Precipitation Formation Differences within Weather Models

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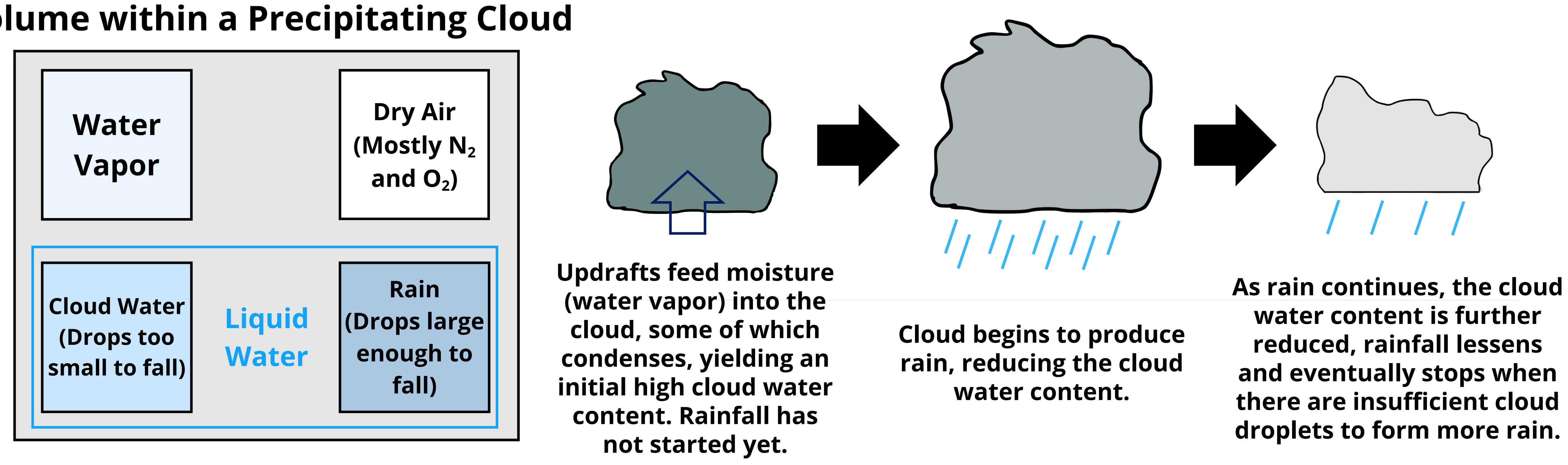
Motivation

Weather models simulate the atmosphere using sets of grid boxes each several kilometers in scale. Physical processes that work at smaller scales are estimated in the model software. How long a cloud lasts and the amount of rain that falls are in part related to the transition of *cloud water*, suspended water droplets too small to fall (typically ~ 0.001 to 0.005 mm diameter), into *rain,* drops with diameters > 0.2 mm, that fall out of the cloud. In this process, thousands of cloud droplets collide and coalesce to form one small raindrop. Users of weather models have several choices for the specific sets of equations, called microphysics schemes, to estimate the transition from cloud water to rain. We examine the differences among the schemes and their plausibility for some simplified example scenarios of commonly occurring clouds.

