The Impact of One- and Two-Moment Microphysical Schemes on Precipitation in an Ordinary Thunderstorm

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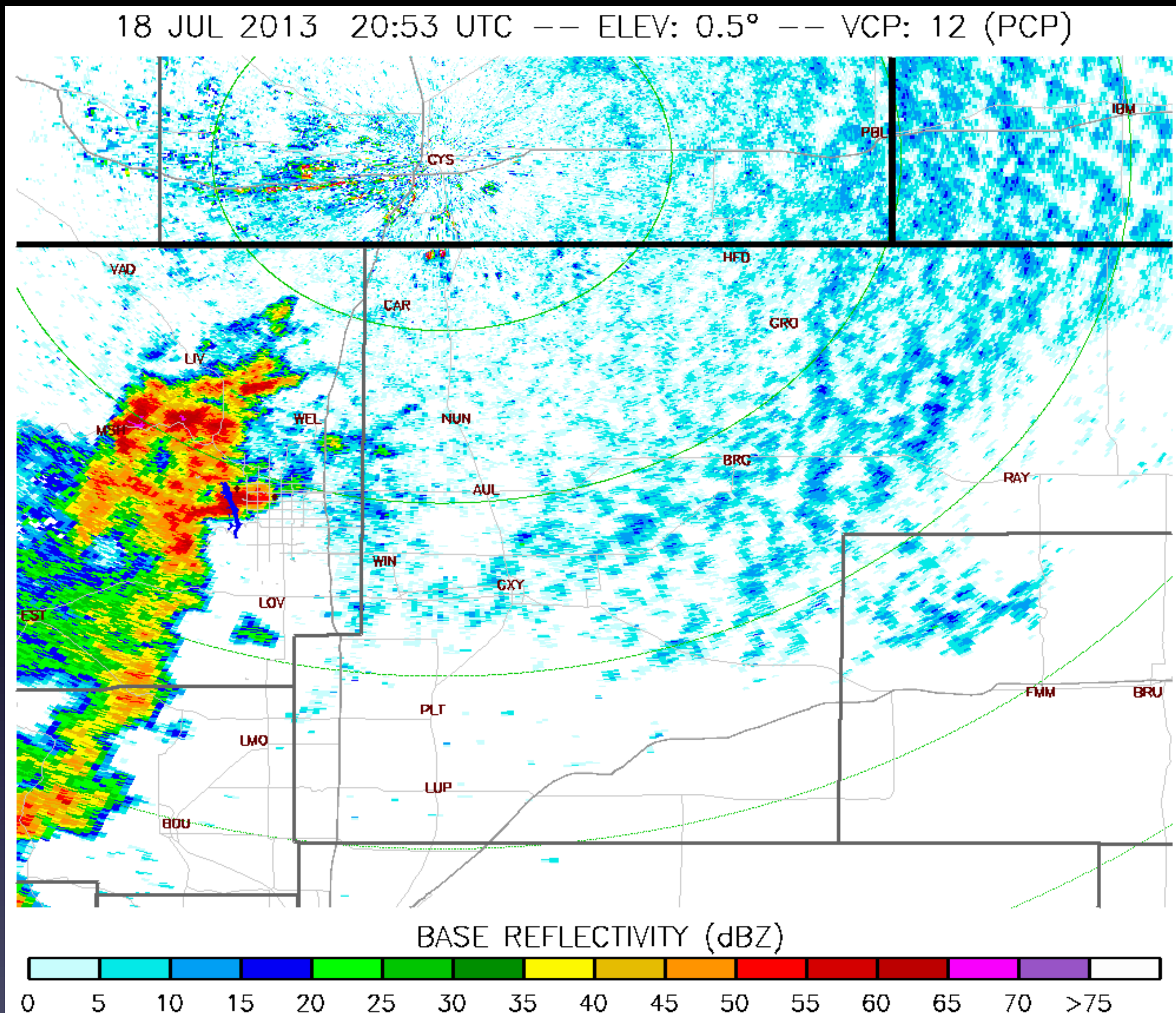
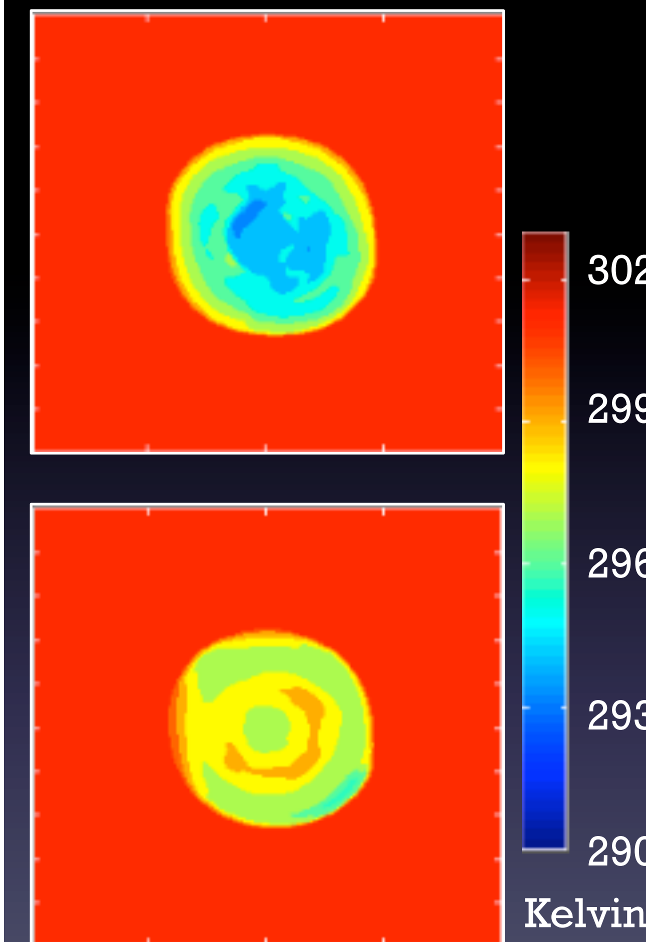


Surface Temperature



- Radar images of storms that occurred July 18th, 2013 show leading edge of cold pool
- Forecast models' accuracy is important

One- vs. Two-Moment Microphysical Schemes

- Both used by atmospheric models (NAM, GFS, etc.) for forecasting, but primarily single-moment

Single Moment:

- $r = {}^{\pi}/_{6} * \rho_{\text{water}} * N * D^3$

mixing ratio
(mass / volume)

