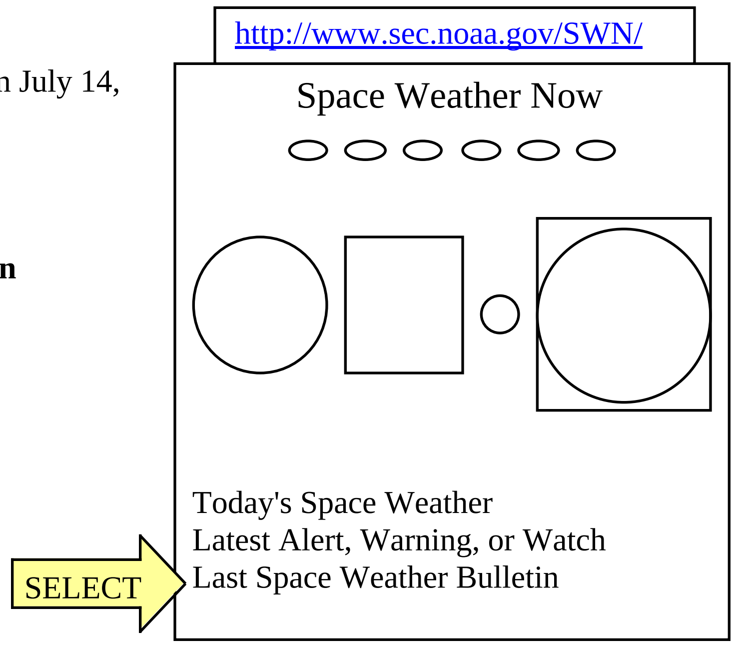
TRACKING A SOLAR STORM – Part 2
A Step-by-Step Example

In this section, the process described in Part 1 will be applied to an actual solar storm: the solar storm of July 14, 2000. The process will be illustrated using screens or partial screens from the websites and the resulting data screens will also be shown.

1. Space Weather

Monitoring **Space Weather Now** on July 14, 2000 would have revealed:

Select **Last Space Weather Bulletin**



SPACE WEATHER BULLETIN #00- 10
2000 July 14 at 10:14 a.m. MDT (2000 July 14 1614 UT)

**** RADIATION STORM OCCURS , MAGNETIC STORM PREDICTED ****

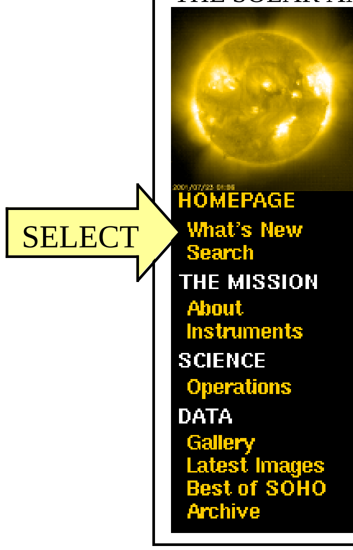
A large, complex sunspot group has produced one of the largest solar flares and associated radiation storms seen in recent years. The flare peaked at 4:24 a.m. MDT (1024 UTC) on July 14 and resulted in a radio blackout that reached R3 (strong) levels and a solar radiation storm that reached S3 (strong) levels. The solar radiation storm, which continues at the time of this advisory, is the largest observed since October, 1989. Images from NASA's SOHO/LASCO spacecraft showed that a large, fast-moving coronal mass ejection (CME) followed the flare and is headed Earthward. NOAA space weather forecasters predict that the CME will impact the Earth's magnetic field on Saturday afternoon and will cause a geomagnetic storm that is expected to reach category G3 (strong) to G4 (severe) levels. The radiation and geomagnetic storms are expected to produce adverse effects on spacecraft operations, power systems, high-frequency radio communications, and low-frequency navigation signals. In addition, the geomagnetic storm is expected to produce aurora displays that will be visible over much of the U.S.

The sunspot group responsible for this event will be visible from Earth until it crosses the Sun's west limb on July 21 and more spaceweather storms are possible until that time.

The European Space Agency's Solar and Heliospheric Observatory, SOHO, keeps a constant watch on the sun from its vantage point 1.5 million kilometers from Earth between the Earth and the sun. If you had gone to the SOHO site on July 14 and looked under **What's New**, you would have seen the following.

http://sohowww.nascom.nasa.gov/

THE SOLAR AND HELIOSPHERIC OBSERVATORY



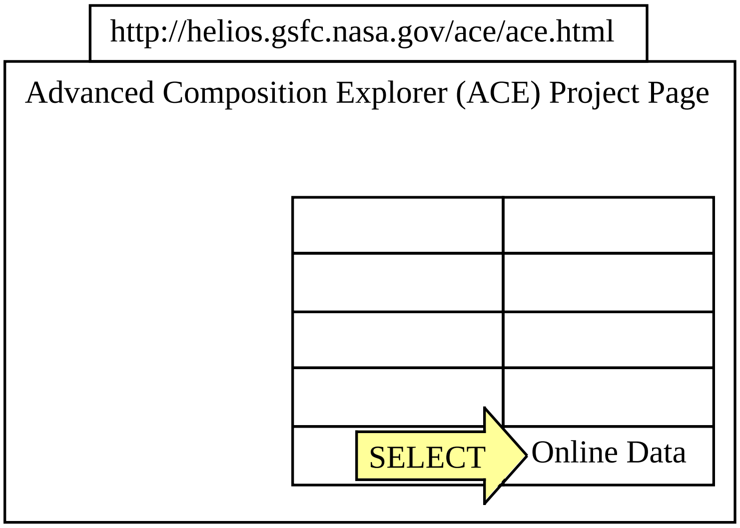
July 14, 2000

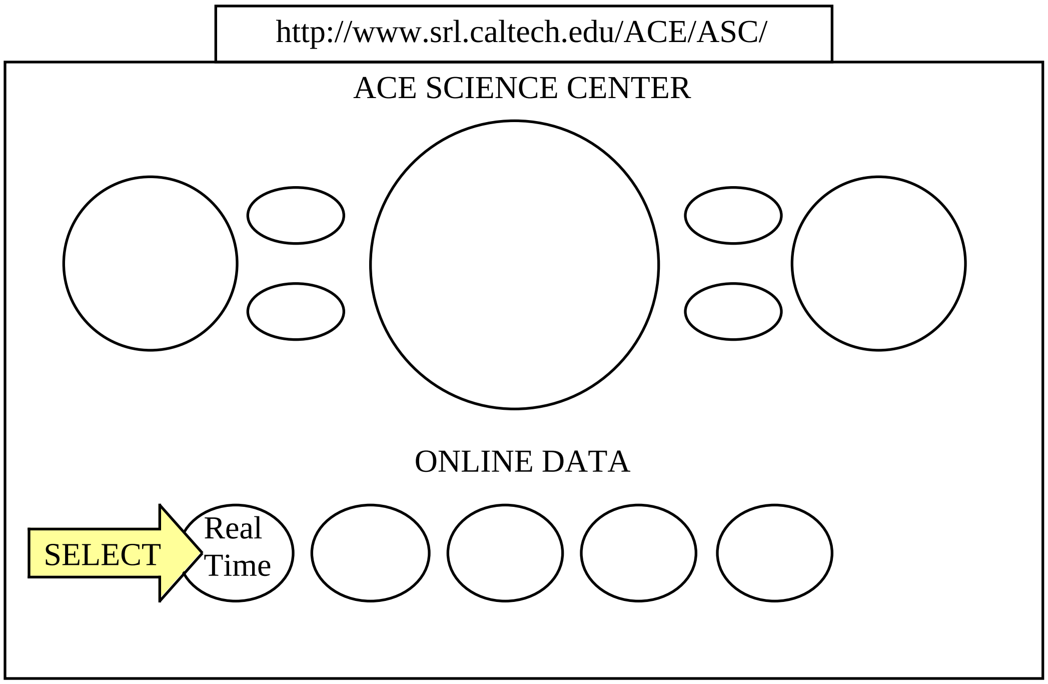
SOHO sees biggest particle event of cycle so far.

A powerful solar flare on July 14th triggered an intense radiation storm in the vicinity of Earth. The eruption was followed by a fast-moving coronal mass ejection that is expected to strike Earth's magnetosphere as early as Saturday. The impact could trigger Northern and Southern Lights bright enough to be seen in spite of this weekend's brilliant full Moon. Such a display is by no means guaranteed, but it is possible. Observers across the Pacific could be in for a very rare treat: the sight of shimmering colorful aurora during the total lunar eclipse of July 16, 2000.

2. Solar Wind Observing Satellites

Checking ACE Real-Time data later in the day on July 14 would have shown the following.





http://www.srl.caltech.edu/ACE/ASC/rtsw.html

ACE Real-Time Solar Wind Data

SELECT → ACE Real-Time Solar Wind (RTSW) Data from NOAA's Space Environment Center (SEC) provides up to an hour's advance warning of unusual solar activity, such as solar flares and coronal mass ejections, which can cause geomagnetic storms.

http://sec.noaa.gov/ace/ACErtsw_home.html

ACE
Real Time Solar Wind

Introduction

Real Time Data:

SELECT → Dynamic Plots
1&5 min Lists
Hourly Lists

http://sec.noaa.gov/ace/ACErtsw_home.htm

ACE
Real Time Solar Wind

Introduction

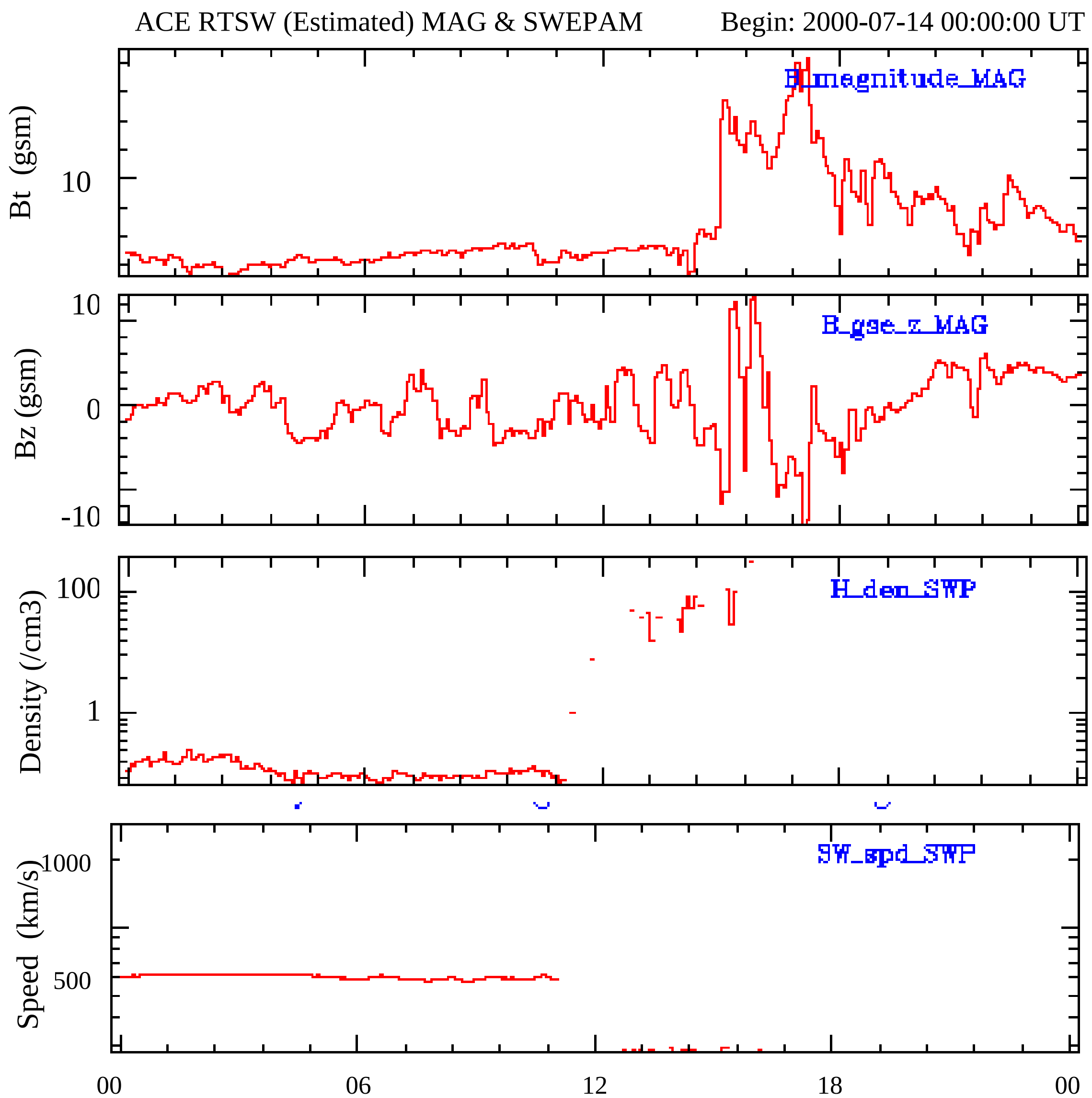
Real Time Data:

Dynamic Plots
1&5 min Lists
Hourly Lists

Dynamic ACE RTSW Plots

6 hrs	MAG_SWEP	MAG	SWEPA
24 hrs	MAG_SWEP	← SELECT	SWEPA
3 days	MAG_SWEP	MAG	SWEPA

This will return a set of graphs similar to the following. In the real time display, the top two graphs are combined and the third and fourth below are the third and fourth on the real time display.



The top two graphs show the disruption of the solar magnetic field as reported in the Space Weather Bulletin from a CME reported as occurring at:

2000 July 14 at 4:24 a.m. MDT (2000 July 14 1024 UT)

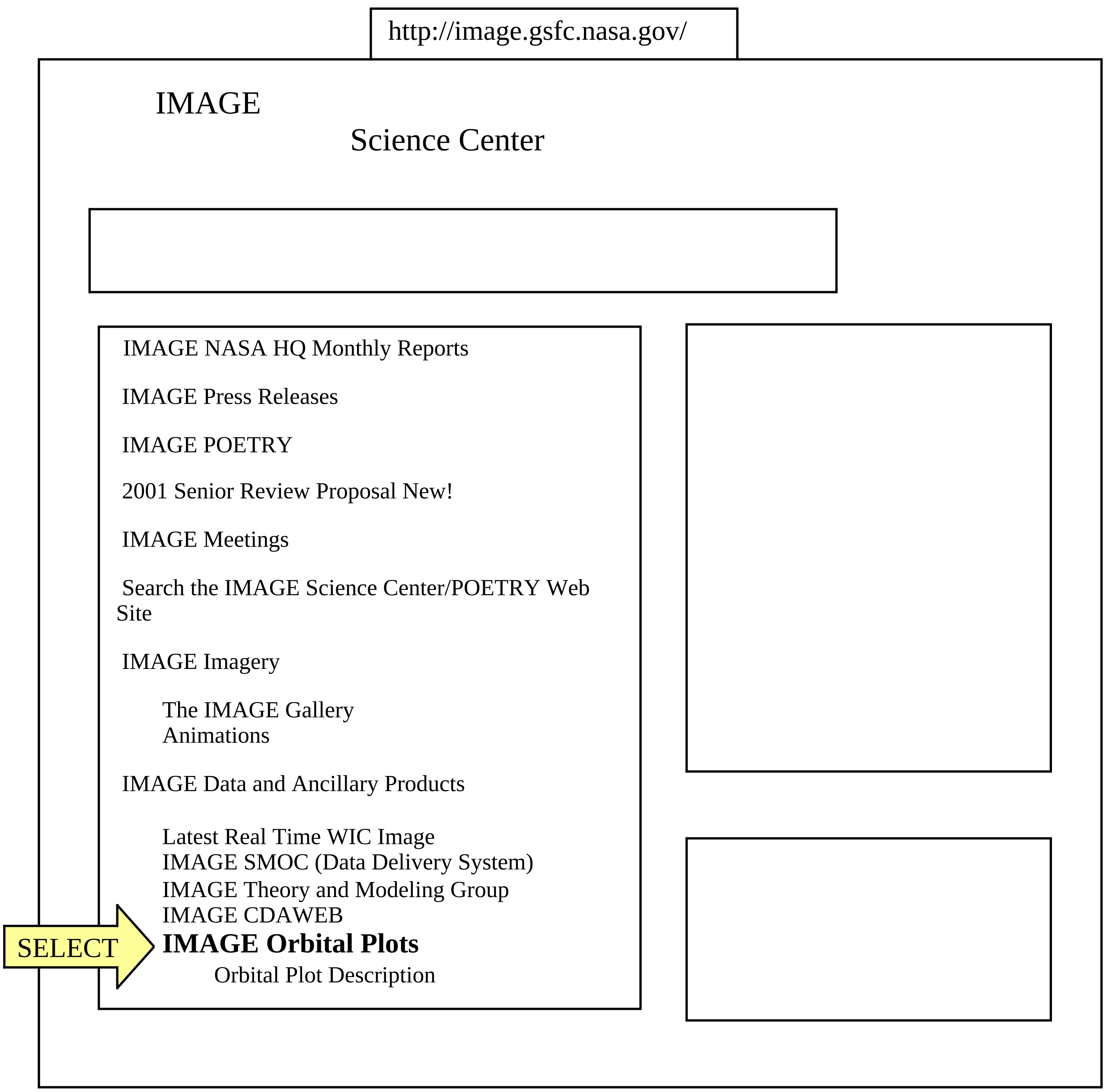
We can see from these plots that the magnetic field disruption occurred about 3-4 hours after the CME. The bottom two graphs show the proton density and speed of the solar wind. These two quantities both abruptly increased about 30 minutes after the CME. The increase in these two quantities was so abrupt and large that the instrument on ACE making the measurements (SWEPAM) temporarily malfunctioned and failed to measure the two quantities accurately.

