The challenge of adequately representing deep convective dynamics, bulk microphysics, and their interaction in CRM and LAM simulations

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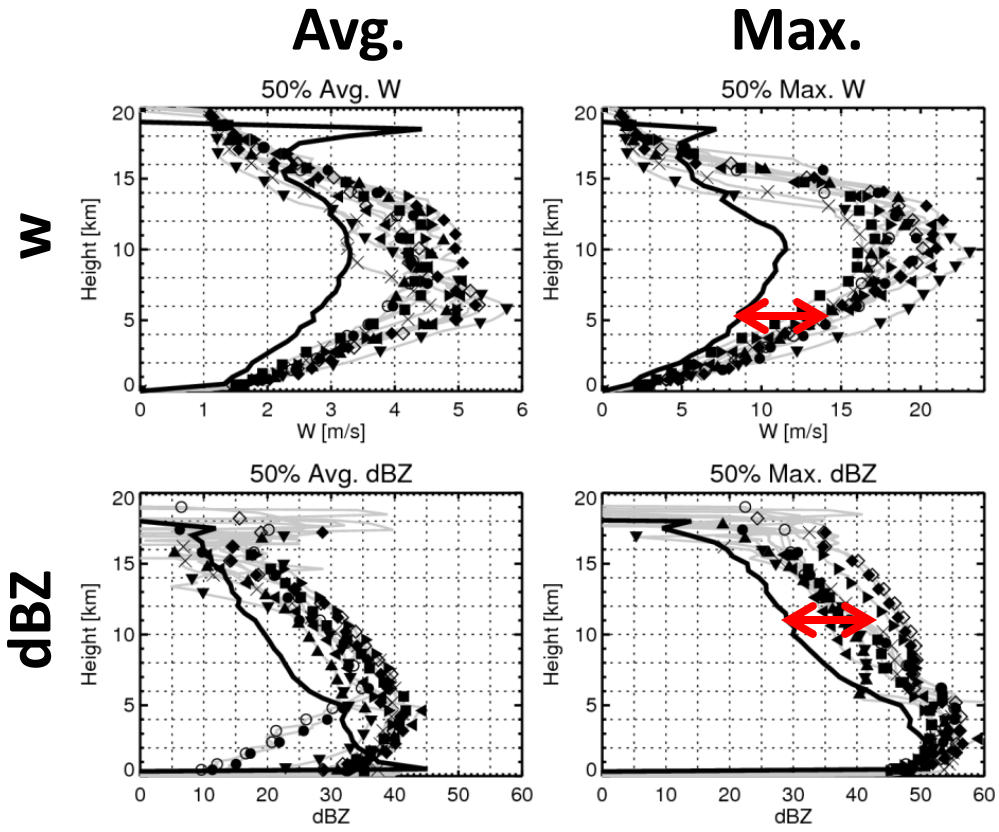
What are we after?

- If we want to know advection to stratiform and anvil regions, then we really want to know convective updraft and downdraft properties
- How do we know if they are properly represented in models?
  - Observations and Retrievals
  - Intercomparison
  - LES and bin schemes as closer to “truth”

What are the updraft properties?

- For deep updrafts (start in PBL and end near tropopause), models have stronger w and higher dBZ than dual Doppler retrievals
  - Dynamics?
  - Microphysics?



Dual Doppler from Scott Colis

The driver of convection

$$\frac{Dw}{Dt} \cong -\frac{1}{\bar{\rho}}\frac{\partial p'}{\partial z} + g\left(\frac{\theta'}{\bar{\theta}} + 0.61 q_v' - \frac{c_v}{c_p}\frac{p'}{\bar{p}} - q_h\right)$$

