Evaluation of Cloud-Resolving Model Intercomparison Simulations Using TWP-ICE Radar and Satellite Data

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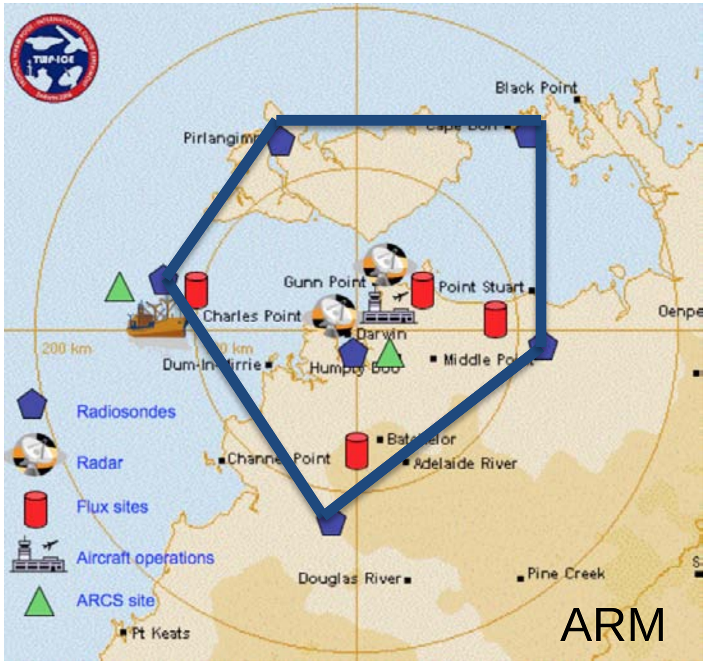
Motivation

- GCMs are hindered by inadequate representation of tropical convection, its thermodynamic and radiative effects, and its relation to environmental properties
  - A key aspect to addressing this problem is improving the cloud-resolving models that help guide GCM parameterizations
- Using a forcing derived from TWP-ICE observations, 9 different CRM simulations are compared to observations over the 6-day active monsoon
  - Convective properties during the active monsoon are similar to the tropical oceanic convective regime that covers a large portion of the world



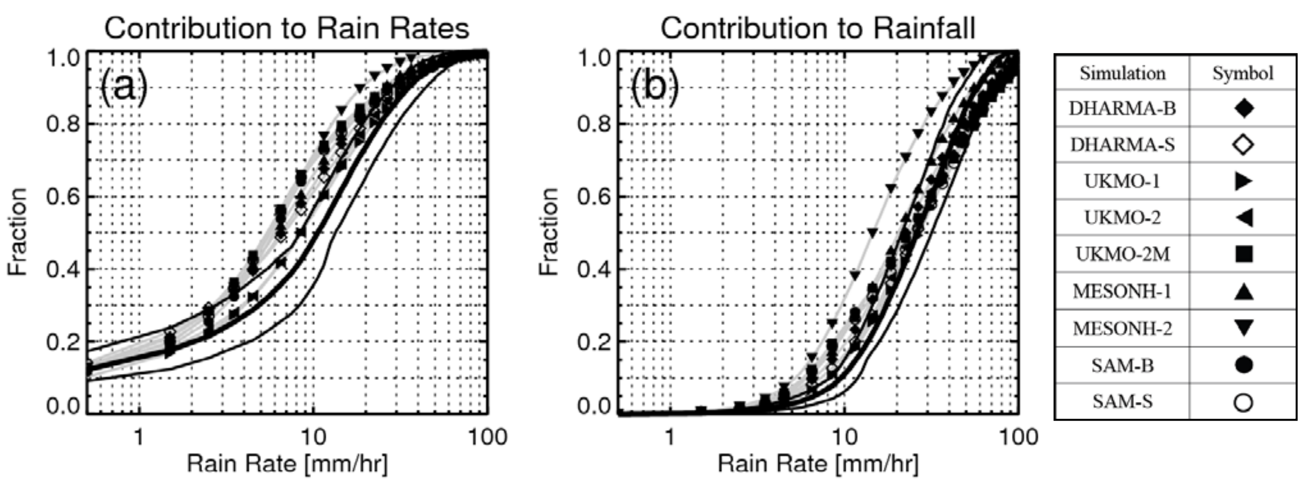
Model Simulations

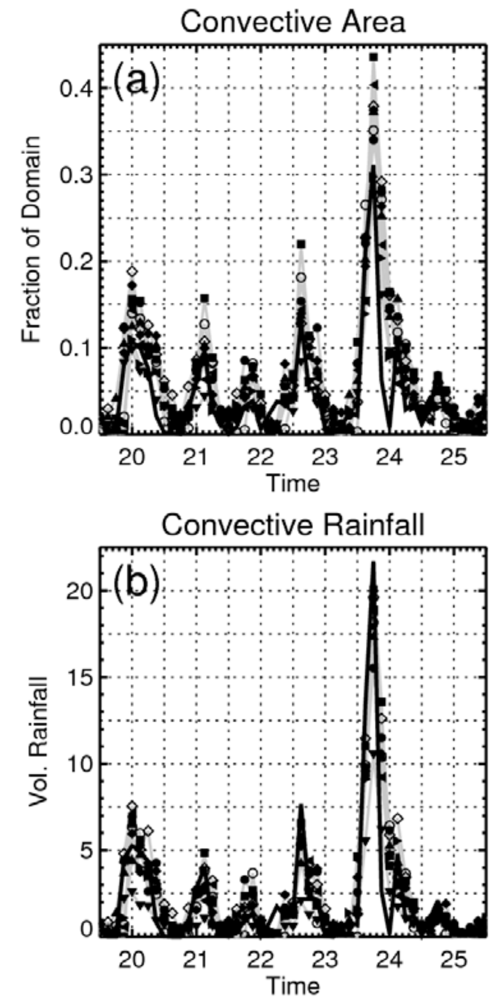
Model Simulation Configurations					
Simulation	Symbol	Domain	Δx	Δz	Microphysics
DHARMA-B	◆	$(176\ km)^2$	917 m	100-250 m	1-moment
DHARMA-S	◇	$(176\ km)^2$	917 m	100-250 m	1-moment
UKMO-1	▶	$(177\ km)^2$	917 m	225-500 m	2-moment (i)
UKMO-2	◀	$(177\ km)^2$	917 m	225-500 m	2-moment (i,g,s)
UKMO-2M	■	$(177\ km)^2$	917 m	225-500 m	2-moment (i,r,g,s)
MESONH-1	▲	$(192\ km)^2$	1000 m	100-250 m	1-moment
MESONH-2	▼	$(192\ km)^2$	1000 m	100-250 m	2-moment (i,w)
SAM-B	●	$(192\ km)^2$	1000 m	100-400 m	2-moment (i,w,r,g,s)
SAM-S	○	$(192\ km)^2$	1000 m	100-400 m	2-moment (i,w,r,g,s)

