Report SDSMT/IAS/R-86/08 December 1986

T-28 DATA ACQUISITION DURING COHMEX 1986

By: Dennis J. Musil and Paul L. Smith

Prepared for:

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
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Final Report on Contract No. NAS8-36489

(NASA-CR-179001) T-28 DATA ACQUISITION DURING COHMEX 1986 Final Report (South Dakota School of Mines and Technology) 24 p N87-17426
CSCL 04B Unclas
G3/47 43857

Institute of Atmospheric Sciences

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ABSTRACT

This report summarizes the flight operations and data collected by the armored T-28 meteorological research aircraft during the summer 1986 COoperative Huntsville Meteorological EXperiment (COHMEX). Observations are available from 74 mid-level storm penetrations made during 14 research flights in the vicinity of Huntsville, Alabama. The data include temperatures, vertical winds, turbulence, hydrometeor spectra, and electric field measurements.

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1. INTRODUCTION

This report summarizes the data collected by the armored instrumented T-28 meteorological research aircraft during COHMEX 1986. COHMEX was a multi-component program (Dodge et al., 1986) centered in northern Alabama and including:

SPACE: The Satellite Precipitation And Cloud Experiment.

MIST: The MIcroburst and Severe Thunderstorm project.

FLOWS: FAA-Lincoln Laboratories Operational Weather Study.

The T-28 participation in COHMEX was arranged under the SPACE component of the experiment. The T-28 observations were intended to support investigations of hydrometeor and precipitation evolution in mature storms and studies of the relation of storm electrical activity to precipitation and dynamical processes. They were also intended to support investigations of experimental remote sensing systems working in the visible, infrared or microwave regions and carried on high altitude aircraft. For the latter, coincidence of observations from the T-28 with ones from the high altitude aircraft was a desirable goal in the flight plans.

The T-28 data are, of course, available for use in connection with MIST or FLOWS studies where appropriate. In return, data from those COHMEX components, particularly the CP-2 radar data, will be important in interpreting and analyzing the T-28 observations.

Specific objectives of the T-28 work were to acquire a data set comprising hydrometeor, temperature, vertical wind, electric field and other observations from the interiors of mature storms during COHMEX. The specific data set to be acquired include:

1. Hydrometeor spectra, from cloud droplet through hailstone sizes.

2. Profiles of vertical wind speed across the storms.

3. Electric field measurements from the storm interiors and environment.

4. Observations of other quantities such as cloud liquid water concentration, temperature, and turbulence.

Johnson and Smith (1980) described the basic instrumentation complement on the T-28. The data system was upgraded in 1982 to include an on-board minicomputer for controlling the data acquisition and recording functions. Some examples of recent studies of mature storms using T-28 data can be found in Heymsfield and Musil (1982); Musil et al. (1986); and Waldvogel et al. (1987).

2. SUMMARY OF FLIGHT OPERATIONS

Table 1 presents a summary of the T-28 flight operations conducted under this contract. The table indicates the date and total flight hours for each flight; for the research flights in Alabama, the specific takeoff and landing times are also given. Including test and ferry flights and the research flights in the Huntsville area, a total of 41.0 hours were flown under this contract.

The research was aided by the addition of a Particle Measuring Systems (PMS) 2D-P probe loaned by the University of Wyoming and two electric field mills made available by the NASA Marshall Space Flight Center (MSFC). The 2D-P probe was simply a plug-in substitute for the 2D-C probe normally carried. The installation of the field mills was completed during the hiatus in T-28 flight operations occasioned by a lightning strike that damaged the propeller deicing equipment during the 28 June flight. Replacement parts could not be located during the field program; after a couple of flight opportunities had been missed, a decision was made to resume operations, with subsequent flights restricted to altitudes below the 0°C isotherm to avoid potential icing problems.

The flights were directed from the CP-2 radar station. Information about the radar reflectivity structure of the storms to be penetrated, as well as the ancillary Doppler and differential reflectivity data, were used to select the desired storm penetration tracks. T-28 flight tracks derived from the FAA air route traffic control radars were received over telephone lines and inserted into the CP-2 PPI displays to determine the aircraft positions with respect to the storms. (Tracks for other COHMEX aircraft, including the high altitude ER-2 or U-2, were also presented.) Then guidance was passed by radio to the T-28 pilot to set up the storm penetrations. Delays in updating of the flight tracks, and occasional interruptions of the track data, frequently made it difficult to carry out the storm penetrations in an optimal manner.

The main further operational problem encountered was a flat tire on the nose wheel on landing after the 24 July flight. Our spare tire also proved to be defective, and no replacement could be located on short notice. We had already logged the expected number of research flights, an average of about one flight every three days being the usual T-28 experience, and were within a few days of the planned termination of the flight program in any case. Consequently, no further research flights were made. A temporary tire repair, adequate for the ferry flights back to Rapid City, was effected. Perhaps a couple of additional opportunities for data collection were missed as a result, but by this time the high altitude aircraft were no longer operating in the COHMEX area anyway. (The T-28 nose wheel has subsequently been modified to accommodate tubeless tires, which are more readily available.)

