Motor vehicle sources of particulate matter: Source trends and related metrics

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Transport Knowledge Hub Environment - Emissions Group
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Context

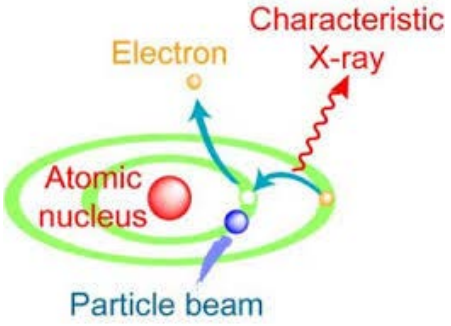
GNS Science has been researching the composition and sources of air particulate matter in NZ (and overseas) for over 20 years.

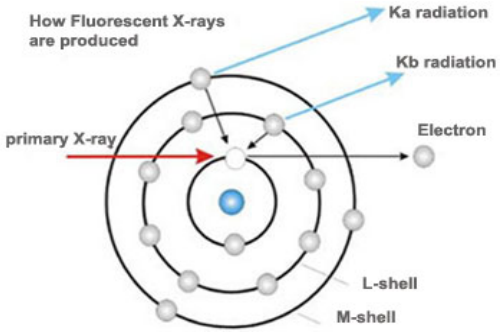
Drivers for this research include:

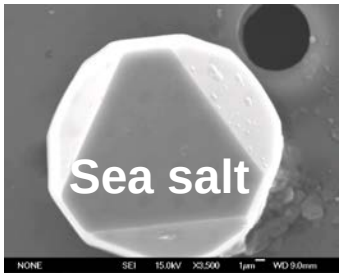
- **Understanding human health effects (particle size and composition)**
- **Air quality management (sources and source contributions to total PM)**
- **Changes over time (trends and step changes)**
  - **policy evaluation**
  - **effectiveness of regulation**
  - **impact of technology**

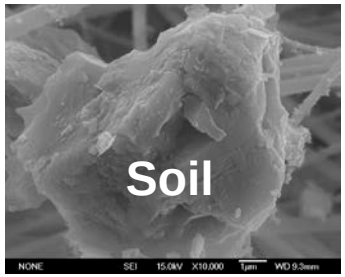
Air particulate matter composition and derivation of sources

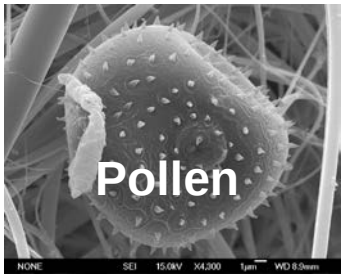
- A complex mix of elements and compounds from multiple emission sources and atmospheric chemistry (gas↔particle)
- Compositional analysis by nuclear analytical techniques (IBA or XRF) for elements Na to U, black carbon (BC) by light reflectance
- Each source or source type of particulate matter has a distinctive particle size range and chemical composition
- Multivariate covariance analysis and other data analytics across multiple samples to identify sources

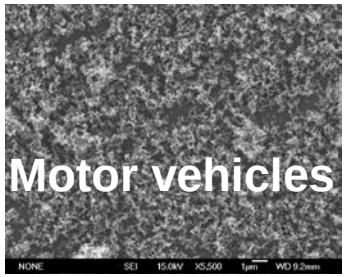


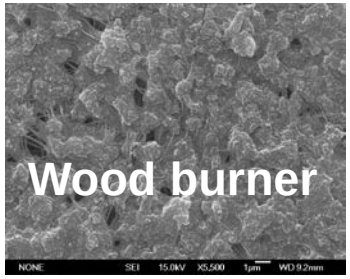












Auckland PM Speciation monitoring sites

- BC data from 1997 onwards
- Auckland dataset continuous since 2004

Site	PM size fraction	Number of filter samples	Sample period
Takapuna	$PM_{2.5}$	1164	November 2006 – June 2016
	PM_{10}	1328	December 2005 - December 2018
Queen Street	$PM_{2.5}$	1127	December 2005 - November 2015
	PM_{10}	3515	December 2005 - December 2018
Khyber Pass	$PM_{2.5}$	1072	December 2005 - April 2015
	PM_{10}	1039	December 2005 – April 2015
Penrose	$PM_{2.5}$	1044	January 2006 - June 2016
	PM_{10}	2061	May 2006 - June 2016
Henderson	PM_{10}	1250	August 2006 – December 2018

Auckland PM Speciation monitoring sites

All AC sites are either next to motorways:

- **Penrose, Khyber Pass Rd, Takapuna**

Or arterial routes:

- **Henderson**

Or both:

- **Khyber Pass Rd, Takapuna**

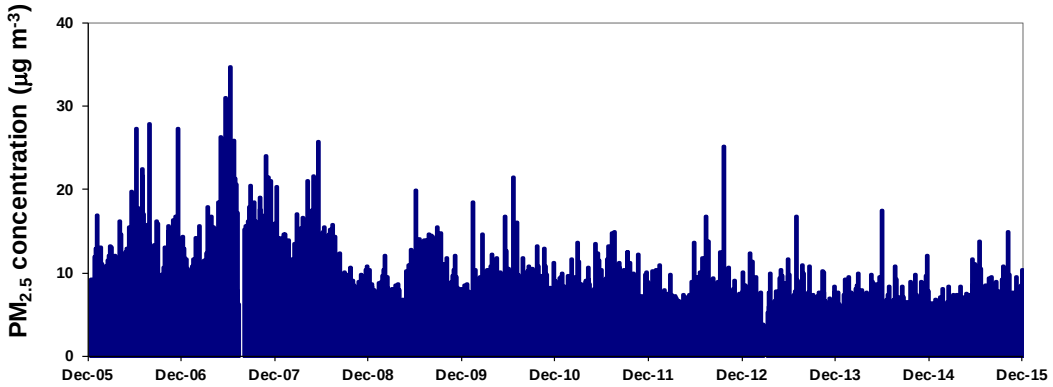
Or in a street canyon

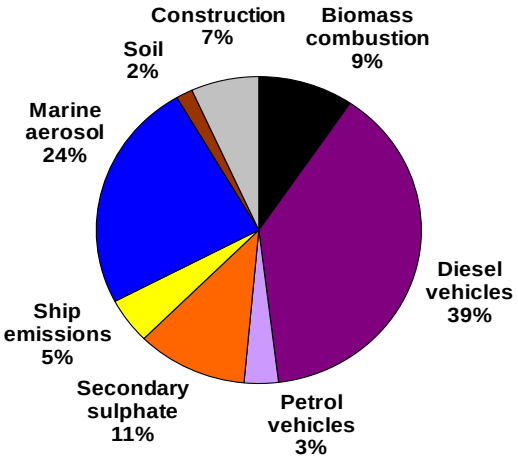
- **Queen Street**
- **The impact of motor vehicle emissions on AC PM concentrations and composition is significant**
- **The flipside is that we can extract a reasonable amount of information on what is going on in the (Auckland) motor vehicle fleet**

