What datasets and results we can provide from MC3E

Xiquan Dong
University of North Dakota

Jingjin Tian, Jingyu Wang, Ning Zhou, Ron Stenz, Baike Xi, Tony Grainger, Uni. of North Dakota
Zhe Feng, DOE PNNL
Pat Minnis and Mandy Khaiyer, NASA Langley
Scott Giangrande and Tami Toto, DOE BNL
MC3E results we can provide

1. 2D and time-height NEXRAD over SGP and its classified DCS components (Convective core, Stratiform region, and Anvil clouds).
2. Surface precipitation from NEXRAD Q2 and OK mesonet measurements
3. Time series of NEXRAD and corrected KAZR reflectivity, fall speed, LWP, rain rate, and surface rain drop diameter (disdrometer)
4. UND citation aircraft in situ measurements
5. GOES retrieved cloud properties

These datasets will be used to study the DCS cloud properties, life cycle, precipitation, and to provide a ground truth for modelers to validate their simulations.
There are 15 flights during MC3E

<table>
<thead>
<tr>
<th>Date</th>
<th>Sortie</th>
<th>Takeoff</th>
<th>Landing</th>
<th>Hours</th>
<th>Notes</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/22</td>
<td>MC3E-1</td>
<td>22337</td>
<td>005710</td>
<td>2.4</td>
<td>Severe convection, anvil; legs</td>
<td></td>
</tr>
<tr>
<td>4/25</td>
<td>MC3E-2</td>
<td>092119</td>
<td>122229</td>
<td>3.0</td>
<td>MCS and stratiform; steps</td>
<td></td>
</tr>
<tr>
<td>4/27</td>
<td>MC3E-3</td>
<td>080207</td>
<td>112245</td>
<td>3.4</td>
<td>Stratiform; spiral</td>
<td></td>
</tr>
<tr>
<td>5/1</td>
<td>MC3E-4</td>
<td>162839</td>
<td>184213</td>
<td>2.2</td>
<td>Cold season stratiform; spiral</td>
<td></td>
</tr>
<tr>
<td>5/10</td>
<td>MC3E-5</td>
<td>214937</td>
<td>001048</td>
<td>2.4</td>
<td>Stratiform; spiral &amp; porpoise</td>
<td></td>
</tr>
<tr>
<td>5/11</td>
<td>MC3E-6</td>
<td>160209</td>
<td>192706</td>
<td>3.4</td>
<td>Stratiform; steps</td>
<td></td>
</tr>
<tr>
<td>5/18</td>
<td>MC3E-7</td>
<td>072010</td>
<td>092156</td>
<td>2.0</td>
<td>Deep convection, precipitating anvil;</td>
<td></td>
</tr>
<tr>
<td>5/20</td>
<td>MC3E-8</td>
<td>130539</td>
<td>170204</td>
<td>4.0</td>
<td>Severe convection, stratiform; steps, spiral over ARM SGP</td>
<td></td>
</tr>
<tr>
<td>5/23</td>
<td>MC3E-9</td>
<td>212942</td>
<td>004129</td>
<td>3.2</td>
<td>Severe convection; anvil</td>
<td></td>
</tr>
<tr>
<td>5/24</td>
<td>MC3E-10</td>
<td>201825</td>
<td>222750</td>
<td>2.1</td>
<td>Precipitating anvil; spiral</td>
<td></td>
</tr>
<tr>
<td>5/27</td>
<td>MC3E-11</td>
<td>210309</td>
<td>000405</td>
<td>3.1</td>
<td>Shallow cumulus;</td>
<td></td>
</tr>
<tr>
<td>5/30</td>
<td>MC3E-12</td>
<td>122204</td>
<td>160034</td>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/1</td>
<td>MC3E-13</td>
<td>163000</td>
<td>174429</td>
<td>1.3</td>
<td>Shallow cumulus;</td>
<td></td>
</tr>
<tr>
<td>6/1</td>
<td>MC3E-14</td>
<td>190636</td>
<td>220246</td>
<td>2.9</td>
<td>Precipitating anvil; spiral</td>
<td></td>
</tr>
<tr>
<td>6/2</td>
<td>MC3E-15</td>
<td>144124</td>
<td>181847</td>
<td>3.6</td>
<td>Cirrus; steps, spiral</td>
<td></td>
</tr>
</tbody>
</table>
Now we focus on three cases

