National Aeronautics and Space Administration
Goddard Institute for Space Studies
New York, N.Y. 10025

Columbia University
IN THE CITY OF NEW YORK

WRF and GISS SCM Simulations of Convective Updrafts During TWP-ICE

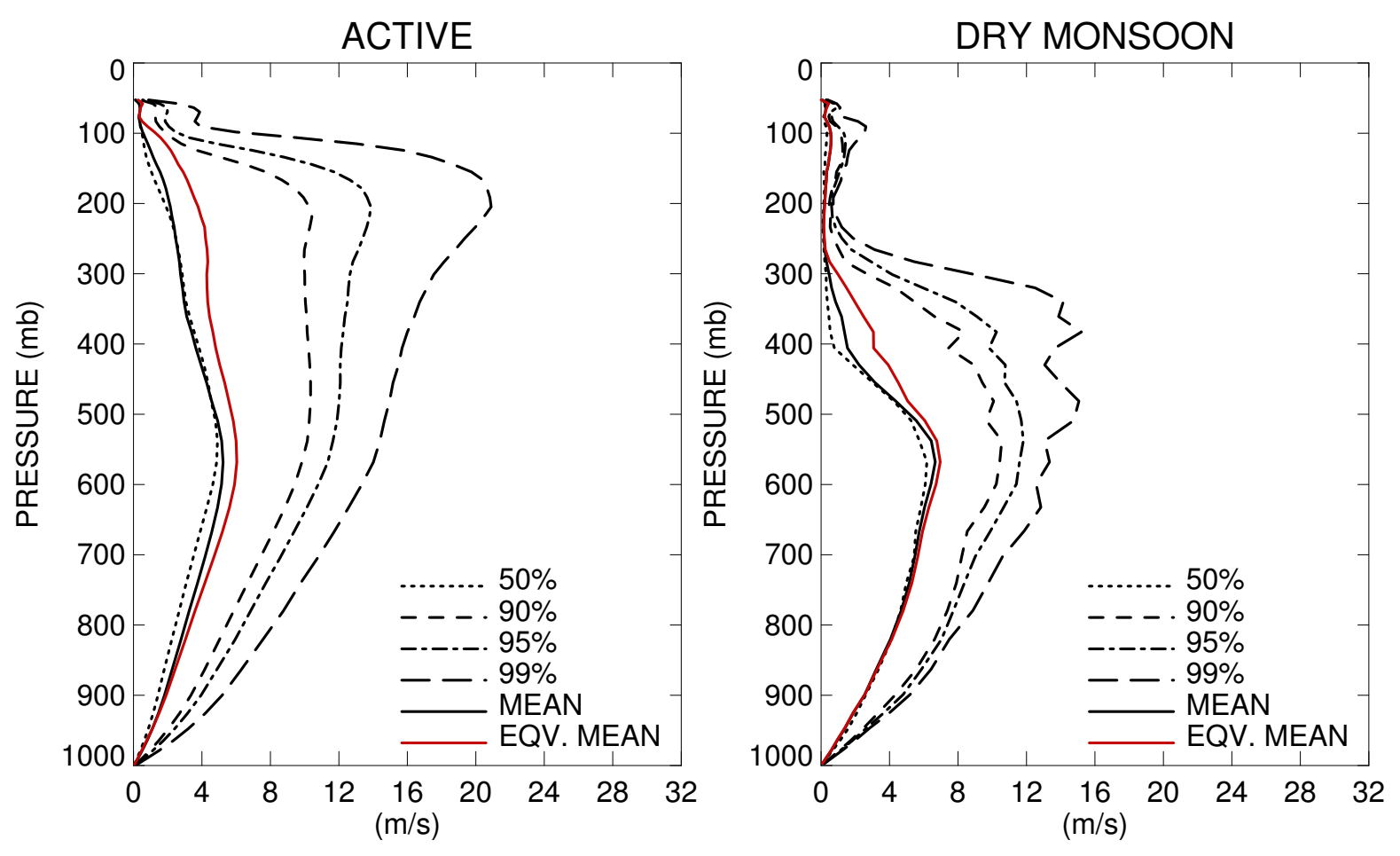
Jingbo Wu (Columbia U.), Anthony D. Del Genio (NASA/GISS)

