JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Exposure Assessment in a Military Environment: Tools and Methods

Jennifer Therkorn, PhD, MPH
Senior Scientist
Jennifer.Therkorn@jhuapl.edu

Outline

Opportunities for exposure assessment tools and methods – highlighting 3 areas under development at Johns Hopkins University Applied Physics Lab (JHU/APL)

Tool / Method	Air Pollutants
Silicone wristbands	Organic compounds
Low cost sensors	Particulate matter
Satellite remote sensing	Varied

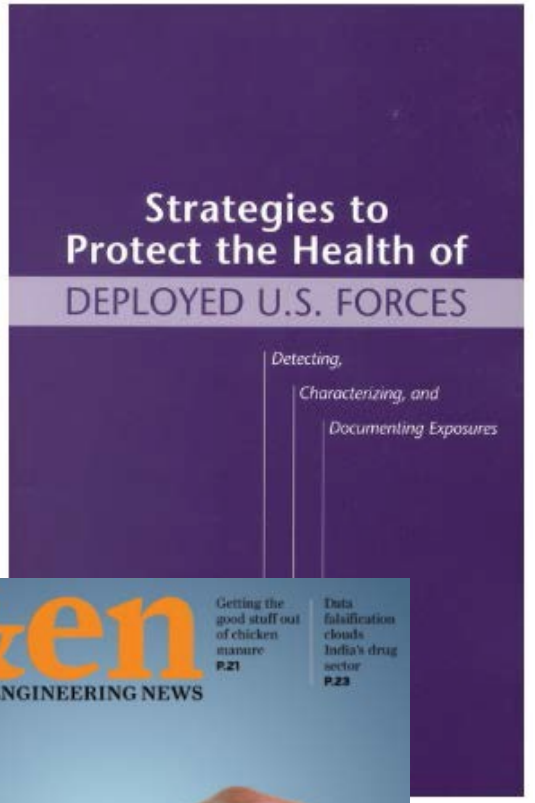
Outline

Opportunities for exposure assessment tools and methods – highlighting 3 areas under development at JHU/APL

Tool / Method	Air Pollutants
Silicone wristbands	Organic compounds
Low cost sensors	Particulate matter
Satellite remote sensing	Varied