Methodology

- We want to compare precipitation and cloud structure to establish differences between models and observations and then investigate why these differences exist
  - Use radar reflectivity and geostationary IR satellite data to evaluate model output
  - For radar related properties, precipitation is separated into convective and stratiform regions

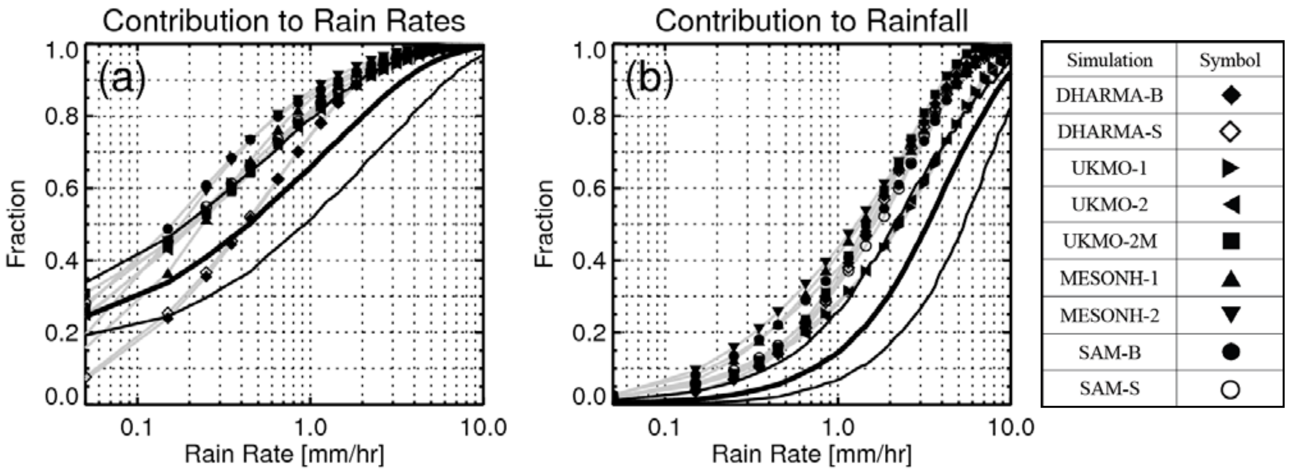
Convective Rainfall

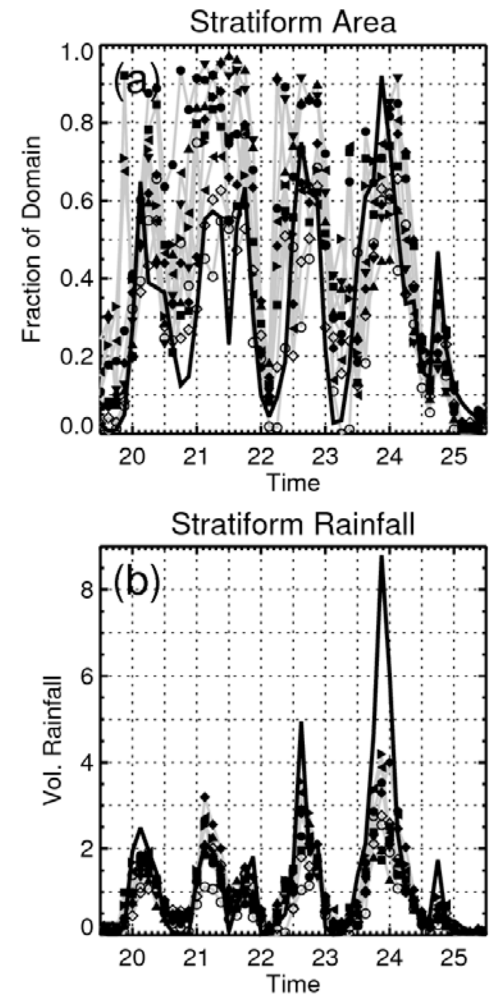




- Convective area is overestimated in most simulations, but rainfall is only slightly overestimated due to far more small to moderate rain rates in simulations than in observations

