Long-term variability of the superrotation and planetary-scale waves at around Venusian cloud top

Takeshi Horinouchi (Hokkaido Univ.) w/

Kouyama, T., Imai, M., Murakami, S. Y., Lee, Y. J., Yamazaki, A., Yamada, M., Watanabe, S., Imamura, T., Peralta, J. & Satoh, T.

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UV observations & dayside cloud tracking

- Long tradition since Mariner-10 (Limaye 1981)
- 365-nm imaging (helped by the unknown absorber): conducted by the three long-term operating orbiters, Pioneer Venus Orbiter (PVO), Venus Express (VEx), Akatsuki
- Novelty of the UV imaging by Akatsuki
  - Covers the both hemispheres simultaneously
  - Additional wavelength: 283 nm (SO_2 + unknown absorber)

Mean wind variability

Venus Express findings

Kouyama et al (2013)

long-term variability of superrotation (SR):

Increasing trend + periodic ~250 days

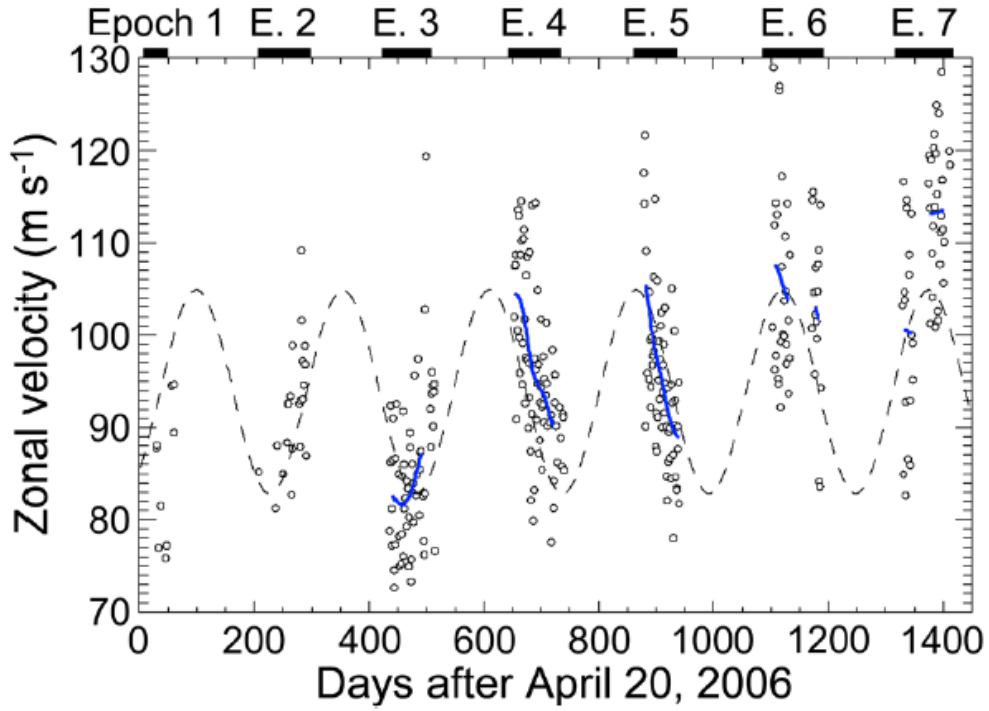
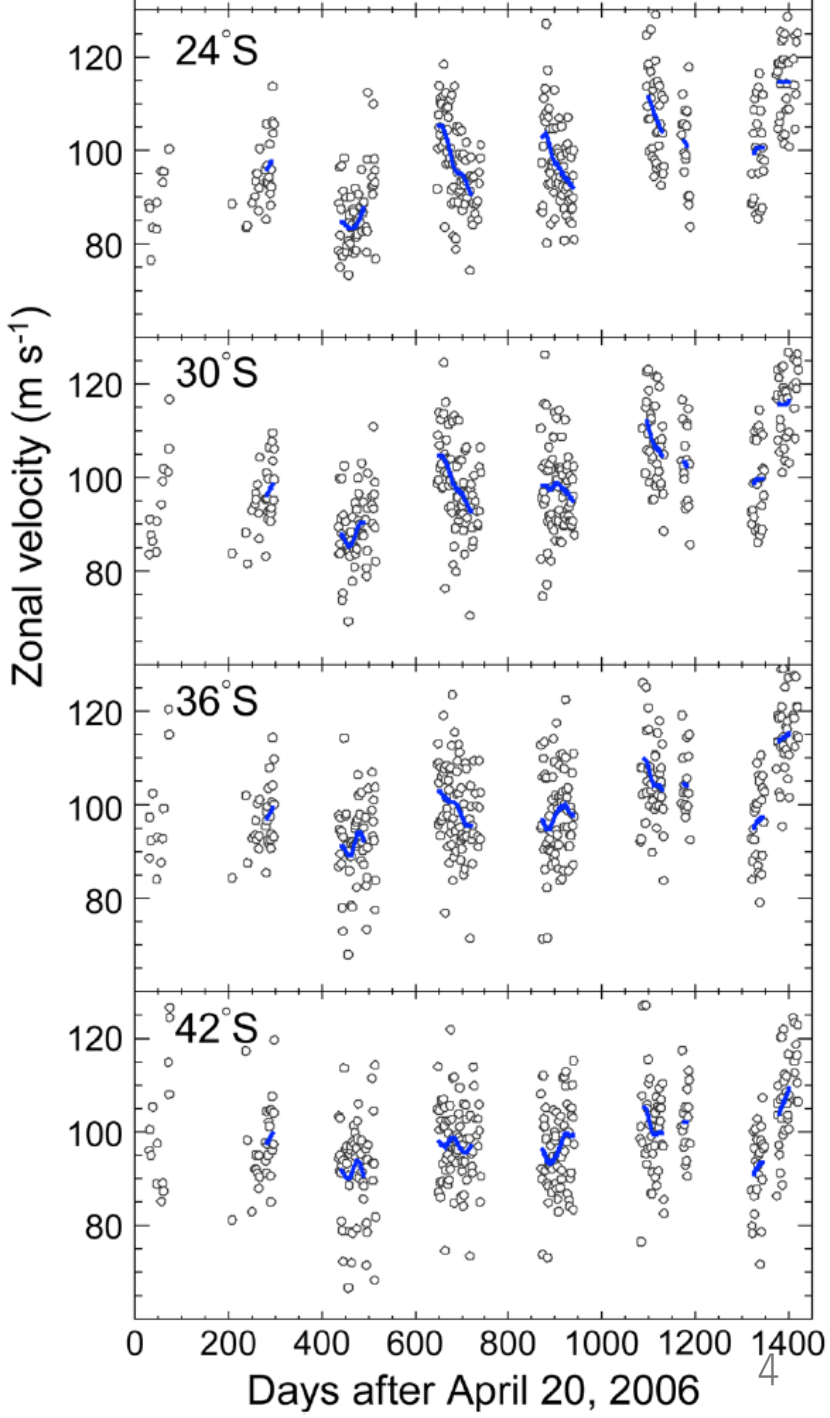
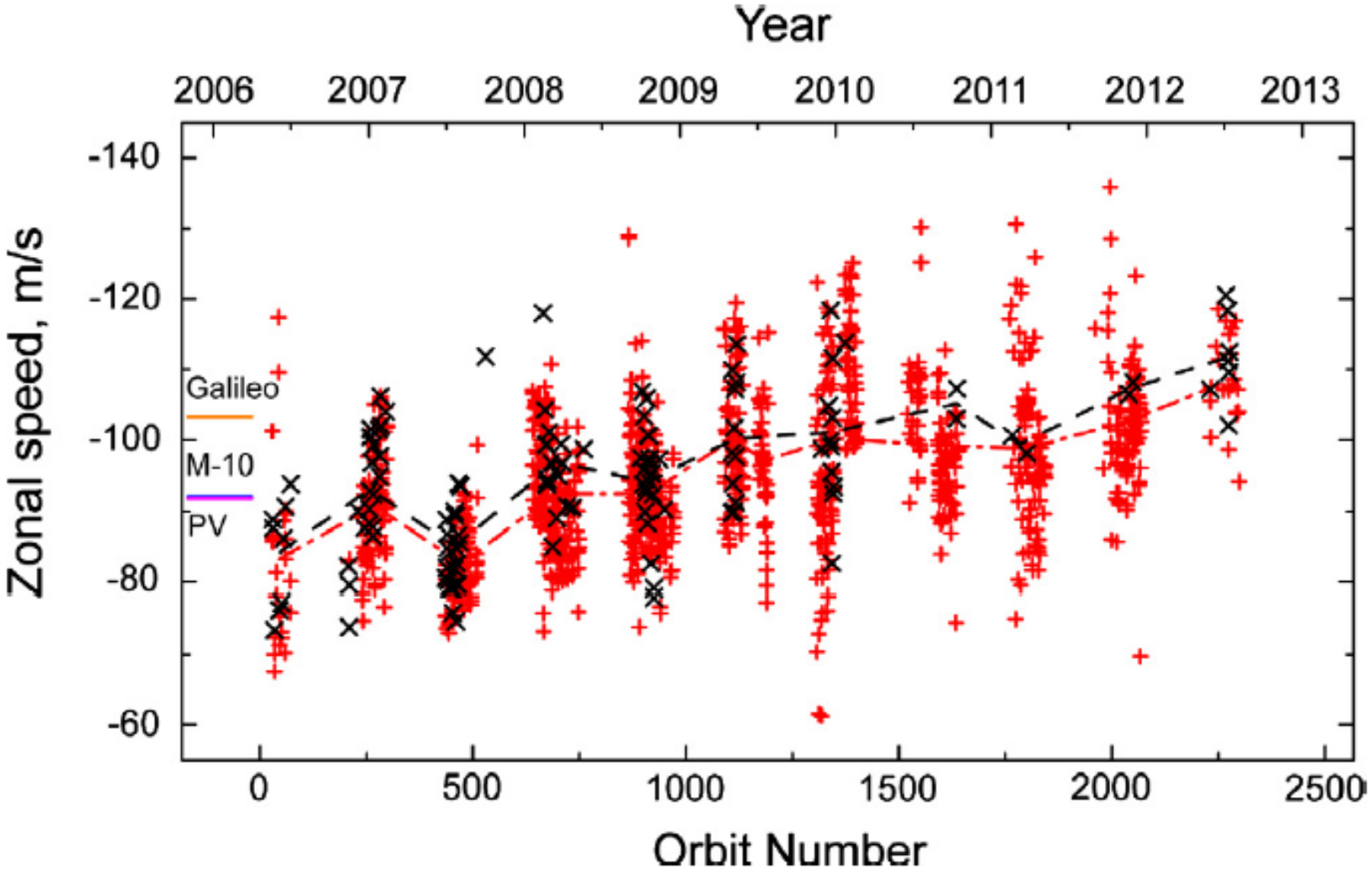


Figure 8. A sinusoidal function representing the 255 d period oscillation retrieved by a spectral analysis (dashed curve) superposed on the observed zonal velocities at 18°S (open circles) and the smoothed time series (blue curves).



Khatuntsev+ (2013)



Khatuntsev+ (2013)

Negative about the reality of ~250 d periodicity:

"Our interpretation is that the peak at 238 days resulted from superposition of the observation window period of 222 days, long-term trend (Fig. 14), and Venusian sol (116.8 days)."

