Three Years of Airborne Measurements in Mali, West Africa

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Research Modification

- West Africa has experienced sever droughts in the recent past.
- There is a desirer to protect and promote agriculture activities.
- Develop methods of adapting operational programs from other locations to the Mali region.
- Advance local scientific knowledge and infrastructure.

Measurement Hypothesis

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





Airborne Measurement Objectives

- Determine the variability of aerosol and cloud properties in Mali and how they compare to other regions.
- Understand the natural precipitation formation processes in Mali.



Droplet Measurement Technologies Cloud Condensation Nuclei Counter

Aircraft Instruments

University of Wyoming Cloud Condensation Nuclei Counter



Forward Scattering Spectrometer Probe Passive Cavity Aerosol Spectrometer Probe

Laboratory Comparison UWyo CCN Counter DMT CCN Counter



University of North Dakota Graduate Student, Gökhan Sever, conducted lab test to compare the performance of the University of Wyoming (Uwyo) Cloud Condensation Nuclei (CCN) counter and the Droplet Measurements Technologies (DMT) CCN counter.

CCN Counter Comparison



Ratio of the 1 % supersaturation CCN concentration as measured by the UWyo Cloud Condensation Nuclei (CCN) counter and DMT CCN counter while sampling ammonium sulphate aerosol.

2006 Aircraft Flight Tracks



During 2006, a total of 22 flights (34 hours) were conducted with a Cheyenne instrumented aircraft (N233PS) between July 24 and August 30.

2007 Aircraft Flight Tracks



During 2007, a total of 30 flights (82.5 hours) were conducted with a Cheyenne instrumented aircraft (N233PS) between July 20 and September 30.

2008 Aircraft Flight Tracks



During 2008, a total of 9 flights (20.1 hours) were conducted with a King Air 200 instrumented aircraft (N811ND) between September 22 and October 8.

2006 Cloud Concentration



The 1 Hz FSSP ambient cloud droplet concentration versus pressure altitude for all Mali 2006 measurements with concentrations above 50 #/cm³.

2007 Cloud Concentration



The 1 Hz FSSP ambient cloud droplet concentration versus pressure altitude for all Mali 2007 measurements with concentrations above 50 #/cm³.

2008 Cloud Concentration



The 1 Hz FSSP ambient cloud droplet concentration versus pressure altitude for all Mali 2008 measurements with concentrations above 50 #/cm³.

2007 Liquid Water Content



Histogram of the LWC for all Mali 2007 measurements (1 Hz) where the cloud droplet concentration was above 50 #/cm³ and the temperature below 0 °C.

2008 LWC Example

08_10_08_15_30_36.wmi 8 6 Hot Wire Probe LWC [g/m³] 4 2 0 -2 15:40:00 15:50:00 16:00:00 16:10:00 16:20:00 16:30:00 Time [UTC]

Example of the noise on the DMT hotwire probe (25 Hz) from the October 8, 2008 Mali research flights.

2007 LWC Example



Example of the noise on the DMT hotwire probe (1 Hz) from the August 4, 2007 Mali research flights.

Typical 2008 Hotwire Noise



Example of the typical type of (random) noise observed on the DMT hotwire probe from the April 8, 2009 Saudi Arabia research flights.

Hotwire Noise Change

09_04_09_12_32_25.king.raw 2 Hot Wire Probe LWC [g/m³] 12:50:00 13:05:00 13:20:00 13:35:00 13:50:00 14:05:00 14:20:00 Time [seconds]

Example of the noise, with rapid jump, observed on the DMT hotwire probe from the April 9, 2009 Saudi Arabia research flights.

Conclusions

- The cloud droplet concentration observed in 2007 were much lower than the concentrations observed in 2006 and in 2008 (measurements limited end of wet season).
- Based on our conceptual model, the microphysical difference observed in Mali indicate that different seeding methods may be best applied at different times.
- The Hot Wire probe had a very large amount of noise during 2008 season.
- The noise on the Hot Wire probe was not present during 2007; however, it is present on other field projects (POLCAST², Saudi Arabia).

Future Work

- Finish the quality assurance of the complete 2006, 2007 and 2008 Mali data set.
- Fully analyze the data set in terms of year to year variability and try to related the observed variability to external forcing.
- Determine the effect that the observed year-to-year variability has on precipitation and the opportunities for cloud seeding.

Future Analysis



Hotwire Voltage Power Spectrum



Example of the typical type of (random) noise power spectrum from the DMT hotwire probe from the April 8, 2009 Saudi Arabia research flights.

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).

Quality Control Quality Assurance







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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.	445±157 #/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	Time	
Australian Coast	120 #/cm ³	
North Atlantic Ocean	145-370 #/cm ³	
High Planes, Montana	290 #/cm ³	
Australia, Africa, USA	600 #/cm ³	
High Planes, 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 Condensation Nuclei (CCN) concentrations (black) and Optical Particle Counter (OPC) concentrations (red) measured east of Bamako on September 8, 2007 near cloud base.



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.