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

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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-

- Continental
- Maritime

Larger ice particle over land
Widely distributed raindrop over land
Deep convection is invigorated over land, because land is HOTTER, DRYER, and DIRTIER.

Land-Ocean cases from DOE ARM IOPs
-WRF Domains-

MC3E: Continental

Oklahoma, ARM site
May 23-24: Super cell

TWP-ICE: Maritime

Darwin Island, Australia
Jan 23: Tropical MCS “Landphoon John”
dBZ: Reflectivity (OBS)

Sampled convective regime only!

MC3E

TWP

MC3E - TWP

TRMM PR Climatology

Z represents the size and density.

Good Agreement to TRMM PR climatology
HID: Hydrometeor Identification (OBS)

Sampled **convective regime** only!

**MC3E**

- Sampled convective regime only!

**TWP**

- Sampled convective regime only!

**HID Stacked Frequency of Altitude Diagrams (SFADs)**
MERRAero Overview

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>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</td>
</tr>
<tr>
<td>Aerosol Data Assimilation</td>
<td>Local Displacement Ensembles (LDE) MODIS reflectances AERONET Calibrated AOD’s (Neural Net) Stringent cloud screening</td>
</tr>
<tr>
<td>Period</td>
<td>mid 2002-present (Aqua + Terra) 2000-mid 2002 (Terra only)</td>
</tr>
<tr>
<td>Resolution</td>
<td>Horizontal: nominally 50 km Vertical: 72 layers, top ~85 km</td>
</tr>
</tbody>
</table>

Particles categories and bins in the updated WRF-SBM

43 bins

droplet

dendrite

ice crystals

Snow aggregate

Fire melting fraction

Rimming fraction

Hail

Melting fraction

graupel

Melting fraction

Aerosols (13 bins)
dust

Black carbon

Organic carbon

Sea salt

Sulfate

Bulk radius -10 -1 -0.1 1 10 100 1000 10000

Dynamical Downscaling (aerosol only)
dBZ: Reflectivity (WRF-SBM)

WRF-SBM captured the observed MC3E-TWP contrast in reflectivity CFADS
HID: Hydrometeor Identification (WRF-SBM)

MC3E

HID SFADs

TWP

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

**MC3E**

Dry-Cold

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

**TWP-ICE**

Wet-Warm

Big differences in buoyance profiles

<table>
<thead>
<tr>
<th>P-level (hPa)</th>
<th>CCN (#/cm³; SS1%)</th>
<th>P-level (hPa)</th>
<th>CCN (#/cm³; SS1%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>146.8</td>
<td>500</td>
<td>2.7</td>
</tr>
<tr>
<td>700</td>
<td>638.2</td>
<td>700</td>
<td>3.5</td>
</tr>
<tr>
<td>850</td>
<td>2000.7</td>
<td>850</td>
<td>39.3</td>
</tr>
<tr>
<td>925</td>
<td>1398.5</td>
<td>925</td>
<td>77.2</td>
</tr>
</tbody>
</table>

CAPE = 3069 J/kg

CAPE = 3061 J/kg
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 $< MC3E$).
No change in mixed-phase zone.

Raindrop invigorated in TWP.
Not much changed.....

Enhanced hail

Reduced graupel

Enhanced hail

MC3E (POLLUTED)

TWP (CLEAN)
Vertical Velocity

**Default Aerosols**

**MC3E (POLLUTED) & TWP(CLEAN)**

**Swapped Aerosols**

**MC3E (CLEAN) & TWP(POLLUTED)**

TWP invigorates $w$.

MC3E weakens $w$. 
The answer is C.

*TWP-ICE convection is still weaker than MC3E.*

**Implication of Physics:**

- Thermodynamics structure is 1\textsuperscript{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.