New Air Quality Measurement Method: Low-Cost Sensors on UAV's

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Abstract

- Air pollution is a global concern due to its detrimental impacts on humans and the environment. However, detecting atmospheric pollutants is costly and time-intensive.
- The Environmental Protection Agency (US EPA) utilizes filter-based, stationary techniques to measure ground-based particulate matter (PM) in the atmosphere.
- The development of low-cost sensors has helped in combatting the high cost associated with achieving these measurements.
- Low-cost sensors are light, and small, still allowing for measurements of atmospheric pollutants(1).
- We propose placing low-cost air quality sensors on Unmanned Aerial Vehicles (UAVs)(2).
- Sampling will be conducted seasonally in diverse areas, and PM concentrations will be compared to those using the EPA's methods.

Figure 1: Tarot-T18 used for flying the Vaisala AQT 4000 sensor.

Introduction

- The EPA measures harmful atmospheric pollutants, named as criteria pollutants, namely: ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, lead, and PM.
- Criteria pollutants are measured in over 4000 locations (Figure 2) in the US by regulated EPA collection devices.
- These collection devices are operated and maintained by state agencies to determine compliance with National Ambient Air Quality Standards (NAAQS).

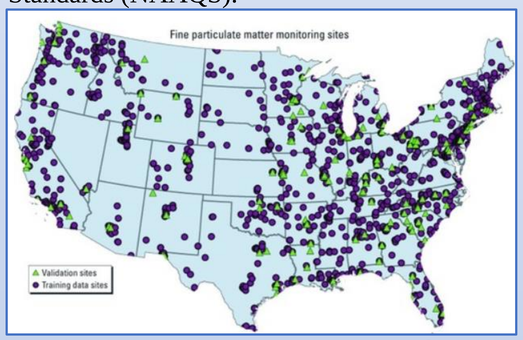

Figure 2: EPA PM monitoring sites in the US.

Objective

- ***Goal:*** Develop the technology for placing low-cost sensors on UAV's while achieving reliable measurements for all criteria pollutants.
- ***Motivation:*** Detect PM and other criteria pollutants at various elevations in diverse areas (remote and congested cities).

Figure 3: M-100 UAV used for flying the OPC-N3 sensor.

Methodology Development

Site Selection

- Flights are conducted at three sites, namely: Daytona Beach (Suburban), Coe Field (Rural), and Orlando (Urban) (Figure 4).
- Diverse sites allow for contrasting PM concentration measurements at different geographical points.

★ Daytona Beach (Suburban)

★ Coe Field (Rural)

★ Orlando (Urban)

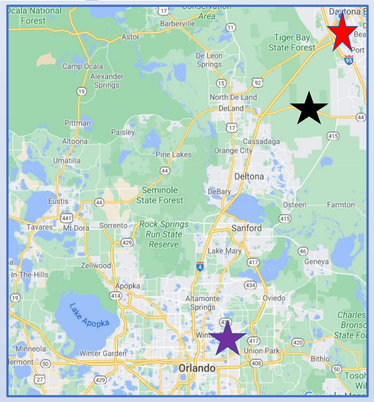

Figure 4: Map showing locations used in this study.

Selection of Low-Cost Sensors

- Three air quality low-cost sensors are selected for comparison: (1) PMS7003, (2) SDS011, and (3) OPC-N2.

Air Quality Low-Cost Sensors	PMS 7003	SDS011	OPC-N2
			
Weight (g)	30	50	100
Price ($)	24.97	29.99	39
Dimensions (mm)	48x37x12	71x70x23	75x60x63.5
Accuracy (x/100)	0.83-0.89	0.87-0.9	0.84
Power Supply Voltage (V)	4.5-5.5	5	5
Working Current (mA)	<100	220	180
Life Expectancy	1 year	1 year	1 year

Table 1: Comparison of various low-cost sensors.

Sensor Validation

- The Alphasense OPC-N3 sensor is an optical particle monitor that measures three sizes of PM: $PM_{1.0}$, $PM_{2.5}$ and PM_{10}.
- OPC-N3 was selected because of its high accuracy, and consistent results even at high humidity in previous studies(3).
- ***Validation 1:*** OPC-N3 is compared to the local, stationary EPA PM monitor in Daytona Beach.
- ***Validation 2:*** Vaisala AQT4000 sensor (Figure 5) is used to validate the PM measurements, in addition to other criteria pollutants.
- The code has been created for both sensors and integrated into the UAV's (Figure 1, Figure 3).

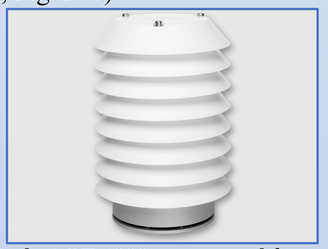

Figure 5: Vaisala AQT 4000 sensor used for method validation.

Future Work

- Trial flights for the OPC-N2 and Vaisala AQT4000 sensors will commence in January 2021.
- Collocation of different air quality sensors will take place to test the performance of other sensors as well.

Acknowledgments

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References

•Badura, M., Batog, P., Drzeniecka-Osiadacz, A., Modzel, P., "Evaluation of Low-Cost Sensors for Ambient $PM_{2.5}$ Monitoring", *J. Sensors*, vol. 2018, **2018**.

•Gu, Q.; R. Michanowicz, D.; Jia, C., "Developing a Modular Unmanned Aerial Vehicle (UAV) Platform for Air Pollution Profiling", *Sensors* **2018**, *18*, 4363.

•Li B., Cao R., Wang Z., et al. "Use of Multi-Rotor Unmanned Aerial Vehicles for Fine-Grained Roadside Air Pollution Monitoring", *Transportation Research Record*, **2019**; 2673(7):169-180.