Characterization of Mixing and Venting Processes in the Cloud-Topped Boundary Layer Using Airborne Radon Measurements

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Radon-222 is a radioactive noble gas emitted from terrestrial surfaces at a rate that is quasi-uniform and steady on diurnal timescales. As its only significant atmospheric sink is radioactive decay, radon is recognised as a excellent tracer for continental air and is widely used in evaluations of transport models and estimations of regionally-integrated fluxes of climatically sensitive gases. Within the atmospheric boundary layer (ABL), radon can be used to construct quantitative measures of the degree of mixing and exchange with the surface and the free atmosphere. Radon therefore represents a useful tool in the effort to reduce systematic errors in the reproduction of diurnal and seasonal cycles in weather and climate prediction models. ANSTO develops and applies state-of-the-art systems for radon detection through the lower atmosphere, including continuous tower-based measurements of radon gradients in Sydney and The Netherlands, and now a novel sampling system for detecting radon from airborne platforms.

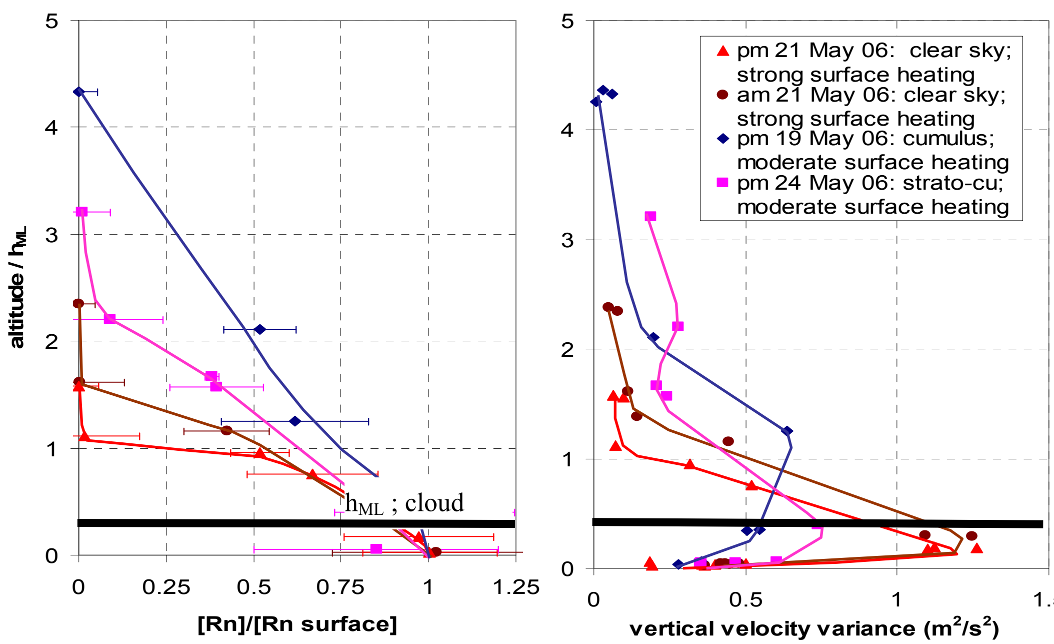

Figure 1. Profiles of radon and turbulence statistics in convective daytime ABLs over rural inland Australia are presented, for conditions ranging from clear skies to moderately developed fair-weather cumulus and strato-cumulus. As can be seen in the figure above, radon displays a strong gradient within the (sub-cloud) mixed layer despite significant turbulent mixing in all cases (see vertical velocity variance profiles). This distinctly "unmixed" shape in the radon profiles is a result of the characteristically "top-down" nature of radon diffusion in the ABL. Due to its 3.8-day half-life, radon concentrations in the free atmosphere are constrained to be 1-3 orders of magnitude lower than near-surface values. This ensures that a large gradient is maintained between the ABL and the air high above, leading to significant entrainment of radon across the ABL top even when the entrainment mass flux is moderate. This process is further enhanced in the presence of active boundary layer clouds, and in the two cloudy cases shown above radon concentrations remain high in the cloud layer. Given that the aircraft flew mainly in the spaces between clouds, the radon data thus indicates the extent to which air is being detrained out of the clouds in what is effectively an enhanced ABL venting process forced by the action of the clouds.