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AN UPDATE ON LOW-COST SENSORS FOR THE MEASUREMENT OF ATMOSPHERIC COMPOSITION

February 17, 2021
21h CET

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Updating the report

SCAN ME

- Six sections
  - Introduction
  - Main Components and Principles **
  - Calibration and Quality Assurance/Quality Control **
  - Evaluation Activities
  - Sensor Characterization
  - Communicating LCS to Society **
- Expert consensus and advice
- Example Costs

International Effort

- **Lead authors**

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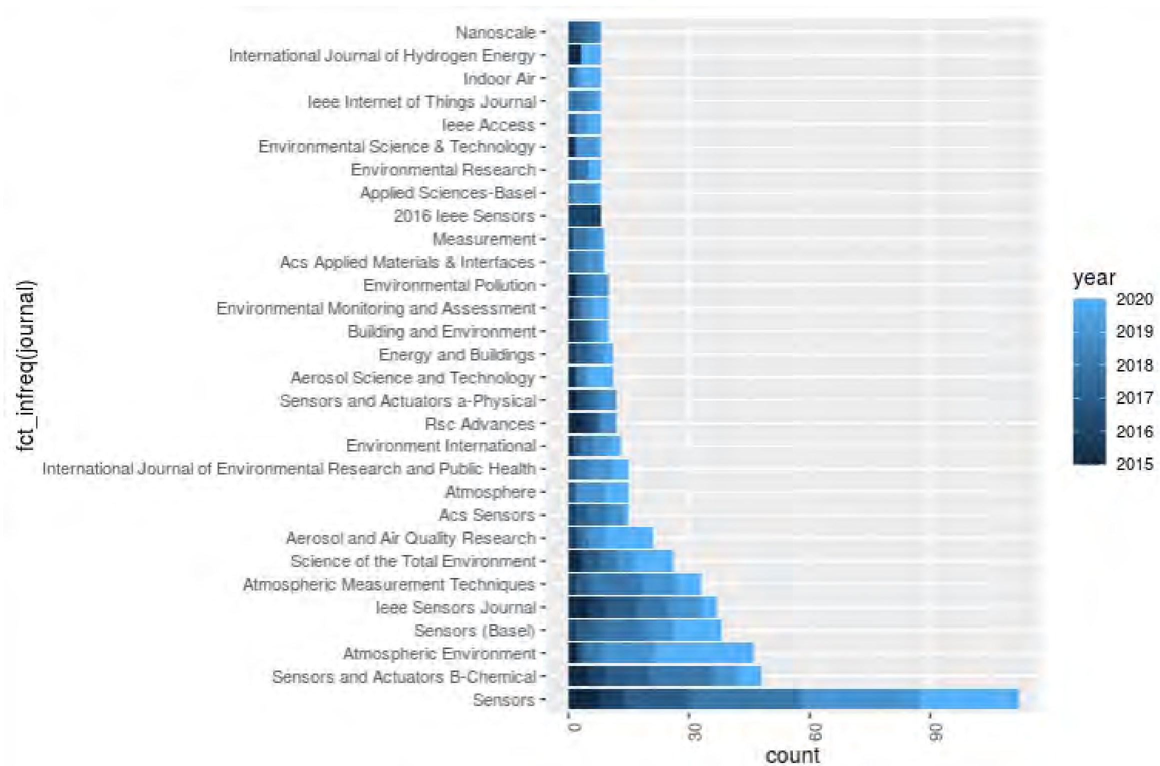
Update Details

- Inclusion of LCS-related science through August 2020, primarily from peer reviewed literature.
- About 2600 references reviewed (2015-Aug 2020)
- Lead author teams responsible for drafting. Section final drafts reviewed by another team.



