Mild Space Weather during Solar Cycle 24*

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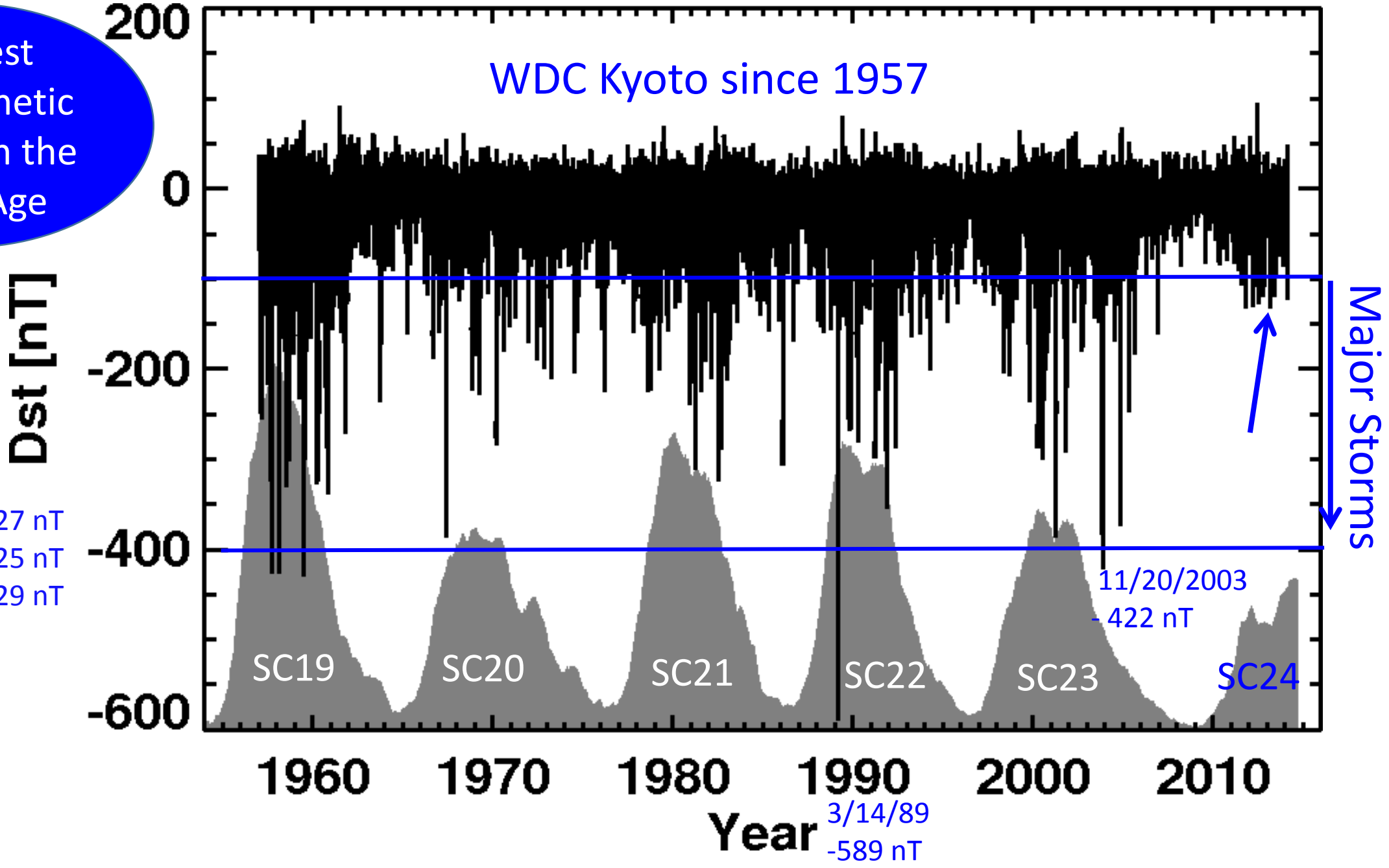
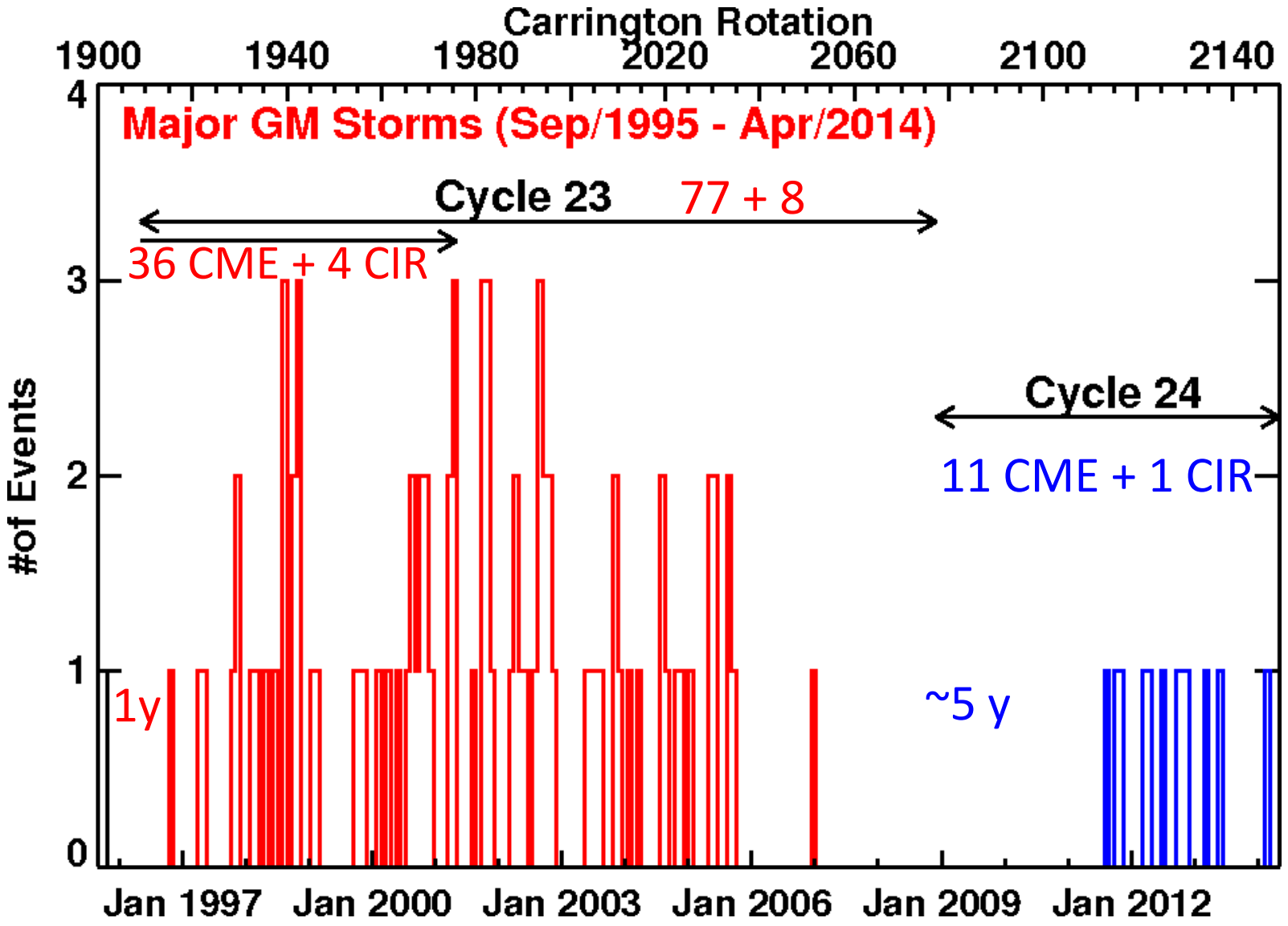
*Weakest geomagnetic storms since the dawn of Space Age
Very few high- energy SEP events

