CGMS

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ANOMALIES FROM SOLAR EVENTS

In response to Action 38:04

NOAA-WP-05 provides examples of new space weather products under development, the progression and prediction of the solar cycle, a summary of recent significant space weather events, and a discussion on how space weather observations and models contribute to space debris and collision mitigation activities. The satellite anomalies product will serve customers, such as the satellite industry and those who depend on conditions in the space environment that affect satellites used for communication, navigation, and other daily activities. The extreme ultraviolet (EUV) product will support those who conduct activities that depend on conditions in the ionosphere such as GPS and HF communication customers. Predictions are given for the year and magnitude of Solar Cycle 24 maximum. The consensus prediction is that the new cycle will be smaller than recent cycles and reach maximum in May 2013. This prediction, of great importance for planning activities affected by solar activity, will be updated as needed. Information is provided that shows space weather activity increasing during August 2010 through July 2011, as we emerge from the recent solar minimum. Finally, we describe how space weather data and models contribute to those concerned with space debris and collision avoidance.

ANOMALIES FROM SOLAR EVENTS

1 INTRODUCTION

This paper documents significant space weather for the summary period AUG 2010 – JUL 2011. Previous CGMS papers have addressed Solar Cycle 23 and the extended solar minimum leading into Cycle 24. Now, following solar minimum in December 2008, the report discusses the rise toward solar maximum in Solar Cycle 24. Following is an update of CGMS XXXVIII NOAA-WP-05.

2 SERVING CUSTOMERS WITH NEW PRODUCTS – Satellite Anomalies

Space weather can have harmful impacts on many systems, including satellites in near-Earth space. Energetic particles streaming from the sun as well as those trapped within Earth's magnetosphere can temporarily disable or permanently damage sensitive satellite electronic components. In the next year, the NOAA National Geophysical Data Center (NGDC), which has provided some tools related to space weather induced satellite anomalies for many decades, will be expanding its