3. Impacts on Earth's Magnetosphere

The IMAGE satellite uses remote sensing instruments to create images of features of the Earth's magnetosphere. The orbit of IMAGE is very elliptical with the IMAGE to Earth distance varying from an altitude of 1000 kilometers to an altitude of 7 Earth radii (7 R_E). In order to correctly interpret the data images, it is important to view the images from a consistent perspective. The best location to view the data images from is when IMAGE is near apogee in its orbit. (Apogee is the point in its orbit where IMAGE is farthest from Earth.) The following procedure shows the steps for determining the times of apogee for IMAGE.

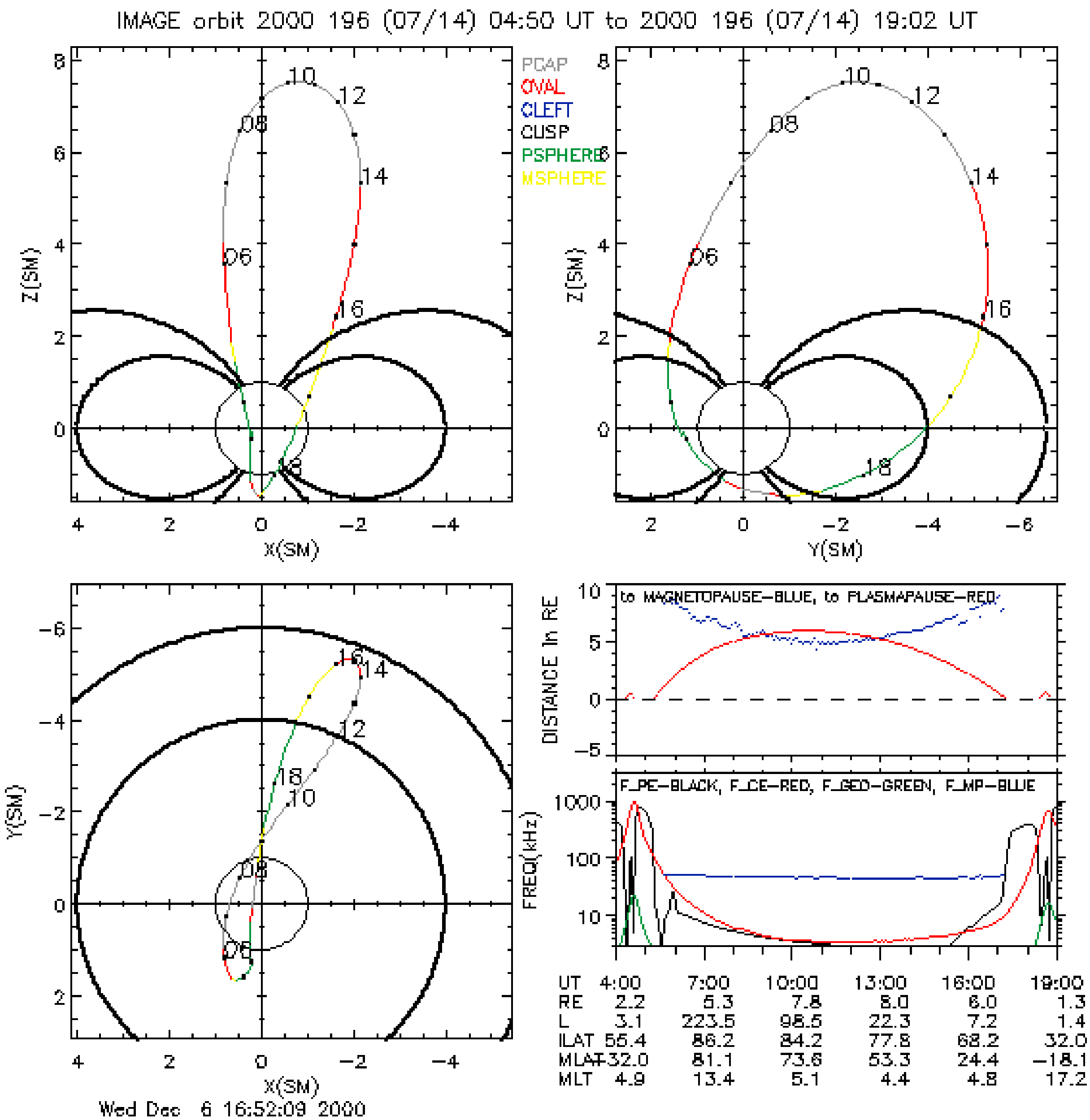
From the IMAGE Science Center page, select **IMAGE Orbital Plots**:

IMAGE Science Center



This will display a four-panel series of plots for the first day of the image mission (March 27, 2000). Below the plots, fine the **Date:** box and below that the **Date Format:** box. From the **Date Format:** box, select **YYYYMMDD** and in the **Date:** box enter **20000714** (the day of the CME.

Select Update Date/Plot Type

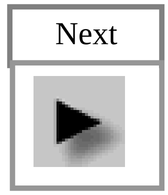


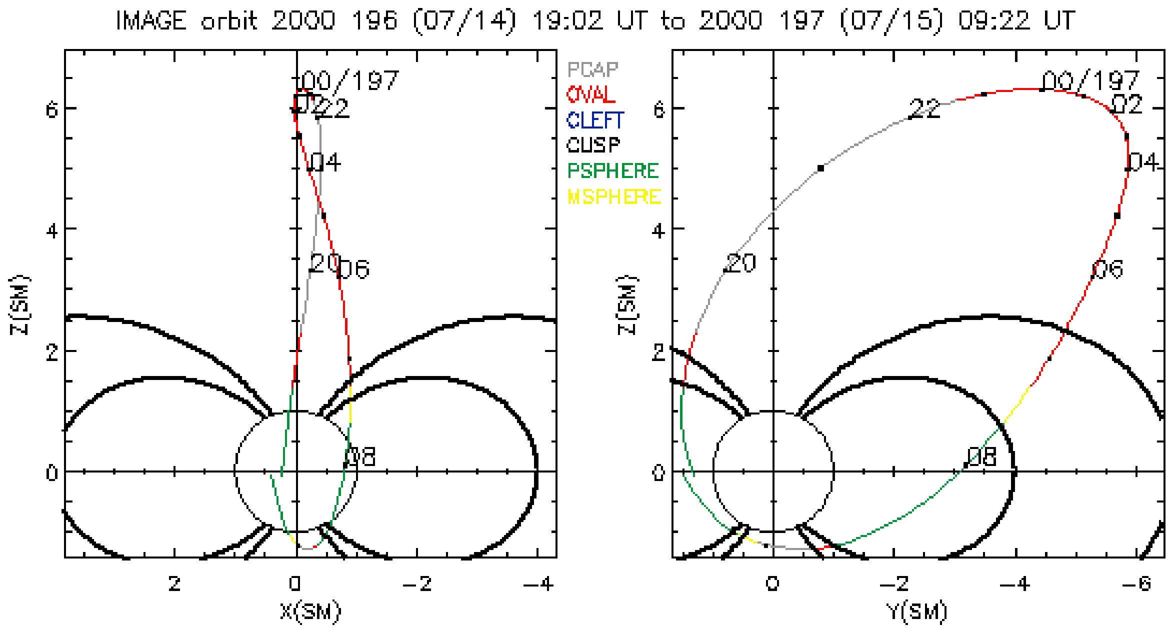
We will be using the top two plots to get an estimate of the time of apogee. From the top left plot, apogee appears to be around 11 UT; the top right plot looks more like an apogee time of 12 UT. Choosing either of these times will do. Make a note of the apogee time including the date:

Apogee: 2000 07 14 1200 UT.

Near the bottom of the screen, click on

This will advance the plot one orbit.





The top two panels from this orbit are shown above. Apogee time appears to be:

Apogee: 2000 07 15 0100 UT. Add this to the list of apogee times.

Continue this process for the next several orbits. Apogee times are:

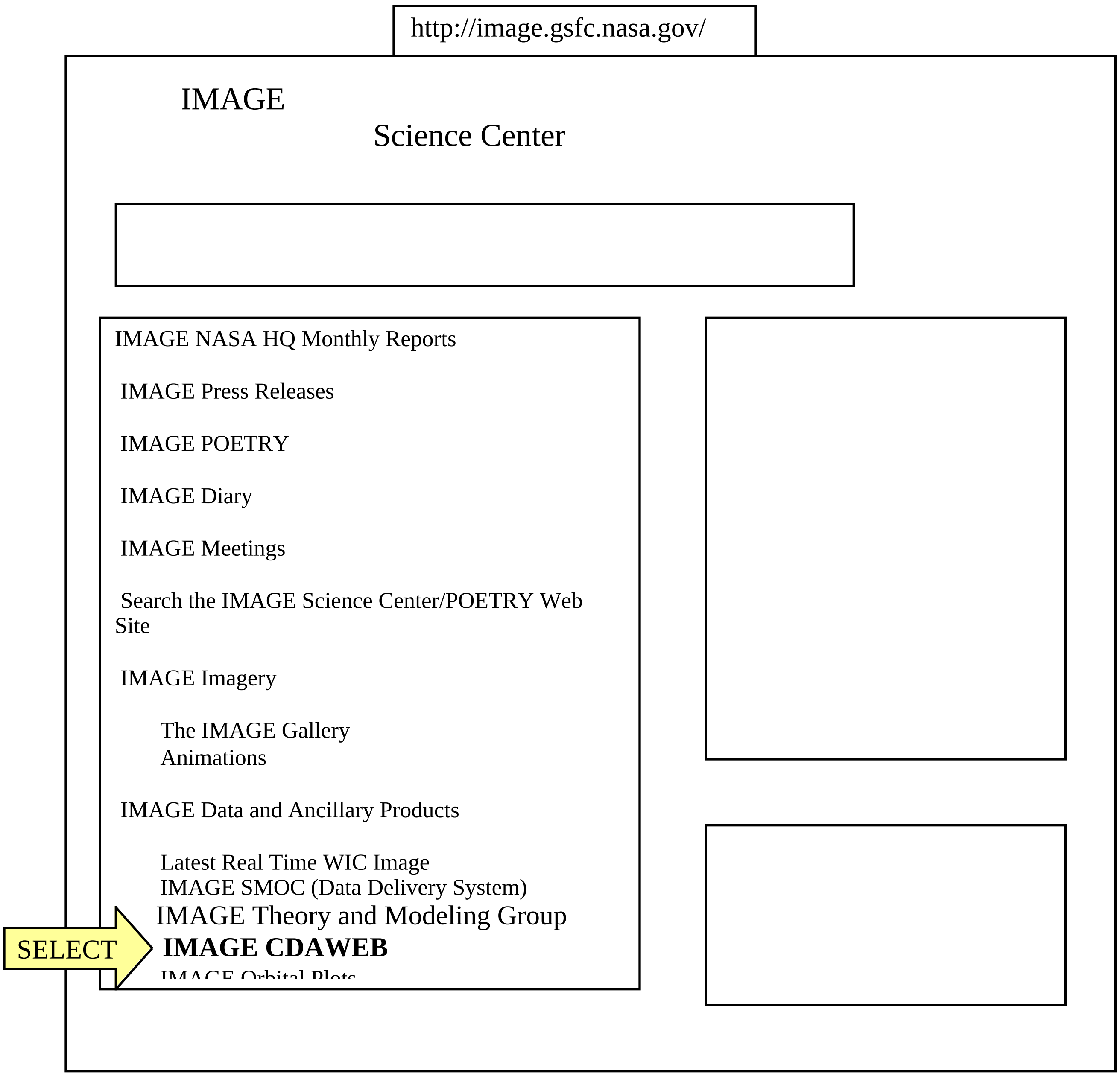
2000 07 14 1200 UT
2000 07 15 0100 UT
2000 07 15 1500 UT
2000 07 16 0600 UT
2000 07 16 2000 UT
2000 07 17 1000 UT
2000 07 18 0000 UT
2000 07 18 1400 UT

Notice that the orbital period of IMAGE (14 hours) is approximately the time spacing between apogees.

The first instrument we will consider is **FUV**. This instrument, using the WIC camera, shows images of the northern aurora.

Go to: http://image.gsfc.nasa.gov/

IMAGE Science Center



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Coordinated Data Analysis Web (CDAWeb)

CDAWeb Source Selector Form

Select one or more Sources:

SELECT → ☑ IMAGE

Select one or more Instrument Types:

☐ Engineering
☐ Ephemeris
☐ Imager
SELECT → ☑ Imagers (space)

SELECT → Submit   Reset

The next screen will come up with all instruments selected. It is best to look at the instruments one at a time. To **unselect** an instrument, just click on it. For other instruments in this guide, this screen will not be repeated. Instead, an instruction such as **Select IM_KO_WIC** will be used for this step in the process

CDAWeb Data Selector

For additional detailed information supplied with a data set, click on the data set name.

You may unselect one or more data sets from the list below and then press the "submit" button:

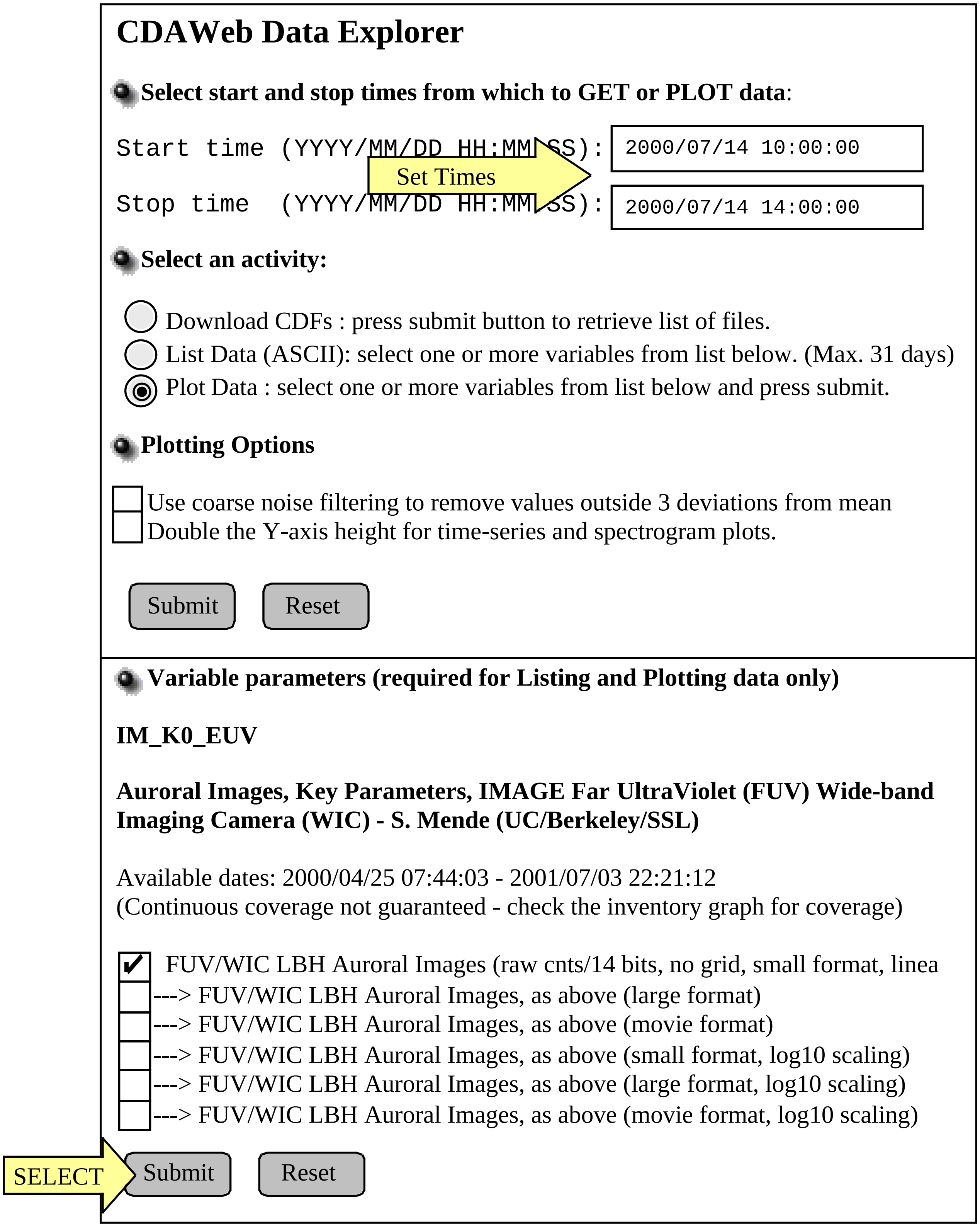
Unselect all but the instru- ment you want

☐ IM_K0_EUV: (null) -
☐ IM_QL_EUV: (null) -
☐ IM_K0_HENA: Image HIGH ENERGY NEUTRAL ATOM IMAGER
☐ IM_K0_LENA: IMAGE Low Energy Neutral Atom (LENA) Imager
☐ IM_K0_SIP: Image Spectrographic Imaging Camera
☐ IM_K0_SIE: Image Spectrographic Imaging Camera
☐ IM_K0_RPI: RPI Key Parameters: Plasmagram/Echomap
☐ IM_K1_RPI: RPI Key Parameters: Dynamic Spectrogram
☐ IM_K2_RPI: RPI Key Parameters: Fixed Frequency Measurement
☑ IM_K0_WIC: Image Wide-Band Imaging Camera

