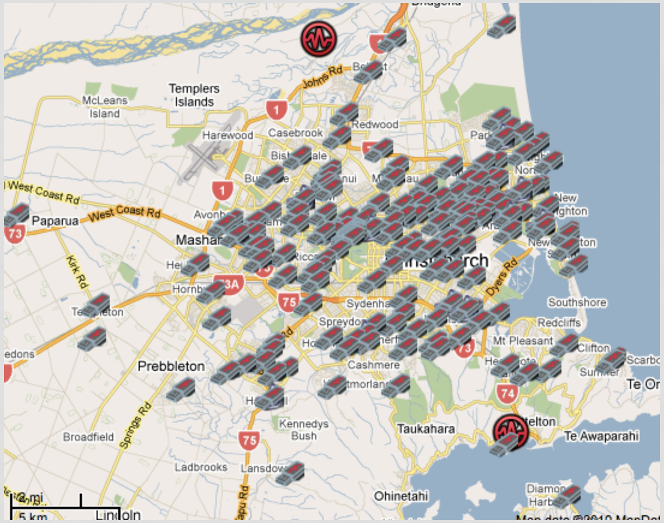

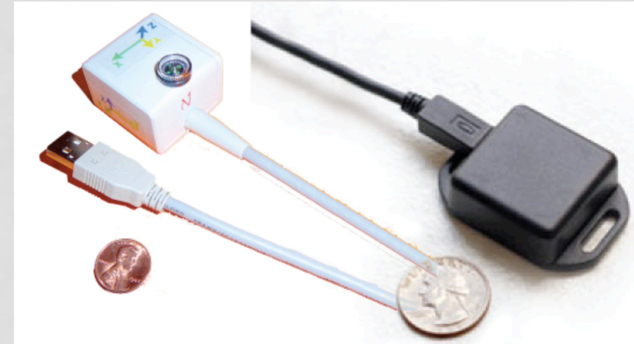

The Quake-Catcher Network

The Sensors, the Science, and the outreach

ELIZABETH S. COCHRAN

Core Project Members

Co-PI:
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Co-PI:
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PhD Student
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I. INTRODUCTION TO QCN

Low cost seismic network that utilizes:

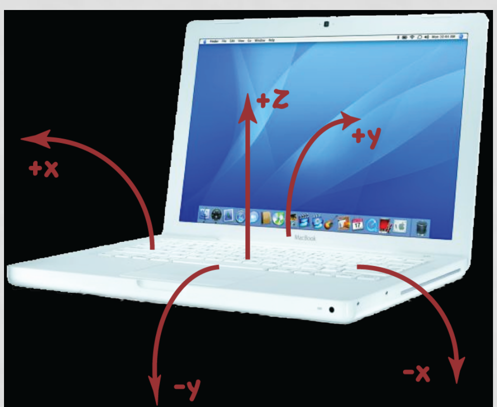
1. MEMS Sensors

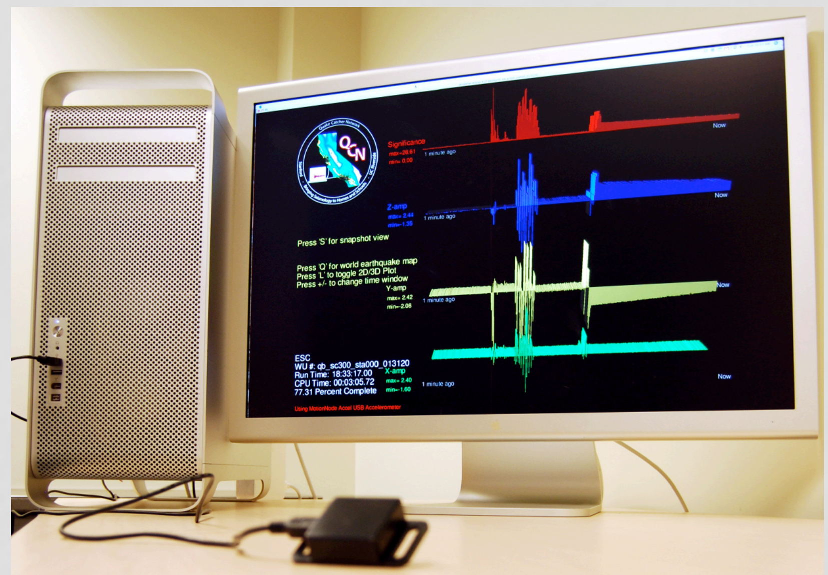
We use triaxial MEMS accelerometers internal to laptops or connected to desktops via USB

Benefits: Very low cost sensing

$0 – laptops

$30-150 – desktops





USB-connected triaxial accelerometer

I. INTRODUCTION TO QCN

Low cost seismic network that utilizes:

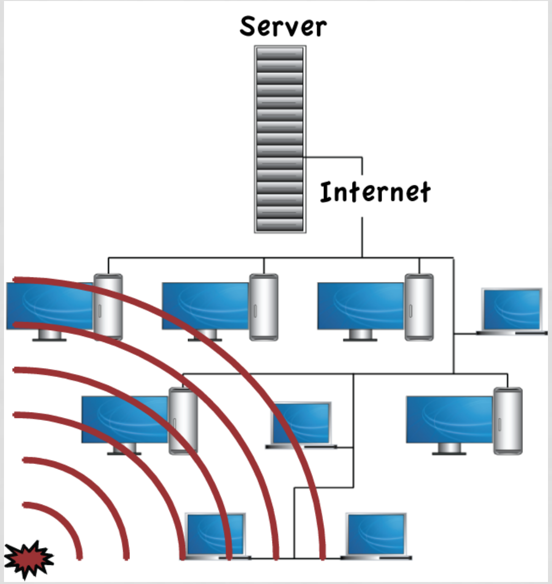
2. Distributed Computing

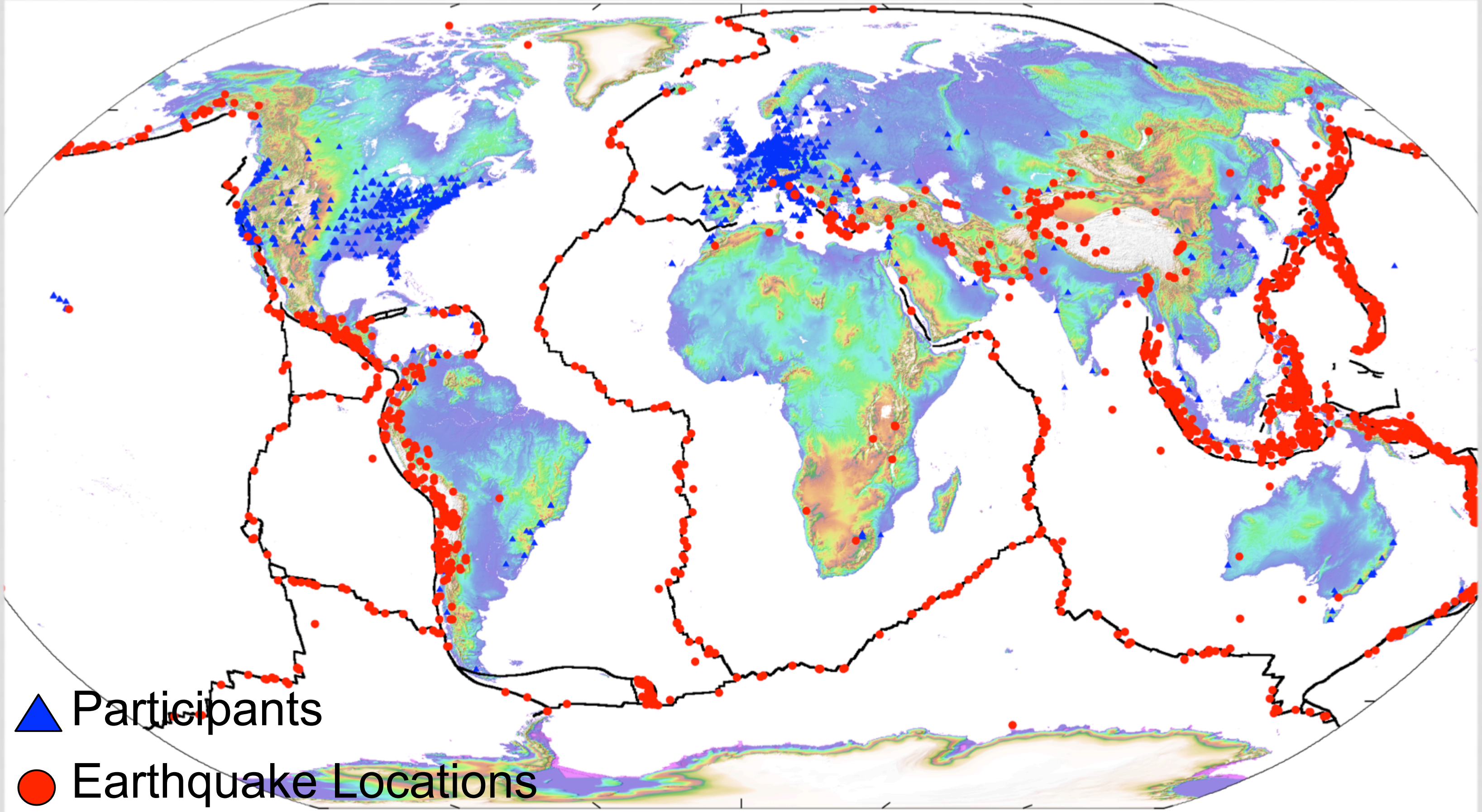
Volunteers donate CPU time to monitor sensors attached to their computer.