Stratiform Rainfall

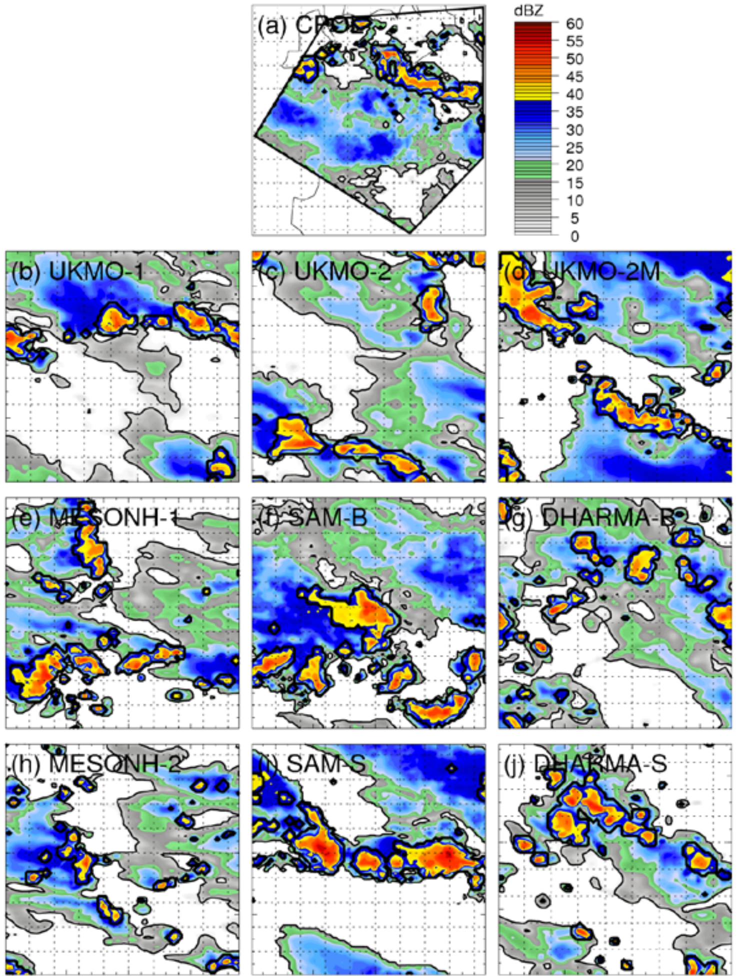




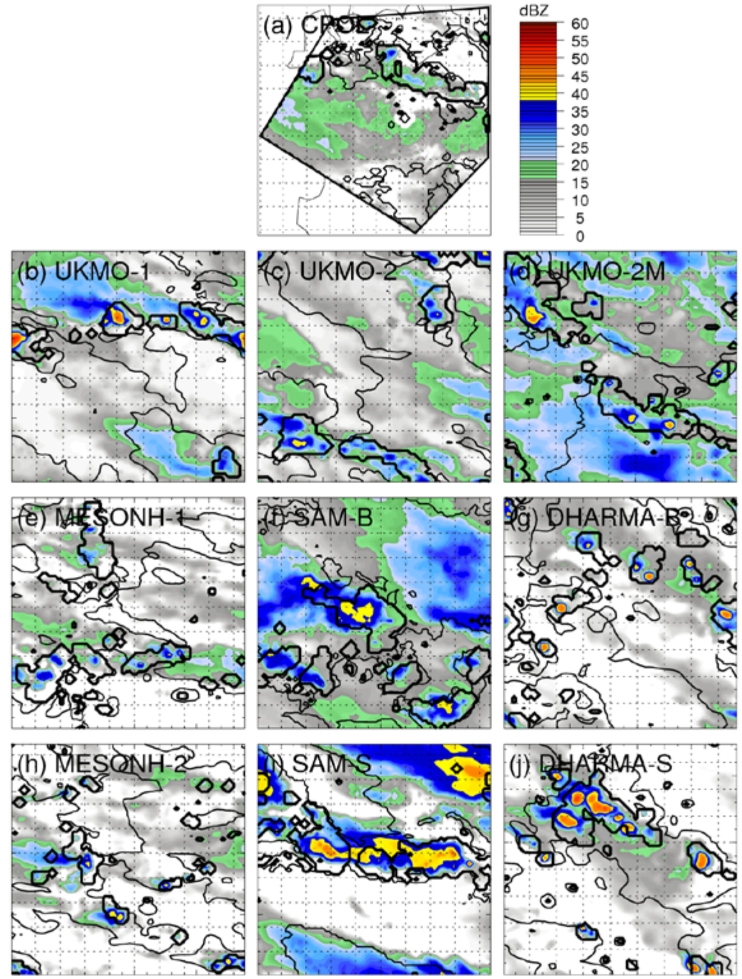
- Stratiform area is overestimated in all baseline simulations, but rainfall is underestimated in all simulations because rain rates are greatly underestimated

