Evaluation of Mali, West Africa Airborne Measurements to Access the Potential of Enhancing Precipitation using Cloud Seeding Techniques

David Delene
Department of Atmospheric Sciences
University of North Dakota

Research Motivation

- Worldwide Water Resource Stresses
- Severe Weather Hazards
- New Observational, Computational, Statistical Technologies
- Operational Programs with Little Scientific Basis
- Population and Demographic Changes
- Inadvertent Weather Modification

Measurement Objectives

- Determine if cloud seeding in Mali could be beneficial.
- Identify optimal seeding method for enhancing precipitation in the Mali region based on conceptual models.

Measurement Importance

- The potential to enhancing precipitation is strongly dependent on the natural microphysics and dynamics of the clouds that are being seeded.
- Cloud properties can vary significantly from one geographical region to another and with the time of year in the same region.

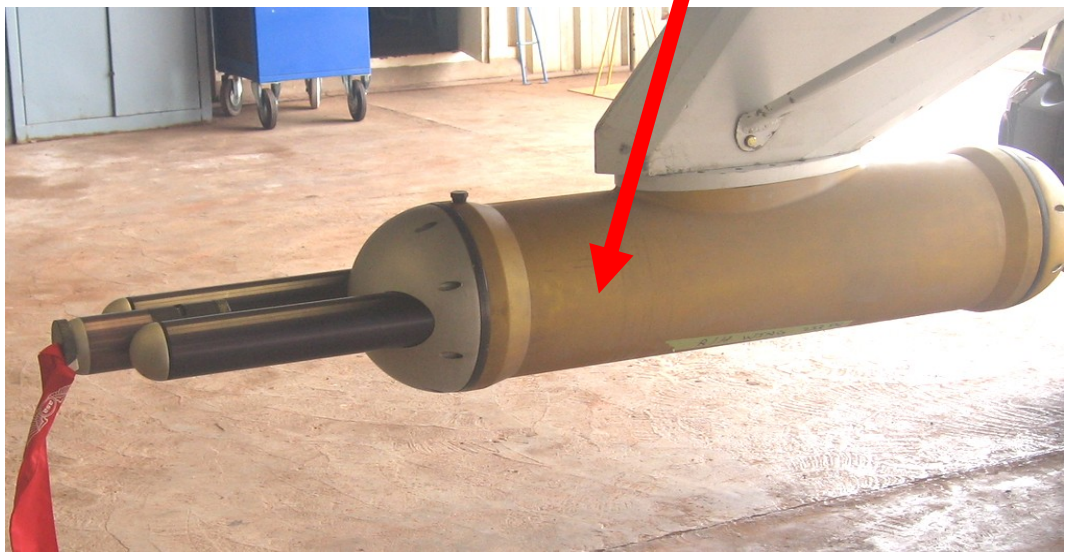
Lower Aerosol Concentrations

- The natural processes of rainfall formation is more efficient.
- Effects from hygroscopic cloud seeding are less effective.

