Modeling Airport-Related Air Pollutant Concentrations and Health Impacts

Project 18

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ASCENT
AVIATION SUSTAINABILITY CENTER

Motivations

- Multiple recent publications have concluded that aircraft arrival emissions can contribute significantly to ultrafine particulate matter (UFP) concentrations at appreciable distances from the airport, but it is unclear whether the findings are physically interpretable and robust
- Challenges for UFP:
  - High spatiotemporal variability
  - Complex pollutant dynamics
  - Multiple contributing sources/source sectors
  - Lack of ambient monitoring infrastructure
  - Limitations in emissions inventories (particle number vs. mass)
  - Limitations in dispersion models

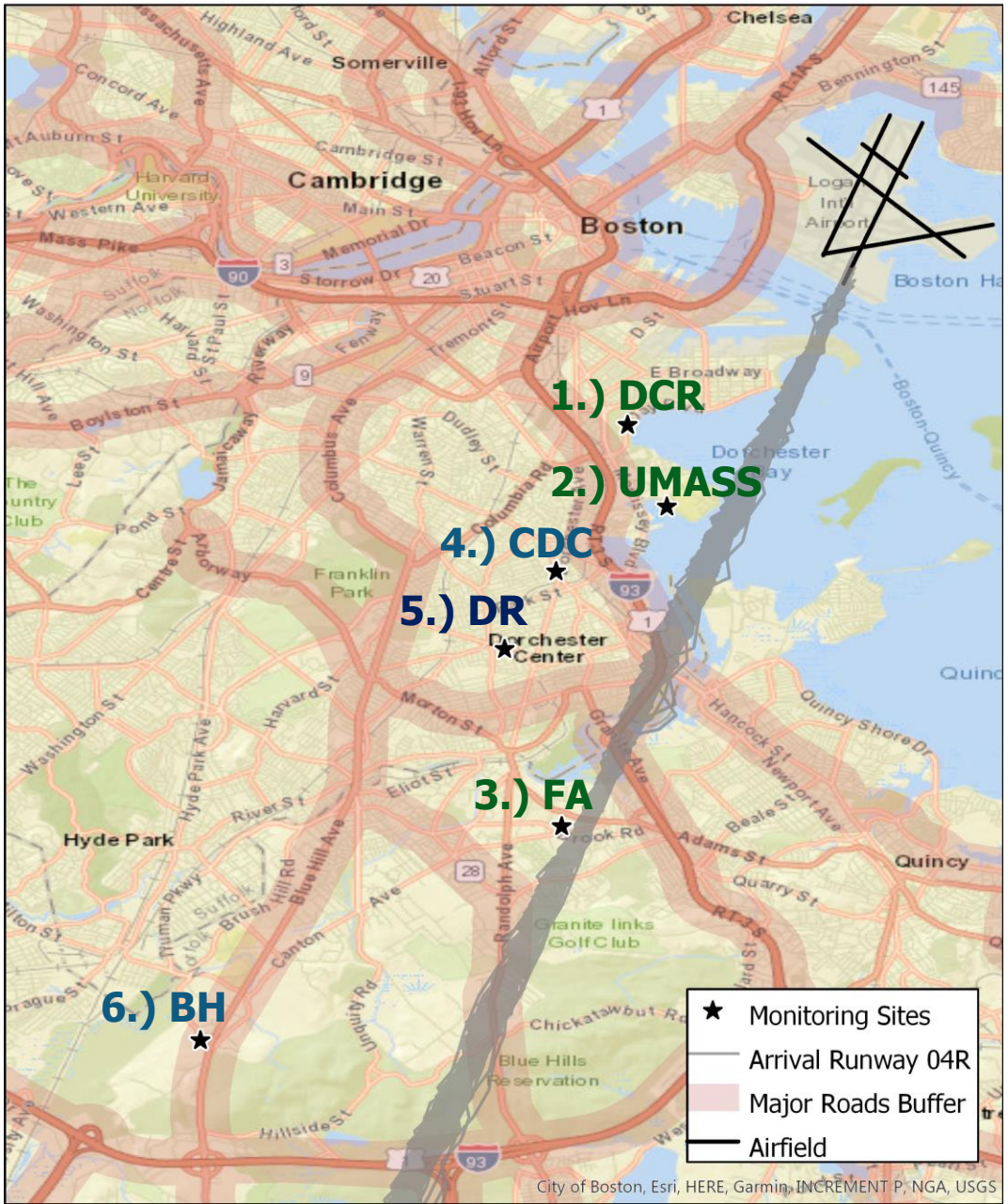
Objectives

- Near-term
  - Measure UFP and BC concentrations at strategically selected sites near arrival flight paths
  - Quantify the contribution of flight arrivals to measured concentrations
- Long-term
  - Design follow-up field campaign to address unanswered questions related to aviation source attribution
    - Additional pollutants, additional sites, consideration of departures as well as arrivals
  - Implement follow-up field campaign and analyze data