<table>
<thead>
<tr>
<th>Date</th>
<th>Sortie</th>
<th>Takeoff</th>
<th>Landing</th>
<th>Hours</th>
<th>Notes</th>
</tr>
</thead>
</table>
| 4/25 | MC3E-2  | 092119  | 122229  | 3.0   | MCS and stratiform; steps  
  ➢ Lower radar reflectivity associated with clean airmass, AOD~ 0.2  
  ➢ Higher LWP~ 4000-5000 gm\(^{-2}\),  
  ➢ Huge rain rates= 10-20 mm/hr,  
  ➢ Larger max rain drop Diameter~ 4-5 mm at surface  
  ➢ Higher IWC~ 1 gm\(^{-3}\), and re~ 400 um |
| 5/20 | MC3E-8  | 130539  | 170204  | 4.0   | Severe convection, stratiform; steps, spiral over ARM SGP  
  A classic DCS case |
| 5/23 | MC3E-9  | 212942  | 004129  | 3.2   | Severe convection; anvil  
  ➢ Higher radar reflectivity associated with polluted airmass, AOD~ 0.4  
  ➢ Lower LWP~ 1000-2000 gm\(^{-2}\),  
  ➢ Rain rates < 10 mm/hr,  
  ➢ Max rain drop Diameter< 5 mm at surface  
  ➢ Higher IWC~ 0.9 gm\(^{-3}\), and re~ 800 um |
A Case Study: May 20

- From Surface, aircraft and satellite observations and retrievals
System moved from SW to NE, passed over ARM SGP site
Max daily precipitation can reach up to 120 mm over central OK.
Time series of Surface Radar and other obs

NEXRAD
Cross-section $Z_c$ & Classification (2011.05.20)

LWP~ 4000 gm$^{-2}$

Rain Rate < 5 mm/hr

Max rain drop diameter
~ 2-4 mm at surface
Fall Speed derived from KAZR reflectivity
Above 4 km, Fall speed ~ 1 m/s
Below melting layer, FS ~ 10 m/s

Based on V~r
Above 4 km, water droplet radii are 110 to 150 um (≈ r_{ice}=240-340 um)

Below melting layer, rain drop radii range from 1 to 2 mm, consistent to Disdrometer measurements (D ~ 2-4 mm)
Good agreement between radar retrievals and aircraft. Re values are ~ 200-300 um.

Radar retrieved re values also agree well with aircraft (re ~ 1 to 3 mm) below melting layer, and also with surface rain drop diameter (D~ 2 to 4 mm)
Step or Spiral up/down over SGP site
Most aircraft in situ measurements located 30 km of SGP

Flight time from 13 to 17 UTC.
Comparing NEXRAD and its classification with GOES results

2011.05.20 15:45 UTC/Flight Time 15:45 UTC

(a) 2500 m $Z_e$

(b) Classification

(c) Cross-section $Z_e$ & Classification
GOES retrieved cloud properties at 15:45Z

Ice phase

T_{top}=210K

H_{top}=13 \text{ km}

Thickness=10 \text{ km}
GOES retrieved cloud properties at 15:45Z

- $D_{\text{eff}} = 80 \text{ um}$
- $\tau = 100$
- $IWP > 2000 \text{ gm}^{-2}$
Challenge and difficulty for modeling DCS clouds

Quite often, models can simulate large-scale frontal systems, but not for local systems.
Thanks for your attention
1. NEXRAD 3D structure and classification
1. NEXRAD 3D structure and classification

(a) 2500 m $Z_e$

(b) Classification

(c) Cross-section $Z_e$ & Classification
2. Surface precipitation from NEXRAD Q2 and OK mesonet measurements

April 25

Daily Precip up to 150 mm on April 25 over East OK and MO/AR
3. Time series of Surface Radar and other obs

**NEXRAD**
Cross-section $Z_c$ & Classification (2011.04.25)

- **LWP~ 4000-5000 gm$^{-2}$**
- **Rain Rate~ 10-20 mm/hr**
- **Max rain drop diameter ~ 2-5 mm at surface**

---

**Aircraft**

- DCS CC associated with heavy Rain rates and large rain drops
3. Time series of Surface Radar and other obs

DCS CC associated with heavy Rain rates and large rain drops

May 23

LWP~ 1000-2000 gm⁻²

Rain Rate < 10 mm/hr

Max rain drop diameter
~ 3 mm at surface
4. UND citation aircraft in situ measurements

April 25

UND Aircraft In–Situ Measurements during MC3E (4/25/2011)

- Height (MSL, km)
- Cloud Temp (°C)
- LWC=0.027
- IWC=0.216
- \( N_{\text{Total}} = 16.8 \)
- \( N_{\text{CDP}} = 15.6 \)
- \( N_{2 \text{DC}} = 1.19 \)
- \( N_{\text{HVPS}} = 0.018 \)
- \( r_{e,\text{Comb}} = 406.4 \)
- \( r_{e,\text{CDP}} = 8.1 \)
- \( r_{e,2 \text{DC}} = 259.1 \)
- \( r_{e,\text{HVPS}} = 656 \)

