Lessons from the Shared Air / Shared Action: Community Empowerment through Low Cost Air Pollution Monitoring Project

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Air Sensors International Conference

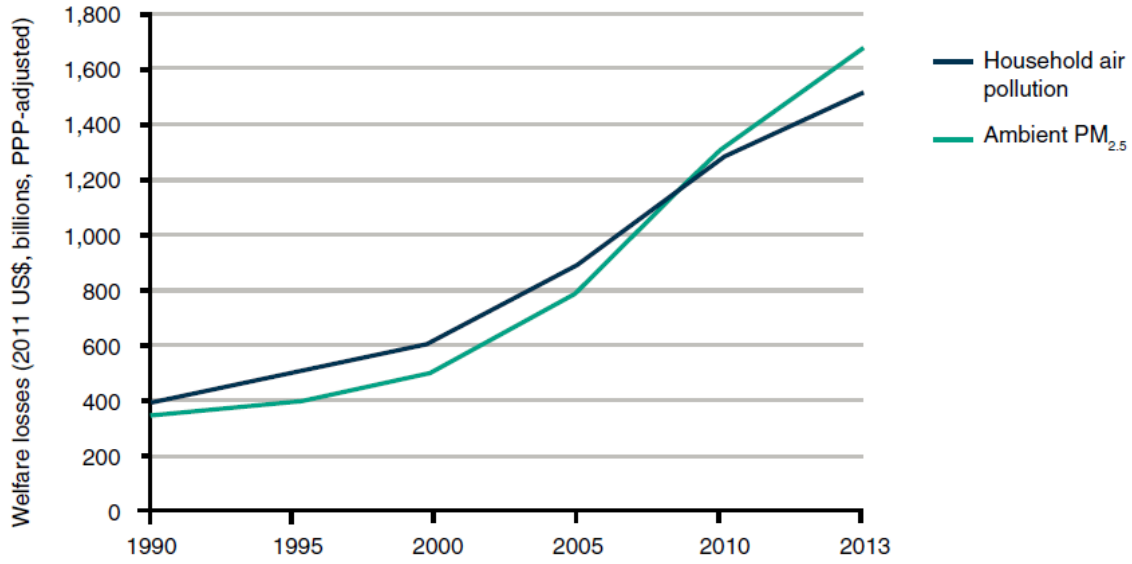
Air Quality is Important

- Annual premature deaths from air pollution
  - 3.7 million globally (WHO 2014)
    - Mostly in middle- and low-income countries
  - 200,000 in the US (Caiazzo et al. 2013)
    - 53,000 from tailpipe emissions (largest share)
    - 52,000 from electricity generation (second largest)

Air Quality is Important

- Annual social cost of air pollution
  - $3.55 trillion globally for $PM_{2.5}$ alone (WB 2016)
    - Those losses are growing with urbanization

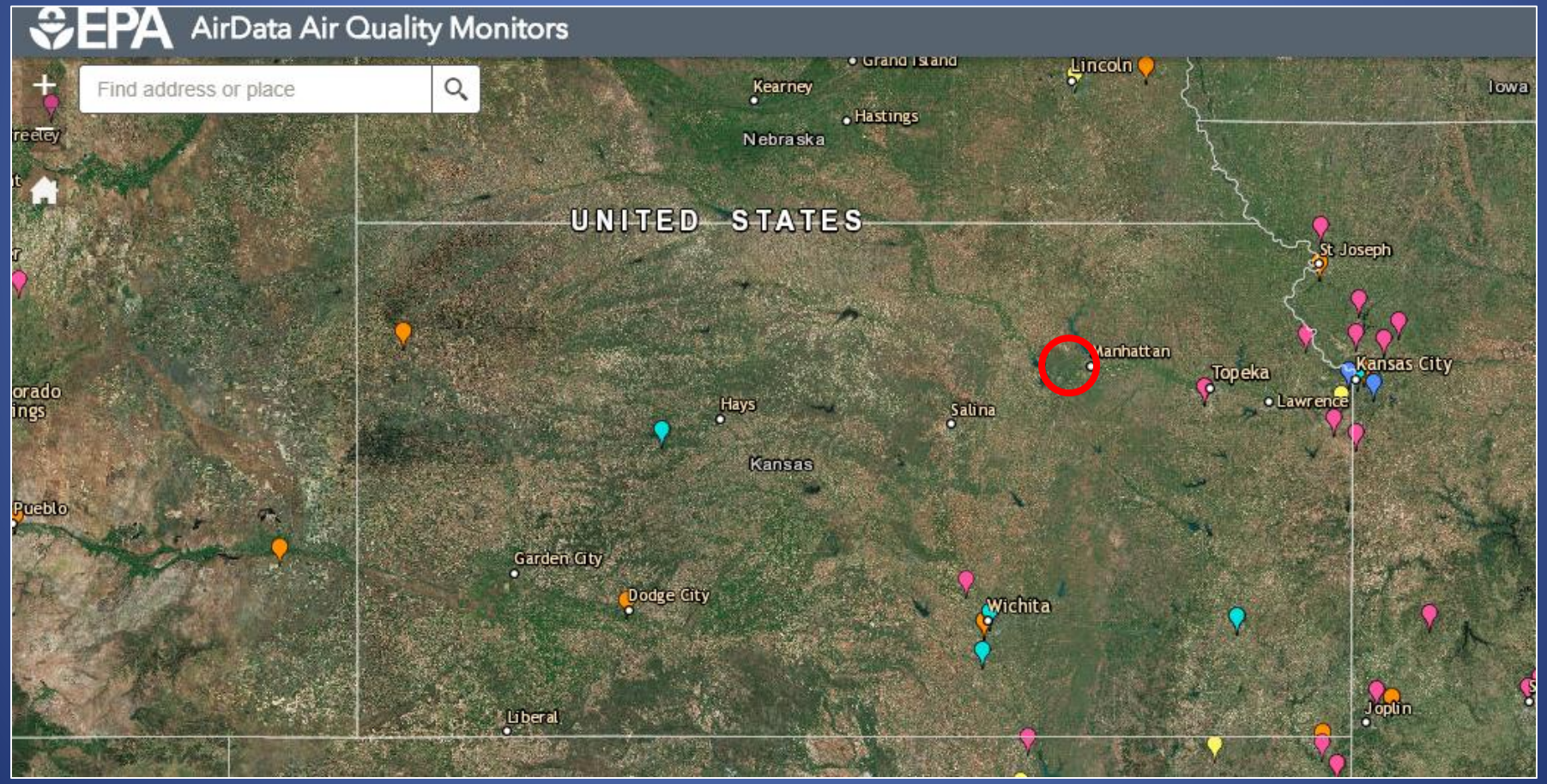
FIGURE ES.2 Welfare Losses from Ambient $PM_{2.5}$ and Household Air Pollution in Low- and Middle-Income Countries, 1990–2013



Sources: World Bank and IHME.

How do we know about our air?

