

2004 Results for Texas

Seeded Clouds : 447

189 small, 131 large,

and 127 type B

(NP, Panhandle, WT, ST, SWT)

TITAN Evaluation Results

Small Clouds: Seeded Sample versus Control Sample (189 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	85 min	55 min	1.54	50 (39)
Area	59.9 km ²	45.2 km ²	1.33	33 (24)
Volume	174.0 km ³	121.6 km ³	1.43	43 (30)
Top Height	7.8 km	7.3 km	1.07	7 (3)
Max dBz	48.7	47.0	1.04	4 (2)
Top Height of max dBz	4.2 km	4.2 km	1.00	0 (-2)
Volume Above 6 km	24.8 km ³	16.3 km ³	1.52	52 (36)
Prec.Flux	436.6 m ³ /s	288.7 m ³ /s	1.51	51 (37)
Prec.Mass	1 775.0 kton	835.4 kton	2.12	112 (93)
CloudMass	143.7 kton	96.9 kton	1.48	48 (30)
η	12.3	8.6	1.43	43 (48)

Increase from small clouds:

$$\begin{aligned} I1 &= 189 \times 0.93 \times 835.4 \text{ kton} \\ &= 146\,838 \text{ kton} \end{aligned}$$

$$I1 = 119\,086 \text{ ac-f}$$

Large Clouds: Seeded Sample versus Virtual Control Sample (131 couples, averages)

Prec.Mass	66 231 kton	43 893 kton	1.51	51
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(Large clouds were affected in average by the seeding operations
in about 70 % of their volume)

$$\mathbf{I2 = 131 \times 0.51 \times 43\ 893\ kton = 2\ 932\ 491\ kton}$$

$$\mathbf{I2 = 2\ 378\ 250\ ac-f}$$

**Type B Clouds: Seeded Sample versus Virtual Control Sample
(127 couples, averages)
(clouds seeded when they were 1 hour old or older)**

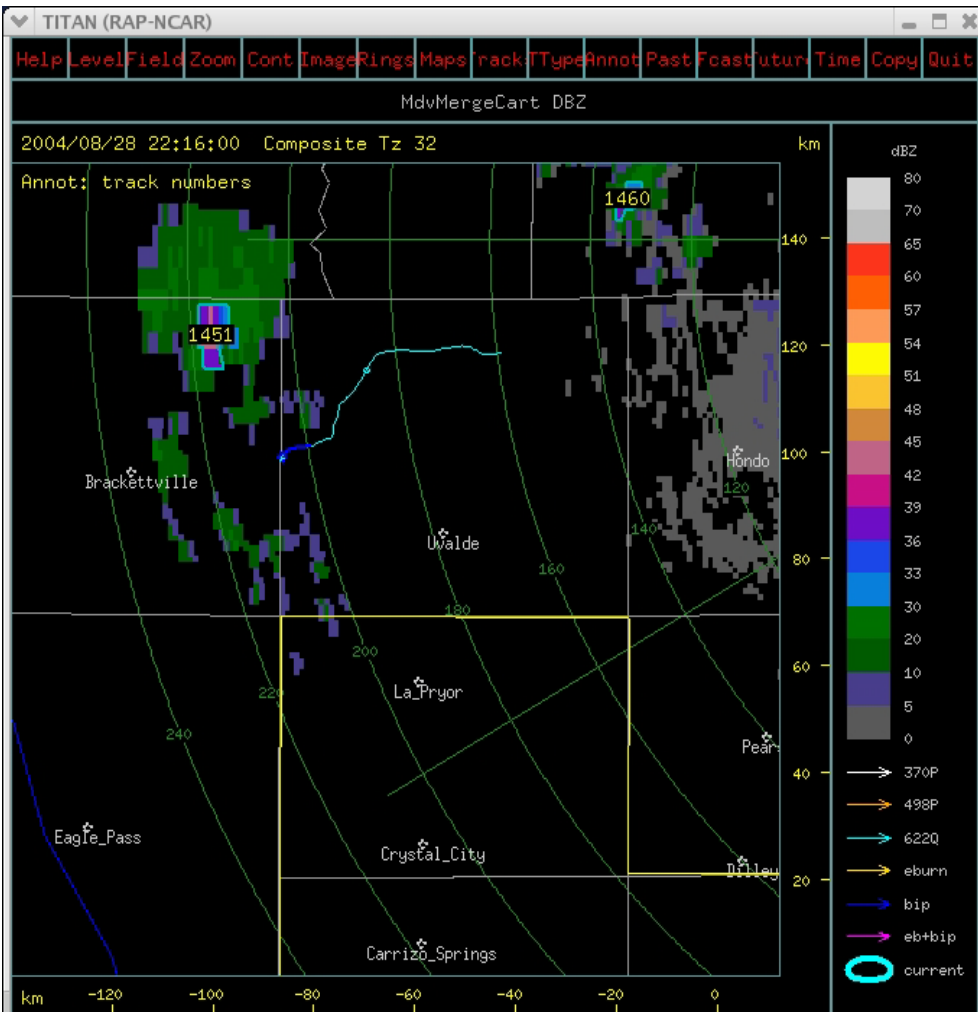
Prec.Mass	107 825 kton	87 972 kton	1.23	23
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(Type B clouds were affected in average by the seeding operations
in about 40 % of their volume)

$$I3 = 127 \times 0.23 \times 87\,972 \text{ kton} = 2\,569\,666 \text{ kton}$$

$$I3 = 2\,083\,996 \text{ ac-f}$$

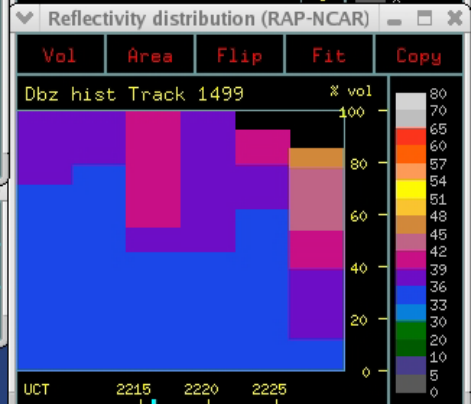
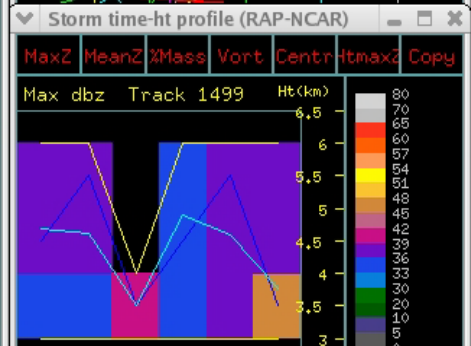
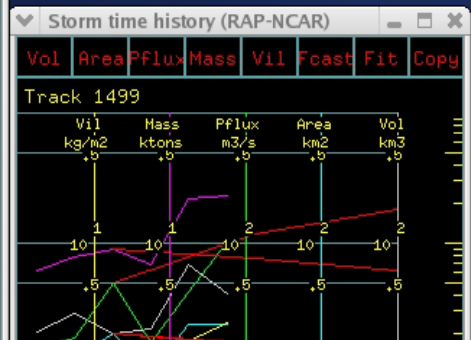
$$I = I_1 + I_2 + I_3 = 4\ 581\ 332\ \text{ac-f}$$



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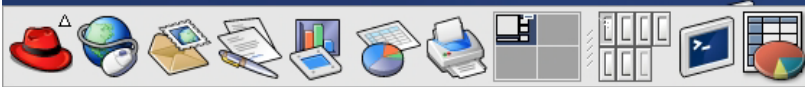


