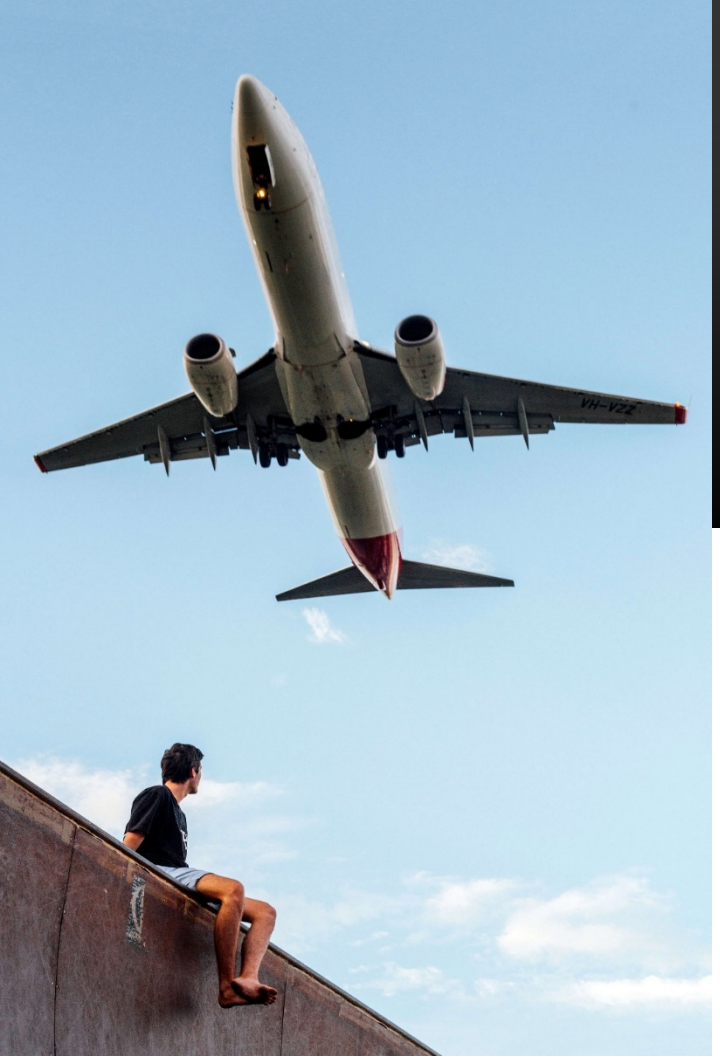

ASCENT Project 18: Community Measurements of Aviation Emissions Contribution to Ambient Air Quality

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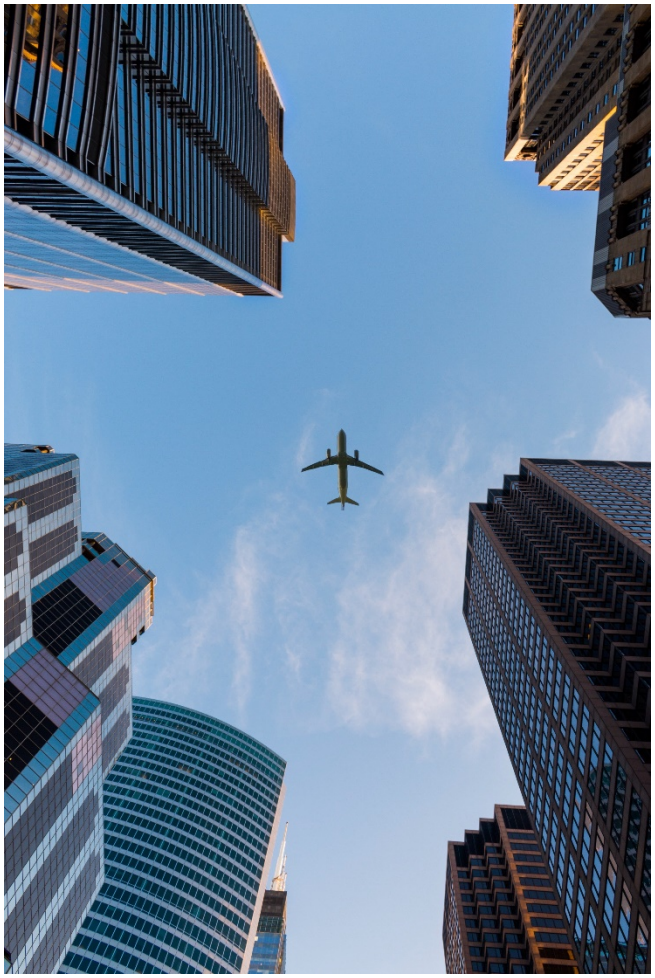
August 25th, 2021

Aviation Activities

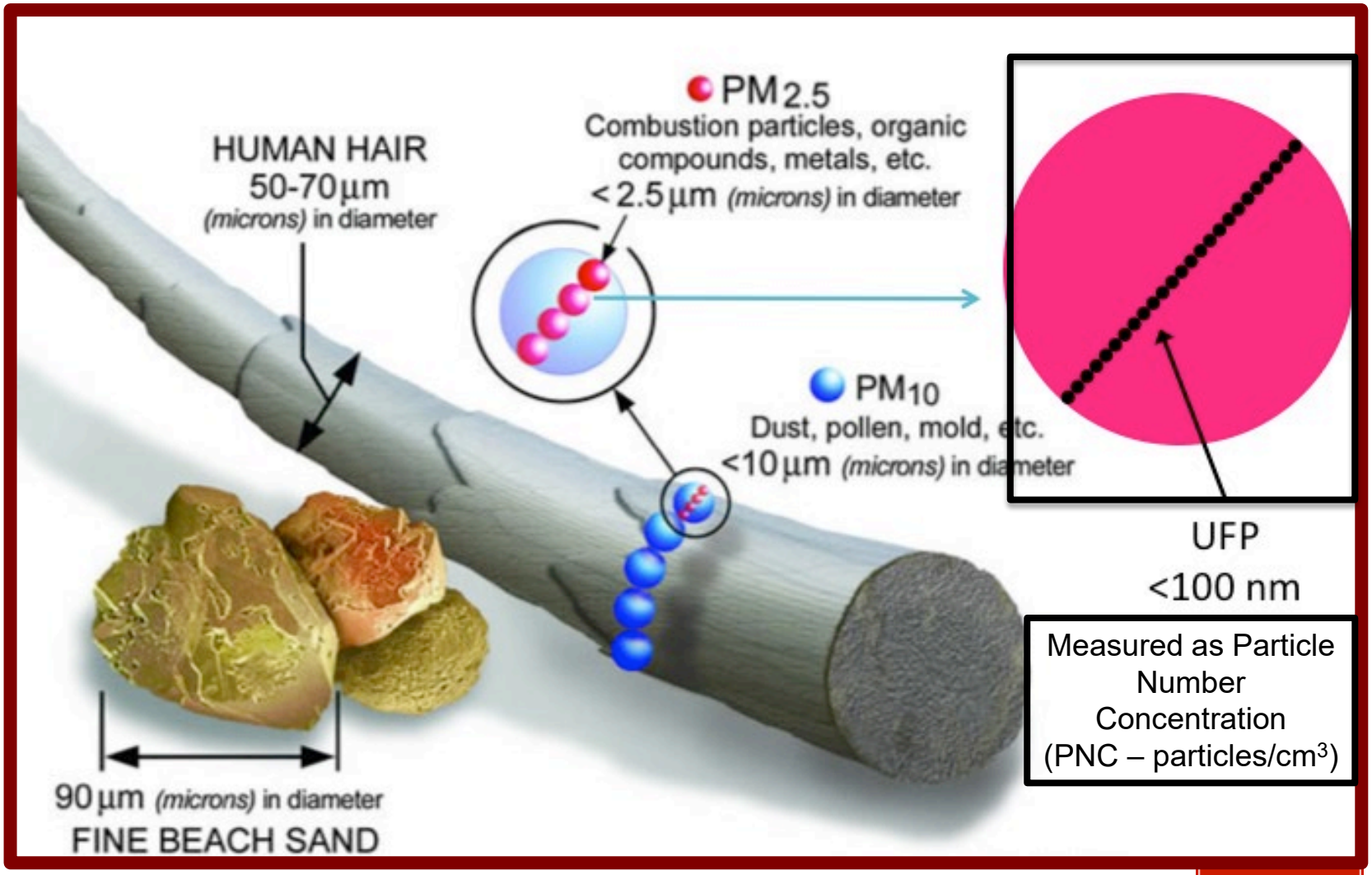
- Activities involving flying aircraft
- A number of social and economic benefits
- Fastest growing transportation mode
- Environmental and public health concerns



