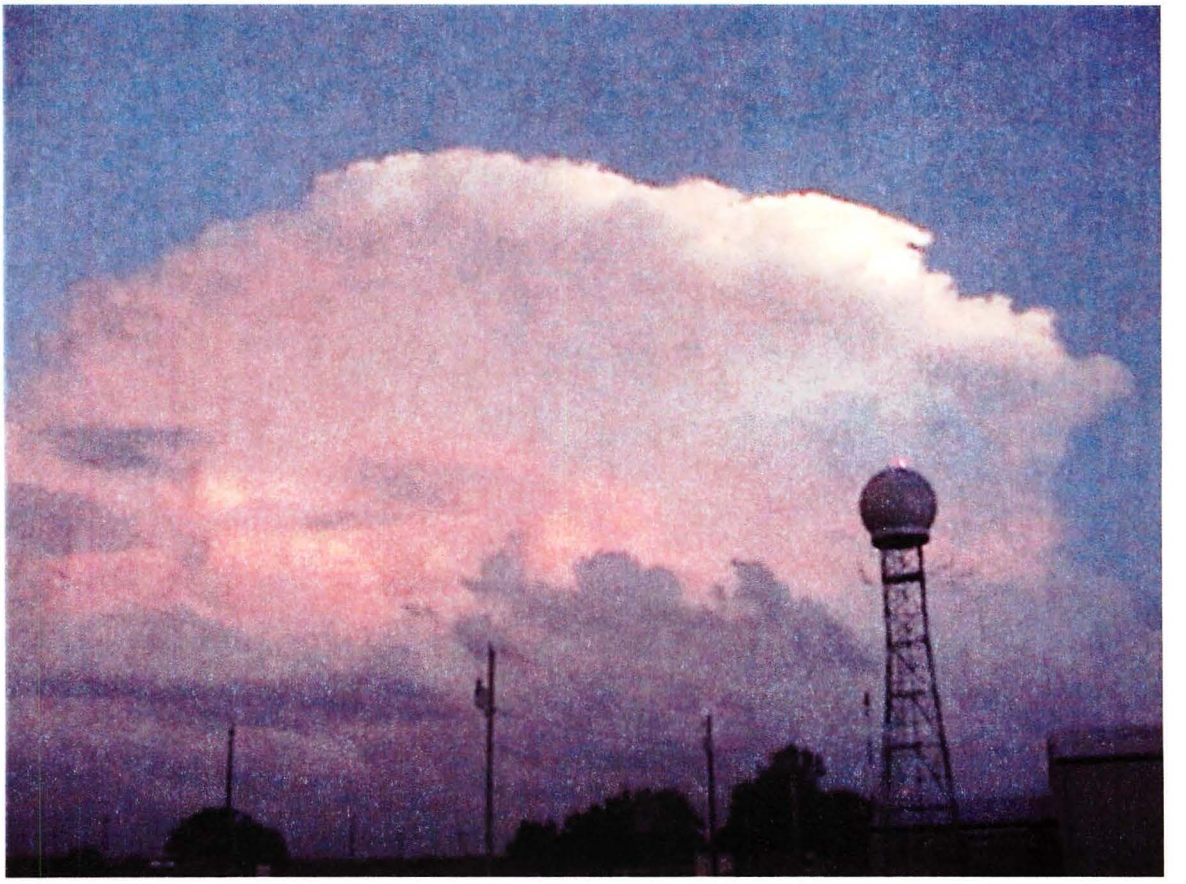
SOUTH TEXAS WEATHER MODIFICATION ASSOCIATION

EDWARDS AQUIFER AUTHORITY TARGET AREA



2006 REPORT

2006 FINAL REPORT

for the

SOUTH TEXAS WEATHER MODIFICATION ASSOCIATION

EDWARDS AQUIFER AUTHORITY TARGET AREA

by

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THE YEAR IN REVIEW

2006 marked the fifth year of operations for the Edwards Aquifer Authority (EAA) by the STWMA. Due to the dry weather experienced during much of the season, there were fewer opportunities for seeding compared to previous years. For the May-October period, there were 14 days on which cloud seeding operations took place within the target area. This compares with 25 days of seeding in 2005, 20 days of seeding in 2004, 22 days in 2003, and 8 days in 2002.

Cloud seeding missions did not take place in May due to convection occurring at night or warnings being issued. June fared a bit better, with two missions taking place during the second half of the month as a tropical airmass affected the area; however, high pressure domainated the area for a good part of the month, effectively capping the convective potential. The weather pattern became more conductive to favorable seeding conditions in July, with seeding taking place on six days. High pressure once again exerted its effects on the area during much of August, although there were four days - two near the beginning of the month and two near the end - where clouds were seeded within the target area. September was quieter than usual, with only two days on which seeding operations took place. This turned out to be the end of the season, as no seeding took place during October.

Once the season concluded, Archie Ruiz, who works for Active Influence performing radar evaluations for the Texas weather modification projects, completed the radar evaluation of the program. Once again, the analysis shows that seeding may have produced favorable increases in rainfall, with apparent lifetime extensions in the seeded clouds along with other positive results. These numbers are presented and discussed towards the end of the report.

Unlike the past, the flight tracks are not included in the hard copy of the 2006 report; instead, they are on a CD attached to this report.

2006 FLIGHT LOG FOR EDWARDS AQUIFER AUTHORITY TARGET AREA

Date	Plane	Flight No.	Take Off Time	Landing Time	Total Time	No. Flares Used	Amount of AgI (g)	Flare Locations
21-Jun	09P	1	17:55	19:35	1.7	3	120	Medina - 3
21-Jun	09P	2	20:22	21:40	1.3	3	120	Medina - 3
30-Jun	47P	3	19:45	22:10	2.4	4	160	Medina - 4
4-Jul	09P	4	18:50	23:00	4.2	2	80	Medina - 2
4-Jul	60P	5	21:05	0:20	3.3	14	1120	Bandera - 2; Bexar - 2; Medina - 10
5-Jul	47P	6	17:35	19:35	2	4	160	Medina - 1; Uvalde - 3
6-Jul	47P	7	17:40	18:55	1.3	3	120	Bexar - 3
20-Jul	47P	8	17:25	20:50	3.4	11	440	Bandera - 5; Bexar - 1; Medina - 5
22-Jul	47P	9	20:48	23:32	2.7	21	840	Bandera - 9; Bexar - 10; Medina - 2
27-Jul	60P	10	0:45	1:24	0.7	5	200	Medina - 5
3-Aug	09P	11	21:45	22:30	0.8	1	40	Bexar - 1
6-Aug	47P	12	21:45	23:35	1.8	5	200	Bexar - 2; Medina - 3
28-Aug	60P	13	19:10	21:15	2.1	4	320	Real - 4
29-Aug	60P	14	19:30	21:20	1.8	7	560	Bandera - 4; Kendall - 2; Medina - 1
12-Sep	09P	15	20:25	22:35	2.2	3	120	Bandera - 3
23-Sep	47P	16	23:25	0:40	1.3	4	160	Bandera - 4
		16 flights			**33**	**94**	**4760**	**Bandera - 27; Bexar - 19; Kendall - 2; Medina - 39; Real - 4**
								Uvalde - 3

Estimated
74,139 ac/A
of enhanced rainfall

MAY 2006

Although a couple of rain events took place in the EAA target area during the month, one involved severe weather and the other occurred before daybreak, so as a result, no seeding missions were conducted in the target area during the month.

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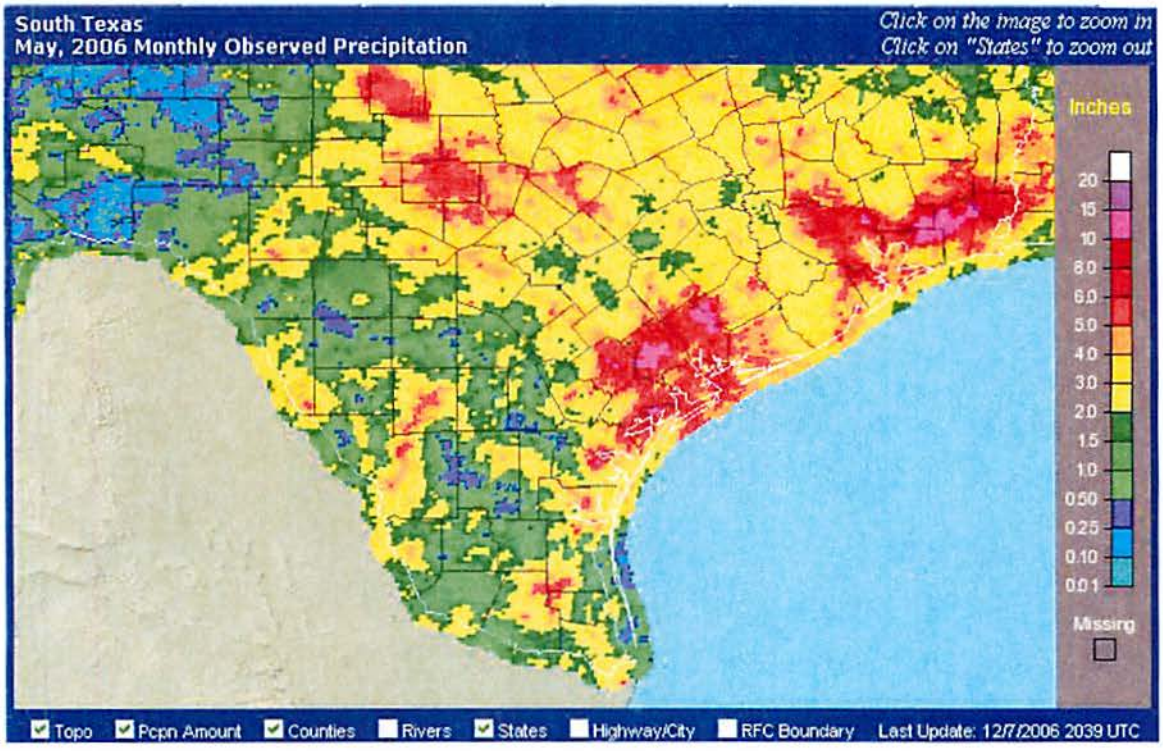

JUNE 2006

June was somewhat disappointing as far as weather modification goes, with high pressure influencing our weather for much of the month. Tropical moisture sat over south Texas for the first couple of days as a warm-core low spun out well to the south of the area. After the system sheared apart, high pressure influenced our weather for roughly the next two weeks, with no seeding missions taking place. Then, during the second half of the month, tropical moisture and a few disturbances affected the area, with a couple seeding opportunities occurring.

Overall, there were only two days on which seeding missions were conducted. Three flights took place in the target area, with all ten flares being used for seeding in Medina County. Total AgI used was 400g.