  - Compare monitoring-based source attribution estimates with those derived from dispersion modeling
  - Develop insights about spatiotemporal patterns of the aviation-attributable portion of multiple air pollutants, determining implications for potential studies of health effects

Outcomes and Practical Applications

- Outcomes
  - Refined statistical approaches for isolating contributions of flight arrivals and departures to ambient pollutant concentrations
  - Quantitative estimates of aviation source contributions relative to other sources
- Practical applications
  - Improved understanding of aviation impacts on air quality at varying distances from airport
  - Insights about both monitoring-based and modeling-based approaches for source attribution
  - Field protocols and observations that could provide foundation for health studies

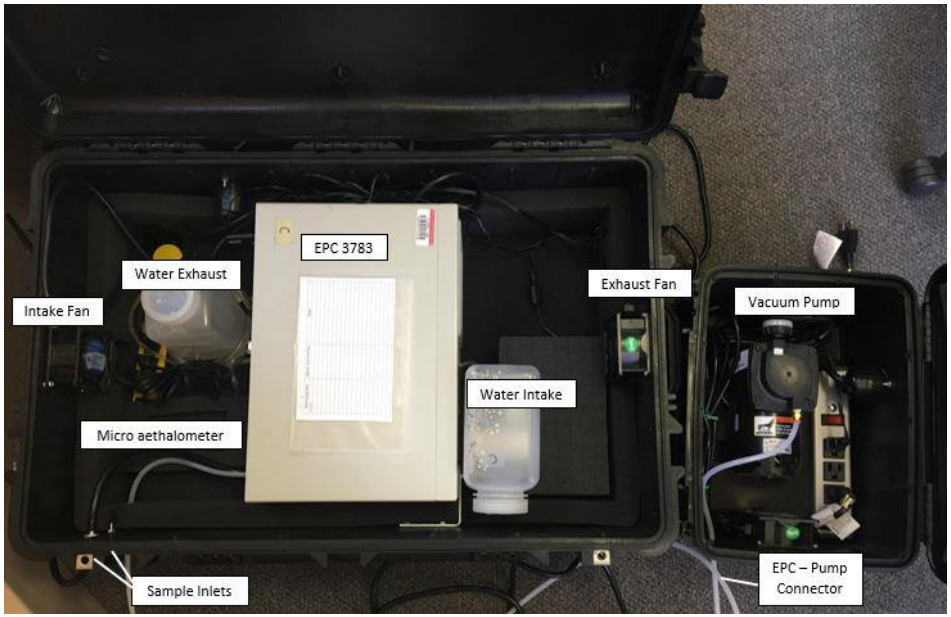
Approach



- **Site Selection**
- Focus on arrivals to Boston Logan International Airport on Runway 4R
- 51,858 arrivals in 2016 (most used runway)
- Flight path largely over populated areas
- Sites chosen to be > 200 m from major roadways, at varying distances from airport and from flight path based in part on projected wind direction and runway usage

