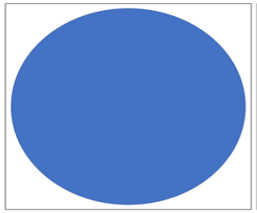
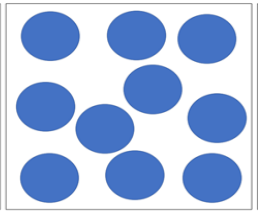
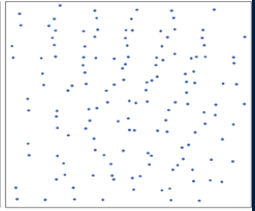
ULTRAFINE PARTICLE TRENDS IN AUSTRALIA AND NEW ZEALAND

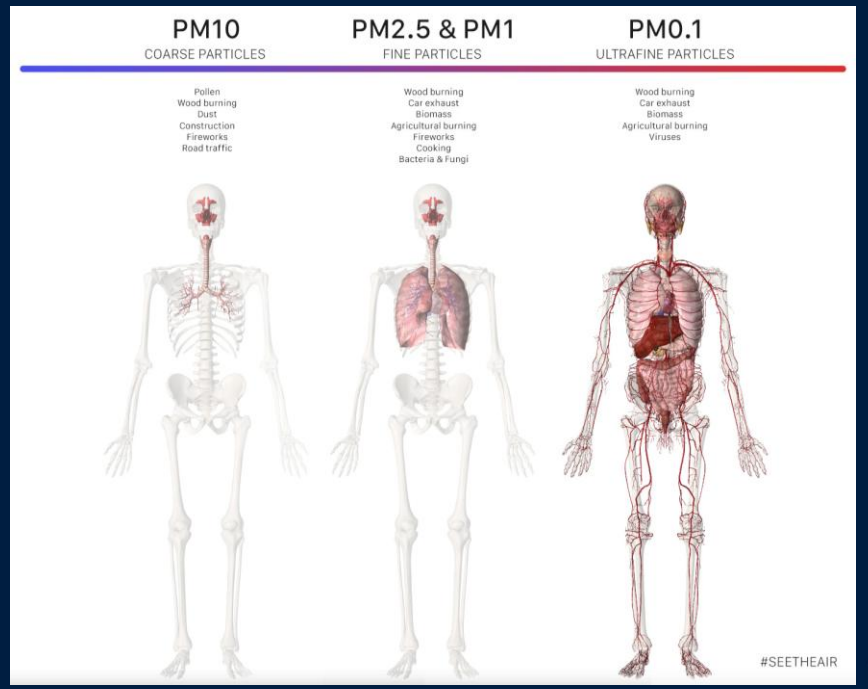
Hamesh Patel[1,5,6],
Parwapath Phunthirawuthi[1], Giorgio Buonanno[1,2], Gunaratnam Gunashanhar[3], Congrong He[1],
Ruhi Humphries[4], Rohan Jayaratne[1], Melita Keywood[4], Zijun Li[1], Matthew Riley[3], Zoran Ristovski[1],
Robyn Schofield[7], Helen Thompson[8], Alicia Josa-Cullere[1], Lidia Morawska[1,9,*]

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Background

- Urban air pollution remains a major environmental health issue
- Air quality management relies on mass-based metrics for $PM_{2.5}$ and PM_{10}
- Ultrafine particles (100nm) are measured using particle number concentration (PNC)
- Limited monitoring has led to limited knowledge, while UFPs remain unregulated
- *"Efforts should be stepped up to utilize the emerging science and technology to advance approaches to the assessment of exposure to UFP for application in epidemiological studies and management."* (WHO, 2021)

	10 µm (Coarse)	2.5 µm (Fine)	0.1 µm (Ultrafine)
			
Total mass	1	1	1
Particle number	1	64	1,000,000
Surface area per particle	1	0.0625	0.0001
Total surface area per mass	1	4	100
	• Filtered in proximal airway • May irritate skin, mucosa	• Reaches peripheral airway • Cannot enter systemic circulation	• Higher adsorbed toxic material on surface • May enter systemic circulation



