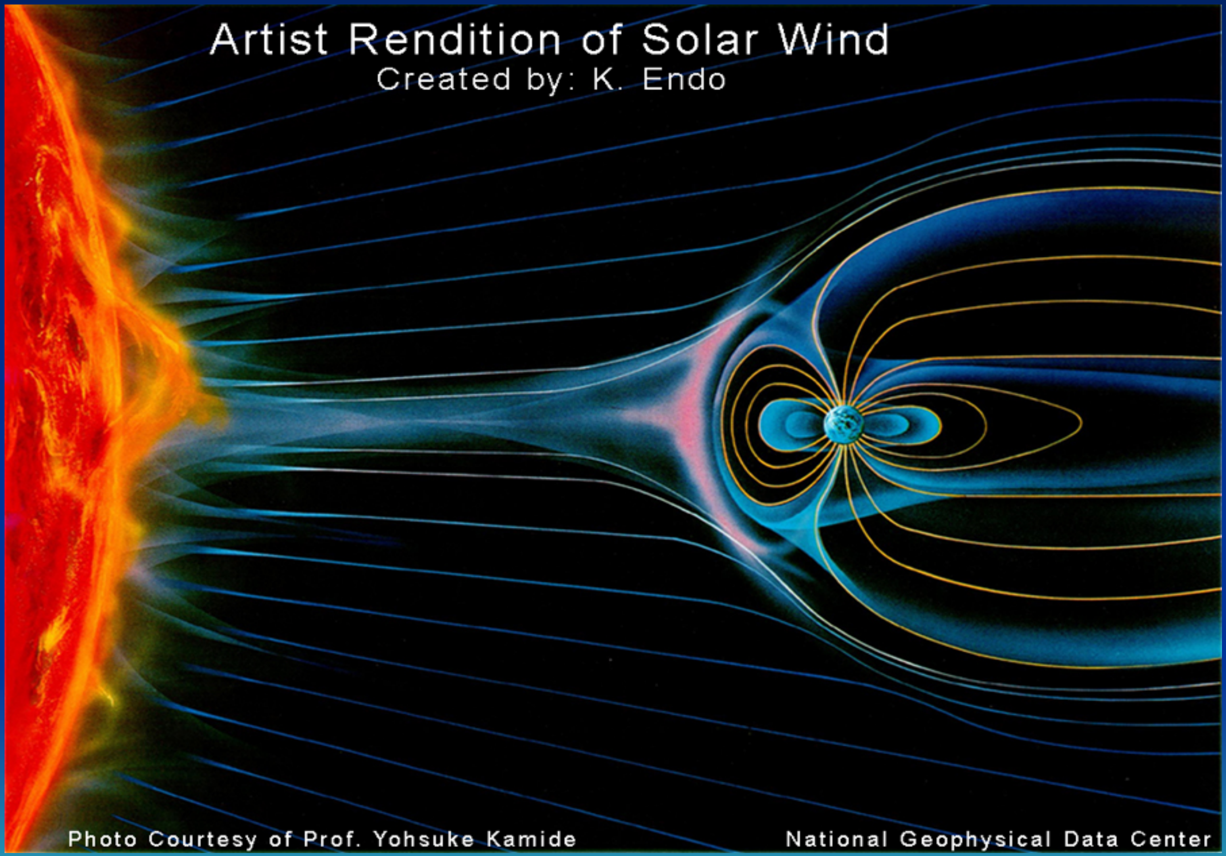
LIGO Magnetometer Data



Sensor Orientation

- Three axes: the X and Y sensors are oriented along arms of the interferometer, Z is up.
- In most magnetic observatories, X is north and Y is east.
- Result: overlap of X and Y components in relation to other observatories
- Raw data from LHO magnetometers has the wrong sign—plots appear inverted compared to other observatories

Traditional Observatory Components

- Horizontal intensity $H = \sqrt{(X2 + Y2)}$
  - Resolving X and Y into H solves the problem of the orientation difference between LHO and other magnetic observatories
- Declination D = Arctangent (Y/X)
  - Measured in minutes arc positive eastward
- Z is the same for LHO and other magnetic observatories

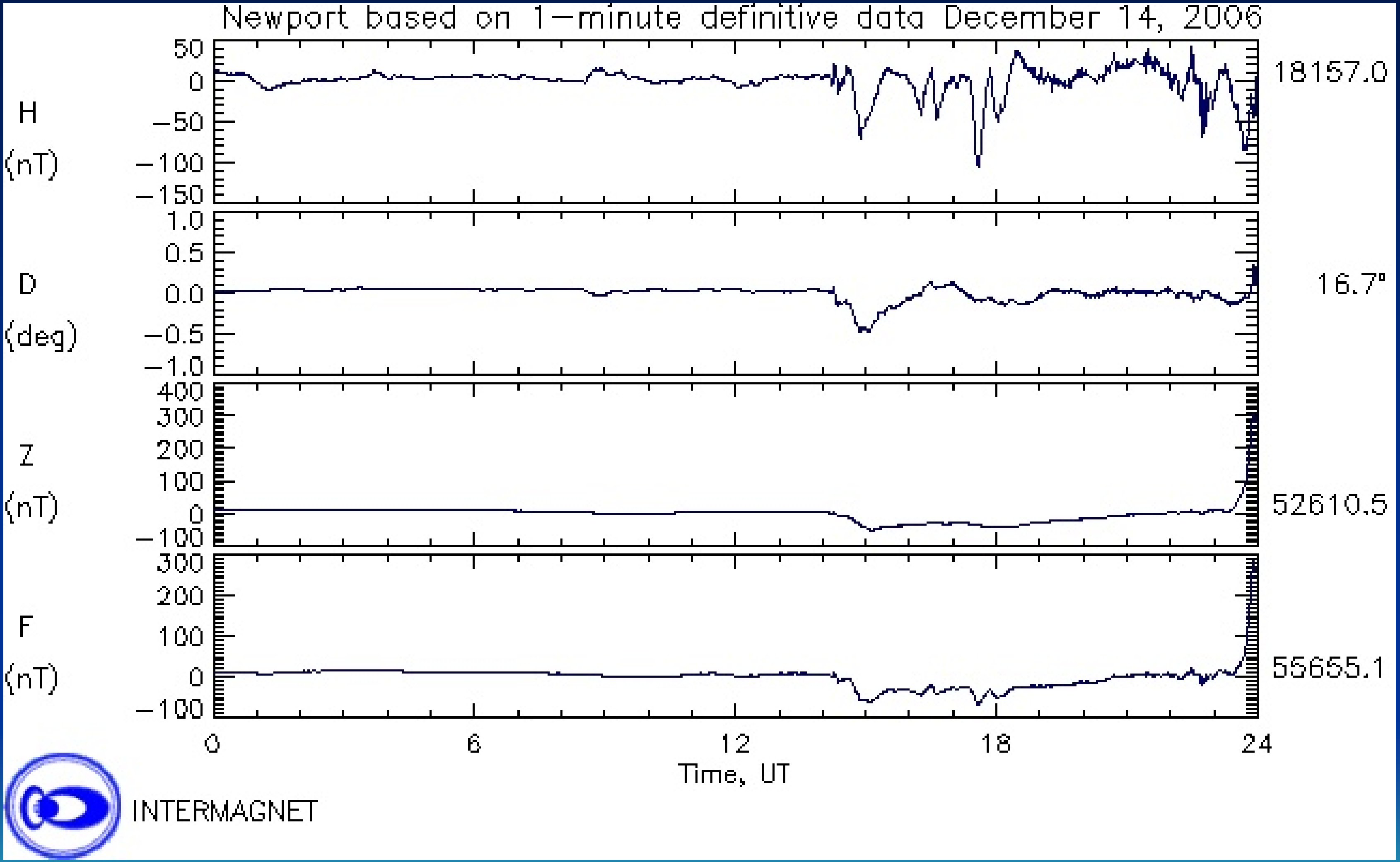
Filtering

- Special highpass-lowpass filter applied before data gets to the DAQ
- Allows high frequency (above 80 Hz) and low frequency (below 0.0035 Hz) signals to be detected with the same instrument
- Best resolution at low frequency = ~5 minute trends
- USGS data filtered to produce 1-minute trends

