

Characteristics of pulsation signatures during the April 2023 Geomagnetic Storm

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Problem statement

- What is the frequency distribution of magnetic pulsations in different geomagnetic activities?
- How does the strength of these pulsations evolve during the geomagnetic storm of 23–24 April 2023?

Background

- Magnetic pulsations are ultra-low frequency (ULF) oscillations in Earth's magnetosphere, typically observed in ground-based magnetometer data as variations in the magnetic field (δB). Driven by solar wind–magnetosphere interactions, their frequency structure reflects distinct physical processes, and their spatial distribution depends on latitude and local time (refer to Table 1).

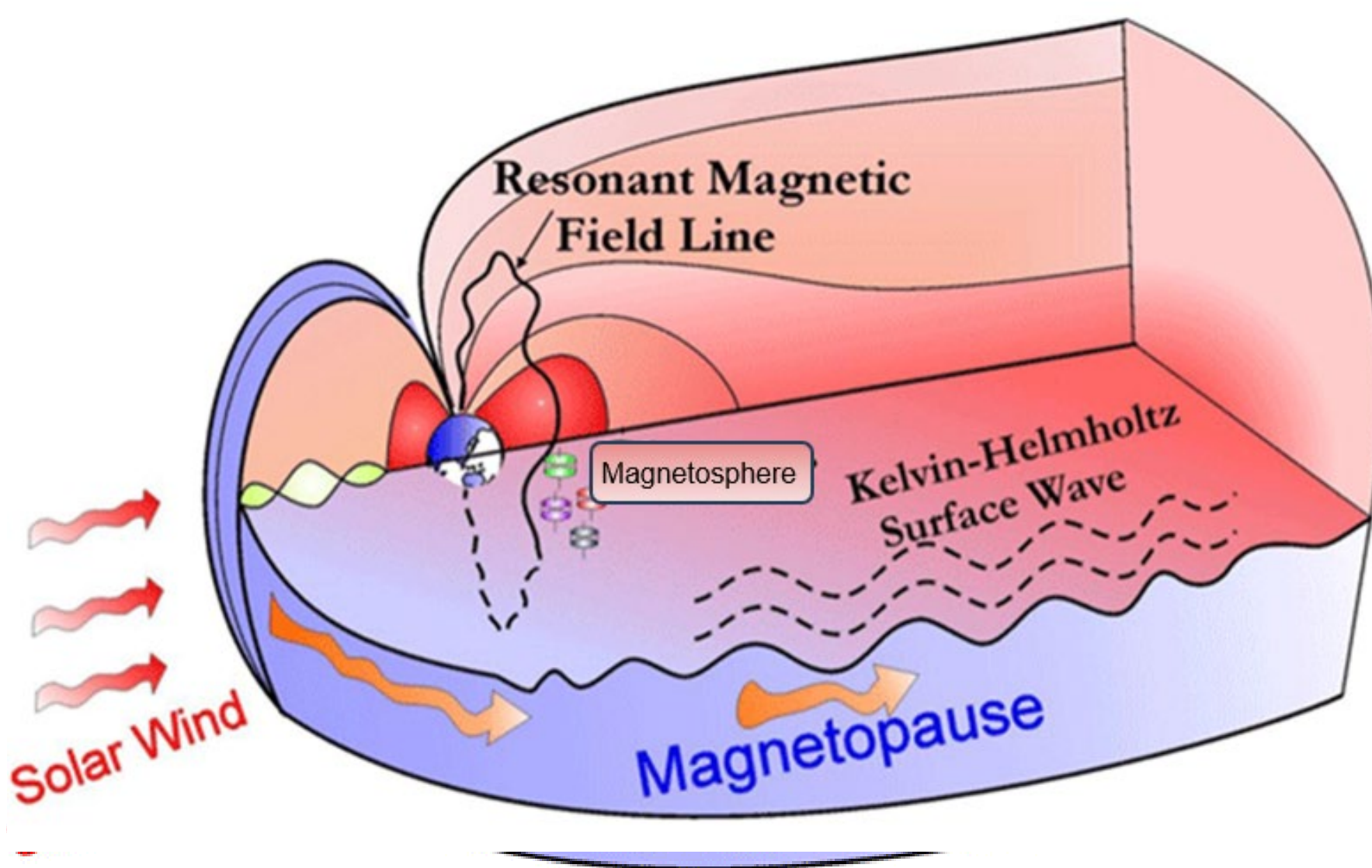


Figure 1: Pulsation activity in Earth's magnetosphere

Notation	Frequency Range (mHZ)	Common Causes
Pc1	200 – 5000	wave–particle interactions in the radiation belts
Pc2	100 – 200	plasma instabilities
Pc3	22 – 100	interaction with Earth's bow shock; IMF control
Pc4	7 – 22	Field line resonances
Pc5	1.7 – 7	Solar wind pressure pulses, Kelvin–Helmholtz instability
Pi1	100 – 5000	Substorm
Pi2	6.7 – 25	magnetospheric substorm onset

Table 1: Classification of Pulsations

Data & Methods

- Use AMPERE, SuperMAG, Omni data to identify substorms and other solar wind drivers
- Ground Magnetometer data processing:

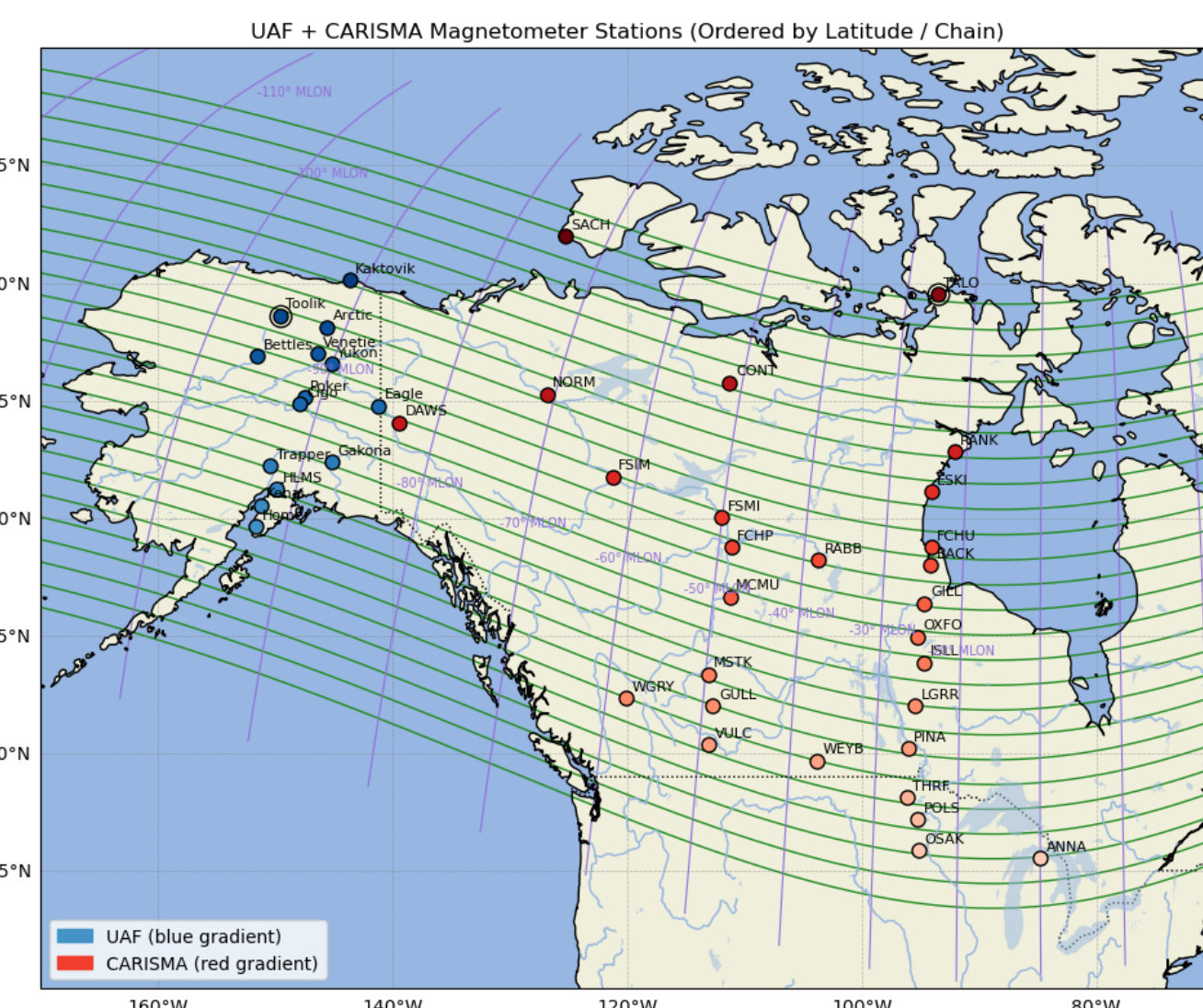