Approach

- **<u>Monitoring Instrumentation:</u>** Chosen to give high-quality data at up to 1-second resolution
  - UFP: TSI Condensation Particle Counters (Model 3783)
  - BC: AethLabs microaethalometers (Model AE51)
  - Meteorological data: Davis Vantage Pro2 weather stations



Approach

- **Monitoring Strategy:**
  - Field deployment from April – September of 2017
  - Three sites are simultaneously measured for one week at a time, rotating among six locations
    - Site selection based in part on projected wind direction and runway usage
    - Equipment set-up, mid-week check-in and data download, end of week pick-up
  - 4R runway construction during sampling period provided potential natural experiment

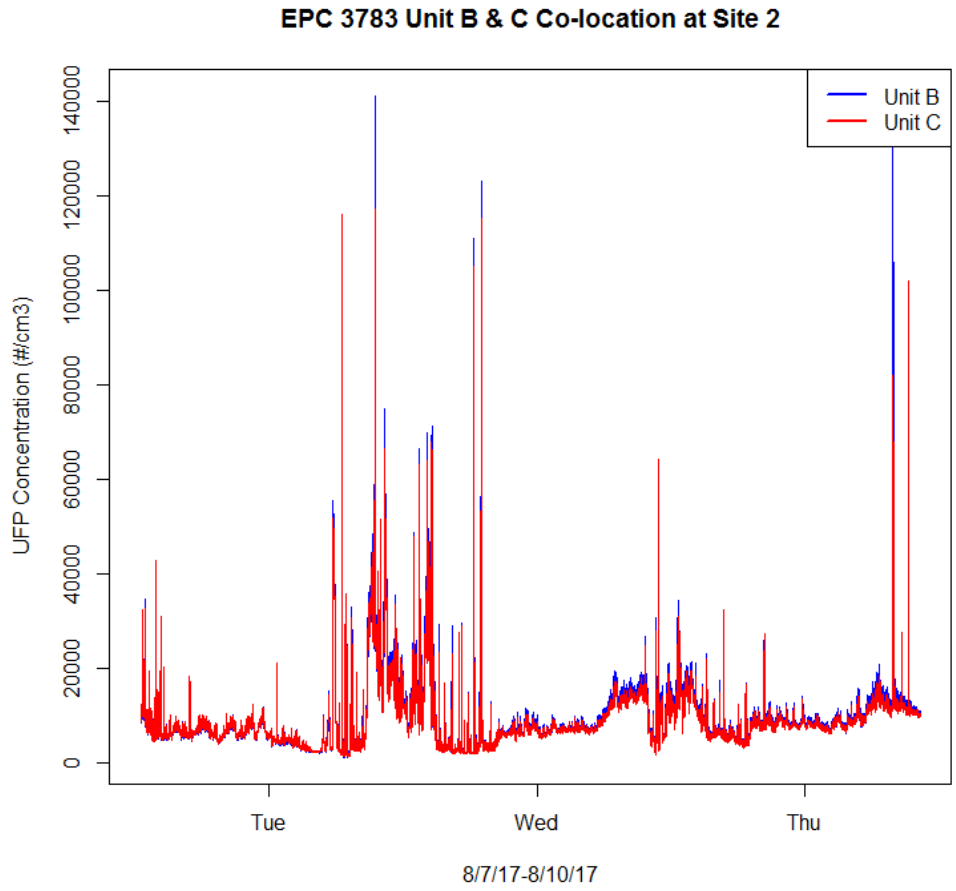
- **Statistical Analysis Strategy**:
  - Descriptive statistics stratified across key covariates (i.e. month, 4R runway configurations and wind conditions)
  - Regression analyses of concentrations accounting for real-time flight locations (lat, long, altitude), meteorology, time of day, day of week