Observation window: from VEx's orbit

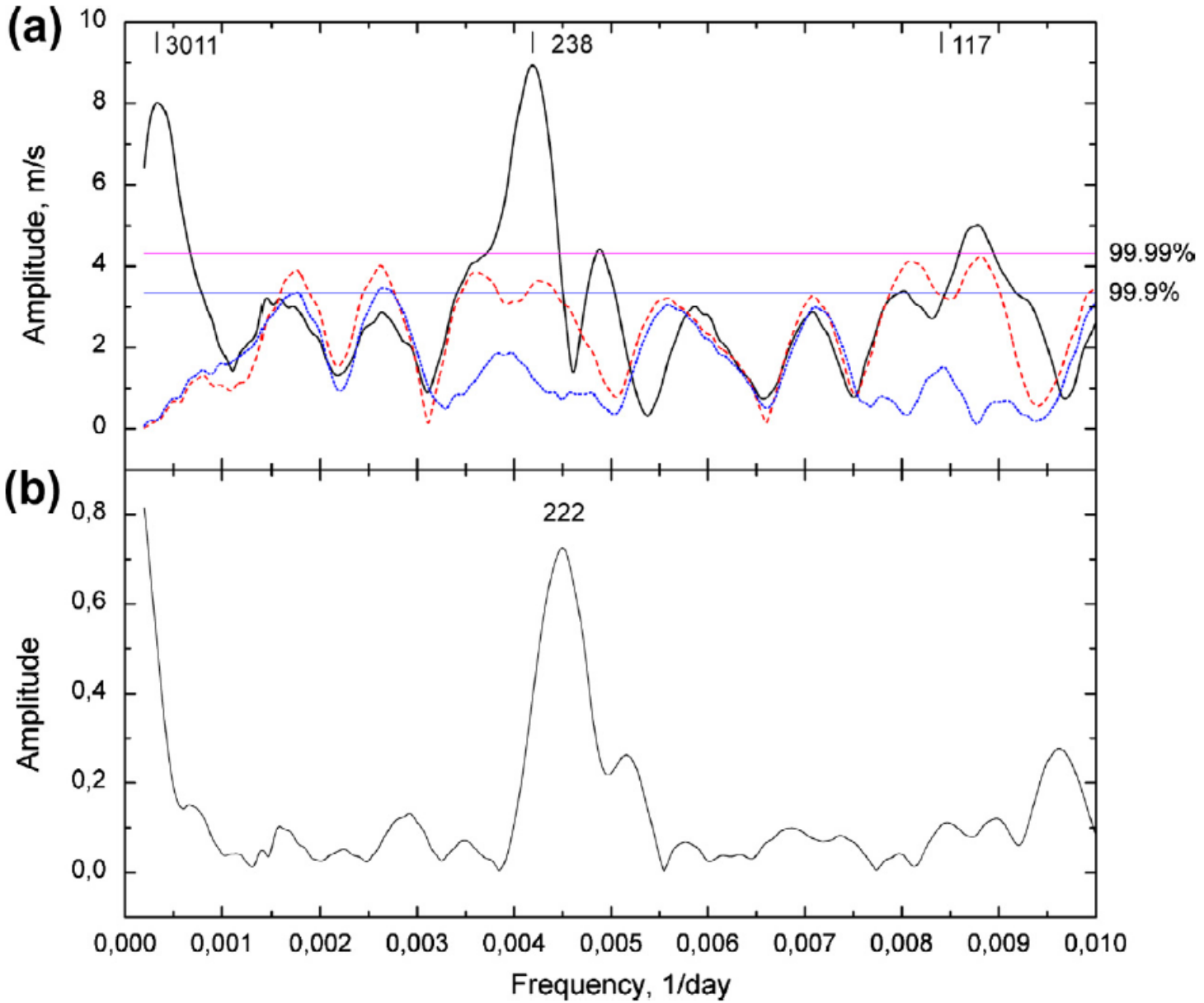
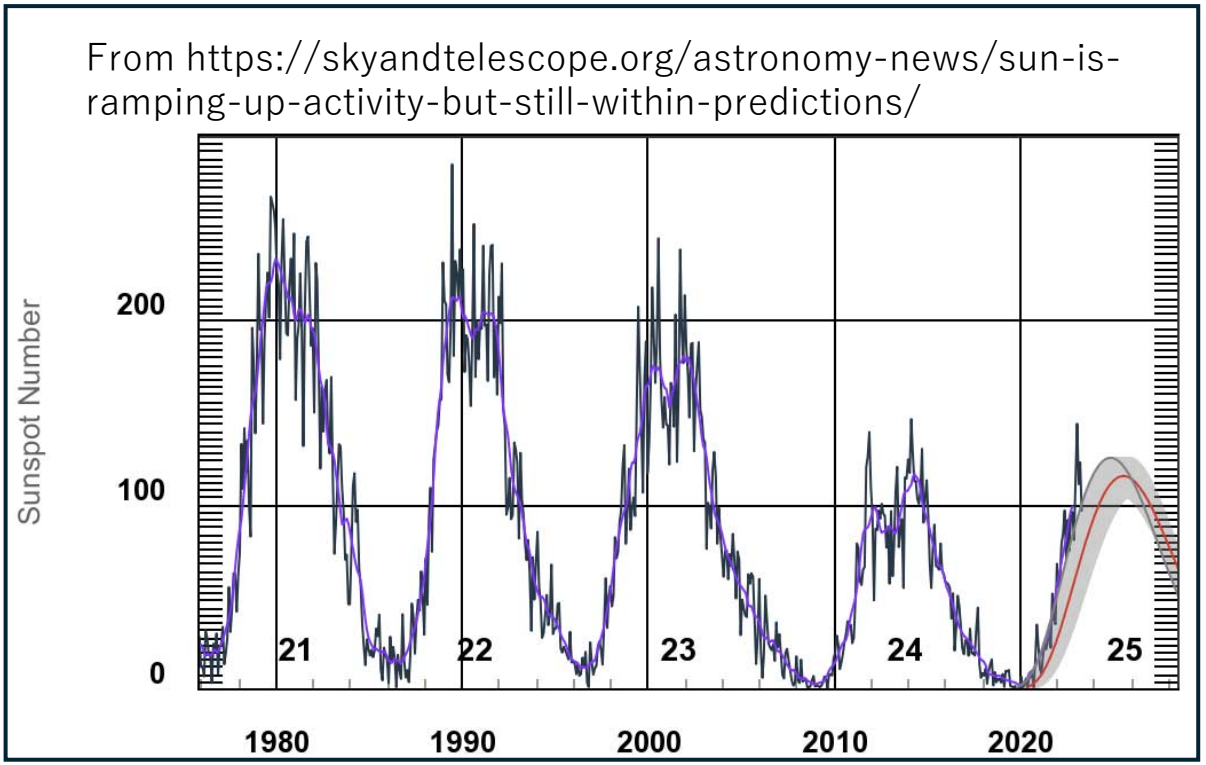


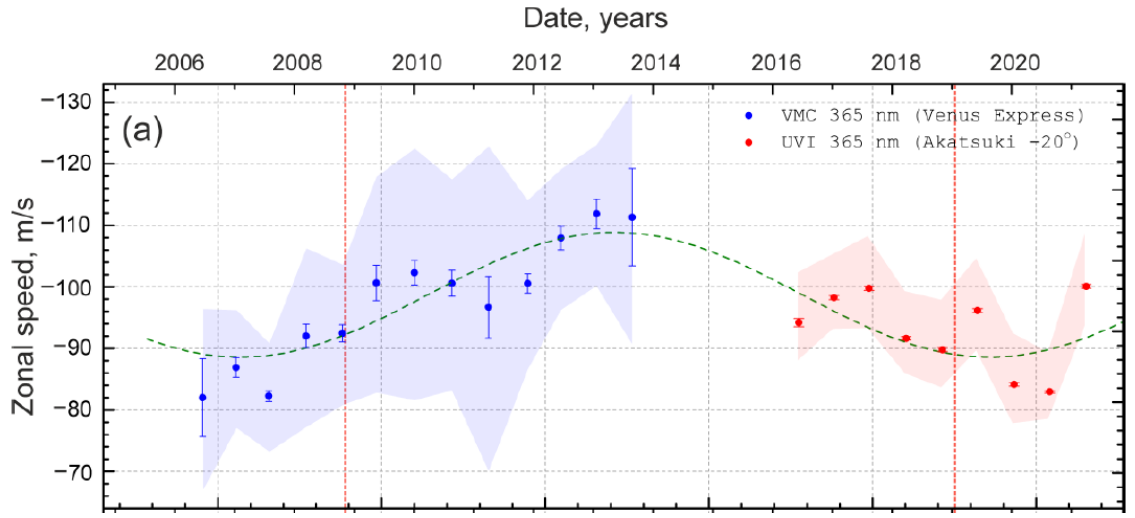
Fig. 17. Periodograms (a) and observation window spectra (b) for the low frequency range (0–0.01). The upper panel shows the original periodogram (solid line), the original periodogram after subtraction of the 3011 days trend (red dashed line), after subtraction of 117 days modulation (blue dots). The peak significance levels are shown to the right. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

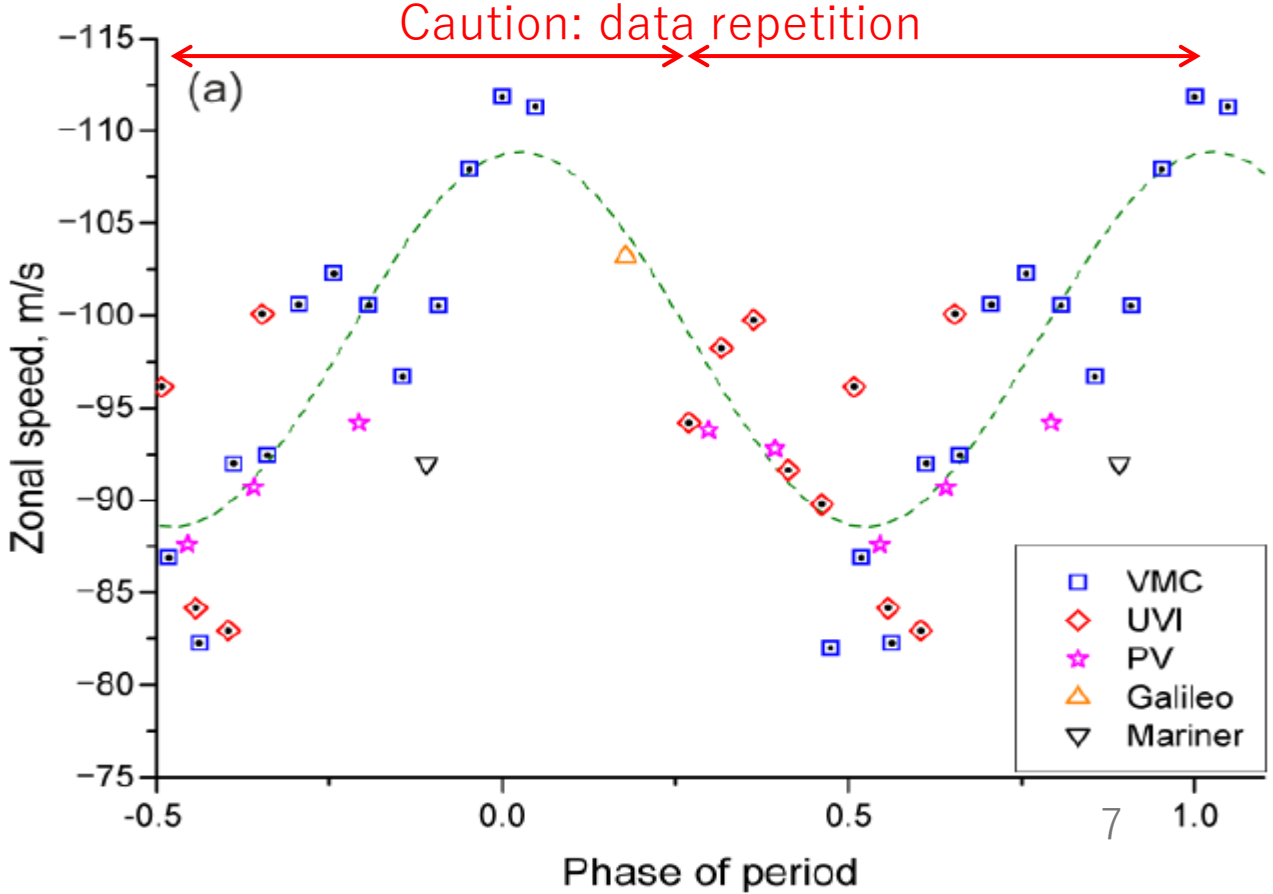
Khatuntsev+ (2023)

Suggested a 12.5-year periodicity of SR (possibly associated with solar cycle)

