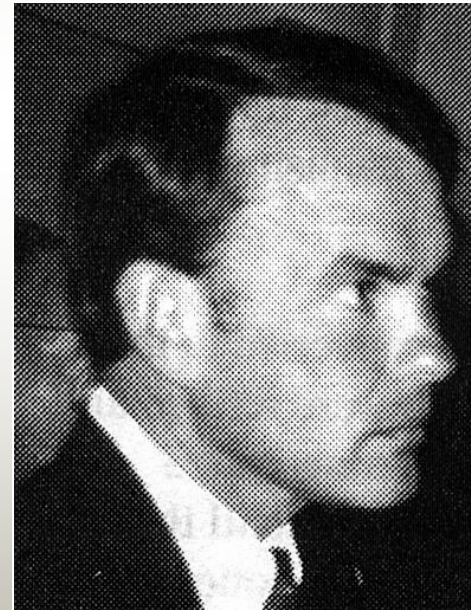


**Prologue:** By 1998, concern was clearly building  
over the upcoming Cycle 23 Solar Max...



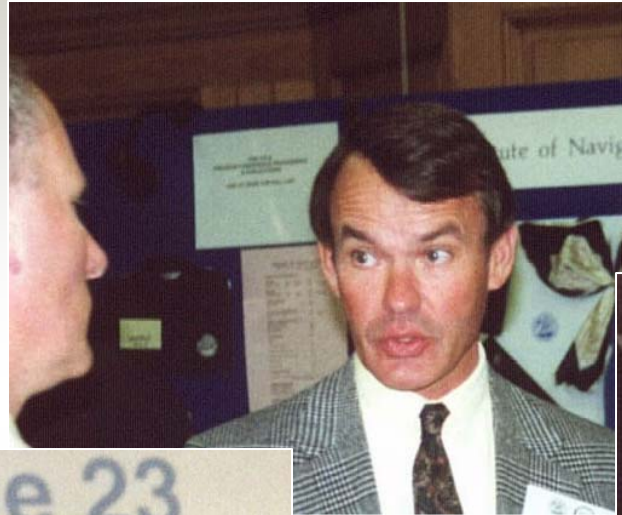
1996...



1998...

More recently, (2001) Cycle 23 must be meeting expectations;

The mood looks much more relaxed!





# Significant Space Weather in 2005

Bill Murtagh and Joe Kunches  
NOAA Space Environment Center  
Boulder, Colorado

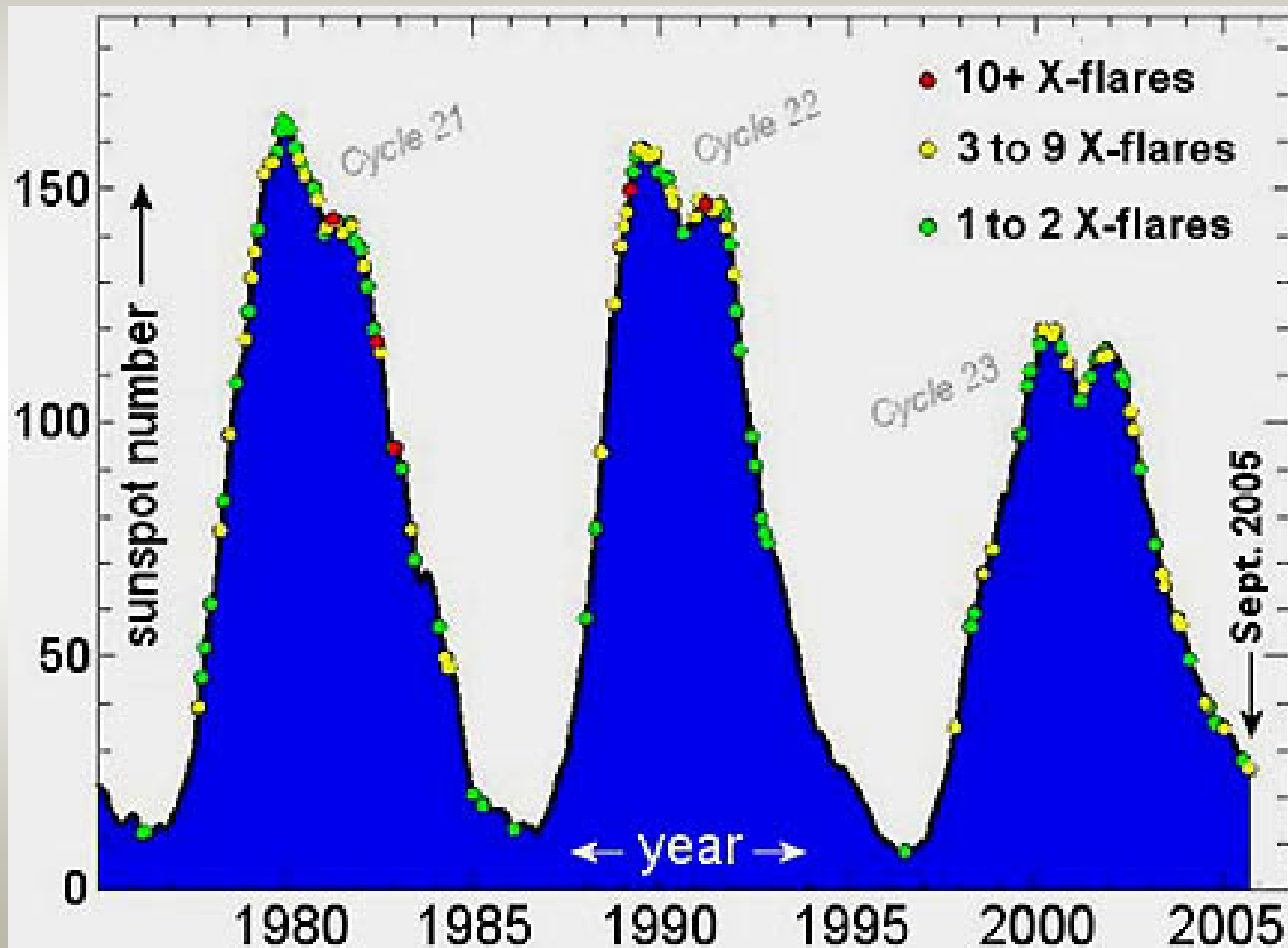
ILA 34<sup>th</sup> Annual Convention  
Santa Barbara, CA  
October 19, 2005

# Overview

- Now in the declining phase of Cycle 23
- Two periods of unusually strong space weather occurred
  - January 2005
  - September 2005
- Many affected systems; i.e., navigation, satellites, communications, manned space flight
- Commercial airlines now flying polar routes were particularly impacted



Solar Cycle 23 continues its very active declining phase, producing many more major flares than the waning years of the previous, and much larger, solar cycle (22).



