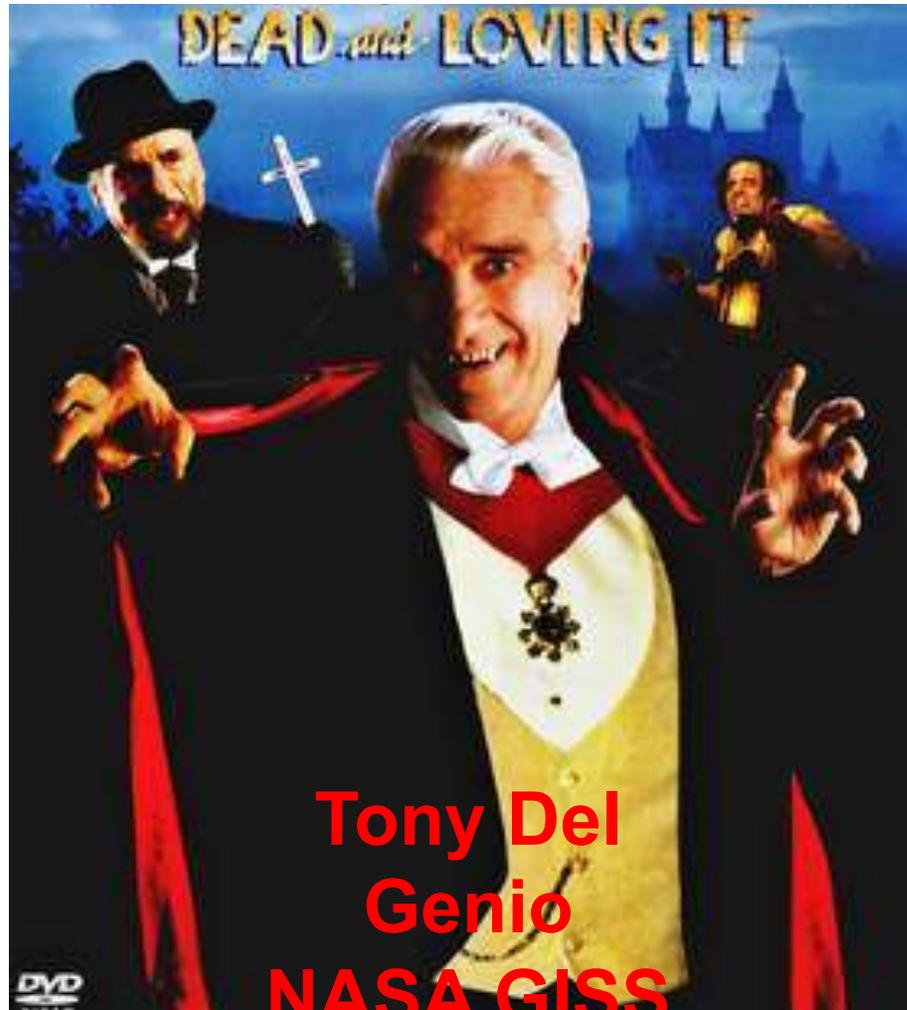


CONVENTIONAL CUMULUS PARAMETERIZATION:



**Tony Del
Genio
NASA GISS**

CMMAP Mtg., 8/9/12

BREAKING THE CLOUD PARAMETERIZATION DEADLOCK

BY DAVID RANDALL, MARAT KHAIROUTDINOV, AKIO ARAKAWA, AND WOJCIECH GRABOWSKI

Deadlock: a state of inaction or neutralization resulting from the opposition of equally powerful uncompromising persons or factions. (Merriam-Webster)

CLOUDS AND CLIMATE: A PROBLEM
THAT REFUSES TO DIE.



Convection in GATE

Rev. Geophys. (1981)

ROBERT A. HOUZE, JR.

Department of Atmospheric Sciences, University of Washington, Seattle, Washington 98195

ALAN K. BETTS

West Pawlet, Vermont 05775

The difficult problem of parameterizing tropical convection in large-scale models of the atmosphere led to the Global Atmospheric Research Program's Atlantic Tropical Experiment (GATE), whose goal was to improve basic understanding of tropical convection and its role in the global atmospheric circulation. A dense network of instrumented ships equipped with upper air sounding equipment and quantitative weather radars were located over the Atlantic Ocean, in the intertropical convergence zone (ITCZ), just west of equatorial Africa. The ship network was supplemented by a fleet of research aircraft and a geosynchronous meteorological satellite. The data obtained show that the deep convection in the ITCZ was concentrated in two types of 'cloud clusters': rapidly moving squall clusters, and slowly moving nonsquall clusters. The clusters were characterized by large mid-to-upper level cloud shields, or 'anvil clouds,' that emanated from penetrative cumulonimbus convection. Accompanying the deep cumulonimbus in each cluster was a log normal spectrum of smaller convective features ranging from moderate cumulonimbus down to tiny precipitating cumulus. The large cumulonimbus were typically grouped within a cluster into one or more mesoscale precipitation features (or MPF's), which were apparently triggered in mesoscale regions of intensified low-level convergence. As an MPF matured it developed a region of stratiform precipitation adjacent to its active deep convective cells. The stratiform precipitation fell from the anvil cloud. Associated with the stratiform precipitation were a mesoscale downdraft below the anvil cloud and an apparent mesoscale updraft within the anvil cloud itself, above the mesoscale downdraft. These mesoscale drafts were distinct from the convective-scale updrafts and downdrafts of the cumulus and cumulonimbus cells of the cluster. Downdrafts, both convective scale and mesoscale, filled the planetary boundary layer in the vicinity of cumulonimbus with stable air of low moist static energy. These wakes of downdraft air exerted a strong control on where future convection broke out. The results of GATE show that to simulate the effects of tropical convection in large-scale numerical models of the atmosphere a variety of phenomena must be accounted for, including not only convective-scale updrafts and downdrafts but anvil clouds with mesoscale updrafts and downdrafts, downdraft-induced boundary layer transformations, and mesoscale convergence patterns. Experimentation with ways of including some of these features of tropical convection in large-scale diagnostic and prognostic studies is under way, but much work remains to be done.

