EPA United States Environmental Protection Agency

EPA Tools and Resources Webinar: Sensor Pod (SPod) – An Approach for VOC Fenceline Monitoring and Data Analysis

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Presentation Outline

The Case for NGEM 1

What is NGEM? – What can it do?

- Some industrial air pollution sources have higher emission uncertainty because they can be spatially variable and randomly occurring (e.g., fugitive leaks, malfunctions)
- These sources have the potential to create environmental and health impacts to workers and nearby populations; emissions uncertainty presents challenges for decision makers
- Emerging ***Next Generation Emission Measurement (NGEM)*** approaches can help industry, regulators, and communities:
  - Improve knowledge of emissions sources
  - Reduce emissions by quickly identifying those in need of repair
  - Assist near-source communities in understanding the air they breathe

The Case for NGEM 2

How can NGEM assist Environmental Agencies ?

NGEM can help:

- Improve emission inventory data for fugitive/stochastic emissions
- Enable new source management strategies
- Inform new regulatory and compliance approaches
- Improve exposure assessments to protect community health
- Build trust with fenceline communities through increased transparency

Goals of NGEM

Use new measurement technologies to reduce emissions, enhance worker safety, improve air quality, and support community wellbeing

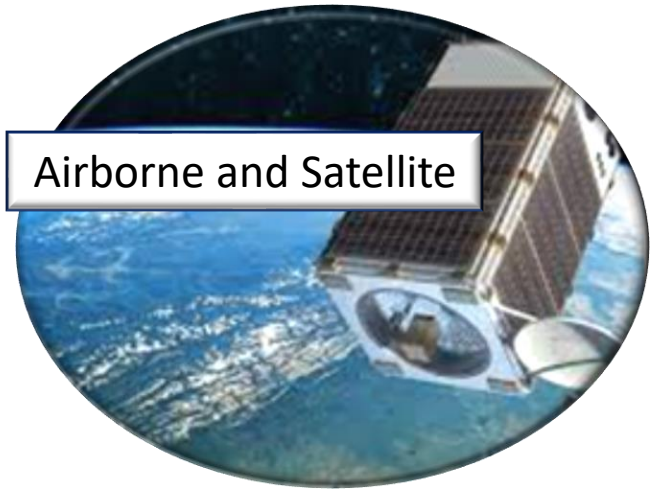
The Many Forms of NGEM

Fenceline Sensors

In-plant Sensors
Hazardous areas

Near-source Sampling

Open-path Fenceline



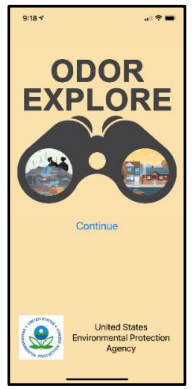
Airborne and Satellite

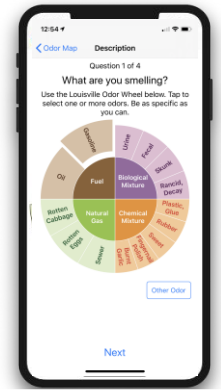
Mobile Measurements

Optical Gas Imaging

Field Instruments

Participatory Science
(EPA Odor Explore App)





Today's Focus

Regulations are Starting to use NGEM

EPA Refinery Fenceline Monitoring

Optical Gas Imaging in Oil and Gas Applications

South Coast AQMD Fenceline Air Monitoring Rule 1180

Government of Canada Regulation on release of VOCs

California Air Pollution Assembly Bill

Bay Area AQMD Petroleum Refining Emissions Tracking

Colorado Act Concerning Emission of Air Toxics

Ontario Regulation on Air Pollution and Local Air Quality

AQMD = Air Quality Monitoring District
VOCs = Volatile Organic Compounds

NGEM Approaches Vary by Distance to Source

Fenceline Sensors

Not Hazardous Area Rated

In-community Measurements

Fenceline Monitoring

Hazardous Area Rated

Emission

In-plant Leak Detection

Today's Focus

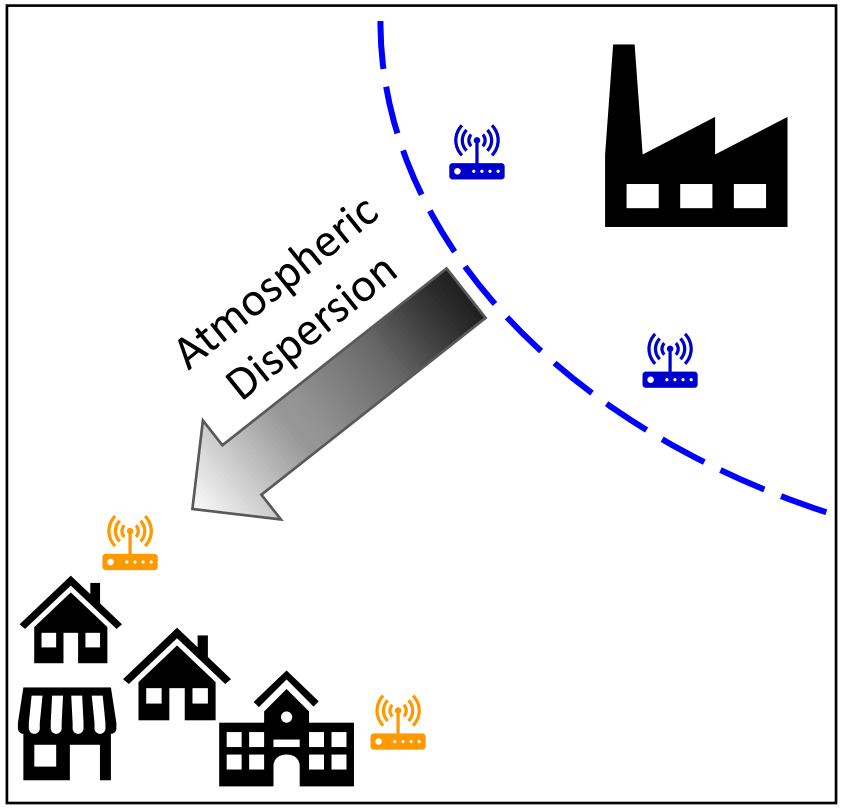
Source Emission Plumes Change with Distance

Application	Purpose	Sensor/Instrument Needs
Fenceline	Detect and characterize VOC emissions	• Fast response is important • Accuracy and sensor baseline drift not as important
Community	Quantify ambient VOC levels	• Fast response not as important • Precise and accurate measurements required; speciation helpful