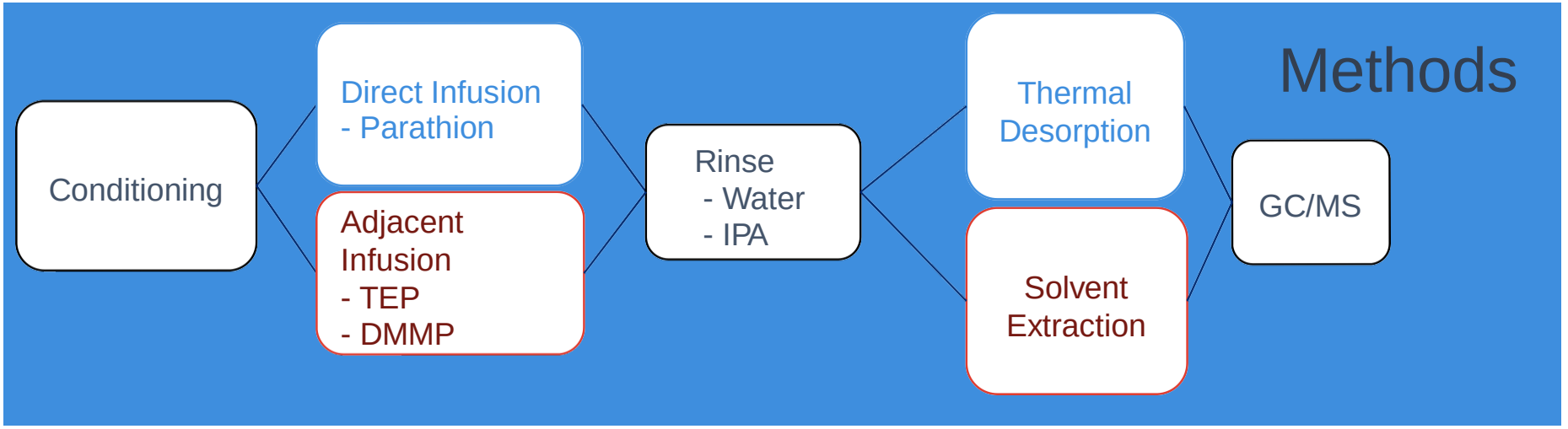
Silicone Wristbands

- Background:
  - **2000**: National Academies report recommended the DoD should develop a simple, wearable sampler to document unknown exposures during deployment
  - **2014-present**: First publications on silicone wristbands for documenting thousands of organic compound exposures
    - Results demonstrating capture and detection of >1500 chemicals
- JHU/APL internal research and development efforts:
  - **Proof of concept**:
    - Are the published results really as good as they seem?
  - **Specific application**:
    - Deployed service member exposures
    - “Thomas Sutto List,” (Naval Research Lab)



Sutto TE. 2011. Prioritization and sensitivity analysis of the inhalation/ocular hazard of industrial chemicals. (NRL/FR/6364--11-10211) Washington, DC: Naval Research Laboratory.

Proof of Concept Tests



Results

Compound	% Recovery of Infused Mass
TEP	60 ± 0.1
DMMP	60 ± 0.2
Parathion	37 ± 0.2

Take-away message: the methods matter*

*See Anderson et al. (2017) Journal of Exp Sci Env Epi, 27:551-559

Field Test: Methods

Sampling conditions

- 1 week (8/7-8/15)
- Avg. temp: 79˚F, 71% RH
- Scattered storms

Samplers

- 3 wristbands
- 3 Radiello passive badges
  - “Gold standard” for long-term passive sampling

Targeted Compounds

- Army Public Health Command called out fuel vapors as a specific concern
- Most commonly reported gasoline health concerns from BTEX compounds
  - Benzene
  - Toluene
  - Ethylbenzene
  - Xylene

Field Test: Results

Sampler: Wristbands

Analytical method: Thermal desorption + GC/MS

Sampler: Radiello

Analytical method: CS2 desorption + NIOSH 1501 (GC/FID)

Compound	Able to Detect?	Able to Quantify?	Able to Detect?	Able to Quantify?
Benzene	Yes	No	Yes	Yes
Toluene	Yes	No	Yes	Yes
Ethyl benzene	Yes	Yes	Yes	Yes
m,p-xylene	Yes	Yes	Yes	Yes
o-xylene	Yes	Yes	Yes	Yes

Field Test: Results

Sampler: Wristbands

Analytical method: Thermal desorption + GC/MS

Sampler: Radiello

Analytical method: CS2 desorption + NIOSH 1501 (GC/FID)

Compound	Able to Detect?	Able to Quantify?	Able to Detect?	Able to Quantify?
Benzene	Yes	No	Yes	Yes
Toluene	Yes	No	Yes	Yes
Ethyl benzene	Yes	Yes	Yes	Yes
m,p-xylene	Yes	Yes	Yes	Yes
o-xylene	Yes	Yes	Yes	Yes

Takeaway message:
Silicone wristbands provide reliable, simple, cost-effective yes/no profiling for organic compound detection

Major technical hurdles:
How to acquire quantitative concentration data?

Correlation between what is detected, and actual exposures?

Outline

Opportunities for exposure assessment tools and methods – highlighting 3 areas under development at JHU/APL

Tool / Method	Air Pollutants
Silicone wristbands	Organic compounds
Low cost sensors	Particulate matter
Satellite remote sensing	Varied

