Data Science

Lecture 1-2: Social Impact of Data Science

University of Amsterdam

Lecturer: Yen-Chia Hsu

Date: Feb 2024

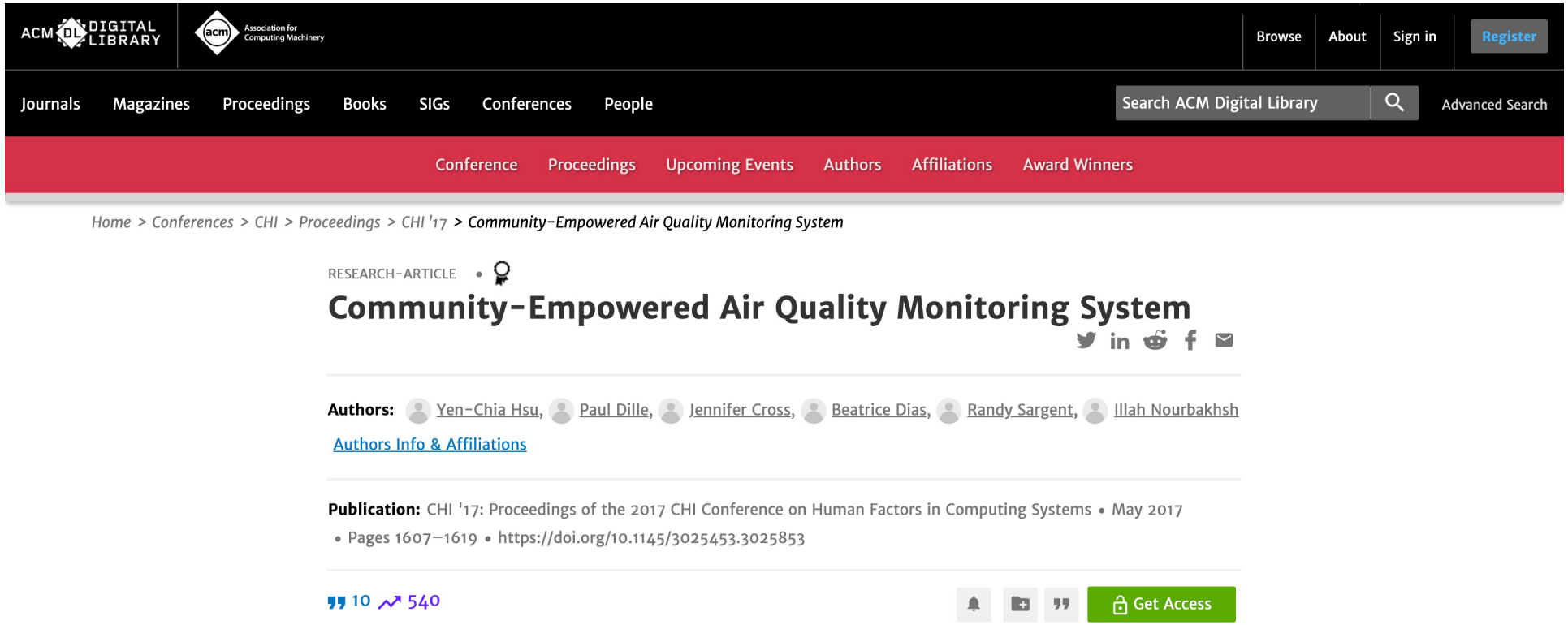
Data science can create a social impact to influence society positively!

This lecture uses my three previous projects to show the social impact of data science.

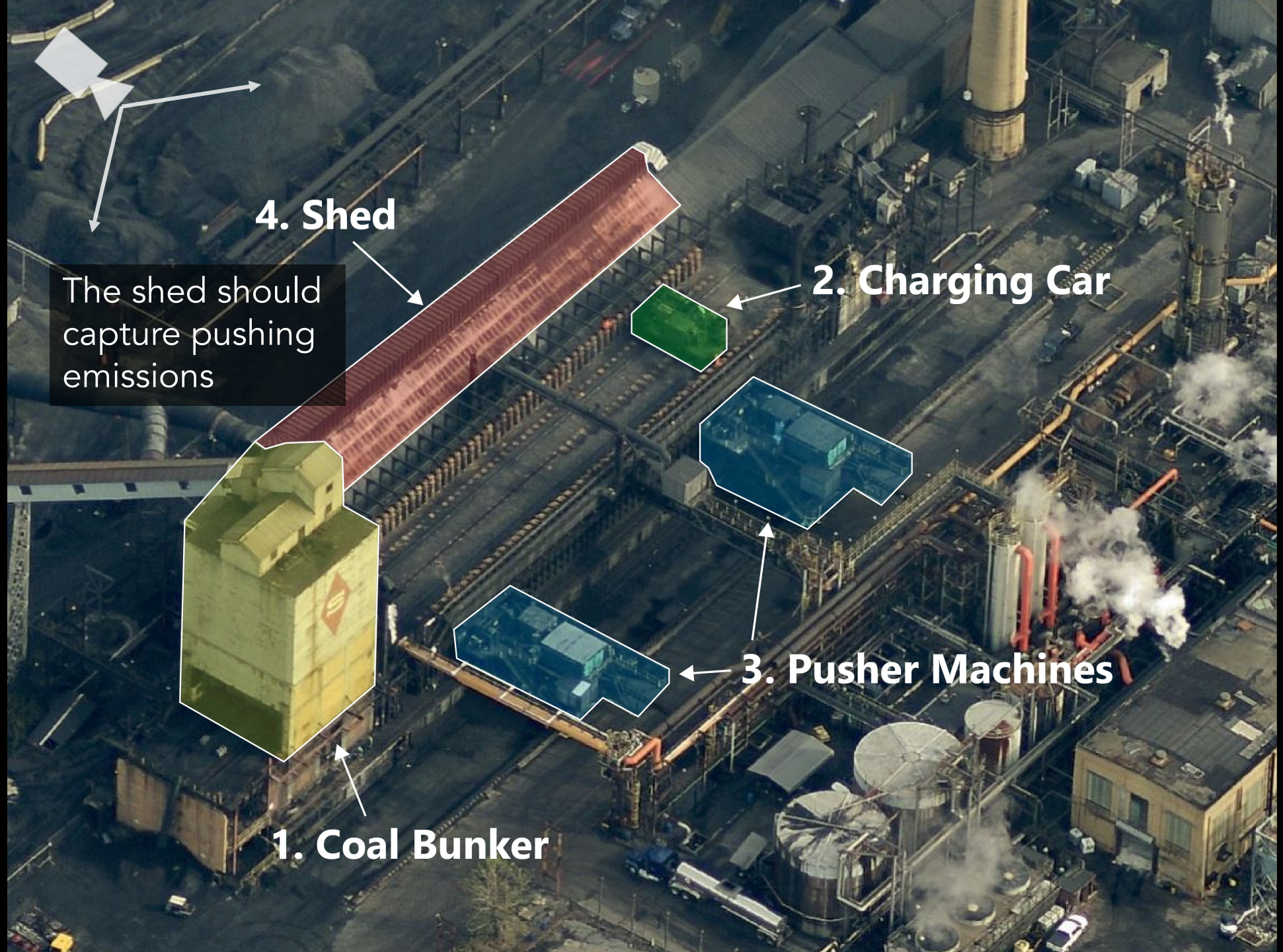
Air Quality Monitoring System

Integrating smoke videos, sensor readings, and smell reports

http://shenangochannel.org




Community
Coke Refinery
CMU
Ben Avon Heights
Ben Avon
Avalon
Bellevue
Ohio River
Stowe Township
Riverview Park
Reserve Township
Millvale
Etna
Allegheny River
LAWRENCEVILLE
GARFIELD
BLOOMFIELD
McKees Rocks
Brunot Island
Ingram
Thornburg
Crafton
EAST ALLEGHENY
STRIP DISTRICT
ALLEGHENY WEST
NORTH SHORE
PNC Park
CULTURAL DISTRICT
Pittsburgh
UPTOWN
NORTH OAKLAND
University of Pittsburgh
Carnegie Mellon University
Google


4. Shed
The shed should capture pushing emissions
2. Charging Car
3. Pusher Machines
1. Coal Bunker

- Co-design to collect evidences of air pollution
- Present them to the government or media
- Raise the public awareness of air quality issues

Residents can integrate the evidence of air pollution and their personal experiences into a story to influence regulators' attitudes and increase the community's confidence.

Hsu, Y. C., et al. (2017). Community-Empowered Air Quality Monitoring System. ACM CHI.

"But what I see in the video," the acting director of U.S. EPA Region III Air Protection Division said, referring to videos from the system that were projected on a screen at the front of the meeting room, "is totally unacceptable."

Community meeting on November 19, 2015 (https://youtu.be/-OxfkU-ql5M?t=4274)


2015-05-27 12:44:10


2015-10-11 17:40:42


2015-06-15 17:44:21


2015-06-11 17:54:00


2015-05-02 10:43:46
2015-08-24 11:00:20
2015-05-10 11:30:19
2015-05-27 15:04:45
2015-05-01 15:41:13
2015-10-15 11:41:27
2015-10-23 11:21:06
2015-05-01 15:19:56
2015-05-27 13:32:20
2015-05-27 13:56:44
2015-05-04 18:54:07
2015-05-08 16:46:30
2015-05-13 08:45:00
2015-05-22 10:12:33
2015-06-15 17:44:06
2015-06-11 17:58:47
2015-05-02 18:24:48
2015-10-11 16:44:47
2015-10-19 17:25:44
2015-07-29 17:52:25
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2015-05-02 08:26:32


