Aviation Noise & Emissions Symposium 2023
May 1-3, 2023, UC Davis

Impact of airport-related pollution on health of near-by communities: LAX as an emerging case study

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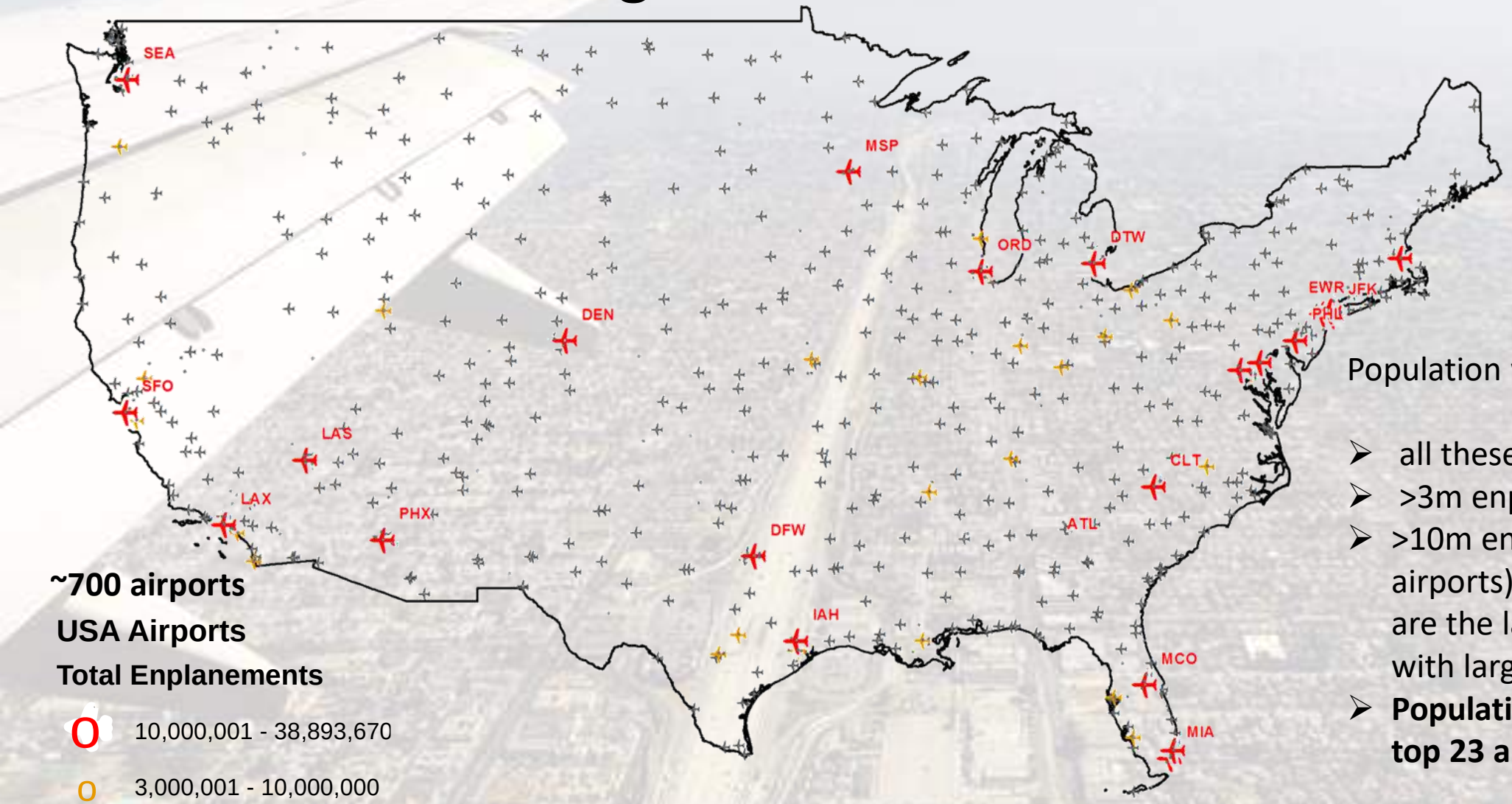
Research has implications for large populations near airports: communities rank high on adverse environmental metrics



~700 airports

USA Airports

Total Enplanements

- 10,000,001 - 38,893,670
- 3,000,001 - 10,000,000
- 257 - 3,000,000

Population within 3 miles of

- all these airports: 34 million
- >3m enplanements: 6.2 million
- >10m enplanements (23 airports): 3.2 million BUT these are the largest of the airports with large impact zones!
- **Population within 10 miles of top 23 airports: 33.3 million**

ADVERSE HEALTH CONDITIONS ARE PREVALENT AT HIGHER INCIDENT RATES IN NEAR-AIRPORT COMMUNITIES

- Exposure to **elevated levels on noise, air pollution or simply residential proximity to airports** has been associated with increased rates of:

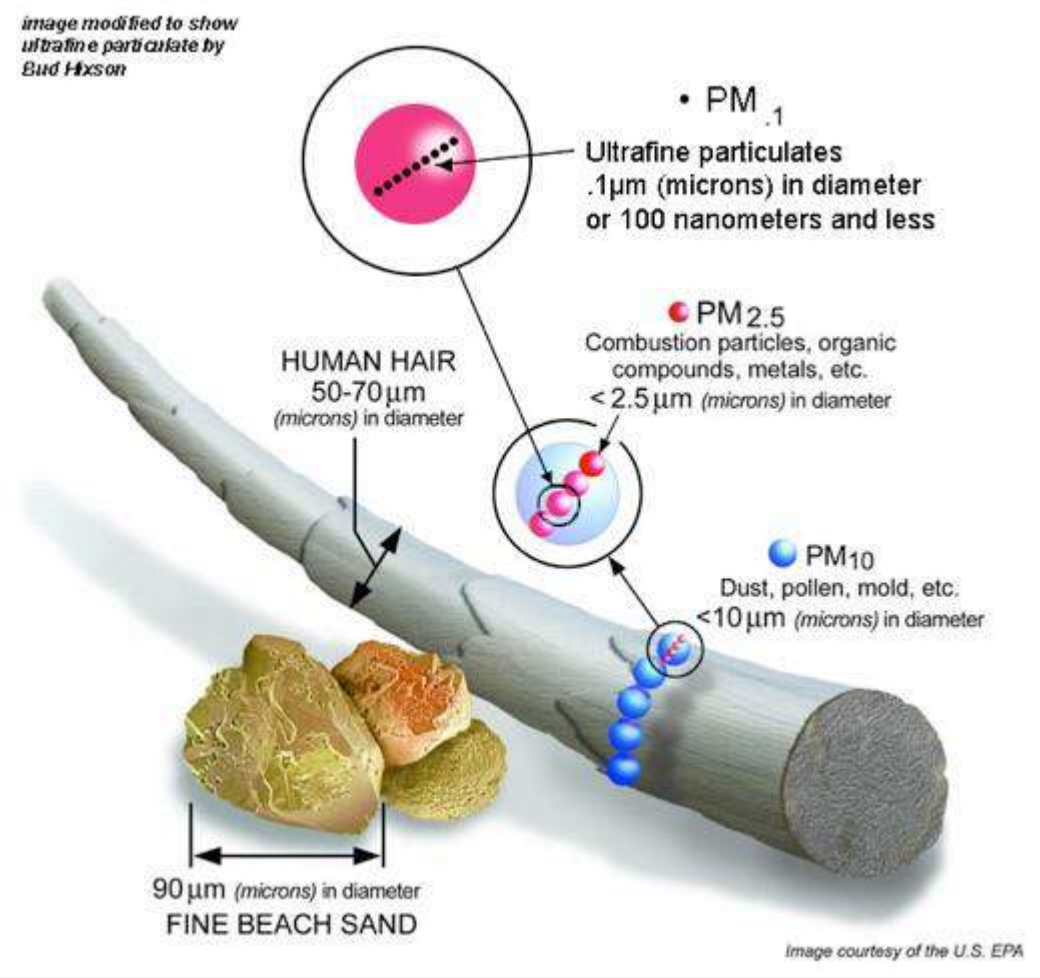
  - hypertension
  - rates of hypertensive medication prescription
  - cardiovascular disease incidence
  - cardiovascular disease related hospitalization
  - adverse learning outcomes in children
  - lately, pre-term birth and brain cancer

and another set of studies that focuses specifically on ultrafines.

