DISASTER AT ST. HIMARK

ANALYSIS OF RADIATION CONTAMINATION

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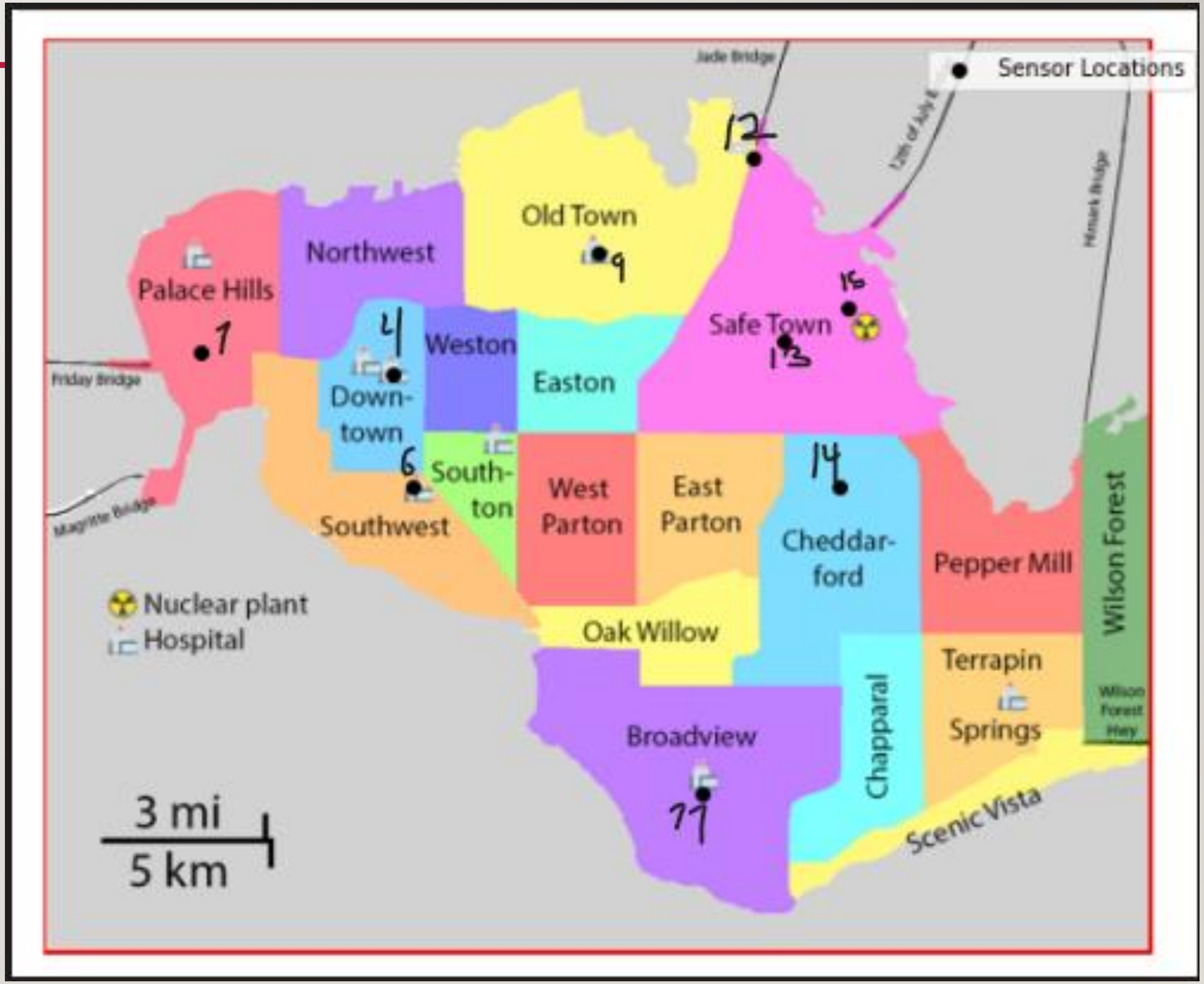
BACKGROUND

The nuclear plant plays a vital role in the economic success of St. Himark as a whole

During the dates of April 6, 2020:12:00 am - April 10, 2020: 11:59 pm (*i.e. 120-hour timelapse*) **St. Himark was struck by an earthquake**.

- **The nuclear plant suffered damage** causing radioactive contamination by leaks. In addition, **coolant containing radioactive waste sprayed the cars** of employees.



DESCRIPTION OF THE DATA

- The data **consists of 3 csv files**
  - 1 file for static sensor data(radiation values only)
  - 1 file for static sensor location data
  - 1 file for mobile sensor data(*location data already included*).

```
----Stationary Sensor Data----
Dimensions: (744000, 4)
```

	Timestamp	Sensor-id	Value	Units
	4/6/2020 0:00	15	11.926	cpm
	4/6/2020 0:00	6	14.816	cpm
	4/6/2020 0:00	1	17.055	cpm
	4/6/2020 0:00	12	16.787	cpm
	4/6/2020 0:00	13	15.009	cpm

Table 2: Preview of temporal and radiation data for Static Sensors

```
----Stationary Sensor Locations----
Dimensions: (9, 3)
```

Sensor-id	Lat	Long
12	0.20764	-119.81556
15	0.16849	-119.79033
13	0.15979	-119.80715
11	0.04147	-119.82861
6	0.12180	-119.90430

Table 1: Preview of spatial data for Static Sensors

```
----Mobile Sensor Data----
Dimensions: (3315711, 7)
```

Timestamp	Sensor-id	Long	Lat	Value	Units	User-id
2020-04-06 00:00:00	15	-119.83035	0.14007	0.0	cpm	CitizenScientist
2020-04-06 00:00:00	22	-119.76075	0.04205	0.0	cpm	HSS
2020-04-06 00:00:00	40	-119.89067	0.11658	0.0	cpm	MutantX
2020-04-06 00:00:00	1	-119.96665	0.18792	0.0	cpm	MySensor
2020-04-06 00:00:00	27	-119.80570	0.01711	0.0	cpm	CitizenScientist

Table 3: Preview of temporal, spatial, and radiation data for Mobile Sensors

cpm	mSv/yr
Small fraction of background < 1.00 cpm Artificial Source (medical equipment) = 1.20 cpm Normal background from natural source < 40.0-60.0 cpm Safe < 150 cpm Max dose of uranium miner < 200 cpm Low cancer risk > 500.3 cpm Occupational regulation = 1000.68 cpm	Small fraction of background < 0.05 mSv/yr Artificial Source (medical equipment) = 0.3-0.6 mSv/yr Normal background from natural source < 40.0-3.0 mSv/yr "Safe < 7.50 mSv/yr \n" Max dose of uranium miner < 10 mSv/yr Low cancer risk > 25.0 mSv/yr Occupational regulation = 50 mSv/yr

Table 4: Conversion of industry standard unit of milli-Sievert to cpm (i.e. the units of the data analyzed).