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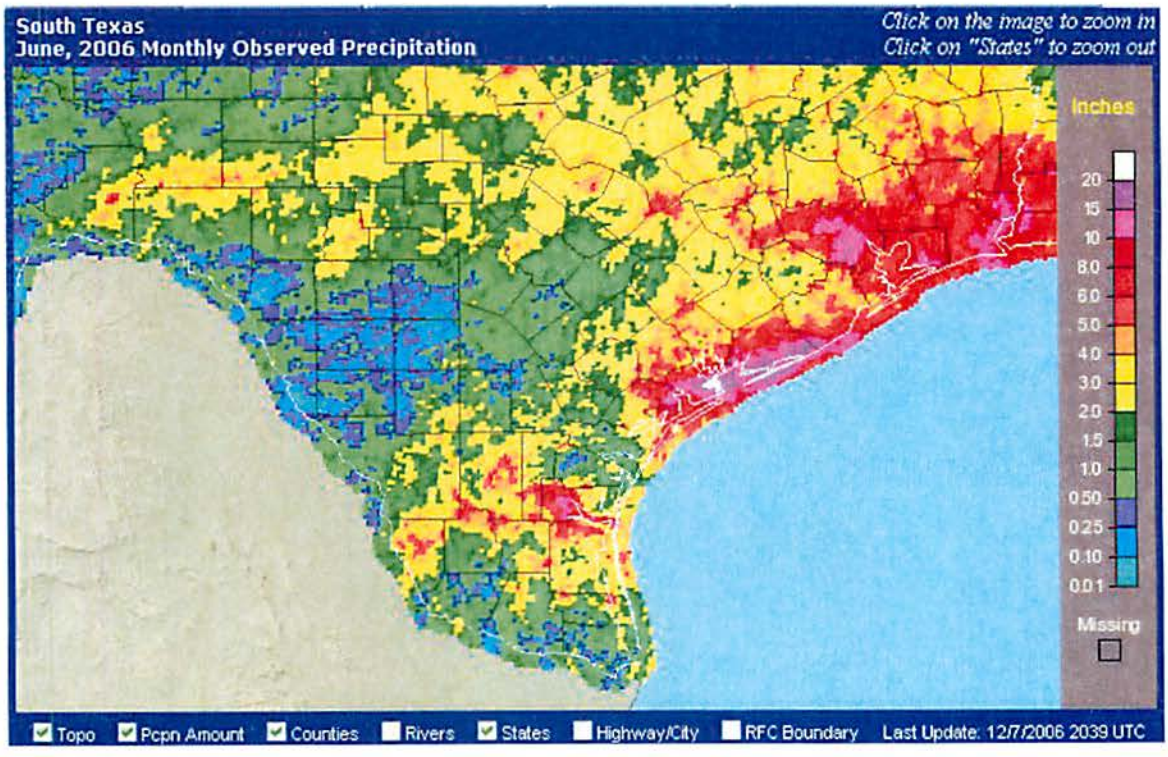

JUNE 21

The mid/upper level low that had brought extreme amounts of rain to the Texas coast was in the process of transitioning into a shear axis today. The atmosphere for the most part remained quite moist, although drier air had filtered in between 5000 and 15000 feet. Still, some convection developed during the afternoon hours, and a flight was launched to investigate and seed clouds in Medina County. The activity didn't last too long, so the flight was ended. Later in the afternoon, additional activity developed in Medina County and a second flight was launched. Again, the activity did not last too long, possibly due to entrainment of drier air at mid levels.

Six flares were used for seeding in Medina County, totaling 240g of AgI.

JUNE 30

Atmospheric moisture levels were on the increase as an upper low over north Texas was aiding in pulling up deeper moisture from the Gulf. In addition, a tropical wave-like feature was approaching southern Texas from the Bay of Campeche. Daytime heating and relatively low convective temperatures resulted in scattered showers and thunderstorms developing around the noon hour, initially south of the EAA target area. A flight took place during mid-afternoon to seed the activity as it moved into Medina County. Apparent results based on radar trends were good, with some cells that initially appeared to weaken regenerate about 20 minutes after seeding ceased.

Four flares were used for seeding in Medina County, totaling 160g of AgI.

JULY 2006

July provided more opportunities for seeding as the weather pattern had finally become more progressive in comparison to the past few months. Still, the seeding opportunities were like bookends to the month, with seeding missions taking place near the start of the month and again towards the end, with a couple weeks in between of no seedable clouds. For the month, there were six days on which seeding missions were conducted. Seven flights took place within the target area. A total of 57 flares (Bandera - 2x80g, 14x40g; Bexar - 2x80g, 14x40g; Medina - 10x80g, 15x40g) were used for seeding in the target area, totaling 2840g of AgI.

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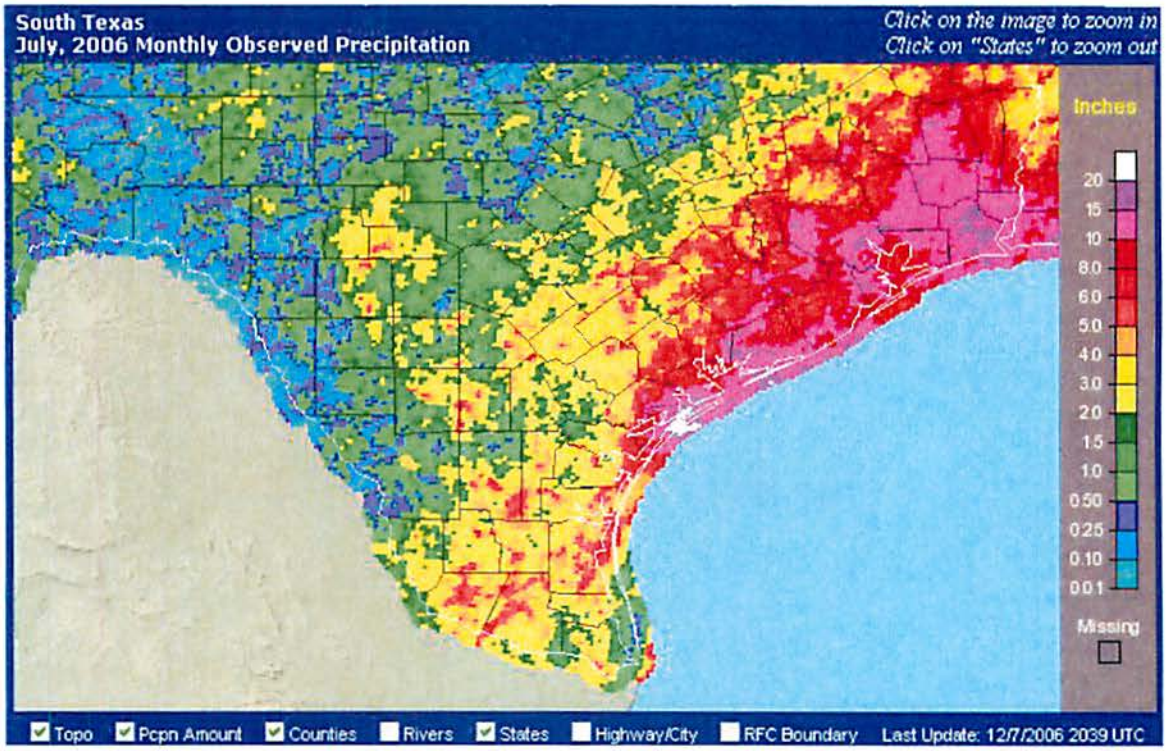

JULY 4

Today was a very active day convection-wise. Strong instability and plentiful low level moisture were in place. With strong daytime heating, showers and thunderstorms began to form in the afternoon over the area. The first flight was launched and soon after, an explosion of convection took place. This warranted the launching of another plane. Seeding was done in all the EAA counties and a positive response was noted.

A total of 16 flares (Bandera - 2x80g; Bexar - 2x80g; Medina - 2x40g, 10x80g) were used for seeding, totaling 1200g of AgI.

JULY 5

Deep moisture was present across south Texas as an upper low near College Station continued to pull moisture north from the Gulf. Despite the moisture, the target area was located on the drier, more subsident side of the low, so convection had a difficult time developing. A few showers developed in the northwestern target area early in the afternoon and a flight was launched to investigate. A few flares were used for seeding, but it appears subsidence may have contributed to an early demise.

One flare was used for seeding in Medina County, totaling 40g of AgI.

JULY 6

Tropical moisture continued to inhabit south Texas, with precipitable water values at or over two inches. Slight cooling of the mid-levels resulted in an unstable airmass, with showers developing and moving southwest across the target area. A flight was launched early in the afternoon to treat various cells. Most of the activity was short-lived (half hour or less).

Three flares were used for seeding in Bexar County, totaling 120g of AgI.

JULY 20

A strong upper level high was situated over Kansas, which was placing Texas on the southern edge of the ridge with easterly flow dominant. Overnight convection had left an MCV (Mesoscale Convective Vortex) near College Station that was translating west-southwest, eventually moving along the extreme northern edge of the target area. Convection began developing near the center of circulation, and a plane flew to the area around Medina Lake to seed developing convection. Late in the day, the seabreeze continued northwest across the target area, additional convection developed along the I-35 corridor from near Pearsall to San Antonio, and this was also treated with seeding agent and appeared to also respond favorably, with this seeded activity being the last area of convection to dissipate. Overall, it was a very good day for seeding...certainly a busy day.

11 flares (Bandera - 5; Bexar - 1; Medina - 5) were used for seeding, totaling 440g of AgI.

JULY 22

South Texas was on the periphery of an upper level ridge, allowing disturbances to move into the area. Convection got started in the early afternoon hours and extended well into the evening as a cold front was located just to the north of the area in the Hill Country. With daytime heating, instability increased and convection developed near the front in the late afternoon hours in the northern parts of the target area. Seeding was done in Bexar, Bandera, and Medina counties. The convection appeared to respond well to the seeding, with an increase in areal coverage and an apparent extension of the cell lifetime compared to untreated cells on the radar.

21 flares (Bandera - 9; Bexar - 10; Medina - 2) were used for seeding, totaling 840g of AgI.

JULY 27

A low with quasi-tropical characteristics was located in northeast Texas, and a second mid-level low was located to the southwest of the area. The latter feature provided the lift necessary for a few light showers to develop south of the EAA target area, where one shower was seeded. New activity developed near this seeded cloud and headed northwest into the target area. A flight was launched in the evening prior to sunset and seeding took place over Medina County. This cell continued on through the northwestern target area and entered Kerr County after sunset, with precipitation continuing to fall.

Five flares were used for seeding in Medina County, totaling 200g of AgI.

AUGUST 2006

August continued the disappointing trend of much drier than normal conditions. There were a few opportunities during the month, one related to the seabreeze, one related to a tropical wave, and two related to an approaching front. For the most part, however, strong high pressure sat over the area squelching convective potential.
There were four days on which seeding took place. Four flights took place, one on each day of seeding. A total of 17 flares were used for seeding (Bandera - 4; Medina - 4; Bexar - 3; plus Real - 4 and Kendall - 2), totaling 1120g of AgI. There was also one day where SWTREA assisted with operations by seeding in Bandera and Medina counties (August 23rd), but this will be included in the monthly report from SWTREA.