Non-hydrostatic Pressure Gradient Force

Temperature

Water Vapor

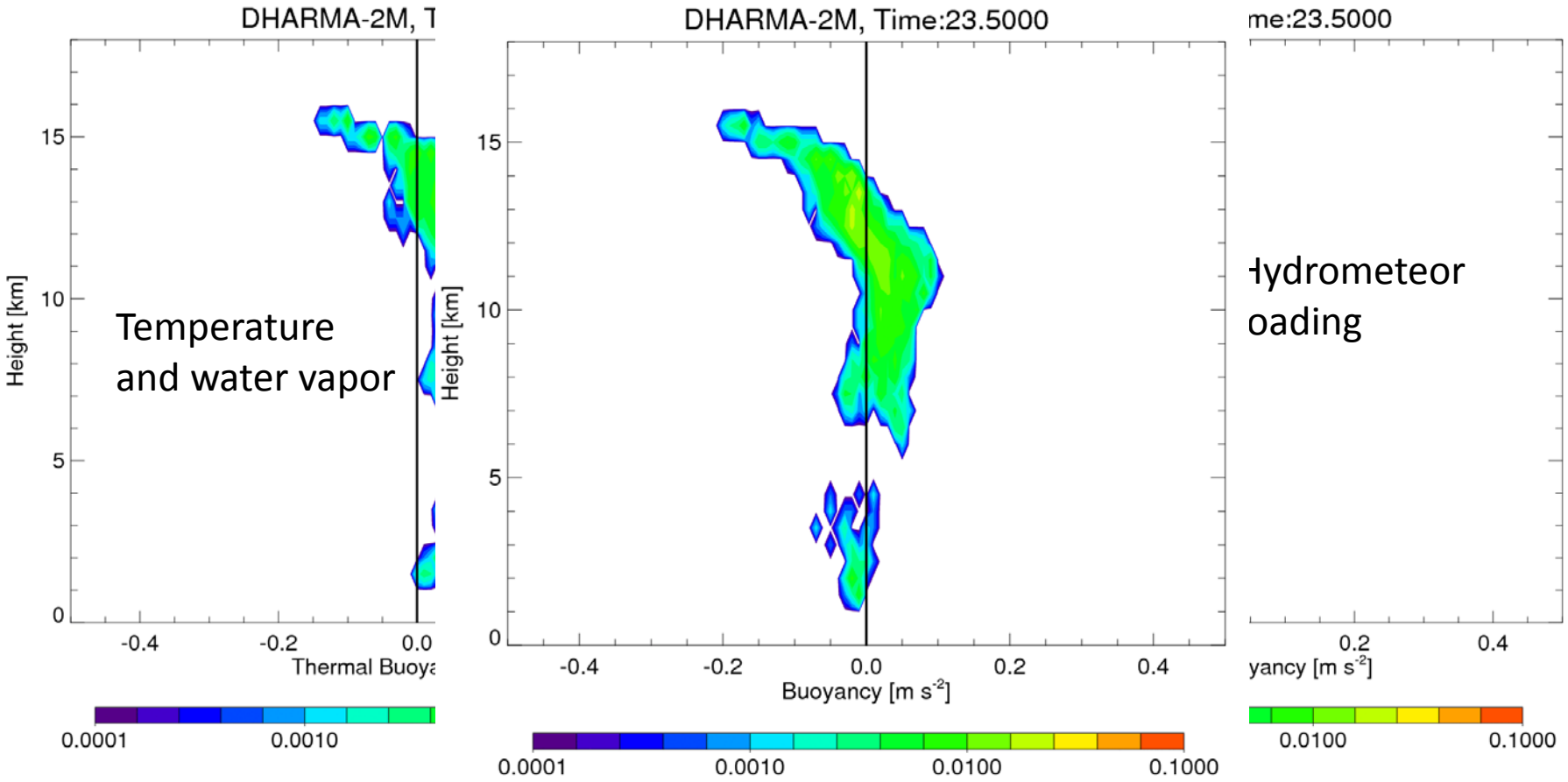
Pressure

Hydrometeor Loading

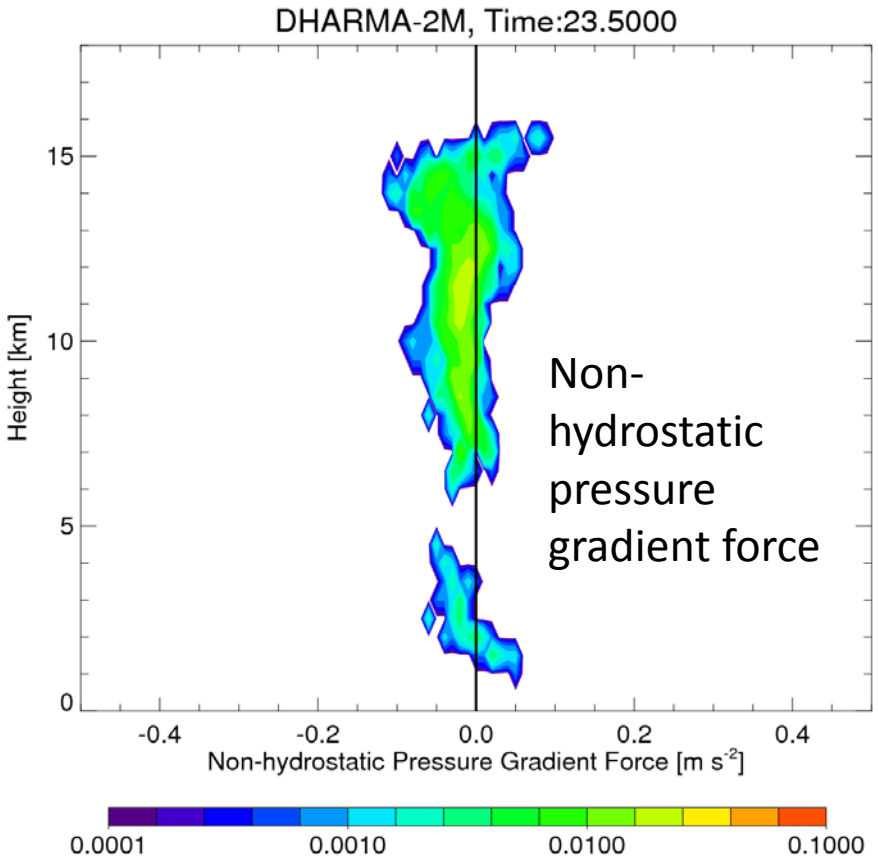
