



# Stanford – USGS Ultra-Low Frequency Electromagnetic Network: Status Report and Data Availability Via the Web

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## Abstract

As part of the PBO (Plate Boundary Observatory) mission we have installed three ultra-low frequency electromagnetic (ULF-EM) recording sites in northern California. We hope to use this data to better understand physical processes associated with earthquakes and to find evidence for the generation of subsurface electromagnetic fields, including the presence or absence of pre-seismic transients. Our ULF-EM sites complement two existing sites maintained by UC Berkeley at Parkfield and Hollister in central California and a growing California network of magnetometers managed by Quakefinder, Inc. (www.quakefinder.com). We installed our first station in 2005 close to the Stanford University campus. In 2006, we completed two additional installations in the North Bay and East Bay. Each site has three orthogonal magnetometers and duplicate sets of orthogonal horizontal electrode pairs, recording signals from 0.001 to 20 Hz, collocated with an existing broadband seismometer. All data are archived at UC Berkeley's Northern California Earthquake Data Center (NCEDC). We have created a website, <http://ulfem-data.stanford.edu/>, that collects and stores ULF-EM data from our stations. Users can request data plots on the website and view them immediately or after a few minutes, depending on whether or not the information is more than a year old. Currently we can display time-series

data on demand from all our stations, with data available 30 minutes after acquisition. In the near-future we will be able to provide spectrograms on demand, and ultimately a range of user-selected transfer functions computed for chosen time periods. 2009 efforts will focus on expanding our network of ULF-EM stations, by installing the first of several new stations, and upgrading primary remote reference stations. Each site will include state-of-the-art magnetic and electric sensors sensitive from 0.001-100 Hz, and data will be fed to the NCEDC. The first phase of this work, which has already begun, involves upgrading twenty-year-old reference stations at Hollister (SAO) and Parkfield (PKD) that provide a necessary reference critical to the general interpretation of EM data from the current Bay Area stations that are located in electromagnetically noisy environments. Part of this upgrade involves the deployment of newly developed electrical-signal conditioning systems for the EM sensors, improved system isolation, and revised power supply and signal digitizers. Later in the year we will install the first of several new stations funded by NASA. In addition to the three present Bay Area stations and two remote reference stations, the network will include two clusters of three ULF-EM stations, centered near the town of Hollister (roughly 70 km south of San Jose) and in the North Bay along the Rodgers Creek Fault, that will be installed over the next three years.

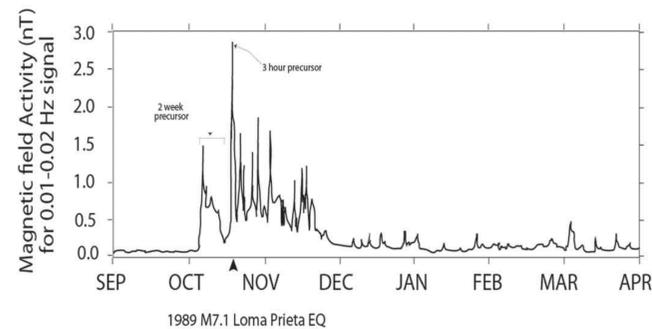
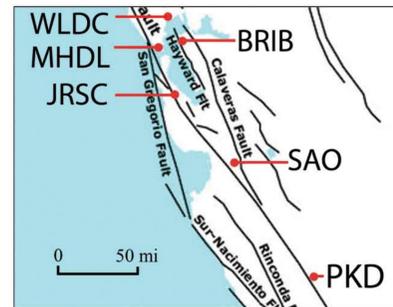


Figure 1: A possible electromagnetic precursor to the Loma Prieta earthquake, showing large increases in EM activity 2 weeks and 3 hours before the event (Fraser-Smith et al., 1990). Our monitoring array is intended to gather a more comprehensive set of multi-component, multi-station data prior to, during and after the next major Bay Area earthquake.

## Monitoring Array

- Our ULF-EM sites complement existing sites:
  - PKD and SAO (Berkeley)
  - Quakefinder's growing magnetometer network
- Each site has:
  - 3 orthogonal magnetometers
  - Duplicate sets of orthogonal horizontal electrode pairs
- Sensors record signals from 0.001 - 20 Hz
- Data archived at NCEDC
- In the future, we plan on upgrading SAO and PKD as well as adding a North Bay site



Figures 2, 3: Site location (above) and information (below)

Site Abbrev	Location	Magnetic	Electric	Date Active
BRIB	Briones	x	x	Jul 2007
MHDL	Marin Hd	x		Oct 2006
JRSC	Jasper Ridge	x	x	Dec 2004
SAO	Hollister	x	x	May 2006
PKD	Parkfield	x	x	Feb 1999
WLDC*	North Bay	x	x	2009

\*New NASA-funded station, to be installed in 2009

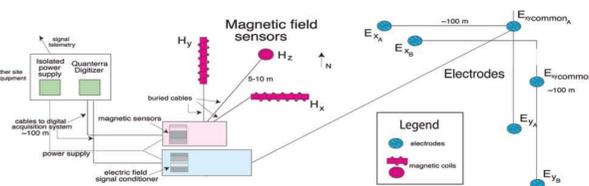


Figure 4: Typical setup of our ULF-EM monitoring stations.

