Project 018 Community Measurements of Aviation Emissions Contribution to Ambient Air Quality

Boston University School of Public Health

Project Lead Investigator

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- PI(s): Kevin J. Lane, Assistant Professor; and Jonathan I. Levy, Professor and Associate Chair
- FAA Award Number: 13-C-AJFE-BU, Amendment 7
- Period of Performance: October 1, 2018 to September 30, 2019
- Task(s):
    1. Construct regression models to determine the contributions of aircraft arrivals to ultrafine particulate matter (UFP) and black carbon (BC) concentrations measured during our 2017 monitoring campaign
    2. Conduct site selection for our 2018 monitoring campaign by analyzing our 2017 measurements and by considering optimal sites to determine multiple types of aviation source contributions (**completed in 2017–2018)**
    3. Measure UFP and other air pollutants at sites near Boston Logan International Airport, as selected in Task 2
    4. Develop platforms that will enable comparisons among atmospheric dispersion models implemented by collaborators on ASCENT Project 19 and monitored pollutant concentrations obtained from Project 18 (**completed in 2017–2018)**

Project Funding Level

This project did not receive funding from the FAA during FY2019.

Investigation Team

- ASCENT BUSPH Director and Project 18 Co-Investigator: Jonathan I. Levy, ScD (Professor of Environmental Health, Chair of the Department of Environmental Health, Boston University School of Public Health). Dr. Levy is the Boston University PI of ASCENT. He initiated ASCENT Project 18 and serves the director of BUSPH ASCENT research.
- ASCENT Project 18 Principal Investigator: Kevin J. Lane, PhD (Assistant Professor of Environmental Health, Department of Environmental Health, Boston University School of Public Health). Dr. Lane joined the Project 18 team

in July 2017. Dr. Lane has expertise in the assessment of UFP exposure, geographic information systems, statistical modeling of large datasets, and cardiovascular health outcomes associated with air pollution exposure. He has contributed to study design and data analysis strategies and, as of 10/1/17, has taken over the primary responsibility for project execution; Dr. Lane also contributes to the manuscripts and reports produced.

- Post-Doctoral Researcher: Matthew Simon, PhD. Dr. Simon joined the Project 18 team in September 2017 and is involved in data analysis, field study design and implementation, and scientific manuscript preparation.
- Graduate Student: Chloe Kim, MPH. Ms. Kim is a doctoral student in the Department of Environmental Health at BUSPH. She has taken the lead on organizing and implementing the air pollution monitoring study and will be responsible for the design and execution of related statistical analyses.
- Graduate Student: Bethany Haley. Ms. Haley is a doctoral student in the Department of Environmental Health at BUSPH. She has taken the lead on field monitoring and in processing the air pollution monitoring study and descriptive statistics.

Project Overview

The primary goal of this project was to conduct new air pollution monitoring beneath flight paths to and from Boston Logan International Airport, using a protocol specifically designed to determine the magnitude and spatial distribution of UFP in the vicinity of arrival flight paths. Data were collected to assess whether aircraft emissions, particularly arrival emissions, significantly contribute to UFP concentrations at appreciable distances from the airport. Task 1 was an extension of the ongoing air pollution monitoring and statistical analysis work performed under the current ASCENT Project 18. Tasks 2 and 3 leverage the infrastructure developed for our field campaign and enable measurements that address a broader set of research questions than those evaluated under Task 1, with additional data collection for UFP size distributions and a new air pollutant (NO/NO_2). These tasks provide a strong foundation for Task 4, which increases the potential for future collaborative efforts with Project 19, in which we interpret and apply the collected measurements to inform ongoing modeling efforts at UNC.

A summary of 2017 project methods and data collection is included below to describe the continued application of Project 18 data, including bivariate statistical analysis and multiple regression model development conducted under Task 1 to inform new site selection for Task 2.

Project 18 Task 1 for the 2016–2017 funding cycle focused on designing and implementing an air pollution monitoring study that would allow us to determine contributions from arriving aircraft to ambient air pollution in a near-airport setting. The objective of this task was to assess whether aircraft emissions, particularly arrival emissions, significantly contribute to UFP concentrations at appreciable distances from an airport.

An air pollution monitoring campaign was conducted at six sites located at varying distances from the airport and the arrival flight path to runway 4R (Figure 1). Near-Airport Site 1 (N1): Office of Department of Conservation and Recreation (DCR), Boston, MA; Near-Airport Site 2 (N2): University of Massachusetts (UMASS) Boston campus; Intermediate-Distance Airport Site 1 (I1): Boston Community Development Corporation (CDC) office; Intermediate-Distance Airport Site 2 (I2): Community member residence; Background Site 1 (F1): Fonte Bonne Academy; Background Site 2 (F2): Blue Hills. Sites were selected through a systematic process, considering varying distances from the airport and lateral distances from the 4R flight path and excluding locations close to major roadways or other significant sources of combustion. These sites were specifically chosen to isolate the contributions of arrival aircraft on runway 4R, which is important for the flight activity source attribution task.

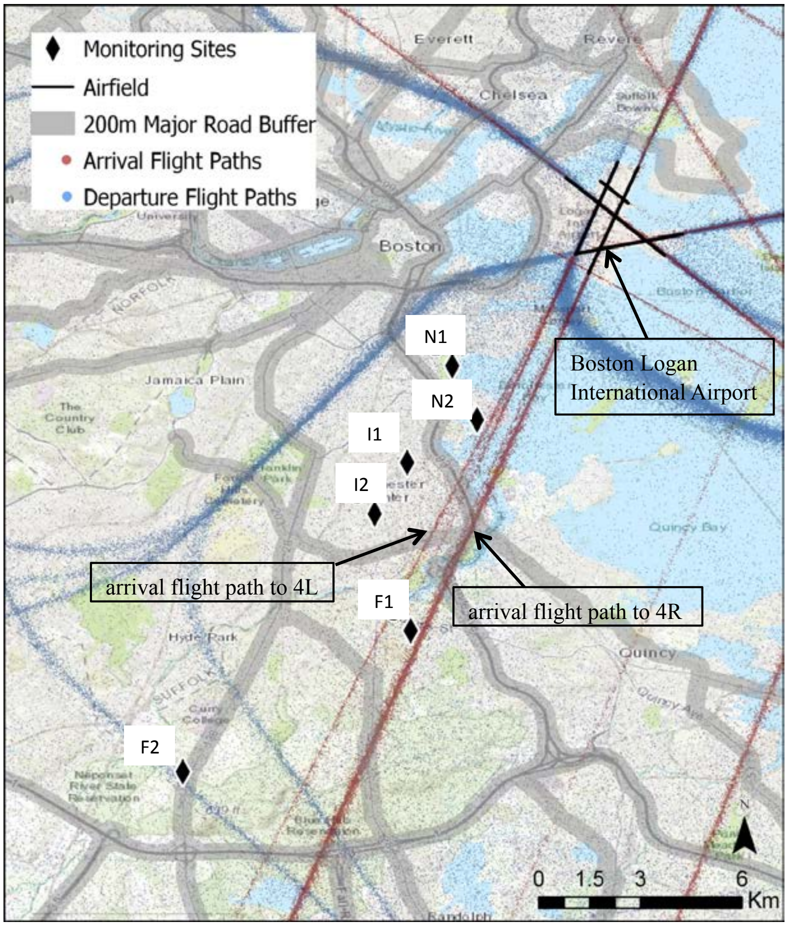


Figure 1. Monitoring sites and runway 4R flight path.