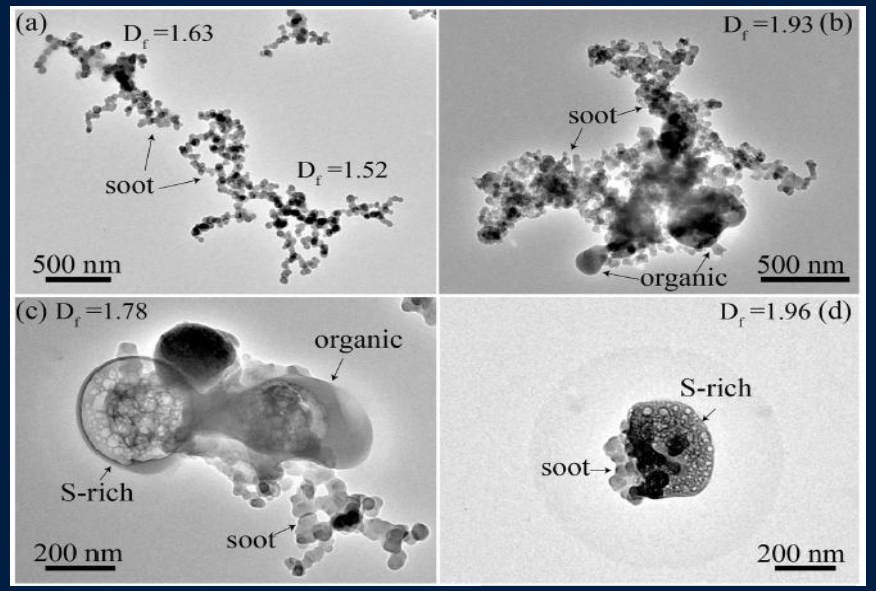
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Waipapa Taumata Rau
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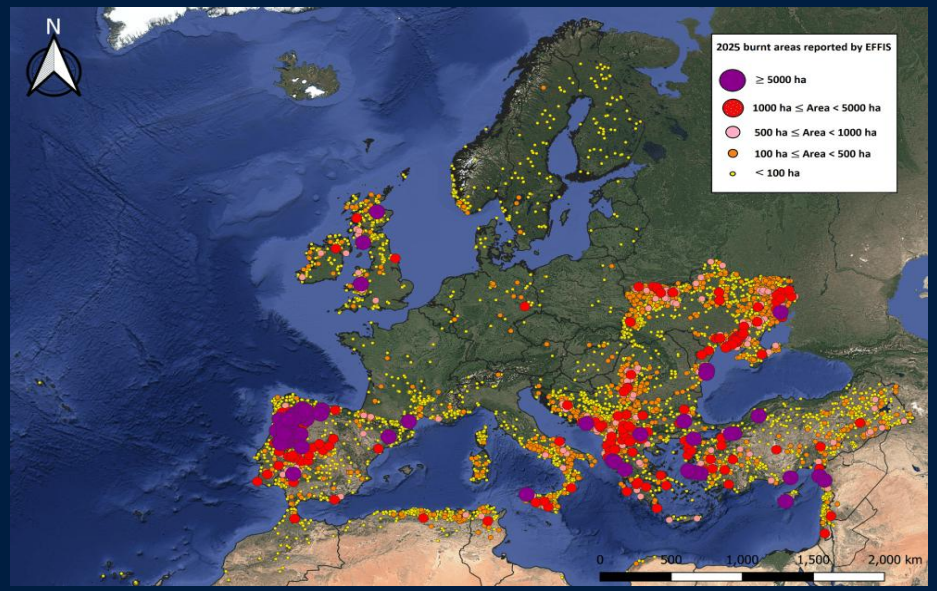
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Background

- UFPs primarily originate from anthropogenic sources:
  - Motor vehicle emissions, domestic home heating, ports, and industry.
  - Natural sources also contribute: marine aerosols and wildfire smoke.
- Changes in UFP emission profiles linked to:
  - Energy transition
  - Uptake of electric vehicles
  - More efficient home heating systems
  - Climate change



