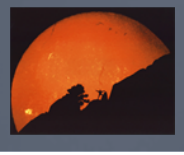
Early Observable Events in Correlation with Geomagnetic Storms

Victoria Strait[1,2] , Bob Rutledge[2], Chris Balch[2]

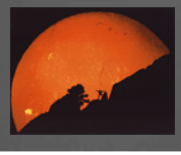
[1]Furman University, Greenville, SC

[2]NOAA/SWPC, Boulder, CO



Overview

- Purpose
- Instruments/Data
- Processes
- Initial Results
  - What worked
  - What didn't
- New Plan
  - New Results
- Training Package
- Conclusion



Purpose

Identify geomagnetic precursors

- Using correlations with early observable solar events

Value in Comprehensive studies

- Variable Relevance
- Index Relevance

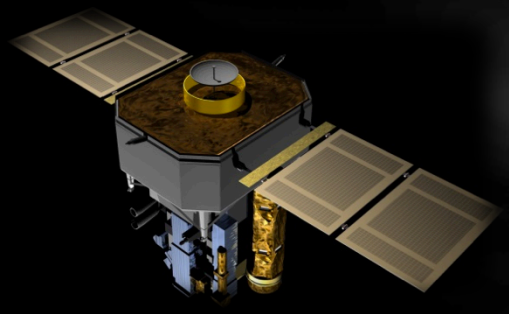
Challenges current thoughts

- Can shake misconceptions

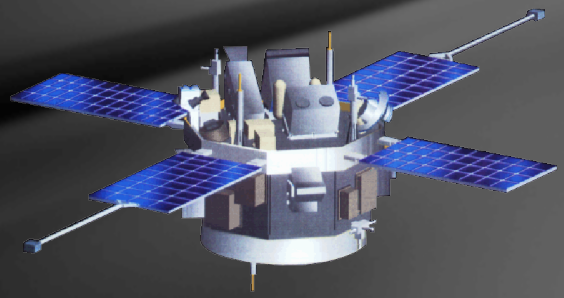
Data Reliability

- Gives clues as to what data is most useful/reliable

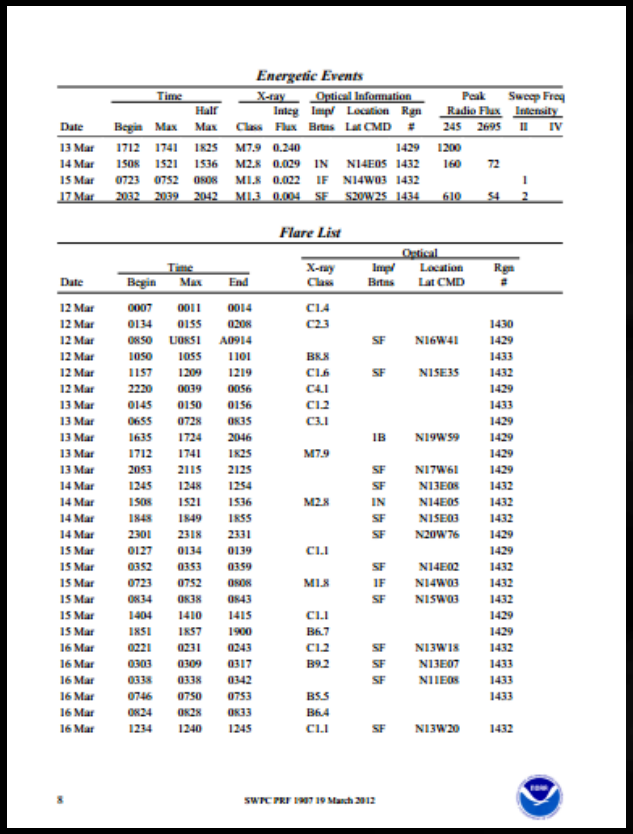
Data



- Weekly Reports
  - Located in the forecast office
- ACE
  - Located at L1
  - EPAM
  - SWEPAM
  - MAG
- SOHO
  - Located at L1
  - LASCO
  - CME Catalog



Weekly Reports



Energetic Events

	Time			X-ray		Optical Information			Peak Radio Flux		Sweep Freq Intensity	
Date	Begin	Max	Half Max	Class	Integ Flux	Imp/ Brtns	Location Lat CMD	Rgn #	245	2695	II	IV
13 Mar	1712	1741	1825	M7.9	0.240			1429	1200			
14 Mar	1508	1521	1536	M2.8	0.029	1N	N14E05	1432	160	72		
15 Mar	0723	0752	0808	M1.8	0.022	1F	N14W03	1432			1	
17 Mar	2032	2039	2042	M1.3	0.004	SF	S20W25	1434	610	54	2	

Flare List

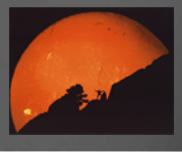
	Time			X-ray	Optical Imp/	Location	Rgn
Date	Begin	Max	End	Class	Brtns	Lat CMD	#
12 Mar	0007	0011	0014	C1.4			
12 Mar	0134	0155	0208	C2.3			1430
12 Mar	0850	U0851	A0914		SF	N16W41	1429
12 Mar	1050	1055	1101	B8.8			1433
12 Mar	1157	1209	1219	C1.6	SF	N15E35	1432
12 Mar	2220	0039	0056	C4.1			1429
13 Mar	0145	0150	0156	C1.2			1433
13 Mar	0655	0728	0835	C3.1			1429
13 Mar	1635	1724	2046		1B	N19W59	1429
13 Mar	1712	1741	1825	M7.9			1429
13 Mar	2053	2115	2125		SF	N17W61	1429
14 Mar	1245	1248	1254		SF	N13E08	1432
14 Mar	1508	1521	1536	M2.8	1N	N14E05	1432
14 Mar	1848	1849	1855		SF	N15E03	1432
14 Mar	2301	2318	2331		SF	N20W76	1429
15 Mar	0127	0134	0139	C1.1			1429
15 Mar	0352	0353	0359		SF	N14E02	1432
15 Mar	0723	0752	0808	M1.8	1F	N14W03	1432
15 Mar	0834	0838	0843		SF	N15W03	1432
15 Mar	1404	1410	1415	C1.1			1429
15 Mar	1851	1857	1900	B6.7			1429
16 Mar	0221	0231	0243	C1.2	SF	N13W18	1432
16 Mar	0303	0309	0317	B9.2	SF	N13E07	1433
16 Mar	0338	0338	0342		SF	N11E08	1433
16 Mar	0746	0750	0753	B5.5			1433
16 Mar	0824	0828	0833	B6.4			
16 Mar	1234	1240	1245	C1.1	SF	N13W20	1432

8 SWPC PRF 1907 19 March 2012

Include:

Summary of flares, solar wind, coronal activity, proton events, and geomagnetic activity

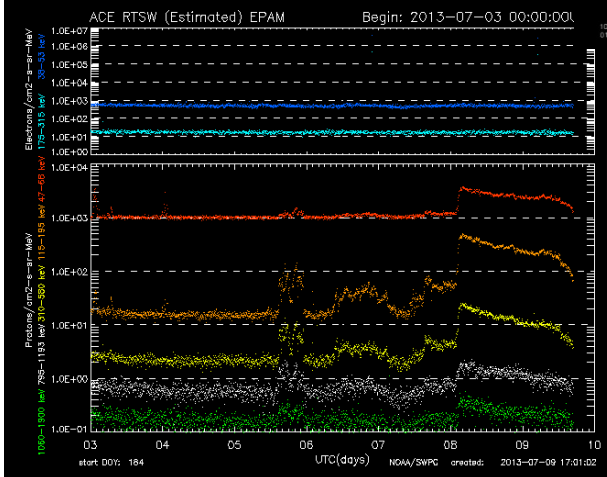
Sunspot Number, region summaries, alerts and warnings, outlooks, and indices



