# Differences among Cloud Water to Rain Water Transitions within Prevalent Microphysics Schemes


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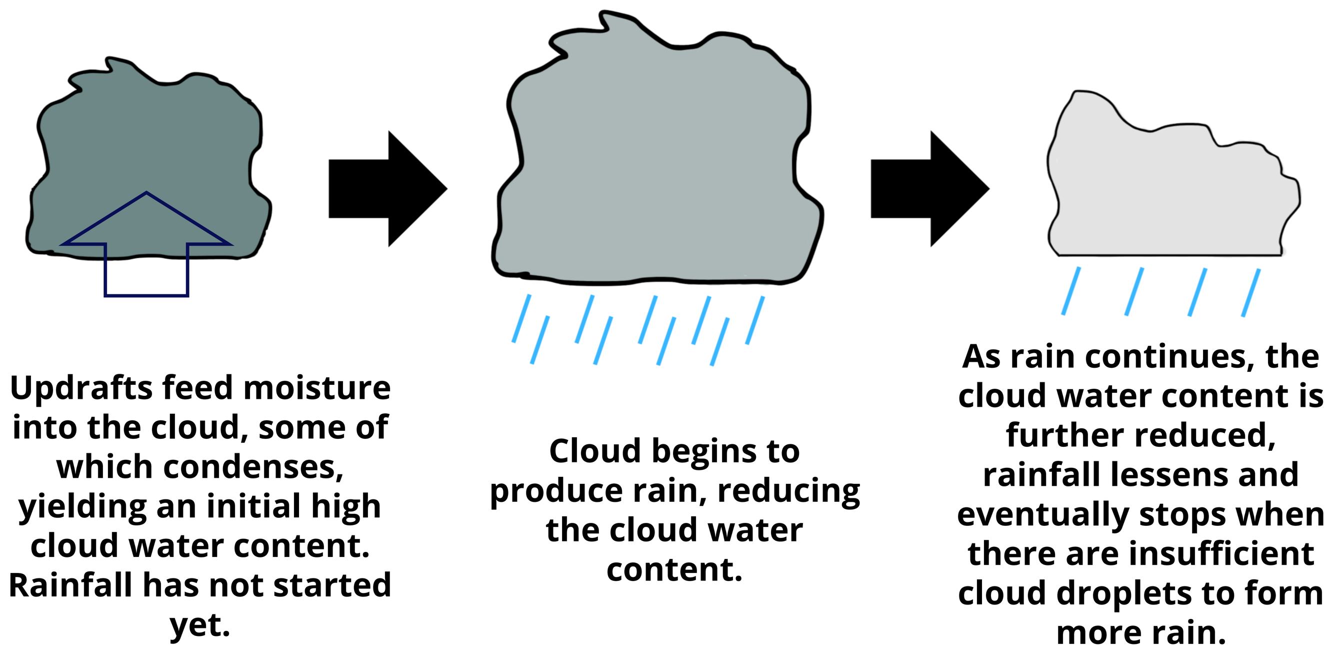
## Motivation

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. Thousands of cloud droplets collide and coalesce to form one raindrop. Weather models have several microphysics schemes to estimate transition rates from cloud water to rain. We examine the differences among the schemes and their plausibility for some simplified scenarios of liquid phase clouds. Understanding these differences will assist in determining which microphysics schemes are appropriate to use in various real-life scenarios.

