Variation of geomagnetic responses to the solar wind input in long term

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

Purpose (motivation)

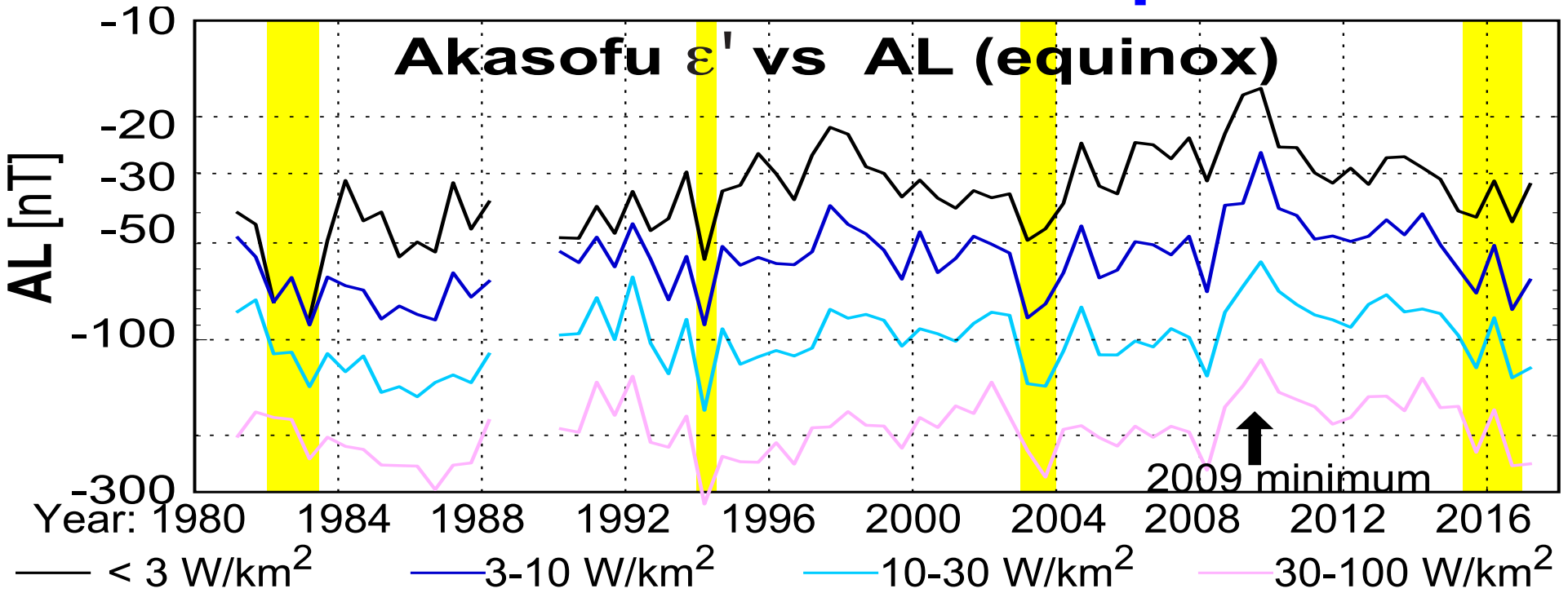
Geomagnetic disturbance for the same solar wind input (we call Sun-Earth coupling efficiency):

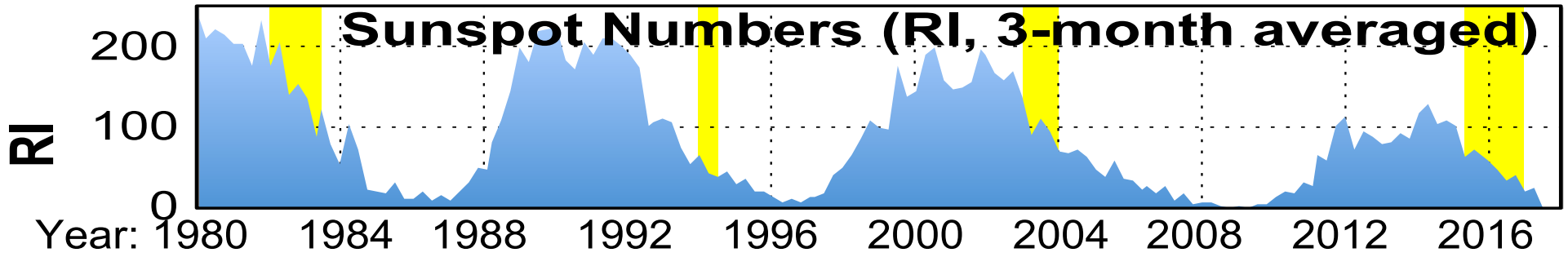
- It has been assumed constant. Is it really constant?
- If it varies, is it due to EUV, location of aurora, or other reason?