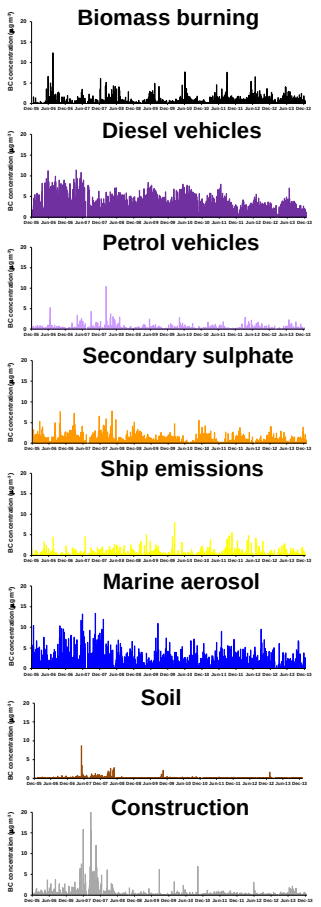
Source apportionment

- PM compositional analysis used to identify sources

Queen Street $PM_{2.5}$ example

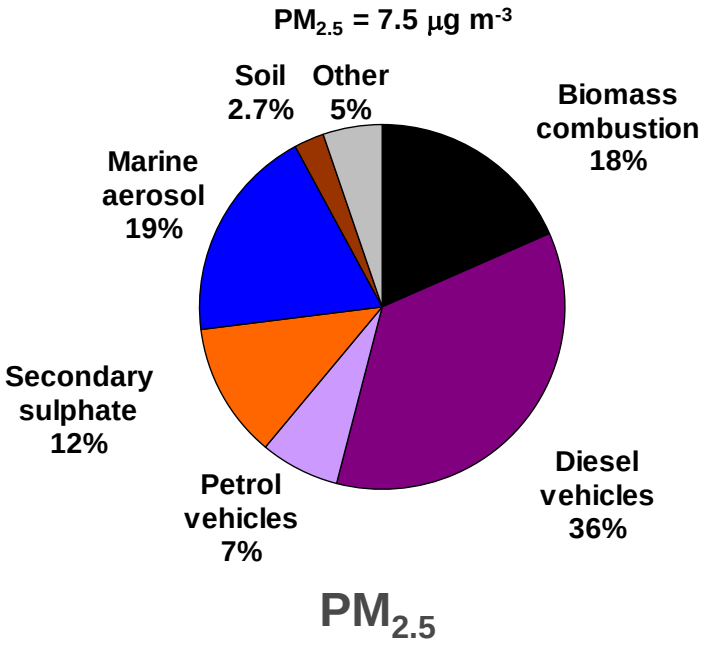


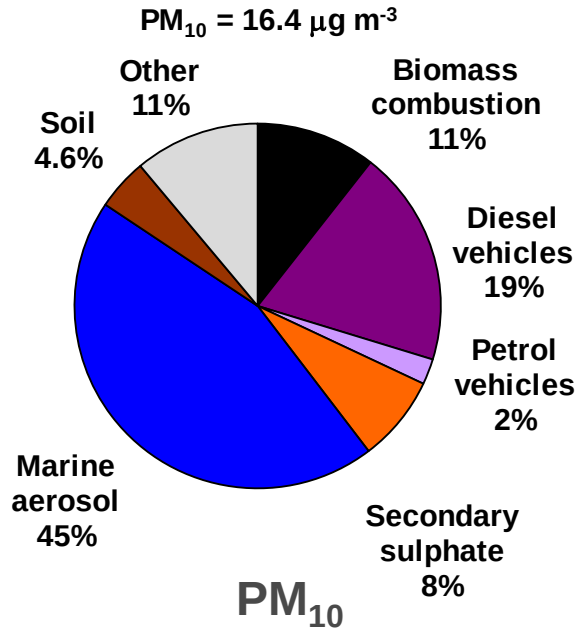




Sources of particulate matter across Auckland

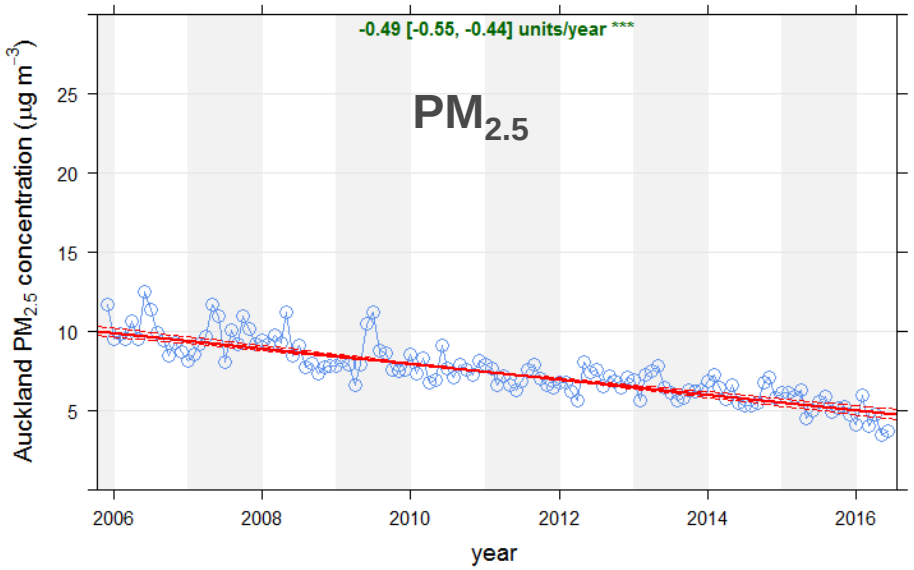
- **Data for common sources aggregated for all sites**
- **Anthropogenic emissions dominate $PM_{2.5}$ (≈ 70 %)**
  - Vehicles, biomass combustion, soil, some secondary sulphate
- **Natural sources significant for PM_{10} (≈ 50 %)**

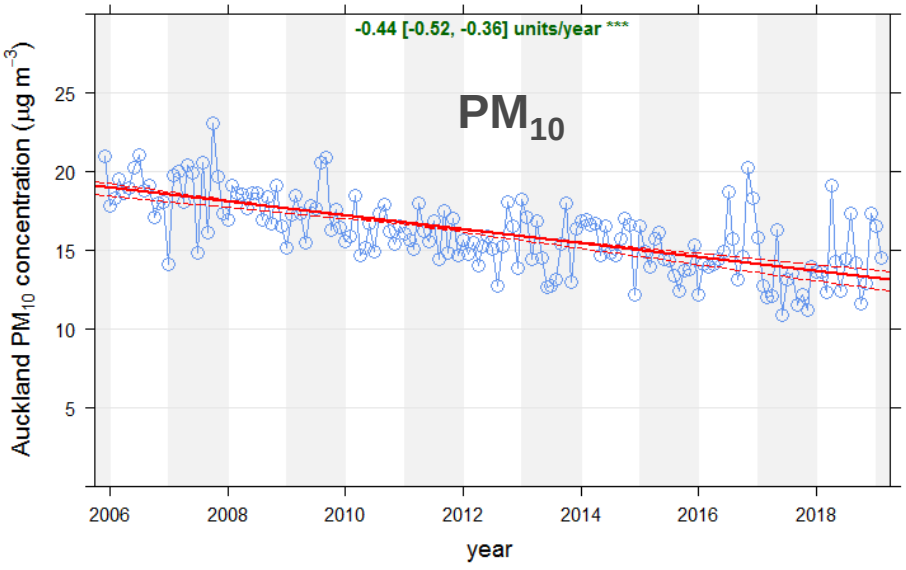




Trends in particulate matter across Auckland

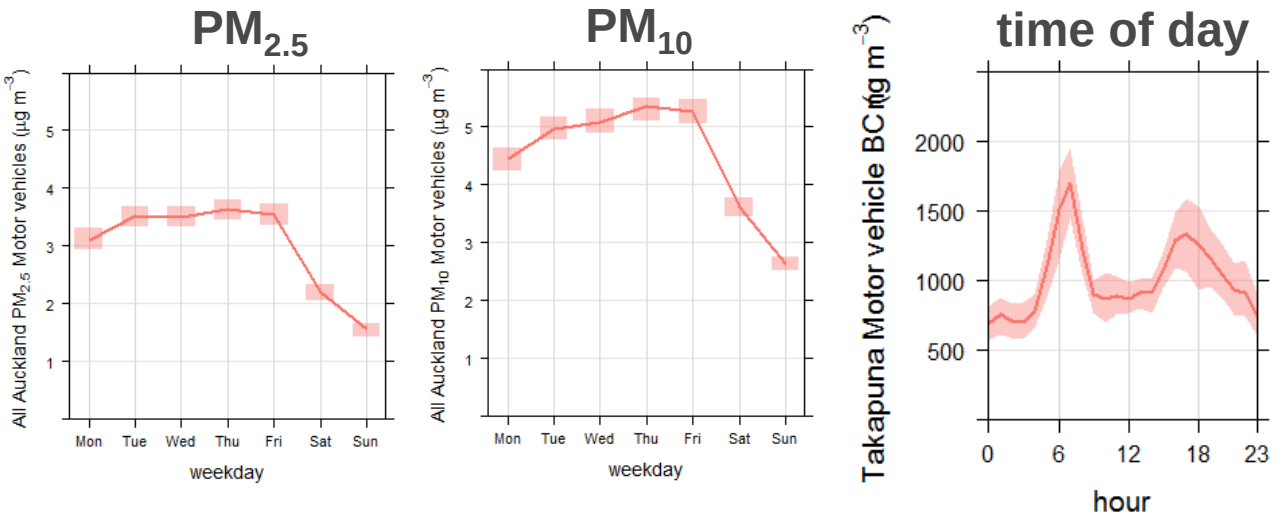
- Data aggregated for all PM speciation sites
- Downward trend observed for $PM_{2.5}$ and PM_{10} (99.9% CI)
- $PM_{2.5}$ apparently responsible for decrease in PM_{10}
- Understanding **'why'** important for AQ management