PVO 1979-85, VEx 2006-14, Akatsuki 2016-2022







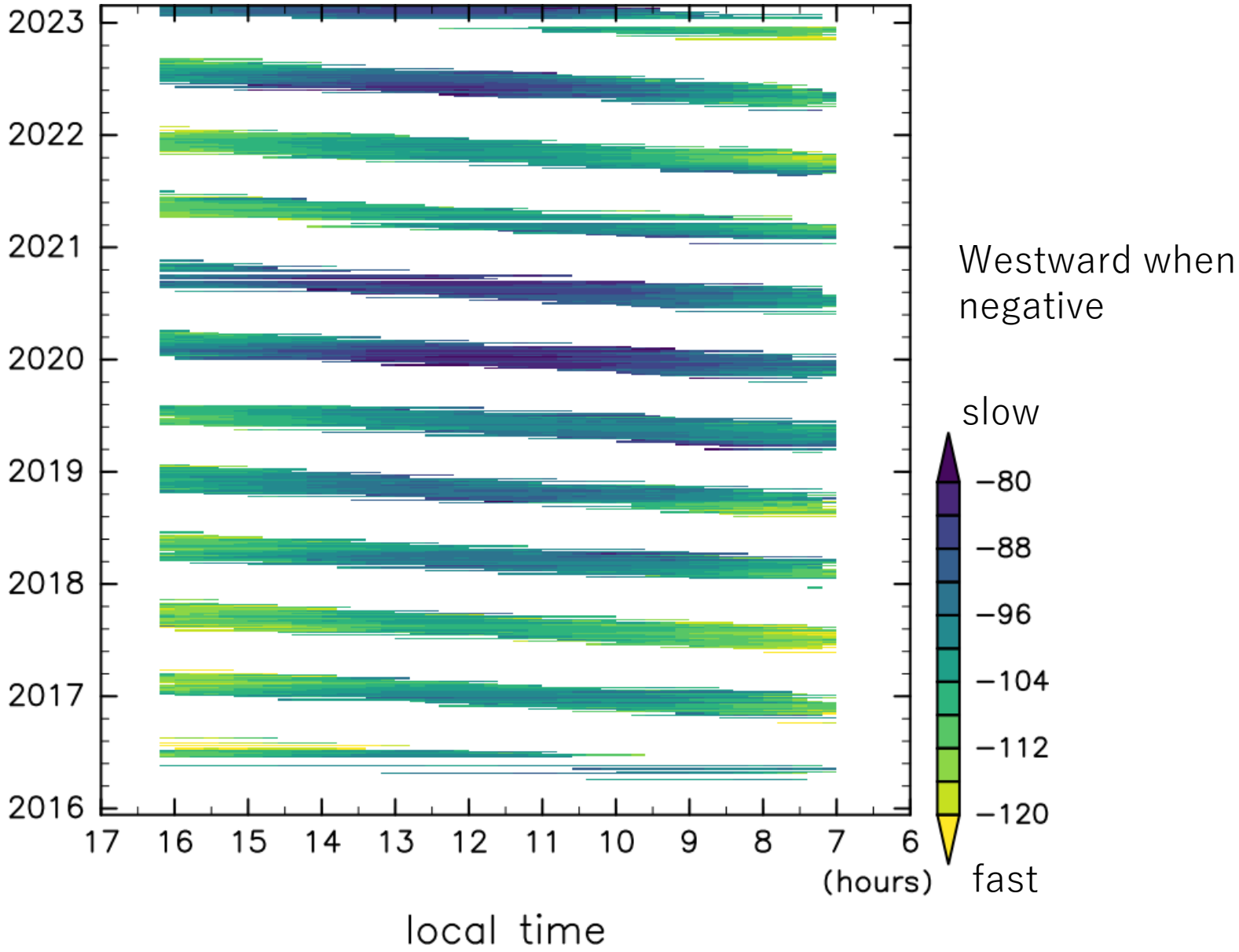
So...

Previous studies have sought for distinct periodicity in SR speed.

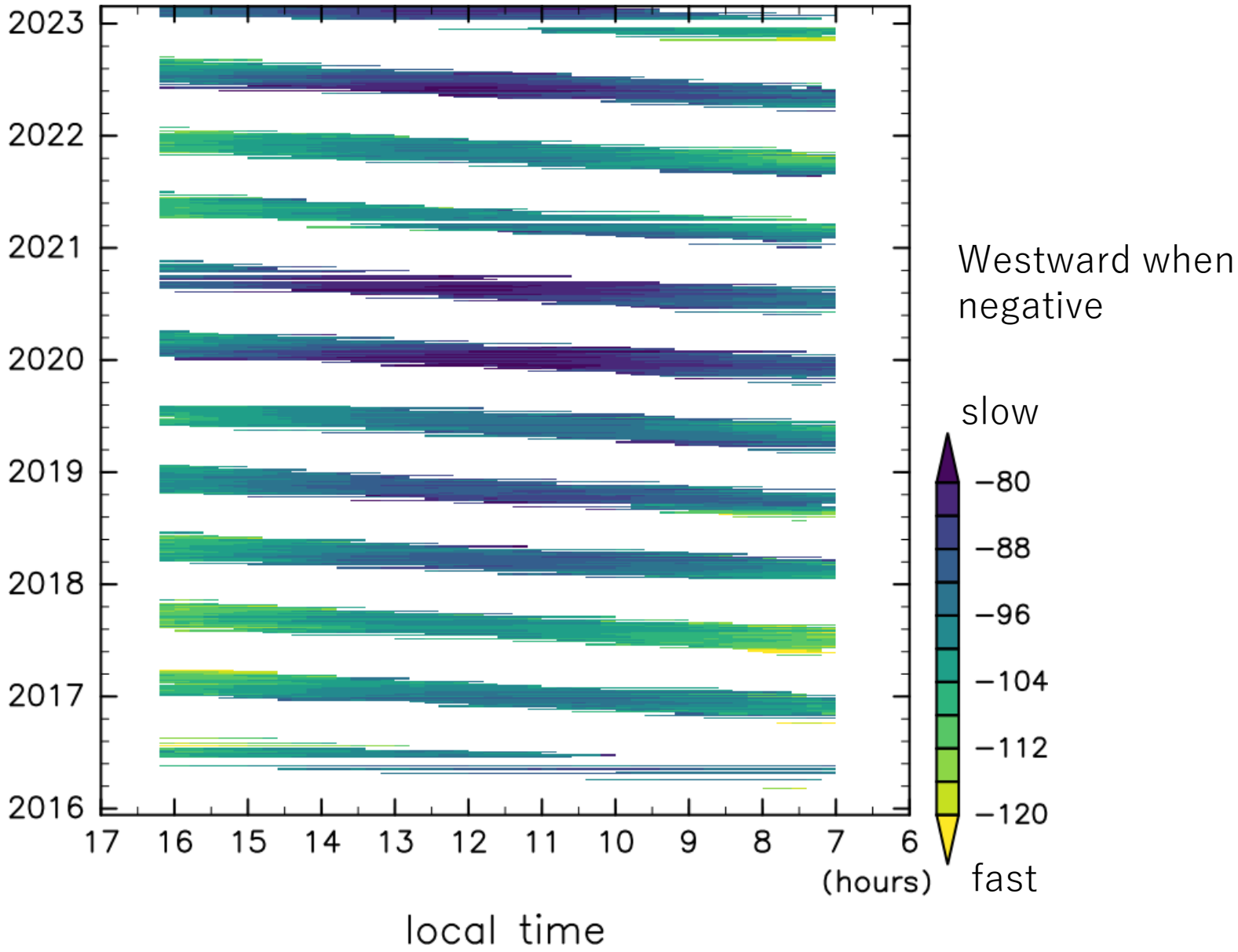
Is that a good approach?

Our results & findings

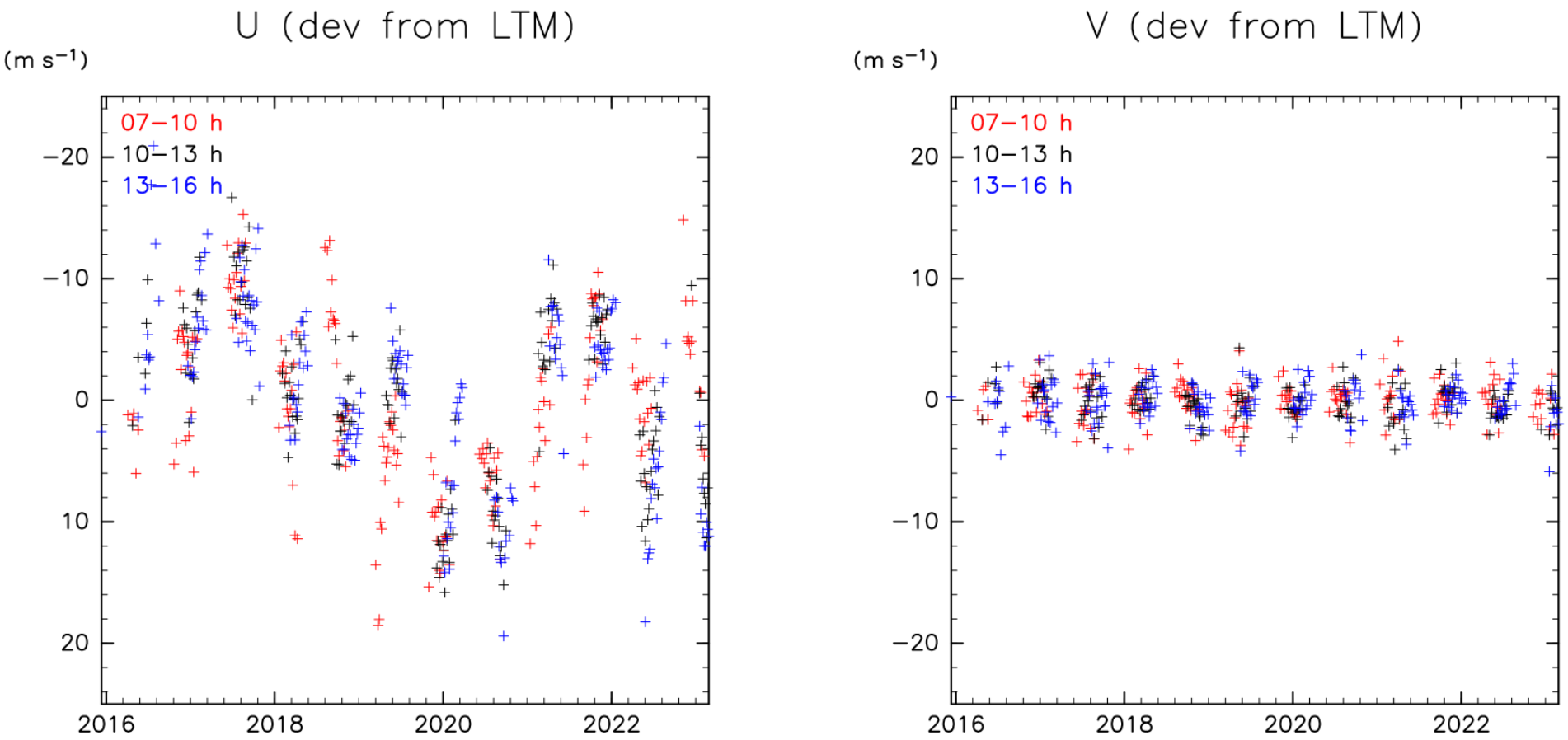
283-nm 5-day-mean zonal wind. Lat(avg): 20S-20N



365-nm 5-day-mean zonal wind. Lat(avg): 20S-20N



283-nm 5-day-mean winds (deviation from long-term mean for each LT) Lat(avg): 20S-20N



- U’ (eastward component anomaly): Rich low-frequency variations: no apparent dominance of single periodicity
- V’ (northward component anomaly): Weak low-frequency variations