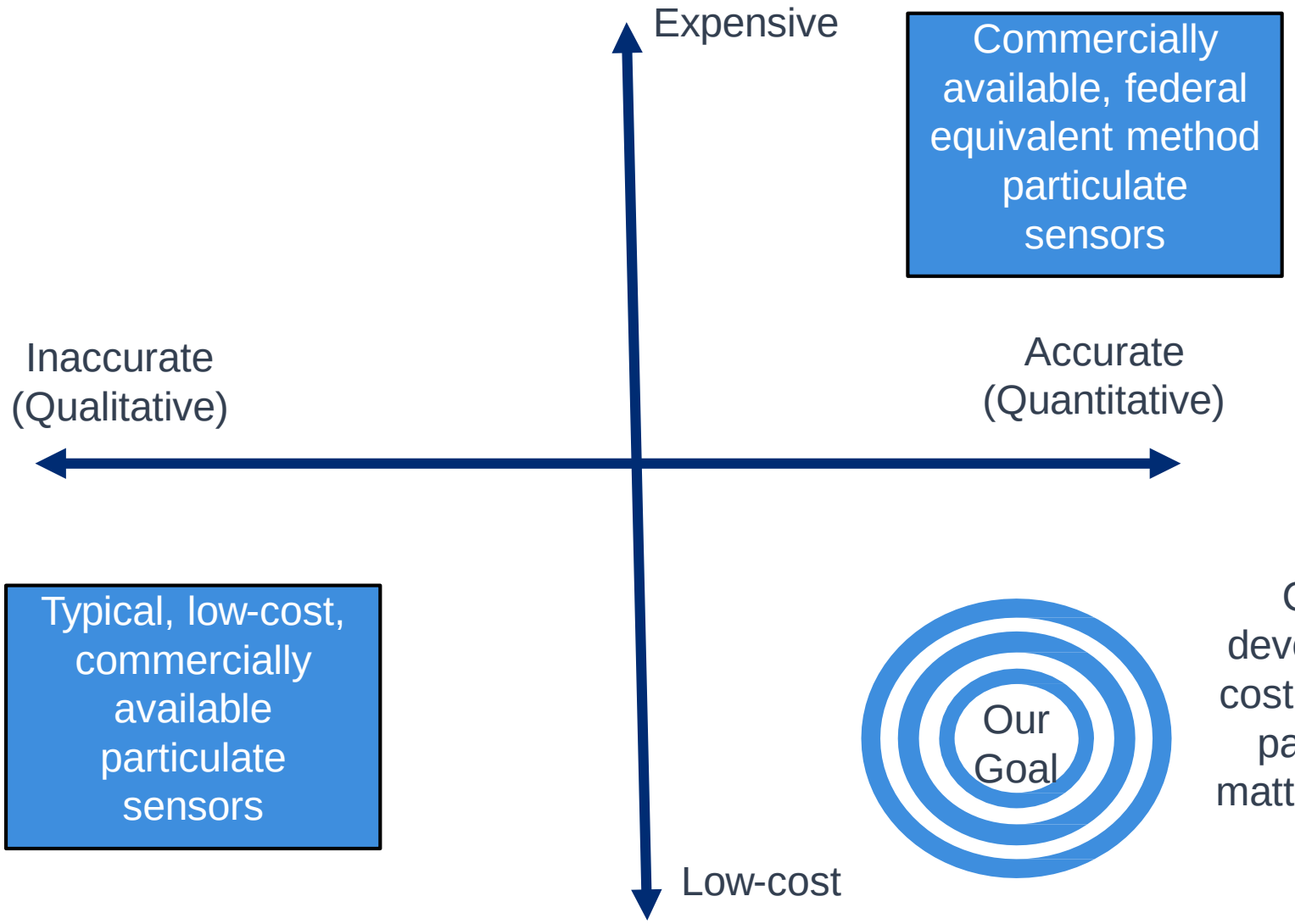
Low Cost Particulate Matter Sensors

Case study: California wildfires

https://www.bbc.com/news/world-us-canada-46198286

https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=90547&src=twitter-nh

Low Cost Particulate Matter Sensors



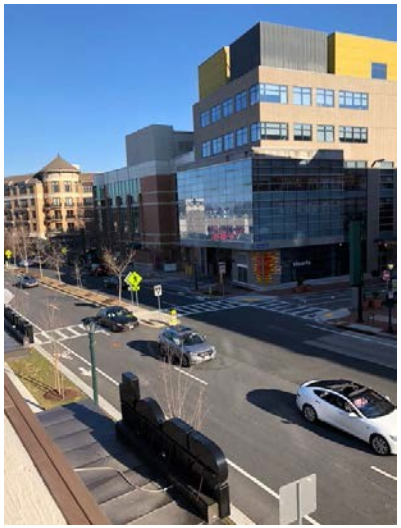
Can we develop a low cost, **accurate** particulate matter sensor?

