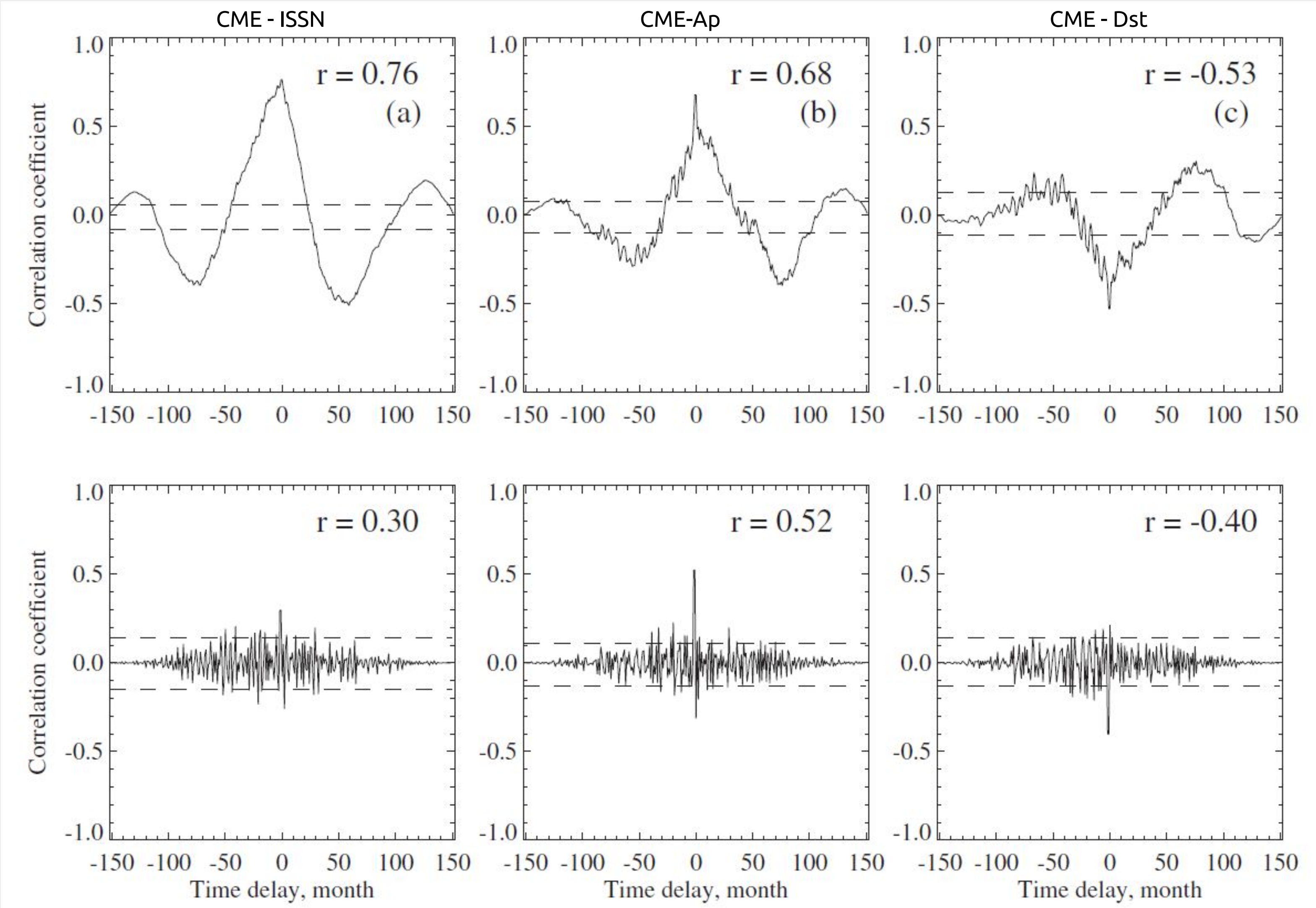
- The CME speed index as a measure of geoeffective solar activity may have advantages over the sunspot numbers in that it is more objective and better reflects the intensity of Earth-directed solar eruptions.

