97. Investigation of precipitation processes with RAMS and observations

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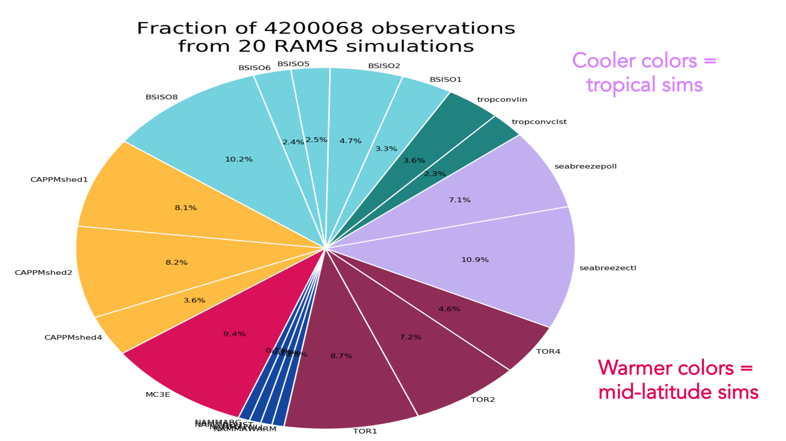
Introduction

- Understanding cloud processes and their impact on surface drop size distributions (DSDs) is fundamental to understanding interactions between microphysics and dynamics within clouds as well as validation of cloud-resolving models and remote sensing retrievals
- Dolan et al. (2018) aggregated over 350,000 rain DSD observations from disdrometers around the globe and observed the same modes of variability in every region with principal component analysis (PCA)
    - This provides a framework to simplify the analysis of DSD variability around the globe and in models
- **Leveraging the PCA framework to recast DSDs into simpler EOF parameter space to analyze precipitation physics using both observations and models, our goals are to:**
    1) compare with observations to assess model's ability to capture physical variability of DSDs
    2) connect cloud processes to surface DSDs through model simulations to contextualize observations

Data

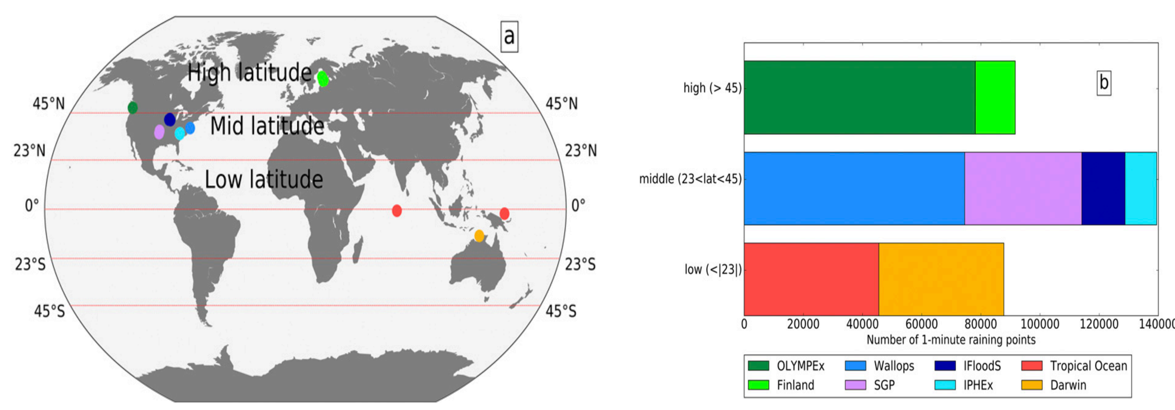
RAMS simulations



Fraction of calculated surface DSDs from RAMS contributed by each model simulation.

