TEXAS HIPLEX
INTERIM PROGRESS REPORT

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16. ABSTRACT
This report includes descriptions of the continuing evaluation of 1976-1978 Texas HIPLEX data and an evaluation of the 1980 operational season. It includes progress reports on mesoscale data evaluation, investigation of cloud microphysics, entrainment, analysis of satellite and precipitation gage data, radar data analyses and interpretation, and operational cloud-sampling and seeding activities.

Unquestionable relationships are revealed between mesoscale convective systems and the Constant Azimuth Reflectivity Maps (CAZM's) prepared from the Skywater radar data. Terrain-induced vertical motion is shown to have magnitudes similar to those induced by mesoscale boundary layer convergence. Skywater radar data provided the basis for detailed Z-R relationship evaluation and indicated that frontal effects must be incorporated into any Case Study analysis of the July 17, 1979 convective event. Also, 1976-1978 digitized M-33 radar data tapes show, among other things, that mesoscale convergence or lifting is a prerequisite for line formation.

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P.O. Box 13087, Capitol Station
Austin, Texas 78711

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October 10, 1980

TEXAS DEPARTMENT OF WATER RESOURCES

1700 N. Congress Avenue
Austin, Texas

October 10, 1980

Dr. Bernard A. Silverman, Chief
Office of Atmospheric Resources Research
Water and Power Resources Service
Building 67, Denver Federal Center
Denver, Colorado 80225

Dear Dr. Silverman:

Re: Texas HIPLEX Interim Progress Report

In compliance with Amendatory Agreement No. 1 to Contract No. 14-06-D-7587 between the WPRS and the Department, we hereby submit twenty (20) copies of the interim progress report for the Texas High Plains Cooperative Program (HIPLEX). The report discloses and explains all Texas HIPLEX work performed and results achieved during the interim period April 1, 1980 through September 30, 1980.

This report consists of a compilation of individual reports prepared by the Department and each of the Texas HIPLEX participants--Texas A&M University, Texas Tech University, the Colorado River Municipal Water District, Meteorology Research, Incorporated, and North American Weather Consultants. The individual reports consist of two sections which: (1) describe all activity for the Report Period; and, (2) outline the Work Planned for the next report period. A Table of Contents and a List of Tables are provided at the beginning of the report for order and ease of reference. An Executive Summary is included for introduction and orientation purposes.

Please direct any questions concerning this report, or the need for further information, to the Department's Weather Modification and Technology Section of the Planning and Development Division.

Sincerely,

Herbert W. Grubb

Herbert W. Grubb
Director, Planning and
Development Division

P.O. Box 13087 Capitol Station • Austin, Texas 78711 • Area Code 512/475-3187

EXECUTIVE SUMMARY

In 1974 the U.S. Water and Power Resources Service (WPRS), Office of Atmospheric Resources Research (alias U.S. Bureau of Reclamation, Office of Atmospheric Resources Management) entered into a cooperative cost-sharing agreement with the Texas Water Development Board, one of three predecessor water agencies to the Texas Department of Water Resources (TDWR), for the purpose of conducting a long-term, comprehensive atmospheric research and weather modification development program known as HIPLEX. The overall goal of the HIPLEX program is to "...establish a verified, working technology and operational management framework capable of producing additional rain from cumulus clouds in the semi-arid Plains States." In order to achieve this goal, three field-research sites in the U.S. High Plains region were established. One site is located in Montana, another is situated in Kansas, and the third site is the Big Spring-Snyder area of West Texas. The Texas HIPLEX site is managed by the TDWR under the overall guidance of the WPRS.

To date, the objective of the Texas HIPLEX program has been to understand more fully the cloud and precipitation processes associated with natural and seeded clouds which develop in the High Plains of Texas. This objective is being accomplished through the cooperative efforts of the following institutions and organizations:

Water and Power Resources Service
Texas Department of Water Resources
Colorado River Municipal Water District
Texas A&M University (Department of Meteorology)
Texas Tech University (Atmospheric Science Group)
Meteorology Research, Incorporated
North American Weather Consultants, Incorporated

This report presents the work performed by these organizations during the six-month period from April 1 through September 30, 1980.

The report discusses the Texas Department of Water Resources' continuing role as manager and administrator of the Texas HIPLEX Program. The Department negotiated, awarded, and/or administered five subcontracts with other Texas HIPLEX participants during the report period. The Department helped develop the 1980 field operations plan and provided staff meteorologists who served as Project Manager, Field Operations Manager and Project Forecaster.

The services provided by the Colorado River Municipal Water District (CRMWD) are discussed. In brief, the CRMWD maintained and operated an extensive network of recording and non-recording raingages and provided the services of a radar meteorologist. Additionally, the CRMWD also provided a multi-engine aircraft for the purpose of performing cloud sampling and seeding flights.

The use of Texas A&M University's network of upper-air meteorological measuring instruments (rawinsondes) is discussed. Rawinsonde data are needed to determine the interrelationships between cloud development and the environment. (Results of previous years' analyses are also presented.)

Texas Tech University's work with satellite and precipitation gage data is presented, along with a discussion of Skywater radar data evaluation. Cloud characteristics derived from satellite imagery and radiance data are discussed, as well as techniques to extract quantitative cloud information--such as cloud top temperature--from the radiance data. Plans for additional study of real-time LASERFAX satellite photographs, which were collected in-house during the 1980 field program, are also discussed.

The results of work by North American Weather Consultants (NAWC) concerning the processing and statistical analysis of M-33 radar data for the 1976-1978 Texas HIPLEX field seasons are presented. Discussed are the findings of the radar-echo evaluation, showing frequencies of occurrence of "warm" and "cold" convective cells, time and area of cell occurrence with respect to synoptic features and the movement and changes which transpire during the cells' lives.

Meteorology Research, Incorporated (MRI) submitted their final report for work performed in the reduction of 1978 CRMWD Aztec aircraft cloud-base data. The raw data were first checked for continuity and then converted into engineering units. The converted data were next documented on magnetic tape as well as hard copy. Results of the evaluation are presented.

It is important that these data of West Texas summertime clouds and the environment be collected and studied to obtain an understanding of the cause and effect aspect of cloud behavior in seeded and unseeded cases. When this level of understanding is reached, the Texas HIPLEX Program may begin to verify predicted changes in seeded clouds and resultant rainfall in the Texas High Plains.

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SECTION I

WORK PERFORMED DURING THE PERIOD

April 1 - September 30, 1980

TEXAS DEPARTMENT OF WATER RESOURCES

LIST OF TABLES

Contract Administration

During the reporting period, April 1 to September 30, 1980, the Department administered five contracts through the Weather Modification and Technology Section of the Planning and Development Division in support of the 1980 Texas HIPLEX program (Table 1).

Table 1. Contracts Administered by the TDWR in Support of the 1980 Texas HIPLEX Program.

Contract No.	Organization	Period (mo-yr) Begin	End	Purpose
14-00027	Colorado River Municipal Water District	1-80	12-80	Operation of raingage network, rawinsonde and radar; equipping and operation of p-Navajo aircraft
14-00026	Texas Tech University	1-80	12-80	Analysis of 1979 and 1980 satellite data; 78-79 precipitation analysis; collection of 1980 radar data and real-time satellite imagery
14-00030	Texas A&M University	2-80	1-81	Analysis of 1979 mesoscale data, development of water budget models, determination of environmental response to convective activity, cloud physics, conduct field program and mesoscale-microphysical interaction
14-00013	North American Weather Consultants	8-79	10-80	Analysis of 1976-1978 Texas HIPLEX digital M-33 radar data
14-00025	Meteorology Research, Incorporated	12-79	8-80	Preparation of M-33 radar data for analysis; movement of M-33 equipment

Texas HIPLEX-related TDWR contracts amended during the reporting period include:

Contract No.	Agency	Purpose
14-00013	NAWC	Acquisition of better quality radar data for evaluation
14-00026	TTU	Extension of Texas HIPLEX field program
14-00027	CRMWD	Equip P-Navajo with FSSP cloud physics probe
14-00027	CRMWD	Extension of Texas HIPLEX field program
14-00025	MRI	Conversion of Aztec cloud data to engineering units
14-00030	TAMU	Inclusion of mesoscale modeling studies

On May 15, 1980 the TDWR Weather Modification Advisory Committee (WMAC) met in Big Spring at the Department's Texas HIPLEX Meteorological Facility. In addition to their regularly scheduled WMAC meeting the WMAC attended commencement exercises for the HIPLEX field season.

In July, the Department submitted five copies of the 1980 Texas HIPLEX Work Plan to WPRS. The Plan describes and consolidates the activities of each participant organization during the 1980 Texas HIPLEX Program. The Work Plan addresses operational and analytical aspects of the Program.

Work began on the TDWR staff report entitled "HIPLEX in Texas: A Summary Report on Five Years of Experimentation." A working outline for this report was developed. Working drafts of the material covered in the outline were prepared in accordance with the outline schedule.

A formal proposal for continued participation in the HIPLEX program beginning in 1981 was drafted by TDWR staff. The proposal covers the 5-year period 1981-1985 and provides a conceptual model which includes mesoscale and microphysical aspects. The 1981-1982 seasons are designed to provide descriptive as well as supportive data to the program, culminating with a consolidated first-generation conceptual model featuring refined mesoscale and numerical microphysical aspects. Research during 1983 is planned to involve a comprehensive, randomized cloud-seeding experiment. Prior to each of the field seasons, extensive re-evaluation and refinement of the conceptual model is planned, based on continuing analyses and statistical evaluations of the mesoscale and microphysical aspects. By 1985, emphasis will be placed on final analysis and re-evaluation of the model.

At the close of the field season TDWR staff performed an inventory listing of federally owned property issued to each Texas HIPLEX participant.

This inventory listing was shipped to the WPRS on September 14, 1980. Additionally, each of the Texas HIPLEX participant organizations submitted inventories to the WPRS of data compiled during the 1980 field season. These data will be consolidated by the WPRS into the 1980 HIPLEX Data Inventory.

1980 Field Program and Meetings at the Big Spring Municipal Airport/ Industrial Park

The 1980 Texas HIPLEX Field Program began as scheduled on May 15, 1980. All daily operations were planned and conducted according to the "HIPLEX 1980-81 Operations Plan, Big Spring-Snyder, Texas" prepared by the TDWR staff prior to the field season and approved by WPRS.

Daily operations followed the schedule as outlined in the Operations Plan. An early morning designation of mesoscale operational status by the field manager was followed by a morning briefing of representatives from all Texas HIPLEX participating entities, at which time current and forecasted weather conditions, current and anticipated equipment status and seeding strategy were outlined. When applicable, post-flight debriefings preceded the morning briefings. As needed, the Project Forecaster informed the Project Manager and/or Field Operations Manager of current weather conditions during the operational period.

During the field season, various Department staff members served as Project Forecaster, Field Operations Manager and Project Manager. A summary of the field season operations is listed as Table 2.

Table 2: Summary of 1980 Texas HIPLEX Field Operations

MONTH/Day	Mesoscale Status GO	: NO-GO	HIPLEX Aircraft Operations Queen Air	p-Navajo
MAY 15	x			
16		x		
17		x		
18		x	Sampling	
19	x			
20		x	Sampling	
21	x		Reconnaissance	
22		x		
23	x			
24		x		
25		x		
26	x		Sampling	
27	x		Reconnaissance	
28	x			
29	x			
30		x		
31		x		
JUNE				
1	x		Reconnaissance	Sampling (1)
2	x		Sampling	Reconnaissance
3	x			
4		x	Cross-country	
5		x	Tower fly-by	Tower fly-by (1)
6		x		
7		x		
8	x			
9	x			
10	x		Reconnaissance	Reconnaissance
11		x		
12		x		
13		x	Tower fly-by(*)	Tower fly-by
14	x		Mesoscale mapg.	
15		x	Interaircraft comparison	
16		x		
17	x			
18	x			
19	x			Sampling (2 events)
20	x			Sampling
21	x			Sampling (2)/Seeding
22	x			Sampling (2)
23		x		
24		x		
25		x		
26		x		
27		x		
28		x		
29		x		
30		x		

1/ Interaircraft comparison */ Also a cross-country cloud sampling mission

Reports

The TDWR published three Texas HIPLEX reports during the reporting period as LP's (Limited Publications). The reports include the following:

Title	Agency	LP#	Publication Date
"Preliminary Cloud Microphysics Studies for Texas HIPLEX 1979"	TAMU	124	4-80
"Determination of Cloud and Precipitation Characteristics from Satellite, Radar and Raingage Analysis"	TTU	127	5-80
"Texas HIPLEX Interim Progress Report"	TDWR	128	5-80

TEXAS A&M UNIVERSITY

Meso- and Synoptic-Analyses

Analysis of the 1979 mesoscale sounding data was begun. With the seven stations it is possible to follow a gridding procedure which has not been possible during previous years. Computer programs were prepared to perform gridded analyses and to contour the gridded fields. The programs were made general so that any gridded variable, whether measured or calculated, can be handled.

Initially, four days were chosen as case study days. The dates are: June 4, and July 3, 6 and 17 of 1979. Contoured fields of temperature, mixing ratio, wind, velocity divergence, moisture divergence, vertical motion and vertical moisture flux were prepared for each sounding time at 50-mb intervals from 850 to 200 mb for which adequate data were available on each case study day. These charts show the temporal and spatial variability of the mesoscale systems. There are unquestionable relationships between the mesoscale systems and the constant altitude reflectivity maps (CAZMs) prepared from Skywater radar data.

Synoptic charts have been prepared and analyzed for the four case-study days. These charts were hand plotted and analyzed from the surface to 200 mb using only National Weather Service data. The features indicated on these charts will be related to the features on the mesoscale charts and the radar-observed convective activity.

Radar

The principal objective of our radar program has been the collection and analysis of radar data in such a way that they are most beneficial to our overall objectives. In addition to the 104 tapes recorded during the 1980 summer season we have developed several computer programs that are, in many respects, unique to our needs.

Eighty-eight constant altitude, contoured radar reflectivity maps have been prepared to assist in the analyses of the mesoscale systems. These cover base tilts and the altitudes of 4, 8 and 12 km and at times of interest to the mesoscale efforts. The contour intervals can and have been controlled in several cases to enhance certain features of interest.