TABLE 1

SUMMARY OF T-28 1986 COHMEX FLIGHT OPERATIONS

Date	Flight No.	Times (CDT) Takeoff	Times (CDT) Landing	Hours	Remarks
10 June	433			1.3	Test at RAP.
11 June	434			1.0	Test at RAP.
16 June	435			1.6	Ferry RAP-YKN.
16 June	436			1.0	Ferry YKN-DSM.
17 June	437			1.5	Ferry DSM-SGF.
17 June	438			1.3	Ferry SGF-DYR.
17 June	439			0.9	Ferry DYR-HSV.
21 June	440	1515	1645	1.6	
23 June	441	1555	1800	1.6	
24 June	442	1550	1740	1.5	
26 June	443	1720	1900	1.5	
27 June	444	1530	1650	1.1	
28 June	445	1648	1835	1.9	Lightning strike to propeller.
08 July	446	1615	1755	1.8	2D-P probe installed.
09 July	447	1500	1645	1.8	2D-C probe re-installed; field mills on.
11 July	448	1600	1730	1.6	
14 July	449	1630	1800	1.8	2D-P probe re-installed.
16 July	450	1655	1835	1.7	CNN photos.
20 July	451	1645	1820	1.8	
22 July	452	1450	1635	1.8	
24 July	453	0650	0745	0.8	Tower fly-by.
24 July	454	1410	1555	1.8	Nose tire flat on landing.
28 July	455			1.6	Ferry HSV-BYH.
29 July	456			1.5	Ferry BYH-SGF.
29 July	457			1.9	Ferry SGF-LNK.
29 July	458			2.2	Ferry LNK-RAP.
04 Nov	459			0.5	Test at RAP.
05 Nov	460			0.6	Field mill calibration.

3. SUMMARY OF DATA COLLECTED

3.1 Overview

Table 2 provides a summary of the research data available from the T-28 flights. (Flights for instrument calibration purposes are omitted.) The time period during which storm penetrations were conducted, and the number of penetrations, are shown for each flight. Coordination of the T-28 operations with flights of the high altitude aircraft is indicated.

The T-28 carries two separate digital tape recorders. The NOVA minicomputer records all of the basic data (such as time, pressures, temperatures, aircraft attitude, and navigation data) and the hail spectrometer data on one recorder. The PMS probe data are recorded on a second tape, together with some duplicate recording of basic data to provide backup for the NOVA system.

The table indicates the availability of data from the main hydrometeor sensors. The PMS FSSP provides cloud droplet spectra, from which estimates of liquid water concentrations can be obtained. The PMS 2D-C or 2D-P probe, which requires the same slot in the T-28 wing pylon, covers different particle size ranges and was alternated as indicated. Cases where parts of the foil impactor data are missing are due to tearing of the foil during a flight. In our judgment that relates to hailstone impacts, or occasionaly to high liquid water concentrations jamming the foil drive system.

In addition to these data, a two-channel audio recording is made during each T-28 research flight. One channel records the pilot's voice comments during the flight; these are often helpful in correlating events during the flight (such as lightning strikes to the aircraft) with the recorded data. Transcriptions of those voice recordings from the COHMEX flights are available.

A microphone placed against the aircraft windscreen is connected to the second channel so that any sounds of hailstone impacts can be recorded. The impact sounds are usually masked by engine noise unless hailstones larger than about 1 cm in diameter are encountered. The hail encountered in the COHMEX flights was generally small, so that we have not noticed any impact sounds on the tapes thus far.

Supporting aircraft flight track data and radar observations of the storms are needed to provide a framework for orienting and interpreting the T-28 observations. The primary source of radar reflectivity data regarding the storms will be the CP-2, from which the T-28 flights were directed. The CP-2 also provided differential reflectivity observations, which can be useful in helping to distinguish among precipitation particle types. Doppler velocity data are also available from the CP-2 as well as from the other COHMEX Doppler radars, making it possible to conduct multiple Doppler studies of the wind fields for selected storms.

TABLE 2

SUMMARY OF 1986 COHMEX T-28 DATA AVAILABILITY

Date	Flight No.	Research Time Period	Coord. with ER-2/u-2	Storm Pens	NOVA Tape	PMS Tape	FSSP	2D-C/ 2D-P	Foil	Hail Sensor	Field Mills	Remarks
21 Jun	440	1628 1632		1	Y	Y	Y	C	Y	N	N	Hail Sensor Not Turned On
23 Jun	441	1651 1736	X	5	Y	Y	Y	N	Y	Y	N	2D-C Failed During Flt
24 Jun	442	1650 1722	X	4	Y	Y	Y	C[1]	Y	0	N	
26 Jun	443	1802 1841		6	Y	Y	Y	C[1]	Y	Y	N	
27 Jun	444	1602 1630		6	Y	Y	Y	C[1]	1 Pen Msg	0	N	
28 Jun	445	1725 1815	X	6	Y	Y	Y	C[1]	3 Pens Msg	Y	N	
08 Jul	446	1650 1740	X	5	Partial	Partial	N	N	1 Pen Msg	Partial	N	FSSP & 2D-P Failed During Flight
09 Jul	447	1540 1630		5	Y	Y	Y	C	Y	Y	Y	J-W Failed During Flt
11 Jul	448	1649 1715		3	Y	Y	Y	C	Y	0	Y	
14 Jul	449	1700 1750	X	6	Y	Y	Y	P[1]	1 Pen Msg	Y	Y	
16 Jul	450	1740 1755		2	Y	Y	Y	P[1]	Y	Y	Y	
20 Jul	451	1710 1810	X	9	Y	Y	Y	P[1]	1 Pen Msg	Y	Y	
22 Jul	452	1515 1620		8	Y	Y	N	P[1]	Y	0	Partial	FSSP Out
24 Jul	454	1435 1535		8	Y	Y	N	P[1]	4 Pens Msg	0	Y	FSSP Out

[1]Manual TAS setting of 100 m s^{-1} used.

