Current Progress
Using Multiple Electromagnetic Indicators
for
Earthquakes in California and Peru

Tom Bleier, Clark Dunson, Steve Roth:	QuakeFinder
Jorge Heraud, Antonio Lira:	PUCP Peru
Friedemann Freund, Robert Dahlgren:	SETI, NASA Ames
Ray Bambery, Nevin Bryant:	NASA JPL/CIT
Dimitar Ouzounov	Chapman University

“Grand Questions”

1. **Are there Electromagnetic (EM) signals prior to earthquakes?**
   - **Need documented evidence using field instruments**

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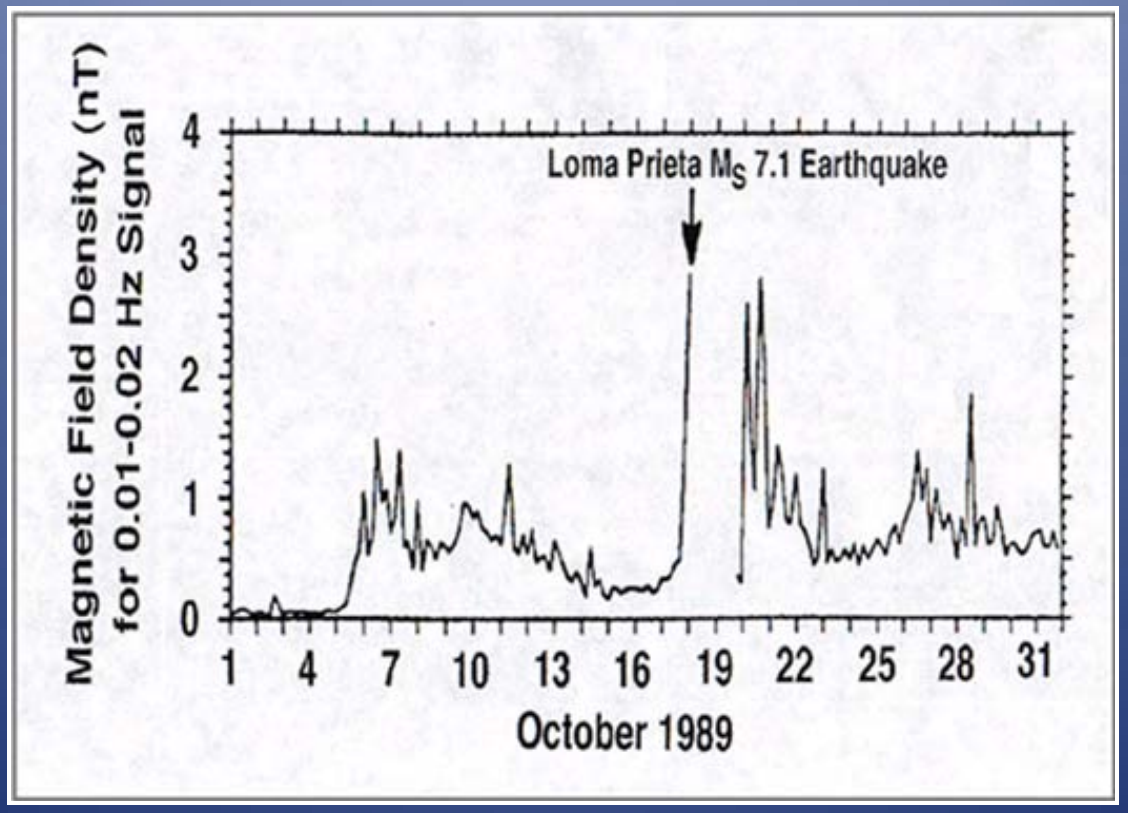
5. **Can we make forecasts based on EM signals?**
   - Can they be made reliable?

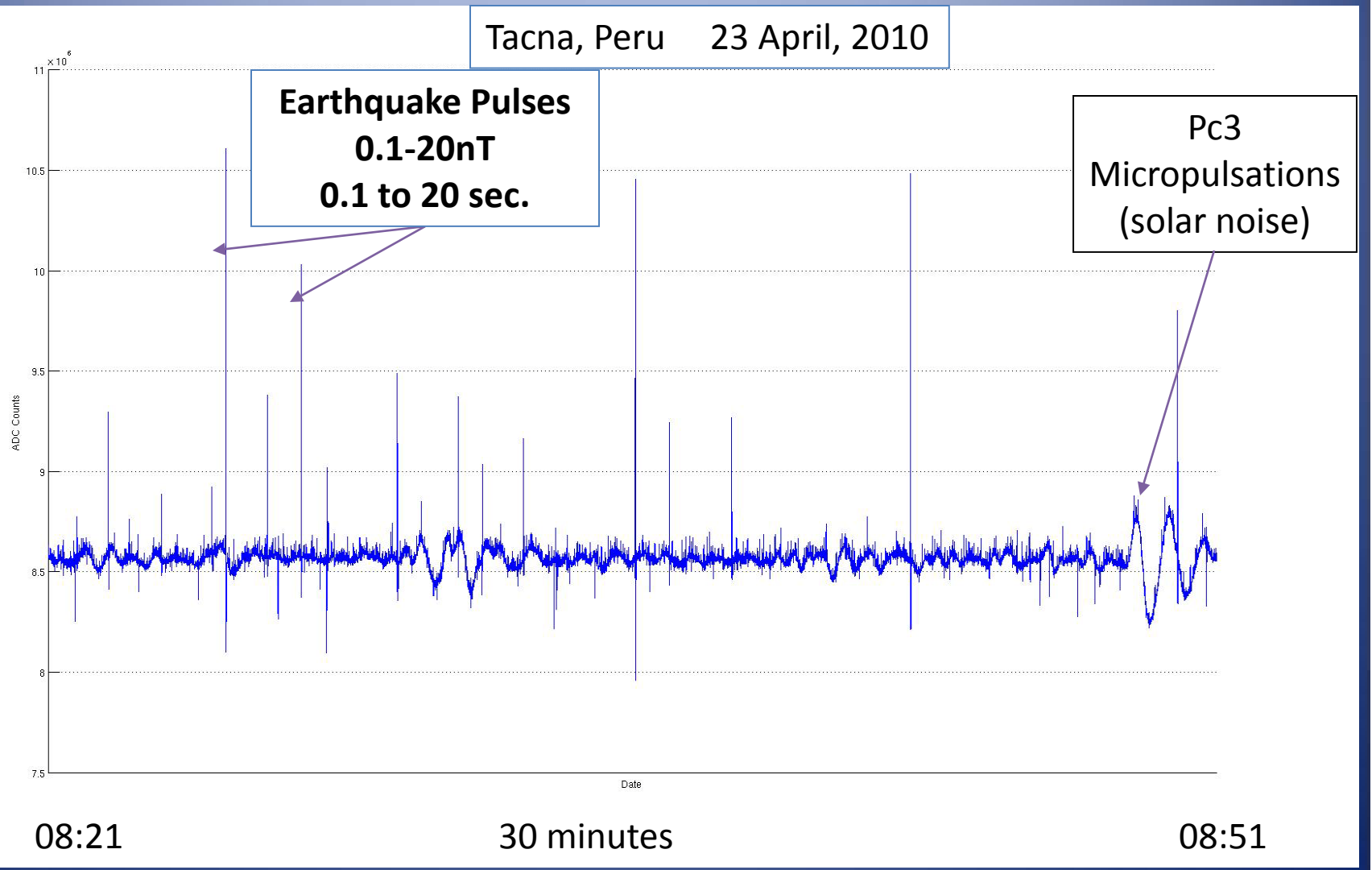
1. Are there Electromagnetic (EM) signals prior to earthquakes? Ultra Low Frequency (ULF) Magnetic fields

- Dr Tony Fraser-Smith (Stanford)
  - 1989 M7.1 Loma Prieta earthquake
  - 30 minute energy averages recorded*
  - Only 1 site*

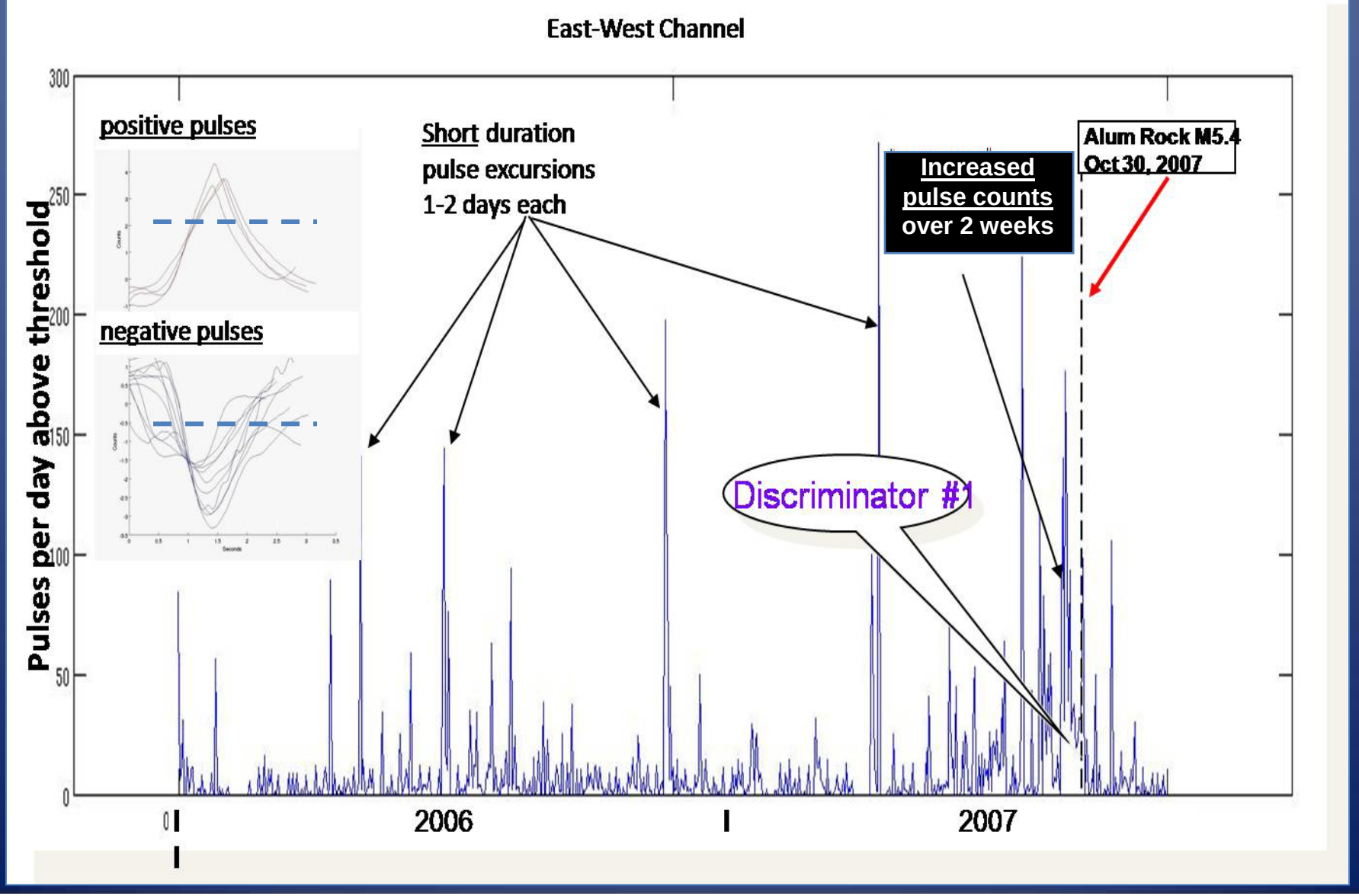


*Not sufficient

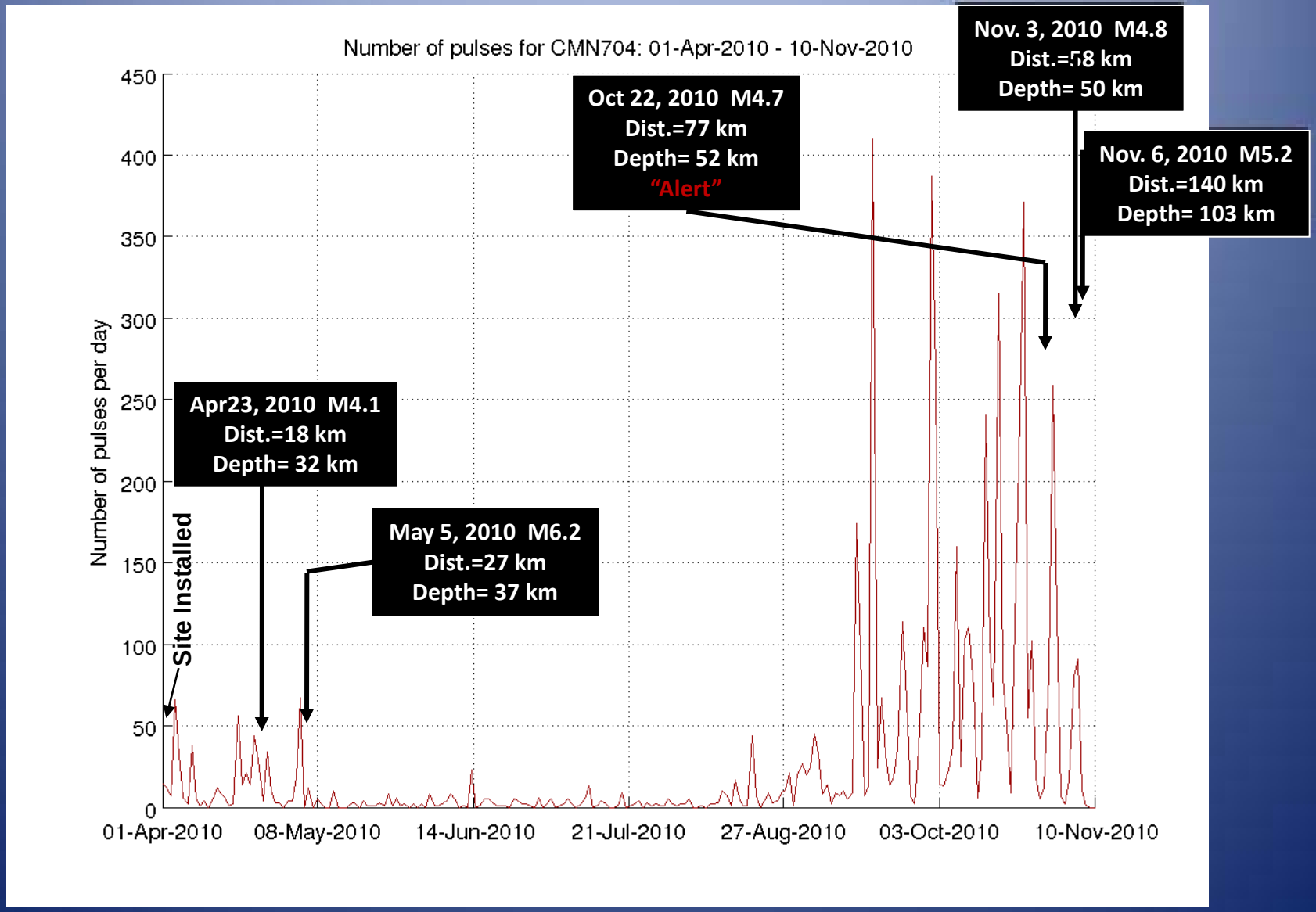
Evidence from multiple earthquakes: “Uni-polar Magnetic Pulses”