Data scaling and offset

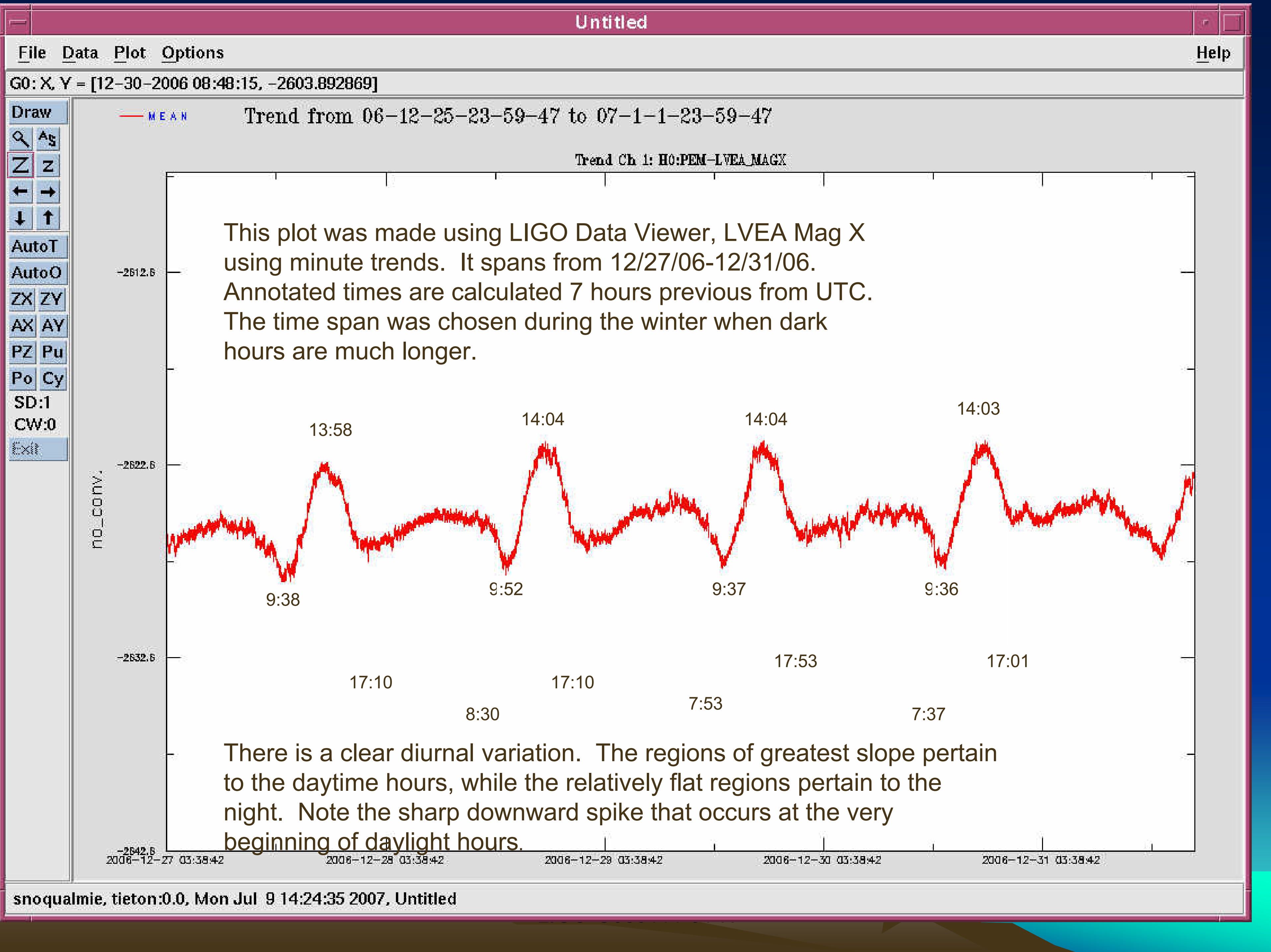
- Raw digital counts must be converted into field strength to be comparable to magnetic observatories
- Conversion factor of 6.1 nT per voltage count
- Magnetic observatory instruments have an offset that must be removed in order to plot data on a common axis

