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INSTALLATION OF THE TUCSON, AZ ACOUSTIC ARRAY

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Installation Note

Introduction

The Department of Geological Sciences at Southern Methodist University is conducting local and regional seismic and acoustic experiments in the Western United States as part of the DTRA funded contract no. DSWA01-98-C-0176. Rock fragmentation explosions at the copper mines in eastern Arizona and western New Mexico are sources for the seismic and acoustic energy.

Acoustic and seismic energy from explosions in these copper mines is routinely detected 600-700 km from the mines at the TXAR seismic and acoustic array in West Texas (Figure 1) (Sorrels *et al.*, 1999). These explosions provide an opportunity to study long distance seismic and acoustic propagation in the western US, to study the relationship between industrial mining practices and the signal characteristics, and to study the relation of near-source seismic energy to the design of the industrial blasts. Near-source instrumentation within the mine provides the opportunity for collaborative studies with mine engineers to study the relationship between near-source seismic signatures, fragmentation efficiency, and explosive charge. The design and installation of the near-source instrumentation has been described elsewhere (Hayward *et al.*, 2000; Thomason, 1999; Stump and Hayward, 2000) and is deployed at Morenci, AZ and Tyrone, NM as illustrated in Figure 1 (yellow stars).

This document describes the installation, characteristics and preliminary data associated with one of the small aperture acoustic arrays deployed at regional distances from the copper mines. The station, Tucson (designated TUC), is 150 - 200 km from the mines (Figure 1). This location provides an opportunity to document the development of both seismic and acoustic signals as they propagate from the mines. The infrasound TUC site in Tucson, Arizona is collocated with the existing TUC Global Seismograph Network (GSN) IRIS-2 system.

The installation trip occurred on 9-12 November 2000. During the trip, the following tasks were completed:

7 November

- Shipped equipment from Dallas to Phoenix by Southwest Airline Freight.

9 November

- Chris Hayward traveled Dallas to Phoenix.
- Picked up shipped station equipment at freight terminal.
- Purchased porous soaker hoses from manufacturer

Moisture Master 5/8" x 25' soaker hose, $8.99 each
Fiskars Consumer Products, Inc.
Garden Tool Division - Phoenix
Watering and Landscape Products
Adam Stern, Sales Manager
610 S. 80th Avenue
Phoenix, AZ 85043-4025
Phone, 623-936-8083; Fax, 623-936-9040
www.fiskars.com

- Purchased materials for installation.

- Traveled Phoenix to Tucson

10 November

- Hayward met David Steinke to begin installation

David Steinke
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- Picked the final site for the installation.
- Completed the installation of four infrasound sensors along with the data acquisition system.
- Began data acquisition.
- Stump traveled Dallas to Tucson.

11 November

- Completed final installation and clean up.
- Gathered example data set.
- Documented the installation
- Traveled to N. Arizona to investigate possible second infrasound site.

12 November

- Visited Sunset National Monument and discussed possible co-location of acoustic array with the National Seismic Network station WUAZ. Talked to National Park Service Employees John Bland and Suzanne Morrison (smorrison@owol.net). Recommended contact the park Resource Management, Todd Metzger or Paul Whitefield (520-526-1157)
- Visited Lowell Observatory, Flagstaff as an alternative site. Possible points of contact, Bob Millis or Nat White, 7742096.
- Returned to Dallas.

