Progress Towards Climate Projections of Central U.S. Rainfall Using a Global Model with Embedded Explicit Convection

Research Highlight

A glimmer of hope may be on the horizon for new climate simulation technology to crack the difficult problem of projecting future summer precipitation changes in the central United States, according to new research published by Mike Pritchard and Richard Somerville of UC San Diego, in collaboration with Mitch Moncrieff at the National Center for Atmospheric Research, and the Center for Multiscale Modeling of Atmospheric Processes.

A large fraction of the summer rainfall feeding the growing season in the mid-continental U.S. comes from long-lived, organized nocturnal mesoscale convective systems.

Historically, the problem has been that the statistical approximations ("parameterizations") used to represent unresolved cloud processes in conventional global climate models do not admit the necessary physics of organized nocturnal mesoscale convection systems.

However, Pritchard and Somerville have discovered that a new technique called cloud "super-parameterization'' may offer a way forward. In super-parameterized climate models, thousands of embedded idealized 2D cloud process-resolving model arrays are used to calculate sub-grid cloud and boundary-layer adjustments to resolved dynamics, instead of conventional statistical parameterizations.

In an analysis of the Super-Parameterized Community Atmosphere Model (SP-CAM*), they document a robust nocturnal organized central U.S. convection signal. In several ways, it looks realistic. The phase and propagation speeds of the storms agree with ground-based radar climatology. Balanced dynamics and interactions with the Great Plains low-level jet appear to sustain the systems throughout the night.

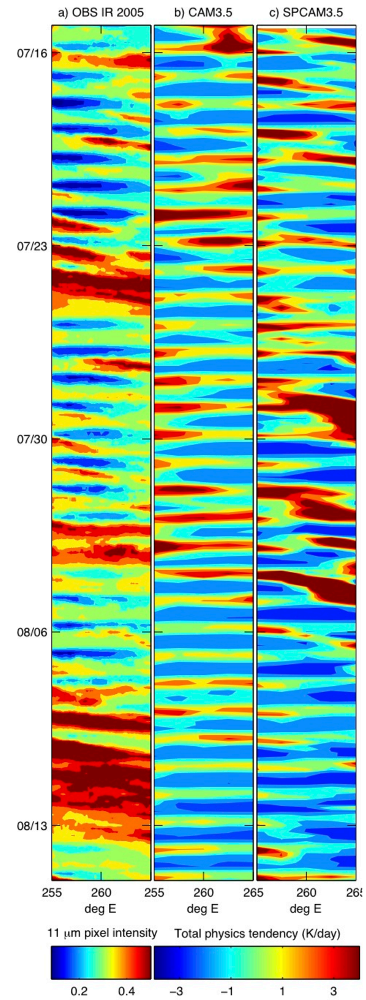
The existence of the signal is surprising, considering the idealizations used in super-parameterized climate models. A key assumption of the super-parameterization approach that makes it affordable for climate simulation is that the 2D cloud-resolving arrays are laterally periodic and isolated from each other. This means that convectively generated cold pools and gravity waves are trapped and cannot have a long-range effect. But Pritchard's analysis of the MMF's embedded cloud-resolving model reveals coherent, condensate meta-structures that transcend the boundaries between isolated CRMs yet propagate coherently (see Figure 2).

The authors are currently pursuing new sensitivity experiments running SP-CAM in forecast mode, where validation against actual mesoscale convective system properties captured by instruments at the ARM Climate Research Facility's Southern Great Plains site will be crucial to untangle the causes of secondary biases in simulated cloud liquid and ice water content at the level of individual systems.

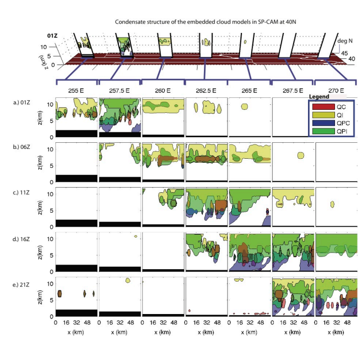
*SP-CAM was developed by Marat Khairoutdinov of Stony Brook University and is a flagship tool of the Center for Multiscale Modeling for Atmospheric Processes (CMMAP), an NSF Science and Technology Center based at Colorado State University with whom the authors collaborate.

In the meantime, this is the first time a global model that is affordable for climate projection has been shown to contain the essential mechanism known to deliver most of the summertime mid-continent U.S. rainfall. The authors are optimistic that refining the super-parameterization approach is a pathway to better projections of how Central U.S. rainfall will adjust to future climate change, in these interim decades before fully global cloud-resolving climate projections become feasible.

Reference(s)



Characteristic time-longitude structure of central U.S. summer diurnal convection (35-45 N) (a) as observed in 2005 from space-borne infrared imagers, and as simulated by (b) the Community Atmosphere Model (CAM) v3.5 versus (c) the Super-Parameterized (SP-) CAM, which captures the propagating nocturnal mode (tilted phase lines).



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Cloud Life Cycle

Time-longitude matrix of x–z sections showing snapshots of condensate within adjacent cloud-resolving models at 40 N in SP-CAM3.5 during a propagating nocturnal convection episode, at five-hour intervals (top to bottom). Shaded transparent contours outline the 0.01 g/kg threshold for non-precipitating cloud water (red), non-precipitating cloud ice (yellow), precipitating cloud water (blue), and precipitating cloud ice (green) within the embedded model. Surface orography is shown in black.

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