2015-07-02 13:13:06
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2015-07-02 19:33:22
2015-07-03 10:47:37
2015-07-04 15:44:28
2015-07-04 18:12:09
2015-07-05 15:11:53
2015-07-05 13:32:32
2015-07-05 17:24:44
2015-07-05 19:44:25
2015-07-06 11:18:35
2015-07-06 14:38:39
2015-07-06 15:40:41
2015-07-08 14:04:50
2015-07-11 09:12:35
2015-07-11 13:07:50
2015-07-11 17:25:36
2015-07-12 15:26:00
2015-07-12 15:43:06
2015-07-14 12:22:11
2015-07-14 16:34:50
2015-07-15 19:01:43
2015-07-15 20:16:52
2015-07-16 14:20:45
2015-07-16 20:36:05
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2015-07-27 16:54:47
2015-07-28 15:07:40
2015-07-30 10:51:56
2015-07-30 20:18:02
2015-07-29 08:44:56
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2015-08-01 18:43:44
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2015-08-28 17:43:28
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2015-08-17 18:59:11
2015-08-21 16:40:54
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2015-08-30 16:39:47
2015-08-28 19:52:27
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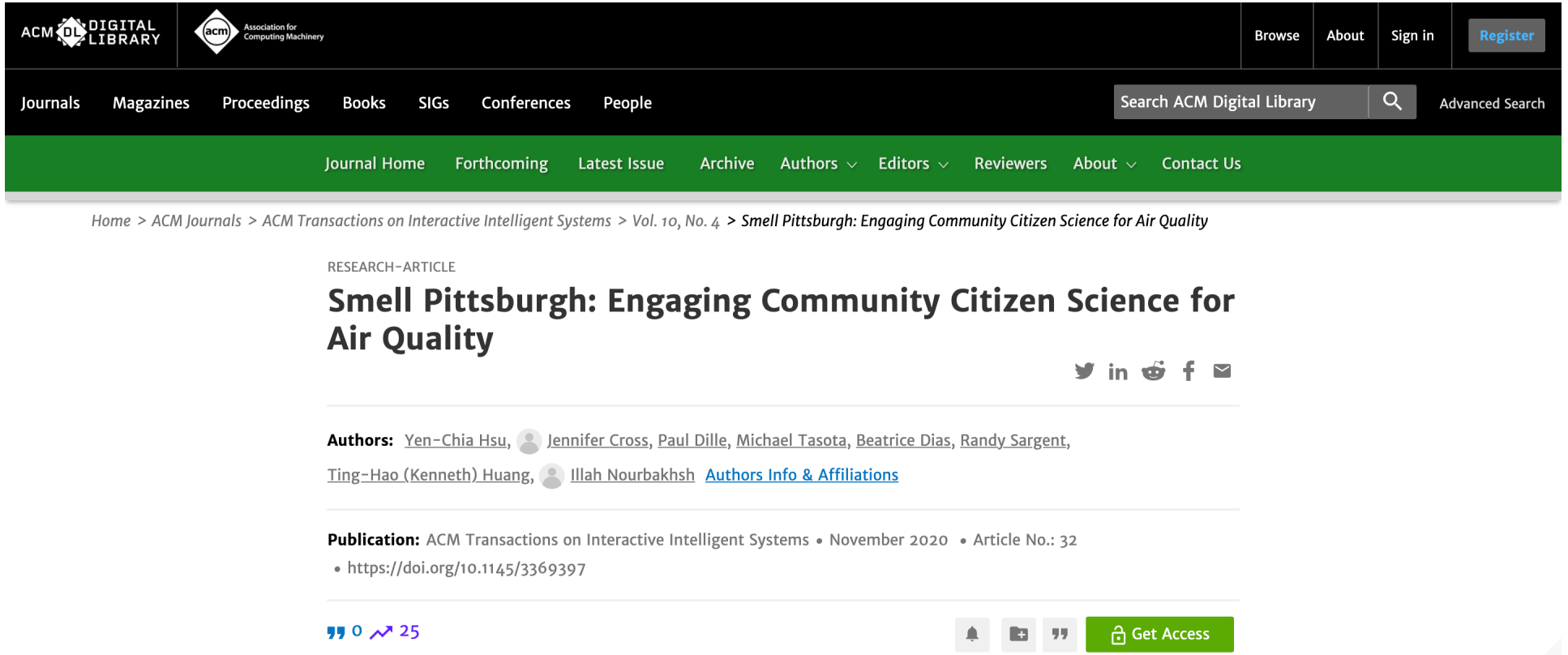
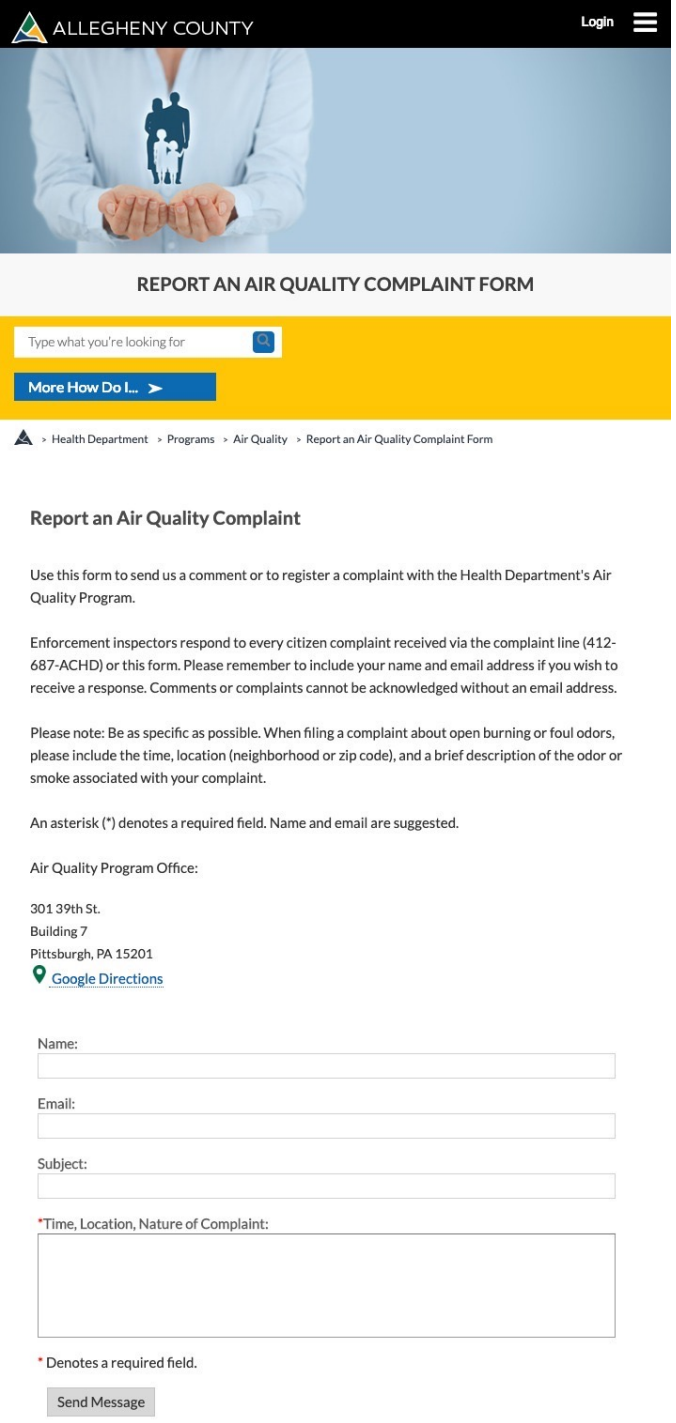
2015-08-22 13:09:04
2015-08-17 16:54:19
2015-08-09 06:32:27
2015-08-10 16:58:49
2015-08-10 19:17:32
2015-08-17 15:50:24
2015-08-15 17:03:00
2015-08-16 13:58:09
2015-08-12 18:26:28
2015-08-14 12:44:51
2015-08-13 17:36:04
2015-08-14 16:16:24
2015-08-09 17:16:26
2015-08-17 18:18:06
2015-08-14 19:07:19
2015-08-27 13:15:13
2015-08-15 17:23:27
2015-06-29 16:24:32
2015-06-29 15:39:47
2015-06-29 14:20:12
2015-06-29 14:04:32
2015-06-29 13:39:53

Smell Pittsburgh

Crowdsourcing and visualizing pollution odors

https://smellpgh.org



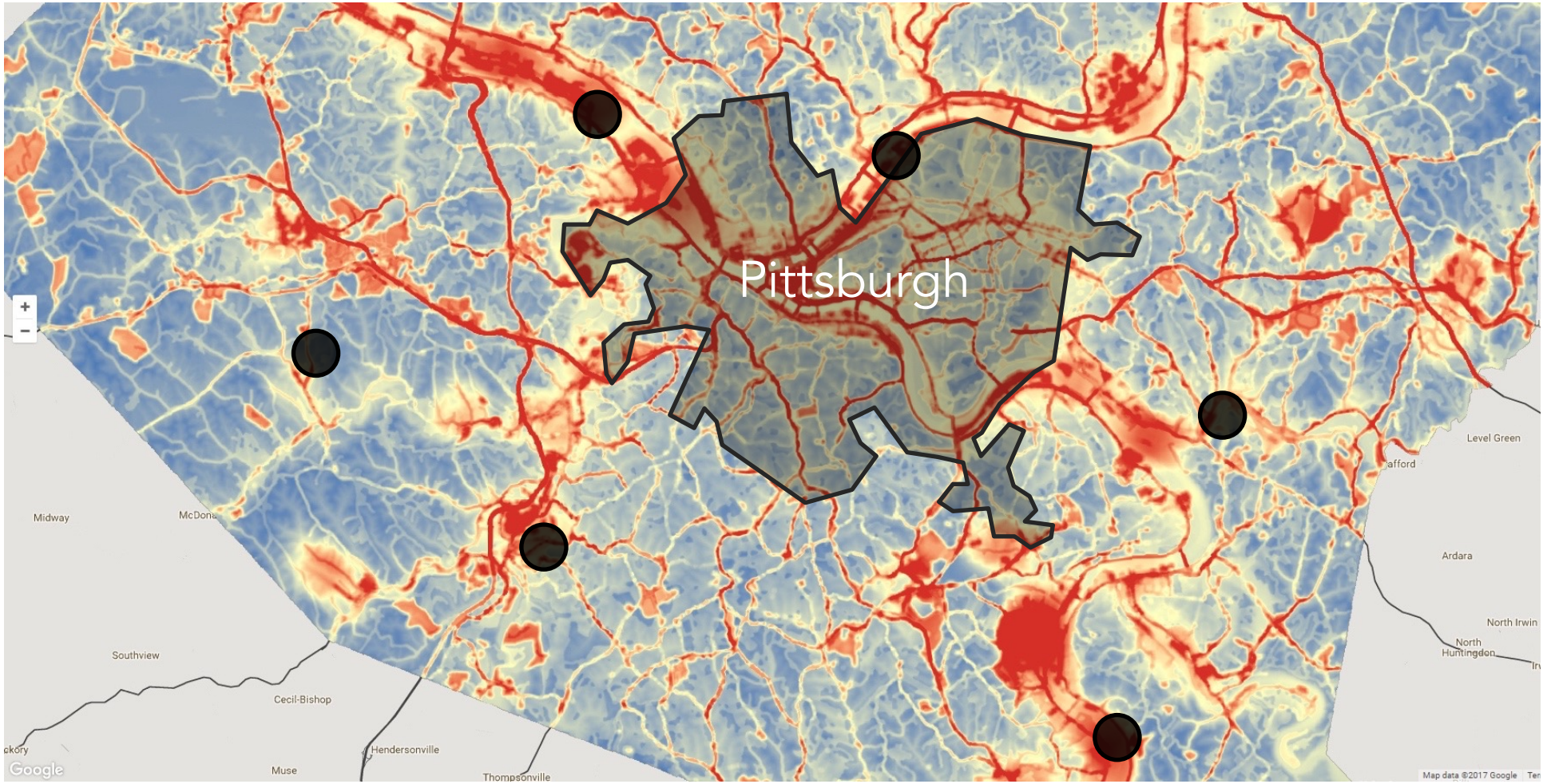


The prior approach that asks citizens to report odor complaints post hoc via forms or phone calls suffers from:

- poor data quality
- non-transparency

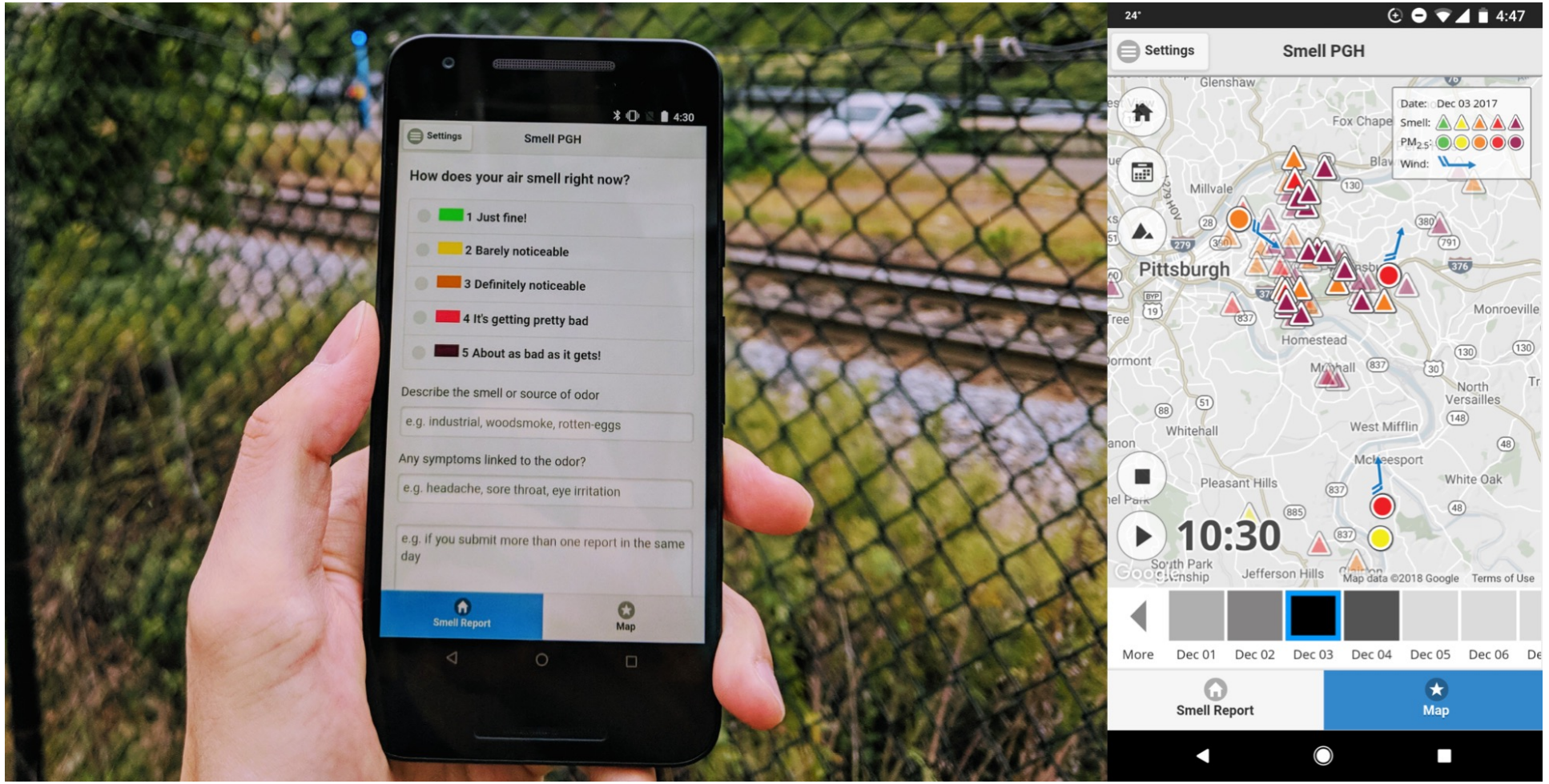
The odor reporting form -- https://www.alleghenycounty.us/Health-Department/Programs/Air-Quality/Report-an-Air-Quality-Complaint-Form.aspx

How can we effectively collect the smell experiences on a city-wide scale with more than 300,000 residents and many pollution sources over many years?



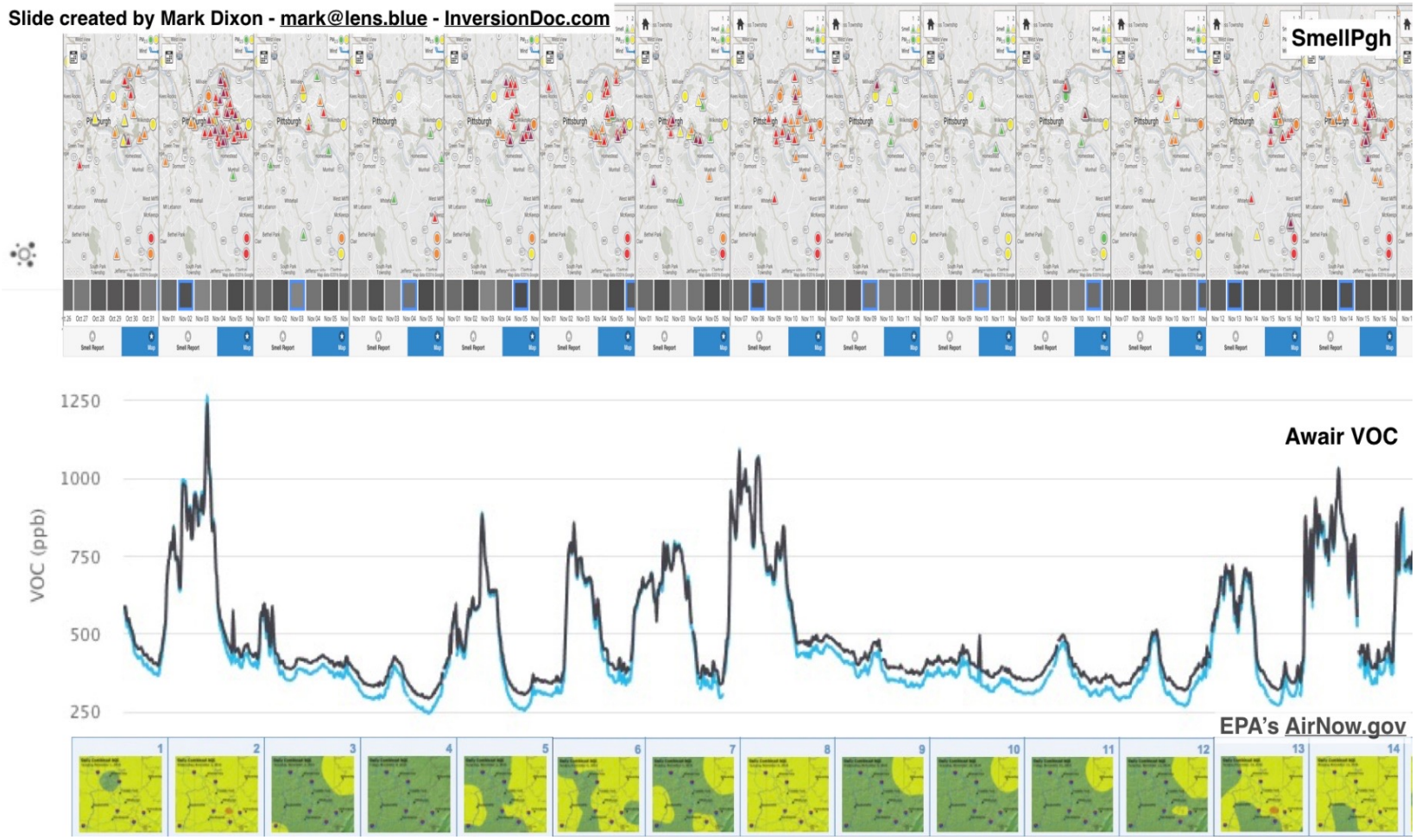
Pittsburgh pollution map -- https://breatheproject.org/pollution-map/

Smell Pittsburgh enables communities to collect data on a large scale. Also, visualizing multi-modal data in real-time can help communities understand local concerns.



Hsu, Y. C., et al. (2020). Smell Pittsburgh: Engaging Community Citizen Science for Air Quality. ACM TiiS.

Community members plot smell reports with self-operated VOC (volatile organic compounds) sensors to find correlations and inspect how pollution impacts them.



Decision-makers in the local health department mentioned that "Every aspect of the activity and operation of these coke plants will have a more stringent standard applied."

Table 1: Distribution of Smell Reports

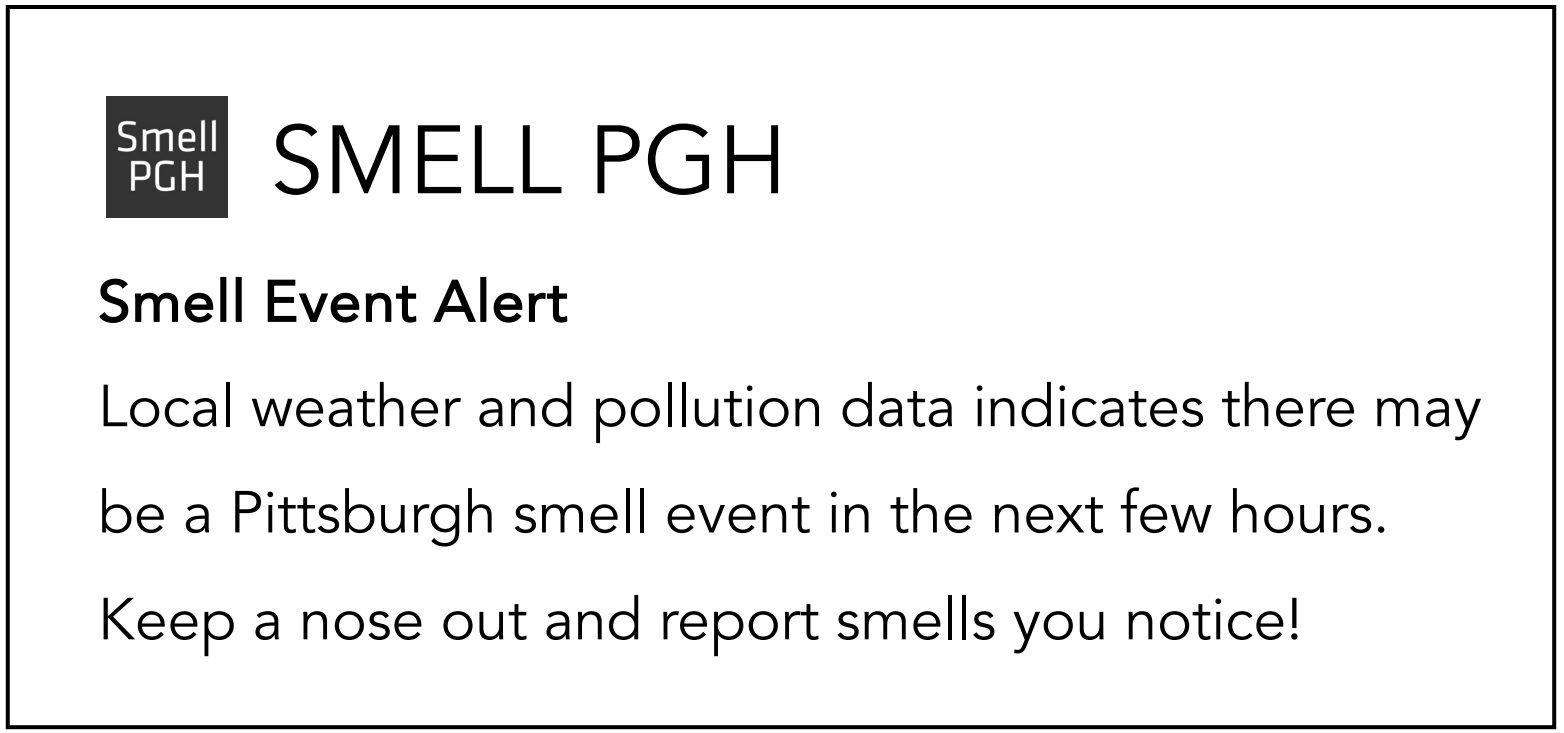
Smell Rating	Description	2022	2021	2020	2019	2018	2017
1	Just fine!	333 (3.6%)	707 (5.7%)	1,565 (8.2%)	1,711 (9.5%)	1,199 (13.0%)	1,658 (20.4%)
2	Barely noticeable	287 (3.1%)	447 (3.6%)	921 (4.8%)	798 (4.4%)	497 (5.4%)	665 (8.2%)
3	Definitely noticeable	1,922 (20.8%)	2,902 (23.3%)	4,436 (23.3%)	4,305 (23.9%)	2,649 (28.8%)	2,246 (27.7%)
4	It's getting pretty bad	3,185 (34.5%)	4,258 (34.2%)	6,014 (31.6%)	5,805 (32.3%)	2,932 (31.9%)	2,171 (26.8%)
5	About as bad as it gets!	3,506 (38.0%)	4,126 (33.2%)	6,082 (32.0%)	5,358 (29.8%)	1,918 (20.9%)	1,372 (16.9%)
Sum		9,233	12,440	19,019	17,977	9,195	8,112

