CGMS XXXIII NOAA-WP-04
Prepared by NOAA
Agenda Item: B.4

Anomalies from Solar Events

NOAA-WP-04 provided an update of the solar activities from July 2004 through September 2005. These occurrences were associated with the most highly energetic proton events of Solar Cycle 23. NOAA discussed the major activities observed from January 2004 through September 2005. Several major solar flares and geomagnetic storms occurred even as the solar cycle continued beyond the solar maximum observed around the year 2000. NOAA informed CGMS that it is typical for energetic electron activity to increase in the waning years of a solar cycle as recurrent coronal holes produce regular intervals of high speed solar wind that interact with the Earth's magnetic field. Two periods of very high levels of electron flux occurred on 28-31 July 2004 and 18-19 May 2005.

Anomalies from Solar Events

1.0 Introduction

This paper will document significant solar activity beginning April 2004. Previous CGMS papers have addressed in more detail the status of the solar cycle, and what follows is an update of CGMS XXXII NOAA-WP-04. SEC recently published NOAA Technical Memorandum SEC-88, available on SEC's website, which documents the significant activity observed during October and November 2003.

2.0 Significant Late-Cycle Events

In 2004 and 2005, several major solar flares and geomagnetic storms occurred even as the solar cycle continued beyond the solar maximum observed around the year 2000. Table 1 illustrates the activity observed from January 2004 to August 2005, with shading highlighting the months of notable high activity.

Table 1: Recent Space Weather Events

	X-Ray Events			Proton Events		Geomagnetic Activity		
	M-class	X-class	F10.7	≥10 SPE	≥100 SPE	AP	Major Storm	Severe Storm
Jan-04	**12**	**0**	**114.1**	**0**	**0**	**22**	**1**	**1**
Feb-04	2	1	107.0	0	0	13	1	0
Mar-04	3	0	112.0	0	0	14	1	0
Apr-04	7	0	101.2	1	0	11	0	0
May-04	1	0	99.8	0	0	8	0	0
Jun-04	1	0	97.4	0	0	13	0	0
Jul-04	**33**	**6**	**118.5**	**1**	**0**	**23**	**1**	**2**
Aug-04	26	2	110.0	0	0	9	0	0
Sep-04	4	0	103.0	2	0	9	0	0
Oct-04	9	1	105.9	0	0	8	0	0
Nov-04	**15**	**2**	**113.7**	**2**	**2**	**25**	**1**	**3**
Dec-04	7	0	95.0	0	0	11	0	0
Jan-05	**21**	**4**	**102.2**	**1**	**2**	**28**	**4**	**0**
Feb-05	1	0	97.2	0	0	11	0	0
Mar-05	0	0	89.9	0	0	12	0	0
Apr-05	0	0	86.0	0	0	11	1	0
May-05	13	0	99.5	1	0	19	3	0
Jun-05	4	0	93.7	1	2	12	2	0
Jul-05	**19**	**2**	**96.5**	**2**	**1**	**14**	**1**	**0**
Aug-05	**8**	**0**	**90.9**	**1**	**1**	**15**	**0**	**1**
Sep-05*	**18**	**8**	**89.2**	**1**	**1**	**29**	**2**	**1**

* through September 15, 2005

July 2004

In July 2004, Region 649 developed into a complex delta configuration and produced a number of major flares, including six X-class flares, the strongest; an X3.6 was observed on 16 July. No CMEs were observed in association with the X-class flares. Region 652 rotated into view from the east limb of the Sun on 16 July and produced a number of very strong M-class flares over the subsequent two weeks. CMEs and radio sweeps were associated with several of these M-class flares. Major and severe geomagnetic storming resulted days later from some of these CMEs.

November 2004

Major and severe geomagnetic storming occurred in early November 2004 from the effects of CMEs produced in association with major flares from Region 696. This activity resulted in 2 of the 10 top geomagnetic storms of Cycle 23, as measured by the Dst index. Region 696 produced a number of M-class flares during the first two weeks of November, an X2.0 flare on 7 November, and an X2.5 flare on 10 November. CMEs and radio sweeps were associated with the X-class and most M-class flares produced by the region. Both $\geq$10 MeV and $\geq$100 MeV activity was observed resulting from a backside CME from 1 November, one of only two proton events this cycle that originated from behind the west limb (the other occurred on 16 August 2001). Additional $\geq$10 MeV and $\geq$100 MeV proton events were caused by the X2.0 and X2.5 flares.

Much like the Halloween Storms of 2003, the Sun was almost spotless for several periods in the two months preceding this outbreak. In fact the total alerts, watches, and warnings, in August and September 2004, related to energetic solar activity, was 20 and 34 respectively. For the period 20 October – 10 November 2004, there were 241 alerts, watches and warnings.

