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T-28 PARTICIPATION IN THE CONVECTION AND PRECIPITATION/ELECTRIFICATION (CaPE) EXPERIMENT

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1. INTRODUCTION

The T-28 research aircraft joined the Convection and Precipitation/ Electrification (CaPE) field project as it began in east-central Florida on 8 July 1991. The aircraft began six weeks of operations that eventually included 19 research flights into small to large thunderstorms. The flights supported multiparameter radar studies and investigations of the micro-physical and electrical structure of thunderstorms by performing penetrations of the active regions of the storms where turbulence, icing, lightning, and hail precluded penetrations by other available research aircraft. It was further intended that the T-28 supply *in-situ* measurements in clouds being scanned from above by various prototype remote sensing instruments on board the National Aeronautics and Space Administration (NASA) ER-2 and T-39 aircraft.

The T-28 participation in CaPE was at the request of V. Chandrasekar from Colorado State University, interested in multiparameter radar studies, and a group of researchers from South Dakota School of Mines and Technology, including Paul Smith, Dennis Musil, and Andrew Detwiler, interested in cloud microphysics and electricity. Allocation of the T-28 to support CaPE was recommended by the National Science Foundation (NSF) Observing Facilities Advisory Panel at its 1990 fall meeting and subsequently endorsed by the Facilities Advisory Council. The T-28 CaPE field operations were funded through the National Science Foundation Division of Atmospheric Sciences facilities deployment pool.

Continuing support from the National Science Foundation and the State of South Dakota, combined with assistance from the National Center for Atmospheric Research (NCAR), the cloud physics group of the Atmospheric Environment Service (AES) of Canada, and Langmuir Laboratory of the New Mexico Institute of Mining and Tehcnology, made it possible for the aircraft and crew to contribute to CaPE with state-of-the-art measurements in hostile atmospheric environments. It is too early to assess the scientific impact of these measurements but early indications are that some of the T-28 data are extremely interesting and will be critical to several scientific investigations resulting from CaPE.

2. SUMMARY OF FLIGHT OPERATIONS

The T-28 facility staff for this project included:

Dan Custis - pilot	Gary Johnson - engineer
Andy Detwiler - facility scientist	Jon Leigh - mechanic
Ken Hartman - programmer	Dennis Musil - project meteorologist

In addition, a physics undergraduate student (Jeff French) participated in the field project under a "Research Experiences for Undergraduates" supplement to one of the CaPE scientific grants.

The T-28 and supporting staff were based at the Melbourne, FL, airport during the July-August 1991 period of CaPE field operations. Thunderstorm frequency in the CaPE region was above normal and mature storm targets drew the T-28 out for 19 research missions (see Table 1). The T-28 flights were directed by radio from the Field Operations Center (FOC) adjacent to the Melbourne airport. The FOC provided the Project Meteorologist with access to NCAR's CP-4 radar data with superimposed aircraft flight tracks obtained from the Federal Aviation Administration (FAA) Air Route Surveillance Radar at Patrick Air Force Base. This and other information of interest could be displayed via NCAR's newly developed *zeb* software system (Corbet and Mueller, 1991).

On most of its flights, the aircraft was involved in coordinated missions with one or more of the seven other aircraft participating in CaPE (University of Wyoming and NCAR King Airs; NCAR sailplane; NASA Lear-25, T-39, and ER-2; and National Oceanic and Atmospheric Administration (NOAA) WP-3). It also coordinated closely with NCAR's multiparameter CP-2 radar on most flights. Appendix A lists the instrumentation carried by the T-28 during CaPE. High quality microphysical data sets accompanied by detailed mapping of the electrical characteristics of storm interiors were obtained on numerous occasions.

A small crack in a propeller blade grounded the aircraft for six days in late July while a replacement was being trucked in and installed. As a result, the aircraft was unavailable for flight for most of a week. Nevertheless, it completed 19 of the requested 20 research flights and accumulated 46 of the planned 50 research flight hours. The 19 research flights resulted in a total of 259 identified cloud penetrations, including a new T-28 record of 26 penetrations during the 15 August flight (although about a third of them were quite brief).

TABLE 1

T-28 Flights Supporting CaPE

DATE (1991)	FLIGHT #	TIME (hrs)	PURPOSE
05 Jul	552	2.6	Ferry Rapid City to DSM
06 Jul	553	2.3	Ferry DSM to MAW
06 Jul	554	2.5	Ferry MAW to CEW
07 Jul	555	2.4	Ferry CEW to MLB
11 Jul	556	1.7	Equipment Test
11 Jul	557	2.4	Research
12 Jul	558	2.7	Research
14 Jul	559	2.3	Research
16 Jul	560	2.4	Research
18 Jul	561	2.1	Research
19 Jul	562	2.5	Research
20 Jul	563	2.0	Research
28 Jul	564	2.5	Research
29 Jul	565	2.6	Research
31 Jul	566	2.0	Research
02 Aug	567	2.6	Research
03 Aug	568	2.1	Research
06 Aug	569	2.0	Test
07 Aug	570	2.8	Research
08 Aug	571	2.8	Research
09 Aug	572	2.5	Research
11 Aug	573	2.7	Research
13 Aug	574	2.5	Research
15 Aug	575	2.3	Research
18 Aug	576	2.0	Research
19 Aug	577	2.3	Ferry MLB to ABY
19 Aug	578	2.5	Ferry ABY to AWM
20 Aug	579	2.3	Ferry AWM to TOP
20 Aug	580	1.3	Ferry TOP to GRI
20 Aug	581	1.9	Ferry GRI to Rapid City

Total Flight Hours: 69.6 (45.8 research)

3. SUMMARY OF DAILY ACTIVITIES

This section presents a chronological summary of T-28 flight activities during CaPE. Flight times shown are takeoff and landing times (all Eastern Daylight Time).

11 July 1991
Flight 556
10:02 - 11:31

The aircraft flew west about 70 n mi to test radio communications, navigation, tracking and data telemetry. The flight was almost entirely in clear air. The aircraft returned to base just ahead of a thunderstorm.

All research instrumentation was operational. The cockpit CRT failed during flight. Telemetry reception was limited to short range. The display of the FAA radar tracking system data in the Operations Center failed during the flight.

Flight 557
16:07 - 18:11

The aircraft flew a line of weak storms to the SE of the CP-2 radar, stepping down from 4.6 to 2.4 km MSL. It coordinated with the NASA Lear-25 while flying radials from CP-2. The penetration altitudes spanned from above to below the freezing level. The storms were dynamically weak; most of the vertical winds were downdrafts. Particles with maximum dimensions up to 16 mm were observed. No cloud-to-ground lightning events associated with the storms were recorded during the flight. Maximum electric field magnitudes remained in the 30 - 40 kV/m range during most of the flight.

12 July
Flight 558
14:07 - 16:20

The aircraft climbed out through cloud, then coordinated with the Lear-25 and the CP-2 radar on two penetrations of a decaying storm SE of CP-2. Then it shifted to the SW and made eight more penetrations of a more active storm about 60 km SSW of CP-2. It stepped down in this storm from 5.5 to 2.1 km altitude at about 0.6 km intervals, attempting to penetrate (but probably missing) a radar bright band. Precipitation was mainly snow and graupel above the freezing level. Foil data showed particle sizes were relatively large, with some greater than 5 mm. The 2D-P probe indicated particles as large as 10 mm maximum dimension. Electric fields were strongest during the first penetration of the second storm, reaching 65 kV/m, then decayed to 10 - 20 kV/m on later penetrations.

The first penetration of the flight occurred on climbout and was not logged with an event marker. Precipitation could be heard on the recording of the windscreen microphone during the first penetration of the second storm. The audio tape ran out during the last penetration.

14 July
Flight 559
16:58 - 19:05

The aircraft flew a multiparameter radar comparison mission with CP-2, working thunderstorms south of the radar. It stepped down from 5.5 to 1.8 km at 0.6 km intervals. The storms were vigorous, with updrafts exceeding 10 m/s and cloud water concentrations approaching 2 g/m^3. Foil and 2D-P data showed particle maximum sizes of the order of several millimeters, at times reaching 5-7 mm.

The bottom field mill failed from 18:38 to 18:43.

16 July
Flight 560
15:23 - 17:32

The aircraft coordinated with the NASA Lear-25 and the CP-2 radar on a study of a line of mature storms oriented along the coast. It flew at 5.8 km (-9°C) along the eastern edge of the storms. Lack of CP-4 coverage prevented deep cloud penetrations. Storms were electrically very active with frequent lightning signatures in the field mill data. The precipitation particles were primarily snow, with maximum dimensions up to 10 mm.

Due to the fragile nature of snow particles found along the fringes of the clouds, the foil registered few impressions.

18 July
Flight 561
15:03 - 16:54

The aircraft coordinated with the CP-2 radar and the NASA T-39. It worked towering Cu, S & SW of CP-2, near their tops at about 5.2 km (-5.5°C) and also in their lower portions at 2.0 km (+14°C). The clouds were short-lived and not very large. Snow and graupel were observed during the higher level penetrations.

The Cannon particle camera malfunctioned part way through the flight. The J-W cloud water probe was inadvertently left off until mid-flight. Foil data were obtained, but the foil was badly wrinkled in spots.

19 July
Flight 562
13:50 - 16:00

The aircraft coordinated with the CP-2 radar and the T-39 in an area to the SW of CP-2. Clouds penetrated were vigorous and in the young to mature Cb stage. Penetrations were mainly at about 5 km (-5°C). Updrafts often exceeded 10 m/s. Cloud water concentrations in these updrafts typically exceeded 1 g/m^3 (and exceeded 2 g/m^3 in the case of a 16 m/s updraft). Graupel particles were most commonly observed, although there may have been a few raindrops mixed in. Maximum sizes in the range 5-10 mm were fairly common. The measured vertical electric field component reached 86 kV/m during the first penetration.

The foil apparently ran continuously from the first time it was activated and therefore was exhausted early in the flight.

20 July
Flight 563
10:20 - 12:00

The aircraft worked west of Melbourne and south of CP-2, flying solo in coordination with CP-2. Mature storms with vigorous updrafts (maximum 12-13 m/s) and frequent lightning were penetrated at 5.5 km (-7°C). Liquid water concentrations were typically low (0.1-0.4 g/m^3), but precipitation particle concentrations were high (up to 80,000 $/m^3$). A mixture of particle habits, with maximum dimensions up to about 7 mm, was observed. These storms also exhibited strong electric fields.

21 July - 27 July

The T-28 was down awaiting arrival and installation of a replacement propeller. During this hiatus, the FSSP was realigned.

28 July
Flight 564
15:35 - 17:35

The aircraft made a series of penetrations through three small thunderstorms in and near the north Doppler lobe. The main coordination was with CP-2; there was some coordination with the T-39, but probably not with the ER-2 (even though the ER-2 was up at the same time). The penetrations were at about 6 km (-10°C). One storm was followed through mature to decaying stage. Updrafts were weak to moderate and cloud water concentrations low, but precipitation particle concentrations and electric fields were high in places. Almost all of the particles observed were graupel smaller than 5 mm.

The Cannon camera frame counter was not working and the film ran out in mid-flight. While the camera was on, it ran at a frame rate of 1.5 per second. The aircraft was involved in a lightning discharge but suffered no serious damage.

29 July
Flight 565
17:03 - 19:08

The aircraft made a series of penetrations through several small storms in and near the north Doppler lobe at the 5.5 km level (-6°C). The aircraft coordinated with CP-2. The storms were electrically quite active. Penetrations 3 through 8 were in the same storm as it went from a developing to a mature stage. Updraft exceeding 20 m/s and cloud water concentration approaching 4 g/m^3 were observed on penetration 6, according to a preliminary data survey. The J-W cloud water probe was saturated at this point and probably underestimating the actual liquid water concentration. Graupel up to 9 mm maximum dimension and a few supercooled raindrops were observed.

The Cannon camera frame counter was again not working, and its film again ran out midway through the flight. The frame rate was again 1.5 frames per second.

31 July
Flight 566
13:01 - 14:50

The aircraft attempted coordination on an early storm study in the north Doppler lobe with the NCAR sailplane. The T-28 did get into the same cloud with the sailplane, near CP-2, for a while but this cloud died shortly afterwards. The T-28 later followed a storm from near the time of initial electrification until it began to collapse. All penetrations were at 5.5 km (-6°C). Cloud water concentrations were generally low, but updraft exceeding 20 m/s and precipitation particle concentrations approaching 90,000/m^3 were found in some regions. Graupel, snow, and a few supercooled raindrops were observed.

The J-W cloud water meter was broken by a particle impact late in the flight.

2 August
Flight 567
16:23 - 18:35

The aircraft flew through several small storms near Orlando at 5.2 km (-5°C). Some had 2 g/m^3 cloud water and updrafts of more than 10 m/s. Downdrafts in these storms were also fairly strong. The storms were electrically active, and evolved rapidly during the 13 penetrations. The precipitation particles were generally graupel, with maximum dimensions typically 5-6 mm.

This was the first flight for aircraft charge and discharge probes mounted on the T-28 by SRI International. The J-W cloud water meter was still out and FSSP data are used to evaluate cloud water concentration. The telemetry receiving system was set up at the hangar at MLB using a directional antenna, and functioned well to about 40 n mi.

3 August
Flight 568
16:44 - 18:28

The aircraft flew repeatedly through a very small storm just S of CP-2. The penetrations started at 6.5 km (-12°C) and descended with the cloud top as the cloud collapsed. The cloud was only weakly electrified on the earliest penetrations and decayed thereafter. Vertical winds were mainly downward and cloud water concentrations were low. Large graupel (up to 9 mm) was observed on the first penetration, but thereafter only particles smaller than 5 mm were encountered.

A new J-W sensing head was carried and appeared to function well. The SRI equipment worked well.

6 August
Flight 569
15:23 - 16:54

Following a one-and-one-half day down period for engine work, the T-28 flew an intercomparison with Storm-2 (Wyoming King Air). No storms were penetrated.

7 August
Flight 570
13:36 - 15:57

The T-28 flew a mission with Storm-9 (sailplane) in the south Doppler lobe. The clouds being worked were visible from the Melbourne Airport. The T-28 penetrated under the sailplane after it had ascended in an updraft to about 8.8 km. Both aircraft worked a second storm in which the sailplane found little lift, after which the sailplane returned to its base. The T-28 continued to penetrate several other active clouds in the area. Most penetrations were at the 4.8 km level (-3°C). Several later penetrations were at 4.2 km (+2°C). Most cells were strongly electrified. Updrafts exceeding 10 m/s were common, but cloud water concentrations were generally low. Graupel was the predominant form of precipitation, with maximum sizes typically being 5-8 mm.

The SRI equipment again worked well.

8 August
Flight 571
12:53 - 14:50

The T-28 penetrated a tower over CP-4, moved on to make several passes in a predominantly warm rain storm over the Melbourne Airport, and then went back to the area over CP-4. The penetrations were made around the 5.2 km (-5°C) level. There was some coordination between the T-28 and Storm-9 (sailplane) in the area near CP-4.

The storm over the airport produced heavy rain at the ground but was not strongly electrified. The storms near CP-4 were strongly electrified and dynamically active, with updrafts exceeding 10 m/s and cloud water concentrations up to 1 g/m^3. Small graupel was found in the storm over the airport, and larger graupel in the storms near CP-4.

Following several storm penetrations there was an intercomparison between the T-28 and the sailplane during which electric fields reached several kV/m. Preliminary comparisons between data from the two aircraft looked good. The T-28 flight ended with an intercomparison between the T-28 and Storm-1 (NCAR King Air). There were also some strong (predominantly horizontal) fields during this intercomparison. Again, preliminary data comparisons looked good.

Current measurement on the discharge wick was swapped out in order to try an aircraft charging experiment with the on-board power supply; however, no charging was obtained. The J-W cloud water meter was inadvertently left off during cloud penetrations.

9 August
Flight 572
13:41 - 15:56

The T-28 coordinated with both King Airs (Storm-1, NCAR, and Storm-2, Wyoming) and the NOAA P-3 (Storm-3) on a penetration of an active storm SE of CP-2, over the Kennedy Space Center area. The stack was Storm-2, Storm-8 (T-28), Storm-1, and Storm-3 at roughly 3.7, 4.9, 5.5, and 6.7 km, respectively. The King Airs then broke off due to strong electrification. The P-3 and T-28 next followed a second storm through almost a complete life cycle. The P-3 dropped to 4.0 km to do rain studies in coordination with CP-2 in this storm, while the T-28 maintained 4.9 km altitude (-3°C). In its early stages, this storm contained updrafts exceeding 10 m/s and cloud water concentrations approaching 2 g/m^3. Graupel with maximum sizes typically 5-7 mm was observed along with a few raindrops. The storm exhibited electric fields up to almost 80 kV/m. On return, the T-28 did an intercomparison with the sailplane (significant fields observed) and the P-3 (no significant fields observed).

The high voltage self-charge test worked well. Discharge current measurement was disabled.

<u>11 August</u>
Flight 573
15:51 - 18:11

The T-28 penetrated a decaying storm and then several groups of growing clouds first near Melbourne and then near CP-2. It then went west towards Orlando and made a pass towards CP-2 that intercepted several small thunderstorms. The last cloud, nearest CP-2, was re-penetrated several times as it grew. It had not reached maturity before fuel limits forced the T-28 to break off. Penetrations were at 4.3 km, near the freezing level. Some clouds had strong updrafts (>10 m/s) and high liquid water concentrations (>1 g/m^3), and some were electrified. Graupel up to almost 10 mm in size, and some raindrops, were observed.

The SRI charge patch returned with the lead wire disconnected. No signal was obtained from the discharge probe. The FSSP was realigned prior to flight.

<u>13 August</u>
Flight 574
15:21 - 17:39

The T-28 made long passes through a line of convective cells extending about 55 km north from a point just west of CP-2. Altitude was 5 km and temperature -4°C. Good coordination was achieved with the ER-2 and Lear-25. Very active convection was encountered with broad strong updrafts (some exceeding 20 m/s), high liquid water concentrations (one exceeding 3 g/m^3), and strong electrification. The strongest electric fields of the project season (>90 kV/m^3) were encountered on this flight. Periods of very heavy precipitation and severe turbulence were also experienced. A mixture of precipitation particle types with maximum sizes up to about 9 mm was observed.

The SRI discharge probe gave no signal. Cannon camera film was exhausted after the second penetration, and the foil impactor also malfunctioned at about the same time. Audio tape ran out midway through the flight. All other data look good.

<u>15 August</u>
Flight 575
16:40 - 18:39

The T-28 made penetrations along a line of storms between CP-2 and CP-3. Initial penetrations were at 5.5 km (-7°C), with two penetrations and numerous brief encounters with small cloud elements at lower altitudes near the end of the flight. Coordination with CP-2 was good; coordination with the Lear-25 started out well, but communication problems forced them to terminate the mission early. Dual-Doppler coverage of the south end of the line was good only for the last 9 minutes of the flight. A total of 26 recognizable penetrations of cloud elements was identified in the data, although a third of those were quite brief and still fewer involve really useful data. The most active portion of the line was on the south end, near CP-3. Updrafts in excess of 20 m/s and cloud water concentrations exceeding 2 g/m^3 were found in this region, as was severe turbulence. The vertical component of the electric field sometimes exceeded 50 kV/m and was mostly positive. Graupel up to 8-9 mm was observed during the early penetrations. Recovery was in rain associated with a convective line just passing over Melbourne.

No SRI equipment was active. The foil impactor iced up and burnt out its motor sometime during the second penetration. Cannon camera film was exhausted during or after the second penetration.

<u>18 August</u>
Flight 576
15:08 - 16:55

The aircraft flew through debris clouds in the vicinity of CP-2. Some coordination with the Lear-25 was carried out. There was essentially no cloud water in the altitude range from 4 to 6 km MSL in these clouds. Observed precipitation-size particles were mainly snow. Vertical motions were weak and mainly downward. The pilot reported he was in or below cloud base at 4 km. Electric fields exceeded 20 kV/m in some pretty tenuous clouds. The aircraft may have been in a 0°C bright band on one penetration. It flew a box pattern at the end of the flight to check the heading indicator.

4. DATA SUMMARY

Appendix B lists all of the variables recorded or routinely computed from the T-28 observations, while Appendix C provides details on how each was determined. Flight tracks for each CaPE flight are compiled in Appendix D.

Good quality data generally were obtained by most T-28 instruments during CaPE. Table 2 summarizes performance of the T-28 microphysical instrumentation by flight, based on preliminary evaluation in the field. In the table, a "+" denotes good data, "ρ" denotes some problems, and "-" denotes no usable data.

We were fortunate in being able to borrow a PMS OAP-2D-P probe, from the Atmospheric Environment Service of Canada, for use during the project. It functioned well, except for intermittent noise which appeared in the first halves of some data buffers. This noise corrupts the time bars, and also the particle images to some extent. We recommend that the first halves of affected buffers be disregarded when processing the 2D-P images by machine.

The FSSP was out of alignment for the first portion of the project, up until the flight on 28 July. It was aligned again prior to the flight on 11 August, following a flight of poor data. Fortunately, good cloud water concentration data were obtained with the J-W probe on most flights.

The reverse flow temperature probe produced poor readings at altitude, typically beginning about one-half hour into a flight, for most of CaPE. Its data should be used with caution, and compared to data from the Rosemount temperature probe, which worked well.

For flights beginning with Flight 567 on 2 August, the T-28 carried a charge patch mounted on the foil impactor housing and a device to measure current from a discharge probe mounted well aft under the rear fuselage. Kathy Giori, of the Electromagnetics Laboratory at SRI International, should be consulted concerning interpretation of data from these devices.

Electric fields are computed by differencing the readings from each pair of oppositely-facing field mills (vertical and horizontal) on the T-28. Self-charging tests provide data that allow subtraction of the effects of charge on the airplane. An intercomparison exercise in 1990 with the New Mexico Institute of Mining and Technology Special Purpose Test Vehicle for Atmospheric Research (SPTVAR) provided data for correction of measured

TABLE 2

Microphysical Instrument Performance
During CaPE Research Flights

Flight #	Date	2D-P	Cannon Camera	Foil	J-W	FSSP
557	11 July	+	+	-	+	-
558	11 July	+	+	+	+	-
559	14 July	+	+	+	+	-
560	16 July	+	+	+	+	-
561	18 July	+	ρ	ρ	ρ	-
562	19 July	+	-	ρ	+	-
563	20 July	+	-	-	+	-
564	28 July	+	ρ	+	+	+
565	29 July	+	ρ	+	+	+
566	31 July	+	+	+	ρ	+
567	2 Aug	+	+	+	-	+
568	3 Aug	+	+	+	+	+
570	7 Aug	+	+	+	+	+
571	8 Aug	+	+	+	-	+
572	9 Aug	+	+	+	+	-
573	11 Aug	+	+	+	+	+
574	13 Aug	+	ρ	ρ	+	+
575	15 Aug	+	ρ	ρ	+	+
576	18 Aug	+	+	-	+	+

fields for the distortion introduced into the ambient field by the aircraft itself. Preliminary examination of data obtained during CaPE intercomparison exercises with the NCAR sailplane and King Air showed reasonable agreement between fields computed in clear air from T-28 measurements and those computed from sailplane and King Air measurements, for field magnitudes ≤10 kV/m.

4.1 Explanation of CaPE Flight Summary Statistics

A summary of T-28 data obtained during CaPE is given in Table 3. Each flight is subdivided into a number of cloud penetrations. A cloud penetration is usually defined by the pilot's in-cloud and out-of-cloud flags entered into the data stream during the flight. In some cases, modifications to the penetration times have been made based on subsequent analysis of cloud water measurements. The statistics in Table 3 are arranged by flight number and penetration, as indicated by the "Time In" entries. Within each penetration period, the following summary statistics are presented; the tabulated values should be regarded as provisional and subject to further refinement after more detailed examination of the data.

Time In - time of cloud entry, Eastern Daylight Time, 24-hour format. Attempts are made to keep the aircraft data system clock set to WWV; small deviations ($\pm$ a second or so) may be present on any given flight.

Dur - duration of cloud penetration, in seconds.

z - average altitude, in geopotential meters in a standard atmosphere, during the penetration period. There may be significant differences (hundreds of meters) between this altitude and actual geometric altitude.

T - average temperature, in degrees Celsius, during the penetration as determined from the Rosemount aircraft temperature sensor. This sensor is subject to wetting effects and the average temperature may be biased low on many penetrations.