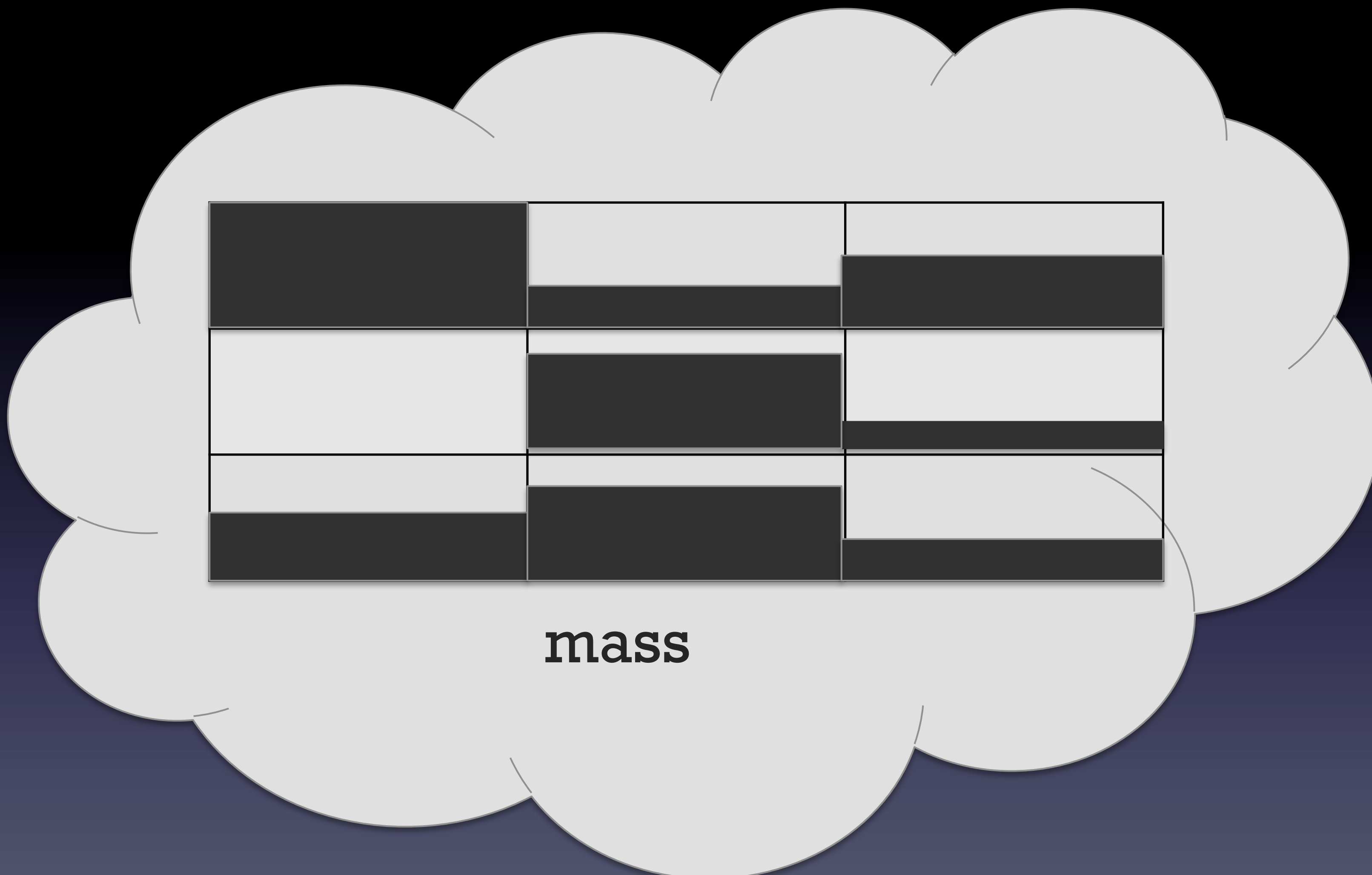
(predicted)

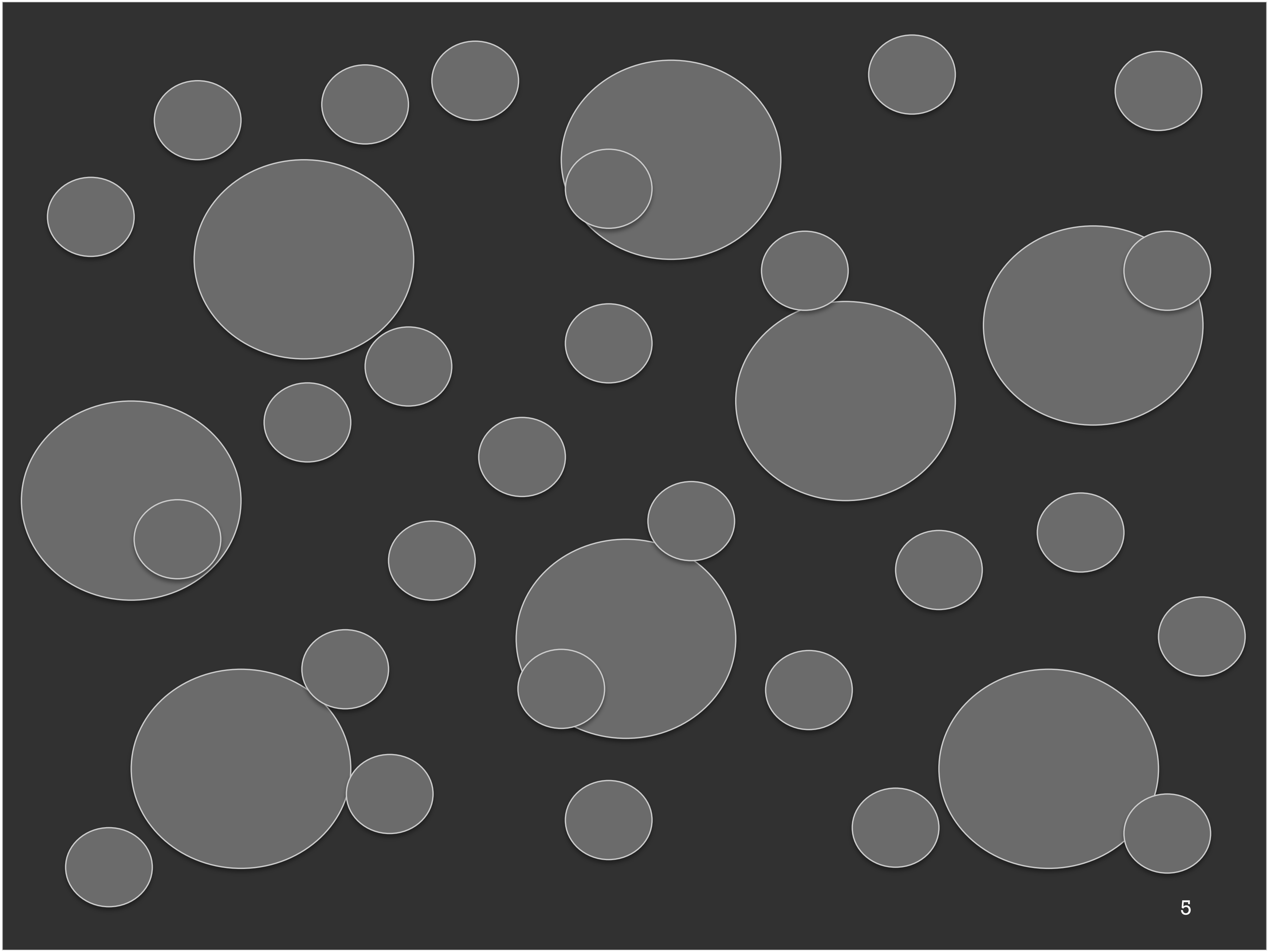
number concentration

(fixed)

diameter

Solve!


mass



Two-Moment Schemes are Better!

