Lessons learned from an atmospheric radiotracer experiment

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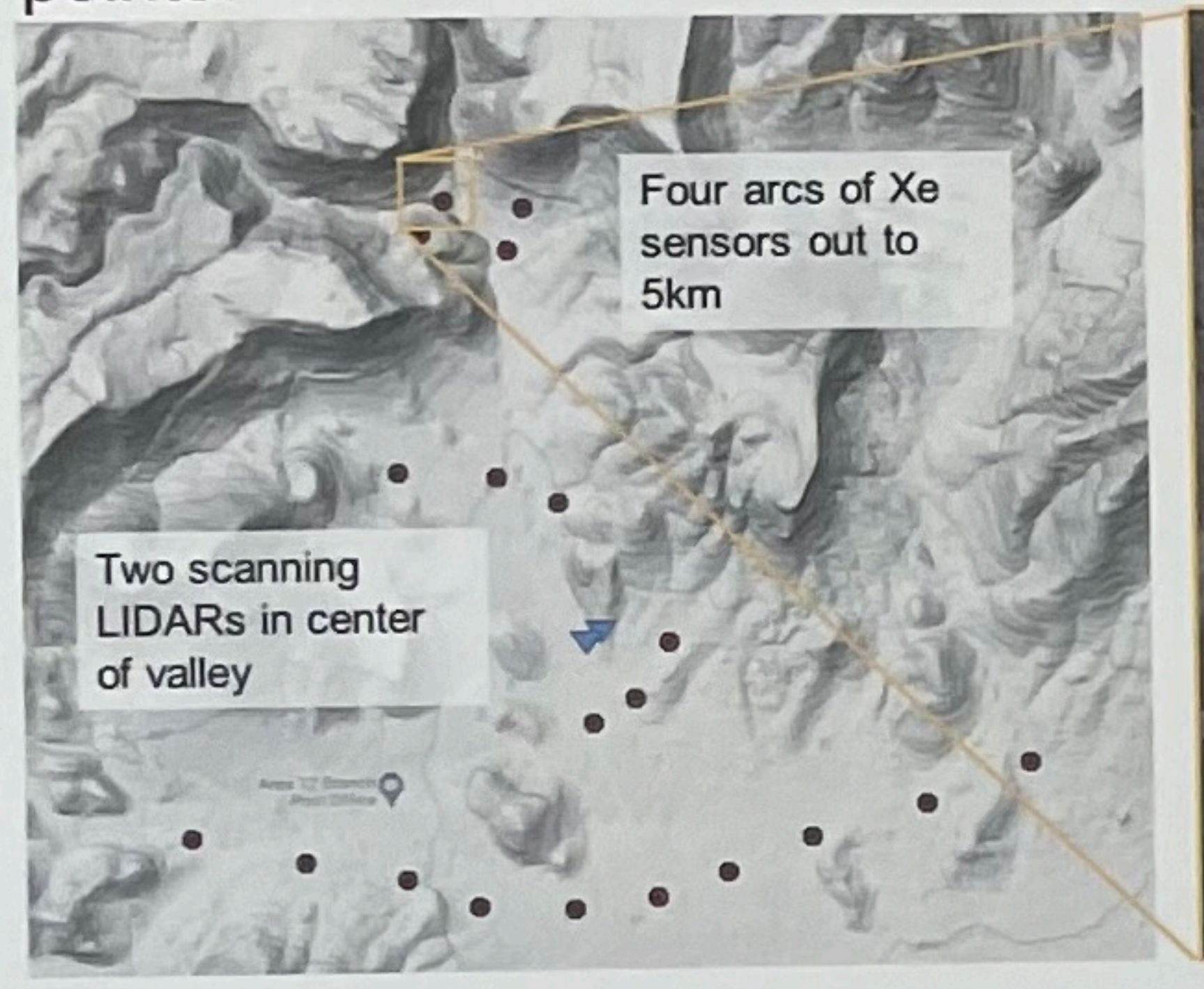
Abstract