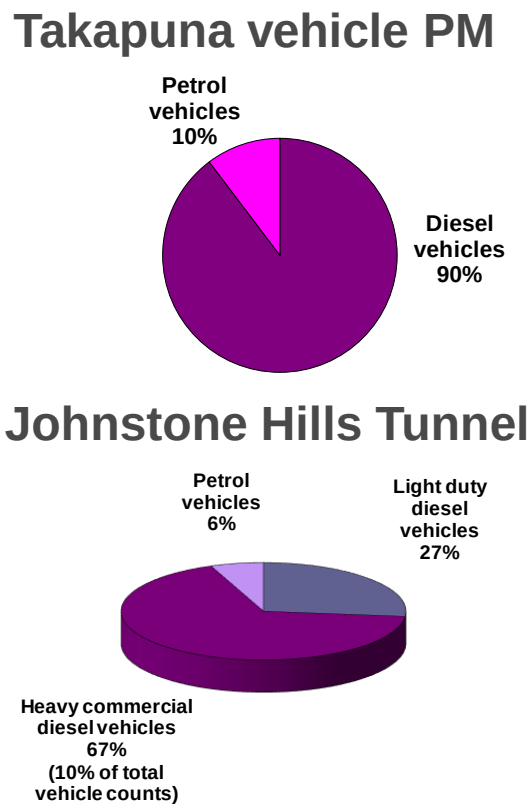




Motor vehicle source activity

- **Difference in weekday/weekend PM concentrations**
  - This and crustal matter are the only sources that show this dichotomy
  - Less HCV (diesel) activity during weekends
- **Mondays affected by public holidays (≈ 15%)**
- **Difference between $PM_{2.5}$ and PM_{10} contributions is road dust component**





Davy PK, Trompetter WJ, Markwitz A. 2011. Concentration, composition and sources of particulate matter in the Johnstone Hills Tunnel, Auckland. 64 p. (GNS Science consultancy report; 2010/296)

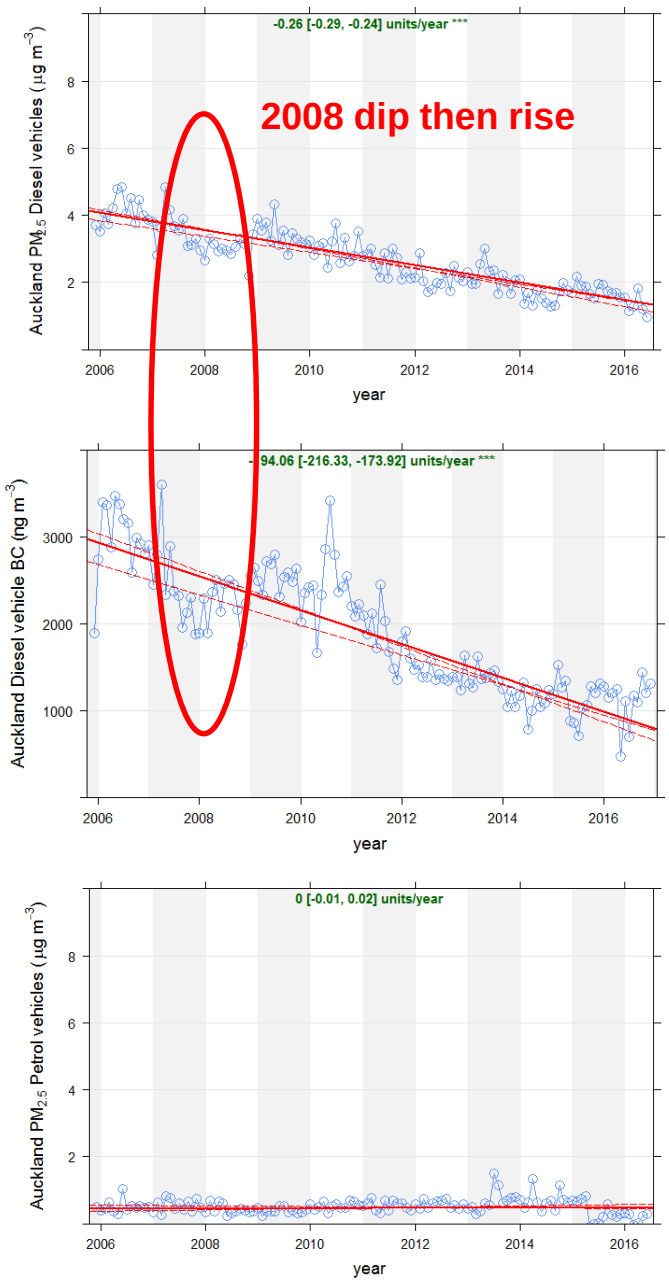
AC Transport PM source trends

- **Diesel vehicle related PM decreasing (Technology impact)**
  - Engine design/emission improvements

  50 % of $PM_{2.5}$ trend ↓
- **Primary tailpipe component is a reduction in BC emissions (representing ultra-fines)**

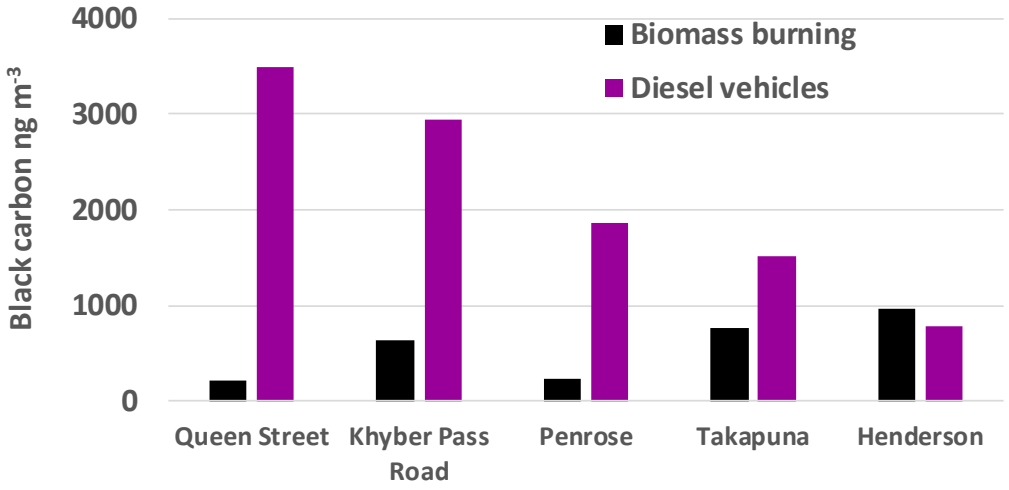
  So it's a good news story!
- **Petrol vehicle PM no change although vehicle numbers increasing (Technology impact)**
  - Fuel efficiency gains