Method

- For diagnosis, we first examine indices (AE, PC, SYM/ASY) which have high resolution data.
- Must remove seasonal variation ⇒ 3-months resolution to separate "equinox" & solstice
- Use 5-min NASA/OMNI data for solar wind condition ⇒ Then calculate coupling functions, e.g., $\varepsilon' = (4\pi/\mu_0)\cdot VB_{tan}^2\sin^4(\theta_C/2)$, $d\Phi/dt = (V^2_{SW}\cdot B_{tan}\cdot\sin^4(\theta_c/2))^{2/3}$
- Travel time from the spacecraft to the Earth is introduced.
- Estimate "integrated input" for 5-60 min before ⇒ we averaged these coupling functions over 5-60 min ⇒ the correlation is best for 60 min average)

Result / overview of "response"

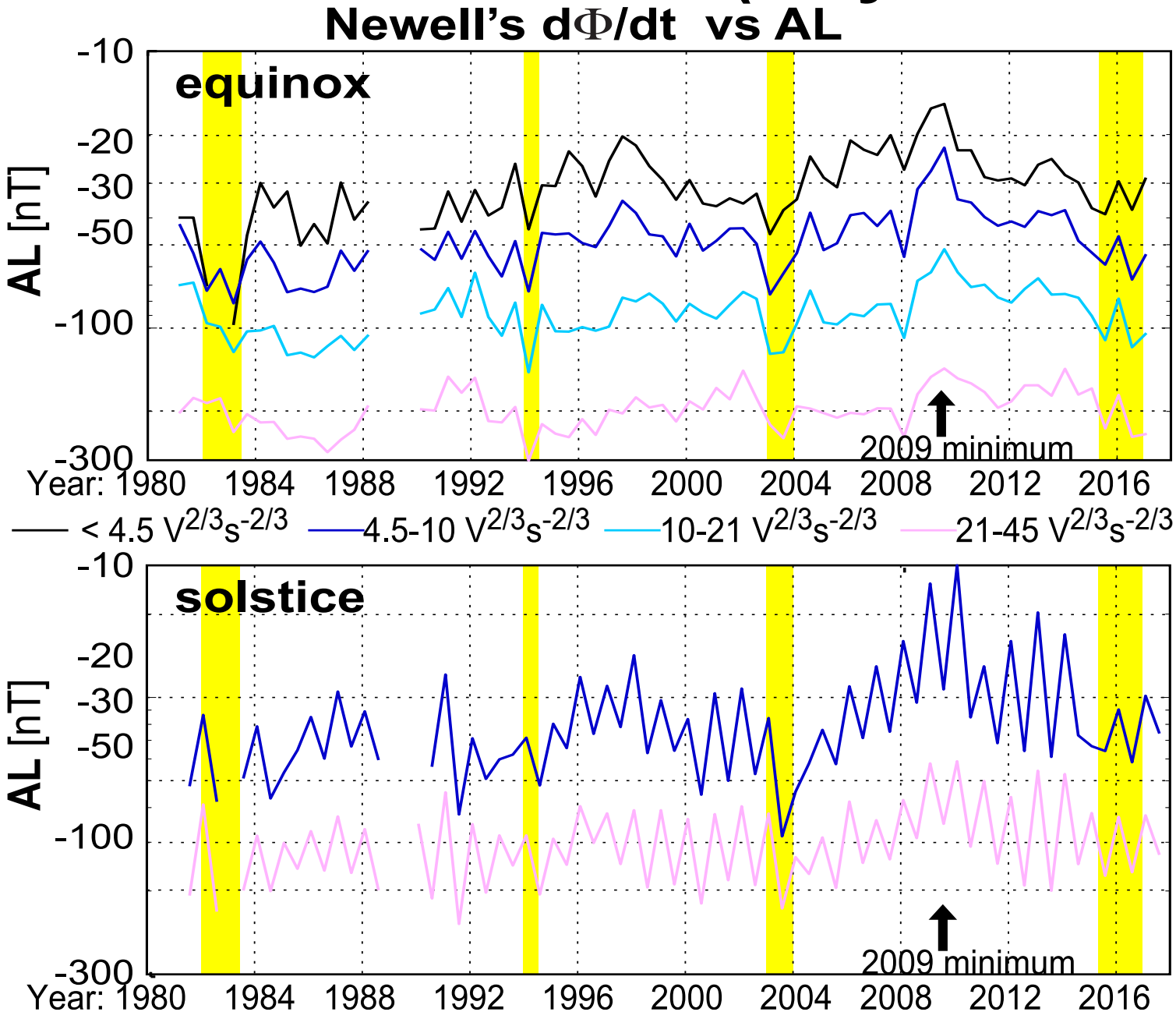




(1) **within a solar cycle: 1-year enhancement** during declining phase?

(2) **longer scale: decreasing trend** with 2009 minimum?