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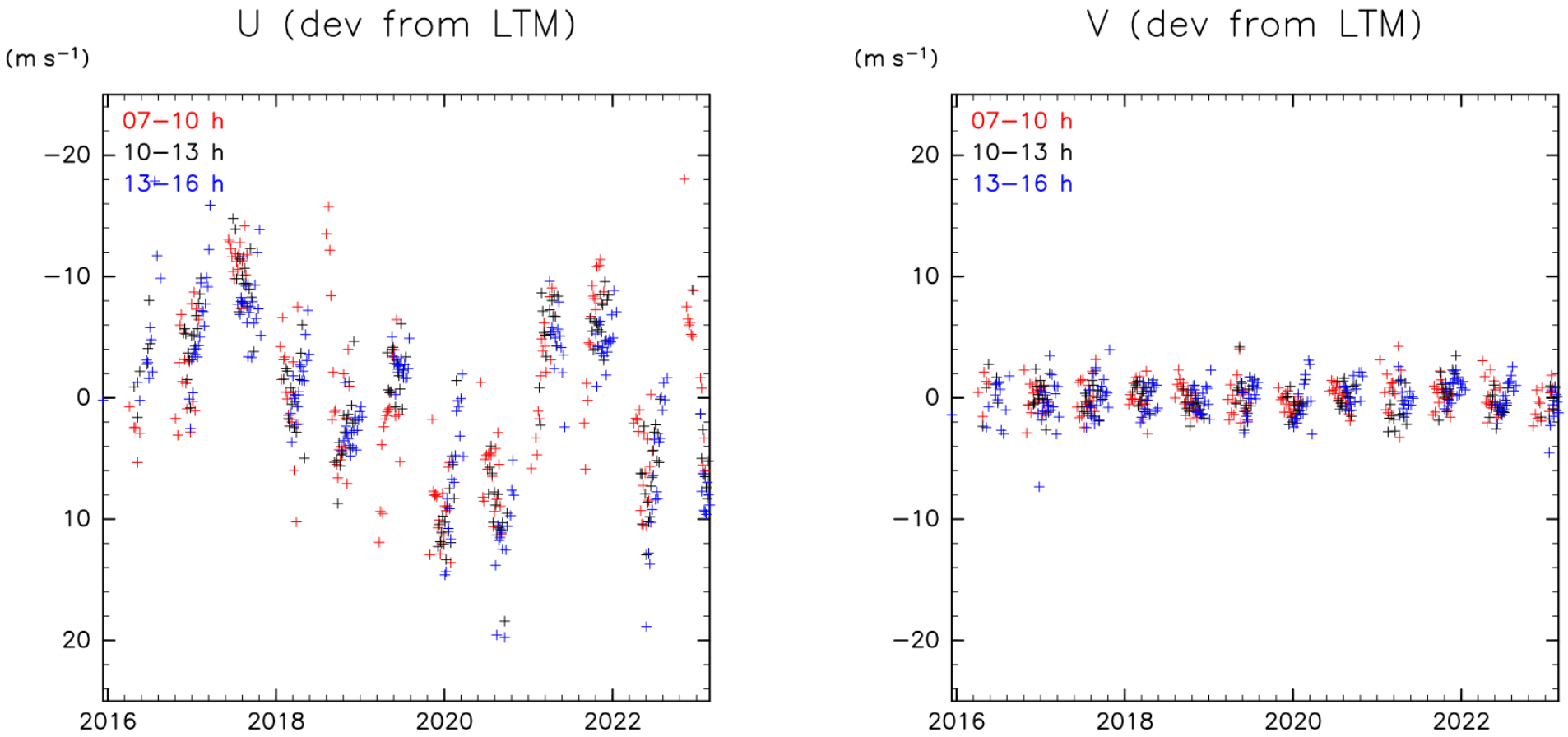

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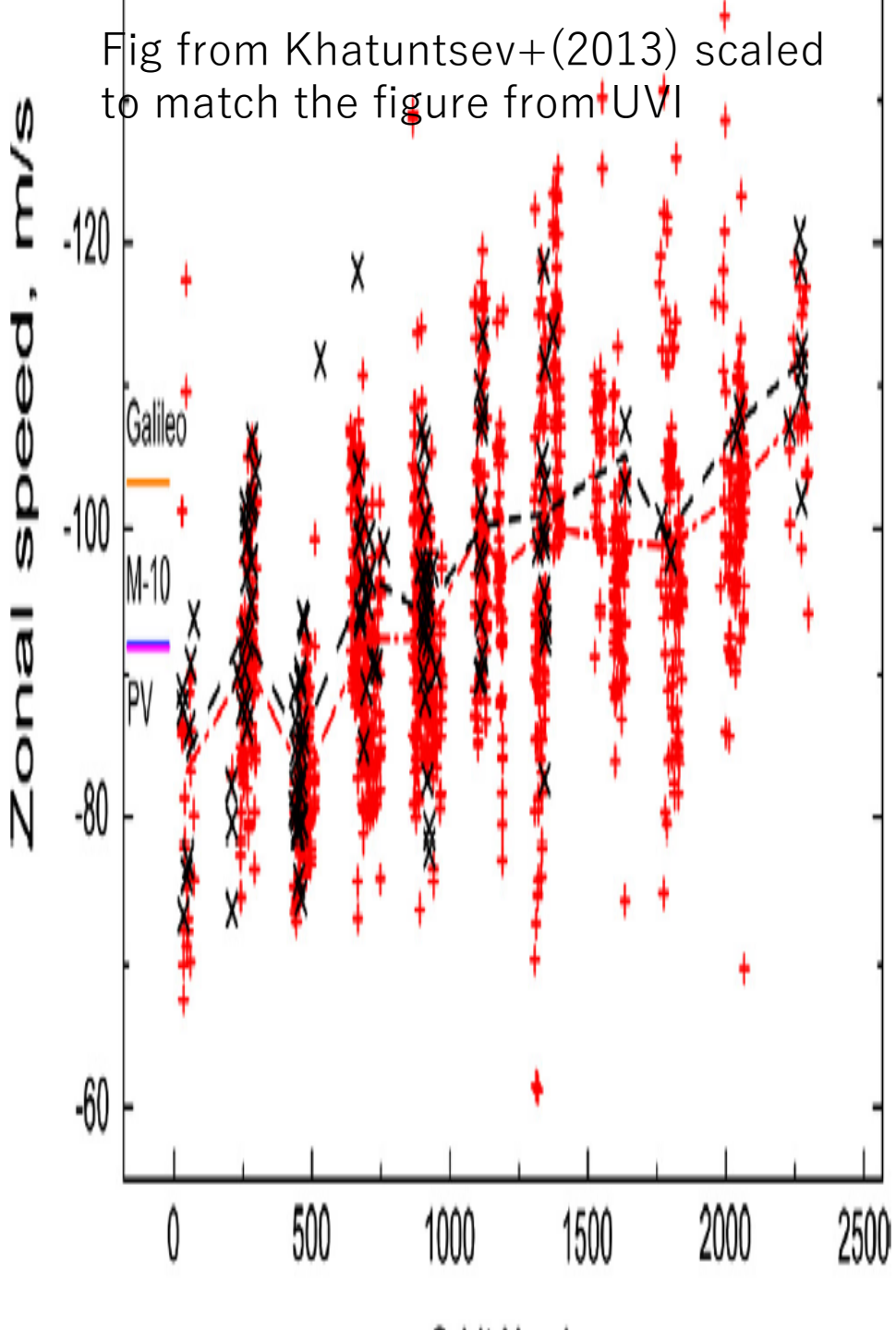
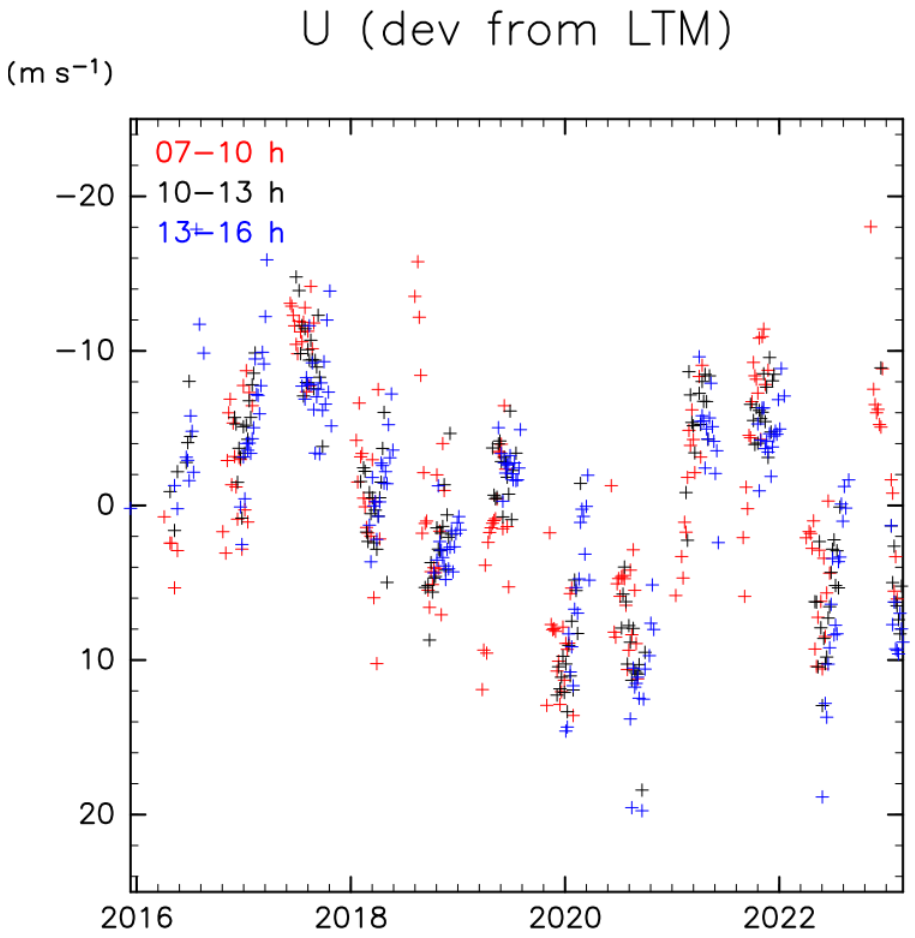
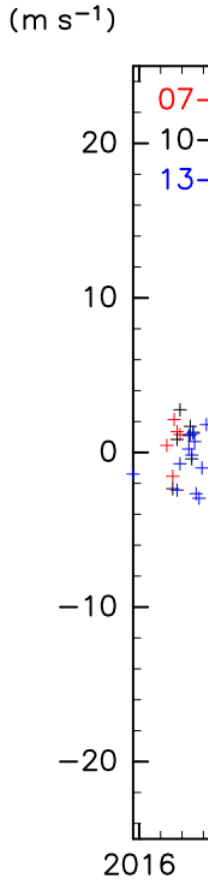
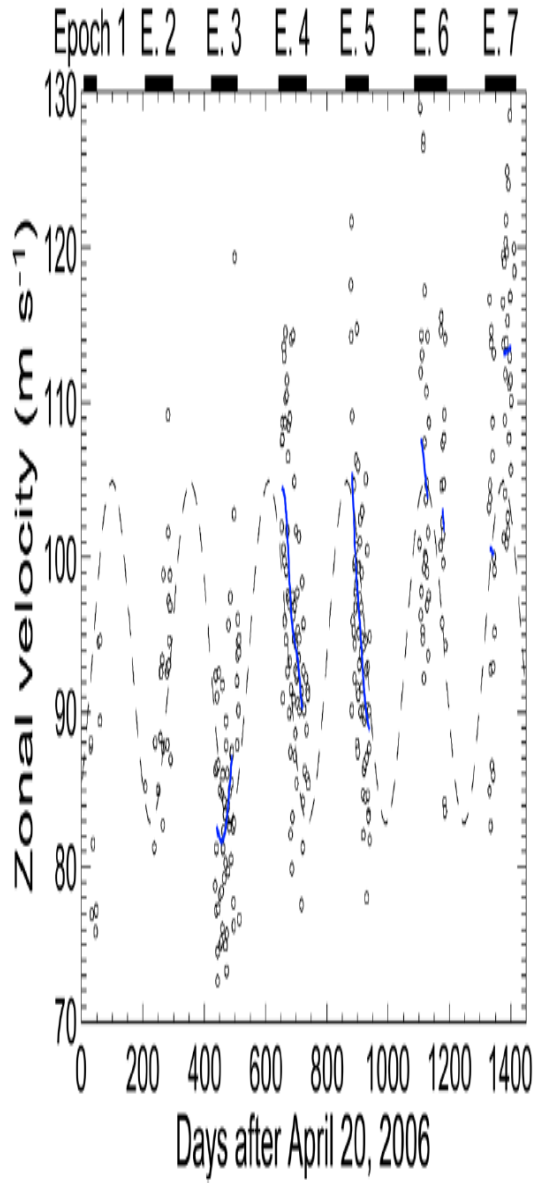
Fig from Khatuntsev+(2013) scaled to match the figure from UVI