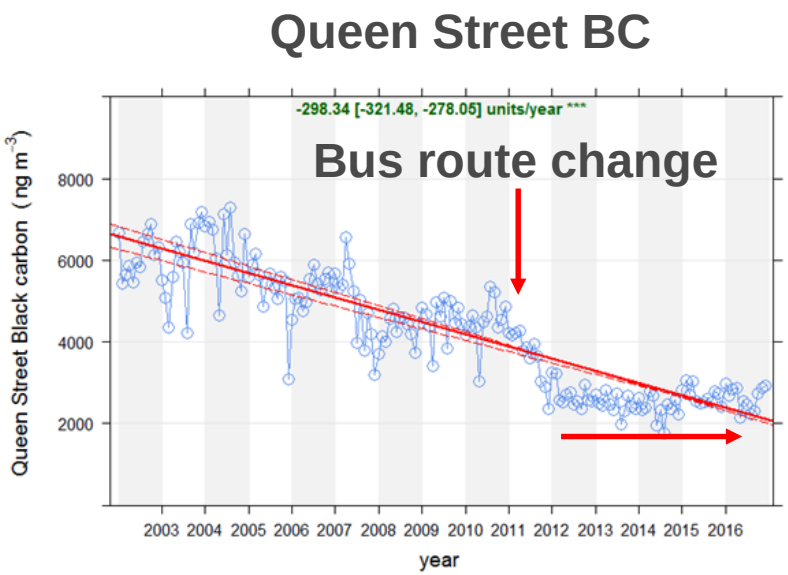
  No impact on $PM_{2.5}$ trend



BC concentrations by source in Auckland

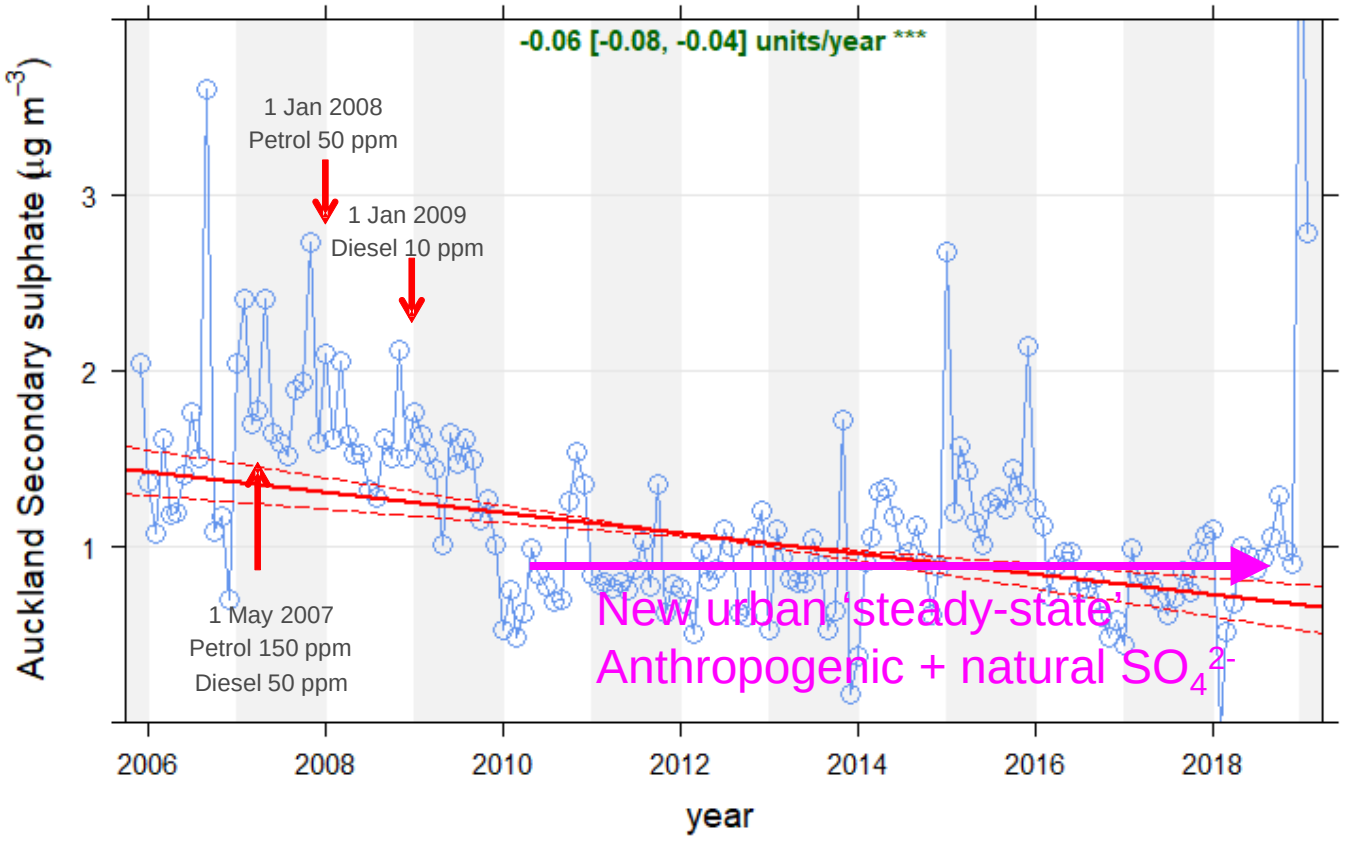
- Influence of roadside sites on average BC source concentrations (2006 – 2018) evident
- Shift in bus route resulted in BC step change at Queen Street
  - – Just shifted the impact to another street canyon
  - ⇨ Localized effects of policy changes





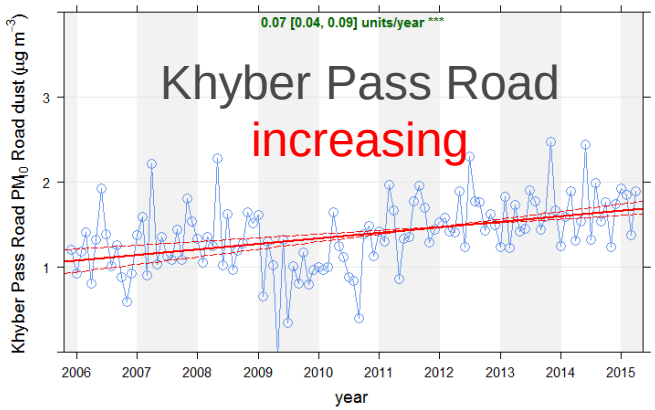
Transport source trends

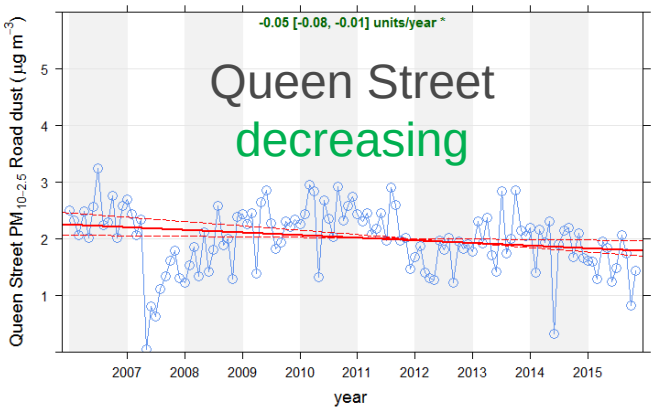
- **Reduction in sulphate concentrations (2006 - 2010) as a consequence of removal of S in fuels**
  - Petroleum Products Specification Regulations 2002, 2007