Entrainment

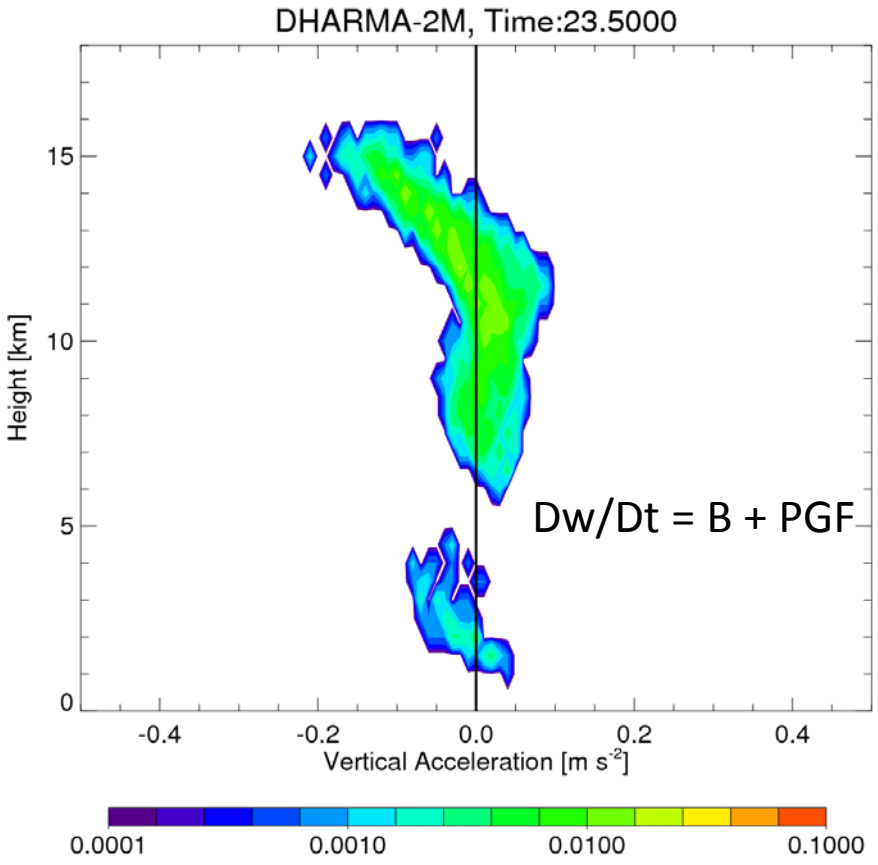
Buoyancy

Buoyancy in updraft cores



B + PGF

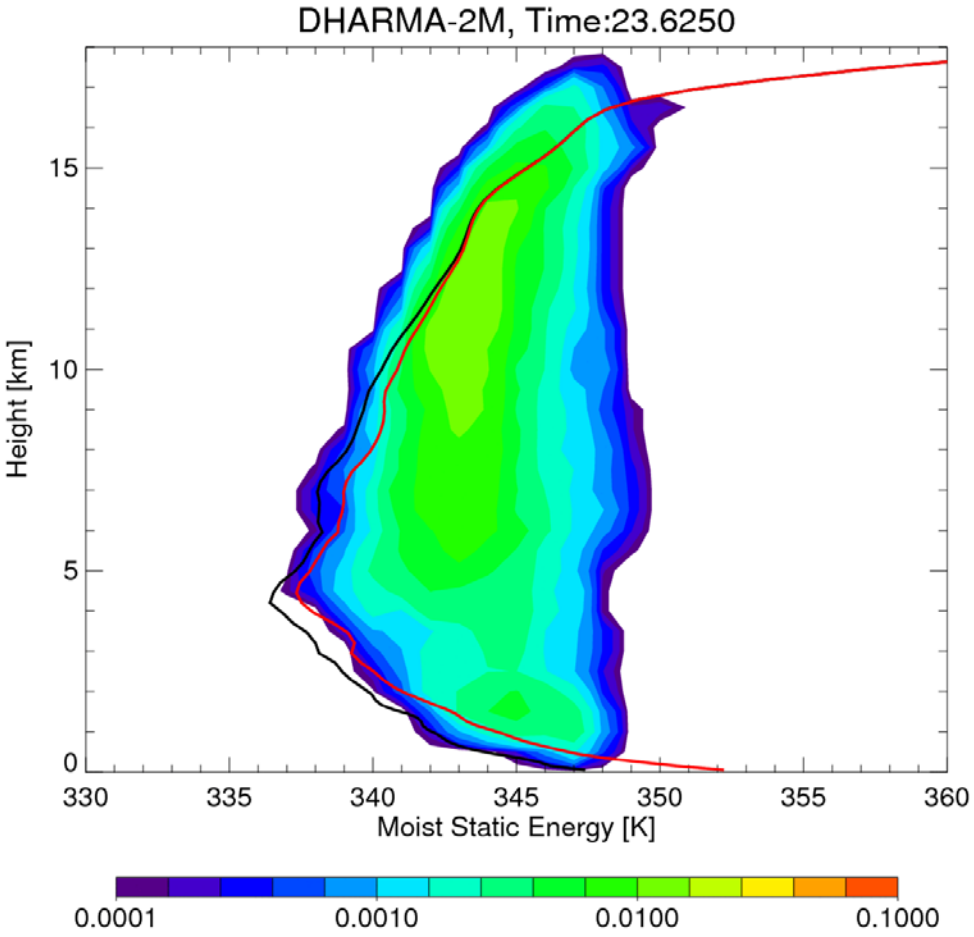

DHARMA-2M, Time:23.5000
Height [km]
15
10
5
0
-0.4
-0.2
0.0
0.2
0.4
Non-hydrostatic Pressure Gradient Force [m s-2]
0.0001
0.0010
0.0100
0.1000
Non-hydrostatic pressure gradient force