$$r = {}^{\pi}/_{6} * \rho_{water} * N * D^3$$

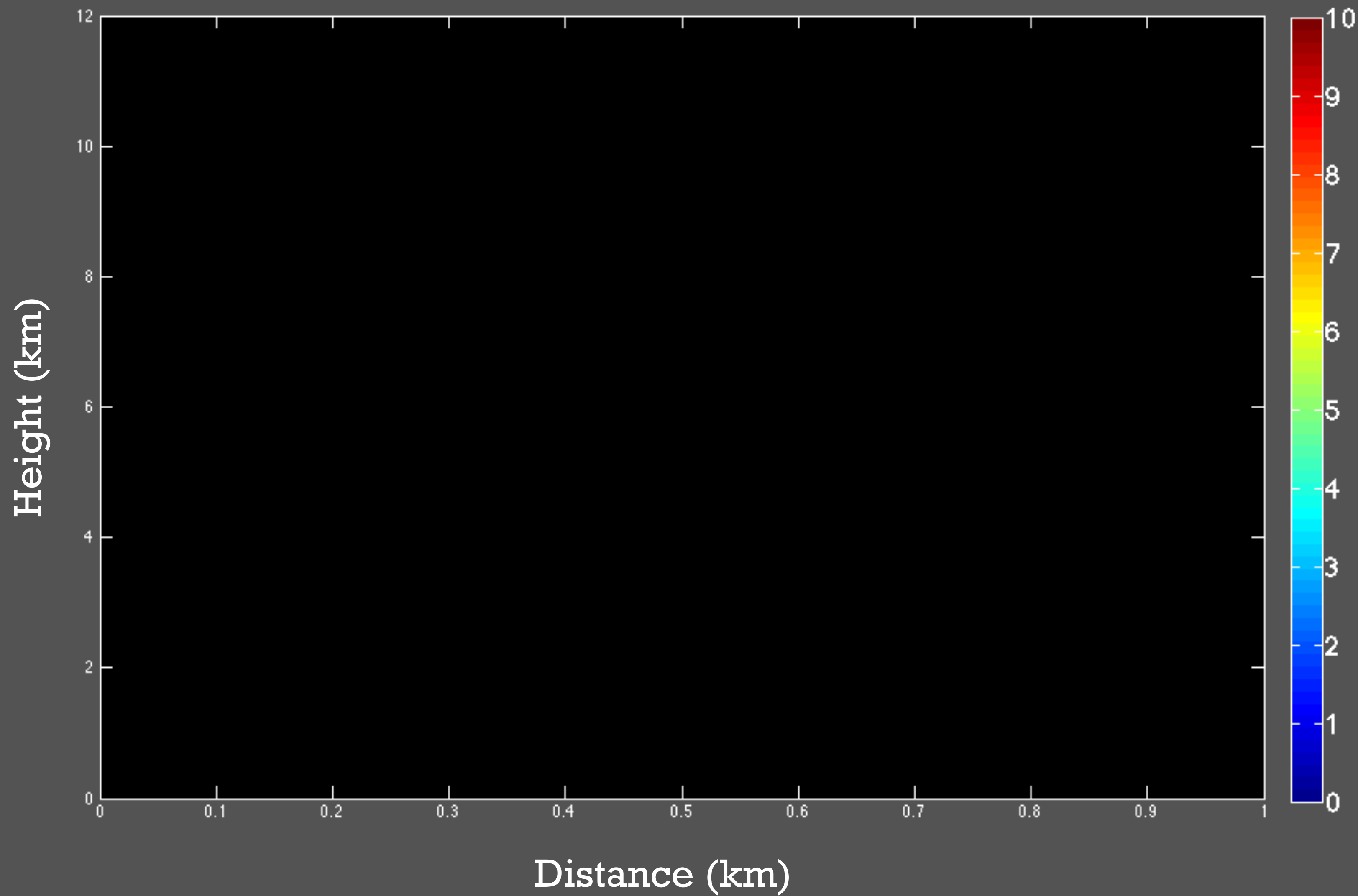
mixing ratio
(predicted)
(varies)

number concentration
(predicted)
(varies)

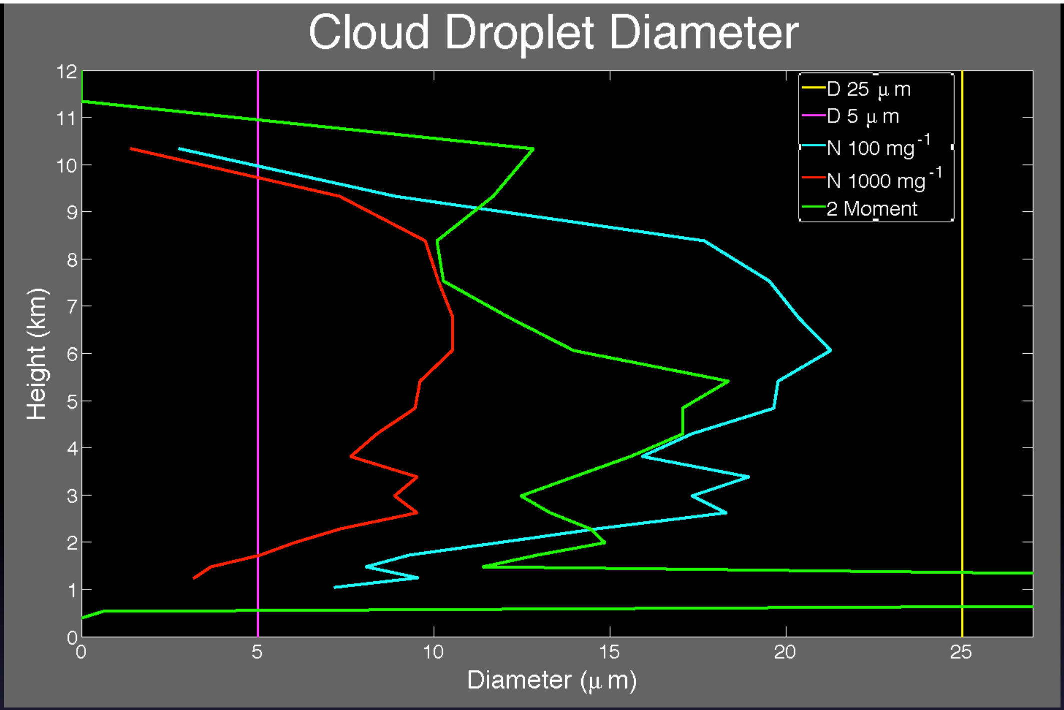
diameter
(solved for)
(varies)

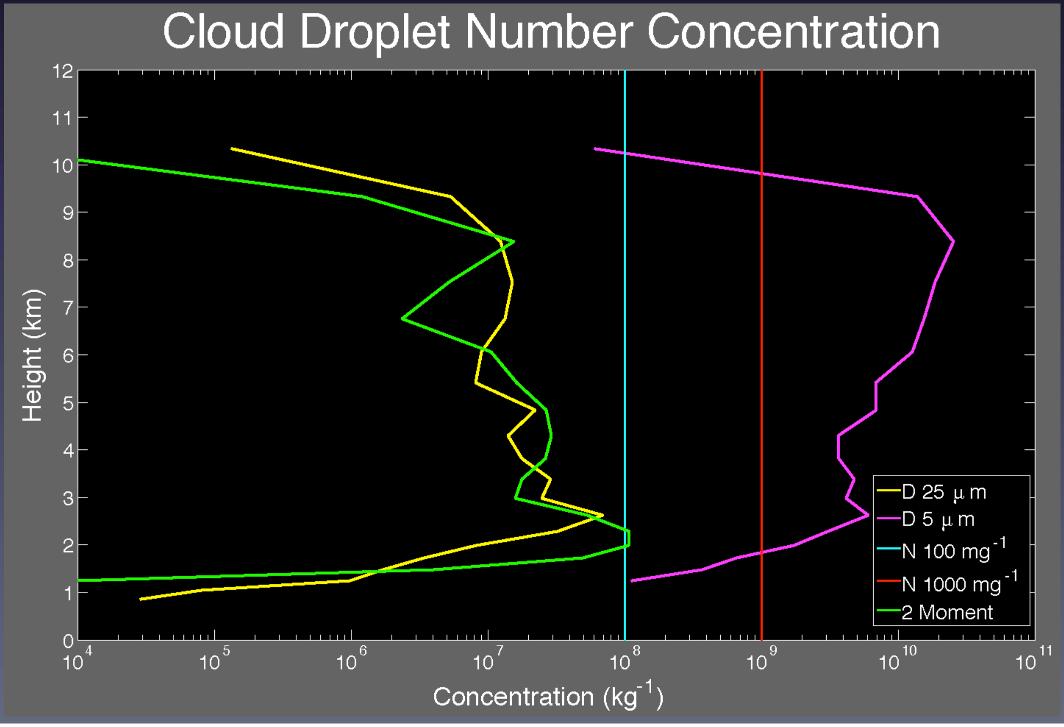
Idealized Thunderstorm

- 5 Thunderstorm Simulations
  - 4 One-moment
    - Fixed cloud droplet diameter of 25 μm and 5 μm
    - Fixed cloud droplet number concentration of 100 mg^{-1} and 1000 mg^{-1}
  - 1 Two-moment
    - Predicted mixing ratio and number concentration
  - Explain resulting differences in precipitation
- Uses RAMS as the forecast model (Walko et al, 1995; Meyers et al, 1997)
- Averaged over whole domain
- Cut off at tropopause
- Rain is the only form of precipitation reaching surface

