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# Study of Cloud Microphysics using Data Aggregation & tuning of standard atmospheric parametrizations

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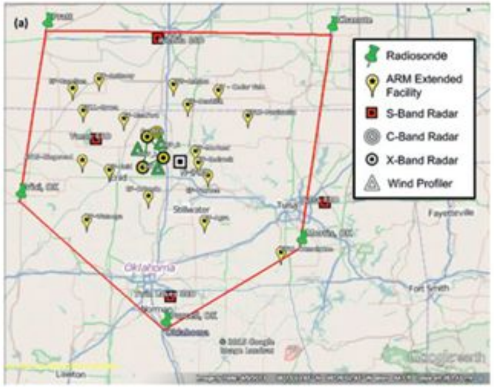
# Motivation

- Minute changes in extent or location of clouds leads to significant changes in atmosphere
- Uncertainties in the numerical weather models are required to be incorporated into these models for accurate estimations
- Potential reasons for uncertainties
  - Gaps in empirical or theoretical description of cloud processes
  - Inherent variability in spatial-temporal structures in clouds
  - High nonlinearity and complexity of cloud processes
- Practical approach to solve this is to depend on parameterizations which only on bulk chemical properties of aerosols and cloud particles

# Objectives

- Test the efficacy of standard parameterizations in literature for CDNC, LWC and LWP
- Develop an automated script to detect cloud base in convective clouds and a spatial-temporal clustering methodology to output time series data
- Analyze the source of uncertainties in standard parameterizations




Data source: ARM's SGP (Southern Great Plains) observatory
Campaign: MC3E Field Campaign

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# Parameterizations under consideration

$$N_d = \frac{2e^{3\sigma_x^2}\rho^2}{9\pi}\frac{\sigma^3}{q^2}$$

Yang parameterization: LWC, Extinction coefficient

$$N_d = C_3^{\frac{2k}{2+k}} N_0^{\frac{2}{2+k}} W^{\frac{3k}{4+2k}}$$

Pinsky parameterization: Temp, CCN, Updraft velocity

$$N_d = \sqrt{\frac{8\alpha^3 <r^6>}{Z * \pi^3 <r^2>^3} \left(\frac{K}{K_w}\right)^2}$$

Lidar parameterization: Backscatter coefficient, Reflectivity factor, Droplet radius distribution

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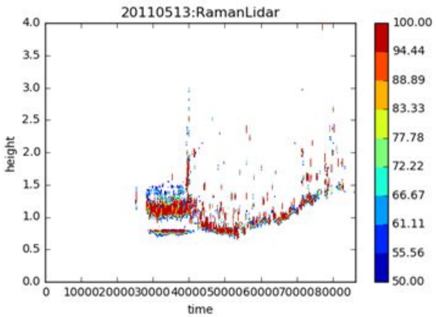
# Task I- Detection of Cloudbase in liquid clouds

Input




Searching Algorithm

$t = [t_0, t_1, t_2, \ldots, t_N]\,; h = [h_0, h_1, h_2, \ldots, h_N], e(t_i, h_i)$: *Extinction at a point*

*for* $t_i$ *in* $t$:

*for* $h_i$ *in* $h$:

*if* $e_{minimum} \leq e(t_i, h_i) \leq e_{maximum}$ :

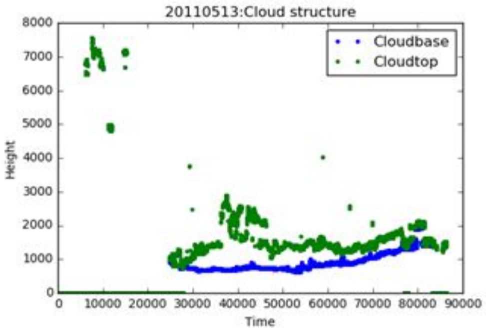
*if* $1000 \leq h_i$ :

*if* $e(h_{i-1}, t_i) \leq e(h_i, t_i) \leq e(h_{i+1}, t_i)$ :