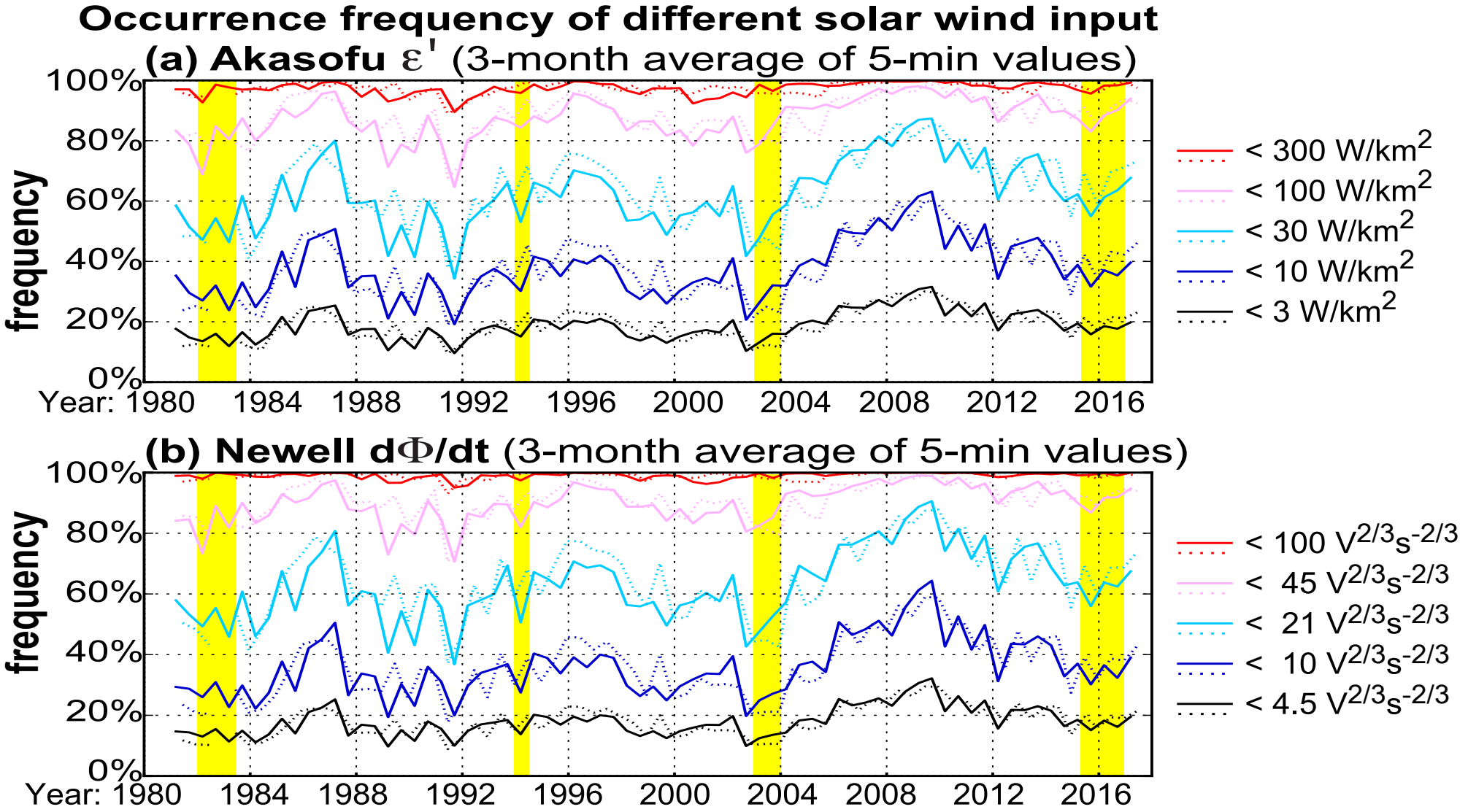
Result / overview (why we take equinox)