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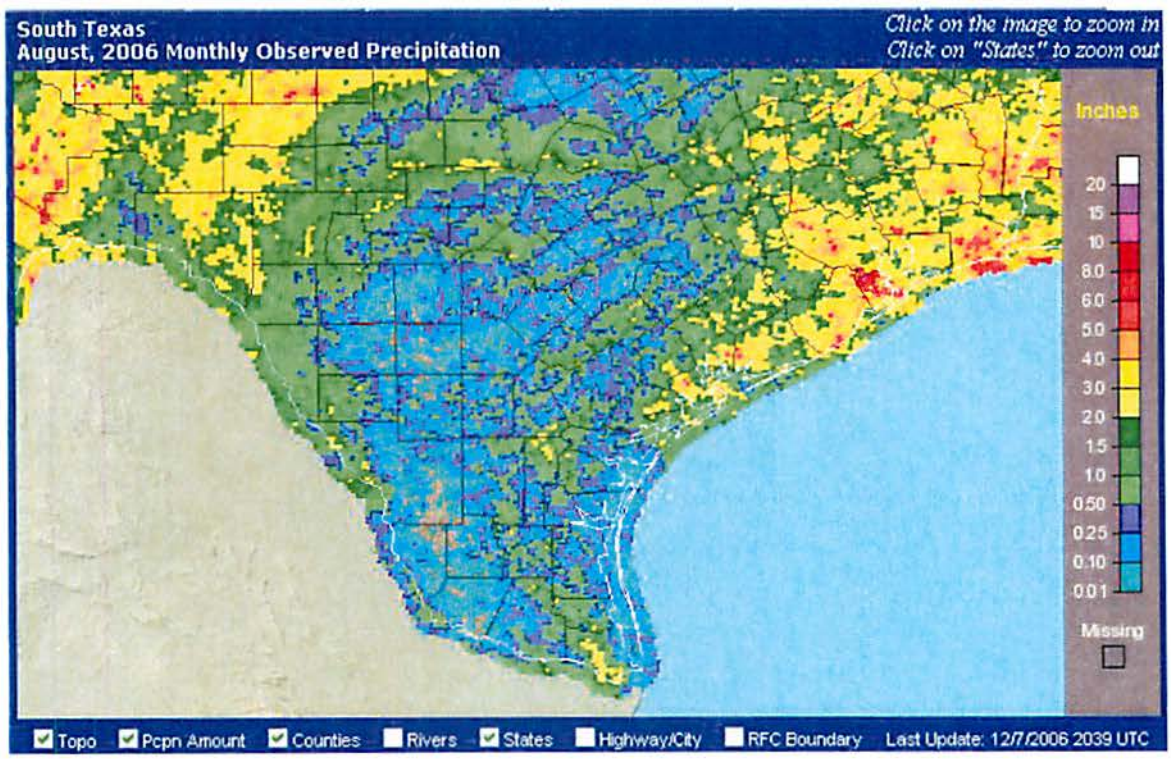

AUGUST 3

An upper low was pushing away from southern Texas heading northwestward around the ridge of high pressure centered over the southeastern part of the country. More than adequate moisture was in place over the area, and convective temperatures were on the low side, so with some heating and the presence of the seabreeze front, a few showers and thunderstorms developed along the aforementioned feature and pushed inland. A flight was dispatched at mid-afternoon to investigate the incoming activity. It appeared that as the activity got further inland, it began to dissipate rather quickly. One shower in southern Bexar County received treatment, but even before the mission was finished, activity began to weaken. Convection had a very difficult time sustaining for more than about 15 minutes.

One flare was used for seeding in Bexar County, totaling 40g of AgI.

AUGUST 6

A tropical wave approached the area from the east, with scattered convection heading west through the area. Clouds were seeded in the EAA target area, with observed areal expansion of the cells noted on radar. Five flares (Bexar - 2; Medina - 3) were used for seeding, totaling 200g of AgI.

AUGUST 28

Early in the day an MCS propagated south-southeast from west Texas towards the Edwards Plateau and western Hill Country. The convection spurned an outflow boundary that moved just ahead of it. As new convective development took place just to the northwest of the target area, a plane was launched anticipating convection moving into Bandera County. A couple of clouds were seeded in Real County as they appeared to be moving into the target area, and this activity appeared robust on radar, but the convection only clipped extreme northwestern Bandera County and instead moved to the northeast, yet still impacting the Aquifer Recharge Zone.

Four 80g flares were used for seeding in Real County, totaling 320g of AgI.

AUGUST 29

Somewhat similar to the day before, an area of showers and thunderstorms was located just north and northwest of the target area, with more of an eastward motion noted. Early in the afternoon, new convection developed in extreme western Bandera County and moved east. A Severe T-storm Warning was issued shortly after it appeared on radar as it intensified rapidly, so seeding could not be done until after expiration, but a plane did manage to seed the activity when it reached eastern Bandera County. The convection fared very well, lasting for over two hours past seeding time, moving east across a portion of the Edwards Aquifer Recharge Zone and dropping two inches of rain in some locations.

Seven flares (80g instead of 40g) were used for seeding (Bandera - 4; Kendall - 2; Medina - 1), totaling 560g of AgI.

SEPTEMBER 2006

The stubborn area of high pressure that had dominated the weather in August had weakened in September. The westerlies which had remained well north of the area for most of the summer periodically shifted south to allow for disturbances to pass across Texas, bringing a few cold fronts through the area. Rainfall was above normal for many areas during the month, although a good portion of the rains fell either as stratiform rain (which is not a seedable situation) or fell during the overnight hours when flying is not done. Only two days this month saw seeding take place, and in both cases they were associated with fronts approaching the area. A total of seven flares were used for seeding, totaling 280g of AgI. All of the seeding was done in Bandera County.

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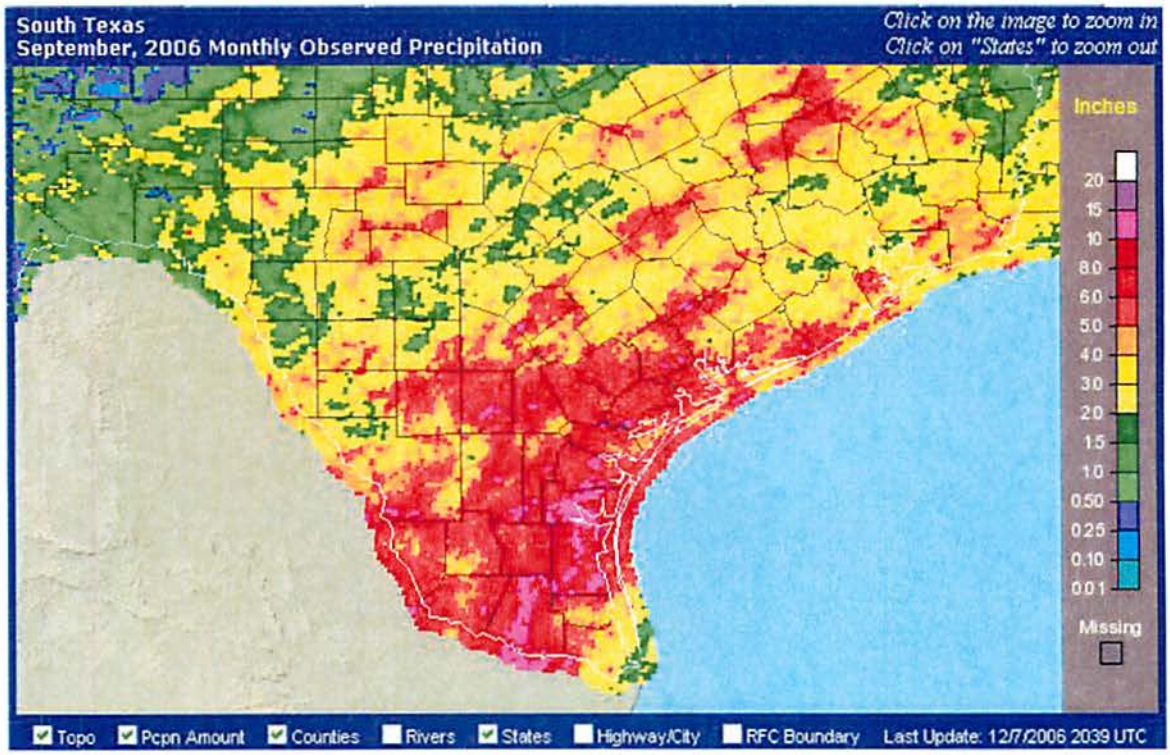

SEPTEMBER 12

Rain and isolated thunderstorms were ongoing south of the EAA target area, with breaks in the cloud cover over the northern parts of Bexar, Medina and Bandera counties. With some daytime heating and the approach of a front, convection developed in Bandera County and a plane investigated the clouds, with three flares used for seeding. Total AgI used was 120g.

SEPTEMBER 23

A hot and very humid airmass had settled over south Texas, with instabilities on the high side. An approaching cold front from the north and an approaching upper level speed max from the west combined with the strong heating and very rich low level moisture to spark convection north of the target area during the afternoon. This activity was located along the front. The convection began to enter the extreme northern target area after 2230 UTC (5:30pm local). After an initial launch, the plane had to return to base due to a mechanical problem, but a second plane took off shortly thereafter and headed to Bandera County. Convection in the eastern part of the county was seeded, and convection in the extreme western part of the county was part of a larger cell being seeded in Uvalde County by SWTREA. A Flash Flood Warning was issued for Bandera just before sunset, and this terminated the mission (along with increasing darkness). The seeded cell moved into Bexar County and merged with other developing storms. Overall a fair day.

Four flares were used for seeding in Bandera County, totaling 160g of AgI.

OCTOBER 2006

The weather pattern began to get a little more active with fronts coming through the area every 4 or 5 days. Most of the rain fell at night or was stratiform in nature, and as a result, no cloud seeding missions were conducted within the EAA target area during the month.

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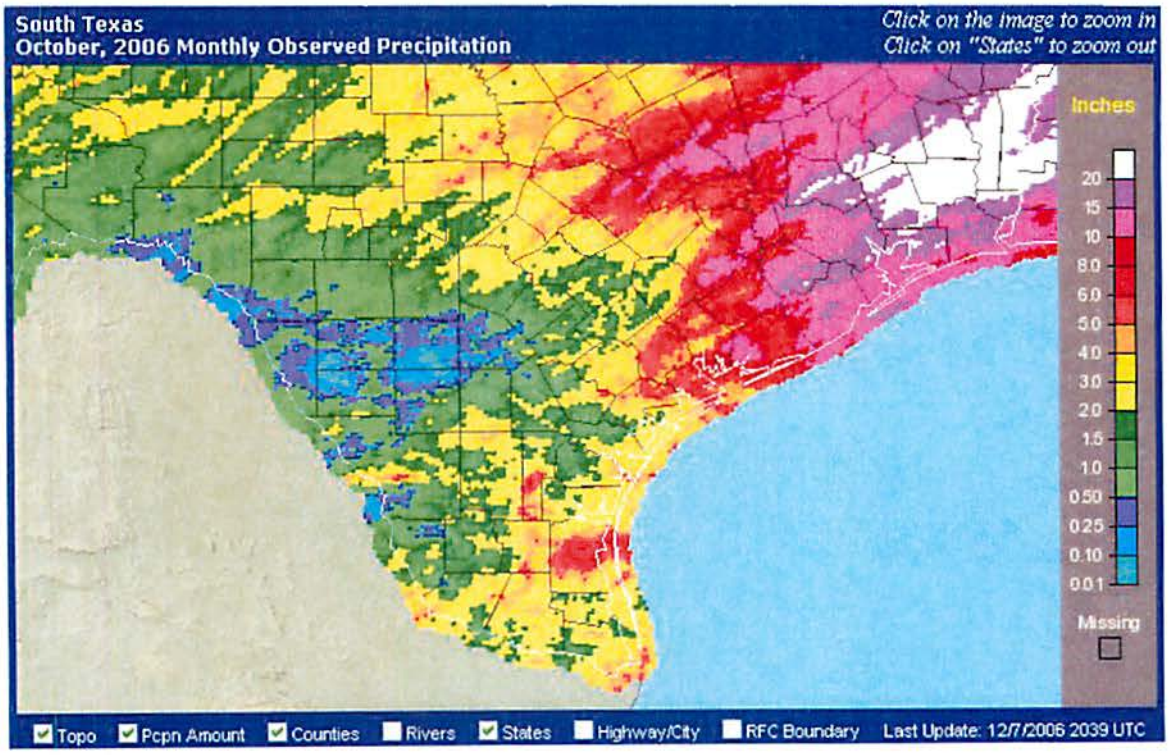


2006 RADAR ANALYSIS FOR THE EDWARDS AQUIFER AUTHORITY

The following is an excerpt from Archie Ruiz' 2006 radar analysis report for the EAA, which includes Bandera, Bexar, Medina and Uvalde counties:

A total of **33 clouds** were seeded and identified by TITAN in **21 operational days**.

