Air Pollution in Megacities: Advances in Monitoring and Modelling

University of Leeds: NCAS Building, Fairburn House

Wednesday 20th March 2019, 10.30 am

Poor ambient air quality is a global health concern affecting all industrialised nations and virtually all of society. It is characterised by harmful surface levels of particulates, ozone and nitrogen oxides, for which epidemiological evidence links chronic and acute exposure to increased morbidity. Worldwide, ~3 million deaths are attributable to air pollution each year according to the WHO, with ~40,000 premature deaths in the UK alone (Royal College of Physicians). Compounded by population growth and urbanisation, air pollution exposure is prevalent in most megacities, especially in developing nations, where rapid economic expansion has been an additional stressor on pollutant emissions, but where effective monitoring infrastructure is limited. Here, we will discuss advances in the monitoring and modelling of air pollution in megacities and consider challenges ahead.

Please bring any atmospheric chemistry posters for presentation during lunch & wine reception. Best early career poster prize sponsored by Air Monitors.

Organisers: Dr Ruth Purvis (Univ. of York) and Dr Ryan Hossaini (Lancaster Univ.)

10.30	***Arrival with tea/coffee***	
11.15	**Welcome and introduction**	**Dr Ruth Purvis**
11.20	**Investigating the sources and impacts of air pollution in Asian megacities**	**Dr Jacqueline Hamilton** University of York
11.45	**Assessing New Delhi's vehicle emissions using remote sensing techniques**	**Prof James Lee** University of York
12.10	**Personal air pollution exposure assessment of rural and urban residents in Beijing**	**Dr Lia Chatzidiakou** University of Cambridge
12.35	**Direct measurements of pollutant emissions above megacities**	**Dr Eiko Nemitz** Centre for Ecology & Hydrology (CEH)
13.00	***Lunch (provided) + posters***	
14.30	**Photochemical impacts of haze pollution in a Megacity**	**Dr Michael Hollaway** CEH/Lancaster University
14.55	**High-resolution WRF-Chem modelling of Beijing during APEC controls: investigating temporal, regional and sectoral contributions**	**Dr Tabish Ansari** Lancaster University
15.20	**Ambient air quality and human health in India**	**Dr Luke Conibear** University of Leeds
15.45	**Challenges and Opportunities Monitoring Air Quality in Africa Using Satellite Observations**	**Dr Eloise Marais** University of Leicester
16.10	***Wine reception + posters***	
17.15	***Meeting closes***	

#RMetSMeet

ABSTRACTS

Investigating the sources and impacts of air pollution in Asian megacities
Dr Jacqui Hamilton, University of York

Abstract: Exposure to poor air quality is the top environmental risk factor of premature mortality globally with an estimated 4 million premature deaths in 2015 from long-term exposure to current levels. Coronary heart disease and strokes are the most common reasons for premature deaths due to air pollution, with other impacts including increases in respiratory and cardiovascular diseases and cancer. The most damaging air pollutant to health is particulate matter (PM). The International Agency for Cancer Research (IARC) has recently classified air pollution as a known carcinogen (group 1), with particle pollution being most closely associated with increased cancer rates. The very high levels of particulate matter experienced in Asian megacities, such as Beijing in China and Delhi in India, have been widely publicized in the news and Governments are taking action to improve air quality. The Air Pollution and Human Health in a Developing Megacity program, is a collaboration between NERC, the Medical Research Council, Natural Science Foundation of China (NSFC) in China, and the Ministry of Earth Sciences (MoES) and Department of Biotechnology (DBT) in India. This talk will introduce the program objectives and highlight some of the initial findings. In both locations, ozone and particulate matter concentrations were found to exceed threshold values, providing an opportunity to study emission sources and the impact of local and regional chemistry on air quality in a polluted megacity.

