Performance evaluation of low-cost PM sensors deployed in Pittsburgh, PA

R Subramanian subu@cmu.edu
Carl Malings cmalings@andrew.cmu.edu
Albert Presto, Rebecca Tanzer, Allen Robinson
Center for Atmospheric Particle Studies, Carnegie Mellon University

Presented at the Air Sensors 2018 workshop
Session 6. PM Focus: Perspectives on Data Quality Objectives
US EPA, RTP, NC

Acknowledgments

- CAPS:
  - Naomi Zimmerman (now faculty at University of British Columbia)
  - RAs: Aliaksei Hauryliuk, Srini Kumar
- Funding:
  - US EPA STAR RD83628601 and RD83587301
  - Heinz Endowments
- Allegheny County Health Department
  - Operate the local regulatory network used to test the PM sensors

Real-time Affordable Multi-Pollutant (RAMP) monitor

- Measures CO, O_3, NO_2, SO_2
- Fine particulate mass, $PM_{2.5}$
  - PurpleAir, $200/unit
    - Two Plantower 5003 sensors
  - Met-One NPM, $2000/unit
  - AlphaSense OPC-N2, $400/unit
    - Tested, but not deployed
- Tested by collocation with reference monitors

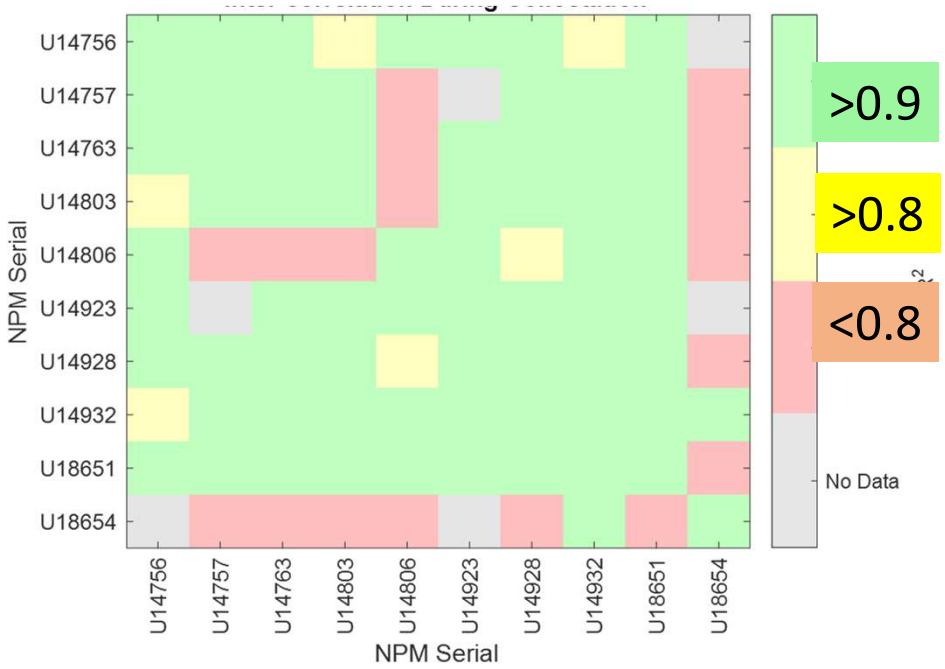
Use cases for low-cost sensors

- Community awareness and citizen science
  - Rapid dissemination, trends
- Hot spot detection in urban areas
  - Regulatory monitors are sparse and often in urban background
- Spatial and temporal variability in air quality across an urban area
  - Annual averages across ACHD network vary by <5 $\mu g/m^3$
- Monitoring near sources
  - Micrometeorology, terrain effects