SUMMARY: Diagnosis of convective updraft speeds in global climate models is important for two reasons. First, the strength of cumulus updrafts determines the vertical convective condensate transport and the detrainment into anvils whose microphysical and radiative properties are important to climate feedbacks. Second, cumulus updraft speeds are also diagnostic of various severe weather phenomena, such as lightning, that contribute to ozone and carbonaceous aerosol climate forcing. The TWP-ICE IOP, with distinctive convection types of weak vs. strong and deep vs. shallow convection, provides a good opportunity to evaluate a model's ability to simulate variable convective updraft strength. The WRF model, run at CRM resolution (1.3km and 0.6km) and driven with reanalysis and observed T,Q profiles, captures the differences among the convection regimes and is fairly robust to changes in resolution and parameterizations. The convective updraft speed diagnosed in the GISS Model E SCM from the thermodynamic profile following Gregory (2001) is similar to that simulated by WRF for the break period when the fractional reduction of parcel buoyancy by entrainment is increased relative to its nominal value in the GCM. For shallower congestus-type convection during the dry monsoon, the SCM is not able to simulate the lower convection top even with strong entrainment. For weak active period convection, the SCM overestimates upper troposphere updraft speed even with strong entrainment.

WRF Results

Table 1: WRF model setups for different runs.

	Horizontal Resol. (km)	Vertical Resol. (layers)	Microphysics Scheme	PBL Scheme	Simulation Length (hrs)
WSM-30	1.33	30	WSM6	Yonsei U.	72
Thompson-30	1.33	30	Thompson	Yonsei U.	72
Thompson-50	1.33	50	Thompson	Yonsei U.	72
Thompson-30-MYJ	1.33	30	Thompson	Mellor-Yamada-Janjic	72
Thompson-44-hori0	0.6	44	Thompson	Yonsei U.	36(active) 24(break)



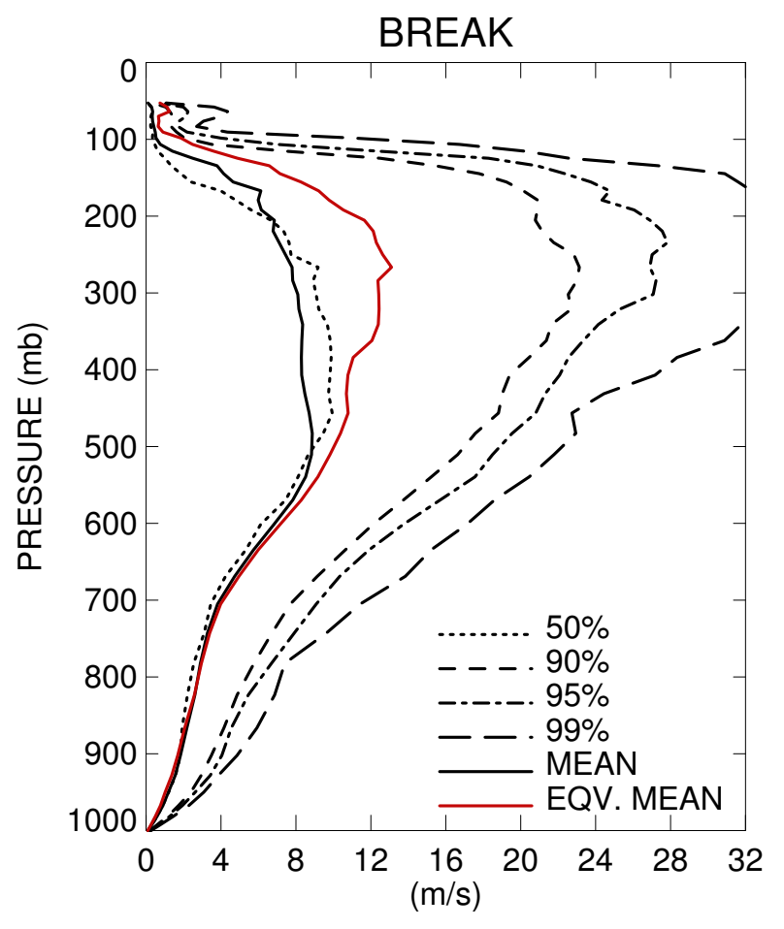


Fig 1: Percentiles of deep convective updraft speed from the Thompson-50 run vs. w_{eq}.

