The Quake-Catcher Network:

A Volunteer Distributed Computing Seismic Network

http://qcn.stanford.edu

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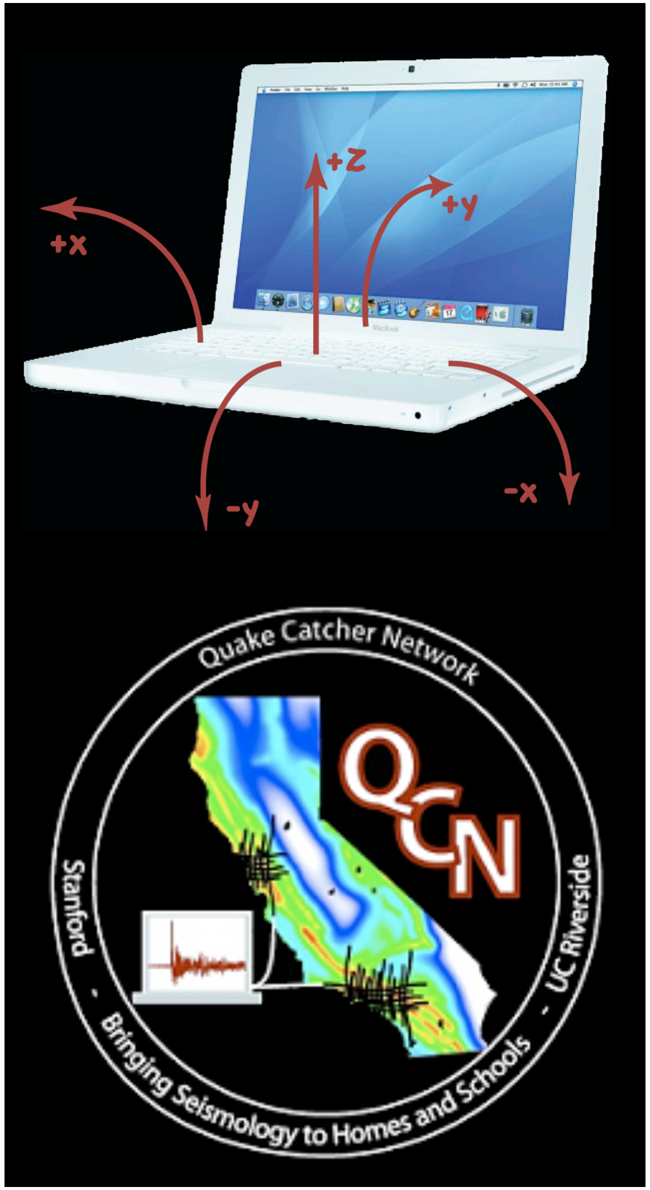
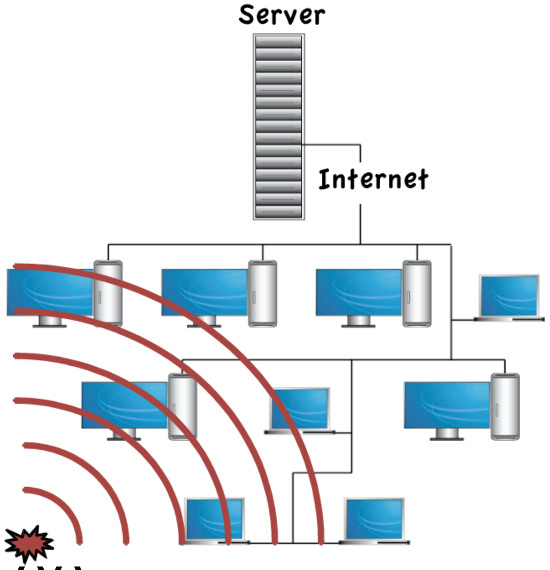
The Quake-Catcher Network

- **The Goal:** To network computers with internal or USB-connected accelerometers for rapid earthquake detection.
- **The Method:** We use distributed (volunteer) computing via BOINC to monitor internal or external (USB) sensors, connected to computers when they are not otherwise being used.



Volunteer Distributed Computing



Advantages:

- Low CPU and network infrastructure costs
- Network 1,000s to 100,000s of CPUs together rather than bridging 10s or 100s
- "Peer-to-Peer computing can provide 70 TFLOPS processing rate (which we may utilize for calcs someday)

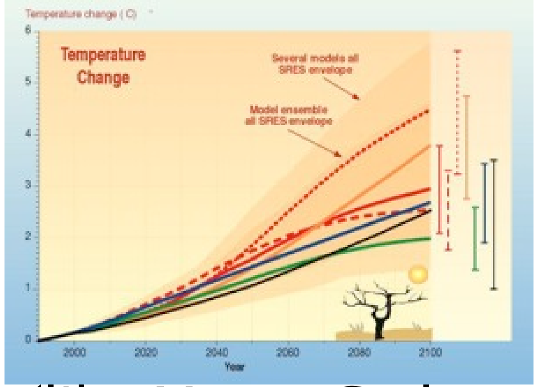
Disadvantages:

- Communication between CPUs is very slow
- CPUs cannot easily share memory
- CPUs have different clock speeds & different network speeds
- Processes can be interrupted by volunteer participants

What is Volunteer Distributed Computing For?

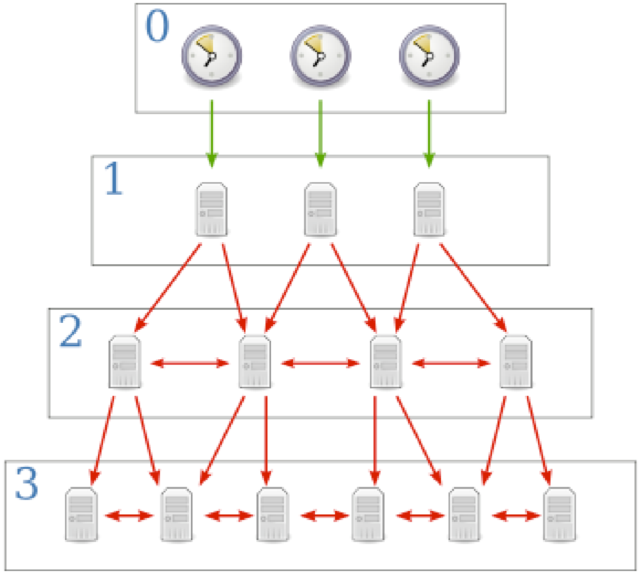
Large scientific computations that require very little inter-CPU communication.