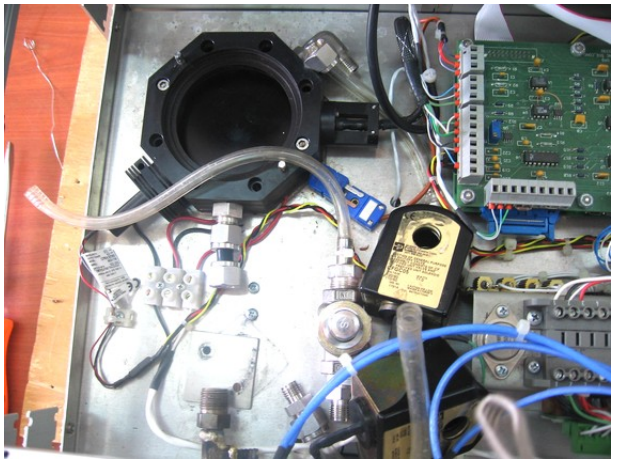
High Dust Concentrations

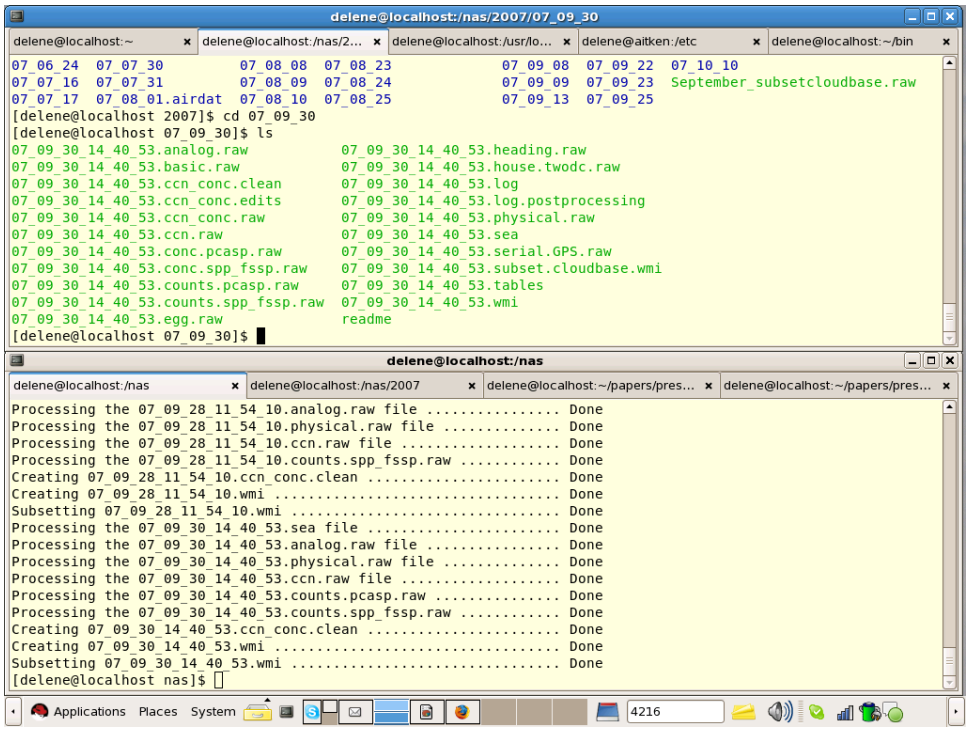
- The natural processes of rainfall formation is more efficient
- Effects from glaciogenic cloud seeding are less effective.