Table 1. Small Seeded Sample versus Control Sample (22 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	70 min	40 min	1.75	75 **(59)**
Area	66.0 km^2	35.1 km^2	1.88	88 **(26)**
Volume	166.1 km^3	81.1 km^3	2.05	105 **(33)**
Top Height	7.8 km	7.5 km	1.04	4 **(3)**
Max dBZ	50.9	49.3	1.03	3 **(1)**
Max dBZ height	4.1 km	4.0 km	1.03	3 **(2)**
Vol > 6km	18.0 km^3	5.2 km^3	3.46	246 **(47)**
Precip Flux	593.1 m^3/s	288.8 m^3/s	2.05	105 **(34)**
Precip Mass	2613.8 kton	770.1 kton	3.39	239 **(140)**
Cloud Mass	136.5 kton	66.8 kton	2.04	104 **(33)**
η	19.1	11.5	1.66	66 **(63)**

Bold values in parentheses are modeled values, whereas **η** is defined as the quotient of Precipitation Mass divided by Cloud Mass, and is interpreted as efficiency. A total of 102 flares were used in this sub-sample with an excellent timing **(94%)** for an effective dose about **105 ice-nuclei per liter**. The seeding operations lasted on average about 15 minutes. An excellent increase of 140% in precipitation mass together with an increase of 33% in cloud mass illustrates that the seeded clouds grew at expenses of the environmental moisture (they are open systems) and used only a fraction of this moisture for their own maintenance. The increases in lifetime (59%), area (26%) volume (33%), volume above 6 km (47%) and precipitation flux (34%) are notable. There were slight increases in maximum reflectivity (1%), and in top height (3%). The seeded sub-sample seemed 63% more efficient than the control sub-sample. Results are evaluated as **excellent**.

An increase of 140% in precipitation mass for a control value of 770.1 kton in 22 cases means:

Δ_I = 22 x 1.40 x 770.1 kton = 23,719 kton = 19,236 ac-ft

The sub-sample of 5 **large seeded clouds** received a synergetic analysis. On average, the seeding operations on these large clouds affected 57% of their whole volume; with a perfect timing (100% of the material went to the clouds in their first half-lifetime). A total of 41 flares were used in this sub-sample for an effective dose about **90 ice-nuclei per liter**.

Also on average, large clouds were 27 minutes old when the operations took place; the operation lasted about 21 minutes, and the large seeded clouds lived 245 minutes.

Table 2 shows the corresponding results:

Table 2. Large Seeded Sample versus Virtual Control Sample (5 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	245 min	200 min	1.23	23
Area	2961 km^2	2613 km^2	1.13	13
Precip Mass	29,255 kton	19,527 kton	1.50	50

An increase of 50% in precipitation mass for a control value of 19,527 kton in 5 cases may mean:

Δ_2 = 5 x 0.50 x 19,527 kton = 48,818 kton = 39,591 ac-ft

The sub-sample of 5 type B seeded clouds received a synergetic analysis. On average, the seeding operations on these type B clouds affected 22% of their whole volume; with an excellent timing (80% of the material went to the clouds in their first half-lifetime). A total of 28 flares were used in this sub-sample for an effective dose about **175 ice-nuclei per liter**.

Also on average, type B clouds were 135 minutes old when the operations took place; the operation lasted about 33 minutes, and the type B seeded clouds lived 300 minutes.

Table 3. Type B Seeded Sample versus Virtual Control Sample (5 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	300 min	275 min	1.09	9
Area	1994 km^2	1904 km^2	1.05	5
Precip Mass	28,950 kton	25,174 kton	1.15	15

An increase of 15% in precipitation mass for a control value of 25,174 kton in 5 cases may mean:

Δ_3 = 5 x 0.15 x 25,174 kton = 18,881 kton = 15,312 ac-ft

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ = 74,139 ac-ft

APPENDIX

Mesoscale Convective System (MCS) is a large complex of showers and thunderstorms at least 100 km (~60 miles) across, and may be as large as 500 km (~310 miles) across.

Vorticity maxima, or vort max as referred to in this report, is defined as a pocket of the atmosphere where rotation of the air about a vertical axis is maximized.

Shortwave, or shortwave trough, refers to a small-scale area of lower pressure, sometimes accompanied by showers and thunderstorms.

Cell refers to an updraft-downdraft couplet in a cloud. Clouds with several updraft-downdraft couplets are called **multicell** clouds. A storm with a single updraft-downdraft couplet (often rotating) that lasts for several hours is called a **supercell.**

Pre-frontal trough refers to an elongated area of low pressure found ahead of an advancing cold front. In south Texas, the passage of a pre-frontal trough usually signals the end of precipitation, as winds tend to turn more to the west or northwest, cutting off moisture supply.

Precipitable Water is the total amount of water vapor in a column of air above a given location. This value is expressed in inches. High precipitable water values (>1.5 inches) are indicative of the potential for heavy rain. Tropical airmasses usually have a precipitable water value in excess of two inches.

Convective temperature is the temperature required at or near the ground in order for convection (surface-based) to occur.

TUTT, or Tropical Upper Tropospheric Trough, refers to a upper level cold core area of low pressure found in the tropical and sub-tropical regions of the Earth. These disturbances are sometimes associated with shower and thunderstorm activity, and are associated with tropical waves.

Theta-e, or equivalent potential temperature, is the temperature a parcel or bubble of air would reach if it was lifted until all of the moisture condensed out, then brought back down to 1000 mb (at/near surface). A forecaster looks at theta-e to see how moisture is distributed over a region. High theta-e values are associated with moist airmasses, which storms may develop in and feed on.

Jet streak refers to the maximum wind speed within a river of faster-moving air (jet stream). Forecasters may look for jet streak locations at 850mb, 700mb, 500mb, and 250 mb in order to assess the possibility of strong/severe thunderstorms.

Cap refers to a warm layer of air aloft which acts as a lid, suppressing convection. The strength of the cap varies with time and location.

Convective Inhibition is the amount of energy required to overcome the cap, or the amount of energy required by a parcel of air to initiate deep convection (i.e., thunderstorms).

Lifetime refers to the length of time a cloud was detected on radar, with a reflectivity maximum of at least 32 dBZ.

Area refers to the two-dimensional space (length x width) covered by a cloud.

Precip Flux refers to the radar-derived volume of water falling through the bottom of the cloud per second.

Precip Mass refers to the total mass of water and ice for all droplets/crystals larger than 100 μm (10^{-4} m) in a cloud.

Small seeded clouds are those clouds with a radar-derived Precip Mass less than 10,000 kilotons.

Large seeded clouds are those clouds with a radar-derived Precip Mass greater than 10,000 kilotons.

Type B clouds are those clouds, small or large, that were not seeded until they were at least one hour old, as determined by their presence on radar.

Control clouds are those clouds within 100 km of the radar that were NOT seeded. Control clouds are used to determine the effectiveness of seeding, as it represents "what would have happened" if seeding had not taken place.

Effective dosage refers to the amount of seeding material that was placed in the cloud. It is expressed as a concentration of ice nuclei per liter of air.

ACKNOWLEDGEMENTS

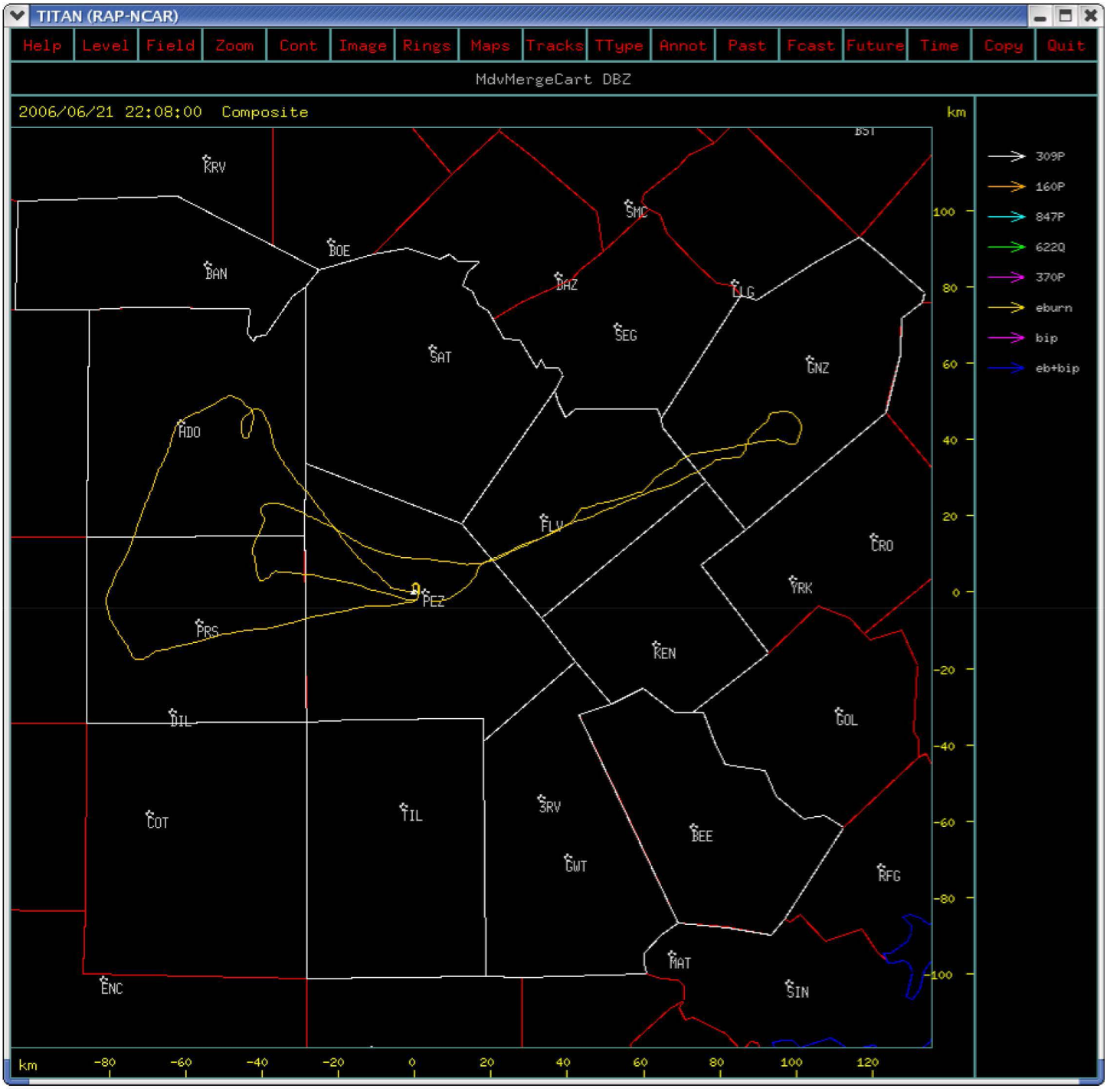
2006 appeared to be yet another successful year of cloud seeding within the Edwards Aquifer Authority target area. Radar analysis showed that seeding effects this year were positive once again. The success of the project comes about through the hard work of many people, and it is here where gratitude must be expressed.

Our two "heads of state", if you will, Tommy Shearrer and Mike Mahoney, continue to do many hours of work to ensure that the project gets past any red tape and runs as smoothly and efficiently as possible. Many thanks go their way, as the project would likely be lost without them. Thanks also go to the board members who regularly meet to discuss purchases, improvements, seeding methods, and any other factors that affect the way the program is run. Their input in the past has helped run a successful program, and we hope they will continue their good work. We certainly couldn't have the great planes and the successful flights without the hard work of our pilots: Tim Pickens, Larry Dement and Craig Funke. They deserve many thanks. We must also thank the mechanics who completed annuals on our planes, Dave Lavelle and Craig Funke. Thanks must also go out to Candi Gonzales, who handles much of the laborious paperwork for the project, and to Larry Akers, who keeps our radar in tip-top shape. Speaking of radars, we must thank the crew at WDT, Inc. for providing us with the NEXRAD feed. An expression of gratitude is extended to Archie Ruiz, who performs the ever-challenging radar analysis. With his work, we may yet find a way to prove once and for all the true success of cloud seeding. The cloud seeding projects may not be here had it not been for George Bomar, who works with the projects and the Department of Licensing and Regulations - thank you. Thanks also to Rick Illgner, Bob Hall and the EAA for working with us this year and in the years to come. Finally, thanks go out to the public, most of who continue to believe in our project and our mission. Without your approval, our project would cease to exist. Thank you all!