Li et al., 2024

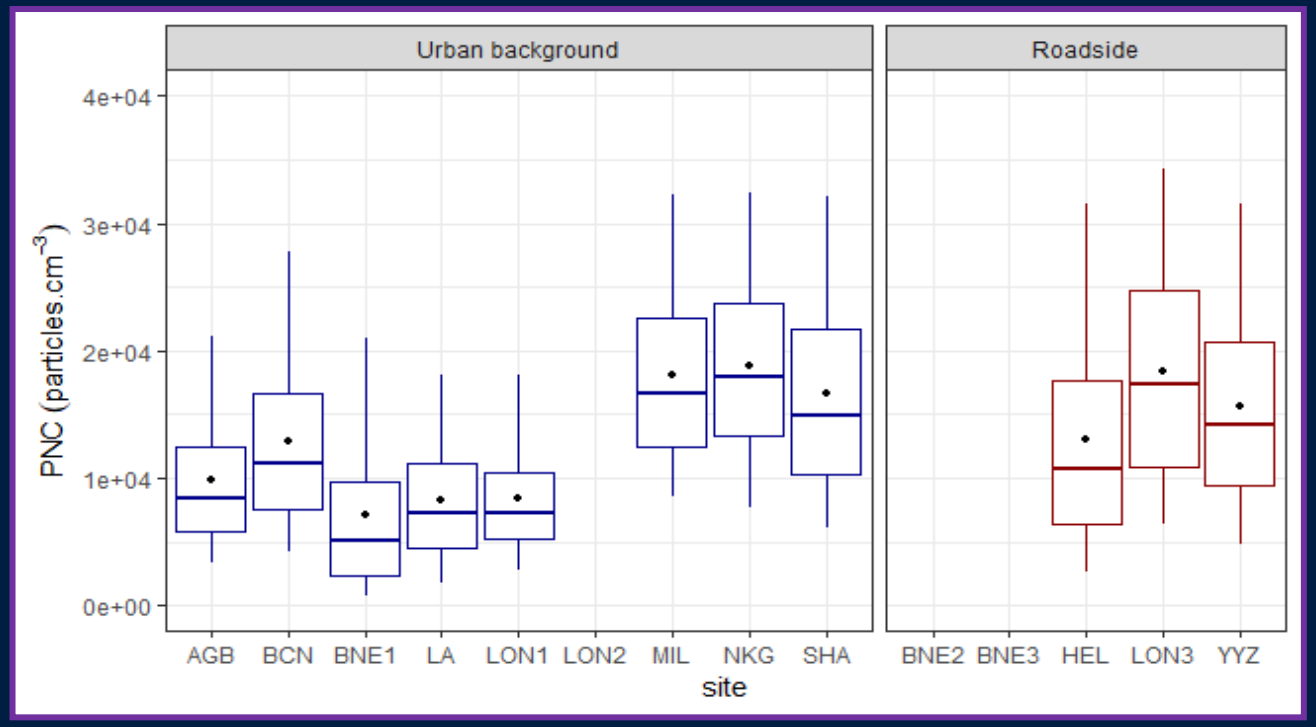


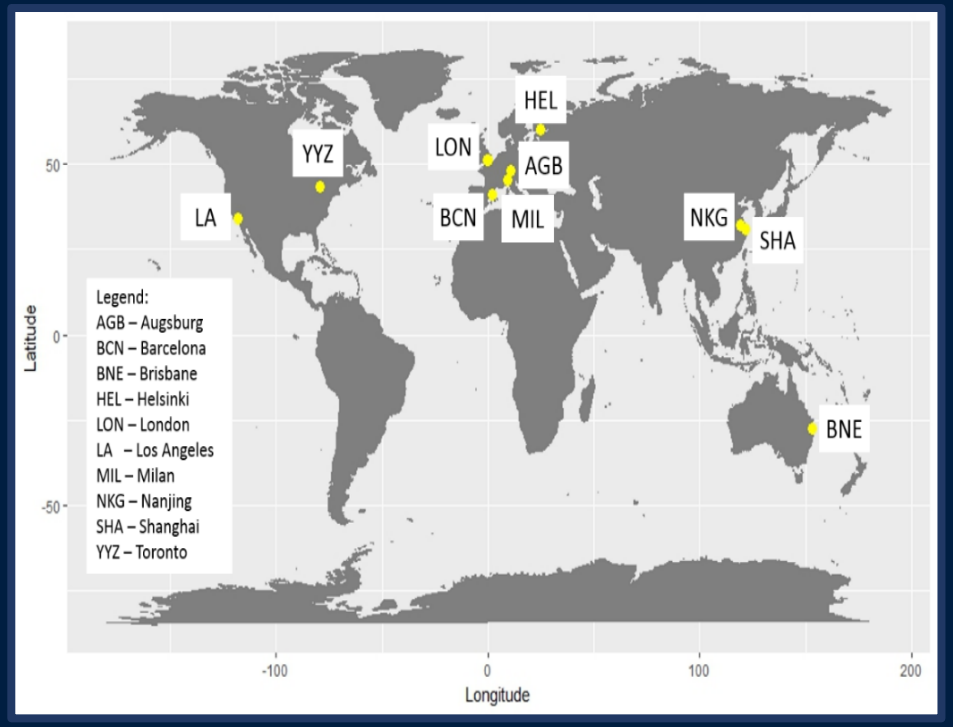
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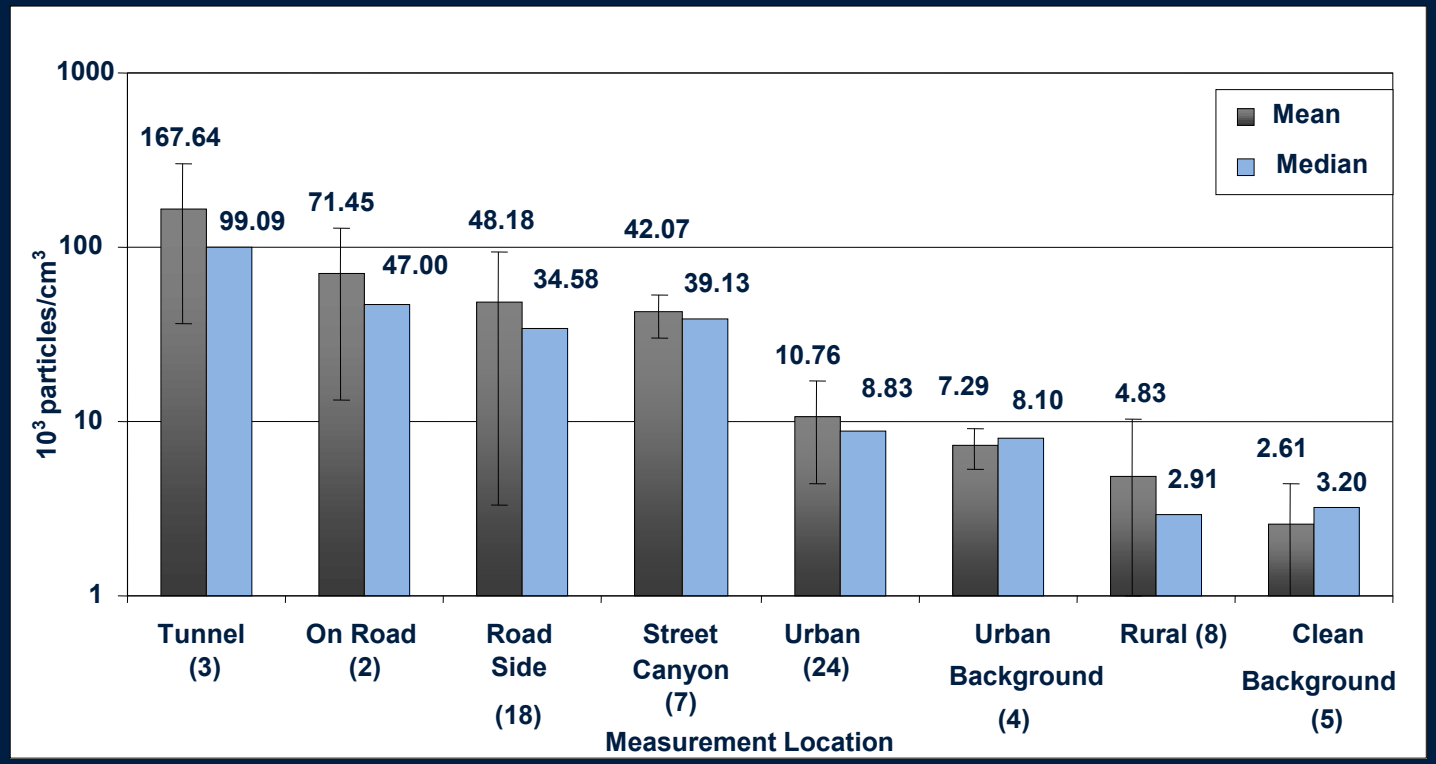
PNC – Global (2019)





De Jesus et al., 2019

PNC – Different Environments



Clean environments: < 10^3

Urban background: ~ 10^4

Near roads/tunnels: > 10^5

Hence: spatial variation in PNC

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Research Objectives

- Historical UFP monitoring across Australia and New Zealand is intermittent and lacked multi-city measurements
- Research Objective:
  - Quantify Particle Number Concentrations (PNC) across key urban centres.
  - Characterise spatial trends across climate zones.
  - Establish co-pollutant relationships





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Methodology

- Four major cities across AU/NZ:
  - Brisbane, Sydney, Melbourne & Auckland
- Data captured over one full year per site to capture complete seasonal cycles
  - 2021 - 2023
- Use ideally the same instruments
  - Scanning Mobility Particle Sizers (SMPS)
  - Scanning Electrical Mobility Sizers (SEMS)
- Monitoring started during the pandemic



