Determining Short-period Sensor Responses: Lessons Learned From Malargüe, Argentina

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I. The Malargüe Seismic Array Experiment

In the beginning of 2012, a large temporary seismic array was installed in the Malargüe region, Mendoza, Argentina. The array recorded until the end of the year and consisted of 38 seismic stations: 37 Sercel 3-component L-22 sensors, and 1 CMG-40T intermediate sensor. The main goals of the experiment were (1) to image the subsurface below the Malargüe plain using ambient seismic noise sources, and (2) to monitor the local seismicity at the newly re-activated Planchon-Peteroa Volcano for hazard assessment purposes. The project was lead by D. Draganov, from Delft University of Technology, Netherlands. Here, we analyze the L-22 sensor response characteristics using the Bird Dog II System to highlight the state of health of the sensors before, during and after the field experiment.

II. Bird Dog II System

The Bird Dog II system is an independent analog to digital acquisition system, especially designed for quality control testing, produced by the Seismic Source Company. The program operations allow measurements of frequency, damping, and sensitivity, by performing a step response test.

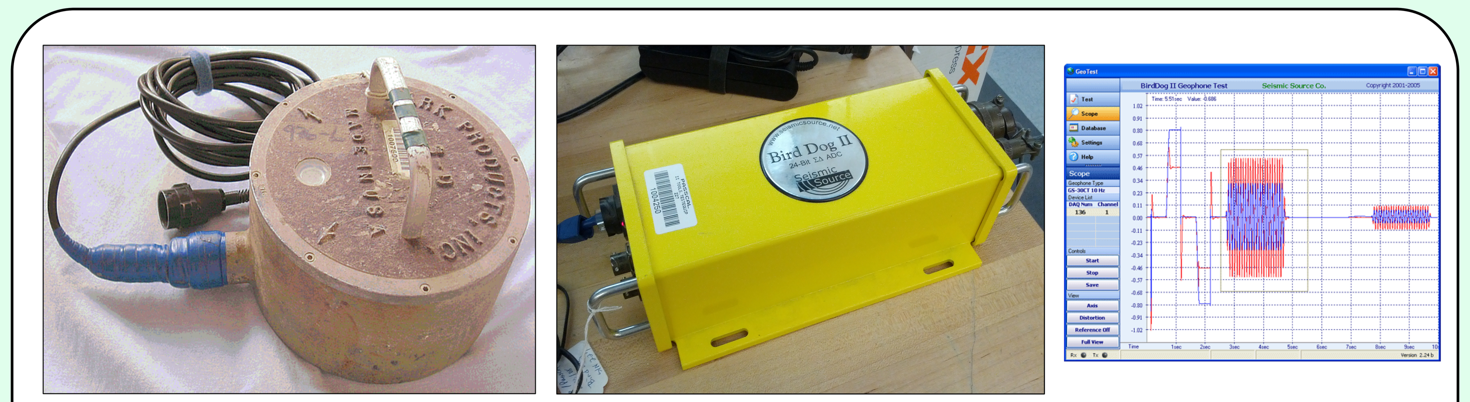


Figure 1. Sercel L-22 sensor (left), DAQLink-II unit and example of Bird Dog test (right).

