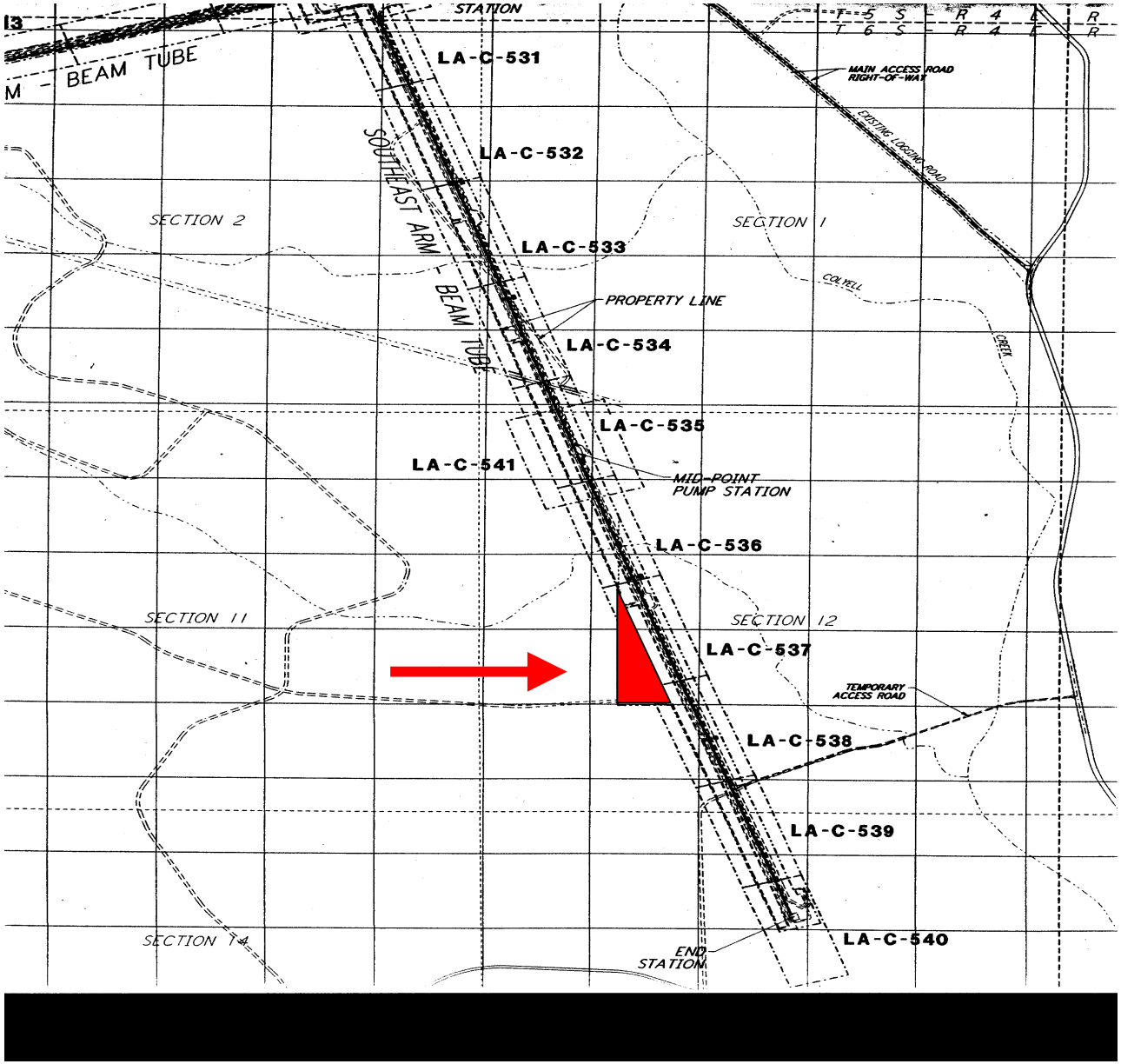
Seismic Measurements at LLO

LIGO-G010338-00-Z

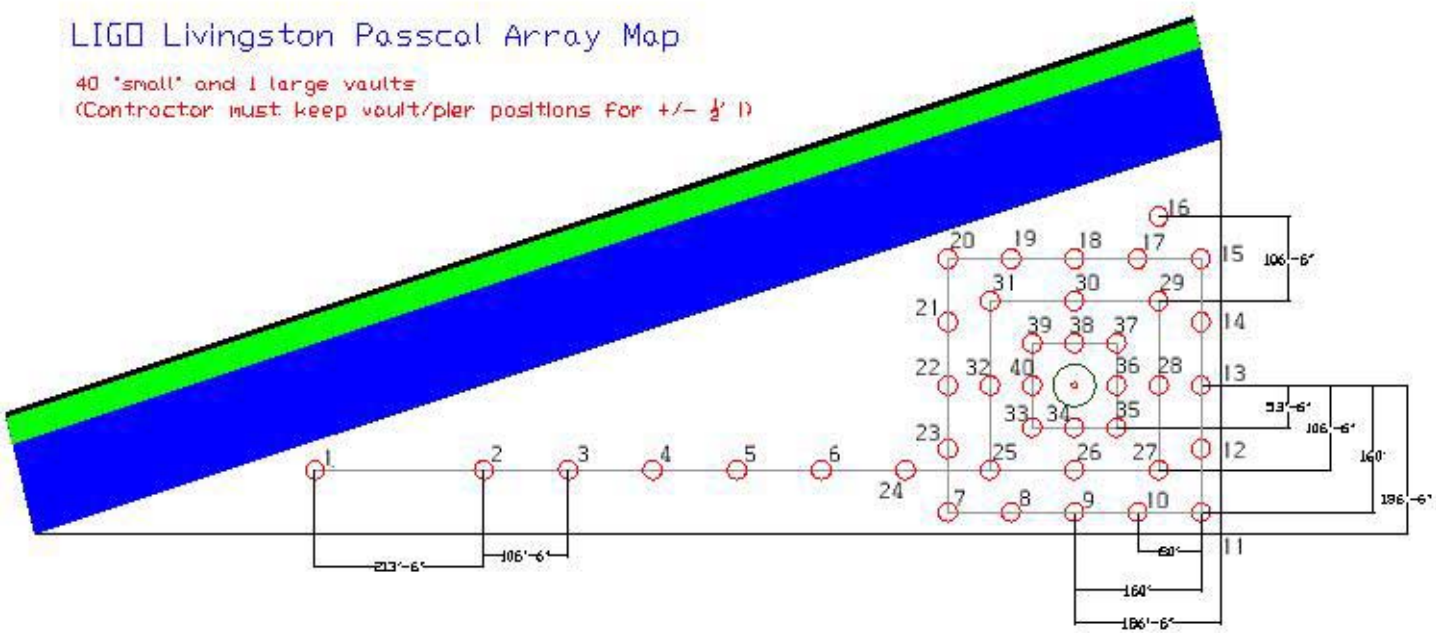
- Dick Greenwood
- Neven Simicevic
- Clay Westbrook
- Nathan Scott
- Mark Coles
- Szabi Marka

Recent Analyses (Greenwood, Westbrook, Scott)

- Investigation of dominant noise bands seen in E3 and E4.
  - 1-3 Hz
  - 5 Hz
  - 10 Hz
- Analysis of appropriate array data taken earlier this year.
- Also data from Summer, 1999.


