SEARCH FOR THE VARIATION IN SEISMIC NOISE DUE TO WIND AT AIGO WESTERN AUSTRALIA

Atul Kumar Singh

July 25 2007

ABSTRACT

This paper describes a study of wind induced seismic noise at the site proposed for a 5 km long baseline laser interferometer gravitational wave detector at AIGO, Gingin, WA.. The power spectral density was observed to increase by 10 fold as wind changes from 10 to 40 Km/hrs (10^{-9} m/sqrt(Hz) to 10^{-8} m/sqrt(Hz) at 10 Hz for east west seismic noise). We show that broadband seismic noise increases approximately to the cube of wind speed up to 50 Km/hrs in the frequency band 2-25 Hz. Below the wind speed of 20 Km/hrs there was no significant correlation between the wind speed and seismic vibration in the frequency band 2-25 Hz. It was found that correlation coefficient between power spectral density and wind speed increased from .2 to .7 when wind speed increased from 10 to 40 Km/hrs.

INTRODUCTION

Gravitational waves are the ripples in space-time. They travel with the speed of light but with very small amplitudes so they need very sensitive detector for their detection. Laser interferometric laboratories such as US LIGO situated in Livingston, Louisiana and Hanford Washington, VIRGO at Cascina in Italy, GEO at Hannover in Germany and Japanese project TAMA, are designed to sense gravitational waves from astrophysical sources. The AIGO site, which is the optimum location in southern hemisphere, proposed for a 5 Km long baseline detector is going to greatly improve angular resolution. AIGO site also has pure silica sand which is ideal for seismic wave attenuation. The site in located 90 km north of Perth city and is approx 20 km far from sea in the west. There are average size tree (4 meter approximately).

There are three main source of noise that affects the sensitivity of the detectors. They are Seismic noise, thermal noise and shot/quantum noise. Seismic Noise is due to vibration of earth crust and is present all over the earth surface. In the very low frequency band (0-1 Hz) they are caused by Ocean waves and tide[4]. In higher frequency band they are affected by human activity, vehicles, wind and machines located at work place.

Wind causes the buildings and trees to shake which contribute to the seismic noise. It was observed that the wind has a broadband effect in 2-25 Hz spectrum. The effect was more prominent in 2-11 Hz band.

EQUIPMENTS AND DATA ACQUISITION

For collecting the seismic data a Guralp CMG-6TD[2], 3-axis (north/south, east/west, vertical), broadband seismometer was used. The seismometer has a GPS time sensor. The seismometer was placed at the corner of the Main Lab Building. The data was collected by Scream 4.3 software at the rate of 50 samples per second for all the 3-axis of vibration in .gcf format.

The wind speed was collected using Heavy Weather Pro-3600[3] software, which collects the data from the weather sensors, fitted on the roof of the main building through the weather station. The weather data was collected with one sample every minute. GMT time was also used for recording the wind data. It was observed that wind is usually high during the day and low during the night at AIGO, Gingin around June, July which created difficulty in separating the human activity and wind induced seismic noises.

The seismic noises due to instruments at AIGO [1] are

1. Main Lab Air conditioner - 11.2, 11.6, 16.8, 22.4, 12.3, 13.6, 17.5, 21 Hz.
2. Meeting Room Air conditioner - 15.4 Hz.
3. Vacuum Pump - 24.1, 20.2 Hz.
4. Hepa Filters 18.5±0.5 Hz.
5. Main Lab Air compressor – 11.1, 16.7, 22.2 Hz.

The data was analysed in the following way

1. The wind data was first analysed and plotted and then the sections of low (<10 Km/hrs) and medium (>20 Km/hrs) wind were identified.
2. The high wind (>40 Km/hrs) was also observed during extreme weather condition on July 2 ,2007.
3. The seismic data during low, medium and high wind was separated and Velocity Power spectral (m^2/s^2/Hz was performed using Welch method.
4. The velocity power spectral density was converted to power spectral density units (m/sqrt (Hz)).
5. For finding the correlation the following steps were involved
    1. For every 10 minute interval Welch PSD (m/sqrt(Hz)) plot was made.
    2. The frequency band was divided into intervals of 1 Hz each.
    3. For every PSD plot the average power spectral density was found for every frequency band.
    4. The average wind speed was calculated over the same 10 min.
    5. Then in different frequency band the average PSD and the average wind speed was plotted & correlated.

RESULTS AND INTERPRETATION

The power spectral density plots of the seismic noise for the east-west, north-south and vertical axis of vibration are plotted in Figure1 (a), Figure1 (b) & Figure1 (c) respectively. The whole spectrum (1-25 Hz) shifts upward as the wind speed increases. As the wind increased from 10 to 40 Km/hrs the velocity PSD has gone up by more than a factor of 10 in all direction of vibration. The frequency band 2-10 Hz has more increase in velocity PSD than the 13-25 Hz band. The strange part of PSD spectrum near 12 Hz is due to the seismic noise created due to the Main lab Air conditioner and Air compressor.

The microseismic peaks were also observed to go high during the extreme weather condition. This is due to the large oceanic waves during that time.