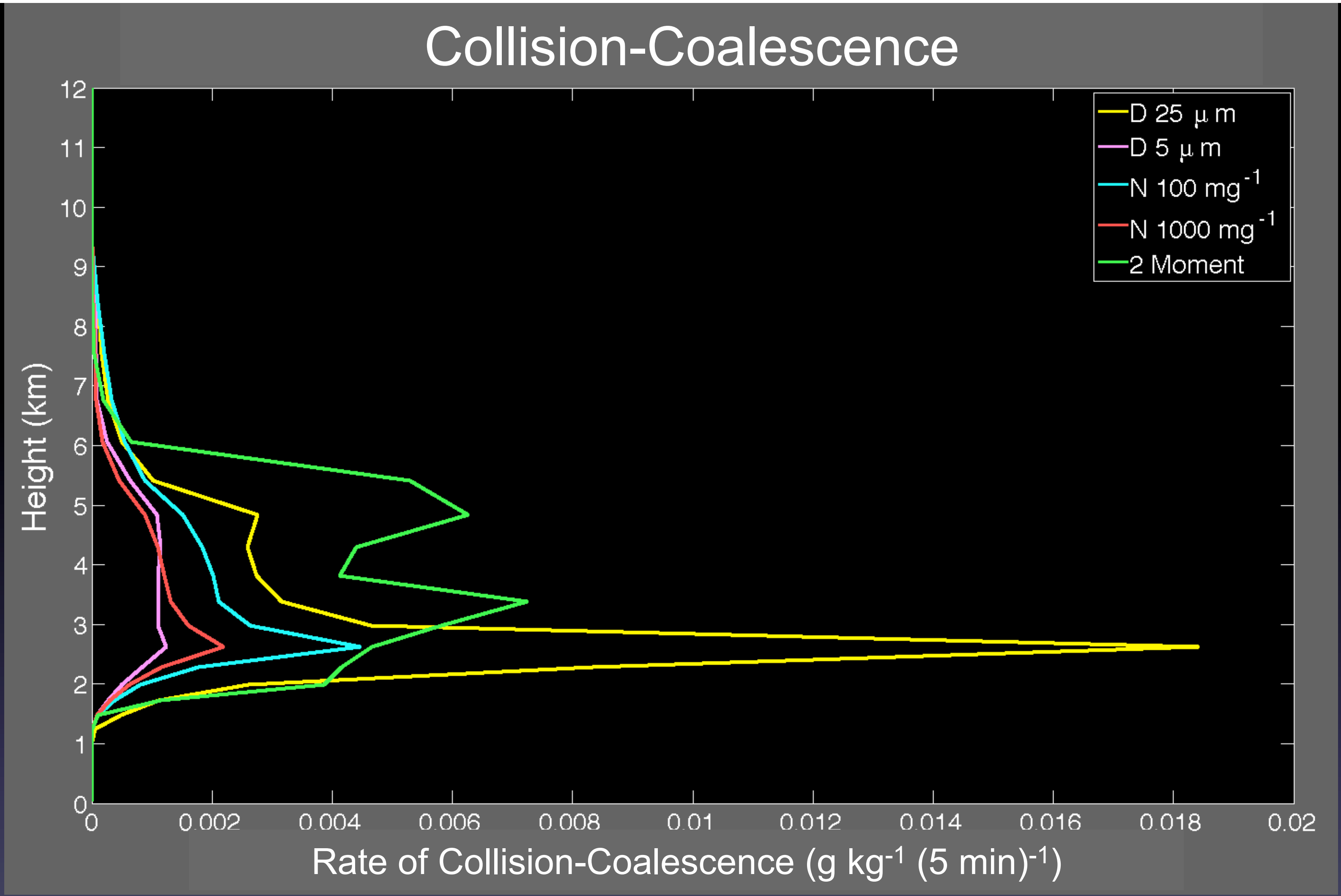


Cross-sectional animation of storm progression, composed of ice, cloud, and rain mixing ratios.