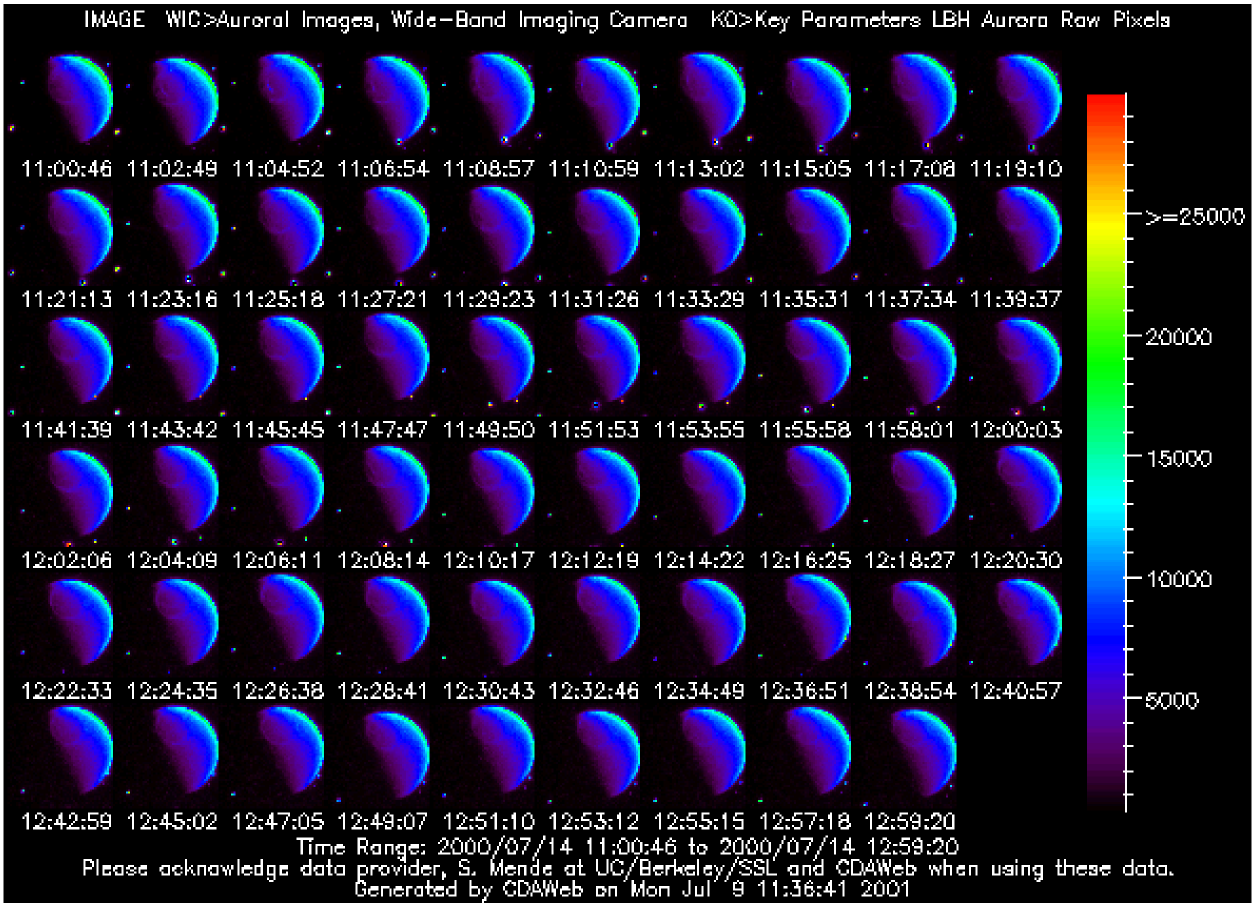
SELECT → Submit   Reset

Choose a **Start time** 2 hours before apogee and a **Stop time** that is 2 hours after apogee.

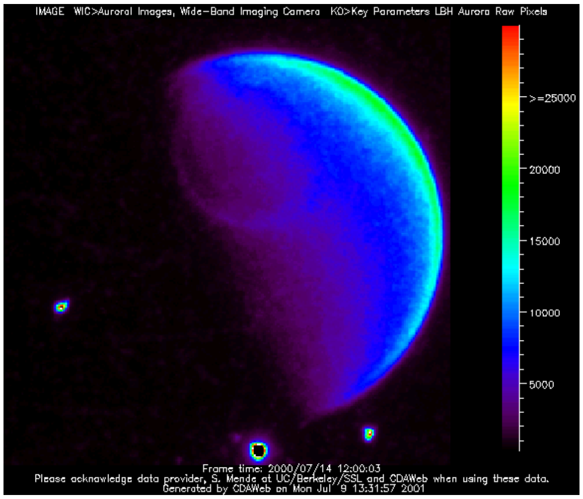
Under **Variable parameters**, select **`FUV/WIC LBH Auroral Images.`**



The following is the data displayed for a time interval of 2 hours; from one hour before apogee to one hour after apogee. (The 4-hour interval will return more data images.)

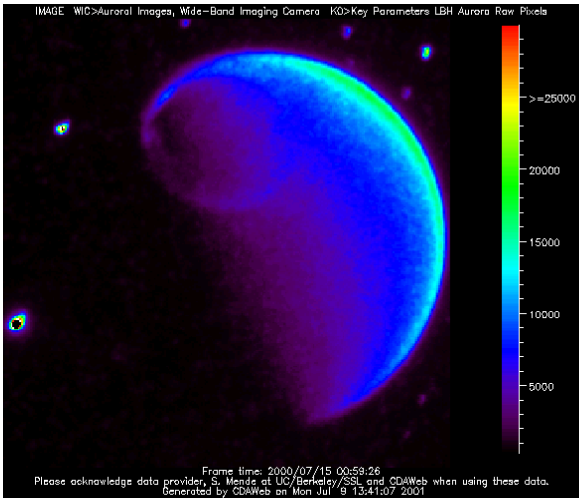


Clicking on any individual image will return an enlarged view.

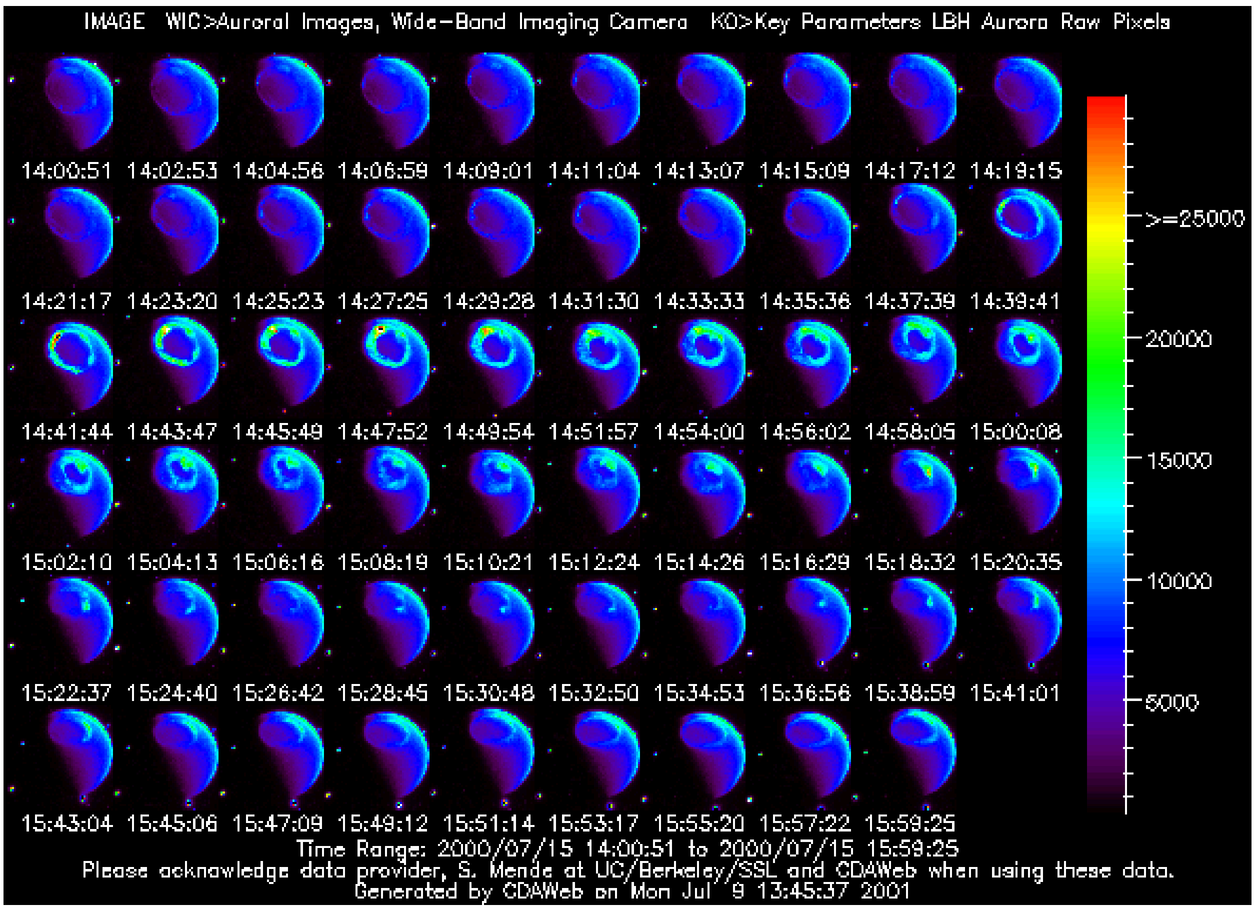


This is the view of the image closest to apogee (12:00:03 UT). Careful examination of this image reveals the presence of a faint auroral oval in the top center of the image. Since this is the apogee before the CME event, this can provide a reference for a “quiet” aurora.

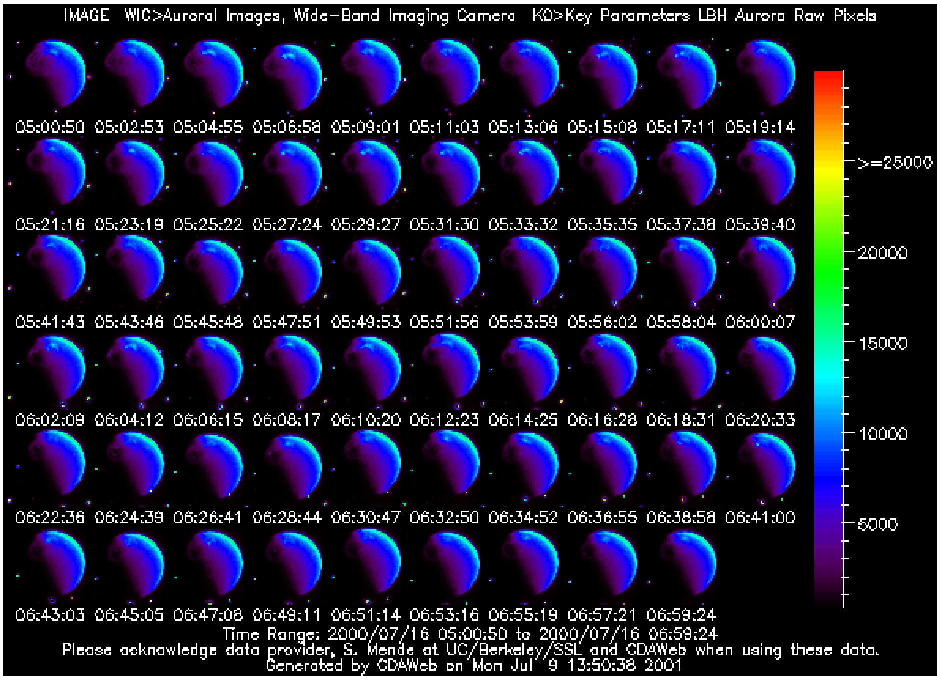
Use the BACK button to return to the CDAWeb Data Explorer and change the time interval to include the next apogee time. Make enlargements of the image closest to apogee and any others that look different.



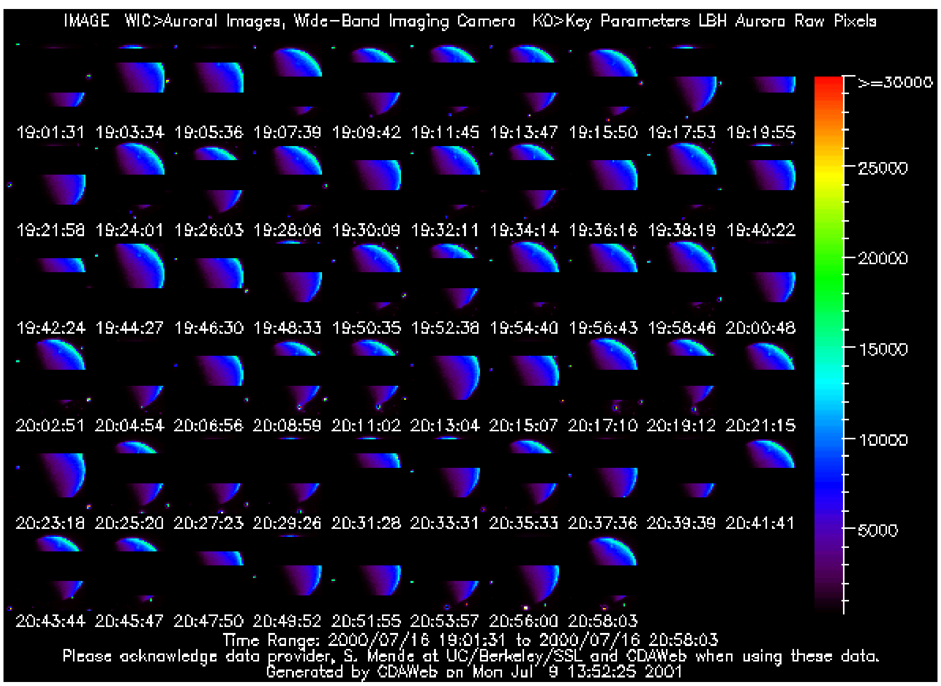
This is the image closest to the next apogee time (2000/7/15 00:59:26 UT). We are looking for change in the aurora that will indicate the arrival of charged particles from the CME. The aurora is still quiet.



This is the 2-hour time span around the next apogee (2000/07/15 1500 UT). The changes in the aurora are striking. There is an abrupt increase in auroral activity starting at 14:34:41 UT and, by the end of this sequence, at 15:59:25 UT the aurora has pretty much returned to its “quiet” state. Note the times of the increased activity and proceed to the next apogee time.



At 2000/07/16 0600 UT the aurora is quiet. Continue to check the next several apogee times looking for changes in the aurora.



At 2000/07/16 2000 UT the aurora appears quiet even thought most of the images are partials. Quiet conditions prevail for the next several apogees. The effect of the CME ion the aurora has been determined.

Next, the HENA instrument will be used to look for effects on the ring current. From the **CDAWeb Data Selector** screen, unselect all but **IM_K0_HENA:**.

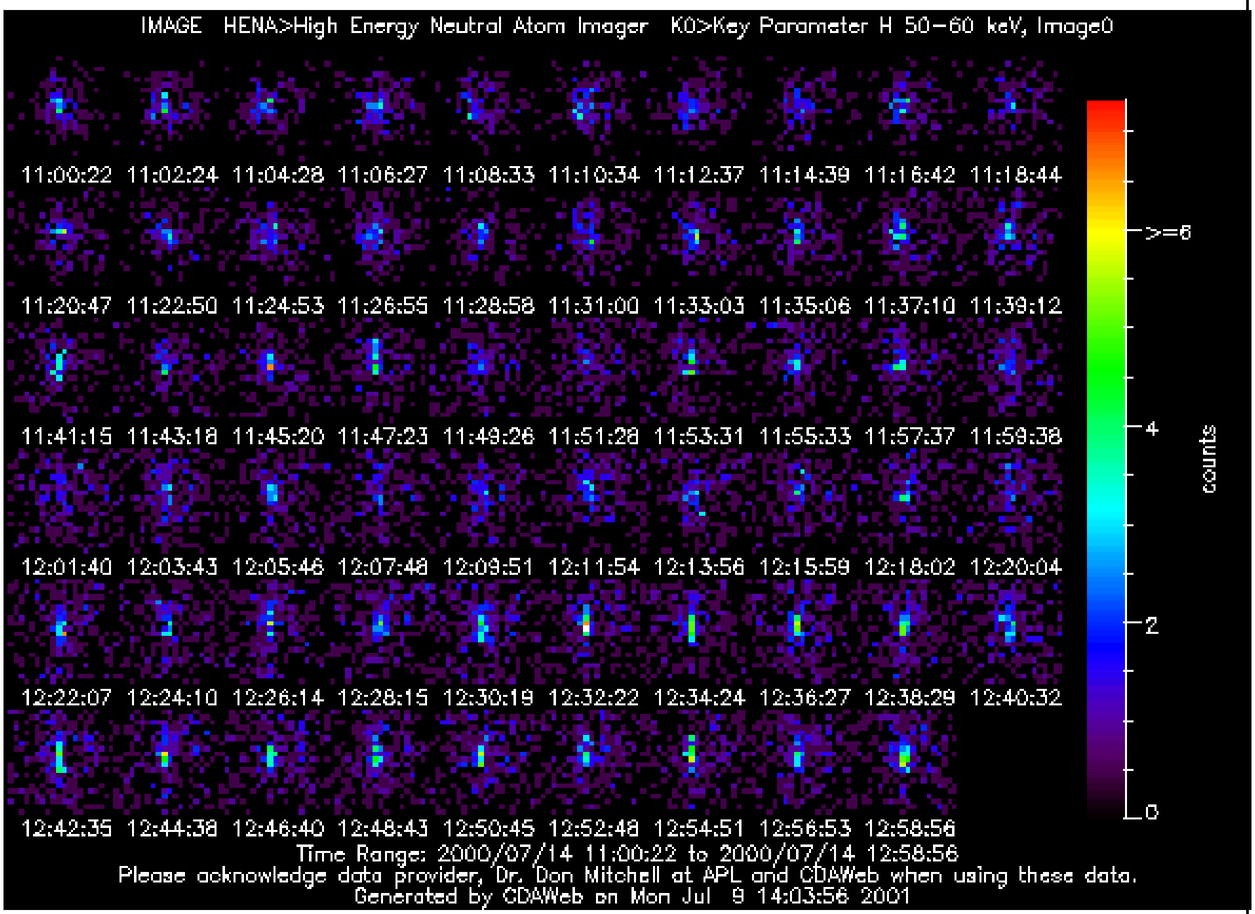
Choose a **Start time** 2 hours before apogee and a **Stop time** that is 2 hours after apogee.