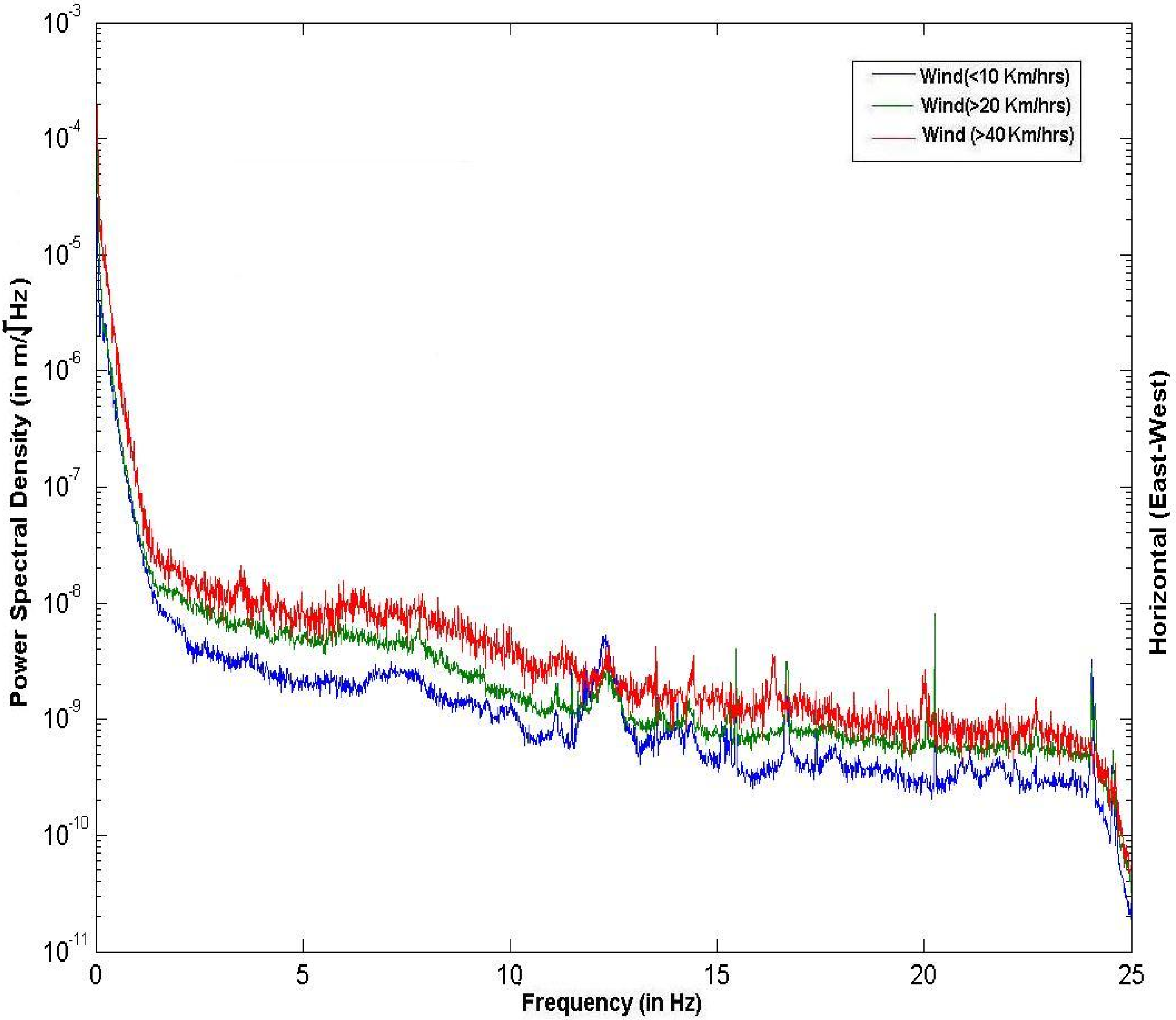


Figure 1(a) Power spectral density for the horizontal (East West Seismic noise).The red curve is PSD for high wind on July 2 (0320 to 0820 Hrs (GMT)) when average wind speed was greater than 40 Km/hrs. The green curve is for medium wind (>20 Km/hrs) and blue curve is for low wind (<10 Km/hrs) collected from different time intervals between June 1, 2007 and June 13, 2007. Notice the increase in PSD as Wind speed increases.