Graphic courtesy David Hathaway, NASA

# *The January 2005 Activity*

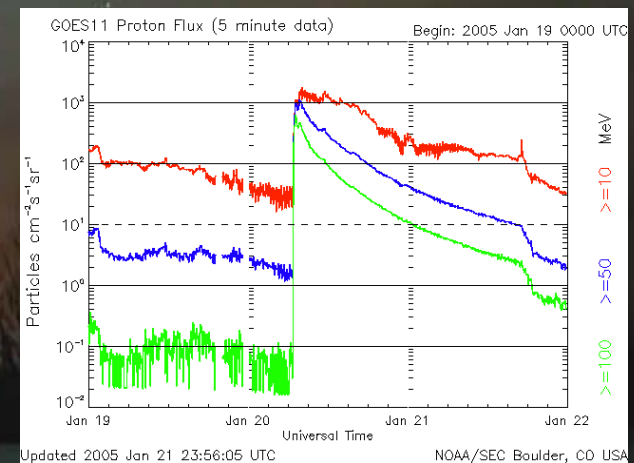
- Five X-class and 19 M-class flares
- Strongest high energy radiation storm since 1989
- Three days of minor to severe geomagnetic storming

Flights rerouted, polar routes abandoned altogether

ISS astronauts took precautionary shelter

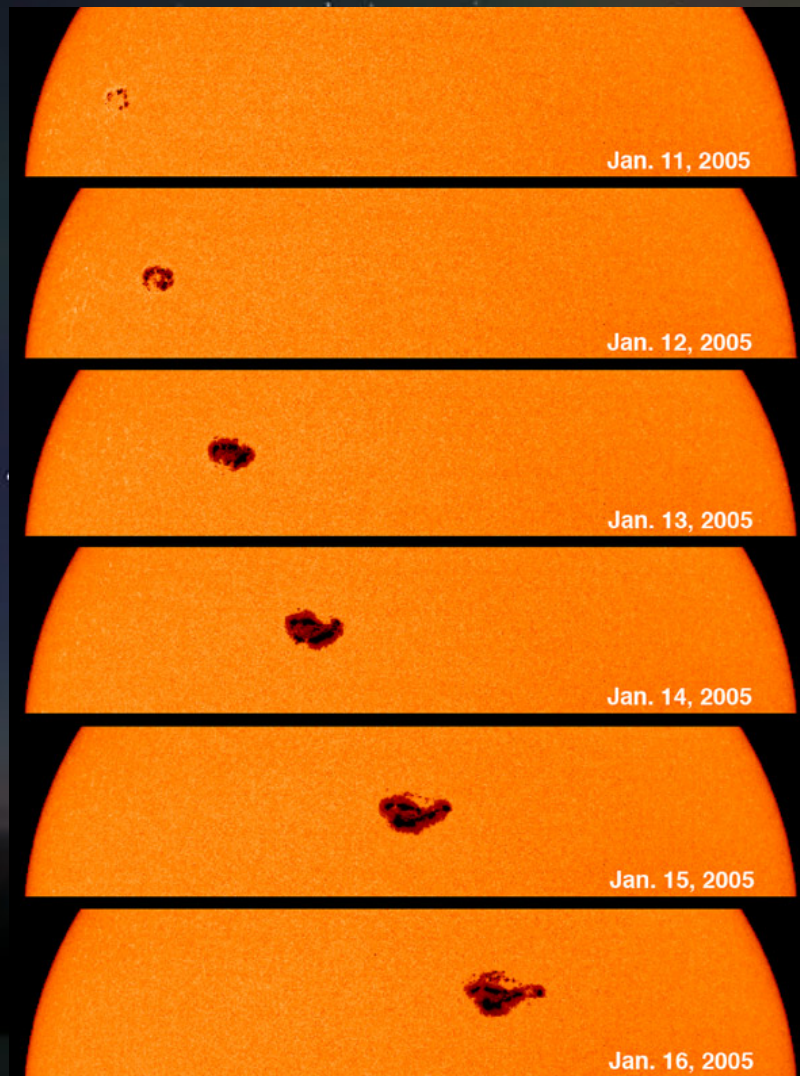
Several satellite anomalies

Extended HF comm problems

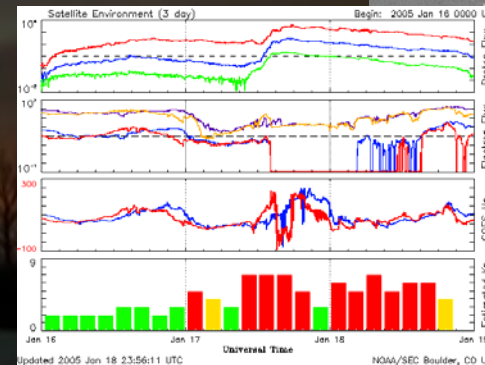
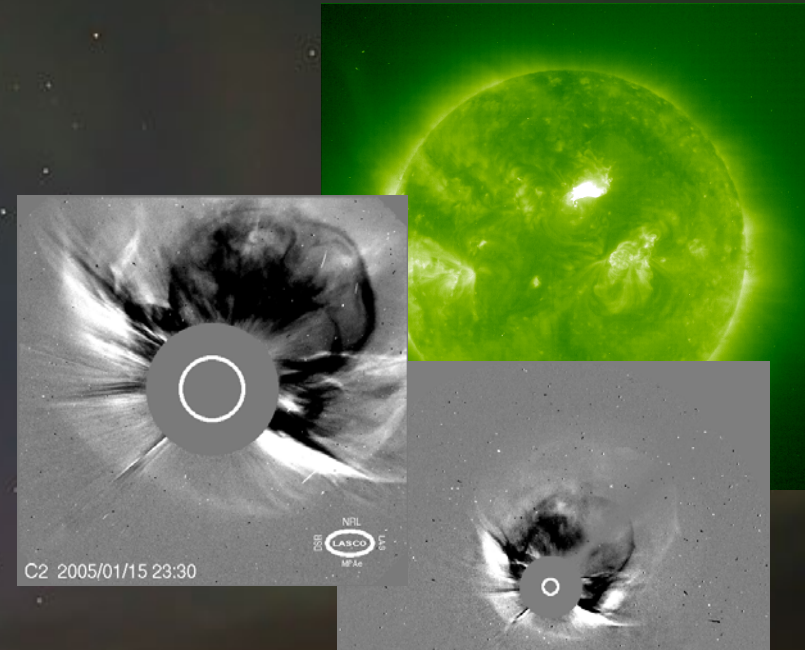


## Region 720

Developed rapidly into a naked eye sunspot group exceeding 1500 millionths in area.



The fastest LASCO CME on record occurred on 15 January 2005. The LASCO team measured the rate of expansion at 2890 kilometers per second in the plane of the sky.