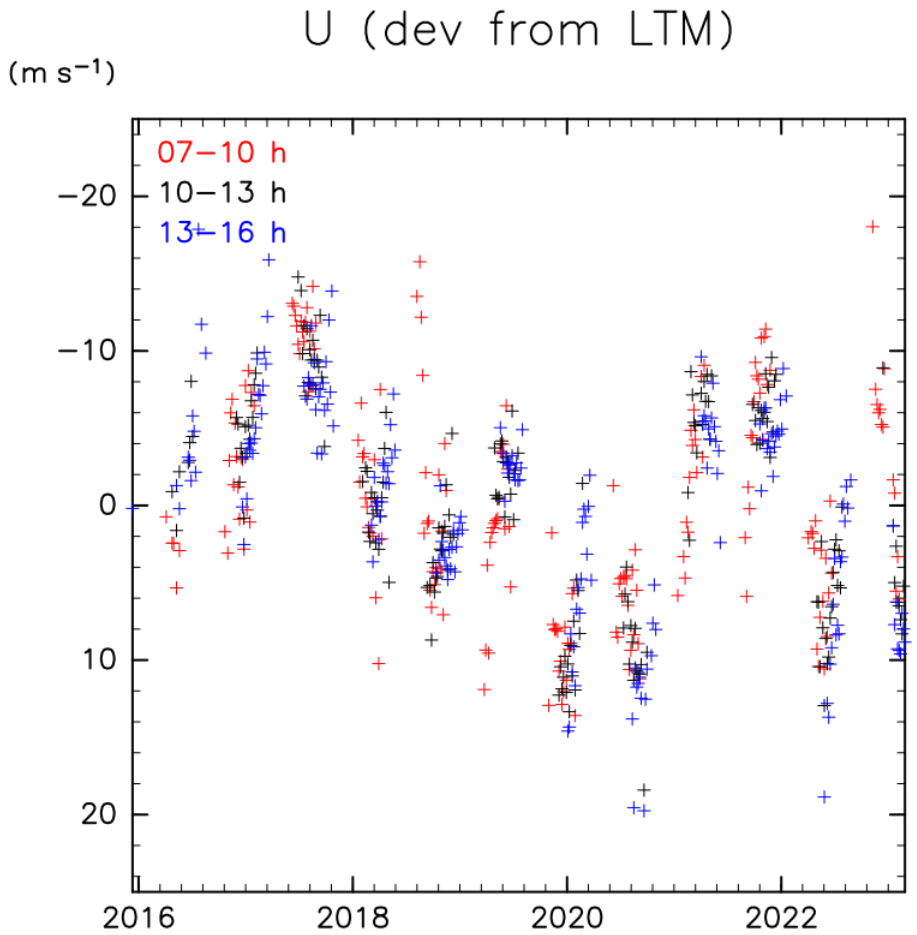


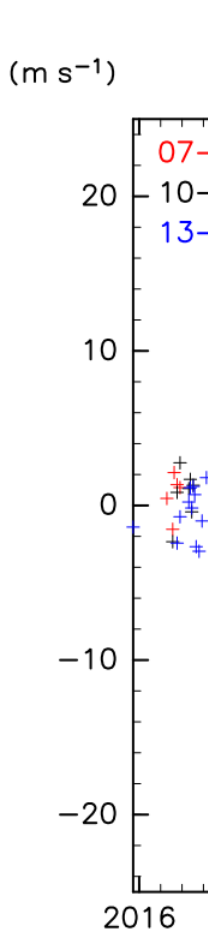




ltm_winds.rb cmv_48x48_nt3ll/daily_uvi_nmin3_365_eps20_pp0hvlen2.0_LT.nc --epsmax 20 --latran −20..20 --uran 25..−25 --ed







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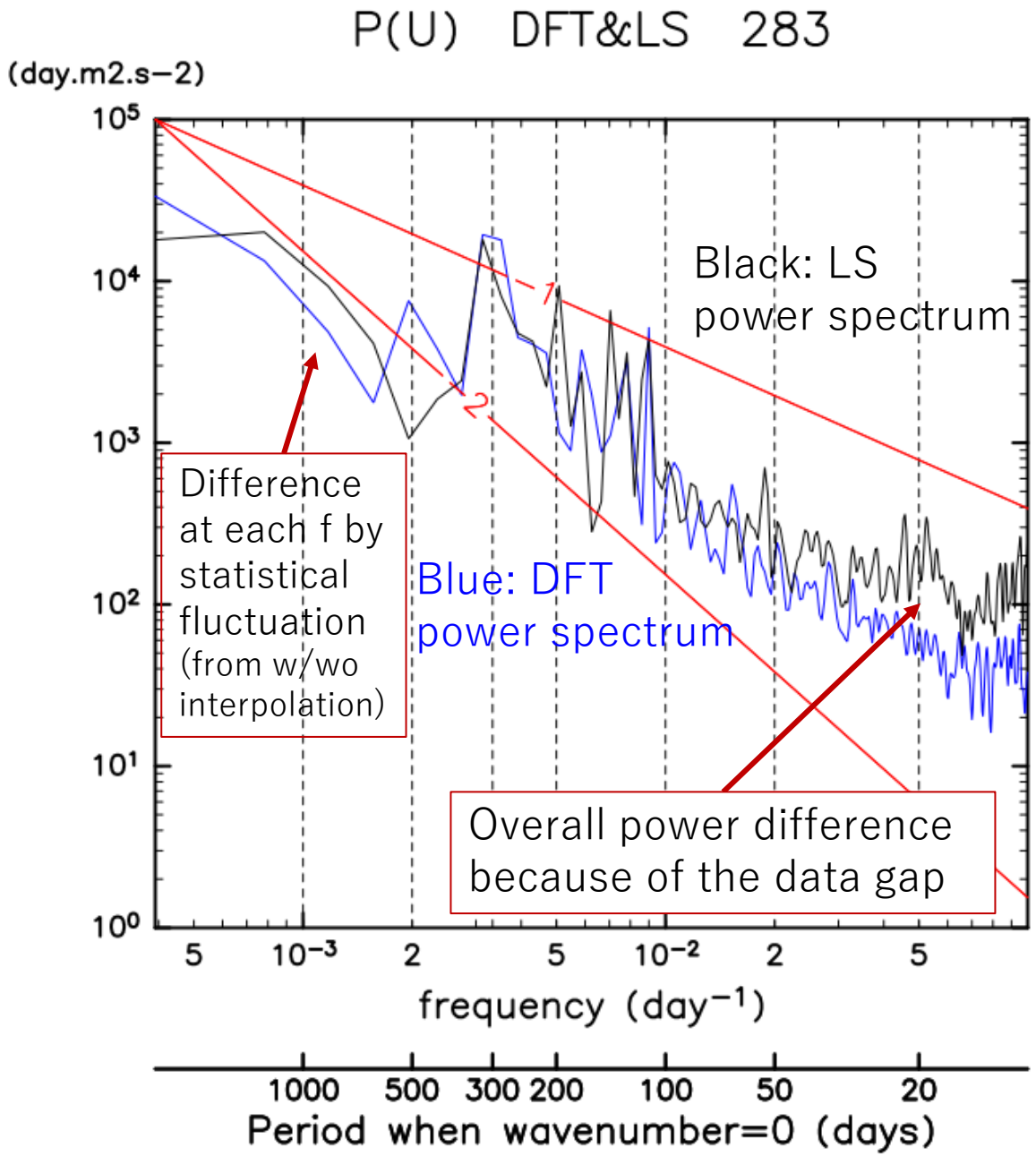
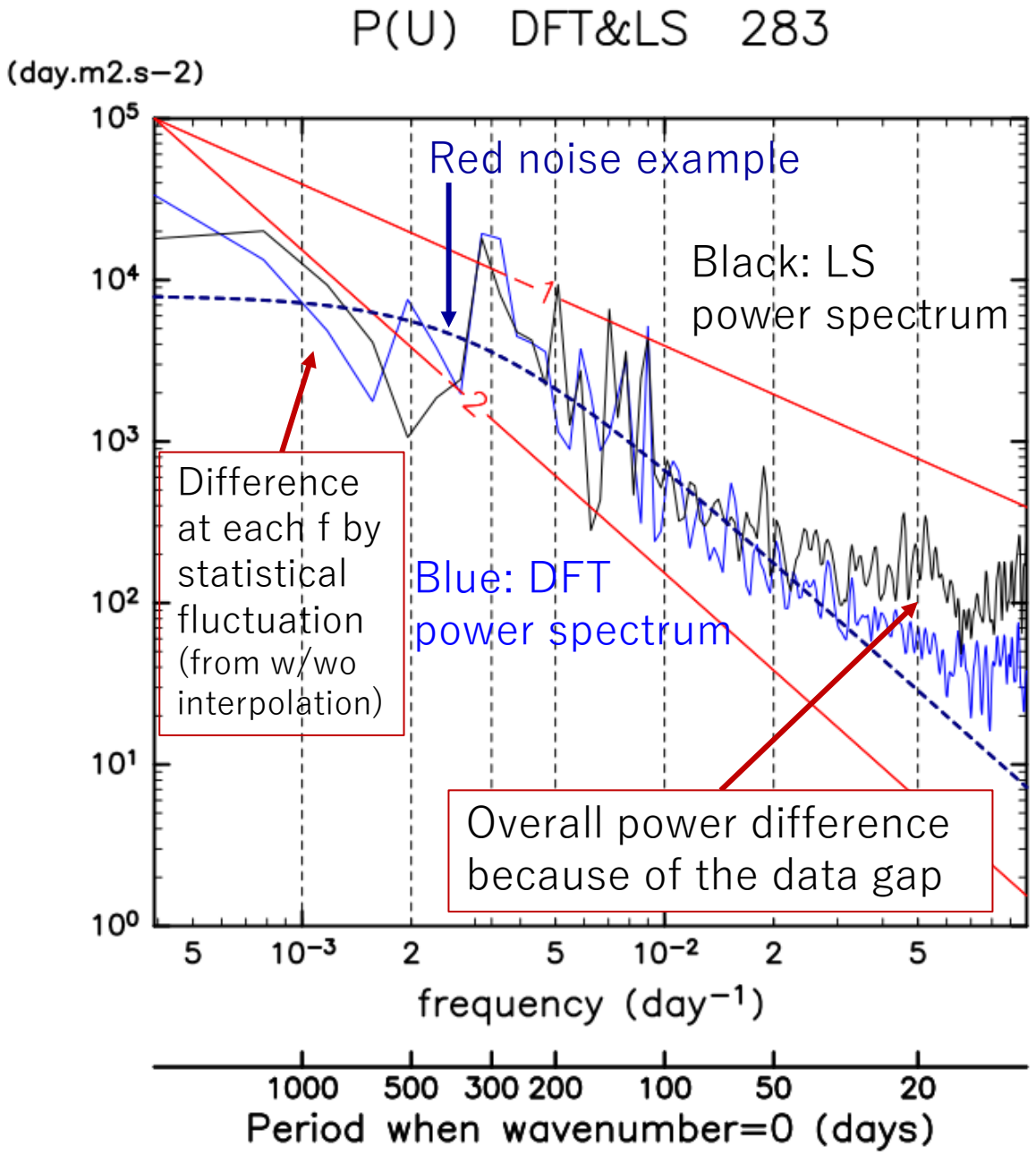


- Used daily mean U from 2016-03 to 2023-02
- longitude grid → LT grid & longtime mean at each LT&lat are subtracted to remove tidal component
- Binned over latitude for every 9° between 30S-30N
- Averaged over LT for each day to reduce temporal data gap
- Then LS and DFT power spectrum is computed and averaged over 30S-30N (DFT ← interpolate)
- Smoothed with f by the 1:2:1 filter once for f>0.01, twice for f>0.02 and three times for f>0.04



