SPACE WEATHER WARNING TECHNIQUES

Presenter: John Clem

Original work developed by
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Continuation of this work is on-going by
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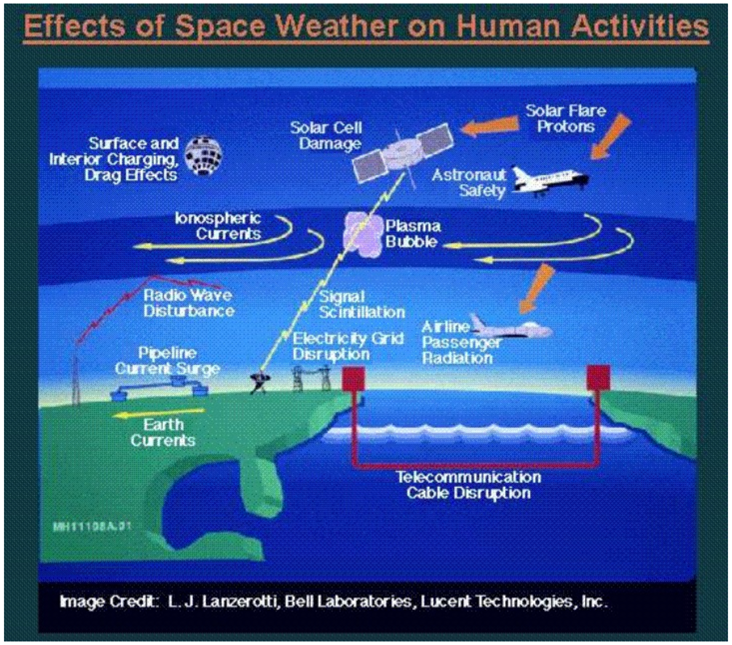


Loss Cone Precursor to an ICME

Key references: Nagashima et al. [1992], Munakata et al. [2000], Leerungnavarat et al. [2003]