Monitoring Sites & Instrumentation

Parameter	Brisbane	Melbourne	Sydney	Auckland
Area	15,842 km²	9,993 km²	12,369 km²	4,941 km²
Population	2.53 M	4.92 M	5.23 M	1.66 M
Climate (Köppen–Geiger code)	Humid subtropical (Cfa)	Mild and temperate (Cfb)	Humid subtropical (Cfa)	Maritime subtropical (Cfb)
Site classification	Urban	Regional	Suburban	Roadside
Instrument	Brechtel SEMS, model 2100	TSI SMPS with EC3080, CPC 3772	TSI SMPS 3910	TSI SMPS with EC3080, CPC 3775
Detectable size range	5.08 – 974 nm	14.6 – 661.2 nm	11.5 – 365.2 nm	5.94 – 289 nm
Data resolution	5-minute	5-minute	1-minute	5-minute
Monitoring periods	Sep 2022 to Aug 2023	Sep 2021 to Aug 2022	Mar 2022 to Feb 2023	Sep 2021 to Aug 2022
Pollutant monitored	NO, NO_2, NO_x, CO, $PM_{2.5}$, PM_{10}	NO_2, O_3, PM_{10}	NO, NO_2, SO_2, CO, O_3, $PM_{2.5}$, PM_{10}	NO, NO_2, NO_x, SO_2, BC, $PM_{2.5}$

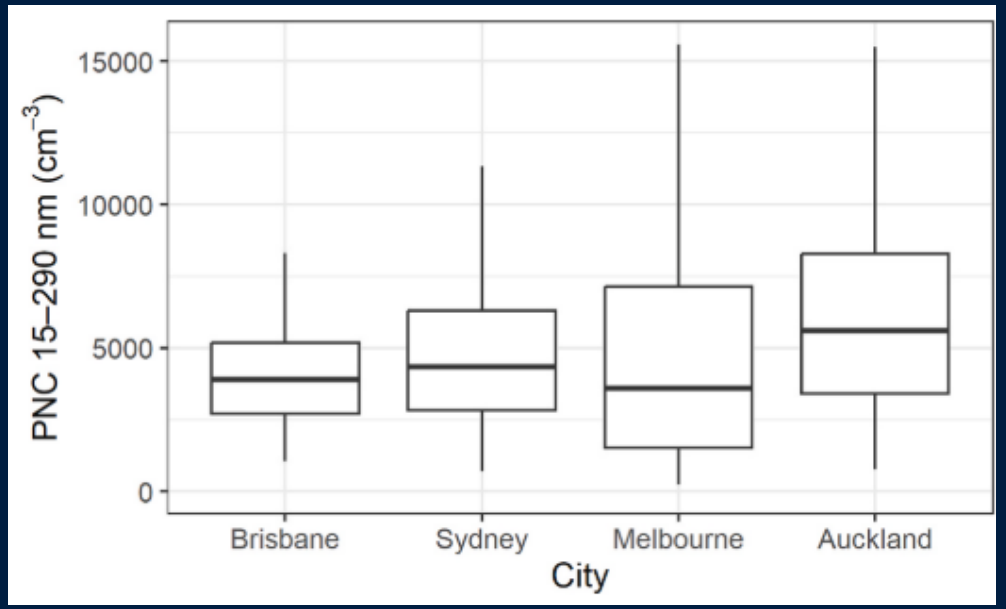
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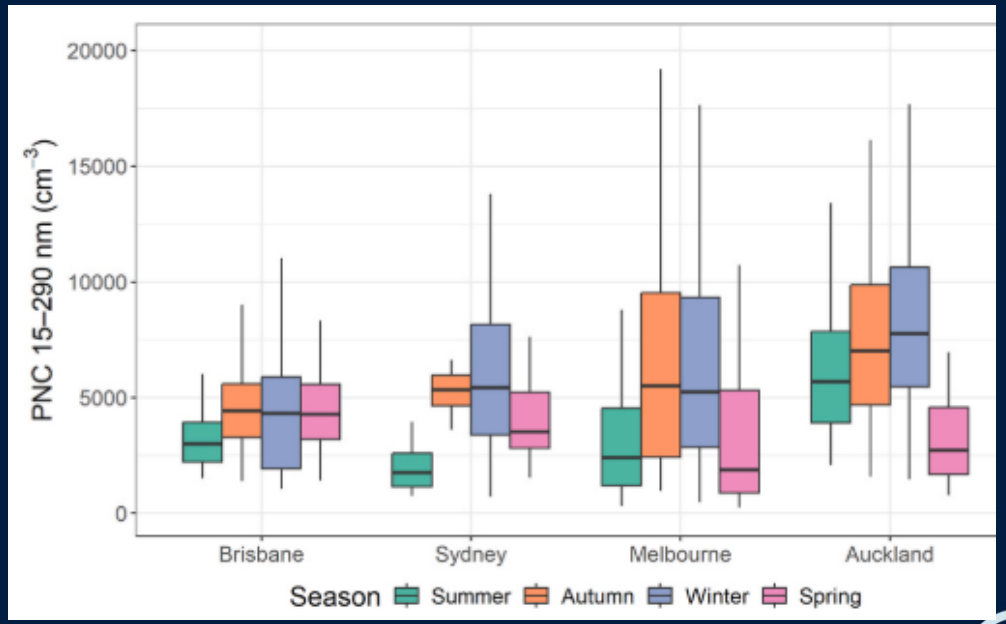
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Results