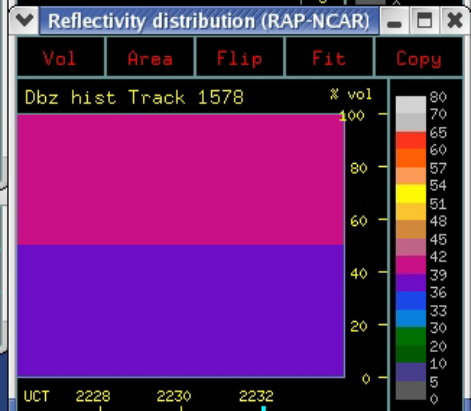
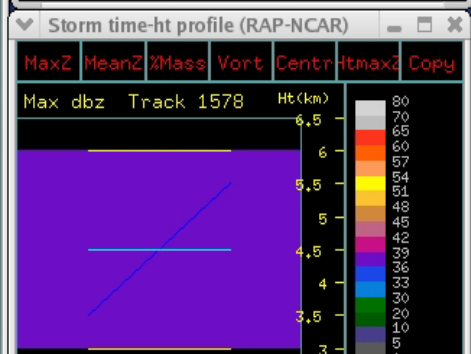
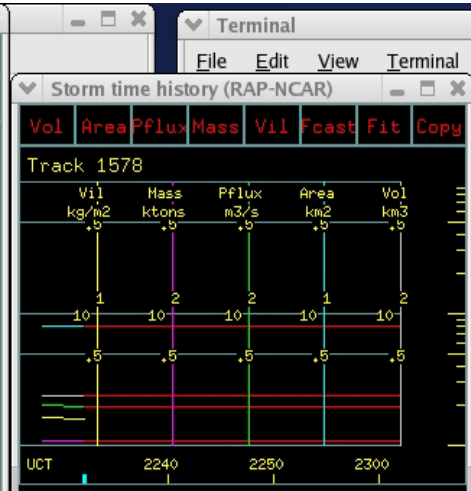
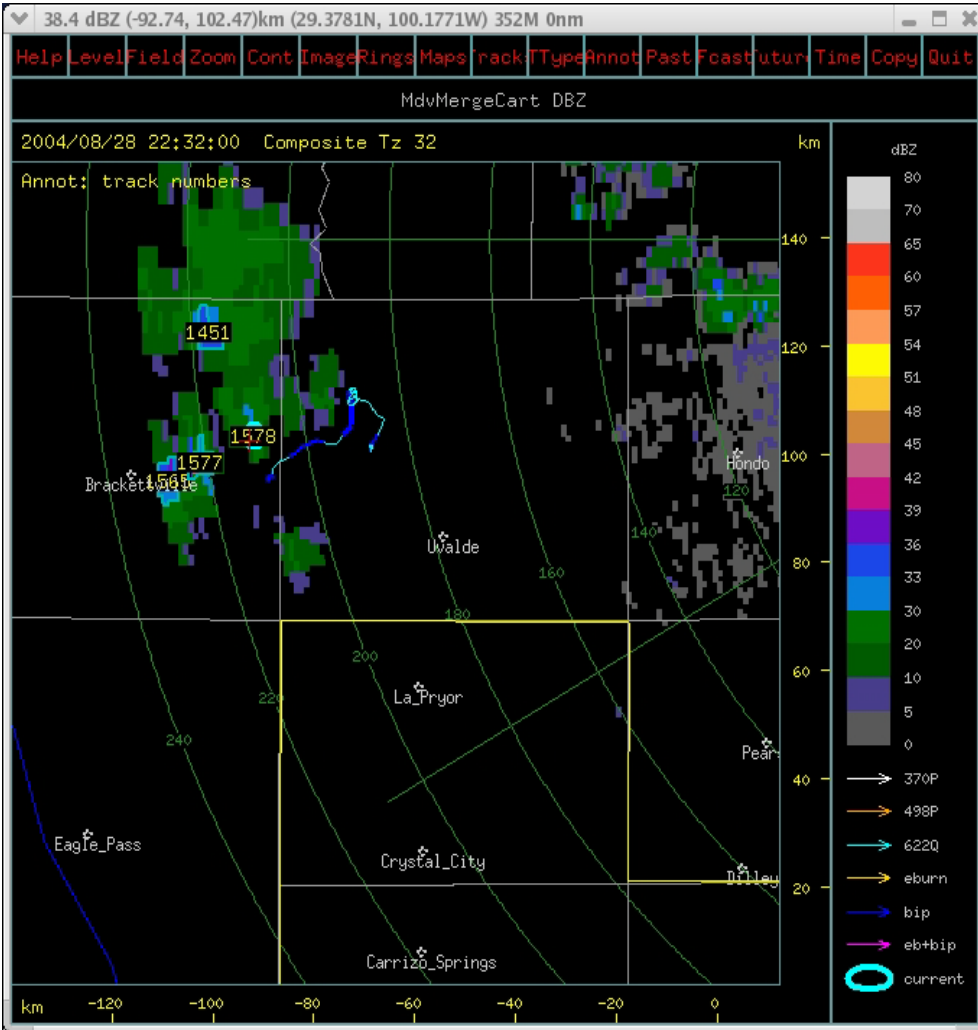
Track data time scale (RAP-NCAR)

