Report for SEG Foundation: An Educational Seismic Network: Tomographic Imaging of the Gulf Coast Lithosphere by *Juan M. Lorenzo, Louisiana State University*

Summary

I have prototyped a low-cost, short-period, borehole-seismograph recording system suitable for use in education. Data and images are updated and made available daily to the public online. At its present location the seismometer is too distant and/or in too noisy an environment to be able to detect events originating from deep-water, offshore commercial seismic experiments. A poster presentation of this project was made at the June 9, 2005 Geophysical Symposium, Southeastern Geophysical Society of New Orleans. I created a website:
http://www.geol.lsu.edu/Faculty/Juan/GCESN/index.html
to facilitate distribution of seismic data, and research projects that have a Louisiana and regional emphasis to member teachers and students in public area high schools -- SEG is fully credited with support of this project. An NSF-Geo-Ed proposal is in preparation to expand the number of seismographs in Gulf Coast schools to at least three.

Figure 1. Amy L., undergraduate major in geology testing auger prior to drilling seismograph borehole

Prototype Educational Seismic Network Station

Local, low-cost seismological networks exemplify one effective model of earth science education in the United States and abroad (Hamburger and Taber, 2003). Educational seismological networks can capture the interest of students because the data they collect can be used to solve relevant, societal problems including management of water resources, and earthquake prediction. Modern data acquisition tools, and accompanying methods of quantitative scientific analysis are inherent to the field of seismology, and are readily applicable for teaching fundamental scientific communication and thinking skills.

Up to now, I have focused on prototyping a low-cost seismic sensor for use in monitoring oil and gas seismic experiments (active seismology). In my region of the country, even moderate-sized earthquakes (~M5) are rare but active seismic experiments are common and constitute a data set that can grow into a long-term, valuable scientific data set that could be used to image the lower crust of the Gulf Coast.

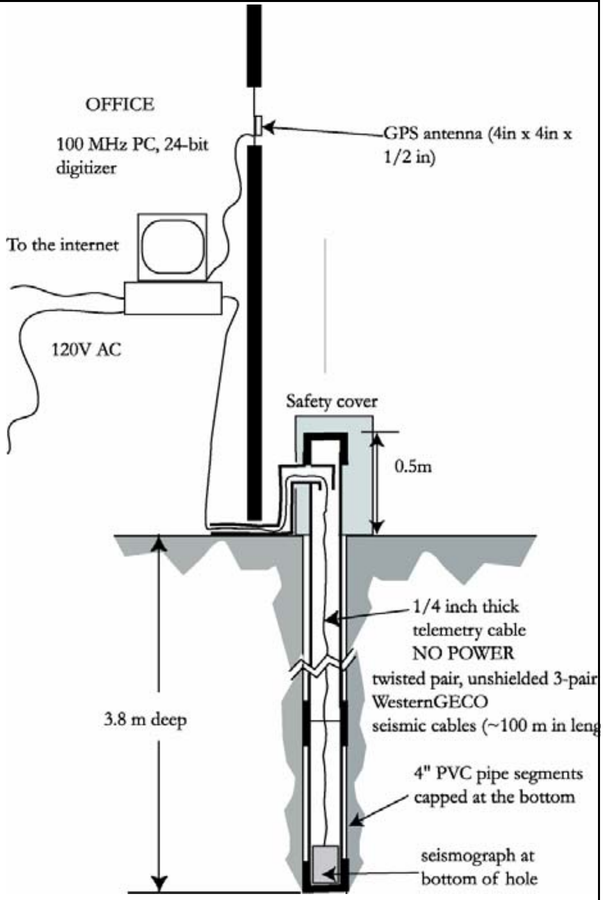

Figure 2: Seismograph layout presented to the University engineers. Station Location based on averaged from GPS data collected continuously over a period of one week 30.4120450 N and 91.1792067 E, ~ 60m NAD88 from BJ4051 National Geodetic Survey Marker, 3.8 m below ground level. The horizontal accuracy from GPS is estimated to be +/- 10 m.

A Prototype Station for an Educational Seismic Network on the Gulf Coast

This prototype system comprises low-priced, independent software and hardware components that are readily-available in the market. Whereas I can not expect in practice that K-12 school groups can build sophisticated electronic components needed for seismograph installations, a minimal reliance on single vendors of seismograph components does place more responsibility of in-house construction on students and thereby increases the potential educational experience.