STP13 Xi'An, China, October 12-18, 2014

Weakest Geomagnetic Activity in the Space Age



Major Storms in Cycles 23 & 24



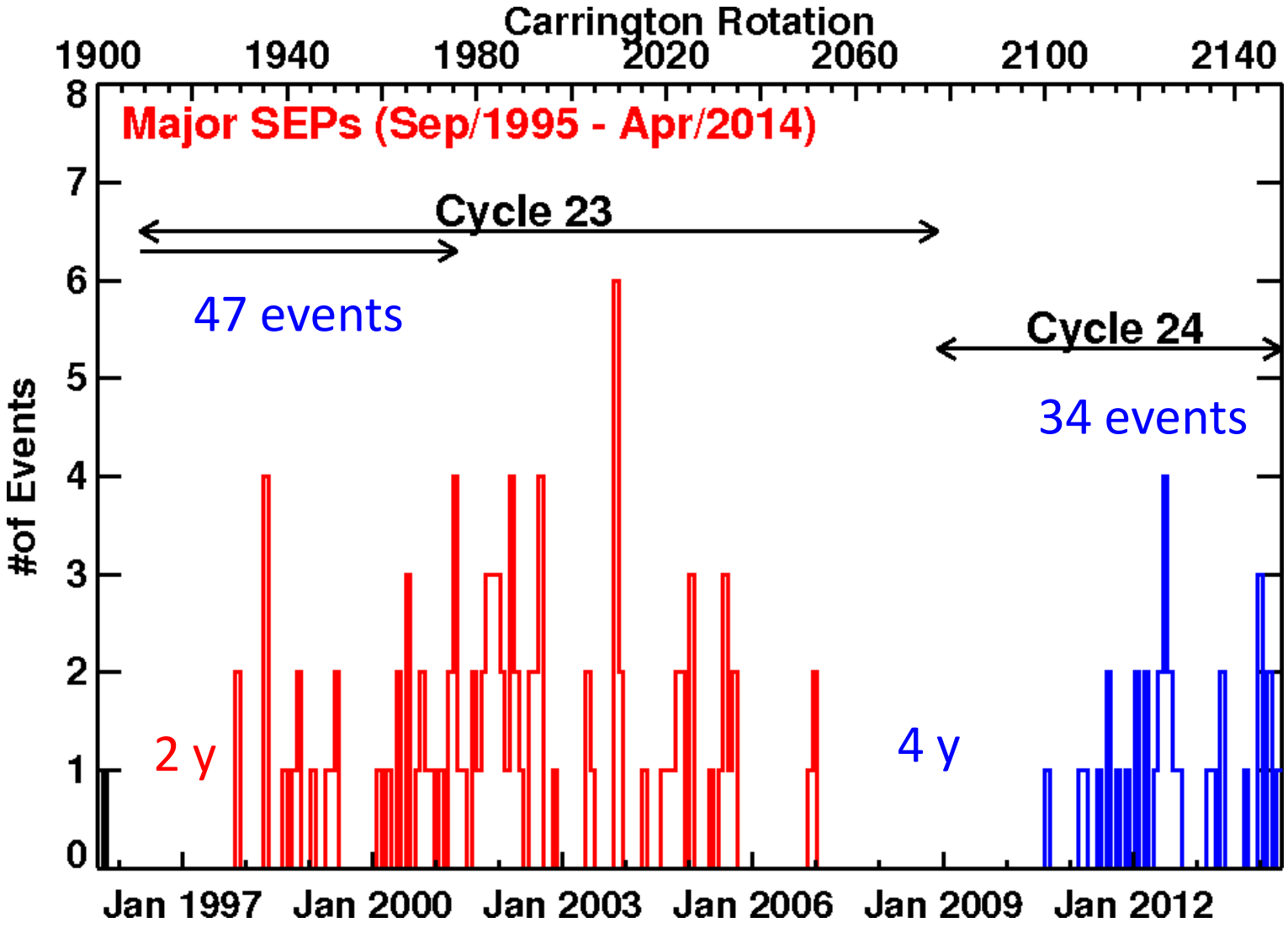
Very late onset of storm activity

Major storms drop by 72% in SC24

True for CME and CIR storms

Compare:
Drop in SSN 44%
Drop in Fast & Wide CMEs 30%

Large SEP Events 9/1995 – 4/2014



Drop in # of SEP events is lower than that in SSN (28% vs. 44%)

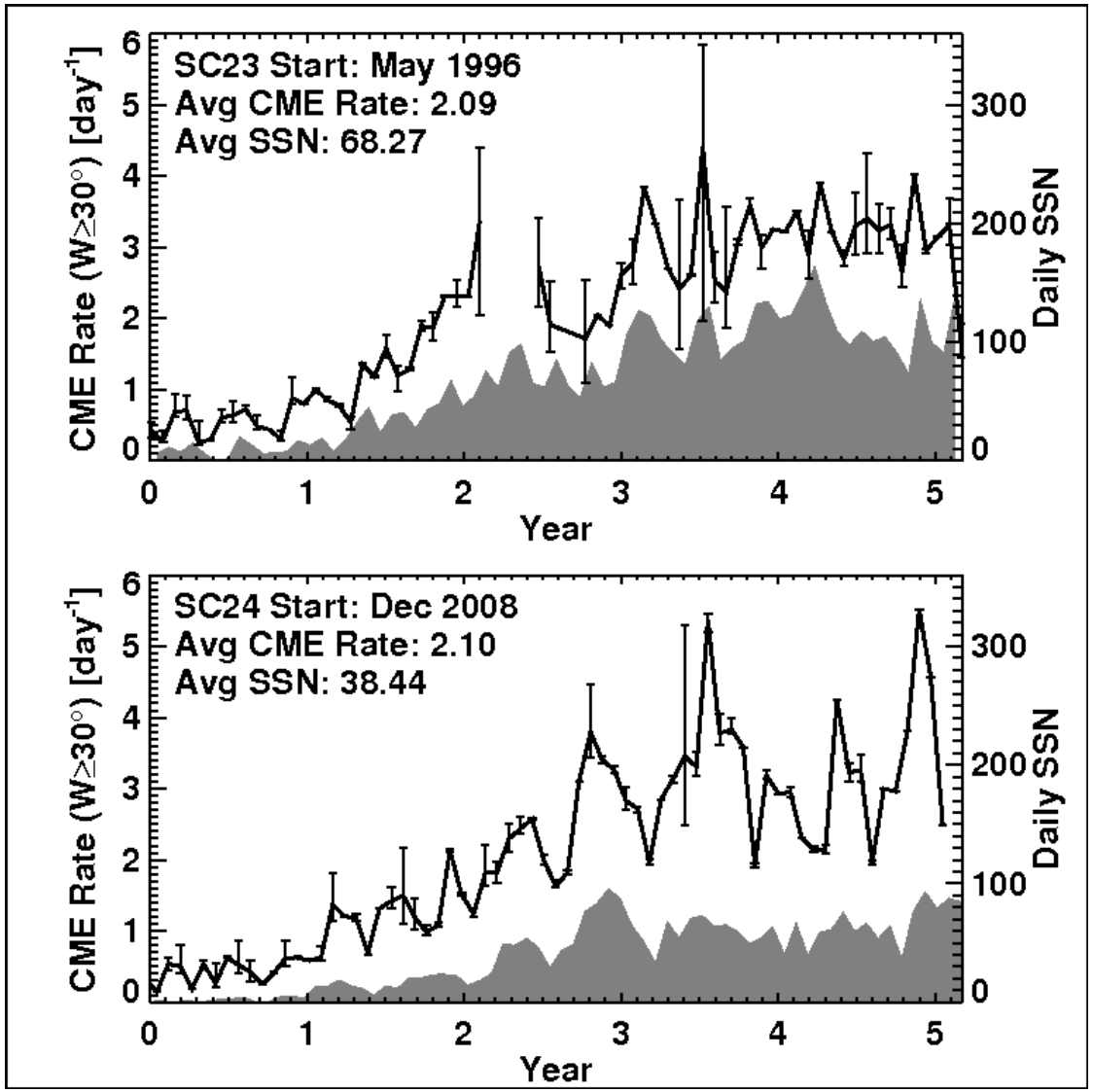
Drop similar to that of energetic CMEs (28% vs. 22%)

