SPACE WEATHER WARNING TECHNIQUES. J. M. Clem[1], [1]Department of Physics & Astronomy and Bartol Research Institute, University of Delaware, 217 Sharp Laboratory, Newark, DE 19716. (jmc@udel.edu)

Introduction: Cosmic rays (CR) entering the Earth's atmosphere are messengers from space carrying information about large-scale heliosphere structure, local space environment and solar activity. Some of these cosmic rays possess enough energy to initiate a particle air shower that reaches the ground and be detected by a Neutron Monitor (NM), and/or a Muon detector (MD). When linked together in real-time coordinated arrays, the combined network can make valuable contributions to the forecasting and the analysis of major space weather events.

Measurements of a Forbush Decrease (FD) can provide valuable insights for understanding Interplanetary Magnetic Field (IMF) conditions. It is generally accepted that the IMF disturbances, produced by Interplanetary Corona Mass Ejections (ICME), are the primary cause of FD, while the accumulation of these disturbances in the Heliosphere gives rise to Solar Modulation. As such, FDs are usually accompanied by a Geomagnetic storm (GS), however variations in the GS magnitude do not necessarily correlate with the associated FD amplitude, but instead correlates strongly with the magnitude and direction of Bz–component (North-South) of the IMF in advance of the approaching ICME.

Precursory Anisotropy: CR-intensity variability begins before the arrival of the ICME at Earth. The observed effect is a combination of pre-increases and pre-decreases of the CR intensity. Generally, particles with large pitch angles, with respect to the IMF, approaching the shock are reflected and are observed as pre-increases, while particles with small pitch angles experience a "loss cone" effect and are observed as pre-decreases. The resulting anisotropy in cosmic rays can be observed by NMs and MDs. Pioneering observations of the anisotropy of GCRs [1] typically employed a single ground-based detector and relied on Earth's rotation to provide a range of viewing

With the NM and MD network, observing multiple directions simultaneously, it is possible to extract the anisotropy with time resolution of roughly 1 hour or better [2]. Thus, it becomes possible to study transient anisotropies in the pre-existing the GCR population produced by ICMEs. Precursor "loss-cone" anisotropies can potentially provide up to ~12 hours advance warning of major geomagnetic storms [3-8] that is directly important for Space Weather predictions. A near real-time (~10-minute delay) anisotropy loss-cone chart was implemented on the Bartol Neutron Monitor webpage(http://neutronm.bartol.udel.edu/spaceweather/welcome.html). We anticipate future improvements such as options to increase the number of stations, to scan archival data and implement Bz prediction algorithm.

Bz Prediction: The capability to predict the interplanetary magnetic field B is a crucial parameter for estimating the level of geomagnetic activity from an approaching ICME impact. The z-component (north-south component) of the IMF Bz is particularly important, because of the key role that Bz plays in driving magnetic reconnection at the nose of the magnetosphere [9]. For short-term forecasts, a spacecraft at L1 can provide forecasts of the field ~½ to ~1 hour in advance.

Bieber et al. [10] demonstrated that Bz can be inferred from NM data by applying quasilinear theory to derive an expression relating fluctuations in the cosmic-ray distribution function to fluctuations in the magnetic field integrated along the reverse particle trajectory. In their analysis, they considered 161 events from a published list of interplanetary coronal mass ejections and compare the predicted field with the actual field measured later. They found the percentage of events with positive correlation between predictions and measurements of Bz varies from about 85% for predictions 1 hour into the future to about 60% for predictions 4 hours into the future. The current Bz model will be incorporated into the real-time anisotropy loss-cone chart and will be evaluated with archive data. An improved model of predicting Bz using NM and MD network data should be a priority for supporting the advancement of Space Weather predictions of geomagnetic storms.

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References:

[1] Pomerantz, M. and Duggal, S. (1971) Space Science Reviews, 12, 75. [2] Bieber, J. and. Evenson, P. (1995) ICRC, 4, 1316. [3] Leerungnavarat, K, et al., (2003) ApJ 593, 587. [4] Mavromichalaki, H., et al. (2011), Advances in Space Research, 47, 2210. [5] Kuwabara, T., et al., (2006) Space Weather, 4, S08001. [6] Tortermpun, U., et al., (2018) ApJ, 852, p. L26. [7] Rockenbach et al., (2011) GRL, 31, L16108. [8] Rockenbach et al., (2014) Space Sci Rev, 182:1-18. [9] Gonzalez, W., (2005) GRL 32, 18. [10] Bieber, J., et al., (2013) p. SH53A-2146.