Under **Variable parameters**, select **`ENA H Images @ 50-60 keV`**, the highest energy range.

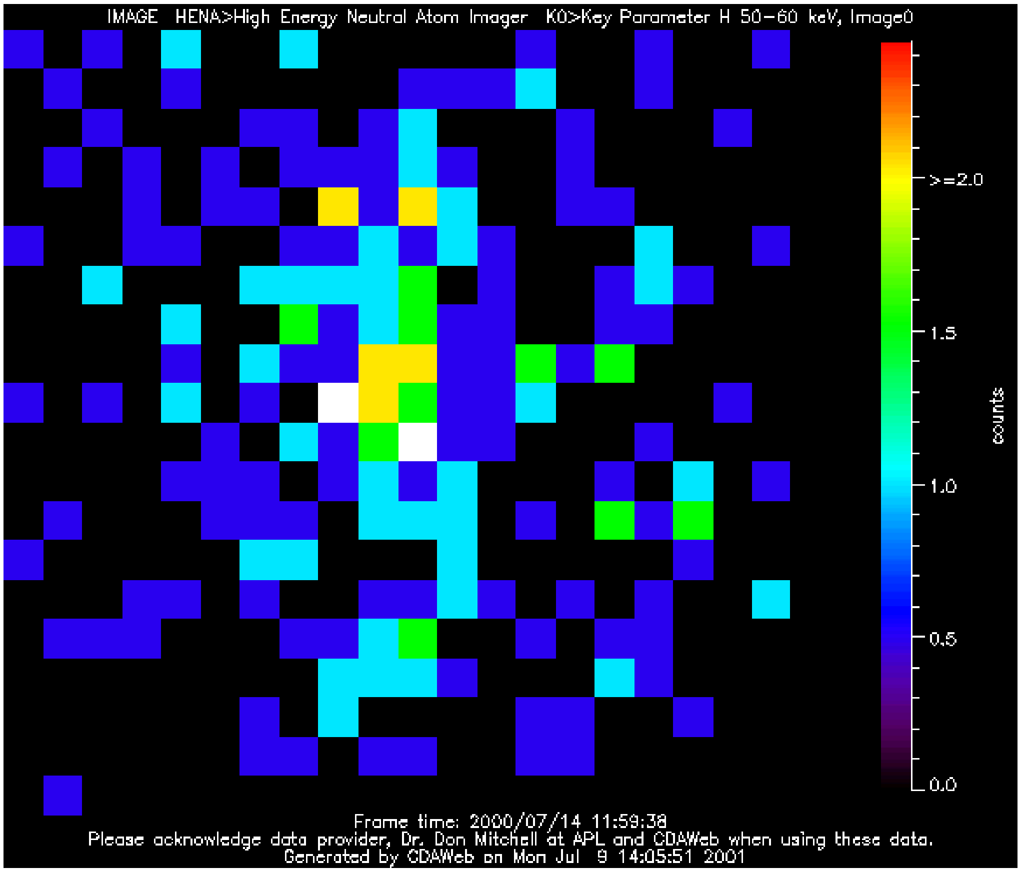
The following is the data for 7/14 from 1100 UT to 1300 UT, before the CME.

Note: Expand by clicking on any image.

IM_K0_HENA



This can serve as a reference for quiet ring current conditions before the solar storm. Note that the “Count” scale on the right ranges in value from 0 to >6.



This is an enlargement of the image closest to apogee

2000/07/14 11:59:38 UT

Notice the "Count" scale here ranges from 0 to >2.

An estimate of the total activity can be obtained by counting the number of pixels of each color and multiplying that number by the count value of each color as determined using the "Count" scale to the right..

Total ring current activity is:

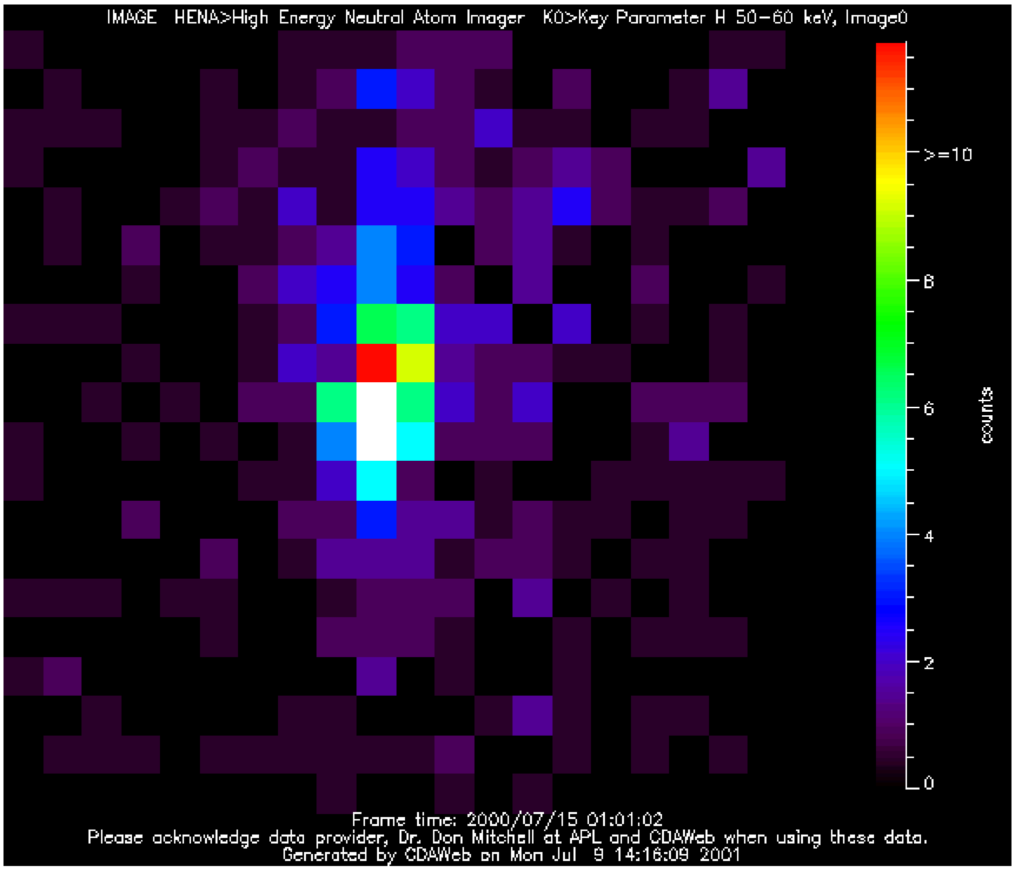
Yellow pixel: 5 pixels x 2 counts per pixel =	10
Green pixel: 10 pixels x 1.5 counts per pixel =	15
Light blue pixel: 38 pixels x 1 count per pixel =	38
Dark blue pixel: 110 pixels x .5 counts per pixel =	55
TOTAL Ring Current Activity:	118 counts

NOTE: Ignore white pixels. The Dark blue pixel count is very approximate!

"Quiet" ring current activity is around 100 counts.

Use the BACK button to the **CDAWeb Data Explorer**

And change the time interval to include the next apogee.



Apogee time: 2000/07/15 0100 UT.

Image time: 2000/07/15 01:01:02 UT.

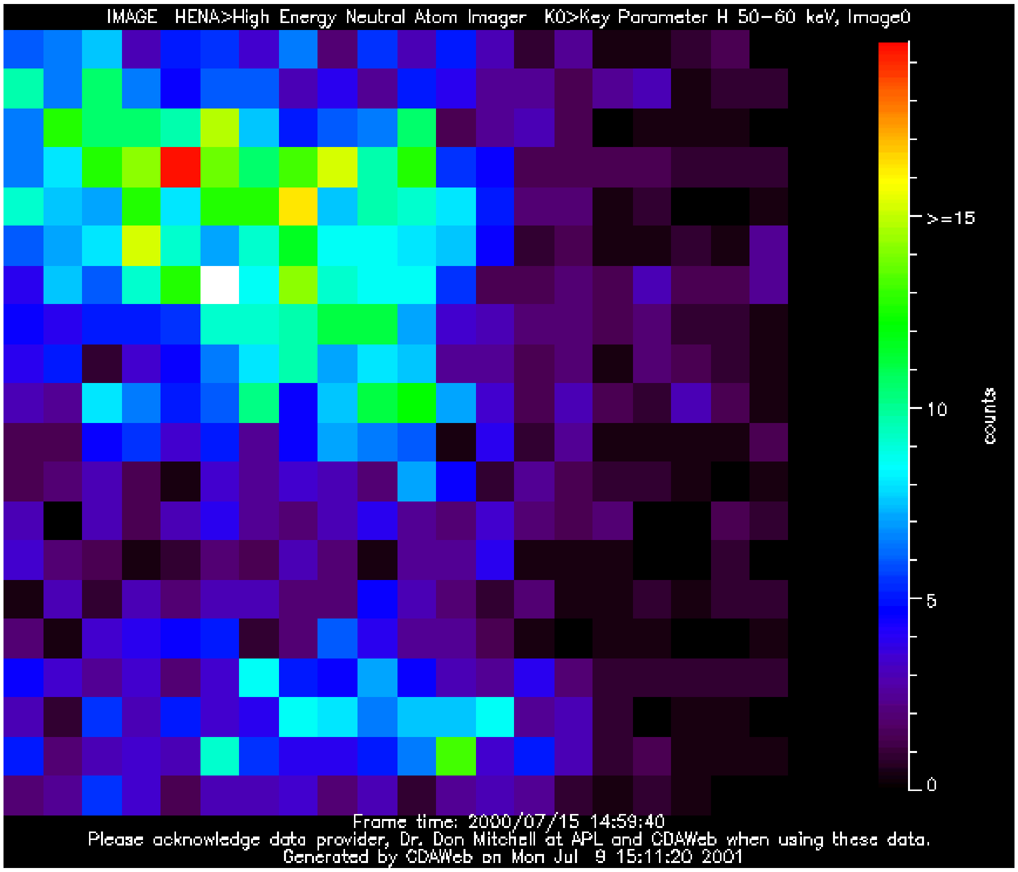
“Count” scale range from 0 to >10.

Total ring current activity is:

Red pixel = 12 counts	1 x 12 =	12
Yellow pixel = 9 counts.	1 x 9 =	9
Green pixel = 8 counts.	4 x 8 =	32
Light blue pixel = 5 count.	2 x 5 =	10
Dark blue pixel = 3 counts.	25 x .3 =	75
Purple pixel = 1 count.	69 x 1 =	69

TOTAL Ring Current Activity: 207 counts

NOTE: There are shades of dark blue and purple. Use your judgment in assigning colors.



Apogee time: 2000/07/15 1500 UT.

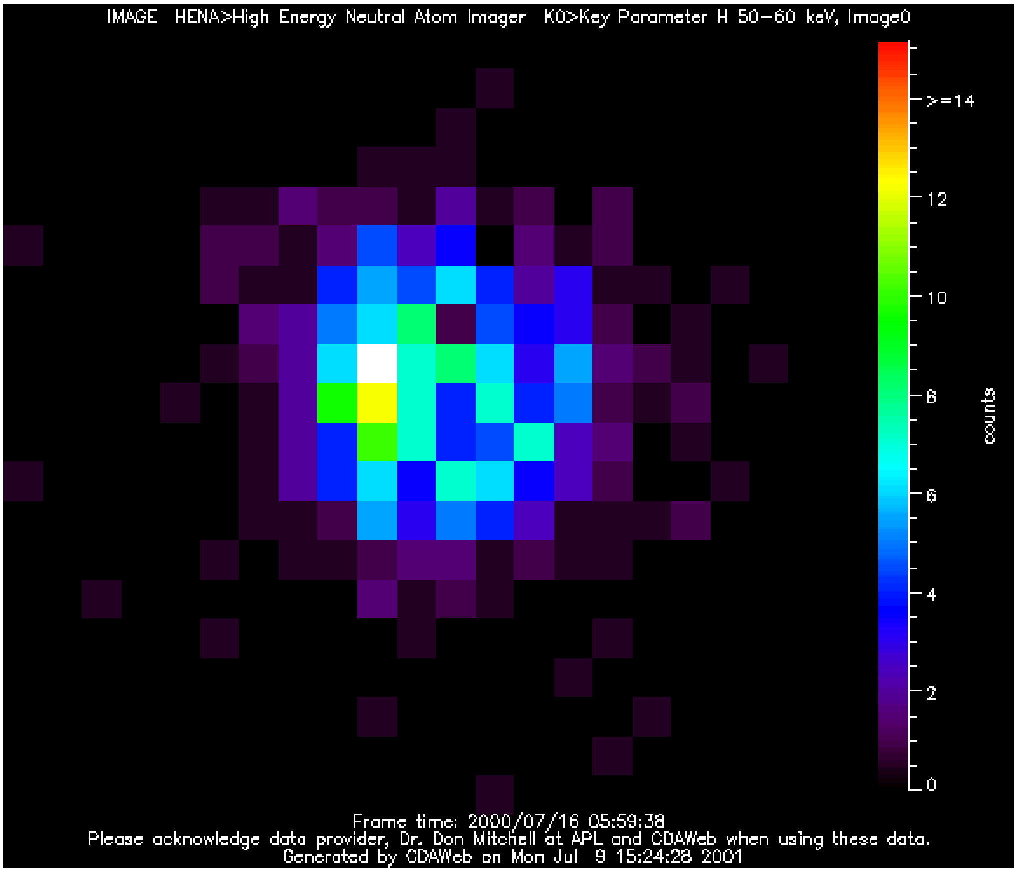
Image time: 2000/07/15 14:59:40 UT.

“Count” scale range from 0 to >15.

Total ring current activity is:

Red pixel = 19 counts	1 x 19 =	19
Yellow pixel = 16 counts.	4 x 16 =	64
Green pixel = 12 counts.	23 x 12 =	276
Light blue pixel = 8 count.	26 x 8 =	208
Dark blue pixel = 5 counts.	68 x 5 =	340
Purple pixel = 2 counts.	112 x 2 =	224
	TOTAL Ring Current Activity:	1131 counts

Notice the activity level is now substantially above the “quiet “ level.



Apogee time: 2000/07/16 0600 UT.

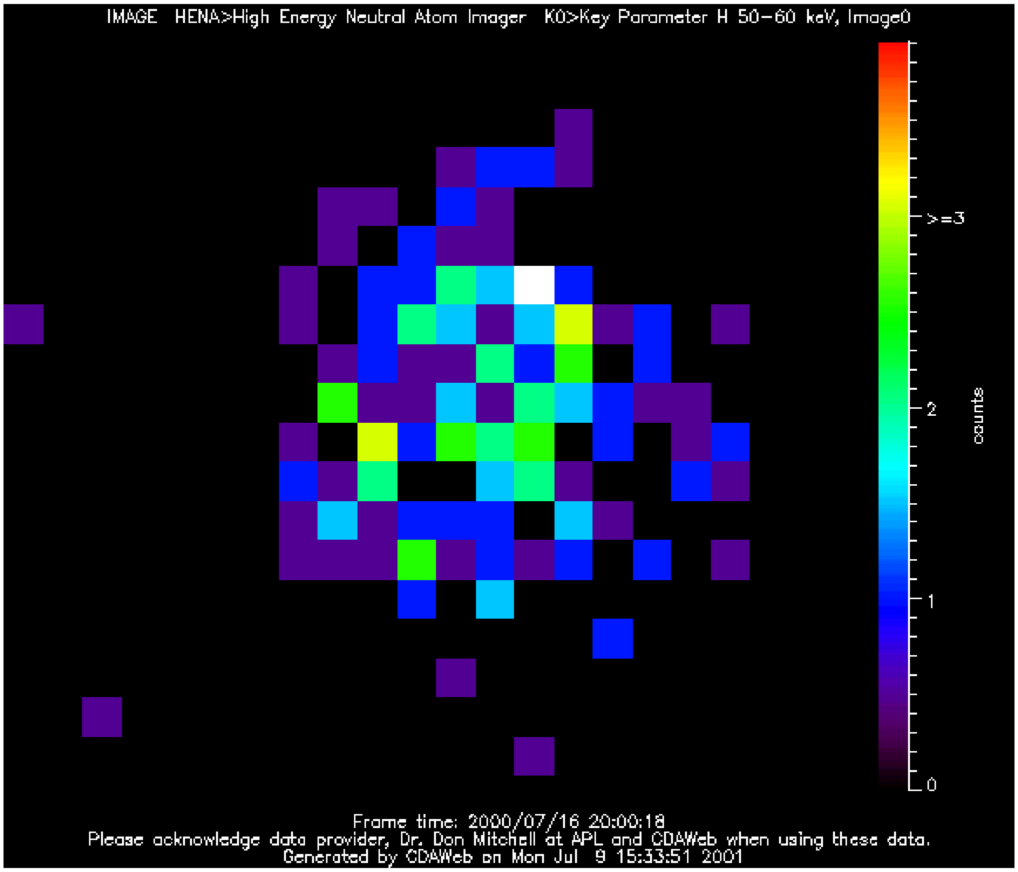
Image time: 2000/07/16 05:59:38 UT.