Lack of Highest Energy Particles
- Not entirely due to drop in FW CMEs

Property	Cycle 23*	Cycle 24	Ratio
# Large SEP Events	47	34	0.72
# >500 MeV SEP Events	12	5	0.42
# GLE Events	7	2	0.29
Avg CME speed (SEP) km/s	1425	1533	1.08
Halo CME fraction (SEP)	65%	100%	1.54
# FW CMEs (W20-W90)	55	43	0.78

*Same phase as cycle 24

CME Rate & SSN



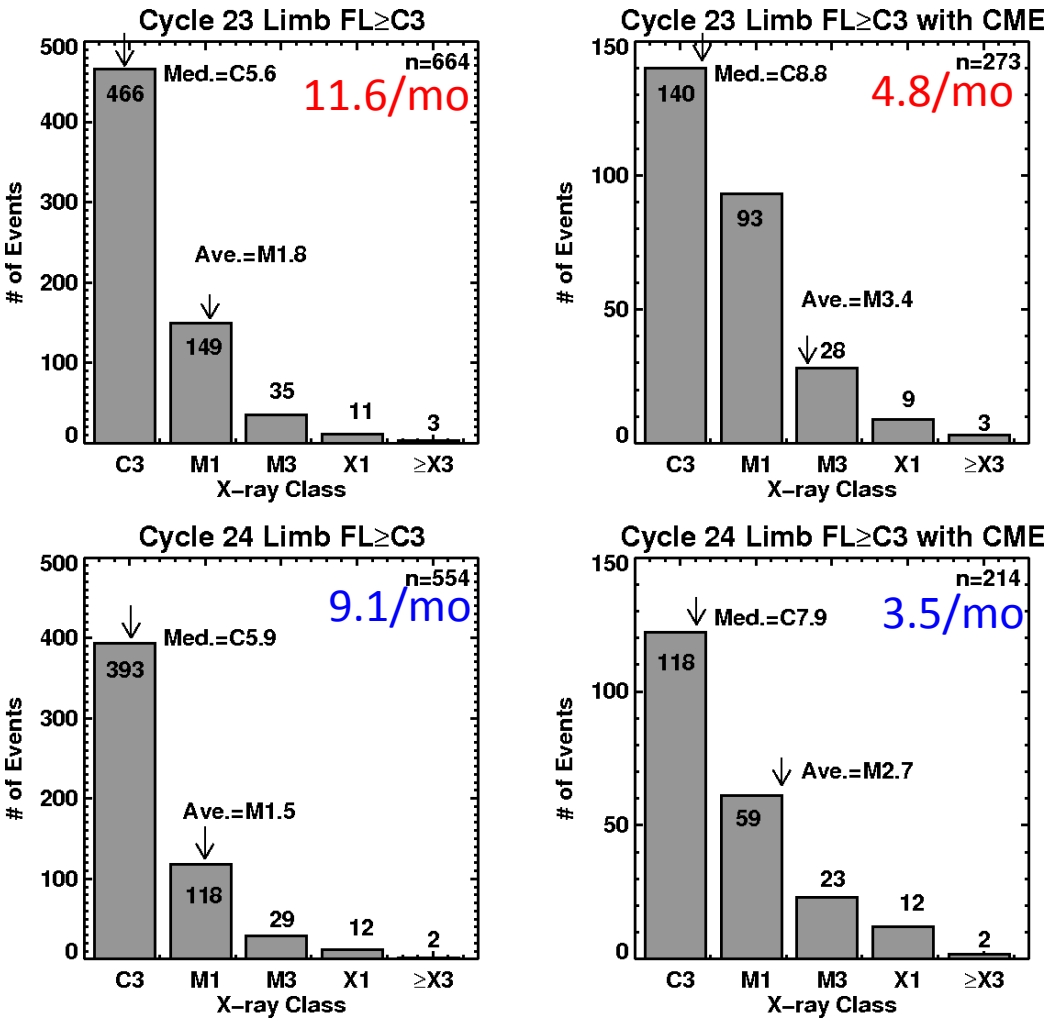
SSN is significantly lower in SC 24 (down by 44%)

The CME rate is similar in SC 24 and 23

CMEs are responsible for major magnetic storms (Dst < -100 nT) and large SEP events

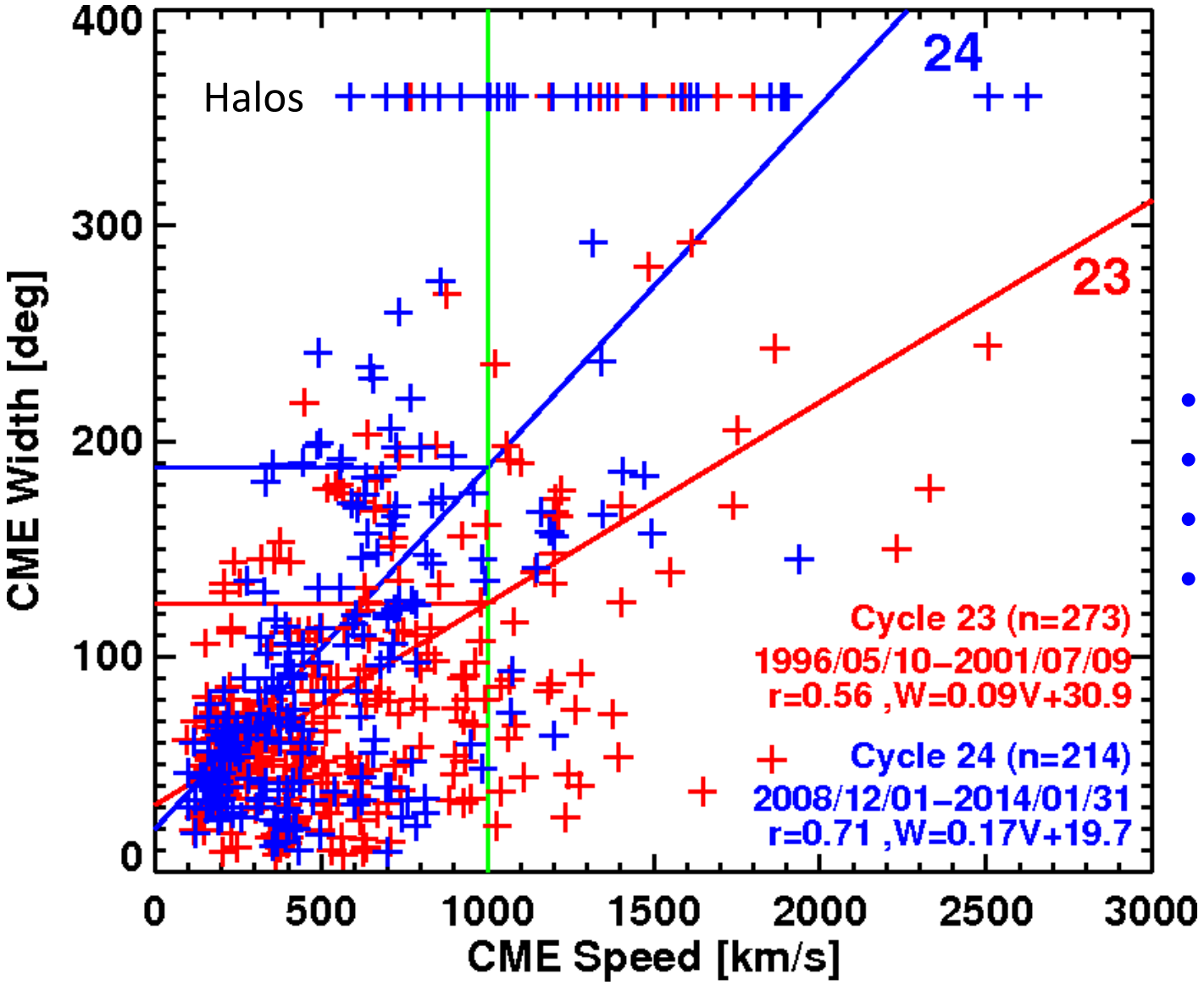
How can we explain the weak geomagnetic storms and SEP events using CME properties?

