FIELD TESTS OF A UAV-COMPATIBLE SPECTROMETER TO EVALUATE ITS SUITABILITY FOR DETAILED SOIL RADON POTENTIAL MAPPING

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Three Key Points

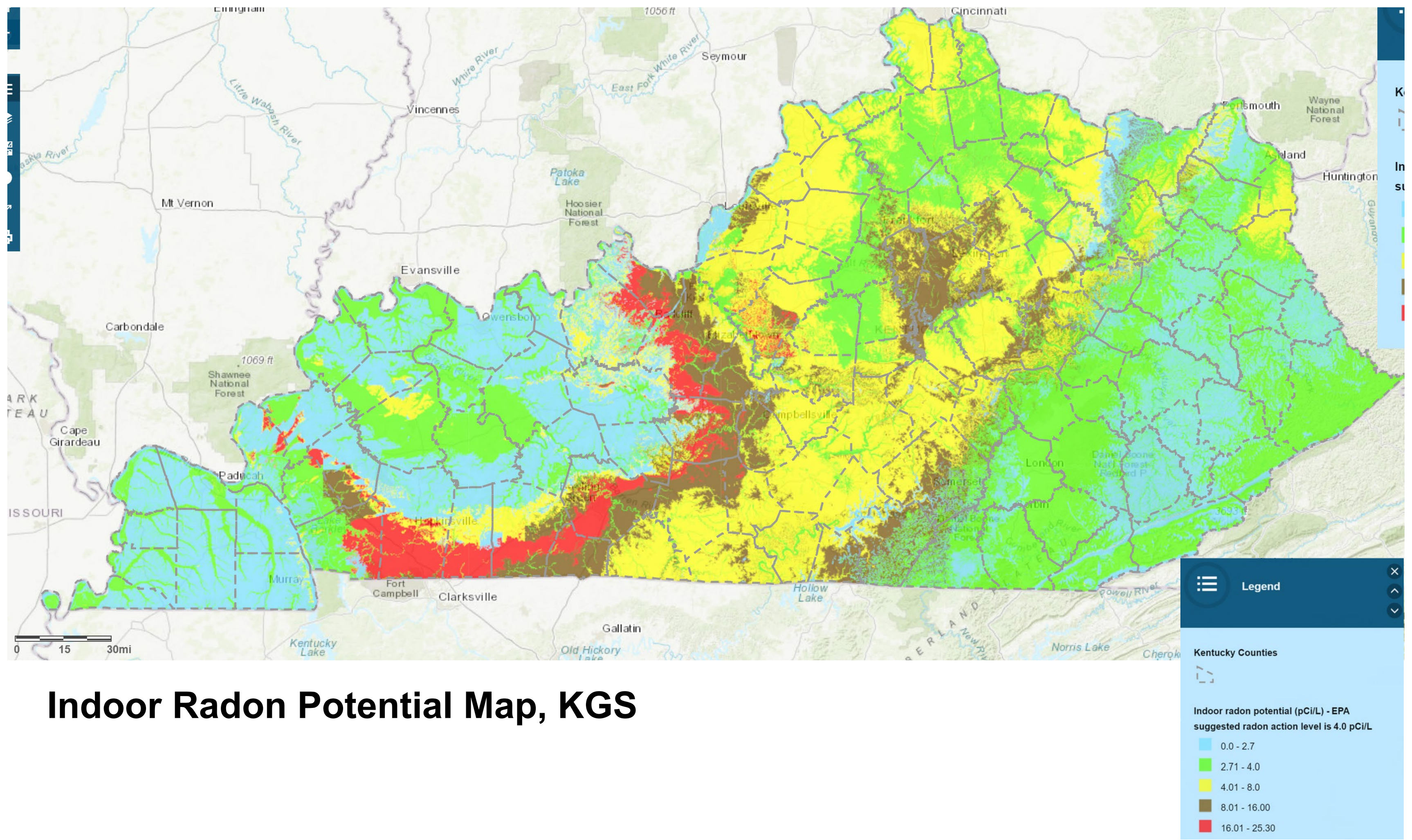
- Radon is the 2nd leading cause of lung cancer in the US
- Identify local variation in a low-signal-to-noise environment
- Understand the sensitivity and spatial resolution of sUAV-mountable gamma-spectrometer

Small, unmanned aircraft system. A person with proper certification is required to be present for each flight performance.