5

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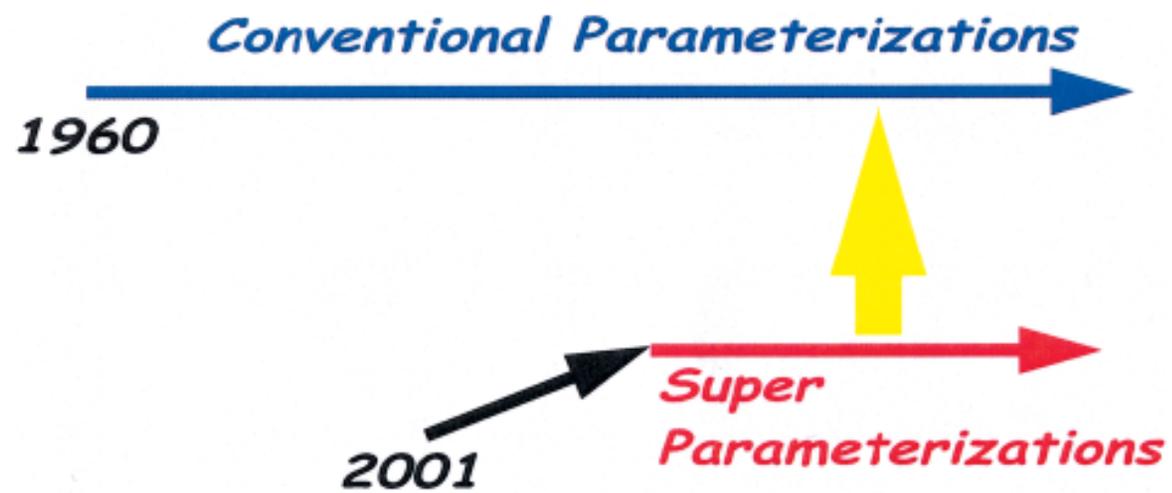
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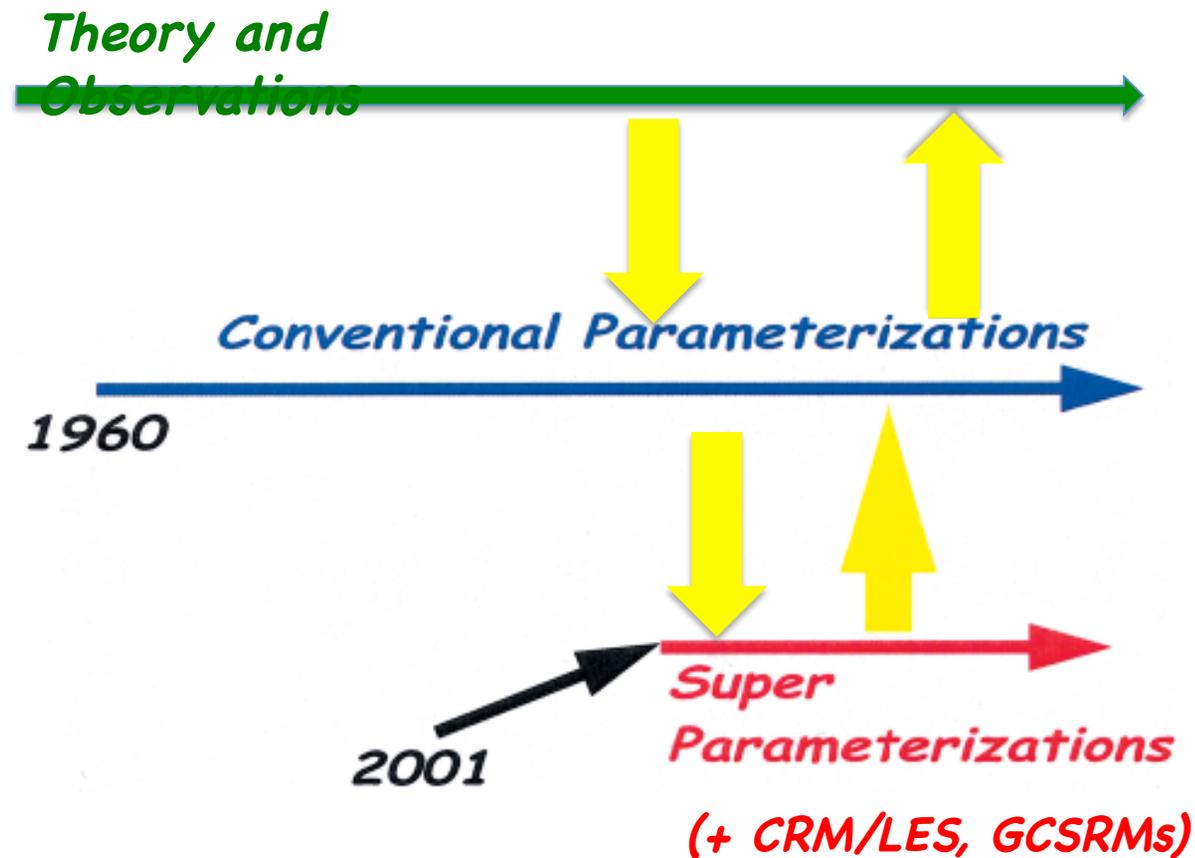
~2003 - present: Conventional parameterization – dead to undead?

- Practical emphasis on missing physical process components in convective systems, departures from quasi-equilibrium
- GCSS (now GASS) begins to fulfill its promise
 - Pre-deadlock: CRMs are better than SCMs
 - Post-deadlock: CRM/LES models being used to diagnose unresolved processes and inform conventional parameterization
- Great new datasets (ARM, TRMM, CloudSat/CALIPSO, DYNAMO,...)
- “New blood”

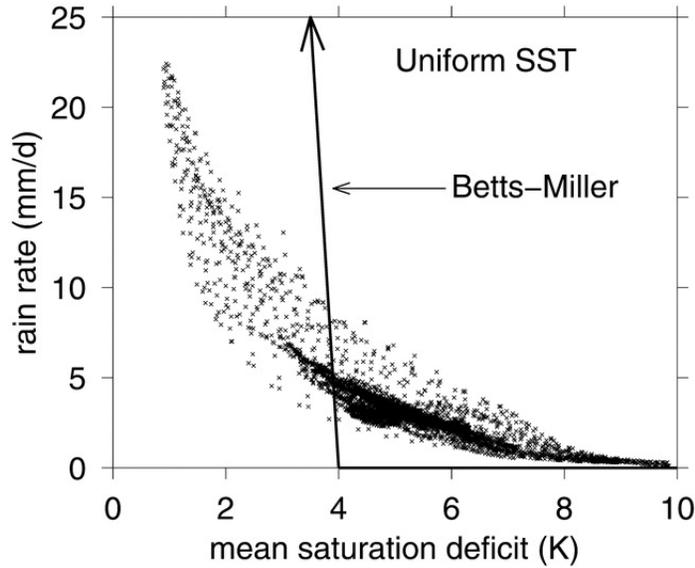




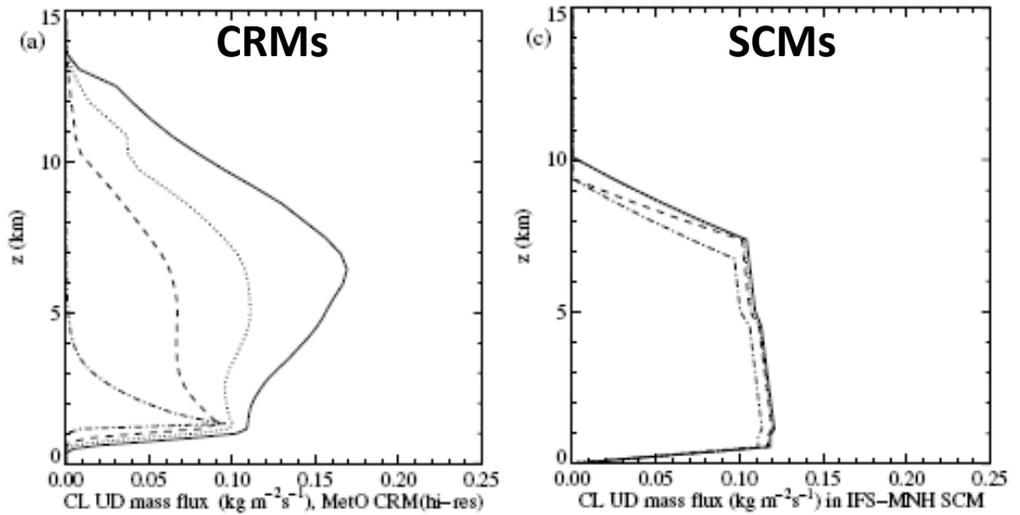
A continuing role for conventional parameterizations: Ask questions and evaluate the answers



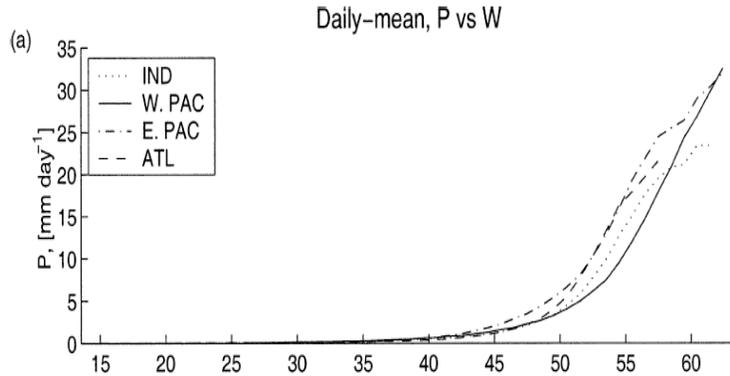
Case study: Moisture-convection interactions in the MJO