Typical magnetic observatory plot

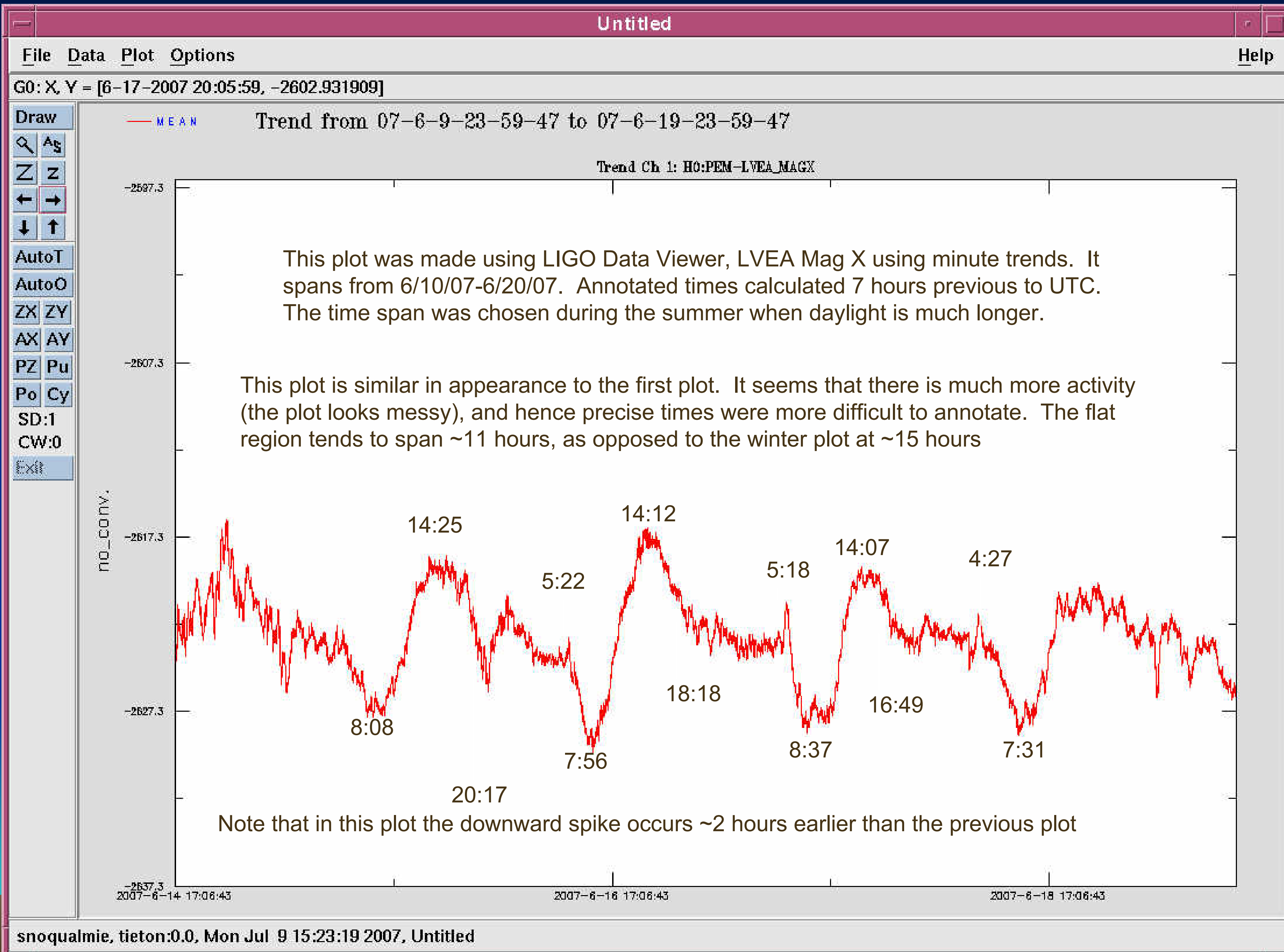


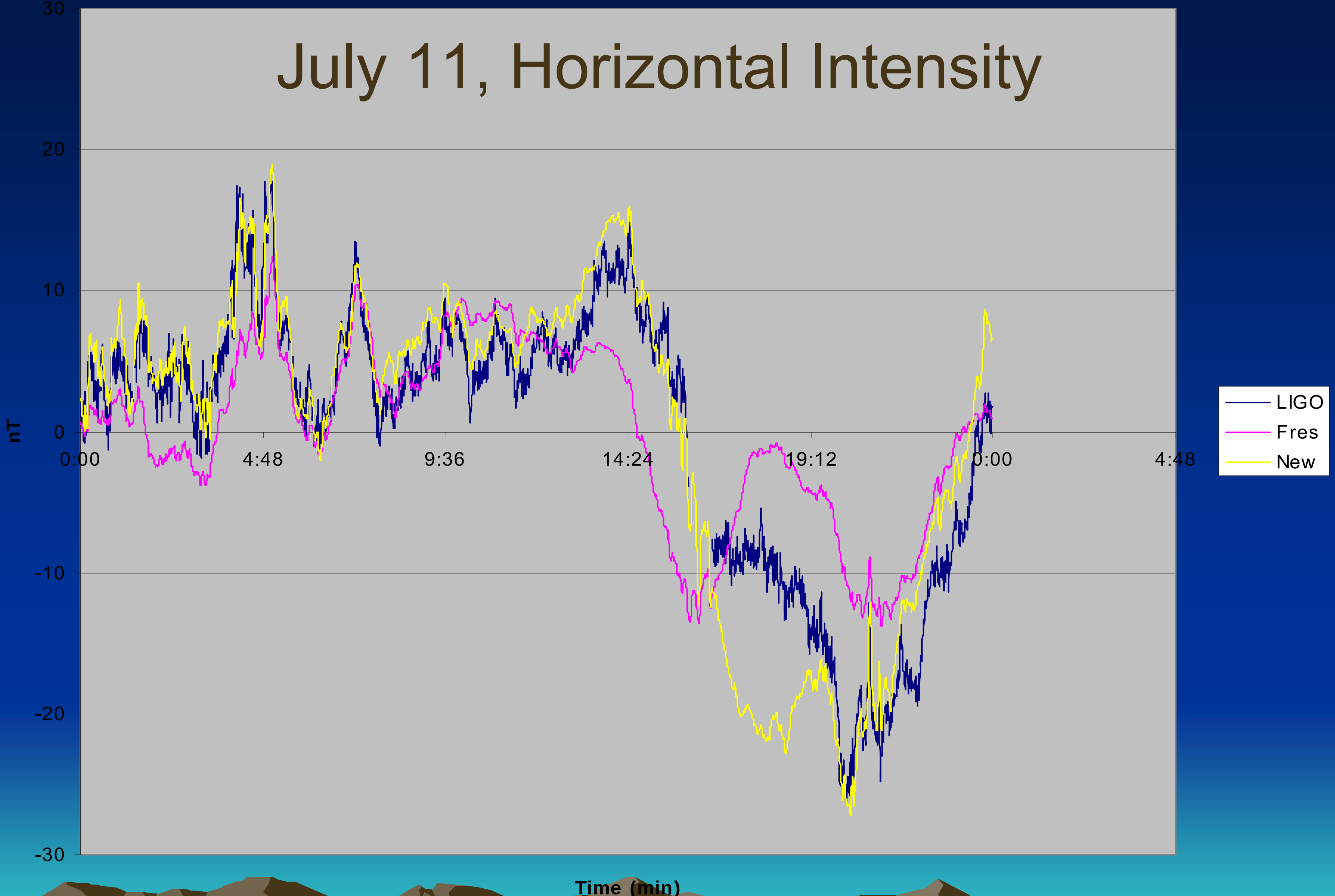
Sq: Solar Quiet Variation

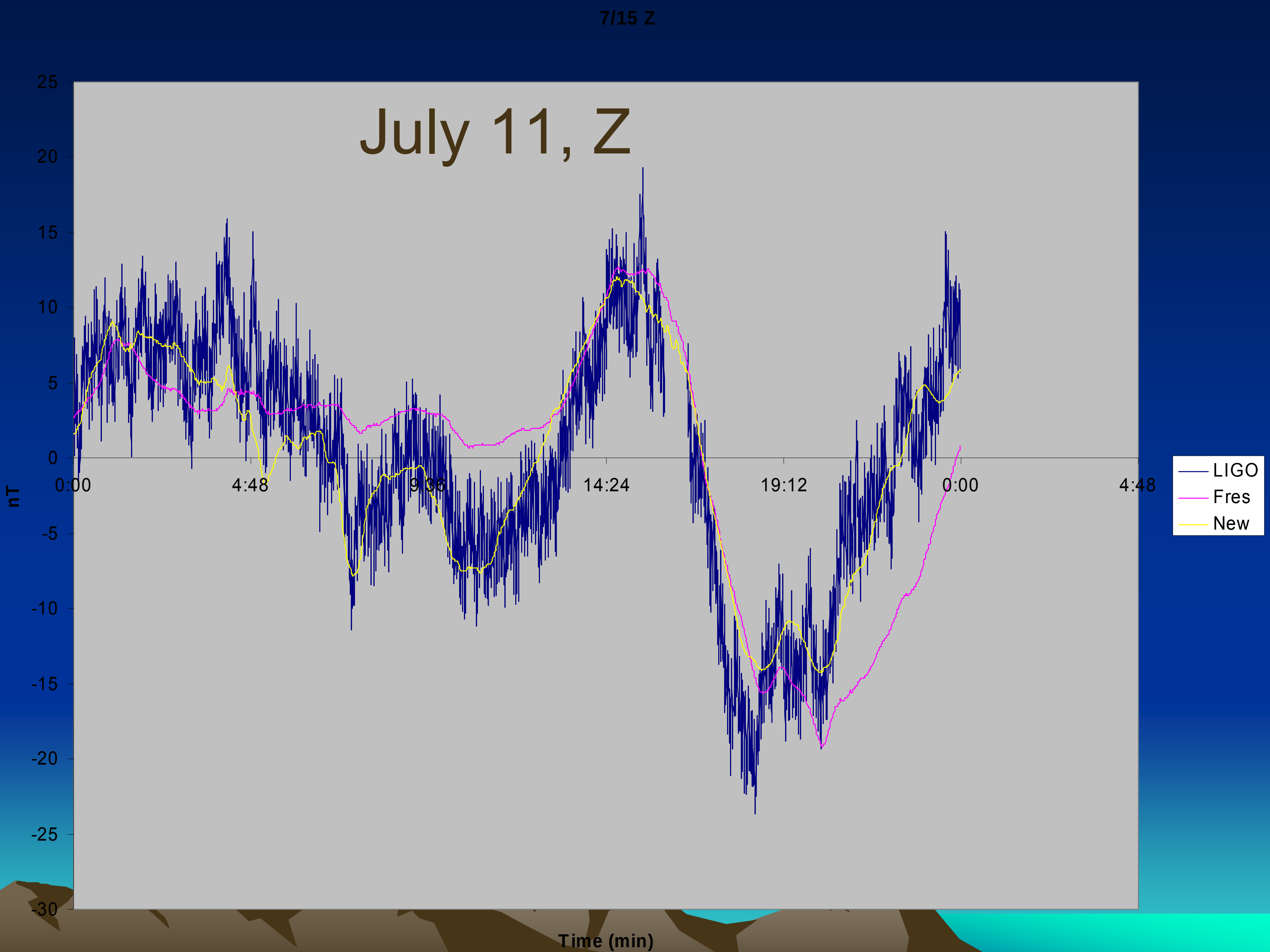
- Periodic daily changes in the earth’s magnetic field strength
- Caused by distorted field lines from solar wind; expansion, contraction and tidal forces in the ionosphere; plasma currents in the Van Allen belts
- Sq appears is affected to some extent by lattitude and season



Untitled
File Data Plot Options
Help
G0: X, Y = [12-30-2006 08:48:15, -2603.892869]
Draw
AutoT
AutoO
ZX ZY
AX AY
PZ Pu
Po Cy
SD:1
CW:0
Exit
MEAN
Trend from 06-12-25-23-59-47 to 07-1-1-23-59-47
Trend Ch 1: H0:PEM-LVEA_MAGX
no_conv.
-2612.6
-2622.6
-2632.6
-2642.6
2006-12-27 03:38:42
2006-12-28 03:38:42
2006-12-29 03:38:42
2006-12-30 03:38:42
2006-12-31 03:38:42
This plot was made using LIGO Data Viewer, LVEA Mag X using minute trends. It spans from 12/27/06-12/31/06. Annotated times are calculated 7 hours previous from UTC. The time span was chosen during the winter when dark hours are much longer.
13:58
14:04
14:04
14:03
9:38
9:52
9:37
9:36
17:10
8:30
17:10
7:53
17:53
7:37
17:01
There is a clear diurnal variation. The regions of greatest slope pertain to the daytime hours, while the relatively flat regions pertain to the night. Note the sharp downward spike that occurs at the very beginning of daylight hours.