CONTENTS

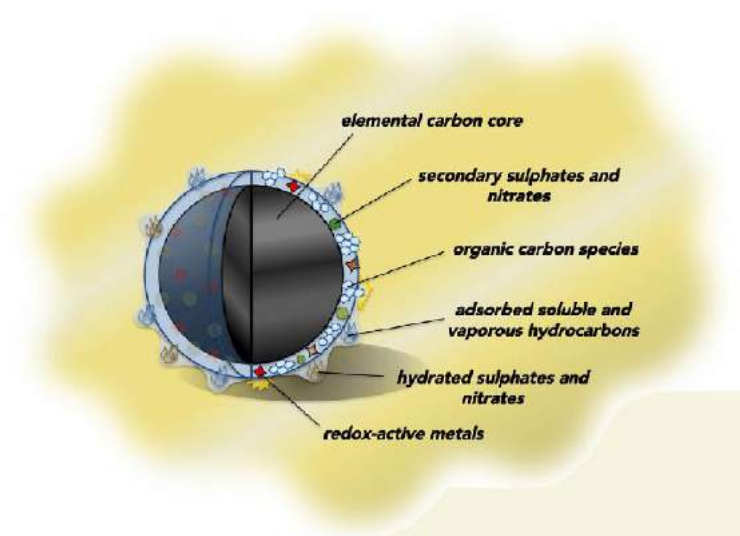
- Ultrafine particles and airplane exhaust
- Summarize some characterization studies
  - US: Boston; Los Angeles; Seattle
  - Europe: Schiphol (Amsterdam); Berlin, Heathrow (relatively near-field), Zurich
- Summarize some health-effect investigations
  - Lots of literature investigates adverse health effects near airports
  - Relatively little investigates association with ultrafine particles in particular
  - A decade of evolution of LAX-related studies
  - Summary of other efforts – Schiphol, Berlin, etc.
- Future Opportunities

ULTRAFINE PARTICLES: **NUMBER AND SIZE ARE USED AS MARKERS OF FUEL COMBUSTION**



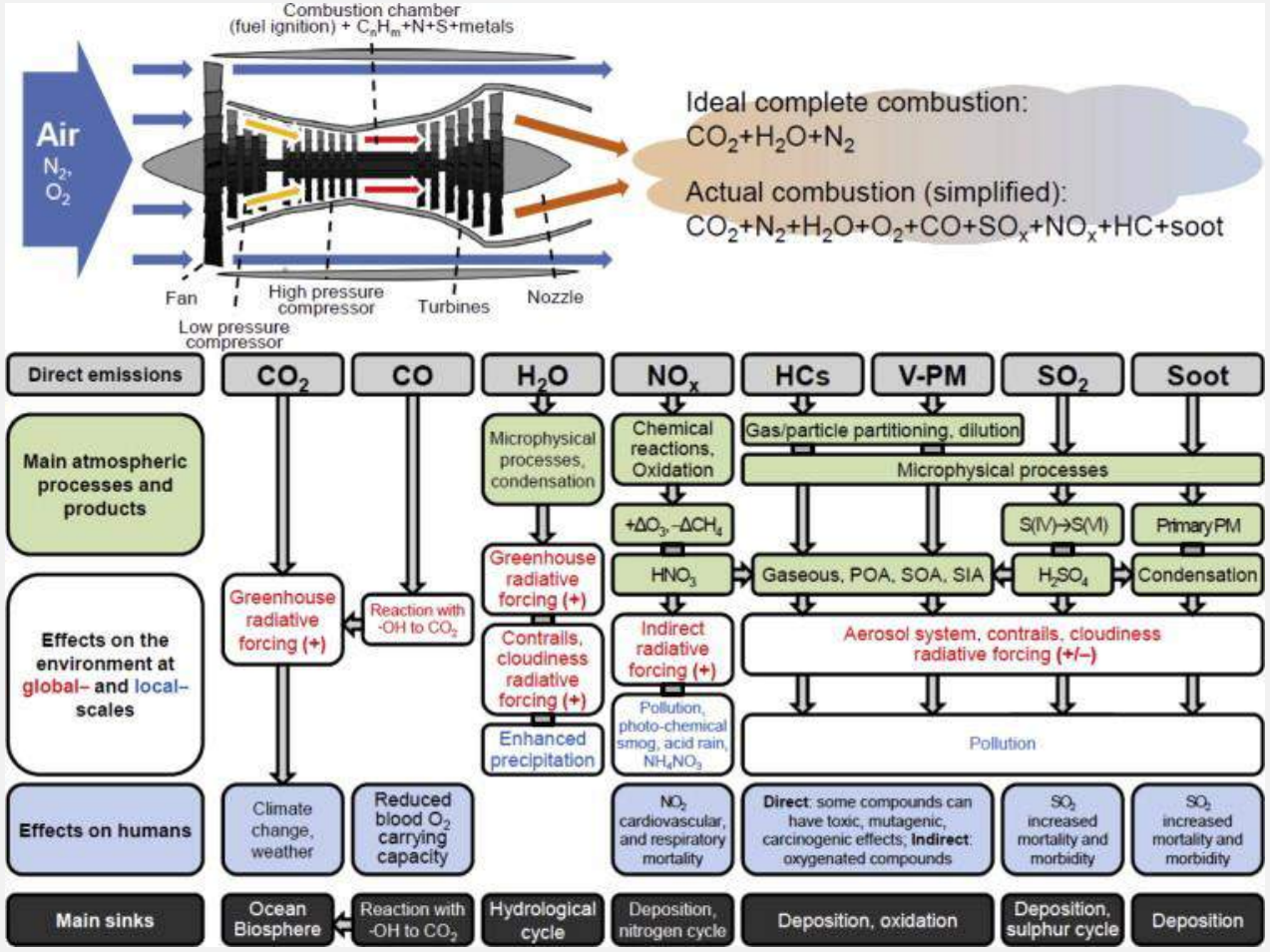
Ultrafine particles are:

- ❑ smaller than 100 nm
- ❑ reported as a count in one cm^3
- ❑ markers of fuel combustion emissions
- ❑ emitted in huge numbers by jet planes!



Sizes of particulate matter compared to human hair and beach sand. Illustration: Eda Lu, based on US EPA "Particulate Matter (PM) Pollution" from the book "Particles in the Air" https://now.tufts.edu/articles/toxic-air-we-breathe

AIRPLANE EXHAUST IS A COMPLEX MIXTURE OF POLLUTANTS.



Masiol et al., 2014, Atmospheric Environment

Ultrafine particles (UFP):

- It is physical, size-based lens to look at this complex mixture.
  - *There is some very involved chemistry in size distribution, chemical composition, plume dynamics and evolution!*
- Furthermore, it is the physical form of pollution that is abundantly present near airports because it is abundantly emitted from airplanes.

QUESTIONS THAT INFORM A HEALTH STUDY

What is the spatial extent of the impact?

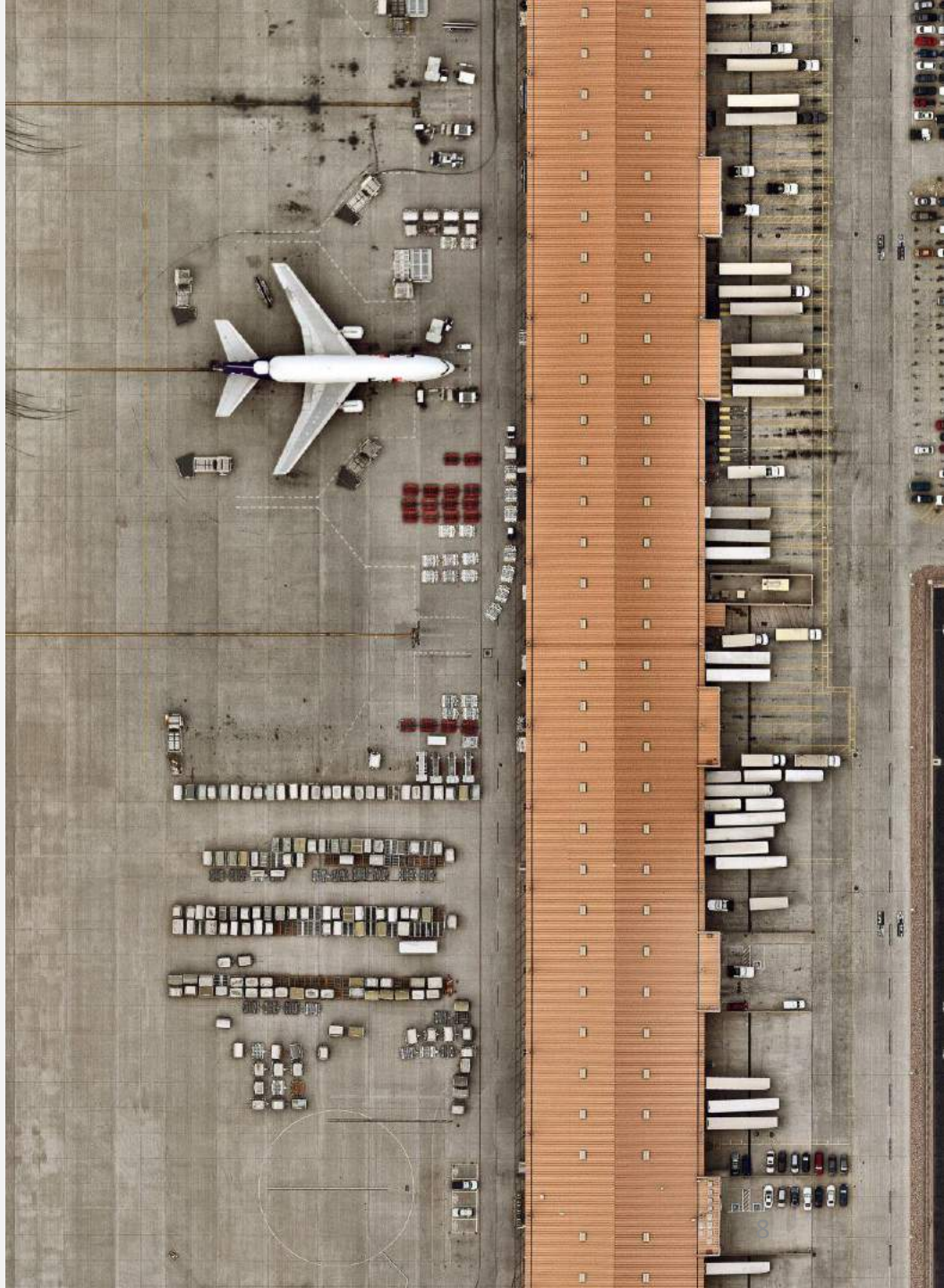
What is the impact – characterization or quantification or exposure assessment?

Who and how much questions that can be answered by taking many different, situation-specific approaches.

WHAT IS THE SPATIAL EXTENT OF THE IMPACT?