Methods

Each flight was conducted in five different locations within the Fayette County district. Outside of the Mining and Minerals Research Building shielding experiments, a two-phase profile, and a three-phase profile were observed. The shielding experiments were done using a radiation-blocking vest lying above, below, and away from the gamma-spectrometer. Then, the two-phase profile was walked at 1m height, and the three-phase profile was walked at 1.2m height. Next, at Jacobson Park a two-phase 1m profile was walked, a two-phase horizontal profile was flown at 5m and 20m at less than 5m/s, and a 40 m vertical profile was flown. At World Games Way, a two-phase horizontal profile was flown at 5m, 10m, 20m, and 40m at less than 5m/s. At the Earth Analysis and Research Library, a two-phase horizontal profile was walked at 1m height. These location profiles mimic the behavior a fault would reflect due to the visible change in surface material in the measurements. Lastly, at the Berea Road Soccer Complex, a stationary open shielding observation was taken before and after we took a two-phase horizontal profile from upland to floodplain and only in the upland followed by two small footprints with different walking patterns, all at 1m height. This location mimics the behavior of a sinkhole with the data from the floodplain.

Abstract



Indoor Radon Potential Map, KGS

As part of our ongoing research on radionuclide mapping and radon hazard characterization, we performed field tests to evaluate the suitability and limitations of a sUAV-compatible gamma spectrometer. To date, we have completed stationary data collection, mobile ground collection, and multi-level sUAV flights over a known material transition, as well as redundant ground and multi-level UAV data collection over a relatively uniform area. We chose to use total counts as a measure of soil radionuclide levels for our data collected above background because, although our test sites were in regions underlain by bedrock with high indoor radon levels, uranium counts were barely above background levels. The spectrometer can delineate obvious surface material contrasts (e.g., grass versus asphalt or concrete) analogous to boundaries such as faults juxtaposing different rock units. As the height of the instrument increases above a single surface type, the sensitivity of the spectrometer decreases linearly above the ground while the on-ground footprint increases geometrically. This limits the ability to resolve geologic boundaries. In areas covered by distinctly different surface types, the variation in counts is a function of both altitude and the proportion of each surface type within the footprint of the spectrometer at that location and height. In some cases, height appears to contribute to an increase in counts if the instrument is over a low-count surface material, but the complete spectrometer footprint is dominated by a high-count surface material. Our ongoing research will quantify background variability to help identify local variations in a low signal-to-noise (low gamma) environment, including the feasibility of stacking results from multiple single-height flights or profiles to cancel noise and amplify changes across geologic boundaries. Results from multi-level flights will also contribute to our understanding of instrument sensitivity and spatial resolution as functions of flying height.

