Cloud Size Distributions from many different Large Eddy Simulations of Shallow Cumulus Convection

Nicholas Barron, Thijs Heus, Dorothy Pharis, Shawn Ryan t.heus@csuohio.edu - Cleveland State University

Introduction

- A good understanding of size-dependent behavior of clouds is necessary for modern scale-aware parameterizations (e.g., ED(MF)^n)
- **Research question 1**: Does the cloud size behave according to a specific distribution (e.g., powerlaw)
- And if so: Is this distribution generic across cases?
- **Research question 2**: How can we reconcile observed chord length distributions with cloud area distributions necessary for parameterizations?

Take Home Messages

- Cloud Size Distributions from many different LES simulations were calculated
- Double Power Law appears slightly preferable over other possible distributions
- Distinct differences in coefficients for different cases, and also between LES models
- Cloud height distribution appears a power law distribution as well (over shorter range)
- Discrepancy between chord length distribution and area distribution can be explained with a double-gamma kernel

Future Work

- Implement simulators to compare LES cloud size distributions with observations
- Compare against the Romps & Vogelmann analytical method (JAS, 2017)
- What sets the coefficients for the CSDs and CHDs?
- Start evaluating cloud properties as a function of cloud size

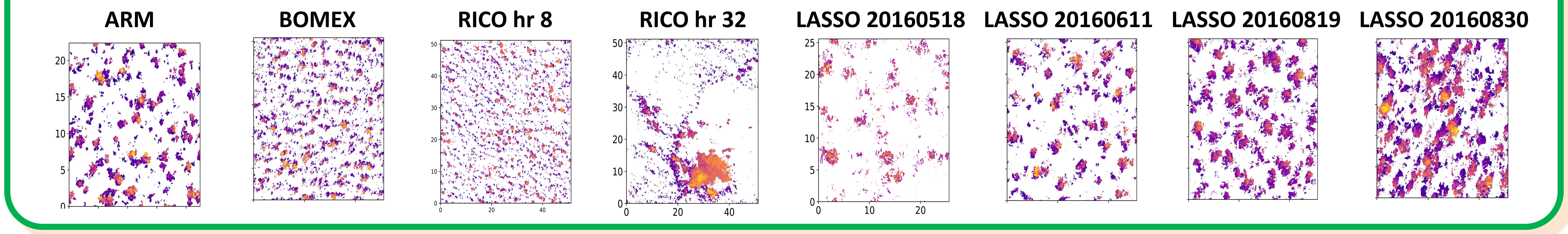
Methodology

- Different LES simulations are used, based on BOMEX, RICO (both maritime) and ARM intercomparison cases
- Also includes are 12 cases from the LASSO alpha 2 database. For each day the WRF setup with the best cloud score is used to setup large domain simulations
- BOMEX, RICO and SAM use UCLALES, with 25m resolution and domain size between 12.5 and 50km
- Original LASSO runs use WRF and SAM, typically at 100m resolution, and domain size up to 24km
- LASSO reruns are done with MicroHH-GPU, with a 25m resolution and 25km domain size
- For each field, the cloud area and the chord length distributions are determined
- Maximum Likelihood Estimators determine the fits

Acknowledgments

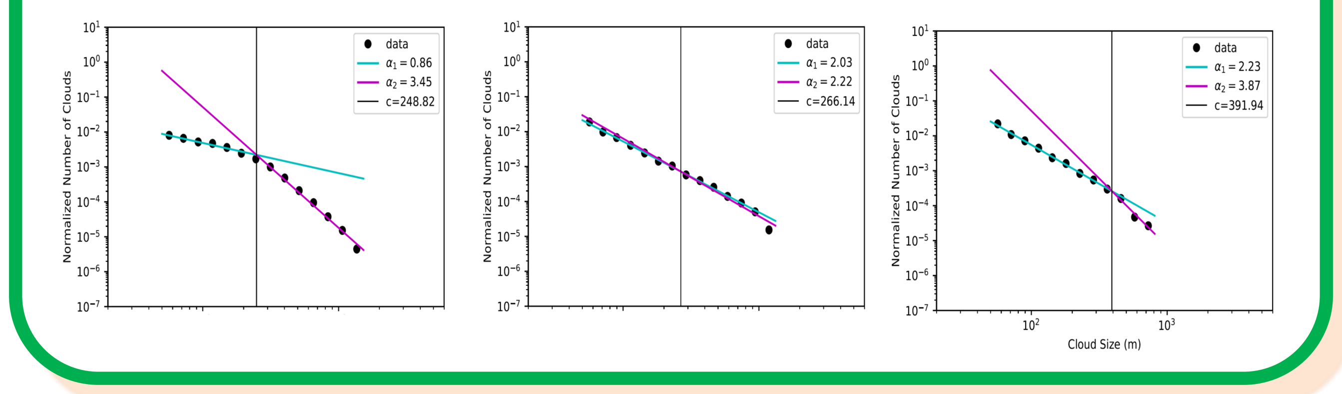
- This work is funded by grant DE-SC0017999 of the Department of Energy's Atmospheric System Research program
- Dorothy Pharis and Nicholas Barron were partially funded by Cleveland State University's Undergraduate Summer Research Program
- We thank the Ohio Super Computer Center for making the computational resources available