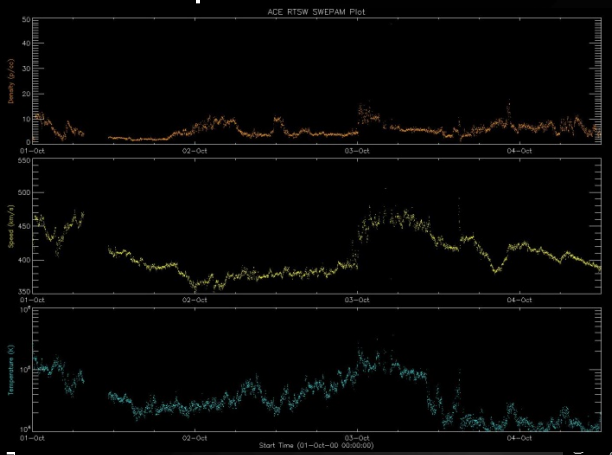
ACE (Advanced Composition Explorer)

EPAM (Electron, Proton, and Alpha Monitor)

- 5 telescope apertures
- 2 which measure proton flux levels >50 keV



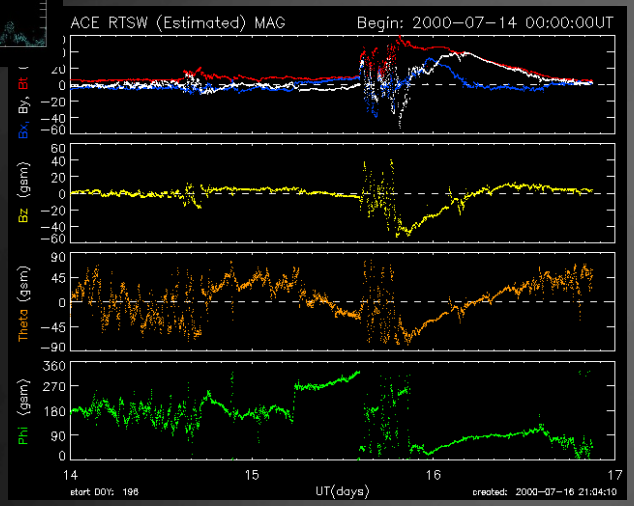
SWEPAM (Solar Wind Electron, Proton, and Alpha Monitor



- Measures plasma parameters: velocity, density, temperature

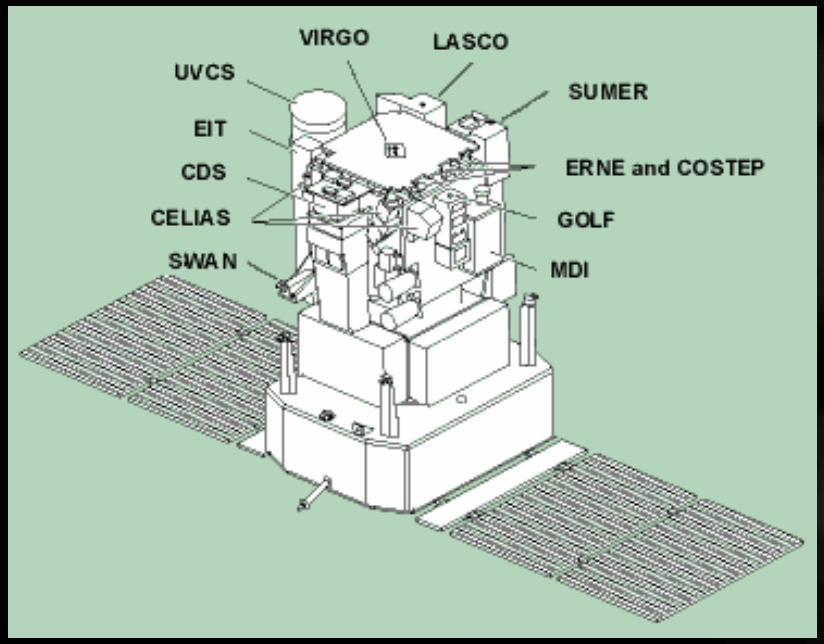
MAG (Magnetometer)

- Measures direction and magnitude of local interplanetary magnetic field



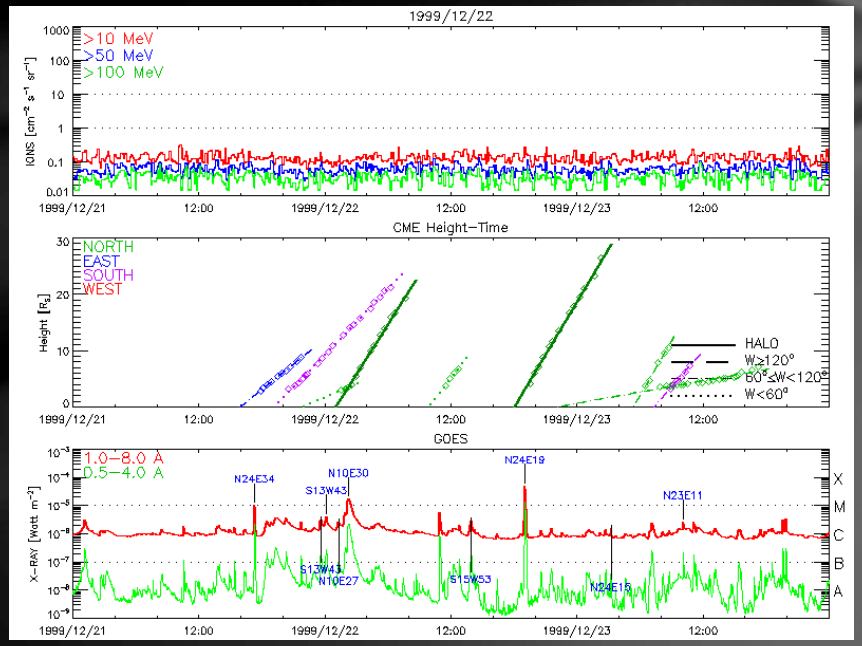
SOHO (Solar and Heliospheric Observatory)

LASCO (Large Angle and Spectrometric Coronagraph)



Consists of 3 coronagraphs, each imaging a specific field of view

CME Catalog



Includes speed, mass, angle for most CMEs

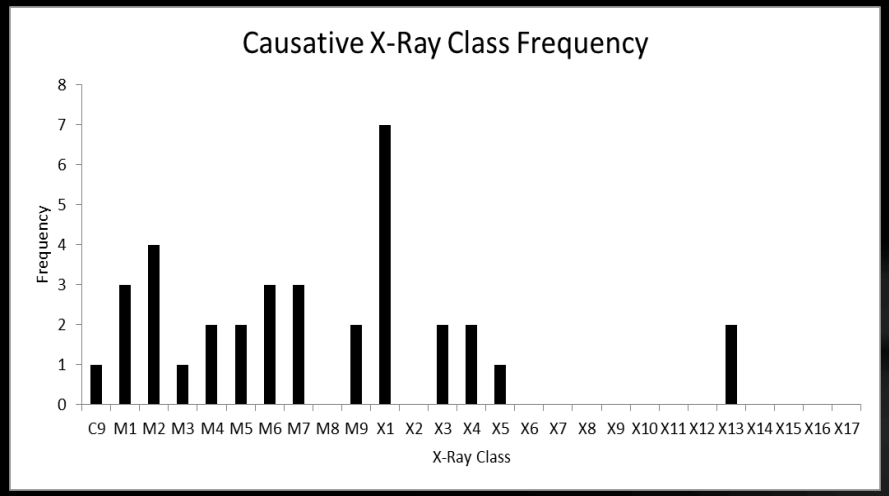
Indices

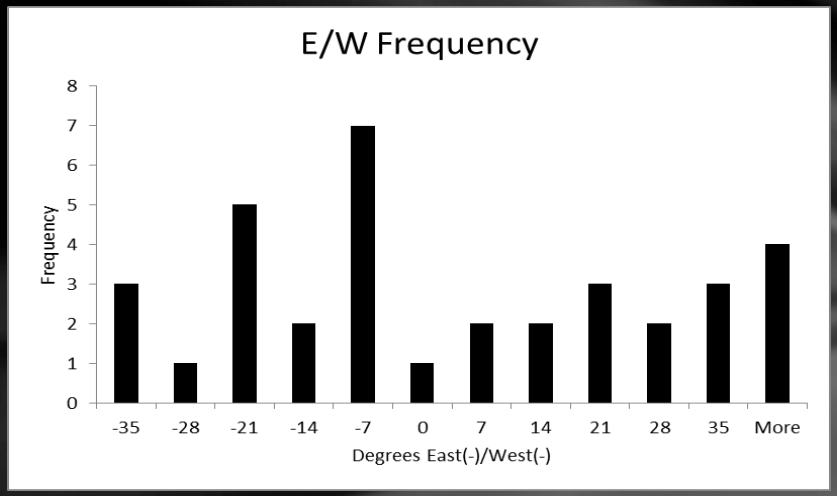
- Kp
  - Each of 13 observatories ranks activity on a K scale from 0 to 9 (quiet to disturbed)
  - Every 3 hours, these numbers are mapped onto a 0-27 Kp scale, eliminating altitudinal and seasonal difference
- ap
  - Maps the quasi-logarithmic Kp scale to a linear one