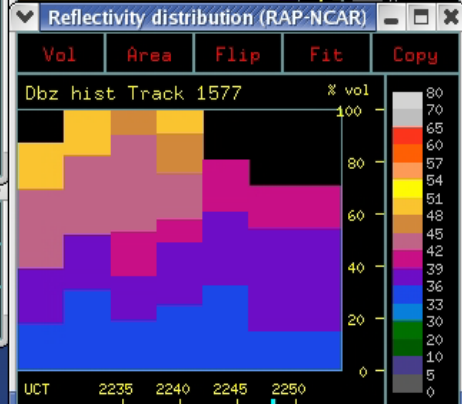
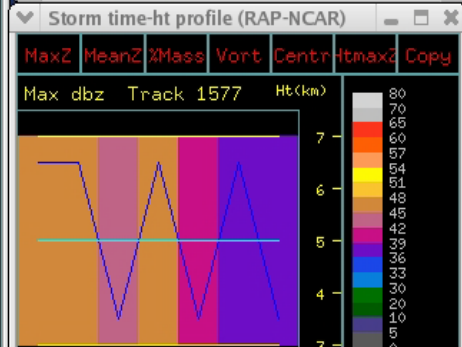
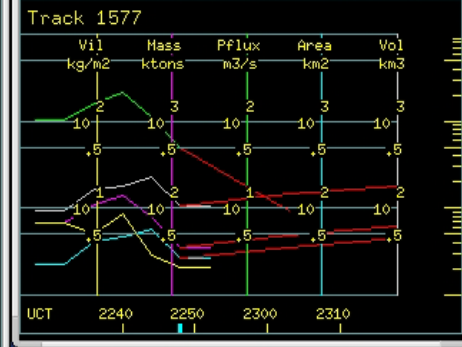
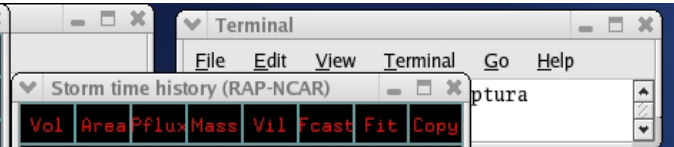
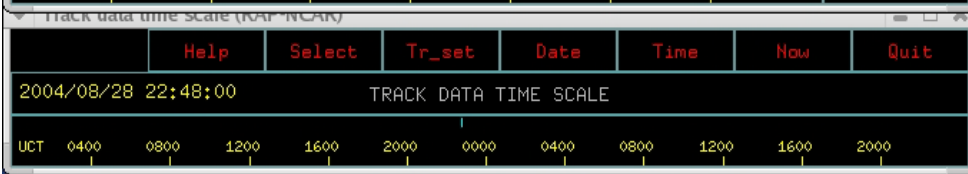
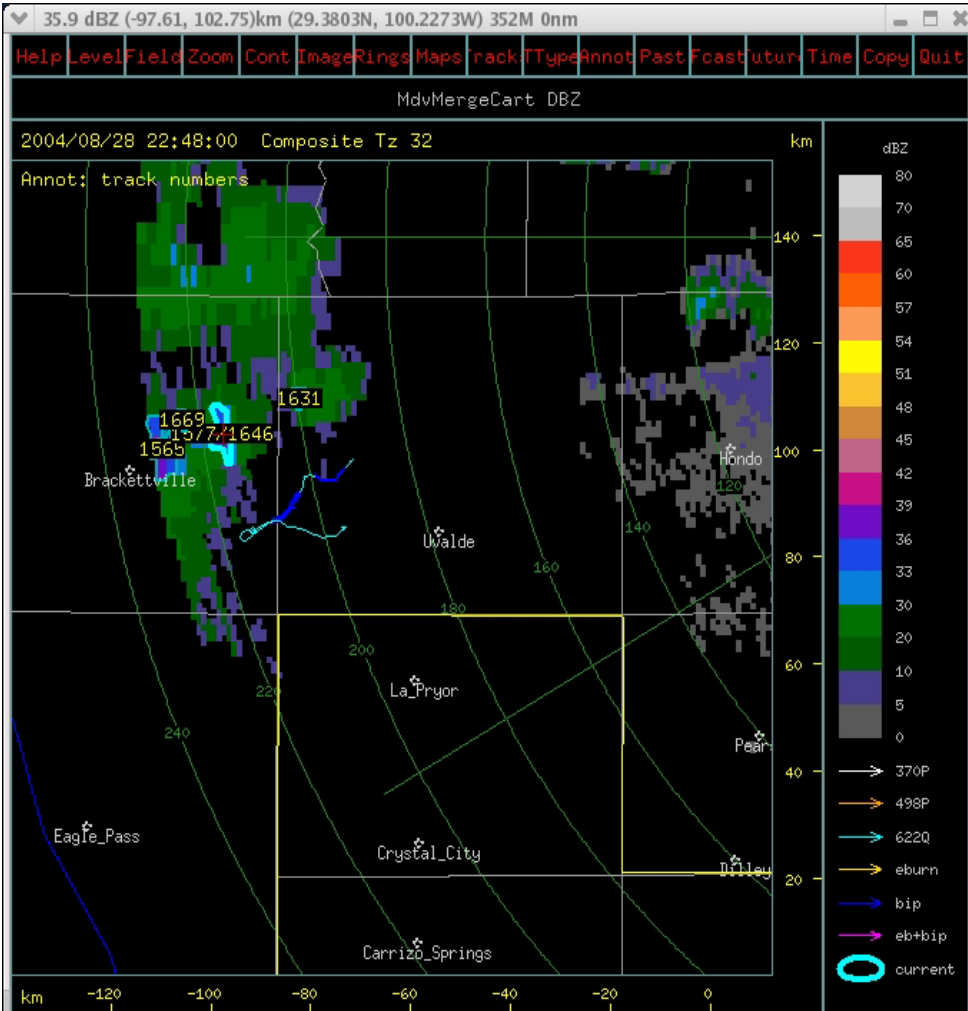
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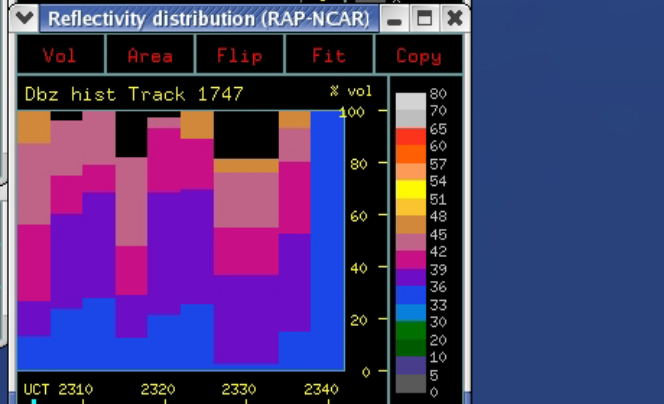