C: 2D-C Probe
N: No
NA: Not applicable

P: 2D-P Probe
Y: Yes
0: No hail recorded

Flight track data are available from two sources: The FAA air route traffic control radar flight tracks and the VOR/DME data recorded on board the T-28. The FAA flight track data being archived at NASA MSFC are expected to be the more useful because they will be available directly in the same coordinate system as the CP-2 radar data. However, the on-board VOR/DME data are available as a backup and for cross checking with the FAA tracks.

3.2 Kinematic and Related Data

The kinematic data obtained by the T-28 permit calculations of vertical winds and turbulent energy dissipation rates. Kopp (1985) described the procedure used to estimate the vertical winds, while the method used to obtain the turbulence values is outlined in Sand et al. (1976). Figure 1 presents an example including vertical wind and turbulence values for Penetration No. 6 on the 14 July flight. The third trace from the top shows the calculated vertical velocity, while the bottom trace indicates the intensity of the turbulence. The maximum measured updraft speed of about 12 m s^{-1} is fairly typical of the stronger updrafts found in the COHMEX storms. The relatively uniform turbulence across the updraft is unusual compared to previous T-28 observations in other locations. More commonly, high turbulence values occur at the edges of updraft regions, with relatively lower turbulence inside the updrafts.

The kinematic observations are most useful when they can be related to other data about the storm, such as the aircraft microphysics or temperature data and radar observations of the storm. To illustrate this, Fig. 1 also shows values of the cloud liquid water concentration and the hailstone concentration (particles >5 mm in diameter) recorded during the same penetration. The top trace shows the hailstone concentration, while the second trace indicates the observed cloud liquid water concentrations. The coincidence of hailstones (or perhaps large graupel particles) and cloud liquid water in the updraft region provides an indication that particle growth is probably continuing in that region.

3.3 Hydrometeor Data

The hydrometeor sensors available for the T-28 cover the size range from cloud droplets through hailstones (with a gap in the range of approximately 50-100 μm). It is not easy to present the hydrometeor data in a concise summary form, but illustrative examples may be useful.

To start with the cloud droplets, two sensors provide relevant information. The Johnson-Williams (J-W) hot wire sensor gives values of cloud liquid water concentration, while the Particle Measuring Systems (PMS) FSSP, furnished by the NCAR Cloud Systems Division, measures droplet size spectra from which liquid water concentration values can be calculated. The FSSP obtains a spectrum for each second