“Count” scale range from 0 to >14.

Total ring current activity is:

Yellow pixel = 12 counts.	1 x 12 =	12
Green pixel = 10 counts.	4 x 10 =	40
Light blue pixel = 7 count.	14 x 7 =	98
Dark blue pixel = 5 counts.	23 x 5 =	115
Purple pixel = 1 counts.	39 x 1 =	39
	TOTAL Ring Current Activity:	304 counts

Activity level has decreased considerably.



Apogee time: 2000/07/16 2000 UT.

Image time: 2000/07/16 20:00:16 UT.

"Count" scale range from 0 to >3.

Total ring current activity is:

Yellow pixel = 3 counts.	1 x 3 =	3
Green pixel = 2.5 counts.	10 x 2.5 =	25
Light blue pixel = 1.5 count.	12 x 1.5 =	18
Dark blue pixel = 1 count.	25 x 1 =	25
Purple pixel = .5 counts.	38 x .5 =	19
	TOTAL Ring Current Activity:	90 counts

Activity level has decreased to "quiet" levels.

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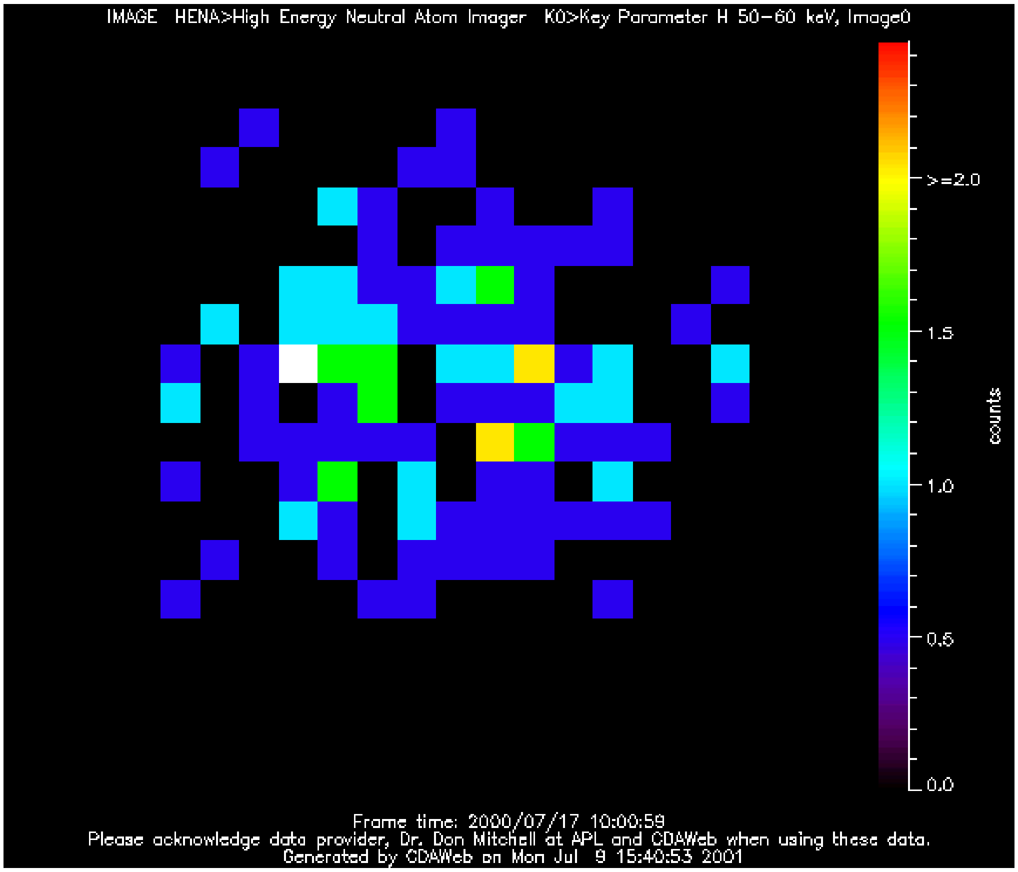


Apogee time: 2000/07/17 1000 UT.

Image time: 2000/07/17 10:00:59 UT.

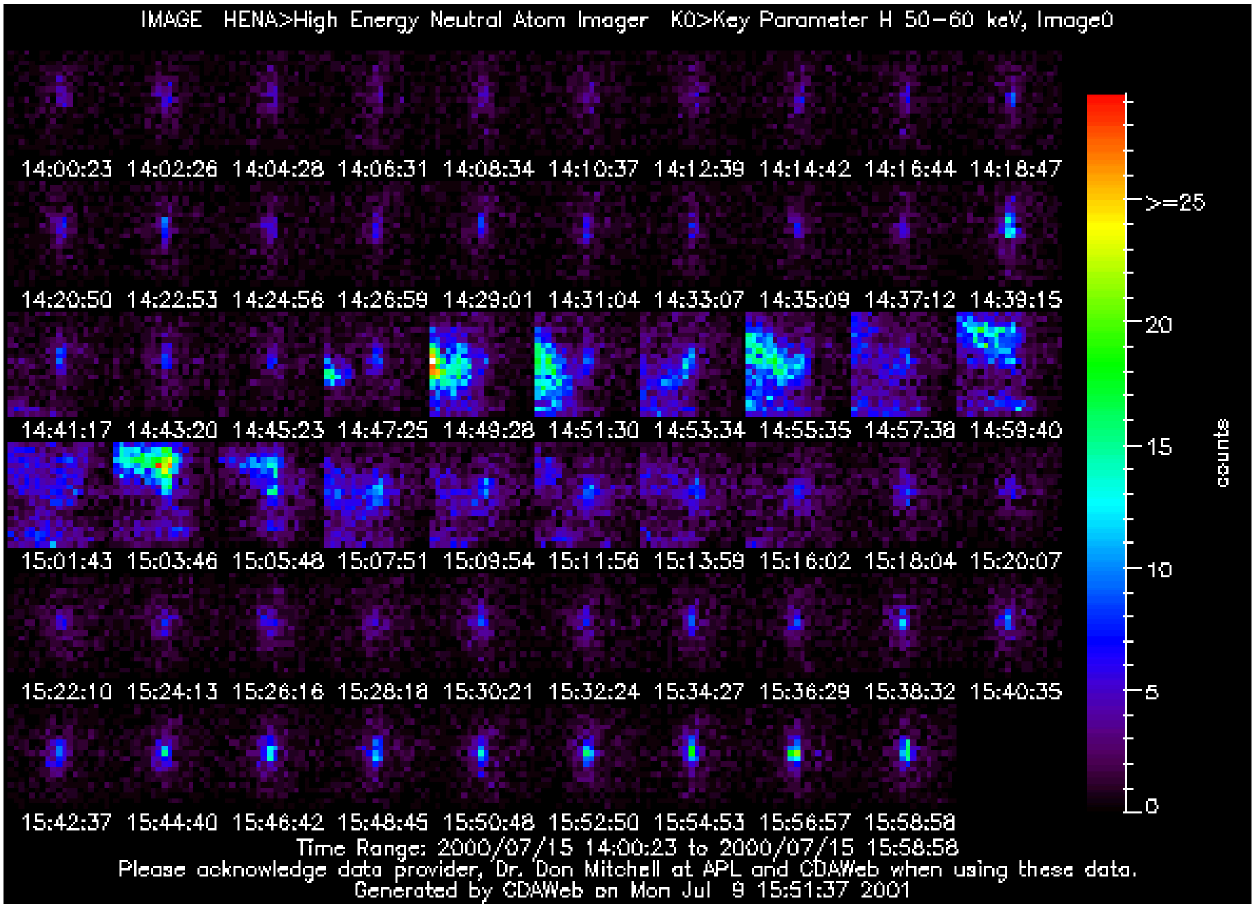
"Count" scale range from 0 to >2.

Total ring current activity is:

Yellow pixel = 2 counts.	2 x 2 =	4
Green pixel = 1.5 counts.	6 x 1.5 =	9
Light blue pixel = 1 count.	20 x 1 =	20
Dark blue pixel = .5 count.	62 x .5 =	31
Purple pixel = .2 counts.	0 x .2 =	0
	TOTAL Ring Current Activity:	64 counts

Activity level remains "quiet".

Clearly, activity peaked some time near the apogee at 2000/07/15 1500 UT. Another look at the complete 2-hour data panel shows the following:



Activity is strongest in the third and fourth rows of images which include a time from 1447 UT to 1503 UT. Comparing this time with auroral activity, we see that ring current activity started about 10-15 minutes after the increase in the auroral activity and quieted down about 55 minutes before the decrease in auroral activity.

Next, the EUV instrument will be used to look for effects on the plasmasphere. From the

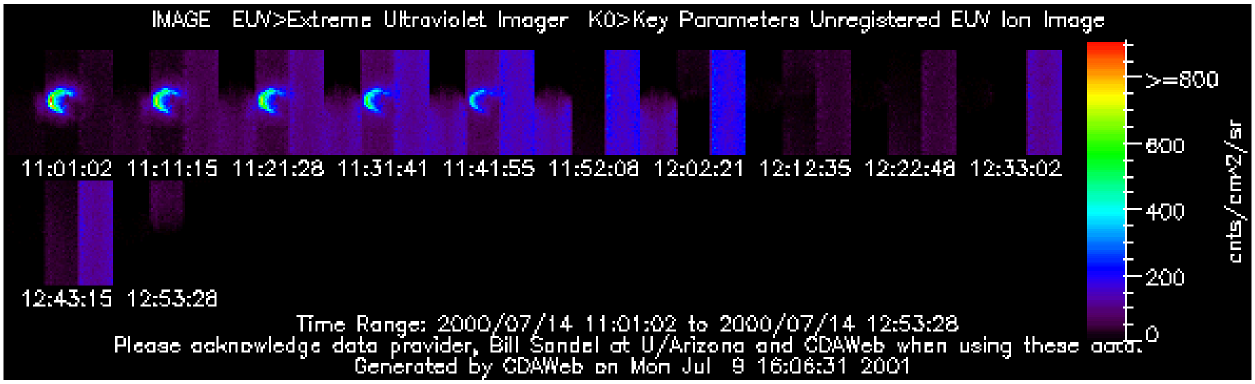
CDAWeb Data Selector screen, unselect all but **IM_K0_EUV: Ion Images, Key …**

Choose a **Start time** 2 hours before apogee and a **Stop time** that is 2 hours after apogee.

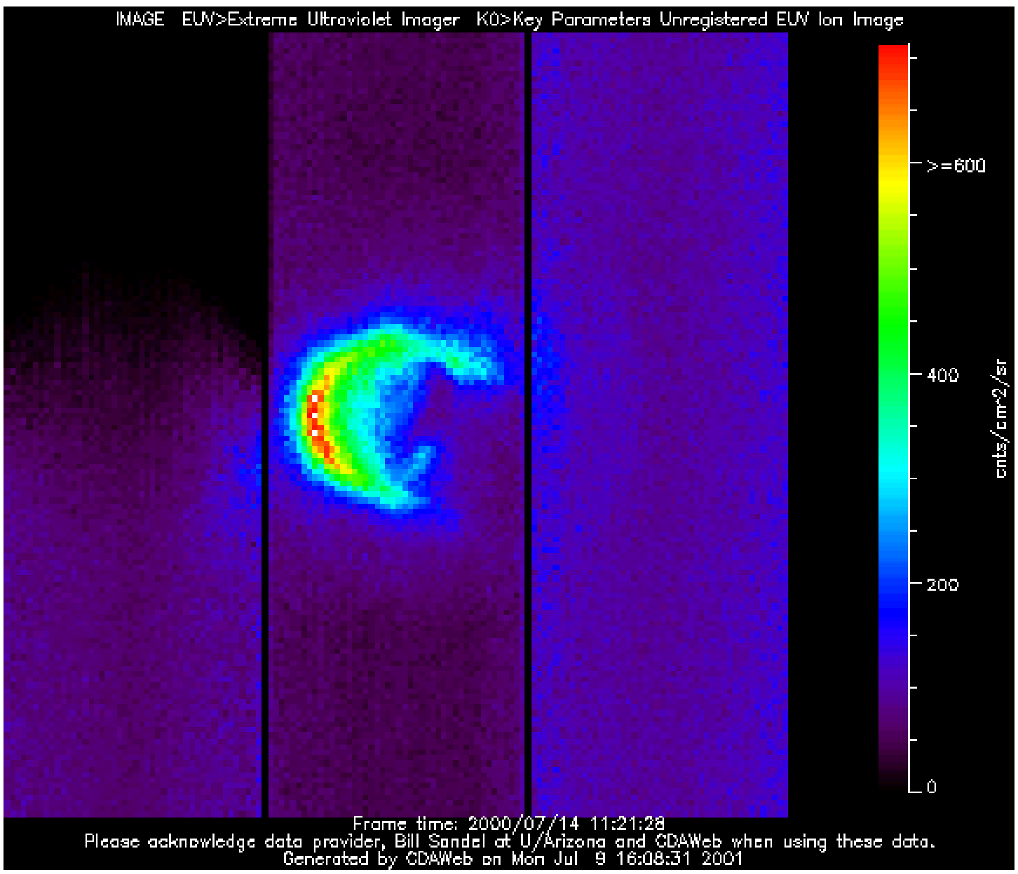
Under **Variable parameters**, select

`EUV ion (He+) images of earth and surrounding plasmasphere …`

The following is the data for 7/14 from 1100 UT to 1300 UT, before the CME.



Notice that there is very little data from this 2-hour interval. There are no images near the apogee time of 1200 UT, so one of the first 5 images can be chosen to represent this time. Let's look at the third image:



Apogee time:

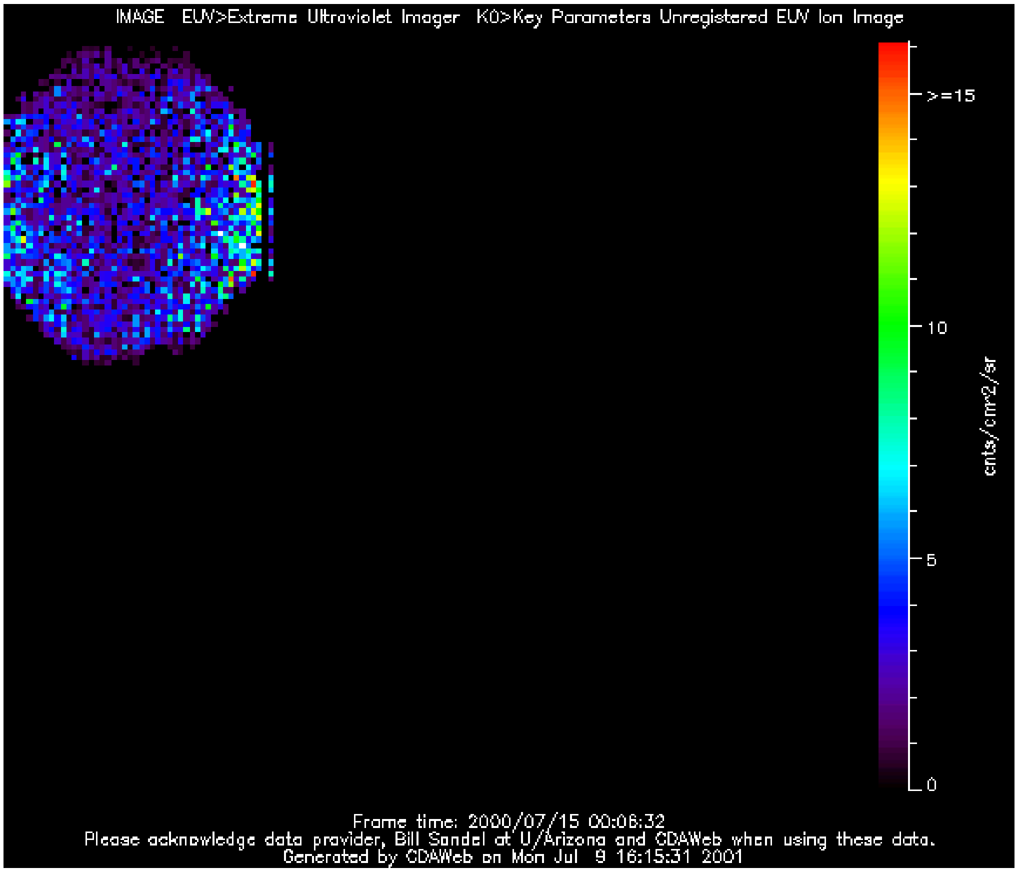
2000/07/14
1200 UT

Image time:

2000/07/14
11:21:28 UT

This is before the CME and will serve as as the "quiet" state reference.

