Different Sun-Earth energy coupling between different solar cycles

M. Yamauchi

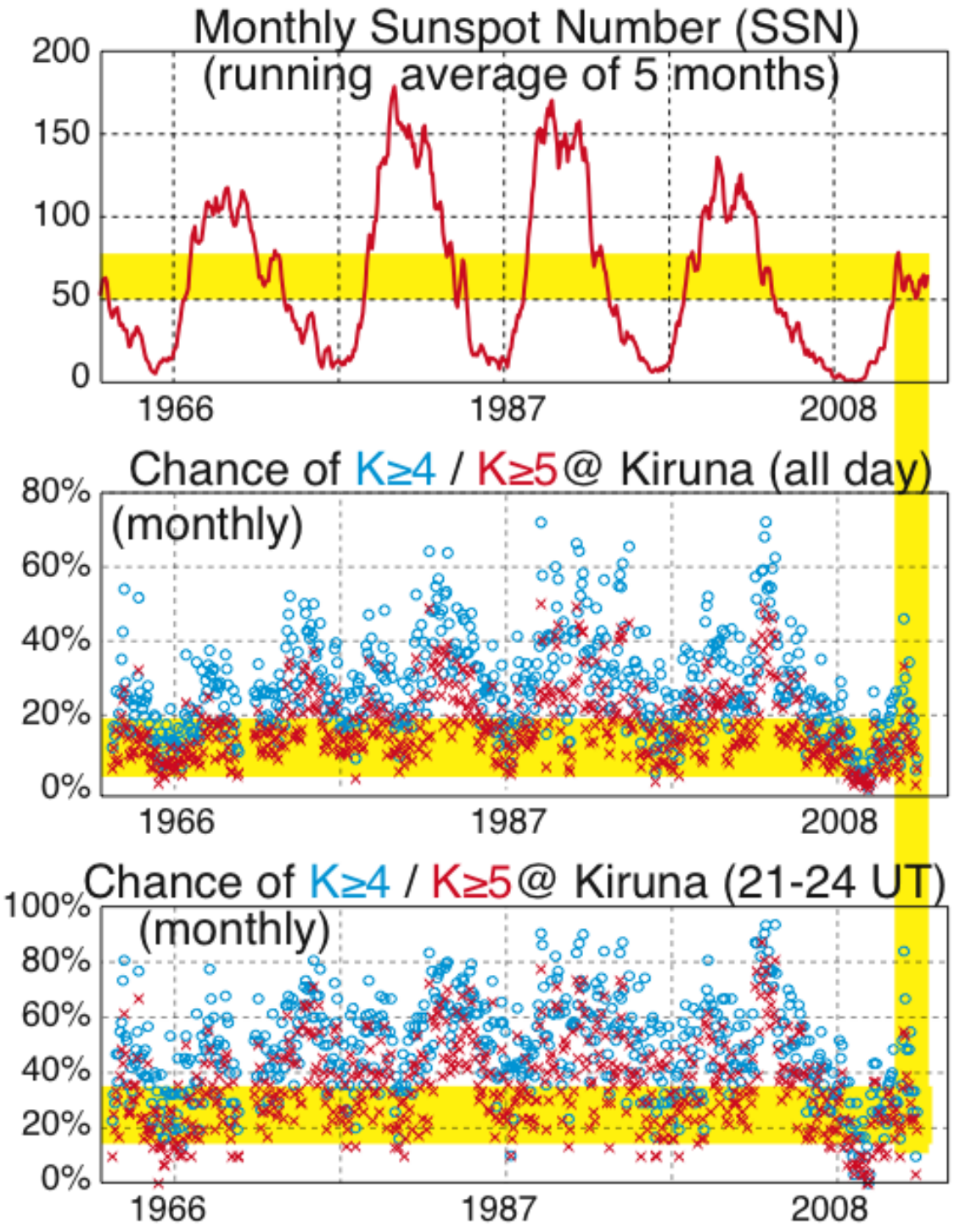
Swedish Institute of Space Physics, Kiruna (M.Yamauchi@irf.se)

Acknowledgement: Dst, Kp, AL, and sunspot numbers (RI) are official IAGA and IAA endorsed indices that are provided by World Data Center for Geomagnetism, Kyoto University, Japan (Dst and AL), GFZ, Adolf-Schmidt-Observatory Niemegk, Germany (Kp), and the Royal Observatory of Belgium, Brussels (RI). Including these indices, all data in hourly values are obtained from NASA-GSFC/SPDF through OMNIWeb (http://omniweb.gsfc.nasa.gov/ow.html).

Motivation

For the same level of sunspot numbers, chance of large aurora (high K) decreased for cycle #24.

⇒ Is this due to change in SW condition?



Method

(1) Use 50 years NASA OMNI data (1965-2014) of

* Solar wind parameters (1-hour values)

Akasofu ε' = $VB_{tan}^2\sin^4(\theta_C/2)$, **$N_P$**, **$P_{SW}$**, **$E_Y$**=$-VB_Z$.