- Signal detection or signal processing of many separate files for fast turnaround (each CPU analyzes a different signal and returns a single result).
  - e.g. SETI@HOME
  - Einstein@Home



- Serial problems that are run over and over (like Monte Carlo simulations).
  - e.g. climateprediction.net
- Or now -- monitoring sensors!

Time and Location

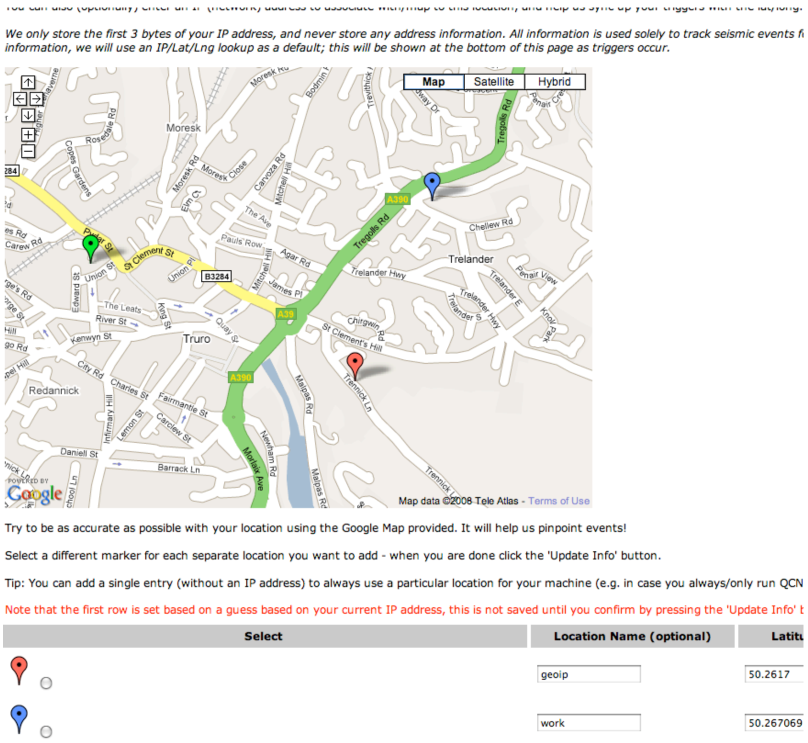


Network Time Protocol (NTP):

- Multi-tier system grounded to GPS Clocks, Atomic Clocks, Radio Clocks
- Peer-to-peer method often provides better than 0.1 second accuracy, often +/- 20 msec. [Frassetto et al., 2003]
- Non-system-level ntpdate client syncs to our reference Stanford server providing time offset

3-step Location System:

- Estimate location based on last known router (GeoIP / maxmind.com web service in BOINC scheduler)
- Google Maps Interface web page (lookup table in BOINC scheduler)
- Register at our "Where were you?" site a la USGS "Did you feel it?" site (future development).
- Future – USB accelerometers with GPS?



We only store the first 3 bytes of your IP address, and never store any address information. All information is used solely to track seismic events f information, we will use an IP/Lat/Lng lookup as a default; this will be shown at the bottom of this page as triggers occur.

Try to be as accurate as possible with your location using the Google Map provided. It will help us pinpoint events!

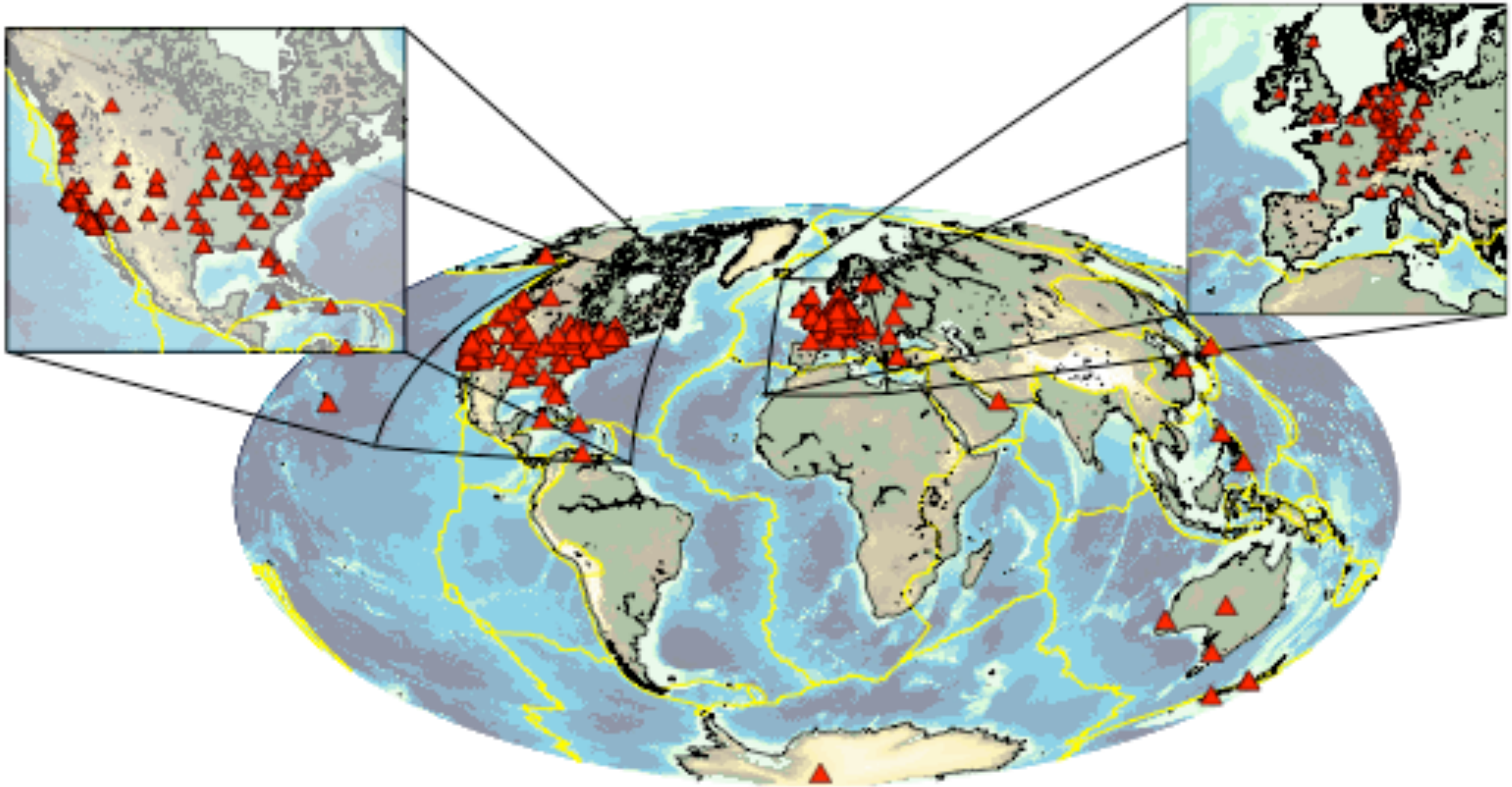
Select a different marker for each separate location you want to add - when you are done click the 'Update Info' button.

