

Spatial and Temporal Analysis of Emissions from Oil and Gas Development

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Background

TENORM - Technologically Enhanced Naturally Occurring Radioactive Material
- materials exposed due to human activity

Radionuclides commonly found in TENORM are **radium, radon, uranium, potassium and thorium.** (US EPA)

"When it comes to oil and gas exploration and production, the greatest radiation health risk is cancer due to **Radium-226 and Radium-228.**" (NRDC)

Soil and water (sludge) obtained from reserve pits used in unconventional natural gas mining was analyzed for TENORM Laboratory analysis confirmed **elevated beta readings** recorded at 1329 ± 311 pCi/g. (ALISA L. RICH ERNEST C. CROSBY)

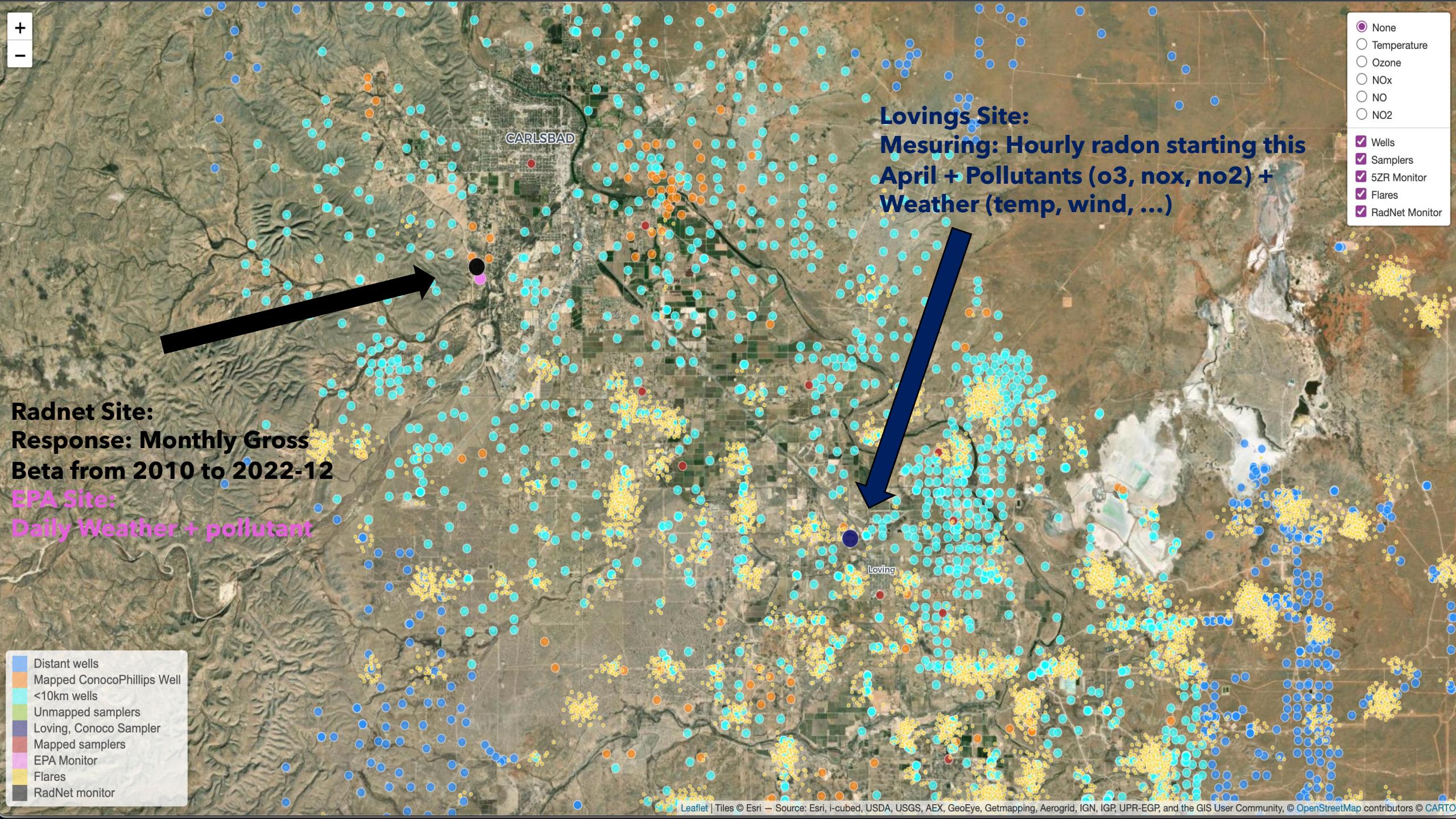
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- Unconventional Oil and Gas Development - the practice of using hydraulic fracturing (fracking)
 - greater access to resources & common
- "Where there is fracking, there is often natural gas flaring. Flaring is the act of burning off excess natural gas (methane) from oil wells when it can't economically be stored and sent elsewhere."
- **VIIRUS Nightfire- satellite data**
 - **contains the most comprehensive listing of gas flares worldwide.**