Snapshots



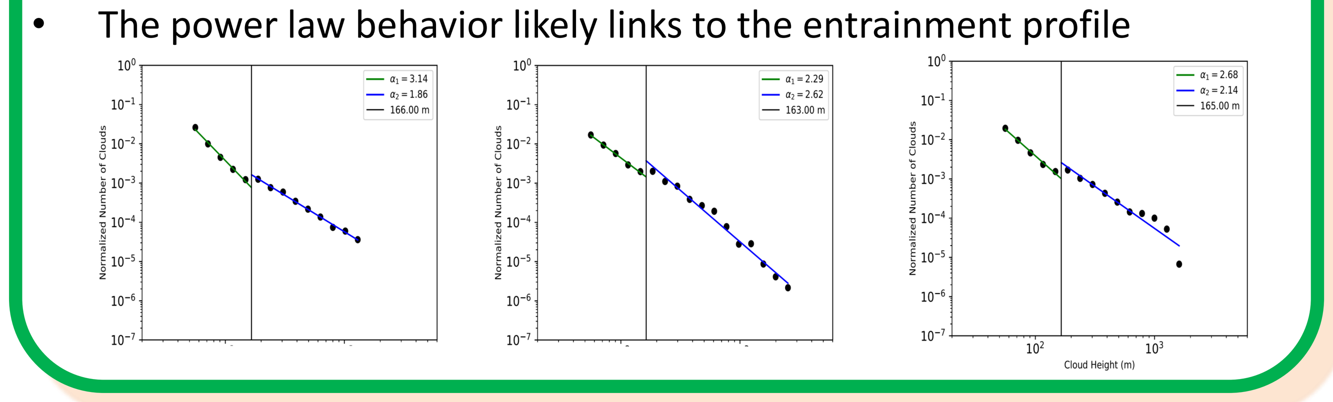
Cloud Size Distributions (CSDs)

- CSDs generally have a similar form from case to case
- Coefficients fluctuate significantly from scene to scene
- The drop off for large cloud sizes depends on time of day (ARM) and organization (RICO)



Cloud Height Distributions (CHDs)

- The cloud height distributions also follow a power law, though naturally over a much smaller range
- A consistent break occurs around ~150m
- This break is likely associated with a transition from forced to active clouds
- The power law behavior likely links to the entrainment profile