- Federal Reference Monitors (FRMs) in Kansas



Original Low Cost Air Monitor

- Canary in a Coal Mine

Environmental Data Monitoring

- Key Technological Developments
  - Sensor miniaturization
  - Wireless connectivity
  - Cloud-storage
  - Internet delivery
  - **Reduction in unit cost!**

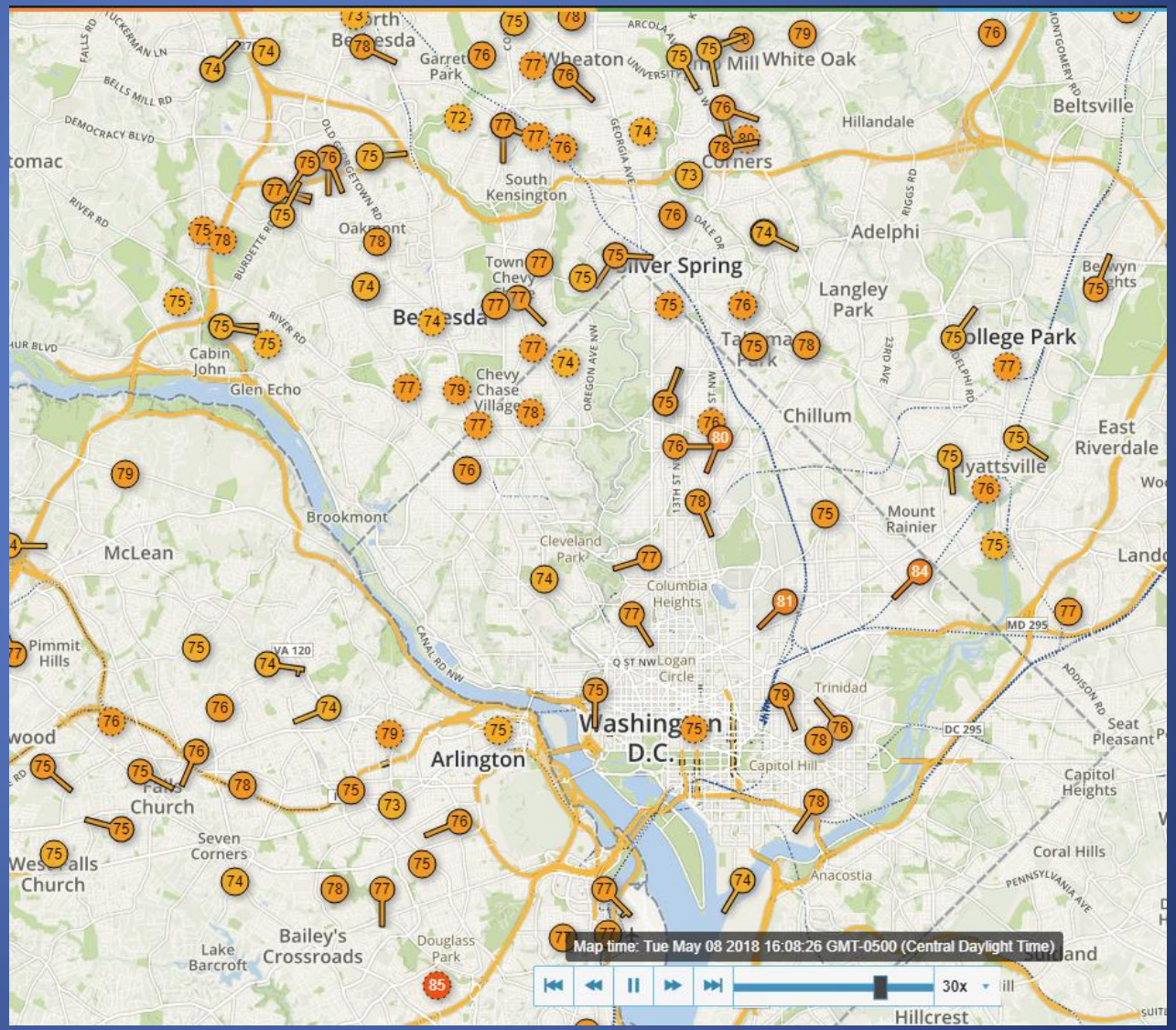
Environmental Data Monitoring

Old School

New School

Environmental Data Monitoring

- WU Stations



Potential of Low-Cost Sensors

- New market entrants
  - Individuals, non-profits, municipalities, schools
  - Democratization of information
- Higher deployment densities
  - No longer single point, but net
  - Fine-grained mapping of conditions
- Better environmental management (ideally)

