

The QuakeFinder Earthquake Forecasting Process

Electromagnetic Signals:
Magnetic Pulses
Air Conductivity
Infrared

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Topics

- What is QuakeFinder?
- QF instruments
- Examples of “quiet days” and “pre-earthquake” days
- Simultaneous 3 indicator “patterns”
- QF and Partner Networks
- How the data is ingested and quality checked
- How QF algorithms work today
- QF “process” of checks and balances to reduce false alarms
- Current “challenges” handling ambient noise

Future options being considered:

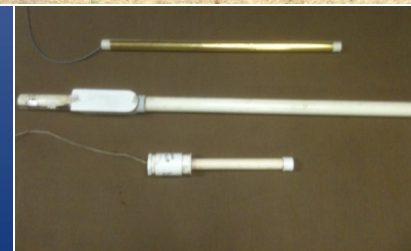
- Documenting Future (QF) “Forecasts” with CSEP
with Time, Distance, Magnitude , Confidence Levels

What is QuakeFinder?

- Stellar Solutions: Satellite Sys. Engineering Co.
- Humanitarian R&D Division: QuakeFinder
 - Give back to Community
 - Mission/Goal: To save lives by forecasting major earthquakes
 - Develop EM Techniques for Short Term Forecasts
 - Days to Weeks
 - Data Provider to Gov.
 - Funded by Stellar Solutions
 - Supplemented by NASA ES, PG&E, Telefonica, Musk, Vodafone

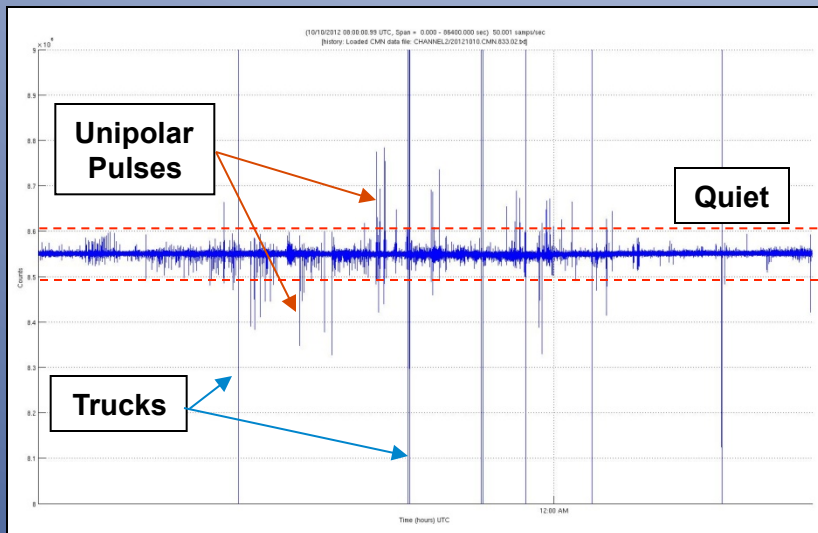
QuakeFinder Instruments (Ver. 6)

- 3 Axis Induction Magnetometers
 - 0.1pT at 1 Hz noise floor, 24 bit A/D
- Positive and Negative ion sensors
 - 10^6 ions/cc/sec range
 - 500 ions/cc/sec resolution
- 60MB data per day thru Cell
 - Solar Powered or 120/240 VAC
- Instrument for Noise:
 - Rel. Humidity, geophone