snoqualmie, tieton:0.0, Mon Jul 9 14:24:35 2007, Untitled


Untitled
File Data Plot Options
Help
G0: X, Y = [6-17-2007 20:05:59, -2602.931909]
Draw
AutoT
AutoO
ZX ZY
AX AY
PZ Pu
Po Cy
SD:1
CW:0
Exit
MEAN
Trend from 07-6-9-23-59-47 to 07-6-19-23-59-47
Trend Ch 1: H0:PEM-LVEA_MAGX
no_conv.
-2597.3
-2607.3
-2617.3
-2627.3
-2637.3
2007-6-14 17:06:43
2007-6-16 17:06:43
2007-6-18 17:06:43
This plot was made using LIGO Data Viewer, LVEA Mag X using minute trends. It spans from 6/10/07-6/20/07. Annotated times calculated 7 hours previous to UTC. The time span was chosen during the summer when daylight is much longer.
This plot is similar in appearance to the first plot. It seems that there is much more activity (the plot looks messy), and hence precise times were more difficult to annotate. The flat region tends to span ~11 hours, as opposed to the winter plot at ~15 hours
14:25
14:12
14:07
5:22
5:18
4:27
18:18
16:49
8:08
7:56
8:37
7:31
20:17
Note that in this plot the downward spike occurs ~2 hours earlier than the previous plot
snoqualmie, tieton:0.0, Mon Jul 9 15:23:19 2007, Untitled


July 11, Horizontal Intensity
30
20
10
0
-10
-20
-30
nT
0:00
4:48
9:36
14:24
19:12
0:00
4:48
Time (min)
LIGO
Fres
New

