Enhanced Diurnal Variations in Neutron Monitor Count Rates at Northerly Locations in November 2022

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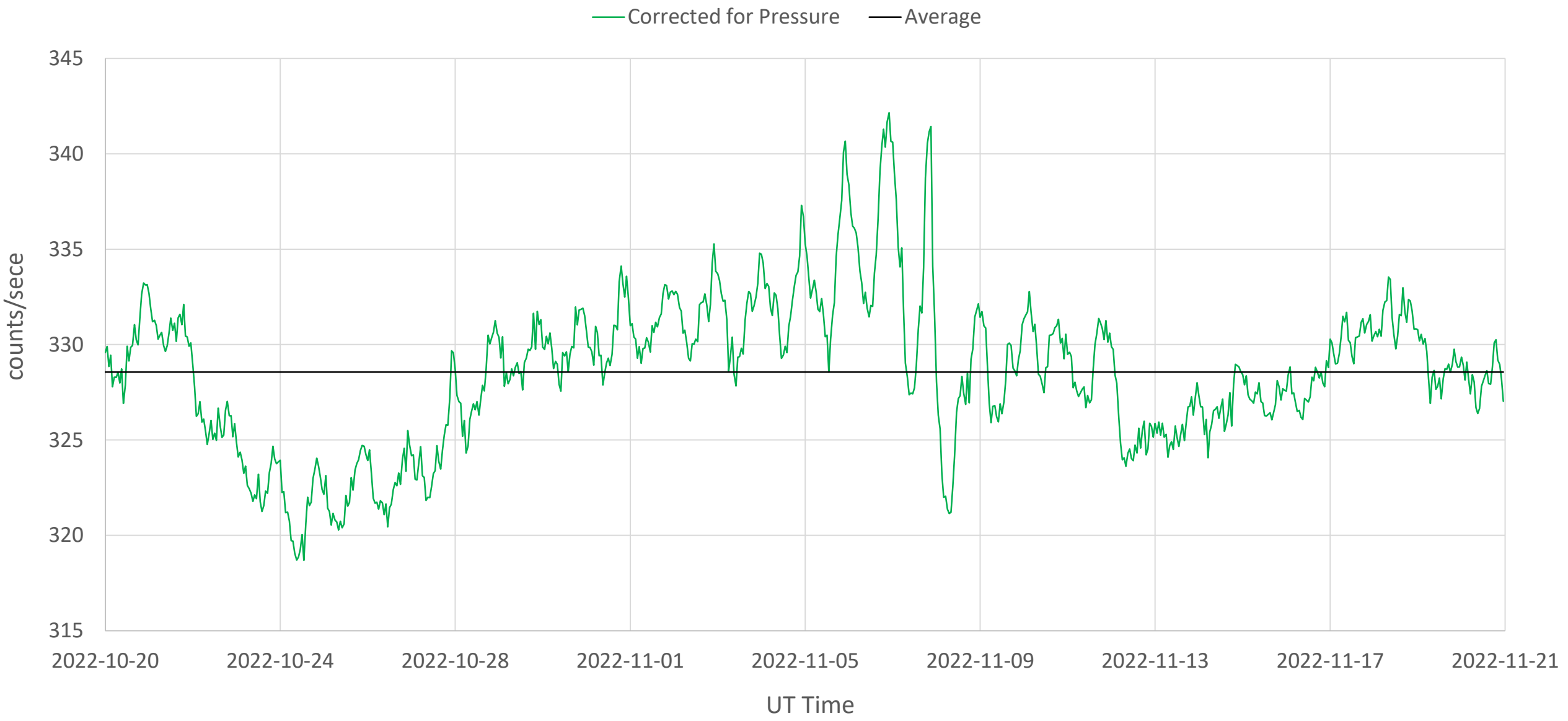
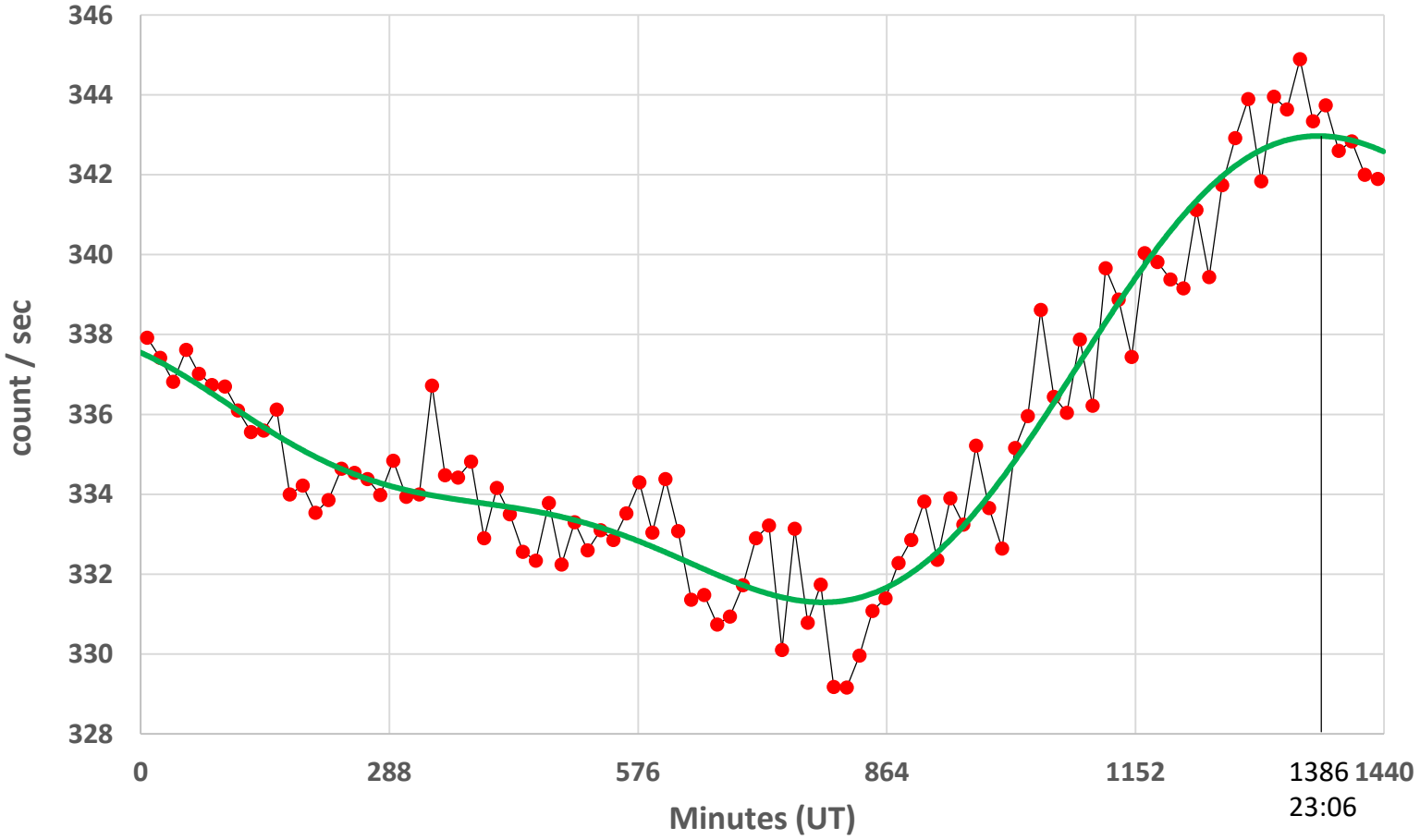
Calgary NM Count-Rates, October 20 - November 20, 2022