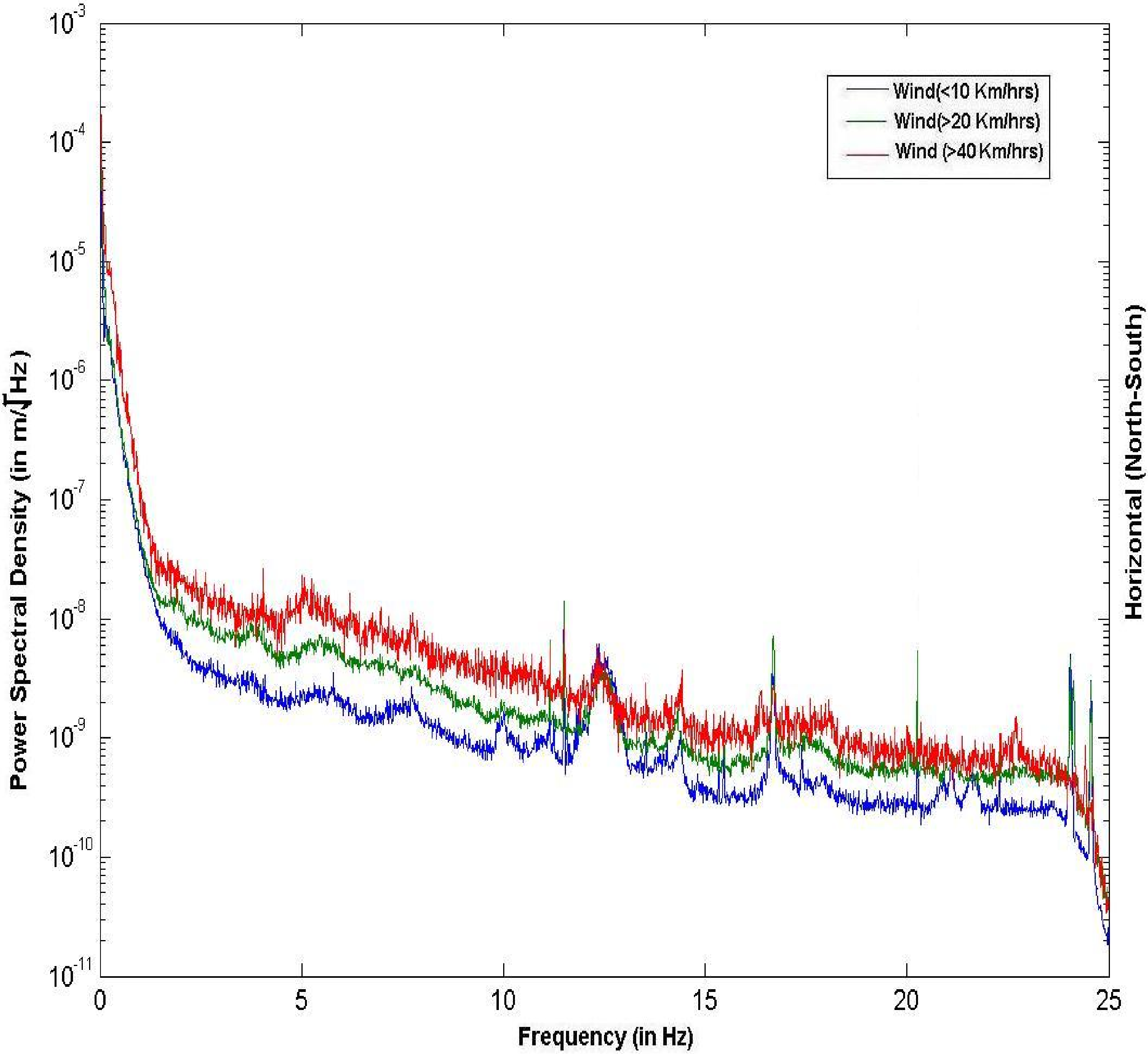


Figure 1(b) Power spectral density for the horizontal (North South Seismic noise) for data during same time period as in Fig 1(a).Notice the increase in PSD spectrum in 2-10 Hz band is more compared to 13-25 Hz band.