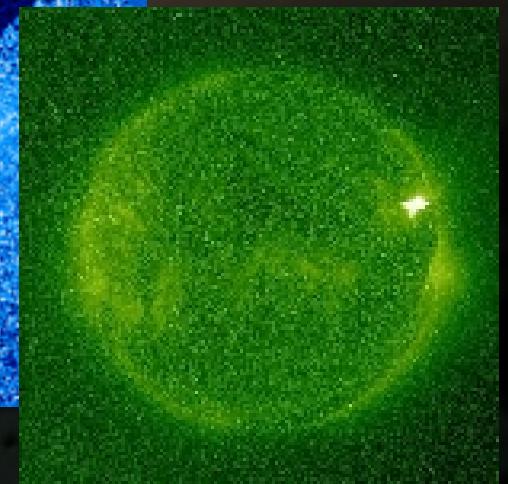
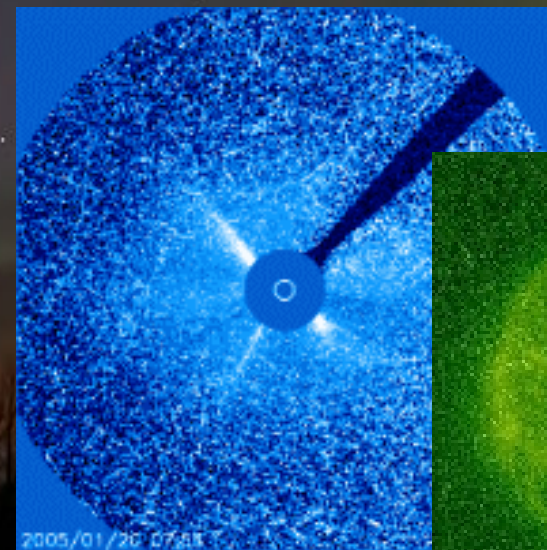
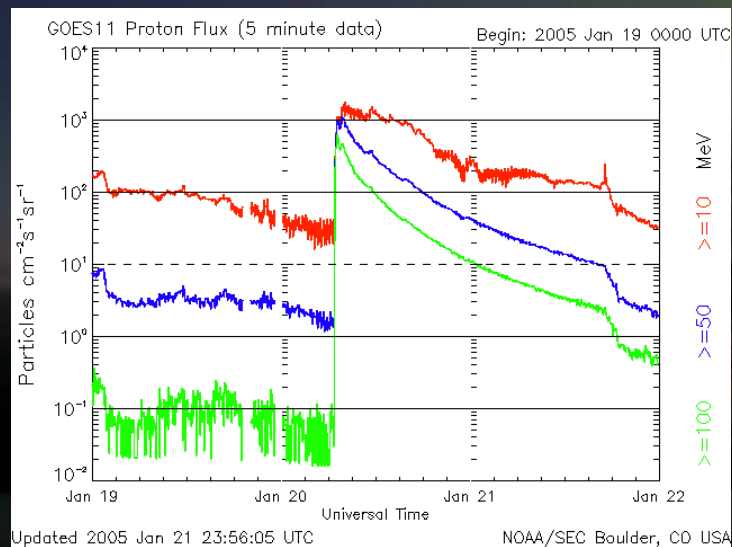
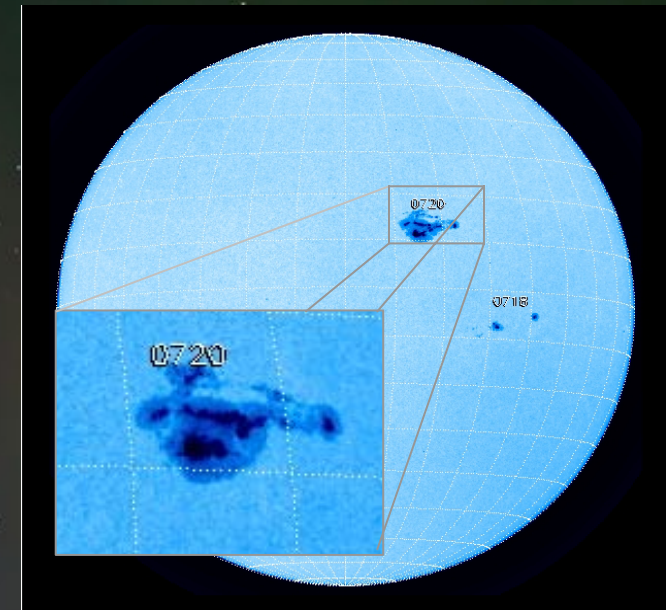


18 LDE with intense 160,000 sfu burst on 410 MHz



# January 20, 2005 – Region 720 Produces Powerful Radiation Storm

The X7 flare on 20 January 2005 was associated with the most highly energetic radiation storm of Solar Cycle 23. The  $\geq 100$  MeV protons reached 652 pfu, the strongest  $\geq 100$  MeV event of this cycle and the strongest since Oct 1989 (680 pfu).



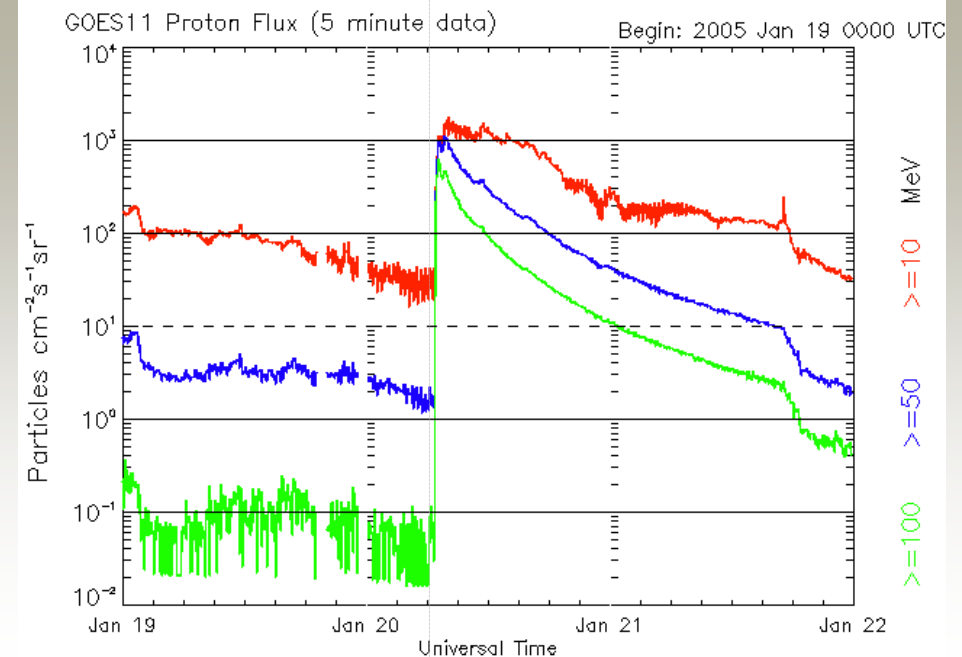


# ***GOES Proton Flux January 20, 2005***

The X7 flare began at 20/0636 UT and peaked at 20/0701 UT. The intense  $>100$  MeV radiation storm peaked at 20/0710 UT.

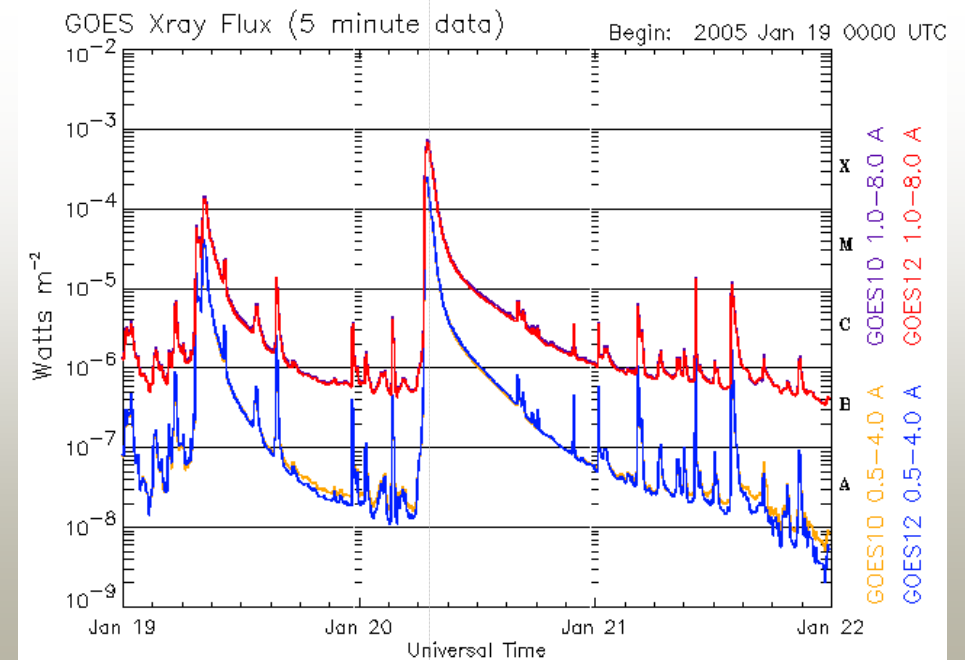
The CME is first seen in LASCO C2 at 20/0654 UT.

This event highlights perhaps the biggest challenge facing space weather forecasters as NASA embarks on the Space Exploration Initiative.



