Study of geonagnetic cutoff rigidity of cosmic rays in higher latitudes

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Introduction

- We investigate numerically the time variations of geomagnetic cutoff rigidities of cosmic rays.
- It is fonud that there is a region where the cosmic ray can enter the magnetosphere easily, as a result we define a polar hole of the cosmic ray using the Geomagnetic Cutoff Rigidities.
- As a simple case we calculate the geomagnetic cutoff rigidities of protons for the periods of both quiet and disturbance.

Stormer (1955) showed that in a pure dipole magnetic field a potential barrier shields particles of a given rigidity (mvc/q) from an inner forbidden region defined by the equation

$$r = \sqrt{\frac{Mq}{mvc}} \frac{cos^2\lambda}{1 + \sqrt{1 + cos^3\lambda}} \tag{1}$$

where M is the dipole moment, λ is the latitude and r is the radial distance from the center of the dipole. This equation can be inverted to give the cutoff rigidity at any point in space

$$R(Gv) = \frac{C}{r^2} \frac{cos^4\lambda}{(1 + \sqrt{1 + cos^2\lambda})^2} \tag{2}$$

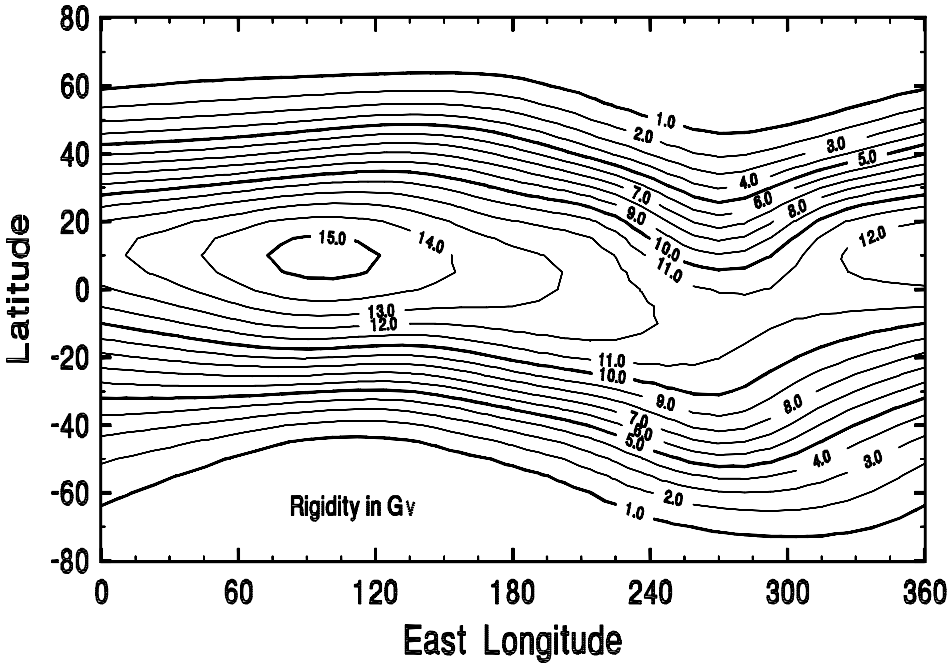
where C (60) is a constant determined by the dipole moment.

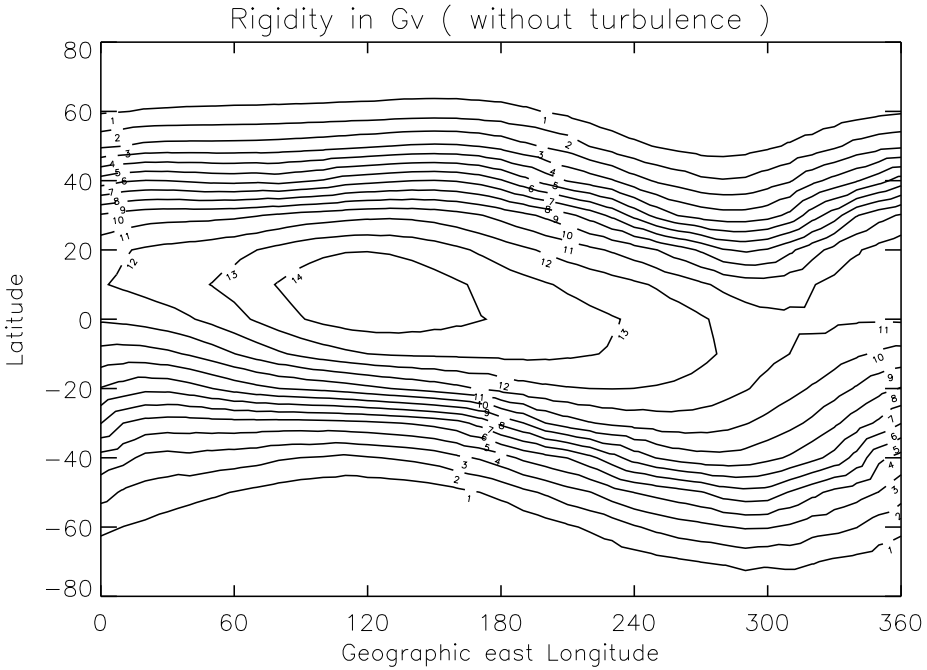
- The effective vertival cutoff rigidity of charged particles is calculated on the basis of generalization of the results of extensive trajectory calculations for trial particles moving in the geomagnetic field.
- We use the Newton-Lorentz Equation to calculate the particle's trajectory.

$$\frac{d(\gamma\vec{v})}{dt} = \frac{q}{m}(\vec{E} + (\vec{v} \times \vec{B})/c) \tag{3}$$