Table 2: User Engagement with The Smell PGH App

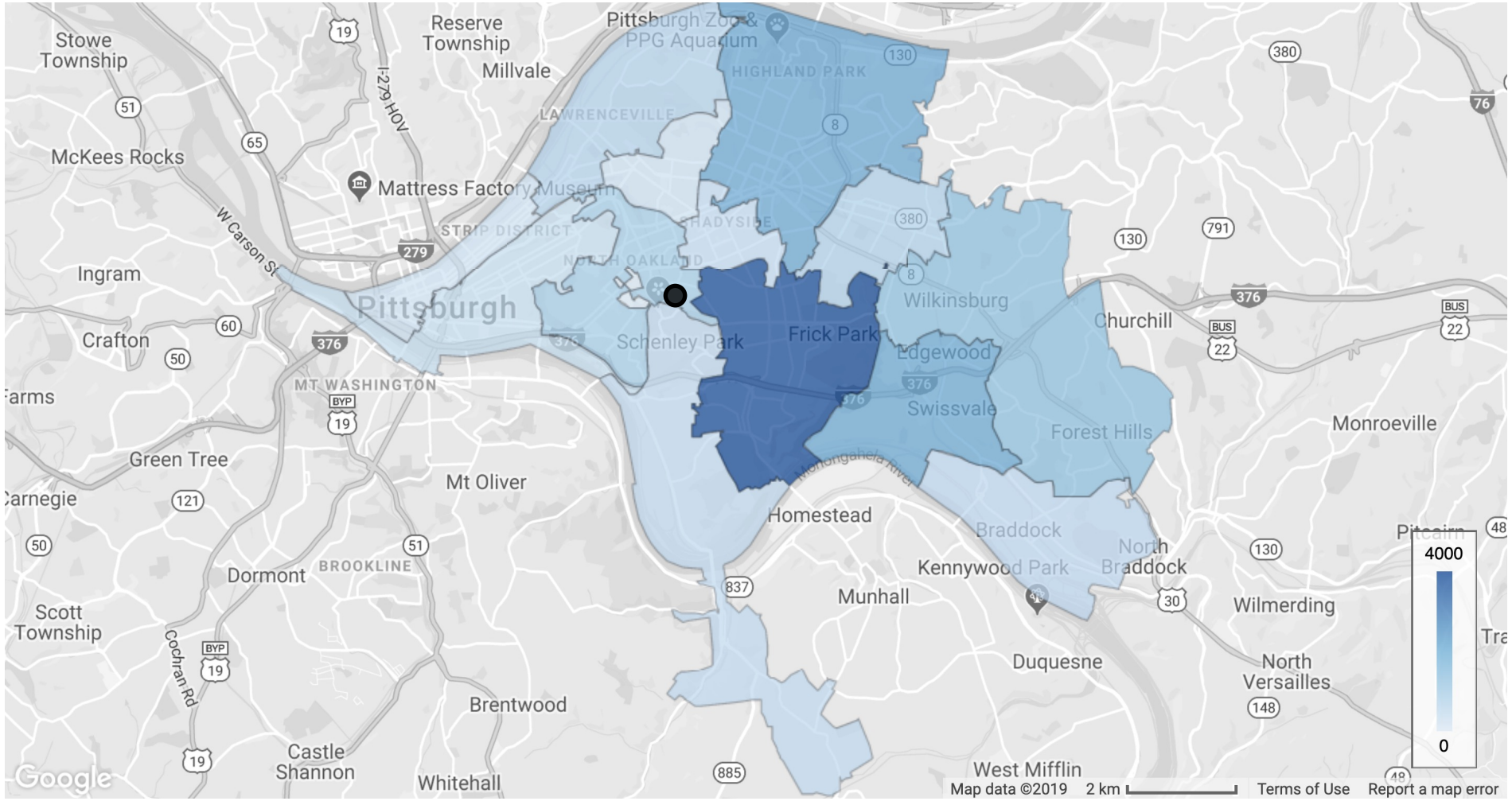
Number of Unique Users	2022	2021	2020	2019	2018	2017
Submitted Reports	1,242 (37.0%)	1,804 (41.5%)	2,688 (46.8%)	3,274 (50.9%)	1,769 (66.9%)	1,308 (58.4%)
Used the Map	3,054 (90.9%)	3,919 (90.2%)	5,227 (91.0%)	5,708 (88.8%)	2,248 (85.0%)	1,949 (87.0%)
Participated (N)	3,358	4,347	5,743	6,429	2,645	2,239

Is smell data useful in predicting local air pollution events and identifying patterns?

Smell Pittsburgh predicts upcoming smell events (based on the collected reports) and send push notifications to inform users and encourage engagement.



A geographic region in Pittsburgh is manually selected when predicting the smell events. The black dot is Carnegie Mellon University.



Number of smell reports aggregated by zip codes -- https://smellpgh.org/analysis#figure9

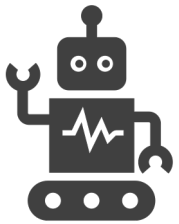
We use a Random Forest (a machine learning model) to predict smell events from air quality data (obtained from government-operated sensor stations).

O_3: 26 ppb	CO: 127 ppb
H_2S: 0 ppb	$PM_{2.5}$: 9 µg/m^3
Wind: 17 deg	…

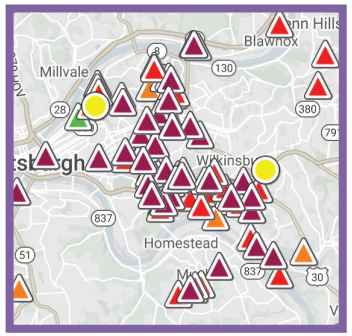
Observation 1

O_3: 1 ppb	CO: 1038 ppb
H_2S: 9 ppb	$PM_{2.5}$: 23 µg/m^3
Wind: 213 deg	…

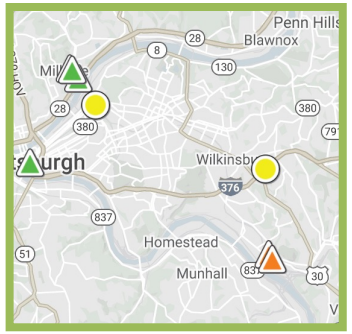
Observation 2



Machine Learning

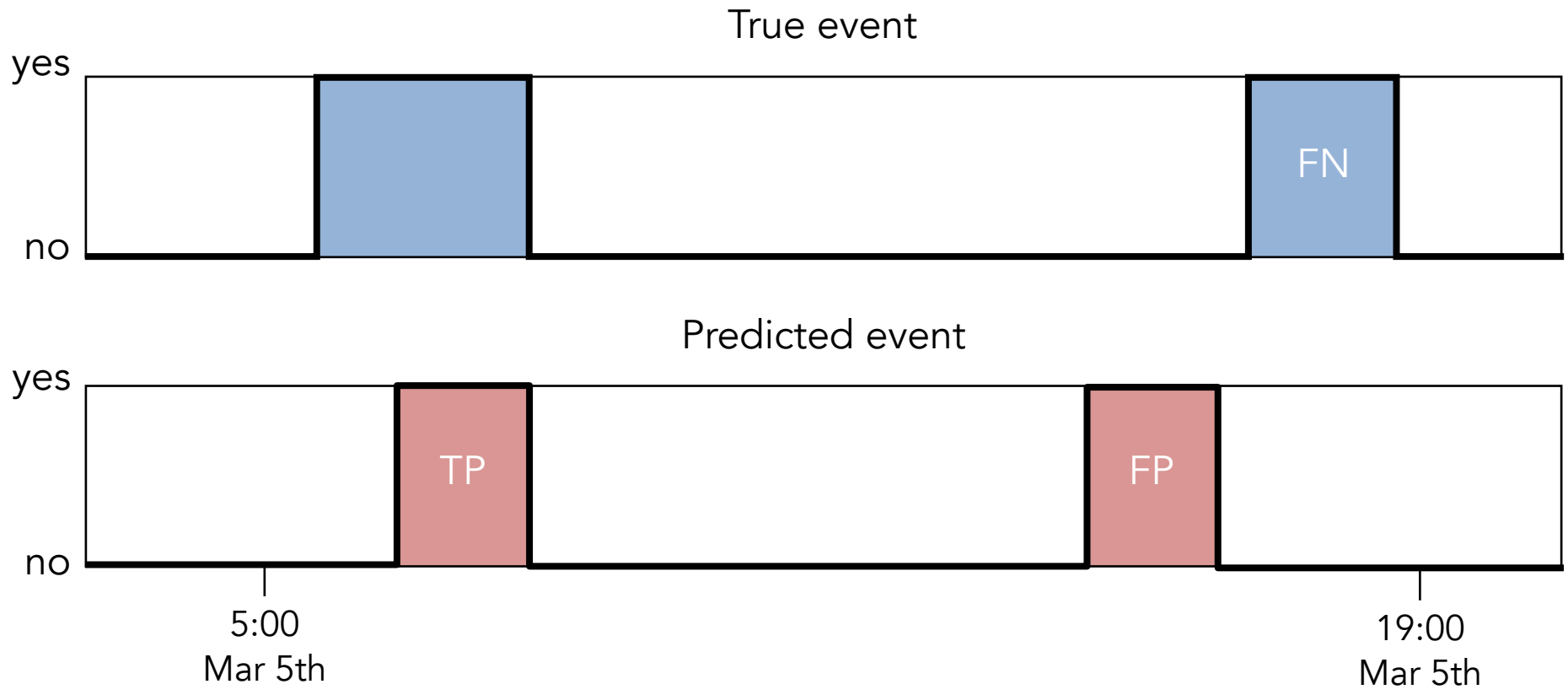


Has Event

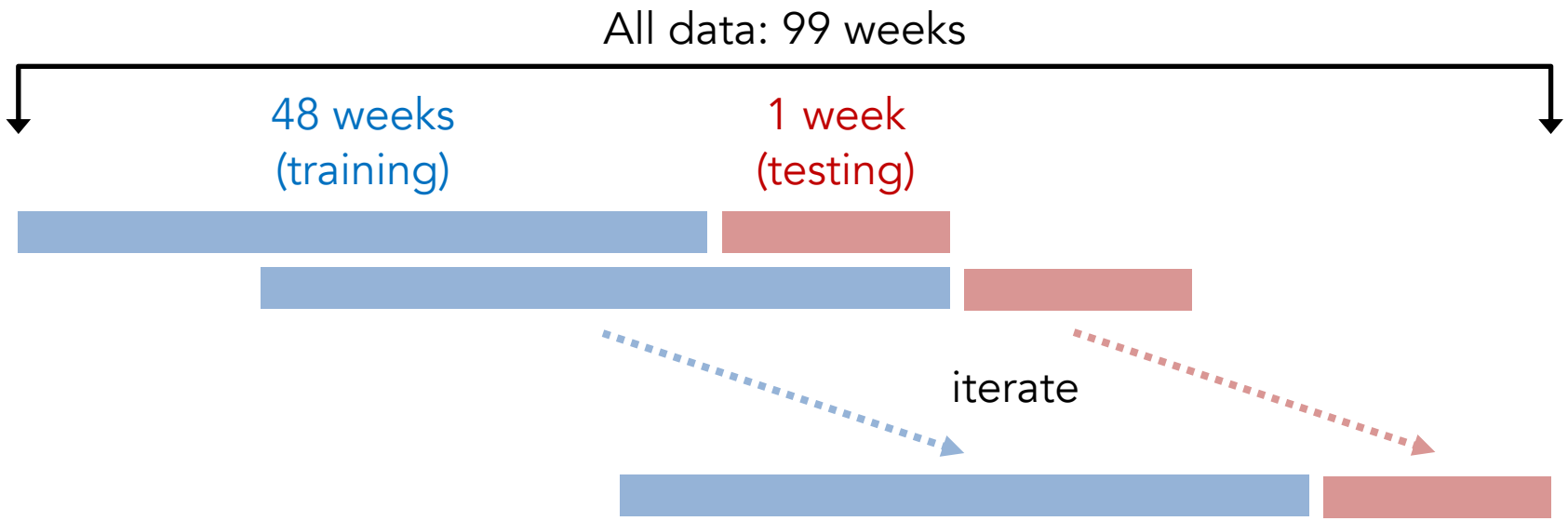


No Event

To evaluate models, we first compute true positives (TP), false positives (FP), and false negatives (FN) for smell events.