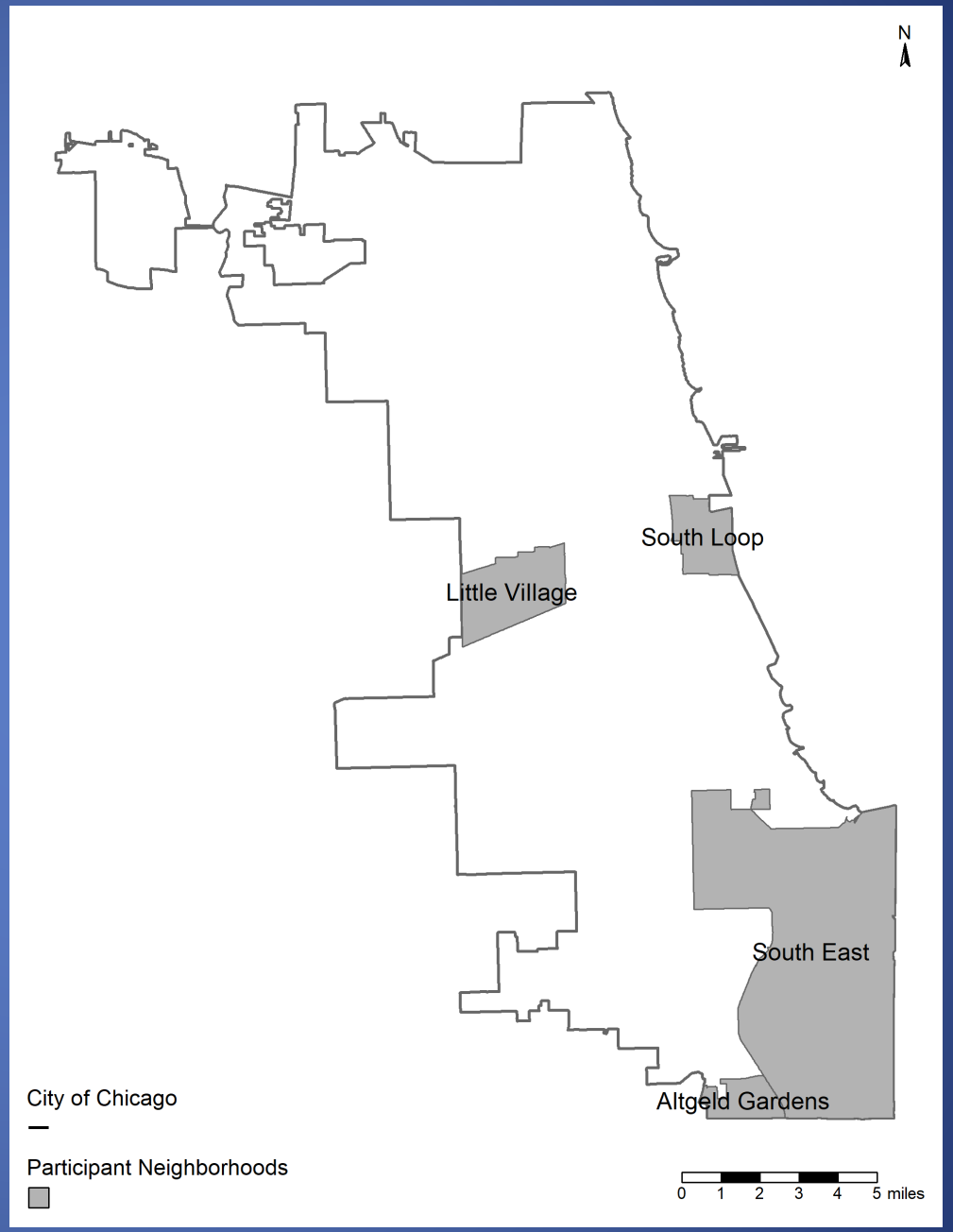

SHARED AIR
SHARED ACTION

Eight Initial Partners

Type	Name		EJ	Mission
University	University of Illinois, Chicago	UIC		Environmental health disparities and risk assessment
	Kansas State University	KSU		Sustainability, remediation, community outreach
Non-Profit	Delta Institute			Sustainable development
	Respiratory Health Association	RHA		Advocacy and education related to lung disease
Community	Alliance for a Greener South Loop	AGSL		Environmental improvement/ sustainability for South Loop
	Little Village Environmental Justice Organization	LVEJO	*	EJ, self-determination for Little Village
	Southeast Environmental Task Force	SETF	*	EJ/sustainable growth for Southeast community
	People for Community Recovery	PCR	*	EJ for Riverdale Community

Community Info

- Lower Income
- Far from monitors
- Many polluters
  - coal ash repositories
  - metal shredders
  - trucking and rail
  - landfills
- High rates of asthma among children



Key Points

- Lived environmental experience in these neighborhoods does not accord with existing (limited) information on air quality
- Low cost monitors can empower community members* to explore local air quality

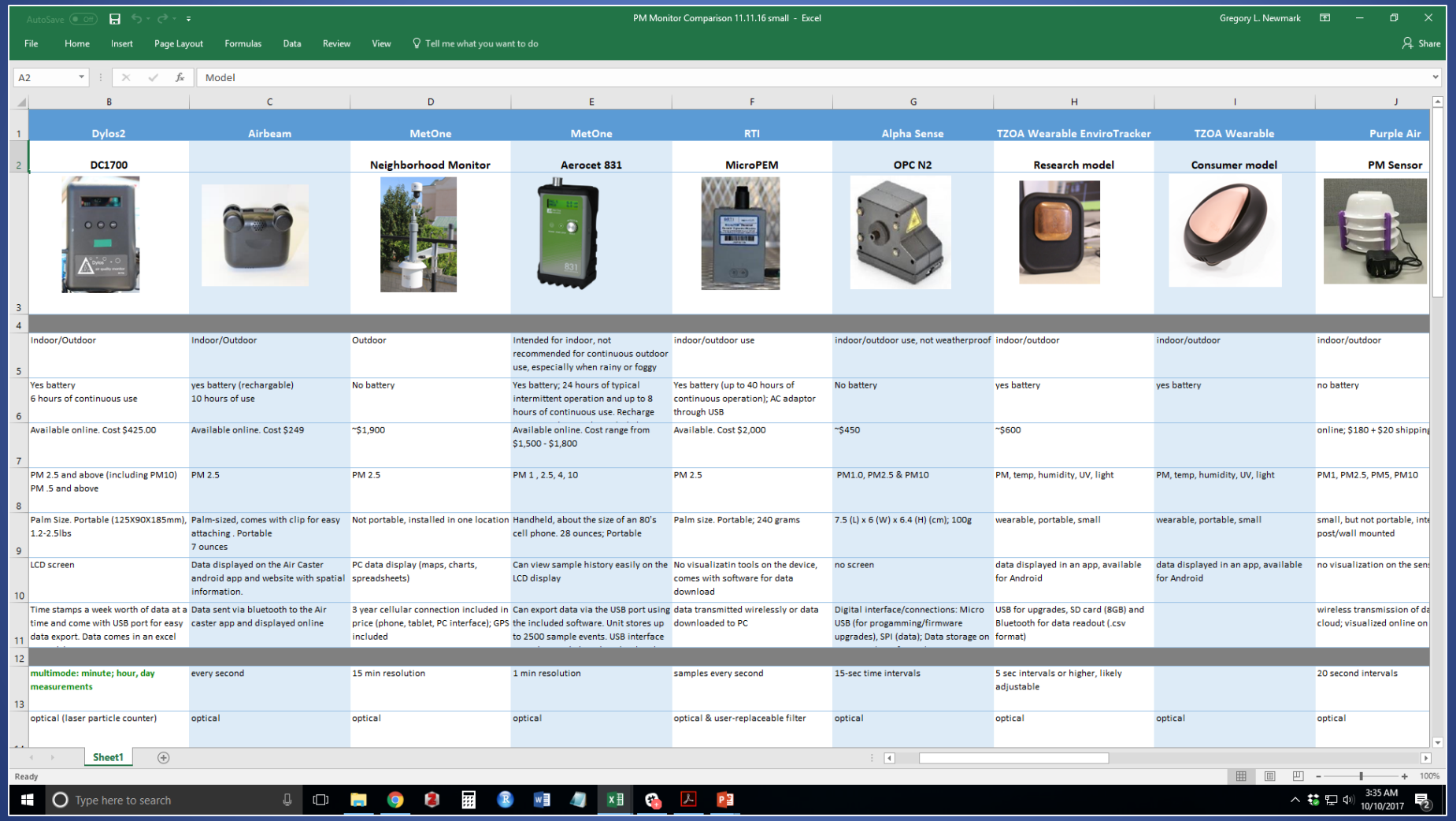
*Note: While traditionally this would be called Citizen Science, we are reframing to community member to avoid the legal connotations associated with citizen

Research Plan

- Test low-cost monitors in four neighborhoods over four weeks in winter and in summer
- Compare low-cost monitors with Federal Reference Method (FRM) or Federal Equivalent Method (FEM) samplers

