Comparative Analysis of Deep Convective Cores between MC3E and TWP-ICE Cases: Impact of Aerosols

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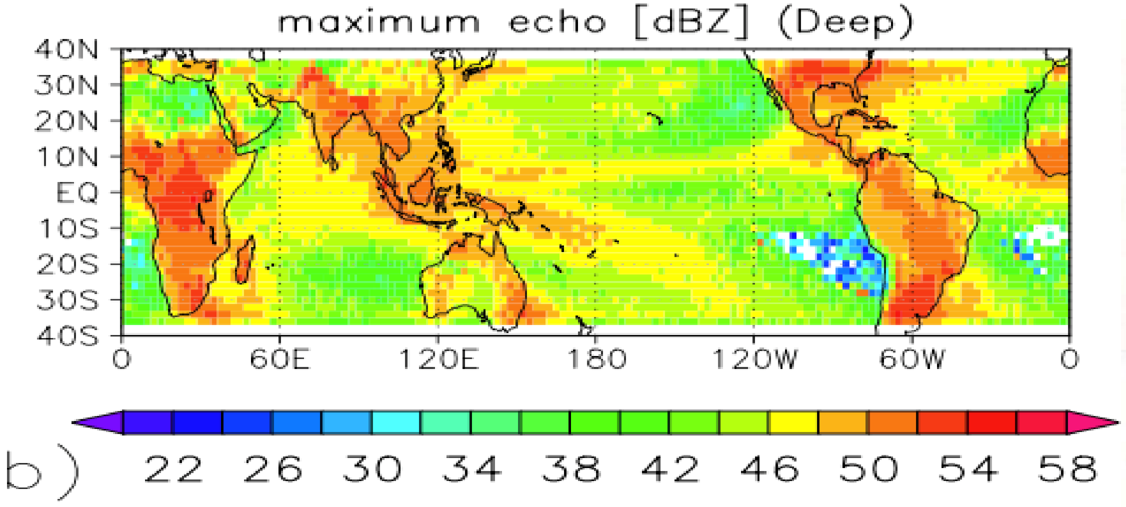
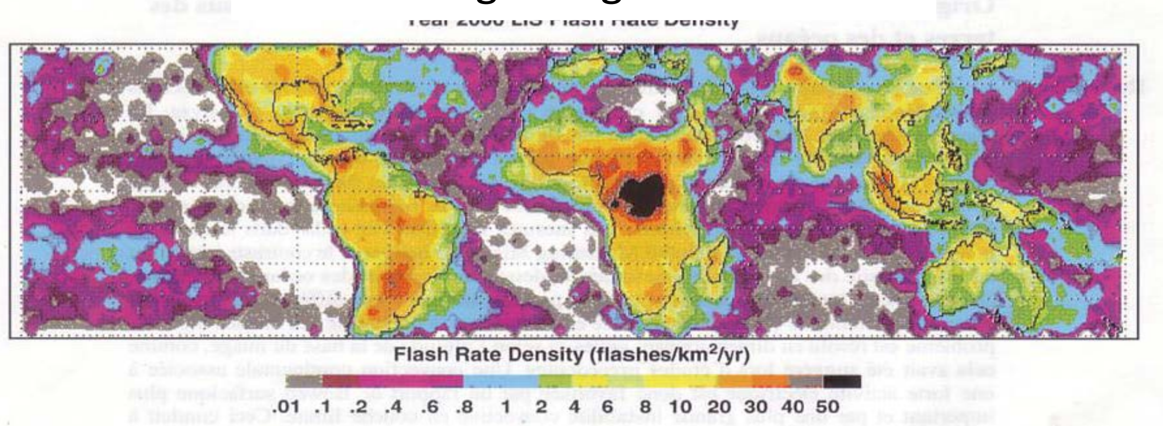
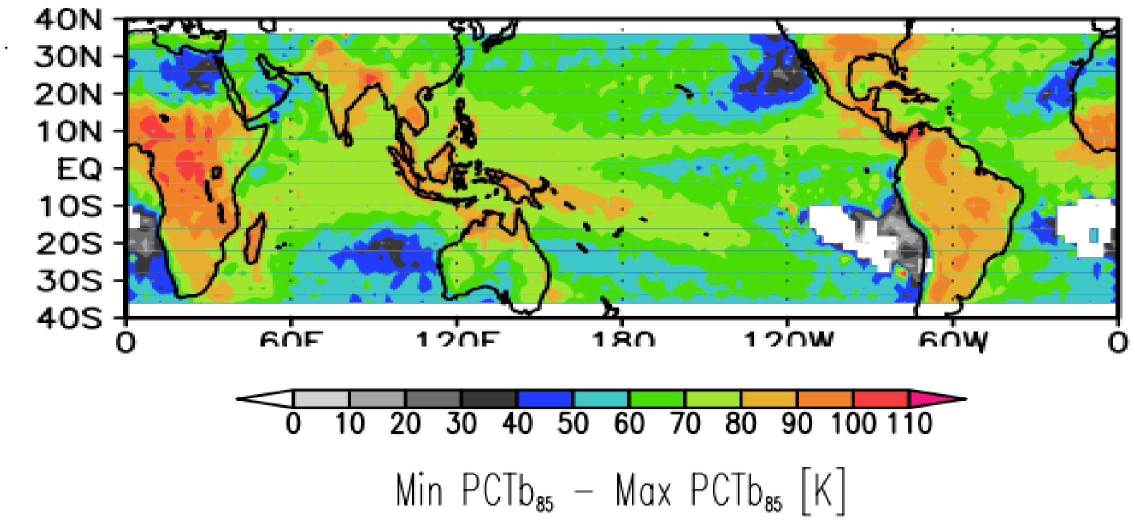
TRMM View of Continental Convective Vigor



Lightning Rate



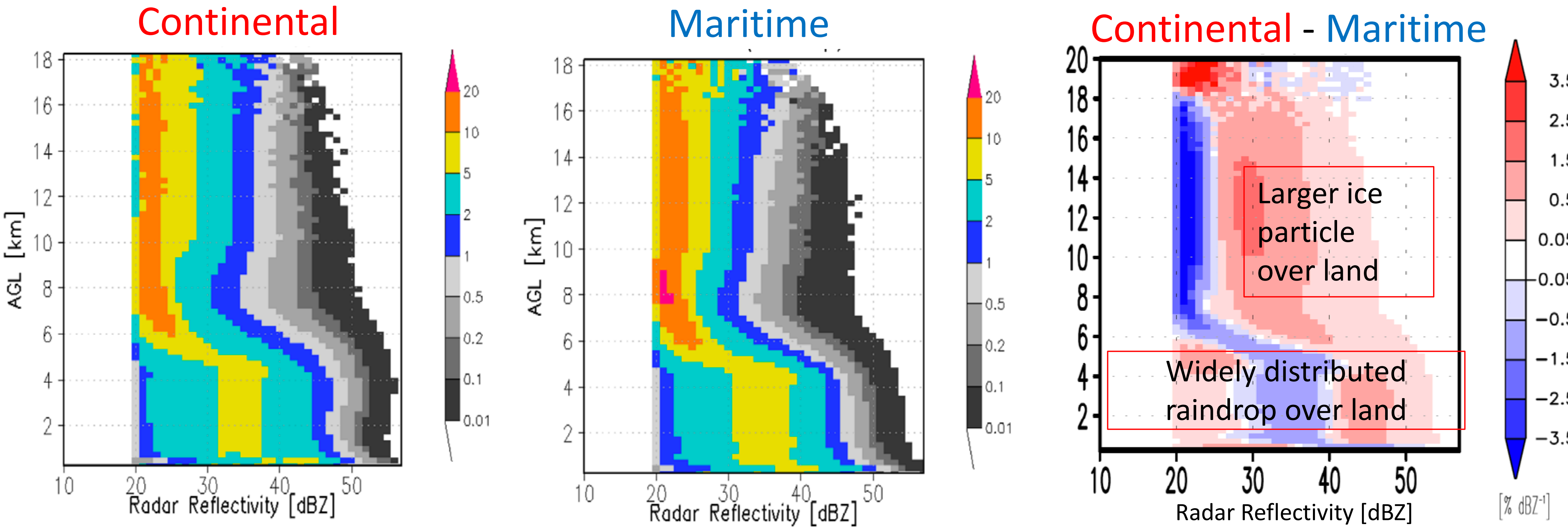
Maximum $PCTb_{85GHz}$ Scattering index



- *Deep convective clouds over land tend to have*
  1. *larger radar echo (bigger rain drops),*
  2. *larger microwave scattering (heavier riming), and*
  3. *more lightning flash rate (frequent ice-to-ice collision).*

