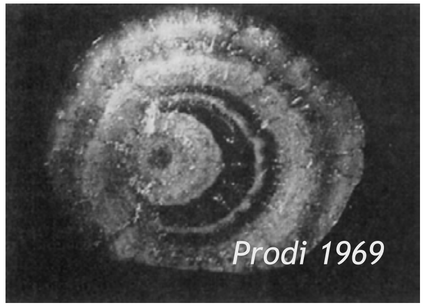
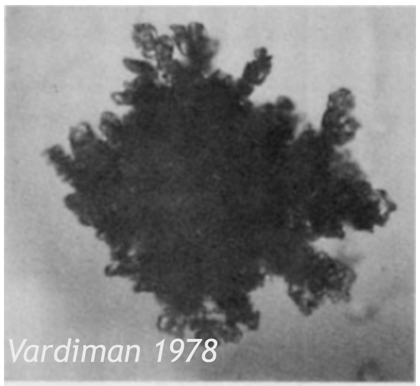
Connecting Microscale Processes to Mesoscale Phenomena: Improving Cold Pool Parameterizations





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ILLINOIS

Blue Waters Symposium

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BLUE WATERS
SUSTAINED PETASCALE COMPUTING

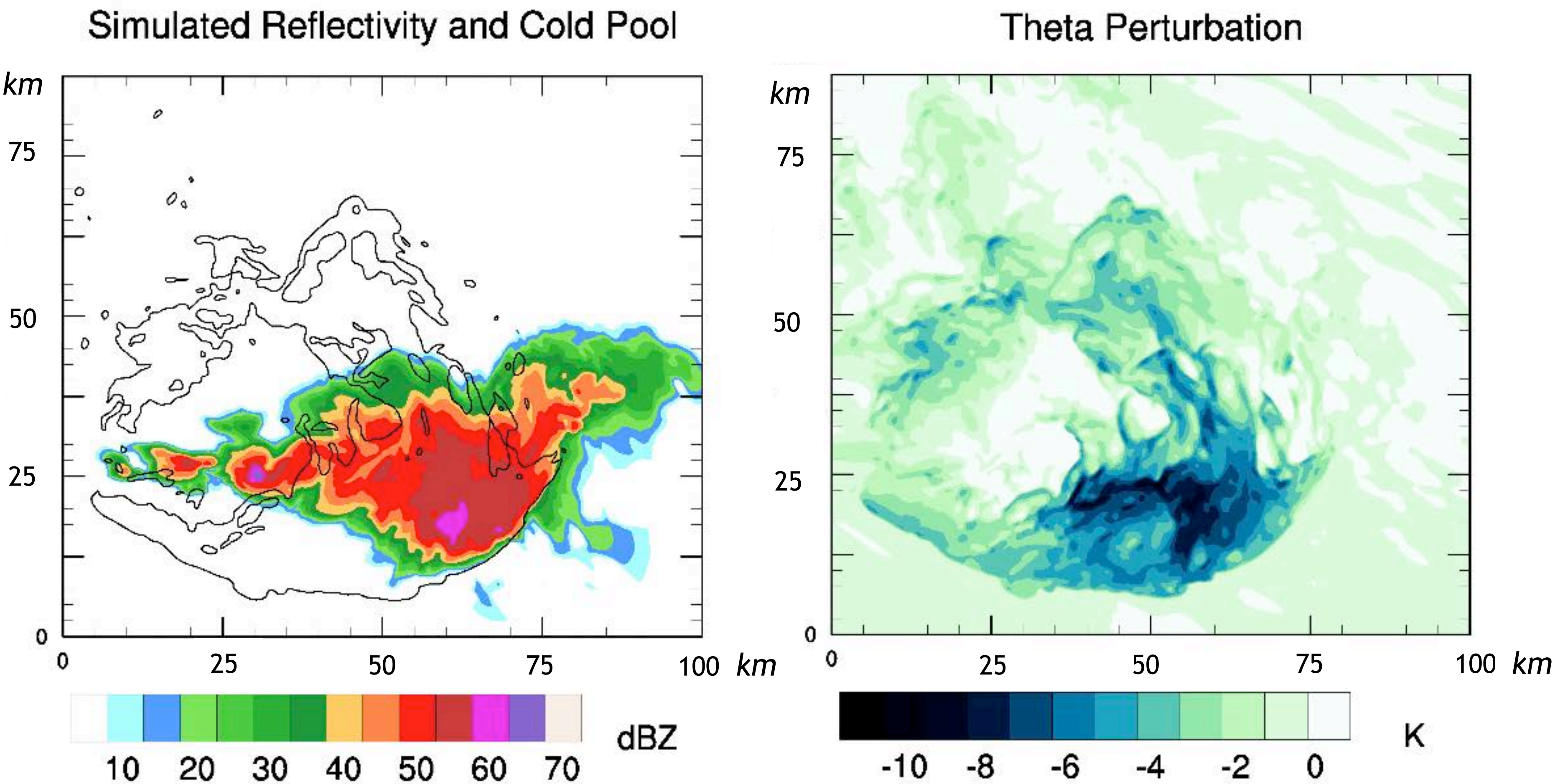
I use Blue Waters to...