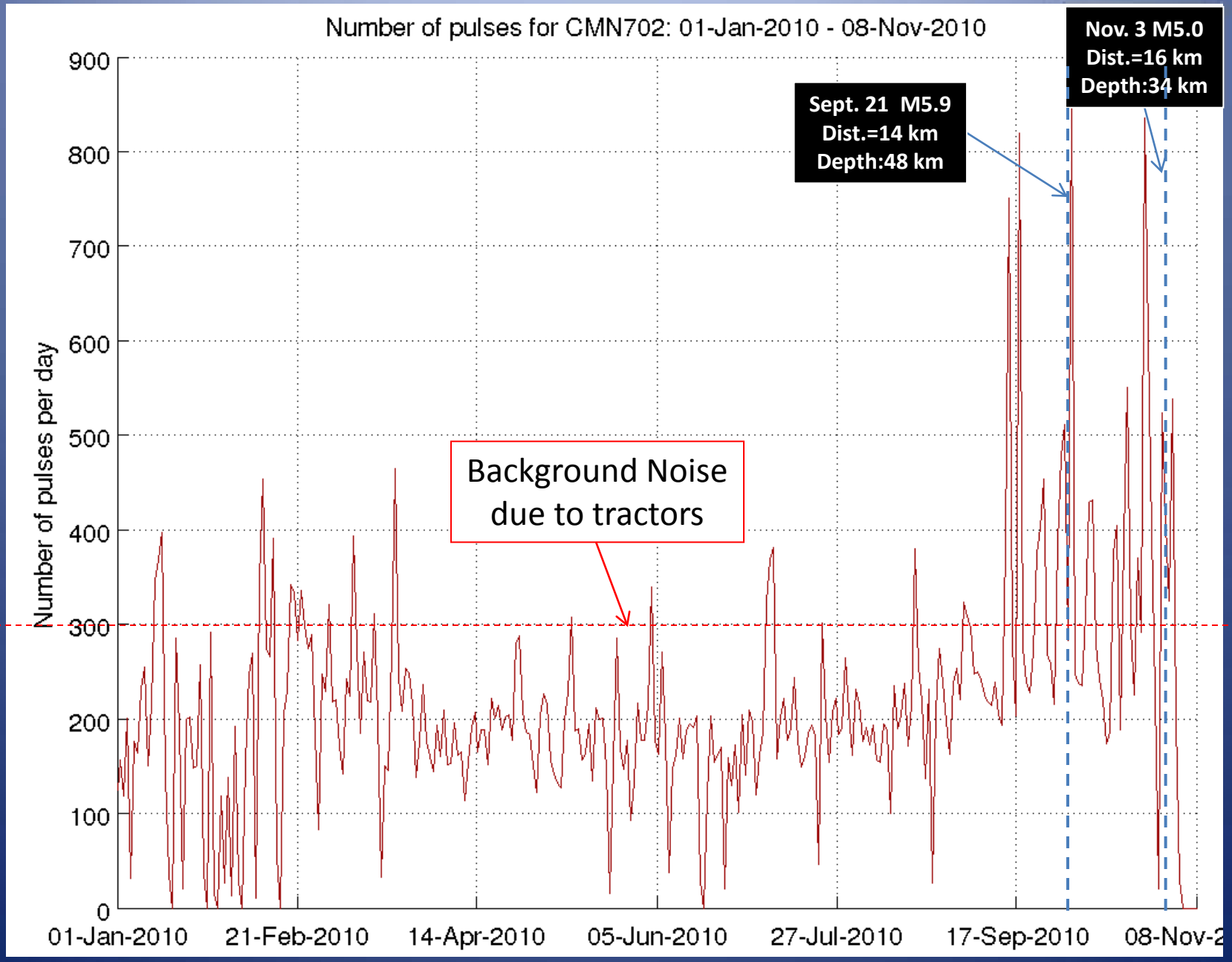
1. Are there Electromagnetic (EM) signals prior to earthquakes? Ultra Low Frequency (ULF) Magnetic Fields (Alum Rock, Ca)



New: Pulse and Quake Activity: Tacna Apr. 1 to Nov 10

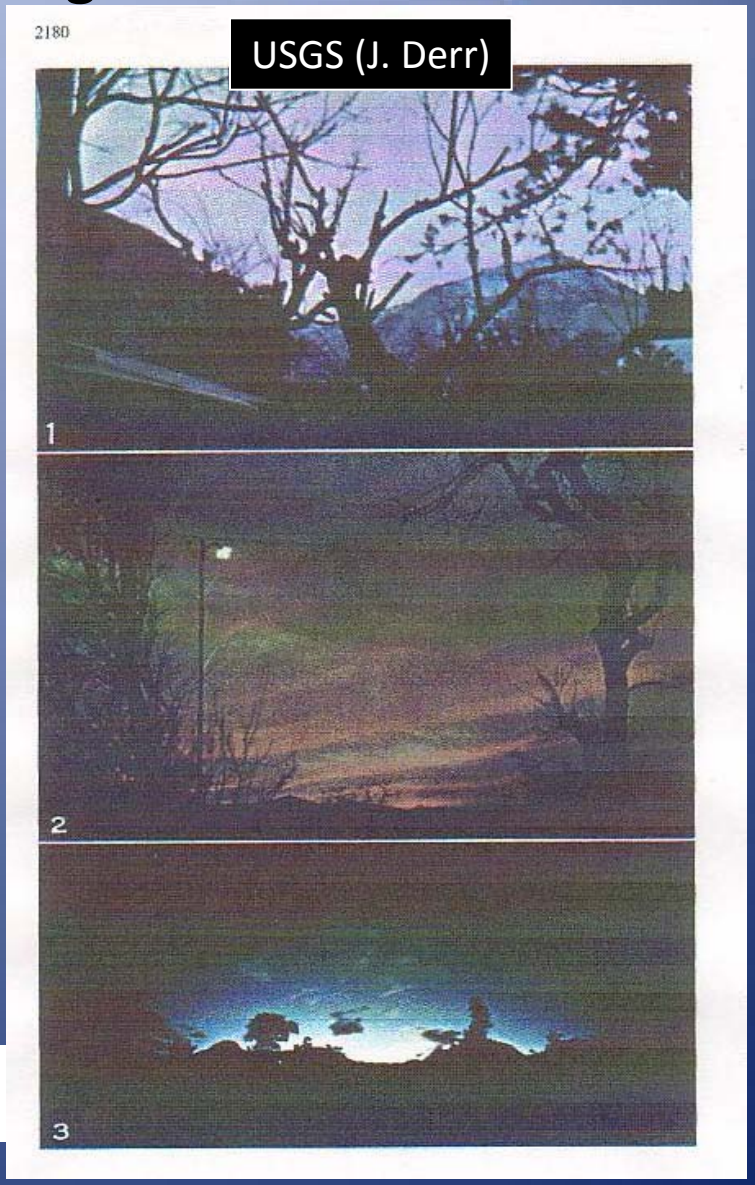


New: El Carmen, Peru Pulse Count 2010



1. Are there Electromagnetic (EM) signals prior to earthquakes?
"Earthquake Lights"

- **Visible Light Signatures "Earthquake Lights"**
- **Minutes before/after earthquake**

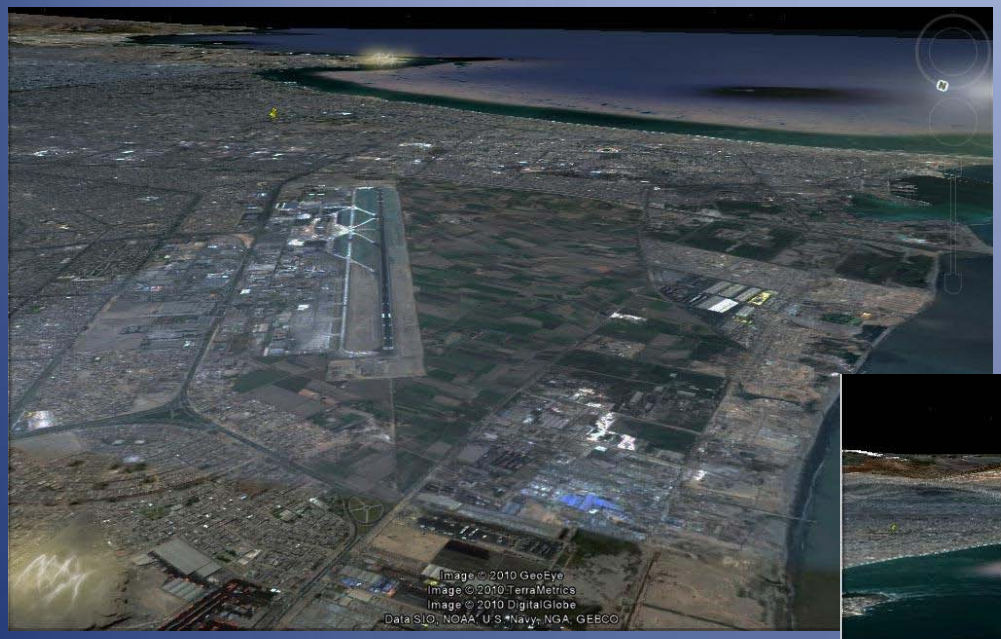


Figures 1 to 19 show earthquakes lights as published by Yasui (1968). All are from the Matsushiro, Japan area and are samples of the only known pictures of earthquake lights. They were taken by a Matsashiro dentist, Mr. T. Kuribayashi.

Pictures taken in Japan '70-'80's

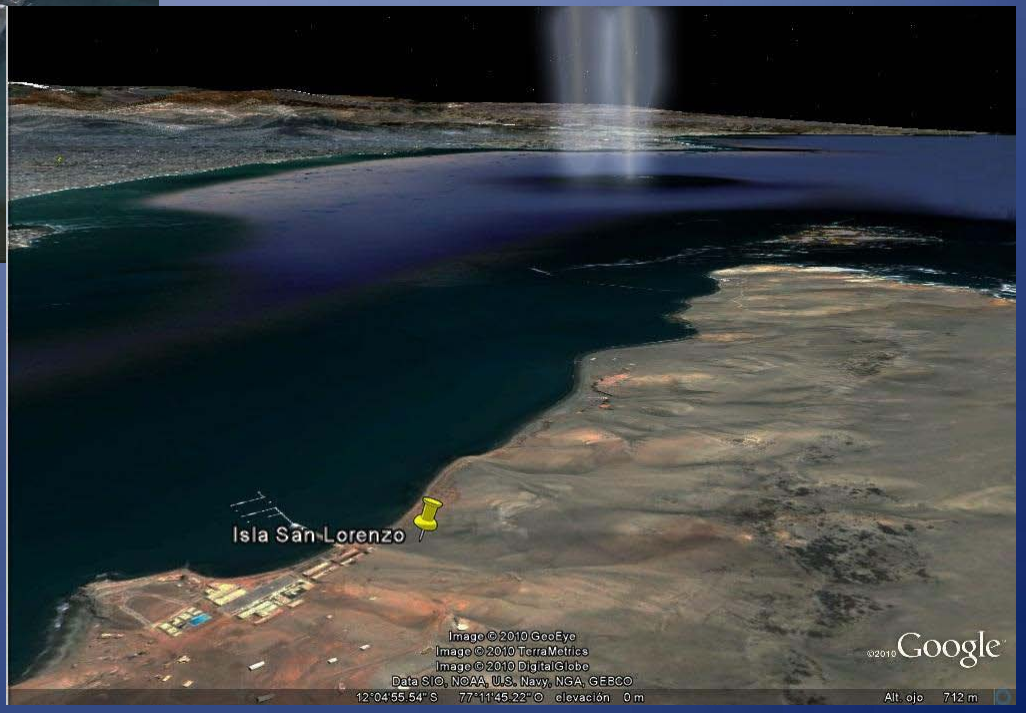
New: Earthquake Lights:

Lima Peru, 15 August, 2007 at 18:41:00 LT,

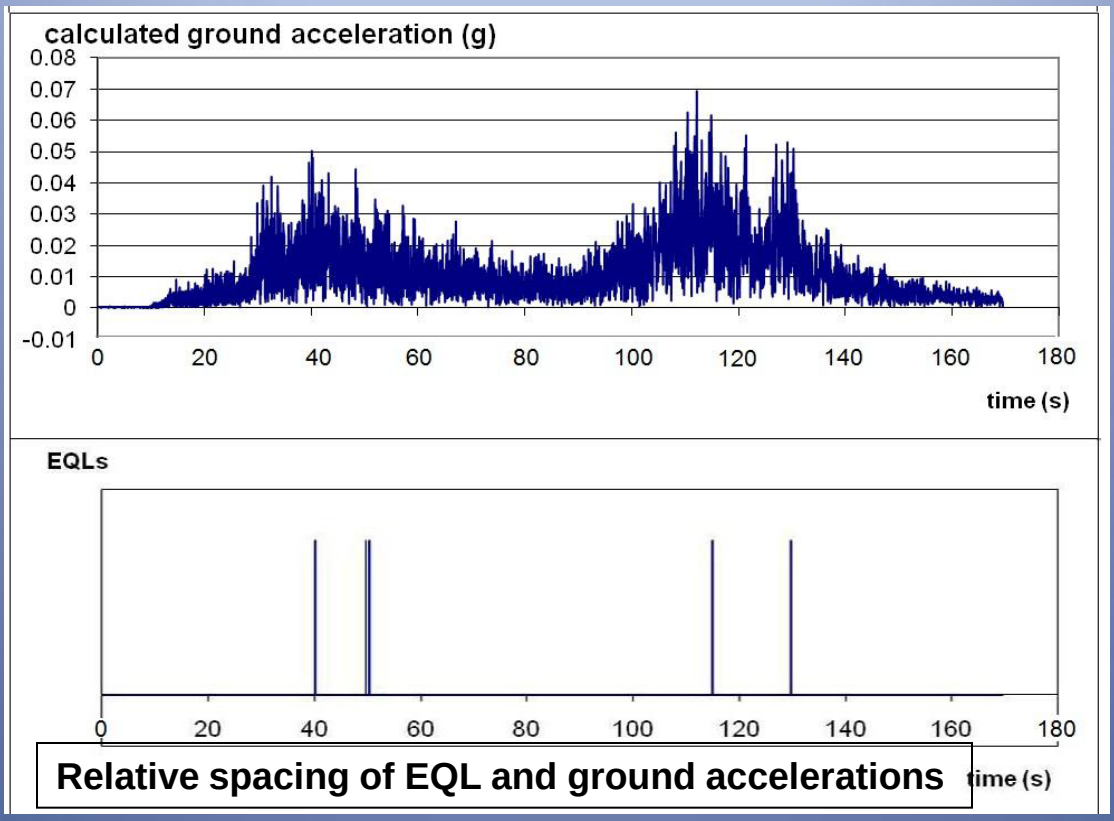


160 km north of the M8.0 epicenter
Near time of P, S Wave arrival

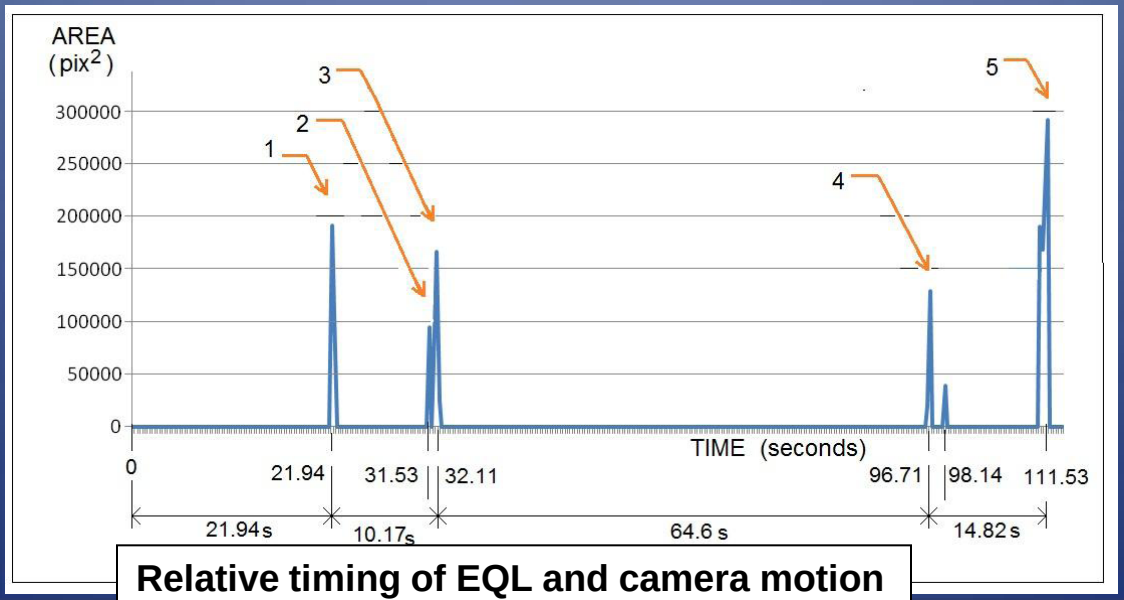
Artist rendering
from eye witness reports



Jorge Heraud, Antonio Lira: PUCP Peru

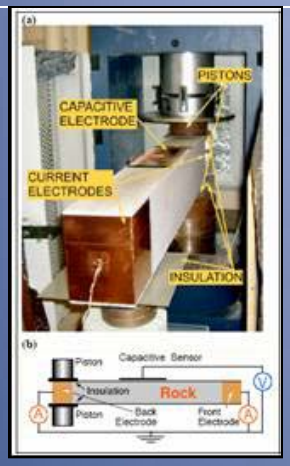


Relative spacing of EQL and ground accelerations



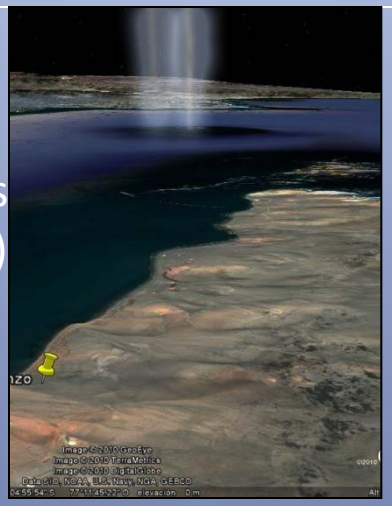
Relative timing of EQL and camera motion

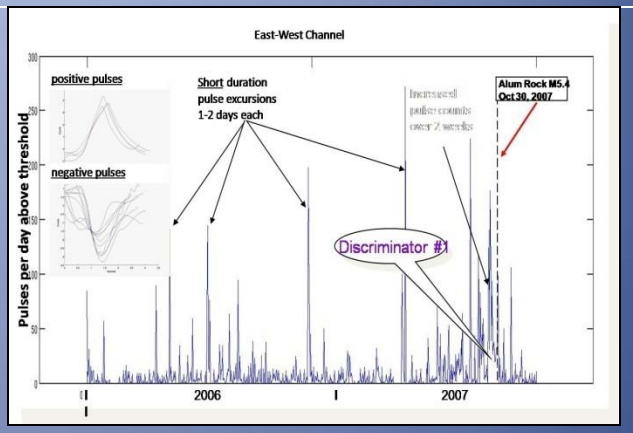
2. Is There a Reasonable Theory to Explain EM Signals?



