Environmental Influences on Precipitation Intensity in Simulated Convective Storms

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May 25, 2009

Challenges of Precipitation Forecasting

- When and where are conditions supportive?
- Which individual storms will be heavy rain producers?

- Key physical principles
  - Precipitation efficiency
  - Updraft water vapor flux
  - Storm motion
  - (Usually, all of these are important.)
Challenges of Precipitation Forecasting

- Contributing environmental factors to heavy rainfall:
  - Moist, deep-layered air mass
  - Deep low-level warm layer
  - Strong inflow
- Relevant sounding parameters:
  - High PW, CAPE
  - Low LCL, high LFC (within reason)
  - Strong shear (at least at low levels)

The niche for this paper...

- Detailed study of the *environmental* influences on precipitation
  - Profiles of temperature, humidity, wind
  - Impacts of storm motion

- What we cannot study:
  - Hydrologic aspects
    - Topography, watersheds
    - Groundwater, streamflow, channel characteristics
  - These are often as important as the storm itself.
Model dataset

- Simulations from the Convection Morphology Parameter Space Study (COMPASS)
- Broad spectrum of convective environments and modes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Possible Values</th>
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<tbody>
<tr>
<td>Bulk CAPE</td>
<td>800, 2000, 3200 J kg⁻¹</td>
</tr>
<tr>
<td>Semicircular hodo. radius</td>
<td>8, 12, 16 m s⁻¹</td>
</tr>
<tr>
<td>Shape of buoyancy profile</td>
<td>Two choices per CAPE</td>
</tr>
<tr>
<td>Shape of shear profile</td>
<td>Two choices per CAPE</td>
</tr>
<tr>
<td>LCL-LFC configuration</td>
<td>0.5-0.5, 0.5-1.6, 1.6-1.6 km</td>
</tr>
<tr>
<td>Precipitable water (PW)</td>
<td>Roughly 30 or 60 mm</td>
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<tr>
<td>RH above LFC</td>
<td>Constant, 90%</td>
</tr>
</tbody>
</table>

- LCL-conserving thermal bubble, in a 75 km × 75 km homogeneous domain; single moment microphysics

Sample profile configurations

Left: PW ~ 30 mm
Right: PW ~ 60 mm

Radii: 8, 12, 16 m s⁻¹
(U = -4 m s⁻¹ at LCL)
Effects of Environmental Wind Shear

- Increasing shear leads to larger precip. footprint
- Faster storm motions; heaviest rain spread over larger area
- QR also increased—more rain falling at the surface

- Weak shear: Max pcpn.: 55 mm, Area > 10 mm: 432 km², Avg. QR = 4.64 g kg⁻¹
- Moderate shear: Max pcpn.: 46 mm, Area > 10 mm: 720 km², Avg. QR = 5.37 g kg⁻¹
- Strong shear: Max pcpn.: 38 mm, Area > 10 mm: 1057 km², Avg. QR = 6.97 g kg⁻¹

Constant in these 3 simulations: CAPE = 2000 J kg⁻¹, concentrated buoyancy and shear, LCL = LFC = 1.6 km, PW ~ 30 mm

Effects of precipitable water

- In persistent storms, surface rainfall properties are nearly the same regardless of PW

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Other Influences

- Effects are nonlinear
  - Example: reducing PW can affect storm motion

- LCL and LFC
  - Storm motions slightly faster when LFC is raised
  - Greater PE, so water mass distributed over a larger area
  - But, high LCL means more subcloud evaporation

What does not influence precipitation?

- (Only the persistent updrafts are considered here)

- Low-CAPE storms that exist are just as likely to produce heavy rain as high-CAPE storms

- No statistically significant effects as CAPE is varied

- Caveat: CAPE does affect the number of storms
Relationships to Climate Change

- “Trends” in storm behavior as certain parameters may become altered:
  - CAPE: little affect on amount of precip from an individual updraft
  - Shear: obvious importance, but competing effects
  - Others: LCL, LFC, PW

- Important to remember:
  *Multiple aspects of the profile are important.*

Summary

- Environmental shear greatly impacts precipitation
  - Effects are dichotomous
  - Storms can produce more precip, but will move more quickly

- CAPE does not appear to influence an updraft’s precipitation to a significant degree

- Further investigations possible:
  - Precip. and intra-storm processes
  - More study of shear vs. storm motion effects on precip
Acknowledgments

National Science Foundation
(Grant ATM-0126408)

Additional Thanks to:
Dr. Charles Cohen
Dr. Kevin Knupp
Dr. Don Perkey

Project website: http://space.hsv.usra.edu/COMPASS