Comparison of the maximum CME speed and the ISSN for solar cycle 23

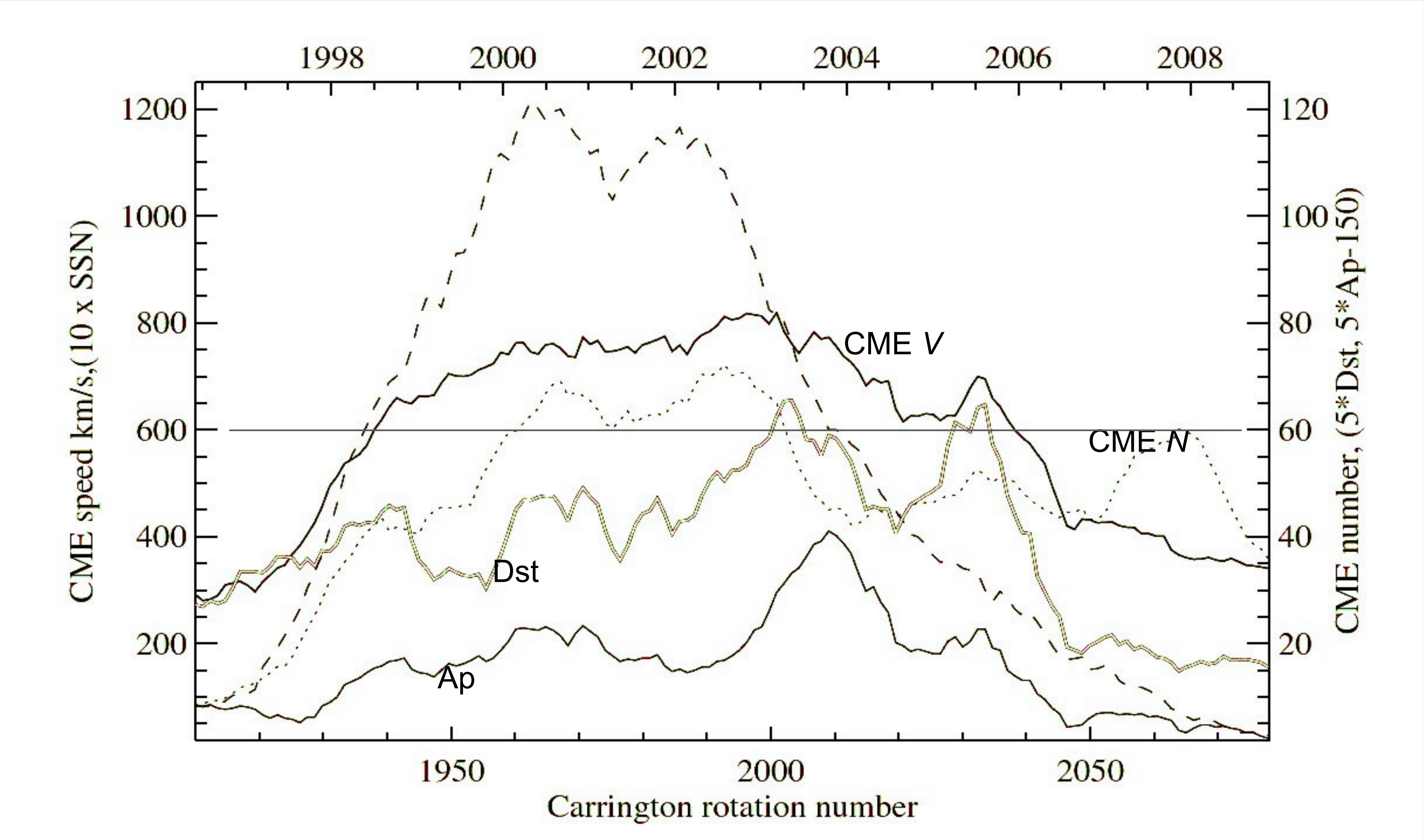


Comparison of monthly geomagnetic Ap and Dst indices in solar cycle 23

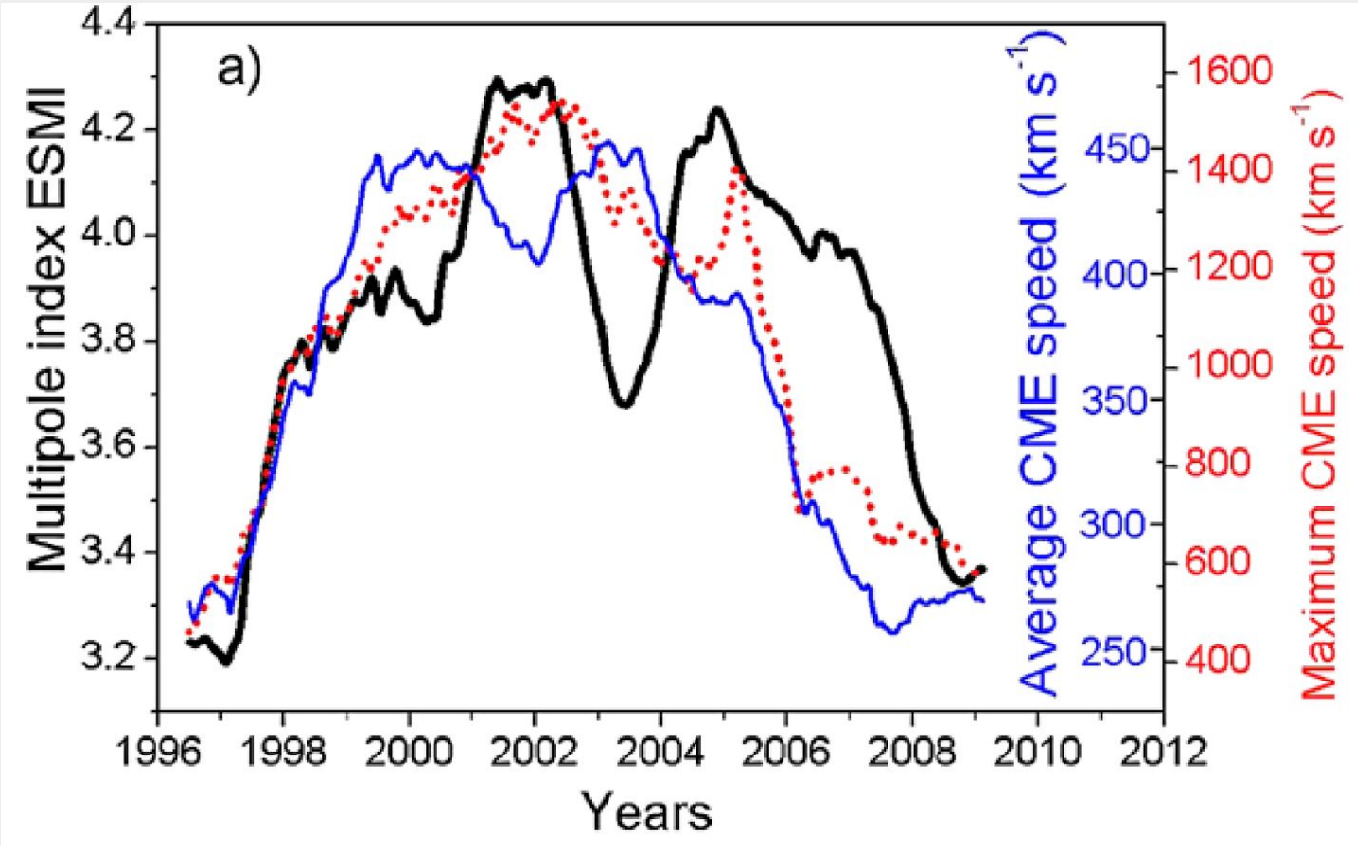




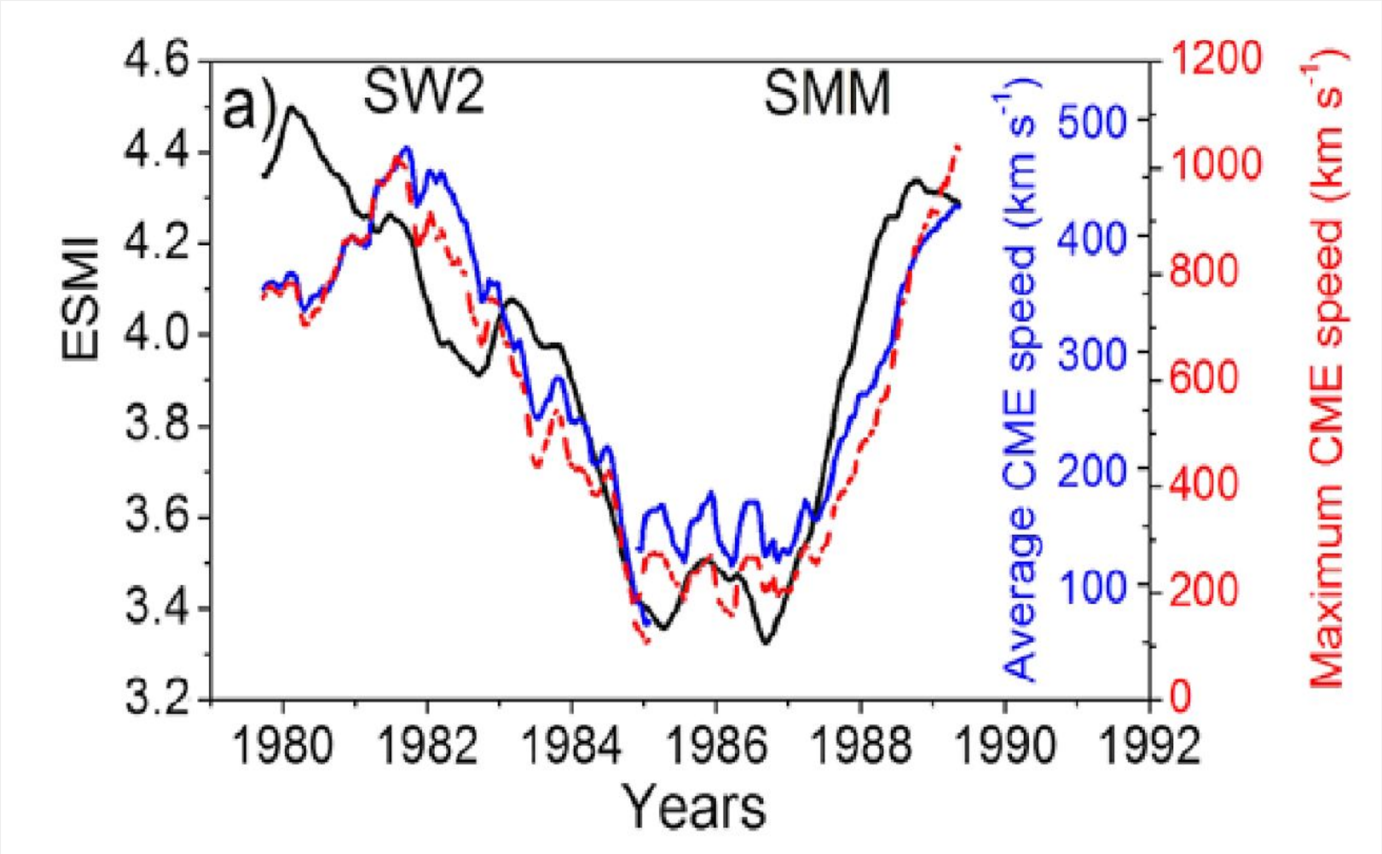
Results of cross-correlation analysis between the CME speed index and the ISSN (left panels), Ap index (middle panels), and the Dst index (right panels). The upper row of panels show results for observed data, while the bottom panels show results for detrended data sets. The error levels were calculated by using the Fisher's test.



