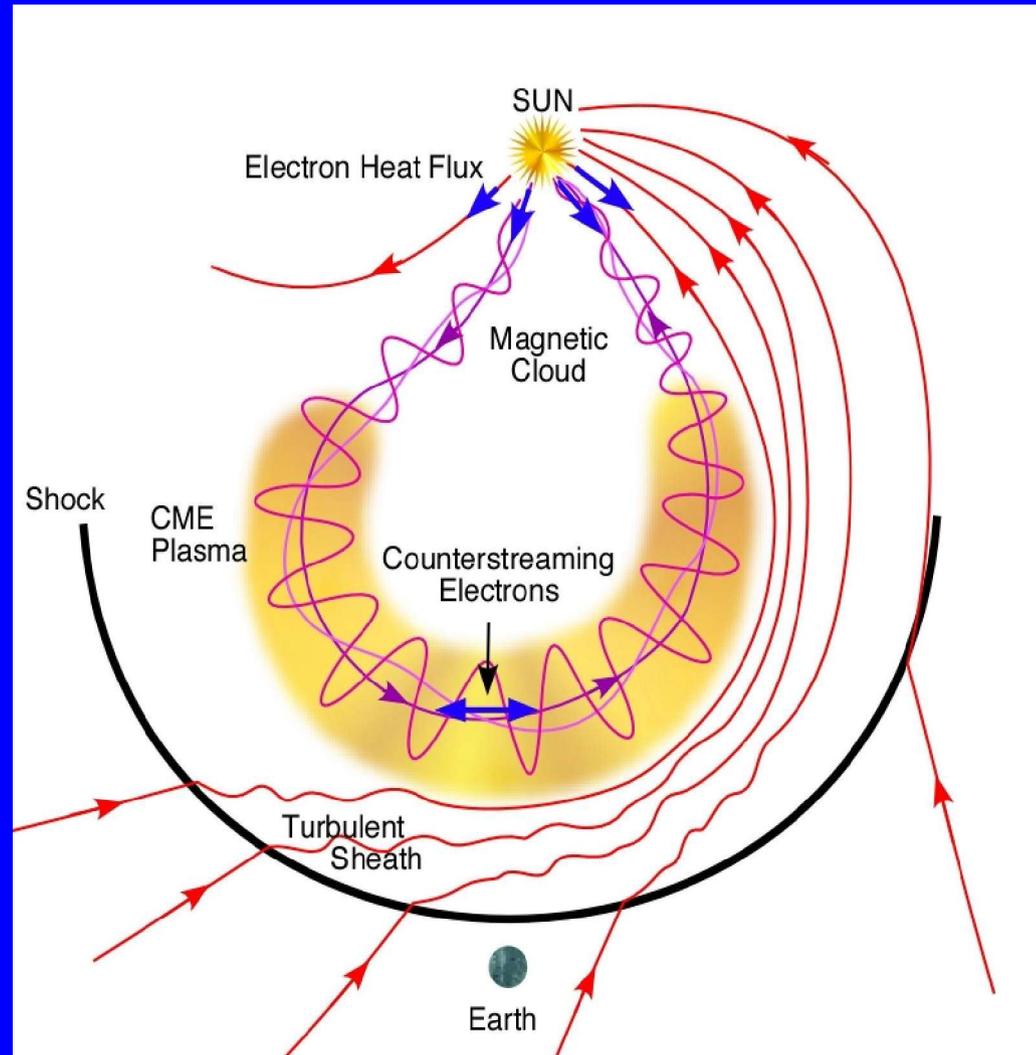


Variation in Average Solar Wind Conditions During the Solar Cycle: Is There a Role for ICMEs?

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Schematic of ICME/magnetic cloud driving an interplanetary shock



Zurbuchen &
Richardson, 2005

ICMEs are indisputably important solar wind phenomena, e.g., drivers of most major geomagnetic storms.

Coronagraph (e.g., LASCO) and in-situ observations show that CMEs and ICMEs are more numerous (by a factor of ~ 10) at solar maximum than at minimum.

LASCO has seen thousands of CMEs moving out into the solar wind.

