Muon Flux Variation in Real-time and its Correlation with Space Weather Activity

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Introduction

- Interplanetary space filled with the solar wind having frozen-in magnetic fields and cosmic ray particles
- Highly affected by solar magnetic activity resulting in cosmic rays flux modulations in space and on earth (Fig. 1) [1, 2].

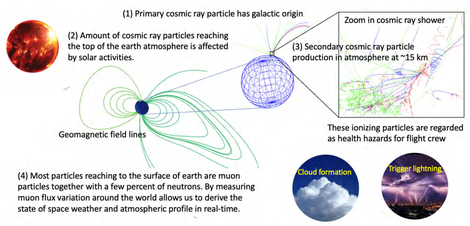

Figure 1: *Cosmic ray interactions*

- Challenge is to monitor space and earth weather on a global scale
- Find the effects on flux variations from earth's atmosphere and sensitivity to the solar activities and geomagnetic disturbances in real-time.

Motivation

- Develop low cost, portable cosmic ray detectors for a global network to monitor changes in space and earth weather.
- Cosmic ray flux measurements as a potential forecasting tool to predict geomagnetic storms arrival on earth.

Detector setup and data sources

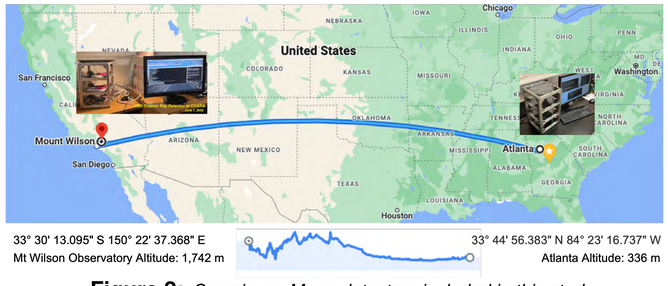

Figure 2: *Cosmic ray Muon detectors included in this study*

- Focus on the analysis of data recorded by two detectors which are ∼3,500 km apart (Fig. 2).