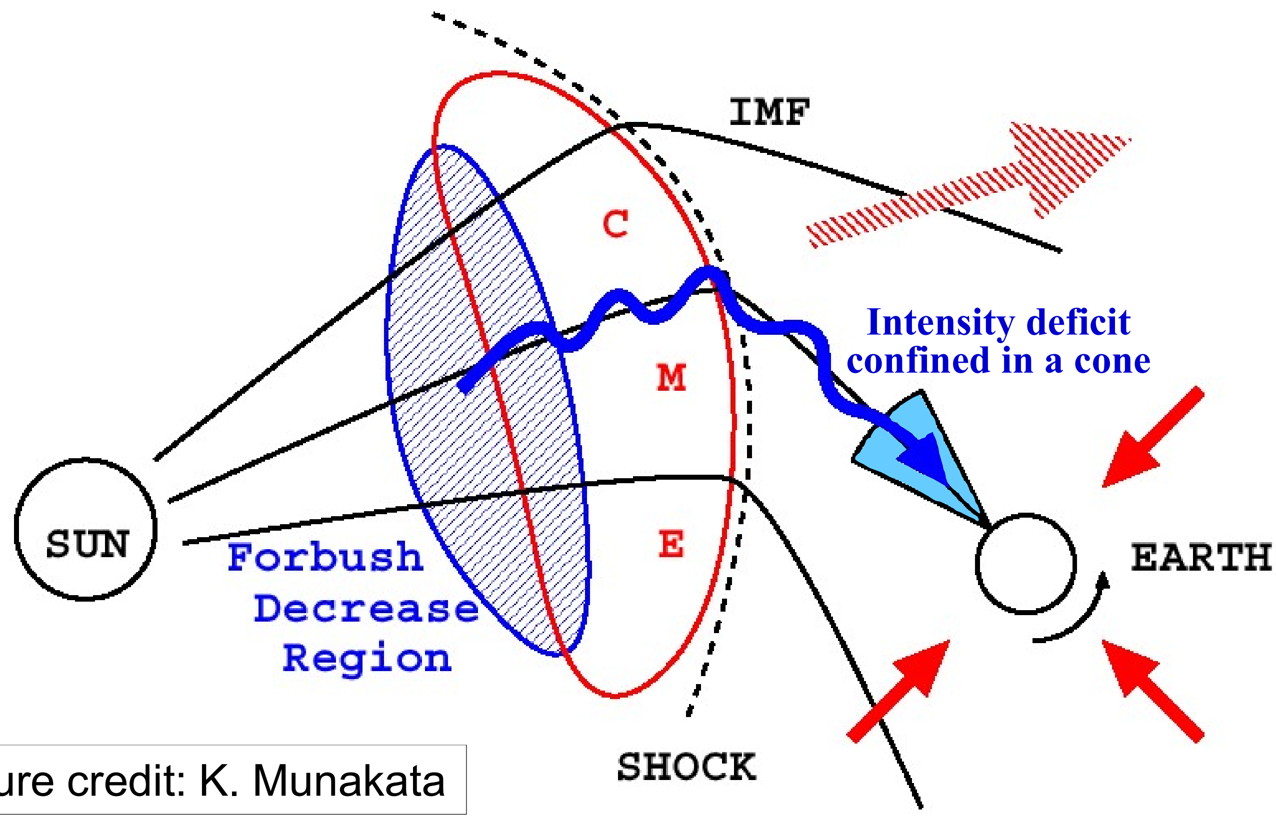
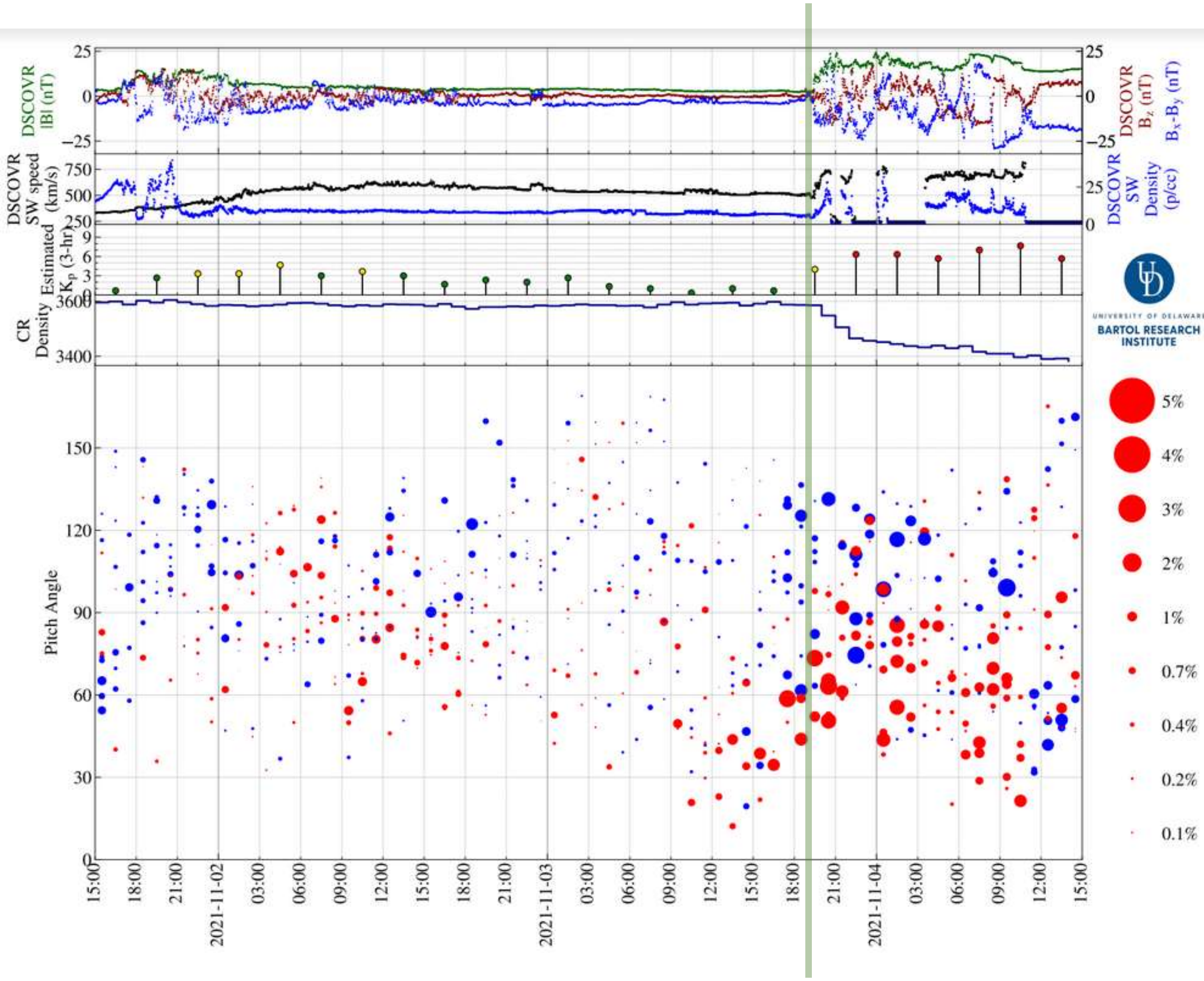