Radar Reflectivity

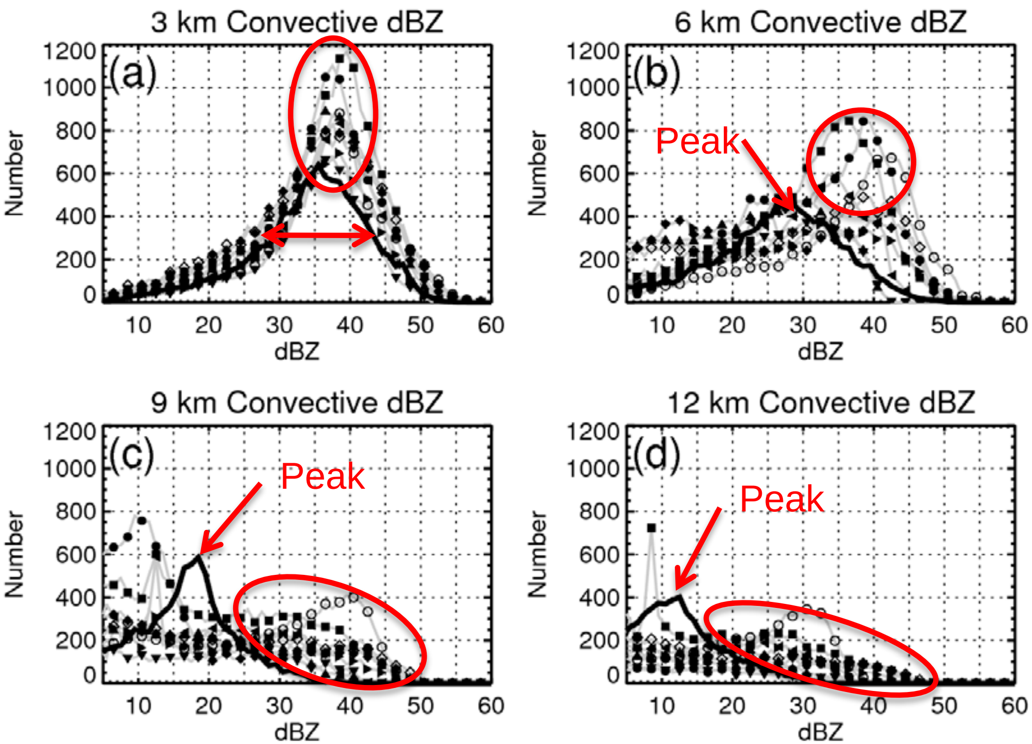
2.5 km



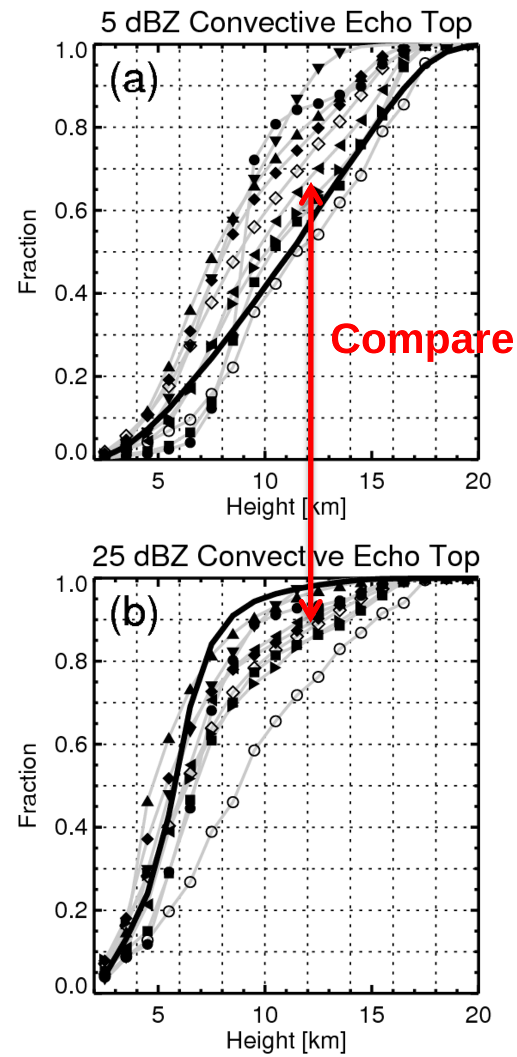
7.5 km



Convective Radar Reflectivity

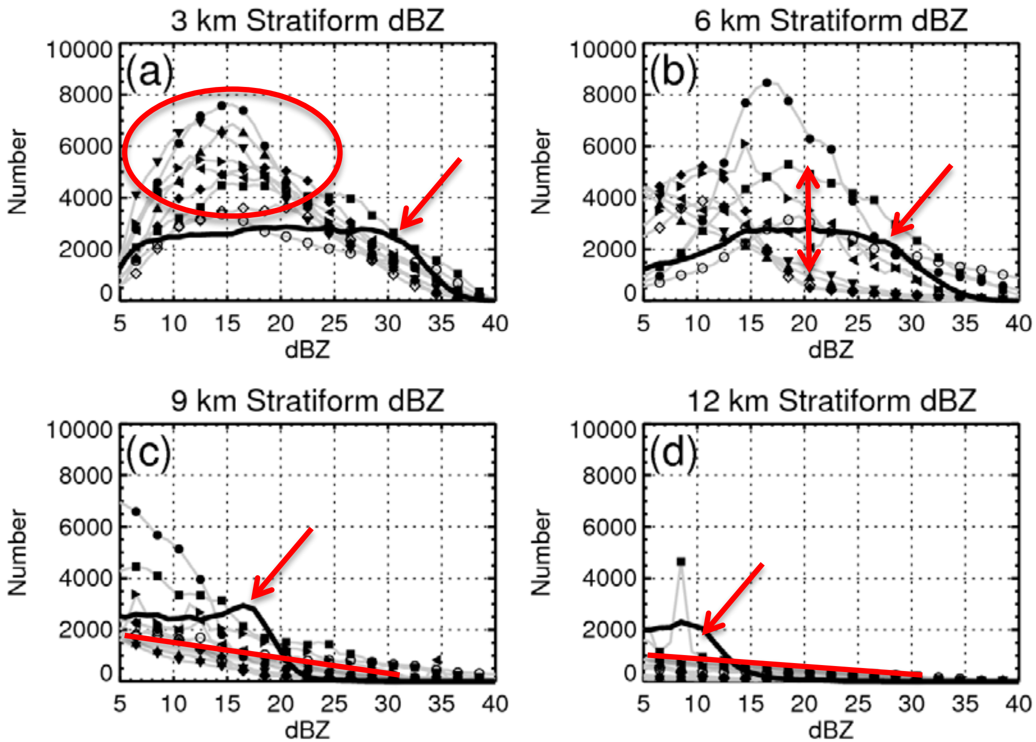


Simulation	Symbol
DHARMA-B	◆
DHARMA-S	◇
UKMO-1	▶
UKMO-2	◀
UKMO-2M	■
MESONH-1	▲
MESONH-2	▼
SAM-B	●
SAM-S	○