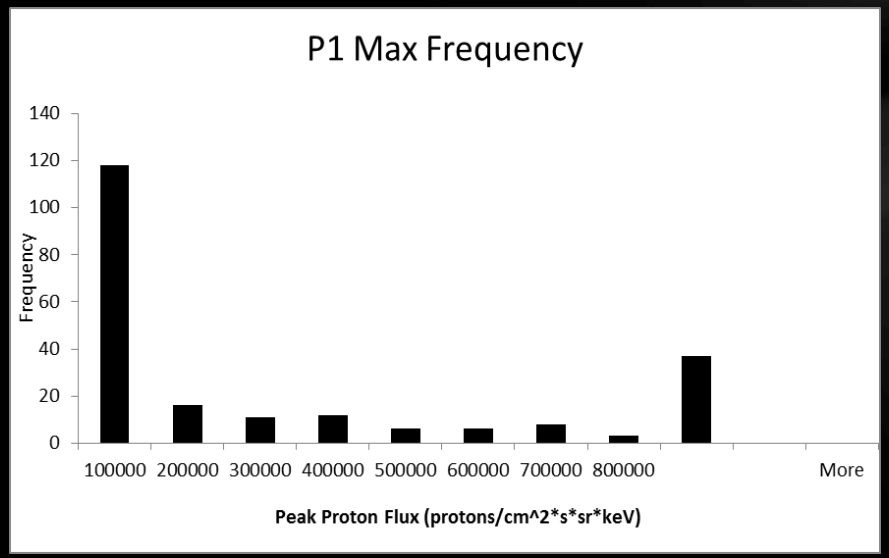
Kp	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Ap	0	2	3	4	5	6	7	9	12	15	18	22	27	32	39	48	56	67	80	94	111	132	154	179	207	236	300	400

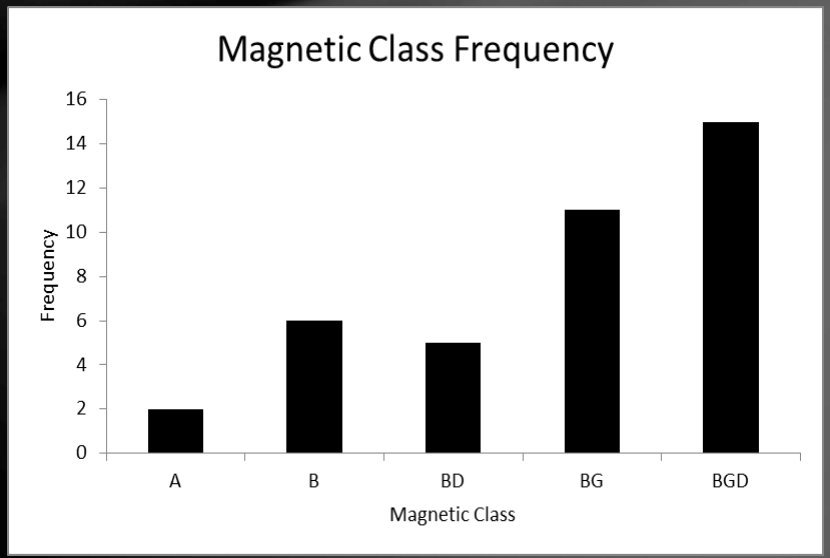
- Ap
  - Daily average of ap
  - Units: nT