CHARACTERIZE CHANGES IN RADIATION LEVELS OVER BACKGROUND

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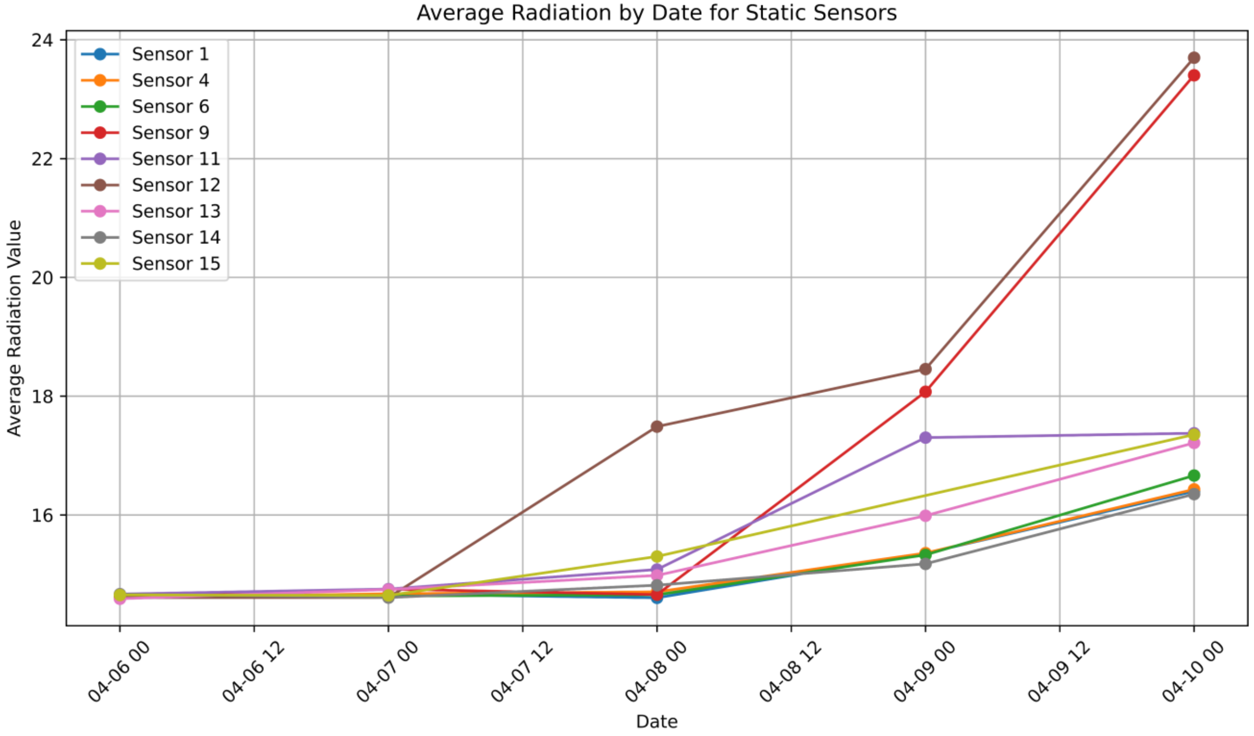
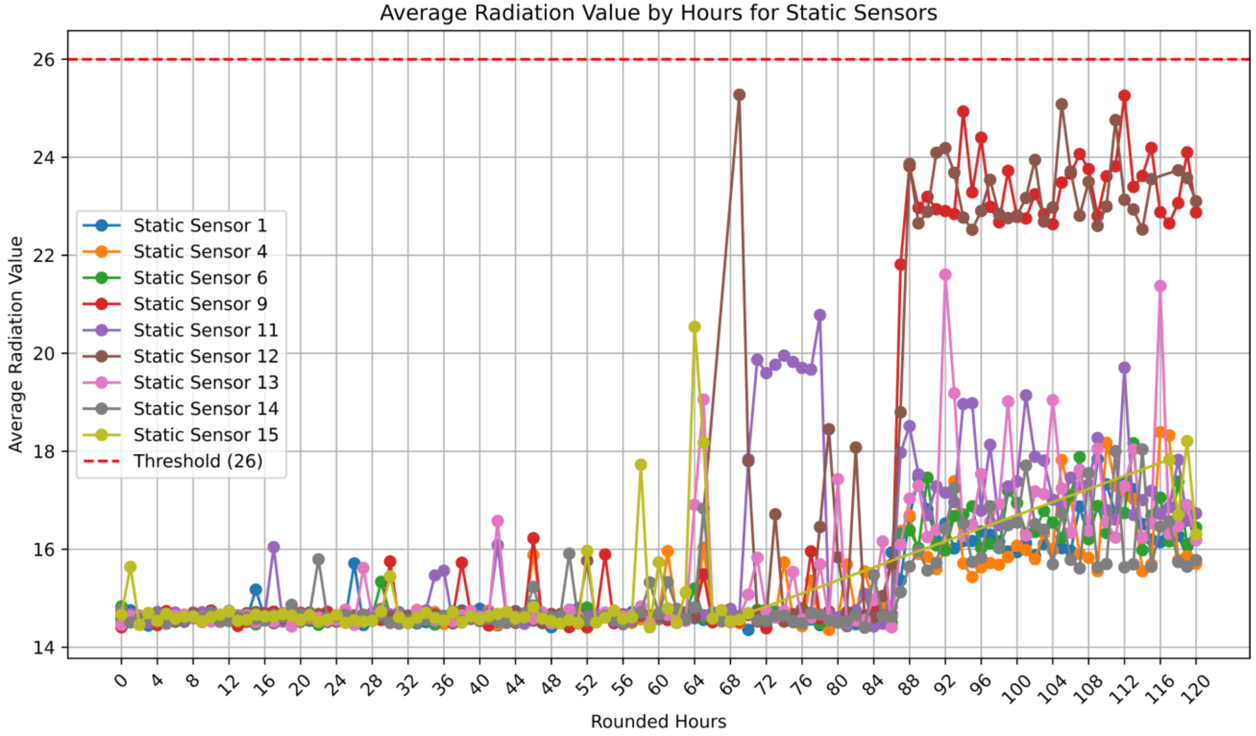
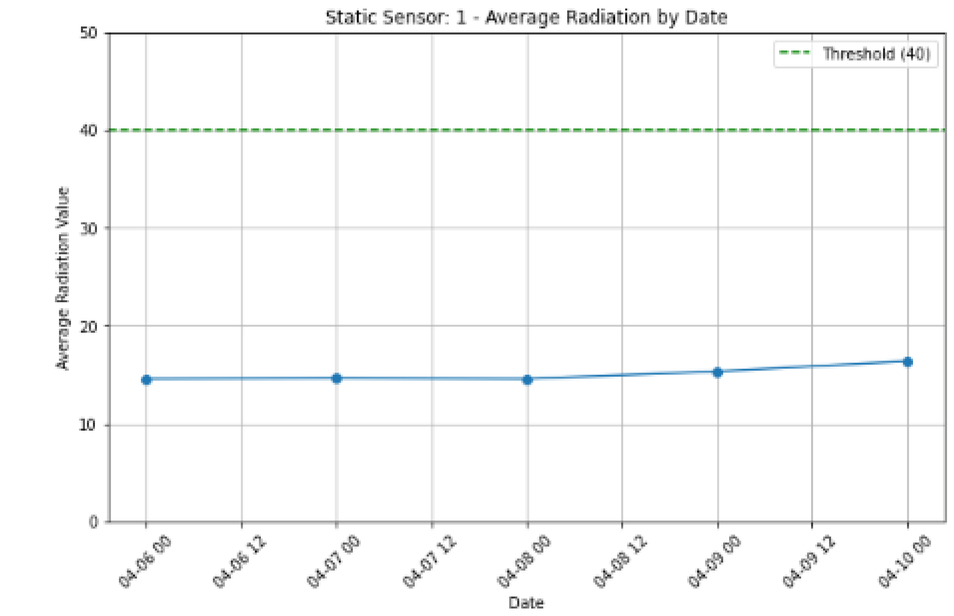
- When **initially powered on, there is a large spike** in readings before returning to actual surrounding values *(i.e. warmup spike*)
- When **powered down, sensors remain at current reading** until powering back up, where the warm-up spike occurs. The amount of time a sensor has been off does not appear to be correlated with whether a warmup spike occurs
- **Not all** spikes are form warmups
- The **challenge being to identify whether a sensor is in cool down, or if a mobile sensor is driving into or out of a contaminated area**.

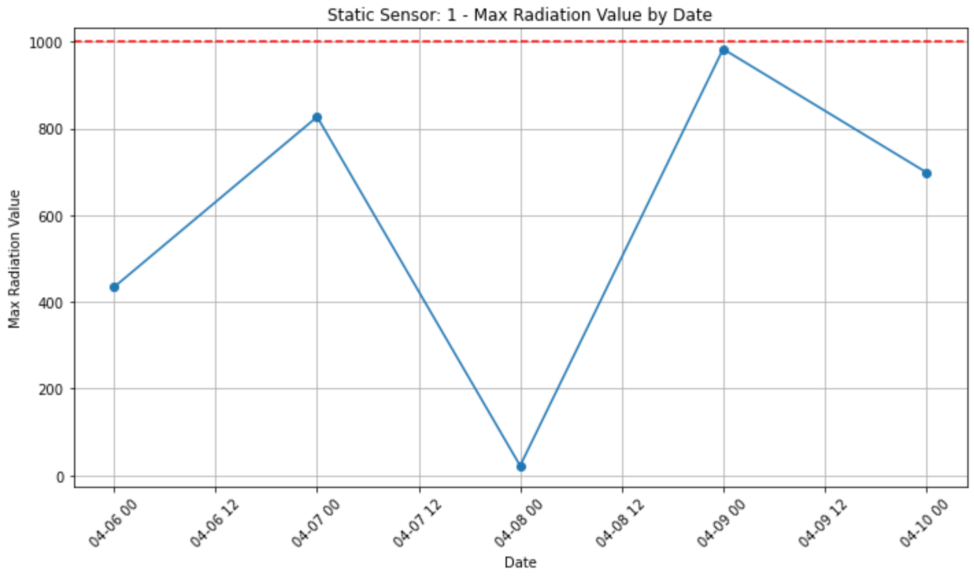
Average Radiation over Time (Static Sensors)

