LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Comparative Analysis of LHO Magnetometer Plots

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1 Abstract

Comparisons were made between LHO magnetometer data and selected USGS magnetic observatory plots. It was found that the sign of LHO magnetic data was reversed. After scaling the data and removing the offset it was found that LHO magnetometer plots correlate very well with those of regional magnetic observatories. This is despite the fact that the steel buildings that house the instruments and the close proximity of electrical devices provide a less-than-ideal environment for geomagnetic research. It was found that during solar quiet periods the diurnal variation of magnetic field strength measured at different latitudes within the continental United States conformed very closely one to another. In contrast, during a magnetic storm, higher latitude observatories experienced a greater degree of magnetic flux than those at lower latitudes. It was also found that magnetic flux oscillates periodically during solar quiet times and during solar storm times. The period of the oscillations remains the same during solar quiet and solar storm times, but the magnitude of the oscillations is much greater during a magnetic storm.

2 Methods

Comparisons were made between the LHO LVEA magnetometer and USGS magnetic observatories in Newport, Washington, Fresno, California, and Del Rio, Texas. All LHO data was obtained via the LIGO Analysis Tool through the I2U2 website. Newport was chosen as a control magnetometer with a similar latitude and longitude as LHO. Fresno was chosen because it lies in a similar time zone, but lower latitude. Del Rio was chosen because it was the closest magnetic observatory to LLO that was recording data during the December 14-15 magnetic storm.

3 Results

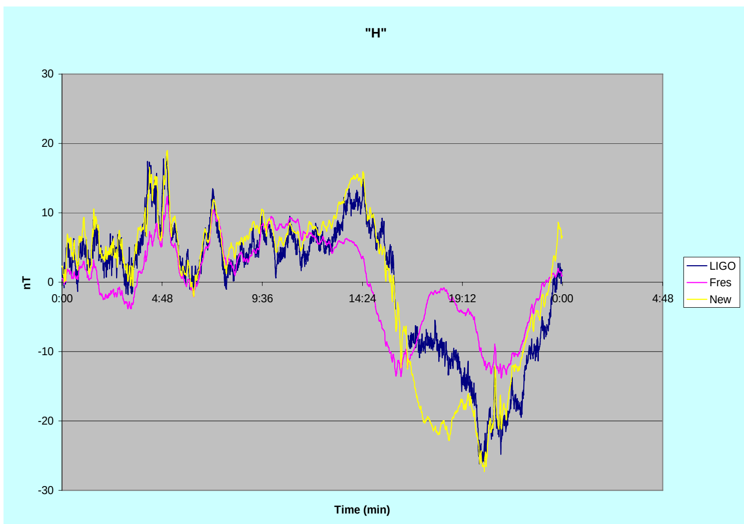
<u>Sign swap</u>: When LHO data is plotted against USGS magnetometers, the LHO plots are inverted. According to Robert Schofield, the reversing of the sign of the data is most likely the result of the mounting of the magnetometer. In most observatories, the magnetometers are mounted so that each individual sensor faces a designated direction, X-north, Y-east, Z-up. In the case of LIGO, the magnetometers are mounted so that the sensors face the direction of the arms of the interferometer. Due to constraints during the mounting of the devices, the designated X, Y, and Z axes of the sensors may not face the direction of their corresponding arms. However, the output of each sensor, regardless of its designated orientation, is routed to the appropriate data input port that corresponds with the direction the sensor actually faces relative to LIGO's arms. The result of switching the orientation of the sensors from their intended direction does not affect the magnitude of the data, but it does switch the sign. In order to make LIGO's magnetic data comparable to other observatories, the raw values must be multiplied by -1 or the plots will appear inverted.