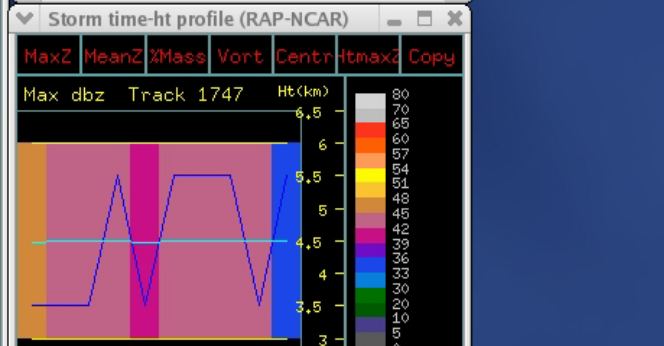
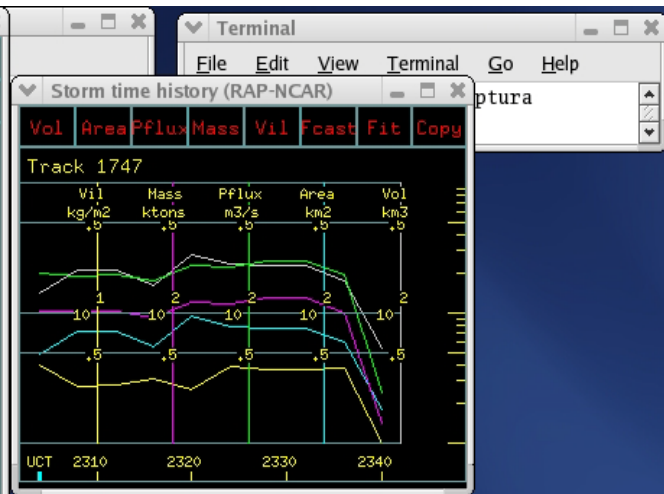
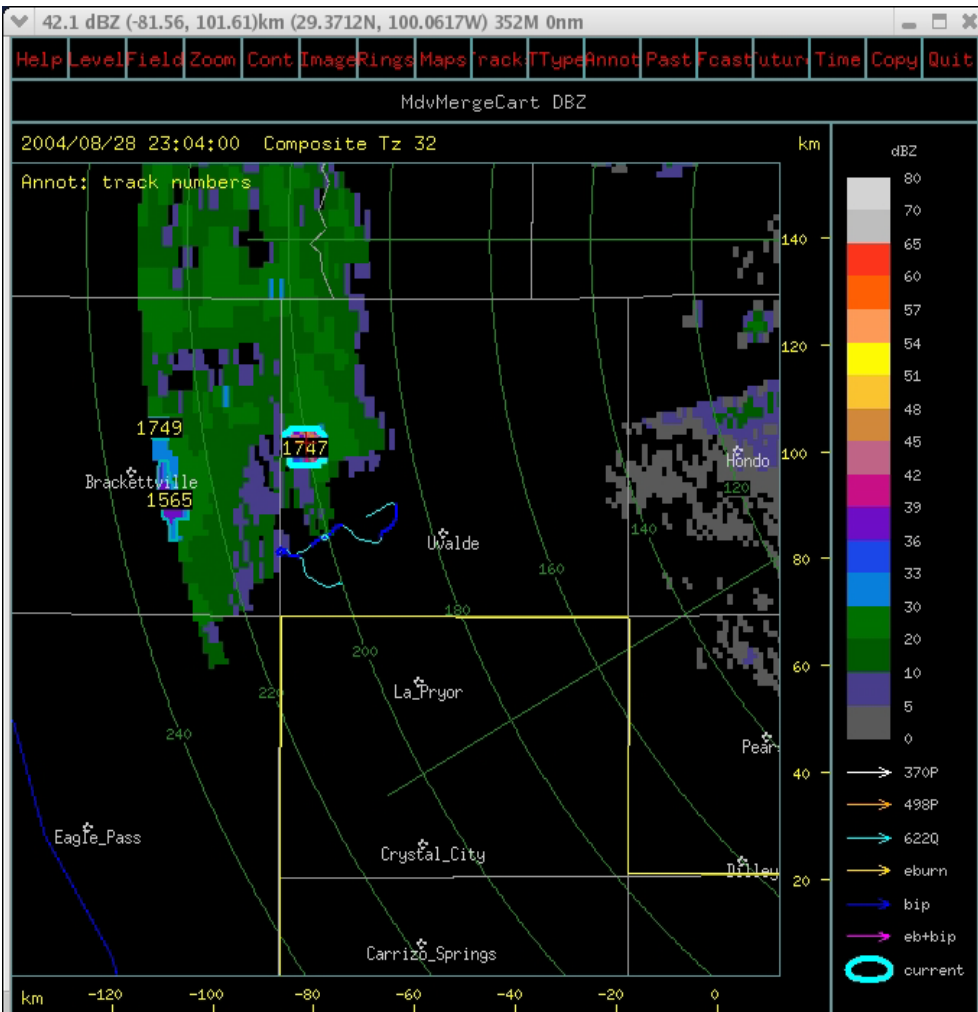
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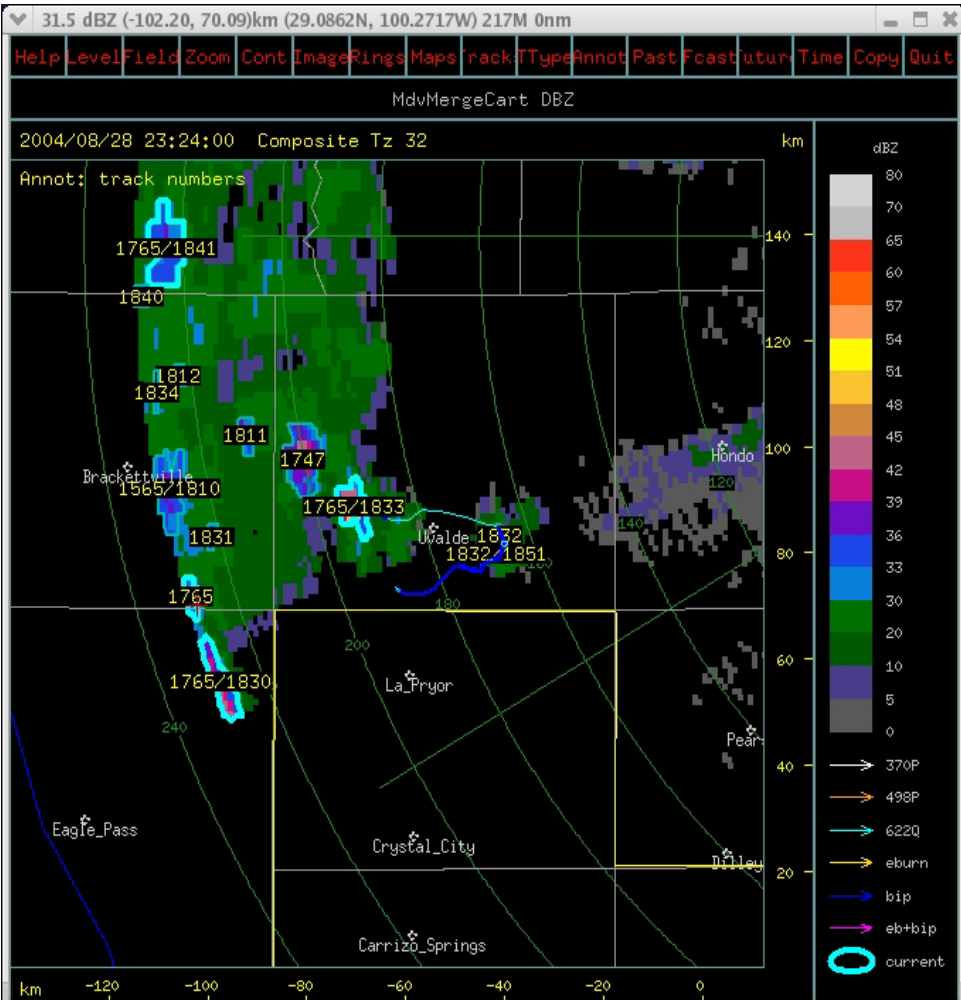
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Track data time scale (RAP-NCAR)