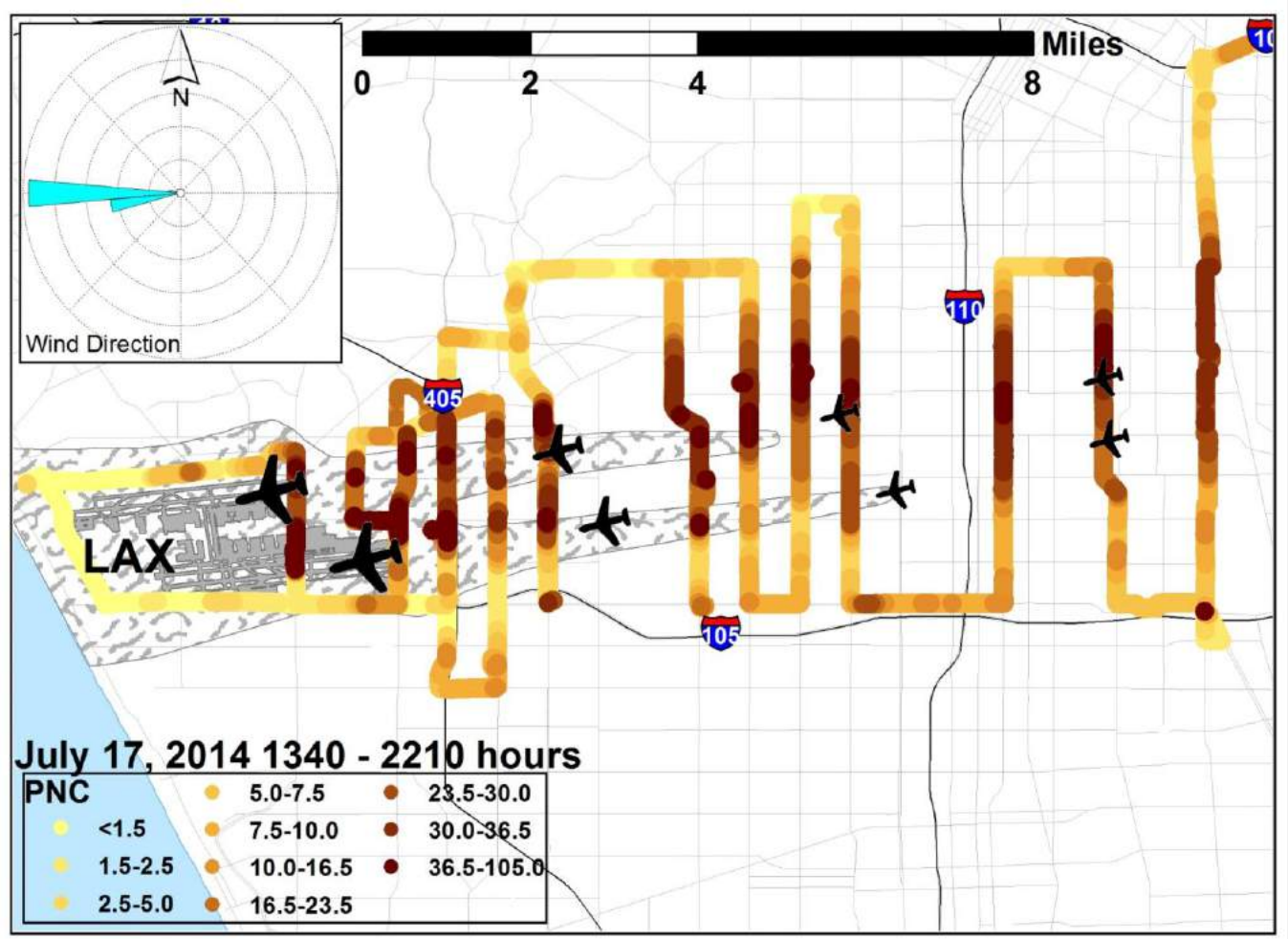
- Answering this question requires sorting out the impacts from confounding sources. For example,
  - Transportation infrastructure that supports an airport
  - Nearby highways

- In 2012, an opportunity presented itself at LAX:
  - I-405 in Los Angeles was shut-down



LOS ANGELES INTERNATIONAL AIRPORT IMPACT EXTENDS TO DISTANCES GREATER THAN 10 MILES FROM THE AIRPORT

Aviation activity at Los Angeles International Airport (LAX) produces ground-level ultrafine particle concentrations more than twice the nearby ambient levels at distances up to 16 km away from the airport.



LOS ANGELES INTERNATIONAL AIRPORT IMPACT EXTENDS TO DISTANCES GREATER THAN 10 MILES FROM THE AIRPORT

Hudda et al. 2014 EST

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Emissions from an International Airport Increase Particle Number Concentrations 4-fold at 10 km Downwind

Neelakshi Hudda,[†] Tim Gould,[‡] Kris Hartin,[§] Timothy V. Larson,[‡] and Scott A. Fruin*[,†,∥]

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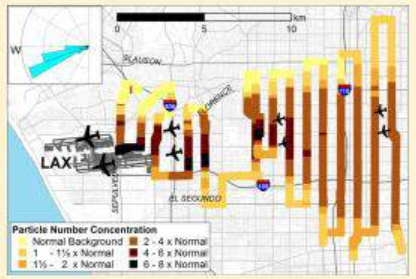
Supporting Information

ABSTRACT: We measured the spatial pattern of particle number (PN) concentrations downwind from the Los Angeles International Airport (LAX) with an instrumented vehicle that enabled us to cover larger areas than allowed by traditional stationary measurements. LAX emissions adversely impacted air quality much farther than reported in previous airport studies. We measured at least a 2-fold increase in PN concentrations over unimpacted baseline PN concentrations during most hours of the day in an area of about 60 km^2 that extended to 16 km (10 miles) downwind and a 4- to 5-fold increase to 8−10 km (5−6 miles) downwind. Locations of maximum PN concentrations were aligned to eastern, downwind jet trajectories during prevailing westerly winds and to 8 km downwind concentrations exceeded 75 000 particles/cm^3, more than the average freeway PN concentration in Los Angeles. During infrequent northerly winds, the impact area remained large but shifted to south of the airport. The freeway length that would cause an impact equivalent to that measured in this study (i.e., PN concentration increases weighted by the area impacted) was estimated to be 280−790 km. The total freeway length in Los Angeles is 1500 km. These results suggest that airport emissions are a major source of PN in Los Angeles that are of the same general magnitude as the entire urban freeway network. They also indicate that the air quality impact areas of major airports may have been seriously underestimated.



Hudda et al. 2016 EST

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International Airport Impacts to Air Quality: Size and Related Properties of Large Increases in Ultrafine Particle Number Concentrations

N. Hudda and S. A. Fruin*[,†]

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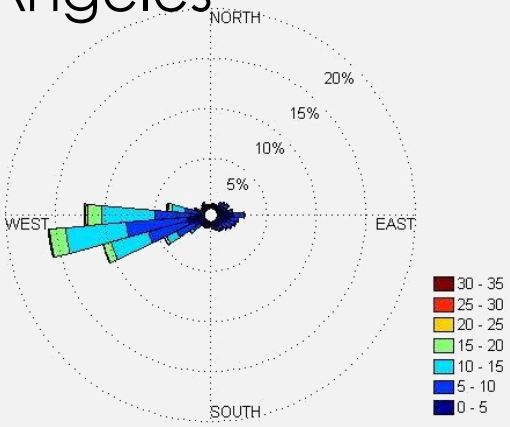
Supporting Information

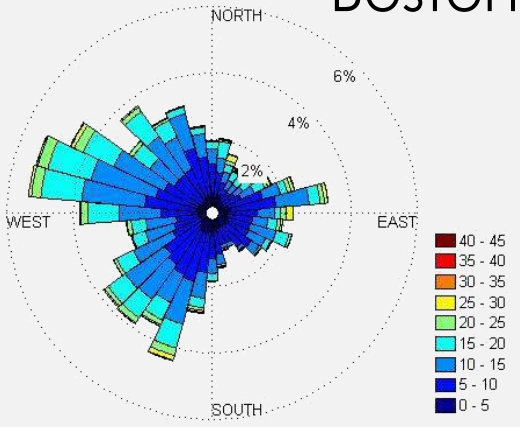
ABSTRACT: We measured particle size distributions and spatial patterns of particle number (PN) and particle surface area concentrations downwind from the Los Angeles International Airport (LAX) where large increases (over local background) in PN concentrations routinely extended 18 km downwind. These elevations were mostly comprised of ultrafine particles smaller than 40 nm. For a given downwind distance, the greatest increases in PN concentrations, along with the smallest mean sizes, were detected at locations under the landing jet trajectories. The smaller size of particles in the impacted area, as compared to the ambient urban aerosol, increased calculated lung deposition fractions to 0.7−0.8 from 0.5−0.7. A diffusion charging instrument (DiSCMini), that simulates alveolar lung deposition, measured a fivefold increase in alveolar-lung deposited surface area concentrations 2−3 km downwind from the airport (over local background), decreasing steadily to a twofold increase 18 km downwind. These ratios (elevated lung-deposited surface area over background) were lower than the corresponding ratios for elevated PN concentrations, which decreased from tenfold to twofold over the same distance, but the spatial patterns of elevated concentrations were similar. It appears that PN concentration can serve as a nonlinear proxy for lung deposited surface area downwind of major airports.

