Smart Sampling of Noble Gases to Detect Underground Nuclear Explosions

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Abstract

One element of the Comprehensive Nuclear Test Ban Treaty (CTBT) is the provision for an on site inspection (OSI). The purpose of an OSI is to monitor for the occurrence of an underground nuclear explosion (UNE) in violation of the treaty. Detection of certain rare radioactive noble gases transported to the surface can be an excellent indicator of a UNE. These gases can be very difficult to capture and require specialized sampling methods. This study aims to determine an algorithm that will increase the efficiency of the subsurface gas sampling technique being used to detect UNEs. Continuous sampling of subsurface gases was determined not to be as efficient as triggering the start of sampling by a barometric algorithm or by an algorithm using a percentage of the maximum soil-gas radon level. By using such algorithms to increase the concentration levels of the samples we collect, we also increase the probability of detecting a UNE during an OSI.

Introduction

The method that we are using to detect UNEs is the sampling of noble gases Ar-37 and Xe-133 through the use of the LLNL-developed smart sampler. The smart sampler uses barometric pressure fluctuations or soil-gas radon levels as an indicator for the best time to capture a subsurface gas sample containing the gases of interest. One barometric pressure-based, sample-triggering algorithm that we considered involved turning on the smart sampler when the barometric pressure was a fixed constant below the current maximum or the same constant above the current minimum. Alternatively, radon concentration is known to increase when soil gases are moving towards the surface and represents another possible indicator for triggering the smart sampler. The purpose of this project is to determine which algorithm is superior for capturing the best noble gas signal using data collected from a recent experiment involving chemical tracers released at depth.

Test Site

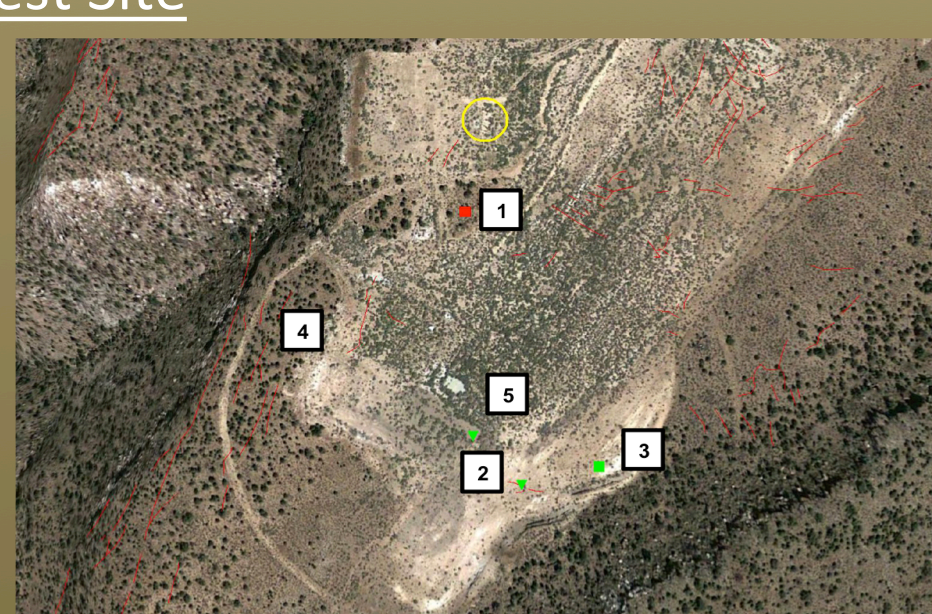


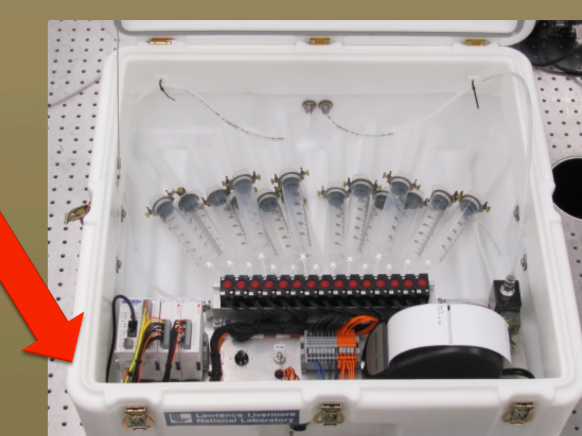
Figure 1: The five sampling locations at the Nevada test site.