LWC - maximum 1-s value of total cloud water concentration as determined by the Johnson-Williams cloud water meter. This instrument has been shown to respond mainly to droplets with diameters less than 30 micrometers. On flights where J-W data were incomplete or not available, FSSP values are substituted (see Table 2).

Up/Down - peak positive and negative vertical winds during the period, estimated from changes in aircraft pressure altitude computed from centered 2-s differences with some corrections applied. [See *Kopp,* 1985]

TABLE 3

Flight Summary Statistics

	Time In (EDT)	Dur (s)	z (m)	T (C)	LWC (g/m^3)	Up m/s	Down m/s	Ez (kV/m) max-	Ez (kV/m) min+	Ey (kV/m) max-	Ey (kV/m) max+	Max Sh/Or Conc ($1/m^3$)	Max 2DP Conc ($1/m^3$)	Max 2DP Size (mm)	Hydromets
11 July	Flt 557														
	16:41:04	104	4580	-1.4	0.2	2	-7	-7	0	0	13	5969	6029	3.2	dr
	16:45:02	150	4580	-1.7	0.4	3	-7	-3	0	-2	0	10956	8440	3.2	dr
	16:48:11	41	4580	-1.2	0.2	0	-5	-3	0	0	0	4701	8230	2.2	dr
	16:52:16	25	4580	-1.2	0.2	0	-5	-43	16	0	14	23350	29050	8.0	sn,gr
	16:53:49	42	4570	-1.5	0.3	0	-6	-47	0	0	14	16009	17846	5.2	sn,gr
	17:04:29	270	4250	0.2	0.1	1	-5	-43	40	-8	13	6515	8332	15.9	sn,gr
	17:10:06	256	3650	3.3	0.0	2	-5	-31	27	-10	7	2061	2903	7.2	sn,gr,dr
	17:27:39	191	3030	7.9	0.0	1	-3	-30	4	-10	2	1099	2391	10.3	dr
	17:32:34	232	3030	7.8	0.0	0	-4	-33	0	-1	12	1970	2701	4.9	dr
	17:46:10	206	3660	3.4	0.0	0	-4	0	33	0	15	2406	4354	12.7	dr
	17:54:58	85	2430	11.7	0.0	1	-3	0	6	0	8	774	1363	9.7	dr
12 July	Flt 558														
	14:10:00	180	1160	18.7	0.1	2	-4	0	0	0	0	1235	1376	6966.0	dr
	14:24:60	240	3660	4.0	0.5	4	-4	-5	32	-22	19	4773	5562	4.2	sn
	14:37:45	435	5460	-6.0	0.1	2	-8	-52	35	-14	27	78926	91485	9.9	sn
	14:48:43	271	4990	-3.4	0.0	1	-5	-65	41	-16	16	36511	43204	7.8	sn
	15:05:13	259	5470	-6.0	0.5	4	-7	-24	3	-21	3	40471	24391	6.2	gr
	15:14:25	221	4880	-2.7	1.4	8	-7	-37	21	-12	20	14539	12958	10.1	gr/sn
	15:23:35	199	4580	-1.3	0.6	8	-4	0	14	-6	12	17524	18270	5.5	gr
	15:29:49	286	3990	1.8	0.3	8	-4	-12	18	-9	18	11665	11015	4.2	dr
	15:42:53	283	3350	5.1	0.9	8	-5	-10	16	-13	18	9838	8797	5.9	dr
	15:52:19	389	2720	8.9	0.8	8	-4	-12	12	-8	6	11126	8257	7.2	dr
	16:05:29	334	2120	12.8	0.3	1	-4	0	29	-10	19	1873	2400	5.7	dr
14 July	Flt 559														
	17:47:49	80	5490	-1.2	0.7	5	-10	0	0	0	0	4513	13319	4.3	gr,dr
	17:54:06	61	4910	-5.9	0.5	7	-7	-4	0	0	9	11665	13503	6.7	gr,dr
	18:00:47	157	4310	-3.4	1.9	11	-9	-1	0	0	0	15775	17541	4.8	gr,dr
	18:10:30	32	3710	0.5	0.9	12	-7	-4	20	-12	8	44333	27153	7.3	gr,dr
				2.6	0.5	5	-4	-4	4	-3	2	27986	11230	4.3	dr
	18:17:19	162	3060	7.5	1.5	8	-7	-2	20	-4	9	10534	8578	5.4	dr
	18:24:55	110	2440	11.3	1.3	7	6	0	5	-2	2	3173	3519	5.0	dr
	18:34:25	188	1830	14.7	1.0	5	-7	0	7	-1	1	1196	1144	4.0	dr
	18:41:31	124	1830	15.1	0.9	5	-8	0	24	-3	2	702	1111	1.1	dr
	18:46:46	475	1830	14.8	1.1	2	-12	0	6	-3	4	8050	9328	4.3	dr

TABLE 3 (continued)

Flight Summary Statistics

	Time In (CDT)	Dur (s)	z (m)	T (C)	LWC (g/m^3)	Up m/s	Down m/s	Ez (kV/m) max-	Ez (kV/m) min+	Ey (kV/m) max-	Ey (kV/m) max+	Max Sh/Or Conc (1/m^3)	Max 2DP Conc (1/m^3)	Max 2DP Size (mm)	Hydromets
16 July	Flt 560														
	16:05:41	430	5770	-8.1				-4	16	0	23	2764	4754	6.4	sn
	16:14:59	380	5790	-8.1				-4	7	-18	0	1847	1971	6.6	sn
	16:24:05	377	5780	-8.5				-3	3	-2	15	1431	2573	9.7	sn
	16:33:31	656	5790	-9.0				-7	3	-10	4	16529	19697	3.8	sn
	16:44:40	699	5770	-9.1				-42	31	-24	25	135496	101358	10.1	sn,gr
	17:00:03	477	5770	-9.3				-29	31	0	23	69335	67282	9.2	sn
	17:11:44	251	5780	-9.1				-44	38	-22	24	101860	177064	5.8	sn
18 July	Flt 561														
	15:20:21	14	4660	-2.1	M	0	-12	-2	0	0	1	312	998	2.4	sn,gr
	15:24:55	116	5200	-5.5	M	2	-6	-29	8	-26	0	14942	10372	7.3	sn
	15:30:33	88	5190	-5.2	M	0	-11	-1	23	-7	1	11964	14486	9.5	sn
	15:37:04	102	5230	-5.4	M	18	-8	-1	33	-4	23	5657	9503	7.2	gr
	15:41:00	68	5170	-5.8	M	5	-9	-8	11	0	27	23890	22753	5.8	gr
	15:45:04	100	5200	-5.5	M	8	-6	-5	52	-23	6	23012	19488	5.0	gr
	15:50:26	105	5190	-5.6	M	6	-4	-25	27	-6	16	16835	18726	5.4	gr
	15:57:14	60	5220	-5.7	1.2	8	-8	-31	0	-20	11	47207	34475	5.0	gr,sn
	16:16:24	65	1970	13.6	0.8	3	-7	-6	6	-14	0	2568	3970	4.3	dr
	16:19:19	79	1960	14.0	0.5	-3	-5	-13			10	1704	2214	6.4	dr
	16:23:52	85	1990	13.8	0.8	5	-5	-15	3	-8	13	1509	2255	9.9	dr
	16:30:39	49	1990	14.3	0.1	4	-3	-1	17	-1	7	2425	3712	4.7	dr
19 July	Flt 562														
	14:17:10	174	5100	-5.6	0.4	10	-5	-86	27	-24	11	46778	32624	6.9	gr
	14:23:47	124	5040	-5.6	0.6	10	-9	-19	10	-14	23	10391	17376	6.9	gr
	14:28:55	166	4990	-4.9	0.1	0	-5	-56	13	-22	17	15508	20658	7.7	gr
	14:32:49	56	5040	-5.1	1.0	6	-7	-7	0	-9	2	17361	18045	3.9	gr
	14:37:48	225	4980	-4.4	0.2	2	-7	-41	20	-21	27	16692	12292	9.7	gr,sn
	14:45:03	419	5000	-4.6	1.3	12	-10	-36	36	-19	22	27518	31159	8.8	gr,sn
	14:56:02	62	4975	-4.4	0.6	1	-7	-8	20	0	25	6671	8090	4.9	gr
	14:59:08	118	4990	-4.9	0.8	2	-9	-16	0	-21	0	8317	9743	3.2	gr
	15:10:30	68	5000	-4.7	0.2	6	-7	-2	2	0	5	19657	21412	2.8	gr
	15:12:46	21	5020	-6.0	0.4	2	-7	-1	0	0	0	36452	38667	2.1	gr
	15:14:19	87	5000	-5.2	0.2	4	-6	-4	3	-1	28	34411	32296	4.1	gr
	15:19:13	8	5020	-4.7	0.1	0	-2	-40	0	-17	0	11503	18806	2.7	gr
	15:19:23	49	5010	-4.9	0.1	0	-8	-53	0	-23	5	22193	16481	6.2	gr

TABLE 3 (continued)

Flight Summary Statistics

		Time In (CDT)	Dur (s)	z (m)	T (C)	LWC (g/m³)	Up m/s	Down m/s	Ez (kV/m) max-	Ez (kV/m) min+	Ey (kV/m) max-	Ey (kV/m) max+	Max Sh/Or Conc (1/m³)	Max 2DP Conc (1/m³)	Max 2DP Size (mm)	Hydromets
19 July	Flt 562		(cont'd.)													
		15:22:03	49	5020	-5.2	0.8	12	-5.5	-3	12	-15	0	21458	17597	5.9	gr,dr?
		15:26:37	172	5050	-5.1	2.3	16	-12	-5	3	0	16	57143	42705	3.2	gr
		15:36:12	183	4820	-4.2	0.4	9	-10	-20	47	-33	11	16022	20392	7.1	gr
		15:42:12	121	4890	-4.0	1.4	11	-13	0	27	0	29	44125	32018	7.3	gr,dr?
		15:44:52	79	4810	-4.1	0.4	3	-9	-1	3	0	5	17394	20832	3.4	gr,dr?
		15:46:33	111	4820	-4.3	0.6	11	-13	-35	2	-4	38	25223	25271	4.1	gr
20 July	Flt 563															
		10:37:06	10	3710	2.4	0.1	4	-7	0	9	0	-4	4188	4861	1.3	gr,dr
		10:37:30	89	4040	0.6	0.9	12	-6	-1	2	-7	0	44184	27524	4.3	gr,dr
		10:53:56	101	5510	-7.1	0.2	7	-6	-10	24	-9	22	24150	22287	4.7	gr
		10:57:60	153	5440	-6.8	0.1	4	-9	-11	24	-11	13	32505	40196	4.5	gr
		11:05:24	193	5530	-7.0	0.4	13	-7	-63	23	-31	22	54581	35377	6.5	gr,sn
		11:12:36	159	5470	-6.9	0.1	8	-3	-7	32	-25	21	63749	62294	4.7	gr
		11:21:46	278	5450	-7.0	0.1	9	-8	-82	26	-21	19	80486	64467	7.3	gr,sn
		11:30:44	237	5440	-7.1	0.2	12	-12	-28	59	-30	26	75616	55374	5.8	gr,dr
		11:38:40	161	5440	-7.2	0.2	9	-8	-61	25	-26	22	48625	52483	4.5	gr
		11:43:37	176	5460	-6.8	0.1	6	-5	-84	39	-13	24	78406	69068	5.2	gr,sn
28 July	Flt 564															
		16:08:56	76	6200	-10.0	0.2	3	-3	-28	0	-2	5	48098	28370	30.0	gr
		16:15:58	51	6170	-10.0	0.1	2	-4	0	10	0	5	46908	28498	4.5	gr
		16:22:03	59	6210	-10.0	0.0	0	-4	0	0	0	0	54282	25037	4.9	gr
		16:28:01	35	6180	-9.9	0.1	5	-5	0	1	0	0	8160	10596	8.4	gr
		16:37:35	58	6210	-9.5	0.7	8	-6	0	18	-6	6	21581	27252	4.3	gr
		16:43:49	75	6200	-9.8	0.2	9	-5	0	26	-5	14	41219	27158	3.6	gr
		16:50:36	90	6100	-9.6	0.1	3	-5	-55	5	-7	8	78464	77766	3.7	gr
		16:55:16	50	6170	-10.2	0.1	4	-5	-11	23	-22	13	63444	51160	4.3	gr
		17:00:44	14	6090	-9.1	0.1	2	-6	-72	0	-11	6	55147	44866	3.6	gr
		17:01:09	20	6120	-9.4	0.1	0	-3	-2	18	-18	15	76917	28528	1.5	gr
		17:07:32	38	6430	-10.9	0.1	0	-6	-19	18	-10	9	84622	58634	2.8	gr
		17:14:13	64	5820	-7.6	0.1	3	-5	-11	2	-3	24	33663	21945	3.4	gr
29 July	Flt 565															
		17:29:20	66	5560	-6.1	0.1	6	-7	-31	8	-9	35	17973	22040	5.0	gr
		17:34:60	84	5540	-6.0	0.1	3	-6	-37	0	-2	26	44522	36322	5.2	gr
		17:42:50	84	5570	-5.7	0.1	7	-10	-2	13	-1	10	27876	25378	7.3	gr

TABLE 3 (continued)

Flight Summary Statistics

Date	Time In (CDT)	Dur (s)	z (m)	T (C)	LWC (g/m³)	Up m/s	Down m/s	Ez (kV/m) max-	Ez (kV/m) min+	Ey (kV/m) max-	Ey (kV/m) max+	Max Sh/Or Conc (1/m³)	Max 2DP Conc (1/m³)	Max 2DP Size (mm)	Hydromets
29 July	Flt 565	(cont'd.)													
	17:49:18	69	5540	-5.8	0.2	5	-8	-9	51	-33	-1	14630	12969	4.5	gr
	17:55:27	97	5650	-6.7	0.7	13	-4	-4	30	-13	3	24507	17803	5.9	gr
	18:01:37	155	5590	-5.9	3.9	22	-8	-14	15	-26	2	28793	18843	9.5	gr,dr
	18:11:50	165	5520	-5.8	0.2	7	-5	-27	21	-11	25	63925	49780	6.4	gr,dr
	18:19:12	145	5530	-6.5	0.7	11	-8	-16	25	-17	13	63528	57299	4.7	sn,gr
	18:26:49	94	5530	-6.4	0.0	4	-7	-2	56	-16	24	22544	19464	6.8	gr
	18:33:21	134	5540	-6.2	0.1	14	-6	-11	64	-26	17	15222	15726	5.9	gr
	18:38:19	93	5520	-6.1	0.1	4	-10	-27	10	-19	13	17849	23892	5.2	gr
	18:41:51	103	5530	-6.1	0.1	4	-6	-9	20	-8	24	36082	27961	3.9	gr
31 July	Flt 566														
	13:33:01	136	5510	-6.1	0.1	3	-4	-40	6	-8	23	72449	67417	5.8	sn,gr
	13:37:13	97	5530	-5.7	0.1	5	-7	-74	1	-20	24	40152	39160	4.3	gr
	13:39:30	90	5510	-5.8	0.4	12	-6	-4	9	-12	0	61207	34741	5.8	gr,sn
	13:44:56	153	5520	-5.5	0.9	8	-7	-14	4	0	6.5	48560	72775	3.6	gr,sn
	13:49:35	12	5470	-5.1	0.0	1	-6	-1	1	-4	3	21555	20317	1.9	gr
	13:49:49	85	5580	-5.8	0.2	9	-5	-10	9	-27	1	38618	42761	3.9	gr
	14:00:48	181	5600	-6.0	0.2	12	-8	-36	13	-20	7	68750	36484	7.1	gr,dr
	14:08:34	175	5550	-5.7	0.2	13	-7	-21	38	-20	20	87463	78778	8.6	sn,gr
	14:17:06	107	5610	-5.9	0.5	22	-10	-2	43	0	22	57644	33486	4.3	gr,dr
	14:22:01	157	5520	-5.5	0.1	16	-6	-22	38	-12	19	87463	75281	7.9	gr,sn
	14:26:44	114	5510	-5.4	0.1	2	-6	-28	22	-16	15	47617	72069	3.9	gr,sn
2 August	Flt 567														
	17:03:33	166	5190	-5.0	1.6	6	-13	-1	22	-4	21	23727	14138	9.2	gr
	17:10:28	160	5170	-4.3	0.4	3	-8	-23	31	-29	3	7062	9451	4.7	gr
	17:17:18	134	5330	-5.6	2.5	15	-9	-3	6	0	10	24989	16752	4.9	gr
	17:22:60	140	5150	-4.5	2.3	10	-10	-6	14	-28	1	14227	10216	5.2	gr
	17:26:01	17	5160	-4.6	0.7	1	-2	0	0	-1	0	10319	2258	2.1	gr
	17:31:13	112	5170	-5.2	1.4	5	-10	-16	6	0	20	8759	14750	3.6	gr
	17:37:51	171	5150	-4.7	2.5	6	-14	-8	23	-16	2	8973	9347	5.6	gr
	17:46:16	92	5200	-4.9	1.2	5	-14	-2	23	-5	10	10267	13853	5.4	gr
	17:49:43	39	5100	-4.9	0.9	5	-9	-1	1	0	5	15664	12691	5.0	gr
	17:55:55	256	5190	-4.6	0.8	5	-12	-18	28	-26	9	9305	9715	5.2	gr
	18:01:60	89	5120	-4.5	1.7	1	-12	-1	0	0	0	21906	28583	3.8	gr
	18:06:60	231	5170	-4.9	1.9	11	-10	-23	1	-21	1	25132	13753	6.5	gr
	18:14:11	58	5160	-4.2	2.3	10	-6	0	16	-1	2	21048	21092	6.4	gr,dr

TABLE 3 (continued)

Flight Summary Statistics

Date	Flight	Time In (CDT)	Dur (s)	z (m)	T (C)	LWC (g/m³)	Up m/s	Down m/s	Ez (kV/m) max-	Ez (kV/m) min+	Ey (kV/m) max-	Ey (kV/m) max+	Max Sh/Or Conc (1/m³)	Max 2DP Conc (1/m³)	Max 2DP Size (mm)	Hydromets
3 August	Flt 568															
		17:23:45	39	6450	-12.2	1.4	18	-8	0	0	0	0	21224	19860	9.2	gr
		17:29:10	45	6060	-9.2	0.0	0	-14	-8	0	-14	0	92048	44386	2.8	gr
		17:31:57	19	5930	-9.1	0.2	0	-9	0	0	0	0	904	9557	2.8	gr,str
		17:37:59	62	5990	-9.2	0.1	7	-5	-1	1	0	1	31380	22435	5.0	gr
		17:44:01	41	5810	-7.7	0.8	5	-8	-4	0	0	1	18168	15157	2.8	gr
		17:51:43	41	5180	-5.0	0.2	9	-5	0	1	0	0	10963	10116	3.4	gr
		17:57:49	67	4840	-2.7	0.1	2	-5	0	5	0	4	4350	10325	3.2	gr
		18:02:45	13	4270	0.6	0.0	2	-4	0	0	0	0	819	2086	1.0	gr
		18:08:09	43	4250	0.3	0.4	1	-12	0	0	0	0	3017	3422	4.9	gr
7 August	Flt 570															
		14:00:56	65	4840	-2.0	0.0	0	-5	0	37	-3	25	2490	2699	7.3	gr
		14:06:03	18	4820	-2.7	0.1	3	-5	0	0	0	0	6190	10615	5.2	gr
		14:09:51	43	4860	-2.4	0.2	11	-6	0	1	0	0	19410	20324	3.7	gr
		14:13:24	34	4860	-2.2	0.3	3	-12	0	3	-2	0	12062	16117	3.0	gr
		14:22:15	67	4680	-1.5	0.3	10	-9	0	22	-3	3.4	22602	17872	5.8	gr
		14:31:21	71	4900	-3.4	0.9	12	-7	0	3	-1	1	20151	18764	4.5	gr
		14:36:48	65	4920	-3.0	0.4	19	-5	0	8	0	7	17524	18722	3.7	gr
		14:44:03	65	4870	-3.6	0.2	12	-6	0	29	-14	7	24690	13703	9.2	gr
		14:47:07	106	4830	-2.3	0.1	10	-6	0	57	-2	23	14702	19636	6.4	gr
		14:52:50	127	4860	-2.8	0.5	14	-5	0	44	-27	21	14578	18597	5.2	gr
		14:56:53	179	4840	-2.9	0.4	9	-24	-3	44	-6	16	9311	13262	5.6	gr
		15:02:41	69	4840	-2.6	0.0	2	-7	-4	31	0	23	1990	2394	3.7	gr
		15:10:09	78	4820	-2.7	0.0	2	-6	0	45	-2	23	17010	15158	5.2	gr
		15:14:58	126	4840	-3.2	0.3	6	-10	-12	30	-24	0	22466	22884	8.0	gr
		15:21:13	64	4220	1.8	0.1	2	-4	-7	26	-13	21	5033	8289	4.7	gr
		15:25:37	28	4230	1.4	0.2	0	-5	-2	0	-4	0	20658	24462	6.2	gr
		15:29:43	106	4220	1.4	0.9	12	-8	-8	8	-8	3	42421	35908	7.1	gr
		15:33:01	144	4220	1.3	0.9	8	-10	0	18	-2	4	27434	33725	7.7	gr
		15:38:27	153	4230	1.2	0.8	12	-8	0	32	-8	14	21867	16862	7.1	gr,dr
8 August	Flt 571															
		13:20:11	30	5340	-6.4	0.3	2	-6	-16	0	0	8	3719	6575	1.9	gr
		13:25:51	32	5190	-5.4	0.6	3	-7	-1	0	0	4	13466	14306	2.2	gr
		13:30:14	27	5210	-5.7	0.5	2	-7	-2	0	-3	0	12413	13523	2.8	gr
		13:36:35	19	5170	-4.9	0.4	0	-9	0	0	0	0	5215	12460	1.3	gr
		13:40:18	11	5170	-5.1	0.1	0	-6	0	0	0	0	4838	8660	3.6	gr

TABLE 3 (continued)

Flight Summary Statistics

	Time In (CDT)	Dur (s)	z (m)	T (C)	LWC (g/m³)	Up m/s	Down m/s	Ez (kV/m) max-	Ez (kV/m) min+	Ey (kV/m) max-	Ey (kV/m) max+	Max Sh/Or Conc (1/m³)	Max 2DP Conc (1/m³)	Max 2DP Size (mm)	Hydromets
8 August	Flt 571	(cont'd.)													
	13:43:33	110	5200	-5.2	1.0	14	-6	0	37	-21	14	9858	9910	5.0	gr
	13:52:36	83	5230	-5.2	1.0	12	-12	-6	18	-15	14	27681	19652	4.5	gr
	13:59:25	82	5190	-5.0	0.8	11	-11	-18	18	-11	10	13714	14677	10.7	gr
	14:09:11	112	5150	-4.8	1.0	7	-7	-9	22	-12	7	4714	5798	4.9	gr
9 August	Flt 572														
	14:09:40	50	4910	-3.9	0.0	0	-6	-38	0	-8	0	9734	21872	1.7	gr
	14:11:21	38	4890	-3.4	0.1	0	-6	-4	0	-2	0	17023	13211	6.0	gr
	14:15:29	62	4880	-4.1	1.3	9	-10	-1	7	-5	1	9695	5504	4.3	gr
	14:20:45	76	4890	-3.8	1.5	5	-8	-6	24	-7	8	17830	9539	4.5	gr
	14:26:46	101	4880	-3.2	1.7	11	-8	-11	42	-22	25	18460	16908	4.6	gr
	14:34:08	140	4840	-3.3	1.7	14	-12	-4	0	-7	0	2685	5596	7.0	gr
	14:40:46	68	4940	-4.0	2.2	15	-7	0	14	-5	4	5924	6098	6.7	gr,dr
	14:46:15	172	4880	-3.8	0.9	9	-8	-10	13	-20	1	6886	5792	7.1	gr,dr
	14:54:00	98	4870	-3.2	0.3	6	-7	-38	31	-1	36	6535	9990	6.5	gr
	15:09:37	126	4850	-3.1	0.1	5	-5	-3	79	-23	0	5904	8597	5.6	gr
	15:13:22	26	4810	-3.2	0.3	0	-9	0	9	0	5	3511	3568	5.4	gr
	15:22:03	42	4840	-2.7	0.0	0	-7	0	64	-32	1	5950	10318	4.4	gr
11 August	Flt 573														
	16:11:39	6	4270	1.4	0.8	0	-8	-1	0	-1	0	358	0	0.0	str
	16:12:46	19	4290	0.0	0.7	1	-8	0	0	0	0	280	1191	3.0	str
	16:14:19	13	4300	0.6	1.5	6	-4	-1	0	0	0	390	2706	2.6	str
	16:18:31	34	4560	-1.0	0.3	0	-8	0	0	0	0	540	2408	0.9	str,tny
	16:22:17	5	4550	-0.3	0.0	0	-8	0	0	0	0	325	0	0.0	str
	16:25:02	27	4250	0.8	0.9	1	-10	0	0	0	0	507	1353	2.8	str
	16:27:45	38	4280	0.7	0.7	2	-13	0	0	0	0	416	2325	2.7	str,tny
	16:32:43	8	4280	2.1	0.4	0	-6	0	0	0	0	91	0	0.0	str
	16:37:18	13	4290	1.2	1.0	0	-9	0	0	0	0	280	1052	0.9	str
	16:50:24	63	4570	-1.1	0.6	2	-8	0	10	0	4	5176	5200	6.5	gr
	16:57:12	70	4540	0.3	0.2	1	-6	-1	8	-16	4	3225	4249	3.0	gr
	17:03:35	55	4280	2.2	0.3	2	-8	-1	0	0	0	553			gr
	17:23:28	30	4580	0.6	0.0	1	-4	-1	3	-7	0	988	1472	4.3	gr
	17:24:20	25	4580	0.2	0.0	0	-5	-1	0	-3	0	1079	1512	1.5	gr
	17:25:07	90	4480	-0.5	0.5	2	-9	0	7	0	6	4057	5983	6.3	gr,dr
	17:27:23	35	4570	-1.4	0.9	0	-10	-1	0	0	0	338	1898	3.5	gr,str
	17:29:02	62	4520	-0.8	0.4	2	-11	-7	1	-2	3	8759	8704	5.6	gr
	17:30:30	80	4540	-0.7	0.1	11	-6	0	1.7	-2	0	8440	11621	6.4	gr