Proof of Concept Experiment

Can we accurately quantify particulate matter loading onto filters by a cost-effective method?

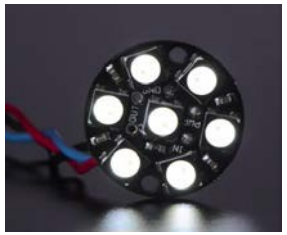
1) Particulate matter pollution collected onto filters in an urban setting

Filter samples



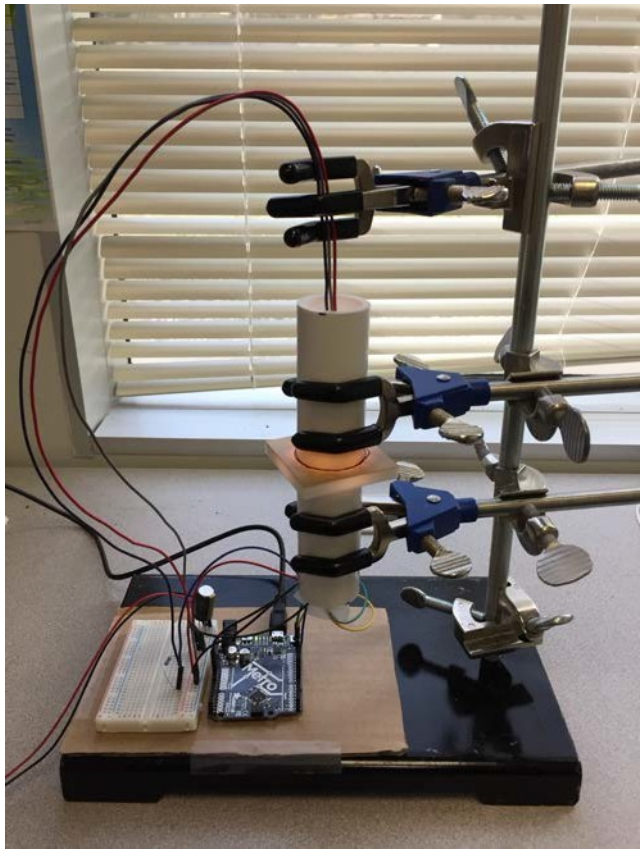
2) Investigated sensitivity of a light sensor to detect filter loading changes with filter backlit by an LED

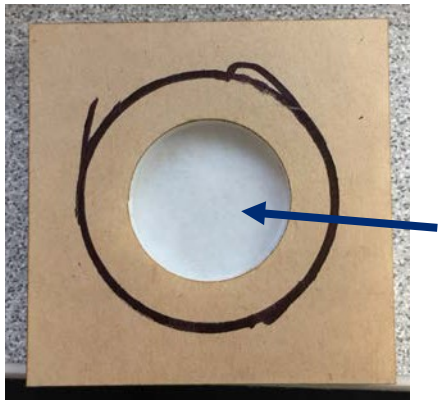
High dynamic range digital light sensor
Adafruit
$6.95