$$\gamma = 1/\sqrt{1 - v^2/c^2} \tag{4}$$

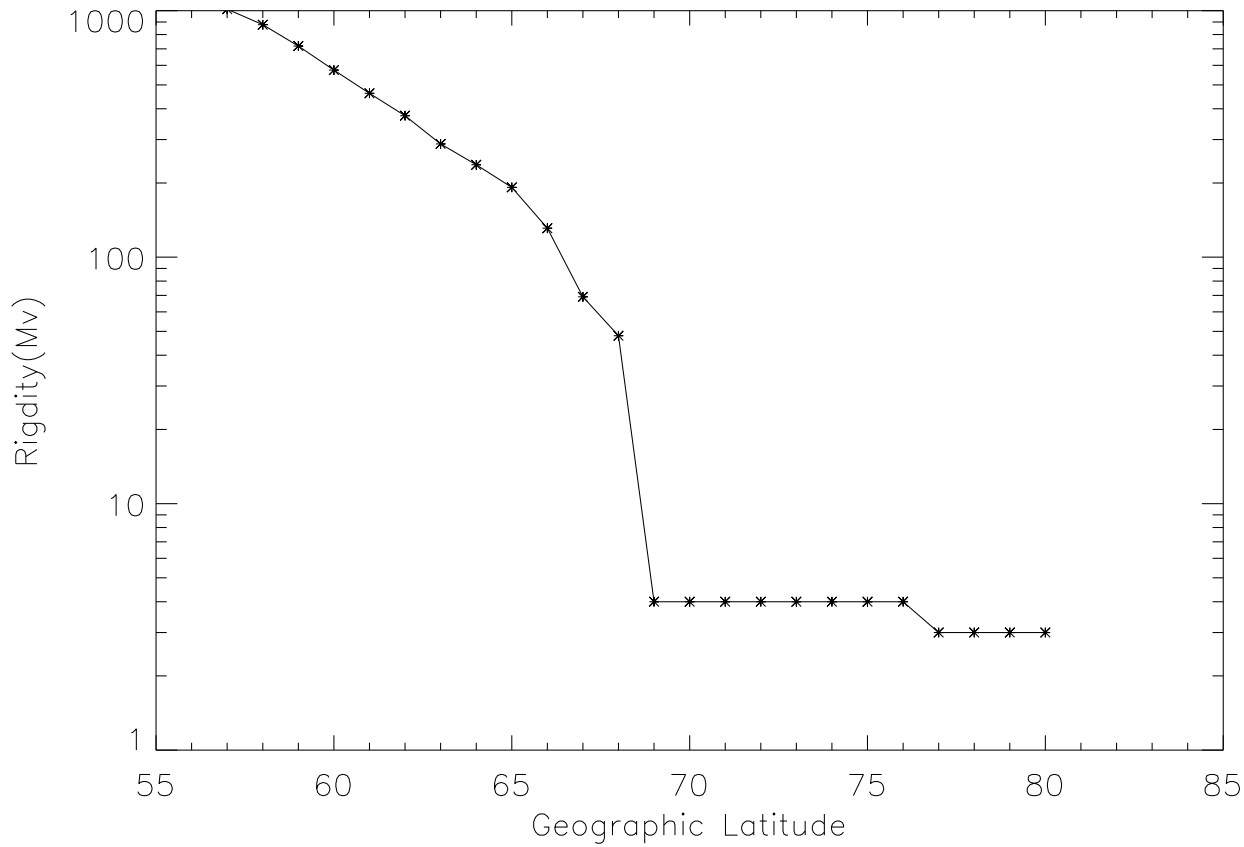
Equation is solved using a 4th order Runge-Kutta integrator with the step size adjusted at each step.





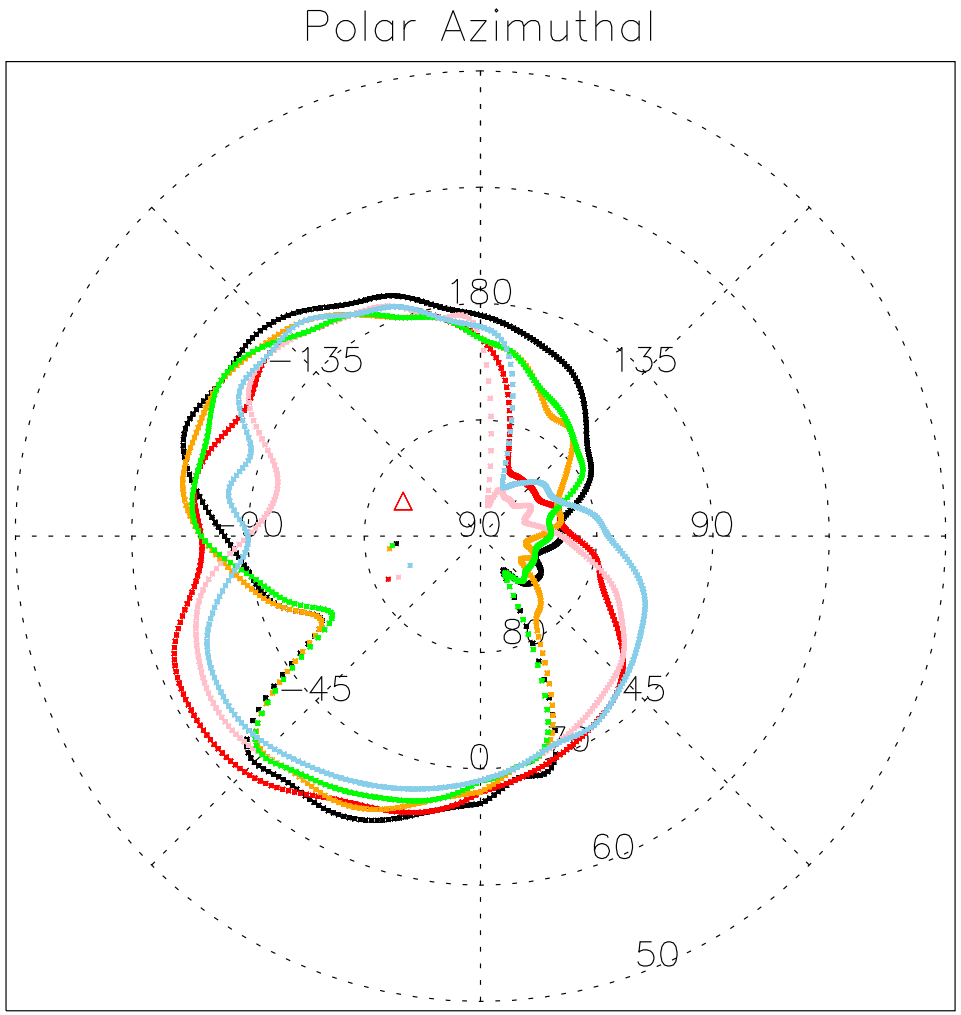
- Smart's (Smart et al., 2004) result (left) and our simulation (right).
- This two figures are both calculated according to the combined IGRF internal magnetic field and the magnetospheric (T89) model.