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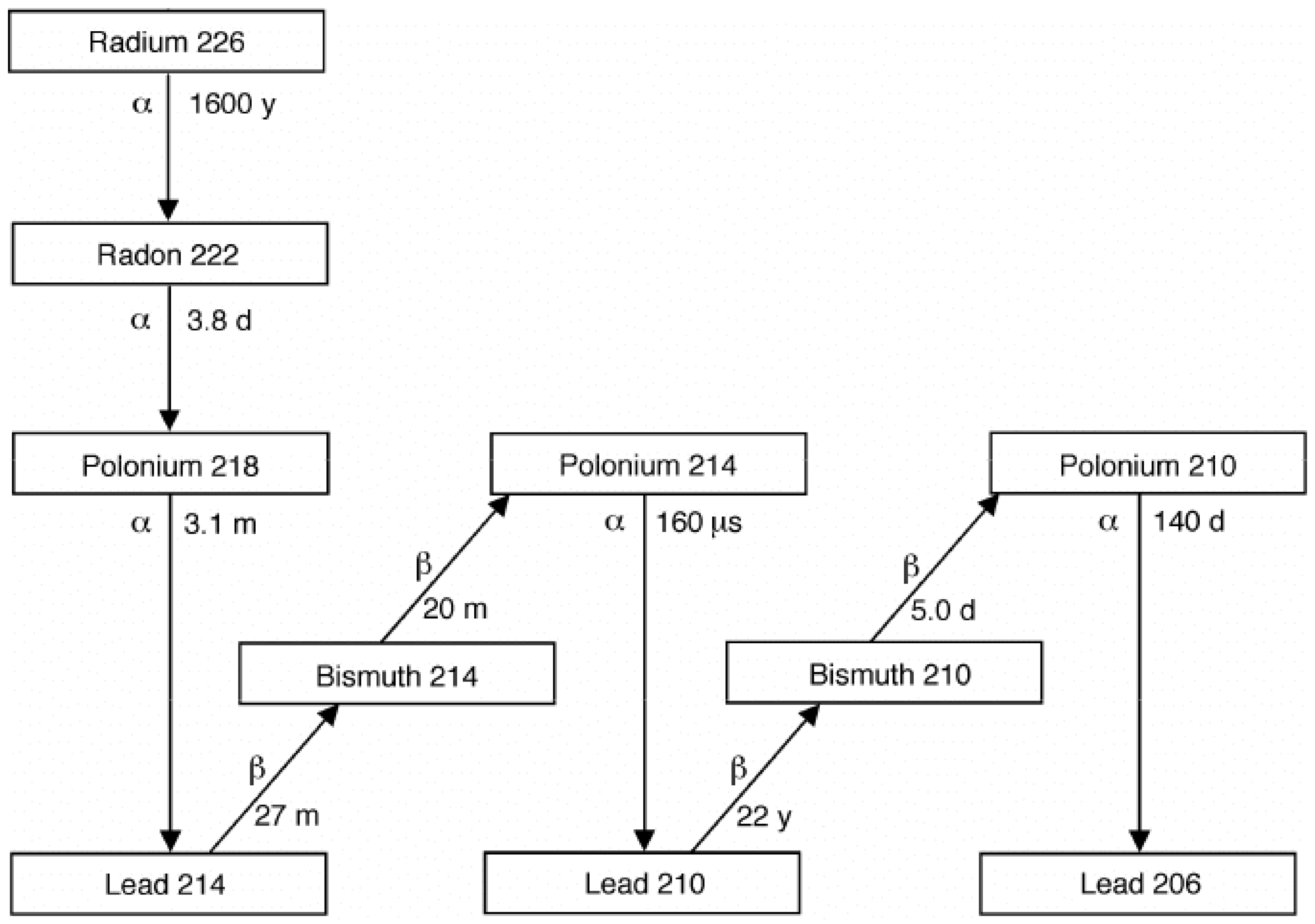
Background

As of 2022, there have been 236,740 diagnoses and 130,180 deaths per year caused by lung cancer. Radon is a naturally occurring, odorless, colorless gas than can quickly disperse into the air. This allows for exposure rates to go unnoticed for long periods of time, therefore leading to sickness and/or death. This gas is produced by the radioactive decay of Uranium 238 to Lead 206. Felsic volcanic rocks, granite, igneous rocks, dark shales, phosphate-rich sedimentary rocks, and some metamorphic rocks are associated with high radon values. This is due to the fact the radon readily moves through fractures, openings, and pore spaces between the grains quickly. Its mobility is dependent on water content, porosity, and permeability. Typically, the bedrock units with high uranium levels correlate to the soil at ground level.