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Section: Main Principles and Components

Lead authors: Fabienne Reisen

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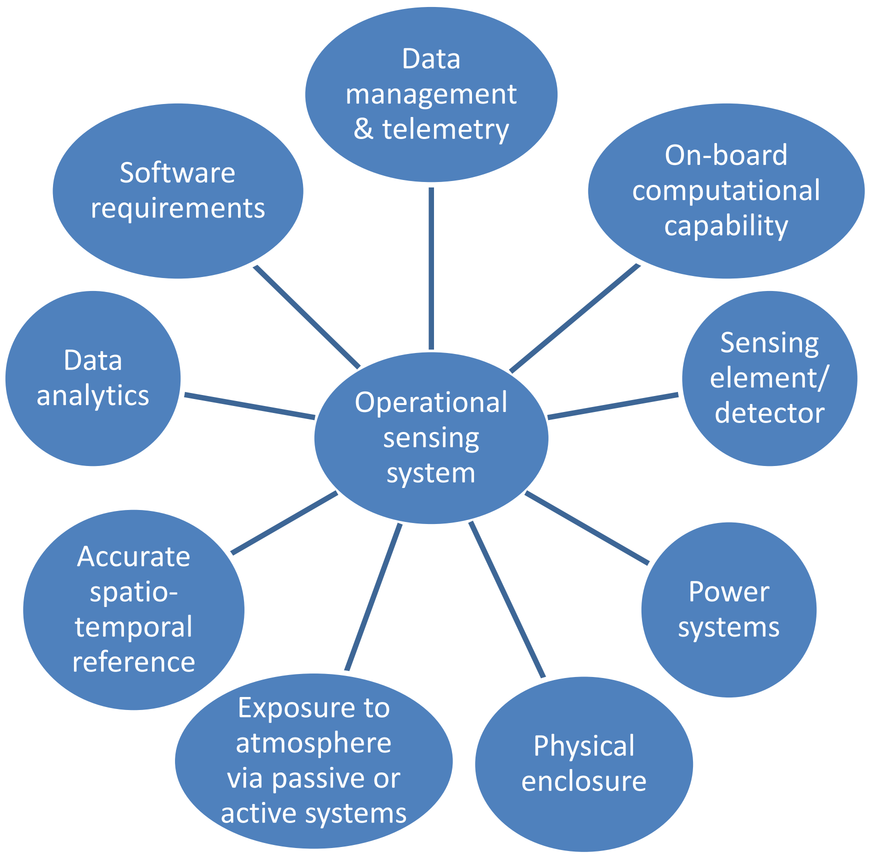
Purpose

The main components and principles of low-cost sensor systems

– Understanding the cost of a LCS system means understanding the core components and supporting hardware required to ensure that meaningful information can be derived from the sensing system or network

Post-processing and data management

- Owner's data management system
- Included data management system with sensor purchase
- Sensors-as-a-service framework



- Routine maintenance
- Robust site-specific support systems
- Deployment cost
- Calibration assessments

Strengths and Complexity

Strengths and complexity of LCS systems

- Large scale deployment as networks
- Use of advanced data fusion algorithms that enable collection of valuable AQ information
- Require improved data management systems to handle complexity of dataflow

Fast-evolving developments in LCS systems

- Time-lag between publication of performance assessment of sensors and development of sensors
- Applications and capacities of LCS evaluation limited to subset of possible component-driven effects

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AN UPDATE ON LOW-COST SENSORS FOR THE MEASUREMENT OF ATMOSPHERIC COMPOSITION

Section: Calibration and Quality Assurance/Quality Control of LCSs

Lead authors: Christoph Hueglin, Michele Penza
Contributing authors: Philipp Schneider, Christoph Zellweger

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The section is about

- QA/QC of Low-Cost Sensors

- Quality assurance (QA) is the process of ensuring that the data arising from a sensor is consistent with the same data arising from a known standard measurement.

