Long-term trends in chromospheric activity

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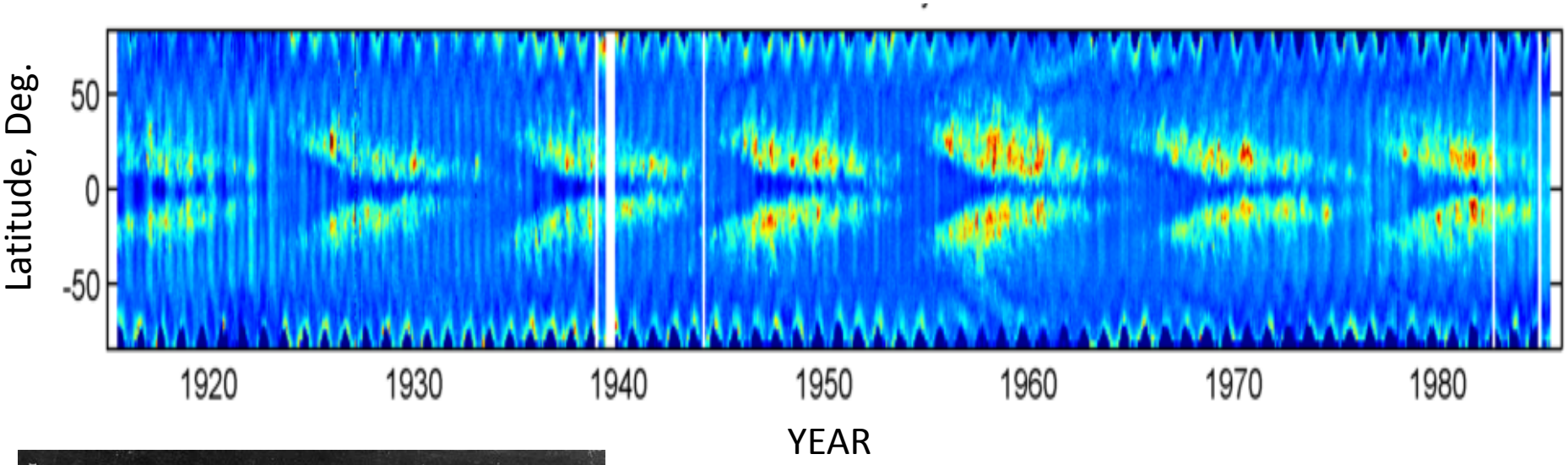
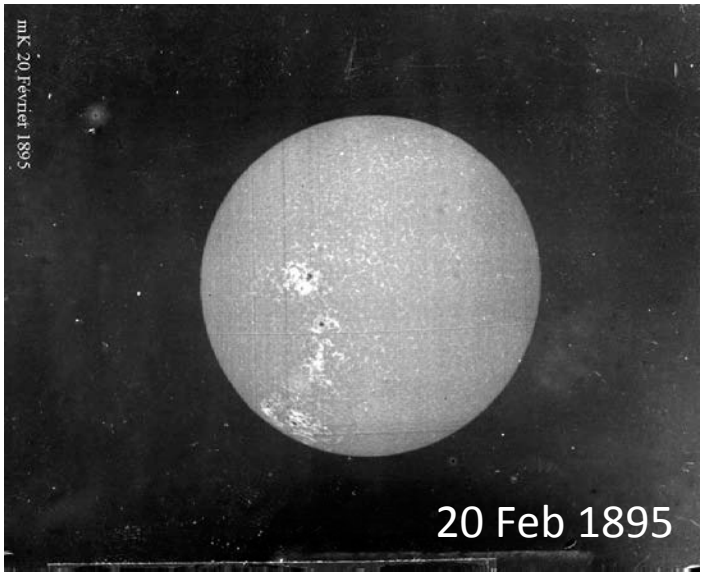
Historical Observations in Ca II K

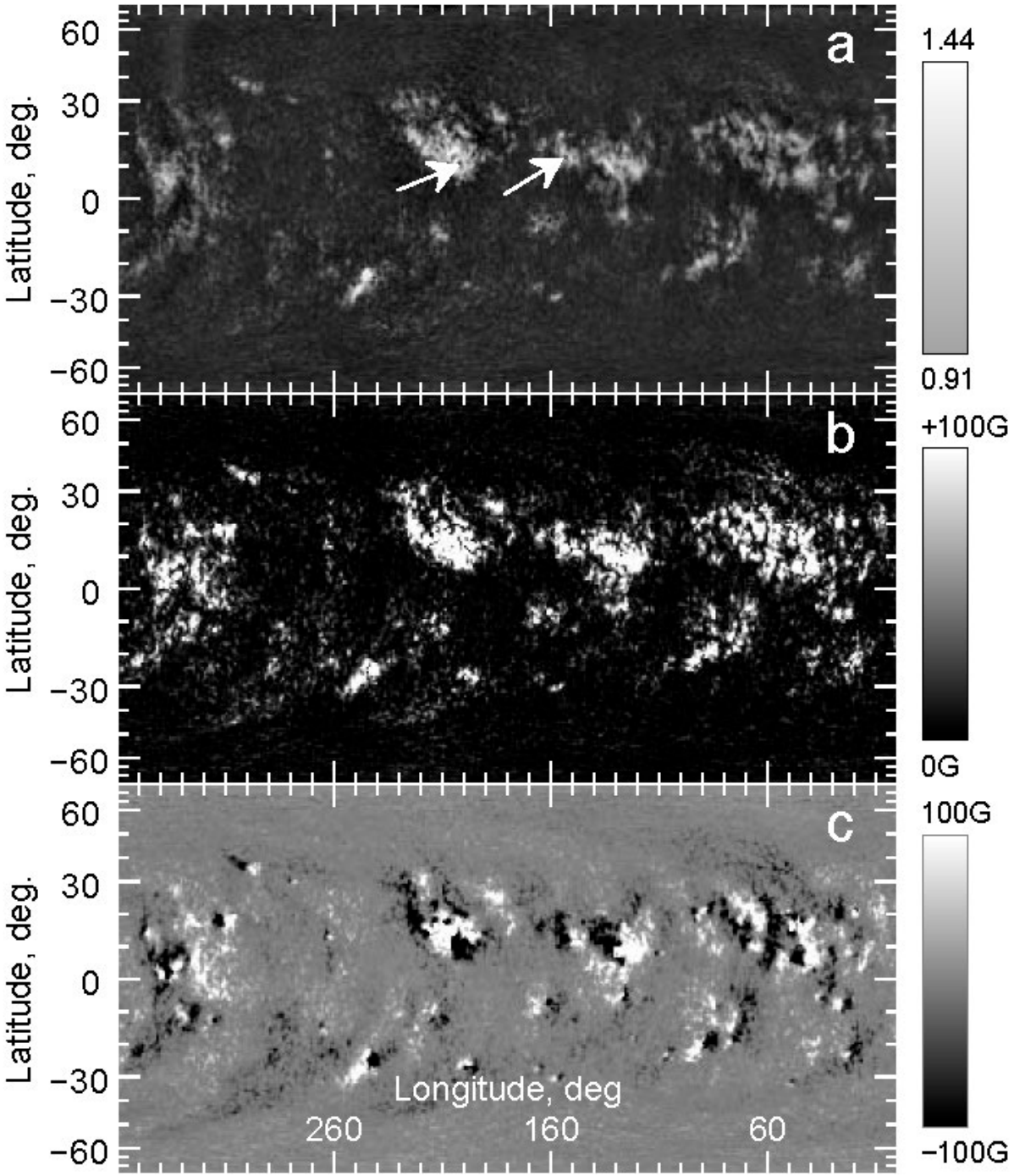
- Longest records of spectroheliograms – Kodaikanal Observatory (late 1904-2007) and MWO – 1915-1985.
- Other: Observatoroir de Paris/Meudon (1893–present), Kislovodsk Mountain Astronomical Station (1953–present), Arcetri Astrophysical Observatory (1926-1974), AO Coimbra University (1926-present), NSO/Sac Peak (1960–2002), NAOJ (1917–1970), Baikal Astrophysical Observatory, Russia (1995–present), the San Fernando Observatory (USA) since 1988, the Precision Solar Photometric Telescopes (PSPT) – Mauna Loa Solar Observatory (MLSO, Hawaii, USA) and the Osservatorio Astronomico di Roma (Italy).