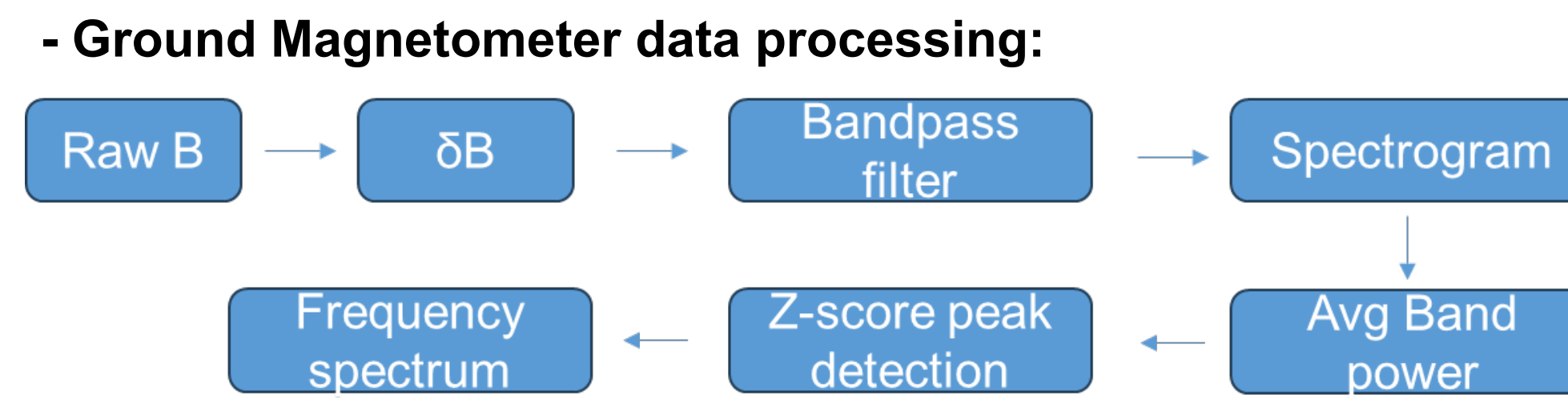