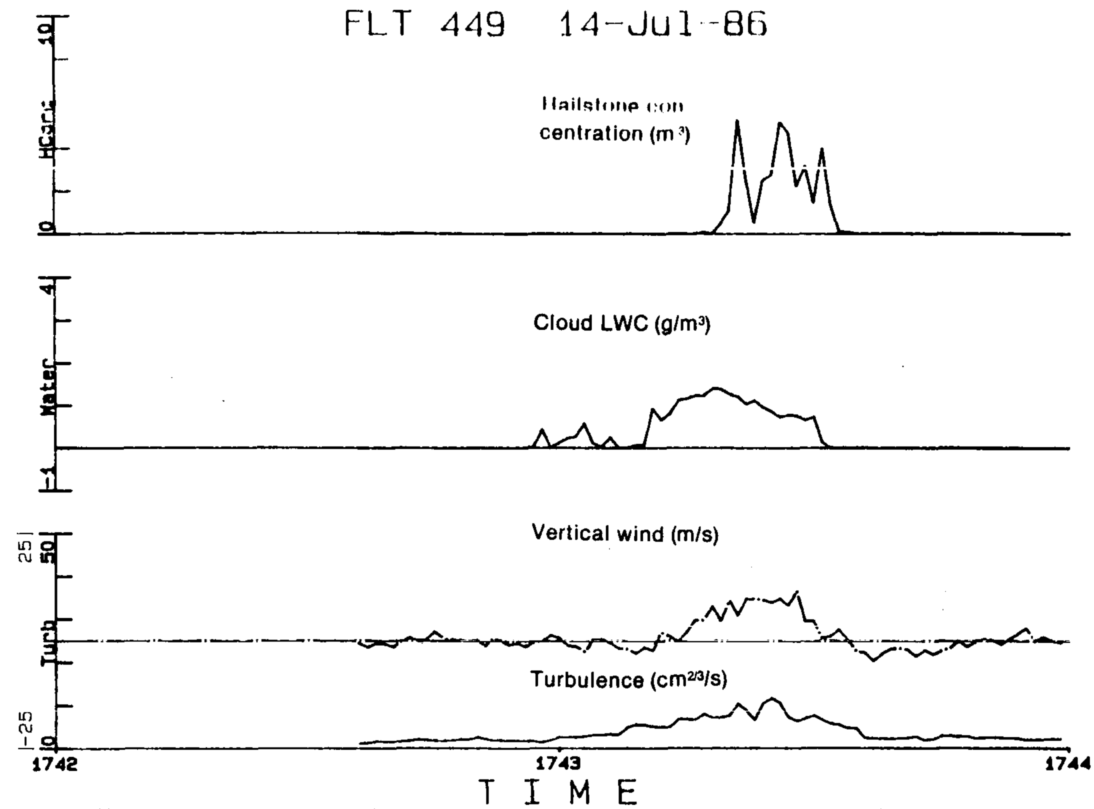

Fig. 1: Time plot of selected data from the sixth T-28 penetration on 14 July 1986. Hailstone concentrations are from the hail spectrometer and cloud liquid water concentrations (LWC) from the FSSP. The time scale can be converted to an approximate distance scale using the nominal T-28 flight speed of 0.1 km/s.

of flight; Fig. 2 shows a composite spectrum covering 18 s (or about 1.8 km of flight path) in the strong updraft region of Penetration 6 on 14 July (the same penetration as is shown in Fig. 1). The mode droplet diameter was about 15 μm and droplets >40 μm in diameter were observed. The largest droplet size sensed by the T-28 FSSP was 45 μm, but it is likely that some even larger droplets were present. The total droplet concentration was rather high, nearly 700 cm^{-3}.

The J-W sensor does not respond well to droplets larger than about 30 μm in diameter. As larger droplets appear in the spectra, the FSSP estimates of liquid water concentration are likely to be more accurate. They are used wherever available (as in Fig. 1), with the J-W values (which were usually somewhat lower) used for backup.

The PMS two-dimensional imaging probes were oriented on the T-28 to provide vertical silhouettes of the particles. The PMS 2D-C probe, also furnished by the NCAR Cloud Systems Division, covers the size range from about 100 μm to 1 mm. The exact limits are not sharply

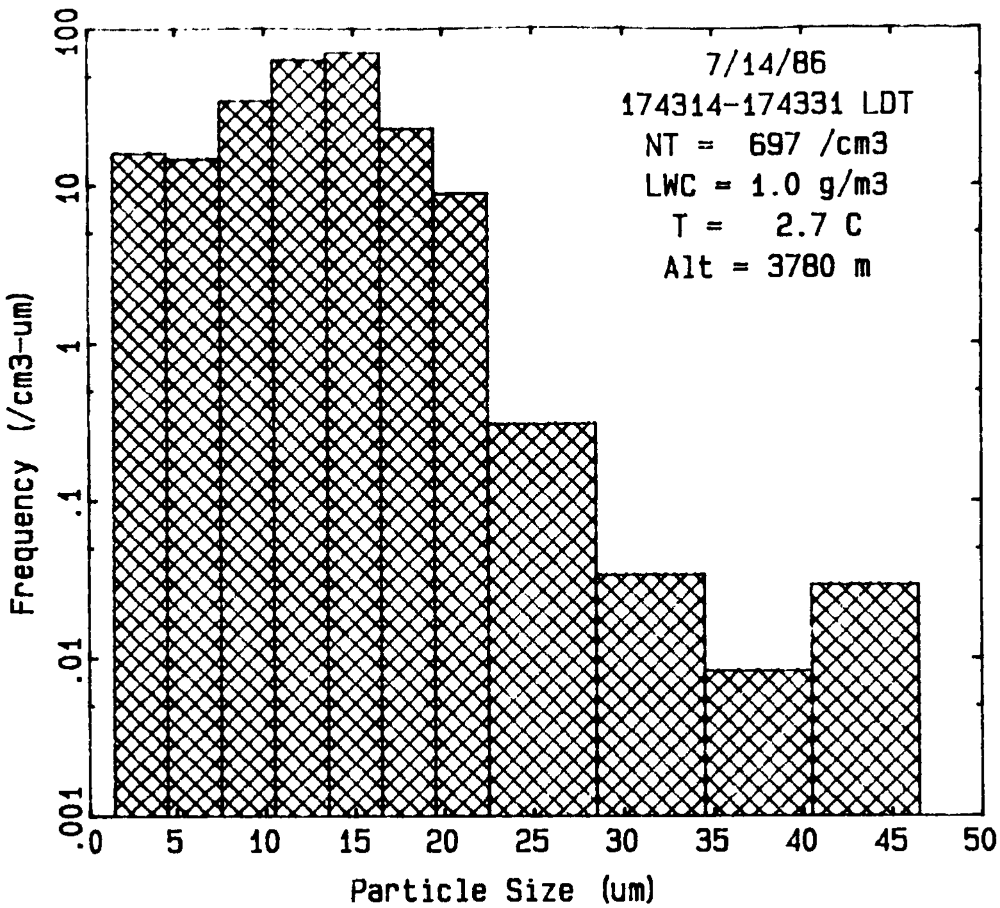

Fig. 2: Composite FSSP cloud droplet size spectrum for an 18-s period in the updraft region of Penetration No. 6 on 14 July 1986. N_T = average droplet concentration (cm^{-3}); LWC = liquid water concentration (g/m^3); T = observed temperature (°C); Alt = flight altitude (m above MSL).

defined because the pixel size corresponds to about 30 μm and reliable identification of small particles requires images at least a few pixels across. At the upper end of the range, the aperture of the 2D-C is 1 mm across, but partial images of larger particles are often adequate to permit identification and size determination.