NASA (F. FREUND)
Lab Experiments

Small Currents
(small sample)

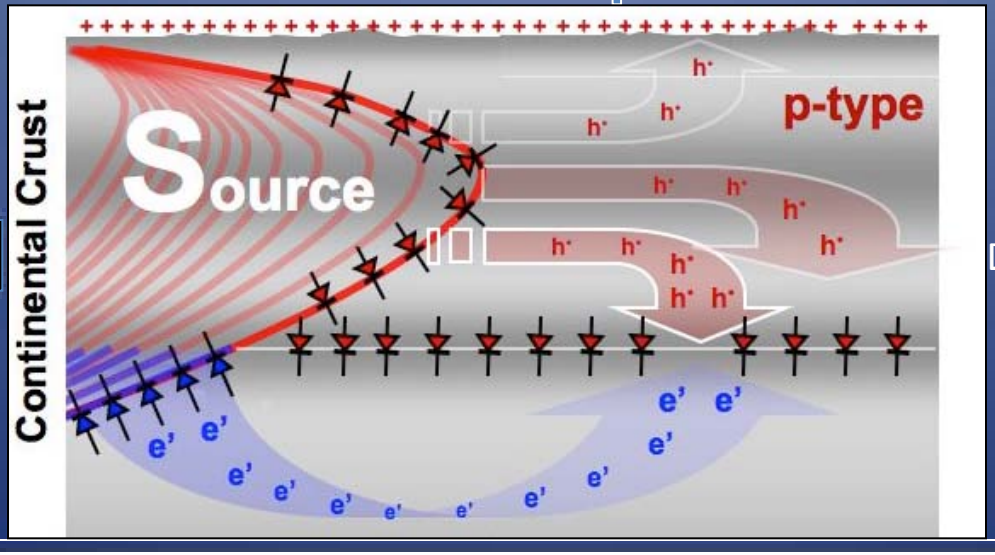




Air Conductivity
Sensor

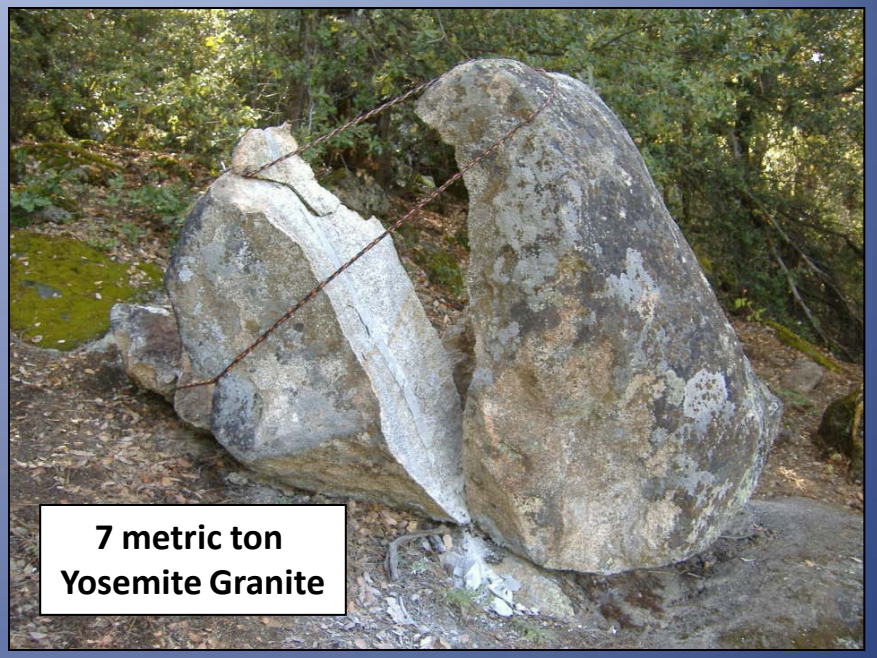
ULF magnetometers

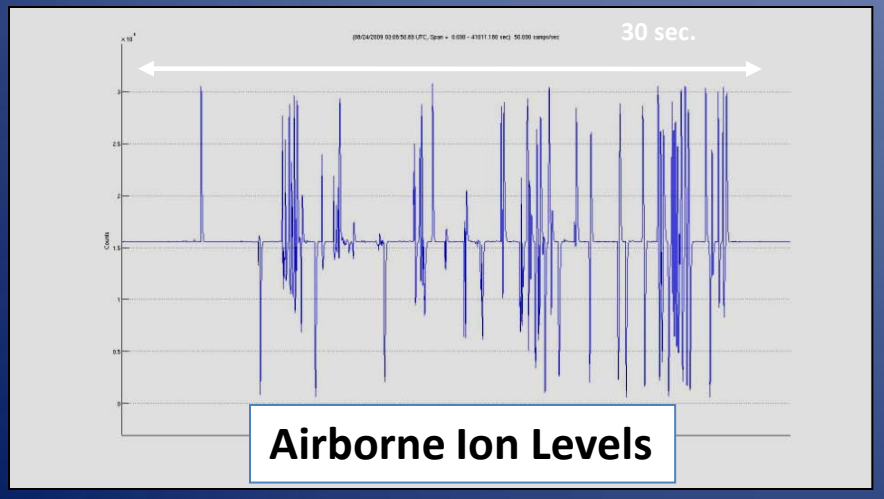
Hypothesis

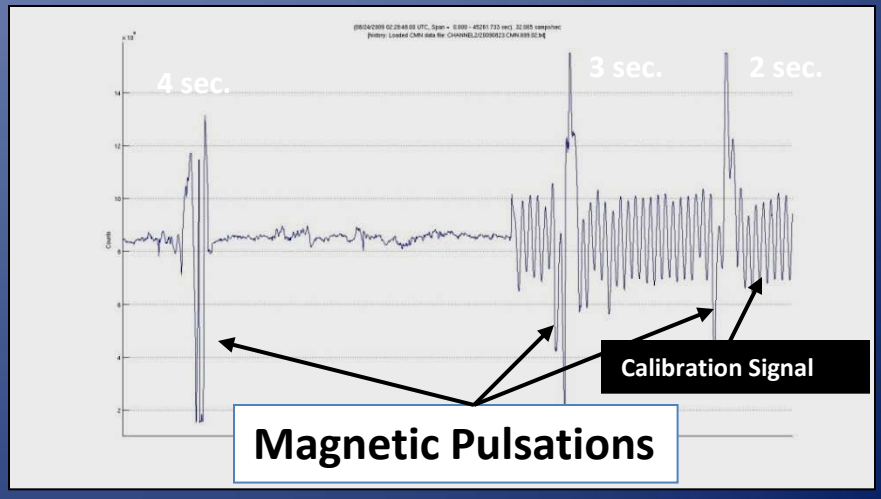


Defect Electron Migration
P-Hole Carriers

Pulse Comparison with Field Tests Aug, 2009 Bass Lake, Ca.







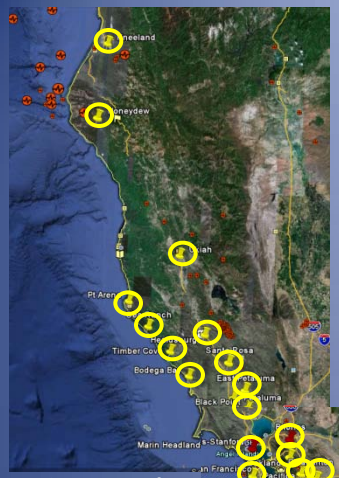
3. Can we detect these unique EM signals?

QuakeFinder formed in 2000 to Investigate

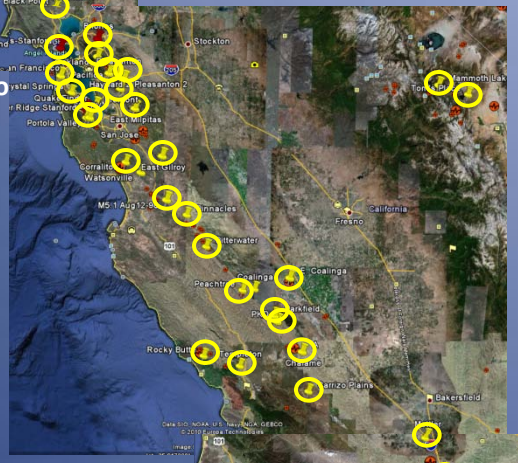
- **QuakeFinder Observatories**
  - California, Peru, Taiwan
  - Instruments
- **Magnetic Signals**
  - Pulse Structure
  - Pulse Counts
  - Pulse Azimuth Clusters
- **Air Conductivity**

Magnetic Observatories

QuakeFinder, USGS, Berkeley, PUCP (Peru), NCU (Taiwan)



San Francisco



Los Angeles

Mexico

California

60+ sites total

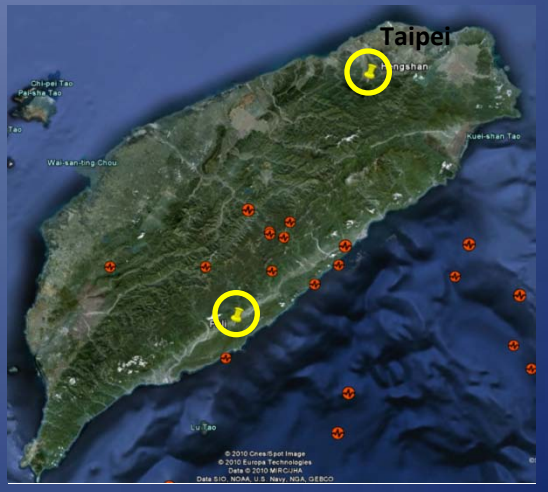
Site Location

Historical Earthquakes 1973+

Lima

Chile

Peru



Taipei

Taiwan

Southern California

Northern California

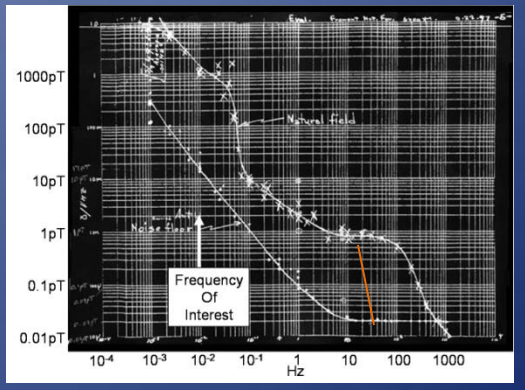
Original combined
Air Conductivity sensor

New dual (+/-)
Air Conductivity sensors

New QF-2010 mag. new (top)
QF-1005,1007 mag. (middle)
QF-1003, H.S. mag. (bottom)

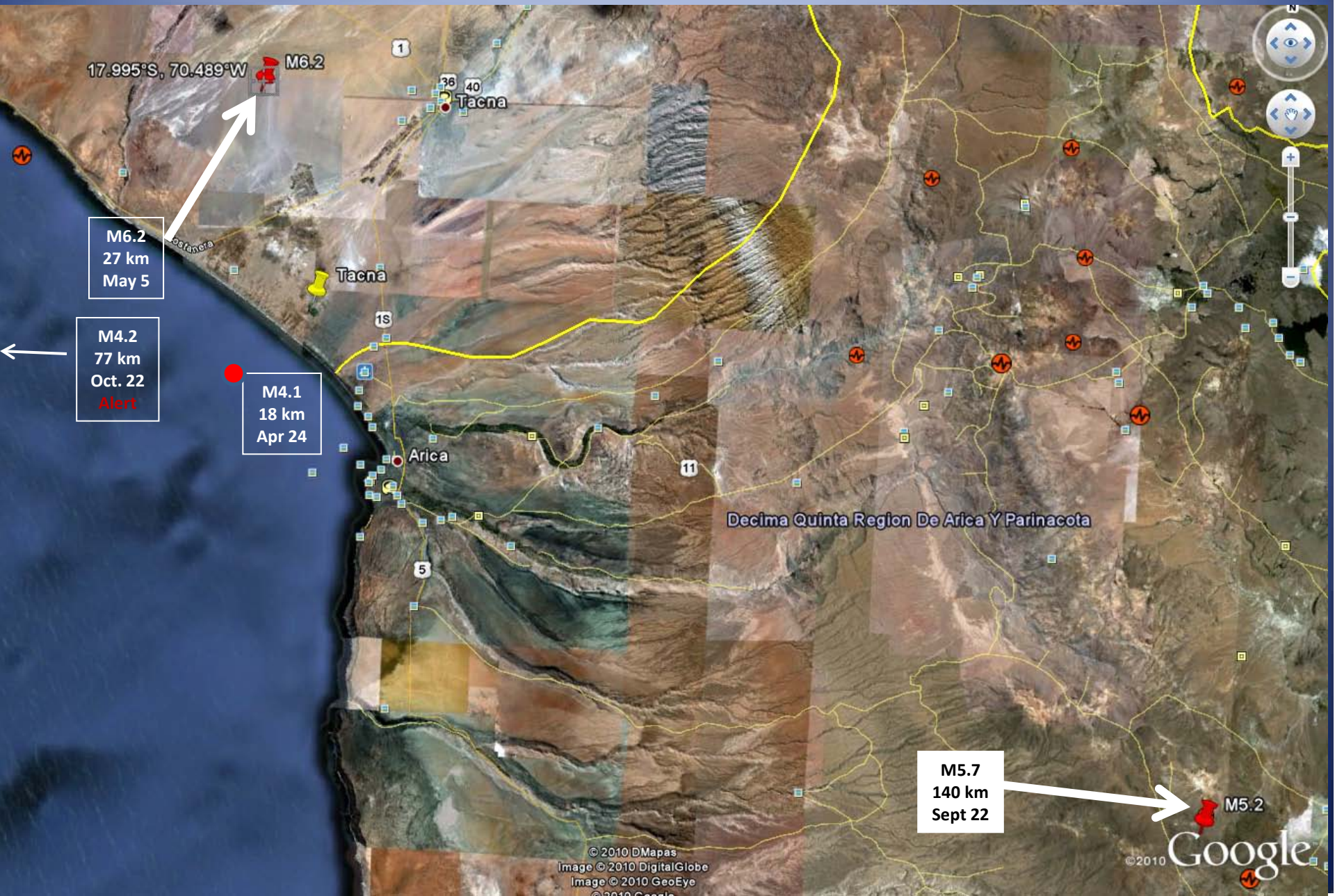
Tacna, Peru

Fuli, Taiwan

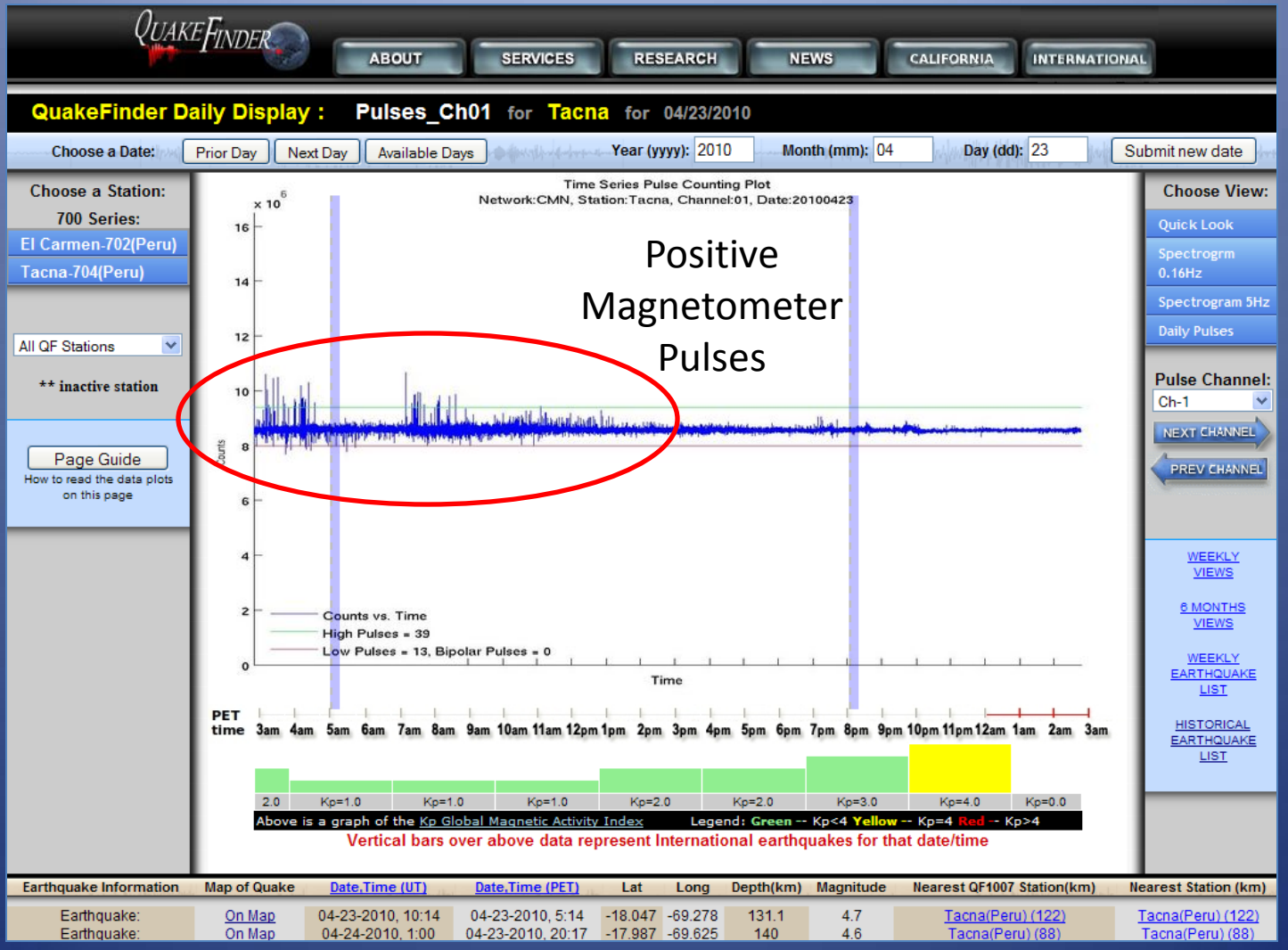


QF-1005,7 mag. response
Noise floor, (bottom)
Ambient signal (top)