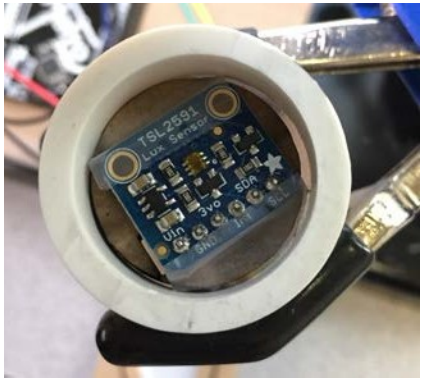


NeoPixel Jewel LED
Adafruit
$6.95

Experiment Setup



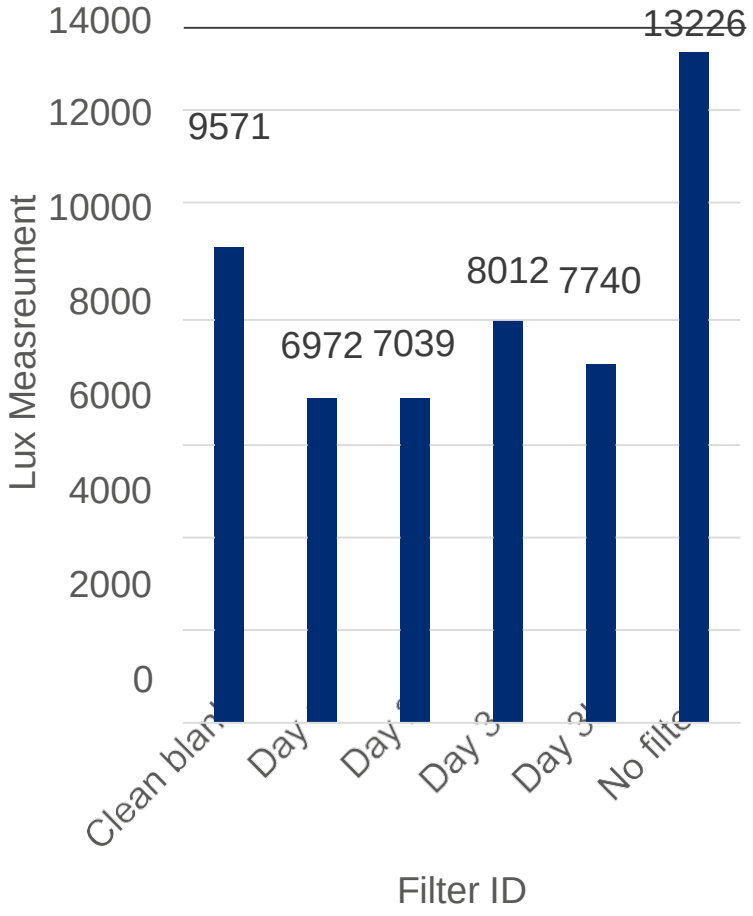




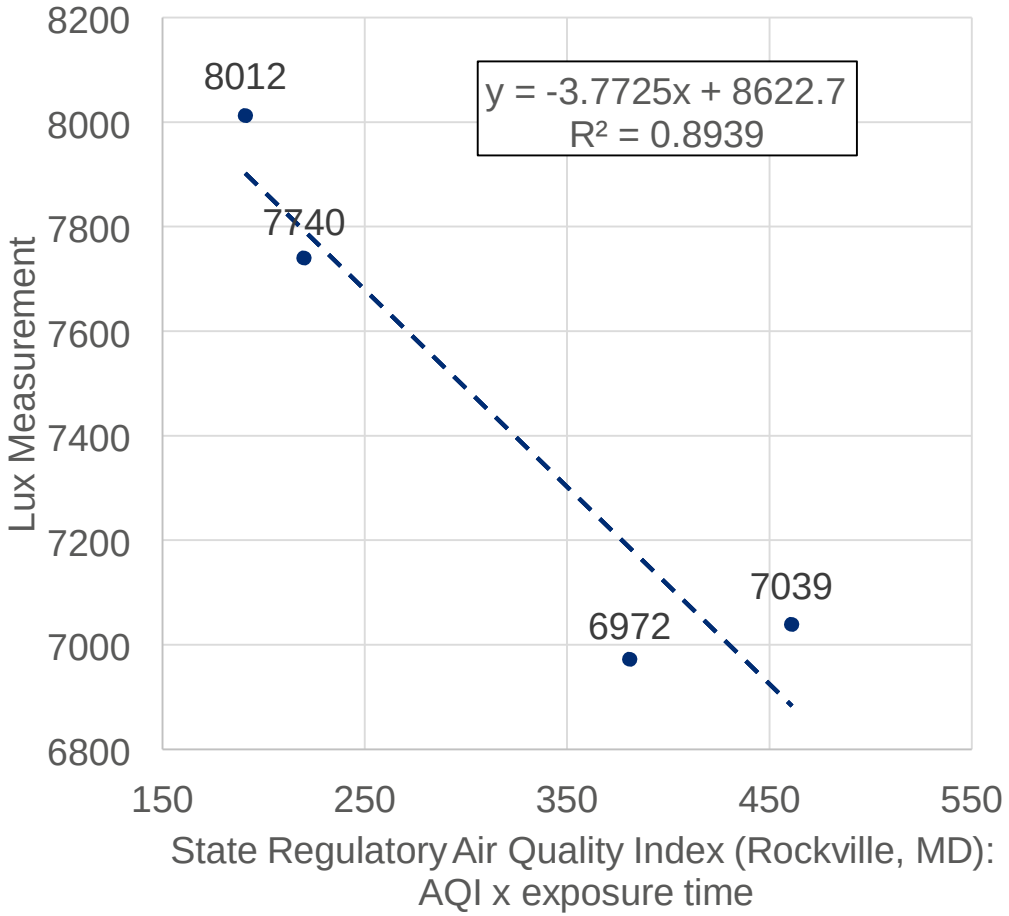
- Different filters from field test measured for light penetration in filter holder
- LED on one side of filter and light sensor on other side
- Setup designed to standardize the amount of background light and distance of sensor / LED from filter