Background

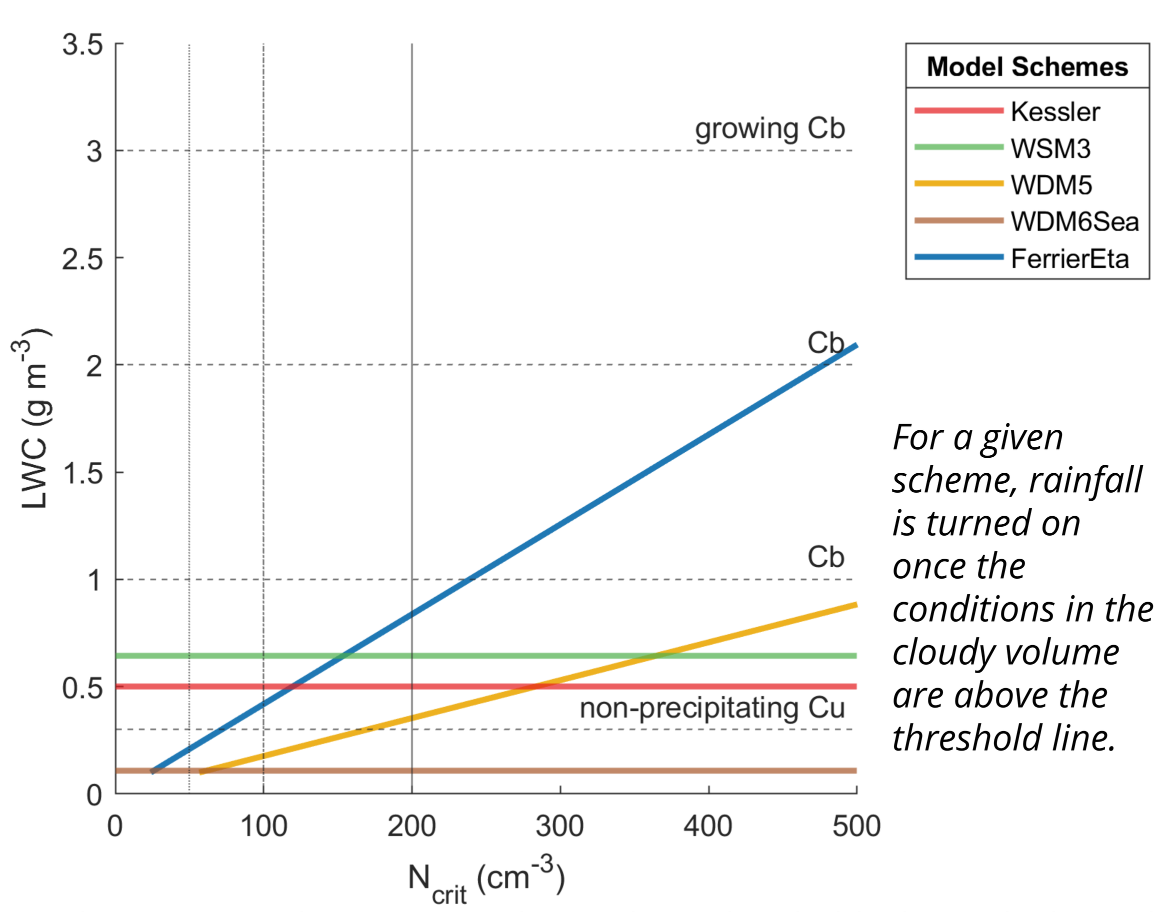
Volume within a Precipitating Cloud



Methods

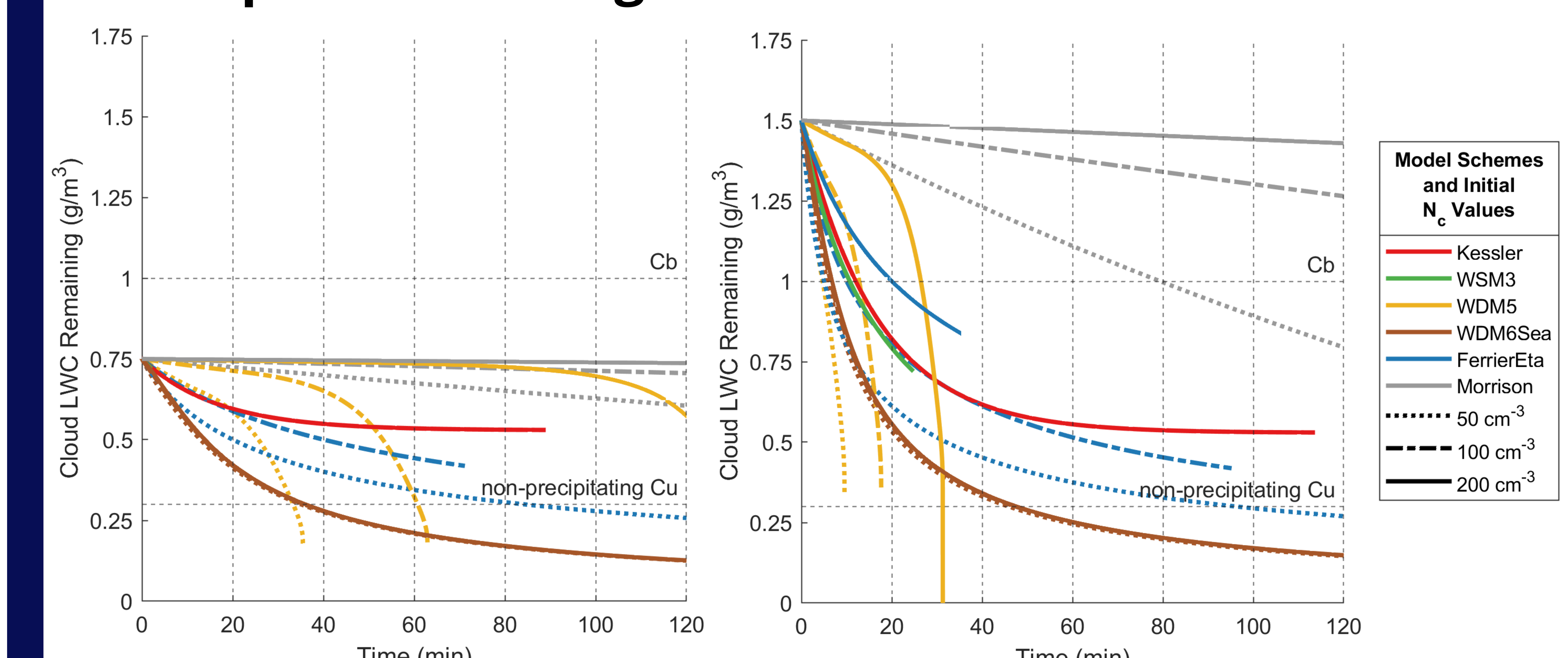
We scrutinized the source code for the National Center for Atmospheric Research's Weather Research and Forecasting (WRF) model to identify the equations that calculate the conversion from cloud water to rain within six commonly used microphysics schemes. Each scheme includes specific threshold conditions within the cloud for when to turn on and off rainfall and how quickly rain forms as a function of the cloud water mass and number of cloud droplets. We use the equations to examine how the transition from cloud water to rain works in isolation to deplete the liquid in the cloud over time. Other cloud processes, including evaporation, are ignored. We compare among schemes and variations in initial liquid water contents (LWC, mass per unit volume of air in g/m^3) and number concentrations (N_C, the number of cloud particles per cm^3 of air).

Rain Process Thresholds



Kessler, WSM3 and WDM6Sea schemes have thresholds that only depend on LWC. Ferrier and WDM5 have thresholds that vary with LWC and cloud droplet number concentration (N_{crit}). The Morrison scheme does not have a specified cloud droplet number threshold.

Comparison among Schemes and Initial Conditions



Cloud water depletion over time with the given starting conditions and only the cloud water to rain transition active. (left) Scenarios similar to a cumulonimbus cloud in a typical summer storm, (right) scenarios comparable to a cumulonimbus cloud in a stronger storm.

Summary

- As expected, all the schemes deplete cloud water faster
  -- for higher starting cloud LWC values
  -- for lower starting cloud droplet concentrations (which implies larger initial cloud droplet sizes).
- Substantial differences among the schemes for minimum conditions for rain to start to form
- The differing details among the schemes yield a very wide range of times (up to an order of magnitude difference) to deplete cloud water by a given amount.
- These simplified scenarios overestimate cloud rain out times since other processes that reduce cloud water are ignored.

Future Work

- Additional microphysics schemes from the WRF model will be added for further comparisons and analysis of the differences in the models' behaviors.
- Additional relevant processes will be accounted for, and results from simple scenarios will be compared to observations.

References and Acknowledgements

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