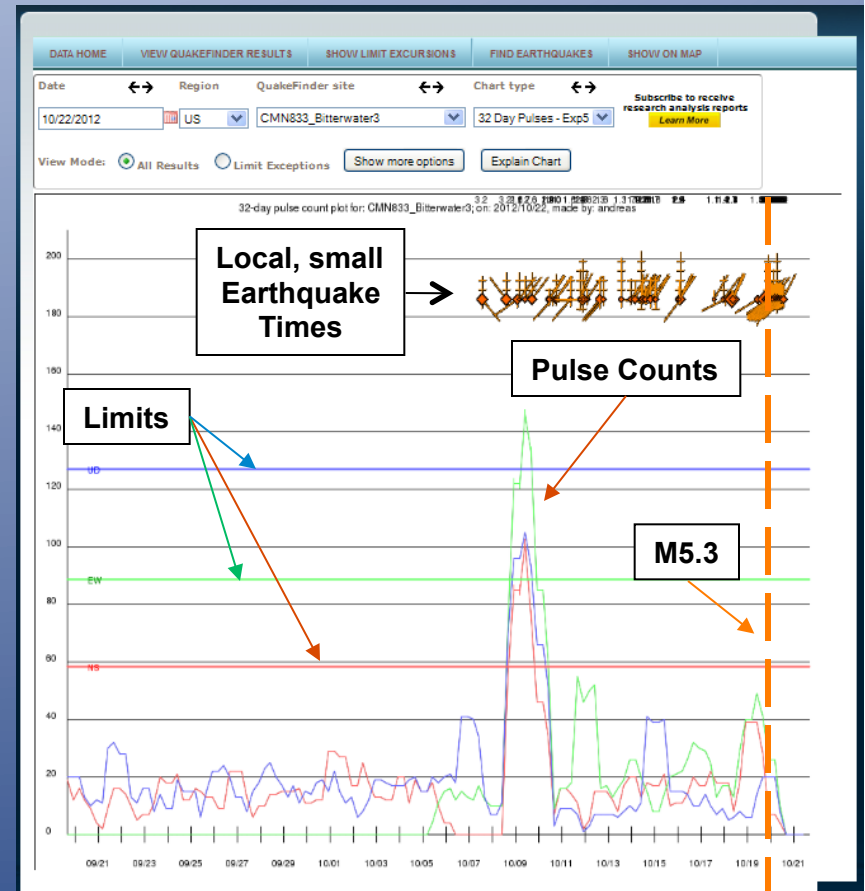


Examples of "Quiet Days" and "Pre-Earthquake" Days