III. Statistical Analysis

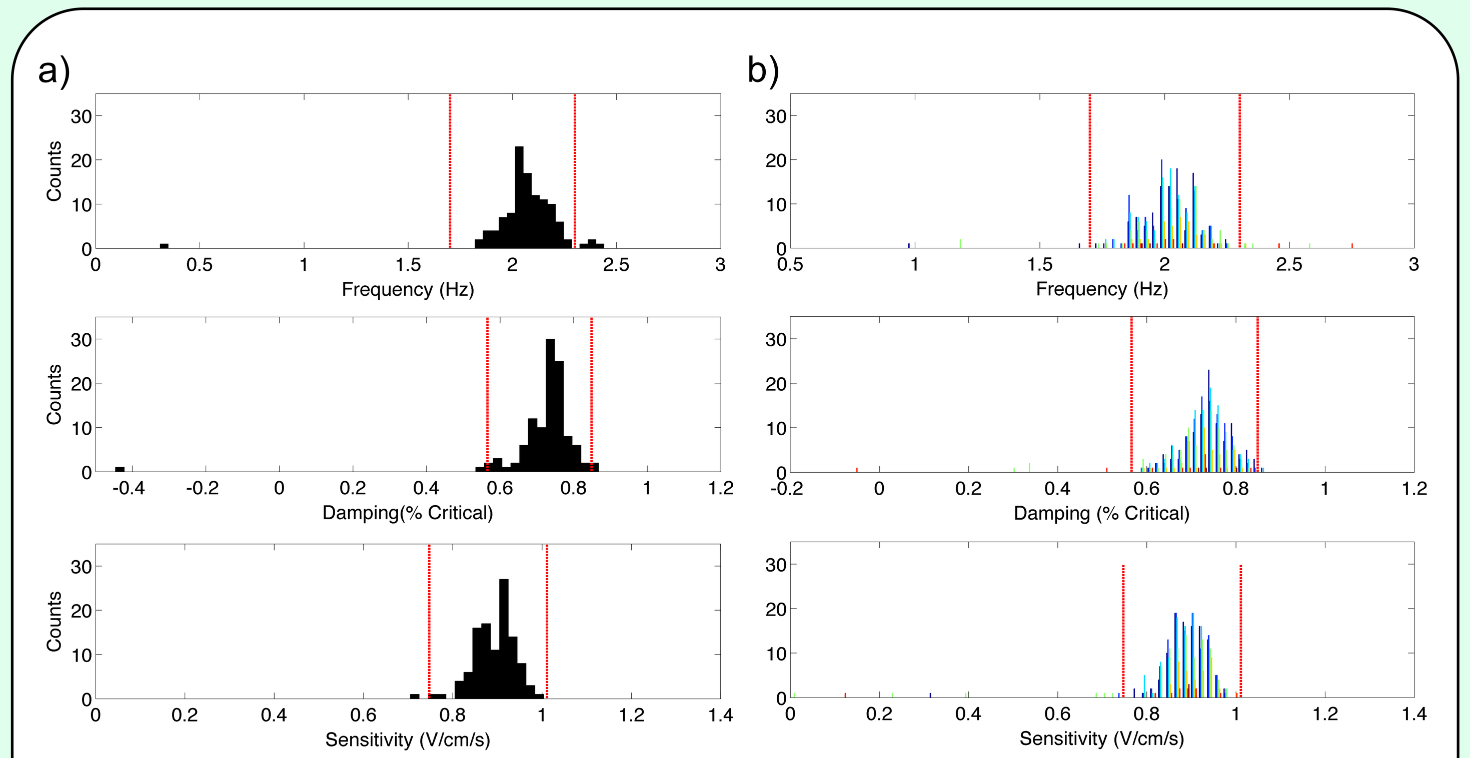


Table 1. Manufacturer's Specifications versus Average of Test Results

Parameter	Spec	Test values	Std. Dev.	% Diff
In-lab tests (BEFORE):				
Frequency, f_0, (Hz)	**2.0**	2.025	0.104	1.2
Damping, ζ, (% critical)	**0.707**	0.736	0.051	4.1
Sensitivity, G, (V/cm/s)	**0.88**	0.890	0.038	1.1
In-situ tests:				
Frequency, f_0, (Hz)	**2.0**	2.065	0.176	3.2
Damping, ζ, (% critical)	**0.707**	0.720	0.106	1.8
Sensitivity, G, (V/cm/s)	**0.88**	1.154	1.618	31.1
In-lab tests (AFTER):				
Frequency, f_0, (Hz)	**2.0**	2.028	0.172	1.4
Damping, ζ, (% critical)	**0.707**	0.716	0.083	1.3
Sensitivity, G, (V/cm/s)	**0.88**	0.870	0.130	-1.2

* values BEFORE and AFTER correspond to Bird Dog test results immediately before and after the field experiment.

