Introduction

Cloud Cluster

- Definition
  1. The oval-shaped cloud mass region of T_0 (equivalent black-body temperature) lower than -50 °C is about or larger than 100 km in diameter
  2. Horizontal gradient of T_0 is large near the rim of the cloud mass (at least a part of the rim)
- Among four major types of Heavy Precipitation Systems (HPSs) over the Korean peninsula, cloud clusters occur most frequently and produce large amount of rainfall over broad area

Table 1. Frequency of heavy precipitation systems for each type of precipitation system for 2000-2006.

<table>
<thead>
<tr>
<th>Type</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow</td>
<td>4</td>
<td>2</td>
<td>11</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>12</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Hail</td>
<td>3</td>
<td>1</td>
<td>17</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rain</td>
<td>2</td>
<td>1</td>
<td>25</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>3</td>
<td>53</td>
<td>8</td>
<td>3</td>
<td>11</td>
<td>12</td>
<td>5</td>
<td>12</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

- Environment
  1. In the eastern part of low-level trough (or cyclone) or along the activated monsoon front trailing behind a trough (or cyclone)
  2. Over a stationary monsoon front far from the trough

- Movement
  Generally move along the front or move together with the pressure system in which they are embedded

Objective

To investigate the structure and evolution of cloud cluster occurred on 2 July 2008 by using various observational data and numerical simulation.

Observational analysis

- At 00 UTC 2 July, a 300 hPa jet streak associated with the upper level trough over the north-eastern China extended from eastern China to Northern Korea
- Upward motion existed over east China and the south of Yellow sea in advance of 500 hPa shortwave trough
- 850 hPa upward motion appeared in front of the west-southwesterly low-level jet (LLJ)
- Surface low-pressure center strengthened over the northwest of the Korean peninsula

- High relative humidity appeared in the layer between 1000 and 850 hPa
- After 06 UTC, 900 hPa wind changed from southerly to west-southwesterly and wind speed began to increase
- After 06 UTC, dry region (RH<80%) appeared at 850 hPa

Numerical simulation

Weather Research and Forecasting (WRF) Model V3.1

Table 2. Model configuration.

<table>
<thead>
<tr>
<th>Domain</th>
<th>D01</th>
<th>D02</th>
<th>D03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal grid spacing</td>
<td>30 km</td>
<td>10 km</td>
<td>3.3 km</td>
</tr>
<tr>
<td>Vertical layers</td>
<td>41 layers (model top: 50 hPa)</td>
<td>41 layers (model top: 50 hPa)</td>
<td>41 layers (model top: 50 hPa)</td>
</tr>
<tr>
<td>Microphysics</td>
<td>WSM b-class graupel scheme</td>
<td>WSM b-class graupel scheme</td>
<td>WSM b-class graupel scheme</td>
</tr>
<tr>
<td>Longwave radiation</td>
<td>RRTM scheme</td>
<td>RRTM scheme</td>
<td>RRTM scheme</td>
</tr>
<tr>
<td>Shortwave radiation</td>
<td>Dudhia scheme</td>
<td>Dudhia scheme</td>
<td>Dudhia scheme</td>
</tr>
<tr>
<td>IC &amp; BC</td>
<td>NCEP FNL Output of D: Output of D2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Moisture Flux Convergence (MFC)

\[ \text{MFC} = -V \cdot (\nabla \nabla \cdot + \nabla \nabla \cdot - \nabla \nabla \cdot \ ) \]

- Configurable Interactive Data Display System (CDDS) is available for high resolution radar data analysis
- C2 shows a bow-shape echo
- Strong mid-level wind appeared at the rear of convection

Numerical forecast of 0600 UTC 2 July.

Moisture Flux Convergence (MFC)

- High \( \theta \) air is supplied toward convective region by strong west-southwesterly in the layer between 1000 and 900 hPa
- Strong horizontal gradient of parallel component wind speed appear in the layer between 850 and 600 hPa at the convective region
- Dry region appear in the layer between 900 and 700 hPa at the rear of convection
- Large value of convergence term of MFC coincide well with upward motion

Summary & Future Plan

- Existence of warm and moist air and its strong convergence in the low-level play an important role in sustaining the active convection
- The formation of bow-shape echo might be affected by low \( \theta \) air in the mid-level at the rear of convection
- It needs to be identified explicitly what is the role of the dry region in the mid-level for the formation of bow-shape echo
- It also has to be studied what relationship exists between the circulation induced by active convection and the dry region in the mid-level at the rear of convection

Acknowledgement

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