# Lidar Based Cloud Droplet Concentration Retrieval in Supporting Aerosol-Cloud Interaction Study in Low Clouds

Zhien Wang, Tao Luo, Damao Zhang, and Jeff Snider

University of Wyoming

# Motivations

- Droplet number concentration is important, but with limited observations.
- Expensive to collect a large dataset with aircraft
- Ground-base lidar measurements allow us to better link aerosol and cloud droplet concentrations.

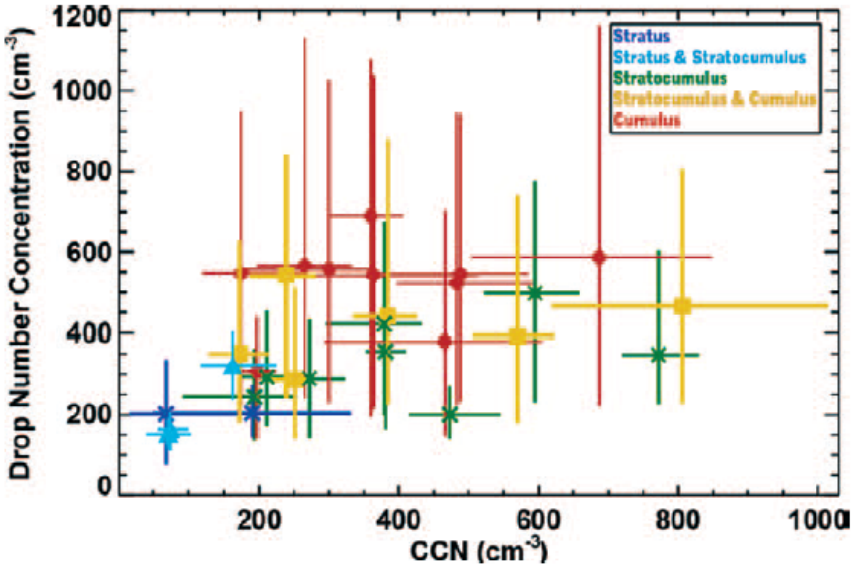



FIG. 9. Cloud drop number concentration and CCN. The relationship between cloud drop number concentration and CCN (at 0.2% SS) is given for all RACORO cloud flights. Each point represents the full flight of data when CAS LWC > 0.01 g m$^{-3}$. The cloud drop number concentration is from the CAS for drop diameters 2.3–34.3 $\mu$m. The point represents the median

Vogelmann et al. 2012

# The Approach

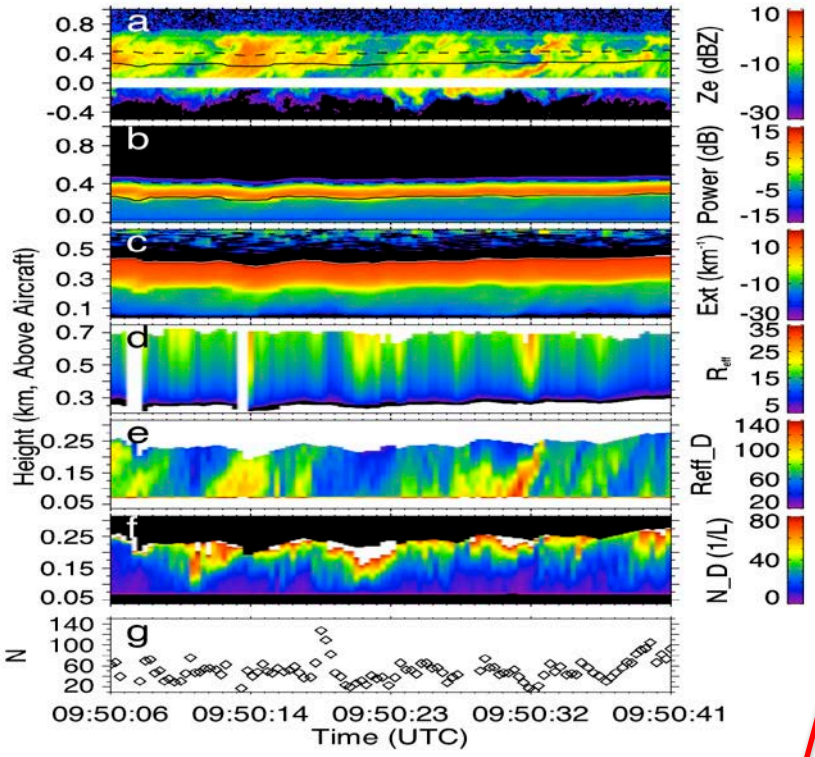
- Combining lidar derived extinction with adiabatic LWC to estimate number concentration with assumed log-normal size distributions
- Assumptions:
  - Vertical consistent N in stratiform clouds
  - Within~200 m of stratiform cloud base, cloud vertical properties (LWC and extinction) close to adiabatic profiles.