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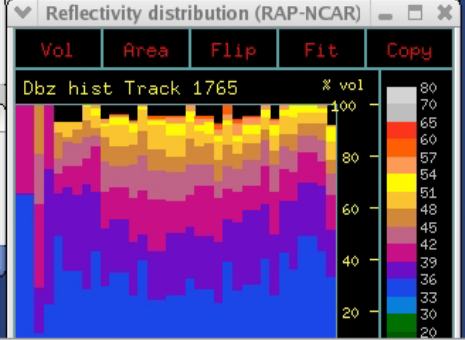
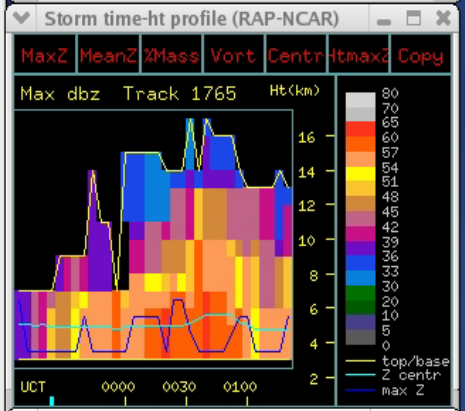
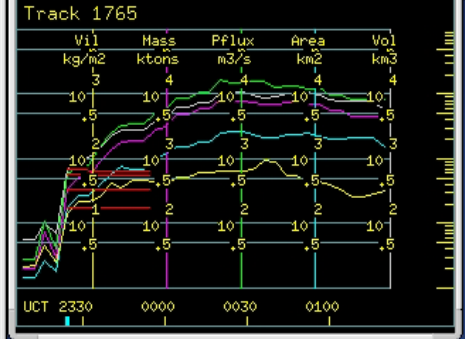
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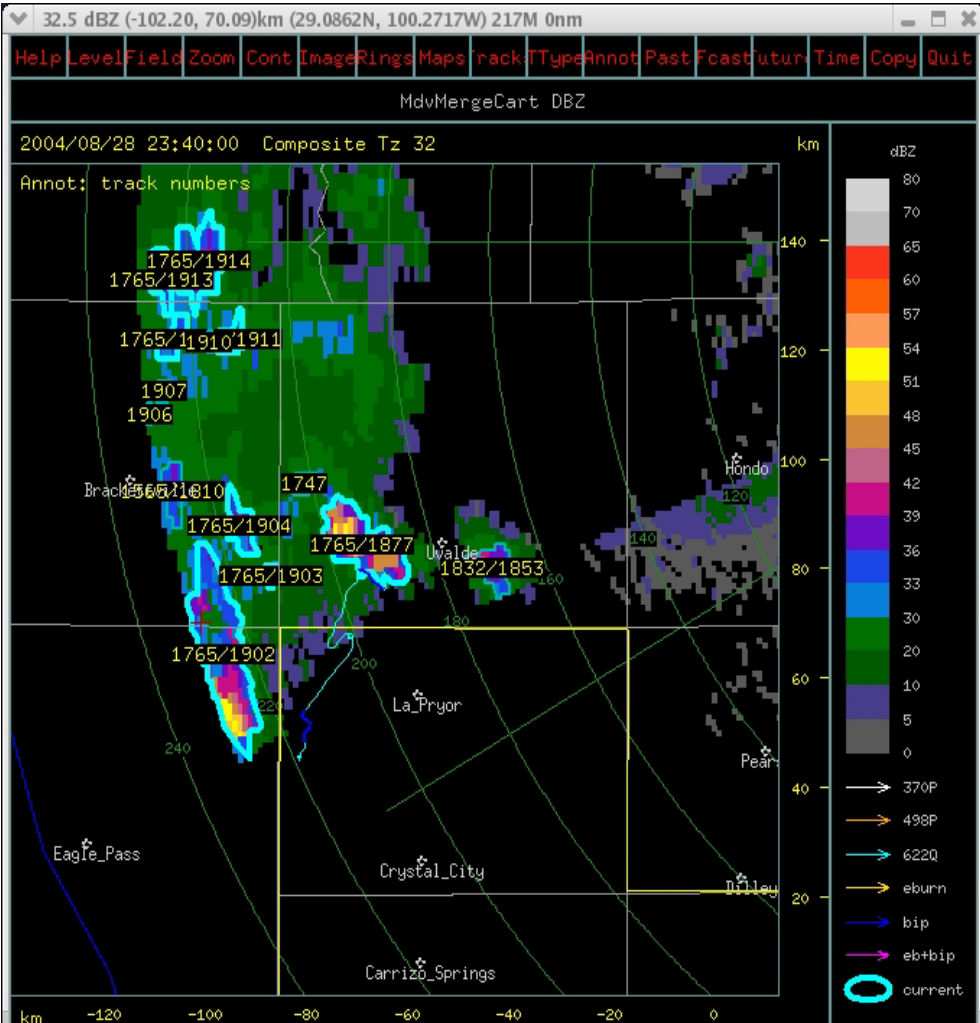
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Track data time scale (RAP-NCAR)