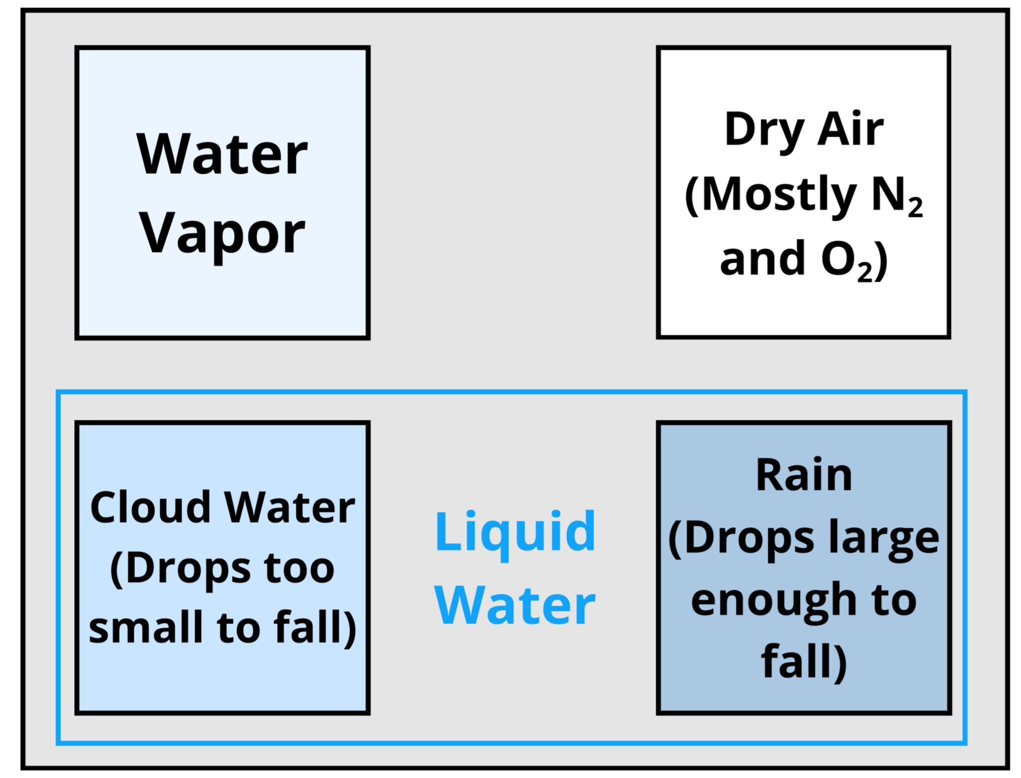



## Methods

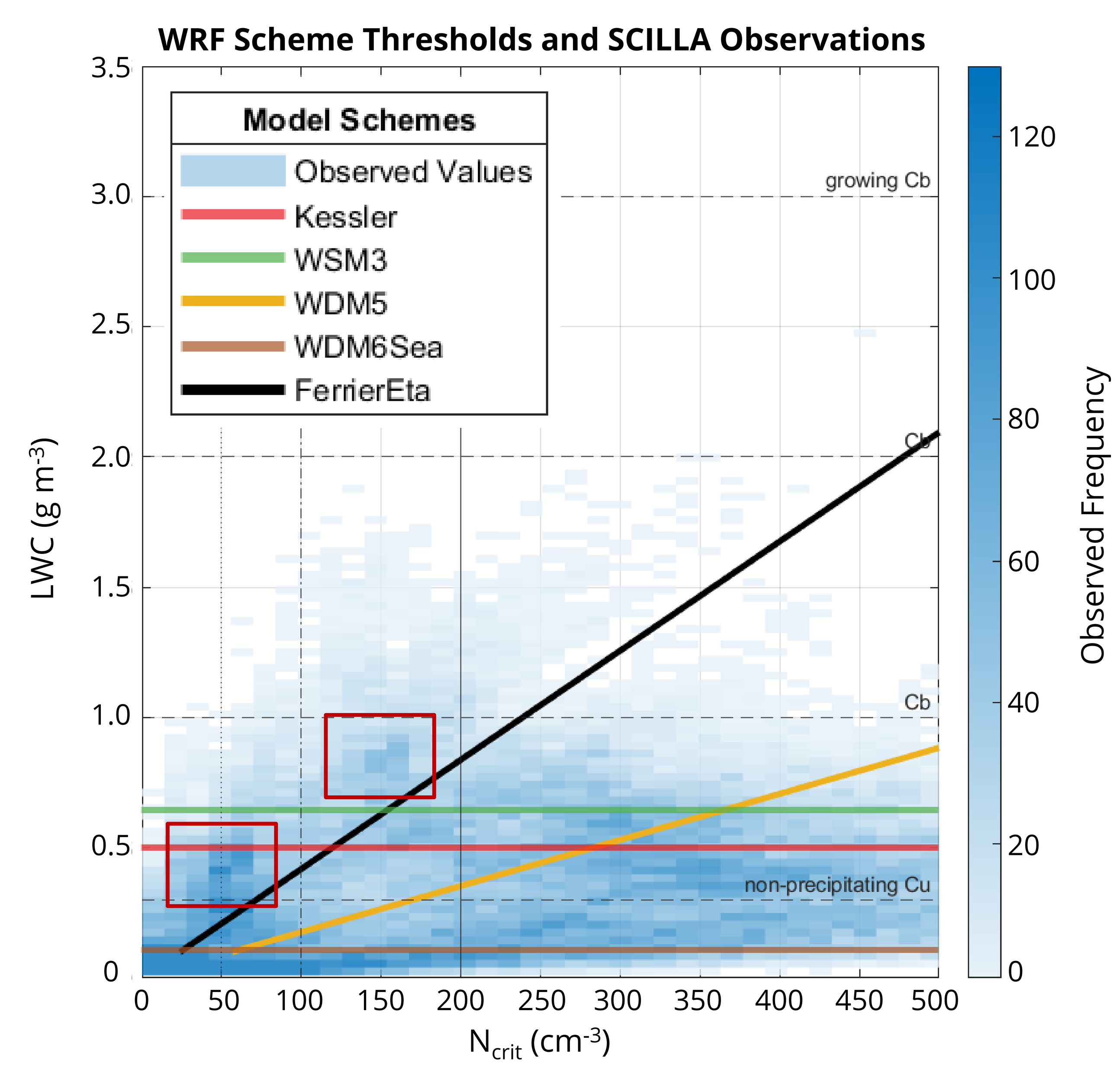
We scrutinized the source code for the National Center for Atmospheric Research's Weather Research and Forecasting (WRF) model to identify the equations that calculate the conversion from cloud water to rain (autoconversion and accretion) within six commonly used microphysics schemes. Each scheme includes specific threshold conditions within the cloud for when to turn on and off rainfall production and equations to calculate the rate of conversion from cloud water to rain water as a function of the cloud water mass and number of cloud droplets. In situ microphysics data for liquid phase low clouds from the 2023 Southern California Interactions of Low cloud and Land Aerosol (SCILLA) project are used to assess the validity of these thresholds.