Fig 2: Equivalent mean updraft speed for the active, the dry monsoon, and the break period (3-day runs).

Equivalent Mean Updraft Speed:

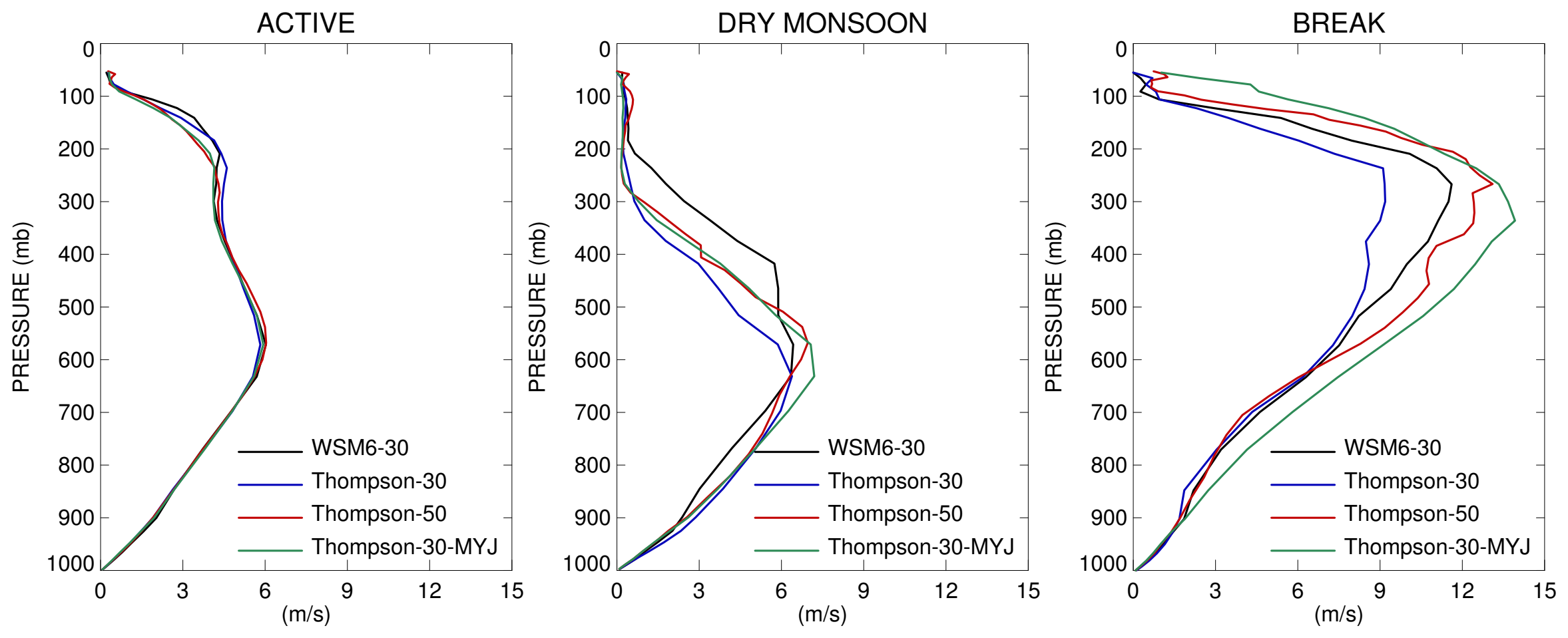
$w_{eq} = \langle w q_h \rangle / \langle q_h \rangle$ where

w = updraft speed in deep convective columns

$\langle\ \rangle$ = domain mean over half-hour periods

q_h = hydrometeor water content in the corresponding columns

w_{eq} is somewhat larger than the mean updraft speed, indicating that the stronger updrafts transport more condensed water.