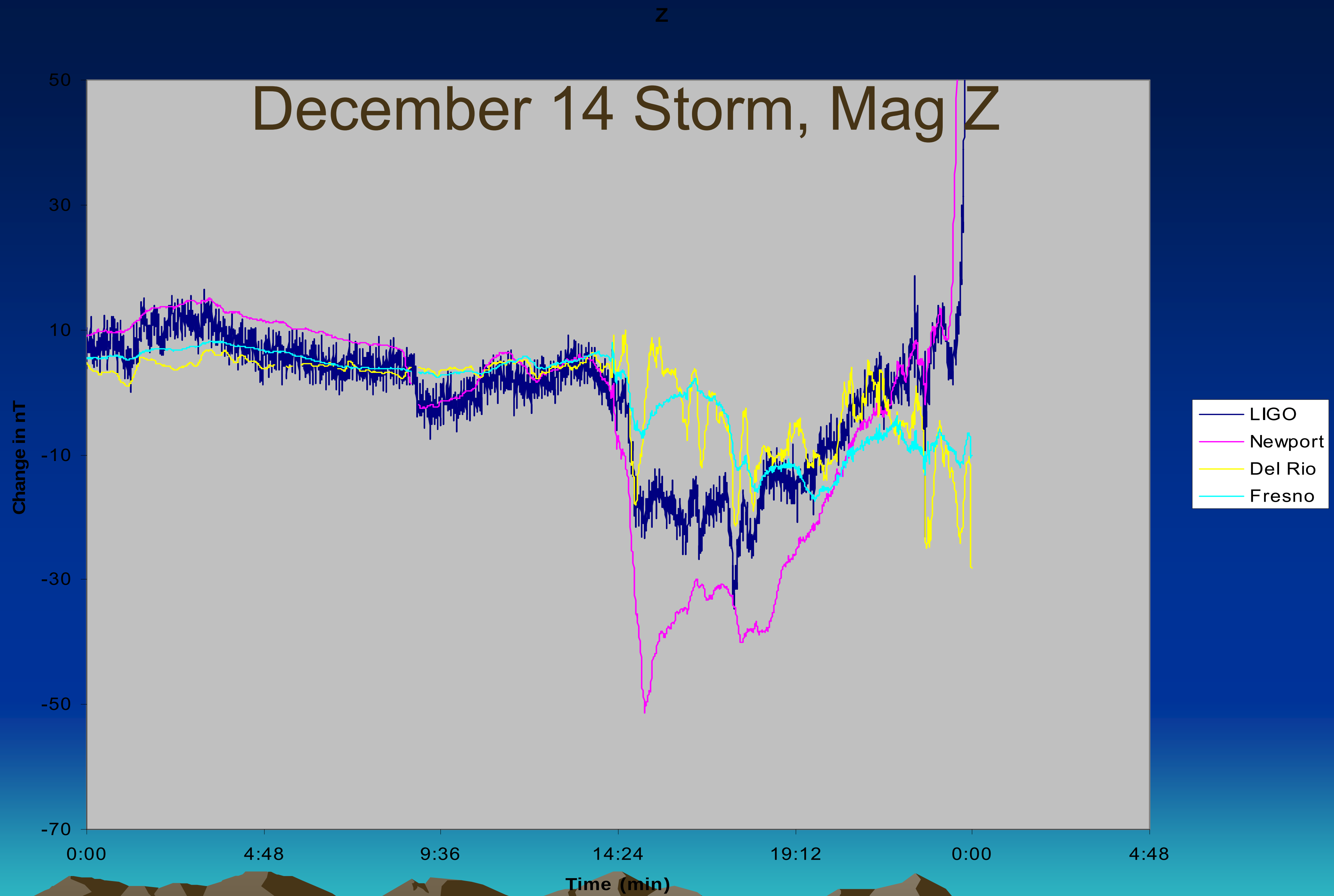


LIGO-G080111-01-H

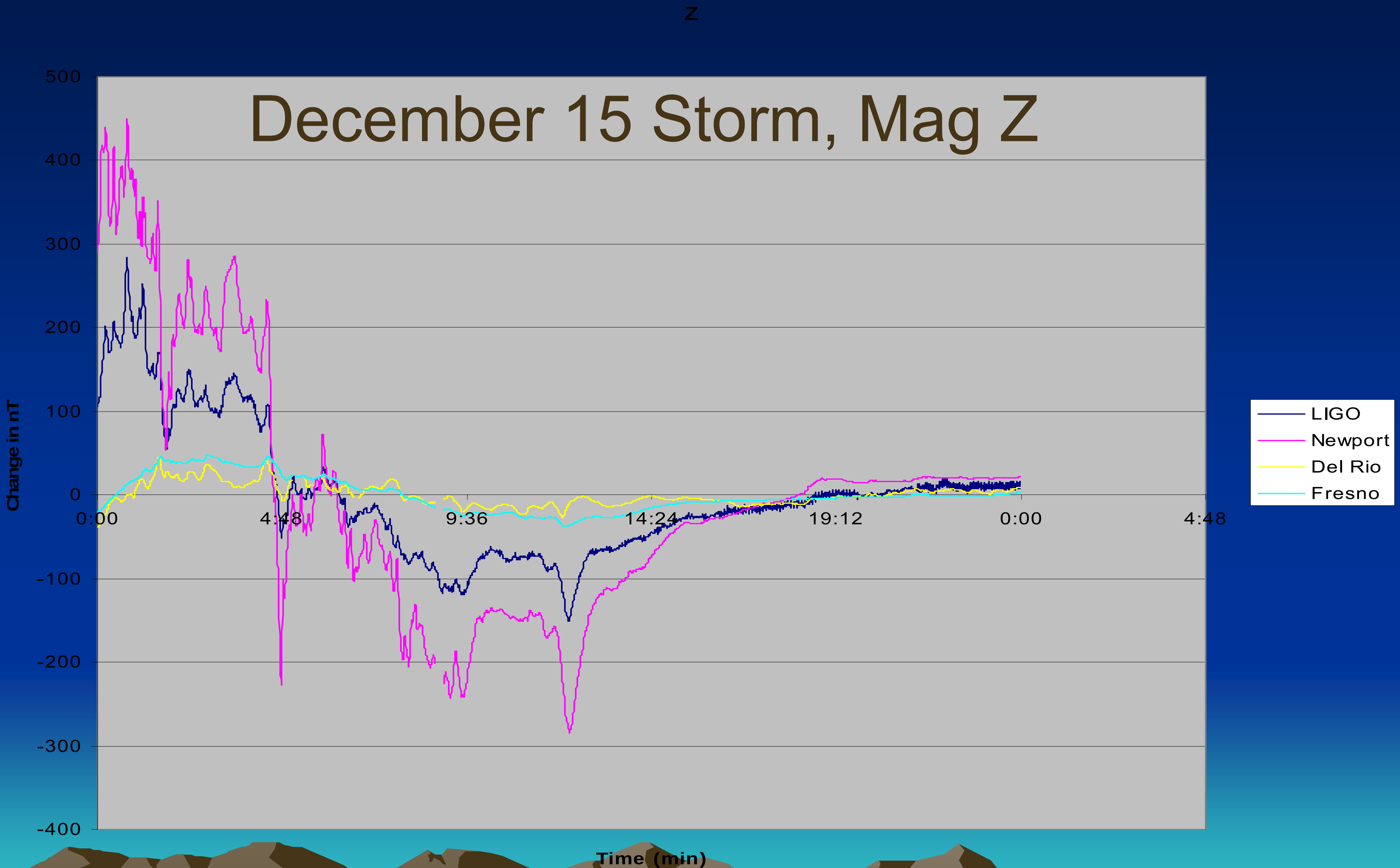
Magnetic Storms

- Produced by solar flares and coronal mass ejections
- Produce low frequency flux signals that can affect electronics on earths surface
- December 14-15, 2006 magnetic storm was the strongest in S5 (Robert Schofield)
- Latitude has a substantial affect upon the degree of change in the magnetic field