*break*

Output

1D Time Series of the Cloud Base and Cloud Top

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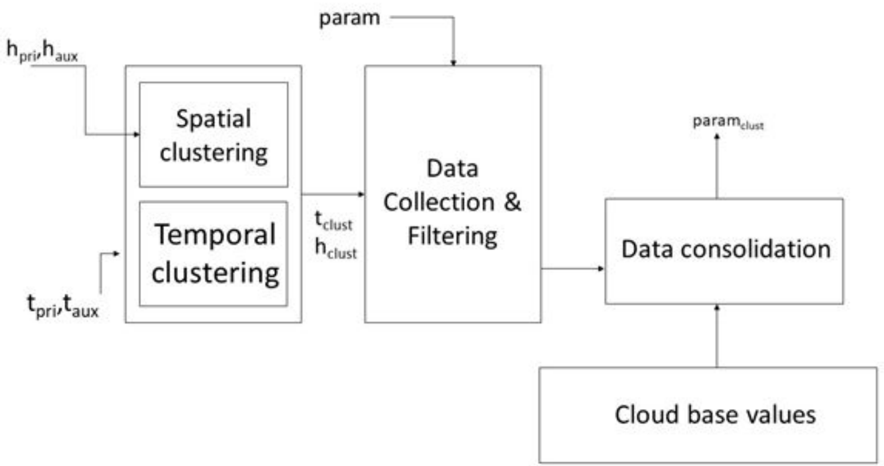
# Task II: Automated Code for Spatial-Temporal Clustering

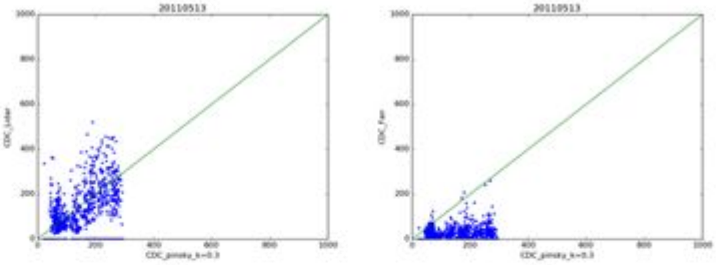



```
Generating indices for extinction
--------Start of clustering cycle--------
Changing time resolution from 21600->2880
Changing height resolution from 596->667
You are decreasing time resolution
You are increasing height resolution
--------End of clustering cycle--------
Clustering of Retrieved Liquid Water Concentration took 5.26 s
Filtering of Retrieved Liquid Water Concentration took 145.87 s
Total time: 152.22083568572998s
Clustering of Mean Doppler velocity took 4.65 s
Filtering of Mean Doppler velocity took 163.41 s
Total time: 169.7653408050537s
Clustering of Spectral width took 6.52 s
Filtering of Spectral width took 155.09 s
Total time: 162.78985214233398s
Clustering of Reflectivity took 4.76 s
Filtering of Reflectivity took 142.07 s
Total time: 147.98419713974s
Processing temperature
--------Start of clustering cycle--------
Changing time resolution from 144->2880
Changing height resolution from 198->667
You are increasing time resolution
You are increasing height resolution
--------End of clustering cycle--------
```

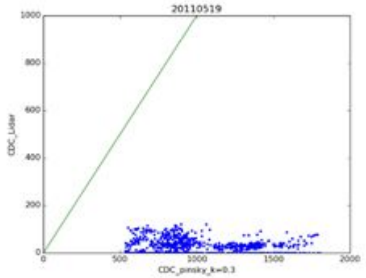
```
Processing CCN
--------Start of clustering cycle--------
Changing time resolution from 1440->2880
Changing height resolution from 1000->596
You are increasing time resolution
You are decreasing height resolution
--------End of clustering cycle--------
Generating Output file
Date 2880
Time 2880
Height 2880
LWC 2880
LWC_SD 2880
Velocity 2880
Velocity_SD 2880
Spectral_Width 2880
Spectral_Width_SD 2880
Reflectivity 2880
Reflectivity_SD 2880
Temperature 2880
Extinction_low 2880
Extinction 2880
Extinction_high 2880
CCN 2880
Time taken so far 674.44
```