Geomagnetic Cutoff Rigidities in higher latitudes



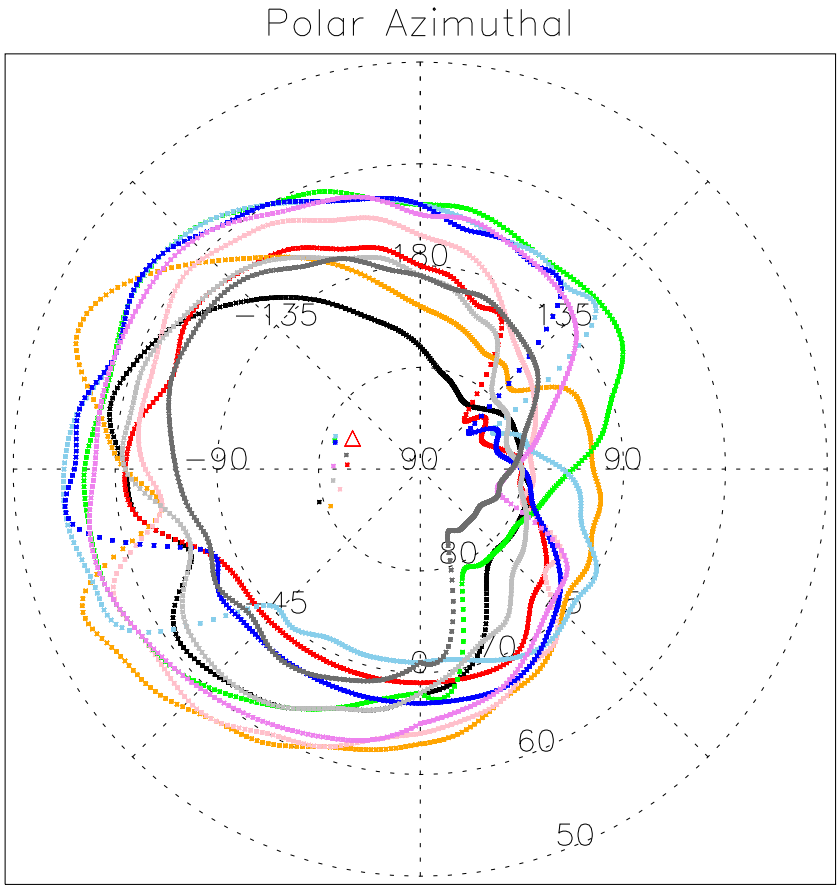
- The sketch of the cutoff rigidities at the higher latitudes.
- There is always a rigidity jump at the high latitudes.
- So we define a threshold value as the boundary of the polar hole.

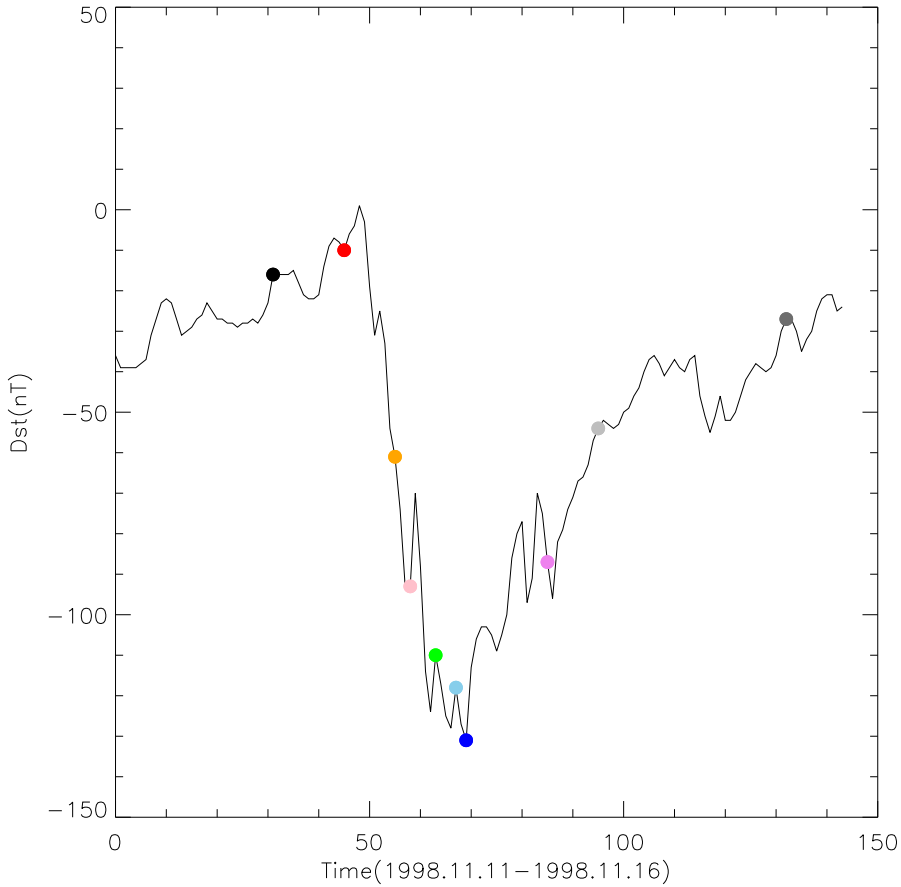
The boundary of the polar hole of the cosmic rays



- The boundary of the pole of the cosmic rays.
- The different color represents different time.

