The effects of organization on convective and large-scale interactions using cloud resolving simulations with parameterized large-scale dynamics

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Forms of convective organization



One Coherent Clump

Scattered Blobs

Are these differences important?

Tobin et al. (2012)

Approach: SAM + PLSD (Kuang 2008)

More or less organized convection via altering domain geometry, or adding shear

Double x-dimension, halve y-dimension



CSRM: System for Atmospheric Modeling (SAM)



- Prescribed radiation profile
- Prescribed background vertical velocity profile

SAM with parameterized large-scale dynamics





128 km

Snapshots of 15 min avg. rainfall

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Domain Shape vs. Max Precip



Can we understand the 512 km x 32 km optimum?

Can changes in precipitation oscillation magnitude be explained by sensitivity differences to a prescribed perturbation?

e.g. Tulich and Mapes (2010), Jones and Randall (2012)

Prescribe large-scale vertical velocity



Specify w & T_{ref}, q_{ref}

CSRM given same largescale forcing across domain setups

$$\frac{\partial T}{\partial t} = w \left(\frac{\partial T_{ref_{128}}}{\partial z} - \frac{g}{c_p} \right) + \left(\frac{\partial T_{conv}}{\partial t} \right) - \varepsilon_T$$
$$\frac{\partial q}{\partial t} = w \left(\frac{\partial q_{ref_{128}}}{\partial z} \right) + \left(\frac{\partial q_{conv}}{\partial t} \right) - \varepsilon_q$$

Specified large-scale w profile



- Vertical velocity chirp
- 1-hr positive burst balanced by subsidence spread evenly over remaining time of 10-day period
- 7 ensemble members

Ensemble avg. precipitation response to specified large-scale vertical velocity



 Systematic decrease in prec max beyond 256 km x 64 km domain



- Each contour 6 K day-1
- Thick line is zero contour
- Integral over 10-day period is zero



- Each contour 6 K day-1
- Thick line is zero contour
- Integral over 10-day period is zero



Each contour 6 K day⁻¹
Thick line is zero contour
Integral over 10-day period is zero



 Q1 weakens and localizes from 3D -> 2D

3D more inhibited

- Each contour 6 K day-1
- Thick line is zero contour
- Integral over 10-day period is zero



Domain Shape vs. Max Precip



Can we understand the 512 km x 32 km optimum?

Summary & Conclusions

Shear simulations results:

- Convective squall lines
- > Shear and non-shear runs similar in 3D isotropic domain

Change in domain shape results:

Infinite line of convective blobs spaced increasingly farther apart
 512 km x 32 km optimum (i.e. largest post-coupled precip.)

Mean state sensitivity experiments:

Coupled system indifferent to changes in background mean state

Prescribed large-scale w experiments:

3D more inhibited than 2D – more intense, both local & non-local convective heating response

Organization via shear and degree of "2D-ness" give different convective oscillations for the coupled system.

Ways Forward...

SST forcing experiments like Wang and Sobel (2011)

- Larger 3D domains
- Different shear profiles
- > Apply multiple k's in LS wave equation
- Superparameterization full physics of large scale

Results robust to:

- 2,500 & 10,000 vs. 5,000 km large-scale λ
- 2- and 4-day vs. 10-day damping

avera

- Different combos of u-, T-, and q-damping 0
- Large-scale w advecting $T(z, t) \& \overline{q}(z, t)$
- Fixe $\frac{\partial^2}{\partial z^2} \left(\frac{\partial(\rho w)}{\partial t} \right) = -k^2 \rho g \left(\frac{T'_v}{T_v} \right) \varepsilon \frac{\partial^2(\rho w)}{\partial z^2} \text{ hange } \text{las}$
- Fixed $\frac{\partial T}{\partial t} = w \left(\frac{\partial T_{ref}}{\partial z} - \frac{g}{c_p} \right) + \left(\frac{\partial T_{conv}}{\partial t} \right) - \varepsilon_T$ $\frac{\partial q}{\partial t} = w \left(\frac{\partial q_{ref}}{\partial z} \right) + \left(\frac{\partial q_{conv}}{\partial t} \right) - \varepsilon_q$ DGA w-b domain-Back

Mean State Sensitivity



Comparing the average over the last 50 days of a 100 day *uncoupled* run in indicated domain set-up to 128 km x 128 km uncoupled average.

- Longer, narrower domains drier, yet more unstable (in vertically averaged sense)
- Perhaps stretched domains too dry to support convectively coupled waves.



Are changes in precipitation oscillation magnitude due to mean state differences vs. form of convection?

$$\frac{\partial^2}{\partial z^2} \left(\frac{\partial(\rho w)}{\partial t} \right) = -k^2 \rho g \left(\frac{T_v}{T_{v ref_{128}}} \right) - \varepsilon \frac{\partial^2(\rho w)}{\partial z^2}$$
$$T_v'(z) = \overline{T_v}_{CRM}(z,t) - \overline{T_v}_{ref_{128}}(z)$$



128 km x 128 km uncoupled sounding in each domain setup



Domains got moister sounding than they would otherwise compute

Indifferent to specified T_{v ref} profile

Coupled system adjusts to foreign snd.



Mean lat, Ion of wide (red) and narrow (blue) EOs



Morphed composite: 2011-07-10 00:00:00 UTC Total Precipitable Water (mm) n Latitude -10SSMI/AMSRE -20 -30 Longitude

Column water vapor (MIMIC) shows summertime low-level flow

Representative summer 2006-9 cloudsat radar echo objects <200km in horizontal width



now with >200km ones in red

Organization (wide cbs) prevails in environment that generally favors suppressed convection