To assist in the analyses of cloud physics data we have begun deriving products to give maximum possible spatial resolution for certain times and places along aircraft tracks. Most other products will average, with proper weighting functions, the reflectivity reading to produce contoured values of the reflectivity factors. For the analyses of cloud physics factors we are working with very small parcels of space. We, therefore, print out the reflectivity value in dBz for each radar element of volume along and near the aircraft tracks. This enables the cloud physicist to derive the maximum resolution possible from radar data.

A new computer procedure is being developed to store each individual radar data record in fixed length records such that each successive scan can be stored according to azimuth readings. This will allow call-up of data for any one azimuth and computation of range-height scans using minimum computer time and storage. This also enables computation of constant altitude contours using much less computer time and storage. In summary, this procedure promises to provide easier access and with less expense for many radar presentations that have not been previously requested because of the extensive computer time required.

Determination of Environmental Response to Convective Activity

Several approaches have been examined to determine the environmental response to convective activity. Each examination indicated that a basic analysis of the principle flow components in the thunderstorm environment was necessary to predict the amount and extent of thunderstorm/environment interaction. Thus, a set of models utilizing potential flow theory was constructed in which the principle flow components are represented. These models were compared to aircraft data collected in five independent experiments and were proven representative in the regions for which they were designed.

Application of the models to thunderstorms observed during HIPLEX is dependent on an empirical evaluation of the thunderstorm's mass flux. A method was devised which allows mass flux determination using HIPLEX mesoscale sounding data. Additionally, previous research has provided useful guidelines and results which may be incorporated when applying the models.

Cloud Microphysics

In April a technical report by Dr. Alexis Long, entitled "Preliminary Cloud Microphysics Studies for Texas HIPLEX," was published by TDWR. This report was based on the data collected by the two instrumented aircraft used in 1979. It covers the procedures laid out for collecting the data and provides an assessment of how closely these procedures were followed in practice. The report presents, in a form especially useful to the non-specialist, the scientific approach taken in analyzing the data. Data analyses are presented for the case study days of June 4, 1979 and July 17, 1979, and a study is presented of the data that aims at determining the precipitation mechanisms involved in the clouds sampled in 1979.

In April and May computer programs were developed to take 1979 MRI Navajo and p-Navajo data and plot them in various graphical forms. Computer-drawn maps of aircraft flight tracks also were developed.

In April and May Dr. Long participated in a training program at NCAR where training was provided to operate the instrumentation on the Queen Air N306D being provided to the Texas HIPLEX project by the NCAR Research Aviation Facility.

During the 1980 Texas HIPLEX field program Dr. Long served as aircraft observer on the NCAR Queen Air, provided orientation to the observer (Dr. Jurica of Texas Tech) on the p-Navajo, and generally worked to ensure that the airborne cloud sampling program was conducted in a manner that would yield significant amounts of meaningful, scientific data. Dr. Long is presently compiling a report on the aircraft operations in the 1980 field season.

Recommendations were provided to the TDWR for research, including cloud physics research, to be conducted in the 1981 Texas HIPLEX Program. These recommendations were based on a study made of the essential components of rain enhancement research, as recognized by scientists at weather modification programs world wide.

Field Program

Texas A&M University's participation in the 1980 Texas HIPLEX field program consisted of three major operations: Training of personnel, equipment preparation and installation and data collection.

Personnel training began in March 1980 and consisted of both classroom and field instruction. Although about half of the personnel were new to the field program, at least one experienced operator was located at each site.

In April and early May, hygrothermographs and microbarographs used in the surface network were cleaned and calibrated. Wind equipment was moved from the National Center for Atmospheric Research (NCAR) to TAMU and cleaned, calibrated, repaired and checked. Parts for many of the wind recorders had to be borrowed from NASA and installed in the recorders. All wind equipment was then calibrated. Shelters were built to house the wind recorders in the field and the rawinsonde unit from TAMU was checked and overhauled. Test soundings taken before the field program assured its correct operation. The remaining five rawinsonde units were checked before the field program at NASA in Huntsville, Alabama to ensure their correct operation. Computer pgorams for the TI-59 real-time analysis were prepared and checked. An analysis routine to be used on real-time sounding data was compiled and entered into the WPRS computer. This required a trip to Denver by a TAMU programmer. Finally, miscellaneous supplies, such as forms and operating equipment, were purchased and sorted for each of the seven sounding stations and the surface network.

Equipment for mesoscale sounding and surface networks were transported and installed in the field between May 6 and 13. By May 13, all TAMU personnel were in the field and at their stations. Soundings were collected at all stations on 22 days between May 15 and June 30, and on several more days at Big Spring for forecast and aircraft purposes. Surface data were collected every day from May 15 to June 30. Equipment problems were less common than in previous years due to generally drier conditions and the improved efficiency of TAMU technicians. NCAR wind equipment was an exception. The last sounding was taken on June 29, and stations were packed and moved by July 4. Operators returned to TAMU between July 1 and 6 and began cleaning and storing equipment. Most personnel were working on data processing within several days following their return to TAMU.

Processing of Mesoscale Surface and Rawinsonde Sounding Data

A quasi-interactive computer system was utilized to handle the vast quantities of data created in the combined HIPLEX upper air and surface network. This system allows access, retrieval and use of any portion of the data set in a matter of minutes.

Sounding data from each operational day was coded by the rawinsonde operators onto a form for keypunching and sent to Texas A&M. A complete inventory was maintained by both field coordinators and the data specialists at Texas A&M. The data were then keypunched and stored onto computer disks to facilitate easy access by the use of an interactive computer terminal.

Error checking of the raw data began before the operators returned from West Texas. The original ordinate and angle data were checked with a computer program which singled out discontinuous values. This process also helped to locate keypunching and coding errors. The next step of the error checking procedure involved computing actual values of temperature, dewpoint, wind, etc., from the sounding data.

Checking computed values involved three additional steps. A computer program which isolates the discontinuous values of temperature, dewpoint, wind direction and wind speed was run. This program identified errors which went undetected in the first phase.

The second step isolated soundings which were not spatially consistent. Constant pressure maps were plotted at 850,500 and 200 mb using data from the seven HIPLEX rawinsonde stations. Values of temperature, dewpoint depression, geopotential height, wind direction and wind speed were plotted for every sounding time and were analyzed to find inconsistencies.

The third check involved analyzing time cross-sections of each station for each operational day for the same values plotted on the constant pressure maps. The computer was used to put the data in the correct format for both the constant pressure and time cross-section analyses.

Final corrections were then made to the upper-air data set. Throughout the procedure the data sets on computer disks were continually being modified. A computer tape was updated in the same manner to serve as a backup to the disk. Data tapes consisting of ordinate computed soundings for each pressure contact and soundings interpolated to 25-mb intervals were prepared. This is the last step in the rawinsonde data reduction process.

Data from the HIPLEX surface network was checked using a program similar to the one used on computed values of upper air data. Discontinuous values were identified and checked by the surface network operators. This data set is also on computer disk until final compilation on magnetic tape can be accomplished.

Entrainment

Several approaches have been utilized to develop a model for determining entrainment into cumulus clouds. Each approach seemed plausible up to a point, then required assumptions that seemed too restrictive. Work on this problem continues with the hope that a suitable model can be developed or, at least, a field experiment can be developed for evaluating entrainment.

Development of Mesoscale Numerical Model

Progress has been made in the areas of Task 1 and 2. In addition, as will be obvious from the following detail, it has been found convenient to start work on Task 3 (formulation of the mesoscale model).

Task 1: Establish mesoscale conditions to be included in the model. Texas HIPLEX reports (Scoggins, et al., 1979; Sienkiewicz, et al., 1980; Williams, et al., 1980) are being studied with a view to discovering the character of the mesoscale environment in which convection in the HIPLEX area develops. These reports are voluminous and will need some time before they are completely analyzed. Our tentative assessment is that the assembled data will be adequate for initializing a model adapted for experimental forecasts. The data also will be useful for the verification of computed forecasts. The specific approach to the formulation of the initial conditions for the model will be undertaken after a model is finally formulated. In any case, a procedure will have to be established for interpolating the observed data to the grid points of the model.

Task 2: Select most suitable existing model. It is rather safe to assume that the leading models for mesoscale hydrostatic processes are those by Pielke (1974), Perkey (1976) and Anthes and Warner (1978). The theoretical implications of these models have been studied and the code for Perkey's model has been procured. All these models are relevant to our research. However, we find that considerable modification will be necessary if we want to adopt any one of them. Pielke's model in z coordinates has not been adapted for variable terrain elevation and has a rather crude incompressible continuity equation. Perkey's model, while also being in z coordinates without terrain elevation, has a sophisticated method of evaluation of vertical motion by a compressible continuity equation (Richardson equation), and is adapted for the spherical geometry over the areas of the contiguous United States. However, this geometry brings with it certain complexities which we do not appear to need in the smaller HIPLEX area. Anthes and Warner use sigma coordinates and a plane horizontal geometry with a map factor. We do not consider the sigma coordinates a good choice for our model since we may turn later to nonhydrostatic computation. We do not believe the hydrostatic model will be accurate enough when, at a later point in the analyses, we want to resolve the convective scale.

Task 3: Formulate a mesoscale numerical model.

In view of the disadvantages of the available mesoscale models for our purpose, work has been initiated toward formulating a model incorporating the desirable properties of the available models. We have developed a preliminary set of equations in a new coordinate system with a nondimensional height. This coordinate system follows the terrain so that the lower boundary conditions are geometrically very simple. With this coordinate system the kinematic boundary conditions at the surface incorporates the terrain-induced vertical motion which Scoggins et al., (1979) and Siekiewicz et al., (1980) have found to have magnitudes comparable with those of vertical motion induced by mesoscale convergence in the boundary layer.

COLORADO RIVER MUNICIPAL WATER DISTRICT

During the reporting period the CRMWD performed weekly monitoring of the Belfort recording raingage network. Each recording gage was checked weekly to discourage vandalism and for the purpose of assessing area rainfall. Chart rotation was performed weekly and rainfall amounts documented on the computer coding sheets for keypunching. All coded rainfall data have been forwarded to Texas Tech University for processing.

Due to vandalism and the unavailability of spare parts, recording gage TH-5 remained inoperative during the reporting period.

The CRMWD also provided a pressurized Navajo (N7330L) equipped with specially designed cloud physics instruments to determine both in- and near-cloud conditions. In addition, the aircraft was capable of performing certain cloud-seeding functions. Among the instrumentation that allowed the recording of in-flight data were:

Air Temperature (2): - Rosemount 101E
- Reverse Flow

Dew Point: EG&G Model 137
Johnson-Williams, Liquid Water Content
CIC/Lawson, Cross-Polarized Ice Crystal Counter
NOAA Total Water Content Probe
PMS - 2D Probe
PMS - Forward Scattering Spectrometer Probe
Accelorometer, Vertical Motion

All data were recorded and displayed in real-time by use of a 9-track recorder and mini-computer located inside the aircraft's cabin.

A total of 27 flights were flown during the HIPLEX field season, accounting for 42 hours of aircraft time. This does not include flights to Boulder, Colorado and Miles City, Montana where the instrument installation and calibration was performed. The following documents the dates, times and the purpose of each HIPLEX-related flight.

DATE	TIME (HRS)	PURPOSE
6-1-80	1.1	Observation
6-2-80	1.4	Observation
6-5-80	.9	Tower Fly-Bys
6-10-80	1.0	Sampling
6-13-80	.9	Tower Fly-Bys
6-14-80	2.6	Meso-Scale Mapping
6-19-80	1.7	Sampling
6-19-80	.6	Sampling
6-20-80	1.2	Sampling
6-21-80	2.6	Seeding and Sampling
6-21-80	1.0	Sampling
6-22-80	2.1	Sampling
6-22-80	1.2	Sampling
7-1-80	2.1	Sampling
7-8-80	1.6	System Test
6-16-80	1.1	Inter-Air Comparison
7-19-80	1.2	Tower Fly-By
7-20-80	1.1	Sampling
7-21-80	1.3	Sampling
7-21-80	1.7	Sampling
7-22-80	2.1	Sampling
7-22-80	2.0	Sampling
7-22-80	2.1	Sampling
7-25-80	2.0	Sampling
7-26-80	2.6	Sampling
7-27-80	1.6	Sampling
7-28-80	1.0	Tower Fly-By

Prior to each of the above-shown flights, all aircraft sensing instruments were calibrated against a recognized standard. In this instance, instruments were calibrated against instrumentation aboard the University of Wyoming's King Air aircraft at Miles City, Montana. During two inter-aircraft comparison flights it was determined all instruments were functioning within their designed tolerance limits.

Recommendations

Future consideration should be given to replacing the existing reciprocating aircraft engines on N7330L with turbine engines. It appears that the aircraft is now carrying all the internal and external instruments it can without modifying its present recommended power plant capability.

TEXAS TECH UNIVERSITY

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Field Program

Digitized radar data were collected on 21 days by the Skywater SWR-75 radar located at the Howard County Industrial Park (32° 18.5'N 101° 26.3'W) in Big Spring, Texas, in support of the 1980 Texas HIPLEX field program. A total of 91 data tapes were recorded, covering 114.8 hours. Each tape was recorded in one of the four scanning modes described in Table 1. Sixty-nine (76%) of the tapes were recorded in the monitoring mode, covering 104.8 hours. Seventeen (19%) of the tapes were recorded in the aircraft near-in mode, covering 8.1 hours. Four (4%) of the tapes were recorded in the aircraft far-out mode, covering 1.6 hours. One (1%) tape was recorded in the Z-R mode, covering 0.3 hours. The times, dates, and recording mode for each tape are Table 2.

The color television display on the Skywater radar was recorded on 25 one-hour cassette videotapes during selected periods of particular interest, especially aircraft operations. Table 3 lists the times and dates of these video tapes.

The color display was also recorded on 16 mm movie films when data were recorded digitally. Three 100-foot rolls of movie film covered the 1980 field season. The times and dates of data recorded on each of these films are listed in Table 4.