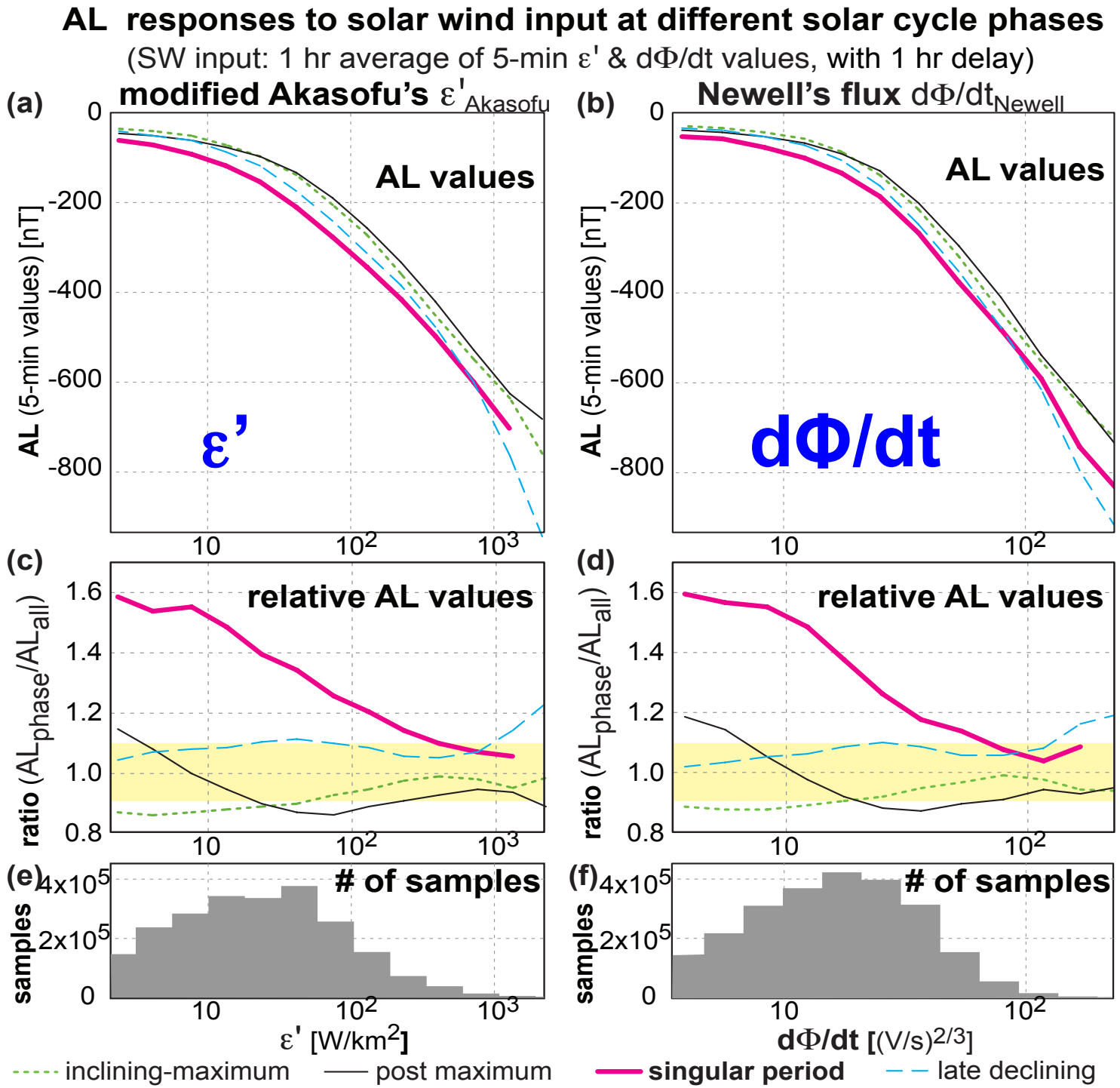


same result for **dΦ/dt** as **ε'**

solstice: more AE/SYM stations in the northern hemisphere

The singular period does not match with the declining phase peak of solar wind input



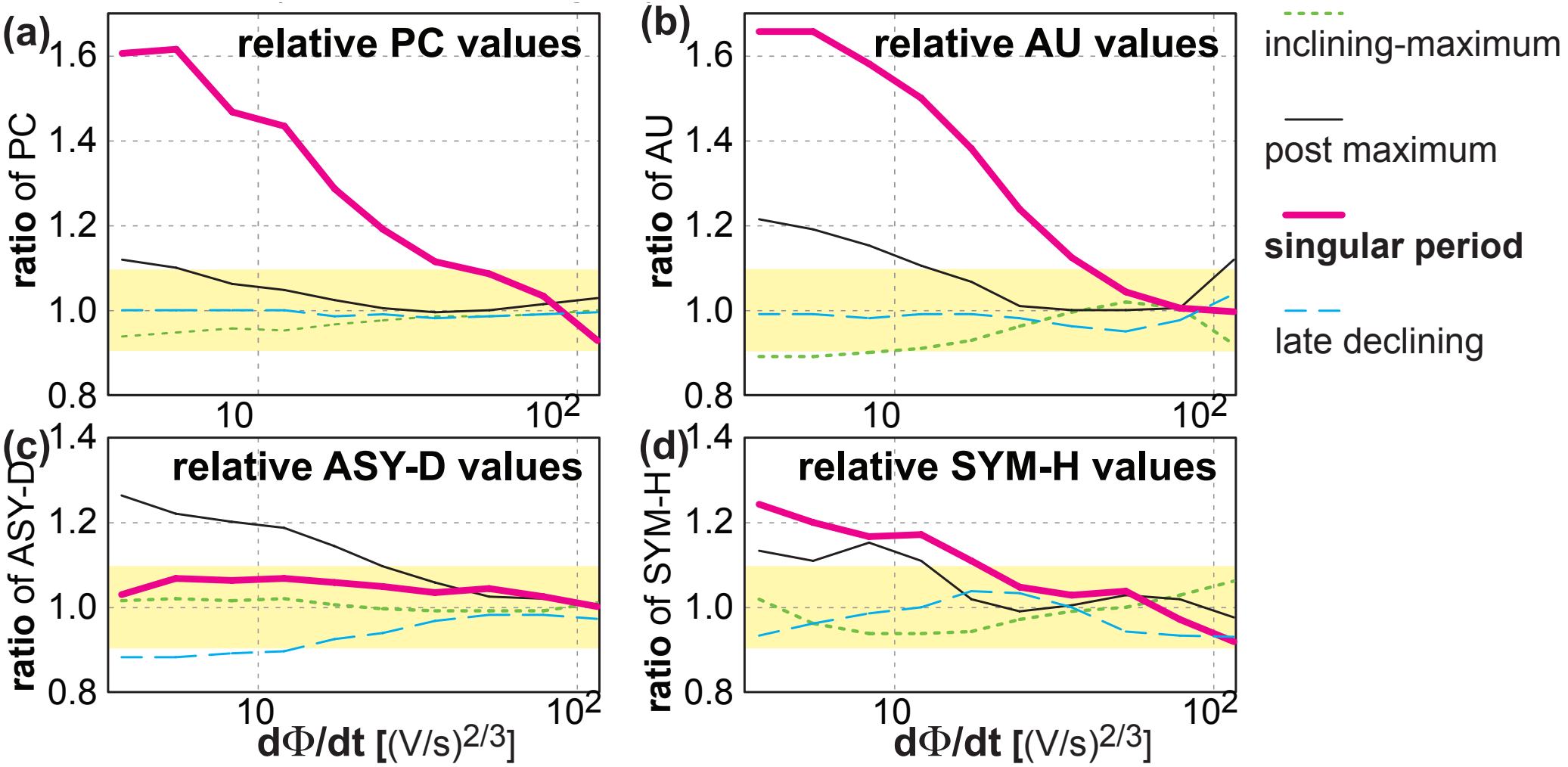


Phase difference

- divide into 4 phases
- take relative values against average

Result: outstanding < moderate activities (**not storms!**)