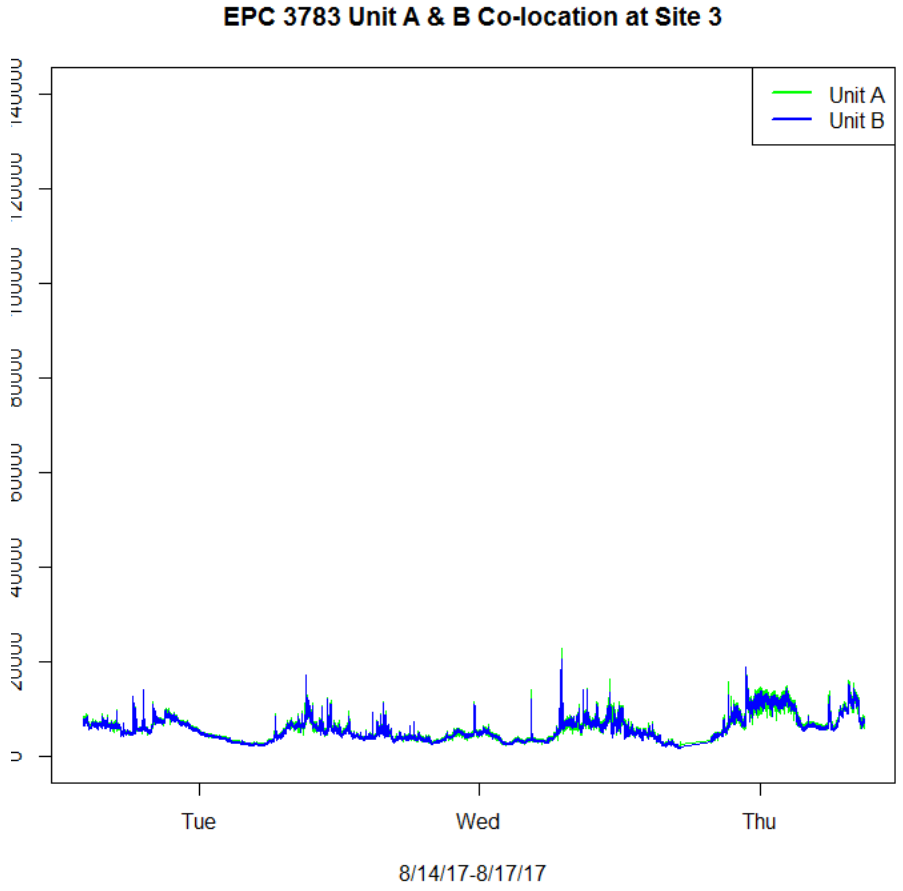
Schedule and Status

- Fall/Winter 2016-2017: Protocol development, instrument selection, site selection
- April – September 2017: Field measurements (3 sites/week)
  - On time with target data capture, in final week of deployment
- Fall 2017: Complete analytical dataset, review monitoring data and identify optimal sites for follow-up field campaign, purchase and prepare field equipment
- Winter 2017-18: Update field protocols and obtain permission to sample at new sites
- Spring-Summer 2018: Conduct monitoring campaign

Recent Accomplishments and Contributions

- Performance Testing: Equipment has shown high-quality UFP data; reliable (co-location R^2 = 0.98) and able to capture short-term concentration spikes