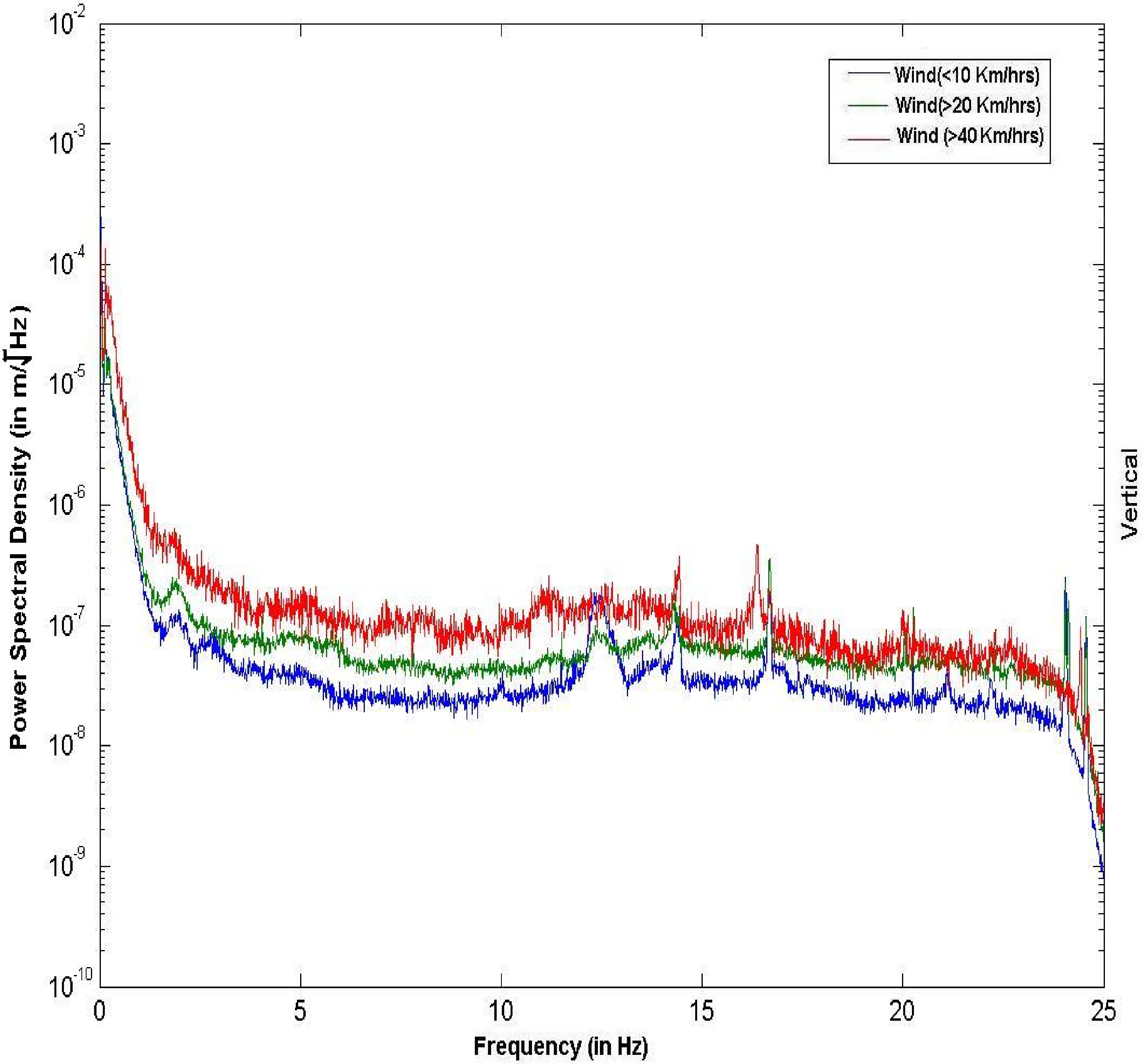
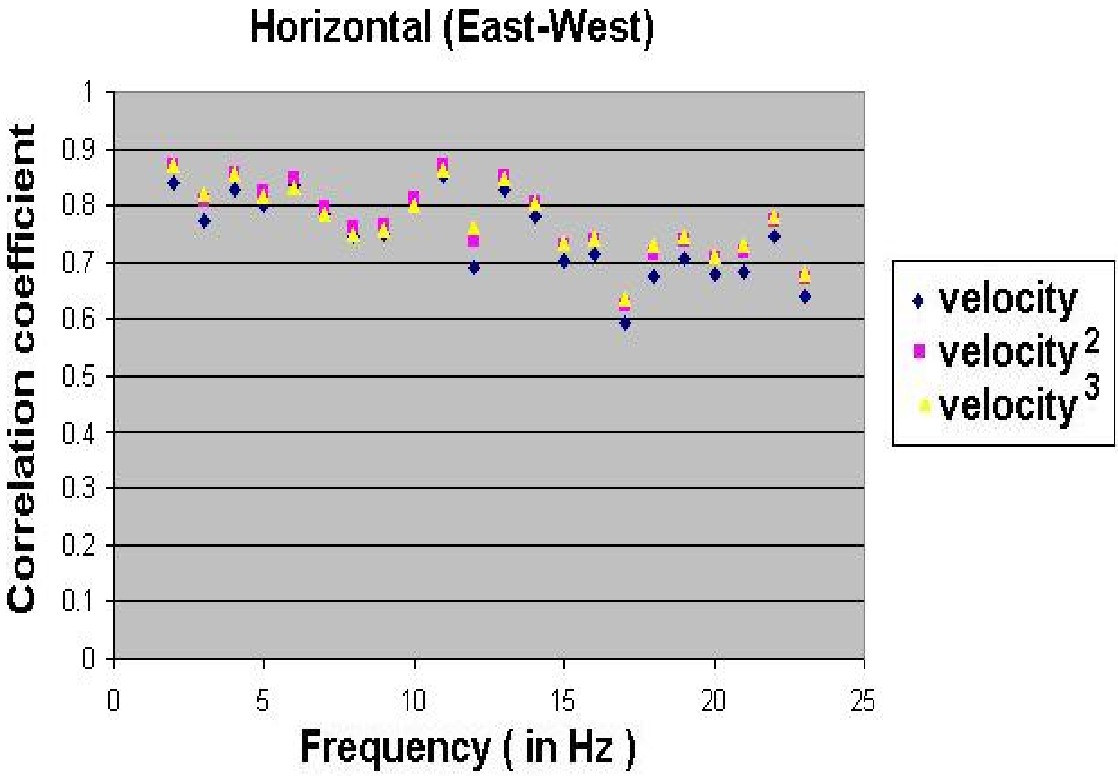