Updated 2005 Jan 21 23:56:05 UTC

NOAA/SEC Boulder, CO USA



Updated 2005 Jan 21 23:56:03 UTC

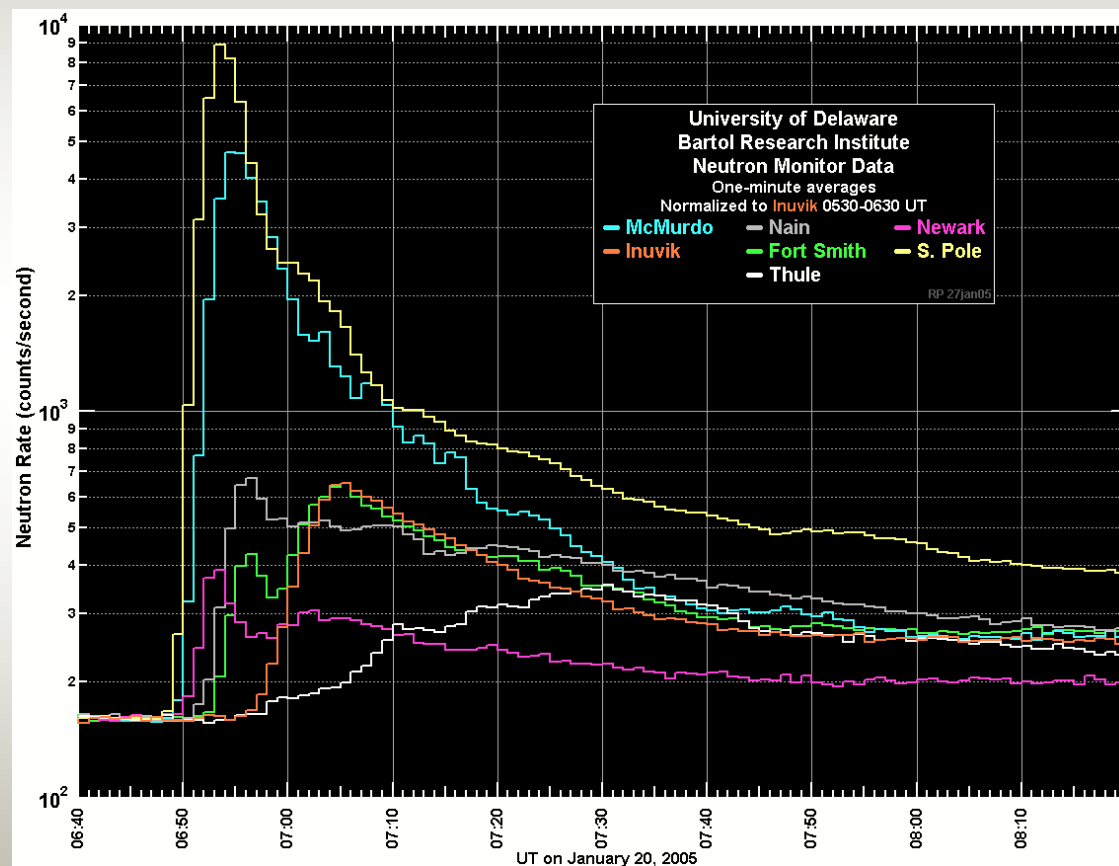
NOAA/SEC Boulder, CO USA

# Intense Ground Level Event (GLE)

This GLE had a higher peak than the September and October 1989 GLEs, but was shorter in duration.

## GLEs

Inuvik Canada	~125 %
Newark, Delaware	~60 %
Oulu, Finland,	~225 %
Apatity, Russia	~170 %
Mawson, Antarctica	~200 %
Tixie Bay, Russia	~300 %
Moscow, Russia	~105 %



The McMurdo increase was the largest observed at sea level since the famous 1956 GLE, which was the largest ever recorded.

# The "Benign" Sun on Sept. 07, 2005

N  
E W  
S



From the 07 Sep SEC Forecast...

*III. Event Probabilities 08 Sep-10 Sep*

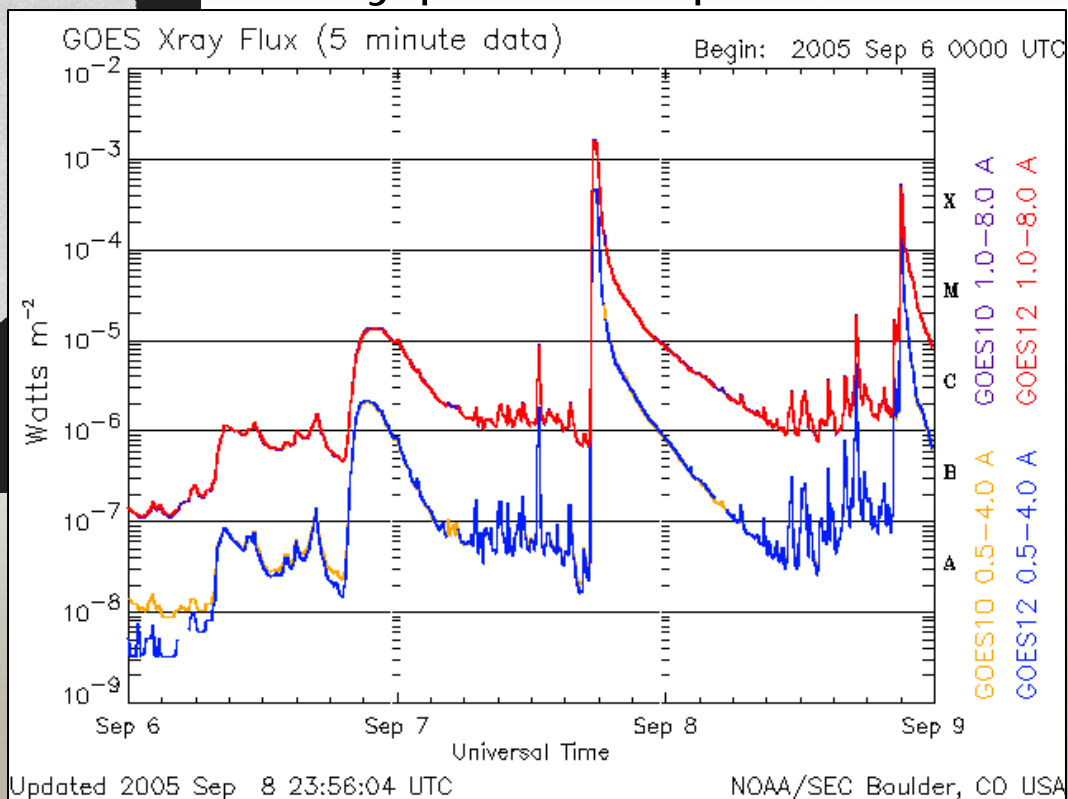
*Class M 70/75/75*

*Class X 30/30/30*

*Proton 60/50/40*

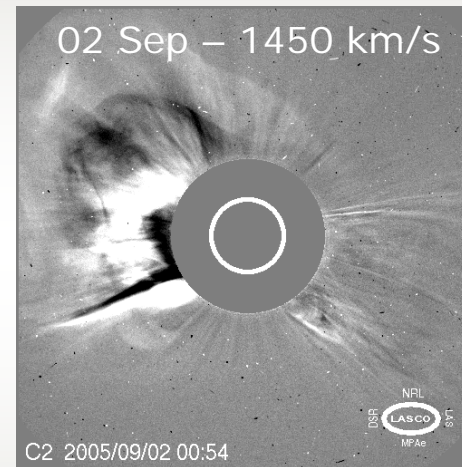
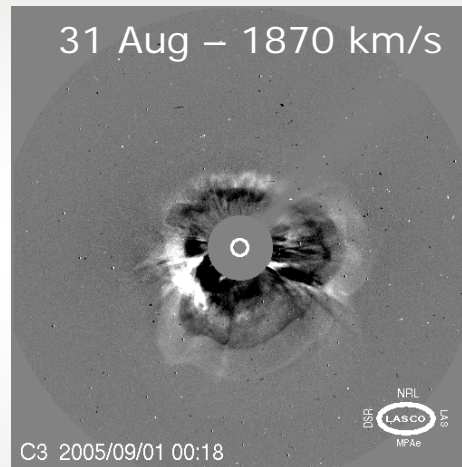
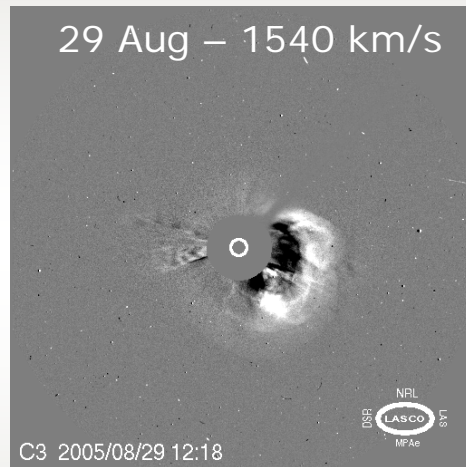
The x-ray plot on Sep 07, 2005!