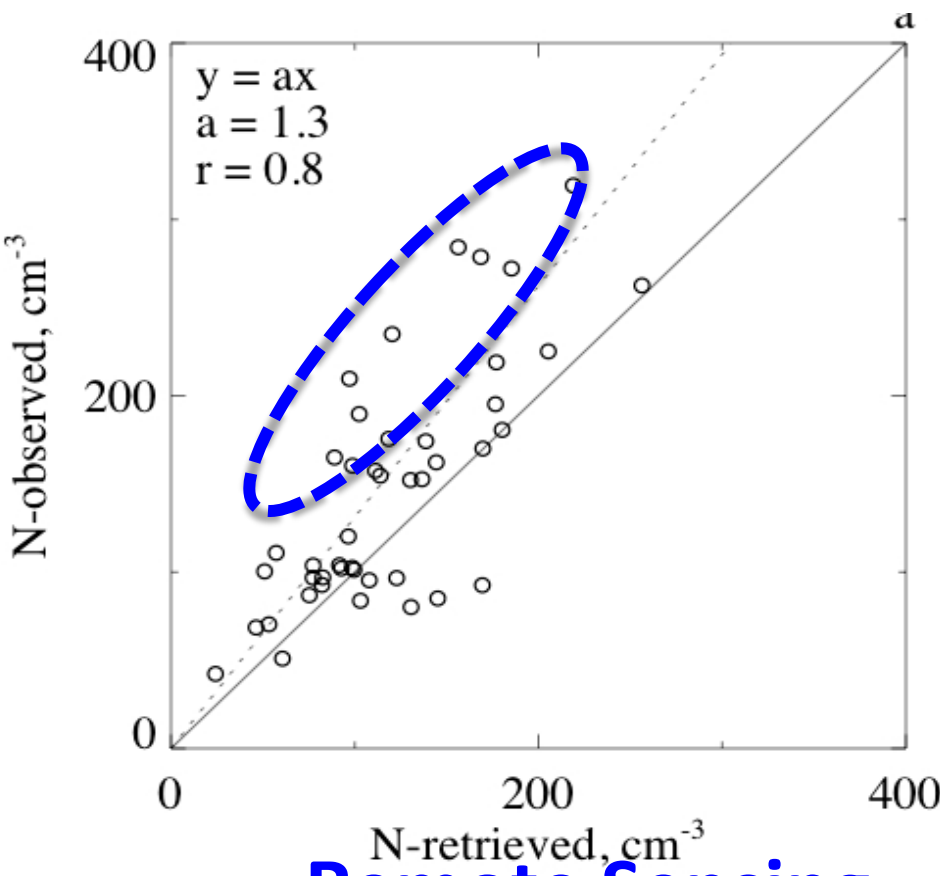
$$N = \frac{2\sigma^3 e^{3\sigma_x^2} \rho_w^{\ 2}}{9\pi {q_l}^2} = C\frac{\sigma^3}{{q_l}^2}, \qquad C = \frac{2e^{3\sigma_x^2}\rho_w^2}{9\pi}$$

# Multiple Scattering Correction In Lidar Measurements

- Two approaches
  - Using linear depolarization as a measure of MS contribution in attenuated backscattering coefficients ( Hu et al. 2007).
  - Iterate correction:
    - Initial extinction retrieval -> MS calculation with Eloranta (1998) method→ correct MS effect in the original signals-- extinction retrieval -> MS calculation with Eloranta (1998) method→ …
    - Two iterations is enough normally.