Figure credit: K. Munakata

Real time Loss Cone display . 2021-11-04 CME event



http://neutronm.bartol.udel.edu/spaceweather/welcome.html

Top Panel: DSCOVR IMF magnitude |B| (green), north-south component Bz (dark-red) and Bx-By (blue) in GSE coordinates

Second Panel: DSCOVR solar wind speed (black) and density (blue).

Third Panel: Kp index.

Fourth Panel: Cosmic ray density

Fifth Panel (Loss Cone Display): Each circle represents an hourly average of the cosmic ray intensity measured by a single ground-based detector.

Red circles indicate deficit intensity, blue circles indicate excess intensity, and the size of the circle scales with the magnitude of the deficit or excess.

Horizontal axis is time and vertical axis is pitch angle of the station. Pitch angle is the angle between the IMF and the viewing direction or asymptotic direction of the station (median rigidity particle)

The defining characteristic of a loss cone precursor is a suppression of cosmic ray intensity for particles arriving from the IMF direction. Thus large red circles, concentrated near small pitch angles, are indicative of a loss cone anisotropy. This is shown a few hours before the CME

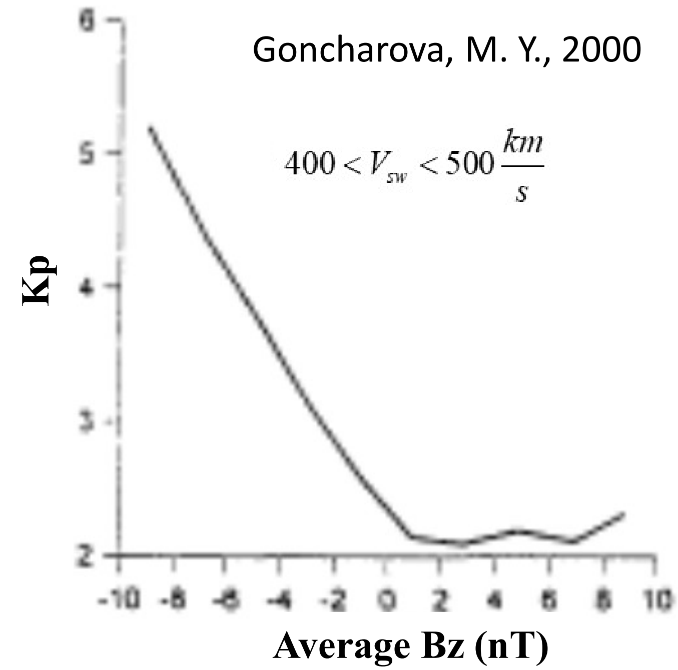
Prediction of Bz with NM data

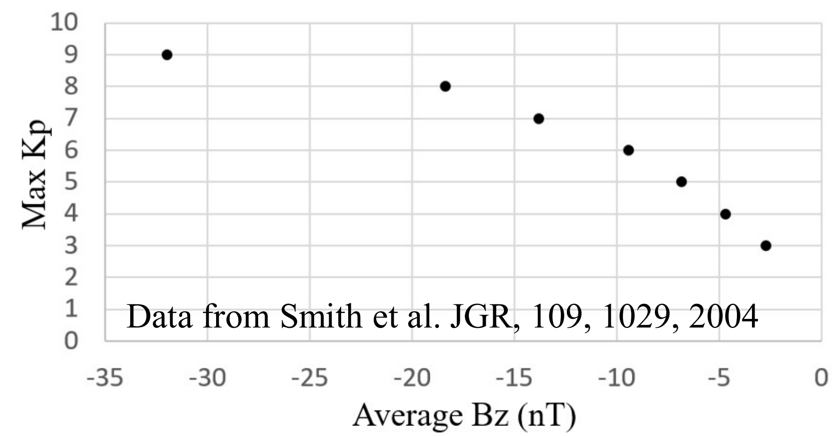
The capability to predict the interplanetary magnetic field B is a crucial parameter for estimating the level of geomagnetic activity from an approaching ICME impact.