STATION
BEAM TUBE
LA-C-531
LA-C-532
SOUTHEAST ARM - BEAM TUBE
SECTION 2
LA-C-533
SECTION 1
PROPERTY LINE
LA-C-534
LA-C-535
LA-C-541
MID-POINT PUMP STATION
LA-C-536
SECTION 11
SECTION 12
LA-C-537
TEMPORARY ACCESS ROAD
LA-C-538
LA-C-539
SECTION 14
LA-C-540
END STATION
MAIN ACCESS ROAD RIGHT-OF-WAY
EXISTING LOADING ROAD
COLVILL
CREEK

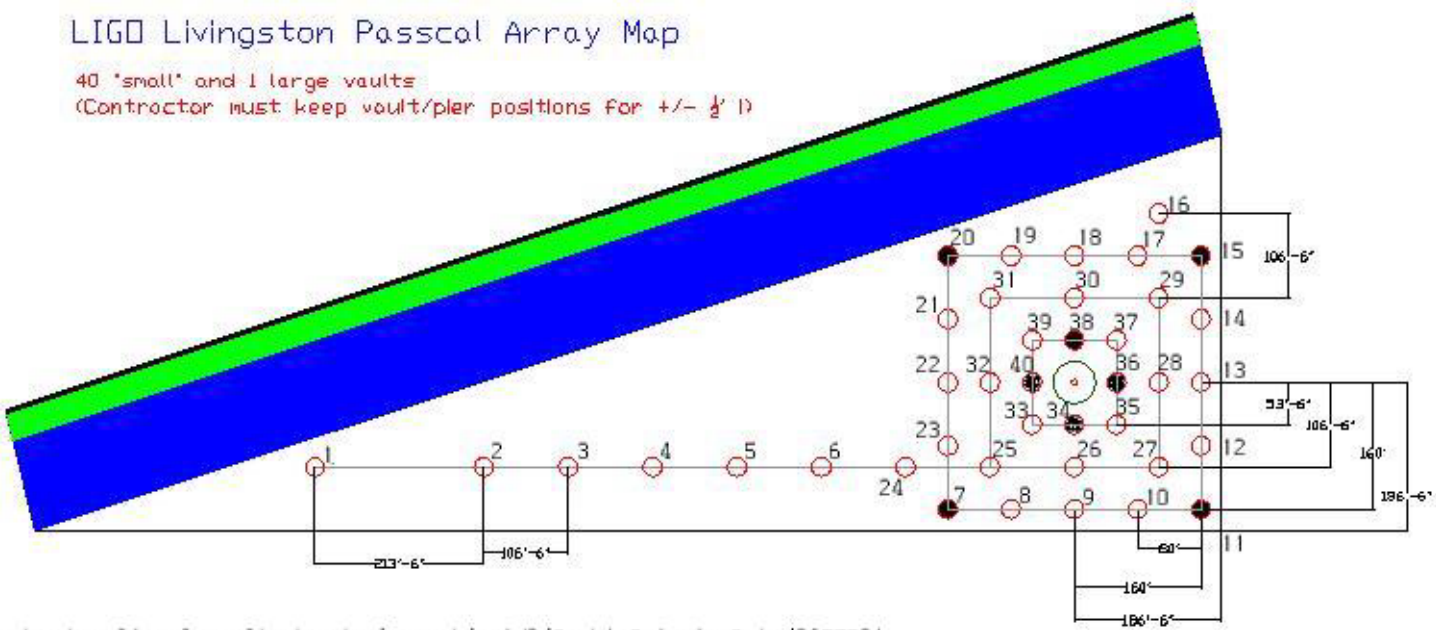
Choose sub-array where 3 sensors are close as possible (~30 m here)



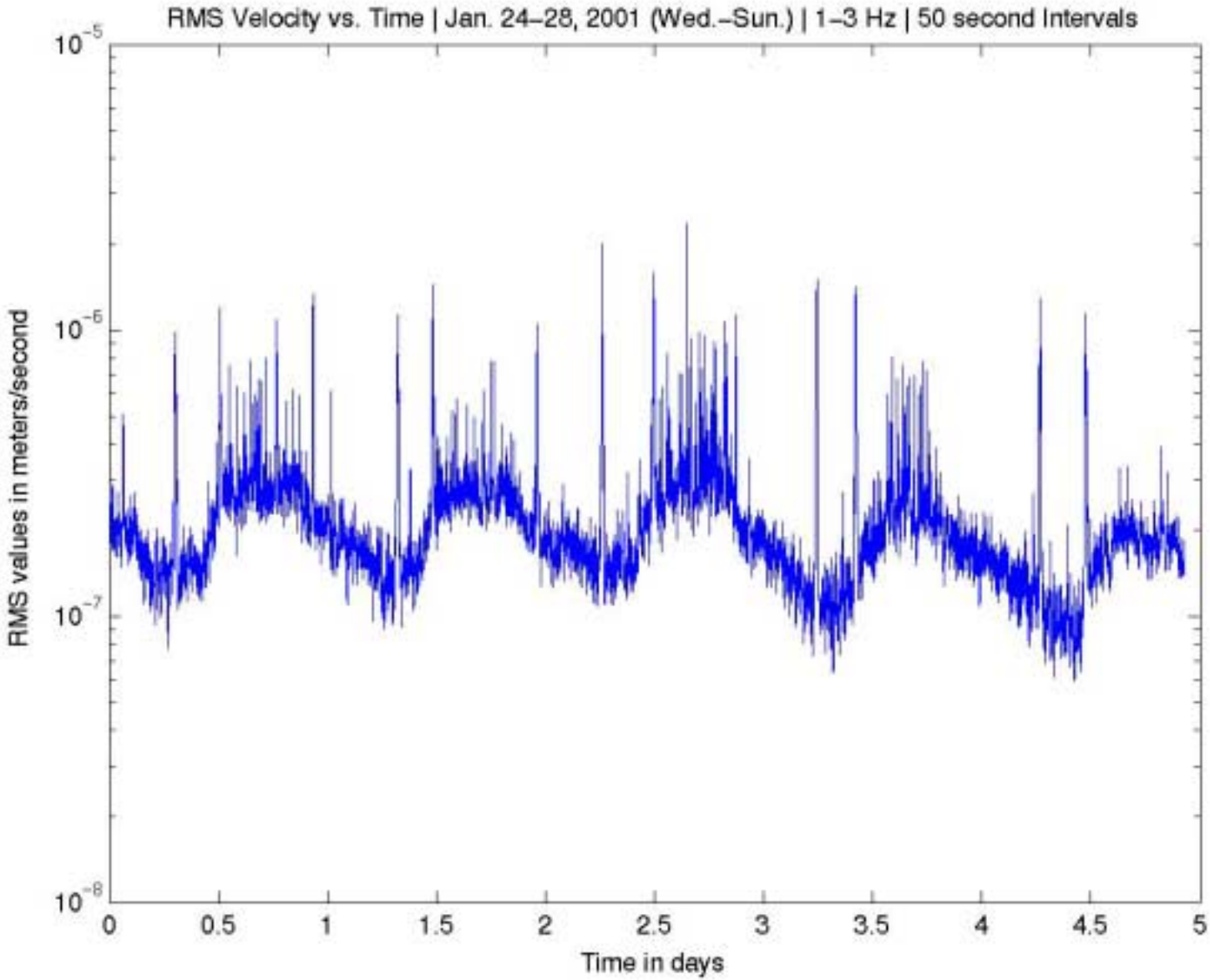
Choose sub-array where 3 sensors are close as possible (~30 m here)