Met One E-FRM

Challenge #1: Monitor Selection



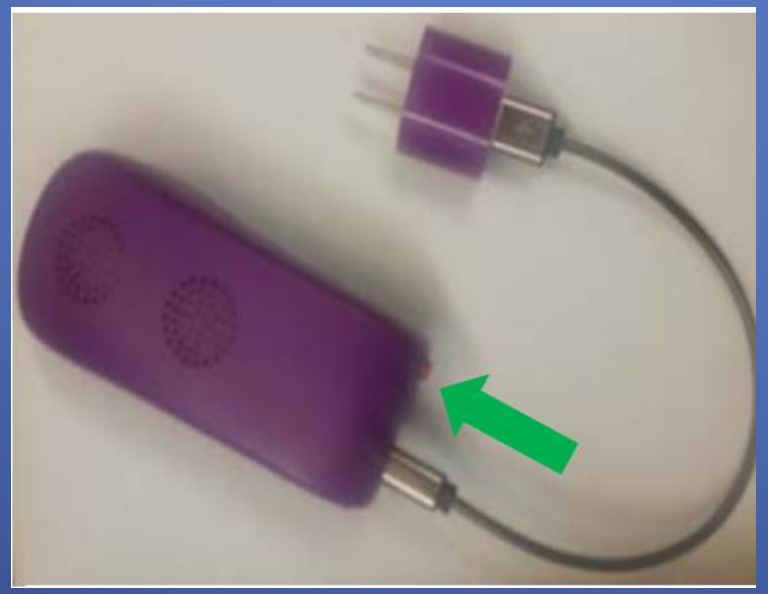
	Dylos2	Airbeam	MetOne	MetOne	RTI	Alpha Sense	TZOA Wearable EnviroTracker	TZOA Wearable	Purple Air
	DC1700		**Neighborhood Monitor**	**Aerocet 831**	**MicroPEM**	**OPC N2**	**Research model**	**Consumer model**	**PM Sensor**
	Indoor/Outdoor	indoor/Outdoor	Outdoor	Intended for indoor, not recommended for continuous outdoor use, especially when rainy or foggy	indoor/outdoor use	indoor/outdoor use, not weatherproof	indoor/outdoor	indoor/outdoor	indoor/outdoor
	Yes battery 6 hours of continuous use	yes battery (rechargable) 10 hours of use	No battery	Yes battery; 24 hours of typical intermittent operation and up to 8 hours of continuous use. Recharge	Yes battery (up to 40 hours of continuous operation); AC adaptor through USB	No battery	yes battery	yes battery	no battery
	Available online. Cost $425.00	Available online. Cost $249	~$1,900	Available online. Cost range from $1,500 - $1,800	Available. Cost $2,000	~$450	~$600		online; $180 + $20 shipping
	PM 2.5 and above (including PM10) PM .5 and above	PM 2.5	PM 2.5	PM 1 , 2.5, 4, 10	PM 2.5	PM1.0, PM2.5 & PM10	PM, temp, humidity, UV, light	PM, temp, humidity, UV, light	PM1, PM2.5, PM5, PM10
	Palm Size. Portable (125X90X185mm), 1.2-2.5lbs	Palm-sized, comes with clip for easy attaching . Portable 7 ounces	Not portable, installed in one location	Handheld, about the size of an 80's cell phone. 28 ounces; Portable	Palm size. Portable; 240 grams	7.5 (L) x 6 (W) x 6.4 (H) (cm); 100g	wearable, portable, small	wearable, portable, small	small, but not portable, inte post/wall mounted
	LCD screen	Data displayed on the Air Caster android app and website with spatial information.	PC data display (maps, charts, spreadsheets)	Can view sample history easily on the LCD display	No visualizatin tools on the device, comes with software for data download	no screen	data displayed in an app, available for Android	data displayed in an app, available for Android	no visualization on the sens
	Time stamps a week worth of data at a time and come with USB port for easy data export. Data comes in an excel	Data sent via bluetooth to the Air caster app and displayed online	3 year cellular connection included in price (phone, tablet, PC interface); GPS included	Can export data via the USB port using the included software. Unit stores up to 2500 sample events. USB interface	data transmitted wirelessly or data downloaded to PC	Digital interface/connections: Micro USB (for progamming/firmware upgrades), SPI (data); Data storage on	USB for upgrades, SD card (8GB) and Bluetooth for data readout (.csv format)		wireless transmission of da cloud; visualized online on
	multimode: minute; hour, day measurements	every second	15 min resolution	1 min resolution	samples every second	15-sec time intervals	5 sec intervals or higher, likely adjustable		20 second intervals
	optical (laser particle counter)	optical	optical	optical	optical & user-replaceable filter	optical	optical	optical	optical

Monitor Selection (Particulates)

- Particulate Matter
  - MetOne Neighborhood Monitor
  - PurpleAir PM Sensor
  - AirBeam

Monitor Selection (Gaseous)

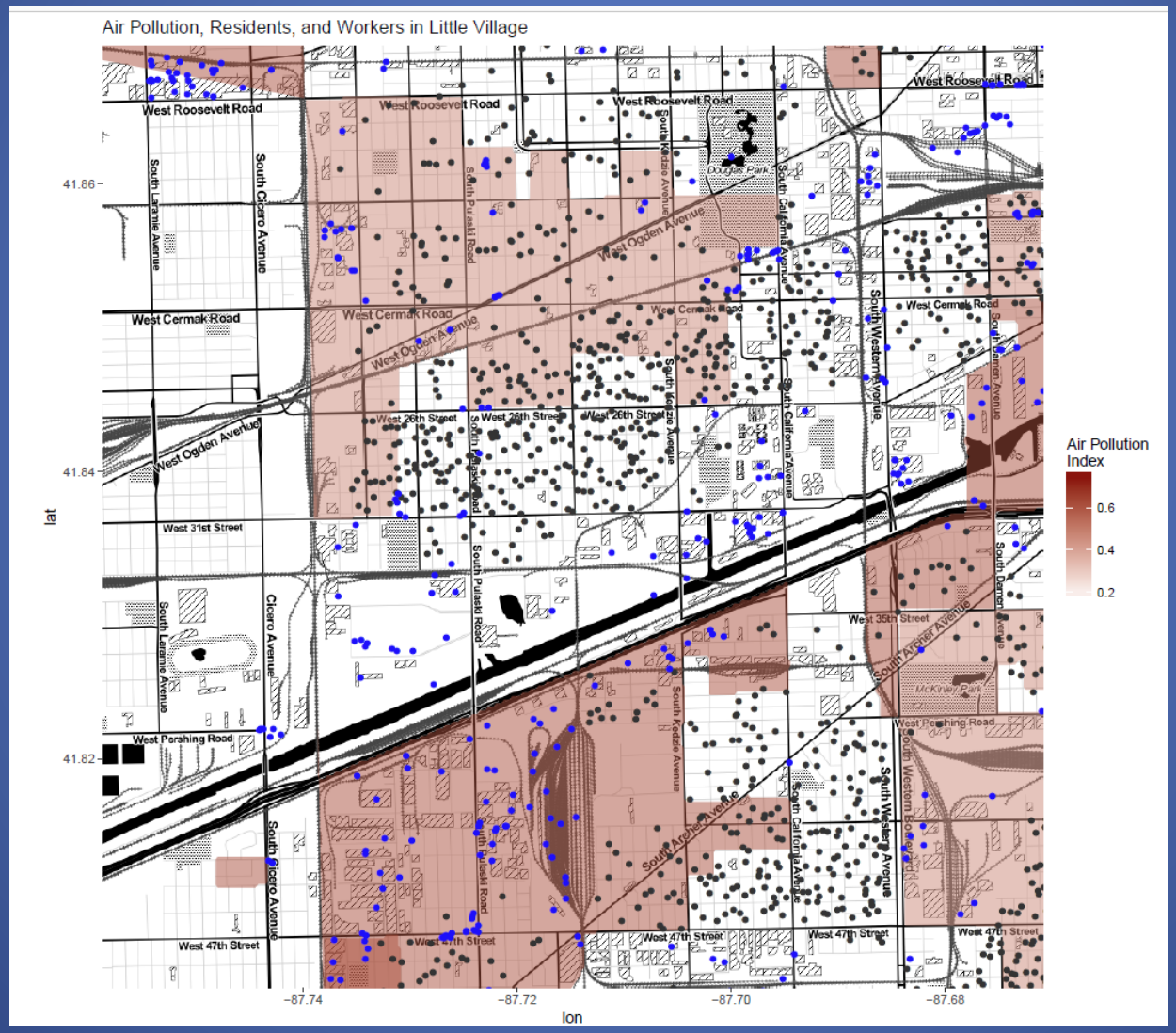
- Carbon Monoxide and Nitric Oxide
  - Terrier
- Nitrogen Dioxide and Ozone
  - Aeroqual 500