Flares in Cycles 23 and 24



- Cycle 24 has slightly less number of flares
- All flares: number ratio is 0.78
- CME-associated flares: the ratio is 0.73

Anomalous Expansion of CMEs in Cycle 24



- Limb CMEs to avoid projection effects
- CMEs associated with ≥C3.0 flares
- Compare Cycles 23 & 24

- Speed – Width relationship holds
- Slope is significantly different
- For a given speed, cycle 24 CMEs are wider
- For V=1000 km/s, W=125 (23) & 190 (24)
  - 52% wider in cycle 24
  - anomalous expansion of CMEs

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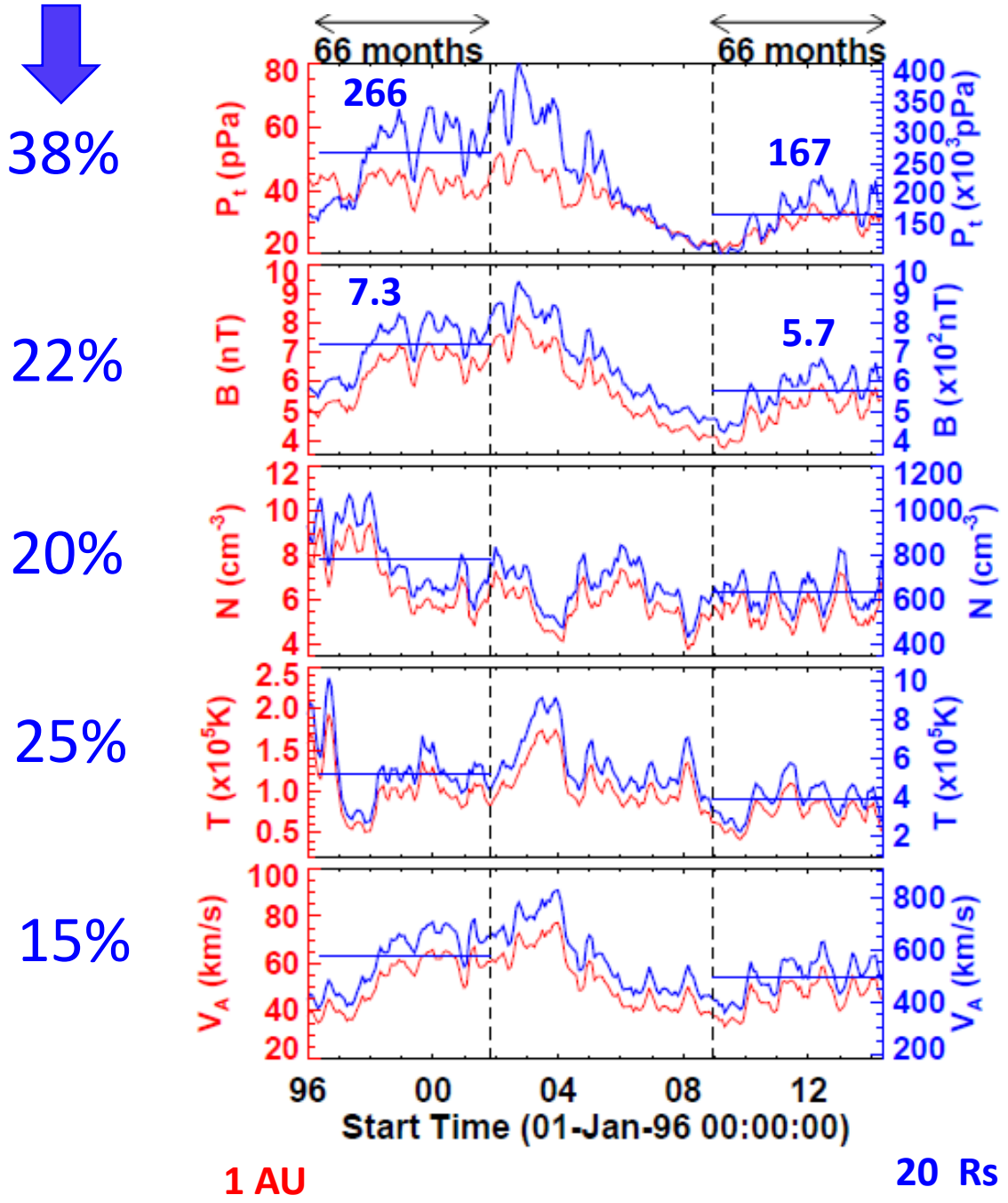
Why do SC 24 CMEs expand more? State of the Heliosphere!



Reduced total Pressure (38%)

→ CMEs expand more

→ This reduces CME magnetic content

→ Cloud storms are weak

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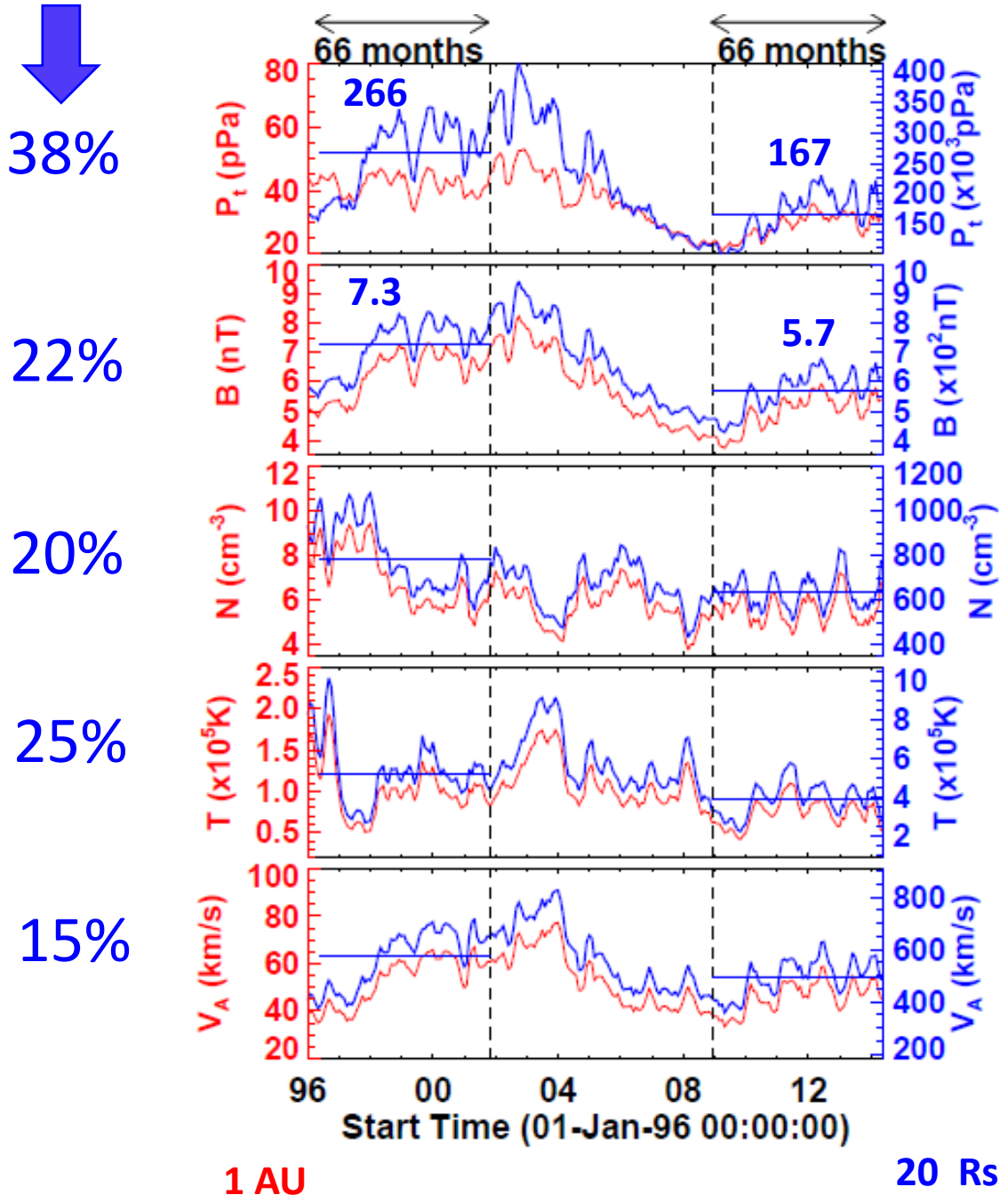