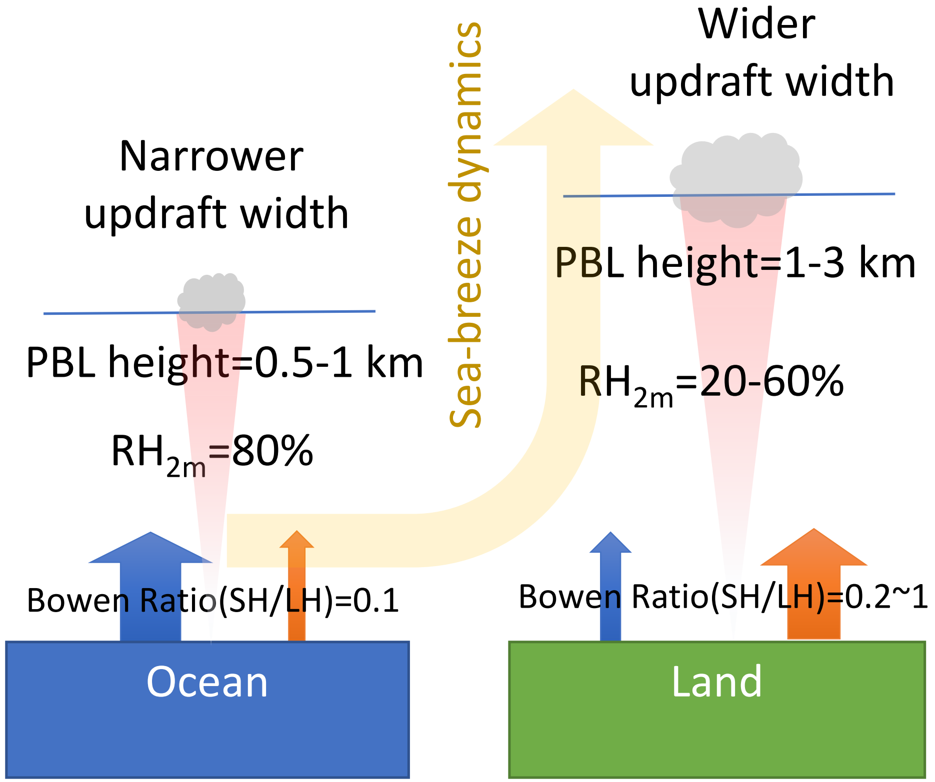
Matsui et al. 2016, JHM

TRMM PR (Ku-band) Reflectivity CFADs
-climatology-

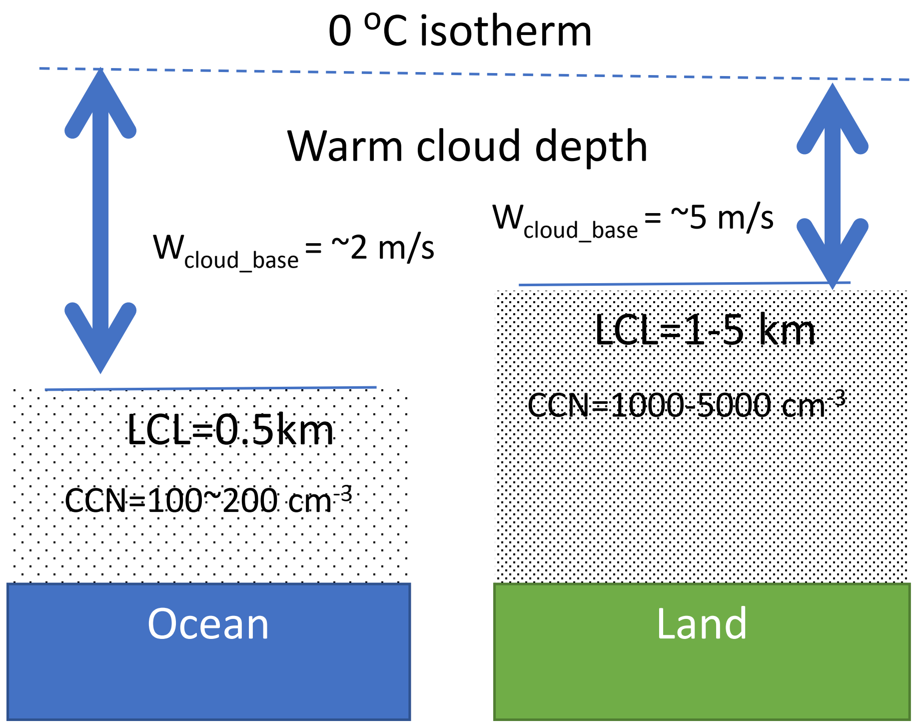


Physics Background

Thermodynamics



Microphysics



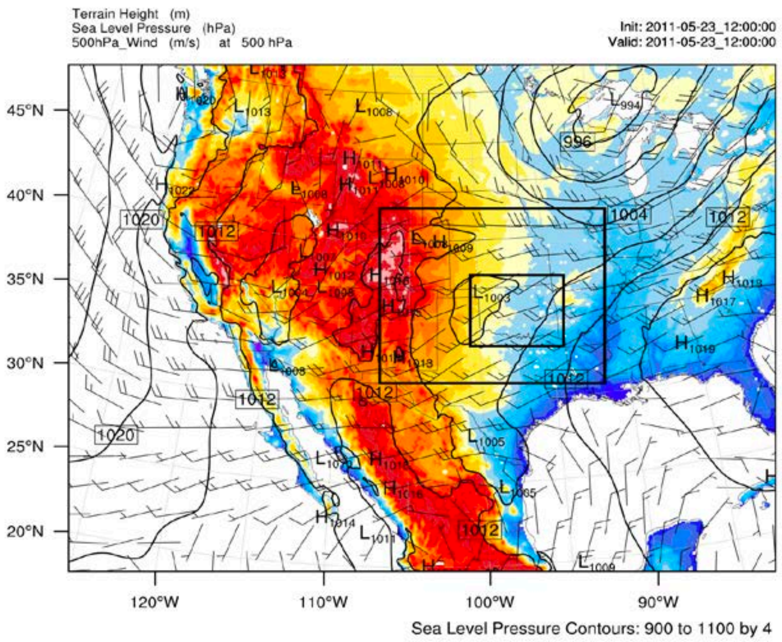
Deep convection is invigorated over land, because land is HOTTER, DRYER, and DIRTIER.

(Lucas et al. 1994, Williams and Stanfill 2002, Zipser et al. 2006, Robinson et al. 2011, Stolz et al. 2015, Matsui et al. 2016)