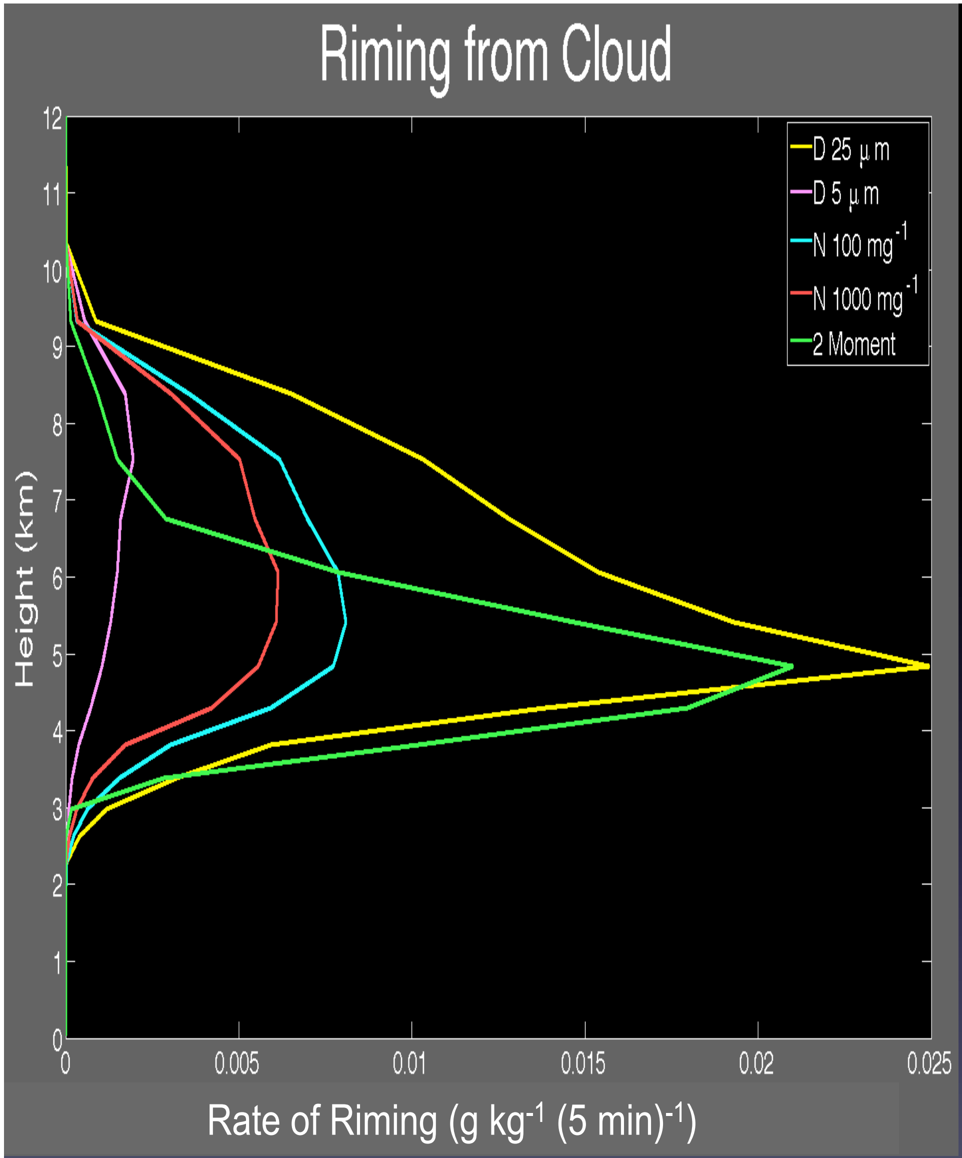


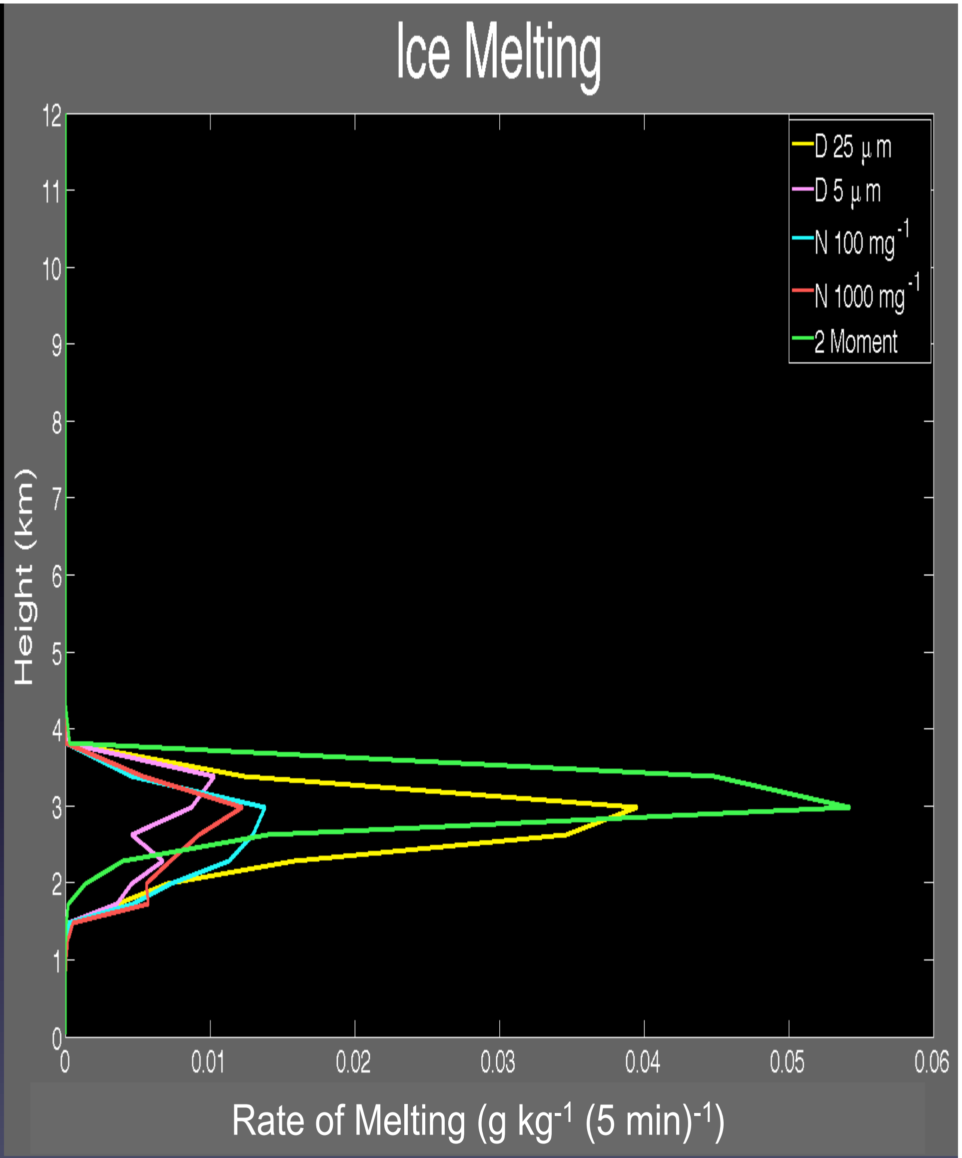


- Fixed diameters of D 25 and D 5 are reversed in concentration
- Same is reflected for N 100 and N 1000
- $r = {}^{\pi}/_{6} * \rho_{water} * N * D^3$



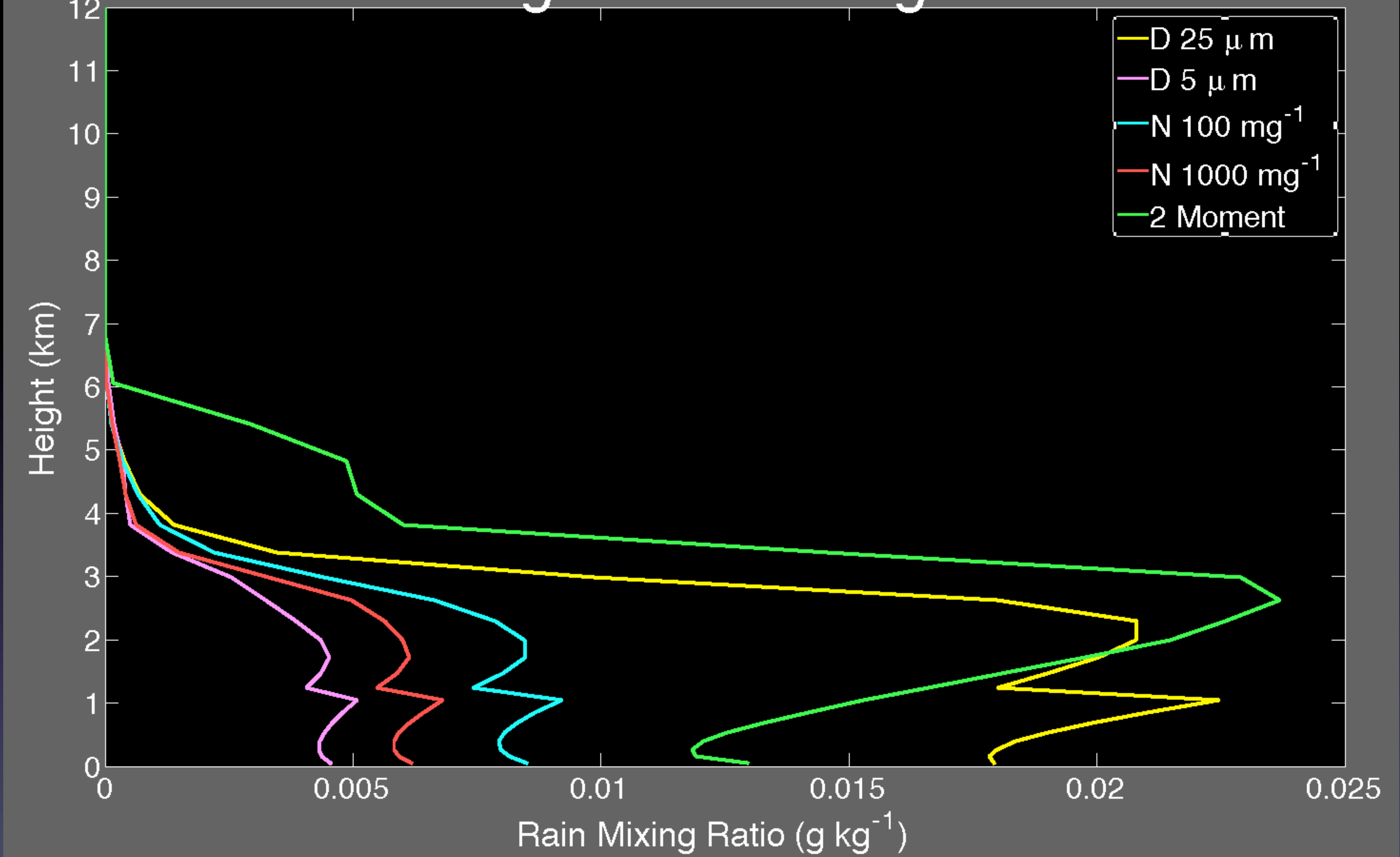
- Larger droplets must exist for process to work efficiently
- D 25 μm and 2 Moment have largest maxima
- Shows importance of droplet diameter