Figure 2: Ground magnetometers

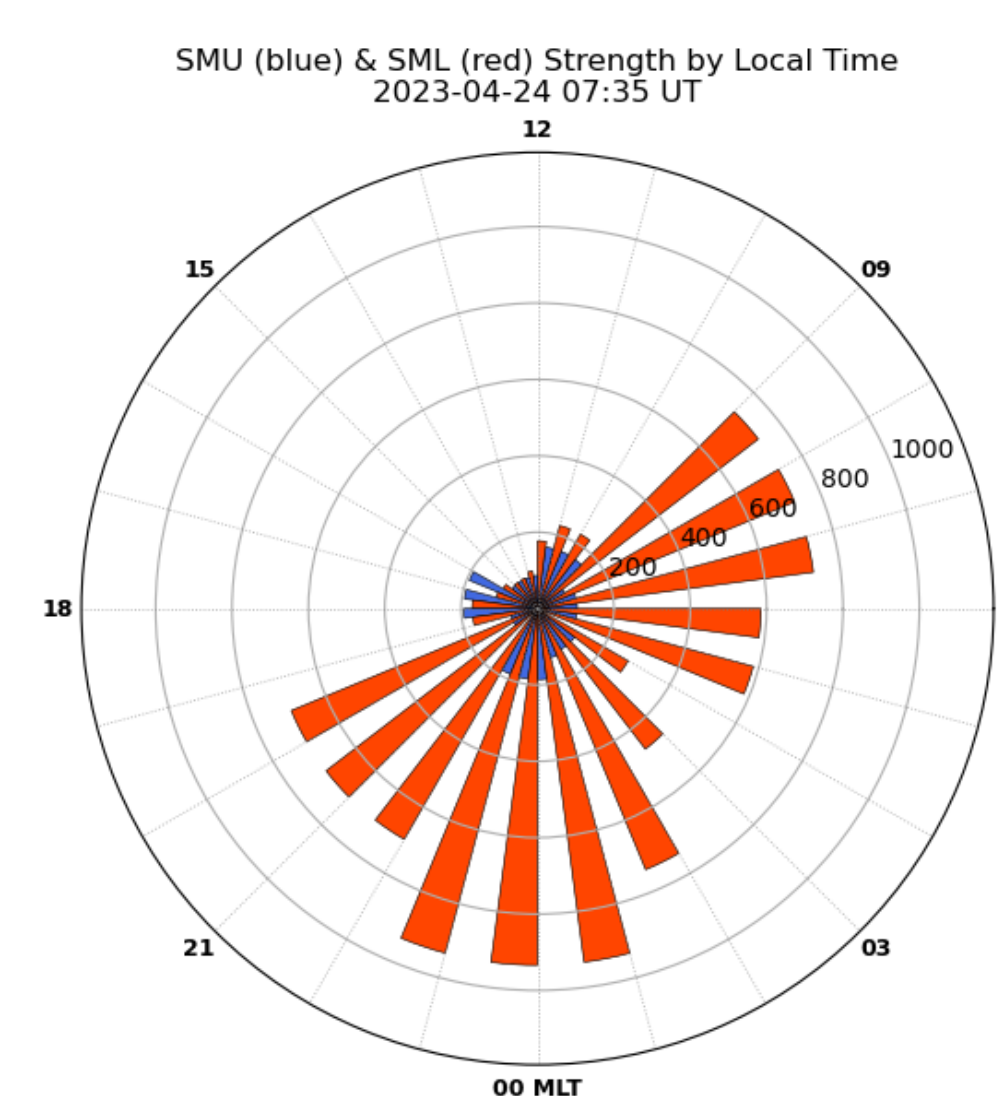


Figure 3: Local-time SML index

Results

- Pc3, Pc4 pulsation excited by the foreshock of a CME
- Super-substorm caused strong broadband pulsation in mid-latitude stations
- Observed a substorm at 0730 UT 24 April using spectrogram & SML_LT index
- Pulsations at high latitudes associated with IMF orientation & Alfvén speed (bow shock)

