CGMS-XXVIII
UA-WP-04
Agenda Item: B.3

ANOMALIES DUE TO SOLAR EVENTS

Early Examples of Satellite ANOMALIES in the Current Solar Maximum
This paper examines the satellite anomalies reported to the Space Environment Center in July 2000 during a period of severe radiation storms followed by an extreme geomagnetic storm.

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EARLY REPORTS OF SATELLITE ANOMALIES DURING THE CURRENT SOLAR MAXIMUM

1. INTRODUCTION

Earlier this year, after an assessment of the progress of solar cycle 23, NOAA's Space Environment Center announced a change in the consensus forecast of the occurrence of the solar maximum for Cycle 23. SEC has changed the expected date of sunspot maximum from March 2000 to December 2000 and the expected size downwards from 160 to 140.

Cycle 23 so far has been running slightly lower than predicted with somewhat fewer sunspots, solar flares, energetic particle events, and geomagnetic storms. However, lest satellite operators be lulled into a false sense of security by these facts, this cycle is also demonstrating the principle that the number of solar events does not correlate well to the **severity** of these events. The events of July 10-19 produced highest ever observed values for some solar phenomena and caused widespread effects on satellites. Interestingly, the most widespread troublesome effect observed was the degradation of data quality below useful levels for the duration of the storms in the very instruments SEC uses to monitor space weather.

2. CHRONOLOGY OF THE EVENT

A period of intense solar activity occurred during the period of July 10-19, 2000. Four major flares were successively produced by a large magnetically complex active region on the sun. Two of the flares were accompanied by coronal mass ejections (CMEs). Three interplanetary shocks associated with these CMEs were experienced by NASA's ACE satellite stationed at the L1 point. A geomagnetic storm, reaching category 5 (extreme) occurred later in the period as a consequence of this activity.

Proton events of greater than 100 MeV and 10 MeV occurred at geosynchronous orbit following the X5/3B flare of July 14th. The greater than 100 MeV proton event was the largest radiation storm since 1989, and one of the largest ever recorded peaking at 410 pfu. The greater than 10 MeV proton event peaked at 24000 pfu, the largest reading since 1991. The severe radiation storm (category R4) was the source of most of the reported satellite anomalies, and had a major impact on the ability of forecasters to give warnings of the extreme geomagnetic storm which would arrive hours later, and of the potential for satellite operators to experience deep dielectric charging.

3. REPORTED IMPACTS

Satellites

1. Data contamination caused by high proton levels:
   a. GOES SEM > 2 MeV electron flux data - no alerts of potential for satellite deep dielectric charging for days
   b. ACE plasma detectors - no velocity and density data for incoming geomagnetic storms for days
   c. SOHO coronagraph - speckled images - degraded ability to calculate velocity of on-coming CME
   d. GOES 8/10/11 Vis and IR imager bands - speckling in images
   e. ACE magnetometer - data problems affected certainty of geomagnetic storm warning

2. Navigation
   a. GOES Vis and IR speckling affected Image Navigation and Registration systems
   b. GOES spacecraft experienced a temporary increase in spacecraft momentum on July 15th possibly to the satellite experiencing a geomagnetic boundary crossing as a result of the geomagnetic storm
   c. star tracker problems and Single Event Upsets reported on some geosynchronous-orbit spacecraft.

3. Communications
   a. Commercial geosynchronous spacecraft lost a transponder due to Solar Proton Event.

4. Power
   a. SOHO experienced 1-year equivalent permanent degradation in their solar panel.

Other Customers

Fortunately, the extreme geomagnetic storm was not as lengthy in duration as the geomagnetic storm of March 1989. Nevertheless many utility system impacts were reported. Three nuclear plants lowered their plants capacity for protection but one experienced significant transformer damage. Several industry monitoring systems reported geomagnetically induced currents on transmission lines. There were also several reports of capacitor banks tripping, and voltage swings were noted.

HF Communications systems were unusable for days due to a polar cap absorption event of 49dB.

Discussion

Since under-reporting of satellite anomalies is a well documented phenomena of the space weather field, these reported effects should be regarded as illustrative rather than comprehensive. The space weather community's own operations were particularly hard hit by the phenomena of data contamination which severely hampered their ability to provide timely and effective warnings during this dangerous period. Sensor redesign for future satellites is already being seriously considered. It is also worth noting that the satellites reporting early impacts to NOAA were all in geostationary or Lagrange (L1) orbits.

The experience of July 2000 illustrates a point made in the equivalent paper on this subject in last year's CGMS i.e. that multiple space weather phenomena in differing combinations and sequences can have unique impacts on a particular space weather customer community. Customers should expect such situations during solar maximum, and expect to experience new vulnerabilities.

4. FUTURE OF THE CYCLE

It is intuitive to expect most major solar activity to occur during the solar maximum year (2000). However, it is important to note that major activity episodes have historically occurred during any year of a given solar cycle; with the majority of episodes clustered within a few years, plus or minus, of solar maximum.

SEC's space weather projections indicate it is likely that strong to extreme (category 3 to 5) space weather storms will occur during the remaining years of Cycle 23. Based on these projections, the majority of category 3 to 5 storms will occur during the next three years with year 2002 expected to be the most active year.