The PMS 2D-P probe, provided by the University of Wyoming, covers the size range up to 6.4 mm with a pixel size of 0.2 mm. Again, a minimum image size of a few pixels is required for reliable identification and sizing. Figure 3 shows a sample of the 2D-P image data from the same region from which the examples in Figs. 1 and 2 were taken. The presence of particles 2-3 mm in size is conspicuous, but many smaller particles are also present. Some of the particles have irregular outlines and appear to be ice particles, but it is hard to see where they would have originated as these observations were taken in an updraft region at about +2.5°C. Images of the usual "streakers" and other artifacts are also evident.

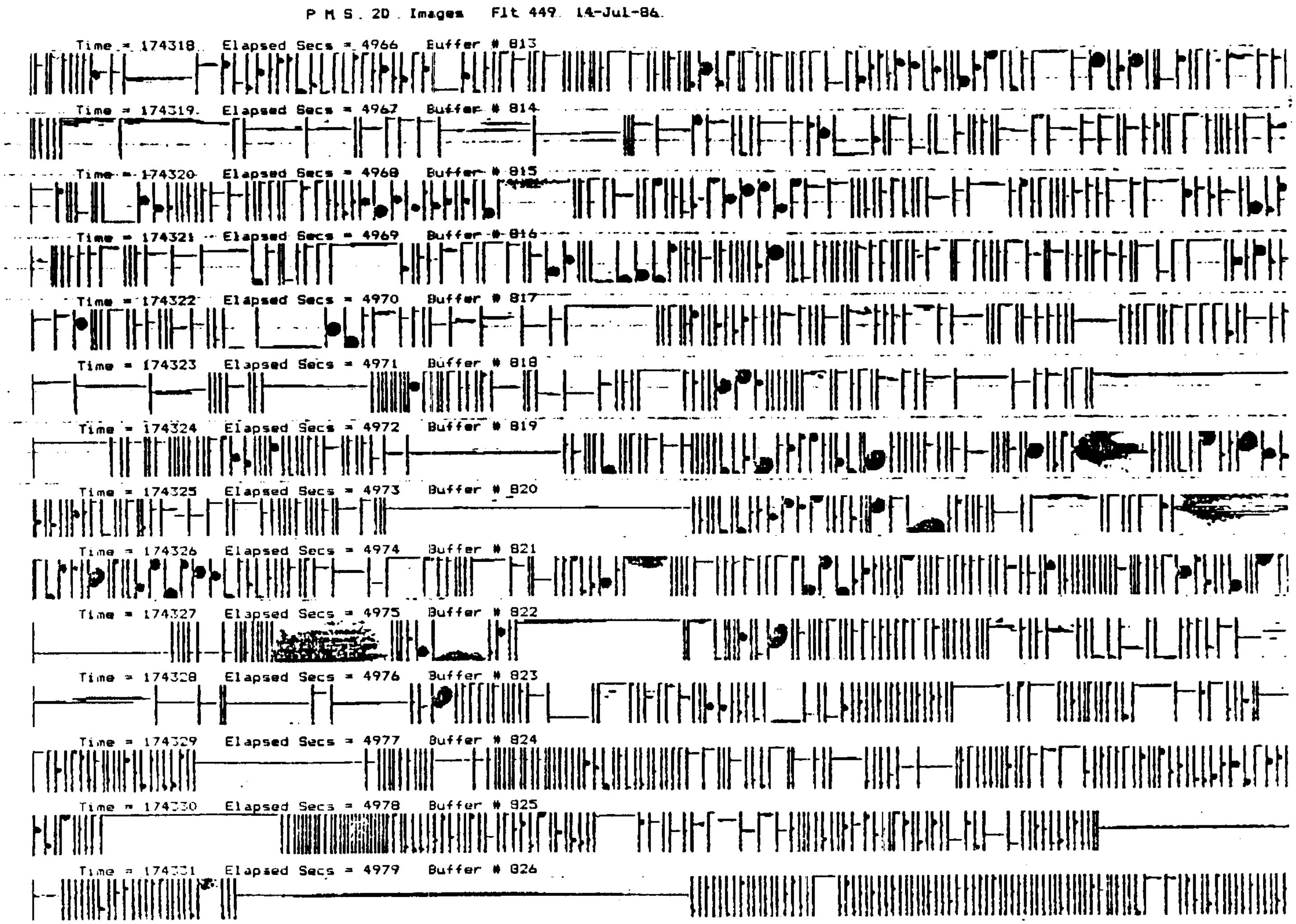

Fig. 3: Example of PMS 2D-P particle images from a 14-s period in the main updraft region of Penetration No. 6 on 14 July 1986. The height of each strip corresponds to the 6.4-mm widtn of the instrument sampling aperture.