Ca II K line spectroheliograms





One of the first
spectroheliograms
from Paris Observatory



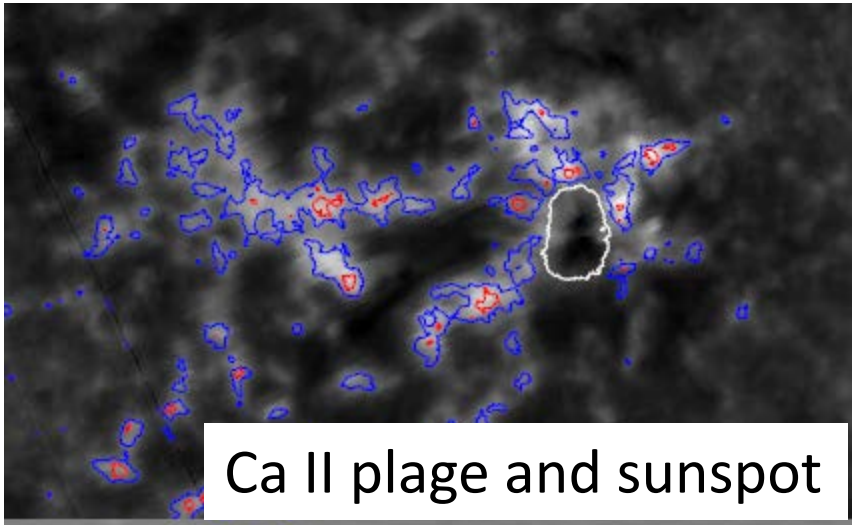
Ca II K synoptic map

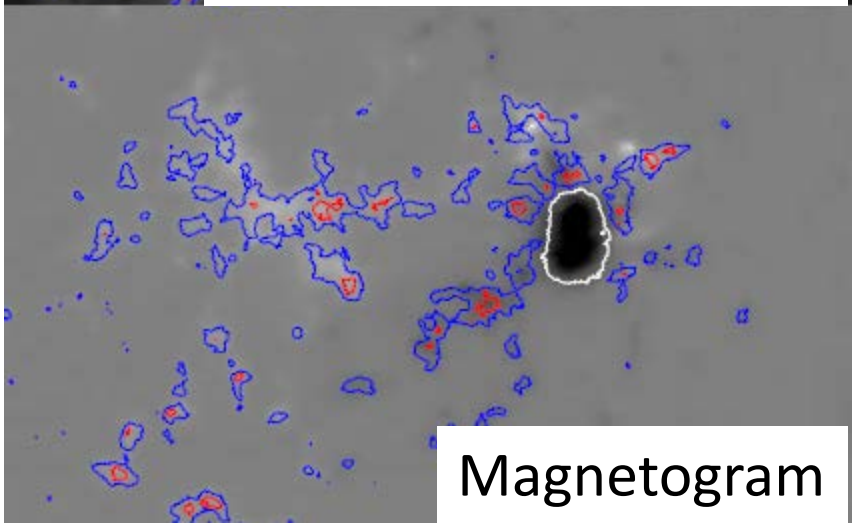
Unsigned magnetogram

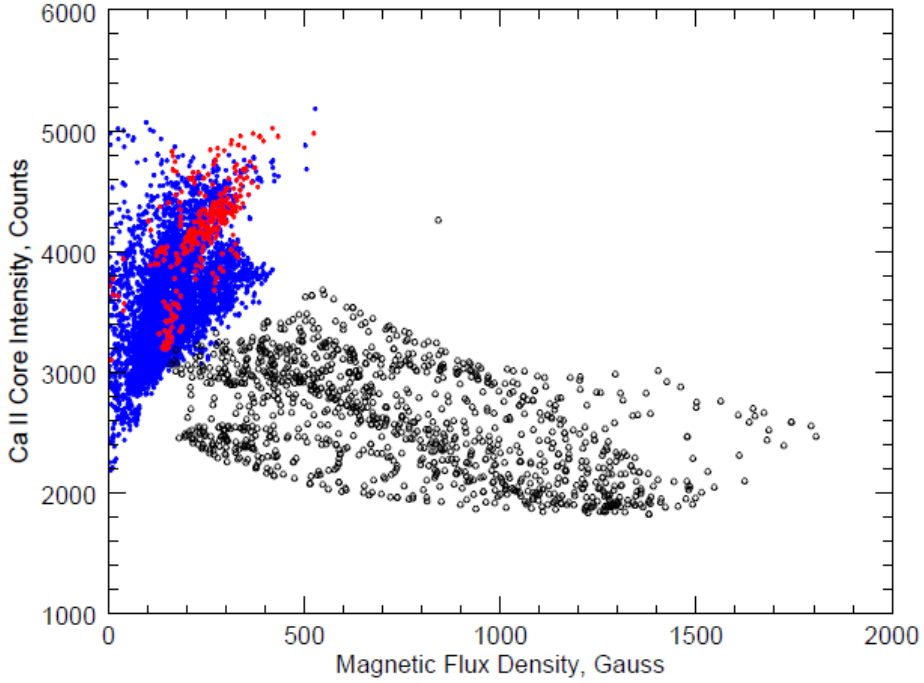
Signed magnetogram

Pevtsov et al (2016)

Ca II K vs. Magnetic Flux



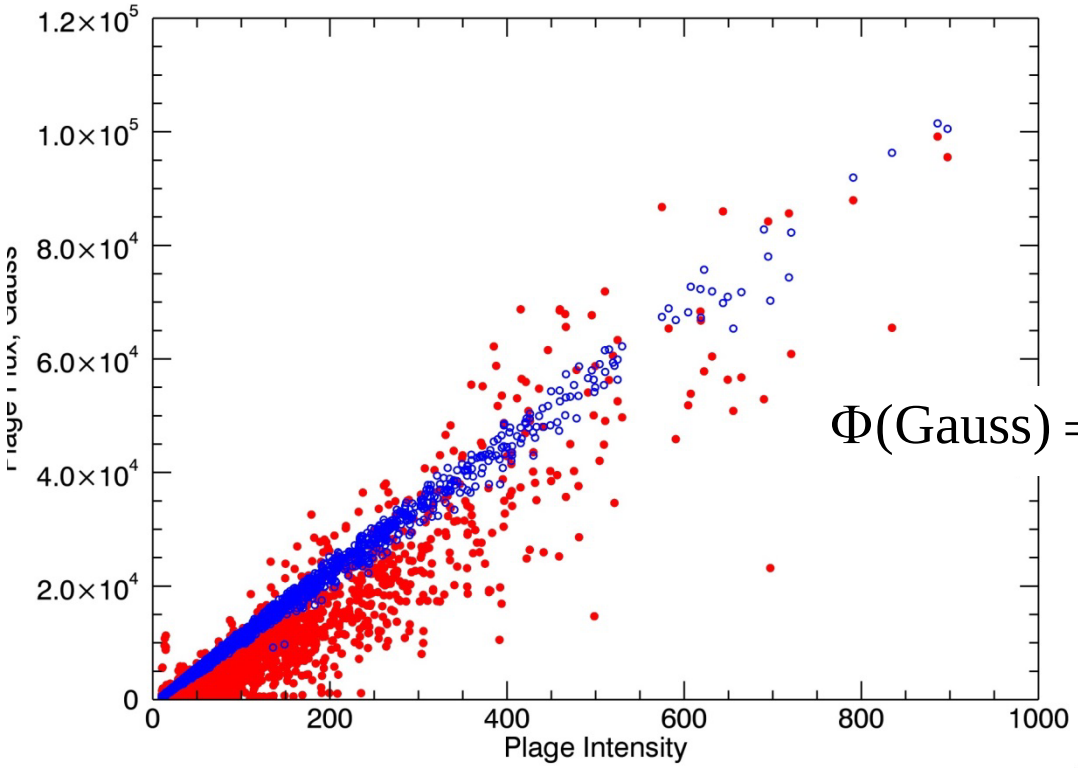




Ca II K image could serve as proxy for magnetic field, but quantitative relation may not be well-defined.

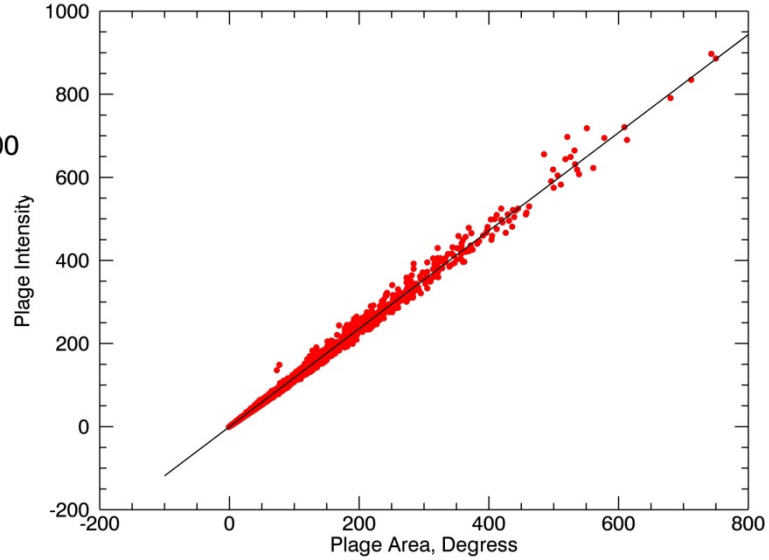
Pevtsov et al (2016)