Connect small-scale (precipitation) processes to larger-scale (thunderstorm) phenomena

- What kind(s) of precipitation are most important for forming, sustaining, and determining cold pool properties
  - A stronger storm outflow can generate new storm development ***however***…
  - Parameterizations in larger-scale models lack sufficient representation of convective components (i.e. cold pools)
  - Thus larger-scale models fail to predict longer episodes of convective activity!
- Improving parameterizations requires a detailed understanding of the physical drivers of cold pools
  - **Requires multiple realizations of high-resolution simulations, with high-frequency output of large data files to quantify**

BLUE WATERS SUSTAINED PETASCALE COMPUTING **has allowed us to pursue these questions!**

Cold Pool Overview



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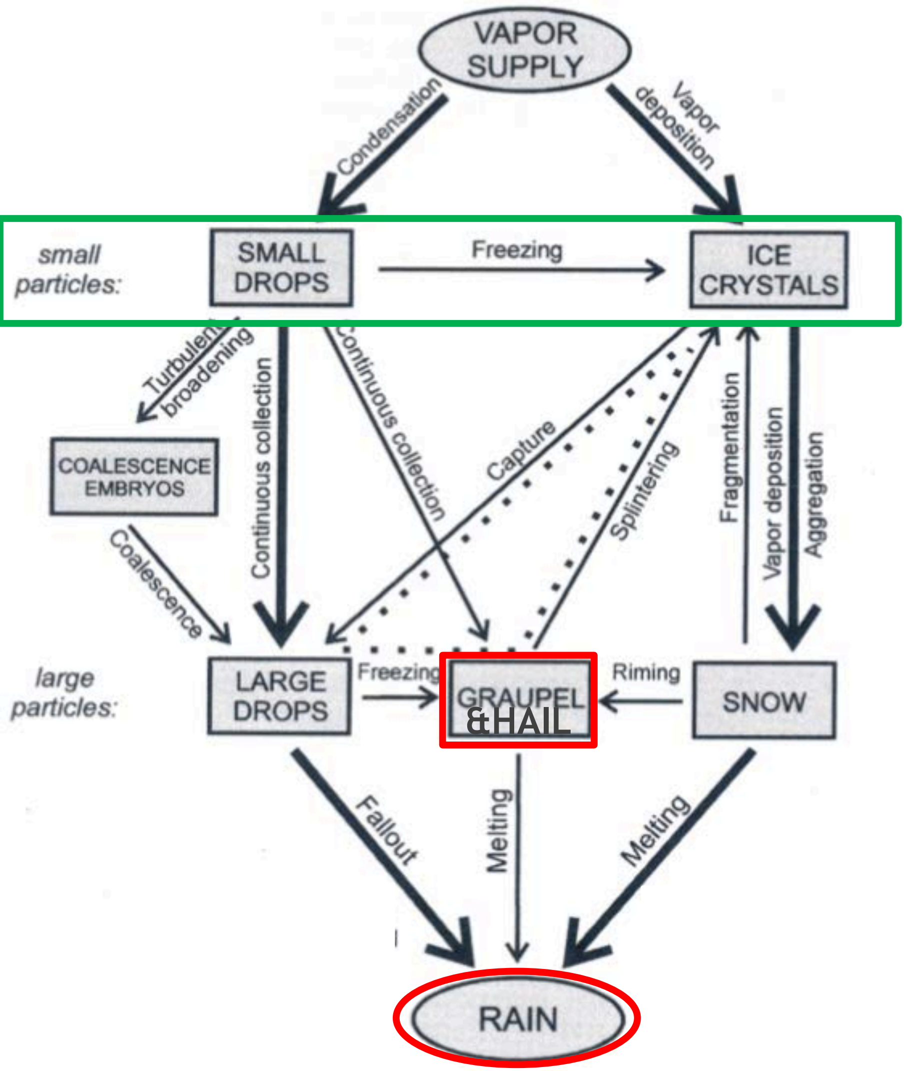
Precipitation Processes