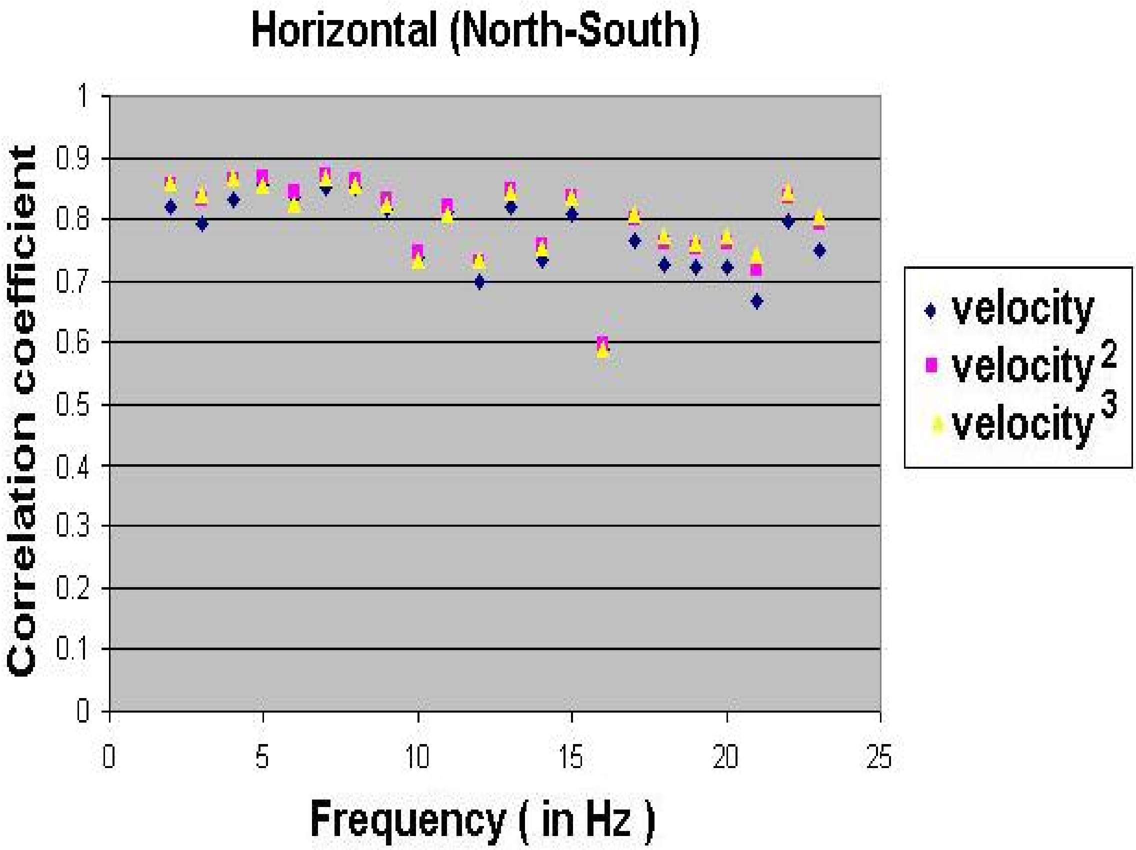