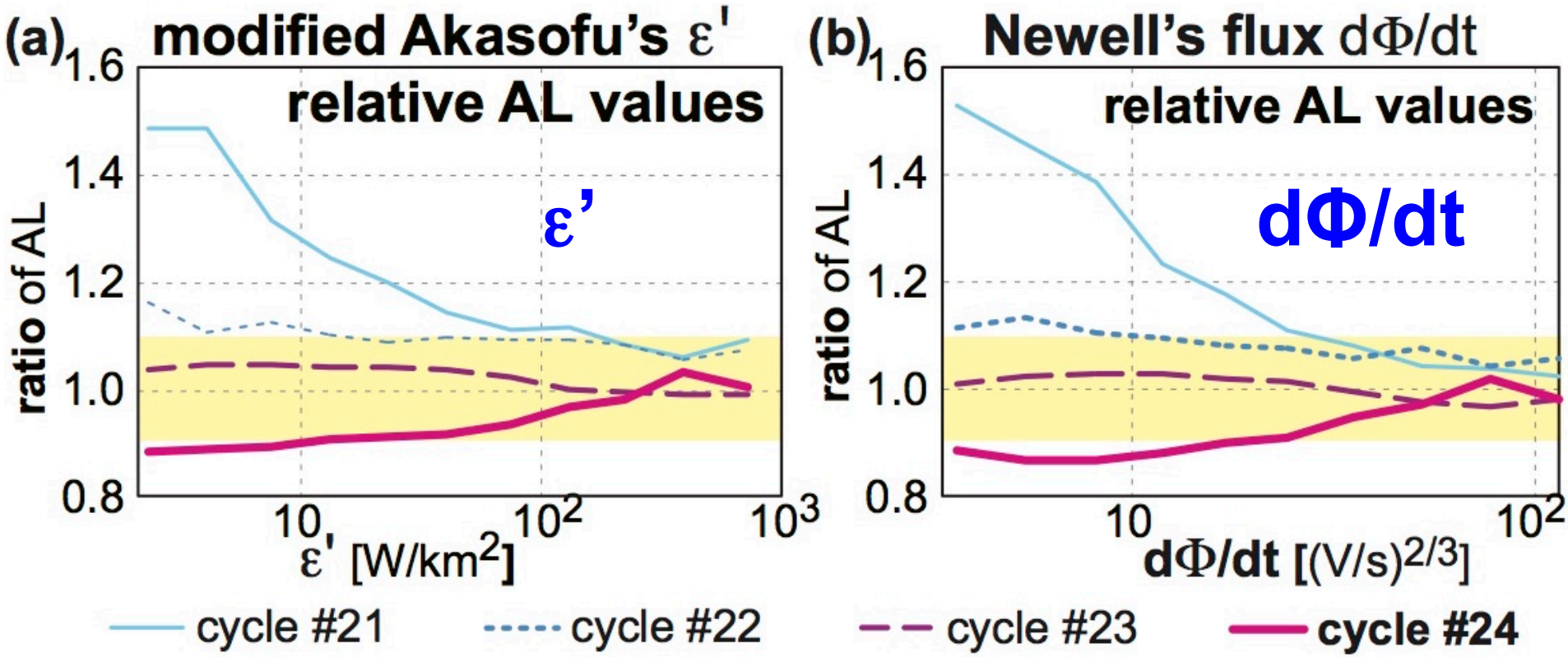
How about different latitude?