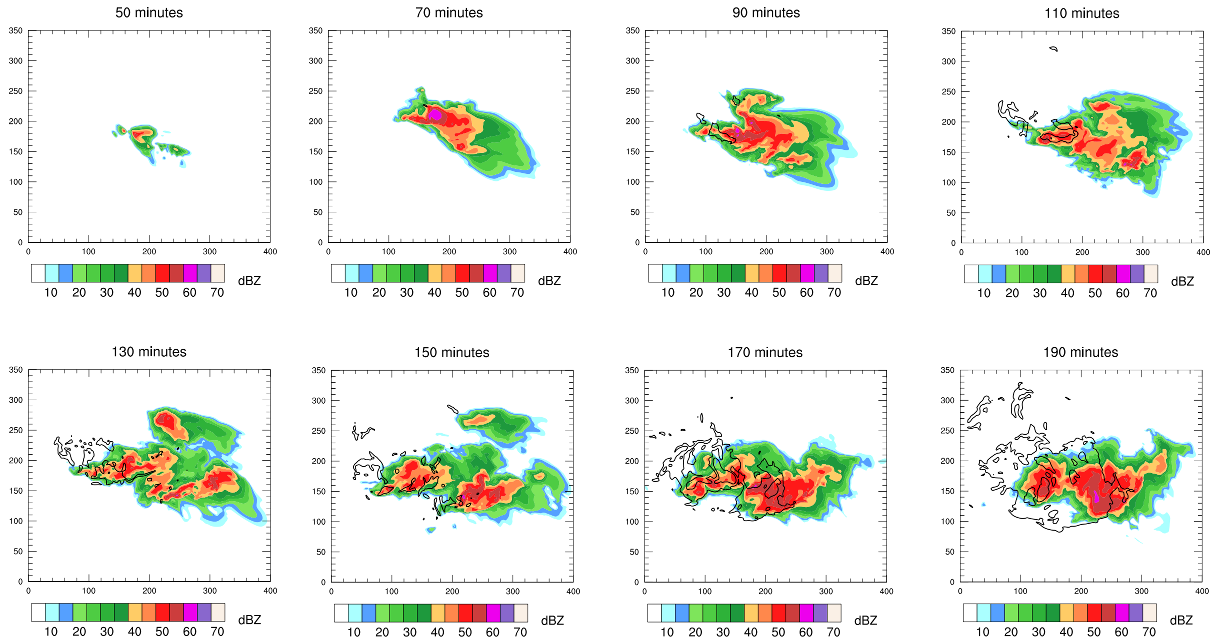
- **Recall:** Improving parameterizations requires a detailed understanding of the physical drivers of cold pools



- To accomplish this, we want to change the precipitating hydrometeor's properties
- Variability in the initial fields creates variability in the precipitation properties (i.e. "trickle-down" effect)
- This changes microphysical characteristics of storms while keeping dynamics relatively unchanged!

To summarize…

We change the initial **precipitation processes** to look at how **hydrometeors** influence **cold pools**



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Requires multiple realizations of high-resolution simulations, with high-frequency output of large data files to quantify