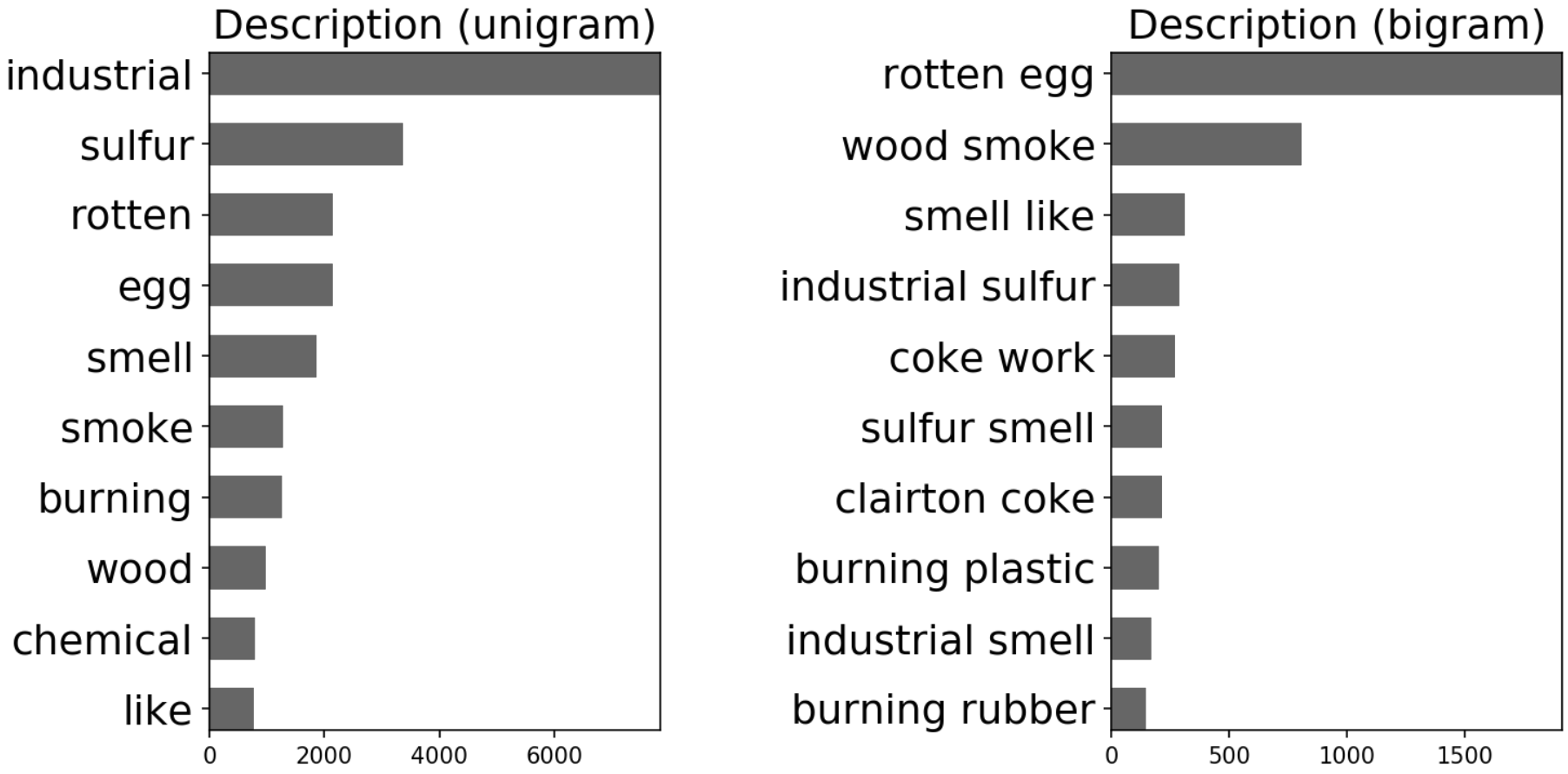


We apply time series cross-validation of several pairs of training and testing sets to evaluate the model performance.



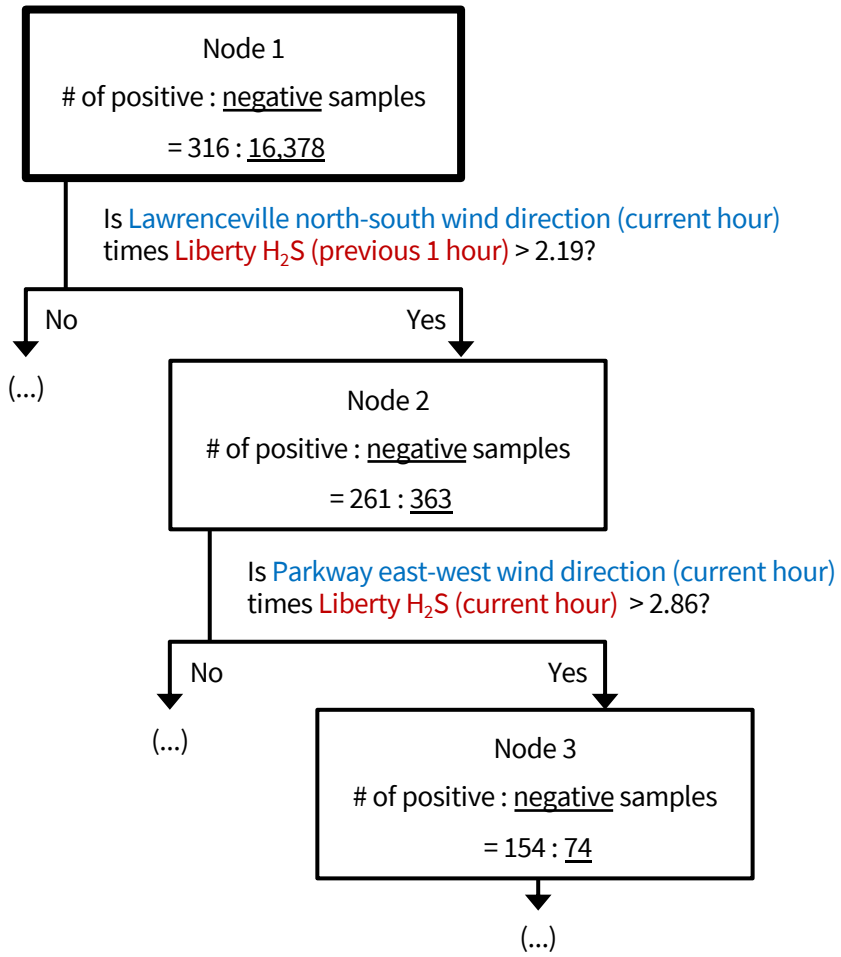
	Precision	Recall	F-score
Our best model	0.87±0.01	0.59±0.01	0.70±0.01
Always yes	0.2	1	0.33

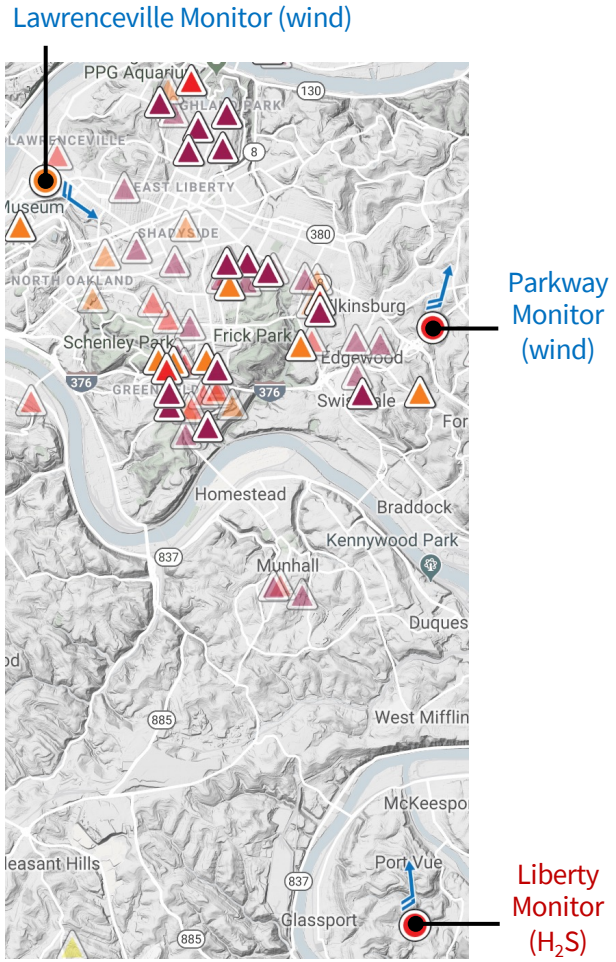
High-frequency words and phrases in smell reports mostly describe industrial pollution odors, like hydrogen sulfide.



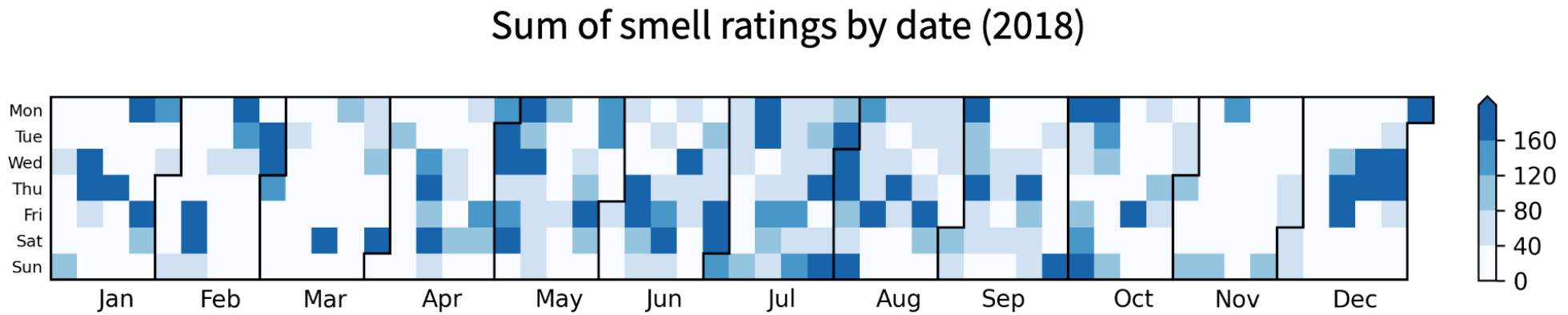
Content analysis of smell reports -- https://smellpgh.org/analysis#figure11

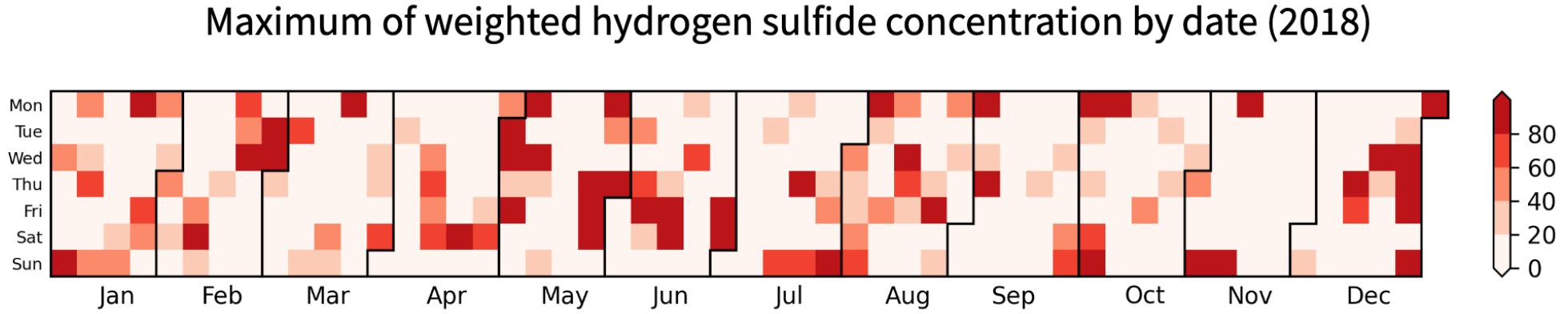
We also use Decision Tree (a machine learning model) to explain about 30% of the smell events, which is a joint effect of wind information and hydrogen sulfide.