TABLE 3 (continued)

Flight Summary Statistics

	Time In (CDT)	Dur (s)	z (m)	T (C)	LWC (g/m^3)	Up m/s	Down m/s	Ez (kV/m) max-	Ez (kV/m) min+	Ey (kV/m) max-	Ey (kV/m) max+	Max Sh/Or Conc (1/m^3)	Max 2DP Conc (1/m^3)	Max 2DP Size (mm)	Hydromets
11 August Flt 573		(cont'd.)													
	17:34:15	92	4600	-0.7	1.1	10	-11	0	9	-2	16	6554	7154	9.9	gr,dr
	17:37:33	76	4610	-1.2	1.8	12	-10	-1	25	-22	1	5716	7865	7.7	gr,dr
13 August Flt 574															
	17:53:26	411	4910	-3.8	1.2	7	-11	-16	25	-7	12	20788	9884	6.4	gr,dr
	18:01:60	388	4970	-4.0	3.6	17	-7	-26	39	-26	23	39677	20039	8.6	gr,dr
	18:14:12	229	4920	-3.7	0.8	13	-8	-7	54	-18	27	20814	16680	8.0	gr,dr
	18:18:38	62	4880	-3.0	0.0	3	-4	-4	1	0	7	10781	5525	4.7	sn
	18:19:60	72	4890	-3.9	1.4	11	-6	-1	2	-2	1	5800	5516	3.2	gr
	18:21:34	306	4880	-3.3	0.3	6	-6	-7	41	-27	18	26413	30798	8.8	gr
	18:27:00	435	4890	-3.6	1.9	11	-10	-4	89	-13	29	31309	47918	5.8	gr
	18:34:35	13	4880	-3.7	0.0	1	-2	-3	1	0	4	332	0	0.0	nothing
	18:36:40	203	4940	-3.5	2.2	22	-9	0	16	-26	13	9220	12194	7.7	gr
	18:41:02	36	4830	-4.4	0.8	6	-8	0	7	0	8	13258	15766	2.8	gr
	18:43:08	154	4970	-3.8	2.2	23	-15	-9	32	-26	15	34150	19084	8.8	gr,dr
	18:50:60	140	4880	-3.1	1.7	12	-10	0	62	-4	28	8616	13604	9.2	gr,dr
	18:53:52	77	4900	-3.2	0.0	2	-6	0	66	-3	10	32284	41320	5.0	gr
	18:55:39	441	4900	-4.1	0.5	14	-15	-37	93	-18	26	35210	36798	5.8	gr,sn
	19:02:60	196	4900	-4.2	0.8	9	-14	-7	71	-25	28	23018	23803	7.5	gr
	19:07:24	58	4870	-3.0	0.1	2	-5	0	13	0	10	5059	9968	1.7	gr
	19:08:47	33	4900	-3.5	0.0	0	-4	-3	4	0	7	10436	15332	4.7	sn
	19:11:13	91	4910	-3.6	1.1	18	-14	-2	43	-19	19	17908	18069	9.0	gr
	19:13:37	17	4870	-4.0	1.0	4	-6	0	4	0	4	910	1819	2.4	gr
	19:14:25	134	4860	-3.3	1.0	15	-8	0	36	-25	33	21542	15870	9.4	gr,dr
15 August Flt 575															
	17:05:04	879	5520	-6.6	2.1	19	-9	-22	63	-24	23	132752	57293	8.6	gr,sn
	17:20:17	16	5530	-7.4	0.1	0	-6	-2	0	0	1	2770	4428	1.1	tny
	17:20:45	252	5560	-6.5	2.2	22	-10	-16	32	-11	34	28617	30162	6.2	gr
	17:27:60	77	5510	-6.5	2.7	11	-15	-1	0	-2	0	15547	10154	4.5	str,tny
	17:30:16	705	5540	-7.1	2.8	22	-9	-63	58	-25	30	123831	33744	7.9	gr
	17:47:01	115	5480	-6.9	1.5	12	-8	-1	8	0	7	16080	14956	5.0	gr,str
	17:49:01	120	5420	-7.2	0.8	8	-9	-1	5	0	13	13382	15980	9.2	gr,str
	17:53:50	30	5010	-5.2	0.1	0	-10	-3	6	-26	1	22472	14687	3.7	tny,sn
	17:55:42	60	4900	-4.2	0.9	7	-8	-2	4	-2	0	9858	10446	3.7	gr,dr,str
	17:57:28	5	4950	-4.3	0.4	0	-3	-1	0	0	0	2217	3941	2.1	str,tny
	17:58:26	8	4940	-3.5	0.9	6	-2	-1	0	0	0	3238	1819	2.1	str,tny
	17:59:16	31	4880	-4.3	0.8	2	-8	-2	0	0	1	14305	11071	1.9	gr,str

TABLE 3 (continued)

Flight Summary Statistics

	Time In (CDT)	Dur (s)	z (m)	T (C)	LWC (g/m^3)	Up m/s	Down m/s	Ez (kV/m) max-	Ez (kV/m) min+	Ey (kV/m) max-	Ey (kV/m) max+	Max Sh/Or Conc ($1/m^3$)	Max 2DP Conc ($1/m^3$)	Max 2DP Size (mm)	Hydromets
15 August Flt 575		(cont'd.)													
	18:00:18	92	4930	-4.0	0.7	9	-4	-6	44	-26	16	28006	24393	6.2	gr,dr
	18:07:06	118	4300	0.0	0.2	4	-6	-26	55	-4	35	24677	15130	5.4	gr,str
	18:09:20	12	4400	-1.2	0.3	1	-2	-3	0	0	3	1242	3575	1.3	tny
	18:09:45	106	4380	-0.5	1.4	8	-6	-2	0	0	1	2607	3414	4.1	gr
	18:13:13	31	4100	-0.2	0.5	2	-4	-1	0	0	0	715	1477	3927.0	tny,str
	18:13:53	24	3930	0.8	0.3	0	-8	-1	0	0	0	858	1980	2431.0	tny,str
	18:14:23	8	3840	1.3	0.1	0	-9	-1	0	0	0	33	1559	0.7	tny,str
	18:15:23	7	3700	2.8	0.0	0	-7	-1	0	0	0	111	0	0.0	nothing
	18:15:40	8	3720	2.5	0.1	0	-4	-1	0	0	0	72	0	0.0	nothing
	18:16:02	29	3720	2.8	0.1	3	-2	-1	0			2029	2520	3.2	gr
	18:16:58	80	3680	3.2	0.7	5	-3	-1	0	0	0	2497	5099	3.4	gr,str
	18:18:29	125	3690	2.6	0.6	9	-6	-2	9	-8	1	36030	16313	5.6	gr,dr
	18:23:36	139	3380	4.6	1.8	10	-4	0	2	-2	2	3160	4686	5.4	dr
	18:26:23	31	3150	5.3	0.1	0	-8	-1	0	0	0	423	1828	0.7	tny
18 August Flt 576															
	15:24:55	95	4050	2.1	0.0	0	-4	0	0	0	0	878	0	0.0	tny
	15:26:40	63	4370	-0.3	0.0	2	-4	0	0	0	0	2542	5007	5.0	sn
	15:29:17	378	5120	-3.7	0.1	2	-5	-49	42	-30	20	60205	86142	10.5	sn
	15:36:39	250	5760	-7.2	0.0	2	-11	-13	12	-4	3	70343	88994	6.7	sn
	15:44:26	235	6170	-9.6	0.0	3	-9	-44	10	-20	10	124475	125786	7.1	sn
	15:49:44	79	6160	-9.7	0.0	3	-5.4	-21	6	-8	12	126413	101646	1.5	sn
	15:51:42	46	6190	-10.4	0.0	3	-2	0	1	-2	0	32739	11187	1.3	sn
	15:53:24	234	6170	-9.9	0.0	3	-10	-22	22	-14	8	146414	94040	5.0	sn
	16:01:16	504	6150	-10.0	0.0	3	-6	-5	40	-15	14	148020	79386	9.2	sn
	16:10:19	77	6040	-8.9	0.0	7	-10	-1	0	0	0	16080	20672	3.0	sn
	16:12:02	71	5940	-8.4	0.0	0	-8	-1	0	0	0	16575	31389	3.6	sn
	16:13:50	140	5840	-7.5	0.0	3	-20	-1	0	0	0	10267	21083	9.0	sn
	16:16:44	128	5880	-7.5	0.0	3	-19	-1	0	0	0	7666	16685	7.9	sn
	16:19:44	115	5920	-7.8	0.0	0	-22	-1	0	0	0	5325	9188	11.0	sn
	16:22:12	46	5720	-7.2	0.0	0	-15	-1	0	0	0	2913	6143	1.5	sn
	16:24:20	351	4360	0.0	0.0	5	-4	-18	33	-10	6	7419	9024	13.1	sn

Ez - vertical electric field, kV/m, as determined from the T-28 electric field mills and corrected for aircraft shape effects and the roll angle of the airplane. Peak negative and positive values during the period are given. A positive vertical field component would force a positive test charge to drift upward, and is indicative of positive charge below the aircraft and/or negative charge above the aircraft.

Ey - horizontal electric field, kV/m, as determined from the T-28 electric field mills and corrected for aircraft shape effects and the roll angle of the airplane. Peak positive and negative values observed during the period are given. The sign convention is that a positive horizontal field component would influence a positive test charge to drift to the right of the aircraft direction of motion, indicating positive charge to the left of the aircraft and/or negative charge to the right.

Max Sh/Or Conc - maximum precipitation particle concentration, number per cubic meter, observed during the penetration. This estimate is based on the maximum value of 1-s counts of the number of particles entering the PMS 2D-P probe sample volume, per second. This probe responds to particles larger than roughly 187 micrometers diameter. Only the edge of a particle need be in the sample volume to trip the probe. The probe sweeps out a cubic meter in about 6 s. The concentration is computed assuming all particles activating the probe are entirely within the geometric area scanned by the probe. This assumption is not strictly true and can lead to overestimates of the particle concentrations.

Max 2DP Conc - maximum precipitation particle concentration, number per cubic meter, computed from the 2D-P image data in a manner described in *Detwiler and Hartman* (1991). These estimates are based on periods over which the probe was active for a total of 1-s, which may involve several seconds of flight time. Artifact images are rejected and some particles partially in the field of view are reconstructed and included in the count. This approximately doubles the volume sampling rate of the probe for the largest particles compared to the volume sampling rate obtained if only images entirely within the field of view are included. These maximum concentration estimates are typically similar to the ones based on the shadow/or counts when the probe is operating properly. The peak values are somewhat dependent on the time chosen for the beginning of the penetration, as the sample accumulation process for each 1-s period will involve different portions of the cloud if it is started at different times. See *Detwiler and Hartman* (1991) for more details.

Max 2DP Size - maximum particle size (mm) observed by the 2D-P probe during the period. Since an attempt is made to reconstruct partial images, and the maximum dimension may be in the along-flight direction, the maximum size may exceed the nominal 6 mm effective width of the 2D-P array. Attempts are made to exclude artifact images such as splashes and streakers, but the automated rejection scheme is not 100% effective. These data have been checked with one pass of visual inspection through the most-probably misclassified images, but further examination would be prudent before basing any detailed analyses on these values.

Hydromets - a qualitative description of the most common particle type observed during a penetration, based on visual inspection of a sample of the images from each penetration.

rn = raindrops

sn = snow (dendrites, columns, etc., showing little or no riming)

gr = graupel

agg = aggregates of snow crystals

tny = tiny (particles too small to characterize)

str = streakers (water streaming off probe tips gives images of streaks - an indication of relatively high cloud water concentration).

4.2 Summary Examples

Figure 1 gives a histogram showing the frequency of occurrence of cloud penetration temperatures during CaPE. Two hundred and fifty-nine penetrations, at temperatures ranging from -12°C to +20°C, were identified. Most of the penetrations were made in the -2 to -6°C temperature range.

Figure 2 shows the maximum observed cloud water concentration during a penetration as a function of the maximum observed updraft during that penetration. Note that the region of the cloud containing the maximum cloud water concentration may not have coincided with the peak updraft. No strong correlation is evident, but the figure does show a tendency for a wider range of maximum liquid water concentrations in clouds containing stronger updrafts.

Finally, Fig. 3 shows the most positive and most negative vertical electric fields observed during a penetration as a function of penetration altitude. Larger magnitudes are observed in the 4 to 6 km range, but this is also the range containing most of the penetrations, so the appearance of larger magnitudes there may be due solely to more frequent sampling in that altitude range.

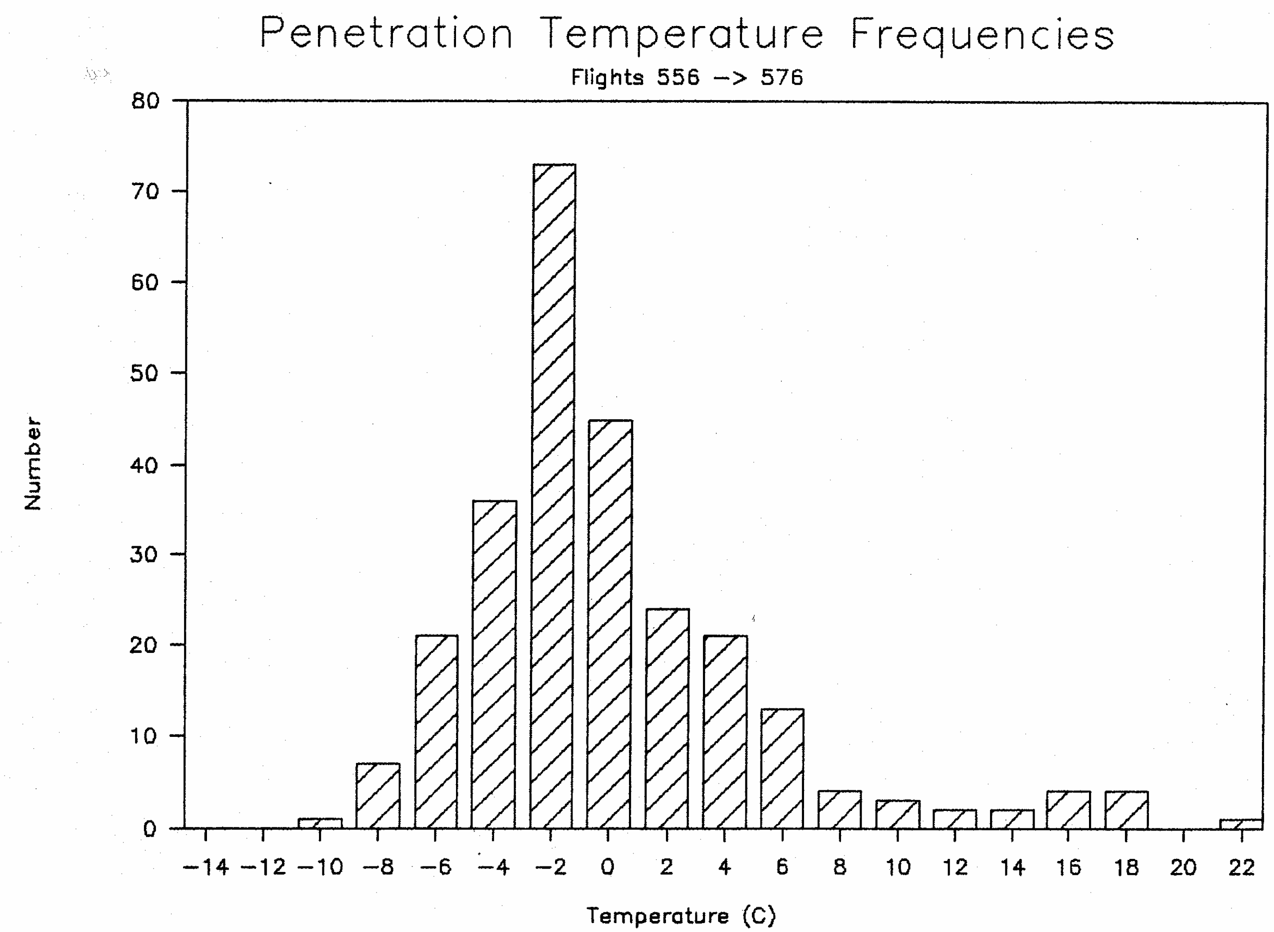

Figure 1: The distribution of T-28 penetration mean temperatures during CaPE.

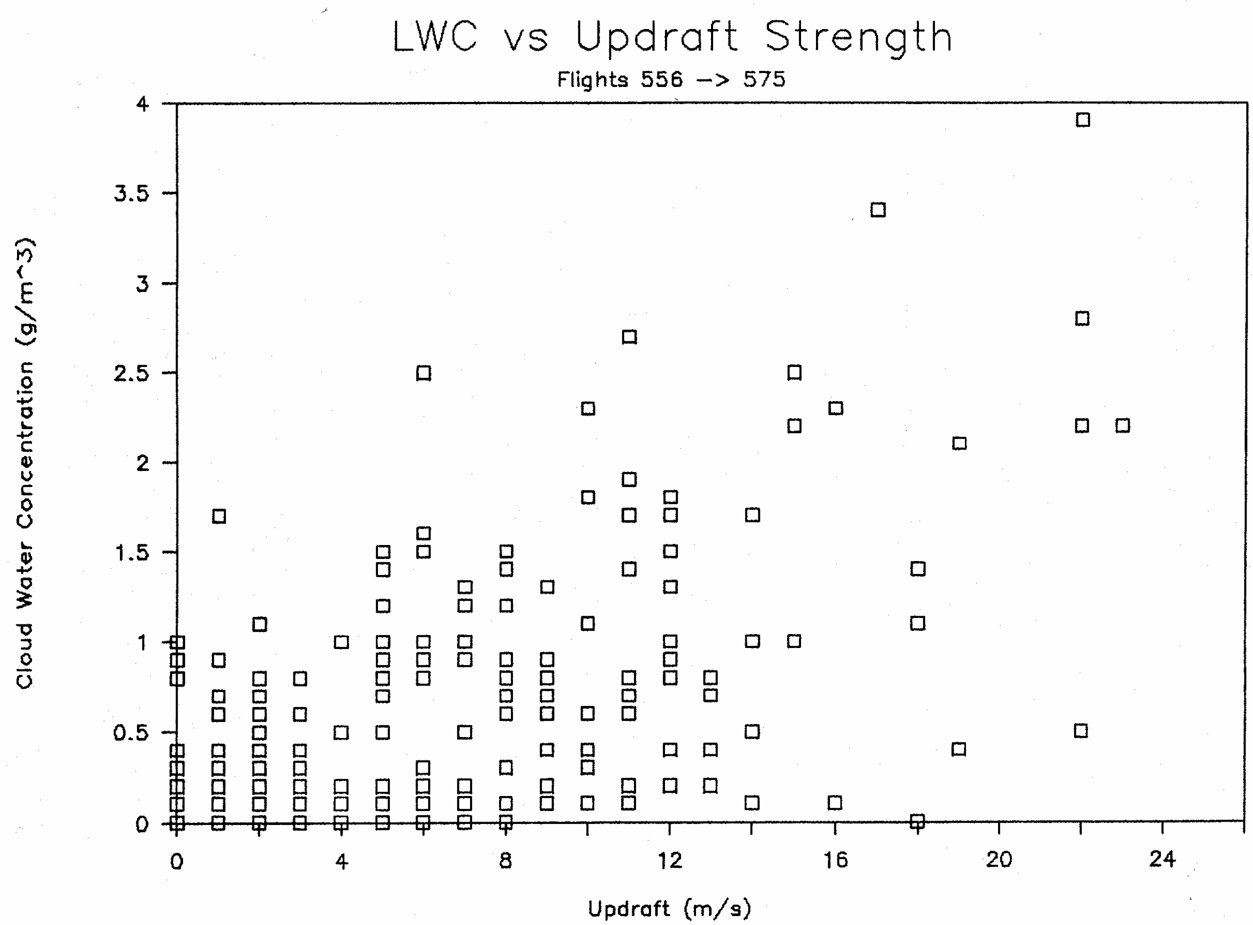

Figure 2: Maximum cloud water concentration as a function of maximum updraft observed during each T-28 penetration during CaPE. The peak value of cloud water was not necessarily coincident with the peak updraft within the penetration period.

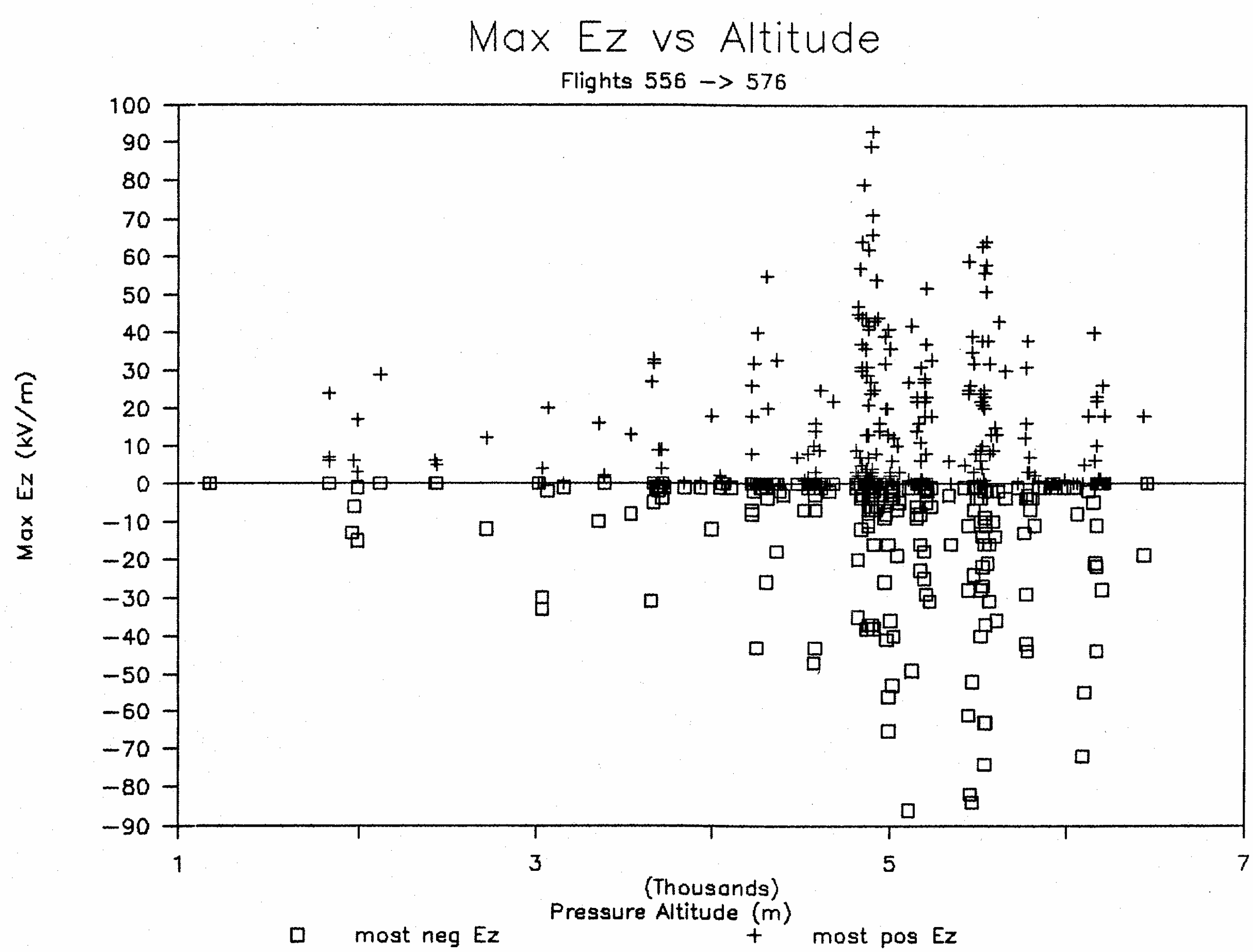

Figure 3: **Most positive and most negative vertical electrical field as a function of penetration mean pressure altitude is shown for all T-28 penetrations during CaPE.**

5. DATA AVAILABILITY

All T-28 data obtained during CaPE are available to interested researchers, although reimbursement for costs of duplication may be required if the request involves large volumes of data. Software for extracting selected data, replaying the flight via the display of aircraft flight tracks and selected variables, and displaying and analyzing 2D-P image data, can be supplied on request. Our software runs under DOS on IBM-compatible PC's. Data can be also supplied in ASCII format on 9-track tape for use on other types of machines.