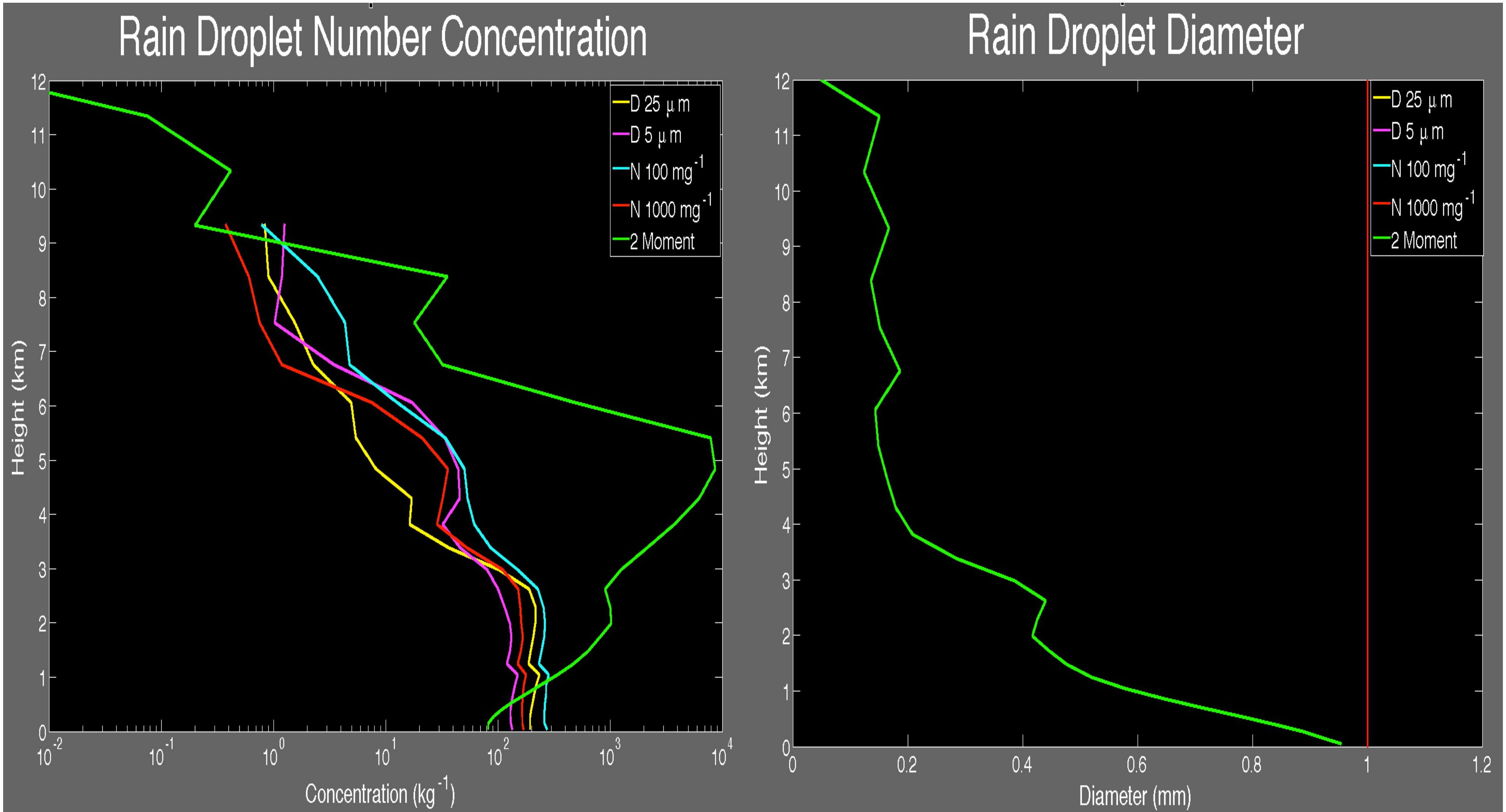


- Riming occurs when ice particles flow through super-cooled cloud droplets
- Super-cooled droplets exist below freezing temperatures in liquid form

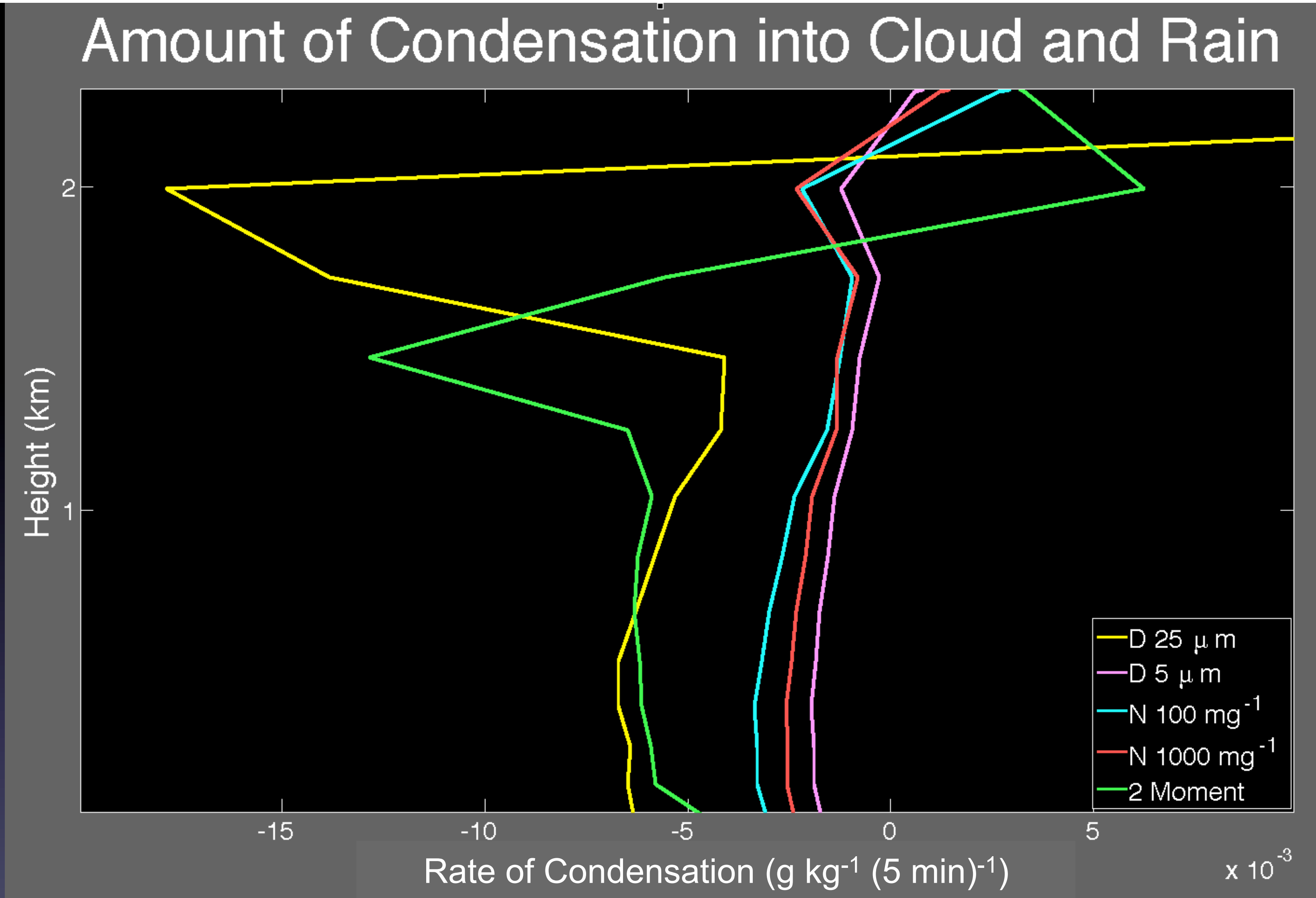
Average Rain Mixing Ratio



- In same order as cloud droplets and ice into rain
- 2 Moment and D 25 have highest rain mixing ratio