Example of Daily Variations on November 5, 2022

Fitting Expression: $$Y = a \cdot \mathrm{Sin}\left[\frac{2\pi}{24 \cdot 60}(t + \Phi)\right] + b\ \mathrm{Sin}\left[2 \cdot \frac{2\pi}{24 \cdot 60}(t + \Psi)\right] + c \cdot t + d$$

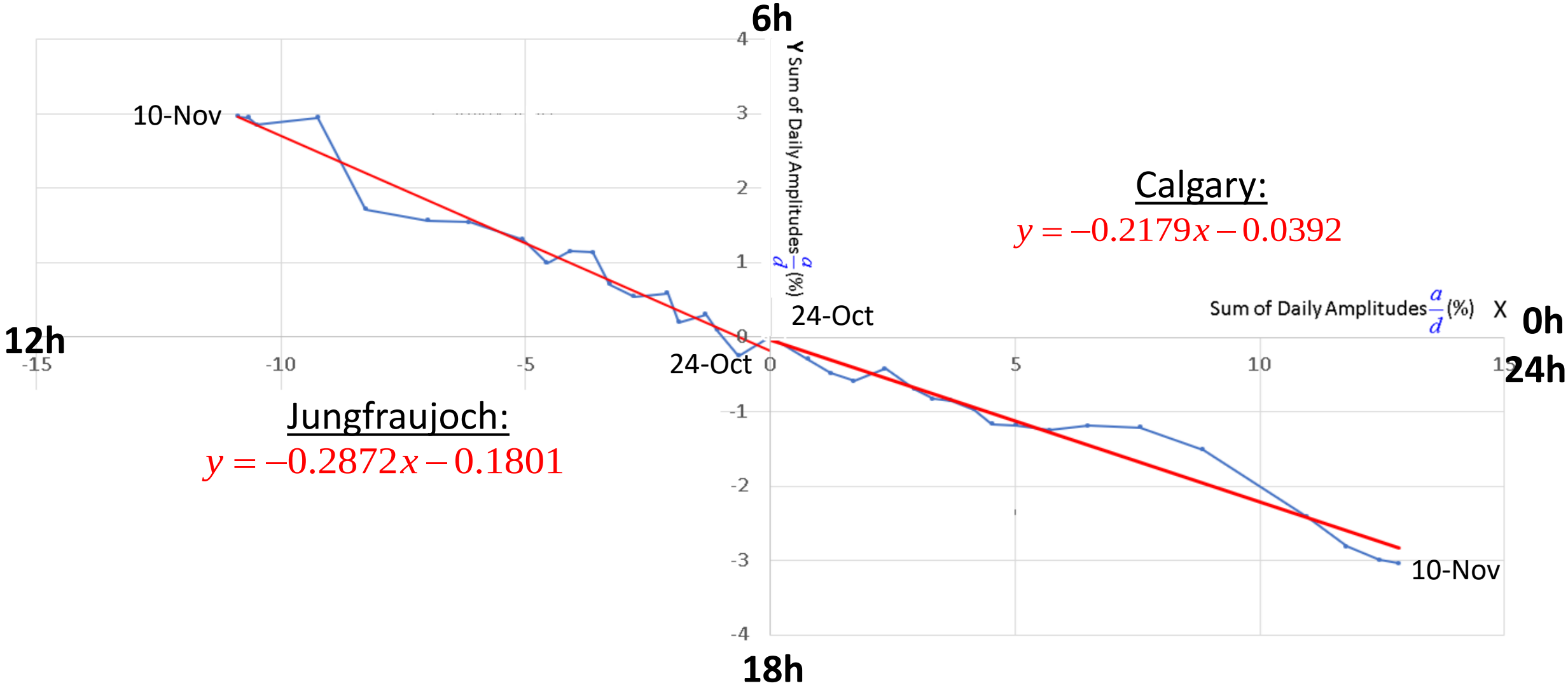
Fitting software: "ALGLIB (http://www.alglib.net), Sergey Bochkanov".