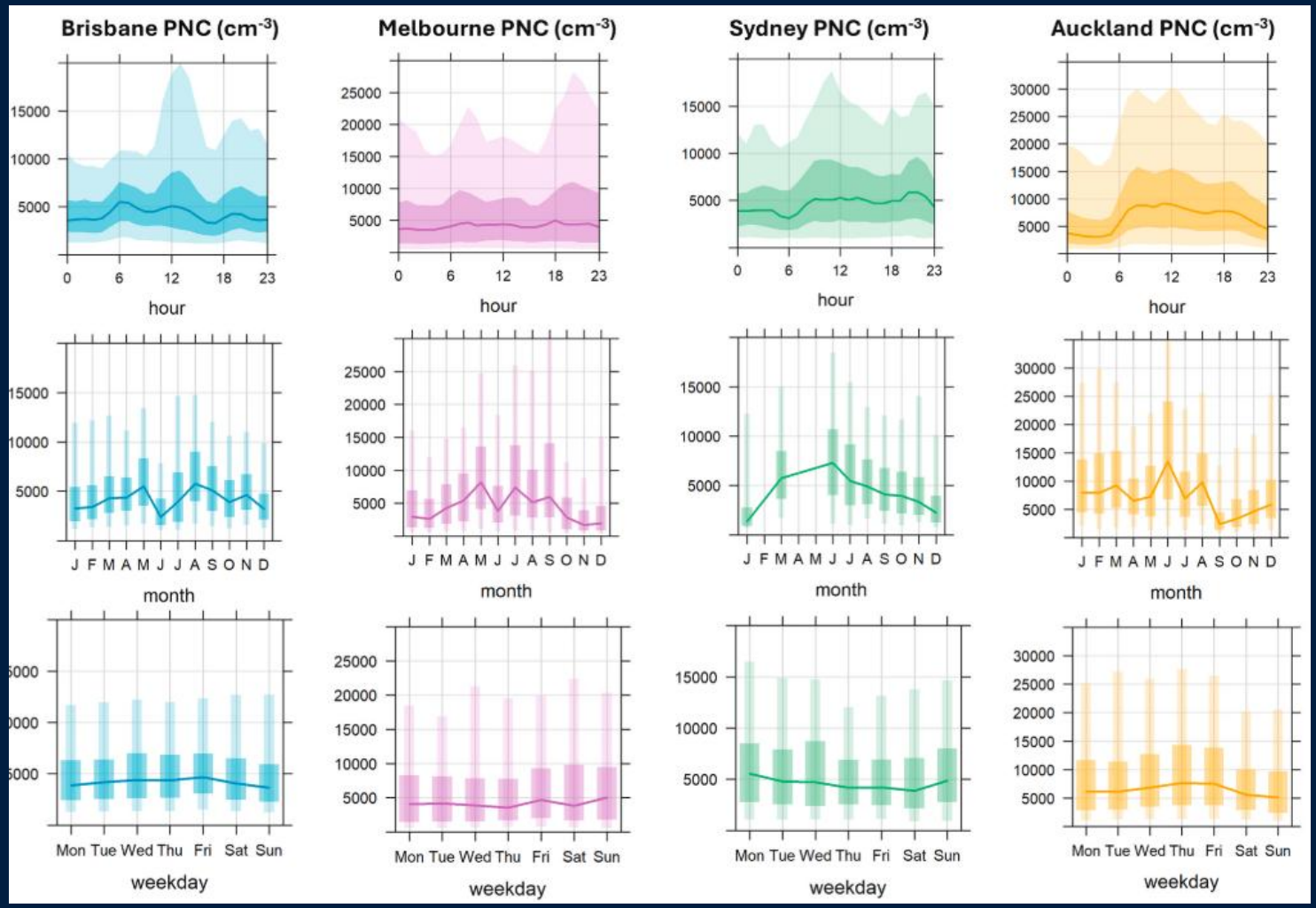
- Daily median PNC across all four cities ranged between 3.6 - 5.6 × 10^3 cm^{-3} :
  - Melbourne - 3.6 × 10^3 cm^{-3}
  - Brisbane - 3.9 × 10^3 cm^{-3}
  - Sydney - 4.3 × 10^3 cm^{-3}
  - Auckland - 5.6 × 10^3 cm^{-3}
- Seasonal patterns differed among cities:
  - Highest PNC values observed during winter.
  - Lowest PNC in the warmer months
- Brisbane showed a less pronounced seasonal tendency