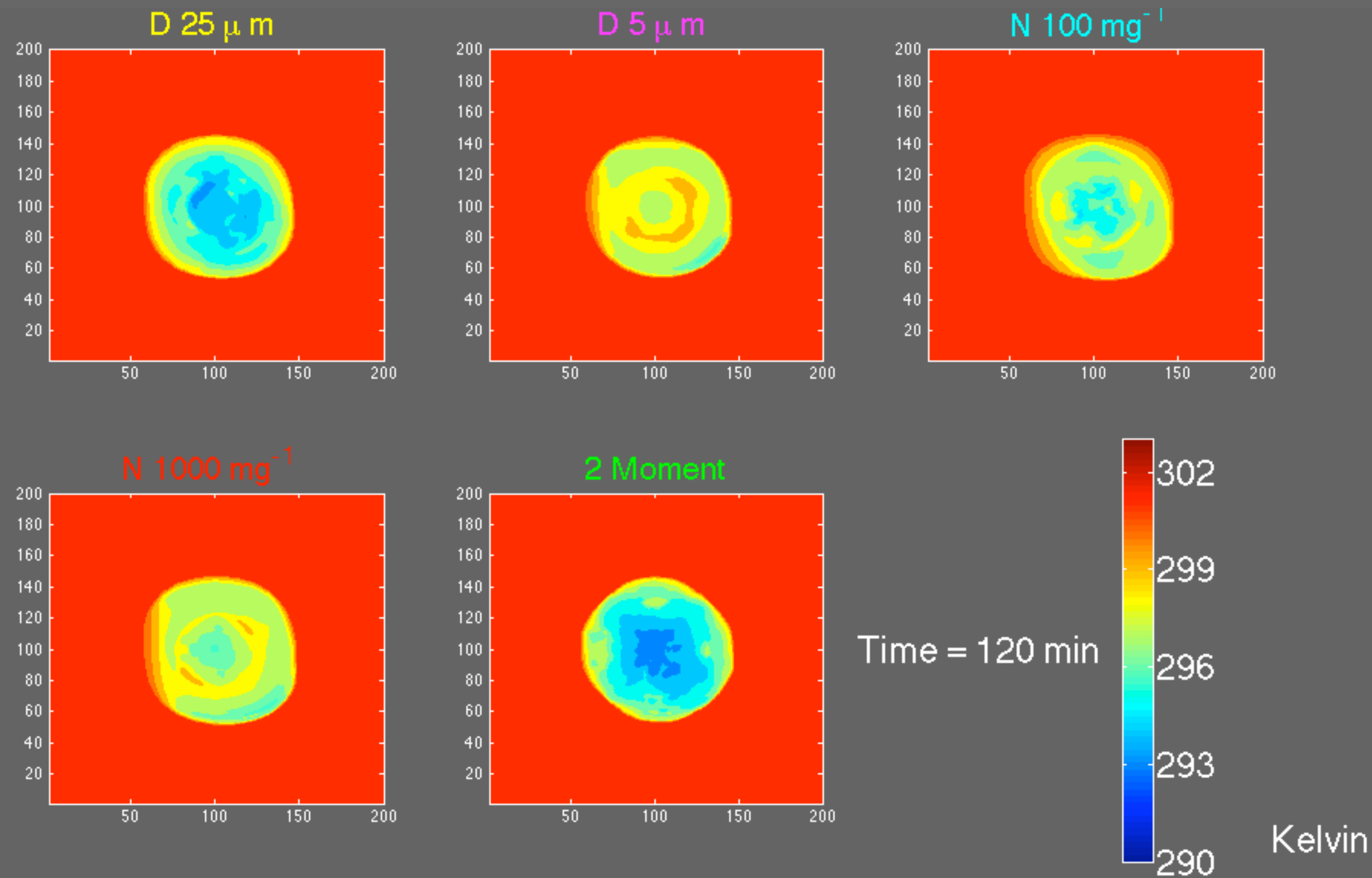


- $R = {}^{\pi}/_{6} * \rho_{water} * N * D^3$
- Predicted rain droplet diameter was much less than standard size used in forecast models