Methods

Soil gas from subsurface

Water trap – 5 sample lines

5-Channel soil gas sampler



15-syringe automated sample acquisition

Analysis (1)

Comparing Radon concentration with Freon tracer concentrations

Correlation Coefficient = 0.75

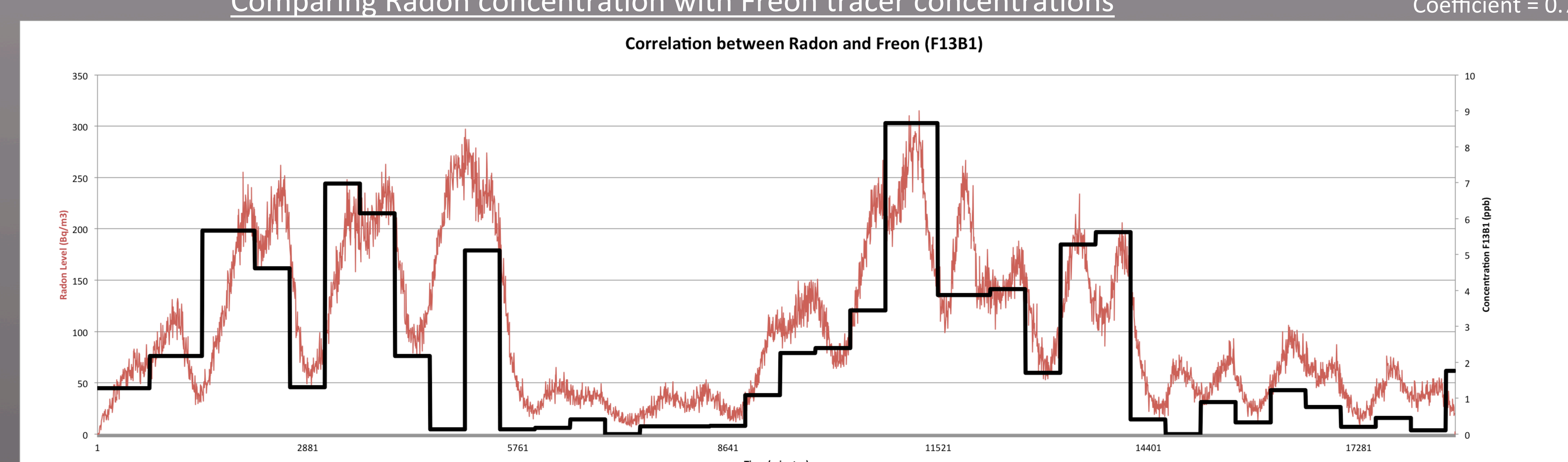


Figure 2: Graph shows the correlation between radon (red) and F13B1 (black). Demonstrates that radon is a strong indicator of the presence of the Freon (F13B1) tracer.

Analysis (2)

Comparing barometric triggering with Freon tracer concentrations

Correlation Coefficient = -0.57

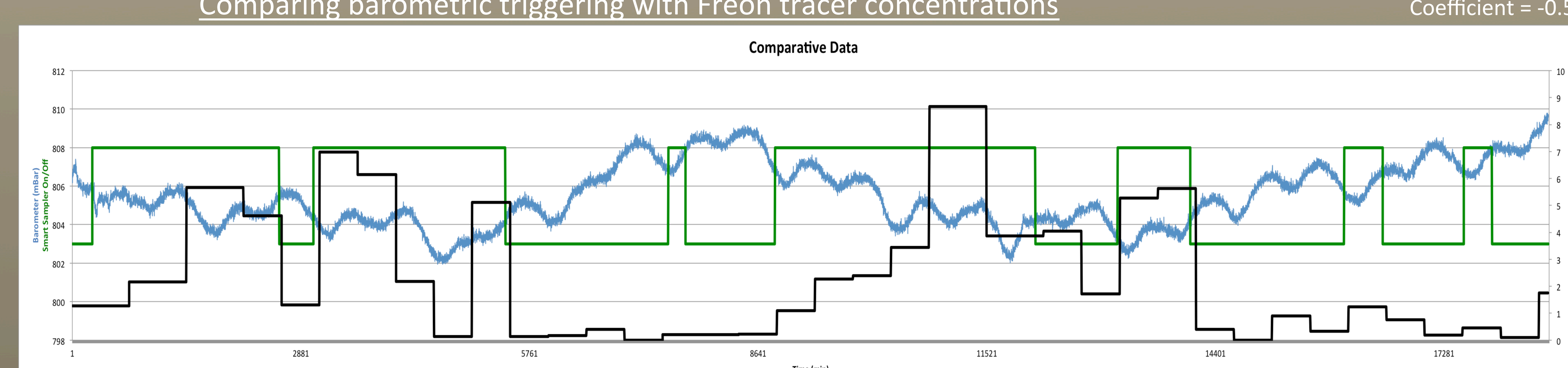


Figure 3: This is a plot of barometric pressure (blue) and F13B1 concentration in the soil (green) as a function of time in minutes. The orange line (high value= sample being taken, low value= no sample being taken) shows when the smart sampler turns on using the improved barometer algorithm.

Figure 4: Charles Carrigan adjusting the smart sampler in Slovakia.

Figure 5: Team member setting up the smart sampler to begin testing at the Nevada test site.

Conclusion

- A barometric pump-switching algorithm that turns on the pump at 1.2 mBar below a maximum and turns off 1.2 mBar above a minimum significantly improves tracer concentrations
- Average F13B1 levels increased by 50% compared to continuous sampling when the 1.2 mBar barometer delta method is used
- Over the same period, average F13B1 levels were increased by more than 50% over the continuous sampling values when using the percentage of maximum radon method.
- Sample acquisition using either barometric or radon triggering to turn on the sampler provided higher concentrations than continuous sampling alone. However, the overall superiority of one indicator over the other could not be determined and will require more exhaustive evaluation.

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