Monitor Selection

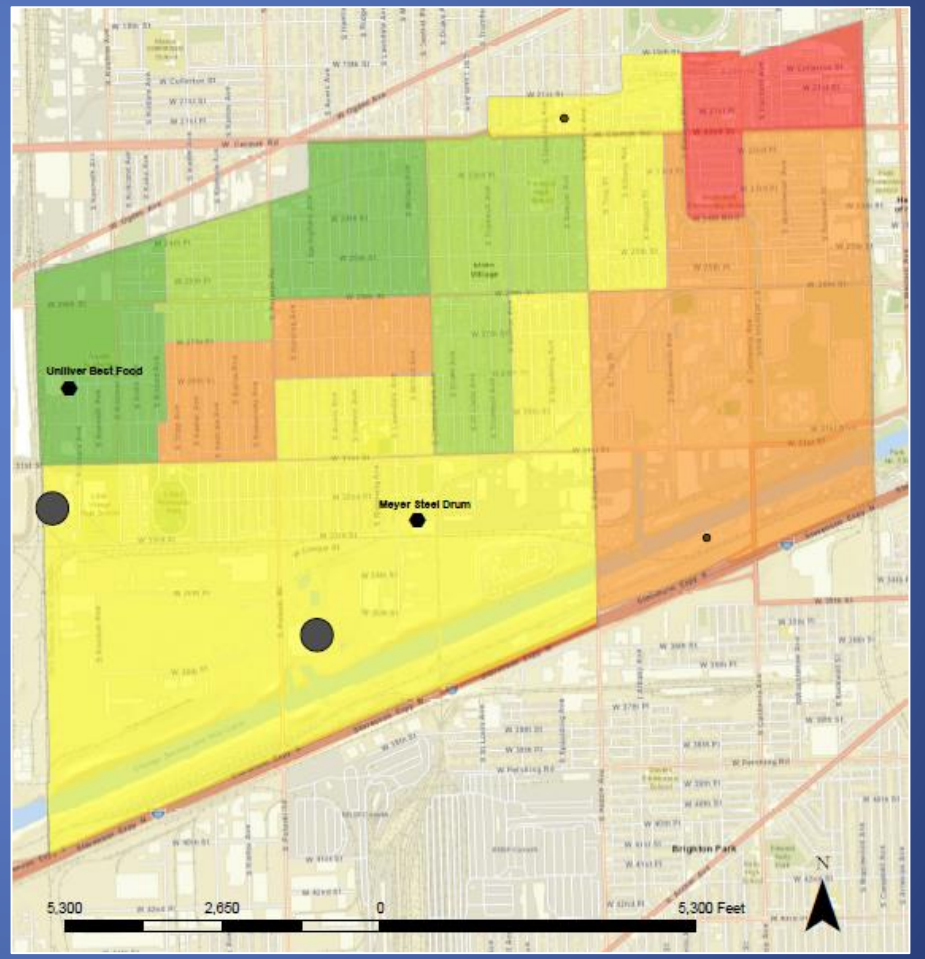
- Rapidly evolving field without standardization
  - Providers generally very accessible
- Very difficult to navigate for non-experts
  - EPA and SCAQMD Testing very helpful
- Market entrants come and go
  - Terrier is already off the market
- Disjunction between what low cost sensors monitor and community concerns
  - CAPS vs. VOCs

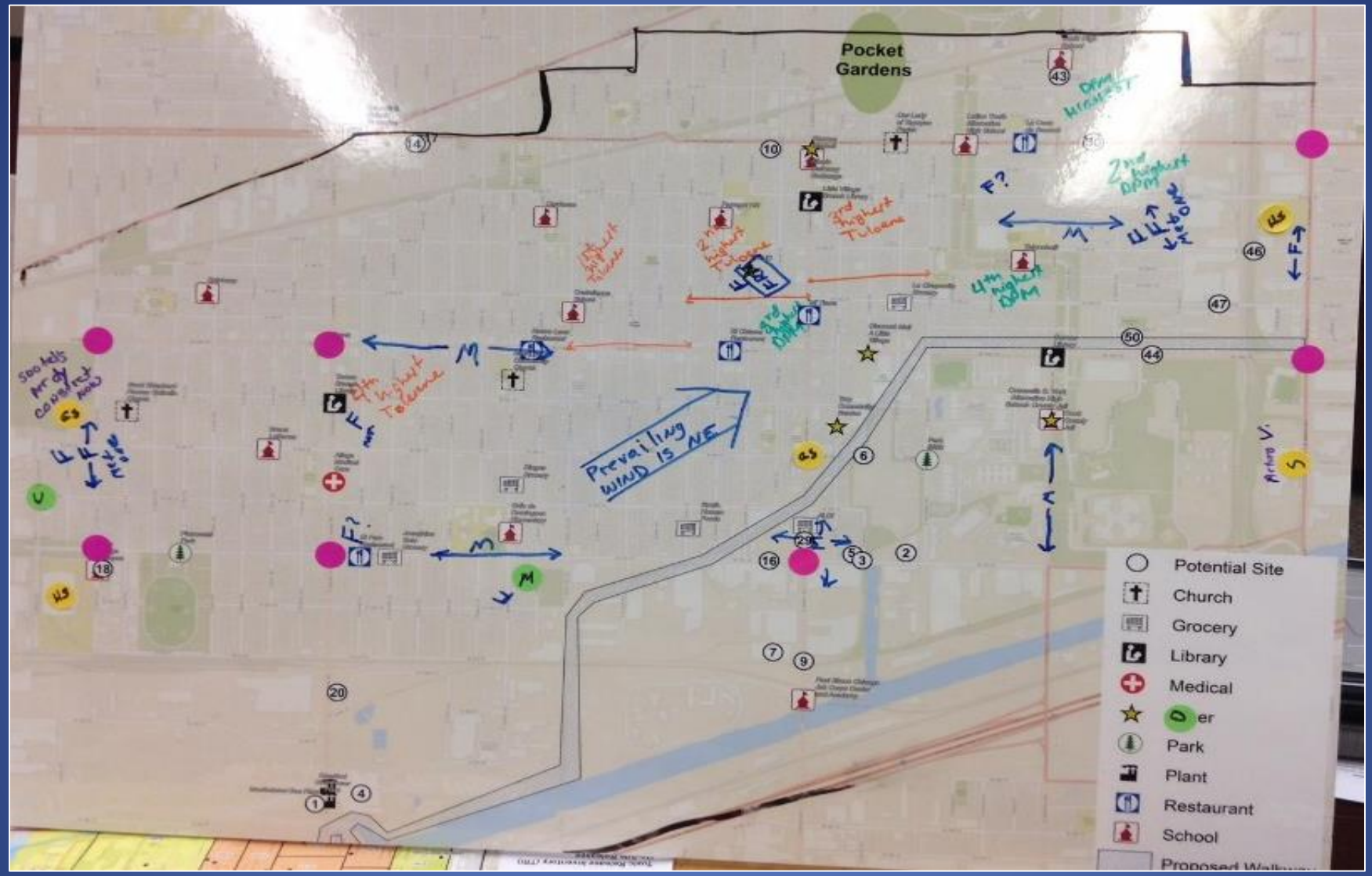
Challenge #2: Air Monitoring Plans



Community Air Monitoring Plans

- Diesel PM from NATA





F: Fixed air monitoring sites; M: Mobile routes; Pink Dots: Intersections/Roadways of concern to community; Green Text: Tiers of DPM concentrations (high to low); Orange Text: Tiers of toluene concentrations (high to low)