VOC = Volatile Organic Compound

Fenceline

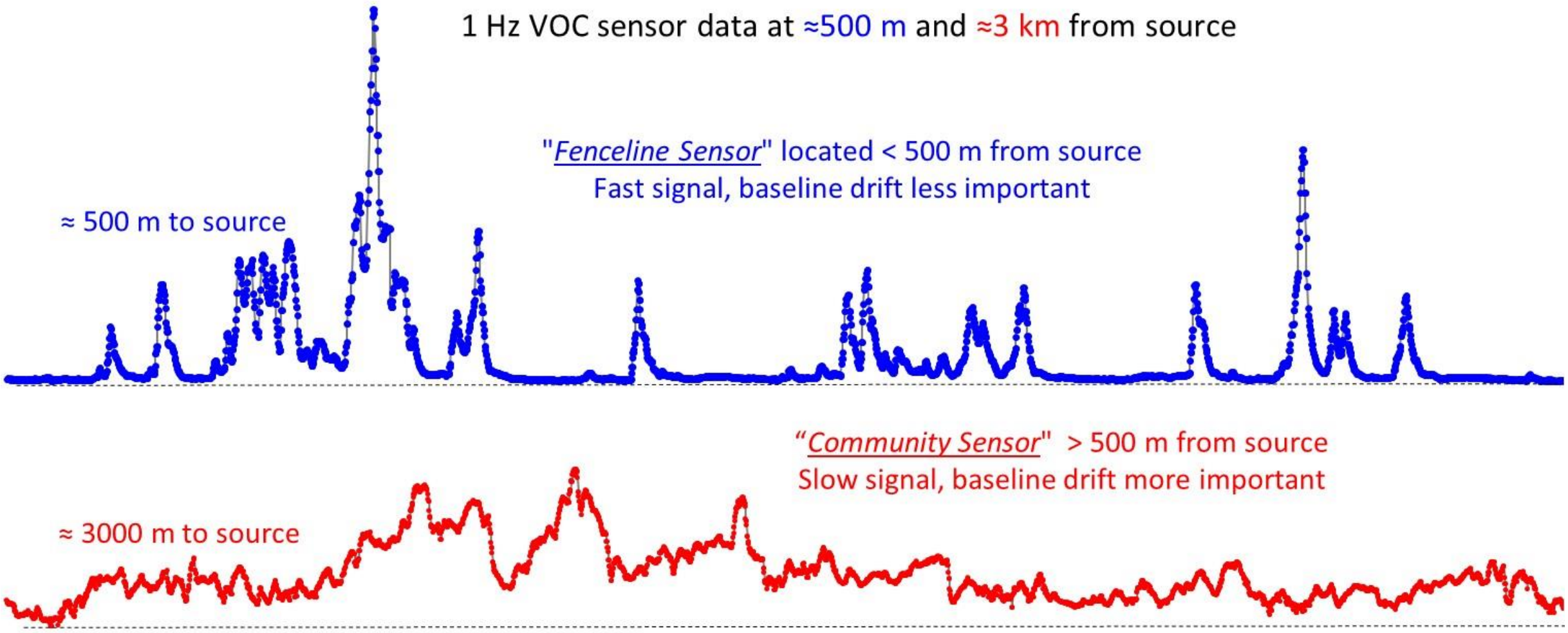
Higher, faster source signal



Community

Lower, slower source signal

Sensor Data Analysis Changes with Distance

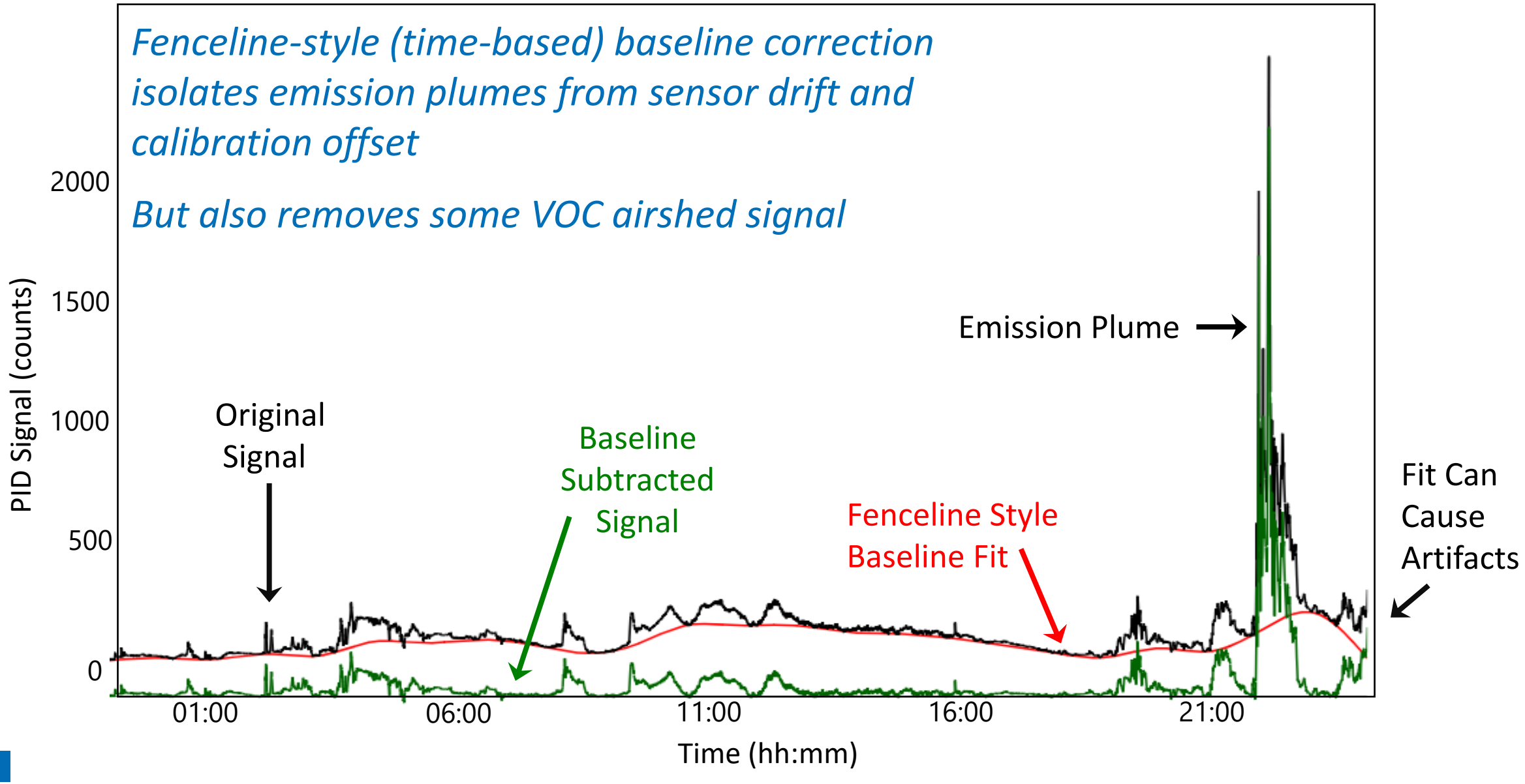


VOC = Volatile Organic Compound

Environmental Conditions Impact Baseline Drift

Adapted from: Thoma, et al. "Rubbertown next generation emissions measurement demonstration project." Int. J. Environ. Res. Public Health 16.11 (2019): 2041.

Simple Time-based Baseline Correction



SPod and Leak Detection Sensor Development

EPA United States Environmental Protection Agency

EPA Initial SPod Research

SPod Fact Sheet

In-plant Leak Detection Sensors CRADA*

EPA Prototype SPod Research

Ongoing SPod Research and Analytics

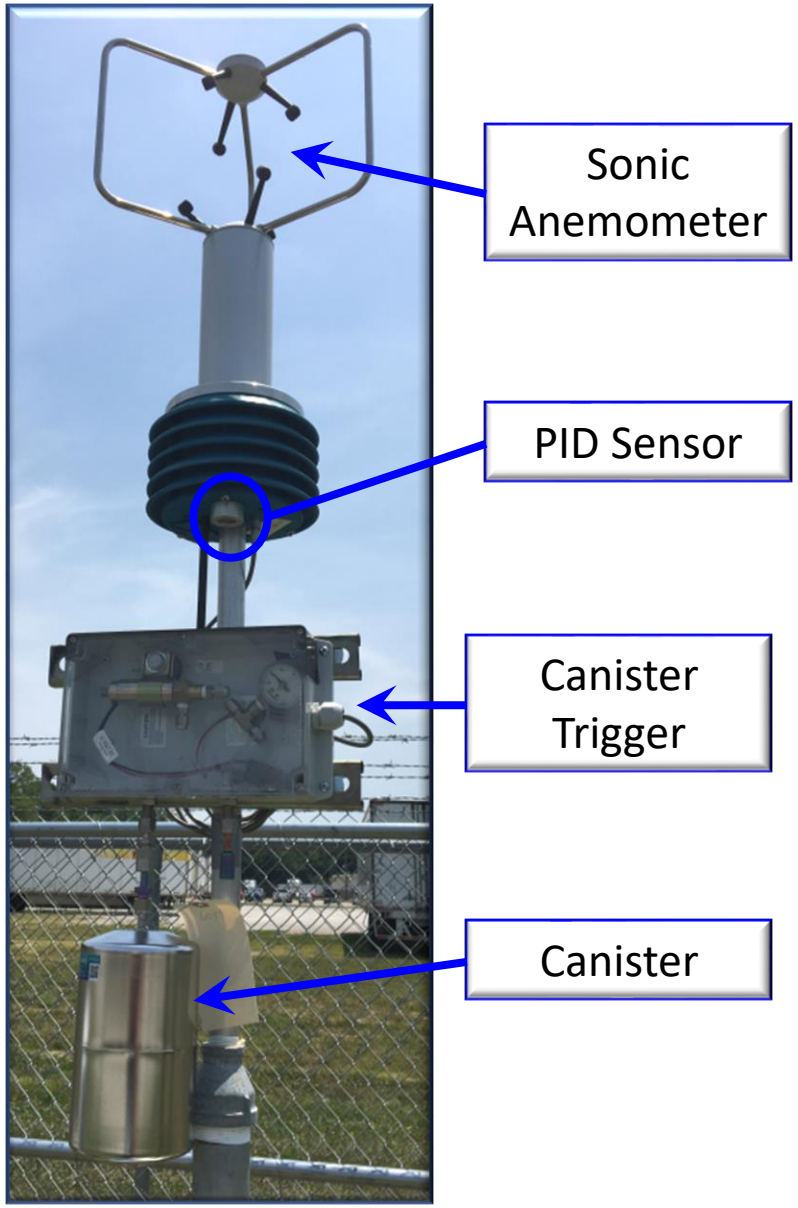
2014 2015 2016 2017 2018 2019 2020 2021 2022

Time (years)