Transport source trends
Road dust – a mixed bag

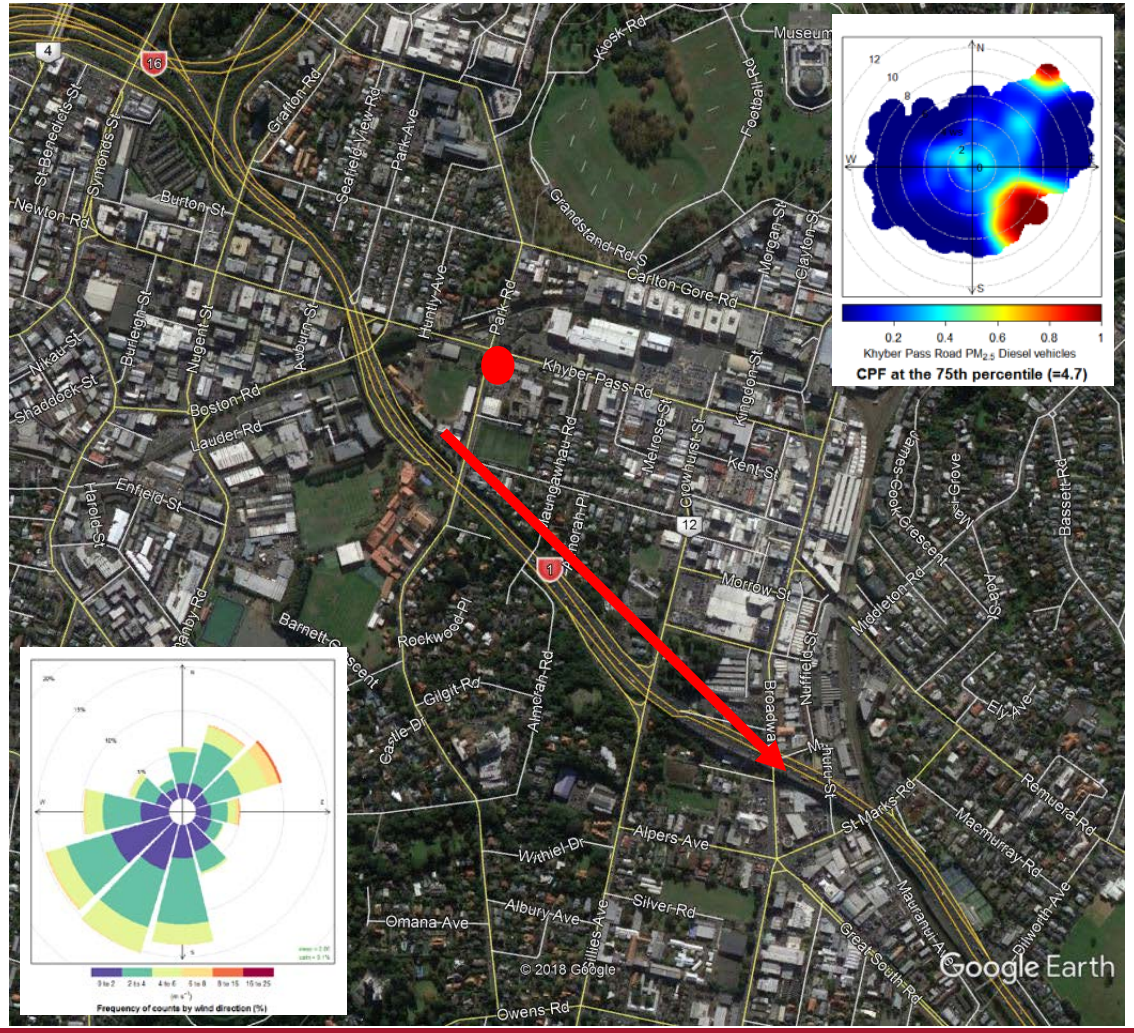
- **Contributions to PM are location dependent**
  - Proximity to road
  - Vehicle size, number, speed
  - Road surface type
- **Multiple components**
  - Brake wear (Fe, Cu, Zn, Ba, Sb, Ni….)
  - Tyre wear (Zn, S, BC)
  - Road surface wear (Al, Si, Ca…)
  - Deposited material from other sources
- **Electric vehicles will not reduce road dust component**





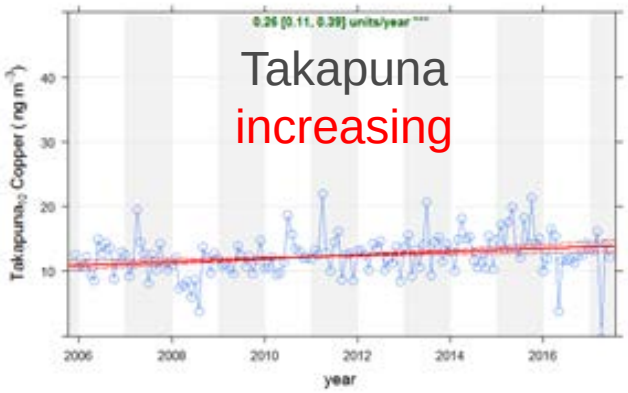
Impact zones of PM from motor vehicles – Khyber Pass road example

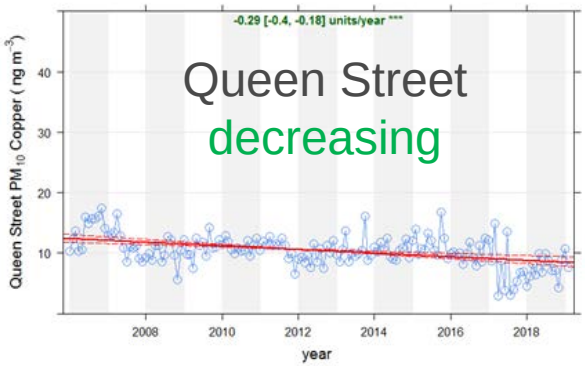
- Highest concentrations aligned with centreline of motorway (South East ‘fetch’ 20km+)

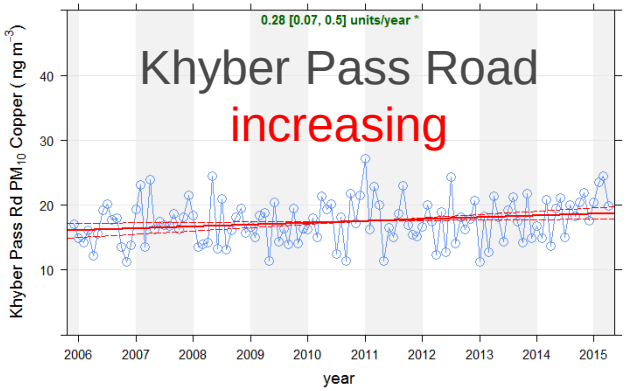


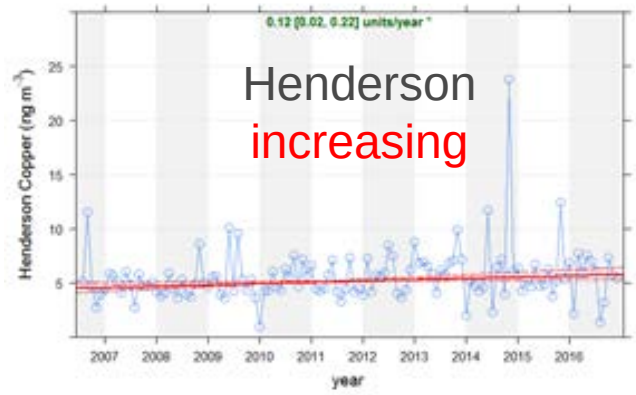
Transport source trends - PM_{10} brake dust copper

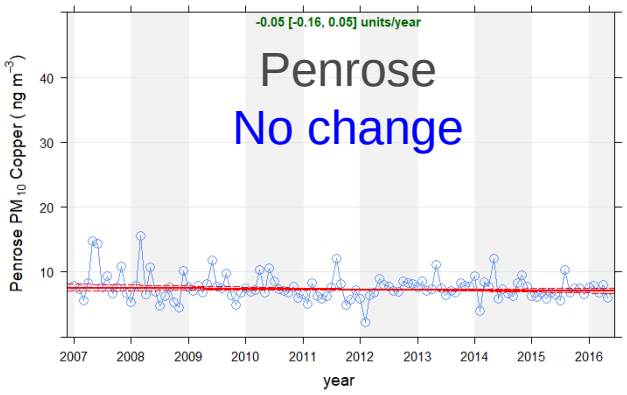
- Reflect road dust component and traffic volumes
- Also implications for deposition and water runoff
- Impact may change with brake pad composition (e.g. asbestos)