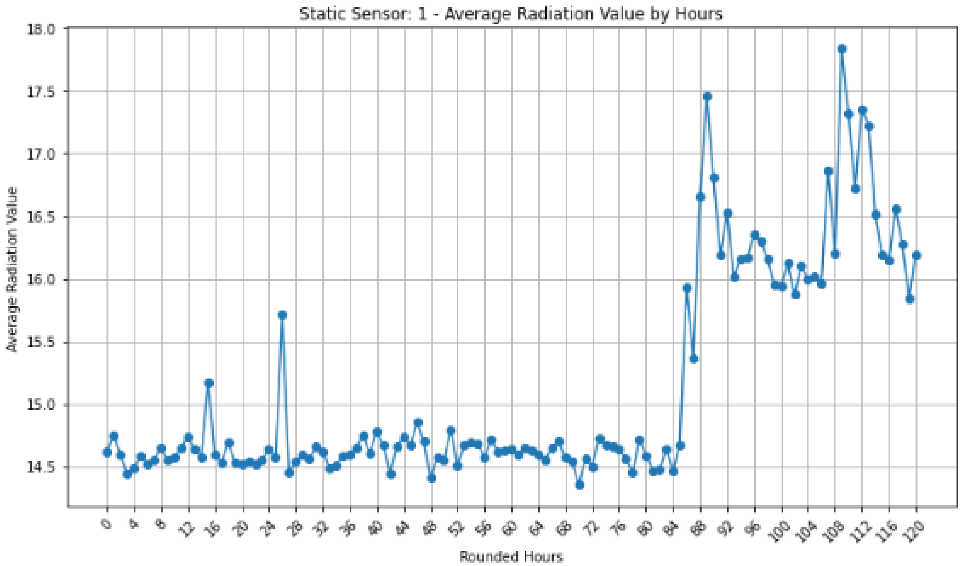


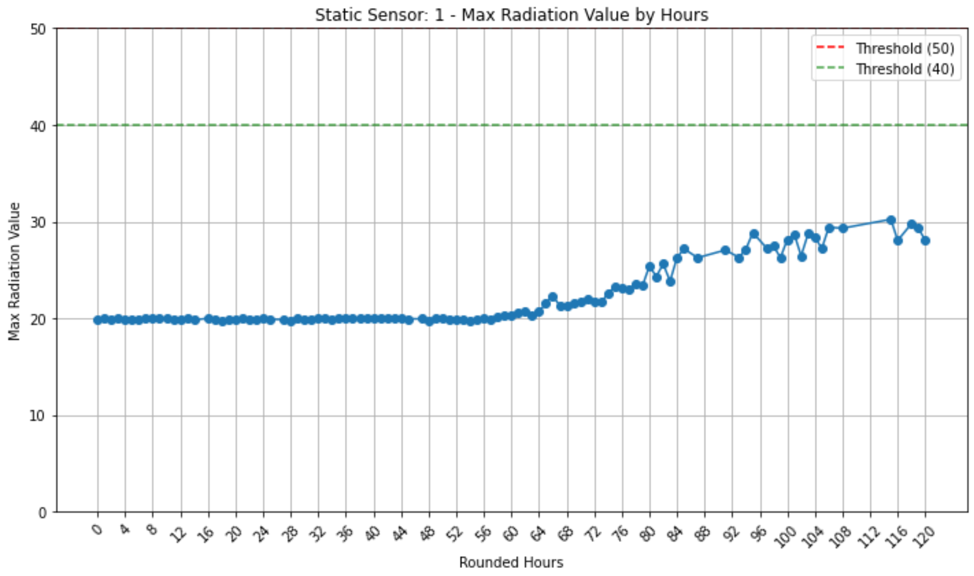


Maximum Average Radiation over Time (Static Sensor 1)

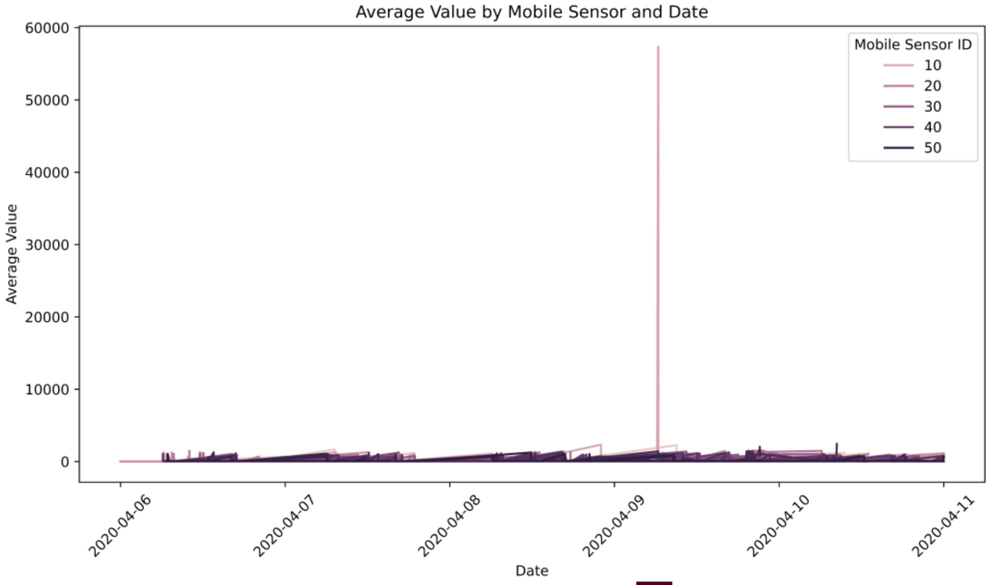


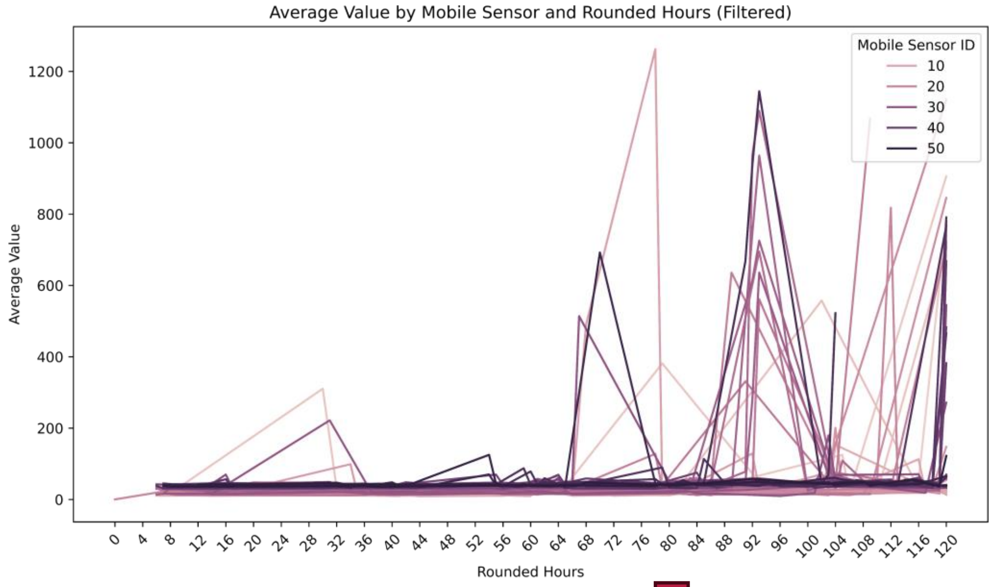




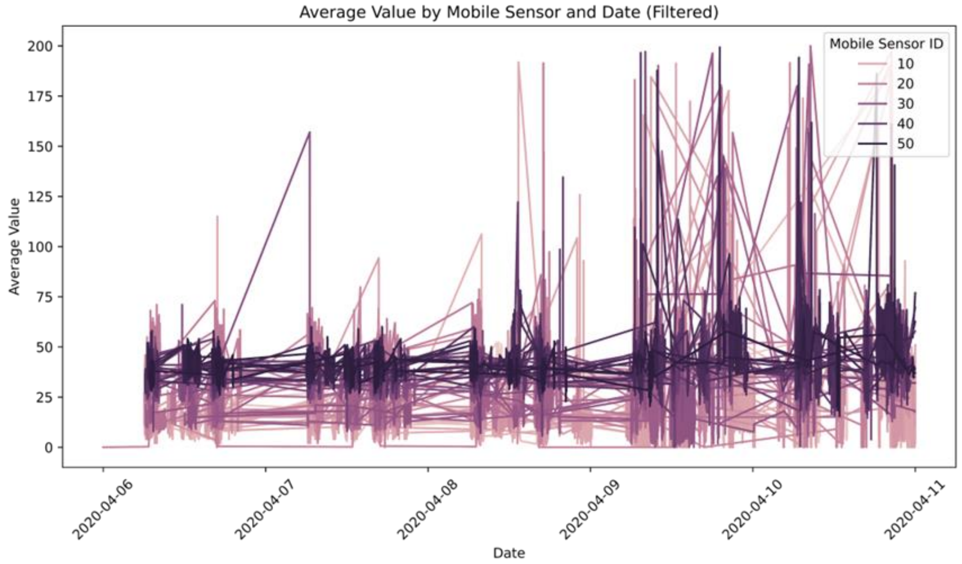


Unfiltered Average Radiation over Time (Mobile Sensors)