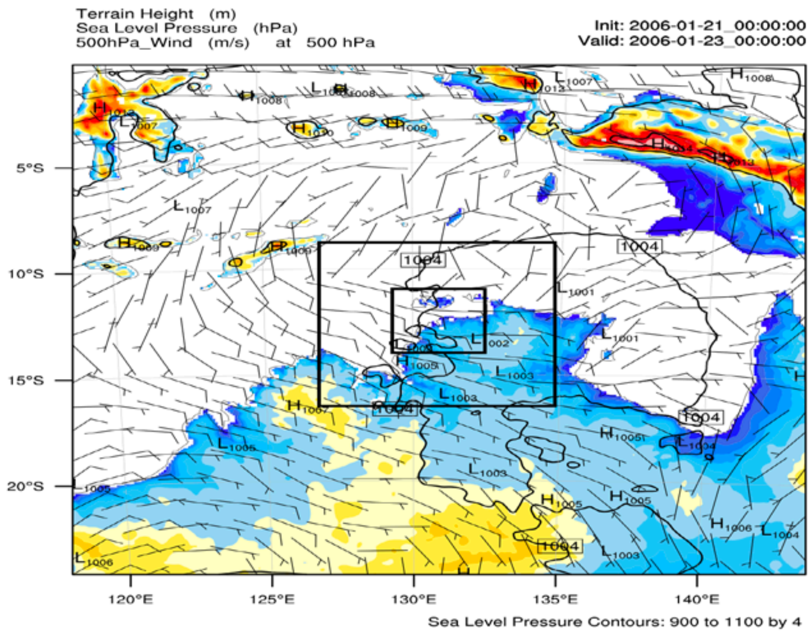
Land-Ocean cases from DOE ARM IOPs

-WRF Domains-

MC3E: Continental



TWP-ICE: Maritime



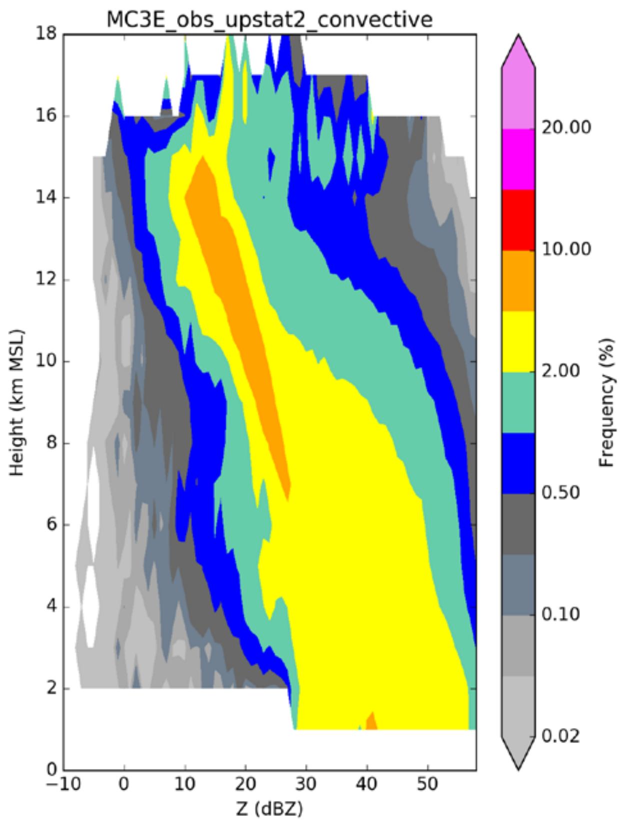
Oklahoma, ARM site
May 23-24: Super cell

Darwin Island, Australia
Jan 23: Tropical MCS “Landphoon John”

dBZ: Reflectivity (OBS)

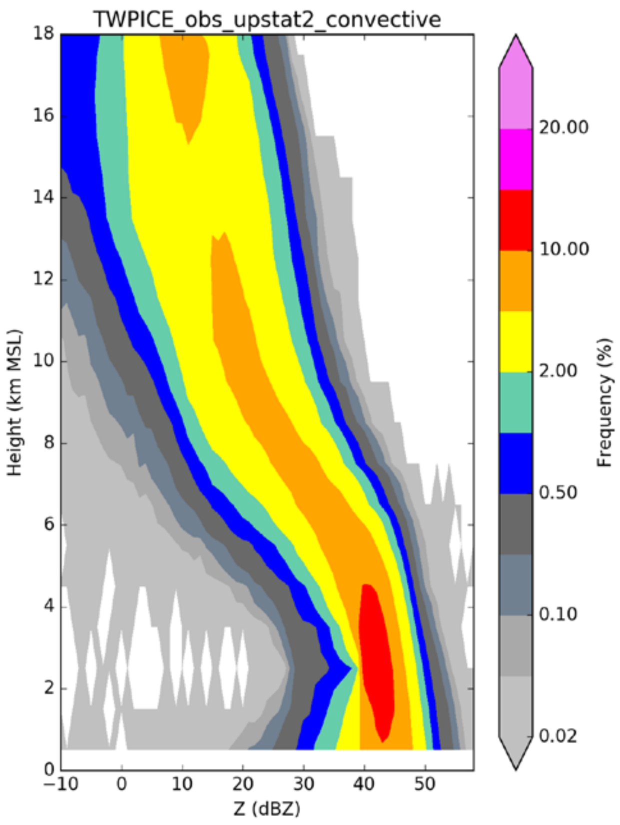
Sampled convective regime only!

MC3E



CSAPR

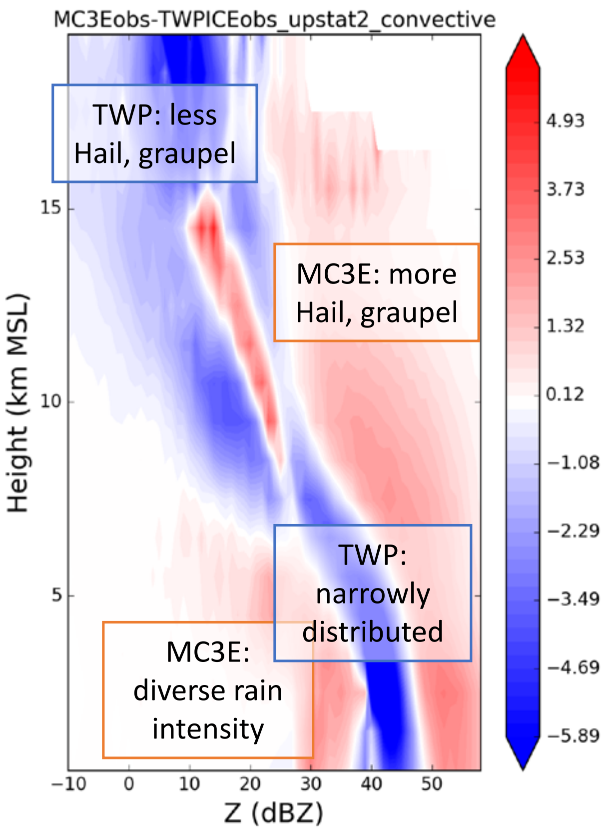
TWP



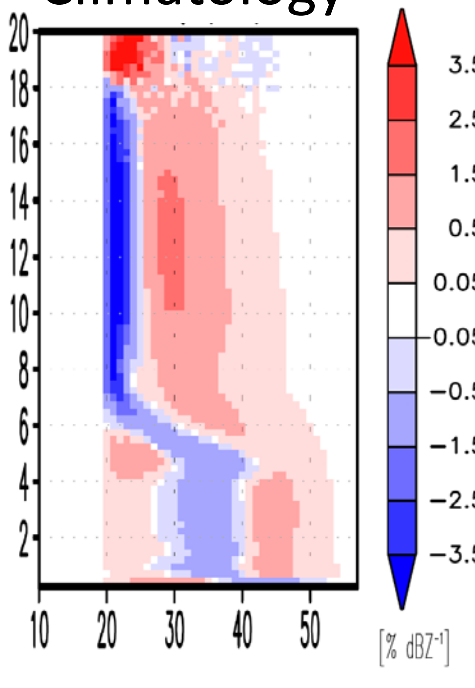
CPOL

Z represents the size and density.

MC3E - TWP



TRMM PR Climatology

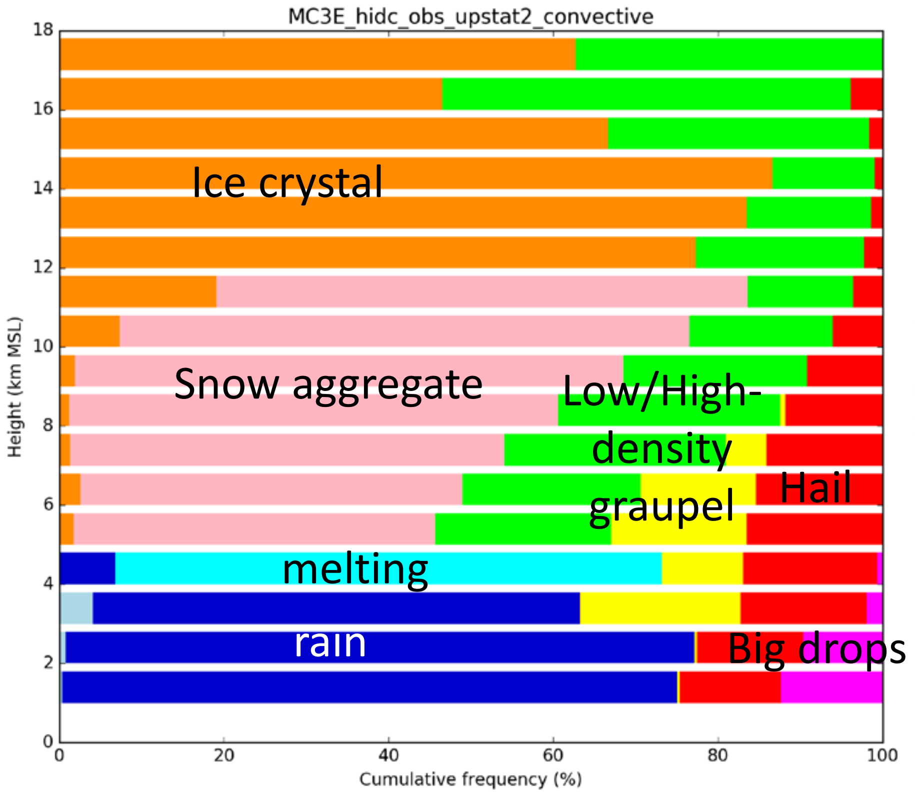


Good Agreement to TRMM PR climatology

HID: Hydrometeor Identification (OBS)