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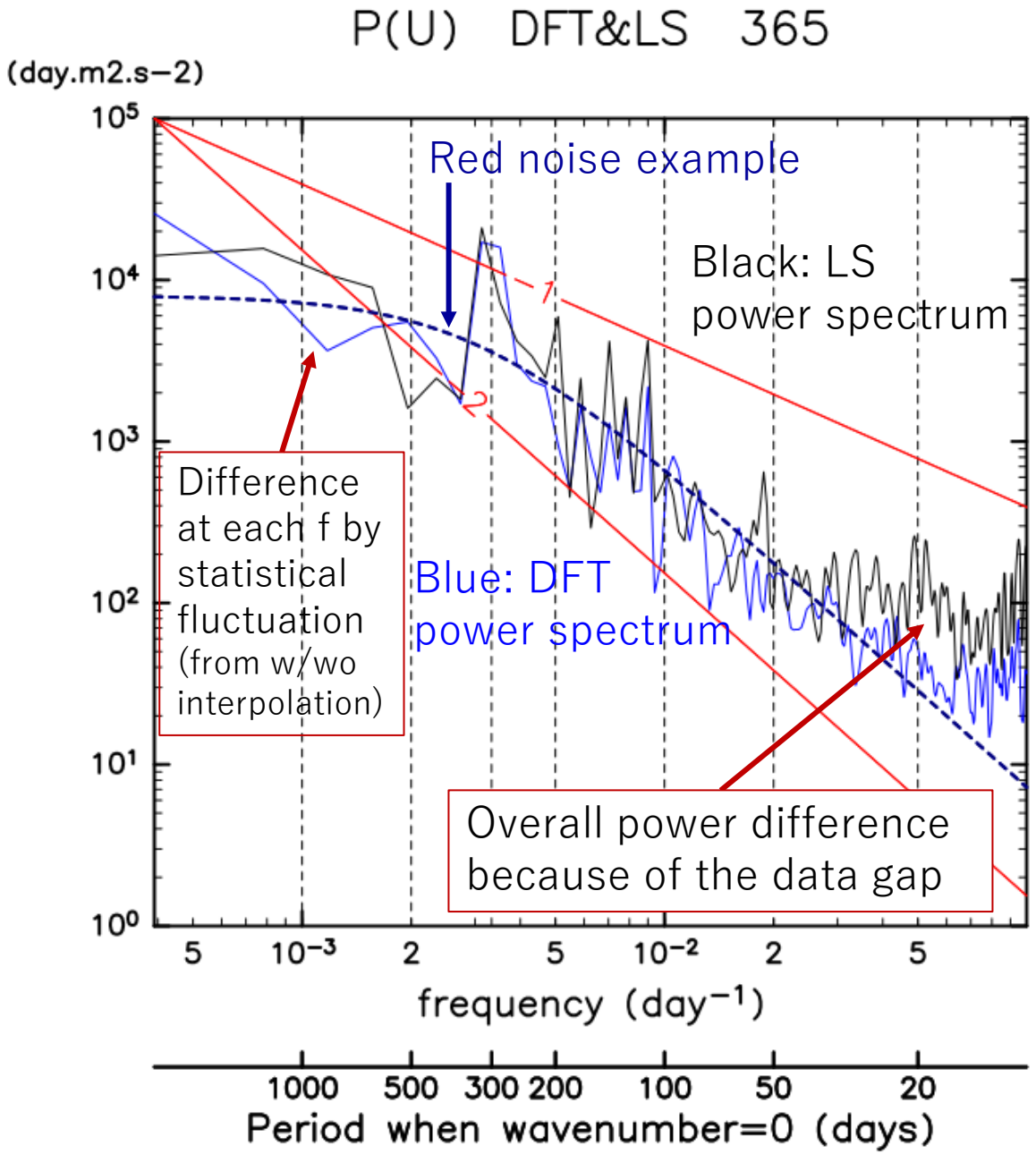

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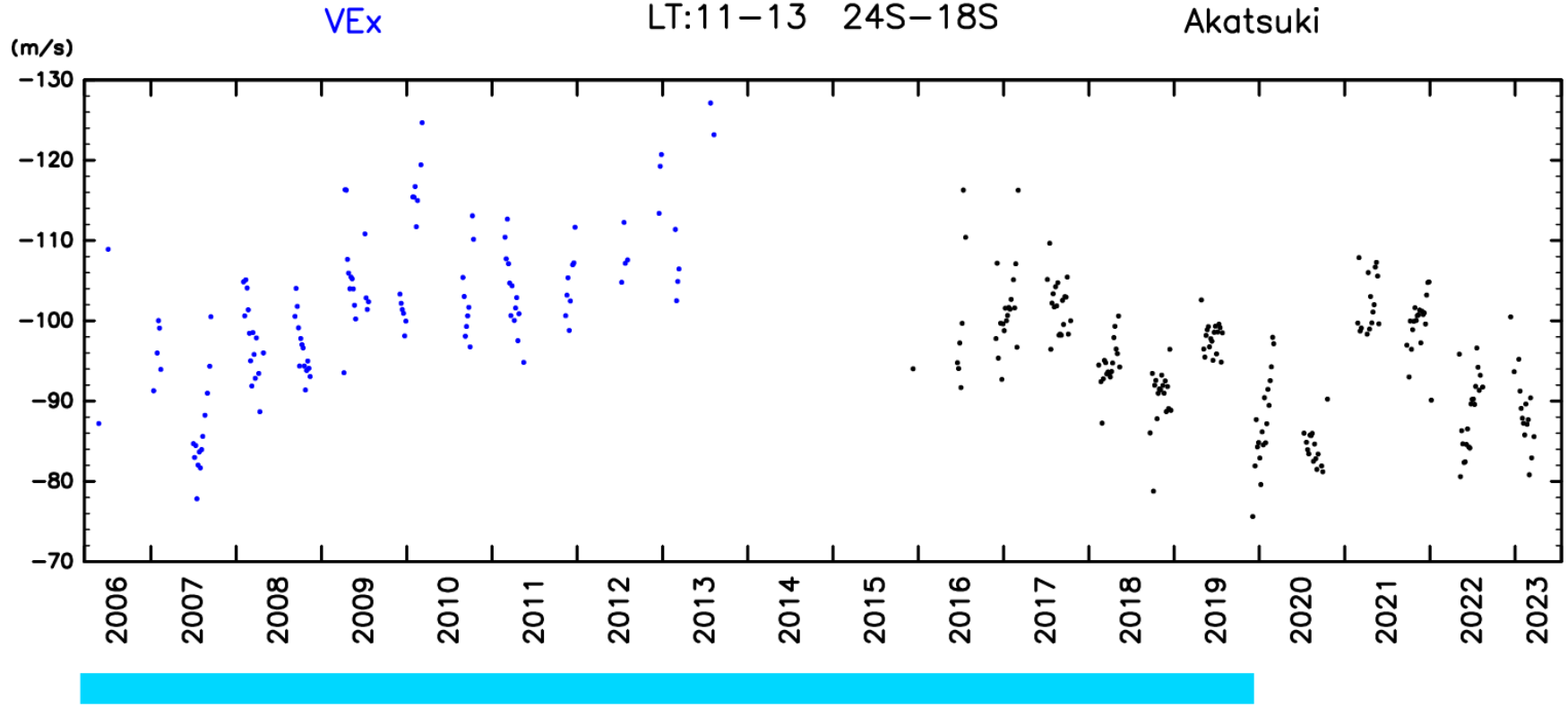
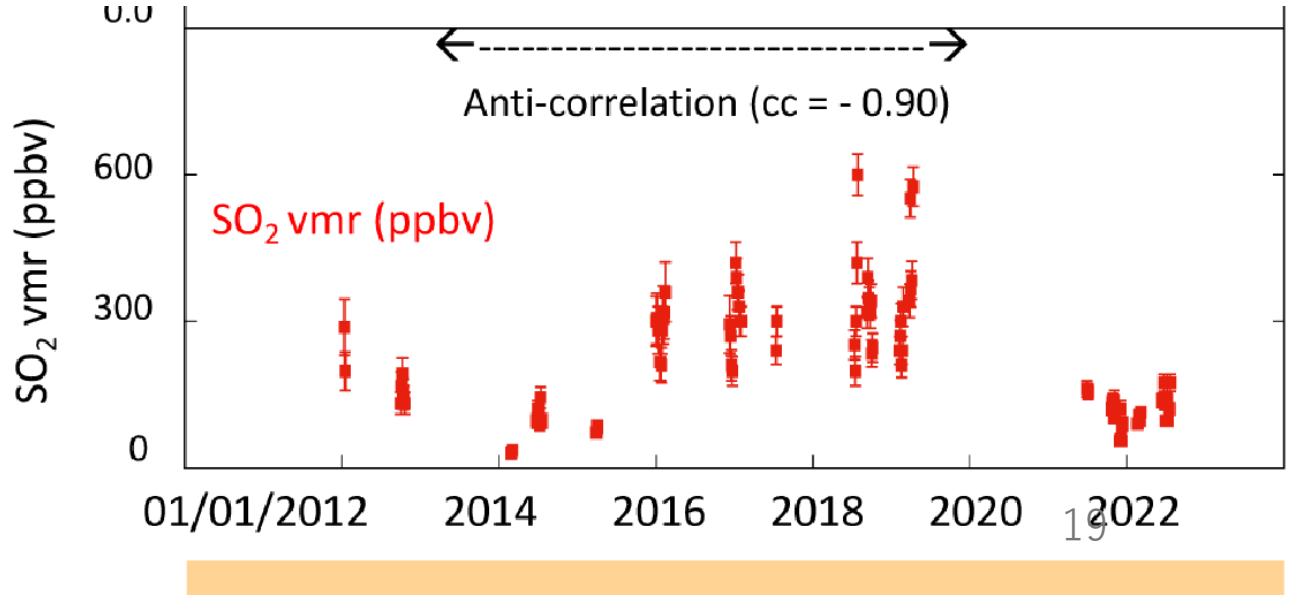
Mean winds and minor constituents (ground-based observations by Encrenaz et al. 2023)