Result: PC/AU are similar

SYM-H is unclear, ASY-D not at all

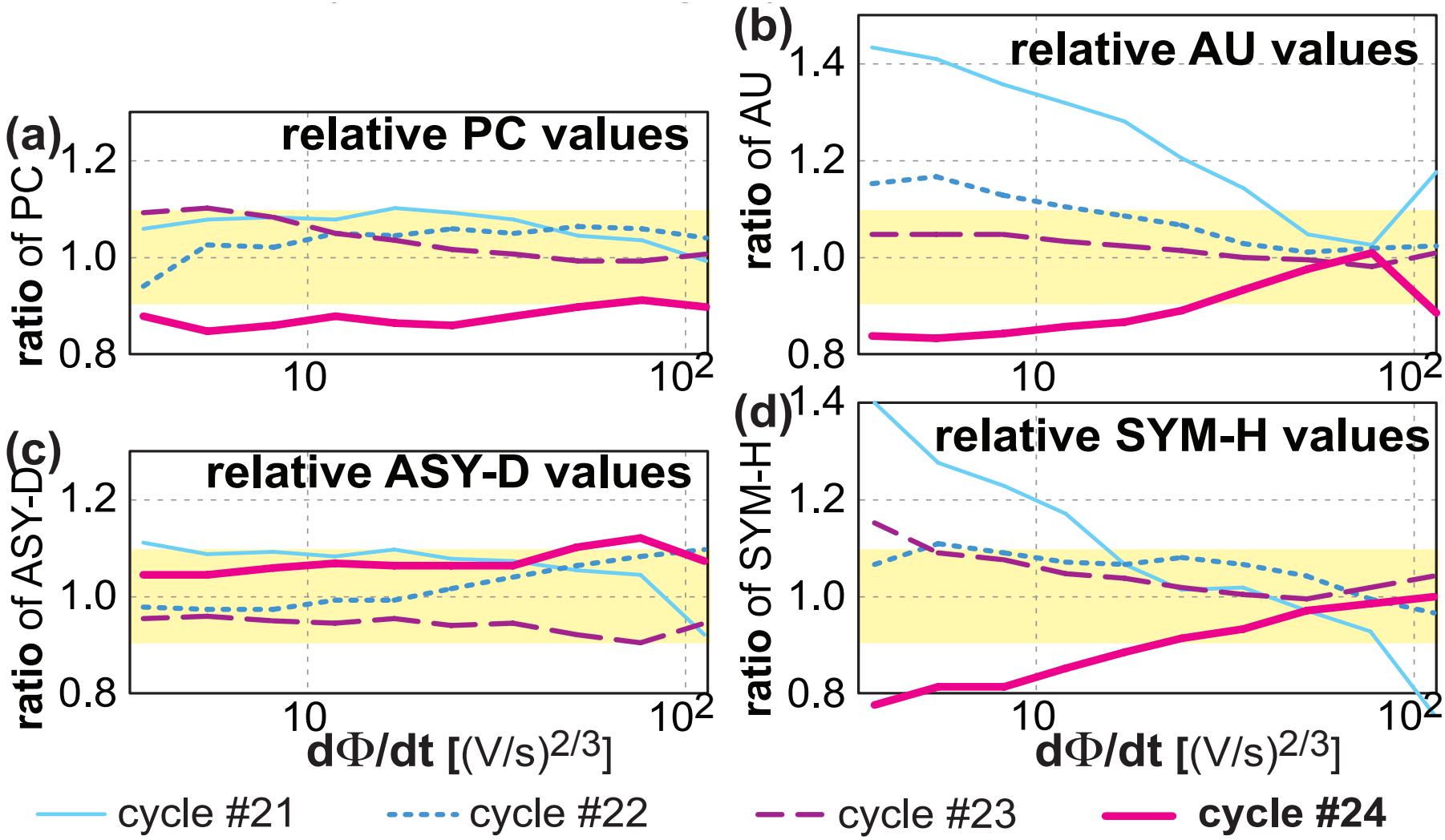
Long-term (cycle-to-cycle) trend



- divide into different cylcles (#21 and #24 are not complete, though)
- take relative values against average

Result: decreasing trend over 4 cycles

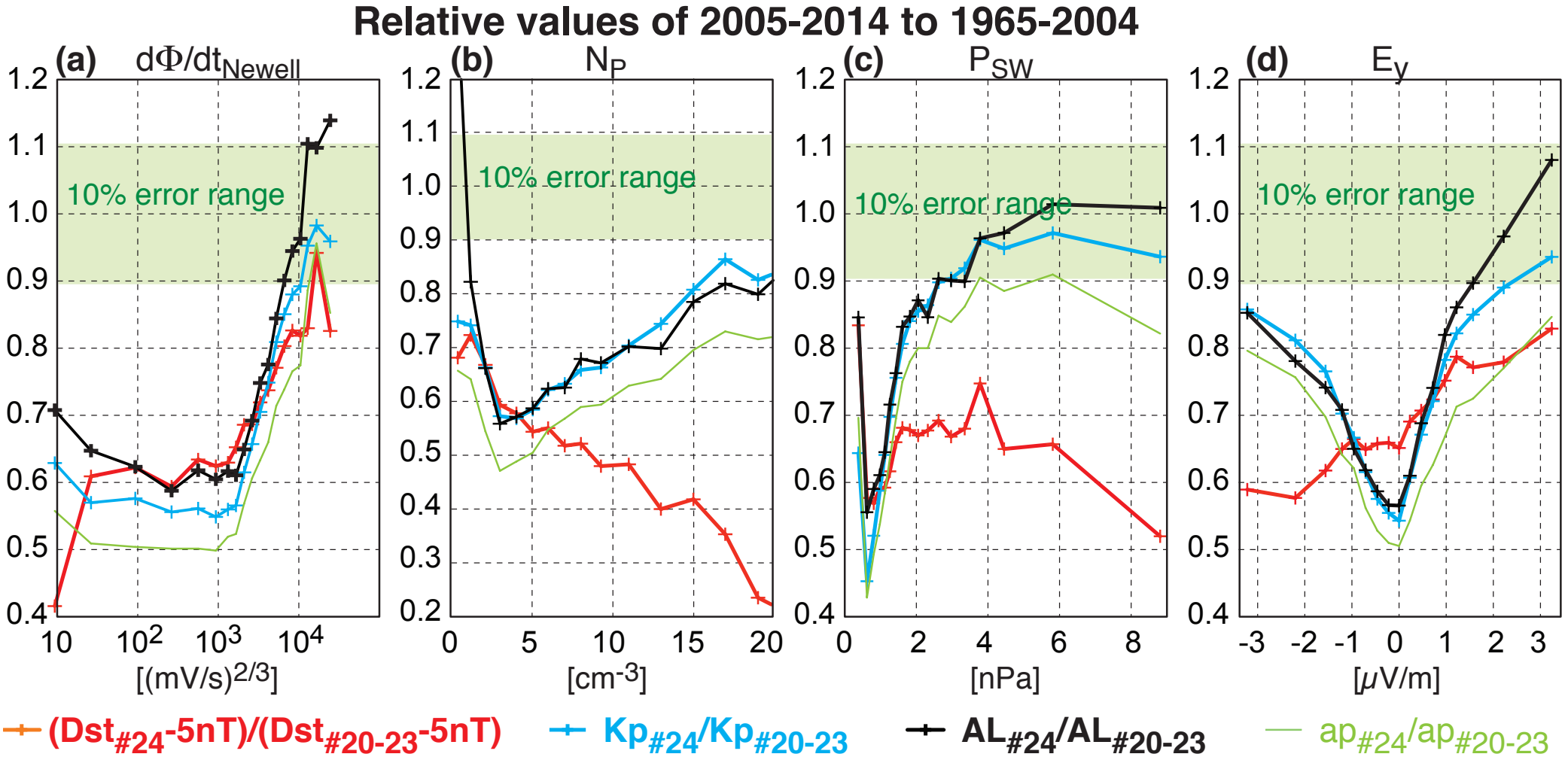
How about different latitudes?