Figure 1(c) Power spectral density for the vertical Seismic noise for data during same time period as in Fig 1(a). Notice that the vertical noise is larger compared to horizontal noises. Also the vertical seismic noise is same for most part of the spectrum (5-23 Hz). However the increase in PSD spectrum in 2-10 Hz band is more compared to 13-25 Hz band.


Horizontal (East-West)
Correlation coefficient
Frequency (in Hz)
velocity
velocity 2
velocity 3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25


Horizontal (North-South)
Correlation coefficient
Frequency (in Hz)
velocity
velocity 2
velocity 3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25

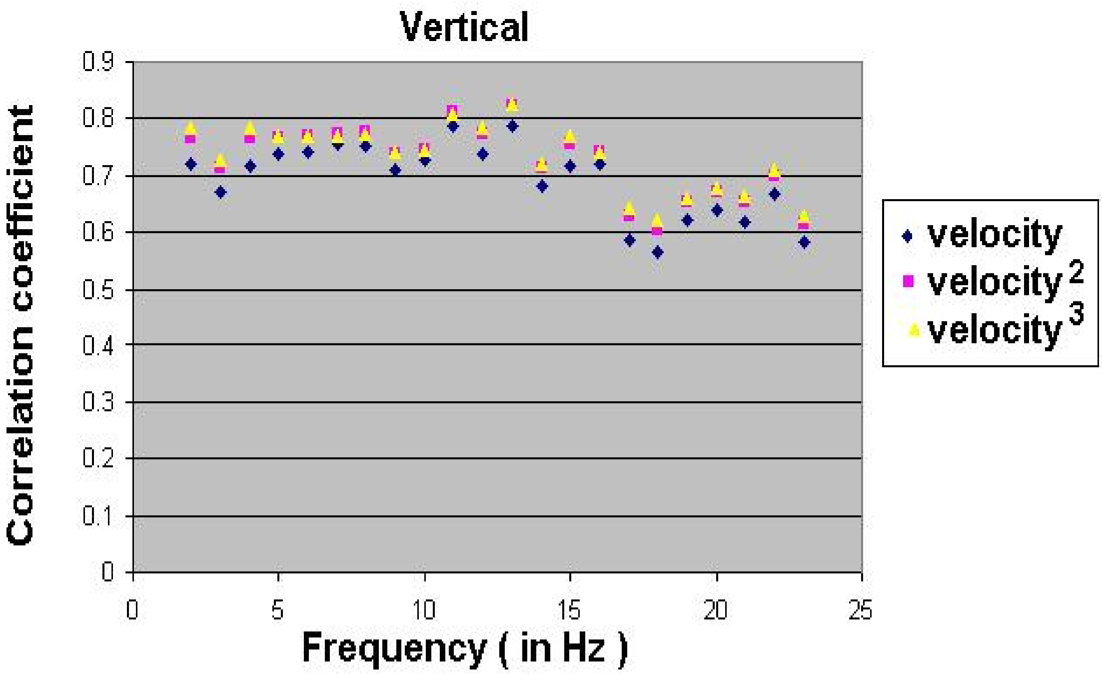


Figure 2.The correlation coefficients plotted between wind speed and power spectrum density in different frequency band for the data on July 2 (extreme weather). Notice that the east-west and north-south have larger correlation coefficient than vertical seismic noise.
Also note that the correlation coefficients have higher values in the frequency band 2-9 Hz. The blue, pink and the yellow colour represent the correlation coefficients calculated with wind velocity, velocity^2 and velocity^3 respectively.
Note that correlation is better with the velocity^2 and velocity^3 as compared to velocity.

The correlation coefficients were calculated for the data on July 2, 2007. The north south, east west direction of vibration was found to have larger values of the correlation coefficients as compared to vertical direction. It was also noted that the correlation coefficients were more in the frequency band (2-8 Hz) as can be seen in Figure 2.The correlations were observed to be maximum with the wind velocity (either square or cube).

For each direction of vibration the maximum correlation in a frequency band was found to be

1 East West (2-3 Hz)- 0.87011 (velocity^3)
2 North South (7-8 Hz) – 0.87258 (velocity^2)
3 Vertical (13-14 Hz) -0.82593 (velocity^3)

Each of these was plotted in Figure 3(a), Figure 3 (b), Figure 3(c) respectively. The low wind data in these plots was on from data on June 9, 2007.

