Cluster Space Weather Anomalies

by Mike Paniccia

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Cluster Mission

- The aim of the Cluster Mission is to study small-scale structures of the magnetosphere and its environment in three dimensions.
- Cluster consists of four identical spacecraft that will fly in a tetrahedral configuration.
- The separation distances between the spacecraft will vary between 600 km and 20,000 km, according to the key scientific regions.

What is an Anomaly?

- An unexplained error in satellite functioning that causes data loss or interruption.
- There are 131 anomalies that I am investigating and attempting to find the cause of the disturbance
- Anomalies range from August 2000 through March 2005.

Types of Anomalies

- Surface Charging - When a charge from geomagnetic storms is built up on the spacecraft thus resulting in electrical discharge.

- Single Event Upset - When a high energy particle happens to hit a device in just the right spot to cause disruption.

- Deep Dielectric Discharge - When a charge builds and discharges within a spacecraft after long bombardment from high energy electrons

Other Types of Anomalies

- Spacecraft drag (<1000 km)
- Total dose effects
- Materials degradation
- Debris
- Meteorite impact
- Spacecraft orientation
- Photonics Noise
- Solar radio frequency interference and telemetry scintillation

Data Accumulated

Single Event Upset:

- 10.7 Solar Flux
- Solar Flares
- Solar Wind Speed
- Proton Density
- Proton Flux

Surface Charging:

- Dst, AE, Kp indices
- Magnetic Field

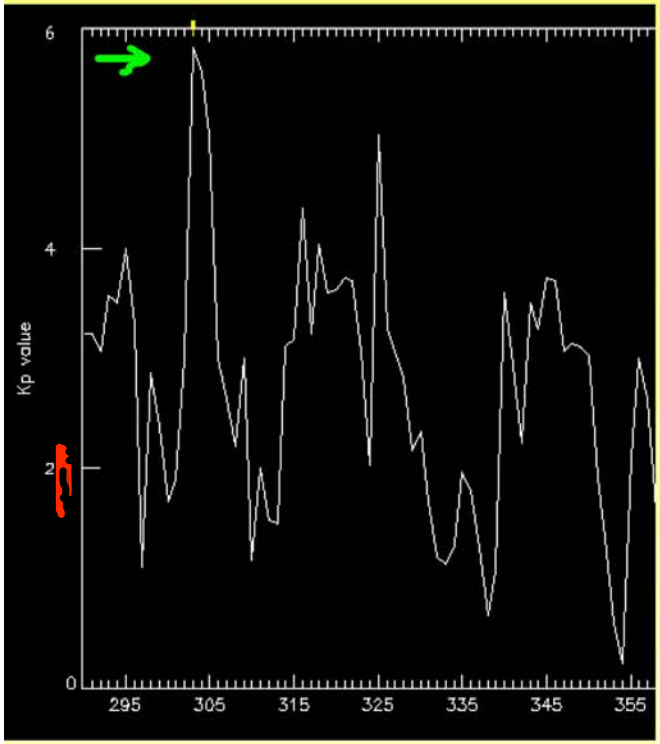
Dielectric Discharging:

- Electron Density
- Electron Flux

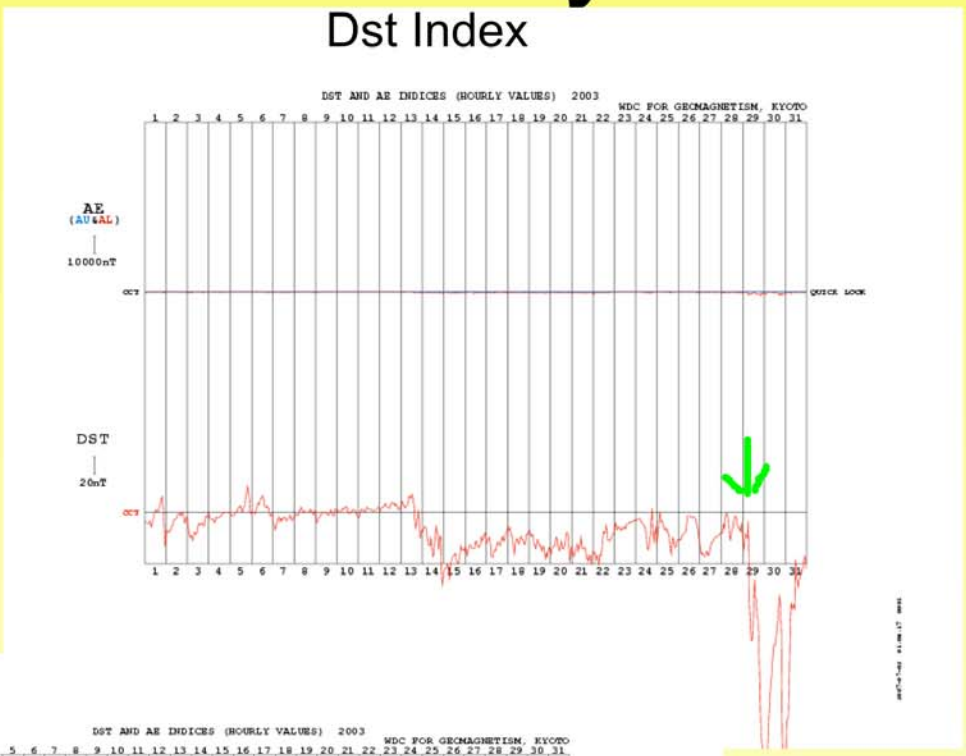
Indices

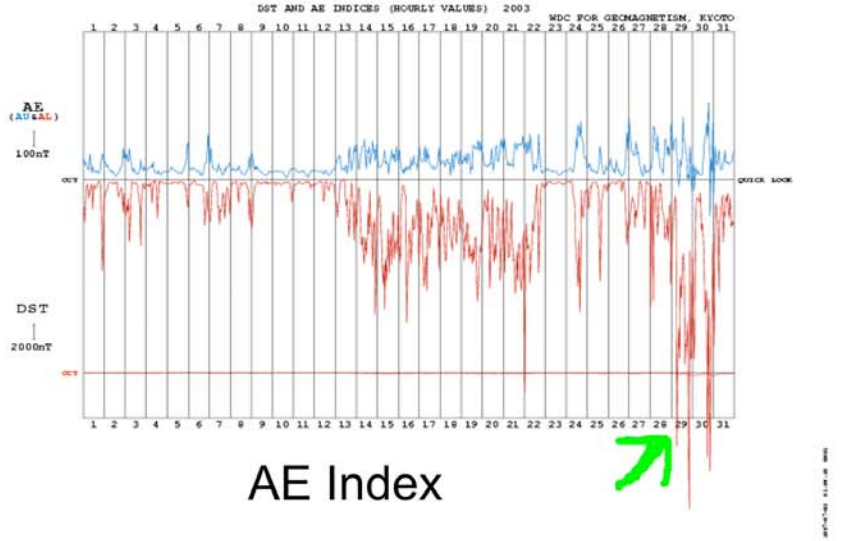
- Dst – Measures the worldwide magnetic storm level through the observation of the intensity of the ring current.
- Kp – Measures the worldwide geomagnetic level from auroral activity at mid-latitudes.
- AE – Measures various events in the auroral zone. A large spike is called a magnetospheric substorm.