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APPENDIX A

T-28 Instrumentation

VARIABLE	INSTRUMENT	RANGE	ACCURACY	RESOLUTION (as recorded)	NOTES
STATIC PRESSURE	ROSEMOUNT 1301-A-4B	0-15 psi (0-103 kPa)	±0.015 psi (±0.1 kPa)	0.0002 psi (0.002 kPa)	• Bench calibration, 3/89
	ROSEMOUNT 1301-A-4B	5-15 psi (35-103 kPa)	±0.015 psi (±0.1 kPa)	0.0002 psi (0.002 kPa)	• Bench calibration, 3/89
TOTAL TEMPERATURE	ROSEMOUNT 102AU2AP	-30 - +30°C	±0.5°C	0.001°C	• Platinum wire • 2 s time constant
	NCAR REVERSE FLOW	-30 - +50°C	±0.5°C	0.001°C	• Diode • Several seconds time constant • Bench calibration, 3/89 • Recovery factor adjusted, 5/89
CLOUD WATER AND CLOUD DROPLETS	JOHNSON-WILLIAMS LIQUID WATER CONCENTRATION	0 - 6 g/m^3	±20%	0.0001 g/m^3	• Accurate if all droplets have d <30 μm
	PARTICLE MEASURING SYSTEMS, INC. FORWARD SCATTERING SPECTROMETER PROBE	Size -1 < 57 μm Concentration 0 -2000 droplets/ cm^3	±1 size channel in size and ±1% in concentration at -50/cm^3	1 size channel	• 15 discrete size channels spread over an adjustable range • Sampling rate 300 cm^3/km • Accuracy of computed liquid water concentration ±20%. Depends on processing.
PRECIPITATION PARTICLE SIZES AND CONCENTRATIONS	WILLIAMSON FOIL IMPACTOR	1 - 20 mm	0.2 mm	0.2 mm	• Sampling rate 1.4 m^3/km
	PARTICLE MEASURING SYSTEMS, INC. 2D Precipitation Probe	Size 200 - 6400 μm	±200 μm	200 μm	• Computed ice and water concentration can vary ±50% with processing technique • Sampling rate: 1.66 m^3/km; DAS can accept ~250 particles/sec (2500/km)
	CANNON PARTICLE CAMERA	Size >50 μm	50 μm	50 μm	• Sampling rate up to 2 m^3/km
	NCAR PARTICLE SAMPLER				• A batch sampler, primarily for hailstones • Sampling rate 2.6 m^3/km
AIRCRAFT MOTION	NCAR TRUE AIRSPEED COMPUTER	0 - 250 kts (0 - 130 m/s)	±3 kts (±1.5 m/s)	0.125 kt (0.07 m/s)	• True airspeed
	HUMPHREY SSA09-D0101-1 VERTICALLY STABILIZED ACCELEROMETER	-1 to +3 g's pitch -50° to +50° roll -50° to +50°	0.004 g 0.2° 0.2°	0.00006 g 0.002° 0.002°	
	ROSEMOUNT 1301-D-1B DYNAMIC PRESSURE	-3 to +3 psi (-20 to +20 kPa)	±0.1%	0.0001 psi (0.0006 kPa)	• Indicated airspeed • Bench calibration, 3/89
	ROSEMOUNT 1221-F-2A DYNAMIC PRESSURE	-2.5 to +2.5 psi (-18 to +18 kPa)	±0.1%	0.0001 psi (0.0006 kPa)	• Indicated airspeed • Bench calibration, 3/89
	GIANNINI 45218YE MANIFOLD PRESSURE	0 to 50 in Hg	±2%	0.008 Hg (0.03 kPa)	• Used in one vertical velocity calculation • Bench calibration, 3/89
	BALL ENGINEERING 101A VARIOMETER	-6000 to +6000 ft/min (-30 to +30 m/s)	±200 ft/min (±1 m/s)	0.2 ft/min (0.001 m/s)	
AIRCRAFT LOCATION	NARCO NAV-122 VOR	0 - 360°	±2°	0.005°	
	CESSNA 400 DME	0 - 100 nmi (0 - 185 km)	0.1 nmi (185 m)	0.002 nmi (3 m)	• Maximum 2 s to lock on and acquire range
	TRIMBLE TNL3000 GPS/LORAN	(global)	30 m (GPS)		
ELECTRIC FIELD	NMIMT Model E-100 DC Electric Field Meter	- ± 200 $\frac{kV}{m}$		0.01 $\frac{kV}{m}$	

NOTE: Many of these instruments do not behave as ideal instruments. The use of one measure of accuracy over the entire range of measurement is, in many cases, questionable. An accuracy representative of the most useful part of the range is given here.

APPENDIX B

List of Variables Recorded or Routinely Computed from T-28 Observations

Each different variable in the data stream is indexed with a unique tag number. Those used for CaPE are listed here.

TAG	VARIABLE	REMARKS
100	**Time**	The T-28 data system is always set to local time, and recorded in a 24-hour format. It is maintained within a second of WWV unless otherwise noted.
101	**Dynamic Pressure 1**	
102	**Dynamic Pressure 2**	Both dynamic pressures are read from the same pitot tube line (with the inlet out on the right wing) using two different but nearly identical sensors. [[hPa]
103	**Rosemount Static Pressure 1**	
104	**Rosemount Static Pressure 2**	Both static pressures are read from the same static pressure line (inlet on the rear fuselage) using two different but nearly identical sensors. [hPa]
105	**Rate of Climb**	The instantaneous rate of change of aircraft altitude, read from a standard aircraft variometer. The recorded data are unfiltered and much noisier than the damped cockpit display. [m/s]
106	**Rosemount Temperature**	This is static temperature sensed by a standard, de-iced, Rosemount aircraft total air temperature probe. It commonly suffers from wetting and reads low in clouds. [°C]

107	**Reverse Flow Temperature**	This is static temperature sensed by a thermistor placed inside a custom-design "reverse-flow" housing. It does not normally get wet in supercooled clouds, but may get wet in warm clouds or in regions of high precipitation water concentration. Apparently, ice may sometimes build up to such an extent on the housing that temperature readings are affected even though the sensor is not wetted. For most of CaPE, this sensor was not operating properly due to an unidentified electronic problem. [°C]
108	**Manifold Pressure**	Pressure inside the engine manifold (an indicator of power being developed by the engine) recorded from a standard aircraft engine pressure sensor. [inches of mercury]
109	**Acceleration**	Vertical acceleration as determined by a Humphrey aircraft accelerometer. [g's]
110	**Pitch**	The accelerometer also gives angle of the fuselage relative to horizontal. [deg]
111	**Roll**	Finally, the accelerometer gives angle of the wings relative to horizontal. Angle is positive for a left bank (left wing down) [deg]
112	**J.W. Liquid Water**	The J.W. probe yields concentration of water in clouds represented in droplets less than approximately 30 μm diameter. [g/m^3]
113	**VOR**	The VOR gives the direction to the VORTAC (a radio direction-finding beacon used by aircraft) to which it is tuned. [deg]
114	**DME1**	This is distance to the VORTAC to which the #1 DME is tuned. [n mi]

115	**DME2**	This is distance to the VORTAC to which the #2 DME is tuned. If they are tuned to different VORTAC's, the recorded distances from the two DME's may be used to reconstruct the aircraft flight track. [n mi]
116	**Voltage Regulator**	Research system voltage. [V]
117	**Heading**	Indicates direction (from magnetic north) towards which the aircraft is heading. [deg]
118	**NCAR true air speed**	True airspeed as computed by an analog computer built at NCAR during the NHRE project in the 1970's to clock the 2D-C imaging probe. [m/s]
121	**Interior Temperature**	Temperature inside the data acquisition system computer in the baggage bay. If it climbs much above 32°C, one should be wary for possible data system malfunctions. [°C]
127	**RFT Ch6**	Recording of reverse flow temperature probe temperature on a second data system channel. [°C]
128	**Kathy charging**	Voltage proportional to charge current to a charge patch installed on the foil impactor pylon under the right wing for several flights during CaPE in 1991, beginning with Flight 568. Not calibrated. [V]
129	**Kathy discharging**	Voltage proportional to discharge current from rear-fuselage discharge wick. Not calibrated, but a positive voltage corresponds to a negative discharge current. [V]
130	**Event Bits**	Bits corresponding to various events recognized by the data system, including such things as the in-cloud switch activated by the pilot when visually entering cloud, activation of the cockpit voice recorder, etc.

131	**GPS Warning Codes**	Byte corresponding to various status messages from the GPS system.
140	**FSSP size counts**	This tag contains information concerning the number of counts in each of the 15 available FSSP size channels. [number per channel per second]
141	**FSSP total counts**	The total number of droplets counted by the FSSP during a second.
142	**FSSP average diameter**	The average diameter of all droplets recorded during a second. [μm]
143	**FSSP concentration**	The actual concentration of droplets computed from FSSP counts divided by the volume sampled in one second. [#/cm^3]
144	**FSSP Water**	The liquid water concentration computed from the FSSP data for a second. [g/m^3]
145	**FSSP Activity**	The fraction of time the FSSP was active during the previous second.
146	**PMS 2DP Shadow Or Count**	The number of times the 2D-P probe was triggered out of its wait state by the passage of a new particle. [#/s]
158	**Cannon Camera Frame Count**	The number of frames exposed from the beginning of the flight to the end of the last second.
160	**Top Field Mill (low res)**	The electric field indicated by the low sensitivity channel on the field mill mounted in the aircraft canopy looking up. Field mill data are recorded at 20 Hz. [kV/m]
161	**Bottom Field Mill (low res)**	The electric field indicated by the low sensitivity channel on the field mill located in the baggage bay door looking down. [kV/m]

162	**Left Field Mill (low res)**	The electric field indicated by the low sensitivity channel on the field mill mounted in the left wing tip facing outward. [kV/m]
163	**Right Field Mill (low res)**	The electric field indicated by the low sensitivity channel on the field mill mounted in the right wing tip facing outward. [kV/m]
164	**Top Field Mill (high res)**	The electric field indicated by the high sensitivity channel on the top field mill. [kV/m]
165	**Bottom Field Mill (high res)**	The electric field indicated by the high sensitivity channel on the bottom field mill. [kV/m]
166	**Left Field Mill (high res)**	The electric field indicated by the high sensitivity channel on the left field mill. [kV/m]
167	**Right Field Mill (high res)**	The electric field indicated by the high sensitivity channel on the right field mill. [kV/m]
172	**Latitude**	Computed internally in the GPS receiver. [deg]
173	**Longitude**	Also computed internally in the GPS receiver. [deg]
174	**Groundspeed**	Computed internally in the GPS receiver (basically by differentiating the position data with respect to time). [m/s]
175	**Ground Track Angle**	The direction towards which the aircraft is moving relative to the ground, with respect to magnetic north. [deg]
176	**Magnetic Deviation**	The difference between magnetic north and true north as indicated automatically by the GPS receiver based on the current position. [deg]

177	**Time Since Solution**	The time since the GPS was last able to compute an accurate position solution based on a sufficient number of satellites. It updates the position based on dead reckoning if it does not have a sufficient number of satellites in view.
200	**Date**	As indicated by the data acquisition system computer clock. [yymmdd]
201	**Month**	mm [integer number]
202	**Day**	dd [integer number]
203	**Year**	yy [integer number]
204	**Flight**	A serial number assigned to each T-28 flight beginning with the first flight in 1972.
205	**Altitude**	The altitude in a standard atmosphere corresponding to the recorded pressure. [m]
206	**Theta e**	The equivalent potential temperature corresponding to the recorded temperature and assuming saturation with respect to liquid water. [K]
207	**Saturation Mixing Ratio**	The mixing ratio of water vapor corresponding to saturation with respect to liquid water at the recorded temperature. Computation is done with a formula given in A. Buck, 1981: *J. Appl. Meteor.,* **20**, 1527-1532. [g/kg]
208	**Point dz/dt**	The rate of change of altitude of the aircraft, computed by differentiating the pressure altitude with respect to time. This represents an independent estimate of the rate-of-climb to be compared to tag 105. [m/s]

209	**Indicated Air Speed**	What the airspeed would be if the aircraft were flying at sea level and indicating the observed dynamic pressure. [m/s]
210	**Updraft (uncorrected)**	The estimated upward speed of the air relative to the ground, computed from changes in the aircraft altitude and other factors, but not corrected for horizontal aircraft acceleration. [m/s]
211	**Calculated TAS**	The true speed of the aircraft relative to the air, computed from the observed dynamic and static pressures, and temperature. [m/s]
212	**Updraft Correction Factor**	A correction to the simple (uncorrected) updraft calculation that accounts for horizontal accelerations of the aircraft. [m/s]
213	**Cooper Updraft**	The sum of the uncorrected updraft and the correction factor. [m/s]
214	**Kopp Updraft**	An updraft calculated somewhat differently than the Cooper updraft. The calculation is described in F. J. Kopp, 1985: *J. Atmos. Ocean. Tech.,* **2**, 684-688. It is basically an inversion of the aircraft equation of motion. In most situations, it yields a less noisy and more physically plausible updraft result for the T-28. [m/s]
216	**Turbulence**	The turbulent energy dissipation rate computed by doing a Fourier transform on 16 successive values of true airspeed, weighting each Fourier component by wave number to the 5/3 power, and taking the average. [$cm^{2/3}/s$]

217	**Air Density**	Computed from the recorded temperature and static pressure. [kg/m^3]
218	**JW Mixing Ratio**	The mixing ratio of cloud water per unit mass of dry air based on the JW reading and computed air density. [g/kg]
219	**FSSP Mixing Ratio**	The same thing, but calculated from the FSSP water concentration. [g/kg]
260	**Ambient Vert Electric Field**	The component of the ambient electric field that is vertical in the aircraft frame of reference. Positive means a positive test charge would drift upward relative to the aircraft in the field. [kV/m]
261	**Plane Vert Electric Field**	The field due to charge on the aircraft, computed by summing the readings of the top and bottom mill and normalizing based on self-charging tests. Positive means a positive test charge would be repelled away from the aircraft by the field. [kV/m]
262	**Ambient Hor Electric Field**	The ambient field oriented perpendicular to the aircraft along the wings, positive meaning a positive test charge would drift to the right in the field. [kV/m]
263	**Plane Hor Electric Field**	The field due to charge on the aircraft, computed by summing the wingtip mill readings and normalizing. Positive means a positive charge would be repelled away from the aircraft due to its charge. [kV/m]
264	**Ambient Vert Field (roll cor)**	The component of the ambient field that is truly vertical with respect to earth coordinates. [kV/m]

265	**Ambient Hor Field (roll cor)**	The component of the ambient field perpendicular to the aircraft path and truly horizontal with respect to earth coordinates. [kV/m]
272	**Latitude (deg)**	
273	**Latitude (min)**	
274	**Longitude (deg)**	
275	**Longitude (min)**	GPS coordinates broken into separate degree and minute components.
276	**Ground Track Angle (True N)**	The direction of motion relative to the ground with respect to true north, derived from the GPS ground track angle with respect to magnetic north.

APPENDIX C

Reduced Data Items Computed for CaPE, Melbourne, FL, July-Aug, 1991 *0

Tag #	Description		# Values Output	Units	Method of Computation	Last Mod (if this year)
101	Dynamic Pressure #1	(10 Hz)	1	hPa	6.280525E-3 * Raw + 0.88244	
102	Dynamic Pressure #2	(10 Hz)	1	hPa	5.268222E-3 * Raw - 0.22955	
103	Static Pressure #1	(2 Hz)	1	hPa	1.5809E-2 * Raw + 528.1485	
104	Static Pressure #2	(2 Hz)	1	hPa	1.09617E-2 * Raw + 688.7589	
105	Rate of Climb		1	m/s	5.625E-4 * Raw, for Raw > = 0	
					5.287E-4 * Raw, for Raw < 0	
106	Rosemount Temp		1	deg C	mach2 = 5*((1+dyn_pr/stat_pr)**(2/7)-1)	
					divisor = 1 + 0.195 * mach2	
					temp = (1.83105E-3*Raw+243.16)/divisor-273.16	
107	Reverse Flow Temp		1	deg C	divisor = 1 + 0.153 * mach2	*3
					temp = (1.7962E-3*Raw+244.3775)/divisor-273.16	
108	Manifold Pressure		1	" Hg	3.1098E-3 * Raw + 0.159275	
109	Acceleration	(10 Hz)	1	g's	6.25E-5 * Raw + 1.0	*2
110	Pitch	(5 Hz)	1	deg	-3.05175E-3 * Raw + 50	
111	Roll	(5 Hz)	1	deg	3.05175E-3 * Raw - 50	
112	J.W.Liquid Water		1	g/m3	1.83125E-4 * Raw	
113	VOR		1	deg	1.117534E-2 * Raw - 1.155475	
114	DME #1		1	naut mi	3.03269E-3 * Raw - 0.24536	
115	DME #2		1	naut mi	3.03269E-3 * Raw - 0.046623	
116	Voltage Regulator		1	volts	1.5258789E-4 * Raw	
117	Heading	(5 Hz)	1	deg	device not hooked up	
118	NCAR true? air speed		1	m/s	3.96744E-3 * Raw	
119	End Element #1		1	volts	1.52588E-4 * Raw	
120	End Element #2		1	volts	1.52588E-4 * Raw	
121	Interior Temp (computer)		1	deg C	3.05175E-2 * Raw	
128	Charging (Kathy Giori)	(20 Hz)	1	volts	1.52588E-4 * Raw	new 8/2/91
129	Discharging (Kathy Giori)	(20 Hz)	1	volts	1.52588E-4 * Raw	new 8/2/91
130	Event Code bits		1	flags	bit 0 = 1 --> system running	
					bit 1 = 0 --> in cloud	
					bit 2 = 0 --> foil on	
					bit 3 = 0 --> voice recorder on	
131	GPS warning codes		1	flags	11 bit codes	new 1991

APPENDIX C (continued)

Reduced Data Items Computed for CaPE, Melbourne, FL, July-Aug, 1991 *0

Tag #	Description		# Values Output	Units	Method of Computation	Last Mod (if this year)	
140	FSSP counts		15	number	Raw		
141	FSSP total counts		1	number	Sum of tag 140s		
142	FSSP ave diameter		1	microns	sum of diams / number		
143	FSSP concentration		1	#/cm3	vol = 0.229 * tas denom = 1 - .55 * activ / 100 conc = tot_count / vol / denom		
144	FSSP water		1	g/m3	mass = sum of counts * volumes water = mass/vol/denom*1.E6		
146	Probe Activity		1	???	Raw / 10		
147	PMS 2d Shd Or		1	number	Raw		
158	Cannon Camera frame count		1	number	Raw		
160	Top field mill, low res	(20 Hz)	1	kV/m	-1.982574E-2 * Raw + 0.026	Spring 1991	(*1)
161	Bottom field mill, low res	(20 Hz)	1	kV/m	-1.982574E-2 * Raw + 0.104	Spring 1991	(*1)
162	Left field mill, low res	(20 Hz)	1	kV/m	-9.7023E-2 * Raw - 0.5442	5/3/91	(*1)
163	Right field mill, low res	(20 Hz)	1	kV/m	-9.7778E-2 * Raw - 1.9651	5/3/91	(*1)
164	Top field mill, hi res	(20 Hz)	1	kV/m	-3.11585E-4 * Raw + 0.027	Spring 1991	(*1)
165	Bottom field mill, hi res	(20 Hz)	1	kV/m	-3.10364E-4 * Raw + 0.04	Spring 1991	(*1)
166	Left field mill, hi res	(20 Hz)	1	kV/m	-1.5323E-3 * Raw + 0.1614	5/3/91	(*1)
167	Right field mill, hi res	(20 Hz)	1	kV/m	-1.5361E-3 * Raw + 0.0835	5/3/91	(*1)
172	GPS latitude		1	deg	degree + (minute + hundredths/100)/60	new 1991	
173	GPS longitude		1	deg	degree + (minute + hundredths/100)/60	new 1991	
174	GPS groundspeed		1	m/s	1852 / 36000 * Raw	new 1991	
175	GPS grnd track angle (mag N)		1	deg	Raw / 10	new 1991	
176	GPS magnetic deviation		1	deg	Raw / 10 (Raw is 32-bits, not 16)	new 1991	
177	GPS time since solution		1	s	Raw / 10	new 1991	
178	GPS track angle error		1	deg	Raw / 10 (Raw is 32-bits, not 16)	new 1991	
200	Date		1	yymmdd			
201	Month		1	number			
202	Day		1	number			
203	Year		1	2-dig			
204	Flight number		1	number			
205	Altitude		1	meters	4.43077E4*(1-(stat_pr/1013.3027)**0.190284)		

APPENDIX C (continued)

Reduced Data Items Computed for CaPE, Melbourne, FL, July-Aug, 1991 *0

Tag #	Description	# Values Output	Units	Method of Computation	Last Mod (if this year)
206	Theta e	1	K	tempk = RFT temp in K svp = 6.1078*exp(17.26939*rft/(tempk-35.86)) smr = svp / (stat_pr - svp) * 0.622 ts = tempk * (1000/stat_pr)**0.286 thetae = ts*exp(597.3*smr)/(0.24*tempk))	
207	Saturation mixing ratio	1		smr from above	
208	Point dz/dt	1	m/s	alt - prev_alt	
209	Indicated airspeed	1	m/s	c = 1 + dyn_pr / 1013.3027 ias=sqrt(5.79E5*(c**(2/7)-1))	
210	Updraft (uncorrected)	1	m/s	u1 = change in alt ((i+1)-(i-1))/2 u2 = (27 - man_pr) * 92 u3 = (1.94254 * ias - 140) * 17.7 updr = u1 + (u2 + u3) * 0.00508	
211	Calculated TAS	1	m/s	sqrt(rftuc*mach2*401.856/divisor)	
212	Updraft correction factor	1	m/s	calc_tas*(change in calc_tas)/2/9.775	
213	Cooper Updraft	1	m/s	updraft + updraft correction	
214	Kopp Updraft	1	m/s	dens = 0.34838 * stat_pr /tempk ang = pitch * 0.0174533 Kopp=u1+62.12*accel*9.775/(dens*calc_tas) -(0.02028+ang)*calc_tas	
216	Turbulence	1	cm**2/3/s	Much too complicated to write here. Static and dynamic pressure values, along with RFTs, are fed into a fast Fourier transform routine. Consult program listing.	
217	Air density	1	kg/m3	0.34838 * stat_pr / tempk	
218	JW mixing ratio	1	g/kg	jw_water / density	
219	FSSP mixing ratio	1	g/kg	FSSP_water / density	
260	Ambient vert EF	1	kV/m	(tfm / 1.9 - bfm) / 5.6	5/5/91 (*1)
261	Plane vert EF	1	kV/m	(tfm / 2 + bfm) / 4	5/5/91 (*1)
262	Ambient lateral EF	1	kV/m	(rfm - lfm) / 44.8	5/5/91 (*1)
263	Plane lateral EF	1	kV/m	(rfm + lfm) / 21.6	5/5/91 (*1)

APPENDIX C (continued)

Reduced Data Items Computed for CaPE, Melbourne, FL, July-Aug, 1991 *0

Tag #	Description	# Values Output	Units	Method of Computation	Last Mod (if this year)	
264	Ambient vert EF (with roll)	1	kV/m	cosr = cos(roll_rad) sinr = sin(roll_rad) t264 = t260 * cosr + t262 * sinr		(*1)
265	Ambient lat EF (with roll)	1	kV/m	t265 = -t260 * sinr + t262 * cosr		(*1)
272	GPS deg lat	1	deg	integer portion of tag 172 (t172)	Spring 1991	
273	GPS min lat	1	min	fractional part of t172 * 60	Spring 1991	
274	GPS deg long	1	deg	integer portion of tag 173 (t173)	Spring 1991	
275	GPS min long	1	min	fractional part of t173 * 60	Spring 1991	
276	GPS true bearing	1	deg	mod(t175+t176+360,360)	Spring 1991	

*0 - In some cases the equation variables are averages. Consult the listing of REDUCE.C for exact details. All parameters are recorded at 1 Hz unless otherwise noted.