- Simulated dBZ is too high aloft and does not have the observed peaked distribution
- Observed dBZ decreases much more gradually with height than simulated dBZ

Stratiform Radar Reflectivity



Simulation	Symbol
DHARMA-B	◆
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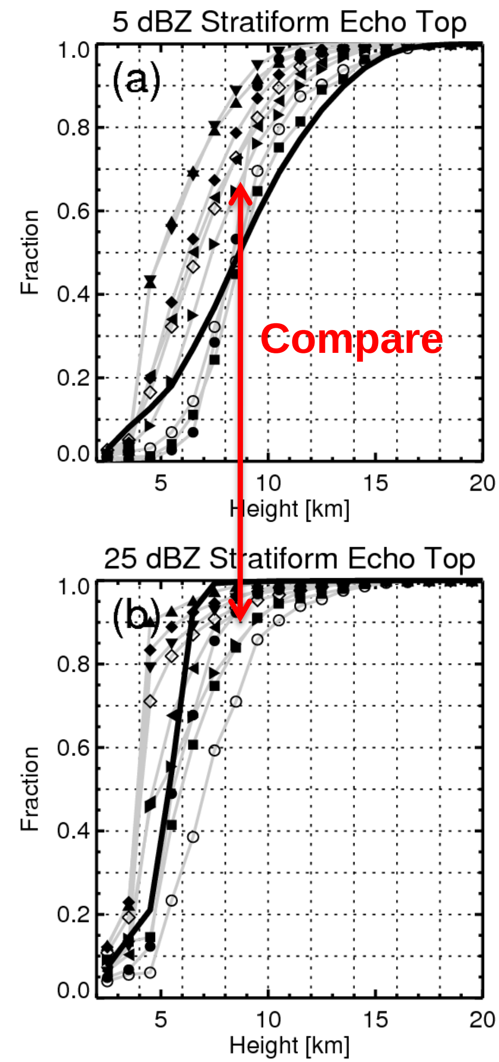
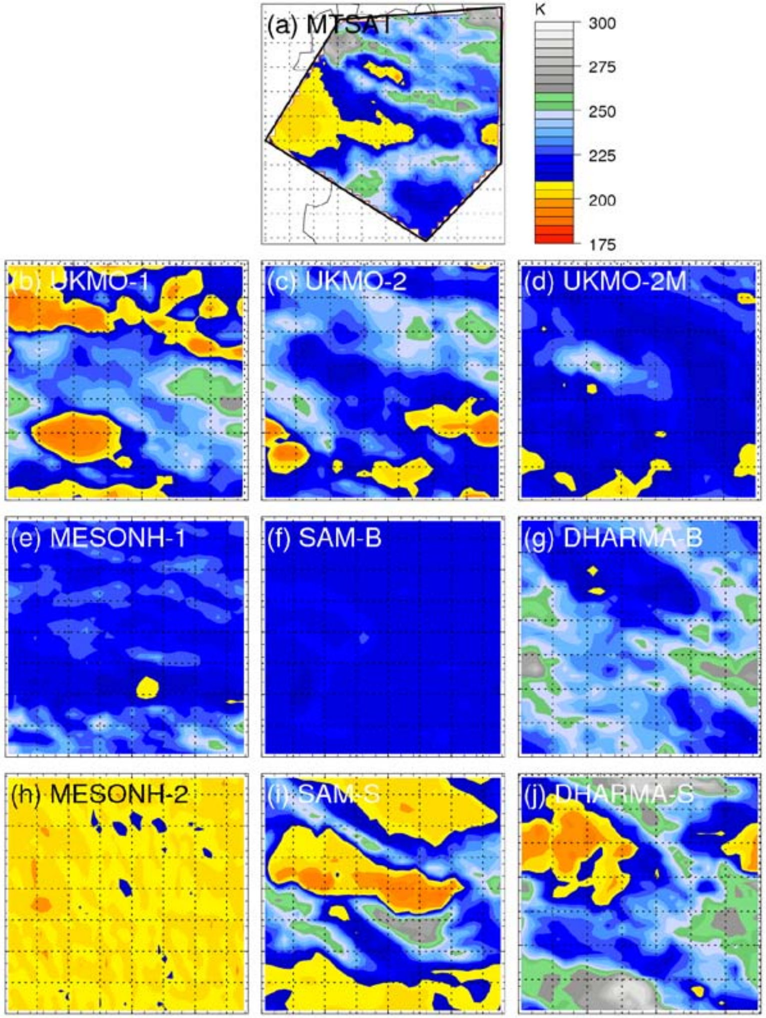


- Simulations cannot reproduce the distinct observed distribution shape
- Obs. show deeper stratiform regions and dBZ decreasing more gradually with height