Recording raingage data were collected and digitized by personnel at the Colorado River Municipal Water District (CRMWD) in Big Spring. The data were forwarded to Texas Tech University (TTU) where they were edited and written on magnetic tape for archival purposes. The data inventory for the HIPLEX experimental period is given in Table 5. There were 36 precipitation events occurring on 28 days.

An event with particularly heavy rainfall occurred on May 15. Network rainfall volume is shown as a function of time in Figure 1. During the storm period, the network received 4.1 x 10^5 acre-feet of water which represents an average precipitation of 2.99 inches. An intensive case study of this period is underway.

Laserfax imagery was collected from May 15 to July 29, 1980 in support of the field operation. The satellite photographs were used as part of the daily forecasting operation as well as in the deployment of aircraft for cloud sampling missions. Photographs were collected at 30-minute intervals 24 hours a day, and consisted in general of alternating visible and infrared images during the day and infrared images at night. The laserfax imagery has been archived at TTU.

In support of the cloud microphysics field program, TTU provided the on-board scientist for the NCAR Queen Air (a duty which was shared with TAMU) and for the CRMWD p-Navajo. The Queen Air operated as a mid-level cloud physics aircraft while the p-Navajo operated as an on-top cloud seeding and cloud physics aircraft. The instrumentation package provided by Colorado International Corporation (CIC) obtained measurements as given in Table 6. A sample of the data recorded on 9-track magnetic tape is provided in Figure 2. A particularly valuable feature of the data system is the PMS 2-D particle probe. A sample of the images which can be obtained from this instrument is given in Figure 3. A brief summary of all CRMWD p-Navajo flights in support of Texas HIPLEX during 1980 is given in Table 7. The 9-track data tape number listed are for tapes archived at Denver by the WPRS.

Analysis

Case Study of July 17, 1979

A detailed case study designed to integrate radar, raingage, satellite and aircraft data is underway. The study has provided descriptions of the radar echo pattern, the synoptic situation within which the radar echo pattern developed and several preliminary results.

Radar Echo Pattern on Tuesday, July 17:

1500 GMT: The western extremity of a large echo pattern was situated about 170 km east-north-east of the Big Spring radar site. The most intense echoes in this pattern were clustered in its southwestern tip. Highest intensities were in the vicinity of 25 dBz, and the echo tops in this area were in the 7-8 km range.

A weak echo (<5 dBz) was located about 50 km northeast of the radar, and an echo with maximum intensity of about 40 dBz was situated 10 km south of the radar.

1800 GMT: The large echo pattern east-northeast of the radar had by this time broken up and shifted southwestward. Meanwhile, a large echo pattern built up around the radar site. At 1800 GMT, the southern perimeter of this pattern was 20-30 km away from the radar site while the northern perimeter was about 100 km away. The most intense echoes were of about 40 dBz intensity and were scattered to the southeast, east and northeast of the radar. The highest echo tops generally corresponded to echoes of high intensity, with these tops generally around 10 km. The maximum top was 16 km and corresponded to a 40 dBz echo about 130 km northeast of the radar.

2100 GMT: The overall echo pattern was now roughly in the form of a wide band of echoes stretching from northwest to southeast across the field of the radar, with the radar site located near the southwestern edge of this band. Forty and 50 dBz echoes were scattered throughout the band. Highest tops were in the vicinity of 15 km and were situated to the north and northeast of the radar. There were numerous large gaps in the band where no precipitation occurred.

0000 GMT: The general echo pattern by this time had an irregular shape surrounding the radar. Intense echoes reaching 30 and 40 dBz were clustered to the south and southeast and to the north and northeast of the radar and were primarily beyond 100 km from the radar. Echo tops to the north and northeast exceeded 13 km in places while tops to the southeast reached as high as 15 km.

0200 GMT: The echo pattern on the radar had broken up considerably. Three small 40 dBz cells appeared in the pattern while all other echoes were weaker. Echo tops exceeding 13 km corresponded to a 40 dBz cell situated about 150 km to the southeast of the radar. All other tops were below 11 km. The radar site at this time was situated near the northern perimeter of the overall echo pattern, implying that the pattern had shifted southward considerably during the past few hours.

Comparison of RHI's to PPI's and Echo Top PPI's:

A set of RHI's was printed for 20:53:40 GMT. At 0.0^{o} azimuth the RHI shows a region of high intensity centered about 54 km from the radar. According to the RHI, this echo reaches an intensity of 50 dBz at its center. The PPI for 20:59:16 GMT shows a 50 dBz cell located such that the 0.0^{o} azimuth RHI would intersect it at about 54 km. Thus, the PPI and RHI concur at this time and location.

The RHI indicates a maximum cloud top of about 18 km situated directly over the 50 dBz echo. The echo top PPI for this time indicates a maximum cloud top height at about the same location, but with a height of only about 15 km.

At 340^0 azimuth the RHI shows a 50 dBz cell located at 50 km from the radar. This same echo appears on the PPI at 34.0^0 azimuth. The RHI shows echo tops at 12-13 km with one sharp spike to 18 km. The echo top PPI shows maximum top heights at this azimuth of 13 km.

From these examples one can conclude that the RHI and PPI plots agree extremely well while the RHI and echo top PPI's are somewhat inconsistent, with the echo top PPI's generally yielding lower top heights.

Synoptic Situation Over West Texas for July 16-18, 1979:

A. Surface Analysis (NWS 3-hourly maps):

(i) Monday, July 16:

0000 GMT: The western extremity of a cold front extended across the Texas Panhandle with a southwest-northeast orientation. Thundershowers were reported at Amarillo, just south of the front. Winds there were southerly at fifteen knots. Winds further to the south, at Lubbock and in the vicinity of the Texas HIPLEX area, were southeasterly and ranged from ten to fifteen knots. Temperatures to the south were in the mid-nineties, Fahrenheit, while the temperature at Amarillo was seventy-five.

0600 GMT: The front had advanced to just past Amarillo and was now described as stationary. Winds at Amarillo were now northerly, while to the south winds remained southeasterly. The temperature at Amarillo had dropped to sixty-six and temperatures further to the south had fallen to the low eighties and upper seventies.

1200 GMT: The front was described as a cold front and was passing through Lubbock with a more north-south alignment than it previously had; thundershowers had begun at Lubbock within the last hour. Winds there were northeasterly at ten knots, while to the south, in the HIPLEX region, winds remained southeasterly. Temperatures at Lubbock and to the south were now in the mid-seventies.

1800 GMT: The front had receded into New Mexico, leaving both Lubbock and Amarillo to its east. Winds at Lubbock had reverted back to the southeast, and temperatures there and to the south were in the upper eighties.

(ii) Tuesday, July 17:

0000 GMT: Winds at Lubbock were now from the north, and the temperature was down to seventy-nine with thundershowers in the vicinity. The front held the same alignment as at 1800 GMT on Monday.

0600 GMT: The front had returned to a southwest-northeast orientation, and was between Lubbock (to the north) and Midland and Abilene (to the south). Winds were as at 0000 GMT, and temperatures near the front had dropped to the low eighties and upper seventies.

1200 GMT: The front was approaching Midland and Abilene. Scattered cloud cover and no precipitation was reported at these stations. Winds there were southerly while at Lubbock they were easterly. Temperatures on both sides of the front were in the seventies.

1500 GMT: The front had an almost east-west orientation and was passing through Abilene. Winds at Abilene were northeasterly, while winds at Midland continued out of the south. Temperatures along the front were in the low eighties.

1800 GMT: The front was in the same position as at 1500 GMT. Winds at Abilene were now easterly. No precipitation was reported along the front.

2100 GMT: The front was just past Abilene and had reached Midland. Thundershowers had begun within the last hour at Abilene, where winds were now southerly. At Midland the winds continued southwesterly, while temperatures at Midland and Abilene were ninety-five and eighty-seven, respectively.

(iii) Wednesday, July 18:

0000 GMT: The front was now just past Midland, with light rain reported near Midland but no precipitation at Abilene. Winds at both stations were northeasterly.

0600 GMT: The front was well south of the Texas HIPLEX region. Light rain was reported at Midland. Winds there and at Abilene were easterly. Temperatures at those stations were in the low seventies.

1200 GMT: The front was approaching the border of Mexico. Winds at Midland and Abilene were northeasterly. Temperatures were in the low seventies.

B. 850 mb Analysis

(i) Monday, July 16:

0000 GMT: A high pressure area was situated over East Texas and a low pressure area stretched from Mexico, across New Mexico and Arizona and into Nevada and Utah.

1200 GMT: The pattern was about the same as at 0000 GMT but heights had generally increased, in some places by as much as fifty meters.

(ii) Tuesday, July 17:

0000 GMT: The situation at 0000 GMT was roughly the same as at 1200 GMT.

1200 GMT: Heights had dropped somewhat in East Texas and had increased over New Mexico. A high pressure center was situated over South Dakota and a low was centered over Nevada.

(iii) Wednesday, July 18:

0000 GMT: Heights had generally dropped, falling as much as 20 m from 1200 GMT on Tuesday over West Texas. The pattern was about the same as at 1200 GMT Tuesday.

1200 GMT: The low in Nevada was weaker, and the high was now centered in Nebraska. Heights over West Texas had risen slightly from 0000 GMT.

C. 500 mb Analysis:

(i) Monday, July 16:

The entire Southwest was dominated by a high pressure system. A local high was centered over Central Oklahoma. Heights over West Texas rose slightly during the course of the day.

(ii) Tuesday, July 17:

Between 0000 GMT and 1200 GMT, heights fell over West Texas as much as thirty meters. Heights fell generally over the Southwest.

Between 1200 GMT and 0000 GMT on Wednesday heights remained fairly stable.

(iii) Wednesday, July 18:

Between 0000 GMT and 1200 GMT, heights fell over West Texas as much as forty meters.

Preliminary Findings

1. N.W.S. three-hourly surface charts clearly show that precipitation over West Texas on July 17, 1979 was coincident with the passage of a cold front. The direction of motion of the front was generally southward, and its speed ranged from zero to about ten knots, as given in Table 8.

Frontal effects shall have to be taken into account in this case study.

2. Radar echo movements over the Texas HIPLEX area were varied on July 17, 1979 but were predominantly southward at speeds comparable to that of the front. Echo movements at 2300 GMT seemed to correspond to the 700 mb flow, suggesting that 700 mb was the steering level for the system at this time.

3. The overall echo pattern was disorganized, lacking a distinct leading edge. This was consistent with the light winds observed at 700 mb and with relatively slow and variable propogation of the front.

4. At the mature stage of the system of July 17, 1979 several intense convective cells were observed. These were centered around narrow vertical bands of high reflectivity and generally included overshooting of precipitation above 18 km. Later, in the dissipating stages, large areas of horizontally uniform precipitation were observed, with horizontal bands of high reflectivity similar to those described by Leary and Houze (1979)[1] for the case of tropical convection. Temperature and dewpoint profiles near these areas indicate the presence of mesoscale unsaturated downdrafts.

A survey of the 1979 radar data is being made to determine the extent to which the July 17, 1979 case is similar to and different from other cases

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1 Leary, C.A. and R.A. Houze, Jr., 1979: Melting and Evaporation of Hychometers in Precipitation from the Anvil Clouds of Deep Tropical Convection, JAS, 36 (4) pp. 667-689.

on the 32 days in the 1979 season during which radar data were recorded. To the extent that similarities exist, the conclusions reached in the case study will have broader applicability.

Z-R Relationship Determination

Comparisons between radar and raingage data aimed at obtaining a Z-R relationship have begun. Surface drop-size measurements were not available during the 1980 field season because the surface probe did not arrive until after the major precipitation events and no rain fell on the sensor. The large quantities of radar and raingage data from 1979 and 1980 as well as some aircraft data, however, provide an extensive source of data for determining a preliminary Z-R relationship.

Rainfall Analysis

A complete analytical inventory of precipitation events for the 5-year period 1976-1980 is nearing completion and should be published as a separate technical report early in 1981. Storm descriptions include average depth, duration, intensity, rainfall volume, spatial distribution and velocity for each storm affecting the raingage network.

Case Studies of 1977 days

A series of detailed case studies of four days from the 1977 Texas HIPLEX field program has been completed and is being published as a separate technical report. This study involves the determination of cloud properties from satellite radiance data and the integration of the satellite data with radar and raingage data.