- Quality control (QC) is the act of monitoring the long-term performance of a LCS during deployment in a sensor network to ensure it remains in calibration

- LCS are in many ways different from reference instruments and therefore require adoption of new and different approaches for QA/QC

Validation and Calibration of LCSs

- Currently, there are two main approaches to calibrating LCSs: laboratory calibration against reference materials and field co-location with reference monitors
- In order to increase data quality and confidence in a measurement, it is important to follow the hierarchy of validation as high as possible

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Calibration of LCSs

– Calibration of LCS is a complex task that requires expert knowledge and resources

– Calibration of LCSs involves determining a model that can be used to convert the measured parameter (e.g. voltage) into desired output (e.g. pollutant concentration)

– It is important that the data processing performed during QA/QC of LCS is transparent and properly documented

– Another important issue is ensuring the robustness of calibrated sensors to re-location. The data quality of sensors used for co-location calibration may be different from those in a new location

Quality Control

- When LCSs are deployed, several parameters should be monitored over time including baseline drift and changes in sensitivity

- Like reference instruments, LCSs have a limited service lifetime that yet has to be determined for many LCSs, and can depend greatly on the environment in which a LCS is deployed (e.g. high pollution environments can cause PM sensors to foul, low humidity environments can cause sensitivity decay in electrochemical gas sensors)

- Quality control is also the method for determining end-of-life for a sensor. A user should apply quality control statistics to define the end-of-life for LCSs if using them over a sufficiently long period of time

- Several approaches to quality control have been proposed in the literature, however, these approaches are still under active development

Data processing during QA/QC

- The data processing steps performed for calibration and during QA/QC of sensors in networks should clearly be communicated
- Without transparency about the amount and type of performed data processing, users do not know when sensor data depart from an independent measurement and are rather a type of model output
- LCS manufacturers may prefer to retain their proprietary information on data processing methods, but in doing so, can make it difficult for an end user to understand how their measurement was determined
- Whenever and wherever possible, it is important to produce data in a transparent manner

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Section: Communicating LCS to Society

Lead authors: Tim Dye, Erika von Schneidemesser
Contributing authors: Àlex Boso, Jessica Seddon

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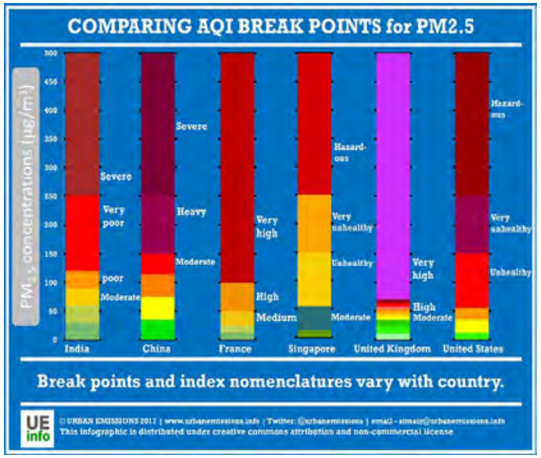
Communicating LCS to Society

New Section



- Air Indexes used to communicate data from reference stations
- LCS many networks and communication platforms growing rapidly
- Challenges with LCS:
  - Variable performance/lack of certification
  - Interferences that affect sensor performance (e.g., weather)
  - No standardization of sensor siting
  - Lots of data (e.g., data point every second)

- Result: Communicating and interpreting air quality data from LCS can have a lot of pit-falls and added complexity

Communicating LCS data needs to be open and transparent to build trust in the new and rapidly evolving technology.

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Communicating LCS to Society

Framework for best-practice use in communicating data from LCS

Identify the purpose or objective for collecting the data

Describe data collection and processing

- Calibration/adjustments
- Maintenance and operations
- Quality control steps
- Uncertainty
- Limitations of the data and air sensors

Document the metadata

Interpretation of the data

The framework we lay out here can foster responsible use, and effective communication of robust air quality information for the benefit of all.