38%

22%

20%

25%

15%

Consequence of CME expansion for geomagnetic response

Reduced total Pressure (38%)
→ CMEs expand more
→ This reduces CME magnetic content
→ Cloud storms are weak

Heliospheric Magnetic field is also reduced (22%)
→ Compressed sheath field is less
→ This reduces sheath magnetic content
→ Sheath storms are weak
→ CIRs storms are weak

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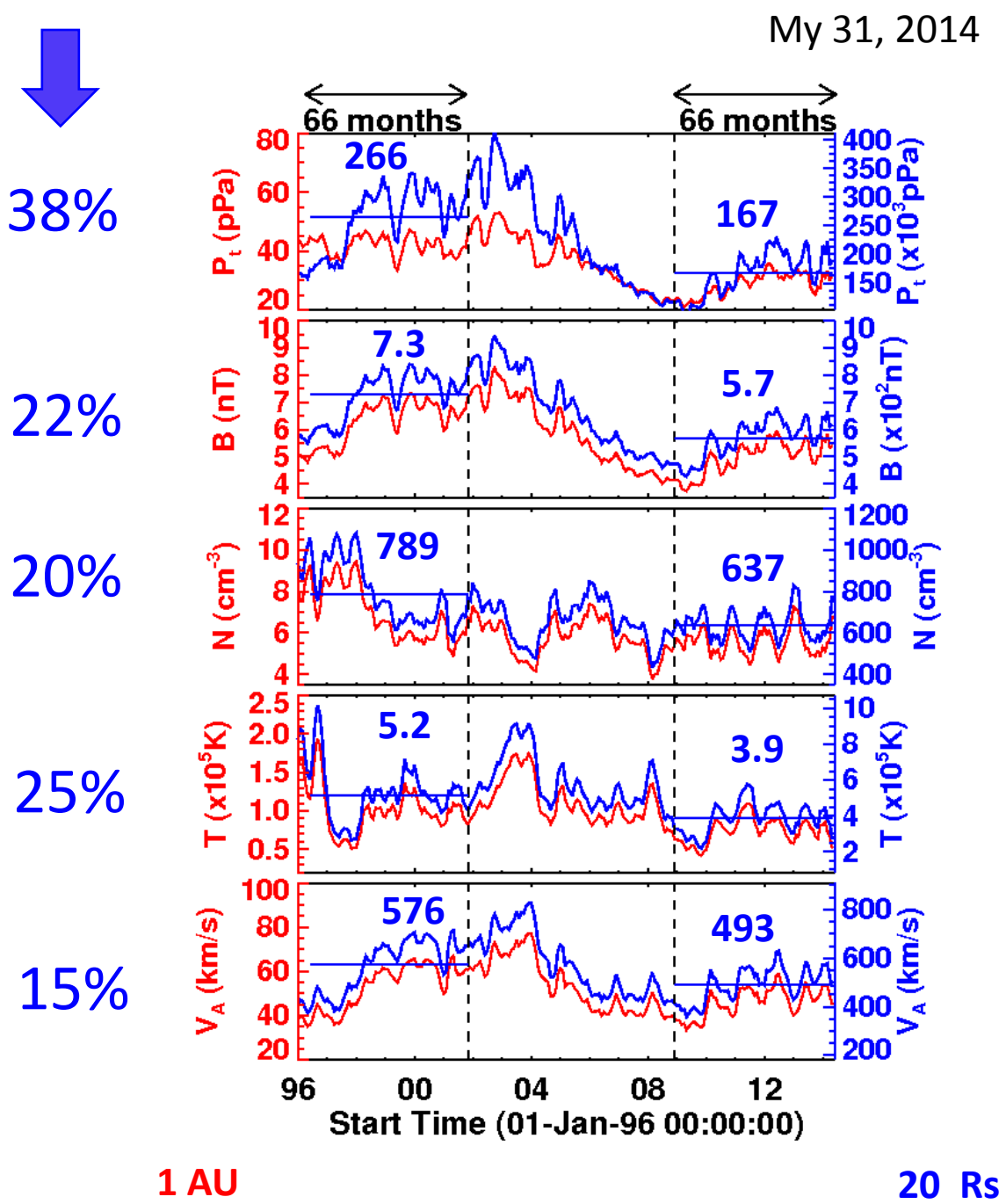
State of the Heliosphere



Reduced total pressure
→ CMEs expand more

Reduced B
→ Reduced acceleration efficiency (Kirk, 1994)
$dE/dt \propto B$ (rate of energy gain or acceleration time scales $\propto B^{-1}$)
With the available time of ~10 min, it is difficult to accelerate SEPs to GeV energies