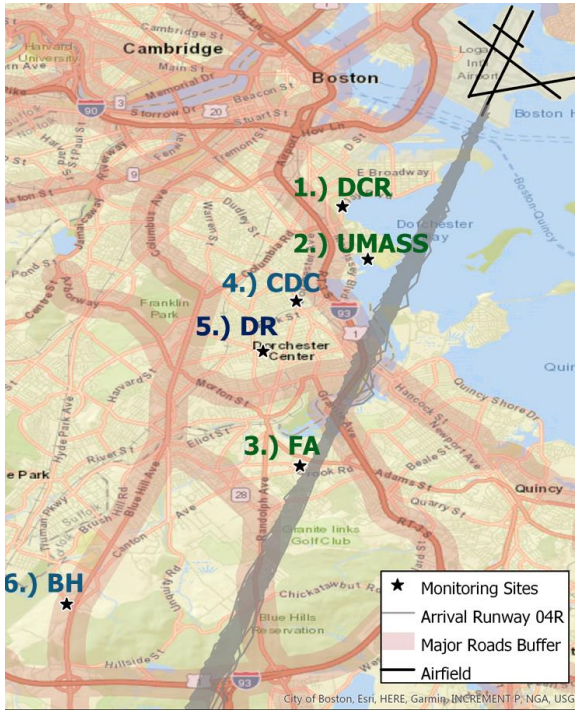


Recent Accomplishments and Contributions

PRELIMINARY RESULTS

UFP Measurements (Particles/cm^3) at Six Study Sites near Boston Logan International Airport

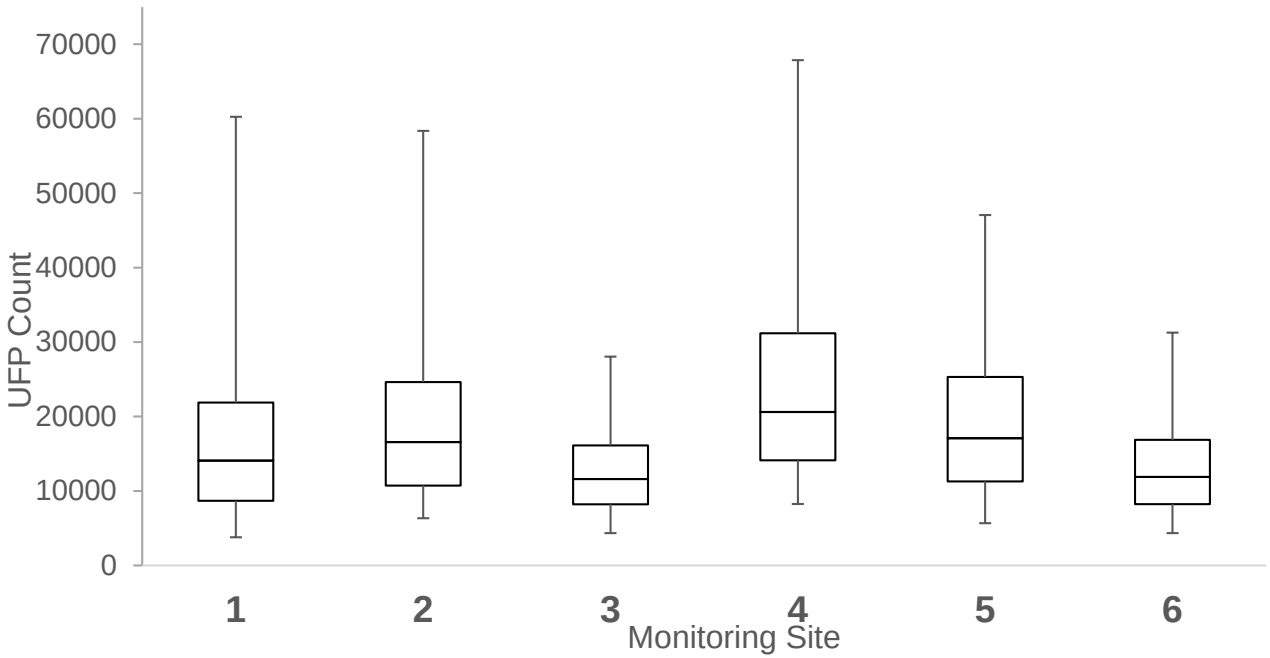
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Sample Size (days)	67	71	57	61	57	62
Sample Size (seconds)	5,262,301	5,301,907	4,126,007	4,363,564	4,233,284	4,661,517
0.1st percentile	818	1,093	1,610	2,480	1,957	1,822
1st percentile	1,961	2,898	2,520	5,147	2,906	2,465
5th percentile	4,279	5,832	4,336	8,243	5,703	4,332
50th percentile	14,080	16,575	11,597	20,614	17,097	11,948
95th percentile	55,613	63,003	28,041	67,865	47,074	31,379
99th percentile	116,807	119,157	47,390	103,151	70,687	50,521
99.9th percentile	180,231	206,594	87,471	150,776	96,457	95,780