Newell $d\Phi/dt$ = $(V^2B_{tan}\sin^4(\theta_C/2))^{2/3}$,

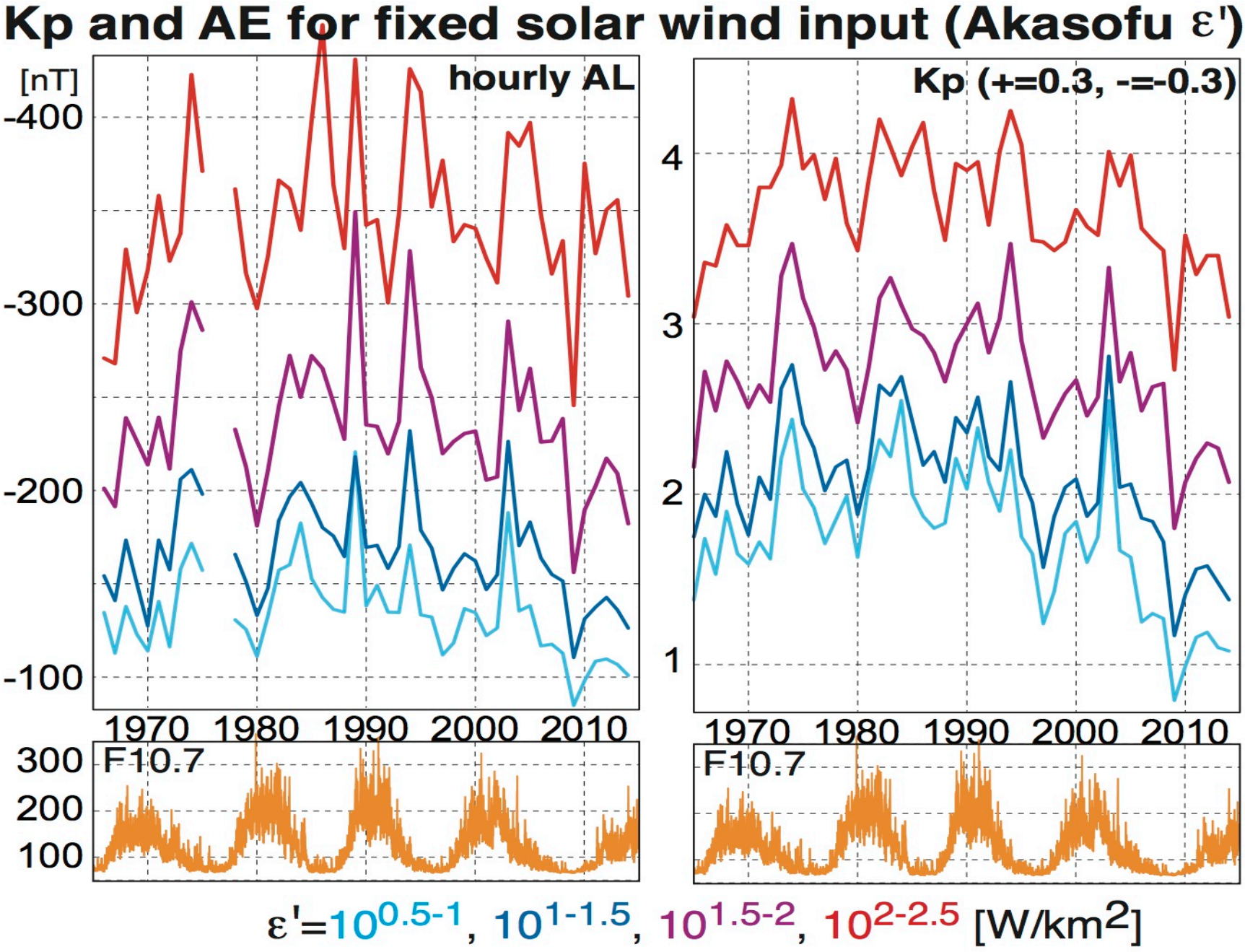
* Hourly geomagnetic indices (Dst, Kp, AL)

(2) Divide data into **5 x 10 year** or **50 x 1 year** and

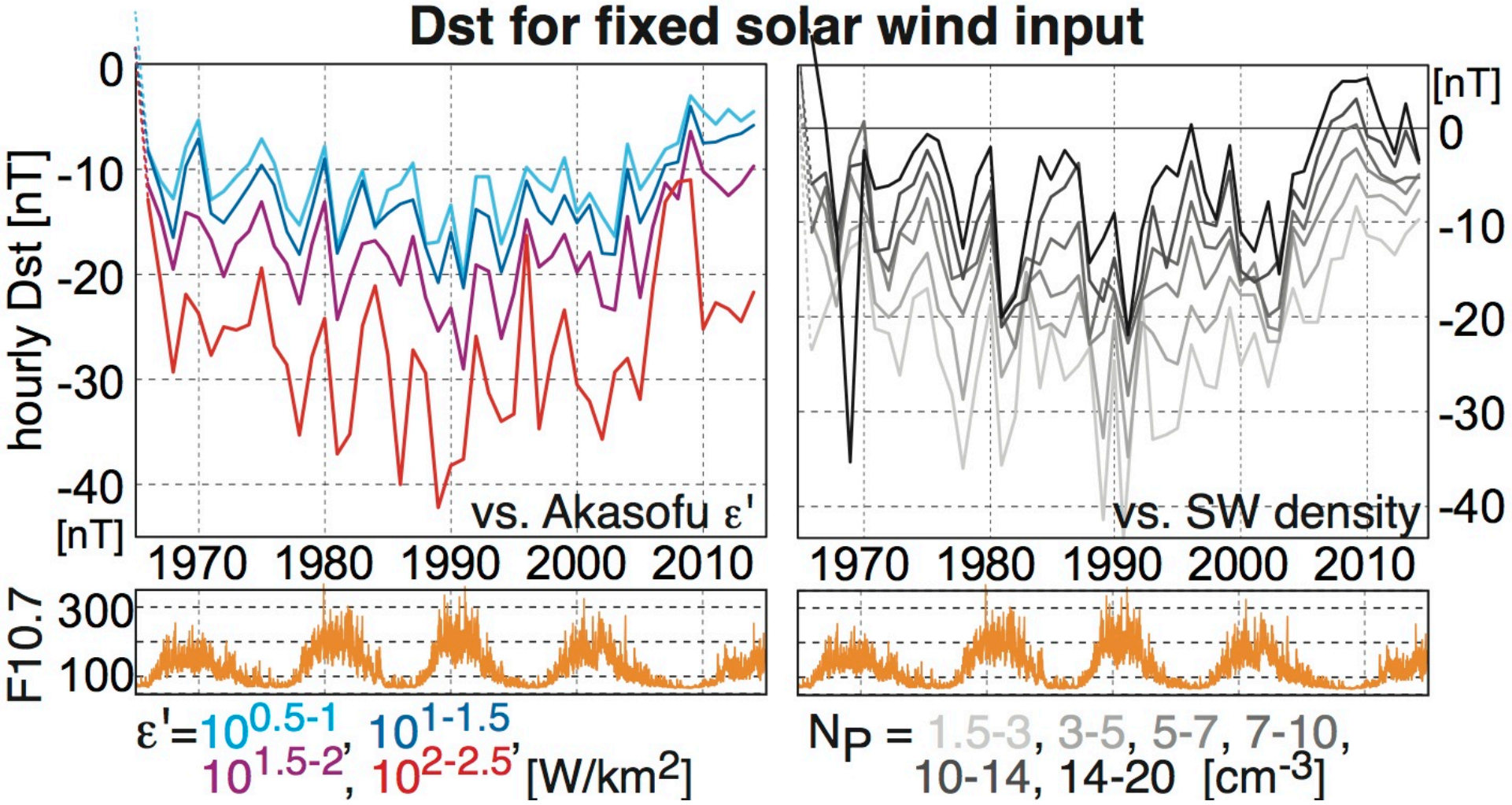
* Obtain average geomagnetic response (index) to the same solar wind input for each period

(3) Examine the same including F10.7

Annual averages



Dst is more drastic than AL



Similar profiles for both the solar wind energy input (Akasofu ε) and density (Np).

Quick summary (1/3)

• Spike years during declining phase (1974, 1983, 1994, 2003) ⇒ **We need to examine with high-resolution data.**

• Otherwise, the Sun-Earth coupling efficiency (response of Dst, Kp, AL) is rather constant until 2004.