Decay Series of Radon Gilmore et. al., 2010

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Results

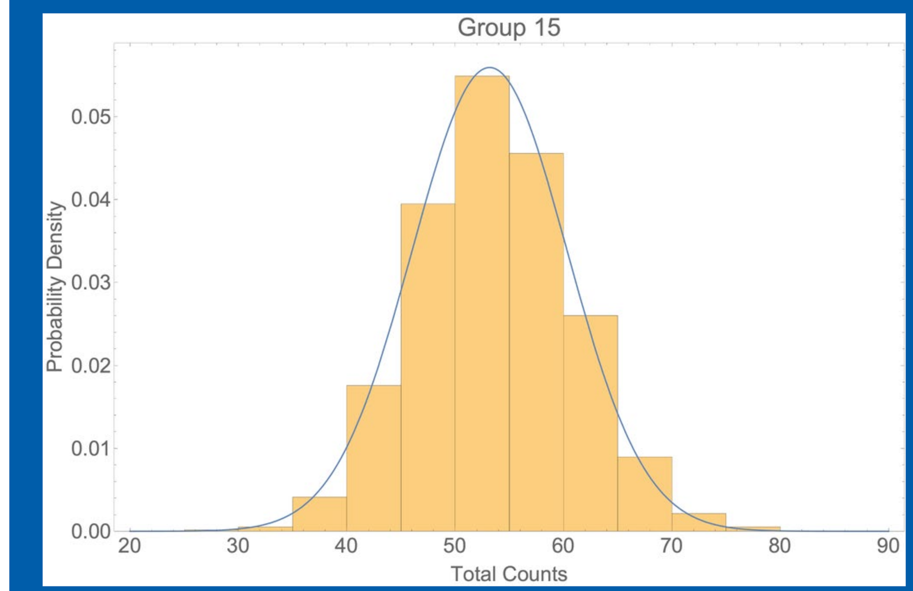
Preliminary statistical analysis (Haneberg):
Imported each of the Group 15, 19, and 24 CSV files.

Calculated basic statistics: N, min, max, mean, median, standard deviation, 95% mean confidence interval, and 95% normal confidence interval.

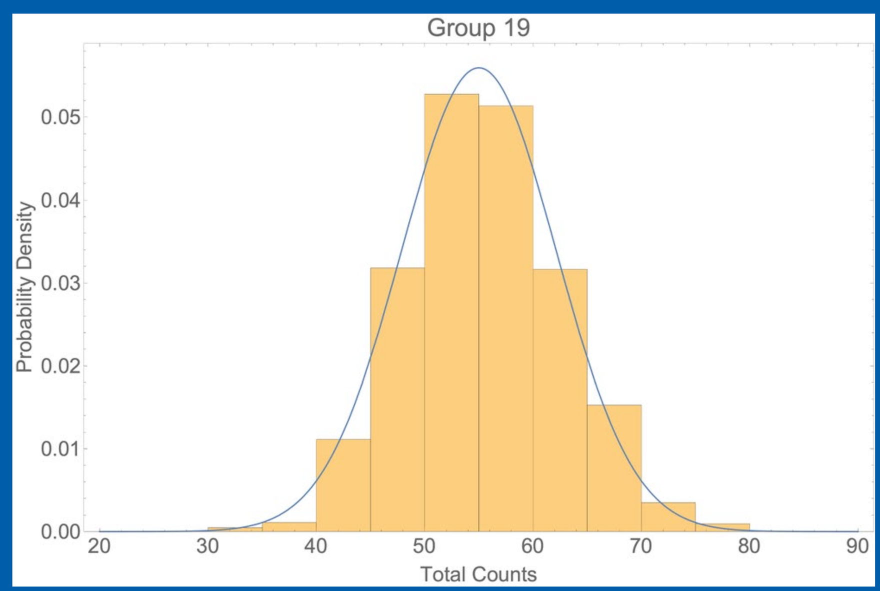
Tested for normal distribution using Cramér – von Mises test ($p > 0.05$ means we cannot reject normal distribution at a 95% confidence level, which is what we want) and mean: median ratios (a semi-quantitative but easy to use assessment of normality)

Plotted histograms and superimposed normal distributions calculated using the distribution mean and standard deviation