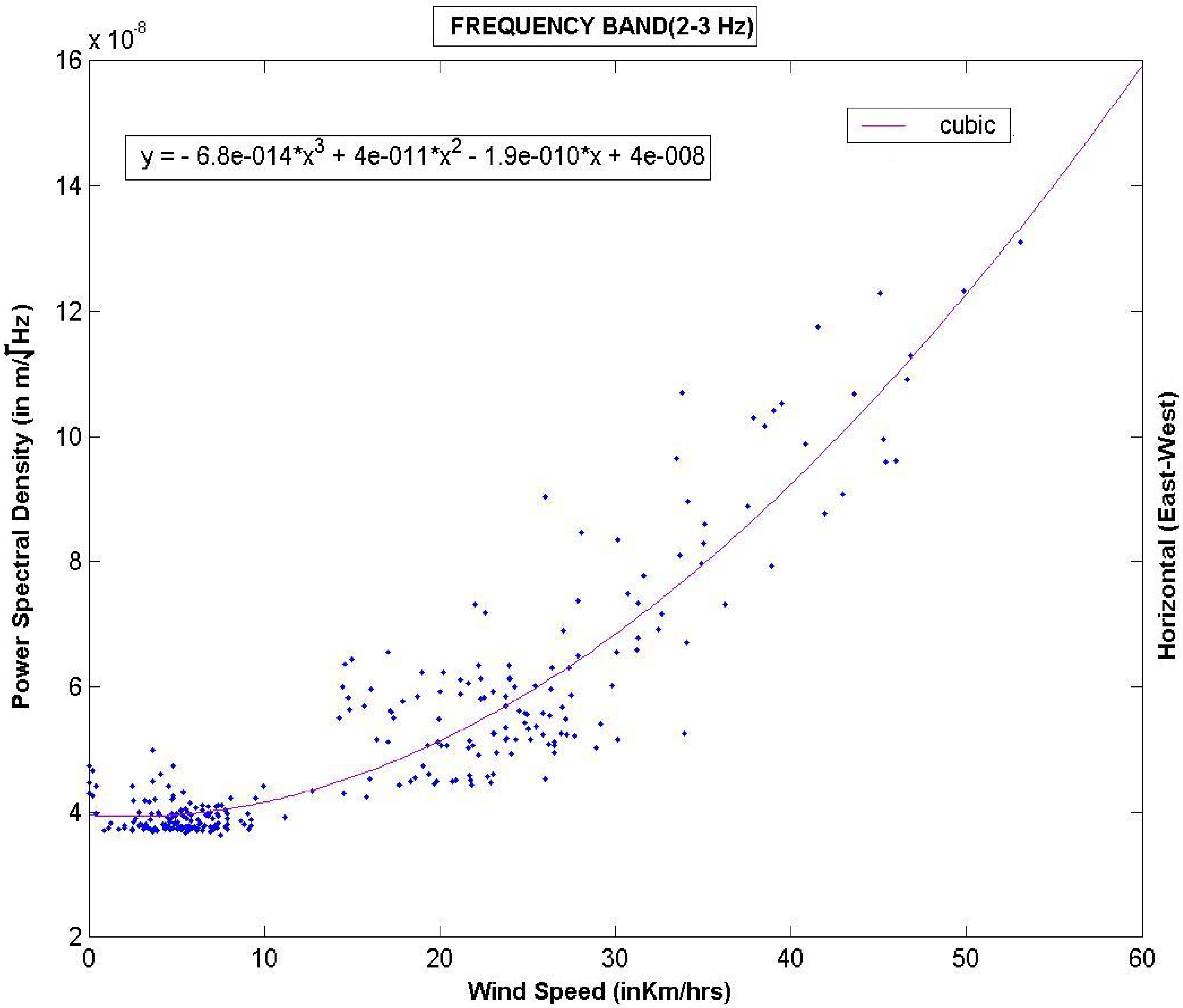


Figure 3(a). Power spectral density plotted against wind speed in Frequency band 2-3 Hz for the east west seismic noise. The data used are on June 9 (for low wind) and July 2(for high wind). Notice the cubic increase in the PSD as a function of wind.

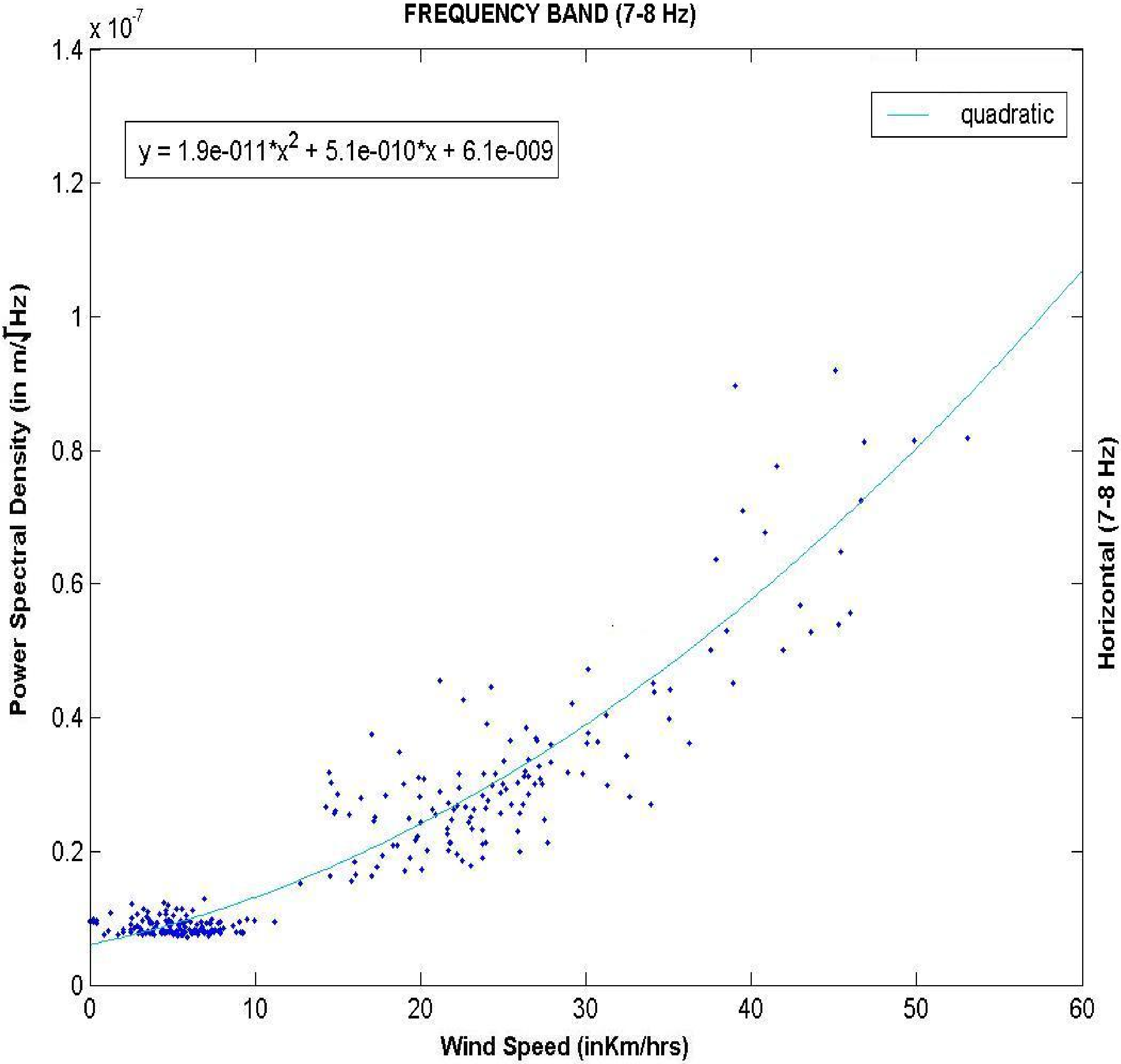


Figure 3(b).Velocity power spectral density plotted against wind speed in Frequency band 7-8 Hz for the north-south seismic noise. The data used are for the same time period as in Fig 3(a). Notice the quadratic increase in the PSD as a function of wind speed