Tip: You can add a single entry (without an IP address) to always use a particular location for your machine (e.g. in case you always/only run QCN

Note that the first row is set based on a guess based on your current IP address, this is not saved until you confirm by pressing the 'Update Info' b

Select	Location Name (optional)	Latitu
○	geoip	50.2617
○	work	50.267069

Expansion of the Network
May, 2008



Triggering Algorithm

Significance Level Filter:

- Compare each point to the standard deviation of the signal in the long-term window prior to the trigger

Standard Deviation

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(y_i - \bar{y}\right)^2}$$

Running Variance

$$\sigma_i^2 = \sigma_{i-1}^2 + \frac{\left(y_i - \bar{y}_i\right)^2 - \left(y_{i-N-1} - \bar{y}_{i-N-1}\right)^2}{N}$$

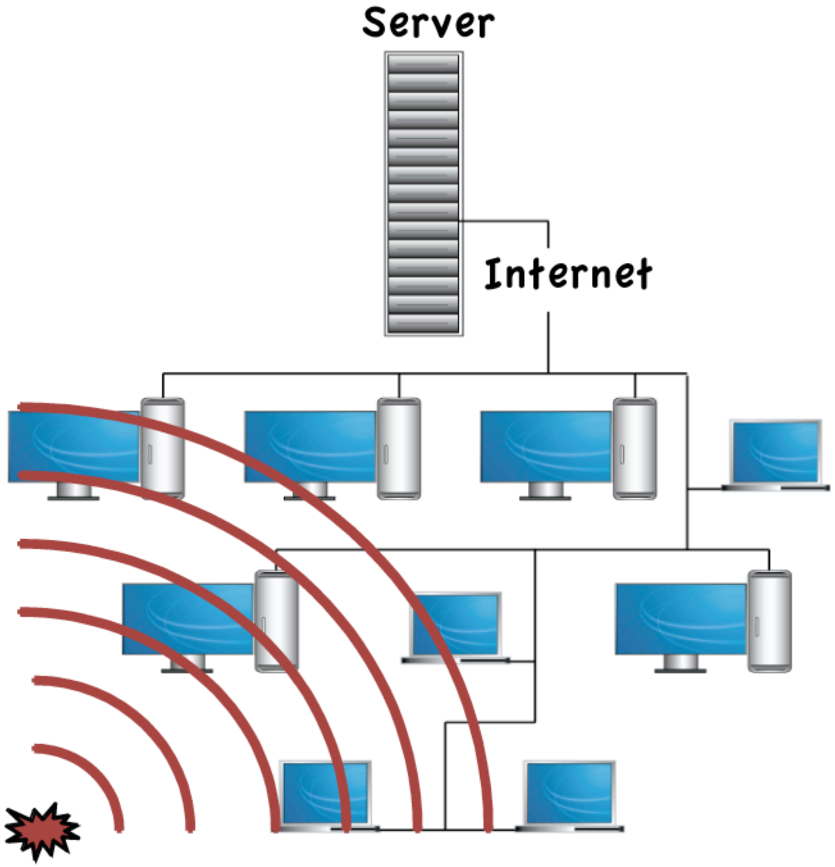
Significance Level

$$SL_i = \sqrt{\left(y_i - \bar{y}_i\right)^2} \Big/ \left(\sigma_i + wl\right)$$

- SL = $(|y_i| / s_i)$ provides the confidence level (e.g. SL > 2 gives a 95% confidence) that an emerging signal is statistically not representative of the prior long-term average (Gaussian)
- Extremely Fast, all CPU in the sensor monitoring loop (50 Hz)
- Computer records 1 minute before and 2 minutes after trigger to disk (SAC file I/O)