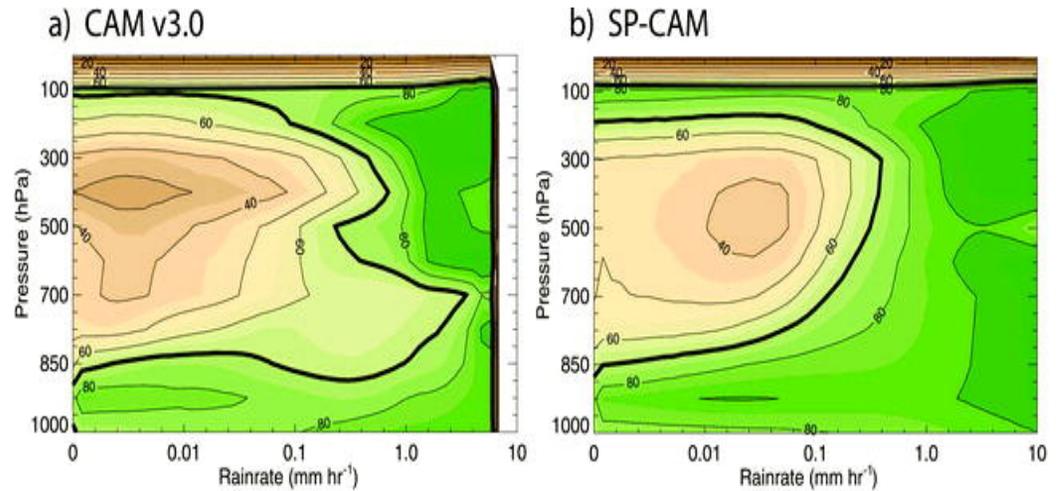
Raymond (2000, 2001)



Derbyshire et al. (2004)



Bretherton et al. (2004)



Thayer-Calder et al. (2009)

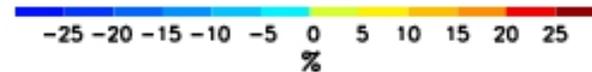
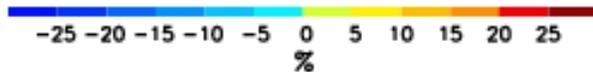
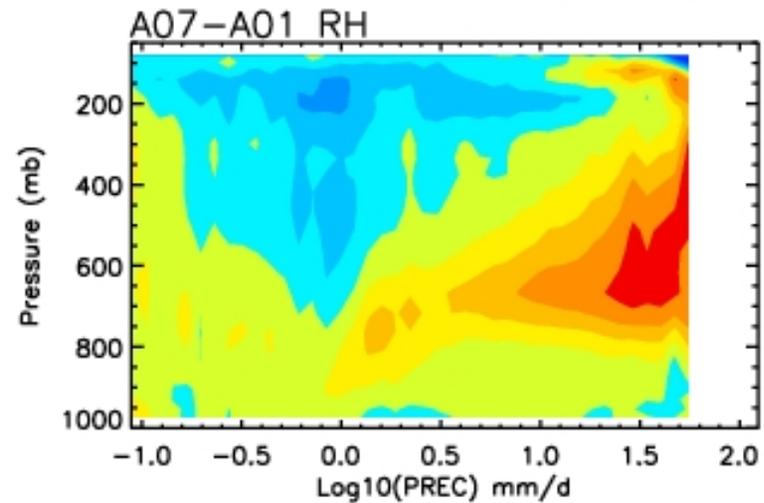
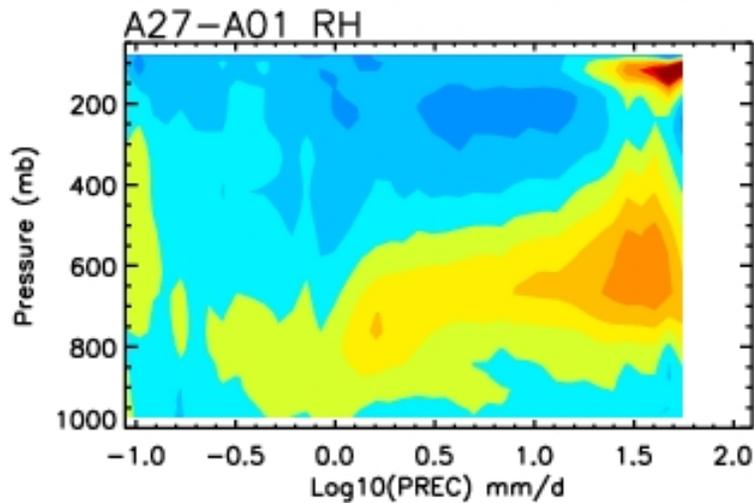
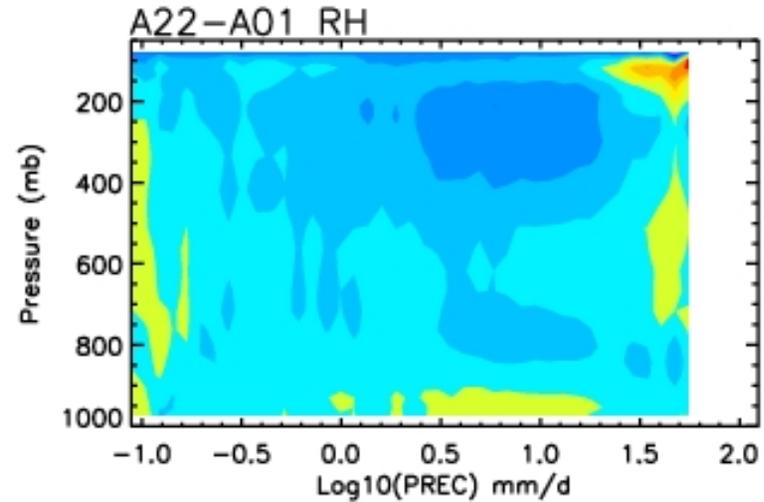
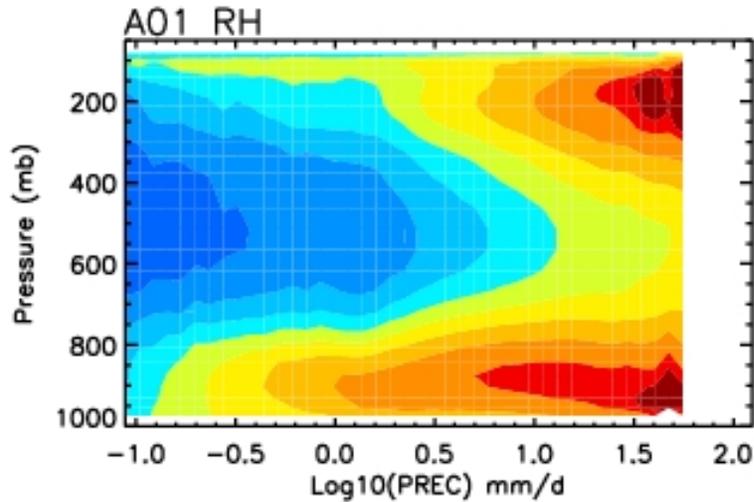
Does the convection-humidity relationship need to be two-way?