Table 1 presents the characteristics for each monitoring site.

Table 1. Characteristics of each monitoring site.

Site	Distance to flight path 4R (km)	Distance to airport (km)	Average altitudes of arrival aircraft (m)	Monitoring configuration
N1	1	3	210	Indoor*: second-floor office space facing the ocean
N2	< 0.5	4	300	Outdoor: open shed on a boat dock
I1	2	7	400	Indoor*: first-floor restroom facing a small parking area
I2	2	9	460	Outdoor: open shed in the backyard in a residential area
F1	< 0.5	12	610	Indoor*: second-floor classroom
F2	4	17	850	Outdoor: greenhouse at a farm

* For indoor deployment cases, the monitor was placed indoors with tubing running outside to measure ambient concentrations.

Task 1 - Construct Regression Models to Determine the Contributions of Aircraft Arrivals to UFP and BC Concentrations Measured During our 2017 Monitoring Campaign

Boston University School of Public Health

Objective(s)

Under Task 1, we developed regression models to examine contributions from arriving aircraft to ambient air pollution in a near-airport setting. The objective of this task was to determine whether aircraft emissions, particularly in-flight arrival and departure emissions, significantly contribute to ground-level UFP concentrations at appreciable distances from the airport.

Research Approach

Utilizing the air pollution data collected during the 2017 monitoring campaign, we examined average UFP concentrations for days in which the 4R runway was or was not in use under all wind conditions, with the aim of determining the overall impact of arrival aircraft on ambient UFP concentrations at the study sites. We also examined the correlations of UFPs measured simultaneously at multiple study sites to examine the similarities and variations in aircraft impact at different monitoring sites under varying meteorological conditions and flight activity levels. Prior to constructing regression models, we examined space–time plots of our data to identify distinct patterns of plume movement and potential time lag differences between the sites under specific meteorological conditions. Results from these descriptive analyses were used to inform the regression model development process.

For the regression models, we developed multivariate regression models to examine the predicted UFP patterns, using covariates such as meteorology, flight activity, and other ground source contributions such as localized traffic. Each study site was modeled individually to investigate the location-specific impact of aircraft arrivals in addition to meteorological and other local environmental conditions. We also explored novel statistical approaches, i.e., elastic nets and random forest modeling, to elucidate the importance of key covariates at different temporal and distributional scales of analysis.

Milestone(s)

The core milestones for Task 1 included complete regression modeling of UFP and associated manuscript development.

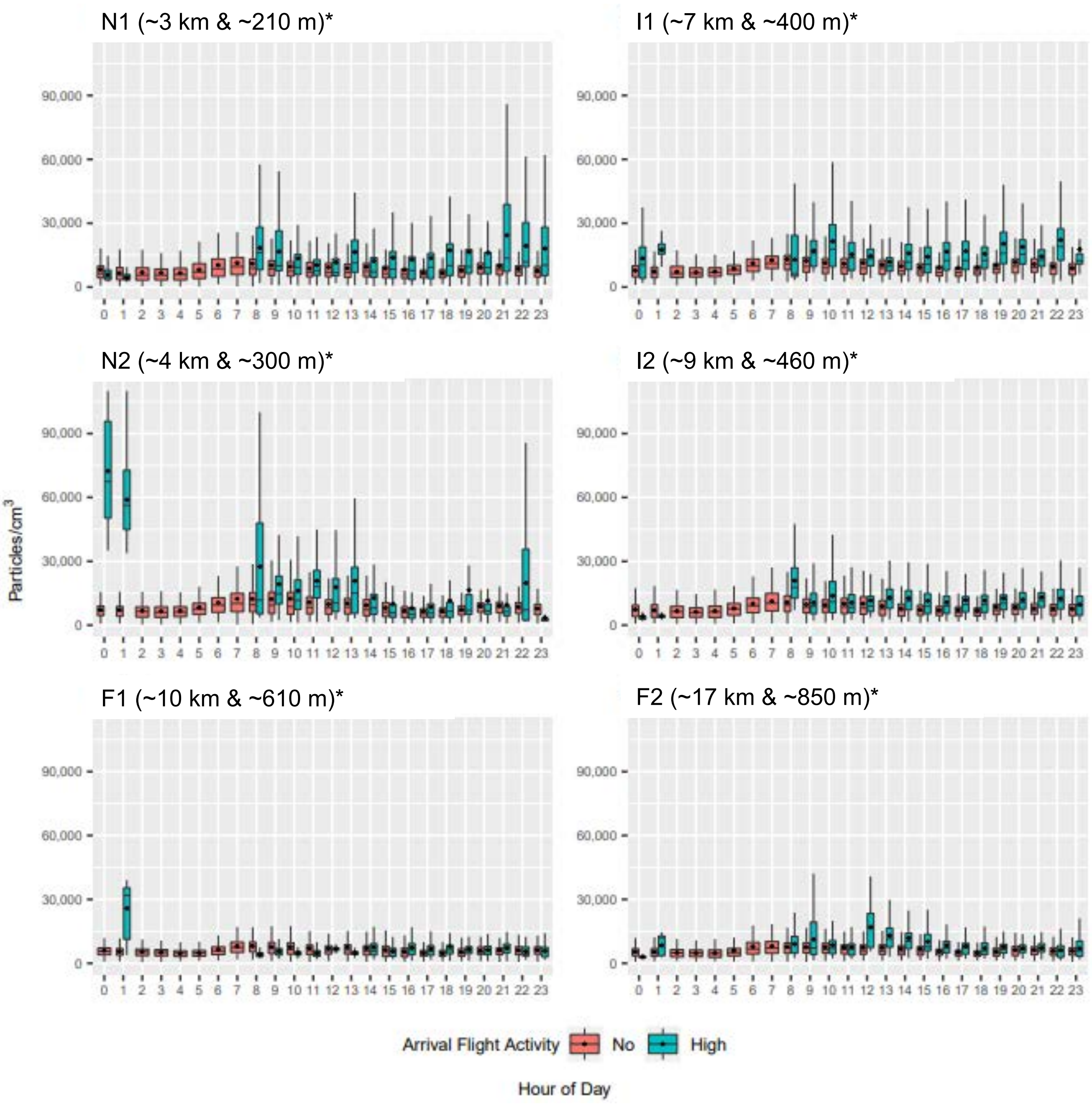
The regression model development is being finalized, and manuscripts are being prepared for submission to peer-reviewed journals.

