# Agreement in Radon Variability Between Proximate Houses

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## ABSTRACT

Radon is a naturally occurring gas that is hazardous to human health, making it desirable to minimize exposure. Radon can infiltrate buildings and accumulate to concerning levels, especially in those with tight exterior envelopes and low fresh air exchange rates. Previous research has suggested that air sealing, a common tool for improving building energy efficiency, can increase indoor radon concentrations (Pigg et al. 2017). However, since radon levels naturally fluctuate over time, both short term and seasonally, it can be difficult to conclusively attribute a change in radon levels to retrofit activities. Significant efforts have been made to study this relationship, using a "difference-of-differences" approach, where proximate homes not undergoing substantial modifications are measured concurrently and used as control sites to correct against natural radon variation (Francisco 2020). An investigation into this control correction method was conducted to determine its necessity and applicability. Results suggest that although the correlation in radon readings decreases as distance between the sites increases, the relationship with distance is not strong, and there are many instances where similar nearby buildings have weak or even sometimes negative correlations to each other.

## METHODS

This analysis is based on data collected during a previous study (Francisco 2020), which was not designed specifically for this research question. The original study was investigating changes in radon levels in houses undergoing weatherization through the Department of Energy Weatherization Assistance Program (WAP). These participant houses were corrected against volunteer control houses that were not involved with WAP or undergoing any planned building upgrades. The control houses were monitored with real time continuous radon monitors (RadonAway RadStar RS300, modified for long-term continuous recording) typically for 4~6 months at a time. Although the instruments provide hourly data, the analysis is presented with data averaged to 6-hour intervals to reduce some of the variability noise in the measurements. Site pairs with less than 1-week (28 six-hour data points) of overlap were excluded due to insufficient data, leaving 1,214 pairs.

Overall there were sixty-six control sites used in this analysis spread out over four US states (Colorado, Iowa, Pennsylvania, and Tennessee), representing a variety of climate types, the physical distribution of sites is shown in Figure 1. Several sites had data ranging multiple years, where the sensor(s) were deployed, collected during the off-season, and

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then redeployed again in subsequent years. Due to the multi-year duration of the study and the staggered seasonal testing window, not all sites had temporal overlap with all other sites. Data was typically collected during the heating season when windows would likely remain predominantly closed, as open windows generate large air exchanges, that can artificially dilute radon concentrations, with the exception of the Tennessee data that was collected over the summer.

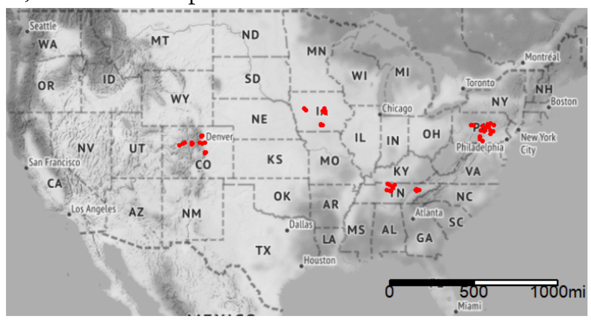



**Figure 1 -** Physical Distribution of Control Sites

## RESULTS

Figure 2 shows the Pearson correlation coefficient (PCC) for the 6-hour averaged data between sites vs the physical distance between sites. A PCC of 1 indicates a perfect relationship where both values change at the same rate, a value of 0 indicates no relationship between the two values, and a value of -1 indicates a perfect inverse relationship, where one value decreases at the same rate that the other increases. The opacity of the data points indicates the quantity of overlapping available, with the darkest data points indicating ~500 days (2000 6-hour samples) of (non-continuous) overlap. The blue trend line does not take into account the quantity of overlap, and weights all points equally. Although there is a lot of variability in the data, there is a clear trend where PCC decreases as distance between the sites increases.

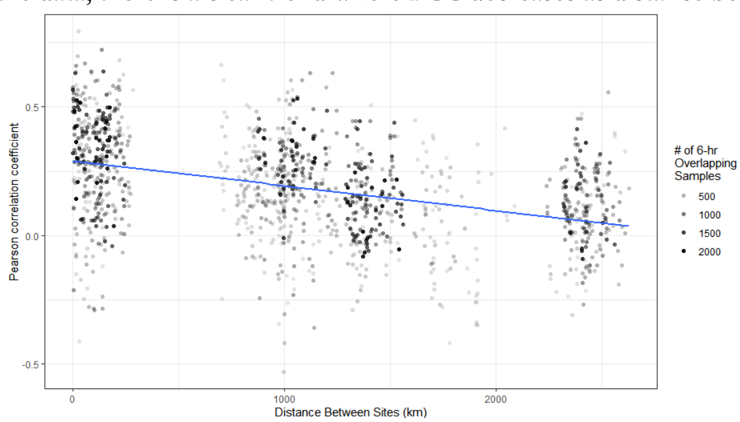
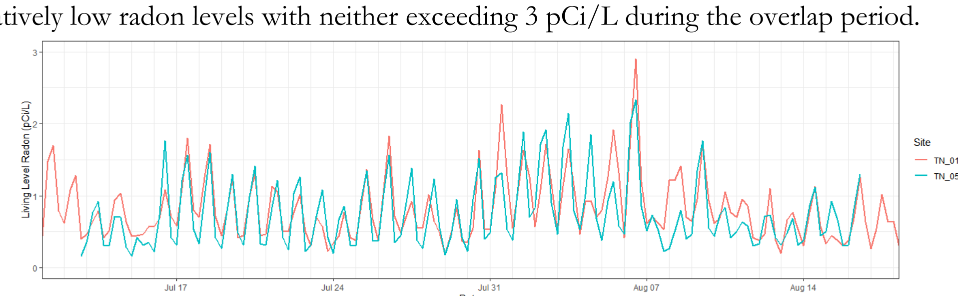



**Figure 2** – Pearson correlation coefficients between sites

The site pair with the highest PCC were in Tennessee and located ~27 kilometers away from each other. Both of these sites exhibited strong diurnal trends where the radon concentrations would cycle throughout the day. Both of these sites had relatively low radon levels with neither exceeding 3 pCi/L during the overlap period.



