Session: Cloud Measurement and Parameters
Presentation: Poster

AN OVERVIEW OF THE COMPLEX LAYERED CLOUD EXPERIMENT (CLEX-5) FIELD CAMPAIGN DURING THE PERIOD NOV-DEC 1999

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ABSTRACT

The CLEX addresses a better physical understanding of the morphology of extensive layers of non-precipitating clouds in the middle and upper troposphere. The DoD Center for Geosciences, at the Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, is now entering the second year of it's 4-year phase III research effort. During this new phase, CIRA is continuing to expand it's phase II CLEX field program to gather and process a unique dataset for the investigation of non-precipitating mid-level clouds. A coordinated land, air, and space-based data collection produced a unique research data set during phase II. Data were collected from the NASA DC-8 airborne 95-GHz cloud radar, the U. Wyoming King Air *insitu* microphysical collection systems, GOES, DMSP, and AVHRR meteorological satellites, Penn State Univ. 94-GHz cloud radar, and the Desert Research Inst. Mobile Microwave Radiometer, and a wide range of ground based systems at the Oklahoma ARM-CART site. In November-December of 1999, CLEX-5 collected another unique data set with the addition of the SPEC CPI instrument aboard the UND Citation. The focus of CLEX-5 was to sample mixed-phase mid-level clouds. This paper will present a brief summary of data collected during the CLEX-5 field campaign.

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1. INTRODUCTION

The Center for Geosciences recently completed the fifth in an ongoing series of field programs connected with the Complex Layered Cloud Experiment (CLEX). The motivation for CLEX is to further our understanding of the processes inherent to the formation, maintenance and dissipation of mid-level, non-precipitating mixed phased clouds. A better understanding of mid-level clouds has many applications for both military and civilian purposes. For example, during DESERT SHIELD/STORM, mid-level cloud systems often masked target areas and hampered use of electro-optic sensors and weapons systems. For civilian pilots, poorly forecast mid-level clouds often restrict flight visibility and can create icing hazards.

During CLEX-5 (5 Nov - 5 Dec 1999), the University of North Dakota Citation II research aircraft took in-situ microphysical measurements of mid-level clouds over the central and northern Great Plains of the United States. The experiment yielded four mixed-phase cloud cases from 11 Nov and 2, 4, and 5 Dec 99. The 11 Nov 99 case was a Lagrangian measurement over east-central Montana, while the December cases were sampled over the Atmospheric Radiation Measurement (ARM) site in north-central Oklahoma. We now describe the instrumentation, aircraft sampling strategy, and discuss preliminary research results from the 11 Nov case study. A

brief look at the subject of cloud glaciation will be performed. Finally, we will compare our measurements to those obtained in previous studies of this cloud type by several authors (Heymsfield, et al., 1991; Hobbs and Rangno, 1985, 1998; Paltridge, et al., 1986; Pinto, 1998; Tulich and Vonder Haar, 1998).

2. INSTRUMENTS

All of the measurements for CLEX-5 were obtained aboard the University of North Dakota's Citation II research aircraft. The basic instrumentation package measures temperature, dewpoint temperature, pressure, winds and cloud microphysics, along with aircraft position, attitude and performance information.

The associated CLEX-5 presentations at this conference focus on the cloud microphysical measurements, which were made with an array of Particle Measuring System (PMS) probes. These probes include the Forward Scattering Spectrometer Probe (FSSP), one-dimensional (1D-C) and two-dimensional (2D-C) optical array imaging probes, and the King Liquid Water Probe. All of these instruments are described in detail in NCAR's Research Aviation Facility Bulletin 24 (Baumgardner, 1981). We also employed the Cloud Particle Imager, a relatively new instrument, which records high- resolution (2.3 micron) digital images of cloud particles and processes them "on the fly" (Lawson and Jensen, 1998).

3. SAMPLING STRATEGIES

We used three basic flight patterns in CLEX-5: a racetrack pattern over a fixed point, Lagrangian racetracks, and a slow, spiral sounding. The racetrack is the basic sampling pattern. It involves a series of racetrack-shaped patterns at different altitudes. For a typical cloud of one kilometer thickness, we made five racetracks at different altitudes: one above cloud, three in-cloud, and another below cloud. Relative rapid descents were made between racetracks. Lagrangian racetracks were horizontally displaced from one another so the aircraft drifted with the horizontal wind at mid-cloud level. We sampled the wind speed and direction during the first mid-cloud racetrack and used this information to determine the horizontal position of subsequent racetracks, so that we stayed in the same relative cloud parcel for the duration of the measurement time.