Major Accomplishments

Descriptive maps and PNC wind rose plots

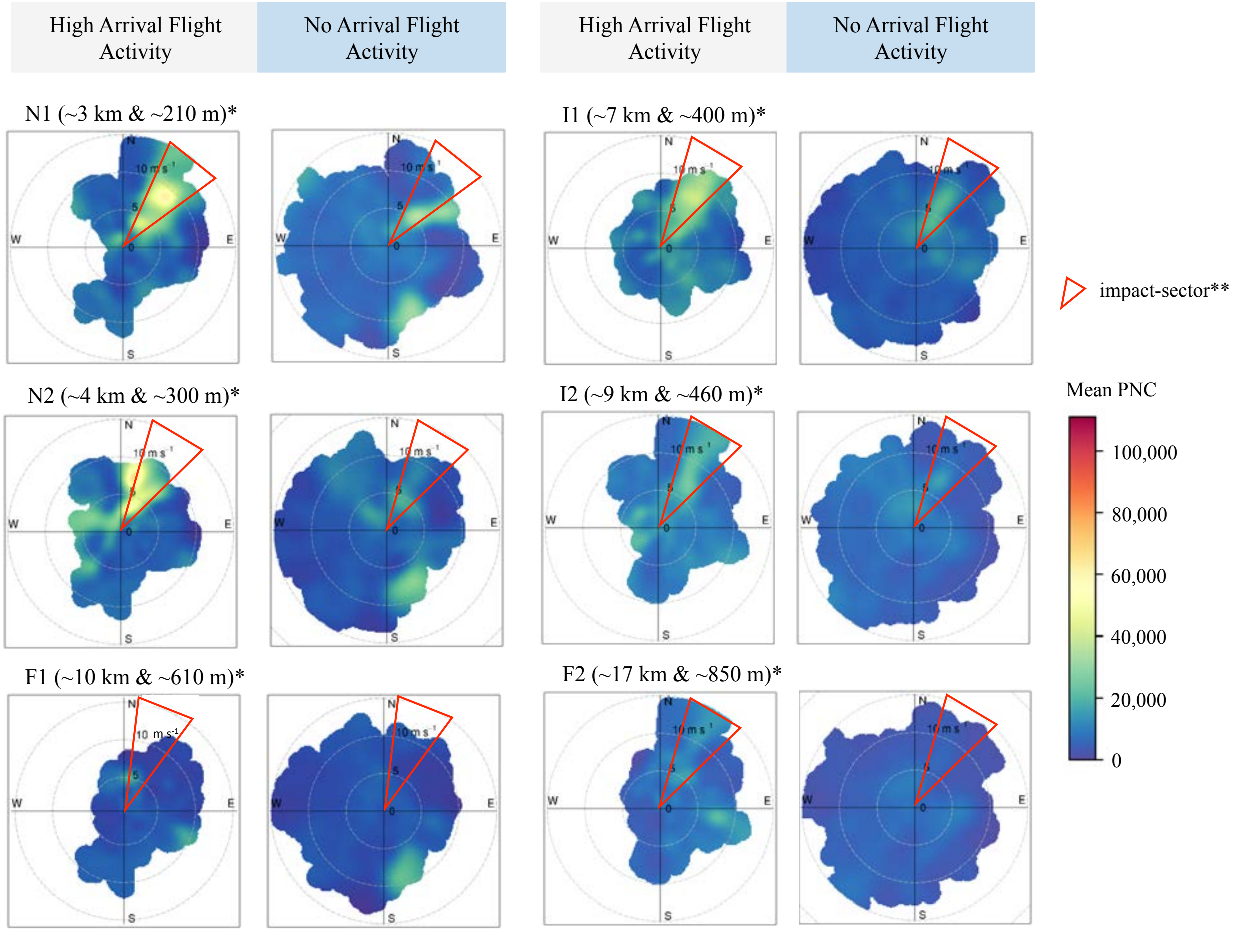
The statistical analysis for Project 18 was expanded to improve our understanding of the effect of wind direction, wind speed, flight activity, and aircraft engine type on ground-based particle number concentration (PNC) measures. The following figures present the patterns observed over the 2017 data sampling period. Figure 2 displays boxplots of hourly PNCs when the 4R runway had high flight activity, defined as more than 30 flights per hour, compared with no flight activity. In general, the PNC was higher during high flight activity compared with no flight activity. During high flight activity, sites N1 and N2 had higher PNCs compared with the intermediate and background sites. These findings support the hypothesis generation for regression modeling, as they indicate the importance of timing and flight activity.

Additional analysis is being conducted to examine PNCs at different temporal resolutions below 1 hr. Previous studies have focused on analyzing the median or mean hourly concentrations, but due to the intermittent nature of flights, it may be important to examine more finely resolved data, with resolutions below 1 hr, and potential peak exposures in the 95th and 99th percentiles. We have started to plot and analyze 1-s PNC data with corresponding meteorological conditions to investigate the simultaneous relationships among wind direction, wind speed, flight activity, and PNC at each monitoring site. With this aim in mind, we created wind rose PNC plots to identify hotspots under different meteorological conditions at each site (Figure 3). Wind direction is based on the weather station at the airport. Ideal wind conditions (15–45 degrees) exhibited higher concentrations at near-source sites compared with cases in which the monitors were upwind of the arriving aircraft (45–145 degrees). Wind direction had a weaker impact on background site concentrations. We are also further exploring relative wind direction and subcategorization of the operational flight activity to identify periods during which arrivals into 4L were occurring instead of 4R for the nonoperational time periods. These results highlight potential site-specific interactions that may occur between meteorological conditions and flight activity to inform ground-level PNC source attribution.



* distance to the airport and average altitudes of arrival aircraft over the site

Figure 2. Diurnal pattern of particle number concentrations (PNCs) under high vs. no arrival aircraft activity conditions.