December 14 Storm, Mag Z



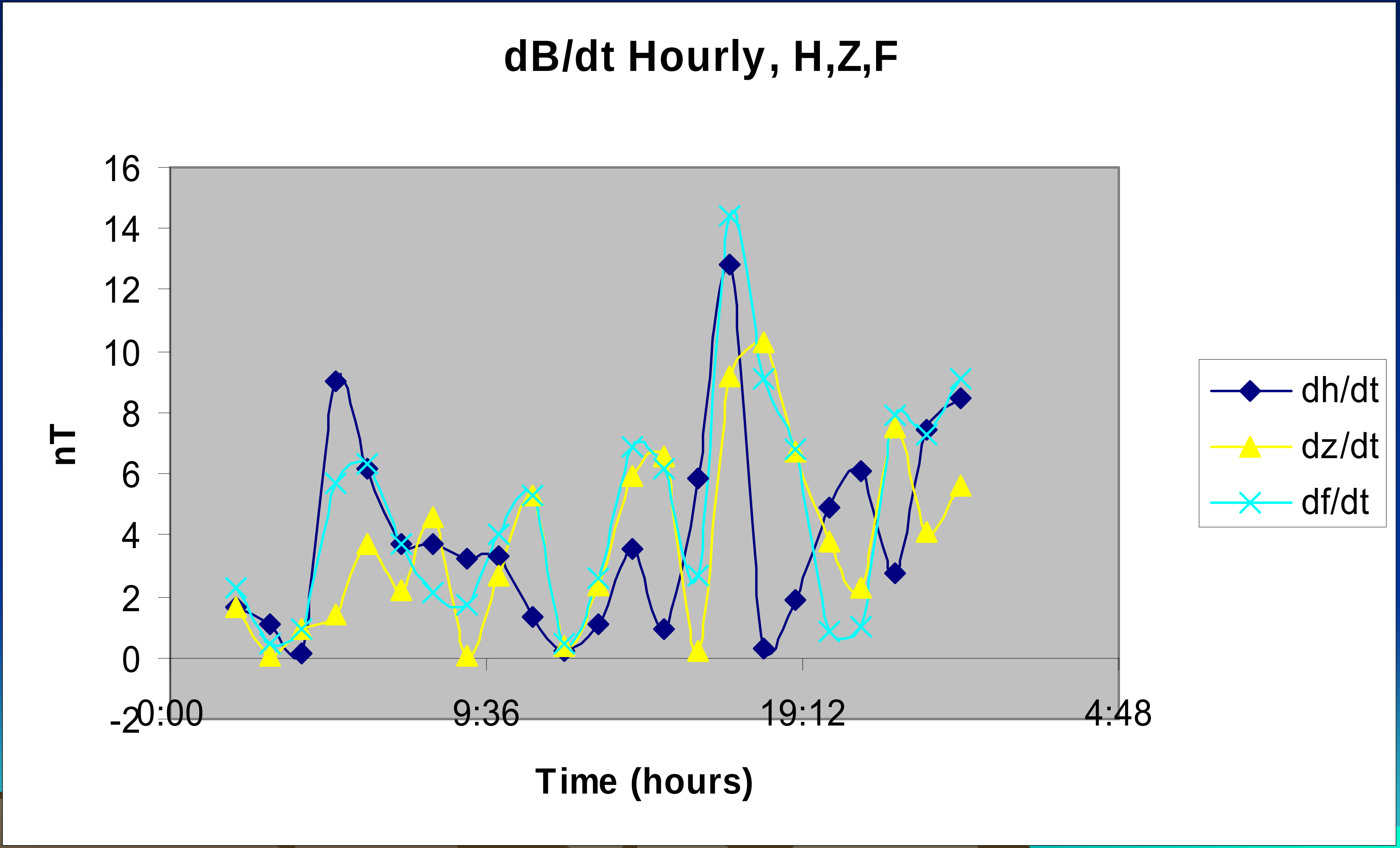
December 15 Storm, Mag Z



Magnetic Flux Periodicity

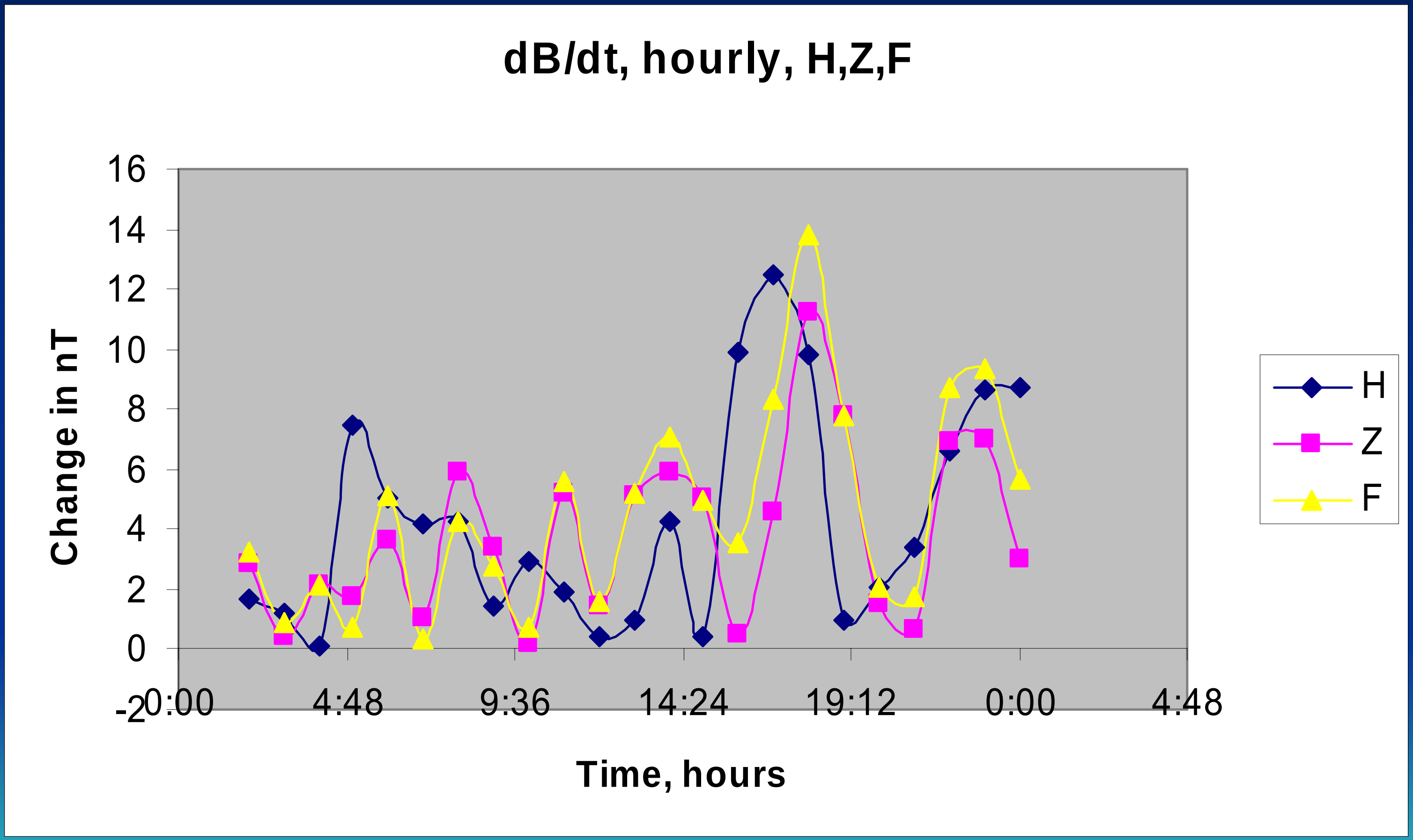
- There appears to be some periodicity associated with magnetic flux during quiet times and during storm times