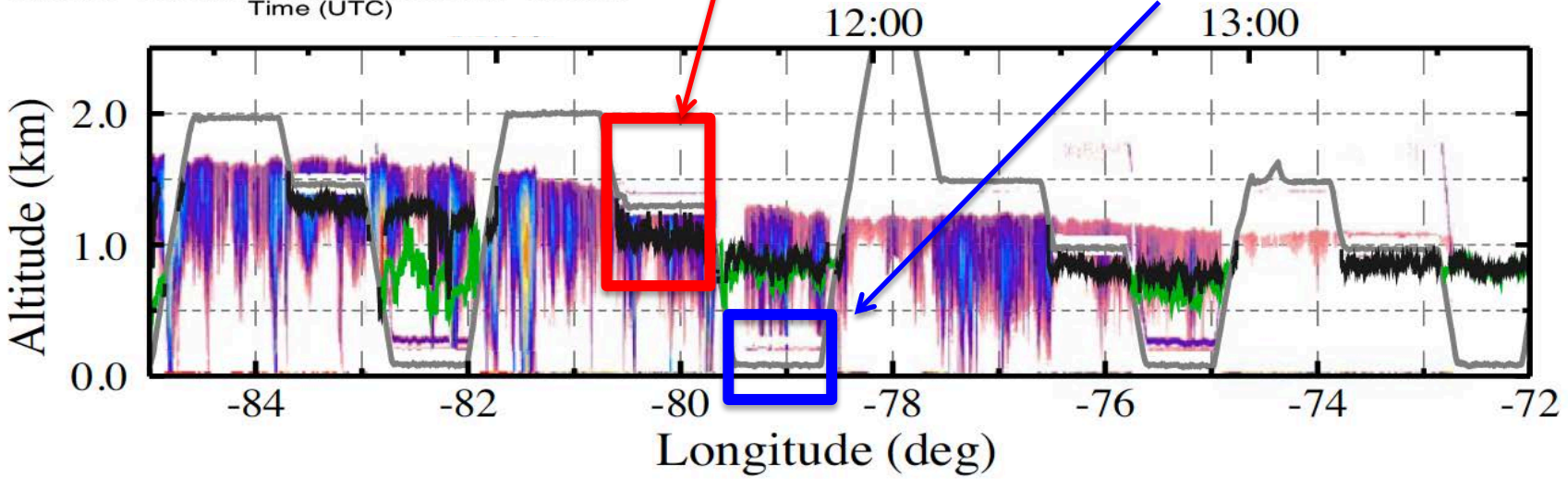
# Evaluation




In-situ

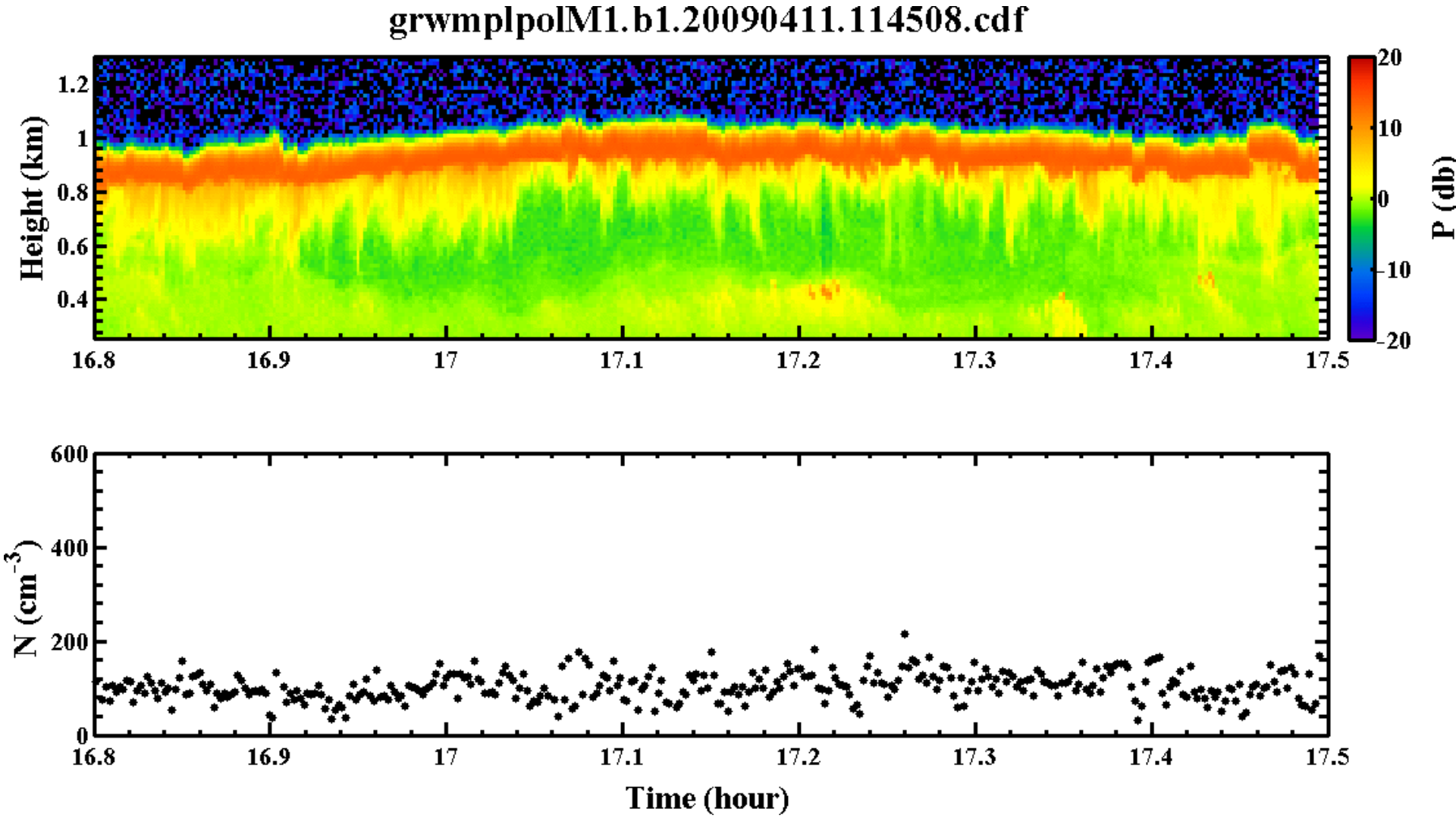
Remote Sensing



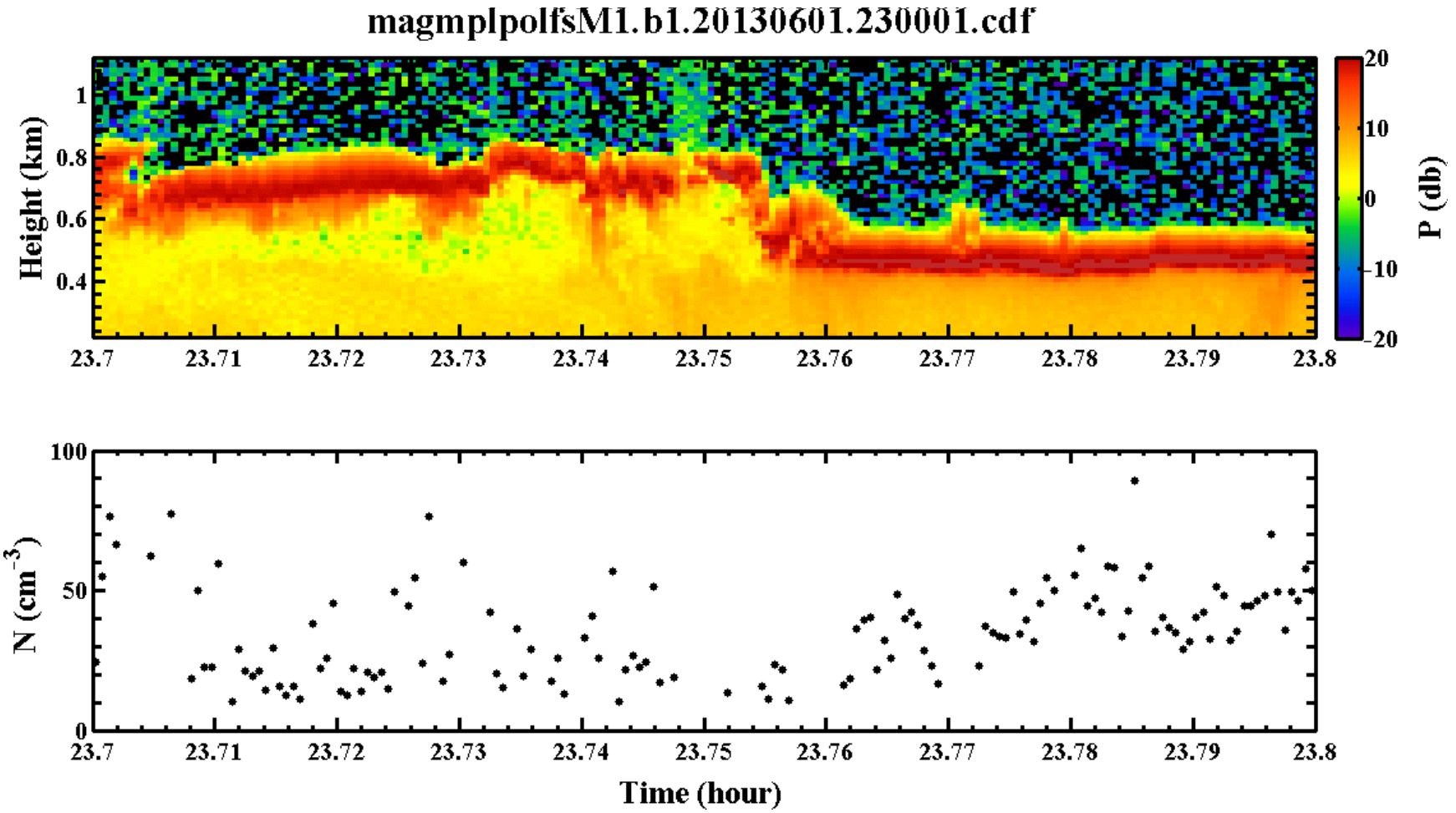
# MPL-based Retrieval Examples

- **Azores**: Remote ocean
- **MAGIC**: Remote ocean and coastal regions
- **Hefei**: Continental high aerosol loading and different types of clouds