* distance to the airport and average altitudes of arrival aircraft over the site
** wind sector that positions monitoring sites downwind of the airport and the arrival flight paths to 4L/4R runways

Figure 3. Particle number concentration (PNC) wind rose plots for each monitoring site by flight activity on 4R and 4L during high and no flight activity periods. The monitoring sites correspond to map in Figure 1.

Each plot above presents monitoring data for each site-specific wind rose, centered at each monitor geophysical positioning system (GPS) location, with the airport located northeast of each site. Each quadrant represents the direction in which the wind is blowing from, while the circular dashed lines indicate the wind speed in miles per hour. The color represents the PNC range. From the plots, several key points can be inferred and applied for further exploration:

- When flights are occurring, PNC levels are higher than when no flights are occurring.
- Closer sites have elevated PNC hotspots; specifically, DCR (N1) and UMASS (N2), which are closer to the airport, have higher levels than the other sites.
- Hotspots of higher PNC are more pronounced when the wind comes from the airport direction at DCR (N1) and UMASS (N2) during flight activity compared with no flight activity.
- Background sites F1 and F2 have more PNC hotspots during flight activity compared with no flight activity.

Overall, PNC levels are higher when wind comes from the airport direction and when aircraft are flying at lower altitudes, such as at the N1 and N2 sites. For an aircraft arriving into Logan overhead a monitoring site location further away, similar detectable PNC levels are not produced at our background sites under ideal wind conditions, potentially because these aircrafts are at a higher altitude.

PNC regression modeling

The descriptive analyses above informed regression modeling efforts, as presented below. The PNC has a non-normal distribution and is commonly examined as the natural log (LN). Covariates included in this regression model have been found to have a significant univariate relationship with LN PNC. The multivariable linear regression model enables an initial examination of the relationship between spatial–temporal meteorological, flight activity, and other potential ground contributions from traffic sources on the association with the hourly LN PNC. Results from this model should be considered as developments to assist in refinement, as the current model is being expanded to include additional covariate contributions and interactions among predictive factors. Initial regression models have been developed for each monitoring site to compare the total model R^2. Additionally, covariates have been held constant for all models to examine the explanatory power of each variable between sites, thus enhancing our understanding of the relative contributions from flight activity, meteorology, and other local contributions, such as traffic, for source attribution of ground-measured PNCs.

In Table 2, we present preliminary regression model results for the hourly LN PNC at two near-source sites 1 and 2 and a background site 3. Each model includes meteorological variables (wind direction, wind speed, and temperature), temporal information (weekend/weekday and time of day), and flight activity on runway 4R/4L (categorized as no flights, low flight activity [1-10 arriving flights/hr], and high flight activity [>10 arriving flights/hr]). The results obtained by modeling the 99th percentile data are not presented, as they are similar to the results for the 95th percentile PNC. Overall, our regression models indicate a significant positive association between 4L/4R arrival aircraft frequency and measured PNC. In general, the hourly regression models showed a larger increase in PNC associated with 4L/4R arrival activity than the 10-min average regression models (with the exception of the 95th percentile model for site N1), and the 95th percentile models had a larger increase in PNC than the mean models. Because the models have different intercepts, the exponentiated coefficients from different models are not directly comparable, but we can still compare the absolute contributions of 4L/4R activity across the sites by considering both the intercept and the relative 4L/4R arrival aircraft contribution, while holding all other variables constant. For example, at I1, the estimated percent change in the measured 95th percentile 10-min PNC for one additional 4L/4R arrival aircraft was 1.1%, compared with 0.3% for the mean model, with a larger intercept for the 95th percentile PNC model. In other words, the estimated absolute contribution of 4L/4R arrival aircraft on PNC at I1 is larger in the 95th percentile model than in the mean model. In contrast, the impacts of all other aircraft activity at all sites were fairly similar between the mean and 95th percentile models. The coefficients for aircraft activity, including both the 4L/4R arrival aircraft and all other aircraft activity, were lower at the far site (F1) compared with the near and intermediate sites (N1 and I1).

Table 2. Multivariable regression model results for hourly and 10-min mean particle number concentration (PNC) at multiple monitoring sites, accounting for autocorrelation. The monitoring sites correspond to map in Figure 1.

	Mean PNC			
	Hourly		10-Min	
	Exponentiated Regression Coefficients	95% Confidence Interval (CI)	Exponentiated Regression Coefficients	95% Confidence Interval (CI)
	N1			
Intercept	15,100	(9,800, 23,100)	9,500	(6,500, 13,900)
4L/4R runway arrival aircraft frequency	1.016	(1.013, 1.020)	1.008	(1.001, 1.015)
All other aircraft activity frequency	1.007	(1.006, 1.009)	1.002	(0.999, 1.005)
Temperature (Celsius)	0.982	(0.969, 0.994)	0.989	(0.976, 1.001)
Relative humidity (%)	0.993	(0.990, 0.997)	1.000	(0.997, 1.002)
Wind speed (m/s)	0.934	(0.910, 0.959)	0.983	(0.971, 0.995)
Mixing height (m)	1.000	(1.000, 1.000)	1.000	(1.000, 1.000)
Atmospheric pressure (mbar)	0.986	(0.976, 0.997)	1.011	(0.998, 1.025)
Precipitation (mm/hr)	0.966	(0.934, 1.000)	0.989	(0.970, 1.008)
Weekday vs. weekend	1.062	(0.889, 1.267)	1.050	(0.844, 1.306)
Impact sector (yes)	1.119	(0.855, 1.466)	0.941	(0.868, 1.020)
Wind speed (m/s)*Impact sector (yes)	1.114	(1.056, 1.176)	1.031	(1.014, 1.047)