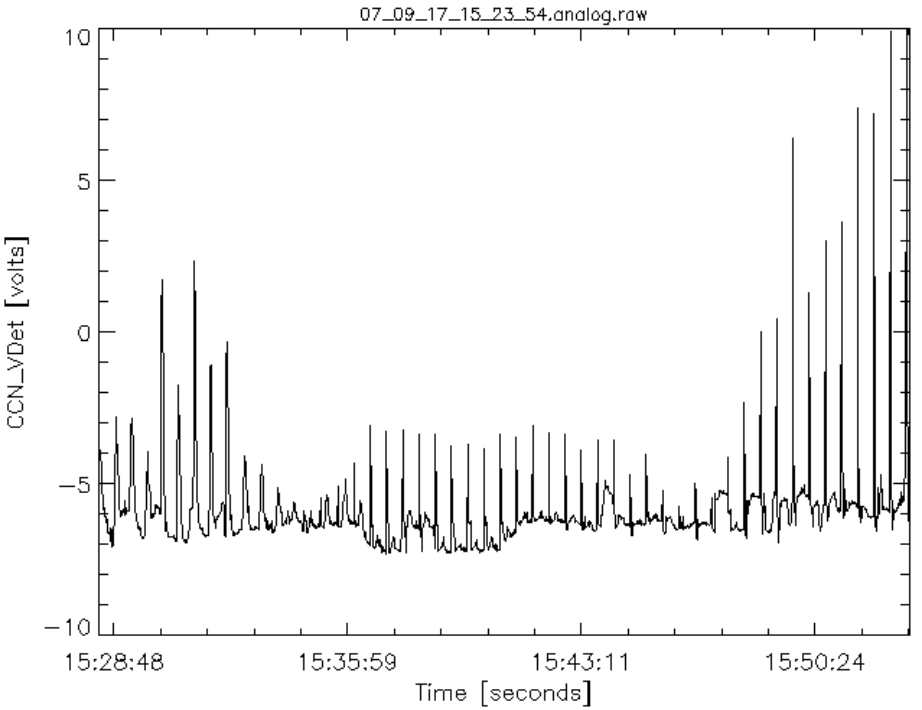
Aircraft Instruments

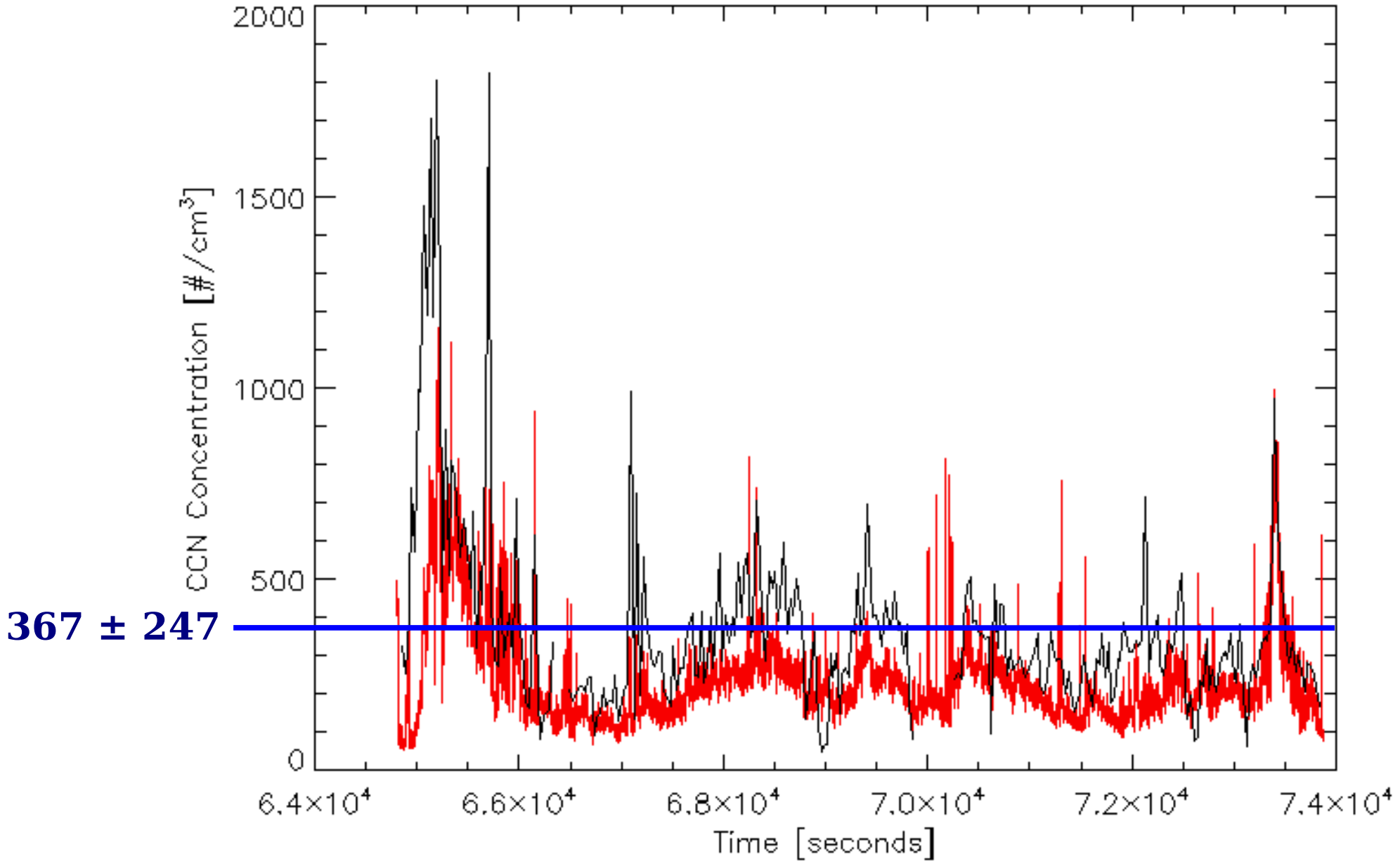


Quality Control
Quality Assurance









Cloud Condensation Nuclei (CCN) concentrations (black) and Optical Particle Counter (OPC) concentrations (red) measured east of Bamako on September 8, 2007 near cloud base.

CCN Measurements

Location	Time	Altitude	CCN
Wyoming, USA*	Winter	Lower Trop.	146±20 #/cm^3
Wyoming, USA*	Summer	Lower Trop.	445±157 #/cm^3
New Zealand*	Summer	Lower Trop.	964±17 #/cm^3
Bamako, Mali	Sep. 8, 2007	Cloud Base	367±247 #/cm^3
Bamako, Mali	Sep. 2007	Cloud Base	461±346 #/cm^3

Cloud Condensation Nuclei (CCN) concentrations at 1% supersaturation measured by a University of Wyoming CCN counter in the lower troposphere at various locations.