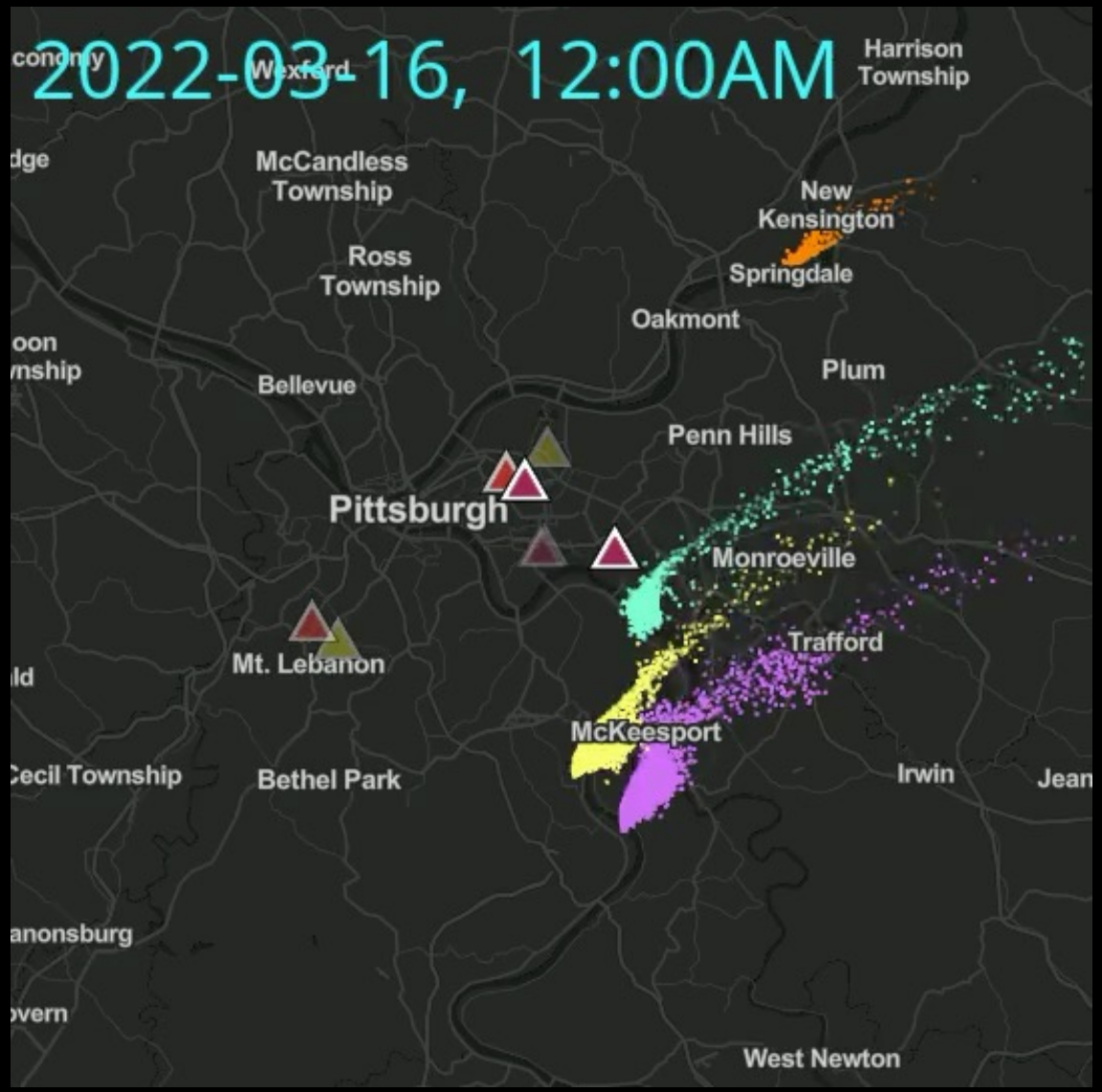


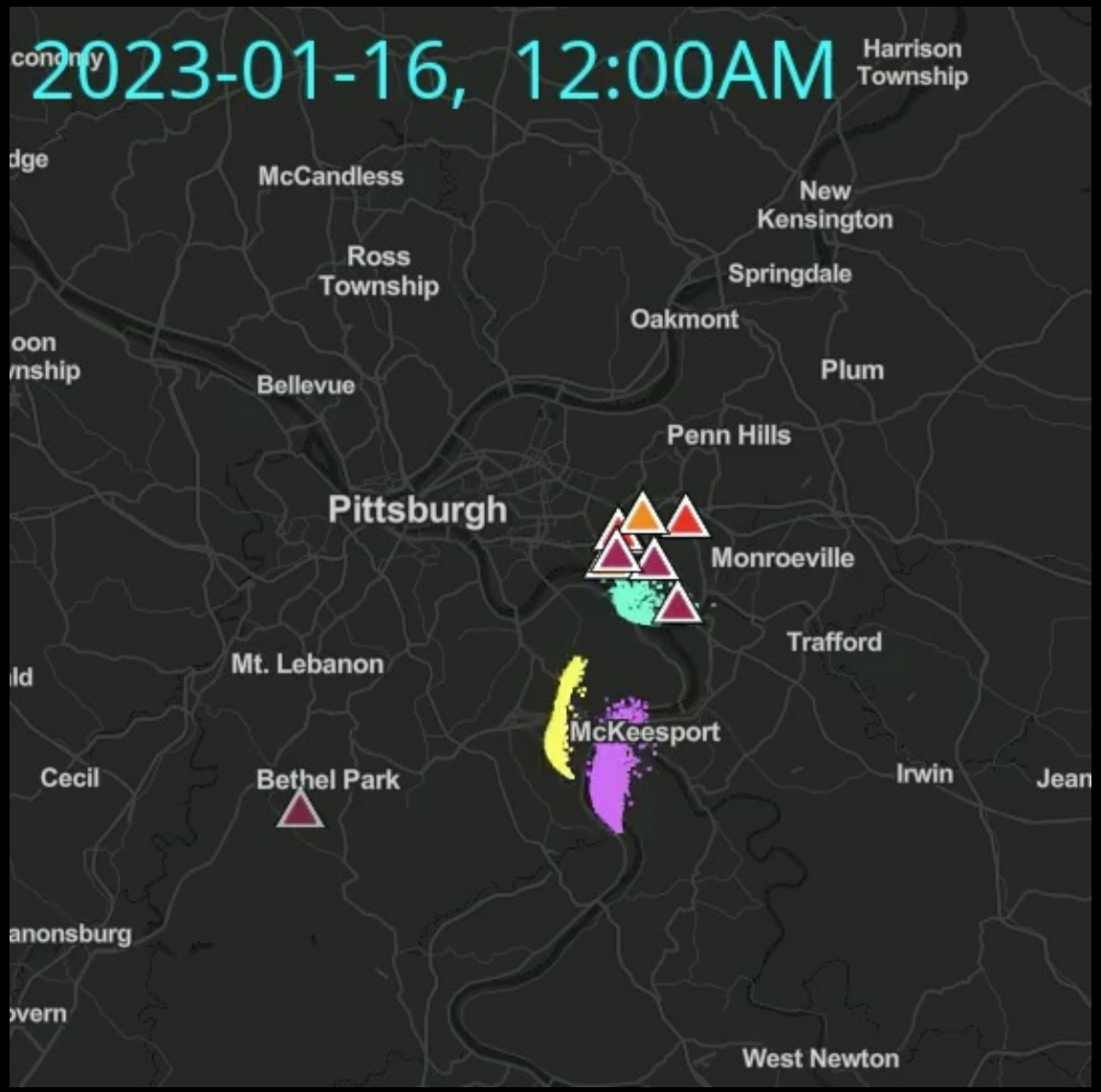
We further compute and visualize the relationship between the sum of smell ratings and the maximum concentration of weighted hydrogen sulfide for each day.



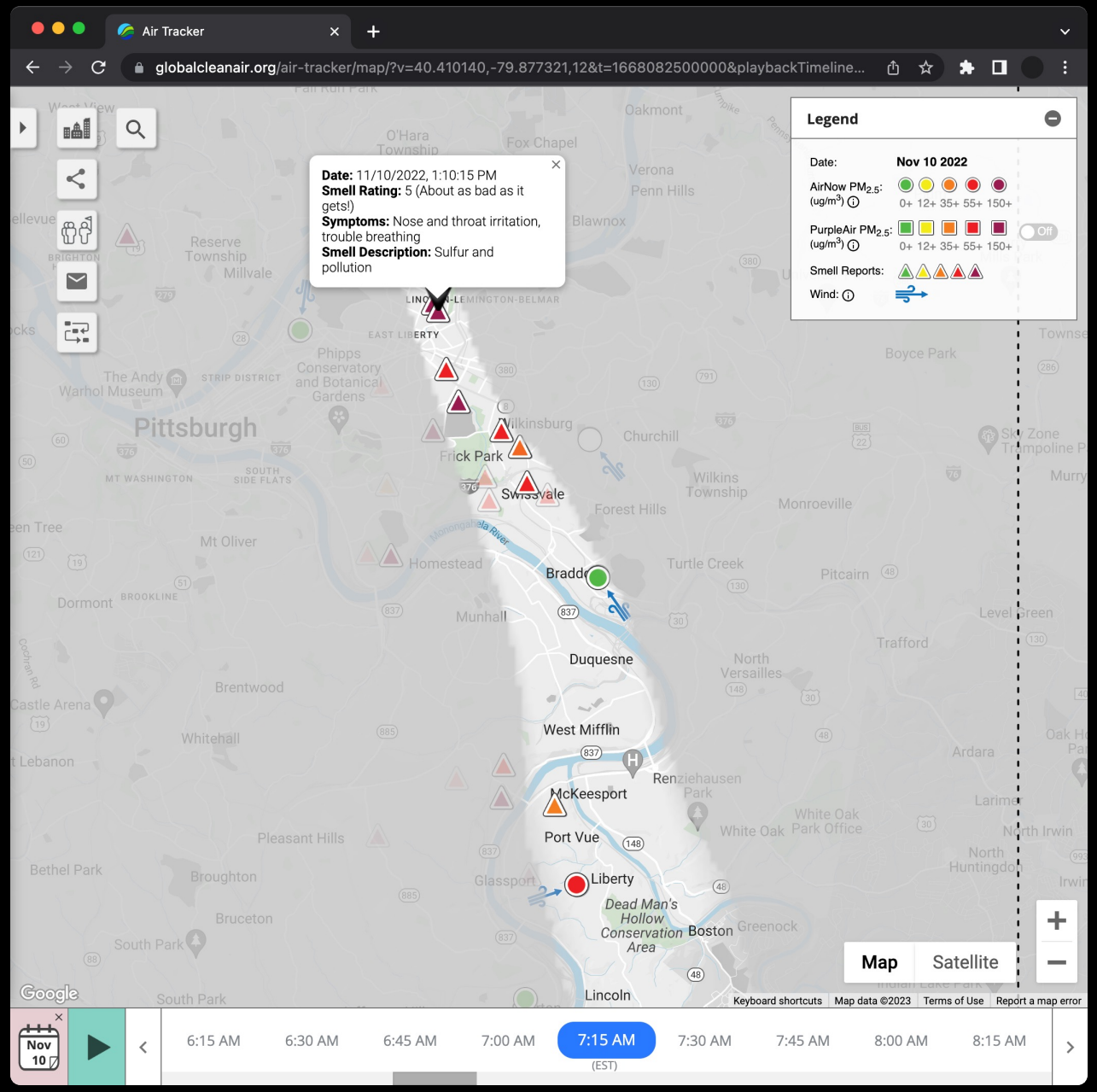


Relationship between smell reports and hydrogen sulfide -- https://smellpgh.org/analysis#figure14





