



Earthquake Forecasting R&D

QuakeFinder

i-PCGRID Workshop 2018

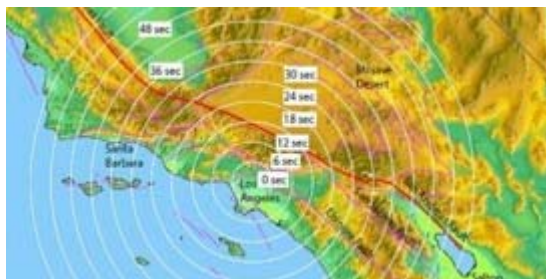
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Current methods provide:



Seconds of warning

- Earthquake “Early” Warning (EEW) systems
- Based on seismic detection of a quake after it has occurred



Days of warning

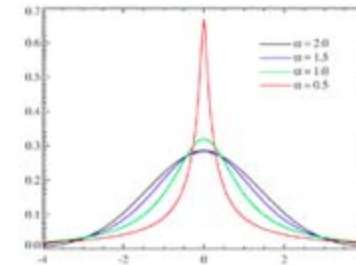
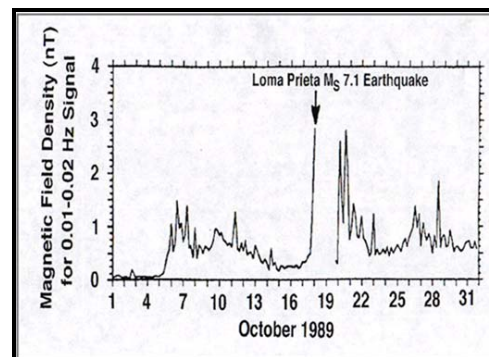
QuakeFinder