RUNWAY UTILIZATION AND WIND DETERMINE LOCATION OF IMPACT

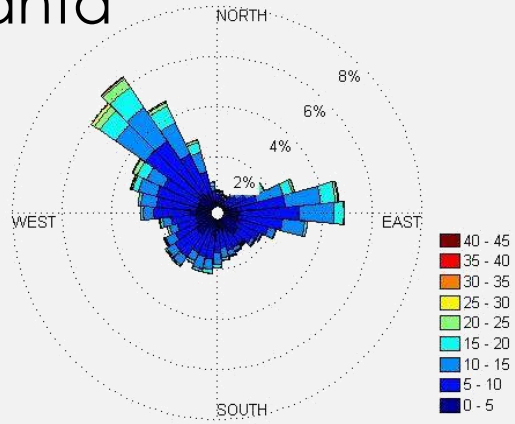
Los Angeles



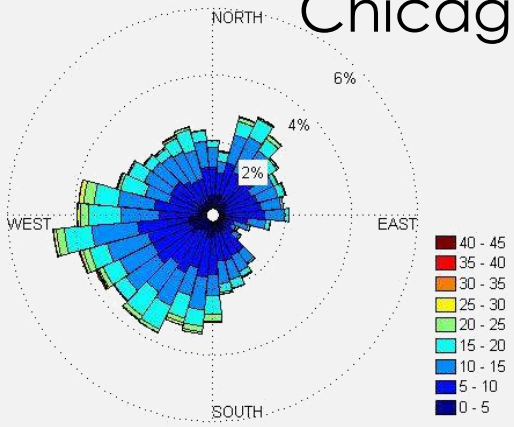
Boston



Atlanta



Chicago



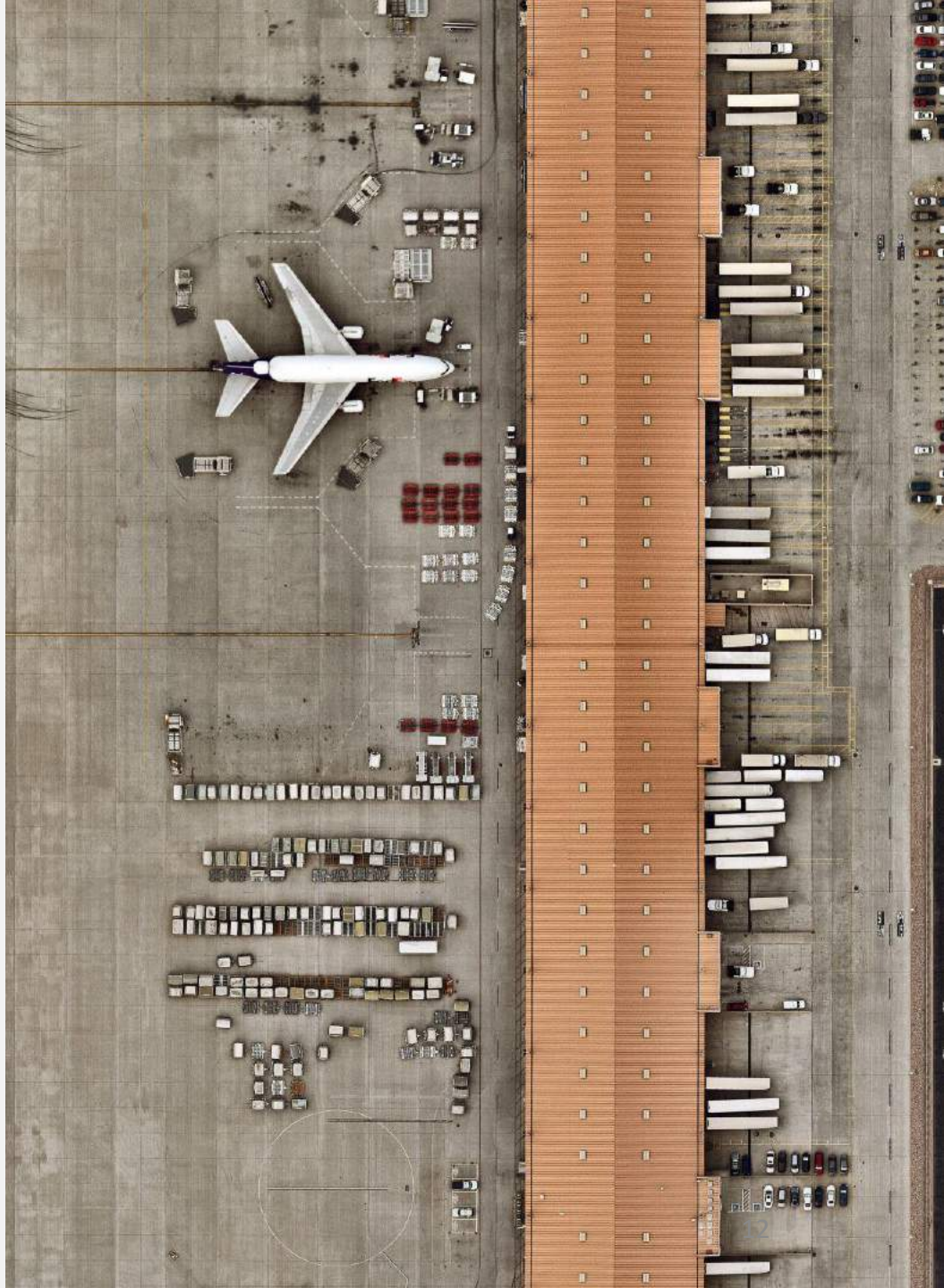
Wind dictates which community is impacted and presents some challenges:

- ❑ Shifting winds
- ❑ Multiple runway configurations
- ❑ Resulting impacts are intermittent and dispersed over many downwind sectors.

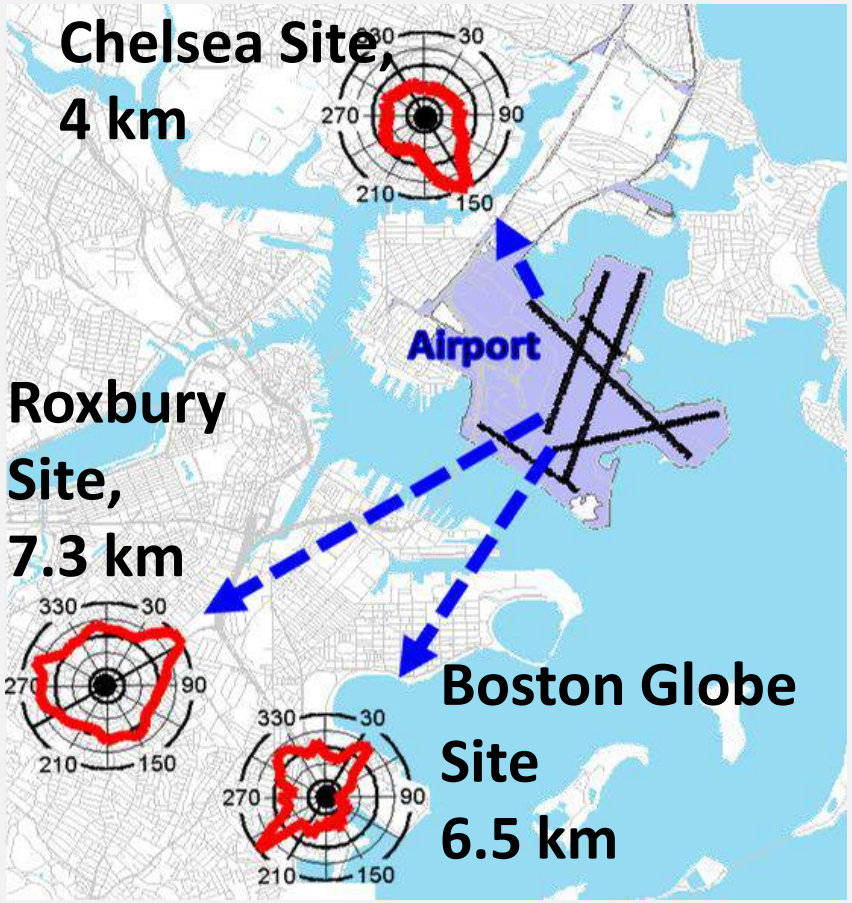
WHAT IS THE IMPACT – CHARCATERIZATION or QUANTIFICATION

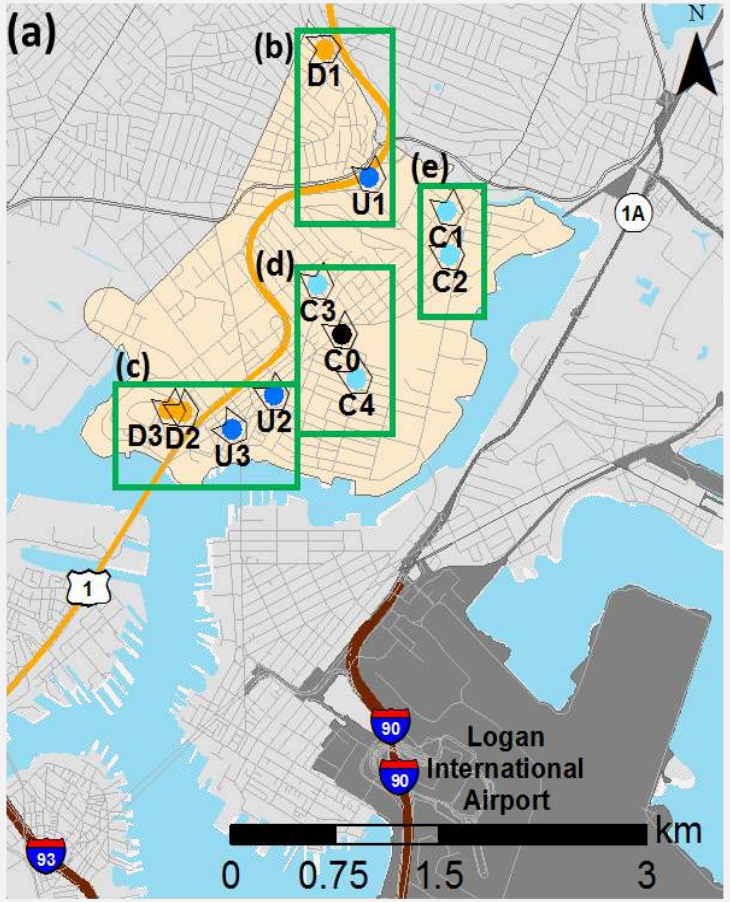
- Answering this question similarly requires sorting out the impacts from confounding sources.
- Representative measurements and robust modeling

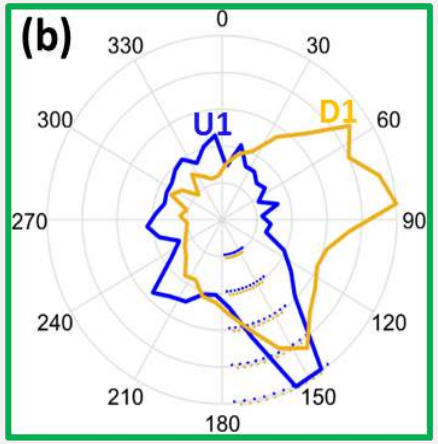
  - Measurements that reflect variation (diurnal, seasonal, intra and inter-annual, meteorological factors, terrain, etc.)