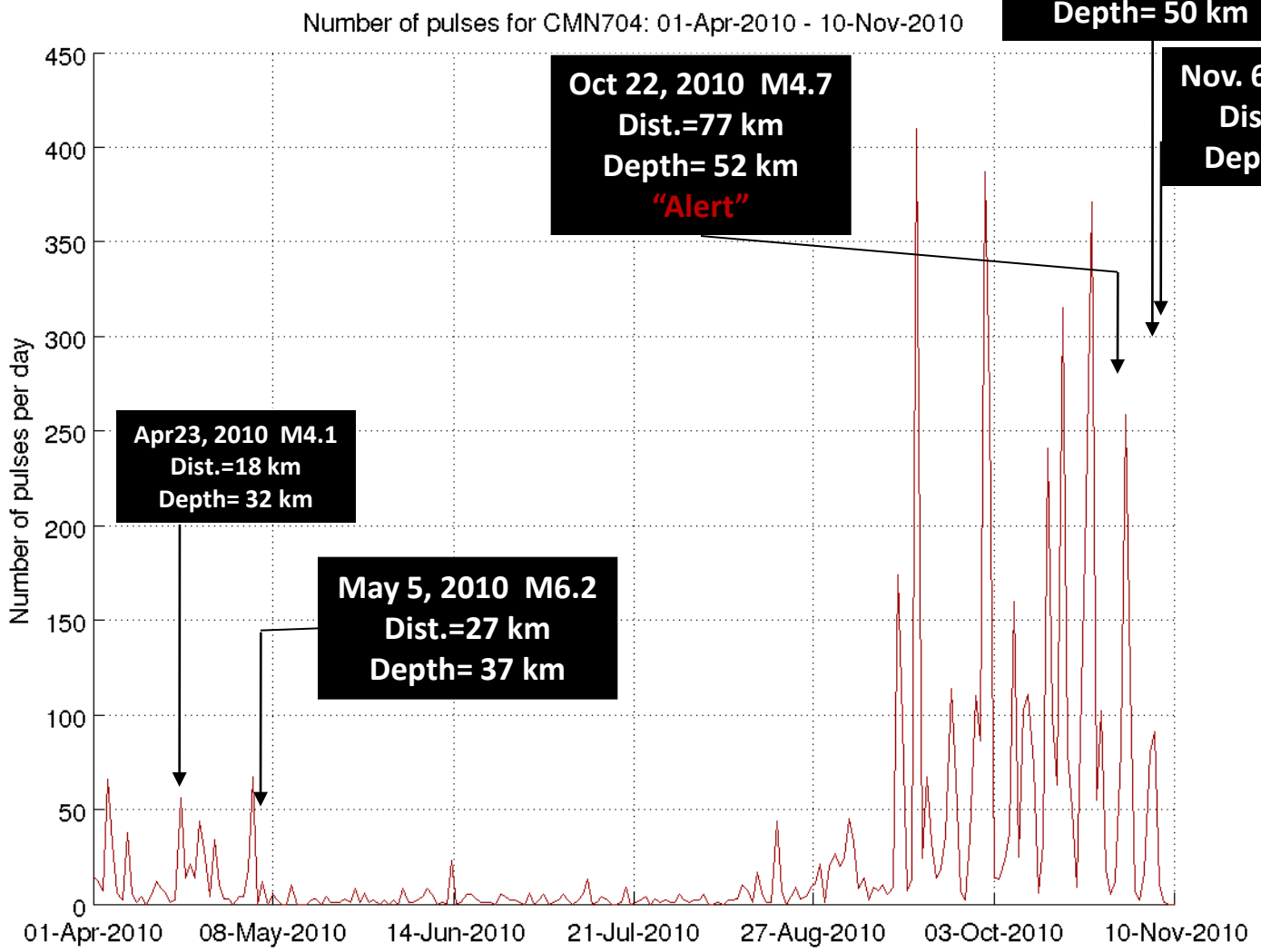
Tacna, Peru


17.995°S, 70.489°W
M6.2
Tacna
M6.2
27 km
May 5
Tacna
M4.2
77 km
Oct. 22
Alert
M4.1
18 km
Apr 24
Arica
Decima Quinta Region De Arica Y Parinacota
M5.7
140 km
Sept 22
M5.2
© 2010 DMapas
Image © 2010 DigitalGlobe
Image © 2010 GeoEye
©2010 Google

Tacna: 13 days Prior to M6.2 at 29km Distance



Pulse and Quake Activity: Tacna Apr. 1 to Nov 10



Other EM Indicators

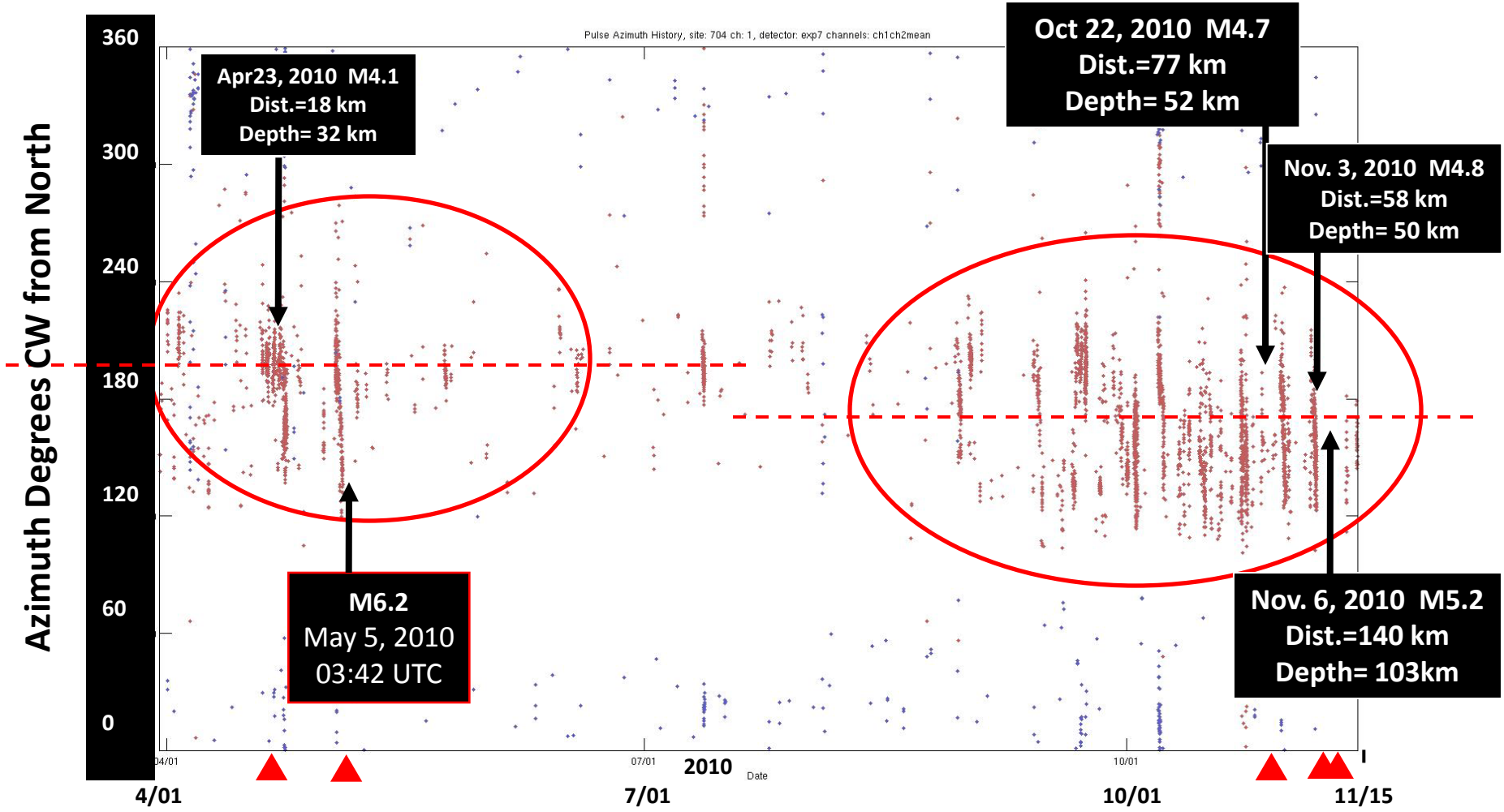
- Pulse Azimuth Clusters
- Air Conductivity Changes
- Infra Red Signatures
  - Night time heating (GOES, MeteoSat)
  - “Hot Spots” (MODIS)
- Simultaneous Indicators

Tacna Pulse Azimuth Plot

Channel 1 (N-S), Exp-7 Pulse Detector

Most pulse azimuths (direction of arrival) are random

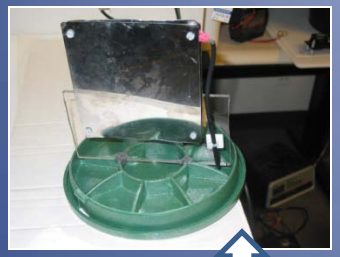
These pulses tended to “cluster” along a common direction of arrival