	I1			
Intercept	24,900	(17,600, 35,300)	12,300	(8,900, 17,000)
4L/4R runway arrival aircraft frequency	1.015	(1.012, 1.018)	1.003	(0.997, 1.008)
All other aircraft activity frequency	1.010	(1.009, 1.012)	1.003	(1.000, 1.005)
Temperature (Celsius)	0.964	(0.954, 0.974)	0.989	(0.978, 1.000)
Relative humidity (%)	0.995	(0.993, 0.998)	0.999	(0.997, 1.001)
Wind speed (m/s)	0.913	(0.893, 0.933)	0.986	(0.977, 0.995)
Mixing height (m)	1.000	(1.000, 1.000)	1.000	(1.000, 1.000)
Atmospheric pressure (mbar)	1.003	(0.994, 1.012)	1.012	(1.000, 1.024)
Precipitation (mm/hr)	0.991	(0.963, 1.02)	0.997	(0.983, 1.012)
Weekday vs. weekend	0.904	(0.796, 1.025)	0.996	(0.813, 1.221)
Impact sector (yes)	1.244	(1.021, 1.516)	0.963	(0.908, 1.022)
Wind speed (m/s)*Impact sector (yes)	1.038	(0.997, 1.079)	1.021	(1.007, 1.036)
	F1			
Intercept	20,100	(13,100, 30,8003)	6,100	(4,500, 8,100)
4L/4R runway arrival aircraft frequency	1.010	(1.007, 1.013)	0.999	(0.994, 1.003)
All other aircraft activity frequency	1.004	(1.003, 1.005)	1.001	(0.999, 1.002)
Temperature (Celsius)	0.982	(0.970, 0.994)	1.000	(0.990, 1.010)
Relative humidity (%)	0.990	(0.987, 0.993)	0.999	(0.997, 1.000)
Wind speed (m/s)	0.904	(0.884, 0.925)	0.992	(0.985, 1.000)
Mixing height (m)	1.000	(1.000, 1.000)	1.000	(1.000, 1.000)
Atmospheric pressure (mbar)	0.997	(0.986, 1.007)	1.012	(1.000, 1.023)
Precipitation (mm/hr)	1.024	(0.979, 1.071)	1.004	(0.986, 1.022)
Weekday vs. weekend	1.094	(0.946, 1.266)	1.094	(0.900, 1.330)
Impact sector (yes)	1.079	(0.861, 1.354)	1.016	(0.963, 1.072)
Wind speed (m/s)*Impact sector (yes)	1.023	(0.964, 1.086)	0.995	(0.908, 1.009)

To directly compare the varying contributions of arrival aircraft to the ambient PNC across different models while accounting for other predictors, we calculated PNC estimates using hourly 95th percentile model coefficients under two different arrival aircraft scenarios (zero vs. actual arrival aircraft in 1 hr). While accounting for other predictors in the model, there was a clear contribution of arrival aircraft at all six study sites. The aircraft contribution at N1 was the largest among all sites (Figure 4). For the 27% of 1-hr periods with arrival aircraft on 4L/4R, the estimated arrival aircraft contribution at site N1 had a mean of 11,100 particles/cm^3 (50% of the total PNC). The second and third largest aircraft contributions were observed at I1 and N2, with estimated arrival aircraft contributions of 9,200 and 6,500 particles/cm^3, respectively, during the 1-hr periods with arrival aircraft activity. Both the background-level PNC and aircraft contribution at I2, F1, and F2 were lowest compared with those of the other sites, with aircraft contributions ranging from 2,300 to 5,000 particles/cm^3. Across all hours (not restricting the data to hours with 4L/4R arrival aircraft activity), the mean predicted arrival aircraft contributions ranged from 7% to 26%, with the highest value observed at N1 and the lowest value at F1.

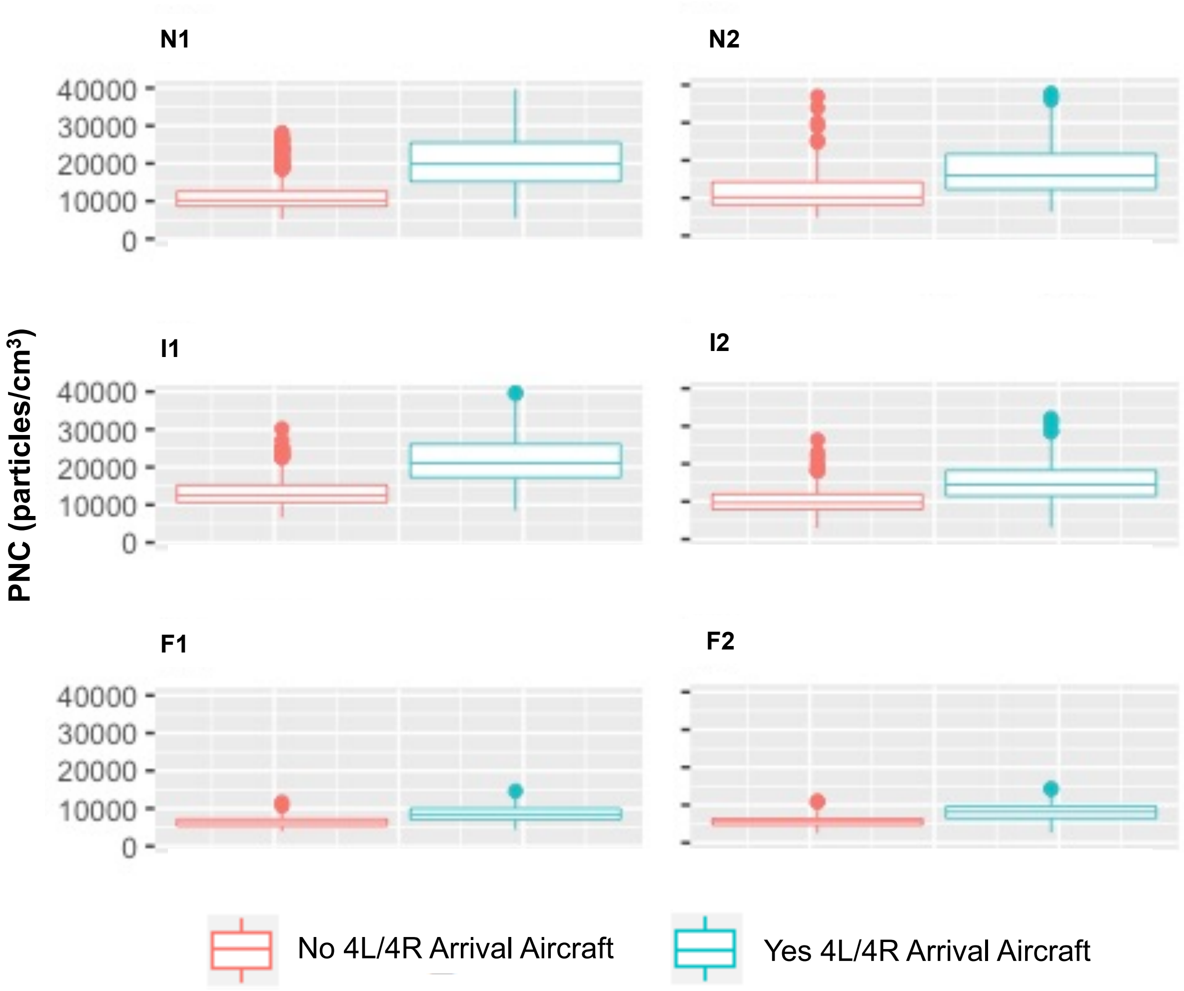
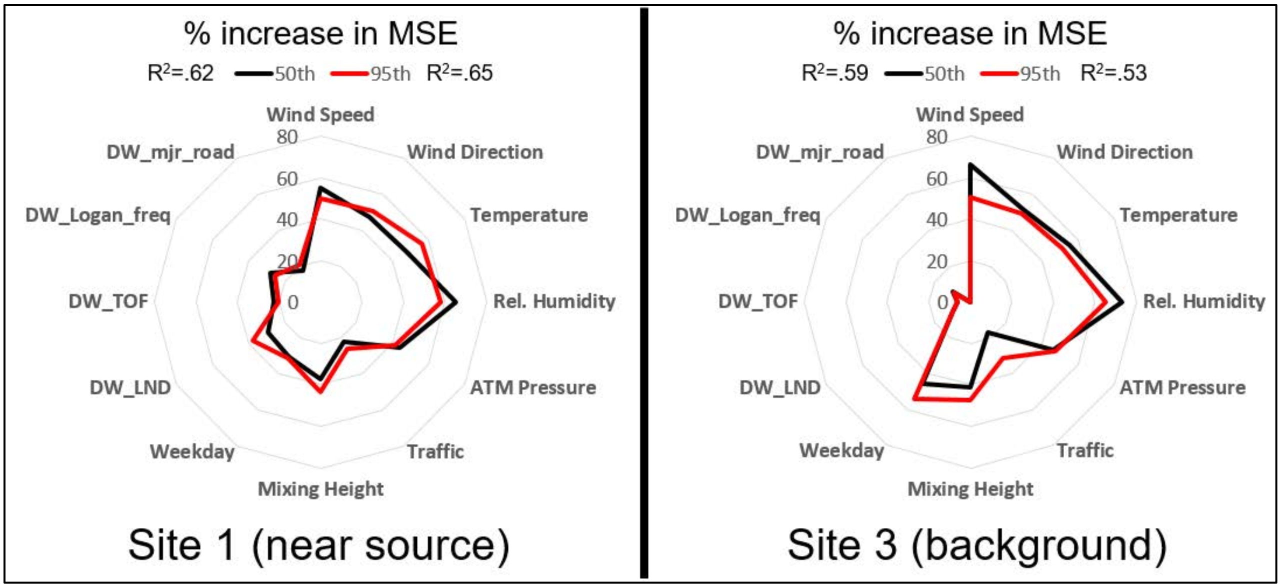


