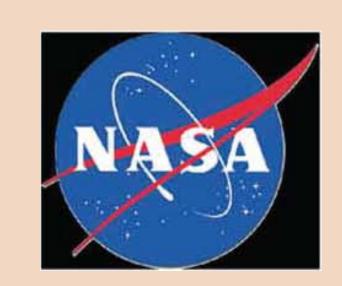


THE SAN ANDREAS FAULT SEISMO-ELECTROMAGNETIC MONITORING SYSTEM: A FOCUSED ARRAY FOR ASSESSING THE EXISTENCE OF PRE-SEISMIC SIGNALS





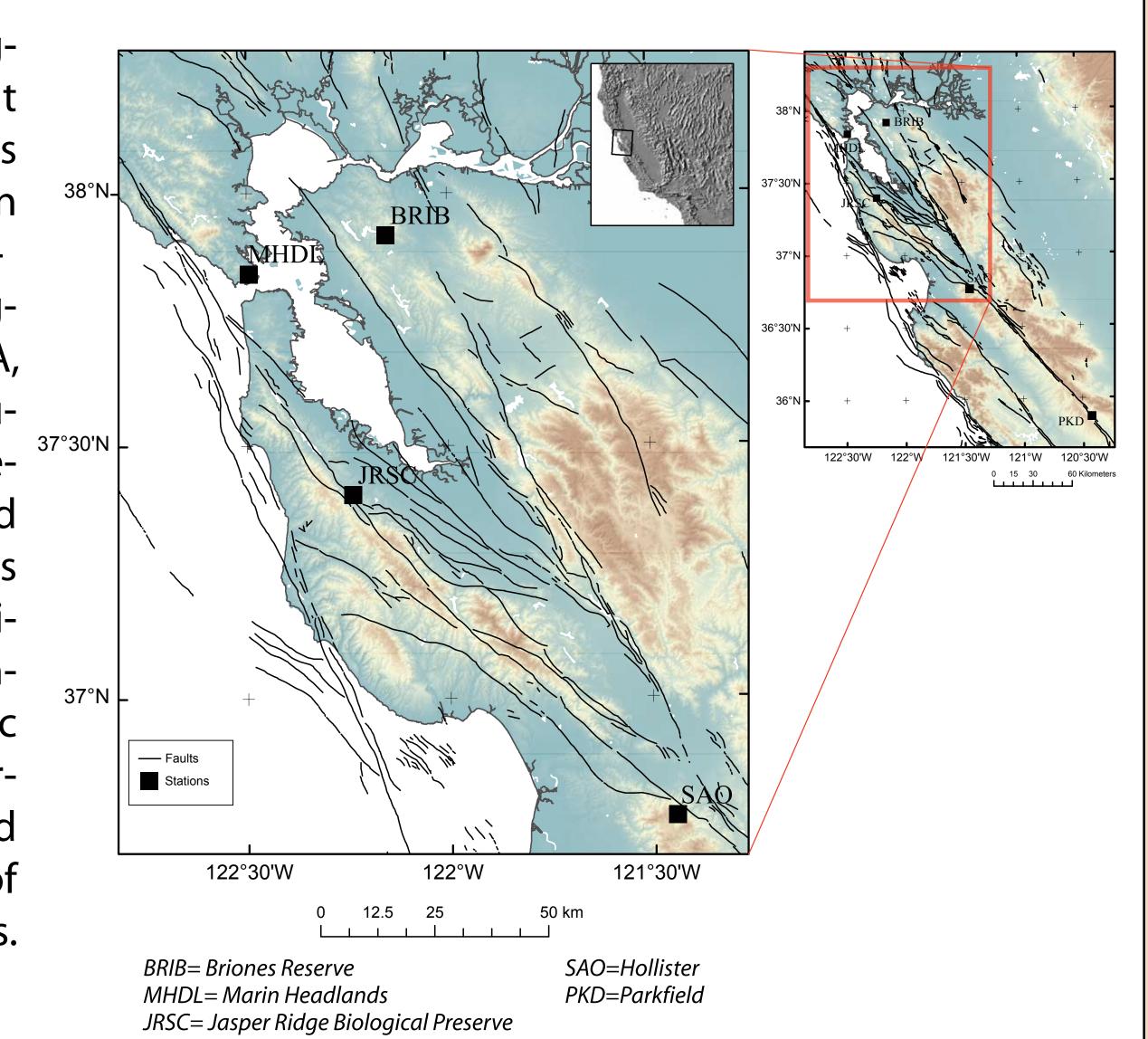
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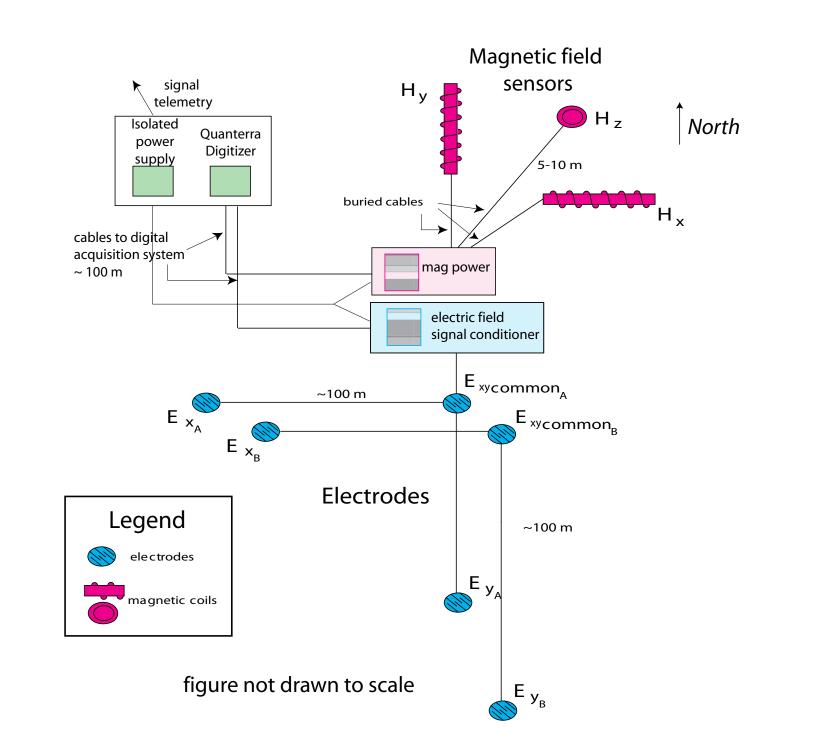
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1. INTRODUCTION