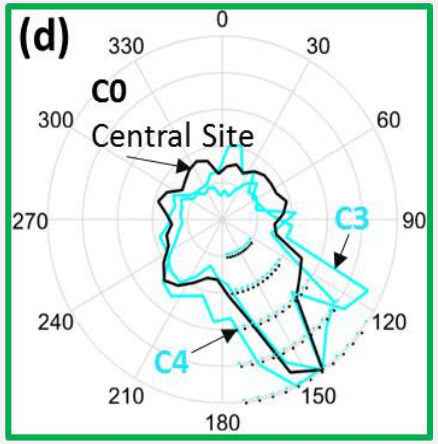


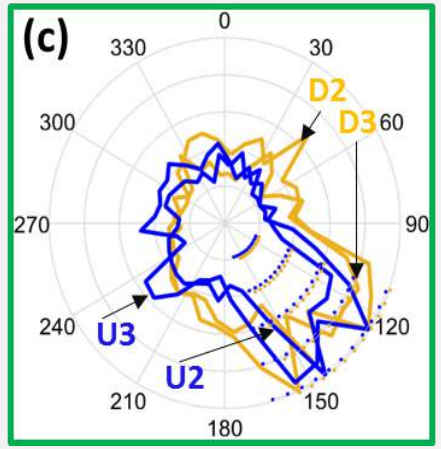
IN NEAR-LOGAN COMMUNITIES, BOTH AMBIENT AND INDOOR CONCENTRATIONS HIGHEST WHEN HOMES WERE DOWNWIND OF THE AIRPORT

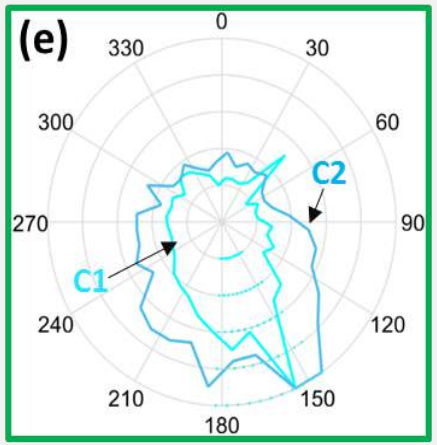








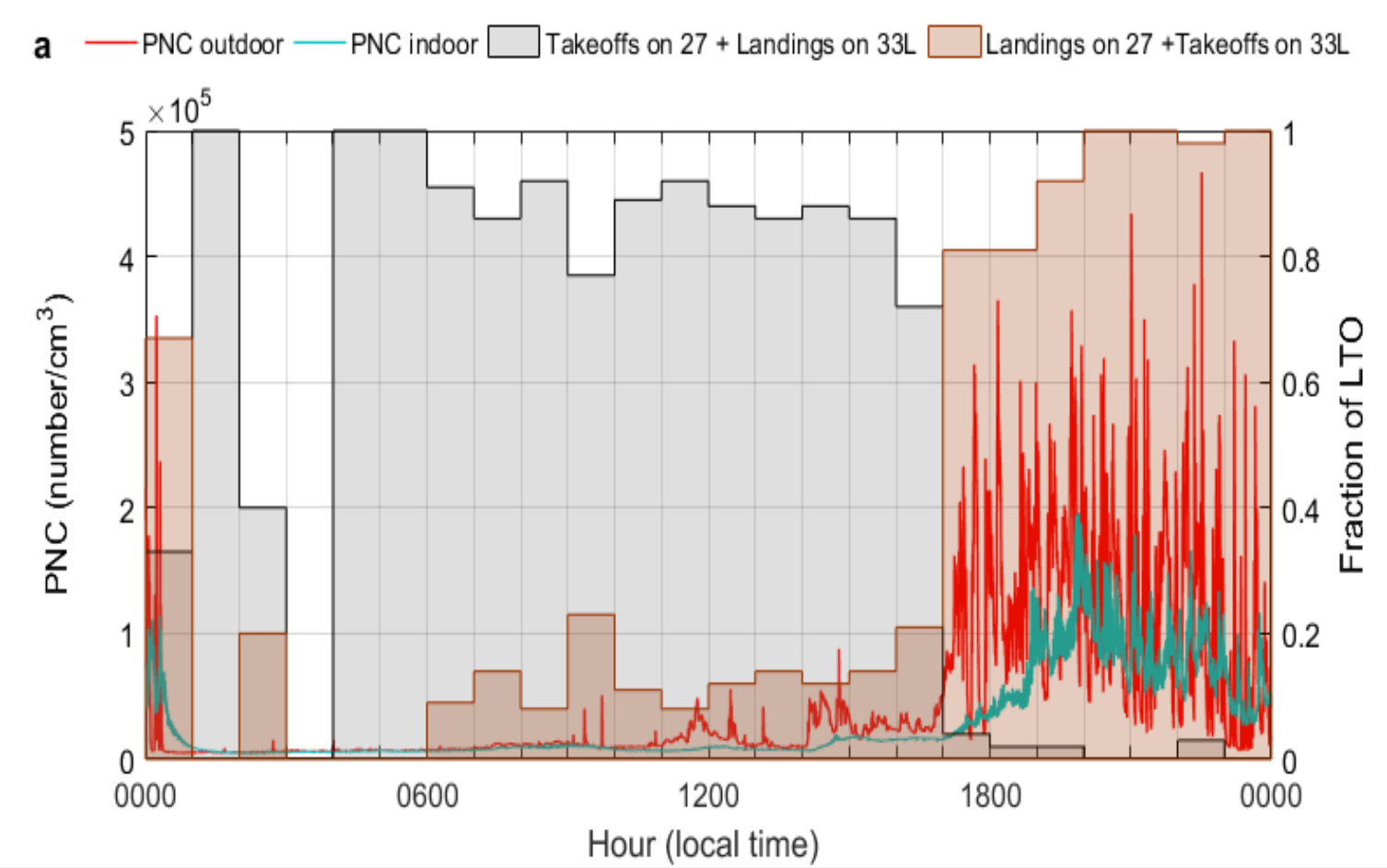




Hudda et al., 2016 EST

Hudda et al., 2018 EST

WHEN JETS LAND OVERHEAD, INDOOR CONCENTRATIONS IN A NEAR-AIRPORT HOME CAN BE SAME AS THAT ON A HIGHWAY



- Concentrations elevated when home is downwind of the airport
- Concentrations elevated by 10X fold and same as that on a busy highway when jets are landing overhead.
- Flight activity and runway utilization make a remarkable difference

Hudda et al., 2020 EST

DEVELOPMENT OF AIR QUALITY CHARACTERIZATION AND EXPOSURE ASSESSMENT STUDIES AT LAX

- LAX studies began ~ 10 years ago
  - Mobile Monitoring
    - Mobile allows us to capture spatial variation (>temporal information) in the study area.
    - Fast response to changes
  - Real-time measurements: aim is to characterize the spatial patterns
  - To capture temporal patterns, we conduct a systematic campaign with mobile labs
    - Systematically capture seasonal, diurnal and meteorological influence.

Preterm birth rates among mothers exposed to ultrafine particles from jet exhaust (Wing et al. EHP, 2020)

- The highest quartile of pregnancy-average UFP exposure was associated with a 1.32 (CI: 1.27-1.39) odds ratio (OR)* in comparison with the lowest quartile.

- Controlling for covariates (demographic risk factors, traffic pollution and noise) the OR for PTB in the highest quartile of UFP exposure was 1.14 (CI: 1.08-1.20) compared to lowest.

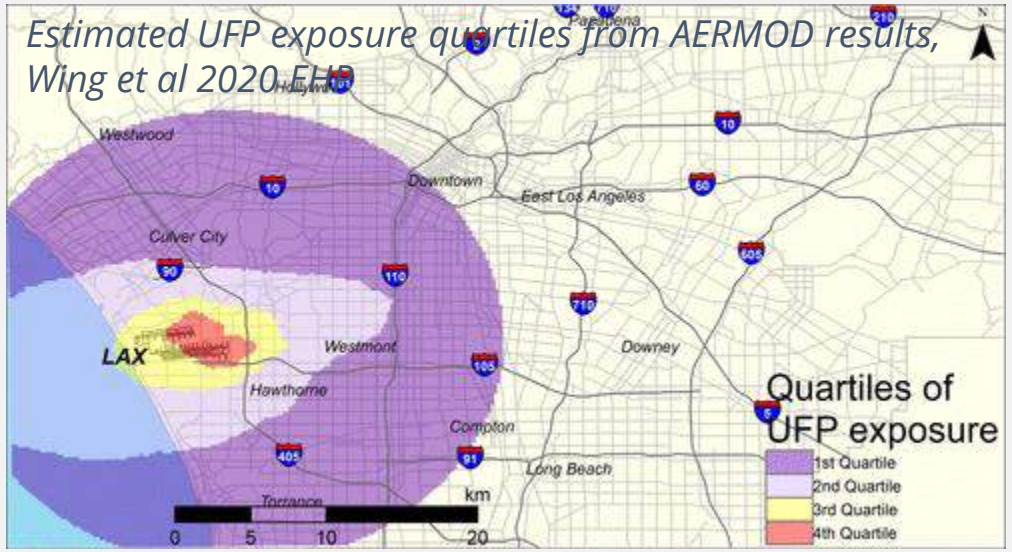


Table 2. Adjusted odds ratios (ORs) [95% confidence intervals (CIs)]