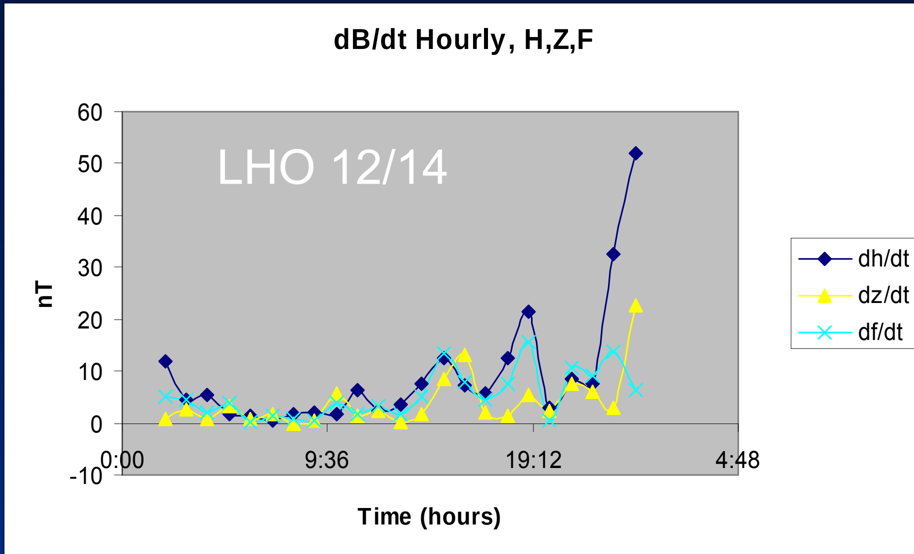
July 11, LHO

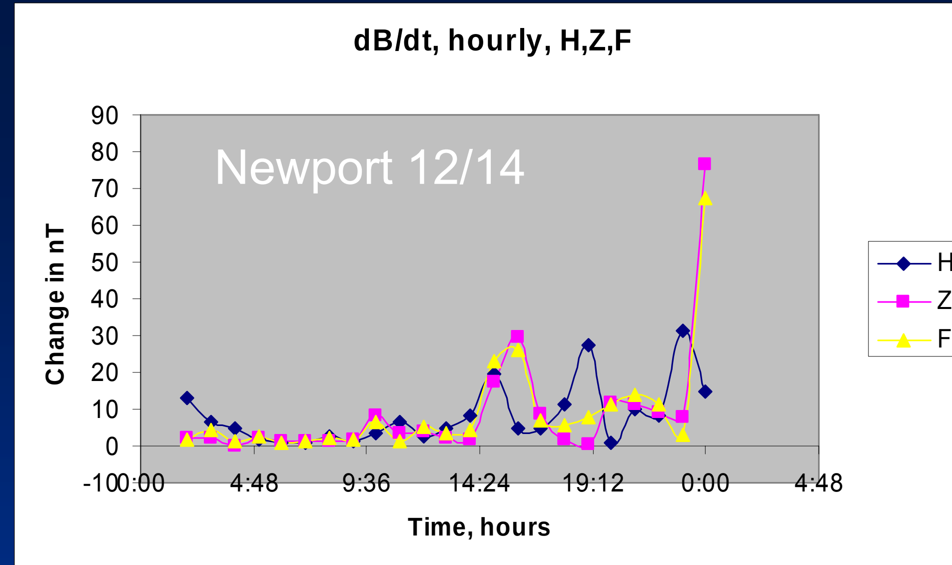


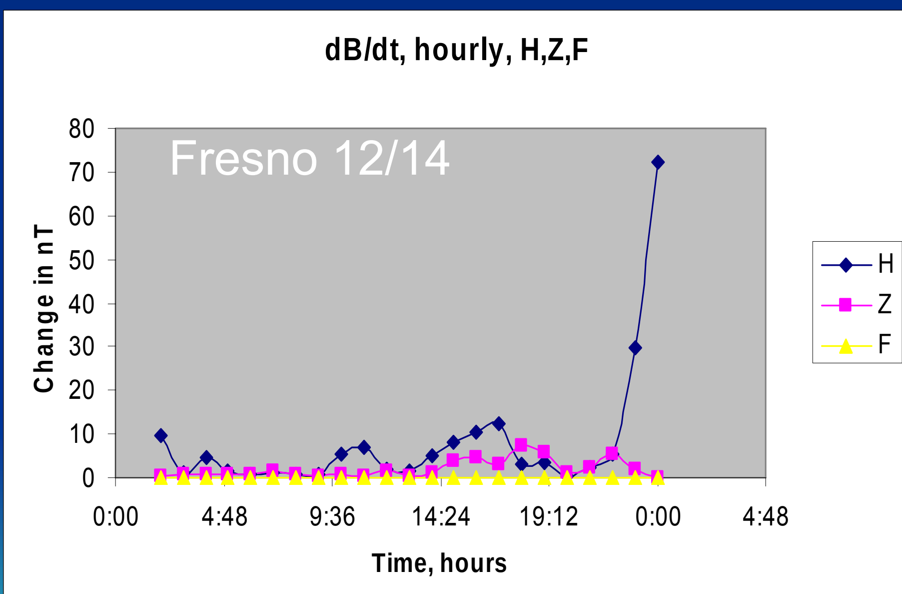
dB/dt Hourly, H,Z,F
16
14
12
10
8
6
4
2
0
-2
nT
0:00
9:36
19:12
4:48
Time (hours)
dh/dt
dz/dt
df/dt