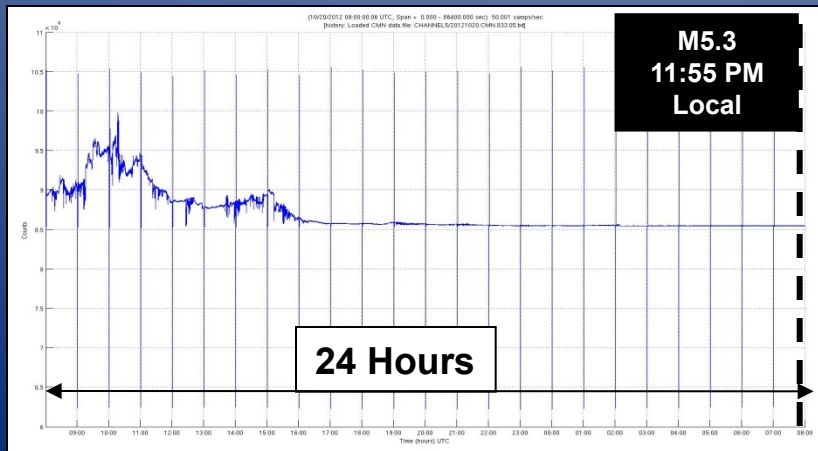
24 Hr Time Series: Pulses



Pulse Counts



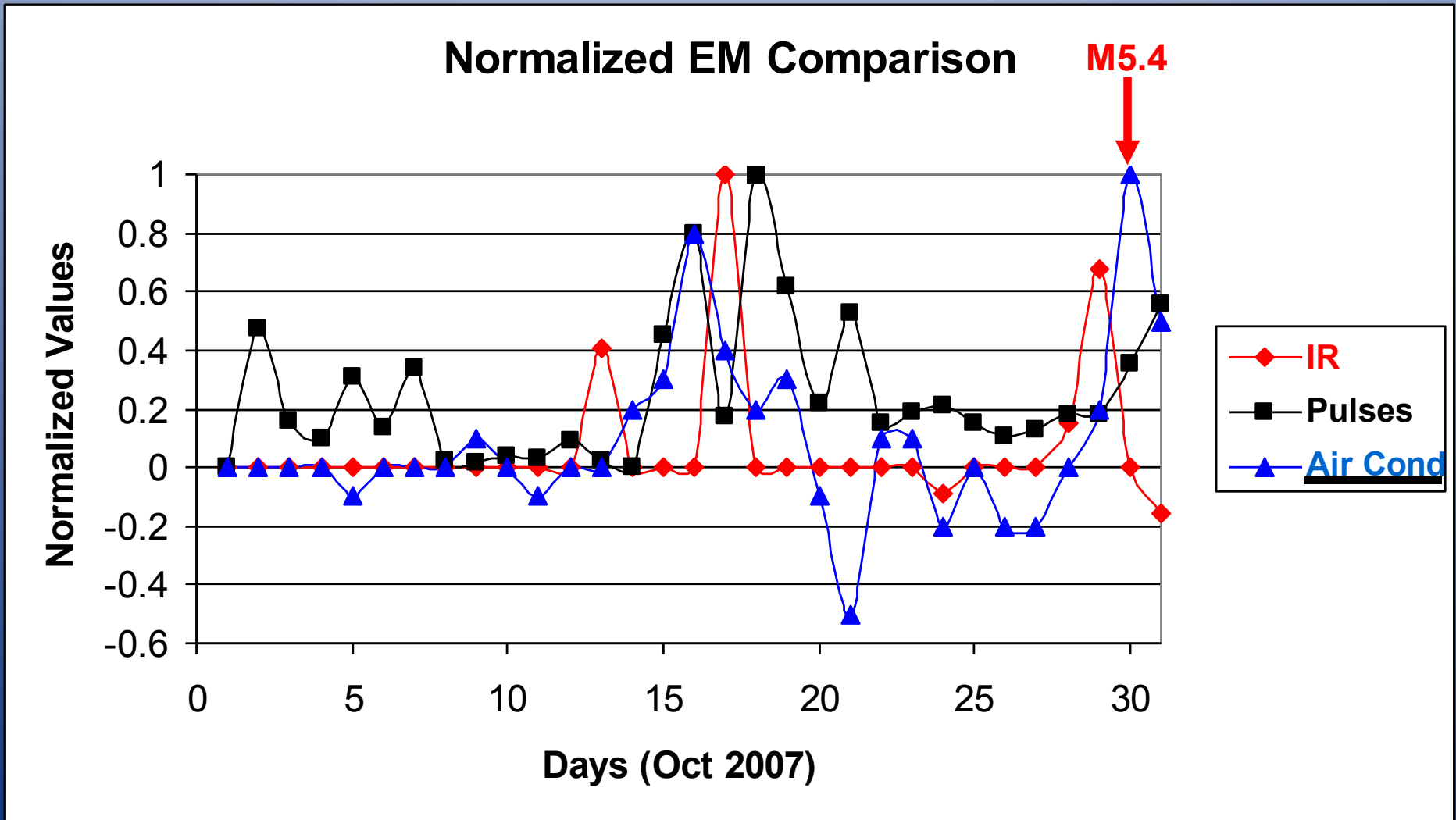