#	Coefficients		Value
1	Amplitude Diurnal	a	21.33
2	Phase Diurnal	Φ	377.2
3	Amplitude Semi-Diurnal	b	6.748
4	Phase Semi-Diurnal	Ψ	345.5
5	Linear	c	0.017466
6	Const Shift	d	1665.6

Hodographs: Jungfraujoch, Switzerland vs. Calgary

Each line segment represents Daily Amplitudes $\frac{a}{d}$(%) (its length) and phase (UT, its direction), of the diurnal variation at that NM



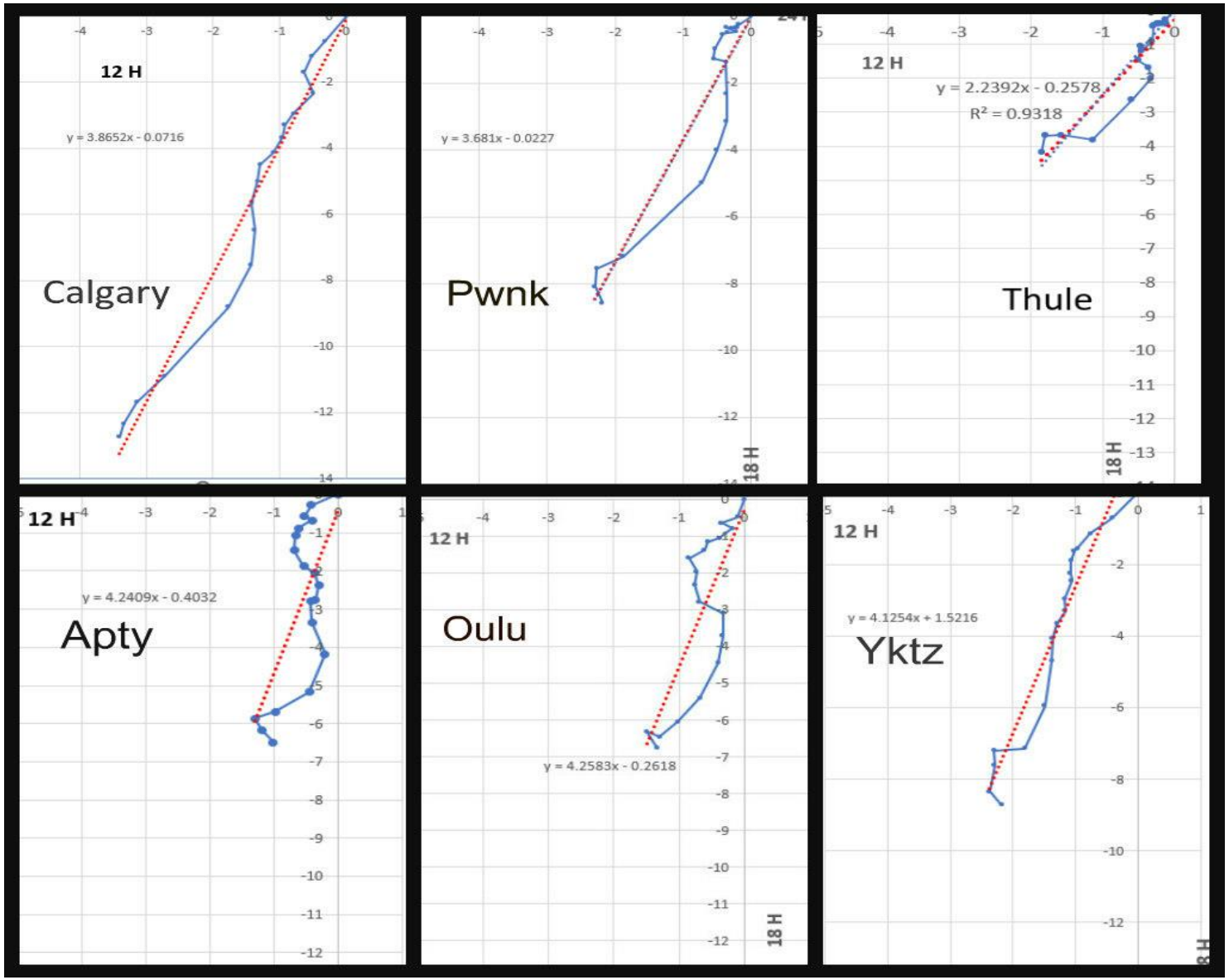
Jungfraujoch:

$y = -0.2872x - 0.1801$

Calgary:

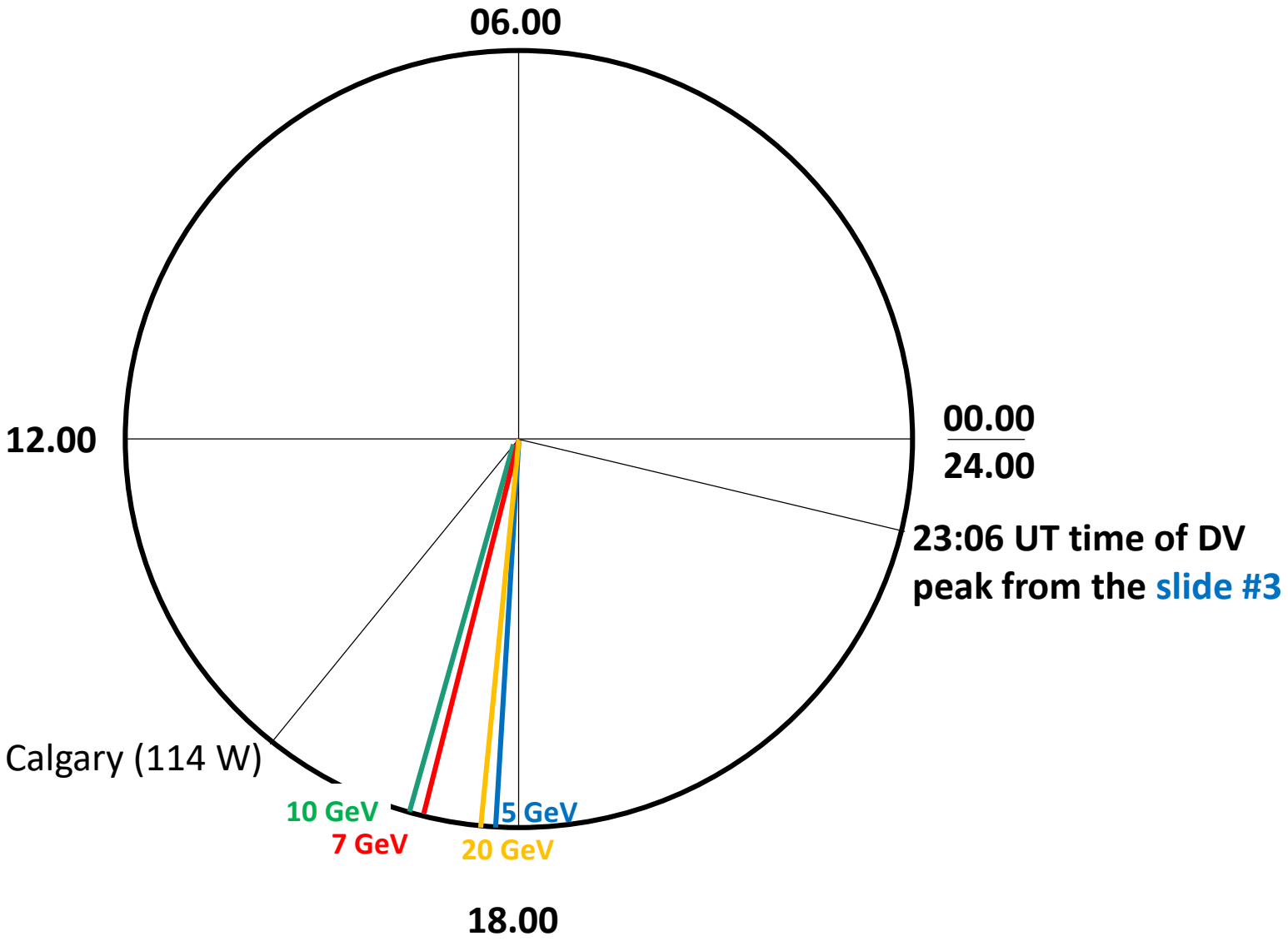
$y = -0.2179x - 0.0392$

Hodographs for Six Neutron Monitors: Calgary, Peawanuck, Thule, Oulu, Apatite, Yakutsk