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.

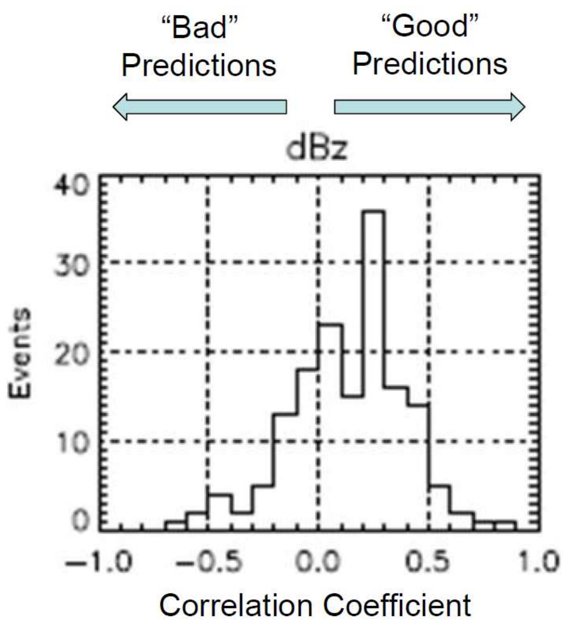
A spacecraft at L1 can provide forcast of the field ~½ to ~1 hour in advance.

Gonzalez, W., (2005)

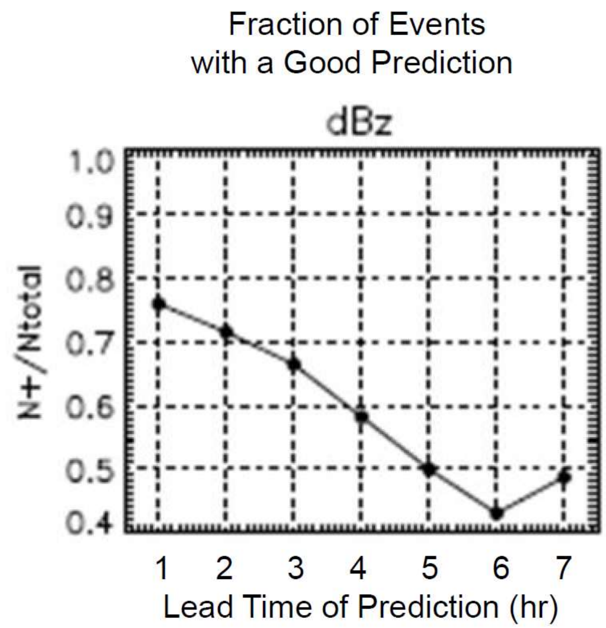




Bieber et al. 2013 demonstrated that Bz can be inferred from NM data by applying quasilinear theory to derive an expression relating fluctuations in the cosmic-ray distribution function to fluctuations in the magnetic field integrated along the reverse particle trajectory.
In their analysis, they considered 161 events from a published list of interplanetary coronal mass ejections and compare the predicted field with the actual field measured later.



Histogram of the entire dataset (161 events) binned according to the correlation between predicted and observed δBz obtained in each individual event for a prediction time of 2hrs.



Fraction of events with a positive correlation between predicted and observed δBZ plotted as a function of the lead time of the prediction.

Bieber, 2013

The current Bz model will be incorporated into the real-time loss-cone chart and will be evaluated with archive data.

An improved model of predicting Bz using Neutron Monitors and Muon Detector network data should be a priority for supporting the advancement of Space Weather Predictions of Geomagnetic Storms.

There are numerous possibilities for improving the reliability and success rate of the method, for instance:

– Incorporate more neutron monitor stations in the analysis, providing better sky coverage (i.e., more values of δf at distinct values of pitch angle and gyrophase).

– Use additional wave modes in the Fourier representation of the fluctuating magnetic field.

– Use a more realistic turbulence model.

Bieber, 2013

Summary

Cosmic Rays recorded by ground-based detectors can play an important role in forecasting ICME impacts and geomagnetic storms.

The global network of stations located at high latitude measure the cosmic ray flux from different directions and the combined data provide a three-dimensional distribution of cosmic rays in real-time.

This capability provides a direct means to identify the Loss-Cone of an approaching ICME

Ground-based cosmic ray observations made by neutron monitors can yield predictions of the future IMF that are significantly better than would be obtained from chance correlations.