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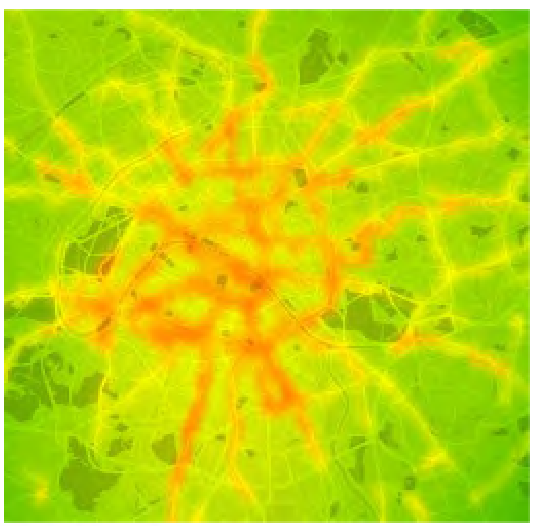
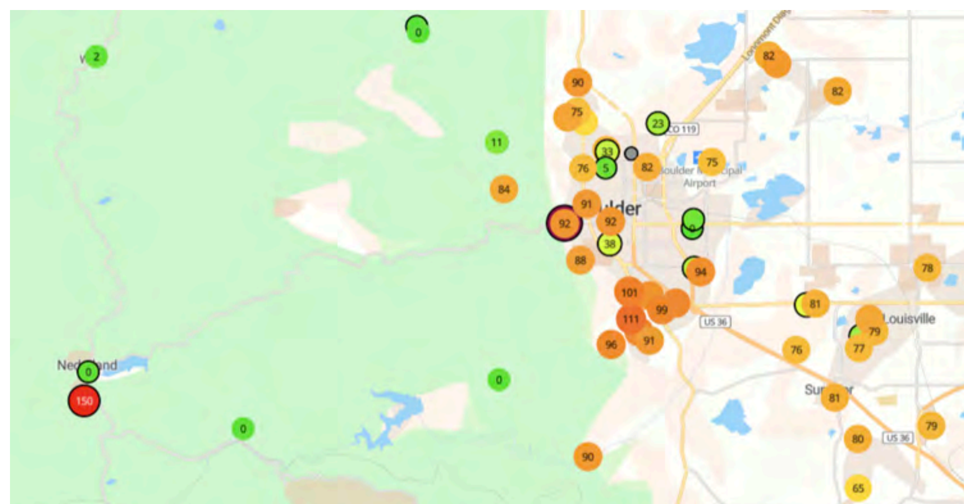
Communicating LCS to Society