January 2005

Active Region 720 produced an impressive series of space weather events during its transit across the visible disk for the period 10-22 January 2005. The region first emerged near the east limb as a small and insignificant sunspot on 10 January. By 14 January, following a period of rapid growth, Region 720 was approaching center disk as a very large and complex delta sunspot cluster covering over 1500 millionths of white light area. Region 715 produced several M-class and X-class flares, along with associated CMEs and radio sweeps. Arrival of CMEs associated with this solar activity resulted in major geomagnetic storming. Later in the month, Region 720 produced eleven M and three X-class flares, including an X3.8 on 17 January and an X7.1 on 20 January. CMEs and radio sweeps were also associated with both of these flares, as well as $\geq$10 and $\geq$100 MeV energetic proton events. Major and severe geomagnetic storming occurred as CMEs associated with this flare activity arrived at Earth.

The X7 flare on 20 January warrants special attention. This event was associated with the most highly energetic proton event of Solar Cycle 23. The $\geq$100 MeV protons reached 652 pfu, making it the strongest $\geq$100 MeV event of this cycle and the strongest since Oct 1989 (680 pfu). The largest this cycle was 410 pfu on 14 Jul 2000 (X5 - Bastille Day). The $\geq$10 MeV was 1860 pfu, making this a very hard event.

August-September 2005

In late August 2005, severe geomagnetic storm conditions were observed as a result of the arrival of a CME associated with several long duration M-class flares that occurred several days before. K≥7 alerts were issued during this period of severe storming.

On 7 September, an active solar region just beginning to transit when the east limb of the Sun erupted with an X17 flare. The X-ray flux was so large that the GOES Solar X-ray sensor, which only measures flux up to the X17 level, was saturated for over five minutes. A CME was observed on a ground based coronagraph based at Mauna Loa, and both ≥10 MeV and ≥100 MeV energetic protons were observed to increase about six hours after the peak of the solar flare. This active region, numbered 808, grew to a size of over 1430 millionths of the solar disk in white light, and had a very complex beta-gamma-delta configuration. The region produced an additional 7 X-class flares through September 15, 2005 and associated Type II and IV radio bursts as well as CMEs.

3.0 Energetic Electron Activity

It is typical for energetic electron activity to increase in the waning years of a solar cycle as recurrent coronal holes produce regular intervals of high speed solar wind that interact with the Earth's magnetic field. For instance, in 2004, electron flux levels at geosynchronous orbit were observed at high levels (1.0E+3 pfu) for 48% of the days of that year. In 2005, January through August, that percentage rose to 62%. Two periods of very high levels of electron flux (5.0E+4 pfu) occurred on 28-31 July 2004 and 18-19 May 2005.

4.0 Space Weather Effects on Satellites

Satellite failures or event upsets can be caused by space weather effects, although the exact nature of the role of space weather is hard to define. Usually, cumulative bulk surface charging occurs in an environment of high electron fluence, which can lead to a major discharge event, possibly causing temporary or permanent satellite disruptions. Satellite disruptions which may be the result of space weather activity include:

July 2004

- Double Star satellites:
  - In a two week period, several TC-1 & 2 instruments experienced multiple resets.
  - Both the main and redundant computers of the satellite attitude control system failed on TC-2.

November 2004

- Failure of the Intelsat Americas-7 satellite. It is difficult to clearly establish causation for this failure, but it is certainly true that the space environment was conducive to bulk charging which can lead to damaging electrostatic discharges.
- GOES-12 did experience a peculiar impact: On November 03, 0401Z, the GOES SAR (search and rescue) receiver signal strength flagged red high intermittently. Engineers were notified. By 03/0420z the receiver signal strength returned to normal for no apparent reason. Further analysis revealed a GOES-Earth-Sun alignment during a strong radio burst. The GOES SAR receiver uses a 406 MHz signal and at that particular time a

solar radio burst of 7200 sfu was measured on 410 MHz at Learmonth. Bottom line – a boat in distress would not have successfully transmitted its distress signal during this time. This obviously would be a rare event, but possible nonetheless.

January 2005

- **Gravity Probe B Mission**: Two multi-bit errors (MBE) in the SRE electronics. Lost track of the guide star. They experienced a huge increase in single-bit errors (SBE)—81 in a 24-hour period, where the norm is around 9 SBEs per day.
- **ACE SWEPAM**: Particle contamination for extended periods resulted in lost data between 17/1322 - 18/2241 UT, and again between 20/0700 - 21/0402 UT.
- **SOHO:** LASCO imagery was contaminated and rendered useless for a period on 20 January following the onset of the very energetic radiation storm. The Coronal Diagnostics Spectrometer (CDS) & the UltraViolet Coronagraph Spectrometer (UVCS) were safed.
- Unconfirmed reports of impacts or safing actions on **Deep Impact, Spitzer Space Telescope, Wilkinson Microwave Anisotropy Probe** - and others.

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