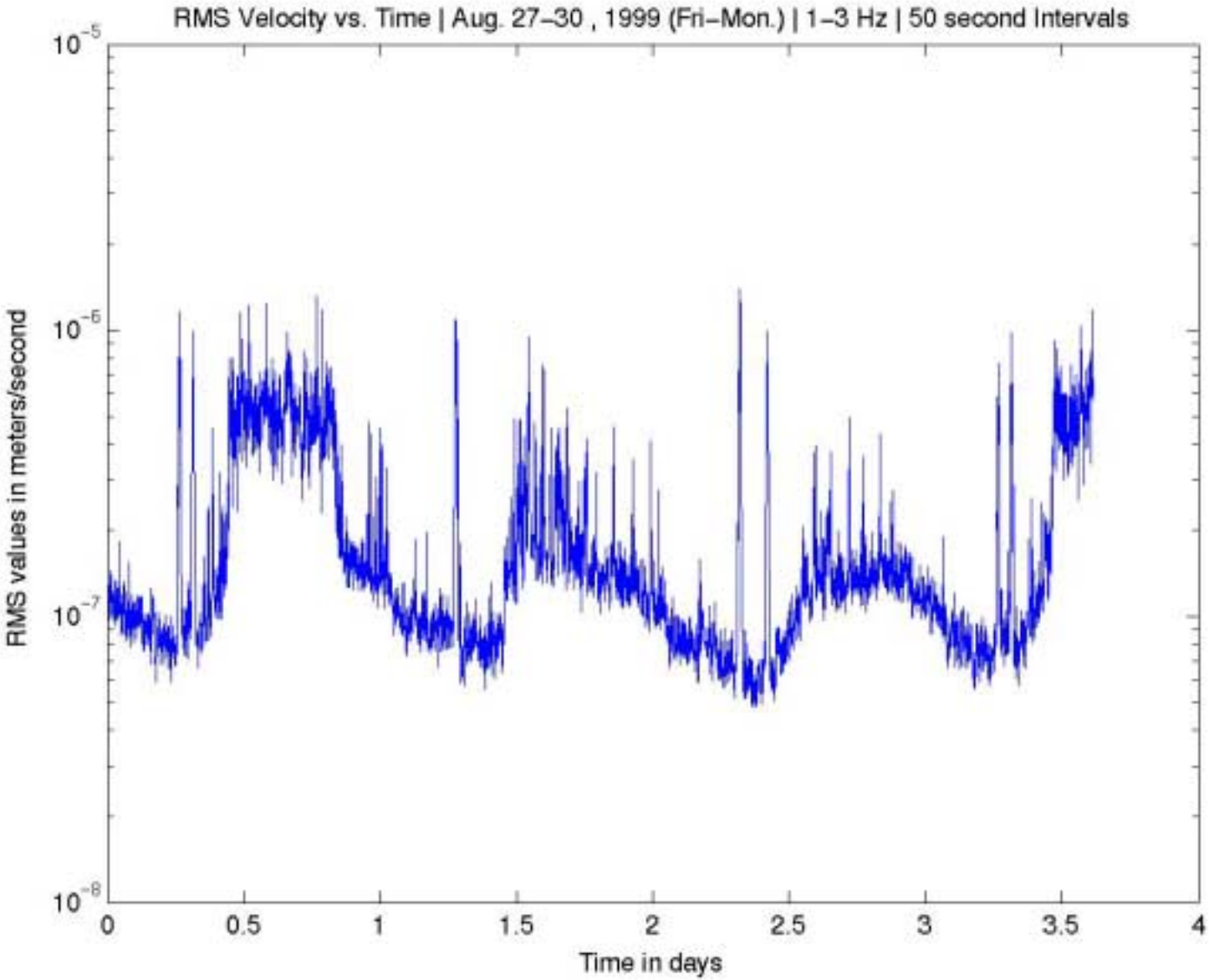
Array2_LLO_Seismic.ps
This data was 'dumped' on 26FEB01

DAS#:	Vault#:	DAS#:	Vault#:
7343	20	7454	40
7348	7	7296	34
7447	11	7444	36
7333	15		



decatur.ligo-la.caltech.edu:/export/raid0/Szabi_Seismic_Data/26FEB01


RMS Velocity vs. Time | Jan. 24–28, 2001 (Wed.–Sun.) | 1–3 Hz | 50 second Intervals
RMS values in meters/second
Time in days
10^-5
10^-6
10^-7
10^-8
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


RMS Velocity vs. Time | Aug. 27–30 , 1999 (Fri–Mon.) | 1–3 Hz | 50 second Intervals
RMS values in meters/second
Time in days
10^-5
10^-6
10^-7
10^-8
0
0.5
1
1.5
2
2.5
3
3.5
4

Wavenumber Analysis for the Frequency Band 1 - 3 Hz

- Use Seismic Analysis Code (SAC) macro BBFK to perform Maximum Likelihood Method estimations of seismic wave power density spectra for an array of sensors.
- The combined power of all the sensors during a time interval is contoured on a 2-D wavenumber plane.
- The wavenumber corresponding to the peak power on the plane yields a direction of approach and velocity.