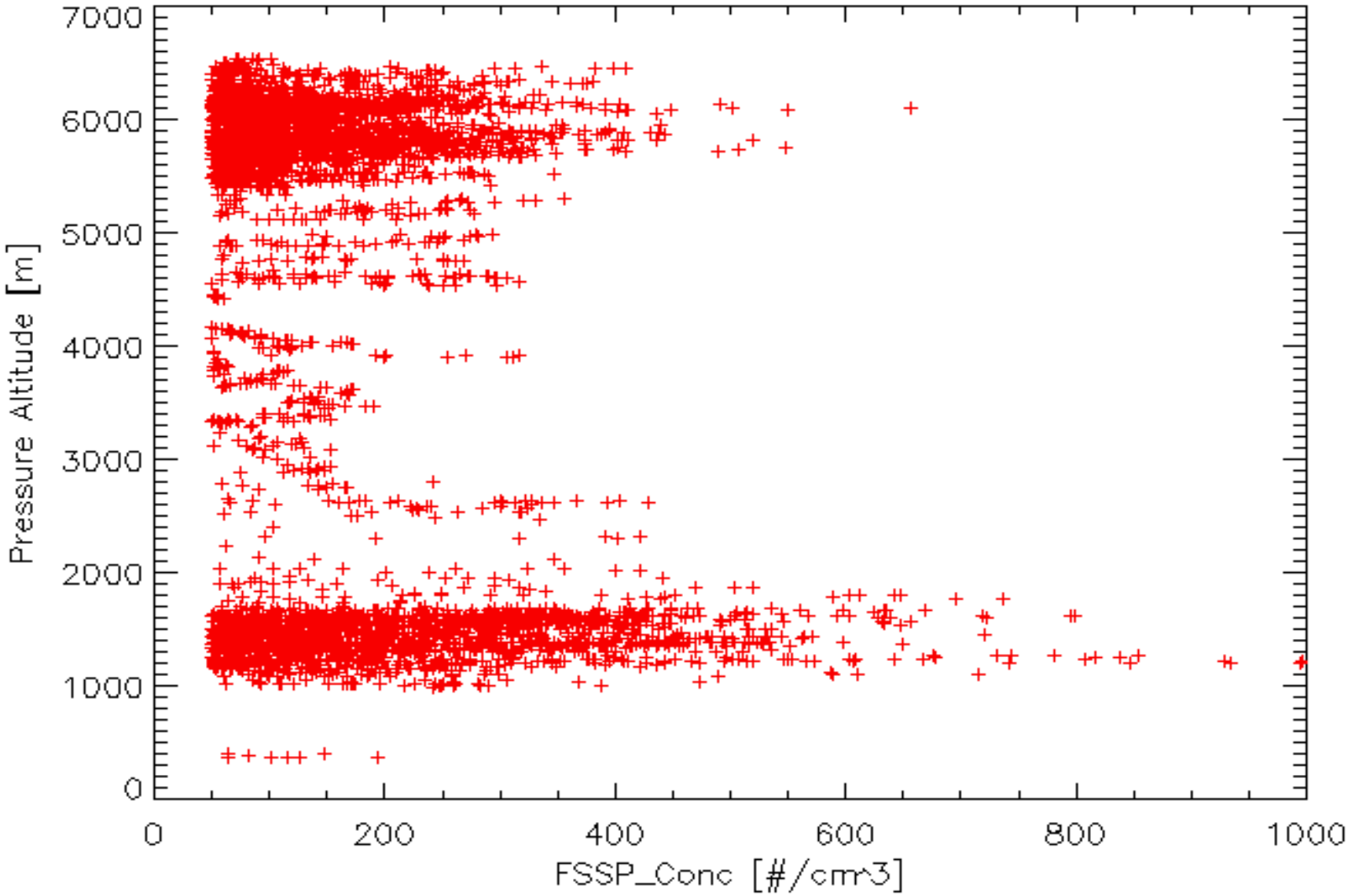
*REF: Delene, D. J. and T. Deshler, Vertical profiles of cloud condensation nuclei above Wyoming, Journal of Geophysical Research - Atmospheres , 106, 12579-12588, 2001.

CCN Measurements

Location	Concentration
Australian Coast	120 #/cm^3
North Atlantic Ocean	145-370 #/cm^3
High Plains, Montana	290 #/cm^3
Australia, Africa, USA	600 #/cm^3
High Plains, Montana	2000 #/cm^3
Buffalo, New York	3500 #/cm^3
Texas, USA	3000-5000 #/cm^3