Challenges





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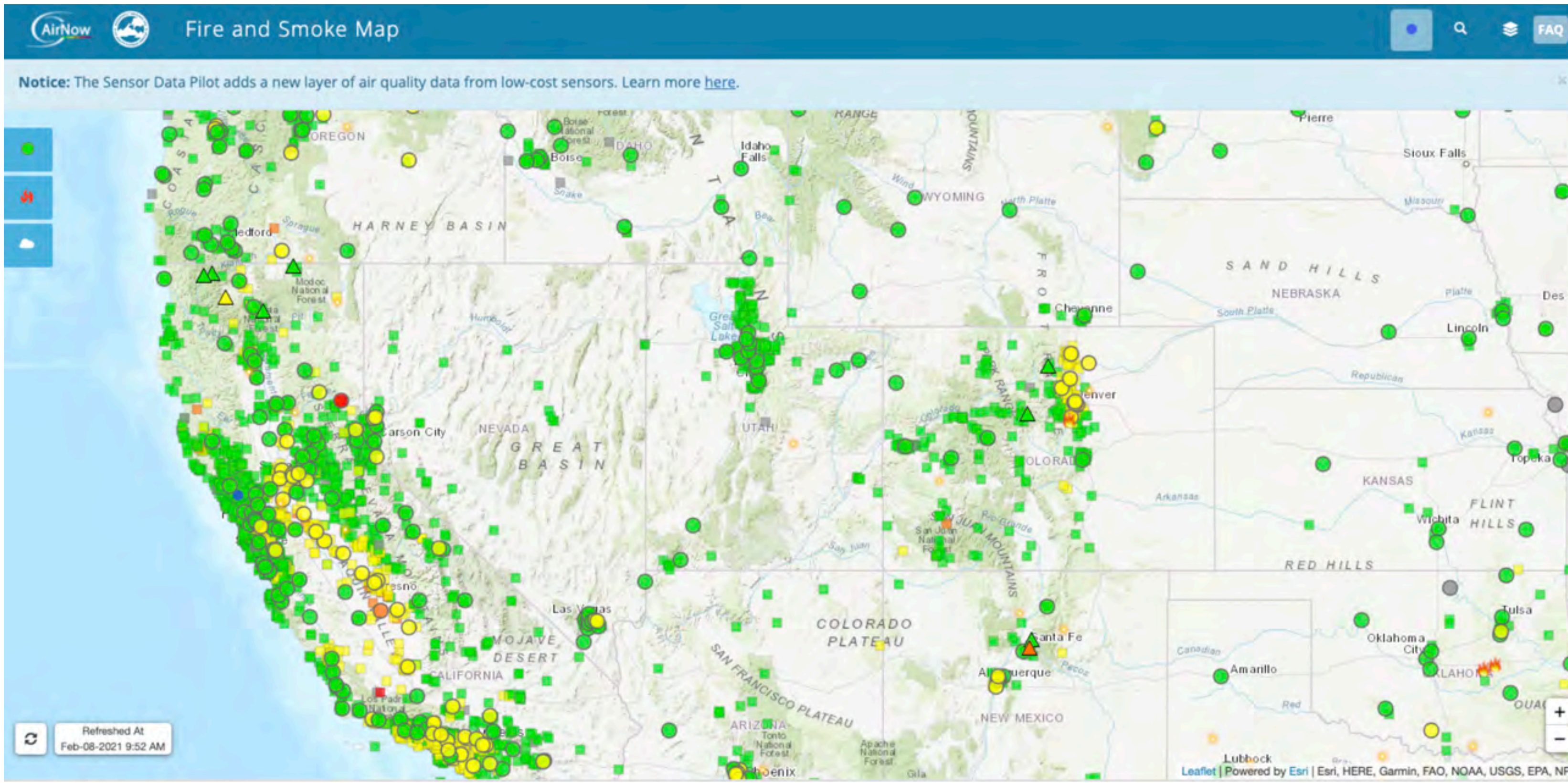
Communicating LCS to Society