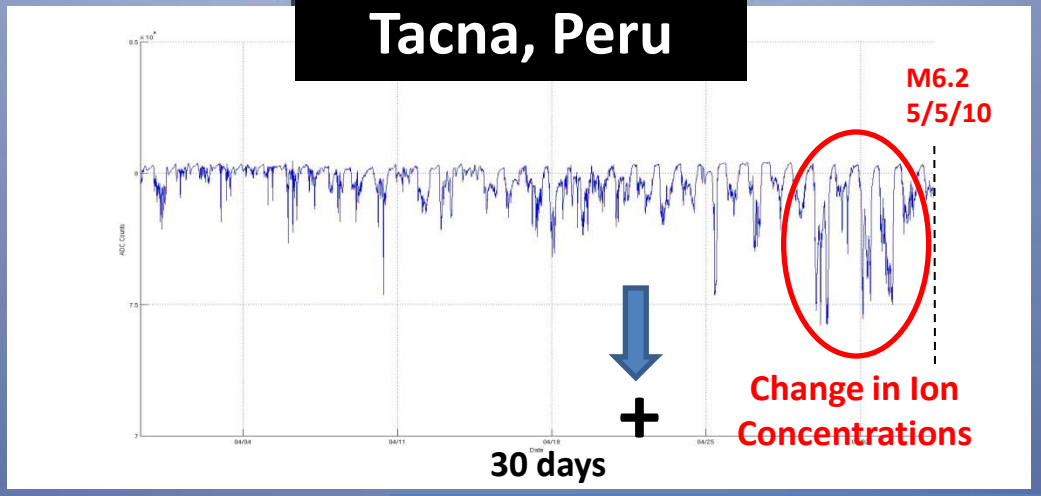


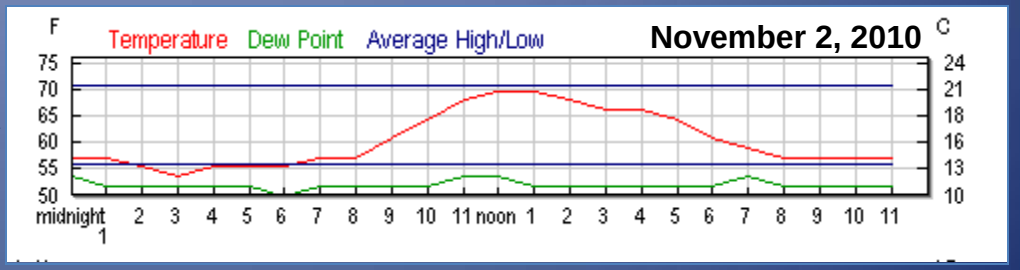
Air Conductivity

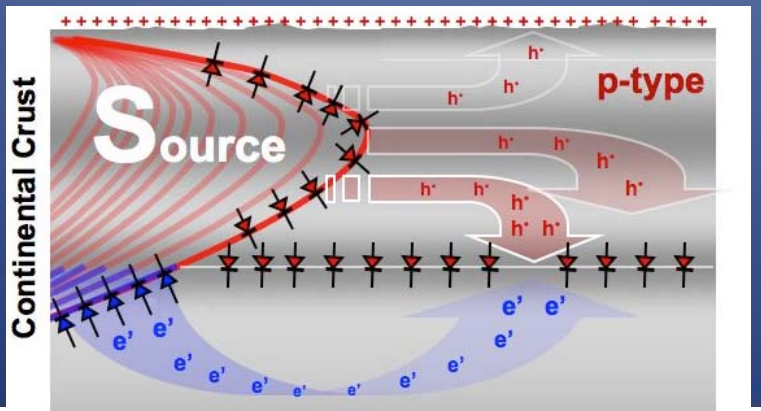
Electromagnetic Theory and Effects

Air Conductivity Changes

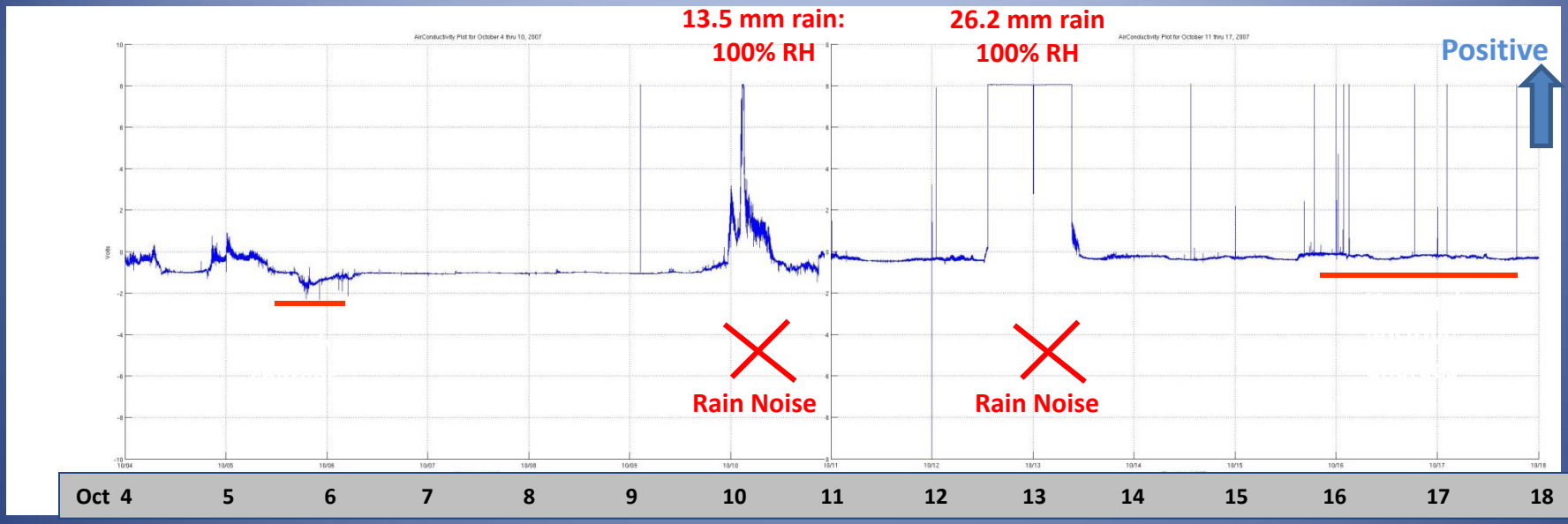


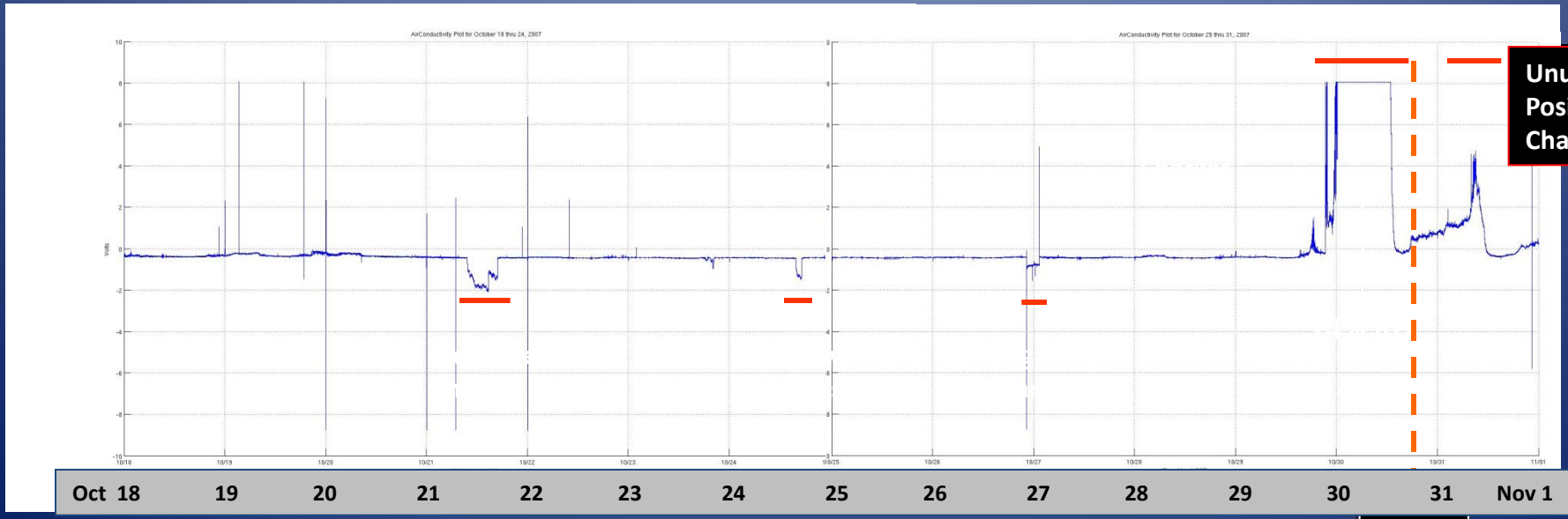






Air Conductivity at Alum Rock





Date

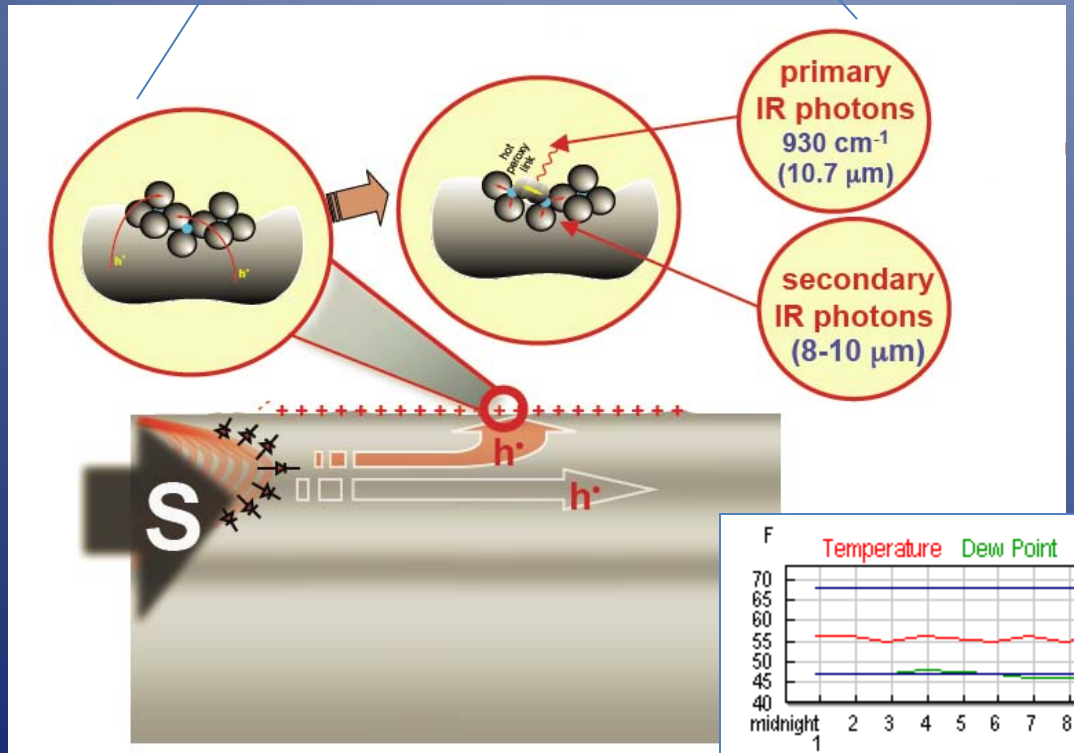
M5.4
20:04

Infra Red Signals

Theory and Effects

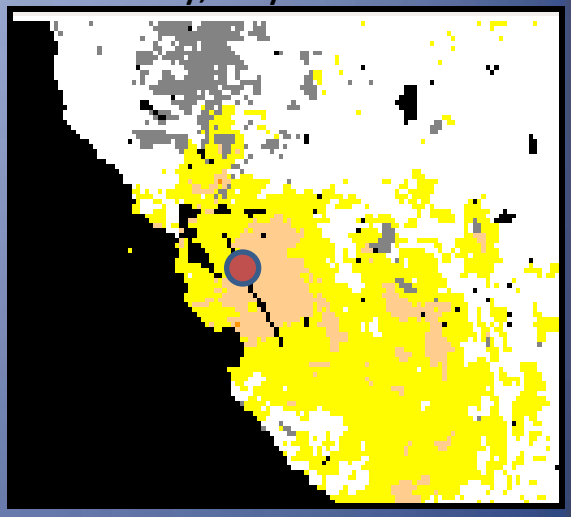
Infra Red Apparent Heating

GOES
Weather
Satellite



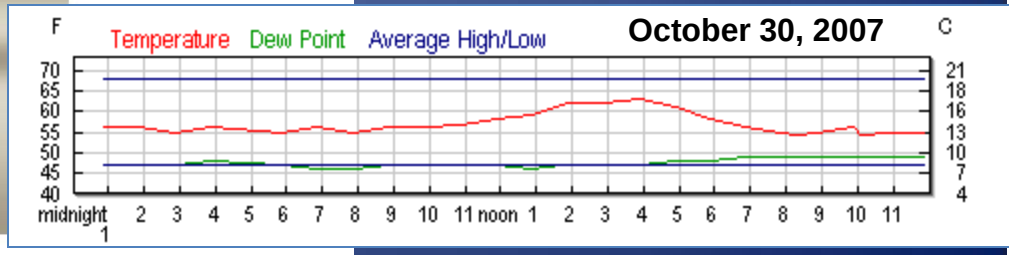
Friedemann Freund

Bambery, Bryant NASA JPL



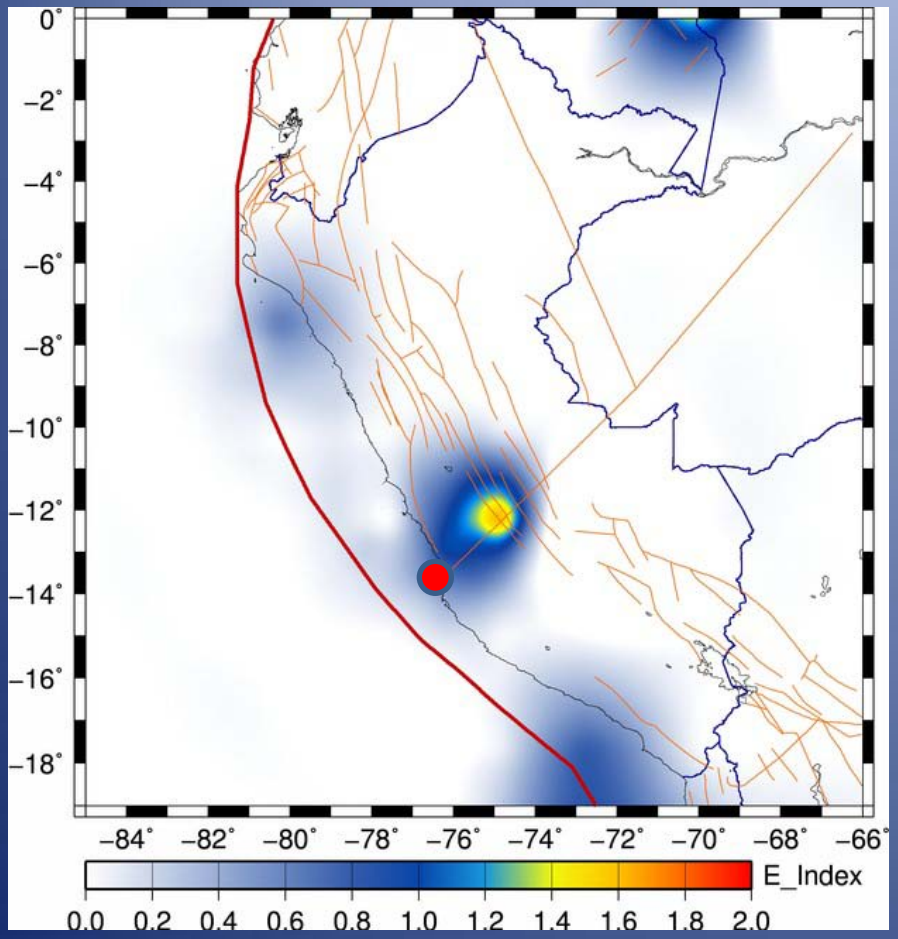
Oct 17, 2007
+0.3616

Night time cooling slope
(Alum Rock M5.4 Oct 2007)

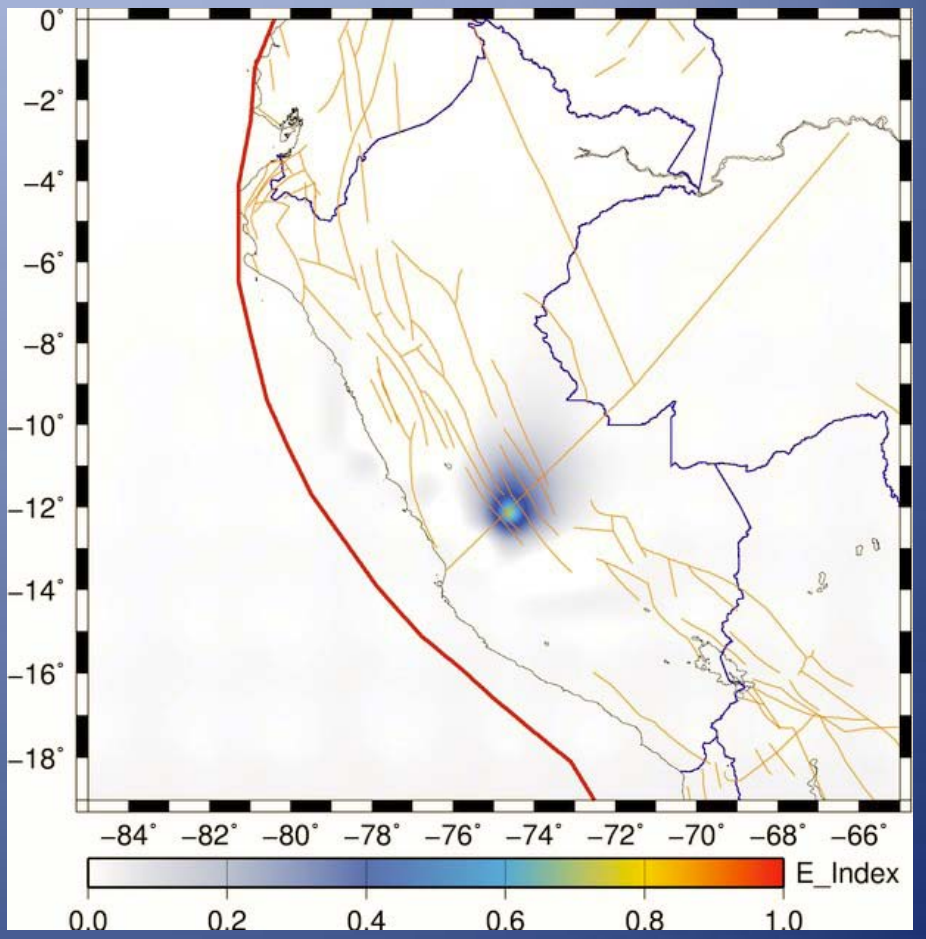


IR "Hot Spot" (NASA AQUA/AIRS Data)

(D. Ouzounov Chapman University)



Nov. 11, 2010

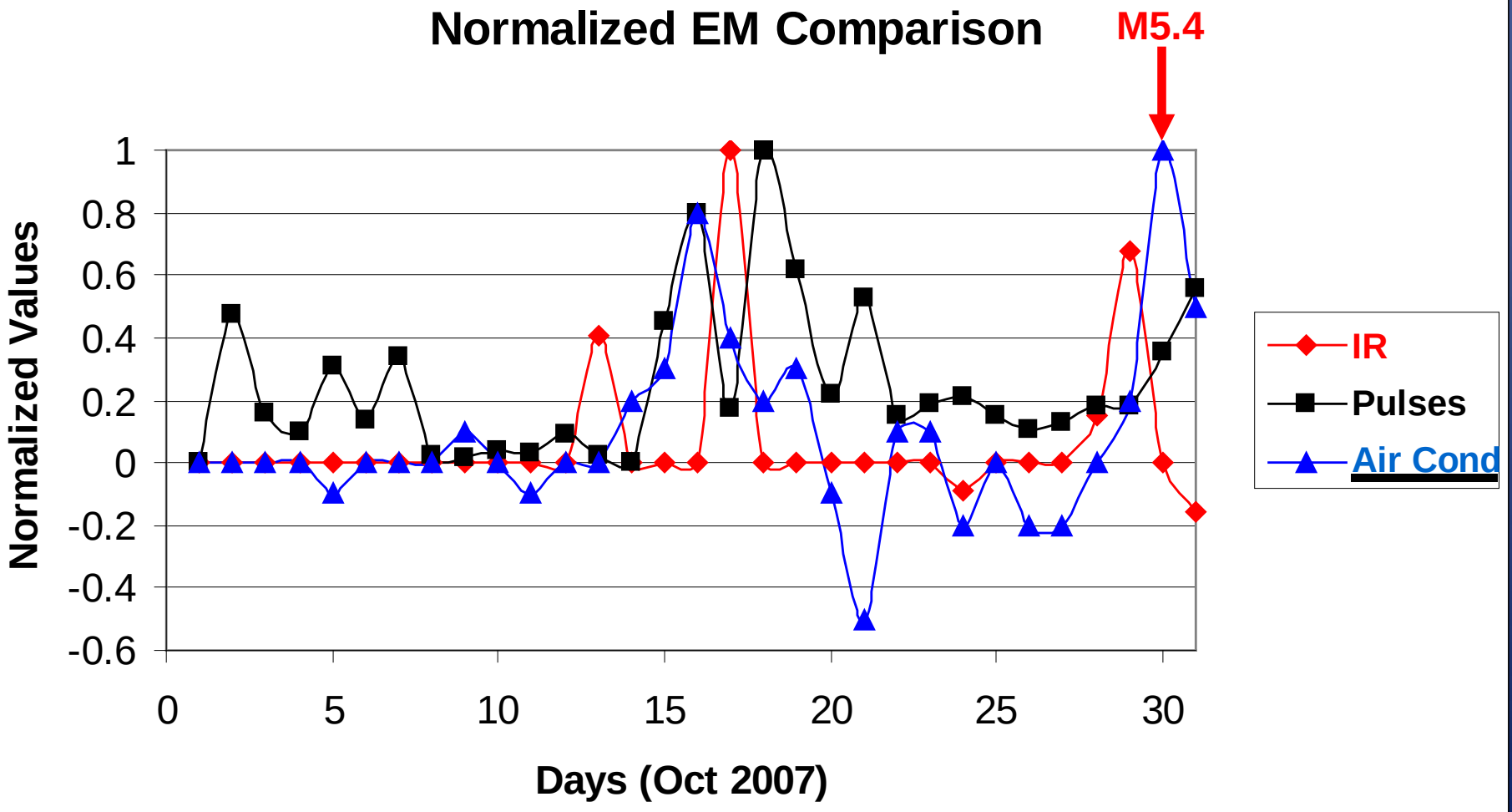


Nov. 14, 2010

M5.9 Sept 21
M4.8 Nov 3

ouzounov@chapman.edu

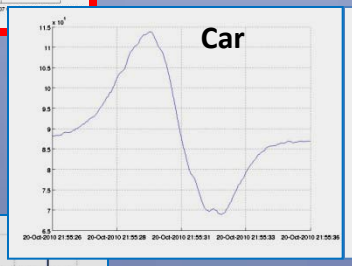
Simultaneous EM Signature Comparison
Alum Rock M5.4