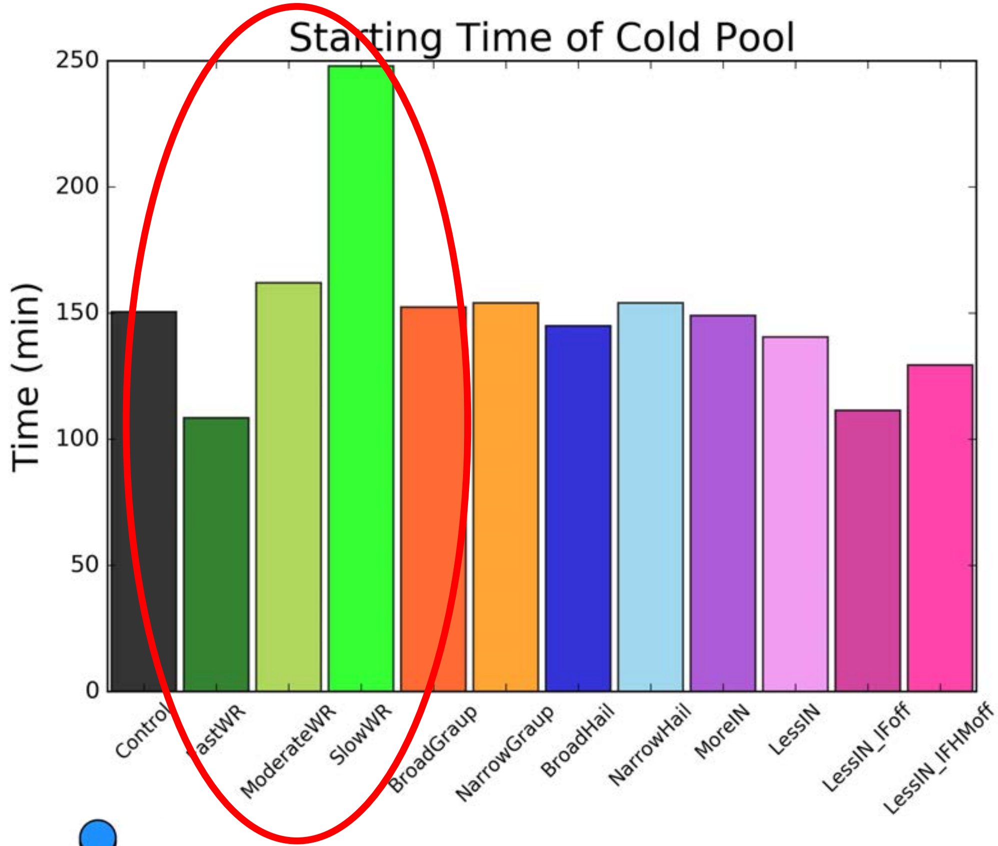
Model and Analysis Tools

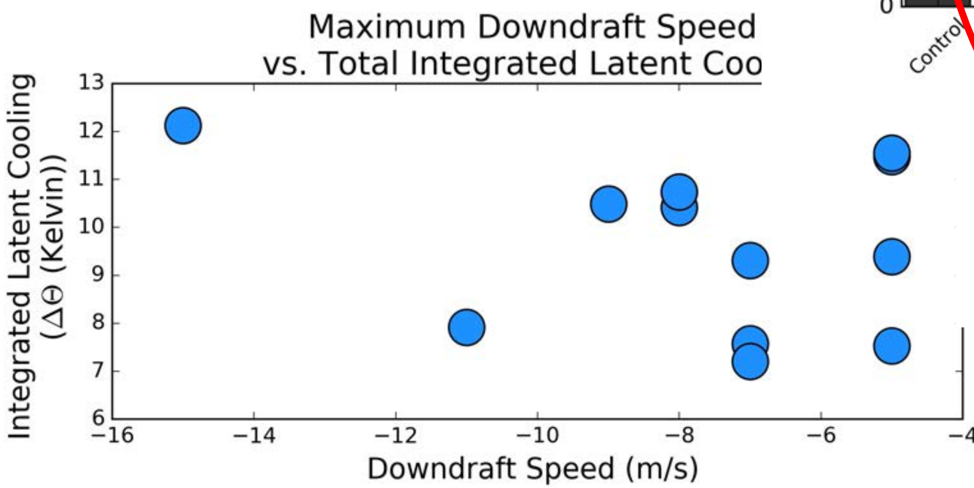
- **CM1 Model- Dr. George Bryan, NCAR**
  - Coarse-grained, pure MPI, 3D cloud model, designed to scale to tens of thousands of processors, written in FORTRAN
  - 3rd-order RK integration; 5th/6th order advection
  - **NSSL double-moment microphysics (important for precip. development, but increases number of calculations and memory required)**
  - Domain sizes are 250 kilometers wide; grid spacing is 250 m with a time step of 1 second
    - 80 million grid boxes in domain
    - 800 node hours per run

This is the most number of simulations and the highest resolution that has been used to address this topic

Cold Pool Formation

- **Still ambiguity regarding most important downdraft properties forming cold pool**
- Variability in dominant hydrometeor
- Range of downdraft strengths that form the cold pool
- However…speed of rain formation (warm-rain process) appear most important for determining cold pool onset





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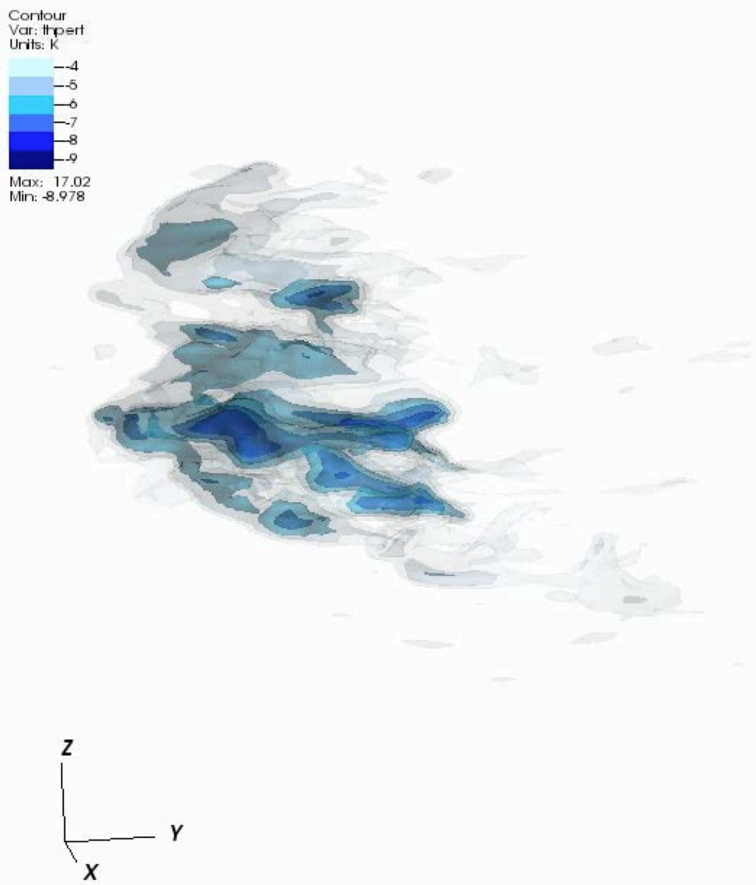
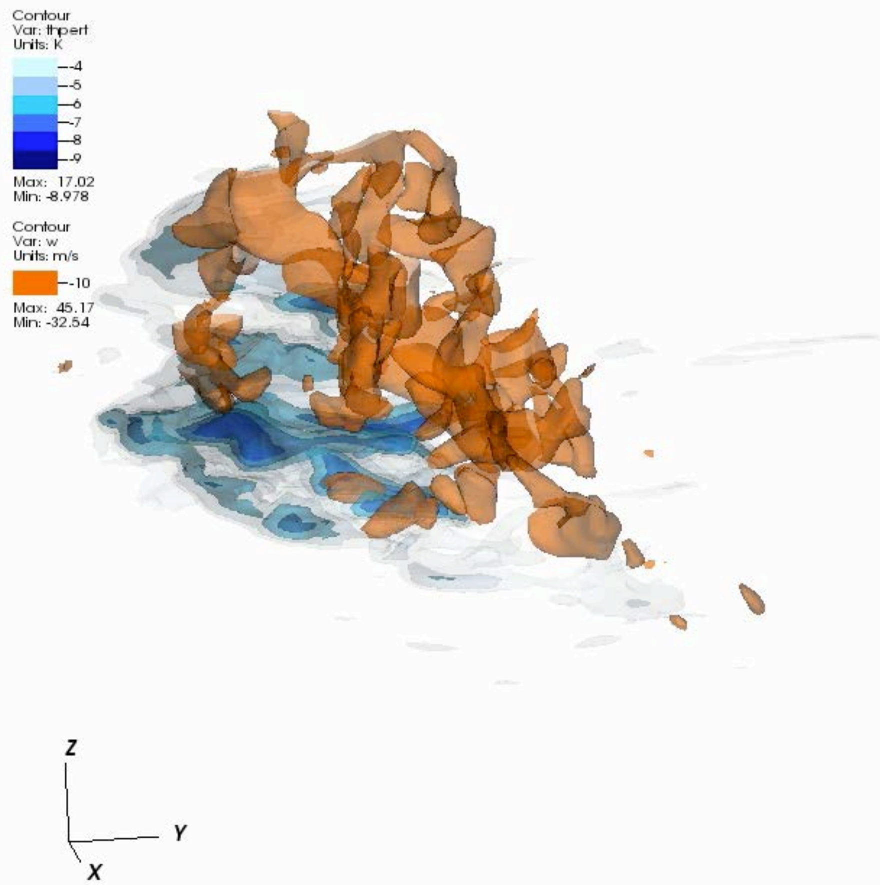
Cold Pool Sustenance