*1 - The sign convention for field mills was reversed from pre-1991.

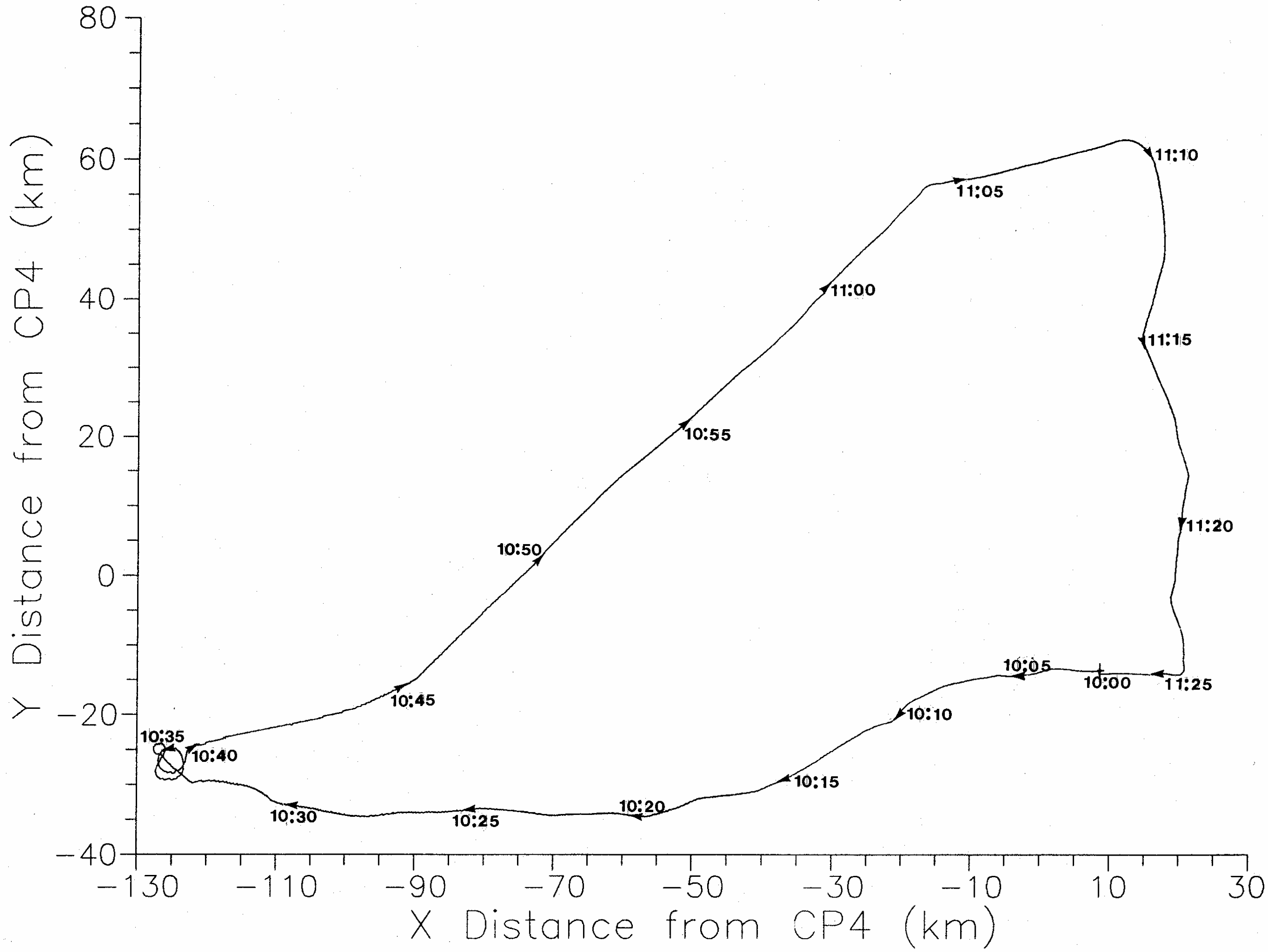
*2 - Because the RFT readings suffered from noise problems, tag 106 was used in computations which normally use tag 107.

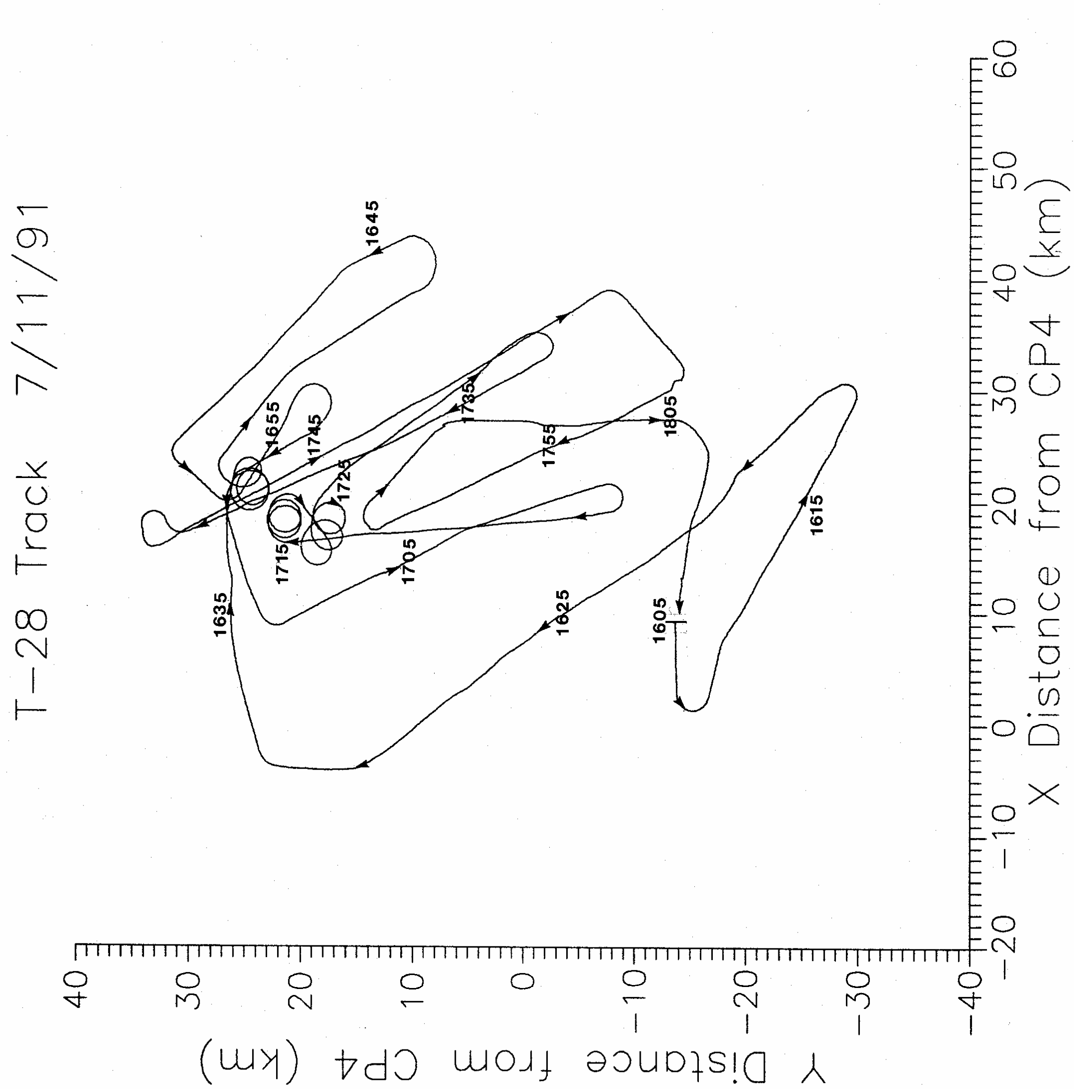
*3 - For flight 566 tag 127 was used as a duplicate channel recorder for RFT. Since it, too, suffered from noise, its use was then discontinued.

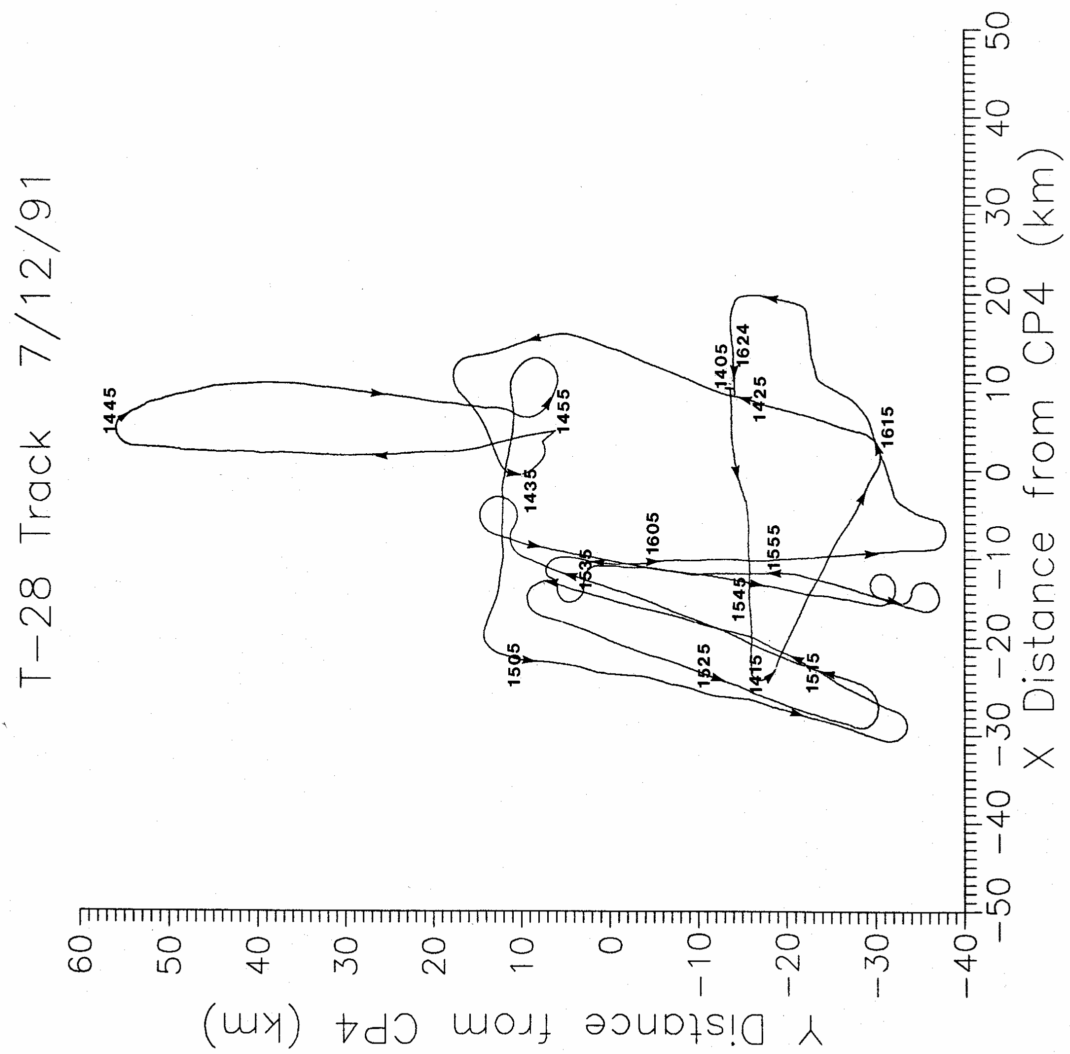
APPENDIX D

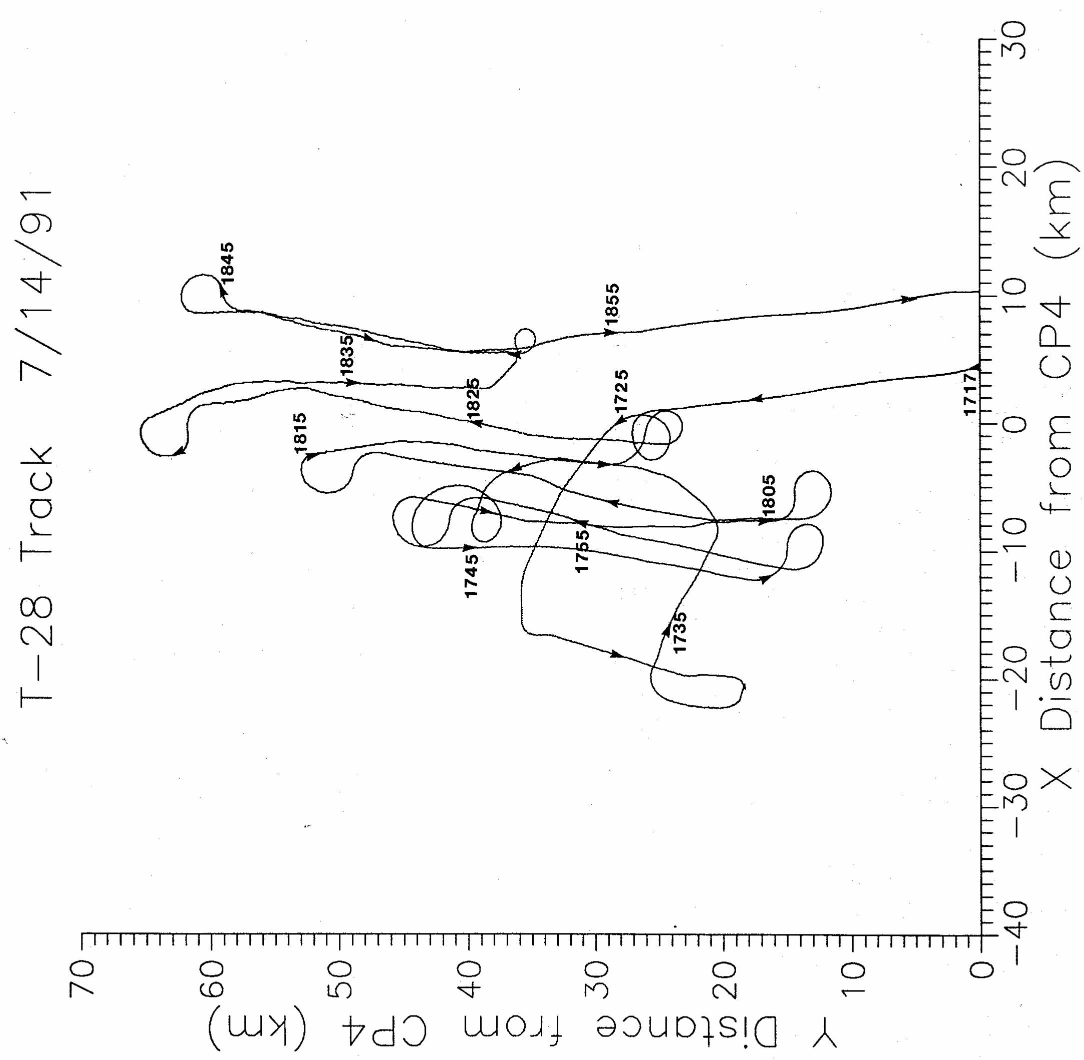
T-28 CaPE Flight Tracks

T-28 Track 7/11/91

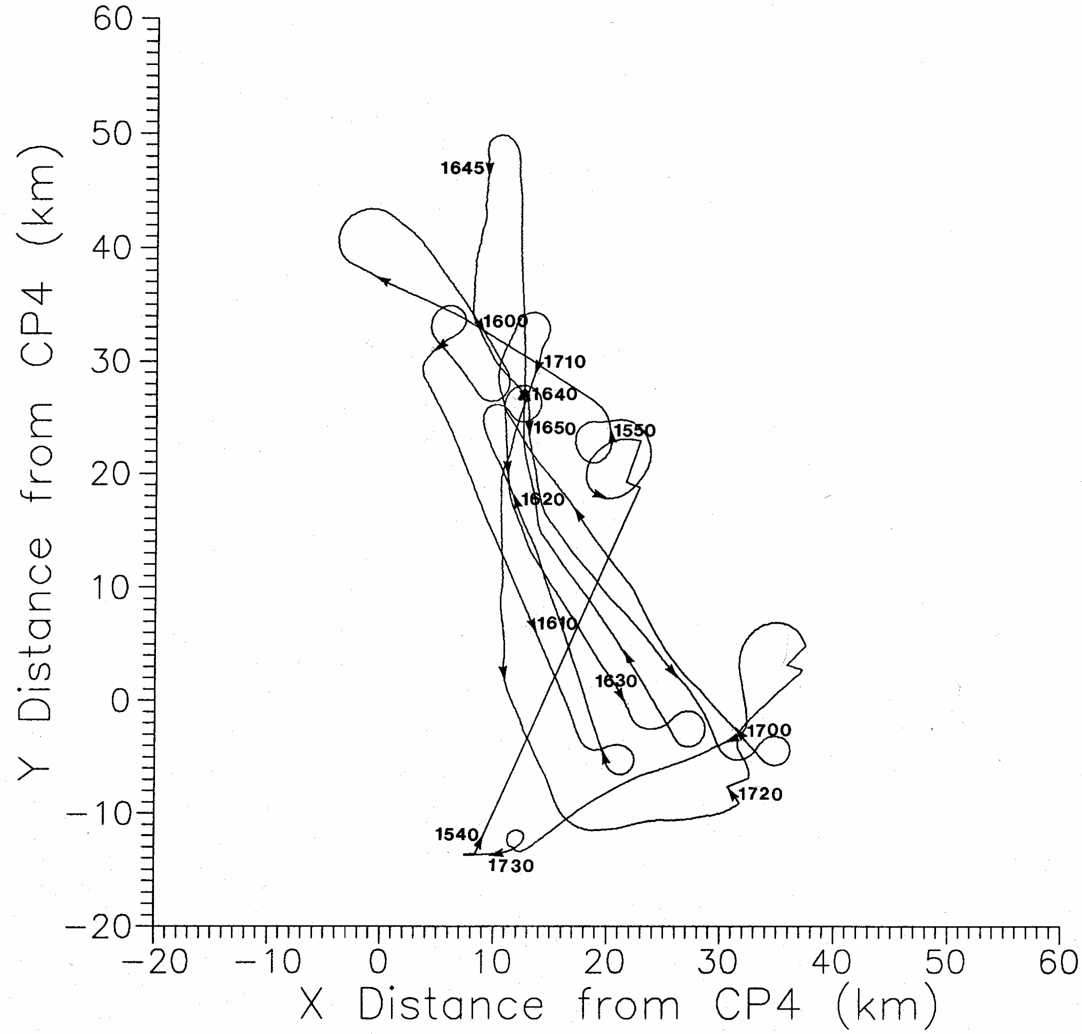


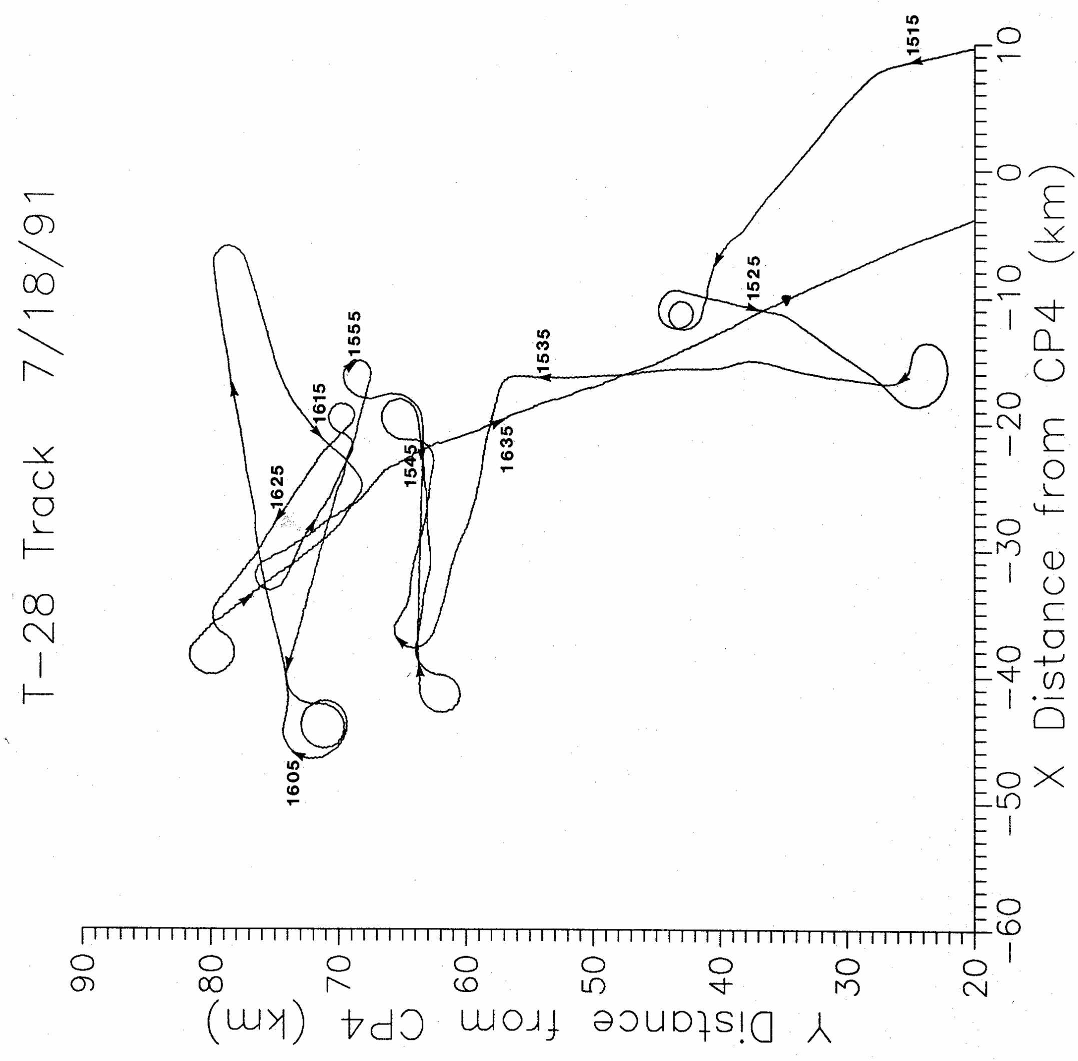

T-28 Track 7/11/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
1605
1615
1625
1635
1645
1655
1705
1715
1725
1735
1745
1755
1805
-20
-10
0
10
20
30
40
50
60
40
30
20
10
0
-10
-20
-30
-40