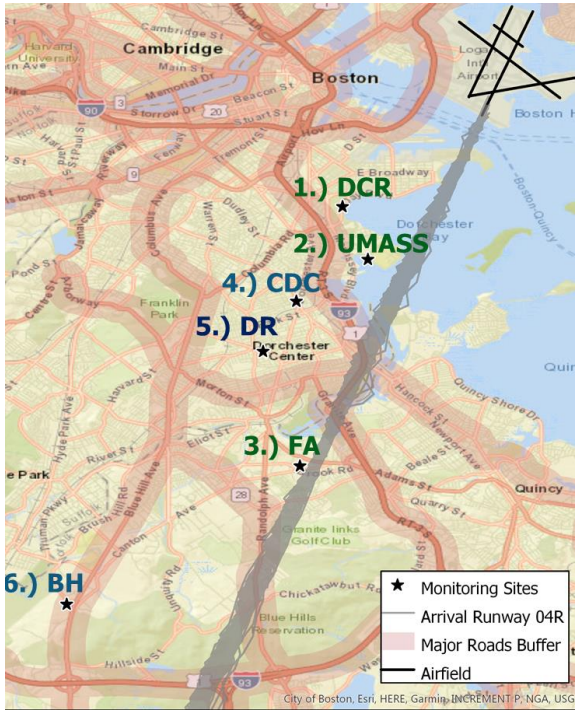


Recent Accomplishments and Contributions

PRELIMINARY RESULTS

Boxplot of UFP Measurements at Six Study Sites near Boston Logan International Airport