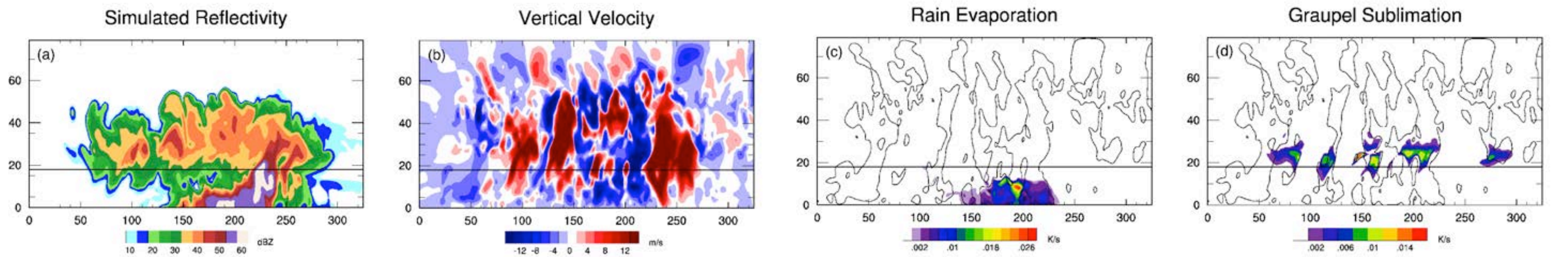
Theta Perturbation

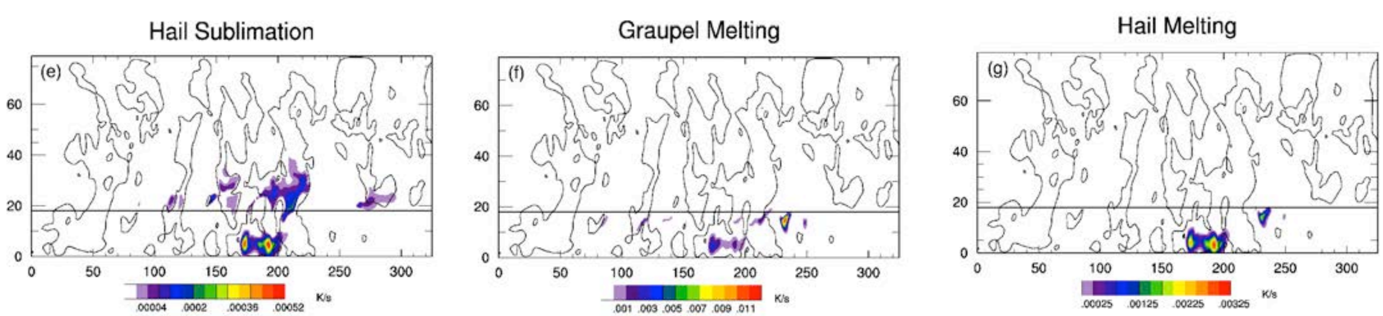


Theta Perturbation and Strong Downdrafts

Cold Pool Sustenance

- Calculations of latent cooling in downdrafts (offline):
  - NCL/FORTRAN code searches for cold pool & associated downdrafts connected to it at each output time