Initial Results





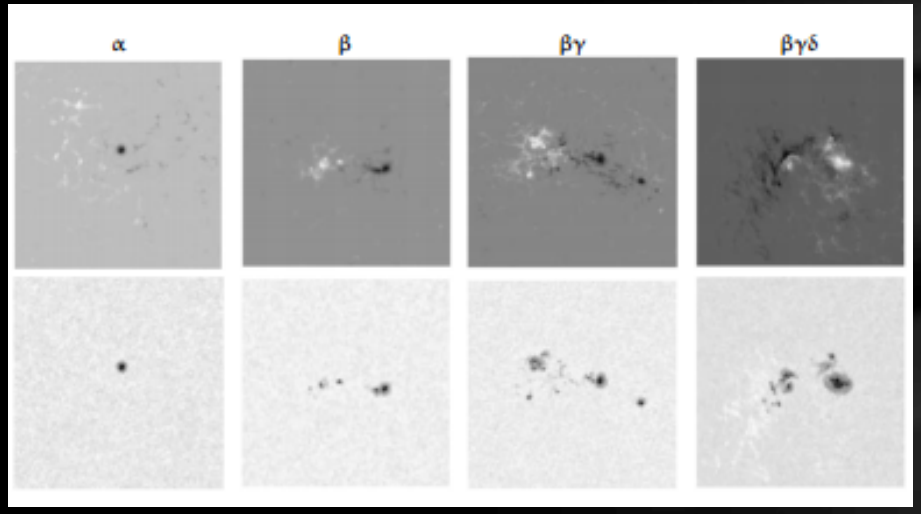




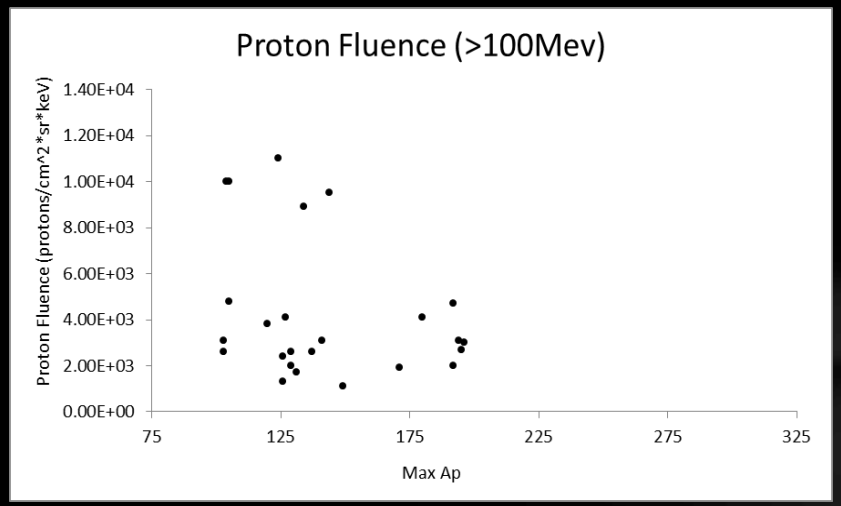
Magnetic Classes

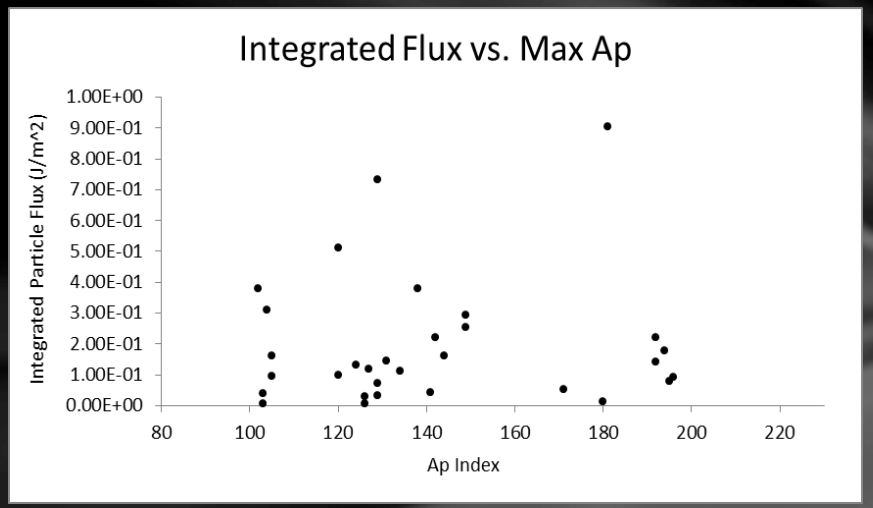
Mount Wilson Classification

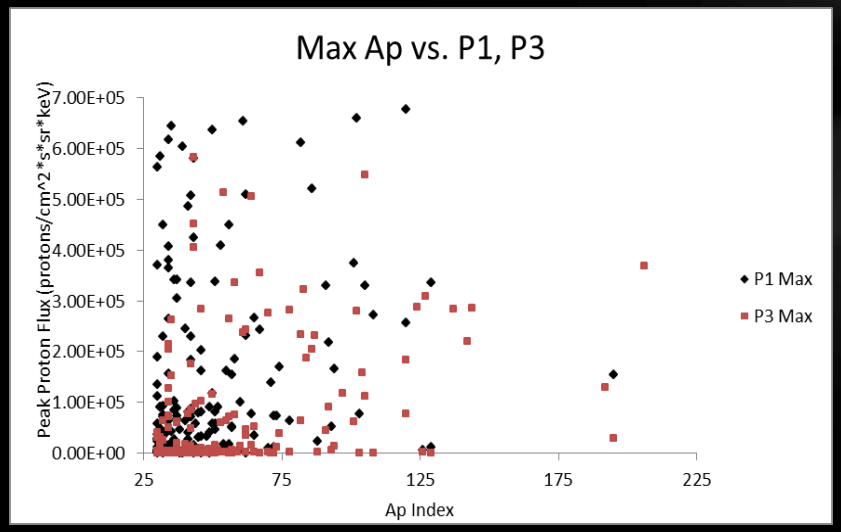
- Classified by order of magnetic complexity

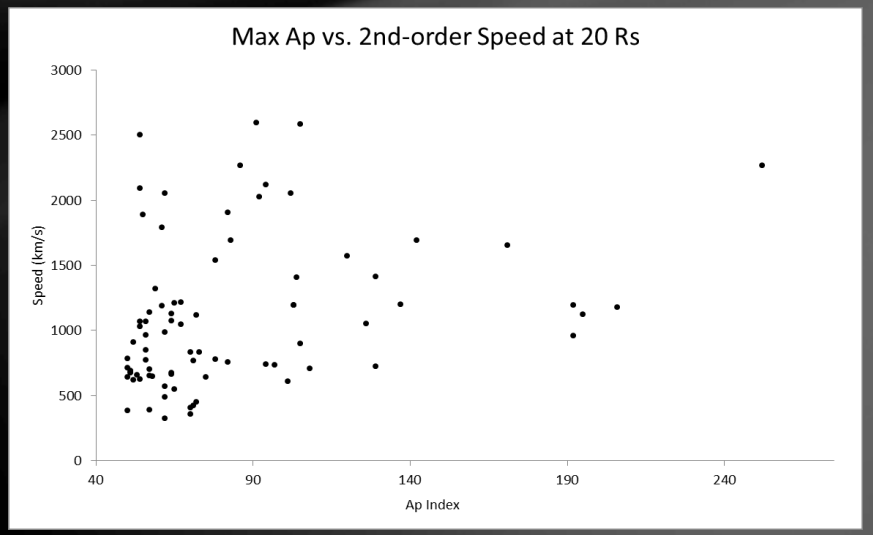


Initial Results (Cont.)





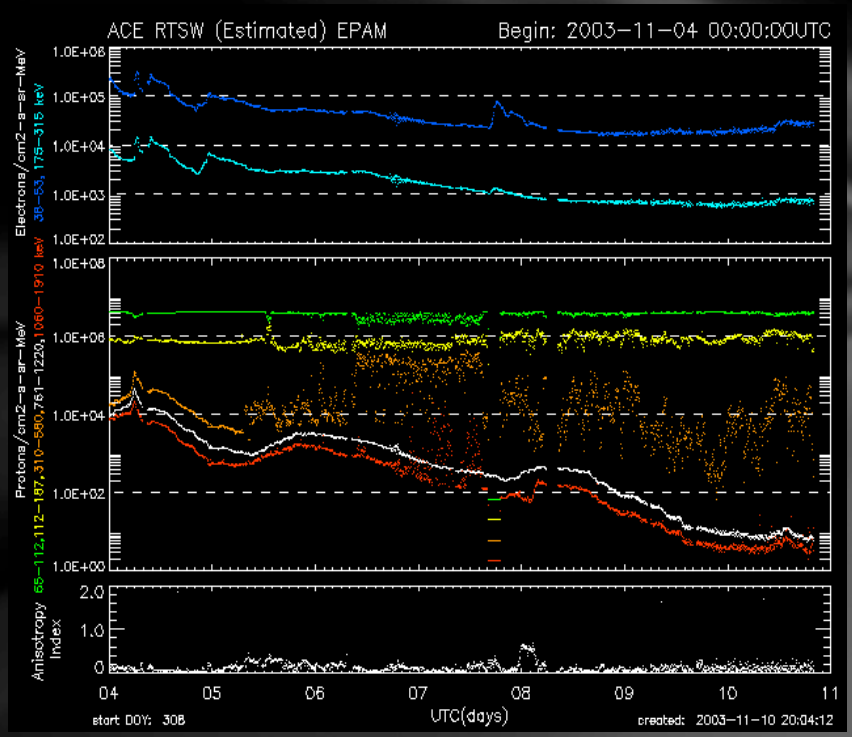




No direct correlation between Max Ap and several variables