Variable	Unadjusted model	Adjusted model 3[d]
UFP		
Quartile 1 (<5,340 particles/cc)	Ref	Ref
Quartile 2 (5,340–8,600 particles/cc)	1.17 (1.11, 1.22)	1.03 (0.98, 1.08)
Quartile 3 (8,600–14,600 particles/cc)	1.27 (1.22, 1.33)	1.08 (1.02, 1.13)
Quartile 4 (>14,600 particles/cc)	1.32 (1.27, 1.39)	1.14 (1.08, 1.20)
NO_2		
Quartile 1 (<21.8 ppb)	—	Ref
Quartile 2 (21.8–23.8 ppb)	—	1.10 (1.05, 1.16)
Quartile 3 (23.9–25.5 ppb)	—	1.11 (1.05, 1.15)
Quartile 4 (>25.5 ppb)	—	1.15 (1.09, 1.22)
Exposed to noise >65 dB CNEL	—	1.10 (1.01, 1.19)

**The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure. Szumilas M. 2015 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2938757/*

Corresponding peer-reviewed publication:
Wing, S. E.; Larson, T. V.; Hudda, N.; Boonyarattaphan, S.; Fruin, S.A., Ritz, B. **Preterm Birth among Infants Exposed to in Utero Ultrafine Particles from Aircraft Emissions**. *Environ. Health Perspect.* 2020, *128* (4), 047002. https://ehp.niehs.nih.gov/doi/full/10.1289/EHP5732

Also see: **Move Over, Traffic: Aircraft Emissions and Preterm Birth**, Konkel et al., EHP Science Selection, 2020 https://doi.org/10.1289/EHP7161

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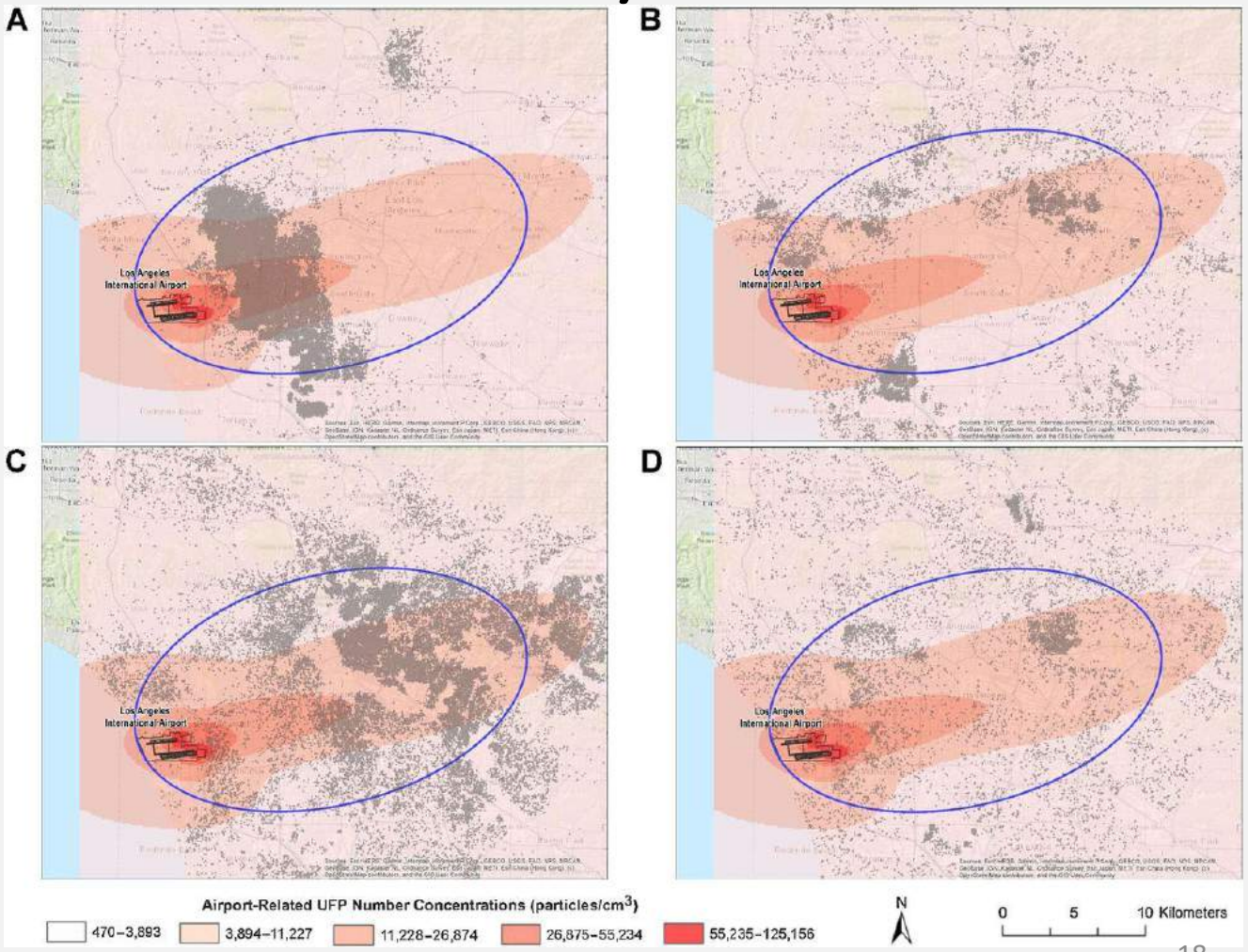
Association between Airport-Related Ultrafine Particles and Risk of Malignant Brain Cancer: A Multiethnic Cohort Study (Wu et al. Cancer Research 2021)

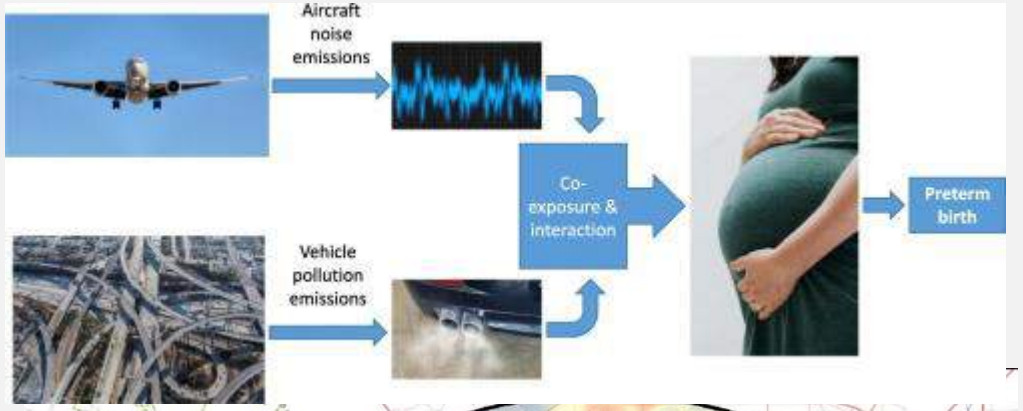
- Malignant brain cancer risk in all subjects combined increased 12% per interquartile range (IQR) of airport-related UFP exposure (~6,700 particles/cm3) for subjects with any address in the grid area surrounding the LAX airport.
- In race/ethnicity-stratified analyses, African Americans, the subgroup who had the highest exposure, showed a OR of 1.32 for malignant brain cancer per IQR in UFP exposure.

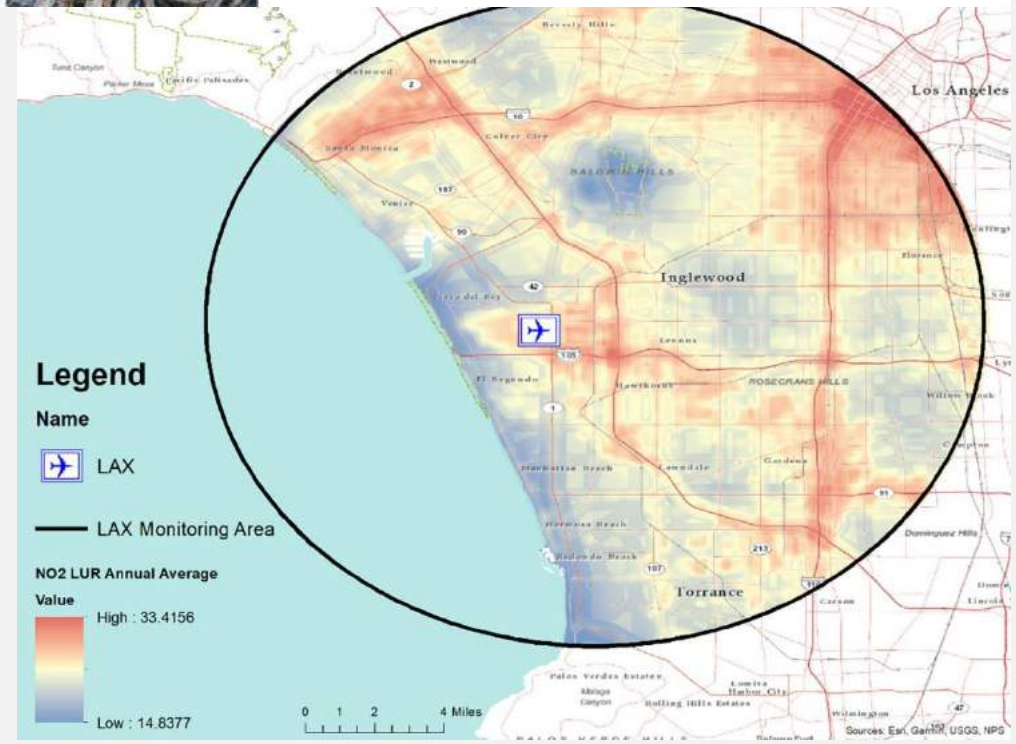


https://cancerres.aacrjournals.org/content/81/16/4360

Aircraft noise and vehicle traffic-related air pollution interact to affect preterm birth risk in Los Angeles, CA (Wing et al STOTEN 2022)