MLM

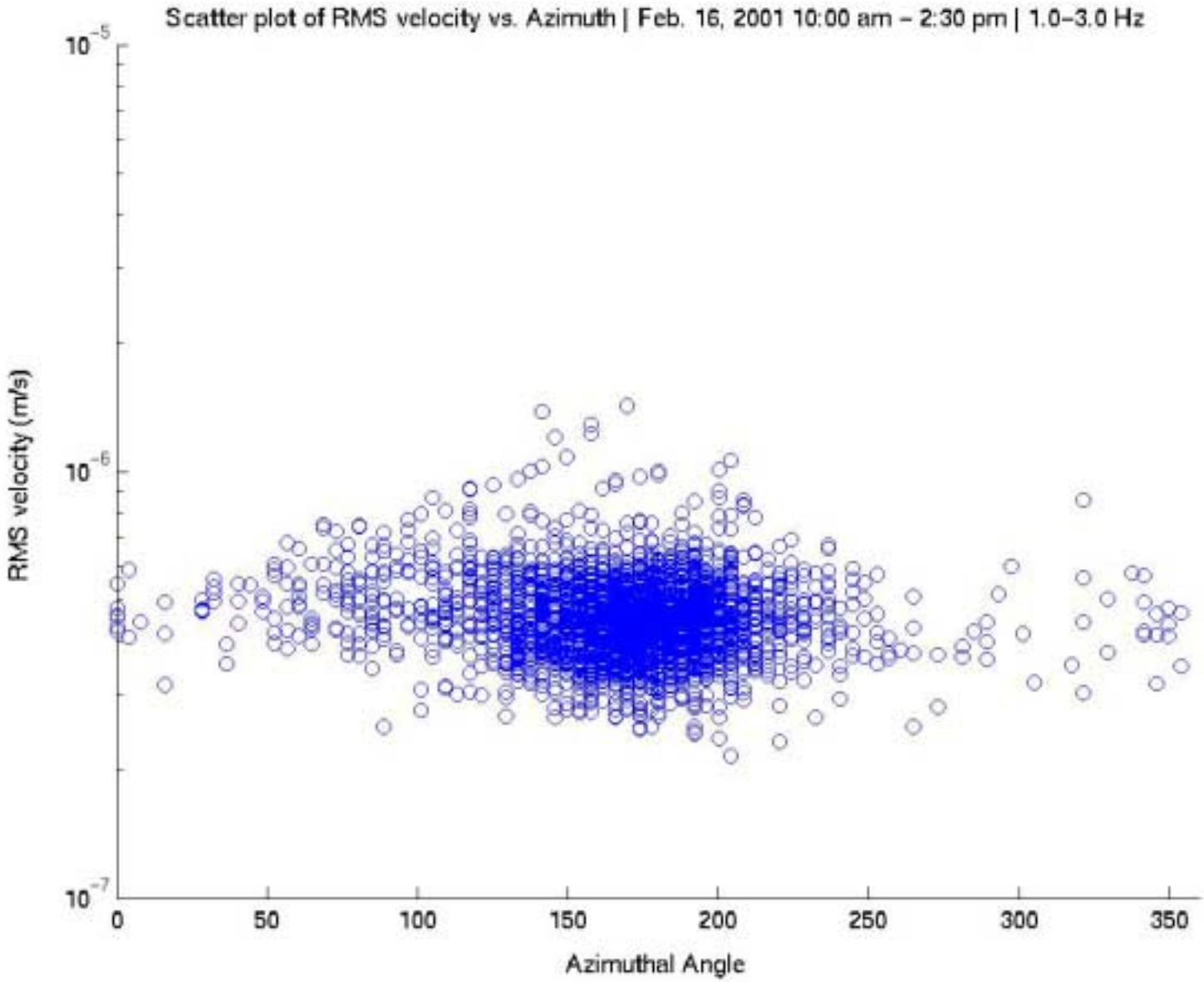
- **The MLM estimator generates a spectral estimate which is the power output of a bank of narrow band pass filters which have been optimized to reject out-of-band power.**

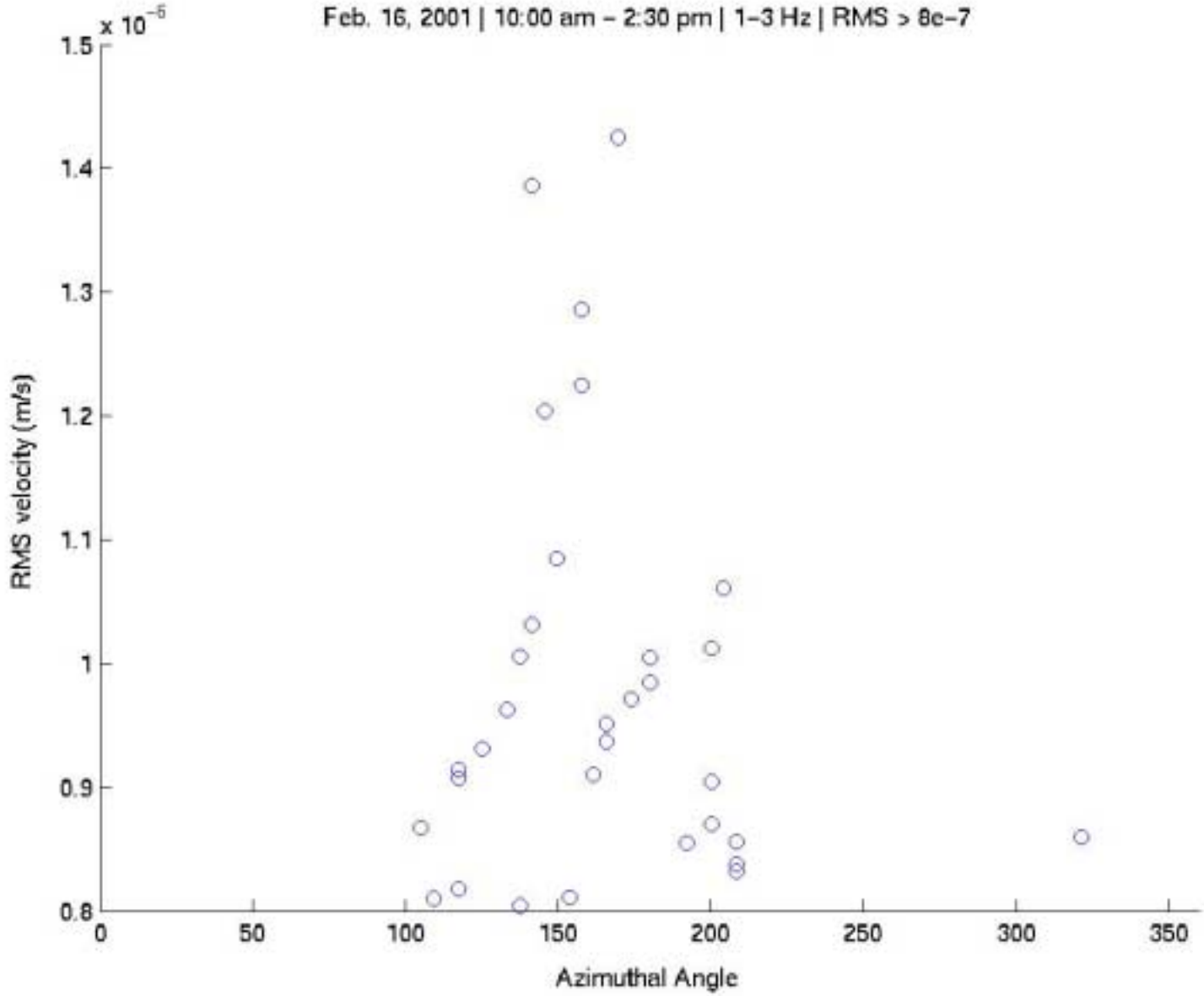
- **The result is a smoothed, parametric estimate of the power density spectrum.**