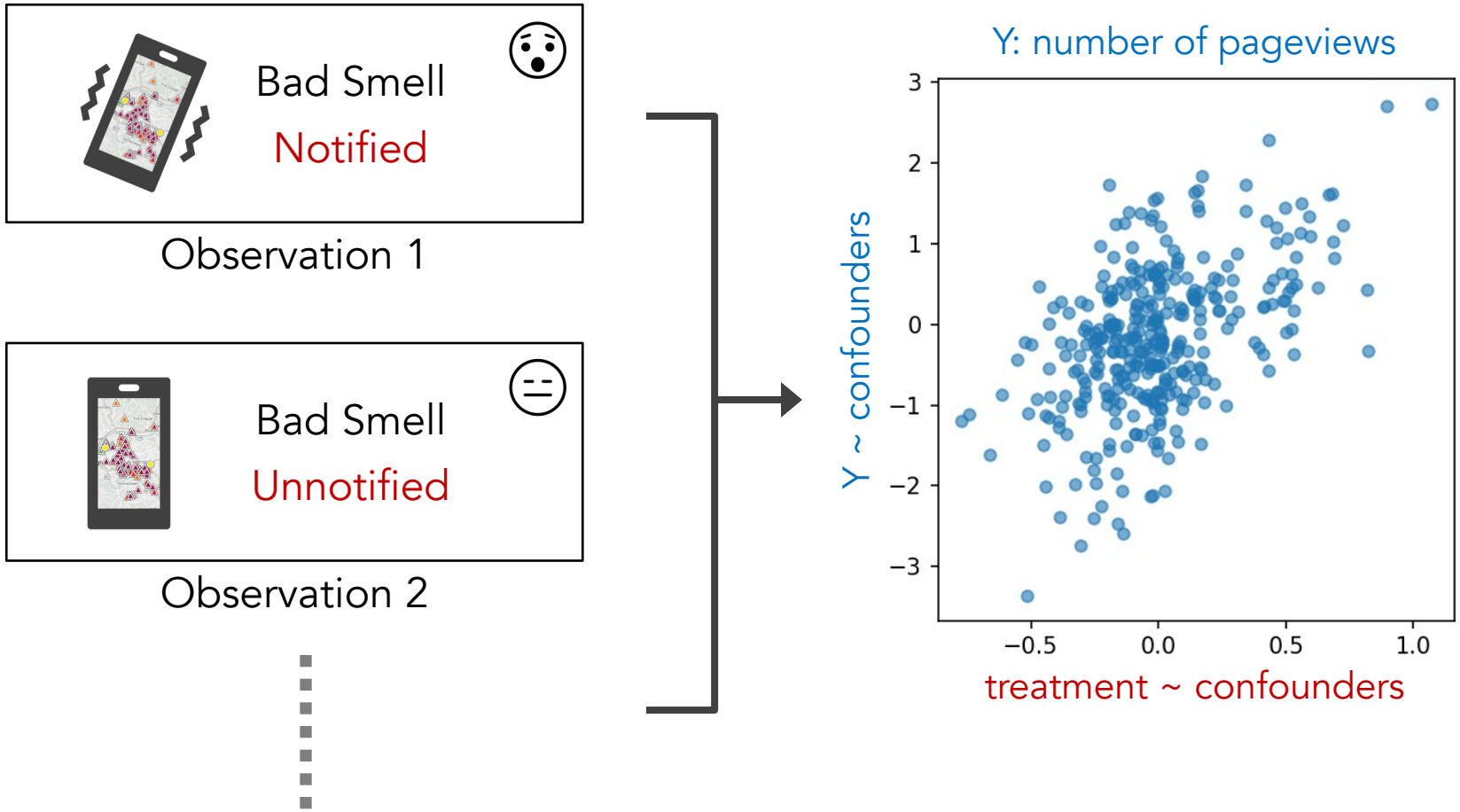
Visualize how pollution emissions can align with smell reports -- https://plumepgh.org/?date=2022-03-16



Track potential air pollution sources -- https://globalcleanair.org/air-tracker/map/

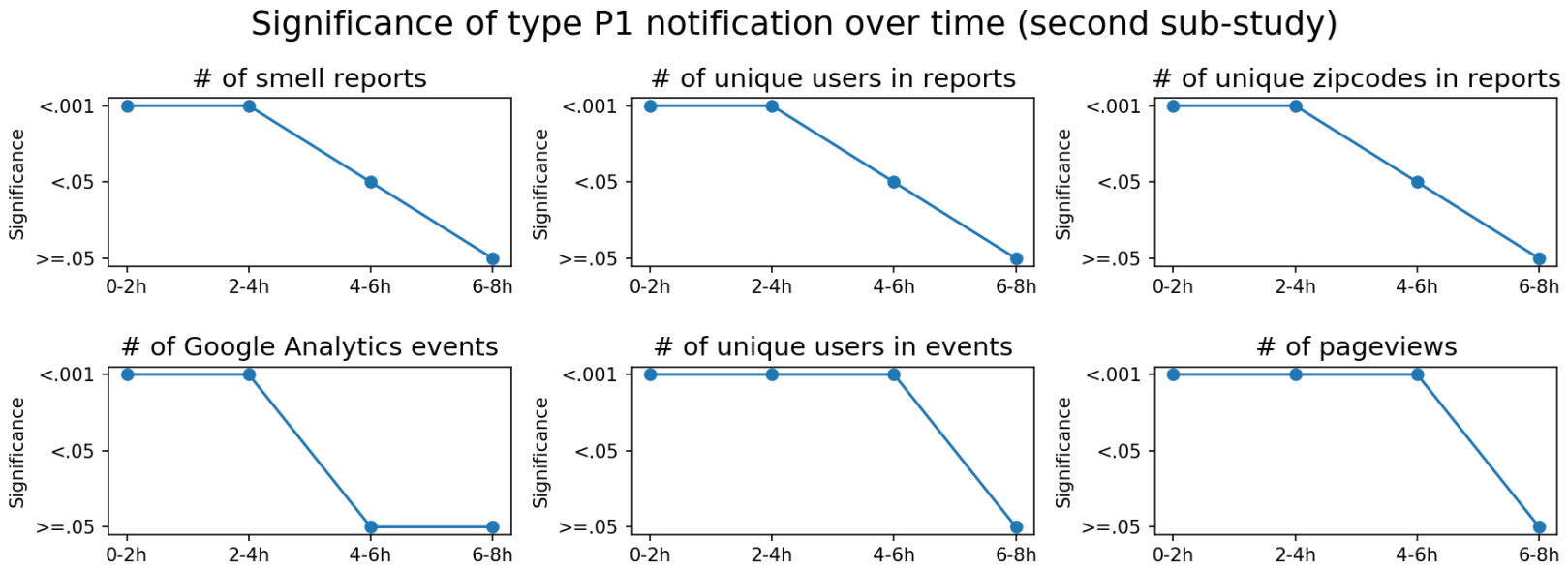
Does sending predictive push notifications of bad smell events affect user engagement?

Regression analysis shows notifying users (treatment) is related to user engagement increase after confounders adjustment.



After four hours, the coefficient β_1 of the treatment factor X_1 becomes statistically insignificant using Wald test. The null hypothesis is that the coefficient β_1 is zero. A low p-value ($p < .05$) indicates that changes in X_1 are related to changes in Y.

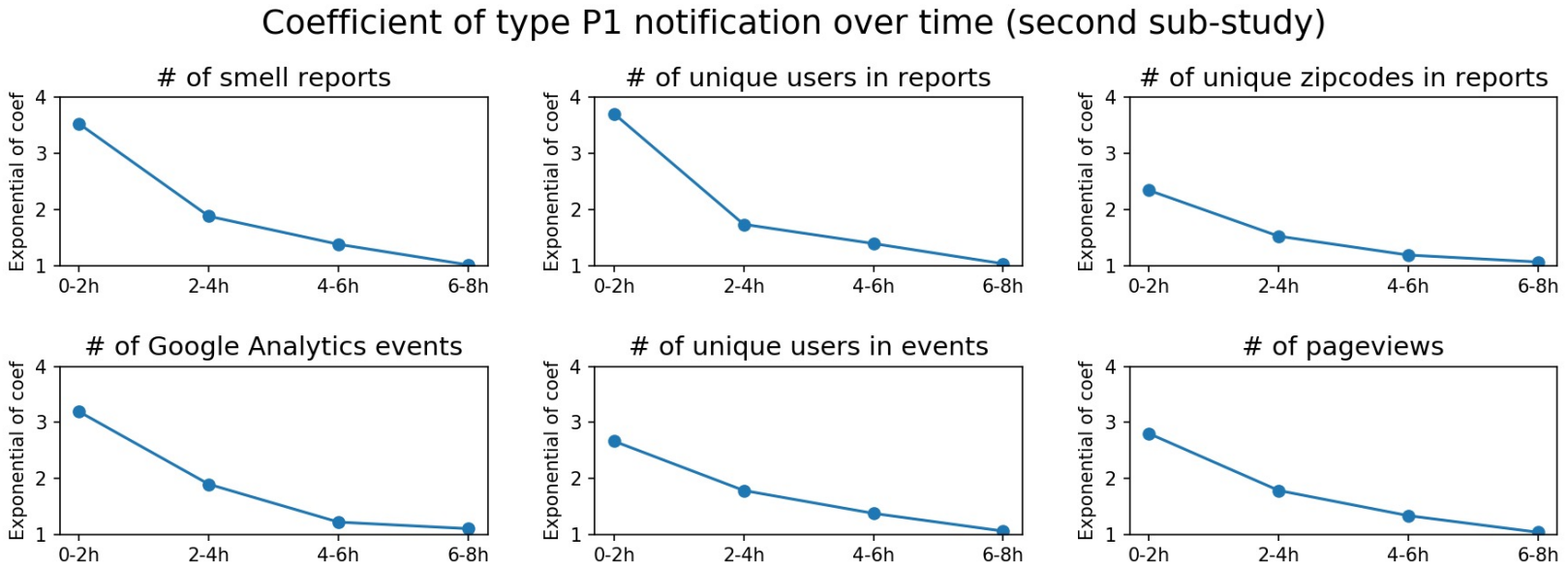
$$g\big(E(Y|X)\big) = \beta^T X = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{m-1} X_{m-1}$$