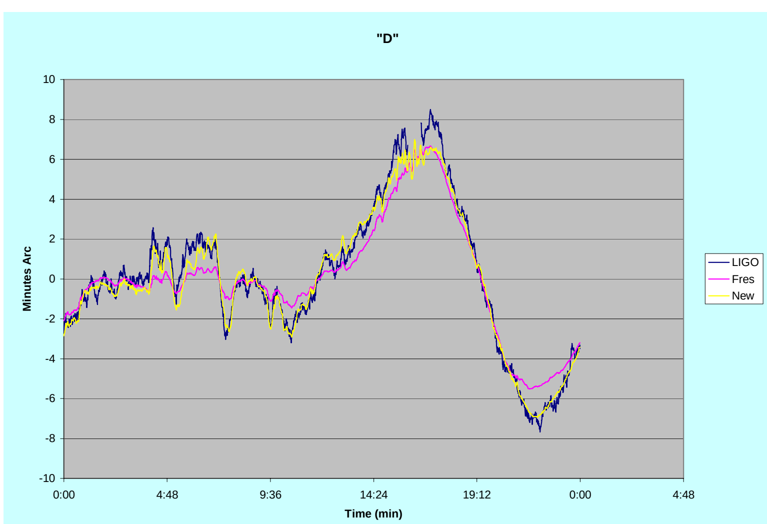
<u>Close correlation with regional magnetic observatories</u>: Despite the potential for magnetic noise in the magnetometer's environment, LHO magnetic data correlates surprisingly well with observatories designed for geomagnetic research. In order to make this comparison, the X and Y components of the LHO data were synthesized into the traditional magnetic observatory

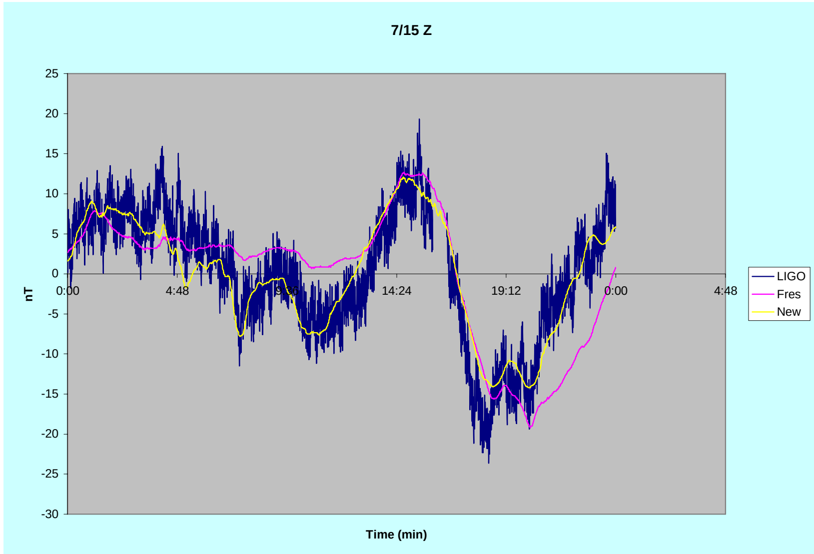
components of H (horizontal intensity) and D (declination). This was done using the following equations:

- Horizontal intensity $H = \sqrt{(X^2 + Y^2)}$
- Declination D = Arctangent (Y/X)

This conversion was necessary because LHO magnetometers are oriented along the arms of the interferometer, rather than the geographical north and east directions, as is the case with magnetic observatories. The combining of the vector components corrects for the offset in the bearing of the sensors. The following plots show LHO data superimposed on plots from two other stations, Newport and Fresno. The data spans 24 hours starting at 00:00 UTC on July 15. The plots clearly show a close correlation between LIGO magnetic data, and that collected at USGS geomagnetic observatories. Also note the close correlation of the Fresno station to the Washington stations, even though they differ greatly in latitude.