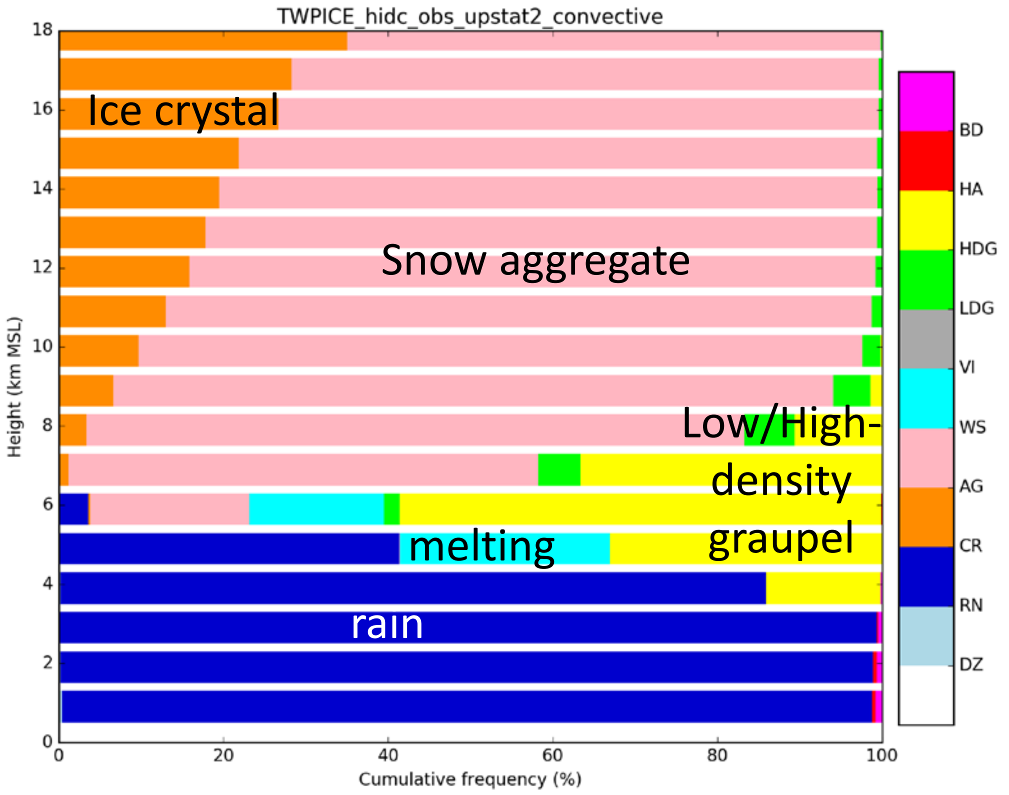
Sampled **convective regime** only!

MC3E



CSAPR

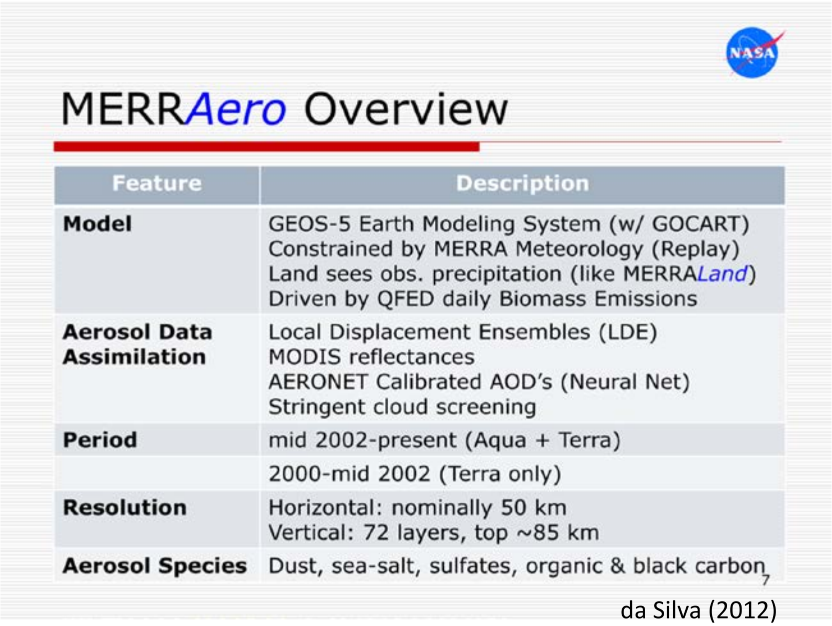
TWP



CPOL

HID Stacked Frequency of Altitude Diagrams (SFADs)

WRF-SBM



MERRAero Overview

Feature	Description
Model	GEOS-5 Earth Modeling System (w/ GOCART) Constrained by MERRA Meteorology (Replay) Land sees obs. precipitation (like MERRA*Land*) Driven by QFED daily Biomass Emissions
Aerosol Data Assimilation	Local Displacement Ensembles (LDE) MODIS reflectances AERONET Calibrated AOD's (Neural Net) Stringent cloud screening
Period	mid 2002-present (Aqua + Terra)
	2000-mid 2002 (Terra only)
Resolution	Horizontal: nominally 50 km Vertical: 72 layers, top ~85 km
Aerosol Species	Dust, sea-salt, sulfates, organic & black carbon