Reduced Alfven speed near Sun
→No major reduction in the # SEP Events

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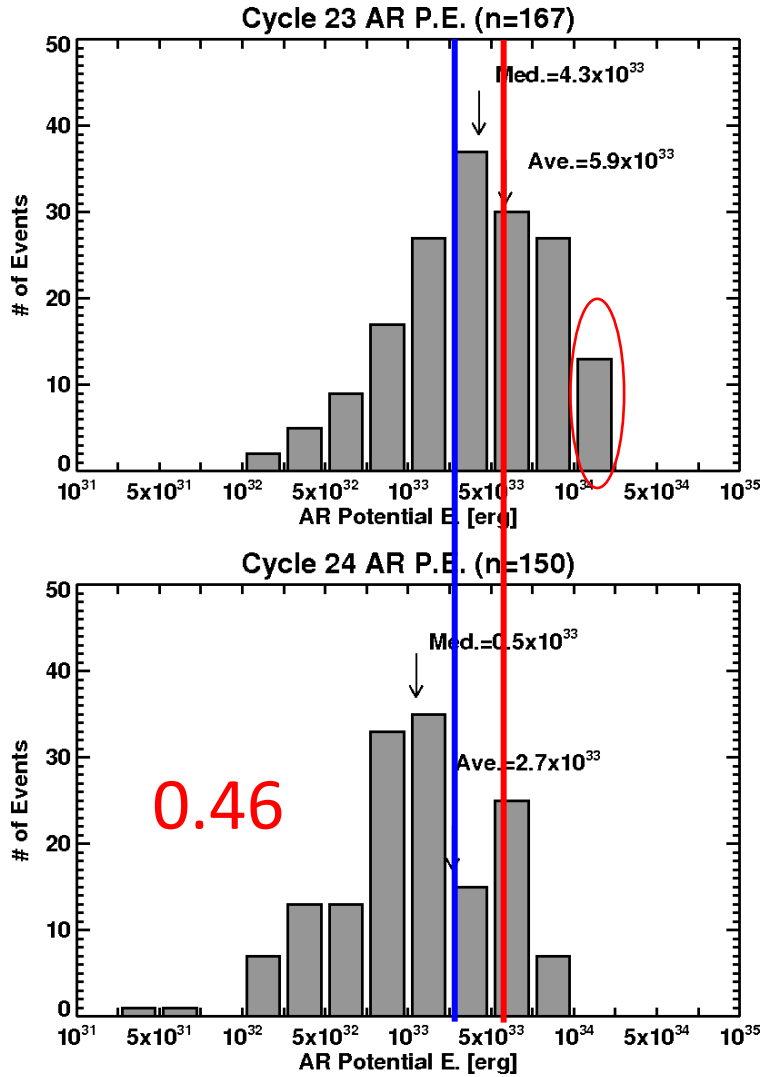
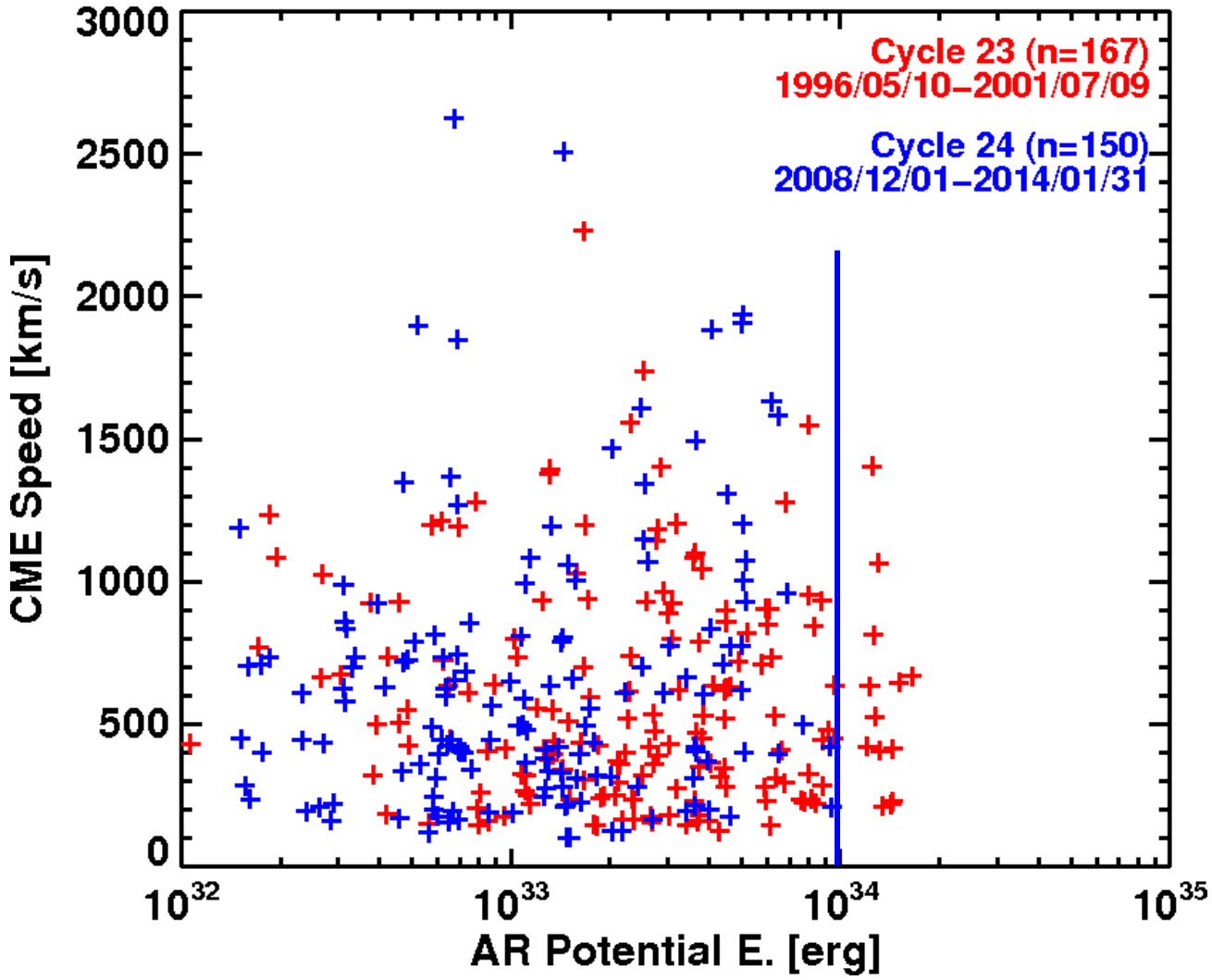
AR Potential Energy

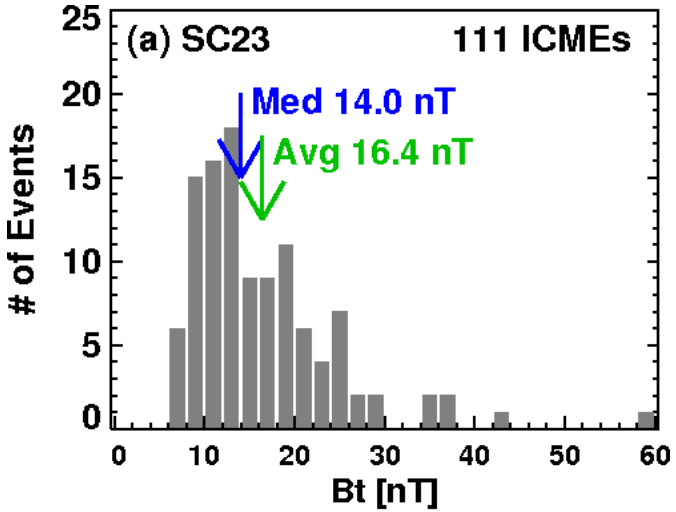


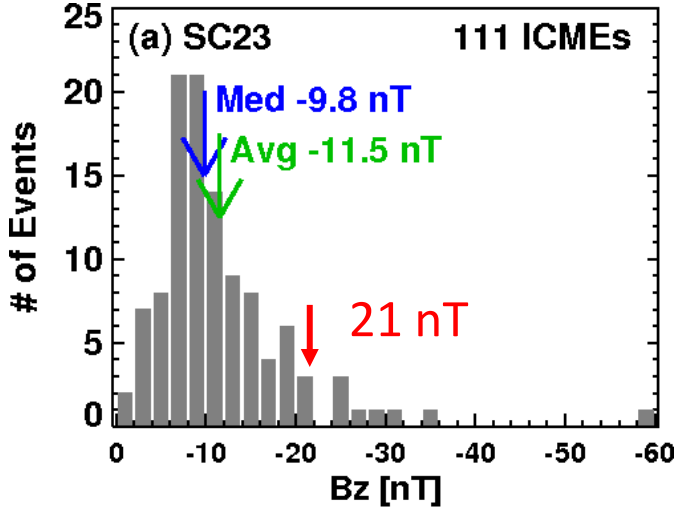


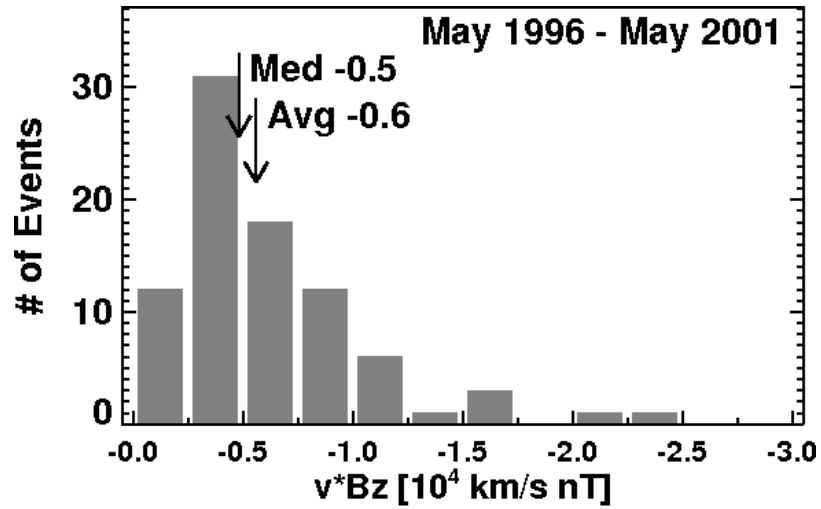
ICME Max B

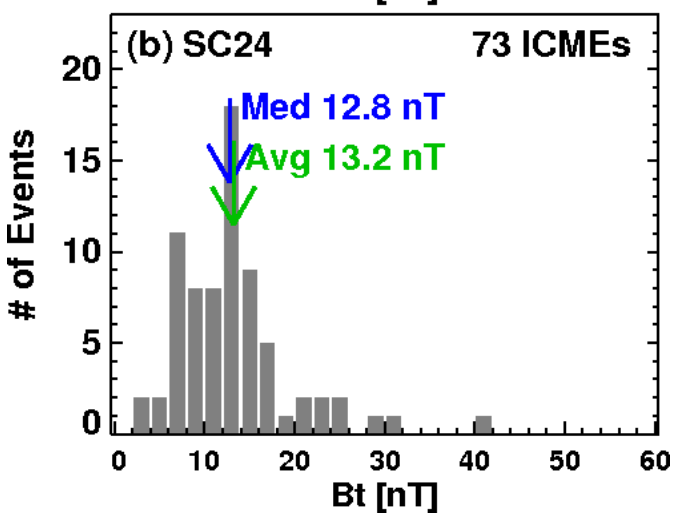
The number of ICMEs dropped in cycle 24 by 34%
The average B dropped by 20%
The average Bz dropped by 22%