Time profiles of 12 point running averaged monthly data sets. In this plot, the dashed line shows the sunspot numbers, the bold solid line the CME index, the dotted line the CME number, the double line the Dst index, and the thin solid line represents the Ap index.



Obridko et al. 2012 compared the multipole (ESMI) and CME speed indices. Increase in the size of the magnetic field structural elements (increase in ESMI) reflects the appearance of a relatively large unipolar regions, clustering of large ARs, as well as formation of a complex of several ARs joined by coronal arch systems. When this complex exists for a long time, the effect of an active longitude occurs. When the size of the field elements increases in the declining phase of the cycle (*i.e.*, when ESMI decreases), the formation of a large active complex becomes less likely.



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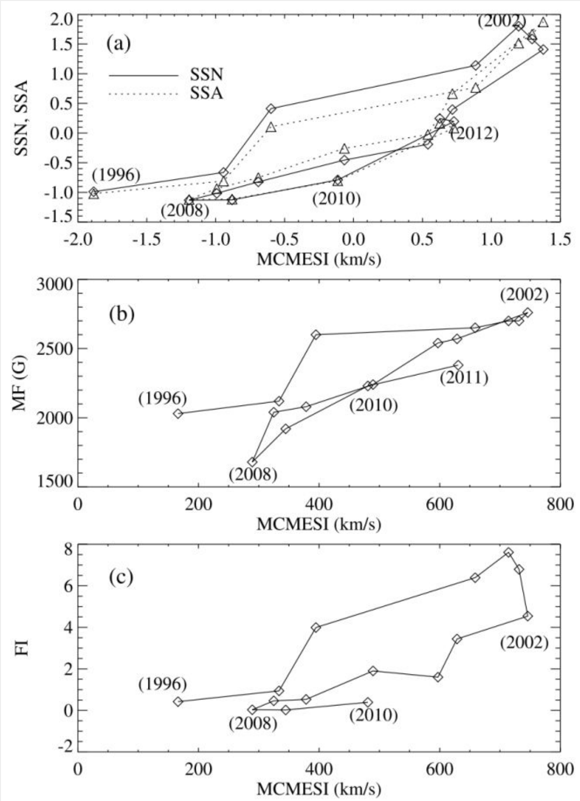
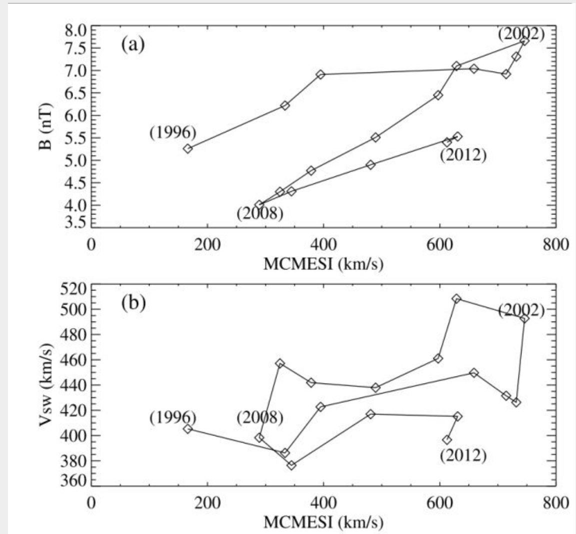
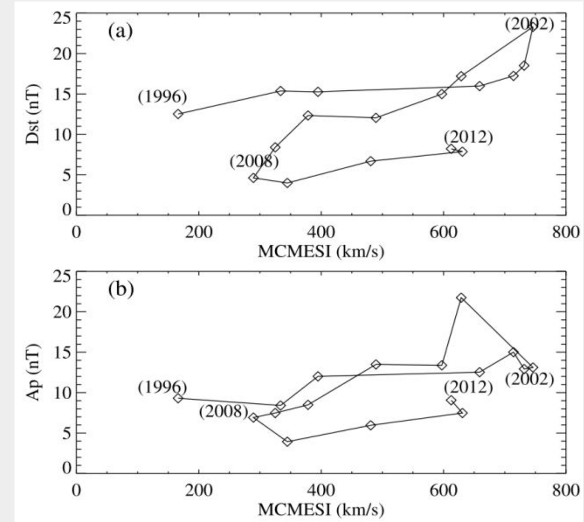
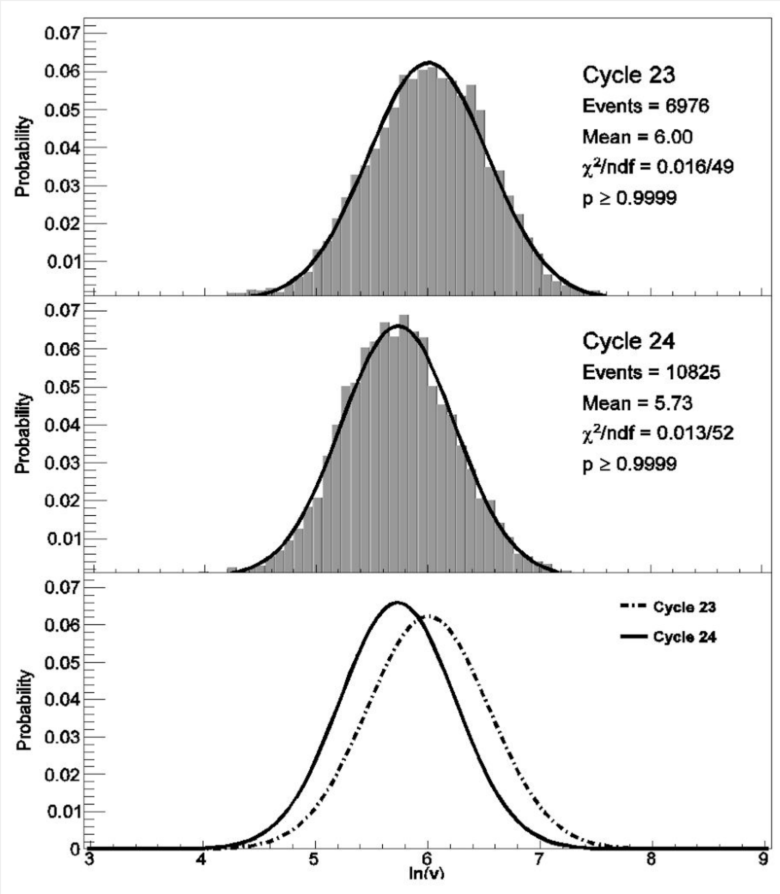