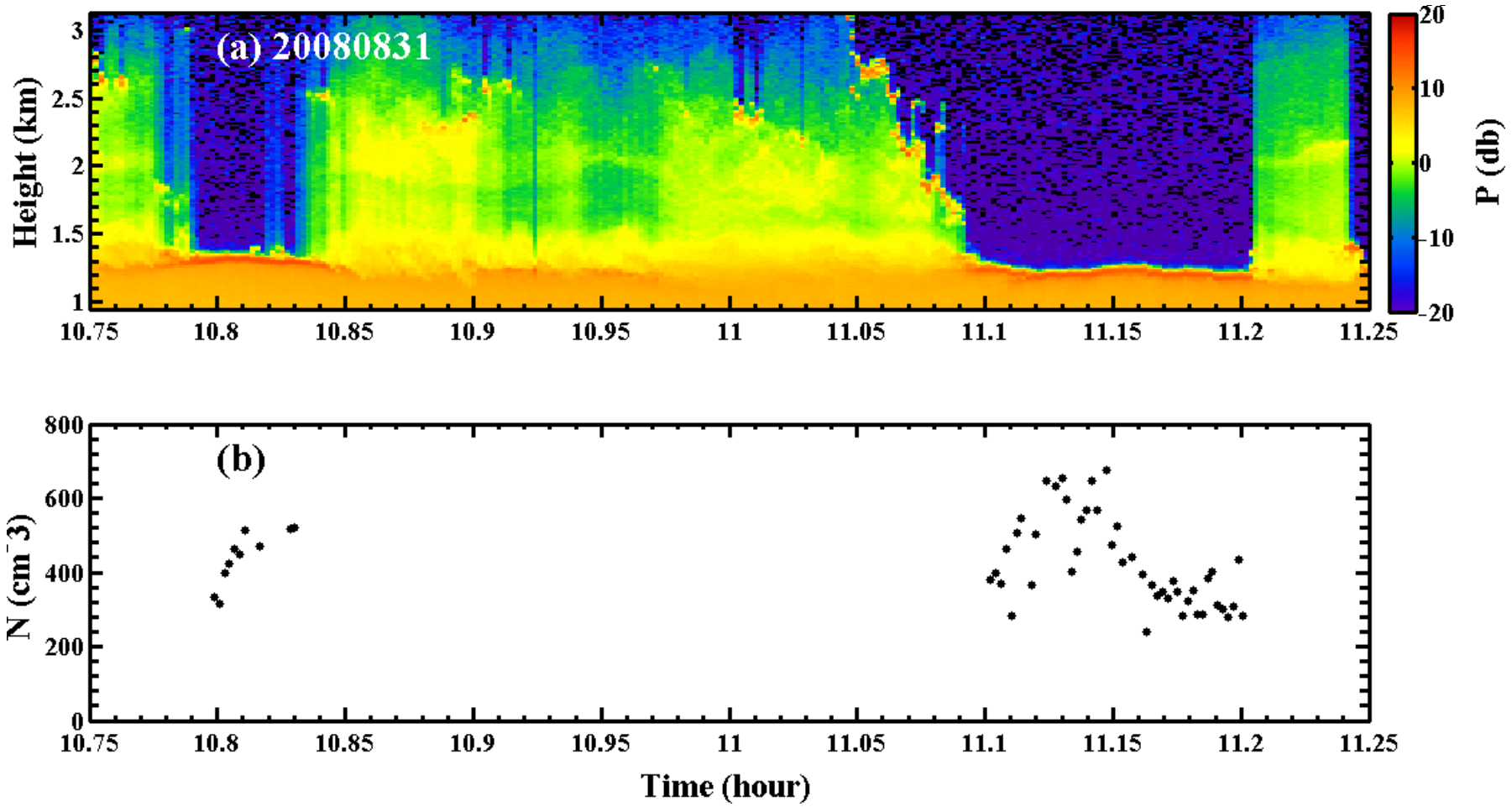
# Azores Cases



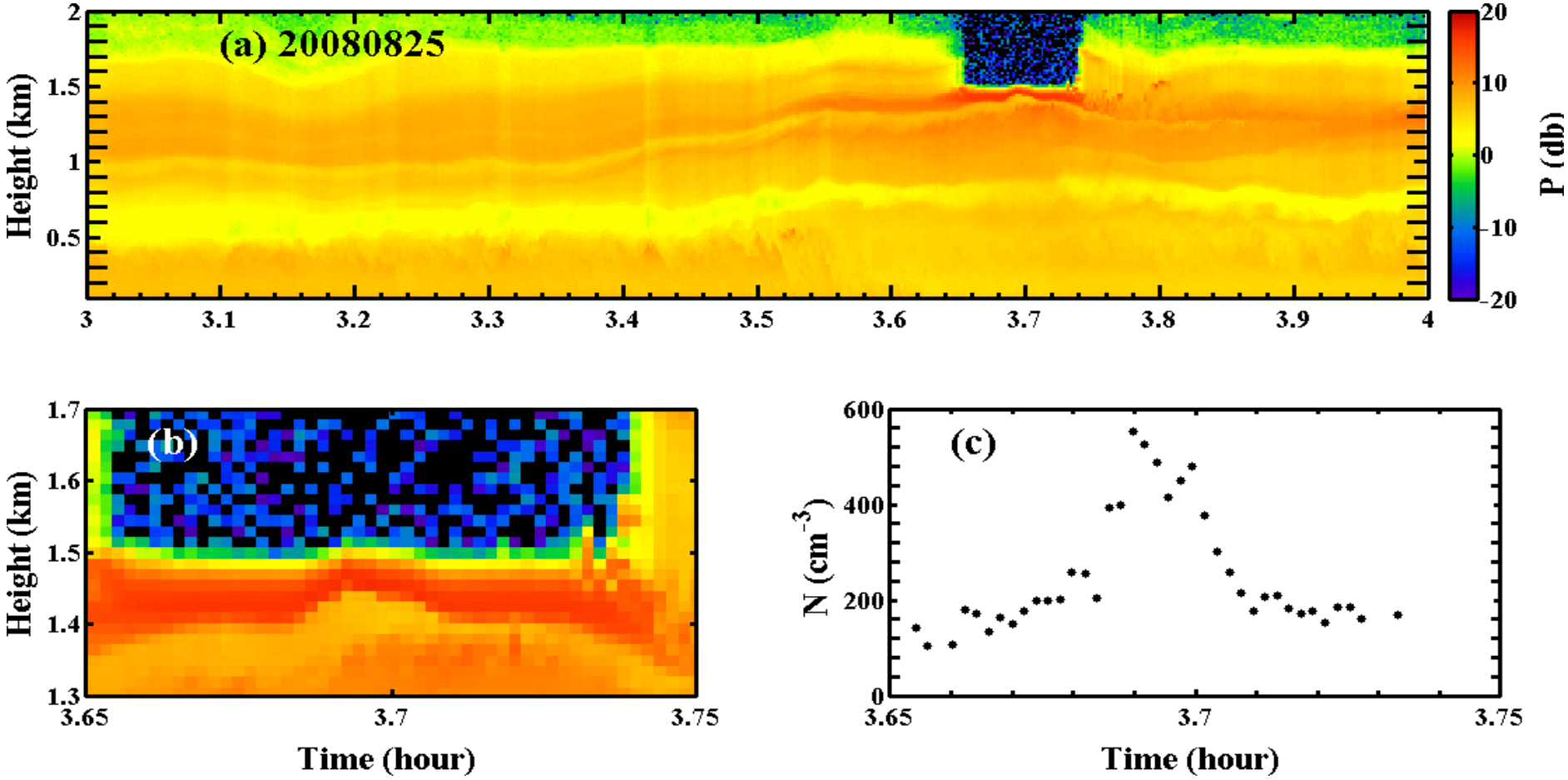
# MAJIC Cases


magmplpolfsM1.b1.20130601.230001.cdf
Height (km)
1
0.8
0.6
0.4
23.7
23.71
23.72
23.73
23.74
23.75
23.76
23.77
23.78
23.79
23.8
20
10
0
-10
-20
P (db)
N (cm$^{-3}$)
100
50
0
Time (hour)