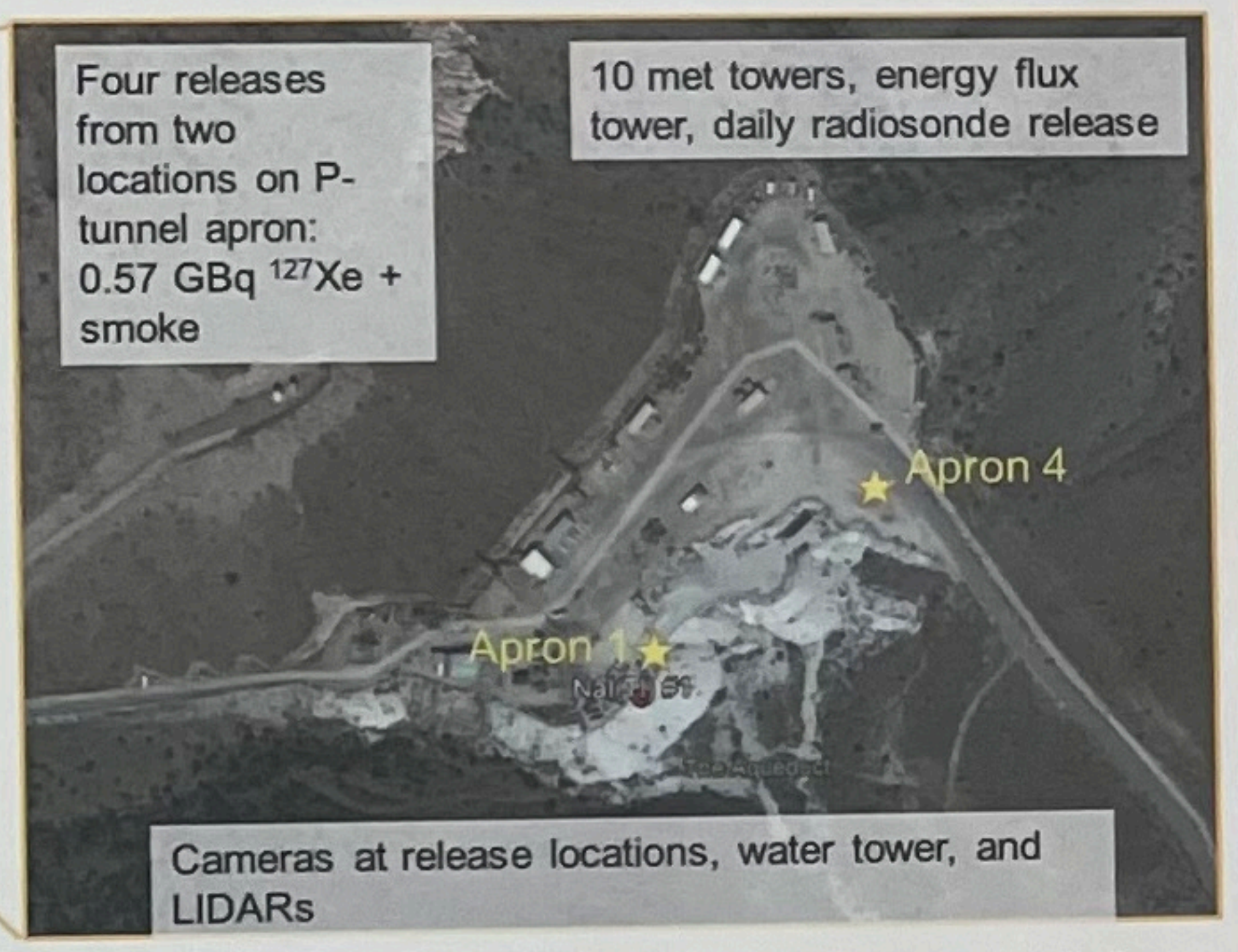
An atmospheric radiotracer experiment was conducted at the Nevada National Security Site in 2022 to test near-field transport models [1]. Here we examine the real-time detection results and provide lessons learned for monitoring radioxenon backgrounds from medical isotope production facilities.