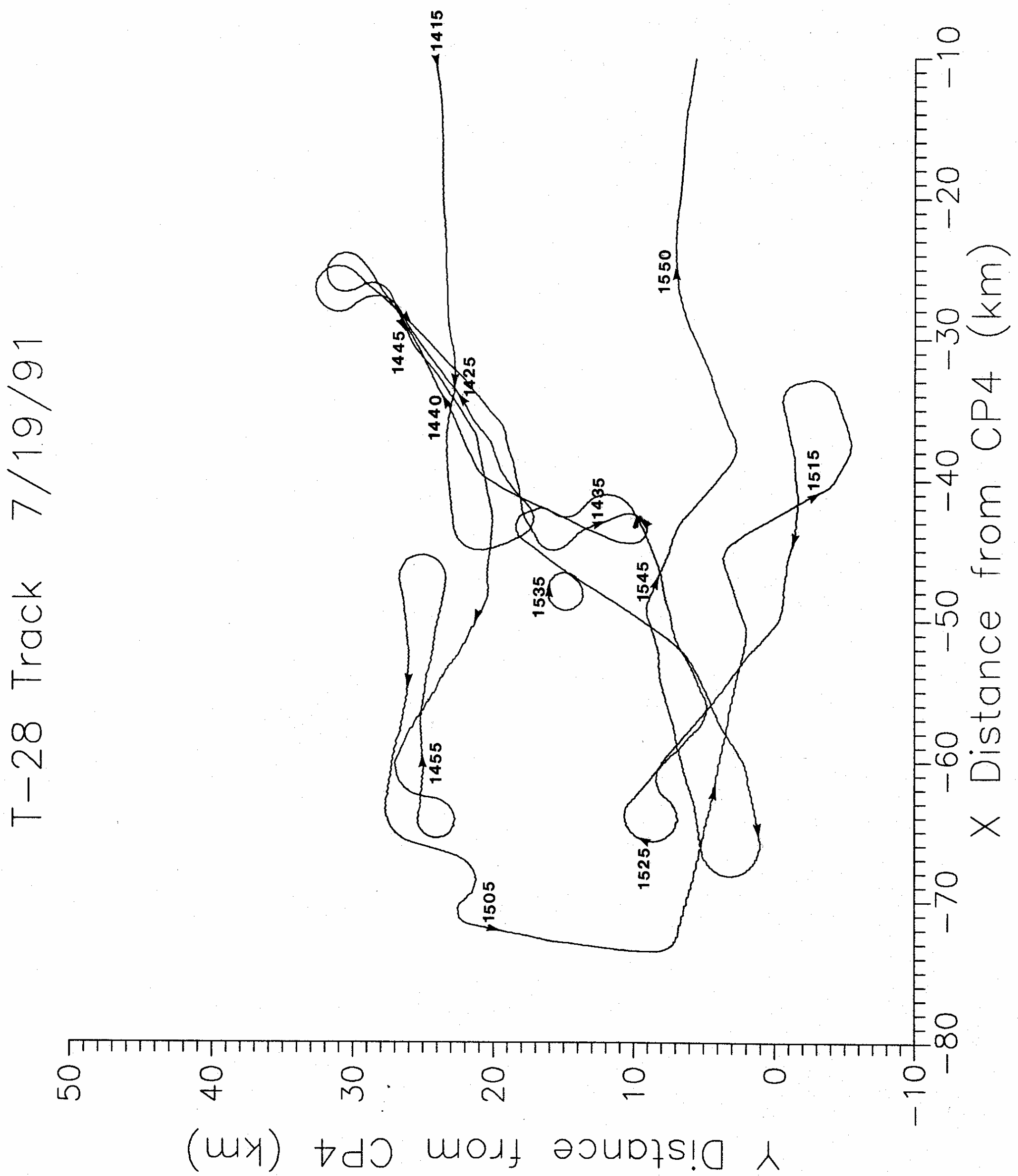

T-28 Track 7/12/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
1445
1455
1435
1405
1624
1425
1615
1605
1555
1535
1545
1505
1525
1415
1515

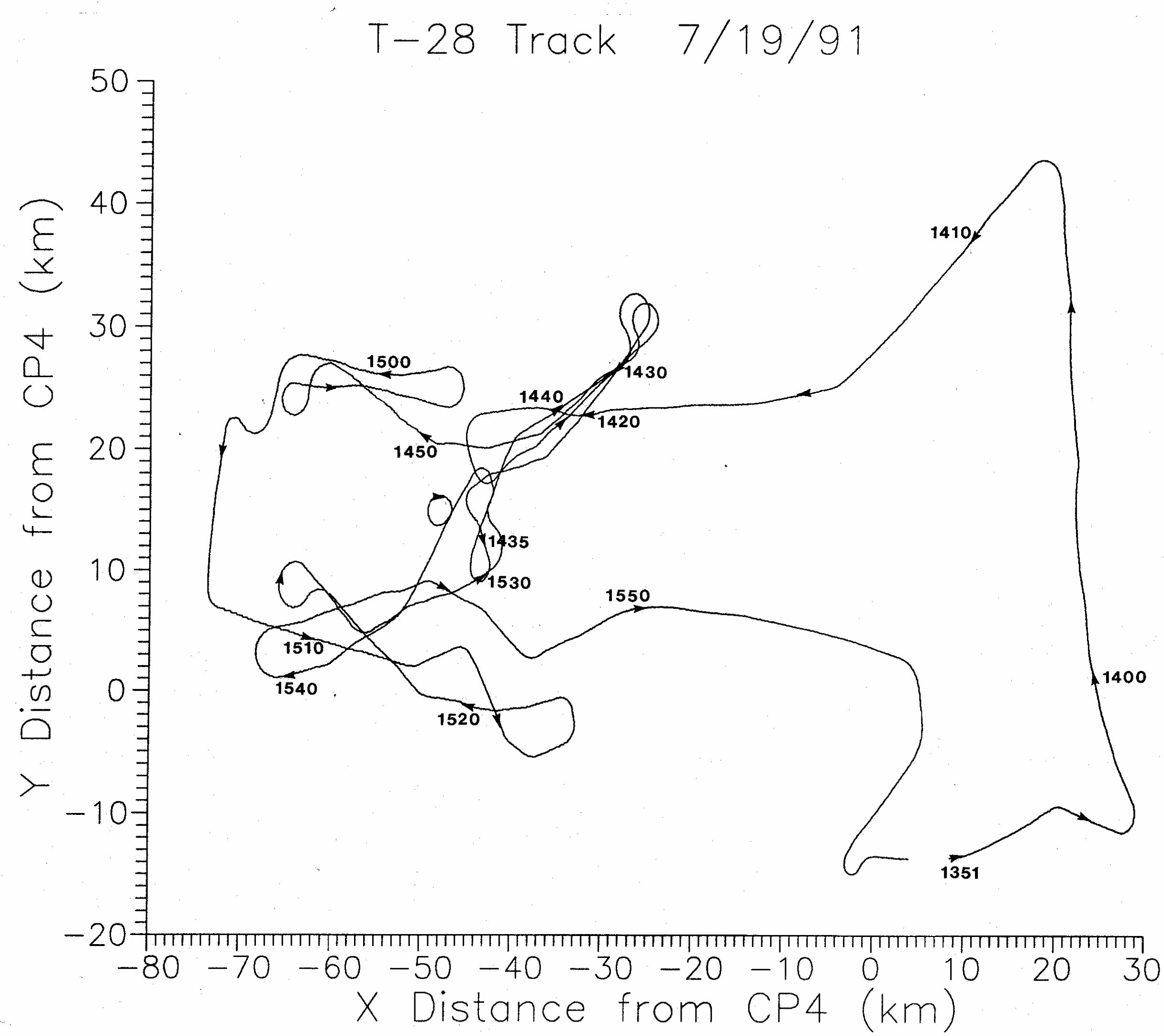

T-28 Track 7/14/91
Y Distance from CP4 (km)
X Distance from CP4 (km)
70
60
50
40
30
20
10
0
−40
−30
−20
−10
0
10
20
30
1717
1725
1735
1745
1755
1805
1815
1825
1835
1845
1855

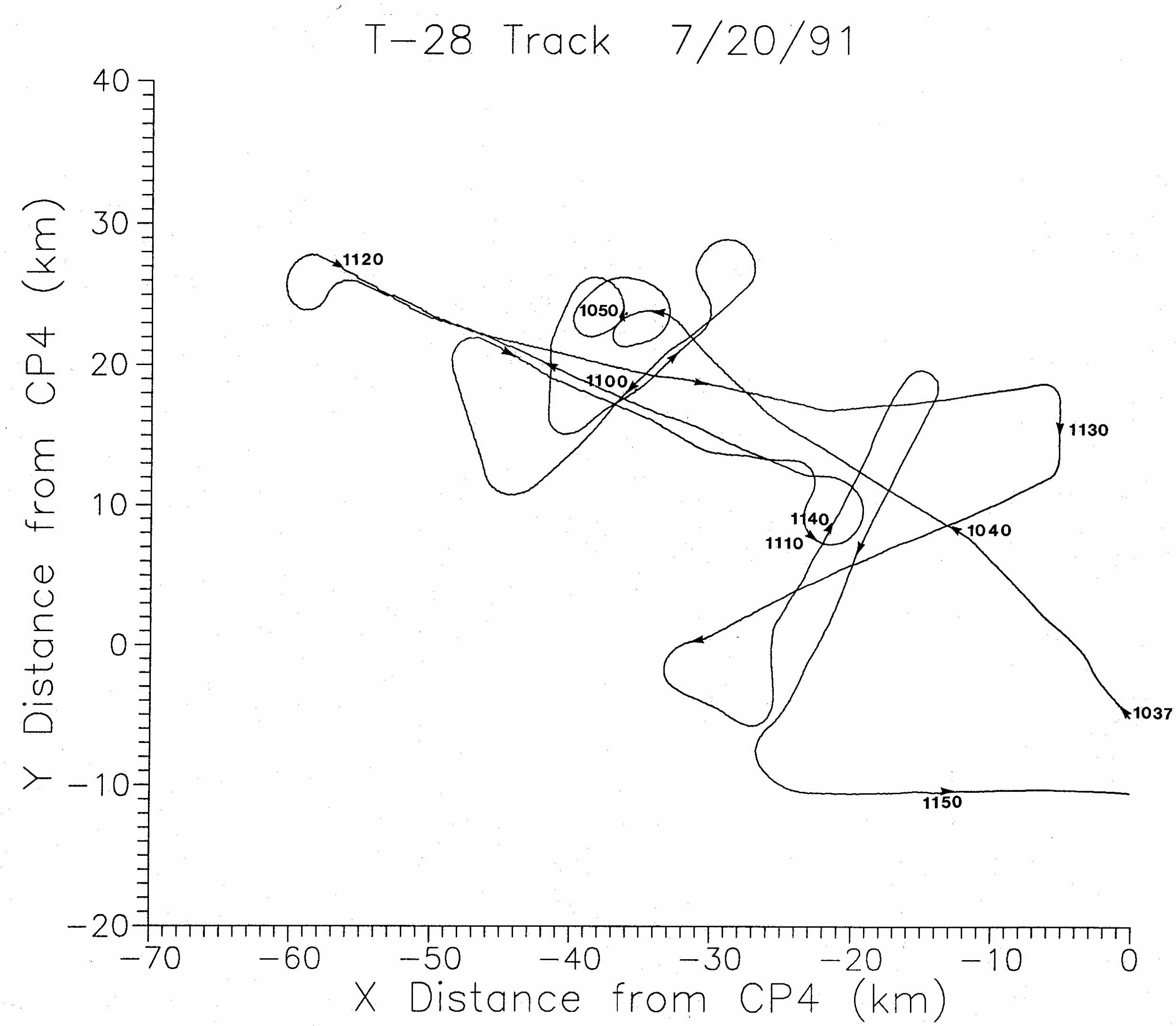
T–28 Track 7/16/91

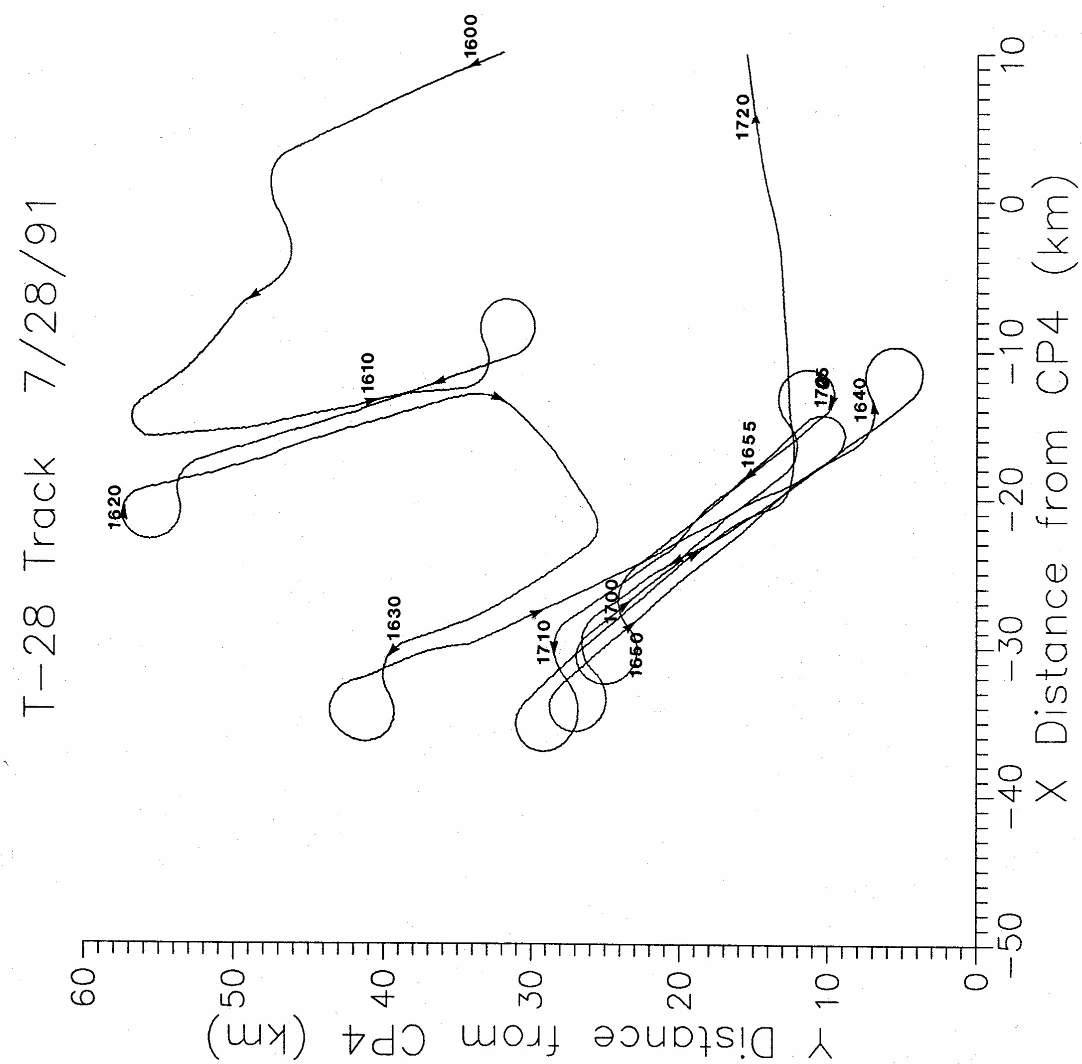



T-28 Track 7/18/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
1515
1525
1535
1545
1555
1605
1615
1625
1635

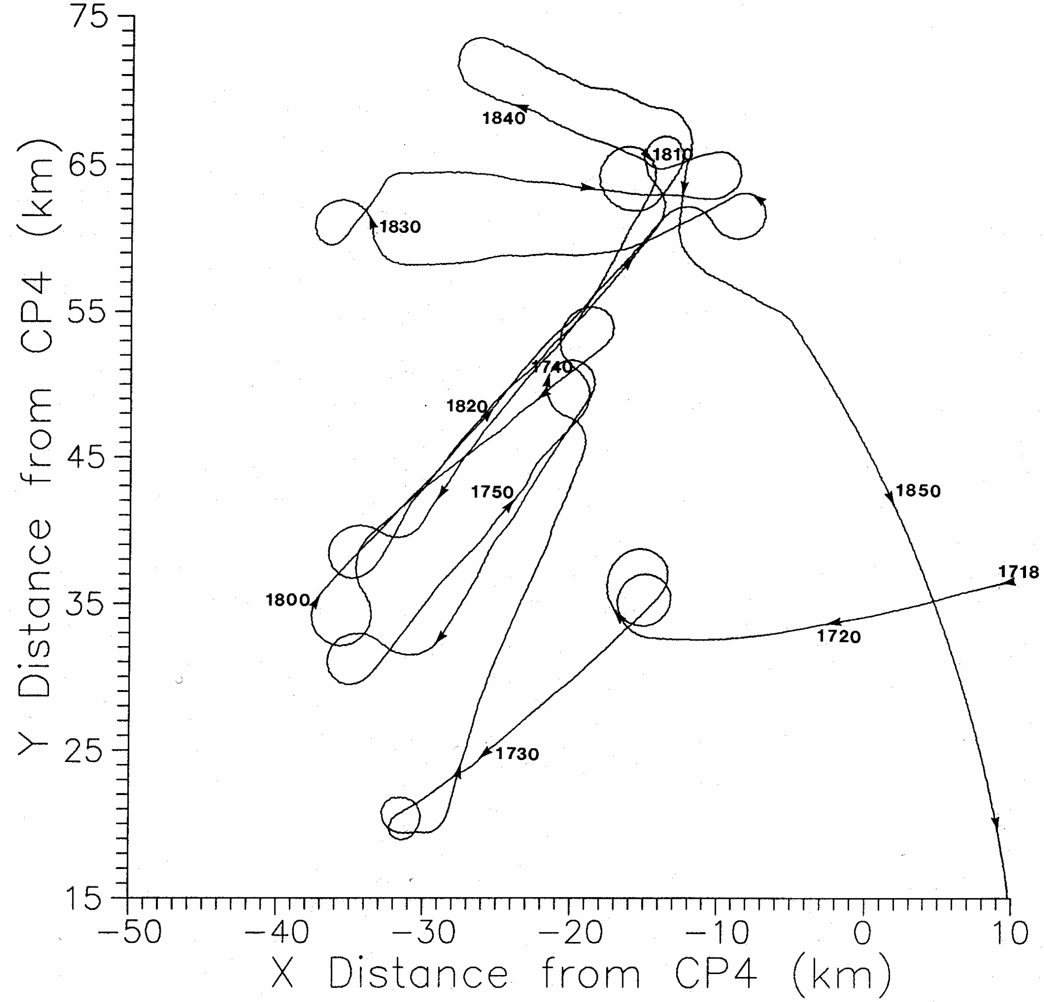

T–28 Track 7/19/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
−80
−70
−60
−50
−40
−30
−20
−10
50
40
30
20
10
0
−10
1415
1425
1435
1440
1445
1455
1505
1515
1525
1535
1545
1550

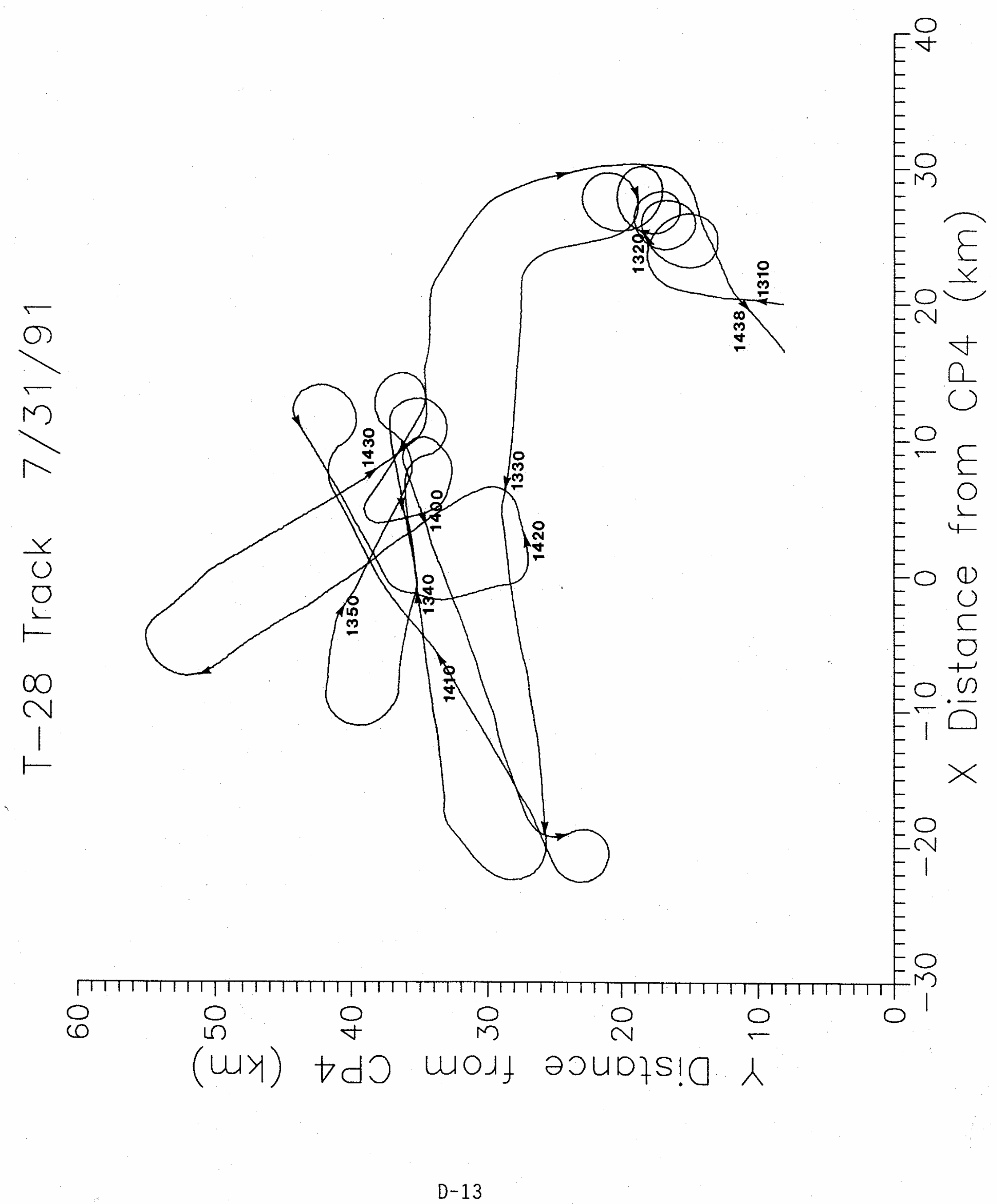

T-28 Track 7/19/91
Y Distance from CP4 (km)
X Distance from CP4 (km)
50
40
30
20
10
0
−10
−20
−80
−70
−60
−50
−40
−30
−20
−10
0
10
20
30
1351
1400
1410
1420
1430
1435
1440
1450
1500
1510
1520
1530
1540
1550

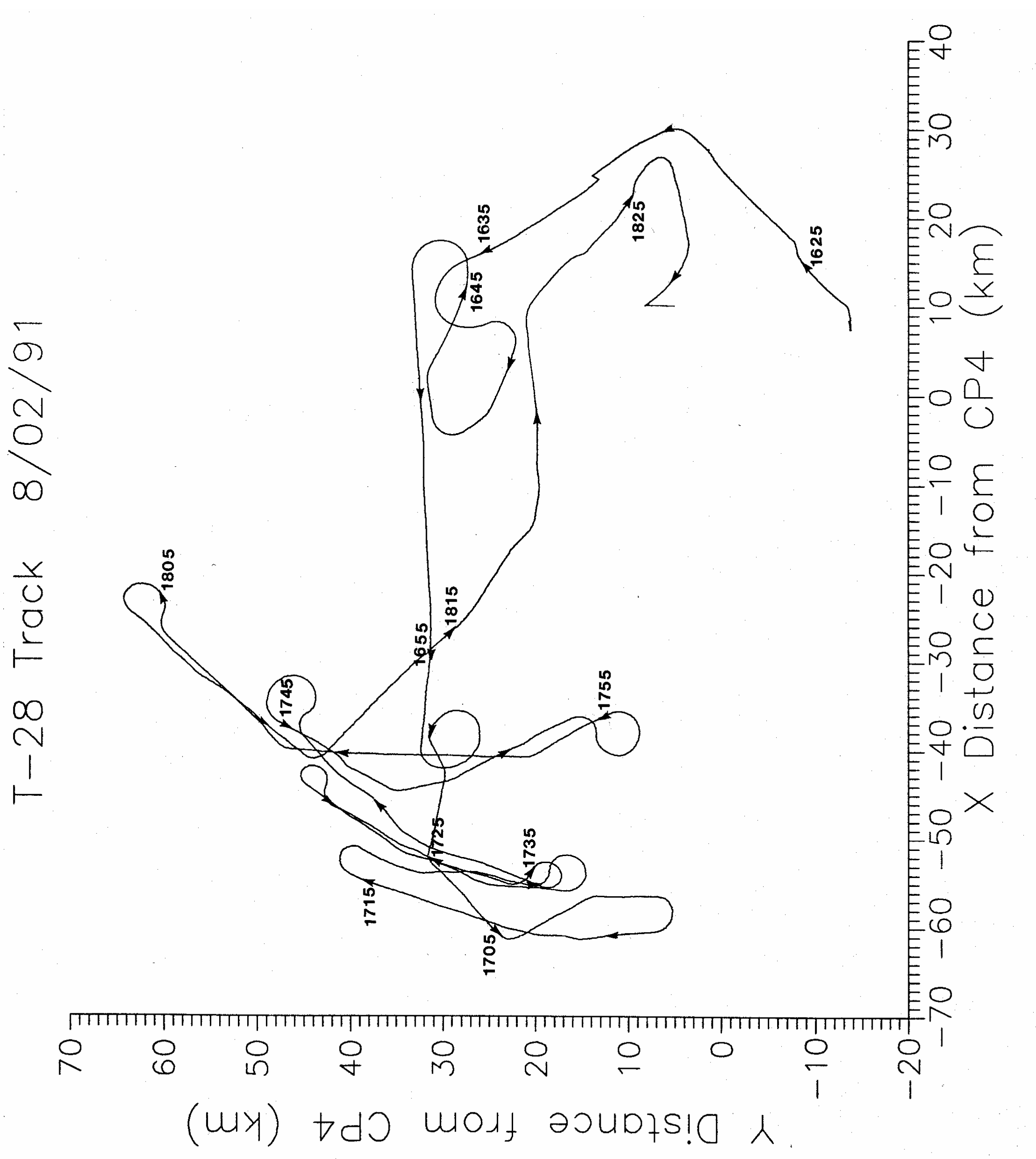

T-28 Track 7/20/91
Y Distance from CP4 (km)
X Distance from CP4 (km)
40
30
20
10
0
-10
-20
-70
-60
-50
-40
-30
-20
-10
0
1120
1050
1100
1130
1140
1110
1040
1037
1150