10/29/2003 Anomaly



Kp Index

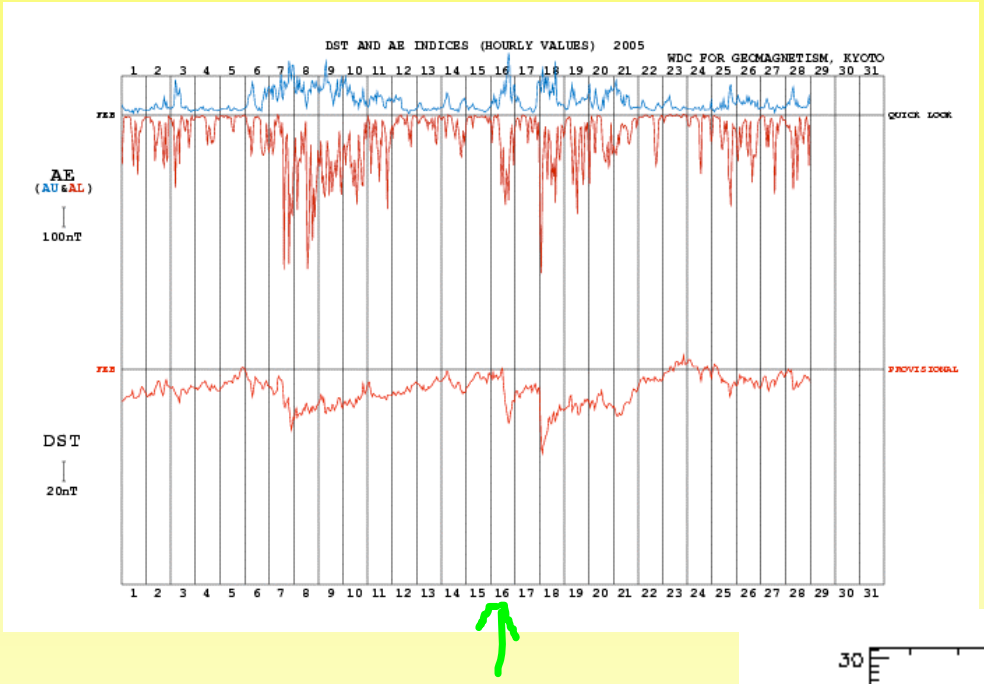




AE Index

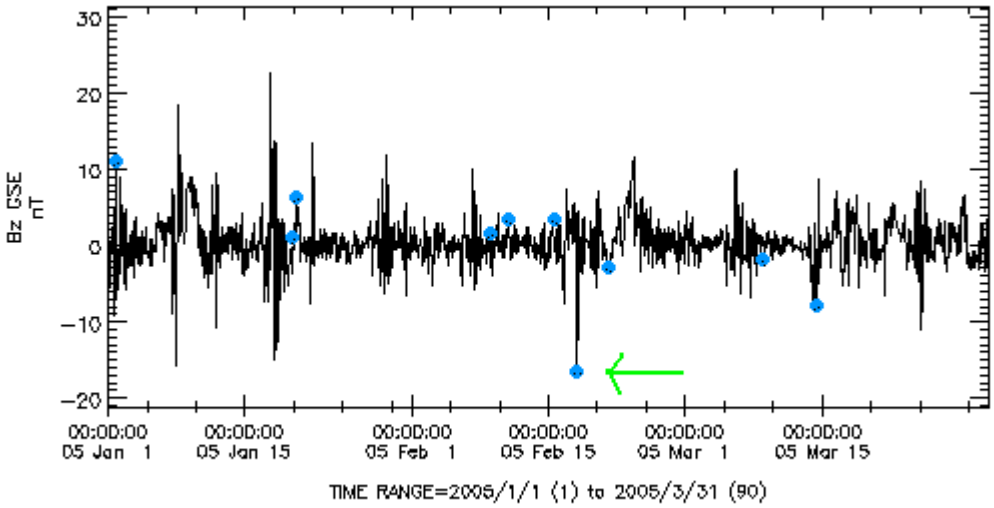
Surface Charging

2/16/2005 Anomaly (SC)

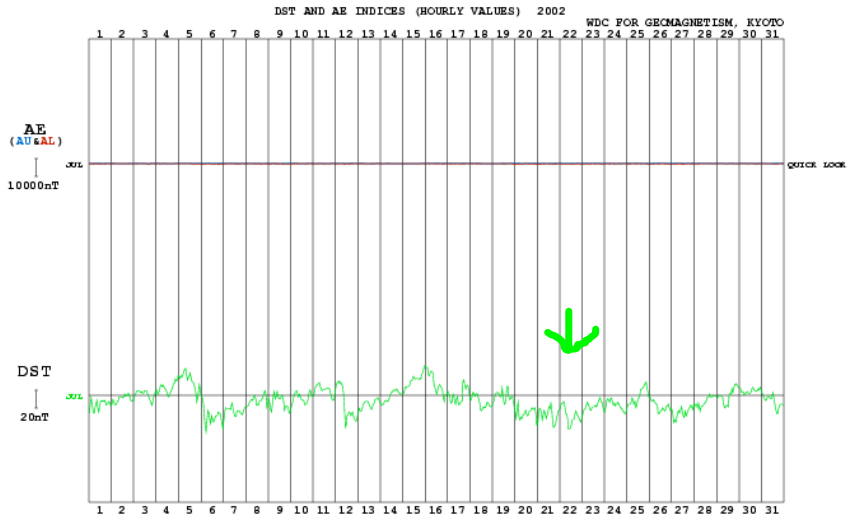


There are no major spikes on the indices.

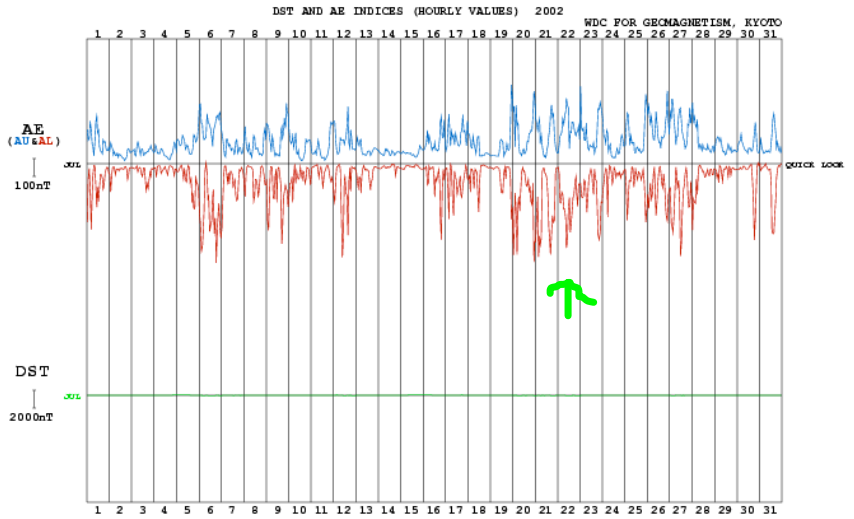
There is, however, a large spike on the Bz value.



