Clean Air and Urban Landscapes Hub

National Environmental Science Programme

CAUL Project 1, Milestone 30: PM2.5 LUR Model and Health Outcomes

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About the Clean Air and Urban Landscapes Hub

The Clean Air and Urban Landscapes Hub (CAUL) is a consortium of four universities: the University of Melbourne, RMIT University, the University of Western Australia and the University of Wollongong. The CAUL Hub is funded under the National Environmental Science Programme of the Australian Government's Department of the Environment. The task of the CAUL Hub is to undertake research to support environmental quality in our urban areas, especially in the areas of air quality, urban greening, liveability and biodiversity, and with a focus on applying research to develop practical solutions.

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Introduction

As part of CAUL Project 1, we have continued to work with the Centre for Air pollution, energy and health Research (CAR) to develop the PM2.5 LUR model and to investigate health outcomes in the NSW-based 45 and up cohort study. In particular we have worked with the following researchers from CAR: Dr Geoff Morgan, Dr Bin Jalaludin, Dr Christine Cowie, Dr Farhad Salimi, Dr Ivan Hanigan, Dr Luke Knibbs and Dr Margaret Rolfe.

Validation of PM2.5 LUR for Australia and Western Sydney

This project is being led by Dr Luke Knibbs who is developing the model for $PM_{2.5}$ (2006-present) using similar methods to Global Burden of Disease approach. [1][2] Dr Knibbs has previously developed an Australia wide LUR for NO2 using similar methods. The model uses multiple satellite sources of aerosol optical depth (AOD) combined with local calibration factors from ground-based sun photometer networks, in addition to LIDAR-observed aerosol scattering profiles and tropospheric column-to-surface scaling ratios from chemical transport model simulations (WRF-CHEM). This approach aims to reduce uncertainty with estimating $PM_{2.5}$ from space due to Australia's highly variable land surface conditions and aerosol sources by combining AOD with traditional local-scale LUR predictors to capture maximum spatio-temporal variability in measured $PM_{2.5}$, following the NO2 approach.

All data has been obtained and model fitting is currently in progress by a statistician at UQ. Validation of the model with be undertaken using hold-out and 5-fold cross validation. Campaign PM2.5 Data from Perth and Western Sydney will be used as an external validation dataset.

We expect the PM2.5 LUR work will be completed by March 2018 and a related validation paper to be submitted by June 2018.

Blending of Fixed site, Satellite PM2.5 LUR and CTM exposure data

This project is being led by Drs. Ivan Hanigan and Geoff Morgan and will further develop the methods applied to NO2 and published in 2017: Hanigan IC, Williamson GJ, Knibbs LD, Horsley J, Rolfe MI, Cope A, Barnett AG, Cowie CT, Heyworth JS, Jalaludin B, Serre M, Morgan GG. 2017 Blending Multiple Nitrogen Dioxide Data Sources for Neighborhood Estimates of Long-Term Exposure for Health Research. Environmental Science and Technology; 51(21):12473-12480. doi: 10.1021/acs.est.7b03035. Epub 2017 Oct 10.

A Bayesian maximum entropy approach was used to blend NO2 data from fixed-site monitors, chemical transport models, and satellite-based land use regression models to estimate neighbourhood annual average NO2. The spatial model produced a posterior probability density function of estimated annual average concentrations that spanned an order

of magnitude from 3 to 35 ppb. These estimates will be used in studies of health effects and should minimize misclassification bias.

This research was also presented at the ISEE2017 conference (Sydney). The abstract entitled, 'Bayesian blending of nitrogen dioxide air pollution data for neighbourhood estimates for health research,', was selected as the winner for the Asia, Africa, Latin America/Caribbean and Oceania region in the ISEE Students and New Researchers Network (SNRN) New Investigator Abstract Competition.

In 2018 these methods will be applied to blending data from measured and LUR modelled PM2.5. A sub analysis for western Sydney will be conducted for both NO2 and PM2.5

A manuscript describing this work has been published:

Long-term Exposure to Low Concentration Air Pollution and Respiratory Hospitalisations

This project is being led by Farhad Salimi and Geoff Morgan. Using the NSW 45 and Up cohort study the relationship between air pollution and asthma hospitalisations was investigated. This study was restricted to the 100,084 participants residing in the Sydney Metropolitan Region and this cohort was linked to hospital admissions data for respiratory illness from 1 July 2001 to 30 June 2014. NO_2 and $PM_{2.5}$ concentrations were estimated at the baseline residential addresses of participants using a land use regression model, and a chemical transport model blended with fixed site monitor data respectively. Cox proportional hazard models were used to assess the associations between hospital admission for respiratory diseases and exposure to air pollution while adjusting for gender, smoking status and education.