Result: AU/SYM-H are similar

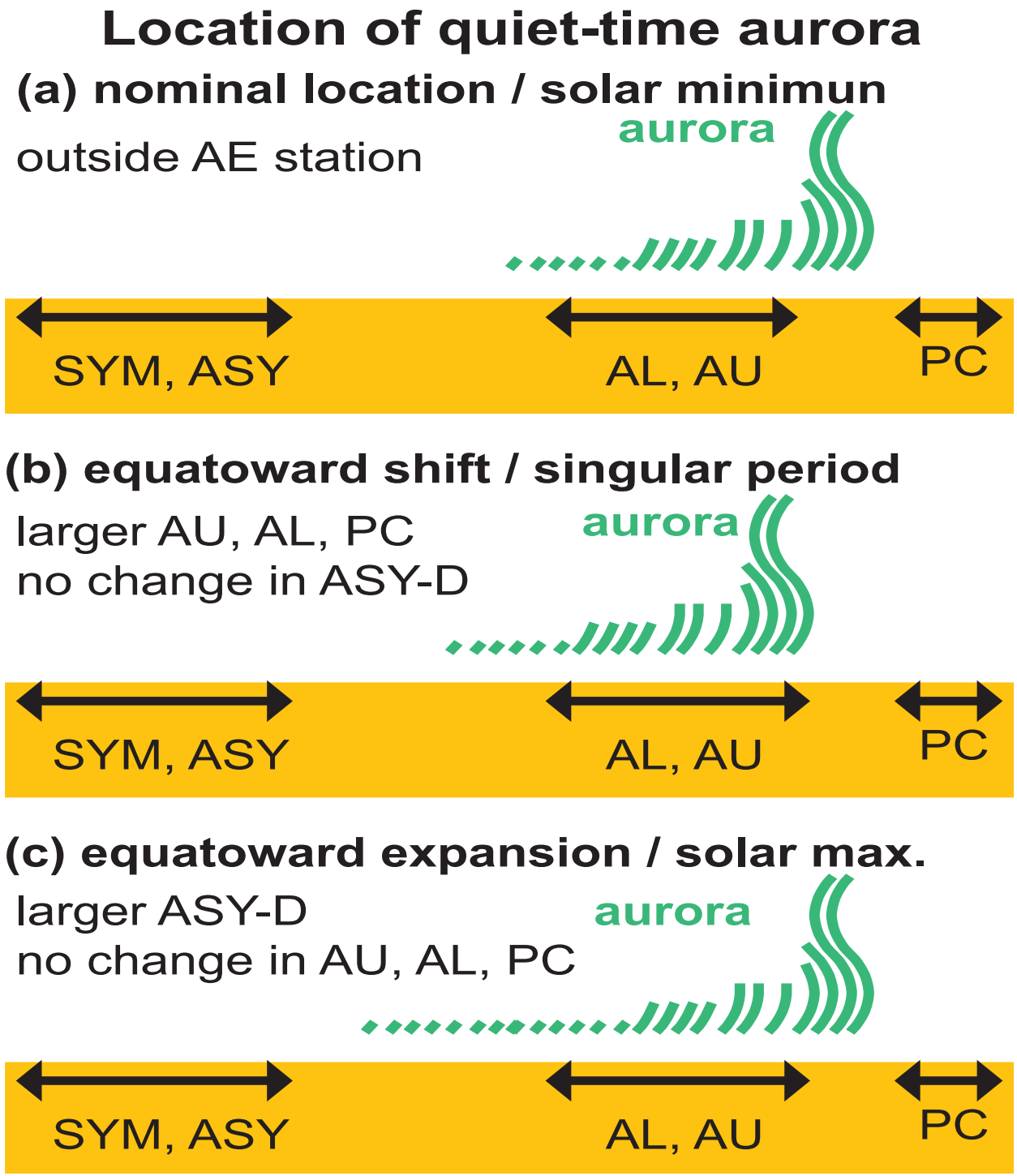
PC only clycle #24, ASY-D not at all

Same for longer time series (but hourly value)



Result: smaller during 2005-2014 (x ~ cycle #24) than before (Yamauchi, 2015)

due to shift of quiet-time aurora?