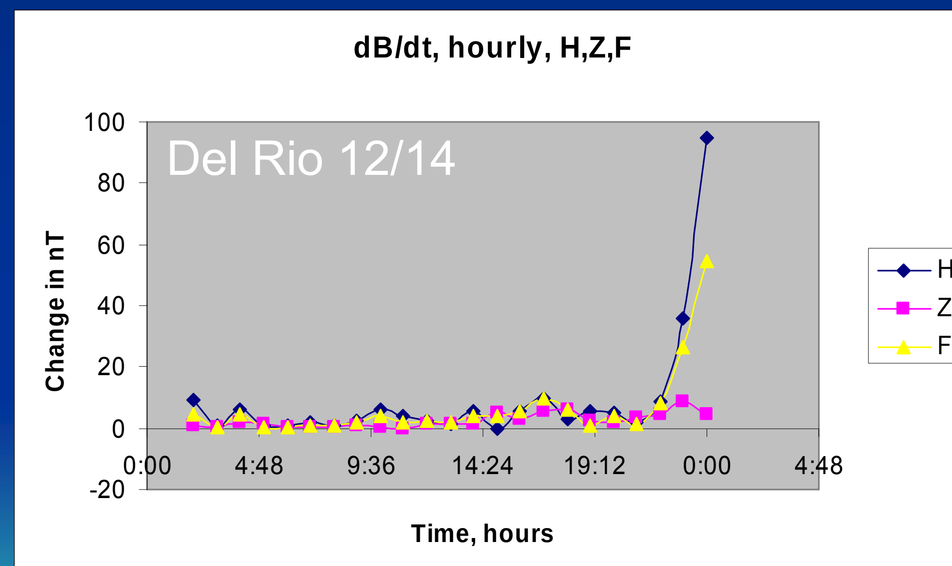
July 11, Newport

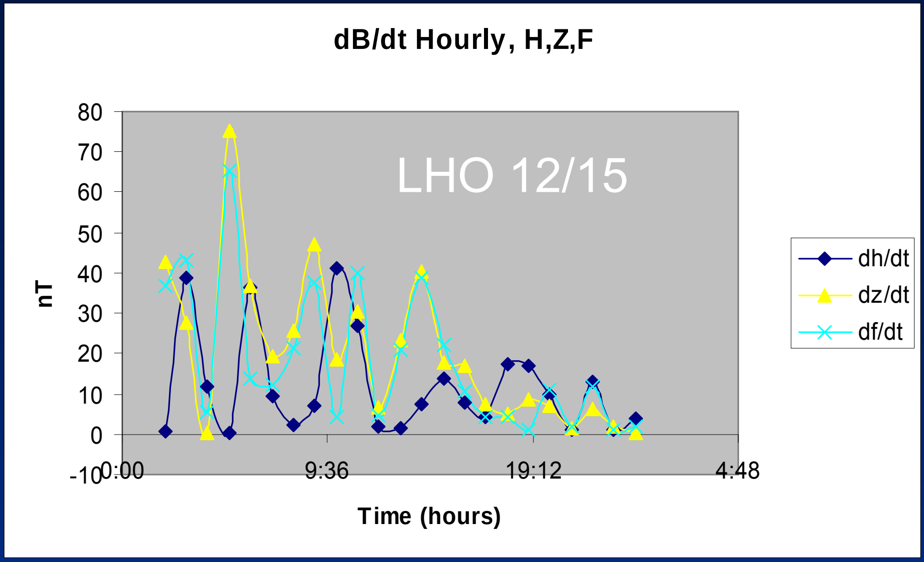


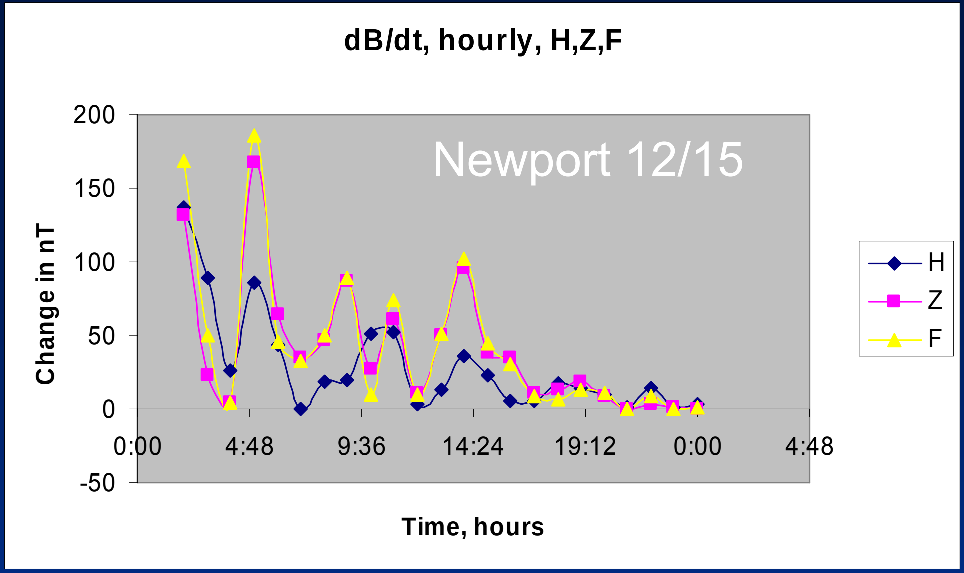

dB/dt Hourly, H,Z,F
LHO 12/14
nT
Time (hours)
dh/dt
dz/dt
df/dt
60
50
40
30
20
10
0
-10
0:00
9:36
19:12
4:48

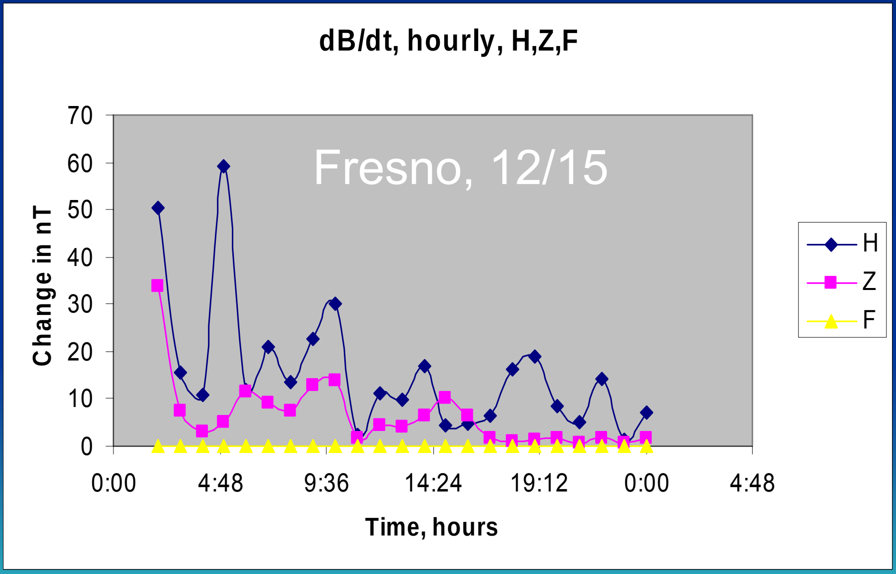

dB/dt, hourly, H,Z,F
Newport 12/14
Change in nT
Time, hours
H
Z
F
90
80
70
60
50
40
30
20
10
0
-10
0:00
4:48
9:36
14:24
19:12
0:00
4:48

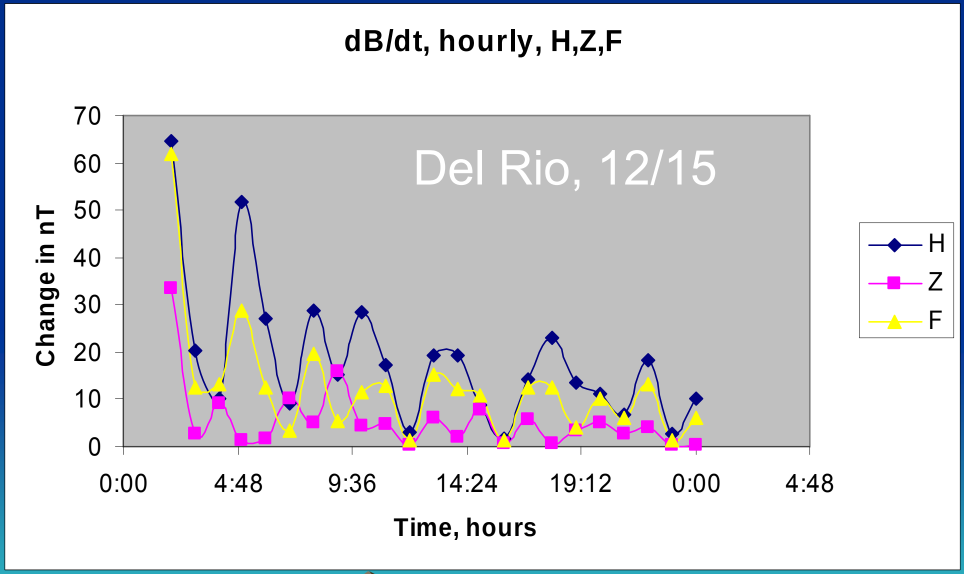

dB/dt, hourly, H,Z,F
Fresno 12/14
Change in nT
Time, hours
H
Z
F
80
70
60
50
40
30
20
10
0
0:00
4:48
9:36
14:24
19:12
0:00
4:48


dB/dt, hourly, H,Z,F
Del Rio 12/14
Change in nT
Time, hours
H
Z
F
100
80
60
40
20
0
-20
0:00
4:48
9:36
14:24
19:12
0:00
4:48


dB/dt Hourly, H,Z,F
LHO 12/15
nT
80
70
60
50
40
30
20
10
0
-10
0:00
9:36
19:12
4:48
Time (hours)
dh/dt
dz/dt
df/dt


dB/dt, hourly, H,Z,F
Newport 12/15
Change in nT
200
150
100
50
0
-50
0:00
4:48
9:36
14:24
19:12
0:00
4:48
Time, hours
H
Z
F


dB/dt, hourly, H,Z,F
Fresno, 12/15
Change in nT
70
60
50
40
30
20
10
0
0:00
4:48
9:36
14:24
19:12
0:00
4:48
Time, hours
H
Z
F


dB/dt, hourly, H,Z,F
Del Rio, 12/15
Change in nT
70
60
50
40
30
20
10
0
0:00
4:48
9:36
14:24
19:12
0:00
4:48
Time, hours
H
Z
F