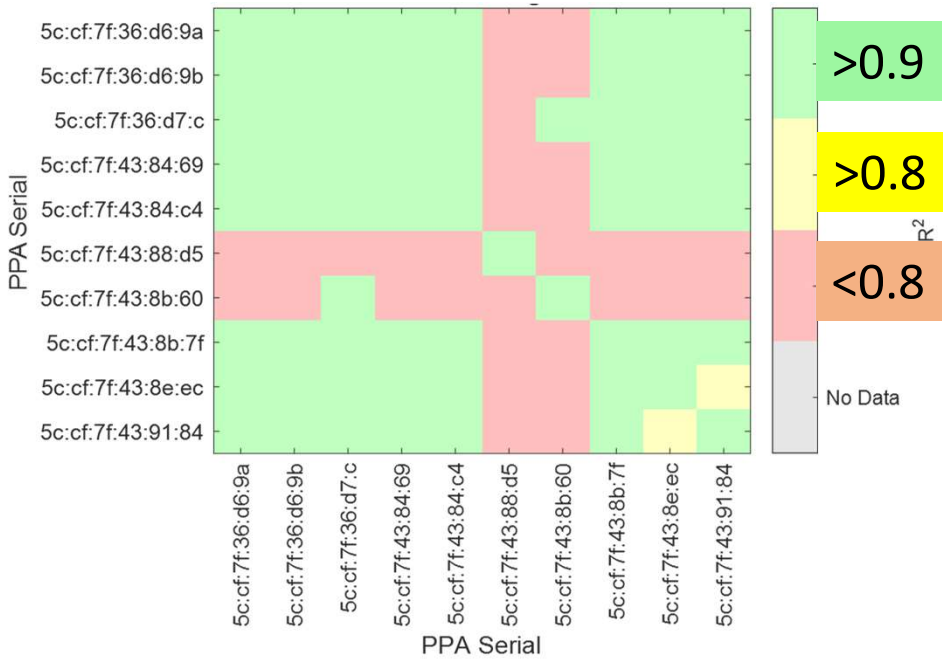
Community awareness and citizen science

- Trends, plumes, spatial variability…?
  - Official data often 3-4 hours behind
  - Inversions build up overnight, is it clear again? (Mark Dixon, @inversion_doc)
- Fog and high humidity interference can create false positives/show levels up to two times higher than regulatory-equivalent
  - check RH levels and characterize sensor response
- Sensor error should not be interpreted as differences in PM levels
  - Collocated testing of PM sensors necessary
  - Manufacturer-tested sensors may still read erroneously. Dual sensors useful for in-use QA.