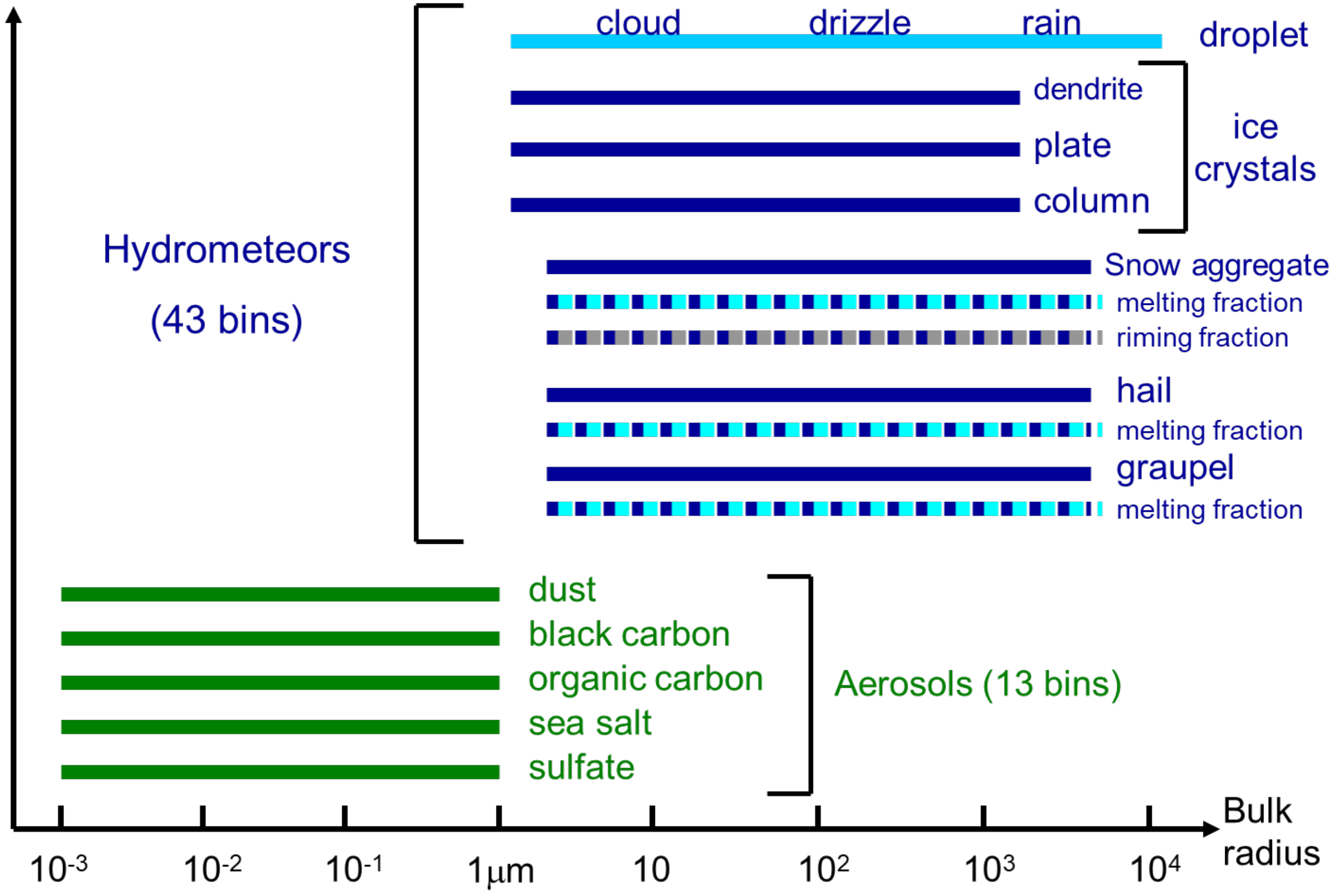
7

da Silva (2012)

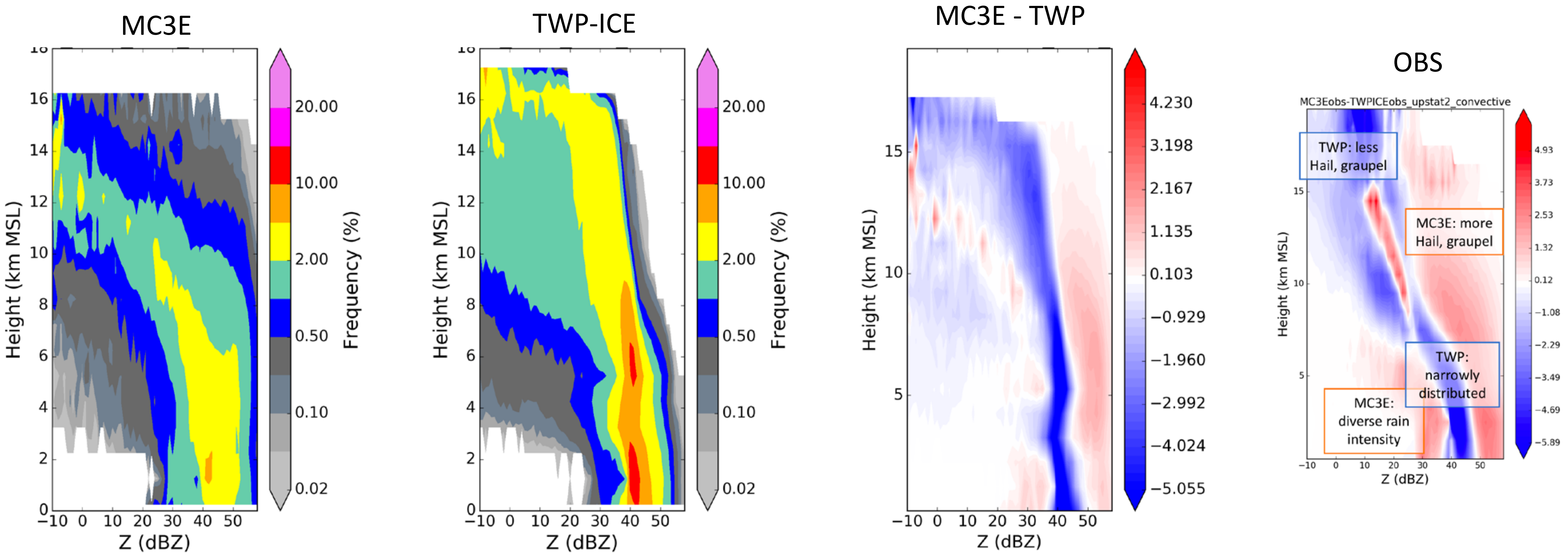
MERRAero2
WRFSBM

Dynamical Downscaling
(aerosol only)

Particles categories and bins in the updated WRF-SBM
43 bins



dBZ: Reflectivity (WRF-SBM)

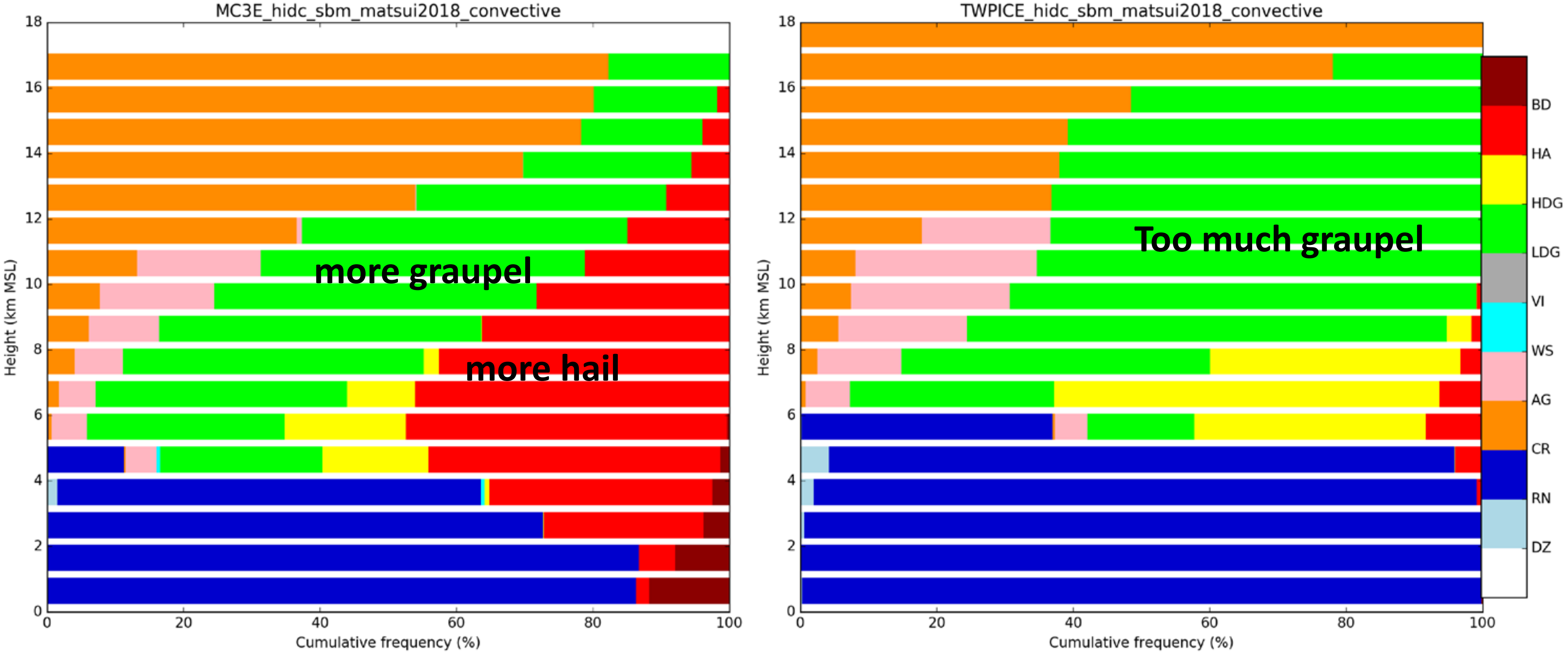


WRF-SBM captured the observed MC3E-TWP contrast in reflectivity CFADS

HID: Hydrometeor Identification (WRF-SBM)

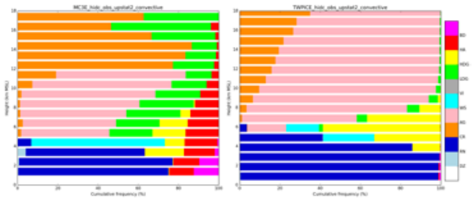
HID SFADs

MC3E **TWP**



MC3E TWP

obs



WRF-SBM overestimate riming process.
Too much dry collection?