Opportunites



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https://fire.airnow.gov/

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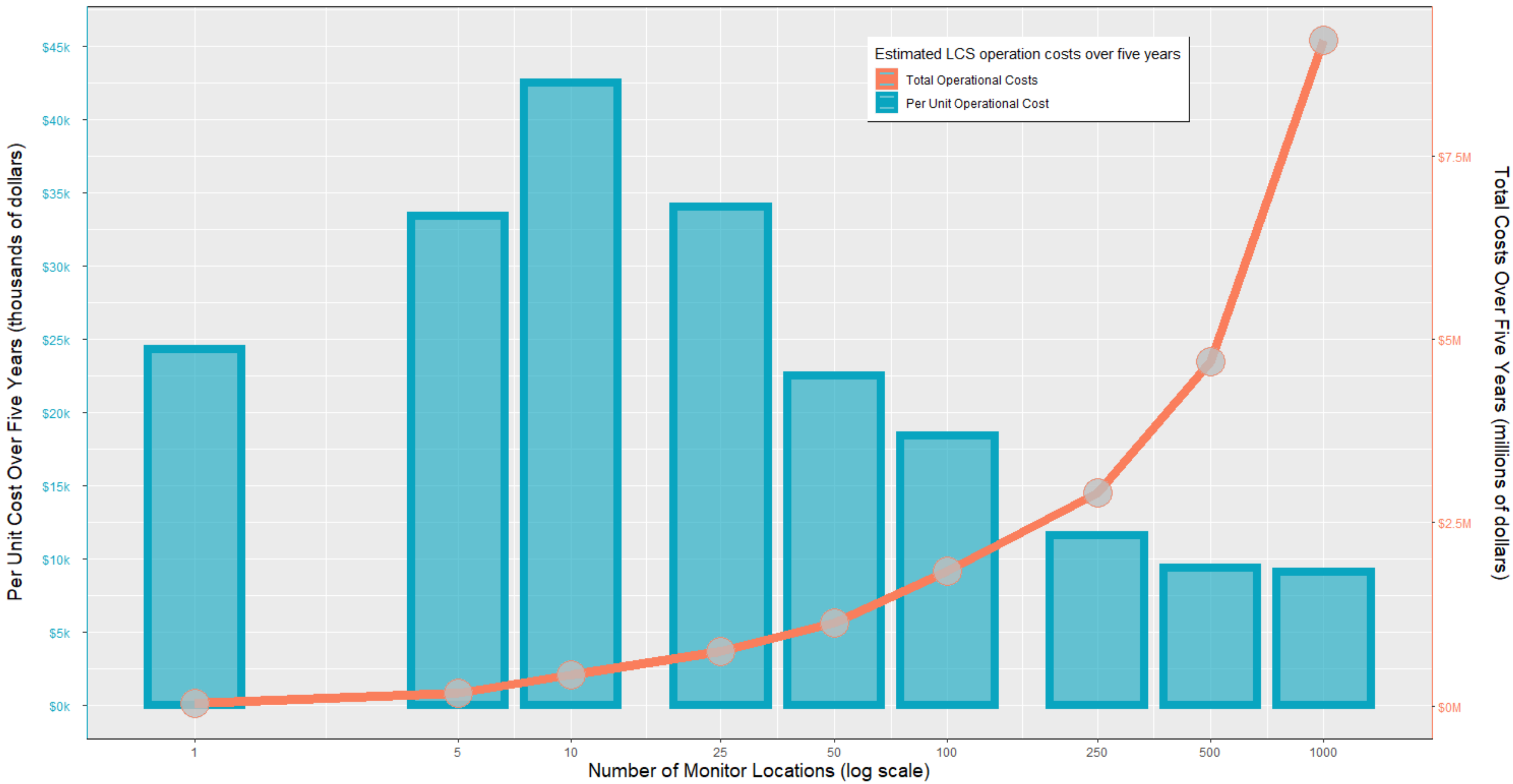
Expert Consensus

- Rapid growth, and are likely to continue to do so.
- Not yet suitable for replacing reference monitoring networks.
- Rigorous quality assurance and quality control is essential.
- Almost all LCS have known and still-unknown issues: cross-sensitivity, temperature and humidity effects, varied response times, and drifting baselines.
- Community engagement and outreach, and the use of LCS in educational contexts, are a particular strength of these devices.
- A logical tool to assess air quality in regions of the world that lack high quality atmospheric composition observations.
  - But it is important to support these methods with appropriate calibration and validation platforms to ensure high quality data

An Estimate of LCS Costs



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Recommendations:
Manufacturers and System Providers

- Provision of sensor performance information is important; controlled laboratory testing is view as incomplete evidence.
- Better information on sensor lifetimes are needed.
- Improve transparency on data manipulation algorithms; examples exist in earth. observation community where IP protection is retained but scientific scrutiny can be maintained.

Recommendations:
Users and LCS Operators

- Define application/scope to ensure fit-for-purpose LCS.
- User community should make efforts evaluate their sensor performance against reference monitors. Support to do this already exists.
- Users should actively monitor sensor performance across different measures.
- Harmonized performance metrics are not yet in use, but they are expected. At a minimum, R^2, RMSE, and MAE).
- Intersensor performance still a concern; when evaluating performance, multi-sensor co-location is important.
- LCS users can, and should, explore new environments. This will lead to new understanding, but it is essential to document these efforts.

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Recommendations:
Regulators and Environmental Decisionmakers

- LCS not yet robust to replace reference monitors, chiefly because of lack of widespread QA/QC methods.
- LCS can be coupled to reference monitor networks to expand understanding, but with increased uncertainty in the data.
- Encourage establishment of regional reference monitoring platforms to evaluate LCS under real-world conditions across different global environments.

Recommendations:
Broader Community

- Better communication still needed between users and manufacturers.
- Adopt open access data, including metadata, helps to ensure data quality.
- Continue to support LCS applications in wider range of environmental conditions.

One more acknowledgement

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Open Questions and Answers

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