- The CSU regional atmospheric modeling system (RAMS) model is a cloud-resolving model with bin-emulating bulk microphysics
- Included simulations use two-moment microphysics predicting on number concentration and representative size with fixed shape parameter (μ)
- Want similar sampling of storm types as in global disdrometer observations
    - 20 different simulations encompassing different environments and storm types
    - 50/50 tropical/mid-latitude breakdown

Disdrometer observations



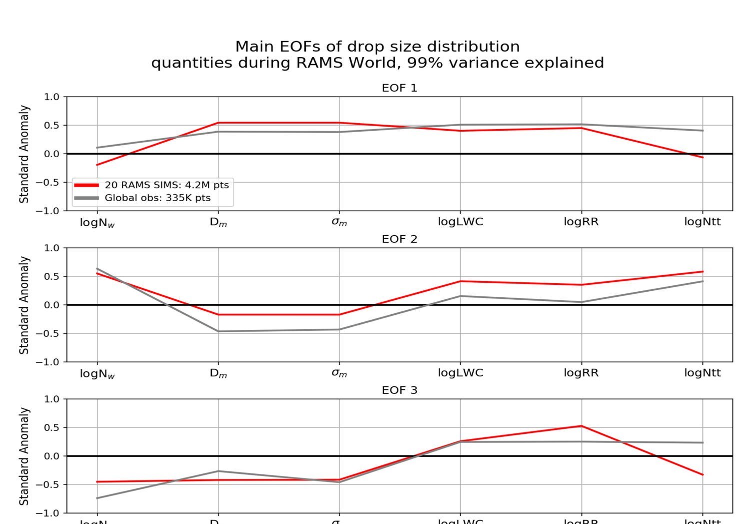
Map of global disdrometer observations and number in each latitude band from Dolan et al. (2018)

- 350,000 observations and continually growing
- Primarily ARM and NASA data
- Ocean, continental, all latitude bands
- Limited to rain observations

- DSD (N_w, D_0) calculated at the surface, run through the PCA using 6 parameters: Nw, D0, μ, RR, LWC, Nt
- PCA recasts data using different basis vectors (empirical orthogonal functions; EOFs) explaining the most variance in descending order, and principal components (PCs) indicative of resemblance to each EOF vector
- Clustered obs into 6 groups by PC1 and PC2 values, analyze observations that strongly resemble EOF 1 and 2

Does the model reproduce observed variability?

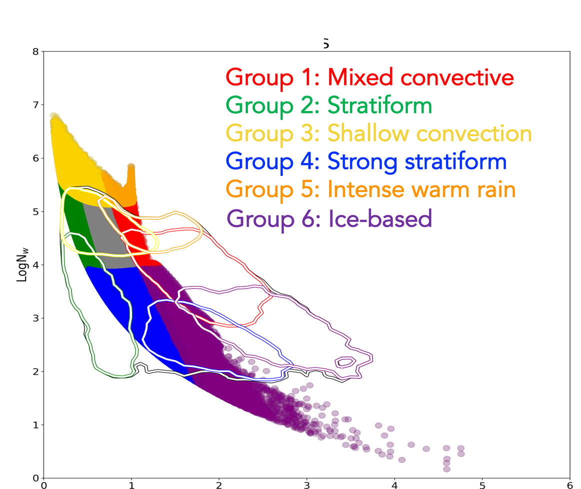
EOFs



First 3 EOFs calculated from RAMS surface DSDs in red, observed global DSDs from Dolan et al. (2018) in gray

- Surprisingly similar EOFs
- Does depend on the simulations included

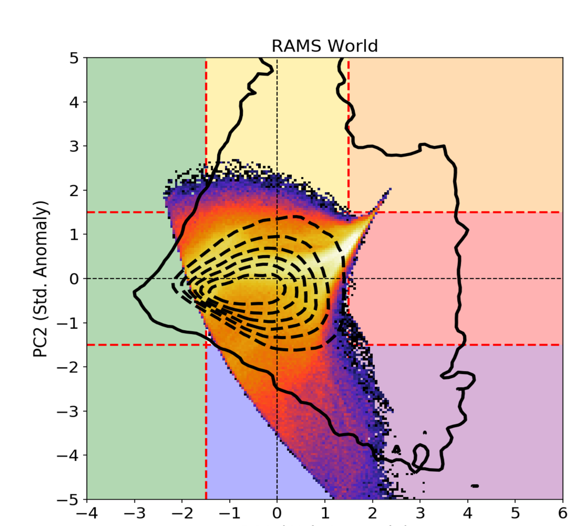
Microphysical Groups



RAMS surface DSDs (points) by group, global disdrometer observation frequency (contours)