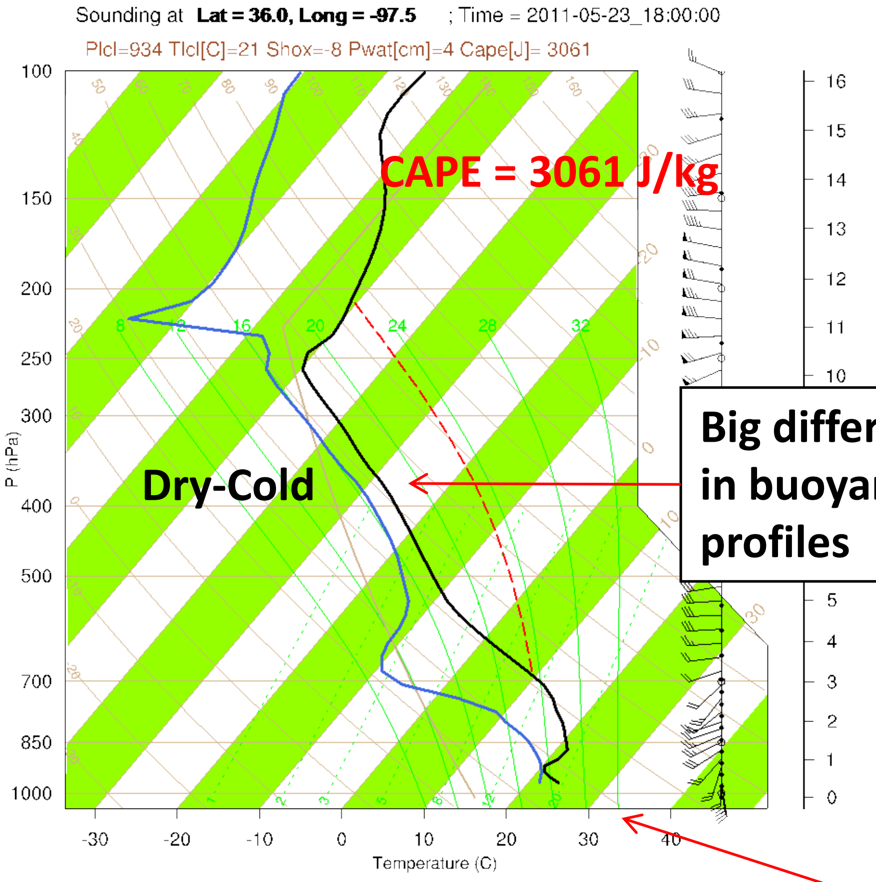
P-level (hPa)	CCN (#/cm3; SS1%)
500	146.8
700	638.2
850	2000.7
925	1398.5

Pre-Storm Conditions

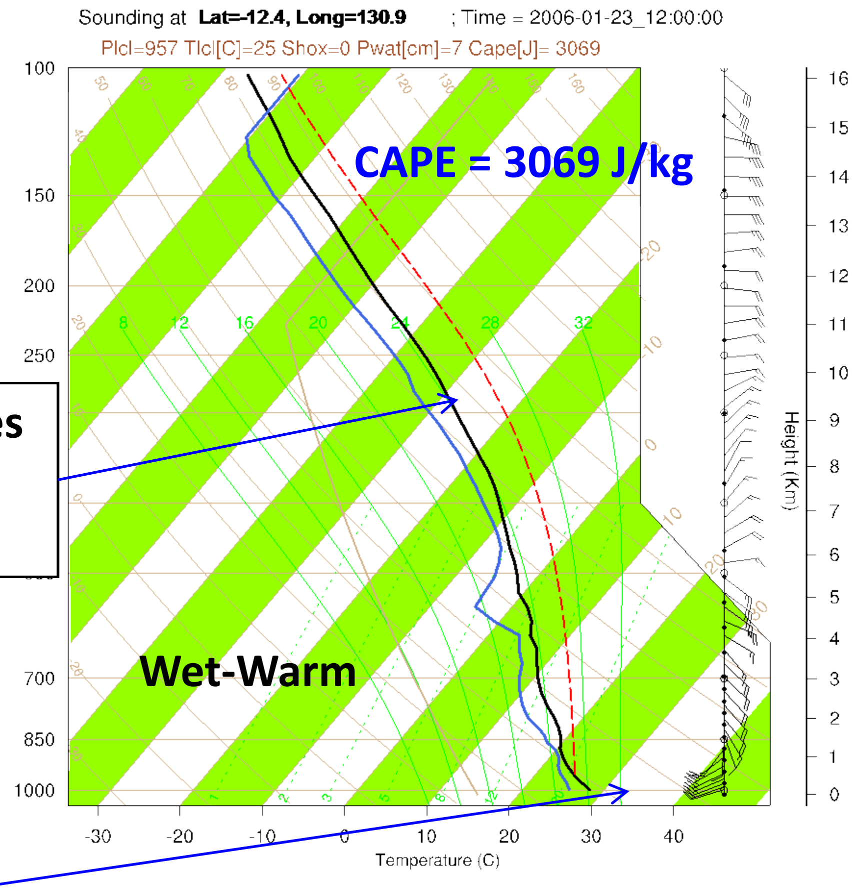
- WRF-SBM -

P-level (hPa)	CCN (#/cm3; SS1%)
500	2.7
700	3.5
850	39.3
925	77.2

MC3E



TWP-ICE



Big differences in buoyance profiles

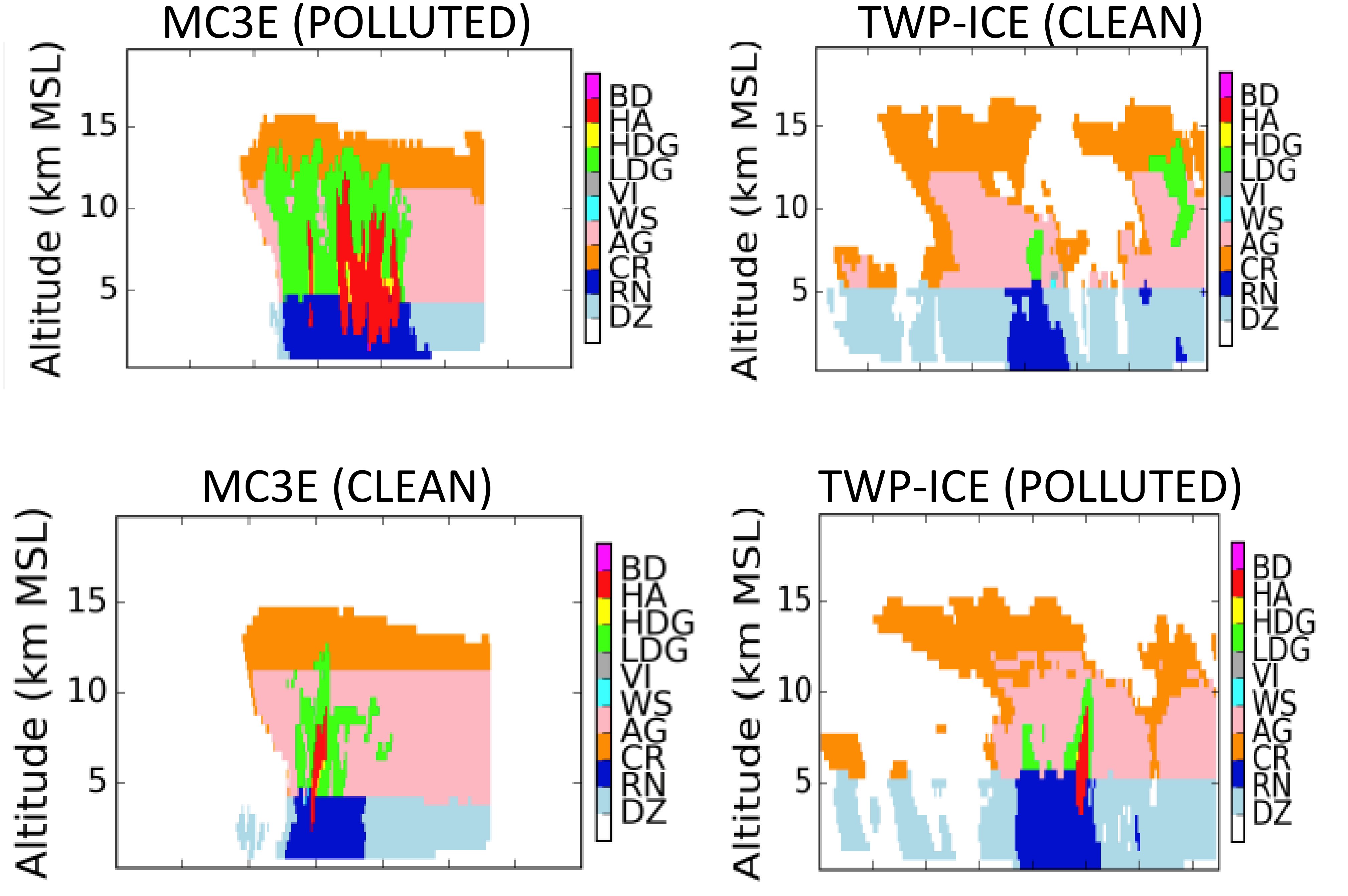
Similar Surface Air Temperature and Humidity and Near-surface wind shear

Q1) If we exchange background aerosols between TWP-ICE and MC3E , what will happen to deep convective core?