Figure 4. Boxplots displaying 4L/4R arrival aircraft contributions to the estimated ambient particle number concentration (PNC) (95th percentile, 1-hr average) using multivariable regression model predictions for actual arrival activity and no arrival aircraft, restricted to time periods with nonzero 4L/4R arrival aircraft activity.

In addition to linear regression modeling, we explored the use of machine learning regression approaches to identify key covariates and to optimize hourly PNC predictions at each site. This research focused on applications to the UMASS site using a random forest approach, which is a decision-tree-based machine learning algorithm. Each tree is grown by a bootstrap sample, and a random subset of predictors is selected at each split. Predictions are obtained by averaging the results of different trees. Using the random forest model approach, we developed three models to predict the PNC at different hourly scales: hourly median PNC, hourly 95th PNC, and hourly 99th PNC. Figure 5 presents the relative contributions of the covariates to the PNC prediction, measured as the mean square error.

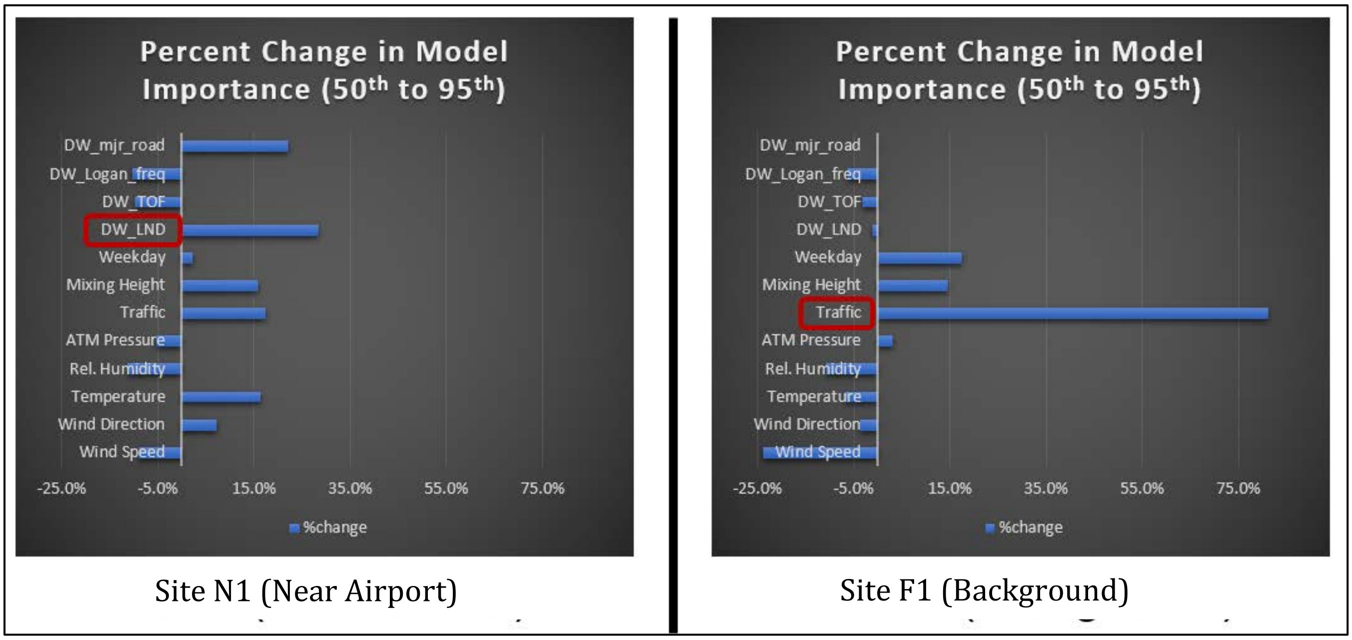


Site 1 (near source)

Site 3 (background)

Figure 5. Spider plot showing the importance of each variable in the random forest model based on the mean decrease in model accuracy (as measured by the mean square error).

The mean model regression performance measured as R^2 improved by more than 20% when the random forest approach was applied ($R^2 = 0.56$). Flight frequency (DW_Logan _Freq) has the largest percent gain in model importance between the median and 95th percentile models (Figure 6). Additionally, the overall random forest model performance had a higher variance for the 50th percentile model compared with that of the 95th percentile model. The random forest modeling approach is being combined with generalized linear regression modeling to identify the best PNC prediction for each site, while also providing interpretable results.