Experiment Overview

^{127}Xe gas was released near ground level in a location with complex terrain. ^{127}Xe was selected for its easily detectable primary gamma emission at 203 keV (68%) and its 36.4-day half-life, which is sufficiently long for logistical purposes. Two releases were conducted from each of two locations over the course of three days, and gamma-ray spectra were measured from 22 NaI(Tl) sensors installed within 5 km of the release points.



Google Earth map of 22 NaI(Tl) sensor locations. Sensors were arranged in four arcs out to 5 km.



Four releases from two locations on P-tunnel apron: 0.57 GBq ^{127}Xe + smoke

10 met towers, energy flux tower, daily radiosonde release

Cameras at release locations, water tower, and LIDARs

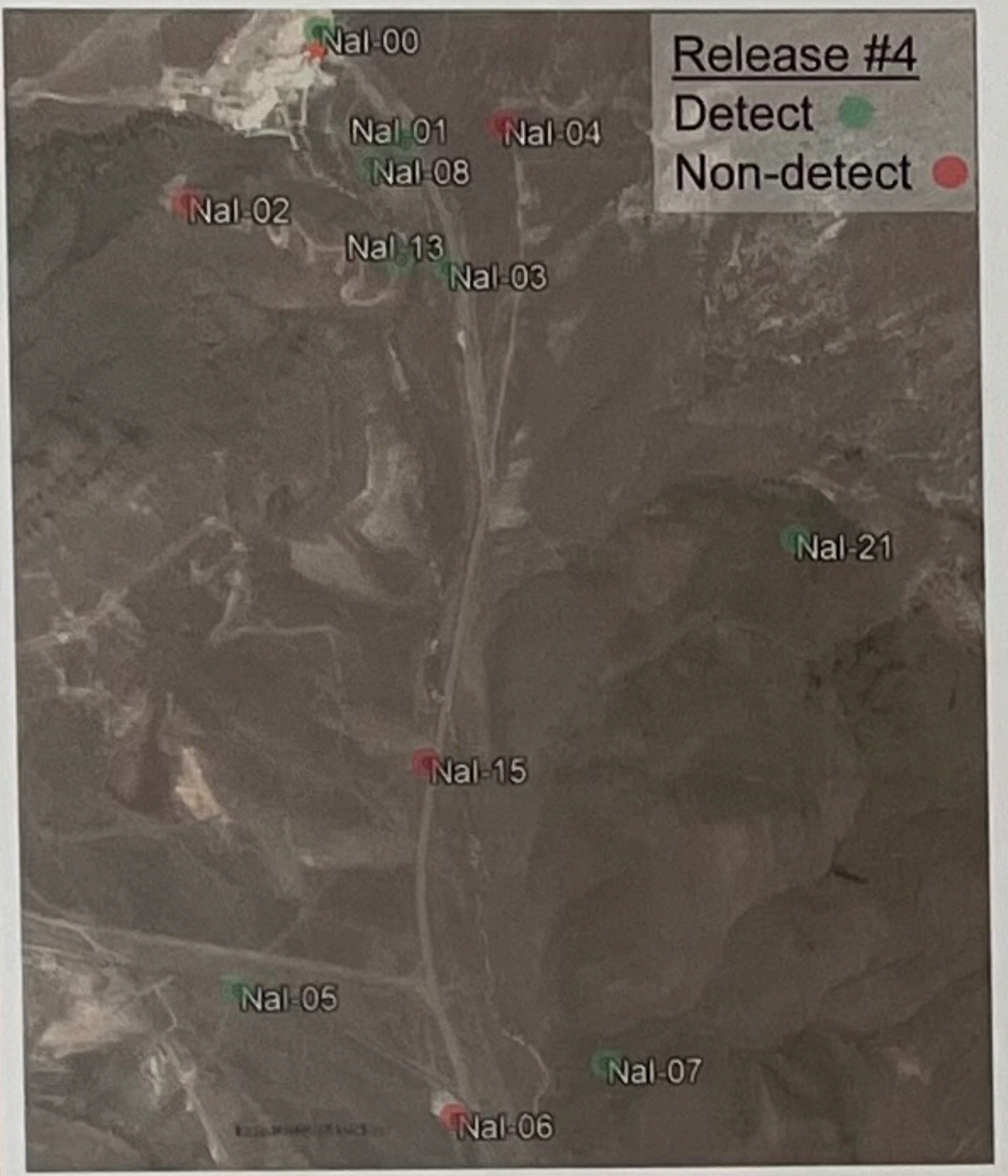
Release locations ("Apron 1" and "Apron 4") for the tracer experiment overlayed on the Google Earth image of the U12p Tunnel apron.