Air Monitoring Plans

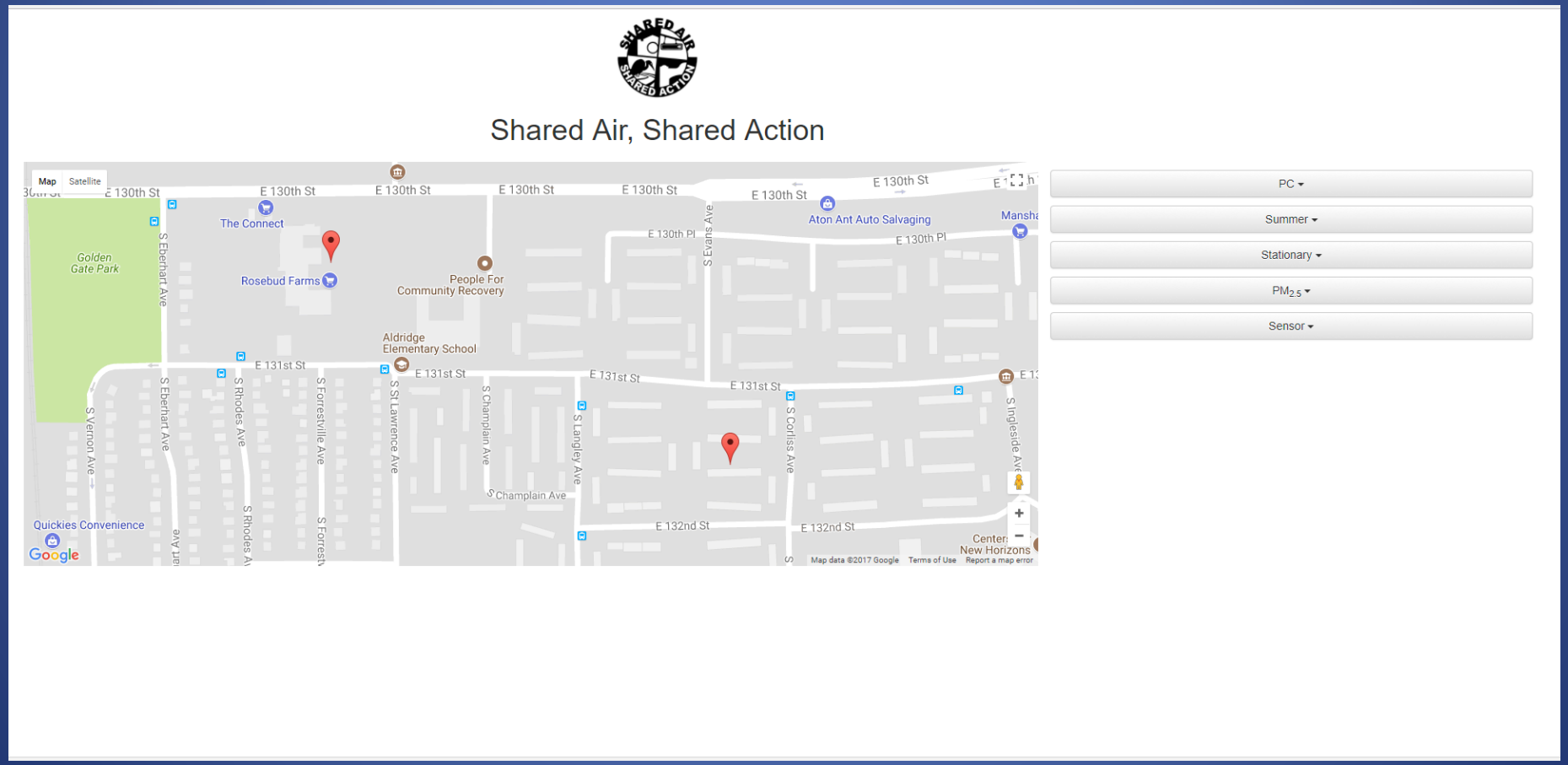
- Require bringing together an array of data
  - Local knowledge and external data sources
- Requires community education on air quality
  - Particularly to match monitors to problems
- Plans dependent on community partners
  - Hosts for stationary monitors
  - Participants for mobile monitoring
- Trade-offs between detail and coverage
- Iterative process and ideally on-going

Challenge #3: Monitoring

- All the devices are different
  - We provided training guidance and protocols
  - Set up was complicated – particularly registration
  - New devices or new apps added confusion
- All require ancillary gear
- Data protocols vary among devices
  - Downloading – automated vs. cloud
  - File types and structures
  - APIs change

Monitoring

- Need to bring data together in “real time”



