Application of Micro- and Bio-Sensors for Forest Fire Smoke

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Objectives

- Outline project to relate fire exposure to non-invasive health patterns
- Report initial results of portable air monitoring tests
- Overview follow-up plans
**Project Objectives**

- Evaluate wearable sensors for ability to quantify health-related biomarkers:
  - Heart rate
  - Heart rate variability
  - Body/skin temperature
  - Blood pressure
  - Blood oxygen content

- Evaluate stationary and personal air quality monitors for human exposure estimates
  - Suspended particulate matter (PM)
  - Nitrogen Dioxide (NO₂)
  - Ozone (O₃)
  - Carbon monoxide (CO)
  - Volatile organic compounds (VOCs)
  - Black and Brown Carbon

- Apply data mining and artificial intelligence techniques to eliminate noise, data dimensionality, and indicate adverse environmental effects

- Create wearable software that combine acquired sensor data, determines adverse patterns, and transmits warnings to individuals and health providers
Galaxy 5 Smartwatch couples with Galaxy Wearable and Samsung Health apps on smartphone
Current Limitations for wearable detection of non-invasive biomarkers

- Existing Galaxy Wear features are not amenable to our application, but OS Wear is becoming standard for non-Apple wearables which offer greater customization opportunities.
- A coupled smartphone with cell service is usually needed but LTE versions are also available.
- Cell service will not be available for all applications, so other communication systems need to be explored. A LoRaWan application has just become commercially available.

- Communication via LoRa: communication range up to 1.5KM line-of-sight, 500~1000Meters in dense urban, compatible with any LoRaWAN network.
- Build-in GNSS+ WIFI (optional)chip, Indoor & outdoor real-time tracking
- Heart rate, body temperature, blood pressure, step monitor: the measurements are made at a configured frequency and automatically send to the LoRaWAN network.
- Real-time Alarm: When the heart rate exceeds the standard, an alarm is sent.
- SOS in emergency
- Long Battery Life: Battery life as long as 7 days @ 15mins uplink duty
Personal and stationary monitor evaluation

Tests at DRI (high elevation) and RENO4 Ncore (valley floor) collocated with ARA solar-powered filter samplers

DMT Microsensors measure black carbon, brown carbon, and selected gases

Personal sensors are being evaluated for durability and communications

Sensitivities to and control of environmental variables are being determined
Personal monitoring detects fire exposures and changes with location

- Atmotube monitor uses active sampling for different PM size fractions
- Indoor measurement before and during worst fire day (9/11/2022) with outdoor exposure indicated by large morning increase
- High exposure locations are mapped when associated with phone or smartwatch GPS
DST monitors filter attenuation at 880 nm and 405 nm

- **Modular:** Measure BC and up to 2 gases (CO, NO₂, O₃, SO₂, H₂S,...)
- **Weight and Size:** (600 g) (120 x 80 x 45 mm)
- **Connected:** WiFi, LTE, and more
- **Internal Battery:** 5V power supply, 40 hr between charges

880 nm and 405 nm Attenuation:
BC=7.8ATN(880)
BrC=18.49[ATN(405)-ATN(880)[\(\lambda_{880}/(\lambda_{405})\)]¹]
Replaceable filters are used for attenuation with one for collection and one for reference.
Data are uploaded to a cloud-based website.
Shows time series and downloads, indicating fire episodes
BrC has some relationship to IMPROVE_A OC, especially during the fires, but it is not calibrated. BC is more closely aligned with IMPROVE EC.
CO concentrations are somewhat correlated with reference instrument at RENO4, but calibration is off.

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y = 1.4526x - 0.0154 \\
R^2 = 0.7295 \\
N=1456
\]
DST BC and BrC are somewhat correlated with similar measurements from AE33 aethalometer, but calibrations differ.
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DMT follow-up tests

- Software modifications to adjust flow rate according to filter darkening (higher flows for low attenuation, shift to lower flow rate when darkening rate increases)

- Apply temperature/humidity measurement adjustments for CO electrochemical sensitivity

- Evaluate performance for different combustion source emissions

- Evaluate more precise calibration methods (e.g., filter films with traceable attenuation levels)