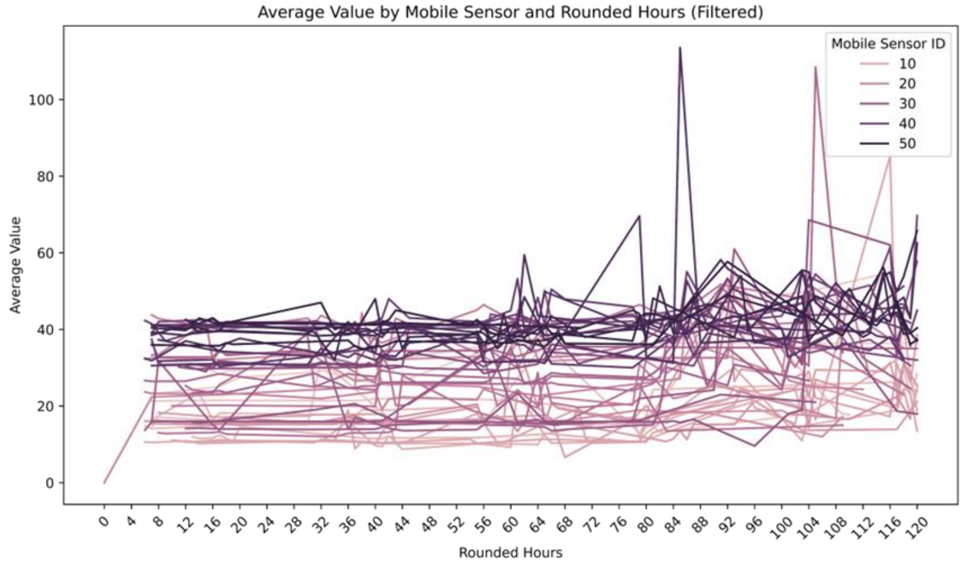




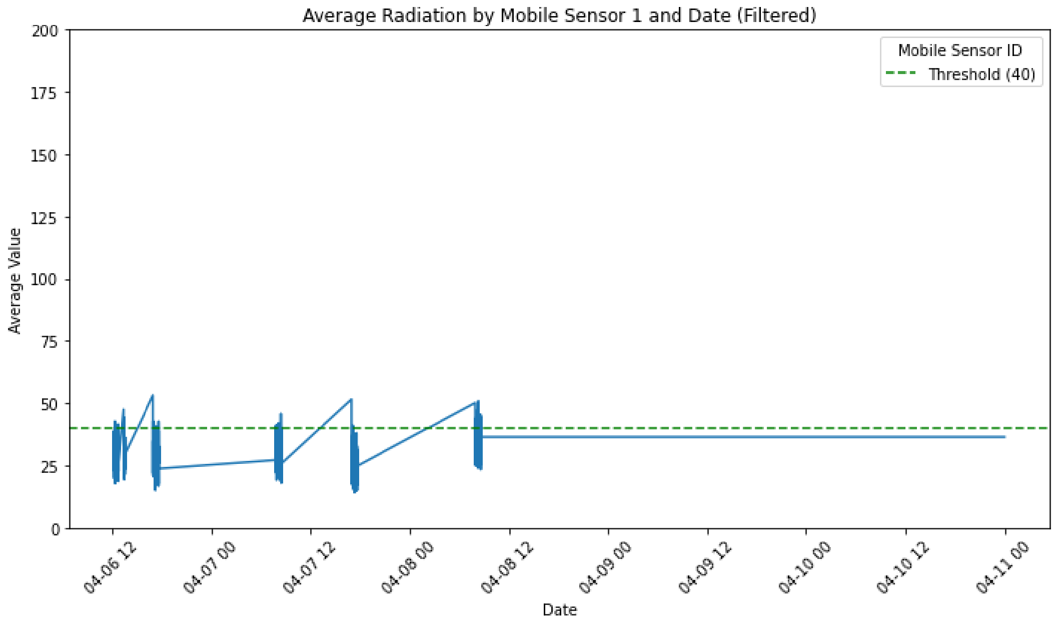
Limit to readings of about 200 cpm

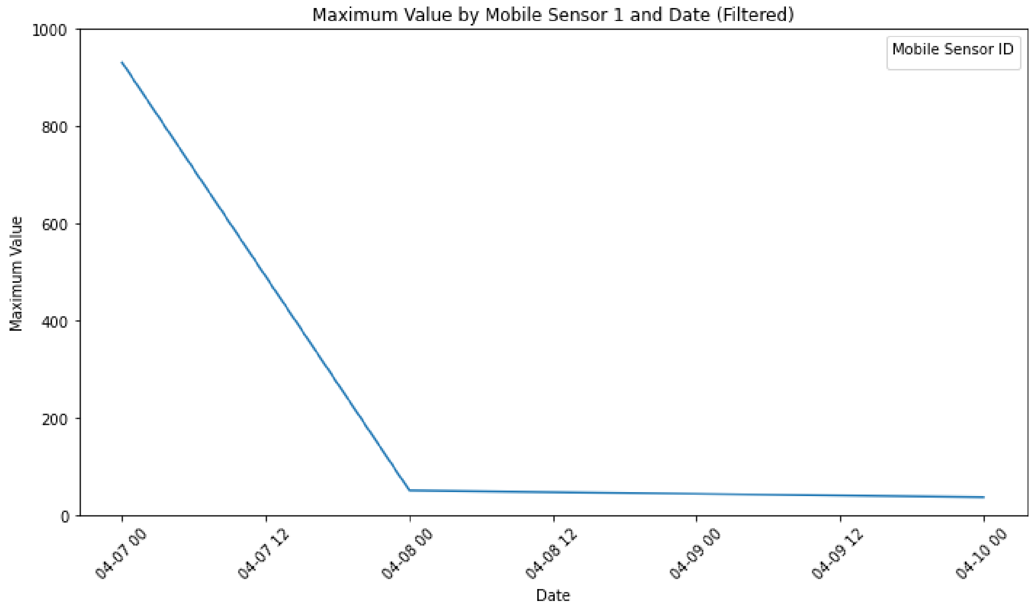


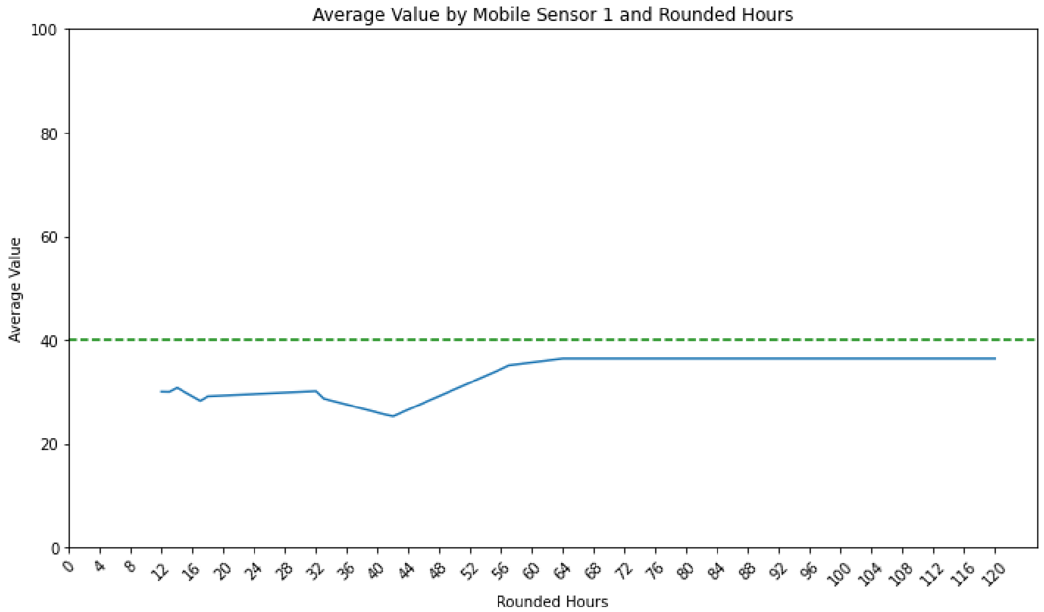
Limit to readings of about 100 cpm

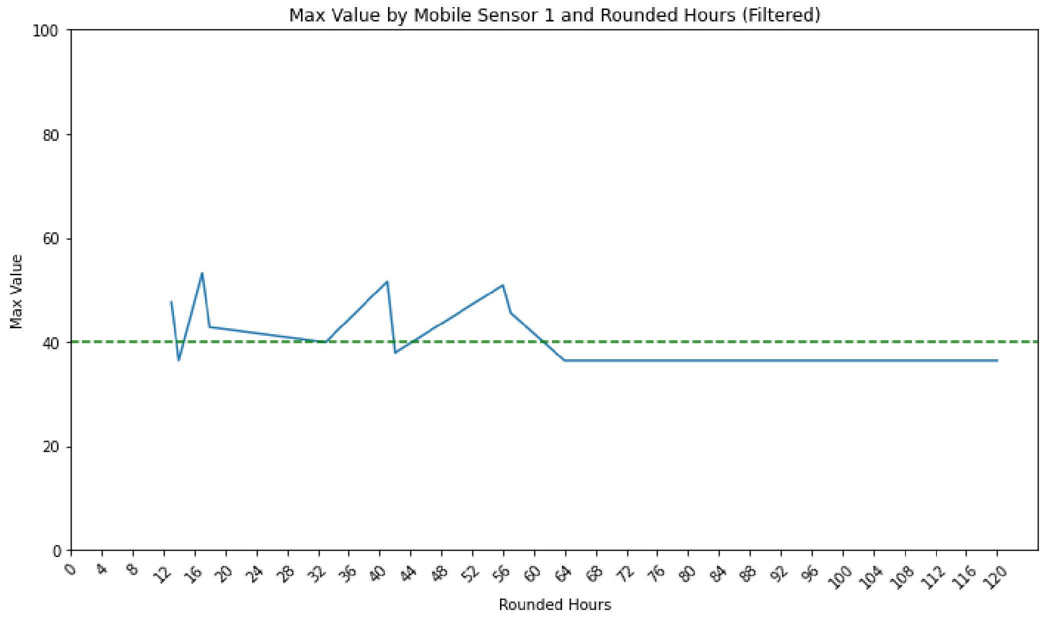


Maximum and Average Radiation over Time (Mobile Sensor 1)