We compare the depletion of cloud LWC with time among the schemes in a simplified framework that only includes autoconversion and accretion (entrainment and evaporation are ignored) for several initial liquid water contents (LWC, mass per unit volume of air in g/m$^3$) and number concentrations ($N_c$, number of cloud droplets per cm$^3$). We examine the differences in the time scales at which each scheme depletes cloud water as well as how each scheme partitions depletion via autoconversion versus accretion as a part of the total depletion.

## Volume within a Precipitating Cloud

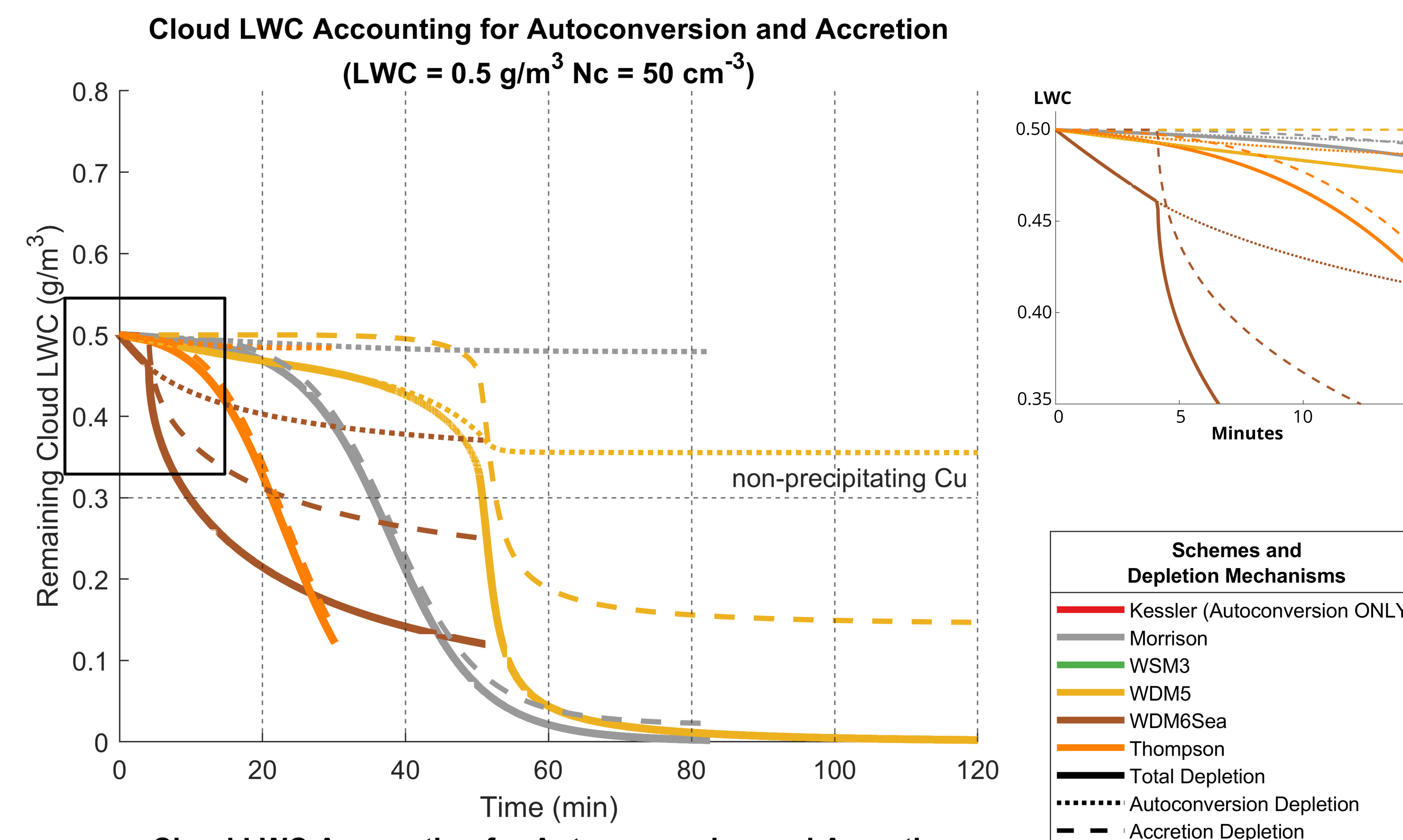


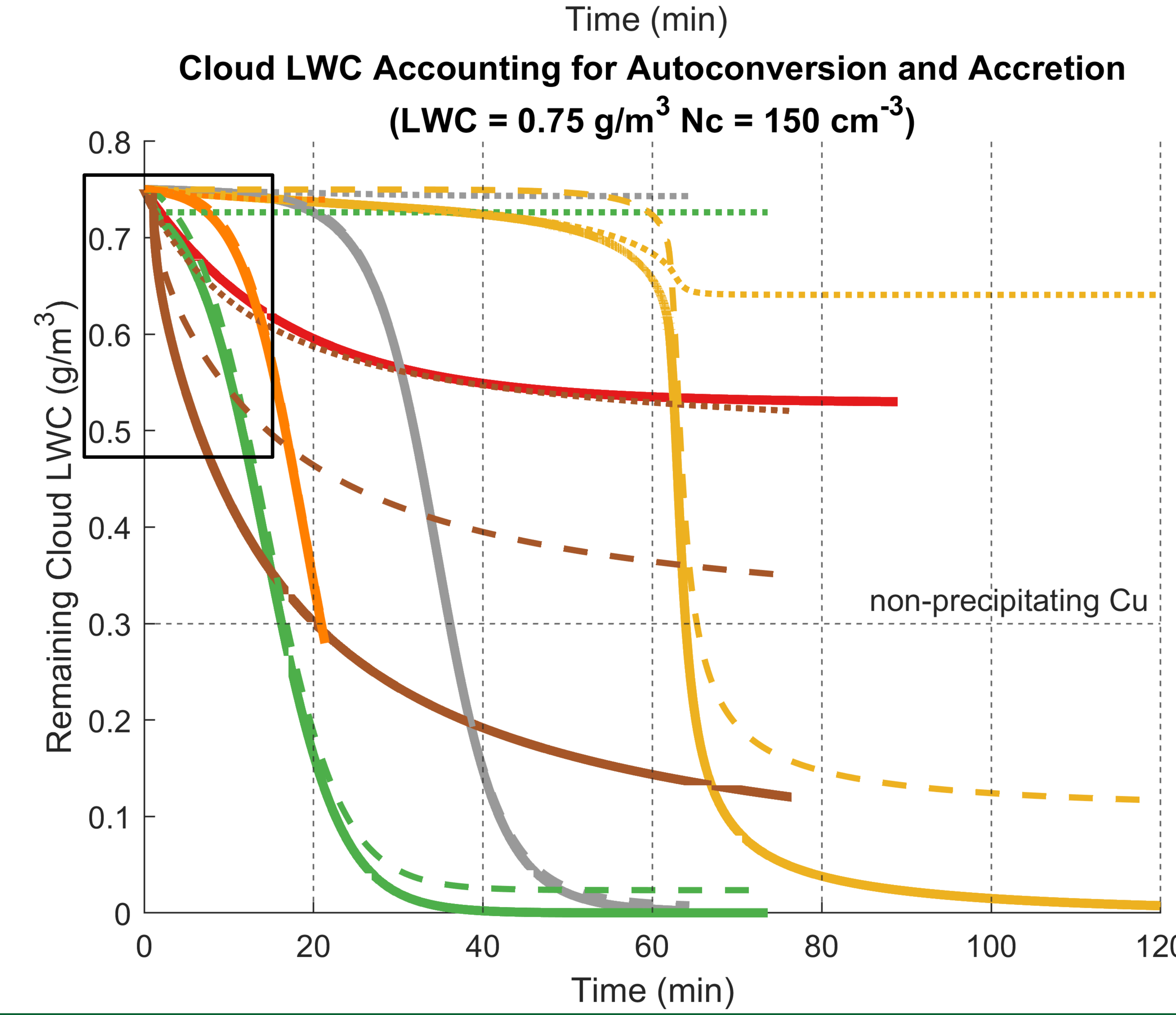

## Thresholds and Observations

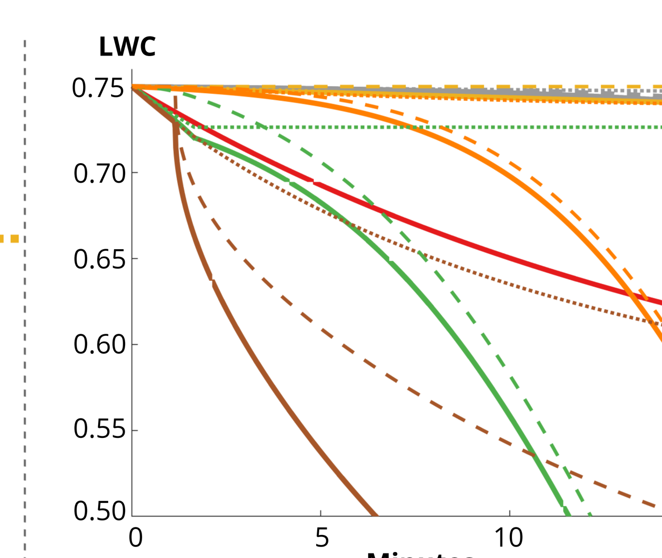



*The Morrison and Thompson schemes consider autoconversion to be "continuous" (i.e. any non-negligible LWC triggers autoconversion) and are therefore not plotted here. The Kessler, WSM3, and WDM6Sea schemes only use LWC to trigger autoconversion while WDM5 and Ferrier Eta have thresholds based on both LWC and a critical number concentration ($N_{crit}$). Observed clusters of frequent observations are boxed in red and served as the basis for choosing initial conditions in comparing depletion.*

## Comparing Depletion of Cloud LWC




*These plots show the changes in cloud LWC with time, accounting only for the transition of cloud water to rain. The boxes to the right show the first 15 minutes when autoconversion plays a relatively larger role than in the remainder of the depletion time.*

## Summary and Future Work

**There is up to an order of magnitude difference in times to deplete cloud water by a given amount among the schemes.** In most of the schemes (except for Kessler which does not include accretion), the accretion process dominated in depleting cloud water, especially after the first 15 minutes of each scenario. **There are substantial differences among the microphysics schemes for the thresholds at which rain starts to form**. Some thresholds (Kessler and WSM3) would not produce rain in observed scenarios where rain was produced. We will expand this analysis to additional schemes in the WRF model and further assess the relative realism of parameterization outcomes to observations.

## References and Acknowledgements


NCAR WRF's open-source code available at www2.mmm.ucar.edu/wrf/users/download/get_source.html. Airborne microphysics data for the threshold and observation plot from the SCILLA project courtesy of Mikael Witte, NPS.



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