*CRADA = Cooperative Research and Development Agreement

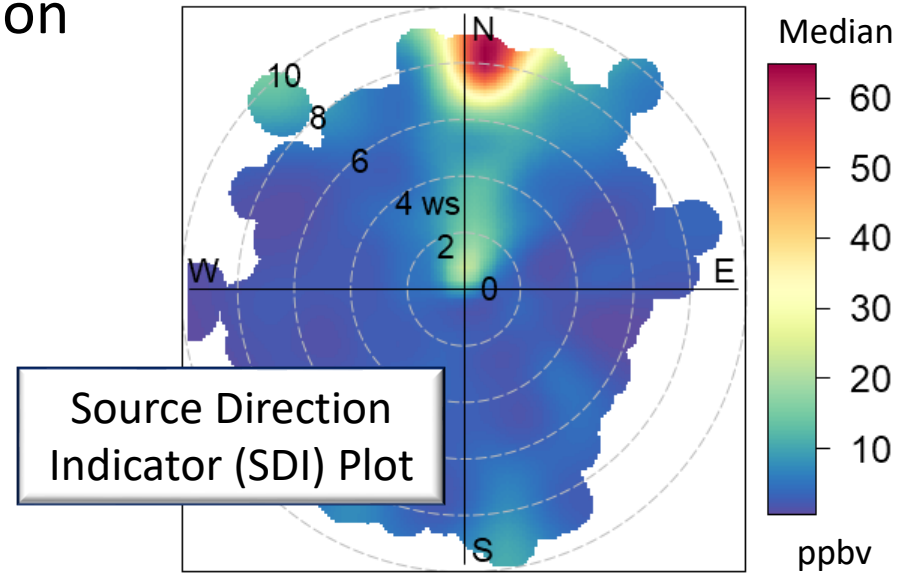
Prototype VOC Fenceline Sensor Pod (SPod)

- SPod combines 1 Hz wind measurements with non-speciated volatile organic compound (VOC) data to help detect and locate source emissions plumes
- SPod can automatically trigger a canister grab sample while in an emission plume for laboratory speciation
- EPA's prototype open-source SPod fenceline design is now being commercialized
- Current SPods use a heated 10.6 eV photoionization detector (PID) sensor element (detects select VOCs)
- Similar concepts to SPod are now available for other compounds like methane

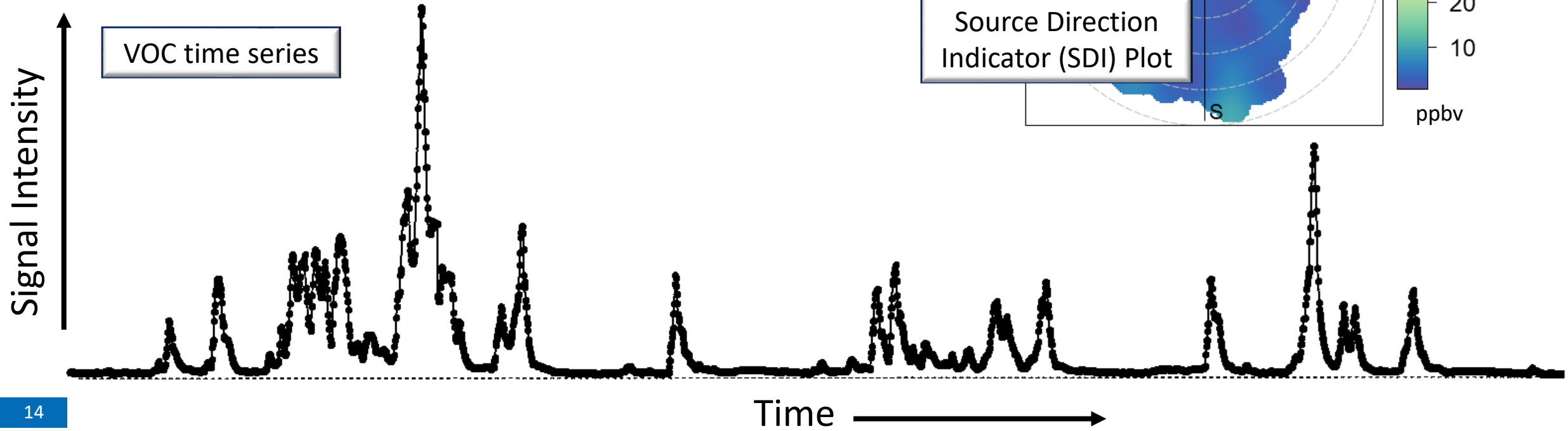


SPod VOC Emission Detection and Location

- Modulated VOC time series is caused by emission plume moving on and off the SPod
- Combine VOC and wind data to inform source location
- This source is northeast of the SPod site