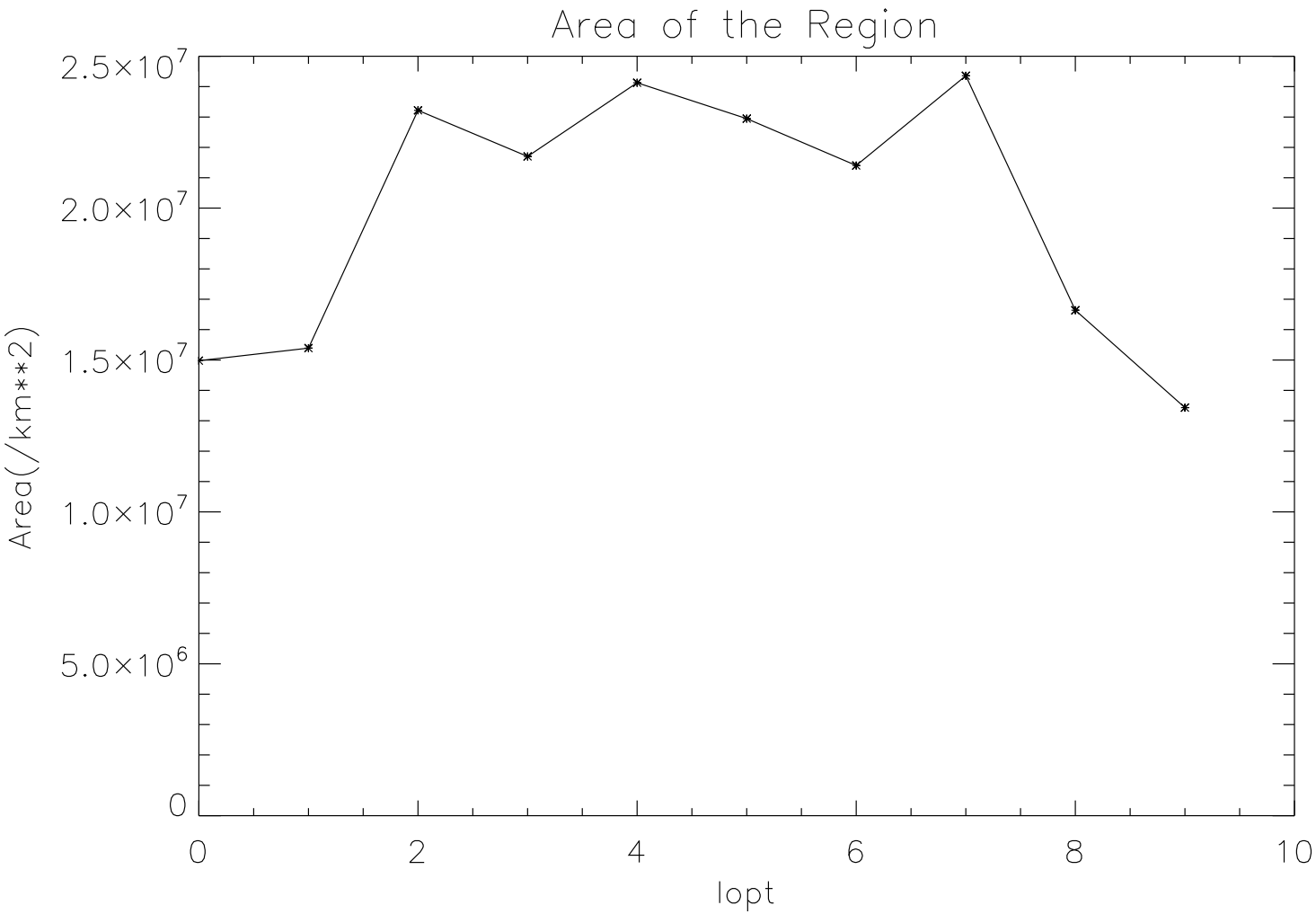
The boundary and Dst index



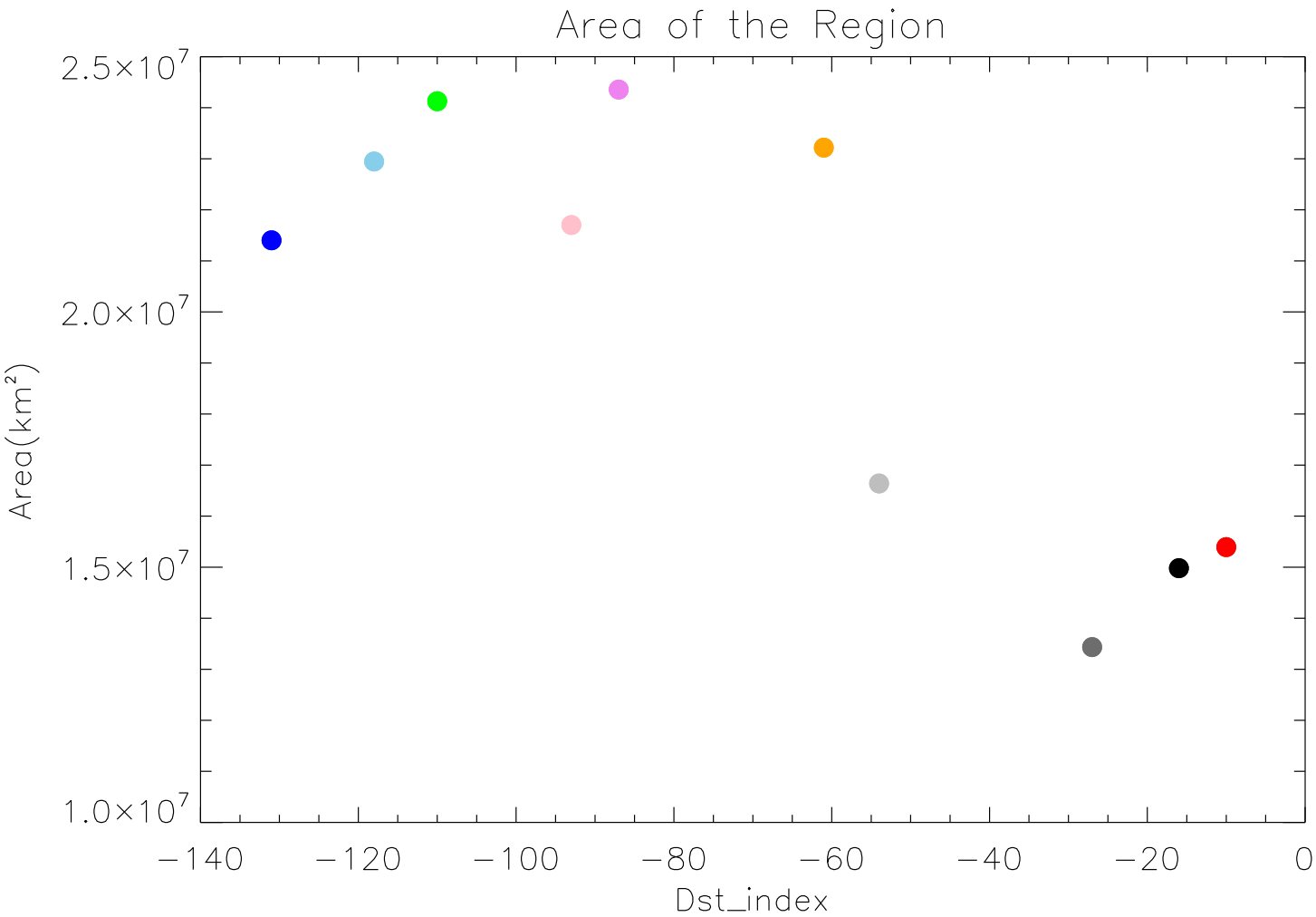


- The boundary of the pole of the cosmic rays duiring the time of disturbance.
- The different color represents different time.