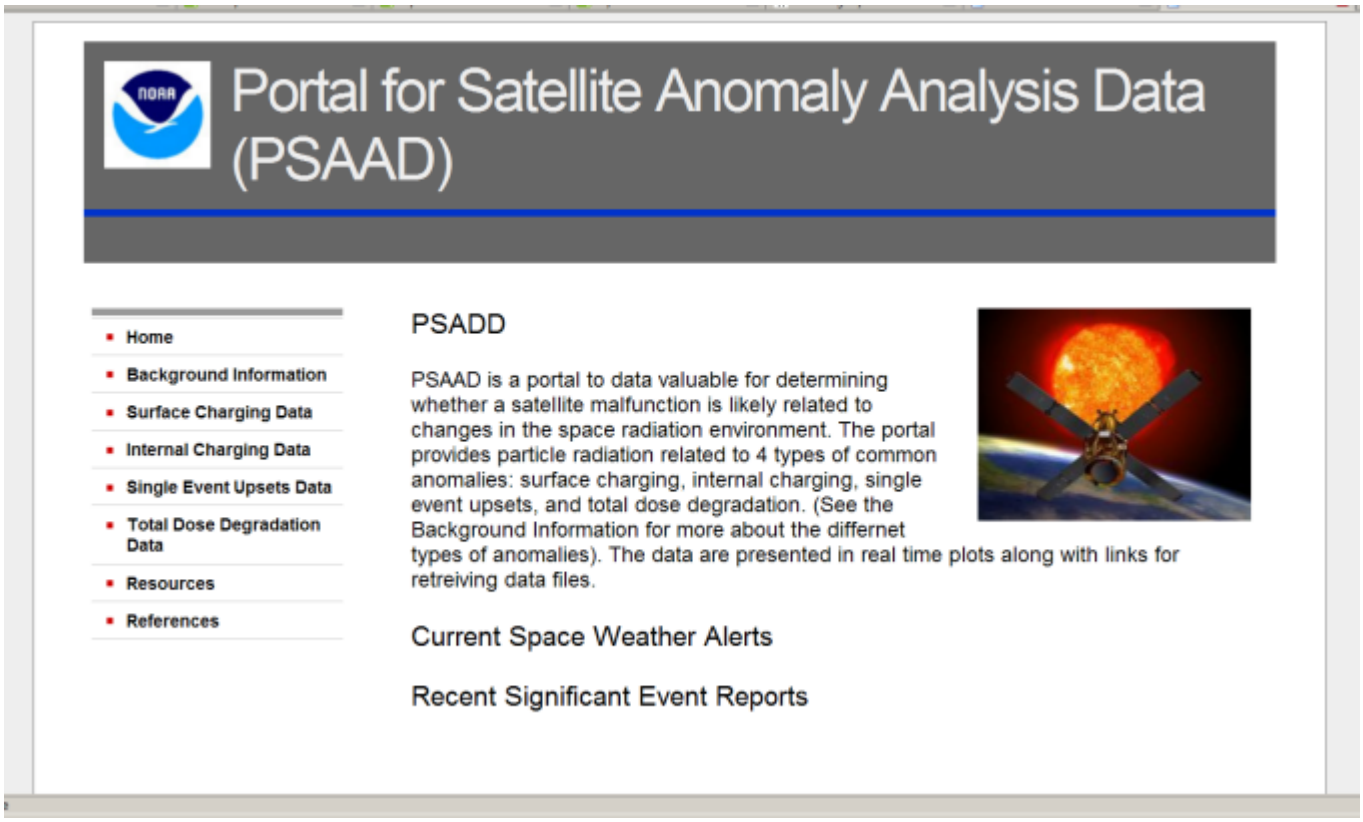

Figure 1: Illustration of web page, Portal for Satellite Anomaly Analysis Data (PSAAD), under development. (Courtesy Janet Green)

products and services. NGDC has always maintained the archive and provided access to the historical high-energy particle data from the NOAA GOES and POES satellites that are instrumental for determining whether or not satellite malfunctions are related to space weather. They also maintained a database of satellite anomalies

for many decades. Last year NGDC and the Space Weather Prediction Center (SWPC) put together a tiger team report on the space weather surrounding the long-duration Galaxy 15 satellite anomaly. As a complement to the SWPC real-time products for the satellite industry, NGDC is currently working on a new website tailored to the satellite community that would be a portal for data and information needed for near real-time and post-satellite anomaly investigations. The portal will provide data organized by the four most common types of space weather related satellite anomalies: surface charging, interior charging, single-event upsets and total dose degradation. The portal will provide real-time plots of the particle populations most often associated with each type of anomaly as well as flow charts and steps for quickly assessing whether a recent anomaly is likely related to space weather. Figure 1 illustrates the web page under development to serve satellite customers.

3 SERVING CUSTOMERS WITH NEW PRODUCTS – EUV Irradiance

Solar Extreme Ultraviolet (EUV) irradiance is one of the key drivers of the Ionosphere/Thermosphere (I/T) system. Of the three primary forcing functions of the I/T systems; geomagnetic activity, tropospheric waves, and solar irradiance, solar EUV irradiance, and its variations, produce the largest response. The solar EUV photons collide with the atoms and molecules of the upper atmosphere providing both heat and the source of ionization that creates the ionosphere itself. Changes in solar EUV irradiance produce variations in neutral and electron densities on time scales from minutes to years. Over the course of a solar cycle, the electron and neutral density change by a factor of ten as a result of changes in the solar EUV irradiance. Models of the I/T system typically use F10.7 radio flux as a proxy for EUV which is only available at a daily cadence. Recent improvements in physical understanding and model capabilities have reached the point that the biggest errors come from the inputs themselves. Thus, a more accurate input for solar EUV irradiance is required with higher time cadence.

The GOES EUV data will be provided in three broad spectral bands or channels. These three spectral bands were identified as most critical for capturing the variability and brightest portions of the spectrum. The EUV-A channel covers the 5 to 18 nm band. The EUV-B channel covers the 26 to 34 nm band which is dominated by the He 30.4 nm line. The EUV-E channel covers the 118 to 124 nm band which is dominated by the very bright H Lyman-Alpha line. Two other channels cover other parts of the spectrum but are not considered part of the primary observing sequence.