7/23/2002 Anomaly



Dst Index



AE Index

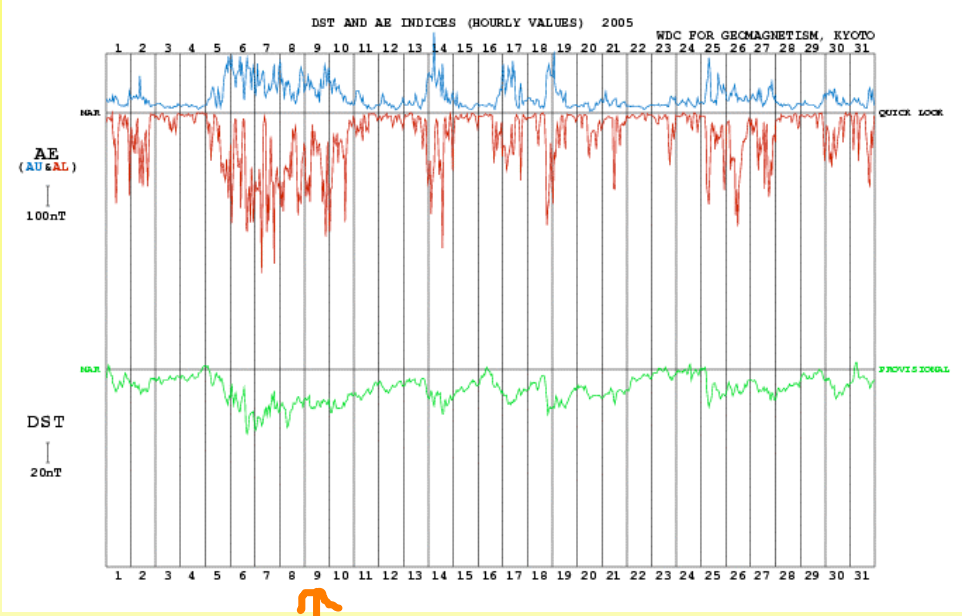
Not surface charging.

Flare: Jul 20 9:30 PM Single Event Upset.

Anomaly: Jul 23 9:58:25 AM

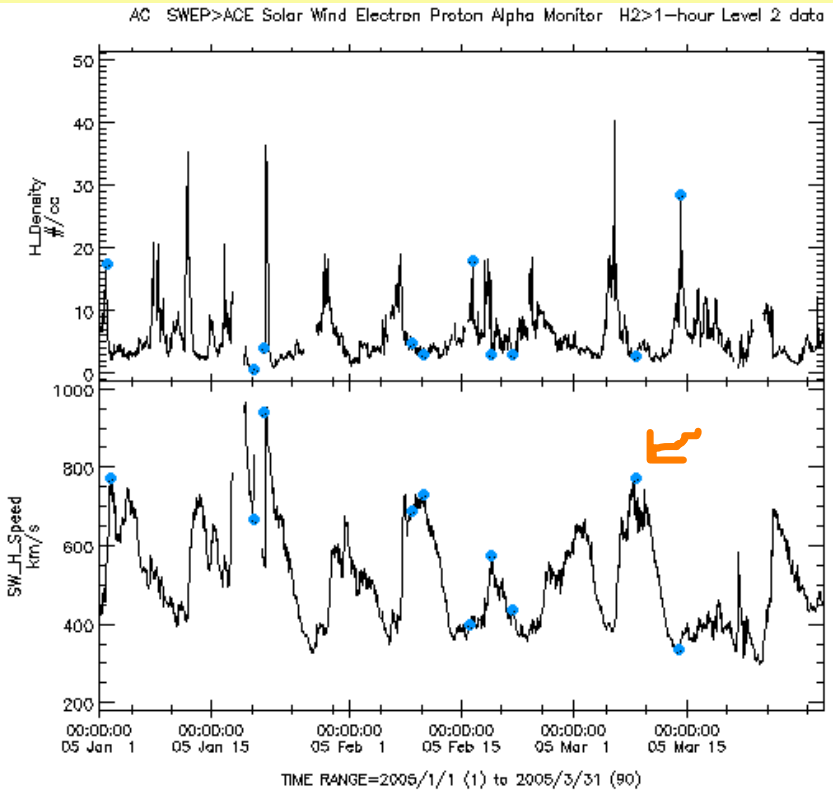
Peak Particle Event: Jul 23 10:25 AM

3/9/2005 Anomaly (SEU)

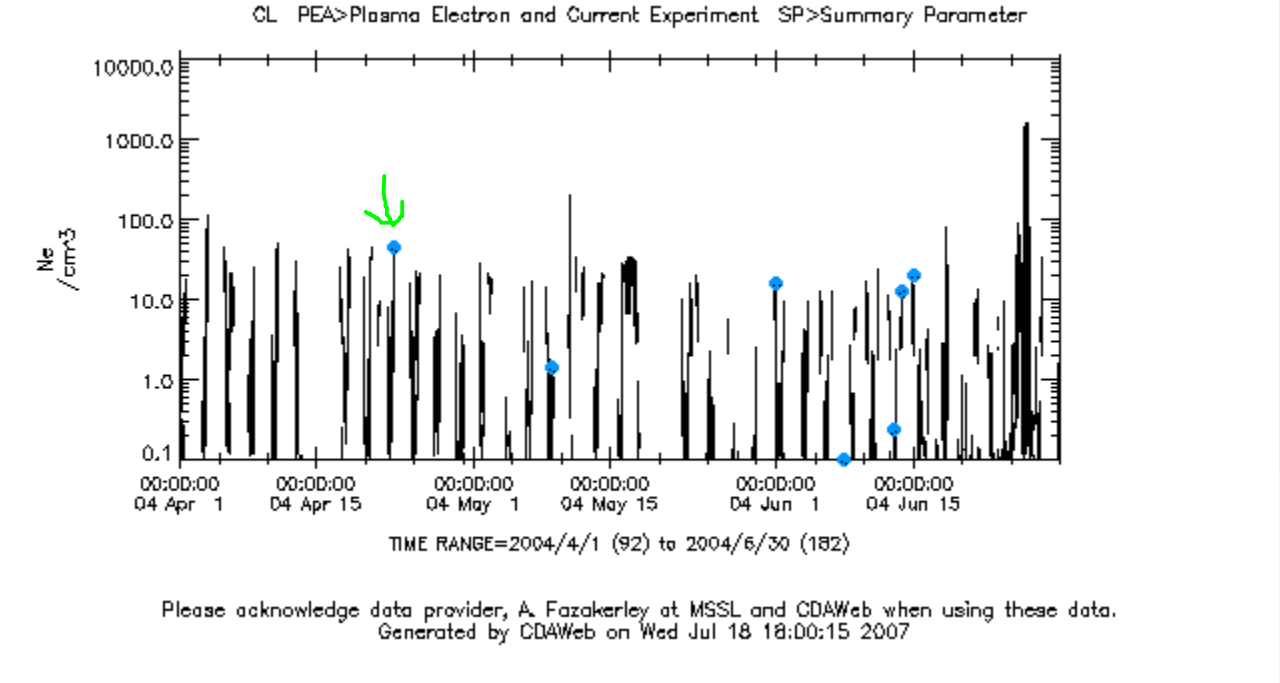


Again, There are no major spikes on the indices.