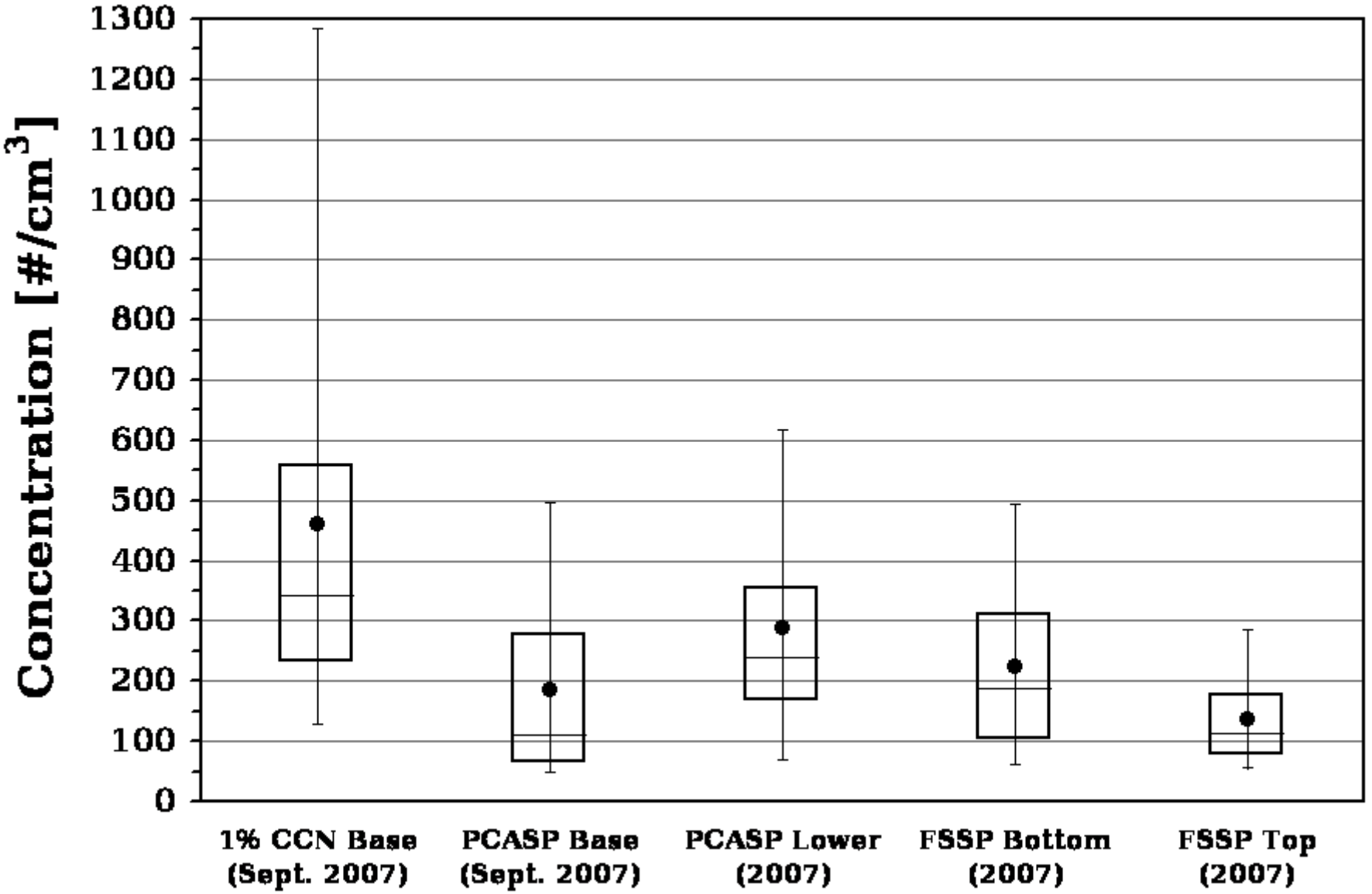
Cloud Condensation Nuclei (CCN) concentrations at 1% supersaturation measured at various locations. Values taken from Pruppacher, H. R., and J. D. Klett, Microphysics of Clouds and Precipitation, pp. 287-289, Kluwer Acad. Norwell, Mass., 1997.

Cloud Droplet Measurements



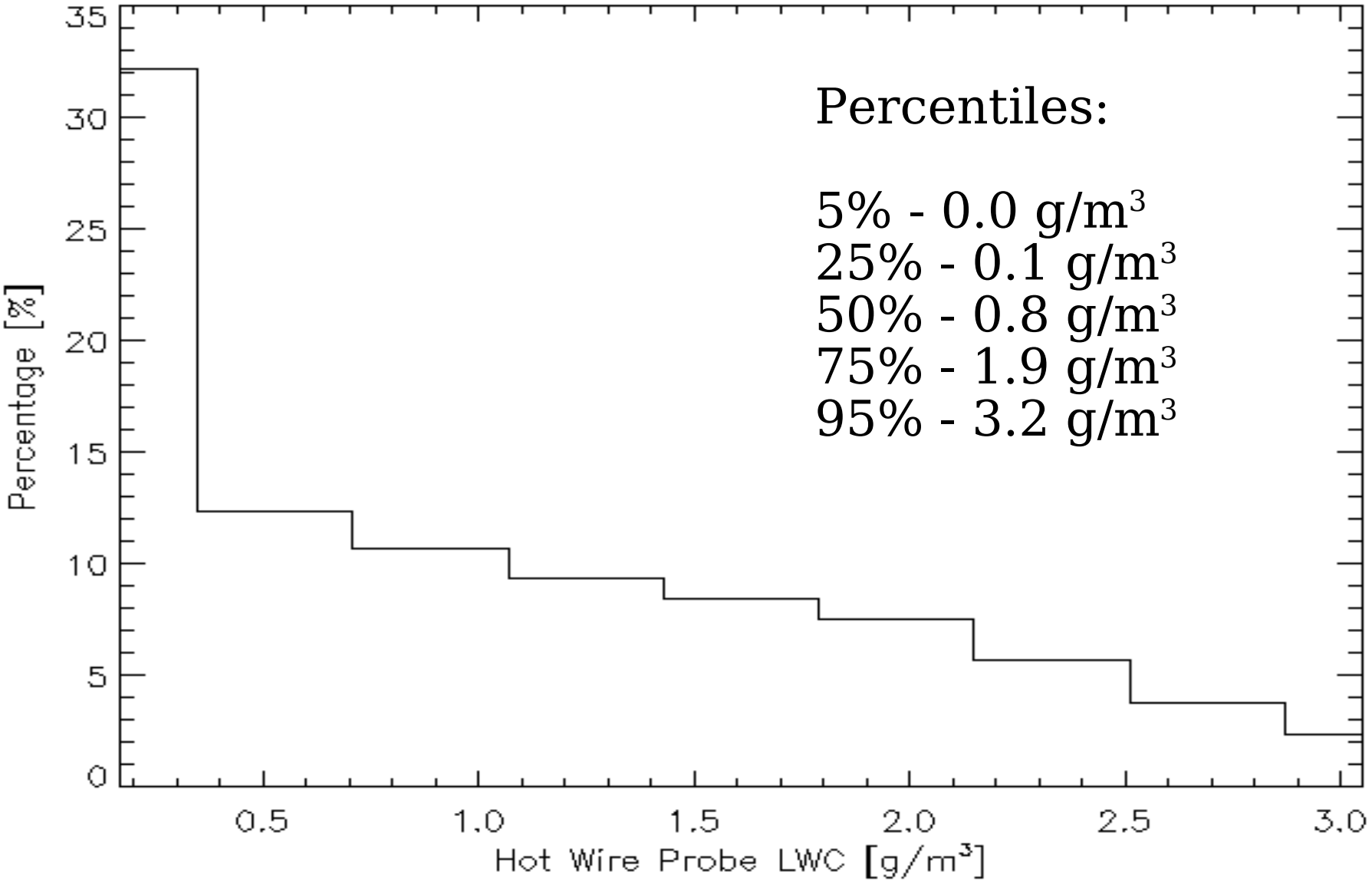
The 1 Hz cloud droplet concentration versus pressure altitude for all Mali 2007 measurements with concentrations above 50 #/cm^3.