Background

- Ultrafine particulate matter: Particles < 100 nm in aerodynamic diameter
  - Typically combustion products
  - Large reactive surface area
  - Limited removal in lung
  - Potential to translocate ➔ effects beyond respiratory system
- Epidemiological evidence fairly limited 10 years ago, growing rapidly
  - Ohlwein 2019: 85 studies 2011-2017, including long-term studies

Particle Matter Pollution

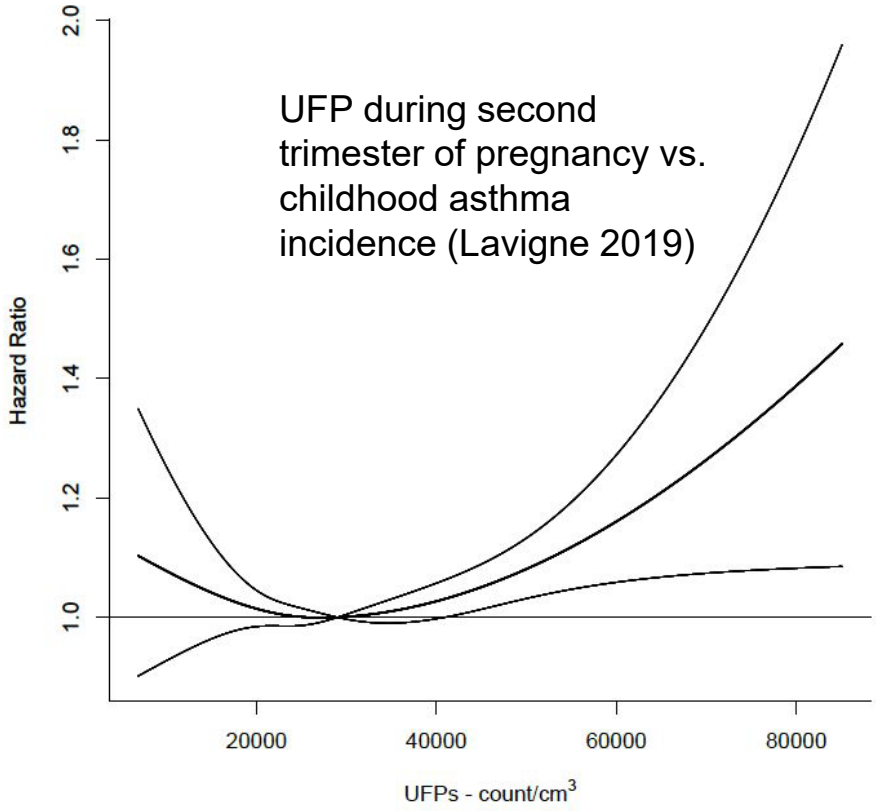


UFP Health Effects: Cardiovascular

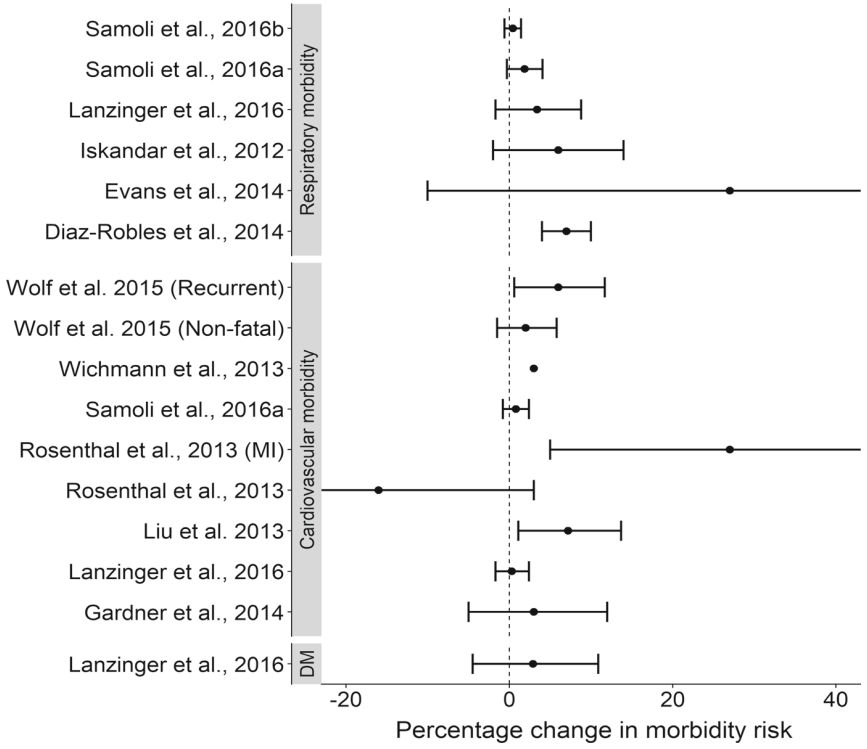
- Increases in biomarkers of inflammation related to cardiovascular disease (Lane et al. 2016; Devlin et al. 2014)
- Changes in heart rhythm and vasomotor function (Vora et al. 2014)
- Decreased microvascular function (Karottki et al. 2014)
- Recurrent myocardial infarction (Wolf et al. 2015)
- Systolic blood pressure and hypertension (Corlin et al. 2018), though with mixed evidence (Magalhaes et al. 2018)
- Cardiovascular and cerebrovascular disease in a prospective cohort study (Downward et al. 2018)
- Cardiovascular mortality (Ostro et al. 2015; Hennig et al. 2018)

Cardiovascular epidemiology fairly consistent and generally positive, ranging from pre-clinical outcomes to mortality

UFP Health Effects: Respiratory effects



Cause-specific emergency department visits or hospital admissions (Ohlwein 2019)