Big Bear Solar Observatory  
2005-09-07 23:34:16 UT

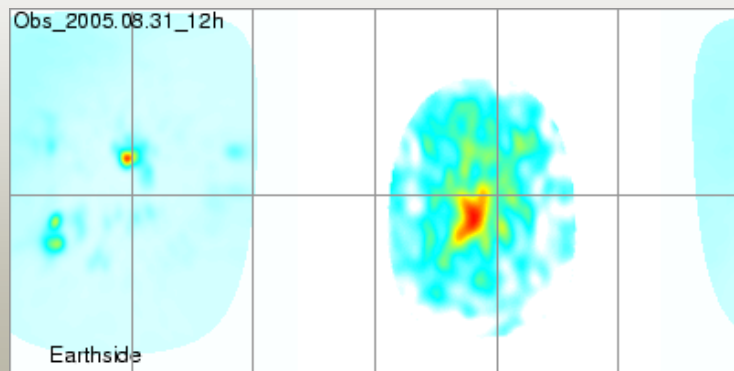




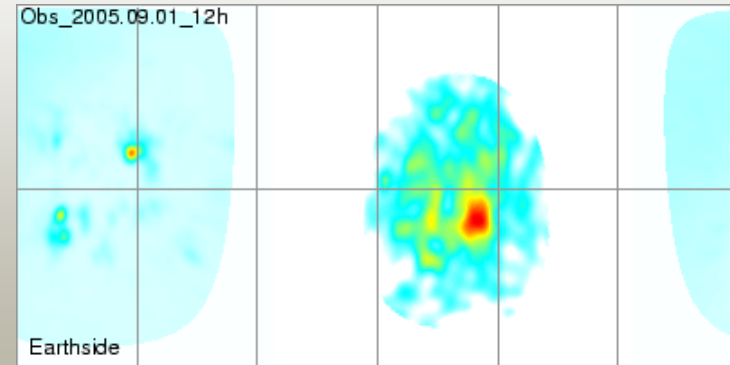
***SEC forecasters were not blindsided thanks to SOHO data! A series of fast ( $>1500$  km/s) backsided CMEs on LASCO suggested that these were likely proton flares.***



A total of 7 fast, full or partial halo CMEs were observed between 23 Aug – 5 Sep



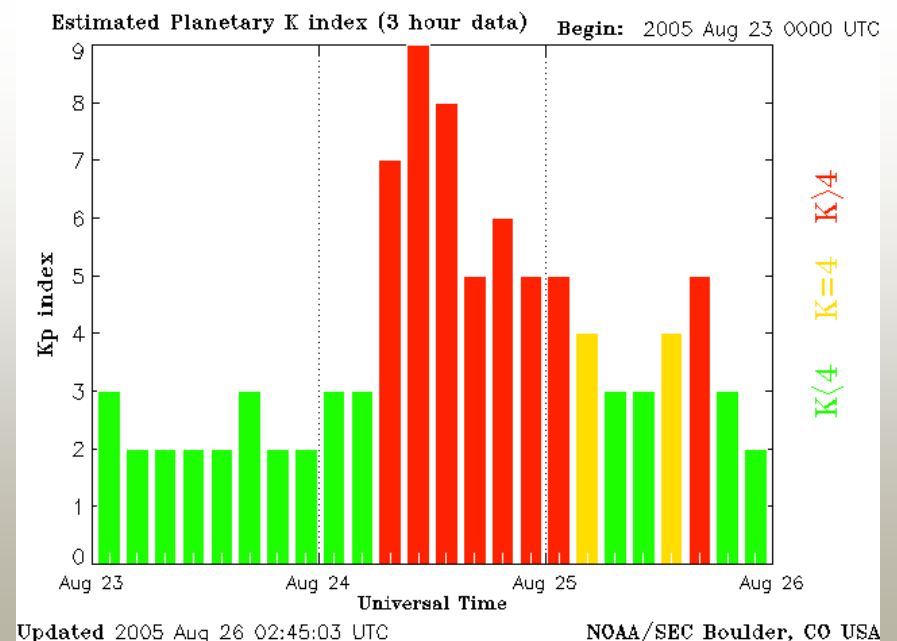
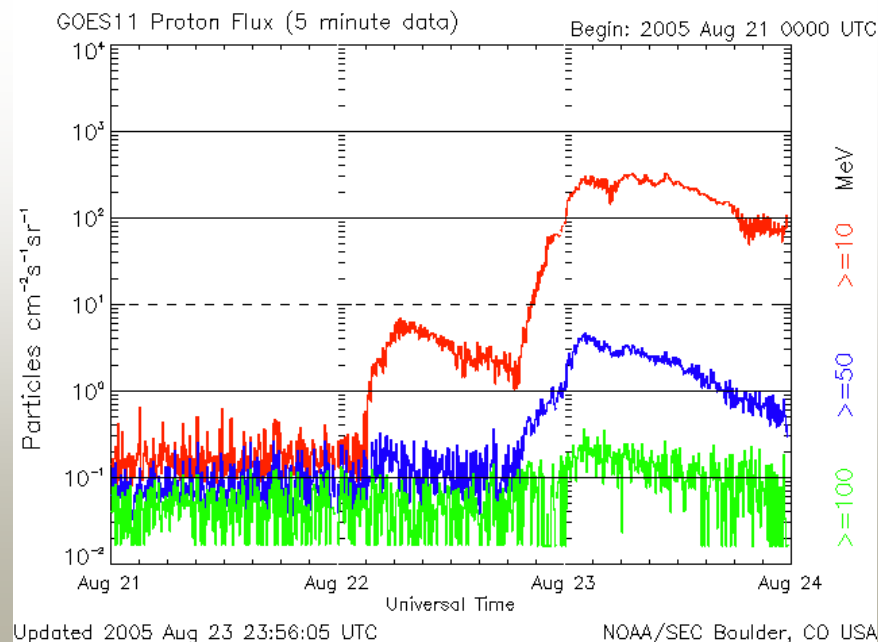
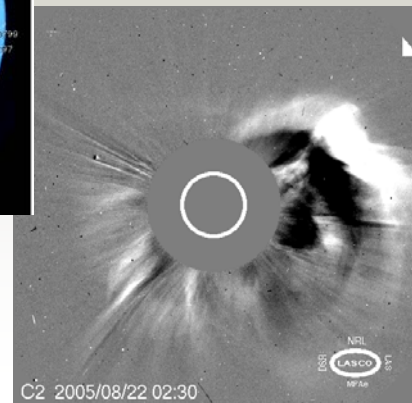
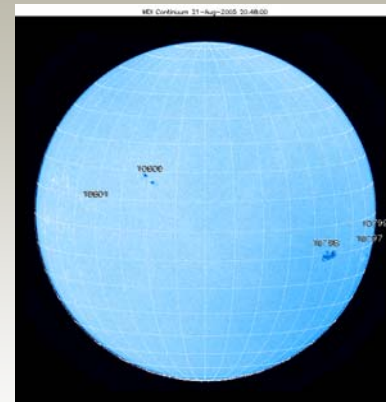
31 Aug 2005