After four hours, the magnitude of the effect of sending the predictive notification drops to near 1 (i.e., no effect). Notation $g(\cdot)$ means the natural log function, $E(\cdot)$ means the expected value, $\tilde{Y}$ means the increased response (e.g., page views).

$$g\big(E(Y|X)\big) = \beta^T X = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{m-1} X_{m-1}$$

$$\tilde{Y} = \exp\Big(\ldots + \beta_k(X_k + 1) + \ldots\Big) = \exp(\beta_k) \cdot \exp\Big(\ldots + \beta_k X_k + \ldots\Big) = \exp(\beta_k) \cdot Y$$



Project RISE

Recognizing **I**ndustrial **S**moke **E**missions

https://smellpgh.org

Proceedings of the AAAI Conference on Artificial Intelligence

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Project RISE: Recognizing Industrial Smoke Emissions

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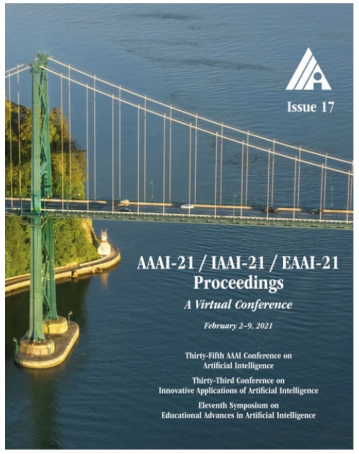
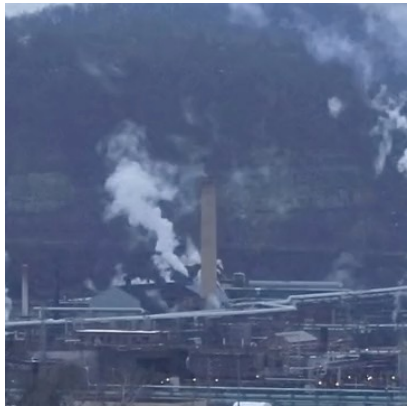


This project aim to recognize industrial smoke emissions automatically on the videos obtained from a camera monitoring network.

http://smoke.createlab.org

Has smoke

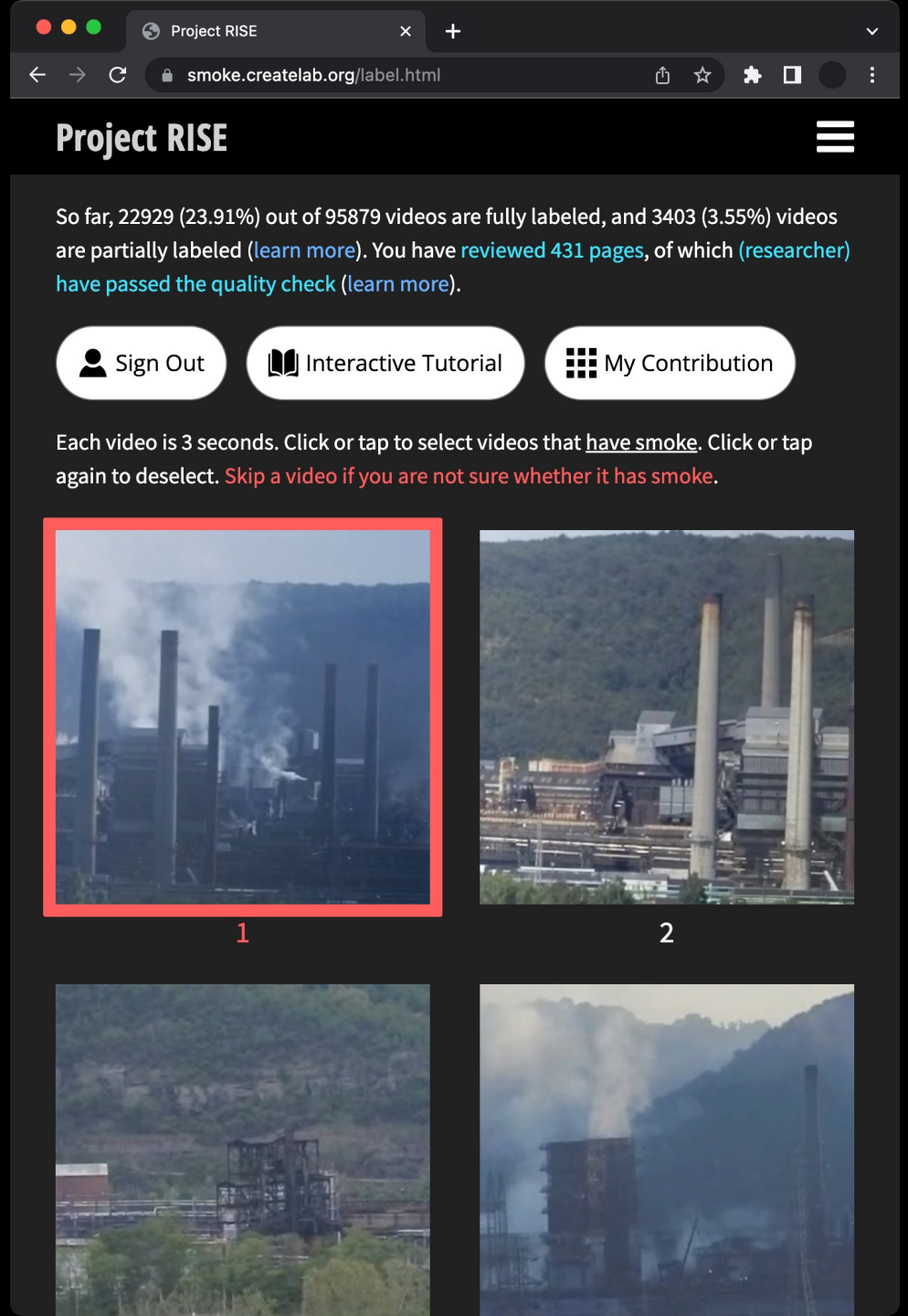
Has smoke



No smoke

Has smoke

We invite communities to annotate if the videos have industrial smoke emissions using a web-based tool.







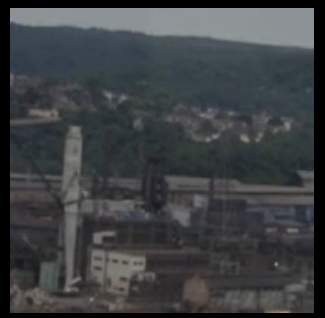








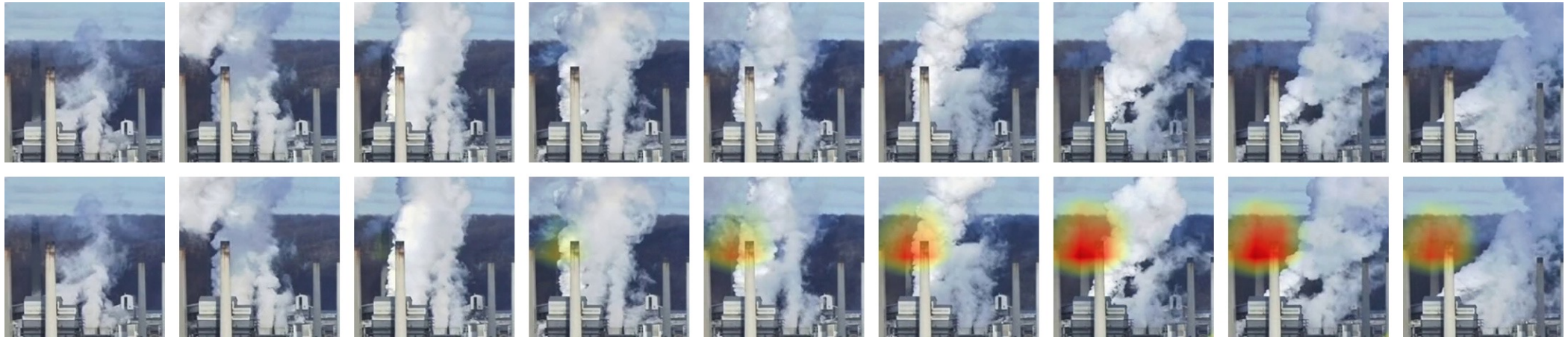






19
Views


The data enables Computer Vision applications using deep neural networks, and our baseline model (I3D+Timeception) can find emissions with reasonable performance.



	Precision*	Recall*	F-score*
Our best I3D model	0.86	0.79	0.82
Always yes	0.41	1	0.58

*Average of the metric for all data splits (training, validation, and test)

Hsu, Y. C., et al. (2021). Project RISE: Recognizing Industrial Smoke Emissions. AAAI.

Project RISE

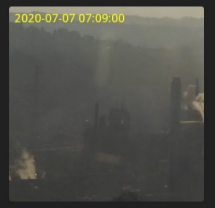
smoke.createlab.org/event.html?date=2020-07-07&...

Project RISE

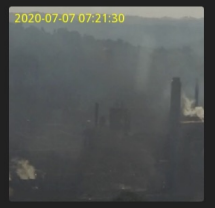
This page shows videos that the Artificial Intelligence model thinks have hazardous smoke emissions. The following image shows the camera view ID and location.

The timeline below shows smoke events (learn more), where the x-axis means hour of day. To show videos, select a date 2020-07-07 and compare the events with Smell Pittsburgh. Also, select a camera ID 2 and view ID all to filter videos.

07/07/2020, 06:48
Duration: 4.7 min
View ID: 2-3
Link to Viewer

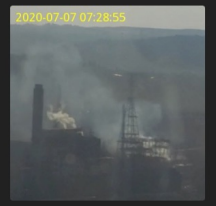


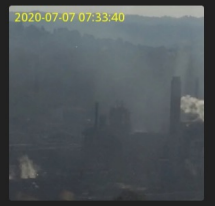
07/07/2020, 07:08
Duration: 7.8 min
View ID: 2-3
Link to Viewer

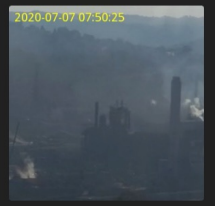


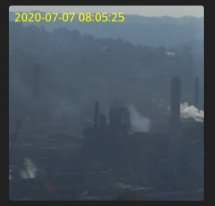
07/07/2020, 07:19
Duration: 3.3 min
View ID: 2-3
Link to Viewer

07/07/2020, 07:25
Duration: 6.2 min
View ID: 2-3
Link to Viewer









07/07/2020, 07:27
07/07/2020, 07:32
07/07/2020, 07:47
07/07/2020, 08:02

Video Gallery - Breathe Project

breatheproject.org/video-gallery/jsf/jet-engi...

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Credit: Mark Dixon

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Clairton Coke Works – Thanksgiving Day, Nov. 24, 2022

From Breathe Cam

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Edgar Thomson Brown Plume – June 17, 2020

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Metalico Scrap Metal Fire, Neville Island – April 14, 2021

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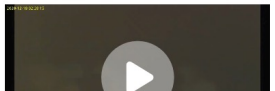

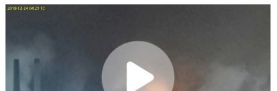

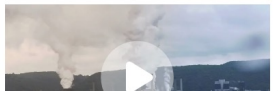

Questions?

- Yen-Chia Hsu – http://yenchiah.me
- Air Quality Monitoring – http://shenangochannel.org
- Smell Pittsburgh – https://smellpgh.org
- Project RISE – https://smoke.createlab.org