Experiment Results

Can we detect differences in light penetration? - Yes



Do the measurements correlate with real-world data? - Yes

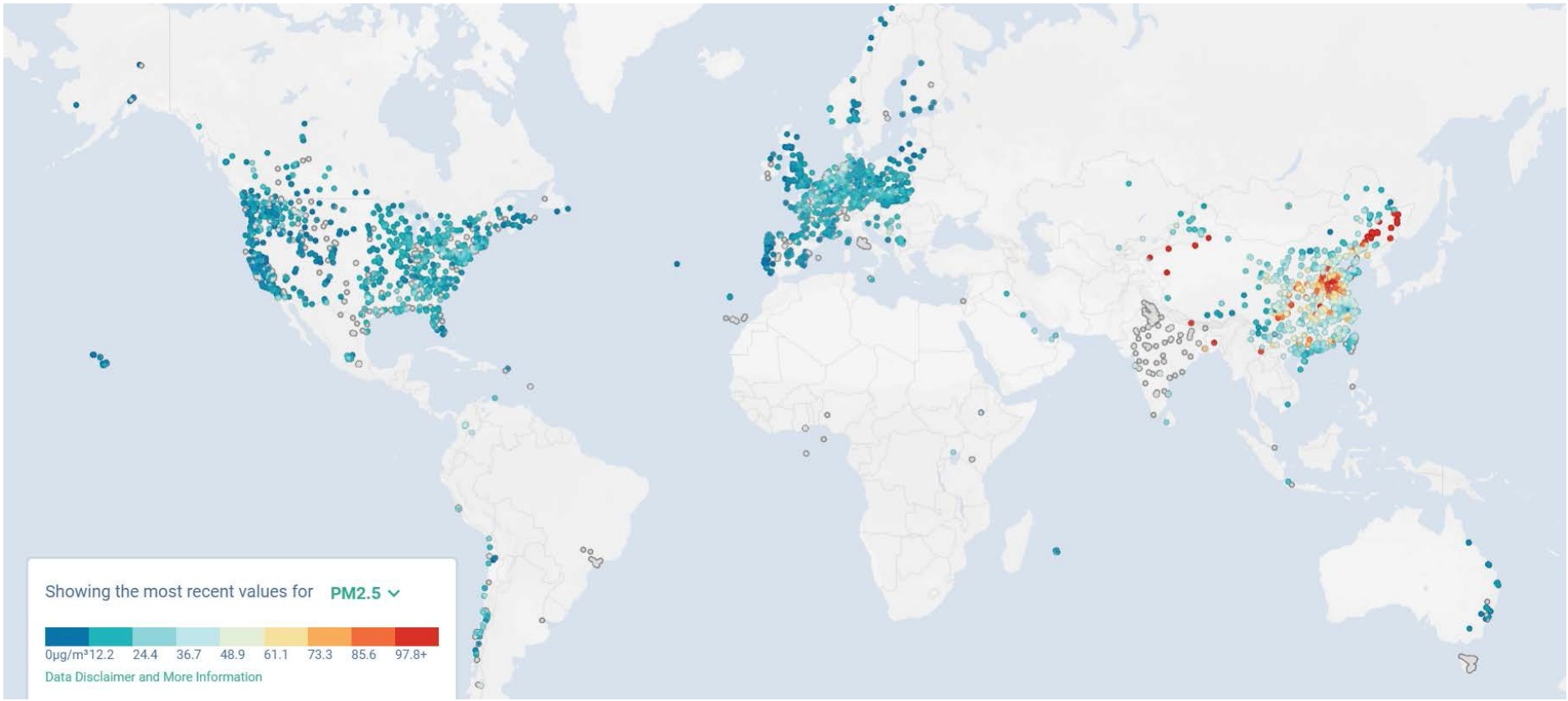


Outline

Opportunities for exposure assessment tools and