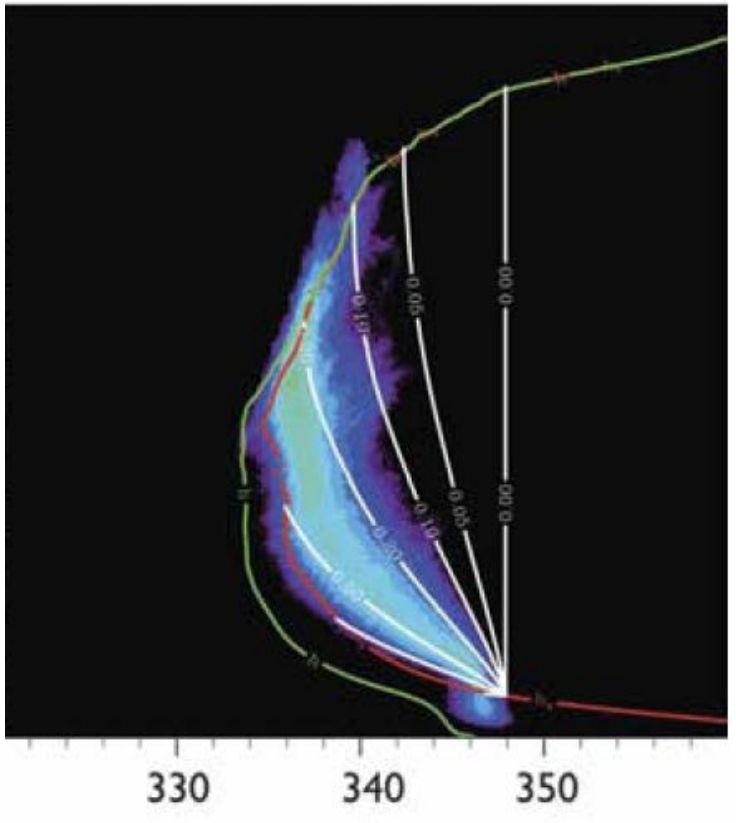

DHARMA-2M, Time:23.5000
Height [km]
15
10
5
0
-0.4
-0.2
0.0
0.2
0.4
Vertical Acceleration [m s-2]
0.0001
0.0010
0.0100
0.1000
Dw/Dt = B + PGF

Entrainment – the biggest unknown

- How can we know if this is being represented properly?
  - Turbulent = No nice equations
  - But it is a mixing process – can look at conserved variables such as moist static energy