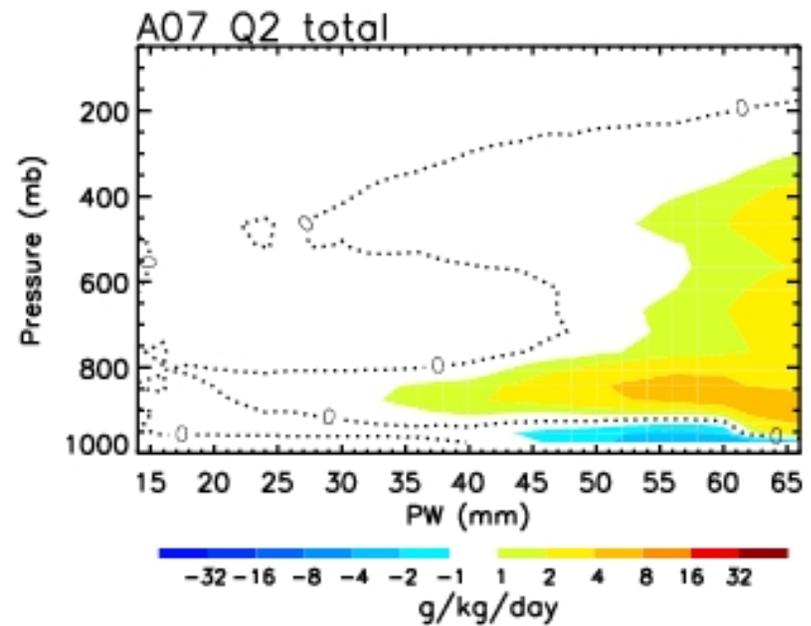
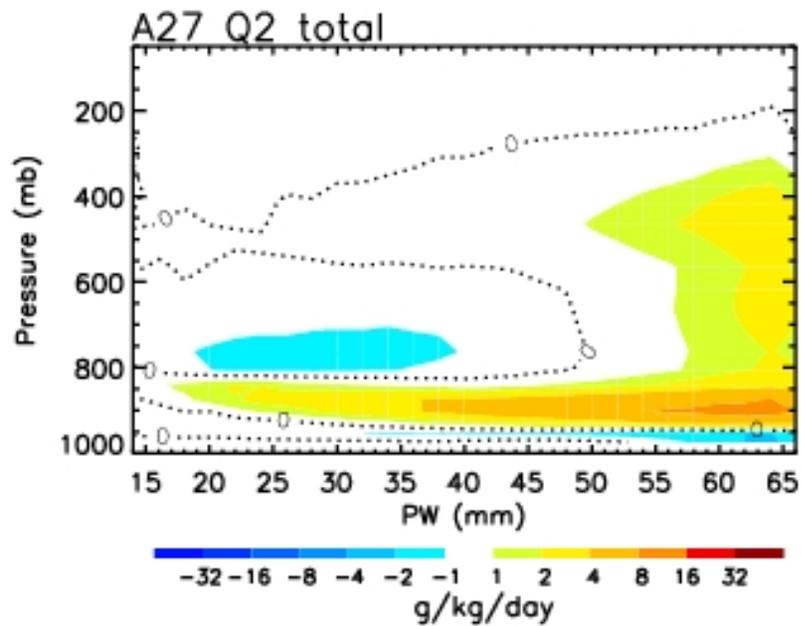
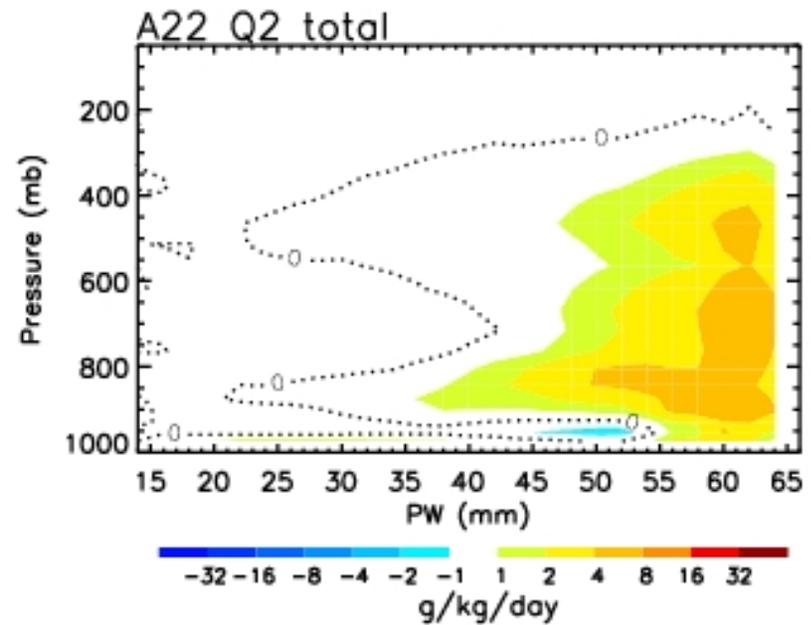
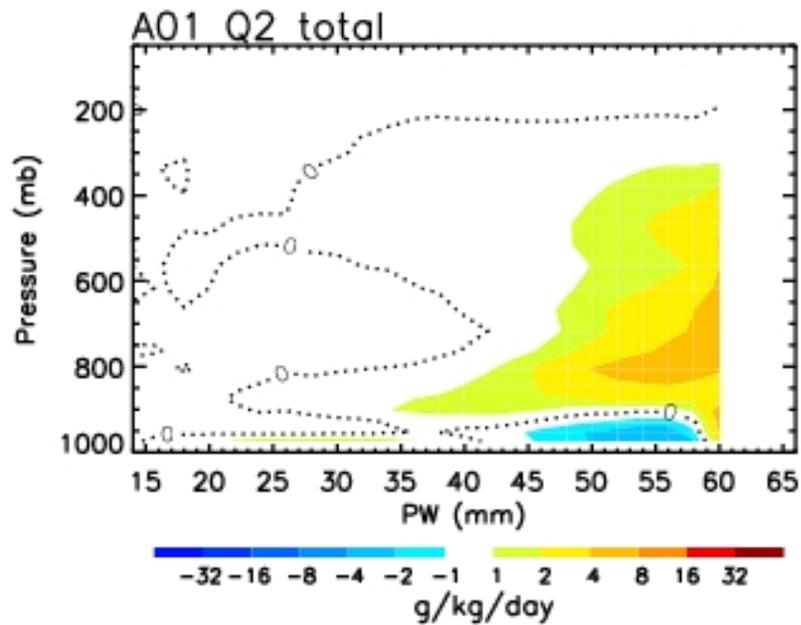
A01 = CMIP5 (no MJO)

A27 = A22 + stronger rain evap (MJO)

A22 = stronger entrainment (MJO)

A07 = best mean climate (MJO)



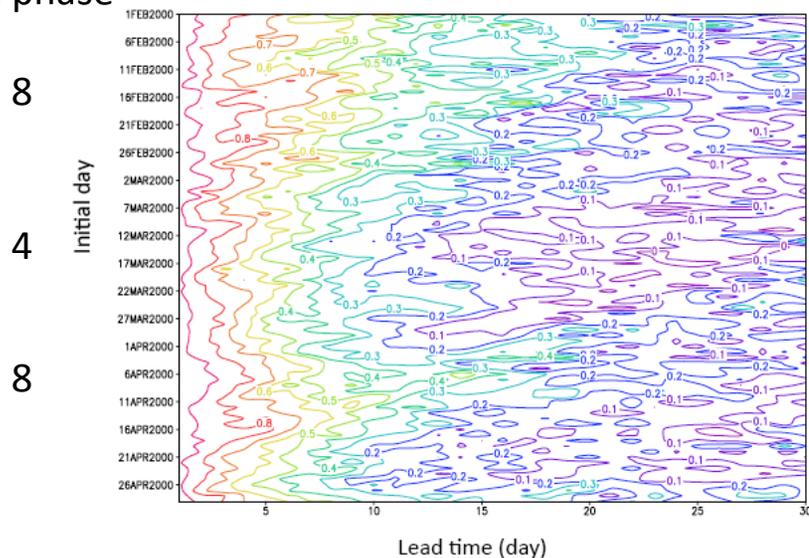


Convective moistening similar in models with and without an MJO

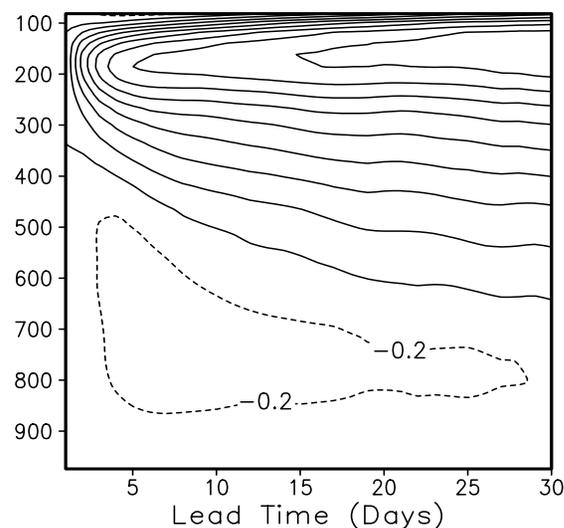
How quickly does a bad model ruin a good MJO?