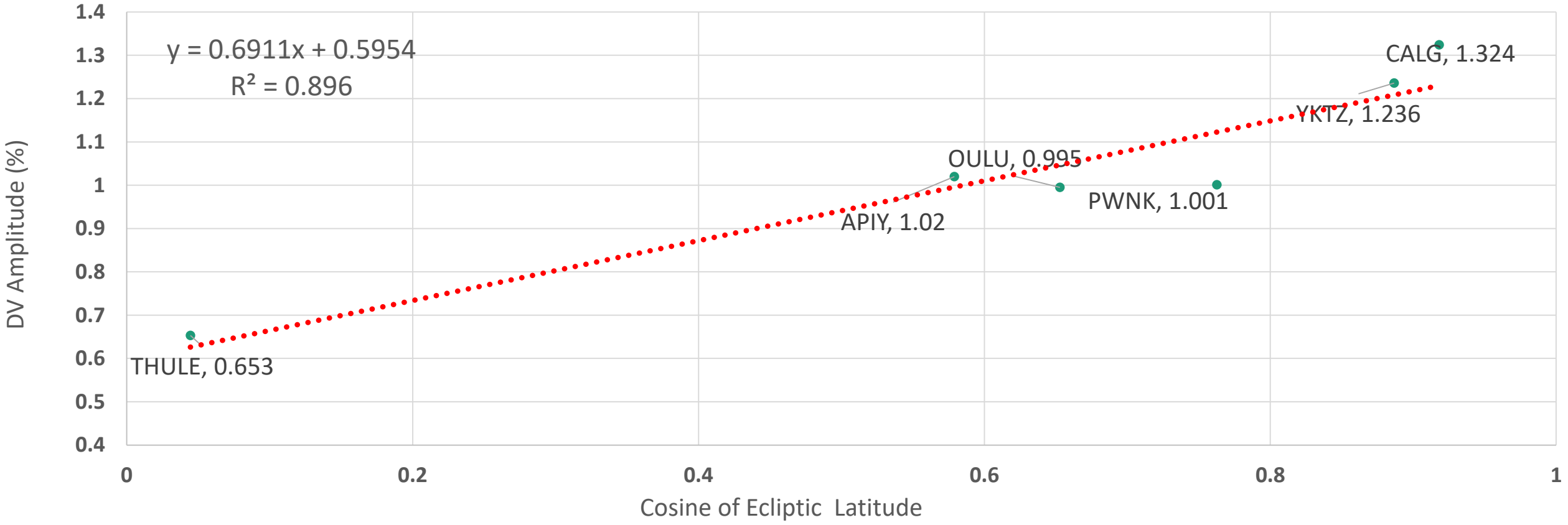
In each graph, segments show the amplitude and phase of the DV for each day from Oct.24 to Nov.10, 2022.

Cosmic Ray Asymptotic Direction for Calgary



Asymptotic direction calculations are based on a Leap Frog ray tracing for proton propagation in IGRF geomagnetic field (***Kouznetsov and Knudsen,* 2013**)