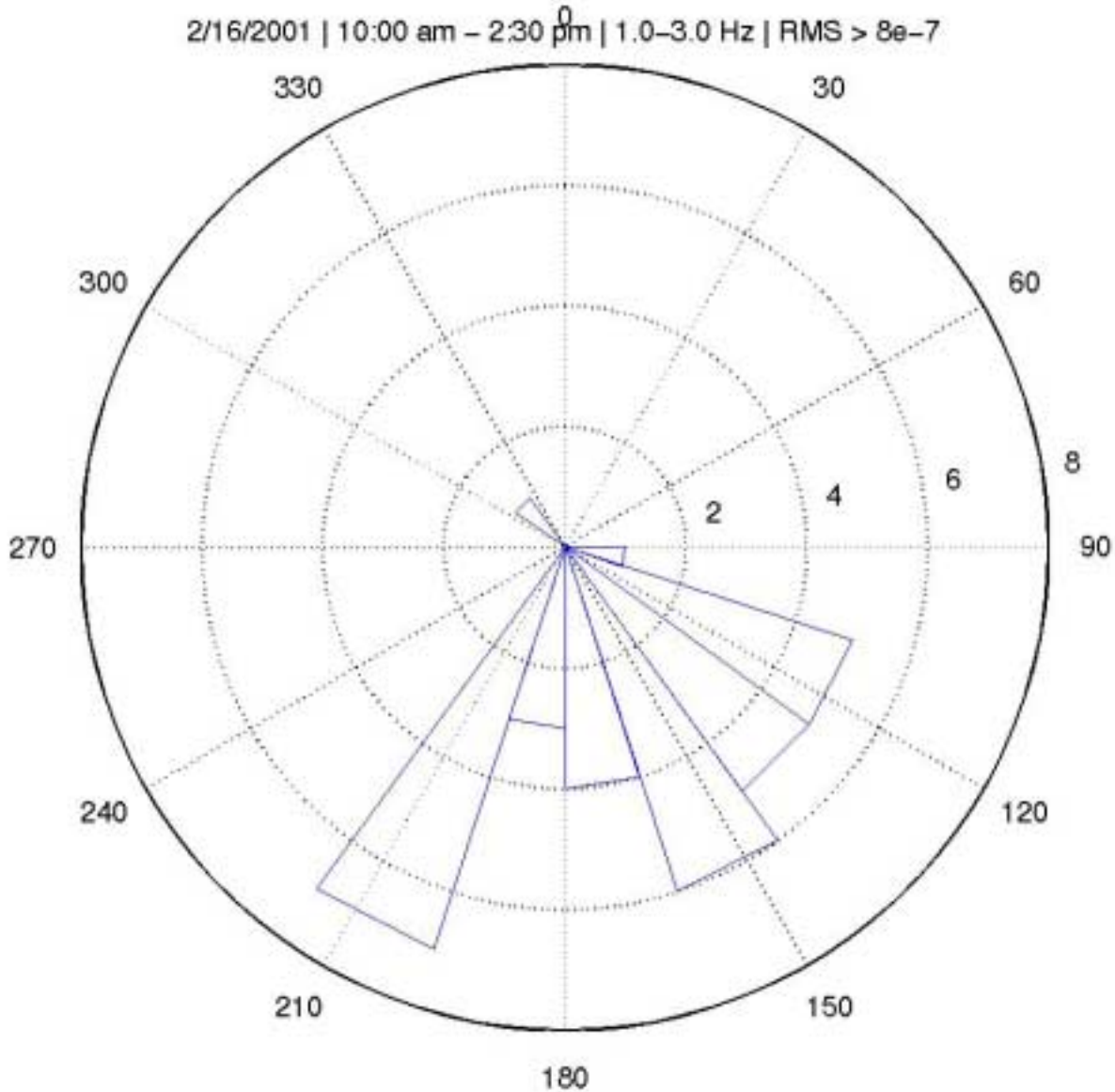
- **Documentation for this method can be found in the paper by Richard Lacoss in the IEEE book ``Modern Spectrum Analysis'' by Donald Childers.**

BBFK (continued)

- input: sensor output, sensor latitude, longitude, time, delT, frequency band
- analysis: projects the power of the combined signals of all the array sensors onto a 2-D wavenumber plane
- Output: backazimuth angle, spectral amplitude, wavenumber corresponding to the peak power amplitude during delT.