Pattern correlation of precipitation over the warm pool region

W-H phase



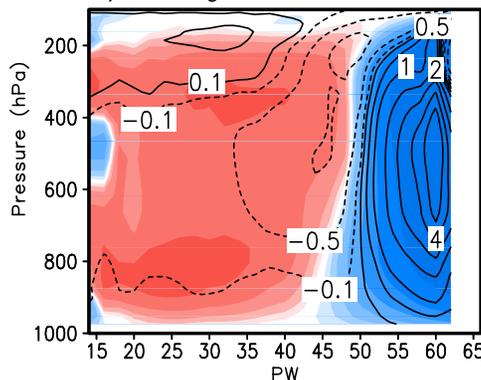
a) T deviation (K)



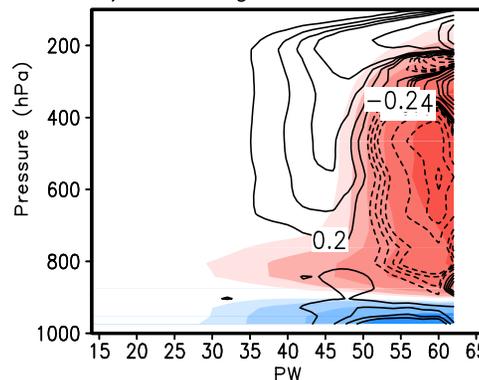
So is the MJO a Q1 problem (deep heating organized into a few large areas) rather than a Q2 problem? Or is it a Q3 problem?

Lead time (day)

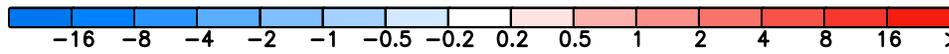
a) Omega



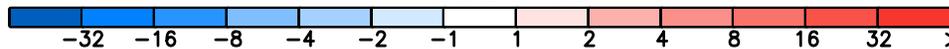
b) Heating



Omega [$\times 10^{-4}$ mb s^{-1}]

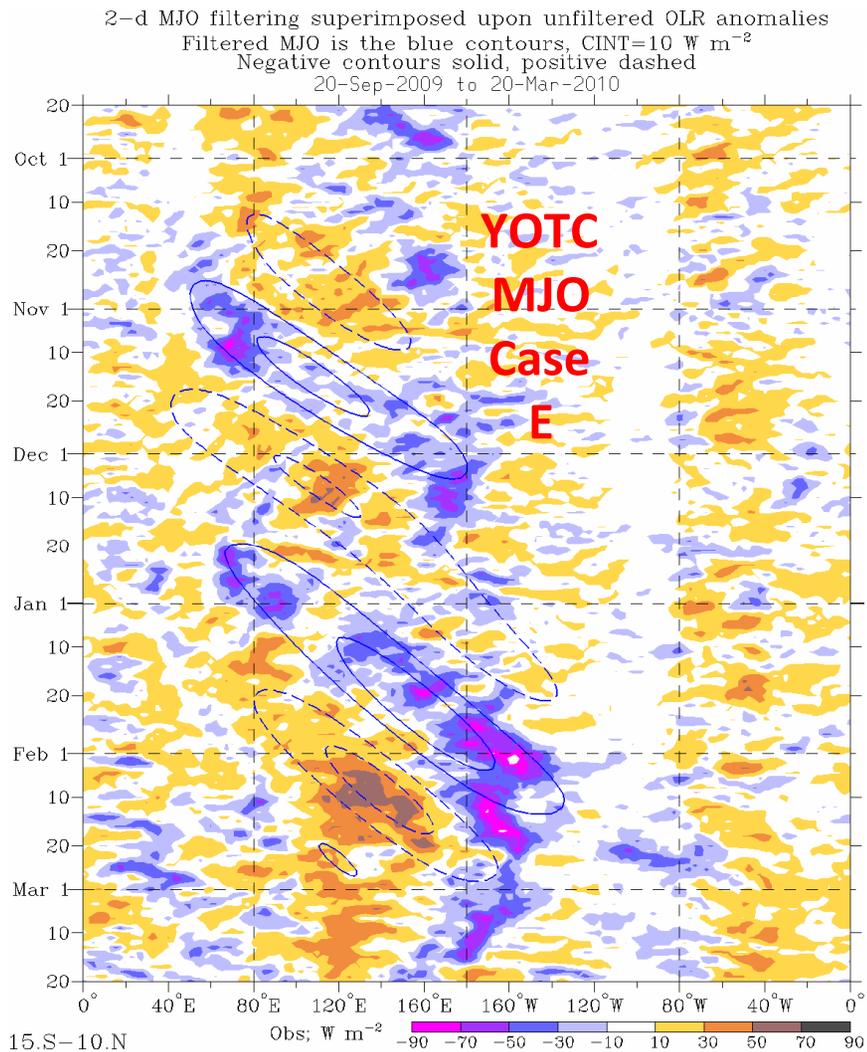


Heating [K/day]



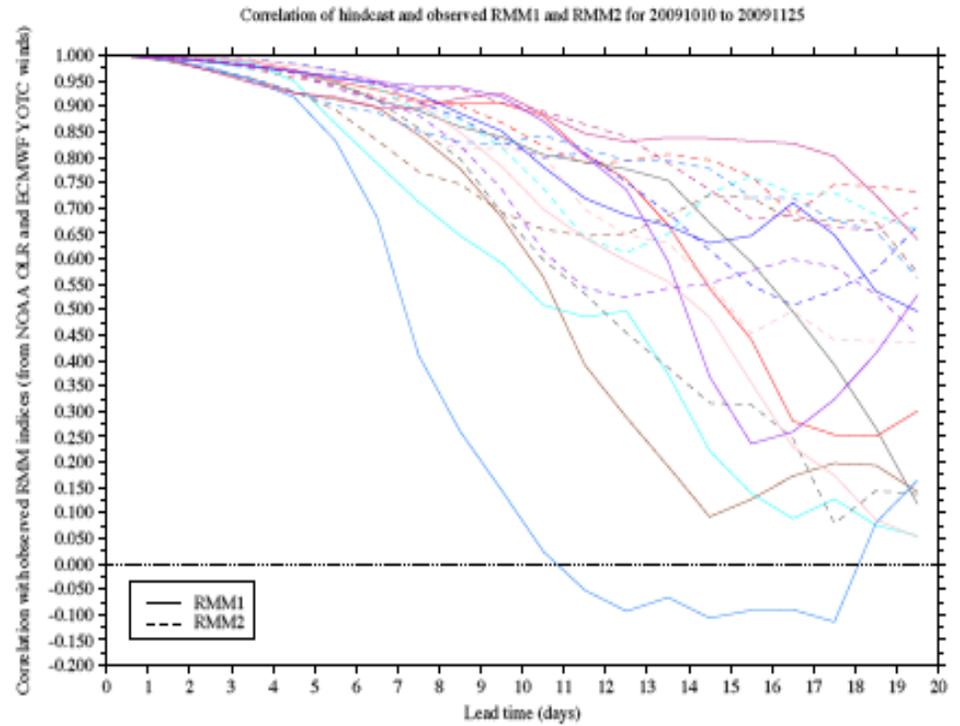
Kim et al. (2012)

How quickly does a not-so-bad model ruin a real MJO?