These data are currently available at cadences as high as ten seconds. It is believed however that the typical model of the I/T system will require solar EUV irradiance data at a one minute cadence. For climatological studies, daily averages may be adequate. Operational models of the I/T system are already using solar EUV data from other sensors (such as the SOHO Solar EUV Monitor). The GOES EUV data will continue these observations for decades to come. These data will be available in real-time to drive operational models. A full-physics I/T model can provide both specification and even forecasts of various ionospheric parameters such as the Total Electron Content (TEC) for GPS users and bottom-side ionospheric densities for HF communication applications. Solar EUV irradiance from NOAA's Space Weather Prediction Center will be a critical input for these models.

4 SOLAR CYCLE PROGRESSION

Monthly, the Space Weather Prediction Center updates the Solar Cycle Sunspot Number progression using the latest predictions from the International Space Environment Services (ISES). The official NOAA, NASA, and ISES Solar Cycle 24

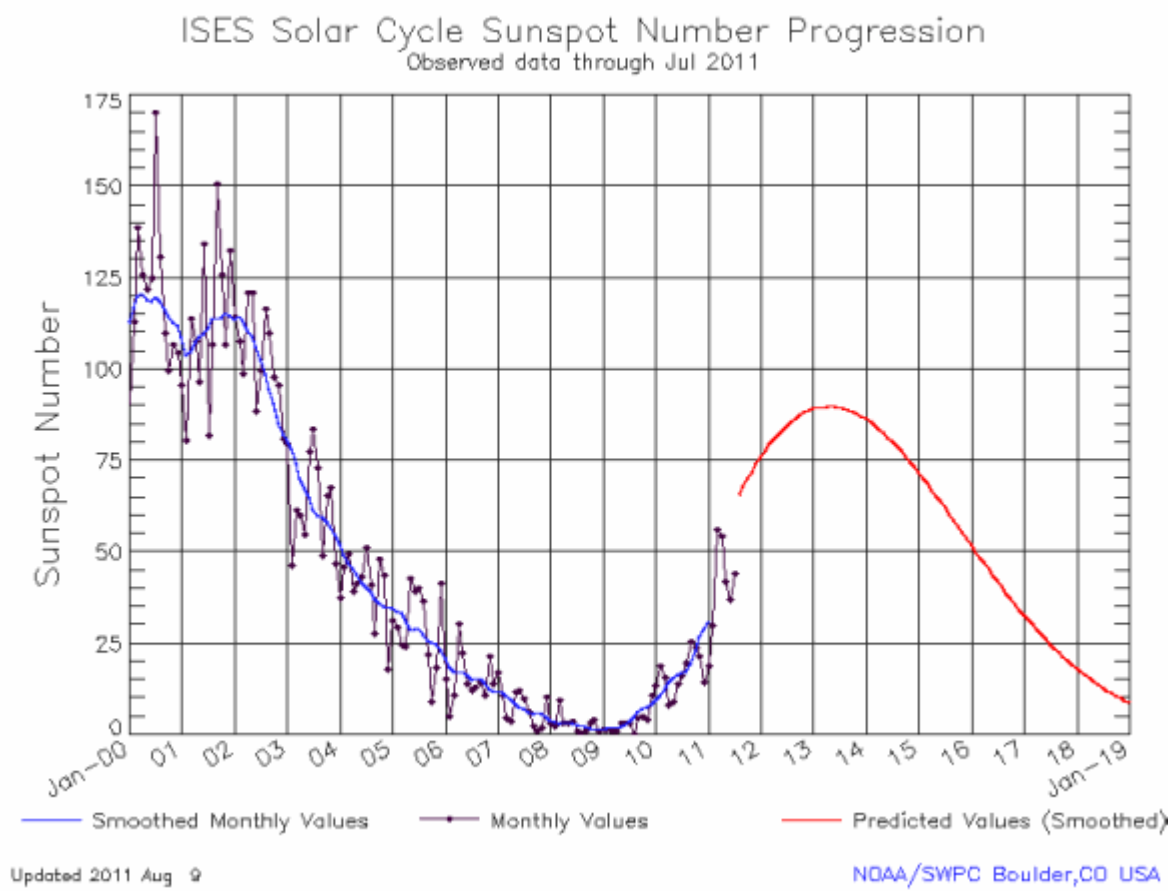

Figure 2: Solar Cycle Sunspot Number Progression and Prediction

prediction was released by the Solar Cycle 24 Prediction Panel on April 25, 2007 and most recently updated on May 8, 2009. The Prediction Panel included members from NOAA, NASA, ISES and other US and international representatives. As shown in Figure 2, the most recent Panel consensus predicts solar cycle minimum in December 2008 and solar cycle maximum in May 2013. The predicted maximum sunspot number of 90 is below average. The Panel issues this prediction as needed to serve our many customers who make economic decisions based on the level of solar activity and its affect on human and technological systems.

5 SIGNIFICANT CYCLE-24 ACTIVITY

Like terrestrial weather, space weather is always present and makes itself apparent in many forms. This section summarizes significant space weather for the period AUG 2010 – JUL 2011.

Space weather activity ramped up as the increasing phase of Cycle 24 continued (Cycle 24 began in December 2008).