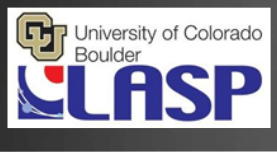
Issues

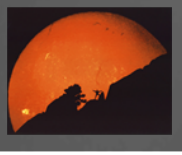
- Weekly data prior to 1998 may be unreliable
- Timing (naming source event)
- Contaminated data during active periods
- Ap Index washes out information



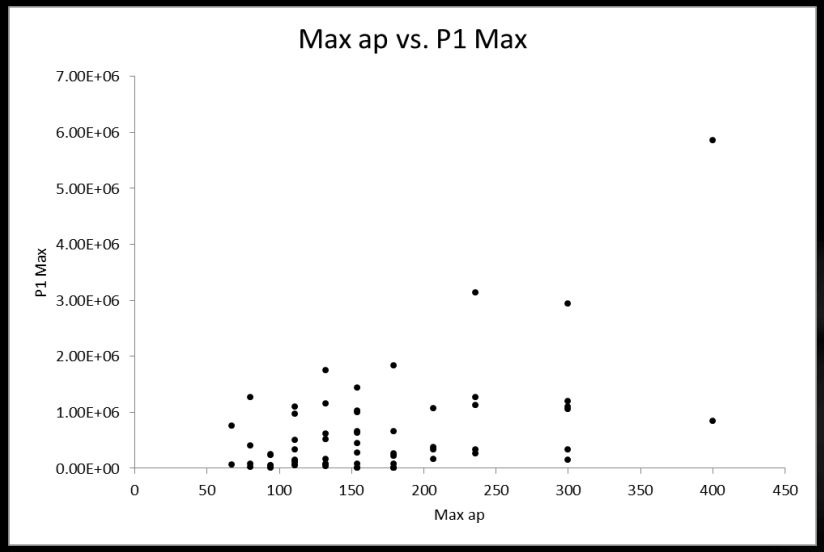
New Plan

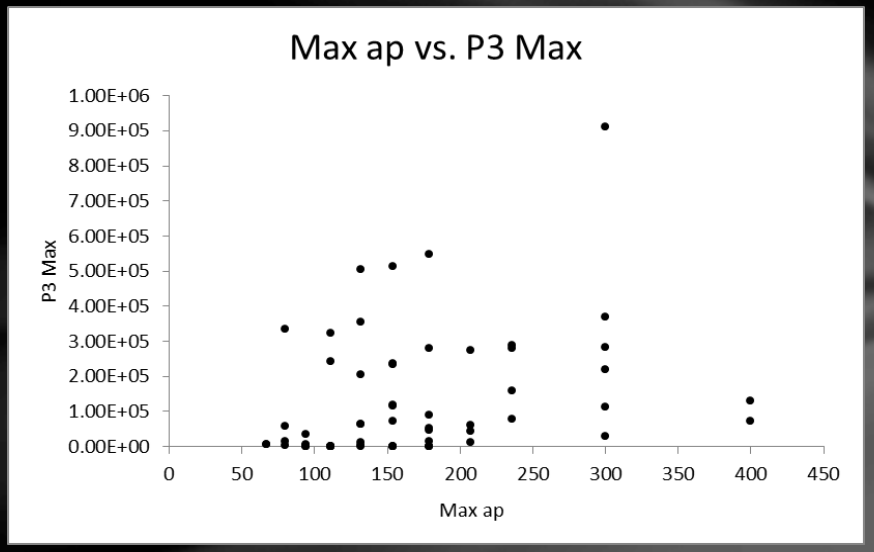
- Try new indices
  - ap (linearly scaled to quasi-logarithmic Kp)
  - # Kp of 9, 8, 7, 6, 5 observed within 24 hours of storm