is developing technology to provide forecasts

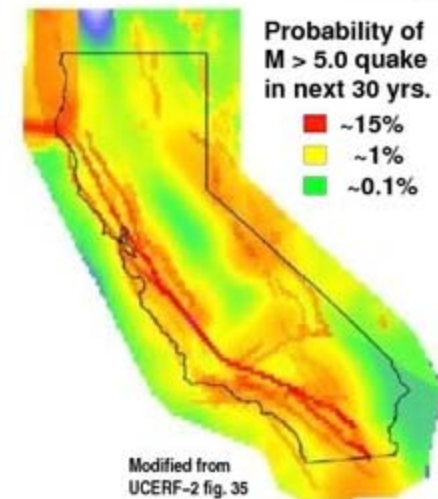
days or weeks

in advance of earthquakes



Decades of warning

- 30-year probabilities
- Based on statistical analysis



Modified from UCERF-2 fig. 35

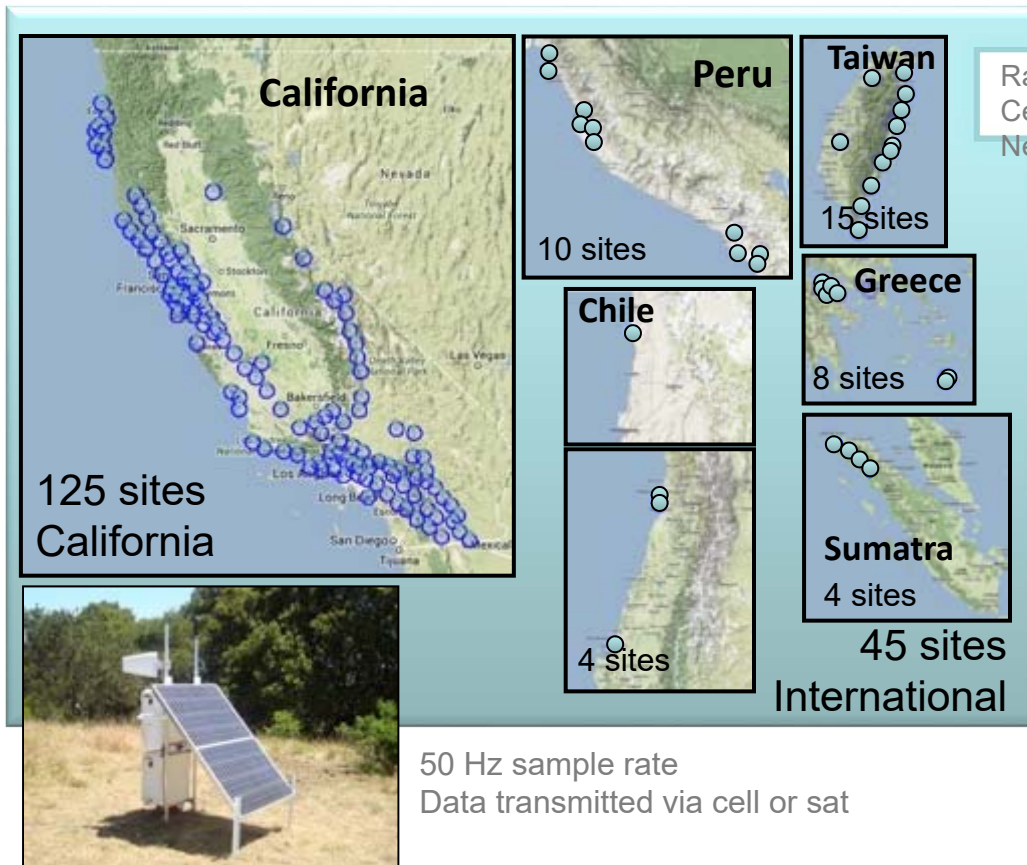


- Established in 2000 in Palo Alto, CA.
 - *Humanitarian* R&D Project
 - Parent Company: Stellar Solutions Inc - an industry-recognized leader in aerospace systems engineering services
- Significant investment to date
 - Funded by Stellar Solutions, Inc.
 - Augmented with sponsor funding and donations: NASA, PG&E, Musk Foundation, Vodafone, Telefonica
- We serve as the focal point for international community research in the field of electromagnetic pulse monitoring as precursor to earthquakes

Mission:

Save Lives By Forecasting Earthquakes

Instruments/sensors



Data Center



Palo Alto, CA
80 TB of data to date
Secure back up in NV
>250 Earthquakes captured

Raw Data,
Cellular
Net

Processed Data
Available to Partner via
Internet

- 200 MB/day/station
- 1.3 TB per year for 18 stations

Research Partner



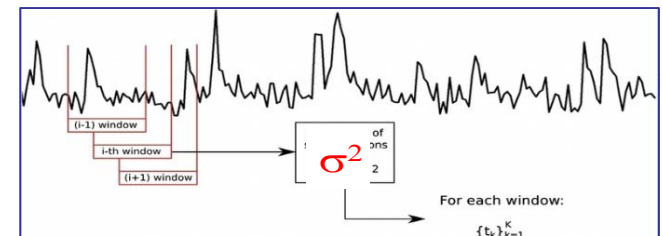
Options:

- QF pushes to partner server
- AWS
- QF stores data and partner 'pulls'

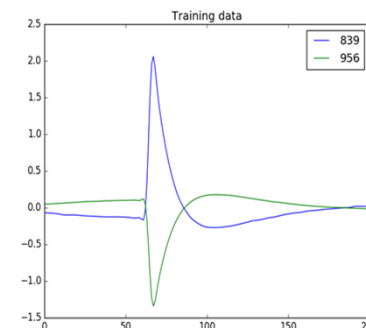
In this phase of the project, we use known earthquakes near our instruments to build and qualify algorithms to detect earthquake precursor signals

- Algorithm Framework Built
- STA/LTA (Short Term Average/Long Term Average)
 - Uncovers signals and energy levels above running threshold
 - Filters applied for vehicles and lightning
 - Data is windowed into short time spans from which characteristics can be drawn
 - Results in statistical method (ROC or Molchan)
 - Being converted to an Operational system now

STA/LTA

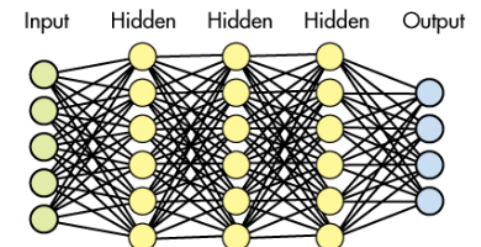


- Simultaneity
 - Using data from adjacent stations, locate common pulses
 - Method to help filter noise