Real-Time Xenon Sensors

Each 2L NaI(Tl) spectrometer was installed on a tripod vertically ~1 m above the ground. Solar powered batteries provided power for the unit. Data were read out remotely and analyzed in an Amazon Web Service cloud space.

Spectra from each sensor were gain stabilized, and a region of interest (ROI) summed to provide measured count rates from 20-220 keV. Background was estimated using an exponentially weighted moving average (for any time slice with a less than 1-sigma detection), and then subtracted from measured ROI count rates.

Experiment Results

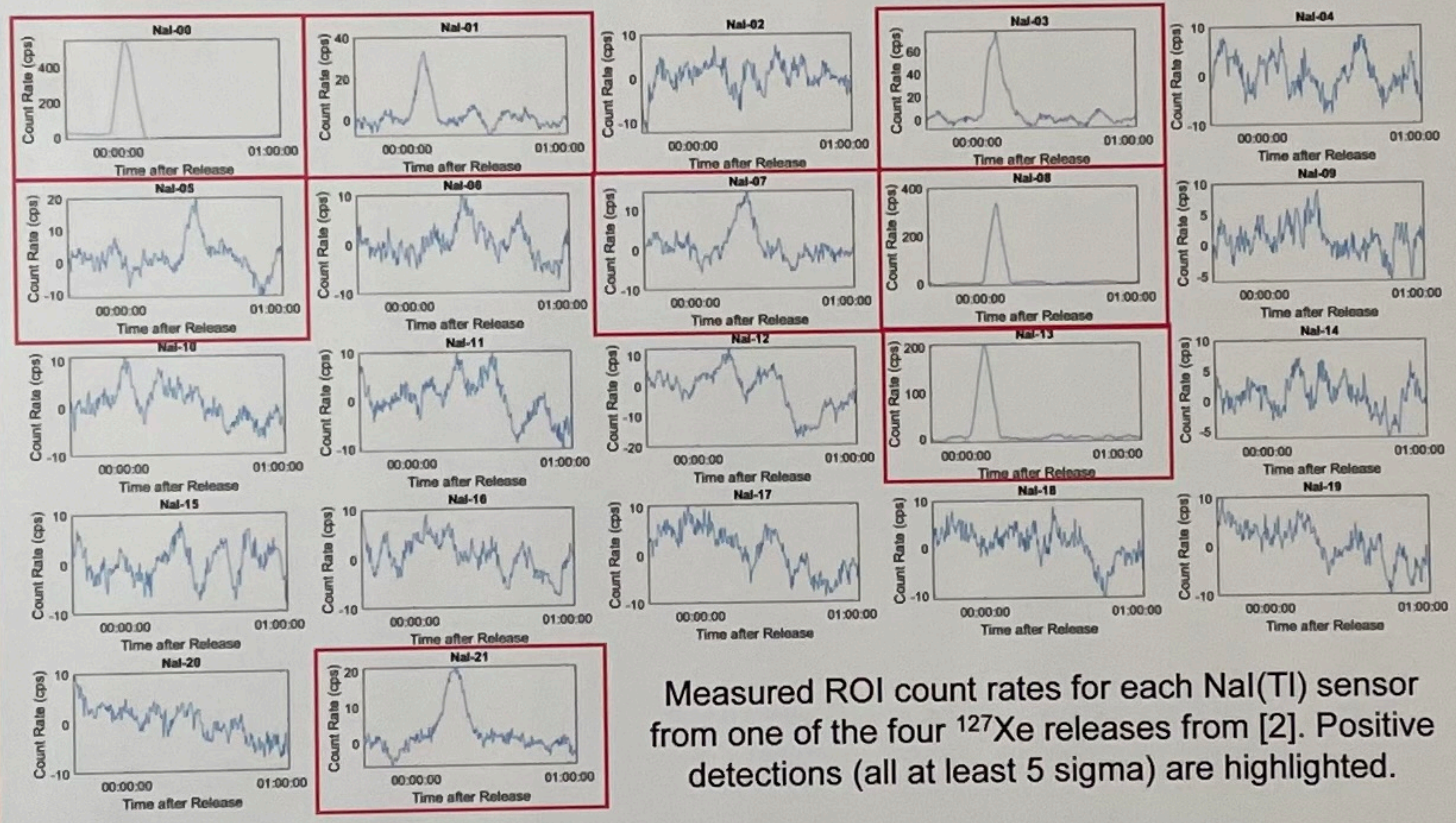


Of the four releases conducted:

- 2 were detected by only 1 downwind sensor
- 1 was detected by 3 downwind sensors
- 1 was detected by 8 downwind sensors, 4 of which had been moved closer to the release point

In all cases, all positive detections were within 2 km of the release location.

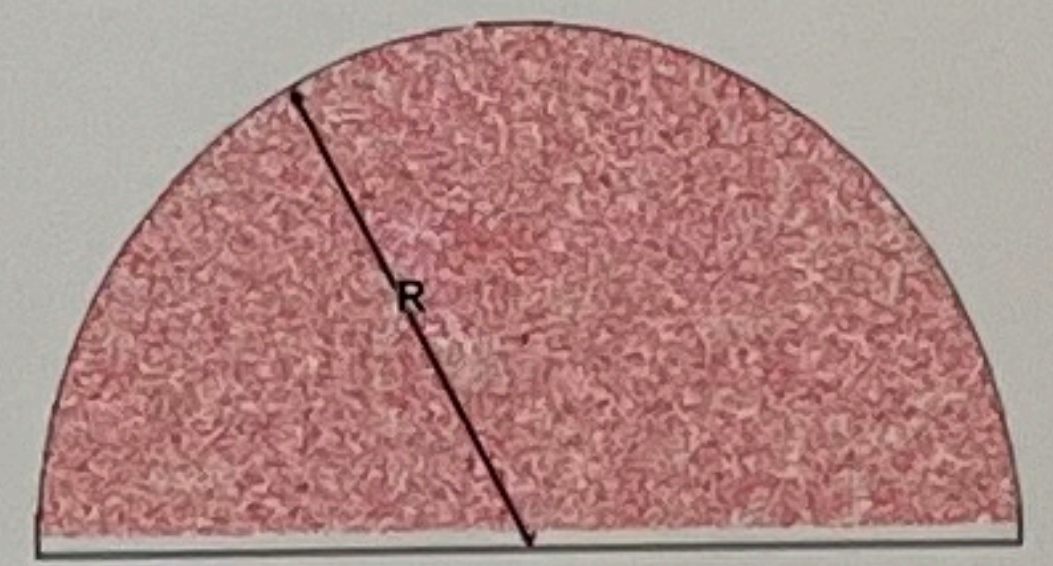
Data were not used to estimate airborne concentrations.