Met-One NPM



PurpleAir PM



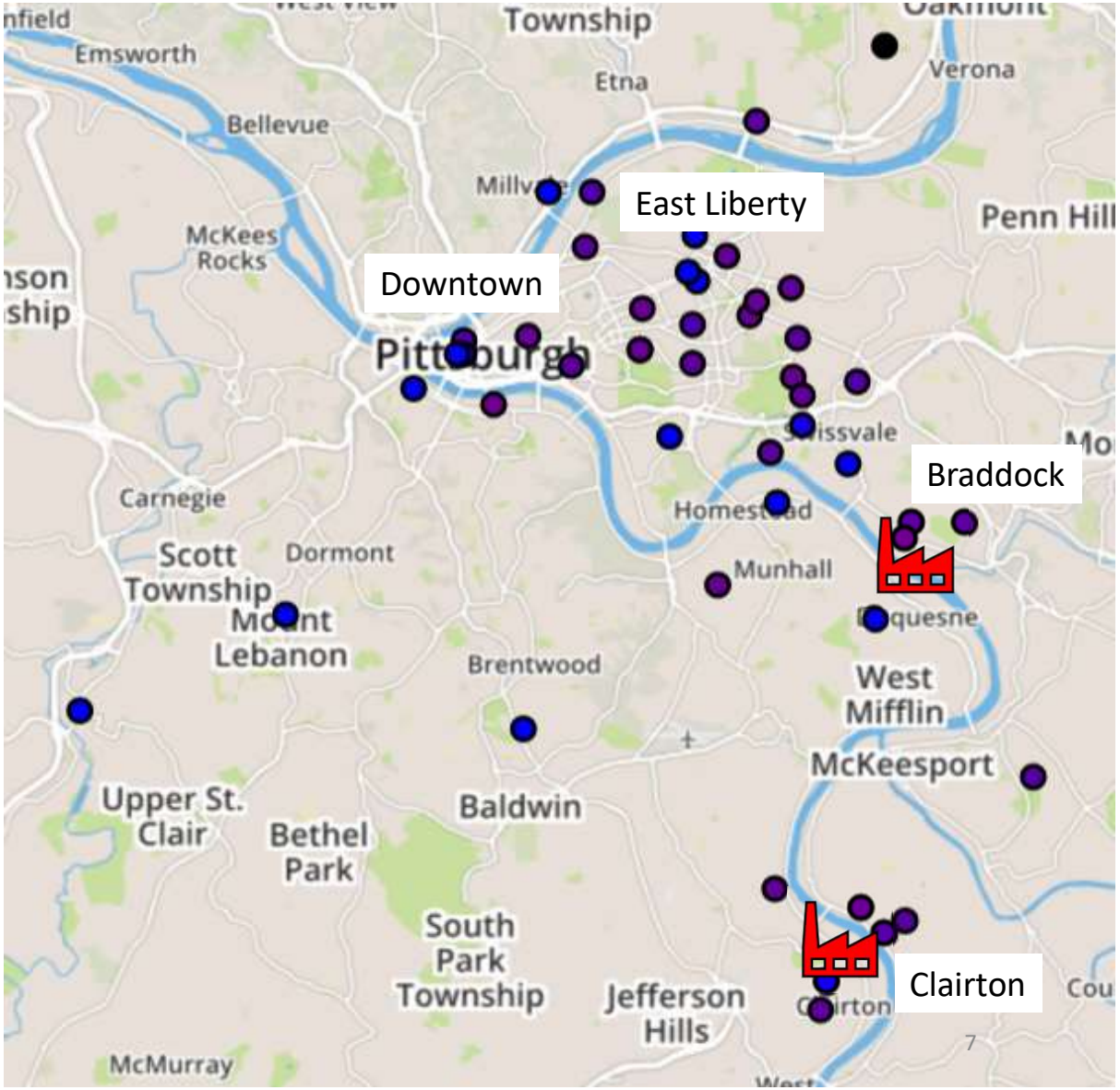
Precision of low-cost PM sensors: r^2

RAMP deployments in Allegheny County, PA

- 50 RAMPs currently deployed across Pittsburgh, Clairton, and Braddock
- Inter-RAMP distance ~1 km
- Collaboration with Albert Presto and Allen Robinson
- Risk perception: Julie Downs