A network of five high-precision electromagnetic (EM) stations within the San Andreas fault system in Northern California measures continuous ULF (ultra-low frequency: 0.01-10 Hz) EM signals in order to determine the existence and origin of preseismic, co-seismic and post-seismic ULF-EM signals. This monitoring array, supported by NASA, NSF, and the USGS, was installed as a multi-institutional collaboration of USGS and academic researchers (including U.C. Berkeley and Stanford University) to better understand physical processes associated with earthquakes and to search for evidence of the generation of subsurface EM fields, including the presence or absence of pre-seismic transients. Our array provides long-term EM reference data for a wide range of EM investigations and complements a growing California network of magnetometers aimed at monitoring earthquakes.

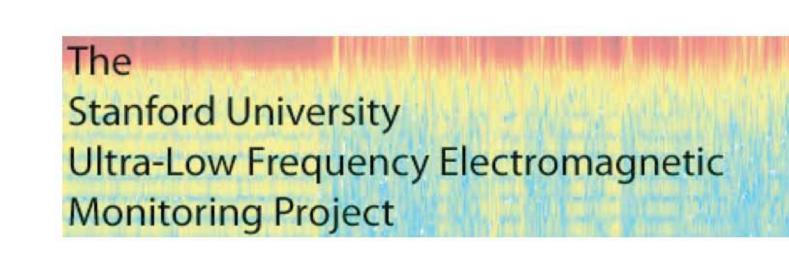


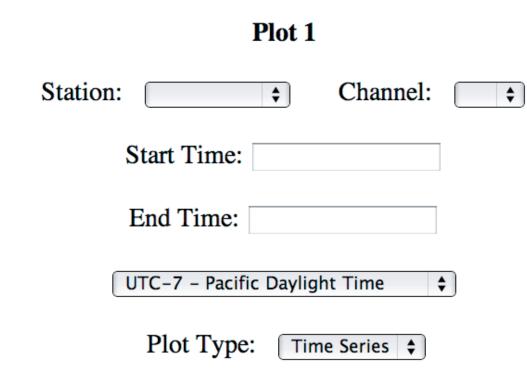
2. ULF-EM STATION SET-UP and DATA AVAILABILITY



Schematic diagram of a typical site (from Karakelian et al., 1998)

Each ULF-EM site has three orthogonal magnetometers and duplicate sets of orthogonal horizontal electrode pairs (except site MHDL, which has magnetic sensors only) and is collocated with an existing broadband seismometer. Our system employs Schlumberger BF-4 and BF-7 magnetic field induction sensors sensitive from 0.0001 to 1,000 Hz, with a resolution less than 1 pT above 0.01 Hz. Non-polarizing Pb-PbCl2 electrodes buried 100 m apart measure the electric field.