Notice the pixel size is very small, so counting the pixels to obtain a total activity level is not feasible. The range on the scale goes from 0 to >500 counts per square centimeter per steradian (cnts/cm-2/sr). We can use this count scale and the general appearance of the image to give us some idea of the plasmasphere activity.



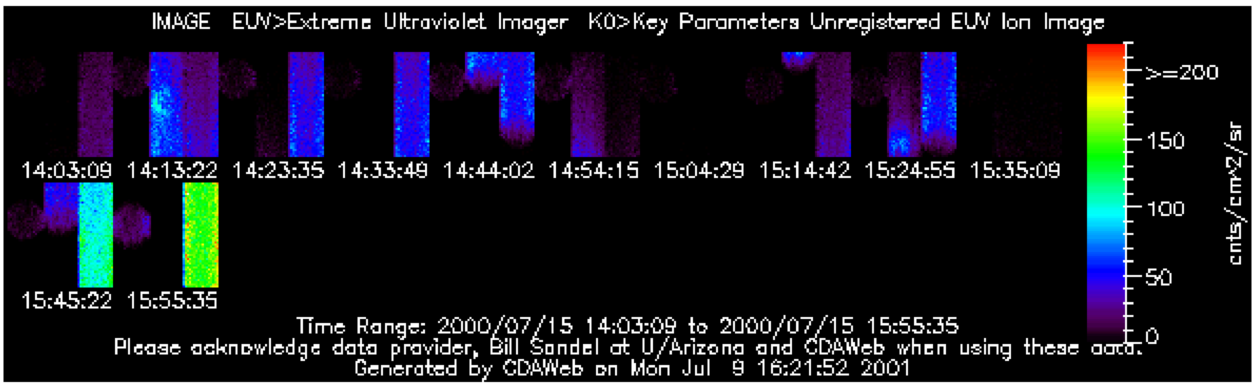
Apogee time:

2000/07/15
0100 UT

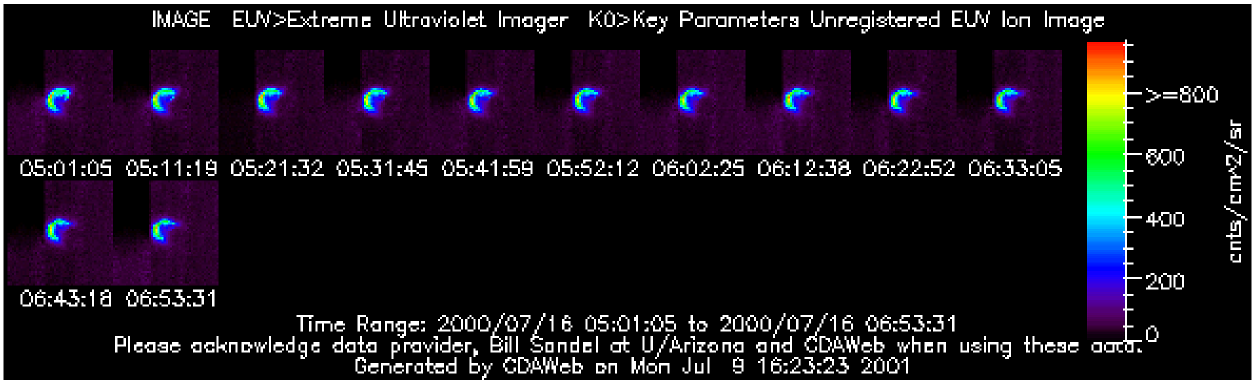
Image time:

2000/07/15
00:06:22 UT.

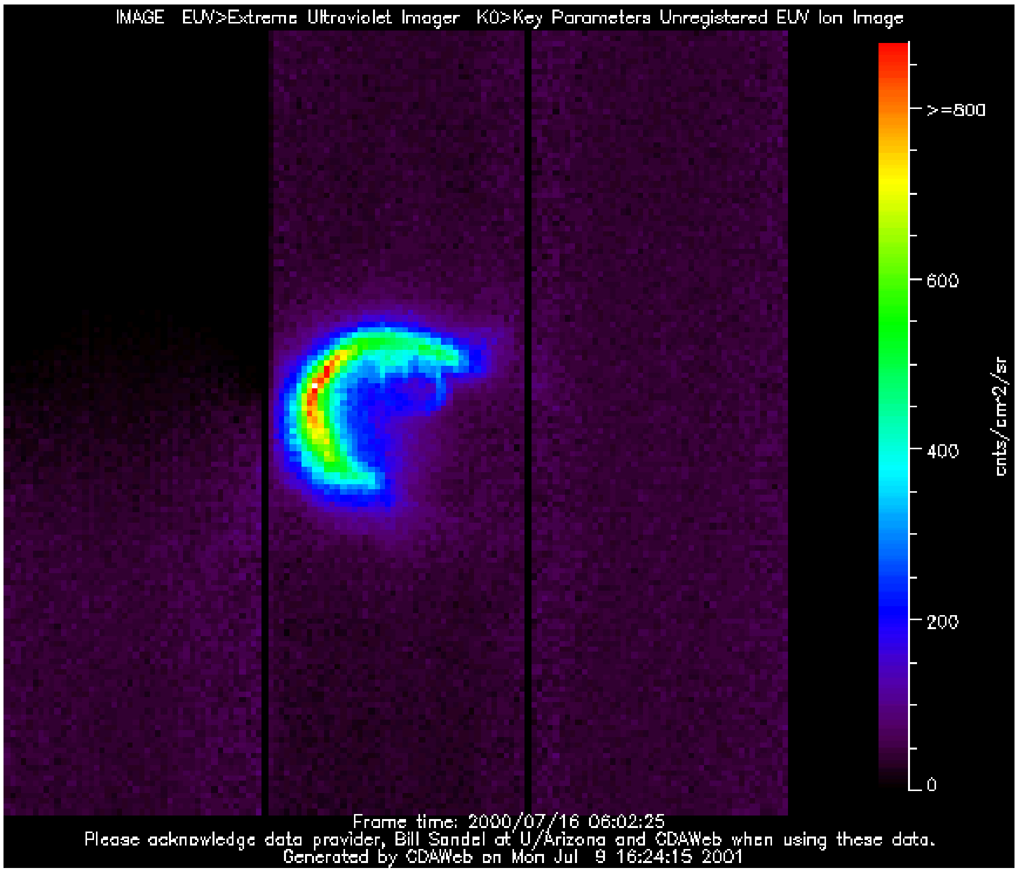
This is the only image in this 2-hour interval. It is not clear how to interpret this image.



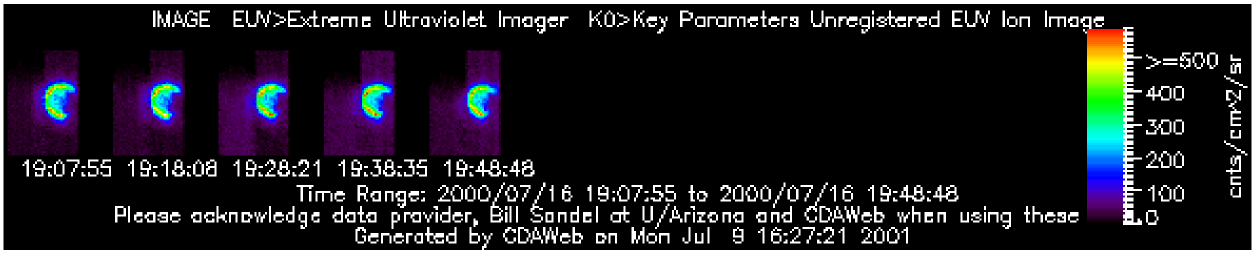
Apogee time: 2000/07/15 1500 UT. Again, the data is very incomplete and difficult to interpret.



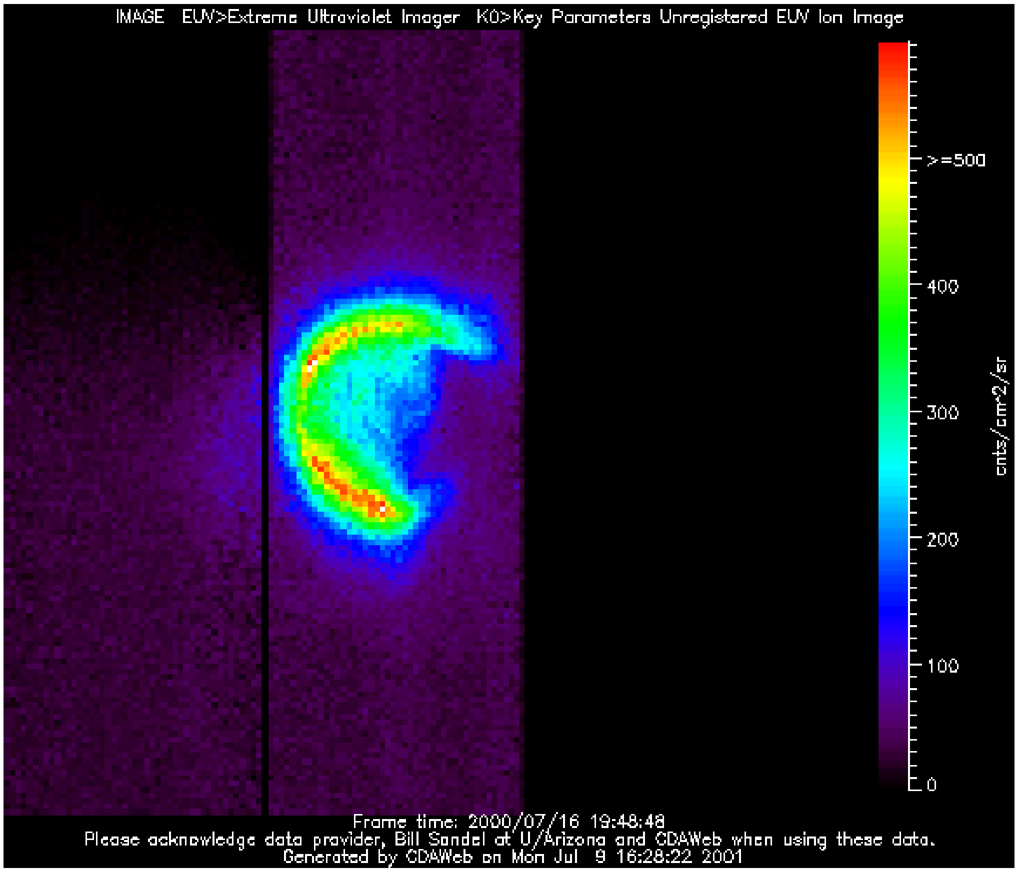
The image closest to apogee is at 06:02:25 UT:



The scale range is from 0 to >500, which is the same as on the first image from EUV. This image resembles the "quiet" image.



The last data image is closest to apogee time.



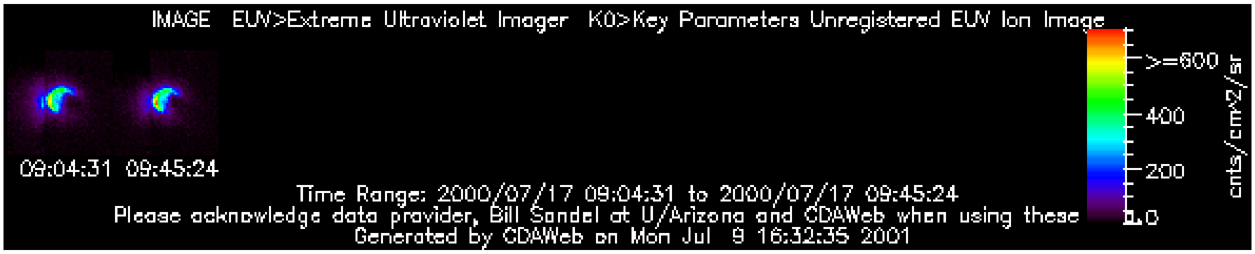
Apogee time:

2000/07/16
2000 UT

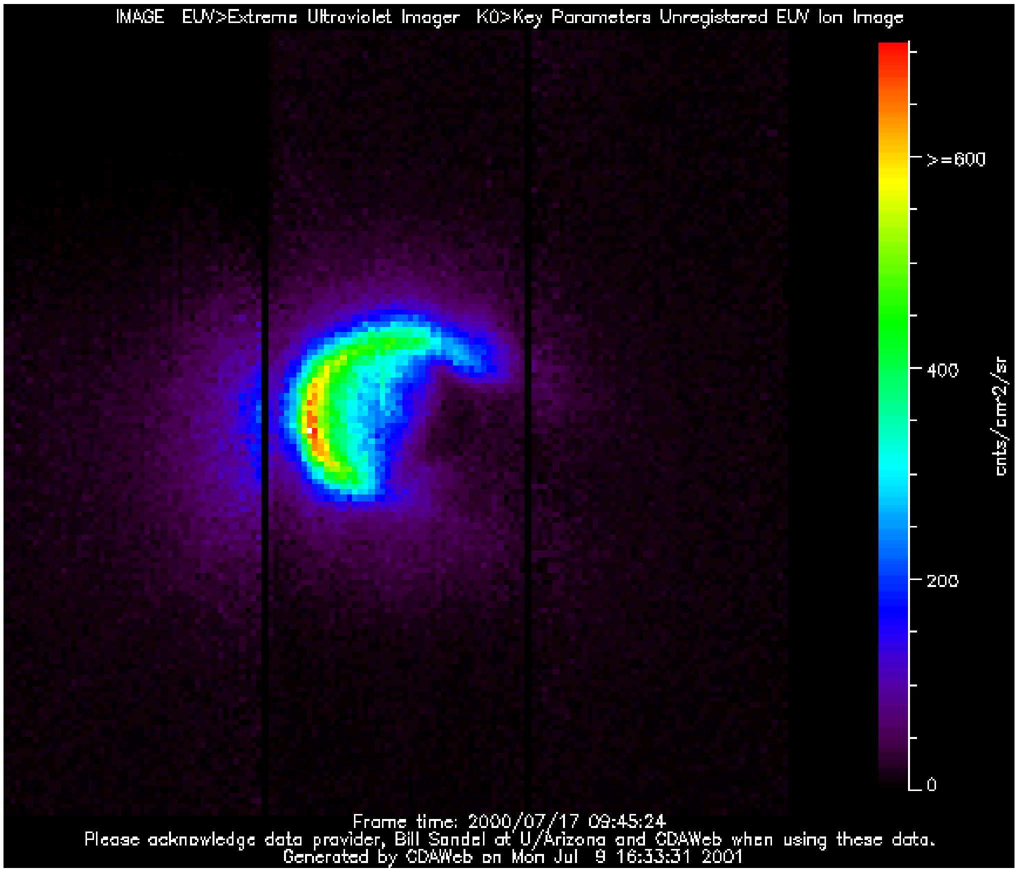
Image time:

2000/07/16
19:48:48 UT

The red region is in two parts and extends farther to the top and bottom of Earth.



At the next apogee, data is again incomplete.



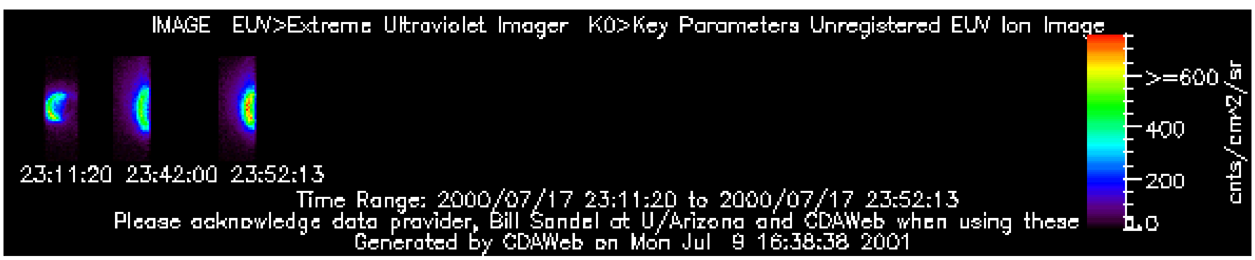
Apogee time;

2000/07/17
1000 UT

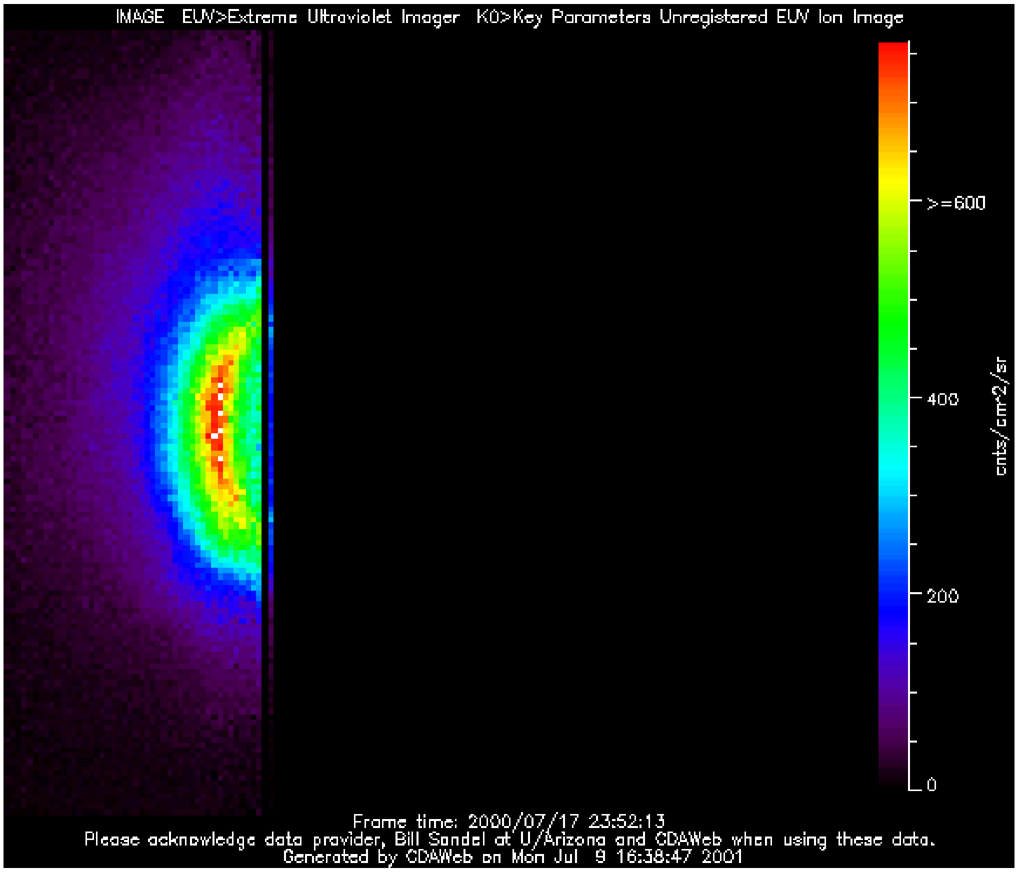
Image time:

2000/07/17
09:45:24 UT

Again, no apparent change in activity, but the data is incomplete.