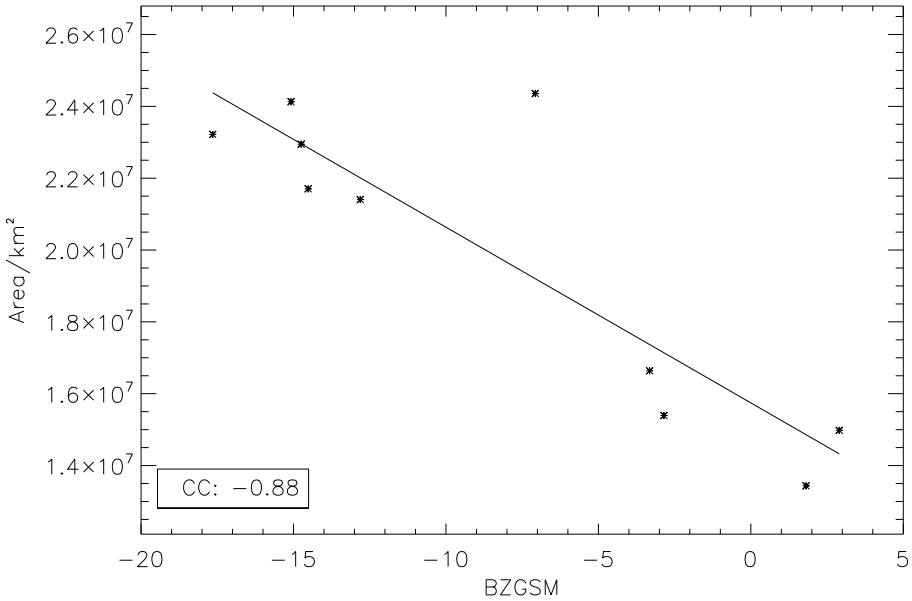
Geomagnetic Cutoff Rigidities

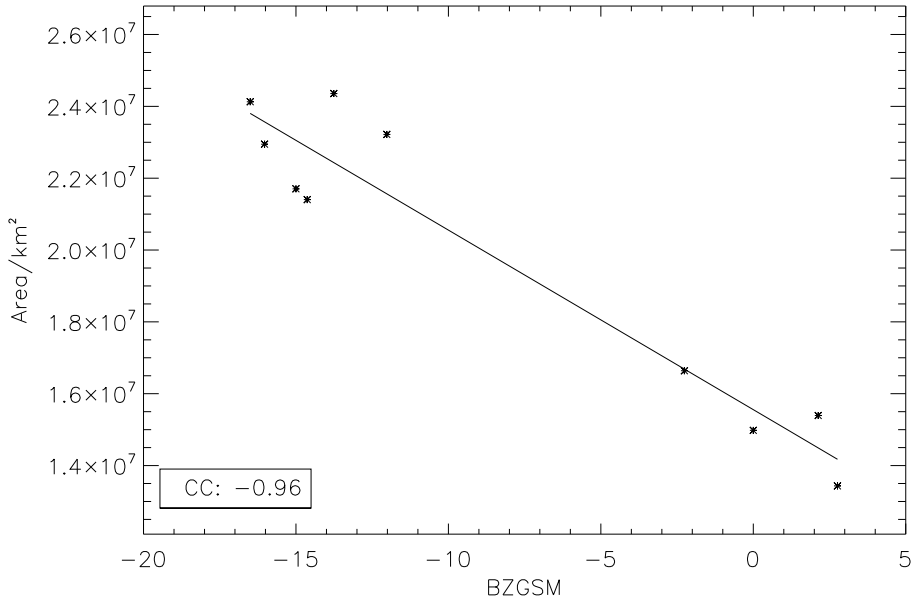


The Area and Dst index



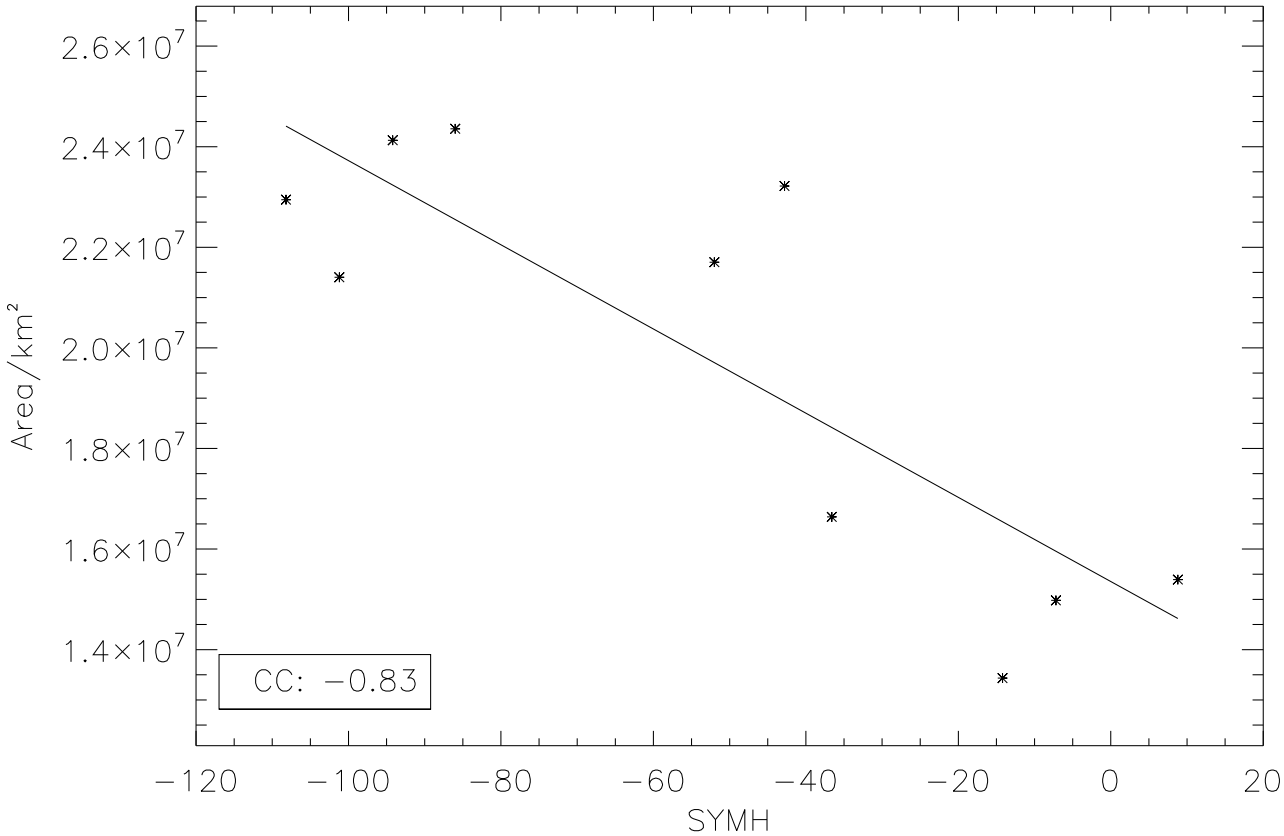
The relationships between the solar wind condition and the area





- The correlation coefficient between the area of the hole region and bz.
- The left figure is calculated at the same time and the right is calculated before 2.5 hours.