Respiratory epidemiology has some inconsistencies (i.e., associations with lung function) but with robust indication of effects on individuals with lung disease

UFP Source Attribution

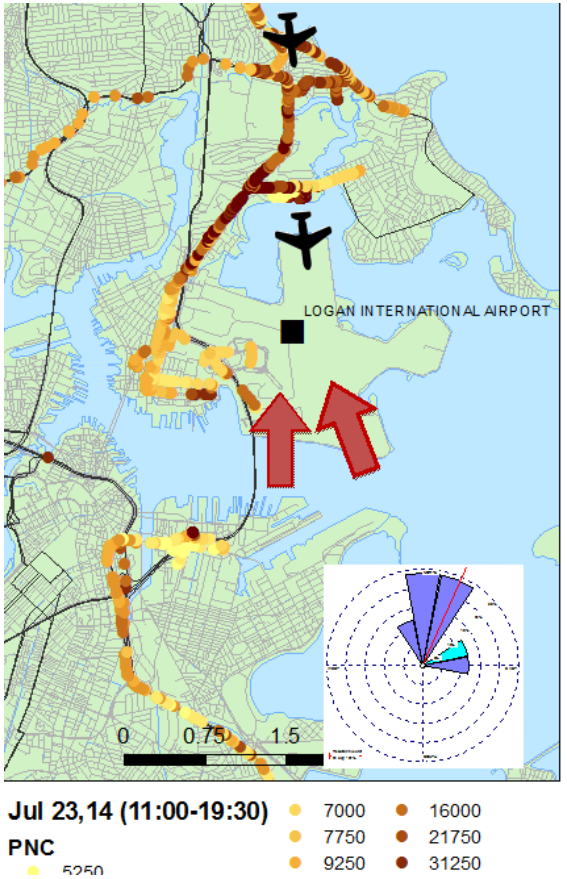
- High spatiotemporal variability
- Multiple contributing sources/source sectors
  - Mobile sources – automobiles and aircraft
  - Restaurants, wood burning, construction operations
- Lack of ambient monitoring infrastructure
  - Challenges in developing dispersion models
  - Imprecise exposure assessment for epidemiological studies

UFP Source Attribution from Aviation Activities

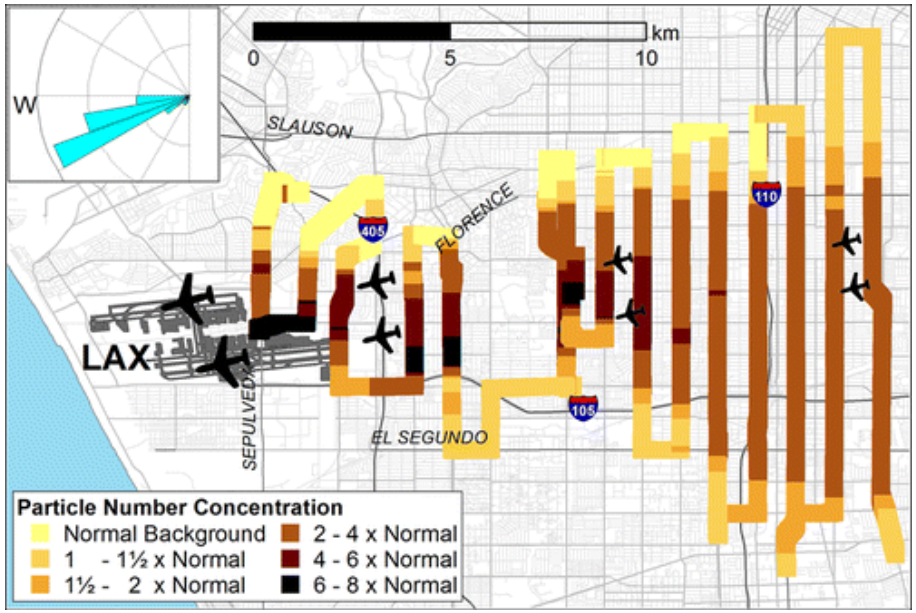
- High-temperature plumes
- Wing-tip vortices
- Vertical and horizontal dispersion
- Variability in lag
- Intermittent in-flight aircraft contribution

Mobile monitoring of spatial variation

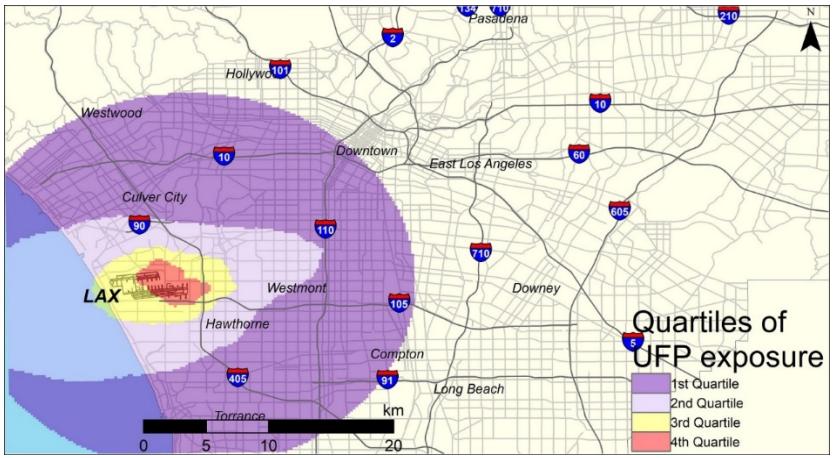
Ultrafine particles, particle size distribution, CO, CO_2, NO, NO_2, NO_x, black carbon, $PM_{2.5}$, GPS



Monitoring and modeling of PNC near LAX:

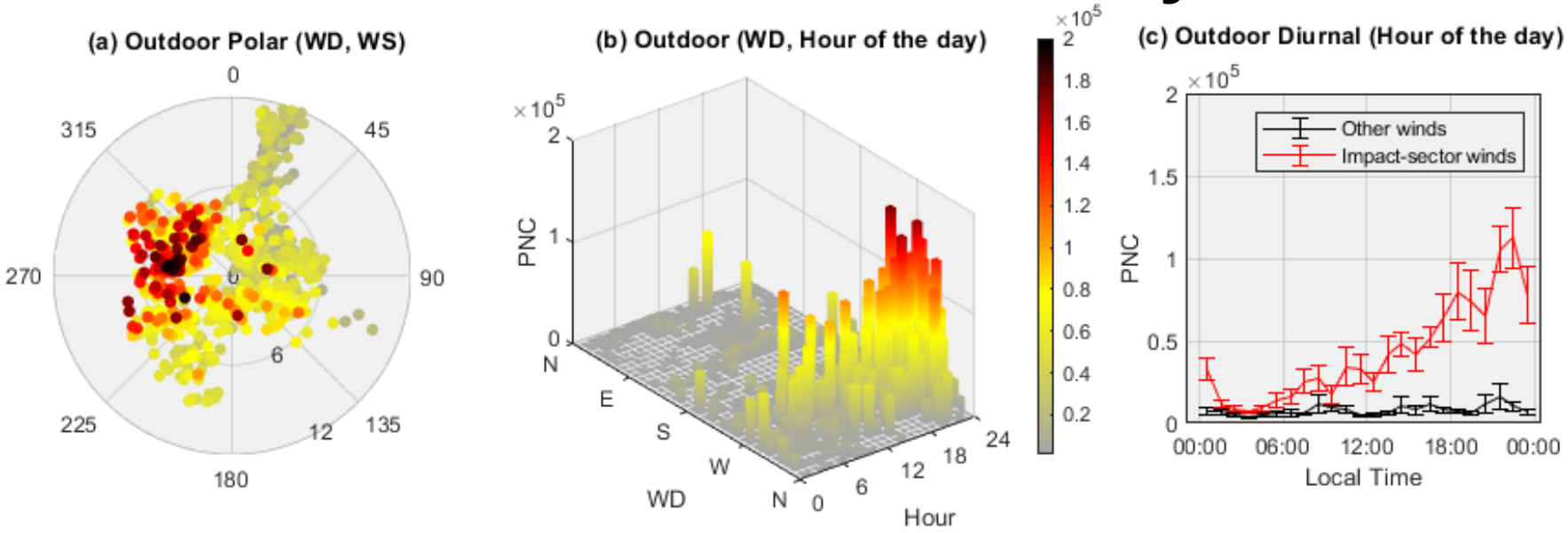


Hudda et al., 2014, EST



Wing et al., 2020, EHP

Ultrafine particle number concentrations vary with wind direction and time of day:



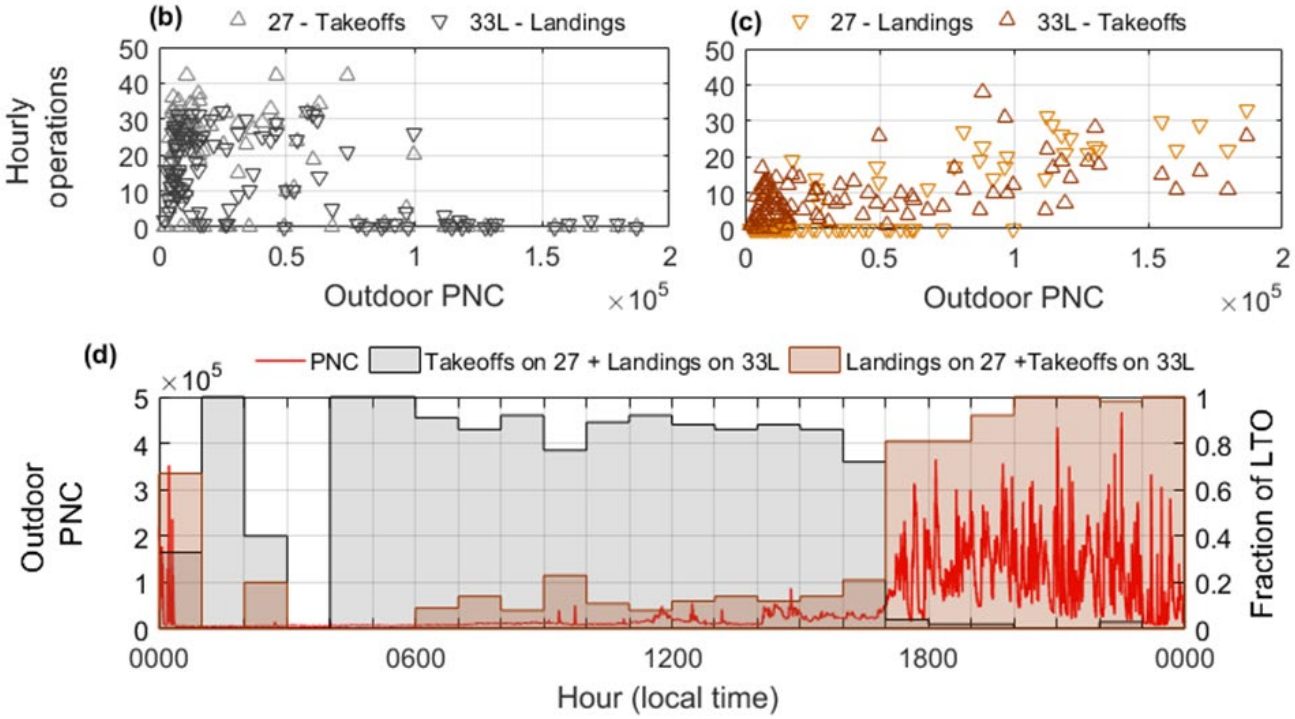
(a) Polar plots of outdoor **Particle Number Concentrations** (PNC) at hourly resolution; radial axis shows wind speed in m/s. (b) PNC patterns with respect to wind direction (WD) and hour of the day; data was binned into 36, 10-degree-wide WD and 24 hourly bins. (c) Average diurnal trend for outdoor PNC for impact-sector and other winds.

Hudda et al., 2020

Ultrafine particle number concentrations also vary with runway usage:

Hourly operations on runways 27 and 33L vs. outdoor PNC during impact sector winds

PNC vs. fraction of flight activity on runways 27 and 33L during impact sector winds over a single day (09/11/17)



Hudda et al., 2020

Literature on Aviation Activities and PNC

- What we know
  - Geographically widespread impact of aviation activities on ambient PNC[1-6]
  - Being downwind of airport associated with increased PNC[1-6]
  - Higher emission rates for departures vs. arrivals, but narrower geographic spread of departure impact vs. arrivals[7]

- Limitations in previous studies
  - Sites located close to major roads
  - Lack of variability in meteorology
  - Use of low temporal resolution data
  - Limited distinction between in-flight vs. airport contribution

[1]Hudda et al. 2014, [2]Hudda & Fruin 2016, [3]Hudda et al. 2016, [4]Hsu et al. 2012, [5]Keuken et al. 2015, [6]Riley et al. 2016, [7]Tesseraus 2004

Recent Aviation-Related PNC Studies

- Total concentration of UFP (10 - 1000 nm) measured as PNC did not distinguish roadway and aircraft features.
- Traffic and aircraft UFP emissions were separated using a combination of mobile monitoring and statistical modeling.
- There were PNC particle size distribution variation for roadway and aircraft features with aviation associations observed with particles below 20 nm .
- Landing aircraft activity was associated with particles between 10-20 nm.