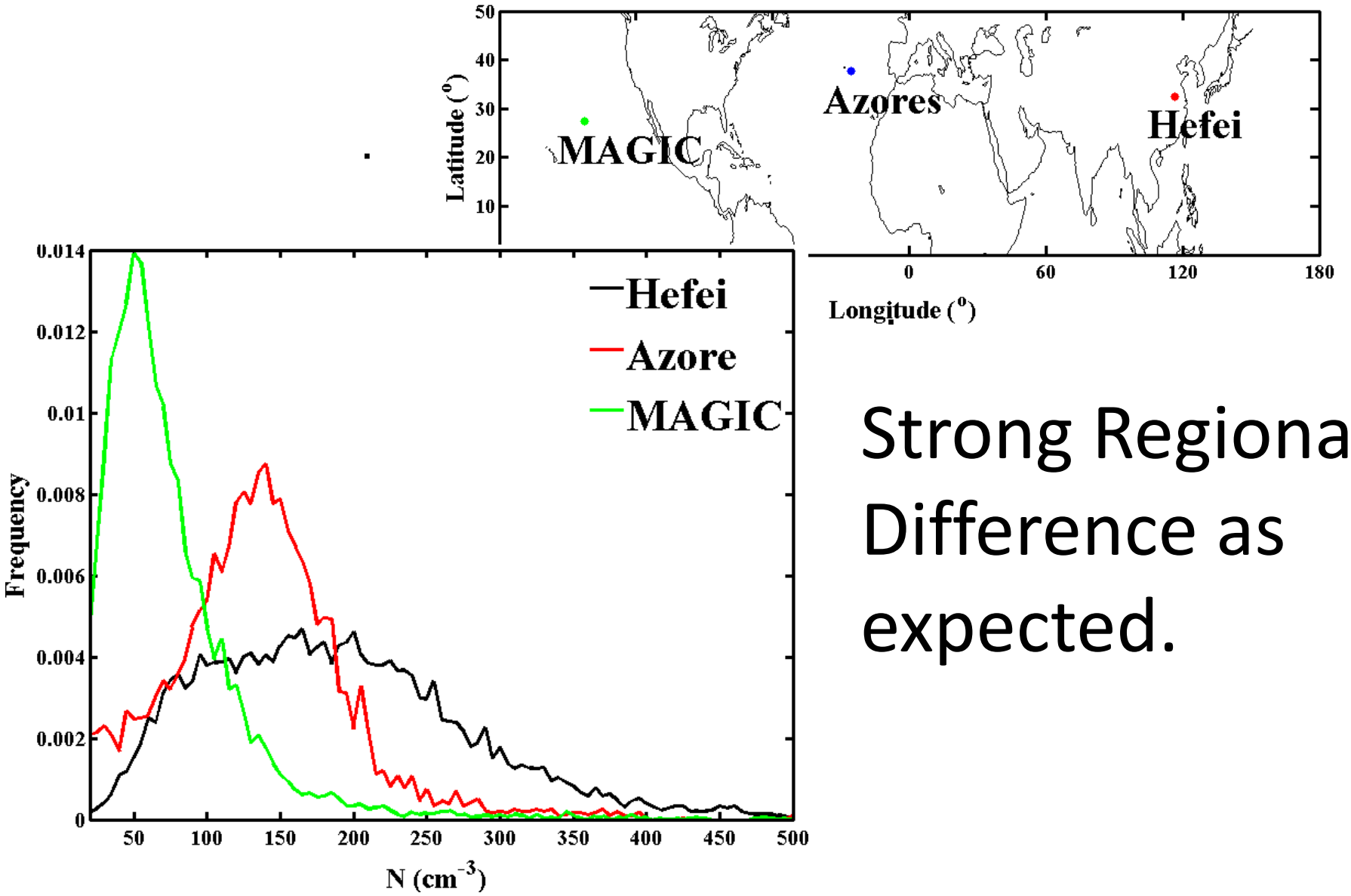
# Hefei Cases


(a) 20080831
Height (km)
3
2.5
2
1.5
1
10.75
10.8
10.85
10.9
10.95
11
11.05
11.1
11.15
11.2
11.25
20
10
0
-10
-20
P (db)
(b)
N (cm^-3)
800
600
400
200
0
Time (hour)

# Droplet Concentration: aerosol vs dynamics?



# Statistics from Limited Cases




Strong Regional Difference as expected.

# Summary

- Perform well with MPL measurements for warm clouds, **but** more coding work to be done to process large among data.
- Can be implemented with HSRL.
- Offer new capabilities to facilitate aerosol-cloud interaction study with ARM observations:
    - **Aerosol properties**– surface sampling and lidar measurements
    - **Vertical velocity**---Radar and Doppler lidar
    - **Cloud properties**– Lidar + radar+radiometer

# Future

- Develop a data base for process study and model evaluation.

**Model Simulated cloud droplet number concentration (CDNC)**

KRAVITZ ET AL.: GEOMIP MARINE CLOUD BRIGHTENING

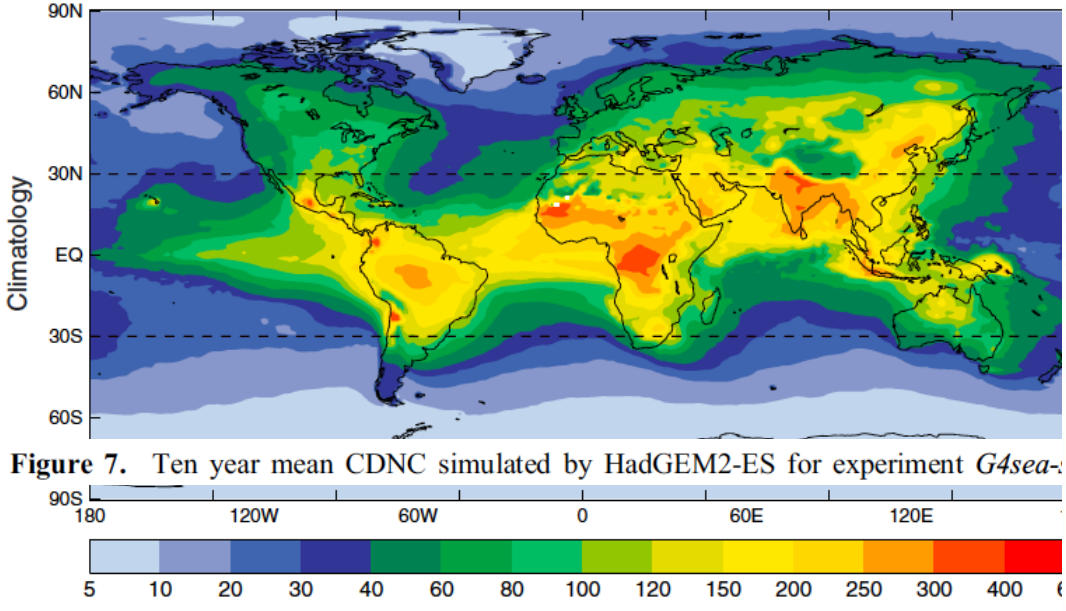



**Figure 7.** Ten year mean CDNC simulated by HadGEM2-ES for experiment *G4sea-*

**ARM Sites**

# HSRL-based Retrieval Example