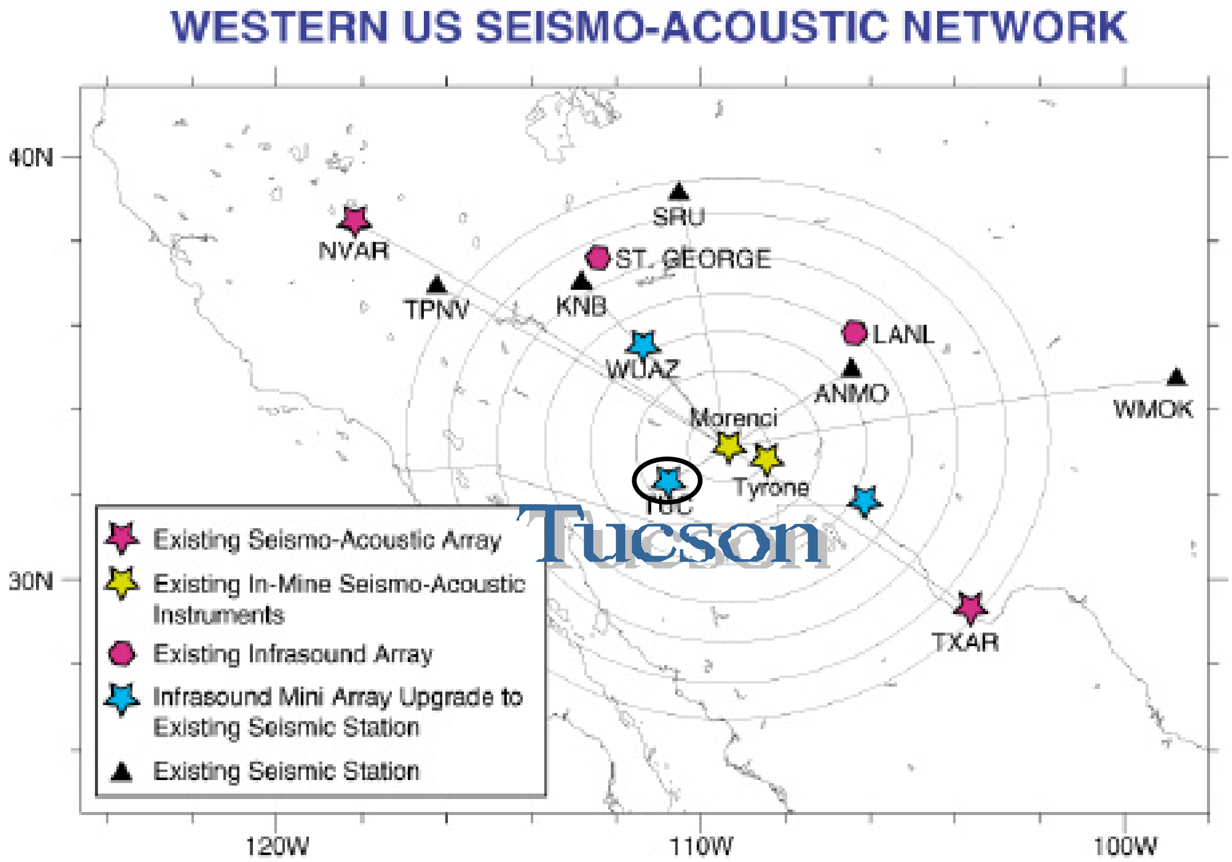

Figure 1. Map illustrating the existing and proposed stations that will make up the Western US seismo-acoustic network. The station installation described in this document is Tucson and highlighted with a circle in the accompanying figure.

This installation includes four acoustic gages, a digitizer, and disk and omits the seismometer used at other sites, since TUC is co-located with an existing seismic station. The equipment was placed in an unused corner of the existing TUC seismic vault. The vault also provides commercial power for the equipment. A panoramic photograph of the site overlooking Tucson is given in Figure 2. The infrasound elements are arranged in a triangular pattern with the fourth element at the center of the triangle.

Figure 2: Panoramic view from TUC1. The large concrete structure on the left third is a water reservoir under construction.

Site Location and Characteristics

The Tucson acoustic installation is NE of the city of Tucson in the foothills of the Santa Catalini Mountains (Figure 3a). The detailed geometry of the acoustic array relative to the NSN station TUC, is given in Figure 3b (TUC0-TUC3 represent the four elements of the array). The latitude and longitude for each of four-infrasound sites and TUC are reproduced in Table 1.