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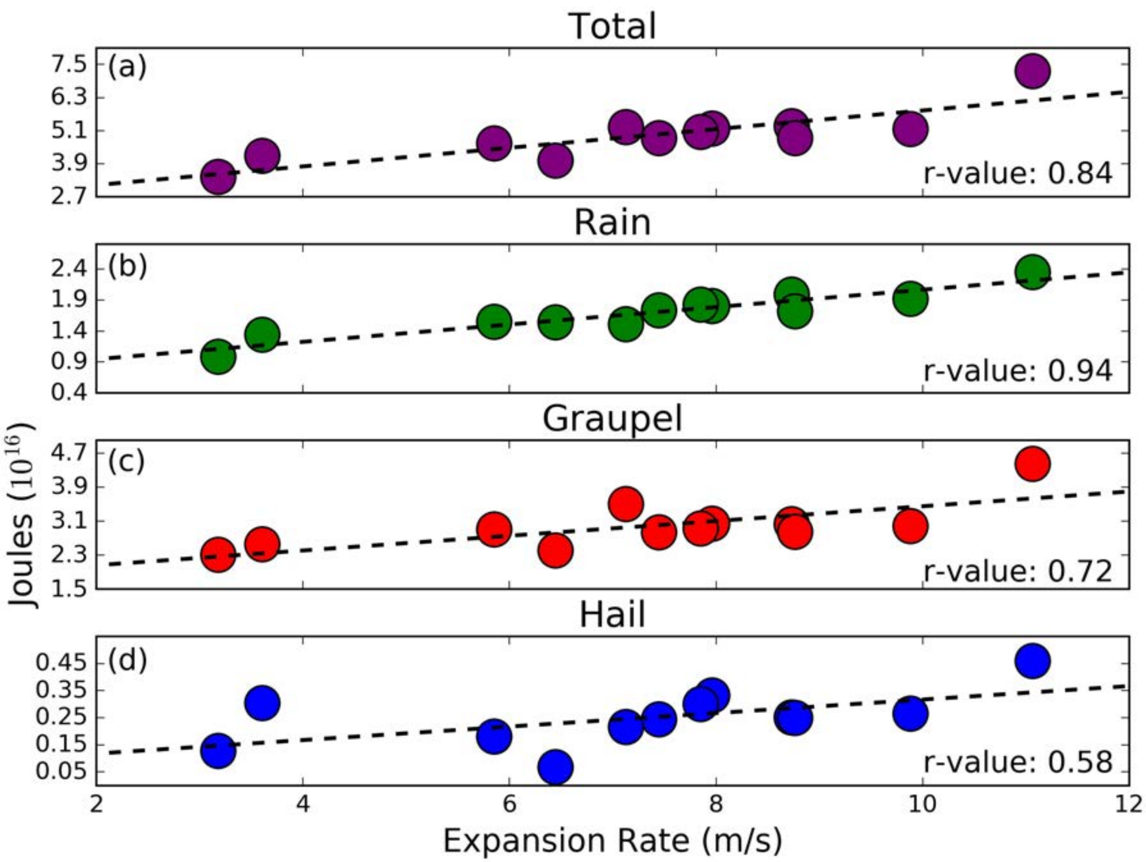
Cold Pool Sustainment

- Graupel is the dominate hydrometeor in all realizations despite differences in the initial microphysics
- But rain evaporation has the strongest influence on:
  - Expansion rate
  - Depth
  - Strength