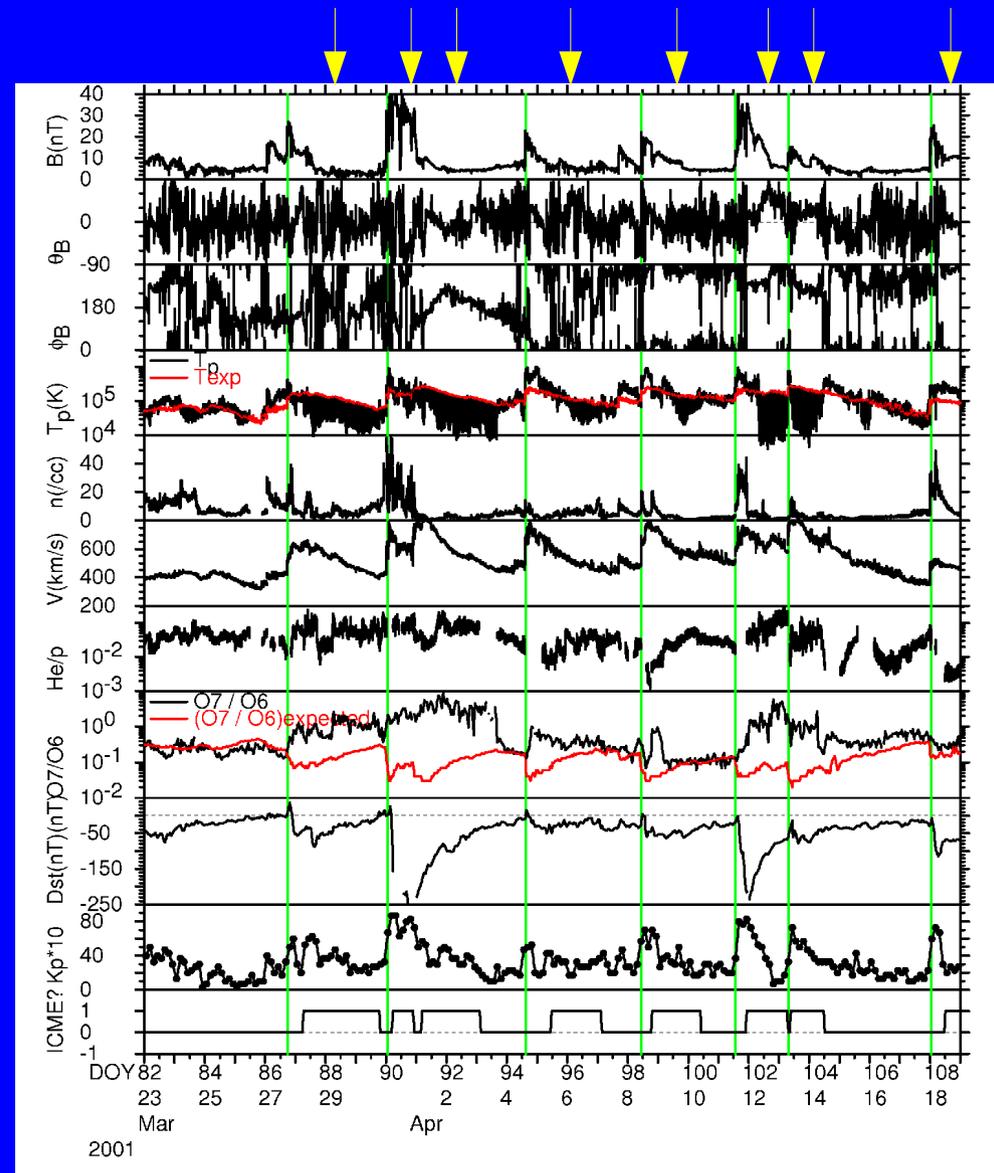
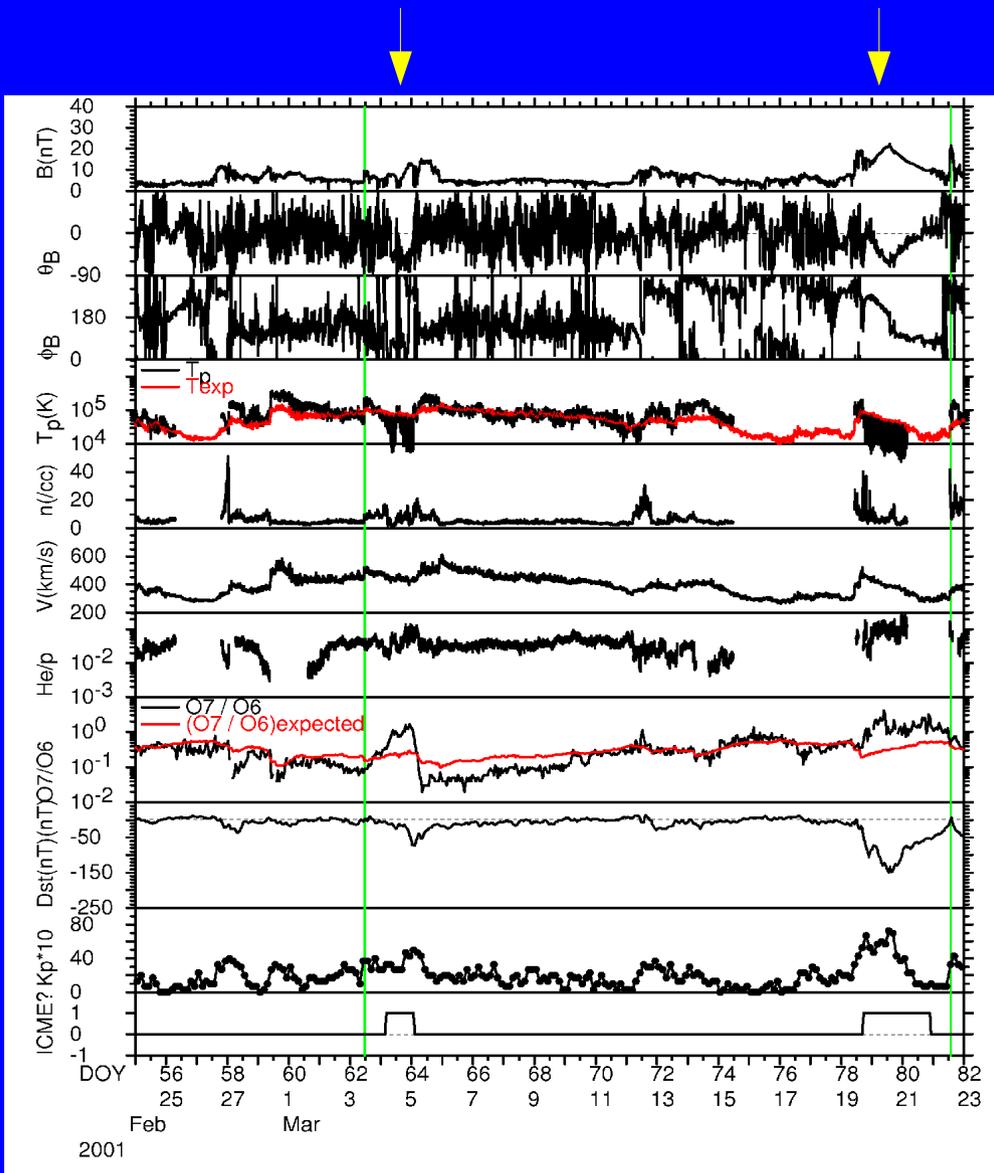
LASCO movies show “spectacular” sequences of CMEs at times of high activity.