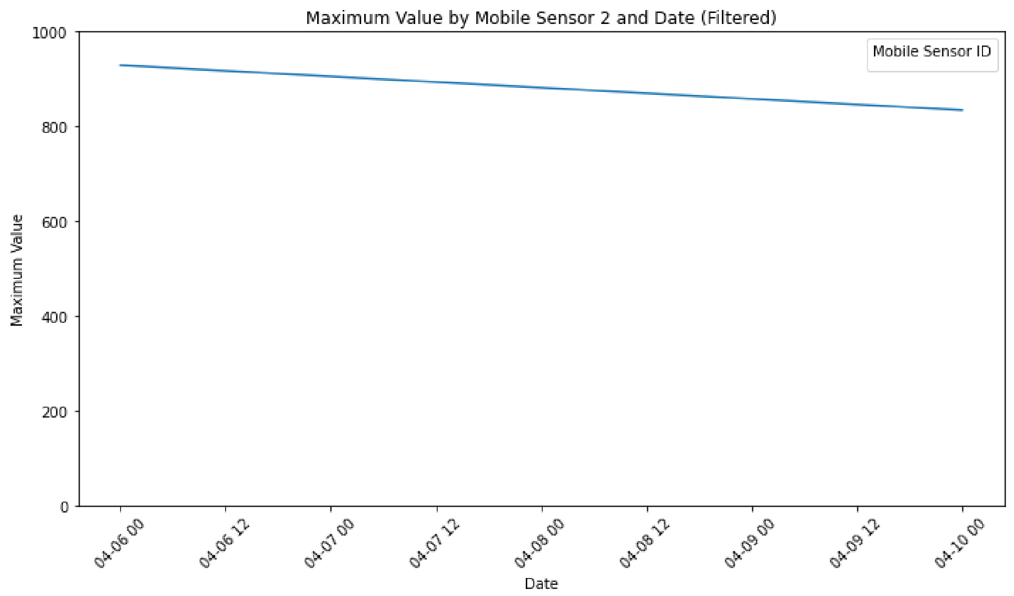


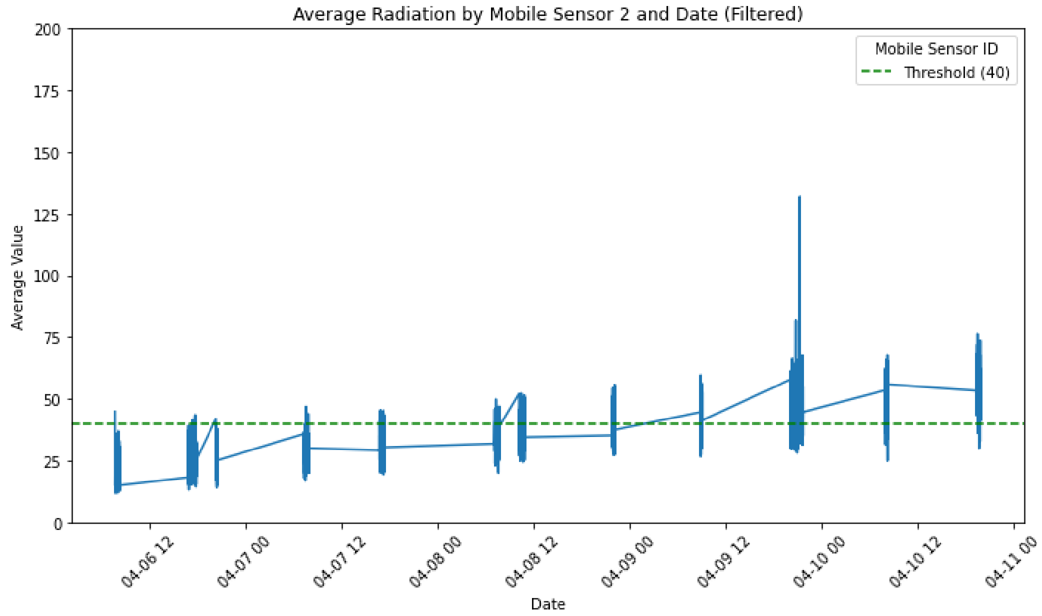


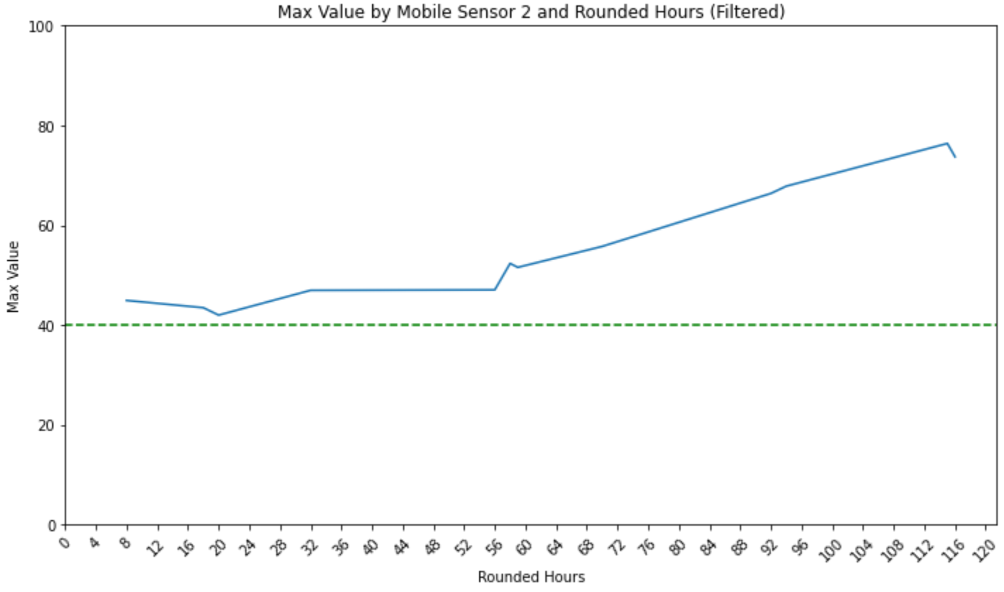


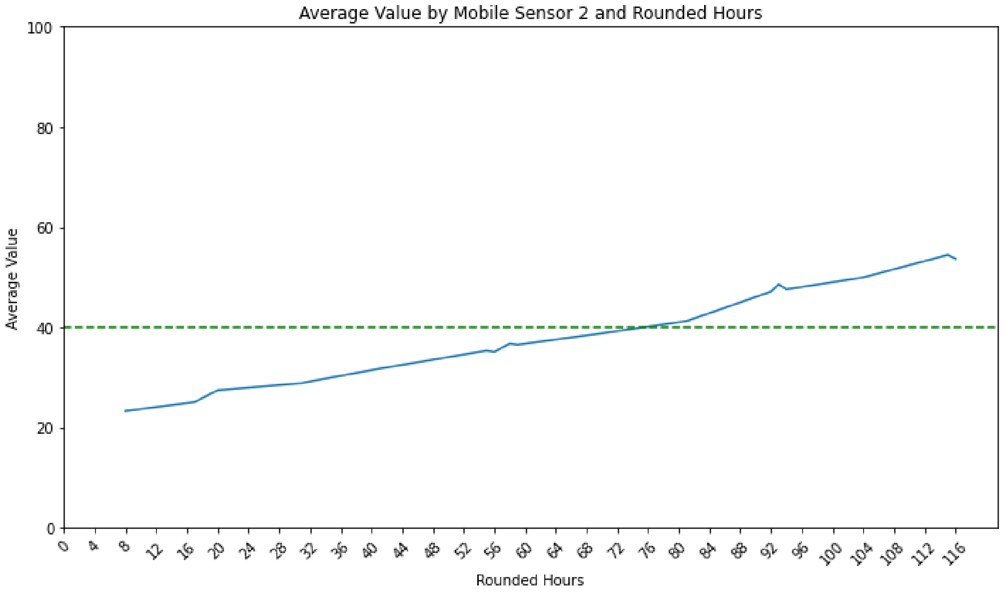


Maximum and Average Radiation over Time (Mobile Sensor 2)









REPRESENT AND ANALYZE UNCERTAINTY IN THE MEASUREMENT OF RADIATION ACROSS THE CITY

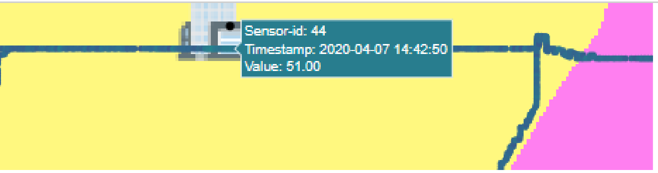
WHAT EFFECTS DO YOU SEE IN THE SENSOR READINGS AFTER THE EARTHQUAKE AND OTHER MAJOR EVENTS? WHAT IS THE DATE OF THE EARTHQUAKE? WHAT EFFECT DO THESE EVENTS HAVE ON UNCERTAINTY?