We use the Berkeley Open Infrastructure for Network Computing (BOINC) open-source distributed computing platform

Advantages:

1) Reduced infrastructure costs (existing networked computers process data and send information to us
2) Easy to modify software and push changes to participants



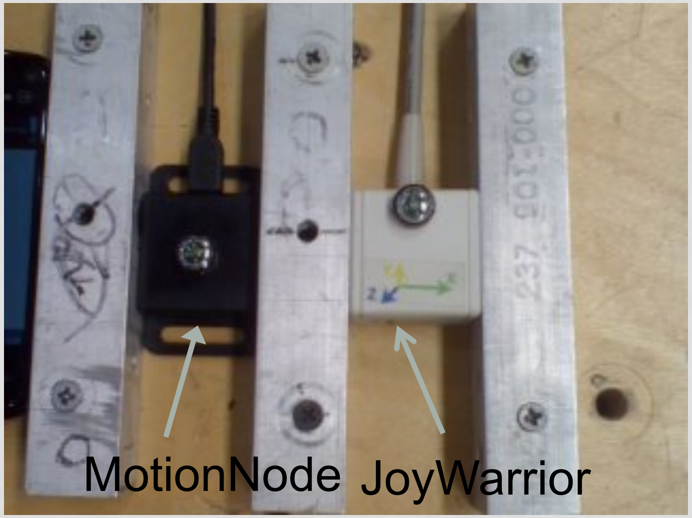


CURRENT NETWORK

2000+ STATIONS GLOBALLY IN 67 COUNTRIES

II. DATA COLLECTION

MEMS Sensor Specifications



Previous Generation

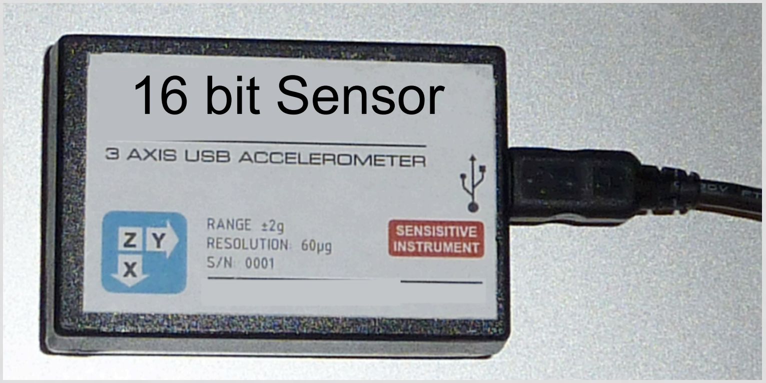
- JW24F8 – 10 bit sensor (4 mg)
- MotionNode – 12 bit sensor (1 mg)

Current

- JW24F14: 14 bit sensor (.24 mg; $50)

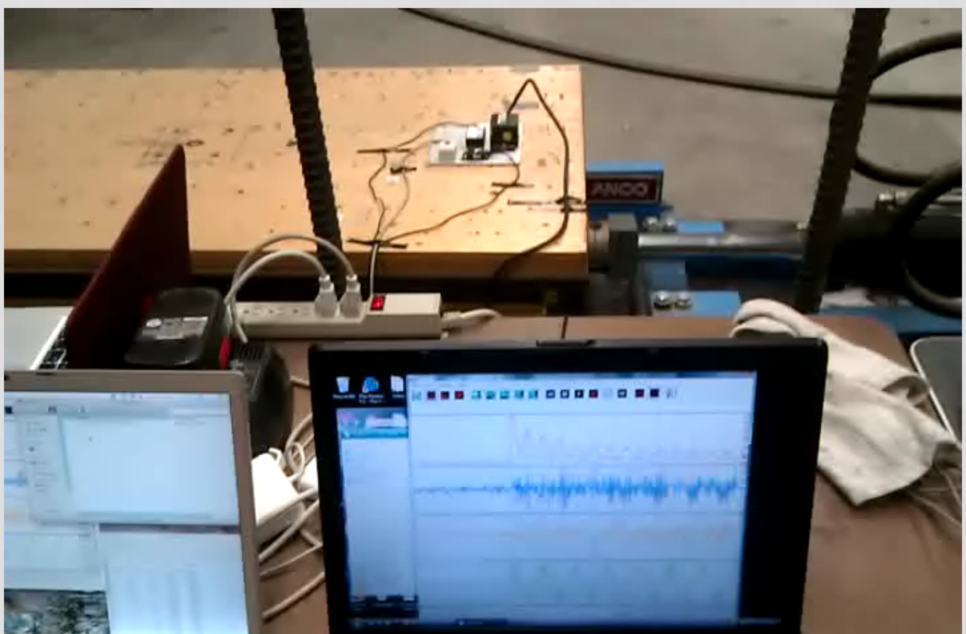
Next Generation (2011-2012)

- ON-16: 16 bit sensor (6 μg; $50)
- ON-24: 24 bit sensor (0.24 μg; $130)