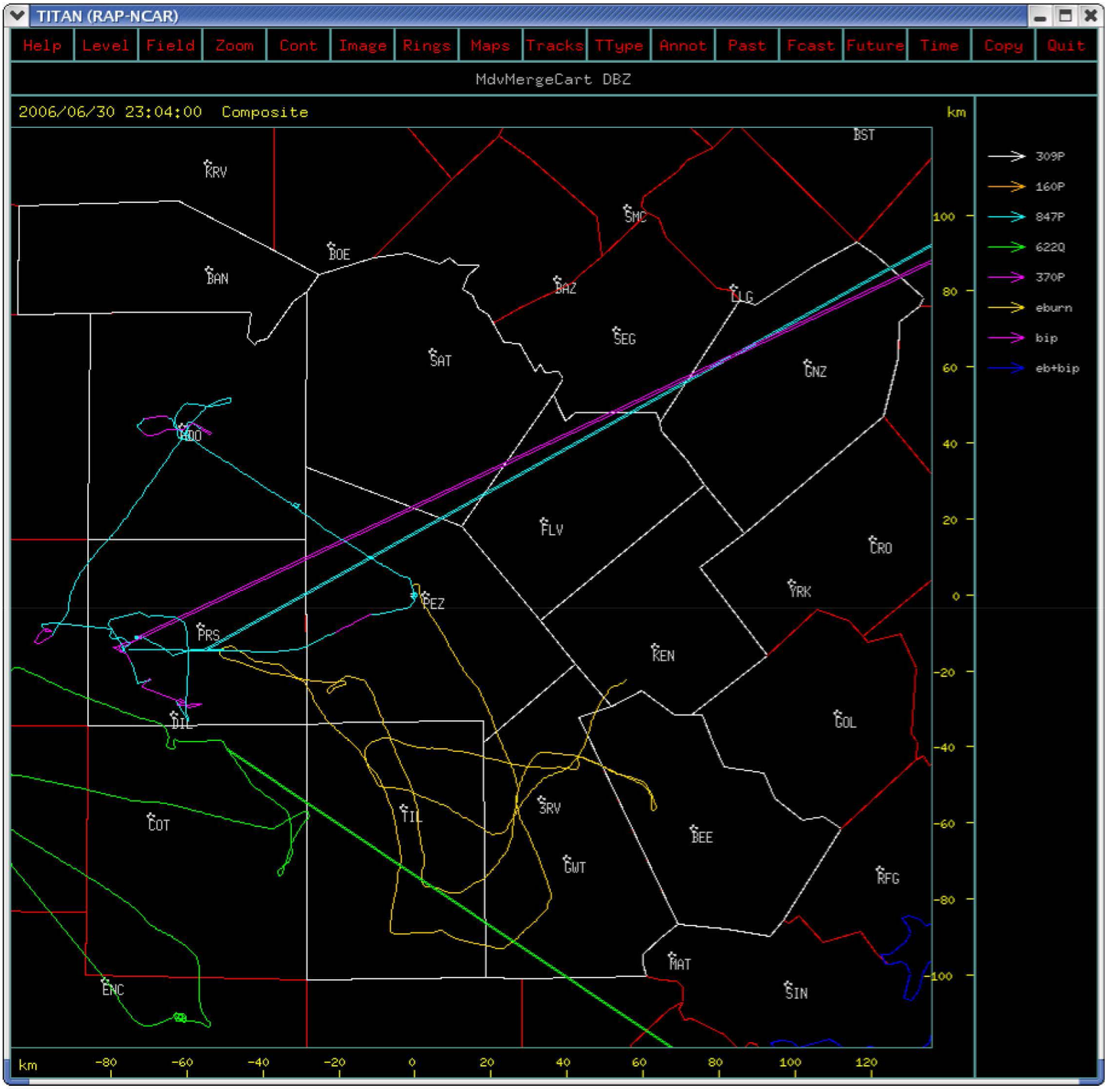
Rainfall maps for 2006 came from the following website:
http://www.srh.noaa.gov/rfcshare/precip_analysis_new.php

Radar analysis numbers came from Archie Ruiz's final report of the 2006 season for the EAA (6 pp).