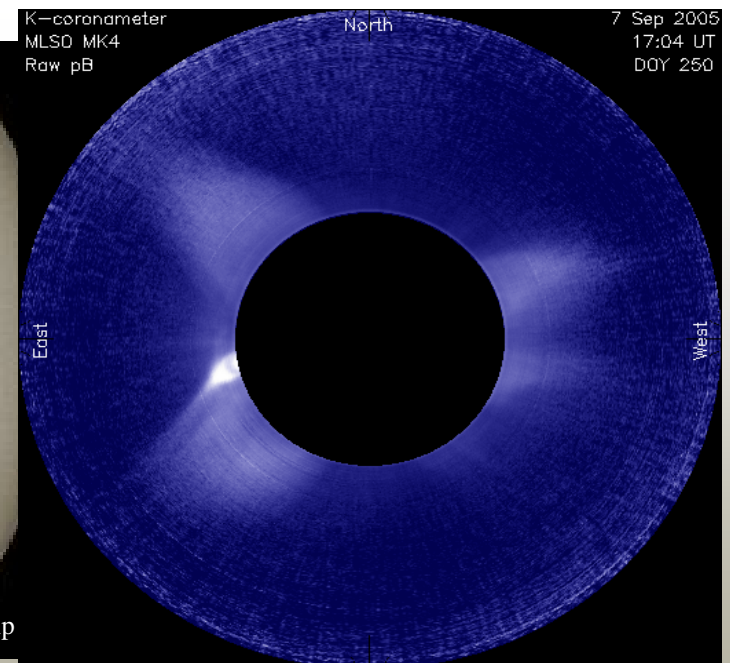
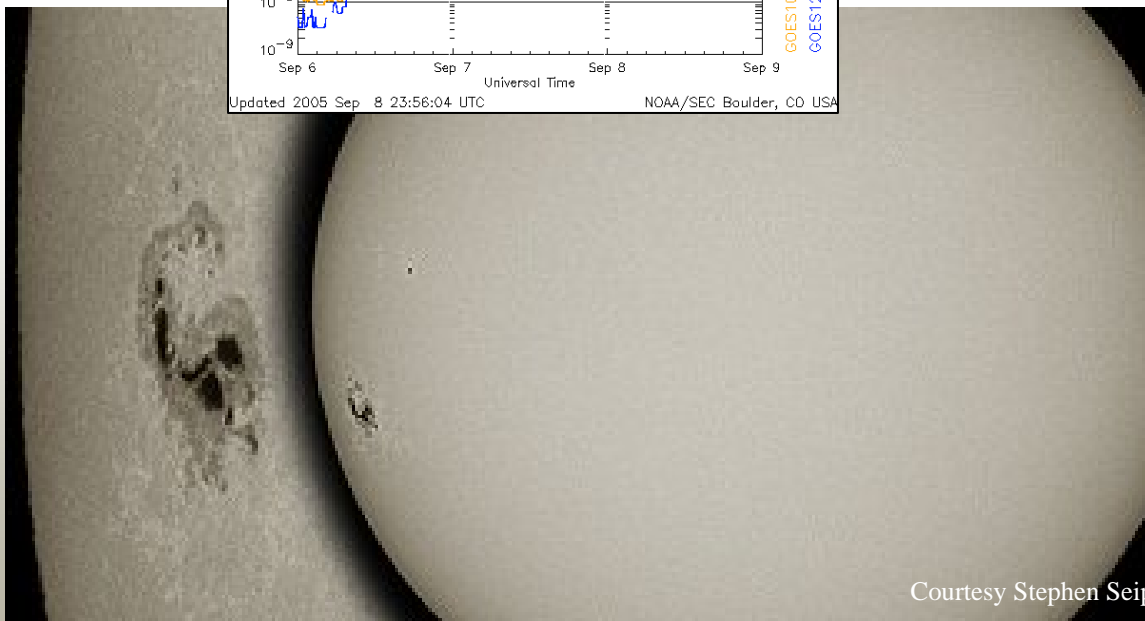
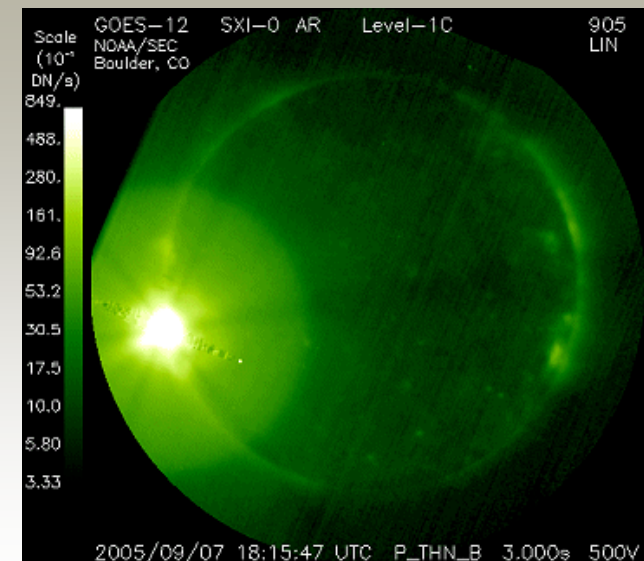
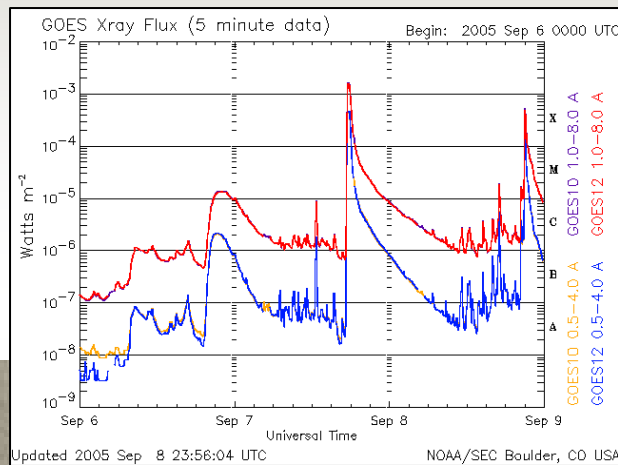
01 Sep 2005

**Region 808 actually emerged on the disk on 14 Aug as Region 798.**

**The first significant events occurred on 22-23 Aug when the region was approaching the west limb. Three M class flares occurred, all with powerful CMEs. The geophysical response included a proton storm and a K9 geomagnetic storm.**



Region 808 rotated into view on 07 Sep and promptly produced one of the largest flares on record – an X17/3b flare and powerful CME.