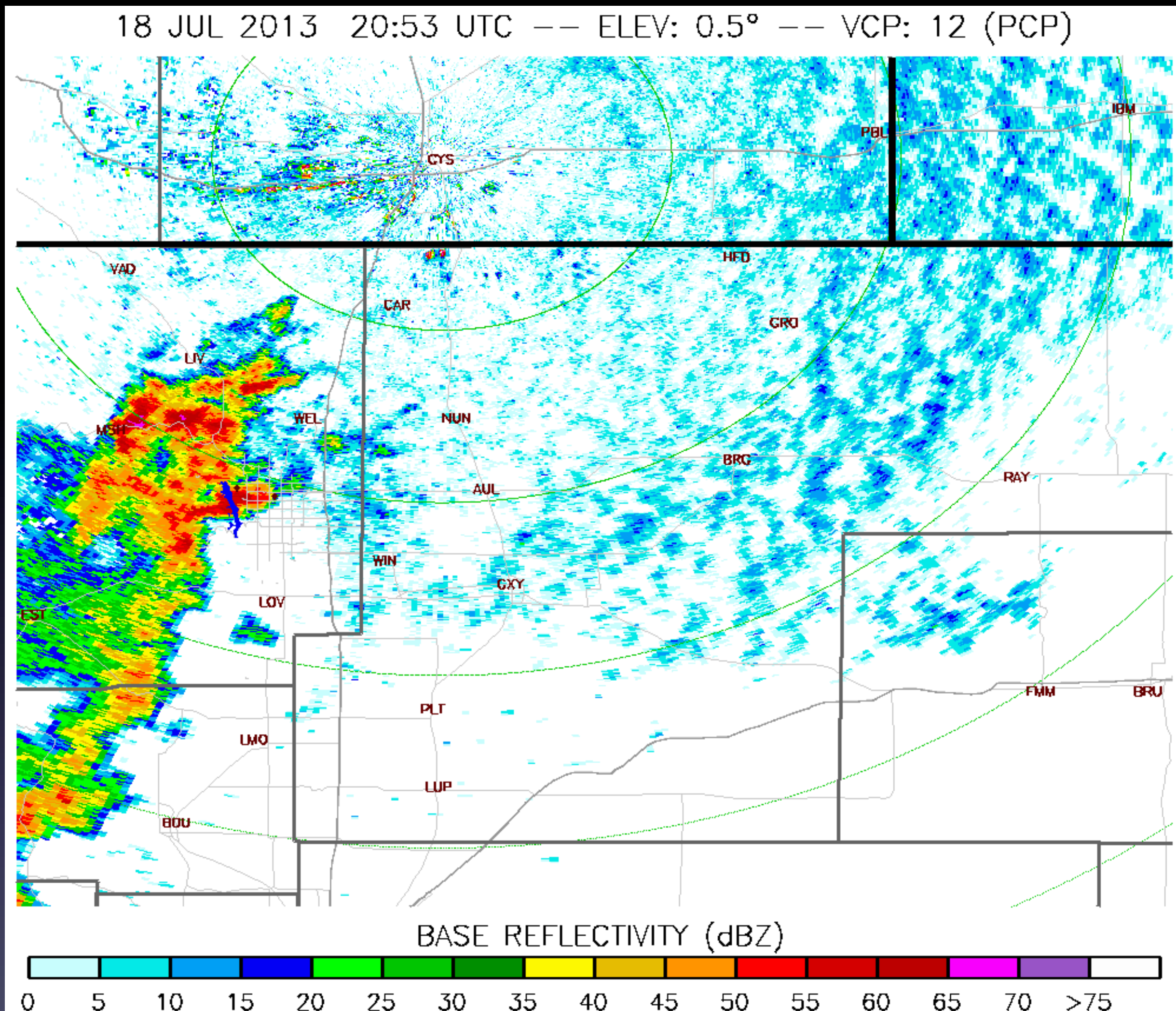


- Both Diameter 25 μm and 2 Moment have high amounts of evaporation
- Evaporation of rain cools the surface air

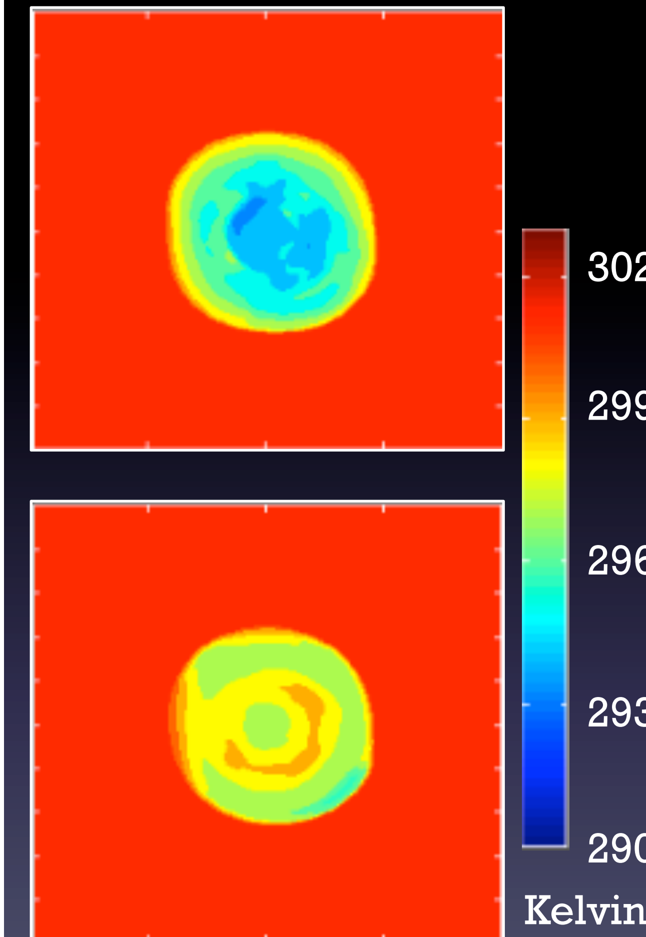
Surface Temperature



- D 25 and 2 Moment have greatest cold pools
- Cold pools act as lifting mechanisms



Surface Temperature



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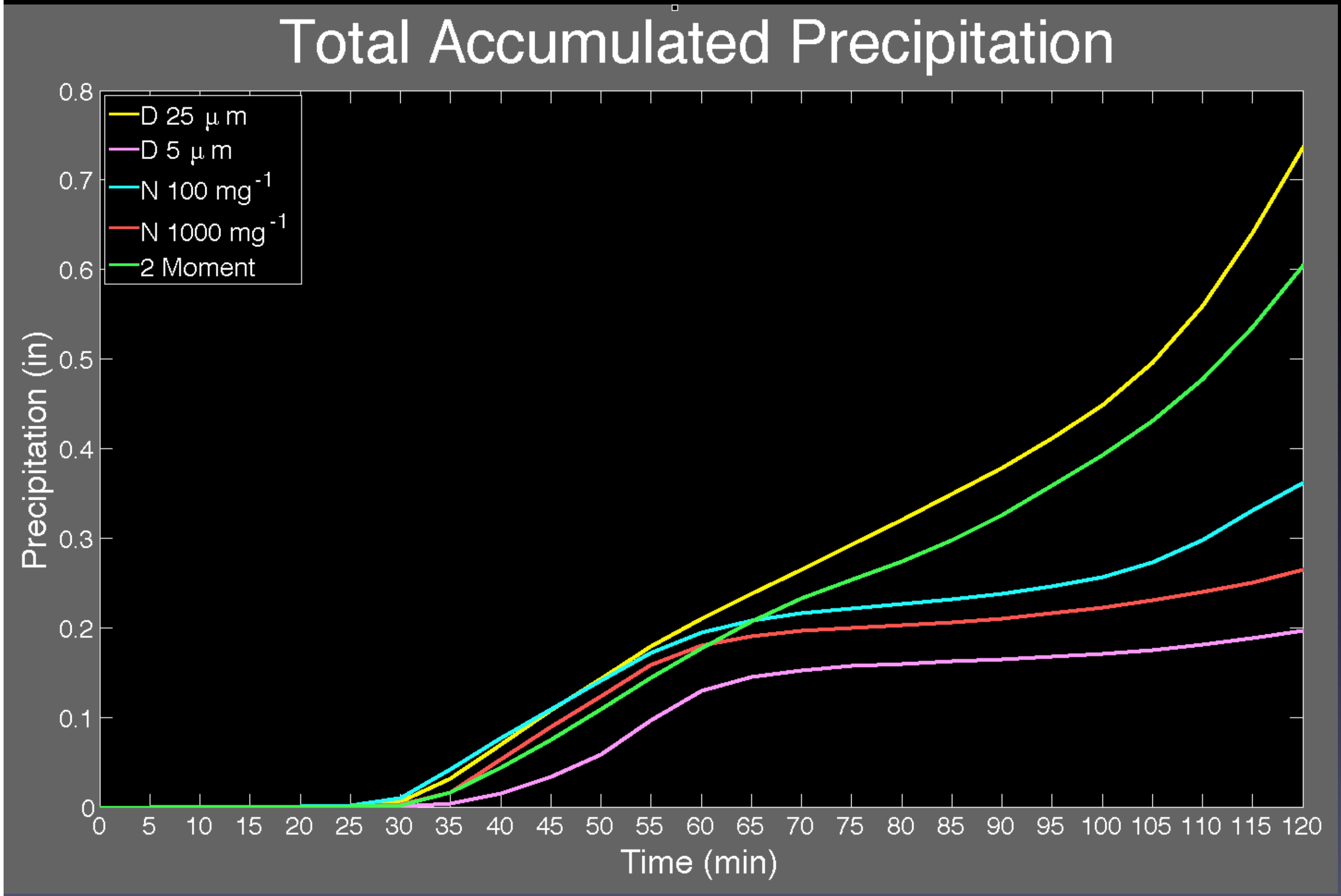

- D 25 and 2 M precipitate the most
- D 5 has a late start and precipitated the least
- D5, N 100, and N 1000 plateau

Conclusions

- Significant differences between single- and double-moment schemes
- Larger cloud droplet diameter and 2-Moment were stronger storms and precipitated the most
- Smaller cloud droplet diameter precipitated the least
- Precipitation production was more sensitive to a change in diameter than in number concentration
- Double-moment schemes are more realistic
- A switch to double-moment schemes could improve forecasts

Thank you