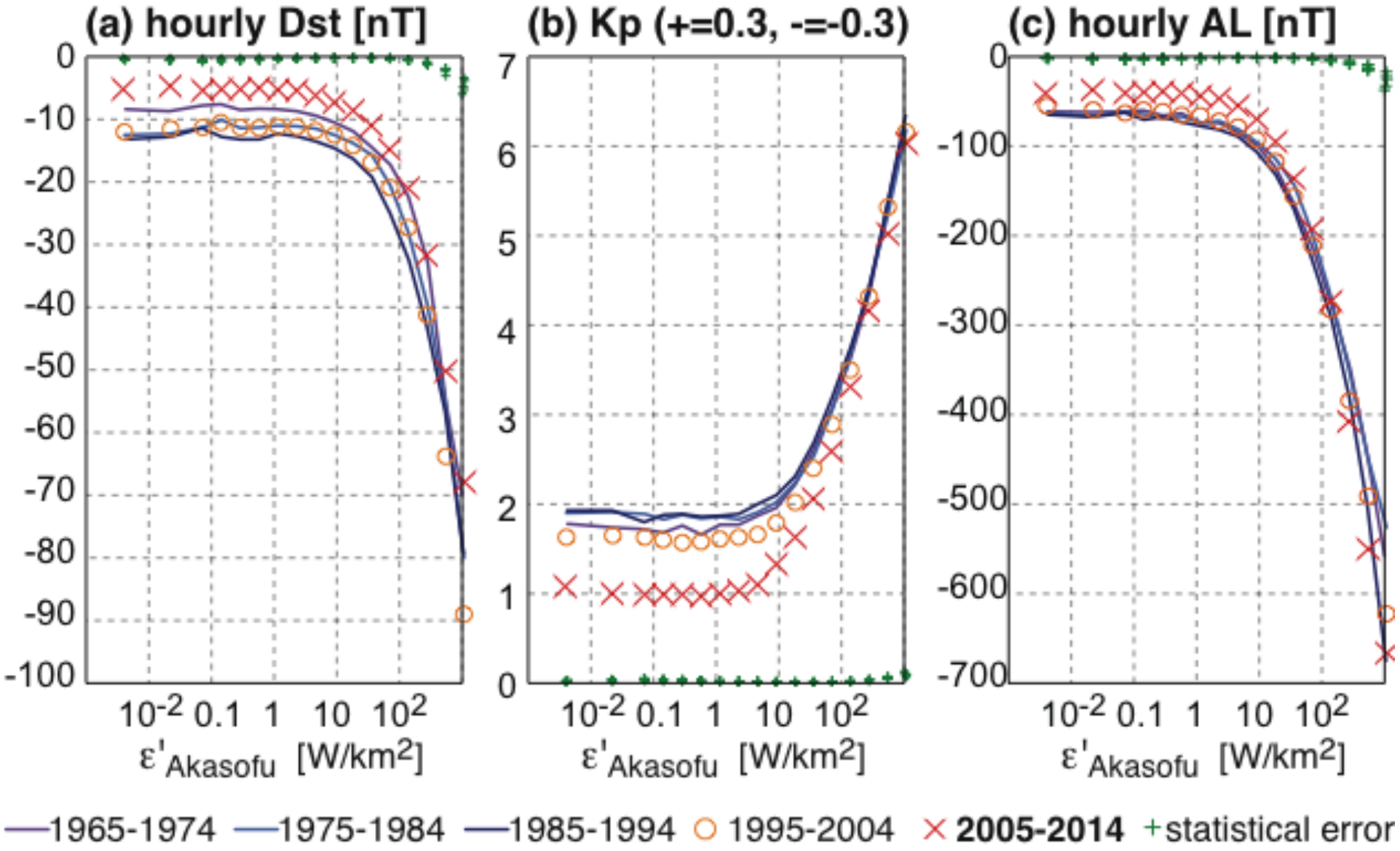
• However, the coupling efficiency decreased from ~2006 (with a sharp drop in 2009).

• Even for the same FUV, the efficiency is decreased after 2006 ⇒ ionospheric conductivity **is not** the major caused of #24 specialty.

• Dst is more outstanding than AE ⇒ M-I coupling auroral current system **is not** the major caused of #24 specialty.

• Envelope is somewhat similar to the envelope of solar activity.

10-year averages



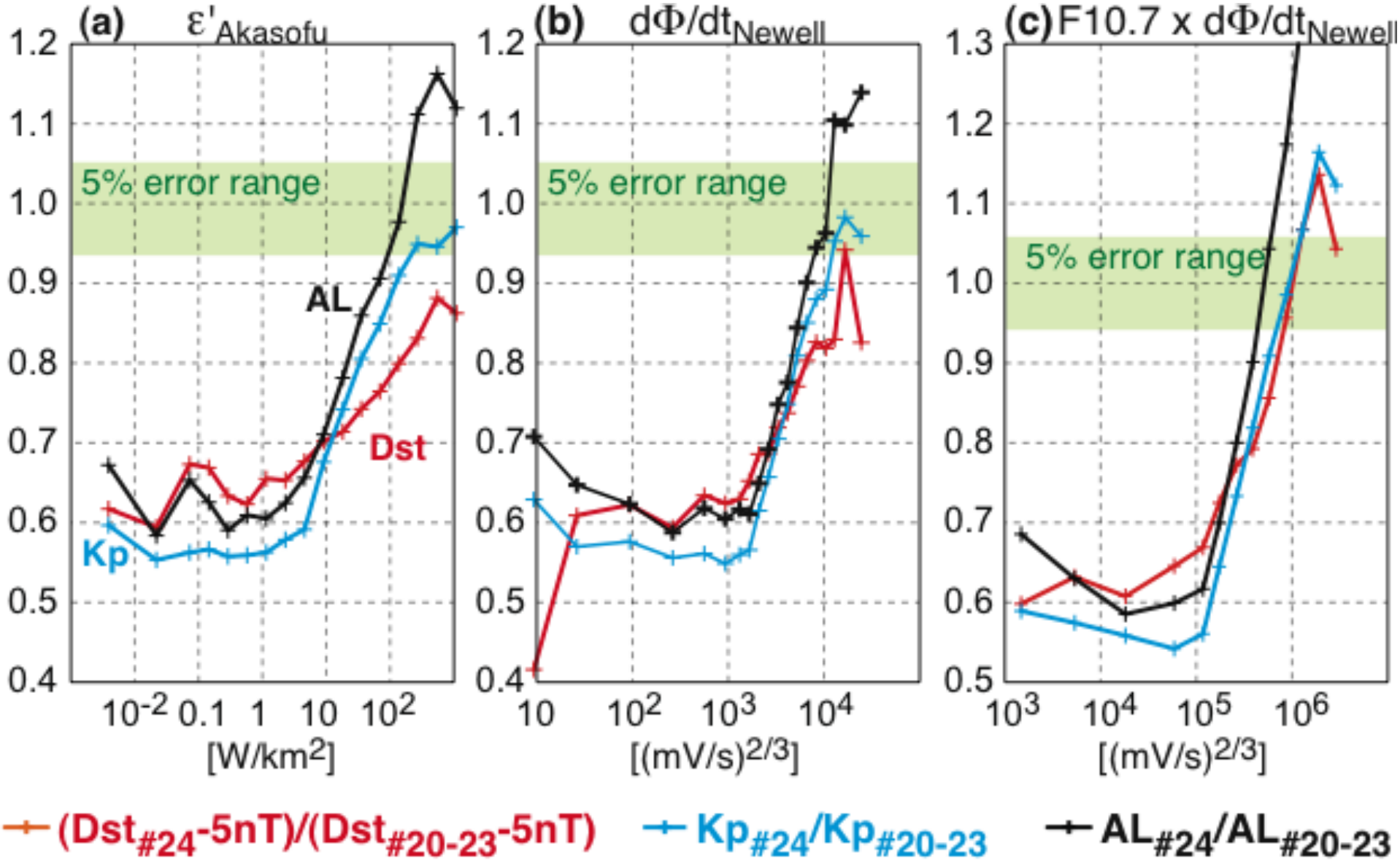
Quick summary (2/3)