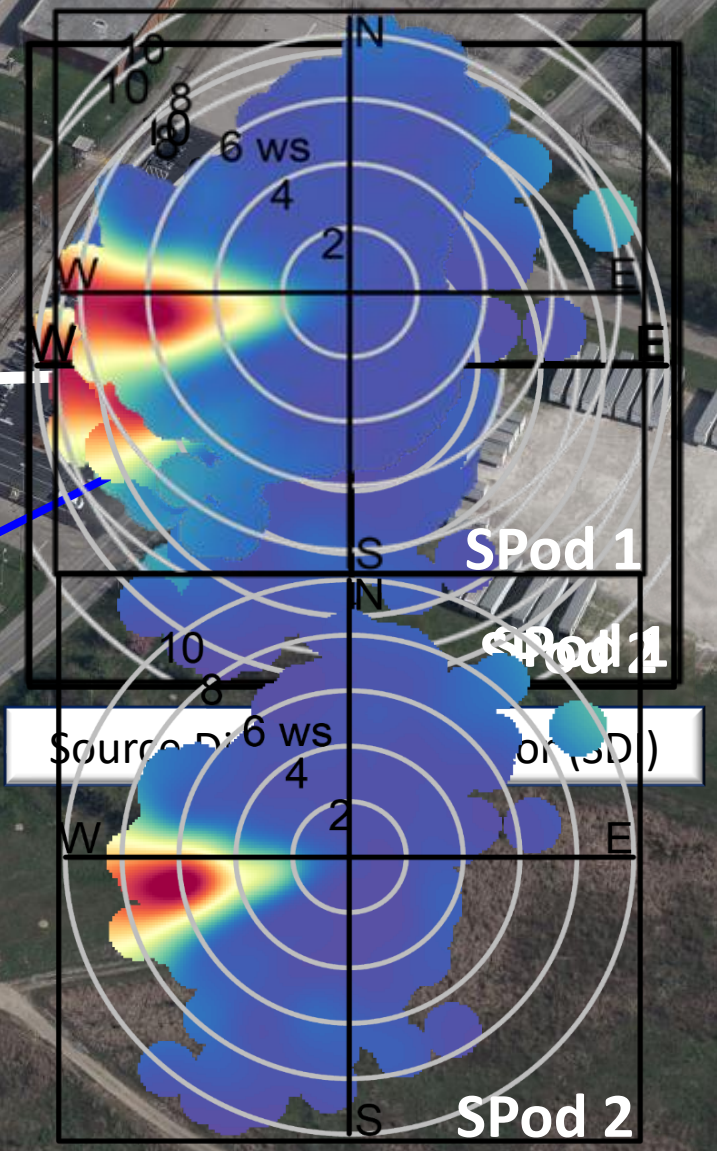
Source Direction Indicator (SDI) Plot



Rubbertown NGEM Demonstration Project

SPod Site located near a facility in west Louisville, KY

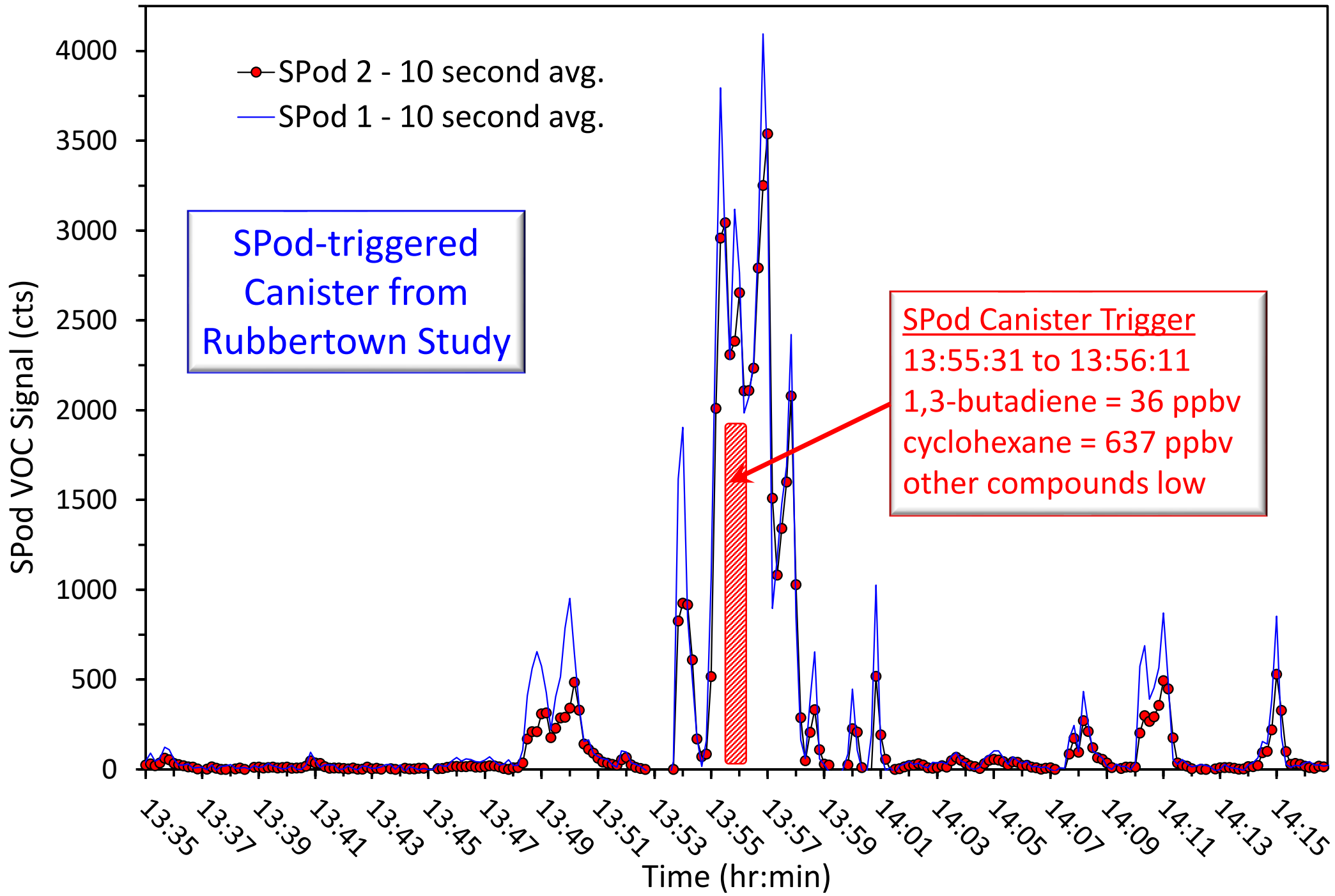
≈ 450 m



Two EPA SPods with different 10.6 PID sensors were compared over 19 months and over 200,000 time-aligned 5-minute datapoints

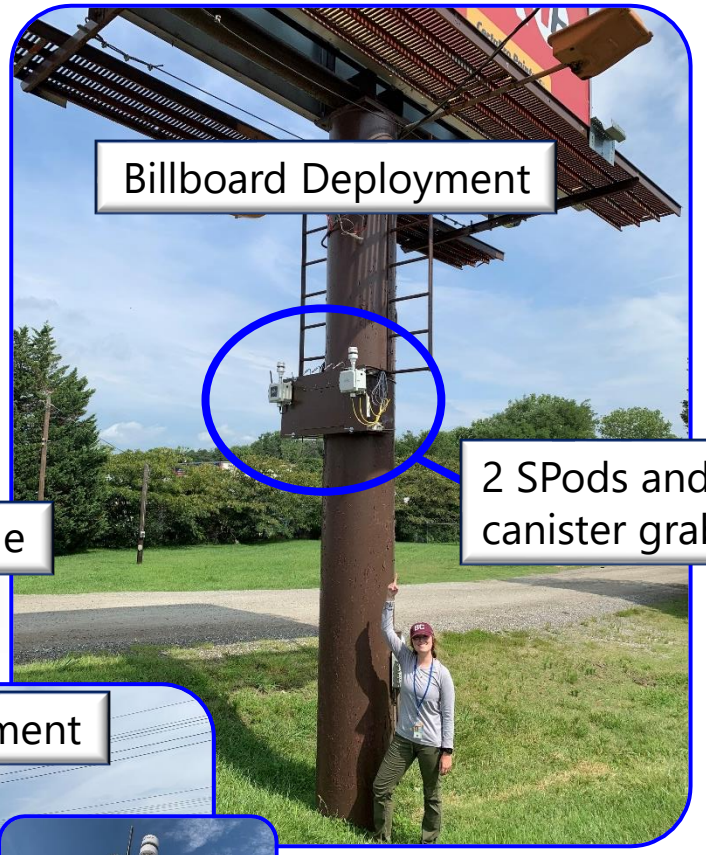
Images from: MacDonald, M.; Thoma, E.; George, I.; Duvall, R. Demonstration of VOC Fenceline Sensors and Canister Grab Sampling near Chemical Facilities in Louisville, Kentucky. *Sensors* **2022**, *22*, 3480. https://doi.org/10.3390/s22093480

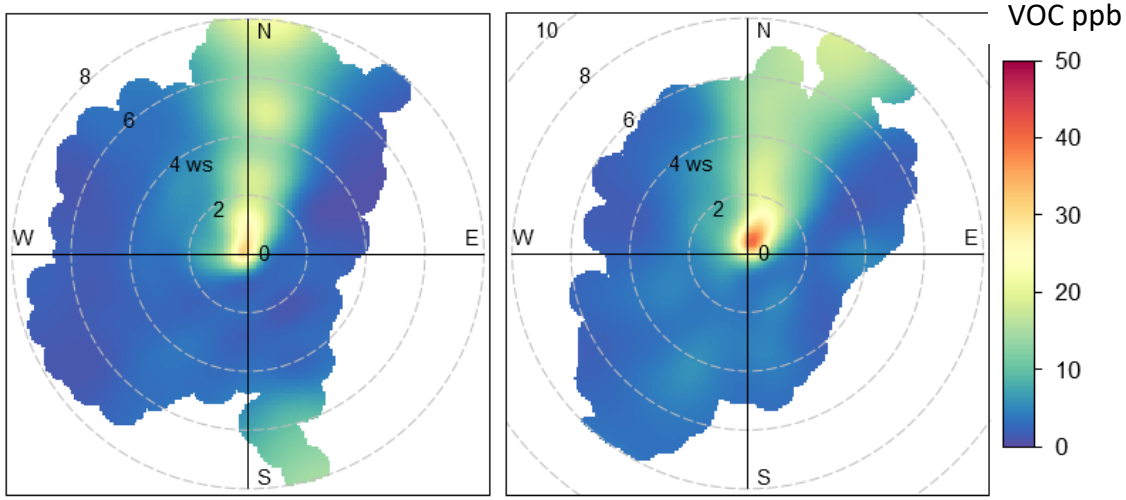
Image from Bing Maps


SPod 2 - 10 second avg.
SPod 1 - 10 second avg.
SPod-triggered Canister from Rubbertown Study
SPod Canister Trigger
13:55:31 to 13:56:11
1,3-butadiene = 36 ppbv
cyclohexane = 637 ppbv
other compounds low
SPod VOC Signal (cts)
4000
3500
3000
2500
2000
1500
1000
500
0
13:35
13:37
13:39
13:41
13:43
13:45
13:47
13:49
13:51
13:53
13:55
13:57
13:59
14:01
14:03
14:05
14:07
14:09
14:11
14:13
14:15
Time (hr:min)

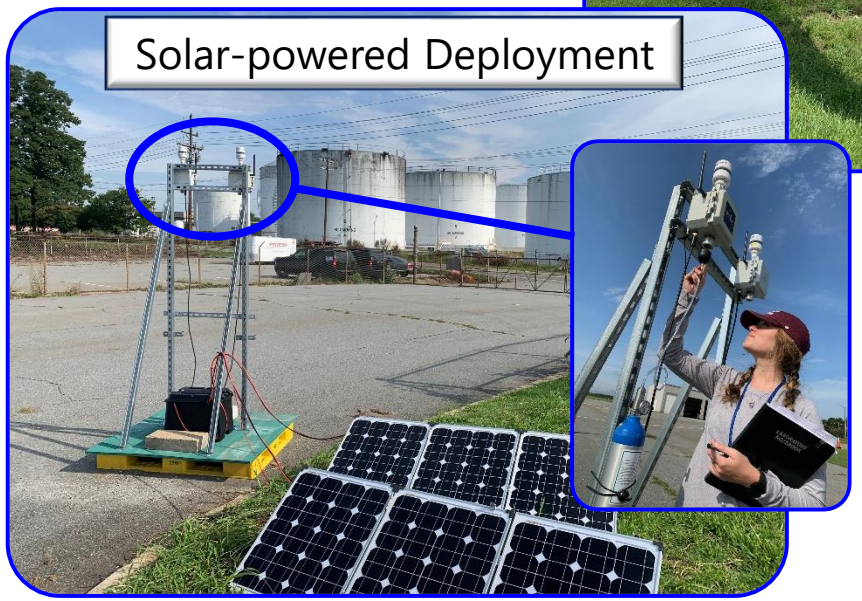
Informing VOC Emissions from Storage Tanks

- SPod fenceline sensors and triggered grab samples
- Greensboro, NC study in process (4 sites)
- Optical gas imaging (OGI) visualization
- Inverse source modelling