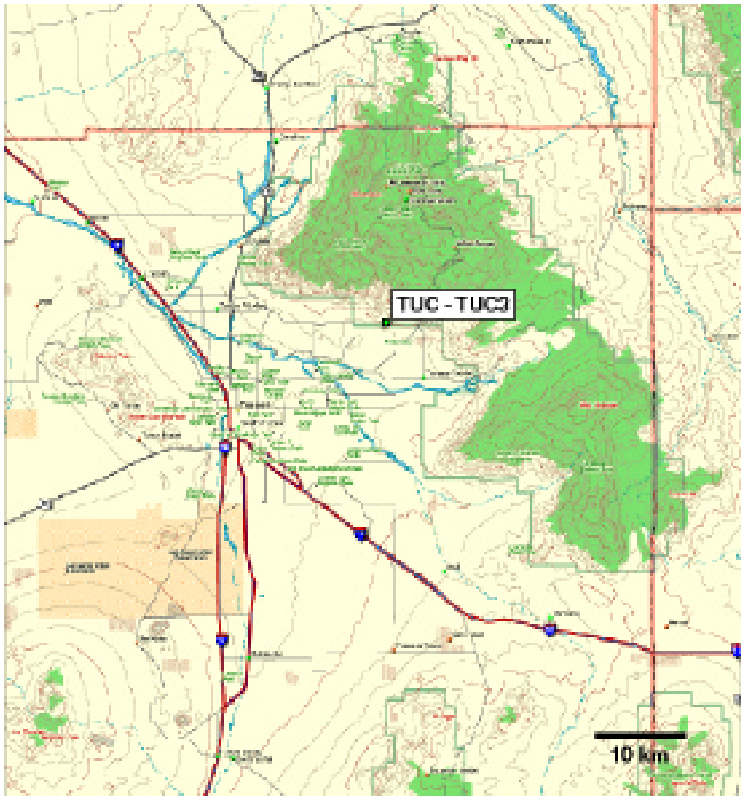

Figure 3a: Map illustrating the location of the Tucson infrasound array (green dots) relative to the city of Tucson.

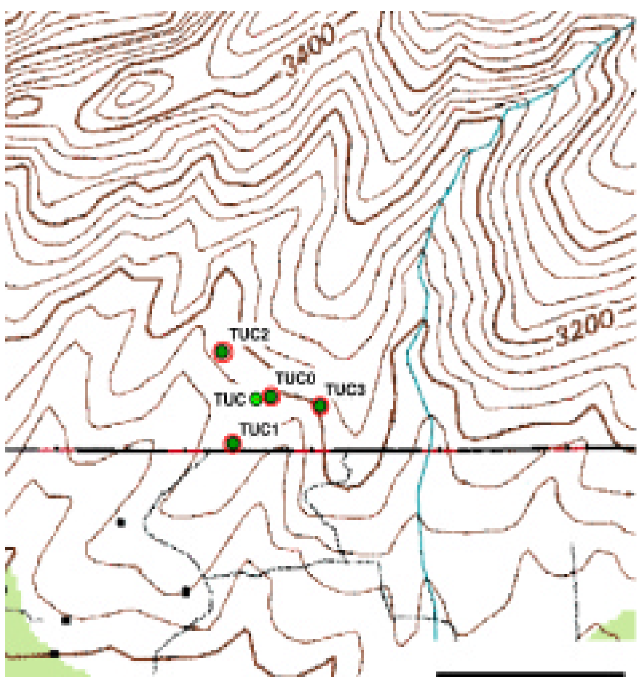

Figure 3b: The location of the NSN station TUC (green dot) and the four elements of the infrasound array (TUC0-TUC3) (green dots surrounded by red circle).

Station Name	Latitude (N)	Longitude (W)	Ref Tek Channel	Serial Number
TUC0	32.30978°	110.78452°	4	1295
TUC1	32.30912°	110.78519°	1	1399
TUC2	32.31041°	110.78538°	2	1317
TUC3	32.30964°	110.78364°	3	1320
TUC	32.3096°	110.7846°		

Table 1. Latitude and Longitude of the acoustic instruments (TUC0-TUC3) and the seismometer (TUC) at Tucson.

The sites are all located in gneiss and other high grade metamorphics. Soil cover is sparse and bedrock is exposed at all infrasound sites other than TUC0 (in fill from the TUC vault). The FDSN Station Book for TUC identifies the surface rocks as granite. The large variety of cacti growing at the sites provide limited wind protection.

The separation of the outside elements of the acoustic array ranges from 140 to 180 m (Figure 3b). Distances from TUC0, the central element, and the three outlyers ranges from 80 to 100 m. The existing TUC seismometer nearly coincides with the central acoustic site (Figure 3b). Although the array is on the slopes of Santa Catalini Mountains, all four acoustic sites are nearly the same elevation. The elevation difference between the site the highest site, TUC3, and the lowest, TUC1, is only 60 feet.

The city of Tucson is expanding National Forest Boundary at the base of the mountains in the NE. As a result there are homes and structures within half a kilometer of the site. The panoramic view from TUC1 (Figure 2) illustrates some of the development close to the site.

In spite of the urban encroachment, collocation with station TUC, provides an infrastructure, a catalog of accessible high quality seismic signals, site access, and security. Professor Terry Wallace and Mr. David Steinke, University of Arizona, were invaluable with their cooperation.