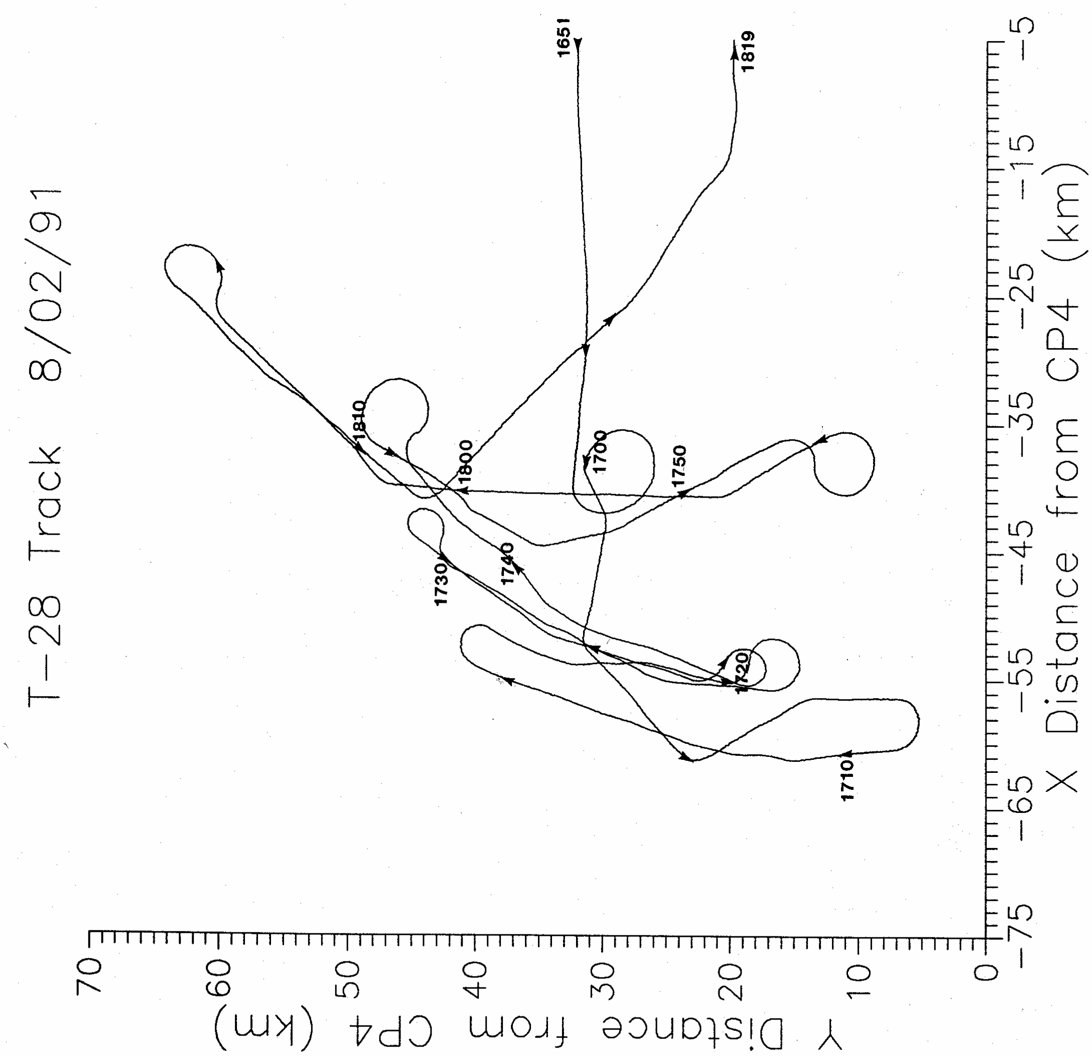

T-28 Track 7/28/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
1600
1610
1620
1630
1640
1650
1655
1700
1710
1720
-50
-40
-30
-20
-10
0
10
20
30
40
50
60

T-28 Track 7/29/91

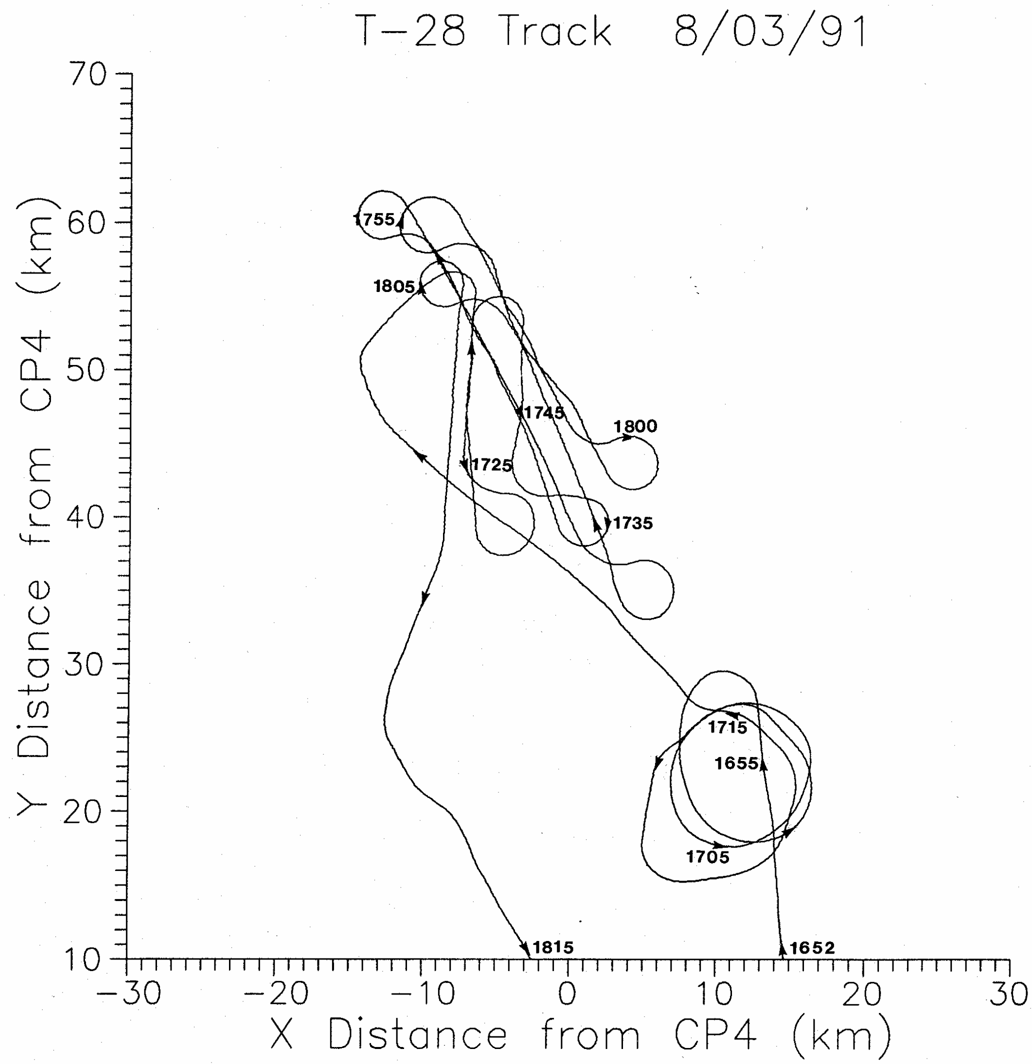


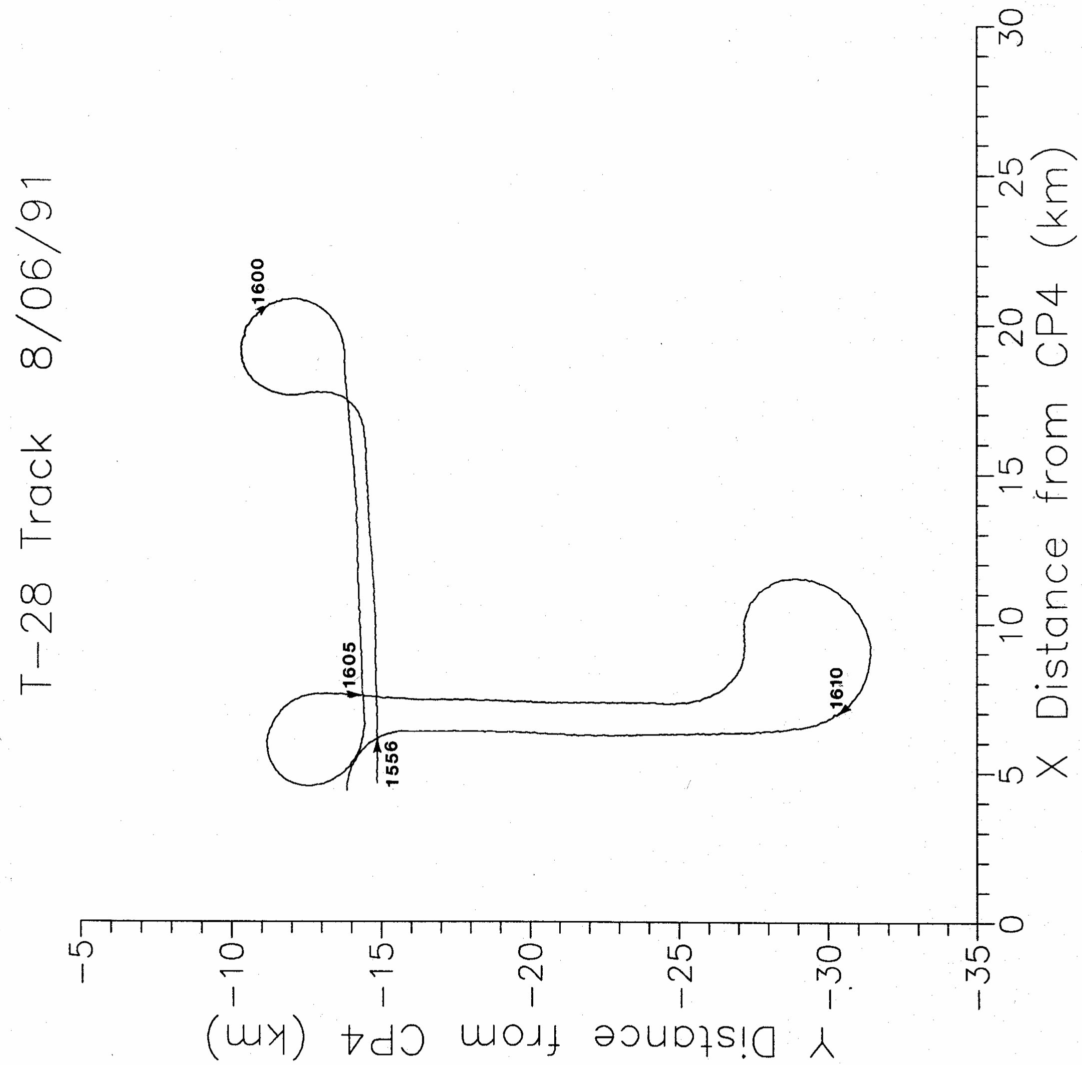

T-28 Track 7/31/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
1310
1320
1330
1340
1350
1400
1410
1420
1430
1438

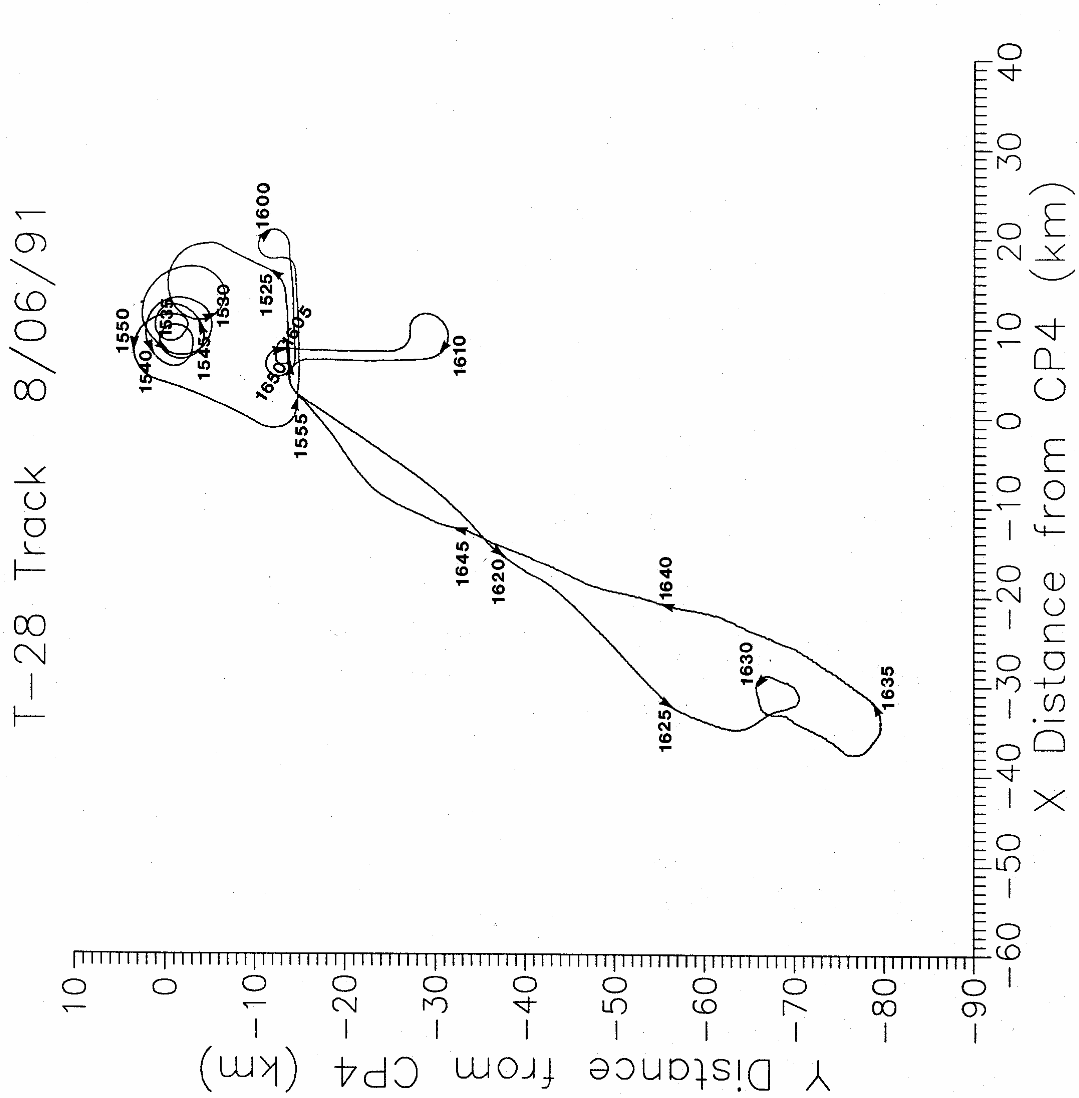

T-28 Track 8/02/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
1625
1635
1645
1655
1705
1715
1725
1735
1745
1755
1805
1815
1825



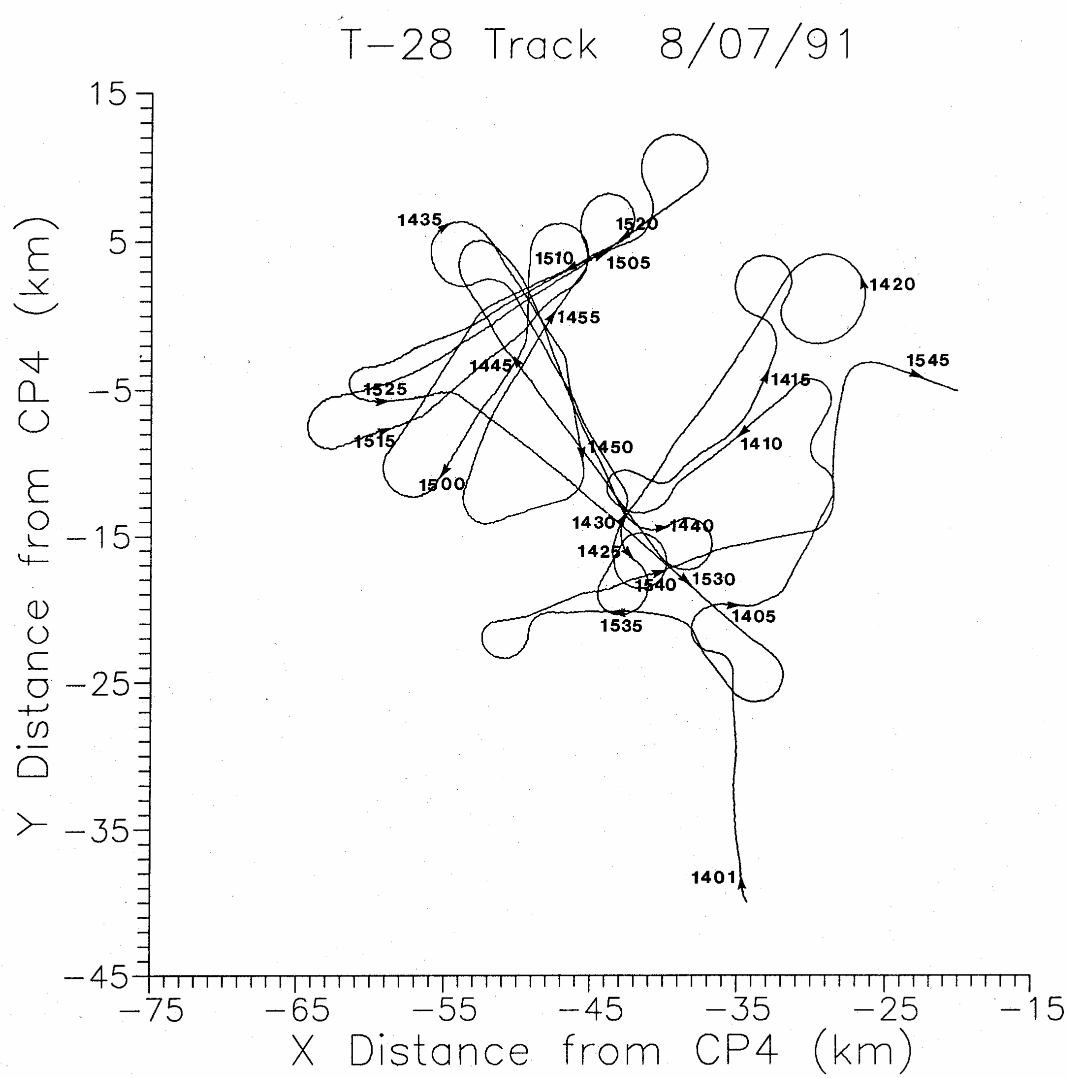
T−28 Track 8/02/91
Y Distance from CP4 (km)
X Distance from CP4 (km)
0
10
20
30
40
50
60
70
−75
−65
−55
−45
−35
−25
−15
−5
1651
1700
1710
1720
1730
1740
1750
1800
1810
1819

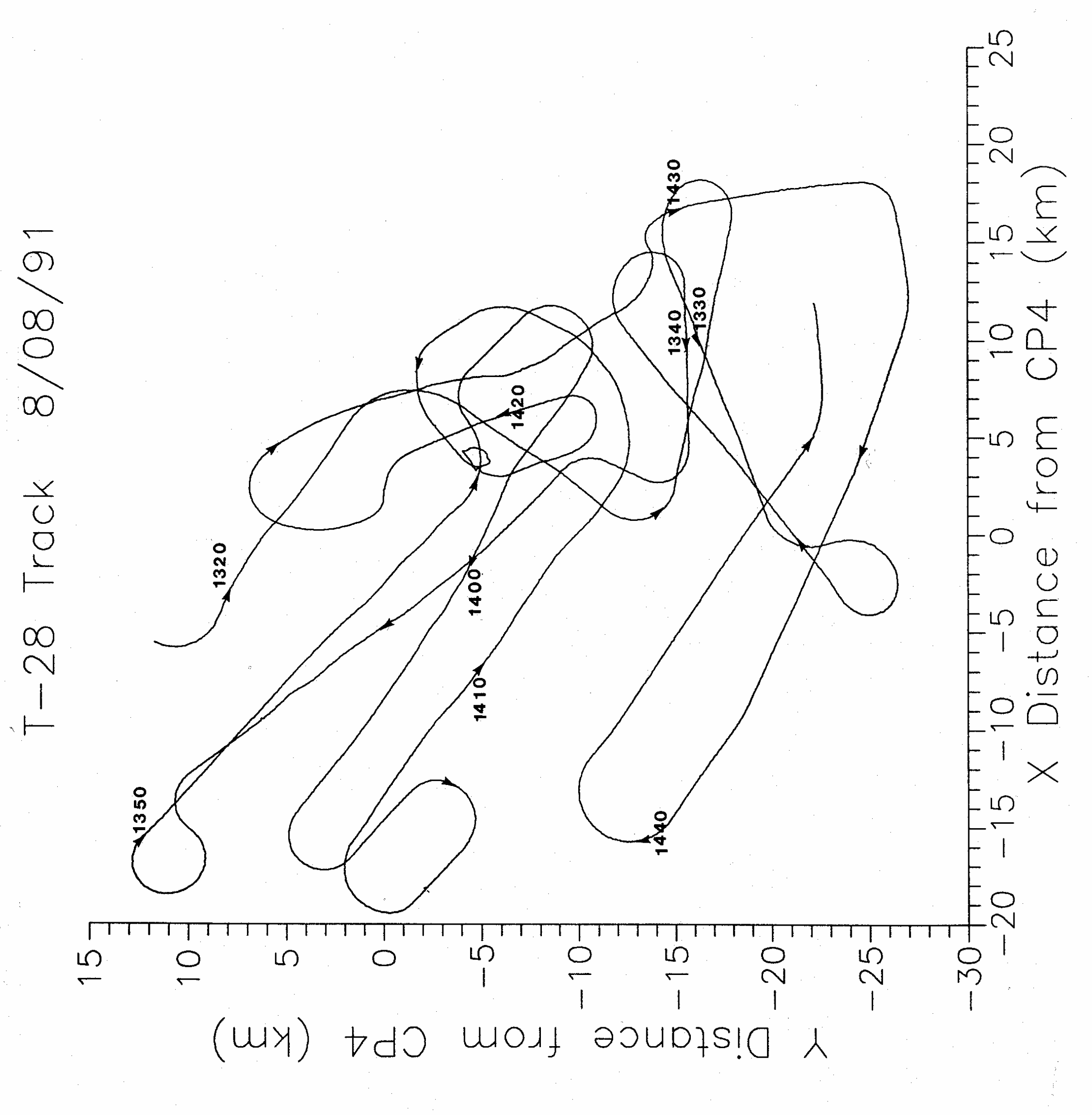

T-28 Track 8/03/91
Y Distance from CP4 (km)
X Distance from CP4 (km)
70
60
50
40
30
20
10
-30
-20
-10
0
10
20
30
1755
1805
1745
1800
1725
1735
1715
1655
1705
1815
1652