Atmospheric effect on muon flux

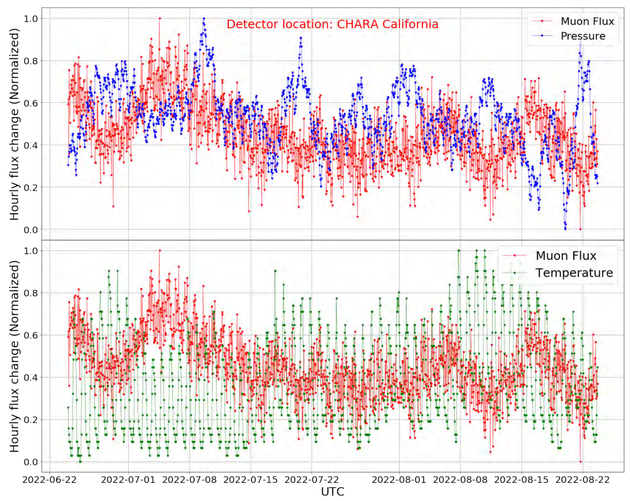

Figure 3: *Muon flux vs pressure and temperature*

Cross comparison of cosmic ray data

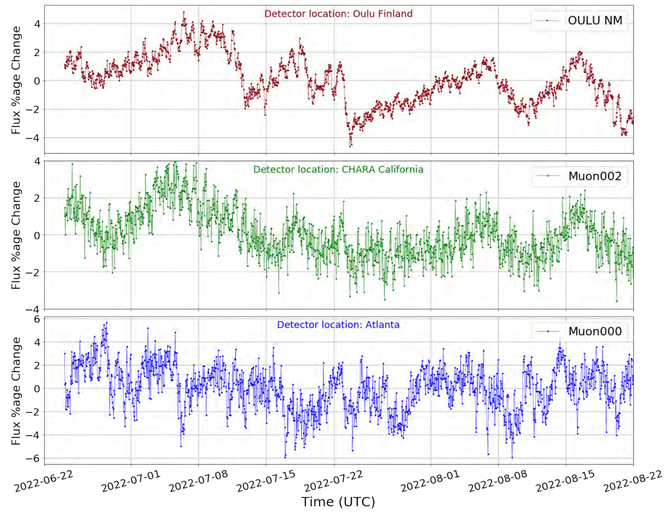

Figure 4: *Cosmic ray flux after temperature and pressure correction*

- Visual correlation of of neutron counts with the flux percentage changes in two muon detectors.
- Pearson correlation coefficient between Oulu vs Muon002 is 0.70.

Space weather activity

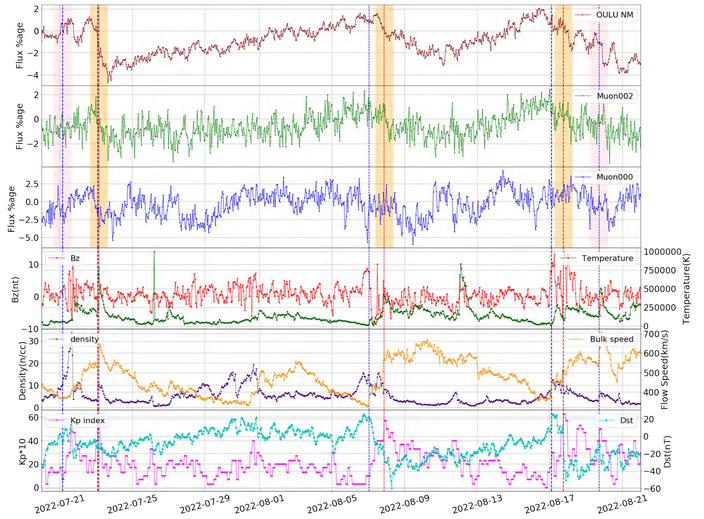

Figure 5: *Cosmic ray flux and Space parameters*

Table 1: *Transient rates of flux percentage at times of storms.*

	Slope in ±12 hr (%/h)			Slope in ±6 hr (%/h)			Slope in ±3 hr (%/h)		
	GS1[a]	GS2[b]	GS3[c]	GS1	GS2	GS3	GS1	GS2	GS3
Muon000	-0.27	0.03	0.20	-0.68	-0.13	0.42	-0.41	1.4	-0.20
Muon002	-0.26	-0.03	-0.007	-0.18	-0.41	0.13	-0.14	-0.03	-0.06
Oulu	-0.45	-0.14	-0.16	-0.50	-0.24	-0.15	-0.77	-0.27	-0.19

[a]Geomagnetic Storm 1 (2022-07-23 03:59:00, G1). Preceding events: 2022-07-23 02:28:00 (IP)
[b]Geomagnetic Storm 2 (2022-08-07 21:00:00, G1). Preceding events: 2022-08-07 00:45:00 (IP, HSS).
[c]Geomagnetic Storm 3 (2022-08-17 18:00:00, G1-3). Preceding events: 2022-08-17 02:14:00 (IP)

Summary

- Oulu and Muon 002 show similar response to space weather events.
- Decreasing trend in cosmic ray flux before the geomagnetic storm.

Acknowledgement

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References

[1] A Maghrabi, A Aldosari, and M Almutairi. Correlation analyses between solar activity parameters and cosmic ray muons between 2002 and 2012 at high cutoff rigidity. *Advances in Space Research*, 68(7):2941–2952, 2021.

[2] Kazuoki Munakata, John W Bieber, Shin-ichi Yasue, Chihiro Kato, Morikazu Koyama, Shigenobu Akahane, Kazuhiko Fujimoto, Zenjiro Fujii, John E Humble, and Marcus L Duldig. Precursors of geomagnetic storms observed by the muon detector network. *Journal of Geophysical Research: Space Physics*, 105(A12):27457–27468, 2000.