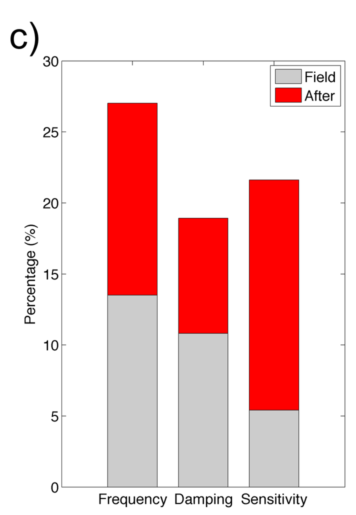
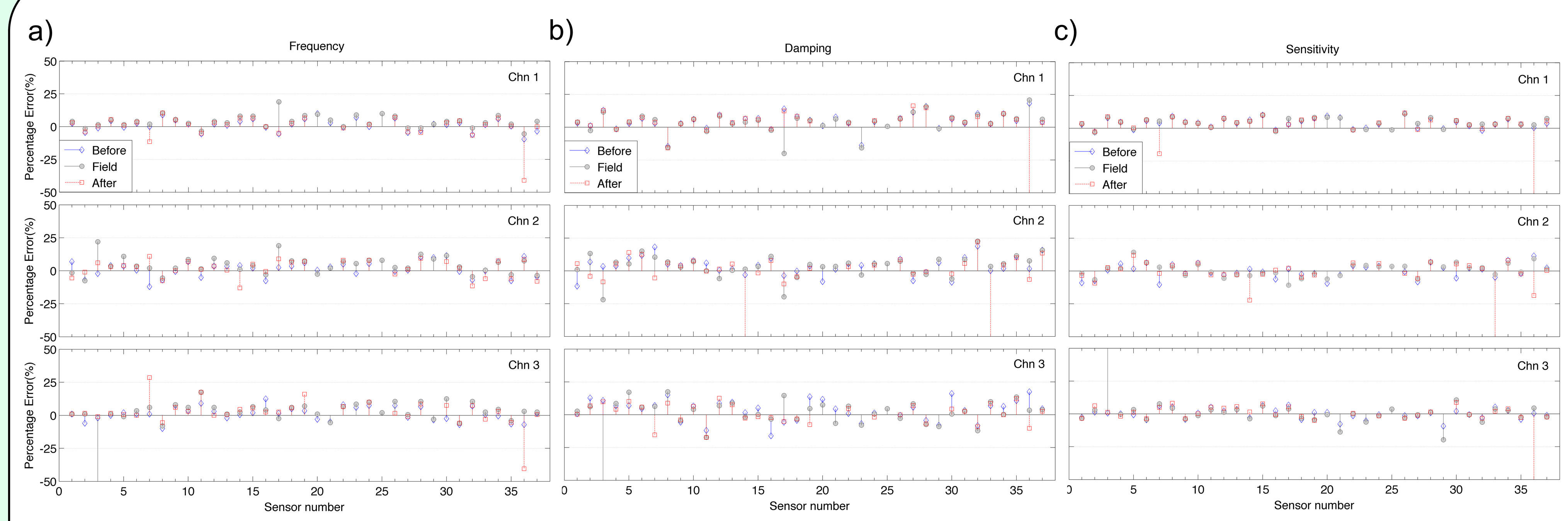


Figure 2. Distribution of frequency, damping and sensitivity values measured in the field (a) before and after the experiment (b). c) Percentage of sensors that show values exceeding the allowable tolerances for each test.