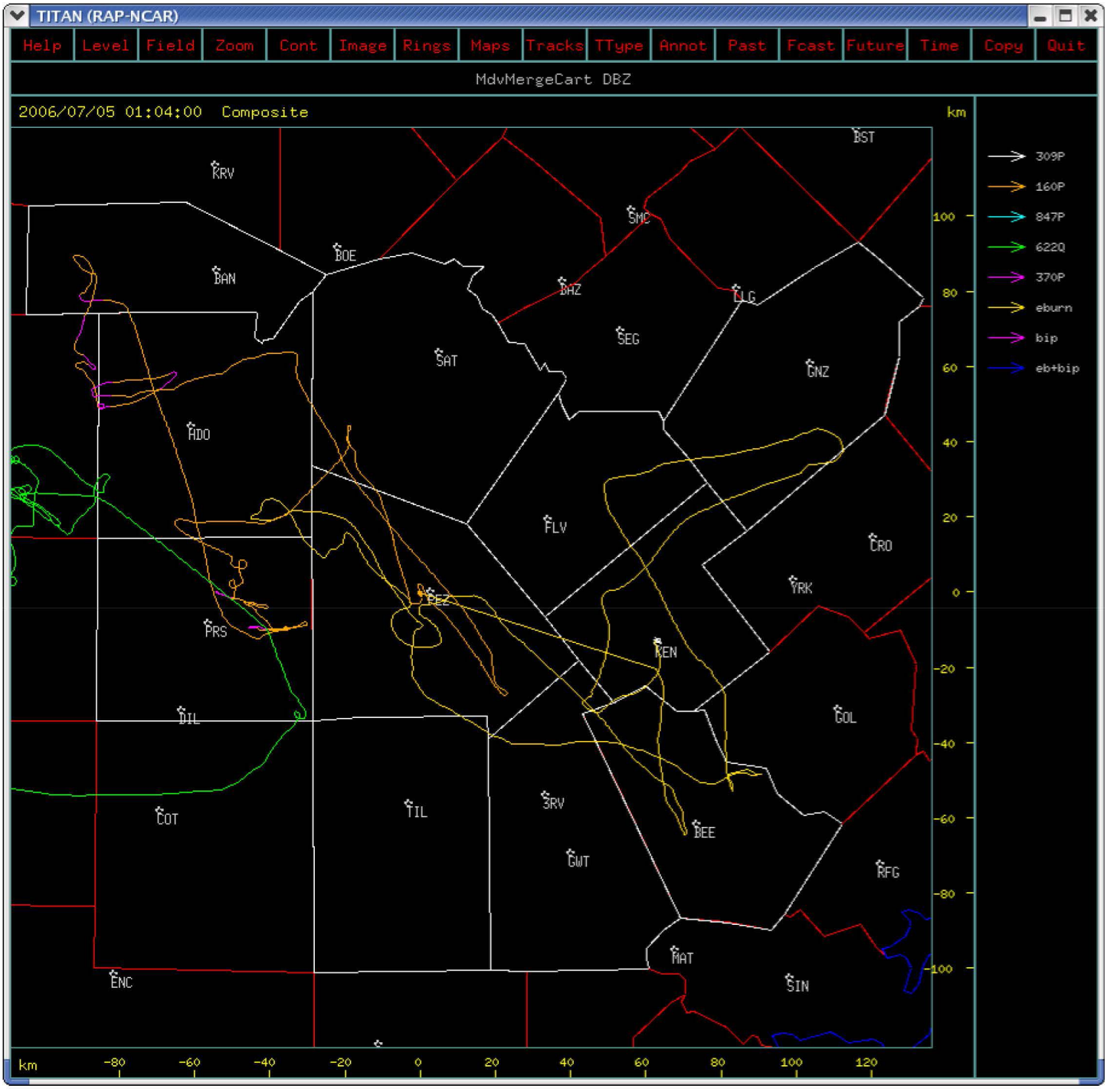
Flight Path: June 21



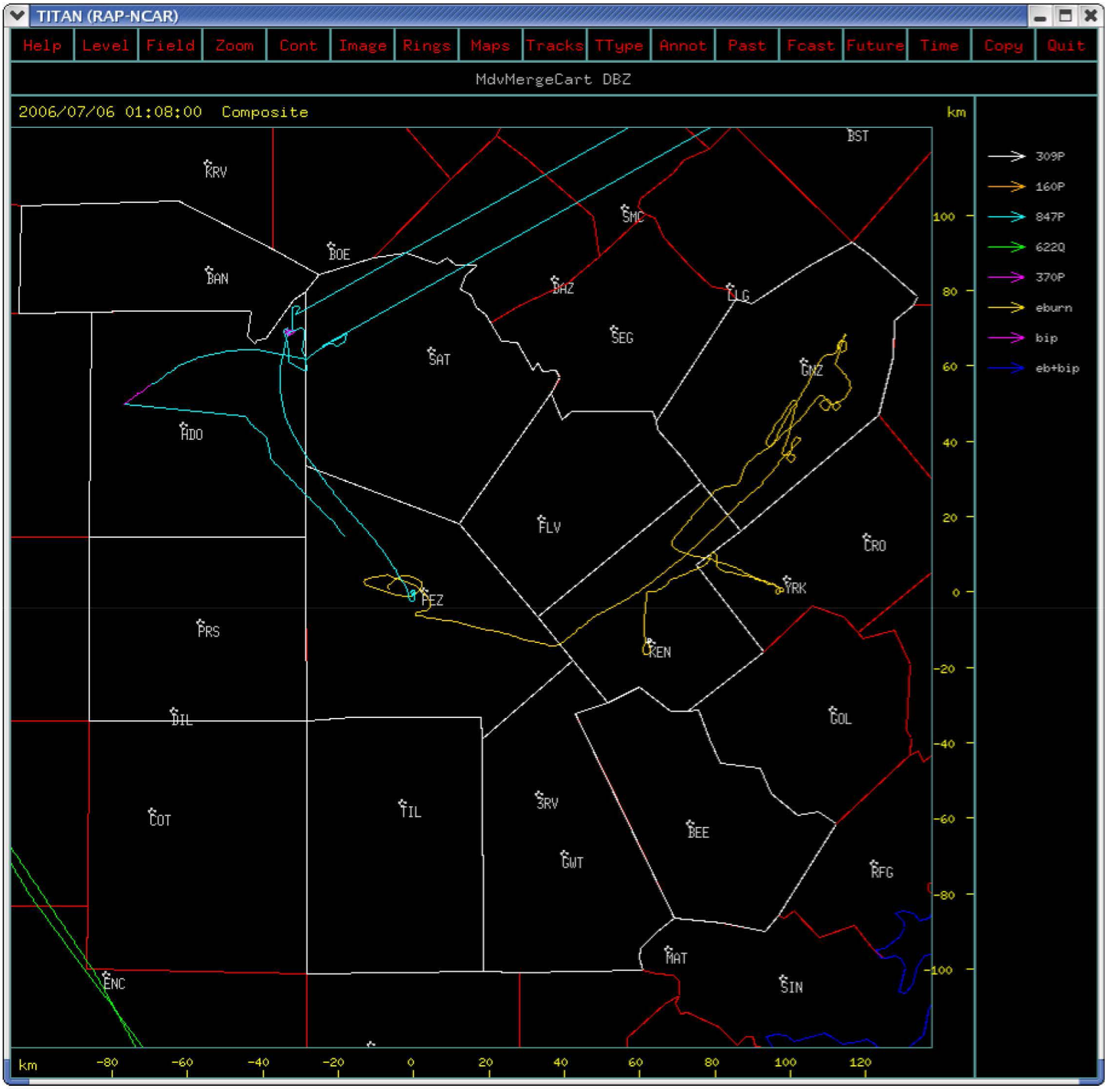
Flight Path: June 30



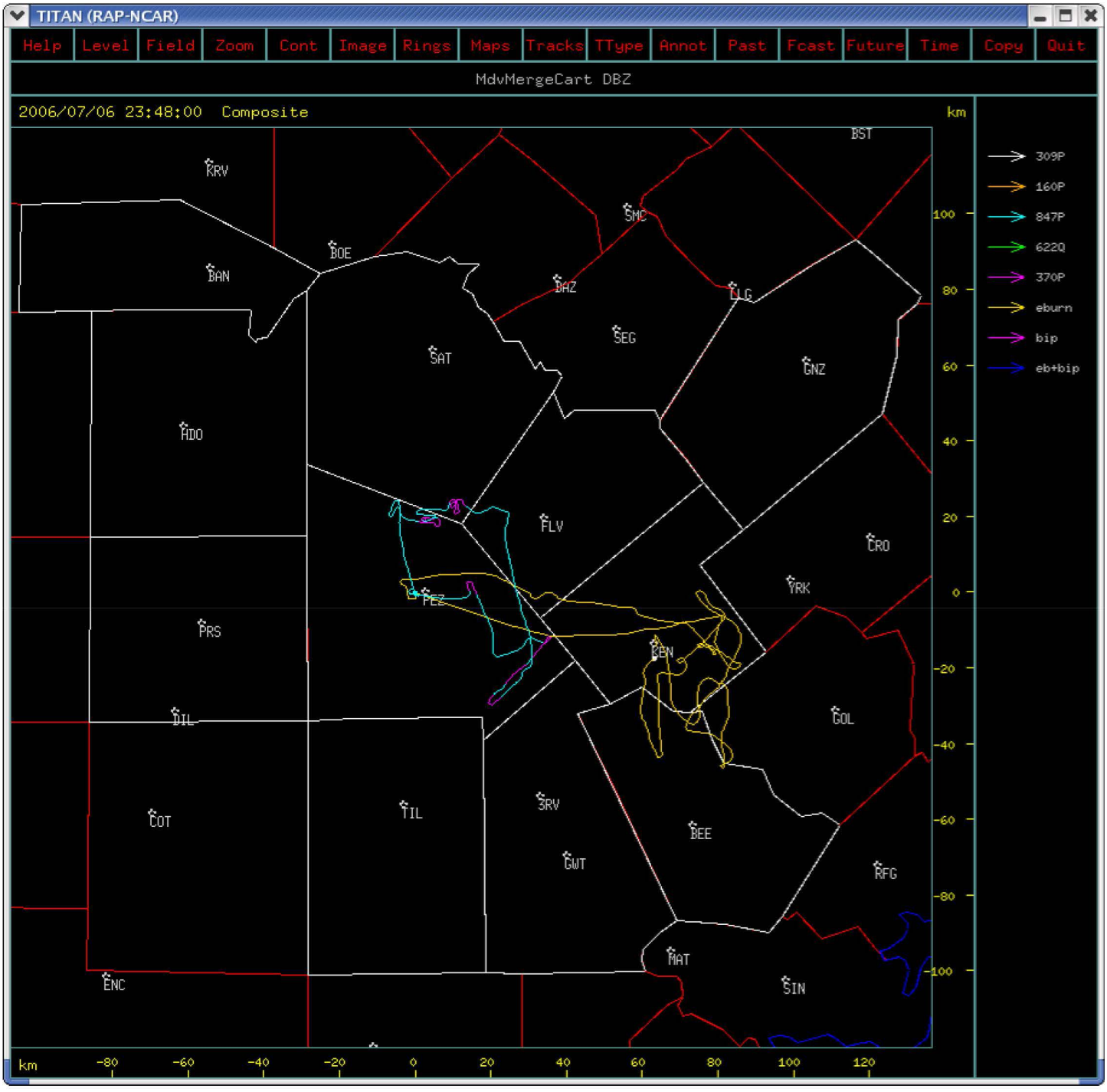
Flight Path: July 4



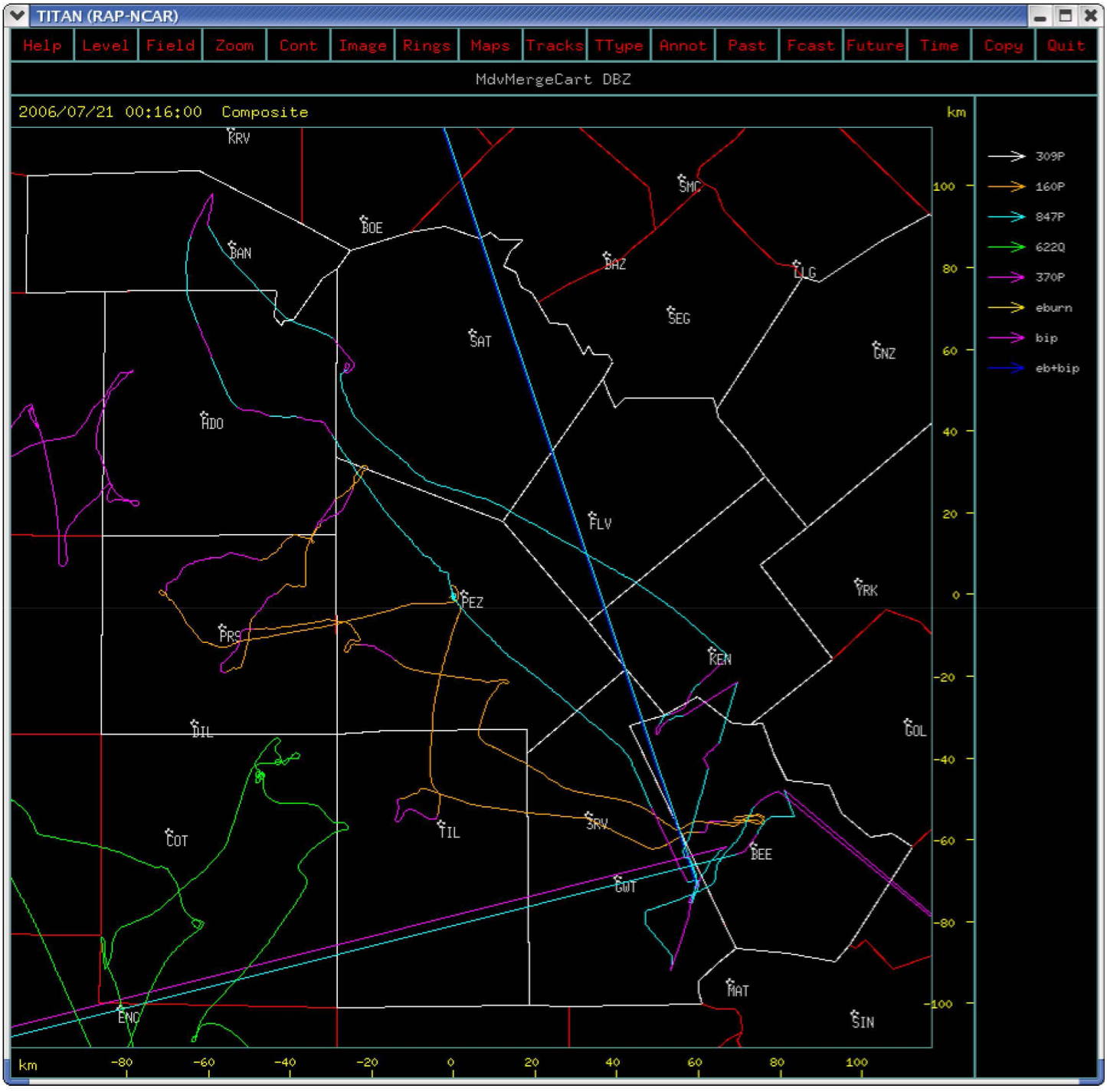
Flight Path: July 5



