



Can observation-based atmospheric mixing state reduce filtering sensitivity in GHG inversions? Lessons from the UK GEMMA programme

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Uncertainty in atmospheric transport models, especially boundary-layer mixing and turbulence, still limits confidence in top-down GHG emission estimates. In inversion workflows, observation selection is commonly supported by empirically tuned filters based on modelled meteorological variables (e.g., boundary-layer height, wind speed). The selection prioritises periods when transport is expected to be well represented. This motivates continued work to characterise atmospheric mixing and its associated uncertainties using observations.

In the UK GEMMA programme, we investigate whether observation-based atmospheric mixing state can provide complementary information to support uncertainty characterisation in UK CH₄ inversions. We demonstrate the framework at UK sites with radon measurements and at a newly instrumented site in Scotland where only meteorological measurements are available. Where radon is measured, we use it as an independent tracer of near-surface mixing and compare observed radon with radon simulated using the Met Office NAME dispersion model and a radon flux map. This comparison is used to define transport-performance classes (periods of relatively better vs poorer agreement) and associated atmospheric mixing state. At the Scotland site, we derive atmospheric mixing regimes from in situ meteorological measurements alone, using a vertical profile sampled every 10 m to characterise stratification and mixing.

We show how the resulting atmospheric mixing state and transport-performance classes can be used in two operational ways: (i) as additional information to support observation selection alongside existing practice, and (ii) to define regime-dependent uncertainty characterisation within inversion frameworks rather than assuming a single fixed error model. We illustrate the approach using two UK CH₄ inverse methods (InTEM and RHIME) and discuss how observation-based mixing information can improve transparency and reproducibility in hybrid (inventory + atmospheric) emissions estimation for IG3IS-aligned information services.

