Quantifying the role of the transport sector on observed variations of PM2.5 over the National Capital Territory of Delhi, India. [Industry funded]

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Project Background The World Health Organization (WHO) recently announced that particulate matter (PM) now affects more people than any other pollutant. Here, we focus on PM less than 2.5 microns in diameter (PM2.5) as they pose a greater risk to human health via respiratory and cardiovascular diseases. We focus on Delhi, India for three main reasons: 1) according to the WHO it is the most polluted megacity in the world with annual median PM2.5 values typically exceeding 100 micrograms/m3 (cf annual median of 5 micrograms/m3 Edinburgh, UK, 2015), 2) the transportation sector is one of the largest sources (~30%) of PM2.5 in Delhi, and 3) we can take advantage of a new UK-India measurement programme, the scope of which is currently being finalized. Working in Delhi presents numerous scientific challenges not least because of its mix of biogenic, anthropogenic, and pyrogenic gases and particles, high temperatures, and high level of NOx.

PM2.5 consists of complex mixture of organic and inorganic compounds. Inorganic compounds are relatively few in number, including sulfate, nitrate, ammonium, elemental carbon, and some trace metals from a variety of combustion, construction, and agricultural sources. The organic component of PM2.5 can include thousands of organic compounds and typically represents 20-50% of PM2.5. Organic aerosol (OA) can also be split into primary and secondary sources. The origins and formation mechanisms of fresh primary and secondary OA result in them having different chemical and microphysical properties (e.g., hygroscopicity). Primary organic aerosol (POA) denotes directly emitted material, including vehicle exhaust, cooking, and biomass burning. Recent laboratory studies have shown that POA remains semi-volatile and undergoes gas-particle conversions as function of volatility, ambient OA concentrations, temperature and nitrogen oxides (NOx). Secondary organic aerosol (SOA) describes the gas-particle conversion of oxidized trace gases that result in low volatility oxidation products. These precursor gases can also include semivolatile and intermediate volatile organic compounds. Here, we use a model tool that accounts for these effects, guided by available experimental constraints, to describe the aging of OA aerosol on urban spatial scales.

Key research questions

1) What is the relative importance of physical and chemical processes in describing observed variability of surface PM2.5 over Delhi?
2) How important is the transport sector on the distribution of surface-level PM2.5 over Delhi?
3) [If time] Are the associated atmospheric scales of variability of PM2.5 components appropriate to observe from space-based instruments?

Methodology

The volatility basis set (VBS) model is a well-established approach, developed primarily by colleagues at Carnegie Mellon University, for describing the aging of PM2.5, which scientific groups are still developing as more laboratory and field data become available. VBS describes OA as a series of saturation mass concentrations successively separated by an order of magnitude (e.g., 0.1, 1.0, 10.0... micrograms/m3) with less volatile material associated with smaller saturation mass concentrations. By using this approach both POA and SOA are assumed to be semi-volatile and photochemically reactive. We will use a 2-D version of the VBS approach that also includes the oxygen content (O:C) as the second dimension as a way to describe the OA composition. The most recent version of the 2-D VBS model, freely available in the MATLAB programming language, includes the effect of NOx on the formation of aerosol formation and will be the starting point for this project. We will translate this 2-D VBS model into Fortran and integrate it with an existing comprehensive multi-phase atmospheric box model, CAABA/MECCA. The resulting model will be numerically integrated along pre-calculated trajectories from a Lagrangian atmospheric dispersion model, driven by scene dependent meteorological fields and emissions. The model will be used to generate forward trajectories to map out PM2.5 across Delhi and assess the sensitivity of results to different assumptions about emissions and atmospheric chemistry. We will run the model using climatological environmental conditions indicative of Delhi during different seasons of the year (e.g., emissions, temperature, precipitation). We will also consider conditions that are more indicative of anomalous conditions, e.g. heatwaves.

Training As part of the E3 DTP and via the supervisory team you will receive a comprehensive training programme that includes specialist scientific training and generic transferable and professional skills. Specialist training will include: (1) atmospheric chemistry, and (2) computer modelling for simulating global 3-D atmospheric chemistry.

Requirements The successful candidate will have a degree in the physical sciences and most likely physics, chemistry, or applied mathematics. This is a computational project: no prior computing experience is necessary but some knowledge of coding would be useful (e.g., Python and Fortran).

Further reading or any references referred to in the proposal

- Description of 2-D VBS model: doi:10.5194/acp-11-3303-2011
- Example application of VBS over China, doi:10.1038/srep28815
- Overview of Delhi pollution: doi:10.1038/534166a
- Real time Delhi air pollution: http://aqicn.org/city/delhi/

A project summary

Development of a high-resolution atmospheric chemistry model to understand the role of the transport sector in determining observed variations of surface PM2.5 over Delhi, India.