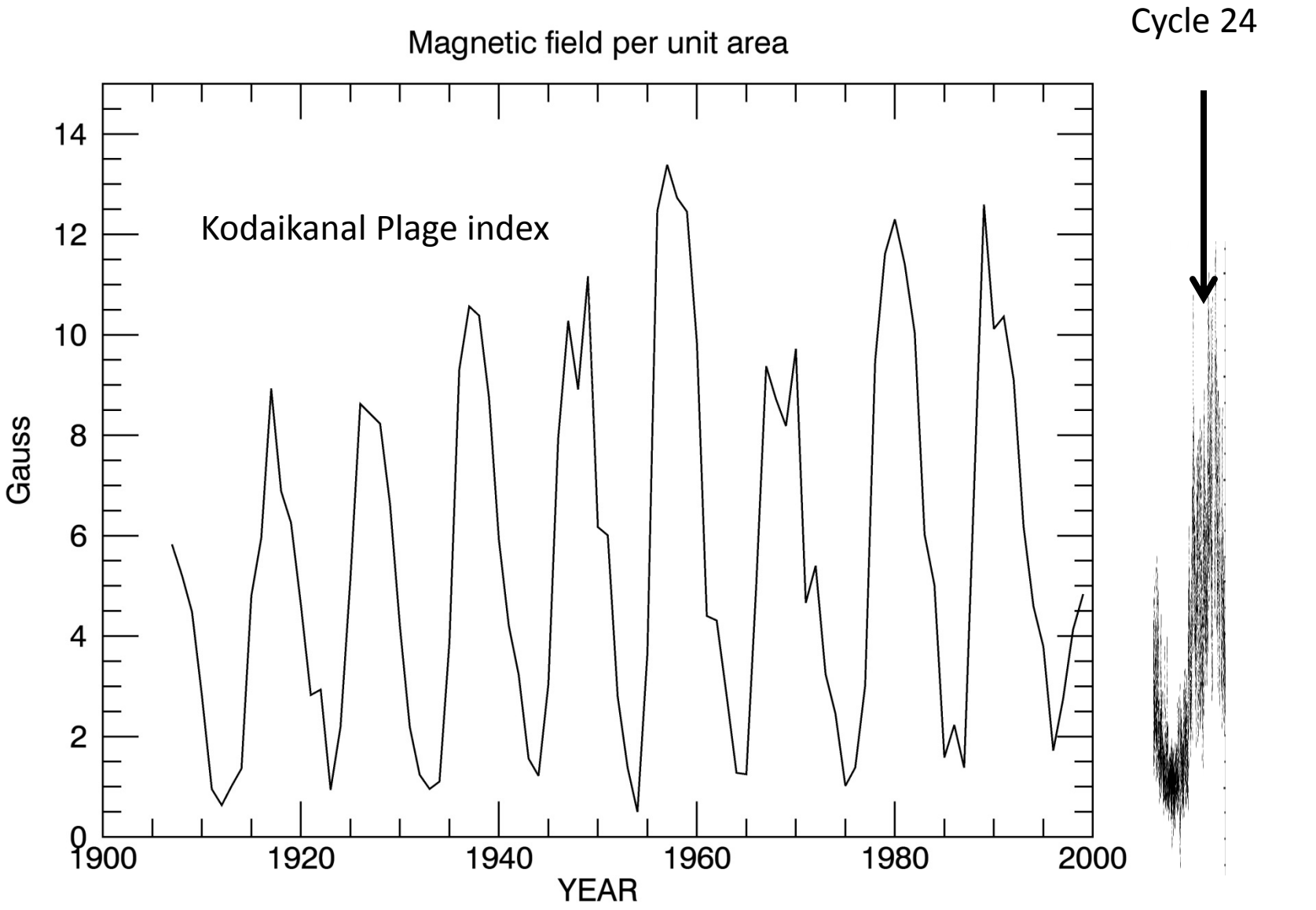
33264 individual plages, CR1625-1763, NSO/KPVT magnetograms, MWO Ca II K synoptic maps.

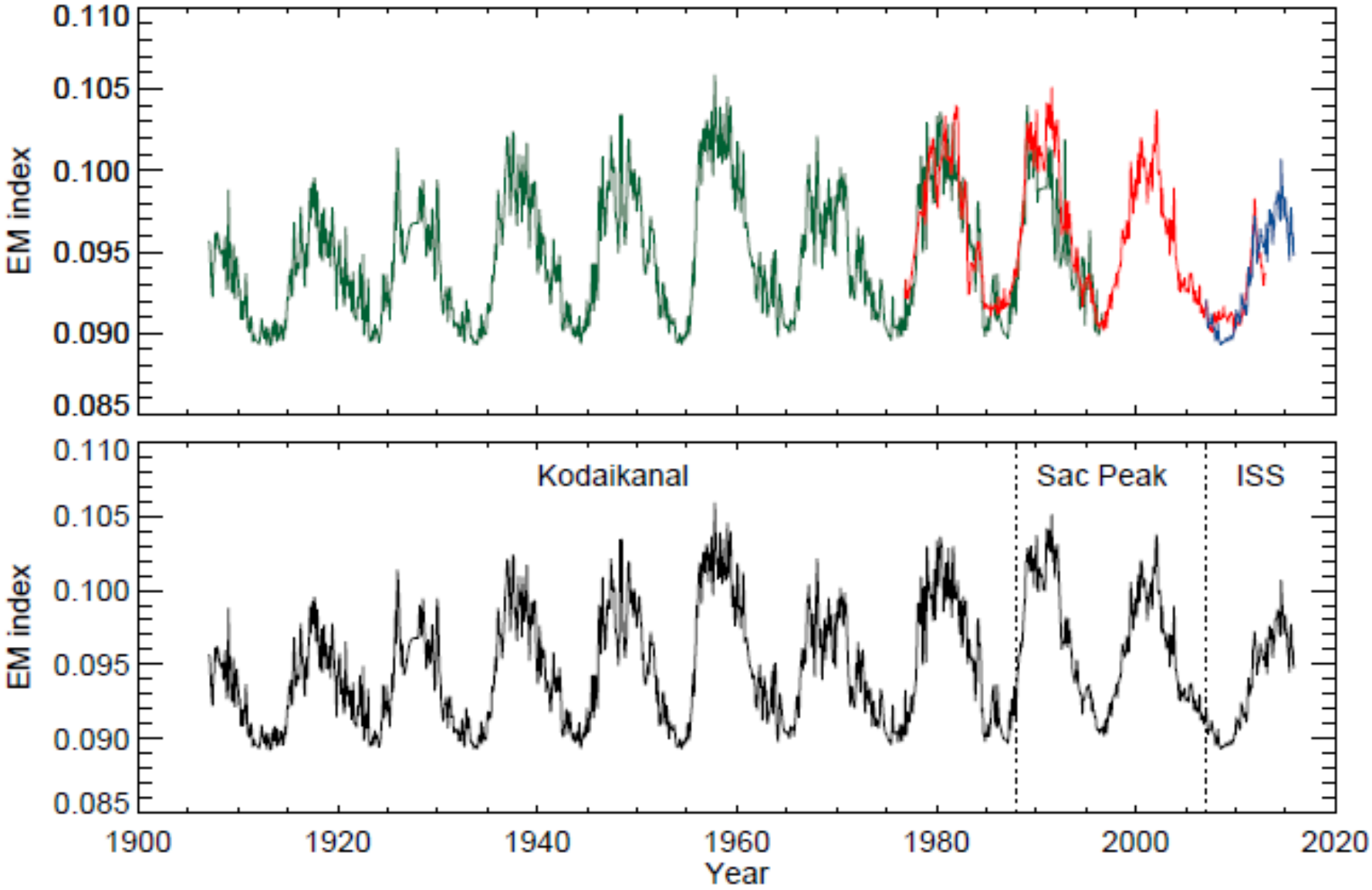


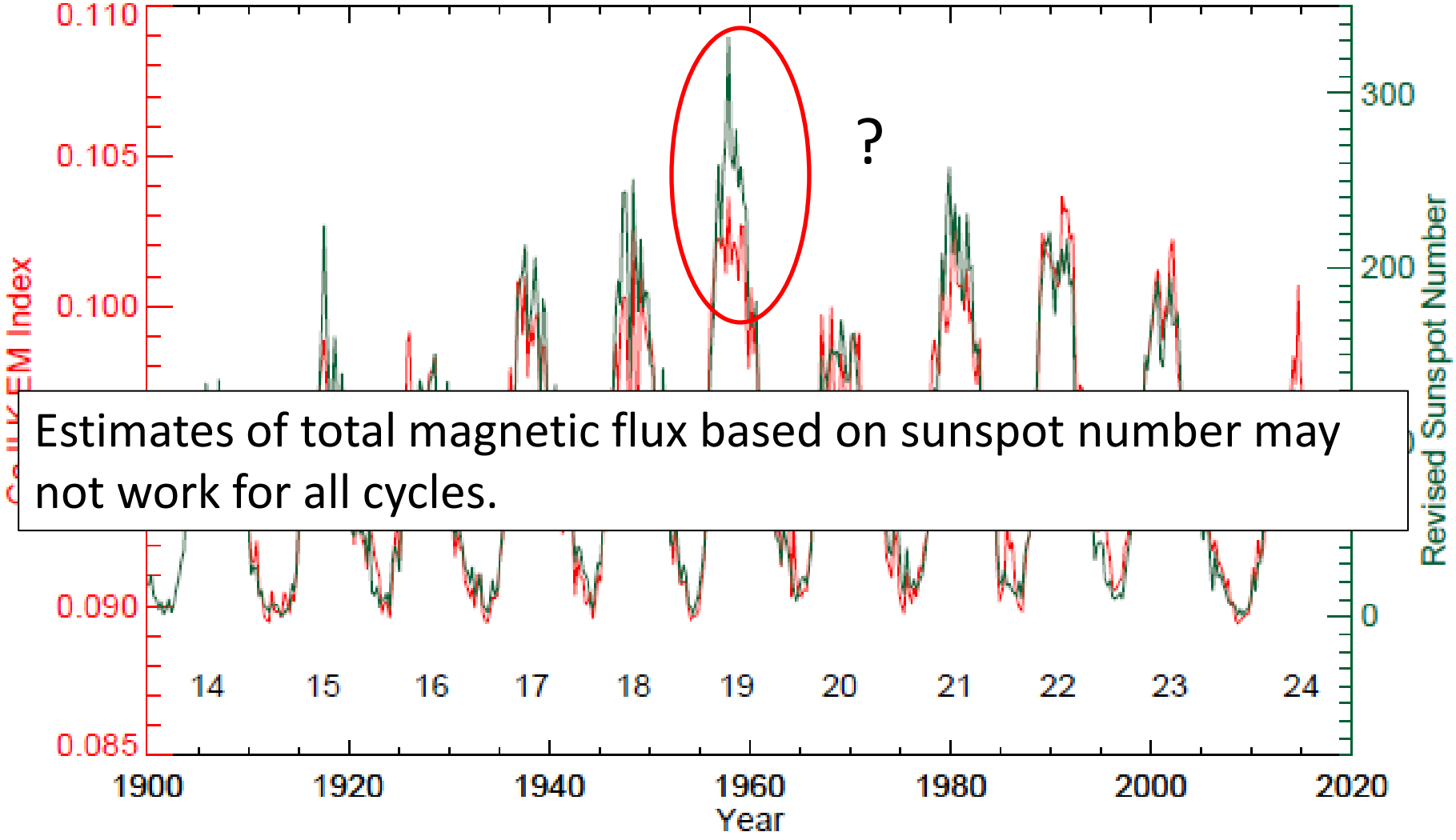
Area (aka plage index)

$$\Phi(\text{Gauss}) = 230.35 \cdot S_{\text{plage}}(\text{sq.degree}) - 777.96$$



