Anomalous EM signals and Changes in Electrical Resistivity at Parkfield: Collaborative Research Between the Universities of California at Berkeley and Riverside and Oregon State University

External Grant Award Number: 01HQGR0047

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NEHRP Element: I **Keywords:** Geophysics, Earthquake Forecasting

Investigations Undertaken:

This project is part of a collaborative observational study of possible electromagnetic (EM) earthquake precursors on the Parkfield segment of the San Andreas Fault. EM data are currently being collected by researchers at UC Berkeley (two magnetotelluric systems, at Parkfield and near Hollister) and UC Riverside (an array of long electric dipoles). The work at Oregon State University supports these efforts, with a focus on development and application of data processing methods for the EM data. Our ultimate goal is removal of ionospheric and cultural EM noise, to improve chances of detecting (and verifying the source of) possible EM signals generated inside the earth by tectonic activity. During the current project period efforts have been focused on development of (a) a fully automated processing system for routine daily processing of the UCB MT data; and (b) an interface for reprocessing of archived data, and for more careful interactive examination of residuals.

The automated code is now installed and running on the Berkeley Seismological Laboratory (BSL) computers. Each day data from the previous day are extracted from SEED volumes and processed with the frequency domain multiple station codes of Egbert (1997. During the past year the processing software was modified to directly extract system response information from the SEED volumes, and the accuracy of the archived system responses has been verified. Processing results, including daily estimates of MT inpedances, inter-station transfer functions, estimates of noise amplitudes, and summaries of frequency and time domain residual amplitudes are archived for statistical analysis and correlation in space and time with seismicity at Parkfield and Hollister. Whenever estimated signal-to-noise ratios fall below a prescribed level, the processing software sends email to UCB staff responsible for maintenance of the array. The automated processing software thus now plays a central role in data quality control and routine array maintainence.

The user interface developed for interactive reprocessing has been developed in MATLAB and includes modules for downloading MT data archived at the BSL, for

plotting time series and diagnostics of data quality, and for running frequency domain analysis programs. The interactive software can also be used for time domain filtering and display of residuals. The program has been developed to allow new approaches to be easily implemented and tested. Several novel approaches for improved computation of residuals are now under development as part of this system. One approach is a multivariate prediction method that can use all data channels, reducing the effects of local noise on predicted EM fields, and allowing for more complex sources. This scheme shows promise for more effectively dealing with cultural noise from the San Francisco Bay area. A second approach in the early stages of development is to use a complex invertable wavelet transform for transformation into the frequency domain. In combination with the frequency domain multiple station processing, this approach should allow for a more reliable isolation of anomalous EM signals.

Results:

Figure 1 shows examples of the routine outputs of the automated processing system. Here signal-to-noise ratios (SNRs) estimated using the multivariate scheme of Egbert (1997) are plotted as a function of frequency and day for selected channels. Low SNRs in the period range 30-300s have been found to be an excellent indication of system malfunction. Whenever SNRs in this range fall below 15 dB the automated system generates a warning, and sends email to appropriate personnel. The system has been operational since late summer.

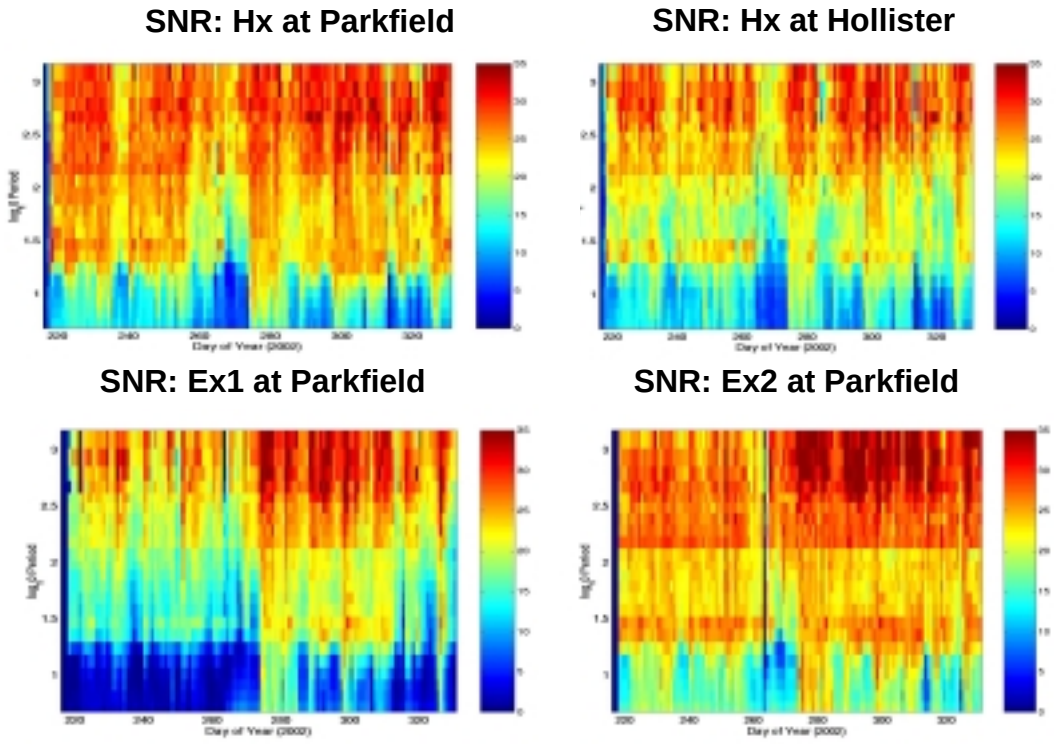

Figure 1. Estimates of signal-to-noise ratio for 4 of the 12 data channels in the UCB MT monitoring array, as a function of frequency for each day since installation of the automated data processing scheme. The SNR estimates are used to monitor the health of the array; low values at selected periods automatically generate warnings via email to UCB personnel responsible for array maintainence.