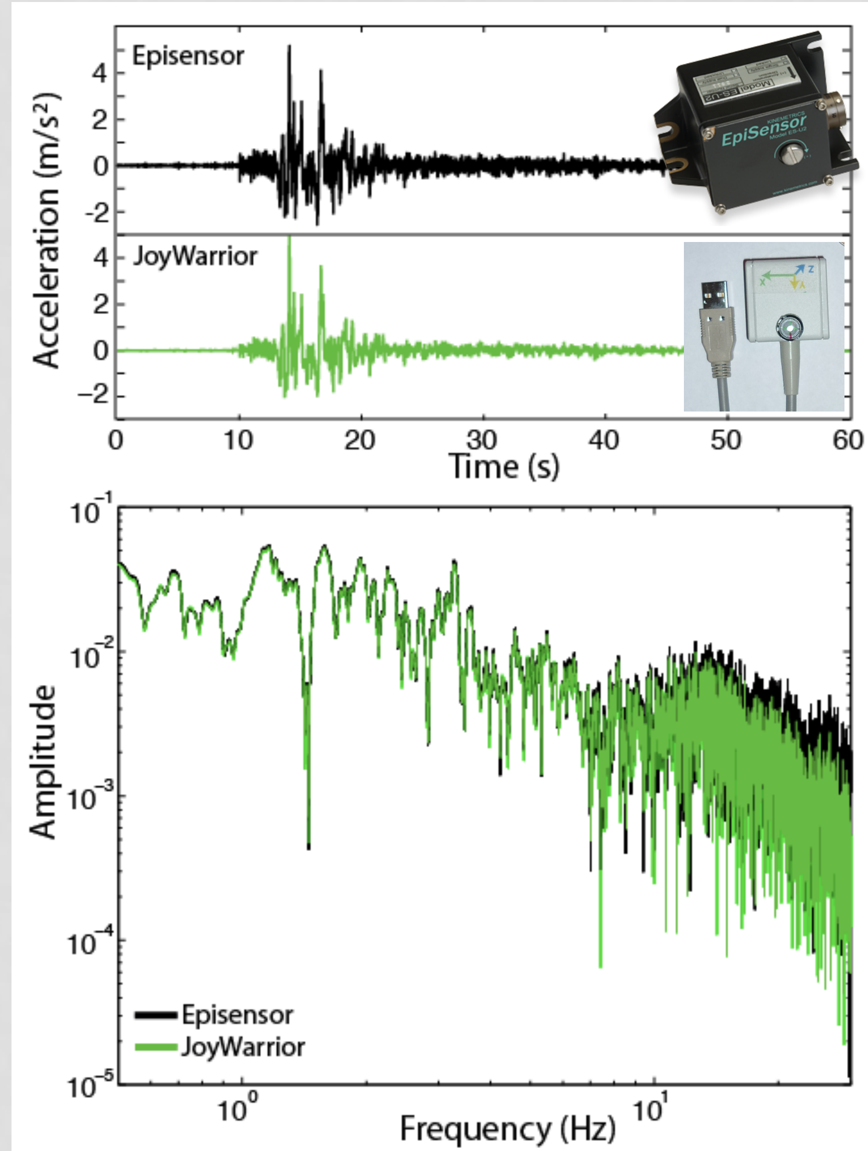


Shake Table Tests

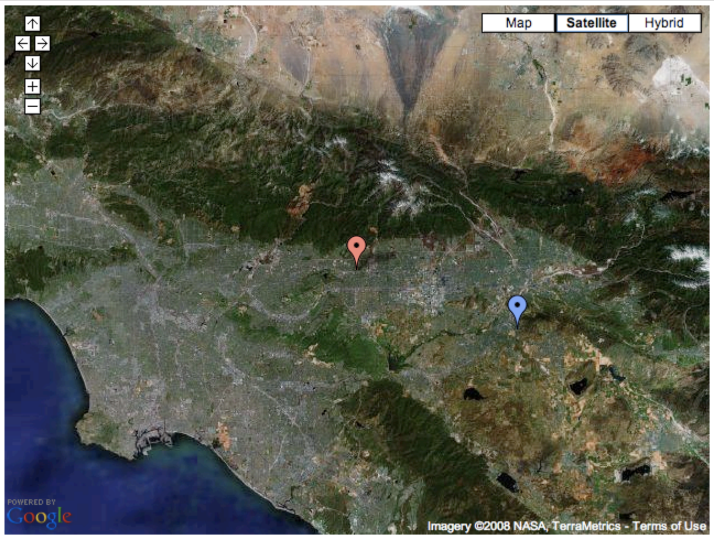
- Single harmonic
  - Frequencies range 0.2 – 10 Hz
  - Acceleration range 0.03g – 2g
- Earthquake ground motion
  - Scaled Northridge (0.5g and 1g)



M6.7 Northridge scaled to 0.5 g



II. DATA COLLECTION



Location

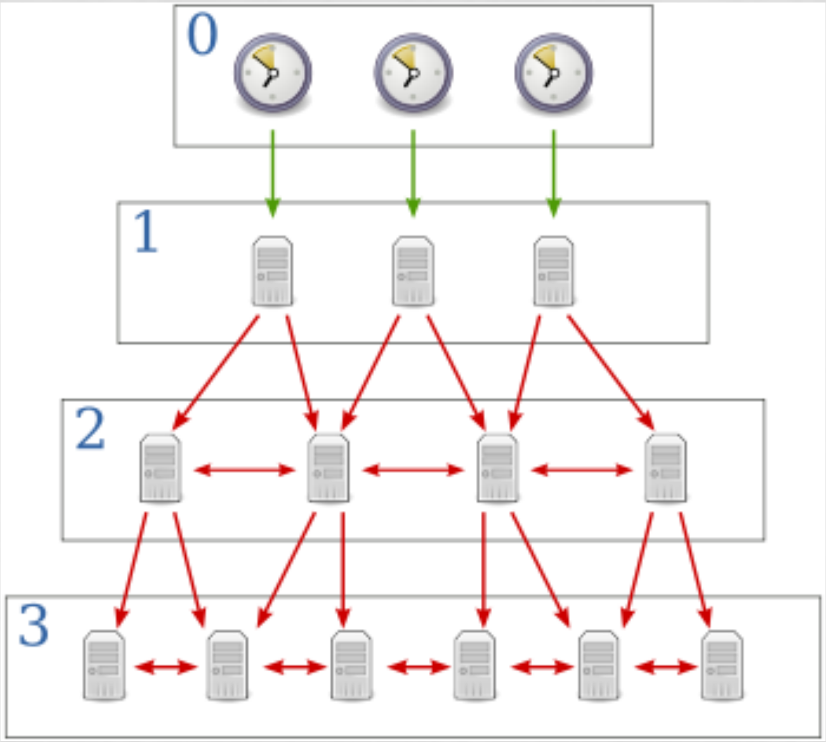
Initial location based on IP address

More accurate location from participant input into a Google Map interface

Select	Location Name (optional)	Latitude	Longitude	Net (IP) Addr	Set Net Addr	Clear Net Addr
	Home	34.0971731803043	-117.72793114185	76.170.119	Set Current	Clear
	Work	33.9745572764349	-117.32615232467	138.23.128	Set Current	Clear
					Set Current	Clear
					Set Current	Clear
					Set Current	Clear
	Update info					

II. DATA COLLECTION

Timing



http://en.wikipedia.org/wiki/Network_Time_Protocol

Network Time Protocol (NTP):
Since 1985

Multi-tier system grounded to
- GPS Clocks
- Atomic Clocks
- Radio Clocks

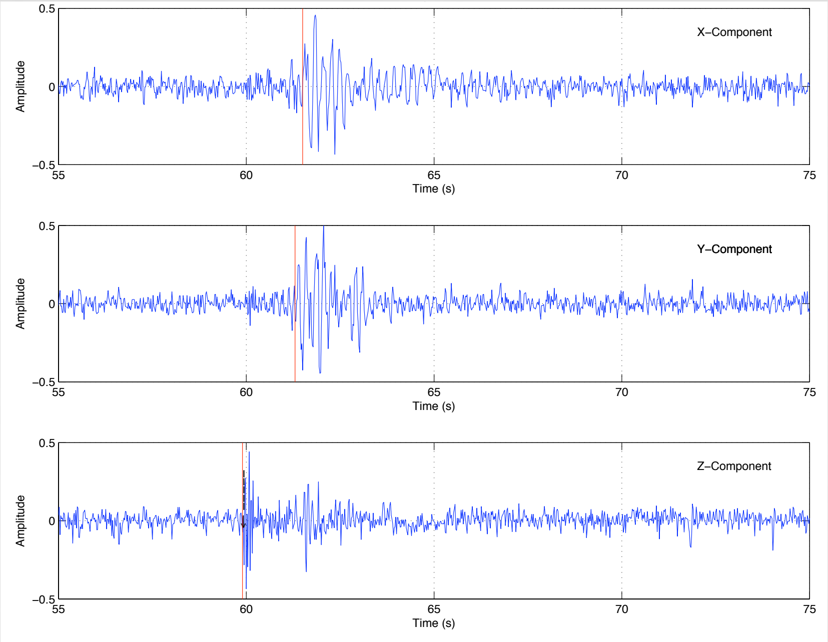
Peer-to-peer method often provides better than 0.1 second accuracy, often +/- 20 msec.