- Same relative locations of groups in N_w-D_0 space
- Model 2D density distribution is narrower
    - Model lacks larger drop sizes
    - Very apparent peak at about 1mm in sims

PC distributions



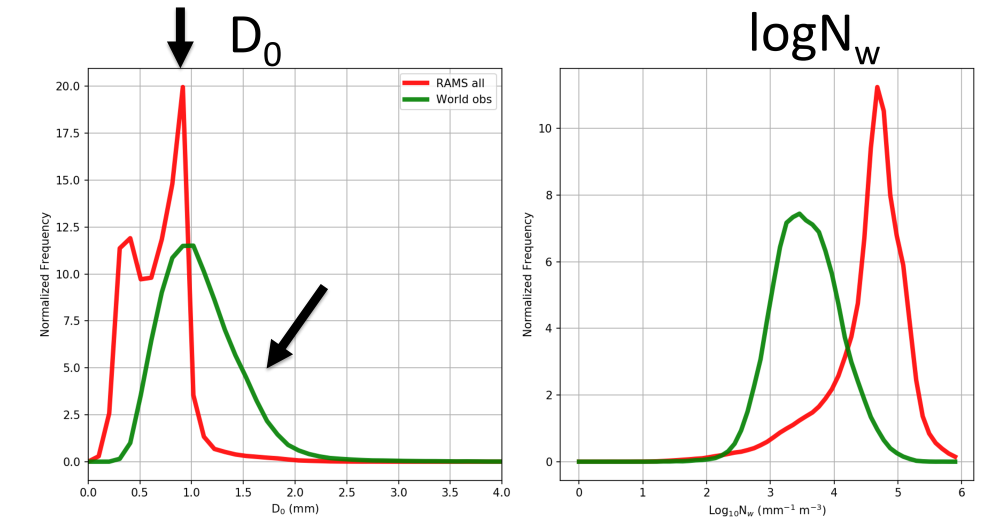
Joint distribution of PC1/PC2 for RAMS calculated DSDs (color fill) and corresponding global observations (contours) for comparison

- RAMS PC 1 and PC2 are correlated, while obs are not
- Do not occupy similar 2D distributions

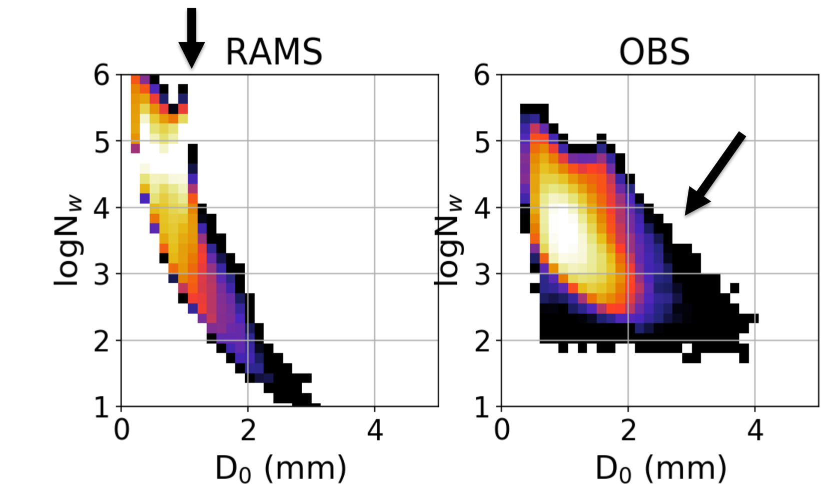
- Promising results -- similar EOFs and relative groups emerge from simulations compared to disdrometer dataset. However, important differences are noted, such as the lack of breadth in simulations and the apparent correlation between PC1 and PC2

The problem of drop breakup

- Comparisons of D_0 and N_w reveal a notable peak in drop sizes around 1 mm and low frequency of large drop sizes in simulations
    - Large N_w and low D_0 differences may be below detection of disdrometer
    - D_0 peak around 1 mm is noted in every simulation considered and conspicuous in a variety of analysis metrics