The relationships between the solar wind condition and the area



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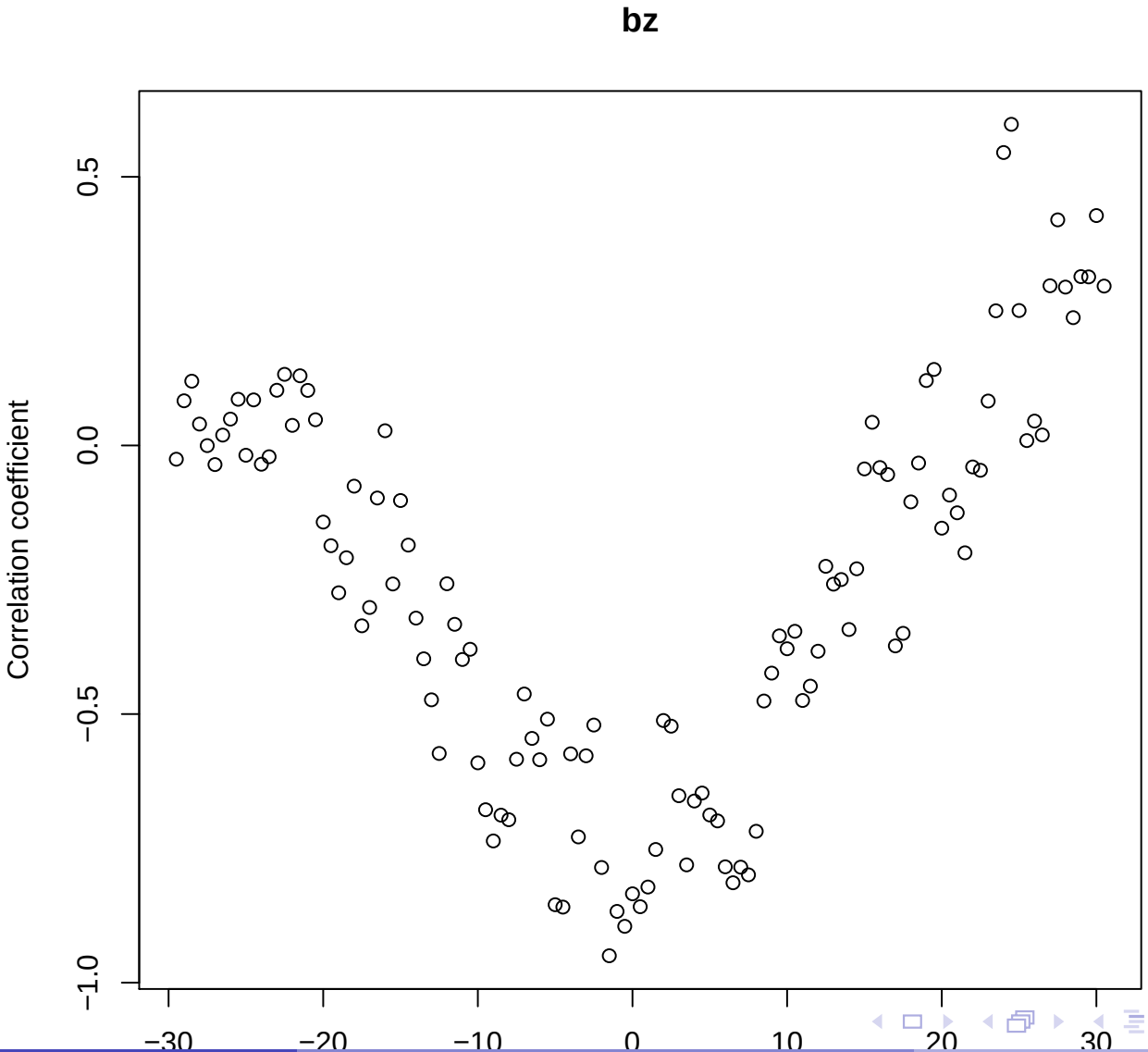
The relationships between the solar wind condition and the area



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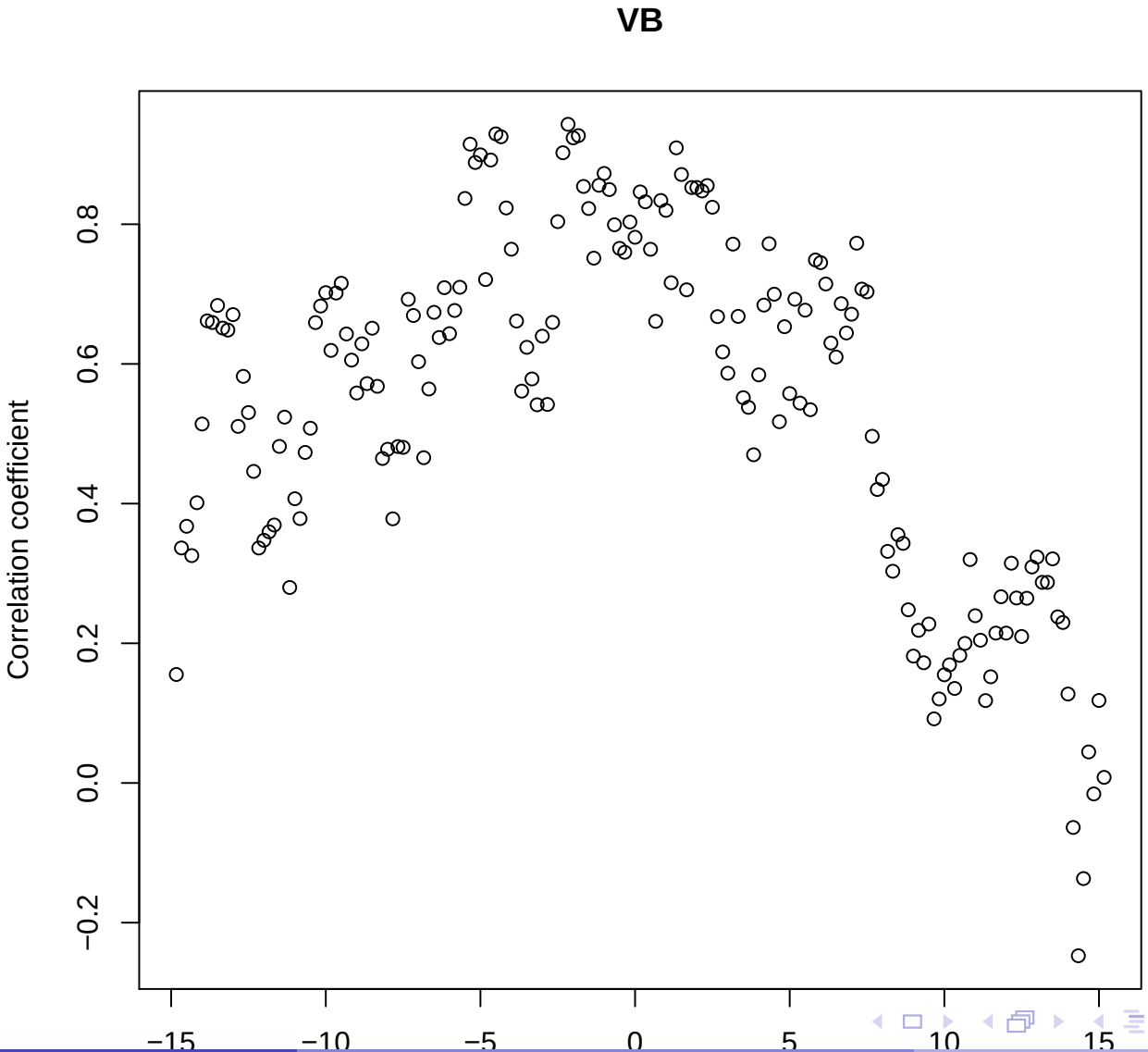