- Nearly the same for #20-23, and #24 is special

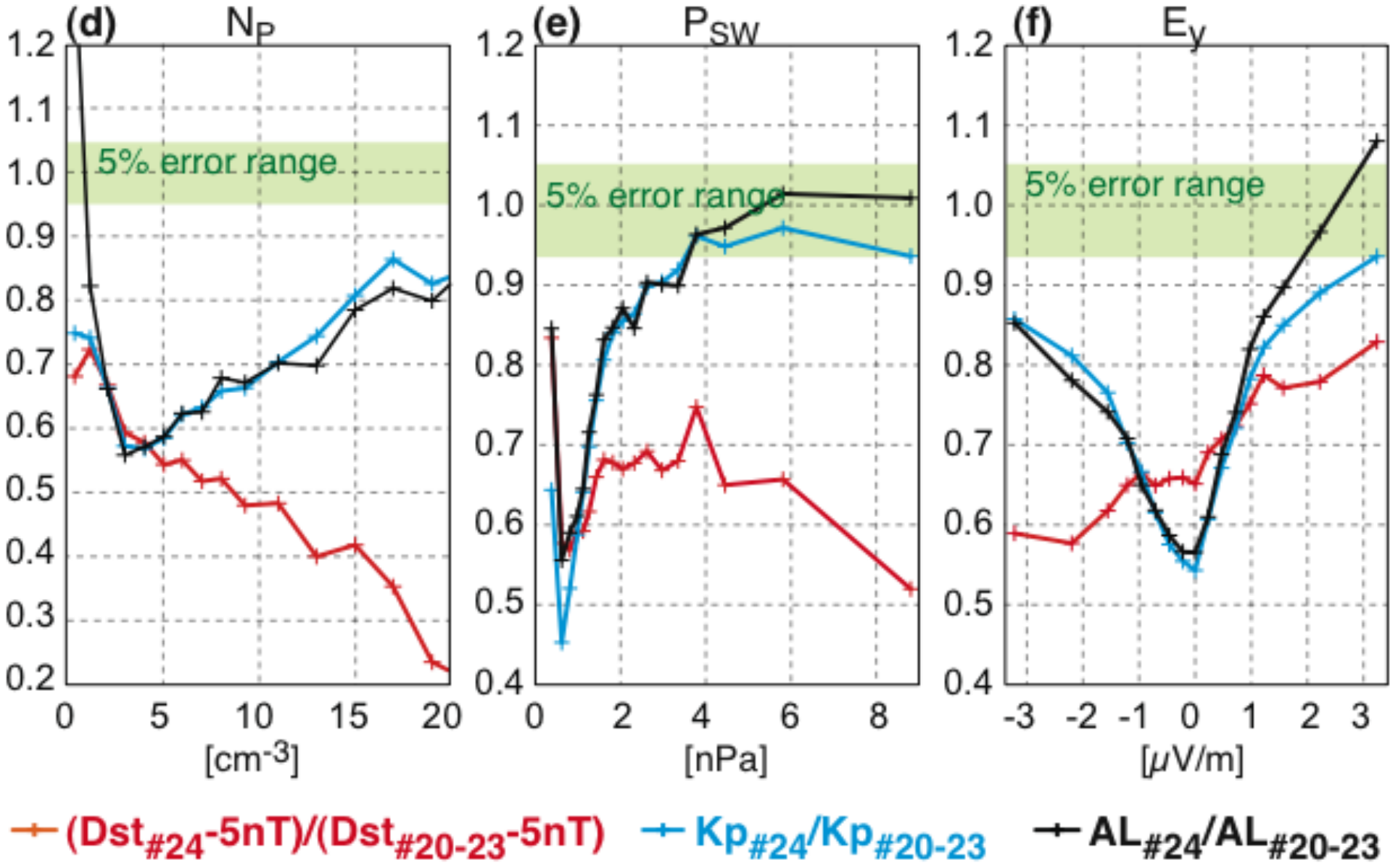
- Decreased coupling efficiency is seen only for low to moderate solar wind conditions ($\varepsilon' < 10^2$ W/km^2)

- Again Dst is more outstanding than AE $\Rightarrow$ M-I coupling auroral current system **is not** the major caused of #24 specialty.

Degree of decrease (cycle #24/#20~#23)



Valid for the other input parameters



Quick summary (3/3)

- For all types of parameters, decreased coupling efficiency for cycle #24 repeated (during low to moderate solar wind condition). It is valid even moderately southward IMF.

- Ratio saturated at 60% level of previous decades for $\varepsilon < 1$ W/km^2

- For super-storm conditions ($\varepsilon > 1000$ W/km^2), the coupling efficiency of cycle #24 could be higher $\Rightarrow$ **We need more statistics**

Summary and conclusions

• **The Sun-Earth energy coupling efficiency decreased significantly from 2006** for moderate solar wind energy input is moderate ($\varepsilon < 1$ W/km^2 that covers 90% of hours), with a sharp drop of response in 2009.

• Decrease is the most outstanding at lower latitude (Dst, Kp) than higher latitude (AE). The FUV flux is not the major player for this decrease. ⇒ M-I coupling does not explain (unlike 2009 drop).

Implications

• The current scheme of space weather forecast must be modified for coming declining phase.

• The current scheme of re-constructing the solar condition from geomagnetic data need some modification (even after considering F10.7).

• "Strength of the solar cycle" might control the Sun-Earth coupling efficiency ⇒ solution to the above problems?