WRF captures the differences in cumulus updraft speed between the active and break periods, with weak updrafts for the active period and strong updrafts for the break period. It also captures the primarily middle-level convection for the dry monsoon period. For the break period, the updraft speed is moderately sensitive to resolution and parameterizations above the freezing level, and as expected, differences between the runs increase with longer simulation length. But overall, the ability of the WRF model to differentiate the sub-periods based only on differences in the thermal structure is quite robust.

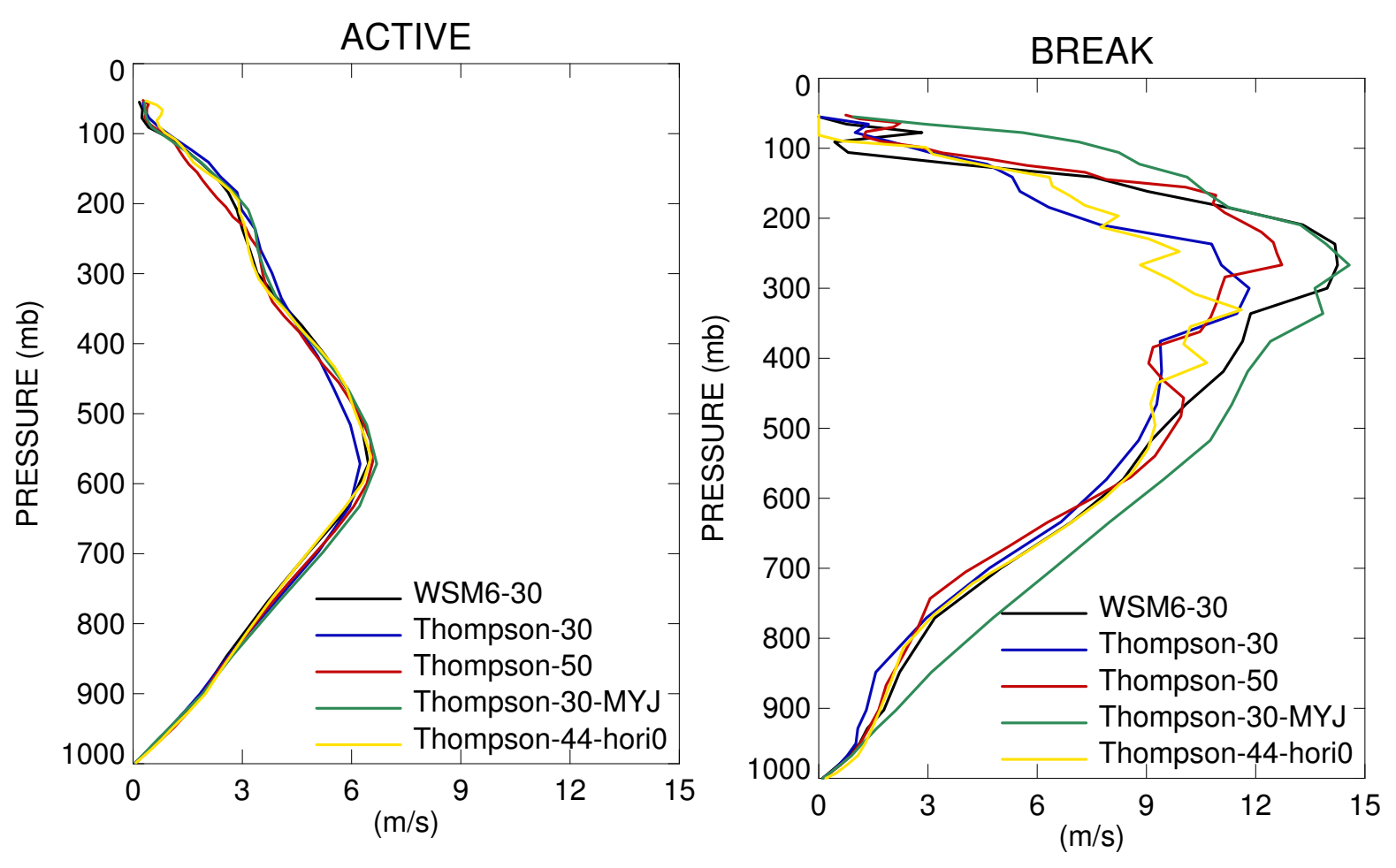


Fig 3: Same as Fig 2 but with shorter simulation length: 36-hr (active); 24-hr (break).