“Common” picture is that the solar wind is “dominated” by CMEs at maximum

e.g., (question at AGU Spring Meeting)

“Why do potential field models (e.g., Wang-Sheeley-Arge) continue to predict the 1 AU solar wind so well at solar maximum when there are so many CMEs present?”

Solar wind magnetic field/plasma/geomagnetic data during two successive 27-day intervals in February-April 2001 with 2 ICMEs (low/typical rate) and ~8 ICMEs (high rate)



“ICME-Related” Solar Cycle Variations: Reality or “Plausible Myths”?

Increase in IMF strength around solar maximum:

- More ICMEs carrying strong fields (think “magnetic clouds”) are present at maximum.
- Legs of ICMEs remain attached to the Sun for extended periods, building up IMF in inner heliosphere.

Increase in He/p ratio with increased solar activity:

- ICMEs have high He/p values; increased ICME occurrence leads to increase in He/p.

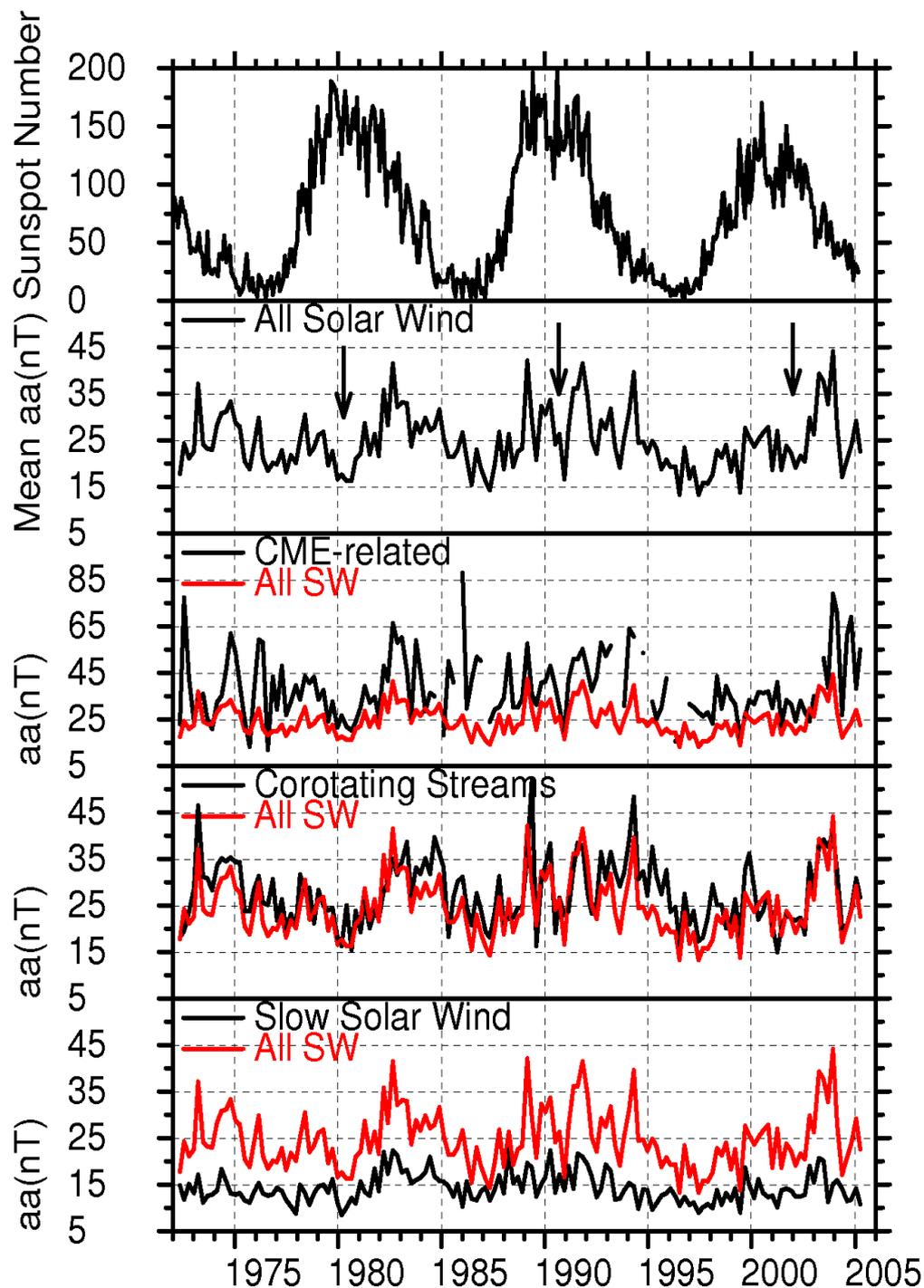
Cosmic Ray modulation:

- ICMEs produce short term modulations; multiple ICMEs can combine to form expanding shells that modulate incoming cosmic rays.
- High-latitude CMEs are particularly important (Lara et al., ApJ, 2005)

Geomagnetic activity:

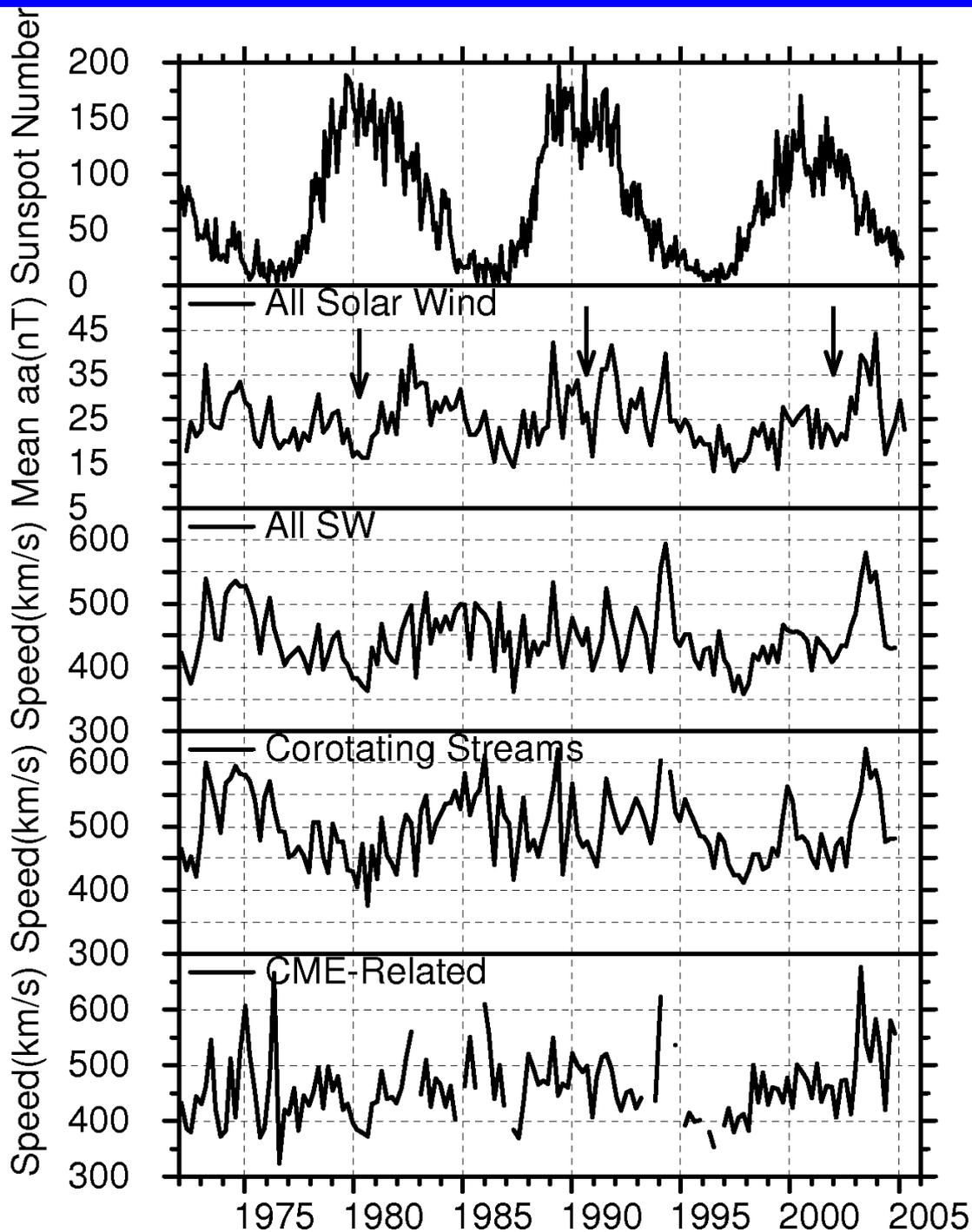
ICMEs produce large geomagnetic storms, hence average geomagnetic activity levels increase with solar activity