Site N1 (Near Airport)

Site F1 (Background)

Figure 6. Relative change in the importance of each variable in the random forest model between the median (50th percentile) and the 95th percentile model.

Publications

N/A

Outreach Efforts

- Dr. Jonathan Levy presented and sat on a panel on “Modeling aviation-related ultrafine particles from background concentrations” at the Aviation Emissions Characterization Meeting, National Academy of Sciences, DC, U.S., 2019.
- Dr. Kevin Lane presented and sat on a panel on “Modeling aviation-related ultrafine particles from background concentrations” at the Aviation Emissions Characterization Meeting, National Academy of Sciences, DC, U.S., 2019.
- Dr. Matthew Simon presented an oral presentation entitled “A Machine Learning Approach to Model Community-Level Ultrafine Particle Emissions from Arriving Aircraft” at the International Society for Environmental Epidemiology annual meeting in August 2019.
- Doctoral student Chloe Seyoung Kim presented an oral presentation on a portion of the major accomplishments of Project 18 at the International Society for Exposure Science annual meeting in October 2017.

Awards

None.

Student Involvement

Chloe Seyoung Kim, a doctoral student at BUSPH, was involved in the descriptive analysis and regression modeling of 2017 PNC data. Dr. Kim graduated in December 2020 and has joined the Electric Power research Institute as a research scientist. Bethany Haley, a master’s student at BUSPH, has been involved in the descriptive analysis of 2018 sampling data.

Plans for Next Period

Task(s) proposed over the next study period (10/1/18–9/30/19):
Finalize manuscripts for submission to articles.

Task 2 - Conduct Site Selection for our 2018 Monitoring Campaign by Analyzing our 2017 Measurements and by Considering Optimal Sites to Determine Multiple Types of Aviation Source Contributions

Boston University School of Public Health

Objective(s)

Task 2 for the 2017–2018 funding cycle focused on designing and implementing an air pollution monitoring study that would allow us to determine contributions from arriving aircraft to ambient air pollution in a near-airport setting. The objective of this task was to determine whether aircraft emissions, particularly in-flight arrival and departure emissions, can significantly contribute to ground-level UFP concentrations at appreciable distances from the airport.

Research Approach

An air pollution monitoring campaign was conducted at five sites located at varying distances from the airport and arrival/departure flight paths for Boston Logan Airport (Figure 7). Sites were selected through a systematic process, considering varying distances from the airport and laterally from each flight path and excluding locations close to major roadways or other significant sources of combustion. These sites were specifically chosen to isolate the contributions of in-flight aircraft, which is important for the flight activity source attribution task.

PNC (a proxy for UFP) monitoring instruments were established at each monitoring site in a preselected scheme to allow for multiple levels of comparison (e.g., sites beneath vs. not beneath flight paths given prevailing winds, sites at varying distances from the airport, sites at varying lateral distances beneath flight paths). The PNC was measured using TSI condensation particle counters (model 3783). In addition, BC was measured using AethLabs microaethalometers (model AE51), and meteorological data at each site were collected using Davis Vantage Pro2 weather stations.

Figure 7. Monitoring sites for the 2017–2018 sampling campaign around Boston Logan Airport. The site list corresponds to Table 3.

Milestone(s)

This task was placed on hold during FY2019 due to a delay in funding.

Major Accomplishments

Mobile monitoring tasks were placed on hold during FY2019 due to a delay in the release of FAA funding.

Publications

N/A

Outreach Efforts

N/A

Awards
None.

Student Involvement
None.

Plans for Next Period
Task(s) proposed over the next study period (10/1/19–9/30/20): no new tasks are currently planned.

Task 3 - Measure UFP and Other Air Pollutants at Sites Near Boston Logan International Airport, as Selected Under Task 2
Boston University School of Public Health

Objective(s)
Given the sites chosen under Task 2, we conducted a monitoring campaign in 2018 to inform an aviation source attribution analysis as an expansion of the Task 1 regression model development. Our instrumentation and protocol were similar to that of the 2017 monitoring campaign, but with some key enhancements to improve insights regarding aviation source contributions.

Research Approach
At the sites chosen under Task 2, we conducted a monitoring campaign in 2018 to inform ground contributions from in-flight aviation sources beneath multiple landing and take-off runways at various distances from the airport and flight path. The instrumentation and protocol used were the same as the 2017 monitoring campaign, but with some key enhancements to improve insights regarding aviation source contributions to NO/NO_2. The monitoring instruments included the TSI model 3783 water-based CPC for UFP, our primary measure of interest, which was used in the 2017 monitoring campaign. The 3783 model is intended for long-term deployment and can record 1-s average concentrations, which is a valuable time resolution for capturing short-term concentration spikes. Of note, because the model 3783 CPC is temperature-sensitive, we developed and deployed instrumentation in a temperature-conditioned space to protect against extreme heat and cold, allowing for long-term deployment.

In addition, the AethLabs model AE51 microaethalometer was used to measure BC. We also deployed the Alphasense NO/NO_2 sensor, which gives high-fidelity outputs and can be used in future studies with simultaneous real-time measurements at numerous sites. This approach provides an additional pollutant for future comparisons with atmospheric dispersion model outputs, which can help isolate factors that influence predictions of particulate matter vs. gas-phase pollutants. Local Davis Vantage Pro2 weather stations were used to capture real-time wind speed/direction and other meteorological parameters at each sampling site.

Similar to the 2017 campaign, obtaining flight activity data from the FAA for the sampling time periods is essential for future regression model development, which will include the location of each flight as well as basic aircraft characteristics, which can be linked using the AEDT to determine aircraft-specific attributes that may be predictive of emissions and corresponding concentrations.

Milestone(s)
- Obtained permission to resample and/or sample new locations and developed a sampling schedule
- Obtained new monitoring equipment and completed annual manufacturer cleaning and calibration of CPCs
- Implemented air pollution monitoring protocols, including measurements of meteorological parameters

Major Accomplishments
As described above, the air pollution field monitoring campaign was conducted from November 2017 to September 2019 at sites located at varying distances from the airport under multiple arrival and take-off flight paths into Logan Airport (Figure 7). The monitoring was stopped due to a funding delay, but site boxes have been maintained without monitors to allow for redeployment if new funding is obtained. All targets have been met for sample size and data capture, providing a strong foundation for future statistical analyses.

Table 3. Particle number concentration (PNC) distribution at five monitoring sites.