## Neighboring Sites

Two sets of sites were neighbors with less than 500m distance between either set. These nearby houses, tested at the same time, with the same foundation type, represent the best-case scenario for control matching when doing this type of research. Figure 3 top shows the relationship between the radon readings. The Iowa pair (left) had a PCC of 0.48 and the Colorado pair (right) had a PCC of 0.58, the R-squared values of the presented trend lines are displayed on the graphs. Figure 3 bottom shows the relationship in the 6-hr averaged time series data from these two sets of sites. It is clear that the general trend seems to match each other as is expected from the relatively high PCC values. However, there are several instances where a short-term change at one site is not reflected at the other.

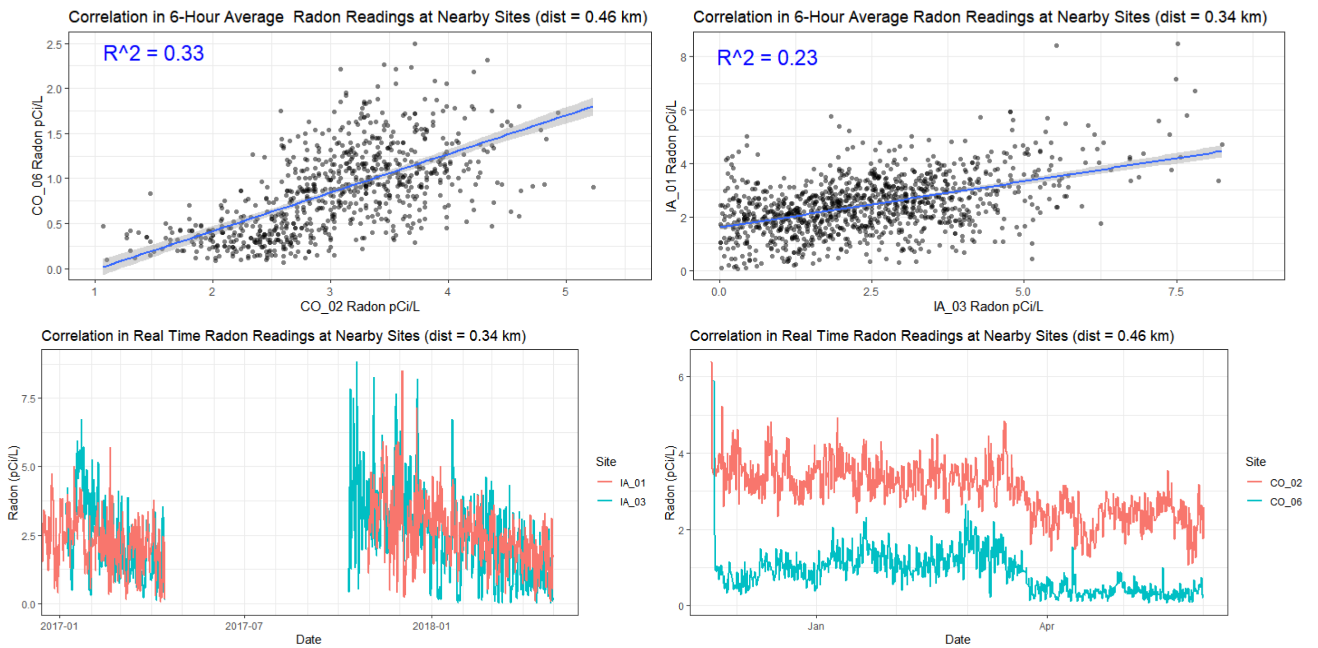



**Figure 3 –** (top) Relationship between concurrent radon measurements at most nearby sites in (left) Iowa, and (right) Colorado, and (bottom) time series data

## CONCLUSIONS

Radon is an inconstant contaminant and levels are affected by factors including weather, soil conditions, geology, & building conditions such as foundation characteristics, window operation, and mechanically or stack induced pressures. The correlation vs distance relationship confirms that although proximity (i.e. local environmental conditions) affect radon, other factors (e.g. house specific characteristics & occupant activities) are also very important to consider. Ideally, studies investigating relationships between radon and changes in physical building characteristics would use a self-control where a change is implemented and reversed at intervals to reduce the chance of coincidental natural variations being attributed to changes in the building, and reducing the uncertainty and complexity involved with using external controls. Although this study design could be easily accomplished when investigating the effects from a singular small change to the house (e.g. use of continuous ventilation), it is impractical for any large-scale building changes where the modifications are not quickly and easily reversible, such as the case with most energy retrofit projects.

## REFERENCES

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Pigg, S., D. Cautley, and P.W. Francisco. 2017. "Impacts of weatherization on indoor air quality: a field study of 514 Homes." Indoor Air 28(2):307-317.