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Satellite-based monitoring of particulate matter pollution at very high resolution: the HOTBAR method

Robin Wilson, Edward Milton, and Joanna Nield
University of Southampton, Geography & Environment, United Kingdom (robin@rtwilson.com)

Particulate matter air pollution is a major health risk, and is responsible for millions of premature deaths each year. Concentrations tend to be highest in urban areas – particularly in the mega-cities of rapidly industrialising countries, where there are limited ground monitoring networks. Satellite-based monitoring has been used for many years to assess regional-scale trends in air quality, but currently available satellite products produce data at 1-10km resolution: too coarse to discern the small-scale patterns of sources and sinks seen in urban areas. Higher-resolution satellite products are required to provide accurate assessments of particulate matter concentrations in these areas, and to allow analysis of localised air quality effects on health.

The Haze Optimized Transform-based Aerosol Retrieval (HOTBAR) method is a novel method which provides estimates of PM2.5 concentrations from high-resolution (approximately 30m) satellite imagery. This method is designed to work over a wide range of land covers and performs well over the complex land-cover mosaic found in urban areas. It requires only standard visible and near-infrared data, making it applicable to a range of data from sensors such as Landsat, SPOT and Sentinel-2.

The method is based upon an extension of the Haze Optimized Transform (HOT), which was originally designed for assessing areas of thick haze in satellite imagery. This was done by calculating a 'haziness' value for each pixel in an image as the distance from a 'Clear Line' in feature space, defined by the high correlation between visible bands. Here, we adapt the HOT method and use it to estimate Aerosol Optical Thickness (a measure of the column-integrated haziness of the atmosphere) instead, from which PM2.5 concentrations can then be estimated. Significant extensions to the original HOT method include Monte Carlo estimation of the 'Clear Line', object-based correction for land cover, and estimation of AOT from the haziness values through radiative transfer modelling.

This novel method provides a 'step-change' in the level of detail which can be provided by satellite estimates of air pollution, and will enable a range of air quality research that has not been previously possible.