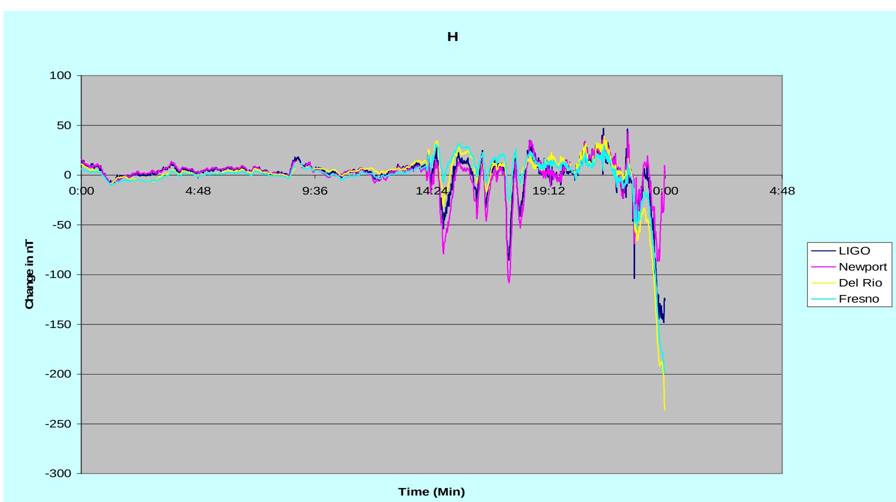


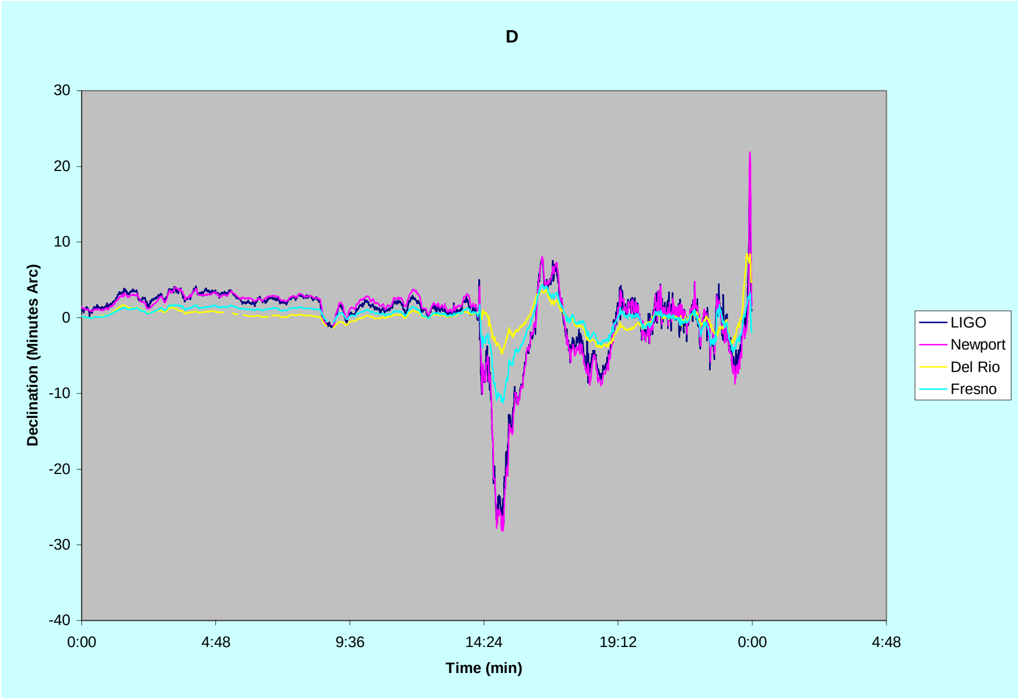


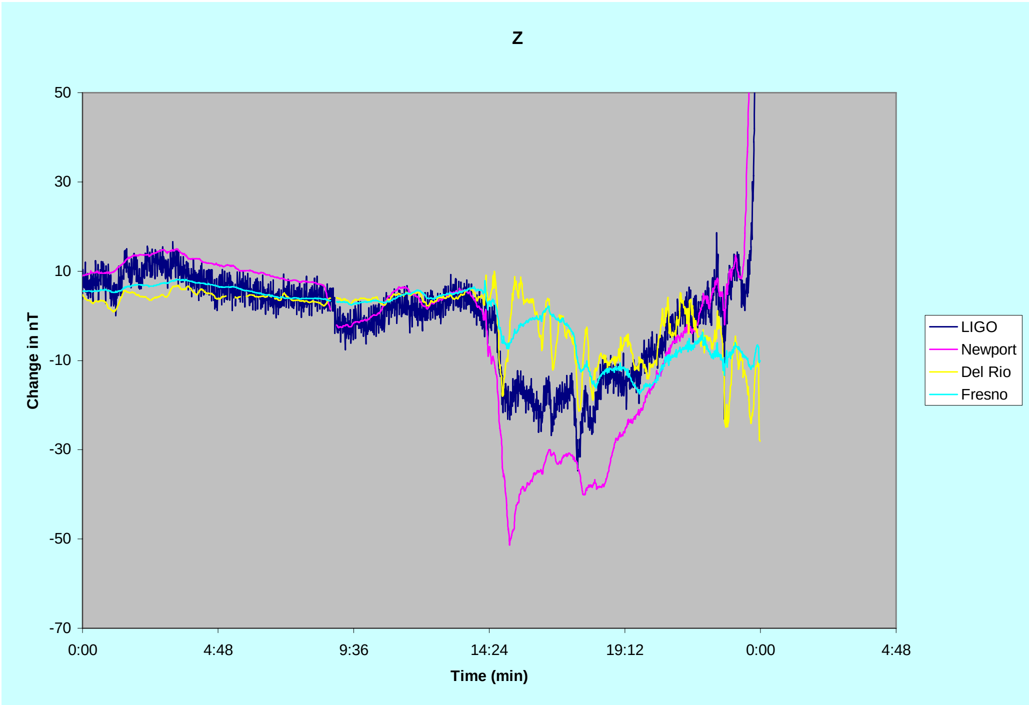


<u>Latitude has little effect on the magnitude of solar quiet variation, while it has a large affect on the magnitude of storm time signals:</u>

The following plots demonstrate that during solar quiet times, the diurnal variation of magnetic signals is not highly dependant on latitude for the stations measured. In contrast, when a magnetic storm hits, higher latitudes experience stronger signals. The following plots show data superimposed from four different stations on December 14, 2006, starting at 00:00 UTC and spanning 24 hours. At about 14:00 UTC the largest magnetic storm in the S5 run begins (see LHO E-Log entries by Robert Schofield on 7/19/2007). Note that all four stations follow each other very closely until the storm hits. During the storm the stations with the highest latitude have the strongest signals.