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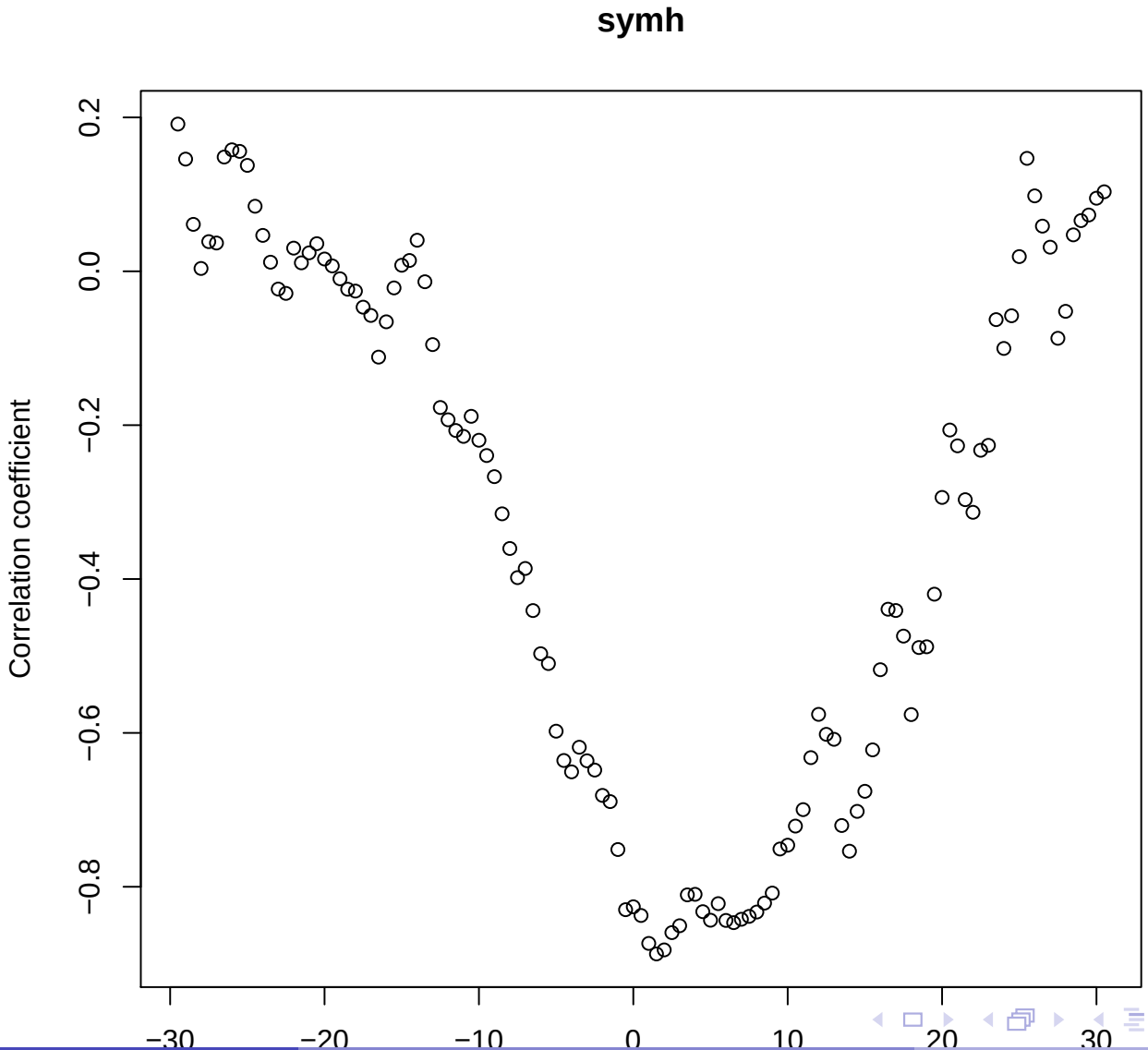