IV. Variations Between Sensor Responses



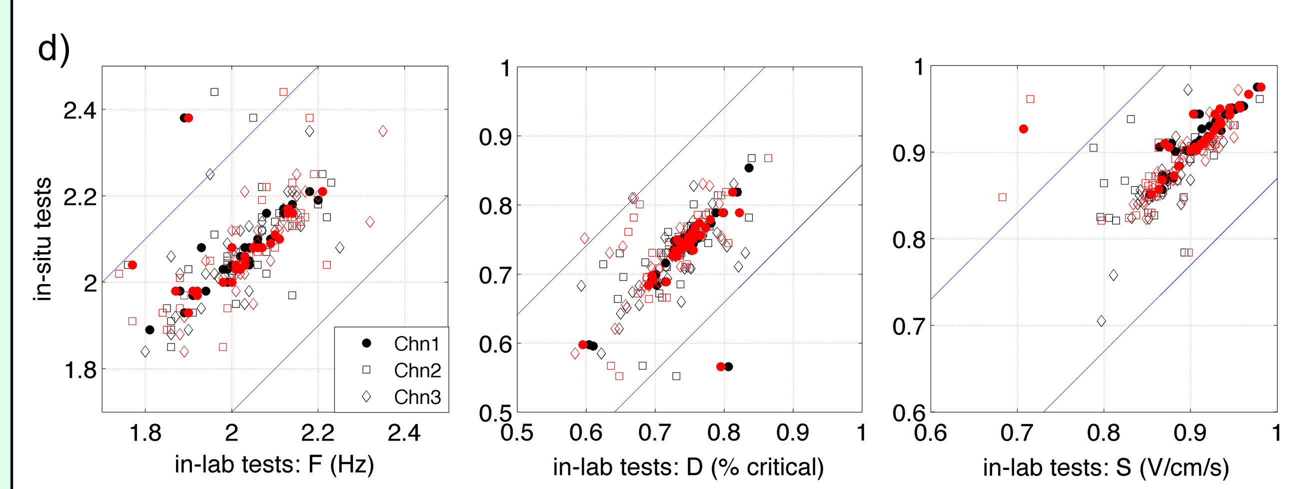