	UMASS	Chelsea	East Boston	South Boston	Winthrop
Sample Size (days)	264	250	167	123	43
Location	Ground Level	Roof 4th Floor	2nd Floor Window	Roof 5th Floor	Ground Level
Other Samplers	BC, meteorology, NO, NO2	BC, meteorology, NO, NO2	BC, NO, NO2	BC, meteorology, NO, NO2	BC, meteorology
0.1st percentile	169	863	172	471	521
1st percentile	379	1750	904	1160	676
5th percentile	975	3270	2020	2610	1400
50th percentile	7440	11900	10800	8260	8680
95th percentile	24500	43700	65000	36300	47000
99th percentile	47200	87800	124000	66300	70300
99.9th percentile	76900	152000	229000	100000	111000

The summary statistics presented in Table 3 cannot provide definitive insights regarding the aviation contributions to the measured PNC, but are helpful for hypothesis generation and for informing future modeling efforts. For example, Chelsea and East Boston have the highest concentrations for the 95th and 99th percentiles of the distribution, which is expected because these sites are closest to the airport and are affected by planes at a lower elevation compared with farther locations such as UMASS. This trend suggests that there may be a more rapid decline in PNC with increasing distance from the airport compared with that observed in the 2017 sampling campaign, which focused on only a single arrival pathway. Consistent seasonal patterns were observed at three monitor sites with data from winter, spring, and summer.

Table 4. Seasonal particle number concentration (PNC) distribution at three monitoring sites.

	UMASS			Chelsea			East Boston		
Sample Size (days)	80	79	93	64	75	105	20	85	54
Season	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
0.1st percentile	493	309	139	1460	1090	552	879	137	862
1st percentile	1040	496	262	2460	1660	1610	1260	564	1300
5th percentile	3250	1640	547	4350	3210	2950	3290	1810	2230
50th percentile	10100	5970	6390	14100	11200	11100	13800	10600	9920
95th percentile	28600	20200	22800	42200	42100	46000	60100	65400	66100
99th percentile	50500	44800	45300	79900	92200	90300	172000	127000	113000

The median PNC levels were consistently elevated during winter at all three sites, with greater variation at the 95th and 99th percentile. It should be noted that East Boston did not have the same number of sampling days over the winter season. As shown in Table 4, East Boston and Chelsea exhibit an elevated PNC at the median and 95th percentile compared with the UMASS sites across all seasons. Additionally, lower PNC levels were observed during the summer compared with the winter and spring across all three sites.

Table 5. Multi-year seasonal particle number concentration (PNC) distribution at UMASS long-term monitoring site.

	Summer 2017–18	Winter 2017–18	Spring 2018	Summer 2018	Fall 2018	Winter 2018–19	Spring 2019
Dates	6/1/18–8/31/18	12/1/17–2/28/18	3/1/18–5/31/18	6/1/18–8/31/18	9/1/218–11/30/18	12/1/18–2/28/19	3/1/19–5/30/19
Total Days	90	90	80	87	76	42	86
Number of Readings	7,537,890	7,654,161	6,160,559	6,446,895	5,871,405	3,515,138	6,609,864
0.1st percentile	500	1,000	700	300	600	1,200	800
1st percentile	1,300	2,300	1,000	500	1,400	2,000	2,100
5th percentile	2,400	7,200	3,400	1,100	2,800	5,100	3,700
50th percentile	7,500	22,900	14,300	10,100	15,900	22,400	14,700
95th percentile	28,000	55,000	49,000	33,000	53,000	57,000	52,000
99th percentile	58,000	93,000	91,000	67,000	100,000	102,000	96,000
99.9th percentile	110,000	132,000	132,000	140,000	145,000	14,800	144,000

Table 5 provides the PNC distribution by season, ranging from summer 2017 to spring 2019 at the UMASS (N2) monitoring site. Seasonal consistency is observed in the PNC distributions over these two years at the median and higher exposure percentiles. The lowest PNC levels were observed for summer at both the median and higher 95th and 99th percentiles compared with winter and spring.

Publications

N/A

Outreach Efforts

N/A

Awards

None.

Student Involvement

Bethany Haley, a doctoral student at BUSPH, has been involved with field monitoring of the 2018-19 sampling data, data cleaning, and calculations of descriptive statistics.

Plans for Next Period

Task(s) proposed over the next study period (10/1/18-9/30/19): no new tasks are planned during the NCE period.

Task 4 - Develop Platforms that Will Enable Comparisons Between Atmospheric Dispersion Models Implemented by Collaborators on ASCENT Project 19 and Monitored Pollutant Concentrations Obtained from Project 18

Boston University School of Public Health

Objective(s)

While the primary objective of Tasks 1–3 informed aviation source attribution using ambient pollution measurements, insights from the monitoring data and models can be combined with atmospheric dispersion models applied at the same location and dates. Within Project 19, UNC researchers are implementing SCICHEM to examine air quality impacts due to the emission of various air pollutants from aviation, with a current focus on UFP modeling. If Project 19 applies atmospheric dispersion modeling tools focused on locations near Boston Logan International Airport in the future, comparative analyses (modelling and monitoring) could be performed. The purpose of this task is to develop data processing systems that will enable these comparative analyses.

Research Approach

To aid the efforts of Project 19, we developed two output files under Task 4. First, the UFP measurements collected during the 2017 monitoring campaign were processed and provided in the format requested by Project 19. These measurements reflect contributions from both aviation and other sources and are being directly compared with all-source dispersion models such as SCICHEM. In the second phase, regression models are being developed under Task 1, an analogous database with aviation-attributable UFP concentrations has been processed, and outputs are being compared with dispersion model results.

Milestone(s)

The core milestones for Task 4 include the development of an analytical dataset estimating aviation source contributions from the 2017 monitoring campaign, which has been shared with UNC to inform potential collaborative manuscripts.

Major Accomplishments

UFP data from the Project 18 2017 field campaign were cleaned, combined with flight activity and meteorology information, and shared with Project 19. During this time, we collaborated through teleconferences on dispersion modeling efforts conducted by Project 19, resulting in an abstract that has been accepted to the CMAS conference on PNC modeling.

Publications

N/A

Outreach Efforts

Dr. Moniruzzaman Chowdury from Project 19 presented “An integrated modeled and measurement-based assessment of particle number concentrations from a major US airport” at the CMAS conference.

Awards

None.

Student Involvement

Chloe Seyoung Kim, a doctoral student at BUSPH, was involved in the preparation of data to be shared with Project 19 and in the comparison of regression model and dispersion model outputs. Dr. Chloe Kim graduated in December 2020 and is currently working for the Electric Power Research Institute as a research scientist.

Plans for Next Period

No new tasks are planned for this task during the no-cost extension period.