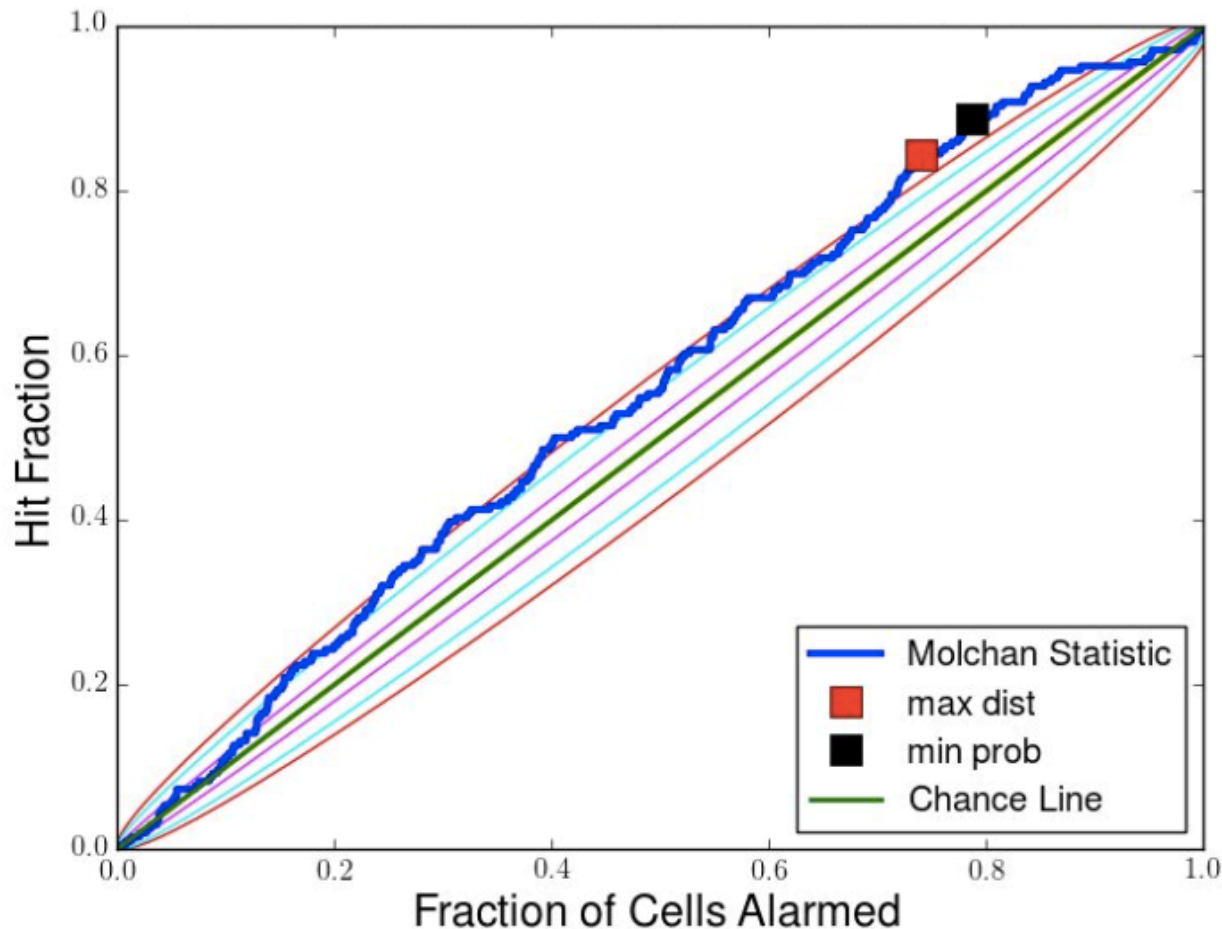
- PCA and Time-Domain PCA
 - Results are encouraging, effort paused for feature extraction improvements

Deep neural network



- Machine Learning
 - Partner in Silicon Valley established. In work now.

QuakeFinder Achieves Milestone



- Achieved 2.9σ Statistical Correlation between pre-earthquake EM signals and earthquakes
- i.e. ~99.9% probability the signals are not random
- Sample size of 206 quakes
- 'Molchan' Diagram (left) employed to show statistical results
- Will continue to improve as we reduce sources of false-positives
- Publishing results now

What is 3σ Statistical Correlation?

In Particle Physics - considered strong evidence of a particle discovery

In Space Risk Analysis – considered sufficient for human spaceflight

In Clinical Trials – considered invulnerable to false discoveries



Thank you.

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QF-2012 Instruments

Magnetometers: (3)

- Induction Type Magnetometers (Models ANT4 and QFIDO-3)
- Optimized for Earthquake research
- Length: 76.2 cm (30 In.)-QFido3, 127 cm (50 In.) Ant4
- Width: 3.8 cm (1.5 In.) QFido 3, 8 cm (3 in.) Ant4
- Weight: 0.927 kg. (2lb. 0.7 oz) QFido3, 25.3 kg. (11.5 lb) Ant4
- Frequency Range: 0.01 to 12 Hz (low pass filter @12 Hz)
- Sensitivity @1Hz: 0.1 V/nT QFido3, 1.0 V/nT Ant4
- Noise Level: 0.1pT per root Hz @1 Hz; 0.02pT per root Hz@10Hz
- Sampling Rate: 50 sps
- Analog Filters: 100db for 60 Hz suppression
- Sensor sampling: Differential coupled to 8 channel, 24 bit, analog-to-digital converter
- Includes OP Amp Low Pass Filter with a 13 Hz cutoff for 50/60 Hz noise rejection



Air Conductivity Sensors: (2)

- 1 measuring positive ions; 1 measuring negative ions
- Type: "Gerden Tube", with a fan which pulls air through the meter at a calibrated rate
- Unit is enclosed in a static-shielded, PVC tube with cover for rain protection
- Conditions: Air Ion Counter -10°C to 50°C, Wind Speeds < 15 km/hr (9mph)
- Range/Resolution: 1 million ions / cc / sec. range 500 ions /cc/sec resolution
- Accuracy: +/- 25% of reading

Also: 4 Hz Geophone, Humidity, Temp. health data, solar powered, Verizon cell phone connectivity, 60MB/day, 10 sec "Heartbeat" messages, GPS timing, Processed data shown on web each day