Summary

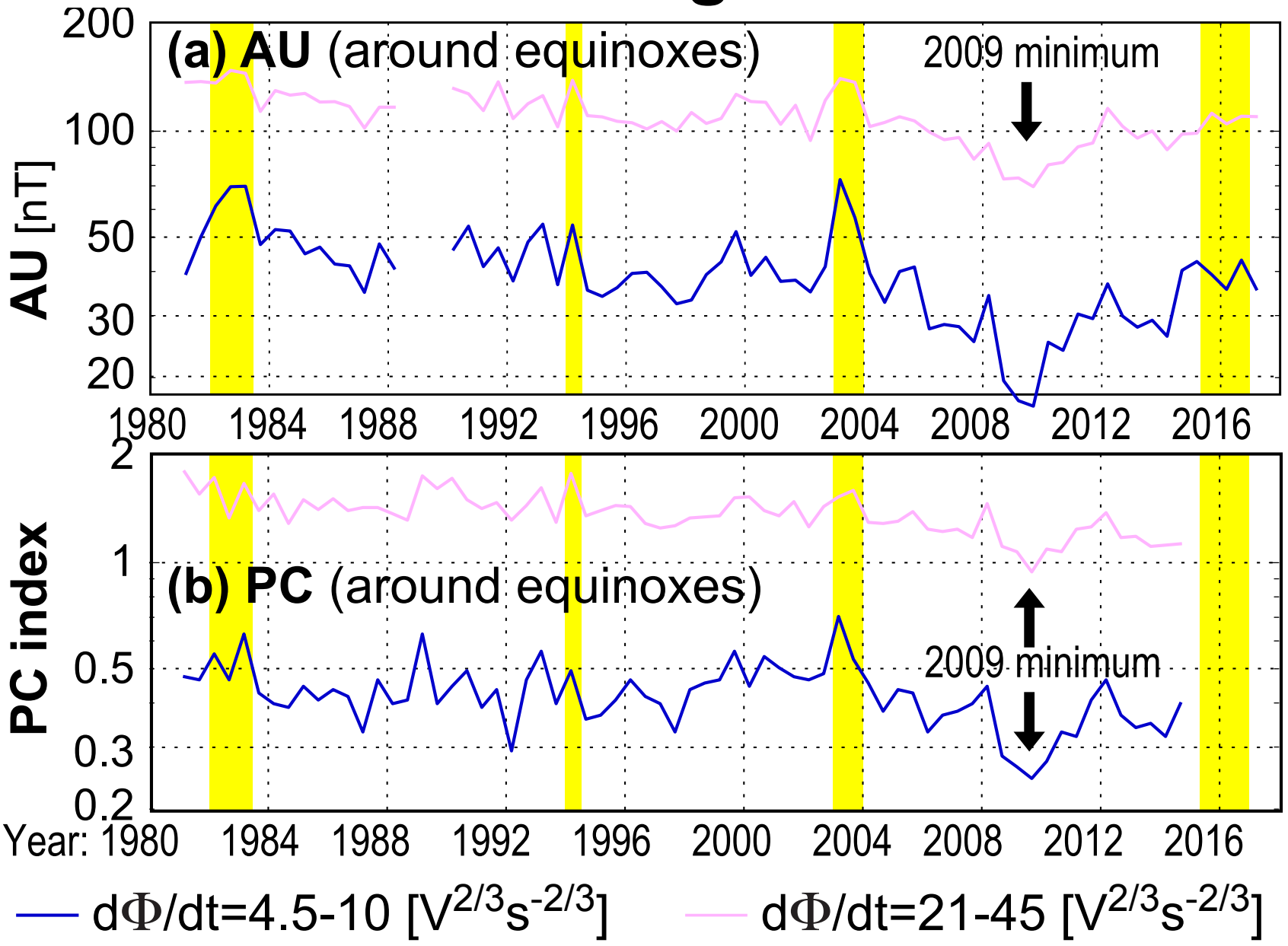
(1) For quiet to moderate solar wind input (corresponding to |AL| < 400 nT activity on average), the AL, AU, and PC responses to the same input values increased much beyond the fluctuation level for about 3-12 months during 1983, 1994, 2003, and 2016, all during the early declining phase of solar cycles. Some increase for SYM-H, but non at all for ASY-D (enhance rather post-maximum)

(2) Except during these periods, AL and AU responses to the same range of solar wind input continuously decreased at least until 2009.

The first result can be attributed to equatorward shift of the quiet-time polar cap boundary during the singular periods.

Possible future work: same analyses **using IMAGE** midnight data? identify auroral location?

Overview for higher latitude?



Overview for lower latitude?