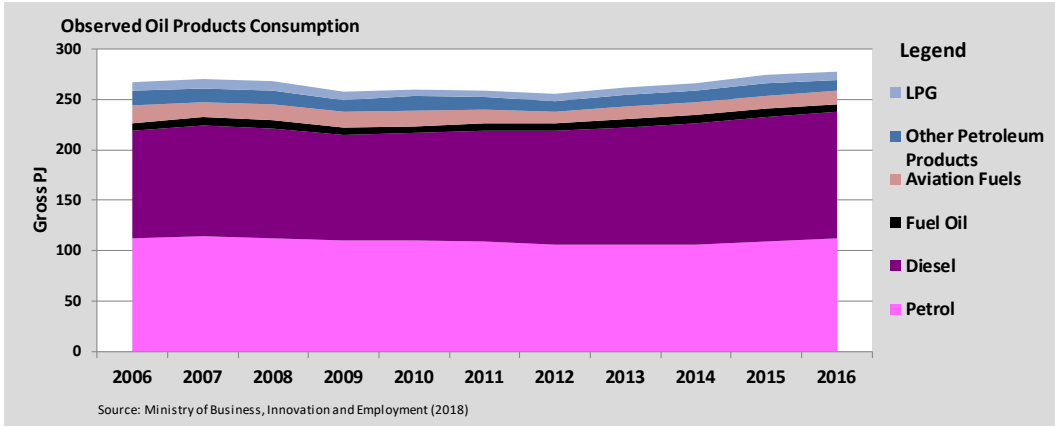


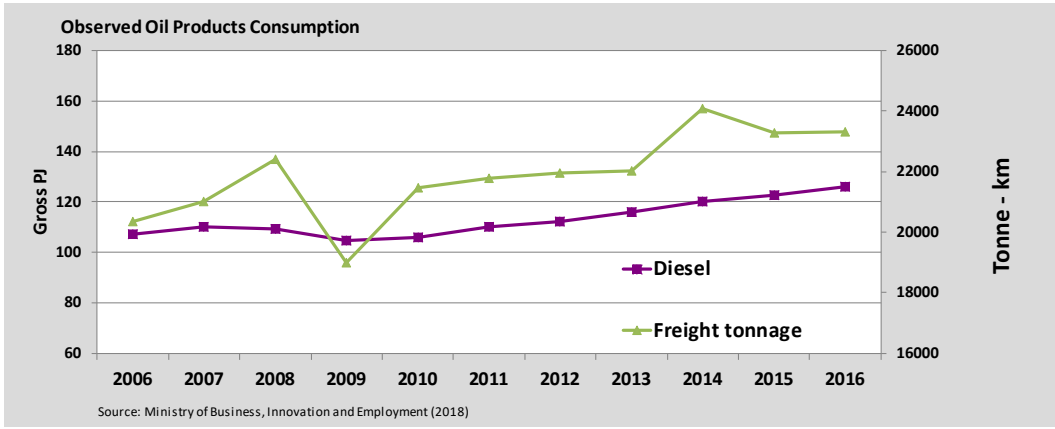


Transport activity trends (Fuel consumption)

Domestic land transport data

- Diesel fuel consumption rising
  - Engine improvements offset **PM** emissions from more fuel use
  - (check whether this includes off-road consumption?)
- Petrol consumption flat
  - vehicle numbers increasing (fuel efficiency gains)
- HCV freight (tonne-km) increasing (note 15% dip at 2008-2009)

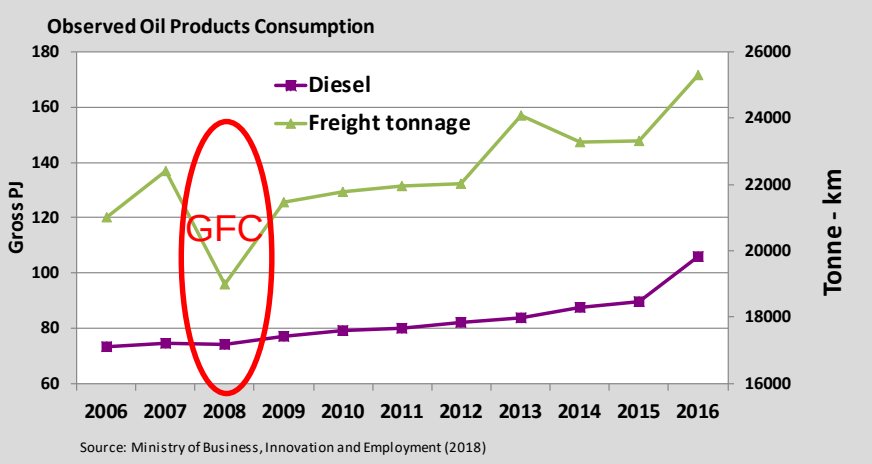




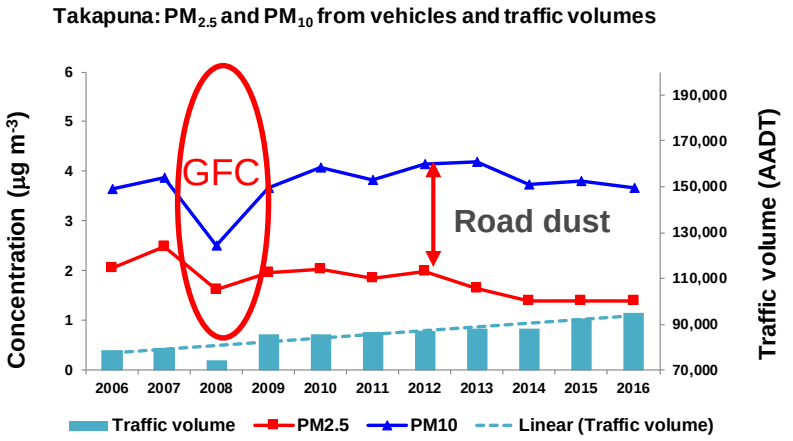
Trends in PM contributions and traffic volumes

	Penrose	Takapuna
Motor vehicle $PM_{2.5}$	↓	—
Traffic volume	—	↑
Motor vehicle PM_{10}	↓	↑

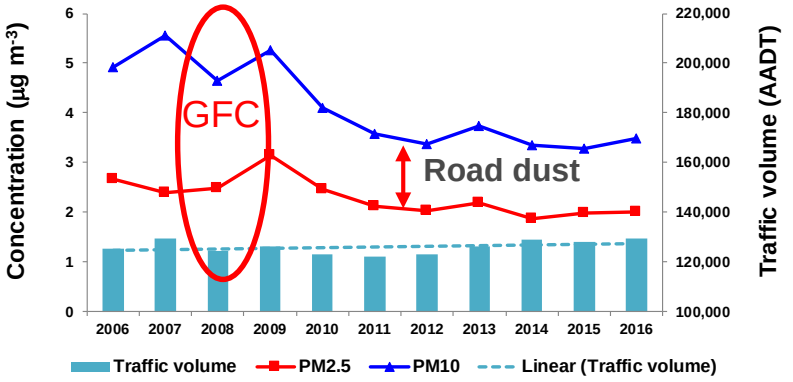
- Emissions improvements offset by local traffic volume increase
- Macro-economic effect: **G**lobal **F**inancial **C**risis



Takapuna

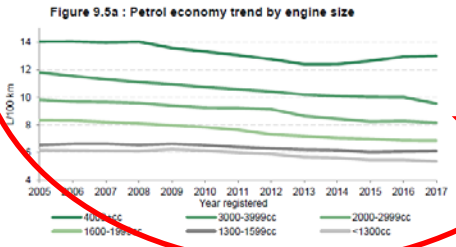


Penrose



Sector Air Quality Impacts – Transport metrics

Fuel economy/efficiency (L/100km) – Success!



Fleet size and composition (diesel/petrol) - Challenge

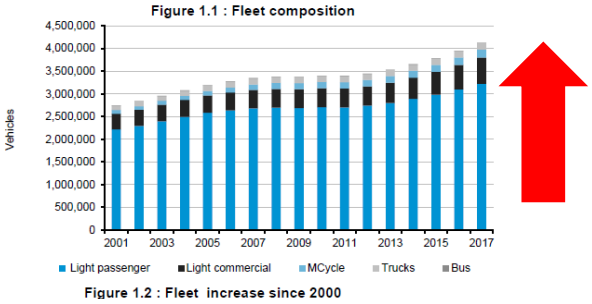
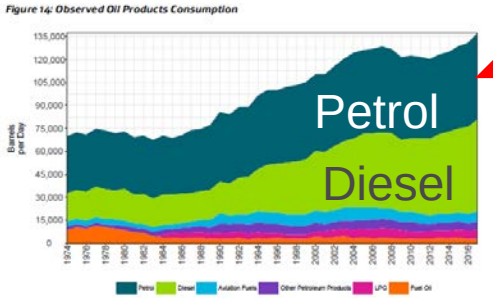


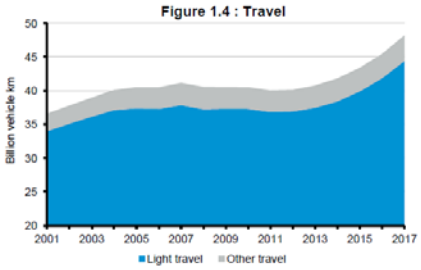
Figure 1.2 : Fleet increase since 2000

Fuel consumption - Challenge

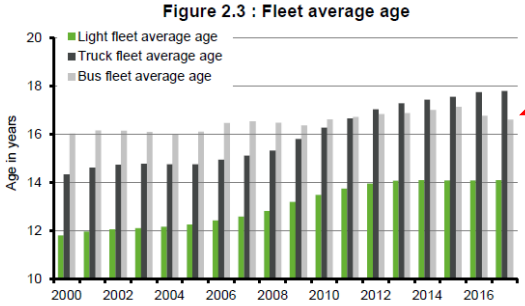


Petroleum Products Specifications Amendment Regulations 2007
Success!