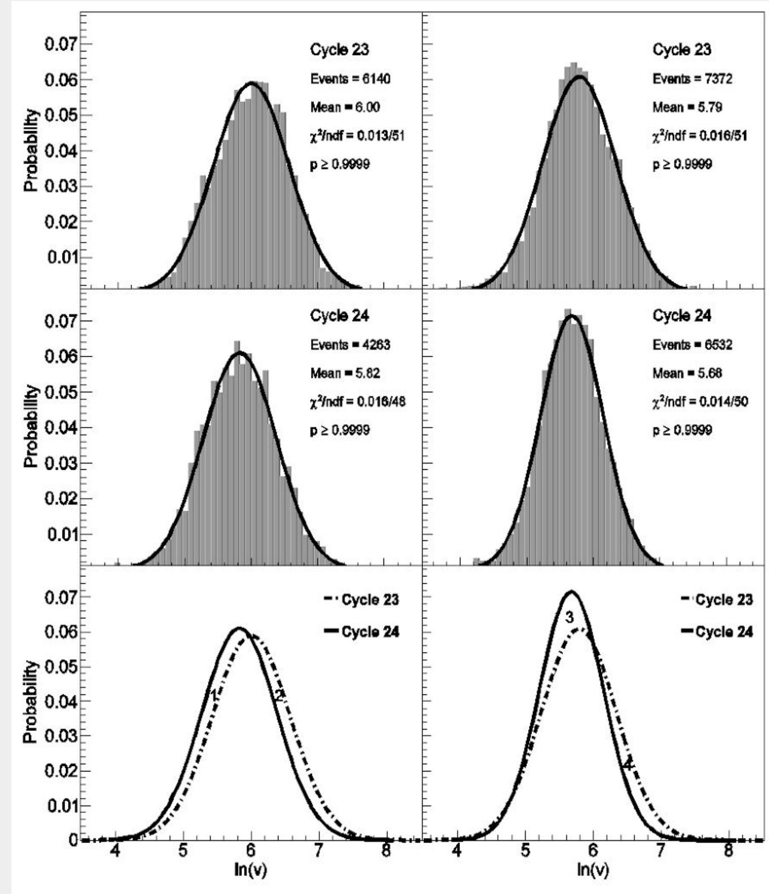


MCMESI is to the greatest extent correlated with the sunspot magnetic field MF and total sunspot area, with the magnitude of the interplanetary magnetic field *B*, and with the geomagnetic *D*st index; to a lesser extent with the sunspot number and with the flare index FI; and to a still lesser extent with the solar wind speed *V*sw and geomagnetic *A*p index (Figures 1a – d). In the indices we studied here, we found hysteresis effects that are approximately regarded as simple phase shifts, and we quantified these phase shifts in terms of lag times behind the leading index, MCMESI (*Ozguc et al. 2016*).