Sunspot No. and 3-Solar Rotation Averages of the aa Geomagnetic Index, 1972 - 2005



- Poor correlation with solar activity cycle
- Local minimum near solar maximum
- 3-rotation-averages tend to follow aa for corotating streams.

Updated from Richardson et al., JGR, 2001

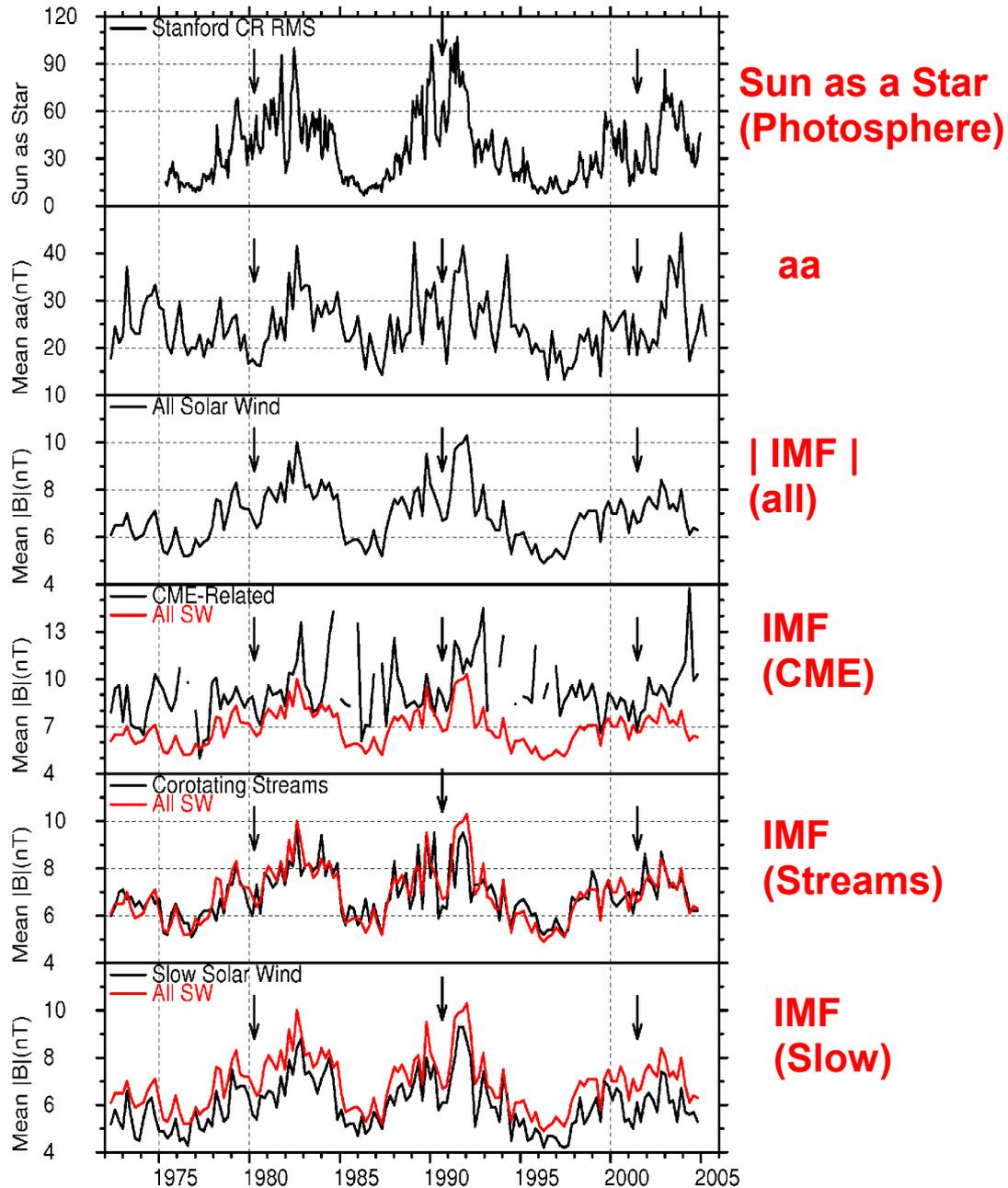


SSN, mean aa, and mean Vsw in all solar wind, streams and CME-related structures.