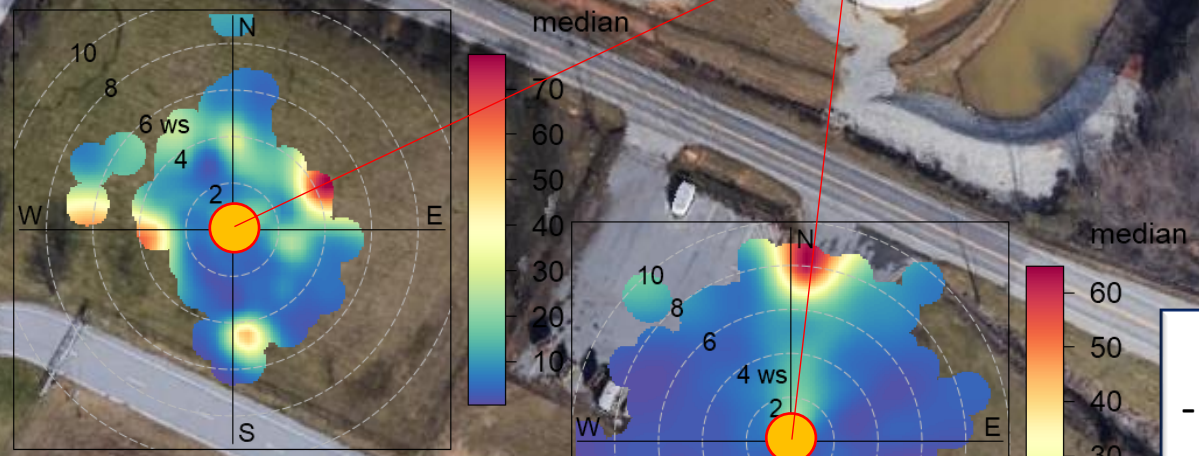
SPods provide wind and VOC data on source direction



Commercial SPods based on EPA open-source design

SPod Signal Triangulation

SPod Sites located near a terminal storage facilities in Greensboro, NC



Site 1A

- 1 sensor
- 6/30/22 – 9/27/22
- 13,720 5-min values

Site 1

- 4 sensors (2 collocated)
- 10/26/21 – 10/17/22
- 178,468 5-min values

Standardizing SPods Methods

Transition from prototype to commercial forms

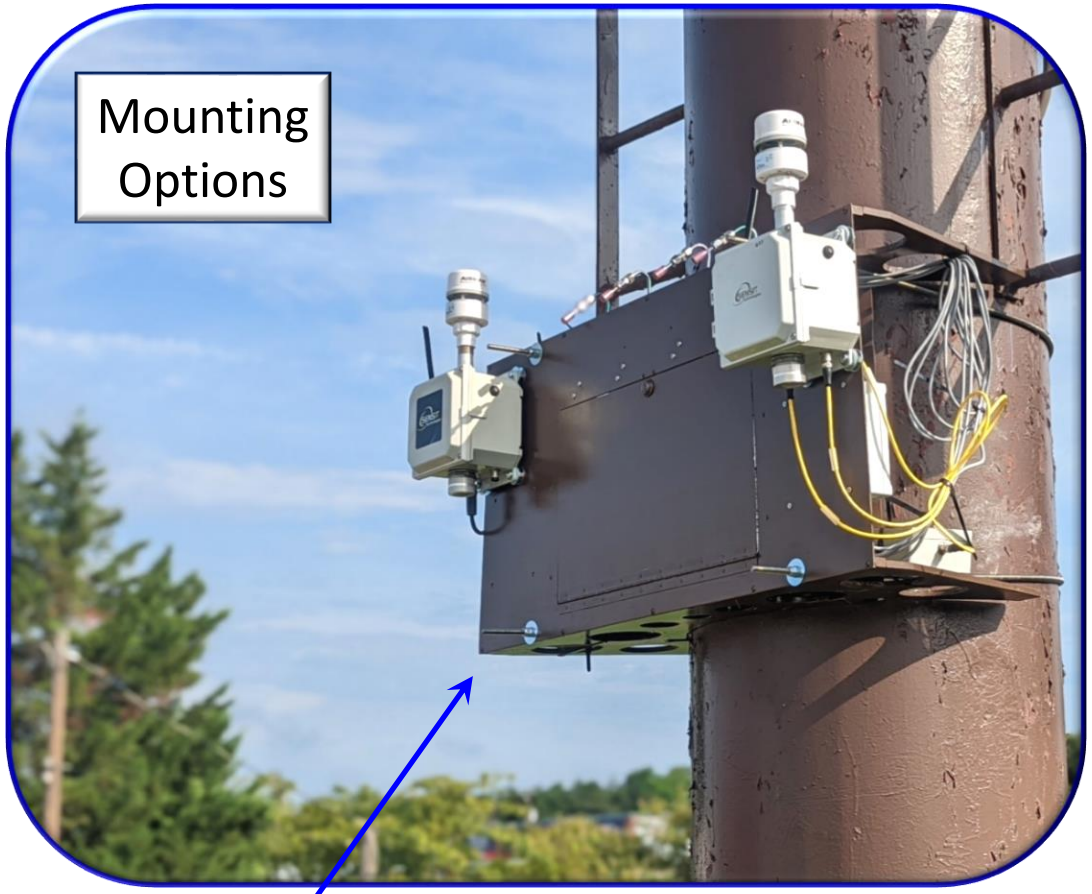
- Wider SPod adoption requires standard procedures and commercial availability
- Emerging commercial SPods offer robustness and communication advantages over the home-made EPA prototype SPods
- EPA is currently using one commercial VOC fenceline sensor for near-term field work (the Sensit SPOD)*
- This sensor performed acceptably in EPA fenceline collocated precision studies and replicates aspects of EPA's open-source SPod design
- EPA continues development of open-source fenceline methods and analysis software that can work with any similar commercial SPod-type sensor

EPA Prototype SPod

Sensit Commercial SPod

**EPA's current use of the Sensit SPOD dose not constitute an endorsement or recommendation for use (your application needs may vary)*

Standardizing SPod Deployment



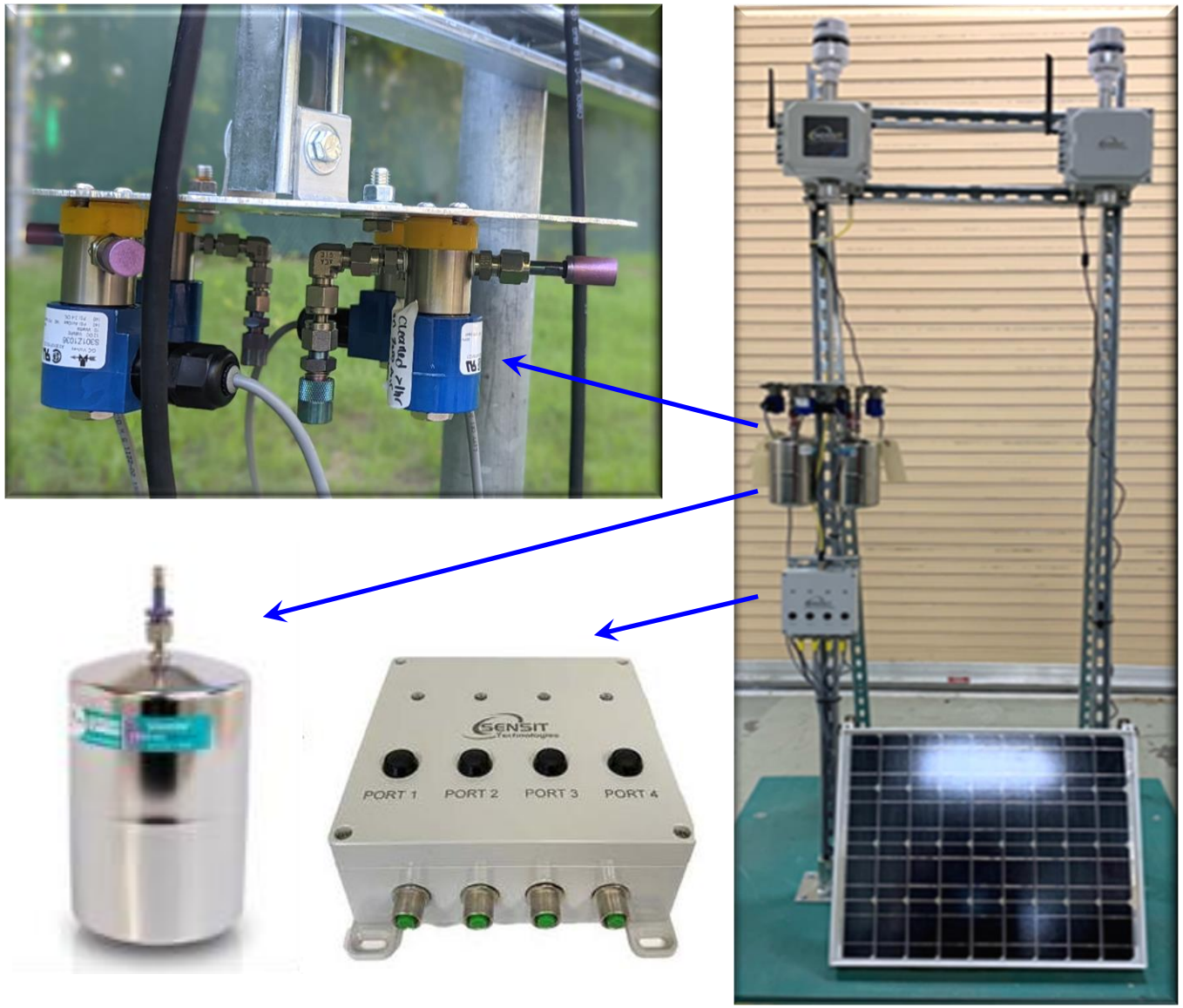
Ground or elevated mounting (e.g., billboard) with canister enclosure