Austin et al. 2021 Environ. Sci. Technol. 2021, 55, 5, 2847–2858
https://doi.org/10.1021/acs.est.0c05933

ASCENT Project 18

- Measure UFP and BC concentrations at strategically selected sites near arrival flight paths
- Quantify the contribution of flight arrivals to measured concentrations along a single arrival pathway

- Current Study (Arrivals and Departures)
  - Expanded field campaign to address unanswered questions related to aviation source attribution
  - Develop insights about spatiotemporal patterns of the aviation-attributable portion of multiple air pollutants, determining implications for potential studies of health effects
  - Compare monitoring-based source attribution estimates with those derived from dispersion modeling

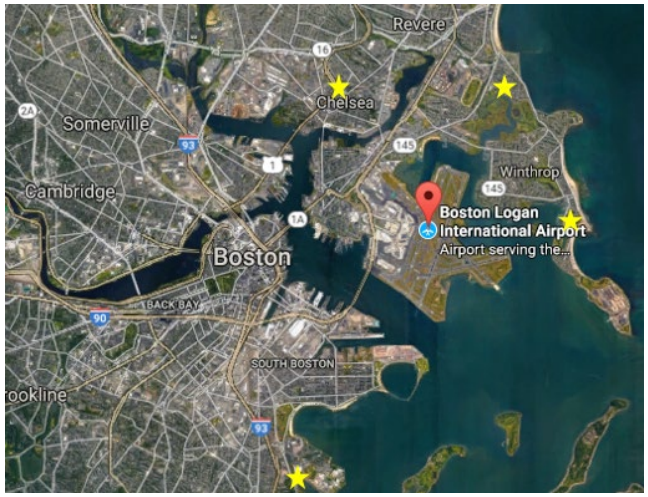
Particle Number
TSI CPC 3787
(1 sec)

Particle Size Distribution
TSI FMPS 3091
(1 sec)

Stationary and Mobile Monitoring

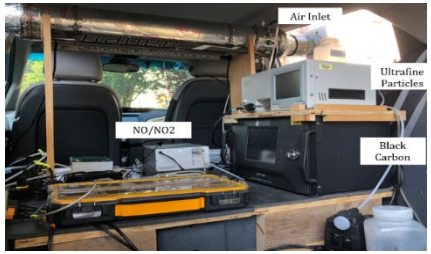
Stationary Site Selection

- PNC Monitoring sites
- Sites chosen to be > 200 m from major roadways
- Near population areas
- At varying distances from multiple runways based in part on historical wind direction and runway usage



Mobile Monitoring Route

- Routes chosen to be away from major roadways
- Through population areas
- Want to capture a wide range of meteorological conditions.