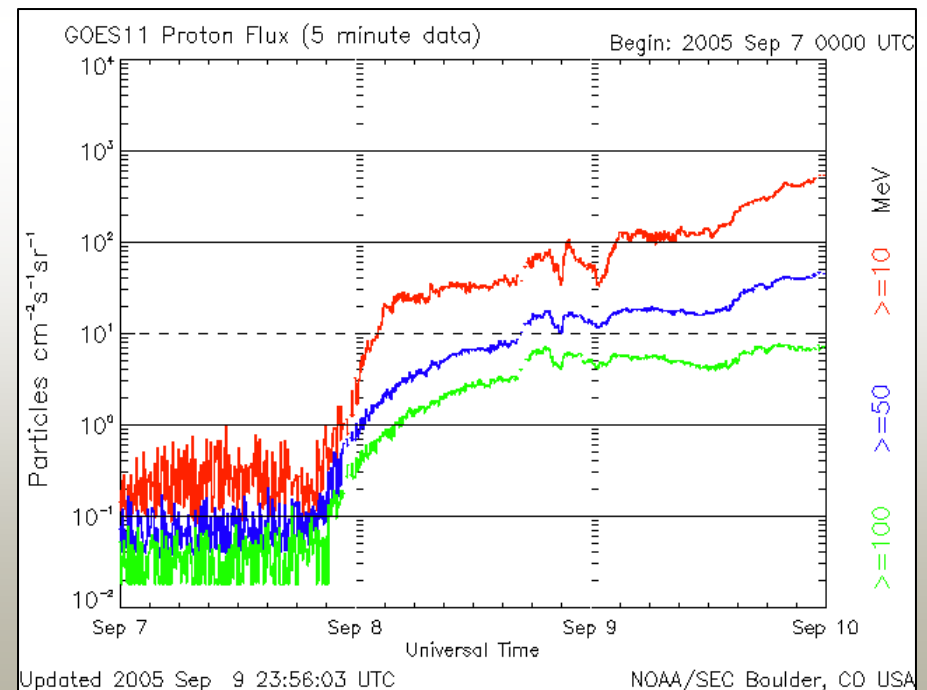
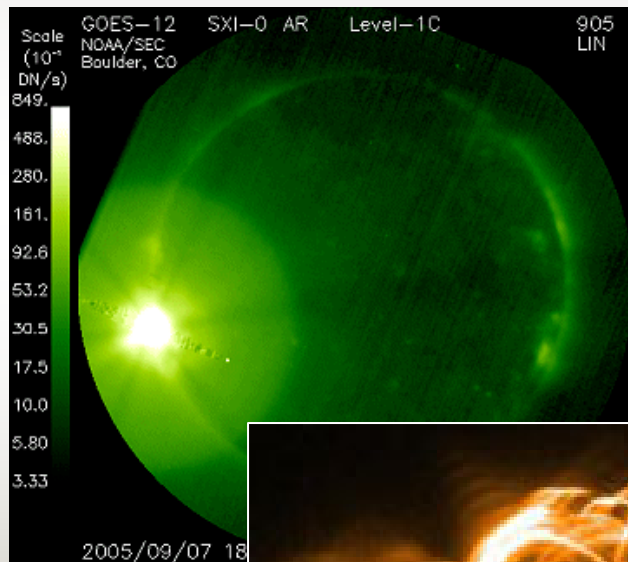


Courtesy Stephen Seip



# *A Rare, High Energy Proton Producer*

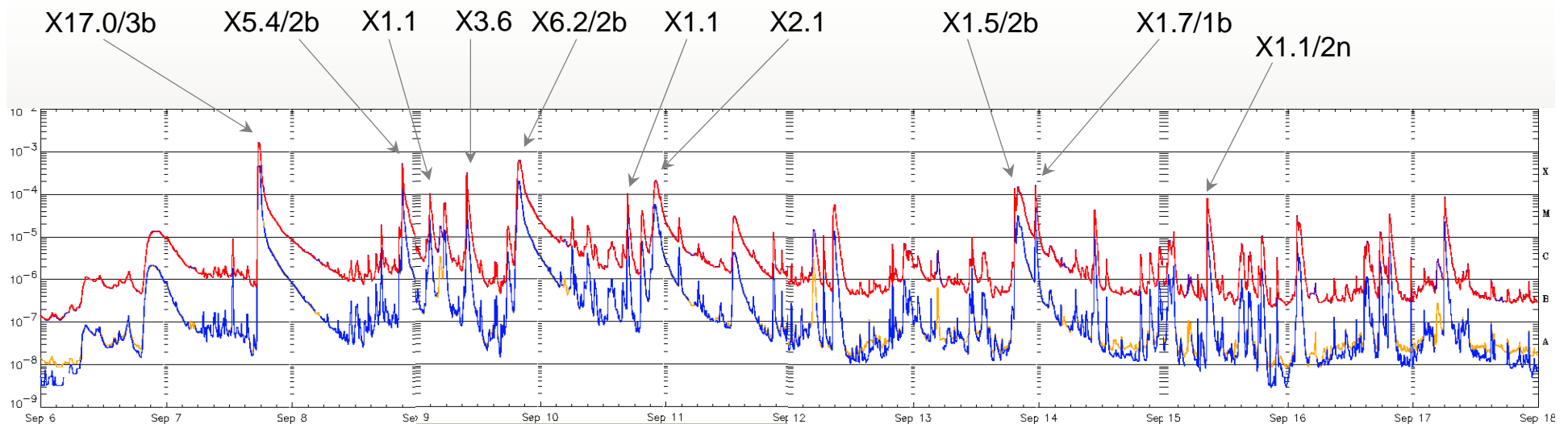
A  $>10$  and  $>100$  MeV proton event began following the X17 flare on the southeast limb. This is the only  $>100$  MeV proton from a source region east of E60 in the historical record (since 1976)!



This region produced 13 major flares ( $\geq M5$ ), including ten X-class and three ( $\geq M5$ ) M-class during its passage across the visible disk between 6 - 21 Sep.

Region 10808 has produced more major flares than any other active region in Solar Cycle 23.

Sixteen halo CMEs were observed on LASCO (some were missed due to down time and proton contamination!).

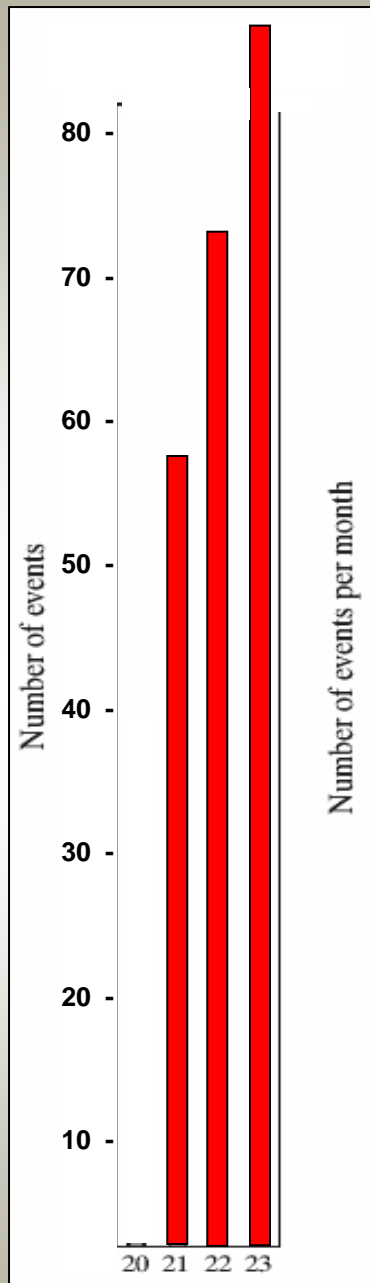


# Cycle 23 Radiation Storms

The Sep 2005 radiation storm was the 91<sup>st</sup> >10 MeV radiation storm of Solar Cycle 23.

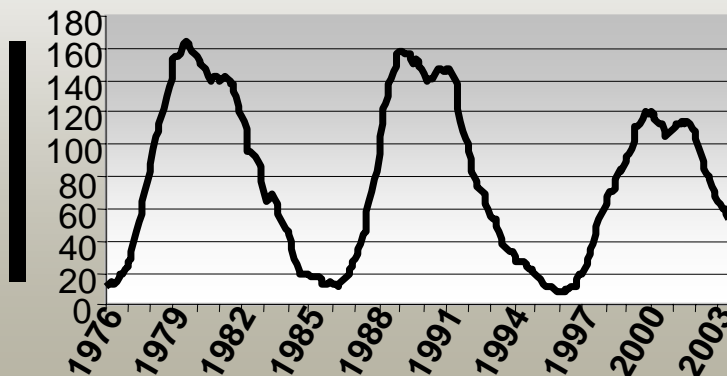
**Totals = S3 (10) S4 (6) S5 (0)**

Solar Cycle 23 produced 31 >100 MeV radiation storms.