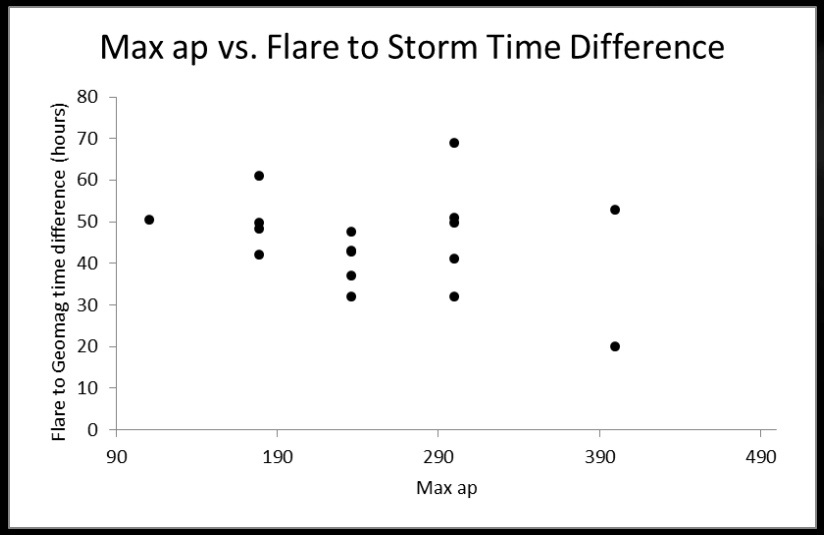


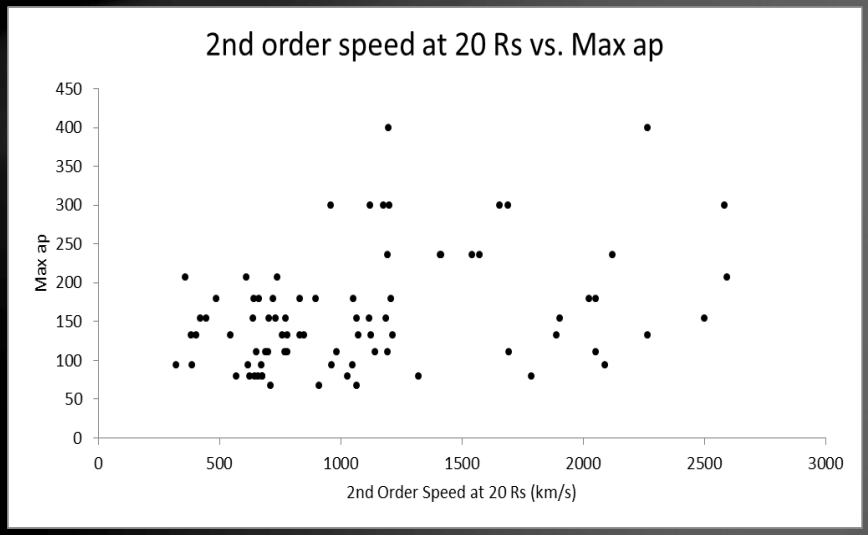


Results Using ap

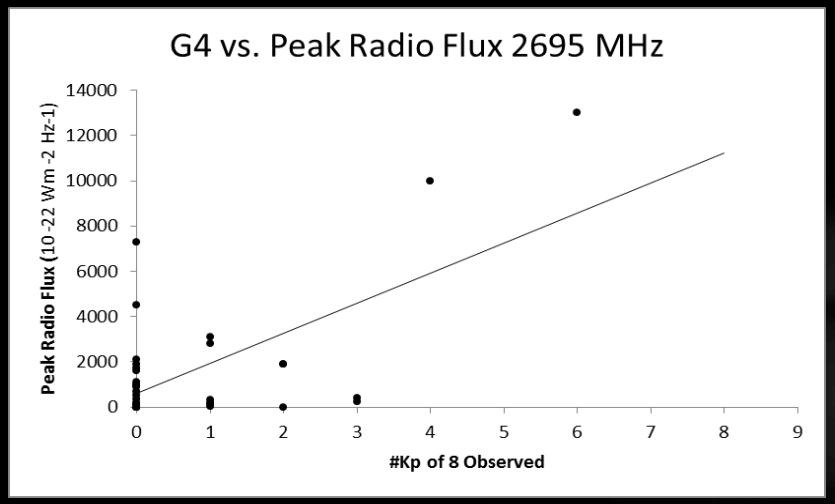


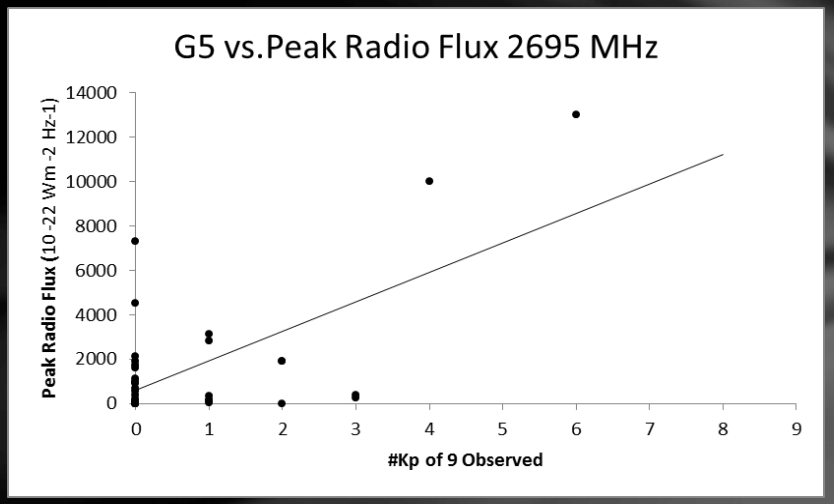


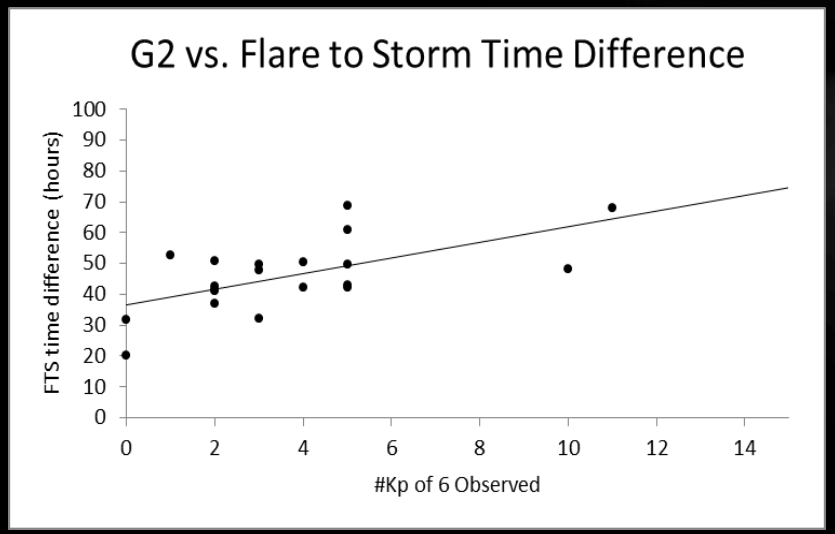


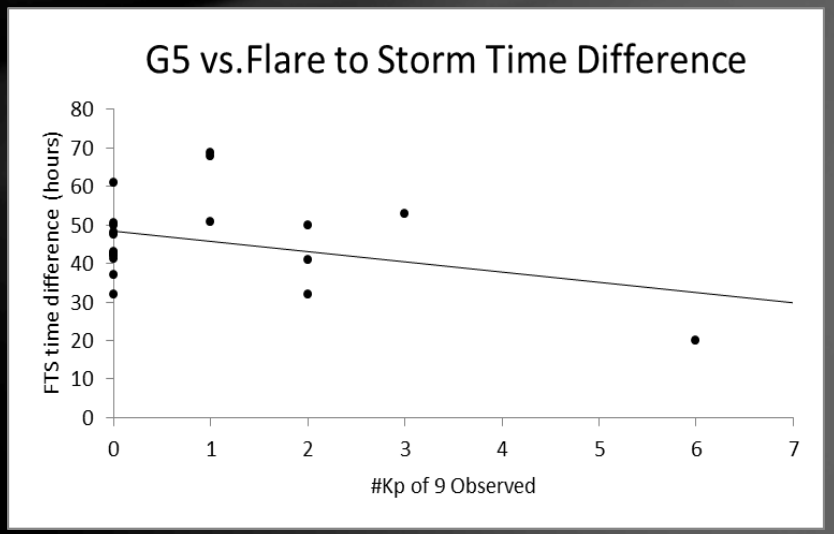


Results Using Kp Frequency

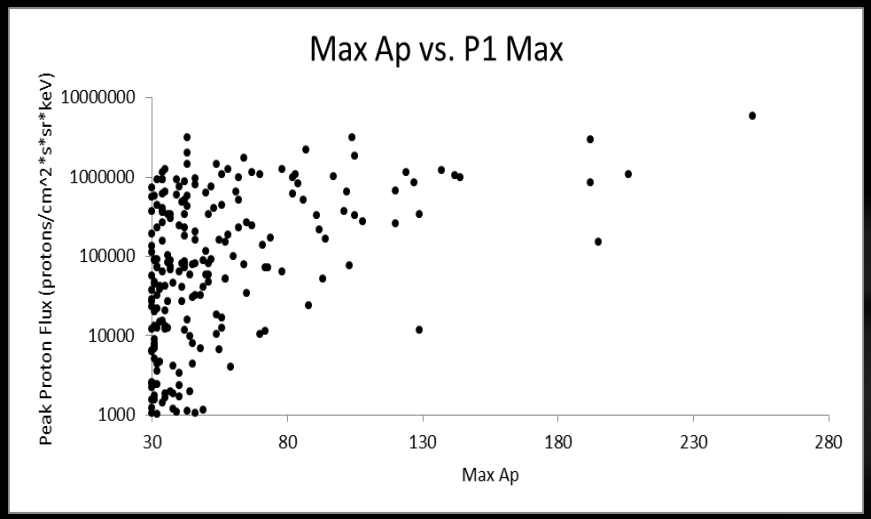


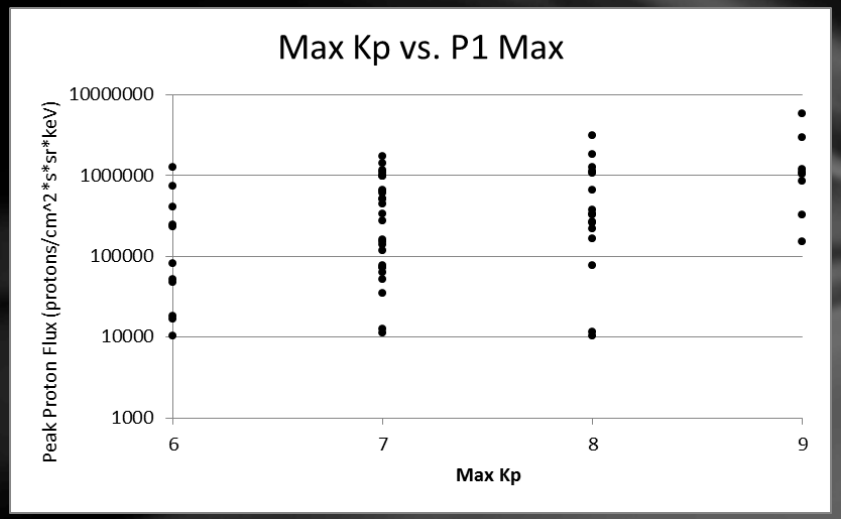


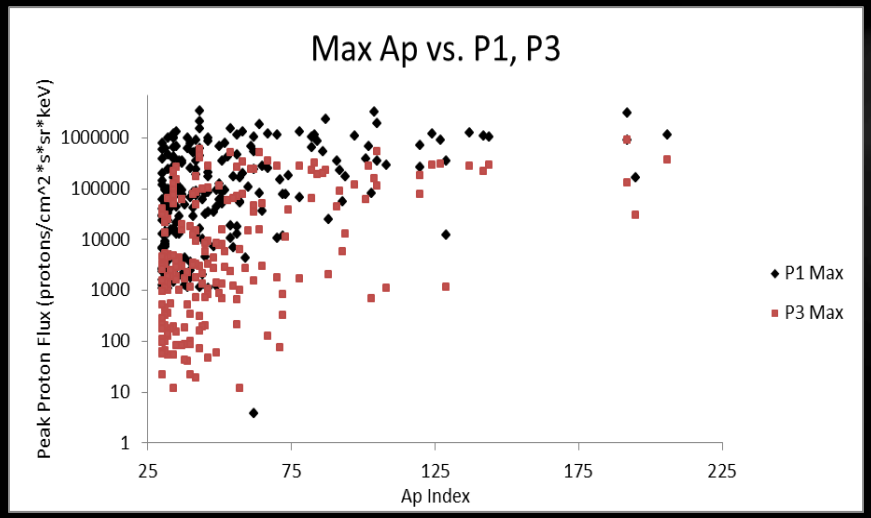


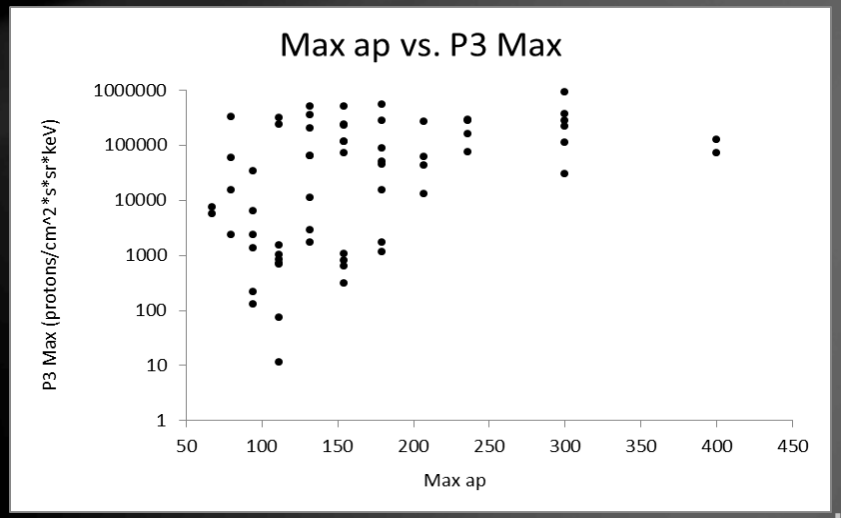


EPAM Results









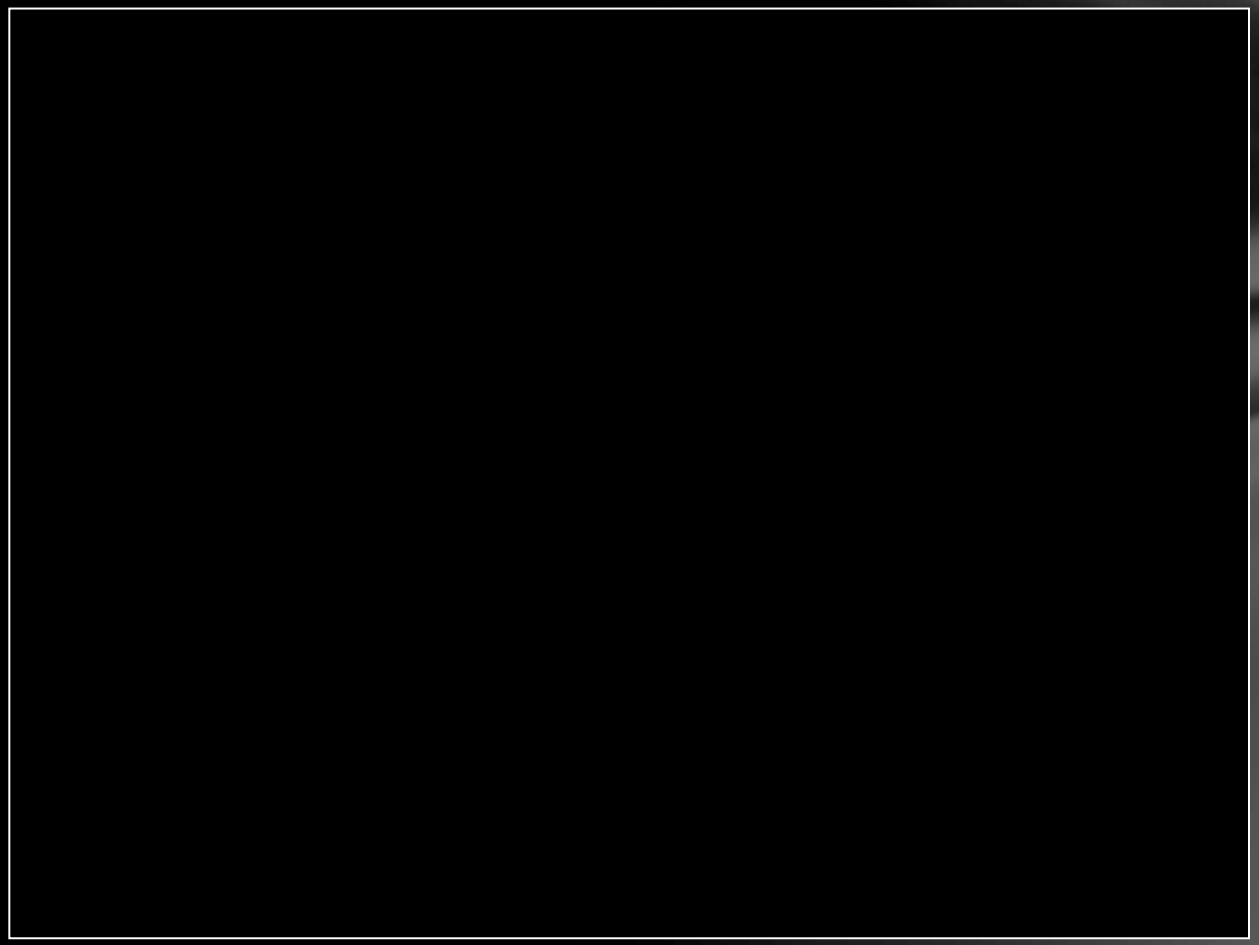
Conclusions

- Some information is washed out by Ap and ap indices