Air Conductivity



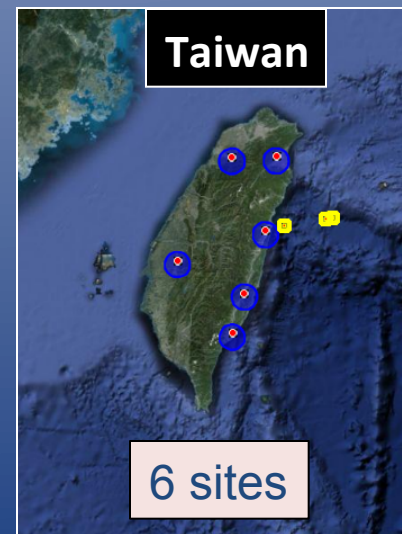
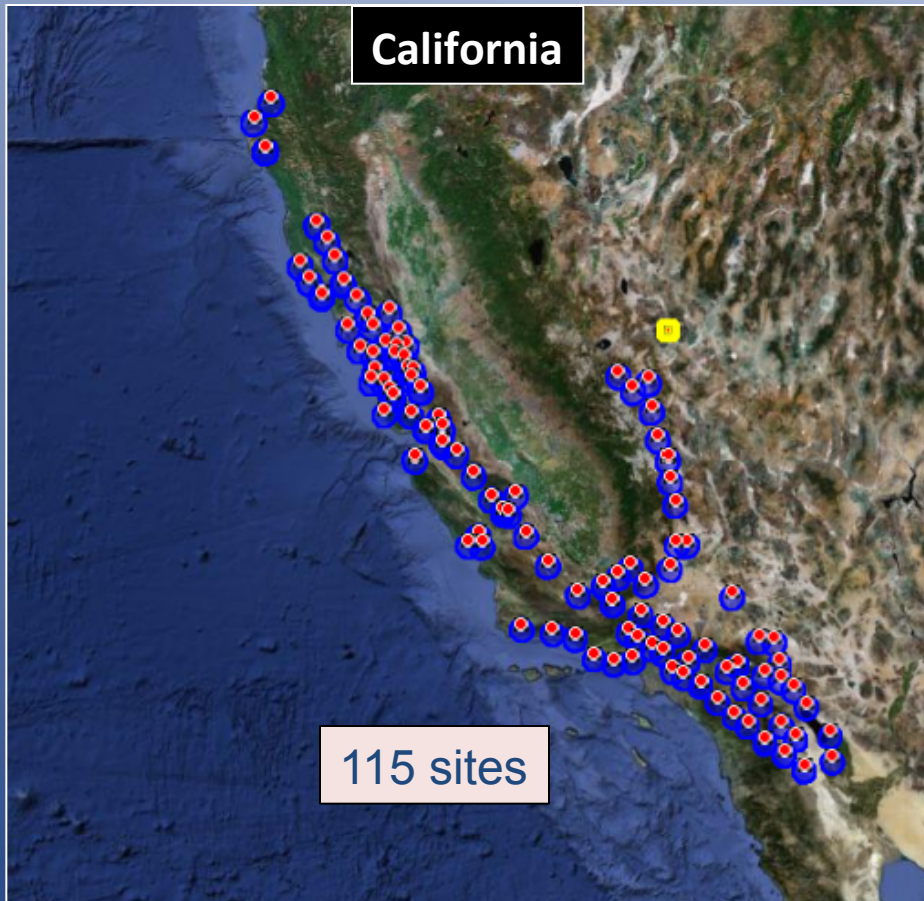
32 Days