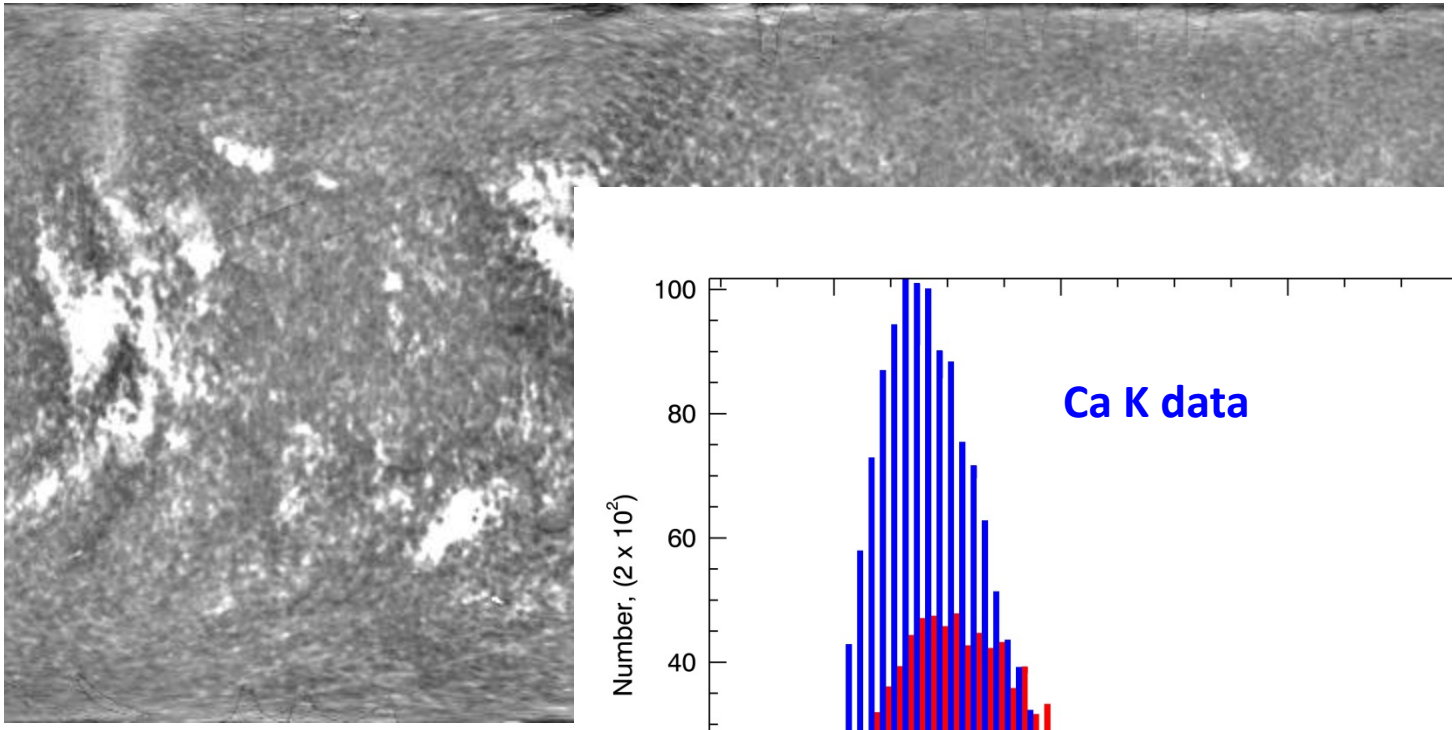

Magnetic field per unit area
Kodaikanal Plage index
Gauss
YEAR
0
2
4
6
8
10
12
14
1900
1920
1940
1960
1980
2000
Cycle 24
SOLIS/VSM


0.110
0.105
0.100
0.095
0.090
0.085
EM index
Kodaikanal
Sac Peak
ISS
1900
1920
1940
1960
1980
2000
2020
Year



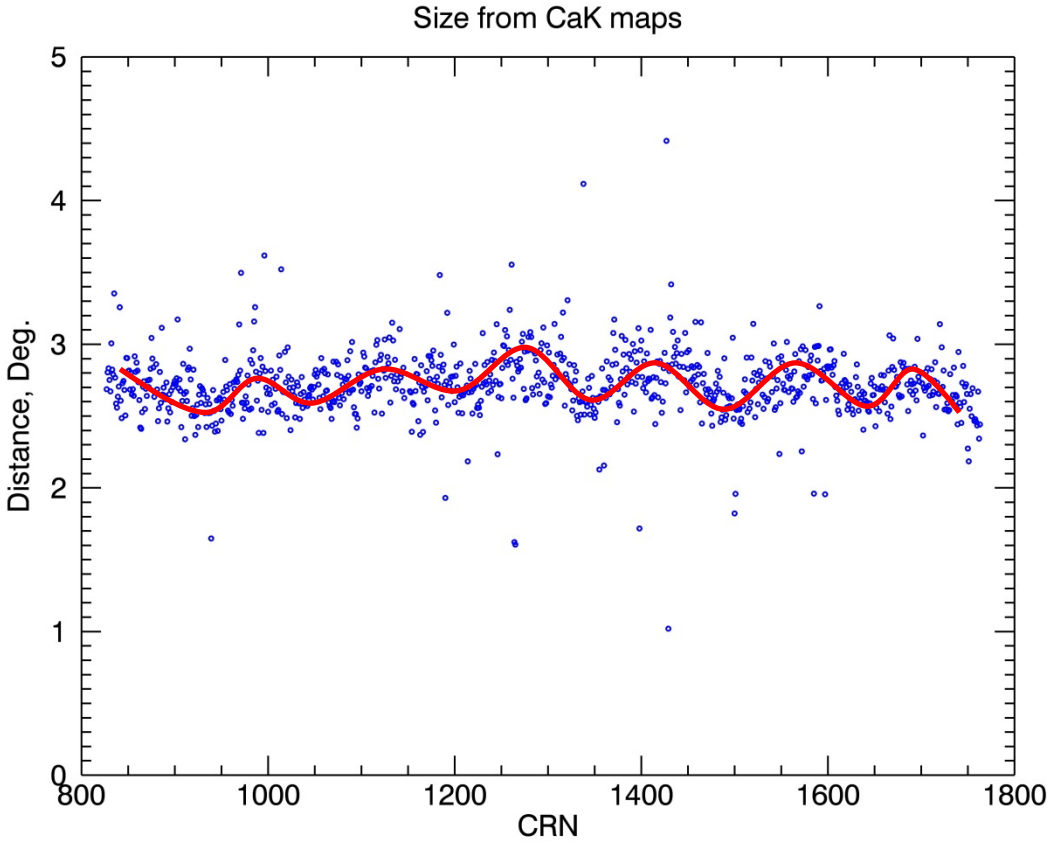
Estimates of total magnetic flux based on sunspot number may not work for all cycles.

