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Evaluating the Representation of Transport Processes in Climate Models using Idealised Radioactive Tracers

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The mean age of air is now widely adopted as a diagnostic to compare stratospheric transport in climate models. This can be constrained using observed values of long-lived chemical tracers, and is often derived in models using a passive tracer with infinite lifetime by measuring the elapsed time since last contact with the source region. This method can be extended to derive a tropospheric mean age, which has been used to compare tropospheric transport between models. However, it is difficult to validate this using observations due the limited number of measurements and the complexity of tropospheric transport and chemistry, as a large number of processes with different timescales contribute to the observed tracer values. We probe tropospheric transport in models using radioactive tracers with lifetimes spanning from minutes to years, matching the timescales of relevant transport processes. We derive a tracer transport spectrum similar to that in oceanic studies using the maximum-entropy method from mixing ratios of these idealised radioactive tracers emitted at the surface. Diagnostics calculated from the transport spectrum are used to estimate the relative contributions of tracers with different timescales to the final tracer mixing ratio. Such a transport spectrum can also be constructed using observations of chemical species with different lifetimes. We compare model results from FRSGC/UCI chemistry-transport model and the UK Met-Office Unified Model/UKCA and evaluate the differences in terms of model representation of various processes.