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Approximation, random error, and the coupling of radiation calculations to dynamical models

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Radiation is one of the most pure exercises in parameterization in atmospheric models: Because the correct answer to fully specified problems is known to great accuracy, radiation parameterizations primarily seeks to balance accuracy with computational cost. Acceptable accuracy has remained so expensive that radiation fields are typically updated much less frequently than any other model field; this reduced frequency represents one possible approximation whose error characteristics are not well understood. But the error characteristics are crucially important in determining whether an approximation affects model evolution. In particular, several threads of work have demonstrated that model evolution is not sensitive to uncorrelated noise introduced to the fluid at the grid scale. In other words, unbiased algorithms that introduce even quite substantial noise in heating rates can be more accurate (in the sense of introducing smaller changes in model evolution) than detailed algorithms used infrequently.

We explore various paths to accuracy using a new radiation package developed for the ECHAM climate model. PSrad is unique in that only a small sample of the full broadband spectral integration is performed but these calculations are performed at each time step. This introduces sampling noise, as does the more common use of stochastic samples to represent the subgrid-scale distribution of cloud properties. And though the model is insensitive to even very large grid-scale perturbations to radiative heating rates within the atmosphere, large perturbations in surface fluxes affect the model trajectory both directly and indirectly. We describe methods to bound the error by developing subsets of the broadband calculation chosen to minimize the largest surface fluxes errors. The final algorithm is quasi-optimal for dynamical models at all scales, even as significant noise is introduced into individual calculations.