Chromospheric network

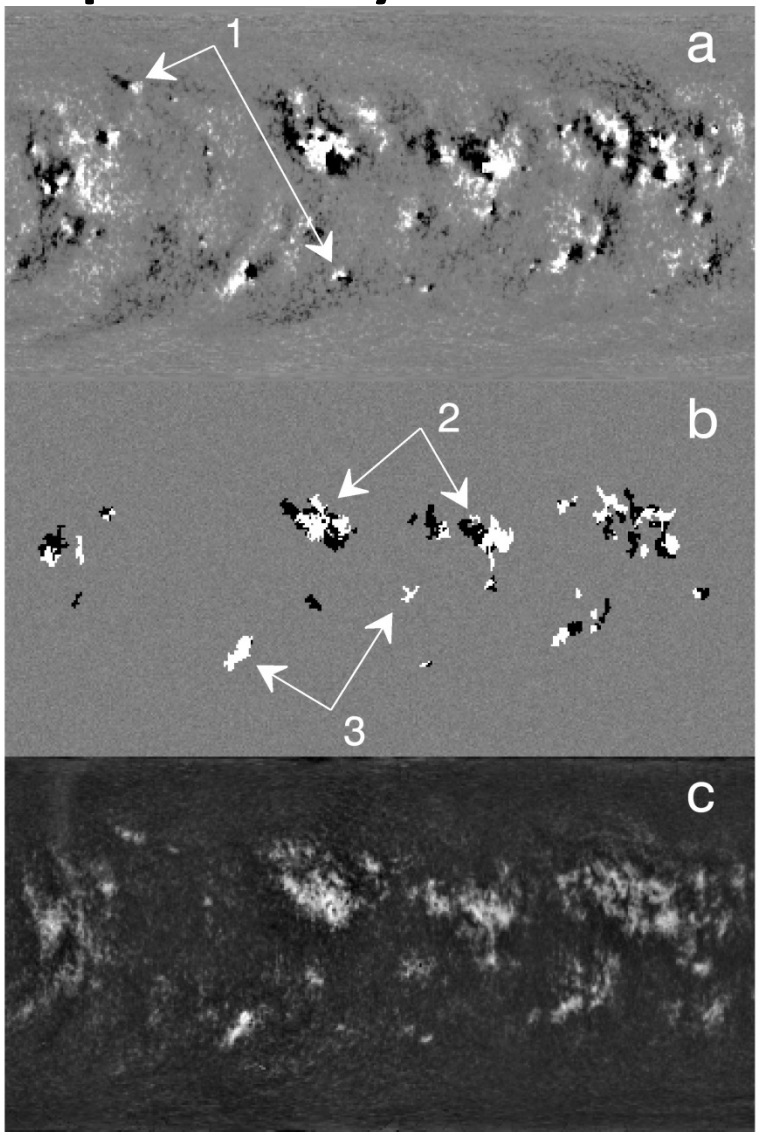


Cycle variations in size of supergranulation?

- Singh and Bappu (1981), etc - anti-correlation with the cycle.
- Wang (1988) Münzer *et al.* (1989) Meunier, Roudier, and Rieutord (2008) – positive correlation.
- Tlatov (2012) – 1.5-year phase shift.



Pseudo-Magnetograms (K-line + sunspot polarity measurements)

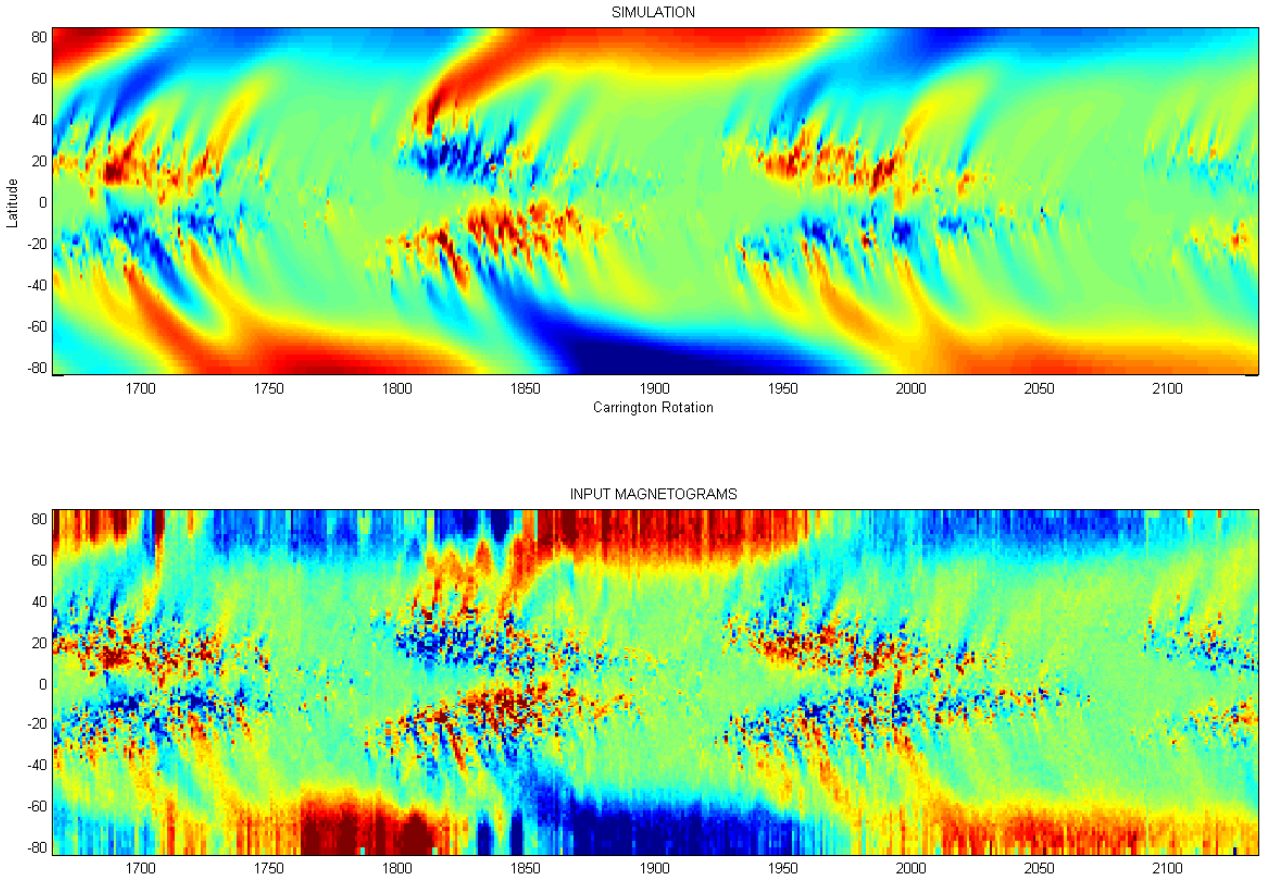


(1)- missing
(2)- good match
(3)- only one polarity

Overall – 80% agreement in pixels polarity

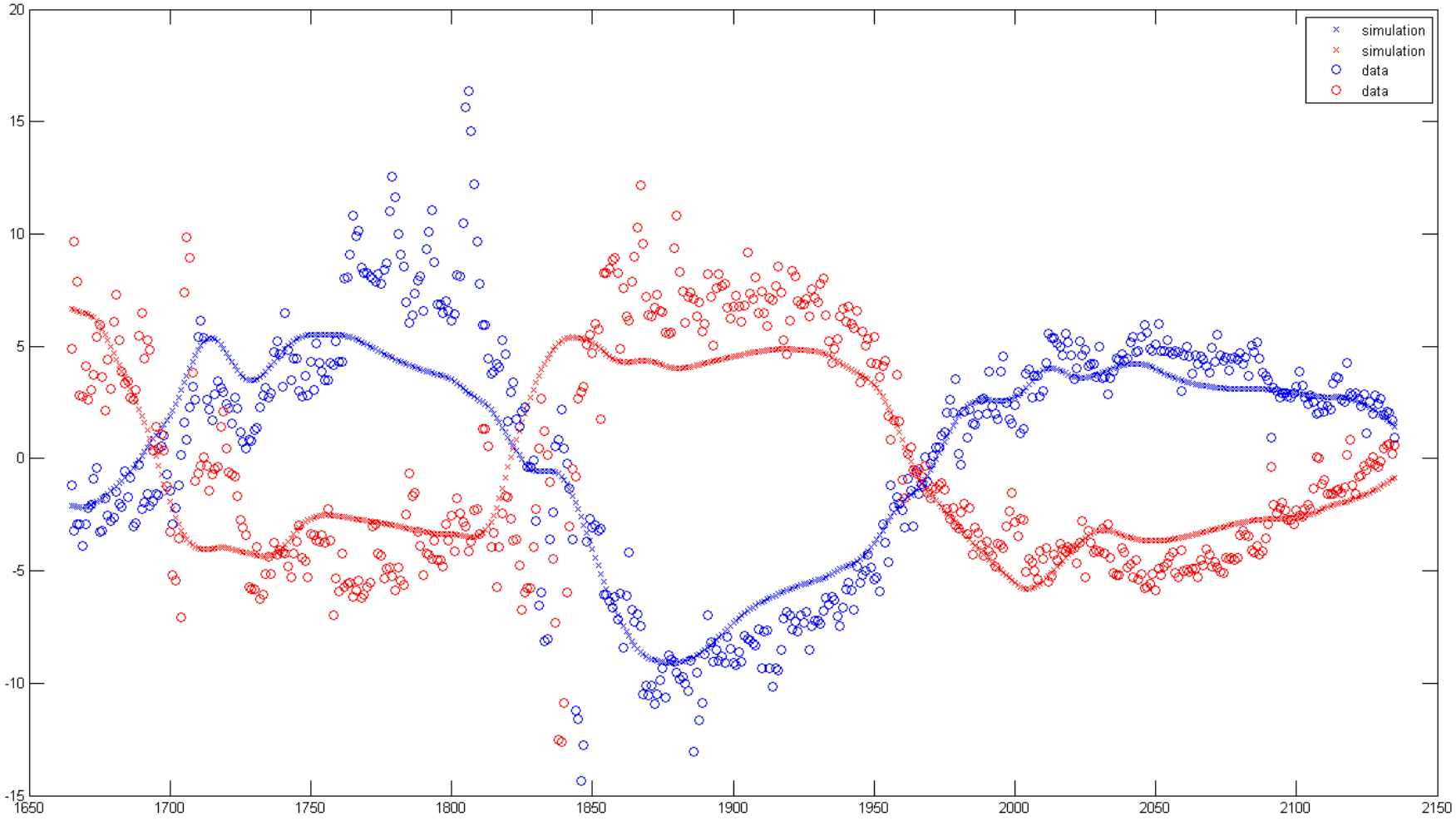
Pevtsov et al (2016)