Results

Good day




Bad day

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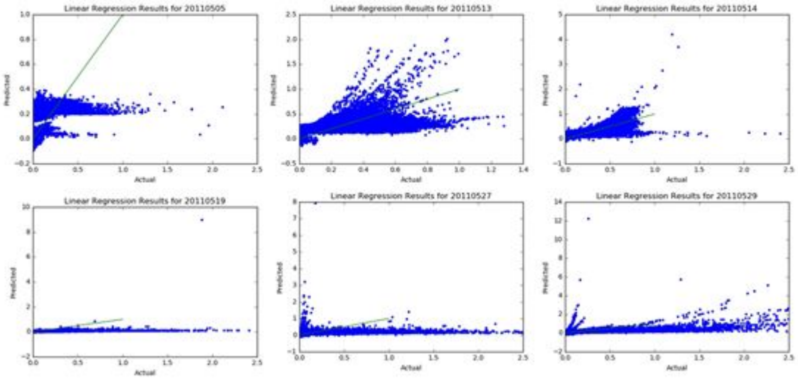
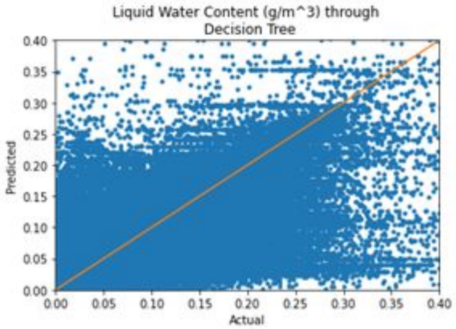
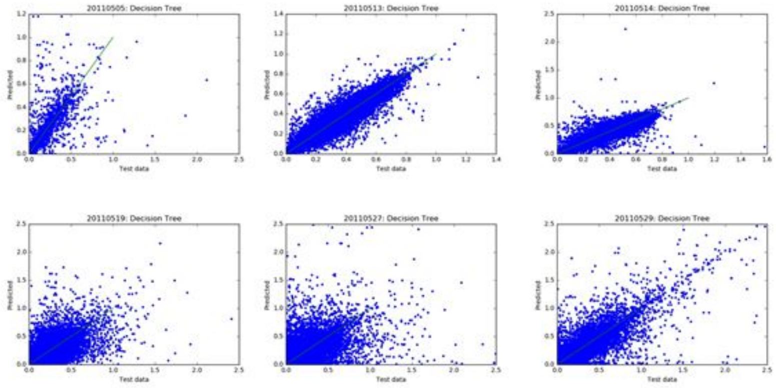
# Task IV: Predictive Models for LWC

Inaccurate models



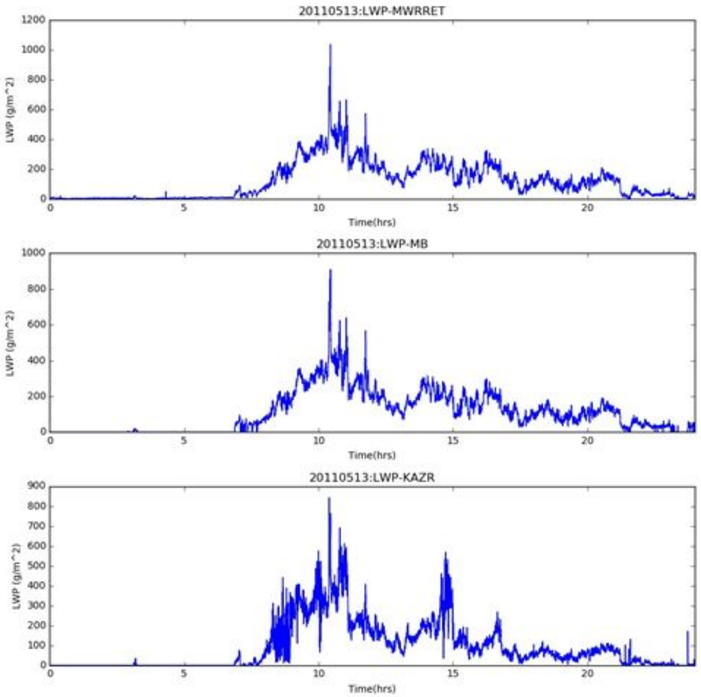




Fair models



# Task V: Analyzing sources of Uncertainties in LWP

$$LWC = \left[\frac{N_d * Z_{liquid}}{3.6}\right]^{\frac{1}{1.8}} \quad + \quad LWP_t = \int_{h_i=c_{base}}^{h_f=c_{top}} LWC_t(h) * dh \quad \Longrightarrow \quad LWP_t = \int_{h_i=c_{base}}^{h_f=c_{top}} \left[\frac{N_d * Z_{liquid}(h)}{3.6}\right]^{\frac{1}{1.8}} * dh$$




Sources of uncertainty:

1. Clustering of data
2. Cloud base detection
3. Empirical relation
4. Numerical integration

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# Accomplishments & Future Work

Accomplishments

- Development of an automated clustering methodology from scratch
- Detection of sources of uncertainty in standard parametrizations
- Baseline predictive models for LWC

Future Work

- Tuning the developed clustering methodology for better time-series estimations
- Higher order prediction models using neural networks

# Acknowledgements

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# References

Go to References section of the complete report:
https://github.com/yashgokhale/CMU-MS-Research/blob/main/Reports/ysg_MastersReport.pdf

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