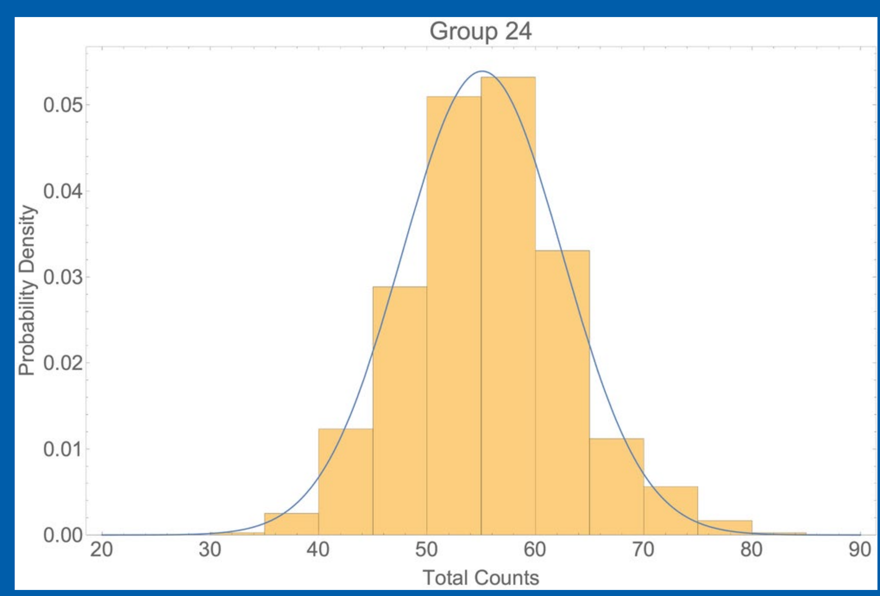
Statistic	Group 15	Group 19	Group 24
N	1115	1285	714
Minimum	26	32	34083
Maximum	79	78	55.1
Mean	53.2	55.0	55.0
Median	53.0	55.0	55.0
Standard Deviation	7.1	7.1	7.4
Mean CI (95%)	52.8 to 53.6	54.6 to 55.4	54.5 to 55.6
Normal CI (95%)	39.1 to 67.2	41.0 to 69.0	40.6 to 70.0
Cramér – von Mises *p*-value	0.17	0.16	0.26



Histogram of total counts recorded using Georadis D230a mobile gamma spectrometer during 19-minute stationary test at ground level near MMRB building on the UK campus. Summary statistics shown in table to right.



Histogram of total counts recorded using Georadis D230a mobile gamma spectrometer during 21-minute stationary test at ground level near Berea Road parking area. Summary statistics shown in table to right. Same location as group00024.

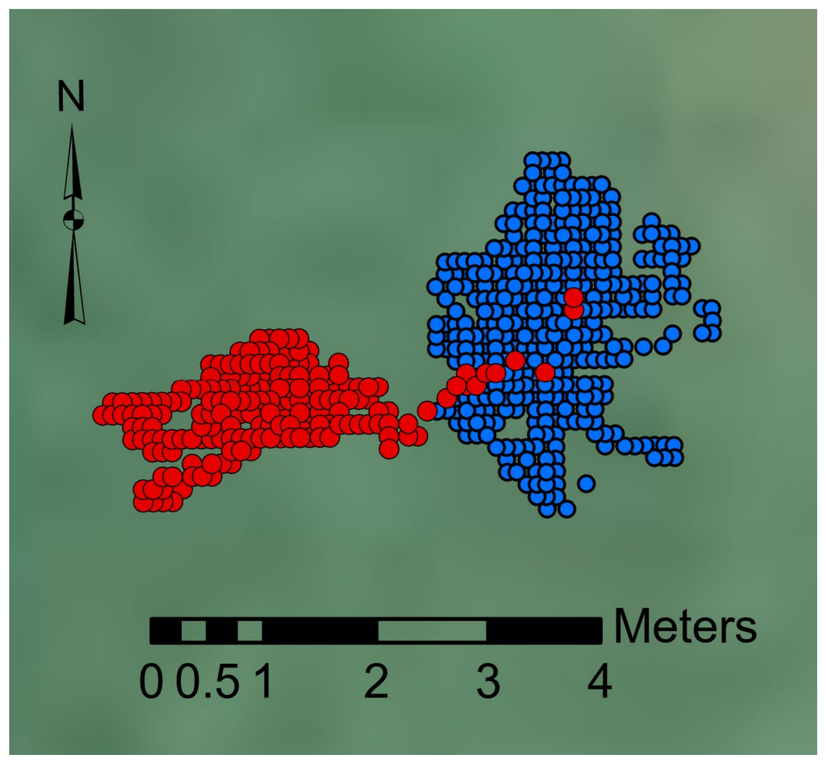


Histogram of total counts recorded using Georadis D230a mobile gamma spectrometer during 12-minute stationary test at ground level near Berea Road parking area. Summary statistics shown in table to right. Same location as group00019.