CAWCR/Bureau of Meteorology

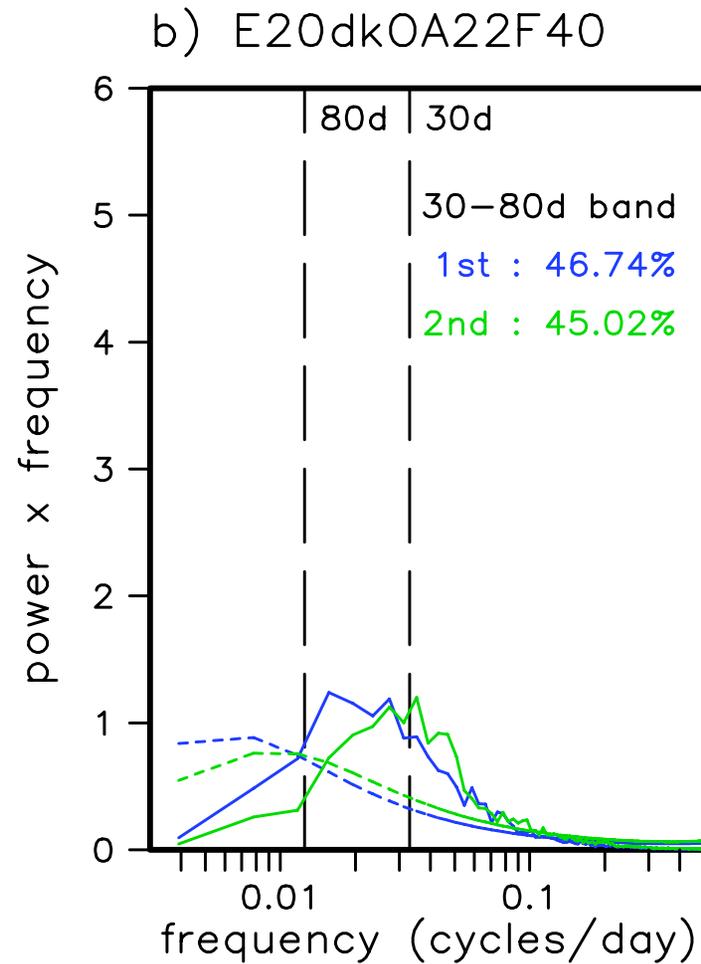
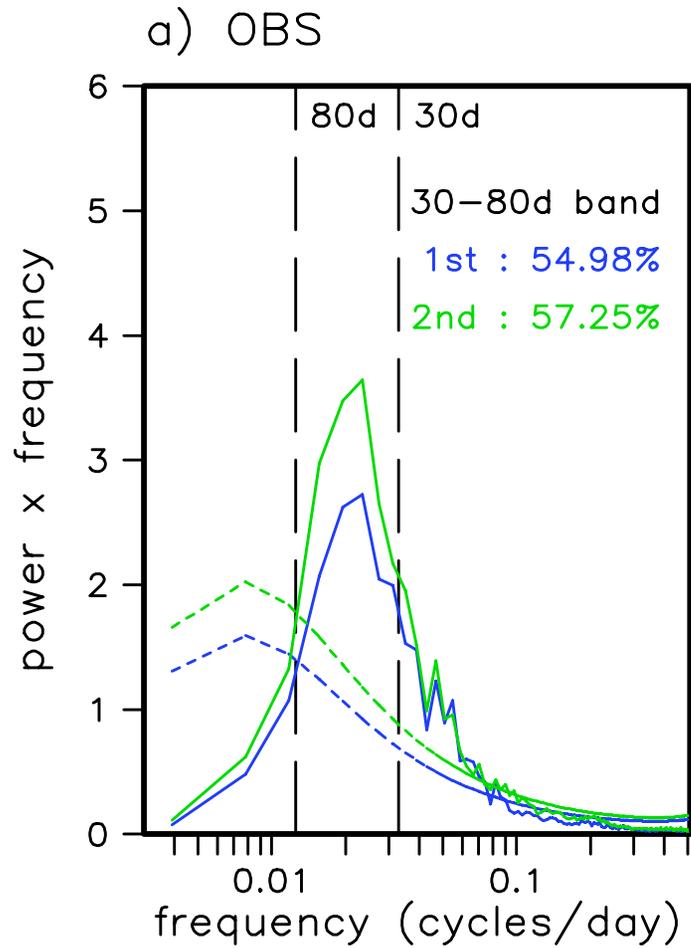
Wheeler (2011)

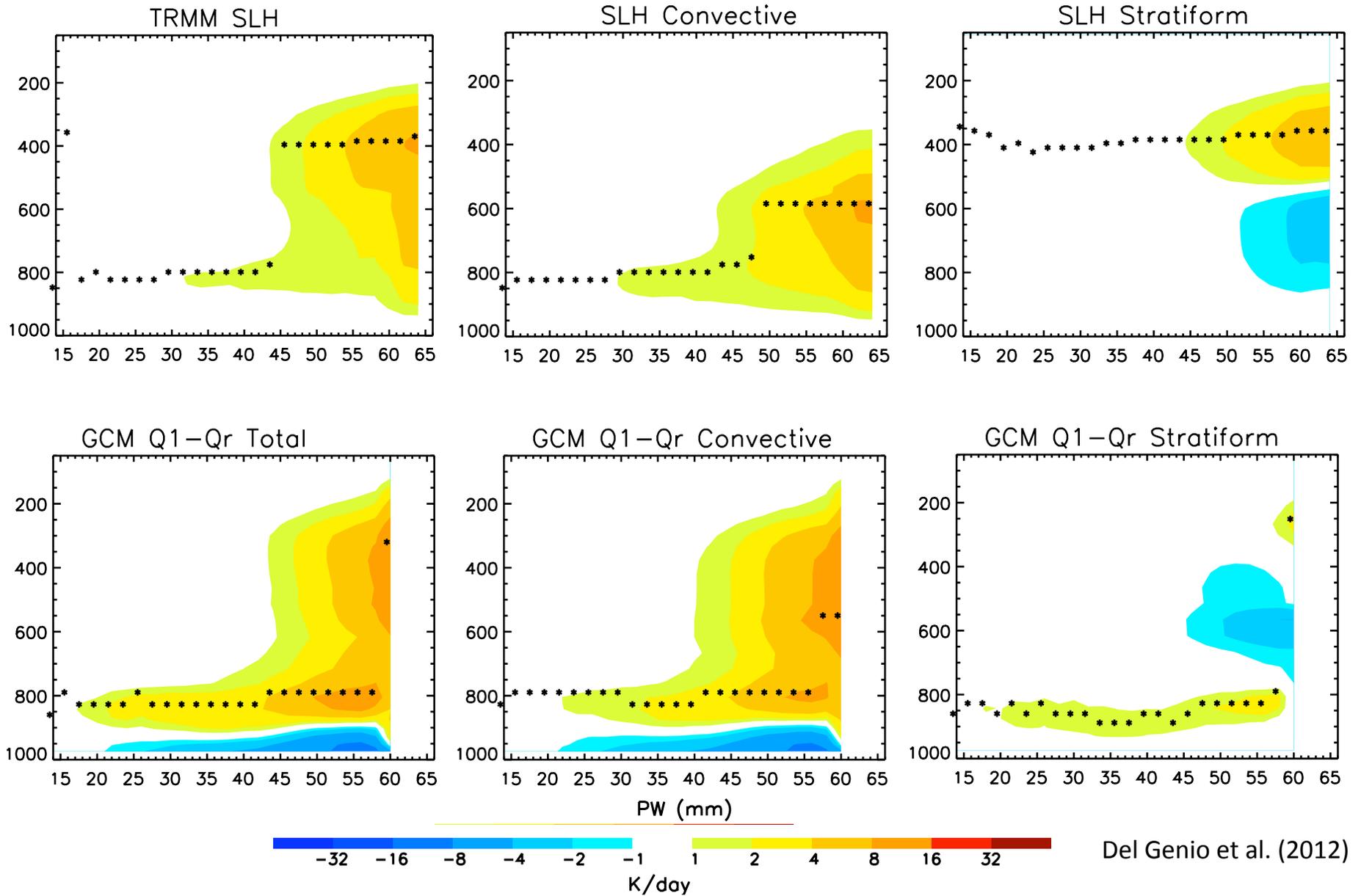


(a) Correlations between modelled and observed RMM1 (solid) and RMM2 (dashed) for case 1 - start dates 2009/10/10 through 2009/11/25.