Scatter plot of RMS velocity vs. Azimuth | Feb. 16, 2001 10:00 am – 2:30 pm | 1.0–3.0 Hz
RMS velocity (m/s)
10^-5
10^-6
10^-7
0
50
100
150
200
250
300
350
Azimuthal Angle

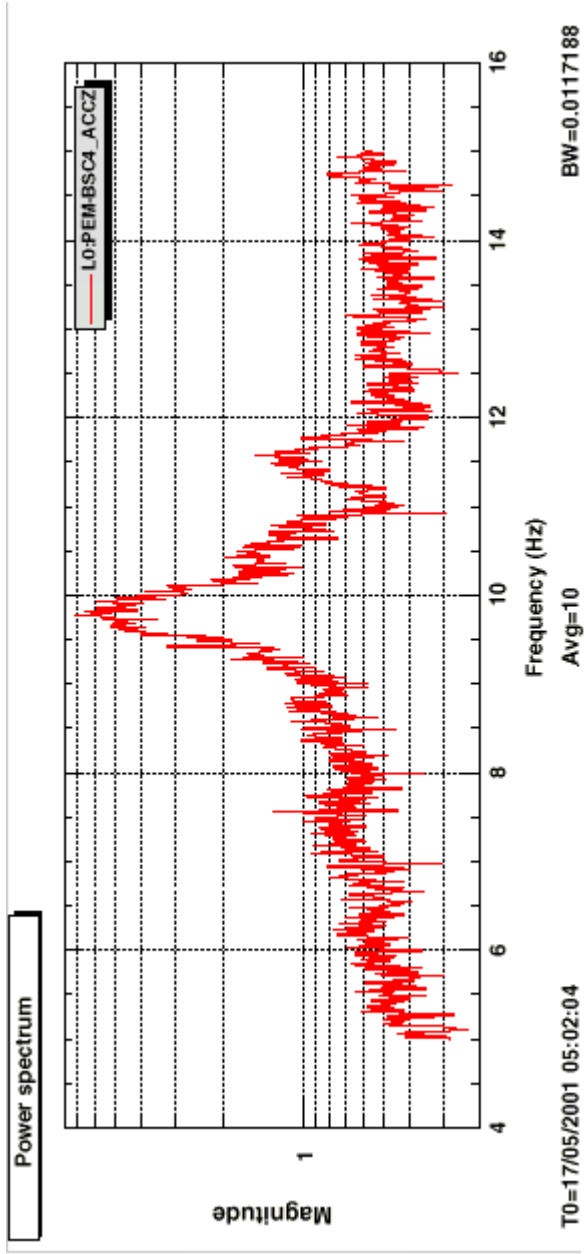

Feb. 16, 2001 | 10:00 am – 2:30 pm | 1–3 Hz | RMS > 8e–7
x 10^-5
RMS velocity (m/s)
Azimuthal Angle
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0
50
100
150
200
250
300
350


2/16/2001 | 10:00 am – 2:30 pm | 1.0–3.0 Hz | RMS > 8e–7
0
30
60
90
120
150
180
210
240
270
300
330
2
4
6
8

Next look at 5Hz & 10 Hz

Here is a power spectrum of data from the LLO PEM ACC on EX during E4-

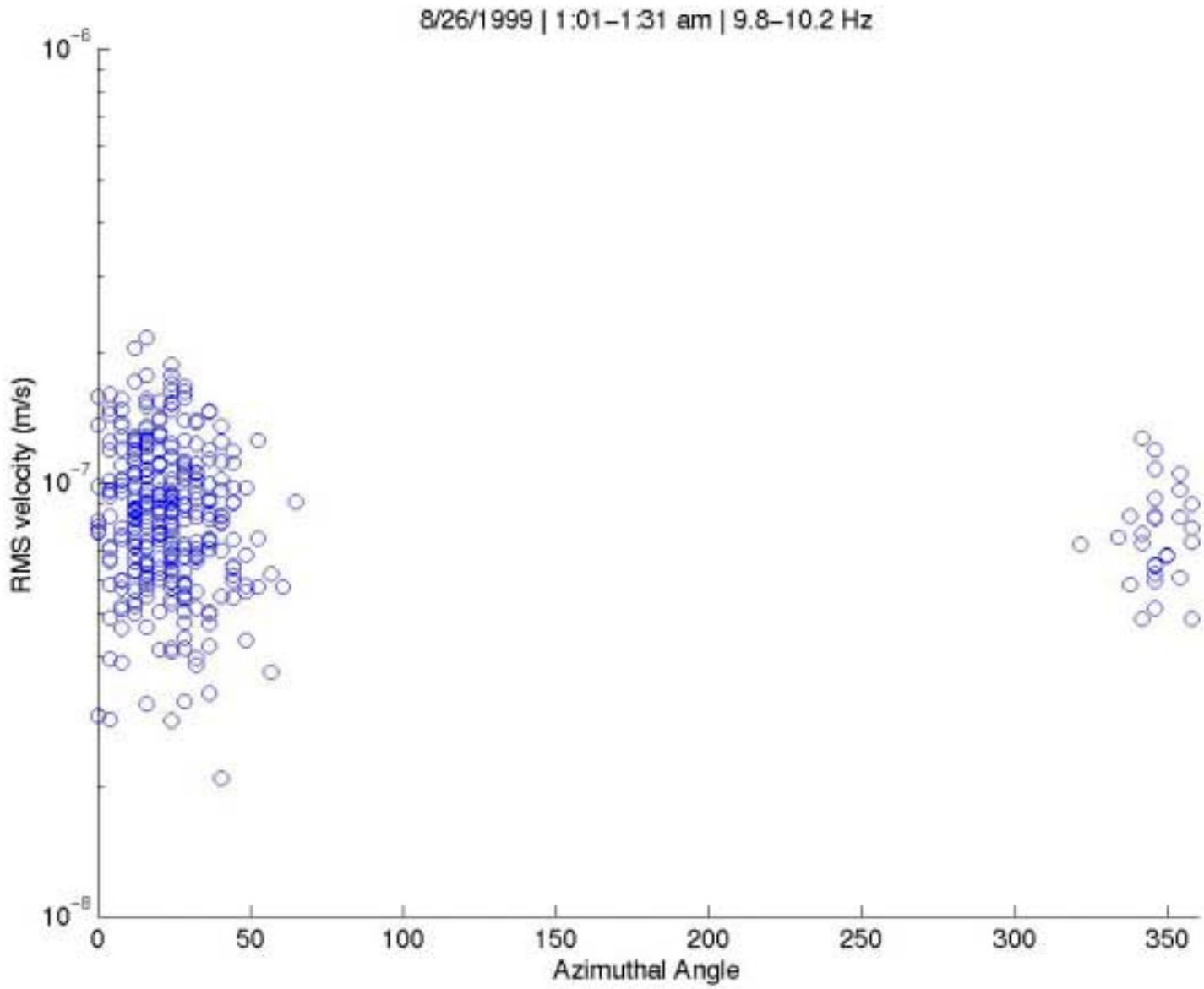
Puzzle: such excursions are not seen on EY.