Flux-transport modeling



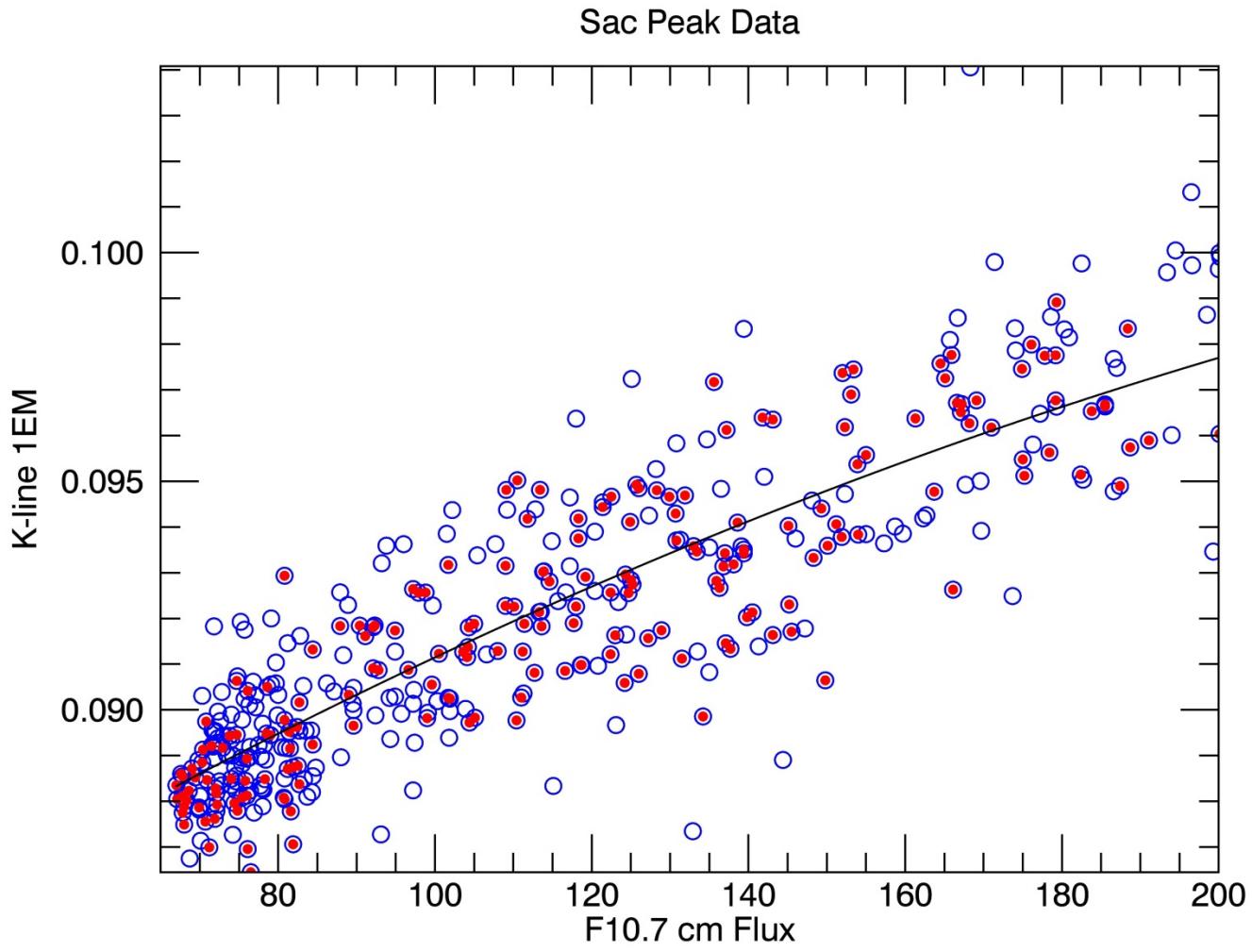
Iiro Virtanen

Polar Field



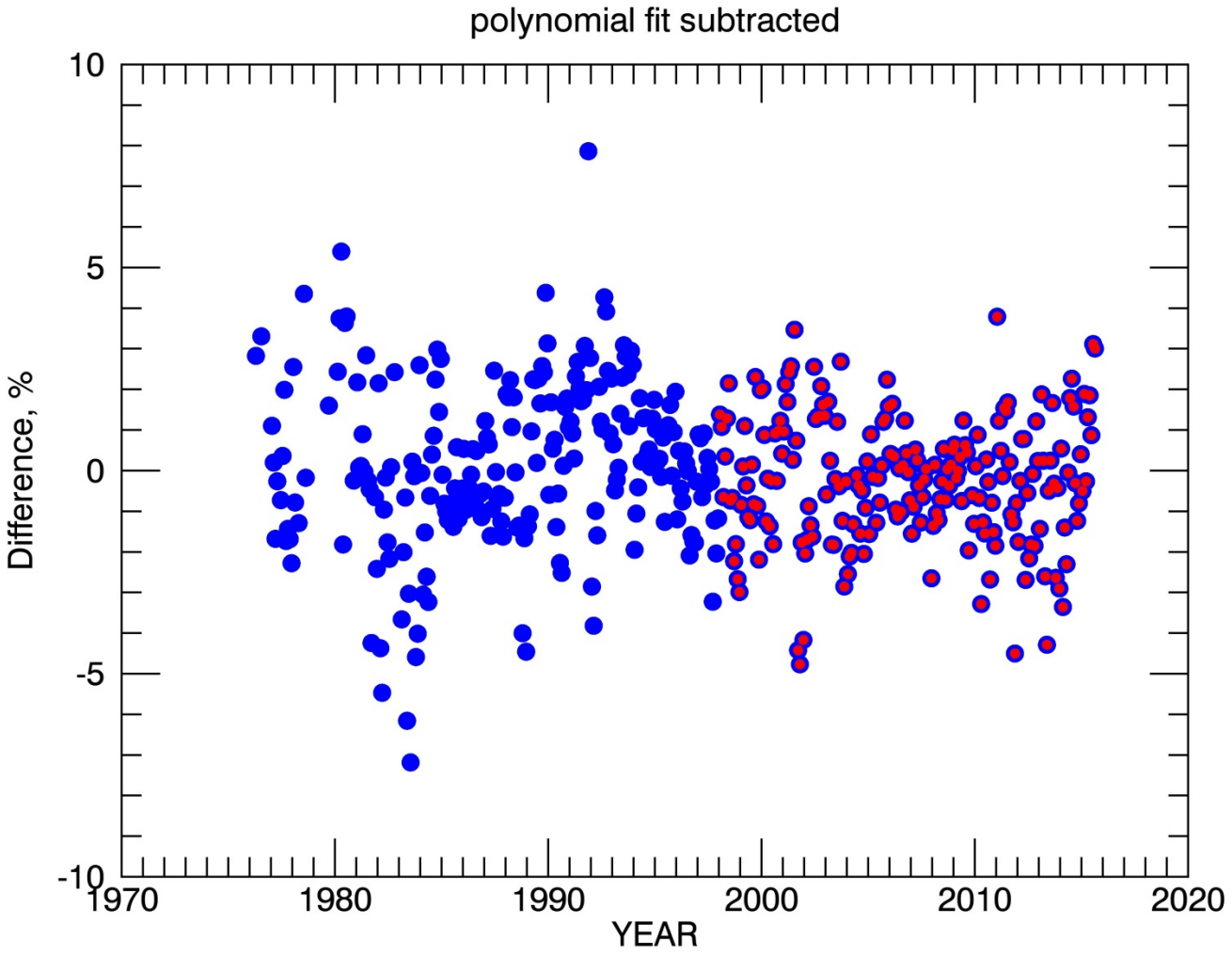
Iiro Virtanen

Ca K II index vs. F10.7 cm

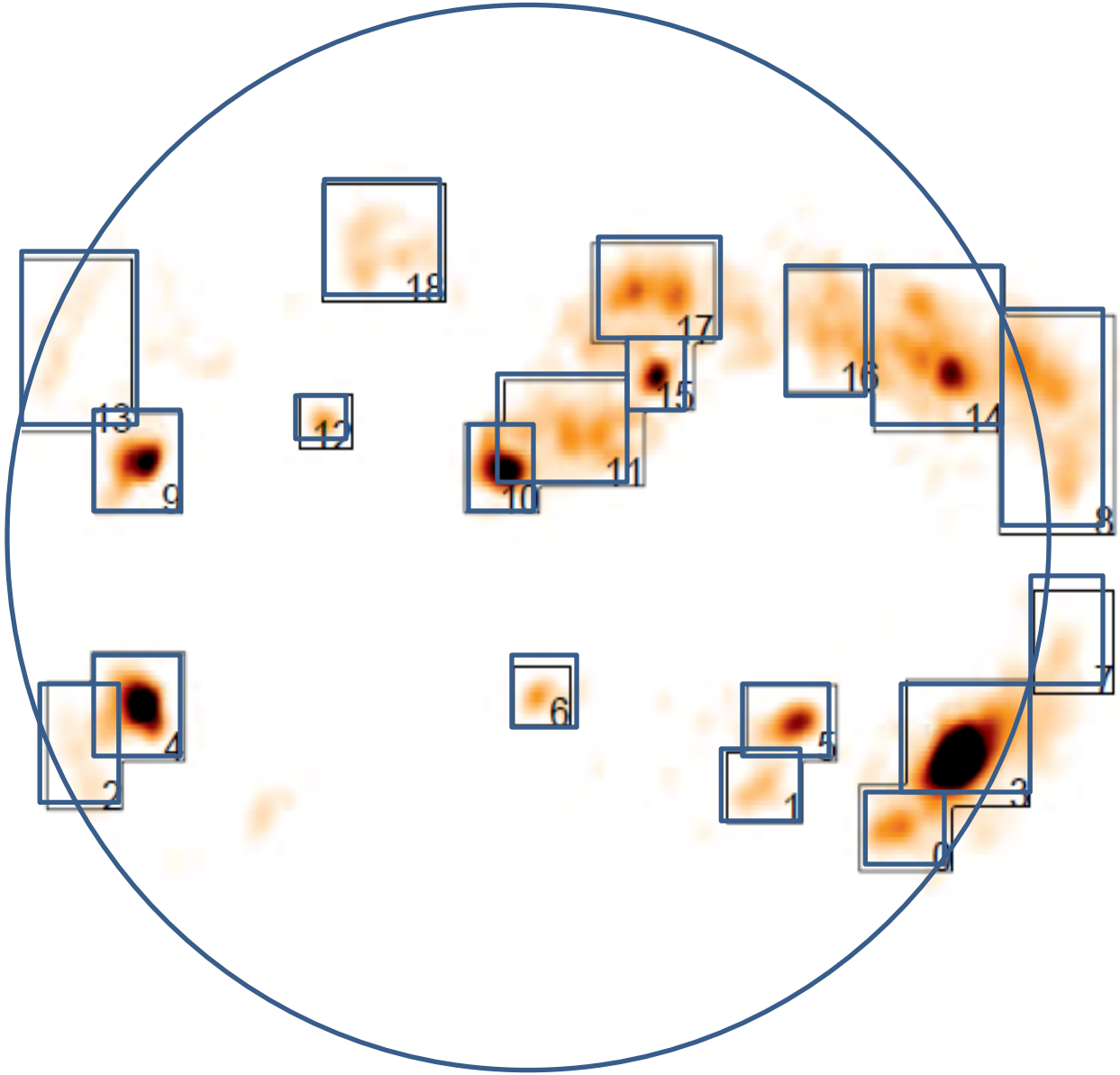