(Preliminary - courtesy of Nick Klingaman)

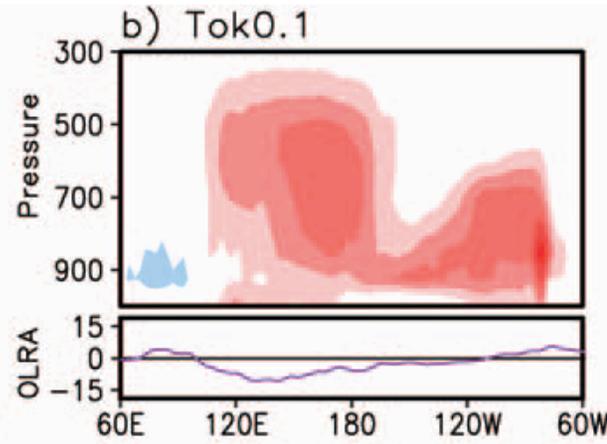
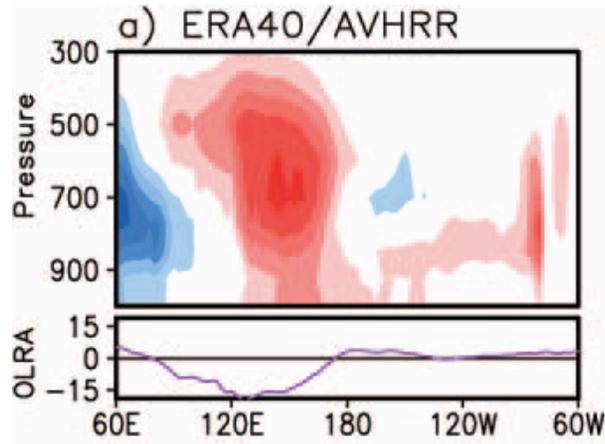
But beauty is only skin deep...



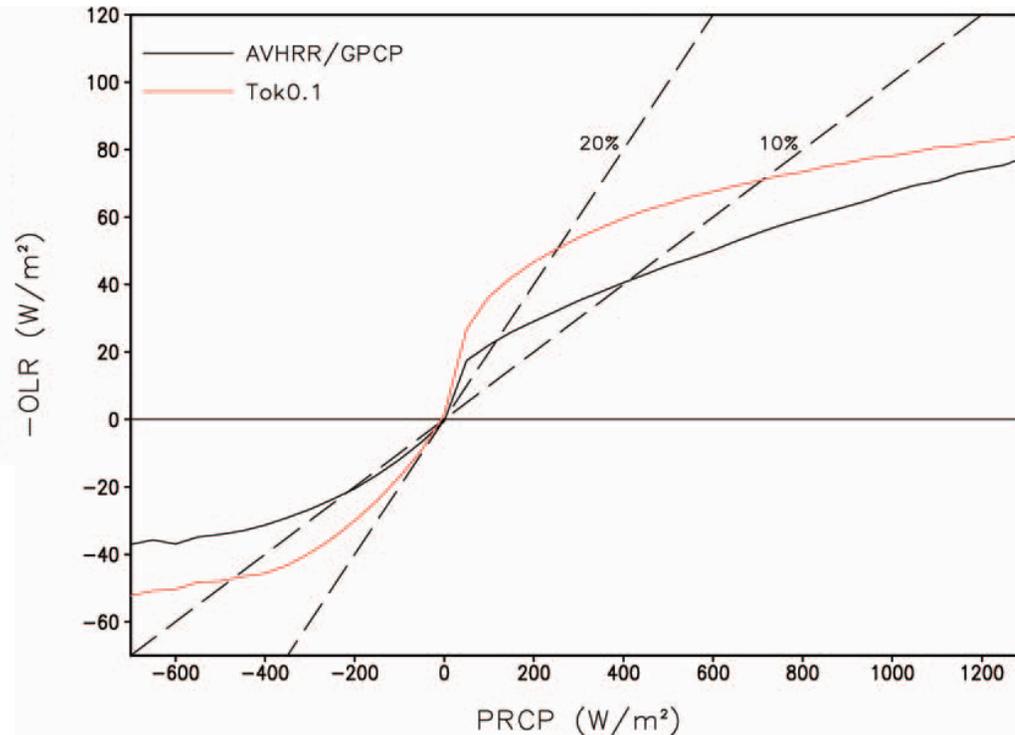
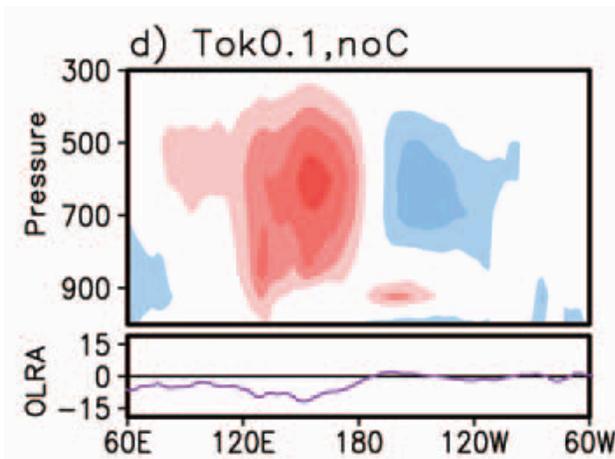


Is missing mesoscale updraft/downdraft heating the answer?

Cloud-radiative interactions?

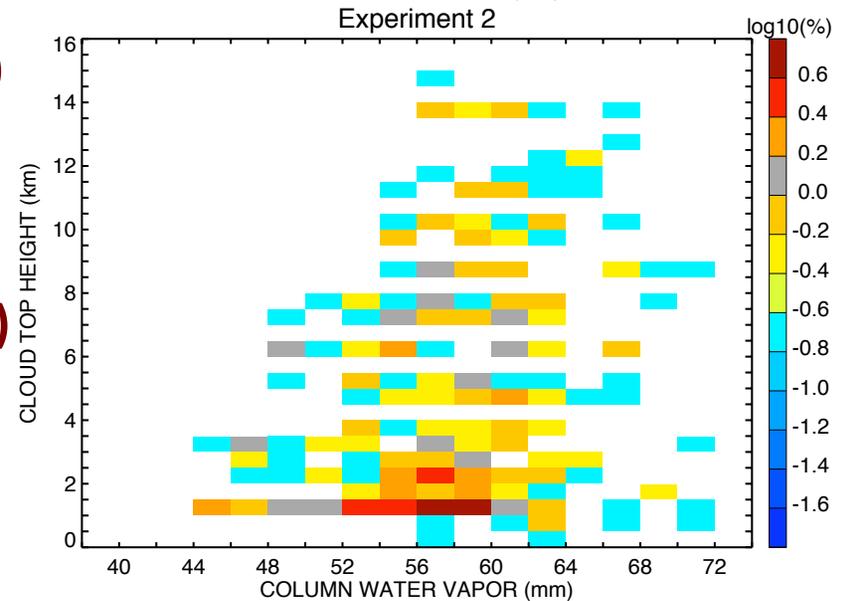
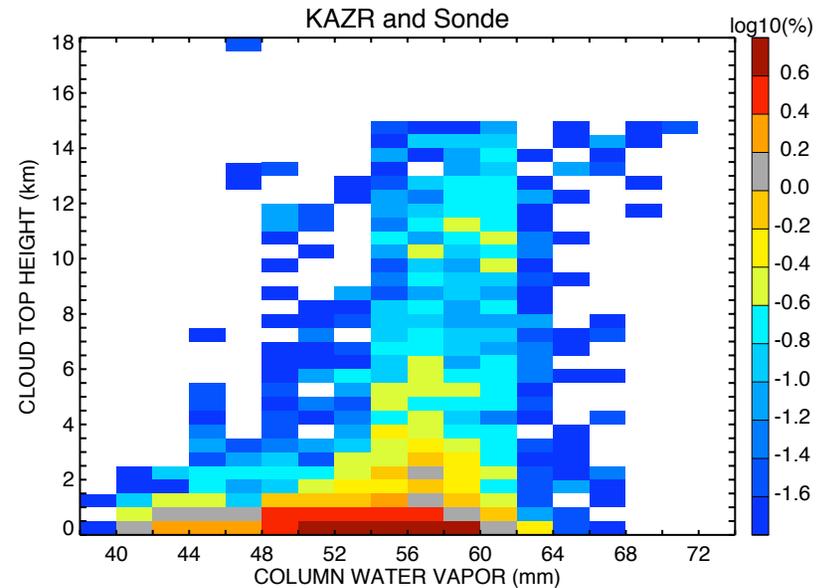
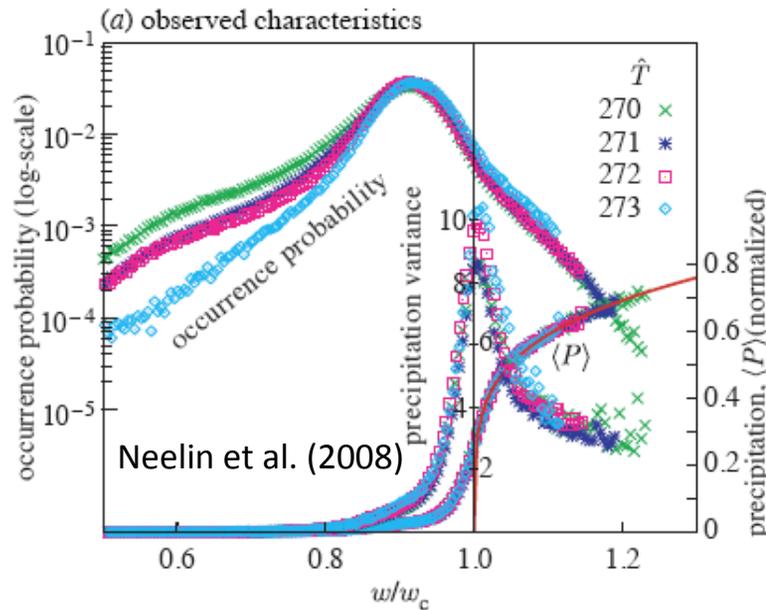