Entrainment

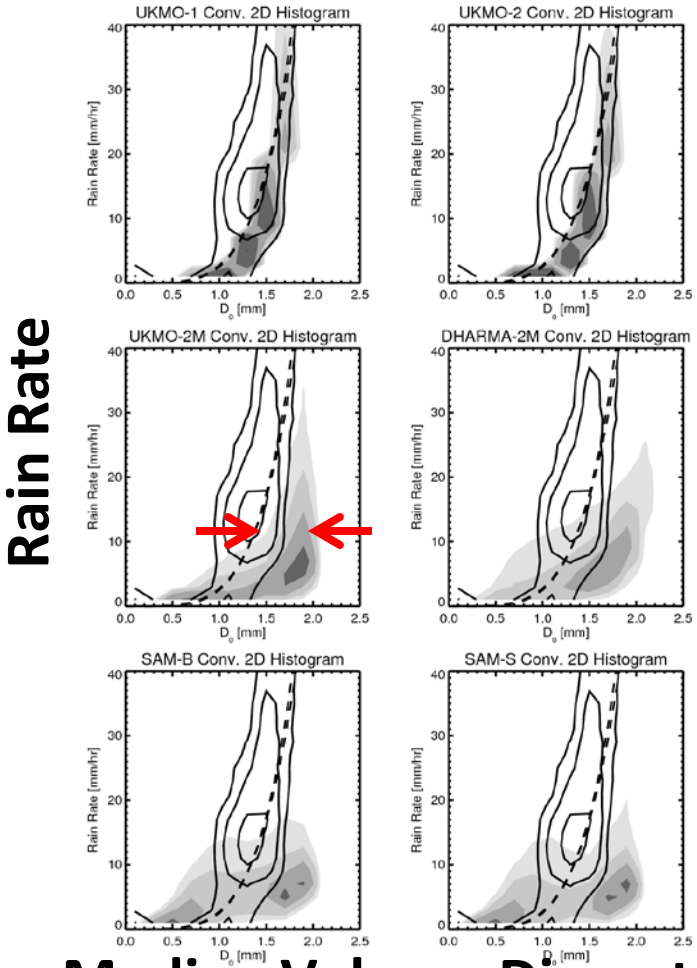




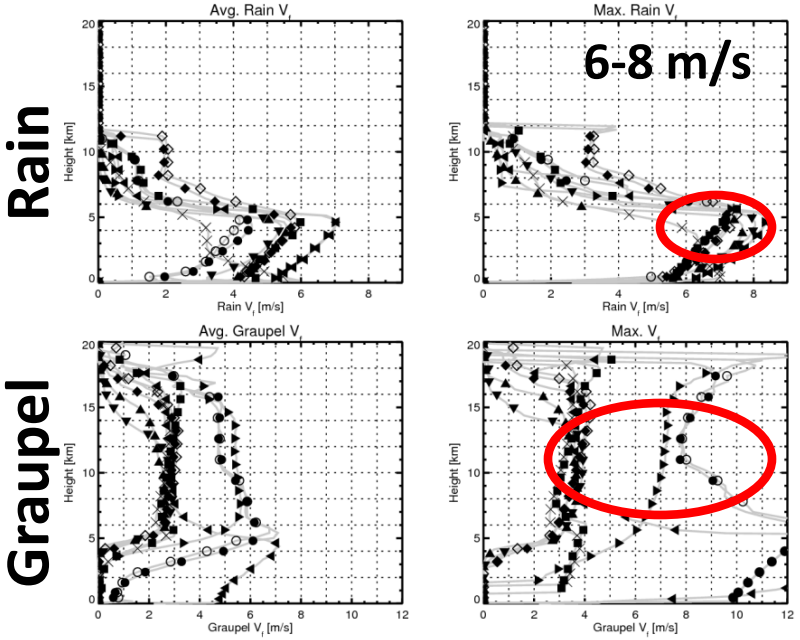
Khairoutdinov and Randall, 2006

Updraft Microphysics

Rain Rate vs. Size

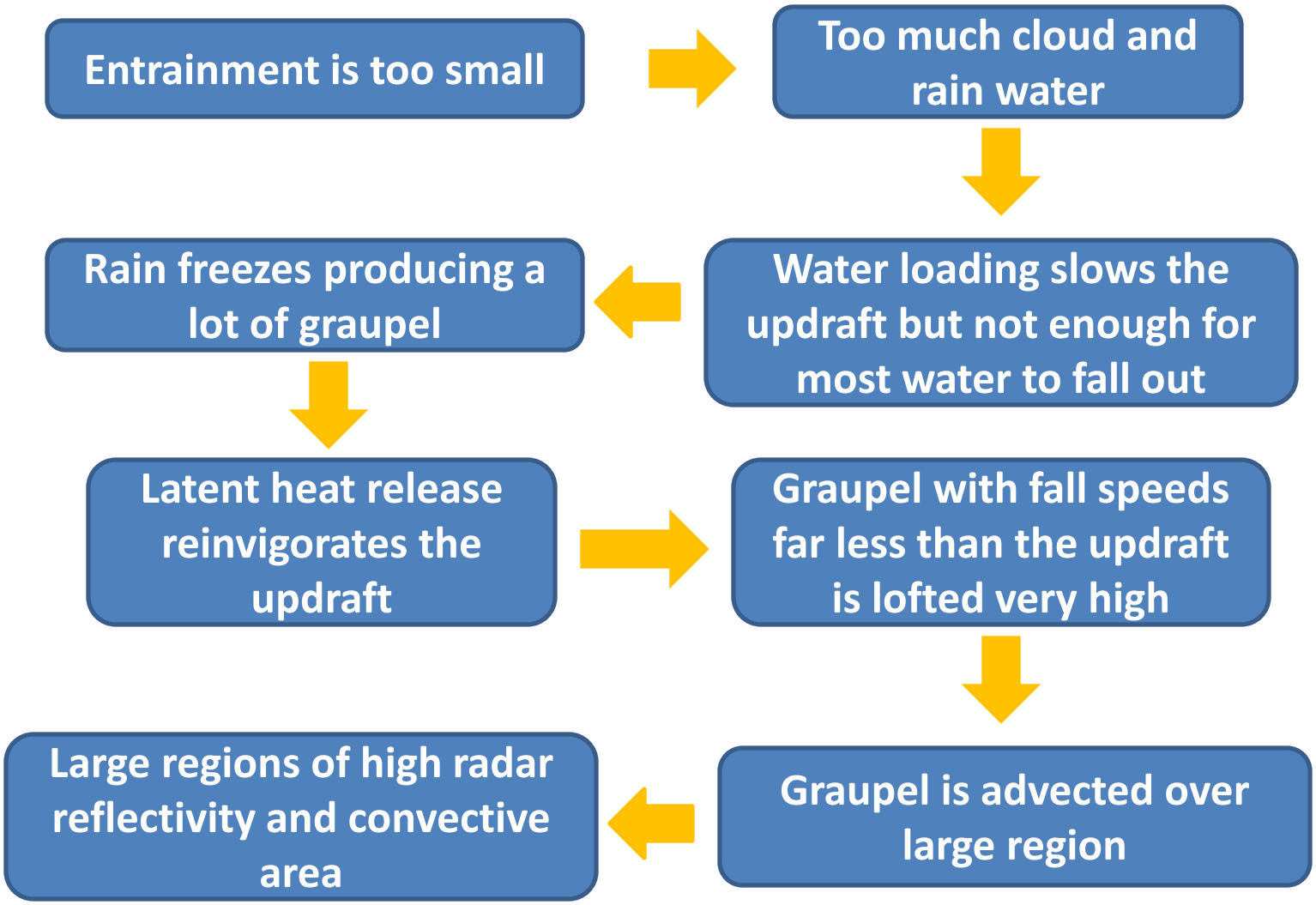


Hydrometeor Fall Speeds

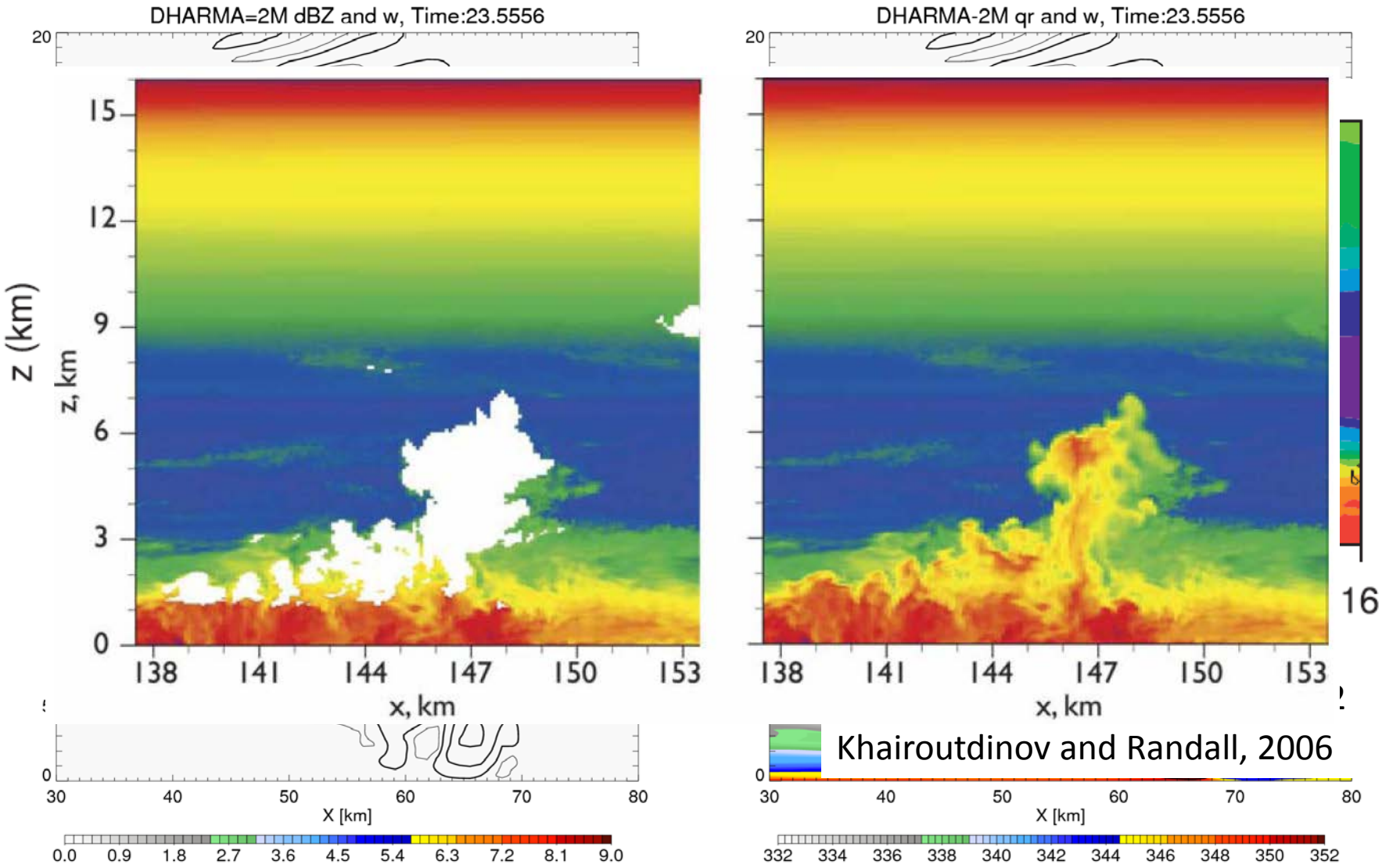


Bringi et al. (2009) retrieval

Interaction of Dynamics and Microphysics



Example Vertical Cross-sections



Khairoutdinov and Randall, 2006

What can we do?

- 1 km resolution appears too coarse for tropical convection with conventional turbulence representation
- Identify bulk microphysics assumptions that significantly improve results without significantly increasing computing
- Understand how dynamical and microphysical terms are interacting in drafts
  - Variables we can measure to get buoyancy and entrainment in different situations (thermal size and large-scale environment)?
  - There is a lot more that can be done with LES to improve CRMs
- Advection to stratiform and anvil regions = deep convective draft properties
  - Correlate stratiform properties to deep convective properties through intercomparison
- Collaboration of people across many specialties