Solar flare events: isolated M-class X-ray flares occurred during most months of the summary period. However, M-class flare activity increased significantly during February – March 2011 (see Table 1). There were seven major flares (X-ray flux ≥ M5), including two X-class flares, most of which occurred during February – March 2011. An X2 flare in February 2011 was the largest observed since December 2006.

Solar proton events: There were four >10 MeV proton events and one >100 MeV event during the summary period (see Table 1). The largest >10 Mev event occurred during 07 – 08 June with a peak flux of 73 pfu. The >100 MeV event occurred during 07 – 08 June as well, with a peak flux of 14 pfu.

Table 1: Summary of Space Weather Events

	X-ray Events		>2 MeV Events	F10.7	Proton Events		Geomagnetic Storms		
	M-class	X-class	Days > 1.0E+03		>10 SPE	>100 SPE	Ap	Major	Severe
AUG 2010	1	0	18	79.5	1	0	7.8	0	0
SEP	0	0	6	81.1	0	0	5.4	0	0
OCT	1	0	8	81.7	0	0	6.0	0	0
NOV	3	0	8	82.5	0	0	5.6	0	0
DEC	0	0	2	84.2	0	0	4.1	0	0
JAN 2011	1	0	7	83.4	0	0	5.5	0	0
FEB	13	1	11	94.5	0	0	6.3	0	0
MAR	20	1	9	115.8	2	0	8.1	0	0
APR	3	0	8	112.5	0	0	8.6	0	0
MAY	2	0	12	95.8	0	0	8.9	0	0
JUN	2	0	14	95.8	1	1	8.0	0	0
JUL	2	0	18	94.1	0	0	8.1	0	0

6 SPACE DEBRIS/COLLISION MITIGATION

Orbit prediction and re-entry forecasts for space assets and debris, and collision mitigation; require neutral density specification and short-term forecasts (3-5 days), which are currently provided by empirical atmospheric models. NOAA Space Weather Prediction Center (SWPC) provides solar and geomagnetic indices as input to these empirical models. SWPC, in collaboration with its cooperative institute partners at the University of Colorado, also conducts research to improve neutral density specification and forecast. This includes improving the geomagnetic index based on solar wind and interplanetary magnetic field data; exploring utility of transitioning to physics-based thermospheric neutral density models; and enhancing

the geomagnetic forecast capability using Sun-to-Earth numerical models of the solar wind.

7 REFERENCES

NOAA/NCEP/SWPC Preliminary Report and Forecast of Solar Geophysical Data (PRF): PRF 1882, 03 AUG 2010 – PRF 1874, 02 AUG 2011.