Results

- Hour-of-day analysis revealed a bi-model distribution during morning and evening traffic peaks across all cities
- Auckland and Brisbane also observed an additional peak around midday
- Day-of-week analysis revealed the usual reduction on weekends (apart from Melbourne)



Results

- Correlation analysis showed strong relationships with pollutants associated with motor-vehicles (NO_x, CO, BC).
- Weak relationship between PNC and $PM_{2.5}$ and PM_{10}



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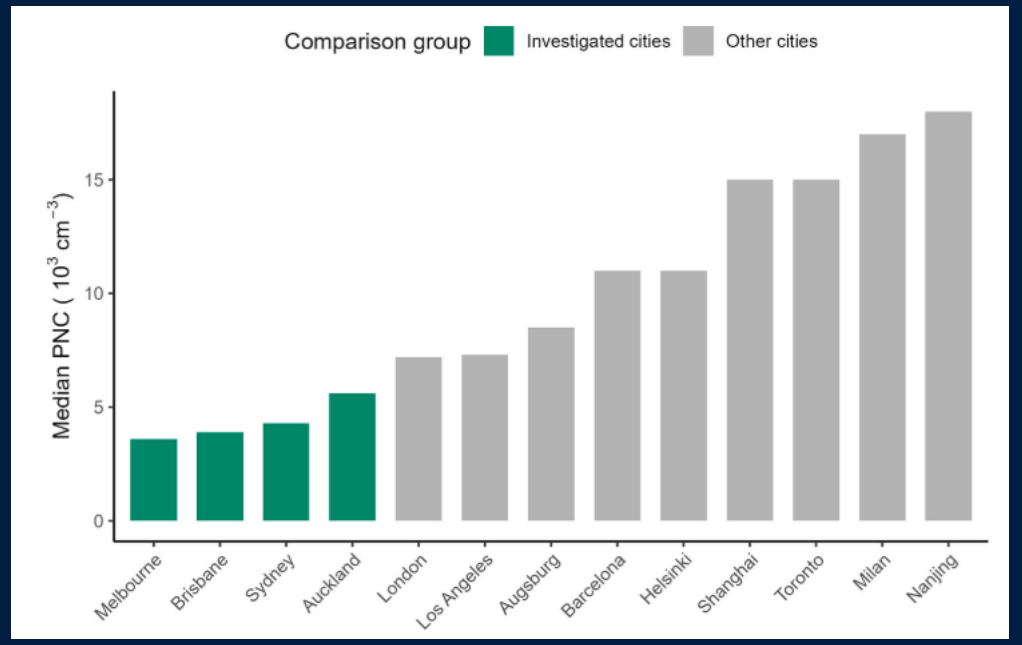
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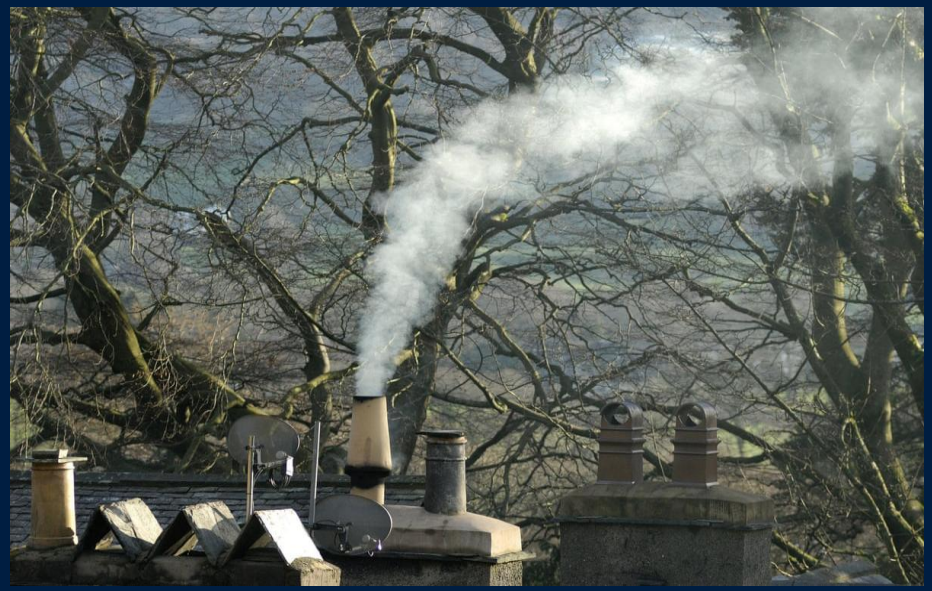
PSD Regimes