OMNI2, 1972 - 2005

Average aa index is well-correlated with variations in average solar wind speed

1972 - 2004



Sun as a Star
(Photosphere)

aa

| IMF |
(all)

IMF
(CME)

IMF
(Streams)

IMF
(Slow)

aa also tends to follow variations in the mean IMF

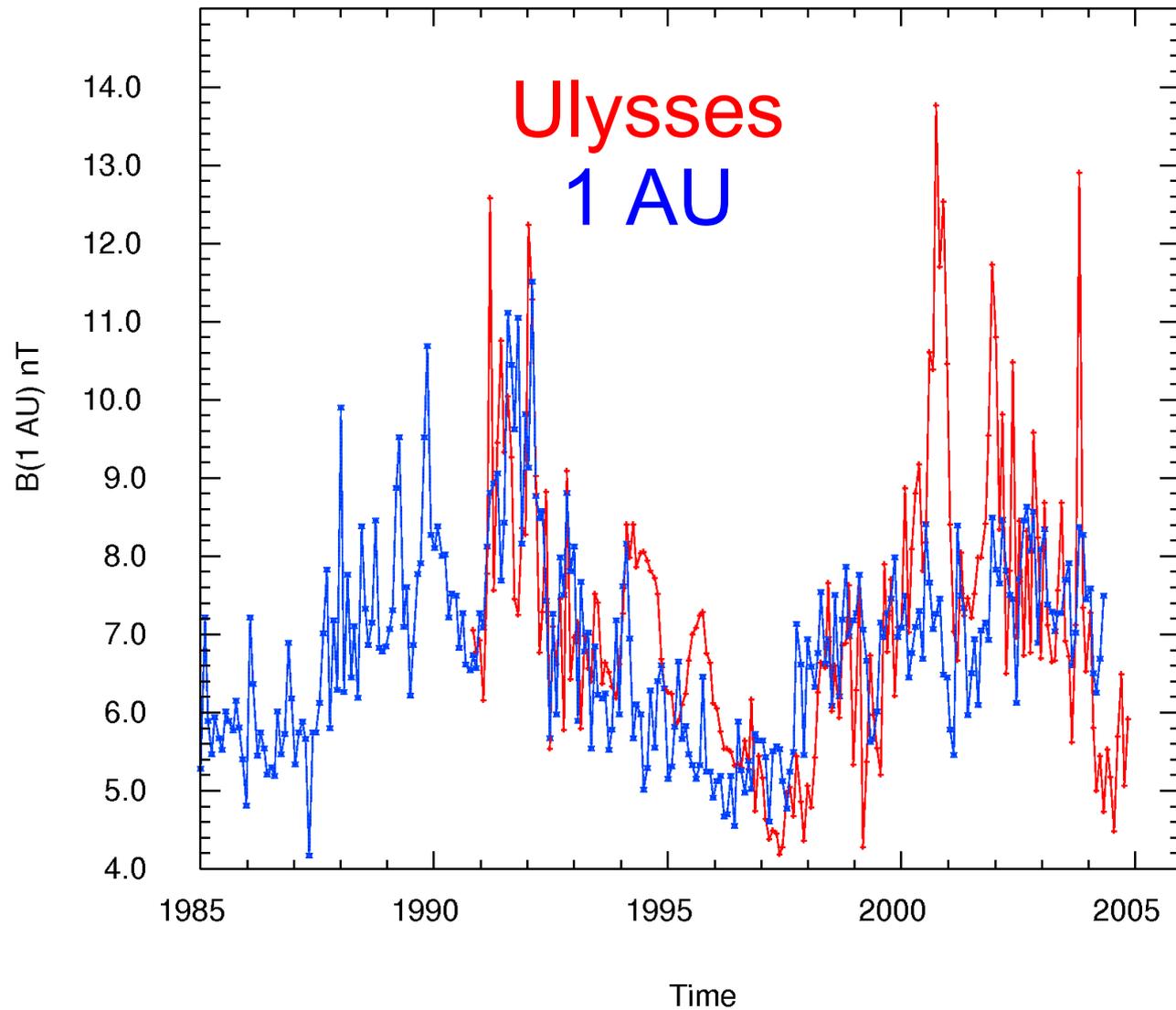
Local minimum in IMF near maximum (solar field reversal)