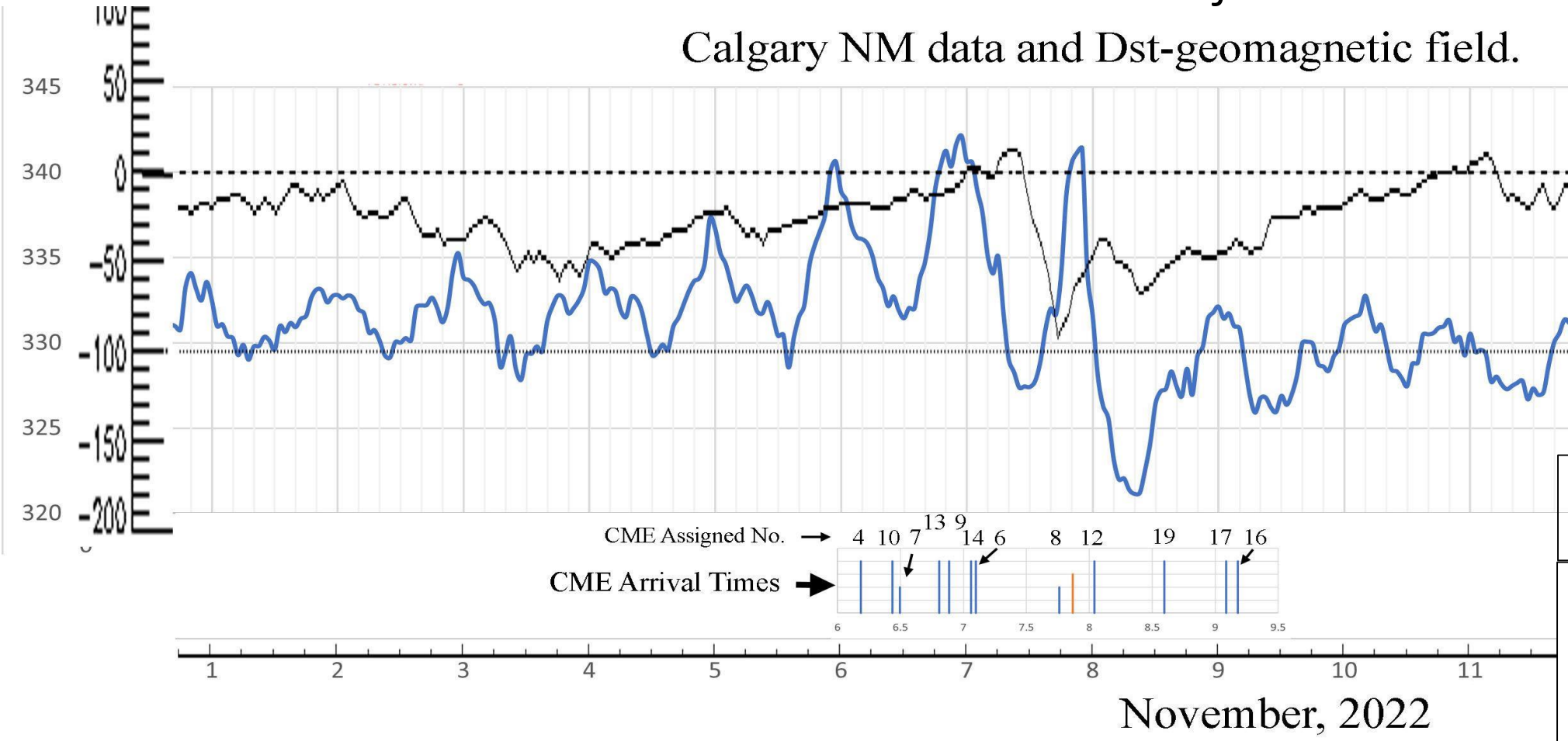
DV Amplitudes versus Cos (Ecliptic Latitude) for Selected Neutron Monitors on November 6, 2022