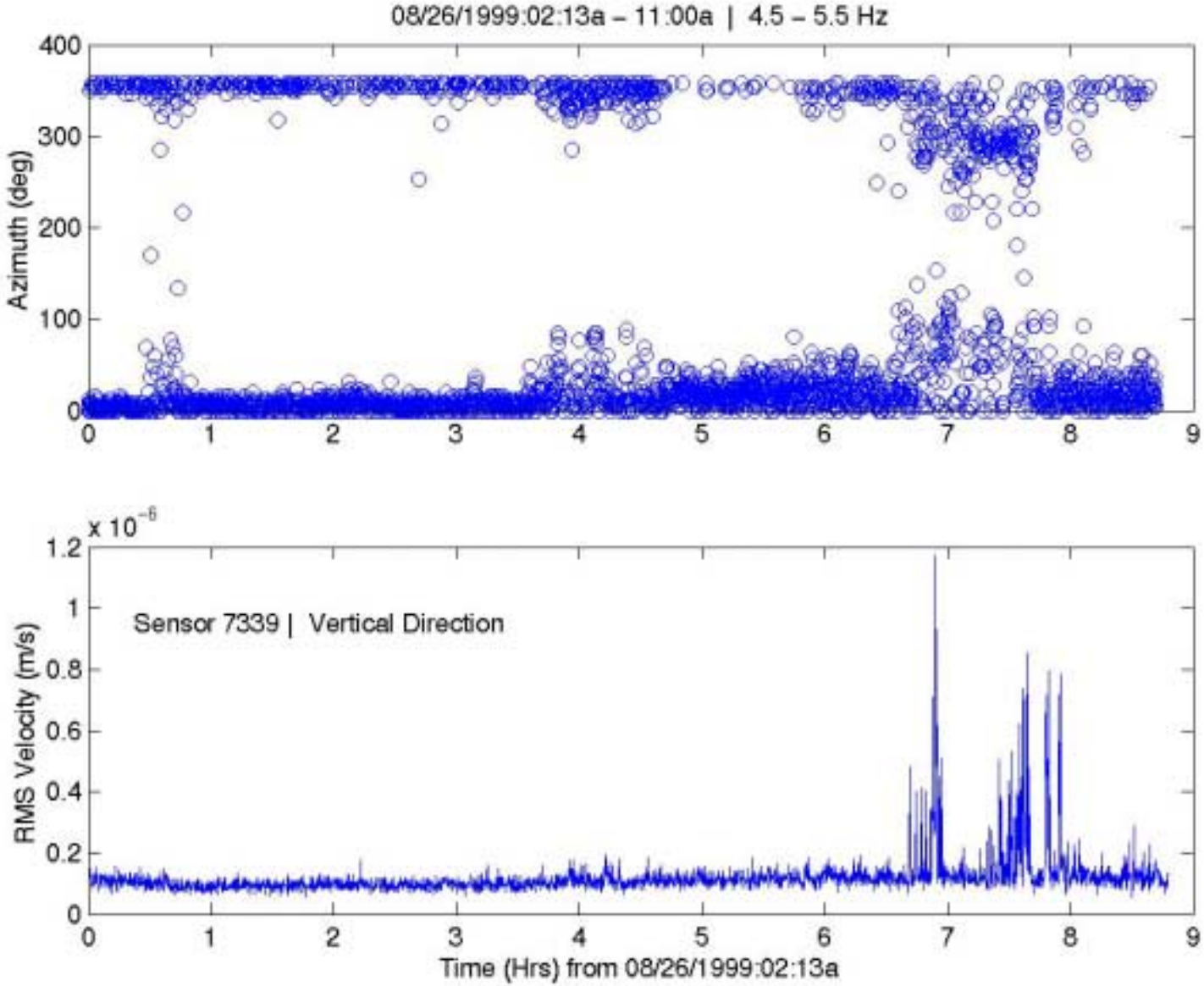


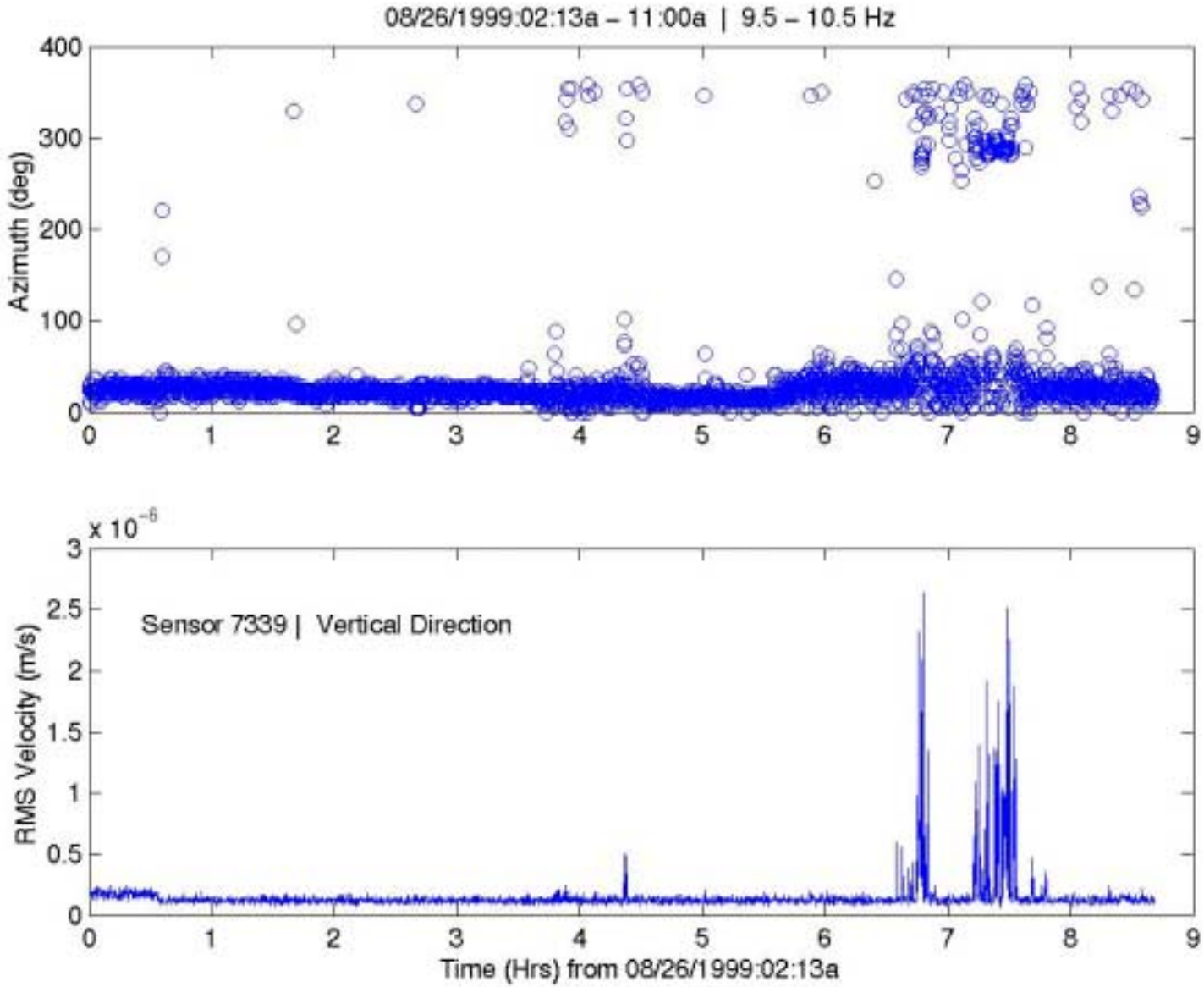
•Use data from a more closely spaced array operated in Summer, 1999.