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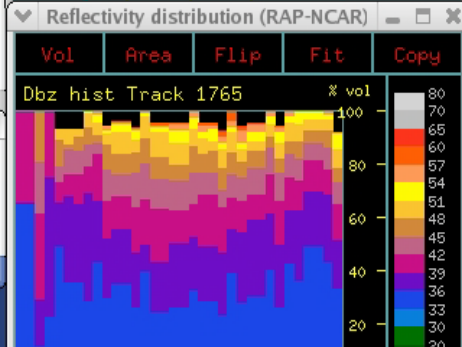
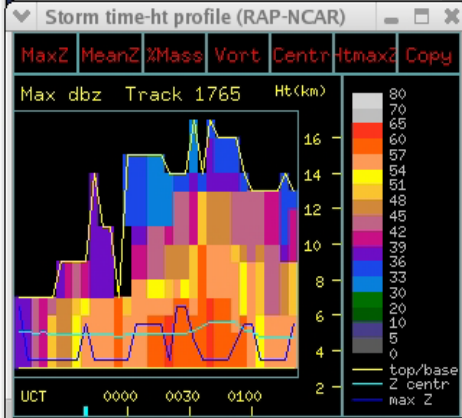
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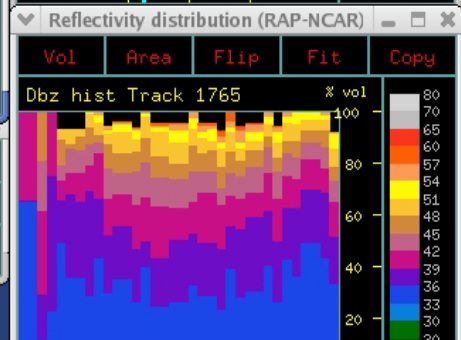
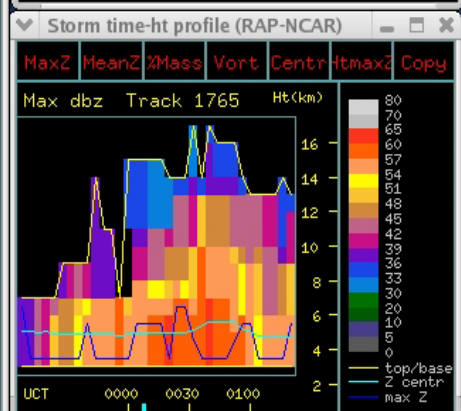
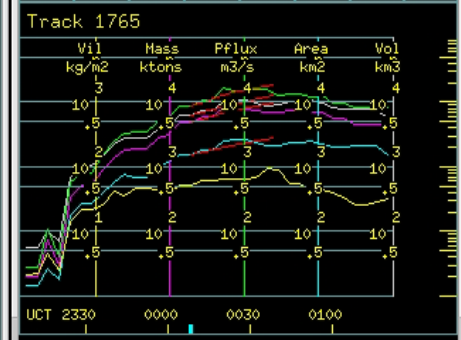
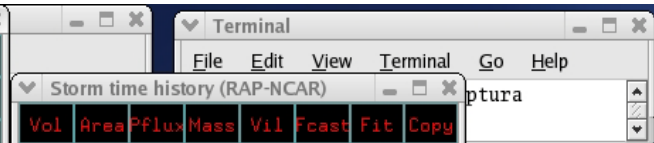
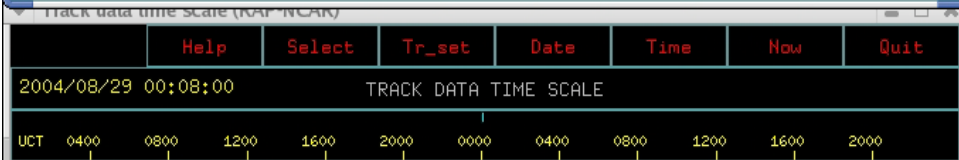
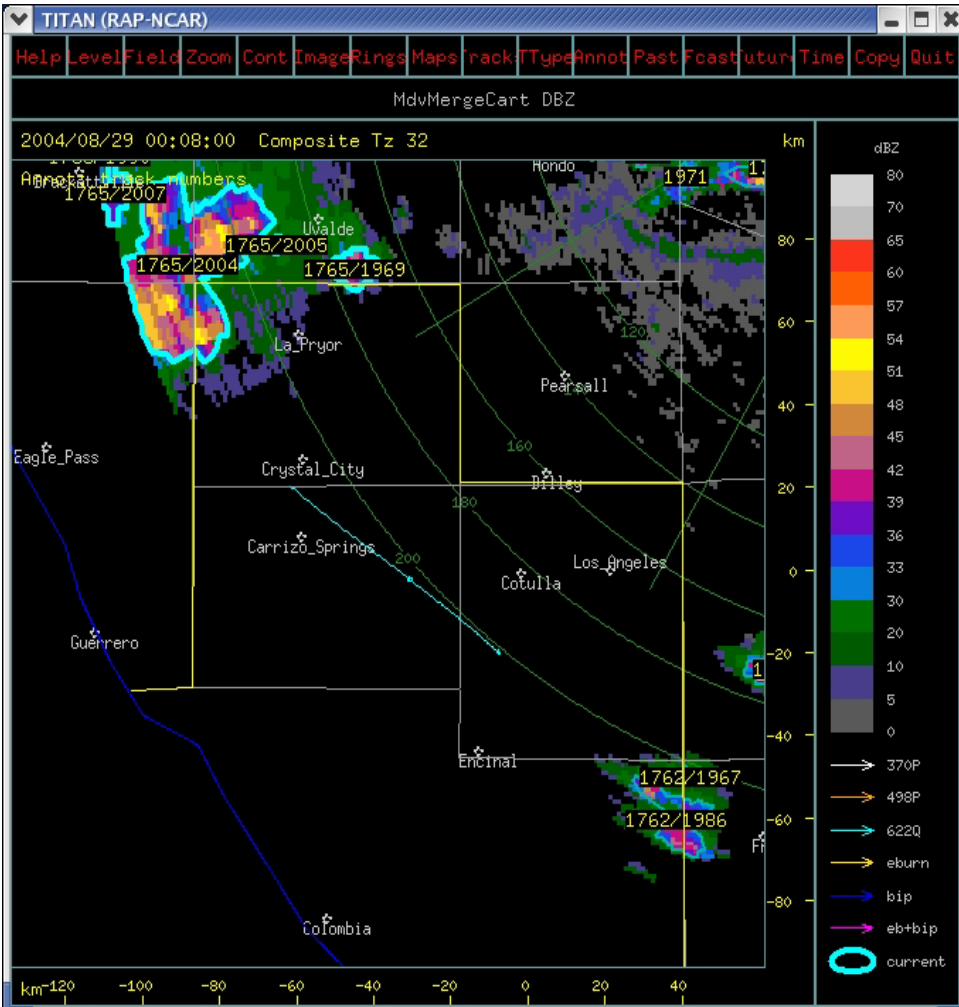
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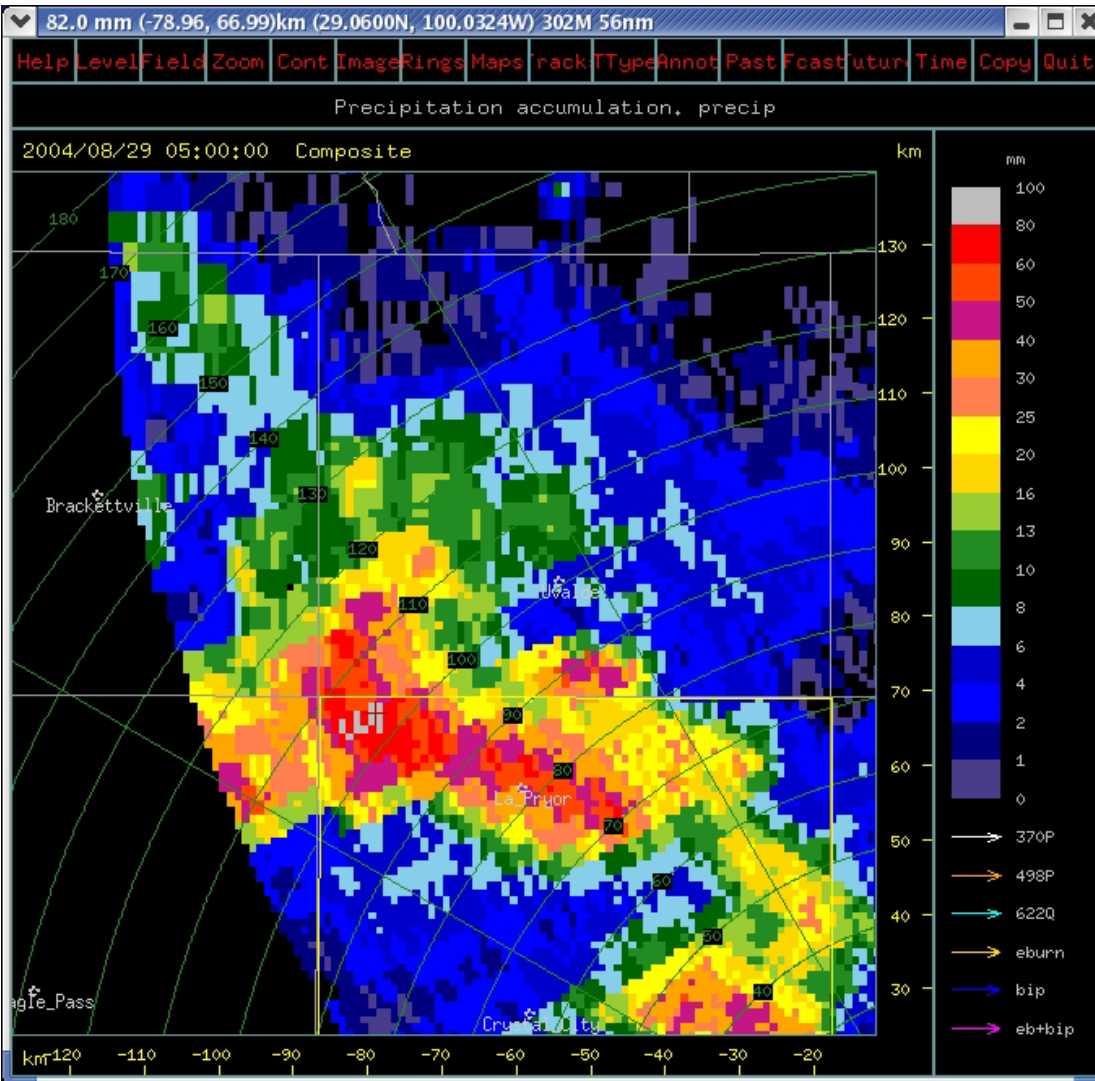
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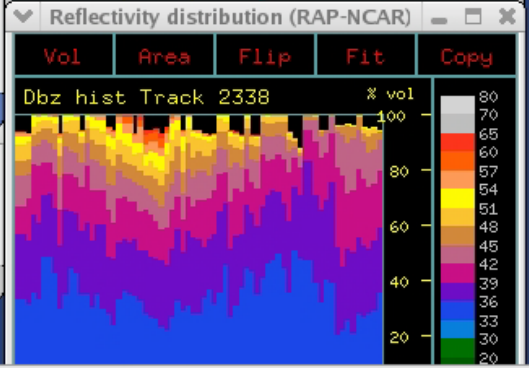
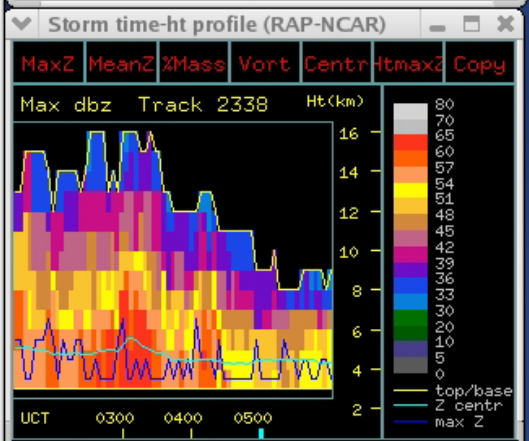
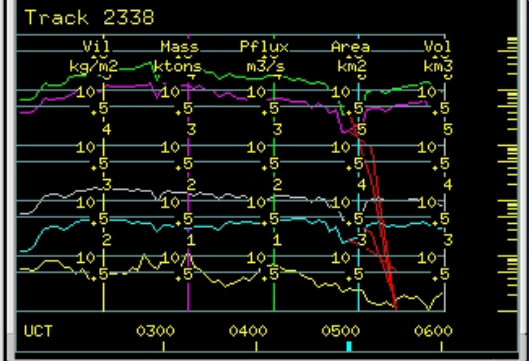