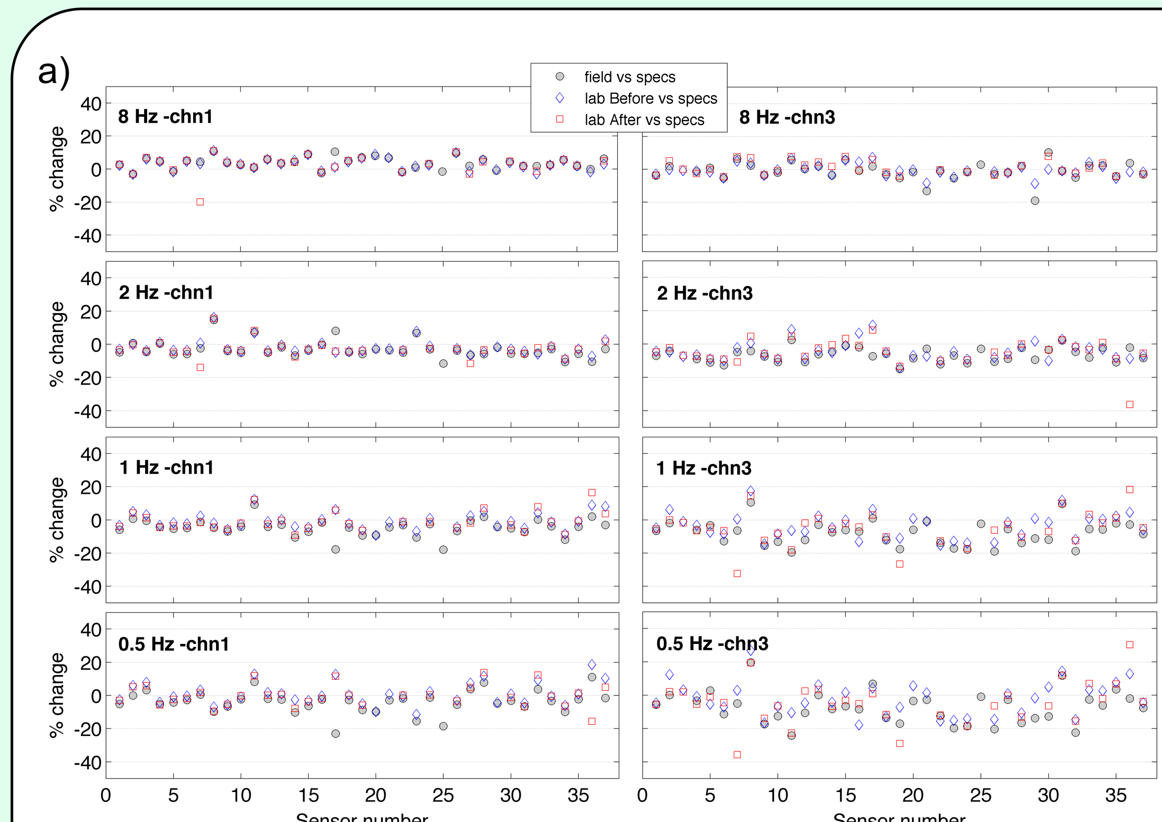
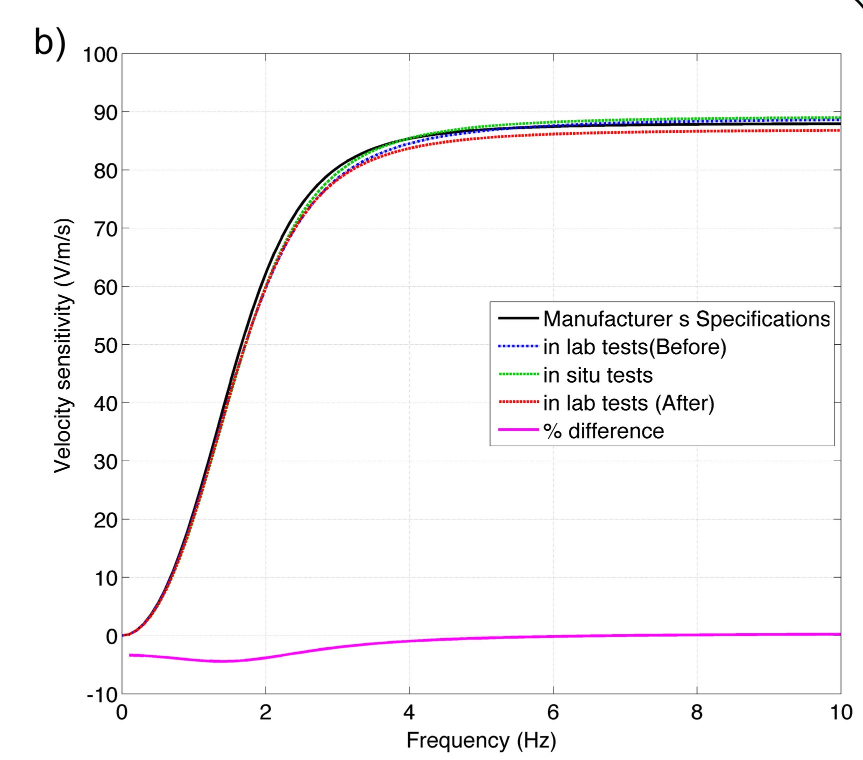