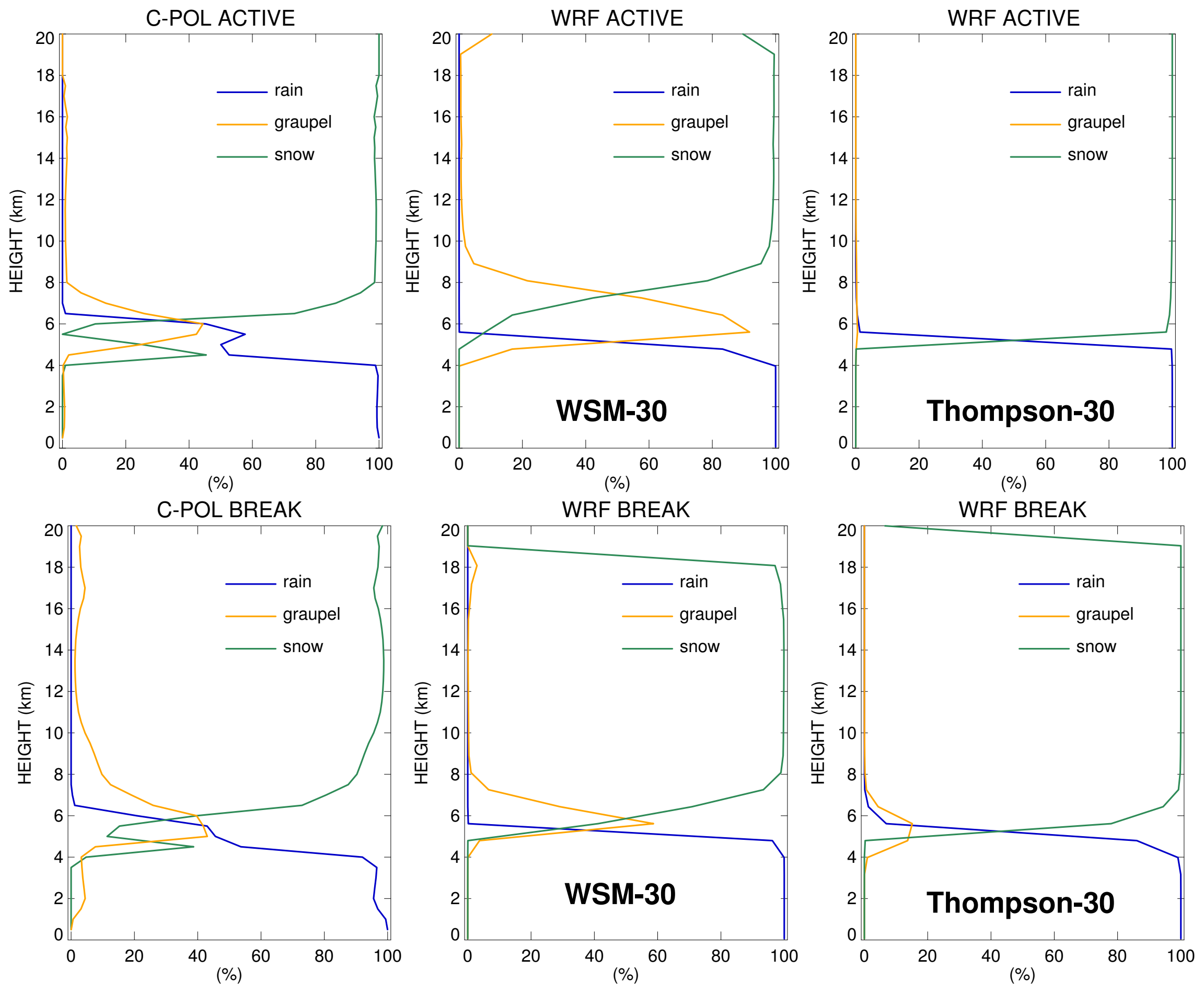


Figure 4 C-POL vs. WRF hydrometeor occurrence.