There is a spike on the Solar Wind graph.

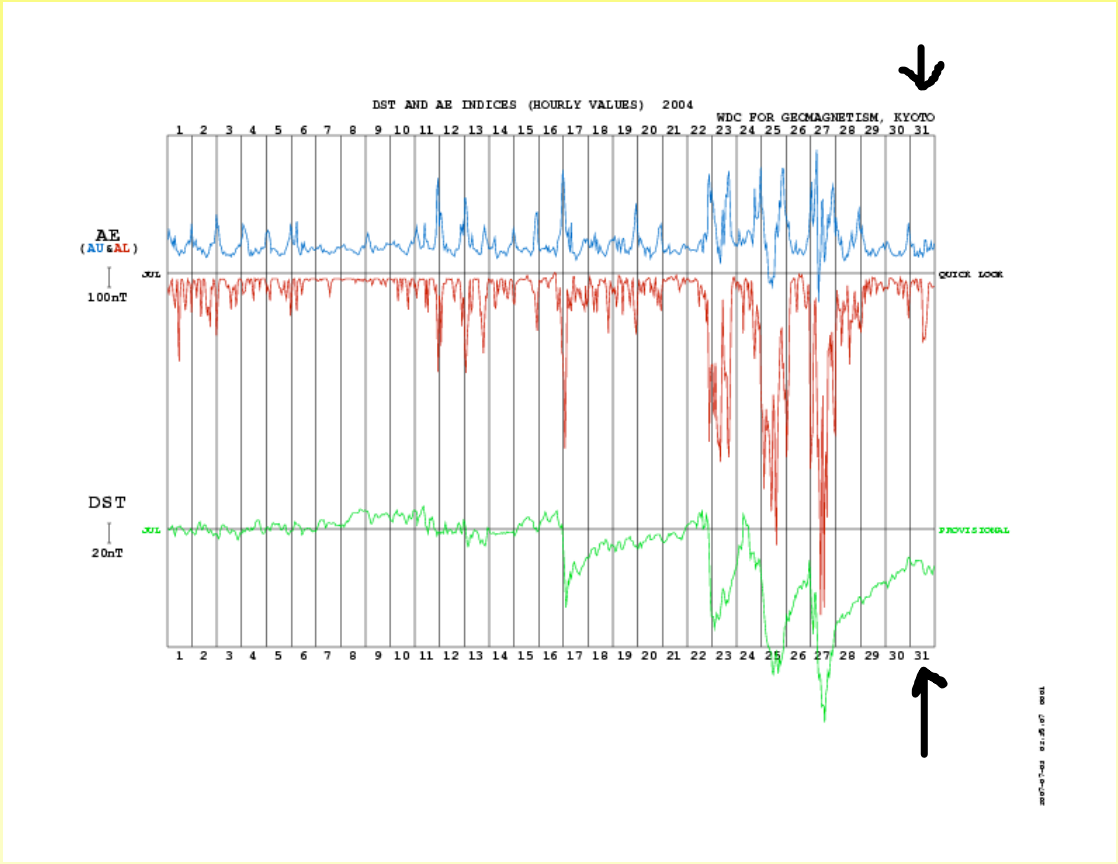


4/23/2004 Anomaly



- The only graph that had a spike was the Electron Density Graph, therefore meaning a Deep Dielectric Discharge.

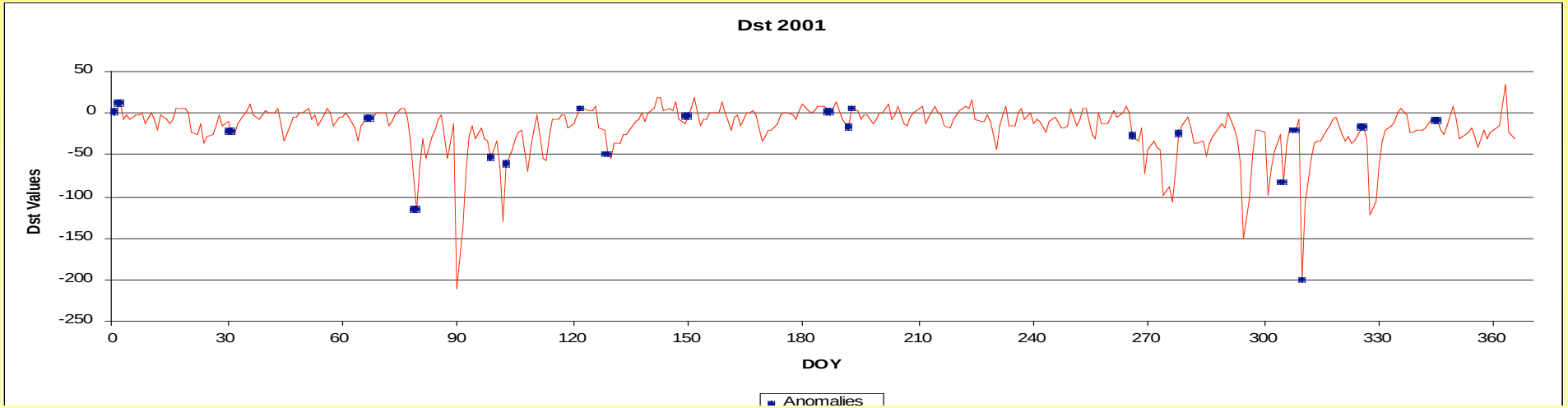
7/31/2004 Anomaly (DDD)

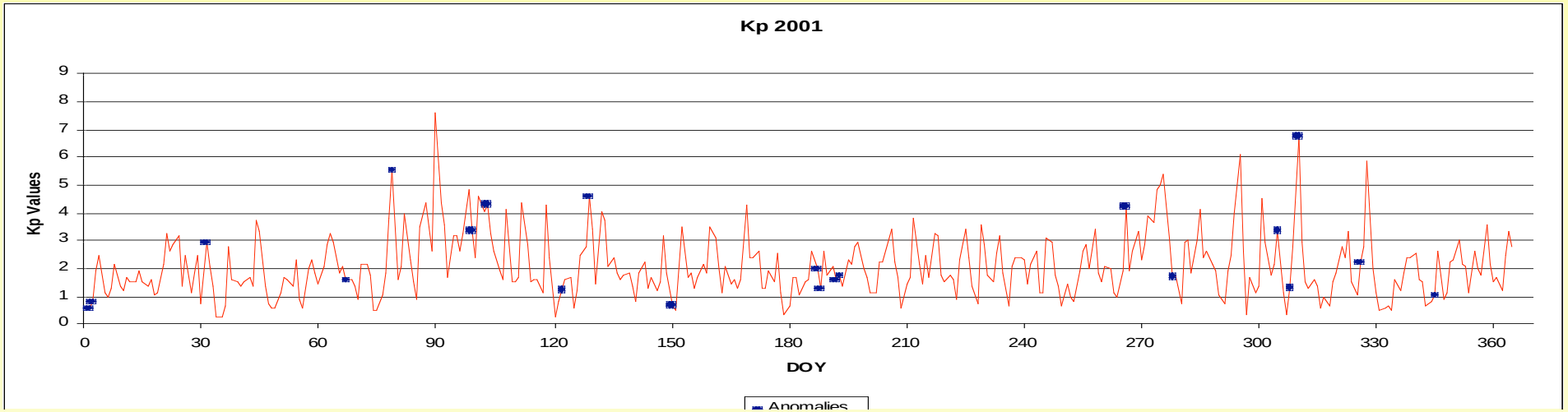


Particle Event occurred on July 25, 2004

Anomaly occurred after a long series of spikes, and is probably the result of a Deep Dielectric Discharge.