Table 1: Precipitation mass increases per county

Project	County	IS	ES	Increase (ac-f)	Increase (in)	Seasonal Precipitation	%
WTWMA (San Angelo)	Glasco	16	18	67 300	1.40	12.75 in	11.0
	Sterling	17	22	123 800	2.51	15.97 in	15.7
	Reagan	16	18	128 200	2.05	14.75 in	13.9
	Irion	10	22	96 700	1.72	19.28 in	8.9
	Tom Green	8	21	72 400	0.89	20.15 in	4.4
	Crocket	16	21	406 200	2.71	23.65 in	11.5
	Schleicher	19	24	215 000	3.08	21.08 in	14.6
	Sutton	7	10	113 000	1.46	27.48 in	5.3

Project	County	IS	ES	Increase (ac-f)	Increase (in)	Seasonal Precipitation	%
STWMA (Pleasanton)	Bandera	7	10	93 700	2.22	22.75 in	9.8
	Medina	13	21	122 900	1.74	22.48 in	7.7
	Frío	14	23	217 800	3.60	21.06 in	17.1
	Bexar	6	13	79 300	1.19	23.68 in	5.0
	Atascosa	27	33	221 600	3.37	22.82 in	14.8
	McMullen	16	20	164 900	2.78	20.98 in	13.3
	Wilson	9	14	75 700	1.76	21.73 in	8.1
	Karnes	15	22	115 700	2.89	22.30 in	13.0
	Live Oak	21	27	117 500	2.13	19.29 in	11.0
	Bee	21	25	123 900	2.64	21.56 in	12.2

Project	County	IS	ES	Increase (ac-f)	Increase (in)	Seasonal Precipitation	%
SWTREA (Cotulla)	Uvalde	10	11	70 500	0.85	17.00 in	5.0
	Zavala	13	21	76 300	1.10	14.75 in	7.5
	Dimmit	16	33	106 600	1.50	15.80 in	9.5
	La Salle	33	43	195 400	2.52	19.70 in	12.8
	Webb	19	25	89 700	0.50	16.60 in	3.0

Project	County	IS	ES	Increase (ac-f)	Increase (in)	Seasonal Precipitation	%
Panhandle (White Deer)	Potter	9	19	155 400	3.22	17.93 in	18.0
	Carson	17	26	148 300	3.02	17.28 in	17.5
	Armstrong	8	10	85800	1.76	17.28 in	10.2
	Robert	7	15	139 500	2.84	20.94 in	13.6
	Gray	11	19	110 600	2.24	19.31 in	11.6
	Donley	2	5	41500	0.84	19.45 in	4.3
	Wheeler	1	6	36700	0.75	24.14 in	3.1

Project	County	IS	ES	Increase (ac-f)	Increase (in)	Seasonal Precipitation	%
NPGCD (Dumas)	Dallam	7	8	89 300	1.11	20.65 in	5.4
	Hartley	12	16	98 200	1.26	17.35 in	7.3
	Sherman	6	13	77 400	1.57	18.56 in	8.5
	Moore	7	15	103 400	2.16	14.34 in	15.1
	Hansford	6	14	103 200	2.10	21.59 in	9.7
	Hutchinson	4	14	151 300	3.20	23.82 in	13.4
	Ochiltree	3	8	74 100	1.51	20.25 in	7.5
	Limpscomb	2	5	55 900	1.12	19.74 in	5.7

Statistical Description of Relative Increases (last column in table 1)

Number of Cases:	38 Counties
Minimum Value:	3.0 % (Webb County)
Maximum Value:	18.0 % (Potter County)
Mean Value:	10.16 %
Median Value:	10.00 %
Standard Deviation:	4.21 %
Percentile 20%:	5.52 %
Percentile 40%:	8.82 %
Percentile 60%:	11.52 %
Percentile 80%:	13.78 %

Midland Annual Precipitation

(1948-1997)