Assessing New Delhi's vehicle emissions using remote sensing techniques
Prof James Lee, University of York

Abstract: Understanding how vehicles emit pollution under 'real-world' drive conditions, is crucial if correct legislative policies are to improve air quality, in megacities such as New Delhi. Presented here are remote sensing measurements, obtained during the DelhiFLUX field campaign, focused on assessing New Delhi's fleet characteristics. The University of Denver's Fuel Efficiency Automobile Test (FEAT) instrument gives a direct spectroscopic assessment of key atmospheric pollutants (NO2, NO, NH3, CO, CO2, SO2 & HCs) emitted from a vehicle under 'real-world' driving conditions. Hundreds of unique vehicles were assessed during the campaign, giving an in-depth characterisation of emissions across the vehicle fleet (e.g. passenger cars, taxis, vans and HGVs). Average tailpipe NOx emissions were found to be a factor of two lower than vehicles measured in London during a similar study in 2018. CO and total hydrocarbons (HCs) emissions, on the other hand, were found to be scientifically higher in New Delhi. By understanding which vehicles contribute most to overall emissions, better controls can be put in place to directly target these vehicles to reduce their impact on the cities air quality.

Personal air pollution exposure assessment of rural and urban residents in Beijing
Dr Lia Chatzidiakou and the AIRLESS team, University of Cambridge

Abstract: Large-scale population studies have associated exposure to air pollution with cardiovascular and lung diseases, which are the primary causes of mortality and morbidity in the developed world, and their rates are accelerating rapidly across the developing nations. However, those large-scale epidemiological cohorts employ outdoor air quality measurements with low spatial and temporal resolution that do not capture the high granularity of total personal exposure. As a result, exposure misclassification of air pollution remains the biggest limitation of epidemiological research preventing the discipline to move from general associations to specific ones introducing both bias and error in health estimations. Taking advantage of rapid advancements in air pollution sensing technologies, highly portable air pollution monitors were deployed in a cardio-pulmonary cohort of 250 participants residing in urban and peri-urban Beijing. Thanks to their significantly reduced costs, smaller size and fast-response, the monitors can increase personal exposure data coverage in space, time, and pollutant type with a much higher degree of fidelity than was previously possible. The high portability and accuracy of operation of the personal monitors can revolutionise epidemiological research by providing exposure metrics at the population scale to investigate the underlying mechanisms of the effects of air pollution on health.

Direct measurements of pollutant emissions above megacities
Dr Eiko Nemitz, Centre for Ecology and Hydrology (CEH), Edinburgh

Abstract: Predictions of air quality and air pollution impacts typically rely on numerical atmospheric chemistry and transport models. The performance of such model is never better than the underlying estimates of the emissions. Diffuse sources such as represented by urban megacity areas are usually estimated through bottom-up emission inventories, where activity figures (e.g. vehicle kilometres driven in each 1 km^2 grid cell) are combined with emission factors (e.g.: grams of NO_2 emitted per vehicle kilometre driven), which are often derived under non-representative (laboratory) conditions. As a result, emission inventories are subject to considerable uncertainty.

Independent verification of such emission inventories is difficult and usually done indirectly by assessing how well the models reproduce measured concentrations using a given estimate of emissions. This relies on good model performance and an accurate characterisation of background concentrations.

Instead, the work presented here uses micrometeorological flux measurement techniques, more commonly applied to measure the pollutant exchange with vegetation, to quantify directly the vertical flux above the city. Fast-response chemical sensors are mounted on city towers to derive fluxes, which, depending on the measurement height, integrate the emissions over several km^2.

This talk will introduce the concept and introduce examples of flux measurements of a range of pollutants (including greenhouse gases, aerosols, NH3, VOCs, CO, O_3, …) from London, Beijing and Delhi, together with some of the sometimes surprising results.