Figure 3. a), b), c) Percentage error between the measured values (in lab and in the field) and manufacturer's specifications for frequency, damping and sensitivity for all three components of the 37 sensors tested. The vertical scale is fixed to ± 50% change; only a total of 9 measurements fall beyond this range. d) Comparison of the frequency (left), damping (center), and sensitivity (right) from the in situ and laboratory tests. Blue lines indicate the manufacturer's tolerances. Black – tests in lab before the field experiment, Red – tests in lab after the field experiment.

V. Sensor Velocity Sensitivity





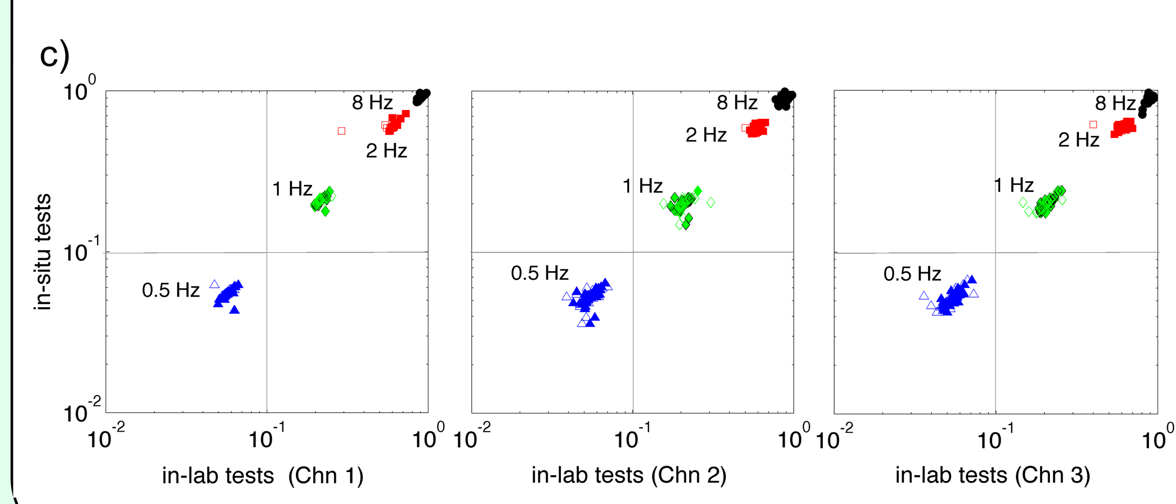
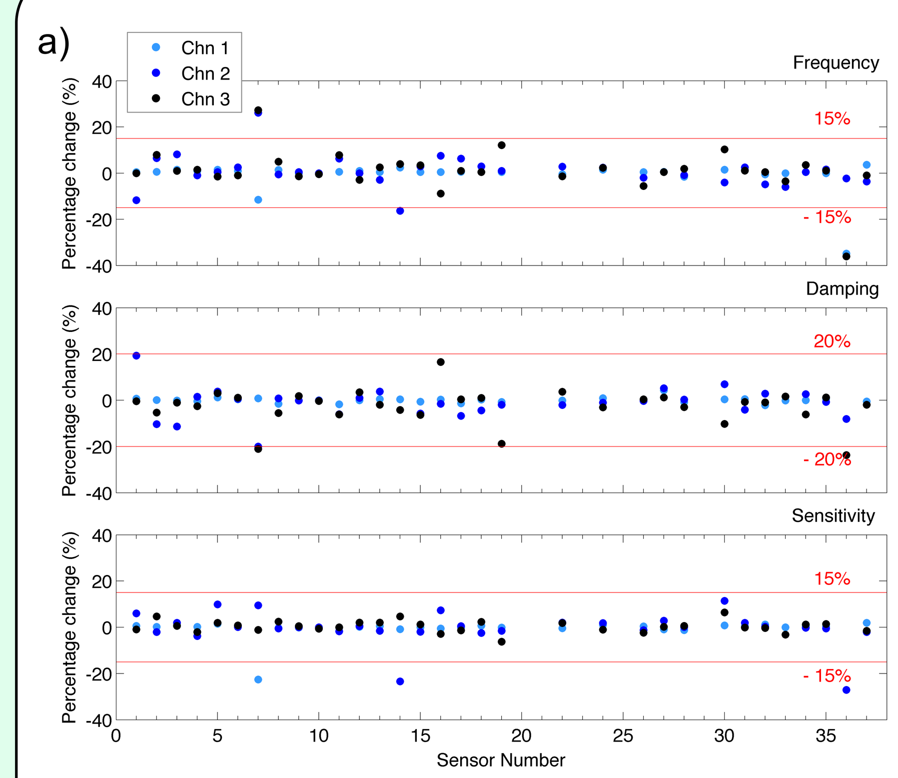