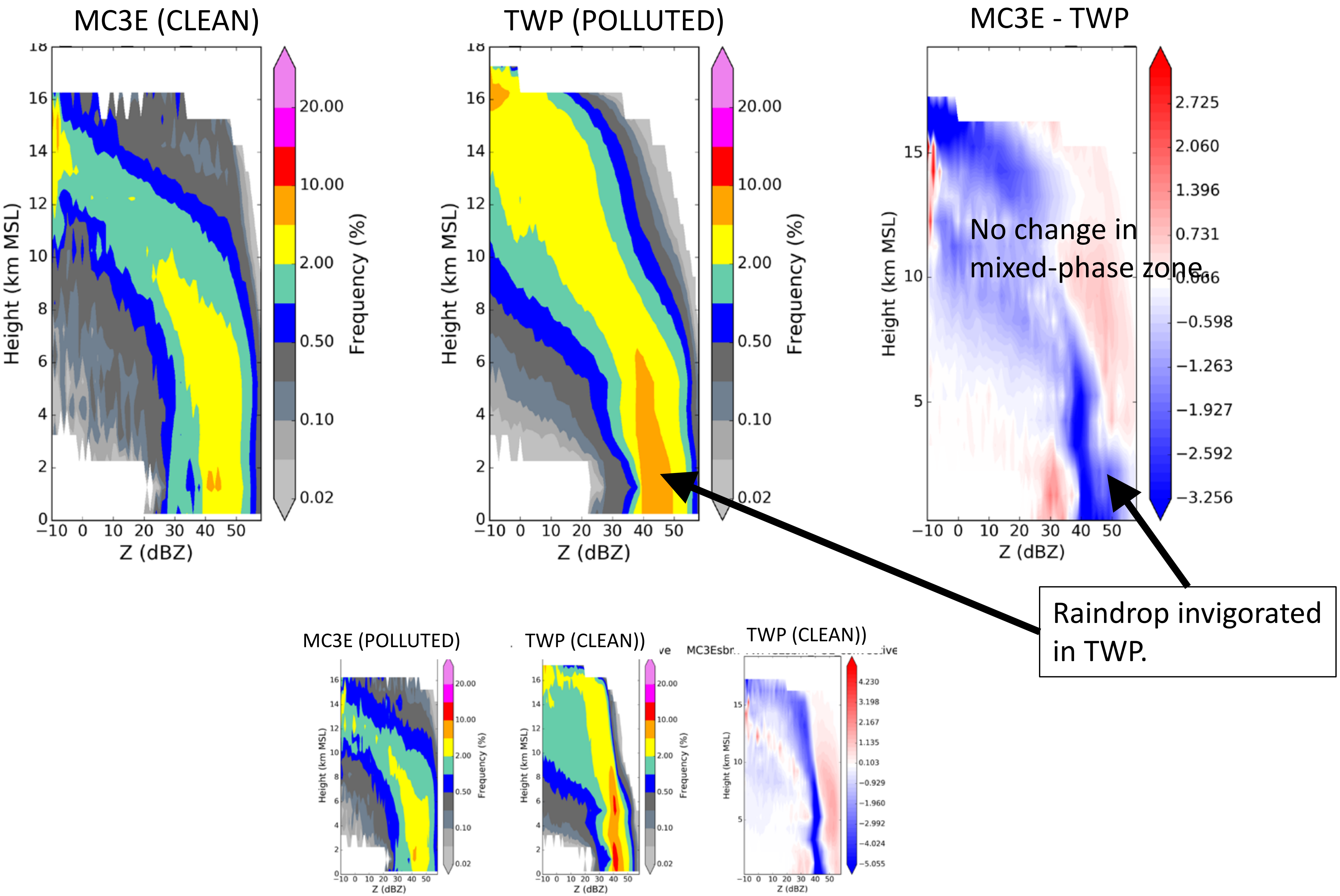
A. *TWP-ICE convection becomes stronger than MC3E (TWP-ICE > MC3E).*

B. *TWP-ICE convection becomes equivalent to MC3E (TWP-ICE = MC3E).*

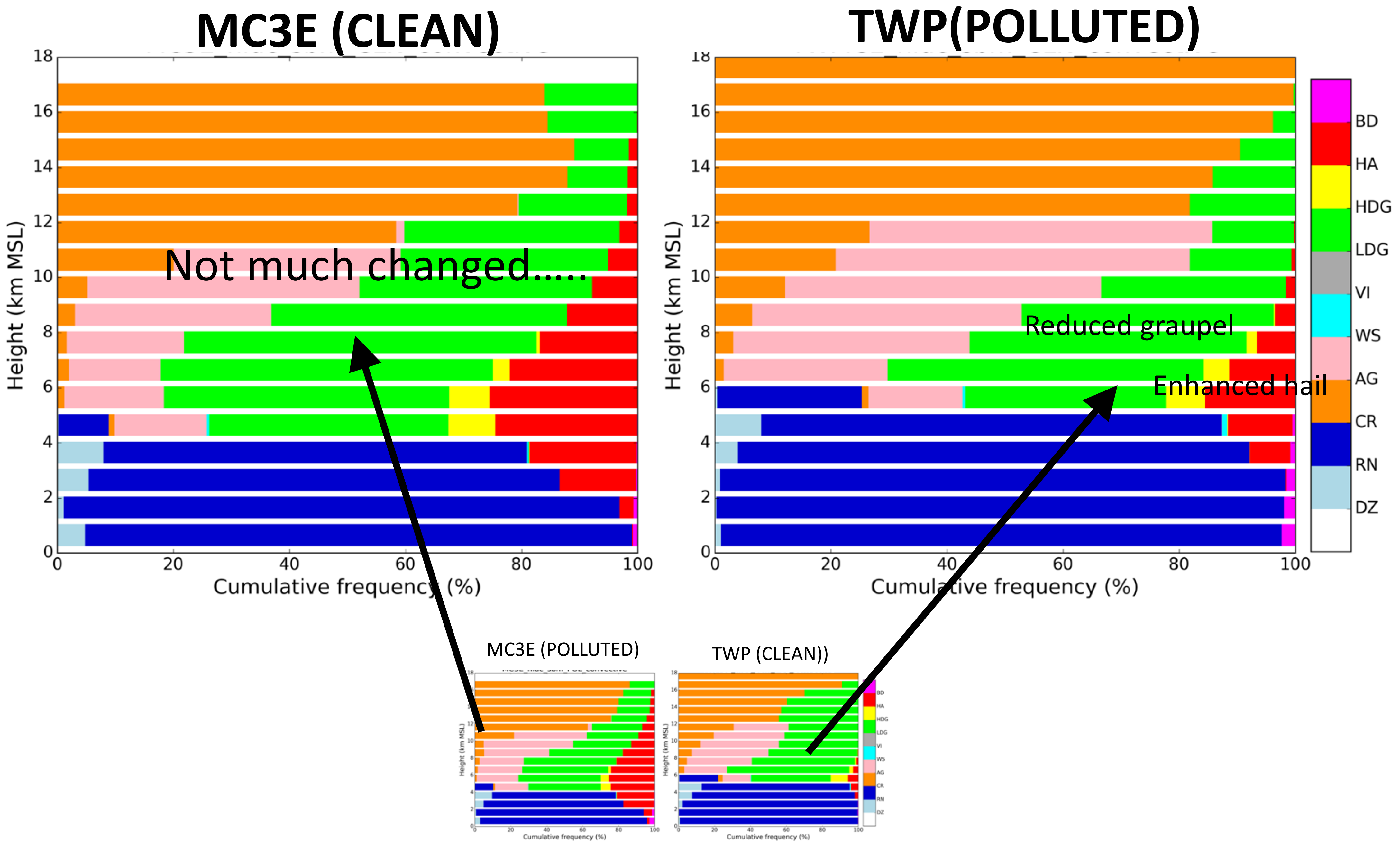
C. *TWP-ICE convection is still weaker than MC3E (TWP-ICE < MC3E).*