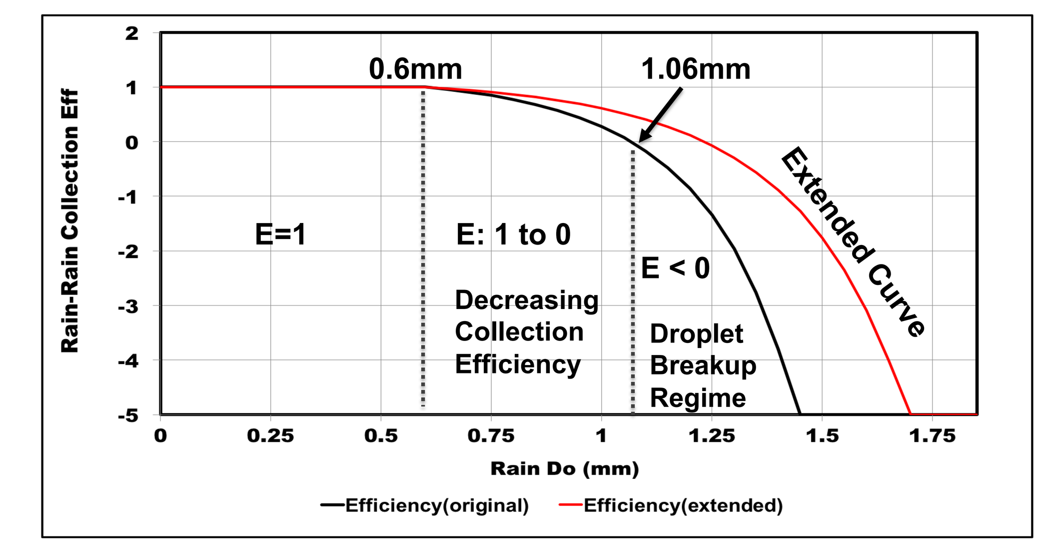


Histograms of global disdrometer data (green) and RAMS simulations (red) for median drop size (D_0, left) and normalized number concentration ($logN_w$, right)

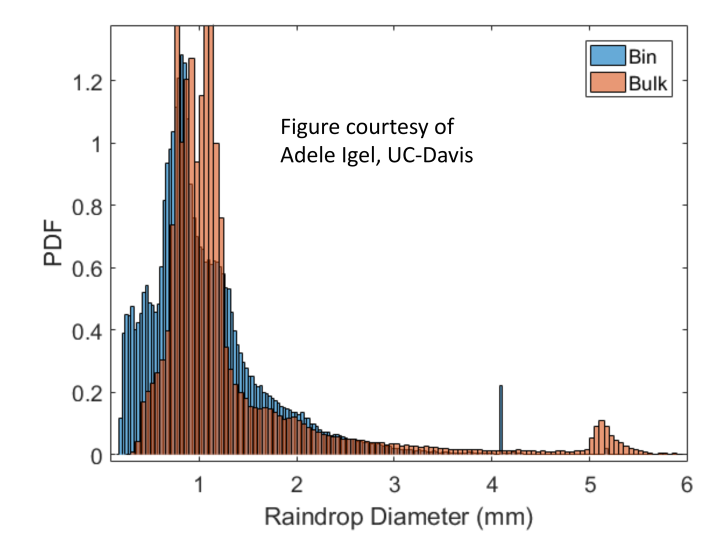


Joint distribution of D_0/N_w for both RAMS calculated DSDs and global observations from Dolan et al. (2018). Darker (lighter) colors indicate low (high) values.

- Sensitivity studies pinpointed the abundance of 1 mm drop sizes to the rain drop self-collection and breakup parameterization (based on Verlinde and Cotton (1993).
    - When drops start to grow larger than an equilibrium size (where the collection efficiency E =0), they are forced to break up
    - Verlinde and Cotton (1993) noted there would be an oscillation around this equilibrium size
    - Nature (disdrometer observations) shows that larger drops are more abundant than is being allowed
    - This parameterization is widely used across microphysics schemes -> no obvious alternative
        - Very limited observations of the process of drop-breakup to guide parameterization!
    - Morrison et al. (2012) showed that the drop-breakup parameterization can have significant impacts on storm dynamics, evolution and structure