Instrumentation

A Refraction Technology 72A-06 digitizer was deployed with a 2 Gbyte disk for data archival (Figure 4). All four infrasound channels are continuously sampled at 40 samples per second. Preamp gains were set at 1 to match the response of the Chaparral microphones. The data logger and power supply are housed in the seismometer vault (Figure 5) built into the side of the mountain. Commercial power in the vault supplies a battery charger that maintains the 12-volt battery supply for the Refraction Technology 72A-06 digitizer and disk.

The central element of the infrasound array, TUC0, is located directly above the seismic vault. Six pair 24-gauge rodent proof (steel armored) telephone cable connect each infrasound sensor to the digitizer. These cables provide power to the active acoustic gauges and return the analog signals to the digitizer. There is little soil at the site and so it was not possible to bury the cable. This type of cable also provides the opportunity to install the infrasound array without disturbing the soils in environmentally sensitive sites. The cable was purchased from ANIXTER and is identified as 0006PR/24 GR PE-89 TYPE (REA) FOAM SKIN/FILLED CORE/CACSP.

Each element of the tripartite infrasound array consists of a surface array of ten, 25-foot porous hoses that connect through a manifold (Figure 6) to a Chaparral Model 2 microphone modified for 12-volt operation (Hayward, 2000).

Figure 4: Installation of the Ref Tek 72A-06 digitizer, disk and battery charger in the seismic vault at TUC.

Figure 5: The seismic vault for TUC where the digitizer (Ref-Tek 72A-06), disk and battery are located. Commercial power is used to charge the 12-volt battery operating the data logger.

The individual infrasound sites, TUC0-TUC3, are pictured in Figures 6a-d. The rocky soil with minimal vegetation is illustrated. The plant types reflect the desert climate. There is some wind protection provided by cacti and small shrubs at the site. These photographs also show the topography of the array and the mountain that rises above the array.

Figure 6a: Infrasound site TUC0, which is directly above the seismic vault. The Chaparral Model 2 acoustic gage is the small white instrument to the left. The summing manifold is connected to ten, 25 foot porous hoses.

Figure 6b: Looking from Infrasound site TUC1 back towards the seismic vault a distance of approximately 90 m. The Santa Catalini Mountains that rise behind the array are seen in the background.

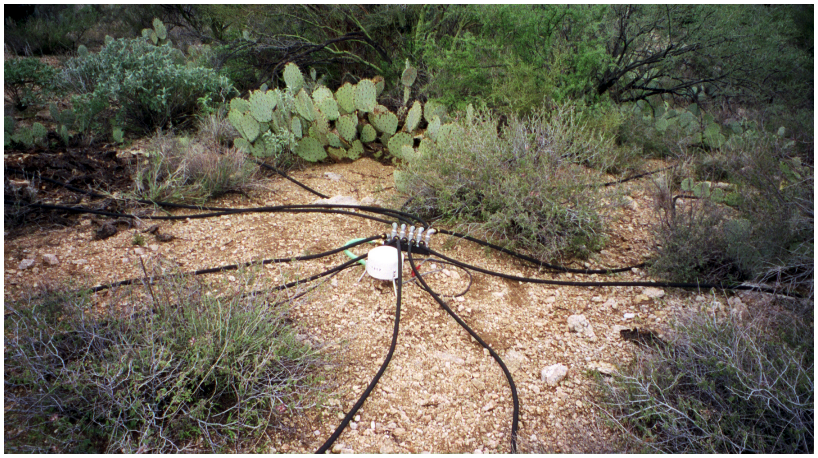

Figure 6c: The infrasound gage at TUC2 is connected to ten, 25-foot porous hoses for purposes of wind noise reduction. This photograph characterizes the surface conditions typical of all array elements.

Figure 6d: TUC3

All acoustic instruments have a sensitivity of 40 mV/μbar (400 mV/Pa).

No wind speed or direction information is currently being acquired at the site. The recording system has two additional data acquisition channels that could be employed for this purpose.

Preliminary Data

Data from a 12-hour time period (Julian Day 316) was recovered for purposes of assessing the array installation. This initial data set spanned the time frame from Friday evening until early Saturday morning, a period where few manmade source of acoustic energy might be expected.

The purpose of this analysis of a small amount of data is to demonstrate the operation of the sensors. A number of possible problems were also identified suggesting some changes to the array at the next visit to the site when a larger sample of data is recovered.