- Is using frequency of Kp 5-9 most helpful?
  - Is observing a particular Kp more insightful than observing another?
- EPAM:
  - It is necessary for a proton flux of $1x10^5$ to occur in order for a Kp of 9 to be observed, but a flux level of $1x10^5$ can occur while only seeing a Kp of 6-8 as well.

Forecaster Training Slideshow

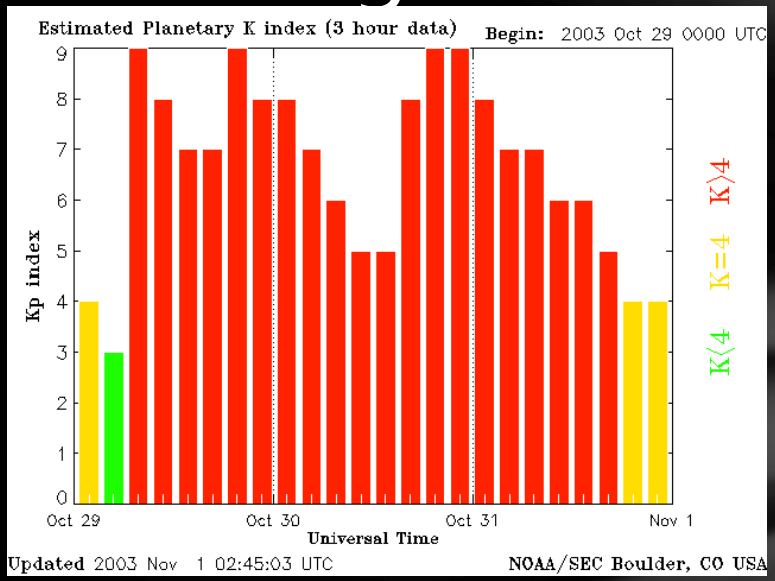
- Current space weather forecasts are somewhat subjective
- Quantitative models are in progress
- So, visual training is the best option for forecasters
- Includes:
  - LASCO C_3 3-day movies of large events
  - Resulting Kp Plots
  - SWEPAM Data
  - MAG Data