The foil impactor data cover about the same size range as the 2D-P observations, but are much more tedious to analyze in detail. However, they do give a good visual impression of particle concentrations and better indications when centimeter-sized particles are present. For example, when the T-28 flew in regions with reflectivity factors of 50-60 dBz, we obtained from the foil data the impression that the reflectivity was due to relatively high concentrations of particles in the size range 4-8 mm. That tends to be confirmed by the hail spectrometer data, which with only a few exceptions indicated no particles larger than 10 mm in size. (The largest particle recorded on Penetration 6 of the 14 July flight was 9 mm, although larger particles were recorded during the first penetration on that day.)

3.4 Electric Field Mill Data

During the COHMEX field project, the T-28 was equipped for the first time with two electric field mills. The instruments were mounted on the aircraft in a vertically opposed orientation, one on the canopy and one on the lower bay door. A high voltage power supply was also installed with discharge points to permit charging the aircraft for calibration purposes.

The mills were carried on seven research flights, starting with 9 July and continuing through the end of the COHMEX season. Preliminary analysis of the data shows that significant electric field strengths, ranging up to approximately -100 KV/m, were measured on four of the flights. During the remaining flights only weak fields, on the order of a few KV/m, were recorded. The instruments performed quite well during these first flights into the interiors of mature storms, with only one failure occurring during the second penetration of the 22 July flight. Analysis of the calibration flight data (obtained on 5 November) is still being carried out to establish the proper scale factors for the field mill data.

3.5 Tower Fly-by

The T-28 made a series of low-level passes by an instrumented tower on the Redstone Arsenal, on the morning of 24 July, for instrument calibration purposes. The plan had called for a total of 9 passes, 3 each at 120, 140, and 160 knots indicated airspeed; however, ground personnel did not arrive at the tower to turn on the recording equipment until after the 4th pass. Since there was no air-to-ground communication with the tower, this was unknown until after the flight. Nevertheless, data from the remaining 5 passes suggest that the T-28 pressure and temperature probes were working properly. Pressure measurements from the T-28 averaged <0.5 mb difference from the tower data, while the temperature measurements were within about 0.5°C of each other. A closer examination of the fly-by data will be accomplished in future analysis work.

3.6 General Impressions Regarding the Data

The T-28 data gathered during COHMEX are summarized by penetration in Table 3. Average temperatures during the COHMEX flights ranged between -7.5°C and +5.5°C. This difference was mostly equipment related; early penetrations were accomplished at temperatures below freezing and those later in the season were accomplished at temperatures warmer than freezing because of the propeller deicing device malfunction. Maximum equivalent potential temperature ranged between 339-347, but usually the values were quite uniform during each penetration. This suggests that the COHMEX storms were quite well mixed. This contrasts with High Plains observations that tend to show very high values in the updraft regions, with low values in other regions of the storms.

The vertical winds were found to be generally weak, the average maximum (updraft) being less than 4 m s^{-1}. Typical maxima were less than 5 m s^{-1} and the absolute maximum was 19 m s^{-1}, observed on 23 June. Downdrafts (minima) were typically between -5 to -10 m s^{-1}.

The updraft regions in the COHMEX storms were generally small, but were usually very turbulent (turbulence values greater than about 9 $cm^{2/3}$ s^{-1} correspond to extreme turbulence). Although values that high were frequently found in High Plains storms, the COHMEX storms usually did not have the additional problem of large hail. Table 3 shows that hail was infrequent, occurring in less than 25% of the penetrations, and the hailstones were usually small. Even in some of those cases, one may question whether some of the particles observed with the T-28 hail sensor could have been large liquid drops; this possibility appears to have some support in the 2D-P data.

The maximum cloud liquid water concentrations (LWC) for each penetration were taken from FSSP data, except for 8 July, 22 July, and 24 July when that device failed. Values from the Johnson-Williams sensor were substituted in those cases. The FSSP observations tended to be slightly larger than those measured by the J-W, but usually they were quite close. In any case, the LWC values were found to be very low, typically much less than adiabatic values.