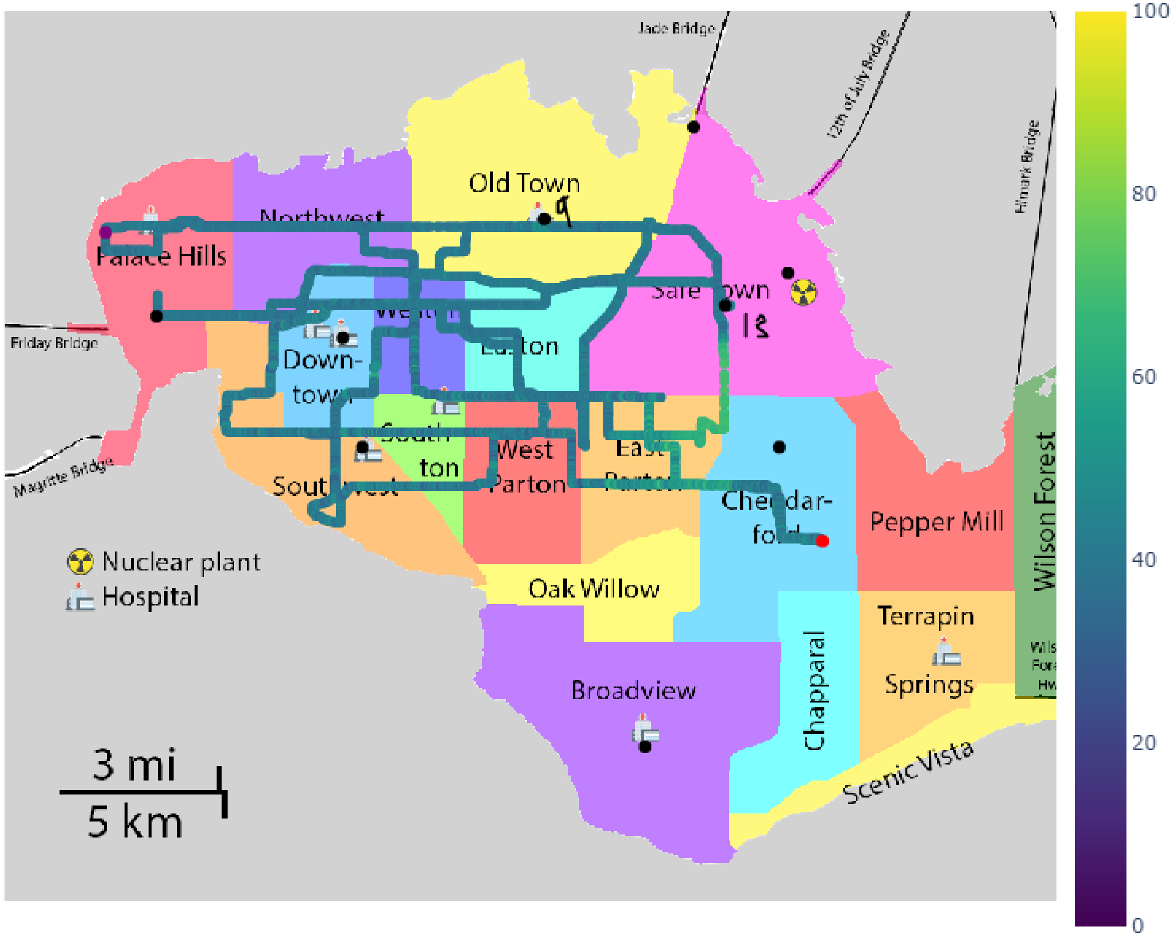
- Main earthquake appears to be the **Morning April 8th. Possible aftershocks occurring on April 9th** due to unaffected static sensors beginning to rise .
- **The some static sensors lost power** and when powered on again, **experienced the same warm-up spikes as mobile sensors**.
- Some **mobile sensors**, while located at nuclear plant and **after April 8th increased to above normal background radiation**(*i.e. contaminated cars*).

Are there sensors that are too uncertain to trust ?

sensor 9

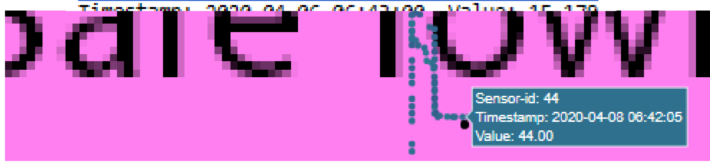
Timestamp: 2020-04-07 14:42:00, Value: 11.175
Timestamp: 2020-04-07 14:42:00, Value: 12.768
Timestamp: 2020-04-07 14:42:00, Value: 11.558
Timestamp: 2020-04-07 14:42:00, Value: 14.135
Timestamp: 2020-04-07 14:42:00, Value: 15.601
Timestamp: 2020-04-07 14:42:00, Value: 12.464
Timestamp: 2020-04-07 14:42:00, Value: 16.492
Timestamp: 2020-04-07 14:42:00, Value: 16.198
Timestamp: 2020-04-07 14:42:00, Value: 17.727
Timestamp: 2020-04-07 14:42:00, Value: 11.045
Timestamp: 2020-04-07 14:42:00, Value: 14.377





Sensor 13

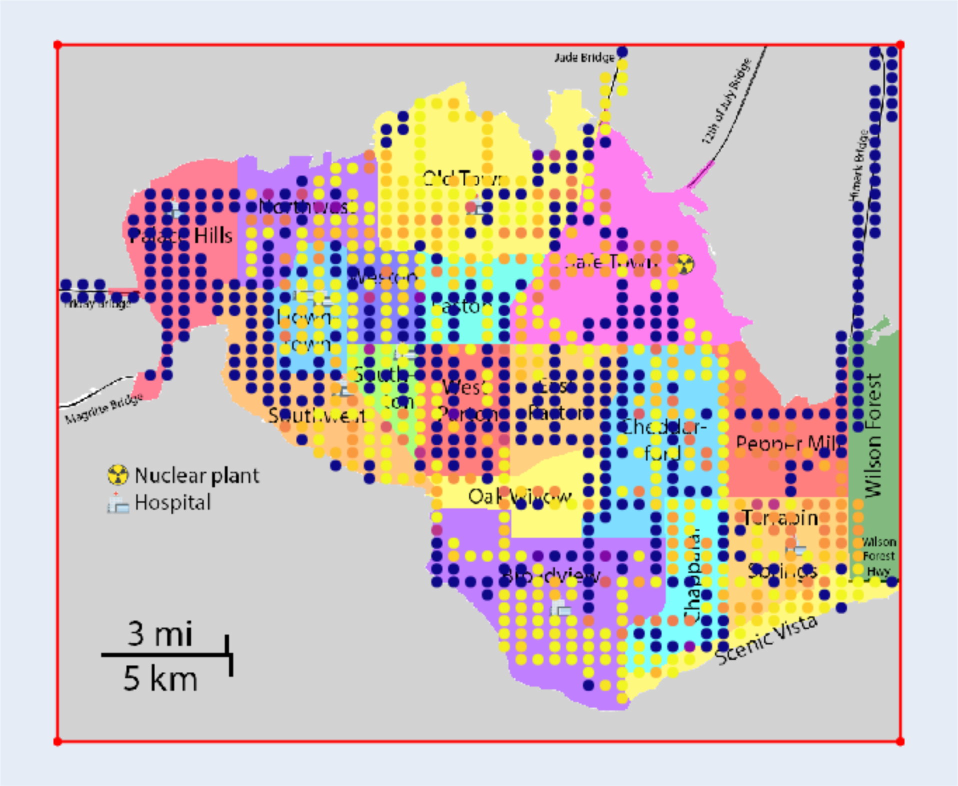
Timestamp: 2020-04-06 06:42:00, Value: 14.424
Timestamp: 2020-04-06 06:42:00, Value: 14.459
Timestamp: 2020-04-06 06:42:00, Value: 16.684
Timestamp: 2020-04-06 06:42:00, Value: 15.707
Timestamp: 2020-04-06 06:42:00, Value: 15.756
Timestamp: 2020-04-06 06:42:00, Value: 16.736
Timestamp: 2020-04-06 06:42:00, Value: 16.237
Timestamp: 2020-04-06 06:42:00, Value: 12.175
Timestamp: 2020-04-06 06:42:00, Value: 16.684
Timestamp: 2020-04-06 06:42:00, Value: 11.332
Timestamp: 2020-04-06 06:42:00, Value: 13.026
Timestamp: 2020-04-06 06:42:00, Value: 13.575



WHICH REGIONS OF THE CITY HAVE GREATER UNCERTAINTY OF RADIATION MEASUREMENT?

- Any neighborhoods a contaminated car drove, where no un-contaminated mobile or static sensors was also present

- Anywhere a mobile sensor did not drive or where a static sensor is located.



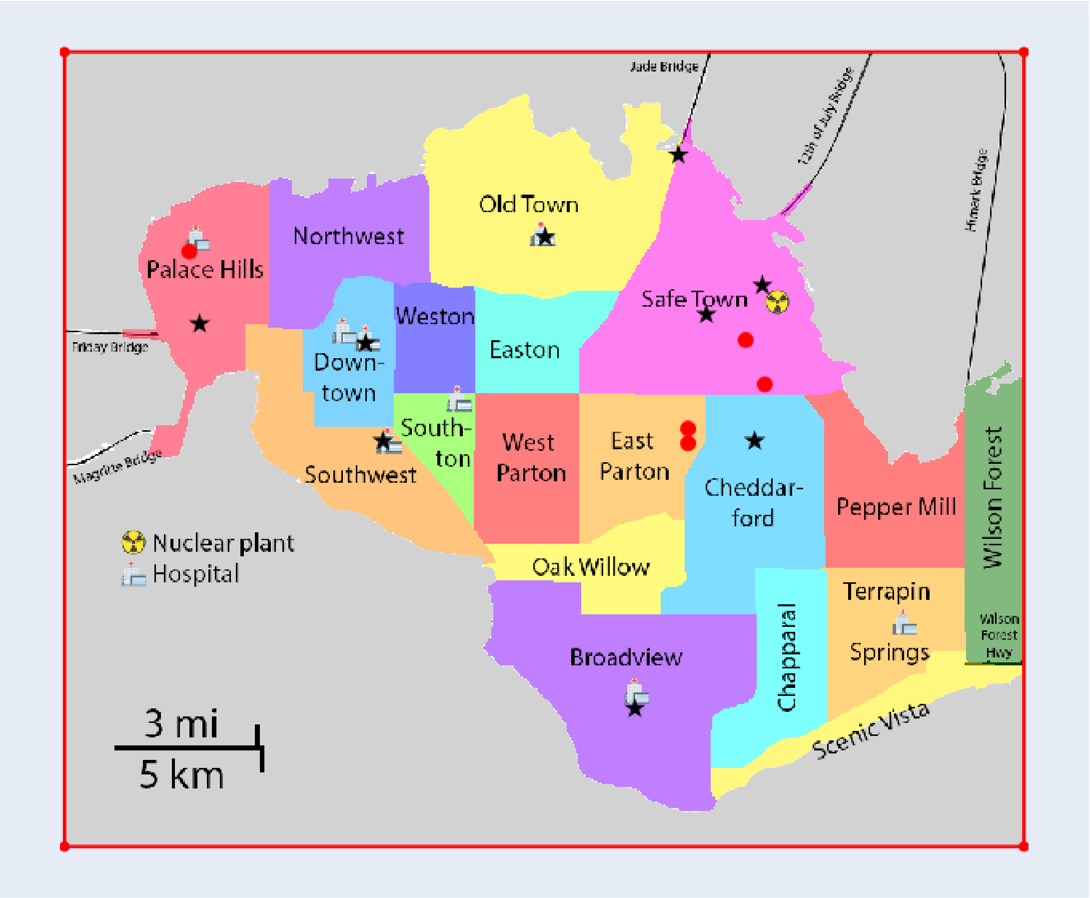
ESTIMATE HOW MANY CARS MAY HAVE BEEN CONTAMINATED WHEN COOLANT LEAKED FROM THE ALWAYS SAFE PLANT. USING RADIATION MEASUREMENTS DETERMINE IF ANY HAVE LEFT THE AREA