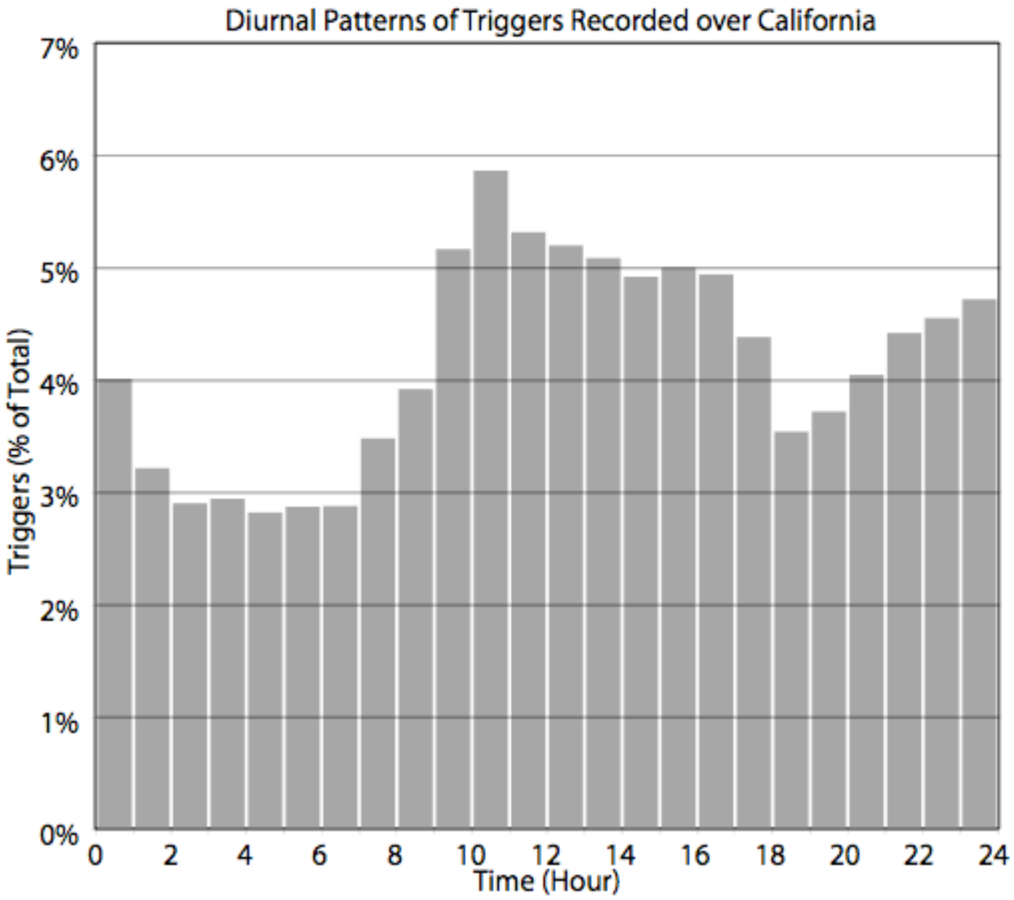
Earthquake Detection

- Probable earthquake detection when the QCN receives many triggers from a region
- Otherwise just people bumping their laptops
- For big earthquakes:
  - only strong vibrations will be detected
  - Only large earthquakes will cause consistent triggers across a region of the network