Regime	Main characteristics	Cities where evident
Traffic-related	Morning/evening occurrence; larger Aitken-mode contribution; associations with traffic-related pollutants	Observed in all sites
Nucleation	Midday occurrence with small particle modes enhancement under favourable photochemical conditions	Most persistent in Brisbane and Auckland, intermittent in Melbourne
Background / aged aerosol	Lower PNC or broader PSD; weaker traffic-pollutant associations	Observed in all sites
Episodic high-PNC profiles	Less frequent clusters with substantially elevated particle numbers	Observed in all sites

Discussion

- Recorded PNC concentrations were generally lower than what was reported globally
  - Europe, North America and Asia median concentrations generally ranged from $7.2 – 18 \times 10^3$ pt. cm^{-3}
- Additional peaks observed in Auckland and Brisbane was hypothesised to be attributed to new particle formation events
- Increased concentrations during the cooler periods associated with domestic home heating and increased atmospheric stability
- Weak relationship with $PM_{2.5}$ and PM_{10} is inline with international literature





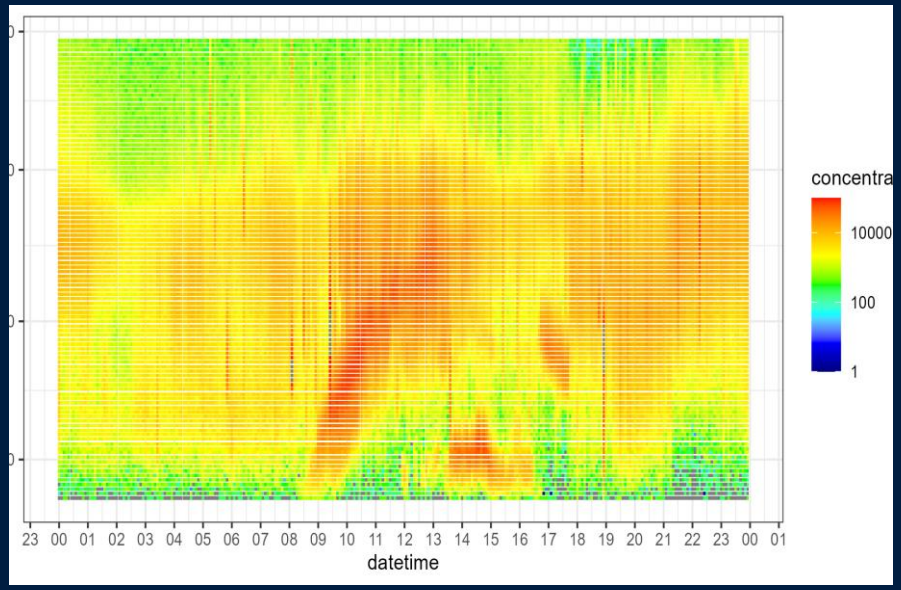
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Limitations & Future Work

- Harmonise instrumentation
- Better understand new particle formation events
- Understand the impacts of the pandemic - NPF
- Extend long-term assessments (beyond one year)
- Source identification with particle speciation and modelling





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Conclusions

- Examined UFP PNC across four cities
- Concentrations were on the lower compared to global median concentrations
- Trends were generally in-line with other co-pollutants
- UFPs moderated by local source proximity, atmospheric stability, and photochemical conditions
- Contributes to the growing body of literature to support UFP understanding to assist in more effective air quality management and targeted mitigation





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Thank you!



Environment International 210 (2026) 110227

Contents lists available at ScienceDirect

Environment International

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Full length article

Ultrafine particles in Australian and New Zealand cities: characteristics, trends, and relationship with ambient air pollutants

Parwapath Phunthirawuthi [a], Giorgio Buonanno [a,b], Gunaratnam Gunashanhar [c], Congrong He [a], Ruhi Humphries [d], Rohan Jayaratne [a], Melita Keywood [d], Zijun Li [a], Hamesh Patel [a,e,f], Matthew Riley [c], Zoran Ristovski [a], Robyn Schofield [g], Helen Thompson [h], Lidia Morawska [a,i,*]

Acknowledgements: This study was supported by Australia Research Council (ARC) Linkage Projects Grant LP180100516: "Airborne ultrafine particles in Australian cities: sources, effects and mitigation". We would like to thank Jason Ward, Adhitya Sutresna for operating the SMPS at Aspendale, Melbourne. We also acknowledge Auckland Council for hosting monitoring equipment and providing access to their data, and Daniel Morrish and Gustavo Olivares for their assistance with equipment access and technical support throughout the programme

Questions?



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