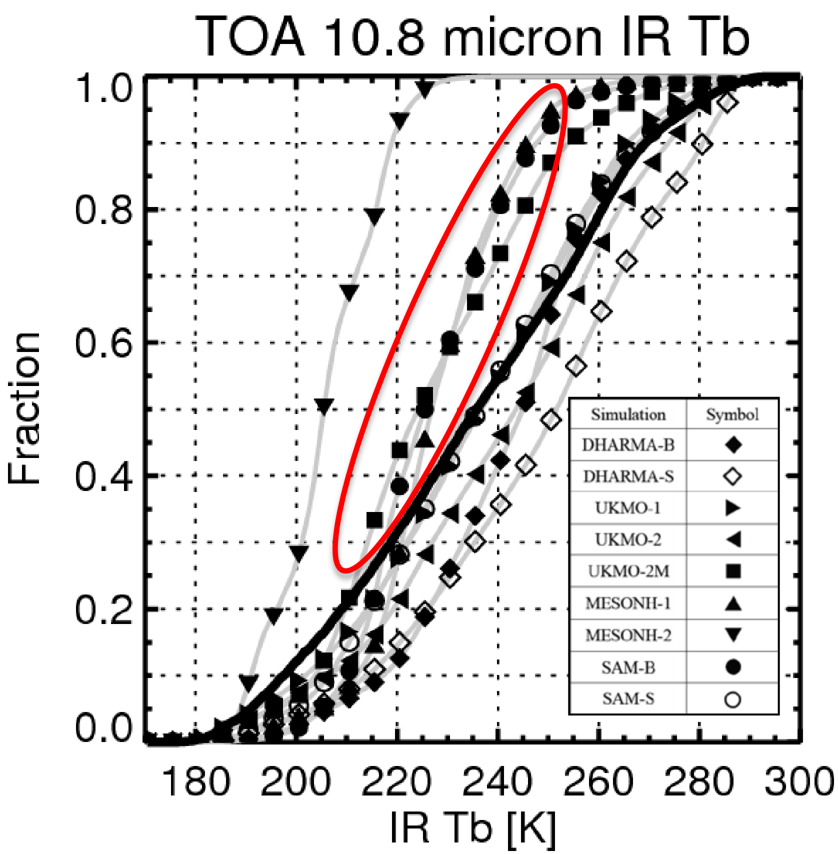
TOA 10.8 µm IR Tb

- Simulated IR Tb calculated with the Community Radiative Transfer Model
- Some simulations are close to MTSAT observations in terms of spatial variability
  - Others produce colder and more uniform IR Tbs than observed



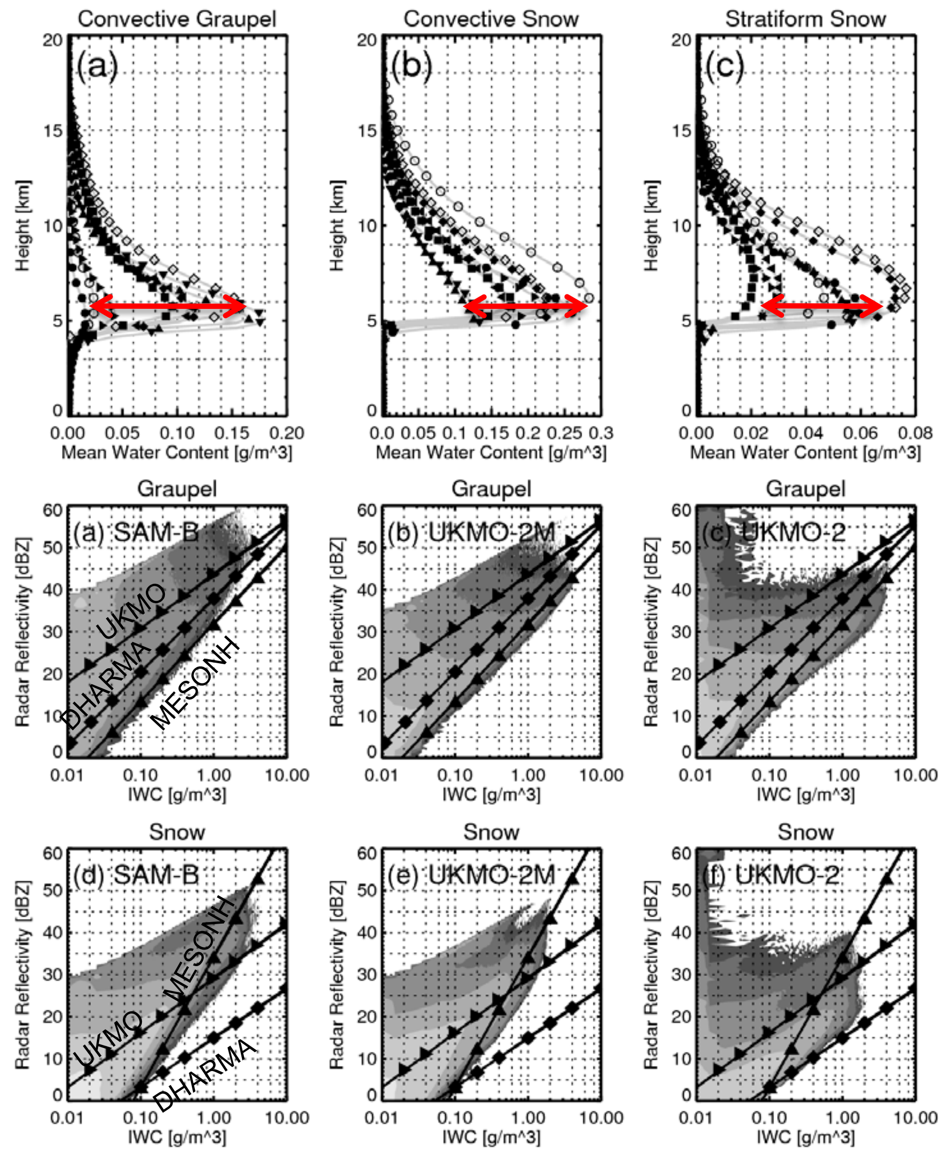
TOA 10.8 μm IR Tb

- Four simulations stand out with more cold brightness temperatures than observed
  - A couple simulations also produce warmer brightness temperatures than observed
- These results do not follow radar reflectivity echo top results



Microphysics

- Despite order of magnitude differences in mean ice water contents, differences in assumed ice size distributions (for a given IWC) play a larger role in radar reflectivity differences between simulations



Conclusions

- Overestimation of convective area by 50% or more is offset by underestimation of mean convective rain rates
- Stratiform rainfall is underestimated by 13% to 53% despite overestimation of stratiform area by up to 65% owing to very low rain rates
- Simulated convective radar reflectivity distributions produce too many high echoes aloft without the observed peaked distribution
- A wide spread in simulated stratiform radar reflectivity is seen with none close to observations