The relatively high occurrence of graupel above 8km during the break period in C-POL suggests a stronger convective updraft speed. For the WRF model, simulations with the WSM6 microphysics produce too much graupel, and higher graupel occurrence for the weaker active period than for the break period. Simulations with the Thompson scheme produce too little graupel, but they are able to capture the difference between active and break, with higher graupel occurrence for the break period.

WRF captures the cloud top height PDF pattern seen by ARSCL for non- and light-precipitating times. For heavy precipitation events, the differences at high levels appear to be due to a bias in the ARSCL retrieval.

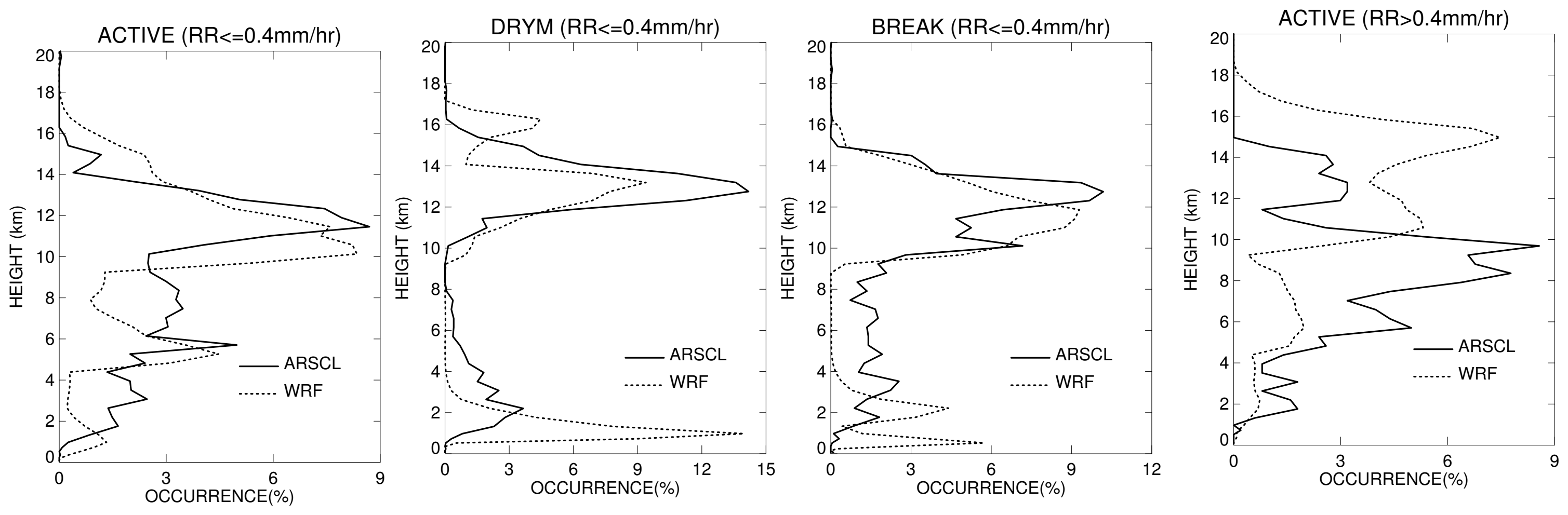


Figure 5: Cloud top height occurrence PDF from ARSCL and WRF T50.

SCM Results

Table 2: SCM setups for different runs.

