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Coupling the GCM and cloud-resolving components in the multi-scale modeling framework

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This paper discusses various approaches in coupling the GCM and 2D or quasi-3D cloud-resolving model (CRM) in Multi-scale Modeling Framework (MMF). In constructing such a framework, we face two basic problems: problems associated with the dimensionality of the CRM and problems associated with the formulation of the coupling. This paper concentrates on the latter problem assuming that the CRM is fully three-dimensional even though it is not usually the case in MMF.

We have identified three basic approaches in formulating the coupling: A. Explicit formulations of the GCM effect on the CRM (forcing) and the CRM effect on the GCM (feedback); B. Mutual adjustments of the prognostic variables of the GCM and CRM; C. Hybrid of A and B. We then extensively investigate the performance of various formulations following these three approaches and their combinations. Comparing the results of simulations using the idealized MMF with those of a straightforward application of the original 3D CRM, we assess the errors due to the splitting of the spectrum with those formulations.

We find these errors are highly sensitive to the way of formulating the coupling, calling for further studies on the problem. This is especially true for surface fluxes and the statistics of dynamic variables. This kind of sensitivity may also be relevant for understanding theoretical and conceptual models that split the spectrum into the cloud and larger scales, and the problem of parameterizability of clouds in general.