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Turbulent dispersion of the 222-Rn family in atmospheric boundary layers

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The turbulent dispersion of 222-Rn and its daughters in atmospheric boundary layers under a variety of stability conditions has been studied. We used large eddy simulation to simulate convective boundary layers in steady state, in unsteady conditions and diurnally evolving. This latter simulation included, for the first time, a first-order decaying system represented by the decaying chain of the radon family.

In the steady-state CBL, radon flux decreases linearly with height. Its flux budget is similar to the one of inert emitted scalars, i.e., a balance between on the one hand the gradient and the buoyancy production terms, and on the other hand, the pressure and dissipation at smaller scales which tend to destroy the fluxes. However, its short-lived daughters have their radioactive decaying contributions acting as flux sources leading to deviations from the linear flux shape. The budget analysis reveals that the gradient contribution to the flux is the most affected term.

In the unsteady boundary layer, radon and its progeny concentrations collapse due to the rapid growth of the CBL and the entrainment of “clean” air from the reservoir layer. In addition, the analysis of vertical distribution of the chemical contributions to the concentrations, i.e. the reacting zone, reveals a discrepancy in height of radon daughters’ radioactive transformations.

A departure from secular equilibrium between radon and its short-lived daughter products prevails in the stable nocturnal boundary layer. This disequilibrium is attributed to the proximity of the radon source and the weak vertical transport. Our analysis reveals that the spatial and temporal evolution of the concentrations of radon and its daughters is directly related to radioactive decay contribution in which turbulent mixing plays the major role. Thus, turbulent transport affects the dispersion of 222-Rn and its progeny by acting preferentially on the radioactive decay.