Evidence of an association between long-term exposure to NO_2 and $PM_{2.5}$ with hospitalisation for asthma in Sydney, where the annual concentrations were well below the current air quality standards, was found. Dr Salimi is currently undertaking a sub-analyses restricted to the cohort residing in Western Sydney.

A manuscript of this work (Long-term Exposure to Low Concentration Air Pollution and Hospitalisation for Asthma: Prospective Cohort Study, Farhad Salimi, Geoff Morgan, Margaret Rolfe, Evangelia Samoli, Christine Cowie, Ivan Hanigan, Luke Knibbs, Martin Cope, Fay Johnston, Yuming Guo, Guy Marks, Jane Heyworth, Bin Jalaludin) has been drafted and it is expected to be submitted early in the new year.

This research was presented at ISEE2017, Sydney and the abstract, Long-term exposure to low concentration air pollution and hospitalisation for respiratory diseases: a cohort study Farhad Salimi et al, will be published the journal Environmental Health Perspectives.

References

[1] Brauer et al., *Environ Sci Technol* 2016;50:79-88

[2] van Donkelaar et al., *Environ Sci Technol* 2016;50:376

APPENDICES

Abstract 1:

Bayesian blending of nitrogen dioxide air pollution data for neighbourhood estimates for health research

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Background/Aim
Exposure to nitrogen dioxide (NO2) pollution has been associated with a range of adverse health outcomes. Annual average pollutant concentrations are often used to estimate exposure, however, these estimates can be imprecise due to difficulty modelling spatial patterns at the resolution of neighbourhoods (e.g. a scale of tens of metres) rather than at a coarse scale (around several kilometres resolution). The objective of this study was to derive improved estimates of neighbourhood level pollutant concentrations for health studies by blending air pollutant measurements with modelled predictions using Bayesian analyses.
Methods
We implemented the Bayesian Maximum Entropy (BME) approach to blend 'hard' data (considered precise) and probabilistic 'soft' data (with uncertainty defined using informative priors). We compiled and harmonised NO2 data from fixed-site monitors, chemical transport models, and satellite-based land use regression models to estimate neighbourhood level

annual average NO2 concentrations in Sydney, Australia. The spatial model integrated the different underlying probabilities to produce a posterior probability density function of neighbourhood exposures. The mean of the posterior density was our estimate of NO2 exposure.

Results

Estimated annual average concentrations from the BME model ranged from 3 to 35 ppb. Validation using independent data from a separate set of samples (using passive sampling methods) showed improvement, with Root Mean Squared Error (RMSE) of 2.6 ppb compared with the land use regression (2.8 ppb) and chemical transport model (3.1 ppb).

Conclusions

Our study implemented state-of-the-art methods for exposure assessment and demonstrated an improvement in validation test statistics. In future work we will explore the impact of these improvements on exposure misclassification bias when used in epidemiological analyses of the impact of air pollution on health.

ABSTRACT 2:

Long-term exposure to low concentration air pollution and hospitalisation for respiratory diseases: a cohort study

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Introduction: Time series studies have found short-term relationship between exposure to ambient air pollution and hospital admission for respiratory conditions. The associations between long term exposure to air pollution and hospital admissions, however, are inconsistent, particularly for areas with low concentration air pollution.

Methods: The 45 and Up cohort study includes 267,153 participants [aged 45 years and above at baseline (2006 –2009)] from the state of New South Wales, Australia. This study was limited to the 100,084 participants residing in the Sydney Metropolitan Region. The cohort was linked to hospital admissions data from 1 July 2001 to 30 June 2014. The first respiratory hospital admission between baseline and 30 June 2014 was defined as the main outcome. NO2 and PM2.5 concentrations were estimated at the baseline residential addresses of participants using a land use regression model, and a chemical transport model blended with fixed site monitor data respectively. Cox proportional hazard models were used to assess the associations between hospital admission for respiratory diseases and exposure to air pollution while adjusting for gender, smoking status and education.

Results: The median estimated NO2 and PM2.5 levels were 9.2 ppb and 4.5 µg.m-3 respectively. PM2.5 concentrations were associated with risk of hospitalisation for respiratory diseases in participants aged between 45 to 60 years at enrolment (HR and 95% CI per 1 µg.m-3: 1.14; 1.03 – 1.27), while no such associations were observed in the same age group with NO2 (HR and 95% CI per 1 ppb: 1.00; 0.97 – 1.03).

Conclusions: Exacerbations of respiratory disease are associated with long-term exposure to relatively low air pollution levels. Long-term exposure to air pollution was associated with increased risk of hospitalisation in a relatively younger age group of a large Australian cohort of adults.