	Convective adjustment time scale(hr)	Buoyancy reduction by entrainment
0.5hr-E0.6	0.5	0.6
0.5hr-E0.9	0.5	0.9
1hr-E0.6	1	0.6
1hr-E0.9	1	0.9

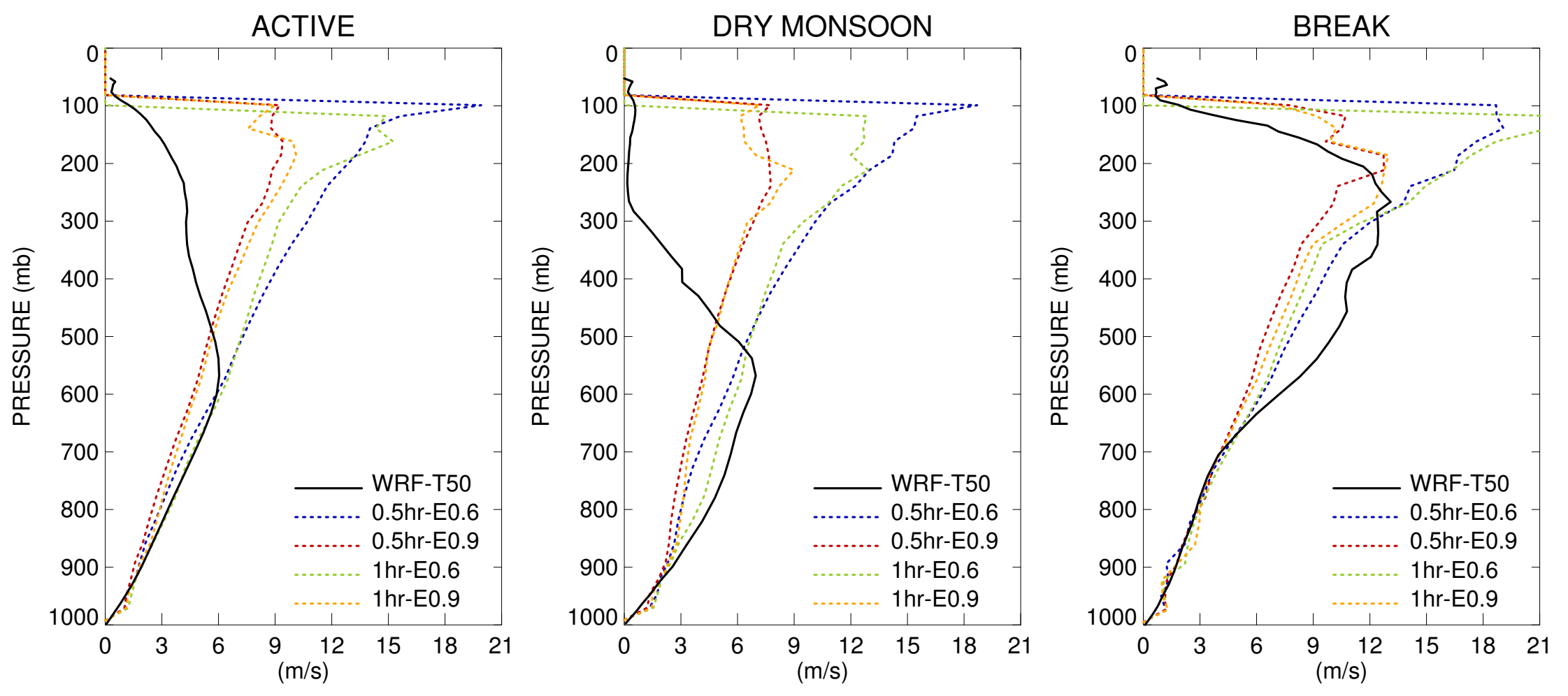


Figure 6: SCM deep convective updraft speeds.

The GISS SCM now includes a diagnosis of cumulus updraft speed following Gregory (2001). We compare this to WRF.

In the SCM control run (0.5hr-E0.6), there are slight differences between the sub-periods, but updrafts accelerate too much in the upper troposphere compared with WRF. For SCM runs with an enhanced entrainment rate, the updraft speed is reduced in the upper troposphere. For the break period, the result is promising, but for the active and dry monsoon periods, even strong entrainment is insufficient to decelerate the updraft, and cloud top is too high for the dry monsoon. This suggests too little drag due to condensate loading or cumulus pressure gradient effects.

CONTACT: JWU@GISS.NASA.GOV