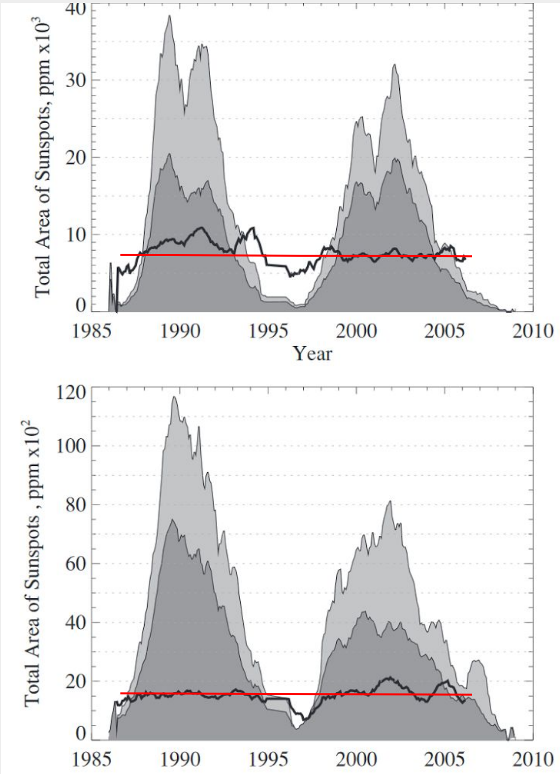
CMEs in solar cycle 24



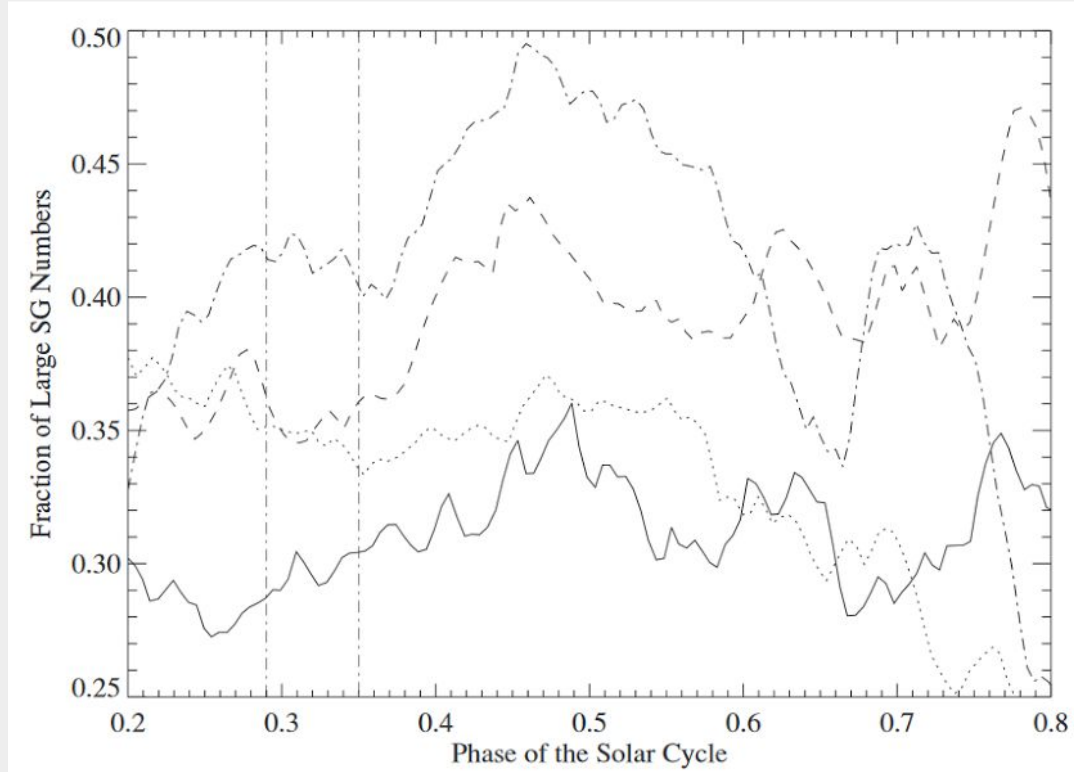
Log normal distributions of CMEs during the ascending and maximum phases of solar cycles 23 (upper panel), and 24 (middle panel). The Comparison of both distributions is presented in the lower panel.