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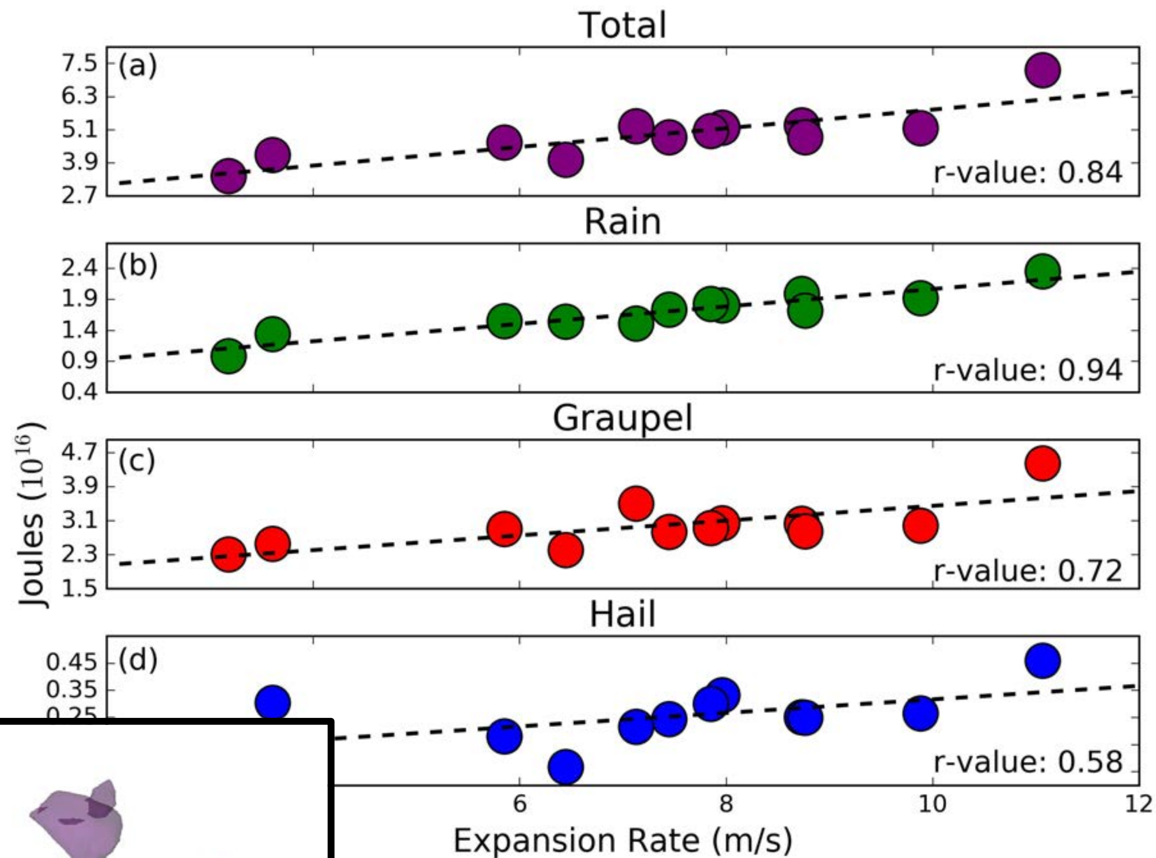
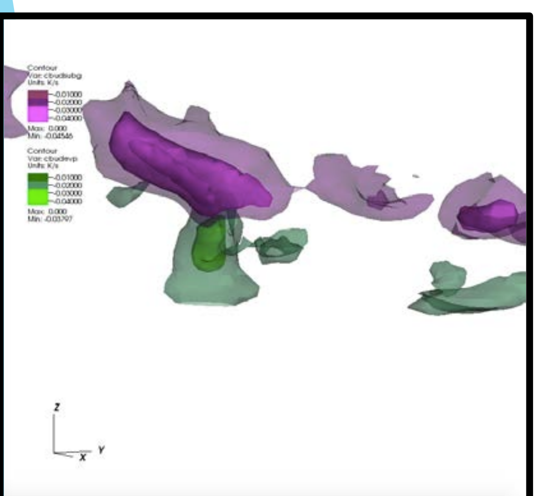
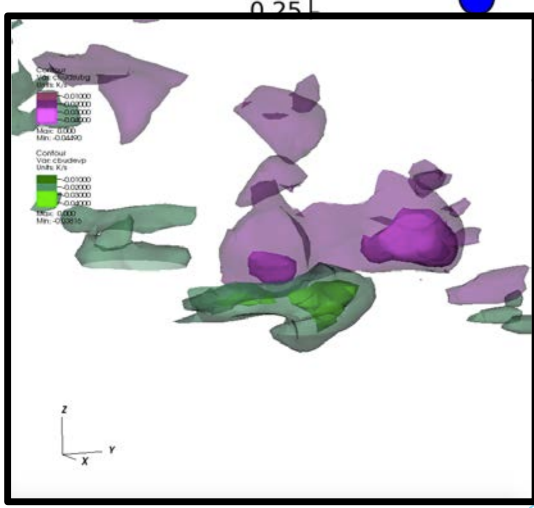
Cold Pool Sustainment

- But rain evaporation has the strongest influence on:
  - Expansion rate
  - Depth
  - Strength
- Theorized this is because rain evaporation is occurring within the cold pool