Conclusions

- Radar reflectivity decreases more gradually with height aloft in observations than in all simulations
- Some simulations produce cold and near uniform IR Tbs that are not observed
- Different ice particle size distributions for a given IWC appear to play a larger role than different IWCs in producing the different radar reflectivities
- 2-moment bulk microphysics schemes do not necessarily lead to better agreement with observations

Future Work

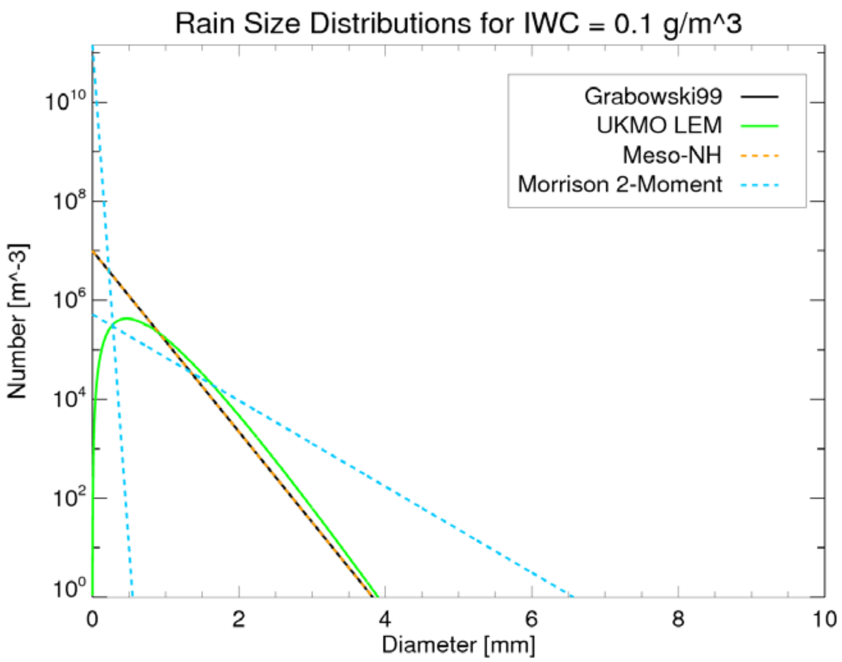
- What is the relative role of updraft vertical velocity to microphysics assumptions and how do these processes interact in the models to produce differences?
- What is the relation of radar reflectivity to the microphysical processes occurring in the model?
- What is the effect of boundary conditions and forcing (compare CRMs to LAMs)?
  - The 2 sensitivity simulations had less stratiform area and more intense/higher convective radar reflectivity

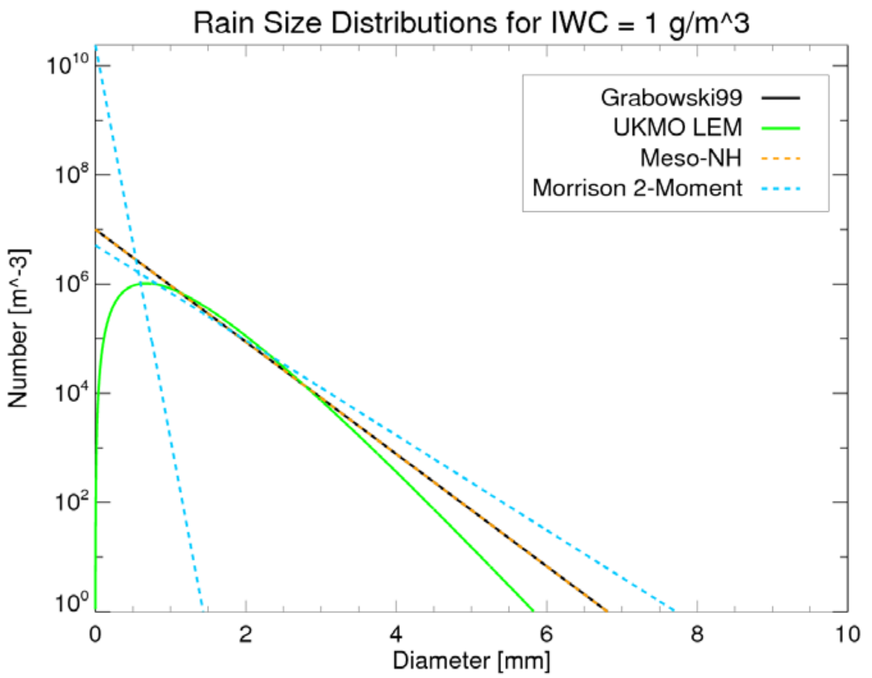
Volumetric Rainfall						
	All		Convective		Stratiform	
	Mean	Difference	Mean	Difference	Mean	Difference
Observed	33.36 (23.66 - 48.51)	-	20.68 (16.19 - 26.59)	-	12.68 (7.48 - 21.92)	-
DHARMA-B	35.66	+ 7%	24.66	+ 19%	11.00	- 13%
DHARMA-S	35.95	+ 8%	27.90	+ 35%	8.05	- 37%
UKMO-1	31.92	- 4%	21.00	+ 2%	10.92	- 14%
UKMO-2	33.18	- 1%	22.45	+ 9%	10.73	- 15%
UKMO-2M	33.43	0%	24.88	+ 20%	8.55	- 33%
MESONH-1	30.78	- 8%	22.11	+ 7%	8.67	- 32%
MESONH-2	19.07	- 43%	11.12	- 46%	7.95	- 37%
SAM-B	34.21	+ 3%	25.18	+ 22%	9.03	- 29%
SAM-S	26.28	- 21%	20.26	- 2%	6.02	- 53%