Instrument Setup

I employ a short-period (1Hz) instrument, suitable to local seismic "events", either natural or human-induced, that have not suffered significant attenuation because their travel path is relatively short (few hundred km). My prototype station is named G*ulf* C*oast* E*ducational* S*eismic* N*etwork* LSU1 and is located adjacent to the Department of Geology and Geophysics Howe-Russell Geoscience Complex at Louisiana State University, Baton Rouge (Figure 1).

This urban, university campus is close to my laboratory which facilitates the development of the prototype tool, its maintenance, and lies close to an internet connection that removes the need for additional telemetric tools. The seismograph is located immediately outside a large teaching hall and is highly visible to students. As expected, more environmental noise is generated during weekday, daytime hours when classes are in session. I employ with success, unshielded, three-twisted-pair cable standard geophone field cable (WesternGECO donation) nearly 100 m long.

Timing accuracy

Timing accuracy suffers from several sources of error and is estimated to be at least +/- 10-to-20 ms. Timing accuracy can not be better than the data sampling interval which is limited to at most 50 S/s-to-100 S/s, constrained by the available digitizer memory buffer.

Neither can timing accuracy exceed the accuracy of the internal PC clock. I use software to read a GPS signal to adjust our internal PC clock every second to within +/-10 ms universal time. GPS satellites emit a 1 pulse-per-second signal (Figure 3) that is used regularly to synchronize data collection activities.

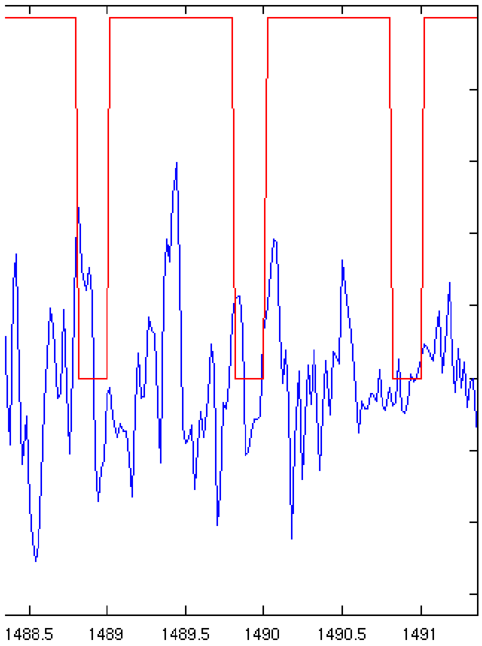

Figure 3 - Seismic amplitude (blue line) is measured as a function of time (secs along the horizontal axis) within an individual hour-long data file. Overplotted red lines indicate bimodal GPS digital signal. Time steps every second occur half-way down along the plotted change in the GPS value. Data is collected at 50 samples per second.

An additional check of the timing accuracy is carried out by comparing the number of seconds measured from the GPS signal to the span of time estimated from the time stamps issued by the digitizer unit. Normally we accumulate an error of about 100-200 samples every 24 hours. At a sampling rate of 50 S/s, and if we assume this error to be distributed randomly throughout a typical 24-hour recording interval, this error is still several orders smaller than the above sources of error. Currently, commercial low-cost systems (e.g. http://www.symres.com/), are comparable to our solution but do not provide a better timing solution. One additional improvement to timing can be achieved with the installation of new digitizer firmware. A firmware update will help reduce any signal latency introduced by data transmission using TCP-IP protocols.

Software Development

I developed a simple server software using Perl and mapping software to process, archive and generate plots (Figure 4). All the software tools are in the public domain.