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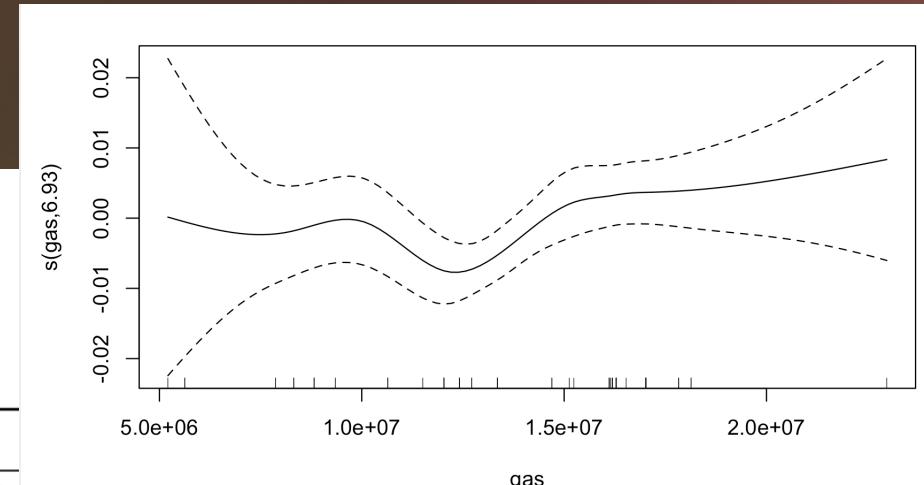
Statistical Analysis

- Model usage: Generalized additive model (GAM)
 - $g(E(Y)) = \beta_0 + f_1(x_1) + f_2(x_2) + f_3(x_3) + \dots + f_m(x_m)$
 - Good balance between flexibility and interpretability
 - Smoothing functions
- Variable of interests for Gross Beta model
 - Flaring related: distance, intensity (rhi), temperature (of flares), area, daily counts
 - Weather: temperature, solar radiation, wind speed, season, wind direction
 - Pollutant: nox, no, no2, o3
 - Oil and gas production data (monthly)
- Variable of interests for Radon & rd-particle models
 - - production

Results

Table 1: Summary Statistics of Gross Beta GAM model after step-regression elimination. The smoothing parameter estimation method is “GCV.Cp”. The smoothing splines for both ‘oil’ and ‘gas’ are cubic regression splines.

Variable	Coefficient	Std.Error	Prob.
(Intercept)	5.618e-03	6.759e-04	6.83e-11 (***)
rhi	8.876e-04	3.066e-04	0.00567 (**)
nox	1.523e-04	8.067e-05	0.06506 (.)
Smooth terms	edf	Ref.df	p-value
s(oil)	4.514	5.459	0.01855 (*)
s(gas)	6.925	7.702	0.00441 (**)
Adjusted R-squared: 0.469	Deviance explained: 58.4%	Num.obs: 63	GCV: 8.7211e-06



Deviance explained of 58.4%, both oil and gas significant as expected

Table 2: Summary Statistics of Hourly Radon GAM model after step-regression elimination. The smoothing spline for ‘date’ is the standard cubic regression spline and cyclic cubic regression spline for ‘hour’.