The next apogee is at 2000/07/18 0000 UT. The closest image is the third one above.



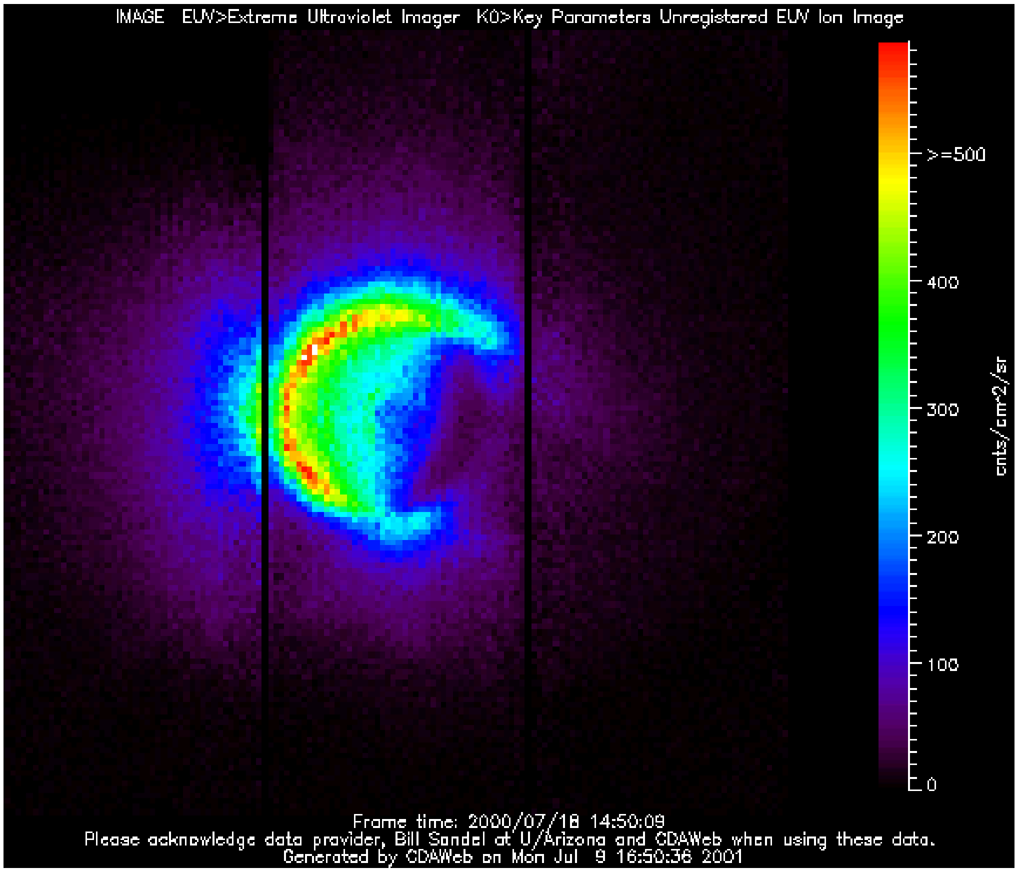
Apogee time:

2000/07/18
0000 UT

Image time:

2000/07/17
23:52:13

This image is incomplete.



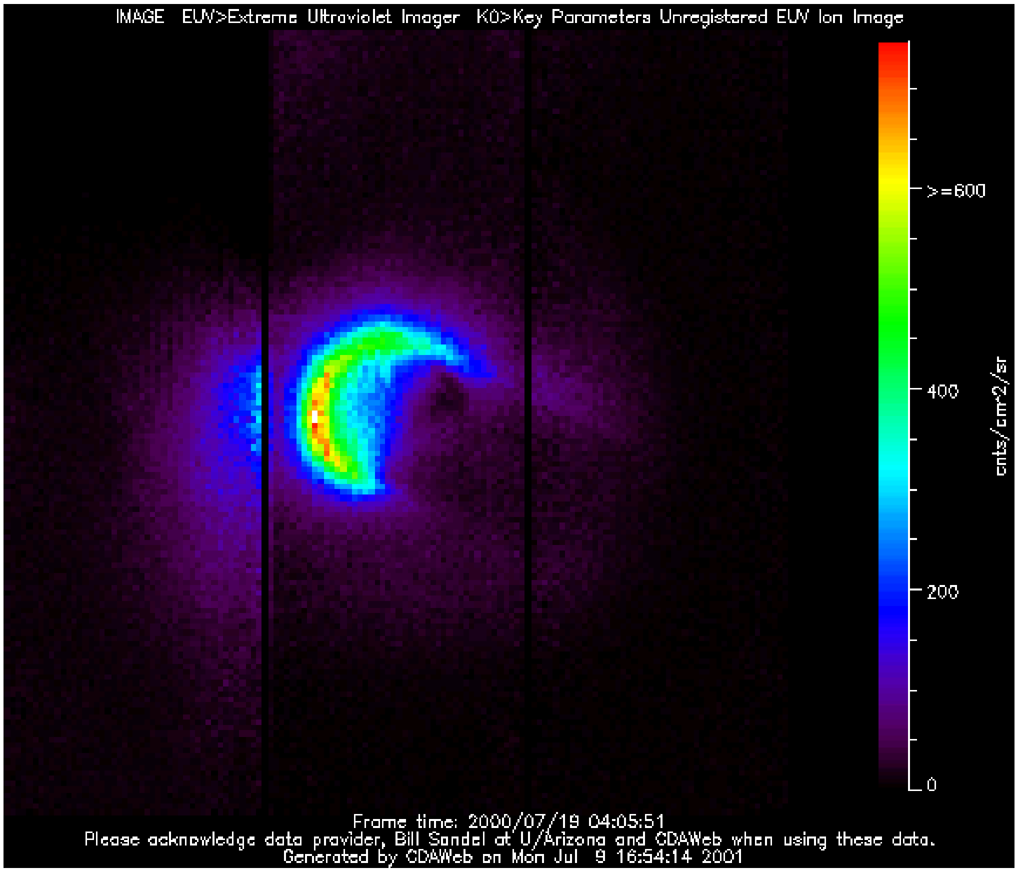
Apogee time:

2000/07/18
1400 UT

Image time:

2000/07/18
14:50:08 UT

There is an apparent increase in activity in this image.



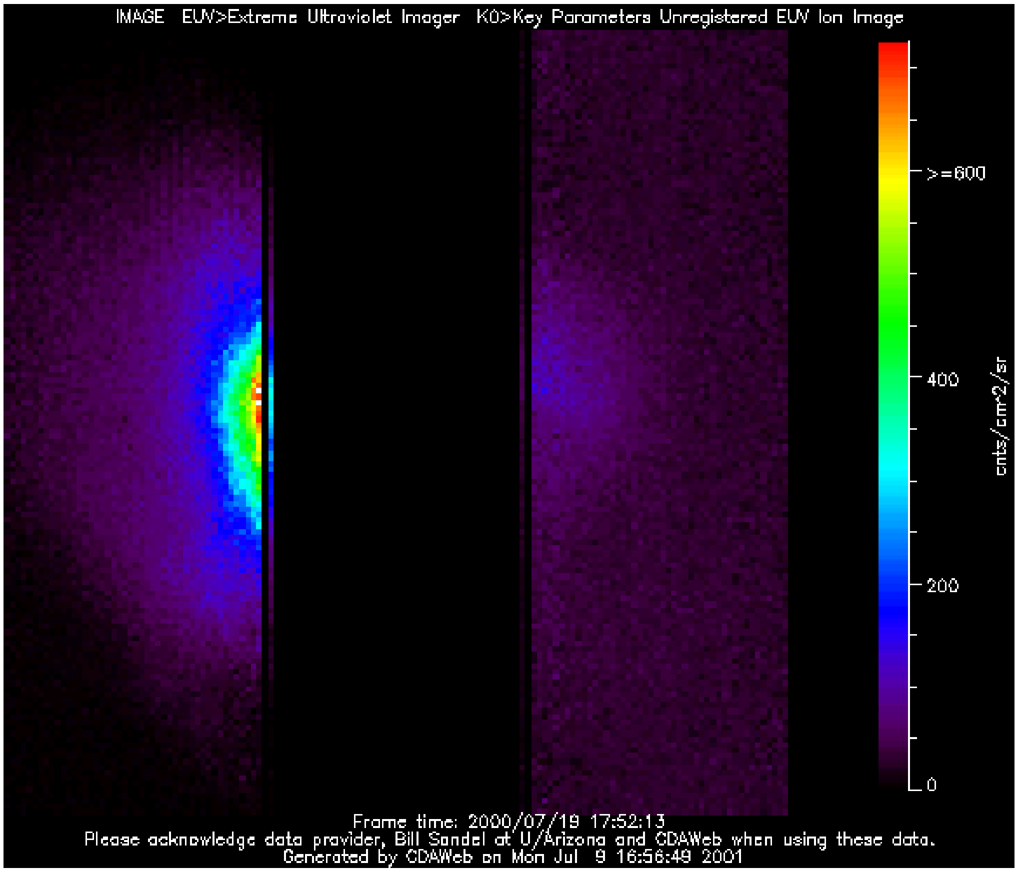
Apogee time:

2000/07/19
0400 UT

Image time:

2000/07/19
04:05:51 UT

Activity seems to be decreasing.



Apogee time:

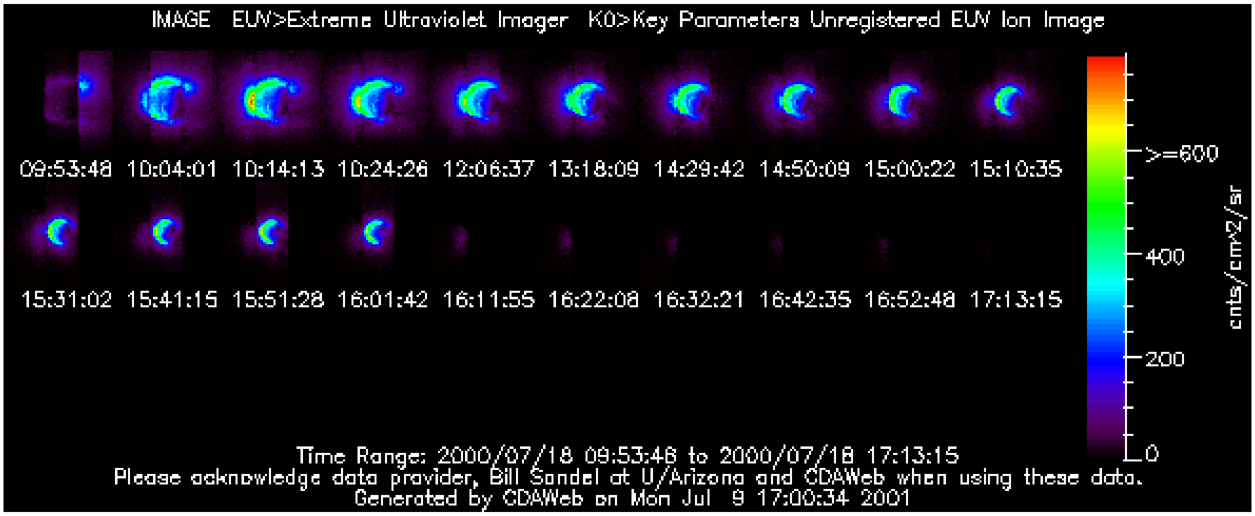
2000/07/19
1800 UT

Image time:

2000/07/19
17:52:13 UT

This is an incomplete data image.

Though the data is not very complete, it looks like an increase in activity in the plasmasphere may have occurred around 1400 UT on 07/18.



This the data on 07/18 from 0600 UT to 2200 UT. A closeup of the third image is below.

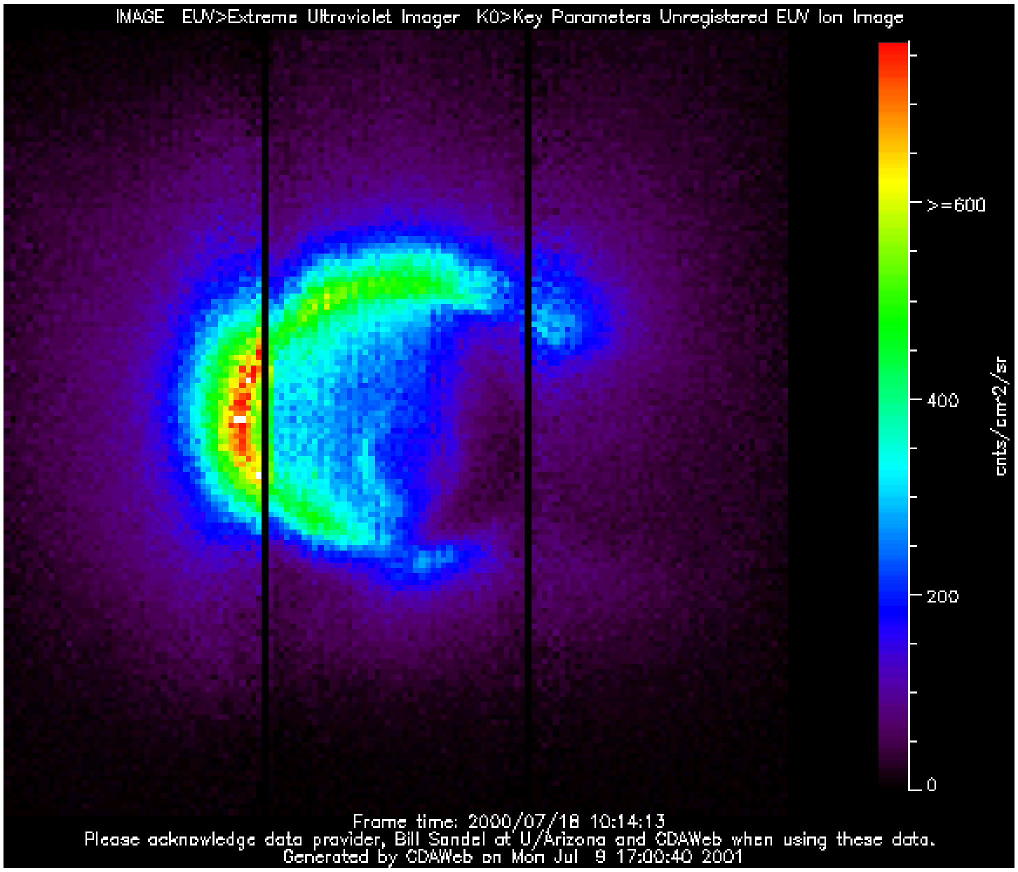


Image time:

2000/07/18
10:14:13 UT

This might represent the time of greatesrt activity in the plasmasphere.

Measurements From Earth's surface

The Kp index is a measure of the disturbance of the geomagnetic field measured at Earth's surface. The scale ranges from 0 to 9 with no units. A Kp of 3 or less is considered undisturbed, a Kp greater than 4 is considered storm conditions.