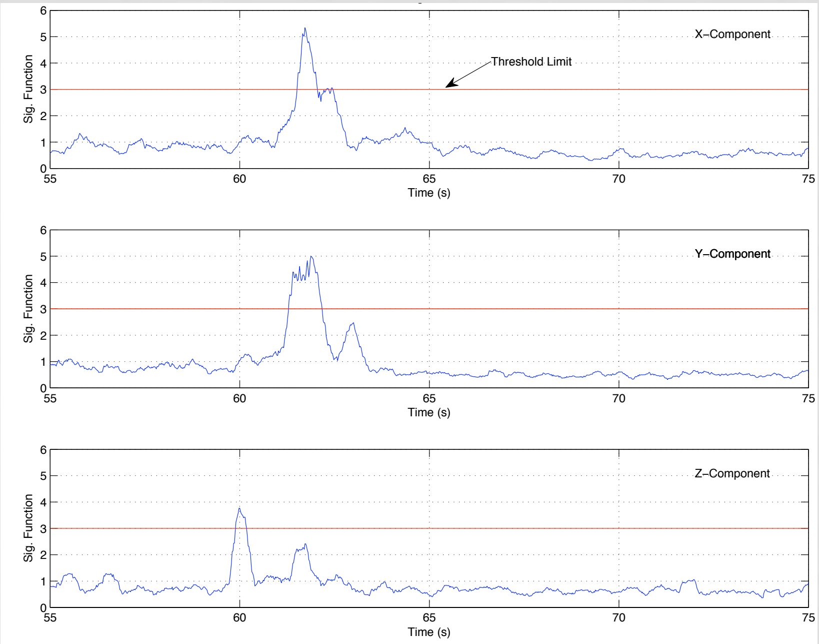
Frassetto et al. (SRL, 2003)

TRIGGERING ALGORITHMS

- **Examined several possible triggering algorithms to:**
  - Maximize true (earthquake) triggers, minimize false triggers
  - Use efficient triggering algorithm for rapid reporting

- **Time domain triggers based on STA/LTA are simple and fast to implement**



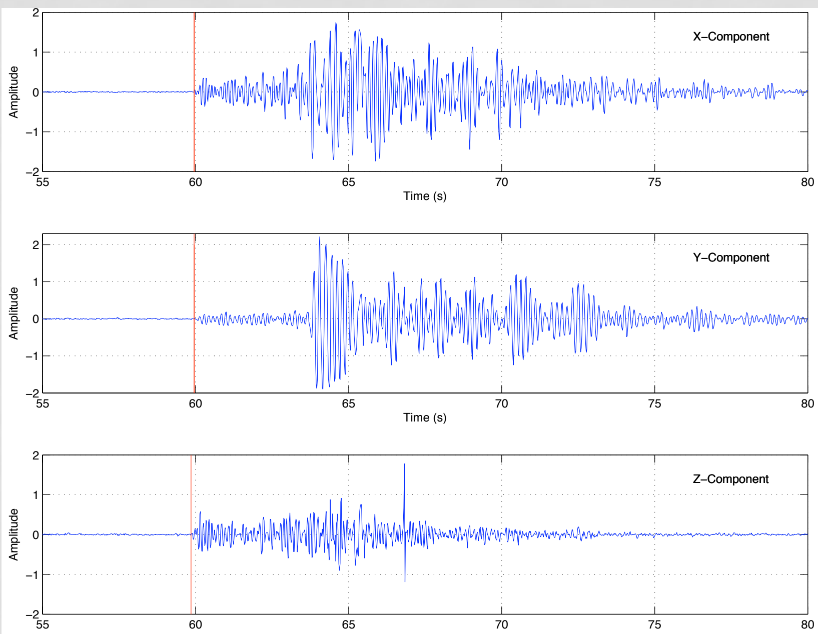


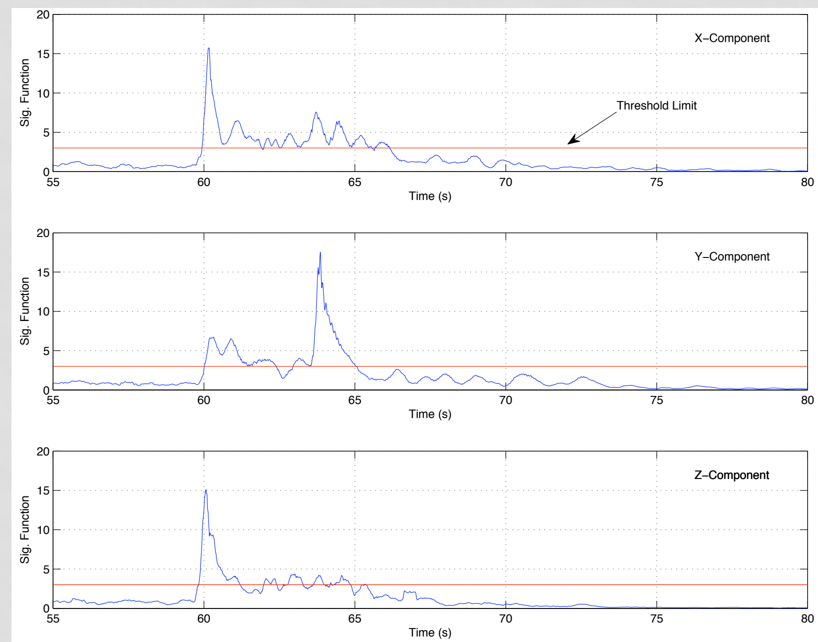
Example 1: M 3.2 Earthquake in San Francisco Region

TRIGGERING ALGORITHMS

- **Examined several possible triggering algorithms to:**
  - Maximize true (earthquake) triggers, minimize false triggers
  - Use efficient triggering algorithm for rapid reporting