TABLE 3

SUMMARY OF DATA BY PENETRATION

Date	Flt	Pen	-----TIMES----- In [CDT]	Out [CDT]	Temp [°C]	Max θe [K]	Vert Vel. Max/Min [m/s]	Max TURB [$\varepsilon^{1/3}$]	Max LWC (FSSP) [g/m^3]	Max Hail [mm]
21 Jun	440	1	162852	163142	-6.5	344	10/- 9	13	2.8	UNK
23 Jun	441	1	165130	165211	-6.5	341	0/- 6	10	1.5	--
		2	165659	170317	-7.0	341	3/- 6	7	0.8	--
		3	171147	171542	-7.5	342	5/- 6	17	1.5	--
		4	172700	172913	-6.5	344	19/-11	13	0.8	6
		5	173308	173541	-7.0	342	14/- 9	13	1.1	6
24 Jun	442	1	161527	161833	-1.8	344	10/- 8	14	1.9	--
		2	165649	165828	-7.0	340	2/- 4	4	0.2	--
		3	171432	171551	-7.0	341	1/- 4	4	0.1	--
		4	171944	172139	-7.0	340	2/- 5	5	0.5	--
26 Jun	443	1	180251	180342	-6.0	343	3/- 8	12	1.2	--
		2	181530	181711	-1.0	342	2/- 6	9	1.2	5
		3	182015	182147	-1.5	343	8/- 5	10	1.4	--
		4	182853	183022	-0.5	342	5/- 4	10	0.7	9
		5	183426	183626	-1.0	340	3/- 6	8	0.7	--
		6	184005	184059	-1.0	341	0/- 5	7	0.4	--
27 Jun	444	1	160233	160322	-6.0	340	0/- 8	8	0.6	--
		2	160628	160732	-5.5	342	3/- 8	9	1.0	--
		3	161241	161604	-6.0	342	4/- 9	13	1.7	--
		4	162120	162250	-6.0	341	6/- 9	10	0.6	--
		5	162315	162408	-6.0	342	4/- 6	7	1.8	--
		6	162818	162910	-5.5	342	1/- 5	8	1.2	--
28 Jun	445	1	172529	172936	-6.5	340	1/- 5	4	0.3	5
		2	173421	174004	-6.0	345	11/- 5	10	1.4	7
		3	174824	175120	-6.5	341	4/- 5	9	1.0	--
		4	175843	180131	-6.0	342	2/- 6	7	0.4	6
		5	180538	180755	-6.0	342	4/- 8	7	0.3	--
		6	181143	181451	-6.0	343	2/- 4	5	0.4	--
8 Jul	446	1	165044	165118	3.5	342	2/- 4	8	0.9[1]	--
		2*	165930	170248	3.0	346	4/- 9	9	0.8[1]	9
		3	171455	171852	M	M	M	M	M	M
		4	172455	172800	M	M	M	M	M	M
		5	173338	173737	M	M	M	M	M	M

* - Tape stopped at 170057, ~50 s before end of penetration.
M - Missing data.
\+ - Ball pressure data used.
-- - Hail sensor worked; no hail observed.
1 - FSSP bad; Johnson-Williams value used.

TABLE 3

SUMMARY OF DATA BY PENETRATION (continued)

Date	Flt	Pen	-----TIME------ In	Out	Temp	Max θe	Vert Vel. Max/Min	Max TURB	Max LWC FSSP	Max Hail
			[CDT]	[CDT]	[°C]	[K]	[m/s]	$[\epsilon^{1/3}]$	[g/m^3]	[mm]
9 Jul	447	1	154146	154819	2.5	342	8/- 5	9	0.5	32
		2	155139	155248	3.0	343	2/- 5	7	1.4	7
		3	161108	161134	3.0	342	- 1/- 4	3	0.3	--
		4	161518	161915	3.0	342	4/- 7	8	1.0	13
		5	162224	162340	2.0	341	3/-10	4	1.4	--
11 Jul	448	1	164848	165213	3.5	344	1/- 4	3	0.4	--
		2	165550	165732	3.0	343	2/- 3	3	0.6	--
		3	170524	170946	3.5	345	1/- 3	3	0.5	--
14 Jul[+]	449	1	170154	171156	1.5	344	17/- 9	17	1.2	32
		2	171735	171912	1.5	339	5/- 4	5	0.1	--
		3	172523	172736	1.5	339	4/- 5	8	0	--
		4	173105	173302	1.5	341	2/- 4	7	1.0	--
		5	173706	173943	1.5	341	9/- 8	10	1.8	5
		6	174236	174543	1.5	340	12/- 5	12	1.4	9
16 Jul	450	1	174022	174357	4.0	345	2/- 8	9	0	--
		2	175042	175359	3.0	345	0/- 6	8	0	8
20 Jul	451	1	171057	171113	5.5	345	0/- 6	5	0.2	--
		2	171941	172154	5.0	346	5/- 7	11	1.2	6
		3	172839	173106	5.0	345	1/- 5	5	0.3	--
		4	173753	174136	5.0	346	3/- 6	8	1.2	--
		5	174408	174518	5.5	346	0/- 5	5	0.9	--
		6	174839	174950	5.5	345	0/- 5	6	0.2	--
		7	175146	175602	5.5	346	2/-11	6	0.4	6
		8	175638	180050	5.5	347	2/- 7	5	0.4	--
		9	180318	180444	5.5	347	2/- 6	6	1.0	--
22 Jul	452	1	151701	151837	5.5	346	2/- 4	4	0.3[1]	--
		2	152252	152337	4.5	343	0/- 6	8	1.2[1]	--
		3	152720	152903	5.5	345	6/- 4	6	1.4[1]	--
		4	153157	153323	5.0	344	2/- 6	6	0.9[1]	--
		5	153829	154106	1.5	342	6/- 6	12	1.3[1]	--
		6	154605	154939	1.0	342	6/- 7	8	1.3[1]	--
		7	155816	160031	1.0	344	10/- 5	8	1.2[1]	--
		8	161553	161820	2.0	342	3/- 3	4	0[1]	--
24 Jul	454	1	143513	143912	1.5	343	3/- 4	9	1.6[1]	--
		2	144301	144658	3.5	343	2/- 5	5	0.3[1]	--
		3	145005	145153	4.0	344	2/- 4	4	0.3[1]	--
		4	150815	150958	3.5	344	4/-10	9	1.6[1]	--
		5	151357	151553	5.5	345	4/- 3	8	1.6[1]	--
		6	152252	152426	1.5	343	1/- 5	8	0.9[1]	--
		7	152745	152947	4.0	344	1/- 4	5	0.3[1]	--
		8	153255	153431	3.5	343	1/- 4	4	0.4[1]	--

4. ANALYSIS PLANS

Plans for more detailed analysis of the T-28 COHMEX data, together with relevant corollary data from other sources, are being formulated. Such detailed analysis of the T-28 data was not part of the objectives of the present contract. This analysis will be carried out under separate funding arrangements.