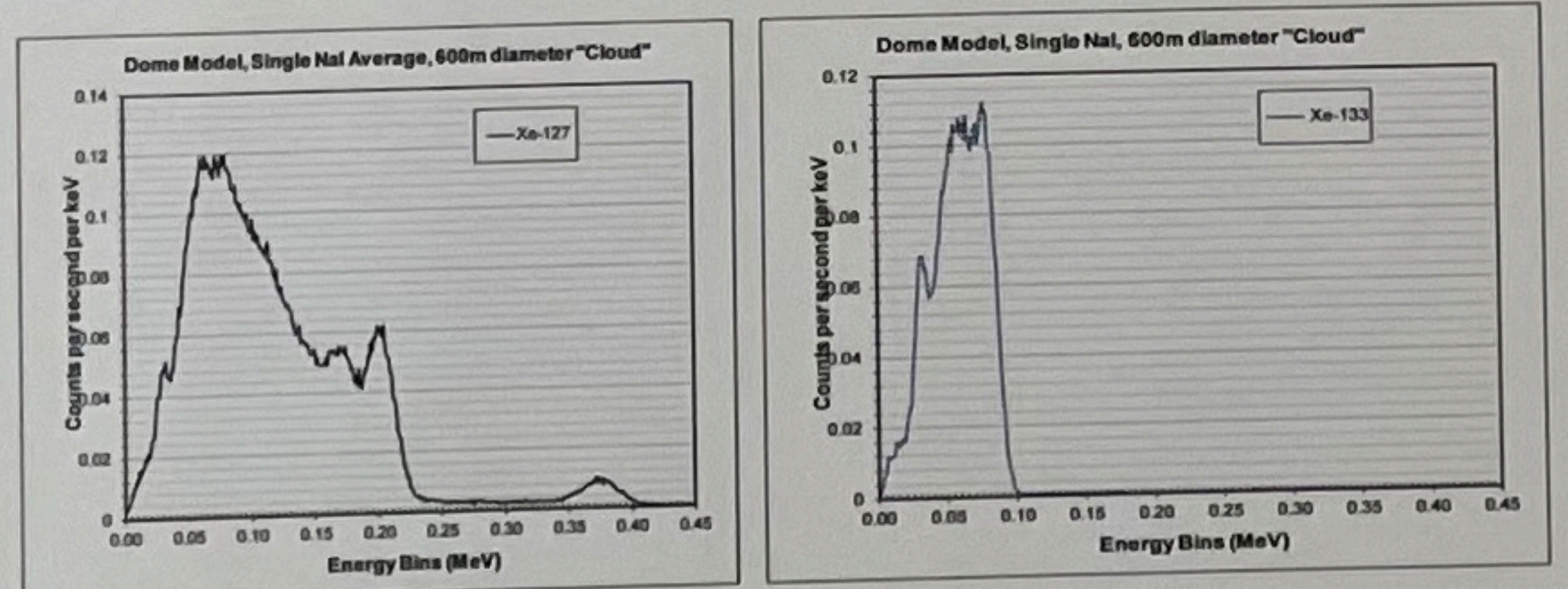


Measured ROI count rates for each NaI(Tl) sensor from one of the four ^{127}Xe releases from [2]. Positive detections (all at least 5 sigma) are highlighted.

Detectability of ^{127}Xe vs ^{133}Xe

Simulations were performed to calculate the detection sensitivity of the NaI(Tl) sensors to both ^{127}Xe and ^{133}Xe, assuming a 300-m radius hemispherical cloud of gas and using measured backgrounds in the ROI [3].