Mean IMF similar to means in high-speed streams/slow SW (i.e., ambient solar wind)

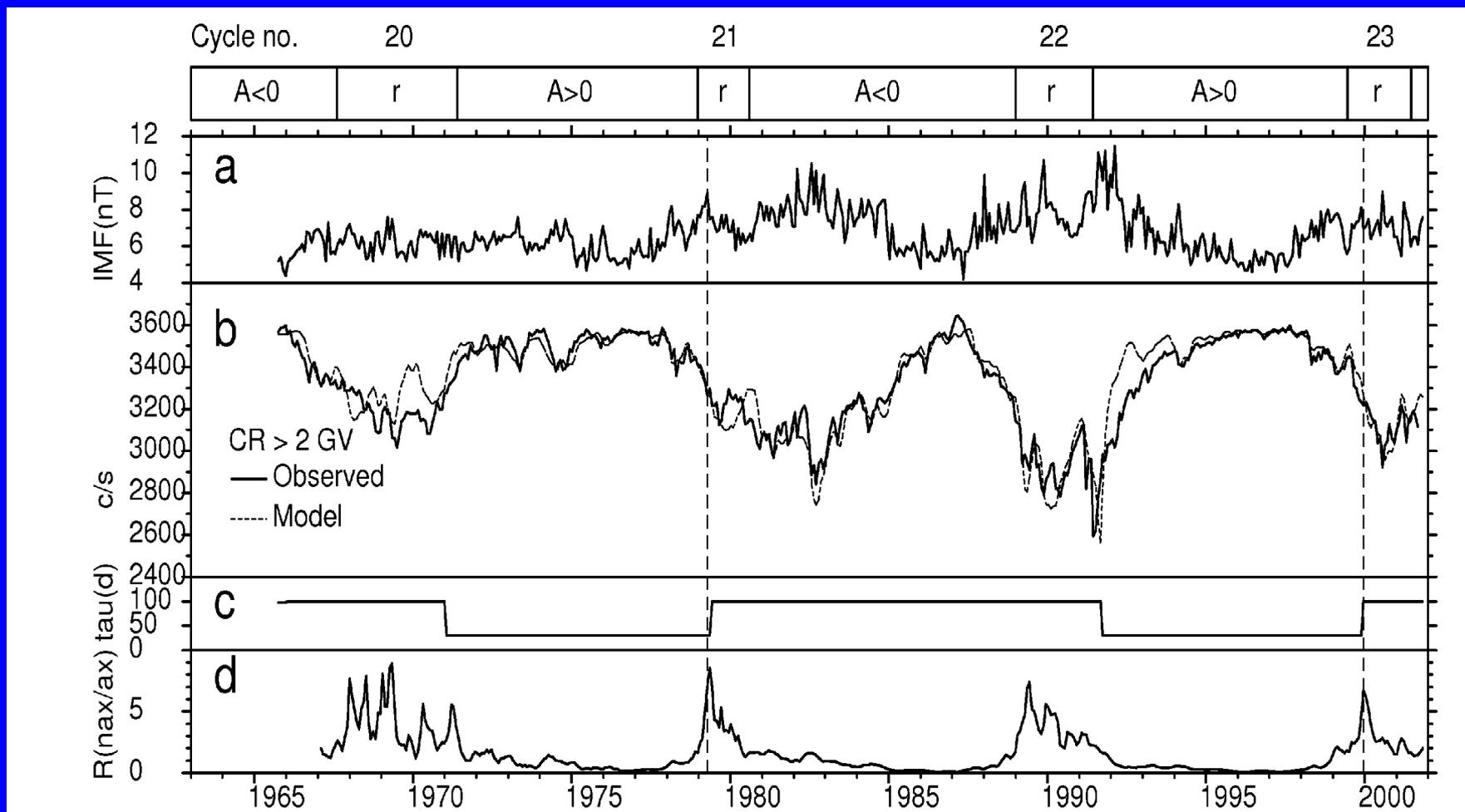
IMF highly correlated with "Sun as a Star" photospheric field measurement (includes no information on CMEs!).