Isobutylene calibration gas

Solar or land power

Canister Grab Samples

- SPods can automatically trigger a canister grab sample
- User-defined VOC trigger thresholds or triggered by wind sector
- We use “mini-cans” for the grab samples (easy to ship)
- Canisters analyzed in the Laboratory (e.g., TO-15 Method)
- Speciated VOC data can be compared to PID response factors to calibrate plume response



SPod Data Processing (SENTINEL)

1. Download raw data from Sensit Connect and store in a file system
2. Access all code via bitbucket repository
3. Process data with processing script and store in 10 sec/ 5 min folders
4. Use these files in the SENTINEL App to analyze data over time
5. Output reports, images, and quality assurance tables for specific times

SENTINEL = SEnsor NeTwork Intelligent Emissions Locator

SENTINEL Data Processing App

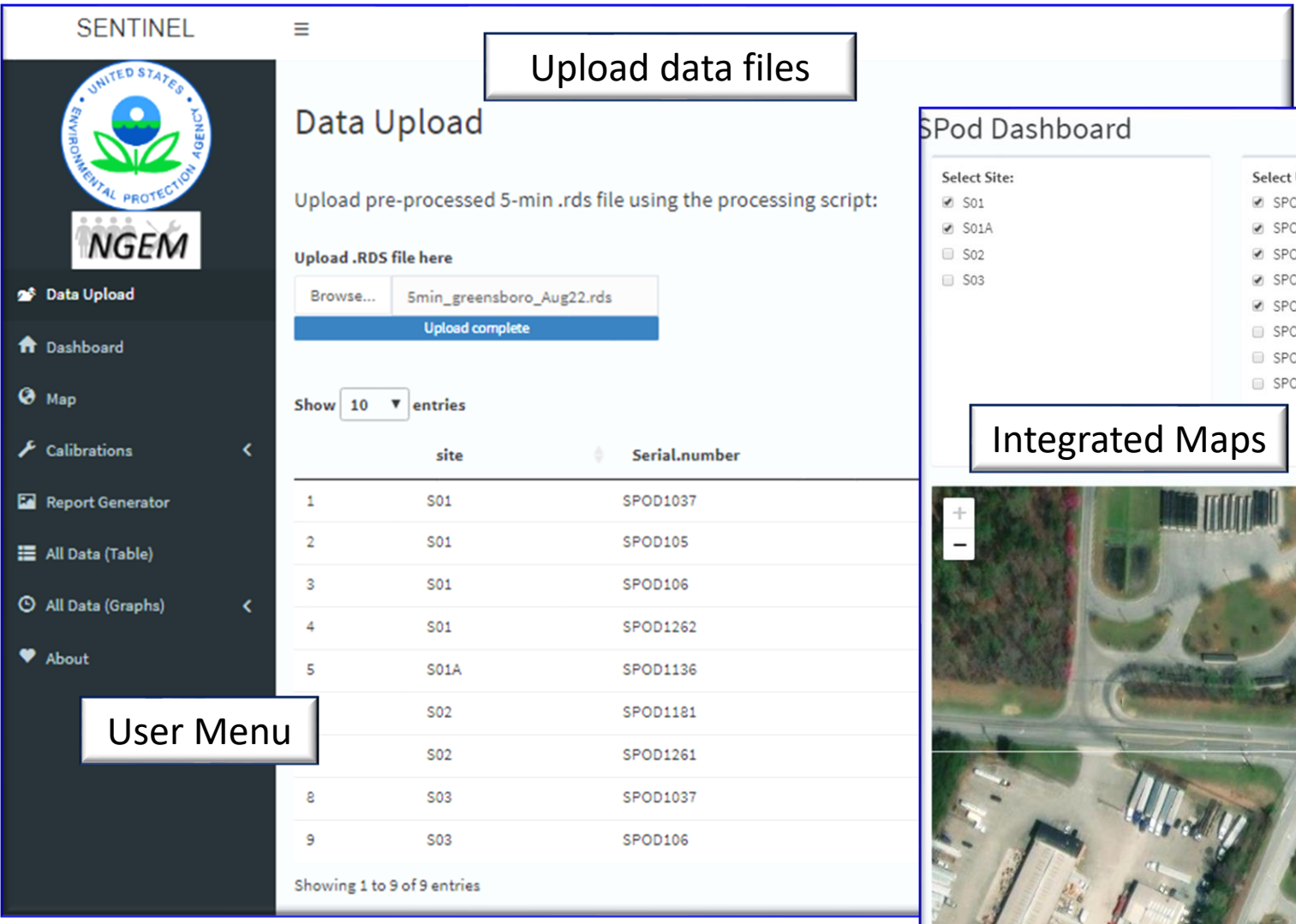
User-friendly, Automated Quality Assurance (QA), Batch-processing, Visualization