Photochemical impacts of haze pollution in a Megacity
Dr Michael Hollaway, CEH / Lancaster University

Abstract: Rapid economic growth in China has resulted in significant increases in aerosol concentrations which in addition to health problems can impact visibility resulting in potential implications for photochemistry. This work uses combinations of aerosol composition data and lidar optical depth from 2 intensive field campaigns in Beijing (winter 2016/summer 2017) to drive the Fast-JX photolysis model. Severe haze pollution events occur during both winter and summer leading to reductions in O_3 photolysis rates of 27.4--34.0% (greatest in winter) and reductions in NO_2 photolysis of 40.4--66.2% (greatest in summer) at the surface. Despite lower PM2.5 concentrations in the summer months, absolute changes in photolysis rates are larger for both O_3 and NO_2. In winter absorbing species such as BC dominate the photolysis response to aerosols leading to mean reductions of 23.8% and 23.1% respectively for J[O1D] and J[NO_2]. In contrast in the summer, scattering aerosol such as organic matter dominate the response leading to mean decreases of 2.0--3.0% at the surface and increases of 8.4--10.1% at higher altitudes (3--4 km). Finally, during these haze events in both campaigns, the feedback of aerosol on photolysis rates dominates over those from clouds.

High-resolution WRF-Chem modelling of Beijing during APEC controls: investigating temporal, regional and sectoral contributions
Dr Tabish Ansari, Lancaster University

We investigate the contributions of major local and regional emission sources to air quality in Beijing to inform short-term emission controls aimed at mitigating major pollution episodes. We use the WRF-Chem model at 3 km horizontal resolution, demonstrating that it captures the magnitude and variability of observed meteorological variables and pollutant concentrations. Considering the October-November 2014 period, we explore the temporal contribution of local and regional sources to air quality in Beijing under a wide range of meteorological conditions. We consider feasible reductions across industry, power, residential and transport sectors of 40-50% similar to those applied during the APEC summit period. We find that while the effect of local emission cuts is greatest (up to 38%) on the day of control, they can still have a small contribution (up to 8%) five days later under stagnant conditions. Controls in surrounding regions have greatest effect (up to 18%) on the second day but may have a negligible effect on clean days when local emissions dominate. To determine the effect of different emission sectors and regions, we consider the four main emission sectors over local (Beijing), near-neighbourhood (Hebei) and far-neighbourhood (North China) regions. We use simple one-at-a-time sensitivity studies to identify the regional and sectoral contributions over a 10-day period that encompasses a range of differing

meteorological conditions. A glimpse into the future work of applying a novel Gaussian Process Emulation approach to build pollutant response surfaces over this period will also be presented.

Ambient air quality and human health in India
Dr Luke Conibear, University of Leeds

Abstract: One-quarter of the global health burden from air pollution exposure is in India where 1 in 6 people die from exposure to poor air quality. 14 out of 15 of the world's most polluted cities are in India and air quality is predicted to worsen there in the future. Despite this, Indian air quality is understudied and our knowledge of the sources causing air pollution here is limited. In this talk, I discuss the current contributing sources to poor air in India and explore possible future scenarios in order to inform effective policies to reduce the huge disease burden.

Challenges and Opportunities Monitoring Air Quality in Africa Using Satellite Observations
Dr Eloise Marais, University of Leicester

Abstract: The number of people living in Africa will rival that in Asia by 2100 and this growth will inevitably worsen air quality on the continent. The majority of the population relies on inefficient energy sources and the continent is yet to experience an industrial revolution. Ground-based observations of air quality are exceedingly rare and there are few incentives and resources to establish an extensive monitoring network. Satellite observations of the atmosphere offer tremendous opportunity to monitor and better understand atmospheric composition, atmospheric chemistry, and air quality in Africa. In this talk, I will share the research underway in my group to obtain precious insights into air pollution and build capacity in Africa to use long-term observations from the NASA Ozone Monitoring Instrument and high-resolution observations from the recently launched ESA Sentinel-5P Tropospheric Monitoring Instrument (TROPOMI) in combination with chemical transport models to determine the consequences of air pollution in Africa on health and the environment.
