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Radon-222, a proxy for vertical mixing of emissions in the urban nocturnal boundary layer

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There has been growing concern in recent decades regarding the health implications of fine particles ($\leq 2.5\mu$m), which are readily deposited deep within the lungs. In the interests of public health, and improving the predictive ability of Chemical Transport Models, it is imperative to improve our understanding of the diurnal variability of primary pollutant and precursor concentrations by, among others, improving our understanding of the underlying physics of transport and mixing processes. From the time of their release until they are removed from the atmosphere, the level of public exposure to emissions is closely related to rates of near-surface horizontal and vertical dispersion, the depth of the atmospheric boundary layer, and the venting from the boundary layer. These parameters, in turn, are dependent upon the amount and nature of mixing, which is closely related to atmospheric stability.

With the exception of bushfires and dust storms, the greatest risk of public exposure to emissions occurs under “inversion” conditions, when the atmosphere is stably stratified. These very conditions are notoriously the most problematic for contemporary weather and chemical transport models. At such times the structure of the lowest 10-100m of the atmosphere can be quite complex, potentially containing multiple disconnected layers, and even stability measures based on surface similarity theory can fail (or yield inconclusive results) without sufficient vertical and temporal measurement resolution.

Near-surface radon measurements provide a direct measure of the degree of dilution of surface-emitted scalar quantities by vertical mixing at night that is completely independent of local meteorological measurements and does not fail under conditions of near calm, which occur on the most stable nights. As such, they are a valuable proxy for potential pollution accumulation. In this study we analyse and discuss 22 months of continuous hourly observations within an urban airshed south of Sydney, Australia, that is affected by a heterogeneous distribution of emission sources. We develop a simple method for characterising and quantifying the strength of atmospheric mixing at night over land, and demonstrate the usefulness of this radon-based technique over and above conventional stability classification measures in identifying atmospheric conditions conducive to the accumulation of significant pollution in the lower atmosphere. Our findings show that at spatial scales comparable to those of a large city, continuous radon observations from a single, economical, low-maintenance detector can provide a clearer indication of potential pollution levels than conventional metorological measurements. Furthermore, despite significant industrial, urban and rural emissions within the airshed, we show that the highest hourly rates of public exposure to $PM_{2.5}$ aerosols in the Wollongong city centre under strongly stable conditions are due to domestic wood smoke emissions from the western foothills.