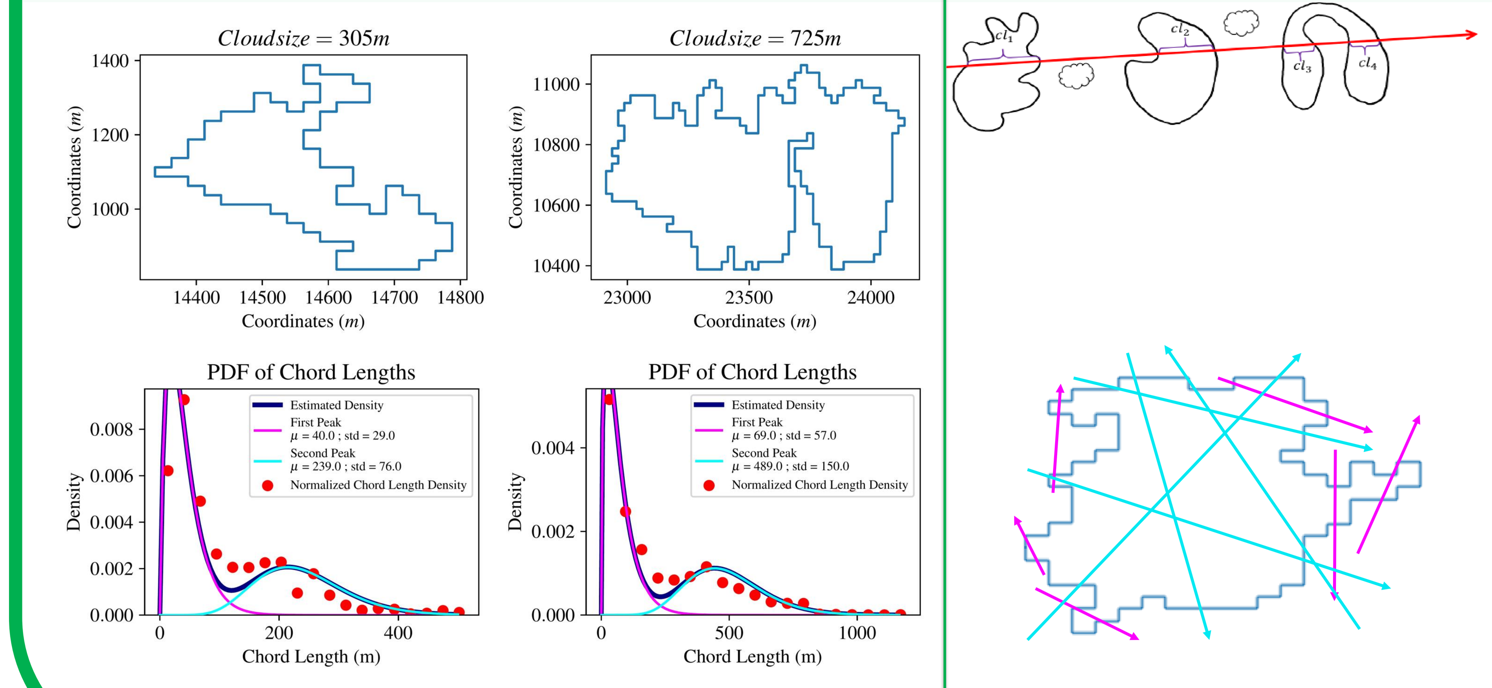


Fitting scores

- Averaged over all the cloud scenes, double power law and log-normal have equal KS score pass ratings
- However, Double PL tends to be ranked high more often, and has a lower coefficient of variation between the cases

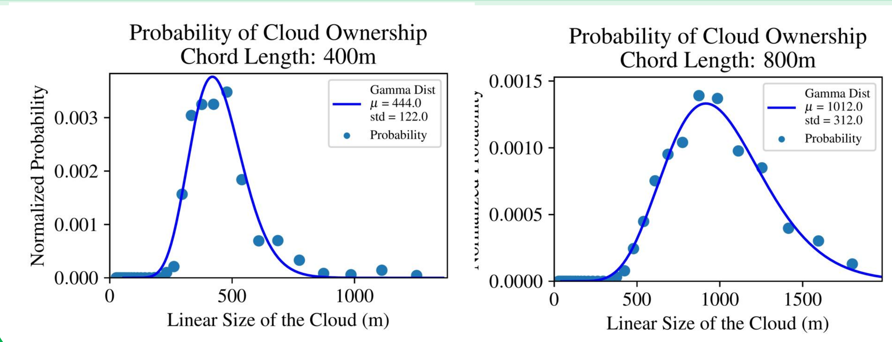
Distribution	Param	Median Value	cv	KS Pass Rate	Rank #1	Rank #2	Rank #3	Rank #4	Rank #5
Power Law	α	2.01	0.0855	0	0	0	0	0	21
Double Power Law	α_1	1.81	0.316	62%	8	5	5	3	0
	α_2	3.05	0.452						
	c	541	0.655						
Power Law w/ Cutoff	α	1.74	0.270	48%	7	7	1	6	0
	λ	0.00114	0.572						
Log-Normal	μ	1.74	1.01	62%	3	4	2	12	0
	σ	1.96	0.337						
Stretched Exp	λ	4.40	1.69	57%	3	5	13	0	0
	β	0.240	0.632						

