

## Allowing for Horizontally Heterogeneous Clouds and Generalized Overlap in an Atmospheric GCM

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While fully accounting for 3D effects in Global Climate Models (GCMs) appears not realistic at the present time for a variety of reasons such as computational cost and unavailability of 3D cloud structure in the models, incorporation in radiation schemes of subgrid cloud variability described by one-point statistics is now considered feasible and is being actively pursued. This development has gained momentum once it was demonstrated that CPU-intensive spectrally explicit Independent Column Approximation (ICA) can be substituted by stochastic Monte Carlo ICA (McICA) calculations where spectral integration is accomplished in a manner that produces relatively benign random noise. The McICA approach has been implemented in Goddard's GEOS-5 atmospheric GCM as part of the implementation of the RRTMG radiation package. GEOS-5 with McICA and RRTMG can handle horizontally variable clouds which can be set via a cloud generator to arbitrarily overlap within the full spectrum of maximum and random both in terms of cloud fraction and layer condensate distributions. In our presentation we will show radiative and other impacts of the combined horizontal and vertical cloud variability on multi-year simulations of an otherwise untuned GEOS-5 with fixed SSTs. Introducing cloud horizontal heterogeneity without changing the mean amounts of condensate reduces reflected solar and increases thermal radiation to space, but disproportionate changes may increase the radiative imbalance at TOA. The net radiation at TOA can be modulated by allowing the parameters of the generalized overlap and heterogeneity scheme to vary, a dependence whose behavior we will discuss. The sensitivity of the cloud radiative forcing to the parameters of cloud horizontal heterogeneity and comparisons of CERES-derived forcing will be shown.