- SO2



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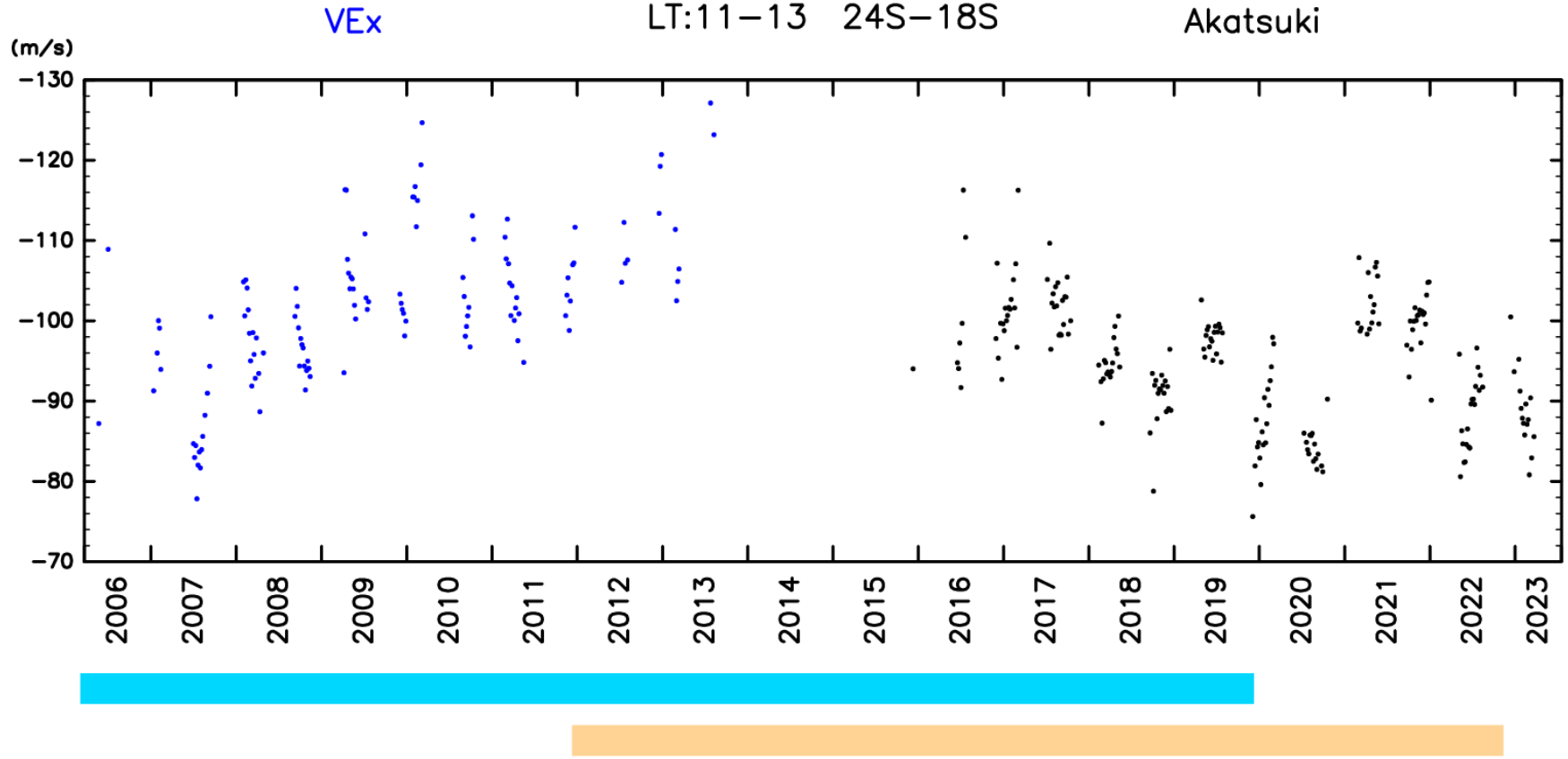
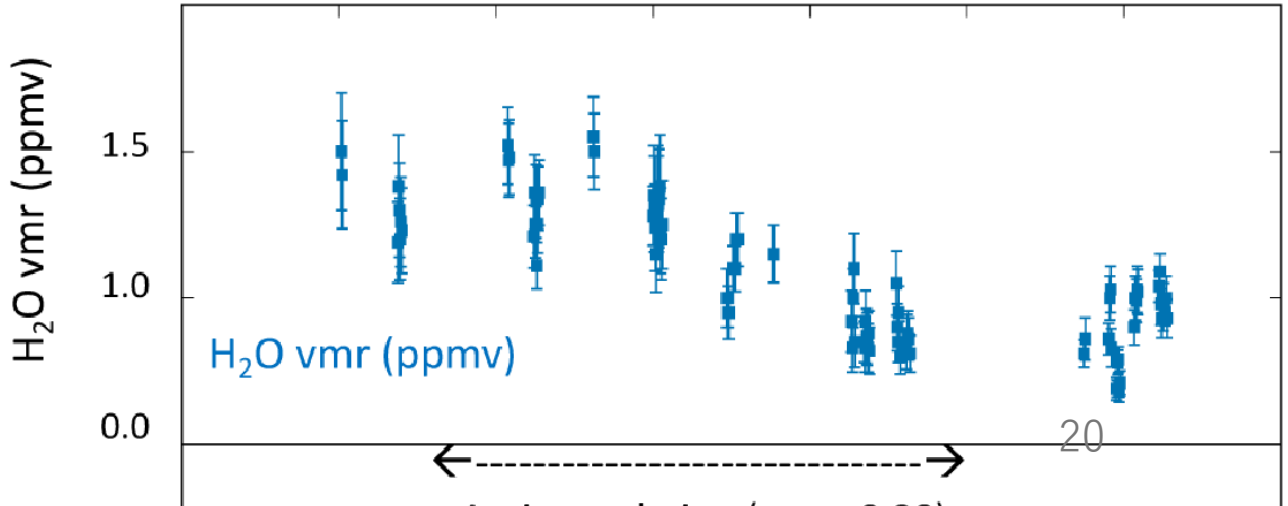


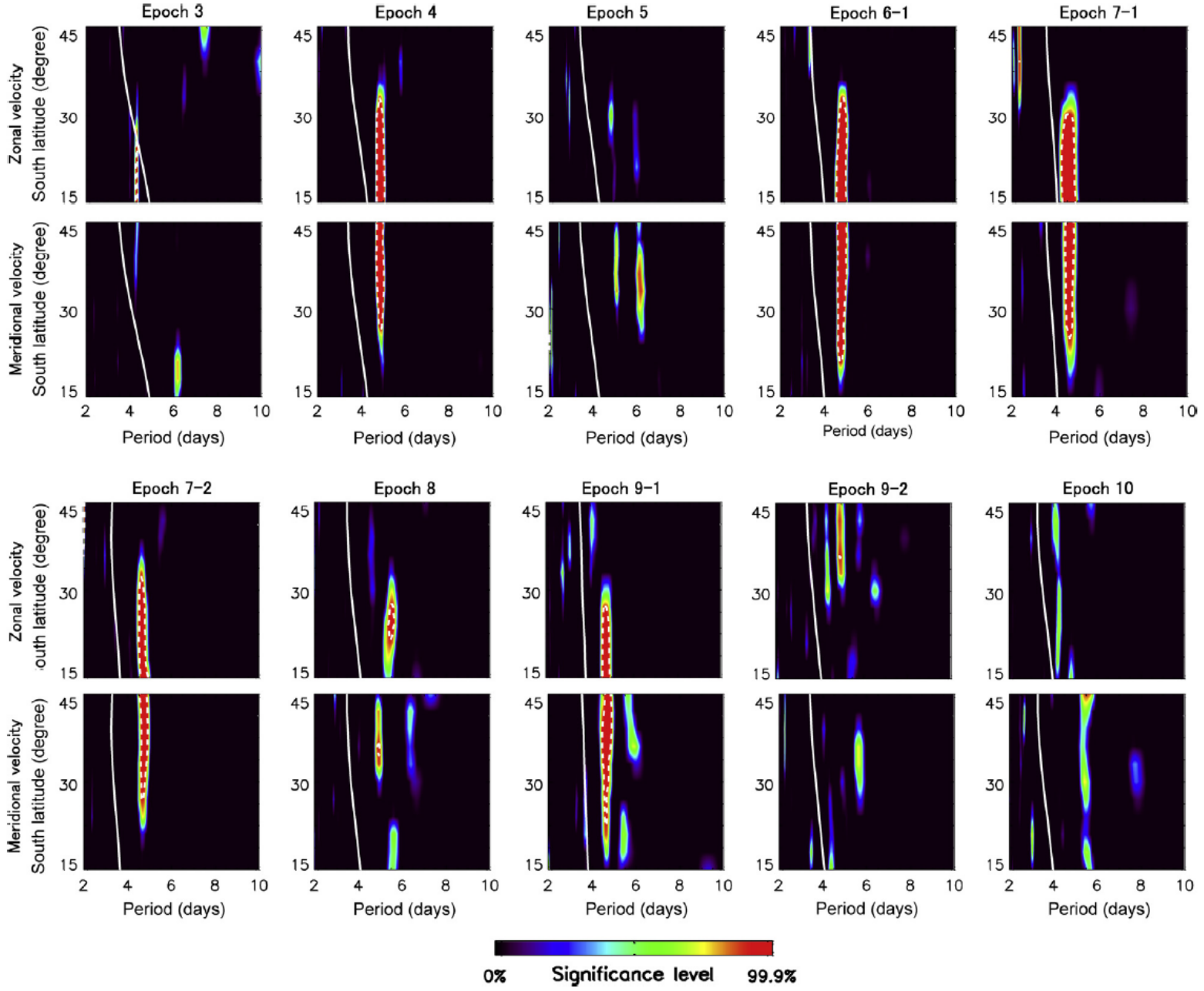
(c) Encrenaz et al. (2023) Fig.10

- H2O from HDO



Variability of planetary-scale waves (and their origins)

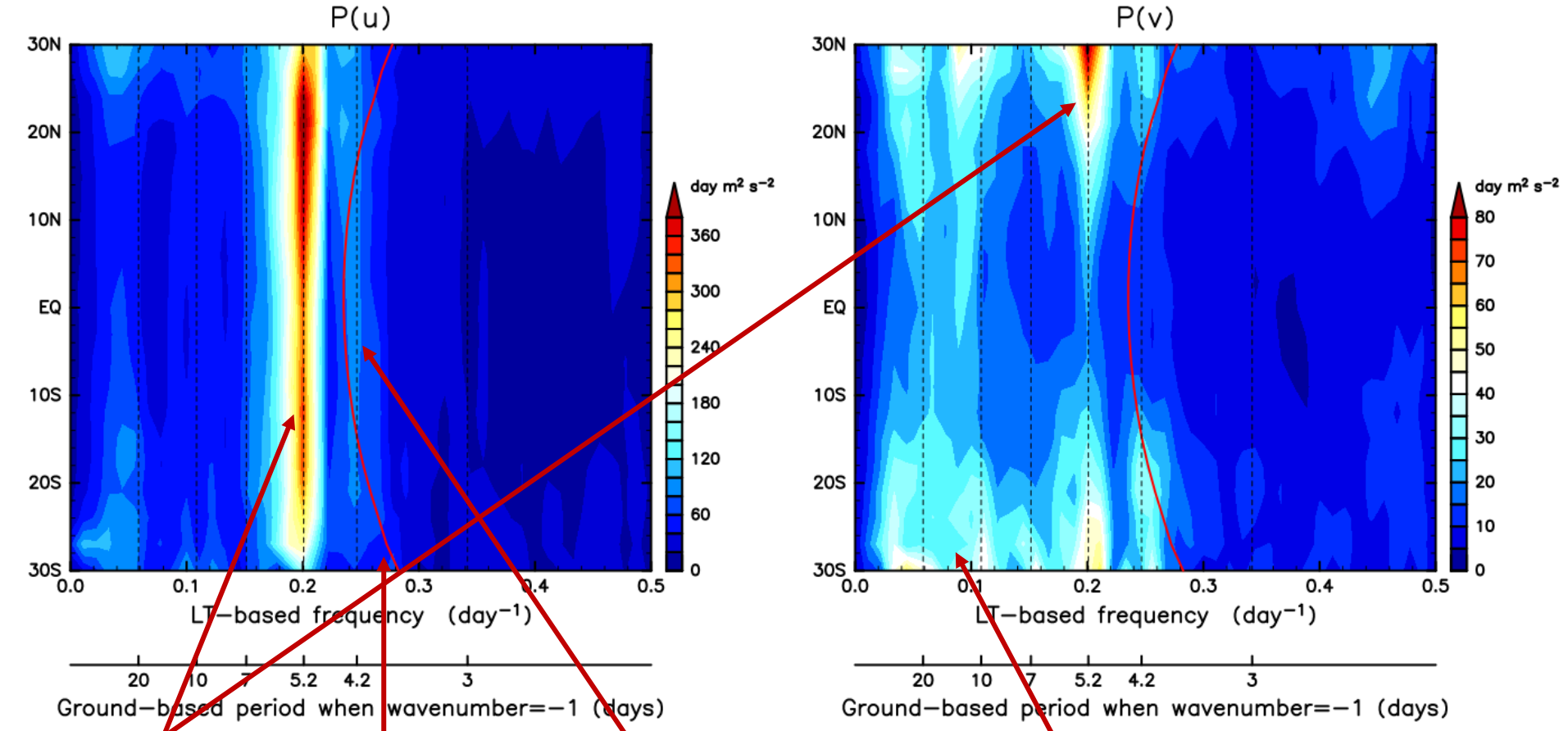
Kouyama et al (2013) Detection of “Kelvin-wave” or “Rossby-wave” signals (depending on observational sub-periods)



Our results & findings

Planetary-scale waves etc. 283 nm

(Mean of the spectra for the 11 sub-periods (from the 2nd).
Used the deviation from the 31-day running mean)



Rossby wave (or possibly Rossby-Kelvin wave)

Mean wind

Kelvin wave (or possibly…)

10 – 20-day variability (may not be waves?)