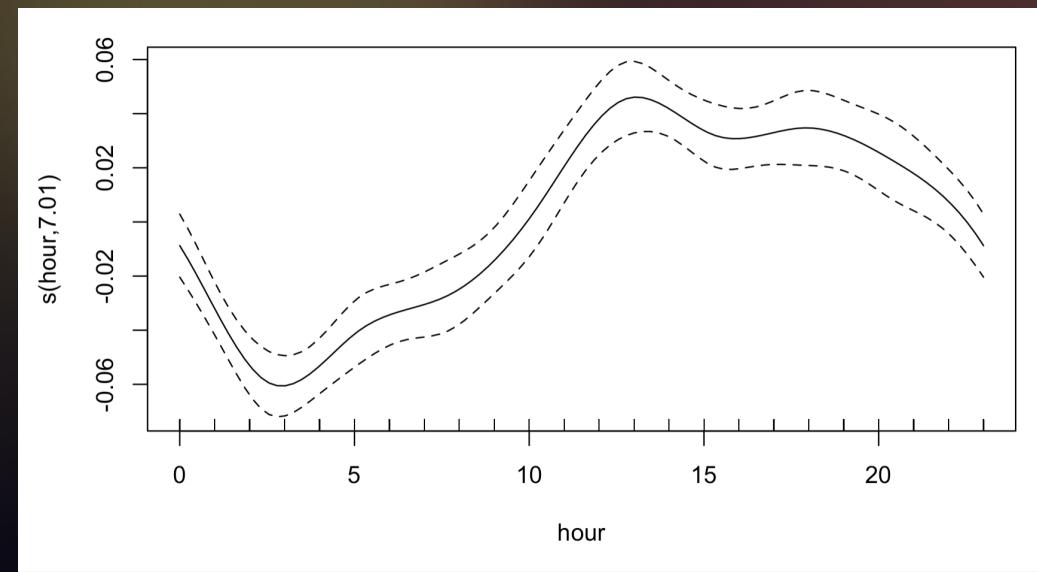
Variable	Coefficient	Std.Error	Prob.
(Intercept)	0.9616	0.0540	< 2e-16(***)
o3	-0.0055	0.0004	< 2e-16(***)
temp_f	-0.0022	0.0007	0.00527(**)
wsp	-0.0311	0.0026	< 2e-16(***)
count (num. flaring)	0.0074	0.0015	2.98e-06(***)
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Smooth terms	edf	Ref.df	p-value
s(date)	7.644	8.529	<2e-16(***)
s(hour)	6.560	8.000	<2e-16(***)
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Adjusted R-squared:	Deviance explained:	Num.obs: 1226	GCV: 0.025349
0.513	52.1%		

Table 3: Summary Statistics of Hourly Rd-particle GAM model after step-regression elimination. The smoothing spline for ‘date’ is the standard cubic regression spline and cyclic cubic regression spline for ‘hour’.

Variable	Coefficient	Std.Error	Prob.
(Intercept)	0.2358	0.0145	< 2e-16(***)
o3	-0.0055	0.0004	< 2e-16(***)
no2	0.0050	0.0004	< 2e-16(***)
wsp	-0.0064	0.0012	1.89e-07(***)
count (num. flaring)	0.0025	0.0007	0.0003(***)
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Smooth terms	edf	Ref.df	p-value
s(date)	8.343	8.875	<2e-16(***)
s(hour)	7.008	8.000	<2e-16(***)
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Adjusted R-squared:	Deviance explained:	Num.obs: 1226	GCV: 0.0048326
0.599	60.5%		

- Deviance explained of 52.1% and 60.5% respectively.

- o3 (ozone) and wind speed both high correlated with response
- count of flaring significant



- Cyclic relationship with hour

Further Steps...



**ML models: RF, XGBoost,
Ensemble models**



Data availability

Update when more data are available as
time progresses



**Investigate other potential
predictors**

Soil serves as an important medium for
radon generation and concentration

Thank you

- Special thanks to Professor Meredith Franklin for her supervision
- Code availability -
https://github.com/WilliamQD/2023_SummerResearch
- Data availability:
 - VIIRS Nightfire -
<https://eogdata.mines.edu/products/vnf/>
 - Radnet -
https://enviro.epa.gov/envirofac_ts/radnet/search
 - Lovings Site - collected real-time from instruments