4. Can We Discriminate Earthquake EM from Noise?

Noise source:	Example	Suppression
• Quake Signal	Uni-Polar	N/A
• Vehicles	Car / Tractor w/ Trailer	Pattern (bi-polar)*
• Lightning		Pattern (fast rise)*
		Weather Reports
• Pc1 and Pc3 (solar)	Pc3	High Pass Filter
Pc1 and Pc3 are solar-generated noise		
• Man-made		Multiple Wave Classifier*

63 sec



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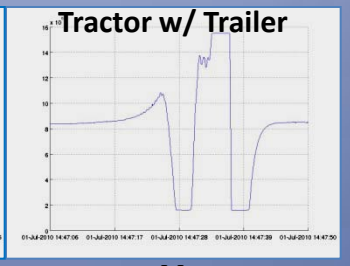

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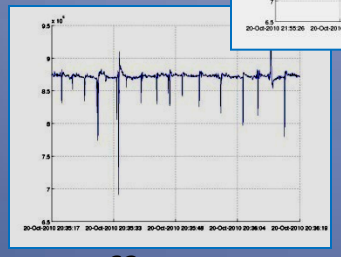

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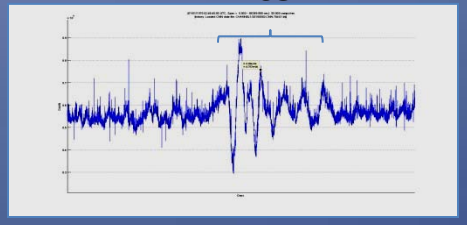

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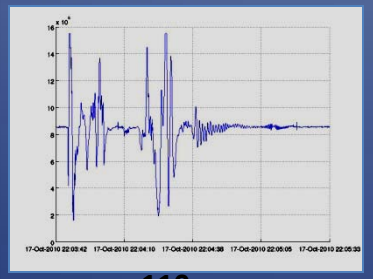

110 sec

* Under development

“Grand Questions”

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  There is now evidence (ULF magnetic pulses, Air Conductivity, IR)
  (Not addressed: radon, ionospheric changes, clouds, animals)

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- **Can we detect them? Time (2 weeks), location (30km), M+/-1)**
  Encouraging (Magnetometers, Air Conductivity, IR—perhaps others)

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  There is now evidence (ULF magnetic pulses, Air Conductivity, IR)
  (Not addressed: radon, ionospheric changes, clouds, animals)
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  Very Important (Requires complex set of algorithms and “tuning”)

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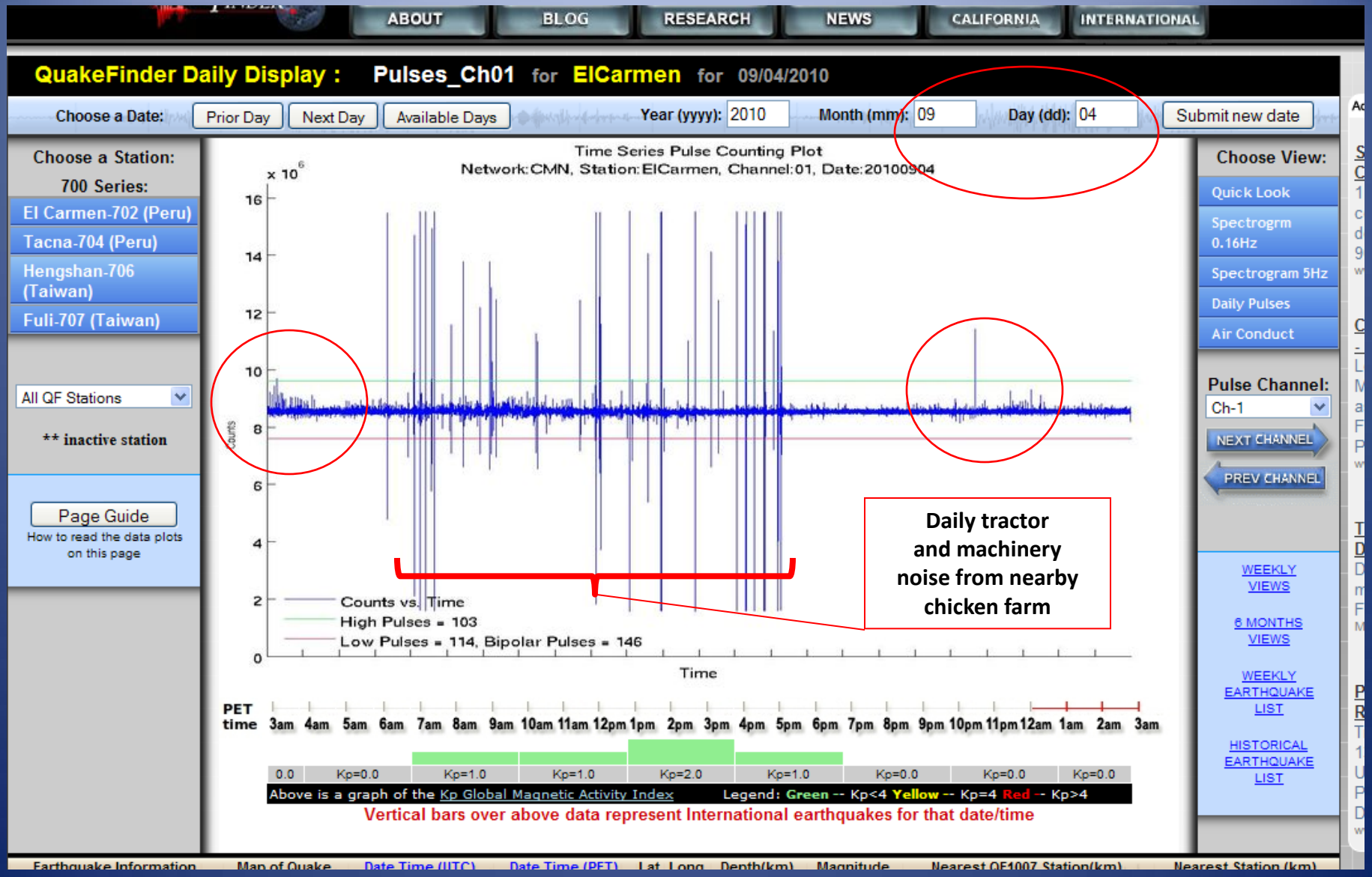
❖ **Can we make forecasts based on EM signals?**
Positive (Need more quake examples and tuning of algorithms)

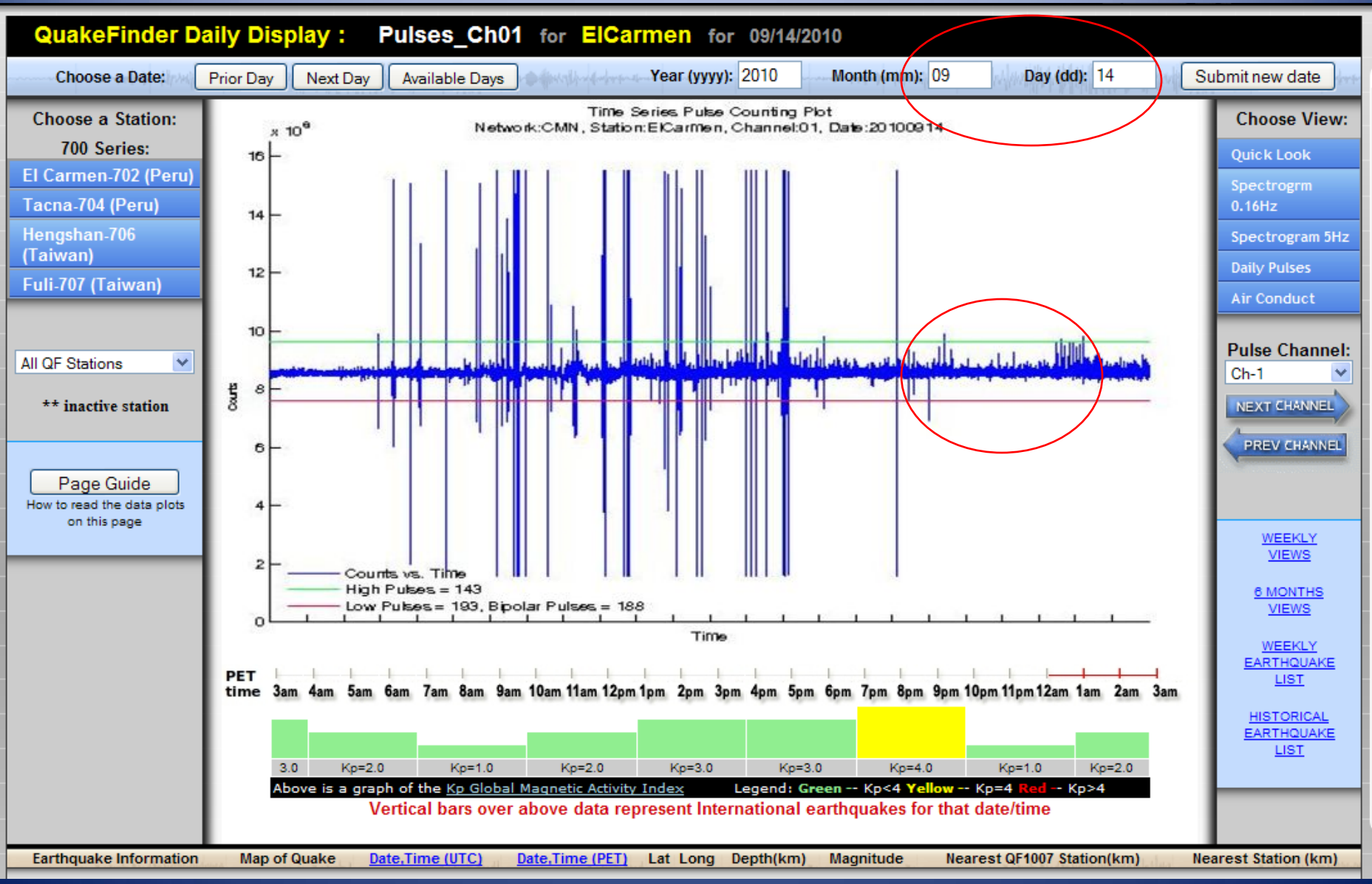
Thank You

Other Pulse Examples: Recent Earthquakes

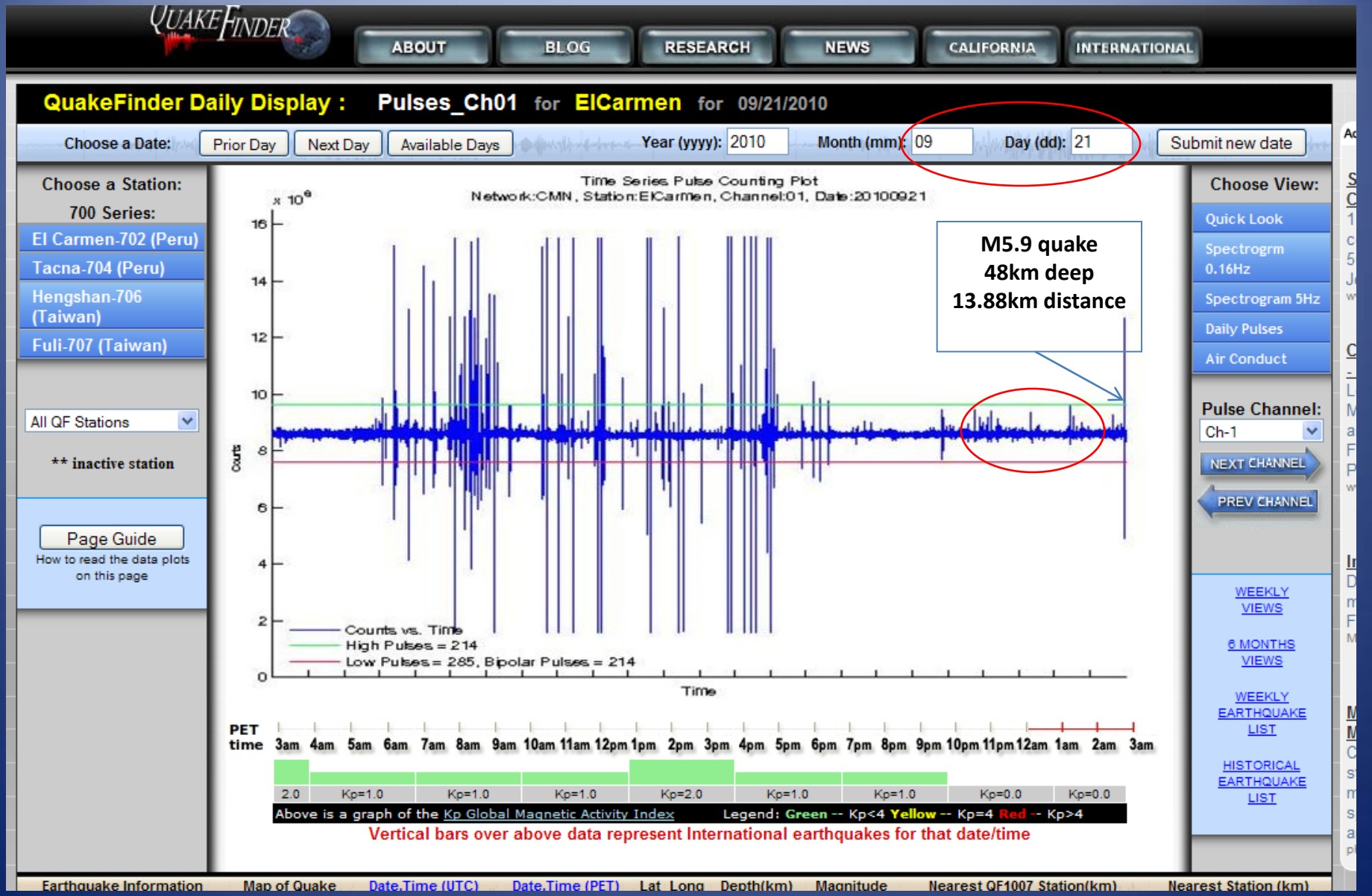
El Carmen, Peru Pulses 17 days Prior to Quake