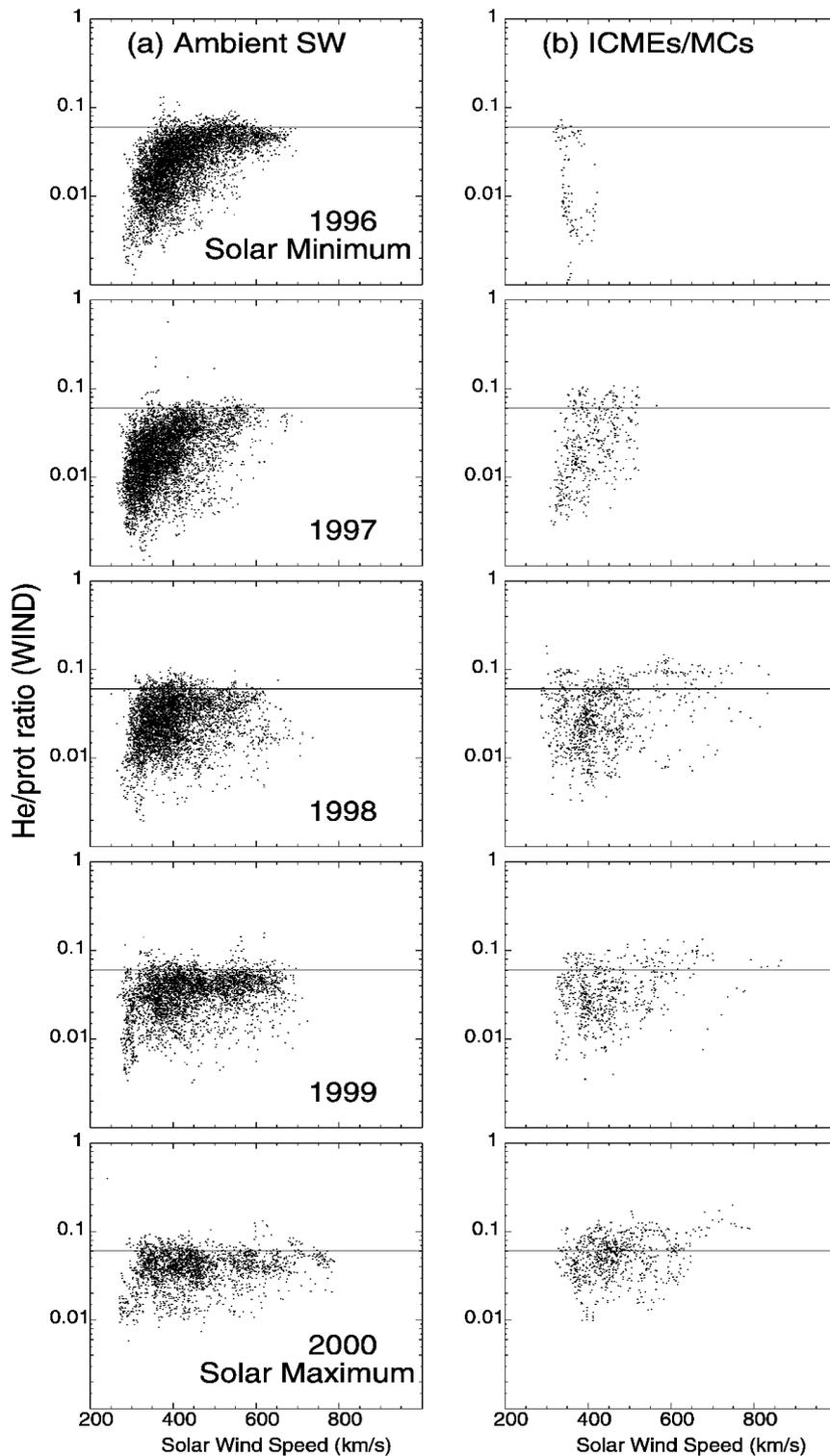
Variations in mean aa driven by speed and IMF variations in the ambient solar wind.

$|B|$ at 1 AU and Ulysses (mapped to 1 AU)



Cosmic ray modulation in cycles 20-23 driven by mean IMF (\sim diffusion coefficient) variations in a simple model (Wibberenz, Richardson, & Cane, JGR, 2002)





He/proton ratio vs. solar wind speed (1-hr averages) in 1996 – 2000 at WIND (courtesy of J. Richardson, MIT)

Change in distribution as activity increases.

Tends towards larger average values.

Change is seen both in the ambient solar wind and ICMEs

Not simply due to ICMEs, which frequently do not have abnormally high He/p

Richardson and Cane, JGR, 2004.

Summary

- Solar cycle variations in solar wind and geomagnetic parameters are not simply a reflection of (and may be unrelated to) the increase in CME/ICME rates as solar activity increases.
- Typically dominated by conditions in the ambient/background solar wind even at solar maximum.
- General association exists between quasi-static solar phenomena and solar wind conditions even at solar maximum, except at unusually high activity levels.