Open circles – prior to 1998, red – after 1998

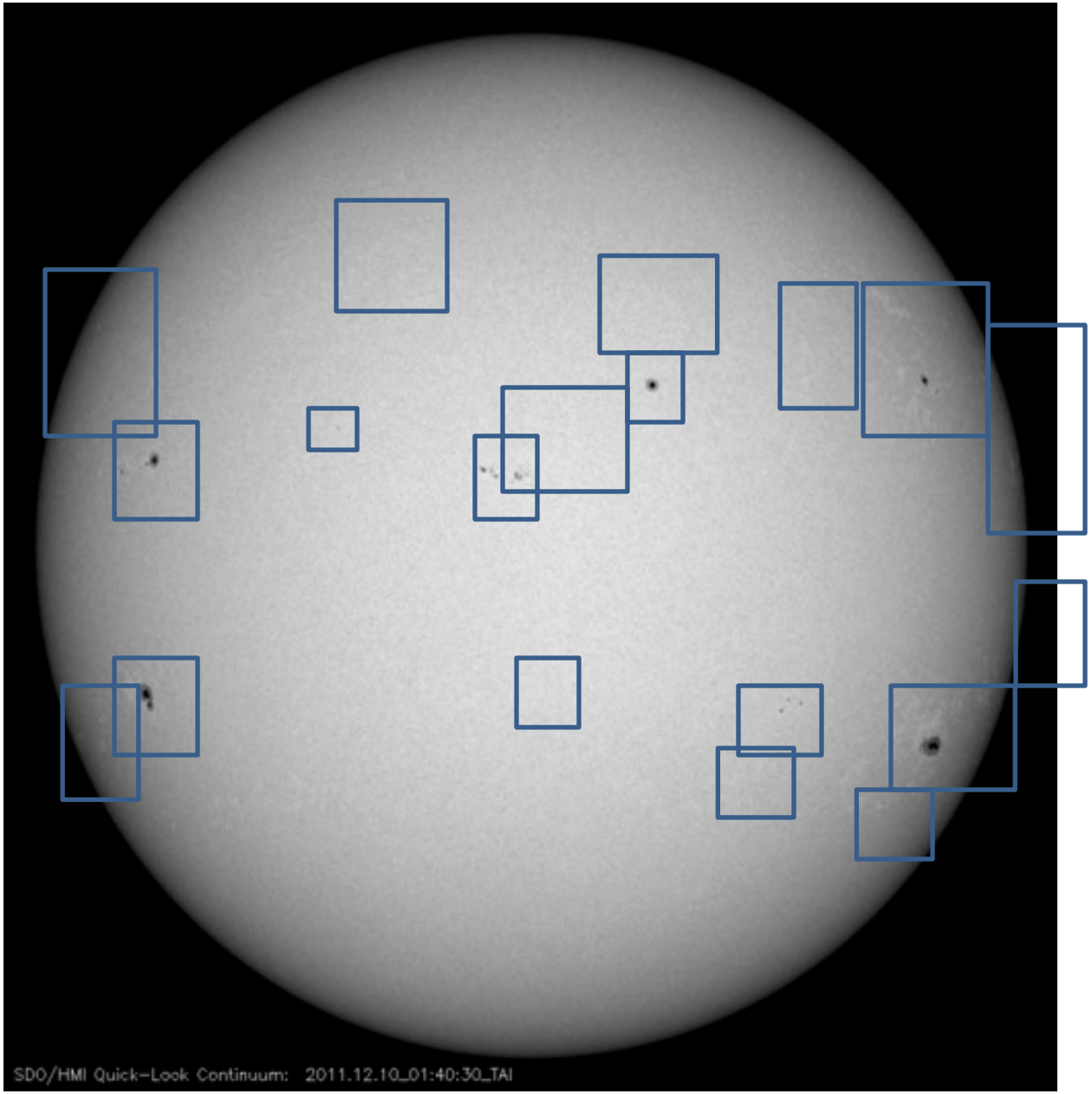
Ca K II index vs. F10.7 cm



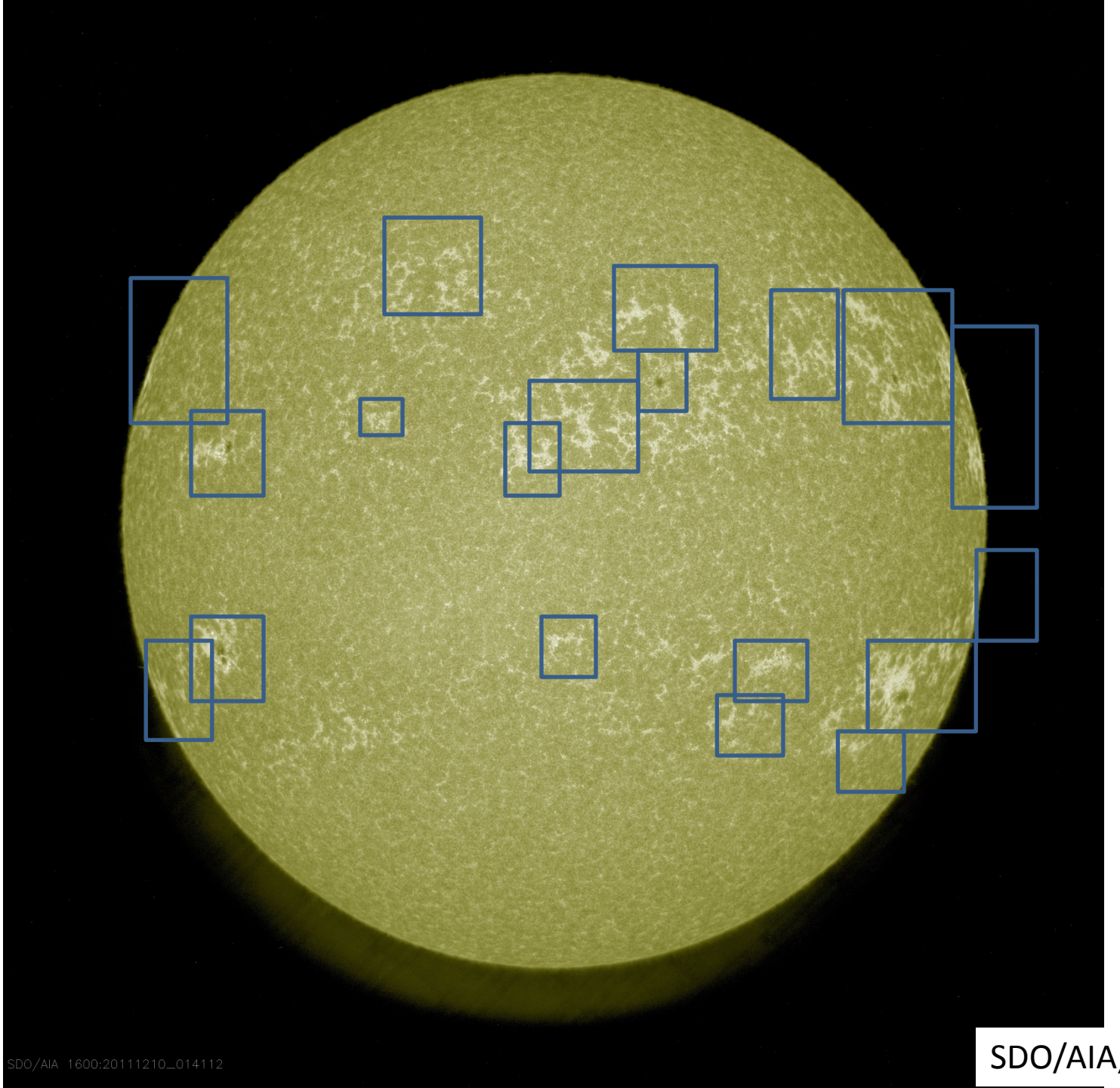
Open circles – prior to 1998, red – after 1998