Upload data files

Interactive dashboard to view SPods

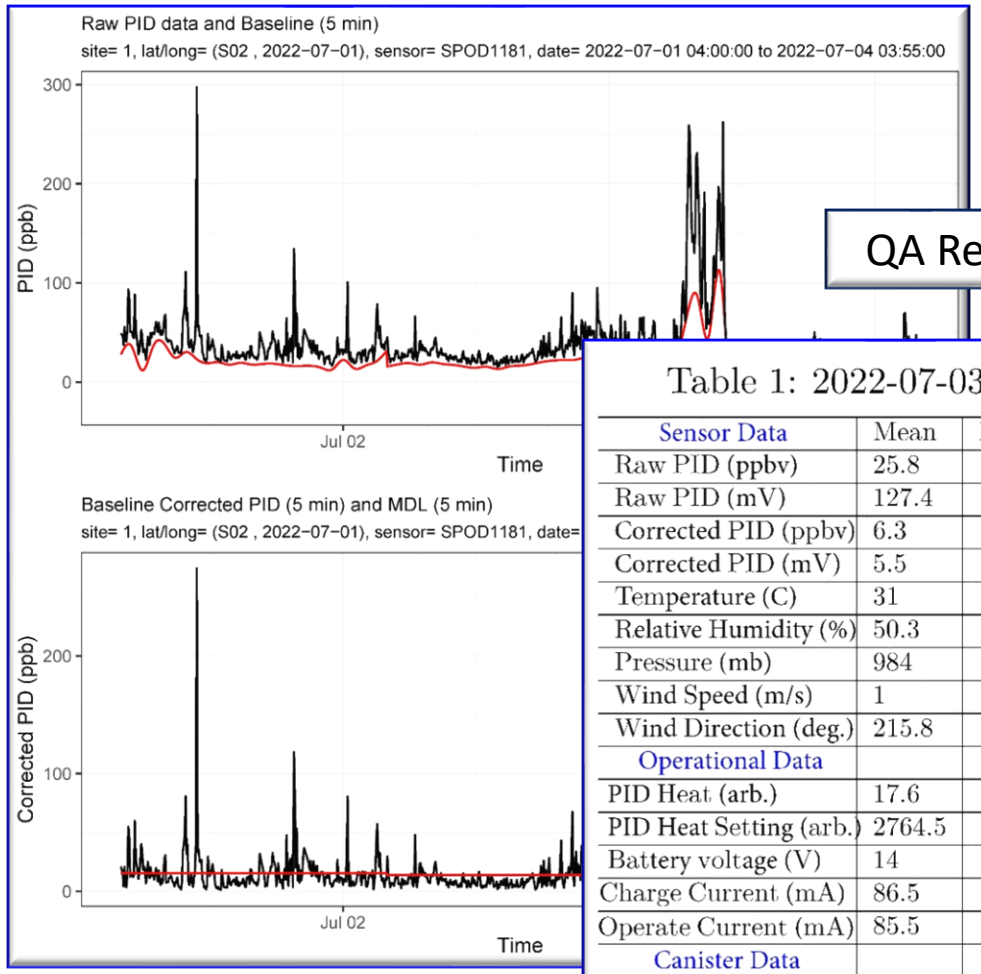
Integrated Maps

User Menu



SENTINEL Data Processing App

User-friendly, Automated Quality Assurance (QA), Batch-processing, Visualization



QA Records

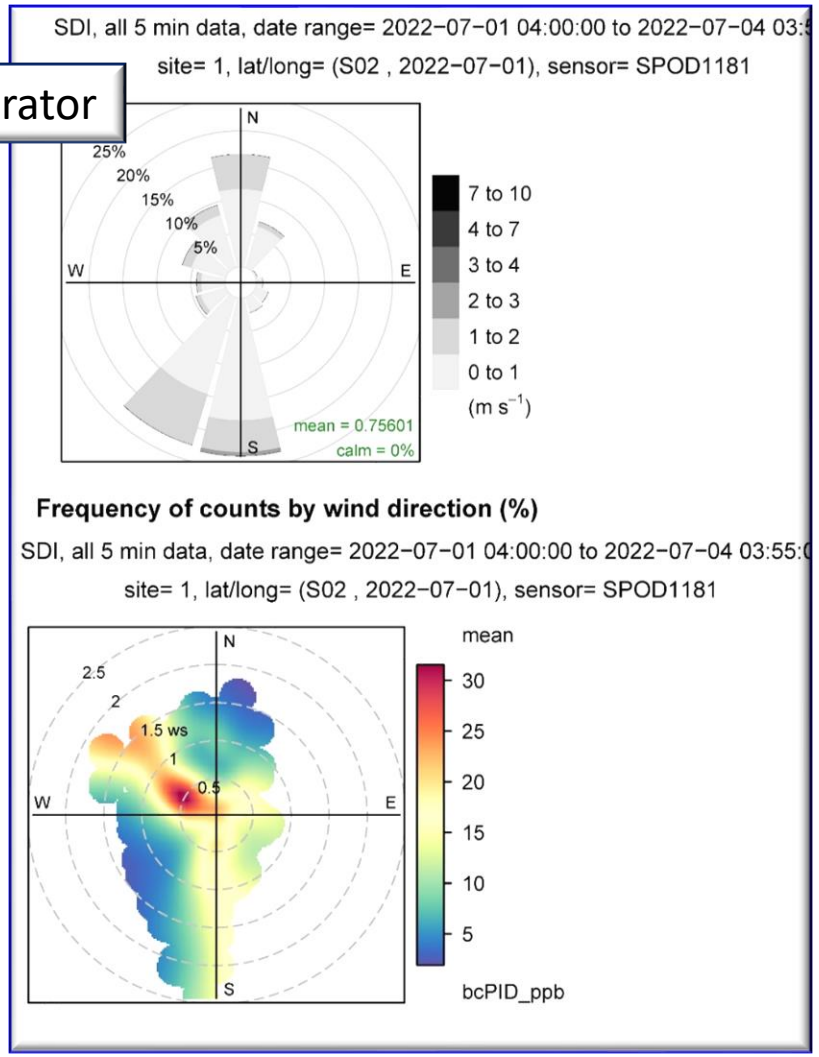
This sensor needs to be zeroed.

Table 1: 2022-07-03 12:00:00 to 2022-07-03 12:59:59

Sensor Data	Mean	Median	StdDev	Min	Max	DataComp
Raw PID (ppbv)	25.8	25.4	3.3	-20.0	37.9	100
Raw PID (mV)	127.4	127.1	2.9	119.9	138	100
Corrected PID (ppbv)	6.3	5.8	3.5	-1.4	19.2	100
Corrected PID (mV)	5.5	5.1	3.0	-1.2	16.8	100
Temperature (C)	31	31.1	0.4	30.3	31.7	100
Relative Humidity (%)	50.3	50.4	2.0	45.6	56	100
Pressure (mb)	984	984.0	0.0	984	984	100
Wind Speed (m/s)	1	1.0	0.5	0.1	2.9	100
Wind Direction (deg.)	215.8	296.8	144.8	2.9	359.6	100
Operational Data						
PID Heat (arb.)	17.6	17.0	1.9	15	23	100
PID Heat Setting (arb.)	2764.5	2768.0	11.6	2743	2787	100
Battery voltage (V)	14	14.0	0.1	13.9	14.2	100
Charge Current (mA)	86.5	0.0	218.3	0	989.5	100
Operate Current (mA)	85.5	83.7	8.2	75.8	128.1	100
Canister Data						
Canister Trig Stat	0	0.0	0.0	0	0	100
Canister Active Port	0	0.0	0.0	0	0	100
Canister Trigger Event	0	0.0	0.0	0	0	100

If a canister is triggered, codes will appear here

PDF report generator



EPA Region 4 Sensor Loan Program

- EPA Region 4 Program to loan commercial SPods to state and local partners*
- Sensor kit with all supplies for deployment
  - SPod/tripod/solar panel
  - Canister grab sample system
  - Calibration gear
- SENTINEL open-source data analysis code
- Technical guidance and assistance provided
  - SPod Operating Procedures
  - SENTINEL App User Guide

**Anticipated program launch in Fall 2022*
R4 contacts Jake Carpenter Carpenter.Jacob@epa.gov and Ryan Brown, Brown.Ryan@epa.gov

SPod Resources for Loan Program

SPod SOP

U.S Environmental Protection Agency
Office of Research and Development
Center for Environmental Measurement & Modeling
Air Methods & Characterization Division
Source & Fine Scale Branch
STANDARD OPERATING PROCEDURE

SOP #J-AMCD-SFSB-SOP-4380-2
Effective Date: August 1, 2022
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9. Procedures

The following procedures describe SPod/CGS set up, operation, select QA/QC procedures, and basic data analysis. Some procedures will vary as noted depending on equipment configuration [e.g., sections 7.1, 7.2, and 7.3 (optional)].

9.1. SPod/CGS Settings Configuration and Example Data File:

As described in the SPod user manual[1], the Sensit SPod/CGS internal system settings can be configured for a variety of power and communication options and selection of the types and threshold levels for canister triggering. To configure this SPod/CGS system, an SPod/CGS Advanced Operator (Section 6.3) must connect a computer with a CoolTerm terminal emulator program to the SPod and follow the procedures in the SPod user manual starting on page 35. This connection requires a special USB to SPod cable that is described in the manual and supplied with the unit. For details on the connection procedure and description and management of settings, refer to the user manual. The settings may be changed based on the project and should be described in the QAPP.

Prior to deployment, the settings of each SPod must be verified to ensure that they are set as per project requirements. Figure 9.1.1 shows a screen image of an SPod's settings that are displayed during unit start-up with CoolTerm communication active. The screen is visible within the first 10 secs of start-up and can also be accessed through the settings menu by entering "YES" before the start-up countdown ends and also by entering "DISPLAY" on the command line. The device settings (e.g., this screen image) must be recorded on the SPod/CGS Settings Configuration Form (Appendix B) and submitted to project records. Any change in settings requires proper documentation through creation of another configuration

```
SPOD Firmware v5.94

Checking For Sampler...SPOD Can v1.9

Sensor ID: SPOD01181
With MET, Filter: 10
System DATE,05/24/22 18:48:41
Network Time: Enabled, UTC
Battery Voltage: 14.37
Power Source: Solar Power
Output Mode: Streaming
Communication Mode: Cellular, Unlocked
Network Selection: Automatic
Cellular Protocol: Periodic HTTP Power Down with TLS
Output Data Rate: 10
Cellular Output Ratio: 90
Server Address: https://api.sensitconnect.net/sensors-data/addSensorsData
Access Point Name: zipitwireless.com.attz
GPS Mode: Disabled
```