Year Long Graphs (2001)



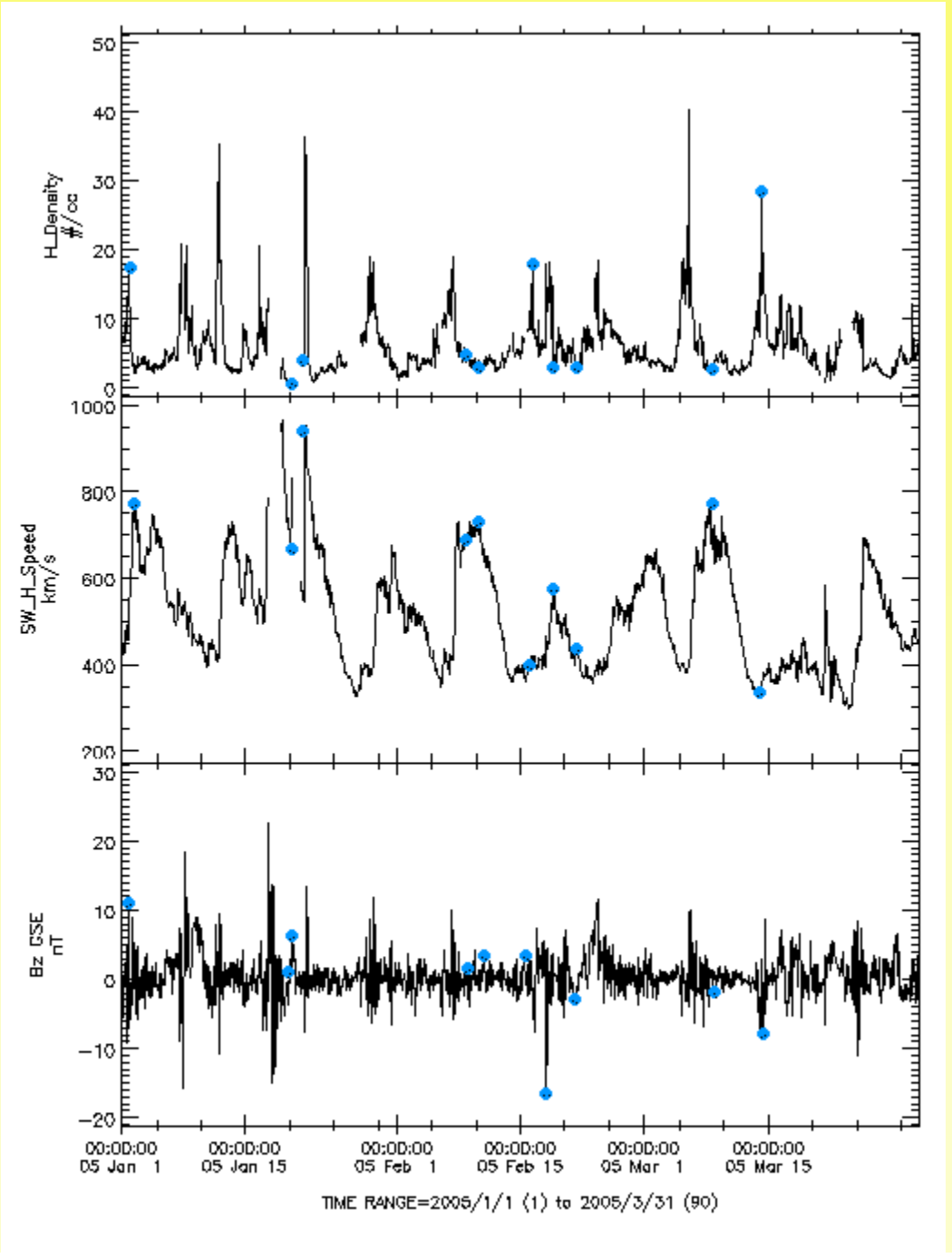


Other data

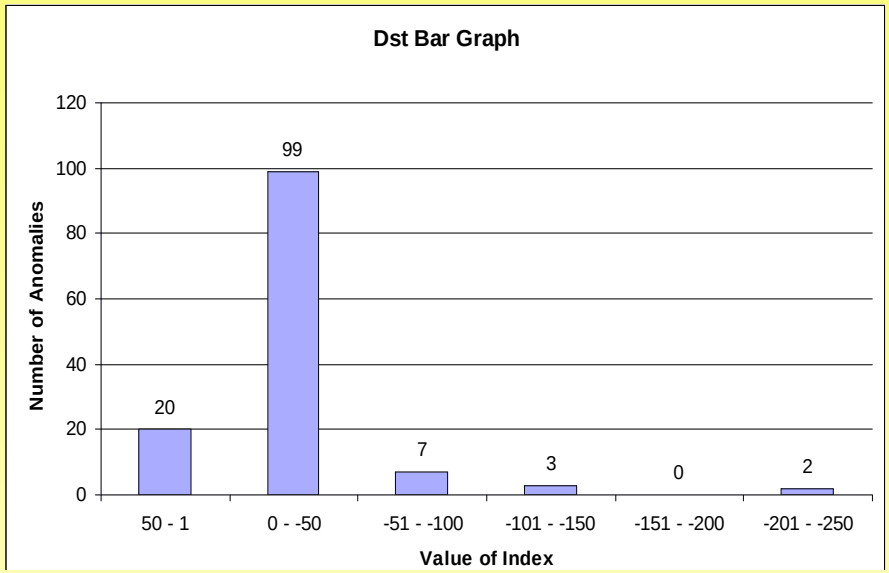
Proton Density:

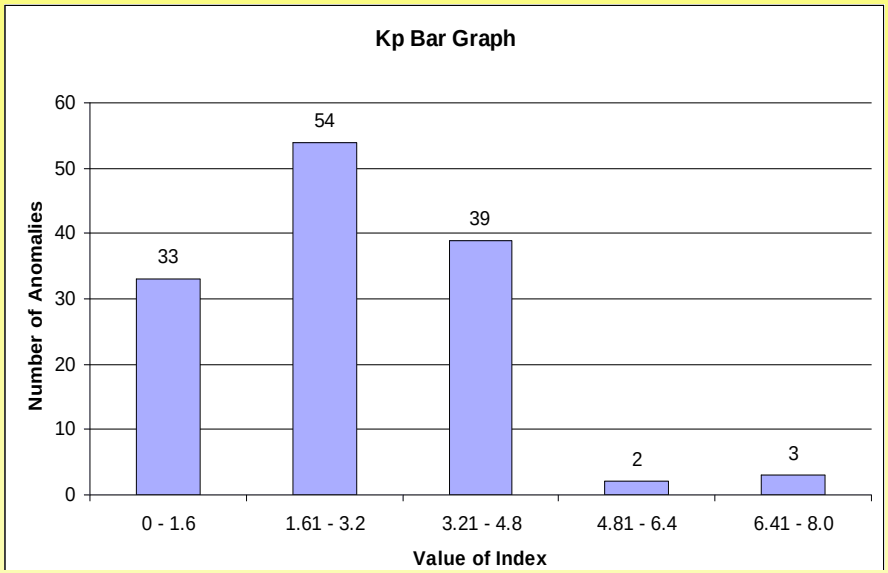
Solar Wind Speed:

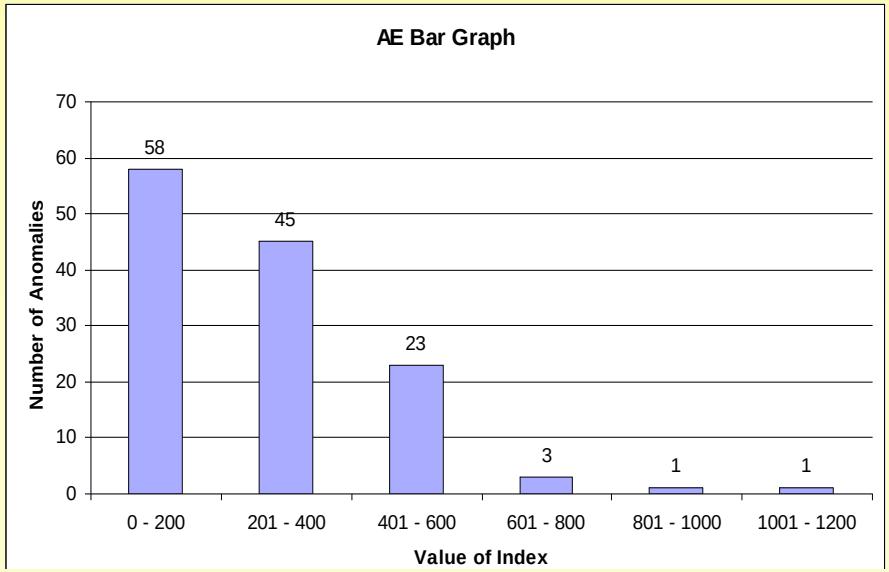
Magnetic Field (Z-axis):

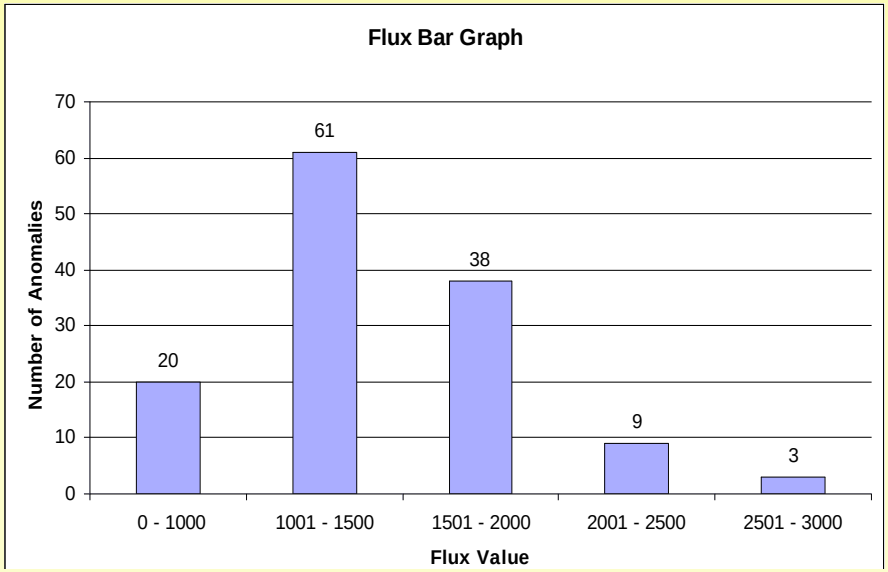


Bar Graphs

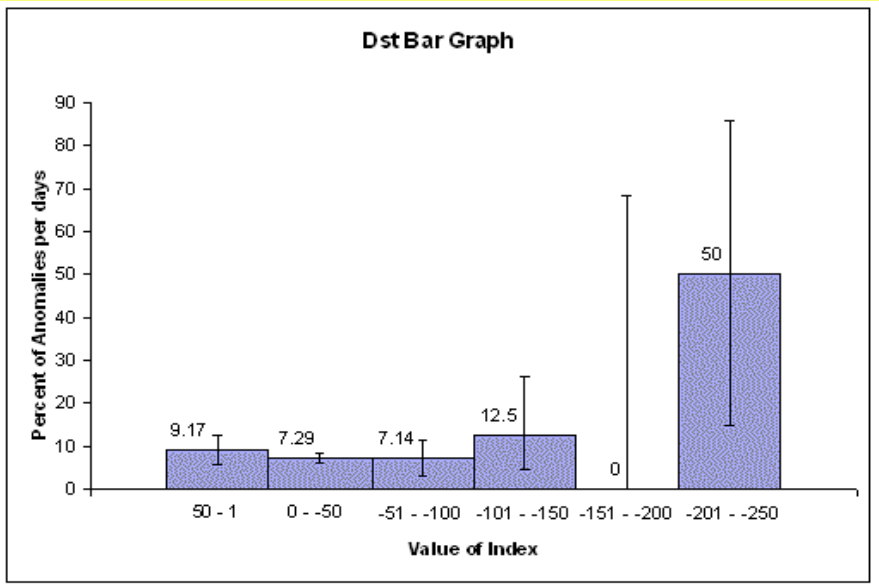

Dst Bar Graph
Number of Anomalies
120
100
80
60
40
20
0
99
20
7
3
0
2
50 - 1
0 - -50
-51 - -100
-101 - -150
-151 - -200
-201 - -250
Value of Index