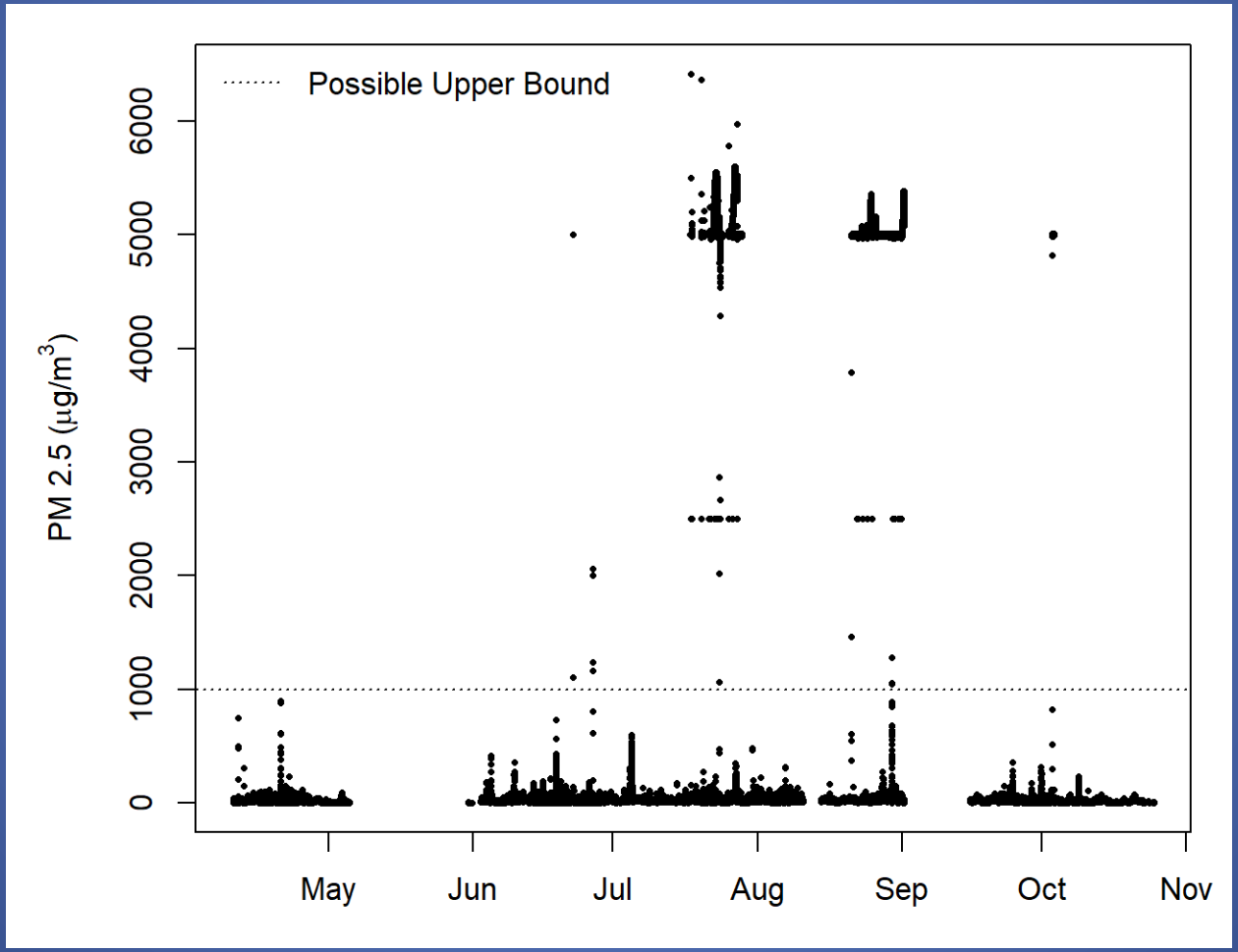
Monitoring

- Mobile data not uploaded immediately
  - Our protocol only looked for the previous day
- Naming conventions not adhered to
  - Lots of retroactive work to track down data
  - Manufacturers very helpful in getting us access

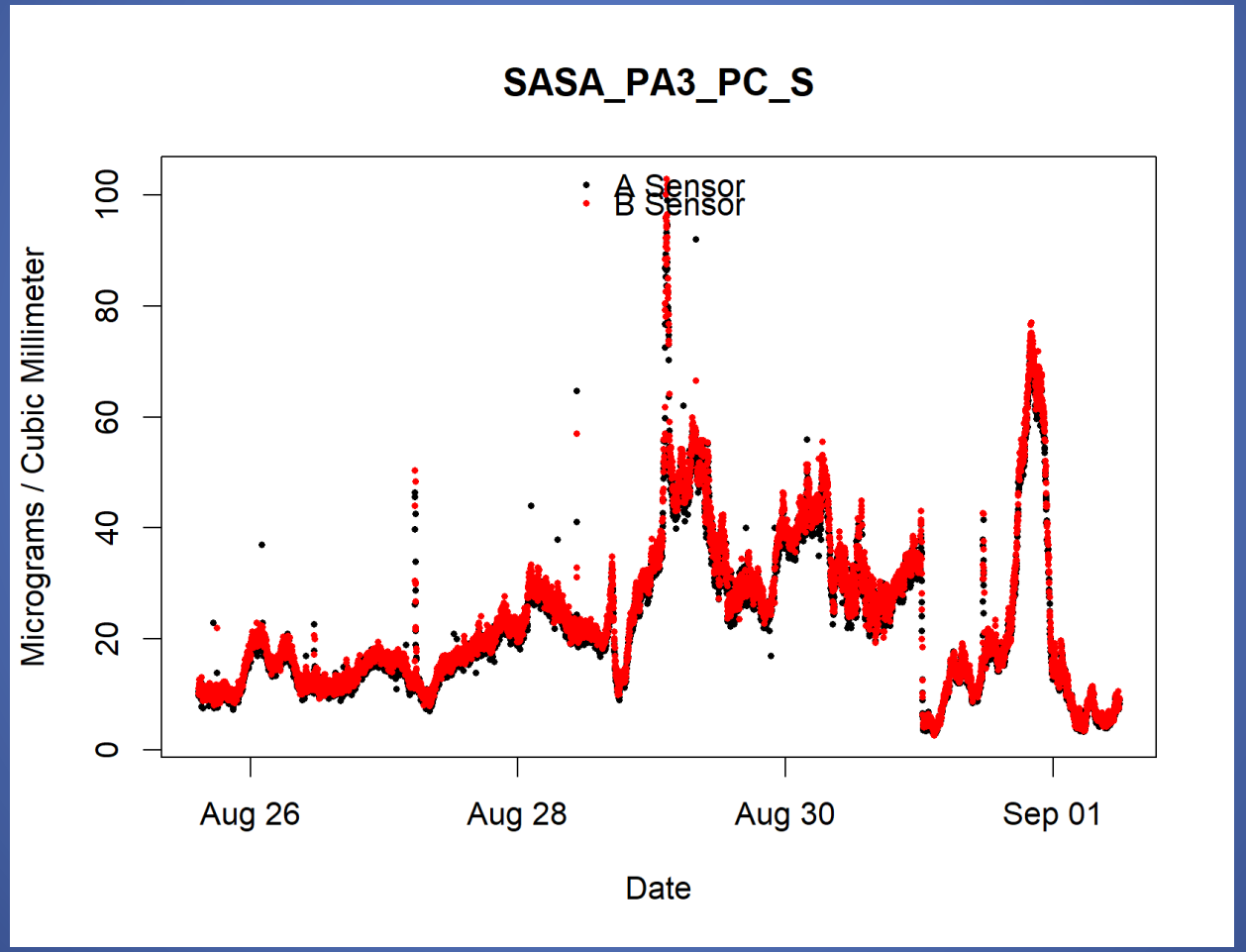
Challenge #4:Data Quality

- Data Cleaning
  - Lots of work clearing out test readings
  - Lots of effort on QAQC with STI guidance
  - Removing outliers
  - Selecting best feed for Purple Air