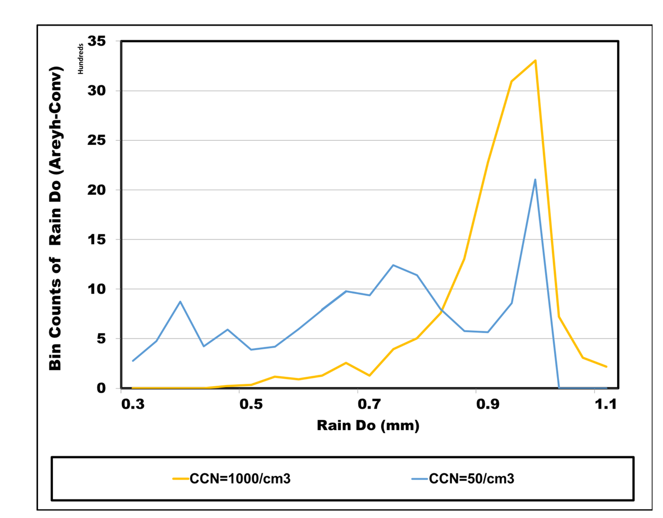


Rain Collection efficiencies, based on Verlinde and Cotton (1993)



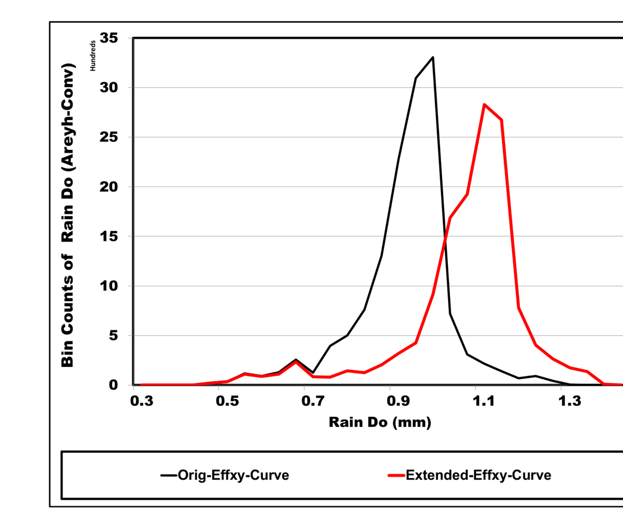
Comparison of mean rain drop diameters from bulk and bin simulation

- Although bin simulation DSDs are less constrained than bulk, there is a notable peak at around 1 mm in both



Aerosol sensitivity of mean drop diameter.

- Both low and high aerosol concentrations demonstrate a peak value at the equilibrium size



Original efficiency curve (black) and test curve (red)

- Extending the efficiency curve illustrates that the peak in rain diameter shifts to the equilibrium size, where E=0

- Parameterization of drop-breakup too aggressive; drops are not allowed to grow and remain large
- This is a widely used parameterization in microphysics models for rain drop breakup
- In-situ or lab-based observations of drop-breakup, especially in a vertical column, are extremely limited and difficult to obtain
- Parameterization of drop-breakup has wide-reaching impacts on simulations (Morrison et al. 2012), from cold pool strength to storm evolution and dynamics

Summary and Future Work

- We have used PCA as a framework for comparing model simulations and observations toward the goal of mutual improvement
- While the current suite of model simulations from RAMS does not fully capture the breadth of parameters such as D_0 and N_w compared to disdrometer observations, the EOFs and relative microphysical groupings are very similar to observations
    - Thus, we can use the model simulations to guide our interpretation of the microphysics driving surface DSDs and the observed variability
- Comparisons between observations and models in this framework revealed an abundance of drops around 1 mm which was found to be due to the aggressive parametrization of rain drop breakup which constrains drops from getting too large
    - We continue to seek ways to bring the parameterizations of rain drop self-collection and breakup toward agreement with observed distributions

Acknowledgements

- This work is supported by DOE grant number DE-00SC17977
- More information on the simulations used in this study can be found in Saleeby et al. (2016), JGR; Marinescu et al. (2016), JGR; Freeman et al. (2016), JGR; Grant and van den Heever (2014), JGR; Grant et al. (2018), JAS; Toms et al. (2018)