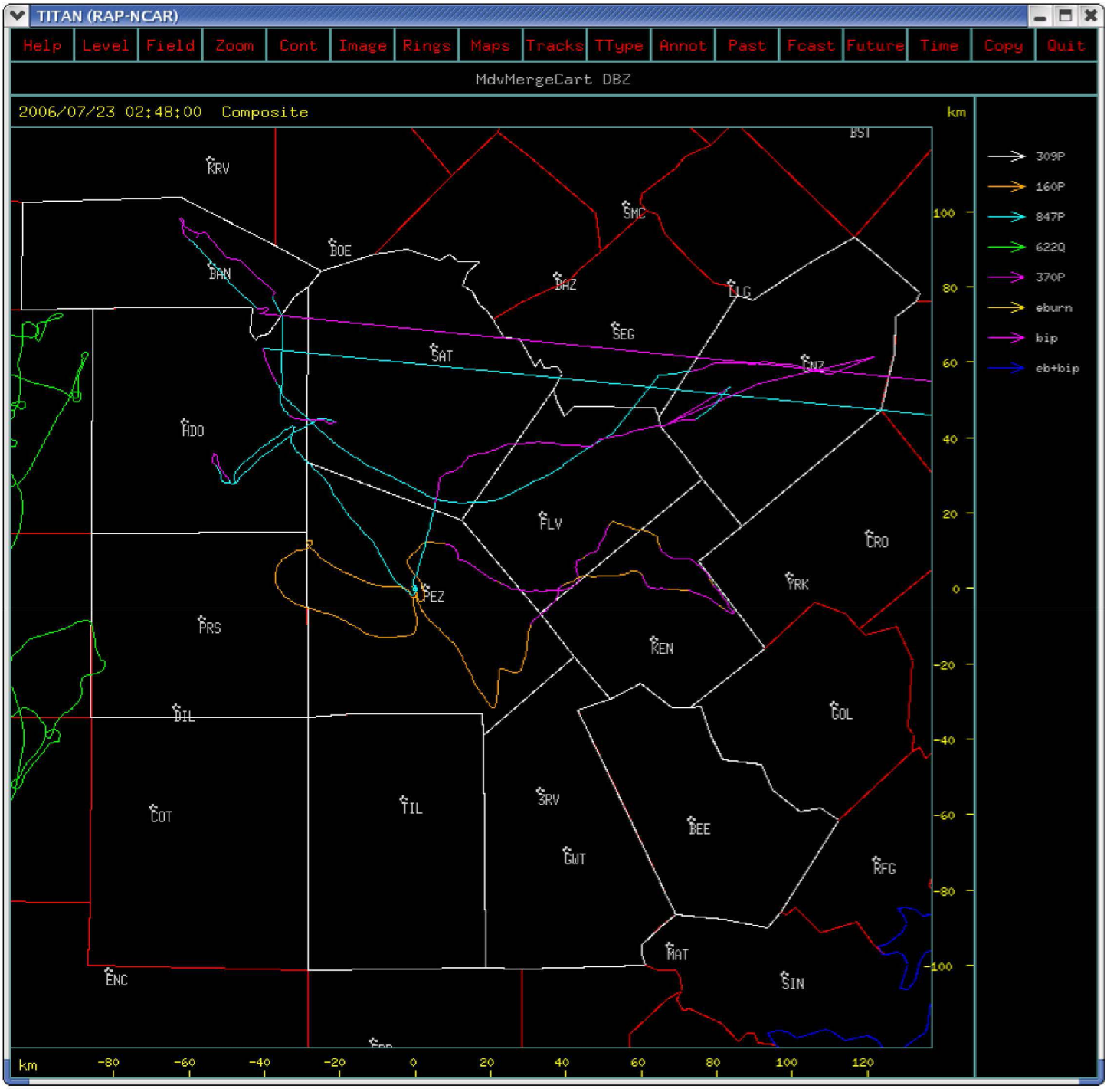
Flight Path: July 6



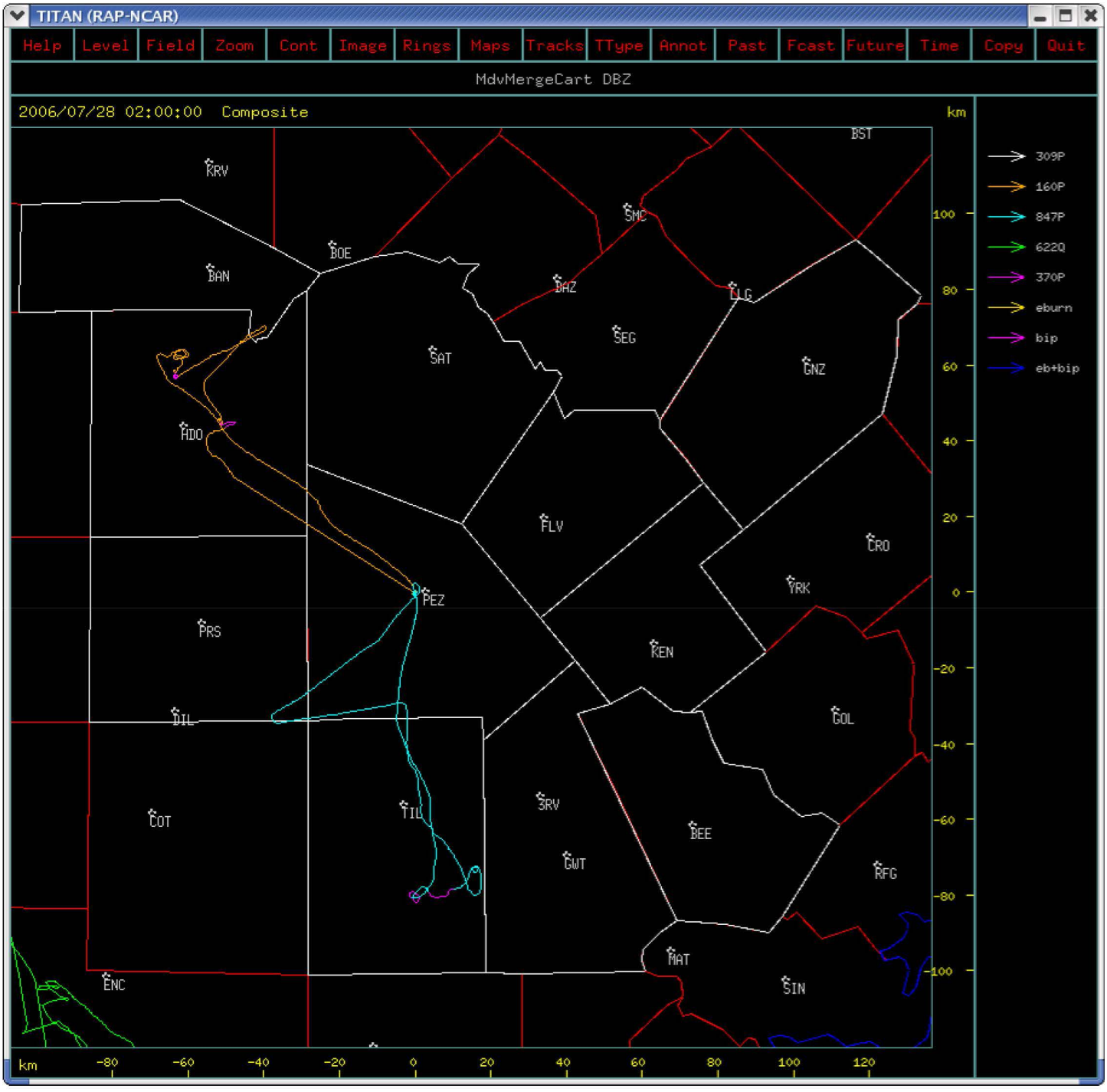
Flight Path: July 20



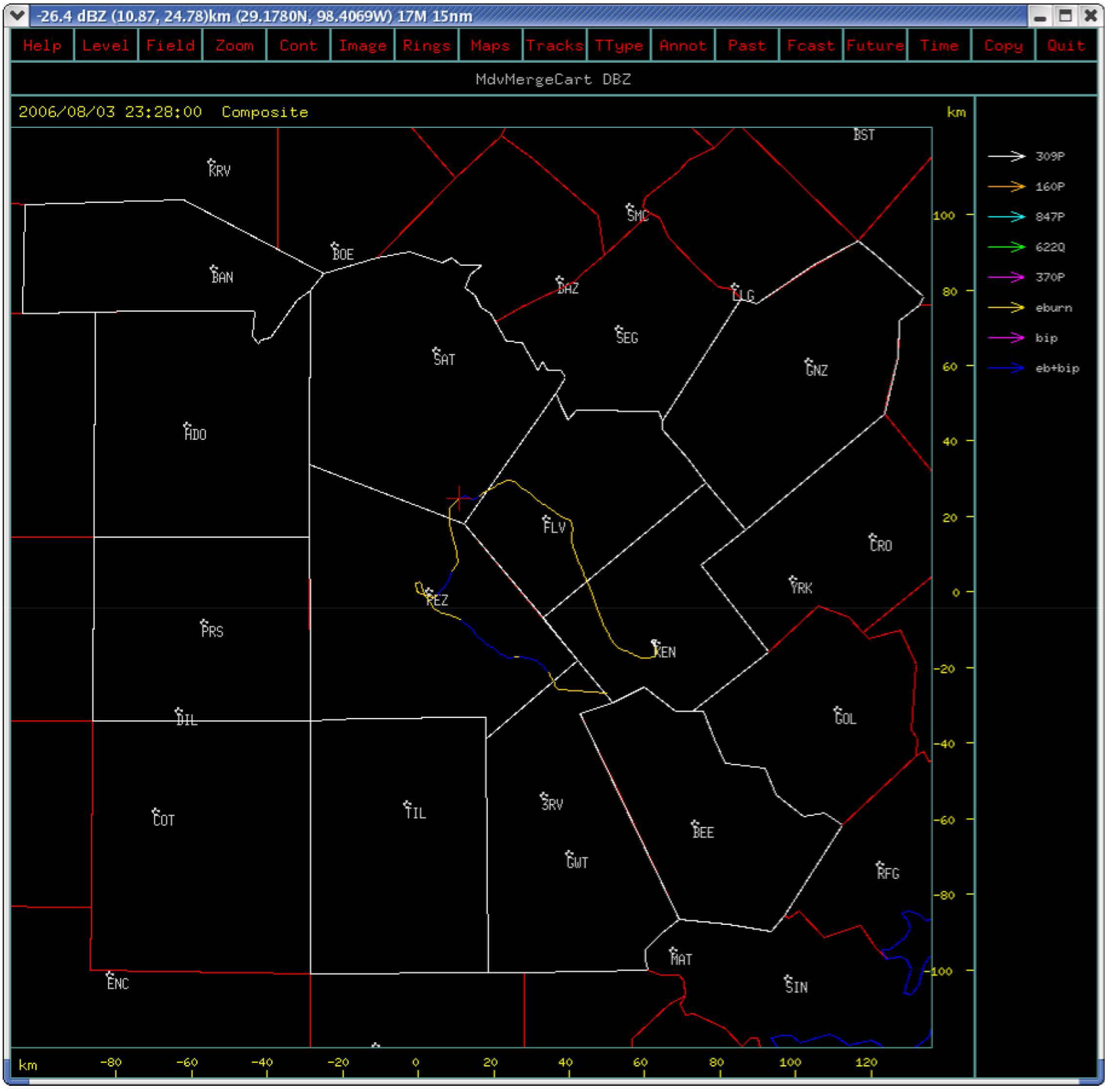
Flight Path: July 22



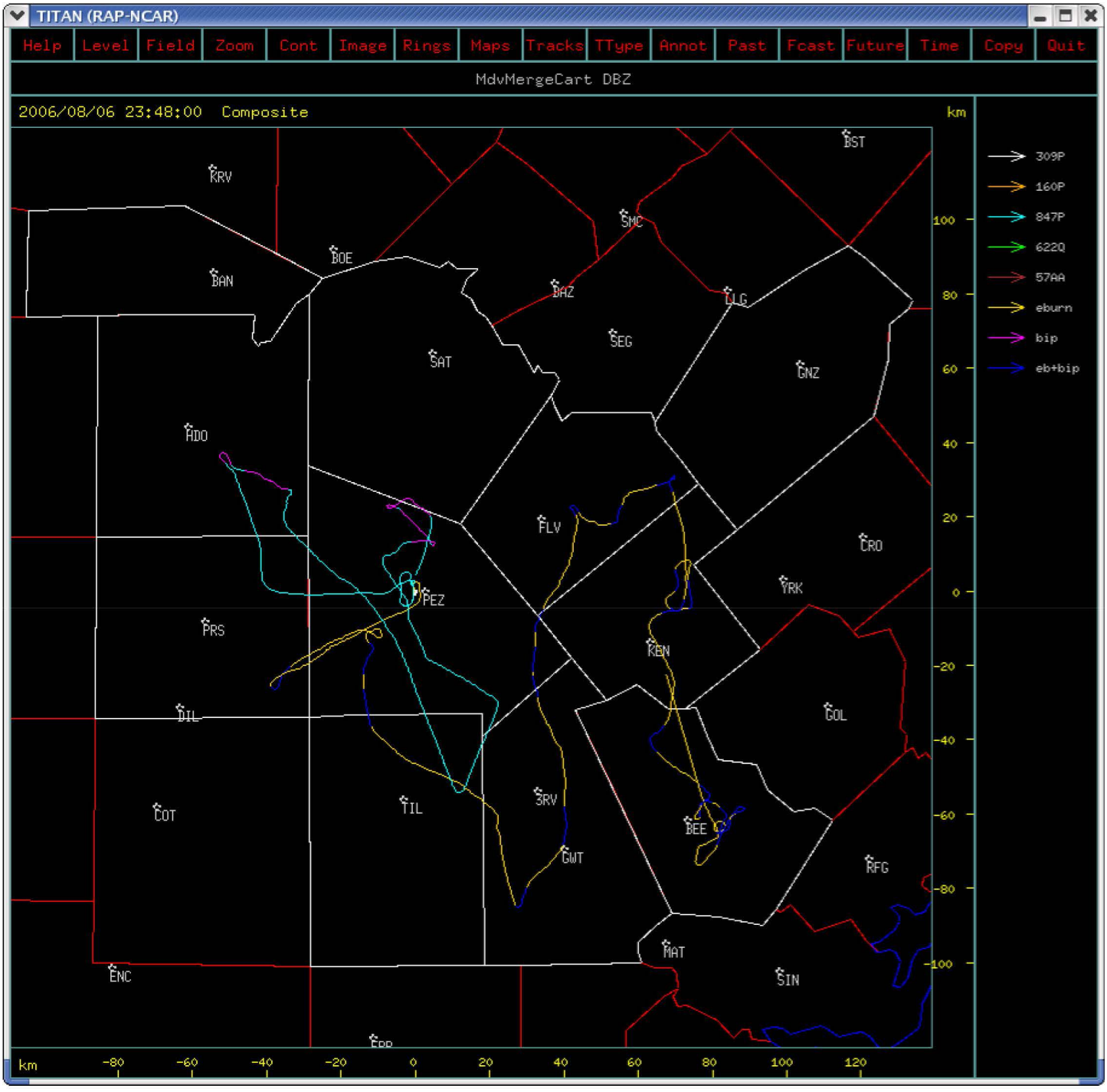
Flight Path: July 27