Simultaneous 3 indicator “patterns”

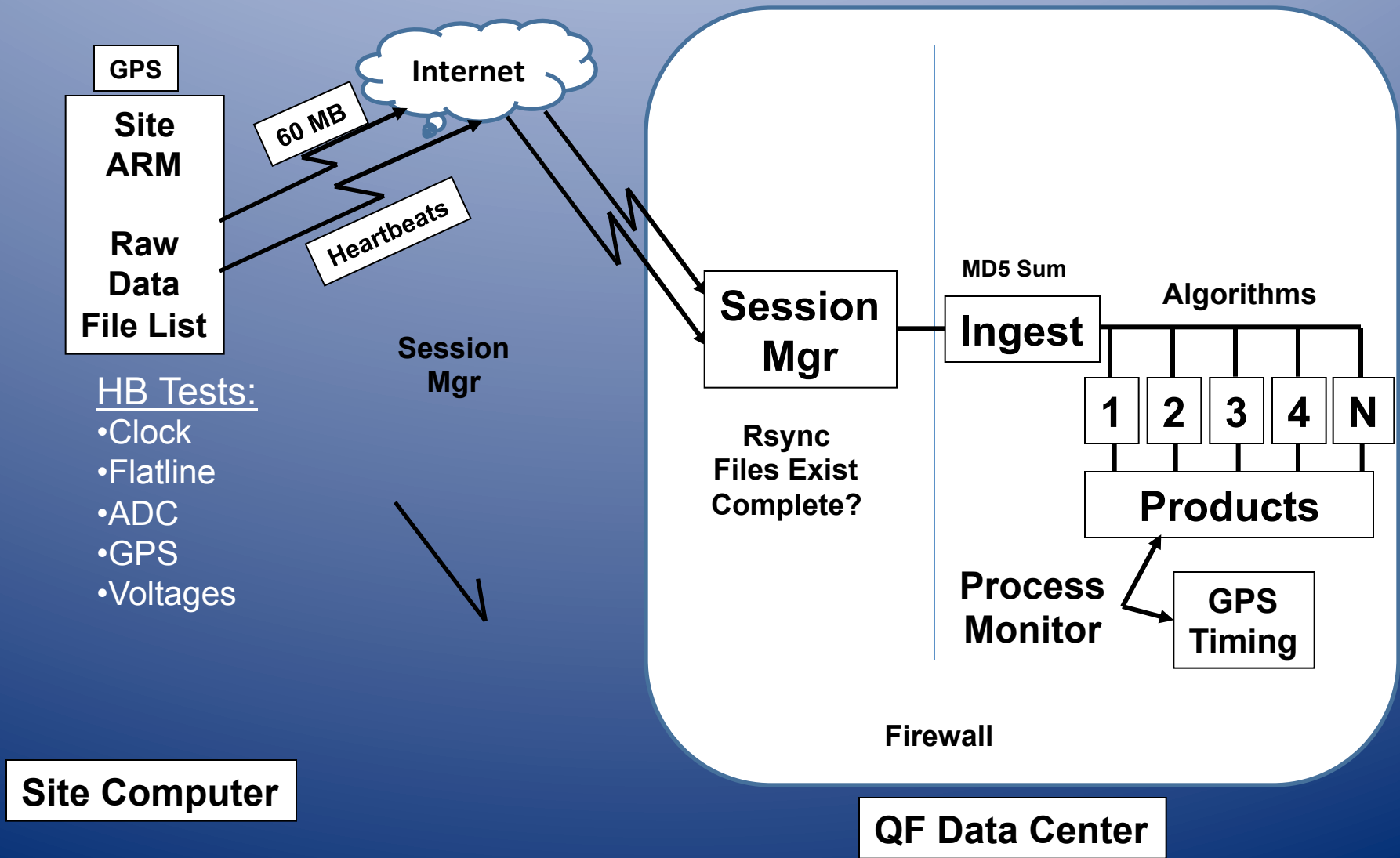
Alum Rock M5.4



QuakeFinder and Partner Networks



Data Ingest and Quality Checks



QF Automated Algorithms

3 Magnetometers (pulses)

Pulse Counts (3-5 levels)

Azimuth Pulses

Direction of Arrival

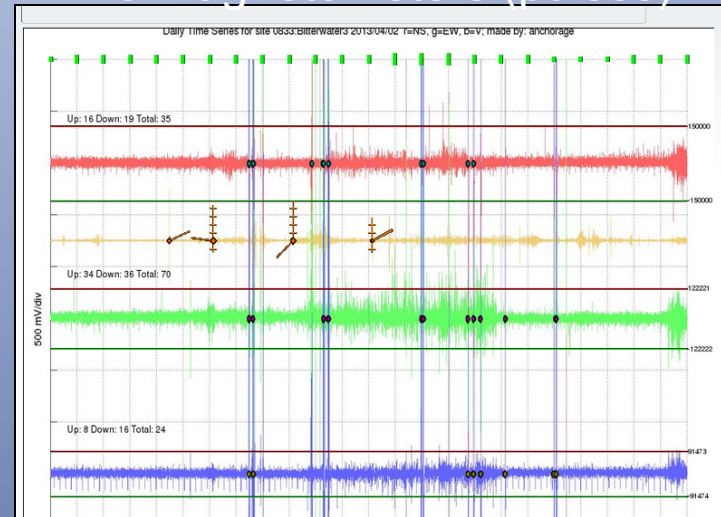
Ion Limits (in work)

Dirty sensor?

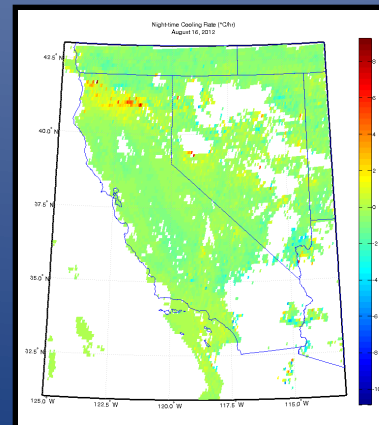
Humidity >95%

Pos or Neg?

Pattern reasonable?