**Are GCM MJOs
“improving”
because of errors
in clouds?**



Kim et al. (2011)

How stochastic do cumulus parameterizations need to be?



Sampling issues (Jones and Randall 2011)

Unresolved variability:

Vertical (Muller et al.)

Horizontal:

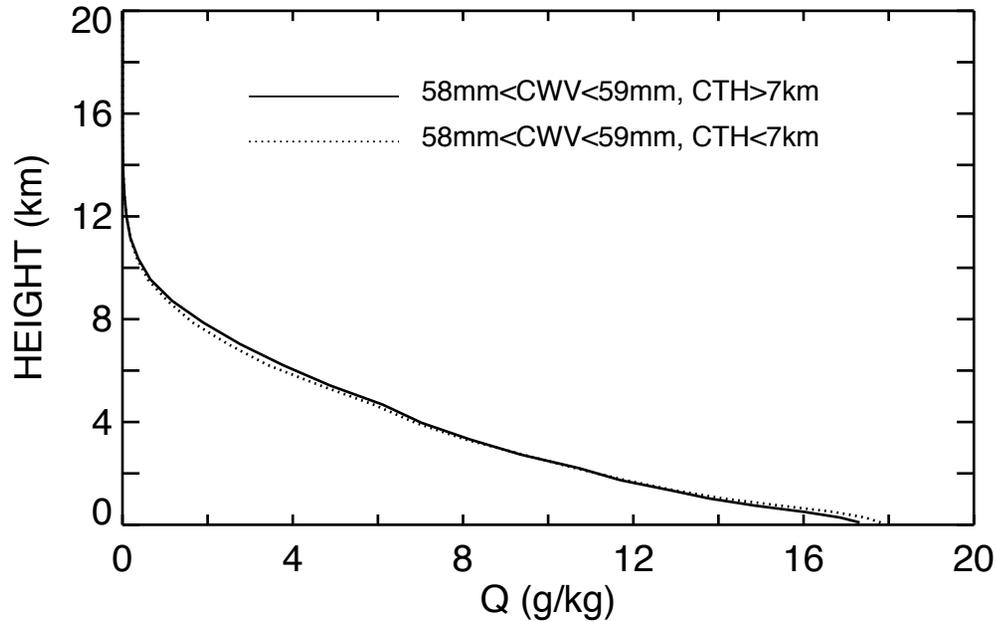
Cloud scale (PBL pdf? Plant and Craig)

Mesoscale (cold pools)?

Episodic (entrainment, glaciation)?

How much is synoptic (dry intrusions)?

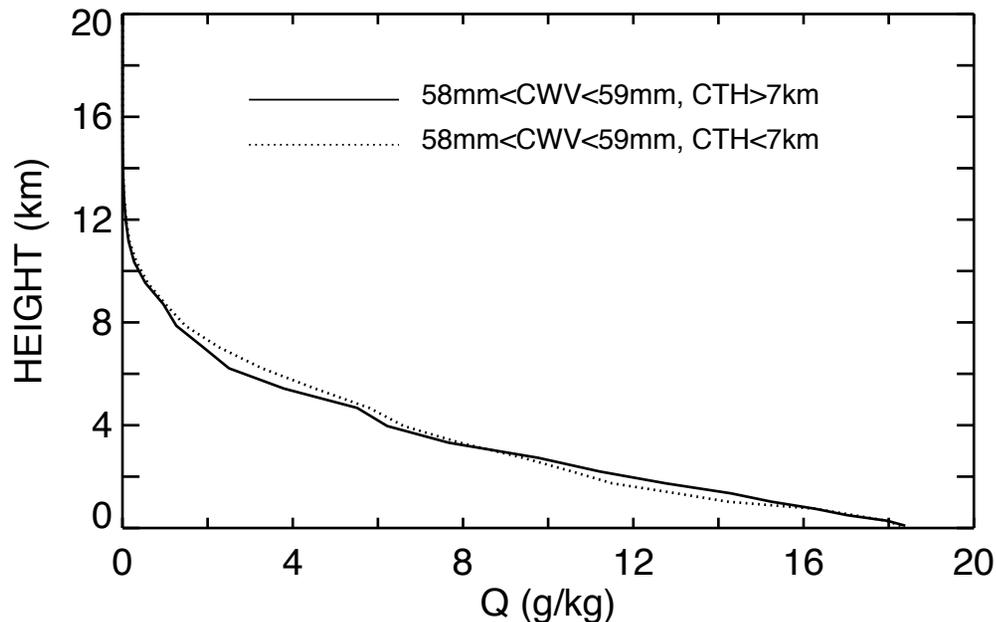
Q PROFILES FROM AMIE-Gan



**AMIE-Gan soundings*
during DYNAMO:**

**For a given PW, shallower
when slightly wetter/drier
within/above PBL –
opposite of Muller et al.
(2009)**

Q PROFILES FROM SCM EXP2



**SCM semi-prognostic test
more consistent with
Muller et al. (2009)**

*** Raw – need to correct for
nighttime moist biases, etc.**

Summary

- **Conventional cumulus parameterizations starting to better resemble what field experiments told us convection was like 35 years ago**
- **Now in a better position to pose questions and evaluate potential answers as more physical components are represented**
- **“Conventional parameterizations will still be needed as ‘encapsulations’ of our (gradually improving) understanding of how clouds interact with the large-scale circulation” (Randall et al. 2003) – *conventional GCMs as final arbiters of tropical climate questions?***
- **Moisture-convection interaction important but not the whole story: Organization? Mostly a heating issue or momentum transport too? Stochastic behavior (and what kind)? Radiative role of clouds?**
- **With great resolution comes great responsibility: “Conventional parameterizations can be improved more rapidly by taking advantage of what we learn by using superparameterizations” (Randall et al. 2003)**

Bias vs. lead time (days), GISS – YOTC ECMWF, 20-day hindcasts

Left: Tropics (30°S-30°N); Right: Indian O. (60-90°E, 15°S-15°N)

