Small Sensors to Augment Future Air Quality Services

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Oct 21, 2020
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Prediction Needs for Air Quality Data

- Air quality concentration data are fed to ECCC’s forecasting models (e.g., GEM-MACH and Firework) to provide AQHI forecast products to the public.

- Significant portions of the country are lacking AQ monitoring data.

- Monitoring gaps are most apparent when trying to predict wildfire smoke.
Service Needs for Air Quality Data

Emergency Management
• Data informs decision makers for evacuations due to wildfire smoke in remote communities.

Health Agencies
• To prepare for increased hospital visits and pharmacy dispensations.

Communities and the Public
• To inform during smoke events to protect vulnerable populations.
• Advice to modify activity (e.g., cancel kids sports), stay indoors, or seek clean air shelters.
Traditional Air Quality Monitoring

- Reliable, high quality data from Federal Equivalence Method (FEM) instrumentation;
- Set at representative locations for compliance and regulatory purposes;
- Costly to set up and operate;
- Large footprint.
New Air Quality Monitoring Methods

• Emerging technologies in small air quality sensors can **augment** existing technologies to reach higher spatial resolution in real-time.
Low-cost sensors

Advantages
• Low Cost
• Small footprint
• Ease of use

Disadvantages
• Lower accuracy and precision
• Limited calibration capabilities
• Unknown reliability
• Distrust by scientific community

Understanding restrictions and limitations can ensure a fit-for-purpose that still takes advantage of new opportunities enabled by low-cost sensors for air quality monitoring.
## Low-cost sensor evaluations

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Parameters</th>
<th>Purchase Cost</th>
<th>Other Costs</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-Cost Sensors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PurpleAir PAII</td>
<td>PM</td>
<td>$250</td>
<td>155</td>
<td>155</td>
</tr>
<tr>
<td>Air Quality Egg</td>
<td>PM, O\textsubscript{3}, NO\textsubscript{2}</td>
<td>$400</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>TSI Blue Sky</td>
<td>PM, O\textsubscript{3}, NO\textsubscript{2}</td>
<td>$400</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Moderate-Cost Sensors – “Near FEM” Sensors</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>AeroQual AQY</td>
<td>PM, NO\textsubscript{2}, O\textsubscript{3}</td>
<td>$2500</td>
<td>$500/s/y</td>
<td>2</td>
</tr>
<tr>
<td>RAMP</td>
<td>PM, O\textsubscript{3}, NO\textsubscript{2}, NO, CO\textsubscript{2}, CO</td>
<td>$3000</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>SCI-608</td>
<td>PM, O\textsubscript{3}, NO\textsubscript{2}, CO, SO\textsubscript{2}</td>
<td>$5905</td>
<td>$850/s/y</td>
<td>2</td>
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<tr>
<td>2B 106-L</td>
<td>O\textsubscript{3} (FEM)</td>
<td>$5000</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Vaisala AQT</td>
<td>PM, O\textsubscript{3}, NO\textsubscript{2}, SO\textsubscript{2}</td>
<td>$8000</td>
<td>$1000*</td>
<td>4</td>
</tr>
<tr>
<td>Ecotech - AQMesh</td>
<td>PM, O\textsubscript{3}, NO\textsubscript{2}</td>
<td>$6900</td>
<td>$480/s/y</td>
<td>0</td>
</tr>
</tbody>
</table>

* Maintenance requires a return to the vendor with a minimum $1000 fee
Collocation Comparisons

Primary sites: Edmonton, Vancouver, Halifax
Collocation Comparisons
Performance Results ($R^2$)