Example of noise segments from acoustic and seismic channels.

Eighty minutes of noise data from the infrasound array are reproduced in Figure 7. One can identify the effects of the variable wind conditions. Relatively long-period signals of approximately 10 s move across the array at speeds of a few m/s. This effect was also observed in the preliminary analysis of the data from the Ft. Hancock array. It is not possible to identify a signal in this time period which is not surprising since it is taken during the night time hours at Tucson.

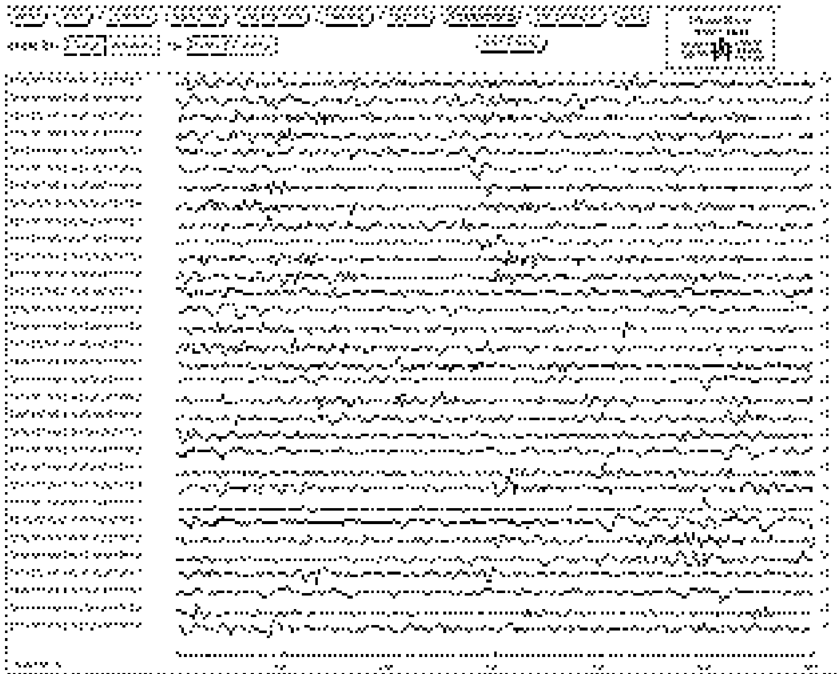

Figure 7: Eighty minutes of data from Julian Day 316 recorded at Tucson. Eight continuous, 600 sec data segments are plotted. Each set of four traces represents the data from the four acoustic sensors TUC1, TUC2, TUC3, TUC0 (Figure 3b) for the same 600 sec time segment.

Example of acoustic signal.

An example of one, small signal with coherence across the array is reproduced in Figure 8. There are signals from five sensors displayed. The first four are from the permanent elements of the array and the fifth channel is from an experimental acoustic sensor co-located with TUC0 during the 12-hour test. The instrument response of the experimental gage is slightly different from the Chaparral Model 2's. The data in Figure 8 has been filtered from 0.5 to 5 Hz in order to eliminate the long-period wind noise illustrated in Figure 7.

The signal is easily identified at sites 0 (channel 4 and 5) and 3 (channel 3) and to a lesser degree at site 2 (channel 2). It is difficult to identify the arrival at site 1 (channel 1) . The higher noise levels at TUC1 may be a result of its location on a ridge top and accompanying higher wind conditions.

No other coherent signals traveling at acoustic velocities across the array were identified during this initial 12-hour data sample. This observation is not surprising since the data was taken at night when manmade sources such as mining explosions typically do not occur.

Pulses from Charging System

Figure 9 illustrates a data acquisition problem that was observed in data taken during the quietest times of the evening. Long-period pulses (~10's seconds) with little or no move out across the array occur on 5 minute intervals. These are most noticeable on the experimental acoustic sensor (channel 5). The higher noise levels on channel 1 (TUC1) masks the longer period noise. The most likely hypothesis for this pulse is that it is the result of cycling of the automatic battery charger. All sensors run directly from the battery. The charging pulse will raise the source voltage by several volts, which could produce the observed signals if there is insufficient power regulation within the sensors.