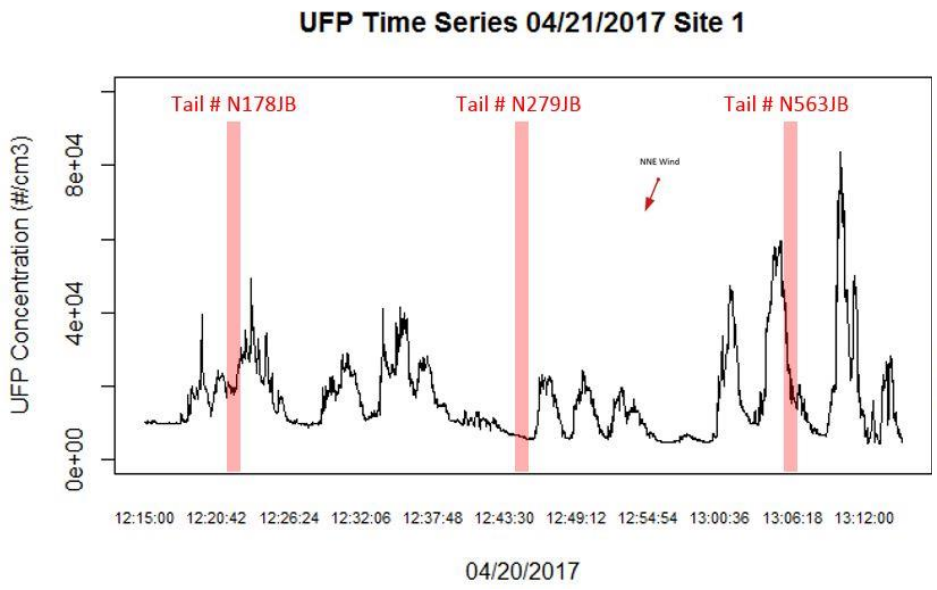


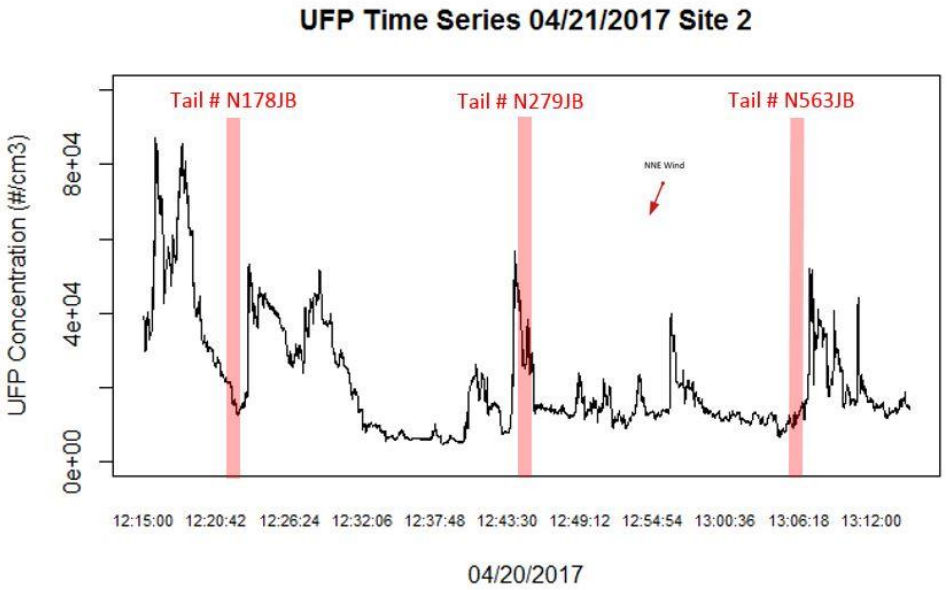


Recent Accomplishments and Contributions

PRELIMINARY RESULTS

Example of UFP Measurements and Flight Data





Summary

- Summary statement
  - Contributions of aircraft arrivals to UFP concentrations are complex to characterize and vary greatly in time and space, and ultimately require fit-for-purpose monitoring and appropriate statistical analyses
  - Summary data and plots reinforce complexity and variability in UFP concentrations over time and space
- Next steps
  - Complete statistical analyses and design follow-up field campaign
- Key challenges/barriers
  - Developing physically interpretable insights about arrival contributions
  - Considering air pollution impacts within a broader exposure/health context

Publications/Presentations

- Kim CS, Tripodis Y, Levy JI. Magnitude and spatial patterns of ultrafine particulate matter associated with aircraft arrivals near Boston Logan Airport. Presented at the International Society for Exposure Science Annual Meeting, October 2016.
- Underhill LJ, Penn SL, Boone S, Arunachalam S, Levy JI (2016). Modeling the health benefits of local and regional emission control policies in the US aviation sector. Presented at the International Society for Exposure Science Annual Meeting, October 2016.
- Underhill LJ, Penn SL, Boone S, Arunachalam S, Woo M, Levy JI. A comparative analysis of health damage functions across pollutants, source sectors, and geographic locations. Presented at the International Society for Exposure Science Annual Meeting, October 2016.
- Penn SL, Boone ST, Harvey BC, Heiger-Bernays W, Tripodis Y, Arunachalam S, Levy JI. Modeling variability in air pollution-related health damages from individual airport emissions. Environ Res 156: 791-800 (2017).
- Penn SL, Arunachalam S, Woody M, Heiger-Bernays W, Tripodis Y, Levy JI. Estimating state-specific contributions to $PM_{2.5}$- and O_3-related health burden from residential combustion and electricity generating unit emissions in the United States. Environ Health Perspect 125: 324-332 (2017).

Acknowledgements

- BUSPH: Jonathan Levy, Chloe Kim, Claire Schollaert, Kevin Lane; Yorghos Tripodis, Stefani Penn, May Woo, Lindsay Underhill
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- UFP monitoring data from Boston Globe site: John Durant (Tufts)