methods – highlighting 3 areas under development at JHU/APL

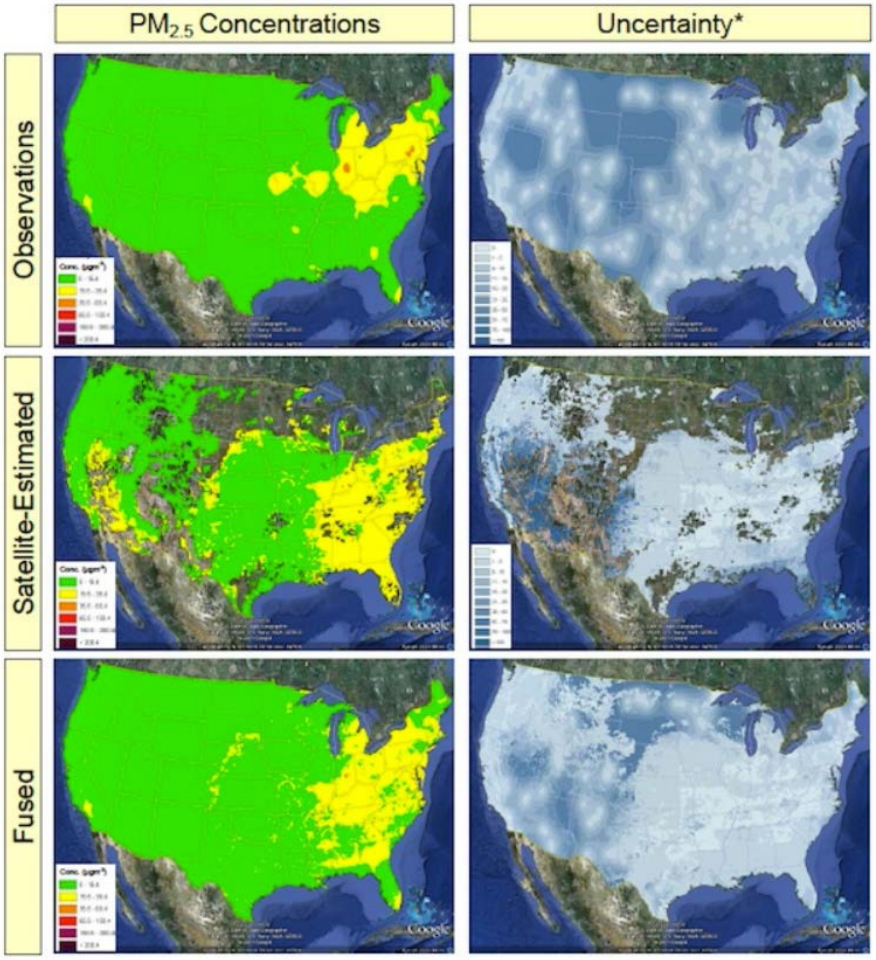
Tool / Method	Air Pollutants
Silicone wristbands	Organic compounds
Low cost sensors	Particulate matter
Satellite remote sensing	Varied

