New results from the Super-Parameterization

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Super-Parameterization™

- Embed 2D Cloud System Resolving Model (CSRM) in each GCM column, with periodic boundary conditions.
- Model subgrid clouds, radiation, dynamics and microphysics with 4 km horizontal resolution and 20 second timestep.
- Include cloud-radiation interactions using the Independent Column Approximation on the cloud scale.
A summary of some results to date

- Intra-seasonal, synoptic, and diurnal variability are more realistic with the MMF.
- Cloud-scale interactions between radiation and other processes are quite important for both low and high clouds.
- The MMF produces excessively strong precipitation systems over the tropical Western Pacific in the northern summer -- the GRS.
- The results obtained with the MMF are sensitive to the parameterized ice microphysics.
Leo showed big differences between 2D and 3D.
Compared to what?

<table>
<thead>
<tr>
<th>MMF</th>
<th>Conventional Parameterization</th>
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<tbody>
<tr>
<td>2D or Quasi-3D</td>
<td>1D</td>
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<tr>
<td>Periodic boundary conditions (or relaxation time scale)</td>
<td>Boundary whats?</td>
</tr>
<tr>
<td>Shallow convection and turbulence must be parameterized.</td>
<td>Same</td>
</tr>
<tr>
<td>Microphysics is simplified but the required input is in pretty good shape.</td>
<td>Microphysics is typically less sophisticated, and the required input (e.g., local vertical velocity) is not available.</td>
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</table>
Trajectory of an idea

Perceived merit

Peak of Inflated Expectations

Eureka

Trough of Disillusionment

Paradigm Plateau

Slope of Enlightenment

Time
Hypotheses:

- More realistic overlap gives more realistic results.

- Cloud-scale covariance between radiative heating and temperature matters for the development of the cloud field.
## Experiments

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<thead>
<tr>
<th></th>
<th>CSRM</th>
<th>GCM</th>
<th>Comment</th>
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<tbody>
<tr>
<td><strong>Experiment 1</strong></td>
<td>CMO</td>
<td>CMO</td>
<td>“Truth”</td>
</tr>
<tr>
<td>(like SP-RAD)</td>
<td></td>
<td>averaged</td>
<td></td>
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<tr>
<td><strong>Experiment 2</strong></td>
<td>CMO</td>
<td>CMO</td>
<td>Domain-averaged radiation, one value for domain, but a proper mean</td>
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<tr>
<td></td>
<td>averaged</td>
<td>averaged</td>
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<tr>
<td><strong>Experiment 3</strong></td>
<td>MRO</td>
<td>MRO</td>
<td>Domain averaged radiation, one value for domain but a biased mean</td>
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<tr>
<td>(like SP-NOR)</td>
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<tr>
<td><strong>Experiment 4</strong></td>
<td>CMO</td>
<td>MRO</td>
<td>Cloud-scale interactions recognized but a biased mean given to GCM</td>
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<td><strong>Experiment 5</strong></td>
<td>Conventional GCM</td>
<td>GCM</td>
<td>Everything parameterized</td>
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</table>
Diagnostic CMO vs MRO Cloud Fraction

Input is vertical profiles of CMO cloud fraction from Exp. 1.
Output is diagnostic calculation of MRO cloud fraction.

Used diagnostically, CMO gives more cloud.
Diagnostic CMO vs MRO CRF

Input is vertical profiles of CMO cloud fraction from Exp. 1. Output is diagnostic calculation of MRO cloud radiative forcing.

Used diagnostically, CMO makes the CRF stronger, consistent with its (diagnostic) higher cloud amount.
Now on to the interactive results...
Exps. 2 and 3 similar, with more cloud--*both non-interactive*.

Exps. 1 and 4 similar, with less cloud--*both interactive*.
Also note that

Dagnostically, CMO gives more cloud.

Interactively, CMO gives less cloud.
Shortwave Cloud Forcing

Exps. 2 and 3 similar, with stronger SWCRF—both non-interactive.

Exps. 1 and 4 similar, with weaker SWCRF—both interactive.
Diagnostically, CMO gives more SWCRF.

Interactively, CMO gives less SWCRF.

The differences are mostly due to ice clouds.
These experiments show that cloud-scale interactions between radiation and ice clouds are important for total cloud amount and SWCRF.

This implies an important role for cloud-scale dynamics, and is consistent with studies by Dave Starr and others.
JJA Low-level Cloud Fraction

SP-NOR

mean = 23.6263

SP-RAD

mean = 29.6656
Why are stratocu so sensitive to the high-resolution radiation calculation?

- Lilly (1968) explained this in terms of radiatively driven turbulence and convection in the cloud layer.

- Convection transports moisture upward and so contributes to the maintenance of the cloud.
Stratus and cirrus

Interactive radiation makes cirrus cloudiness decrease and stratus cloudiness increase.

Why the difference?
Plug-and-pray?

Models should be as modular as possible but not more so.
What drives paradigm shifts?

- Funerals
- New observations
- Faster computers
- Inspiration
Conclusions

- Processes interact on small space and time scales, and it matters.
- Future parameterizations will have to be unified.
- Our results provide an example of how an MMF can be used to learn something that could not have been learned with a conventional GCM.