Time (UTC)
4. UND citation aircraft in situ measurements

May 23

UND Aircraft In–Situ Measurements during MC3E (5/23/2011)

- Height (MSL, km)
- Cloud Temp (°C)
- LWC/IWC (g m⁻³)
- Concentration (cm⁻³)
- Eff. Radius (μm)

- UND Aircraft
- Cloud Temp
- LWC = 0.015
- IWC = 0.375
- \( N_{Total} = 12.6 \)
- \( N_{CDP} = 12.0 \)
- \( N_{2DC} = 0.54 \)
- \( N_{HVPS} = 0.028 \)
- \( r_{e, CDP} = 774.8 \)
- \( r_{e, CDP} = 13.0 \)
- \( r_{e, 2DC} = 362.5 \)
- \( r_{e, HVPS} = 1109 \)
5. GOES retrieved cloud properties

April 25

Cloud-top temp

IWP

May 23

Cloud-top temp

IWP
Highger cloud-top heights (~ 14 km) from ER2 Radar are consistent to GOES retrievals, indicating KAZR ARSCL signals were attenuated out at that level.
GOES retrieved cloud properties at 23:15Z
GOES cloud properties at 11:15Z, April 25
GOES retrieved cloud properties at 23:15Z
GOES retrieved cloud properties at 23:15Z
Cloud droplet terminal fall speed

1) 0 < r < 40 μm, \( V_f = K_1 r^2 \), Stokes’ law, \( K_1 = 1.19 \times 10^6 \) cm\(^{-1}\) S\(^{-1}\)

2) 40 < r < 0.6 mm, \( V_f = K_2 r \), linear law, \( K_2 = 8 \times 10^3 \) S\(^{-1}\)

3) 0.6 < r < 2 mm, \( V_f = K_3 r^{1/2} \), Square root law, \( K_3 = 2.2 \times 10^3 \) (\( \rho/\rho_0 \)^{1/2} cm\(^{-1}\) S\(^{-1}\)). \( \rho \) is air density, \( \rho_0 \) is a reference density of 1.2 kg/m\(^3\). (Rogers and Yau book, P124-126)

---

**TABLE 8.1. Terminal Fall Speed as a Function of Drop Size (equivalent spherical diameter) (From Gunn and Kinzer, 1949)**

<table>
<thead>
<tr>
<th>Diam. (mm)</th>
<th>Fall speed (m/s)</th>
<th>Diam. (mm)</th>
<th>Fall speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.27</td>
<td>2.6</td>
<td>7.57</td>
</tr>
<tr>
<td>0.2</td>
<td>0.72</td>
<td>2.8</td>
<td>7.82</td>
</tr>
<tr>
<td>0.3</td>
<td>1.17</td>
<td>3.0</td>
<td>8.06</td>
</tr>
<tr>
<td>0.4</td>
<td>1.62</td>
<td>3.2</td>
<td>8.26</td>
</tr>
<tr>
<td>0.5</td>
<td>2.06</td>
<td>3.4</td>
<td>8.44</td>
</tr>
<tr>
<td>0.6</td>
<td>2.47</td>
<td>3.6</td>
<td>8.60</td>
</tr>
<tr>
<td>0.7</td>
<td>2.87</td>
<td>3.8</td>
<td>8.72</td>
</tr>
<tr>
<td>0.8</td>
<td>3.27</td>
<td>4.0</td>
<td>8.83</td>
</tr>
<tr>
<td>0.9</td>
<td>3.67</td>
<td>4.2</td>
<td>8.92</td>
</tr>
<tr>
<td>1.0</td>
<td>4.03</td>
<td>4.4</td>
<td>8.98</td>
</tr>
<tr>
<td>1.2</td>
<td>4.64</td>
<td>4.6</td>
<td>9.03</td>
</tr>
<tr>
<td>1.4</td>
<td>5.17</td>
<td>4.8</td>
<td>9.07</td>
</tr>
<tr>
<td>1.6</td>
<td>5.65</td>
<td>5.0</td>
<td>9.09</td>
</tr>
<tr>
<td>1.8</td>
<td>6.09</td>
<td>5.2</td>
<td>9.12</td>
</tr>
<tr>
<td>2.0</td>
<td>6.49</td>
<td>5.4</td>
<td>9.14</td>
</tr>
<tr>
<td>2.2</td>
<td>6.90</td>
<td>5.6</td>
<td>9.16</td>
</tr>
<tr>
<td>2.4</td>
<td>7.27</td>
<td>5.8</td>
<td>9.17</td>
</tr>
</tbody>
</table>