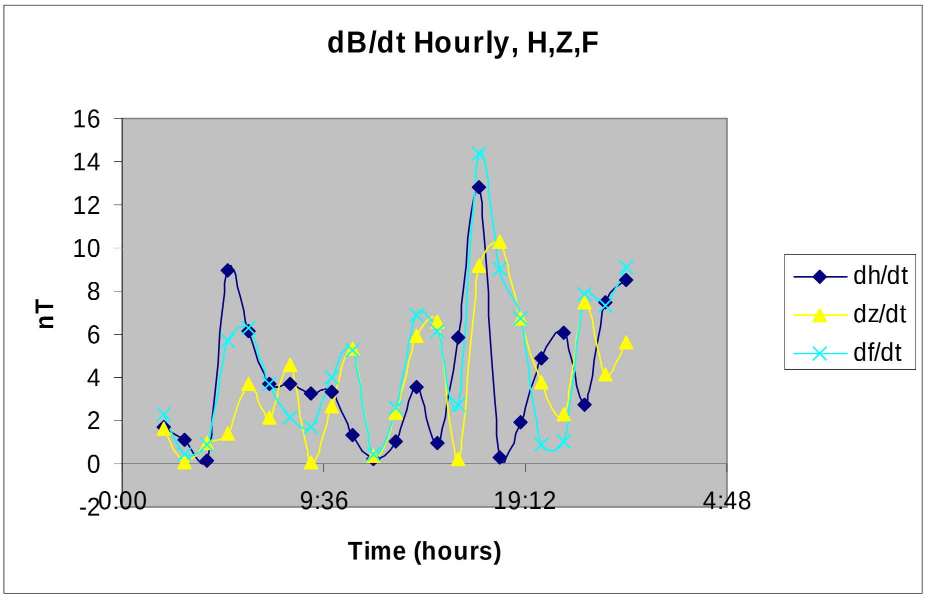



D
30
20
10
0
-10
-20
-30
-40
Declination (Minutes Arc)
0:00
4:48
9:36
14:24
19:12
0:00
4:48
Time (min)
LIGO
Newport
Del Rio
Fresno

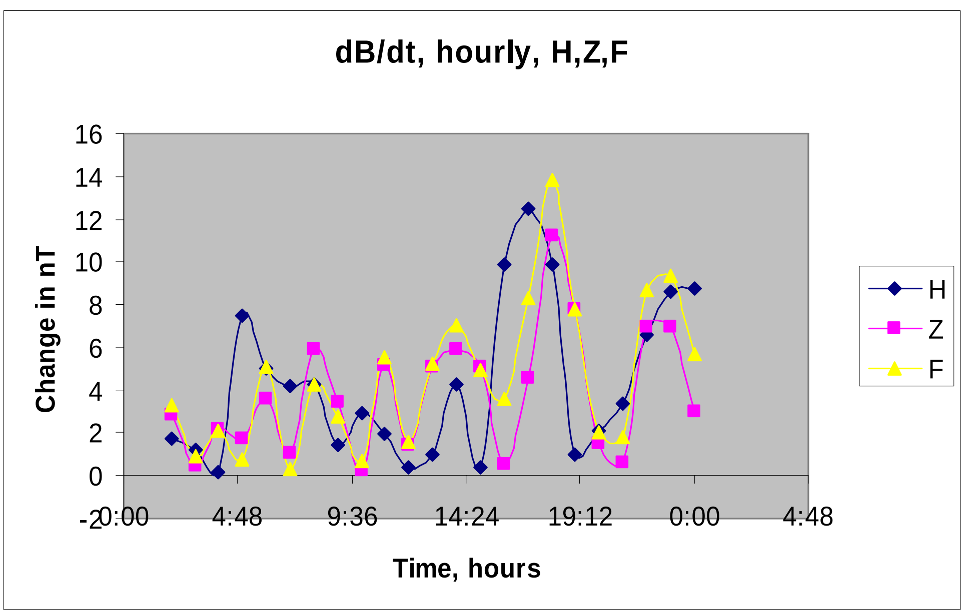

Z
50
30
10
-10
-30
-50
-70
Change in nT
0:00
4:48
9:36
14:24
19:12
0:00
4:48
Time (min)
LIGO
Newport
Del Rio
Fresno

Periodic Oscillations of magnetic flux:

It was found that the earth's magnetic field fluxes periodically at a rate of 1 cycle about every 3-4 hours. This periodicity was observed during solar quiet times and during the December 14, 2006 magnetic storm at multiple stations. Minute trends of magnetic strength from each station were processed into 1-hour rms values of magnetic flux by calculating the rms value of magnetic strength for each hour, then calculating the difference in magnetic strength from one hour to another.



This plot shows the magnetic flux at LHO on a solar quiet day, July 15, 2007. Note the periodicity of the magnetic flux at about 1 cycle every 3-4 hours



This plot shows a similar periodicity on the same date at the Newport station.