• Although we need more statistics, the AL response to hazardous solar wind conditions (e.g., $\varepsilon' > 10^3$ W/km^2) might be higher than the past ⇒ **The coming declining phase can be more dangerous than the past 50 years.**

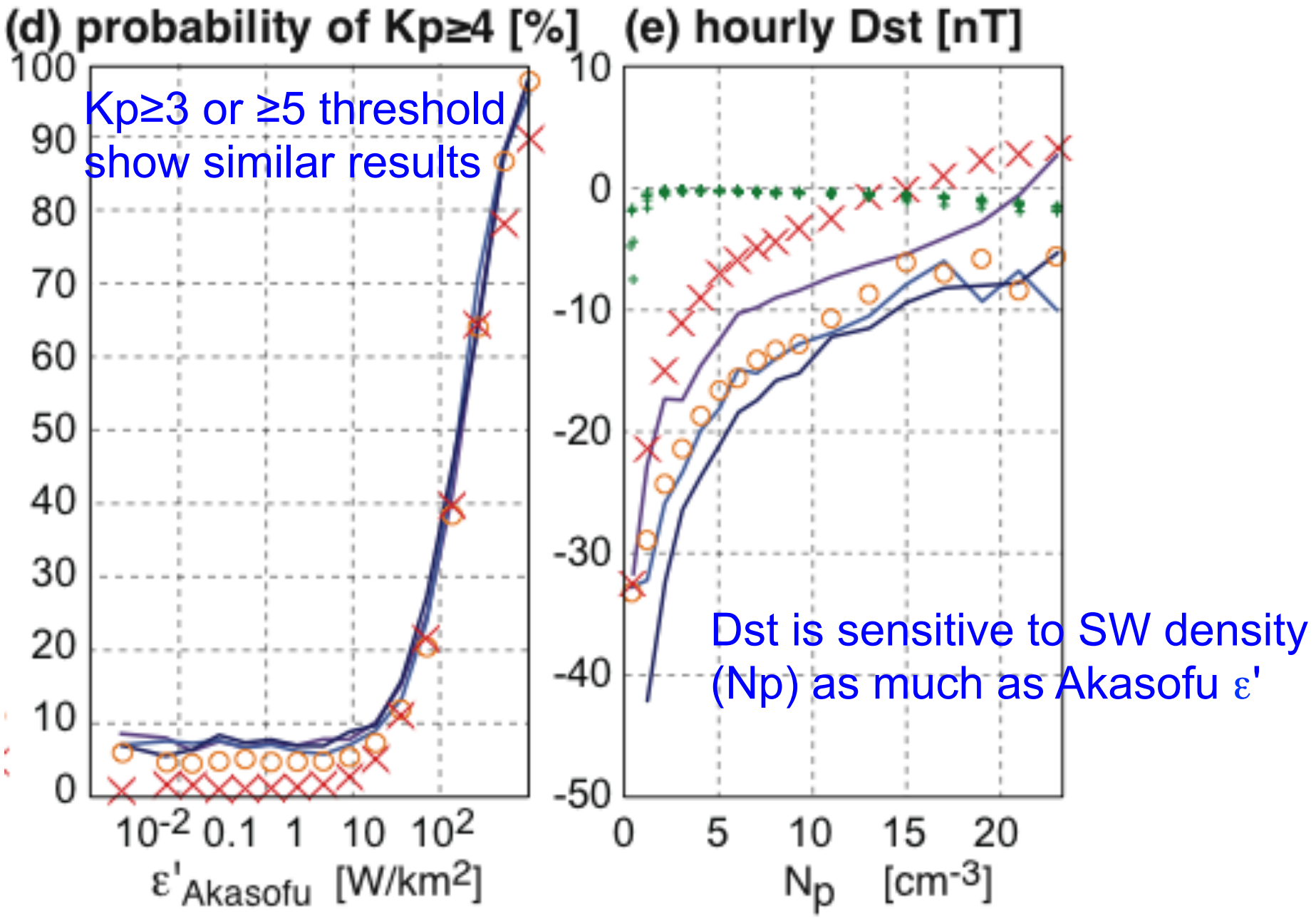
Thank you

Yamauchi (**2015**): Earth, Planets and Space, **67**, 44