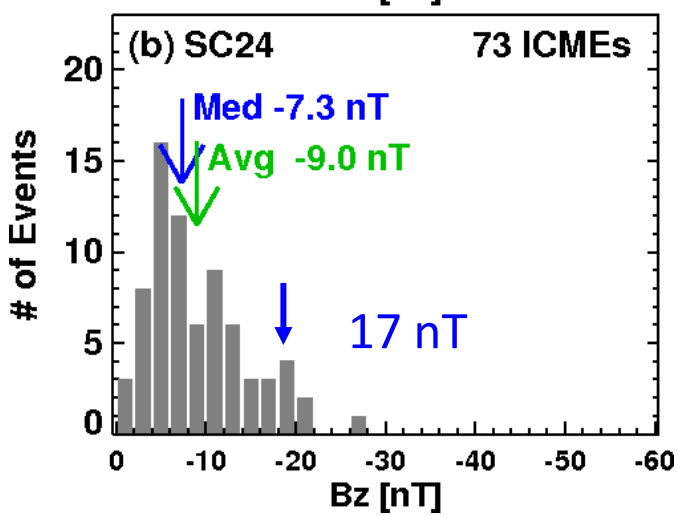
$Dst = 0.01VB_z - 32$ nT

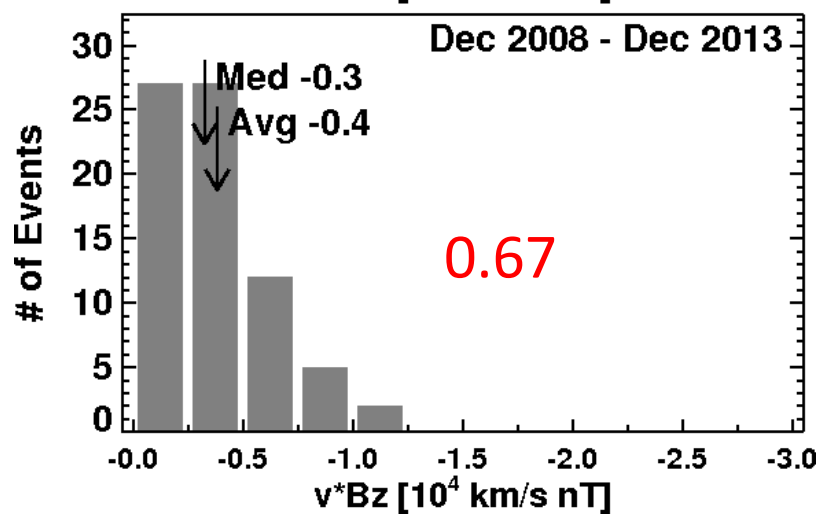












Summary

- CMEs of SC 24 expand more than they did in SC 23 because of the reduced total pressure in the heliosphere
- CME expansion dilutes the magnetic content resulting in weaker and less frequent geomagnetic storms (confirmed by ICME measurements).
- Reduced Alfven speed in the corona makes it easy to form shocks – explains why the number of SEP events did not drop significantly in SC 24
- Reduced heliospheric magnetic field contributes to the lack of high-energy SEP events (e.g. GLE events), weaker CIR and sheath storms, and the highest levels of galactic cosmic rays

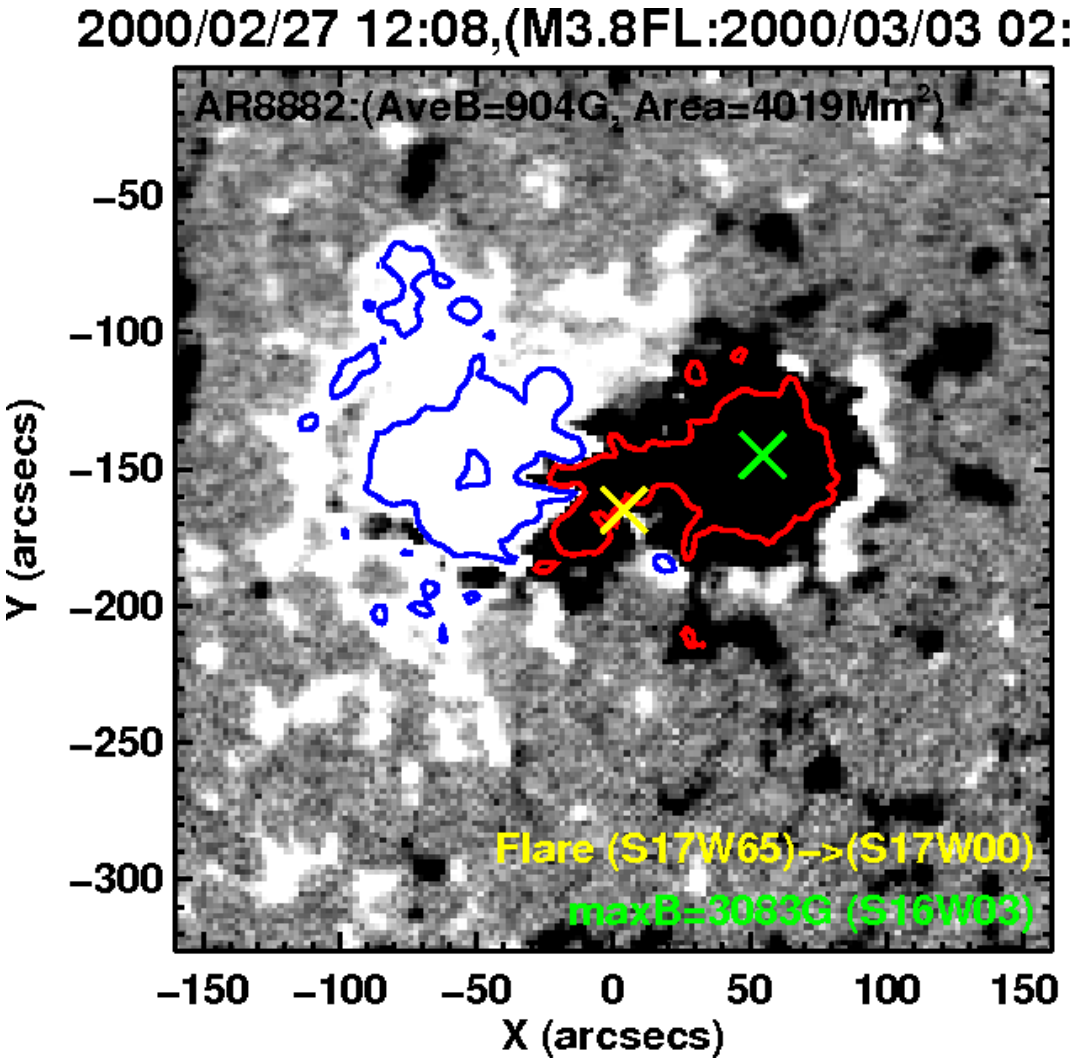
Backup slides

CME Number as a Function of CME Properties

CME Property	Cycle23	Cycle 24	Ratio
All CMEs	5086 (89.2/mo)	8201 (134.44/mo)	1.51
W≥30^o	3354 (58.84/mo)	4294 (70.39/mo)	1.20
W≥60^o	1858 (32.6/mo)	2205 (36.15/mo)	1.13
W = 360^o	178 (2.99/mo)	199 (3.06/mo)	1.02
V≥900 km/s & W≥60^o	189 (3.32/mo)	142 (2.33/mo)	0.70
≥C3.0 flares, limb	273 (4.7/mo)	214 (3.45/mo)	0.73

