Joining the data dots with spatial interpolation

Based on a growing number of medical studies, exposure to fine airborne particles ≤ 2.5µm in diameter (PM$_{2.5}$) is increasingly being associated with adverse human health effects including premature deaths, hospital and emergency admissions, asthma and cardiovascular disease. Particles of this size, approximately 50 times smaller than the diameter of a human hair, are essentially invisible to the eye but can enter our blood stream by inhalation through our nose, throat and lungs which are ineffective at filtering them out. These fine particles can be produced by natural sources such as wind-blown soil and sea spray or generated from man-made combustion sources such as industry, automobiles, domestic fuel-burning heaters or coal fired power stations. So determining the composition, sources and concentration of fine particles that a population is exposed to is of increasingly significant importance for governments and environmental regulators for pollution management.

The aerosol sampling program (ASP) group at ANSTO have been routinely collecting 24-hour PM$_{2.5}$ samples every Wednesday and Sunday at a number of sites located around the greater Sydney basin of NSW, Australia since the 1990’s; from the Wollongong region in the south, through Sydney to the Newcastle and Muswellbrook regions in the north. The greater Sydney basin is home to a significant portion of the Australian population, close to 5 million people, or approximately one quarter of the Australian population.

The twice-weekly collected samples from each of our sites are analysed with ANSTO’s accelerator-based Ion Beam Analysis (IBA) techniques to determine the concentration of 21 key elements, from hydrogen to lead, commonly present in PM$_{2.5}$ aerosols. These IBA techniques are very sensitive and capable of measuring concentration levels as low as one nano-gram (one thousand-millionth of a gram) in one cubic metre of sampled air. The significant advantages of IBA is that this multi-elemental analysis can be accomplished with little or no sample preparation, non-destructively and only requiring a few minutes to analyse each filter. Further details of ANSTO’s unique IBA techniques can be found on our website: [www.ansto.gov.au/iba](http://www.ansto.gov.au/iba).

The data from our sampling sites and analysis continues to be very useful for local councils, regulatory bodies and even private industries for monitoring and managing air pollution levels (some of which is available on our website: [www.ansto.gov.au/asp](http://www.ansto.gov.au/asp)). In fact, over the last 20 years we have sampled at over 90 different local and international locations resulting in a dataset of over 50,000 analysed aerosol filters. We are not aware of any other dataset of fine particle measurements in Australia that can compare both in consecutive years and number of sites. However, this database specifically relates to the various locations from where the samples were collected.
So in an effort to extend these individual site-localised results toward a larger more regional scale, encompassing neighbouring locations where physical sampling was not performed, we have attempted to apply a spatial interpolation technique known as ‘Kriging’ to generate PM$_{2.5}$ concentration maps.

**So what is spatial interpolation?**

Spatial interpolation is essentially the mathematical estimation of an unmeasured value at a location, based on the measured values obtained from surrounding locations. There are a number of interpolation algorithms available (inverse distance squared, spline, triangulation etc.) which can be used to estimate this unknown value as a weighted sum of data from surrounding values. Typically the weighting decreases as the separation distance of the unmeasured location from the surrounding locations increases. The Kriging algorithm assigns weights according to a weighting function that is slightly driven by the data, rather than an arbitrary function, but in most cases will give very similar results to other available interpolation algorithms. For this work, a boundary box was defined using Sydney (located at 151.2086E, 33.8683S) as the centre, and the spatial interpolation was then carried out over the region defined by that box. As only seven coastal sites were used for the interpolation, data outside of these sites were effectively obtained by extrapolation and caution should be used on data further than 100 km from any ASP site (marked as small black squares on the map).

As a preliminary study, Kriging spatial interpolation was applied to our monthly average data; both individual elemental concentrations as well as major sources concentrations such as soil, salt, and organics; from seven of our long-term PM$_{2.5}$ sites in the greater Sydney basin over the period January 2007 to December 2013. The sampling site data included Liverpool, Muswellbrook, Mascot, Richmond, Warrawong, Mayfield and Lucas Heights, the relative locations of which are shown in Figure 1.

The resulting contour maps, as seen in Figures 2 and 3, provide a good visual indication of both the spatial (km) and concentration (ng/m$^3$) distribution of PM$_{2.5}$ components in the greater Sydney basin. The maps also correlated well with expected seasonal and spatial variations. For example, higher potassium (Figure 2) and black carbon concentrations often associated with domestic wood burning for heating increased in the winter months with higher concentration in the inland locations around our Richmond and Liverpool site. On the other hand, salt typically associated with sea-spray was higher in summer and concentrated along the coast due to prevailing on-shore winds from the north east and south-east as seen in Figure 3.

While further work is required, possibly incorporating additional meteorological information, we think this is a promising first step to extract more information from what we believe is already both a unique and valuable database for fine particle research in Australia.