Cloud transects

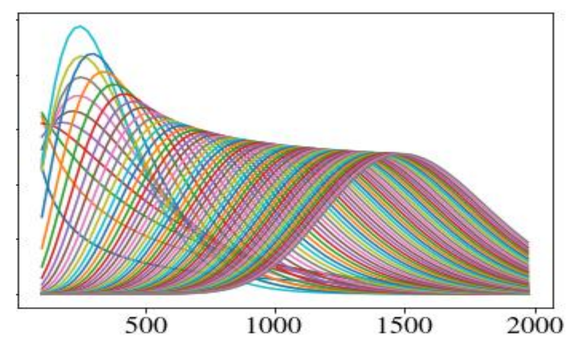


- Through every cloud a number of rays are shot
- This leads to the chord length distribution per cloud
- We notice a double gamma distribution: 1 represents the cloud edge, 1 represents the bulk

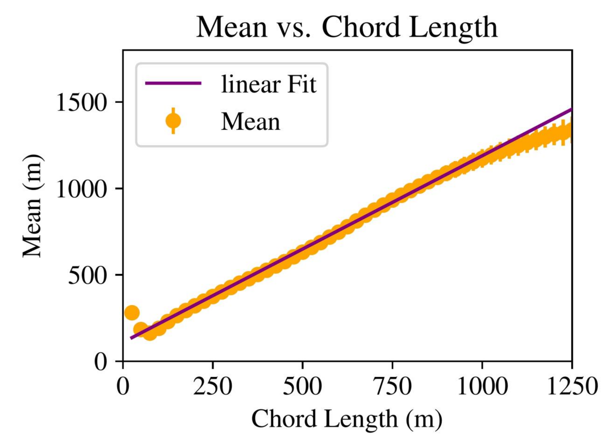
Chord Length to Area



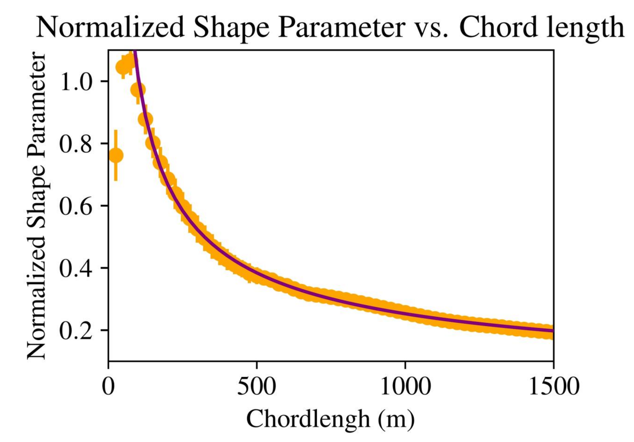
Integration of the CL over all clouds of all cases yields the above gamma distributions as a function of CL



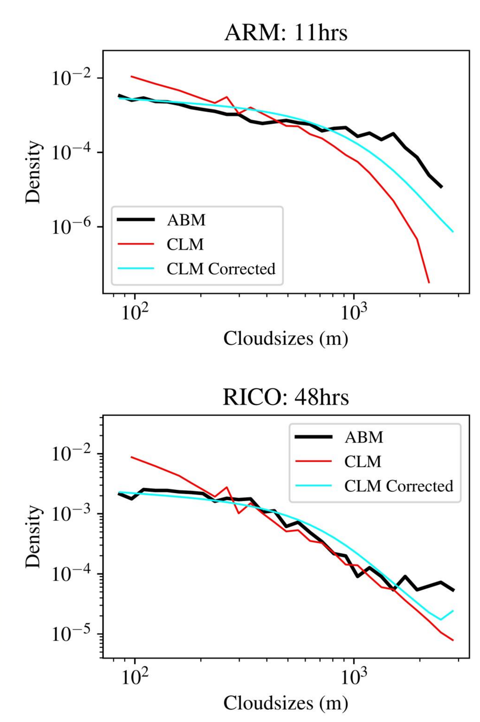
Gamma Parameters



- For sufficiently large chord lengths, the mean chord length goes with a linear fit
- The Shape Parameter begins at a large value and at large chord lengths approaches a constant
- Small chord lengths can come from nearly any cloud in the distribution – raising the mean and lowering the SP



CSD Retrieved from Chord Lengths



- Using the overall mean and *cv*, we can reconstruct the CSD from the chord length distribution
- This method performs well for a variety of datasets