My scripts are available for download by request from the GCSN website:
http://www.geol.lsu.edu/ Faculty/Juan/GCESN/index.html

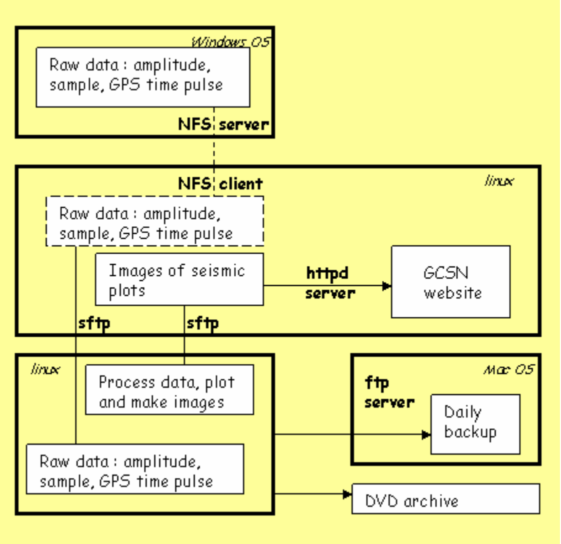

Figure 4: All data and scripts developed for the above networkare available from http://www.geol.lsu.edu/Faculty/Juan/GCESN/index.html A modular, heterogeneous network outlined above has several advantages because it allows use of inexpensive, legacy, hardware, facilitates interchange of hardware for maintenance and minimizes illegal entry by into the system via the internet.

Offshore commercial seismic events

As a test of the equipment and to gain a better understanding of the attenuation characteristics of the Lower Mississippi Valley sediments, I tried to locate seismic arrivals from known commercial seismic cruises in the Gulf of Mexico. WesternGECO informed me of commercial seismic experiments at least 400 km south of the borehole geophone in Baton Rouge, LA. For these distances between source and the borehole geophone, I have not been able to isolate corresponding seismic arrivals from the data (Figure 5). The airgun source used during the seismic experiment does not put out much signal below 6Hz and shots occur approximately every 15 s (pers. com. WesternGECO).

There is a potential that exact location of seismic vessels may not be available in future because of contract confidentiality. I recommend that at least two or three stations with sufficient angular coverage to reduce calculation errors will be needed to invert for shot location.

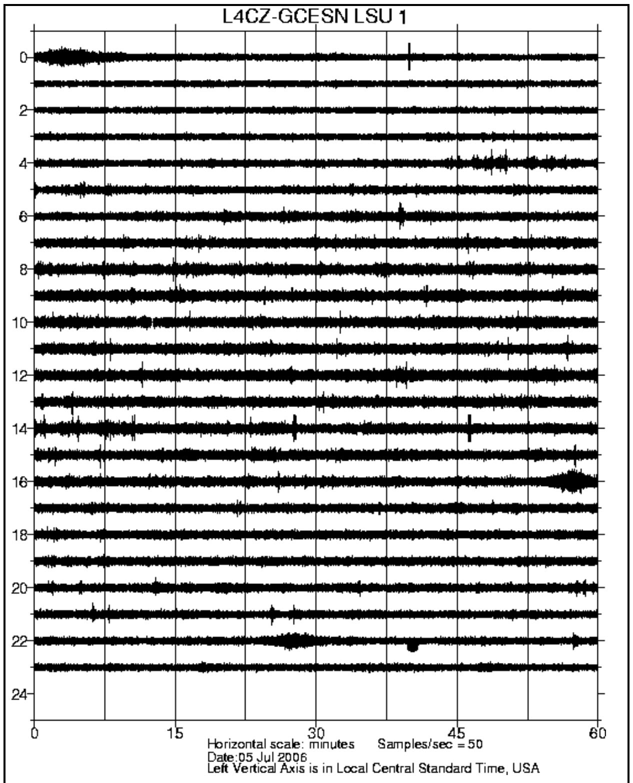

Figure 5: An example daily seismic reading Note noisier daytime records and the passing of local trains (near 0 hours, end of 16th hour and middle of 22 nd hour). Data dates from July 5, 2006, local US CST

Conclusions

I conclude that in the next phase of network installation stations should be located as close as possible to the coast in order to reduce the effects of attenuation and geometric divergence. For example schools should be targeted that lie coastal towns such as Cocodrie, (LA), Grand Isle (LA), and Galveston TX) may provide better site locations in future. Because of the risk of equipment damage by seasonal hurricanes a borehole seismograph is a useful method of deployment to protect the instrumentation.

Future versions of the seismic tool should incorporate a firmware upgrade, if cheaper options for a minimal timing accuracy of about +/- 10 ms are not available.

Acknowledgments

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References

Hamburger, M.W., and Taber, J., 2003, Toward integration of educational seismology programs: The U.S. educational seismology network: Seismological Research Letters, v. 74, p. 603-604.