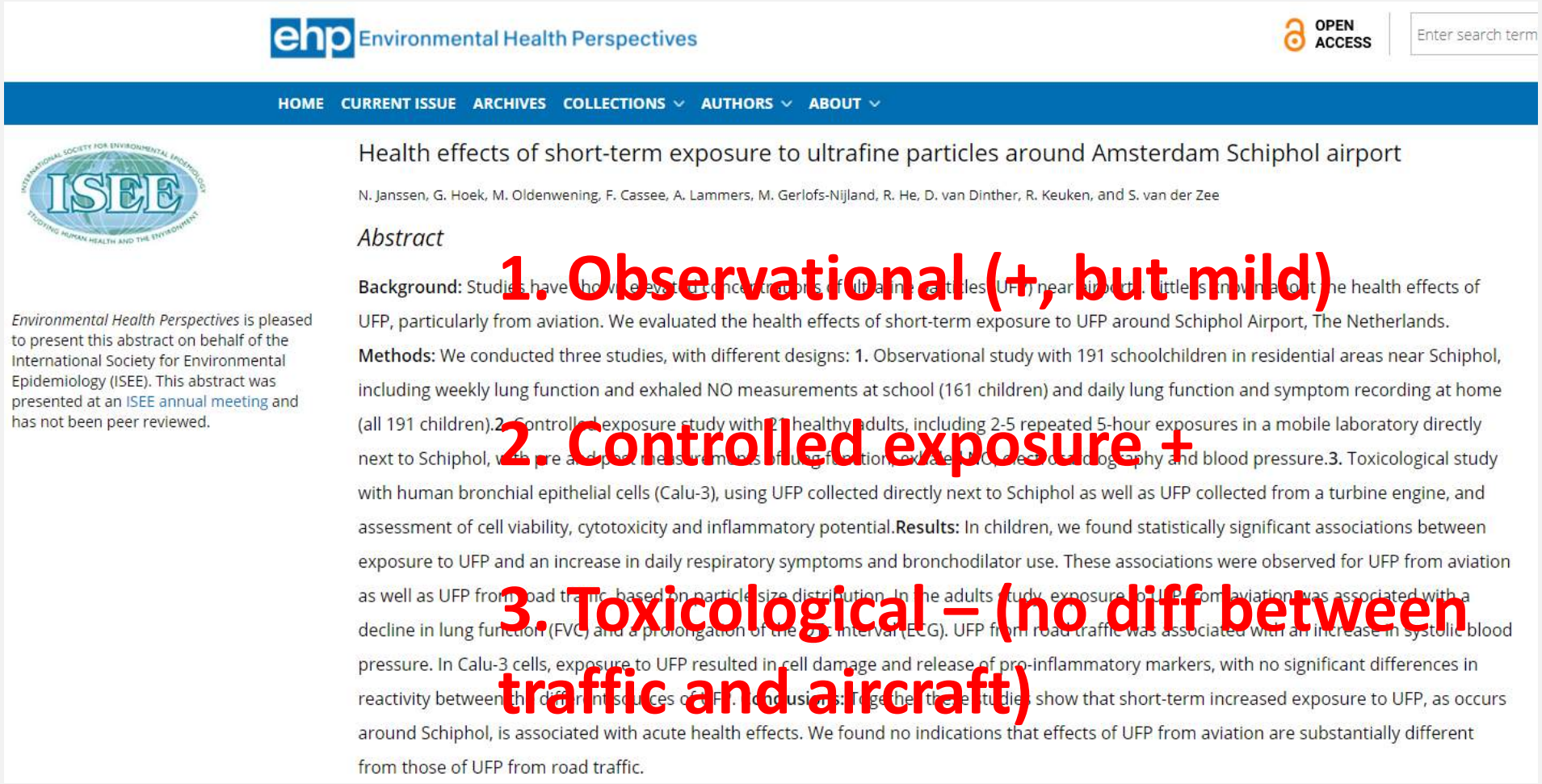
- Although exposure to both noise and air pollution are known risk factors for PTB, our results suggest a possibly important synergism between multiple transportation related sources of exposure for women living close to LAX that negatively impact pregnancy.
- Most importantly the synergism detected was concentrated in low SES neighborhoods.





The adjusted odds ratio (aOR) for PTB from high noise exposure (i.e. > 65 dB) was 1.10 (95% CI: 1.01–1.19). Relative to the first quartile, the aORs for PTB in the second, third, and fourth TRAP quartiles were 1.10 (95% CI: 1.05–1.16), 1.11 (95% CI: 1.05–1.16), and 1.15 (95% CI: 1.10–1.22), respectively. When stratifying by increasing TRAP quartiles, the aORs for PTB with high airport-related noise were 1.04 (95% CI: 0.91–1.18), 1.02 (95% CI: 0.88–1.19), 1.24 (95% CI: 1.03–1.48), and 1.44 (95% CI: 1.08–1.91) (p-interaction = 0.06).

A comprehensive set of studies around Amsterdam Schiphol Airport



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Environmental Health Perspectives is pleased to present this abstract on behalf of the International Society for Environmental Epidemiology (ISEE). This abstract was presented at an ISEE annual meeting and has not been peer reviewed.

Health effects of short-term exposure to ultrafine particles around Amsterdam Schiphol airport

N. Janssen, G. Hoek, M. Oldenwening, F. Cassee, A. Lammers, M. Gerlofs-Nijland, R. He, D. van Dinther, R. Keuken, and S. van der Zee

Abstract

1. Observational (+, but mild)

Background: Studies have shown elevated concentrations of ultrafine particles (UFP) near airports. Little is known about the health effects of UFP, particularly from aviation. We evaluated the health effects of short-term exposure to UFP around Schiphol Airport, The Netherlands.

Methods: We conducted three studies, with different designs: **1.** Observational study with 191 schoolchildren in residential areas near Schiphol, including weekly lung function and exhaled NO measurements at school (161 children) and daily lung function and symptom recording at home (all 191 children).**2.** Controlled exposure study with 21 healthy adults, including 2-5 repeated 5-hour exposures in a mobile laboratory directly next to Schiphol, with pre and post measurements of lung function, exhaled NO, electrocardiography and blood pressure.**3.** Toxicological study with human bronchial epithelial cells (Calu-3), using UFP collected directly next to Schiphol as well as UFP collected from a turbine engine, and assessment of cell viability, cytotoxicity and inflammatory potential.**Results:** In children, we found statistically significant associations between exposure to UFP and an increase in daily respiratory symptoms and bronchodilator use. These associations were observed for UFP from aviation as well as UFP from road traffic, based on particle size distribution. In the adults study, exposure to UFP from aviation was associated with a decline in lung function (FVC) and a prolongation of the QT interval (ECG). UFP from road traffic was associated with an increase in systolic blood pressure. In Calu-3 cells, exposure to UFP resulted in cell damage and release of pro-inflammatory markers, with no significant differences in reactivity between the different sources of UFP. **Conclusions:** Together, these studies show that short-term increased exposure to UFP, as occurs around Schiphol, is associated with acute health effects. We found no indications that effects of UFP from aviation are substantially different from those of UFP from road traffic.

2. Controlled exposure +

3. Toxicological – (no diff between traffic and aircraft)

Jansen et al., 2020, EHP

Controlled exposure - Amsterdam (Lammers et al 2020)

Methods

- 21 healthy non-smoking volunteers (18–35 years) were repeatedly (2–5 visits) exposed for 5 h to ambient air near Schiphol Airport while performing intermittent moderate exercise (i.e., cycling).
- Pre- to post-exposure changes in cardiopulmonary outcomes (spirometry, forced exhaled nitric oxide, electrocardiography and blood pressure) were assessed and related to total- and size-specific particle number concentrations (PNC).

Fig. 1. Exposures were conducted in an exposure laboratory right next to Schiphol Airport **(A)**. It consisted of two chambers: one chamber in which subjects were exposed and one for the exposure monitoring equipment **(B)**.

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Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Road traffic
Airport
Short-term exposure
Human subjects

Methods: In this study, 21 healthy non-smoking volunteers (age range: 18–35 years) were repeatedly (2–5 visits) exposed for 5 h to ambient air near Schiphol Airport, while performing intermittent moderate exercise (i.e. cycling). Pre- to post-exposure changes in cardiopulmonary outcomes (spirometry, forced exhaled nitric oxide, electrocardiography and blood pressure) were assessed and related to total- and size-specific particle number concentrations (PNC), using linear mixed effect models.

Results: The PNC was on average 53,500 particles/cm^3 (range 10,500–173,200). A 5–95th percentile increase in exposure to UFP (i.e. 125,400 particles/cm^3) was associated with a decrease in FVC of −73.8 mL (95% CI −138.8 – −0.4) and a prolongation of the corrected QT (QTc) interval by 9.9 ms (95% CI 2.0 – 19.1). These effects were associated with particles < 20 nm (mainly UFP from aviation), but not with particles > 50 nm (mainly UFP from road traffic).

Discussion: Short-term exposures to aviation-related UFP near a major airport, was associated with decreased lung function (mainly FVC) and a prolonged QTc interval in healthy volunteers. The effects were relatively small, however, they appeared after single exposures of 5 h in young healthy adults. As this study cannot make any inferences about long-term health impacts, appropriate studies investigating potential health effects of long-term exposure to airport-related UFP, are urgently needed.