TABLE 1

SKYWATER RADAR

TEXAS HIPLEX SCANNING MODES

1980

	MONITORING	Z/R	AIRCRAFT FAR OUT	AIRCRAFT NEAR IN
PRF	414	414	414	414
RANGE INTERVAL	1 Km	0.5 Km	0.5 Km	0.5 Km
RANGE DELAY	10 Km*	10 Km*	10 Km*	10 Km*
A-SCAN				
Samples	16	16	16	16
Elevation	1^o	0.5^o	1^o	1^o
B-SCAN				
Samples	16	32	8	8
Start	2^o	1^o	2^o	2^o
Stop	12^o	3^o	12^o	20^o
Steps	1^o	0.5^o	0.5^o	1^o
TIME INTERVAL	5 Min	5 Min	5 Min	5 Min
ONE COMPLETE SCAN EVERY	10 Min	5 Min	5 Min	5 Min

*Starting 20 June, range delay set at 5 Km

TABLE 2

INVENTORY OF DIGITIZED RADAR DATA

TEXAS HIPLEX 1980

DATE	DAY OF YEAR (GMT)	TAPE ID	START TIME (GMT)	END TIME (GMT)	RECORDING MODE
15 May	136	T0136E	22 00	23 24 54	Monitoring
"	"	T0136F	23 31 30	01 25 51	"
"	137	T0137A	01 39 45	02 44 00	"
18 May	139	T0139A	20 21 24	21 25 20	Monitoring
"	"	T0139B	21 34 00	22 03 00	A/C Near In
"	"	T0139C	22 04 09	22 33 35	"
"	"	T0139D	22 34 54	23 04 19	"
"	"	T0139E	23 05 24	23 19 50	"
"	"	T0139F	23 25 18	01 19 39	Monitoring
"	140	T0140A	01 21 10	03 05 30	"
20 May	141	T0141A	21 11 41	22 15	Monitoring
"	"	T0141B	22 22 10	22 51 36	A/C Near In
"	"	T0141C	22 52 46	23 22 10	"
"	"	T0141D	22 23 42	23 38 08	"
"	"	T0141E	23 40 56	00 20	Monitoring
"	142	T0142A	02 24 07	03 07	"
"	"	T0142B	03 35 35	04 59 48	"
21 May	142	T0142C	15 18	17 13 37	Monitoring
"	"	T0142D	17 19 16	19 03 37	"
26 May	147	T0147A	18 58 38	19 32 56	Monitoring
"	"	T0147B	19 36 25	20 00 57	A/C Far Out
"	"	T0147C	20 03 20	20 27 52	"
"	"	T0147D	20 29 42	20 54 12	"
"	"	T0147E	20 55 29	21 20 00	"
"	"	T0147F	21 25 17	23 22 00	Monitoring
"	"	T0147G	23 25 18	01 19 37	"
"	148	T0148A	01 25 18	02 59 37	"
27 May	148	T0148B	15 20 31	17 14 52	Monitoring
"	"	T0148C	17 19 29	19 13 50	"
"	"	T0148D	19 15 49	21 10 10	"
"	"	T0148F	23 13 56	23 40	"
"	149	T0149A	00 07 27	02 01 48	"
"	"	T0149B	02 07 02	03 11 19	"
29 May	150	T0150A	21 28 21	22 52 40	Monitoring

(continued next page)

Table 2 (continued)

DATE	DAY OF YEAR (GMT)	TAPE ID	START TIME (GMT)	END TIME (GMT)	RECORDING MODE
1 June	153	T0153A	15 12 16	17 06 37	Monitoring
"	"	T0153B	17 19 45	19 14 00	"
"	"	T0153C	19 24 30	21 08 50	"
"	"	T0153D	21 10 14	23 04 32	"
"	"	T0153E	23 05 56	23 30 15	"
"	"	T0153F	23 32 12	23 40	A/C Near In
"	"	T0153G	23 56 11	01 50 30	Monitoring
"	154	T0154A	02 18 10	03 12 19	"
2 June	154	T0154B	15 30 42	17 25 01	Monitoring
"	"	T0154C	17 33 56	19 28 16	"
"	"	T0154D	19 33 44	21 28 07	"
"	"	T0154E	21 29 17	23 13 37	"
8 June	160	T0160A	14 42 01	15 41 20	Monitoring
"	"	T0160B	16 32 53	18 26 57	"
"	"	T0160C	18 33 53	20 28 04	"
"	"	T0160D	20 37 44	22 32 04	"
"	"	T0160E	22 38 31	00 32 54	"
"	161	T0161A	00 39 18	02 23 38	"
"	"	T0161B	02 32 52	03 07 12	"
9 June	161	T0161C	15 31 34	17 43 10	Monitoring
"	"	T0161D	17 46 27	19 40 47	"
10 June	162	T0162A	19 12 01	20 36 24	Monitoring
18 June	170	T0170A	22 11 31	00 05 52	Monitoring
19 June	171	T0171A	21 11 11	21 40 37	A/C Near In
"	"	T0171B	21 45 02	23 09 22	Monitoring
"	"	T0171C	23 12 10	23 46 36	A/C Near In
"	"	T0171D	23 55 31	00 17 00	"
"	172	T0172A	00 23 34	02 17 55	Monitoring
"	"	T0172B	02 21 15	04 15 36	"
20 June	172	T0172C	20 41 02	21 05 23	Monitoring
"	"	T0172D	21 07 40	21 27 04	A/C Near In
"	"	T0172E	21 29 01	23 23 21	Monitoring
"	"	T0172F	23 28 42	01 23 01	"
"	173	T0173A	01 28 41	03 23 01	"
21 June	173	T0173B	20 06 16	22 00 35	Monitoring
"	"	T0173C	22 02 06	23 26 27	"
"	"	T0173D	23 31 24	23 55	A/C Near In
"	174	T0174A	00 07 01	00 32	Monitoring
"	"	T0174B	01 21 58	03 16 18	"

(continued next page)

Table 2(continued)

DATE	DAY OF YEAR (GMT)	TAPE ID	START TIME (GMT)	END TIME (GMT)	RECORDING MODE
22 June	174	T0174C	19 54 36	21 48 58	Monitoring
"	"	T0174D	21 50 39	23 44 59	"
"	"	T0174E	23 50 44	00 35 05	"
1 July	183	T0183A	23 20 00	00 24 08	Monitoring
20 July	202	T0202A	20 43 26	22 07 47	Monitoring
"	"	T0202B	22 19 01	23 23 22	"
21 July	203	T0203A	16 52 30	18 00	Monitoring
"	"	T0203B	18 02 35	18 37 00	A/C Near In
"	"	T0203C	18 38 50	19 03 15	"
"	"	T0203D	19 04 46	20 59 05	Monitoring
"	"	T0203E	21 01 03	21 35 29	A/C Near In
"	"	T0203F	21 47 11	22 06 32	"
22 July	204	T0204A	14 14 15	14 32 47	Z-R
"	"	T0204B	14 38 25	15 20	Monitoring
"	"	T0204C	19 39 37	21 33 34	"
"	"	T0204D	21 35 13	23 29 34	"
"	"	T0204E	23 33 23	01 27 25	"
"	205	T0205A	01 28 30	02 00	"

TABLE 3

INVENTORY OF VIDEOTAPED RADAR DATA

TEXAS HIPLEX 1980

ID #	Calendar Date	Day Of Year (GMT)	Start Time (GMT)	Stop Time (GMT)
1	5/18/80	139	21 40 20	22 40 05
2	"	139	22 45 25	23 25 01
3	5/20/80	141	22 26 50	23 29 40
4	"	141	23 34 30	00 15 39
5	5/26/80	147	19 37 17	20 33 41
6	"	147	20 37 50	21 35 10
7	5/27/80	148	22 32 40	23 31 00
8	6/01/80	153-4	23 13 56	00 17 20
9	6/02/80	154	22 28 16	23 02 43
10	6/08/80	160	14 49 47	15 50 31
11	"	160	21 27 05	22 30 22
12	6/10/80	162	19 37 07	20 37 37
13	6/19/80	171	21 15 08	22 18 25
14	"	171-2	23 10 25	00 13 27
15	6/21/80	173	21 25 37	22 28 37
16	"	173-4	23 26 15	00 07 51
17	6/22/80	174	20 24 17	21 27 10
18	"	174	21 31 23	23 34 06
19	"	174-5	23 58 21	00 37 01
20	7/01/80	183	23 22 43	00 21 55
21	7/21/80	203	20 52 30	21 54 26
22	7/22/80	204	14 12 13	15 14 55
23	7/22/80	204	21 40 10	20 37 28
24	"	204	23 52 00	00 54 10
25	7/27/80	209	18 28 33	19 13 06

TABLE 4

INVENTORY OF RADAR DATA ON 16 mm MOVIE FILM

TEXAS HIPLEX 1980

FILM NO.	DAY OF YEAR (GMT)	START TIME (GMT)	STOP TIME (GMT)
1	139-140	20 25 45	03 05 35
	141-142	21 11 59	04 59 48
	142	15 19 34	20 35 54
	147-148	18 59 20	02 59 48
	148-149	14 39 00	03 11 19
	150	21 28 39	22 52 48
	153	15 12 34	15 18 27
2	153-154	16 06 52	03 12 20
	154	15 31 00	23 13 43
	160-161	14 42 15	03 01 23
	161	15 41 53	19 50 26
	162	19 08 43	20 36 32
	166	21 25 00	21 39 12
	171-172	20 30 12	04 15 47
	172-173	20 41 20	00 41 35
3	173-174	21 07 00	03 16 28
	174-175	19 54 56	00 35 17
	183-184	23 20 21	00 24 09
	198	21 38 19	21 42 48
	202	20 24 13	23 23 24
	203	16 52 48	22 06 35
	204	13 32 00	16 08 12
	204-205	19 39 51	02 02 40
	207	22 32 03	22 57 37
	208	18 47 40	19 02 50

TABLE 5
INVENTORY OF RECORDING RAINGAGE DATA
Texas HIPLEX 1980

Date	Event Began	Event Ended	# of Gages with Precip.	# Inoperable
1 May	1345 CDT	1600 CDT	2	0
	1815	2245	3	0
3 May	0530	0630	4	0
	0945	2330	46	0
4 May	0430	0630	4	3
	1500	1915	3	3
6 May	1445	2400	92	4
14 May	1415	2300	87	1
15 May	0145	1445	103	3
	1715	1915	16	7
18 May	1630	2030	10	6
20 May	1815	2315	85	6
21 May	0100	0530	2	11
23 May	0215	0245	4	4
27 May	1800	2115	79	1
28 May	0500	0645	6	0
1 June	0600	0700	3	1
	1815	2200	41	2
7-8 June	2000	0545	91	1
8 June	0745	1915	83	2
11 June	0030	0715	100	5
17 June	2030	2345	8	3
18 June	1730	1845	2	3
	2215	2345	15	2
19-20 June	1800	0015	70	3
20-21 June	1900	0130	24	3
21-22 June	1745	0115	100	4

(continued next page)

Table 5 (continued)

Date	Event Began	Event Ended	# of Gages with Precip.	# Inoperable
1 July	1800 CDT	1845 CDT	1	0
20 July	1930	2145	5	1
21 July	1000	1230	8	1
	1500	1845	15	2
22 July	0415	1100	64	2
	1745	1915	2	6
26 July	2100	2230	9	3
27 July	0445	0645	5	3
	1645	1700	1	3

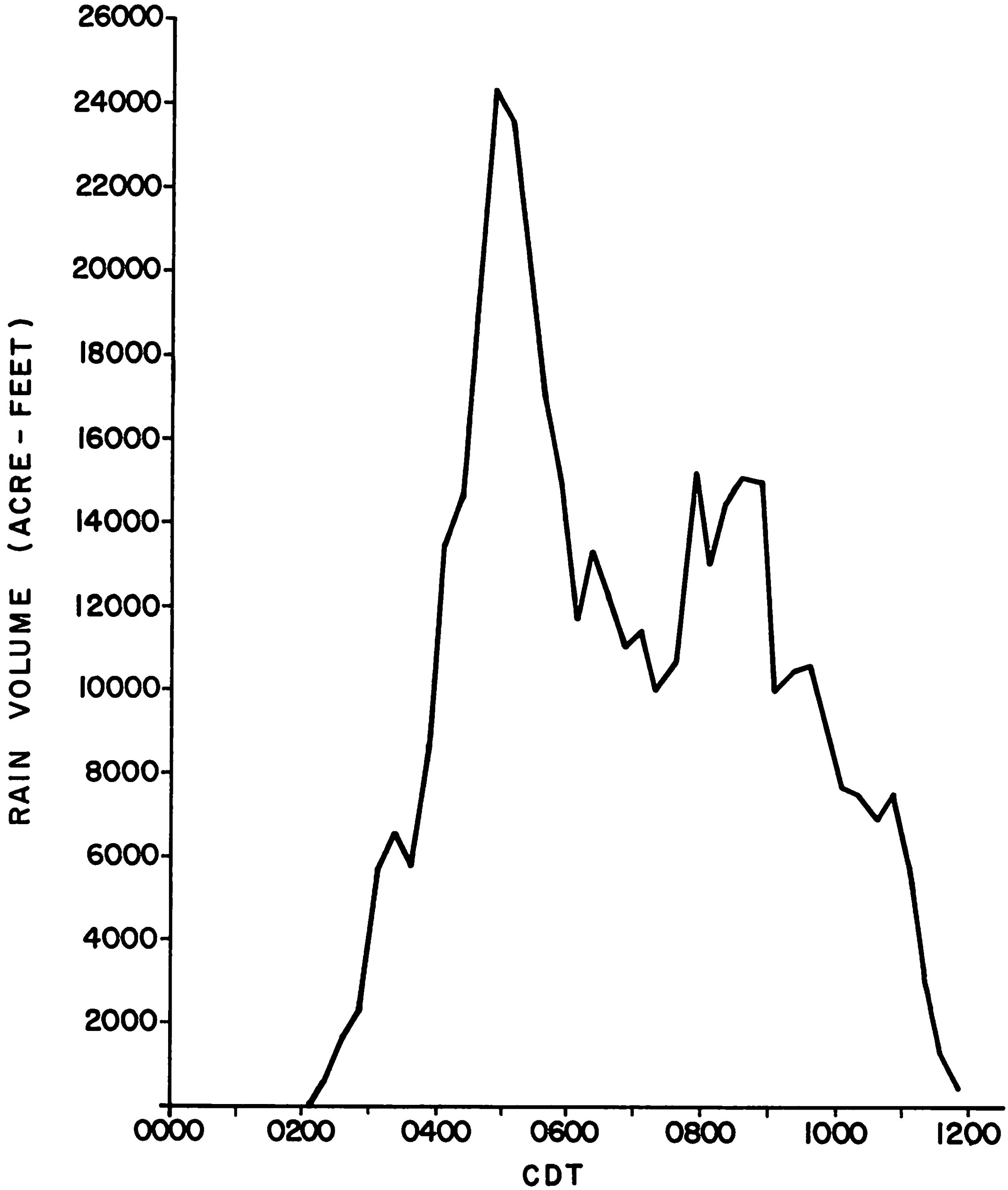

FIGURE I RAIN VOLUME VERSUS TIME
15 MAY 1980

TABLE 6

Variables measured by CRMWD Navajo

Meteorological Sensors

Air Temperature probes; Rosemount Model 101E, Reverse Flow
Housing with Platinum Element
Dew Point Temperature: EG&G Model 137
Johnson-Williams, Liquid Water Content
CIC/Lawson, Cross-Polarized Ice Crystal Counter
Total Water Content Device (NOAA version)
PMS 2-D particle probe (25 to 800 μm)
PMS Forwarding Scattering Spectrometer Probe (FSSP) (2 to 3 μm or
3 to 45 μm)
Accelerometer (Sunstrand)

Aircraft Sensors

Aircraft Position:
Air Speed: Rosemount 506
Altitude: "Pick-Off" from Aircraft Altimeter
VOR/DME: "Pick-Off" from Aircraft Avionics