Planetary-scale waves etc. 365 nm

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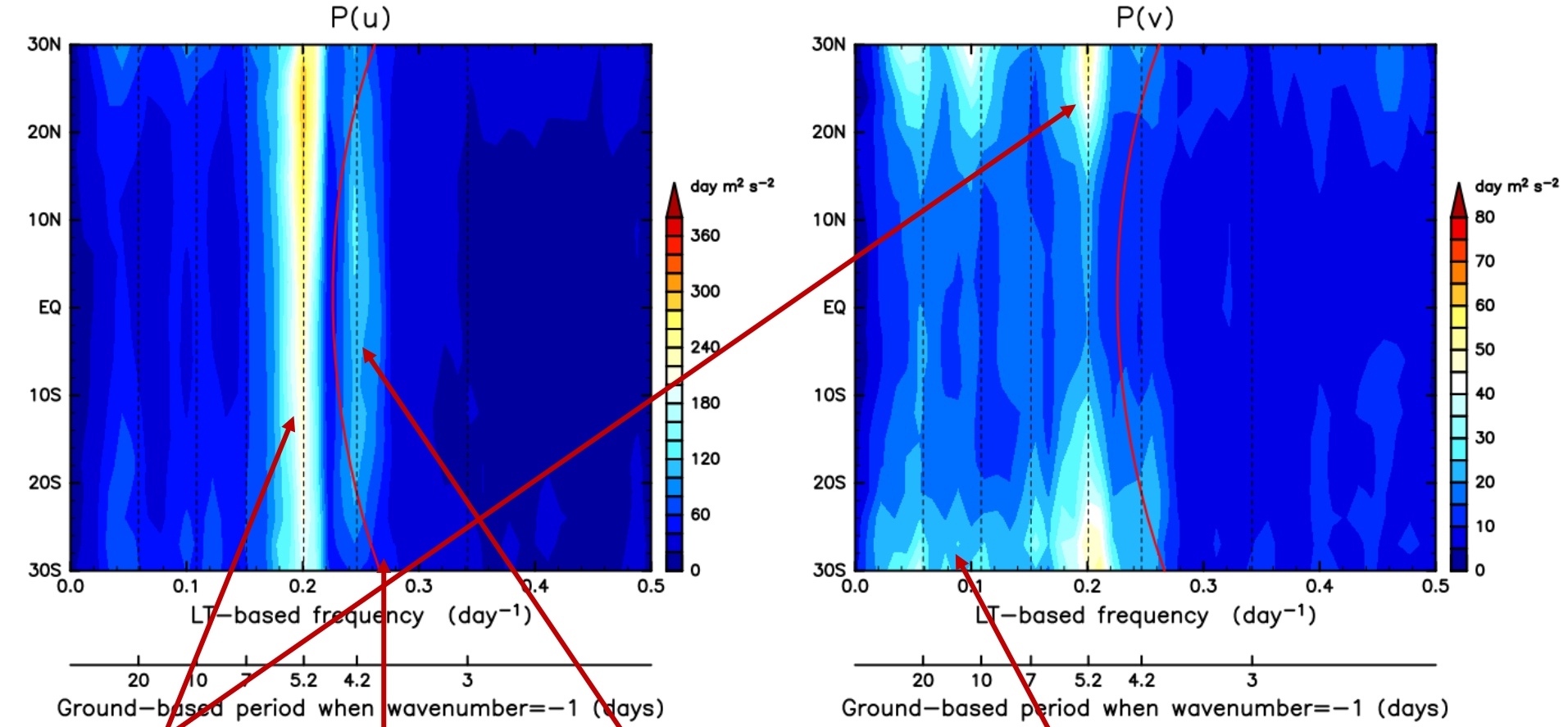

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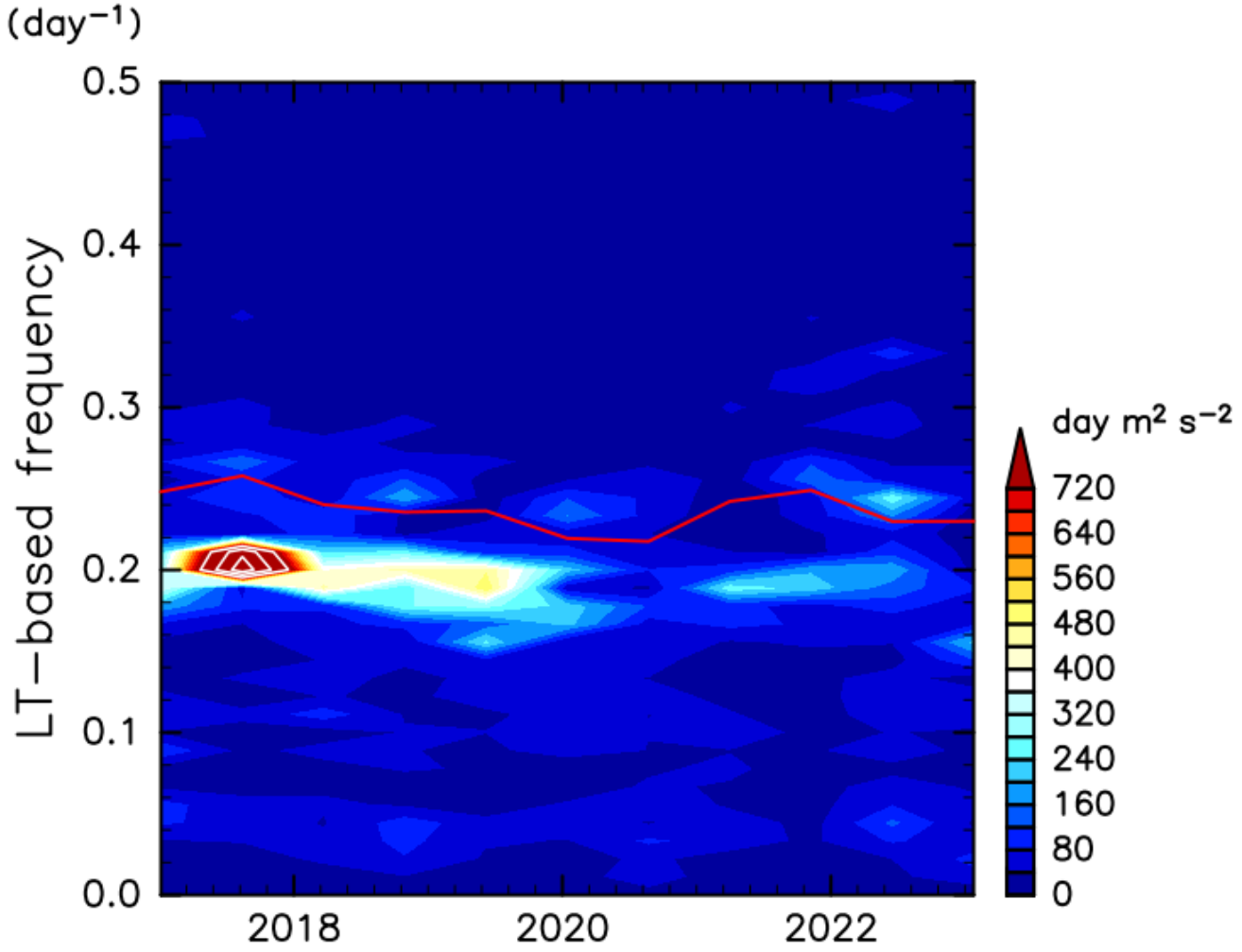
Time sequence over the 11 sub-periods



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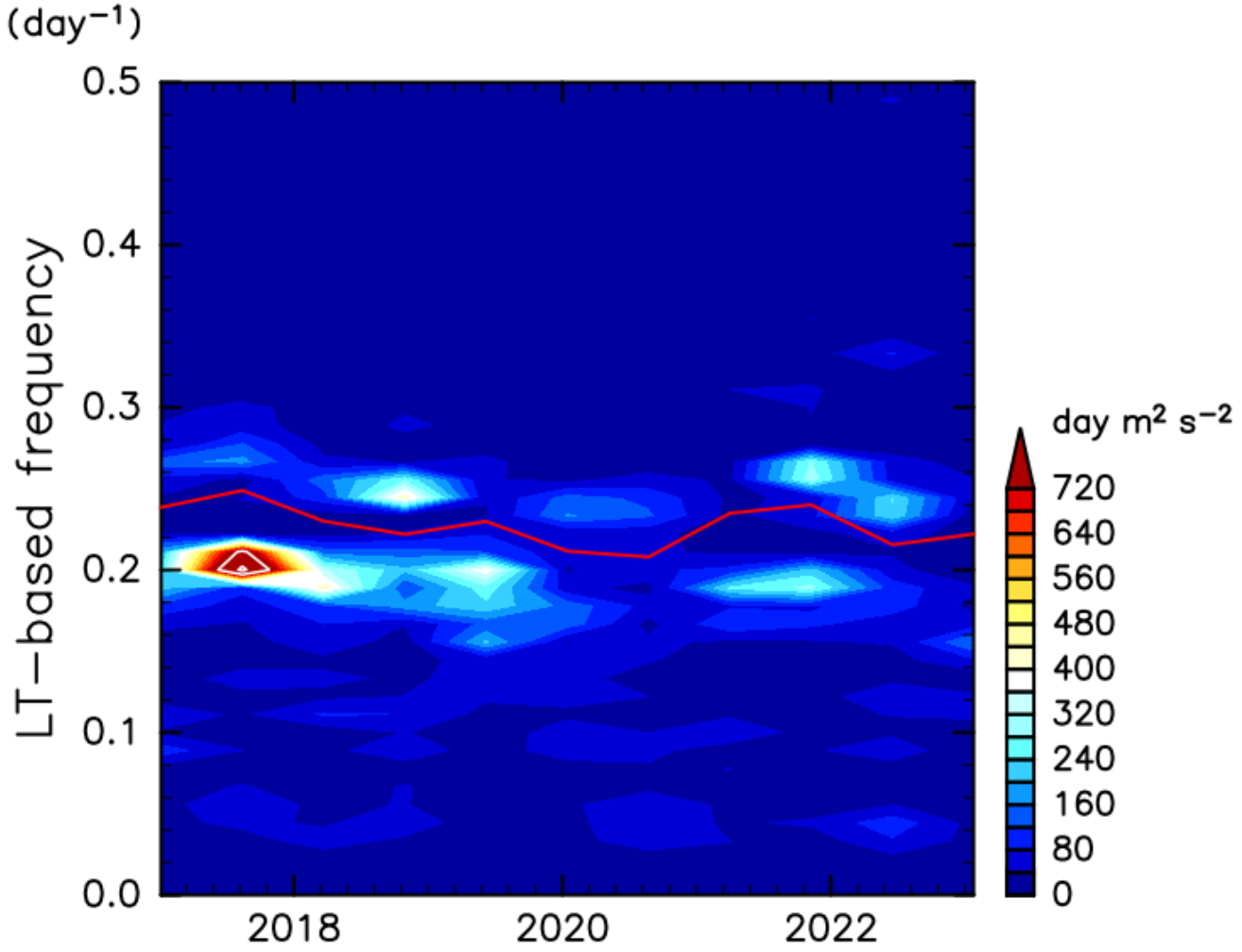

Summary

- Mean winds (SR strength): Low-frequency variability has rich spectra
  - ~Red noise spectra (e.g., from random forcing + relaxation)
  - No obvious distinct periodicity (200-300 d power is not distinct; 12.5 y cycle is unlikely)
  - **Indicating internal variability** rather than periodically forced variability
  - [see H2024 paper] Hemispheric asymmetry varies with time
  - Many pitfalls in spectral analysis; be cautious (see H2024 paper)
- Variations of SR & SO2 are not correlated (weak correlation btwn SR & H2O but need more observations)
- Planetary-scale waves: spectral features change according to mean winds
  - “Kelvin wave” (travelling faster than SR)
    - Frequency changes along with the background wind
    - **Indication: shallow vertical extension (around cloud top); from ~horizontal Rossby-Kelvin coupling?**
  - “Rossby wave” (travelling slower than SR)
    - Frequency changes only slightly
    - Amplitude is greater when the intrinsic frequency is large
    - **Indication: extends to lower clouds; from ~vertical Rossby-Kelvin coupling?**
- Found 10—20-day variability (wave or not?)