Go to: http://sec.noaa.gov/ftpmenu/index.html

SEC's Anonymous FTP Server

Select: Plots of Solar-Geophysical Data

SEC's Anonymous FTP Server
Plots of Solar-Geophysical Data

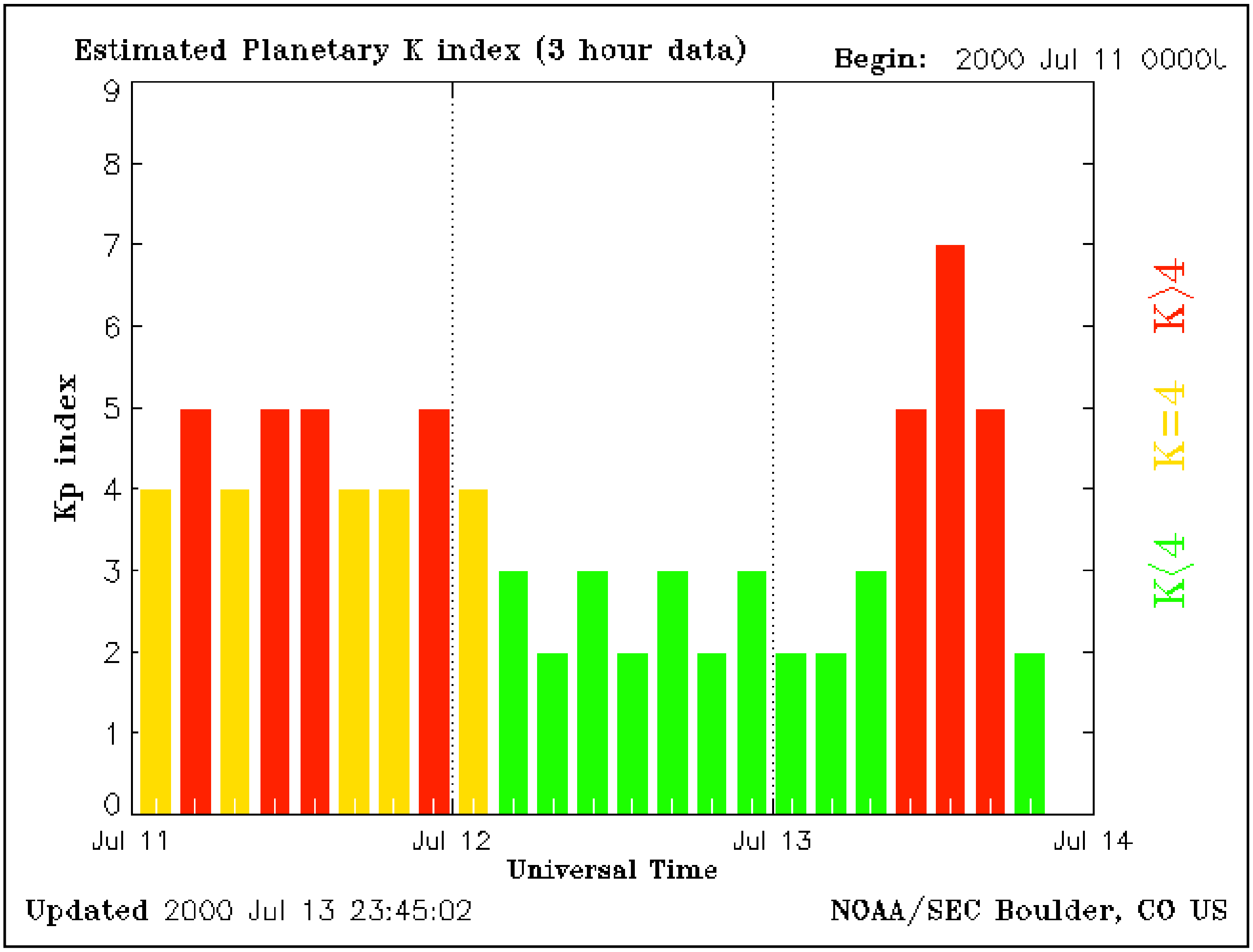
Select: 3-day Estimated Planetary K-indices Plots

(NOTE: Archives of plot files going back to June 1996 are found at the bottom of this page.)

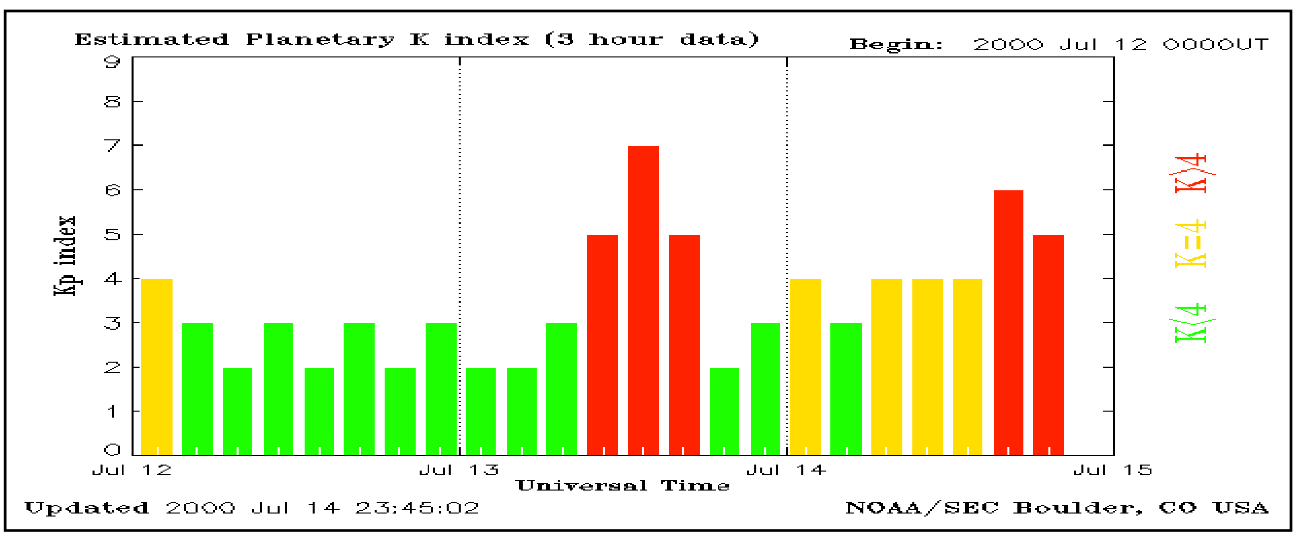
SEC's Anonymous FTP Server
Plots of Solar-Geophysical Data
3-day Estimated Planetary K-indices Plots

Select: (Choose the date you want to look at.)
(First entry is the current date.)

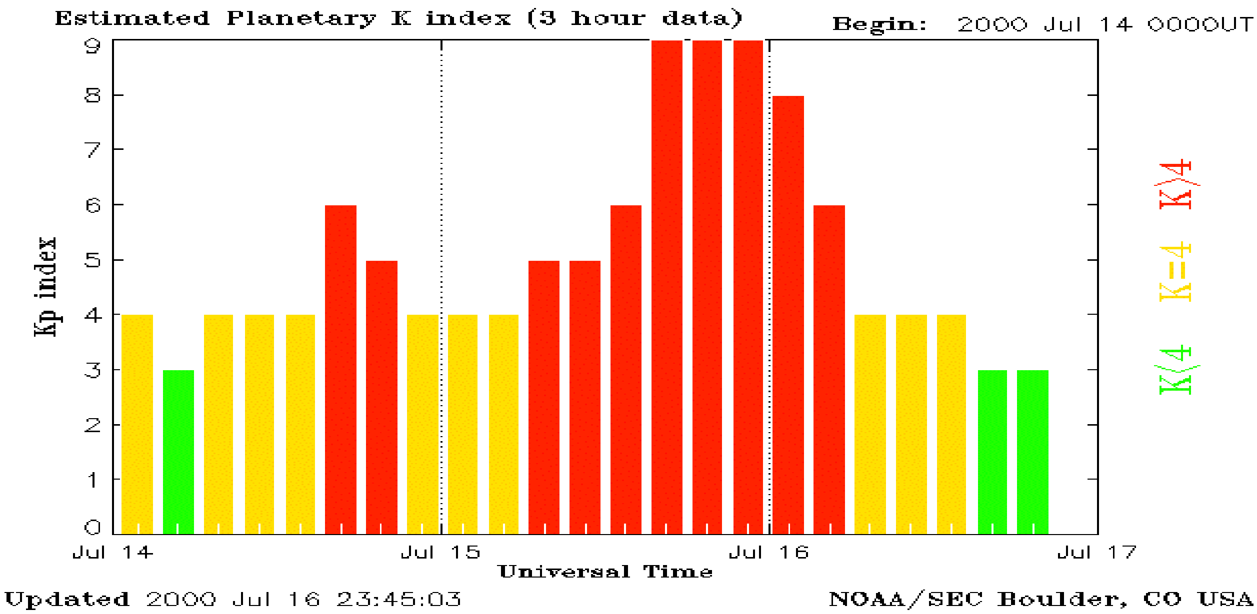
If you had been monitoring the Kp index on a daily basis, on July 13, 2000, you would have seen the following. As you can see, some disturbance in the Kp index had taken place on the 13th, but that was associated with the solar event of July 12th.



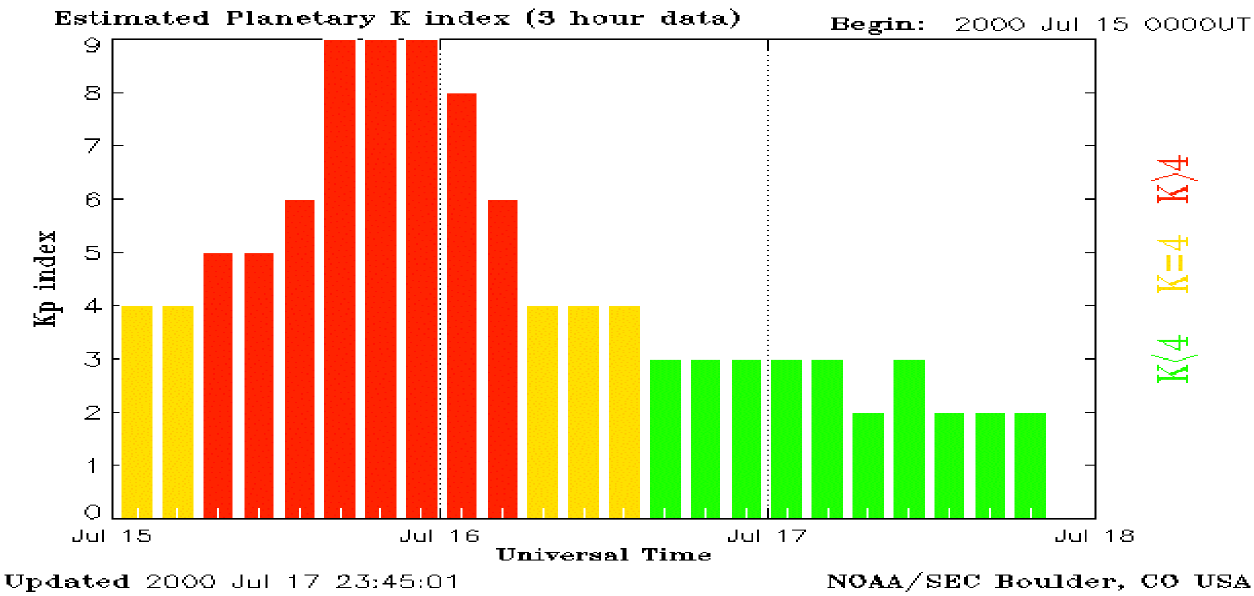
Each bar represents 3 hours of time. On July 14, the Kp index rose above 4 between 1500 UT and 1800 UT.



After subsiding slightly to 4 for a few hours, the Kp index rose to its maximum value of 9 at 1800 UT on July 15, indicating a very strong solar storm.

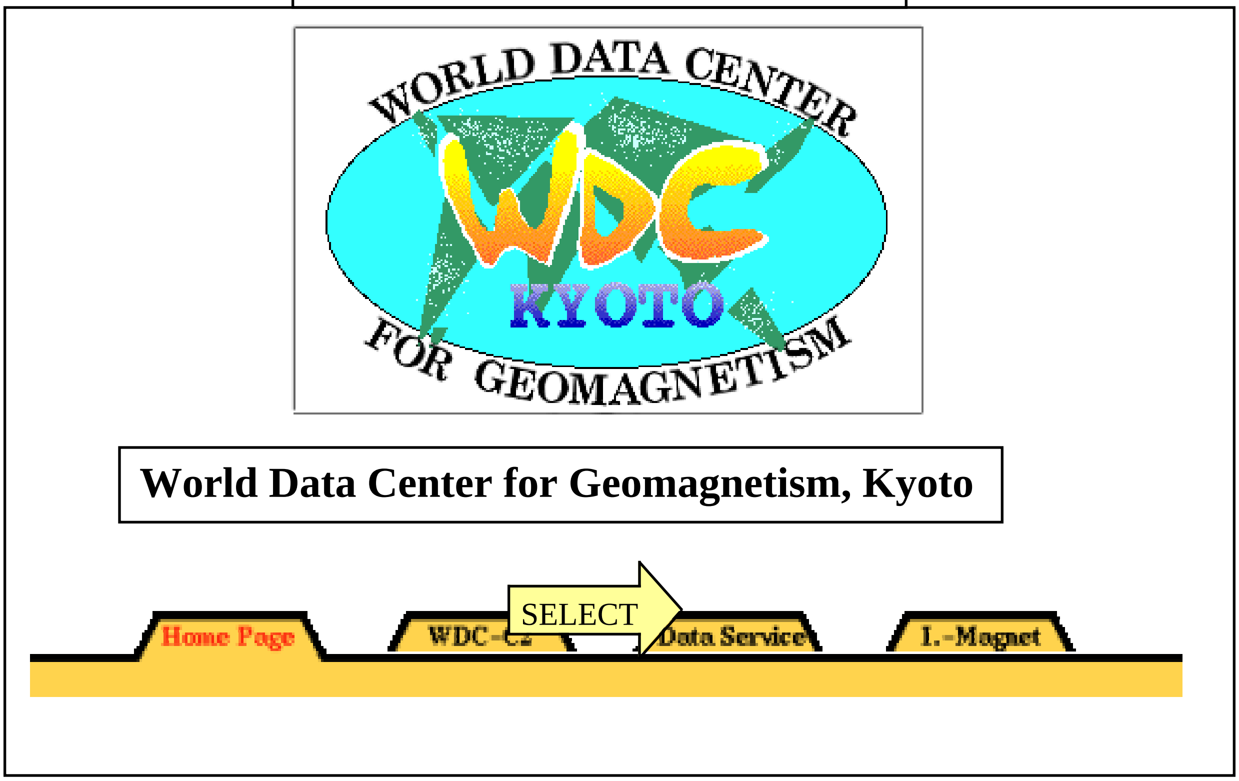


By the end of the day on July 17, things were once again quiet.



To check the Dst Index, go to the **World Data Center for Geomagnetism, Kyoto**:

http://swdcdb.kugi.kyoto-u.ac.jp/index.html



Geomagnetic Data Service

- Indices [AE, Dst, ASY/SYM, Kp, Q- and D-days and others]
- Geomagnetic Field Data [Real Time, Archive]
- Field Models [IGRF/DGRF, and others]
- Miscellaneous [Data Catalogue, Publications and others]

Indices

1. AE index [Since 1957]

SELECT → 2. **Dst index [Since 1957]**

3. ASY/SYM indices [Since 1984] (with AE and Kp)

Welcome to WDC-C2 KYOTO Dst index service

Contents of this Page:

SELECT

1. Near realtime Dst monitor
2. Provisional Dst index service
3. Final Dst index service

Dst index Quicklook Test Page

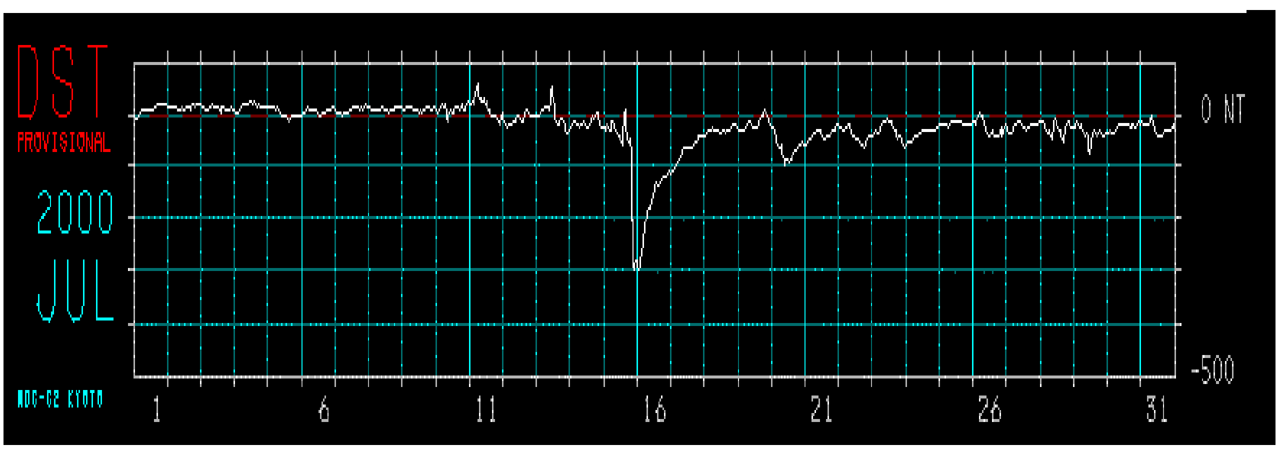
Contents of services :
(note: these figures are only for non-commercial monitoring purpose)

The quicklook Equatorial Dst index is prepared by T. Kamei and M. Sugiura for IAGA Division V:Observatories, Instruments, Indices and Data.

SELECT

- plot of this month (one month)
- plot of the last month (one month)

This will result in a display of Dst data from the first of the current month to the present. The data is shown both as a plot at the top (shown below for July 2000) and in tabular form.



The result of the July 14 CME is apparent on Earth's surface by the large and negative swing in the Dst value late on July 15.. Examination of the table shows that this time represents the onset of the magnetic storm on the surface of Earth.