Microprocessor/Display/Recorder

Microprocessor/16K core: Z-80 with S-100 boards
Sony 7-inch Cathode Ray Tube (CRT)
Sony Audio Cassette Recorder
Axiom Digital Printer
9-Track Incremental Recorder - the data must be in specified
format for direct processing on the Bureau of Reclamation
computer

CRMWD DATA COLLECTED ON 6/ 1/8Ø BY N733ØL FOR HIPLEX

TIME	PRS	ALT	VOR	DME	HEAD	IAS	TAS	TEMP	RFT	DEW	Q	THETA	TH-E	LWC	VV	2-D	IPC	DBAR	SD	CONC	FLWC	R	EVT	FC
18 3 Ø	9[illegible]1	879	186	19.1	174	114	61	29.7	28.9	46.Ø	72.	31Ø.9	582.1	.Ø	3.9	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 3 1	9[illegible]1	883	186	19.1	173	116	62	29.7	28.8	45.9	72.	311.Ø	581.9	.Ø	3.4	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 3 2	9[illegible]1	883	186	19.1	174	114	61	29.8	28.9	45.9	72.	311.Ø	581.5	.Ø	3.2	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 3 3	9[illegible]Ø	891	186	19.2	174	116	62	29.7	28.8	45.9	72.	311.Ø	581.4	.Ø	3.8	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 3 4	9[illegible]Ø	891	186	19.2	173	117	63	29.7	28.8	45.9	72.	311.Ø	581.4	.Ø	3.Ø	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 3 5	9[illegible]9	898	187	19.4	173	119	64	29.7	28.8	45.8	71.	311.1	581.Ø	.Ø	4.6	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 3 6	9[illegible]9	9Ø2	187	19.5	173	117	63	29.6	28.7	45.8	71.	311.1	581.Ø	.Ø	3.2	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 3 7	9[illegible]8	9Ø6	187	19.5	173	12Ø	64	29.6	28.7	45.8	71.	311.1	581.3	.Ø	5.Ø	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 3 8	[illegible]	91Ø	187	19.5	172	12Ø	64	29.5	28.6	45.8	71.	311.Ø	58Ø.9	.Ø	4.4	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 3 9	[illegible]	914	187	19.5	172	121	65	29.4	28.6	45.8	71.	311.Ø	58Ø.5	.Ø	4.8	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	[illegible]
18 31Ø	[illegible]	917	187	19.5	169	121	65	29.4	28.6	45.8	71.	311.Ø	58Ø.2	.Ø	4.7	.2	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	[illegible]
18 311	[illegible]	921	187	19.6	172	121	65	29.4	28.6	45.8	71.	311.1	58Ø.6	.Ø	4.8	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	3	1
18 312	[illegible]6	925	187	19.6	172	122	65	29.4	28.5	45.7	71.	311.1	58Ø.3	.Ø	4.7	.2	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 313	9[illegible]5	933	187	19.8	172	121	65	29.3	28.4	45.7	71.	311.1	58Ø.2	.Ø	4.7	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 314	[illegible]	937	187	19.8	173	122	66	29.3	28.4	45.7	71.	311.1	58Ø.3	.Ø	4.6	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 315	[illegible]	94Ø	187	19.8	173	121	65	29.2	28.3	45.7	71.	311.1	58Ø.Ø	.Ø	5.4	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	[illegible]
18 315	9[illegible]	944	187	19.8	172	121	65	29.2	28.3	45.7	71.	311.1	579.7	.Ø	4.9	.Ø	.Ø	3.Ø	.Ø	.1	.ØØ	Ø	Ø	1
18 317	9[illegible]3	952	187	2Ø.Ø	169	121	65	29.1	28.2	45.7	71.	311.1	58Ø.2	.Ø	5.Ø	.Ø	.Ø	4.5	1.5	.1	.ØØ	Ø	3	1
18 318	9[illegible]3	956	187	2Ø.Ø	172	12Ø	65	29.Ø	28.2	45.7	71.	311.1	58Ø.2	.Ø	4.8	.Ø	.Ø	3.7	1.3	.3	.ØØ	Ø	Ø	1
18 319	9[illegible]3	96Ø	187	2Ø.Ø	169	12Ø	65	29.Ø	28.2	45.6	71.	311.1	58Ø.Ø	.Ø	5.6	.Ø	.Ø	3.Ø	.Ø	.1	.ØØ	Ø	Ø	1
18 32Ø	9[illegible]3	96Ø	187	2Ø.2	172	118	63	29.Ø	28.1	45.6	71.	311.1	579.5	.Ø	5.Ø	.2	.Ø	5.2	2.5	.3	.ØØ	Ø	Ø	1
18 321	9Ø2	963	187	2Ø.2	173	119	64	28.9	28.1	45.6	71.	311.Ø	579.5	.Ø	5.1	.2	.Ø	3.Ø	.Ø	.3	.ØØ	Ø	Ø	1
18 322	9[illegible]2	963	187	2Ø.2	172	12Ø	65	28.9	28.1	45.6	71.	311.Ø	579.Ø	.Ø	3.8	.Ø	.Ø	9.Ø	.Ø	.1	.ØØ	Ø	Ø	1
18 323	9[illegible]2	963	187	2Ø.2	172	121	65	28.9	28.1	45.6	71.	311.Ø	579.Ø	.Ø	4.1	.Ø	.Ø	3.Ø	.Ø	.3	.ØØ	Ø	Ø	1
18 324	9[illegible]2	963	187	2Ø.4	172	124	67	28.8	28.1	45.6	71.	31Ø.9	578.4	.Ø	2.7	.Ø	.Ø	3.Ø	.Ø	.2	.ØØ	Ø	Ø	1
18 325	9[illegible]	967	187	2Ø.4	173	124	67	28.7	28.Ø	45.5	71.	31Ø.9	578.Ø	.Ø	2.2	.Ø	.Ø	4.5	1.5	.1	.ØØ	Ø	Ø	1
18 326	9[illegible]1	971	187	2Ø.5	173	125	67	28.7	28.Ø	45.5	71.	31Ø.9	578.3	.Ø	1.3	.2	.Ø	4.Ø	1.4	.2	.ØØ	Ø	Ø	1
18 327	9[illegible]1	975	187	2Ø.5	169	127	68	28.7	27.9	45.5	71.	31Ø.9	578.5	.Ø	1.6	.Ø	.Ø	3.Ø	.Ø	.1	.ØØ	Ø	Ø	1
18 328	9[illegible]Ø	979	187	2Ø.6	169	127	68	28.7	27.9	45.5	28.	311.Ø	391.9	5.9	1.5	.Ø	.Ø	4.5	1.5	.1	.ØØ	Ø	Ø	1
18 329	9[illegible]Ø	979	187	2Ø.7	169	126	68	28.7	28.Ø	45.5	28.	311.Ø	392.1	2.4	1.7	.Ø	.Ø	3.Ø	.Ø	.1	.ØØ	Ø	Ø	1
18 33Ø	9[illegible]Ø	987	187	2Ø.8	169	126	68	28.6	27.9	45.5	27.	311.Ø	391.5	1.6	1.8	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 331	9[illegible]Ø	983	187	2Ø.8	169	127	68	28.6	27.9	45.5	27.	31Ø.9	391.2	1.2	1.1	.2	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	[illegible]
18 332	[illegible]Ø	987	187	2Ø.9	169	128	69	28.6	27.8	45.5	28.	311.Ø	391.6	1.Ø	2.8	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	[illegible]
18 333	[illegible]9	994	187	2Ø.9	167	127	69	28.5	27.8	45.5	27.	311.Ø	391.2	1.Ø	.5	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 334	8[illegible]9	994	187	2Ø.9	163	128	69	28.5	27.7	45.5	27.	311.Ø	391.2	.8	1.9	.Ø	.Ø	4.Ø	1.4	.2	.ØØ	Ø	Ø	1
18 335	[illegible]8	998	187	21.1	163	128	69	28.5	27.7	45.5	27.	31Ø.9	39Ø.9	.5	2.7	.Ø	.Ø	.Ø	.Ø	.Ø	.ØØ	Ø	Ø	1
18 336	[illegible]	1ØØ2	187	21.1	157	128	69	28.4	27.7	45.5	71.	31Ø.9	577.9	.1	1.9	.Ø	.Ø	3.Ø	.Ø	.1	.ØØ	Ø	Ø	1
18 337	[illegible]	1Ø1Ø	186	21.1	157	127	68	28.4	27.6	45.4	71.	311.Ø	577.9	.Ø	2.7	.Ø	.Ø	5.Ø	1.4	.2	.ØØ	Ø	Ø	1
18 338	[illegible]	1Ø14	186	21.3	155	126	68	28.4	27.6	45.4	71.	311.Ø	578.1	.Ø	2.8	.Ø	.Ø	3.Ø	.Ø	.1	.ØØ	Ø	Ø	1
[illegible]	[illegible]	1Ø18	187	21.[illegible]	157	125	68	28.4	27.6	45.4	71.	311.1	577.9	.Ø	4.2	.Ø	.Ø	3.Ø	.Ø	.1	.ØØ	Ø	Ø	[illegible]
[illegible]	[illegible]	1Ø2[illegible]	187	21.3	151	126	68	28.3	27.5	45.4	71.	311.Ø	577.9	.Ø	4.Ø	.Ø	.Ø	3.7	1.3	.2	.ØØ	Ø	Ø	1

Figure 2. Sample of CRMWD p-Navajo 9-track data

TABLE 7

Summary of CRMWD p-Navajo 1980 Texas HIPLEX Aircraft Missions

Date	Flight Period (GMT)	9-track data tape numbers	Comments
1 June	2026-2200	P801531 P801532	Reconnaissance for a HIPLEX mission. No clouds suitable for sampling. Conducted interaircraft comparisons with NCAR Queen Air.
1 June	2303-0008	P801533	Reconnaissance for a HIPLEX mission. Cirrus shield overhead with no clouds suitable for sampling.
2 June	2154-2322	P801541	Reconnaissance for a HIPLEX mission. Cumulus development was being suppressed from significant vertical growth.
5 June	1212-1309	P801571	Tower fly-by.
10 June	1916-2023	P801621	Reconnaissance for a HIPLEX mission. Small cumulus with no deep vertical growth; one cell outside operational area suitable.
13 June	1223-1318	P801651	Tower fly-by.
14 June	2105-2333	P801661 P801662	Mesoscale mapping in clear air within the upper air sounding network.
19 June	2000-2145	P801711 P801712	Reconnaissance for a HIPLEX mission. Layer of altocumulus with no turrets growing; no clouds suitable for sampling.
19 June	2300-0031	P801713 P801714	Reconnaissance for a HIPLEX mission. Cirrus shield from thunderstorm suppressed other convective growth; no clouds suitable for sampling.
20 June	2052-2200	P801721	Reconnaissance for a HIPLEX mission. Cirrus overhead suppressed convective growth; no clouds suitable for sampling.
21 June	2004-2240	P801731 P801732 P801733	HIPLEX Mission 1. Isolated turret treated from on-top, followed by repeated passes until cell dissipated.

(continued next page)

TABLE 7 cont'd.

Summary of CRMWD p-Navajo 1980 Texas HIPLEX Aircraft Missions cont'd.

Date	Flight Period (GMT)	9-track data tape numbers	Comments
21 June	2318-0021	P801734	Reconnaissance for a HIPLEX mission. Complex of cells with low cloud water and downdrafts; mission terminated due to engine overheating.
22 June	2105-2312	P801741 P801742	HIPLEX Mission 2. Cell near to mature thunderstorm treated from on-top; growth appeared to be suppressed by large cell.
22 June	2338-0049	P801743	Reconnaissance for a HIPLEX mission. Convective complex surrounding one main cell. Little cloud water and high ice counts; no clouds suitable for treatment.
1 July	2202-0002	P801831 P801832	HIPLEX Mission 3. Cell selected from line of convective cells and sampled until further growth suppressed by anvil overhead.
8 July	2015-2101	----	Reconnaissance for a HIPLEX mission. Only small cumulus in operational area. Problem with inoperative transponder terminated mission. No data collected because aircraft remained at low altitude.
8 July	2158-2245	P801901	Reconnaissance for a HIPLEX mission. No clouds suitable for sampling.
16 July	2153-2255	P801981	Intercomparison of data system with CIC Lear, conducted in clear air.
19 July	1200-1303	P802011	Tower fly-by.
[illegible] July	2220-2319	----	Reconnaissance for a HIPLEX mission. Few cells growing from altocumulus layer, but no clouds suitable for sampling. Inoperative transponder caused termination of flight; no data retained because aircraft remained at low altitudes.
21 July	1721-1913	P802031 P802032	HIPLEX Mission 4. Isolated turret sampled but did not grow; no other clouds judged suitable for HIPLEX treatment.

(continued next page)

TABLE 7 cont'd.

Summary of CRMWD p-Navajo 1980 Texas HIPLEX Aircraft Missions cont'd.

Date	Flight Period (GMT)	9-track data tape numbers	Comments
21 July	2041-2210	P802033	Reconnaissance for a HIPLEX mission; no cloud suitable for HIPLEX treatment.
22 July	1345-1545	P802041 P802042	Z-R data collection in a precipitation shaft.
22 July	1943-2140	P802043 P802044	HIPLEX Mission 5. Numerous cumulus congestus in area. Isolated cell selected for on-top sampling; numerous penetrations until cloud dissipated. Very good case.
22 July	2213-0013	P802045 P802046	Reconnaissance for a HIPLEX mission. Two cells sampled repeatedly, but high ice concentrations made them unsuitable for HIPLEX treatment.
25 July	2120-2318	P802071 P802072	Reconnaissance for HIPLEX mission. Low cloud water and weak updraft in small cumulus.
26 July	1828-1921	P802081	Reconnaissance for a HIPLEX mission. Layer of altocumulus with no growing turrets. No clouds suitable for HIPLEX treatment.
26 July	2015-2141	P802082	Reconnaissance for a HIPLEX mission. Sky scattered with altocumulus with low cloud water and weak updrafts. No clouds suitable for HIPLEX treatment.
27 July	1748-1912	P802091 P802092	Reconnaissance for a HIPLEX mission. Several passes through convective line; no clouds suitable for HIPLEX treatment.
28 July	1206-1255	P802101	Tower fly-by.

