Mechanisms of diurnal precipitation over the United States Great Plains: A cloud-resolving model simulation

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The mechanisms of summertime diurnal precipitation in the US Great Plains were examined with the two-dimensional (2D) Goddard Cumulus Ensemble (GCE) cloud-resolving model (CRM). The model was constrained by the observed large-scale background state and surface flux derived from the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program's Intensive Observing Period (IOP) data at the Southern Great Plains (SGP). The model, when continuously-forced by realistic surface flux and large-scale advection, simulates reasonably well the temporal evolution of the observed rainfall episodes, particularly for the strongly forced precipitation events. However, the model exhibits a deficiency for the weakly forced events driven by diurnal convection.
Additional tests were run with the GCE model in order to discriminate between the mechanisms that determine daytime and nighttime convection.
In these tests, the model was constrained with the same repeating diurnal variation in the large-scale advection and/or surface flux.

The results indicate that it is primarily the surface heat and moisture flux that is responsible for the development of deep convection in the

afternoon, whereas the large-scale upward motion and associated moisture advection play an important role in preconditioning nocturnal convection. In the nighttime, high clouds are continuously built up through their interaction and feedback with long-wave radiation, eventually initiating deep convection from the boundary layer. Without these upper-level destabilization processes, the model tends to produce only daytime convection in response to boundary layer heating.

This study suggests that the correct simulation of the diurnal variation in precipitation requires that the free-atmospheric destabilization mechanisms resolved in the CRM simulation must be adequately parameterized in current general circulation models (GCMs) many of which are overly sensitive to the parameterized boundary layer heating.