Summary statistics (above) for group 00015 (MMRB), group00019 (Berea Road), and group00024 (Berea Road repeat). All three tests were stationary at ground level. The data appear to be normally distributed both by virtue of Cramér – von Mises tests > 0.05 and mean: median ratios near 1. Reproducibility of mean values is good for sample sizes we tested. Moderately large standard deviation means that single measurements at the same location may show a large range of variability.

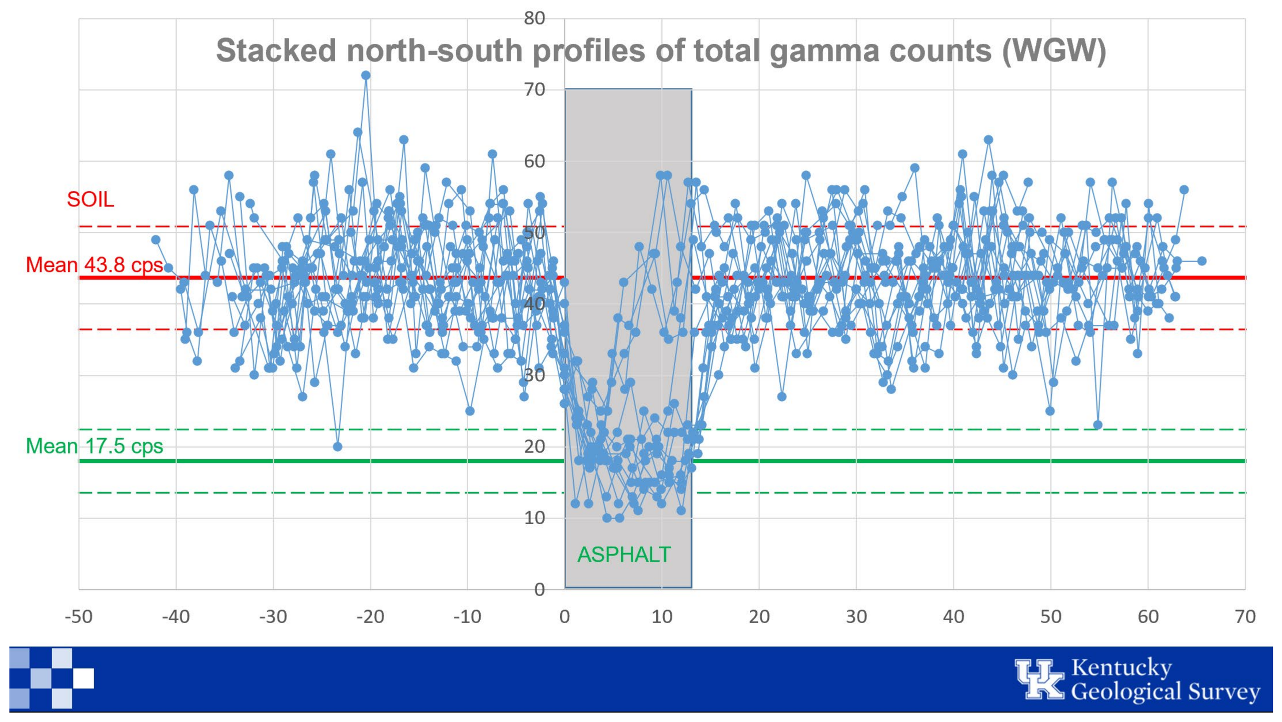
Overall these preliminary data suggest the gamma measurements for Bluegrass soils are consistent, measurements are relatively variable due to the low sensitivity of the detectors in the D230a, but the variability is repeatable at the same location.