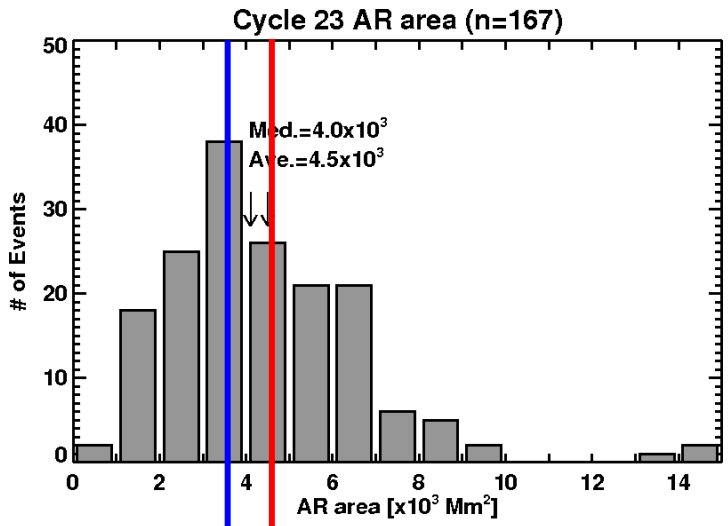
- Many narrow CMEs in cycle 24
- For wider CMEs, the numbers are roughly the same in the two cycles
- The number of energetic CMEs is slightly smaller

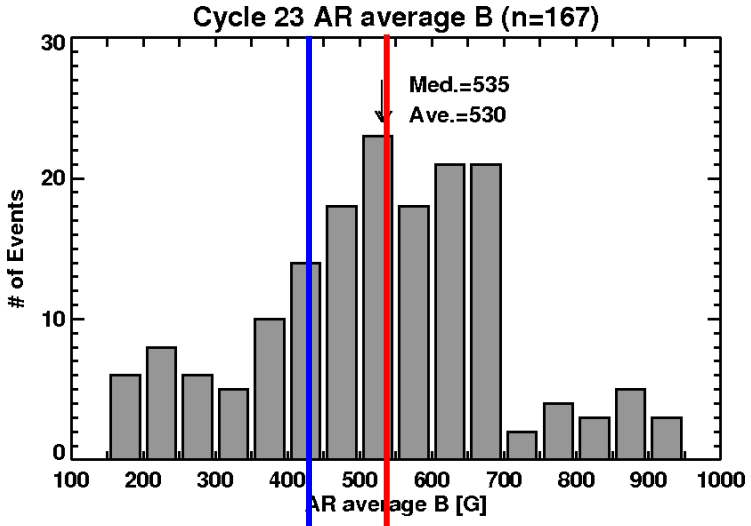
Source Properties

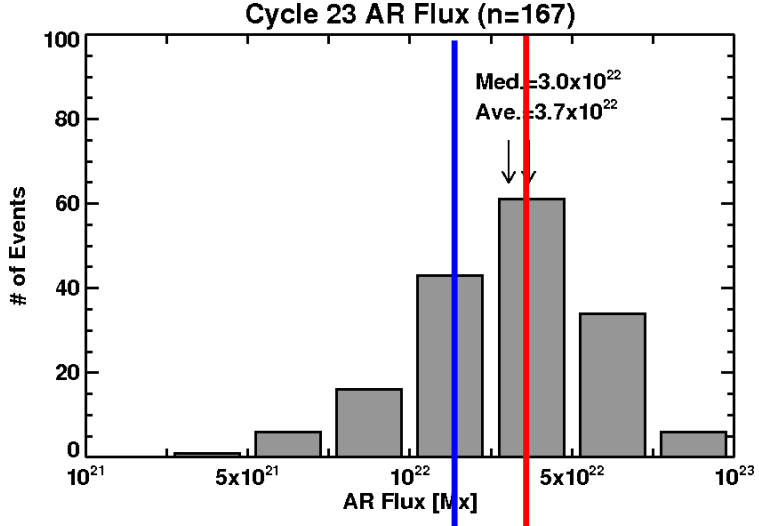


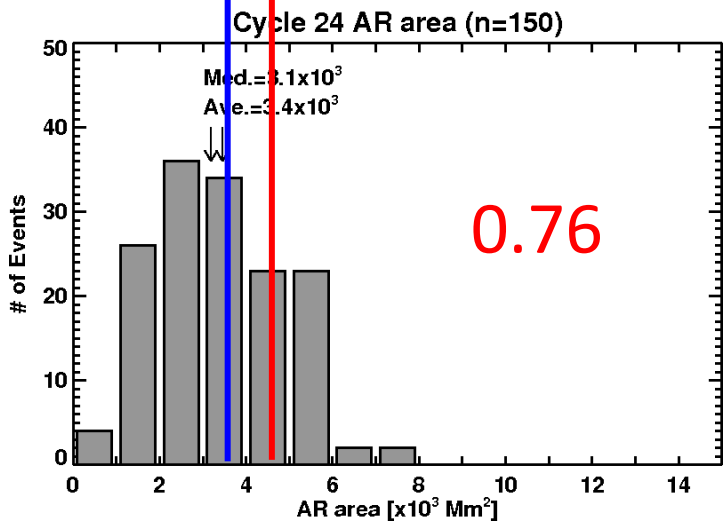
- Examine source regions a few days before or after the eruption depending on the source location
- Define area (A) bounded by a contour at 10% of the peak B
- Define average B as the average unsigned value within A
- Calculate flux ϕ =AB; Potential Energy $E = (A^{-1/2}\phi^2)/8\pi$

Source Properties: B, A, ϕ









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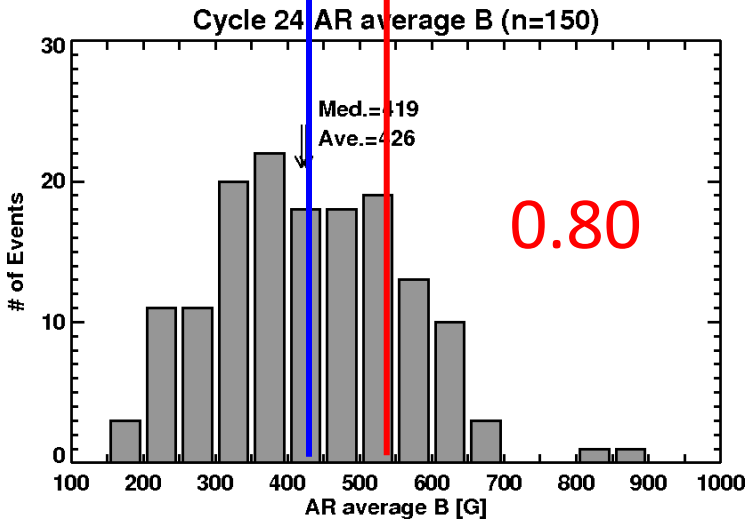

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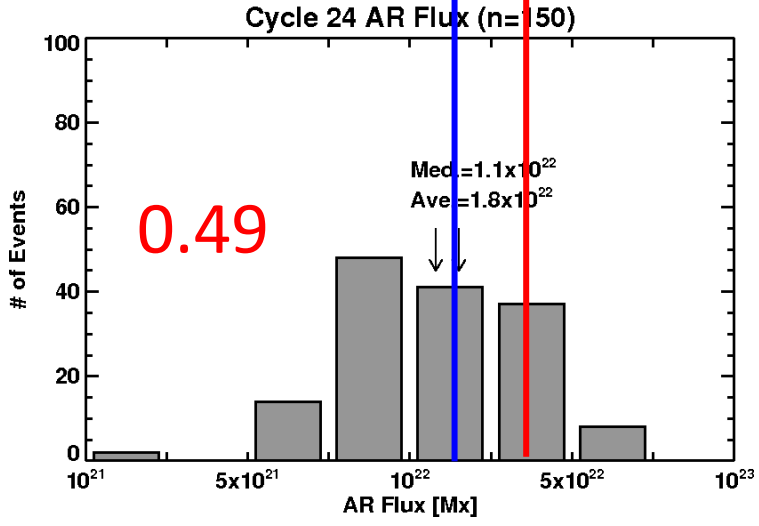

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