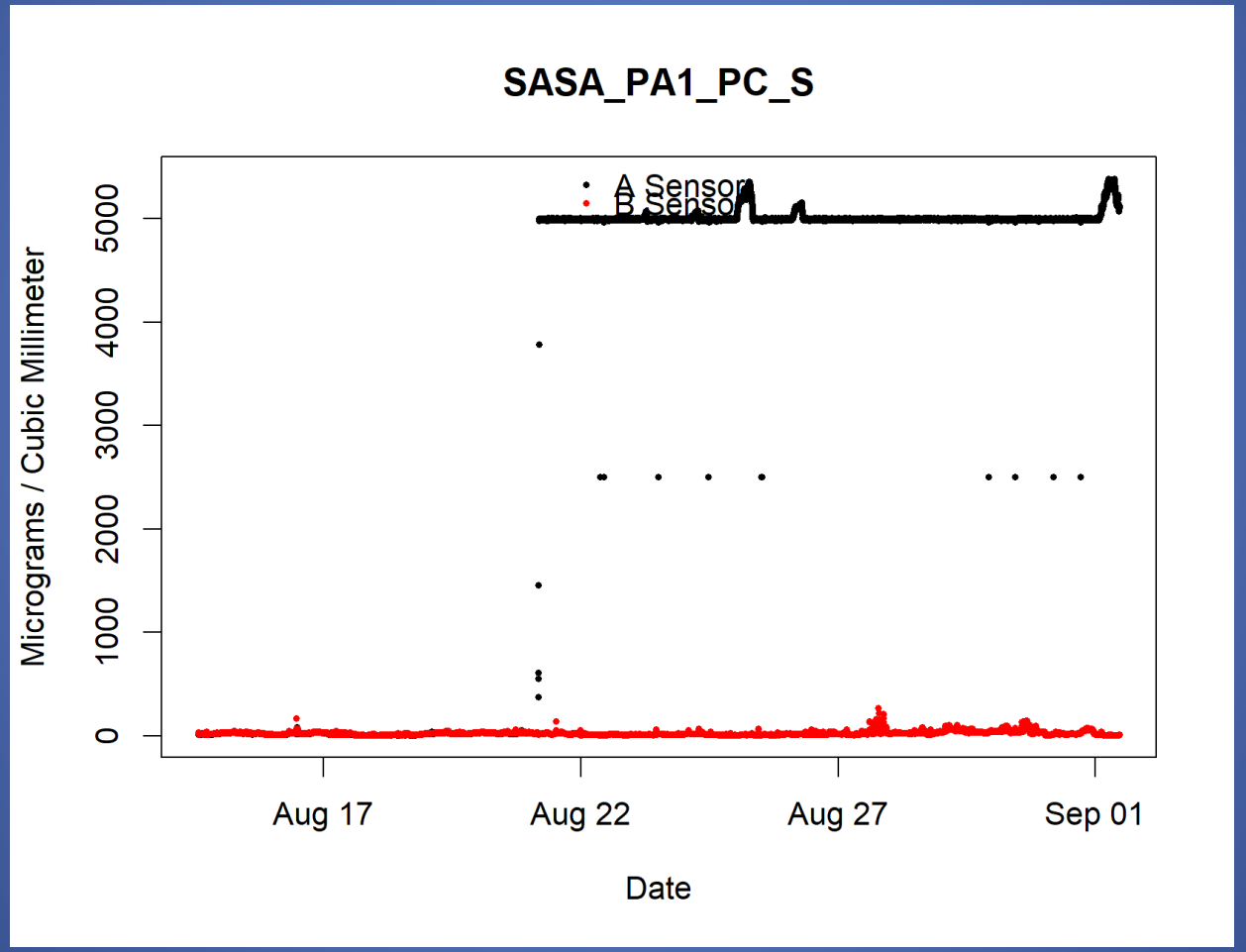
Data Quality



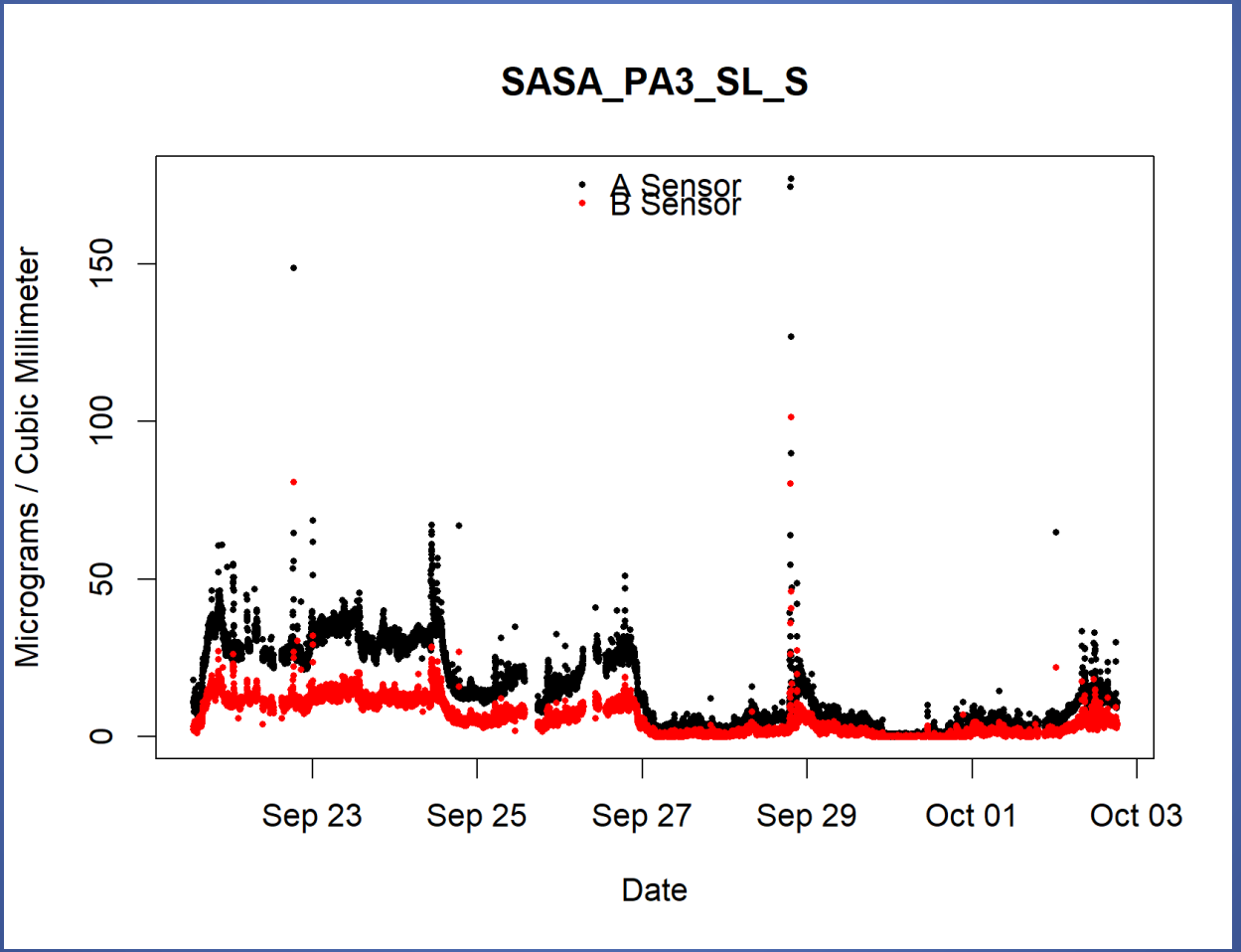
Data Quality – Good Alignment



Data Quality – Clear Divergence



Data Quality - Unclear



Data Quality

- Need for standardized cleaning protocols
  - Ideally conducted by the device
  - At a minimum, problematic data should be flagged
- What, if any, data should be excluded?
  - July 4th saw a spike in PM
  - Daily spike at one location due to smoke breaks

Challenge #5: Data Interpretation

- What can we say about air quality?
  - Should we present our data with AQI bands?
  - Can we argue there is an air quality problem?
  - Do we need to calibrate our instruments?
- Can we use these devices for advocacy and policy making at the local level?
- Challenge for community groups to handle torrents of data
- Need for more education on air quality

Thank you

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