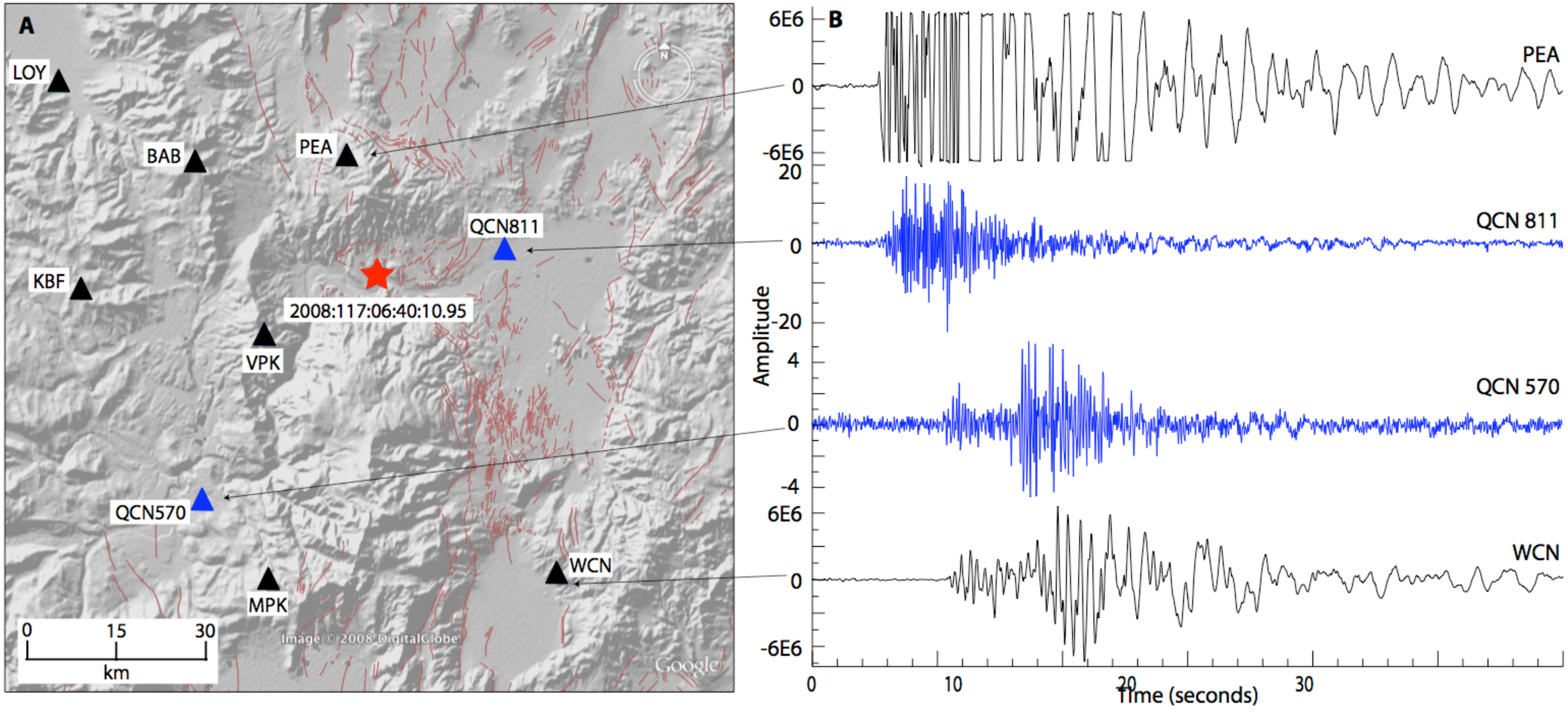


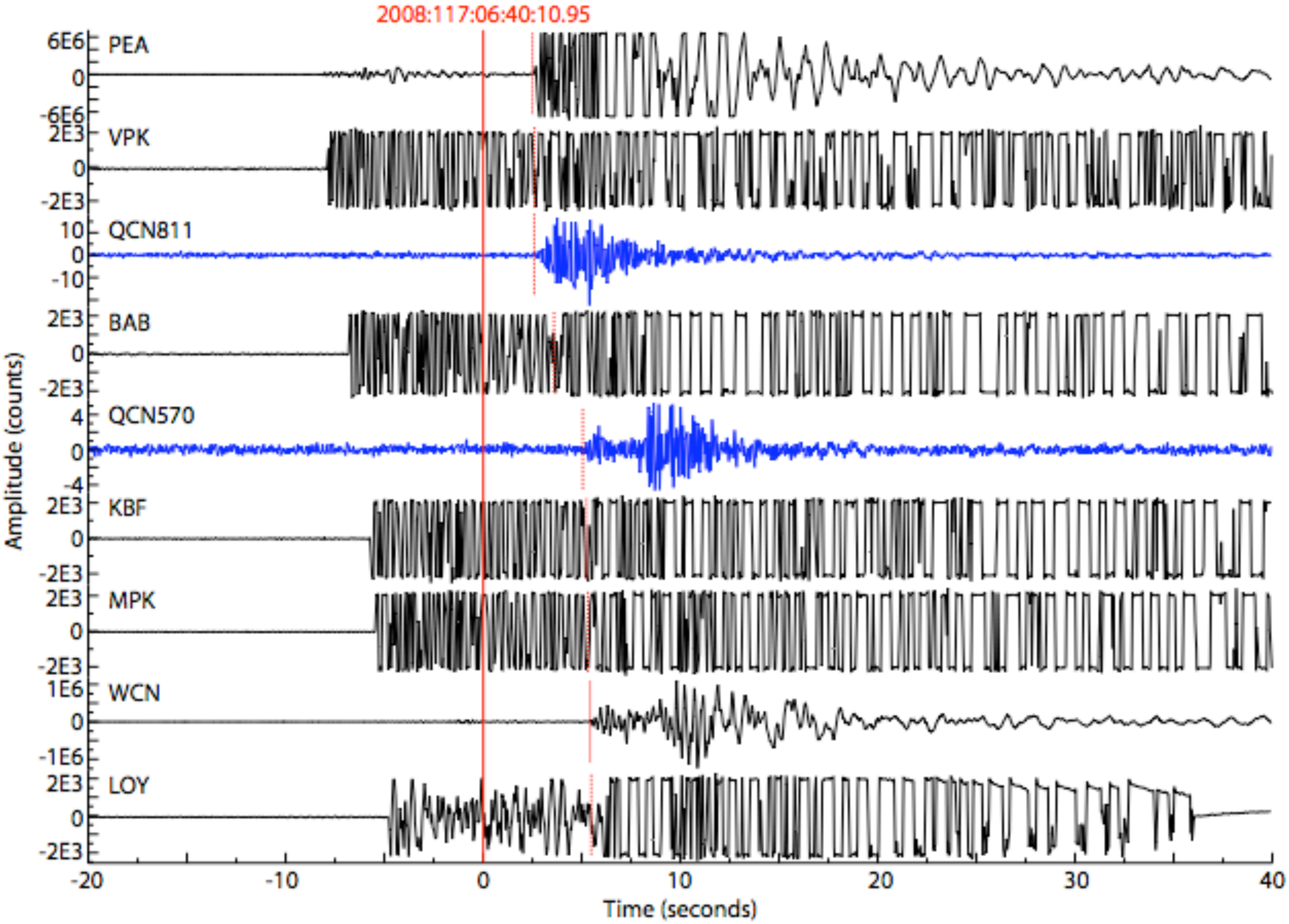
Trigger Statistics

- 1500+ laptops joined by September 2008
- Roughly 30-50 triggers per day from each laptop