TABLE 8

Approximate Motion of Front (17 July 1979)
Determined From 3-Hourly NWS Surface
Analyses

Reference Point	Time	Average Speed of Front in kts.	Average Speed of Front in km/hr
MAF	12-15 Z	3	5.5
ABI	"	11	20
MAF	15-18 Z	0	0
ABI	"	0	0
MAF	18-21 Z	3	5.5
ABI	"	6	11
MAF	21-00 Z	4.5	8.5
ABI	"	4.5	8.5
MAF	00-03 Z	12	22
ABI	"	9	17

NORTH AMERICAN WEATHER CONSULTANTS

LIST OF FIGURES

North American Weather Consultants (NAWC) completed their contribution to the 1980 Texas HIPLEX effort at the close of the reporting period by submitting the final contract report "Analysis of Digitized M-33 Radar Data from Texas HIPLEX, 1976-1978."

In 1976, the M-33 radar located at Winston Field Airport in Snyder, Texas was modified to digitize and record radar data on magnetic tape. The digitizing unit was built by the Illinois State Water Survey (ISWS). Digitized M-33 radar data were collected during the 1976-1978 Texas HIPLEX seasons, and the M-33 system was subsequently replaced by the more sophisticated Skywater SWR-75 radar during the 1979-1980 field seasons.

In late 1978, TDWR published a request for proposals for analysis of the radar data collected during the 1976-78 period. The published request specified the following four analyses:

(1) an examination of cloud characteristics versus seeding;

(2) generation of an echo summary;

(3) production of hourly radar-rainfall maps; and,

(4) interpretation of radar echo patterns in terms of environmental conditions.

NAWC was awarded a contract to perform the analysis in August 1979.

Digitized M-33 radar data from the 1976 through 1978 field seasons of Texas HIPLEX have been analyzed to investigate seeding effects, determine echo statistics, produce hourly radar-derived rainfall maps, and examine environmental controls on radar echo development. Other data used in the analysis to supplement the M-33 radar data included Texas HIPLEX rawinsondes and mesonet surface data, TDWR sectional weather maps, and National Weather Service radar and rawinsonde data from Midland.

Acceptable quality digitized radar data were collected during 33 precipitation events on 35 days during June and July of the three years. The data were reformatted to the WPRS radar data format and then processed at the University of North Dakota through standard HIPLEX software. NAWC developed additional software to perform the four analysis tasks. Each analysis is highlighted below.

Effects of Silver Iodide Seeding

The investigation of seeding effects was compromised by a dearth of randomized seeded cases and by radar data quality problems. The data sample used in the analysis consisted of 10 seeded cases and 22 non-seeded cases, all non-randomized.

Various analyses were performed. None of the results indicated significant differences between the seeded and not-seeded samples. Rather than the lack of success of the seeding technique, non-significance of the results seemed to be related to test cloud selection. More than half of the seeded cases were selected for seeding during the case's declining phase. Additionally, more than half of the cases had echo top temperatures colder than -40^{o}C. A refinement of test case selection was recommended, as was randomization.

Echo Statistics

Radar and supplemental data were combined into a master file, which was processed to yield statistics of selected echo parameters. A total of 11,207 echoes were tabulated and processed into sub-sets of frequency distributions by this process. The sub-sets included distributions for warm (top height below the -5^{o}C level) and cold cells and clusters and for surface and 500 mb patterns.

The 11,207 echoes occurred during 33 precipitation events; an average of 340 echoes per event. Since the Texas HIPLEX area was about one-sixth of the area within radar range, about 57 echoes occurred during each precipitation event in the Texas HIPLEX area. The distribution by echo type in the HIPLEX area was 33 warm cells, 18 cold cells, one warm cluster, and five cold clusters. Line echoes occurred in the HIPLEX area with a frequency of about one line every third precipitation event.

About twice as many echoes were observed during each frontal or post-frontal precipitation event than during non-frontal conditions. Likewise, days with 500 mb troughs resulted in many more echo observations than days with 500 mb ridges. The preponderance of small cells in all situations tended to result in similar echo frequency distributions, regardless of surface or 500 mb weather pattern.

All three types of echoes had a maximum occurrence in the late afternoon, although lines did have another maximum near midnight. Echo centroid movement was erratic. Winds at the 700 mb level tended to be closest to echo movement, but the comparison was not especially good.

Statistics on each of the three echo types are summarized in the following paragraphs. The types are shown schematically in Figure 8-1.

Cells. Warm and cold cells accounted for 58 and 32 percent of all echoes, respectively. Median values for selected warm cell parameters included 4 km^2 maximum area (20 dBz threshold), 4.3 km maximum echo height (with a corresponding temperature of $+2^oC$), 28 dBz maximum reflectivity, and 10 minute duration. More than one-third of all warm cells were first detected after splitting off of another echo. Those warm split-off echoes might better be called echo fragments than convection cells. Median values for cold cells included 8 km^2 maximum area, 7.1 km maximum height,

-14^oC echo top temperature, 33 dBz maximum reflectivity, and 10 minute duration. Many cold cells were also first observed after splitting away from another echo. Relatively more cold cells than warm cells merged into other echoes.

Whether warm or cold, cells developed in a locally drier environment than occurred with clusters or lines. Accordingly, the lifting condensation level (LCL) near cells was higher above ground than the LCL near clusters or lines. The top of the positive area (convective instability top) for soundings near cells was also higher, while the mean positive energy was similar.

Clusters. Clusters made up about ten percent of the echo population, with cold clusters outnumbering warm clusters by six to one. Median value statistics for cold clusters included 140 km^2 maximum area, 9.0 km maximum echo height (-26^oC), 49 dBz maximum reflectivity, and 35 minute duration. Corresponding values for warm clusters were 54 km^2 maximum area, 5.0 km maximum echo height (-1^oC), 40 dBz maximum reflectivity, and 10 minute duration. Like cells, about one-third of clusters originated as split-off echoes. Very few warm clusters merged into other echoes, whereas about one-fifth of the cold clusters merged.

Soundings taken near clusters showed a more moist airmass at all levels than those taken near cells. The LCL was 25 mb lower, as was the top of the positive area. Winds near clusters were relatively similar to those near cells.

Lines. Only 14 lines were observed during the 33 precipitation events of 1976 to 1978. In spite of their infrequence, lines were the dominant echoes in terms of echo dimensions and reflectivities. Median value statistics for lines were 10,000 km^2 maximum area, 15.4 km maximum height

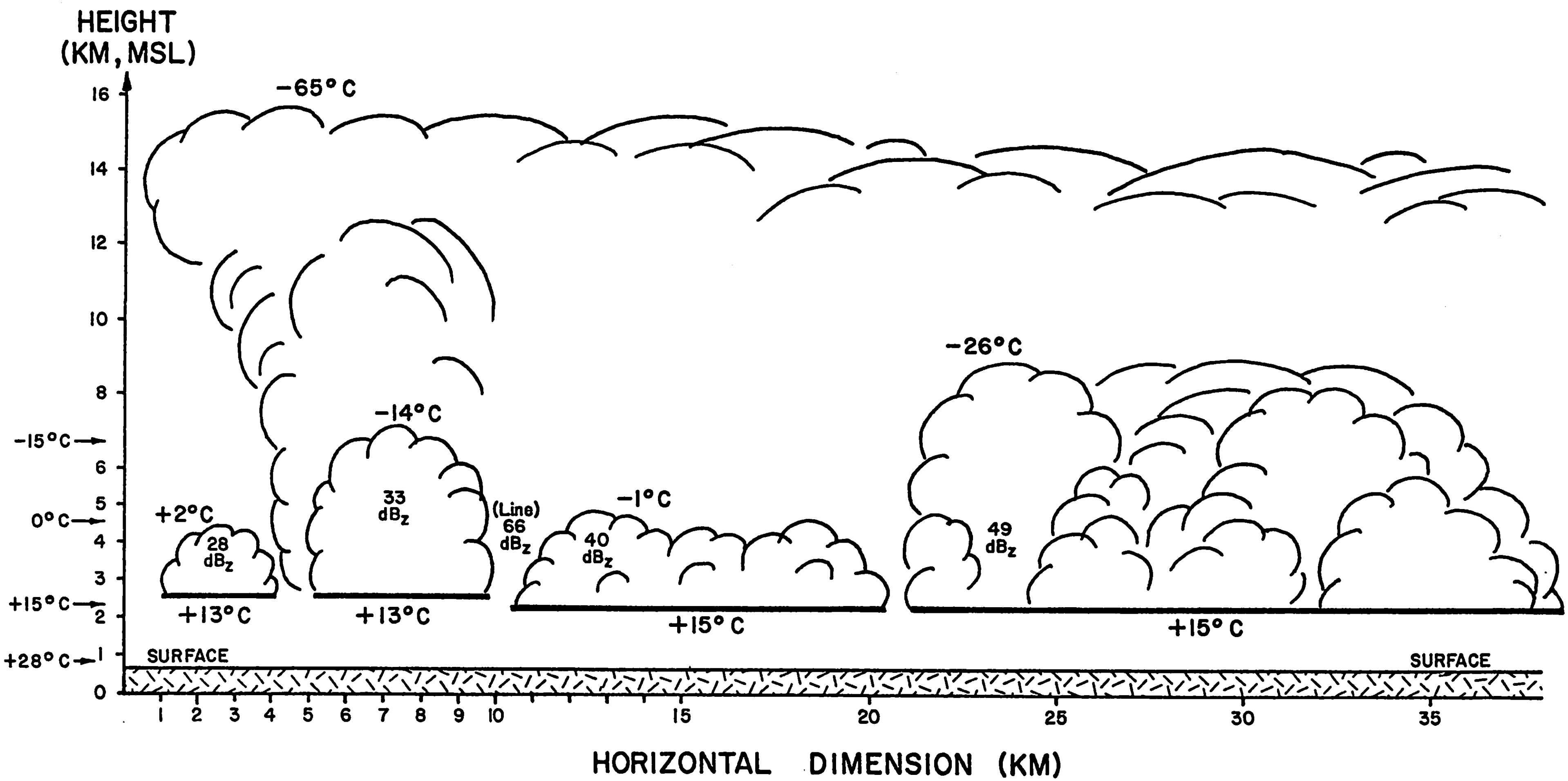

Fig. 1 Schematic depiction of median echo types. Left to right foreground are warm cell, cold cell, warm cluster, and cold cluster. A section of the median line echo is in the background. Median maximum reflectivities are plotted at the median height of occurrence. Horizontal dimension was determined by computing diameter of a circle with the median area. Diameter was increased by 40 percent to account for 20 dBz reflectivity threshold.

(-65^{o}C), 66 dBz maximum reflectivity, and 2.4 hour duration. The high maximum reflectivities were likely the result of hail. Eight of the 14 lines developed locally, while the other six migrated into the area from either New Mexico or the Texas Panhandle. Almost all of the lines lost their organization and were renamed clusters while still in radar range.

Soundings near lines were more moist than those near cells, as was the case with clusters. The mean LCL near lines was 25 mb lower than the mean LCL near cells, and the top of the positive area was 75 mb lower near lines than near cells. Surface and 700 mb winds near lines were lighter than those near the other echo types. However, winds aloft were somewhat stronger.

Relative Precipitation from the Three Echo Types. In terms of echo area, reflectivity, and duration, the echo types were ranked as follows: lines, cold clusters, warm clusters, cold cells, and warm cells. The reverse of that ranking applied for echo frequency of occurrence. To determine the relative contribution to the precipitation, a total rain volume parameter was used. Total rain volume was defined as a function of area, reflectivity (converted to rainfall rate), duration, and frequency of occurrence. When total rain volume was summed for all echo types for the area within radar range, the relative contribution to the sum was as follows:

70 percent for lines
27 percent for cold clusters
1.5 percent for cold cells
1.3 percent for warm cells
0.2 percent for warm clusters.

Based on these results, either seeding experimentation on the more productive echo types or on cell merging is recommended.

Hourly Radar-Derived Rainfall Maps

NAWC developed software to process the dBz files to produce hourly rainfall maps. Except for the example in Section 6, all rainfall maps have been included in Volume 2 of this report. The radar rainfall maps were done in two scales, one roughly covering the Texas HIPLEX experimental area and one covering the entire area of radar data collection. Data collected during six specified days (June 22, June 27, July 8, 1977; and June 5, July 3, and July 23, 1978) were processed to obtain the full area radar rainfall maps. All other radar data were processed to obtain rainfall maps for the HIPLEX experimental area.

Environmental Controls on Echo Occurrence

By associating each day with a surface and 500 mb weather pattern code and with a priority echo type, which was the most organized echo type observed in the HIPLEX area during that day, an analysis was performed to determine weather conditions conducive to the development of echo types. Results are summarized below for the various priority echo types (including no echoes to account for days with no echo development).

--Lines: Of the eleven days with the line priority type, ten days had a 500 mb trough or inverted trough nearby. Lines occurred on five of the 14 days having surface fronts near or within the HIPLEX region. Six lines occurred with no surface front. However, all six occurred on days with 500 mb troughs.

It was shown that soundings near lines were relatively more stable than soundings near cells (that is, the top of the positive area was 75 mb lower for lines). That result and the dependence of lines on either a 500 mb trough or a front indicates that mesoscale convergence and lifting is a prerequisite for line formation.

--Clusters: Clusters were the priority echo type on 21 days. Eleven of the days were characterized by a 500 mb trough, while ten days were under the influence of 500 mb ridge. Six of the 14 days with fronts had clusters as the priority echo type.

--Cells: Cells were the priority echo type on only six days. All six days were non-frontal. Three days with cells occurred with a 500 mb ridge, and three days occurred with a 500 mb trough.

The sounding analysis near cells and the fact that the cell priority type occurred in the absence of organized weather patterns suggests that cells are an "air mass" type of echo.

--No Echo: Seventy days during Texas HIPLEX had no echo occurrences. Most of those days were non-frontal, with a 500 mb ridge.