Concentration Summary



Distribution of the number concentration measured in Mali during 2007. Given are the 5, 25, 50, 75, and 95 percentiles, and the mean value (solid circle).

Liquid Water Content (LWC)



Histogram of the LWC for all Mali 2007 measurements (1 Hz) where the cloud droplet concentration was above 50 #/cm^3 and the temperature below 0 ^{o}C.

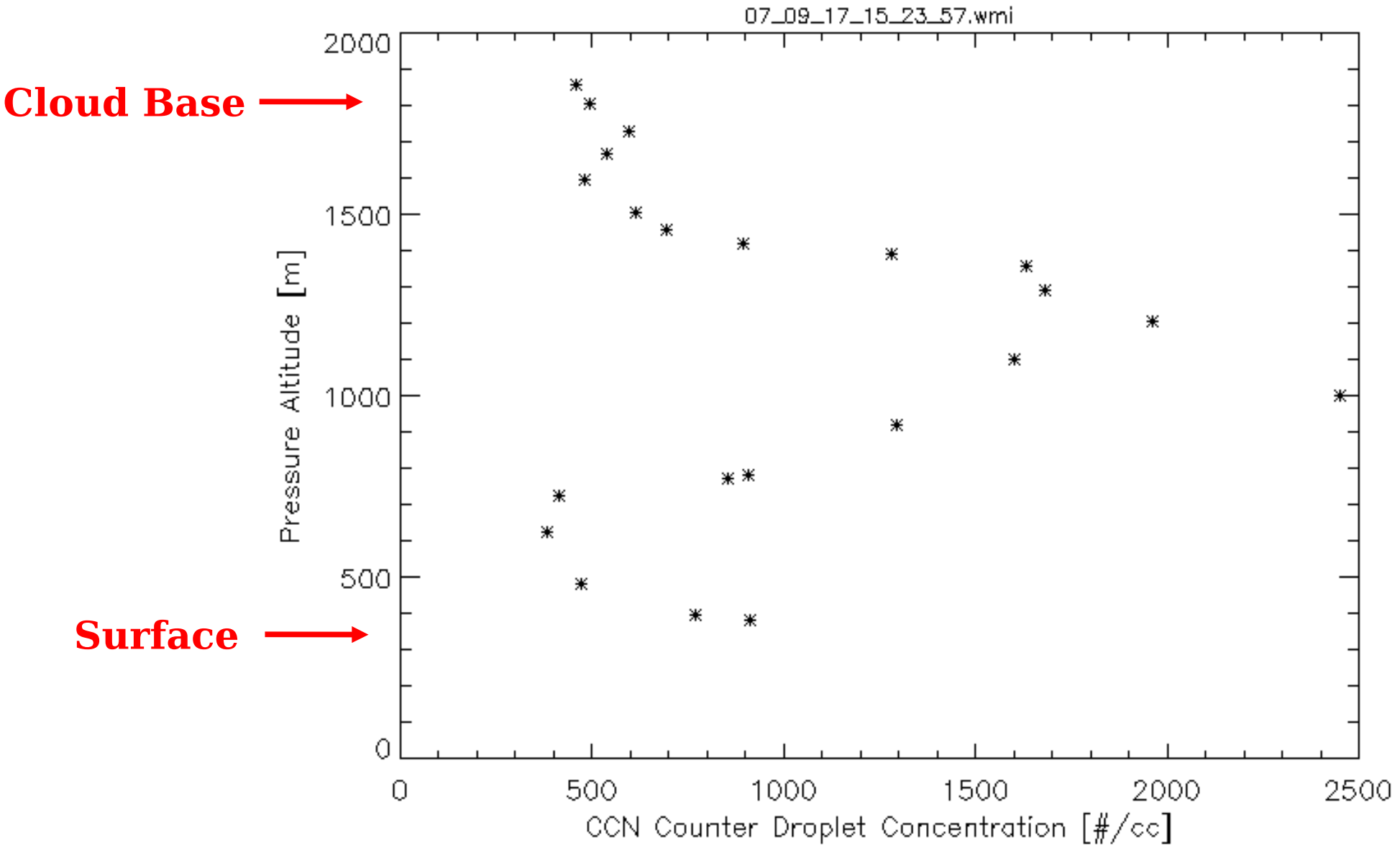
Conclusions

- There is sufficient cloud liquid water for precipitation to form.
- The cloud droplet measurements indicate typical continental conditions.
- Cloud base CCN measurements show mostly clean continental conditions.