- Number of triggers is roughly the same throughout the day (no large day/night difference)
- BOINC “trickles” – turnaround time ~3-5 s



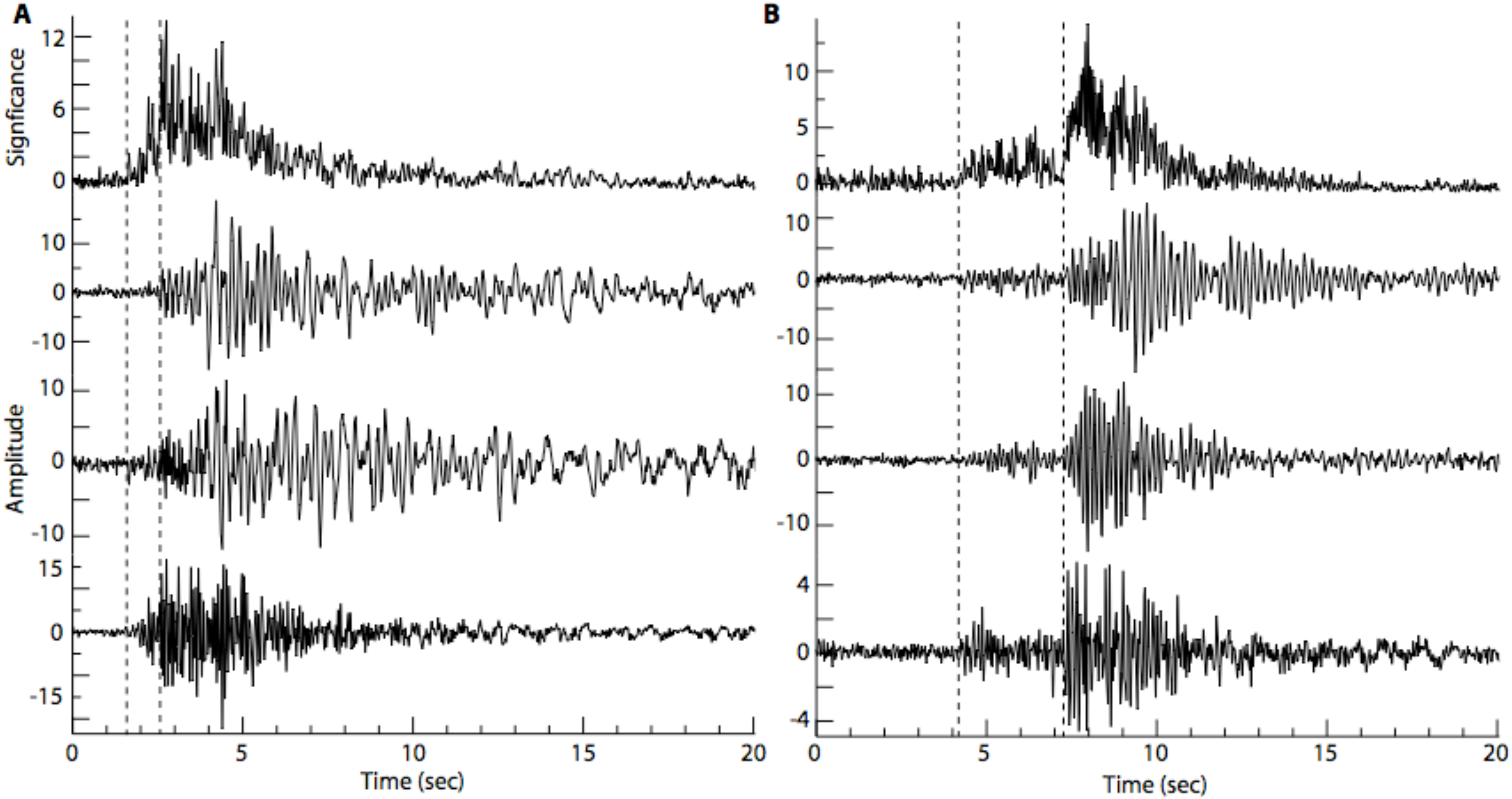
April 2008 Reno Earthquakes Captured!