- **Time domain triggers based on STA/LTA are simple and fast to implement**

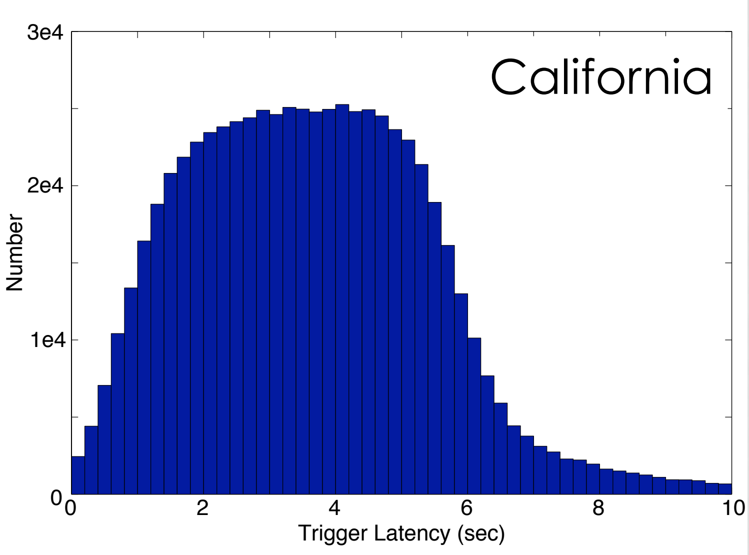


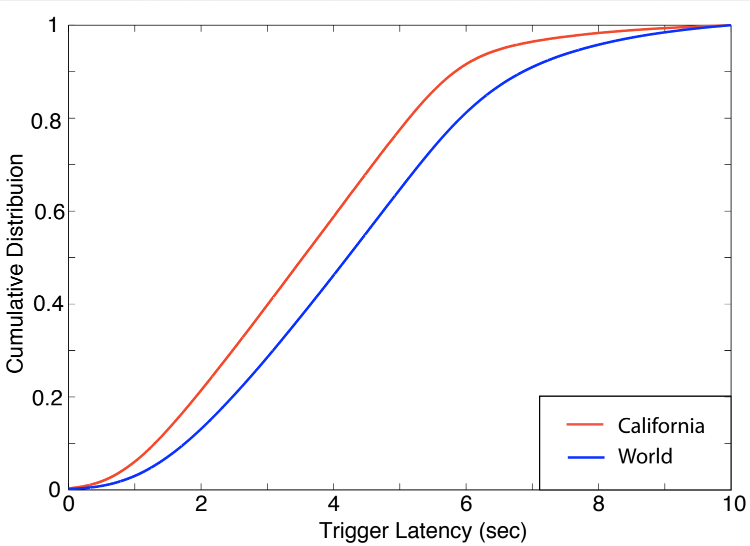


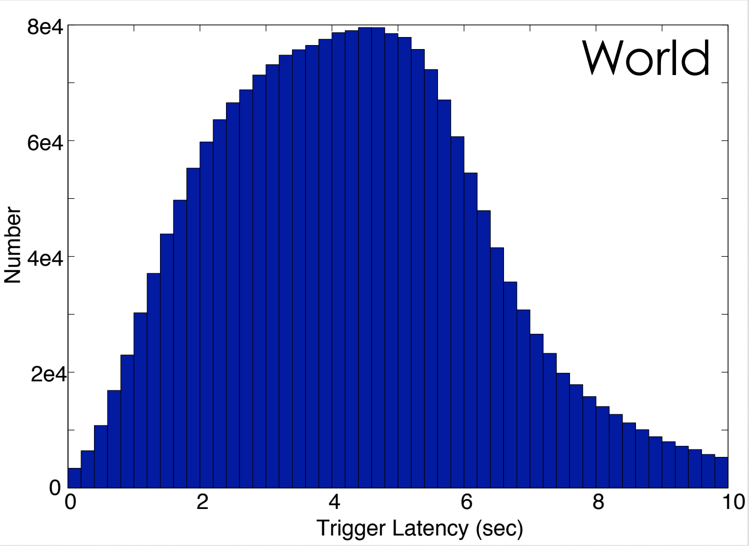
Example 2: M 5.0 Earthquake in Los Angeles Region

DATA TRANSFER LATENCY

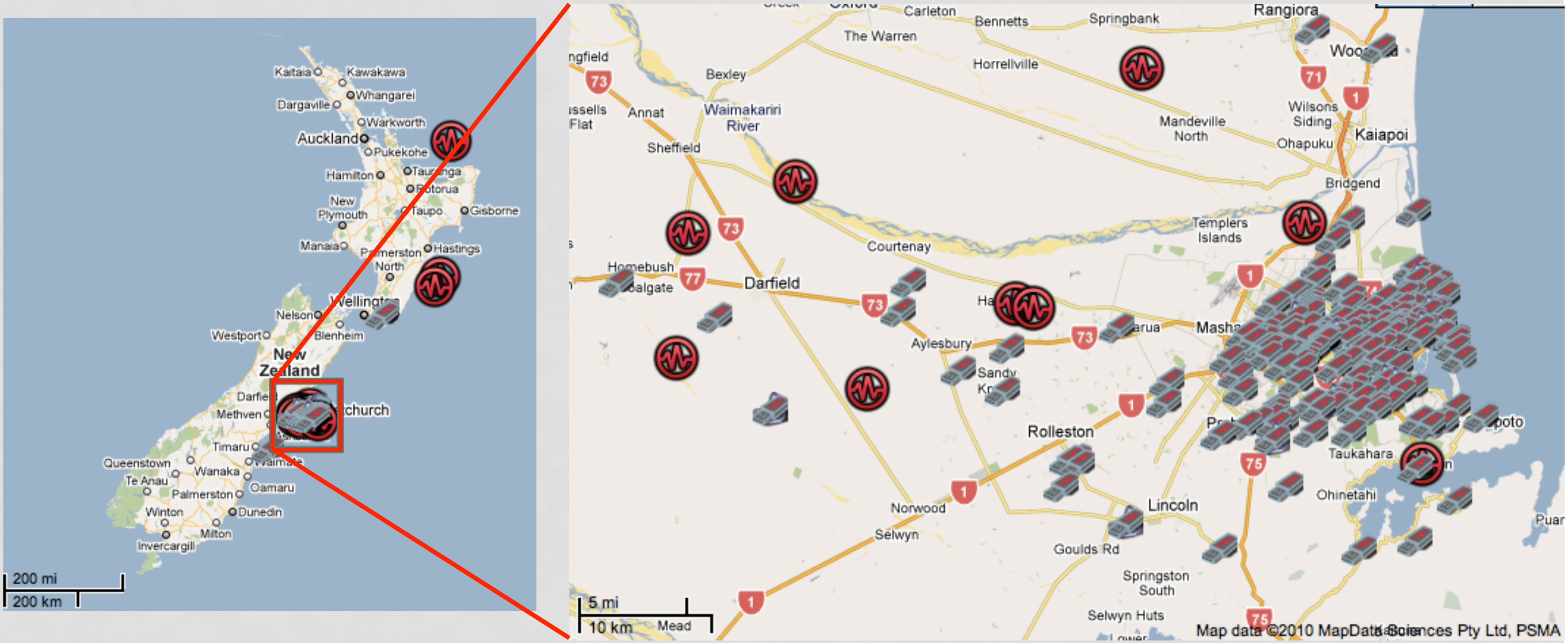
- Initially transfer minimal data:
  - Time
  - Amplitude on each components
  - Significance
  - Station information (location, sensor type)
- Overall small trigger latency:
  - 3.62 seconds within California
  - 4.29 seconds globally







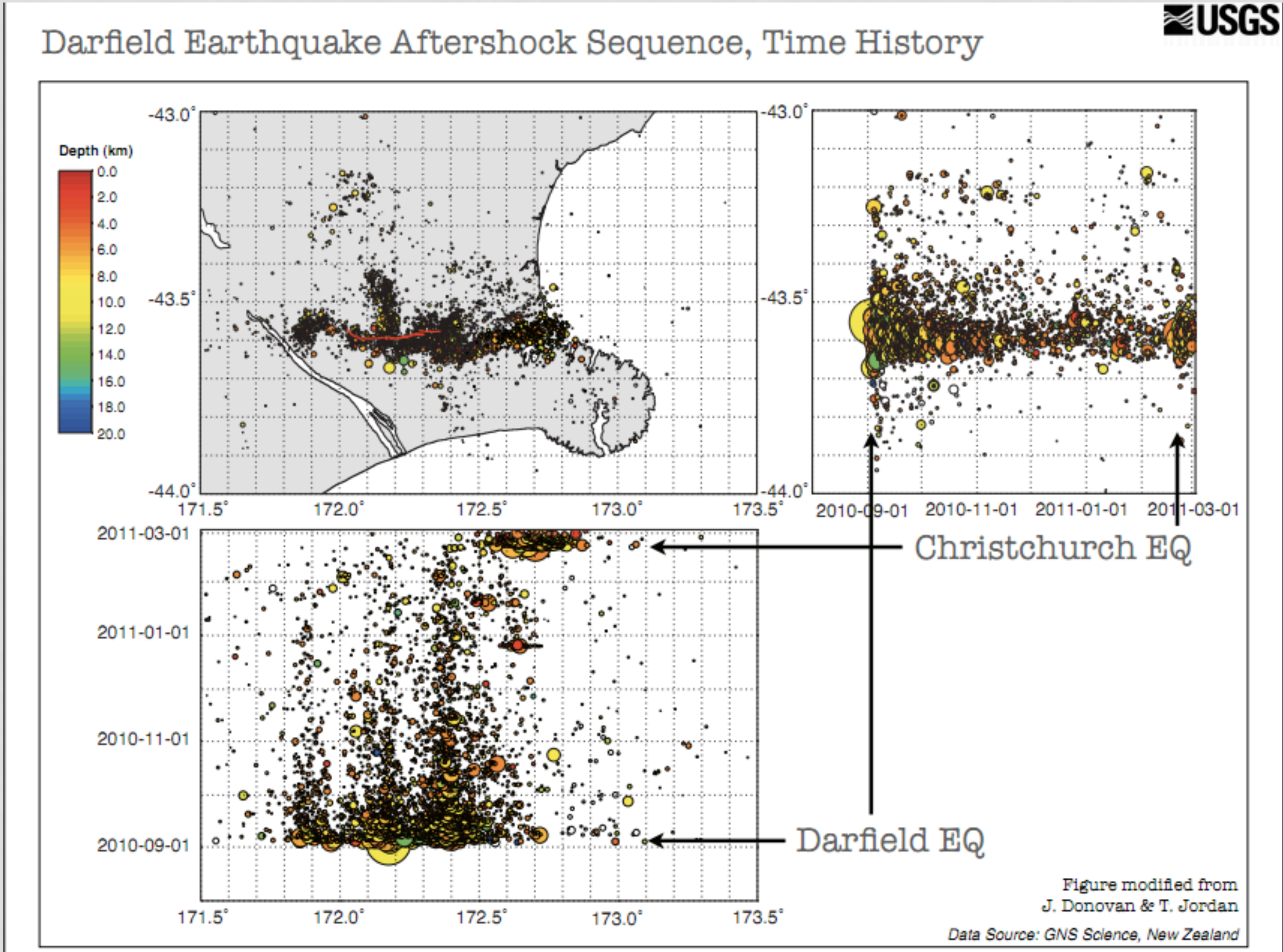
M7.1 DARFIELD NEW ZEALAND RAMP



Installed ~180 sensors in New Zealand in the week following the 3 Sept 2010 M7.2 earthquake