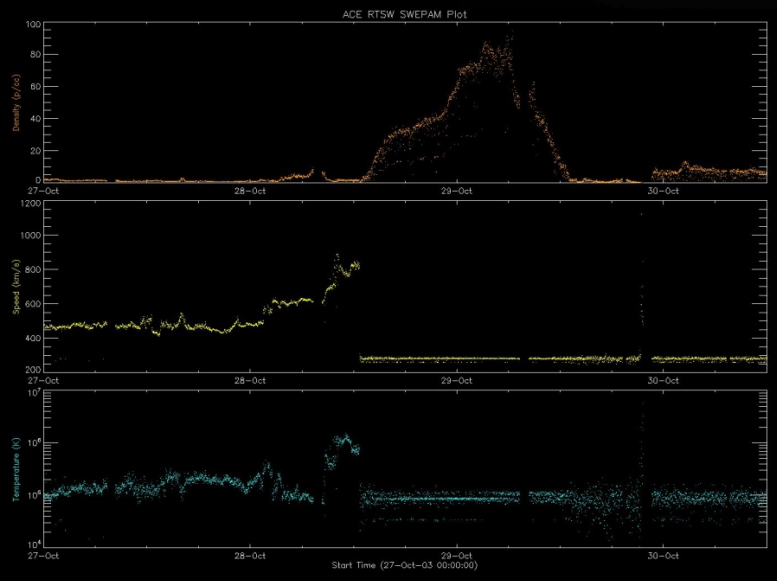
Forecaster Training Slideshow

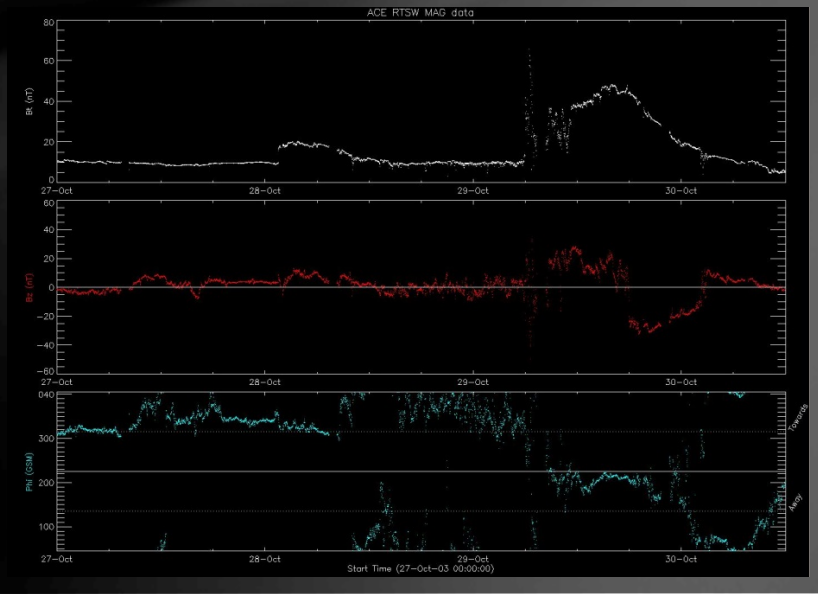


October 28, 2003

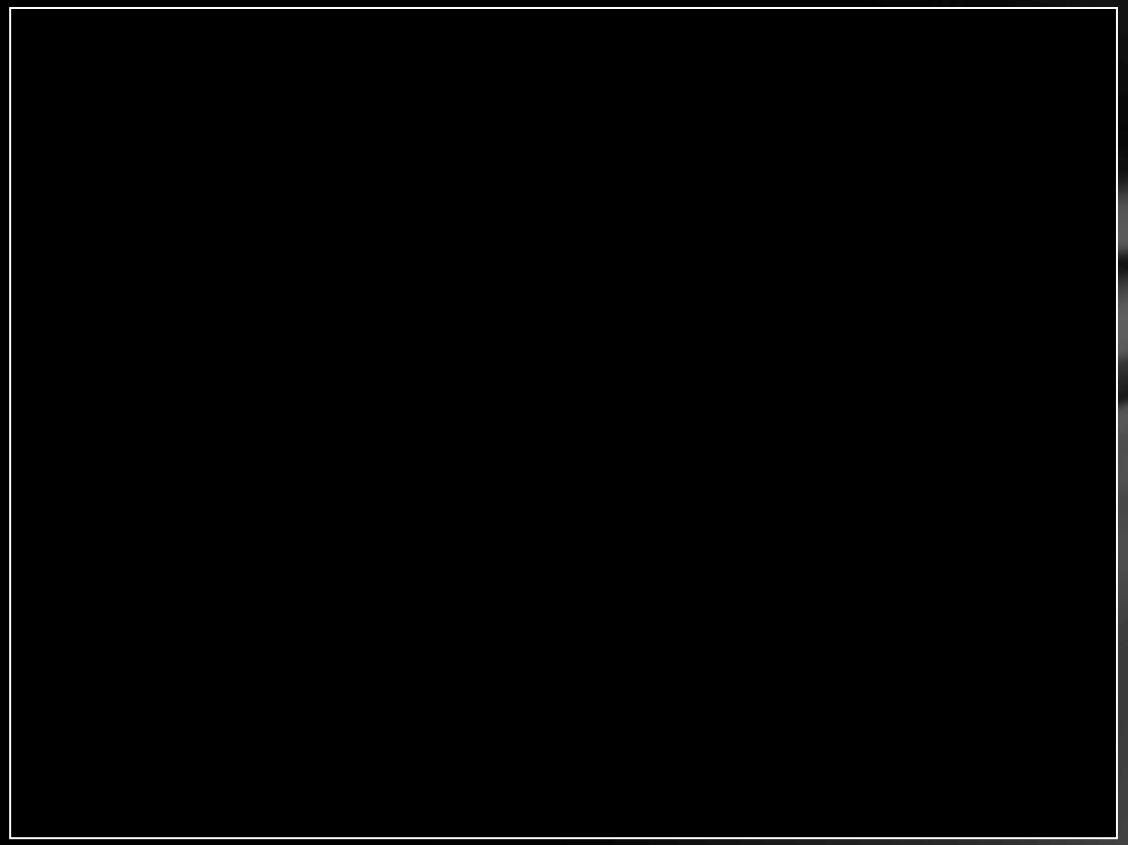
Forecaster Training Slideshow





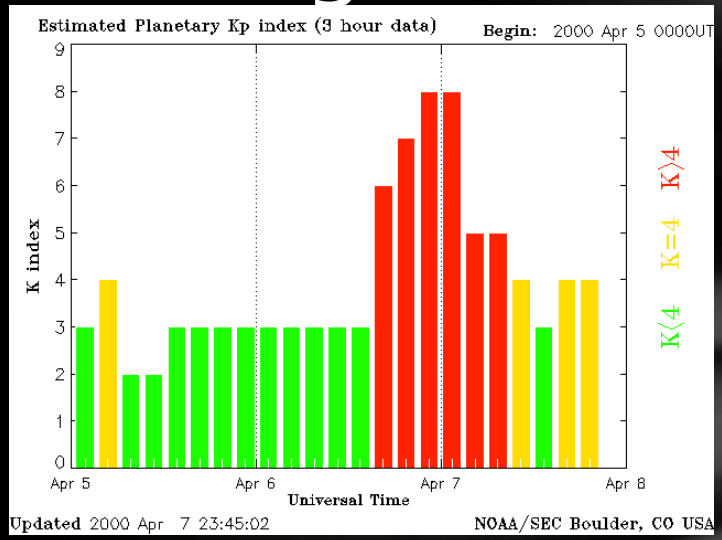


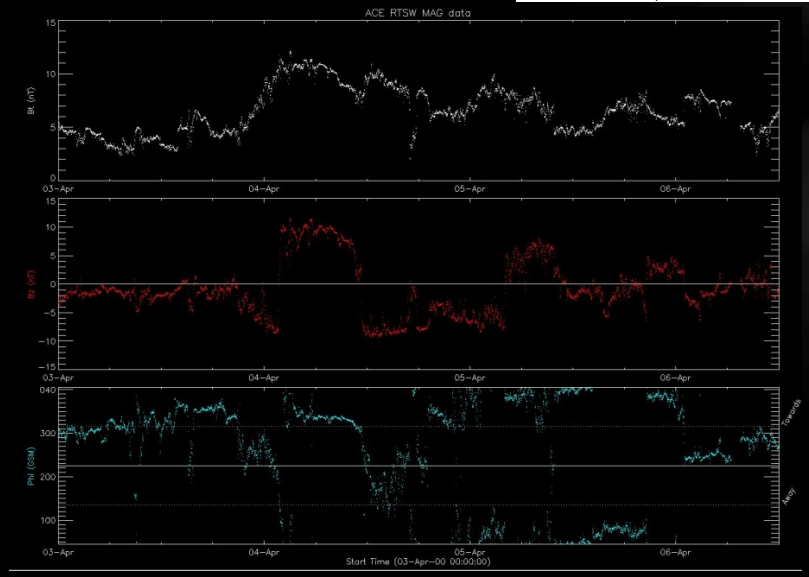
Forecaster Training Slideshow

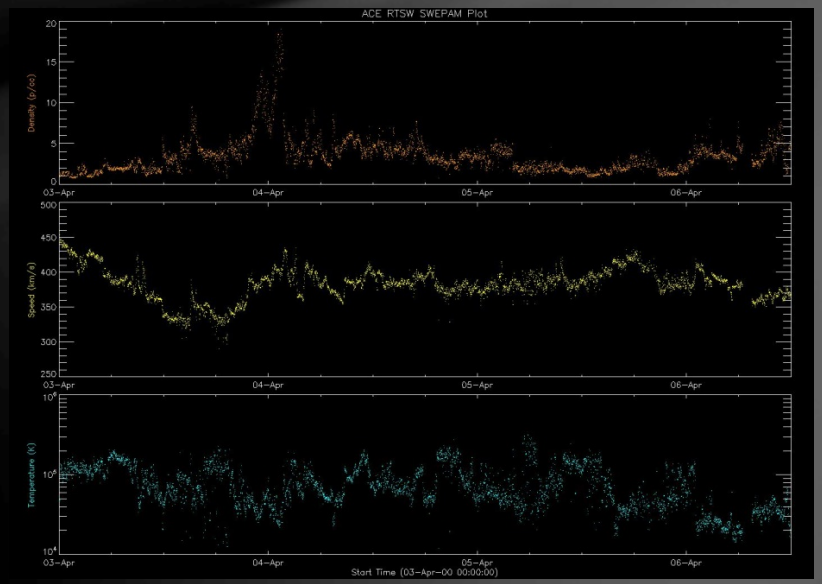


April 4, 2000

Forecaster Training Slideshow







Further Studies

- More detailed EPAM study
  - Use more data, derive more specific probabilities
- Look further into advantages of specific Kps vs. other indices
- Find more reliable sources for variables such as event duration, x-ray class, magnetic class, and identified source events

References

- Smith, Z.K., Murtagh, W.J., 2009, Solar wind low-energy energetic ion enhancements: A tool to forecast large geomagnetic storms, http://www.sciencedirect.com/science/article/pii/S0273117709004384/ (July 30, 2013)
- www.swpc.noaa.gov
- http://science.nasa.gov/heliophysics/

Acknowledgements

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- Erin Wood and Marty Snow
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Questions?
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University of Colorado
Boulder
LASP