San Angelo Annual Precipitation

20th percentile: 10.49 in

13.46 in

40th percentile: 12.77 in

16.25 in

60th percentile: 15.06 in

21.15 in

80th percentile: 18.80 in

24.25 in

Median: 13.93 in

19.16 in

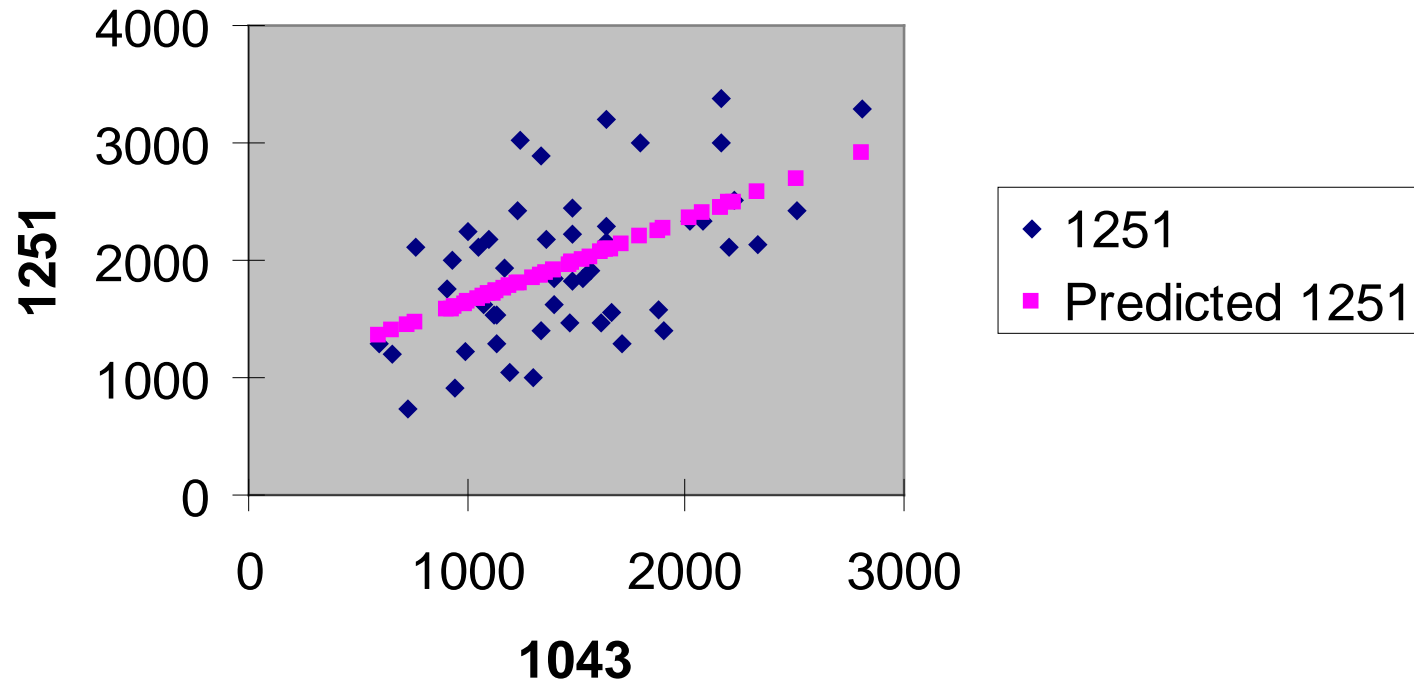
Mean : 15.07 in

19.38 in

σ : 5.51 in

6.49 in

1043 Line Fit Plot



SA = 0.70 Mid + 9.32; r = 0.54; S = 5.50, N= 67, e =1.32

Midland Very Dry years

San Angelo

1948

VD

1951

VD

1952

VD

1953

N

1956

VD

1964

VD

1967

N

1977

VD

1989

N

1996

W

Probability (SA VD / Midland VD) = 0.6

San Angelo



vd

d

n

w

vw

Midland



vd

0.6

0.0

0.3

0.1

0.0

d

0.2

0.3

0.2

0.2

0.1

n

0.1

0.3

0.2

0.2

0.2

w

0.1

0.3

0.2

0.2

0.2

vw

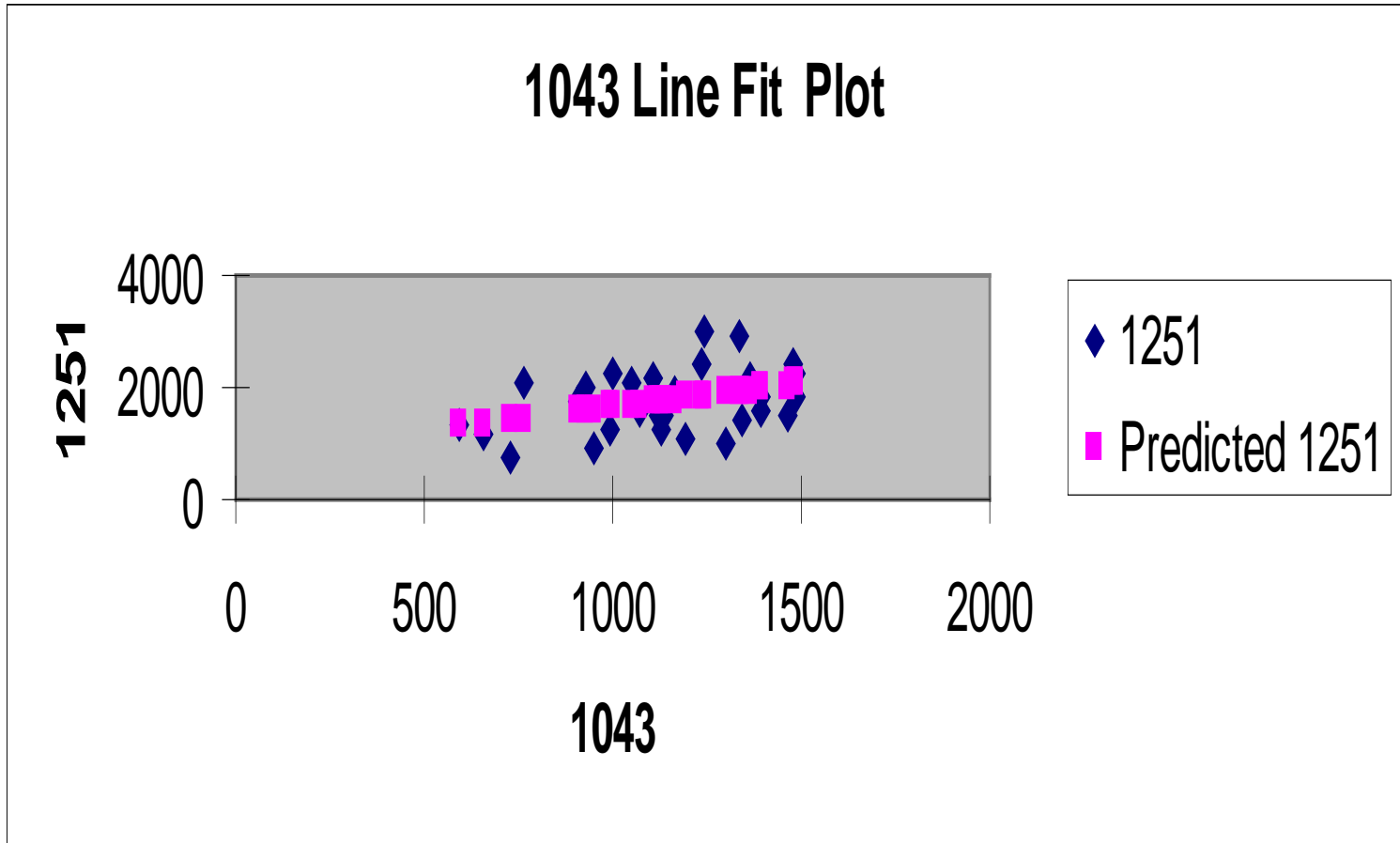
0.0

0.1

0.1

0.3

0.5



$$\mathbf{SA^* = 0.83 \text{ Midland}^* + 8.12; \quad r = 0.37, S = 5.42, N=30, e = 1.93}$$

(stroboscopic principle?)

	Midland	San Angelo	Predicted	D
1998	5.40 in (vd)	12.98 in (vd)	12.60 in	0.38 in
1999	7.60 in (vd)	13.52 in (d)	14.43 in	- 0.91 in
2000	9.65 in (vd)	15.14 in (d)	16.13 in	0.99 in
2001	9.85 in (vd)	18.53 in (n)	16.30 in	2.23 in
2002	9.35 in (vd)	14.41 in (d)	15.58 in	- 1.17 in
2003	11.18 in (d)	19.76 in (n)	17.40 in	2.36 in
2004	21.46 in (vw)	37.37 in (vw)	24.34 in	13.03 in

Midland

San Angelo

1994

d

n

1995

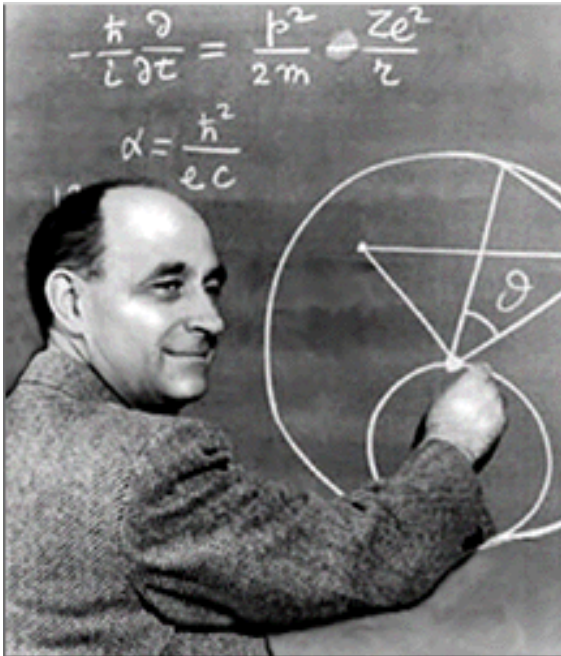
d

n

1996

vd

w



2005: World Year of Physics

**“There are two possible outcomes:
If the result confirms the hypothesis, then
you have made a measurement. If the result is
contrary to the hypothesis, then you have made
a discovery”.**

Enrico Fermi (Rome 1901- Chicago 1954)

A Fermi question is one that emphasizes estimation, numerical reasoning, communicating in mathematics, and questioning skills.