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Improved estimation of total boundary layer radon for budget studies and regional integrations

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Estimation of the total amount of the natural radioactive tracer radon-222 (radon) in a vertical column through the troposphere is a critical step in the process of calculating regionally integrated emissions of important greenhouse gases using radon-calibrated budget techniques. As continuous long-term radon time series used for such calculations are typically gathered at sites located at or near the surface, a rigorous column radon estimate would require knowledge of the vertical distribution of radon through the atmospheric boundary layer (ABL). The most frequent approach to addressing this issue is to assume a uniform radon profile within the ABL, and no radon in the free atmosphere above. This study aims at refining these traditional assumptions by presenting vertical integrations of high-resolution radon profiles, gathered using a motorised glider in and above daytime boundary layers over rural inland Australia under a range of stability and cloud conditions.

On cloudless days, a large drop in radon concentrations across the inversion is evident from the vertical radon profiles. This is a result of radon depletion in the free atmosphere by radioactive decay (radon's half-life is 3.8 days), and the "top-down" diffusion process associated with entrainment of this radon-depleted air into the ABL results in a range of radon gradients observed in the upper part of the mixed layer. When actively coupled boundary layer clouds are present, the profiles indicate strongly enhanced vertical mixing and venting of radon from the sub-cloud layer into the cloud layer. Under these conditions, the proportion of total-column radon remaining in the sub-cloud layer can sometimes be as low as 30%.

Based on the enhanced understanding of vertical radon distributions in daytime terrestrial boundary layers gained from these airborne studies, refinements are suggested to the traditional estimation of total column radon from datasets where only surface-based radon measurements are available. These refinements are shown to result in improved estimates of total boundary layer radon in both clear and cloudy conditions.