Precipitating Area						
	All		Convective		Stratiform	
	Mean	Difference	Mean	Difference	Mean	Difference
Observed	0.363	-	0.044	-	0.319	-
DHARMA-B	0.491	+ 35%	0.068	+ 55%	0.423	+ 33%
DHARMA-S	0.379	+ 2%	0.071	+ 61%	0.308	- 3%
UKMO-1	0.507	+ 40%	0.047	+ 7%	0.460	+ 44%
UKMO-2	0.496	+ 37%	0.053	+ 20%	0.443	+ 39%
UKMO-2M	0.517	+ 42%	0.073	+ 66%	0.444	+ 39%
MESONH-1	0.521	+ 44%	0.068	+ 55%	0.453	+ 42%
MESONH-2	0.521	+ 44%	0.042	- 5%	0.479	+ 50%
SAM-B	0.598	+ 65%	0.072	+ 64%	0.526	+ 65%
SAM-S	0.360	- 1%	0.057	+ 30%	0.303	- 5%

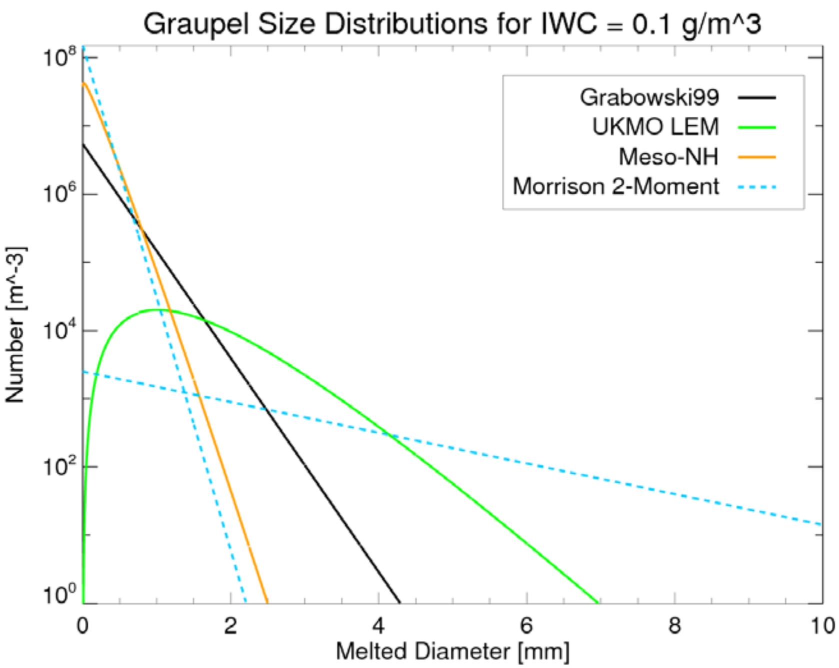
Rain Rate						
	All		Convective		Stratiform	
	Mean	Difference	Mean	Difference	Mean	Difference
Observed	2.95 (2.09 - 4.29)	-	15.14 (11.85 - 19.47)	-	1.27 (0.75 - 2.20)	-
DHARMA-B	2.37	- 20%	11.86	- 22%	0.85	- 33%
DHARMA-S	3.10	+ 5%	12.84	- 15%	0.85	- 33%
UKMO-1	2.04	- 31%	14.47	- 4%	0.77	- 39%
UKMO-2	2.17	- 26%	13.73	- 9%	0.78	- 39%
UKMO-2M	2.09	- 29%	11.08	- 27%	0.62	- 51%
MESONH-1	1.95	- 34%	10.77	- 29%	0.63	- 50%
MESONH-2	1.21	- 59%	8.79	- 42%	0.55	- 57%
SAM-B	1.89	- 36%	11.55	- 24%	0.57	- 55%
SAM-S	2.41	- 18%	11.64	- 23%	0.66	- 48%

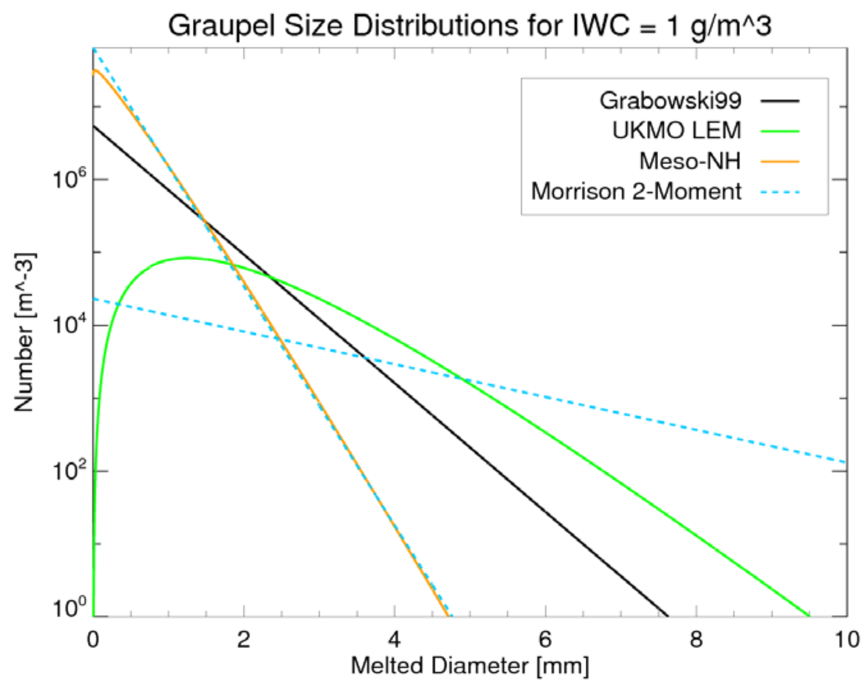
Rain Size Distributions





Graupel Size Distributions





Snow Size Distributions