Chaotic Convection in SP-CAM

David Randall, Mark Branson, and Radha Dutta

Hannah Christensen and Judith Berner have discussed related issues earlier at this Workshop.
Deterministic or not?

Deterministic convection:

\[ C(t) = R[F(t)] \]

Non-deterministic convection:

\[ C(t) = R[F(t)] \]

Width = constant \times mean?
“Non-deterministic” clouds on unresolved scales are not fully controlled by the resolved-scale weather.
A deterministic parameterization simulates “expected values” or ensemble means.

A non-deterministic parameterization simulates individual realizations.
Each CRM runs continuously.
The CRMs do not communicate with each other except through the GCM.
The CRMs and the GCM are coupled in such a way that they remain in synch.
A super-parameterization is non-deterministic because the solution produced by the CRM is sensitively dependent on initial conditions.

Random number generators are not needed.

A super-parameterization produces an individual realization of the cloud field.

Is there a way to explore the ensemble of possible realizations?
Instead of one CRM per GCM grid column, include $N$ copies of the CRM. All copies see the same GCM weather.

The CRMs start from slightly different initial conditions.

Each copy runs independently of the others.
This is what a deterministic parameterization tries to do.
Experimental Design

- The GCM uses a 2.5 x 2.0 degree longitude-latitude grid, with the CAM’s “finite-volume” dynamical core.

- We use 10 CRMs with 32 columns each, oriented north-south, with 4 km grid spacing.

- The GCM initial conditions are taken from an earlier simulation with the SP-CAM.
Individual realizations

Ensemble average
Where & when is strong precipitation predictable?
Standard dev / mean, plotted where the mean > 5 mm day\(^{-1}\)
One day in January

The ratio has some spatial coherence, even though the CRMs communicate only through the GCM.
Where & when is strong precipitation predictable?
Standard dev of daily values / daily mean, counted where the daily mean > 5 mm day$^{-1}$
January average

The width of the distribution is not simply a constant times the mean.
The least predictable precipitation is in the tropics.
The most predictable precipitation is in midlatitude storms, except on their equatorward sides.
Ten days in the life of two selected GCM columns
These are Hovmöller diagrams, with time increasing upward.
The horizontal axis in each panel is horizontal distance in the CRM.

Ten realizations at a tropical point

Ten realizations at a midlatitude point

mm day$^{-1}$
Summary

**SP-CAM**
- One realization of the cloud system
- Feedback from the single realization
- Non-deterministic parameterization

**MP-CAM**
- $N$ realizations of the cloud system
- Feedback from the ensemble mean
- Deterministic parameterization
- Can examine individual realizations
What I want to do with this

• Compare climate with ensemble-mean feedback to climate with feedback from one realization:
  ‣ Systematic differences in extreme precipitation events?
  ‣ Systematic differences in the MJO or other large-scale weather systems?

• Identify the specific weather regimes and physical mechanisms that are associated with strong but unpredictable convection.