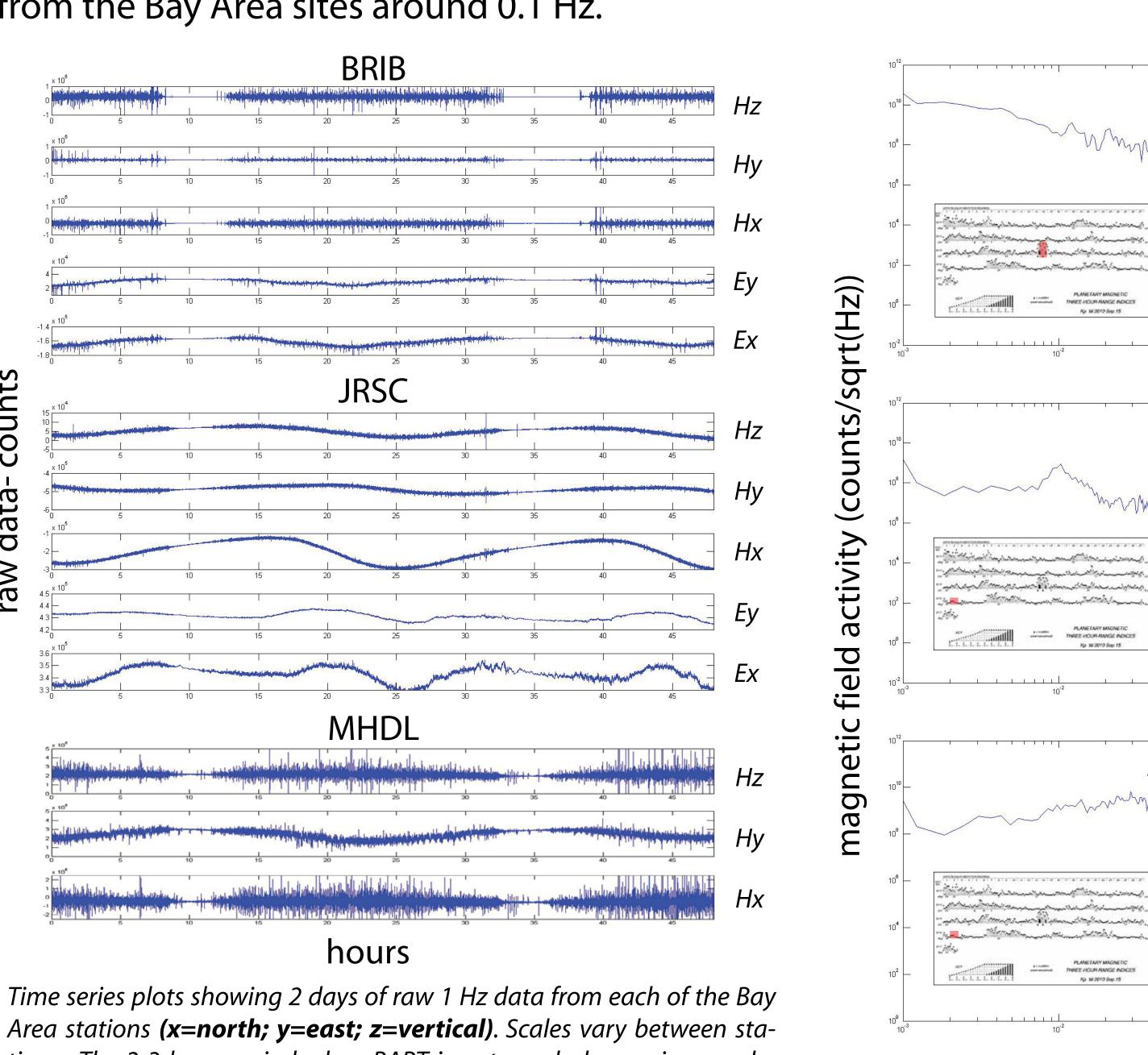
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Screenshot from our website's user-interface

All data are sampled at 40 Hz and are archived at UC Berkeley's Northern California Earthquake Data Center (NCEDC). We have created a website, http://ulfem-data.stanford.edu/(Neumann et al., 2008), that allows users to display ULF-EM data from our stations.