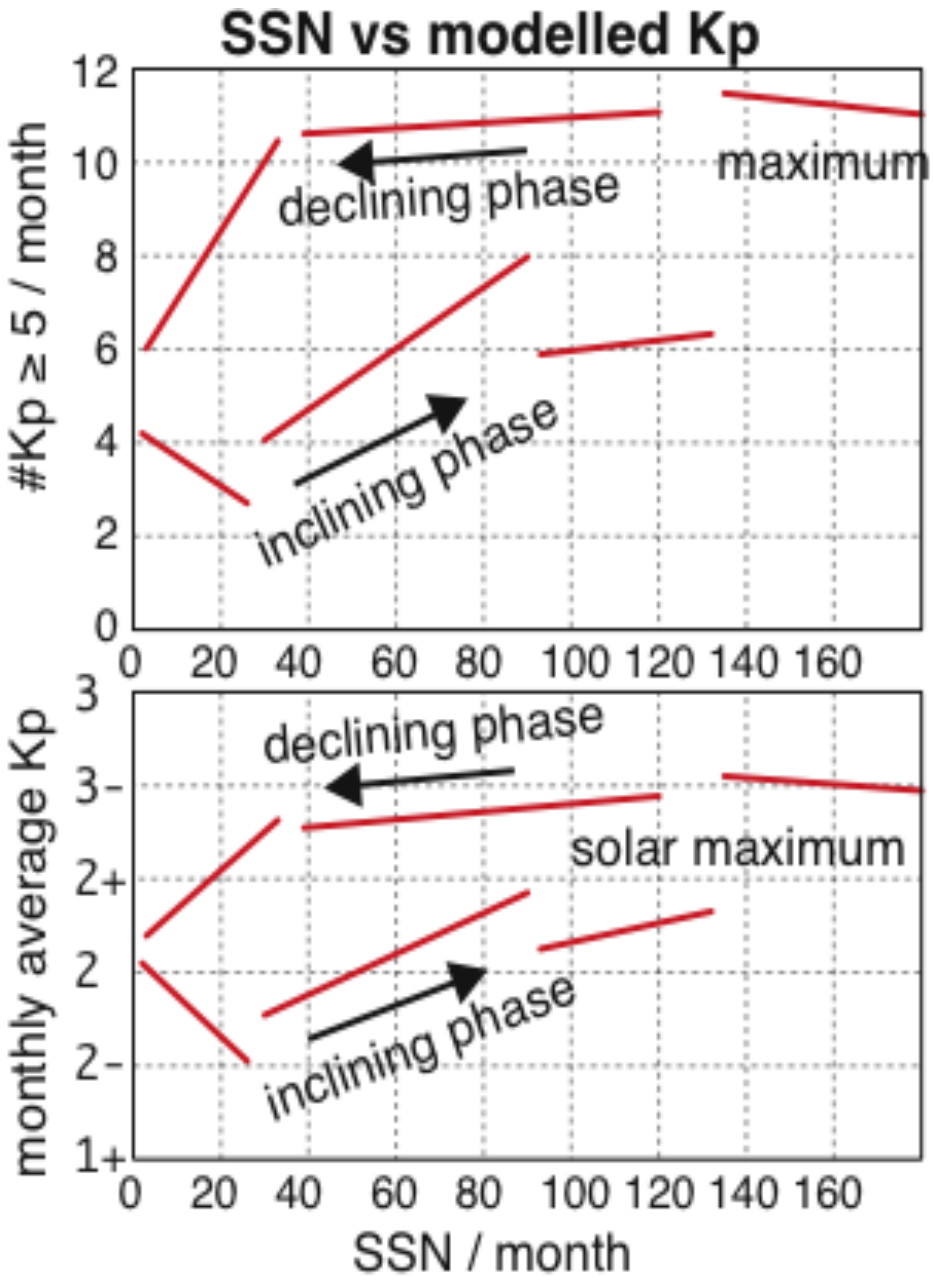
doi:10.1186/s40623-015-0211-5

http://www.earth-planets-space.com/content/67/1/44

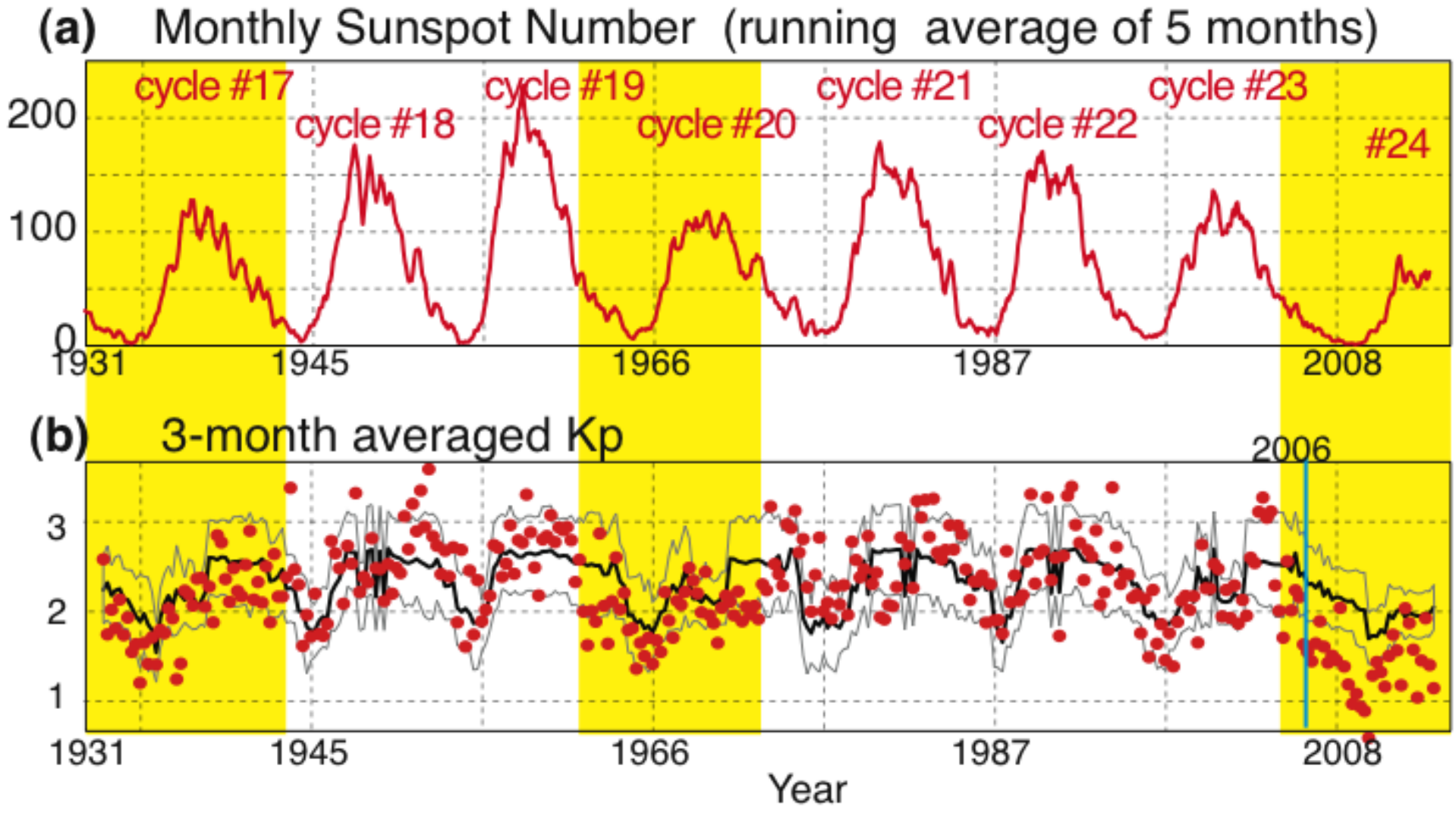
Check further Kp and Dst



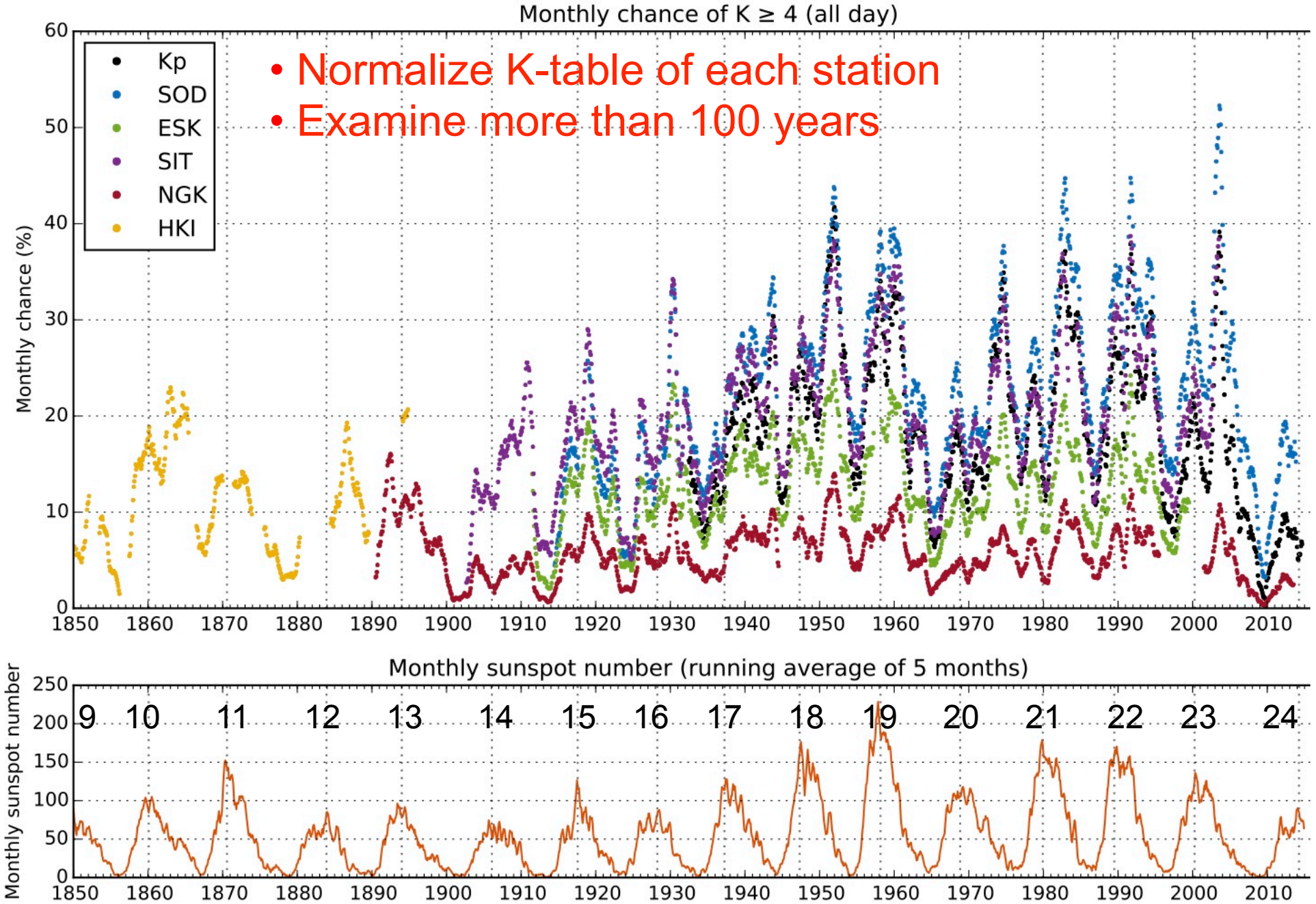
Empirical relation between the sunspot number and Kp