<table>
<thead>
<tr>
<th>Sensor</th>
<th>PM$_{2.5}$ Correlation</th>
<th>O$_3$ Correlation</th>
<th>NO$_2$ Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ECCC</td>
<td>AQ-SPEC</td>
<td>ECCC</td>
</tr>
<tr>
<td>PurpleAir PAlI</td>
<td>&gt;0.9</td>
<td>&gt;0.93</td>
<td>N/A</td>
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<tr>
<td>AQEgg</td>
<td>0.21</td>
<td>&gt;0.85</td>
<td>0.52</td>
</tr>
<tr>
<td>Aeroqual AQY</td>
<td>0.52 – 0.89</td>
<td>0.78</td>
<td>0.11 – 0.84</td>
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<tr>
<td>Sensit RAMP</td>
<td>0.39</td>
<td>--</td>
<td>0.73</td>
</tr>
<tr>
<td>SCI-608</td>
<td>0.89</td>
<td>--</td>
<td>0.91</td>
</tr>
<tr>
<td>Vaisala AQT</td>
<td>0.89; 0</td>
<td>--</td>
<td>0.77</td>
</tr>
</tbody>
</table>

(Air Quality Sensor Performance Evaluation Center: [www.aqmd.gov/aq-spec](http://www.aqmd.gov/aq-spec))
Limitations to comparing $R^2$ values

- $R^2$ can vary significantly depending on concentration ranges.
- Bland-Altman analyses can be more effective when considering differences between methods to determine fit-for-purpose.
Low-Cost Sensor Summary

- **O₃**
  - Aeroqual, SCI, and RAMP sensors showed linear responses
  - The cost associated make these sensors mid-range ($1000's) rather than low cost ($100's) instruments.
  - Sensors have the potential to work in the near future given appropriate corrections

- **NO₂**
  - Only the SCI NO₂ had good agreement with the FEM sensor
  - Often has interferences and short lifetimes following large events
  - Not feasible at this time but will closely monitor emerging technologies

- **PM2.5**
  - shows a linear response in all instruments
  - Has the potential to currently contribute to the AQHI
  - The PurpleAir is currently used due to its low cost, ease of use, reliability, ease of data retrieval
Data Corrections and QC

• Currently using the correction developed by Dr. Peter Jackson at UNBC

• Quality Control:
  • Understand how to automatically detect bad data

• Ongoing effort:
  • Using larger data sets (North America) to examine other variability in the correction factor
  • Considering T/RH effects on PurpleAir
  • Comparisons with US EPA and other correction algorithms
  • Looking into Machine Learning to develop better corrections and QC
Bigger Data

- Over 5000 PurpleAir sensors deployed across North America by many agencies and citizen scientists.

- After data corrections and automated QC, a significant fraction (>90%) of data results in the same AQHI contribution as FEM equipment.
Dissemination of Data

- Internal and external mapping tools have been developed
  - The external mapping product has been in collaboration with Dr. Peter Jackson at UNBC
  - Maps enable users to overlay a variety of layers to suit their needs
https://cyclone.unbc.ca/aqmap
Model Validation – Firework & Low-cost PM sensors Sept 8, 2020

https://cyclone.unbc.ca/aqmap
US EPA – Fire and Smoke Map

https://fire.airnow.gov
Increasing Spatial Coverage

• Include PurpleAir data from other organizations, citizens and agencies
• Collaborate with agencies, organizations and citizen groups who have a similar goal.
  • Develop a national working group
  • Examine areas that have limited measurements and look for partnerships in the region
  • Collaborate with First Nations
• ECCC is sending sensors and developing the real-time mapping tool - collaborators install and provide power and WIFI
Current Collaborations

• UNBC – Prince George Intensive – citizens ~50 PA
• Wildfire Management Branch Saskatchewan Expansion - Northern Saskatchewan ~30 PA
• Health and Social Services Yukon ~15 PA
• Great Plains Air Zone (Southern Sask) ~ 12 PA
• Wildfire Management Branch Sask ~3 PA
• Lyton First Nations – 1 PA
• Saulteau First Nation (Northern BC) – 1 PA
• Steinbeck Manitoba – Citizen - 1 PA
• Northwest Territories – 5 PA
Future Collaborations

- Manitoba Heath Seniors and Active Living
- Port Alberni Air Quality Council
- Calgary Regional Airshed
- First Nations/First Nation Health Authorities
- YOU?

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