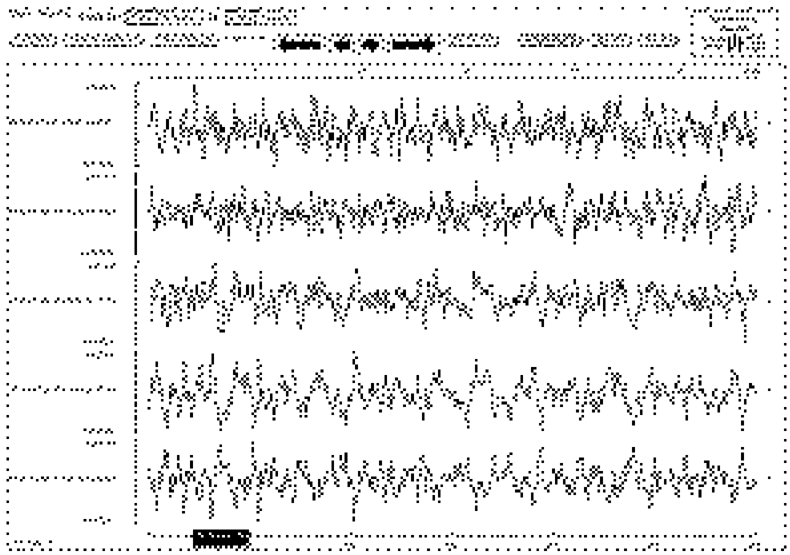

Figure 8: The only example of a coherent, high frequency (0.5-5 Hz) signal observed across the acoustic array.

Solutions to this problem include reducing the charger from its 10-amp setting to a 2-amp setting, powering the sensors from a separate 12-volt power supply, such as a small battery on a linear float charger, or improving the power supply filter in the sensor.

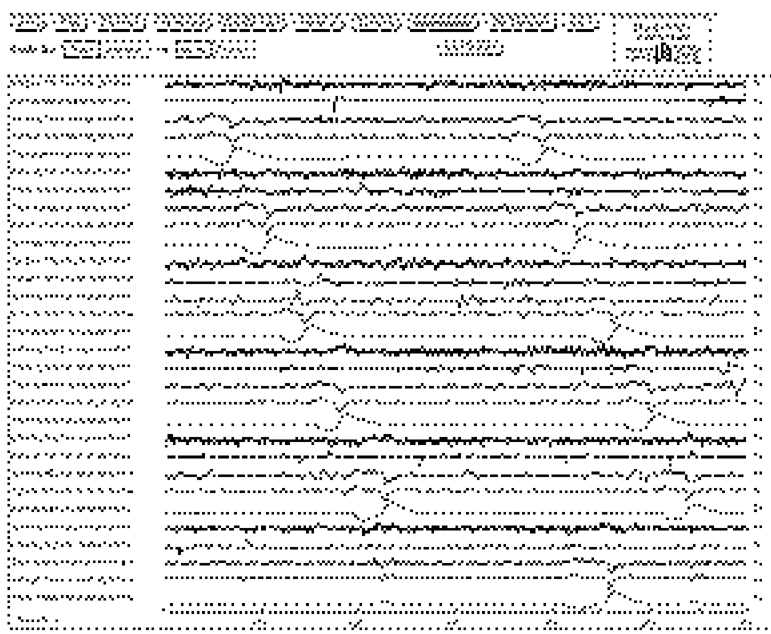

Figure 9: Noise data taken during low wind conditions. Long-period noise may be a result of system charging.

Clipping Under High Wind Conditions

During high wind conditions, the output of sensor at the central site (TUC0), appears to clip well below the maximum clipping voltage of the digitizer (5 volts). This effect is illustrated in Figure 10 where channel 4 is from TUC0. The most likely cause of this effect is an internal regulator in the sensor that is set at too low a voltage. The maximum voltage swing on the Chaparrals is limited to about two diode drops (1.4 volts) below the regulated power supply voltage (~9 volts). This should produce an output that is bounded by ± 3.8 volts. The sensor at TUC0 appears to clip at a peak-to-peak voltage of 4.2 volts, about half the expected output. Since this clipping is only likely to be a problem in strong winds, this problem will be assigned a lower priority.