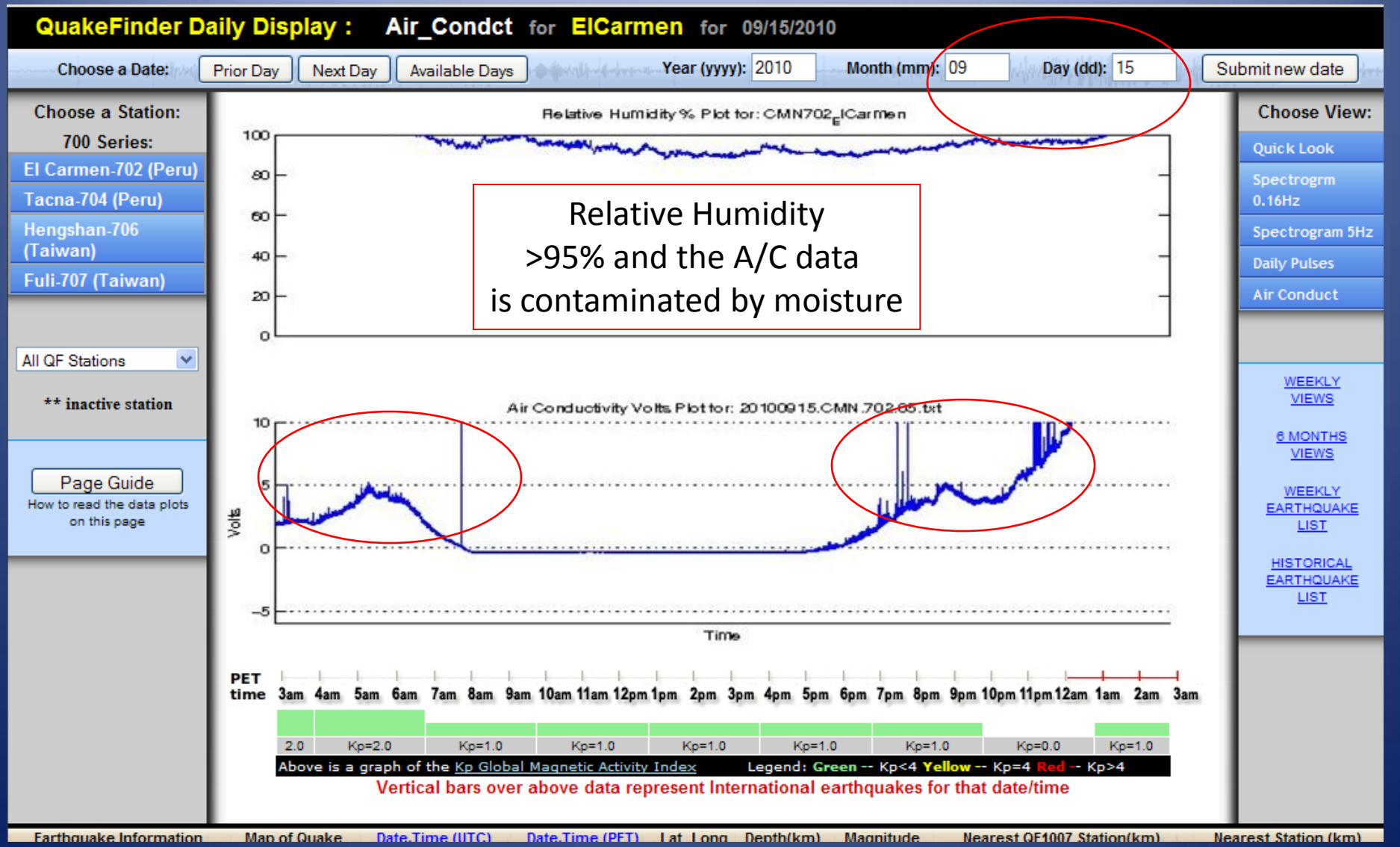
7 Days Prior to Quake



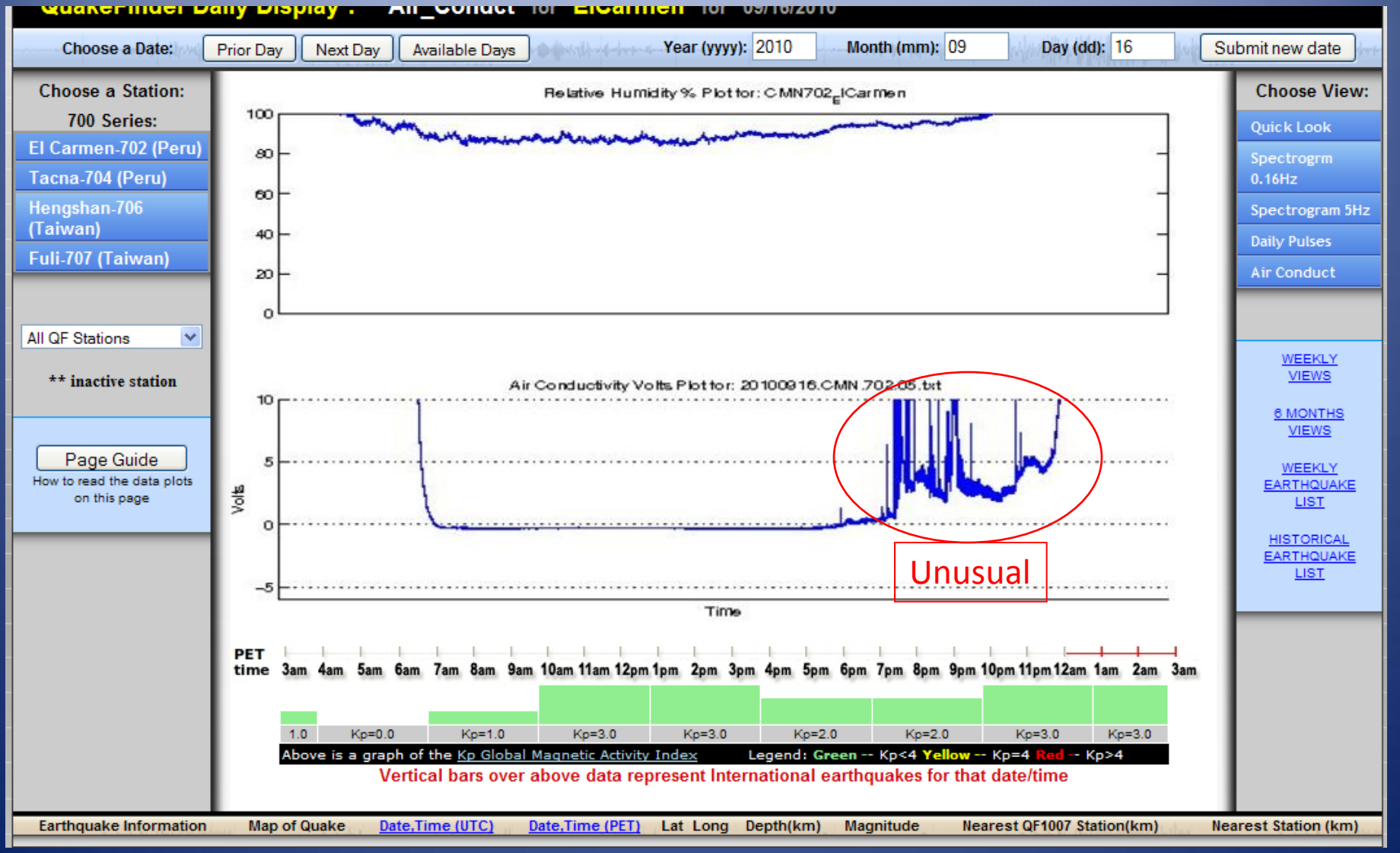
Day of Quake


QUAKEFINDER
ABOUT
BLOG
RESEARCH
NEWS
CALIFORNIA
INTERNATIONAL
QuakeFinder Daily Display : Pulses_Ch01 for ElCarmen for 09/21/2010
Choose a Date:
Prior Day
Next Day
Available Days
Year (yyyy): 2010
Month (mm): 09
Day (dd): 21
Submit new date
Choose a Station:
700 Series:
El Carmen-702 (Peru)
Tacna-704 (Peru)
Hengshan-706 (Taiwan)
Fuli-707 (Taiwan)
All QF Stations
** inactive station
Page Guide
How to read the data plots on this page
Time Series Pulse Counting Plot
Network:CMN, Station:ElCarmen, Channel:01, Date:20100921
x 10^9
Counts
Time
M5.9 quake
48km deep
13.88km distance
Counts vs. Time
High Pulses = 214
Low Pulses = 285, Bipolar Pulses = 214
PET time
3am 4am 5am 6am 7am 8am 9am 10am 11am 12pm 1pm 2pm 3pm 4pm 5pm 6pm 7pm 8pm 9pm 10pm 11pm 12am 1am 2am 3am
2.0 Kp=1.0 Kp=1.0 Kp=1.0 Kp=2.0 Kp=1.0 Kp=1.0 Kp=0.0 Kp=0.0
Above is a graph of the Kp Global Magnetic Activity Index
Legend: Green -- Kp<4 Yellow -- Kp=4 Red -- Kp>4
Vertical bars over above data represent International earthquakes for that date/time
Choose View:
Quick Look
Spectrogrm 0.16Hz
Spectrogram 5Hz
Daily Pulses
Air Conduct
Pulse Channel:
Ch-1
NEXT CHANNEL
PREV CHANNEL
WEEKLY VIEWS
6 MONTHS VIEWS
WEEKLY EARTHQUAKE LIST
HISTORICAL EARTHQUAKE LIST
Earthquake Information
Map of Quake
Date,Time (UTC)
Date,Time (PET)
Lat Long
Depth(km)
Magnitude
Nearest QF1007 Station(km)
Nearest Station (km)

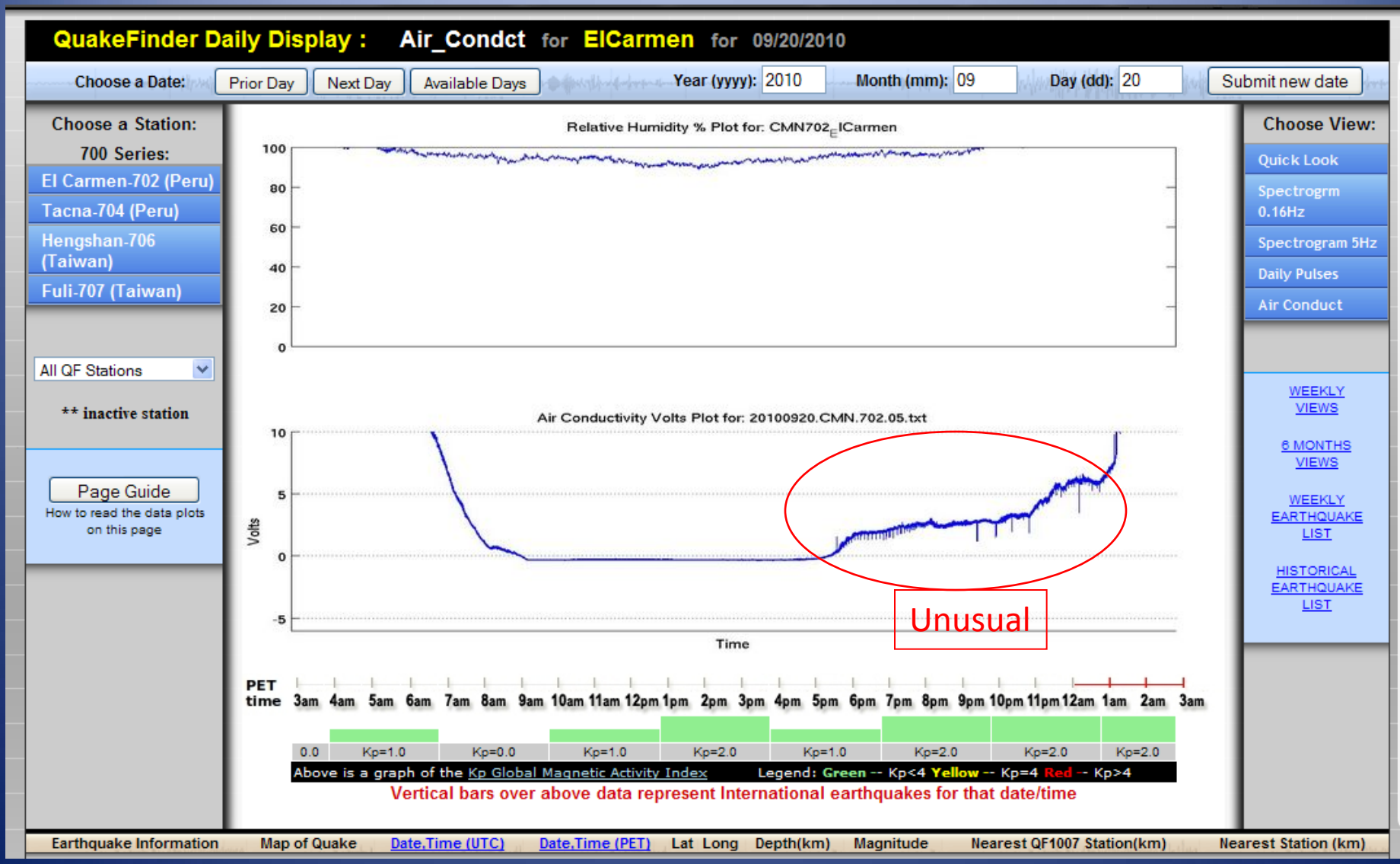
El Carmen, Peru Air Conductivity: 6 days Prior to Quake