- On most operational cloud seeding days during the middle of the wet season (late July, August, September), glaciogenic is the recommend seeding method for enhancing precipitation.

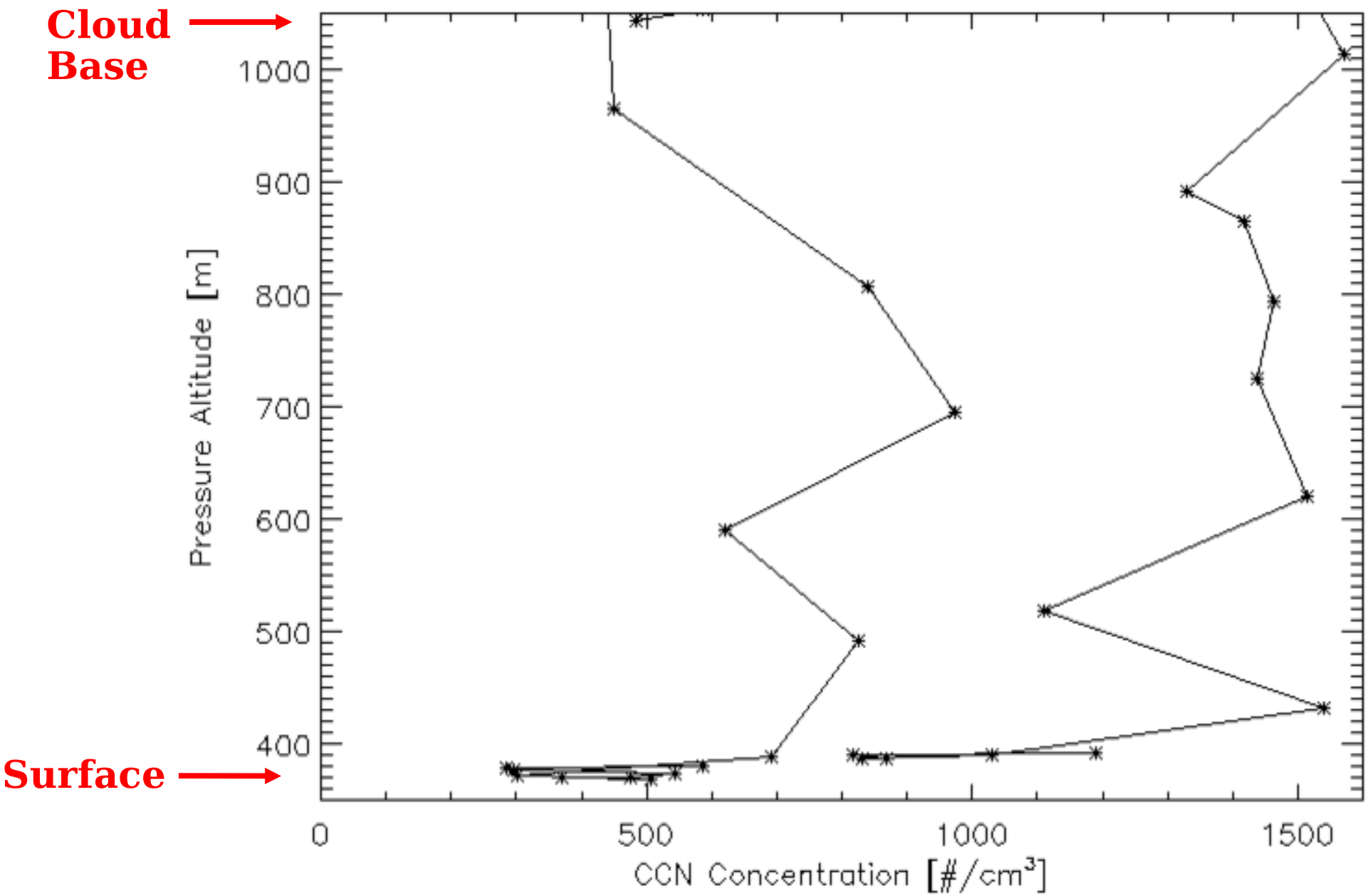
Future Work

- Investigate the source of the high aerosol concentration measured during some days. Do these high aerosol concentrations affect the amount of precipitation?
- Since synoptic conditions are different at the beginning and end of the rainy season, the aerosol and cloud conditions are likely to be different. Conduct measurements in Mali during these times to determine the optimum method for enhancing precipitation.