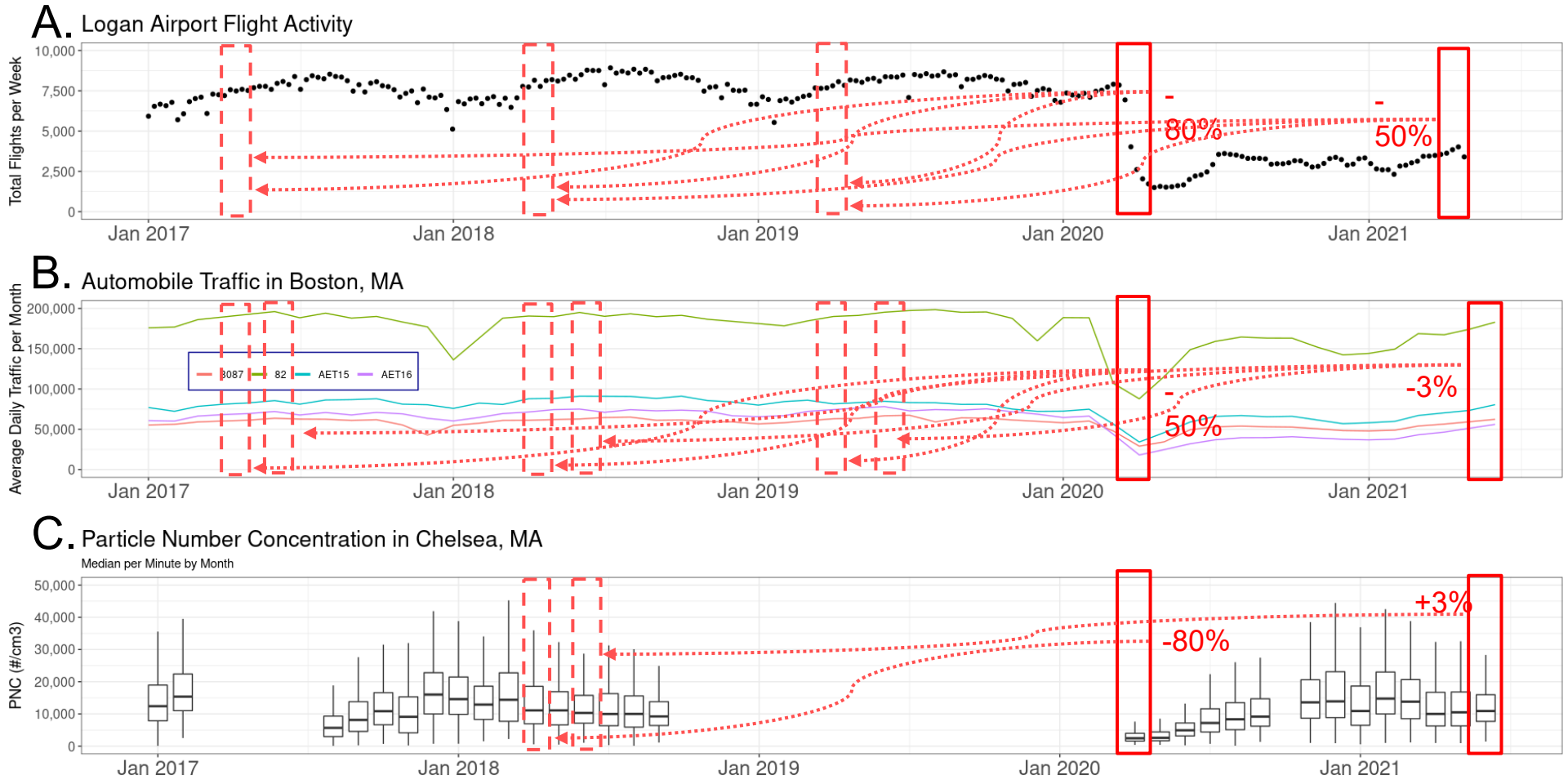


COVID-19 UFP Analysis

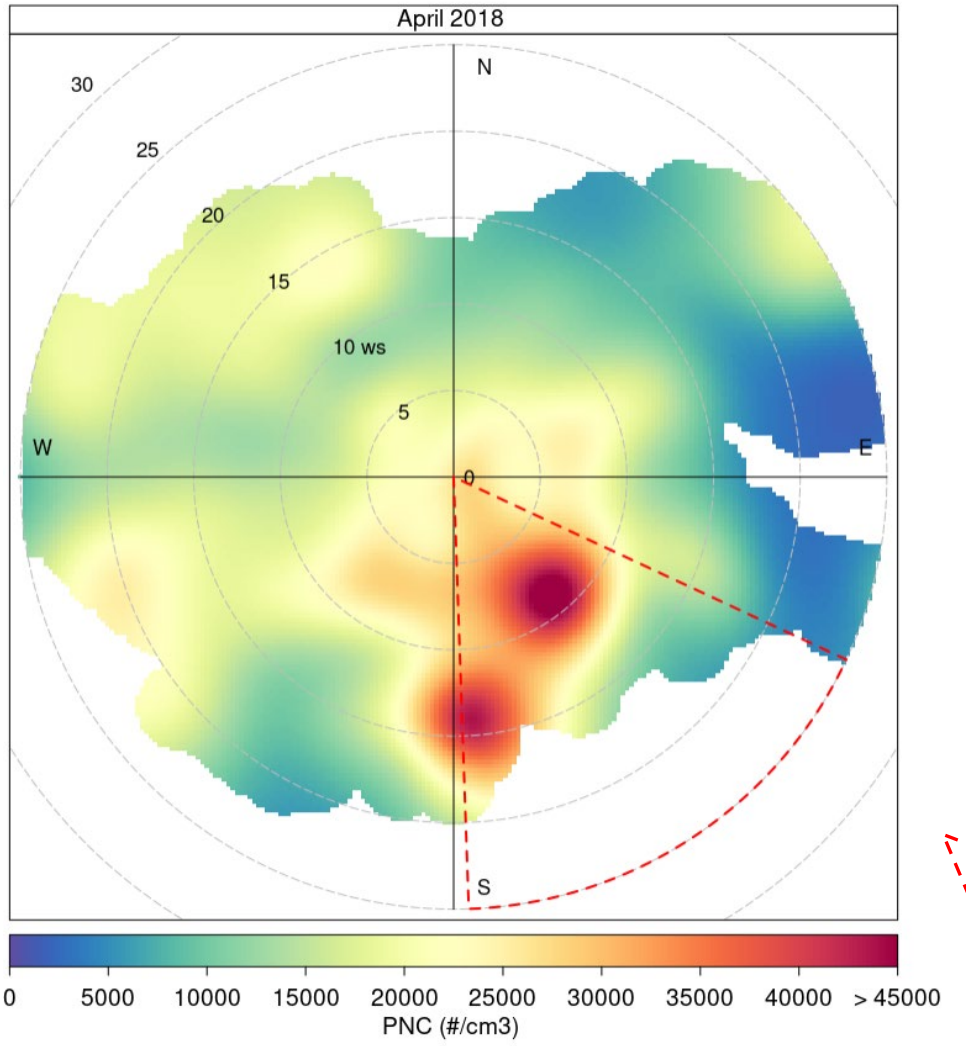
Leverage a set of UFP measurements in a community near a major airport across multiple years to evaluate time trends and contributions from transportation sources

1. Analyze Particle Number Concentrations (PNC) patterns before and during the COVID-19 pandemic to ascertain changes in transportation sector contributions
2. Utilize high temporal resolution data, including wind speed and wind direction, to discern impacts from aviation activity, an intermittent but impactful UFP source

Long-term Stationary Monitor PNC patterns



Bivariate Polar Plot of Chelsea PNC



Downwind of Logan Airport

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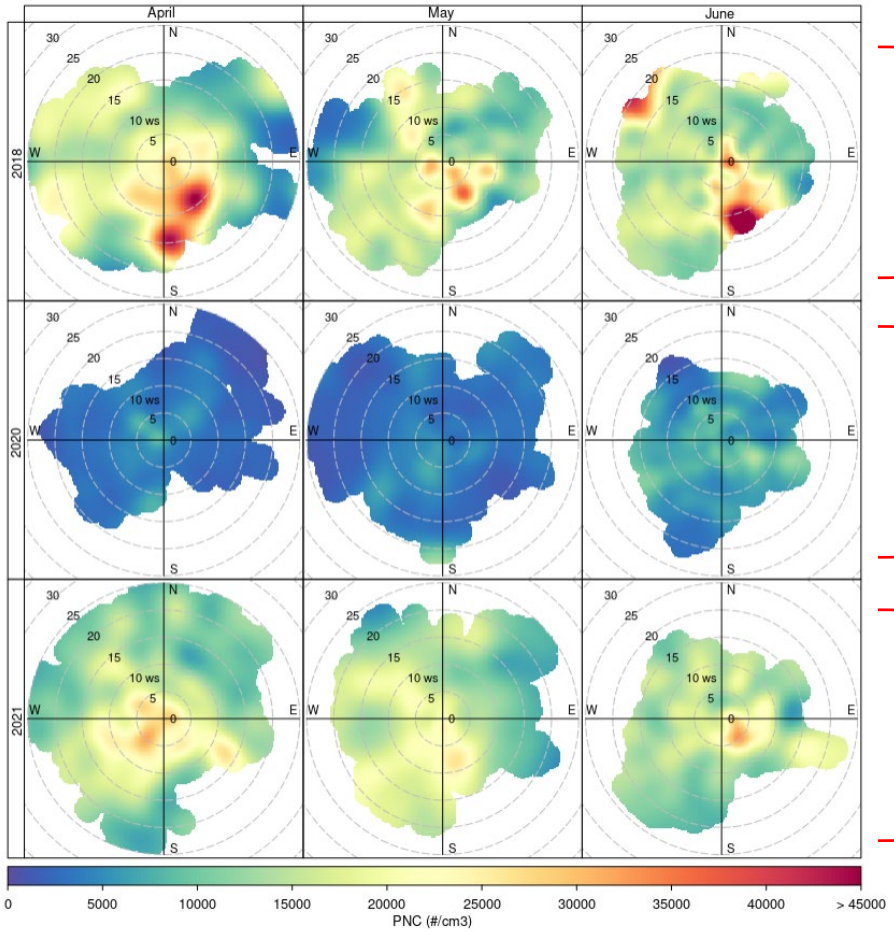
Time Series Polar Plots of Chelsea PNC



Downwind from Logan Airport PNC is **~2x higher** than PNC from all other quadrants

Downwind from Logan Airport PNC is **~1.2x higher** than PNC from all other quadrants

Downwind from Logan Airport PNC is **~1.5x higher** than PNC from all other quadrants

COVID-19 UFP Analysis

Summary Statements

- Novel UFP data before and during the pandemic provides insight that did not previously exist about source contributions

1. Approximately 80% decrease in ambient PNC from COVID-19 pandemic activity restrictions
2. Differential return to pre-COVID-19 activity levels for road traffic and aviation, signaled in PNC patterns by wind direction downwind from Logan Airport

- Source apportionment in urban areas is challenging, reinforcing the importance of long-term monitoring of PNC

Future Research Directions

- Conduct regression analysis to decipher source attributions

Summary

- Contributions of aircraft arrivals and departures 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
- We are producing data and plots that have reinforced the complexity and variability in UFP concentrations over time and space that can be captured with a combined stationary and mobile monitoring platform

- Next steps
  - Complete statistical analyses and work on field campaign
- Key challenges/barriers
  - Developing physically interpretable insights about arrival/departure contributions
  - Considering air pollution impacts within a broader exposure/health context

Acknowledgements

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Questions?