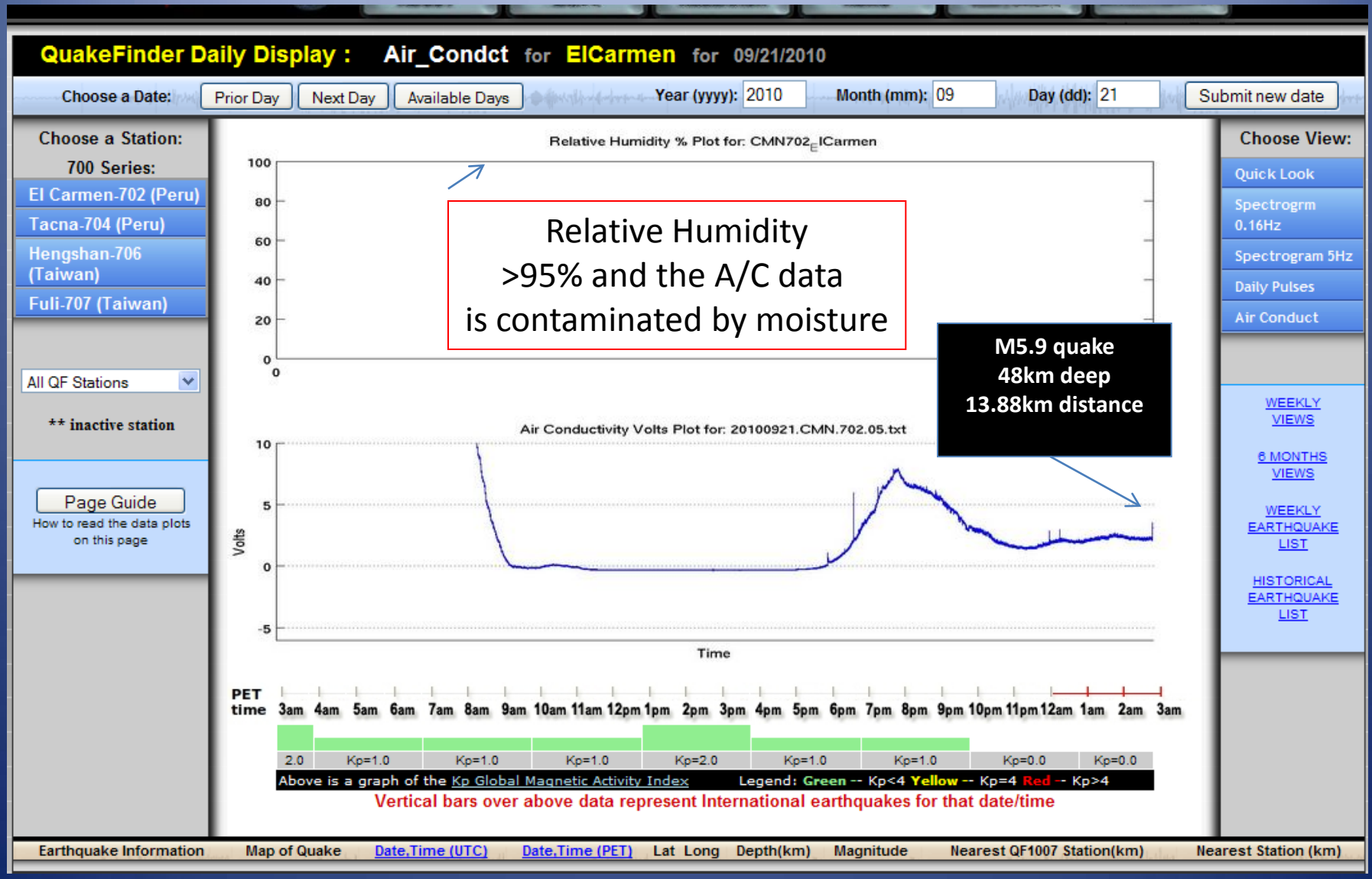
Air Conductivity: 5 days Prior to Quake



Air Conductivity: 1 day Prior to Quake

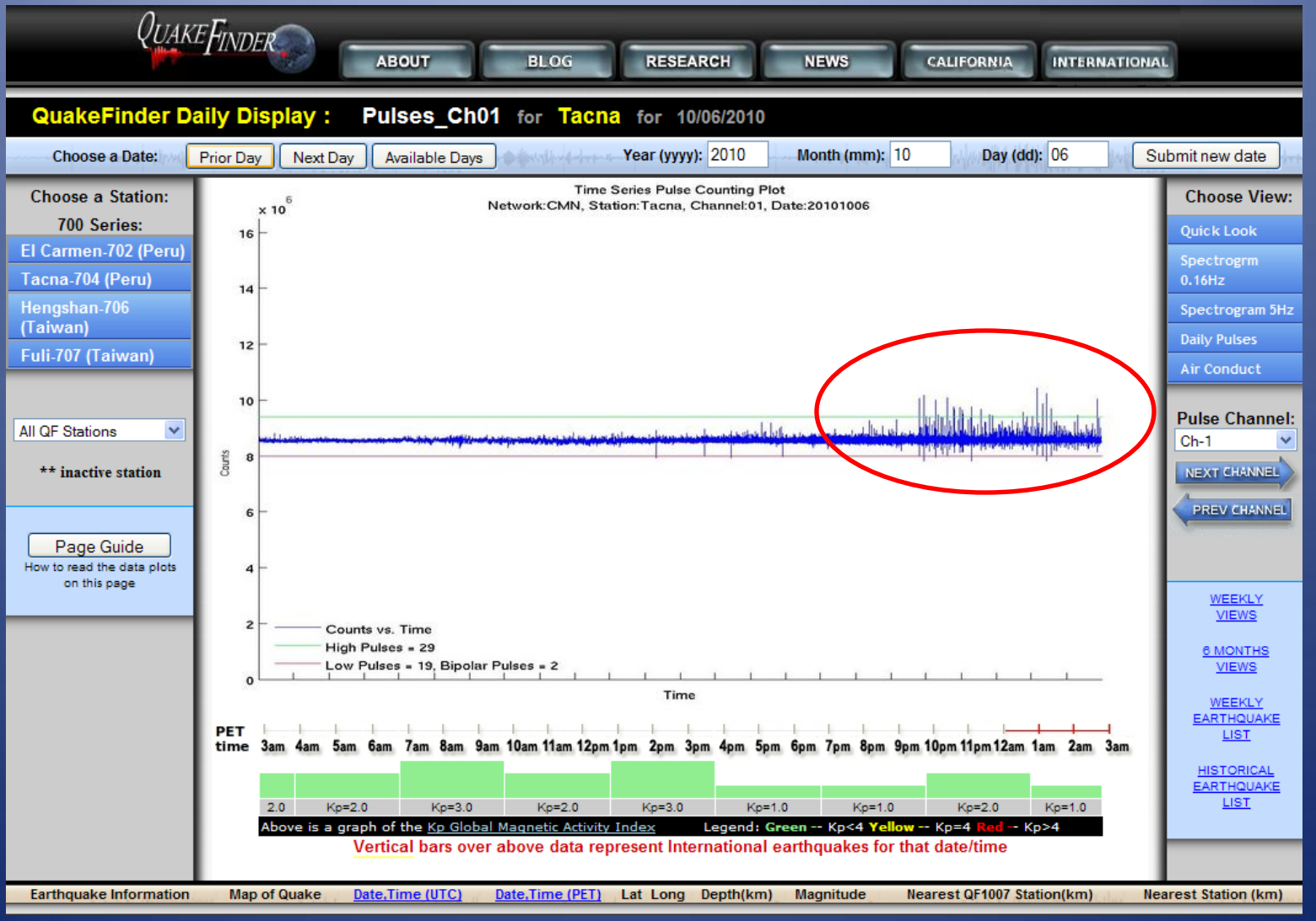


Air Conductivity: Day of Quake

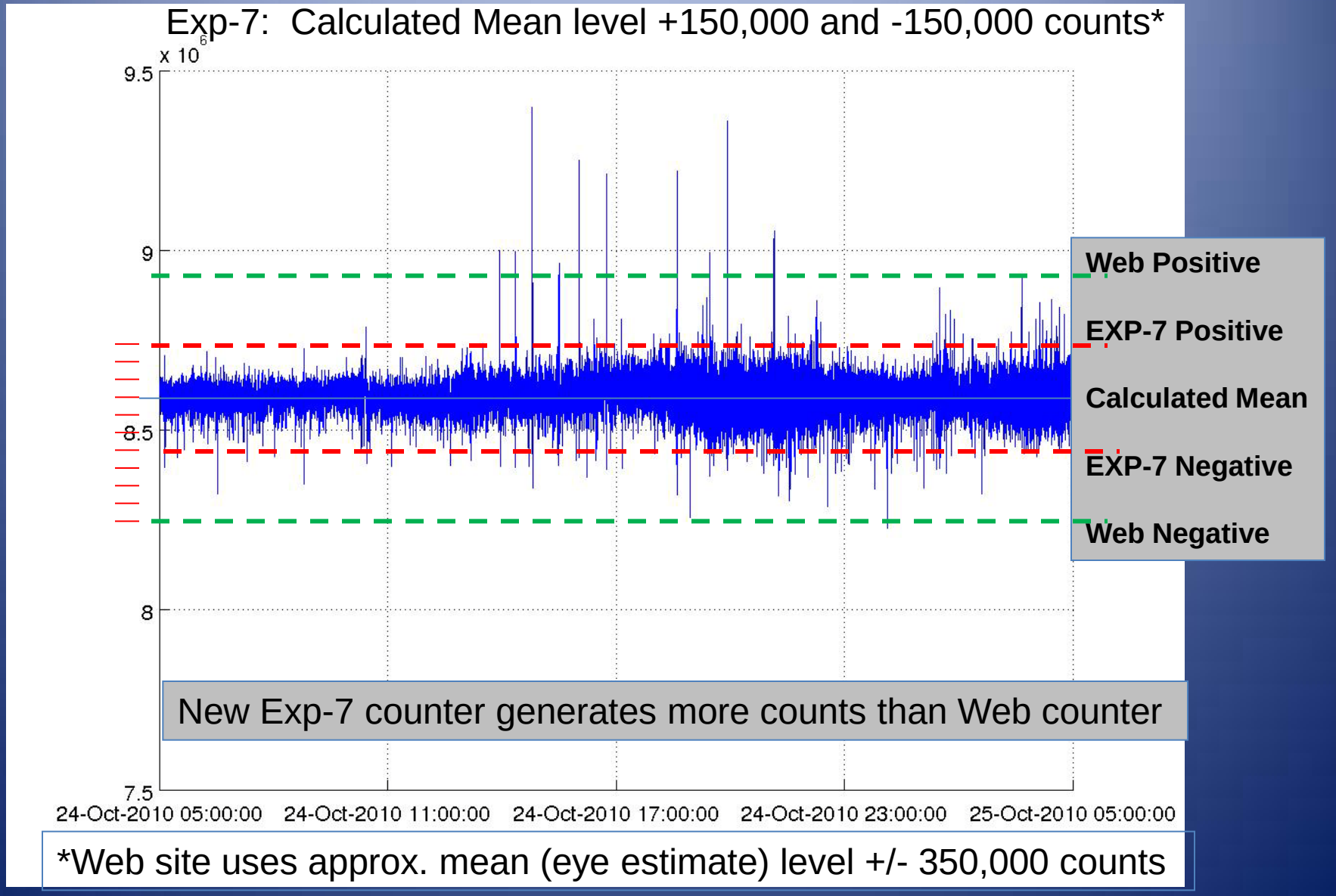


Tacna, Peru 30 Days prior to M 5.2

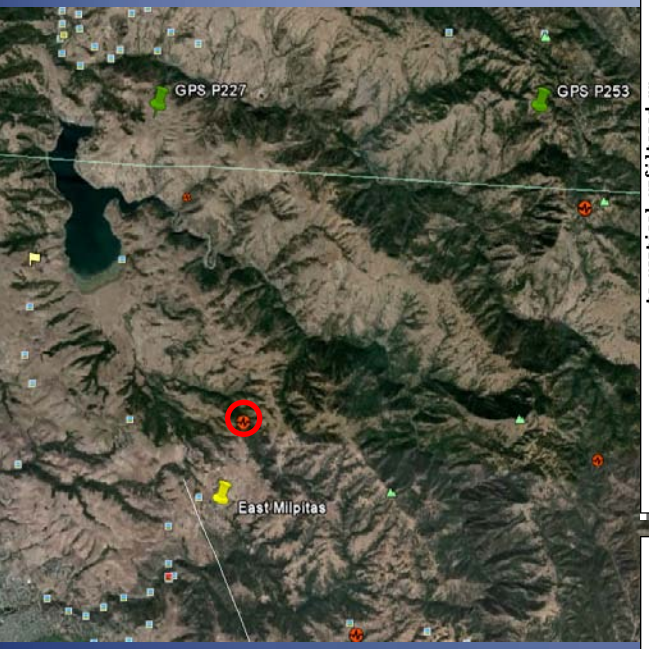
Distance 140 km, Depth 103 km

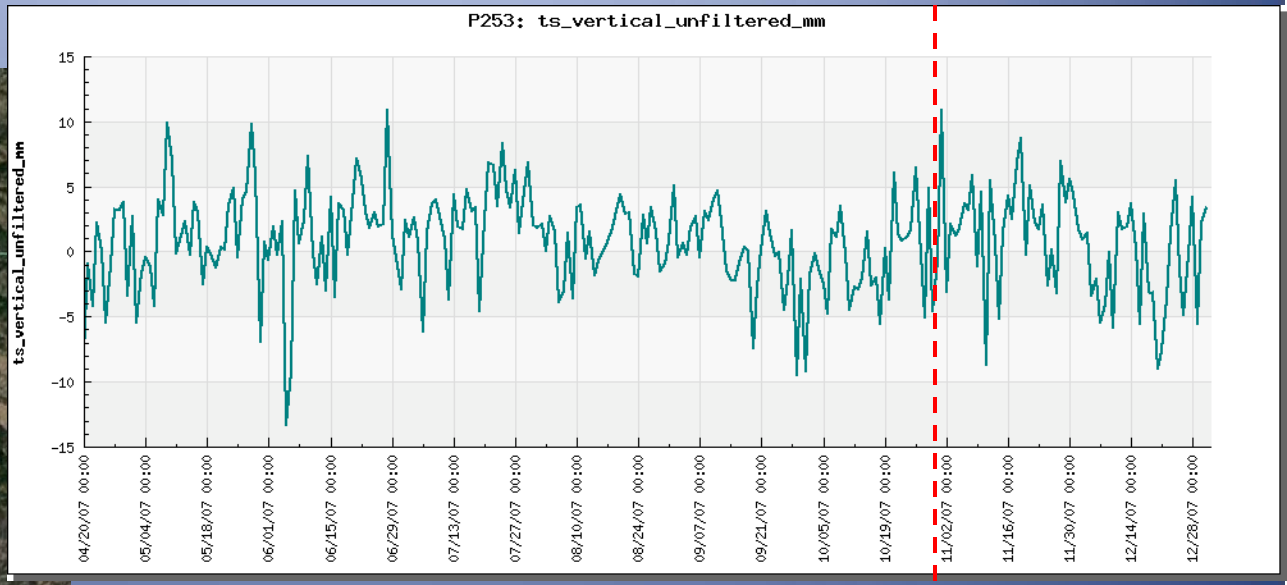


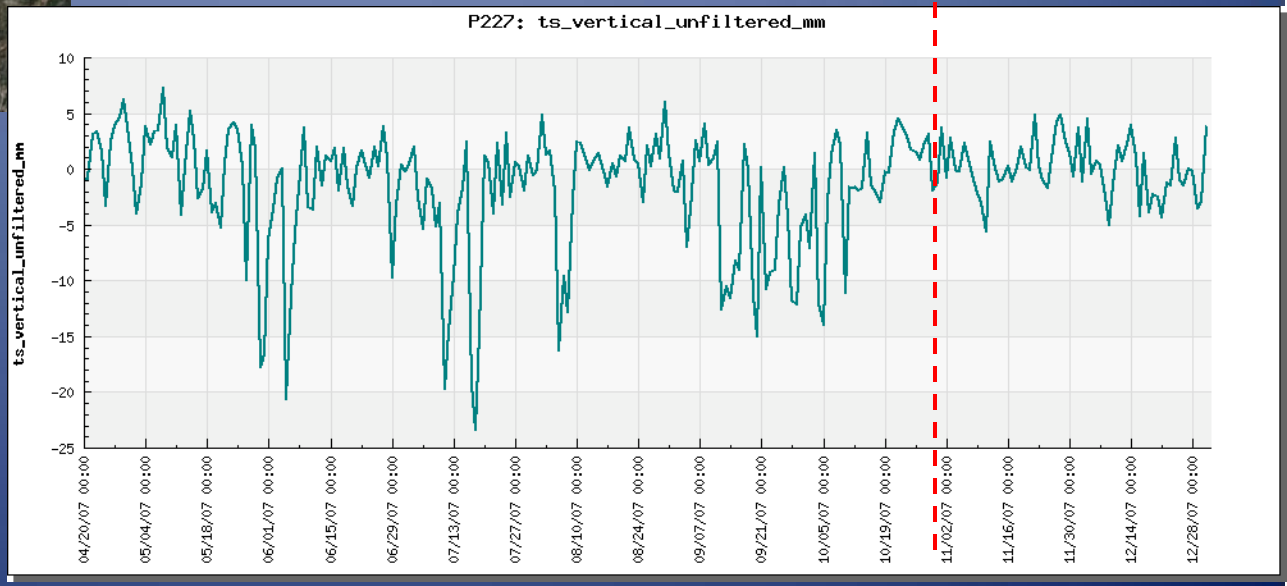
New Pulse Counter (Exp-7) Thresholds



GPS Vertical Displacement: Alum Rock 2007

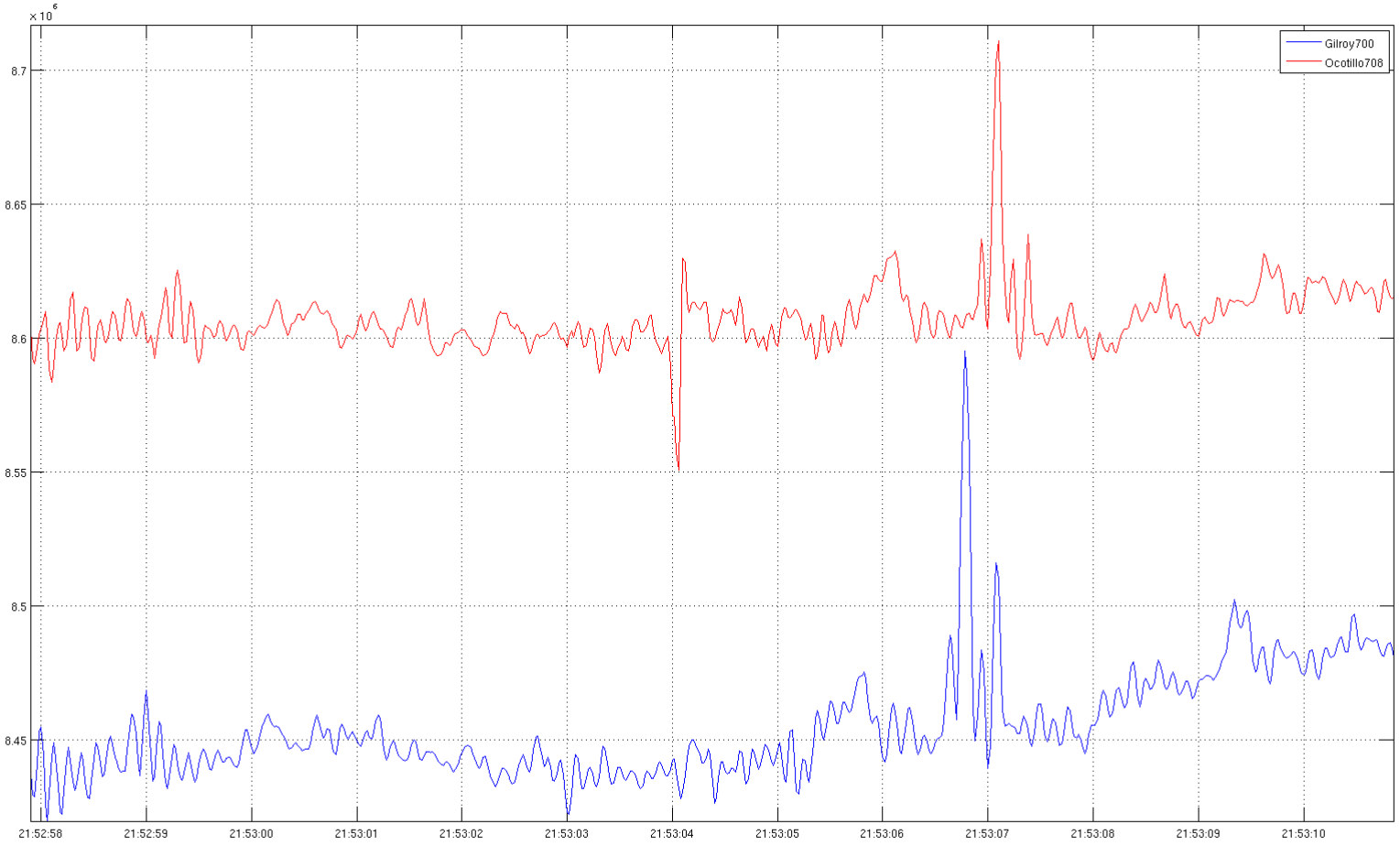






This material is based on data provided by the Plate Boundary Observatory Operated by UNAVCO for EarthScope (www.earthscope.org) and supported by the National Science Foundation (No. EAR-0350028 and EAR-0732947

Example of Uni-Pulse correlation at Ocotillo and E. Gilroy
Gilroy is shifted 226 sec earlier



Example of Uni-Pulse correlation at Tacna and El Carmen Tacna is shifted 402 seconds earlier

QuakeFinder Pulse Detector

Mission:
Detect and List Pulses so they can be studied

Pulse Detector Database

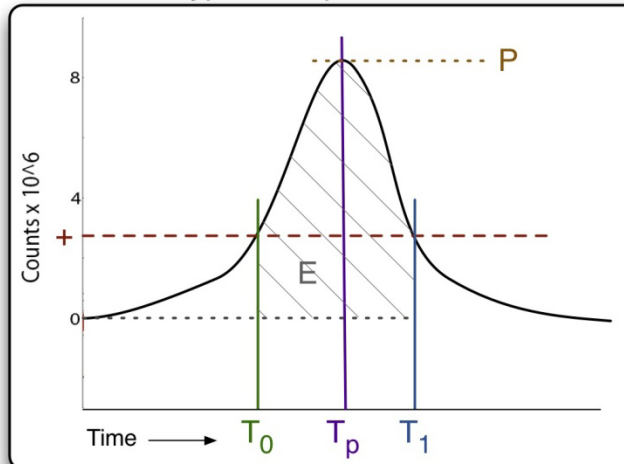
detector parameter set(s)

- name
- type
- pos thresh +
- neg thresh –
- min duration
- max duration

Example:
- "exp7"
- hiPass
- +150000
- –150000
- 0.1 secs
- 15.0 secs

types: abs, rel, hp
thresholds: counts

Typical Unipolar Pulse



Pulse Detector

20 sites
x
3 channels

RAW Data

unsigned counts
$0 - 2^{24}$

- 30db @ 2x max duration

High Pass Filter

Makes zero-centered signal, removes Pc3-4

List up/down excursions

Apply threshold detection

Confirm sequential occurrence

Confirm duration fit

Apply duration & repeat exclusion

Discard all wavetrains

Pulse tables

- T_0 Pulse Start time
- T_1 Pulse End time
- Pulse Sign (+/–)
- Pulse Peak P
- T_p Peak time
- Pulse Energy E

Wavetrain Rule: If next pulse occurs within 2x max duration, discard