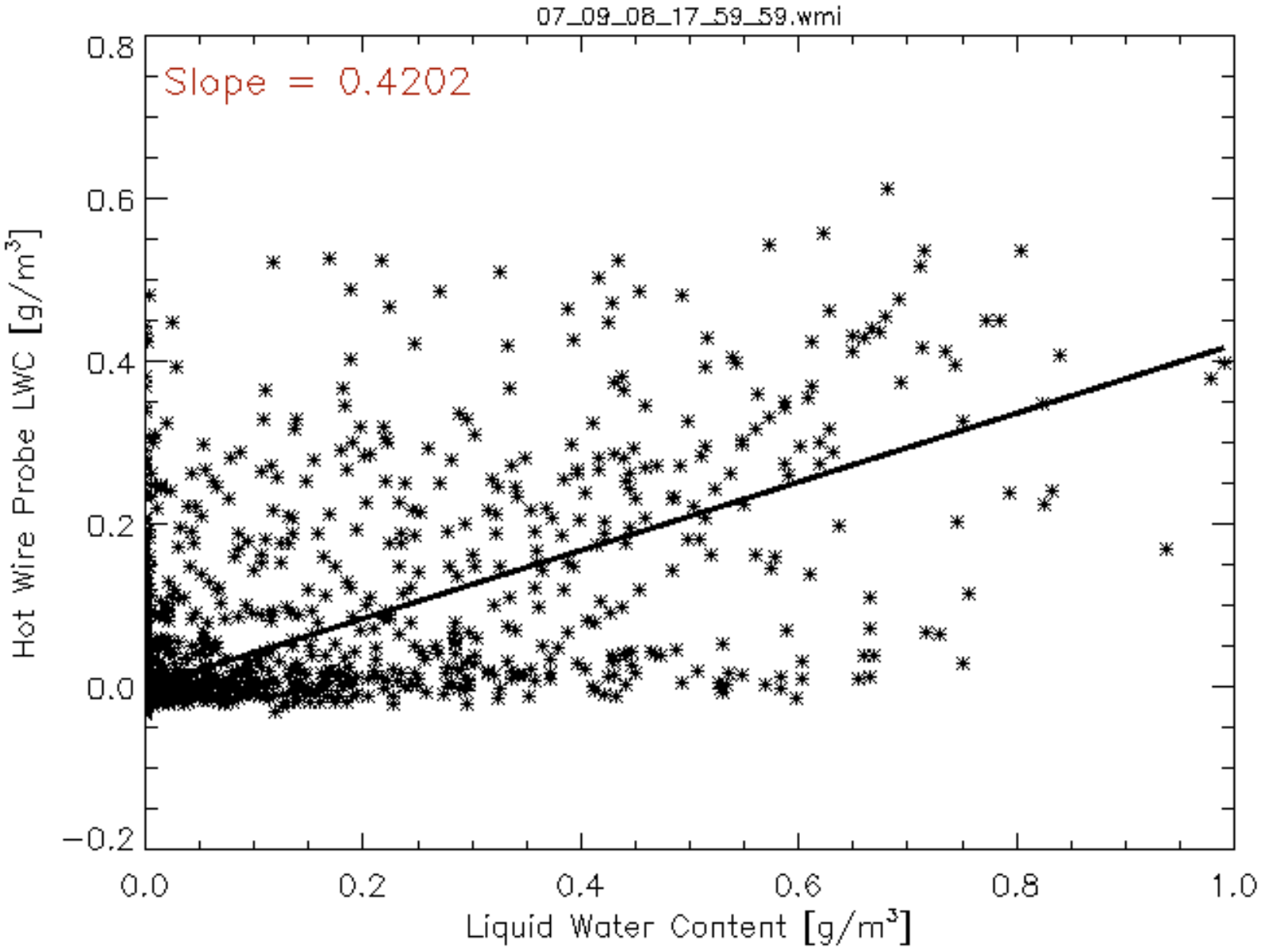
Any Questions?



Cloud Condensation Nuclei (CCN) concentrations versus Pressure Altitude measured during decent into Bamako on the September 17, 2007 flight.



Cloud Condensation Nuclei (CCN) profile over Bamako, Mali on September 18, 2007 over Bamako, Mali. The low concentration profile (left) was measured on ascent (14:30 UTC) and the high concentration profile (right) was measured on descent (17:00).



Comparison of FSSP and hot Wire measurements of cloud liquid water content made in developing cumulus clouds during the September 8, 2007 flight.

Sahelian Trade Winds