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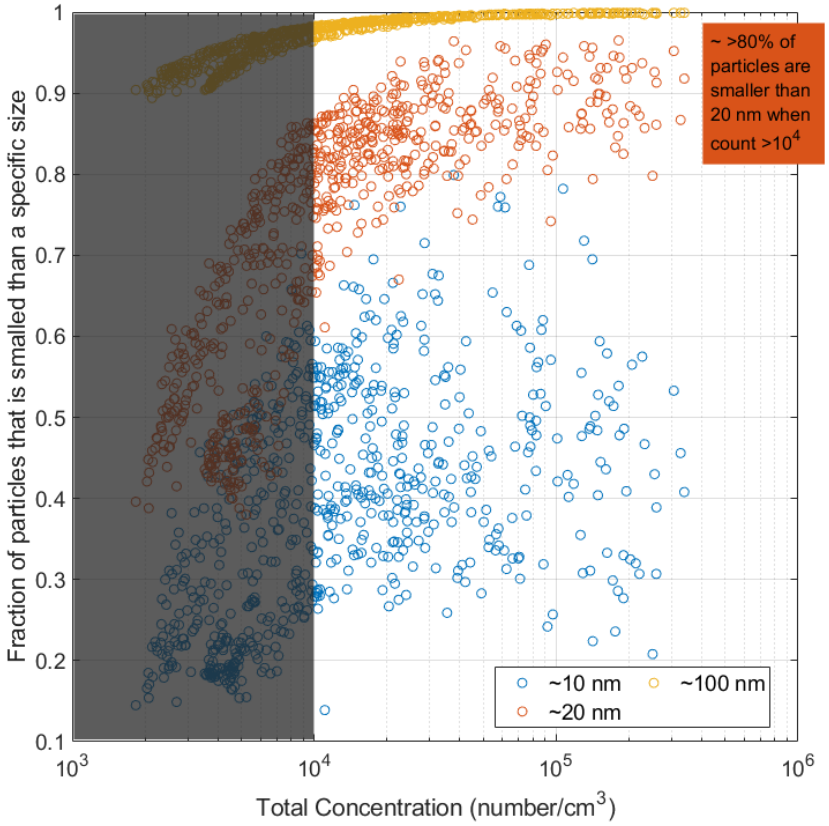
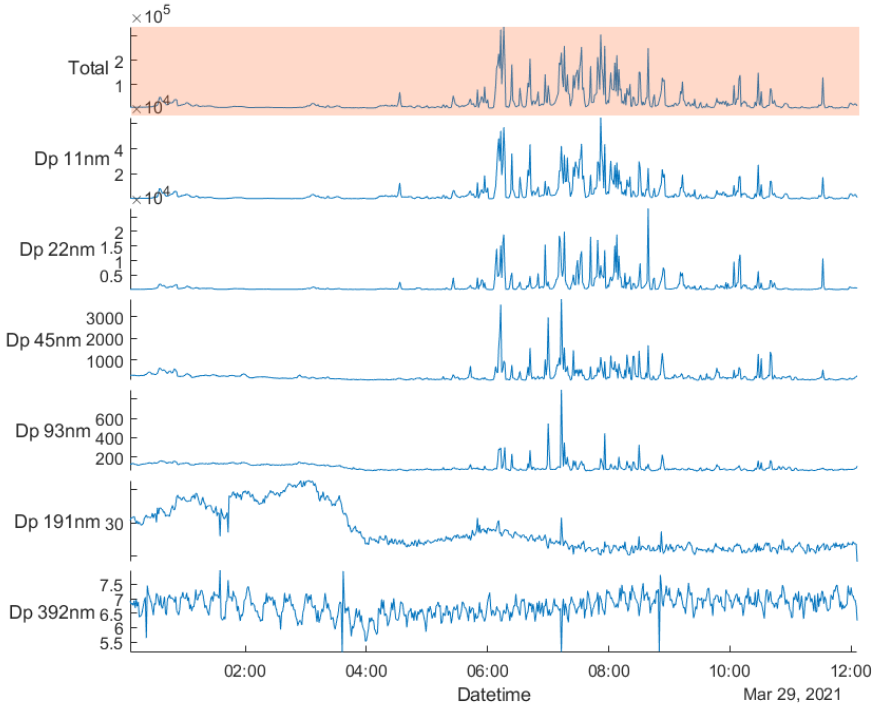
- BACK UP SLIDES

Figure 1: Particle size distribution (a) particle size distribution averaged within two-minute duration as natural log of PNC by particle size bin in nanometers; (b) time series plot of PNC by size distribution.





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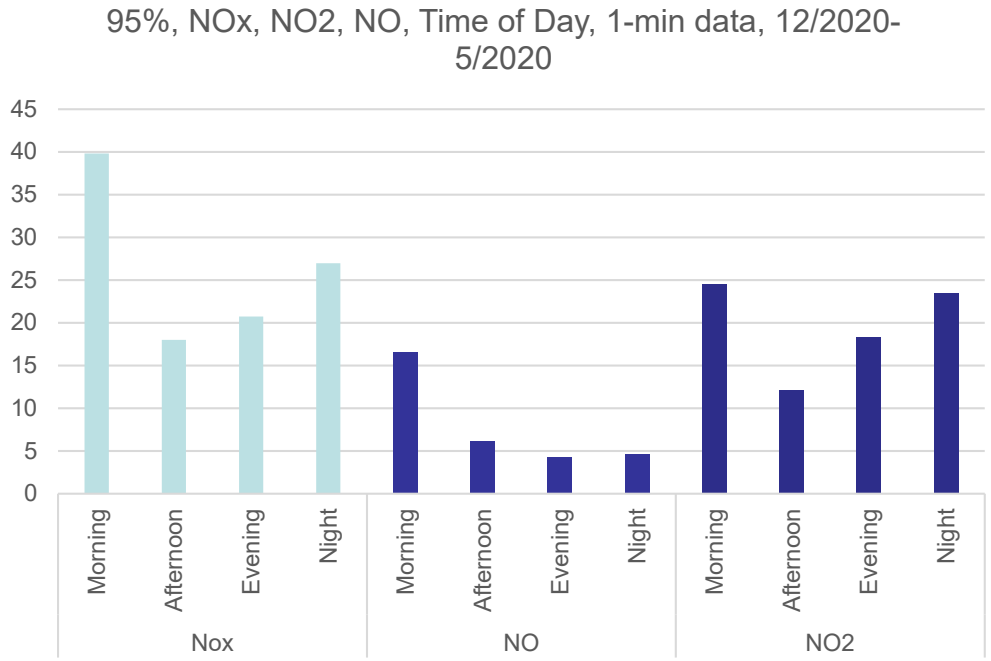
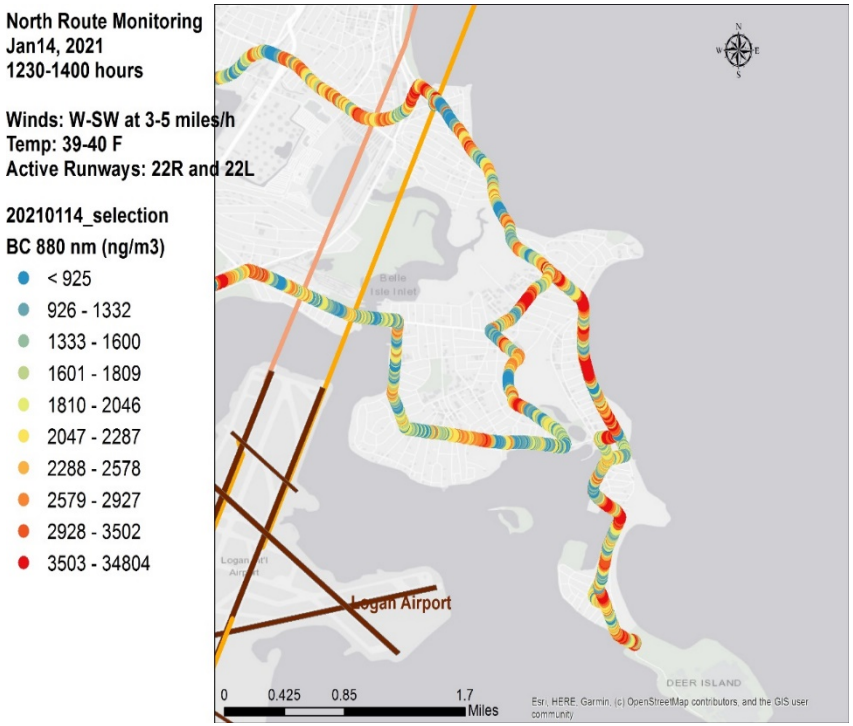
Additional Pollutant Monitoring Black Carbon and NO, NO2 and NOx