## Data distribution and Website

### Motivation

- We designed a website, [ulfem-data.stanford.edu](http://ulfem-data.stanford.edu), so that interested parties can easily retrieve and visualize ULF-EM data

### Implementation

- Our servers download and cache data from the NCEDC at Berkeley
- Our website, [ulfem-data.stanford.edu](http://ulfem-data.stanford.edu), generates time-series plots to visualize data
- Users can immediately access data from 15 minutes to 1 year old, or wait for our servers to download older information. Turn-around is sufficiently rapid that we can use this tool to access data for trouble-shooting and repair in the field.

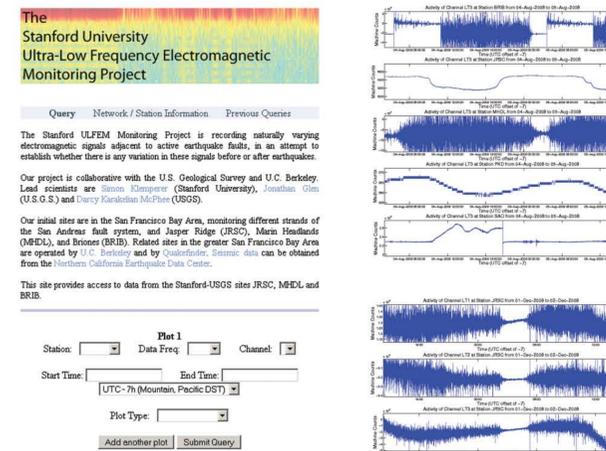


Figure 5: *Left*: A screenshot of our website's GUI *Right*: Examples of data displayed on our website. We chose these displays to illustrate sites with noise or power problems, to exemplify the way in which this quick-look facility can aid our trouble-shooting. *Top*: Comparing a single magnetic channel across all 54 stations *Bottom*: Comparing 3 magnetic channels at one station

## Hardware: Station Upgrades

### Adding total-field magnetometers to our sites:

In a collaboration with Geometrics Inc. of San Jose, CA, at our Jasper Ridge (JRSC) site we have installed a G-881 cesium magnetometer system (below, left), recording absolute total magnetic field with a sensitivity of typically 0.5 nT P-P at 0.1 second sample rate, and absolute accuracy better than 3 nT (capable of detecting an automobile at 100 ft).

This magnetometer is being logged through an entirely separate recording system to provide an independent and redundant measurement to complement our three-axis coils. Data are being continuously acquired starting this week, and these data will be available on our website shortly.

After system testing, we hope that Geometrics will make a long-term loan of identical magnetometers at two more San Francisco Bay Area sites.



Figure 6: total-field magnetometer at JRSC

### Improving system isolation and magnetic-coil stability at our sites:

We have been focussing much of our effort on developing new electrical signal conditioning systems for the EM sensors, improved system isolation, and revised power supply and signal digitizers. This will significantly reduce the need for station maintenance, minimize the stations' vulnerability to lightning strikes, reduce station installation costs and improve the flexibility of the station design by increasing the number of available channels and broadening the sample frequency range. The prototype digitizer system is currently running at UC Berkeley, and will be installed in the field on 2009.

We are also testing new designs for our station coil installation that will improve the life of the coils by reducing the risk of water damage, and making access and maintenance of them much more easy.

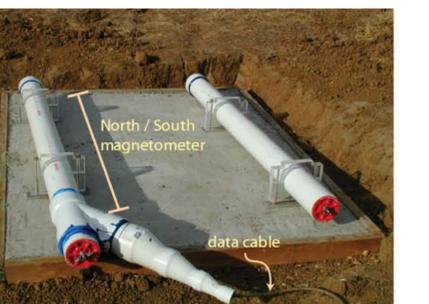


Figure 7: PVC housing / pad at JRSC

- Maintaining the magnetometers in a stable environment is a challenge
- At Jasper Ridge we addressed this by implementing a new magnetometer housing design (above, right), featuring:
  - Buried PVC casing to diminish wind noise
  - Easily accessible endcaps for service and maintenance
  - Duplicate, parallel PVC housing for testing
  - Setup stabilized by a concrete pad