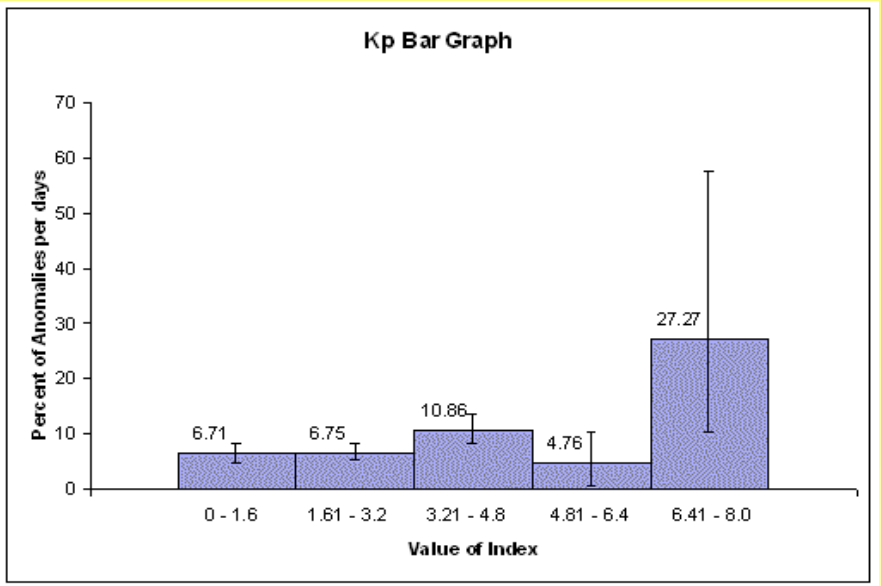

Kp Bar Graph
Number of Anomalies
60
50
40
30
20
10
0
54
33
39
2
3
0 - 1.6
1.61 - 3.2
3.21 - 4.8
4.81 - 6.4
6.41 - 8.0
Value of Index

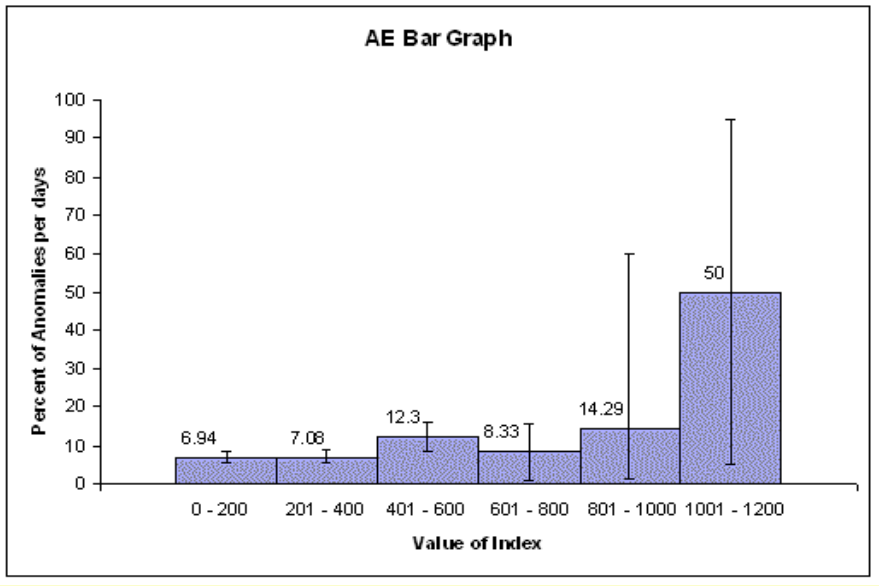

AE Bar Graph
Number of Anomalies
70
60
50
40
30
20
10
0
58
45
23
3
1
1
0 - 200
201 - 400
401 - 600
601 - 800
801 - 1000
1001 - 1200
Value of Index

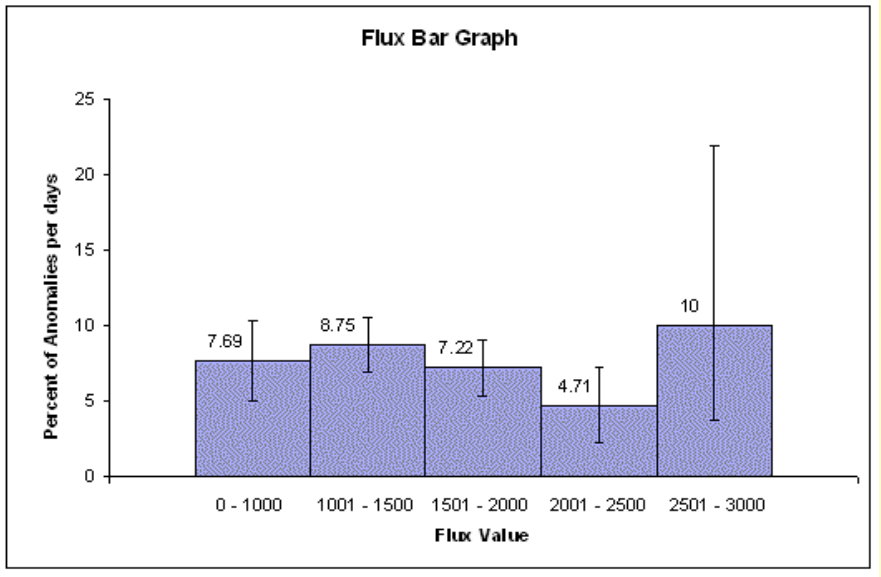

Flux Bar Graph
Number of Anomalies
70
60
50
40
30
20
10
0
61
20
38
9
3
0 - 1000
1001 - 1500
1501 - 2000
2001 - 2500
2501 - 3000
Flux Value

Bar Graph Analysis









Statistical Analysis

r	90%		95%		99%	
			$n = 2$			
0	0	.684	0	.776	0	.900
1	.051	.949	.025+	.975−	.006+	.995−
2	.316	1	.224	1	.100	1
			$n = 4$			
0	0	.500	0	.527	0	.684
1	.026	.680	.013	.751	.003	.859
2	.143	.857	.098	.902	.042	.958
3	.320	.974	.249	.987	.141	.997
4	.500	1	.473	1	.316	1
			$n = 6$			
0	0	.345−	0	.402	0	.536
1	.017	.542	.009	.598	.002	.706
2	.093	.667	.063	.729	.027	.827
3	.201	.799	.153	.847	.085−	.915+
4	.333	.907	.271	.937	.173	.973
5	.458	.983	.402	.991	.294	.998
6	.655+	1	.598	1	.464	1
			$n = 8$			
0	0	.255−	0	.315+	0	.451
1	.013	.418	.006	.500	.001	.590
2	.069	.582	.046	.685−	.020	.707
3	.147	.745+	.111	.711	.061	.802
4	.240	.760	.193	.807	.121	.879
5	.255−	.853	.289	.889	.198	.939
6	.418	.931	.315+	.954	.293	.980
7	.582	.987	.500	.994	.410	.999
8	.745+	1	.685−	1	.549	1

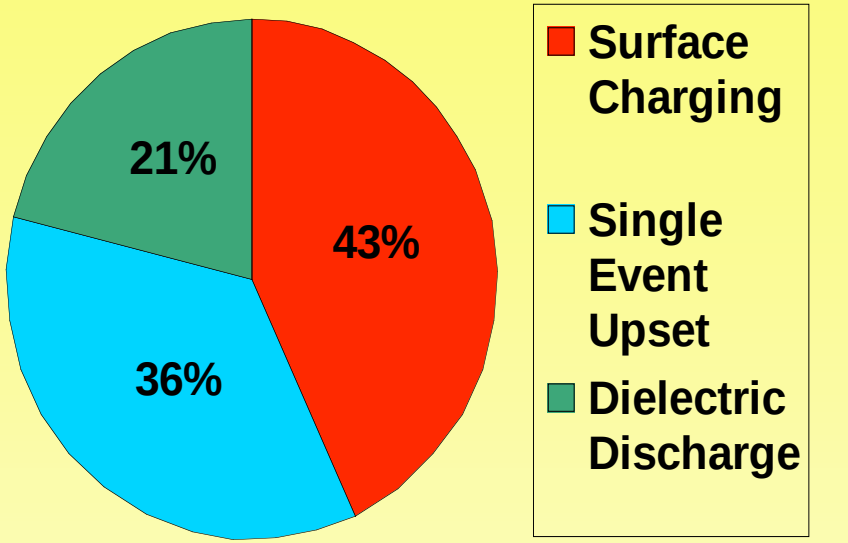
- From the confidence limit table, at 90% confidence, r=2 and n=4 I get a range of 0.143 to 0.857