1. Introduction

It has been established that both short- and long-term exposure to air pollution, especially particulate matter (PM), is associated with adverse health effects, prompting air quality regulations. Adverse effects could range from respiratory (e.g. asthma exacerbations and bronchitis) to cardiovascular (e.g. cardiac arrhythmias and heart attacks), which have been associated with more hospitalizations (Brook cardiopulmonary mortality by 6–11% per 10 μg/m^3 (Beelen et al., 2015; Hoek et al., 2013; Pope et al., 2002).

To date, most studies have focussed on coarse (2.5–10 μm, PM10) and fine (< 2.5 μm, PM2.5) particles, however, concerns about ultrafine particles (< 0.1 μm, UFP) are rising. Compared to larger particles, UFP are potentially more toxic due to their high surface area-to-mass ratio, capability to deposit deep in the lungs, and potential to translocate to other organs (Heusinkveld et al., 2016; Hougaard et al., 2015;

- Short-term exposures to aviation-related UFP near a major airport, was associated with decreased lung function (mainly FVC) and a prolonged QTc interval in healthy volunteers.
- The effects were relatively small, however, they appeared after single exposures of 5 h in young healthy adults.
- As this study cannot make any inferences about long-term health impacts, appropriate studies investigating potential health effects of long-term exposure to airport-related UFP, are urgently needed.

Unique opportunities to quantify impacts and health effects: Natural experiments or opportunistic studies

Closure of Airports

"In 2020, the largest airport in Germany's capital, Berlin-Tegel Airport (TXL), was relocated from the north of the city 26 km to the south. This provided a unique opportunity to measure PNCs on the airfield of TXL before and after it was closed."

"We observe a significant decrease of PNCs after the closure of TXL. The hourly mean PNCs dropped by 41%, and the maximum concentrations from 102,800 # cm−3 to 41,300 # cm−3. We detected these differences only during the day, as these were the times when aircraft movements took place during airport operations. With wind from the airport, these changes are even more pronounced: Average PNCs dropped by 70% and maximum PNCs by 85% after the closure of the airport. We cannot find statistically significant changes for wind from the direction of the motorway."

Sabine Fritz, Sebastian Aust and Tobias Sauter
Frontiers in Environmental Science, 2022

The Berlin-Brandenburg Air Study – a natural experiment investigating health effects from changes in airport-related exposures

Arnt Diener, Sarah Lucht, Sabine Lüchtrath, Lina Glaubitz, Kay Weinhold, Ulf Winkler, Alfred Wiedensohler, Josef Cyrys, Petra Gastmeier, Miriam Wiese Poselt, and Barbara Hoffmann

- The Berlin-Brandenburg Air Study (BEAR) involves 800 elementary school children (ages 8-12) attending altogether 12-16 schools near the closing Tegel (TXL) airport, near the opening Berlin-Brandenburg (BER) airport, and in control areas (CTL) away from both airports and associated air corridors.
- We will analyze short-term effects of UFP as well as long-term effects on lung growth and cognitive development comparing growth trajectories across the three school areas.

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The Berlin Air Study – a natural experiment investigating health effects from changes in airport-related exposures (BEAR Study)

Air pollution is a relevant risk factor for cardiovascular and respiratory diseases, for diabetes and reduced birth weight. Ambient ultrafine particles seem to be very harmful. Due to their small size, UFP can be inhaled deeply into the lungs, enter the alveoli and penetrate biological membranes, enabling them to pass into the systemic circulation, overcome the placental barrier, and finally diffuse into all organ systems including the brain and nervous system. Several studies have already shown that long-term particulate matter pollution is associated with an accelerated decline in neurocognition in old age and a slowed cognitive development in children. In the vicinity of large airports ambient UFP concentrations are strongly elevated. A systematic measurement and health evaluation of ultrafine dusts from road and air traffic has not yet taken place. So far it is not known whether Aircraft-UFPs are related to acute or chronic health effects. In the near future, the Berlin metropolitan area is facing a unique situation, which provides a perfect setup for a natural experiment for studying Aircraft-UFP. The move of Berlin's air traffic from Airport Tegel (TXL) to Berlin-Brandenburg (BER) Airport at the end of 2020 will cause a significant change in the UFP concentrations in parts of the Berlin city area. The Berlin Air (BEAR) study aims to assess the concentration changes in emissions from both airport areas in TXL and BER and to investigate the short and long-term health consequences of these changes for children. To assess the health consequences of changing air pollution concentrations in Berlin we will examine altogether 800 schoolchildren aged 8-12 years in schools downwind of TXL and BER (approximately 2-6 km downwind of the airports) and in schools located in a control area not affected by changes in aircraft traffic or other airport-related exposures. Repeated measurements during a time period of 2 years are planned, in order to assess baseline conditions as well as conditions during and after the relocation of aircraft traffic.

Funding

Duration 01.10.2019 – 01.10.2023

Team Barbara Hoffmann, Vanessa Soppa, Anna Buschka

External collaborators Alfred Wiedensohler (Leibniz Institute for Tropospheric Research), Andreas Held (Institute of Environmental Technology, Berlin), Christoph Schneider (Geography Department, Humboldt-University Berlin), Josef Cyrys (Institute of Epidemiology, Helmholtz Center, München), Petra Gastmeier und Miriam Wiese-Posselt (Charite Berlin), Martijn Schaap (TNO, Netherlands Organization for Applied Scientific Research, Eindhoven NL), Stephan Weber (Technical University, Braunschweig)

Publications

Study before and after expansion: for example, at Tweed Airport in New Haven

- Tweed Airport in New Haven, Connecticut plans to extend their runway, expand their facility, and increase their daily number of flights.
- A local group — 10,000 Hawks — is working with community science organizations to document observed emissions of ultrafine particles and NOx.

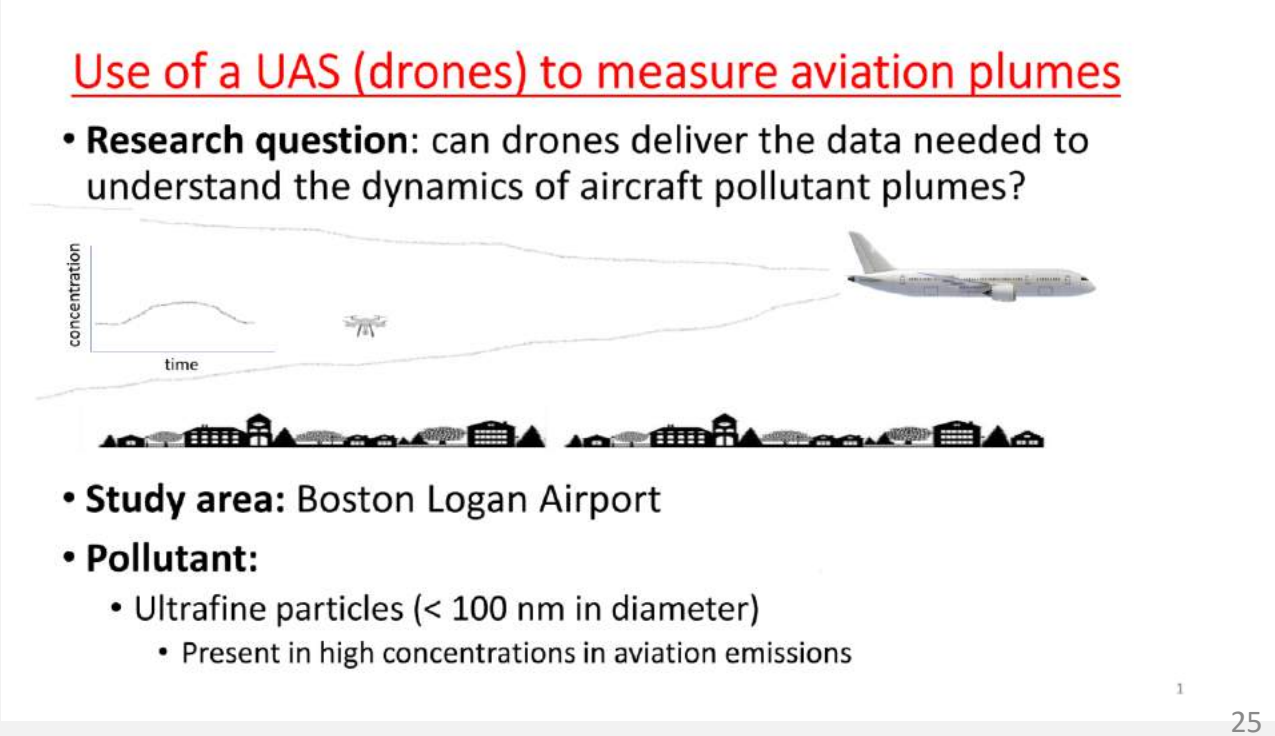
Future Work

1. What is an efficient strategy for characterizing aircraft emissions impact on ground-level air quality?

Data collection → models → exposure assessment → health-effect investigations → mitigation strategy evaluations

Stationary, Mobile, Hybrid, Networks….

Latest work with drones



Future Work

2. The chemical composition of particles and toxicology remain unstudied except perhaps in very near-field.

> Fushimi, A., Saitoh, K., Fujitani, Y., and Takegawa, N.: Identification of jet lubrication oil as a major component of aircraft exhaust nanoparticles, Atmos. Chem. Phys., 19, 6389–6399, https://doi.org/10.5194/acp-19-6389-2019, 2019.
>
> > *"Using size-resolved particulate samples collected near a runway of the Narita International Airport, Japan, we clearly demonstrate that organic compounds in the ambient nanoparticles (diameters: < 30 nm) were dominated by nearly intact forms of jet engine lubrication oil."*

3. What changes should be expected from changing fuel-mix, newer standards, and shift to SAF?

Questions?

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