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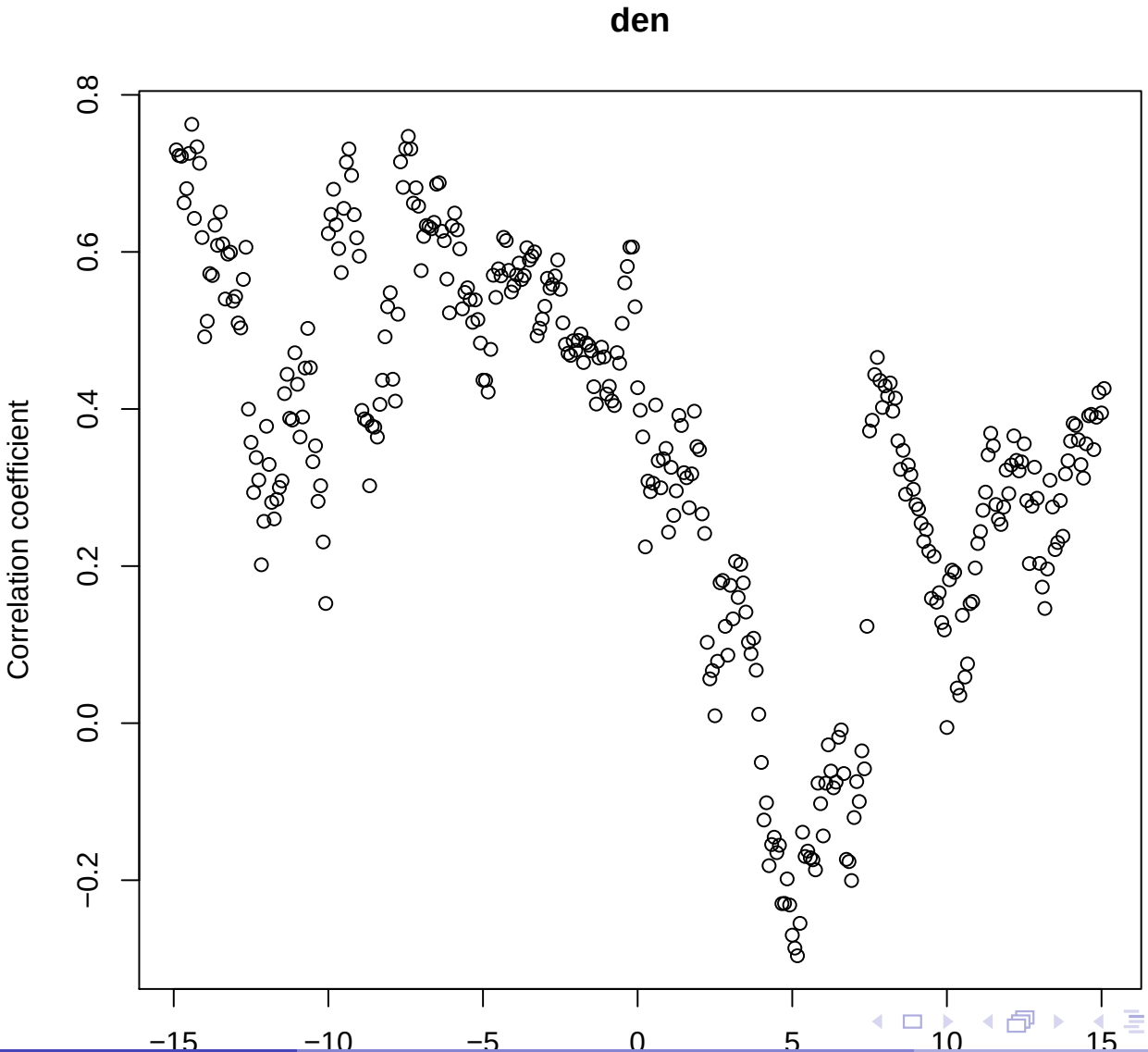


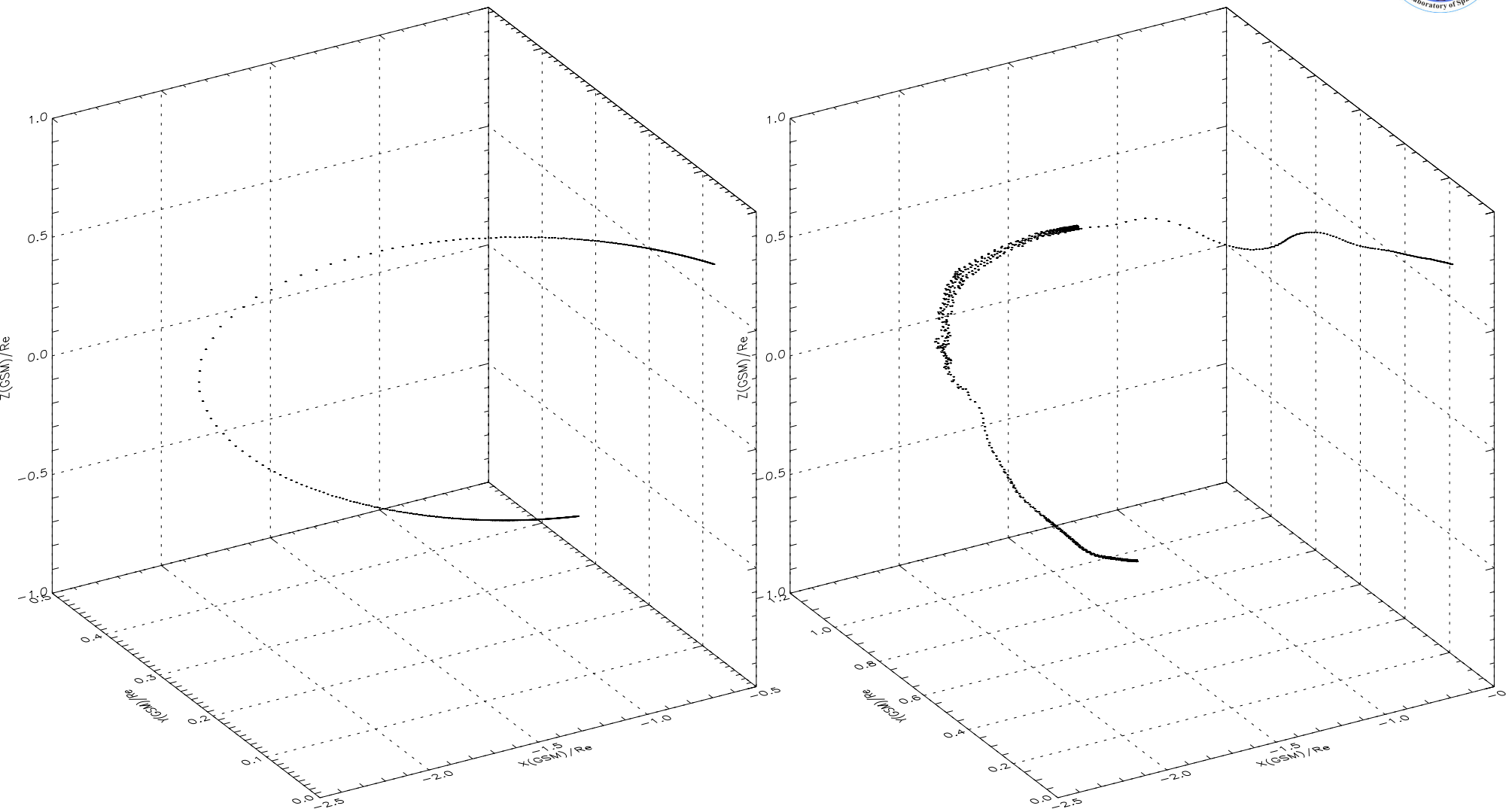
Simple Conclusions

- We find well defined energetic particle cutoff rigidities that exhibit interesting behavior in response to solar wind conditions.
- There is a decay time of hours between the maxmium of the area of the polar hole of the cosmic rays and the Dst index minmimum.

Further Work

- It is found that there exists turbulence in the magnetosphere.
- The turbulence can obsevily affect the behavios of the energetic particle.

Further Work



- The left figure is calculated without turbulende and the right is calculated with turbulence level $db/B_0 = 0.1$.

Thank You!