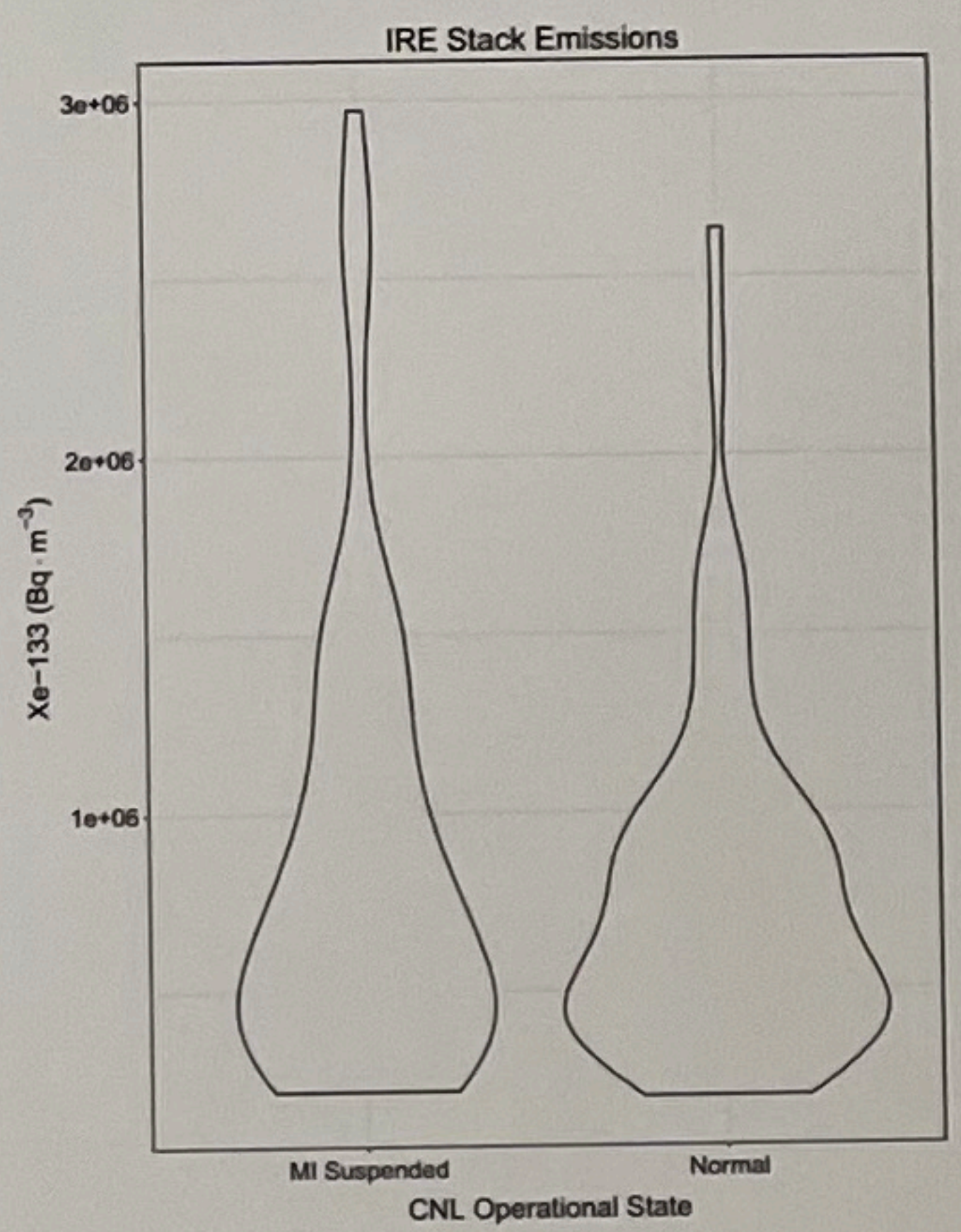




Estimated MDCs are comparable for both isotopes:

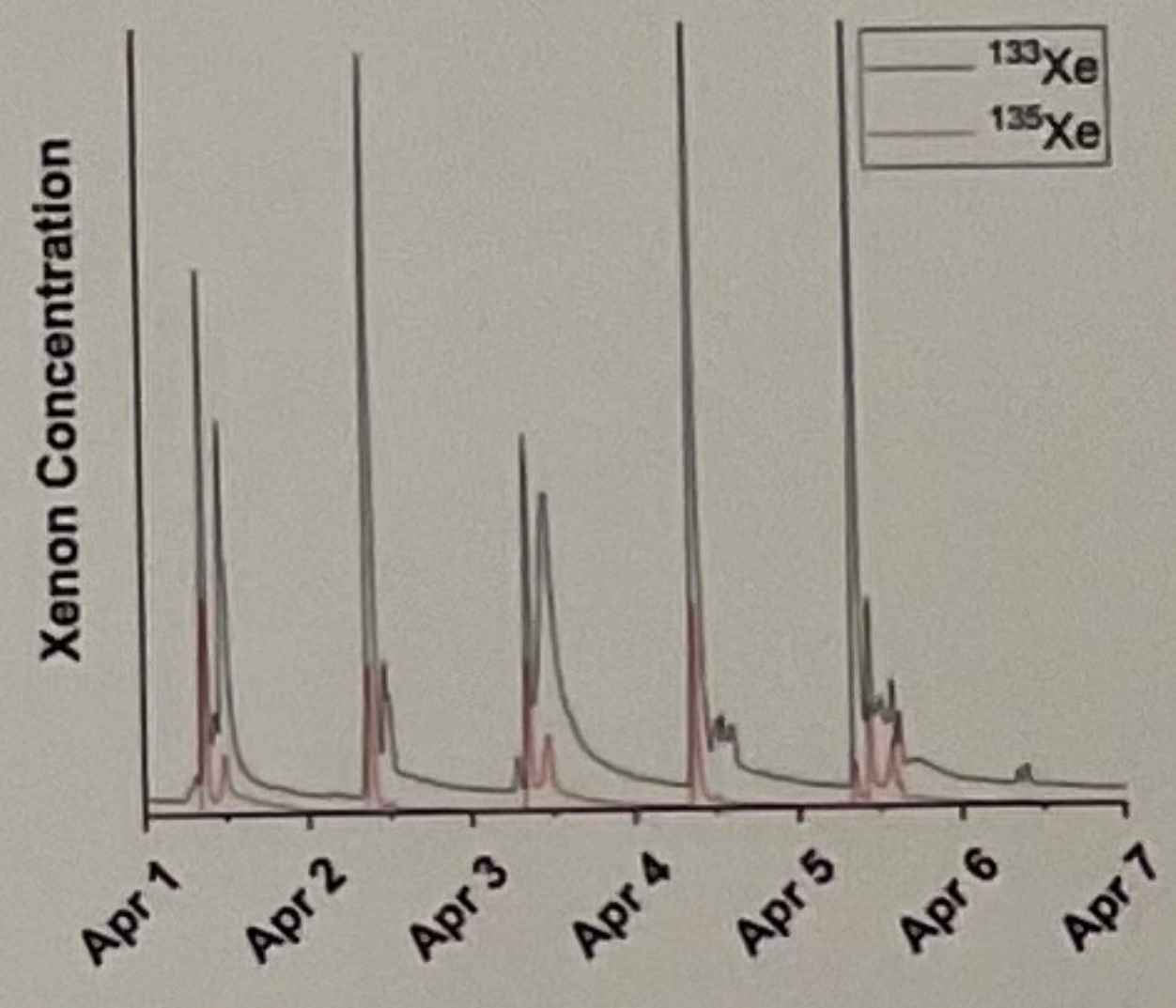
- ^{127}Xe: 3.9 Bq/m^3
- ^{133}Xe: 4.4 Bq/m^3

Comparison to Medical Isotope Releases



Violin plot of calculated ^{133}Xe emissions from IRE, from [4]. The most frequently observed concentration was ~ 0.5 GBq/m^3, or approximately 0.5 GBq/min, assuming the ~ 10^6 L/min stack emission rate quoted in [5].

The tracer experiment released on average 0.572 +/- 0.032 GBq of ^{127}Xe per 5-min release, or 0.114 +/- 0.006 GBq/min. This is comparable to the ^{133}Xe activity measured from STAX data at IRE of ~ 0.5 GBq/min.



Measured profile of ^{133}Xe releases from IRE STAX monitor, from [5].

Lessons Learned

- Radioxenon effluents from medical isotope production facilities could potentially be detected by arrays of 2-L NaI(Tl) sensors within the first 2 km.
- Quantification of xenon releases with such an array would have challenges, but release timing and duration could potentially be monitored without instrumenting the effluent stacks.
- A future radioxenon tracer experiment will explore the impact of vertical plume profiles on downwind transport.

References

1. Seifert, et al., "Design of an atmospheric radiotracer experiment to improve local-scale transport modeling," presented at CTBT SnT 2023, June 22, 2023.
2. Stave, et al., "Real-time Xenon Sensor Analysis Report: FY23." PNNL Report, in progress.
3. Ely, et al., "Xenon Detector for the PE1 Surface Release Experiment", PNNL-29942, May 2020.
4. Hoffman and Berg, Journal of Radioanalytical and Nuclear Chemistry (2018) 318:165–173.
5. Metz et al., Journal of Environmental Radioactivity 255 (2022) 107037.

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