Sensor Technologies: EPA's Ongoing Efforts in Discovery and Application

US EPA’s Emerging Technologies Research Program

Ron Williams
EPA Collaborators and Contacts

• Amanda Kaufman - Air Sensors Toolbox
• Village Green - Sue Kimbrough
• RETIGO - Gayle Hagler
Emerging Technologies
Research Agenda

1. Investigate emerging technologies and potential to meet future air quality monitoring needs
2. Establish market surveys of commercially-available air quality sensors
3. Conduct extensive literature survey on the state of sensor technologies
4. Develop sensor user guides
5. Educate sensor developers and users on the state of low cost sensors
6. Facilitate knowledge transfer to wide range of stakeholders
7. Work with sensor developers to speed up development
8. Support ORD’s Sensor Roadmap by focusing on high priority issues (NAAQS, Air Toxics, Citizen Science)
9. Establish highly integrated research efforts across EPA
10. Apply knowledge gained in hands-on sensor deployment activities

*These areas will be highlighted in our discussion
Ongoing/Planned Activities

2017
- Data sharing with stakeholders
- Summarize state of the science
- New sensor evaluation initiative?
- Field Citizen Science applications
- Designing/building autonomous systems: Village Green Project v. III
- SENTINEL and S-POD advancements
- Data visualization: RETIGO V2

2018
- Data sharing with stakeholders
- Summarize state of the science
- Consider future of performance evaluations
- Citizen Science Collocation Events
- Complete Pilot Project Phase
- Continue advancement with possible commercialization
- Advance use of this tool
Example- Gas Sensors

SENSARIS

AIR CASTING

CAIRCLIP

AEROQUAL

AQ EGG

NODE
Direct Collocation with FEMs
CAMP Denver-CAIRSENSE Deployment

Repeat of Atlanta Design

Interior view

Multiple shelving options

Arduino MicroProcessing

New TSI sensors

New Speck and OPC N2 sensors
Ad-Hoc Testing

- AQMesh: NO₂, NO, O₃, SO₂, CO
- MetOne 831 particle sensor
- Dylos particle sensor
- Air Quality Egg (CO, NO₂, PM, VOCs)
- Aeroqual SM50 O₃ sensor
- Airbeam particle sensor
- Shinyei particle sensor
- Not shown: Cairpol NO₂/O₃ sensor
An Example of In-Depth PM Sensor Evaluation
• Few over-responding events
• Strong agreement between units 2 and 3
• Strong correlation with monitor

\[
\begin{align*}
    r_1 &= 0.80 \\
    r_2 &= 0.78 \\
    r_3 &= 0.81
\end{align*}
\]
- Initial lab audit had 1:1 ratio
- Underreports regulatory monitor $O_3$
- Consistent across seasons
- Strong correlation to regulatory monitor

$r_1 = 0.93$
$r_2 = 0.92$
$r_3 = 0.96$
Sensor Response Normalization ($\text{NO}_2$)
CSAM vs FEM
Most sensors exhibit strong correlation within model types. Correlations with regulatory monitors range from weak to very strong. Hourly average values had strongest correlations.
Laboratory VOC Sensor Evaluation

UniTec Sens-It and GC-FID Response

- UniTec Sens-It
- GC-FID Benzene

Measured concentration (ppb) vs. Time (min)
How can EPA facilitate citizen science?

- What tools are needed?
- What types of interactions best accomplish tool transfer?
- What technologies might be applied in pilot efforts?
EPA’s Recent Community Air Monitoring Training Event

• Goals:
  ▪ To share tools, best practices, and resources from EPA’s Air Sensor Toolbox for Citizen Scientists
  ▪ To educate interested groups and individuals on how to conduct successful air monitoring projects
• 30 in-person attendees, 800+ via webinar
• Training videos now available on Air Sensor Toolbox website
• Ongoing follow-up with Regions/State/Tribal interests
The Sensor Pod - CSAM

- Cyclone inlet
- Nephelometer
- \( \text{NO}_2 \) sensor
- Arduino Uno microprocessor
- Sampling pump
- Temp/RH sensor

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Reporting Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{NO}_2 ) concentration</td>
<td>Parts per billion (ppb)</td>
</tr>
<tr>
<td>PM concentration</td>
<td>Micrograms per cubic meter (( \mu g/m^3 ))</td>
</tr>
<tr>
<td>Temperature</td>
<td>Degrees Celsius (( ^\circ \text{C} ))</td>
</tr>
<tr>
<td>Relative humidity (RH)</td>
<td>Percent (%) at ( ^\circ \text{C} )</td>
</tr>
<tr>
<td>Project / Year</td>
<td>Regional Partner(s)</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>CAIRSENSE (Being summarized)</td>
<td>Region 1,4,5,7,8</td>
</tr>
<tr>
<td>CSAM (Being summarized)</td>
<td>Region 2</td>
</tr>
<tr>
<td>CitySpace</td>
<td>Region 4, Region 6, Region 7</td>
</tr>
<tr>
<td>AirMapper</td>
<td>Region 5, Region 10</td>
</tr>
<tr>
<td>Puerto Rico EJ</td>
<td>Region 2</td>
</tr>
<tr>
<td>Southern California</td>
<td>Region 9</td>
</tr>
<tr>
<td>AIRS platform</td>
<td>OAQPS</td>
</tr>
</tbody>
</table>
Goal: Support community group in using low-cost sensors to explore their air quality

AirMapper

- Designed for use by citizens/students
- Local (on-board) data storage
- Designed for ease of use by non-professionals
- Lessons learned from ORD evaluations integrated into design function (e.g., technology selected /data visualization tools employed)
Recorded data for ~1 hour. We were stationary for ~5 minutes then biked, stopped at library, biked back and walked final 5 min. Highest PM values near highway 54 and library. RETIGO contact is Dr. Gayle Hagler-US EPA
The Take Home Message

• We have examined and are continuing to examine sensors as they become available.

• We are integrating these technologies (either as is or following further development) into a variety of research projects.

• Both lower cost (< $2500) as well as mid-tier ($3000-$10000) sensors are being investigated.

• A wide range in capabilities are being observed. Cost is not necessarily the driver in how well any given device might function.

• Generally speaking, Ozone>PM> CO> NO2>SO2 relative to performance in low cost sector.

• Fewer options available for air toxics. VOCs, ammonia, hydrogen sulfide, methane, etc limited in the low cost category.

• Most citizens unable to handle the large volume of data created by real time sensor devices.

• Demand to understand this technology sector is only increasing in intensity.
Sensor Related Resources

Contacts:
Ron Williams
919-541-2957
williams.ronald@epa.gov

Amanda Kaufman
919-541-2388
kaufman.amanda@epa.gov

Online Resources Available at:
www2.epa.gov/air-research/air-sensor-toolbox-citizen-scientists