IR



IR Night Time Slopes

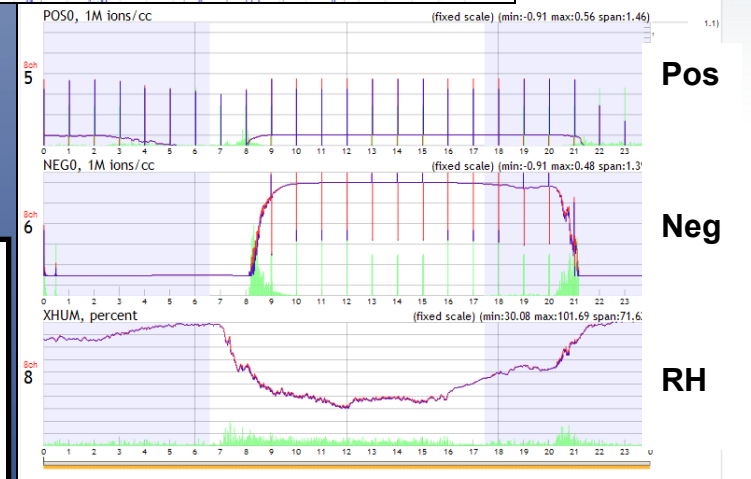
Reasonableness

Cloud Masking

Temp, adjacent pixels, confidence

Pixel Registration

Ground tie points



875

Pos

Neg

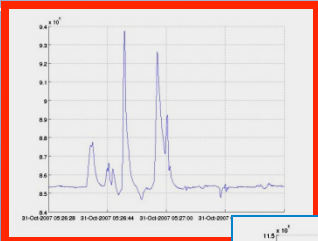
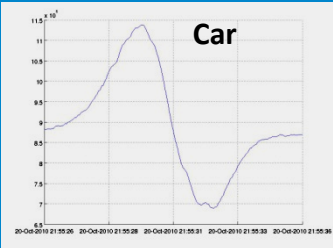
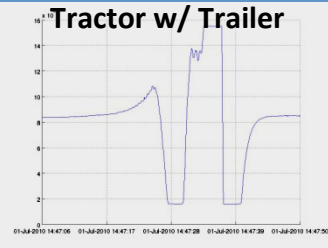
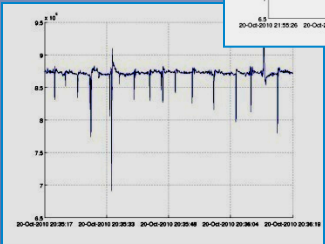
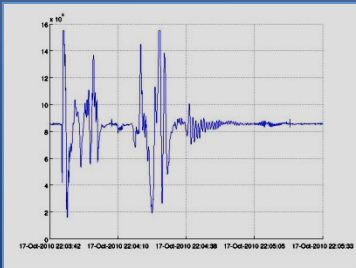
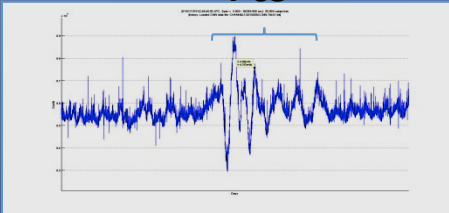
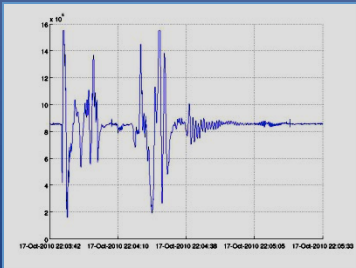
RH

Ion

QF Data Validity Process

- What if we do see 1,2,3 Interesting Patterns?
 - Are they simultaneous per the “template”?
 - Manually Look at Raw Data
 - Check waveforms (a new type of noise?)
 - Check Automated Limit values
 - Check Pulses against Lightning Tables
 - EarthNetworks (soon to be automated)
 - Call Homeowner at Site
 - Is there some activity there? (plowing, pumps, traffic)

Current “Challenges” Handling Ambient Noise

Noise source:	Example	Suppression
<ul style="list-style-type: none"> • Quake Signal 	 <p>63 sec</p>	N/A
<ul style="list-style-type: none"> • Vehicles 	 <p>Car</p>  <p>Tractor w/ Trailer</p> <p>44 sec</p>	Pattern (bi-polar)*
<ul style="list-style-type: none"> • Lightning 	 <p>10 sec</p>	Pattern (fast rise)* EarthNetworks Weather Reports
<ul style="list-style-type: none"> • Pc1 and Pc3 (solar) <p>Pc1 and Pc3 are solar-generated noise</p>	 <p>62 sec</p>  <p>Pc1</p> <p>500 sec</p>	High Pass Filter
<ul style="list-style-type: none"> • Man-made <p>Classifier*</p>	 <p>110 sec</p>	Multiple Wave

* Under development

Documenting Future (QF) “Forecasts” w/ CSEP

(Proposed---No forecasts made yet)

Activity noticed (“Exception” to limits or manual viewing)

- If Data Quality is good AND If Noise is understood
 - Checked with homeowner for unusual activity
- If Pulses are high for 3-5 days (30% confidence)-tbd
- If Pulse Azimuth is “clustering” (20% confidence)
- If Positive Ion sensor is high (20% confidence)
 - Greater than 5 hrs (AND after pulse high span)
 - No high Humidity or dirty plates
- If IR shows Slope > 0 at same area/site (10% confidence)
 - Several pixels, no clouds nearby
- Are other EM researchers observing signals in same area? ++

What would a Forecast look like?

- Location: Within 30km of site location
- Time: Within 12-48 hrs of ion spike start
- Magnitude:
 - Depends on pulse pattern (energy levels, days)
 - Number of sites detecting pulses (1,2,3 sites)
- Confidence (additive as shown before)