3. SITE CHARACTERIZATION

All of our sites are located within several km of the San Andreas fault or the Hayward fault; three of our sites (JRSC, BRIB, MHDL) are located in the San Francisco Bay Area and two additional stations are located at Hollister (SAO) and Parkfield (PKD). SAO and PKD provide a necessary reference critical to the general interpretation of data from the Bay Area stations that are located in electromagnetically noisy environments. The predominant noise source is the 1,000 V DC electric railway (BART) that serves the San Francisco region. Signals from BART dominate the electric and magnetic field records from the Bay Area sites around 0.1 Hz.

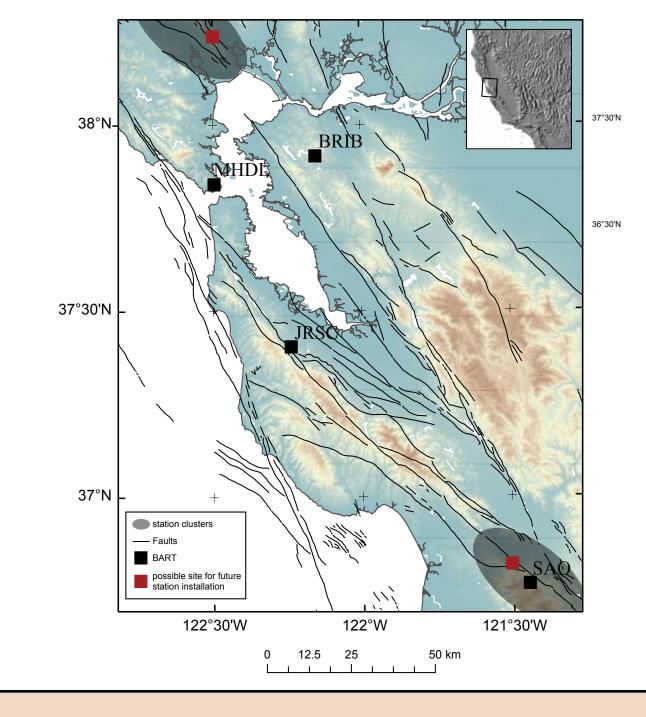


Time series plots showing 2 days of raw 1 Hz data from each of the Bay Area stations (x=north; y=east; z=vertical). Scales vary between stations. The 2-3 hour period when BART is not regularly running can be clearly seen (see data around hour 10 and hour 35). The effect is most obvious at BRIB, the station closest (within 2 km) to BART.

frequency (Hz) Representative power spectra of typical background magnetic field activity measured from BRIB for Hy.

5. FUTURE DEPLOYMENTS

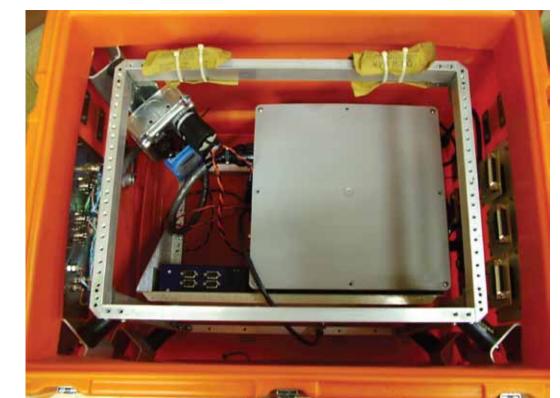
We hope to install several more stations in the next few years to satisfy the need for clustered ULF-EM stations along the San Andreas Fault. Stations will be close enough (<10 km) that multiple stations will record signals from a single earthquake. Two potential clusters near SAO and in the north Bay Area along the Rodgers Creek Fault are highlighted on the map to the right.



4. SITE UPGRADES

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, 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 is currently being field tested at JRSC.