Radiation Storms  
per Cycle

The Large Events (in pfu's)			
14 Jul 2000	410	28 Oct 2003	186
8 Nov 2000	347	29 Oct 2003	110
15 Apr 2001	146	20 Jan 2005	652
4 Nov 2001	253		





# More Totals...

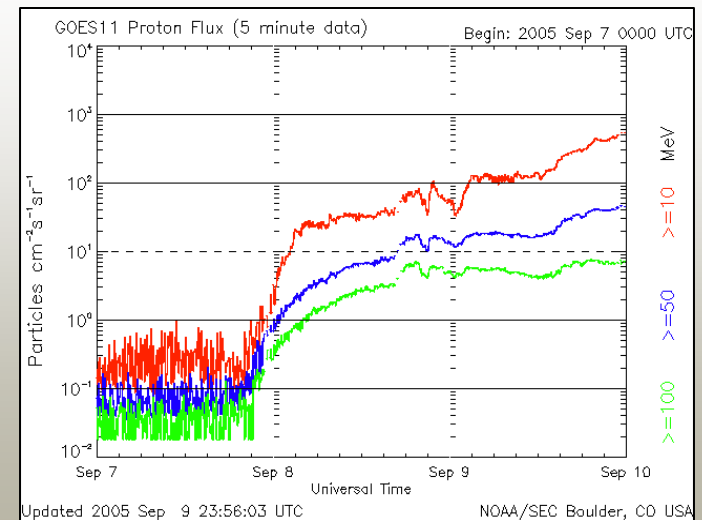
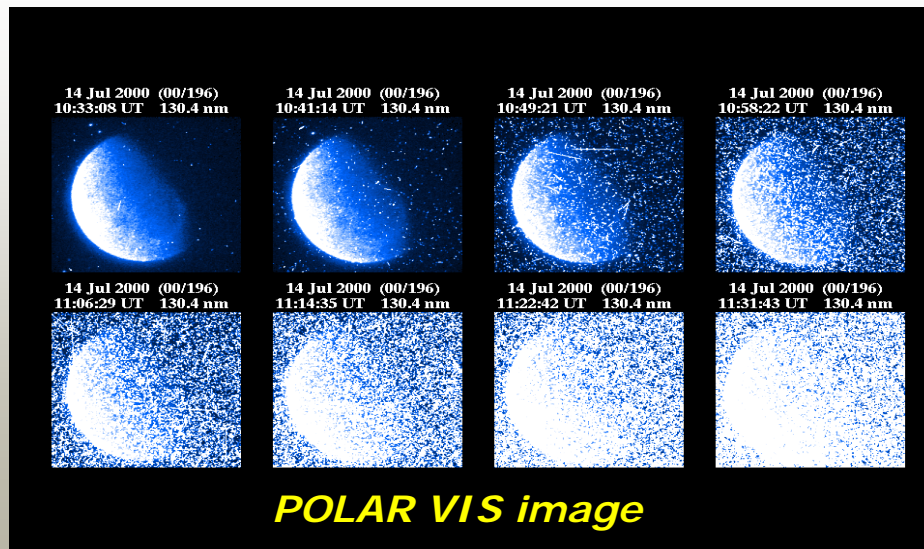
Total number of radiation storms since 1976: 223

S3 = 10

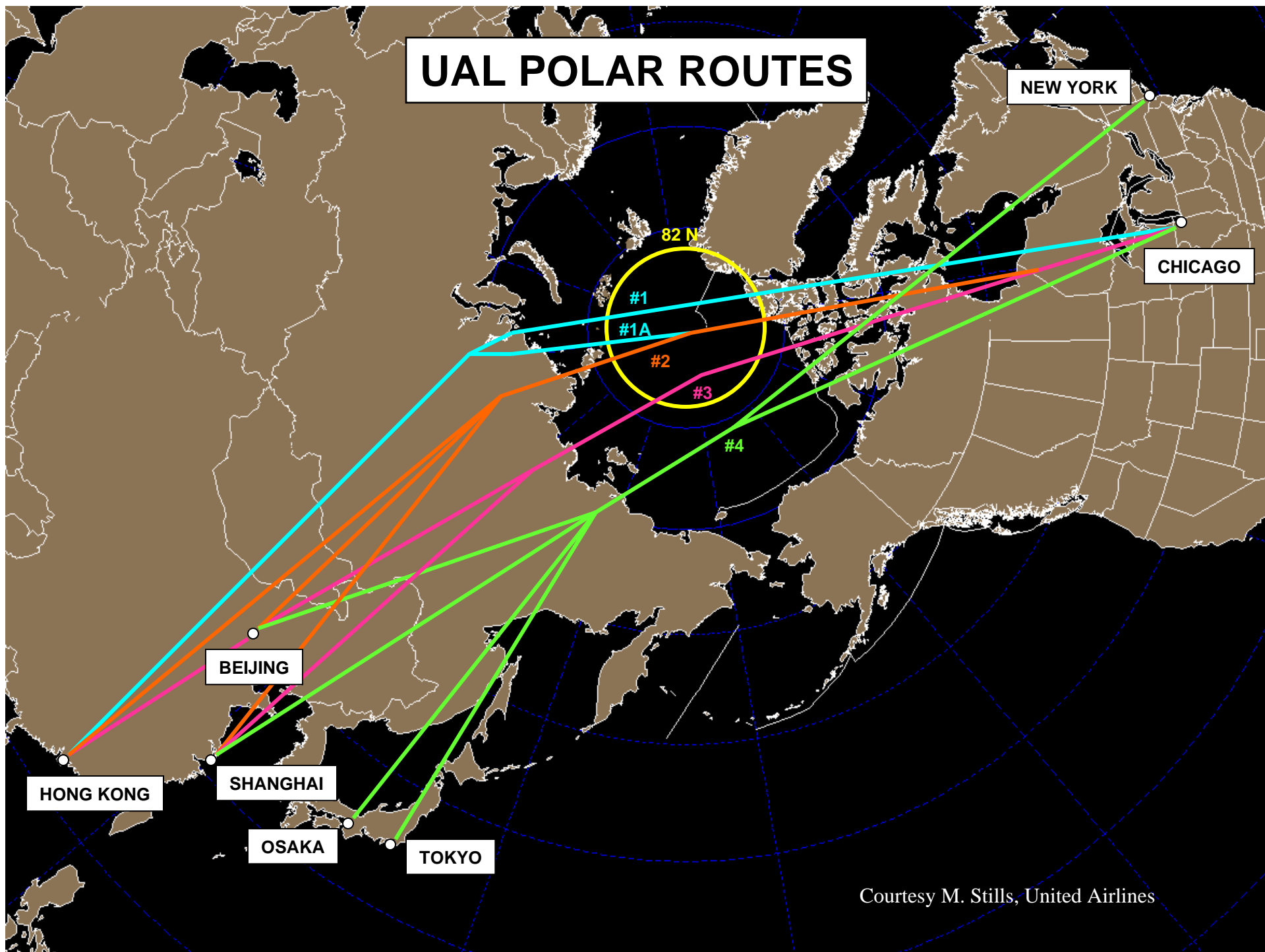
S4 = 25

S5 = 0

The largest radiation storm since 1976: 43,000 pfu (S4) - March 1991  
40,000 pfu (S4) - October 1989



# UAL POLAR ROUTES



Courtesy M. Stills, United Airlines

# Route Closures

- As a result of extremely poor HF quality, during the January event, Polar routes 3 and 4 were closed when Magadan Oceanic (Russia) lost its' satellite capability. The loss of CPDLC (controller pilot data link communication) combined with the lack of HF, negated any ability for communication between aircraft and Air Traffic Control



# **Solar Activity Impact**

**January 17-24, 2005**

The immediate financial impact on polar flight operations during this period was approximately \$250,000 USD.

This amount represents 'visible' costs such as time and fuel. It does not include 'hidden' costs such as passenger misconnect to other flights, landing fees, payload not realized, etc.

Courtesy M. Stills, United Airlines

# Summary

- Significant space weather continues in the declining phase of Cycle 23
- Impacts of that activity are a significant issue for users
- Episodes of disturbed space weather are likely through the end of Cycle 23 (estimated to be early 2007)