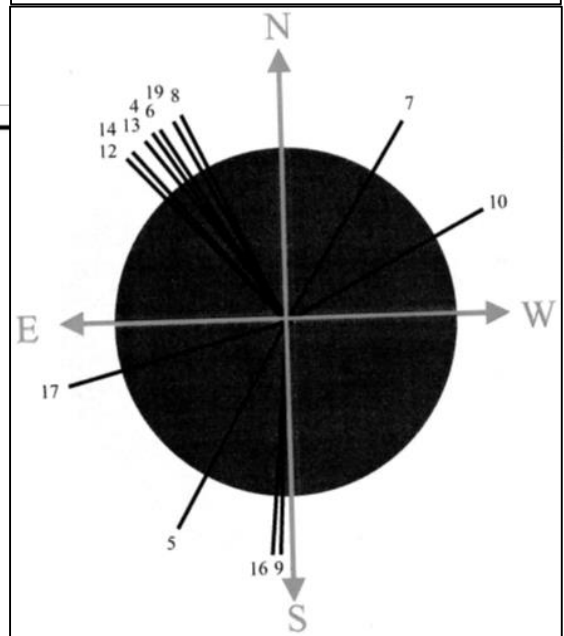
	Calgary	Pinuwik	Thule	Oulu	Apatite	Yakutsk
DV Amplitude	13.19	10.48	4.70	6.88	6.21	9.32
DV Asymmetry Direction	17.03±0.16	16.99±0.19	16.39±0.24	17.02±0.24	17.11±0.31	17.09±0.12
Ecliptic Lat. (of DV)	25.70º	40.87º	80.91º	51.21º	57.61º	35.55º
Cosine Ecliptic Latitude	0.9013	0.7561	0.1580	0.6264	0.5357	0.8136

The DV amplitudes $\frac{a}{d}$(%) are the vector sum of the segments each of which is $\frac{a}{d}$ for that day. Thus, providing an indication of the relative average amplitude. Except for Thule, the times of the DV asymmetry are in good agreement.

Arrival of Coronal Mass Ejections.



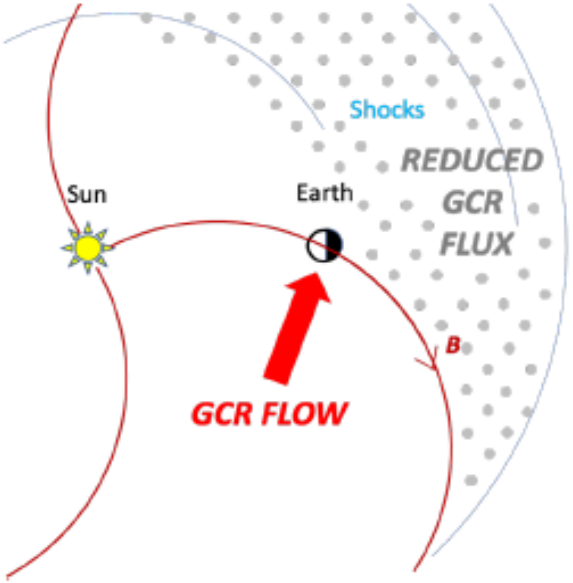
Position angles of CMEs derived from sunward LASCO images for November 1 – 5, 2022



- For this event, 19 CMEs are listed in the SOHO/LASCO catalog.
- The calculated arrival times of the stronger CMEs among the are shown, together with Calgary neutron and D_{st} data.
- The stronger CMEs numbered **14** and **6**, are probably the cause of the Forbush decrease and the D_{st} dip on November 7.
- Note the superposition of the final large DV peak with Forbush decrease.

Possible Causes for the Enhanced DVs.

1. The $\mathbf{B}_{\wedge}\nabla\mathbf{n}$ mechanism (see Hashim &Bercovitch 1972) which arises from a N-S gradient in the GCR density. Our initial calculations show that the effect occurs at higher rigidities (>15 GV). The extent of the N-S gradient has yet to be investigated.



2. Enhanced diffusion perpendicular to the spiral interplanetary magnetic field as illustrated (adapted from *Buatthaisong et al, 2021*) towards a region with shocks from Interacting CMEs

Conclusions

- In this event, **enhanced DVs** appear to **predict a Forbush decrease** and a **geomagnetic disturbance**.

- **Several overlapping CMEs** occur during this event, a glancing collision of the strongest with the earth, **coincides with the Forbush decrease** and **drop in D_{st}**.

- The **amplitude** of the 24-hour wave is **correlated** with the **cosine of the ecliptic latitude** where each monitor is pointing at the time of count rate maximum.

- At least for this event, **neutron monitors in Western Canada** had the **best location for measuring DVs.**

- The **mechanism** causing the enhanced DVs **requires future investigation**.