Major Technical Hurdle: Filling in the Gaps in Air Quality Monitoring in Deployed Locations



https://openaq.org

Potential for Satellite Remote Sensing: Data Fusion with Ground-Based Measurements

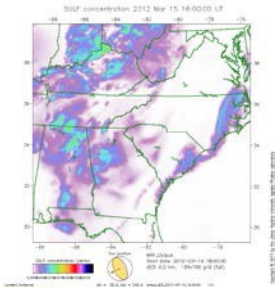


https://blogs.nasa.gov/whatonearth/tag/air-quality/

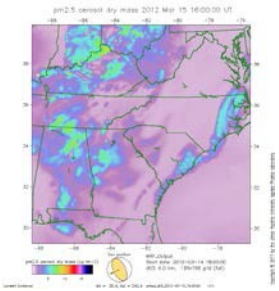
Potential for Satellite Remote Sensing: Data Fusion with Ground-Based Measurements

Example Output from the Weather Research and Forecasting Model coupled with Chemistry (WRF-Chem)

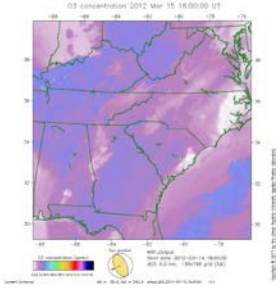
- Measured concentrations of air pollutants in 1x1 km resolution grids from a range of heights off the ground used in databases to initialize the model
- Concentration measurements provided by MODIS with capabilities to provide once daily passes over select regions of earth that can be read into the model as ground truth through data assimilation
- Using multilayer nests, model results can achieve spatial resolutions down to 1 km
- WRF-Chem is running on a dedicated cluster at APL, used by APL personnel since 2012, custom software and products generated in-house



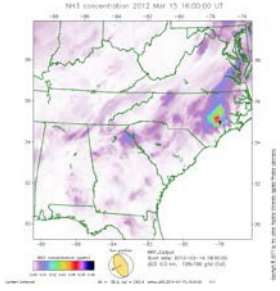
Sulfates



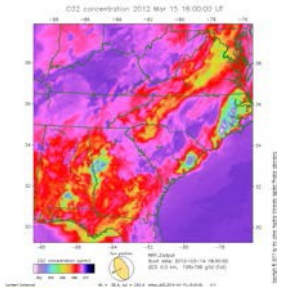
PM2.5 (dry mass)



Ozone



Ammonia



CO2

Path Forward

Tool / Method	Potential Military Applications	Proposed Next Steps
Silicone wristbands	- Individual or area monitoring via various form factors	- Performance testing under harsh conditions (storage and use) - Correlation with internal measures of exposure (e.g. omics)
Low cost PM sensors	- Area monitoring - Input data to plume modelling	- Sampler prototype development - Laboratory and field testing against reference instruments
Satellite remote sensing	- Post deployment exposure documentation - Mission planning for future	- Research study incorporating multi-season investigation of WRF-Chem/remote sensing air pollutant measurements vs. ground-based measurements (CONUS)

Acknowledgements

- Funding:
  - JHU/APL Internal Research & Development grant (National Health Mission Area)
  - JHU/APL Project Catalyst, HELP Ignition Grant

- Project teams:
  - Kaitlin Lovett (AOS/QPA)
  - Kelly Van Houten (AOS/QPC)
  - Jake Mathews (AOS/QPC)
  - Gordon Bewsell (AS DoD)
  - Liz Corson (AOS/QPA)
  - Mary Keller (SES/SRG)

- Analytical methods guidance:
  - Mitch Rubenstein (AFRL)

Questions?

Jennifer Therkorn, PhD, MPH
Senior Scientist
Jennifer.Therkorn@jhuapl.edu

Steven Patterson, MSPH, REHS/RS, CPH
Health Systems Engineer
Steven.Patterson@jhuapl.edu

Martina Siwek, PhD
Program Manager
Martina.Siwek@jhuapl.edu

JOHNS HOPKINS

APPLIED PHYSICS LABORATORY