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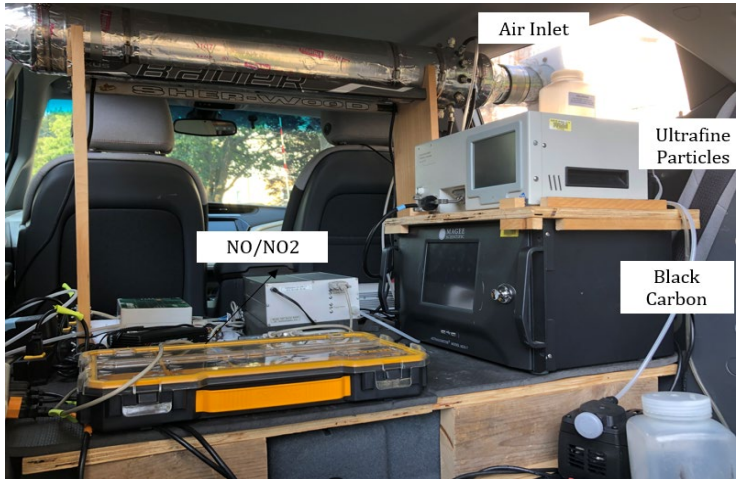
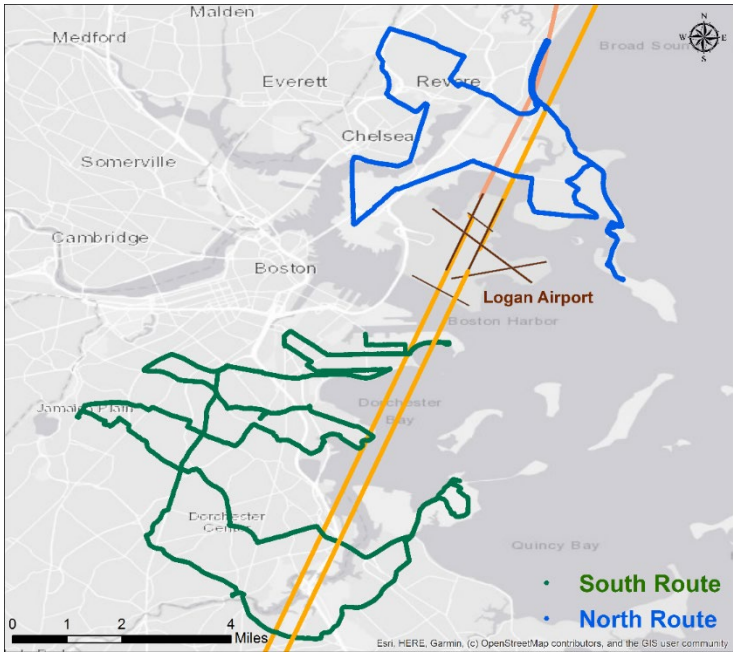
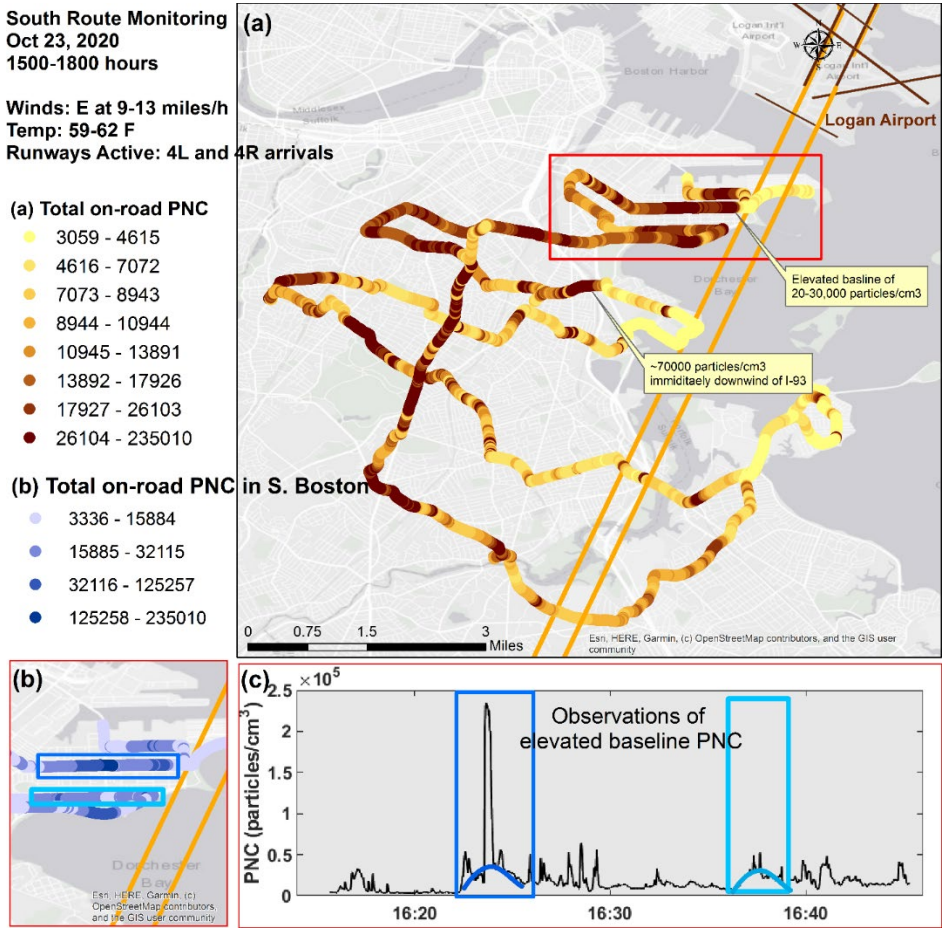
Mobile monitoring using Tufts EV-Air



Instrument	Parameter measured	Instrument Flow Rate (L min-1)	Response Time (s)	Detection Limit, Sensitivity
TSI portable CPC (Ethanol-based) model 3007	UFP count, 10 nm - 1 um	0.8	<9 sec for 95% response	10 nm, <0.01 particles/cm^3
TSI EPC (water-based) model 3783	UFP count, 7 nm - 3 um	3	<3 sec for 95% response	7 nm, <0.01 particles/cm^3
2B Technology Model 408	NO	1	8	Greater of 3 ppb or 3% of reading
Magee Scientific Aethalometer AE-33	BC	5	<60	Proportional to time-base and sample flow rate settings: approximately 0.03 µg/m^3 @ 1 min, 5 LPM.
Garmin GPSMAP 76CSx	GPS location	N/A	1	3 m

Mobile Monitoring Routes





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