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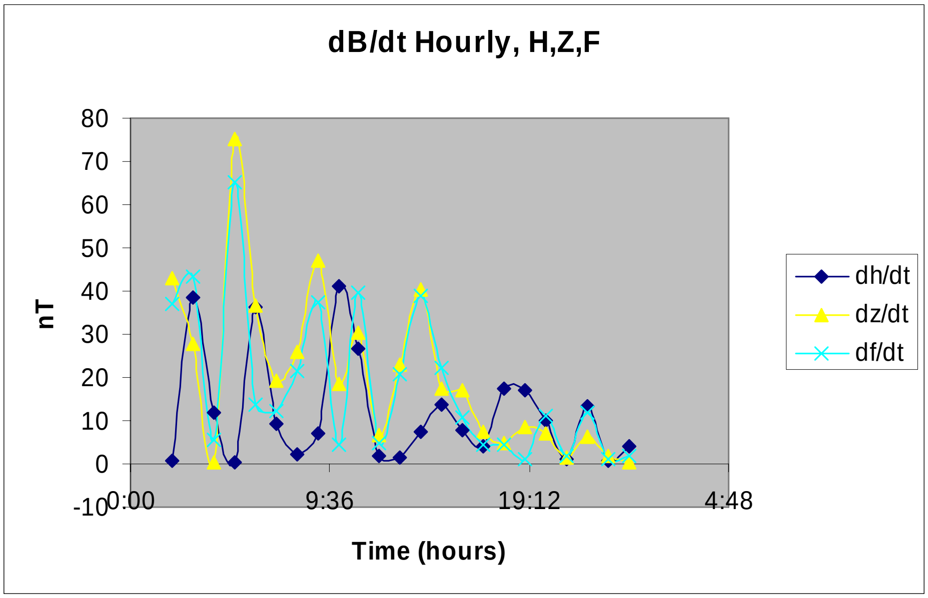
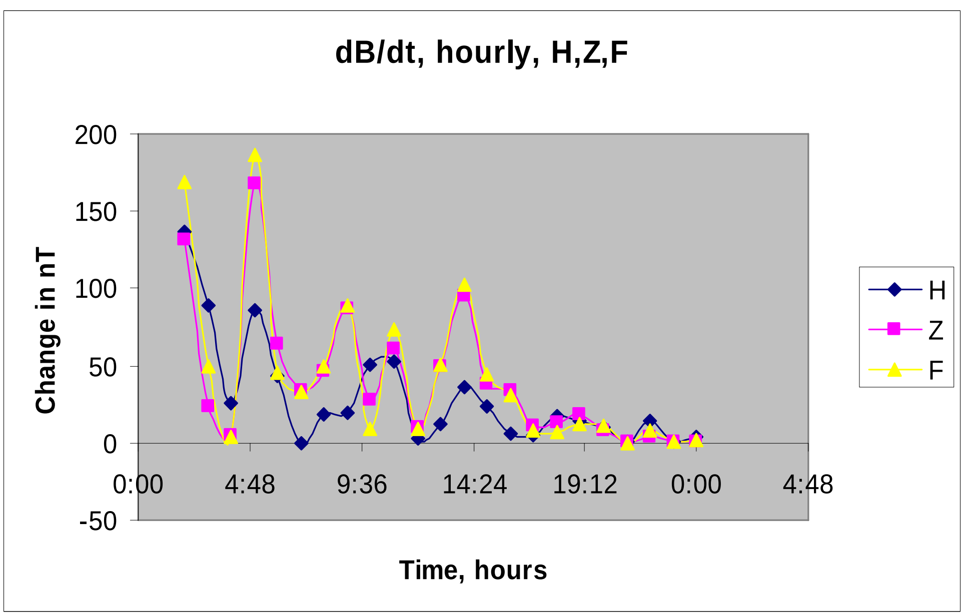


This plot shows the last half of the magnetic storm on December 15, 2006. Note a similar periodicity with a much greater magnitude.



This plot again shows the December 15 storm, but at the Newport station.