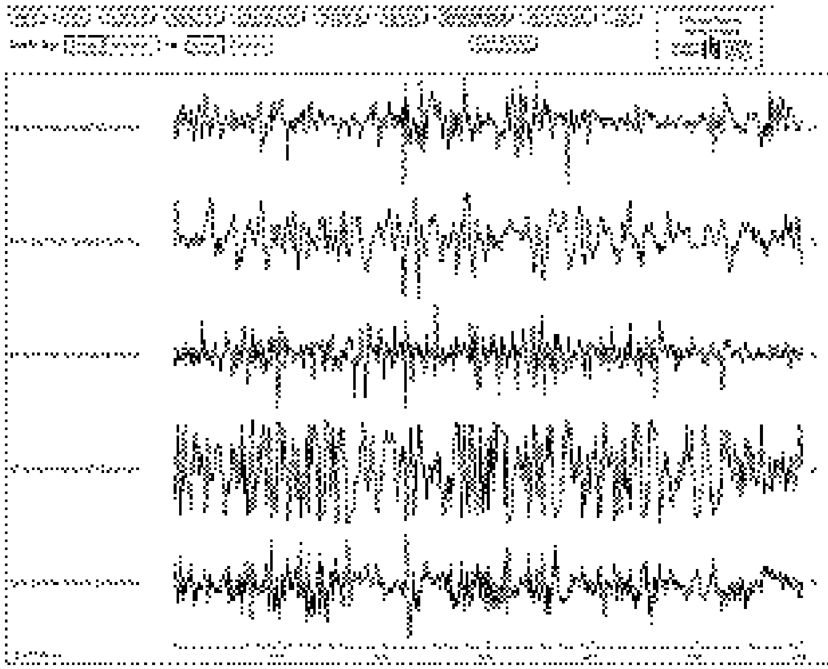

Figure 10: Noise data taken under high wind conditions.

Visit to WUAZ

An additional infrasound array site has been proposed for Northern Arizona to complement the existing station at St. George, Utah operated by Los Alamos National Laboratory (Figure 1). The National Seismic Network Station, WUAZ, in Northern Arizona (Figure 1) would be ideal for such an installation. Since this site already acquires high quality seismic data, a complementary infrasound array would be appropriate. On the last day of the installation trip a visit was made to Wupatki and Sunset Crater Volcano National Monuments to investigate the possibility of such an installation.

WUAZ sits on a hill overlooking the Wupatki Pueblo. The National Park Service maintains the site. A helicorder is installed at the Sunset Crater Visitor Center along with an educational display related to earthquakes. During our stop at the center we spoke with park employees Suzanne Morrison (smorrison@owol.net) and John Bland. They both seemed interested in our work and suggested that we contact Paul Whitefield (520-5261157) who works in Resource Management for the Park Service in Flagstaff. We are in the process of exploring this contact.

A preliminary document has been drafted describing a proposed infrasound installation at WUAZ and is attached as Appendix 1.

Conclusions

A four-element infrasound array was installed at the site of the GSN seismic station TUC in the foothills overlooking Tucson, Arizona. The stand-alone installation is designed to operate unattended for relatively long time periods providing acoustic data for purposes of quantifying source and propagation effects for both atmospheric and solid earth waves. The installation will complement the other elements of the Western US Seismo-Acoustic Network including the ground truth installations at Morenci and Tyrone, infrasound array at TXAR and a seismo-acoustic station at Ft. Hancock, Texas (Figure 1).

The initial installation of the array was relatively simple. Co-location with TUC provided local power and a locked enclosure for the data acquisition system. Professor Terry Wallace and Mr. David Steinke, University of Arizona provided excellent support.

Similar to the installation at Ft. Hancock, Texas, data from the array are recorded to disk that must be periodically exchanged. No provision was made for remote access to the data. Twelve hours of nighttime data were acquired during the installation to assure that the sensors and data acquisition system was acquiring data. Since this data segment was at night, few events were identified. Long period noise, possibly associated with local winds, was identified and is consistent with local effects observed at other sites.

Two problems were identified after careful study of the data. There seems to be a long period noise source that is introduced on five-minute intervals. This noise can only be identified at times of very low noise. One hypothesis is that this noise results from the system used to keep the 12-volt battery charged. The second problem is associated with apparent clipping of one sensor at less than full scale. Neither of these problems eliminates the acquisition of useful data. They will both be addressed at the next site visit.

A visit was made to WUAZ in Northern Arizona, the site of an additional infrasound installation. Preliminary contacts were made. We are currently exploring the possibility of this installation.

Acknowledgements

Special thanks to Professor Terry Wallace and David Steinke of the University of Arizona. Chris Hayward and Brian Stump participated in the installation. Carl Thomason designed the array.

References

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