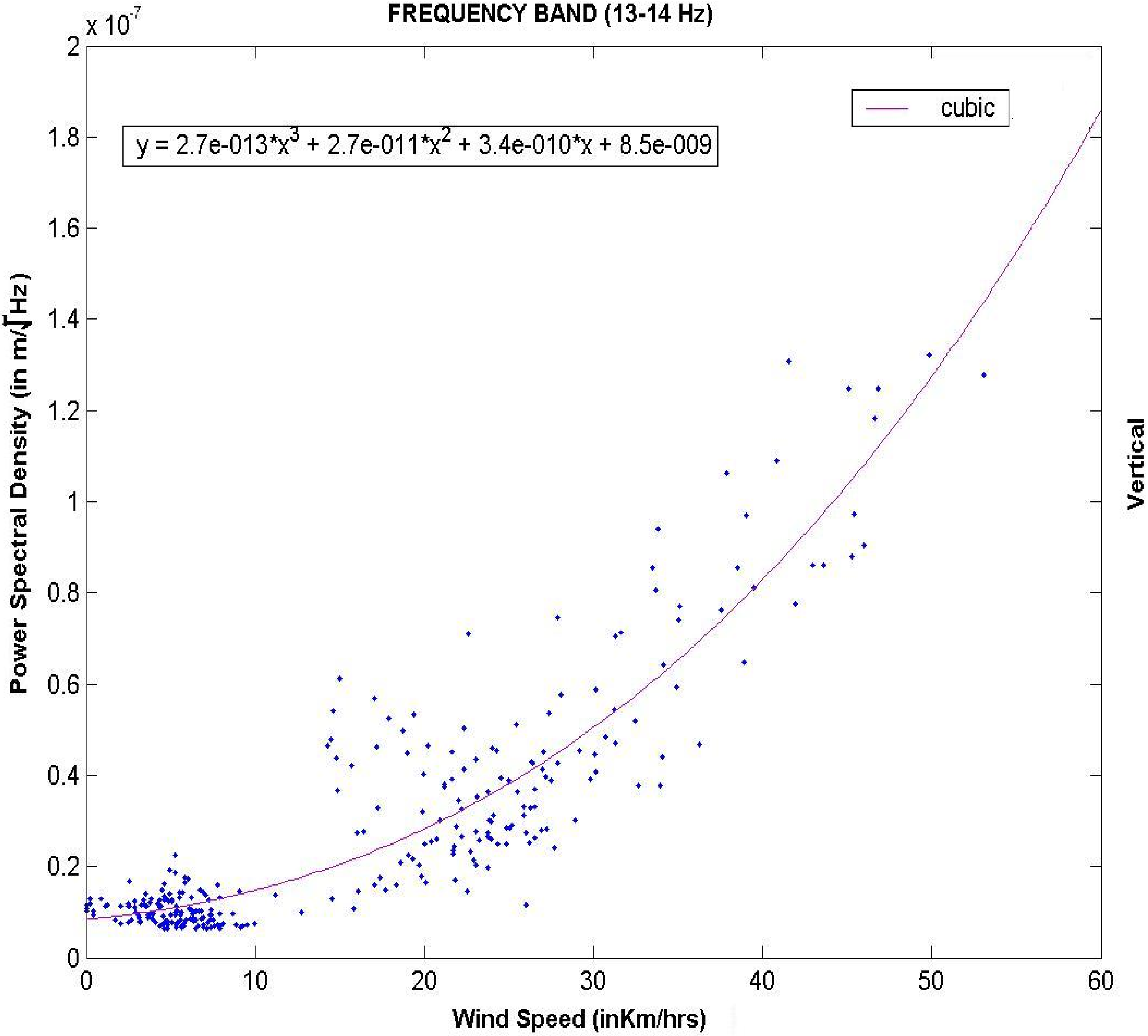


Figure 3(c). Power spectral density plotted against wind speed in Frequency band 13-14 Hz for the vertical seismic noise. The data used are for the same time period as in Fig 3(a). Notice the cubic increase in the PSD as a function of wind speed.

ACKNOWLEDGMENTS

I would like to thanks Prof. David Blair for being a great mentor. I would also like to thank Dr Juli, Dr. Zhao Chunnong and Dr. David Coward for their continuos help through out the project. I would also like to thank AIGO for funding me on this project and for making this opportunity possible for me.

CONCLUSION

The study concluded that wind is really important considering the seismic noise at AIGO Gingin, WA. The wind here caused almost a 10 fold increase in the PSD of seismic noise for all the direction in the total frequency band (2-25 Hz) studied. The effect was most prominent in the frequency band (2-10 Hz).The correlation between the wind and seismic noise was found increase from 0.2 to 0.7 approximately with the change in wind speed from 10 to 40 Km/hrs for the entire frequency band except where instrumental noise were present. The PSD was found to increase cubically or quadratic ally with the wind speed in most frequency band between (2-24 Hz).

REFERENCES:

1. Janni Gorham seismic report on Equipment noises at AIGO (http://www.gravity.uwa.edu.au/docs/presentations/Janni_seismic_report.pdf)
2. Guralp Broadband Seismometer 6TD (http://www.guralp.net/products/6TD/)
3. Heavy weather software (www.heavyweather.info).
4. Turner J., 2005, A Study of Micro-seismic Noise at the Australian Gravitational Observatory.