The T-28 operated on the following "core SPACE operational days" thus far identified:

23, 24, 28 June

8, 14, 20 July

As shown in Table 2, at least rough coordination of the T-28 storm penetrations with overflights of the high-altitude aircraft occurred on all six of those days. Consequently, those days will probably receive the highest priority in our data analysis work. Table 4 shows our ranking of those six core days, in terms of the quality of the T-28 data available.

TABLE 4

RANKING OF COHMEX CORE DAYS

Date	Rank	Remarks
14 July	1	Good day, hail observed.
28 June	2	Lightning strike, possible small hail.
20 July	3	Many penetrations, possible small hail.
24 June	4	Tracking problems.
23 June	5	High concentration of particles on foil, but no 2D-C data.
8 July	6	Data system failed during Penetration 2; also no 2D-P data.

Coordination with other COHMEX investigators in the analysis work has already been initiated. For example, T-28 data for the 22 July flight have been sent to Dr. V. N. Bringi, principal investigator on the CP-2 observations, for comparison with the radar data. Similar comparisons between CP-2 and T-28 data are available from the CCOPE project in Montana (Bringi _et al._, 1983). Initial comparisons of some of the T-28 microphysics data with numerical cloud model results obtained by F. J. Kopp of Dr. H. D. Orville's Numerical Modeling Group at the South Dakota School of Mines and Technology have also been made.

An abstract entitled "Cloud Microphysical Measurements in Support of COHMEX," by V. Keller, D. Musil and P. Smith, has been accepted for the program of the Second Airborne Science Workshop (see Appendix B). The paper will present an initial summary of some of the T-28 COHMEX observations, with comparisons to similar observations from other geographic locations.

ACKNOWLEDGMENTS

We appreciate the support and assistance of Dr. James F. Arnold and Dr. Vernon Keller of the NASA Marshall Space Flight Center (MSFC) during the course of this work. Dr. Hugh Christian of MSFC and Dr. John H. Helsdon, Jr., of the South Dakota School of Mines and Technology, aided with the installation and calibration of the electric field mills. We express thanks to the Cloud Systems Division of the National Center for Atmospheric Research for providing the PMS FSSP, 2D-C and data acquisition system, as well as to the University of Wyoming for loaning us the 2D-P probe for use in COHMEX. The National Science Foundation provided basic funding for the T-28 aircraft and technical supporting staff under Grant No. ATM-8602861.

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APPENDIX A

LIST OF SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY PERSONNEL

Dennis J. Musil Paul L. Smith	Principal Investigators

Kenneth R. Hartman -- Computer Programmer

Gary N. Johnson -- Engineer

Jon E. Leigh -- Mechanic/Technician

Norman R. Vine -- Pilot

John H. Helsdon, Jr. -- Scientist (Atmospheric Electricity)

APPENDIX B

CLOUD MICROPHYSICAL MEASUREMENTS IN SUPPORT OF COHMEX

V. Keller

NASA/MSFC
Huntsville, Alabama 35812

D. Musil and P. Smith

South Dakota School of Mines and Technology
Rapid City, South Dakota 57701-3995

ABSTRACT

As part of the 1986 Cooperative Huntsville Meteorological EXperiment (COHMEX) a cloud physics instrumented T-28 aircraft was used in conjunction with multiple ground based Doppler radars to characterize hydrometeors and updraft structure within developing summertime cumulus and cumulonimbus cloud systems near Huntsville, Alabama.

Particle characterization instrumentation aboard the T-28 aircraft included a Particle Measuring Systems (PMS) Forward Scattering Spectrometer Probe (FSSP), a PMS 2D Cloud Probe and a PMS 2D Precipitation Probe, as well as a hail spectrometer and a foil impactor. Hydrometeor spectra were obtained in the interior of mature thunderstorms over the size range from cloud droplets through hailstones. In addition, vertical wind speed, temperature, Johnson-Williams (JW) liquid water content and electric field measurements were made throughout the clouds. Significant microphysical differences exist between these clouds and summertime cumulonimbus clouds which develop over the Central Plains. One notable difference in clouds displaying similar radar reflectivities is that COHMEX hydrometeors are typically smaller and more numerous than those observed in the Central Plains. This has important implications for remote sensing measurements.

The COHMEX cloud microphysical measurements represent "ground truth" values for the remote sensing instrumentation which was flown over the cloud tops at altitudes between 60,000 and 70,000 ft aboard NASA U-2 and ER-2 aircraft. They are also being used jointly with a numerical cloud model to assist in understanding the development of summertime subtropical clouds.