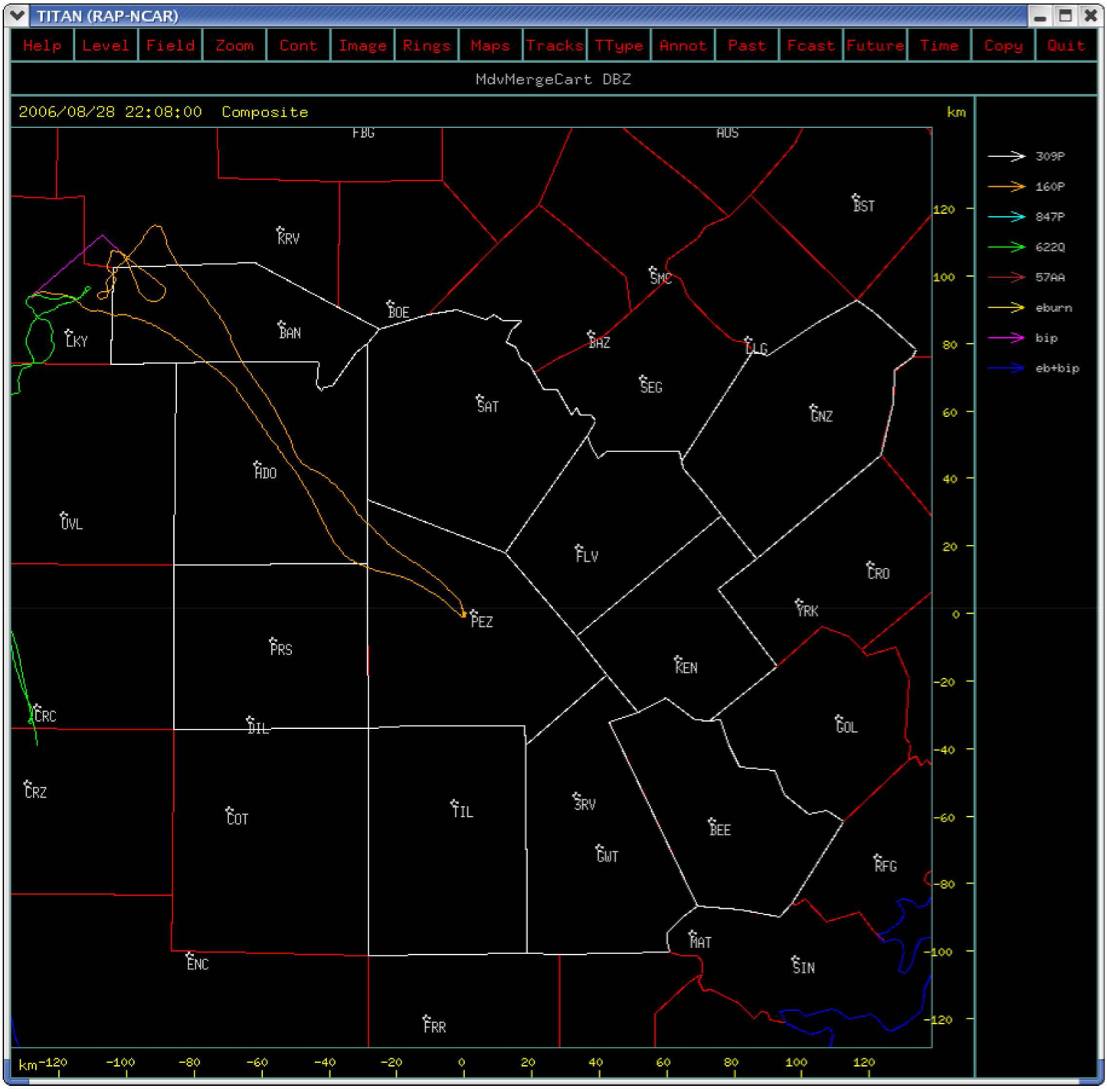
Flight Path: August 3



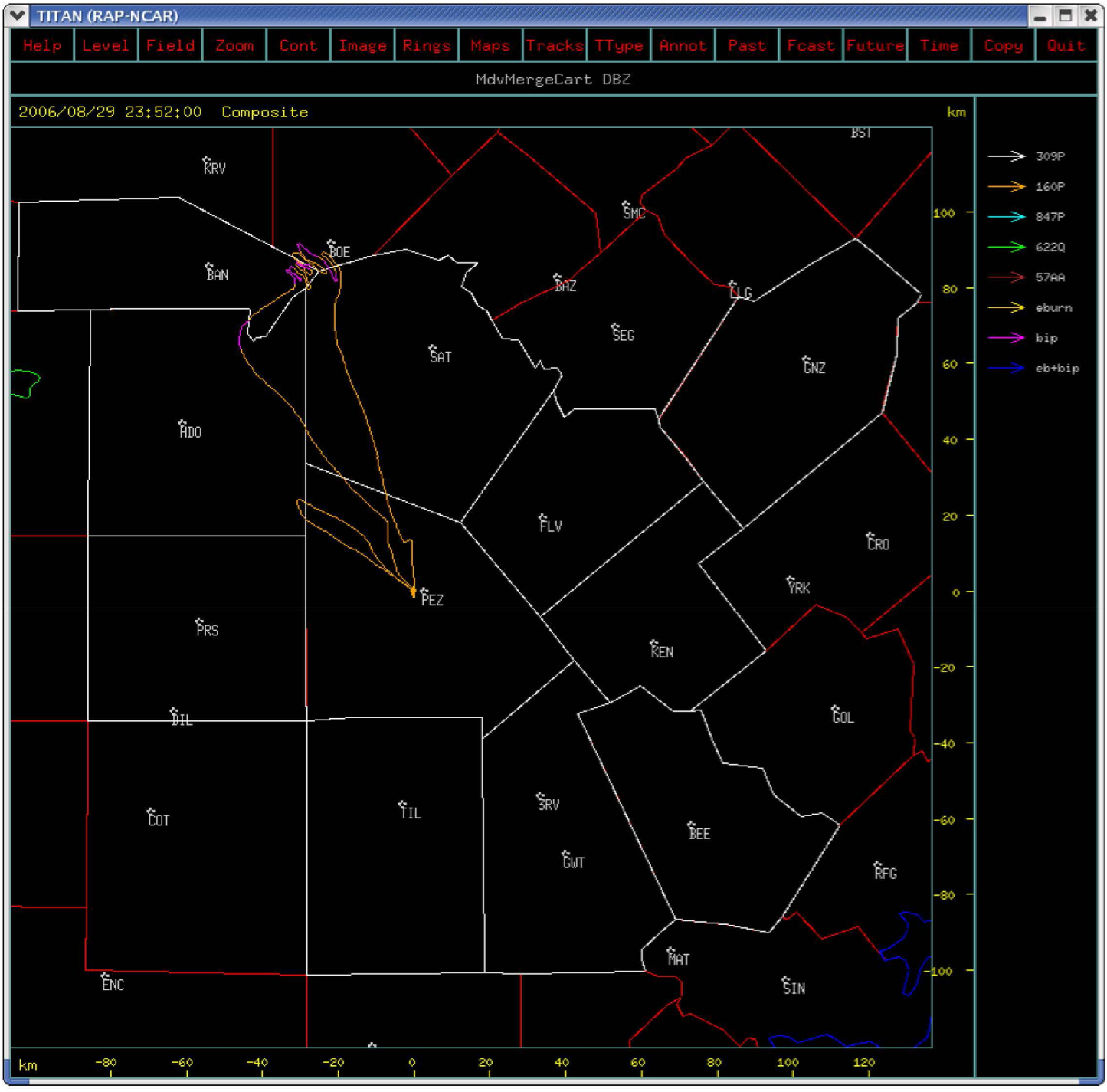
Flight Path: August 6



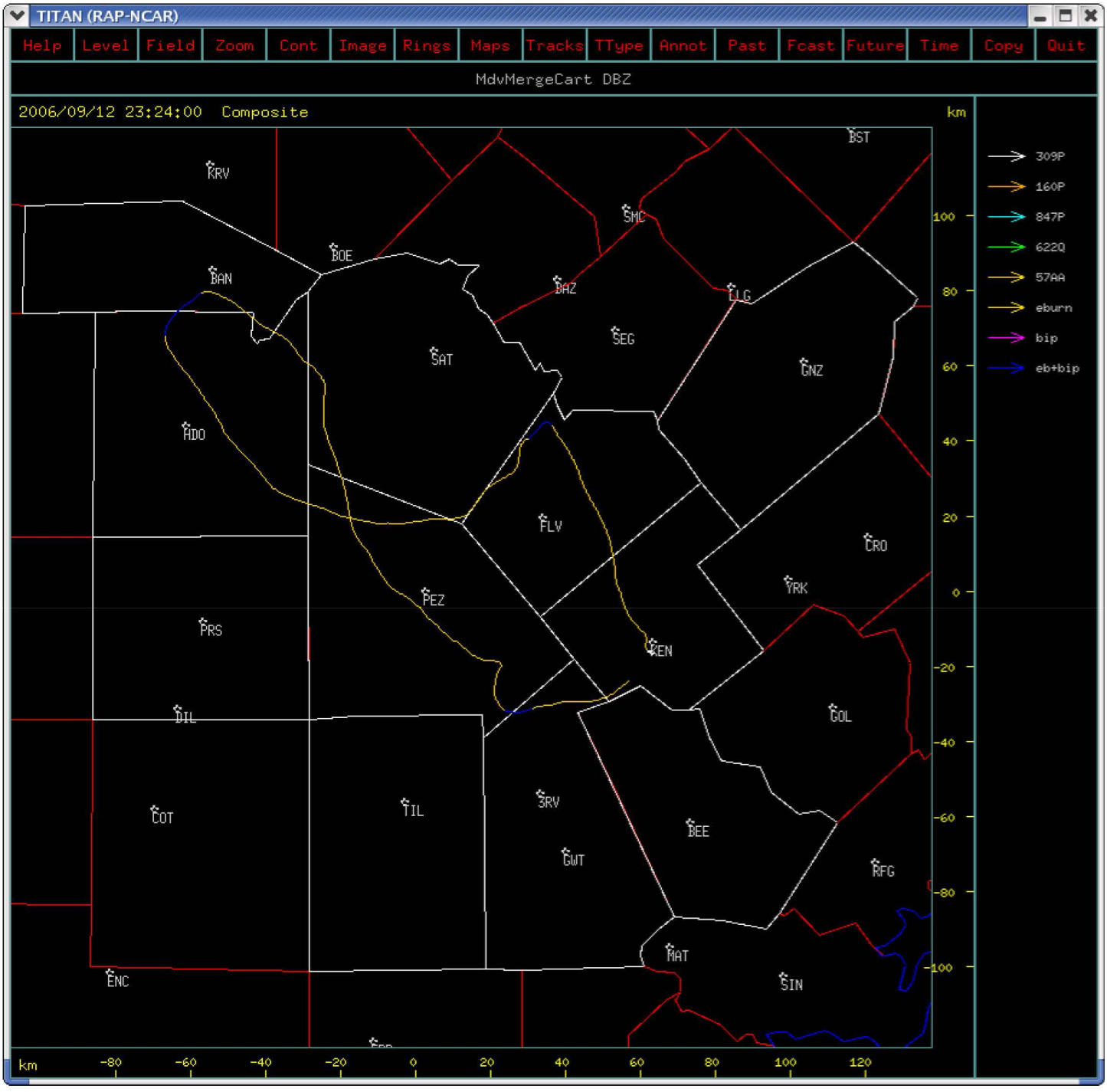
Flight Path: August 28



Flight Path: August 29



Flight Path: Sept 12



Flight Path: Sept 23