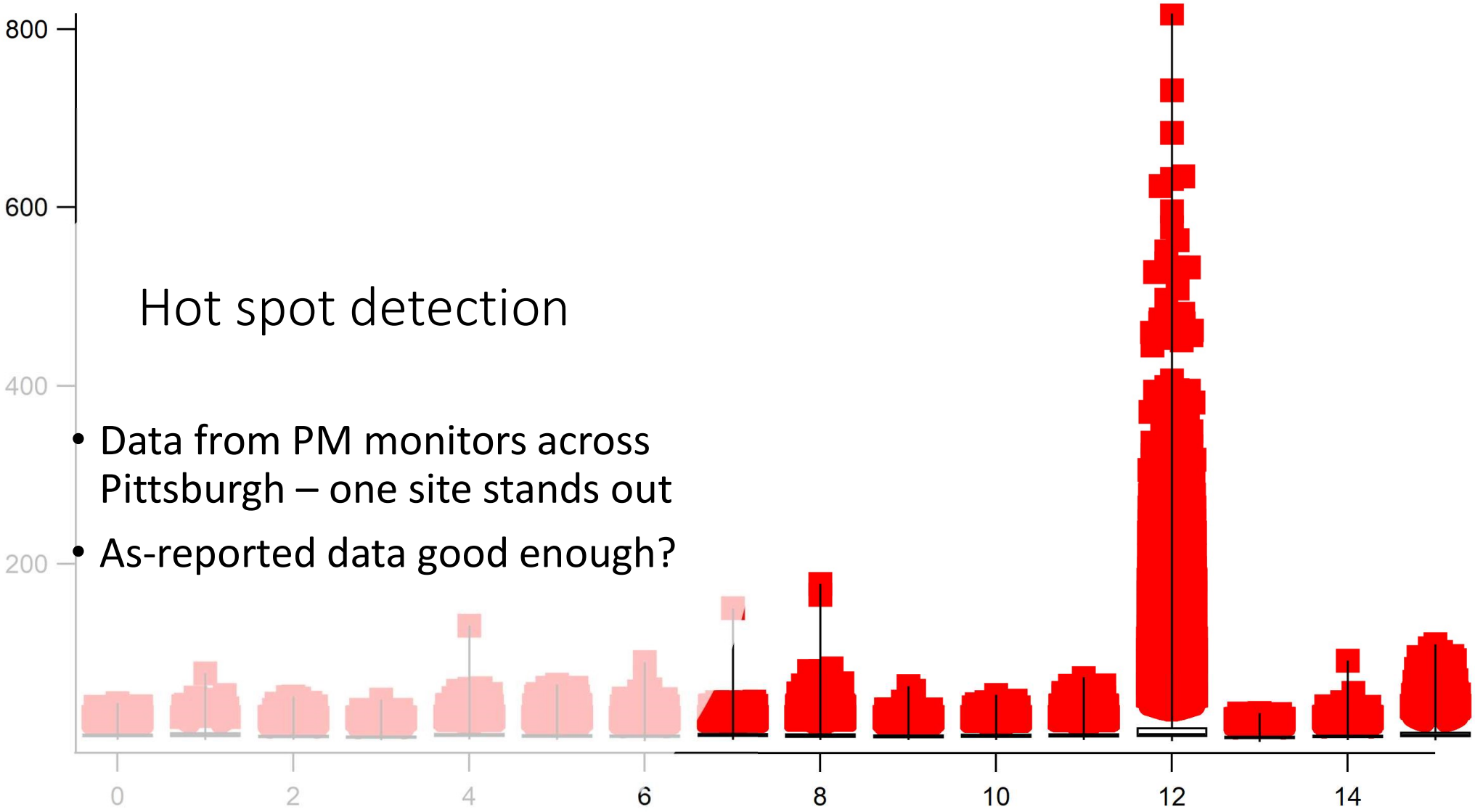
GASP FOR CLEAN AIR

CLEAN WATER ACTION



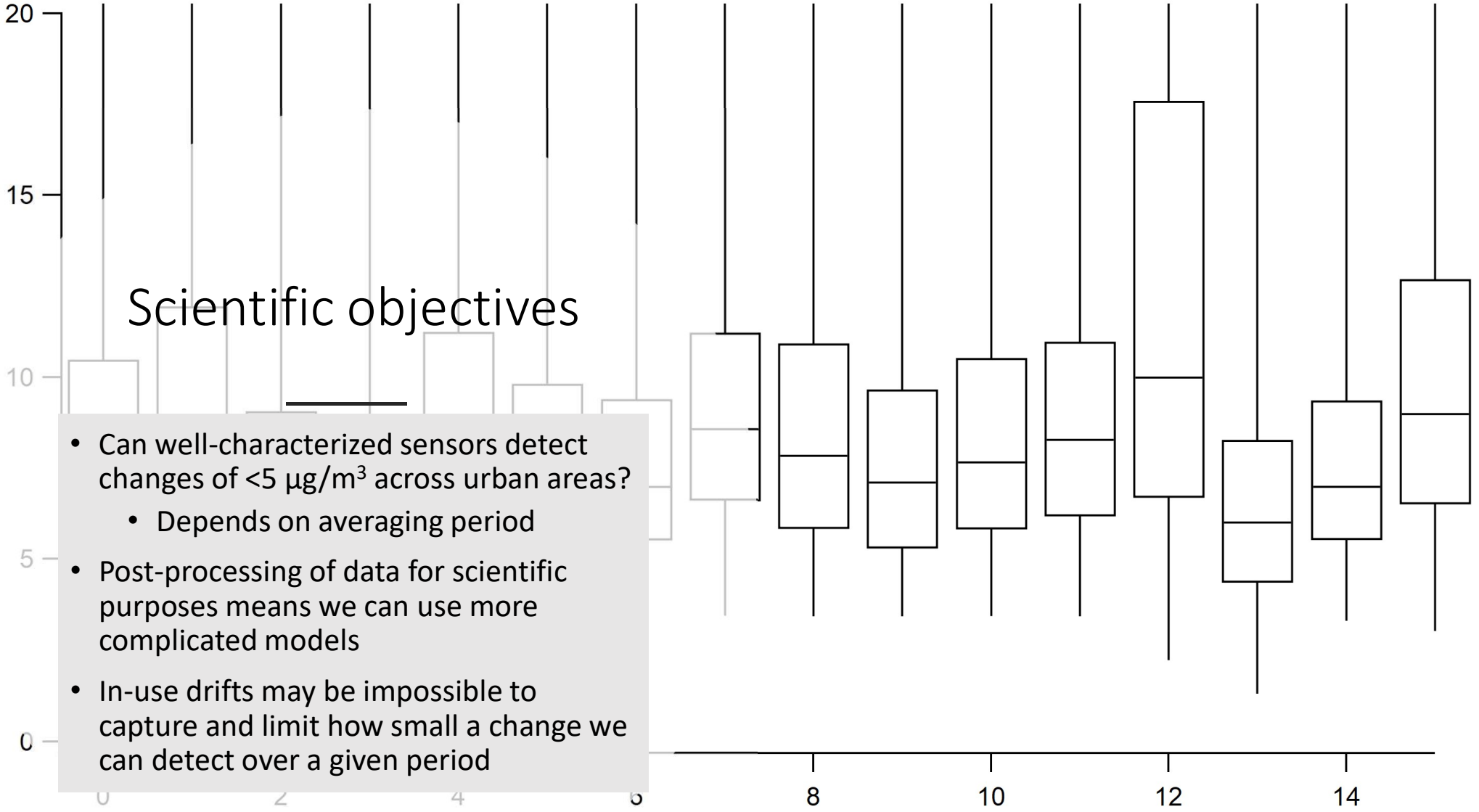
Hot spot detection

- Data from PM monitors across Pittsburgh – one site stands out
- As-reported data good enough?