2008:117:06:40:10.95
PEA
6E6
0
-6E6
VPK
2E3
0
-2E3
QCN811
10
0
-10
BAB
2E3
0
-2E3
QCN570
4
0
-4
KBF
2E3
0
-2E3
MPK
2E3
0
-2E3
WCN
1E6
0
-1E6
LOY
2E3
0
-2E3
Amplitude (counts)
-20
-10
0
10
20
30
40
Time (seconds)

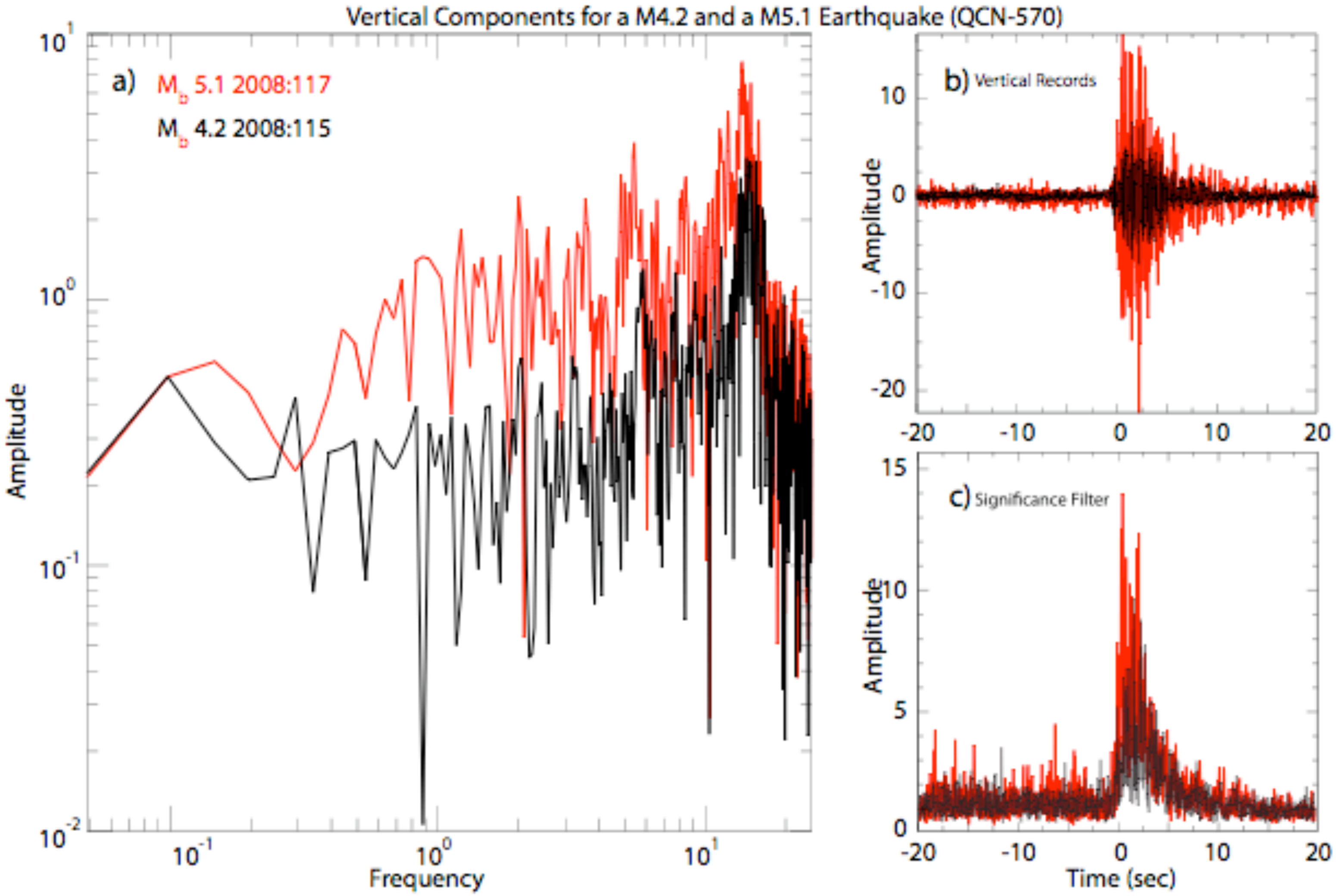
QCN 811 - 10.4 km

QCN 570 - 23.6 km



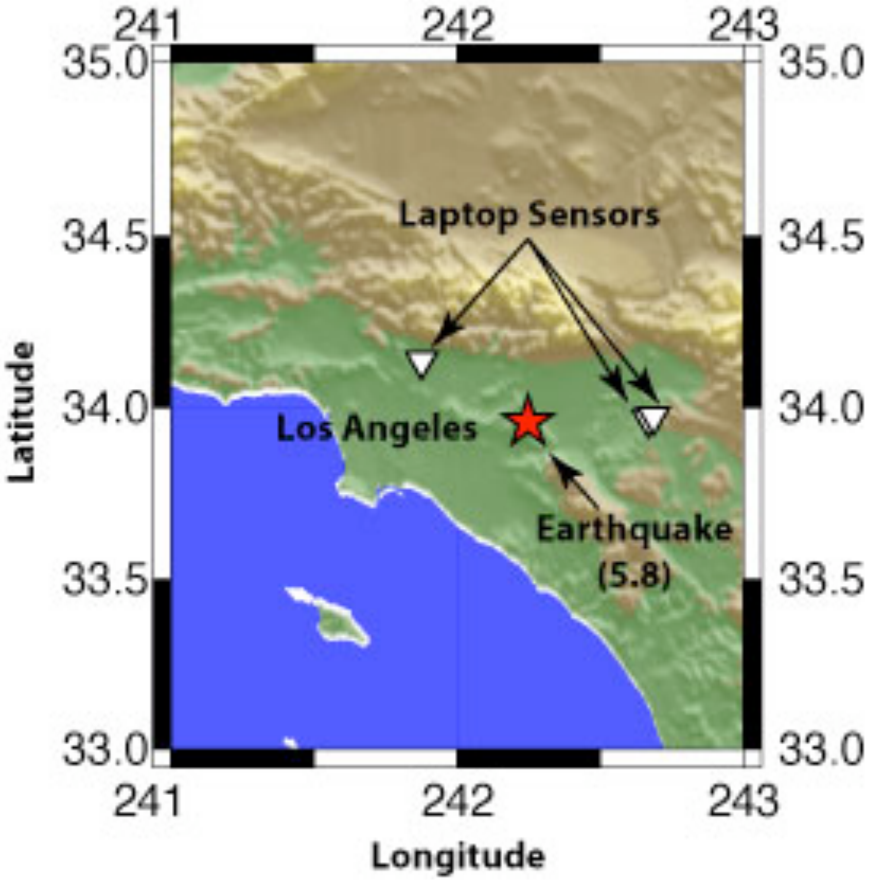
Response Comparison

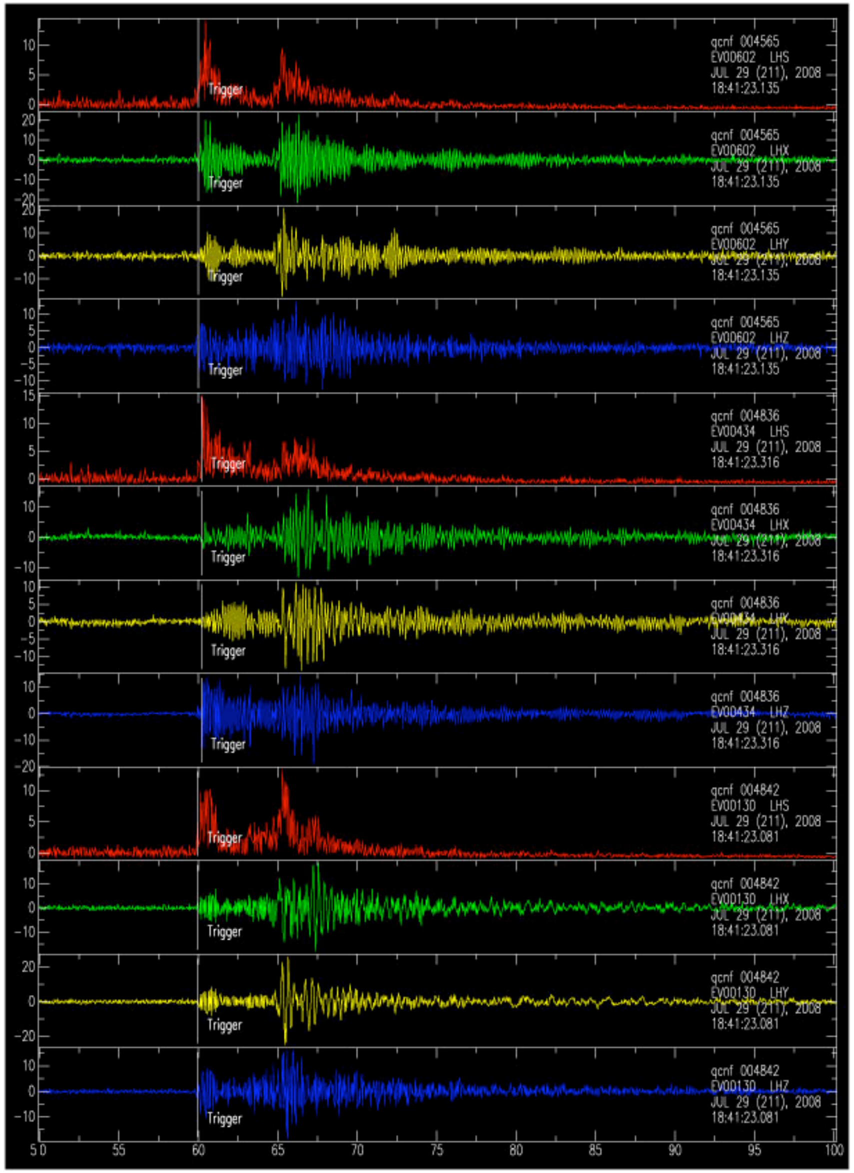
M 5.1 and M 4.2 on QCN 811



July 29th LA Earthquake Captured!