Same data plotted separately for negative (left panels) and positive (right panels) acceleration CMEs. Numbers in the bottom panels show the differences between decelerated (1, 2) and accelerated (3, 4) CMEs between cycle 23 and 24.

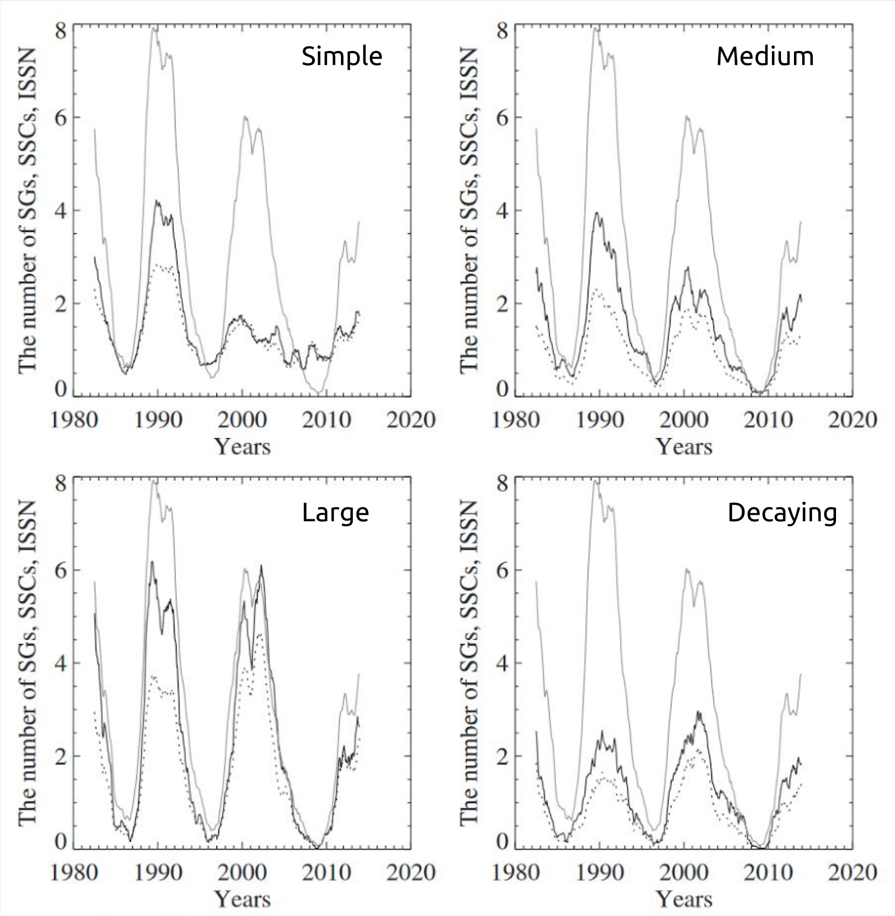


Monthly total sunspot areas (light gray), monthly total number of sunspots (dark gray), and the average area of a sunspot (thick line). The data are for solar cycles 22 and 23, and are presented separately for large (upper panel) and small (lower panel) sunspot groups.



Ratio of the large SG number to the total number of all active regions (i.e., sum of small and large SG numbers) plotted vs. the solar cycle phase. The solid line is cycle 20, the dashed line is cycle 21, the dotted line is cycle 22, and the dashed dotted line is cycle 23. Vertical lines indicate the range of the maximum phase of the ISSN determined for the four studied solar cycles.

Active Regions in solar cycle 24



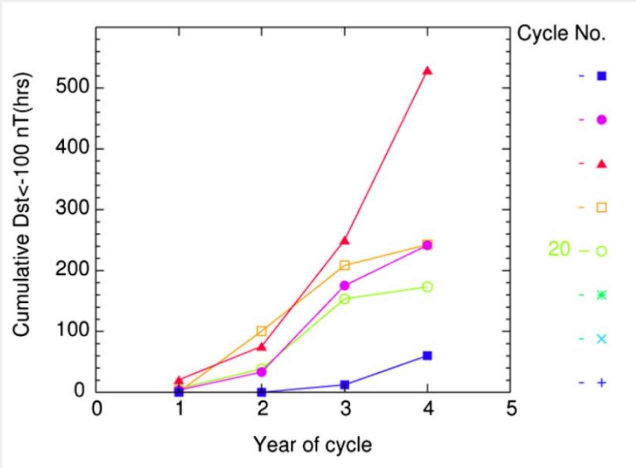
Temporal variations of SSCs (solid line) and the number of SGs (dotted line) for the simple (upper left), medium (upper right), large (lower left), and the decaying (lower right) types of sunspot groups. The gray profiles show the ISSNs for the same time period. For display purposes, the SSCs and ISSN data sets are not up to scale (simple-type SSCs are divided by 2, medium ones divided by 4, large ones divided by 12, and decaying ones divided by 1.4).