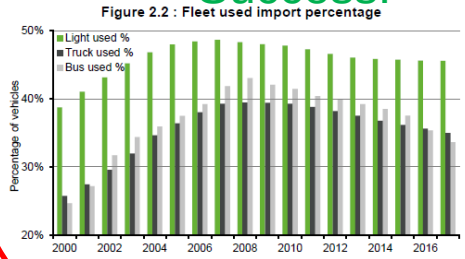
Vehicle kilometres travelled - Challenge



Fleet age - Challenge



NZ new or used import – Success!



Land Transport Rule 2007 Vehicle Exhaust Emissions

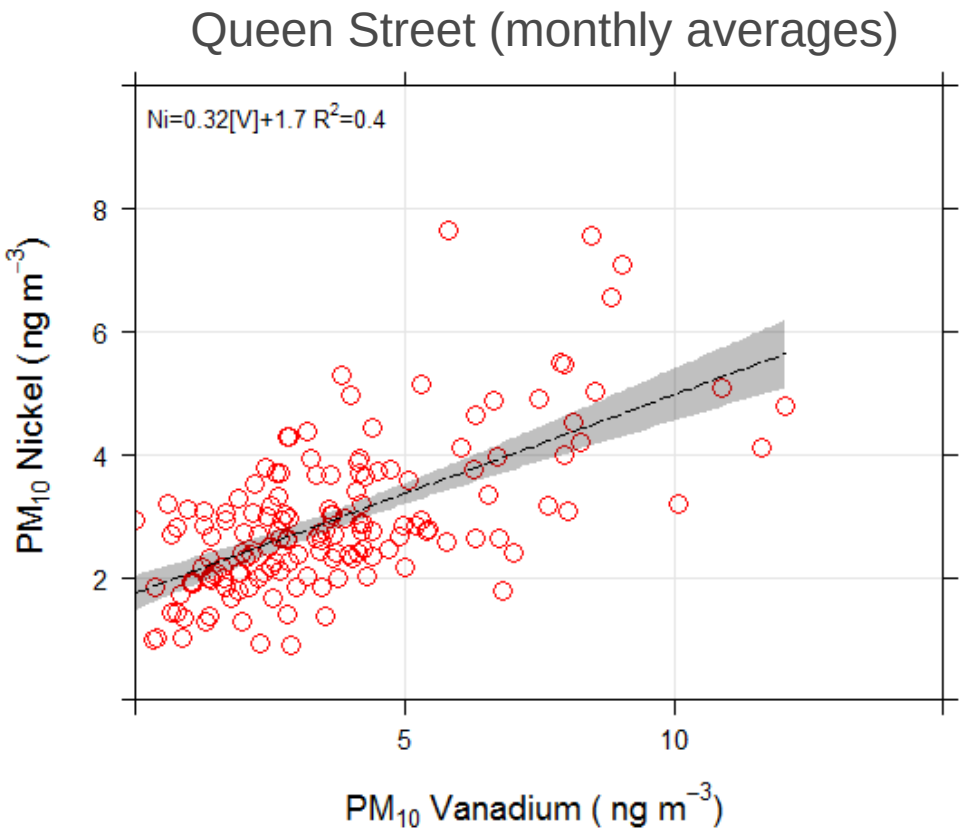
Motor vehicle tailpipe PM emissions Success!

but

Motor vehicle tailpipe gas (CO_2, NO_x) and road dust emissions Challenge!

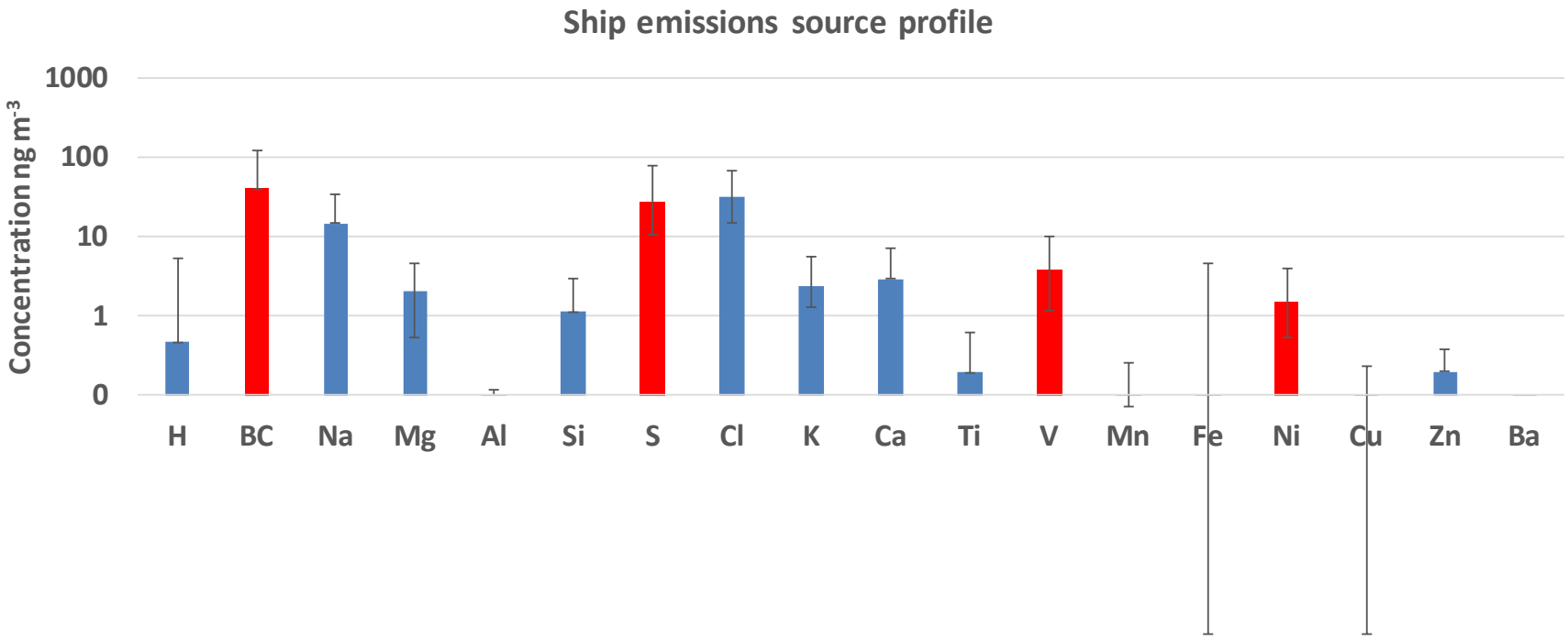
Direct PM emissions from ships engines

- Represent primary emissions from ships engines – this would also include acid sulphur species, PAHs etc
- Ratio of V/Ni measured at Queen Street site is 3:1 same as heavy fuel oils