METEOROLOGY RESEARCH, INCORPORATED

During the reporting period Meteorology Research, Incorporated (MRI) performed a reduction of 1978 cloudbase data from the Colorado River Municipal Water District (CRMWD) Aztec aircraft which was involved in the Texas HIPLEX Program. Used for cloudbase seeding and sampling, this aircraft was equipped with a variety of instruments, among them:

Parameter	Instrument
Pressure	Validyne P24
Temperature	MRI 806 Axial Flow Vortex Thermometer
Dewpoint	EG&G 880
Rate-of-climb	Ball Brothers Variometer
Airspeed (differential pressure)	Validyne P24
Precipitation particles	PMS OAP 200Y

These data were compiled and recorded, but no formal reduction was performed and the raw data were not in a form suitable for analysis. Therefore, MRI was contracted by this Department to reduce the data into standard engineering units. In addition to reducing the data into engineering units, a quality assurance check of the data was performed, with intercomparisons made between the Aztec data and data obtained with other HIPLEX-related aircraft as well as with proximate atmospheric sounding data. Reduced data were then documented on hard copy and on magnetic tape for future use.

A final report, entitled "Engineering Unit Reduction of the 1978 CRMWD Aztec Data," was prepared by MRI. The report describes the data reduction techniques used in the processing of the data. The reduction procedure involved four steps. First, the appropriate calibrations for each device were determined. Second, existing raw data tapes were converted to engineering units and were stored on magnetic tape. Third, the engineering unit data were output onto hard copy. Finally, a quality assurance check was performed on all data. The following is a summary of the findings of that report.

Calibrations

The calibration curves for temperature, dew point, and Delta P are given in Figures 1, 2, and 3. They are presented as functions of data system raw counts. The Fortran statement defining the relationship is also given. The remaining instruments were assigned calibrations by the manufacturer, and these calibrations were checked during intercomparisons with the MRI-Navajo. The Fortran expressions for each are as follows:

```
Pressure        =   0.202650 * counts

Rate-of-Climb   =   [(-0.003049) * counts] + 7.92
```

In addition to the aircraft state parameters, a calibration was performed on the precipitation probe. The results indicated the probe was operating within nominal limits as shown in Figure 4.

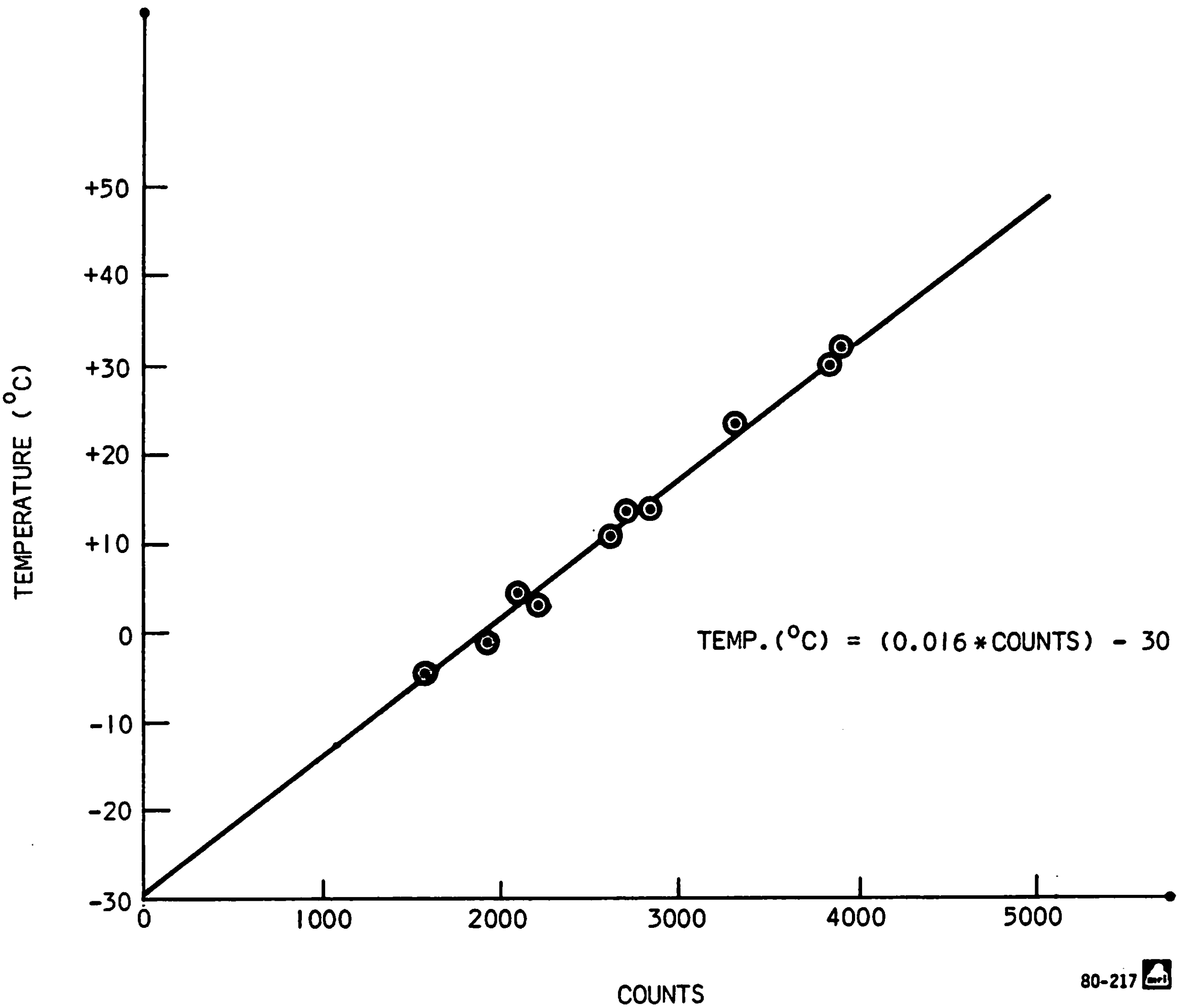

Fig. 1

1978 CRMWD Aztec Temperature Calibration

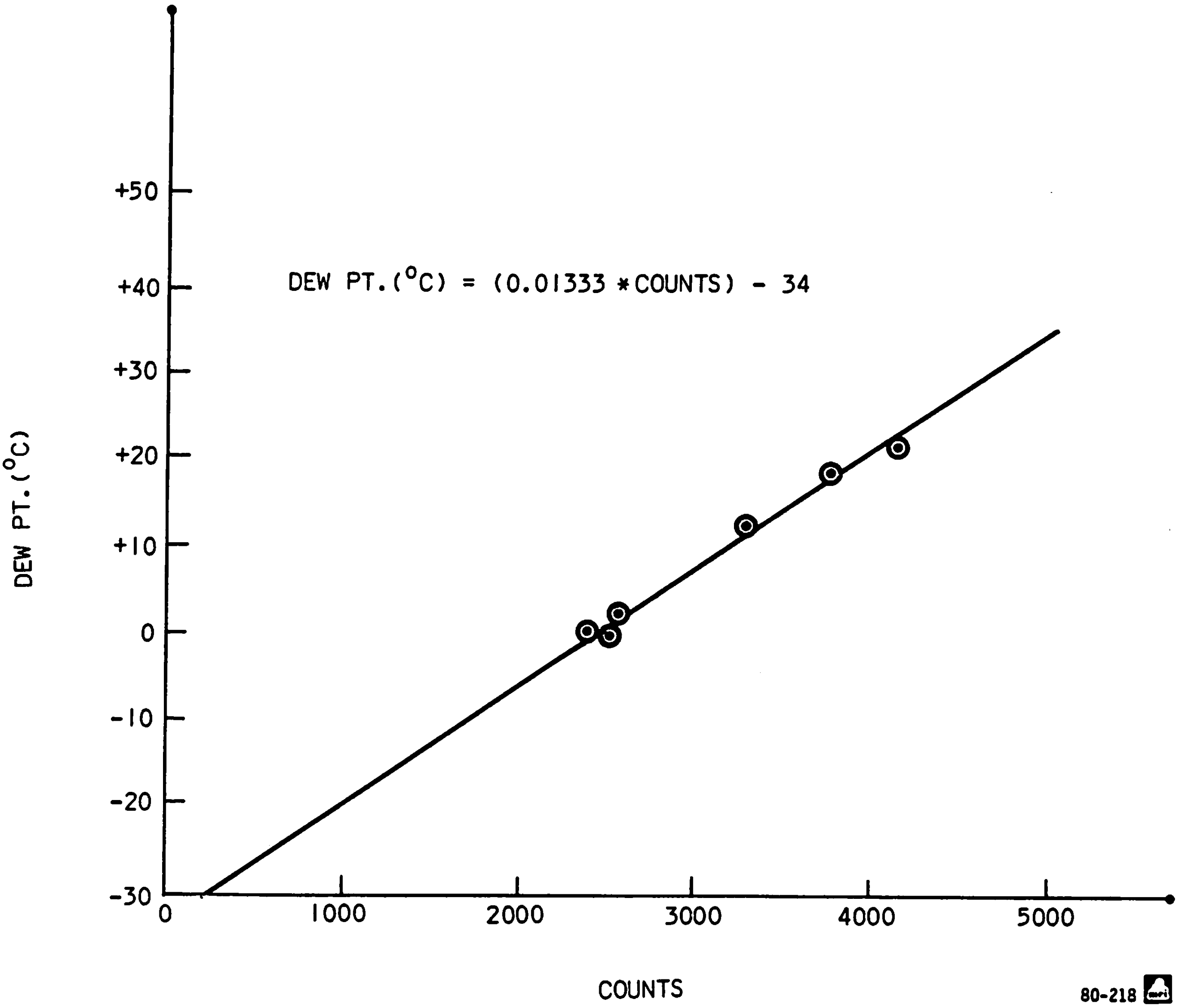

Fig. 2

1978 CRMWD Aztec Dew Point Calibration

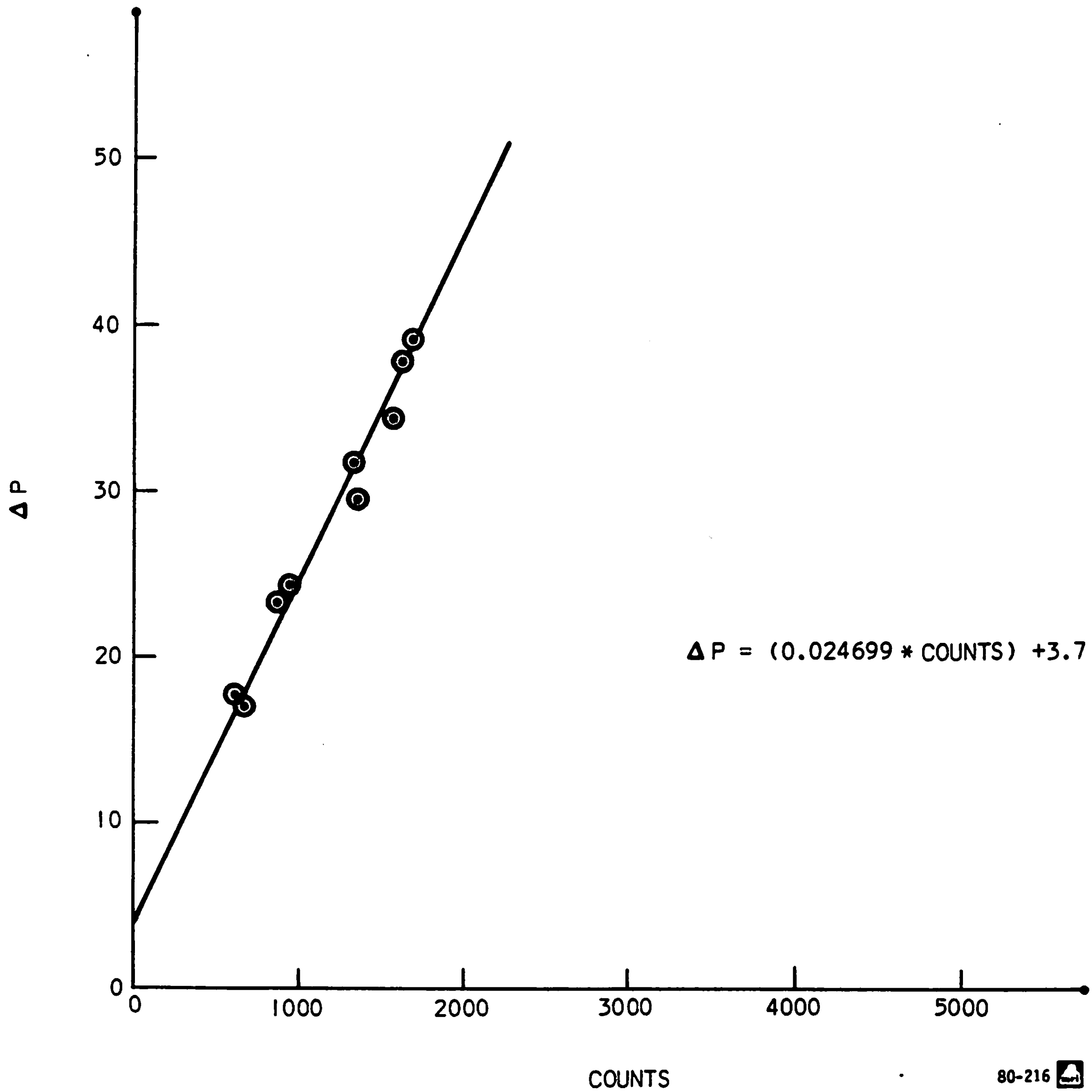

Fig. 3

1978 CRMWD Aztec ΔP Calibration

Size Channel	(1)	(2)	(3)	(4)
		Counts		
1		108		
2		1332	27	
3		1220	254	
4		113	371	
5		37	35	
6		11		
7			224	
8			349	
9			43	
10				
11	73			
12	356			
13	103			
14				
15				
Test Material	3500 3700 BB	800 1100 Glass Beads	1200 1400 Glass Beads	2350 2550 Shot

Fig.4

13 April 1978 PMS Calibration, Aztec - Precipitation Probe (OAP 200Y)

Data Conversion

The second phase of Aztec data processing involved converting the raw data into engineering units. Thirteen raw data tapes (AZT801 to AZT813) were furnished to Meteorology Research, Inc. (MRI). The magnetic tape processing information is given in Table 1. A summary of the Aztec data tapes is given in Table 2. A summary of engineering unit tapes is given in Table 3 (the computer program which accomplished the data conversion output the data to both magnetic tape and paper copy). Table 4 gives the data tape format information. The first 30 records of each file on the engineering unit tapes was listed to verify the accuracy of those files. These listings are included with the data tapes and output paper copy under separate cover.