http://qcn.stanford.edu/EVENTS/2008_211/





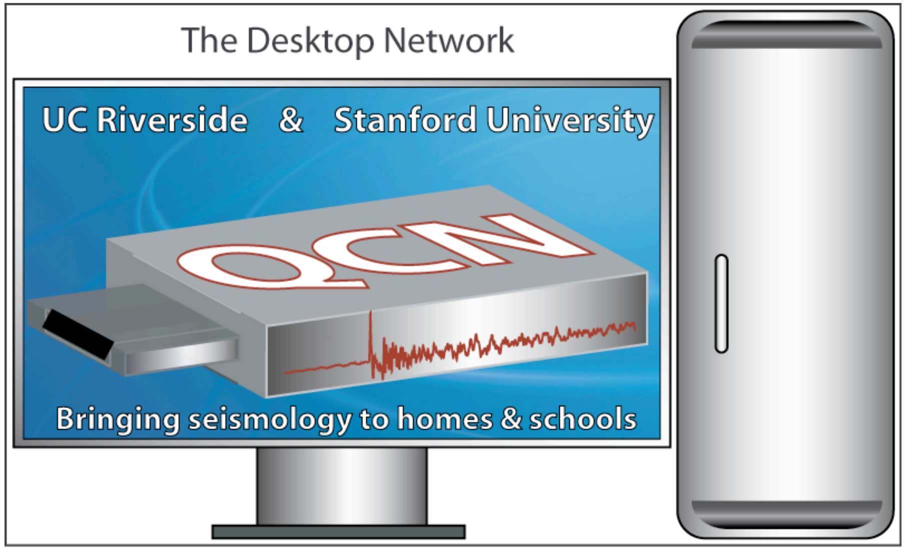
Building The Network

Laptop Network:

a)	Planning & Development:	June, 2007 - March, 2008
b)	Beta-Testing Phase:	March, 2008 - Late 2008
c)	Expand & Monitor:	Summer, 2008 -

Desktop Network:

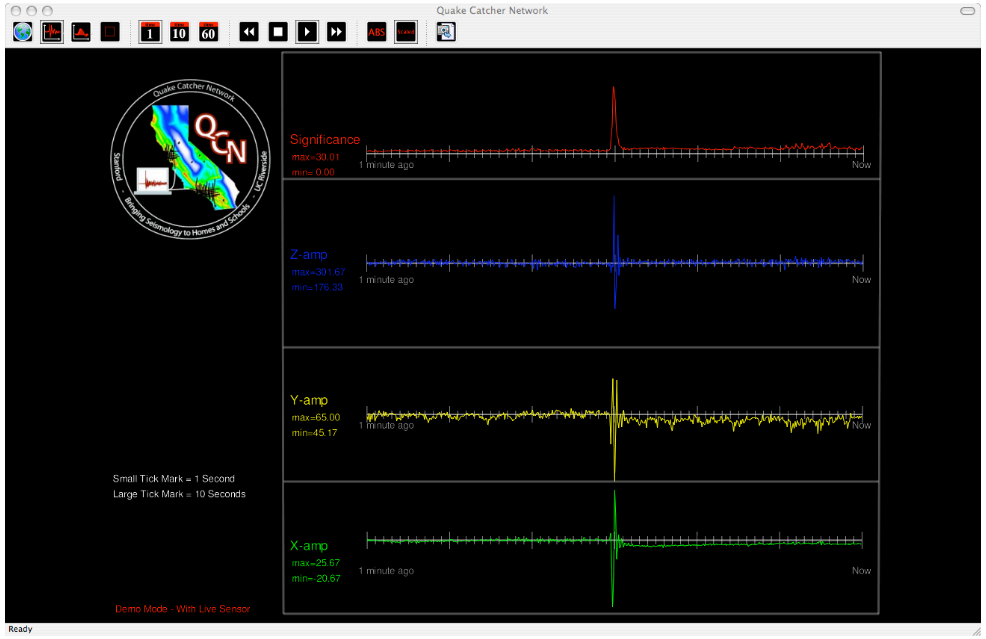
- Purchase USB accelerometers for K-12 schools.
- Use same QCN codes
- Run continuously
- Provides a network backbone



Development Stage: Summer - Late 2008

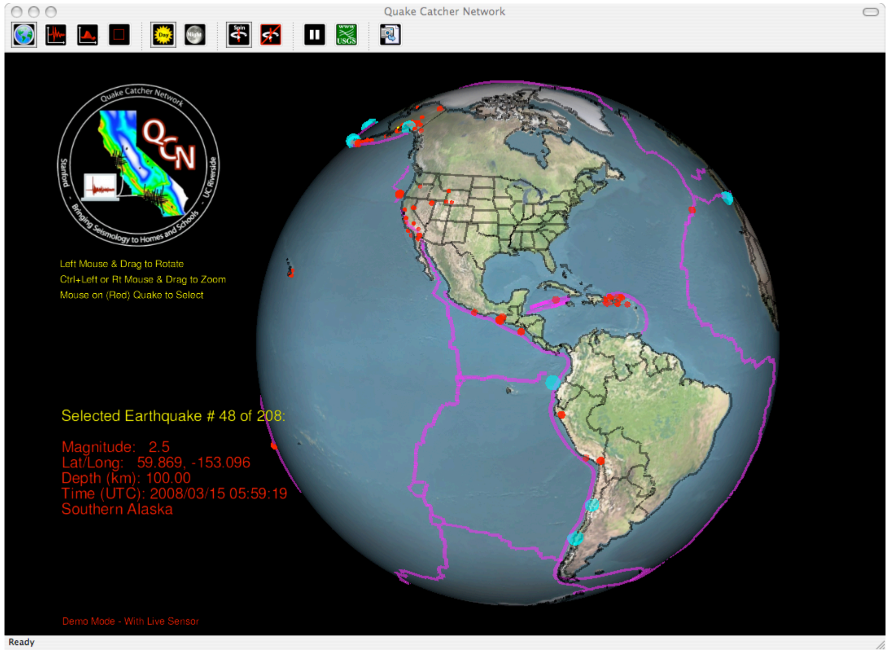
Educational Outreach

- What we provide:
  - Classroom interactive OpenGL demo software based on BOINC screensaver (called "QCNLive")
  - Seismology related in-class activities
  - Classroom USB Sensor
  - Classroom BOINC Software (for live monitoring/reporting)



Small Tick Mark = 1 Second
Large Tick Mark = 10 Seconds

Demo Mode - With Live Sensor



Left Mouse & Drag to Rotate
Ctrl+Left or Rt Mouse & Drag to Zoom
Mouse on (Red) Quake to Select

Selected Earthquake # 48 of 208:

Magnitude: 2.5
Lat/Long: 59.869, -153.096
Depth (km): 100.00
Time (UTC): 2008/03/15 05:59:19
Southern Alaska

Demo Mode - With Live Sensor