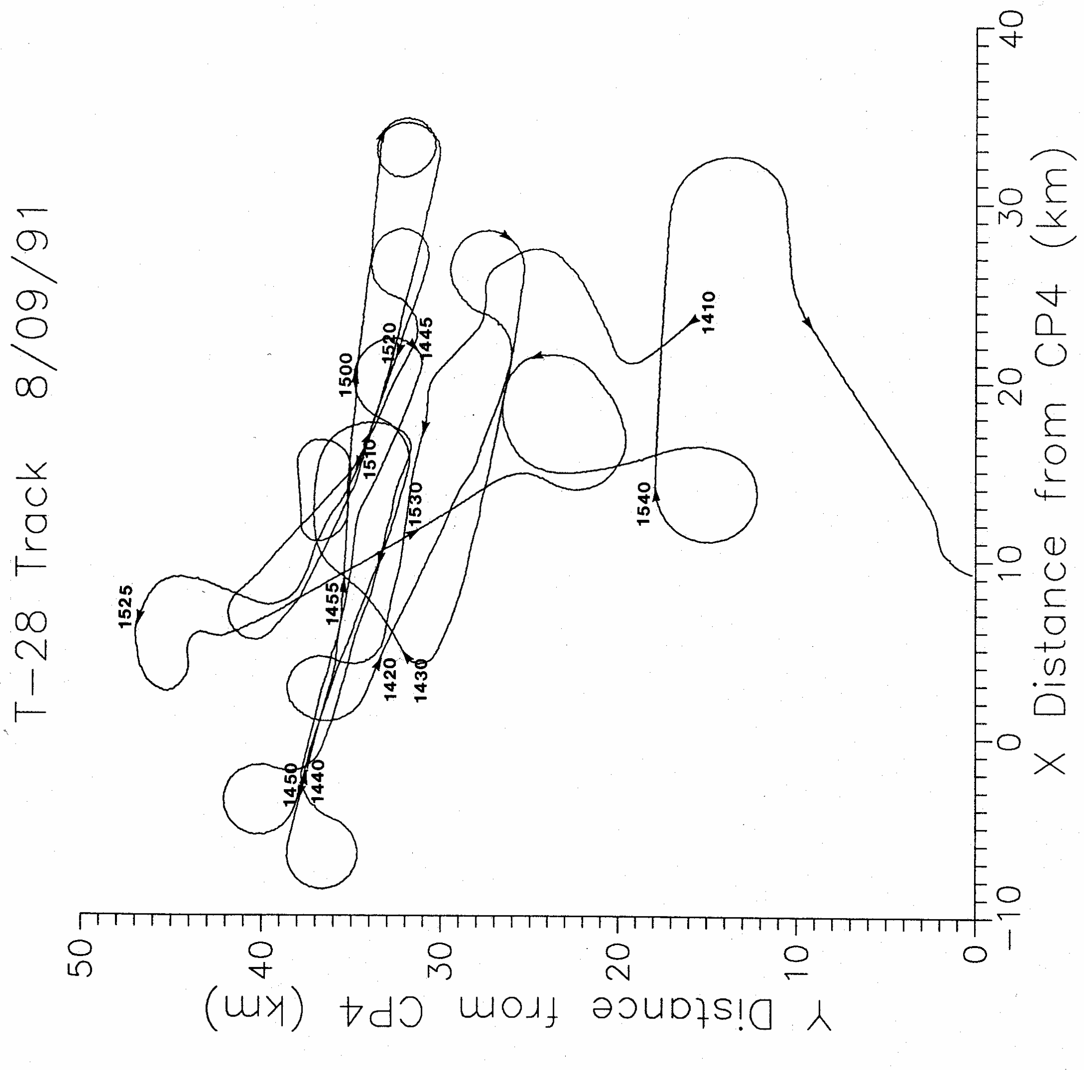

T-28 Track 8/06/91
1600
1605
1556
1610
X Distance from CP4 (km)
Y Distance from CP4 (km)
0
5
10
15
20
25
30
-5
-10
-15
-20
-25
-30
-35



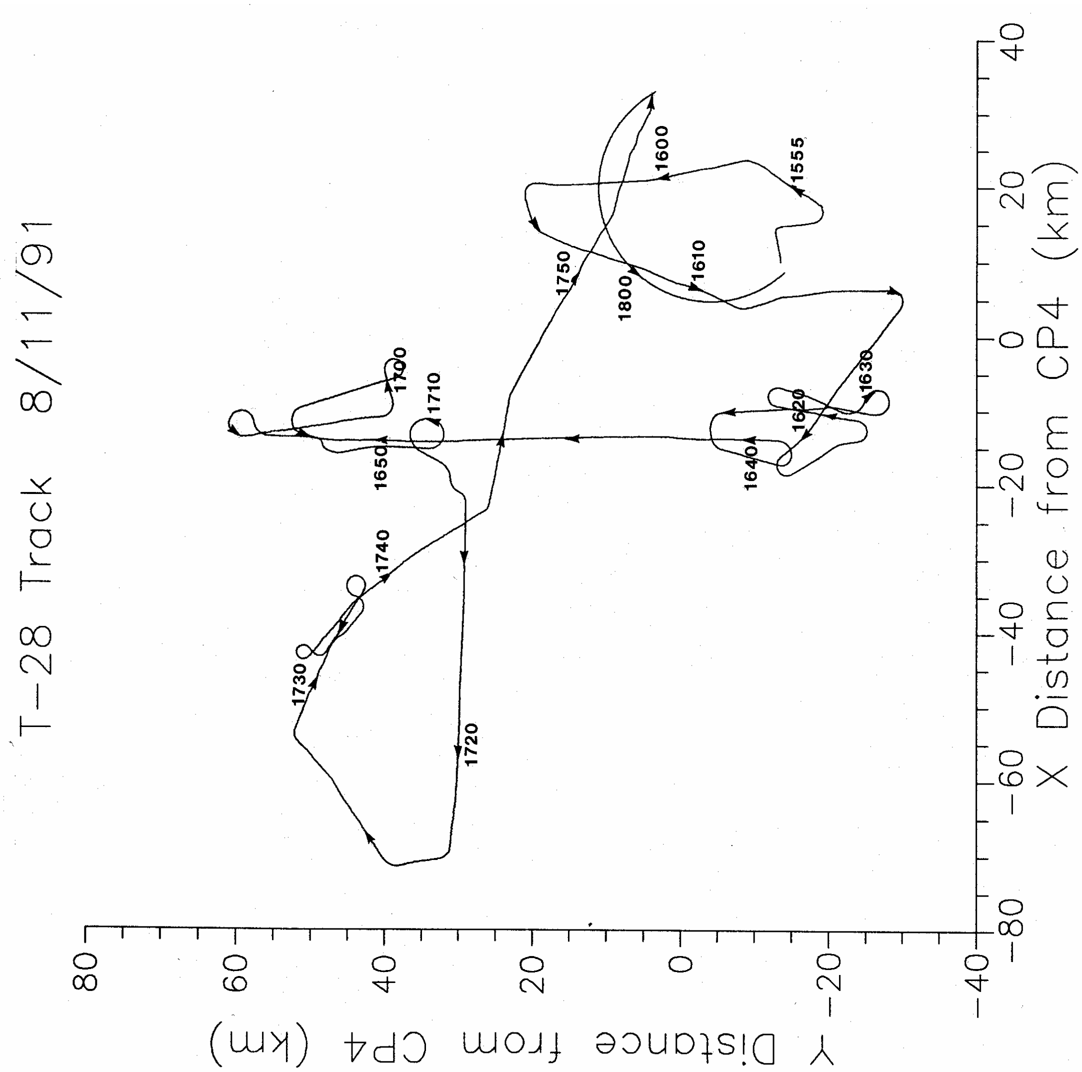
T-28 Track 8/06/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
1525
1530
1535
1540
1545
1550
1555
1600
1605
1610
1620
1625
1630
1635
1640
1645

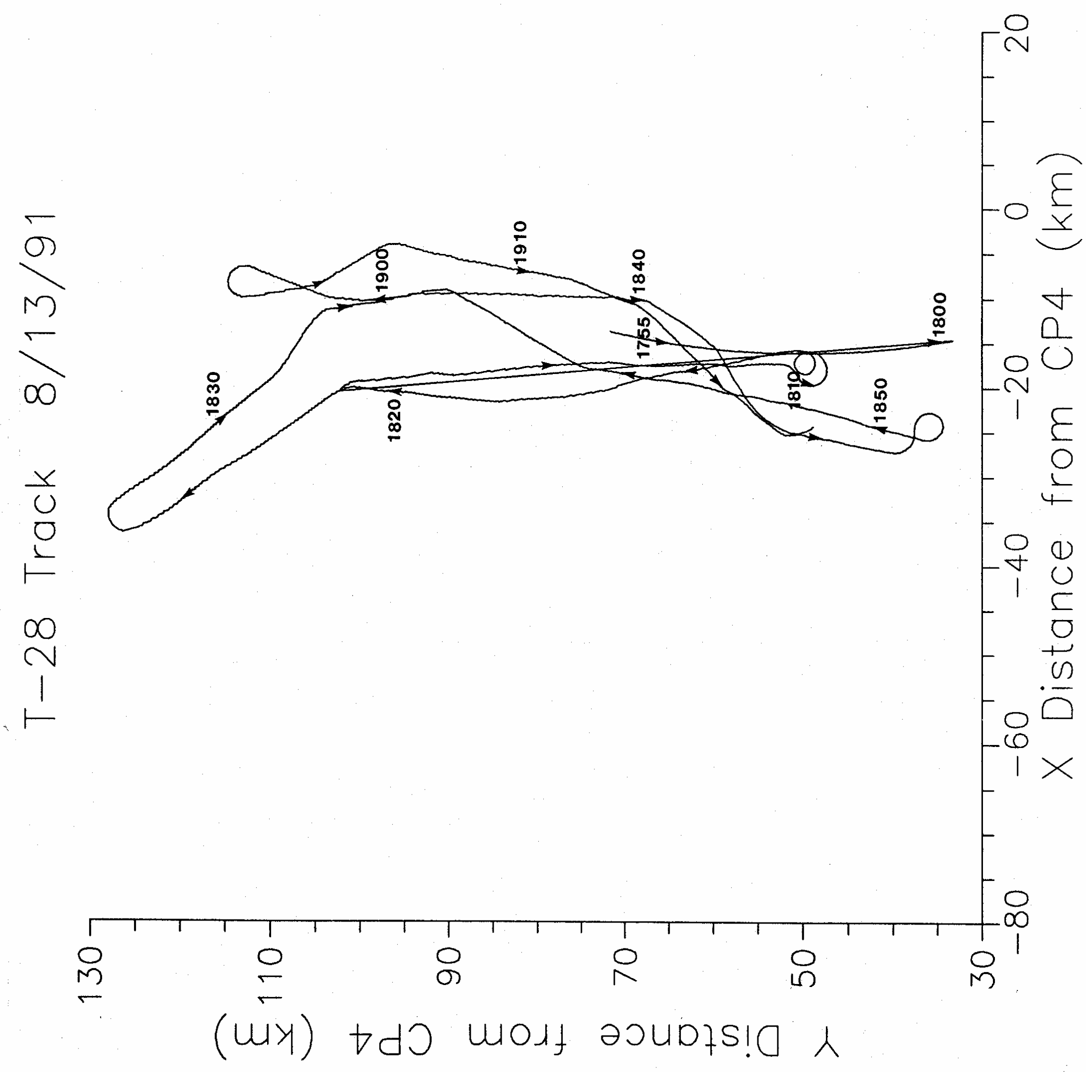

T-28 Track 8/07/91
Y Distance from CP4 (km)
X Distance from CP4 (km)
15
5
-5
-15
-25
-35
-45
-75
-65
-55
-45
-35
-25
-15
1401
1405
1410
1415
1420
1425
1430
1435
1440
1445
1450
1455
1500
1505
1510
1515
1520
1525
1530
1535
1540
1545

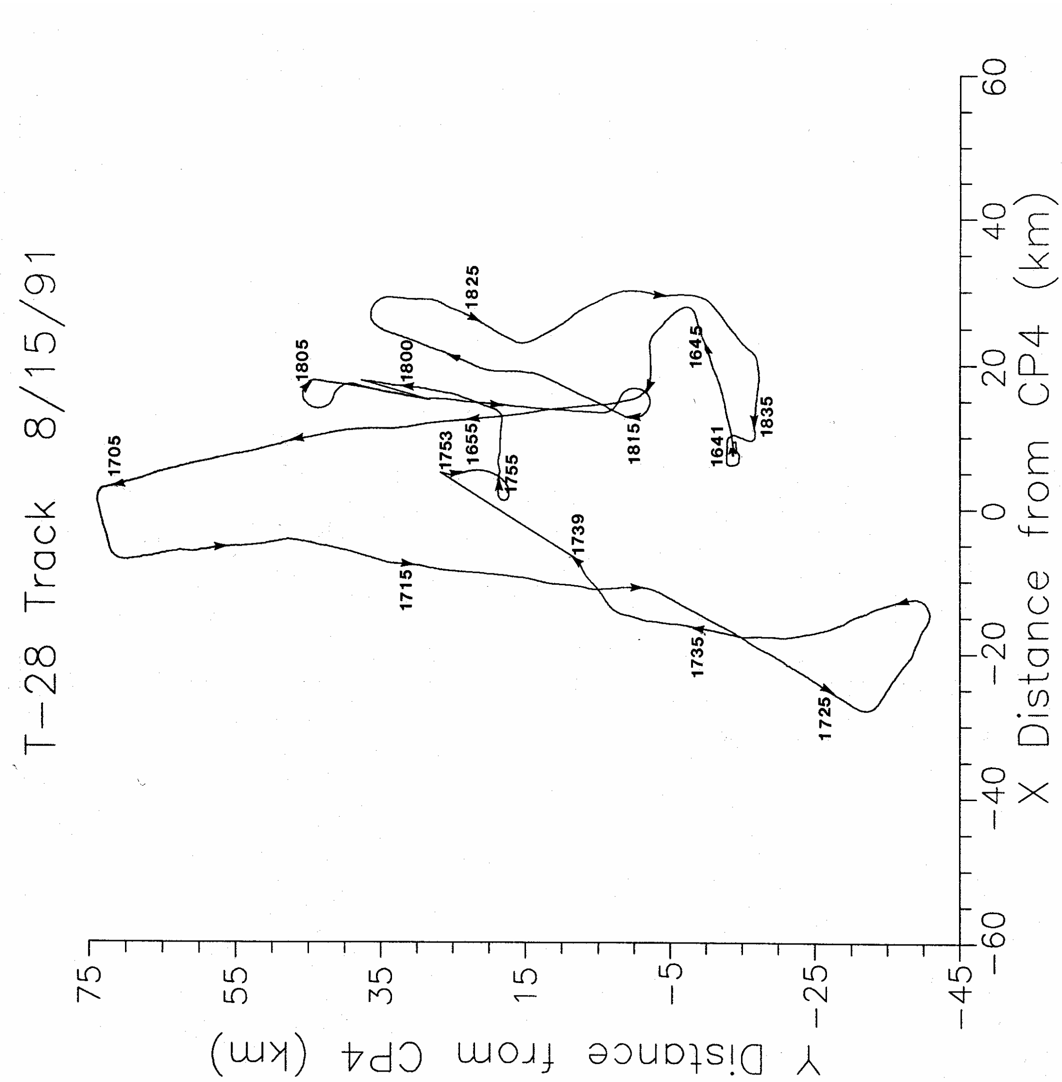

T-28 Track 8/08/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
1320
1330
1340
1350
1400
1410
1420
1430
1440
-20
-15
-10
-5
0
5
10
15
20
25
-30
-25
-20
-15
-10
-5
0
5
10
15



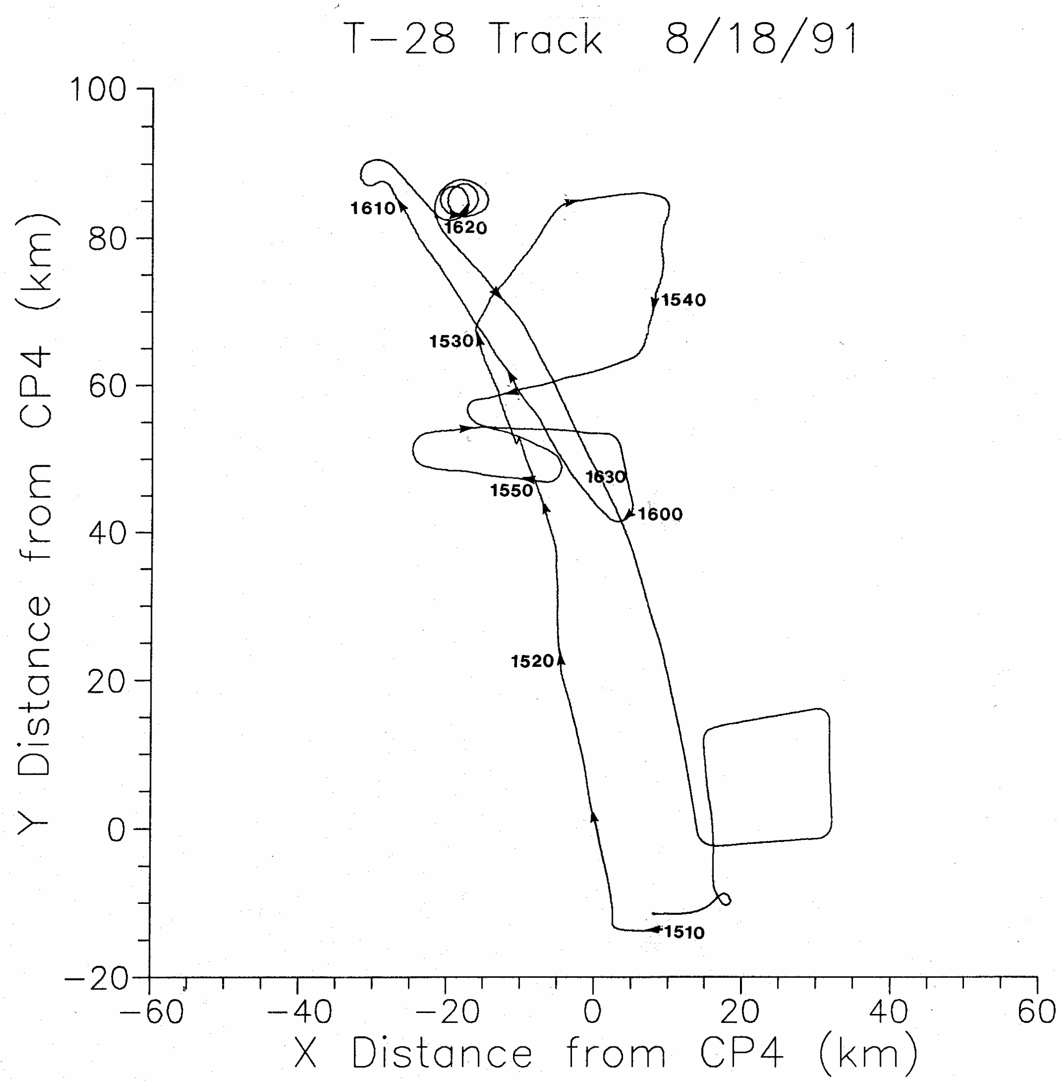
T-28 Track 8/09/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
-10
0
10
20
30
40
50
1410
1420
1430
1440
1445
1450
1455
1500
1510
1520
1525
1530
1540

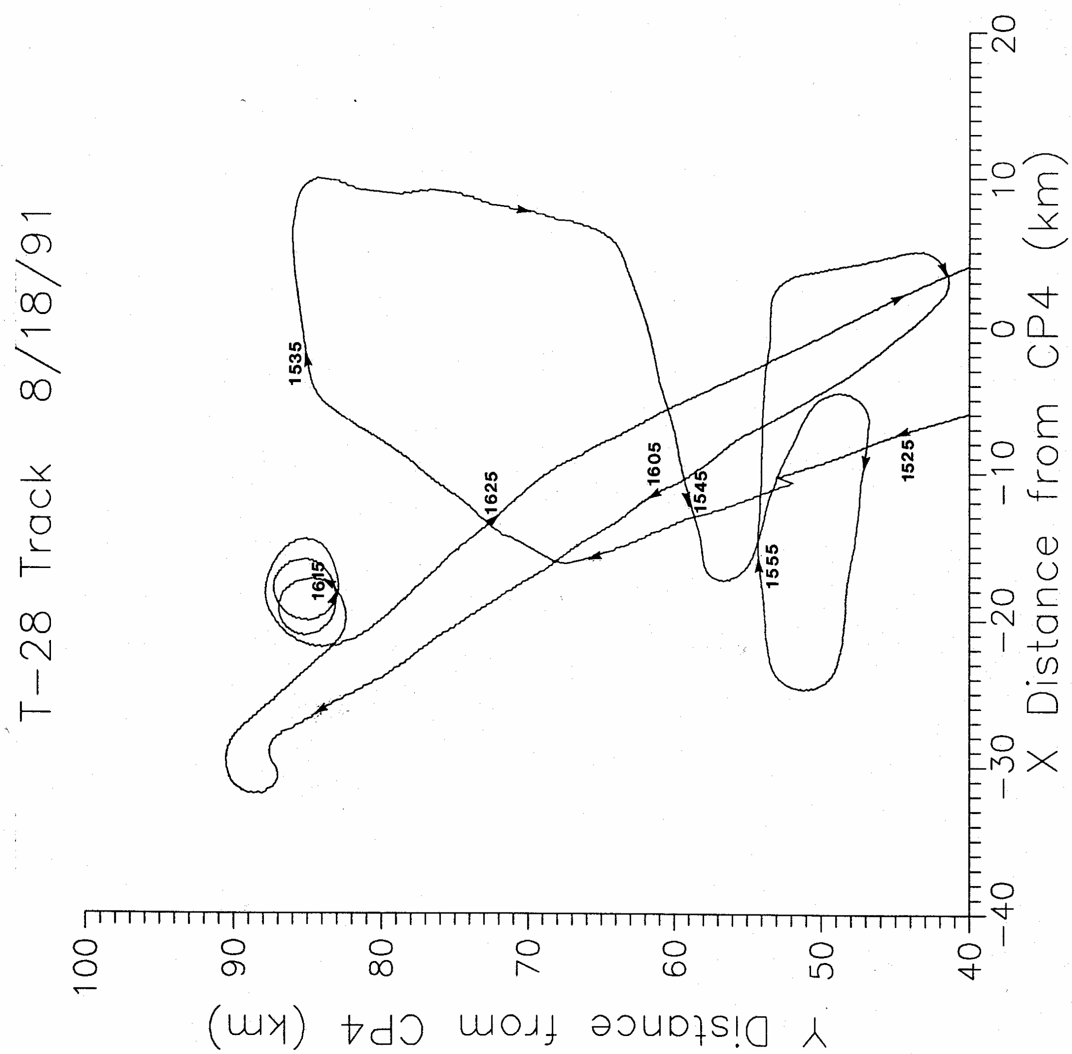

T-28 Track 8/11/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
-80
-60
-40
-20
0
20
40
80
60
40
20
0
-20
-40
1555
1600
1610
1620
1630
1640
1650
1700
1710
1720
1730
1740
1750
1800


T-28 Track 8/13/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
-80
-60
-40
-20
0
20
30
50
70
90
110
130
1755
1800
1810
1820
1830
1840
1850
1900
1910



T-28 Track 8/15/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
-60
-40
-20
0
20
40
60
75
55
35
15
-5
-25
-45
1641
1645
1655
1705
1715
1725
1735
1739
1753
1755
1800
1805
1815
1825
1835


T-28 Track 8/18/91
Y Distance from CP4 (km)
X Distance from CP4 (km)
100
80
60
40
20
0
-20
-60
-40
-20
0
20
40
60
1510
1520
1530
1540
1550
1600
1610
1620
1630


T-28 Track 8/18/91
X Distance from CP4 (km)
Y Distance from CP4 (km)
1525
1535
1545
1555
1605
1615
1625
-40
-30
-20
-10
0
10
20
40
50
60
70
80
90
100