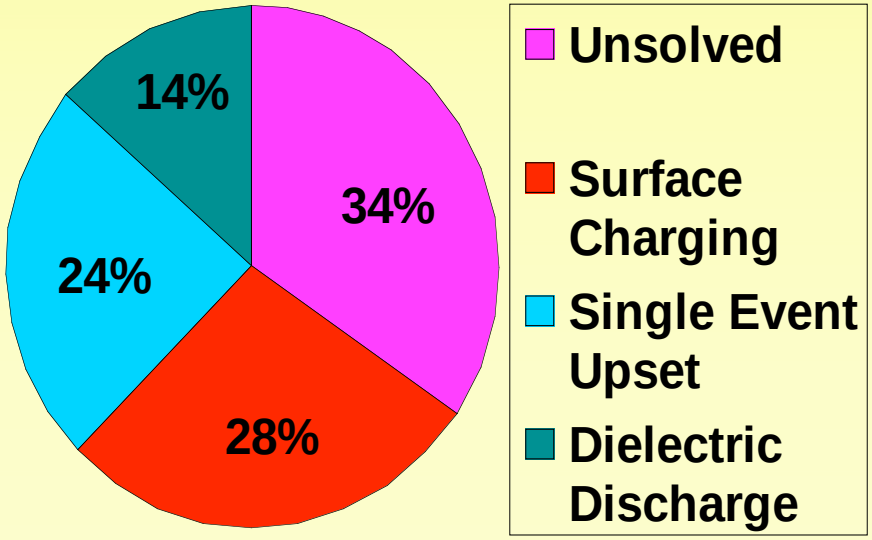
- This means, based on my data I can be 90% confident that the true failure rate of identical satellites in this situation will be from 14.3 % to 85.7%.

Anomaly Results

There were:

- 37 Surface Charging anomalies
- 31 Single Event Upset anomalies
- 18 Deep Dielectric Discharge anomalies
- Adds up to 86/131 anomalies (65.6%)

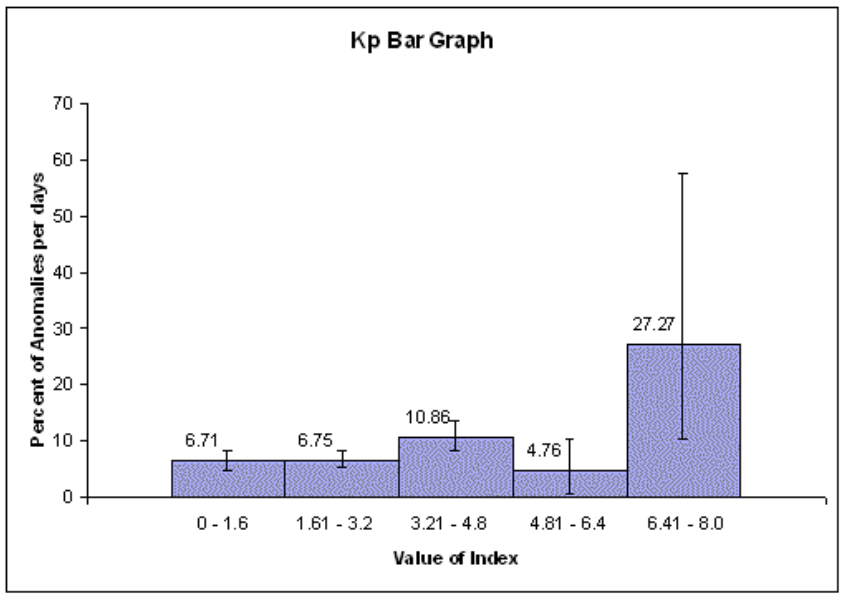


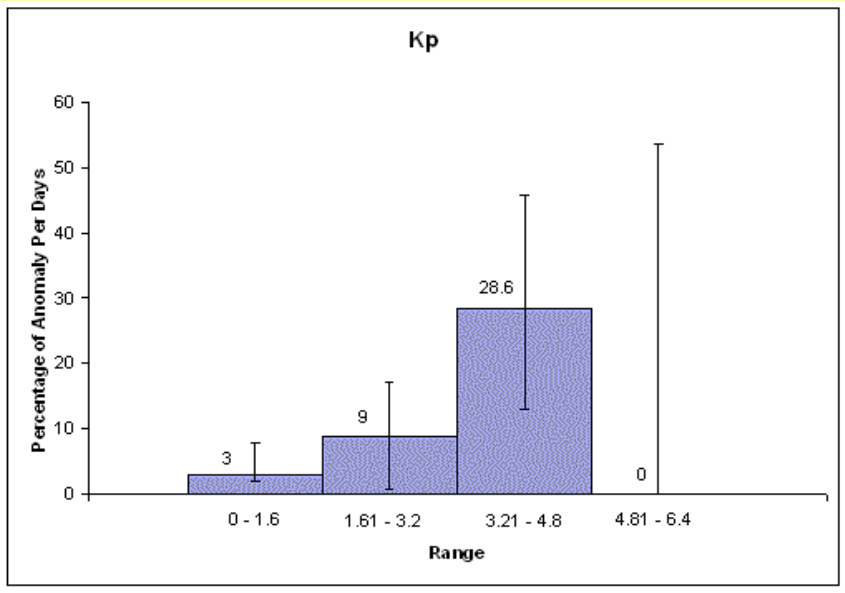


Predictions/Actual for 2005

- 8.8 Anomalies
- 3.8 Surface Charging
- 3.1 Single Event Upset
- 1.9 Dielectric Discharge

- 10 anomalies (12%)
- 7 SC
- 2 SEU
- 1 DD





Other Statistics

- Average anomalies per year is 28.
- 2004 was the year with the most anomalies (31), however, if 2005 continues its trend (10 anomalies in 3 months) there will be 40.
- Anomalies per year are increasing (23, 26, 29, 31).
- All anomalies in 2005 have been accounted for.
- Month (over all years) with the most anomalies is November (20).

Conclusion

- Out of 131 anomalies, 86 have a large value for something relating to space weather.
- Surface Charging is the most common type of anomaly
- 8.8 anomalies predicted, 10 actually occurred in the first 3 months of 2005.
- Prediction of future anomalies is probable, however, predicting which type of anomaly is less likely.
- Anomalies are more likely to occur at higher values of the indices.

References

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