MC3E (POLLUTED)
TWP-ICE (CLEAN)
MC3E (CLEAN)
TWP-ICE (POLLUTED)
Altitude (km MSL)
5
10
15
BD
HA
HDG
LDG
VI
WS
AG
CR
RN
DZ

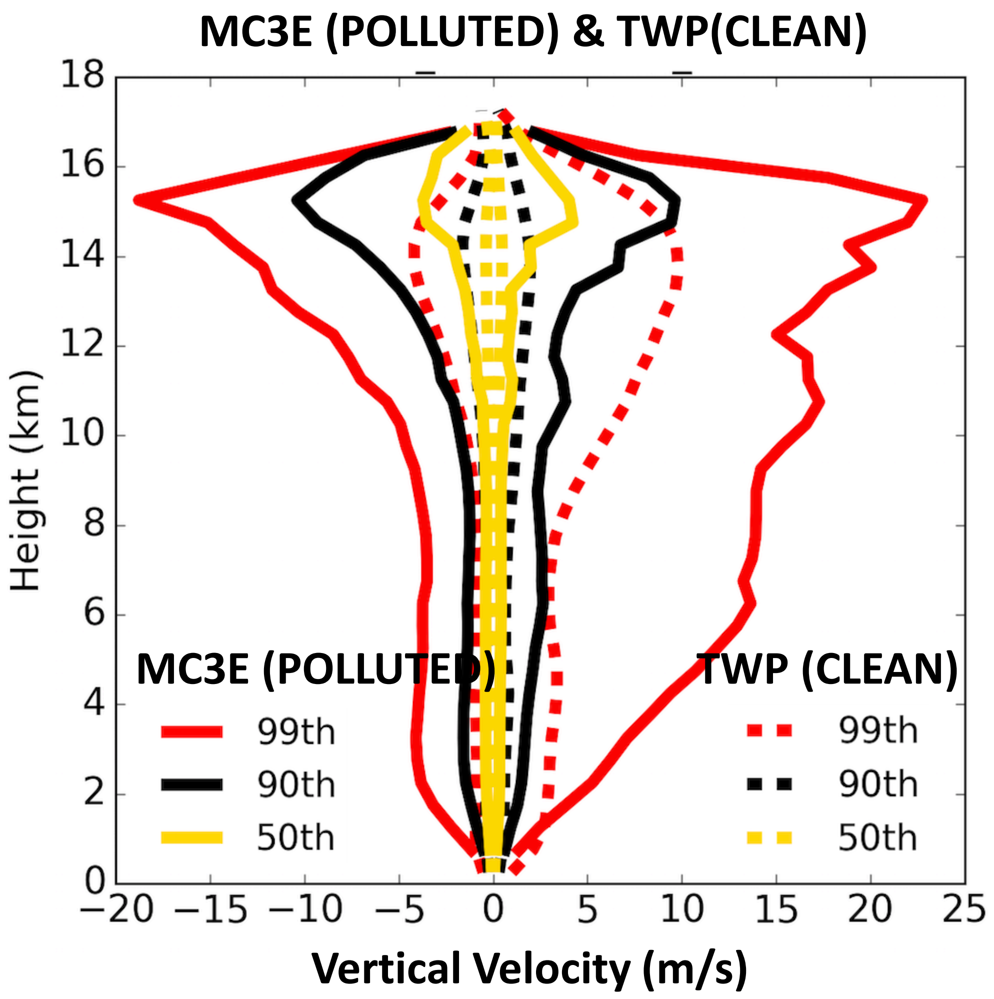


MC3E (CLEAN)
TWP (POLLUTED)
MC3E - TWP
Height (km MSL)
Z (dBZ)
Frequency (%)
20.00
10.00
2.00
0.50
0.10
0.02
2.725
2.060
1.396
0.731
0.066
−0.598
−1.263
−1.927
−2.592
−3.256
No change in
mixed-phase zone.
Raindrop invigorated
in TWP.
MC3E (POLLUTED)
TWP (CLEAN))
TWP (CLEAN))
4.230
3.198
2.167
1.135
0.103
−0.929
−1.960
−2.992
−4.024
−5.055

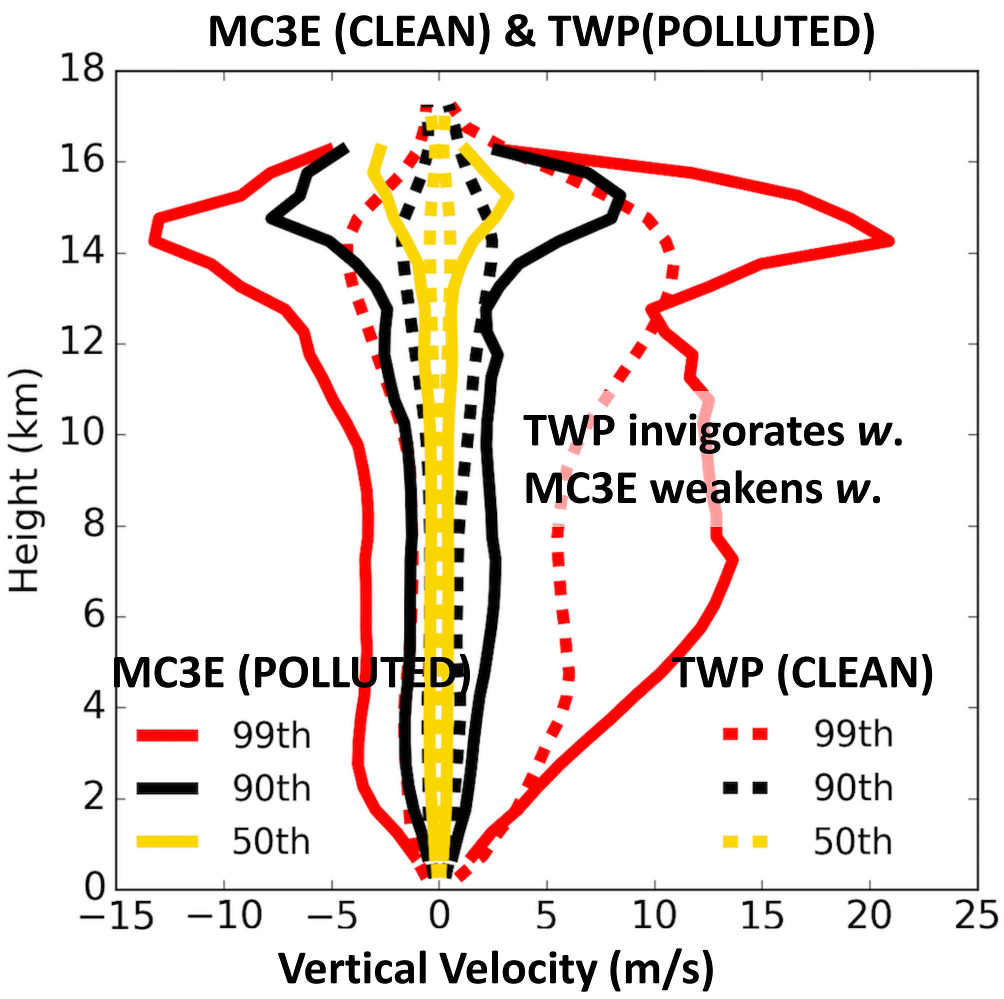

MC3E (CLEAN)
TWP(POLLUTED)
Height (km MSL)
Cumulative frequency (%)
Not much changed…..
Reduced graupel
Enhanced hail
BD
HA
HDG
LDG
VI
WS
AG
CR
RN
DZ
MC3E (POLLUTED)
TWP (CLEAN))

Vertical Velocity

Default Aerosols



Swapped Aerosols



The answer is C.

TWP-ICE convection is still weaker than MC3E.

Implication of Physics:

- Thermodynamics structure is 1^{st}-order physics to invigorate deep convection.
- Continental (maritime) aerosols concentrations invigorate (weaken) deep convective cores, but does not overwhelm thermodynamics impact.
- MC3E thermodynamics likely activates large concentrations of CCN through stronger updraft velocity and super saturation regardless of background aerosol concentrations.