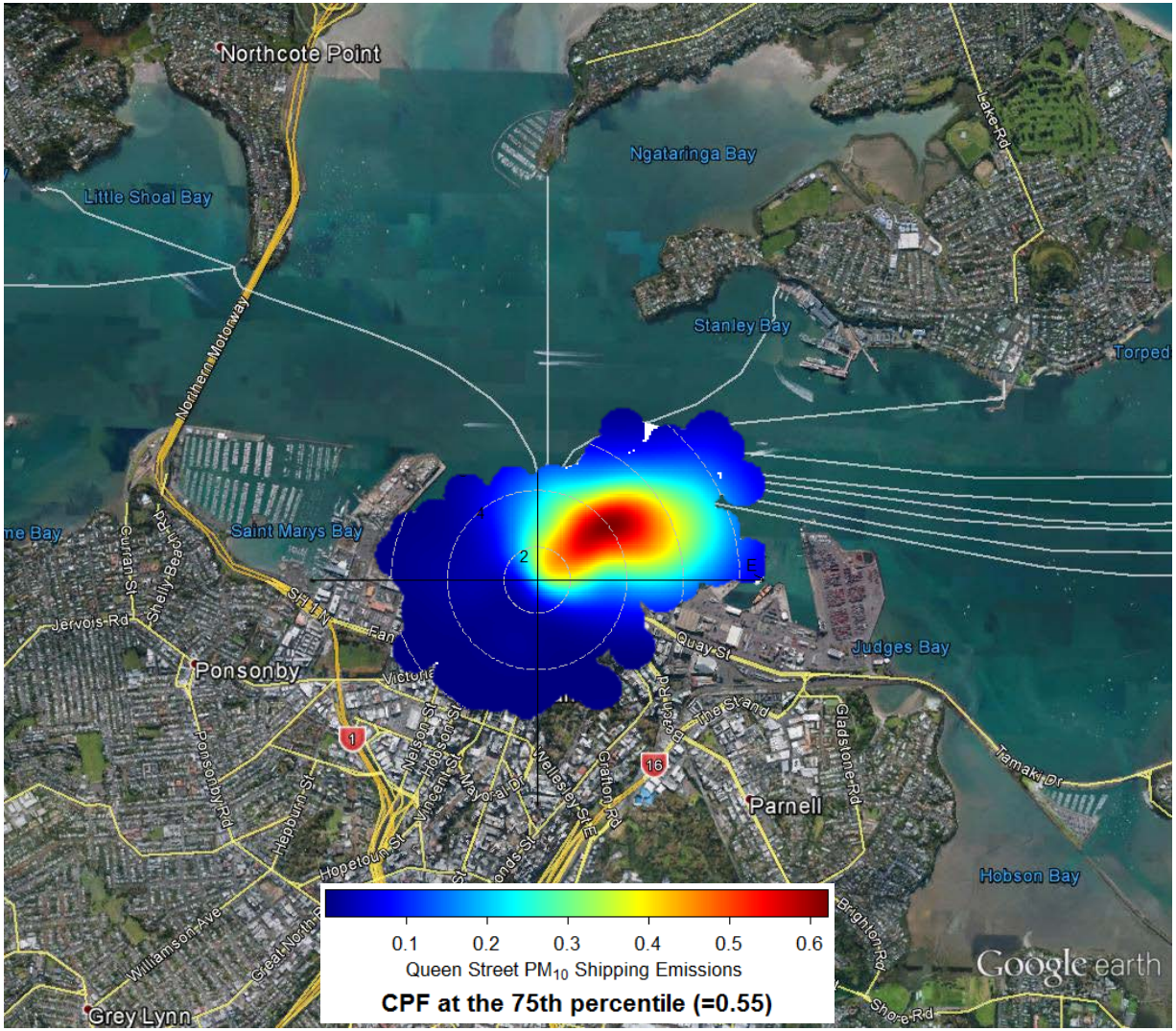


Direct PM emissions from ships engines

- Receptor modelling source elemental profile reflects the primary combustion product components (**BC, S, V, Ni**)
- Ratio of V/Ni is 3:1 same as heavy fuel oils

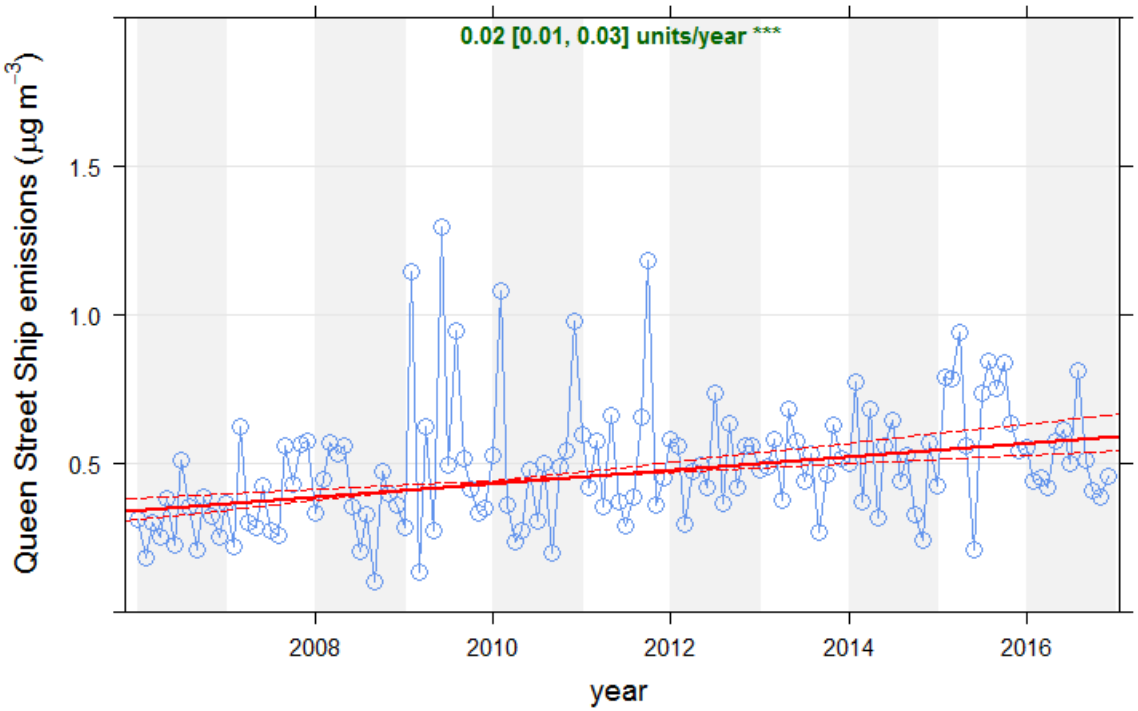


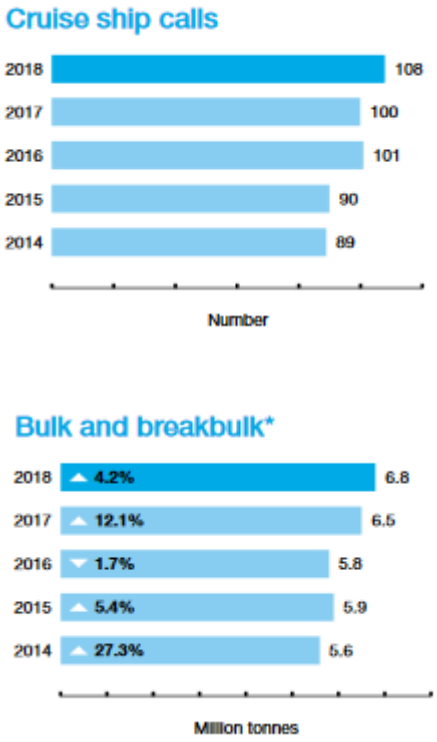
Queen Street CPF plot shows shipping source arrives at the site from the port area



Trends in Auckland ship emission contributions

- Concentrations derived from receptor modelling increasing (99.9 % CI) - reflects shipping activity at the port
- Main impact is on Auckland CBD





Ports of Auckland
Annual report 2018

Summary

- **Engine technology and regulation (fuel improvements, import emission standards) have had a significant downward effect on $PM_{2.5}$ …but traffic volume increases may offset this particularly for PM_{10}**
- **Differential impact on PM by motor vehicle type**
  - Diesel vs petrol
  - HCV vs light duty
- **Shipping impacts are increasing**

<u>Future work</u>

- **Combine PM source apportionment with transport metrics for robust statistics**
- **Signal processing of $PM_{2.5}$/PM_{10} data**