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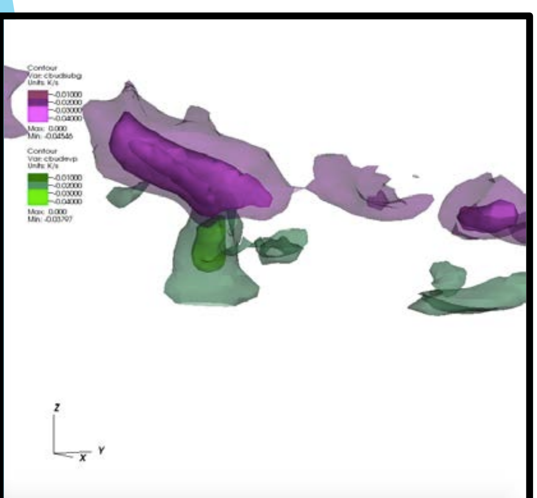
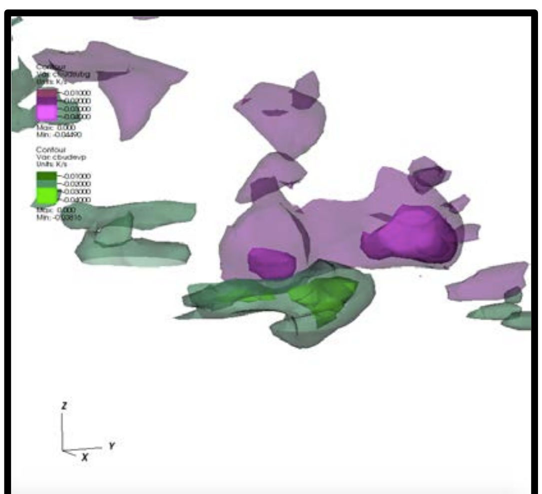
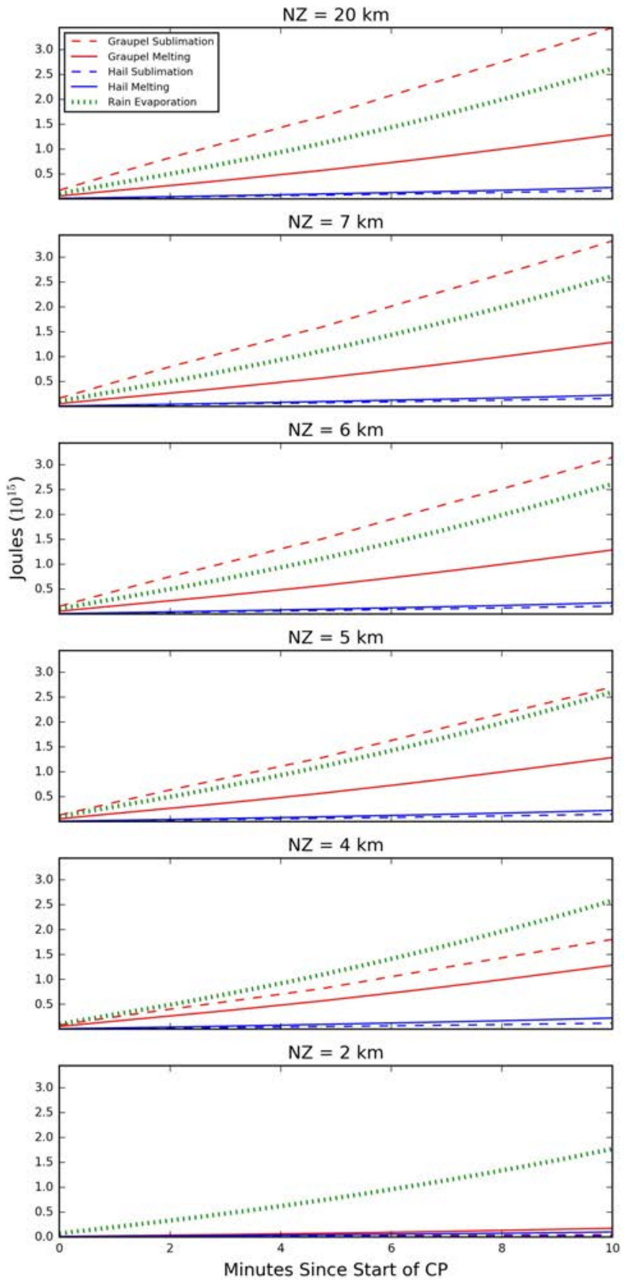
Cold Pool Sustainment

- Theorized this is because rain evaporation is occurring within the cold pool
- Limiting latent cooling calculations to lower heights supports this
- This has also helped reconcile differences seen in past studies
    - Capping latent cooling calculations at 4 km vs. entire domain depth







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Summary

I use Blue Waters to:
Connect small-scale (precipitation) processes to larger-scale (thunderstorm) phenomena

- We achieve this by changing the initial **precipitation processes** to look at how **hydrometeors** influence **cold pools**
- Rain processes determine cold pool formation
- Graupel is the dominant hydrometeor sustaining the cold pool
- Rain evaporation has the strongest influence on cold pool properties

Implications for Larger-Scale Weather and Climate Models

- Consideration of the microphysics in deep convection is necessary to accurately represent cold pools and their effects in parameterizations
- Cold pool onset could be parameterized using local CCN values and cloud-base temperatures
- Large amounts of near-surface rainfall can help parameterize cold pool properties
- Cold pool sustainment is governed by graupel
  - Related to amount of IN (not well quantified)
  - Most schemes only allow for graupel OR hail

Challenges & Solutions

- NCL routines running out of memory
  - Run in subsections or with fewer variables
- Faster analysis with VisIt and NCL codes
  - We trim the data files to remove most of the empty space around the clouds/storms, for analysis and longer-term storage
- Searching large domains for continuous surfaces meeting certain criteria
  - Cumbersome FORTRAN & NCL routines used
  - Development of MATLAB routine with help from Blue Waters team to address memory issues
- Storage of data files while running analysis code
  - Trimming files works to an extent but still trying to think of a better solution

Acknowledgements

- Blue Waters Project and Team, NCSA
- Dr. George Bryan for use of the CM1 community model
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