Figure 4. a) Velocity sensitivity of L-22 sensors compared to the manufacturer's specifications computed for frequencies 8, 2, 1, and 0.5 Hz. b) Comparison of sensor velocity using (1) manufacturer's specifications, (2) the average of both before and after the experiment tests, (3) the average of the in situ tests. The pink line represents the difference, in percent, between the sensitivity determined from the manufacturer's specifications and the average of all our tests. c) Comparison of sensitivity (in V/cm/s) from the in-situ and laboratory tests.

VI. Differences between before and after lab tests



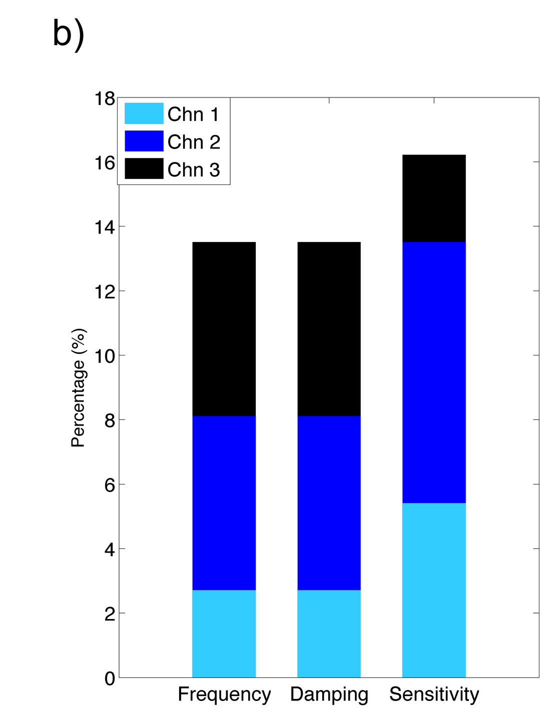


Figure 5. a) Percentage change between frequency, damping, and sensitivity values before and after the experiment, for each sensor, for each channel. b) Percentage of channels which present a change greater than 15% for frequency and sensitivity, and 20% for damping.

Conclusions

1. The sensors are, on average, within the PIC's acceptance tolerances of ± 15% of the design values for natural frequency and sensitivity, and ± 20% for damping.
2. Looking at the response of individual sensors, the vertical components show less variation then the horizontal components, and the sensitivity shows less variation than the fundamental frequency and damping.
3. The differences in geophone velocity sensitivity are higher for the horizontal components. This can be caused if the sensors are not perfectly level.
4. By considering the overall sensor response, the differences in the sensor velocity sensitivity from the manufacturer's specifications are larger for signals below the fundamental frequency (2 Hz).

Future Work

We plan to further test the L-22 sensor responses using the Bird Dog II System in Guatemala at Pacaya Volcano during a PASSCAL experiment scheduled for Fall 2014. Frequency, damping and sensitivity values will be tested before the deployment, during the experiment, and after the equipment is returned to the instrument center. This study will help in assessing the reliability of signals below the 2 Hz natural frequency, especially for volcanic sources, commonly around 1 Hz.

Data and Resources

The instruments used in the Malargue field experiment have been provided by the PASSCAL facility of the Incorporated Research Institutions for Seismology (IRIS) through the PASSCAL Instrument Center at New Mexico Tech. Data collected during the experiment will be available through the IRIS Data Management Center. The facilities of the IRIS Consortium are supported by the National Science Foundation under Cooperative Agreement EAR-0552316 and by the Department of Energy National Nuclear Security Administration.

References

Pratt, T. L., M. E. Templeton, R. Frost, and A. Pierson Shafer (2006). Variations in Short-period Geophone Responses in Temporary Seismic Arrays. *Seismol. Res. Lett.* 77, 377-388.