TABLE 1. 1978 CRMWD AZTEC ENGINEERING UNIT TAPE INFORMATION

Unlabeled
Unblocked
9-Track
800 bpi
ASCII Integer
Written by an HP21MX

TABLE 2. 1978 CRMWD AZTEC DATA SUMMARY

Date	Raw Data Tape No.	Sampling Time (GMT) Start	Stop	Droplet Data	Comments
6/28	AZT801	130125	153149	No	
6/29	AZT802	170730	185858	No	Dew point inoperative
6/30	AZT803	170342	194414	Yes	
7/01	AZT804	180049	201440	Yes	
7/02	AZT805	194726	214622	Yes	
7/03	AZT806	204542	001254	Yes	
7/15	AZT807	231142	004918	Yes	
7/20	AZT808	195413	221709	Yes	
7/22	AZT809	193517	220717	Yes	
7/23	AZT810	174933	201853	Yes	Dew point inoperative
7/24	AZT811	190933	213821	Yes	
7/26	AZT812	202855	214439	Yes	
7/27	AZT813	211329	234601	No	

TABLE 3. 1978 CRMWD AZTEC ENGINEERING UNIT TAPE LOG

Raw Data Tape	Engineering Unit Tape	File No.	No. of Records
AZT801	1	1	9025
AZT802	1	2	6689
AZT803	1	3	9633
ATZ804	1	4	8032
AZT805	2	1	7137
AZT806	2	2	12433
AZT807	2	3	5857
AZT808	2	4	8577
AZT809	3	1	9121
AZT810	3	2	8961
AZT811	3	3	8929
AZT812	4	1	4545
AZT813	4	2	9153

TABLE 4. 1978 CRMWD AZTEC ENGINEERING UNIT TAPE FORMAT

Record 1

MMDDYYNNN

Where: MM - 2-digit integer for month
DD - 2-digit integer for day
YY - 2-digit integer for year
NNN - 3-digit integer for raw data tape number

e.g.: 072378810

Remaining Records

HHMMSSHHHHHPPPPTTTTTDDDDDVVVVVRRRRZZZZQQQQMMMMNNNNN11112222....NNNN

Where:
HH - 2-digit unsigned integer for hour
MM - 2-digit unsigned integer for minute
SS - 2-digit unsigned integer for second
HHHHH - 5-digit unsigned integer for height in meters msl
PPPP - 4-digit unsigned integer for pressure in mb
TTTTT - 5-digit signed integer for temperature in tenths °C (e.g.: -122 = -12.2)
DDDDD - 5-digit signed integer for dew point in tenths °C (e.g.: -122 = -12.2)
VVVVV - 5-digit unsigned integer for true airspeed in tenths m s^{-1} (e.g.: 788 = 78.8)
RRRR - 4-digit signed integer for rate-of-climb in tenths m s^{-1} (e.g.: -25 = -2.5)
ZZZZ - 4-digit unsigned integer for reflectivity in dBz
QQQQ - 4-digit unsigned integer for liquid water content in hundredths g m^{-3} (e.g.: 112 = 1.12)
MMMM - 4-digit unsigned integer for median volumetric diameter in μm
NNNNN - 5-digit unsigned integer for total droplet concentration in #m^{-3}
1111 - 4-digit unsigned integer for number concentration (m^{-3}) in each of 15 size channels divided by 10

.
.
.
.
.

NNNN

Data Hard Copy

A hard copy of the engineering unit data for all thirteen raw tapes is submitted under separate cover.

Quality Assurance

A limited quality assurance review was made of all data. The bulk of the data was seen to have no noticeable errors or irregularities. A few tapes did have some minor problems which are detailed in Table 5.

A comparison of Aztec data with sounding data obtained from Big Spring is given in Table 6.

A comparison of Aztec data with Navajo data during periods of intercomparison flight is given in Table 7.

Both of the latter two tables indicate favorable comparisons and good data quality.

Table 5. 1978 CRMWD AZTEC QUALITY CONTROL SUMMARY

Raw Data Tape No.	Problem	Correction
AZT801	Clock stopped midway in flight	Reproduced time from continuous 1-sec recorded data
AZT802	Hours misset on clock	Inserted appropriate hour
	Dew point sensor inoperative	Not recoverable
AZT806	Data rate switch misset, causing recording every 1/2 sec	Merged 1/2-sec data to form full record
AZT810	Dew point sensor inoperative	Not recoverable

No problems with remaining tapes

TABLE 6. 1978 TEXAS AZTEC SOUNDING COMPARISONS

Raw Data Tape No.	Date/ Time	Pressure (mb)	Aztec Temp (°C)	Aztec Dew (°C)	Big Spring Sounding Temp (°C)	Big Spring Sounding Dew (°C)
AZT803	6/30	900	27.5	13.5	28.2	14.3
	1800 GMT	850	22.5	13.0	19.6	12.9
		800	17.3	11.7	15.1	10.9
		775	15.3	9.2	13.0	9.7
AZT804	7/1	900	30.0	14.2	30.4	Missing
	1800 GMT	850	24.2	14.1	19.0	11.9
		800	19.0	9.9	15.1	9.2
		750	14.1	8.3	11.1	6.6
AZT809	7/22	900	33.5	11.2	27.3	10.3
	2100 GMT	850	27.2	11.1	25.2	7.3
		800	22.9	10.0	20.5	4.6
		750	17.9	8.7	15.8	4.5
		700	12.8	7.0	11.3	0.9
AZT810	7/23	900	26.4	Missing	25.1	19.0
	1800 GMT	850	21.0	Missing	19.0	11.2
		800	16.9	Missing	16.4	9.9
AZT811	7/24	900	26.0	13.2	26.3	15.1
	2100 GMT	850	21.5	12.1	21.0	13.0
		800	16.2	12.0	16.1	11.8
		775	15.5	8.1	13.3	9.1

No sounding data available for remaining tapes

$$\overline{(T_{Aztec} - T_{BS})} = 1.95°C$$

Standard Deviation = 1.79

$$\overline{(\text{Dew Pt}_{Aztec} - \text{Dew Pt}_{BS})} = -1.31°C$$

Standard Deviation = 2.41

TABLE 7. 1978 CRMWD AZTEC - MRI NAVAJO COMPARISONS

Raw Data Tape No.	Date/ Time	Pressure (mb)	Aztec Temp (°C)	Aztec Dew (°C)	Navajo Temp (°C)	Navajo Dew (°C)
ATZ807	7/16	750	19.8	2.2	21.7	5.8
MRI821		800	26.4	5.3	26.8	7.5
AZT805	7/2	760	17.6	-9.6	17.0	Missing
MRI819		800	20.2	-9.1	21.3	Missing
		850	25.2	-8.7	25.6	Missing
		892	29.6	-10.1	29.8	Missing

$\overline{(T_{Aztec} - T_{Navajo})}$ = 0.44°C

Standard Deviation = 0.76

$\overline{(\text{Dew Pt}_{Aztec} - \text{Dew Pt}_{Navajo})}$ = 2.38°C

Standard Deviation = 1.14

SECTION II

WORK PLANNED FOR THE PERIOD

October 1, 1980 - March 31, 1981

Management of the Texas HIPLEX Program and Support Studies

Activities in support of the Texas HIPLEX Program planned for the next reporting period (October 1, 1980 - March 31, 1981) by the Department staff are:

Continued administration of the 1974 agreement between the Department and the WPRS including the review of proposals, negotiation and execution of contracts between the Department and various HIPLEX-related subcontractors;

Distribution of the funds in support of various subcontractors services, including State appropriations and monies obligated to the Texas Program during Federal Fiscal Year 1981 by the WPRS;

Coordination of data-analysis activities by subcontracting organizations which include analysis of mesoscale data for 1979-80, development of various water budget and entrainment models, and an examination of satellite-precipitation-cloud characteristics;

Planning and coordination with the WPRS in developing the 1981 HIPLEX Operations Plan for field experiments to be conducted at Big Spring;

Sponsorship of and participation in meetings and planning sessions with HIPLEX participants and the Weather Modification Advisory Committee;

Further refinement of the Forecast Decision Tree, documenting and summarizing the 1980 Texas HIPLEX field season, analysis of the 1980 rawinsonde data for all HIPLEX sites;

Preparation of Texas HIPLEX monthly and interim progress reports, as well as the 5-year Texas HIPLEX summary report.

Texas HIPLEX Field Operations Summary--1980

Department staff is finalizing a technical report which will fulfill the responsibility of documenting the daily HIPLEX operations conducted in the Big Spring-Snyder area during 1980. Completion of this document is anticipated in November.

Texas A&M University

Work will continue on the analysis of each task discussed in Section I. In addition, comprehensive technical reports will be prepared on meso- and synoptic-scale analyses which incorporate radar data, cloud microphysics, mesoscale surface data and sounding data for the 1980 field program. All rawinsonde soundings will be archived in the WPRS data system.

The study on environmental response to convective activity should be completed during the next report period. This study will become Mr. Myron Gerhard's Masters of Science thesis. A separate report will be prepared on this topic. The study will include the development of an empirical relationship between observed echo characteristics and mass flux into the thunderstorm. Interaction models will be applied to several representative case studies observed during HIPLEX to establish their usefulness in West Texas. Characteristics of thunderstorm-environment interaction as indicated by flow models and echo-mass flux relationships will be integrated into a final report.

Plans for cloud physics research include:

(1) Completing a report on the aircraft operations in the 1980 Texas HIPLEX field program;

(2) Completing case studies of certain clouds sampled in the 1979 field program;

(3) Making improvements to the computer programs that produce graphics output of the 1979 aircraft data;

(4) Developing methods for photogrammetric analysis of 1980 Queen Air data; and,

(5) Assessing the value of the 1980 Queen Air data in view of the known malfunction of the FSSP instrument.

Finally, all previous results will be synthesized and used in the development of a unified Texas HIPLEX Program plan for 1981.

Colorado River Municipal Water District

The Colorado River Municipal Water District will continue to maintain the Texas HIPLEX Belfort recording rain-gage network and the District's fencepost non-recording network during the October-March period. Each Belfort recording gage will be winterized and stored.

Texas Tech University

Work planned for the period October 1, 1980 to December 31, 1980 will emphasize analysis of 1979-1980 data. Specific tasks include the following:

(1) Completion of the 5-year precipitation inventory derived from the recording raingage network.

(2) Development of a technique to refine the spatial resolution of raingage-derived precipitation utilizing radar-echo patterns.

(3) Preliminary work on development of a Z-R relationship applicable to storms in the Texas HIPLEX area.

(4) Preliminary analysis of 1980 aircraft data for selection of case study days.

(5) Continued analysis of the July 17, 1979 case study through the integration of radar, raingage, satellite and aircraft data.

SECTION III

PERSONNEL

Texas Department of Water Resources

John T. Carr, Jr.	Chief, Weather Modification & Technology Section
William O. Alexander	Meteorologist/Forecaster at Big Spring
George Bomar	Meteorologist
Betty Flentge	Secretary
William Hanshaw	Raingage Technician
Thomas Larkin	Meteorologist
Robert Riggio	Meteorologist

Colorado River Municipal Water District

O. H. Ivie	General Manager
John Girdzus	Meteorologist
Jeff Benson	Pilot
Alan Lisonbee	Pilot
Wesley Cox	Raingage Technician
Mark Mickelson	Raingage Technician
Roy Stewart	Airborne Data System Technician

Texas A&M University

James R. Scoggins	Principal Investigator
George L. Huebner	Data Analysis
Alexis B. Long	Data Analysis
Steven F. Williams	Data Analysis
Myron Gerhard	Data Analysis
Ray McAnelly	Data Analysis
Susan Callander	Rawinsonde Operator and Data Analysis

Texas A&M University (continued)

Mark Schwirtz	Rawinsonde Operator and Data Analysis
Russell Billingsley	Rawinsonde Operator and Data Analysis
Dan Neville	Rawinsonde Operator and Data Analysis
Paul Gulig	Rawinsonde Operator and Data Analysis
Dan Tschoepe	Rawinsonde Operator and Data Analysis
David Montplaisir	Rawinsonde Operator and Data Analysis
Timothy Deegan	Rawinsonde Operator and Data Analysis
Darrel Brissette	Rawinsonde Operator and Data Analysis
Ray Jones	Rawinsonde Operator and Data Analysis
James Lynch	Rawinsonde Operator and Data Analysis
Nicholas Horvath	Rawinsonde Operator and Data Analysis
David Templin	Rawinsonde Operator and Data Analysis
Kip Etheridge	Rawinsonde Operator and Data Analysis
Kyle Tupin	Rawinsonde Operator and Data Analysis
Jerry Guynes	Electronics Technician and Data Analysis
Ben Crocker	Electronics Technician and Data Analysis
Meta Sienkiewicz	Data Analysis
Michael July	Data Analysis
John Trares	Data Analysis
Nine-Min Cheng	Data Analysis
Brian Smith	Data Analysis
Phil Reba	Data Processing
Mike Cantor	Data Processing
Kim Harbor	Data Processing
Melinda Culver	Typing and Data Processing

None of the above spent full time on HIPLEX work during the report period. People worked only when needed and only to the extent required to get the work done.

Texas Tech University

Donald R. Haragan	Principal Investigator
Jerry Jurica	Principal Investigator
Colleen A. Leary	Principal Investigator
Mike Lepage	Research Assistant
Eric Pani	Research Assistant
Russell John	Student Assistant
James Taylor	Programmer
Christi Cauble	Secretary
Denise Bentley	Secretary

North American Weather Consultants

Jack Kidd	Principal Investigator
Joe Sutherland	Meteorologist
Douglas Hughes	Senior Programmer
Robert Elliott	Scientific Advisor
R. Rao Kandurkuri	Head of Computer Services
Don Griffith	Managerial Support

Meteorology Research, Incorporated

Gerald Mulvey	Principal Investigator
Mark E. Humbert	Meteorologist
Theordore B. Smith	Senior Meteorologist