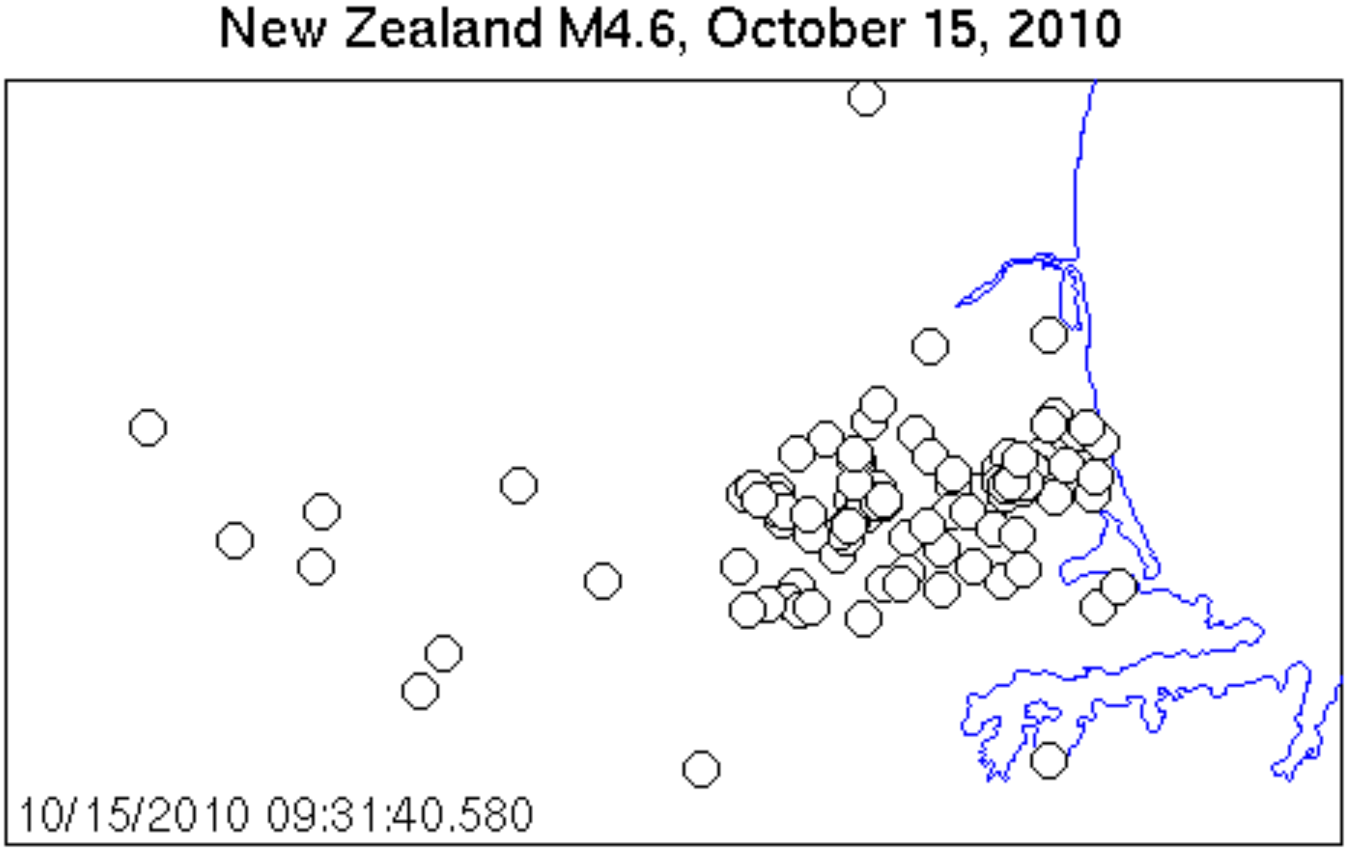
Collaboration between GNS Science and QCN

Darfield earthquake continues to have a vigorous aftershock sequence and is being recorded by the QCN array.



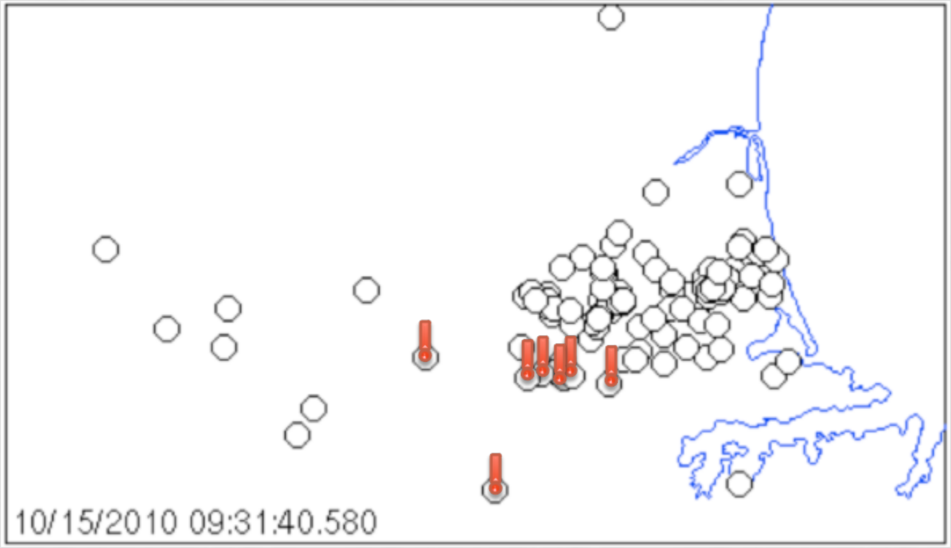
Source: USGS 2011

Wave Propagation Through Christchurch



REAL-TIME EVENT DETECTION

1. Trigger message sent from client station



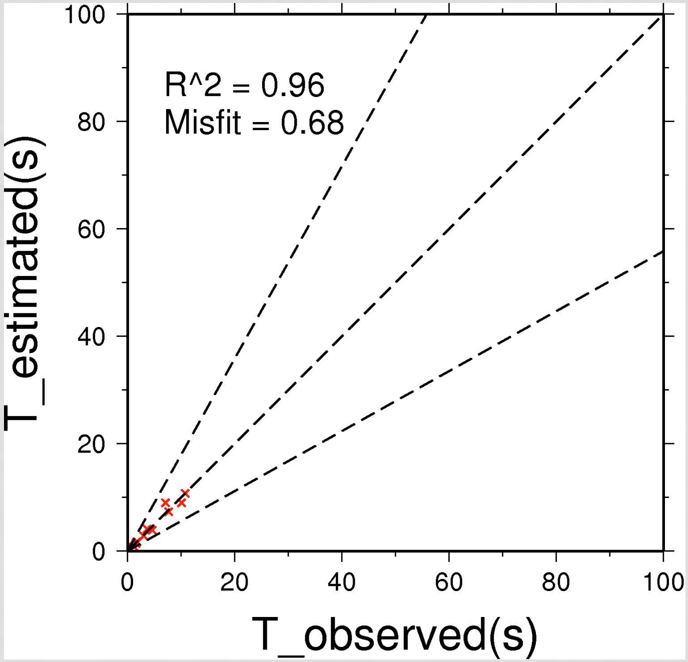
2. Server correlates triggers within:
   - 100 seconds
   - 200 km radius
3. Check moveout
   - Is wave traveling at seismic velocities:

$$\Delta T_{ij} \leq \Delta D_{ij} / V_{\min} + \varepsilon$$

4. Issue a detection if the # of triggers > regional threshold

REAL-TIME DETECTION

After a *detection* is issued we estimate:



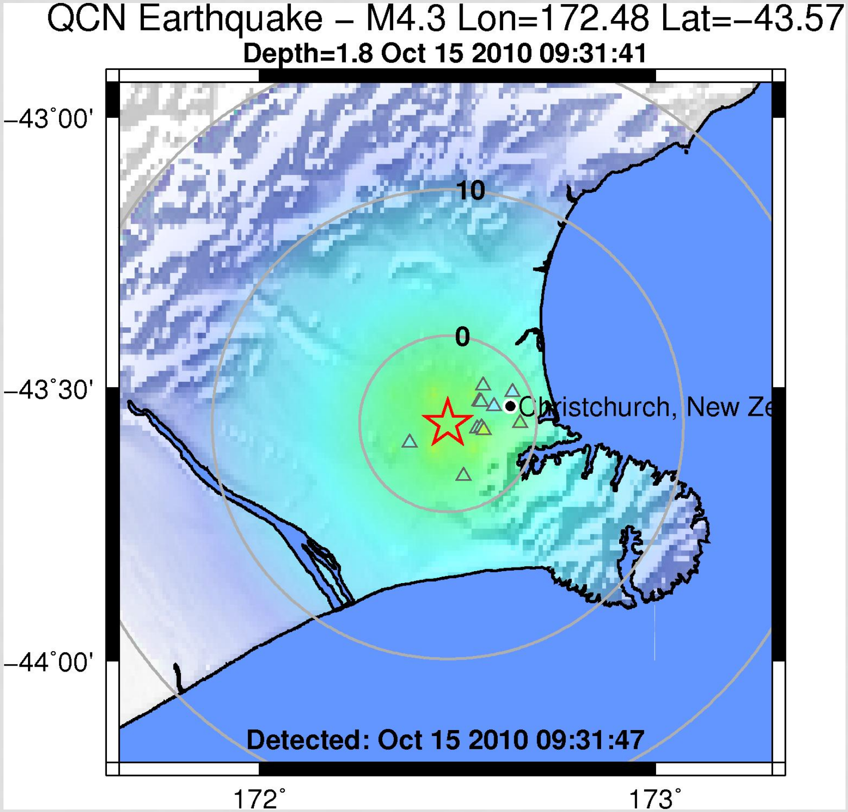
1. Location:
   - Triggers may be P or S arrivals
   - Starting location is set to the location of the first trigger
   - Grid search of possible locations
   - Iterate to find best location

2. Magnitude:
   - Vector sum of PGA: $|PGA|$
   - Updated amplitude every 1, 2, and 4 seconds
   - Use empirical distance-magnitude relationship (e.g. Campbell, 1981; 1989; Wu et al., 2003; Cua and Heaton, 2007):

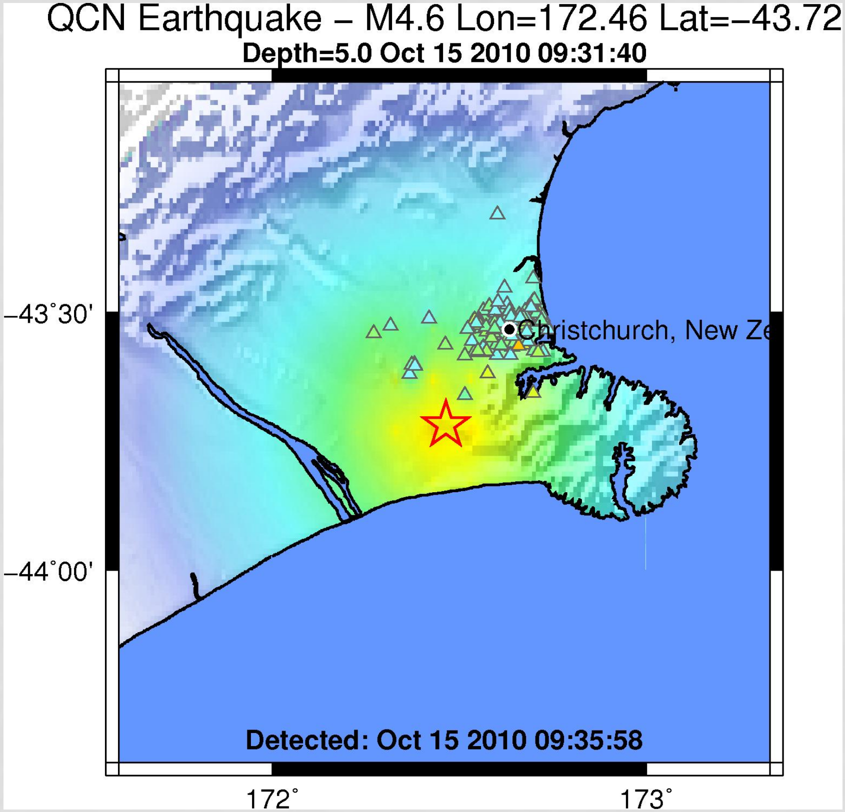
$$|PGA| = \frac{1}{b}\exp\frac{1}{a}\left(M_L - c\ln(R) - d\right)$$

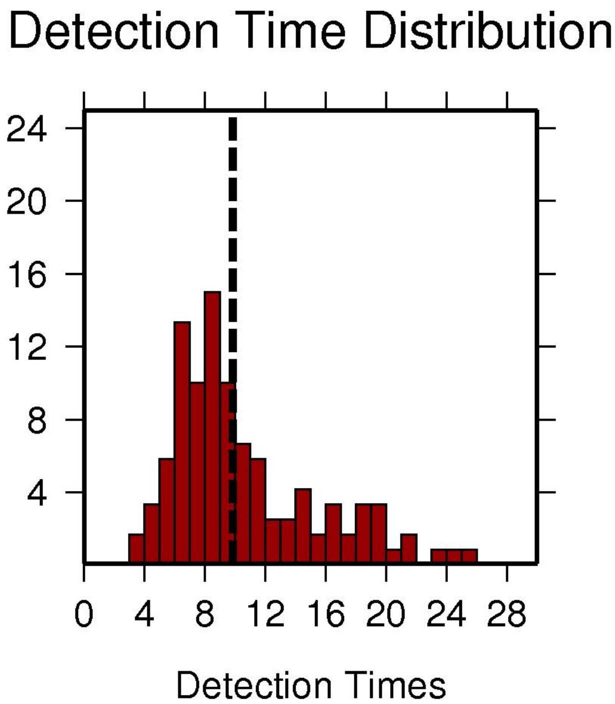
IMPROVING EVENT DETECTION

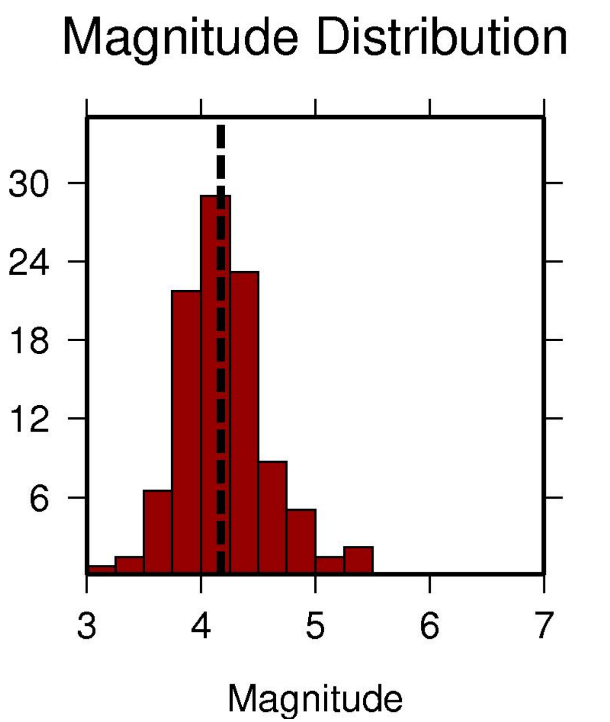
Initial event characterization:
5 seconds after the origin time
11 triggers



