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Investigating fetch effects and local mixing using near-surface radon gradient measurements

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Weather and climate predictions are crucially reliant upon the fidelity of model parameterisations that represent the integrated behaviour of key physical processes responsible for transport and mixing in the atmospheric boundary layer. The distribution of pollutants with respect to their natural or anthropogenic sources, as well as their removal through deposition, is also controlled by these processes. However, our understanding of many aspects of mixing and transport still requires substantial refinement. In the stably stratified boundary layer vertical mixing processes remain poorly understood, particularly in very stable conditions when surface inversions can be extremely shallow and the thermodynamic structure of the lowest 50-100 m very complex.

Radon gradients provide a direct, unambiguous measure of near-surface atmospheric mixing. Since they can be observed using robust, economical instruments, long-term, continuous datasets, that are suitable for characterising a wide range of site-specific characteristics in a statistically meaningful manner, can be routinely collected. Here a 31-month dataset of hourly radon measurements at 2 and 50 m is used to characterise the seasonality and diurnal variability of radon concentrations and gradients at a topographically complex site on Sydney's urban fringe. Vertical differencing allows separation of remote (fetch-related) effects on measured radon concentrations from those due to diurnal variations in the strength and extent of vertical mixing. With the help of back trajectories and model-derived mixing depths, we were able to characterise the pronounced seasonal variability in afternoon surface radon concentrations in terms of air mass fetch, contact time with land, ABL dilution and regional variability of the radon source function.

Diurnal composites, grouped according to the maximum nocturnal radon gradient (ΔC_{max}), reveal strong connections between radon, wind, temperature and mixing depth on sub-diurnal timescales. Comparison of the bulk Richardson Number (R_{iB}) and the turbulence kinetic energy (TKE) with the radon-derived bulk diffusivity (K_B) helps to elucidate the relationship between thermal stability, turbulence intensity and the resultant mixing. On nights with large ΔC_{max}, K_B and TKE levels are low and R_{iB} is well above the "critical" value. Conversely, when ΔC_{max} is small, K_B and TKE levels are high and R_{iB} is near zero. For intermediate ΔC_{max}, however, R_{iB} remains small whereas TKE and K_B both indicate significantly reduced mixing. The relationship between stability and turbulence is therefore non-linear, with even mildly stable conditions being sufficient to suppress mixing.