SENTINEL User Guide

SENTINEL Shiny Application User Guide — NGEM

Dashboard

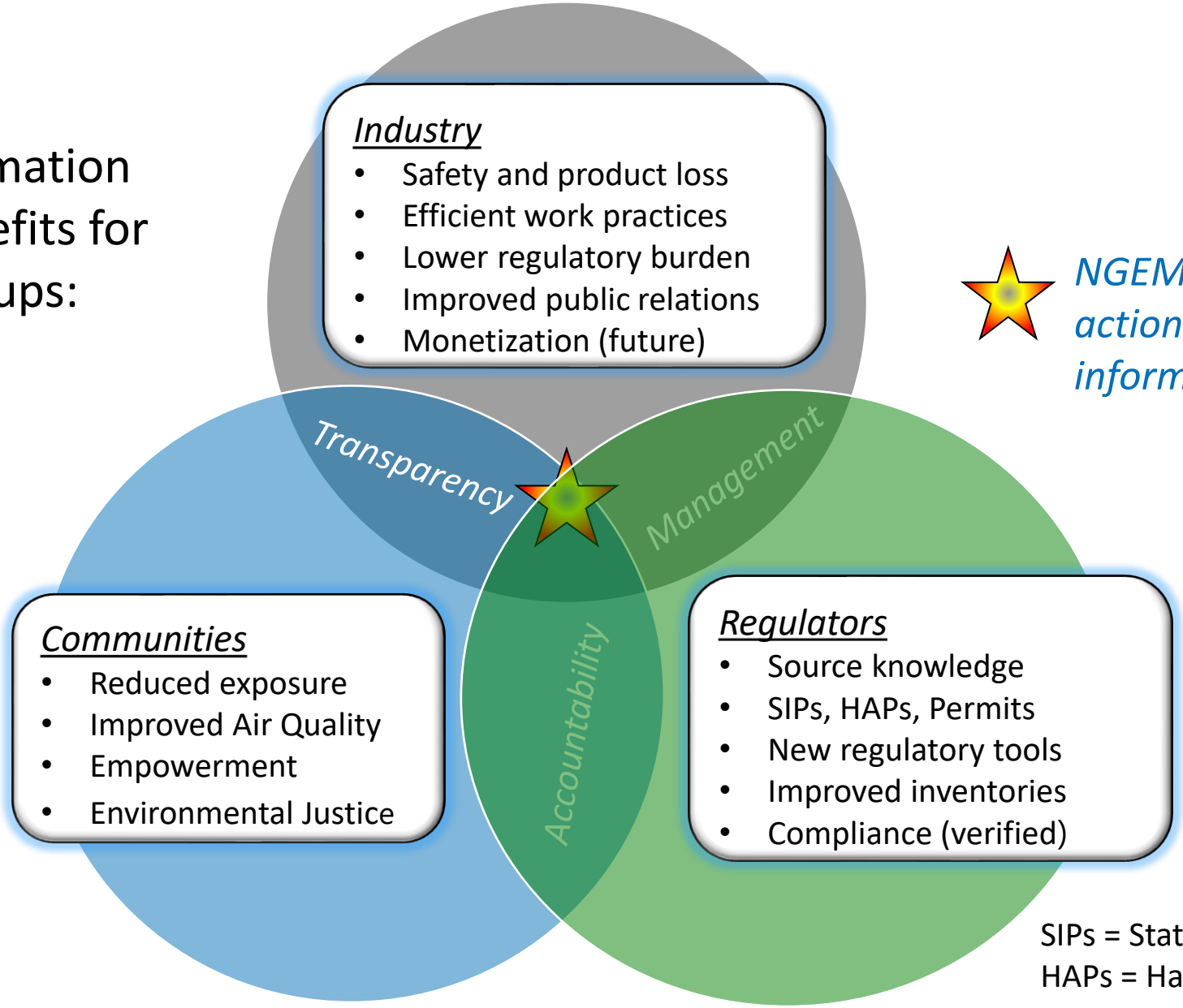
The dashboard provides an interactive snapshot of the SPods units across the sites included in the uploaded file. To display sites, select the boxes next to the site names to display them, and the units within those sites. Units will not automatically be selected just because the site is selected. Selecting more than one unit at a site will combine the units into a single source direction indicator (SDI) plot on the dashboard. The user can use the slider bars to filter wind speed and wind direction for all the graphs on the dashboard. The dashboard can be panned through using the mouse and the zoom buttons in the top left corner. This dashboard along with other SDI plots are built using functions from the Openair package.

Take Home Messages

- NGEM approaches (like the SPod fenceline sensor) can help us understand industrial air pollution sources, creating benefit for industry, regulators, and communities
- EPA's SENTINEL open-source data analysis code helps users make sense of complex fenceline sensor data (development continues)
- Commercial VOC fenceline sensors (like EPA's SPod) are becoming available to early adopters through efforts like the EPA Region 4 SPod loan program

SPod Fenceline Sensor and NGEM Impact

NGEM information unlocks benefits for multiple groups:

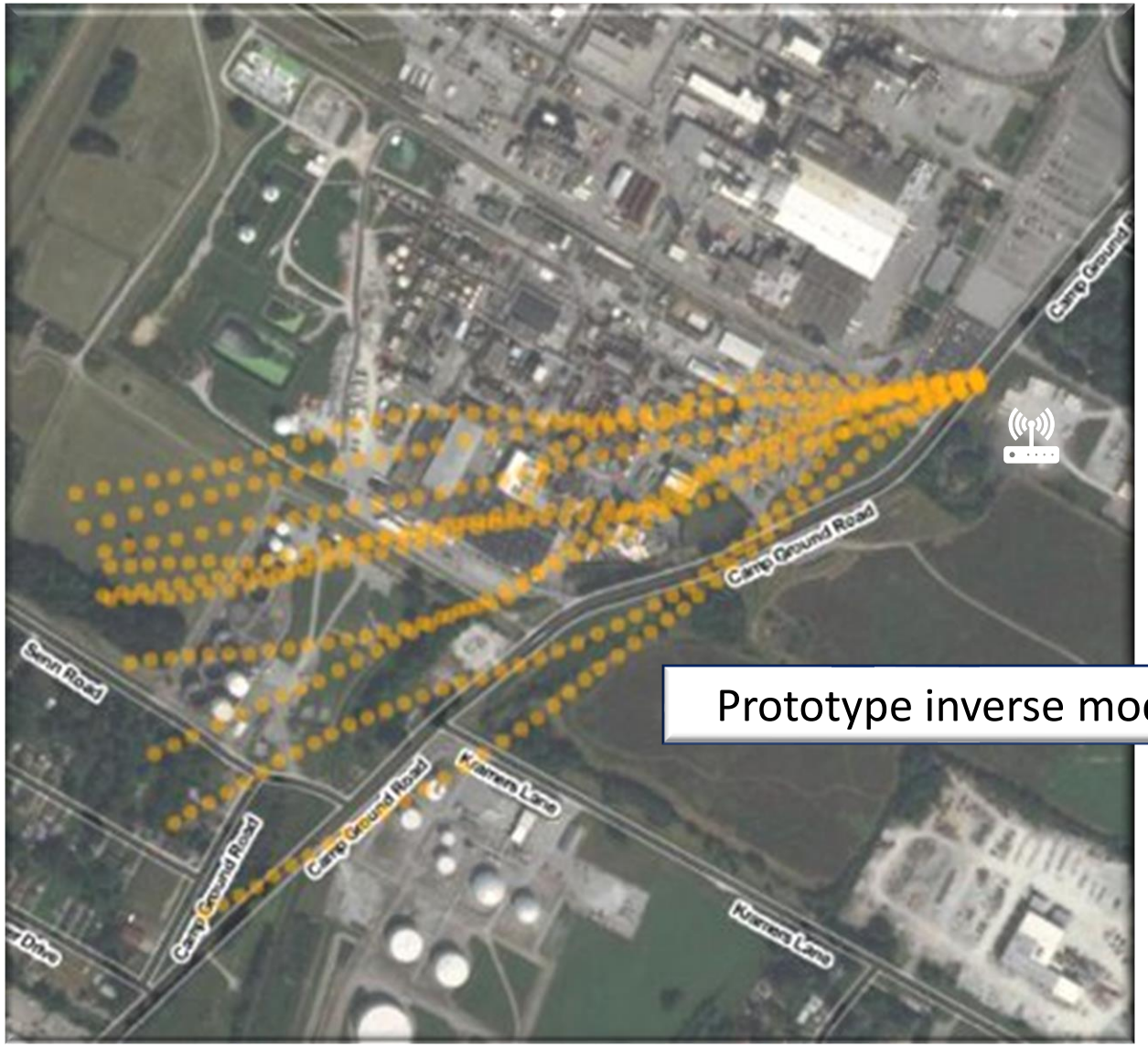


NGEM = actionable information

SIPs = State Implementation Plans
HAPs = Hazardous Air Pollutants

Ongoing Research on Near-source Sensing

- Test commercial SPod-type sensors
- Improve open-source analytics
  - SENTINEL App advancements
  - Automated processing and QA
  - Multiple node triangulation
- Develop better inverse modeling
  - Source emission estimation
- Integrate other near-source data
  - Mobile data
  - EPA's Odor Explore App data



Prototype inverse model

SPod Contributor Acknowledgements

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- EPA Region 3: *CarolAnn Gross-Davis*
- EPA Region 5: *Marta Fuoco, Robin Katz*
- EPA Region 6: *Suzanne Apodaca, James Leathers*
- EPA Region 7: *Alex Edwards, Adam Zachary, Mike Davis*
- EPA Region 8*: Adam Eisele, Mike Stovern*
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- EPA Office of Enforcement and Compliance Assessment: *Dan Hoyt, Nicholas Bobbs*
- EPA Office of Air Quality Planning and Standards: *Jason Dewees, Ned Shappley, Dave Nash*

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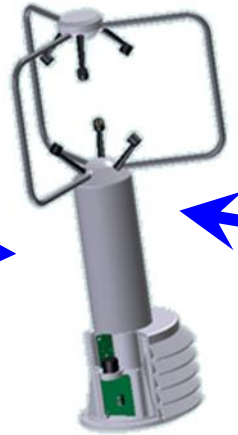
NGEM website

SPod Fenceline Sensors

Improve source understanding and community protection



NGEM at Work