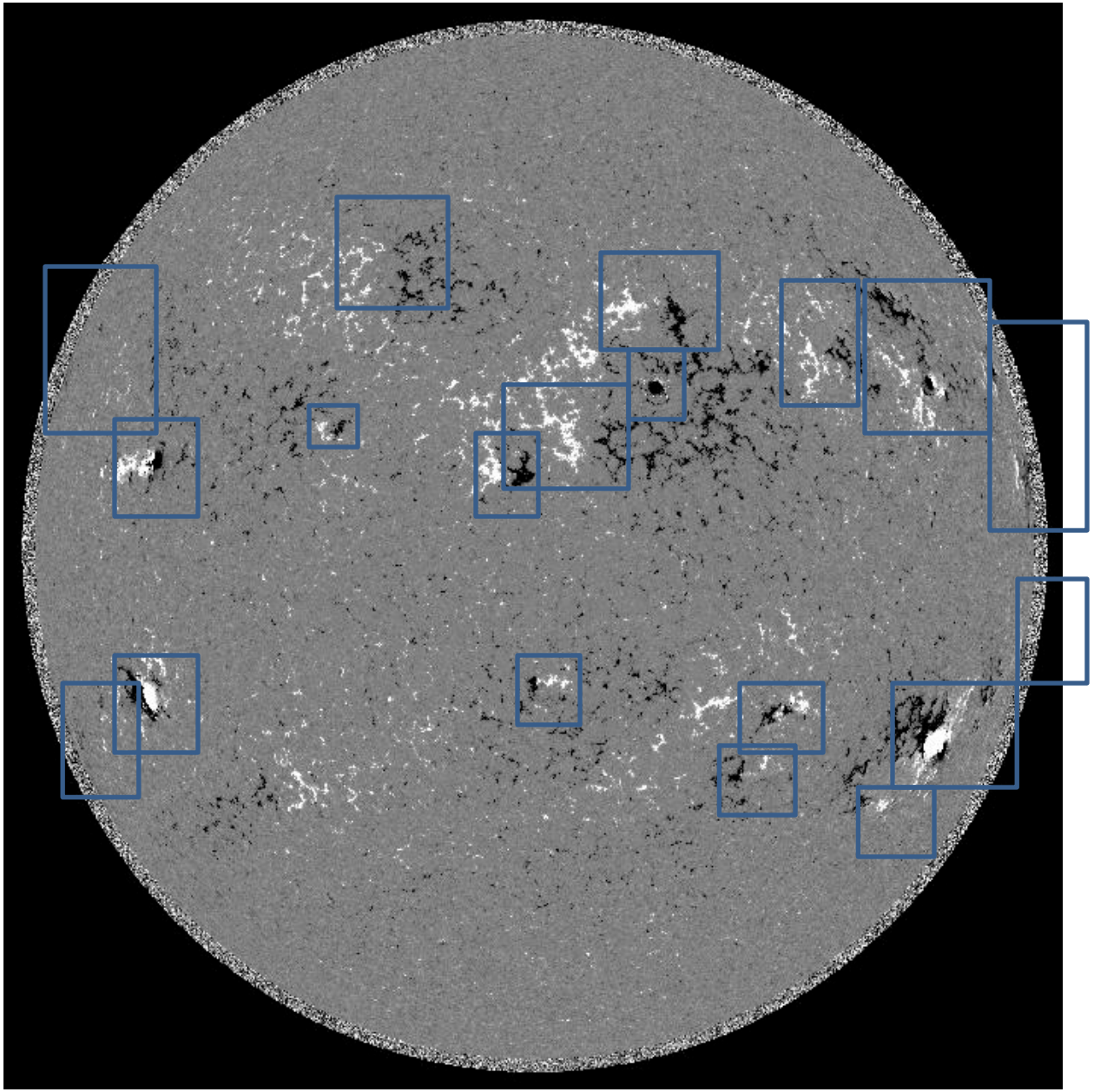
VLA, Schonfeld et al, 2015



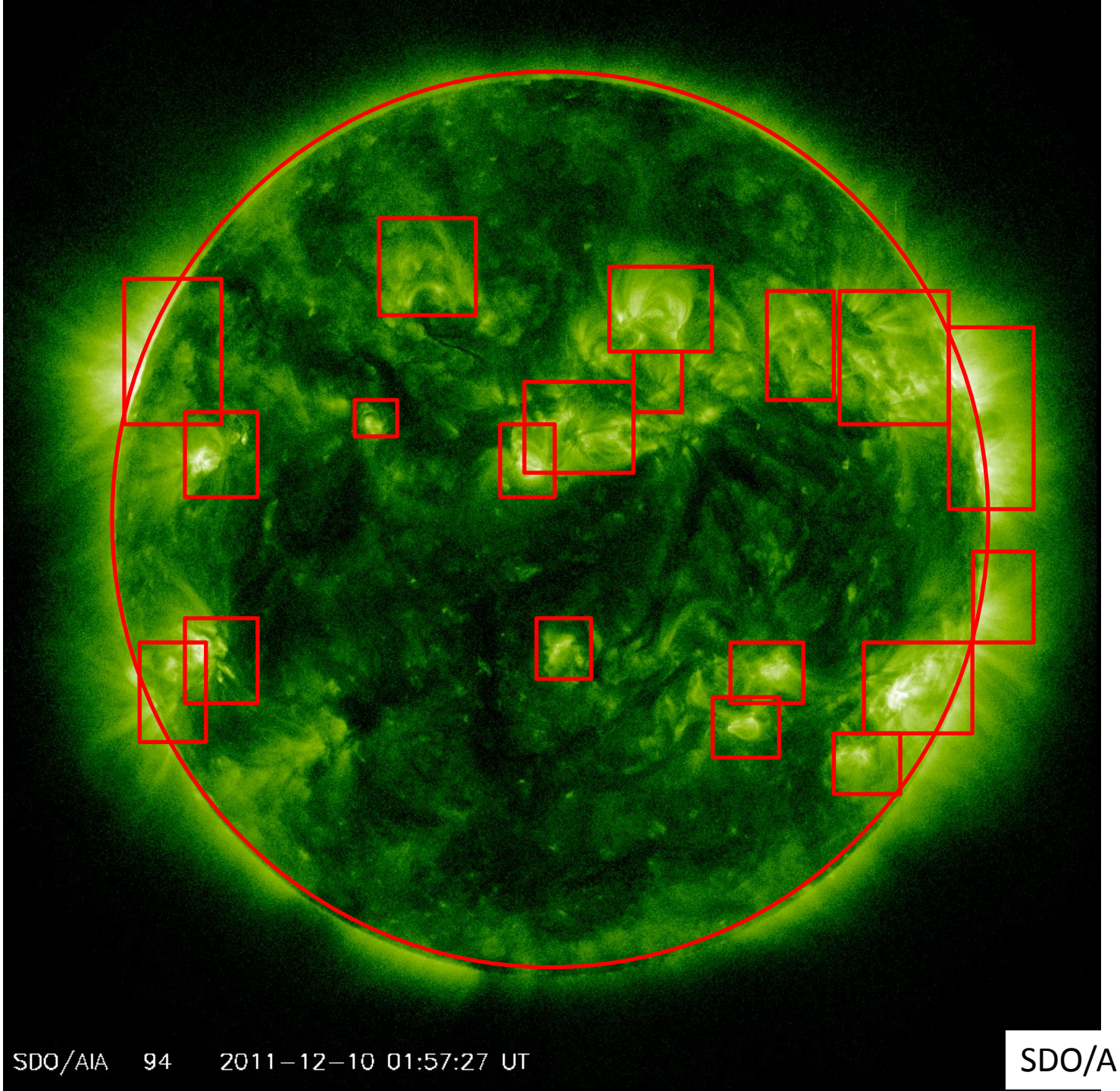
SDO/HMI, white light



SDO/AIA, 1700 A



SDO/HMI, magnetogram



SDO/AIA, 94A

Ca K II index vs. F10.7 cm

$I_{CaKII} \propto f_1(|\Phi|)$; weak/moderate flux density

(enhanced network, plage)

$I_{CaKII} \propto -f_2(|\Phi|)$; stronger flux density (sunspots)

$I_{F10.7cm} \propto f_3(|\Phi|)$; both moderate and strong fields

(some plage, sunspots, upper parts of coronal loops, off limb)

$I_{corona} \propto f_4(|\Phi|)$; both moderate and some strong fields

(no sunspots, diffuse corona above plage/upper parts of coronal loops, off limb)

Conclusions

- Ca II K line plage index offers a direct proxy for total magnetic flux of the Sun
- Size distribution of features in Ca II K images can be used to derive avearge size of the chromospheric network; there appears to be a cycle variation in size of network (supergranulation) at about 20% level.
- In combination with sunspot polarity measurements, existing Ca II K line data offer opportunity to reconstruct synoptic (pseudo) magnetograms for the last century.
- Although F10.7cm flux correlates well with Ca II K (and sunspot number), its relation to solar activity is complex.