2D location map (right) of data points from stationary tests group00019 (blue dots) and group00024 (red dots) at Berea Road, with no GPS post-processing. The raw location shows an expectable level of GPS variability within each data set (roughly +/- 2m) and drift in the GPS system in the roughly 2 hours between the two data set collections.

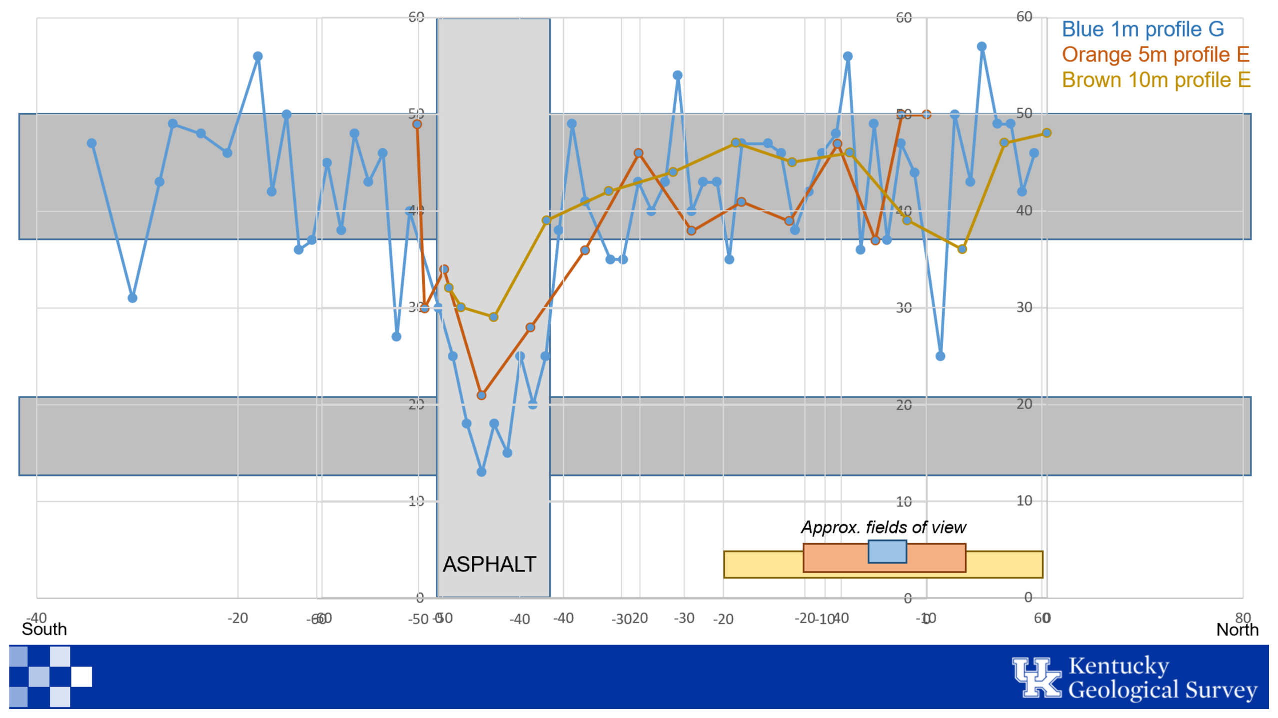


Map (below) showing data density of walking survey (dots) compared to final preliminary interpolated data (natural neighbors, ESRI defaults, for now just for qualitative visualization purposes) for two adjacent data collection surveys. Width of view is roughly 100m.

Stacked walked profiles (1.2m altitude) in a two-phase (soil-asphalt-soil) area at World Games Way. The soil values show a mean of 43.8 total counts, and the asphalt shows a mean of 17.5 total counts. The profiles illustrate the internal variability of materials inferred to be internally consistent, and illustrates the contrast between the two different materials. These data can also be used to infer that the footprint of observation is approximately 3X the altitude of measurement above ground surface.



Stacked multi-altitude profiles (1.2m, 5m, 10m) across a two-phase (soil-asphalt-soil) profile at World Games Way. The spatial footprint of observation increases with altitude, producing decreased resolution of transitions with increasing altitude. In general, the measurements of total counts decrease with altitude (attenuation).



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