Final event characterization:
257 seconds after the origin time
194 total triggers from 104 stations







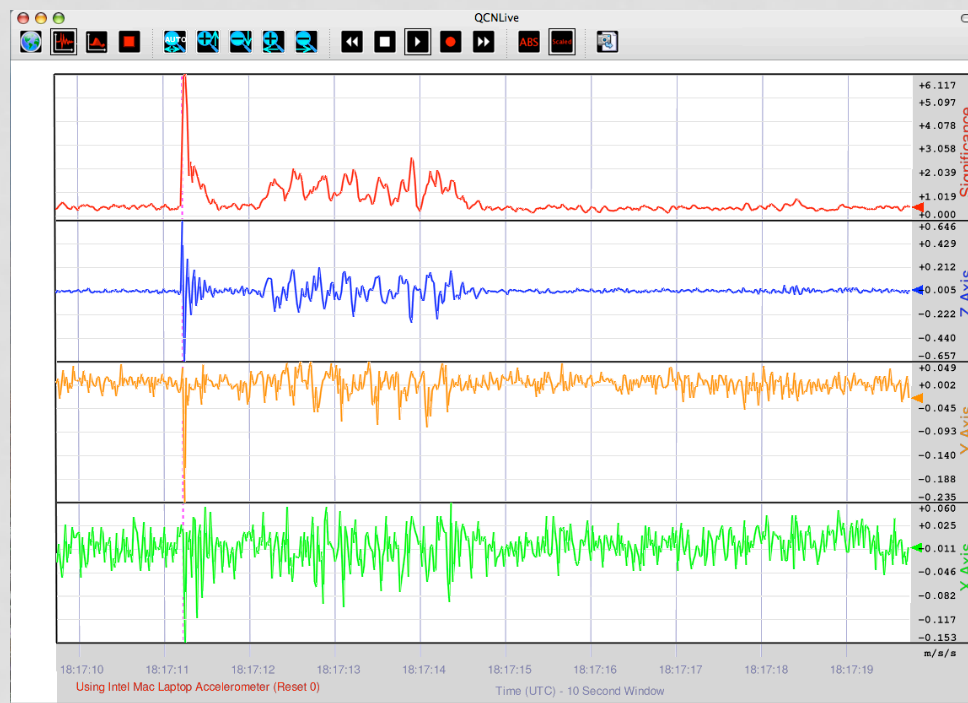
Real-time Detections to date:

- Detection running since mid-September
- All detections in New Zealand – no other location currently has either:
  - Dense enough network of stations
  - Earthquakes
- First detections occur within ~9-10 seconds from the *earthquake origin time*

Event locations and magnitudes are revised using updated amplitude data from 1-4 seconds after the event.

EDUCATION AND OUTREACH

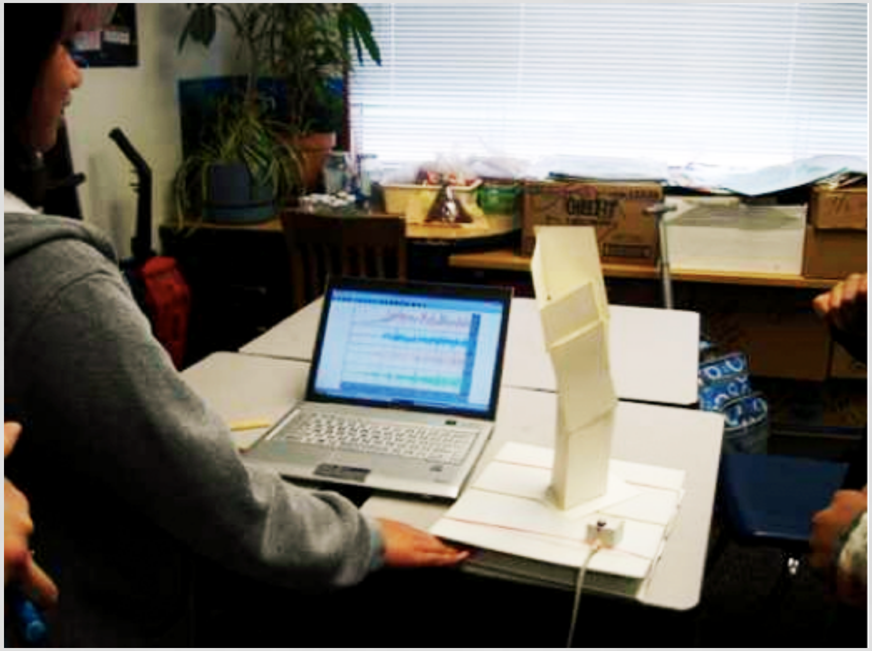
- Increase seismic hazard awareness and earthquake literacy via participation
- Developed interactive software for use in classrooms (QCNLive)
- Creating activities that utilize the sensors and software to teach Earth Science content standards



EDUCATION AND OUTREACH

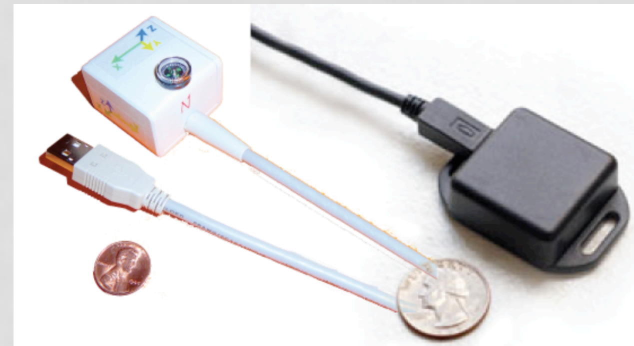
Lessons and Activities – developed by QCN collaborators (M. Hubenthal, D. Kane, D. Kilb, P. Kim, J. Saltzman, IRIS)

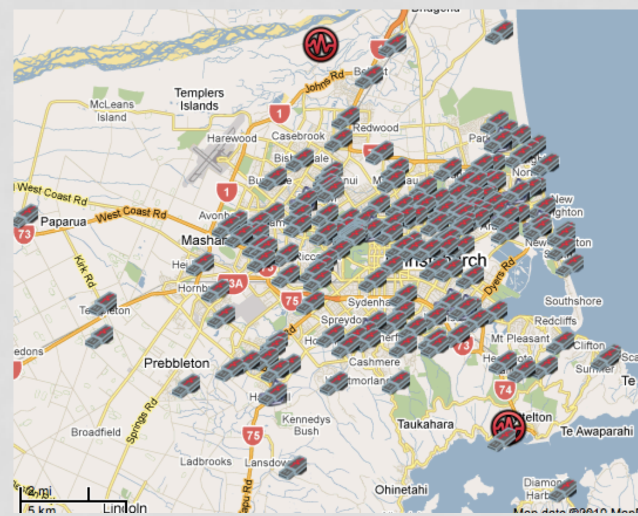
- What is a seismometer?
- Magnitude and intensity
- Exploring three component seismic data with accelerometers
- How hard does the ground shake during an earthquake
- Earthquakes and buildings



SUMMARY

- Current sensor are 14 bit and will be integrating 16 bit and 24 bit soon
- Low-cost MEMS and distributed sensing techniques can provide valuable acceleration data for real-time event detection and characterization
- Creating educational activities to complement the network activities





THE END

Thank you to all of the QCN participants, especially K-12 teachers and classrooms

QCN is funded by:

Project website: qcn.stanford.edu

Any Questions?