Airspace restrictions prevented us from making Lagrangian measurements over the Southern Great Plains ARM site on 2, 4 and 5 Dec 99. Hence, we sampled clouds over the ARM site while centered at a fixed latitude and longitude. The racetracks were contained entirely within a reasonably homogeneous cloud region, with the longer dimension of the racetrack approximately 20 km in length. Above and below cloud racetracks were made far enough away from the cloud so they occurred entirely within clear air. The highest racetrack within cloud was made just enough below cloud top so the racetrack was entirely within cloud. Similarly, the lowest racetrack within cloud was just above cloud base. The racetracks within cloud were vertically separated by 200-500 m, depending on cloud depth. Due to limited upper air data, and the desire to get a vertical sample of the clouds, the aircraft performed slow spiral descents for a thermodynamic sounding. The aircraft sounding extended from about one kilometer above cloud top to a kilometer below cloud base, at a constant 300 meters per minute rate.

3. FUTURE WORK

Future work will center on refinement of the measurements taken thus far, such as retrieving liquid and ice particle sizes and concentrations. We will also be deriving products from the measurements, such as turbulent kinetic energy, potential temperature, lapse rates, radiative heating and cooling rates, etc. Some radiative transfer modeling, as well as cloud microphysical modeling, is also planned. Once the processing of the in-situ data is completed, the next step will to tie the in-situ measurements to satellite imagery, with the emphasis on developing improved forecasting techniques and remote sensing algorithms for mixed phase systems.

CLEX-5 Operation Summary:

Scheduled Intensive Observation Period (IOP) for 4-24 Nov 1999. Satellite, aircraft and ground-based observations over Oklahoma ARM CART and Colorado CSU-CHILL Radar Sites.

CLEX-5 Mission Priorities:

1. Aircraft + Satellite + Cloud over ARM CART
2. Aircraft + Satellite + Cloud over CHILL Radar
3. Aircraft over ARM CART
4. Aircraft over CHILL
5. Aircraft with Satellite Overpass
6. Aircraft and cloud
7. Cloud over ARM CART

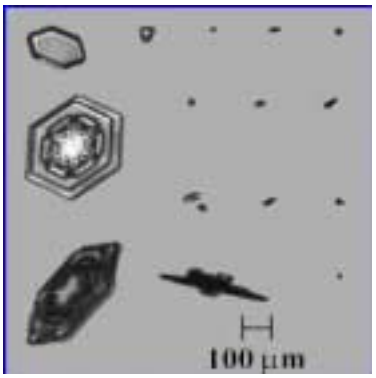
Experiment-Derived Fields:

1. Cloud base/height
2. Temperature/relative humidity profiles
3. Radiometric properties (above, in & below cloud)
4. Cloud liquid water and ice content ratio
5. Three-dimensional wind fields
6. Cloud entrainment/detrainment rates
7. Ice-particle growth habits
8. Cloud particle size & concentrations
9. Satellite observed cloud radiative and optical properties
10. Millimeter cloud radar parameters (dBZ, fall velocity, etc)
11. Cloud moisture and heat fluxes
12. Time rate of change of all quantities

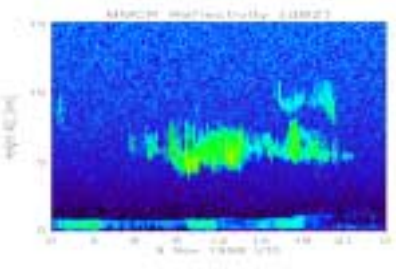
Instruments:

Citation Instrumented Aircraft (UND)

Cloud Particle Imager (CPI)
(sample imagery below)



35 Ghz Cloud Radar (ARM-CART site)
(sample Imagery below)



Several Papers in these proceeding talk about specific CLEX experiments and results (see Fleishauer *et. al.* and Larson, *et. al.*).

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Flight leg	Height	Temp	LWC	Stdev	W	Stdev	Wind spd	Wind dir	Cloud location
	(m AGL)	(°C)	(gm^{-3})	(gm^{-3})	(ms^{-1})	(ms^{-1})	(ms^{-1})	(deg)	
1	**4525**	**-8.31**	**0.000**	**0.0017**	**0.585**	**0.2274**	**23.8**	**268**	**Below**
2	**5279**	**-13.88**	**0.018**	**0.0238**	**1.174**	**0.7347**	**26.3**	**266**	**In Bottom**
3	**5608**	**-16.40**	**0.150**	**0.0635**	**0.593**	**0.6396**	**26.5**	**269**	**In Top**
4	**5794**	**-16.29**	**0.000**	**0.0012**	**1.020**	**0.2857**	**24.5**	**270**	**Above**
5	**5546**	**-15.76**	**0.114**	**0.0579**	**0.602**	**0.6799**	**26.1**	**270**	**In Middle**
6	**5434**	**-14.90**	**0.063**	**0.0306**	**2.170**	**0.8421**	**25.6**	**271**	**In Middle**
7	**5182**	**-12.71**	**0.003**	**0.0038**	**2.868**	**0.5020**	**25.5**	**271**	**In Bottom**
8	**4877**	**-10.02**	**0.004**	**0.0026**	**1.215**	**0.6269**	**25.8**	**273**	**Below**

Table 1. Mean microphysical and kinematic values for each leg of the 11 Nov 1999 cloud sample.