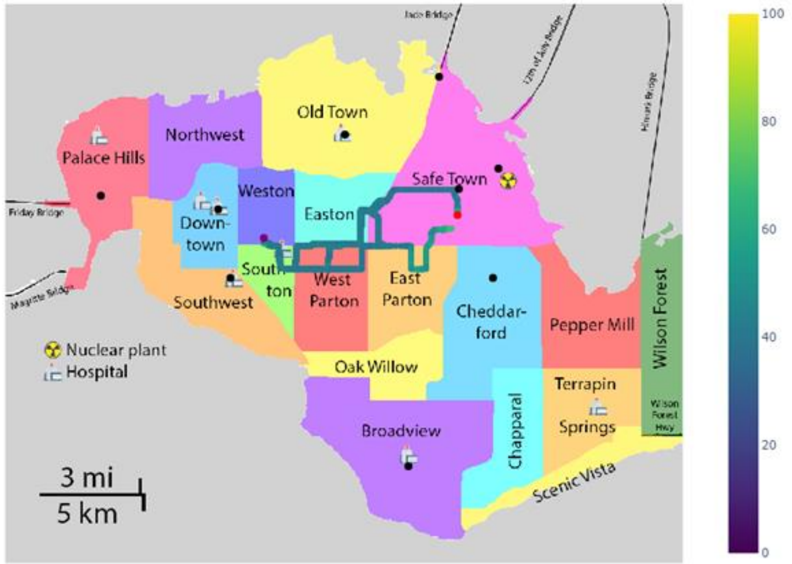
- Cars That drove near and around the nuclear plant

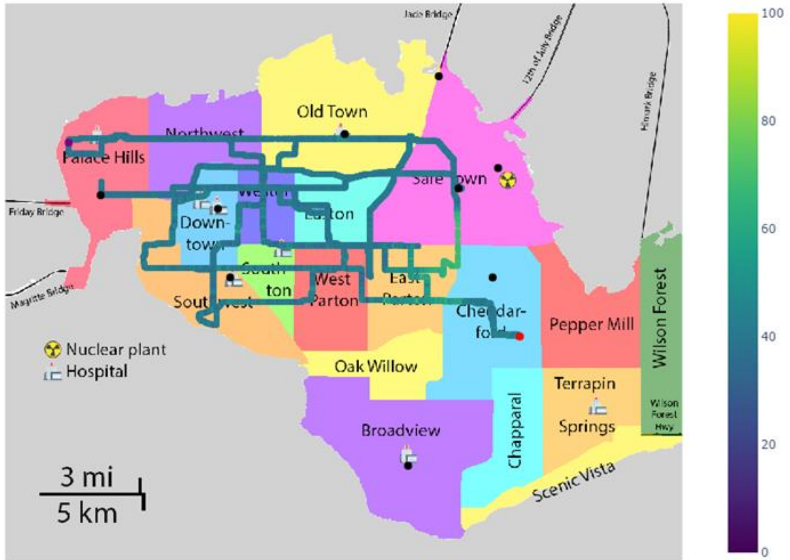
- Contaminated (44, 39, 32, 9, 22,13), all ended up leaving the plant post contamination
- Not contaminated (31, 45, 46)
- Secondary reading of contaminated cars (2 sensed 44)

At the end of the timelapse contaminated mobile sensors **9, 13, 22, 32, 39, 44** are located in southern border of **Cheddarford/PepperMill**, northwest end of **PepperMill,** on the **Scenic Vista Highway** to the mainland, border of **Cheddarford/PepperMill**, southern part of **SafeTown**, and **Cheddarford**, respectively.

Highlight potential locations of contamination the locations of contaminated cars. Should St. Himark officials be worried about contaminated cars moving around the city?







Indicate where you would deploy more sensors to improve radiation monitoring in the city. Would you recommend more static sensors or more mobile sensors or both?

Top 5 Highest Mean Values Plotted

1. Mean Value: 66.35, Border of SafeTown and Cheddarford
2. Mean Value: 61.64, East Parton
3. Mean Value: 53.05, SafeTown
4. Mean Value: 51.77, East Parton
5. Mean Value: 49.36, Palace Hills

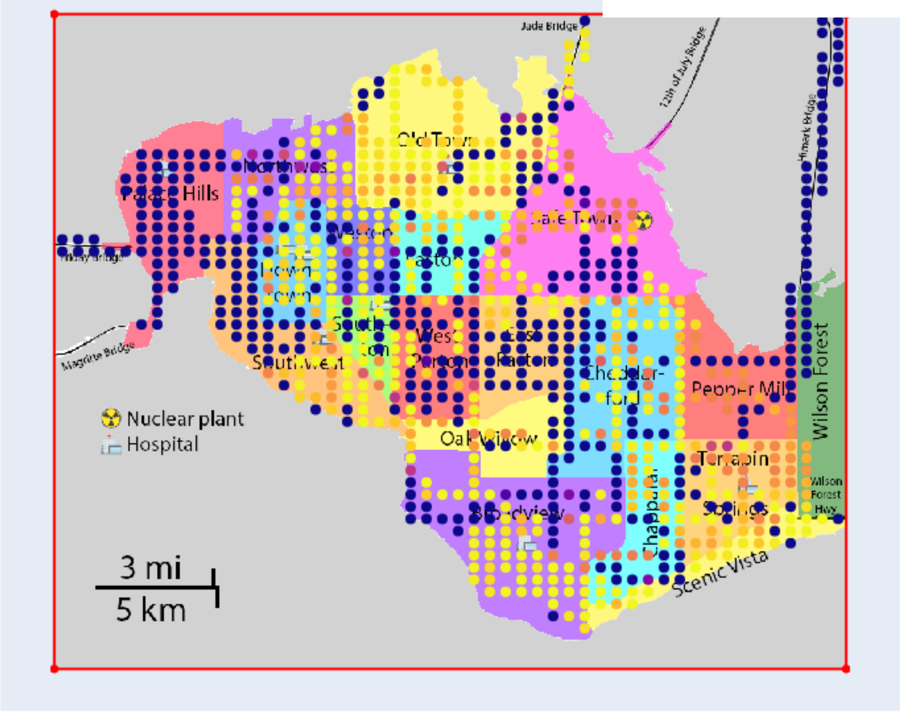


Figure 6: The color scale here is opposite that of the mobile sensor's paths. Darker blue tone means higher radiation and lighter yellow tones means lower mean radiation values.