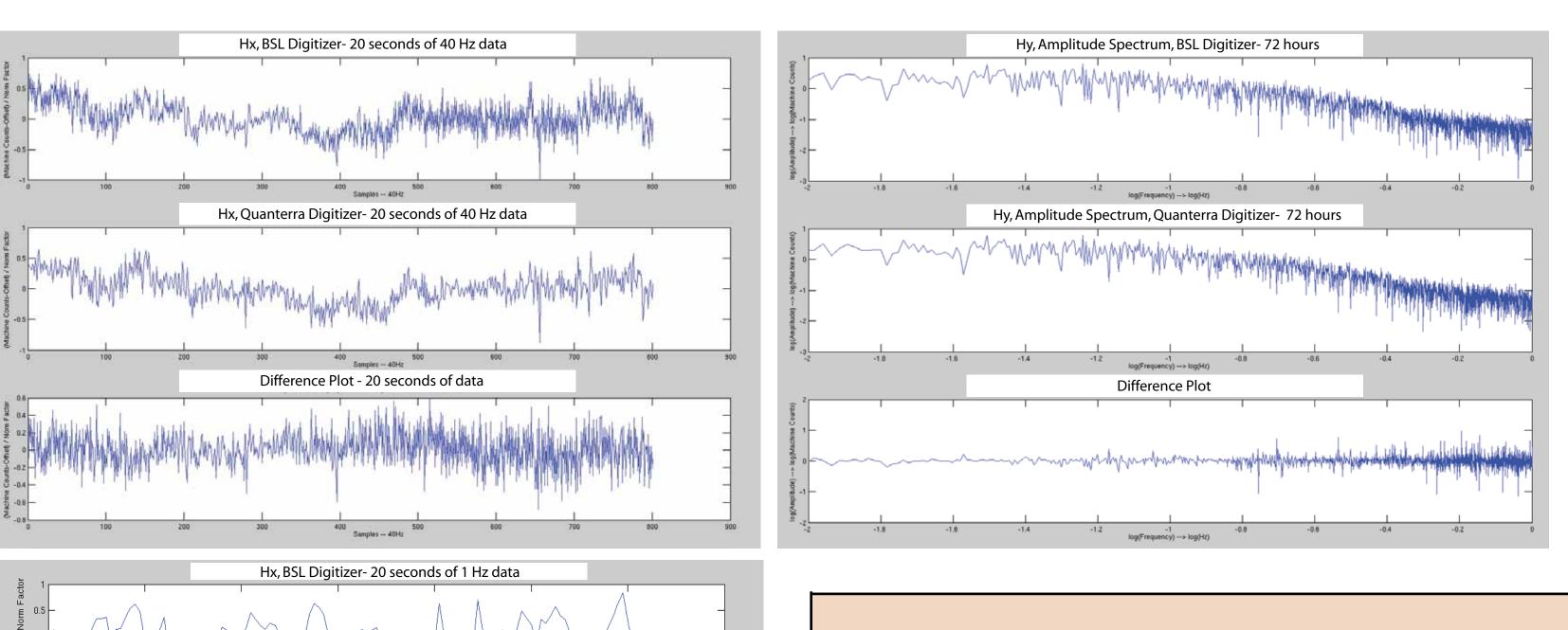


The new digitizer (above photos) is a low cost 24-bit data acquisition device designed and developed by Berkeley Seismological Laboratory, USGS and Stanford University. This is an 8-channel device with a noise floor of 4-bits with a 20-bit dynamic range and also includes a dedicated input for temperature sensing. The timing is given by GPS signal and verified through the use of phase locked loop circuitry. The digitizer works in conjunction with a Linux based single board computer over a serial connection to provide data storage, IP connectivity and operational software. Each input has a unity gain amplifier, can safely digitize signals up to 40 Vp-p, and will accept frequencies from .0001 Hz to 700 Hz. The digitizer and Linux computer will operate off a range of 10-14 VDC and consume < 10 Watts.



Photo of new, unburied coil housing. Each site will have a duplicate, parallel PVC housing for testing purposes.

We are also implementing a new design for our magnetic coil installation that will improve the life of the coils by reducing the risk of water damage, and make access and maintenance easier. In addition, we are experimenting with the design of a calibration coil that will be installed at each site to ensure proper operation of the magnetic coils (Bowden et al, Fall AGU Mtg, 2010).



Data comparison plots (courtesy of Henry Engelland-Gay) for one component of the magnetic field between the BSL digitizer prototype and the Quanterra. We plan to replace the Quanterras with the BSL digitizers at our sites in the future.

Acknowledgments

We thank the folks at the Berkeley Seismological Laboratory, including Barbara Romanowitz, Bill Karavas, Jarrett Gardner, Doug Neuhauser, and David Alumbaugh, for their support in the development of the ULF-EM network. We also appreciate the help of Aaron Enright for his technical support and Karl Kappler for his software support, and the tireless effort of many students, including Henry Engelland-Gay, Daniel Bowden, and Danny Neumann, who have helped with this project. This project is supported by NASA and NSF Earthscope.