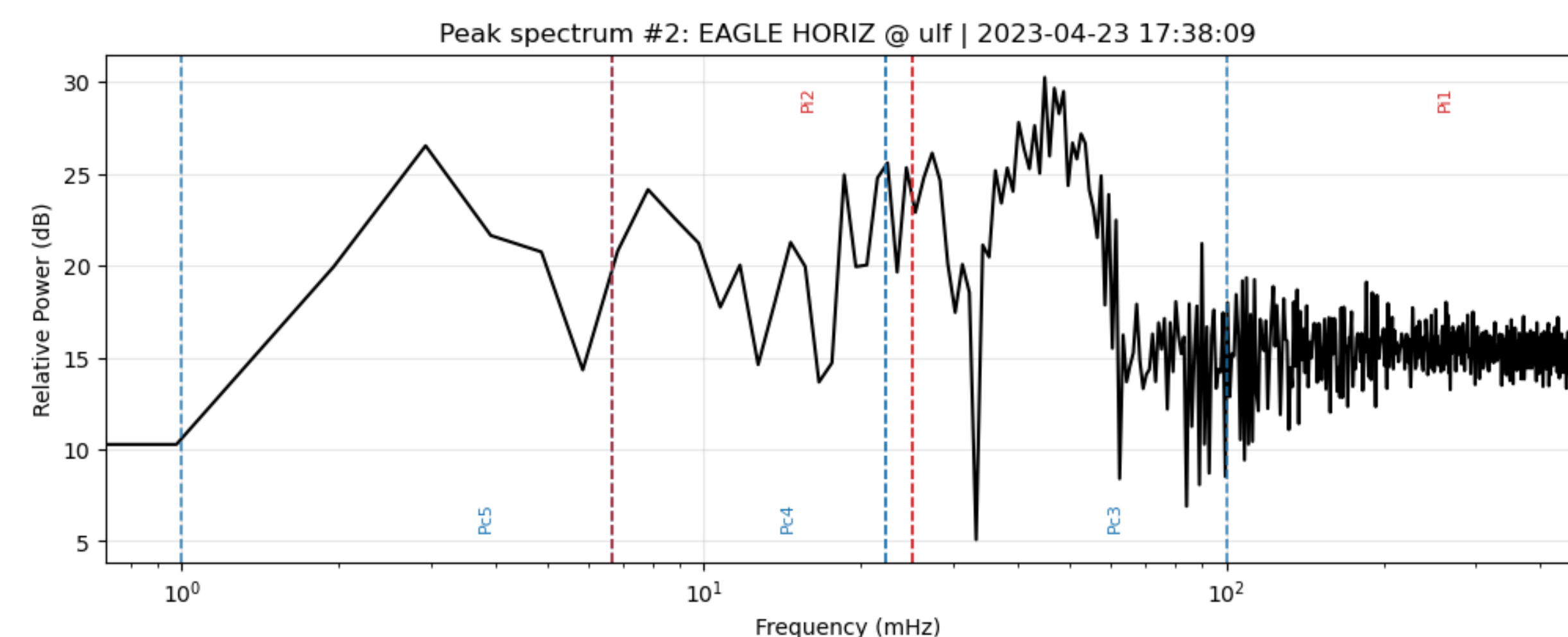


Figure 4: power(dB) vs. frequency (log scale) of pulsation spectra

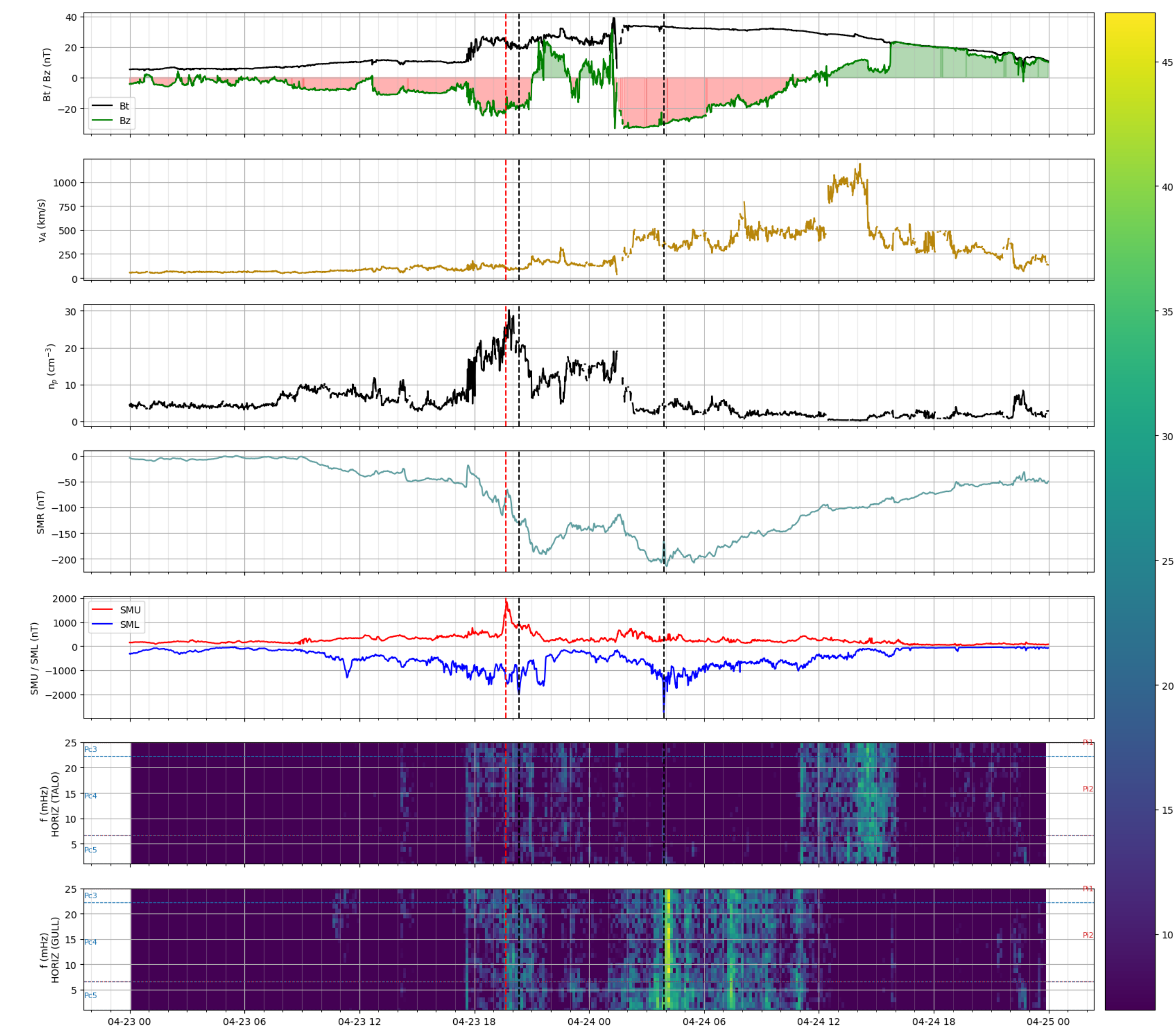


Figure 5: solar wind conditions, global-level magnetic perturbation, pulsation spectrogram plots

Conclusion

- Peak pulsation power can occur simultaneously at different stations, but power distribution is strongly dependent on magnetic local time
- Broadband signature is not uncommon during storm-time dynamics; using a specific frequency range as a substorm onset indicator may be unreliable
- enhanced power in spectrograms + local-time SML index may reveal substorms more clearly than signals in δB data + SMU/SML index
- IMF orientation & Alfvén Mach number associated with strong pulsations in high-latitude stations
- Strong pulsations linked to regions with intense Ground-Induced Current(GIC)

References

- Jacobs, J. A., Kato, Y., Matsushita, S., & Troitskaya, V. A. (1964). Classification of geomagnetic micropulsations. *Journal of Geophysical Research*, 69(1), 180–181.
- Gurnett, D. A., Persoon, A. M., Leisner, J. S., Kurth, W. S., Groene, J. B., Hospodarsky, G. B., & Averkamp, T. F. (2022). Density variations in the outer heliosphere from Voyager plasma wave measurements. *Annales Geophysicae*, 40, 121–134. <https://doi.org/10.5194/angeo-40-121-2022>
- SuperMAG Collaboration, accessed 2026, SuperMAG geomagnetic database, <https://supermag.jhuapl.edu/>