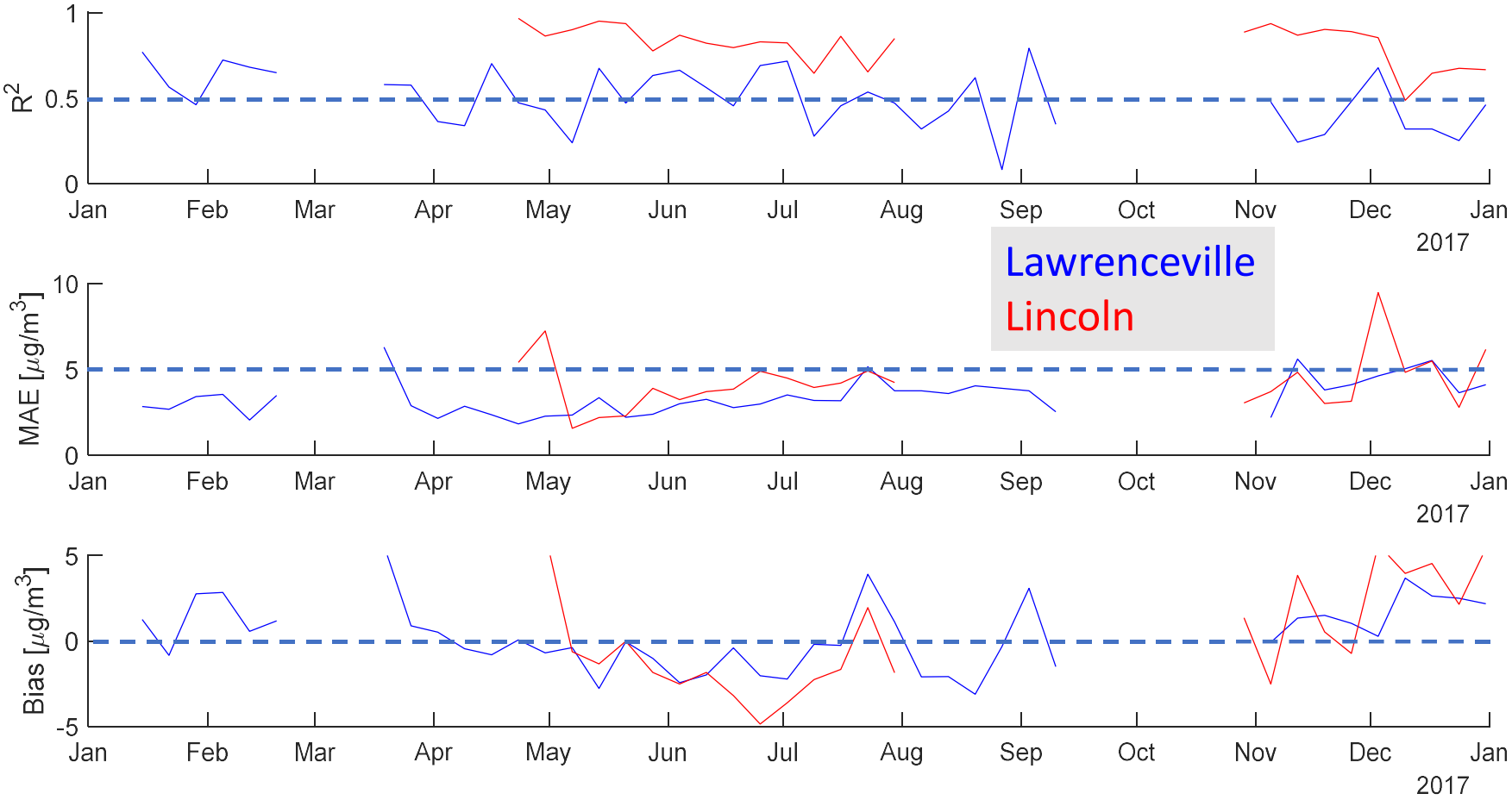


Scientific objectives

- Can well-characterized sensors detect changes of <5 µg/m^3 across urban areas?
  - Depends on averaging period
- Post-processing of data for scientific purposes means we can use more complicated models
- In-use drifts may be impossible to capture and limit how small a change we can detect over a given period



Weekly statistics: NPMs at ACHD sites



Summary/for discussion

- Collocation testing is important for all use cases
- Collocation with regulatory monitors across the expected range of concentrations and environmental conditions can be very helpful
- Correction factors can be relatively simple with scientific guidance
- Data quality assessment:
  - EPA “precision error” and “bias error” metrics are a bit mystifying
  - Pearson r or correlation coefficient (r^2) evaluates precision
  - Mean Absolute Error (MAE) or CvMAE bounds depend on the use case
- Performance and corrections can depend on PM concentrations

Session Questions

- Provide your views on data quality objectives, data quality indicators, and target values that would be relevant to determining future performance targets for PM.
- Which technical parameters would constitute the DQOs/DQIs? And what values or range of values would they comprise?