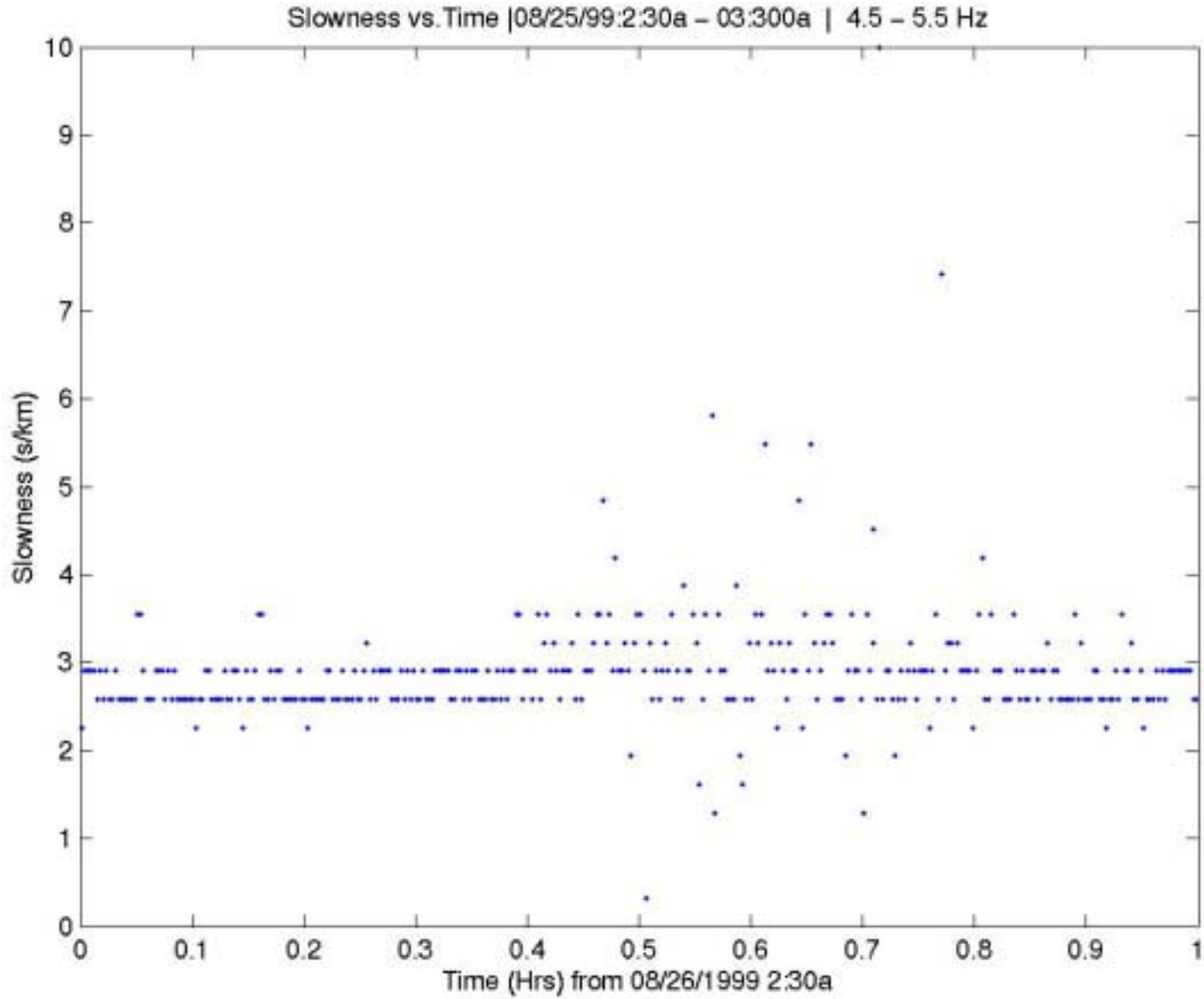
•4 Sensors with 3 forming a triangle and the 4th located in the center. The central sensor was 3 m. from each of the others.

•Array located external to and near the LVEA.


8/26/1999 | 1:01–1:31 am | 9.8–10.2 Hz
RMS velocity (m/s)
10^{-6}
10^{-7}
10^{-8}
0
50
100
150
200
250
300
350
Azimuthal Angle


08/26/1999:02:13a – 11:00a | 4.5 – 5.5 Hz
Azimuth (deg)
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9
x 10^-6
RMS Velocity (m/s)
1.2
1
0.8
0.6
0.4
0.2
0
Sensor 7339 | Vertical Direction
0 1 2 3 4 5 6 7 8 9
Time (Hrs) from 08/26/1999:02:13a


08/26/1999:02:13a – 11:00a | 9.5 – 10.5 Hz
Azimuth (deg)
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
x 10^-6
RMS Velocity (m/s)
3
2.5
2
1.5
1
0.5
0
Sensor 7339 | Vertical Direction
Time (Hrs) from 08/26/1999:02:13a


Slowness vs.Time |08/25/99:2:30a – 03:300a | 4.5 – 5.5 Hz
Slowness (s/km)
Time (Hrs) from 08/26/1999 2:30a
0
1
2
3
4
5
6
7
8
9
10
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Some conclusions -

- LLO has unique and formidable local seismic sources that are being characterized
  - 1-3 Hz noise comes from the direction of Livingston at velocities around 300m/s.
  - 5 Hz and 10 Hz noise measurements are correlated, apparently has a fixed steady state source but can large bursts are seen from a broader range of directions.

Continuing Activities at LaTech and LLO

- Geophones expected from PASSCAL for more dense array
- Analysis of 2001 40T data
- Plan our future measurements in the 40 vault array
- Submit proposal in Sept. to purchase several sensors for use over a long time period.