Several general features of the array performance can be discerned from the SNR sections. Data quality is generally better at Parkfield, due to cultural EM noise from the SF Bay area. The peak in SNR at Hollister near 15 s period results from the PC3 resonance, possibly excited by BART (Egbert et al., 2000). The two electric field components at Parkfield correspond to parallel dipoles of length 100 m (Ex1) and 200 m (Ex2). As a test of electrode performance two different types of electrodes have been used. The lead-lead chloride electrodes used on the 100 m dipoles are expected to be much lower maintenance (e.g., they will not dry out). However they are considerably noisier in this test, particularly at short periods. These electrodes also required a long time to settle in, and were quite noisy at short periods for almost a month after installation.

Figure 2 illustrates some aspects of our efforts to develop improved methods predicting and removing natural source and cultural EM noise from the time series. The left panel shows residuals obtained from a multivariate prediction filter assuming that the source space is of dimension 2, as would be expected for clean MT data. Significant signal remains in the time series with this filtering due to source complications in the period band 15-300 s. The multivariate filtering scheme allows us to extend our prediction model to allow for more complex sources in this band. In the right panel residuals obtained with a filter based on a 4 dimensional source space are much smaller. This should improve our sensitivity to small tectonically caused signals, if these should be present.

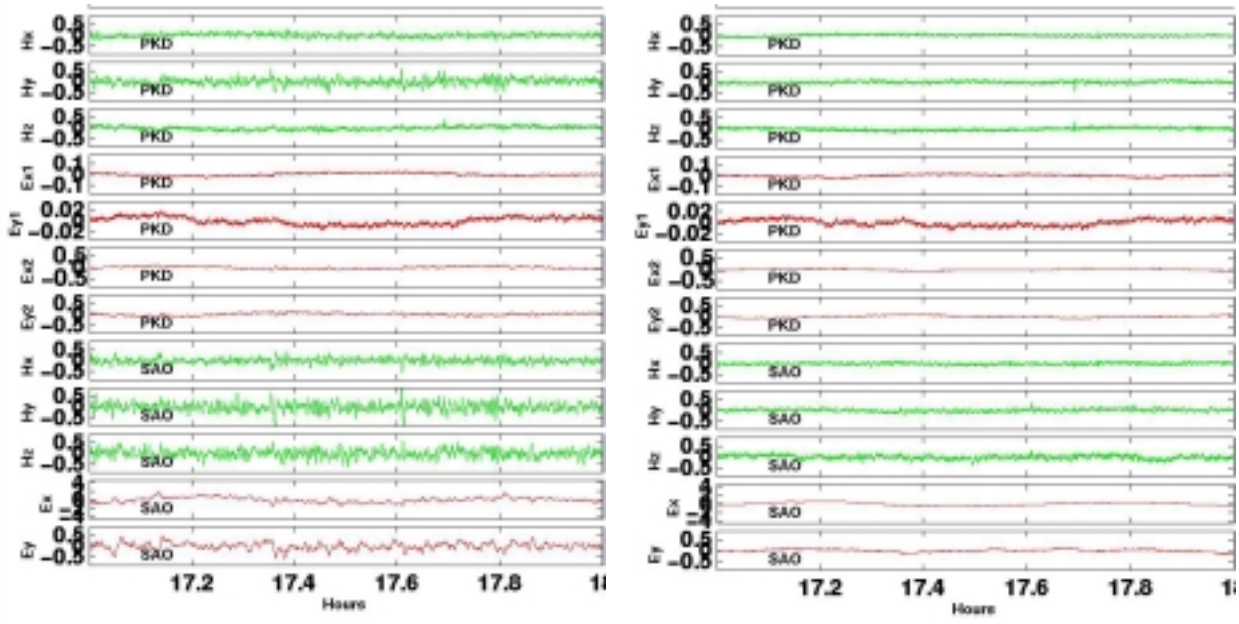

Figure 2. Residuals obtained by filtering the MT data with a multivariate filter (using all data channels for the prediction), assuming a source space of dimension 2 (left panel) and 4 (right panel). The multivariate analysis suggests a coherence dimension of 4 (Egbert et al., 2000). Using a 4 dimensional prediction filter reduces residuals considerably, especially in the Hollister electric fields.

Non-Technical Summary:

This project is part of a search for possible electromagnetic (EM) earthquake precursors on the San Andreas Fault near Parkfield California. There have been a number of reports of anomalous EM signals preceding large earthquakes, and it has been suggested that such signals could be useful predictors of seismic activity. However most observations of EM precursors have been fortuitous, and difficult to verify. This project aims at more systematic monitoring, so that any possible precursors in the Parkfield area would be observed under more controlled circumstances. The work at Oregon State University supports field efforts, with a focus on development and application of data processing methods. Our goal is to remove ionospheric and cultural EM noise, thus improving chances of detecting and better understanding the nature of any EM signals associated with earthquakes.

Reports Published:

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