Reconstruct Kp directly from SSN

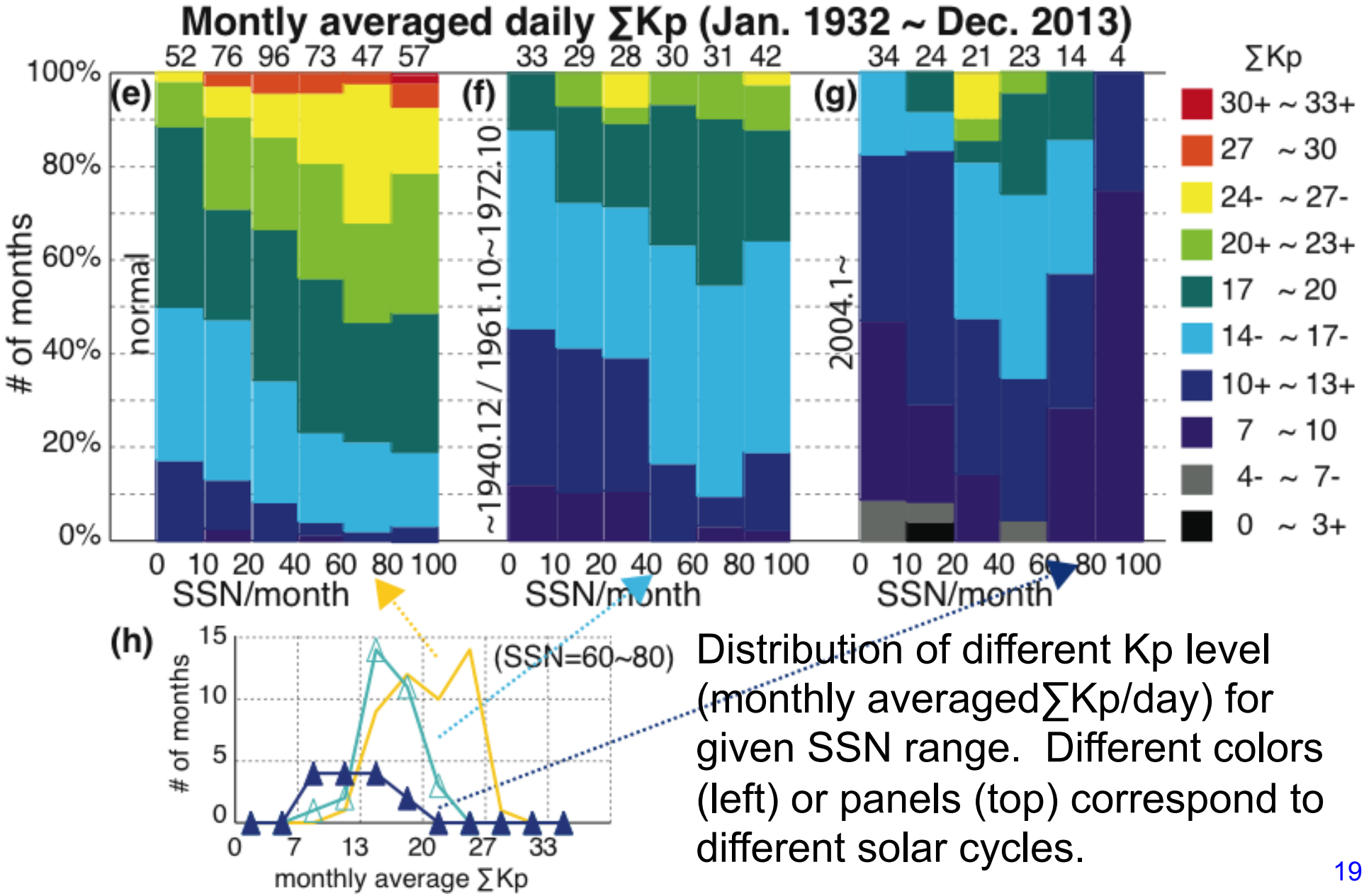


Future work



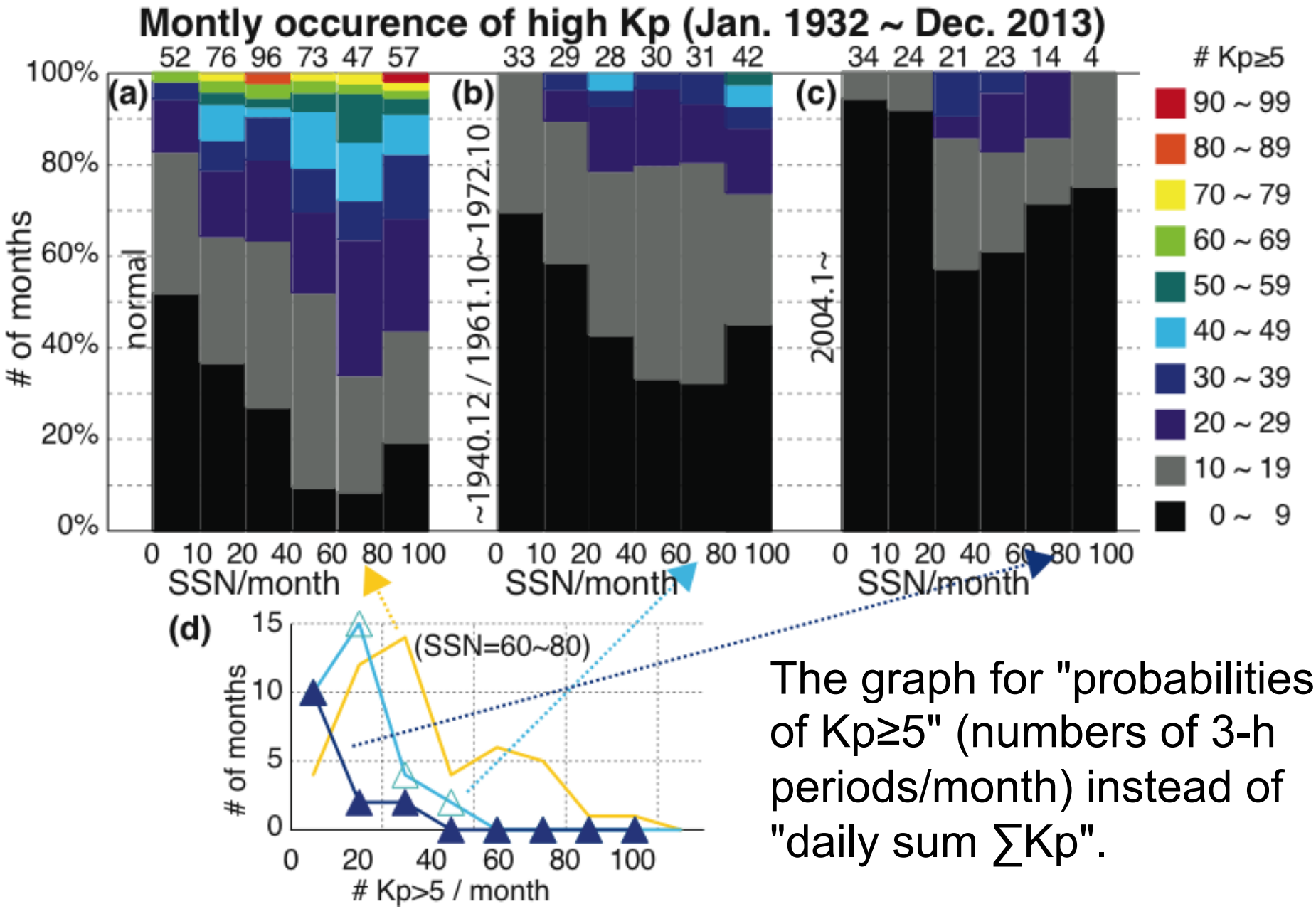
- Normalize K-table of each station
- Examine more than 100 years

Further sorting out by different SSN level



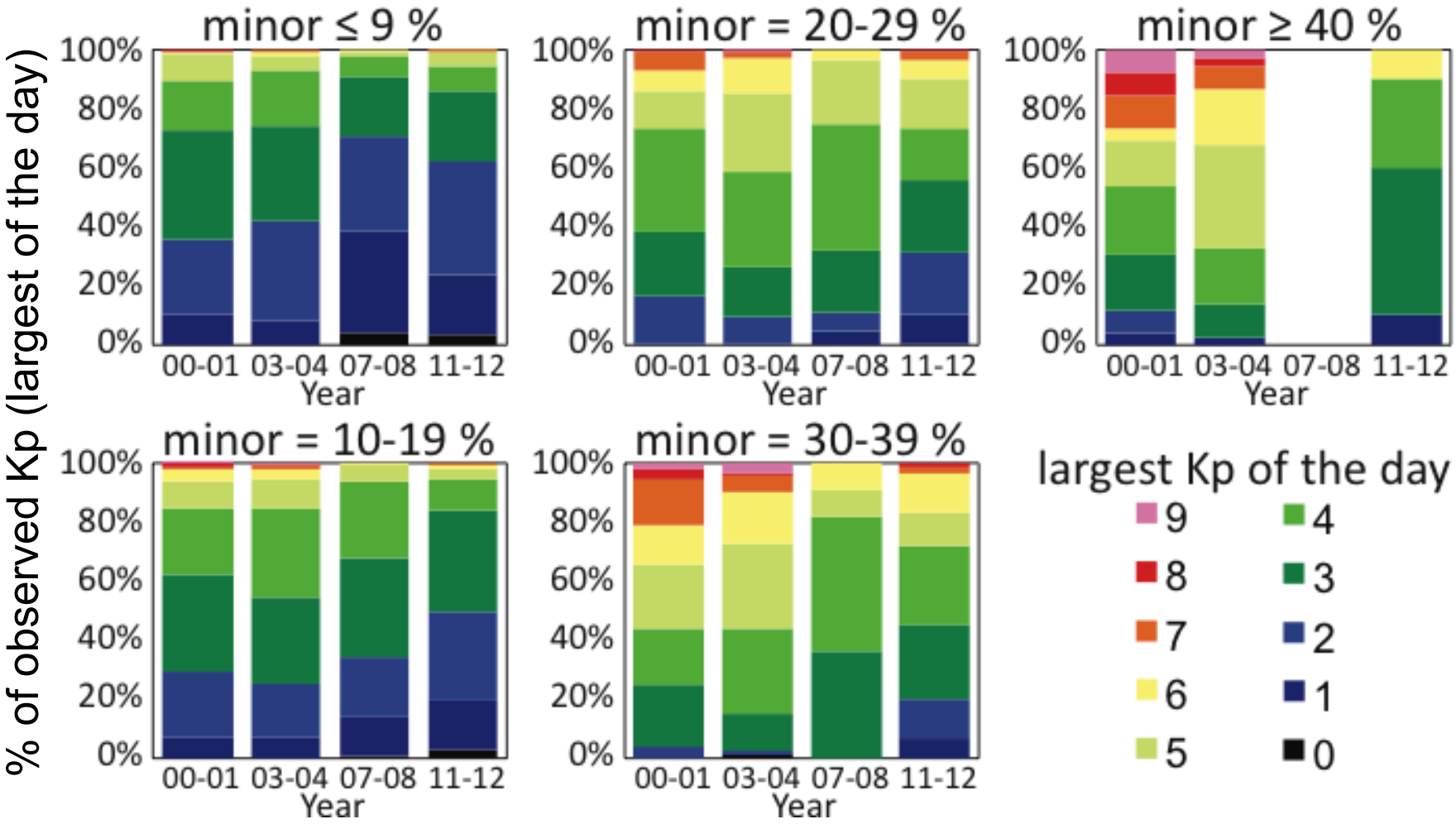
Distribution of different Kp level (monthly averaged∑Kp/day) for given SSN range. Different colors (left) or panels (top) correspond to different solar cycles.

cf. probability of Kp≥5 (instead of average Kp)



The graph for "probabilities of Kp≥5" (numbers of 3-h periods/month) instead of "daily sum ∑Kp".

Prediction vs observation



For the same prediction level of 10-40% (although the model is different between 2000 ⇔ 2011), **observed Kp values are : 2011-2012 < 2000-2001/2007-2008 < 2003-2004**