The ratio of SSCs to ISSNs for small and large group types for the previous cycle 23 was drastically different from those found for cycles 21, 22, and 24; this ratio is quite low for the small groups, and in contrast it is high for the large groups during cycle 23. In addition, the anti-correlation between small and large sunspots found in Nagovitsyn et al. (2012) can also be seen in this study for cycles 22 and 23 between small and large SGs.

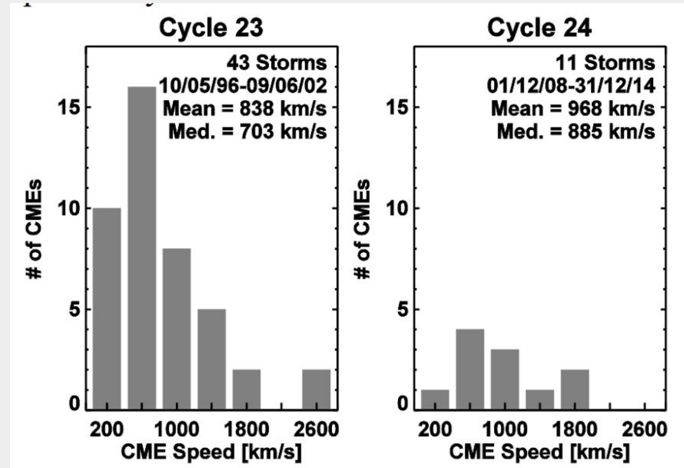
The number of large groups observed during the current cycle 24 is nearly half of those observed in cycles 21–23.

The significant deficit of large groups may have resulted in the very low level of geomagnetic activity measured during the current cycle 24.

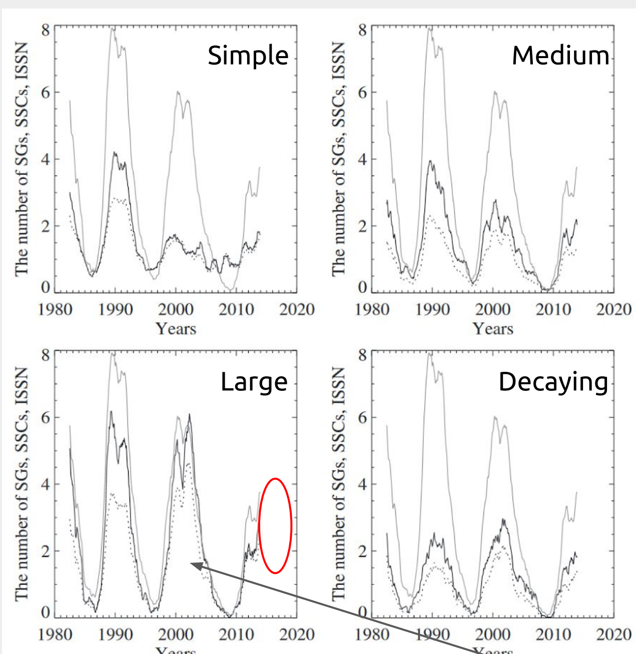
Solar and Geomagnetic Activity in Solar Cycle 24

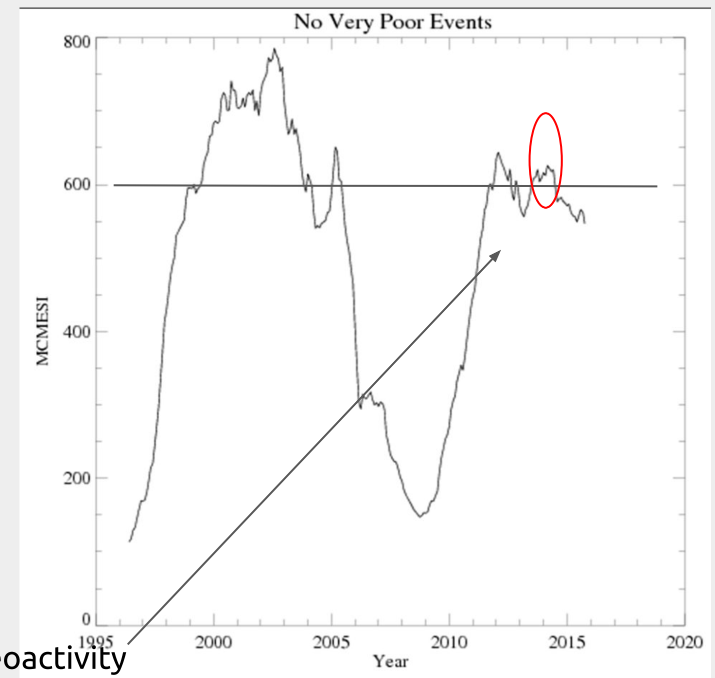


Richardson, 2013, J. Sp. Weather and Climate



Gopalswamy et al., 2015, Sun and Geosphere : more geoactivity during first peak of solar activity in cycle 24





stronger geoactivity