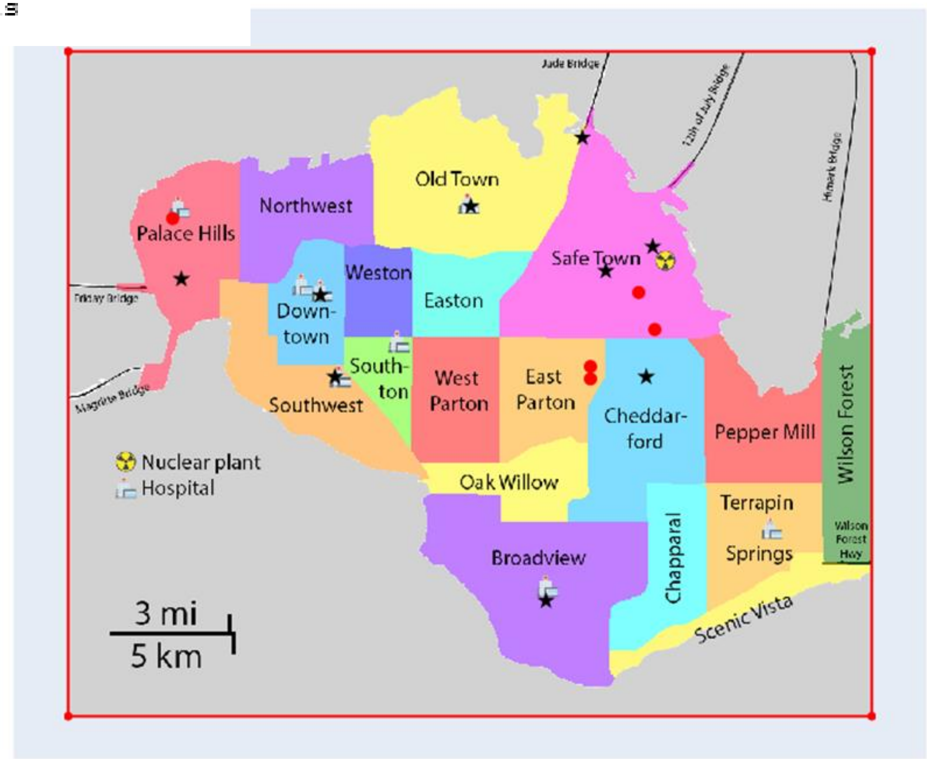
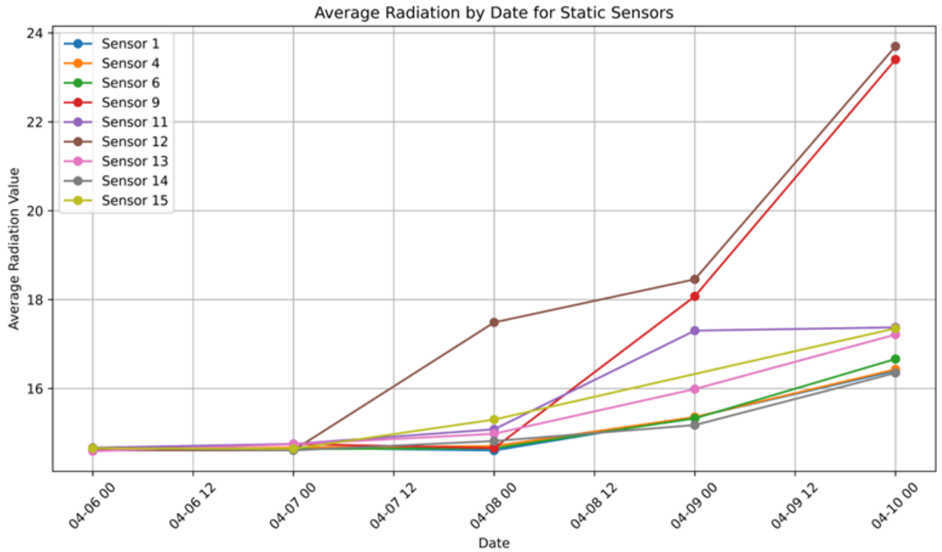
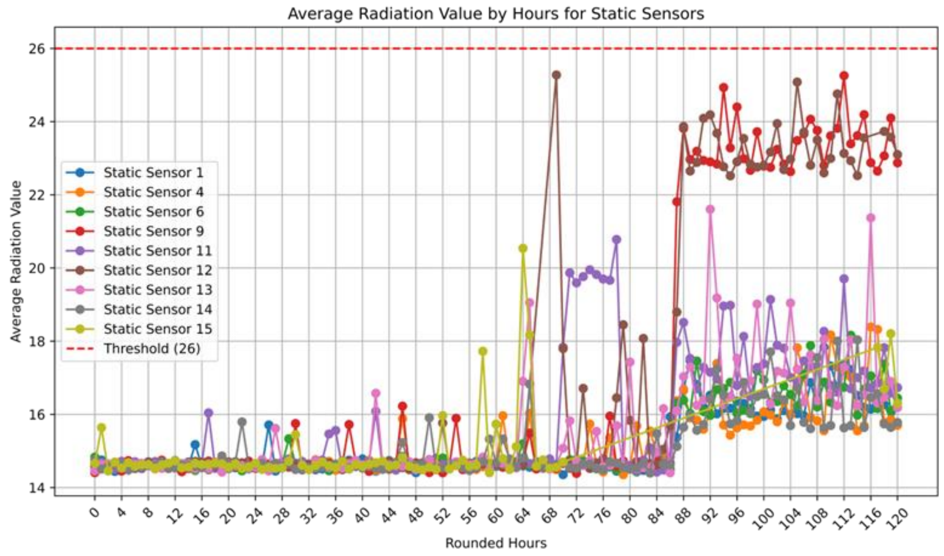
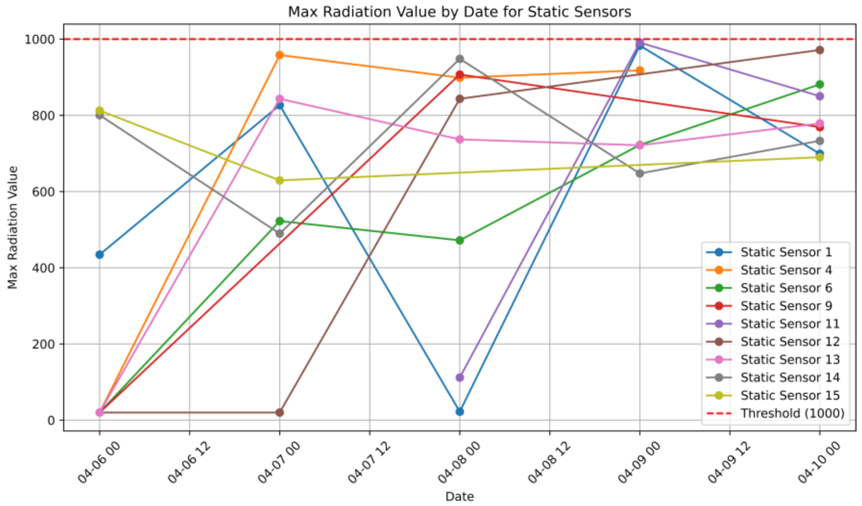


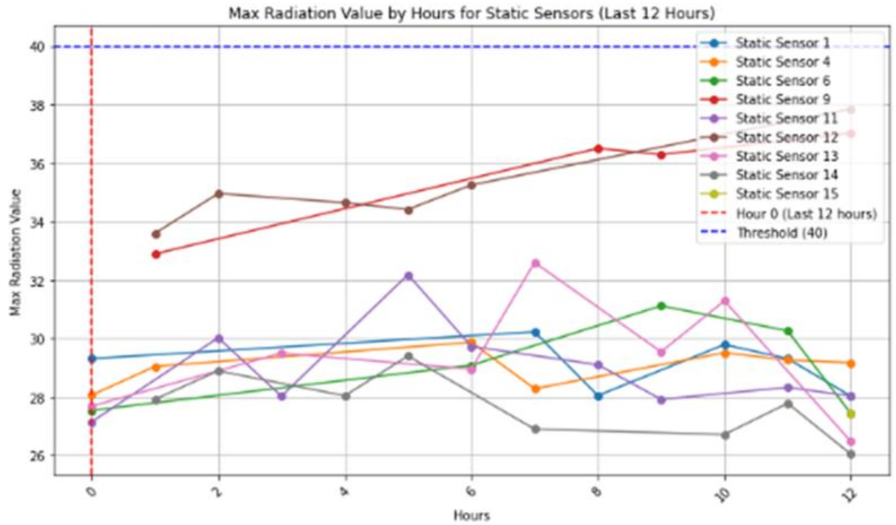
Figure 7: Plotting the top 5 highest readings to identify potential contamination areas by mean radiation level.

STATE OF RADIATION MEASUREMENTS AT THE END OF THE AVAILABLE PERIOD









COMPARING THE STATIC SENSOR NETWORK TO THE MOBILE SENSOR NETWORK

- I believe that having **both sensor types is foundational**, simply by the fact that the only spots areas of St. Himark that lack data are the areas where no mobile sensor drove through, or no static sensor was placed.
- **Given mobile the sensor 44 example** one could mistakenly assume that there was a contamination all the way in in Palace Hills, when it was a contaminated mobile sensor in that area artificially raising average radiation values.
- **Both sensor types share the same weakness of warm-up spikes**, but that is easily addressed by removing or filtering the data to exclude those warm-up values.

18 STATISTICAL REPORT

ANNOVA Test

- Comparing mean radiation of static compared to mobile sensors
  - Results determined that the significantly different mean radiation values.
- Comparing mean radiation of sensors to self, before and after estimated earthquake date of April 8th
  - Results determine mean same sensor readings before and after the earthquake are significantly different from one another (*i.e. readings of non-normal background radiation*).

ANOMALY TESTING WITH ISOLATION FOREST

ARE THE RADIATION MEASUREMENTS RELIABLE ENOUGH TO LOCATE AREAS OF CONCERN?

```
# Create a function to detect anomalies using Isolation Forest
def detect_anomalies(data, contamination=0.05, random_state=42):
    model = IsolationForest(contamination=contamination, random_state=random_state)
    predictions = model.fit_predict(data)
    return predictions
```

Static sensor ID	Percentage of Anomalies
1	4.972337
4	4.977025
6	4.993171
9	4.986227
11	4.988541

Table 5: Preview for percentage of static sensor readings that are considered anomalies by the Isolation Forest mode

Mobile Sensor ID	Percentage of Anomalies
1	21.414914
2	17.230706
3	10.778914
4	11.304348
5	15.369360

Table 5: Preview for percentage of mobile sensor readings that are considered anomalies by the Isolation Forest model

20 CONCLUSIONS

- Analysis has demonstrated that there is not a huge risk to public safety. Other than identified hotspots, **background radiation around St. Himark appears to remain unchanged.** Even the, hotspots are not significantly higher than the upper threshold of what is considered to be a normal amount of background radiation.

- I **don't see it necessary to evacuate any of the neighborhoods**, I think the best course of action would be to make a public announcement to avoid the contaminated zones until readings show normal background radiation levels again.

REFERENCES

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